Light and Life: The Relationship between Light and Life in the Natural World (PLBio 1130)

Tuesdays and Thursdays 8:40-9:55, 114 Plant Sciences Bldg.

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Office hours: Friday 2 PM- 4 PM

Syllabus

Light and Vision: There is more than meets the Eye

"Virtual as opposed to real instruction"

January 25. Light, the eye and the mind: Historical introduction to the elements of vision.

January 27. Geometrical optics and image formation

February 1. Development, anatomy and physiology of the eye

February 3. Eye color and its inheritance

"Real instruction"

February 8. Light, the eye and the mind: Historical introduction to the elements of vision.

February 10. Geometrical optics and image formation

February 15. Development, anatomy and physiology of the eye

February 17. Eye color and its inheritance

February 22. Color and color vision

February 24. Animal eyes and the Darwinian theory of the evolution of the human eye

March 3. Charles Darwin, Samuel Wilberforce, and how we see the color of ants

Light and Energy

March 8. First light: Big bang cosmology

March 10. Production of sunlight and chemical spectroscopy

March 15. Photosynthesis: Converting radiant energy into chemical energy

March 17. Photosynthesis: Converting radiant energy into chemical energy

March 22. Chemical History of the Candle: Converting hydrocarbons into light

March 24. Cellular Respiration: Converting carbohydrate into chemical energy without emitting visible light

Living Light

March 29. Luminescence: Production of light by living organisms

March 31. Field Trip to Rare and Manuscript Collection in Kroch Library

Using Light to Keep Track of Time and Determine Orientation in Space

April 12. Photomorphogenesis in plants

April 14. Melanopsin, circadian rhythms and wellness in humans

Seeing the Invisible: The Photon

April 19. Ultraviolet light and wellness, ozone layer, vitamins, DNA repair, fluorescence

April 21. Plant and animal coloration: Pigments, attraction, camouflage and mimicry

April 26. Plant and animal colorations: Iridescence, sexual attraction and the wave nature of light

April 28. Using the properties of light and pigments to make microscopic organisms, including germs, visible

May 3. Polarized light and bee vision (

May 5. Red, blue and purple dyes

May 10. What is light and what is life? (Calendar due)

Final Paper due at scheduled final exam time (5/17/2022 2:00 PM Plant Science Building 143)

Lecture Notes

My lecture notes are available on Canvas. Scan over them before each lecture—to get a sense of the material that will be covered, the main ideas of the lecture, and the evidence for the main ideas. Read the lecture notes carefully immediately after the lecture to ensure that you understand the main ideas and the evidence for them.

Expectations and Grading:

Calendar: 20% You can make your calendar using any program you choose, including Microsoft Publisher, which is available in Mann Library. You must take a minimum of 12 photographs (with your cell phone camera) that document various aspects of light and life. You must attach a written description, one paragraph to one page long for each photograph that describes how each photograph documents an important aspect of light and life. Save the calendar and the accompanying documentation as a pdf. You can have your calendar printed on cardstock and bound at the Copy Center at Olin Library for a fee. You can turn in this calendar or turn in a collated printed version on normal paper. In either case, you will get it back. I will post the pdfs of your calendar on a class website.

I will make time at the beginning of each class period for people to present and describe a picture that relates to the last lecture.

During a normal semester:

Prelim 1: 20% The prelim will be a combination of short essay questions and problem solving.

Prelim 2: 20% The prelim will be a combination of short essay questions and problem solving.

During Omicron semester:

Dinner Conversations and two quizzes: 40%: Chose the person who is most interesting to you in each set of lecture notes. For each set of lecture notes, write a one-page script of a dinner conversation between you and that person where you discuss the issue that is most meaningful to you and ask a question. Like any conversation, it may be deep, witty, funny, argumentative, as well as informative. You must pass in **18 conversations** (20 pts each). There will also be **2 pop quizzes** (20 pts each) to ensure that you understand and can answer quantitative questions.

Final Paper: 20% This is a creative writing project (approximately 10 pages long or perhaps a music video) in which you use your scientific knowledge and creative writing skills to communicate to a lay audience the beauty and importance of light and life.

Class participation: 20% You will be expected to attend each class and show up on time. You will be expected to do the readings (posted on Blackboard), participate in class discussions, and if you like, draw and present concept maps (http://cmap.ihmc.us/).You will be expected to solve problems on the board. You will be expected to participate in the demonstrations and experiments. You will ***not*** be required to perform a dissection of a cow eye.

Teaching Philosophy

My teaching philosophy is in line with that used in the Freedom Schools of Mississippi. "*Notes on Teaching in Mississippi*" written by The Student Nonviolent Coordinating Committee (SNCC),

began with, "*<u>This is the situation</u>: You will be teaching young people who lived in Mississippi all their lives. That means that they have been deprived of a decent education from the first grade through high school. It means that they have been denied free expression and free thought. Most of all—it means that they have been denied the right to question. The purpose of the Freedom Schools is to help them begin to question*."

"*The purpose of the Freedom Schools is to help them begin to question*."

Do not believe anything I say!

My job is to help you begin or continue to question. I will provide you with enough firsthand experience and primary texts so that you will have access to the available facts and the interpretations of those facts. I want you to develop a relationship with the facts, question the interpretations of those facts, and make up your own mind on important issues. I will encourage you to use the knowledge you learn in this class to be able to explain the line of reasoning that brought you to your answers with conditional certainty. It is possible for each person to answer exam questions differently and still get full credit. I will not "encowardice" you to be mental slaves and merely spit back interpretations that you do not believe to be true.

During a normal semester:

First-Year Dining Discussion Program Information

The Dining Discussion Program allows us to have mealtime discussions in order to provide us with opportunities to explore academic and intellectual interests related to course subjects; enhance our understanding of course materials; provide insights into our experiences in the class; and become comfortable interacting with each other outside of the classroom. Let me know if you are interested. We can eat at any of Cornell's all-you-care-to-eat dining rooms including North Star (Appel), Risley, and Robert Purcell on North Campus; Okenshields (Willard Straight) on Central; and all five of the house system dining rooms and 104 West on West Campus. The meals are free.

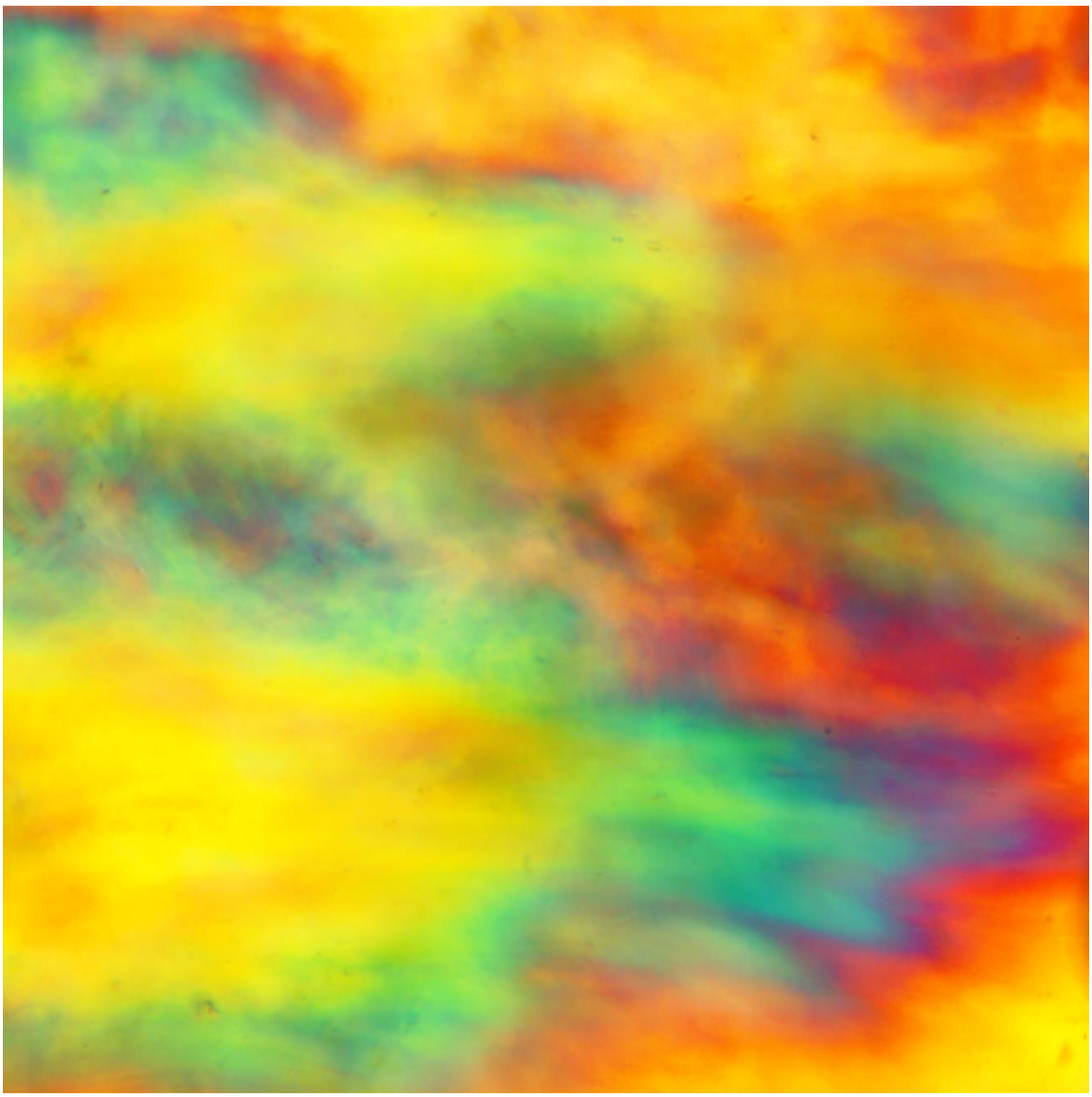
Academic Integrity

College is a time for you to find and develop your character, interests and skills. DO NOT wait for a gap year to do this! I expect that you will be described as someone who is honest, who sees the light, who reflects on the past and who envisions a bright future. The Cornell University Code of Academic Integrity states that, *"Absolute integrity is expected of every Cornell student in all academic undertakings. Integrity entails a firm adherence to a set of values, and the values most essential to an academic community are grounded on the concept of honesty with respect to the intellectual efforts of oneself and others. Academic integrity is expected not only in formal coursework situations, but in all University relationships and interactions connected to the educational process, including the use of University resources. While both students and faculty of Cornell assume the responsibility of maintaining and furthering these values, this document is concerned specifically with the conduct of students.*

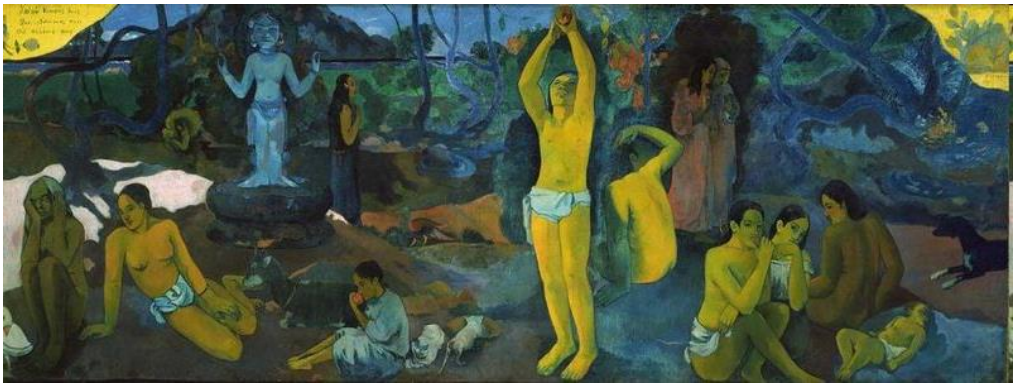
A Cornell student's submission of work for academic credit indicates that the work is the student's own. All outside assistance should be acknowledged, and the student's academic position truthfully reported at all times. In addition, Cornell students have a right to expect academic integrity from each of their peers."

Specific examples of code violations can be found at: http://cuinfo.cornell.edu/Academic/AIC.html.

DNA viewed with a polarized light microscope

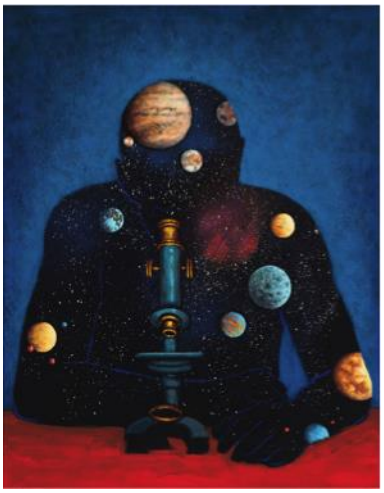


Light and Vision: There is more than meets the eye—an historical introduction to the elements of vision



Science is a way of looking at the world around us in order to make sense of who we are, where we came from, and to help us understand and plan where we are going. Erwin Schrödinger stated that the value of natural science "*is the command of the Delphic deity…get to know yourself."*

We study humans to help understand who we are. We study plants, animals, microorganisms, rocks, stars, air, and water to understand the biotic and physico-chemical world we live in and our relationship to that world. We gather **data** using our five **senses** and even more data that are **invisible** to our senses by using technology based on past scientific advances. We use these data to construct **models** of the world, in an **analogous** way to how our minds create models of the world using the visual information captured by our eyes. When many minds agree on the validity of the model, we call that model a **theory** or a **law of nature**. The laws of nature are **valuable** in helping us understand and appreciate the world around us and to understand our place in the universe. There are also **limitations** in the observational and experimental evidence that contribute to the natural laws. As

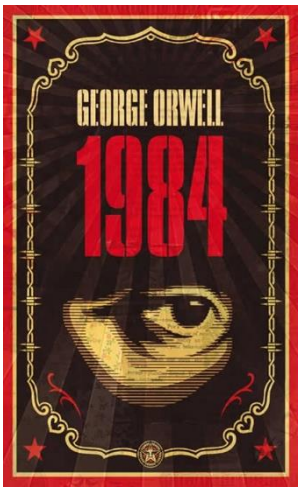


scientists we should realize that the laws are provisional and each of us must make a personal choice about how reliable they are. For example, I think that the laws of thermodynamics are more reliable and fundamental than Einstein's Theory of Relativity and the Uncertainty Principle of Quantum Mechanics.

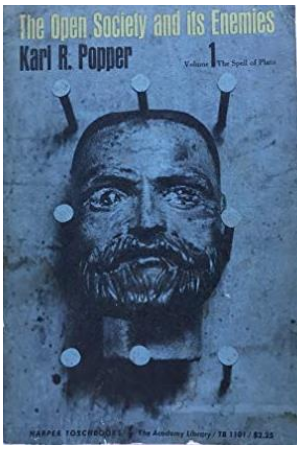
There is currently a national trend to teach only the **value** of current scientific theories and not their **limitations**. The National Center for Science Education (http://ncse.com/creationism/general/academic-freedom-legislation; https://house.mo.gov/billtracking/bills141/biltxt/intro/HB1587I.htm; https://ncse.ngo/fermi-missouri) is fighting "academic freedom bills" that ask teachers to teach "the full range of scientific views regarding biological and chemical evolution," and to help students develop "critical thinking skills" on "controversial issues" by permitting teachers to discuss "the scientific strengths and scientific weaknesses of existing scientific theories."

While there is a movement to teach "*the state of the scientific consensus on the issues*" remember what Eric Blair a.k.a. George Orwell wrote in his book, *1984*:

"*Being in a minority, even a minority of one, did not make you mad. There was truth and there was untruth, and if you clung to the truth even against the whole world, you were not mad. A yellow beam from the sinking sun slanted in through the window and fell across the pillow. He shut his eyes. The sun on his face and the girl's smooth body touching his own gave him a strong, sleepy, confident feeling. He was safe, everything was all right. He fell asleep murmuring 'Sanity is not statistical,' with the feeling that this remark contained in it a profound wisdom.*"



…and remember that re-member means to put ourselves back together.



I love science and the ability of the scientific method for helping us to question, understand, and appreciate the world around us. According to Karl Popper (1962), "*the secret of intellectual excellence is the spirit of criticism; it is intellectual independence. And this leads to difficulties which must prove insurmountable for any kind of authoritarianism. The authoritarian will in general select those who obey, who believe, who respond to his influence. But in doing so, he is bound to select mediocrities. Nothing is less true, as far as intellectual initiative is concerned, than the idea that those who are good in obeying will also be good in commanding… the whole secret of scientific method is a readiness to learn from mistakes*." I am a staunch supporter of questioning any and all authority in order to help us understand and appreciate the world around us. On that note, I will try to provide you with as much personal experience as possible concerning light and life so that you do not have to believe a single thing I say but have enough experience or **original participation** to trust your knowledge while understanding both the **value and limitations** of what you and others know. I want you to be able to say, "I understand" before you say "I agree," "I disagree," or "I suspend judgement" on any scientific issue.

Trust the evidence of your own senses. Remember Plato's story, as told in Theaetetus, of the philosopher whose mind is so separated from his senses that he does not even know what he does not know



Socrates: *And all these things the philosopher does not even know that he does not know; for he does not keep aloof from them for the sake of gaining reputation, but really it is only his body that has its place and home in the city; his mind, considering all these things petty and of no account, disdains them and is borne in all directions, as Pindar says, 'both below the earth,' and measuring the surface of the earth, and 'above the sky,' studying the stars, and investigating the universal nature of every thing that is, each in its entirety, never lowering itself to anything close at hand.*

Theodorus: *What do you mean by this, Socrates?*

Socrates: *Why, take the case of Thales, Theodorus. While he was studying the stars and looking upwards, he fell into a pit, and a neat, witty Thracian servant girl jeered at him, they say, because he was so eager to know the things in the sky that he could not see what was there before him at his very feet. The same jest applies to all who pass their lives in philosophy.*

Trust the information gained by your own senses. Keep your eyes on the sky and your feet on the ground!



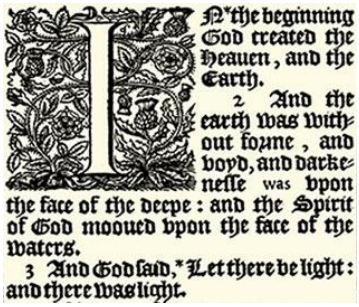
Johann Wolfgang von Goethe coined the phrase ***Thatige Skepsis***, which according to Thomas H. Huxley means, "*An Active Skepticism is that which unceasingly strives to overcome itself and by well directed research to attain to a kind of conditional certainty*" or "*A state of doubt which so loves truth that it neither dares rest in doubting, nor extinguish itself by unjustified belief."*

We all are equals in the search for truth. When I was in high school, there was a poster on the door that had a quote:

Don't walk in front of me…I may not follow.
Don't walk behind me, I may not lead.
Walk beside me…just be my friend.



The quote was attributed to Albert Camus, who I had never heard of, and so I thought Camus, which I pronounced Kā-mus, must be child. Then I learned who Camus was, and I also learned that there was no evidence that he had anything to do with the quote. Indeed, the quote may have come from a friend of Dr. William F. Knox. Knox used the quote in a column in the December 2, 1971 issue of the *Quincy Sun*, entitled, Just Be My Friend.

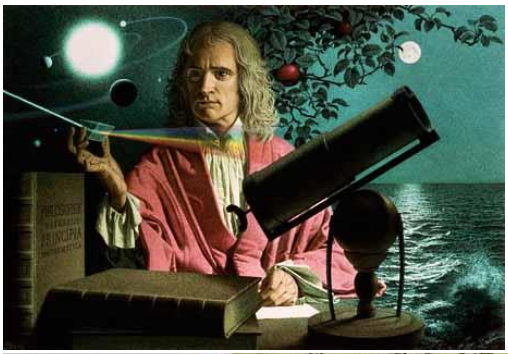

In the beginning God created the heauen, and the earth.
2 And the earth was without fourme, and voyd, and darkenesse was vpon the face of the deepe: and the Spirit of God mooued vpon the face of the waters.
3 And God said, Let there be light: and there was light.

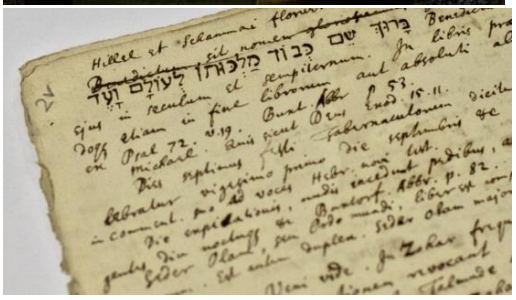
Let's begin talking about light from the beginning. In the Old Testament, Moses (ca. 1500 BC) wrote, ***God Said, "Let there be light," and there was*** *light* (Genesis 1:3), or as it says in the Wycliffe Bible (ca. 1384), *And God seide, Liyt be maad, and liyt was maad*.

According to the Turin papyrus (ca. 1300 BC), for those who lived in Heliopolis in the New Kingdom of Egypt, light was the Sun God Ra seeing: "*I am he who opens his eyes and there is light, who shuts his eyes and there is darkness*." For Zoroaster (ca. 500 BC), God was Ahura Mazda, whose name literally means light wisdom. **Robert Grosseteste** (1175-1253), the Bishop of Lincoln, wrote in *De Luce* that God was the **uncreated light** from which **created light** and eventually **life** arose. Grosseteste is known as the founder of modern scientific thought. He realized that by looking at specific phenomena, it is possible to arrive at universal laws of nature. He also realized that it was possible to use the universal laws of nature to make predictions that could be verified through a controlled experiment (https://plato.stanford.edu/archives/win2010/entries/grosseteste/#SciMet).

Historically, and in many cultures, light has been associated with God and good, and with truth and knowledge. The ancient Hindu festival of lights, known as Diwali, celebrates the victory of light over darkness, good over evil, knowledge over ignorance.







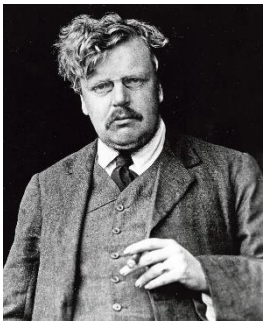
Historically, much of science has been derived from a religious quest to understand the wisdom of God and promote a virtuous world. Isaac Newton, for example, did not make a clear distinction between science and faith. For Newton, light, both particulate and real and symbolic and divine, held a central place in science and theology. In *The First Book Concerning the Language of the Prophets*, Newton wrote, "*Light—for the glory, truth and knowledge wherewith great and good men shine and illuminate others*." What kind of knowledge did Newton illuminate? Newton (1687) wrote in the General Scholium of his *Principia*, "*This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful being…and from his true dominion it follows that God is a living, intelligent, and powerful being."*

This does not sound like the same Isaac Newton described by scientists today. For example, Johnjoe McFadden (2008) wrote in an article entitled, Survival of the Wisest, published on the 150th anniversary of the *Origin of Species*, "*Quite simply, Darwin and Wallace destroyed the strongest evidence left in the 19th century for the existence of a deity. Two centuries earlier, Newton had*

banished God from the clockwork heavens. Darwin and Wallace made the deity equally redundant on the surface of the earth." Had McFadden not read Newton? Darwin or Wallace did not see the deity as being absolutely redundant. Not able to see evidence of a material solution to origins, Charles Darwin (1958) wrote that "*The mystery of the beginning of all things is insoluble by us: and I for one must be content to remain an Agnostic*" and Alfred Wallace (1871) not seeing the application of natural selection to mankind wrote that the "*faculties which enable us to transcend time and space…, or which give us an intense yearning for abstract truth…, are utterly inconceivable as having been produced through the action of a law which looks only, and can look only, to the immediate material welfare of the individual or the race."*

We will begin with an historical account of light and life that is not exclusively **materialistic**, does not marginalize the theological component, and emphasizes the importance of questioning authority, no matter who the authority is (including me).

G. K. Chesterton (1905) elequently wrote in *Heretics* that a materialistic view of nature may not be natural: *Take away the supernatural, and what remains is the unnatural*. http://www.gutenberg.org/files/470/470-h/470-h.htm.



According to one Greek legend, **Prometheus** formed men out of clay and Athena gave the clay figures life by putting a fire within their clay bodies.





Ovid (43 BC-18 AD) wrote that Prometheus "*gave human beings an upturned aspect, commanding them to look towards the skies*." Prometheus then brought to men the gift of fire from Mount Olympus so that they could warm themselves and illuminate the darkness. The Olympic torch lighting ceremony at the Temple of Hera is a reminder of Prometheus' gift of fire.



While fire can warm and illuminate the darkness, it also casts **shadows** of things. In the ***Allegory of the Cave***, Plato tells us of men imprisoned in a cave and chained to a wall so that they cannot see the fire behind them. They also do not know that there is a puppeteer behind them that is casting shadows of puppets and other things on the opposite wall. The prisoners can only see the shadows and they

imagine that the sounds they hear come from the shadows themselves. The prisoners only have reason to believe that the shadows are the real and only entities of the world. One prisoner escaped from the cave and while he was above ground, he found truth and enlightenment in the heavens. He saw shadows of real objects and realized that what he had seen in the cave were only shadows of real objects. Then he realized that the position of the life-sustaining sun, which changed throughout the day and throughout the year, influenced the nature of the shadows. And he came to know the relation between what we see and reality and understood from his path of knowledge, the idea of good and inferred that there is an author of good.



When he returned to the cave to tell his fellow prisoners about his newfound knowledge, they laughed at him as though he had gone mad. Indeed in the meantime, they had set up contests, where the person who could predict the actions of the shadows would win a prize. Plato tells us that we all live in a cave and it is incumbent on us to learn the laws of optics so that we will be able to understand the relationship between what we see and the true and real object.

The ancient Greeks realized that in order to see an object, there must be some kind of **contact** between the eye doing the seeing and the object being seen. They developed several theories of light and vision to explain the nature of the contact. These theories can be reduced into two main opposing classes:

-**Extramission** theories, championed by Empedocles, Euclid and Ptolemy, state that vision results from the emission of visual rays from the eye to the object being viewed.

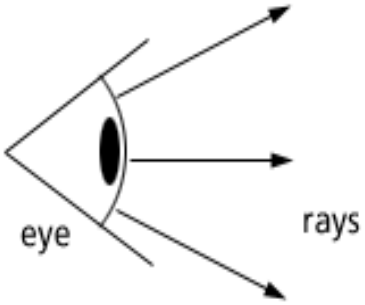
-**Intromission** theories, championed by Lucretius and Democritus, state that vision results from light in the form of a minute replica (eidola) or a thin film (simulacra) of atoms that is emitted from the object and enters the eye.

Both theories relate the sense of vision to the sense of **touch**. However, the extramission theory is analogous to the act of **touching**, while the intromission theory is analogous to the act of **being touched**. In *Saving the Appearances: A Study in Idolatry*, **Owen Barfield** (left) reminds us of the difference between sensation and perception, where touch is the sense that comes closest to sensation without perception and sight is the sense that comes closest to perception without sensation.



Extramission theory is based in part on the belief that the gods endowed us with the "**fire in the eye**." However, the extramission theory was robust enough to explain why we see "stars" when someone strikes our head, why we see light or phosphenes when we rub our closed eyes, why we see images when we sleep in the dark, why we "feel" it when someone stares at us, why we see only the surface of objects and why more than one person can see the same object at the same time.

The intromission theory, by contrast, could only explain why we cannot see in the dark.



Euclid (300 BC) **mathematized** the extramission theory to explain why distant objects appear to be smaller than nearer objects. Euclid used the **geometry of straight lines and angles** to describe how we see the world.

To use geometry to explain vision, Euclid demands (or postulates) that we accept certain assumptions. Euclid's postulates can be summarized like so:

-Infinite straight lines, known as visual rays, proceed from the eye, forming a cone such that the vertex is at the eye and the base is at the surfaces of the objects being seen.

-Objects touched by the visual rays are visible; those untouched by the visual rays are not seen.

-Objects seen through a larger angle appear larger, those seen under a smaller angle appear smaller, and those seen under equal angles appear equal.

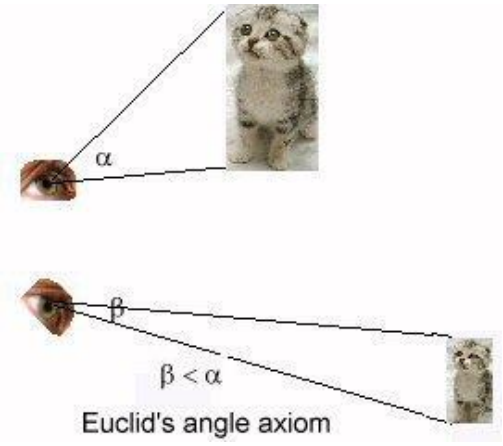
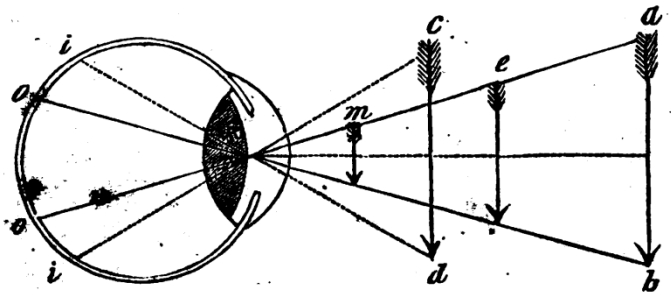


Fig. 183.





Note that the visual angle cannot tell us whether an object is naturally small or naturally large but far away. We are fooled by **forced perspective** photography to see large objects that are really farther away to be as close as the near object, but smaller.
http://digitalphotopix.com/unbelievable/brilliant-examples-of-forced-perspective-photography/

-Objects touched by visual rays coming from more angles, or a greater angle, are seen more clearly.

The visual rays cease to travel in straight lines when they encounter an **opaque** object, which stops them. Euclid's geometrical optics is also useful in describing the shadows and images produced in these cases.

Visual rays also cease to travel in a straight line when they strike a shiny object such as a **mirror** that reflects them. Hero of Alexandria used Euclid's geometry to describe the images formed by reflection and stated that the position of the image can be determined by using the Law of Reflection, where the angle of reflection equals the angle of incidence. The image is formed by the convergence of apparently straight visual rays.

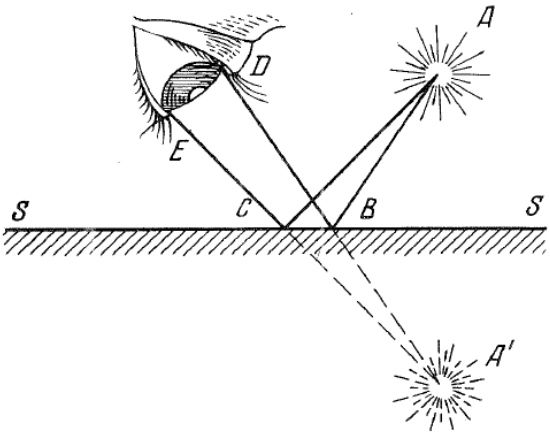
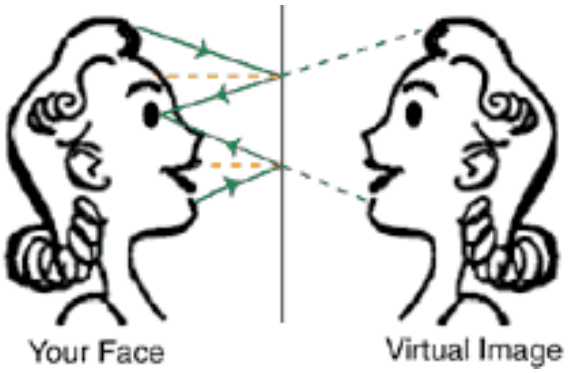


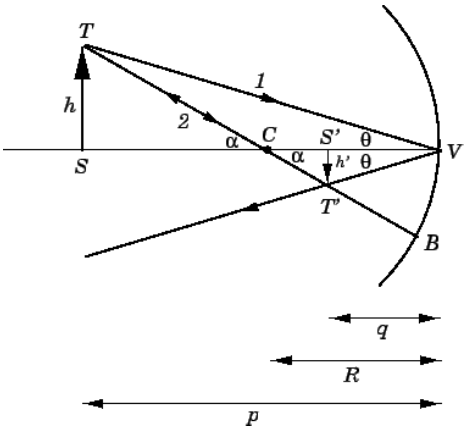
FIG. 3. Observing the reflection of a luminous point in a mirror.

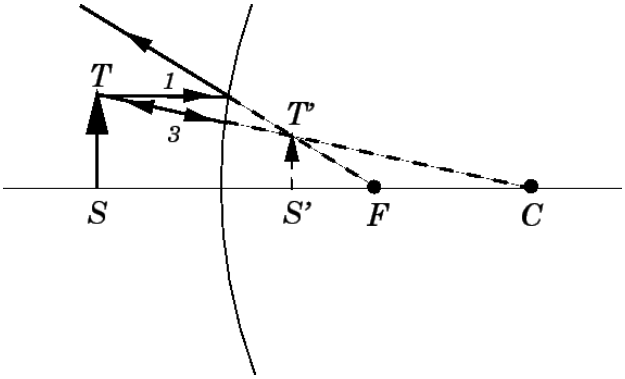




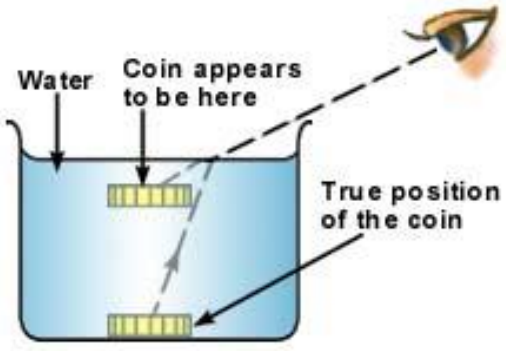


The Law of Reflection can also be used to find the image in concave and convex mirrors. We will go into the geometrical laws of image formation in the next lecture.





Visual rays also cease to travel in a straight line when they pass through a **transparent** medium such as water or the atmosphere that bends them. Euclid knew that "*If something is placed into a vessel and a distance is so taken that it may no longer be seen, with the distance held constant if*



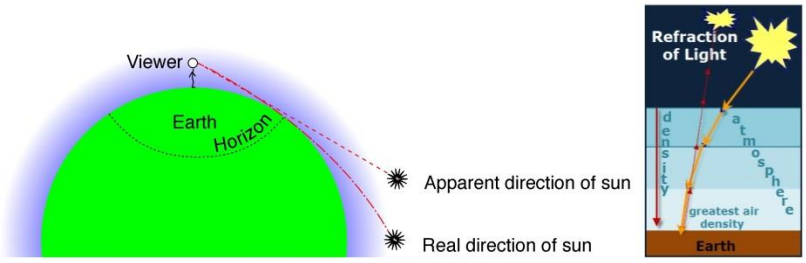
water is poured, the thing that has been placed will be seen again." Ptolemy used Euclid's geometry to explain the position of an image that is refracted or bent by a transparent medium.



Ptolemy (90-168 AD), realized that the position of light had a powerful effect on the bending of plants. In the days when astrology and astronomy were not differentiated, he realized that the **actual** position of the stars at the time of one's birth, and not their **apparent** position would be important for constructing accurate horoscopes. He incorporated the concept of refraction of starlight by the earth's atmosphere to determine the true positions of stars at the time of one's birth in order to construct accurate horoscopes and the true positions of the heavenly bodies which allowed accurate navigation.



Ptolemy knew that when a visual ray passed from a less dense medium to a denser medium, it did not travel in a straight line but was bent toward the perpendicular (e.g. looking at a coin in water) and as it passed from a denser medium to a less dense medium (e.g. seeing a star in the heavens), it bent away from the perpendicular. Ptolemy realized that this meant that we see a star higher in the sky than it really is because our **mind's eye assumes that the visual rays travel in straight lines**. Based on the same assumption, we think that the sun is setting long after it has already set.



Ptolemy did not figure out the ratio of the angles, even though he knew trigonometry. The effect is roughly proportional to the obliquity of the visual rays and the difference in the densities of the media. Next class, we will see that the ratio of the sine of the angles of the incident and transmitted light is equal to a constant.



Demonstration: Make a table of the relationship between the angle of incidence and the angle of transmission. Check out these two formulaic models:

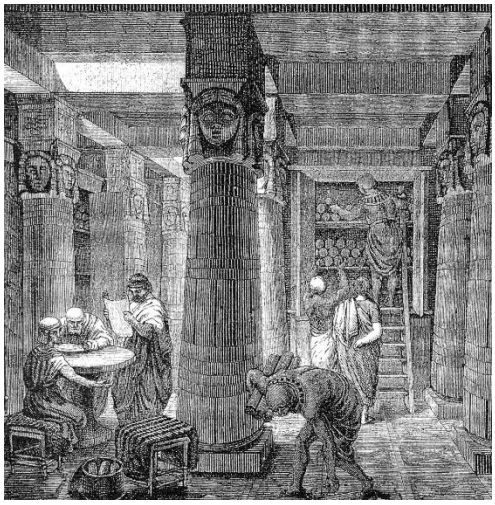
(angle *i*)/(angle *t*) = n

(sin angle *i*)/(sin angle *t*) = n

Which formula seems to be correct and why does it seem to you to be correct?

While Euclid's and Ptolemy's assumption of the reality of visual rays may seem **reasonable** to little children who cover their eyes when playing hide and seek or peek-a-boo, they seem absurd to us. Nevertheless Euclid's geometry, which was based on his theory of vision, became very successful when extended to distant objects like the sun and moon because it made **navigation** to distant places possible. There seemed to be no reason to consider further the **limitations** of the extramission theory, such as why can't we see in the dark, especially at a time when Greek science was in jeopardy.





In 391, under the rule of Emperor Theodosius I, who made Christianity the official religion of the Roman Empire and made pagan thought illegal, Pope Theophilus of Alexandria (385-412) ordered the burning of the last vestige of the great library in Alexandria, which had existed for almost seven centuries and which contained Euclid's texts. Thankfully this was not the end of Greek Scholarship since the Greek scholars who were displaced from the centers of learning found sanctuary in Persia and Constantinople. They brought their manuscripts with them, and Greek cultural thought persisted. http://www.wilbourhall.org/index.html#euclid

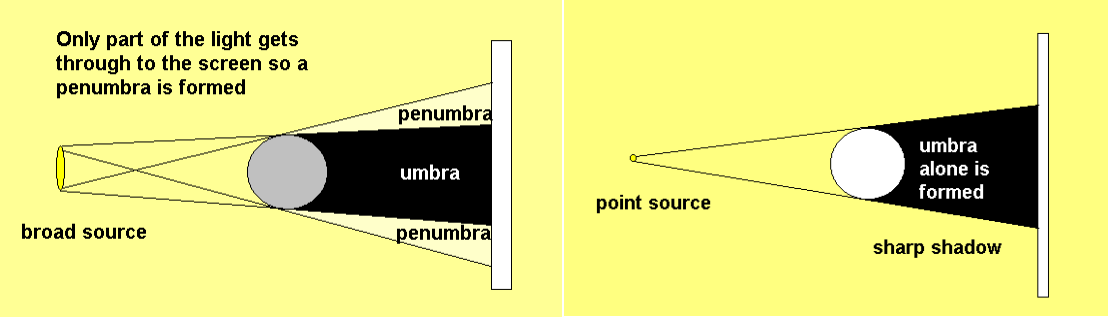
Unfortunately, Greek scholarship suffered again in 529 when Justinian I (482-565), the Byzantium Emperor who also outlawed pagan thought, shut down the Platonic Academy in Athens. At the margins of the Roman Empire, including Sicily, Greek culture also survived because the scholars were left alone.

Sicily, a center of Greek science, was conquered by the Muslims from North Africa in 965, and Euclidean texts became available to Ibn Ishak al-Kindi, Abdullah ibn Sina (Avicenna) and Ibn al-Haytham (Alhazen), who sought to assimilate and further develop Greek Science. **Alhazen** (965-1040), who lived in Cairo, began to study Euclid's theory of light and vision under the Caliph Al Hakim. Alhazen, perhaps a little too full of himself, figured that he could solve any problem with mathematics and so the Caliph ordered Alhazen to stop the Nile from flooding. Unable to carry out the Caliph's request, Alhazen was thrown in prison. Sitting in the dark in prison, Alhazen began to question Euclid's assumption that

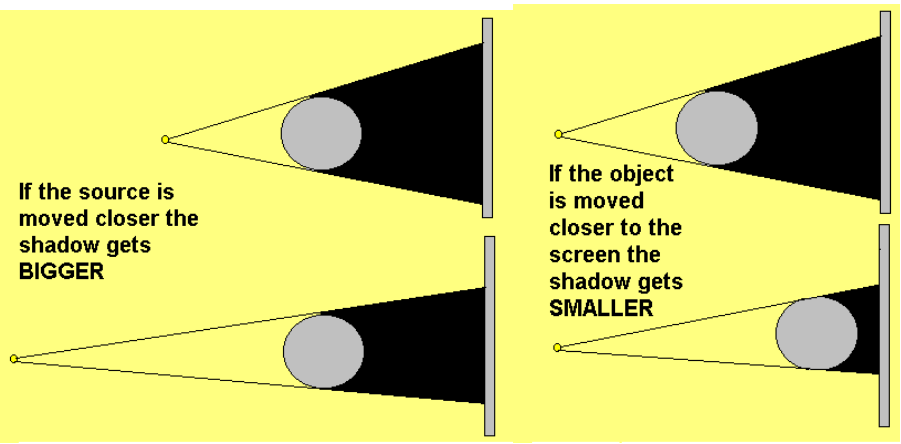
we could see because light emanated by the eye. Alhazen realized that he could only see when the sunlight entered the dark prison cell. He also wondered, if light emanated from his eye, why would looking at the sun cause pain? Alhazen resuscitated the intromission theory and concluded that we see not because visual rays extend from our eyes in straight lines but because light from **luminous** objects or light reflected from **nonluminous** objects follow **straight lines into the eyes**.



What evidence do we have that light travels in straight lines? The shape and size of shadows produced by **opaque** objects tells us that light travels in straight lines. To make the geometry simple, consider the source to be a point source.



The size of the shadow depends on the relative distance between the object, the light source, and the screen.



The fact that light travels in straight lines is used by the Pilobolus Dance Troupe to create their shadow dance.
https://www.youtube.com/watch?v=Znb3lpPnoXc

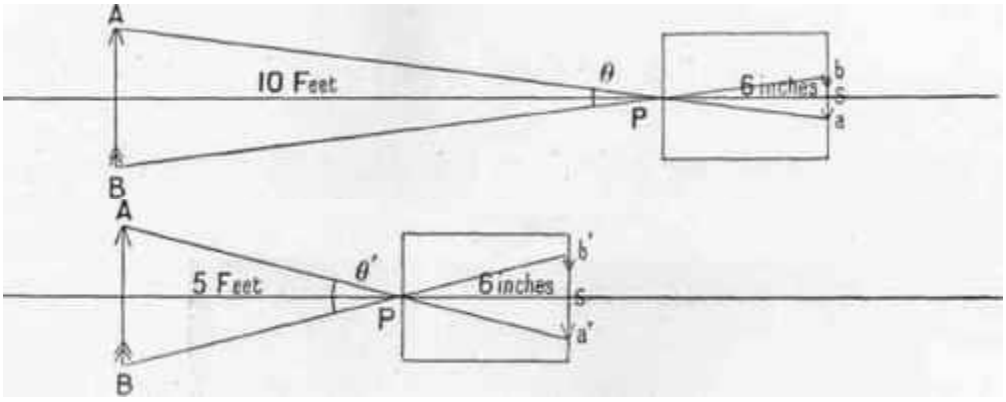


After 12 years in prison, the Caliph died and Alhazen was freed. Alhazen continued making observations and performing experiments and then published a text on optics. In his *Optics*, Alhazen wrote, "*Light emanates in every direction from any luminous body, however it is illuminated. Thus, when the eye faces any visible object that shines with some sort of illumination, light from that visible object will shine on the eyes' surface. And it was shown that it is a property of light to affect sight, while it is the nature of sight to be affected by light. It is therefore fitting to say that sight senses the luminosity of a visible object only through light that shines from it upon the eye.*"

Alhazen used **analogy** (degree of similarity; relevance of similarity) to suggest that the eye formed an image the same way that a ***camera obscura*** (dark room) or pinhole camera formed an image. Alhazen pierced a tiny hole in the wall of a dark room and placed three lamps outside the room and saw that three light spots appeared on the wall across from the pinhole. By placing an obstacle in front of a lamp, he saw that the image of that lamp disappeared and reappeared when he removed the obstacle. The image of a given lamp was always aligned with a straight line from the object to the image. Moreover, obscuring one lamp had no effect on the images of the others. Alhazen described vision, not as the complete transfer of the surface of an object, but as the **transfer of light rays emitted in all directions from individual points on the external surface to the crystalline humor of the eye**. Only the rays that stuck perpendicular to the crystalline humor in the eye were powerful enough to form an image. Thus if image formation by eyes is **analogous** to image formation by pinholes, **the image on the crystalline humor would be a point-by-point representation of the surface of the object**.

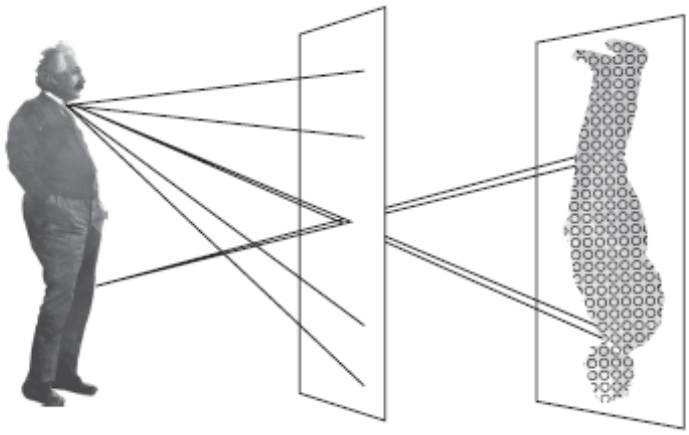


By eliminating the visual rays, Alhazen nullified the foundation of geometrical optics, which has been so successful in understanding vision and



so useful for navigation. Consequently, he reformulated geometrical optics to account **for light rays radiating in straight lines from the object to the eyes** instead of visual rays extending out to the objects.

Demonstration: Turn room into camera obscura. See the effect of aperture size on the image. See the **tradeoff** between brightness and resolution. See how a lens affects this tradeoff and introduces a plane of best focus for an object at a given distance. See that for a pinhole, some information is more valuable than all information. See that **image formation can be explained only if light travels in straight lines**. This valuable truth that light travels in straight lines will find its **limitations** when we study the interaction of light with **small microscopic objects**.



Around 1100, Muslim-ruled Sicily and Toledo, Spain became Christian-ruled and scholars of every religion lived side-by-side peacefully in these linguistic borderlands that became multicultural cities. One of the Toledo translators, known as Gerard of Cremona (1114-1187), translated Alhazen's *Optics* into Latin.

Roger Bacon (1214-1294), a Franciscan monk, who was inspired by Robert Grosseteste's way of mixing science and faith, studied the works of the Islamic scholars such as Alhazen which had recently been translated into Latin. He realized how useful this knowledge was and like Augustine of Hippo (354-400), wanted to reclaim scientific knowledge for the service of the Christian faith. Roger Bacon

asserted that the science of vision (**perspectiva),** which had been neglected by the Latins, was the noblest of the sciences and invaluable for biblical exegesis in the pursuit of wisdom since it offered "**sure experiences** of all that is in the heavens and on earth." After all, light, color, vision, and mirrors were frequently referenced in the Scriptures. For example, In John 8:12 it is written, *When Jesus spoke again to the people, he said, "I am the light of the world. Whoever follows me will never walk **i**n darkness, but will have the light of life"* and in I Corinthians 13:12 it is written, "*For now we see through a glass, darkly; but then face to face: now I know in part; but then shall I know even as also I am known"* or *"For now we see in a mirror dimly, but then face to face. Now I know in part; then I shall know fully, even as I have been fully known*."

Bacon felt that the **truth** given by the Bible could be grasped though the development of **reason**, made precise by **mathematics**, and confirmed by **experience**. He thought that an understanding of the natural world would lead to knowledge of its Creator. According to Roger Bacon, "*in the things of the world, as regards to their efficient and generating causes, nothing can be known without the power of geometry*" and that "*it is necessary to verify the matter of the world by demonstrations set forth in geometrical lines.*" As it says in Isaiah 1:18, "*Yes, Come now, and let us reason together*."



Geometric optics tells us that as objects become more distant, their visual angle decreases and this is why they appear smaller to us. This is why the distance between two parallel railroad rails seems to vanish at the vanishing point. It is sometimes useful to think of the vanishing point, not only as the limit of objects of constant size seen at greater distances, but in terms of binocular vision, where the vanishing point is the intersection of visual rays from each eye.

By studying geometrical optics or perspective as it was known, Roger Bacon could use **lenses**, from the Latin word for lentil, to increase the **visual angle**.

Fig. 173.

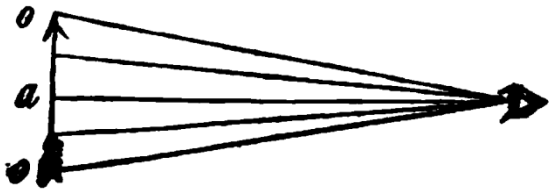
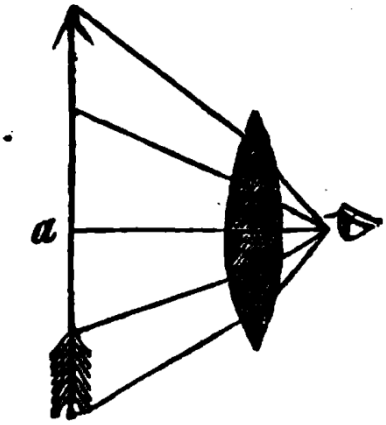


Fig. 174.



To build his knowledge of geometrical optics, Roger Bacon took a new look at **burning glasses**, which had been used since ancient times to light fires. Aristophanes documents the use of burning glasses in *The Clouds* (423 BC):



Strepsiades. "I say, haven't you seen in druggists' shops That stone, that splendidly transparent stone, By which they kindle fire?"
Socrates. "The burning glass?"
Strepsiades. "That's it: well then, I'd get me one of these, And as the clerk was entering down my case, I'd stand, like this, some distance towards the sun, And burn out every line."





Clear glass was also developed to drink and appreciate wine. Aristophanes documents this too. He wrote in *The Acharnians* (425 BC): "*And then they feasted us, and would insist all That we should drink from cups of gold and crystal Their strong sweet wine."* It seems likely that happy and playful wine drinkers would have looked through the glass, that was geometrically similar to burning glasses, and seen small objects magnified.

Roger Bacon studied **refraction** or bending of light and thought that lenses that bent or refracted light might be useful for helping old men read the Bible. Roger Bacon wrote, "*If the letters of a book or any minute objects be viewed through a lesser segment of a sphere of glass or crystal, whose plane base is laid upon them, they will appear far better and larger…And therefore this instrument is useful to old men and to those that have weak eyes. For they may see the smallest letters sufficiently magnified… also that the most remote objects may appear just at hand…."*



For Roger Bacon, light also became a way to dramatize the teachings of the church. The churches and cathedrals were illuminated with candlelight and stained glass windows that illustrated bible stories for the illiterate and were sermons that "*reached the heart through the eyes instead of entering at the ears.*"

Roger Bacon saw knowledge such as the study of optics as a **handmaiden to theology** and not valuable for its own sake. He wrote that "*For every investigation of man that is not directed toward salvation is totally blind and leads*

finally to the darkness of hell." However, Roger Bacon also emphasized the importance of questioning and experimental science in searching for truth. He began his *Opus maius* by discussing **four obstacles to realizing the truth**; obstacles that Moses and Jesus also faced when presenting their message to pharaoh and to the Pharisees, respectively. Bacon also pointed out that, men such as Jerome, who were originally thought of as heretics, were later shown to be right and were made saints.

According to Roger Bacon, **the first obstacle is adherence to flawed and unworthy authority**. **The second obstacle is the persistence of custom, which often favors the false over the true. The third obstacle is popular prejudice, which produces obstinacy and confirms men in their error. The fourth and most serious obstacle error is the tendency to cloak ignorance in a show of wisdom.** Roger Bacon stated that "*Although argument does not suffice for the certification of truth, authority suffices far less….Therefore this [experimental] science wishes to teach that nothing is to be examined by argument or authority unless there is some [confirming] experience*." I want you to provide you with experience and want you to learn to question authority (including me).

Knowledge of **perspective**, as geometric optics was called, allowed later painters, such as Andrea Pozzo (1642-1709), to mathematize the intuitive techniques of *trompe-l'oeil* (using optical illusion to depict objects as three dimensional) or *di sotto in sù* (seen from below) and include architectural elements to develop the technique known as *quadratura* (opening up walls through visual illusion), which creates an imaginary focal point to paint ceilings in churches that appeared to extend to the heavens.







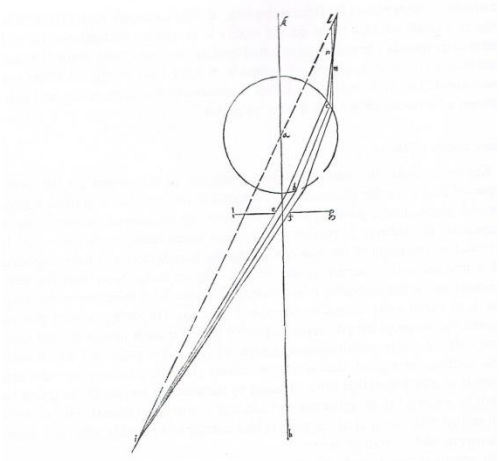
On the right is a beautiful *Trompe l'oeil* of a violin and a bow hanging on a door in Chatsworth painted by Jan van der Vaart (1653-1727). We will hear more about Chatsworth and its gardener Joseph Paxton later in the semester.

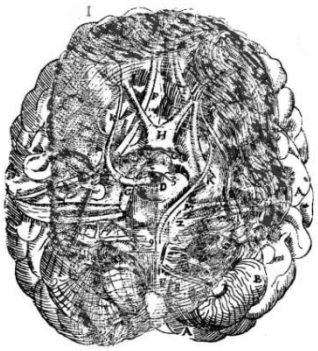
On the right is a *Trompe l'oeil* entitled ***Dipper Missing*** by Darius Cobb (1834-1919). It shows his canteen, battered cap, and knapsack from the Civil War hanging from a door. There is a note nailed to the wall that says "dipper missing" with a picture of a cup on it.



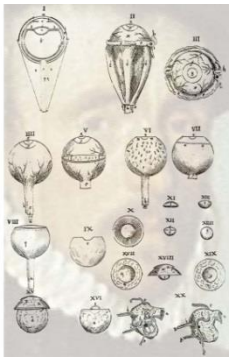


Following work by Alhazen, Leonardo da Vinci (ca. 1500) and others, Giovanni Batitista della Porta (1535-1615), in his book *Natural Magic*, promoted the comparison between the eye and a *camera obscura*. He also popularized the addition of a converging lens to the *camera obscura* in order to maximize the brightness and resolution of the image. This made the *camera obscura* more useful. Johannes Kepler (who actually coined the term *camera obscura*) used the *camera obscura* to survey land and to observe the sun.







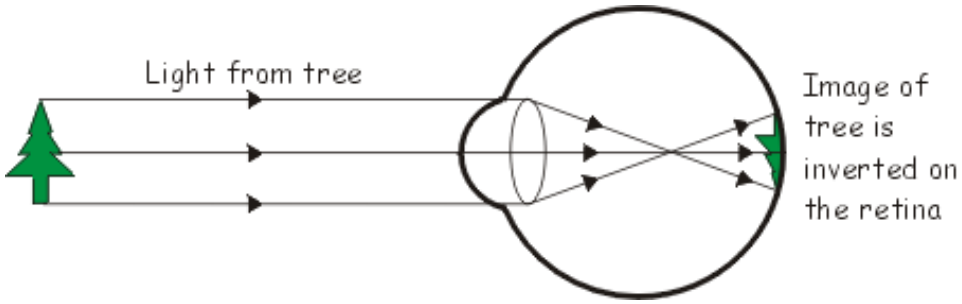


Felix Platter (1583) saw that retina was connected to the brain through the optic nerve and suggested that that the cornea and crystalline lens produced an **erect image** on the retina (from the Latin meaning net, which describes the net-like blood vessels). **Johannes Kepler** (1604) suggested that convergent light rays were bent by the cornea and the crystalline lens together so that an **inverted image** was produced on the retina. Kepler wrote,

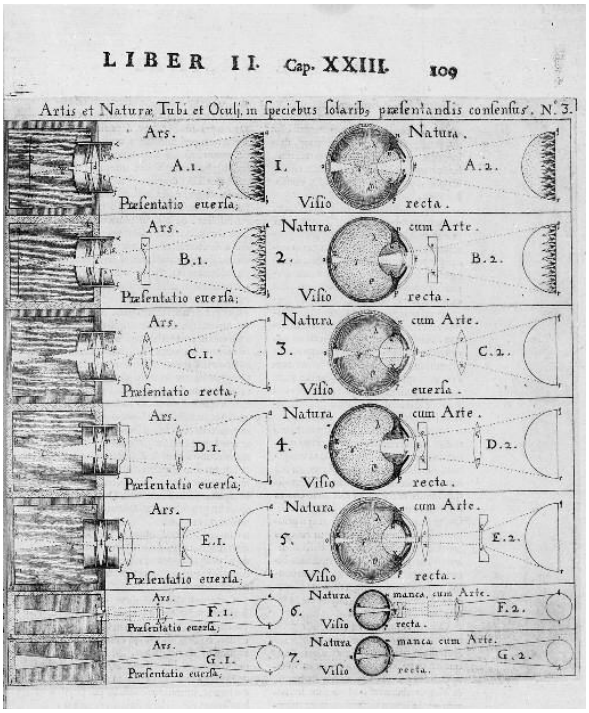
"Vision takes place by a painting of the visible object on the white and concave wall of the retina; the leftward objects are the right side of the wall, the rightward on the left side, the upward on the lower side, the downward on the upper side;

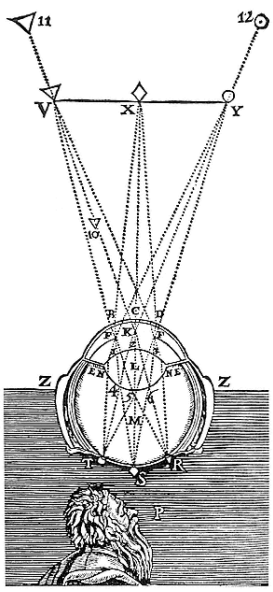
green is painted with the same green color, and in a general manner every object is painted with its original color; so that if this painting on the retina could be exposed to daylight by removing the interposed parts of the eye that serve to form it, and ***if there were a man with sufficient visual acuity****, he could recognize the identical figure of the hemisphere [of vision] on the tiny inside of the retina. Proportions are indeed conserved: the angle under which lines drawn from a given point of the visible object would reach a certain point within the eye is about equal to the angle under which these points are depicted; even the smallest points are not omitted; the sharper is a man's vision, the subtler is this painting in the eye."*

About the inverted image painted on the retina, Johannes Kepler wrote, "*I leave it to the natural philosophers to discuss the way in which this image or picture is put together by the spiritual principles of vision residing in the retina and in the nerves, and whether it is made to appear before the soul or tribunal of the faculty of vision by a spirit with the cerebral cavities, or the faculty of vision, like a magistrate sent by the soul, goes out from the council chamber of the brain to meet this image in the optic nerves and retina, as it were descending to a lower court*."



Christoph Scheiner (*Rosa ursina*; 1630) tested Kepler's theory by placing the eye of an ox and many other animals, including cows, sheep, goats and pigs in which the **sclera** and **choriod** covering the back of the retina had been removed, in the aperture of a *camera obscura*, and saw that an inverted image was formed on the retina the same way it was formed on the wall opposite the pinhole and lens by the *camera obscura* itself. He suggested that the human eye worked the same way.





Rene Descartes (1637) repeated Scheiner's experiment and illustrated it in his Optics book taking into consideration the Snel-Descartes Law of refraction when drawing the light rays. Considering that the image on the retina was inverted, the **mind** must interpret the image and invert it again, indicating that **image formation requires more than optics. It requires the mind**. Descartes wrote, *"…we should consider that there are many things besides pictures which can stimulate our thought, such as, for example, signs and words, which do not in any way resemble the things which they signify….It is only a question of knowing how the images can enable the mind to perceive all the different qualities of the object to which they refer; not how they hold their resemblance."*

Bishop **George Berkeley** agreed that vision was not solely the result of angles and lines. Indeed the **mind**, with all its experiences, was involved in making



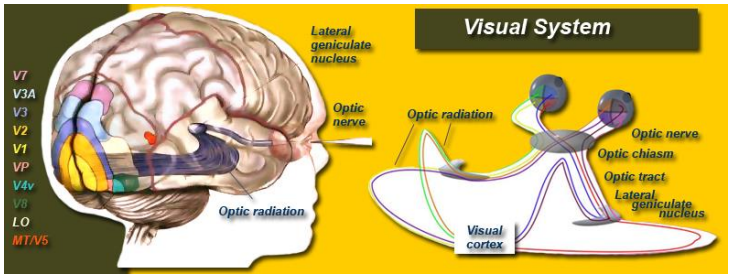
judgments about the nature of the image projected on the retina. He suggested that the inverted image on the retina was judged by the mind to be an erect object, consistent with one's experience with touching the object. According to Berkeley, even the size and distance of objects were not seen directly using lines and angles but judged by the mind. He came to this conclusion after considering the **moon illusion**. That is, even though the moon has a constant size and distance from the earth, it seems larger when it is on the horizon than when it is at its zenith. Berkeley suggested that, just like a word does not have the same significance in our mind when heard in different contexts, an object placed in different contexts will not produce the same image in our mind and an object placed on high will seem smaller than an object placed at an equal distance at eye level. Berkeley showed that an object placed on the top of a one hundred foot high steeple seemed smaller than the same object placed the same distance at eye level. In *An Essay Towards a New Theory of Vision*, Berkeley (1709) concluded that it was the orientation of the head and eyes that determined the apparent size of the object. Bishop Berkeley emphasized that there is a difference between the optical processes of **seeing** in the eye and the final process of **perceiving**, or seeing with the mind's eye. Consequently, vision cannot be left to the simplifications of the mathematicians, but must take into consideration the complications of the mind.

The mind has the ability to correct the image formed on the retina in order to bring it in alignment with reality. In the late 19th century, George Stratton showed that the mind could also learn not to invert an erect image projected on the retina. Stratton wore inverting glasses that produced an erect image on his retina. For four days he saw the world as **upside down** but by the fifth day, his mind brought the visual information in alignment with the tactile information and he began to see the world **right-side up** again. The role of the mind in mediating competing sensory information is known as **perceptual adaptation**.



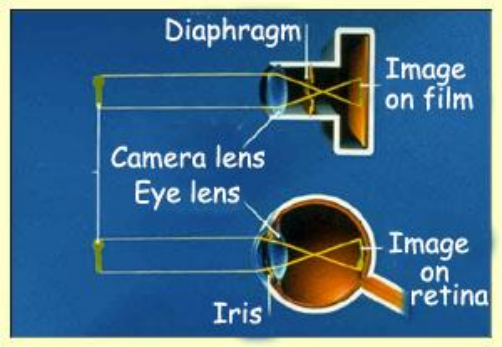
The parts of the brain involved with vision were discovered **serendipitously** as a result of wartime **brain injuries**. People with brain injuries can be blind even though their eyes are perfectly healthy. Following the Russo-Japanese War (1904-1905), Tatsuji Inouye created a map of the visual cortex by correlating **visual field deficits** with regions of the **occipital lobe** of the brain that were damaged by bullets. Gordon Holmes and William Lister (1916) studied the relationship between visual field deficit and regions of the brain that were damaged by bullet wounds in World War I. The spatial resolution of their map compared with Inouye's map was improved because they used X-rays to localize the bullets and the damage was more localized





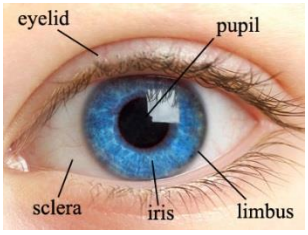
as a result of rifles with greater muzzle velocity and bullets that were smaller and less deformable. Holmes and Lister studied over 2000 soldiers because the WWI British Brodie helmet (as well as the USMC Doughboy helmet) unlike the German (Stahlhelm) helmets did not protect the occipital lobe and the cerebellum.

During WWI, George Riddoch noticed that some soldiers could still perceive **motion** even though they were blind as a result of bullet injury to the visual cortex meant that other regions of the brain were involved in vision. We now know that loss of color vision can occur when there is a lesion outside the visual cortex.



The eye itself can be considered to be an image-capturing, mechanical device **analogous** to a modern day camera. The cornea is the major factor in image formation because of the great difference in the refractive index of the air (n = 1) and the cornea (n = 1.376). The cornea has its own lens cap and lens cleaning system too. The eyelid shuts to protect the cornea; the eyebrows and eyelashes keep out sweat and dust, respectively, and the tears wash the cornea. The light rays are refracted toward the perpendicular by the cornea are slightly refracted away from the perpendicular by the aqueous humor (n = 1.336) on the way to the crystalline lens (n = 1.386-1.406).

The crystalline lens is composed of over 2000 microscopically thin layers. The crystalline lens, with the help of the cilary muscle, fine-focuses the image first made by the cornea. In a human, the distance between the crystalline lens and the retina is fixed, and the crystalline lens, which is elastic, focuses on nearby objects by increasing its



curvature and decreasing its focal length. This process is known as **accommodation**. The inability to accommodate is known as **presbyopia** and can be corrected with reading glasses. In a camera, focusing of nearby objects to take a close-up is effected by moving the lens farther from the CCD (charged coupled device) or CMOS (complementary metal–oxide–semiconductor) chip or film plane.

The color of the eye is determined by the color of the **iris**, named after the goddess of the rainbow. In a later lecture, we will discuss the **inheritance of eye color**. The muscles of the iris control the opening of the pupil. This allows the



amount of light that enters the eye to vary much like the **aperture diaphragm** of a camera lens varies the amount of light that reaches the film. The f-number (focal length/diameter of aperture) of the eye varies from f/8.3 to f/2.1. A larger aperture favors a brighter image with greater **spatial resolution** and less **depth-of-field**, while a smaller aperture favors a dimmer image, with less **aberration** and more depth-of-field. Squinting accomplishes the same results consciously.

The excitation of **photoreceptor cells** captures the image on the **retina** much like a **CCD chip** in a camera captures the image in a camera. In bright light, the retina is analogous to a high resolution color CCD chip or film, while under low light conditions, the retina is analogous to a monochromatic, black and bluish-white CCD chip or film. We will talk more about the development, anatomy and physiology of the eye and color vision over the next two weeks.

The **photoreceptors** that capture the image the retina of the eye are proteins known as **opsins**. The photoreceptor proteins are determined by genes and we will discuss them in terms of **sex-linked inheritance**. When the **chromophores** of the photoreceptors are excited by light, a signal transduction chain is stimulated so that the **radiant energy is transformed into electrical energy** that travels as nerve impulses through the **optic nerve** to the **brain**. The image we perceive however depends on the **mind**, which does the **image processing**. The images captured by digital cameras can also be processed.

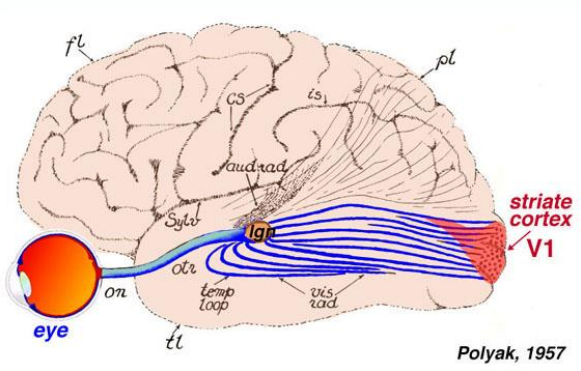


Figure 8. Visual input to the brain goes from eye to LGN and then to primary visual cortex, or area V1, which is located in the posterior of the occipital lobe. Adapted from Polyak (1957).

Our two eyes, which give us **binocular or stereoscopic vision**, are analogous to a stereo camera, which produces two images observed at slightly different angles that the mind processes into a three dimensional image in the minds eye. By taking into consideration the positions of the eyeballs that are creating the visual image, the mind helps us to **judge distance**.



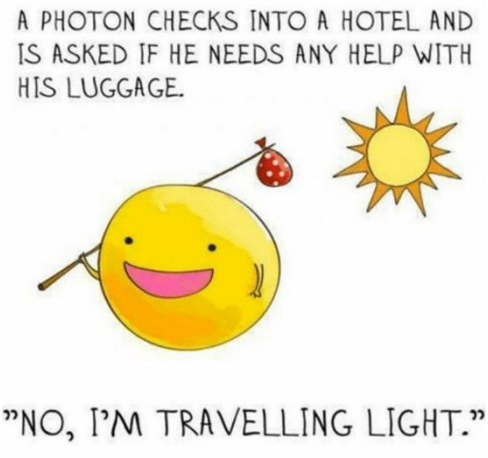


Animals that have two eyes will only have stereoscopic vision that allows them to judge distances if the two eyes are in the same plane so that the two visual fields overlap. This is important for **predatory animals** such as cats and wolves. Primates have stereoscopic vision that allows them to use their hands and to jump from branch to branch. Flounder, which have two eyes in a single plane, also have stereoscopic vision. This helps these bottom-

dwelling predators to catch their prey. Squirrels have eyes that are intermediate between being on the same frontal plane and on opposite sides of their head. There is sufficient overlap of the two visual fields to produce stereoscopic vision which allows depth perception to catch branches and use their hands and also keep a wide angle of surveillance. Small birds that flit through shrubbery have similar eye geometry. Most birds, including the chicken and pigeon, have eyes on the sides of their heads to give them a wide angle for surveillance but must judge distance by moving their heads and focusing with each eye independently. Owls, which are predatory birds, have both eyes in the frontal plane. This gives them stereoscopic vision and the depth perception they need to capture their prey. **Browsing animals** have their two eyes on the sides of their head because surveillance with an all-around view is more important than depth perception. They can see in all directions without moving their head.



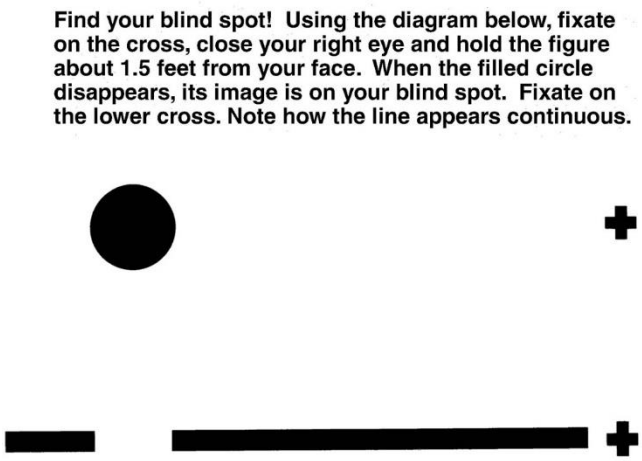
While most animals have two eyes, other animals, like *Cyclops* (a Copepod) have one eye while spiders may have eight.



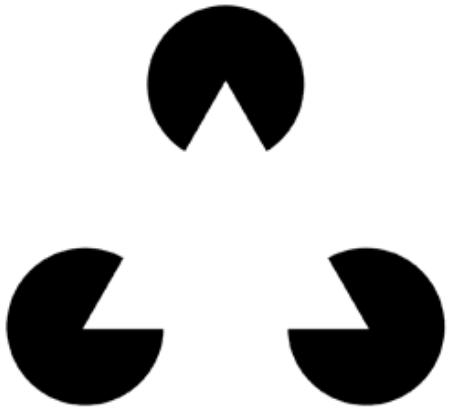
Light, in the form of **photons**, carries **information** about the external world to our retina. The photoreceptors in the retina absorb the photons and transform the spatial information into electrical signals that are encoded by the neural cells of the retina, which include the bipolar cells and the ganglion cells. The electrical signal is then transmitted along the optic nerve and it is further processed by various regions of the brain ultimately forming our **perception**, an image in the mind's eye.

Perception is not determined solely by the physical distribution of light energy in space, but by our mind that searches for the best interpretation of the distribution of light energy in space. That is, our mind combines the sensory information with our knowledge of the world to make the best possible interpretation of the world within a reasonable time. ***Thus we do not perceive the world directly since what we perceive goes beyond the sensory experience of what we see***.

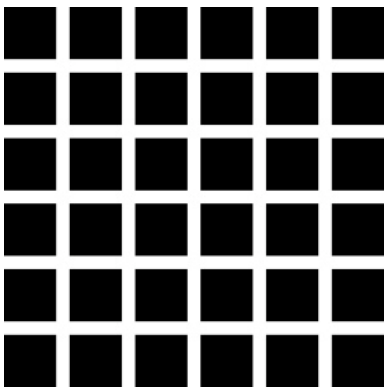
This is clearly demonstrated by the **blind spot test**, in which the way the mind "**completes**" the missing information. As we will see next week, the retina has a region devoid of photoreceptor cells where the optic nerve enters the nasal side of the eye, resulting in a blind spot.



Demonstration: Close your right eye and hold the test pattern 18 inches in front of your eyes. Focus your left eye on the plus sign and move your eye back or forth until the dot disappears.



Usually our perceptions are correct in the way they illustrate the natural world to our mind's eye, but **optical illusions** remind us that this is not always the case. Do you **see** the photons that make up a triangle? Do you **perceive** a triangle? Is a triangle there in reality? What we **perceive** with our



mind's eye is not the **real world**, but is a **testable hypothesis that can be confirmed by experience**. Are we any different from the prisoners in **Plato's cave**?

When we look at the Hermann grid we see the invisible phantom dots at the intersections that are not really there. Again, are we any different from the prisoners in **Plato's cave**?



When we see an **ambiguous image**, which consists of two separately valid images, each of which conforms to a realistic picture of the world, our mind makes a choice between the two i**nterpretations**. We typically cannot see the two interpretations simultaneously, although one can learn how. Do you see a woman sitting at a vanity or a skull in Charles Gilbert's (1920) "All is Vanity?"

Do you see a goblet or two faces in Edgar Rubin's (1915) "Hidden Faces and Goblet?"



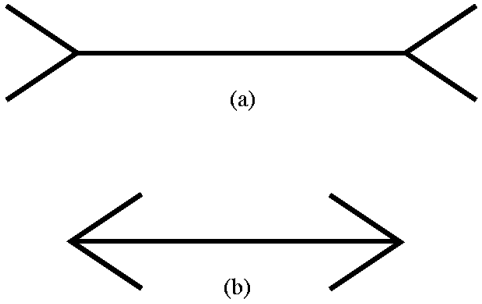
Do you see a young woman or an old woman in this picture on an old German postcard from 1880?



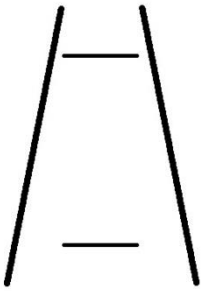
We will use optical illusions to document that we do not perceive the world directly as a camera does because the mind processes visual images. The mind makes certain logical and reasonable assumptions such as the influence of distance on size and that there is only one source of light illuminating the object. In everyday life, the processing gives a rapid and realistic view of the world with a modest number of photoreceptors and neurons. We can confirm the limitations of

the mind's image processing capability when we study objects that we do not realize are optical illusions until we investigate the image using rulers, light meters or touch.

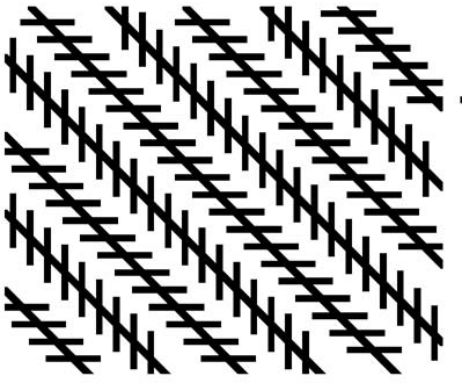
In the Müller-Lyer illusion, the lengths of the horizontal lines in figures (a) and (b) are the same, yet our minds trick us in seeing the line in (a) longer than the line in (b). Even after we measure the lengths of both lines, we still see the line in (a) longer than the line in (b). Why can't our minds fix the illusion in the same manner it erects the inverted image on the retina, to give us the right answer?



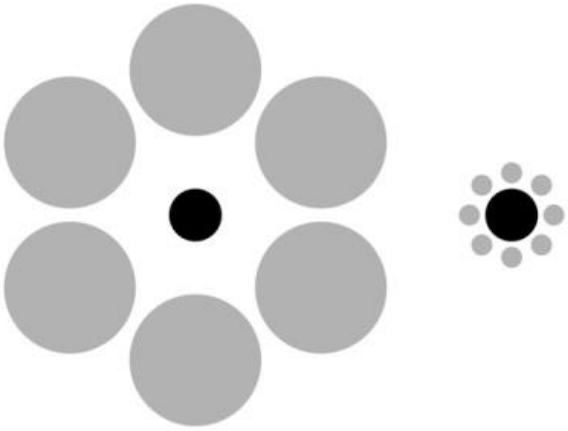
In the Ponzo illusion, the lengths of the two horizontal lines are the same, yet our minds trick us in seeing the upper line as longer than the lower line. Again, even after we measure the lengths of both lines, we still see the upper line as longer than the lower line. Why can't our minds fix the illusion and give us the right answer?



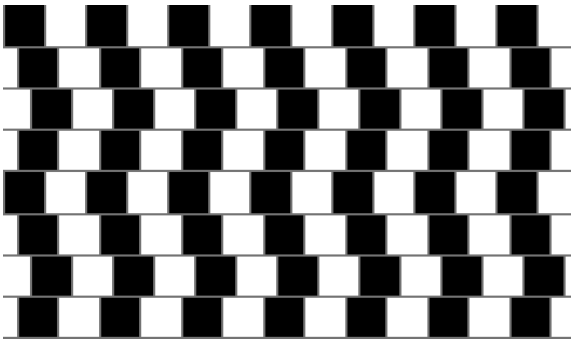
In the Zöllner illusion, parallel lines appear to diverge or converge when the lines are crossed by short lines that appear to be a part of an arrowhead or a barb, respectively. Why can't our minds fix the illusion to give us the right answer?



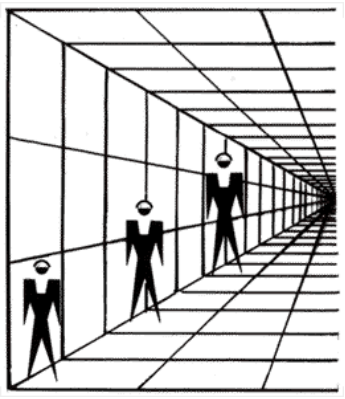
In the Ebbinghouse illusion the central spots are the same size even though the one on the right looks larger. Why can't our minds fix the illusion and give us the right answer?



The mind cannot make the horizontal lines in the figure below straight,

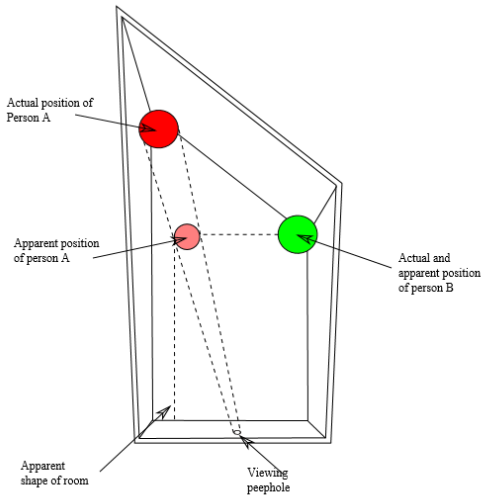


nor perceive the people in the figure on the right to have the same height.



In the **Ames Room illusion**, which is an architectural illusion, we **think** that the room is a cube, even though, in **reality**, it is trapezoidal. Consequently, we **perceive** that a person standing at position A is tiny and a person standing at position B is a giant. A single person walking between position A and position B seems to grow and shrink. Are we any different from the prisoners in **Plato's cave**? What if the cave were trapezoidal shaped?





We discussed **spatial information** that contributes to optical illusions. What about **temporal information**? **When** do we see? Light takes time to travel from an object to our eye, but more importantly now, it takes time to process the visual information. Under low light conditions, it takes more time before a neural cell is sufficiently stimulated to fire. The dimmer the light, the more time it takes to process the image.

Demonstration of the **Pulfrich Pendulum Effect:** Look at the apple pendulum swinging back and forth in a straight line. When you look with both eyes at the pendulum swinging perpendicular to your line of sight, it appears to move in a straight line. When you put a neutral density filter in front of your left eye, the apple will appear to move clockwise in an ellipse and when you put the neutral density filter in front of your right eye, the apple appears

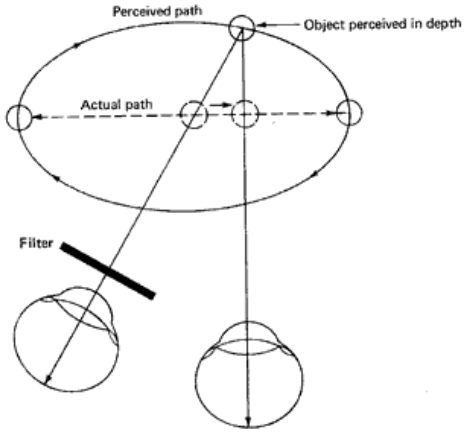
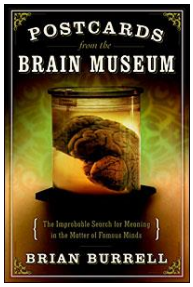


Fig. 13.7. The Pulfrich phenomenon. The attenuated eye perceives the pendulum ball as lagging behind the position as seen by the unattenuated eye. This is consistent with the ball actually traveling in an elliptical path, as shown.

to move counterclockwise in an ellipse. **Try this at home** using sunglasses that only cover one eye at a time.



The **waterfall illusion** observed by Robert Addams (1834) at the Falls of Foyers in Scotland is another **temporal** optical illusion. You can observe the waterfall illusion at Taughannock Falls. When one stares at a waterfall for a period of time and then looks to the side; the stationary rock face beside the waterfall appears to move up. Also after stopping a video of a waterfall, it looks like the water goes up!

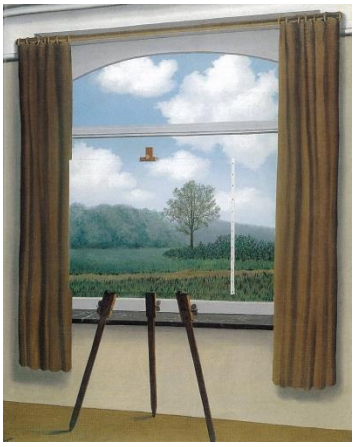


In the "**Allegory of the Cave**," **Plato** warned us of the discrepancy between perception and reality and presented an example of how one man learned the difference. Later on, **Roger Bacon** warned us not to blindly accept any authority's view of reality. It is unlikely that we will ever see true reality, but we can do our best to understand it, and the laws of nature can help us with this.

All too often we take the world around us for granted as we quickly and effectively go from all the point A's in our life to all the point B's. The reason we are able to take the world around us for granted is because our visual system, composed of our eyes and mind, is so effective in creating a seamless and accurate representation of the world in our mind's eye. The mind usually creates seamless and accurate perceptions in real time because most of the assumptions, upon which the image processing takes place, are justified.

However, our creative mind is also **playful** and plays tricks on us. This can be joyful and fun, especially when looking at optical illusions. The playfulness may be a design feature or an evolutionary adaptation to remind us not to take

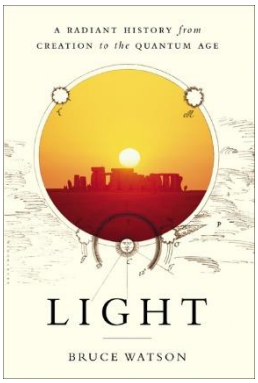
ourselves too seriously. But if we really want to know something about the **natural and objective world** around us, and this applies especially to natural scientists (Tolansky, 1964), we have to get to know the value and limitations of our **assumptions** and how we use our minds to construct our personal hypotheses about the natural world, and how these personal hypotheses can be **generalized** into **laws of nature**. It is the human condition (Magritte, 1933) that we have an amazing ability to distill out the **laws of nature**, which is a shared image of the world, from the paintings on our retinas and the images created immediately by our mind's eye.

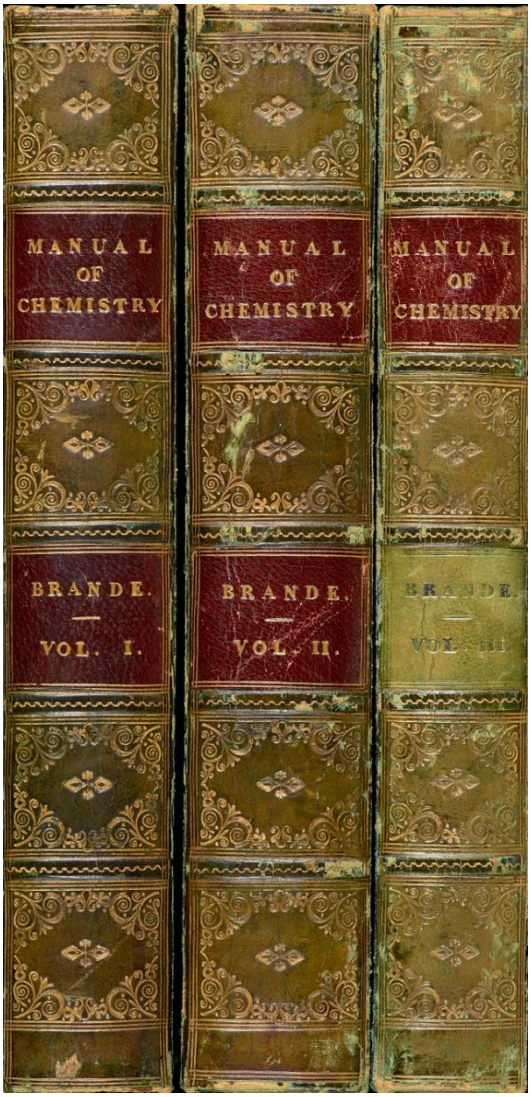


The mind is a *sine qua non* for seeing the world in a meaningful way. **Do you *see* what I mean?** The image in our mind's eye of reality is much like a scientific theory used to describe and explain reality. Both must be considered provisional and both must be tested by experience. According to Joseph Priestley (1787), "*The great superiority of man over brutes consists in the greater* comprehensiveness of his mind*, by means he is, as it is commonly expressed, capable of* reflection*…."* In *The Everlasting Gospel*, William Blake wrote about the importance of the mind/soul in seeing:

This life's five windows of the soul
Distorts the heavens from pole to pole
And leads you to believe a lie
When you see with, not through, the eye.

Bruce Watson wrote an exellent book on light from creation to the quantum age.





William Thomas Brande (1848) wrote in *A Manual of Chemistry*, "***It may seem trite to quote Lord*** [Francis] ***Bacon; but, as experience is constantly showing the neglect of the invaluable doctrines inculcated in his works, and as students, especially, are too apt to throw off the burden and responsibility of thinking for themselves, by adopting the notions of others, without duly weighing their merit or appreciating their correctness, and often only because they are new, I shall call their attention to one of the many relevant passages of this author:—***

'He who would come duly prepared, and fitted to the business of interpretation, ***must neither be a follower of novelty, custom, not antiquity; nor indulge himself in a liberty of contradicting; nor servilely follow authority****. He must neither be hasty in affirming, nor loose and skeptical in doubting; but raise up particulars to the places assigned them by their degree of evidence and proof. His hope must* ***encourage him to labor****, and not to rest; he must* ***not judge of things by their uncommon nature, their difficulty, or their high character****; but by their just weight and use. He must, in his own particular, carry on his view with concealment, and yet have due regard for posterity. He must* ***prudently observe the first entrance of errors into truths, and of truths into errors, without despising or admiring anything****. He must understand his own talents and abilities, or the advantages of his own nature. He must comply with the nature of others. He must, as with one eye, survey the natures of things, and have the other turned towards human uses.* ***He must distinctly understand the mixed nature of words, which is extremely capable both of prejudicing and assisting****. He must lay it down to himself, that the art of discovering will grow up, and improve, along with discoveries themselves. He must not be vain either in delivering or concealing the knowledge he has acquired, but ingenuous and prudent, and communicate his inventions without pride or ill-nature: and this in a strong and lively manner, well defended against the injuries of time, and fit for the propagation of knowledge, without occasioning errors; and, which is the principle thing of all, it must be such as may select and choose for itself a prepared and suitable reader."*"

I will not teach and test you on my own conclusions but will teach you to come up with your own conclusions by reflecting on the things that I present to you and by turning the knowledge presented in this class into your own ideas, your own perspective, your own wisdom. ***Remember, do not believe anything I say***. I will not try to convince you of anything but will give you the resources to stoke your inner fire of passion, logic, and reason so that you can come to your own well-conceived and well-thought-out conclusions and convictions. What is right for one person may not be right for someone else and it follows that there may be many different yet correct answers to test questions. As Socrates said, "*For it is not from any sureness in myself that I cause others to doubt: it is from being in more doubt than anyone else that I cause doubt in others*." Throughout this semester, we will do experiments and make observations that will assist you in developing your own conclusions. I will teach at a level that, in the words of Arthur C. Clarke (1974), "*all the fundamental problems and their solutions can be understood even by anyone who is terrified at the thought of changing a burned-out lamp-bulb*." I want to teach you to make up your own mind, and to make arguments, not based on **talking points** that have become the foundation of groupthink but based on having a **line of reasoning** that seems to be closest to the truth. Knowledge obtained in this way will not only develop strong minds but also tough skins. That is, character.

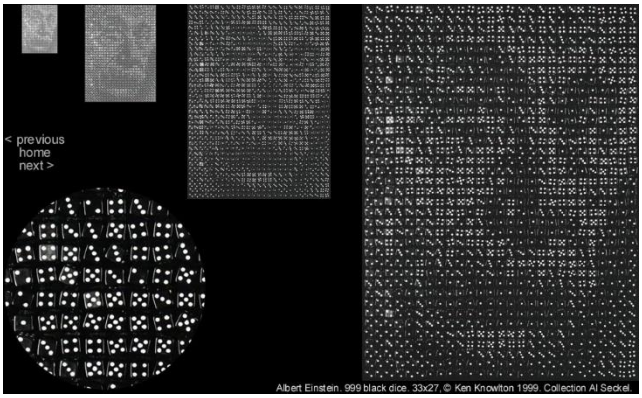




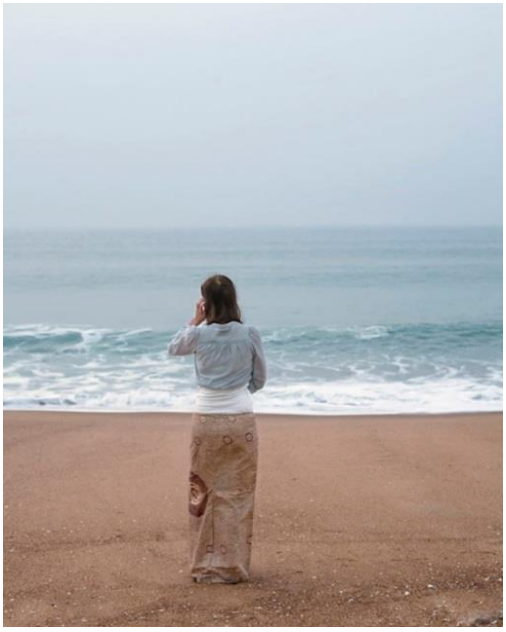
Hannah Arendt (1971) wrote in *The Life of the Mind--Thinking*, "*There are no dangerous thoughts; **thinking itself is dangerous**…*[b]*ut that danger does not arise out of the Socratic conviction that an unexamined life is not worth living, but, on the contrary, out of the desire to find results that would make further thinking unnecessary…However, non-thinking, which seems so recommendable a state for*

political and moral affairs, also has its perils…the readiest to obey will be those who were the most respectable pillars of society, the least likely to indulge in thoughts, dangerous or otherwise…."

I'll end with a reference to divinity. Ken Knowlton (1999) (http://www.knowltonmosaics.com/pages/AEdice.htm) created a mosaic out of dice called, "**God Does Not Play Dice with the Universe**" that is now in the collection of Al Seckel (http://www.ted.com/talks/al_seckel_says_our_brains_are_mis_wired.html) . When you stand back from the mosaic, Albert Einstein's face appears. In contrast to many of his contemporaries and almost all current scientists, Einstein did not believe that the Uncertainty Principle of Quantum Mechanics was fundamental.



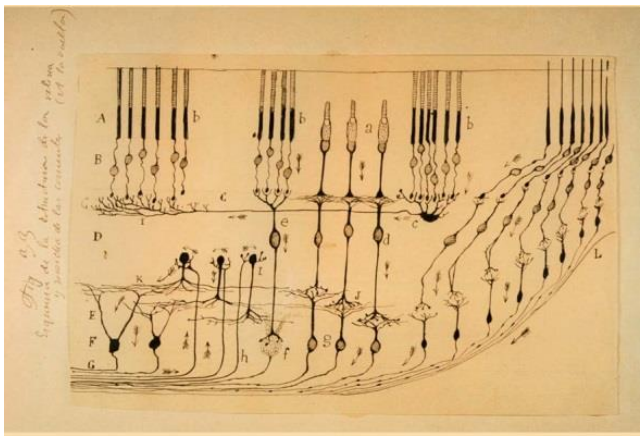
Light and Life: Geometrical Optics and Image Formation



As Plato advised us in the "***Allegory of the Cave***," we can discover and learn the **rules** that relate our perception of reality to reality itself. Today we will talk about the mathematical or geometrical rules known as the **laws of reflection and refraction** that relate the perceived image to the real object. But before we do, I want to remind you of two illusions that demonstrate that the rules that relate perception to reality are not limited to those that are mathematical or geometrical. As Bishop Berkeley predicted, there are also higher-order and "wholistic" rules than cannot be **reduced** currently if ever to geometry.

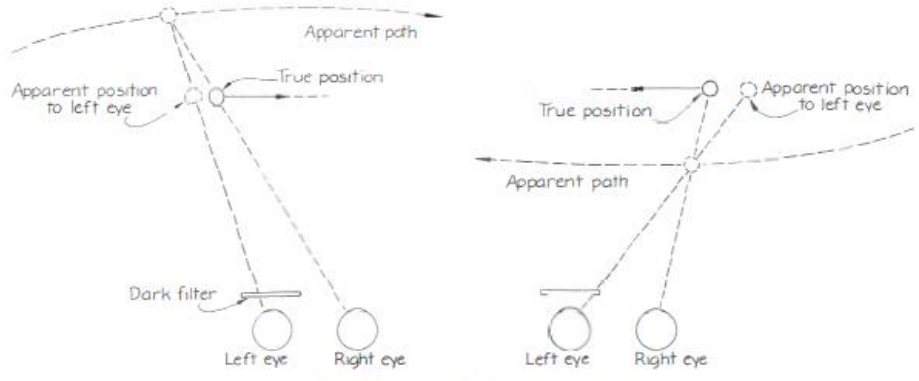
Last class we experienced the **Pulfrich pendulum effect**, which taught us that our **perception** of an object is ***not*** determined solely by the physical distribution of **light energy** at a given point in **space** at a given instant in **time**. Is this illusion an evolutionary maladaptation and/or a deficiency in the design of the visual system or a consequence of evolutionary adaption and/or good design? The eye that we cover with a neutral density filter while observing the Pulfrich pendulum illusion becomes dark-adapted and the rods become the primary photoreceptors (**skotopic vision**). Rods are sensitive to minute levels of light, but the high sensitivity of the rods can result in their occasional "misfiring" in the dark. In order to prevent the perception of would-be annoying twinkling noise from this misfiring, several rods are connected to a single bipolar cell in the retina. Together, the neural cells in the retina **integrate spatially and temporally** the output from several rods so that the ganglion cell only transmits a signal to the brain when the

inputs from the rods surpass a threshold. This integration increases the signal-to-noise ratio by pooling weak signals in the dark-adapted eye before sending an impulse to the brain and withholding from the brain any isolated signal that would most likely represent would-be annoying twinkling noise.



"Schematic representation of mammalian retina structure. Artistic grouping of cells and direction of current flow" A, layer of rods and cones; B, visual cell body layer; C, outer plexiform layer; D, bipolar cell layer; E, inner plexiform layer; F, layer of ganglion cells; G, optic nerve fiber layer; L, central fossa. Modified from a photograph taken from the original (22X32 cm). Drawn on sheet/paper. P.Y. 1901.
S.R. y Cajal Institute - CSIC - Madrid, Spain.

As a result of the **neural integration**, the dark-adapted eye sends a delayed impulse to the brain that reports on the past position of the apple while the light-adapted eye (**photopic vision**), which relies on the **cones** of the **fovea**, sends an immediate impulse to the brain that reports the nearly-present position of the apple. At any instant, the brain receives two messages—one from the light-adapted eye that gives the nearly-present position of the apple and one from the dark-adapted eye that gives the past position of the apple. The mind combines the two images seen at two times into one image. Consequently, we interpret the two messages to mean that the apple is farther away when it moves from the covered eye towards the uncovered eye and closer when the apple moves from the uncovered eye towards the covered eye.



The analogous Pulfrich illusion with a swinging pendulum

The Pulfrich pendulum effect is not necessarily a maladaptation or a design flaw, but a happy consequence of the adaptive and well-designed ability of the neural cells to "**rule**" over the rods they are connected to in order to minimize distracting twinkling. This rule increases the signal-to-noise level in dim light by performing an integration, which is similar to **freshman-level calculus**. Perhaps it is possible, as Richard Dawkins (1987) wrote in "*The Blind Watchmaker*," "*to understand [a complex process such as vision] in terms of simpler parts that we do already understand."* Taking his hierarchical reductionism to the limit, Dawkins **believes** that complex objects and processes will be "*ultimately explained in terms of the smallest of fundamental particles*."



When we see the **waterfall illusion**, it is because the neurons in the brain (at least in a cat's brain in which the electrophysiological experiments have been done) "**rule**" over what we (or the cat) perceive. When we look at a constantly moving object, such as a waterfall, the mind seems to consider it "status quo and safe" and the neurons in the brain that are involved in sensing motion adapt. Consequently, when we change the input to these neurons by looking away or stopping the motion, we temporarily perceive stationary objects as objects moving in the opposite direction. The illusion seems to be a consequence of our mind reducing the priority of constant velocity and increasing the priority of acceleration (= change in velocity). This seems reasonable to anyone who may be considered to be someone else's dinner.



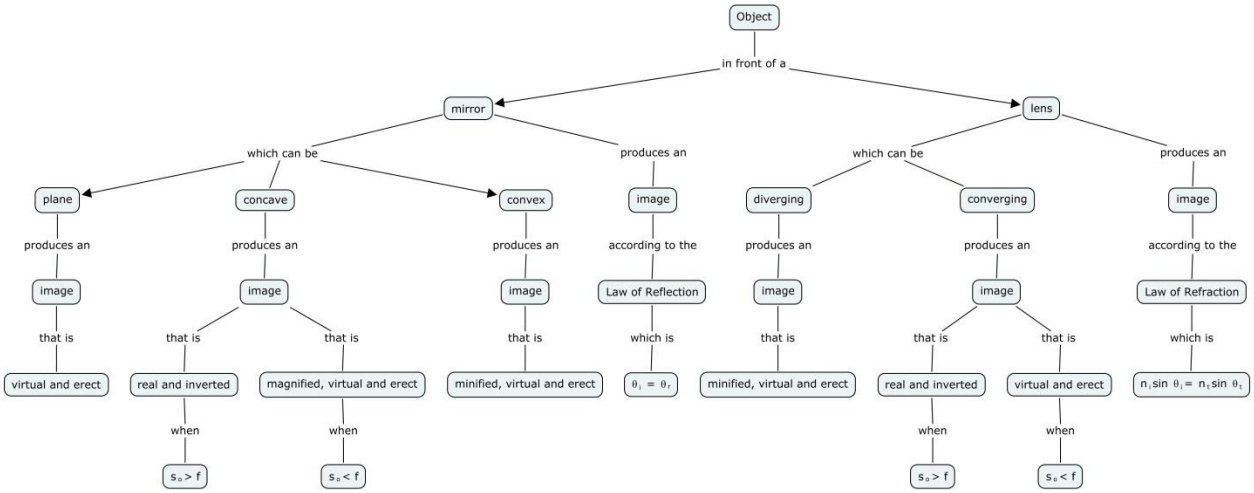
It is generally true that a given **cause** has more than one **effect**. The Pulfrich pendulum effect leads us to the insight that higher-level rules ensure that the

sensitivity of dark-adapted vision is good **enough** but not maximal, since maximal sensitivity would cause us to see annoying twinkling. The waterfall illusion leads us to the insight that everything cannot be the highest priority and higher-level rules ensure that **the mind sets priorities** in terms of perceiving movement. The **tradeoff** that occurs when a **part** of the mind cedes its ability to sense constant movement is that the **whole** mind can be more aware of potentially dangerous movement. By studying nature, we see the universal truth that **too much of a good thing may not be a good thing** and that **everything has values and limitations**.

This truth is concisely demonstrated by the **camera obscura.** We saw that when a piece of translucent vellum is put up to a window it does not produce an image even though it captures most of the image-forming light rays that originate from each point on the objects outside the window. However, when the number of image-forming rays originating from each given point on the object is limited by a pinhole, *mirable dictu*, an image is formed. In fact, the more the aperture reduces the number of image-forming rays, the sharper the image is. Thus, we see, literally and figuratively, that more of a good thing is not always better. There are tradeoffs here too, since the smaller the aperture, the dimmer the image is, and we see that less of a good thing is not always better either.

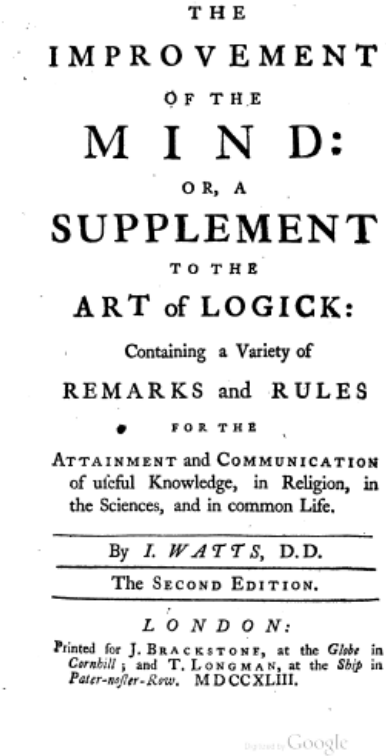
While we are talking about the mind, I want to remind you of, or introduce you to, **concept maps**, which were developed by Joe Novak at Cornell University to help students learn science in a meaningful way. A concept map is a concise representation of ideas that answers a specific **focus question**, such as: What is the relation between the object and the image according to geometrical optics? The very act of constructing a concept map develops logical thinking and a deeper understanding of the concepts because a well-constructed concept map reveals hierarchical connections between concepts and tests your understanding of how the

parts relate to the whole. **Cmap Tools** is software that can facilitate your use of concept maps and is available to you at no cost at http://cmap.ihmc.us/. Here is a concept map that I just drew for the focus question: What is the relation between the object and the image according to geometrical optics?



Concept maps are created by first choosing a **provisional focus question**, which is to be answered by the concept map. It is often the case that the focus question gets revised as you construct the concept map as a result of your understanding becoming more refined. The second step in forming a concept map is to think of the **concepts** that are related to the focus question. Then you do triage on the list to glean the most important concepts. In the above case, important concepts included object, image, law of reflection, mirror, law of refraction, lens, real, virtual, inverted, erect, magnified, minified, the object position (s_o) and the focal length (f). The third step is to choose **explicit linking words** that make **meaningful connections**, known as **propositions**, between the concepts. As you develop the propositions in the map, you create a **hierarchy**, through trial and error, that most clearly and completely answer your focus question.

Notice that this concept map does not even mention the eye or the mind. You can create a different concept map that relates the object to the image on the retina by including concepts such as cornea, aqueous humor, pupil, iris, crystalline lens, vitreous humor, and retina. You can also create a concept map that relates the object to the image perceived by the mind's eye. Cmap Tools will allow you to link related concept maps. It will also allow you to build concept maps with other students in the class. Cmap Tools allows you to attach pictures to the concept, which is a great way of using the photographs that you take for your calendar to help you study.


THE
IMPROVEMENT
OF THE
MIND:
OR, A
SUPPLEMENT
TO THE
ART of LOGICK:
Containing a Variety of
REMARKS and RULES
FOR THE
ATTAINMENT and COMMUNICATION
of uſeful Knowledge, in Religion, in
the Sciences, and in common Life.
By I. WATTS, D.D.
The SECOND EDITION.
LONDON:
Printed for J. BRACKSTONE, at the Globe in Cornhill; and T. LONGMAN, at the Ship in Pater-noſter-Row. MDCCXLIII.
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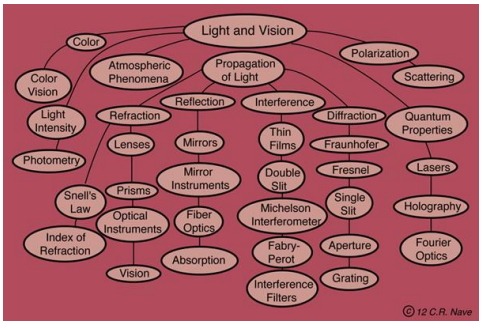
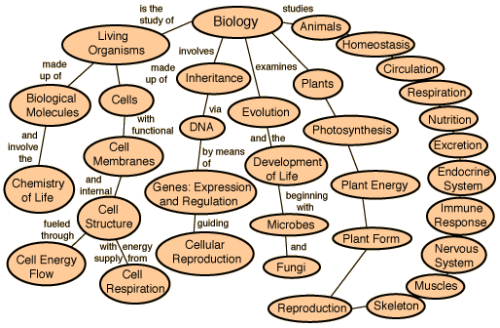
You may be interested in reading the chapter on determining a question in **Isaac Watts**' *The Improvement of the Mind*

XII. IN determining a question, especially when it is a Matter of Difficulty and Importance, do not take up with partial Examination, but turn your Thoughts on all sides to gather in all the ***Light*** *you can toward the Solution of it. Take* ***Time****, and use all the Helps that are to be attain'd before you fully determine, except only where present Necessity of Action calls for speedy Determination.* Aside: Isaac Watts wrote the lyrics to "*Joy to the World*," based on Psalm 98.



The HyperPhysics website, (http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html) makes use of concept maps to explain many concepts in physics, including concepts related to light and vision (http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html).

The HyperPhysics website also includes biology concepts (http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html):

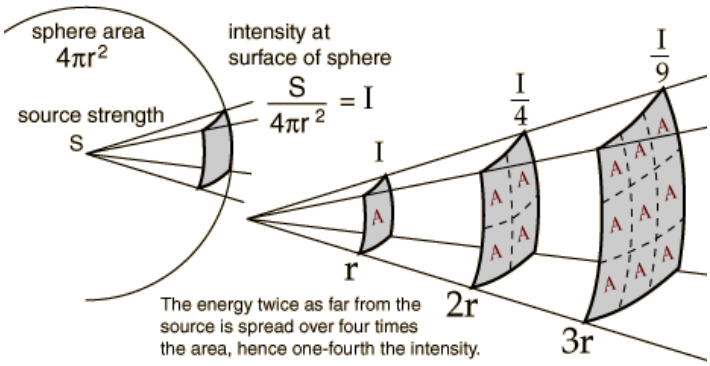






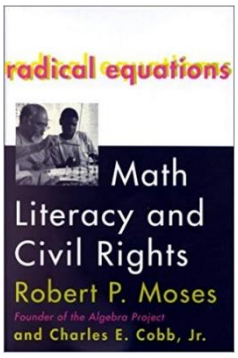
The size and form of the **shadows** cast by opaque objects such as camels lit by sunlight in the desert, trees lit by moonlight, silhouette images (named after the penny pinching Étienne de Silhouette), and the Pilobolus dancers lit by stage light can be most clearly and **parsimoniously described and explained** if **light travels in straight lines**. Likewise, the **images** formed in the **camera obscura** can be most clearly and **parsimoniously described** and **explained** if **light travels in straight lines**.

If light rays radiated in straight lines from a point source of light in all directions, the intensity of the light would decrease by the inverse square of the distance. This is because the radiant power (= energy per unit time) from the source would be spread out over a surface whose **area** is proportional to the square of the **distance** from the source. Since the surface area of a spherical surface is given by ($4\pi r^2$) and the distance is given by the radius (r), the intensity (I_r) of the light striking a constant area size at distance (r) from the source is proportional to the radiant power of the source (S_{source}) and inversely proportional to the square of the radial distance. Let's test the **inverse square law**.

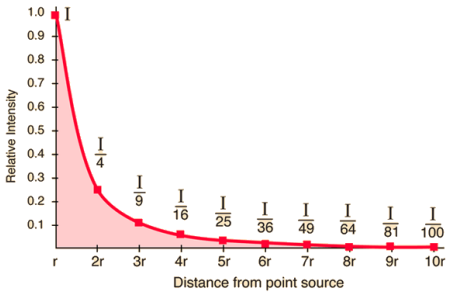


$$I_r = \frac{S_{source}}{4\pi r^2}$$



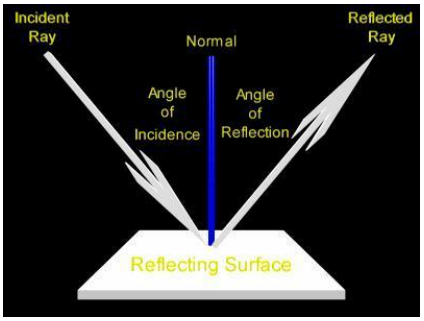


Demonstration: Use a beeswax candle from Monticello as an approximation of a point source of light and measure the intensity at successive distances with a quantum radiometer. Sketch your results and observe the shape of the curve. Are your results described by the **inverse square law**? The quantum radiometer is calibrated in µmol photons m^{-2} s^{-1} (= 6.02 x 10^{17} photons m^{-2} s^{-1}). We will assume that **corpuscles** of light, which Einstein called *lichtquanten*, and are now universally known as **photons**, are moving out from the source along each ray.



Now we will talk about the influence of **reflection** on **image formation**. We now have sufficient empirical evidence to believe that **light travels in straight lines**. However, as was known by the ancient Greek philosophers, when a light ray strikes a mirror it **changes direction** and travels as a different straight line as described by the **law of reflection**. While the mathematical law of reflection had been known for centuries, Dante Alighieri (1265-1321) poetically described the law of reflection in Pugatorio Canto XV of *The Divine Comedy*:

As when from off the water, or a mirror,
The sunbeam leaps unto the opposite side,
Ascending upwards in the self-same measure
That it descends, and deviates as far
From falling of a stone in line direct,
(As demonstrate experiment and art) . . .



…or more succintly, $\theta_r = \theta_i$, **the angle of reflection (θ_r) is equal to the angle of incidence (θ_i).**

Sunlight is reflected from a shiny metal mirror in such a way that a beam of sunlight, composed of parallel rays is reflected at the same angle relative to the normal as the incident beam strikes the mirror. The reflected light leaves the surface as a beam and this is known as **specular reflection**. However, if the surface that the sunlight strikes is not smooth and shiny, but coarse and rough, the rays that compose the beam strike the surface at many angles and the rays of light are reflected at those many angles,

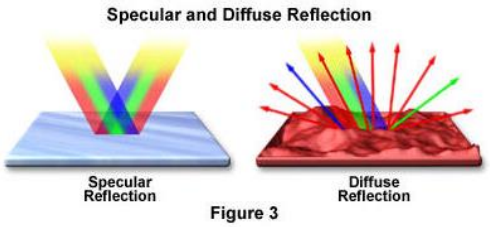
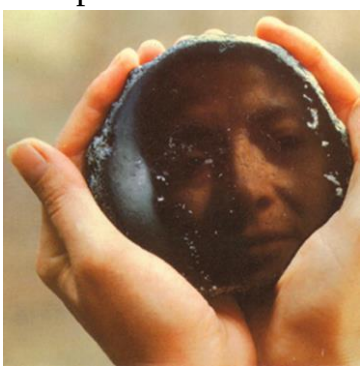
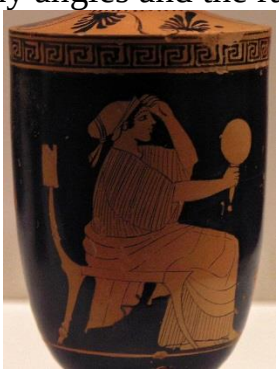
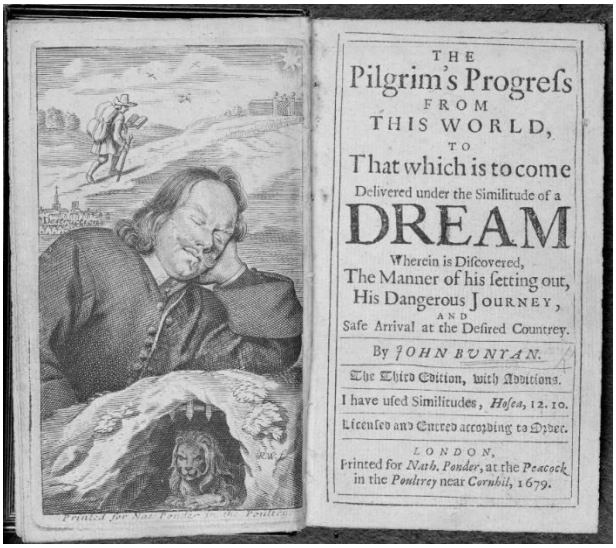


Figure 3






each of which obeys the law of reflection. The reflected light forms a cone and this is known as **diffuse reflection**. In ancient times, the reflection from polished obsidian (6000 BC), stone, or metal mirrors was probably more diffuse than and not as specular as the reflection from mirrors we use today made of flat metal-coated glass. I guess that vanity (from the Latin *vanus*, which means empty) is at least 8000 years old and part of human nature. http://www.ucl.ac.uk/museums-static/digitalegypt//metal/mirrors.html


THE
Pilgrim's Progress
FROM
THIS WORLD,
TO
That which is to come
Delivered under the Similitude of a
DREAM
Wherein is Discovered,
The Manner of his setting out,
His Dangerous JOURNEY,
AND
Safe Arrival at the Desired Countrey.
By JOHN BUNYAN.
The Third Edition, with Additions.
I have used Similitudes, Hosea, 12. 10.
Licensed and Entred according to Order.
LONDON,
Printed for Nath. Ponder, at the Peacock
in the Poultrey near Cornhil, 1679.

Imagine being lighter than emptiness? **John Bunyan** (1679) wrote in *The Pilgrim's Progress*, "Then I saw in my Dream, that when they were got out of the Wilderness, they presently saw a Town before them, and the name of that Town is *Vanity*; and at the Town there is a *Fair* kept, called *Vanity-Fair:* It is kept all the Year long, it beareth the name of *Vanity-Fair*, because the Town where tis kept, is *lighter then Vanity;* and also, because all that is there sold, or that cometh thither, is *Vanity*. As is the saying of the wise, *All that cometh is vanity*."


VANITY FAIR
A Novel without a Hero.
BY
WILLIAM MAKEPEACE THACKERAY
LONDON
SMITH, ELDER & Co 15 WATERLOO PLACE

In *Vanity Fair*, **William Makepeace Thackeray** (1848) wrote, *The world is a **looking-glass**, and gives back to every man the **reflection** of his own face. Frown at it, and it will in turn look sourly upon you; laugh at it and with it, and it is a jolly kind companion; and so let all young persons take their choice.*

Most of us know *Vanity Fair* as a magazine that reflects the times:





Primitive blown glass mirrors coated with metal were developed in Sidon in Phoenicia in 1 AD. Since blown glass is not as flat as plate glass, these mirrors were small and not very planar. Metal-coated glass mirrors improved. In his encyclopedic book, written in the 13th century entitled, ***Speculum Majus*** (which is Latin for Large Mirror) that "*contains that [which] is worth admiring or imitating among the things that have been done or said, in the world visible and invisible*," **Vincent of Beauvais** (1190-1264) extolled the virtues of tin-coated glass mirrors over polished metal mirrors. By the 16th century, reflective and flat mercury-coated **plate glass** mirrors were produced by Venetian glassmakers. The secret process used to make the excellent mirrors became known throughout Europe as a result of industrial espionage. The toxic mercury was finally replaced with silver, tin, and/or aluminum.

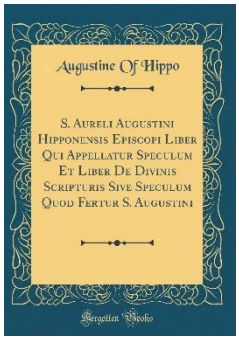


At the time the New Testament was written, the images produced by mirrors (*specula* in Latin) were probably not very sharp. Moreover, the mirrored surfaces were probably made of metal and not glass. Consequently, "*For now we see only a reflection as in a mirror*" was probably anachronistically translated in the 17th century as "*For now we see through a glass, darkly* (*Videmus nunc per speculum in aenigmate)*" (1 Corinthians 13:12).



As **Roger Bacon** (1214-1292) realized, the Bible makes use of many optical analogies involving reflections. It is written in Proverbs (27:19), "*As water **reflects** the face, so one's life **reflects** the heart*." The apostle James (James 1:23-24) wrote, "*Anyone who listens to the word but does not do what it says is like someone who looks at his face in a mirror and, after looking at himself, goes away and immediately forgets what he looks like*." The importance of the Bible as a mirror became part of Christian thought. **Augustine of Hippo** (427) extracted the divine precepts from the Old and New Testaments into a single volume that he entitled ***Speculum***, for those, who were not great readers, so that they could ***reflect*** on their obedience to God. **Pope Gregory the Great** (ca. 600) wrote, "*The Holy Bible is like a mirror before our mind's eye. In it we see our inner face. From the Scriptures we can learn our spiritual deformities and beauties. And there too we discover the progress we are making and how far we are from perfection*."







The word speculation is related to speculum. To **Thomas Aquinas**, speculation meant a consideration of the relationship between two subjects that could be modeled by the relationship between the object and the image produced by a mirror and described by the law of reflection.Thomas Aquinas (ca. 1250) wrote "*To see something by means of a mirror is to see a cause in its effect wherein its likeness is reflected. From this we see that 'speculation' leads back to meditation*."





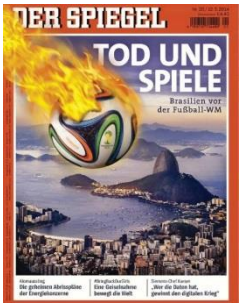


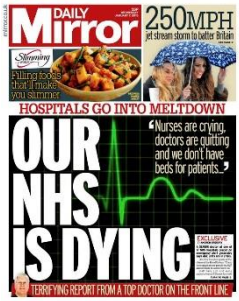
The church was not always supportive of optical knowledge. In the 13th century there was a movement to protect religious orthodoxy and eliminate heresy—"*any provocative belief or theory that is strongly at variance with established beliefs or customs*." The word heresy comes from the Greek word *haireisthai* meaning to choose. **Robert Grosseteste** (1175-1253), a bishop and a scientist, whose optical research (*De Luce*) inspired Roger Bacon, defined heresy as "*an opinion chosen by human perception, created by human reason, founded on the Scriptures, contrary to the teachings of the Church, publicly avowed, and obstinately defended*." The movement to prevent questioning the orthodoxy was ironically known as the *inquistion*—which means a period of prolonged and intensive questioning (*inquisitio* is Latin for inquiry). During the inquisition, one of the questions in the *Summa de officio inquisitionis* of 1270 was aimed at finding those who practiced divination using reflective objects (catoptromancy), "*Have you conducted experiments with mirrors, swords, fingernails, spheres or ivory handles?*"



The mirror was a very powerful symbol—being capable of reflecting the truth and of producing illusions. The German folk legend of **Till Eulenspiegel** (*eulen* and *spiegel* are the German words for owl and mirror, respectively) describes a trickster born around 1300 who carried a mirror and an owl as he traveled through the countryside exposing injustice, lunacy, and hypocrisy. Richard Strauss put Till Eulenspiegel's story to music. In the beginning of *Til Eulenspiegel's Merry Pranks,* the music tells of his trips through the countryside poking fun at and

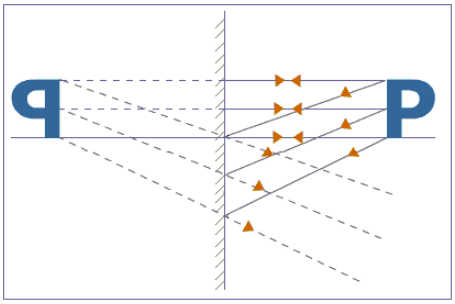
mocking the establishment. The end tells us of his capture by the authorities, his death sentence for blasphemy, and his execution by hanging. After his death, the playful initial musical theme reappears, suggesting that Till Eulenspiegel's message will live forever. https://www.youtube.com/watch?v=S7O9Oa22nsQ





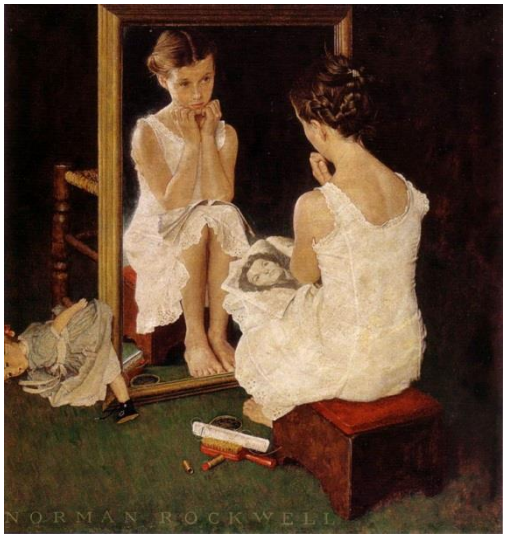
Even today, various mirrors tell us about ourselves and the world around us. In analogy to silvered glass mirrors, we ask, do these newspapers and magazines reflect the truth or produce illusion?

We can determine the position, orientation, and size of an image formed by a **plane mirror** by drawing light rays radiating from at least two different points on the object to the mirror. Then we assume that rays that strike the mirror are reflected in such a way that the angle of reflection equals the angle of incidence. Practically, we find a given image point by drawing two of the infinite number of rays that radiate from a given point on the object. We draw these rays, which are known as **characteristic rays**, using the following rules:

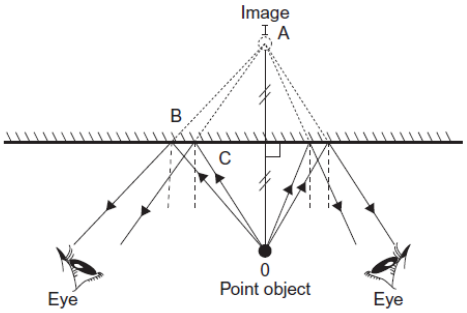


1. From a given point on the object, draw a line perpendicular to the mirror. Because $\theta_i = 0$ then $\theta_r = 0$. Draw the reflected ray and then extend the reflected ray backwards behind the mirror.

2. From the same point on the object, draw another line to any other point on the mirror. Draw the normal to the mirror at this point and then draw the reflected ray using the rule $\theta_r = \theta_i$. Extend the reflected rays backwards behind the mirror, to the other extended reflected ray originating from the same point on the object. The point of **intersection** of the extensions of the reflected rays originating from the same object point is the position of the image of that object point. If the reflected rays **converged** in front of the mirror, which they do not do when they strike a plane mirror, a **real image** would have been formed. A real image is an image that can be projected on a piece of translucent vellum. A real image is composed of radiant energy, and the light intensities of the points that make up a real image can be measured with a light meter. However, since the reflected rays **diverge** from a plane mirror, we extend the rays backwards from where they appear to be diverging. While an image appears in the place from which the rays appear to diverge, a piece of translucent vellum would ***not*** display an image. The image is **virtual**. The cornea and lens in our eyes collect the rays that seem to diverge from each point in the virtual image and form a real image on the retina. The virtual image appears in our mind's eye.



Oddly enough, we can resurrect the **extramission theory** to help us understand the placement of the virtual image. The mind's eye assumes that the diverging rays originate from a single point behind the mirror. This is exactly where the **visual rays** issuing ***from*** the eye would converge. Of course, there are no visual rays, and in fact, light from the object actually enters our eyes after it bounces off the mirror. However, the mind knows where it sees the virtual image because of the **neural signals** that travel between our **neck**, **head** and **eye muscles**, and our **brain** to let our mind know the direction the eyes are looking in order to see the virtual image.



There is a story told in many cultures about a man who, in ancient times, when mirrors were rare, brought home a mirror as a present for his wife. She looked into the mirror and saw another woman who she immediately assumed was her husband's lover and started yelling at her husband. He looked into the mirror not knowing what his wife was talking about and saw another man who he assumed was his wife's lover. A huge ruckus commenced. All I want to say is, learning the laws of geometrical optics may be good for your relationship!

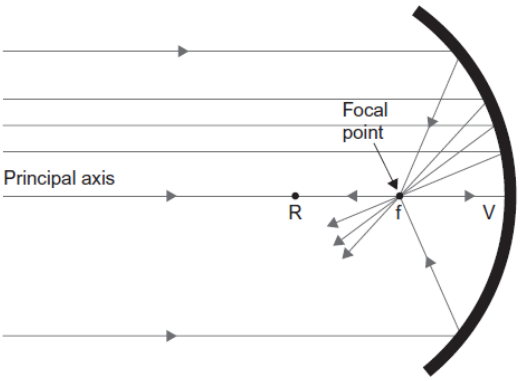


Not all mirrors are planar. We will look at images produced by **concave** and **convex mirrors**.

Demonstration: Place a short candle 40-50 cm from the **convex** mirror and slowly move it toward the mirror and away from you. Describe what happens to the image of the candle as its distance to the convex mirror decreases. Place the candle 40-50 cm from the **concave** mirror and slowly move it toward the mirror and away from you. Describe what happens to the image of the candle as its distance to the concave mirror decreases. Compare the images made by the concave and the convex mirrors. Place the candle approximately 30 cm from the concave mirror. Find the image with the translucent vellum. Move the candle towards the mirror. Find the image with the translucent vellum. Move the candle away from the mirror. Find the image with the translucent vellum. How does the image formed by the concave mirror on the translucent vellum change with the position of the object?



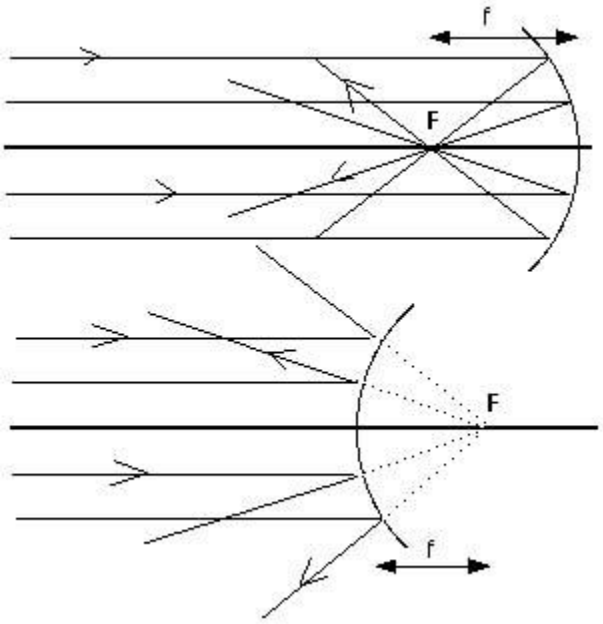
The **center of curvature** of a mirror is defined as the center of the imaginary sphere of which the curved mirror would be a part. The distance between the center of curvature (C) and the mirror itself is known as the radius of curvature (R). For a concave mirror, the radius of curvature is on the object side of the mirror and for a convex mirror, the radius of curvature is on the image side.



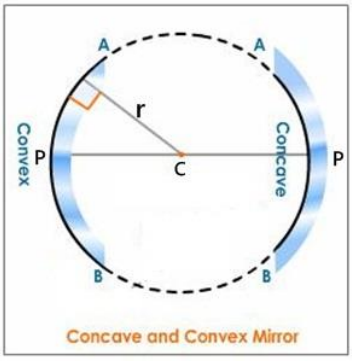
The line connecting the midpoint of the mirror with the center of curvature is called the **principal axis** of the mirror. The **vertex** V represents the intersection of the mirror and the principal axis. The **focus**, which is **positive** for a **concave**

mirror, is on the principal axis midway between the mirror and the center of curvature. The focal length of a mirror is the distance between the focus and the vertex.

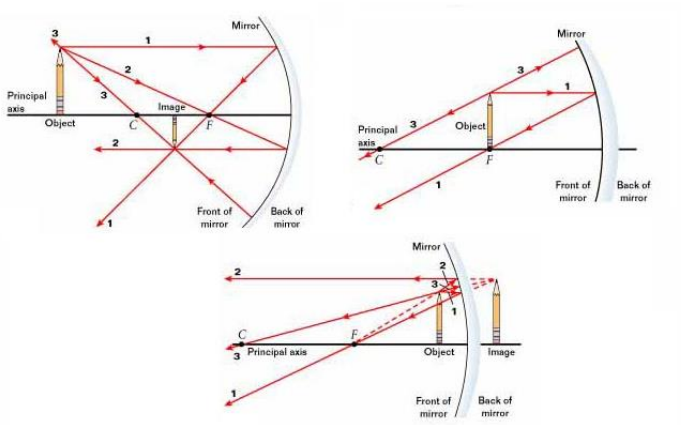
Consider a beam of light that strikes a concave (convex) mirror **parallel to the principal axis**. When a ray of light in this beam moves along the principal axis and strikes the mirror, it is reflected back on itself. When a ray of light in this beam strikes the mirror slightly above or below the principal axis, the ray makes a small angle with the normal and consequently the reflected ray is bent slightly toward (or away from) the principal axis. If the incident ray strikes the mirror farther away from the principal axis, the reflected ray is bent toward (away from) the principal axis with a greater angle. With a concave mirror, in all cases, the reflected rays from every part of the mirror converge toward the **focus**. With a convex mirror, in all cases, the reflected rays from every part of the mirror appear to diverge from the **focus**.



Moreover, a line drawn between the center of curvature and the point on the mirror where a ray parallel to the principal axis strikes, bisects the angle that subtends the incident and reflected rays. Since the line that comes from the center of curvature is radial, it is perpendicular to the surface of the mirror and in all cases, $\theta_r = \theta_i$ and the law of reflection holds.



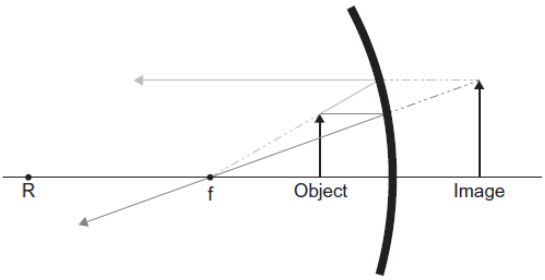
While the position, orientation, and size of the image formed by a **concave mirror** can be determined by any two of the infinite number of rays that radiate from each object point, they are most easily determined by drawing two or three **characteristic rays** that are based on the law of reflection from at least two points on the object (the point on the principal axis is a giveaway):



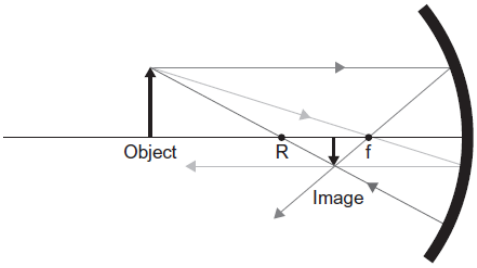
1. A ray traveling parallel to the principal axis passes through the focus (f) after striking a concave mirror.
2. A ray that travels through the focus on the way to the concave mirror or appears to come from the focus, if the object is between the focus and the mirror, travels backwards parallel to the principal axis after striking the mirror.
3. A ray that passes through the center of curvature (R) is reflected back through the center of curvature.

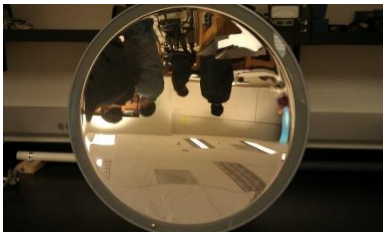
A **real image** of an **object point** is formed at the point where the rays **converge**. If the rays do not converge at a point, a **virtual image** may be formed. To find the virtual image of an object point, one must trace back the ***reflected*** rays to the point from which the extensions of each reflected ray seem to **diverge**. Tracing the reflected rays backward is geometrically equivalent to tracing the visual rays forward.

Here are examples of image formation by a concave mirror when the object distance is less than or greater than the focal length, respectively.

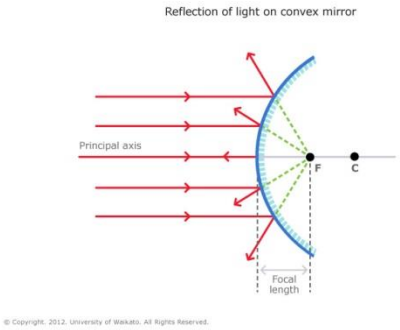




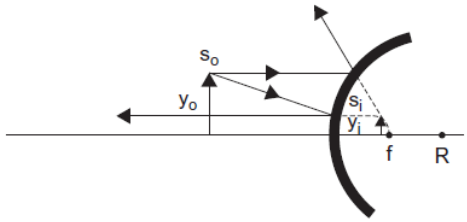


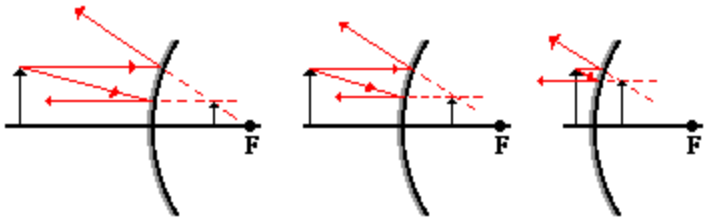


Convex mirrors, by convention, have a positive radius of curvature. When a beam of light parallel to the principal axis strikes a convex mirror, the rays are reflected away from the principal axis, and therefore **diverge**. If we follow the reflected rays backward, they appear to originate from a point behind the mirror, known as the **focus**. Since the focus is behind the mirror, ***f*** and the focal length are **negative**. We can draw a line between the center of curvature and the point on the mirror where a ray parallel to the principal axis strikes. This line, which is perpendicular to the surface of the mirror, bisects the angle that subtends the incident and reflected rays so that in all cases, $\theta_r = \theta_i$, and the law of reflection holds.



We can determine the position, orientation, and size of the image formed by a **convex mirror** by drawing two or three **characteristic rays,** from any two points on the object, that are based on the law of reflection (the point on the principal axis is a giveaway):





1. A ray traveling parallel to the principal axis is reflected from the convex mirror as if it originated from the focus (f).
2. A ray that travels toward the focus on the way to the mirror is reflected back parallel to the principal axis after striking the mirror.
3. A ray that strikes the mirror as it was heading toward the center of curvature (R) is reflected back along the same path.

A real image of an object point is ***never*** formed by a convex mirror. If we trace back the reflected rays to a point from where the extensions of each reflected ray seem to **diverge**, we will find the **virtual image** of the object point. The virtual image is erect and **minified**. The minified image makes us think that the objects are farther than they would appear to be if the mirror were planar, but really, as it says in the convex side view mirror: "*objects in the mirror are closer than they appear*."



The image formed by a convex mirror can be used as a metaphor. Sometimes events that happened in our past may appear closer than they are:

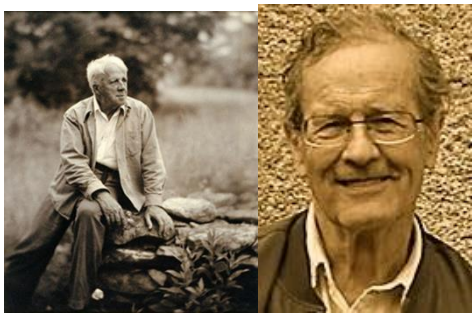
Objects in the Rear View Mirror May Appear Closer Than They Are—Meat Loaf



The skies were pure and the fields were green
And the sun was brighter than it's ever been
When I grew up with my best friend Kenny
We were close as any brothers than you ever knew
It was always summer and the future called
We were ready for adventures and we wanted them all
And there was so much left to dream and so much time to make it real
But I can still recall the sting of all the tears when he was gone
They said he crashed and burned
I know I'll never learn why any boy should die so young
We were racing, we were soldiers of fortune
We got in trouble but we sure got around
There are times I think I see him peeling out of the dark
I think he's right behind me now and he's gaining ground
But it was long ago and it was far away, oh God it seems so very far
And if life is just a highway, then the soul is just a car
And objects in the rear view mirror may appear closer than they are
And objects in the rear view mirror may appear closer than they are
And objects in the rear view mirror may appear closer than they are
And objects in the rear view mirror may appear closer than they are.



Thanks, Robert Frost, by David Ray



Do you have hope for the future?
someone asked Robert Frost, toward the end.
Yes, and even for the past, he replied,
that it will turn out to have been all right
for what it was, something we can accept,
mistakes made by the selves we had to be,
not able to be, perhaps, what we wished,
or what looking back half the time it seems
we could so easily have been, or ought…
The future, yes, and even for the past,
that it will become something we can bear.
And I too, and my children, so I hope,
will recall as not too heavy the tug
of those albatrosses I sadly placed
upon their tender necks. Hope for the past,
yes, old Frost, your words provide that courage,
and it brings strange peace that itself passes
into past, easier to bear because
you said it, rather casually, as snow
went on falling in Vermont years ago.

Henri Poincaré (1901): "*To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection*."



As an alternative to drawing characteristic rays known **as ray tracing**, we can determine **analytically** with the aid of algebra, where the reflected rays originating from a luminous or nonluminous object will converge (or seem to diverge) to form an image. The formula we use is known as the **Gaussian lens equation**:

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

where s_o is the distance from the object to the mirror (in m), s_i is the distance between the image and the mirror (in m), and f is the focal length of the mirror (in m). The magnification (m_T) is defined as ($\frac{y_i}{y_o}$), where y_i and y_o are linear dimensions (in m) of the image and object, respectively, is given by the following formula:

$$m_T = \frac{y_i}{y_o} = -\frac{s_i}{s_o}$$

When using these formulae for concave and convex mirrors, which will be discussed below, the following sign conventions must be observed: s_o, s_i, and f are positive when they are in front of the vertex (V) of the mirror and negative

when behind; and y_i and y_o are positive when they are above the principal axis and negative when below.

When s_i is **positive**, the image formed by a concave mirror is **real**. When s_i is **negative**, the image formed by a concave mirror is **virtual**. The image is erect when m_T is positive and inverted when m_T is negative. The degree of magnification or minification is given by the absolute value of m_T. Let's have a little practice in using the preceding formulae for **concave mirrors**:

Example 1: When an object is placed at infinity ($s_o = \infty$), $\frac{1}{s_o}$ equals zero, and thus $\frac{1}{s_i} = \frac{1}{f}$ and $s_i = f$. In other words, when an object is placed at an infinite distance from the mirror, the image is formed at the focal point and the magnification $(-\frac{s_i}{s_o})$ is equal to zero.

Example 2: When an object is placed at the focus ($s_o = f$), $\frac{1}{f} + \frac{1}{s_i} = \frac{1}{f}$. Thus $\frac{1}{s_i}$ must equal zero and s_i must be equal to infinity. In other words, when an object is placed at the focus, the image is formed at infinity, and the magnification $(-\frac{s_i}{s_o})$ is almost infinite.

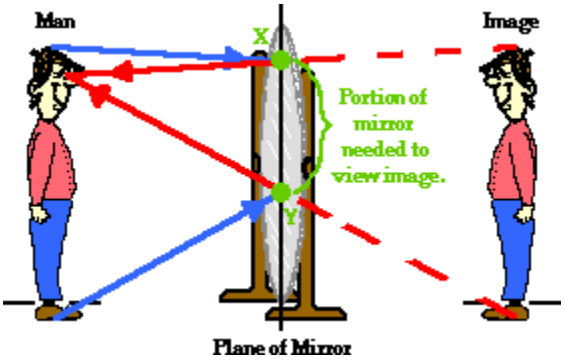
Example 3: When an object is placed at the center of curvature ($s_o = 2f$), then $\frac{1}{2f} + \frac{1}{s_i} = \frac{1}{f}$ and $\frac{1}{s_i} = \frac{1}{2f}$ (remember ½ - ¼ = ¼). Thus $s_i = 2f$, and the image is real and the same distance from the mirror as the object is. The magnification $(-\frac{s_i}{s_o})$ is minus one, and the image is inverted.

Example 4: When an object is placed at a distance equal to $\frac{1}{2}f$, which is between the focus and the mirror, then $\frac{2}{f} + \frac{1}{s_i} = \frac{1}{f}$. Thus $\frac{1}{s_i} = \frac{1}{f} - \frac{2}{f}$ and $\frac{1}{s_i} = -\frac{1}{f}$, and $s_i =$

$-f$. Since s_i is a negative number, the image is behind the mirror and virtual. Since $-\frac{s_i}{s_o}$ equals +2, the image is erect and twice the height as the object.

The **Gaussian lens equation** can also be used to determine the nature of images produced by **convex mirrors**. For convex mirrors, the focal length is **negative**. To form any image in a convex mirror where f is always negative, s_o must be positive. According to the Gaussian lens equation, $\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$, s_i will always be negative and the image will always be behind the mirror and virtual. Since $-\frac{s_i}{s_o}$ will always be positive, the image will always be erect.

The **Gaussian lens equation** can also be used to determine the characteristics of an image formed by a **plane mirror** analytically. When light rays parallel to the normal strike the mirror, they are reflected back along the normal and remain parallel. That is, they never converge and the focal length of a plane mirror is equal to infinity, and $\frac{1}{f}=0$. Thus $\frac{1}{s_o}=-\frac{1}{s_i}$ and $-\frac{s_i}{s_o}$ will always be positive and equal to one. This describes the image in a plane mirror as being erect, the same size as the object, and virtual.



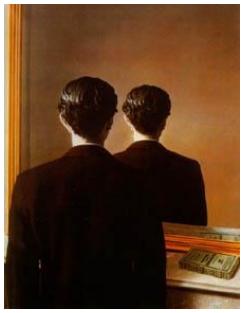
The following table summarizes the nature of the images formed by concave and convex mirrors:

TABLE 2.1 Nature of Images Formed by Curved Mirrors

Location	Type	Location	Orientation	Relative Size
Object		Image in a Concave Mirror		
$\infty > s_o > 2f$	Real	$f < s_i < 2f$	Inverted	Minified
$s_o = 2f$	Real	$s_i = 2f$	Inverted	Same size
$f < s_o < 2f$	Real	$\infty > s_i > 2f$	Inverted	Magnified
$s_o = f$			∞	
$s_o < f$	Virtual	$\lvert s_i \rvert > s_o$	Erect	Magnified
Object		Image in a Convex Mirror		
Anywhere	Virtual	$\lvert s_i \rvert < \lvert f \rvert$	Erect	Minified

For fun, which kind of mirror is depicted in each of the following paintings: *John Arnolfini and His Wife* by Jan Van Eyck, *Venus and Cupid* by Diego Rodriguez de Silva y Veláquez, *Self Portrait* by Parmigianino and *La Reproduction Interdite* by René Magritte?



Roy Lichtenstein's *Girl in Mirror* (1964):



John Ashbery (1974) wrote a poem *Self-portrait in a convex* (http://www.poetryfoundation.org/poetrymagazine/browse/124/5#!/20596528/0 https://www.youtube.com/watch?v=zrvXX9QVAT8). Other paintings that depict

mirrors include, *Vanity* by Hans Memling; *The Moneychanger and his Wife* by Quentin Metsys; *The Bar at the Folies Bergères* by Edouard Manet; *Joking Couple* by Hans von Aachen; *Venus in Front of the Mirror* by Peter Paul Rubens; *Venus in Front of the Mirror* by Titian; *Nude Standing before a Mirror* by Henri Toulouse Lautrec; and *Triple Self Portrait* by Norman Rockwell. See http://larsdatter.com/mirrors.htm.

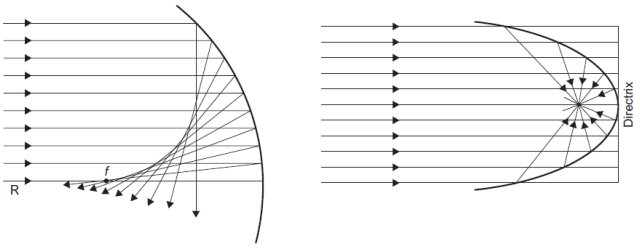


The set in Christopher Wheeldon's performance of Stravinsky's *Scènes de Ballet* is a Russian ballet studio bisected by a barre and an imaginary mirror. Sixty-two dancers are divided between "real" dancers and their "reflections."



How many "real" dancers are in this freestyle dance video called *Mirror Story*? https://www.youtube.com/watch?v=HzZ1K-IRxA4

As long as we consider only the rays that emanate from a given point of an object and strike close to the midpoint of a **spherical** mirror, we will find that these rays converge at a point. However, when the incident rays hit a **spherical** mirror far from the midpoint, they will not be bent sharply enough and will not converge at the same point as the rays that strike close to the midpoint of the mirror. Thus, even though all rays obey the law of reflection, a **spherical** zone of confusion



IGURE 2.11 Because of the law of reflection, where the angle of reflection equals the angle of incidence, a spherical mirror does not focus parallel rays

instead of a luminous point results. The **inflation of a point into a sphere** by a spherical mirror results in **spherical aberration**, from the Latin word *aberrans*, which means wandering. While spherical mirrors are abundant since they are easy and cheap to make, Descartes found that the correct shape of a mirror that leads to a perfect focus is **parabolic**. **Chromatic aberration** occurs when parallel rays of light of different colors are not focused to the same point. While spherical aberration occurs in spherical mirrors, chromatic aberration does ***not*** occur in any mirrors.

Now we will talk about the influence of **refraction** on **image formation. Light travels in straight lines** as long as it remains in a single **homogeneous medium**, however, when a light ray traveling through air strikes a **denser medium** (e.g. water or glass) at an **oblique angle** (θ_i) with respect to the normal, the ray is bent toward the normal in the denser medium. The angle that the light ray makes in the denser medium, relative to the normal, is known as the angle of transmission (θ_t). Ptolemy found that the angle of transmission is always smaller than the angle of incidence but never discovered the true relationship.

The true mathematical relationship between the angle of incidence and the angle of transmission was first worked out by Willebrord Snel van Royen in 1621. Snel, also known as Snellius did not publish his work. René Descartes, who independently worked out the relationship, published the relationship in 1637. The law of refraction, which is known as the **Snel-Descartes Law**, states that when light passes from air to a denser medium, the ratio of the sine of the angle of incidence to the sine of the angle of transmission equal to a constant, called the **refractive index**. The Snel-Descartes Law can be expressed by the following equation:

$$\frac{\sin\theta_i}{\sin\theta_t} = \frac{n_t}{n_i} = n_t \text{ (when } n_i = 1)$$

where n_t is the refractive index of the denser medium and n_i is the refractive index of air (n_i = 1). The Snel-Descartes Law can be written more generally as:

$$n_i \sin\theta_i = n_t \sin\theta_t$$

Demonstration: Make a table of the relationship between the angle of incidence and the angle of transmission through water. Check out these two formulaic models:



$$\frac{\theta_i}{\theta_t} = n_t$$

$$\frac{\sin\theta_i}{\sin\theta_t} = n_t$$

Which formula seems to be correct and why does it seem to you to be correct?

Demonstration: In general, the denser a transparent medium, the greater is its refractive index. We can observe this by measuring the refractive indices of 0%, 5% and 10% (w/v) sucrose solutions with a hand-held refractometer. The solution in the hand-held refractometer bends light in a manner that depends on the refractive index of the solution.

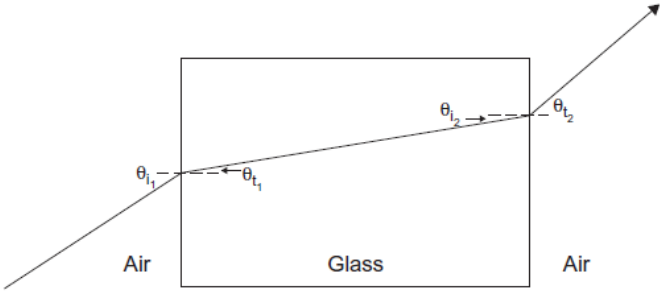


The hand-held refractometer is useful to beer and wine makers and is often calibrated in degrees Brix instead of refractive index. Degrees Brix is equivalent to the percent sugar (*S*). The refractive index of the solution = 1.3333 + (0.0018)(*S*).

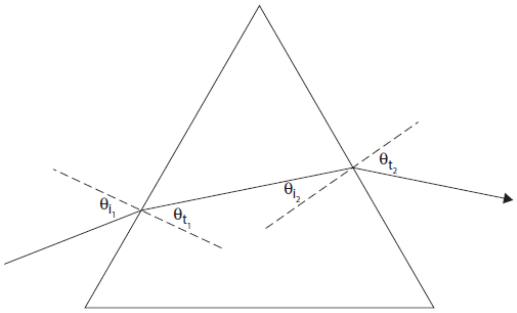
Demonstration: A piece of Pyrex glass becomes invisible when it is placed in a solution of Wesson (soybean) oil, but not in air or water. Can you guess why?



When a light ray passes from **air** through a piece of glass with **parallel edges** and returns to the **air**, the refraction at the far edge **reverses** the refraction at the near edge and the ray **emerges parallel** to the incident ray, although slightly **displaced.** The amount of displacement depends on two things: the **refractive index of the glass** and the **distance the beam travels in the glass**.

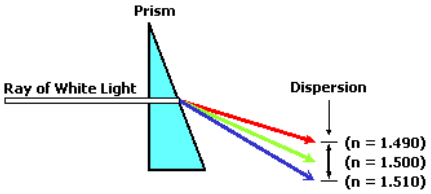


However, when the edges are **not parallel**, the refraction at the far edge will ***not*** **reverse** the effect of the refraction at the near edge. In this case, the light ray will not emerge parallel to the incident light ray, but will be **bent** in a manner that depends on the shape of the edges. Consider a ray of light passing through a **prism** oriented with its apex upward. If the ray of light hits the normal at an angle from below, it crosses into the glass above the normal but makes a smaller angle with respect to the normal since the glass has a higher refractive index than the air. When the ray of light reaches the glass-air interface at the far side of the prism, it makes an angle with a new normal. As it emerges into



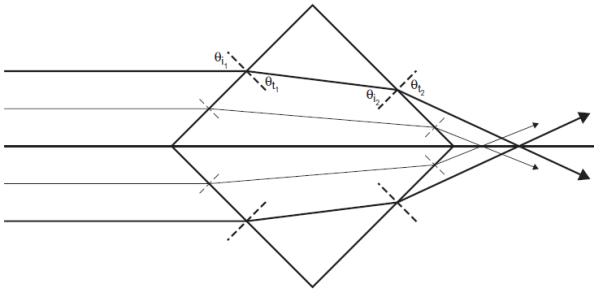
the air it bends away from the normal since the refractive index of air is less than the refractive index of glass. The result is the ray of **light is bent twice in the same direction**.

Aside: The refractive index of glass, or the amount it bends light, is not a constant but varies with the color of light. For this reason, as Isaac Newton discovered, a prism splits or **disperses** white light into its constituent colors in the form of a **spectrum**.

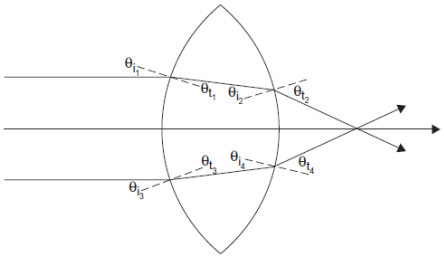


Chromatic Dispersion of White Light

What would happen to a parallel beam of incident light rays that strike two prisms whose bases are cemented together? The light that strikes the upper prism will be **bent downward** toward its base and the light that strikes the lower prism will be **bent upward** toward its base. The two halves of the beam of light will **converge** and cross on the other side. However, the beam emerging from this double prism will not come to a focus since the rays that strike the two corresponding prisms farther and **farther from the principal axis** all strike at the same angles but travel through **less and less glass** and thus will converge at greater and greater distances from the double prism. Is there a particular shape of glass that will bring parallel rays to converge at a **focus**?



A “**lentil-shaped**” transparent object will cause parallel rays to converge at a focus according to the Snel-Descartes Law and consequently, a **lens** got its name from the Latin word for lentil. Everything is botany!!!!



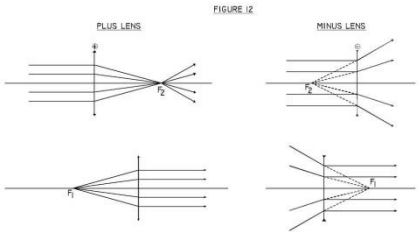




The ability of a lens to bend or refract light rays is characterized by its **focal length**; the shorter the focal length, the greater the ability of the lens to bend light. A lens with a long focal length is relatively flat and a lens with a short focal length is more curved. The power of a lens to bend light is known as the **dioptric power** (D). It is given by the reciprocal of the focal length in meters:

$$D = \frac{1}{f}$$

Lenses have two **focal points**—an **object focal point** and an **image focal point**. The two focal points, which lie on the principal axis, can be found in this way: The image focal point of a **converging lens** is the place where parallel rays passing through the lens converge. The object focal point of a **converging lens** is where you place



a point source of light so that the light that passes through the lens comes out as parallel rays. **Converging lenses** have **positive focal lengths**.

The image focal point of a **diverging lens** is the place where rays diverging from the lens appear to have diverged from. The object focal point is where a virtual point source of light seems to be when parallel rays of light emerge from the lens. **Diverging lenses** have **negative focal lengths.**

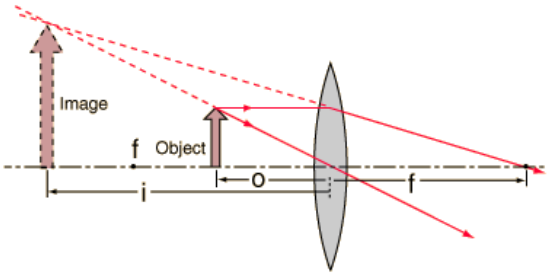
Demonstration: Place the bayberry candle from Monticello at one end of the desk. Look at it close-up through the 0.5 m (2 D) and then the 1 m (1 D) focal length double convex converging lenses. Describe the images formed by the two lenses. Are the images real or virtual? Erect or inverted? Which one forms the larger image? Then place the 0.5 m and 1 m focal length converging lenses side by side about 2 m away from the candle. Find the images behind the lenses by moving the translucent vellum backwards starting at the back of the lenses. Describe and compare the images that are formed by the two lenses. Are the images real or virtual? Erect or inverted? Which one forms the larger image? Place a -1 m (-1 D) focal length double concave diverging lens immediately behind the 0.5 m (2 D) double convex converging lens. Find the image with the translucent vellum. What happens to the image? Compare it to the images formed by the 0.5 m and the 1m focal length converging lenses.



Bayberry (*Myrica pensylvanica*) grows on the patio of the Plant Sciences Bldg. Why might the berries be coated with wax? Why are plants in general, whether they live in the desert or the tropics, coated with wax?

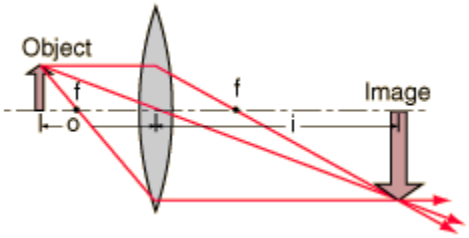


We can characterize the type, location, orientation, and relative size of images formed by converging and diverging lenses using the ray tracing method just as we characterized the images formed by mirrors. We must draw two or three **characteristic rays** from at **least two points** that obey the Snel-Descartes Law (a point on the principal axis is a giveaway):

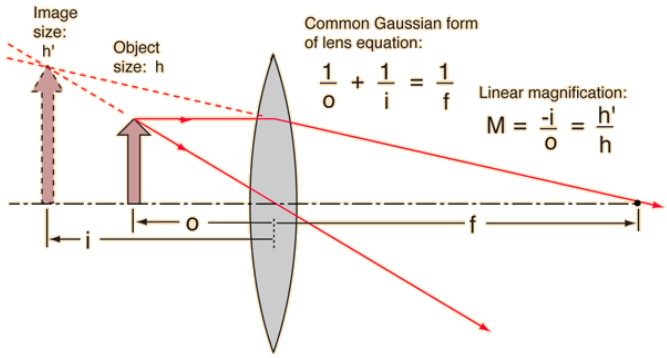


1. A ray that strikes a converging lens parallel to the principal axis goes through the image focus (f_i).
2. A ray that strikes a diverging lens parallel to the principal axis appears to have come from the image focus (f_i).
3. A ray that strikes a converging lens after it passes through the object focus (f_o) emerges parallel to the principal axis.
4. A ray that strikes a diverging lens on its way to the object focus (f_o) emerges parallel to the principal axis.
5. A ray that passes through the vertex (V) of a converging or diverging lens passes through undeviated.

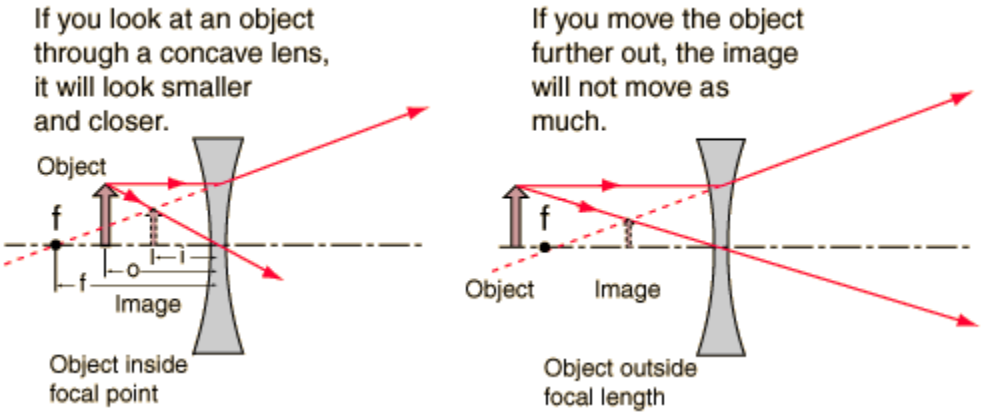
Draw three characteristic rays from each point on the object when the object is **farther than the object focal length** of a **converging lens**. The rays converge and the image is real, magnified, and inverted. As the object moves farther away from the focus, the image goes from magnified to same size to minified.



Draw three characteristic rays from each point on the object when the object is **closer than the object focal length** of a converging lens. Since the rays do not converge, we have to trace them back and see where they appear to diverge from. The image is erect, virtual, and magnified. As the object moves toward the focus, the magnification increases.



Draw three characteristic rays from each point on the object when the object is anywhere relative to the image focal point of a **diverging lens**. Since the rays do not converge, we have to trace them back and see where they appear to diverge from. The image is virtual, erect, and minified. As the object is moved farther from the lens, the image will be more and more minified.



As an **alternative** to **drawing** characteristic rays, we can determine **analytically** with the aid of algebra, where the refracted rays originating from a luminous or nonluminous object will converge to form an image. We use the same **Gaussian lens equation** we used for finding the images formed by mirrors:

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$

where s_o is the distance from the object to the lens (in m), s_i is the distance between the image and the lens (in m), and f is the focal length of the lens (in m). A **converging lens** has a **positive focal length** (f) and a **diverging lens** has a **negative focal length** (f). s_o is positive for a real object in front of the lens. s_i is positive for a real image behind the lens and is negative for a virtual image in front of the lens. The magnification (m_T) is defined by ($\frac{y_i}{y_o}$), where y_i and y_o are linear dimensions (in m) of the image and object, respectively. The magnification is given by the following formula:

$$m_T \equiv \frac{y_i}{y_o} = -\frac{s_i}{s_o}$$

y_i and y_o are positive when they are above the principal axis and negative when they are below the principal axis. When $m_T > 0$, the image is virtual and erect and when $m_T < 0$, the image is real and inverted.

Example 1: When an object is placed at infinity ($s_o = \infty$) in front of a converging lens, $1/s_o$ equals zero, and thus $\frac{1}{s_i} = \frac{1}{f}$ and $s_i = f$. In other words, when an object is placed at an infinite distance from a converging lens, the image is formed at the focal point and the magnification ($-\frac{s_i}{s_o}$) is equal to zero.

Example 2: When an object is placed at the focus ($s_o = f$) of a converging lens, $\frac{1}{f} + \frac{1}{s_i} = \frac{1}{f}$. Thus $\frac{1}{s_i}$ must equal zero and s_i must be equal to infinity. In other words, when an object is placed at the focus of a converging lens, the image is formed at infinity, and the magnification ($-\frac{s_i}{s_o}$) is almost infinite.

Example 3: When an object is placed at the center of curvature of a converging lens ($s_o = 2f$), then $\frac{1}{2f} + \frac{1}{s_i} = \frac{1}{f}$ and $\frac{1}{s_i} = \frac{1}{2f}$ (remember ¼ + ¼ = ½). Thus $s_i = 2f$, and the image is real and the same distance from the lens as the object is. The magnification ($-\frac{s_i}{s_o}$) is minus one, and the image is inverted.

Example 4: When an object is placed at a distance equal to $\frac{1}{2}f$ in front of a converging lens, which is between the focus and the lens, then $\frac{2}{f} + \frac{1}{s_i} = \frac{1}{f}$. Thus $\frac{1}{s_i} = \frac{1}{f} - \frac{2}{f}$ and $\frac{1}{s_i} = -\frac{1}{f}$, and $s_i = -f$. Since s_i is a negative number, the image is is on the same side of the lens as the object, and it is virtual. Since $-\frac{s_i}{s_o}$ equals +2, the image is erect and twice the height as the object.

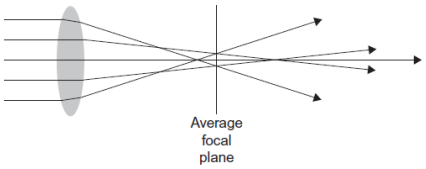
Example 5: When an object is placed at a positive distance equal to $-\frac{1}{2}f$ (remember that f is negative) in front of a diverging lens, which is between the focus and the lens, then $-\frac{2}{f} + \frac{1}{s_i} = \frac{1}{f}$. Thus $\frac{1}{s_i} = \frac{1}{f} - \frac{-2}{f}$ and $\frac{1}{s_i} = \frac{3}{f}$, and $s_i = \frac{f}{3}$. Since s_i is a negative number, the image is is on the same side of the lens as the object, and it is virtual. Since $-\frac{s_i}{s_o}$ equals $+\frac{2}{3}$, the image is erect and two-thirds the height as the object.

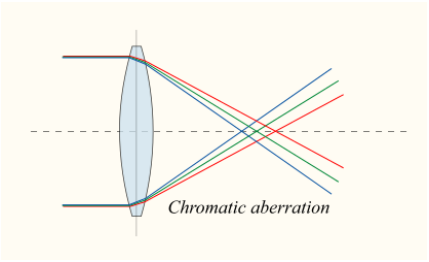
The following table summarizes the nature of the images formed by converging and diverging lenses.

TABLE 2.5 Nature of Images Formed by Lenses

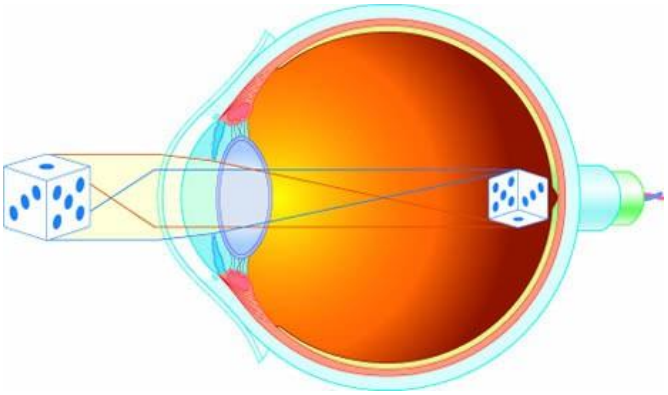
Location	Type	Location	Orientation	Relative Size
Object		**Image Formed by a Converging Lens**		
$\infty > s_o > 2f$	Real	$f < s_i < 2f$	Inverted	Minified
$s_o = 2f$	Real	$s_i = 2f$	Inverted	Same size
$f < s_o < 2f$	Real	$\infty > s_i > 2f$	Inverted	Magnified
$s_o = f$		∞		
$s_o < f$	Virtual	$\lvert s_i \rvert > s_o$	Erect	Magnified
Object		**Image Formed by a Diverging Lens**		
Anywhere	Virtual	$\lvert s_i \rvert < \lvert f \rvert$	Erect	Minified

Refracting lenses can have both spherical and chromatic aberrations. **Spherical aberration** occurs because the rays from any given object point that hit a lens with spherical surfaces far from the principal axis are refracted too strongly, resulting in the inflation of a point into a sphere. Spherical aberration can be reduced by molding or grinding the lens so that it has aspherical surfaces or using only the part of the lens close to the principal axis. **Chromatic aberration** occurs because the refractive index of refracting materials is color dependent. This results in the violet-blue rays being more strongly refracted by glass than the orange-red rays and the image has colored halos.



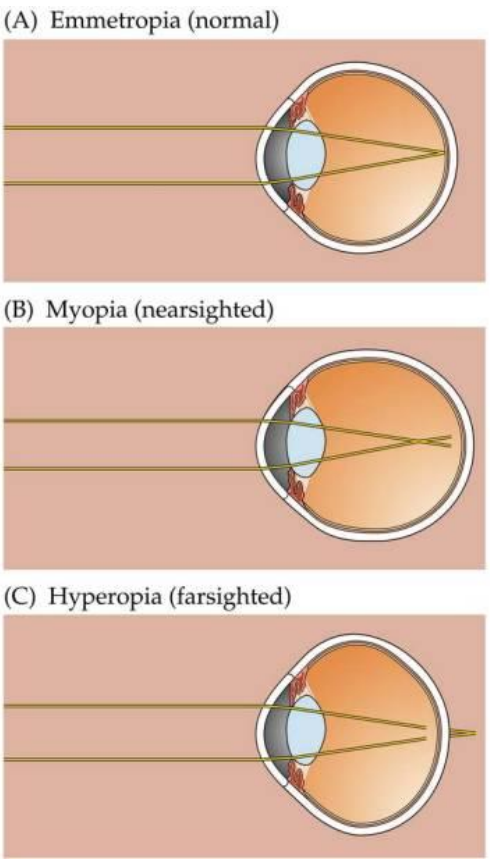


The **eye** too has some spherical and chromatic aberrations, but it is not noticeable to us. Perhaps a small pupil minimizes these aberrations. Children have larger pupils than adults, indicating that the aberrations may get worse with age. Together, the cornea and the crystalline lens act as a converging lens that produces a real reliable minified image on the retina (**emmetropia**).

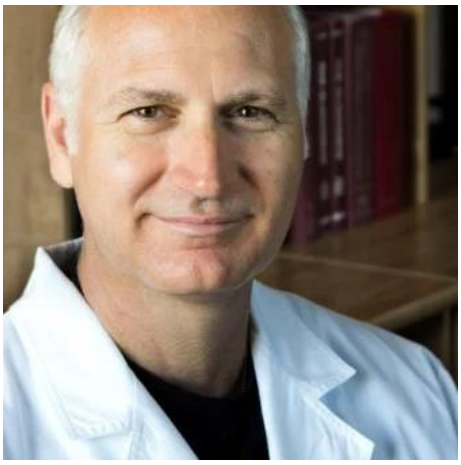


If the focal length of an eye is **too short**, and the dioptric power is too high because the cornea is **too convex** (or the eyeball **too long**), the image will be formed in front of the retina and vision will be nearsighted (**myopia**). Myopia can be corrected by using spectacles with diverging lenses with negative focal lengths and negative dioptric powers. Myopia can also be corrected with Lasik surgery that makes the cornea less convex.

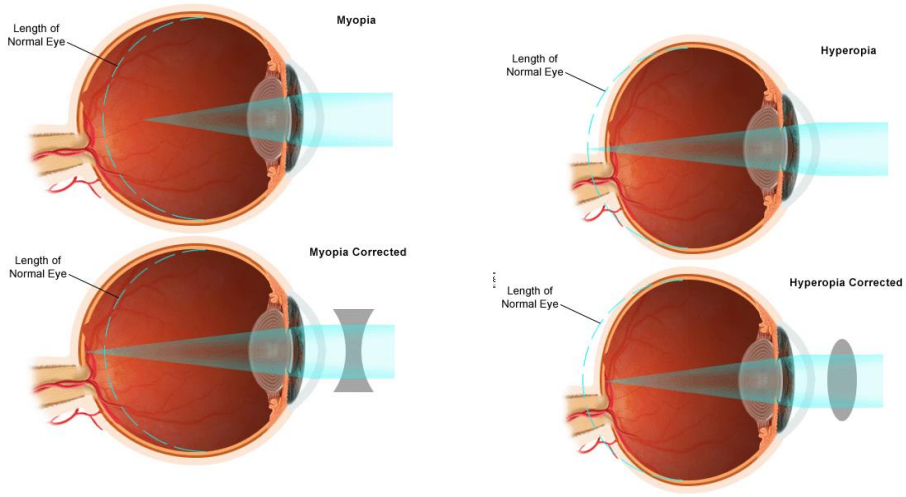
If the focal length of an eye is **too long**, and the dioptric power is too low because the cornea is not convex enough (or the eyeball **too short**), the image will be formed behind the retina and vision will be farsighted (**hyperopia**). Hyperopia can be corrected by using spectacles with converging lenses with positive focal lengths and positive dioptric powers. Hyperopia can also be corrected with Lasik surgery that makes the cornea rounder.



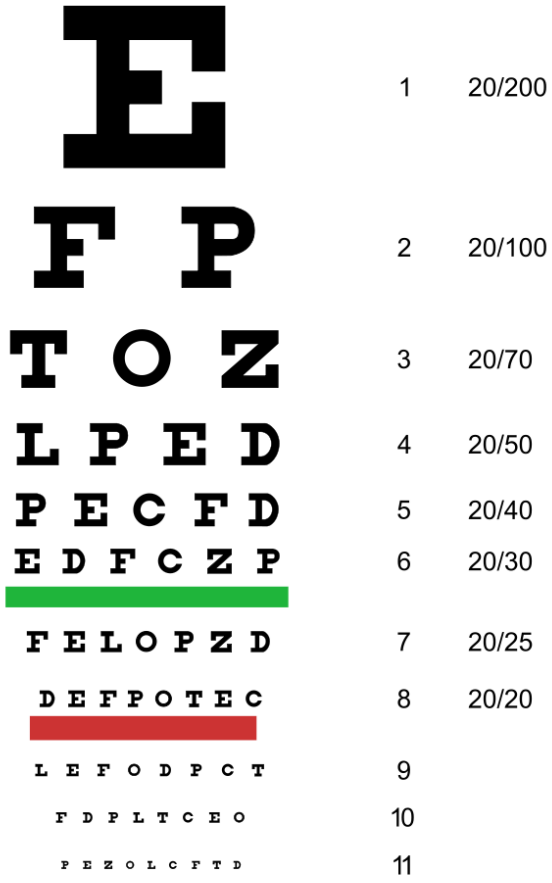
Arleo EYE ASSOCIATES



The effect of spectacles on myopia (nearsightedness) and hyperopia (farsightedness).

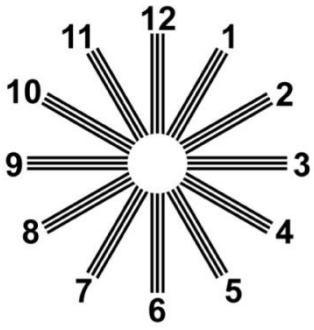


Take an online vision test: https://www.personaleyes.com.au/online-eye-test/index.php that tests the refraction of your eyes using the Snellen eye chart:

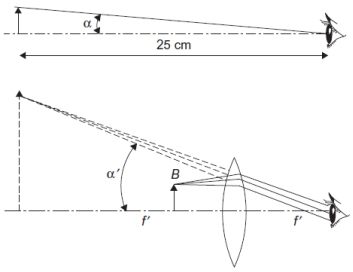


Note that this is a vision test and not an eye exam performed by an eye doctor which exams eye health as well as vision (https://www.aoa.org/online-eye-test; https://www.cnn.com/2017/03/15/health/online-eye-exam-telemedicine-explainer/index.html).

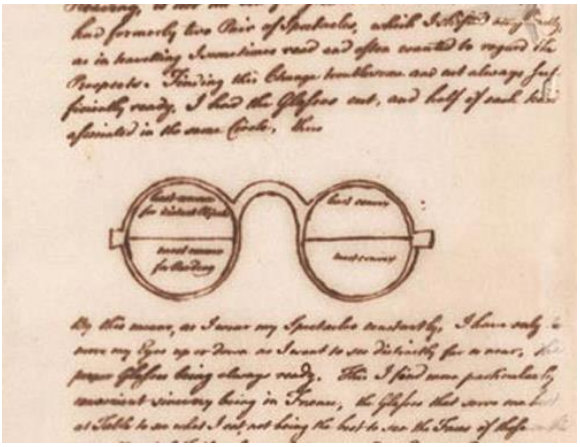
The cornea of some eyes are not symmetrical and the focal length in one radial direction is greater than the focal length in another radial direction. For example in the **astigmatism** test on the right, the lines marked with a 3 may be in focus but the lines marked with a 12 are not. Astigmatism can be corrected with **cylindrical lenses** or with Lasik surgery.



The **cornea** is fixed and can only focus distant objects on the **retina**. The **crystalline lens** is elastic and can change its shape to focus near and far objects on the retina. The ciliary **muscles** contract (**accommodate**) to focus near objects and relax to focus distant objects. As one ages, the crystalline lens loses it elasticity and the ability to accommodate decreases. This is called **presbyopia** and it is corrected with reading glasses made with converging lenses. As Roger Bacon realized, a converging lens used as a magnifying glass increases the angle of the light rays that reach the eye for old men!!!



Bifocals are spectacles that contain lenses with two **focal lengths**. Bifocals were invented by **Benjamin Franklin** and are useful for people with **presbyopia** and either near- or far-sightedness.



Speaking of two prescriptions, *Anableps* is the four-eyed fish that lives on the surface of the water. It needs one kind of lens to look for food in the air (n=1) and another kind of lens to watch for predators in the water (n = 1.333) below.

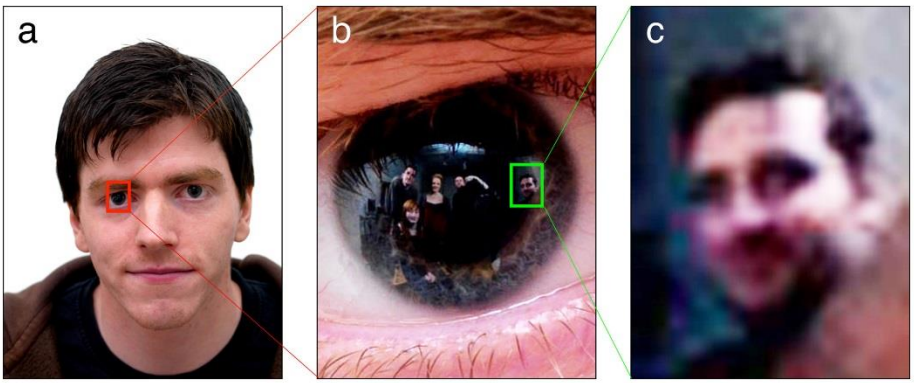


Anyone who gets new glasses knows that the **disagreeable distortions and aberrations** that you first see quickly disappear, not from any change in the glasses themselves, but from a change in the perceiving mind. **The mind knows how to align the perceived image so that it conforms to reality**. Our brain is quite good when it comes to vision, but it still can't fix this:

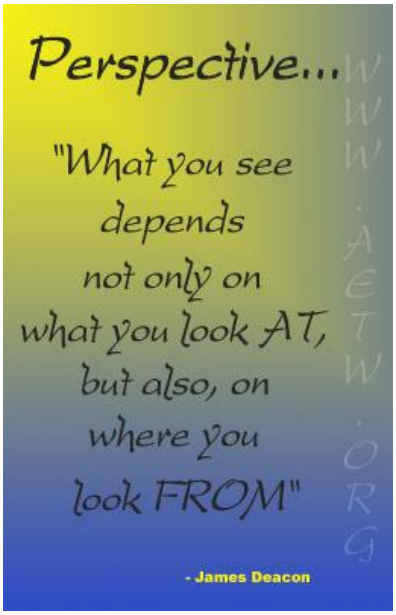


Next lecture we will study the lenses of the eye—but don't forget that the shiny surface of the eye can act as a mirror and reflect the scenery. In fact, as megapixel cameras become more prevalent, zooming in on reflected images in a person's eye may help solve crimes.



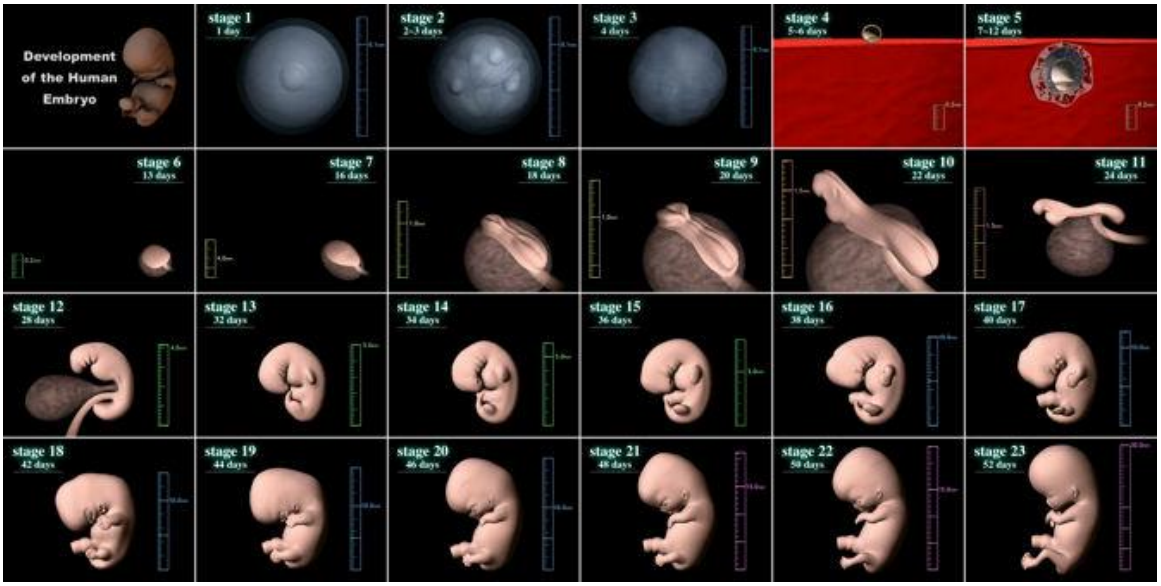


Development, Anatomy and Physiology of the Eye

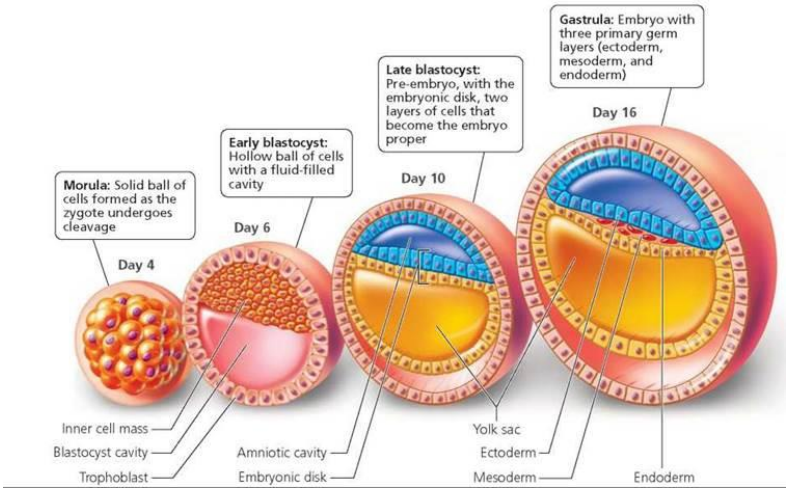


The word **perspective** comes from the Latin *per-* "through" and *specere* "look at". Last week we discussed vision from a **historical perspective** in order to understand how Johannes Kepler, René Descartes, and Bishop Berkeley discovered the importance of the mind in effecting vision. Next, we discussed image formation from a **geometrical and analytical perspective** in order to understand how Euclid, Ptolemy, Alhazen, Kepler, Snel, and Descartes discovered how images were formed by reflecting and refracting elements, including metallic mirrors, glass lenses, and the proteinaceous cornea and crystalline lens of our eye. Today we will talk about the eye and its connections with the brain from the perspective of development, anatomy and physiology.

Our eyes develop to a large extent while we are in the womb from the fourth to the tenth week (28-70 days) following conception: (https://embryology.med.unsw.edu.au/embryology/index.php/Carnegie_stage_13).



Following conception, the fertilized egg divides to form tissues that will connect the embryo to the mother, yolk cells that will give rise to the germ cells, and stem cells. The **embryonic stem cells** give rise to the three embryonic tissues.



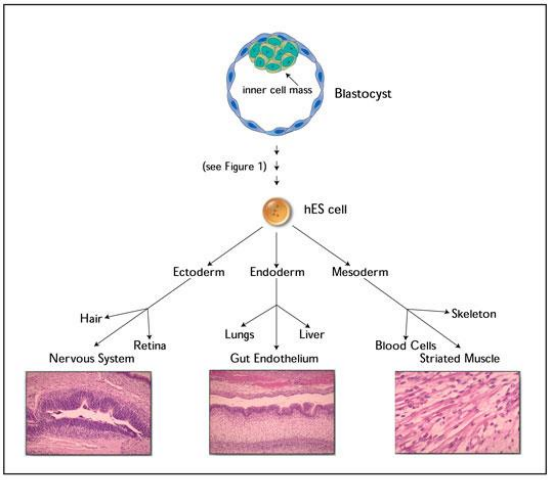
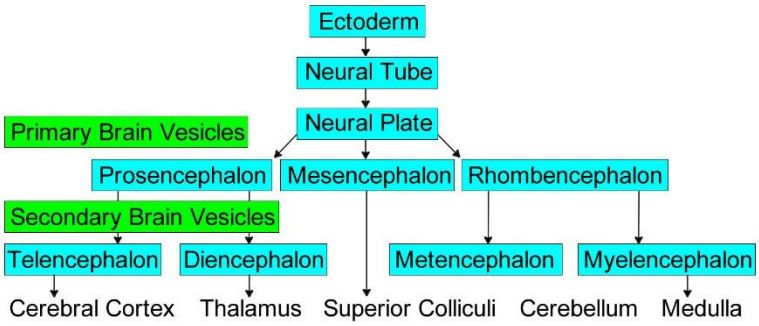
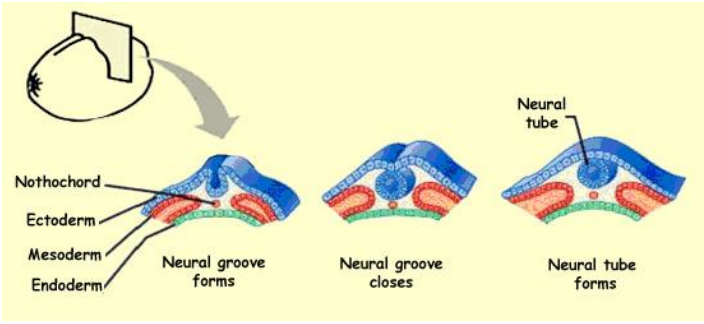


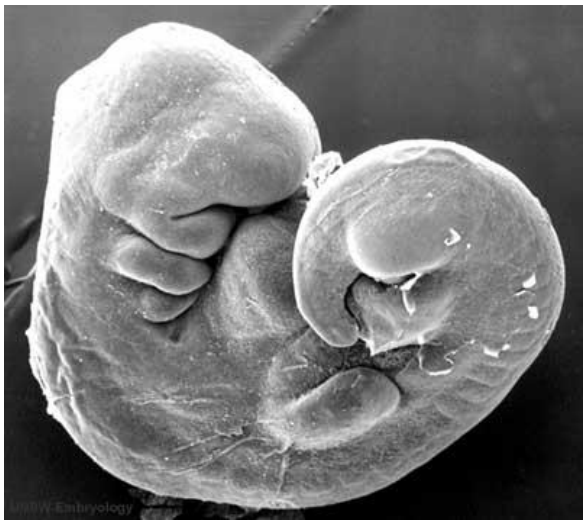
Figure 2: Differentiation of hES Cells into Three Germ Layers

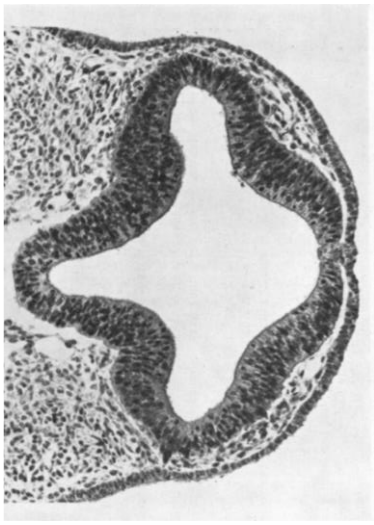
Our eyes have their origin in these embryonic tissues: the lens and the cornea as well as the optic nerve, the retina and the epithelial layers of the iris and ciliary body are derived from the **ectoderm**, while the rest is derived from the **mesoderm**.



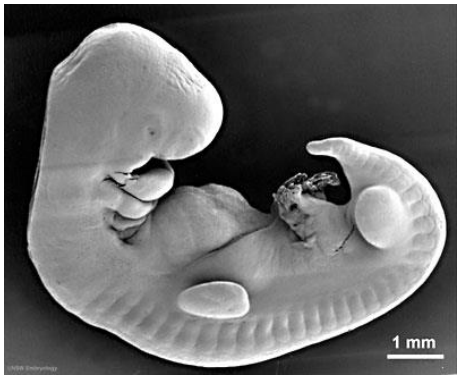


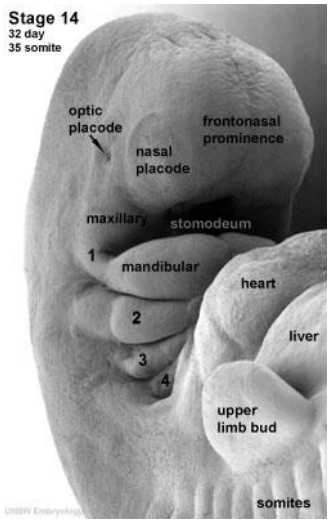
Approximately **four weeks** (28 days) after conception, the **forebrain**, which is derived from the **ectoderm** and from which the optic nerve, the retina, and the epithelia of the ciliary body develop, pushes its way into the surrounding loosely-associated cells known as the **mesochyme**, which is derived from the **mesoderm**, to form the **optic vesicles**.

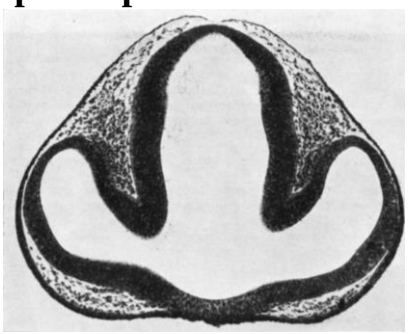


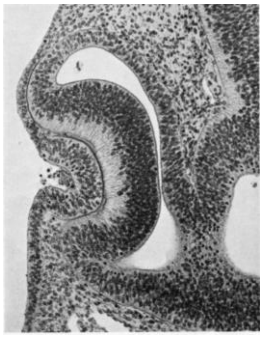


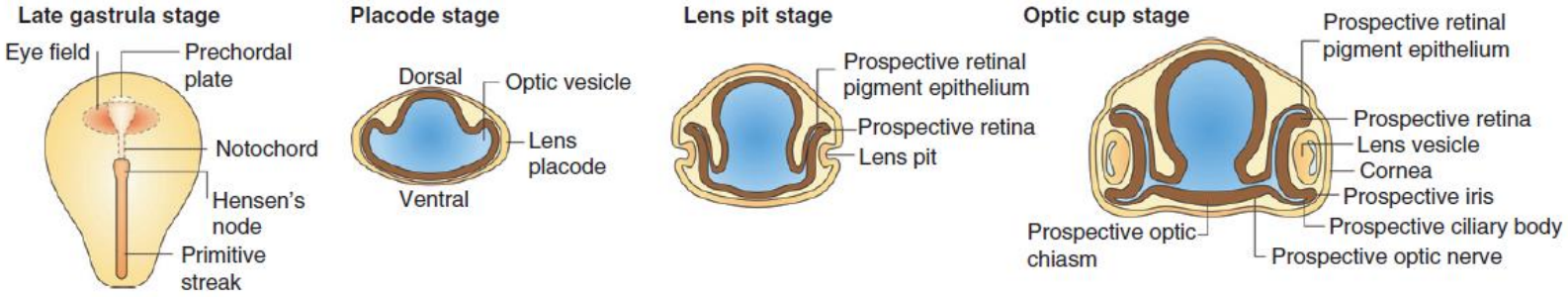
During the **fifth week** (35 days), as each optic vesicle grows, it makes contact with the thickened surface of the **ectoderm** known as the **lens placode** causing it to differentiate into the **crystalline lens** of the eye instead of skin epidermal cells. The contact is also accompanied by invagination of the **optic vesicle** into an **optic cup** where the lumen of the optic vesicle is reduced to a slit. The **inner layer** of the optic cup develops into the **neural retina** and the **outer layer** develops into the **retinal pigmented epithelium**.





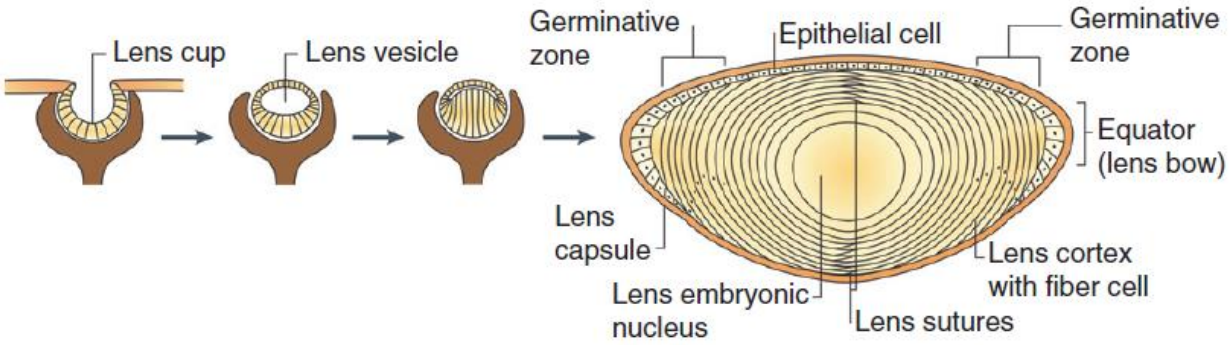






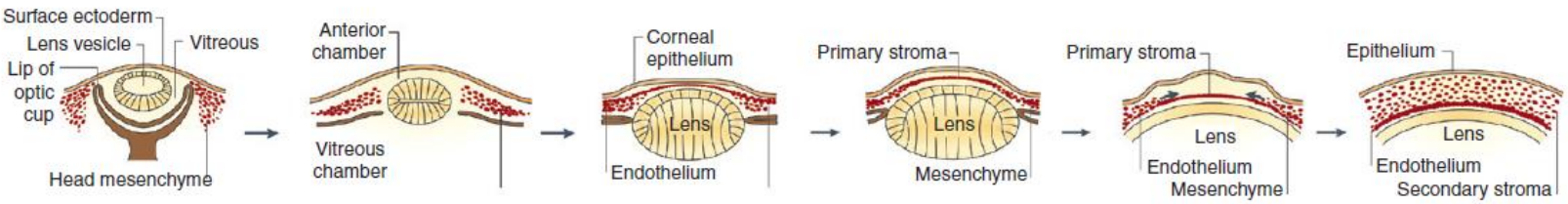
By the **sixth week** (42 days), the **crystalline lens** breaks free within the optic cup where it will continue to develop.

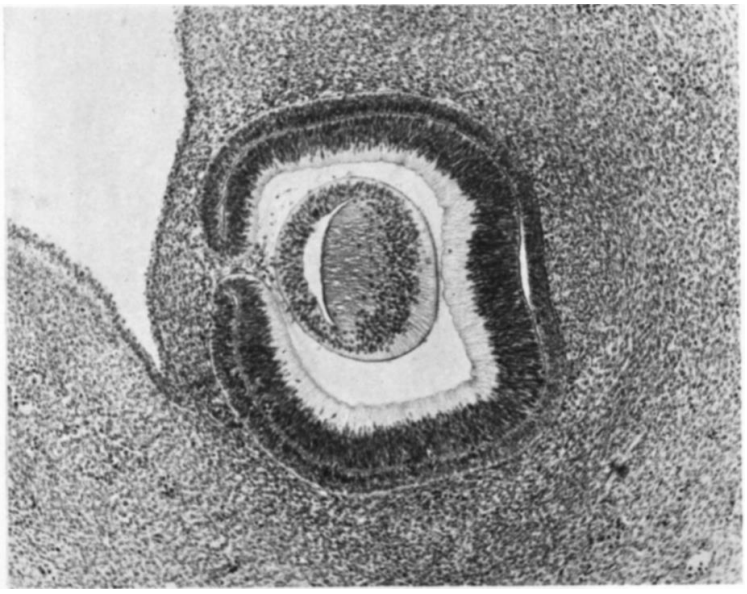




By the **seventh week** (49 days), the **outer layer of the cornea** differentiates from the ectoderm. The mesenchyme surrounding the optic cup differentiates into the **stroma of the cornea**, the **sclera**, and the **choroid.**







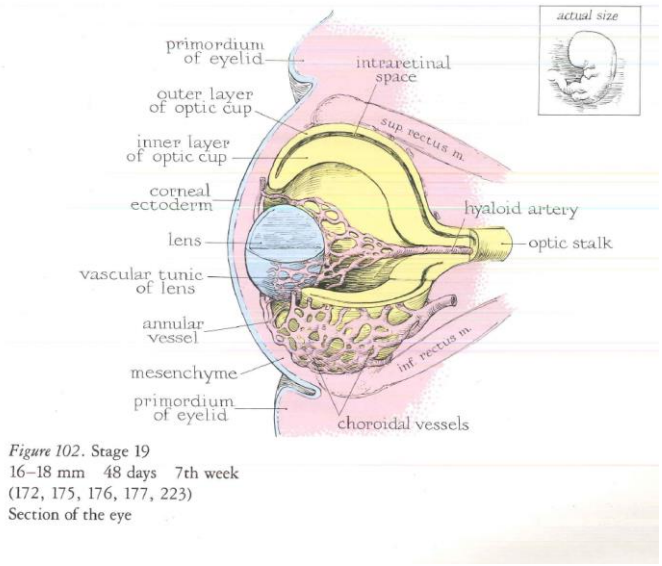
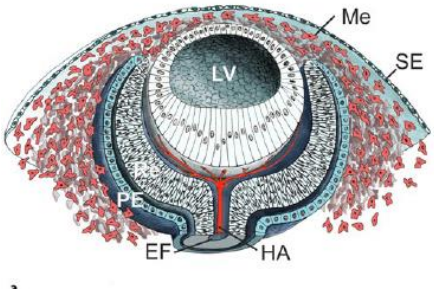
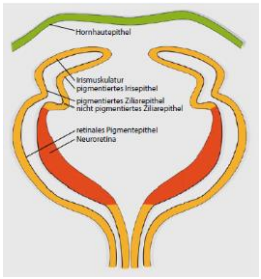


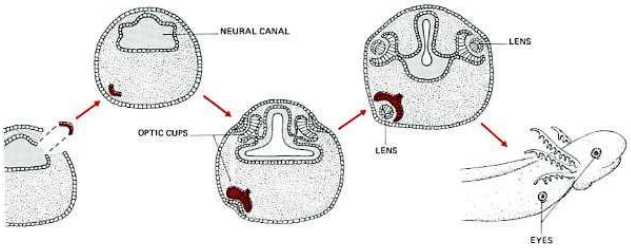
Figure 102. Stage 19
16–18 mm 48 days 7th week
(172, 175, 176, 177, 223)
Section of the eye

While the inner layer of the optic cup develops into the **neural retina**, the leading edge of the optic cup participates in the formation of the epithelial portion of the **iris** and the **ciliary body**. While most of the neural retina will differentiate into a layer of **rods and cones**, it will also differentiate into a layer of **bipolar cells** and a layer of **ganglion cells**. Some of the ganglion cells will extend towards the brain and differentiate into the **optic nerve**. We will talk about the retina in detail next week when we talk about color vision.





Hans Spemann (1924) studied eye development and hypothesized that the optic cup acts as an "*organizer of the lens*." He proved the existence of "organizers" by doing tissue transplants and inducing tissues to develop into other tissues. Spemann won the Nobel Prize in 1935 for his work (http://www.nobelprize.org/nobel_prizes/medicine/laureates/1935/press.html). Below is a proposed model of the role of organizers, which are now known as **localized inducing molecules** or **paracrine factors** that may cause the differentiation of the crystalline lens, the retina, and the cornea.



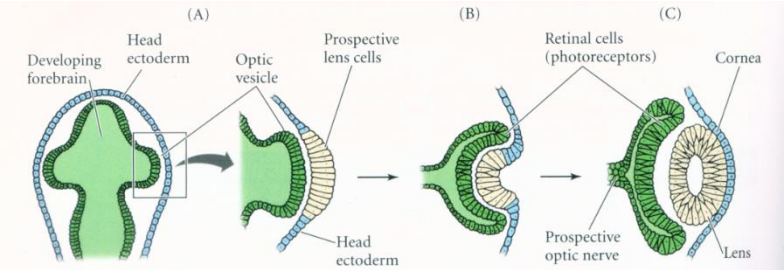
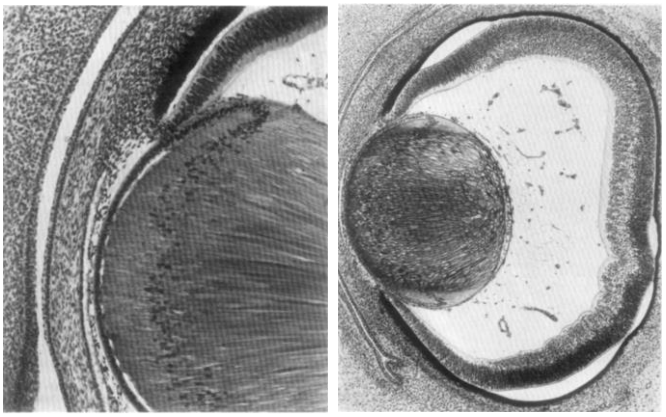


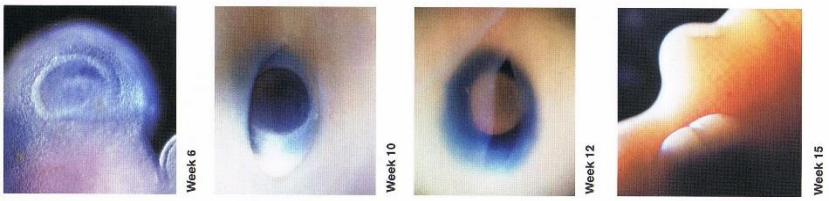
FIGURE 9.4 Reciprocal induction of the eye. (A) Paracrine factors induce a portion of the head ectoderm to become lens tissue. (B) Prospective lens tissue produces different paracrine factors that induce retinal cells. (C) Factors from the retina induce differentiated lens tissue, which in turn causes the retina to fold and help induce the cornea in front of the lens.

During the **eighth week** (56 days), the **stroma of the iris** differentiates from mesochyme as the anterior and posterior spaces on either side of the iris fill with **aqueous humor**. We will talk about the iris in detail next class when we talk about eye color. The **vitreous humor** develops in the space between the crystalline lens and the neural retina. At this stage, the **retinal pigmented epithelium** causes the eyes to be seen as small dark holes on either side of the head.



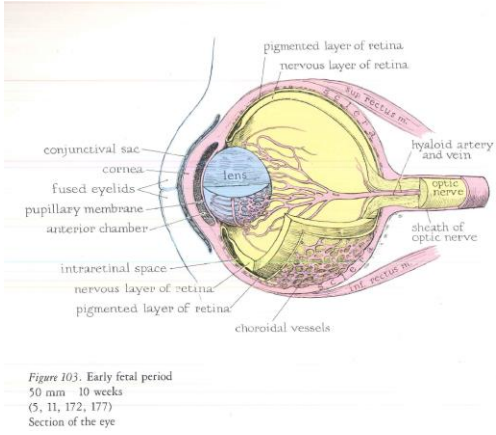


By the **ninth week** (63 days), the **eyelids** are developed. The eyelids will stay closed from the third month until the seventh month (26 weeks).



By the **tenth week** (70 days), although still developing, the eye looks very much like an adult eye.





Ultrasound at 10 weeks: https://www.youtube.com/watch?v=SdXfTqBS-9E

During the **sixteenth week** (4 months), the retina and the neural connections to the brain are still developing. At **six and one-half months**, the eyes are still sealed-shut.



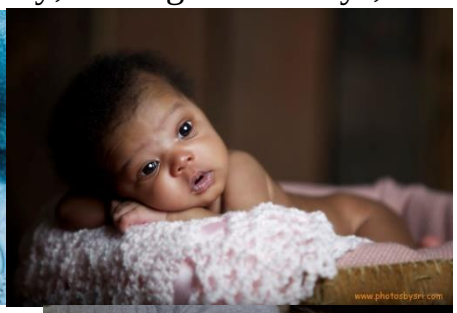
The scientific evidence I presented to you can be taken into consideration in any debate regarding reproductive rights bills.

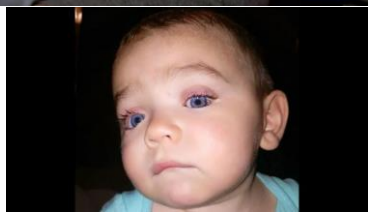
On January 22, 2019, on the 46th anniversary of Roe v. Wade, New York Governor **Andrew M. Cuomo** signed legislation that allowed him to proclaim, "*Today we are taking a giant step forward in the hard-fought battle to ensure a woman's right to make her own decisions about her own personal health, including the ability to access an abortion*." https://www.governor.ny.gov/news/governor-cuomo-signs-legislation-protecting-womens-reproductive-rights



Those who do not support this legislation ask, does a women's fundamental right to control their own body involve the fundamental right to abort a baby right up until the day it would have been born https://www.westernjournal.com/ct/ob-gyn-delivered-2500-babies-blows-lid-off-ny-abortion-law-want-clear-something/ or after https://www.cnn.com/2019/01/31/politics/ralph-northam-third-trimester-abortion/index.html.

African American, Hispanic, and Asian babies are usually, although not always, born with brown eyes while Caucasian babies are usually born with blue eyes. Babies do not always come out the way parents expect: Richie Lopez was born without eyes. His parents hope that he will get an eye transplant or eyes grown from stem cells. http://www.cnn.com/videos/tv/2015/01/27/dnt-az-baby-born-without-eyes.ktvk

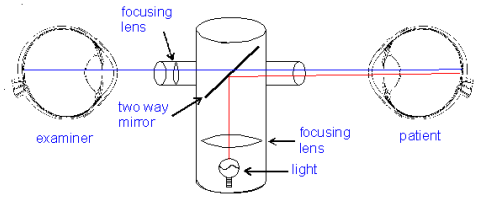





Richie currently has prosthetic eyes: http://www.beeherald.com/news/richie%E2%80%99s-new-look-sight-sore-eyes

When a baby is born the **rods** are fully developed and the baby has low light **black and white scotopic vision**. Approximately three months later, the **cones** form and the baby also has **photopic color vision**.

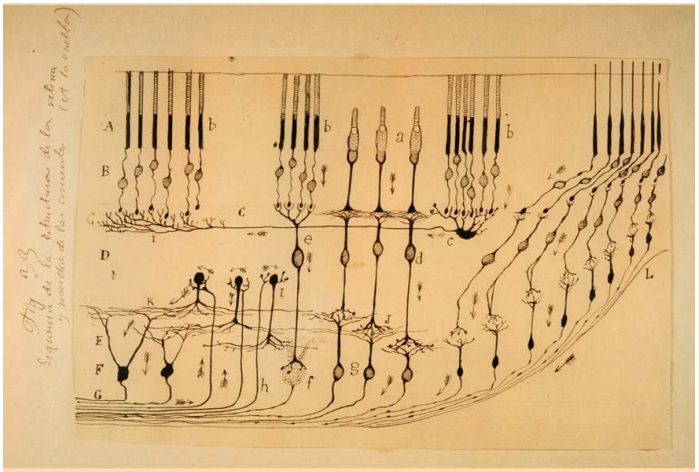
Cicero (46 BC) wrote in the *Orator*, *ut imago est animi voltus sic indices oculi*, which means for *if the countenance is the image of the mind, the eyes are it's interpreters* (http://www.gutenberg.org/cache/epub/9776/pg9776-images.html). The **retina** is derived from the optic cup and some consider the retina to be a part of the brain, having been sequestered but not isolated from it early in development. Interestingly, **the retina is only part of brain that is readily visible to us**. It can be viewed with an **ophthalmoscope**.





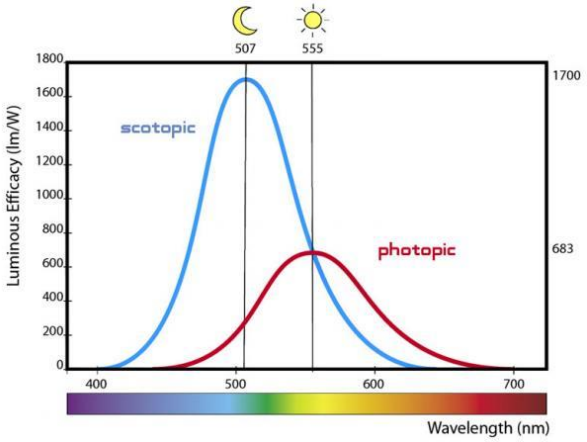
Demonstration: View your classmate's retina with an ophthalmoscope.

The **neural retina** contains the light-sensitive photoreceptor cells, known as **rods** and **cones**. The rods and cones are modified cilia. The rods and cones are on the neural retinal layer closest to the **retinal pigmented layer** and farthest from the external world. The rods are very light sensitive and are involved in dark (**scotopic**) vision while the cones are less light sensitive and are involved in normal color (**photopic**) vision.



"Schematic representation of mammalian retina structure. Artistic grouping of cells and direction of current flow" A, layer of rods and cones; B, visual cell body layer; C, outer plexiform layer; D, bipolar cell layer; E, inner plexiform layer; F, layer of ganglion cells; G, optic nerve fiber layer; L, central fossa. Modified from a photograph taken from the original (22X32 cm). Drawn on sheet/paper. P.Y. 1901. S.R. y Cajal Institute - CSIC - Madrid, Spain.

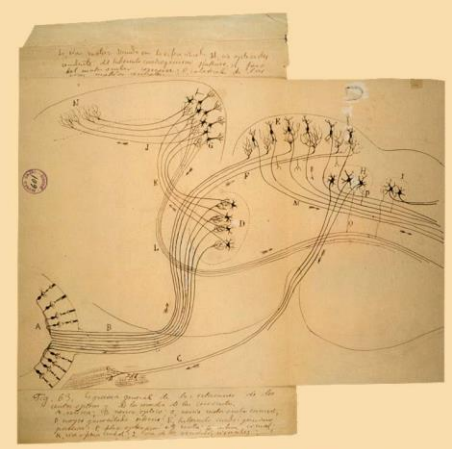
Scotopic vision, effected by the rods is more **efficient** in utilizing light at low light intensities than **photopic vision**, effected by cones. Moreover the range of spectral colors utilized by the rods is blue-shifted relative to the range of spectral colors utilized by the cones. Perhaps this is why objects illuminated by moonlight look black and bluish-white.



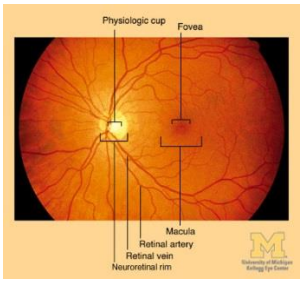
Remember from the Pulfrich pendulum effect, that when we use our scotopic vision, we see things "**in the past**." Night lights in baseball stadiums allow players to play with their photopic vision, so they see, and catch or hit the ball "**in the present**."

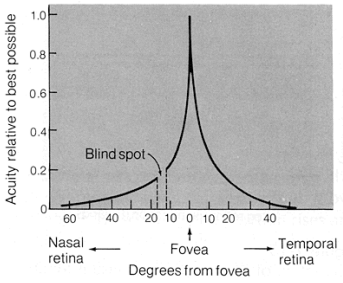


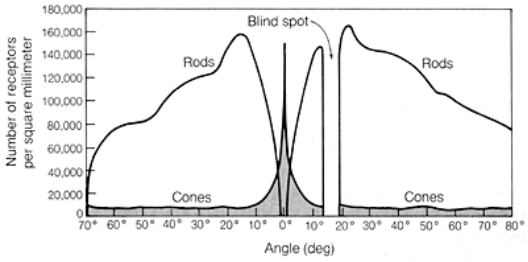
The **cones** are connected to the **retinal gangion cells** and the **rods** are connected to **bipolar cells** which in turn are connected to **retinal ganglion cells**. The retinal ganglion cells are in the layer of the retina closest to the external world. The axons of the retinal ganglia pass through the retina at the **optic disc** to connect with the optic nerve. Since two cells cannot be in the same place at the same time, this precludes the photoreceptor cells from being in the **optic disc**, thus creating a **blind spot** on the nasal side of the retina.



"Schematic of the afferent and efferent pathways of the optic centers". A, retina; B, optic nerve; C, fibers from the oculomotor nucleus; D, lateral geniculate nucleus; E, colliculus; F, optic fibers; G, visual cortex; K, central optic pathway; J, pathway of visual association fibers; L, motor pathway arising from the visual cortex; M, superior colliculus; H, oculomotor nucleus; O, collaterals of the cerebral motor pathways. Modified from a photograph taken from the original (34X28cm). Drawn on sheet/paper. P.Y. 1901. S.R. y Cajal Institute - CSIC - Madrid, Spain.





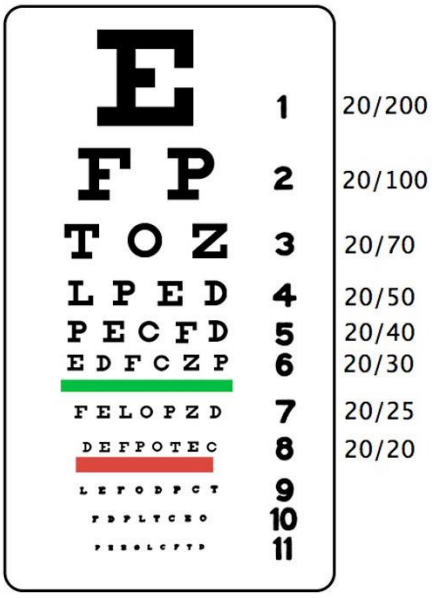


The **rods**, which are used for **scotopic vision**, are located around the periphery of the retina. The most peripheral rods are capable of sensing motion but are not able to produce an image of what is moving. You can tell this by having a friend wave an object such as a **fork or a spoon** at the very edge of your visual field near your ear. You will be able to tell something is moving, and in which direction, but you will have no idea what is moving!

The **cones** that are involved in **photopic color vision** are enriched in the center of the retina known as the **macula**, which is 2.5-3 mm in diameter. The macula is a region of the retina that is rich in retinal ganglion cells as well as cones. The **fovea** is in the center of the **macula**. Just as the **optic disc** excludes the

photoreceptor cells, the **fovea** is a depressed area of the retina, about 0.3 mm in diameter, that excludes the bipolar cells and the retinal ganglion cells so that **light travels directly and unhindered through the rest of the neural retina layer to the cones**. Consequently, this region of the retina gives us the greatest **visual acuity**.

Light is hindered from reaching the rods and cones outside the fovea by the bipolar cells and retinal ganglion cells since the rods and cones outside the **fovea** face the retinal pigmented layer instead of the outside world. The rods and cones may face "**backwards**" so that old discs from the photoreceptor cells are **sloughed off to the back** of the retina so that they do not accumulate in the vitreous humor. It has been suggested that the melanin-containing cells are adjacent to the rods and cones to help them chemically restore the light-sensitive visual pigment in the receptors after it has been bleached by light.



Visual acuity is measured with a **Snellen eye chart**, developed by Hermann Snellen in 1862. To measure visual acuity, a person stands 20 feet away from the chart, covers one eye, and reads the letters starting at the top until they get to the line where they can no longer make out the letters. The last line that they can clearly read, gives their visual acuity. A **"standard" person** has a visual acuity of 20/20. Others have better or worse vision. If someone has a visual acuity of 20/200, it means that he or she can see as clearly at 20 feet as a "standard" person can see at 200 feet. Someone with 20/200 vision is legally blind. If someone has a visual acuity of 20/10, it means that he or she can see clearly at 20 feet what a "standard" person can see at 10 feet.

In angular terms, 20/20 vision is the ability to distinguish between objects that are separated by one minute of arc. The letters on the 20/20 line on the chart are 0.34 inches tall, which at twenty feet (240 inches) subtend 1.42×10^{-3} radians, which equals 0.08 degrees, which equals 4.9 minutes of arc. That means that the limbs of each letter subtend about one minute of arc. (Note: 2π radians = 360° and 1° = 60 minutes of arc).



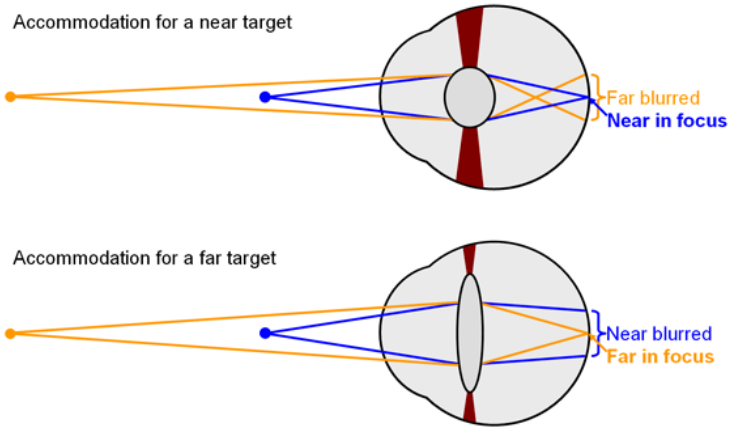
While human visual acuity is excellent, it is not as good as that found in raptors, such as the Bald Eagle.

Image formation by the human eye depends on **two refracting elements**, the **cornea** and the **crystalline lens** that act together to make a **converging lens** with a **variable focal length** and a dioptric power that ranges from 40-53 diopters ($D = \frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$; $s_o = 0.025$ m - ∞ m) in order to project an **in-focus**, **inverted**, **real**, **minified**, **image** of the outside world on the **retina** (the optical distance between the crystalline lens and the retina is $s_i = 0.025$ m). Remember only real images have the **radiant energy** necessary to activate the photoreceptor cells on the retina. The transparent **cornea**, which is the **window of the eye**, is the main refractive element of the eye since there is a great difference in the refractive index between the **cornea** (n = 1.376) and air. This cornea is a powerful lens with a dioptric power of about 40 diopters.

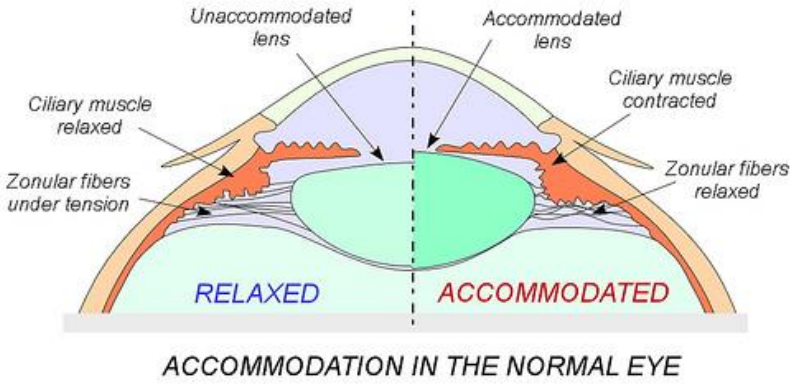
The cornea does not have a blood supply because the choroid does not extend into the anterior of the eye. The cornea is nourished by the aqueous humor, which is refilled every 4 hours. Interestingly, the absence of a blood supply means that **antibodies** made by the immune system of the body ***do not*** reach the cornea. The absence of any rejection response by the immune system has made **corneal transplants** successful since as early as 1905.

The **crystalline lens** (n = 1.386-1.406) is the second refracting element of the eye. When we are young, the crystalline lens can increase the dioptric power of the eye by an additional 13 diopters, giving a total dioptric power of about 53 diopters. The reason that the dioptric power of the crystalline lens, with a refractive index of 1.386-1.406, is less than the dioptric power of the cornea with a smaller refractive index of 1.376, is that the crystalline lens is surrounded by the **aqueous** and **vitreous humors** that have refractive indices 1.336,and 1.337, respectively. The small difference in refractive index, like that of Pyrex glass in Wesson oil, does not allow for much light bending or coarse focusing—only fine focusing.

The crystalline lens is held in place by the **ciliary body** which contains muscles that **contract** in order to increase the curvature of the crystalline lens, which decreases its focal length and increases its dioptric power. The increased dioptric power and decreased focal length allows us to focus near objects on the retina. When the muscles of the ciliary body **relax**, the crystalline lens becomes flatter, the dioptric power decreases, the focal length increases, and we can focus distant objects on the retina.

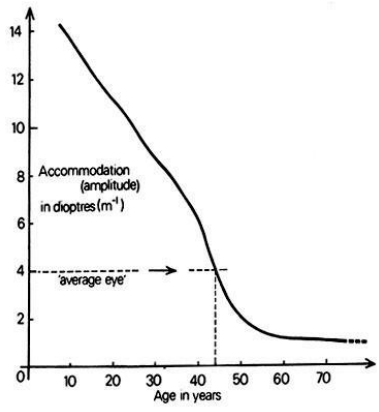


The ciliary muscles act on the crystalline lens through the **zonular fibers** that make up the **suspensory ligament**. The crystalline lens and zonular fibers are both elastic. When the eye is observing **distant objects**, the ciliary muscles are **relaxed**, the zonular fibers are under tension, and the elastic **crystalline lens is maximally flat**. This results in minimal dioptric power and maximal focal length. However, when the eye is observing nearby objects, the ciliary muscle **contracts** and pulls itself forward, releasing the tension on the zonular fibers. This causes the **crystalline lens to become more curved**, and the dioptric power to increase and the focal length to decrease. Note that a camera lens fine-focuses nearby objects by moving the lens closer to the object and farther from the CCD, instead of changing the shape of the lens.



ACCOMMODATION IN THE NORMAL EYE

As one ages, the ability to accommodate decreases and the near point moves toward infinity, making it harder and harder to read small print close up (ask your parents).



Demonstration: Keep your glasses on if you wear them. Block one eye. Have someone hold a book and measure the farthest distance between the book and your eye where you can still read the book ($s_o \approx 1$ m). Take the reciprocal of the distance of the far point and add it to the reciprocal of the optical distance between the crystalline lens and the retina ($D = \frac{1}{f} = \frac{1}{s_o} + \frac{1}{0.025}$) to get the dioptric power of the eye. As an example, if $s_o = 1$ m, the dioptric

power of the eye is 1 + $\frac{1}{0.025}$ = 41 diopters, where $\frac{1}{0.025} = 40$. Move the book closer to you until the words get blurry and measure the closest distance ($s_o \approx 0.08$ m) between the book and your eye where you can still read the book. Take the reciprocal of the distance of the near point and add it to the reciprocal of the optical distance between the crystalline lens and the retina ($D = \frac{1}{f} = \frac{1}{s_o} + \frac{1}{0.025}$) to get the dioptric power of the eye. As an example, if $s_o = 0.08$ m, the dioptric power of the eye is 52.5 diopters. Accommodation range is given by (near point in diopters) – (far point in diopters). In the example, it is 11.5 diopters.



As the crystalline lens of a human ages, the crystalline lens proteins, known as alpha **crystallins fall out of solution** or **precipitate**, the lens becomes cloudy, and **cataracts** are formed. The crystalline precipitates scatter blue light out of the eye so that objects appear more yellowish. At this point the crystalline lens can be replaced with a synthetic intraocular plastic lens.



In 1940, Harold Ridley noticed that when Fighter Lt. Gordon "mouse" Cleaver was shot down in his Hurricane in combat, his eyes were filled with slivers of Perspex (Poly(methyl methacrylate)) that were not rejected by the body's immune system. Ridley realized that the body's tolerance to Perspex, as well as its mechanical and optical qualities, would make Perspex a good artificial intraocular lens material. The medical establishment thought that such an operation was too risky, so in 1949, Harold Ridley performed the first lens transplant in secret. Currently intraocular lens are made of softer material such as silicone and acrylic, making it possible to insert the intraocular lens through a tiny incision.

The **iris** is the colored part of the eye and we will talk about its color next week. The **iris** contains **circularly-arranged sphincter and radially-arranged dilator muscles**. Contraction of the sphincter muscle, which is a striated muscle, **closes the pupil** in response to stimulation by the parasympathetic nervous system, which is active when the body is in the **rest and digest state**. Contraction of the dilator muscle, which is a smooth muscle, **opens the pupil** in response to stimulation by the sympathetic nervous system, which is active when the body is in the **fight or flight state**.

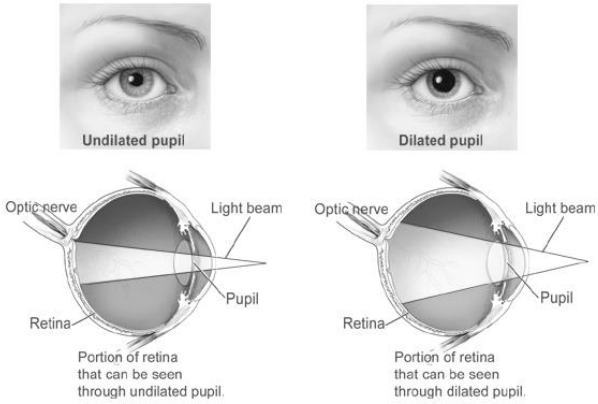
Oxytocin, which is produced by the human body during sexual arousal, also causes pupils to dilate. Eckhard Hess discovered the role of pupil size in communicating attitude. The size of the pupil lets people know our emotional state.

We can mimic emotional states in terms of pupil size with drugs, such as **atropine (belladonna),** hysocyamine, and scopolamine that cause dilation of the pupils known as mydriasis by inhibiting the parasympathetic nervous system. **Opiates** mimic the rest and digest state by inhibiting the sympathetic nervous system and causing an extreme contraction of the pupils known as miosis.

Typically, the adult human pupil is about 2-3 mm in diameter and children have larger pupils than adults. The adult human pupil varies from 2 mm in bright light to 8 mm in dim light.

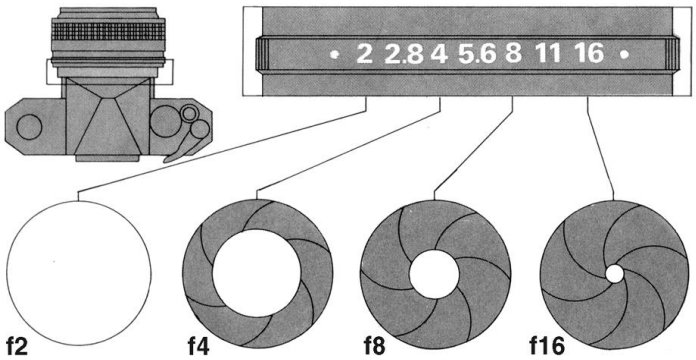
Demonstration: Perform the flashlight test to see your classmate's pupils contract in bright light and dilate in dim light. Both pupils respond the same way, even if you only illuminate one. This **consensual response** indicates that there is higher-level control of pupil size. Also notice that the pupils constrict when your

classmate's pupils go from looking at a distant object to looking at a near object. Did you also notice that your classmate's eyes turn in when going from looking at a distant object to looking at a near object? **Accommodation** is a **global process** that is always accompanied by constriction of the pupils and converging of the eyes. Note that a dilated pupil at night will allow the light of a distant star to hit more rods!

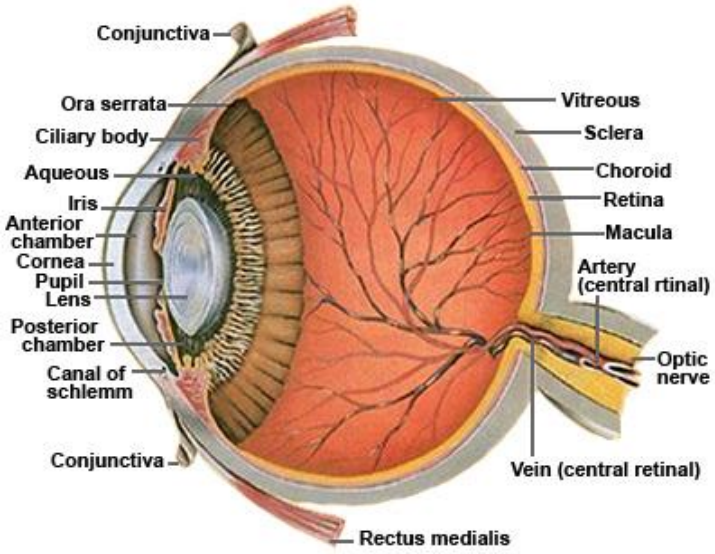


The closing of the human pupil is probably not important in reducing the intensity of light that enters the eye since the area of the pupil varies over a ratio of 16:1 while the eye works efficiently over an intensity ratio of 100,000:1. The closing of the pupil probably functions to limit the rays of light to the central part of the lens, which is the optically best part of the lens that gives maximal acuity, except under low light conditions when the full aperture is needed for maximal light sensitivity (Land and Nilsson, 2012).

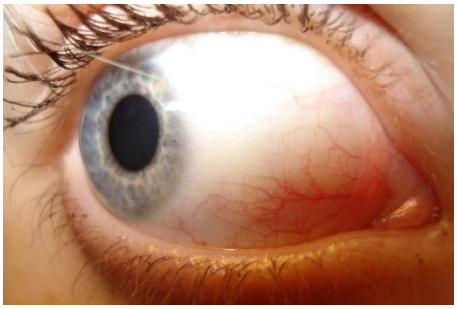
The **iris** and **pupil** allow the amount of light that enters the eye to vary much like the **aperture diaphragm of a camera** lens varies the amount of light that reaches the film. The **f-stop** of the eye varies from f/8.3 to f/2.1. A larger aperture favors a brighter image with greater spatial resolution, more aberration and less depth-of-field, while a smaller aperture favors a dimmer image, with less aberration and a greater depth-of-field. Perhaps children have larger pupils because their young refracting elements have fewer aberrations.



The human eye is a sphere approximately **one inch** in diameter. Most of the eye is surrounded by the **sclera**, which is about 1 mm thick. The word **sclera** is derived from the Greek word for "hard." The tough and hard sclera protects the eye. It is the body part that was immortalized at the Battle of Bunker Hill when Israel Putnam or William Prescott yelled, "*Don't fire till you see the whites of their eyes*," reminding the soldiers not to waste gunpowder when the enemy was not close enough.



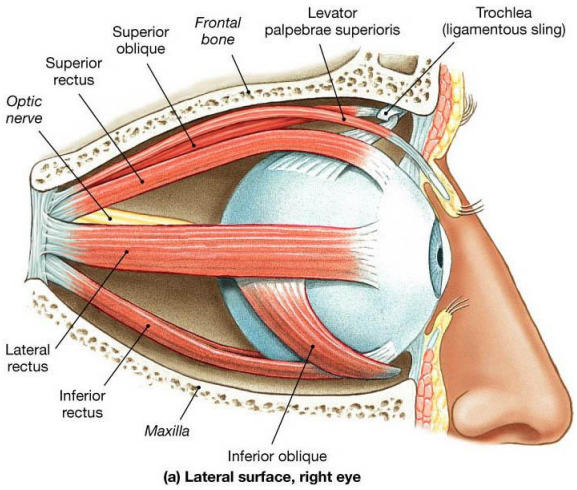
The white part of the eye (sclera) and the inner surface of the eyelid are covered by a membrane, known as the **conjunctiva** that contains blood vessels. Infection of the conjunctiva results in conjunctivitis, commonly known as **pinkeye** (left). Blood can also accumulate in the region between the conjunctiva and the sclera (right). This is known as a subconjunctival hemorrhage and can also be caused by high blood pressure, chemicals, or trauma.







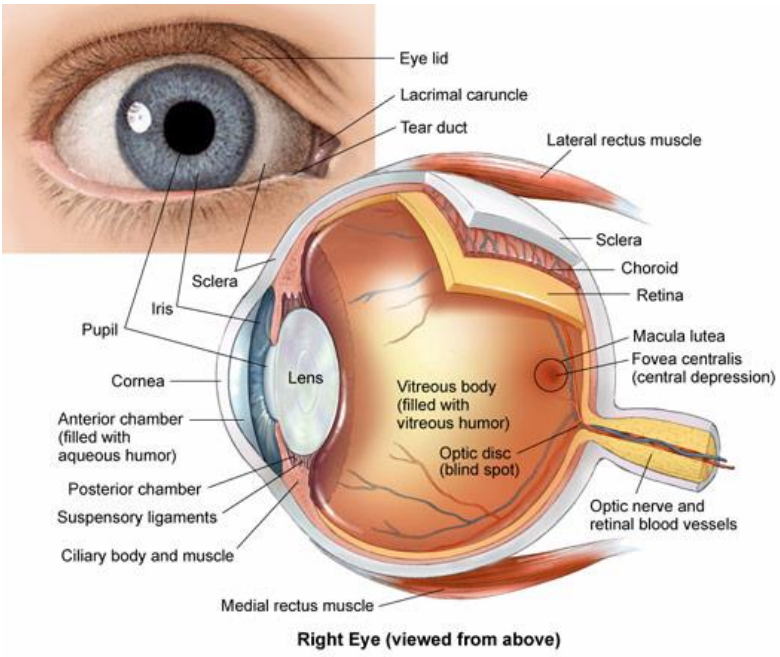
The sclera is covered with **fatty tissue** that insulates the eye from mechanical shock. The sclera also is connected to three pairs of **extraocular muscles** that move the eye up and down, side to side, and to rotate the eyes to counteract head movement. Cows only have four muscles that move the eyes up and down and side to side. **Nerves** innervate these muscles to tell the brain which direction each eye is looking. Information is passed to the brain concerning the **convergence angle** described as the angle each eye turns to look at the same object when the image in each eye is projected on the **fovea** of the **retina** in each eye.



(a) Lateral surface, right eye

The **choroid** is the layer inside the sclera that contains blood vessels that nourish most of the tissues of the eye and remove wastes.

We will dissect a cow or pig eye to understand the anatomy of a human eye:

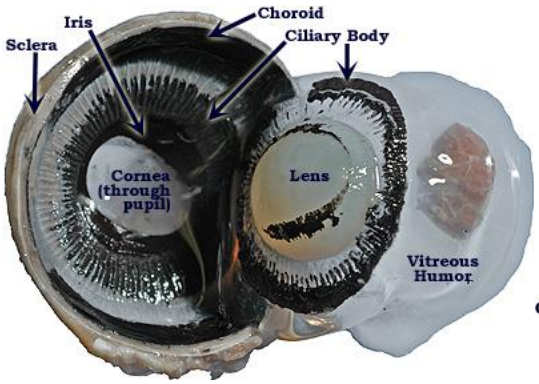


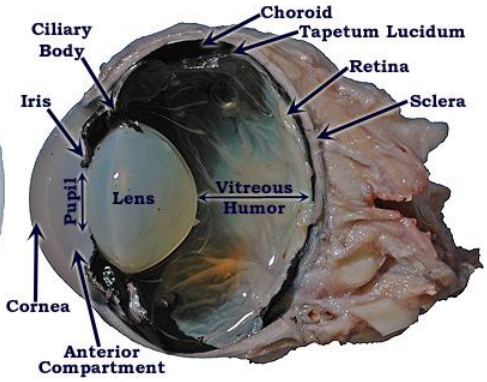
Right Eye (viewed from above)



Dissection of cow eye

The parts of the eye we will see are labelled below:

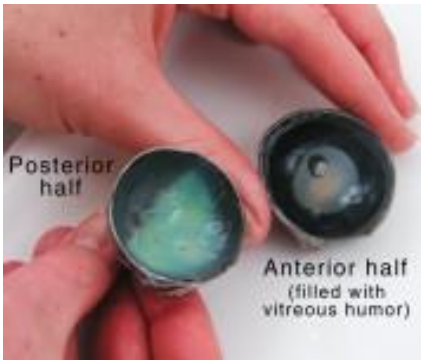




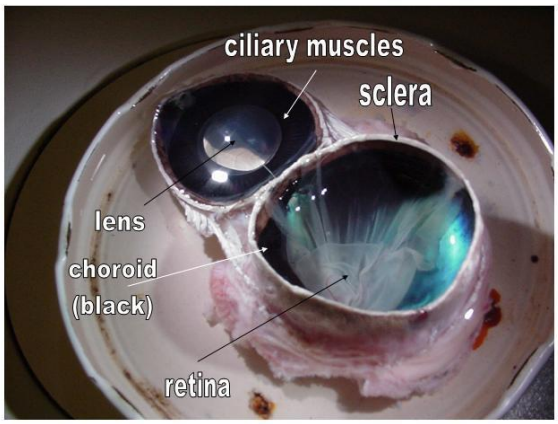


Put on gloves that fit, and get a scalpel, scissors, a tray and an eye. If necessary, remove with the scissors, the fat and the muscles that are attached to the sclera. In the back of the eye, you should see the optic nerve that transmits the visual information to the brain.

Use the scalpel to cut through the sclera at the middle of the eye. Then use the scissors to cut all around so that the eye separates into the anterior and the posterior halves. Hopefully you will have disturbed neither the ciliary body nor the retina. You will see the **crystalline lens**, the **ciliary body**, the **iris**, the **pupil** and the **cornea** in the front half and



the **retina** and the **tapetum** in the back half. The vitreous humor fills the cavity. Bits of cellular debris in the vitreous humor, known as floaters, are the cause of faint shadows on the retina.



Hold the front part of the eye and look through it to get a **cow's eye view of the world**.

Turn the front half of the eye so that the back of the **crystalline lens** is facing up. (The picture is of the top facing up). The crystalline lens is held in place by the **ciliary body** which contains muscles that contract in order to increase the dioptric power of the crystalline lens and we can see nearby objects in focus. When the muscles of the ciliary body relax, the crystalline lens becomes flatter, which decreases the dioptric power of the crystalline lens and we can see distant objects in focus.

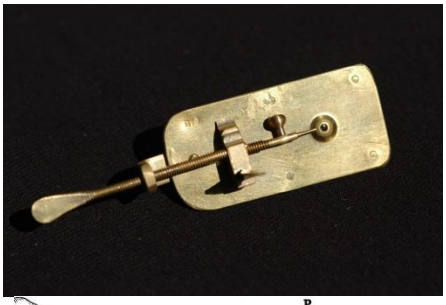


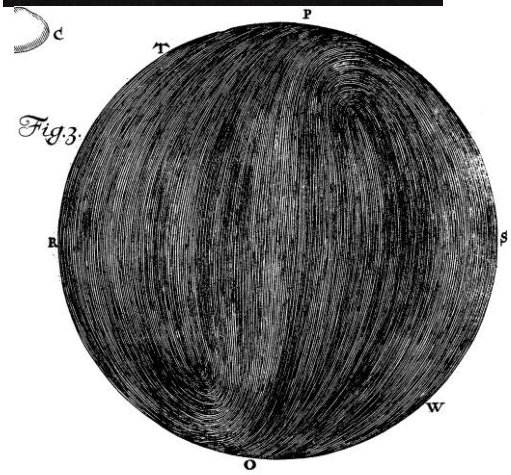
Remove the crystalline lens from the ciliary body. Is the crystalline lens converging or diverging? Is the image real or virtual? How can you tell?





Look through the crystalline lens. The lens is a double convex converging lens that produces an inverted, real image of an object that is more distant than its focal length. The crystalline lens produces an erect, virtual image when the object is closer than the focal point. The elastic properties of the crystalline lens cause it to round up and take the form of an accommodated lens when it is separated from the zonal fibers and the ciliary body. Feel how elastic the crystalline lens is.





Demonstration: Cut a sliver from the crystalline lens and carefully place it on the pin of the **Leeuwenhoek microscope replica**. As you are looking through the pinhole in the window or at the clear blue sky, adjust the specimen height so that the top edge of the specimen is in the middle of the lens and then adjust the distance of the specimen from the lens until the specimen is in focus. Can you see the **fibrous layers of the crystalline lens** like Leeuwenhoek did? Is the lens in the Leeuwenhoek microscope replica converging or diverging? Is the image formed by the microscope real or virtual? How do you know?



Push back the ciliary body and find the **black elastic iris** and the **oblong pupil** whose major axis is horizontal. The pupil regulates the amount of light that enters the eye. When the pupil contracts, it reduces the amount of light, reduces the amount of aberrations, increases the depth of field, and reduces the resolution, just like the iris diaphragm in the pinhole camera. Grazing animals,

like the cow, tend to have horizontal pupils. Since the pupil of the cow is greater in the horizontal direction, the cow can resolve horizontal details more sharply than it can resolve vertical details. Humans, with a round iris, see details equally sharply, independent of their orientation. Remove the iris and look at the **cornea**. The cornea is relatively thin; neither delicate nor tough. Imagine doing Lasik surgery on it!

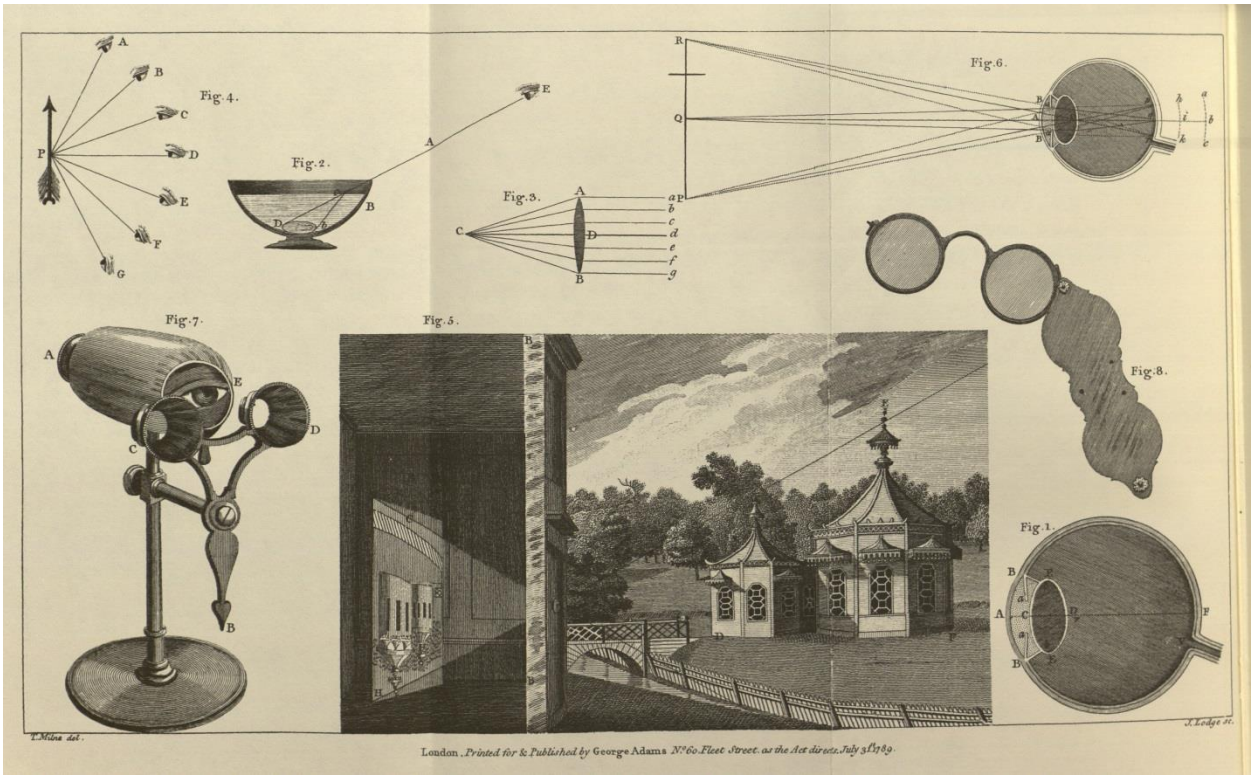
Now look at the back half of the eye. The retina is a very soft tissue, typical of neural tissue.

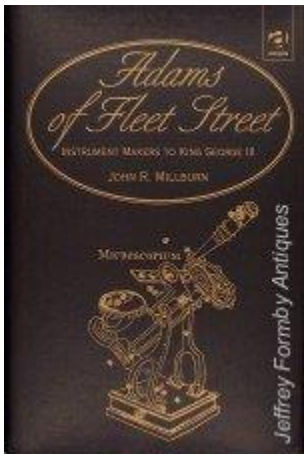


The retina is somewhat gooey. The retinal ganglion cells pass through the **optic disc** to connect to the optic nerve. The **optic nerve** is very shiny because of the high lipid content of the **myelin sheath** that surrounds the neurons.

Humans have a melanin containing pigmented layer in the back of the eye to absorb any photons that are not absorbed by the photoreceptor pigments in order to **minimize any glare** that would come from stray light. On the other hand, it is hard for us to see at night because humans do not have a mirror-like **tapetum lucidum**. Animals including, cows, pigs, raccoon, dogs, cats, alligators, and sharks have a mirror-like tapetum lucidum that reflects light that was not absorbed the first time back to the retina so that they can see better in the dark. Although the tapetum lucidum enhances the ability to see in the dark it makes the image less sharp since the light from a single object point is reflected to nearby photoreceptor cells. The reflection of light from the tapetum lucidum is responsible for the glowing eyes of animals seen in dim light.







The eye is a simple and elegant instrument. **George Adams** (1789, 1792), the instrument maker to King George III, wrote in his *An Essay on Vision*, "*In the structure of the eye we find the most evident manifestations of exquisite art and design, every part elegantly framed, nicely adjusted, and commodiously placed, to answer in the most perfect manner every possible good purpose, and thus evince that it is the work of unerring wisdom, prompted to action by infinite love. So manifold are the blessings we derive from this organ….To it we are indebted for that delightful sensations that arise from the proportion and variety of forms, the harmonious mixture of colours, and the graces of beauty. It enables us to seek, to see, and to chuse our food; to go here and there, as the calls of friendship, or the occasions of business, require; to traverse the ocean, ransack the bowels of the earth, visit distant regions, accumulate wealth, and multiply knowledge. Assisted by it, we become acquainted with the works of the Creator, and can trace his wisdom, his power, and his goodness, in the texture of plants, the mechanism of animals, and the glories of the heavens.*"

Percy Shelley wrote in his *Hymn of Apollo*:



I am the eye with which the Universe
Beholds itself, and knows it is divine;
All harmony of instrument or verse,
All prophecy, all medicine, is mine,
All light of art or nature; - to my song
Victory and praise in its own right belong.

Eye Color and its Inheritance



Color generally provides a **readily visible and reliable attribute, characteristic, trait**, **or quality to easily differentiate or distinguish one individual or group from another**. We often describe people by the color of their eyes, skin, and hair, although it is important to remember not only the **value** but the **limitations** of this description as the Reverend Martin Luther King, who was born Michael King Jr, pointed out on the steps of the Lincoln Memorial on August 28, 1963, when he professed the sentiment described the Book of Samuel[1]: "*I have a dream that my four little children will one day live in a nation where they will not be judged by the color of their skin but by the content of their character."* Out of the seven traits **Gregor Mendel** chose with intention to observe in culinary peas (*Pisum sativum*), three had to do with color. (Two traits had to do with shape, one had to do with length, and one had to do with position).



[1] 1 Samuel 16:7. But the LORD said to Samuel, "Do not consider his appearance or his height, for I have rejected him. The LORD does not look at the things people look at. People look at the outward appearance, but the LORD looks at the heart." The 'I have a Dream' speech, or sermon if you will, was given extemporaneously in Washington D.C. on August 28, 1963, after Mahaila Jackson, who sang, 'I Been 'Buked and I Been Scorned', shouted to MLK, '[t]ell *them about your dream, Martin! Tell them about the dream!*' Encouraged by the audience, MLK put down his prepared remarks and continued speaking. The improvised part of the speech became the landmark statement of the civil rights movement—the dream of all people, of all races and colors and backgrounds, sharing in the freedom of America.



Gregor Mendel was born Johann Mendel but changed his name to Gregor Mendel on October 9, 1843, after he joined the Order of Saint Augustine to become an Augustinian monk. The monastery in Brünn (Brno, Czech Republic) that Mendel joined was run by an Abbot and scientist named Cyrill Napp, who had a great interest in breeding fruit trees and understanding the scientific basis of inheritance. In fact, many of the monks in the Monastery were also scientists.



Mendel read a book by **Carl von Gärtner** entitled, *Versuche und Beobachtungen über die Bastarderzeugung im Pflanzenreiche* (Research and Observations on the Production of Hybrids in the Vegetable Kingdom). The book documented the results of thousands of **hybridization** or **artificial fertilization** experiments that he performed on useful and ornamental plants. Gärtner (1849) showed that sometimes the progeny looked more or less like one parent while other times the progeny looked like intermediates between the two parents. The results did not seem to be generalizable, but that was okay since and Gärtner was concerned with documenting the proposition that **plants were sexual organisms** whose parts could be differentiated into male and female and that pollen was absolutely necessary for the formation of seeds. Mendel, on the other hand, was interested in using artificial fertilization to find a **law of nature** that **explained inheritance**.

In 1865, after eight years of experimentation, Mendel presented his results and his interpretations of his work at a meeting of the Brünn Natural History Society. He began by stating "*Experience of artificial fertilisation, such as is effected with ornamental plants in order to obtain new variations in colour, has led to the experiments which will here be discussed*."

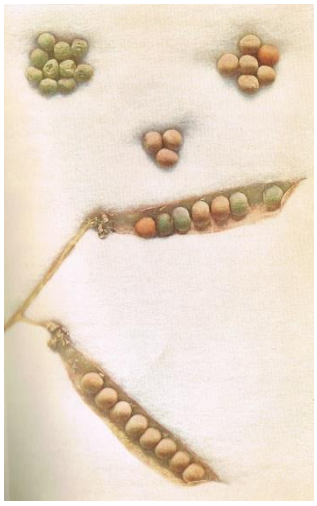


Mendel went on to say, "*among all the numerous experiments made* [by others], *not one has been carried out to such an extent and in such a way as to make it possible to determine the* ***number of different forms*** *under which the offspring of hybrids appear, or to arrange these forms with certainty according to their separate generations, or definitely to ascertain their* ***statistical relations****. It requires indeed some courage to undertake a labour of such far-reaching extent; this appears, however, to be the only right way by which we can finally reach the solution of a question the importance of which cannot be overestimated in connection with the history of the evolution of organic forms."*

Knowing the importance of the question was only the beginning. Mendel had to find the right experimental material to answer the question. Mendel went on to say, "***The value and utility of any experiment are determined by the fitness of the material to the purpose for which it is used****, and thus in the case before us it cannot be immaterial what plants are subjected to experiment and in what manner such experiments are conducted. The selection of the plant group which shall serve for experiments of this kind must be made with all possible care if it be desired to avoid from the outset every risk of questionable results. The experimental plants must necessarily — 1. Possess* ***constant differentiating characters****…*."



Color was a **constant differentiating character**. Mendel performed his experiments using hybrids of peas that varied in **one or two constant differentiating characters**. Because of the shape of the pea flowers, in the absence of bees, pistils of the hybrids were naturally pollinated by pollen from the anthers of the same flower—allowing Mendel to know, with near certainty, who the parents were.



According to Mendel, "*The object of the experiment was to **observe these variations** in the case of **each pair of differentiating characters**, and to **deduce the law** according to which they appear in the successive generations."*
Mendel chose the "*difference in the colour of the seed cotyledons*" to be the constant differentiating character.
"*The cotyledon of the ripe seeds is either pale yellow, bright yellow and orange coloured, or it possesses a more or less intense green tint. This difference of colour is easily seen in the seeds*…."

Mendel noted that for each of the seven traits he selected to study, "*the hybrid-character resembles that of one of the parental forms so closely that the other either escapes observation completely or cannot be detected with certainty. This circumstance is of great importance in the determination and classification of the forms under which the offspring of the hybrids appear. Henceforth in this paper those **characters which are transmitted entire, or almost unchanged** in the hybridisation, and therefore in themselves constitute the characters of the hybrid, are termed the **dominant**, and those which become **latent** in the process **recessive**.*"

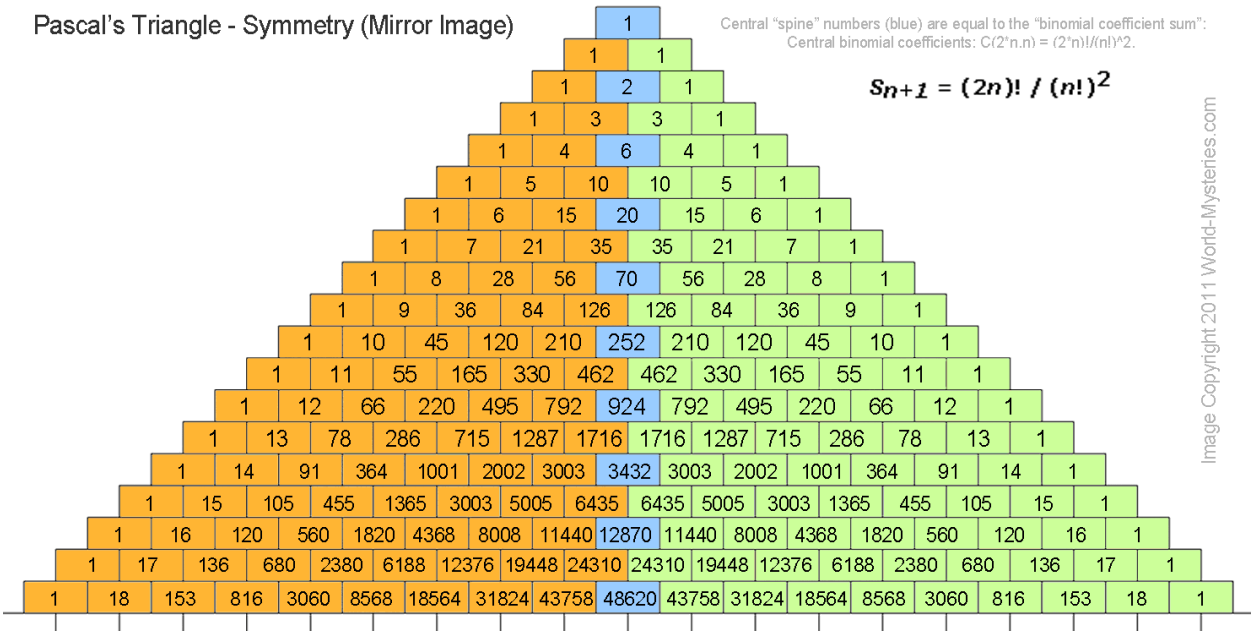
Mendel then presented his results:

Colour of cotyledon. — 258 plants yielded 8,023 seeds, 6,022 yellow, and 2,001 green; their ratio, therefore, is as 3.01 to 1."

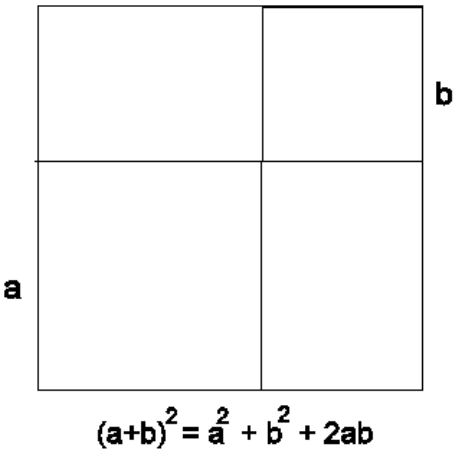
Mendel then **averaged** and **rounded off** to the nearest integer the results from the various experiments to find the essence of the data: "*If now the results of the whole of the experiments be brought together, there is found, as between the number of forms with the dominant and recessive characters, an average ratio of 2.98 to 1 or **3 to 1***."

Mendel then found a way to **reduce the characters to letters** and then **deduce the algebraic model that describes and explains the results***: "If A be taken as denoting one of the two constant characters, for instance the dominant, a, the recessive, and Aa the hybrid form in which both are conjoined, the expression A + 2Aa + a shows the terms in the series for the progeny of the hybrids of two differentiating characters."*

Mendel was good at numbers. We will also get familiar with the power of numbers. Note that 1*A* + *2Aa* + 1*a* looks like the third row of the triangle created by polymaths such as Omar Khayyám (1070) and Blaise Pascal (1653) to visualize the relationships between numbers—especially the numbers involved in a binomial distribution (where there are two possible outcomes like heads or tails; and *bi* means 2).

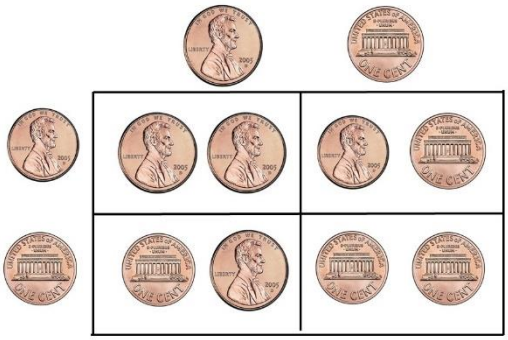


Pascal's triangle is amazing! The rows (0, 1, 2, 3…n) give the coefficients of the binomial expansion, the sum of the values in a row give the value of 2^n, and the powers of 11 can be read off directly from each row. The Binomial Theorem, which relates the parts to the whole, goes back to **Euclid** (Elements II:4) who wrote "*if a straight line be cut at random, the square on the whole is equal to the squares on the segments and twice the rectangle of the segments*." This can be stated algebraically like so:

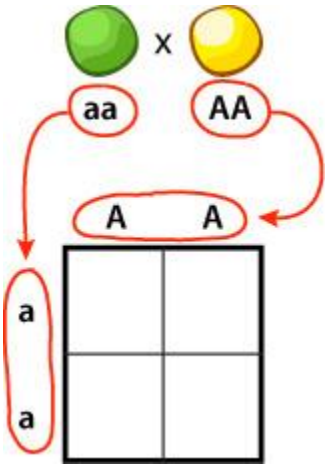


$$(a+b)^2 = 1a^2 + 2ab + 1b^2$$

Pascal's triangle gives the coefficients of the binomial expansion. Imagine that we were flipping two coins (n = 2) and that a is heads and b is tails and there is equal probability of each coin landing on heads or tails. This is known as a Bernoulli trial. Out of the $2^n = 4$ possible combinations, there is one way to get two heads (a^2), one way to get two tails (b^2) and two ways of getting one head and one tail (ab).



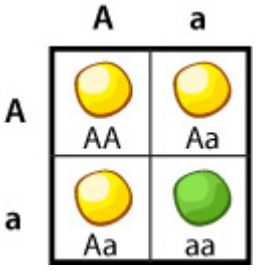
Now imagine along with Mendel that the coins are color genes that come from the mother and father (which makes n = 2). The gene from the mother can land head up (A) or tail up (a) and the gene from the father can land head up (A) or tail up (a). Again, there are $2^n = 4$ possible combinations with one way to get AA, one way to get aa, and two ways to get Aa. This made sense mathematically, but how did Mendel make sense of it biologically?



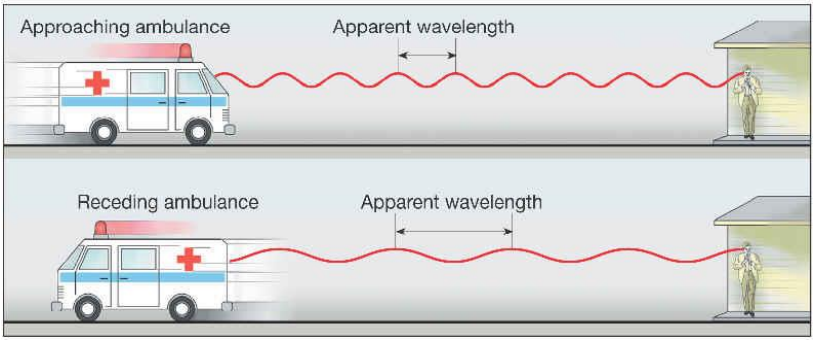
Building on Gärtner's conclusions, Mendel assumed that the anthers produce **sperm-containing pollen** just like male animals produce sperm and the pistils produce **egg-containing ovules** just like female animals produce eggs. (The fusion of egg and sperm in plants was finally observed by Eduard Strasburger in 1884). If this were true and the sperm and egg both carried the hereditary information to make the zygote, the sperm and egg would each have to have half the information contained in the zygote. Otherwise, the amount of information would double at each generation. Mendel assumed that the **gametes** had only one form of each gene.



If the **characters** transmitted from one generation to the next by the sperm and egg were **particulate and** elastic (see **demonstration**), they would be transmitted unchanged from one generation to the next. According to Mendel's **Law of Segregation**, during the formation of gametes, the two factors (e.g. *A* and *a*) that coexist in the parent plant, would **segregate**, each gamete getting only one (e.g. *A* or *a*). Reginald Punnett devised a method, known as the **Punnett Square** to keep track of the segregated factors in the gametes and the predicted characters in the offspring. Assuming that a pea plant of type *Aa* produced pollen that had either *A* or *a* and ovules that had either *A* or *a*, then the ratio of progeny would be 3:1. The **dominant character** would be that one that appears in 75% of the progeny and the **recessive character** would be that one that appears in 25%. In today's parlance, the **phenotype** or outward appearance of the progeny is explained by the **genotype** or internal content of genes.

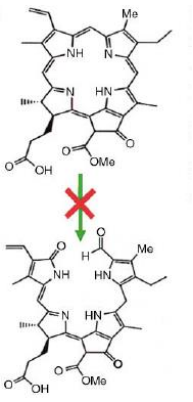


Mendel made so much progress, in part, because he complemented good **experimental design** with **mathematical modeling** and **analysis** in order to understand the **nature of inheritance**. Mendel had learned the power of numbers and the importance of mathematical modeling from his physics teacher, **Christian Doppler**, the man who mathematically modeled and predicted the change in the color of light emitted by moving bodies.



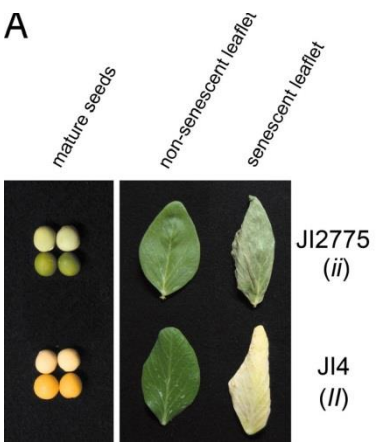
Interestingly, Mendel's work lay buried until it was rediscovered by three botanists in 1900. Perhaps Mendel's work was not taken seriously until 1900;

because his **laws of inheritance** emphasized atomistic, **discrete**, or "digital" traits and neglected the vast number of **continuous** or "analog" phenotypic differences that clearly exist between individuals and could easily be explained by **blending**. In 1900, the atomistic, discrete, **quantum of energy**, which would later be known as the **photon,** was discovered by **Max Planck**. The onset of the twentieth century was a time for appreciating the possibility that **continuous** appearances can result from summing many small **discrete** events. That is, the biologists and physicists arrived at the conclusion that was already well-known to chemists who build up molecules, both on paper and in test tubes from atomic parts. Chemists were the rock stars of the time as a result of the dye and drug industry that could transform black coal tar to mauve, perfume, aspirin, and heroin.

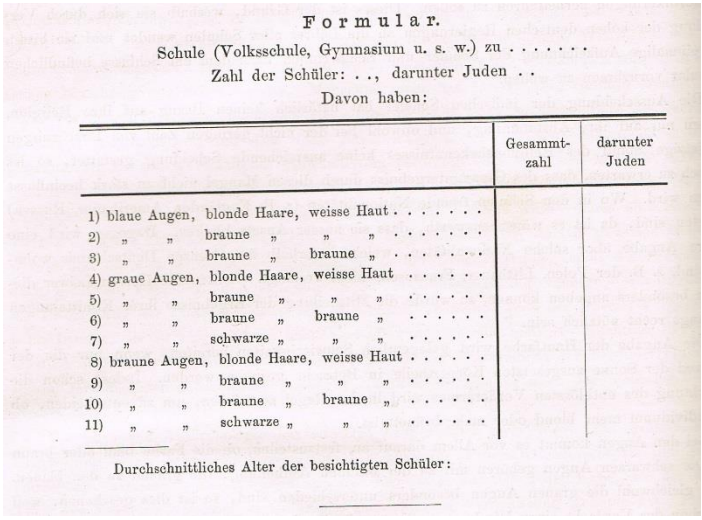


Just over a century after the rediscovery of Mendel, Armstead et al. (2006,2007) and Sato et al. (2007) found the gene itself that causes the seeds to remain **green** instead of turning yellow. The dominant version of the gene codes for an **enzyme** involved in the breakdown (**catabolism**) of **chlorophyll**. The seeds with the **dominant** character are **yellow** because the chlorophyll, which is green, is broken down before the seed dries. The **breakdown of chlorophyll** allows for the **mobilization** of the nitrogen that was originally part of the chlorophyll to the developing seedling where it can be used to make nitrogen-rich amino acids and proteins. In the **green** seeds that exhibit the **recessive** trait, the enzyme does not function, chlorophyll is not broken down, and the nitrogen of chlorophyll is not mobilized to the developing seedling.

The **gene** that determines the color of the seeds also determines the **color of the senescing leaves**. The leaves in the plant with the **dominant** gene turn **yellow** during **senescence** so that the **nitrogen** in its **chlorophyll** can be **mobilized** to the growing part of the plant, especially the seeds. The leaves in the plant with the **recessive** gene remain **green** so that the **nitrogen** is not be **mobilized** to the growing parts of the plant.



Before the rediscovery of Mendel, the inheritance of physical characteristics was of interest to anthropologists. Rudolf **Virchow** (1886), who is famous for saying, "*Omne vivum ex ovo*, which means all living things come from an egg, published a survey on the color of hair and eyes of school children in Germany. He found that only twenty percent of the Jewish (*Juden*) children had blond hair and blue eyes, while fifty percent of the non-Jewish children had blond hair and blue eyes. There was clearly a **relationship between eye color and heredity**.



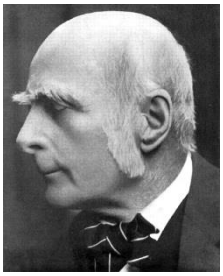
Formular.

Schule (Volksschule, Gymnasium u. s. w.) zu . . . . . .
Zahl der Schüler: . ., darunter Juden . .
Davon haben:

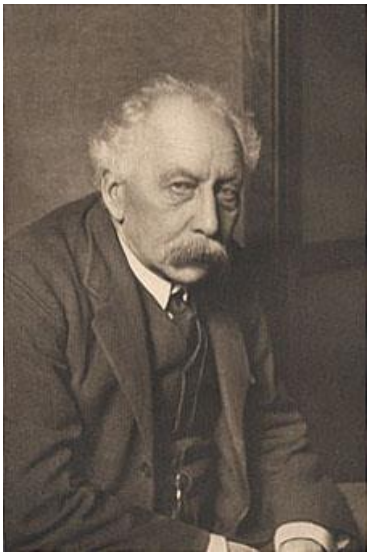
	Gesammtzahl	darunter Juden
1) blaue Augen, blonde Haare, weisse Haut		
2) „ „ braune „ „ „		
3) „ „ braune „ braune „		
4) graue Augen, blonde Haare, weisse Haut		
5) „ „ braune „ „ „		
6) „ „ braune „ braune „		
7) „ „ schwarze „ „ „		
8) braune Augen, blonde Haare, weisse Haut		
9) „ „ braune „ „ „		
10) „ „ braune „ braune „		
11) „ „ schwarze „ „ „		

Durchschnittliches Alter der besichtigten Schüler:

Francis Galton (1889), a cousin of Charles Darwin, stated in his book, *Natural Inheritance*, that eye-color was **non-blending** but inherited as an **either-or trait**, blue or brown.



In 1902, **William Bateson** wrote in his "*Mendel's Principles of Heredity. A Defence*", "*Soon every science that deals with animals and plants will be teeming with discovery, made possible by Mendel's work. The breeder, whether of plants or of animals, no longer trudging in the old paths of tradition, will be second only to the* ***chemist*** *in resource and in foresight. Each conception of life in which heredity bears a part—and which of them is exempt?—must change before the coming rush of facts."* Could Mendel's Laws apply to cabbages and kings, animals and humans?



In 1907, following the rediscovery of Mendel, **Charles Hurst** examined the **eye colors** of 139 pairs of parents and their 383 offspring in Burbage, Leicestershire, England, where he owned a plant nursery, and determined that mating of **blue-eyed** (simplex) parents resulted in **blue-eyed** children and the mating of **brown-eyed** (duplex) parents resulted in **brown-eyed** and **blue-eyed** children in a **ratio of 3:1**. Consequently Hurst concluded that eye color was a **Mendelian trait** where **brown eyes** are **dominant** and **blue eyes** are **recessive**.



In America, also in 1907, **Gertrude and Charles Davenport** published a paper entitled, *Heredity of eye-color in man*. The Davenports wondered, "*Is human eye-color inherited in Mendelian fashion? The importance of knowing whether it is*

depends on the fact that, if Mendelian, the result of any combination of eye-colors of the parents upon the eye-color of the offspring can be, within certain limits, predicted." The Davenports passed out survey cards asking about the eye colors of grandparents, parents and children. They passed out 132 survey cards to principals of schools and friends. They tallied the results and concluded, "*The practical applications of these results to human marriage are as follows: Two blue-eyed parents will have only blue-eyed children…."*



Charles Davenport (1911) tabulated the various studies of eye color in his book entitled, *Heredity in Relation to Eugenics*.

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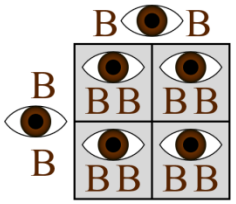
TABLE IV

		HURST		DAVEN-PORT		HOLMES & LOOMIS		TOTAL		P'ORTION	
One Parent	*Other Parent*	*Blue*	*Pig't*	*Blue*	*Pig't*	*Blue*	*Pig't*	*Blue*	*Pig't*	*Blue*	*Pig't*
pure blue	pure blue	101	0	77	0[1]	51	1	229	1	99.5	0.5
pigmented (Pp)	blue	137	121	428	506	89	85	654	712	48.0	52.0
pigmented (PP)	blue	0	66	0	70			0	136	0	100
pigmented (Pp)	pigmented (Pp)	18	45	98[2]	169	5	34	121	248	33	67
pigmented (PP)	pigmented (Pp)	0	195	0	99			0	294	0	100

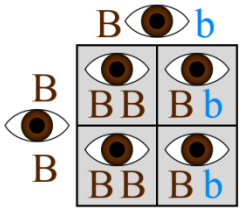
Assume people with brown eyes that have two dominant factors are *BB*, people with brown eyes that have one dominant factor are *Bb* or *bB*, and people with blue eyes that have no dominant factors are *bb*. People with **two identical factors** (*BB* or *bb*) are **homozygous** for the character and people with **two different factors** (*Bb* or *bB*) are **heterozygous**. The following **Punnett Squares**

describe the predicted proportion of each eye color in children of various parents **if only one gene,** with **dichotomous** forms, is involved in eye color.

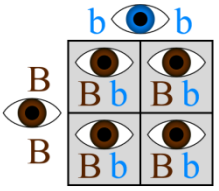
If only one gene is involved in eye color, when two homozygous brown-eyed parents mate, all the children will be homozygous and will have brown eyes. The ratio of the phenotypes and genotypes will be 4:0 and 4:0:0, respectively.



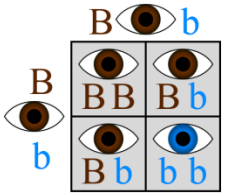
If only one gene is involved in eye color, when one homozygous and one heterozygous brown-eyed parents mate, all the children will have brown eyes, but two will be homozygous and two will be heterozygous. The ratio of the phenotypes and genotypes will be 4:0 and 2:2:0, respectively.



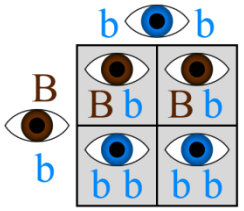
If only one gene is involved in eye color, when one homozygous brown-eyed parent and one homozygous blue-eyed parent mates, all the children will be heterozygous and will have brown eyes. The ratio of the phenotypes and genotypes will be 4:0 and 0:4:0, respectively.



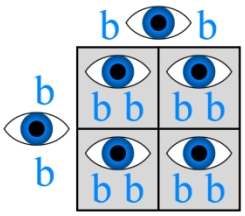
If only one gene is involved in eye color, when two heterozygous brown-eyed parents mate, the ratio of the phenotypes of brown eyes to blue eyes will be 3:1. The genotypes will be 1:2:1.



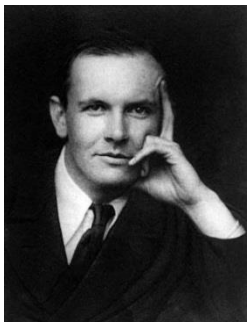
If only one gene is involved in eye color, when one heterozygous brown-eyed parent mates with a homozygous blue-eyed parent, the ratio of the phenotypes and genotypes will be 1:1 and 0:2:2, respectively.



If only one gene is involved in eye color, when two homozygous blue-eyed parents mate, all the children will be homozygous and will have blue eyes. The ratio of the phenotypes and genotypes will be 0:4 and 0:0:4, respectively.



Davenport (1911) analyzed the data in the table: "***When both parents have pure blue eyes all of the children will have pure blue eyes (the discordant case is probably due to an error),***" and he added, "***We have heard of two blue-eyed parents regretting that they had no brown-eyed children. They wished for the impossible***."

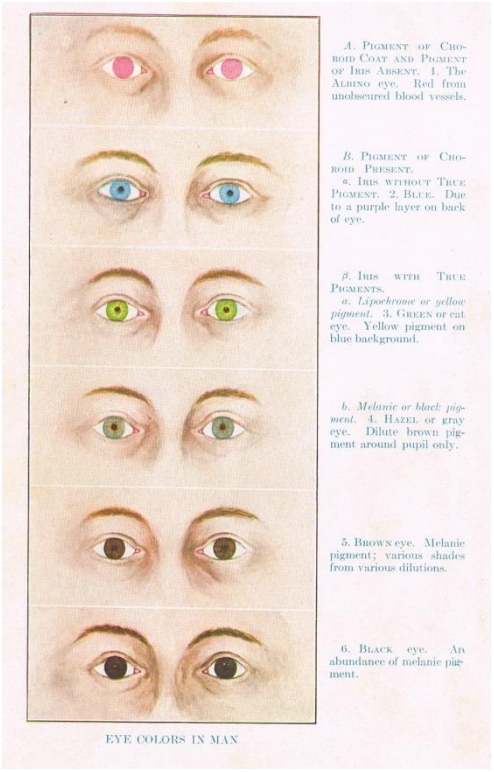


Likewise **Arthur Darbishire** (1912) wrote in *Breeding and the Mendelian Discovery*, "*The offspring of the union of two persons with simplex* [blue] *eyes, whatever their ancestry is,* ***will never have brown eyes***. *At any rate, no exceptions to this rule have yet been observed and recorded."*



Reginald Punnett (1911) wrote in *Mendelism*, "…***no individuals of the brown class are to be looked for among the offspring of blues mated together***."

There you have it, **eye color in humans**, at least as far as the **experts** were concerned, could be **reduced to a single gene** where **brown was the dominant form** and **blue was the recessive form** of the gene. That was the story and they were sticking to it. The geneticists abstracted out of the data that one single gene was important for eye color but what about that one brown-eyed child of two blue-eyed parents? Could it be possible that there was no error in the data, that the wife was not unfaithful, that the milkman was not to blame for the **outlier**? Could it be that the outlier was meaningful and the geneticists who tended towards **reductionism** simplified the story too much? There is a difference between **simple** and **simplistic** (too simple).



Helene Boas, an anthropologist wrote in 1919, "*These conclusions are not convincing because the investigator has been forced to substitute a hypothetical eye-color for the color actually recorded or to "doubt whether the term is used with precision" in order that his results may conform to the Mendelian formula."* Indeed, Boas found, that "*there are here among the children of two blue-eyed parents 12 per cent with brown eyes*." But what does a female anthropologist, who crosses disiplinary lines and contradicts the experts, know about Mendel?



Let's look at the pictures of eyes that you took this week. Is eye color a simple, brown *v* blue, **discrete**, digital and dichotomous trait? If not, is it likely that more than one gene is involved? Is eye color so **continuous** that **many** genes may be involved, or **relatively discrete** so that only a **few** genes would be involved? What if some of the factors have **incomplete dominance** and there is more of a **blending effect**, like Carl Gärtner saw in many of his horticultural hybrids?



Eye Colors
Strum and Frudakis (2004) Trends in Genetics 20:327

How many Mendelian genes with alternative, dichotomous, dominant, or recessive characters might you guess have a major effect on eye color?

Number of Mendelian dichotomous Genes	Number of Phenotypes
1	$2^1 = 2$
2	$2^2 = 4$
3	$2^3 = 8$
4	$2^4 = 16$
n	2^n

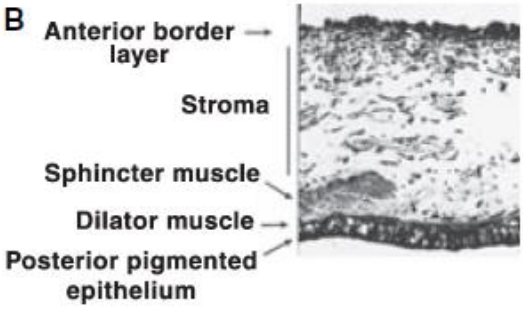
How is reality best described? Are eyes ***either*** brown or blue? Is there a **continuous variation** in color? Are there a **few or several distinct categories** of color? Scientists must consider more than one version of reality simultaneously: The reductionist and the wholistic—otherwise the assumption may incorrectly give the expected conclusion. Remember having an **equation** means that the left side **equals** the right side, or stated differently, the assumptions **equals** the conclusion.

We can **assume** that only one gene is involved in eye color and then we consider brown-eyed children of blue-eyed parents as **outliers** and **conclude** that

eye color is a one gene dichotomous trait. This has been the **textbook version**. We can also say that in general, one gene for blue eyes explains the great majority of the variation in eye color, but there are other factors, as yet unknown. In part our position will depend on the **value** we put on the **individual** or the **mathematics** as the **fundamental reality**. Which version of reality is truer? Is it unreasonable or reasonable to be a dualist where reality may be characterized in two ways?

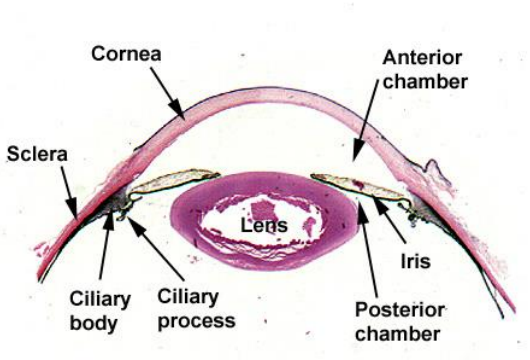
Other examples of the **dual nature of reality** exist. Most people can be described as males with XY chromosomes or females with XX chromosomes; however, 0.005% of males and females have XX and XY chromosomes, respectively. Does this mean that male/female is not a valid dichotomy, and that male/female and XY/XX is not a one-to-one correlation; or does it mean that in general the male/female classification is a good categorization, but we must leave room for individual differences that do not fit into a dichotomous classification system?

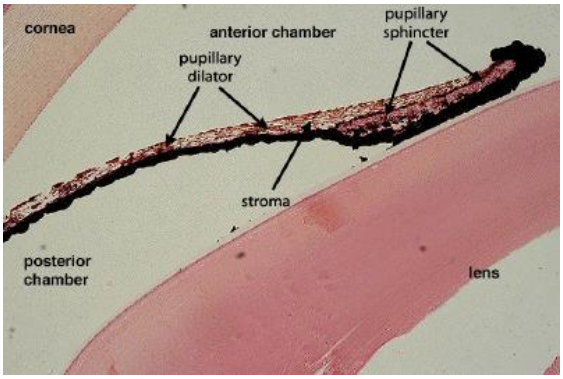
Before we look at the genetic cause of eye color, let's look at the **anatomy of the iris**. The iris is composed of **three layers** that influence eye color. From front to back, they are called, the **anterior layer of the pigmented stroma** (from mesoderm), the internal tissue of the **stroma** (from mesoderm), and the **posterior layer of the iris pigmented epithelium (IPE)** (from ectoderm).



The sphincter muscle causes pupil constriction. It is a striated muscle controlled by the parasympathetic nervous system and inhibited by atropine

(belladonna). The dilator muscle causes pupil dilation. It is a smooth muscle controlled by the sympathetic nervous system and inhibited by opiates.





Layer of Iris	**Pink eye**	**Blue eye (simplex)**	**Brown eye (duplex)**
Anterior layer of stroma (absorption):	--	--	melanin
Internal tissue of stroma (scatter/absorption):	collagen	collagen	collagen melanin
Posterior layer of IPE (absorption):	--	eumelanin	eumelanin
(two cell layers thick)			

People with no melanin in the stroma ***but*** with melanin in the posterior layer of the iris pigmented epithelium have blue eyes:





A person with melanin ***neither*** in the stroma ***nor*** in the posterior layer of the iris pigmented epithelium will have pink eyes. The additional light that bounces around the eye causes **photosensitivity** and leads to **glare** or multiple reflections, which reduces visual acuity.

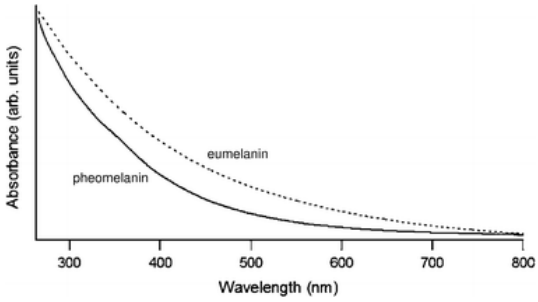


People with melanin in the stroma ***and*** in the posterior layer of the iris pigmented epithelium have brown eyes:





In **brown eyes**, the anterior layer of the pigmented stroma contains a **pigmen**t, known as **melanin** that **absorbs** the majority of the incoming light. The **melanin** may be either **eumelanin**, which absorbs nearly all colors of light and reflects back little light and thus appears black or brown, or **phaeomelanin** that absorbs nearly all the colors of light but reflects back a little more reddish-pink light than eumelanin does. The more melanin in this layer, the less light is transmitted through the colored part of the iris to the internal layer of the stroma. Blue-eyed and pink-eyed people do not have any melanin in the anterior layer, so all the incoming light is transmitted to the internal tissue of



the stroma. Eumelanin and pheomelanin may also occur in the internal tissue of the stroma, providing even more variety in eye color. (Both eumelanin and pheomelanin absorb UV light that may otherwise cause retinal cancer).



An eye of any color will appear red (***red eye***) if it is illuminated with so much light (i.e. from a flash) that the light is not absorbed by the melanin in the pigmented layer in the retina so that the light is reflected from the blood vessels (choroid) in the eye and travel back out through the pupil.

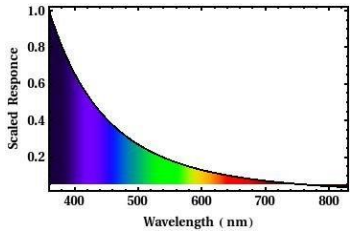
The internal tissue of the **stroma** is composed of transparent **fibers** made of the **protein collagen.** Some of the **collagen fibers** circle the pupil and some radiate from it. The **collagen fibers** are connected to the sphincter and dilator muscles, which close and dilate the pupil, respectively. The collagen fiber is much smaller than the **wavelength of a photon** or perhaps the **photon** itself (my research). Consequently, when white light strikes the collagen molecules, it gets **scattered** in a manner such that the intensity I of light of that color that is scattered is inversely proportional to the fourth power of the wavelength (or inversely proportional to the square of the cross-sectional area ($\frac{\lambda^2}{4\pi}$) of the photon):

$$I \, \alpha \, \frac{1}{\lambda^4}$$

The light is **scattered** by the collagen fibers in all directions, which includes the direction that the light came in. When we look at someone with blue eyes, we see the light that is scattered back out of the eye.

Blue light has a wavelength of about 400 nm, green light has a wavelength of about 500 nm and red light has a wavelength of about 600 nm:

Color	Amount Scattered	Relative Amount Scattered
Blue	3.9×10^{-11}	4.9
Green	1.6×10^{-11}	2
Red	0.8×10^{-11}	1



The **blue light** component of the light is **scattered** almost 5 times more than the **red light** component is. That is, the red light component of the light goes right by the collagen molecules into the posterior layer of the iris pigmented epithelium, where it is absorbed, almost five times better than the blue light component does. The green light component acts intermediately.



Demonstration: Shine the light from a penlight on and through the colorless glass "sunset egg" that is embedded with microscopic particles of cobalt oxide. Observe the opalescence—that is the blue light scattered from the egg when light shines on the egg and the yellow light scattered form the egg when light shines through the egg.



J. M. W. Turner was famous for painting sunsets, and it is rumored that his last words were, "*The sun is God*." In describing the difference between nature and art, **Oscar Wilde** (1889) wrote in The Decay of Lying: An Observation, "*Art creates an incomparable and unique effect, and, having done so, passes on to other things. Nature, upon the other hand, forgetting that imitation can be made the sincerest form of insult, keeps on repeating this effect until we all become absolutely wearied of it. Nobody of any real culture, for instance, ever talks nowadays about the beauty of a sunset. Sunsets are quite old-fashioned. They belong to the time when* ***Turner*** *was*

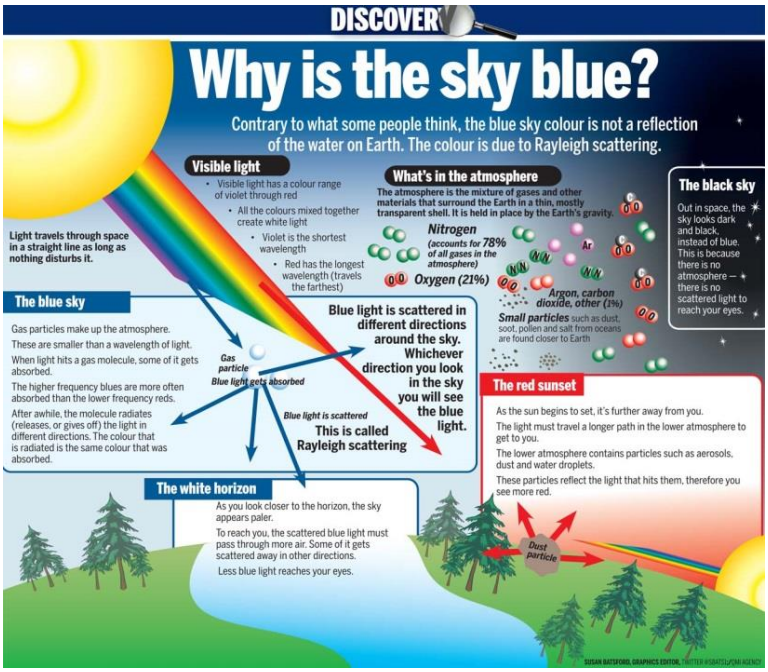


the last note in art. To admire them is a distinct sign of provincialism of temperament. Upon the other hand they go on."

G. K. Chesterton (1913) wrote in Orthodoxy, "*Oscar Wilde said that sunsets were not valued because we could not pay for sunsets. But Oscar Wilde was wrong; we can pay for sunsets. We can pay for them by not being Oscar Wilde*."



The scattering of light from molecules smaller than the wavelength of light is called **Rayleigh scattering**, after Lord Rayleigh, who wanted to describe and explain **why the sky is blue**. Eyes are blue because the incoming light is scattered back out from the eye of the observed person to the eye of the beholder.



Aside: A **mirror** (1 cm) **reflects** all the colors (violet, indigo, blue, green, yellow, orange and red; or ROYGBIV) without discrimination. Imagine making a mirror smaller and smaller until it is as small as a gas molecule (about 0.3 nm) like N_2 or O_2 that scatters sunlight to make the sky blue. **Collagen fibers** are smaller than a mirror and larger than gas molecules. Perhaps light eyes such as **violet** and **gray** eyes result from collagen fibers that are smaller or larger than those in blue eyes. Perhaps violet-eyed people have the smallest collagen molecules and scatter violet light; blue-eyed people have intermediate-sized collagen molecules and scatter violet and blue light; and gray-eyed



people have the largest collagen fibers and scatter violet, blue, green, and red light. The following color simulation allows you to construct gray from blue, green, and red. http://phet.colorado.edu/en/simulation/color-vision



In **blue eyes** and **brown eyes**, the **innermost or posterior layer of the iris pigment epithelium** contains eumelanin. The eumelanin absorbs almost all of the light that reaches it. People with pink eyes ***do not*** have eumelanin in this layer, so the light is transmitted all the way to the blood vessels in the choroid and red light is reflected out from the eye. The combination of red reflected from the blood vessels and blue scattered from the stroma, makes magenta.

The **pupil** is a **hole in the iris** that contains neither melanin nor collagen, so all the light that enters the pupil is transmitted to the retina. The pigment in the stroma of the iris is produced in cells called **melanocytes**. The color of the iris is determined, not by the number of melanocytes, but by the number of the melanin-containing bodies or **melanosomes** in the melanocytes in the stroma of the eye (Imesch et al., 1997). Brown eyes have more melanin in the anterior layer of the iris than do blue eyes.

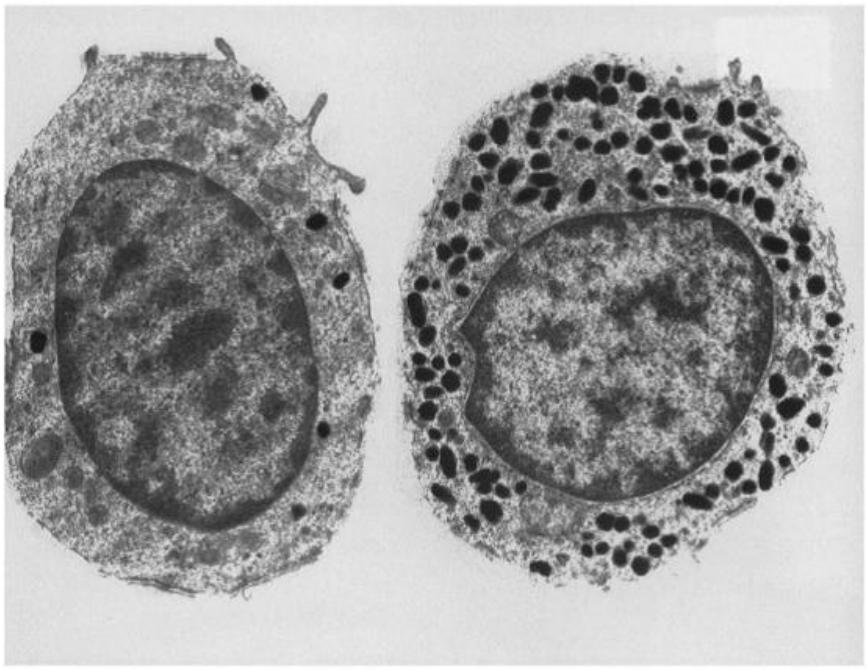
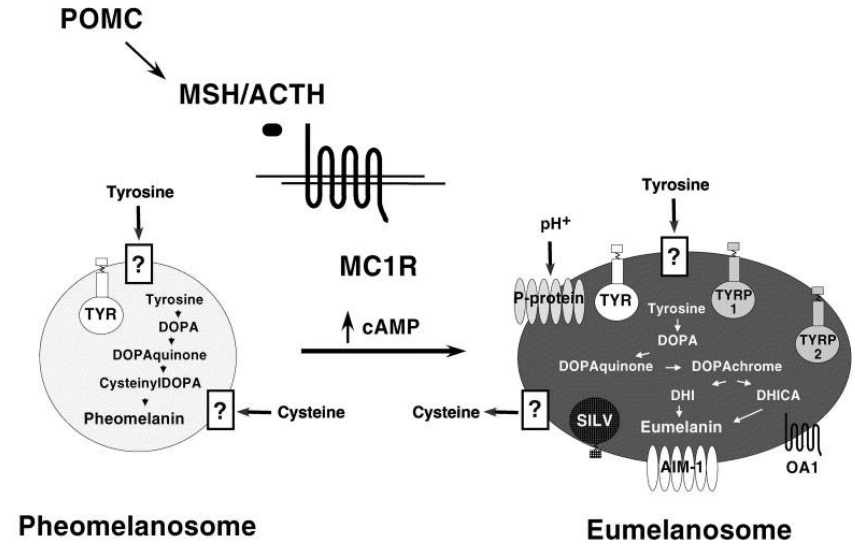


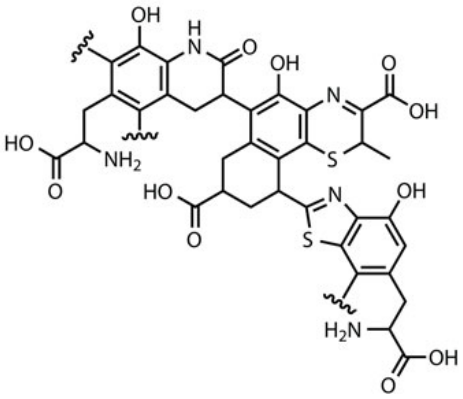
Fig. 2. Electron microscopic photograph at 4000× of a superficial stromal iris melanocyte containing only a few melanin granules from an eye with a blue iris on the left and an example of melanocyte from a brown eye on the right.

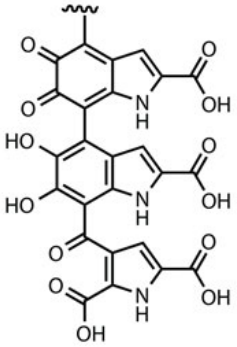
Brown eyes can vary from black to amber. The type of melanin, **eumelanin** and **pheomelanin** in the melanosomes determines the shade of brown (Prota et al., 1998). Eumelanin produces **darker brown eyes** and pheomelanin produces **lighter brown eyes**. Note, both eumelanin and phaeomelanin **absorb ultraviolet light** very well. As we will discuss later in the semester, while ultraviolet light is required to make vitamin D, too much ultraviolet light can do damage to cells.



Melanin is formed in the melanosomes of the melanocytes from the amino acid tyrosine in a pathway that involves **several enzymes**, each of which is encoded by a **gene**.

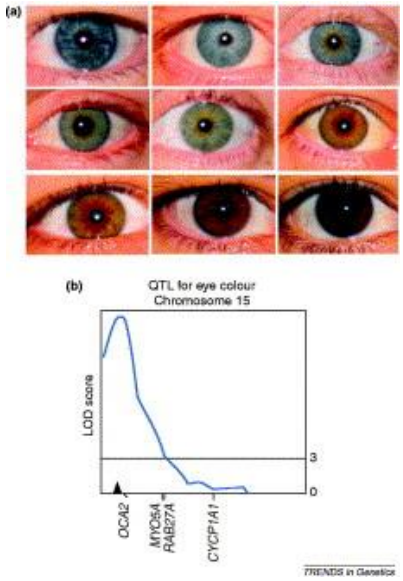




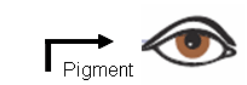


Ocularcutaneous albinism is the lack or reduction of melanin pigment in the eyes and skin. A variation in the ocularcutaneous albinism gene that codes for tyrosinase (OCA1), the enzyme that initiates the transformation of tyrosine to melanin, results in the complete lack of production of melanin. A person with this form of the gene will be an albino with blue or pink eyes.

A variation in another **ocularcutaneous albinism** gene (**OCA2**) is correlated with fair skin, light hair, and blue eyes. Three of the **variations** or **single nucleotide polymorphisms** (SNPs) in the DNA of the OCA2 gene are statistically **correlated** with blue eye color. LOD stands for Logarithm of the Odds. Thus, some versions of the OCA2 gene lead to brown eyes and others lead to blue eyes. There is no direct causal chain between OCA2 and eye color since the function of the OCA2 gene is unknown. However it **is believed** to be an integral membrane protein involved in



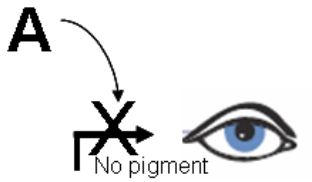
the **transport of tyrosine** into the **melanosome** where it can act as a precursor for melanin synthesis.



OCA2

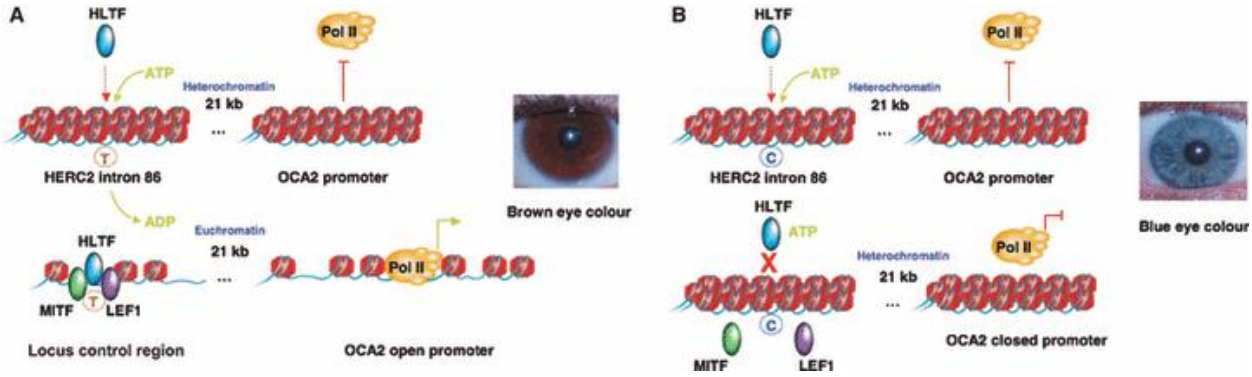


OCA2



OCA2

There is another gene called **HERC2** that is adjacent to **OCA2**. One version of the HERC2 gene DNA sequence (TGACA(T/C)TTAAT) where there is a base change from T to C is highly **correlated** with blue eyes. The following **model** has been proposed by Sturm and Larsson (2009) to explain the interaction of the two genes: The T form of the HERC2 gene binds a helicase-like transcription factor (HLTF) that opens up the OCA2 gene so that RNA polymerase II can bind to OCA2 and the OCA2 gene **can be expressed**. Consequently, the protein for tyrosine transport into the melanosomes is produced. The variation of HERC2 that is correlated with blue eyes (C) prevents the binding of a helicase-like transcription factor (HLTF) and consequently, RNA polymerase II never binds to OCA2 and the OCA2 gene is **never expressed.**



Assume that the form of OCA2 that would lead to brown eyes if only one gene is involved is dominant and is given by B, and the recessive form of OCA2

that would lead to blue eyes if only one gene was involved is given by b. Assume that the form of HERC2 that would allow the expression of OCA2 and would lead to brown eyes is dominant and given by A and the form of HERC2 that would prevent the expression of OCA2 and would lead to blue eyes is recessive and given by a.

If blue eyes were determined by these two genes, there are many possible ways of having blue eyes: AAbb, Aabb, aabb, aaBB, and aaBb. For example, a person with the blue-eyed version of HERC2 (aa) and the brown-eyed version of OCA2 (BB or Bb), would have blue eyes. Here are a few examples:

Aabb x aabb

	ab
Ab	Aabb (blue)
ab	aabb (blue)

AAbb x aaBB

	aB
Ab	AaBb (brown)

aaBb x Aabb

	Ab	ab
aB	AaBb (brown)	aaBb (blue)
ab	Aabb (blue)	aabb (blue)

etc.

Since there are a number of variations in each gene and the proportion of each variation is unknown, we cannot determine the exact probability that two blue-eyed parents can have a brown-eyed child. **Experience tells us that it is rare; our analysis of the inheritance of two interacting genes tells us that it is not impossible**. Studies of the irises of identical twins show that approximately 58-78% of the iris characters have a genetic basis.

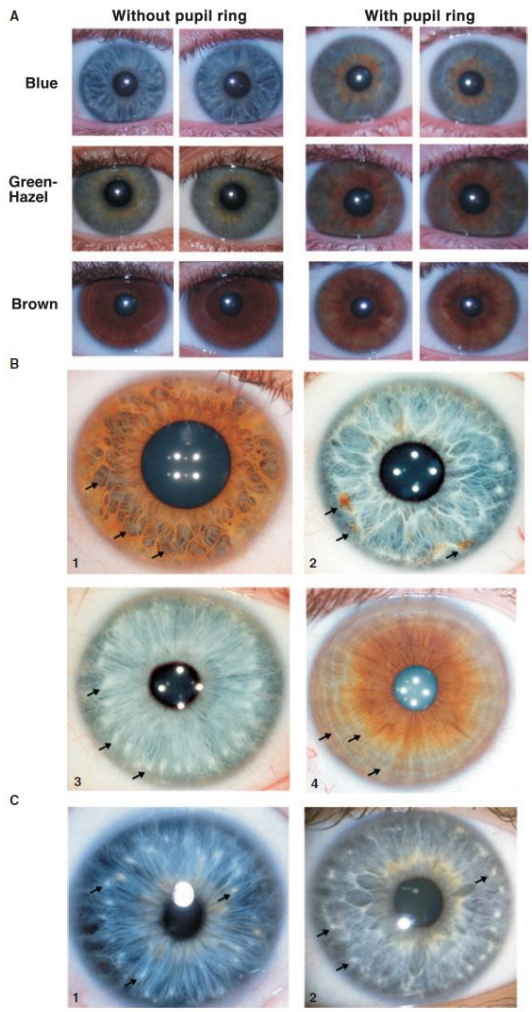
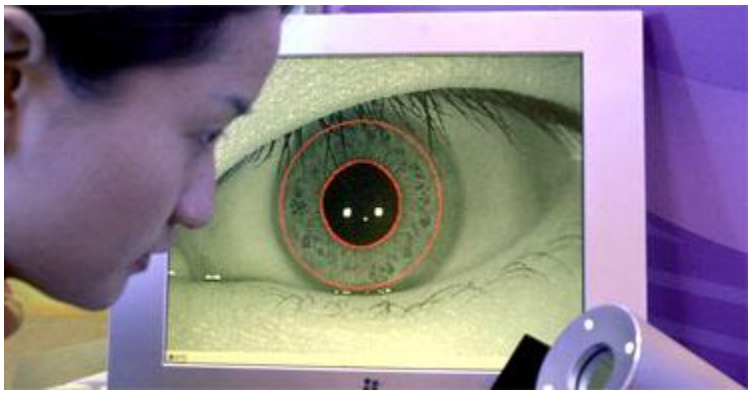
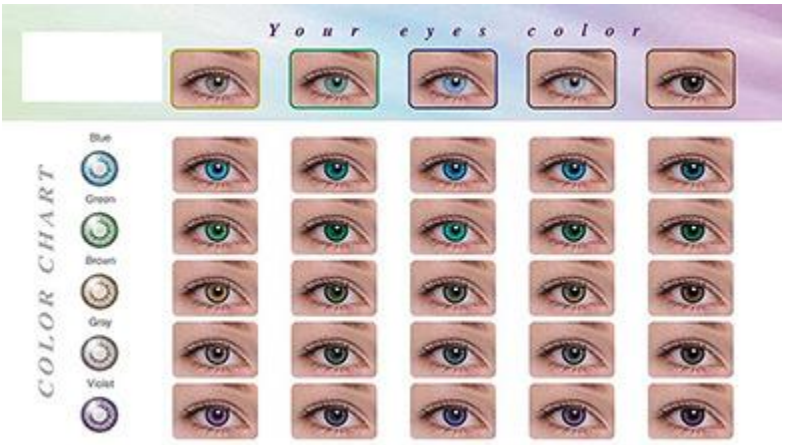


Figure 2. Human iris colour classification and patterns. (A) Three major classes of eye colour are shown as Blue, Green-Hazel, Brown with and without a brown peripupillary ring. (B) Patterns found within the iris highlighted by arrows: 1. Fuchs' Crypts, mild stroma atrophy; 2. Nevi, dots of accumulated melanin; 3. Wolfflin nodules, dots of accumulated collagen fibrils; 4. Contraction Furrows, fold marks in thicker irises due to iris contraction and dilation. (C) Patterns found within the iris highlighted by arrows: 1. Brushfield spots, observed in Downs syndrome; 2. Wolfflin nodules, observed in normal controls.

The human iris shows as many as 240 different features that can contribute to our individuality. In this respect, it is no surprise that the **Iris Recognition Immigration System** (IRIS) is used for individual identification.

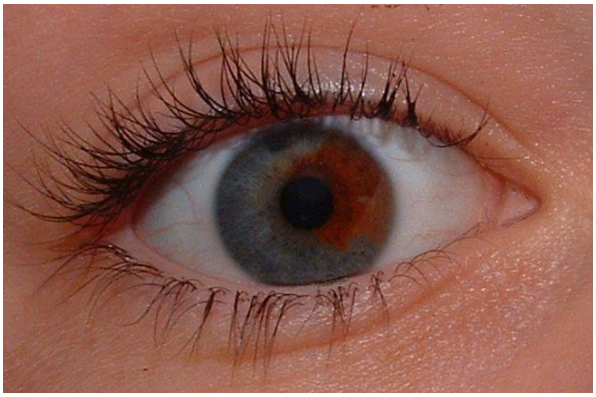


Is it possible that the environment has an effect on eye color? The only data I have that the environment affects eye color is the existence of color contact lenses. A **phenocopy** is someone who has a certain genotype but looks like he or she has a different one.



Because the detailed development of the iris depends on initial conditions in the embryonic mesoderm and ectoderm from which it develops, the phenotypic expression of the two irises possessed by one individual can be different. This is known as **heterochromia**. Heterochromia can also exist in one iris.





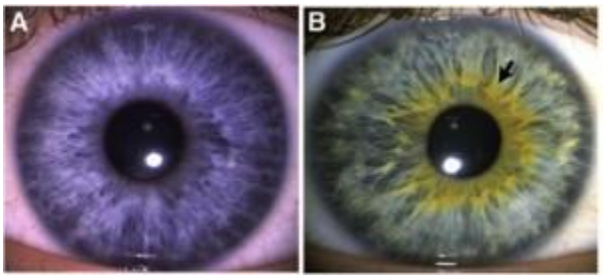


Mendelian genetics was used as a basis of paternity tests. While blue eyes were considered to a simple Mendelian character, one must remember that blue-eyed babies may become brown-eyed children due to the developmental control of melanin production in Caucasian children (Beckman et al., 1960). Note that not many traits are inherited in a simple Mendelian fashion.

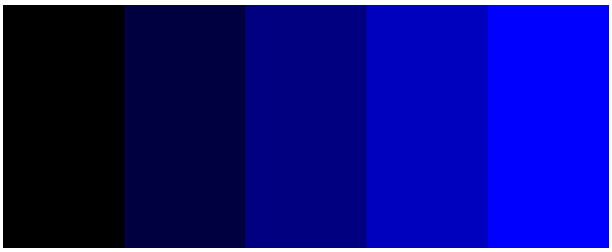
TABLE 32. *Qualitative characters. Summary of the results of the analysis of the family data.*

Character	Nothing contradicts simple inheritance	Inherited though not in a simple way	Sex variation	Age variation	Bilateral variation
Eye color	+		−	+	
Hair color	−	+	−	+	
„ form	−	+	−	+	
„ whorl	+		−	−	
Frontal hair	−	+	+	+	
Hair between the eyebrows	−	+	+	+	
Mid-digital hair	−	+	−	+	−
DARWIN's tubercle	−	−	−	−	−
Ear lobes	−	+	+	+	−
Tongue-rolling	+		−	−	
Chin groove	−	+	+	+	
Eye openings	−	+	−	+	
Folds on the upper eyelids	−	+	−	+	−
Extensibility of the proximal thumb joint	−	+	−	+	+
BONNEVIE's fingerprint formulae	−	−	−	−	
Length of the second toe	−	+	−	+	−
Tasting	+		−	−	

Because our brain judges colors relative to the surrounding or nearby color, the distribution of melanin in an iris may have a great effect on the perceived color of the iris.

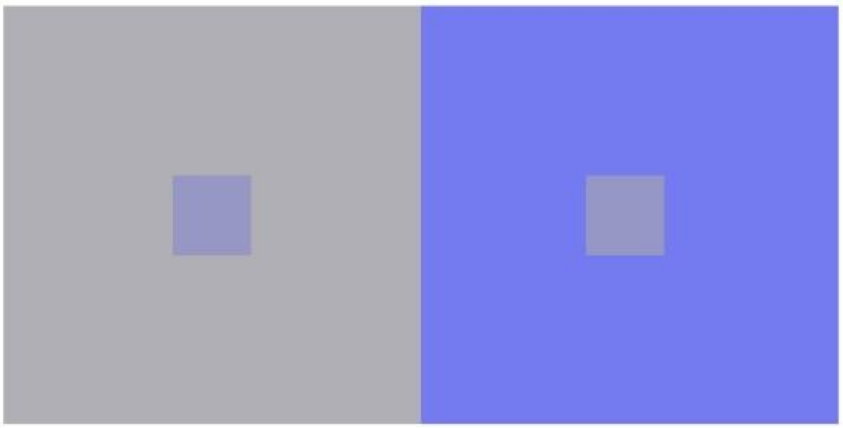


Look at the **Chevreul illusion**. Each rectangle is a homogenous, yet the part next to the lighter rectangle looks darker. The Chevreul illusion works for uneven shapes too, as long as the color family is the same.



This color saturation illusion shows you that nearby colors influence your perception of a given color. While two small squares appear to be different colors, they are the same color. Johann Wolfgang von Goethe emphasized that our perception of the color of something depended on the context!



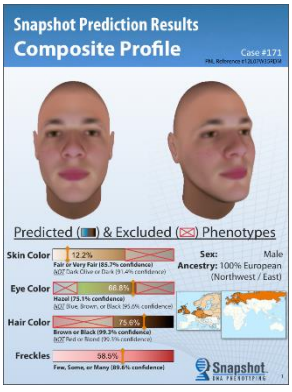


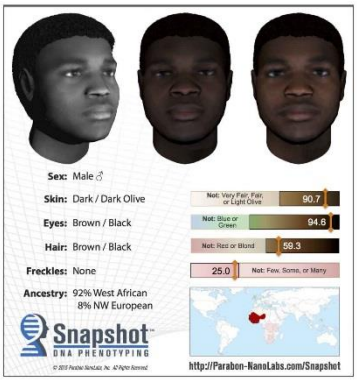
Both irises in the figure below are the same shade of gray, but the red color surrounding the iris makes the iris on the left look blue. But after masking the iris on the left, it looks like the same shade of gray as the one on the right.



We have found that **eye color is not absolutely a single Mendelian trait,** but a **polygenetic trait**. Indeed, there are even more than two genes that are correlated with eye color. You may expect this for two reasons: One, that there are more than two categories of blue-brown eye color; and two, that there are a number of enzymes that are involved in melanin synthesis. **Each enzyme is encoded by a gene and each gene may be regulated by other genes**, like the OCA2 gene is regulated by the HERC2 gene. Moreover, **any gene may exhibit incomplete dominance**. In addition, since only 58-78% of iris characteristics can be explained genetically in identical twins, **the environment** or **chance related to the position of iris cells derived from different cell populations in the embryo** may contribute to iris color.

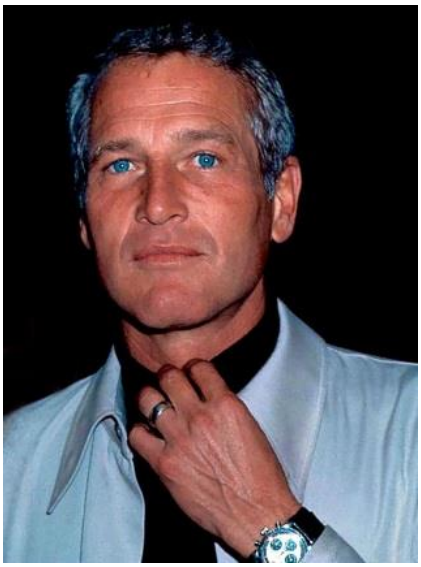
Law enforcement is interested in predicting the eye color of the person who left behind DNA at a crime scene. Currently it is possible to predict the eye color of an individual with greater than 90% accuracy for brown and blue using six single nucleotide polymorphisms (SNPs). http://snapshot.parabon-nanolabs.com/





Melanin production in the iris begins during gestation in African American, Hispanic, and Asian babies. Melanin production is usually delayed up to a year after birth in the irises of Caucasian infants so Caucasian babies are usually born with blue eyes. Within a year melanin production begins if the final color of the eye is going to be brown. Melanin production begins earlier in Caucasian girls than Caucasian boys. Some, like Paul Newman, keep their baby blue eyes.







Aside: Speaking of children, not all kids are so lucky. According to Dr. Abraham C., Nazi physician **Josef Mengele** noticed that a few seven-year old boys in Auschwitz "*had one odd characteristic: they were blond and had brown eyes, so Mengele was trying to find a way to color their eyes blue.*" Mengele tried to find a way to change their eye color and **injected**



their eyes with methylene blue. While the treatment caused severe pain and inflammation, "*their eyes of course did not change."* Robert Jay Lifton (1986) wrote in his book *The Nazi Doctor*, "*But the methylene blue injections are of a different order, not in their cruelty (which was usual) but in their extraordinary scientific naïveté—or, one might more accurately say, their scientific corruption."*

Mengele shared the eyes he obtained from the "*inferior human material*" at Auschwitz with Karin Magnussen, a scientist who worked on eye pigmentation at the Kaiser Wilhelm Institute (KWI) for Anthropology, Human Genetics, and Eugenics, which was directed by Mengele's mentor Otmar von Verschuer. Lifton wrote that Verschuer spoke of the "enormously interesting specimens" of different-colored eyes Mengele had sent him, and seemed "surprised and upset" when he was told him they had come from Gypsies that Mengele had ordered killed because of this abnormality. "*In Verschuer's attitude we encounter a hypocritical academic accessory to Mengele's characteristic pattern of killing for science*."



Race-based progressive science played roles in a wide variety of social policies. **Paul Popenoe** (1934), of the Human Betterment Foundation wrote, "*Germany's eugenic sterilization law, which went into effect on January 1, 1934**, is no hasty improvisation of the Nazi regime. It has been taking shape gradually during many years, in the discussions of eugenists. From one point of view, it is merely an accident that it happened to be the Hitler administration which was ready to put into effect the recommendations of specialists***."

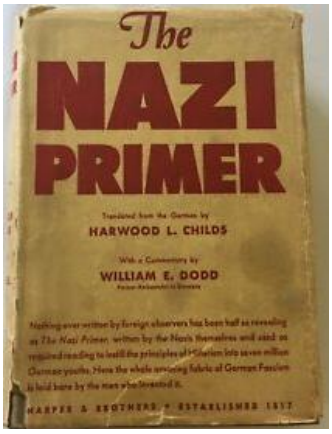
"*But Hitler himself—though a bachelor—has long been a convinced advocate of race betterment through eugenic measures. Probably his earlier thinking was*

colored by Nietzsche, but he studied the subject more thoroughly during his years in prison, following the abortive revolutionary movement of 1923. Here, it is said, he came into possession of the two volume text on heredity and eugenics, by E. Baur, E. Fischer, and F. Lenz, which is the best-known statement of eugenics in the German language, and evidently studied it to good purpose. ***In his book, Mein Kampf, most of which was written during these prison years, and which outlines most of the policies since adopted by the Nazis as a political party, he bases his hopes of national regeneration solidly on the application of biological principles to human society***."

"***The policy of the present German government is therefore to gather about it the recognized leaders of the eugenics movement, and to depend largely on their counsel in framing a policy which will direct the destinies of the German people, as Hitler remarks in Mein Kampf, "for the next thousand years***." *Whether this policy will be carried through successfully, of course remains to be seen. At best, mistakes will be inevitable. But the Nazis seem, as this scientific leadership becomes more and more prominent in their councils, to be avoiding the misplaced emphasis of their earlier pronouncements on questions of race, and to be proceeding toward a policy that will accord with the best thought of eugenists in all civilized countries."*

"***In any case, the present German government has given the first example in modern times of an administration based frankly and determinedly on the principles of eugenics***. *It has thus posed the question in a way that no other people can ignore.*"

Eugenic Archives: "The German Sterilization Law," by Paul Popenoe, Journal of Heredity (vol. 25) (eugenicsarchive.org)



Using science to justify policy has its limits. According *to* *The Nazi Primer: The Official Handbook for Schooling the Hitler Youth*, written by Fritz Brennecke (1938), who described Mendel's laws and characterized races in terms of eye color, "*Even in our day the fact is shown many times that certain men have no feeling for race honor or race shame…Even those occupying the highest places in government during the 'System Time' consciously closed their eyes to the facts of race…* ***We, however, shape the life of our people and our legislation according to the verdicts of the teachings of genetics***."



Joseph Goebbels described one of his first meetings with Adolf Hitler like so: "*Shakes my hand. Like an old friend.* ***And those big blue eyes****. Like stars. He is glad to see me. I am in heaven. That man has everything to be king*."



Interested in eye color, Reginald Punnett (1911) wrote, "*A discussion of eye-colour suggests reflections of another kind. It is difficult to believe that the markedly different states of pigmentation which occur in the same species are not associated with deep-seated chemical differences influencing the character and bent of the individual. May not differences in pigmentation be coupled with and so become in some measure a guide to mental and temperamental characteristics? In the National Portrait Gallery in London the pictures of celebrated men and women are largely grouped according to the vocations in which they have succeeded. The observant will probably have noticed that there is a tendency for a given type of eye-colour to predominate in some of the larger groups. It is rare to find anything*

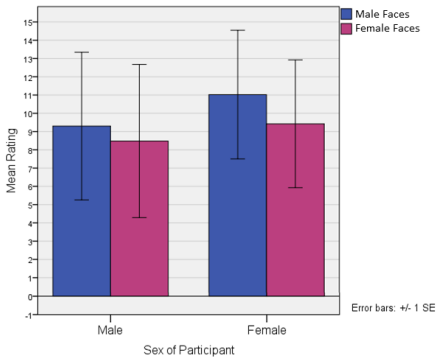
but a blue among the soldiers and sailors, while among the actors, preachers, and orators the dark eye is prominent, although for the population as a whole it is far scarcer than the light. ***The facts are suggestive, and it is not impossible that future research may reveal an intimate connection between peculiarities of pigmentation and peculiarities of the mind."***

Unbelievably to me, this kind of speculation has not stopped. Today there are many studies done by psychologists to understand how "*early expressing genes in the iris, are linked to brain development, and thereby potentially can contribute to identify networks of genes that influences different behavioural tendencies (Larsson et al., 2007)."* Some titles of published papers include, Eye color predicts alcohol use in two archival samples (Personality and Individual Differences 31 (2001) 535-539); Associations between iris characteristics and personality in adulthood (Biological Psychology 75 (2007) 165-175); and Eye color predicts but does not directly influence perceived dominance in men (Personality and Individual Differences 49 (2010) 59-64). Another study asks, Why do blue-eyed men prefer women with the same eye color (Behav Ecol Sociobiol 61 (2007) 371-384)?

Others ask about the evolutionary advantage of blue eyes in Northern climates where they are more common. According to Sturm and Larsson (2009), the ability to overcome seasonal affective disorder (SAD) is linked to lighter eye color. "*Perhaps those with blue eyes may have been able to withstand the dark, depressing days of the Neolithic European winters better than those with brown eye colour*."

The **limbal ring** is the colored annulus at the border of the iris and the sclera. The thickness of the limbral ring decreases as a function of age and health. This led Peshek et al. (Evolutionary Psychology 9(2): 137-146; 2011) to ask, "*Are judgements of facial attractiveness shaped to use the information within the limbal ring in a potentially adaptive way*?" To answer this question, they showed observers photographs of two faces, which were identical except that one face had dark limbal ring and the other had none. Observers thought that the faces with limbal rings were more attractive. The authors conclude that "*Male and female participants rates faces with clearly visible limbal rings as more attractive, suggesting that both sexes have been shaped by natural selection to use the limbal ring as a probabilistic indicator of reproductive fitness....The results could have practical application: Colored contact lenses are now commercially available that mimic the appearance of a limbal ring.*" Note: Positive values indicate preference for faces with a dark limbal ring.







Prosthetic iris replacements made of colored silicone (a polymer made up of siloxane ($-R_2Si-O-SiR_2-$, where R is an organic group) are now available in the United States (http://www.brightocular.com/) and laser surgery to convert brown eyes to blue is being developed (http://www.stromamedical.com).



I think that there is something nice about keeping the eye color we were born with!

Songs about Eyes

Green Eyes: Cold Play https://www.youtube.com/watch?v=whqebes2EFo

Green-Eyed Lady: Sugarloaf
https://www.youtube.com/watch?v=c_DydKnpDsk&list=PLhvjr2FOlNky0ZtMLza8CNVlNxszK5uSO&index=12

Lying Eyes: Eagles https://www.youtube.com/watch?v=r5KtEToyWrI

Sad Eyes: Robert John https://www.youtube.com/watch?v=l5grdfnGUss

Hungry Eyes: Eric Carmen

https://www.youtube.com/watch?v=2ssCL292DQA

Behind These Hazel Eyes: Kelly Clarkson
https://www.youtube.com/watch?v=c_DydKnpDsk&list=PLhvjr2FOlNky0ZtMLza8CNVlNxszK5uSO&index=12

Eyes Off You: Prettymuch
https://www.youtube.com/watch?v=NWA_1lXzGnU

In Your Eyes: The Weeknd
https://www.youtube.com/watch?v=dqRZDebPIGs

Ocean Eyes: Billie Eilish https://www.youtube.com/watch?v=viimfQi_pUw

Brown Eyed Girl: Van Morrison
https://www.youtube.com/watch?v=TWoFl_0UtjQ

I Only Have Eyes for You: The Flamingos
https://www.youtube.com/watch?v=FvzNeh4Mq1o

My Eyes Adored You: Frankie Valle:
https://www.youtube.com/watch?v=CcJDSLg-0uU

Can't Take My Eyes off of You: Frankie Valle
https://www.youtube.com/watch?v=NGFToiLtXro

Blue Eyes Crying in the Rain: Willie Nelson
https://www.youtube.com/watch?v=JA644rSZX1A

Blue Eyes Crying in the Rain: Elvis Presley

https://www.youtube.com/watch?v=SRs3uPMK_Dk

Blue Eyes Crying in the Rain: Vince Gill

https://www.youtube.com/watch?v=Tk5rQmGzrvk

Blue Eyes Crying in the Rain: Willie Nelson and Shania Twain

https://www.youtube.com/watch?v=N6wBxQVBozI

Blue Eyes Crying in the Rain: Dwight Yoakam

https://www.youtube.com/watch?v=CFs5JvxibmM

Blue Eyes Crying in the Rain: Roy Acuff

https://www.youtube.com/watch?v=POTHIP_GjY8

Blue Eyes Crying in the Rain: Hank Williams Sr.

https://www.youtube.com/watch?v=o3fYZ6oFBxM

Brown Eyed Girl: Bruce Springsteen

https://www.youtube.com/watch?v=dLFKEdHKeaw

Brown-Eyed Women (Live at Barton Hall, Cornell University, Ithaca, NY 5/8/77): Grateful Dead

https://www.youtube.com/watch?v=gdvY6BiPPhE

Brown-Eyed Women: Grateful Dead

https://www.youtube.com/watch?v=-Aa-_WqVq-8

Blue Eyes: Elton John https://www.youtube.com/watch?v=JA644rSZX1A

Pale Blue Eyes: Velvet Underground
https://www.youtube.com/watch?v=S23VK1v9dB8

Behind Blue Eyes: The Who
https://www.youtube.com/watch?v=BfuWXRZe9yA

Behind Blue Eyes: Limp Bizkit
https://www.youtube.com/watch?v=8IEQpfA528M

Behind Blue Eyes: Cheryl Crow
https://www.youtube.com/watch?v=lLdAjfa70TY

Suite Judy Blue Eyes: Crosby Still & Nash (written about Judy Collins)
https://www.youtube.com/watch?v=kVUwrifwKrI

Don't It Make My Brown Eyes Blue: Crystal Gayle
https://www.youtube.com/watch?v=C9lz_yzrGZw

In Your Eyes: Peter Gabriel

https://www.youtube.com/watch?v=evN6DIGPIJM

Betty Davis Eyes: Kim Carnes

https://www.youtube.com/watch?v=EPOIS5taqA8

My Eyes Have Seen You: The Doors

https://www.youtube.com/watch?v=Yq3jxRV2kWI

Eyes of Silver: Doobie Brothers

https://www.youtube.com/watch?v=wY4_5kl7B_o

My Father's Eyes: Eric Clapton

https://www.youtube.com/watch?v=wY4_5kl7B_o

Angry Eyes: Loggins & Messina:

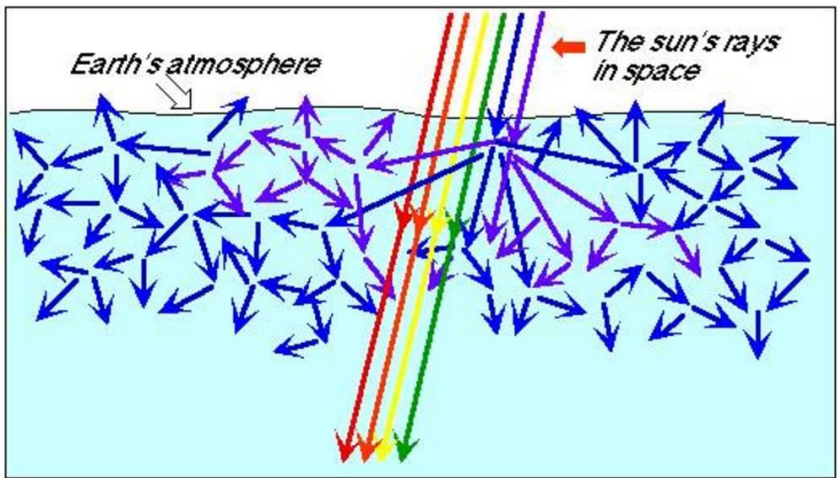
https://www.youtube.com/watch?v=w9iTjVfh558

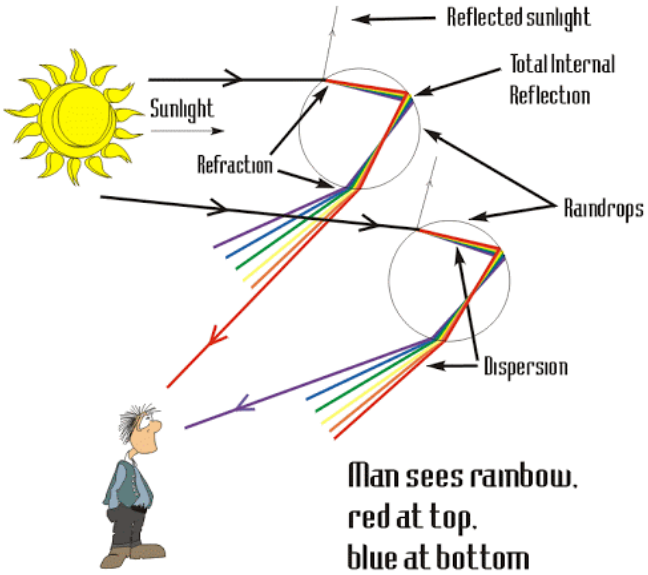
Dark Eyes: Bob Dylan and Patti Smith

https://www.youtube.com/watch?v=w9iTjVfh558

Color and Color Vision

We live in a happy and joyous world of color. As Lord Rayleigh discovered, sunlight before it even reaches the earth is **scattered** by small gas molecules in the atmosphere to give rise to the blue sky as well as warm sunrises and sunsets. As Roger Bacon discovered, sunlight **reflected** and **refracted** through water droplets gives rise to rainbows.





It says in the apocryphal book of Ecclesiasticus (43:11-12), "*Look upon the rainbow, and praise him that made it; very beautiful it is in the brightness thereof. It compasseth the heaven about with a glorious circle, and the hands of the most High have bended it*." In Ephesians (5:13) it says, "*But everything exposed by the light becomes visible—and everything that is illuminated becomes a light*."

Q: How much does a rainbow weigh?

A: Not much, they're actually pretty light.

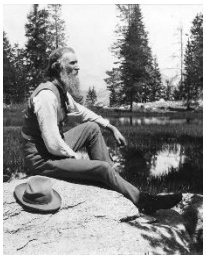
Sunlight falling on **pigment**-containing rock formations in the rainbow mountains in Danxia China is differentially reflected from the rocks in a manner that depends on the mineral content of the sandstone and conglomerates that make up the rock

formations. http://www.huffingtonpost.com/2013/07/31/rainbow-mountains-china-danxia-landform_n_3683840.html







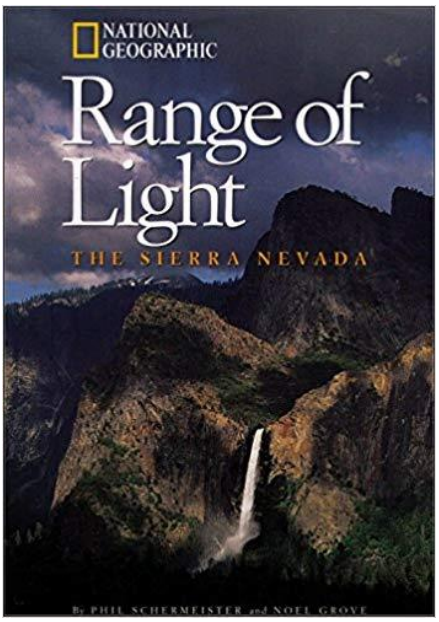



John Muir (1890) wrote in *The Treasures of Yosemite*, "*One shining morning, at the head of the Pacheco Pass, a landscape was displayed that after all my wanderings still appears as the most divinely beautiful and sublime I have ever beheld.*



There at my feet lay the great central plain of California, level as a lake thirty or forty miles wide, four hundred long, one rich furred bed of golden Compositae. And along the eastern shore of this lake of gold rose the mighty Sierra, miles in height, in massive, tranquil grandeur, ***so gloriously colored and so radiant that it***

seemed not clothed with light, but wholly composed of it*, like the wall of some celestial city. Along the top, and extending a good way down, was a rich pearl-gray belt of snow; then a belt of blue and dark purple, marking the extension of the forests; and stretching along the base of the range a broad belt of rose-purple, where lay the miners' gold and the open foothill gardens — all the colors smoothly blending,* ***making a wall of light clear as crystal*** *and ineffably fine, yet firm as adamant. Then it seemed to me the Sierra should be called, not the Nevada or Snowy Range, but the* ***Range of Light****. And after ten years in the midst of it, rejoicing and wondering, seeing the glorious floods of light that fill it, — the sunbursts of morning among the mountain-peaks, the broad noonday radiance on the crystal rocks, the flush of the alpenglow, and the thousand dashing waterfalls with their marvelous abundance of irised spray, —* ***it still seems to me a range of light****.*"



Sunlight falling on **pigment**-containing flowers, fruits, and autumn leaves is transmitted through and reflected from plants creating a spectrum of living color.





Leigh Hunt (1840) wrote in *The Seer; or Common-Places Refreshed*, that "*Colours are the* ***smiles of nature****. When they are extremely smiling and break forth into other beauty besides, they are her laughs; as in the flowers.*" Edwin Matzke (1942) wrote in an article on autumn colors entitled, "The Finest Show on Earth," that "*Perhaps this [autumn colors] is the* ***botanical expression of 'art for art's sake'***."

Sunlight falling on pigment-containing bird feathers is reflected to produce reds. The red color results from the **carotenoid pigments** in the food the birds eat.





The blue in the plumage of birds and the wings of butterflies is not due to pigments. The blue is due to the laminated structure that makes up the feathers or wings. We will talk about structural colors, which is known as **iridescence** later in the semester.





Human beings mimic the colors of nature by creating natural and synthetic **dyes**, such as tekhelet, cochineal, madder, indigo, and mauveine to further color our world. We will learn about the histories (natural and otherwise) of the production of dyes later this semester.








Popularity by Robert Browning (1812-1889)

Who has not heard how Tyrian shells
Enclosed the blue, that dye of dyes
Whereof one drop worked miracles,
And coloured like Astarte's eyes
Raw silk the merchant sells?



I can find no historical evidence that Astarte, the goddess of fertility, had blue eyes. It appears that Lord Byron (1788-1824), and poets, writers, painters (Dante Gabriel Rossetti (Jane Morris as Astarte)), and anime creators after him, gave her blue eyes. Starbucks put her on their logo.

Color inspires wonder. Giovanni Dondi dell'Orologio (ca. 1382) wrote, "*To whatever object the eye first turns, the same is a wonder and full of wonder, if only we examine it a little*."

Painters have captured the colors of nature using pigments made from ground-up rocks, minerals, twigs, roots, leaves, animal exudates, and bugs. Tyrian purple comes from an exudate of a snail, Ultramarine and Klein blue came from the ground gemstone, lapis lazuli, indigo from the *Indigofera* plant, Prussian blue from iron ferrocyanide, cobalt blue from cobalt salts, green vertigris from arsenic, Indian Yellow from the urine of cows that had been fed mango leaves, Cadmium yellow from ground cadmium, Chrome yellow from acidified chromium, Chrome orange from alkaline chromium, and cochineal from ground scale insects.

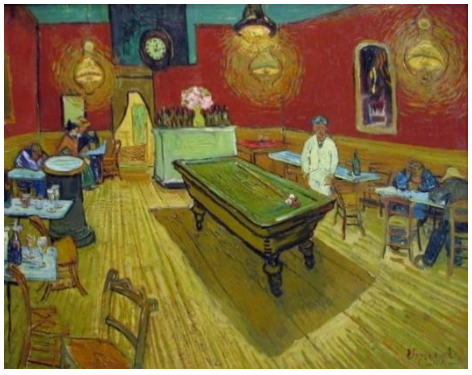








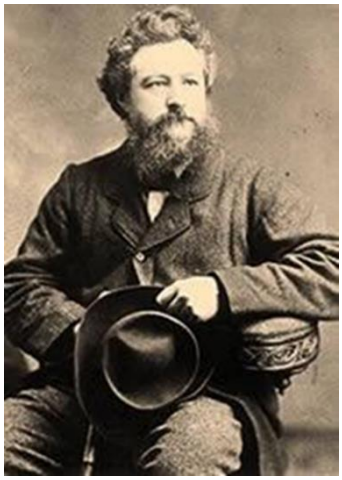




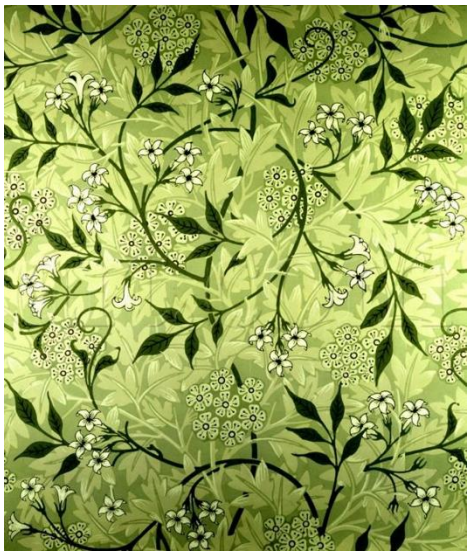


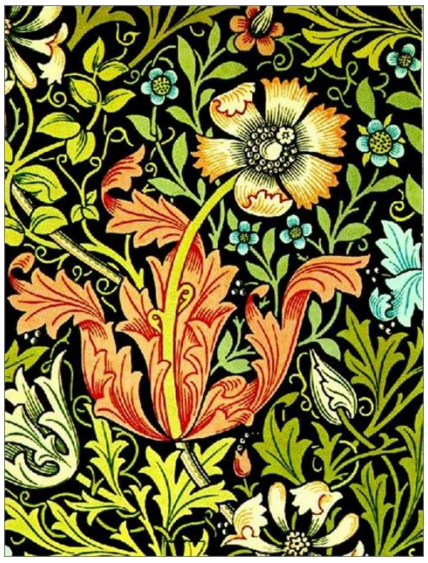






William Morris, an architect, turned decorator and founder of the Arts and Crafts movement, designed textiles and wallpaper with images from nature. He used only natural dyes for the textiles. However, the green paint he used for the wallpaper was made from arsenic. This wallpaper was associated with illness and death because in damp places fungi that lived in the wallpaper released trimethylarsine which is toxic. Interestingly, Morris' father owned Devon Great Consols, the largest producer of arsenic. Morris did not worry about the effect of his wallpaper on health. Morris (1885) wrote to Thomas Waddle, "*As to the arsenic scare, a greater folly is hardly possible to imagine: the doctors were being bitten by witch fever*."

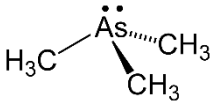




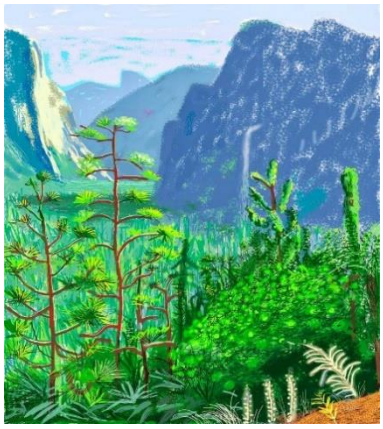


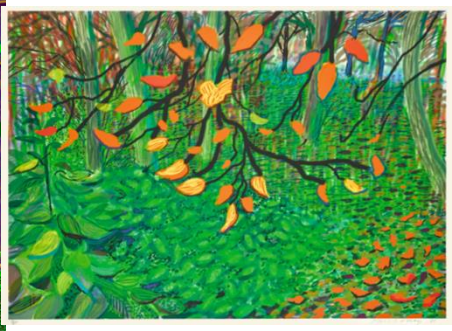






David Hockney has come full circle creating paintings with light itself using a program called Brushes on his iPad.



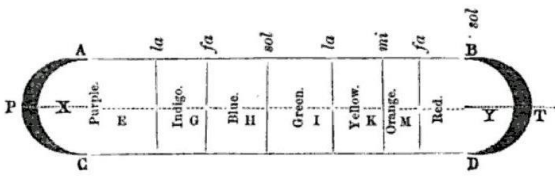


Demonstration: Look at the colors in the photographs you sent me.



Isaac Newton (1675) discovered that sunlight carried the colors of the rainbow, of the sky, and of the sunrises and sunsets within itself. Newton found this out by showing that sunlight streaming through a **pinhole** in the window can be resolved with a glass prism into a **spectrum** of **seven colors**. At the December 9, 1675 meeting of the Royal Society, Newton explained that a prism separated white light into light of "***unequal bignesses****…the largest beget a sensation of a red colour; the least, or shortest, of a deep violet; and the intermediate ones, of intermediate colours; much after the manner that bodies… which according to those bignesses, make several tones in sound… colours, like* ***sounds****, being various, according to the various bigness of the pulses."* He





went on to say that "…*colour may be distinguished into its principal degrees, red, orange, yellow, green, blue, indigo, and deep violet, on the same ground, that sound within an eighth is graduated into* ***tones***."



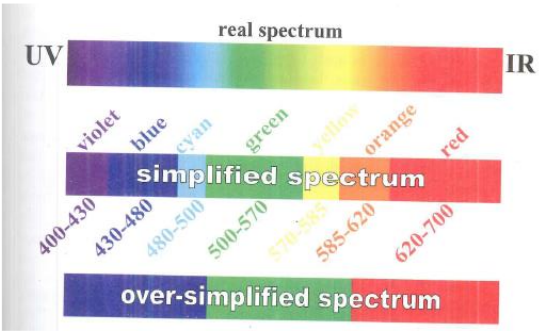
Demonstration: Observe light coming through pinhole and candle light with large water-filled prism.

Newton added, "*Now for the cause of these and such colours made by refraction, the biggest or strongest rays must penetrate the refracting superficies more freely and easily than the weaker, and so be less turned awry by it, that is, less refracted; which is as much as to say, the rays, which make red, are least refrangible, those which make blue and violet, most refrangible, and others otherwise refrangible according to their colour: whence, if the rays, which come promiscuously from the sun, be refracted by a prism, as in the aforesaid experiment, these of several sorts being variously refracted, must go to several places on an opposite paper or wall, and so parted, exhibit every one their own colours, which they could not do while blended together. And, because refraction only severs them, and changes not the bigness or strength of the ray, thence it is, that after they are once severed, refraction cannot make any further changes in their colour."*





Are there really **seven discrete** colors or do colors vary **continuously**? Mendel chose to look at **seven** discrete characteristics of peas. Why **seven**? Could it be that in the Bible, seven symbolizes completeness or perfection? Some examples include:



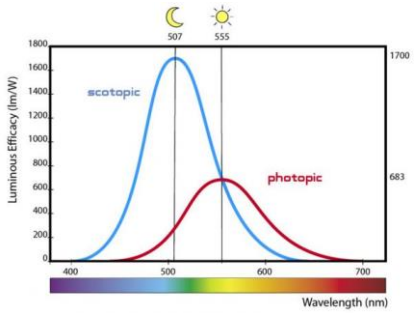
"*By the **seventh** day God had finished the work he had been doing; so on the **seventh** day he rested from all his work. Then God blessed the **seventh** day and made it holy, because on it he rested from all the work of creating that he had done*" (Genesis 2:2-3); "*But in the days when the seventh angel is about to sound his trumpet, the mystery of God will be accomplished, just as he announced to his servants the prophets*" (Revelation 10:7); and "*I saw in heaven another great and marvelous sign: seven angels with the seven last plagues—last, because with them God's wrath is completed*" (Revelation 15:1); and "*The seventh angel poured out his bowl into the air, and out of the temple came a loud voice from the throne, saying, "It is done!"* (Revelation 16:17).

While there may be no ***scientific*** reason to divide the **infinite array of spectral colors** into **seven artificial colors**, there is a natural reason to divide the infinite array into **three primary colors**.

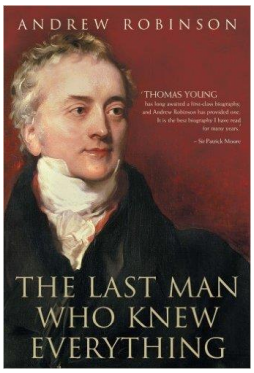


Demonstration: Look at the sky through your **spectroscope**, which uses a diffraction grating to separate the differently-colored light rays. Describe the spectrum of sunlight. Is it **continuous**, **discrete** or **both**?

Demonstration: Look at colorful items in the room when the curtains are open and the lights are on. Describe the colors you

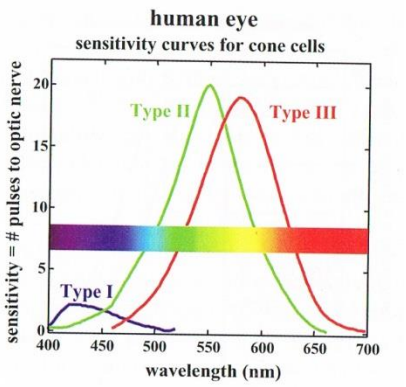


see when you use your **photopic vision**. Now dim the lights and close the curtains. Describe the colors you see when you use your **scotopic vision**.



Since the **three primary colors** are capable of mixing all the other colors, **Thomas Young** (1802), ***The Last Man Who Knew Everything***, guessed that there must be **three color receptors** in the retina. We now know that there are three types of **cones**, each with a different **spectral sensitivity**.

Color vision depends on the **cones.** There are three types of cones in the **retina**: Short (S or Type I) wavelength cones, most sensitive to short wavelengths and bluish (B) colors; mid (M or Type II) wavelength cones, most sensitive to mid wavelengths and greenish (G) colors; and long (L or Type III) wavelength cones, most sensitive to long wavelengths and reddish (R) colors. Here is the original data from George Wald (1964). Note that the sensitivity of the blue cones is less that the sensitivity of the green and red cones. The sensitivity to blue in the subject (R.H. = Ruth Hubbard) shown was about three times greater than that of the average observer. Again, I believe that there is only one reality, but individually, we picture it differently in our mind's eye, in part due to having a



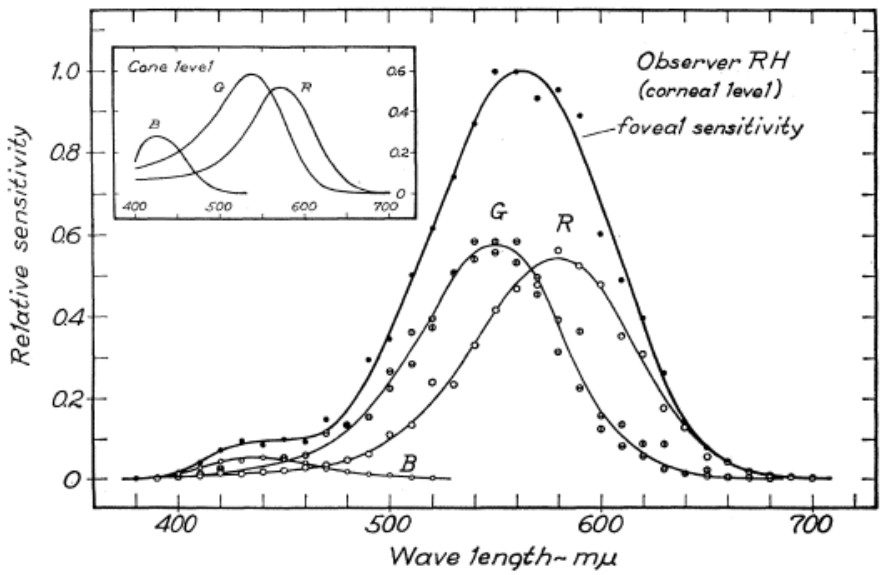


Fig. 8. Contributions of the individual color-receptor mechanisms to the total foveal sensitivity of R.H. The main graph shows measurements at the corneal level, the inset, corresponding curves at the level of the cones. In this particularly blue-sensitive observer, when the total foveal sensitivity is given a maximal height of 1.0, the heights of the *B*, *G*, and *R* curves are as 0.053 : 0.575 : 0.542 at the corneal level, and 0.28 : 0.59 : 0.52 at the level of the cones. In the average observer the blue-component is only about one-third as high.

greater or fewer number of a given type of cone. Speaking of blues, Elijah Wald, son of George Wald and Ruth Hubbard plays the blues guitar. https://www.youtube.com/watch?v=yt5iQen4aBQ; https://www.youtube.com/watch?v=gU3W5Gx9PJU

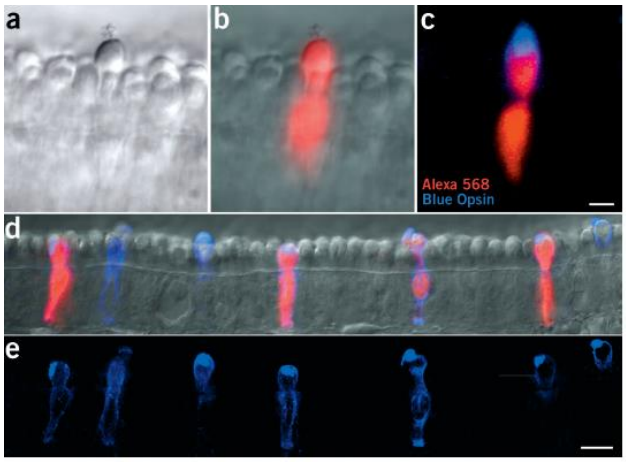
Are the antique teal-colored barbershop sinks in the picture below **bluish** or **greenish**?



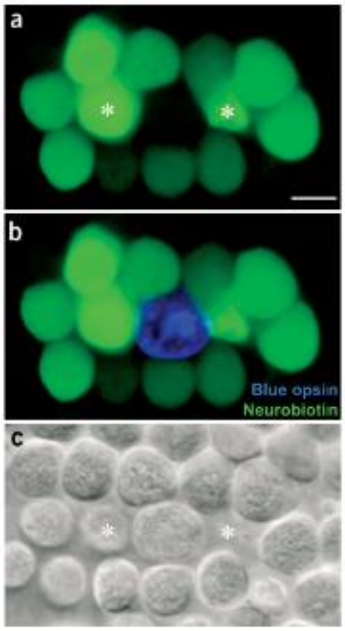


How the absorption of light by the cones results in our perception of color is still a mystery. However, we understand more as a result of studying vision in various animals. For example, the ground squirrel (*Spermophilis tridecemlineatus*) is one animal where color vision is studied because it has a **cone-dominated retina** that resembles the **fovea** of humans. The ground squirrel retina differs from the human retina in that it only has only two cone types, one that is blue sensitive and one that is green sensitive.

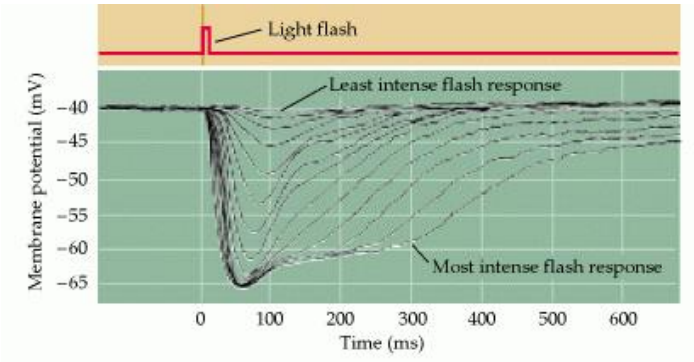
Here is a **tissue slice** of a ground squirrel **retina** showing many **cones**. The **cones** that are most sensitive to blue light are stained with an antibody that fluoresces blue. When the blue light-sensitive cones are injected with a red fluorescent dye, the dye stays in the injected cones, showing that each **blue-sensitive cone is isolated** from the other cones.



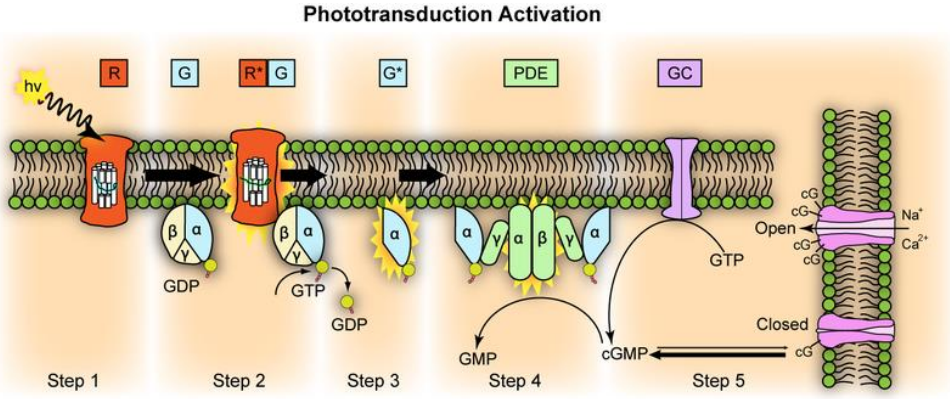
On the other hand, when a fluorescent green dye (neurobiotin) is injected into one green-sensitive cone, it diffuses into nearby green-sensitive cones, but not the blue-sensitive cones showing that the **green-sensitive cones are isolated from blue sensitive cones but interconnected to other green sensitive cones**. The coupling of similar cells increases the **signal-to-noise ratio** when light is limiting but also causes **blurring**, resulting in a decrease in **visual acuity**.



The neural processing of the outputs of the Type I, Type II, and Type III cones of humans must be considered as a **black box** in terms of the connections and functions of the various neurons that connect the cones to the visual cortex. The initial effect of light on the cone is to make the electrical potential of the plasma membrane more negative (**hyperpolarized**).

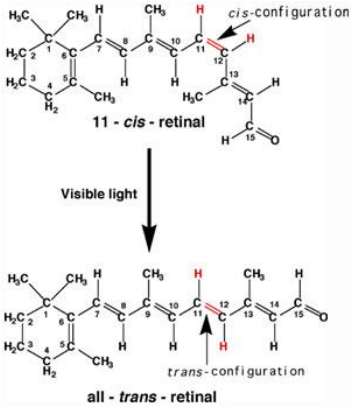


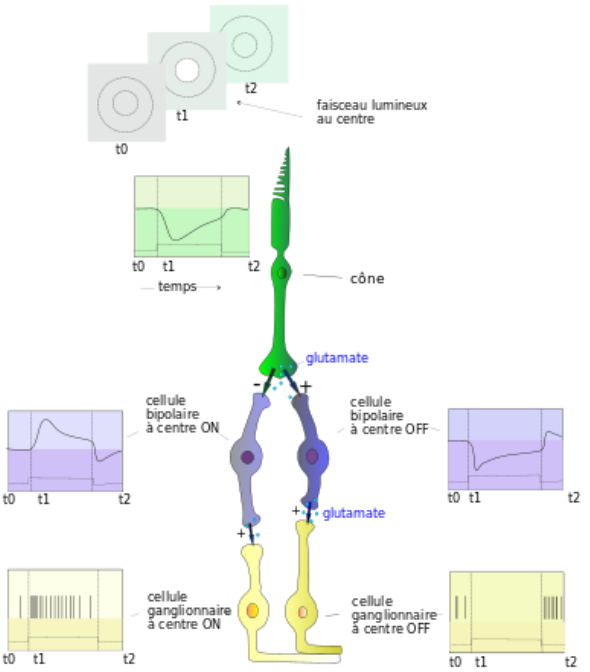
In a cone cell in the **dark**, the **sodium channels** in the plasma membrane are **open**. Sodium ions, with a positive charge, enter the cell along their concentration gradient which causes the plasma membrane of the cone to stay **depolarized**. When the membrane is depolarized, **glutamate** is released. The glutamate is a **neurotransmitter** and the released glutamate causes the plasma membrane of some neurons to depolarize and the plasma membrane of other neurons to hyperpolarize.



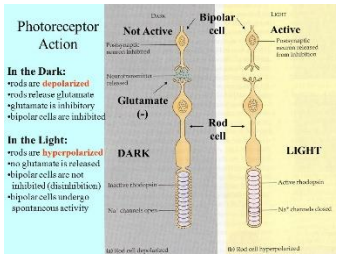
When light is **absorbed** by a **photopsin photoreceptor pigment in** the cone, the pigment becomes active. **Photopsin** is composed of a **chromophore**, known as **11-cis retinal**, which is a derivative of **vitamin A** and the protein **opsin**. The Type I, Type II, and Type III cones in humans have the same retinal chromophore, but the amino acid sequence of the **opsin** protein in each type of photoreceptor cell is different enough to cause the three different spectral sensitivities. In humans, Type I cones are sensitive to violet, blue, and green light; Type II cones are sensitive to blue, green, yellow, orange, and red light; and Type III cones are sensitive to green, yellow, orange, and red light.

When photopsin absorbs light, the **11-cis retinal** is converted into **all-trans retinal**. The all-trans retinal form of photopsin activates a **G protein** known as **transducin** that ***eventually*** causes the sodium channels to **close**. The inhibition of the movement of positively-charged sodium ions into the cell causes the plasma membrane to hyperpolarize, and the hyperpolarization inhibits the release of glutamate. The inhibition of glutamate release results in a change in the neural activity of the nearby ganglion cells and a message that light was absorbed by a particular cone is sent to the **brain**. The neural message carried by the ganglion cell encodes the brightness of the light that hits a cone that is sensitive to a given color region, and the mind sees the neural message as a color at the point. It takes the neural messages of *three different cone types* for the mind's eye to see white. **The mind can see a million different colors in a given point by reconstructing the neural signals that come from three nearby cones with different spectral sensitivities.**

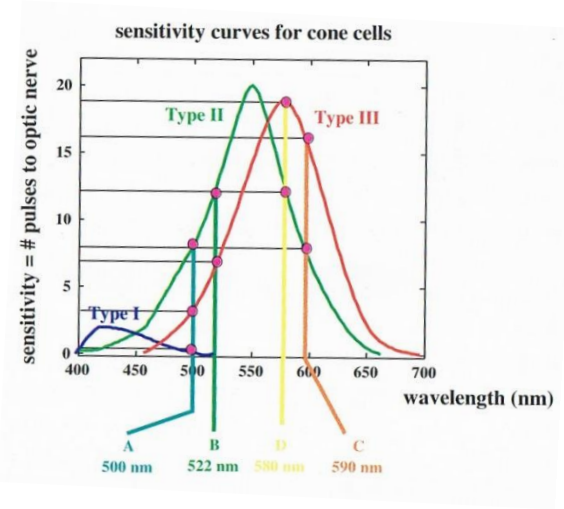




Aside: The **rods** do not play a role in color vision, but I will mention them here for completeness. The rods secrete glutamate in the dark and stop secreting glutamate in the light. Since the bipolar cells are inhibited by glutamate, they do not send a message to the brain when the rod is dark, but they do send a message to the brain when the rod is light.

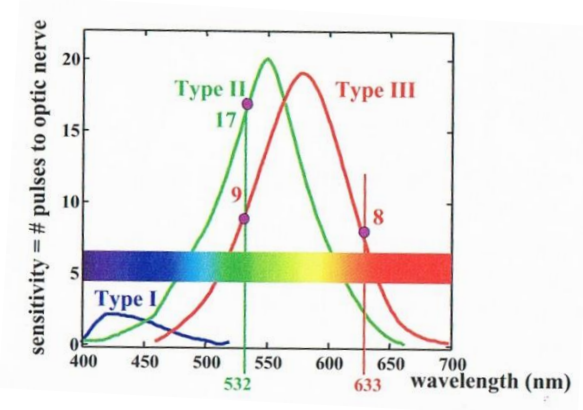


Let's look at the **response of a Type II** cone to four particular wavelengths: 500 nm (cyan), 522 nm (green), 580 nm (yellow) and 590 nm (orange). The Type II cone has the same response to equal intensities of 500 nm and 590 nm light. It also responds identically to equal intensities of 522 nm and 580 nm light. If we only had Type II cones, we could not distinguish cyan from orange or green from yellow.



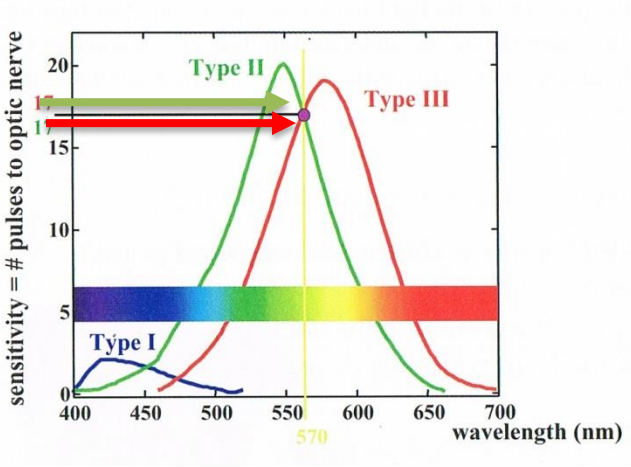
However, by having **three types of cones**, each with a different spectral response, we can differentiate approximately a million colors. Now you can see how: green (500 nm) and orange (590 nm) generate a response of 8 on Type II cones, but green generates a response of 3 on Type III cones while orange generates a response of 17. Green generates a tiny response on Type I cones while orange generates no response on Type I cones. The three types of cones send three messages, encoded into neural pulses, to the brain. The set of three messages define a wavelength: The complete message for 500 nm light is (0.1, 8, 3) and for 590 nm light it is (0, 8, 17).

Demonstration: Look at the spots made by the red and green lights. The peak of the green spot is about 532 nm and the peak of the red spot is about 633 nm. The green spot generates a response of 17 in the Type II cone and a response of 9 in the Type III cone. The red spot generates a response of 2 in the Type II cone and a response of 8 in the Type

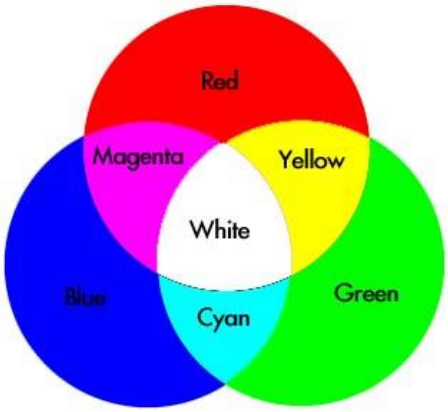


III cone. The message for the 532 nm light is (0, 17, 9) and for the 633 nm light, it is (0, 2, 8).

When the green and red spots overlap, they will generate yellow and the total number of neural responses will be 0 from the Type I cone, 19 from the Type II cone, and 17 from the Type III cone. This neural response (0,19,17) is similar to the neural response that would be generated by a single wavelength of yellow light between 560 and 570 nm. Thus the neural signal that is sent to the brain and decoded into color is the same whether a **pure spectral color** is observed or two or more pure colors that give the **exact same neural response** are **mixed**. This is why we cannot tell the difference between a pure spectral color and a mixed color. Some humans may have four types of cones (**tetrachromats**) instead of three types of cones (**trichromats**). Tetrachromats can differentiate between pure and mixed colors even better than trichromats.



Demonstration: Use the color Addition Spotlights to see the three primary colors and how they add. What color do you get when you add red and green? Blue and green? Red and Blue? A color and it complementary color make white. Which pairs are complementary colors?



Demonstration: The color of an object not only depends on the chemical composition of its surface, but on the spectral quality of the illumination. What color is the red or green apple when it is placed in each color zone?

COLOR OF PIGMENT	COLOR OF LIGHT							
	Violet	Blue	Blue-green	Green	Yellow	Orange	Red	Purple
Violet	Deep violet	Dark violet	Dark violet	Violet	Dark brown	Dark brown	Dark gray	Dark violet
Blue	Light blue	Deep blue	Light bluish gray	Light blue	Dark bluish gray	Black	Gray	Blue
Blue-green	Dark blue	Very dark blue	Dark bluish gray	Dark green	Greenish blue	Dark greenish brown	Black	Dark blue
Green	Bluish brown	Light olive green	Light greenish gray	Intense green	Bright green	Dark green	Dark gray	Dark greenish brown
Yellow	Scarlet	Greenish yellow	Greenish yellow	Greenish yellow	Intense yellow	Yellow-orange	Red	Orange
Orange	Scarlet	Light brown	Light brown	Light brown	Orange	Intense orange	Intense orange-red	Scarlet
Red	Scarlet	Purplish black	Dark maroon	Maroon	Bright red	Orange red	Intense red	Red
Purple	Reddish purple	Dark violet	Maroon	Purplish violet	Light brown	Maroon	Reddish brown	Deep purple

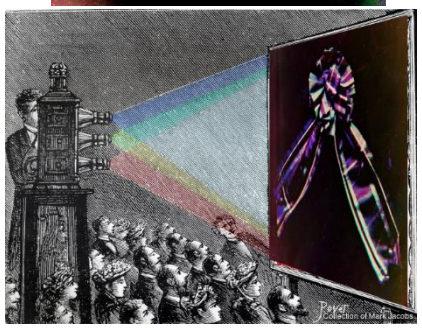
Demonstration: Arrange the three lights to that they make one big white spot. Use your hand to make a shadow by blocking one of the colored lights at a time. The shadow will be the color of the two colors that were not blocked.





Adding equal intensities of the **three primary colors**, red, blue and green results in white. A primary color cannot be matched by any mixture of the other two primaries. Adding red and blue produces **magenta,** adding red and green produces **yellow** and adding blue and green produces **cyan**. A **complementary** color is defined as the color that when added to another color produces white. Magenta is the complementary color of green, yellow is the complementary color of blue, and cyan is the complementary color of red.





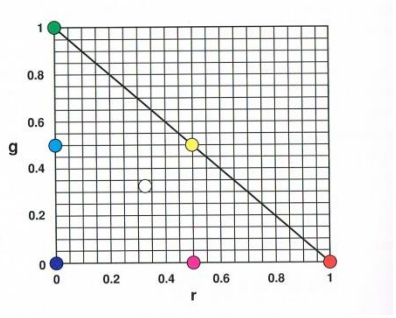
Red, green and blue light can be added together in various proportions to make any color. **James Clerk Maxwell** and Thomas Sutton used this idea in 1861 to create the first color

photograph of a tartan. The creation of any color from the three primary colors can be clearly seen with the color vision program from PhET Interactive Simulations: http://phet.colorado.edu/en/simulation/color-vision. The color (C) formed is described by the following equation:

$$C = aR + bG + cB$$

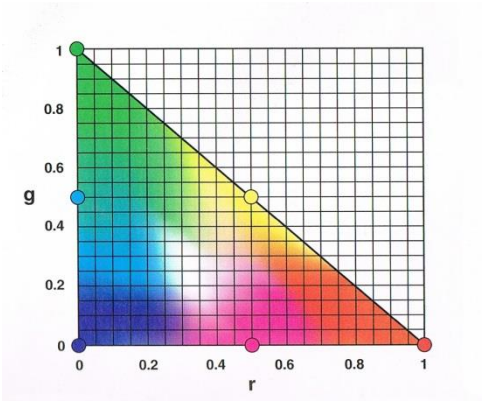
where a, b, and c are the intensities of **R**ed, **G**reen and **B**lue light, respectively.

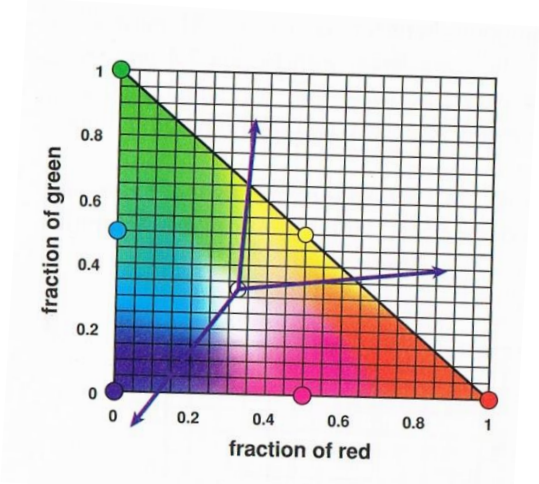
The fraction of the light that is red is given by $r = \frac{a}{a+b+c}$, and the fraction of the light that is green is given by $g = \frac{b}{a+b+c}$. Since all the colors can be made by R, G, and B, then *r*, *g*, and *b* must add up to 1 and $b = 1 - r - g$. Therefore we do not have to calculate *b* directly and we can characterize any color spot with *r* and *g*. The total intensity of the spot is given by $I = a + b + c$.



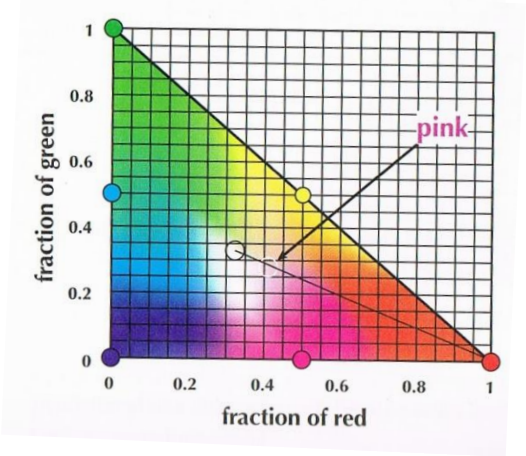
We can use a **color triangle** to characterize most of the colors that a human can see. To use the **color triangle**, plot the value (*r*, *g*) for each color to be added. Then draw a line between them. The resulting color is the middle of the line. Magenta is the midpoint between (0,0) and (1,0); yellow is the midpoint between (0,1) and (1,0); Cyan is the midpoint between (0,0) and (0,1). White is the point (0.33, 0.33).

Any mixed color can be considered to be the **sum of any spectral color** or **hue plus white**. A **high-saturation** color contains no white whereas a **lower-saturation** or pastel color contains more white. One can draw a line *from* the white spot *to* any of the spots representing the primary or secondary colors. Along the line, the **hue** (or **spectral color**) stays the same, but the **saturation** increases. A **hue** or **spectral color** is defined by a single wavelength.



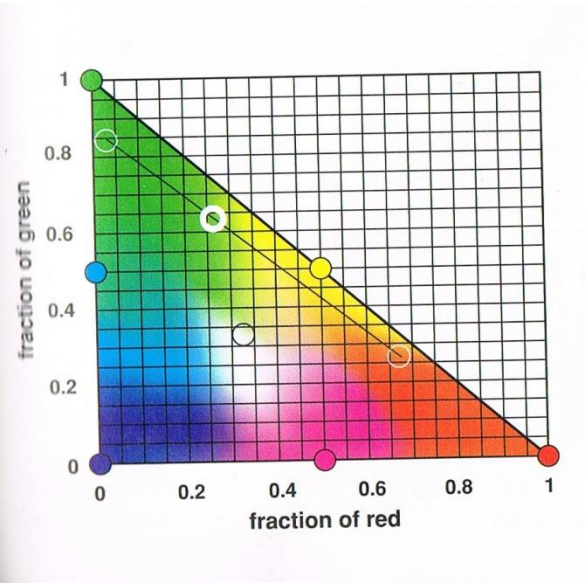


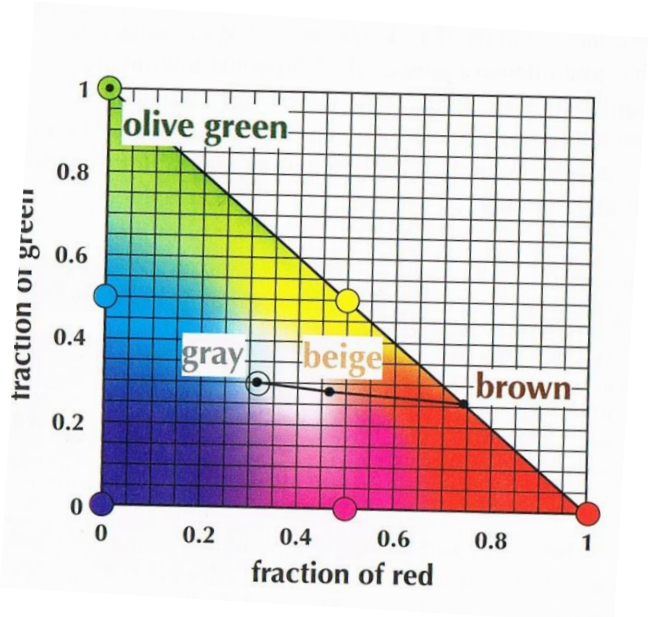
A line drawn from the white spot to any pure spectral color represents a single **hue** with increasing **saturation**.



Pink is a very low-saturation red and falls on the line between white and red.

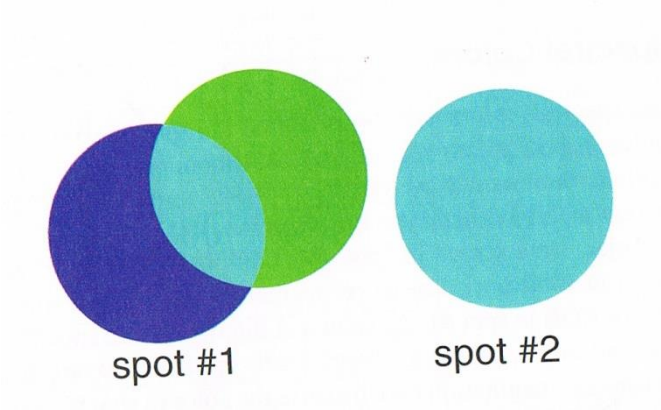
The **color triangle** can be used to predict the color made by mixing any two colors of light. In order to predict the outcome of the mixture, we must find the position of the colored light that will be mixed on the color triangle. If we want to mix equal parts of high-saturation green and high-saturation orange, we draw a line between the two colors and find the midpoint, which is yellow. If we want to mix 2 parts of high-saturation green with 1 part high-saturation orange, we find the point on the line that is one-third of the way from green and two-thirds of the way from orange. The resulting color is lime green. Likewise, gray is low-intensity white and brown is low-intensity orange, and beige is low-saturation brown or low-saturation and low-intensity orange.



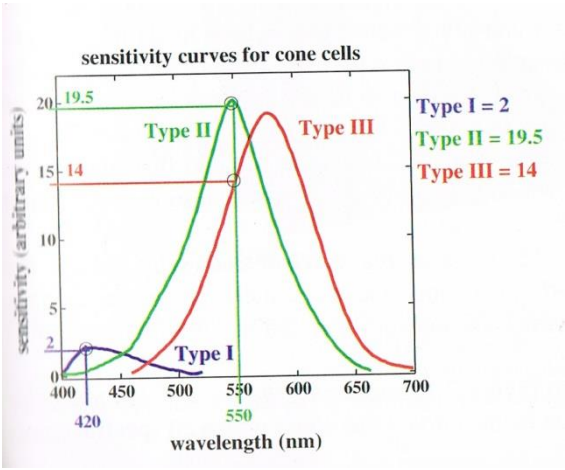


Unfortunately, this simple color triangle does not show every color. For example, it does not show olive green, which is just a low-intensity green. Check this with the color vision program: http://phet.colorado.edu/en/simulation/color-vision.

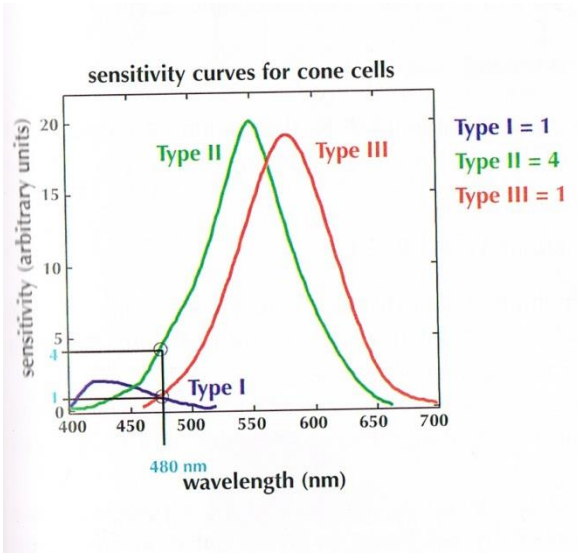
Let's consider the two ways to make cyan. One is with a 480 nm spectral color (spot 2) and the other is to use a combination of RGB (spot 1). The two colors are matched when our visual system with our eyes and brain tell us that they are matched. Spot 2 sends a neural message produced by 480 nm light with the code (1, 4, 1). Spot 1 sends a neural message produced by a mix of 420 nm and 550 nm light with the code (2, 19.5, 14). Clearly, they are not matched!



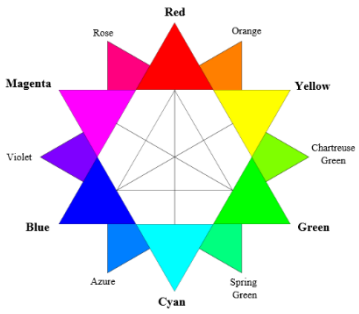
Spot #1



Spot #2

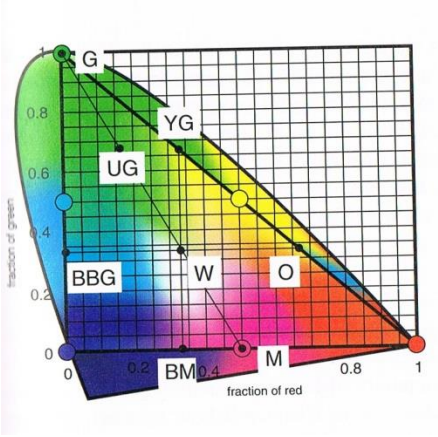


We could get the two neural signals to match if we added red light to spot 2. Since **red is the complement of cyan**, this is equivalent to desaturating the cyan. Adding red to the cyan in spot 2 is mathematically equivalent to adding **negative red** to the violet and green that makes spot 1. Adding negative red will "saturate" the unsaturated cyan to make spectral cyan.

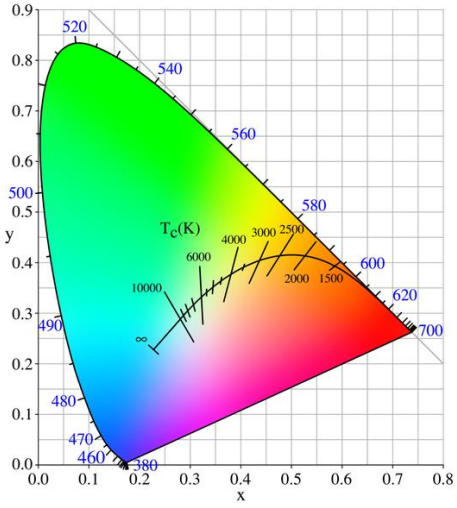


Spectral Cyan + xR = G + B

Spectral Cyan = G + B – xR



We can represent the addition of negative red by using the area *outside* the color triangle as shown in this **CIE Chromaticity Diagram**. (CIE stands for International Commission on Illumination). The horseshoe shaped area is the area of human vision. The spectral colors that we can see and mix with RGB are inside the color triangle. The spectral colors that we *can* see but cannot mix with just positive values of **RGB** are outside the triangle. I like talking about the RGB system because it matches the color sensitivities of our cones, but there are other systems of combining colors such as the Cyan-Magenta-Yellow-Black (CMYK) used in many printers. CMYK is a subtractive process, which means that when a given color is injected, additional light is absorbed to create a unique color tending towards black. By contrast, RGB is an additive process, which means that when a given color is added, the image becomes whiter. It is used for screens.



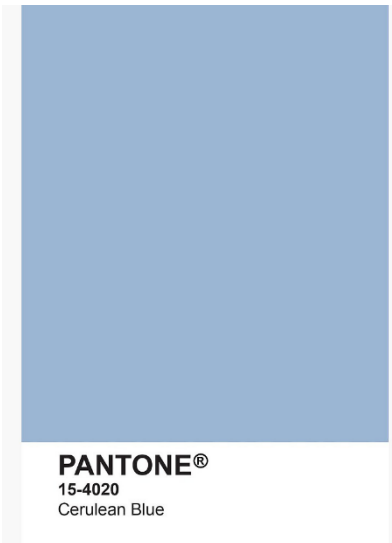
The **CIE Chromaticity Diagram** can be rescaled so that all the values are positive. The rescaled (0-0.8) **CIE Chromaticity Diagram** can be used to describe the spectral qualities of various sources of illumination with different **color temperatures (from 1500 K to 10,000 K)**.

Cerulean (RGB: 152, 180, 212), mazarine (RGB: 39, 60, 118), and navy (RGB: 64,63,111) were some of the blues used for Victorian fashion. Cerulean blue was made form a mixture of cobalt and tin. Marazine blue was made from cobalt. Navy blue was made from indigo.





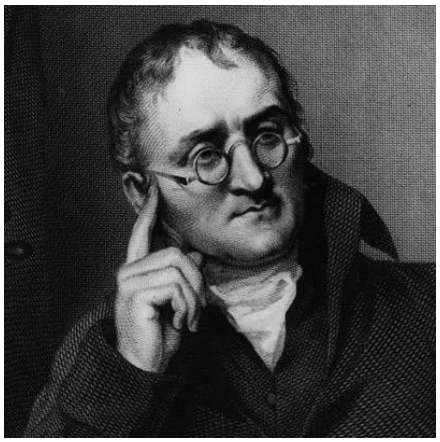








Under the same illumination, not everyone sees an object as having the same color. **John Dalton**, the founder of the **atomic theory**, noticed this in 1794. Dalton wrote, "*It has been observed that our ideas of colours, sounds, tastes, &c. excited by the same object may be very different in themselves, without our being aware of it; and that we may nevertheless converse intelligibly concerning such objects, as if we were certain the impressions made by them on our minds were exactly similar. All, indeed, that is required for this purpose, is, that the same object should uniformly make the same impression on each mind; and that objects which appear different to one should be equally so to others. It will, however, scarcely be supposed, that any two objects, which are every day before us, should appear hardly distinguishable to one person, and very different to another, without the circumstance immediately suggesting a difference in their faculties of vision; yet such is the fact, not only with regard to myself, but to many others also, as will appear in the following account."*



"I was of the opinion, though I might not often mention it, that several colours were injudiciously named. The term pink, in reference to the flower of that name, seemed proper enough, but when the term red was substituted for pink, I thought it highly improper; it should have been blue, in my apprehension, as pink and blue appear to me very nearly allied; whilst pink and red have scarcely any relation."

"In the course of my application to the sciences, that of optics necessarily claimed attention; and I became pretty well acquainted with the theory of light and colours before I was apprized of any peculiarity in my vision. I had not, however, attended much to the practical discrimination of colours, owing, in some degree, to what I conceived to be a perplexity in their nomenclature. Since the year 1790, the occasional study of ***botany*** *obliged me to attend to colours more than before. With respect to colours that were white, yellow, or green, I readily assented to the appropriate term. Blue, purple, pink, and crimson appeared rather less distinguishable; being according to my idea, all referable to blue. I have often seriously asked a person whether a flower was blue or pink, but was generally considered to be in jest. Notwithstanding this, I was never convinced of a peculiarity in my vision, til I accidentally observed the colour of the flower on the Geranium zonale by candle-light, in the autumn of 1792. The flower was pink, but it appeared to me almost an exact sky-blue by day; in candle-light, however, it was astonishingly changed, not having then any blue in it, but being what I called red, a colour which forms a striking contrast to blue. Not then doubting but that the change in colour would be equal to all, I requested some of my friends to observe the phenomenon; when I was surprised to find they all agreed, that the colour was not materially different from what it was by day-light, except my* ***brother****, who saw it in the same light as myself. This observation clearly proved, that my vision was not like that of other persons; and, at the same time, that the difference between day-light and*



candle-light, on some colours, was indefinitely more perceptible to me than to others."

Dalton guessed that the difference between his and his brother's color vision and the color vision of others was a result that the vitreous humor in his and his brother's eyes must be bluish and if so, would imitate the effect of looking at the world through a blue filter.

Demonstration: Look at the world through a blue filter.



Dalton asked that his eyes would be dissected after his death in order to test his hypothesis. Dalton died on July 27, 1844 when he was 78. On the next day, Joseph Ransome performed an autopsy. Ramsome found that both the **aqueous** and **vitreous humors** of the eye were **clear** and **transparent**, although the crystalline lens was yellowish, like anyone's of his age. Luckily Ransome saved and preserved the remains of the two eyes.



Now we know that color blindness usually arises from the lack of one of the three types of cones in the retina. **Deuteranopia** results from the lack of a functional mid wavelength sensitive Type II photoreceptor and **protanopia** results from the lack of a functional long wavelength sensitive Type III photoreceptor. Deuterantopia and proantopia are forms of **red-green colorblindness**.

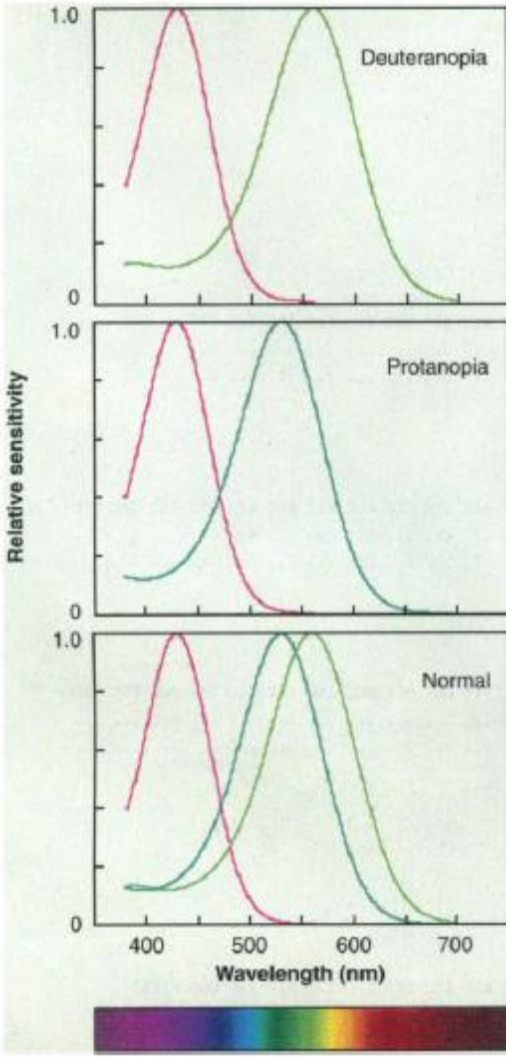
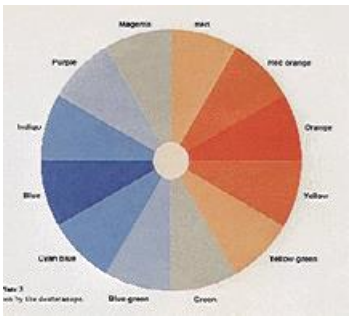
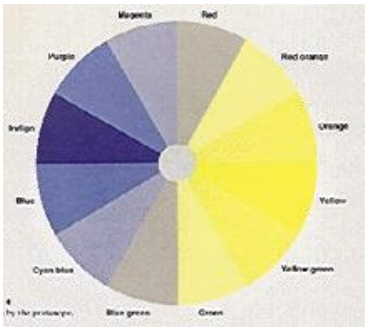


Fig. 3. The spectral sensitivities of the three types of cone photoreceptors in the normal eye (bottom panel), protanopia (middle panel), and deuteranopia (top panel).

Since the three photoreceptors are a result of three different versions of the opsin protein, the genes that code for Dalton's cones could be determined from his preserved eye. Dalton was a deuteranope, who was missing the mid wavelength sensitive Type II photoreceptor.

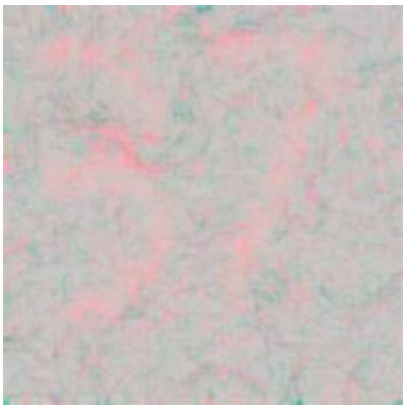
Without a Type II photoreceptor, the world would be to Dalton a mixture of blue and red (left). Without a Type III photoreceptor, the world would be a mixture of blue and yellow (middle). The world of a trichromat is shown on the right.



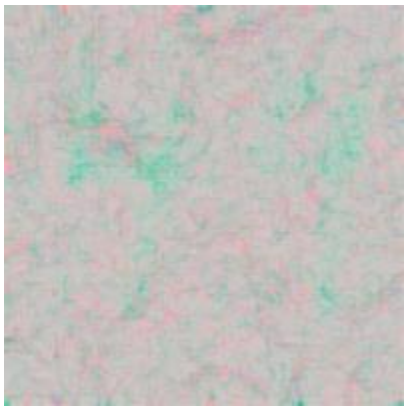




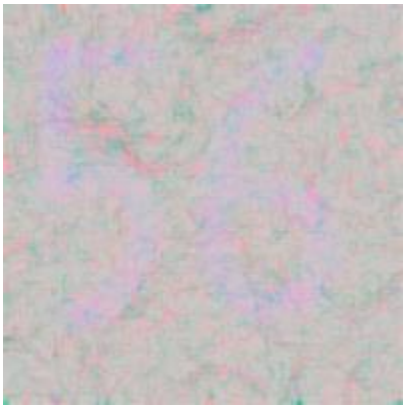
Do you see the number 37? If not, you may be missing Type III comes and have protanopia.



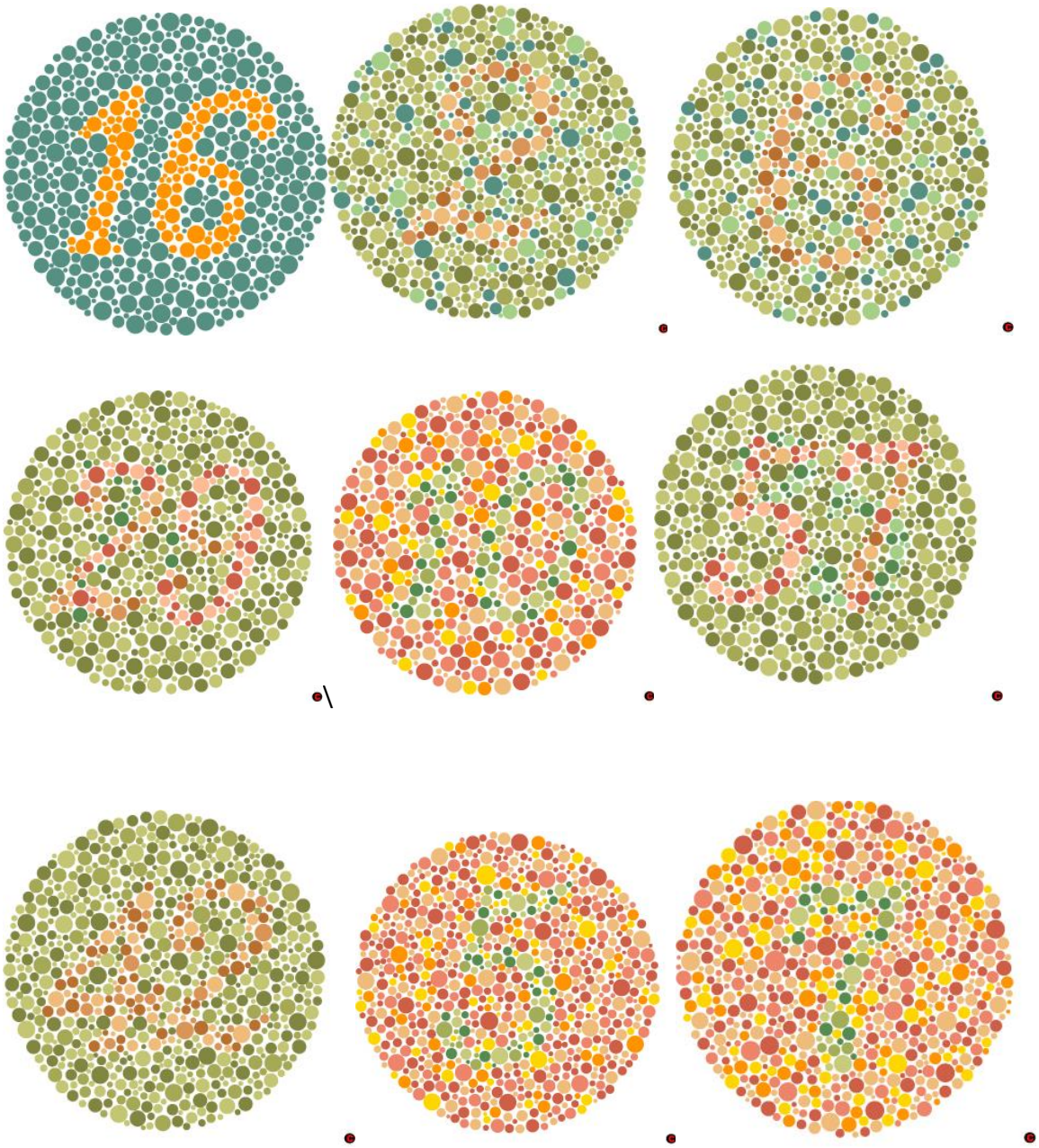
Do you see the number 49? If not, you may be missing Type II cones and have deuteranopia.



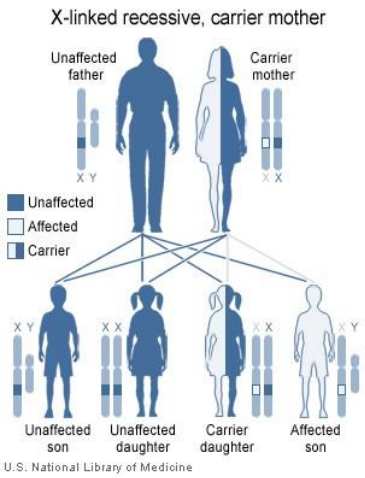
Do you see the 56? If not, you may be missing Type I comes and have tritanopia.



Take the Ishihara Color Vision Test. What numbers do you see?



Dalton and his brother both were colorblind; suggesting that color blindness is a **genetic trait**. The Human Genome Project tells us that **fifty six different genes** on 19 different chromosomes affect colorblindness. Because the major and common (red-green protanopia and deuteranopia) colorblind genes are on the **X-chromosome,** color blindness is often a **sex-linked trait** that is more common in men than in women since women; with two X chromosomes often have one normal copy of the gene that will cover for (or is **dominant** over) the colorblind version of the gene (which is **recessive**).



Color vision requires photopic vision. **Jan Purkinje** noticed that with scotopic vision, blue flowers appeared brighter than red flowers but as the dawn progressed, the red flowers appeared brighter than the blue as photopic vision was used. He wrote, "*Objectively, the degree of illumination has a great influence on the intensity of color quality. In order to prove this most vividly, take some colors before daybreak, when it begins slowly to get lighter. Initially one sees only black and grey. Particularly the brightest colors, red and green, appear darkest. Yellow cannot be distinguished from a rosy red. Blue became noticeable to me first. Nuances of red, which otherwise burn brightest in daylight, namely carmine, cinnabar and orange, show themselves as darkest for quite a while, in contrast to their average brightness. Green*



appears more bluish to me, and its yellow tint develops with increasing daylight only."

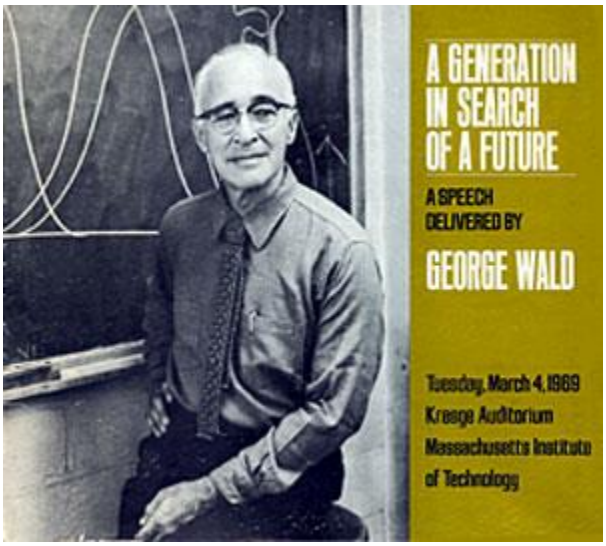


During a full moon, the light is too bright for **scotopic** vision and too dim for **photopic** vision. Could this **mesopic** vision be involved in **lunacy**? Just asking!

The name of colors and the color itself is processed by our brain differently, and that is what makes the **Stroop Test** so fun. Say the name of the color the word is printed in, not what the word represents.

Stroop Effect

YELLOW BLUE ORANGE
BLACK RED GREEN
PURPLE YELLOW RED
ORANGE GREEN BLUE
BLUE RED PURPLE
YELLOW RED GREEN



George Wald discovered **that vitamin A** was necessary for making the visual pigments in the rods and cones. Here is the speech he gave at the banquet when he received the Nobel Prize in Stockholm, December 10, 1967.

Your Majesty, Royal Highnesses, Exellencies, Ladies, Gentlemen, and fellow students:

A scientist should be the happiest of men. Not that science isn't serious; but as everyone knows, being serious is one way of being happy, just as being gay is one way of being unhappy.

A scientist lives with all reality. There is nothing better. To know reality is to accept it, and eventually to love it.

I tell my students to try early in life to find an unattainable objective. The trouble with most of the things that people want is that they get them. No scientist needs to worry on that score. For him there is always the further horizon. Science goes from question to question; big questions, and little, tentative answers. The questions as they age grow ever broader, the answers are seen to be more limited.

A scientist is in a sense a learned small boy. There is something of the scientist in every small boy. Others must outgrow it. Scientists can stay that way all their lives.

I have lived much of my life among molecules. They are good company. I tell my students to try to know molecules, so well that when they have some question involving molecules, they can ask themselves, What would I do if I were that molecule? I tell them, Try to feel like a molecule; and if you work hard, who knows? Some day you may get to feel like a big molecule!

So we have much to be thankful for. With this great honor you cast a radiance upon our science. We who work in vision are happy to have it made so visible.

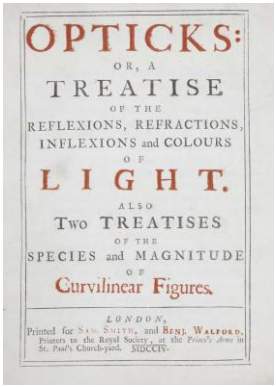
I am glad to be able to bring this offering to the memory of my teacher, Selig Hecht, whose widow Gelia is here with us tonight; to my wife, who is also my closest co-worker; and to my co-workers at home, particularly Paul Brown, who for twenty years has done so much himself, and with us all.

But there is something more. The grocer, the butcher, the taxi man, all seem delighted to share in our pleasure. The Nobel Prize is an honor unique in the world in having found its way into the hearts and minds of simple people everywhere. It casts a light of peace and reason upon us all; and for that I am especially grateful.

Aside: All else being equal, the color of an object affects its temperature. There is a relationship between color of a material and its ability to reflect visible light, or to **absorb visible light and radiate heat**.

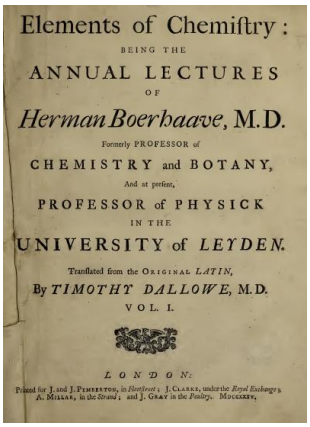


Robert Boyle (1664) noticed that an egg that had been painted black and exposed to the sun cooked faster than a white egg. He wrote in *Experiments and Considerations Touching Colours*, "*SIXTHLY, I remember, that acquainting one day a Virtuoso of unsuspected credit, that had visited hot countries, with part of what I have here delivered concerning blackness, he related to me, by way of confirmation of it, a very notable experiment, which he had both seen others make, and made himself in a warm climate; namely, that having carefully blacked over eggs, and exposed them to the hot sun, they were thereby in no very long time well roasted; to which effect I conceive the heat of the climate must have concurred with the disposition of the black surface to reflect the sun-beams inward: for I remember, that having made that among other trials in England, though in summer-time, the eggs I exposed acquired indeed a considerable degree of heat, but yet not so intense a one, as proved sufficient to roast them.*"


OPTICKS:
OR, A
TREATISE
OF THE
REFLEXIONS, REFRACTIONS,
INFLEXIONS and COLOURS
OF
LIGHT.
ALSO
Two TREATISES
OF THE
SPECIES and MAGNITUDE
OF
Curvilinear Figures.
LONDON,
Printed for SAM. SMITH, and BENJ. WALFORD,
Printers to the Royal Society, at the Prince's Arms in
St. Paul's Church-yard. MDCCIV.

Isaac Newton (1704) asked in Query 6 of his *Opticks*, "*Do not black Bodies conceive heat more easily from Light than those of other Colours*

do, by reason that the Light falling on them is not reflected outwards, but enters the Bodies, and is often reflected and refracted within them, until it be stifled and lost?"


Elements of Chemiſtry:
BEING THE
ANNUAL LECTURES
OF
Herman Boerhaave, M.D.
Formerly PROFESSOR of
CHEMISTRY and BOTANY,
And at preſent,
PROFESSOR of PHYSICK
IN THE
UNIVERSITY of LEYDEN.
Tranſlated from the ORIGINAL LATIN,
By TIMOTHY DALLOWE, M.D.
VOL. I.
LONDON:
Printed for J. and J. Pemberton, in Fleet-ſtreet; J. Clarke, under the Royal Exchange; A. Millar, in the Strand; and J. Gray in the Poultry. MDCCXXIV.

Herman Boerhaave (1735) wrote in *A New Method of Chemistry* (Experiment XIII), "*If this Fire, thus determined by the Sun, falls upon Bodies that are exceedingly black, its Heat will be retained there a considerable time. On this account, therefore, such Bodies grow sooner hot, and acquire a greater degree of Heat from the same Fire, grow dry in a shorter time when they have been wetted with Water, and burn much more readily than any other. We need go no farther for the proof of these assertions, than daily Observation. Take a piece of cloth died a very deep black; another piece of the same cloth, but white; a third, scarlet; and others of different Colours; and hang them up in the Air, and Sun, and you'll find that the black will grow warmest, and much sooner than any of the rest. And of the others of different dies, those always acquire Heat slowest, whose Colours are most vivid, and affect the eyes most strongly: for the white, and scarlet are longest growing warm; and the rest so much sooner as their Colours are less bright, as we see evidently in the weaker Green. And this, those people that live in the hottest countries are well acquainted with; for they find, that if their outward garment is white, it best secures them from the Heat of the scorching Sun, whereas if it is black, it suffocates the Heat, and makes it more troublesome. And it is a common Observation of the manufacturers of Woollen-cloth, that if a parcel of wet cloths are hung up at the same time, and are equally exposed to the Sun, the black will presently grow warm, reak, and dry, the white will retain its wet a long time; and the others will dry so much slower, as their Colour is brigh[t]er. Hence, again,*

white garments, when they are exposed to Heat retain their dampness much longer than others, and thus too keep the Body cool.

It has, yet farther, been observed that black Bodies take fire, flame, and burn, much easier with the same Fire than Bodies of any other Colour. Shavings, for instance, of very white wood will scarcely receive a spark struck upon them, so as to keep it in; but if you burn them to a black coal, the powder of this will easily support it, and be soon kindled all over by one single one. In the same manner a spark won't keep a-light any considerable time in a piece of very clean white linen; whereas, if it falls upon the same when it is reduced to tinder, which is a sort of exceeding thin black coal, it will spread itself all over it. Nor would even Gunpowder itself, so soon take fire, where it not for its blackness; as we see evidently in the powder of very white Nitre rubbed with Sulphur. The Gardeners too have long observed to their disadvantage, that white Earth will hardly grow hot, except just on the surface; whilst the black conceives so great a heat, as to burn the very roots of their Plants. The Chemists, likewise, long ago informed us, that black Bodies committed to digestion, or reduced to it by Art, grow warm with the same Fire easier than others; different degrees of Heat being required in the head of a Crow, the neck of a Swan, and the tail of a Peacock. And lastly, the Philosophers have confirmed the same by ocular demonstration. If you hold a piece of very white paper in the Focus of a burning Glass, it will be a considerable time before it grows hot, and much longer before it takes fire; and when it is just going to kindle, it first loses its whiteness, grows brown, then black, and afterwards flames in an instant."

Joseph Breintnal (January 25, 1736), a friend of **Benjamin Franklin**, performed the following experiment testing the effect of color of a fabric on its

ability to melt snow. Interestingly, he found that clear window glass was as effective as black cloth in melting snow.

"*Experiments with Colours of various Sorts, to shew which imbibe, and which repel (or do not readily admit) the Sun's Rays; made with placing on the level Snow, Bitts of Linnen, Silks, Leather, Paper, Woollen Cloth, Feathers, and other Materials - exemplify'd by six Degrees of melting down or sinking in the Snow. By which it was observable that the different Weights or Kinds of the Subjects made no Alteration; All the Variety of Effects being owing only to Difference of Colours, except the* ***Piece of Glass****, and except the Circumstances of Cloth being closely or loosely wove—*

1st Degree. Shallowest_____ White.

2. Less shallow_____ Light Red. Red &White striped. Light Yellow. Light Azure.

3. Least shallow, meaning next above deep_____ Lively Blood Red. Reddish Brown, or bright Cinnamon.

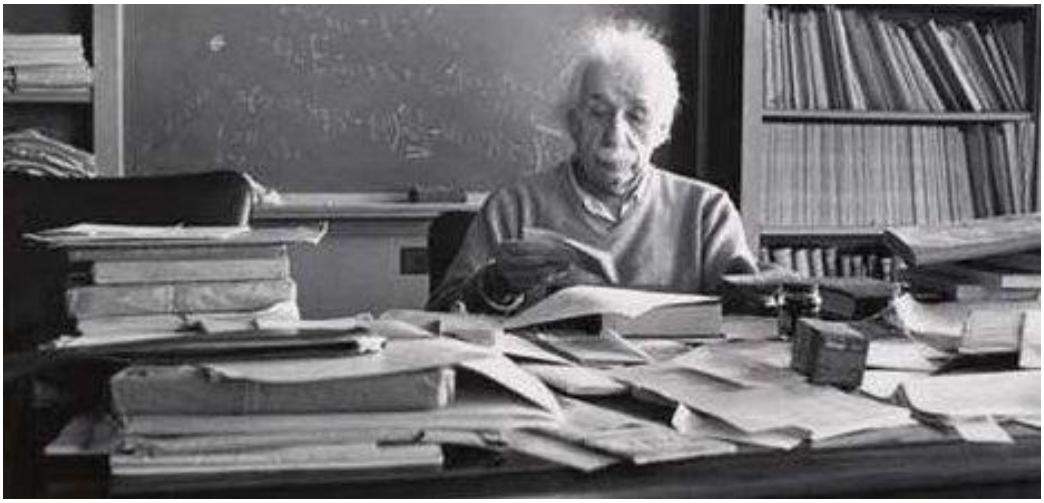
4. Deep Deep_____Grass Green. Yellow Brown, or dirty Yellow.

5. Deeper_____ Deep Blue. Gloomy Red. Dark Olive, or Dark Brown.

6. Deepest_____ Black. Also a piece of ***Window Glass.*****"**

How does window glass melt the snow? The window glass allows the visible light to pass through it. Since we can see the snow through the glass, some of the visible rays reflect off the snow and pass back through the glass to our eyes. However, the rest of the visible rays are converted into heat rays which cannot pass back through the glass. The heat rays build up under the glass and thus melt the snow beneath the glass.

In his advice to youth, Albert Einstein said: "*The important thing is not to stop questioning. Curiosity has its own reason for existence. One cannot help but be in awe when he contemplates the mysteries of the eternity, of life, of the marvelous structure of reality. It is enough if one tries to comprehend a little of this mystery each day. Never lose a holy curiosity. Try not to become a man of success but rather try to become a man of value."* (Life Magazine, May 2, 1955)



True Colors; Cyndi Lauper
https://www.youtube.com/watch?v=LPn0KFlbqX8

Colours: Donovan https://www.youtube.com/watch?v=hoEle04qu_U

Colours of My Life: The Seekers
https://www.youtube.com/watch?v=DQioqPLvG3s

CAN LIGHT BE GOLDEN?

By Owen Barfield



Can light be golden? That can never be,
The well-informed assure us, because light
Is what we see by, never what we see.

But are the well-informed, I wonder, right?
Those painters of the old Italian school
Seem almost to condense it into sight.

I doubt if Cimabue was a fool,
Or faked the background, or the aureole.
Perhaps they worked to some more secret rule

That light observes—not light through Newton's hole
(The force we see by when we are not blind),
But light inbreathed by man's adoring soul.

Can light be golden? Now recall to mind
That seeding whereof Perseus was the flower:
How sad Acrisius' daughter was confined

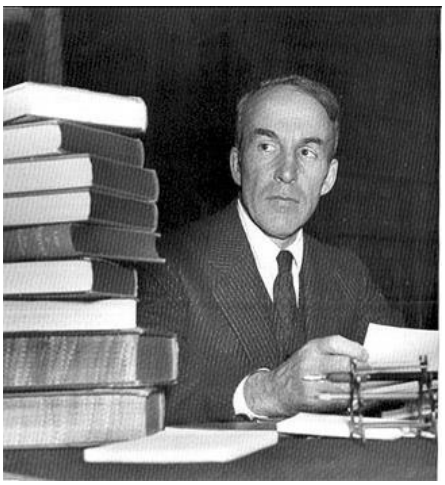
In Argos long ago—the brazen tower—
Then Zeus, the Light of Day, with godlike stride
Descending on it in a Golden Shower,

Breaching its walls to glorify the bride.
Can light be golden? Now the truth comes clear:
It is, when wonder meets it open-eyed—

As I am to the light that streams from her,
When she at last is near, and these old walls
Invading, overwhelms their prisoner:

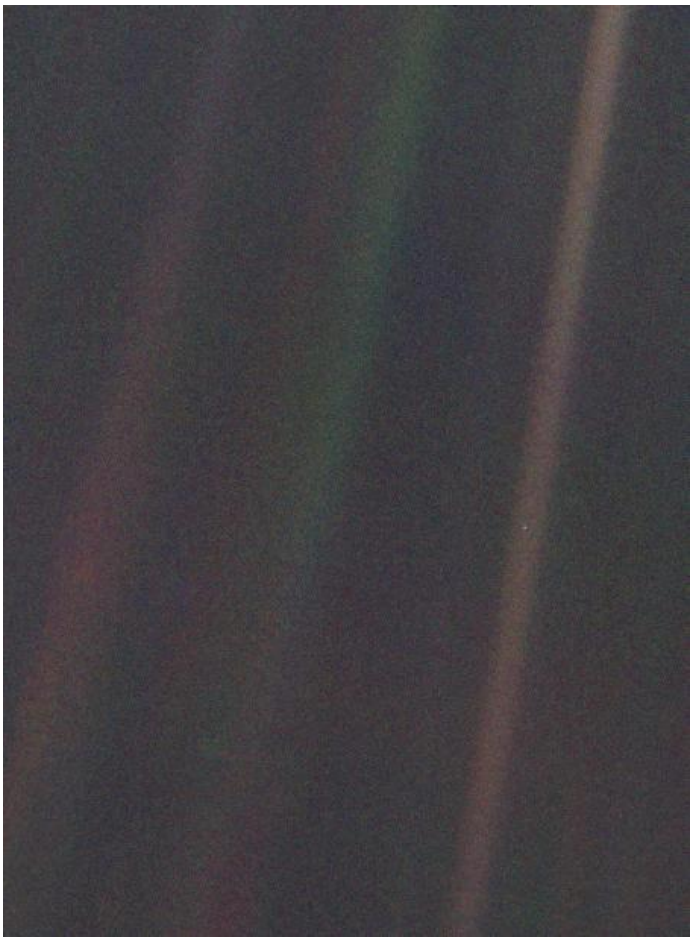
The light that, condescending, disenthralls!
For now the pagan myth's inverted: she
(Look up, and see how smilingly it falls!)
The Shower of Gold; I, wondering Danäe.

The Pale Blue Dot



On Christmas 1968, **Archibald MacLeish** wrote *Riders on Earth Together, Brothers in Eternal Cold*, in which he described the earth.

*To see the earth as it truly is, small and **blue** and beautiful in that eternal silence where it floats, is to see ourselves as riders on the earth together, brothers on that bright loveliness in the eternal cold—brothers who know now they are truly brothers.—The New York Times,* December 25, 1968, p. 1.
https://archive.nytimes.com/www.nytimes.com/library/national/science/nasa/122568sci-nasa-macleish.html?scp=1&sq=%252522medieval%252520notion%252520of%252520the%252520earth%252520put%252520man%252522&st=cse



Carl Sagan (1994) wrote a book entitled, ***Pale Blue Dot*** that was inspired by an image taken, at Sagan's request, by Voyager 1 on February 14, 1990. As the spacecraft was leaving our planetary neighborhood for the fringes of the solar system, it turned it around for one last look at its home planet.

Sagan wrote, "*Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child,*

inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there—on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds.

Our posturings, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.

The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand.

It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

Animal Eyes



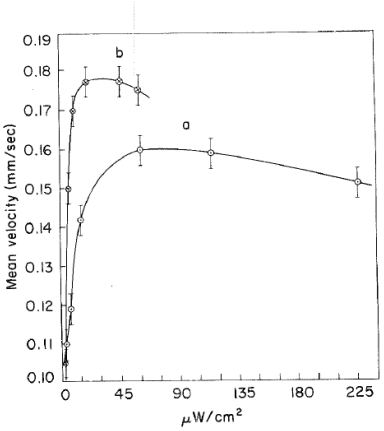


We can learn a lot from the wonder of, and the wonder in, animal eyes. **Aldo Leopold** a pioneer in the conservation movement did. He wrote in *Thinking like a Mountain*, "*We reached the old wolf in time to watch a fierce* ***green fire*** *dying in her eyes. I realized then, and have known ever since, that there was something new to me in those eyes – something known only to her and to the mountain. I was young then, and full of trigger-itch; I thought that because fewer wolves meant more deer, that no wolves would mean hunters' paradise. But after seeing the* ***green fire*** *die, I sensed that neither the wolf nor the mountain agreed with such a view.*" For Aldo Leopold, the green fire in the wolf's eyes symbolized a new way of **seeing** our place in the world, and with his new **insight**, he provided a new **ethical perspective** for the environmental movement. http://vimeo.com/8669977

Light contains information about the environment, and animals without eyes can make use of the information provided by environmental light without forming an image. ***Euglena***, a single-celled organism that did not fit nicely into **Carl Linnaeus'** two kingdom system of classification, quite clearly responds to light. Its plant-like nature responds to light by **photosynthesizing** and its animal-like nature responds to light by **moving** to and staying in the light. Light causes an increase in the swimming speed, a response known as



photokinesis. Light also causes another response in *Euglena*, known as an accumulation response (**phototaxis**). The light sensitive *Euglena* cells sense the direction of light, swim quickly towards the light, and stay in the light. The *Euglena* cell can be described as a **light meter**, not unlike the one that we used to test the **inverse square law**. Jerome Wolken (1995) describes *Euglena* as a **photo-neurosensory** cell.







Demonstration: See how the *Euglena* cells/organisms accumulate in the light.

Light-induced movements in *Euglena* have been studied by **Jerome Wolken**, the father of Jonathan Wolken, a founding member of the Pilobolus Dance Company, who performs Shadowland. The dance company was named after *Pilobolus*, a light-sensitive fungus growing in Wolken's lab that shoots its spores towards the light. Here is a drawing of *Pilobolu*s on the night of November 3, 1911, showing its ability to sense and grow towards the direction of light.

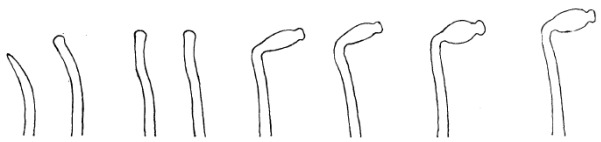
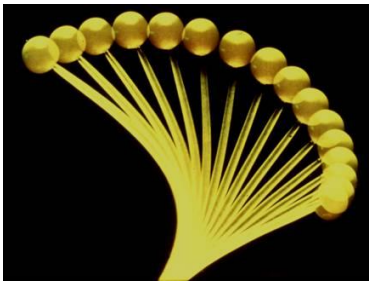
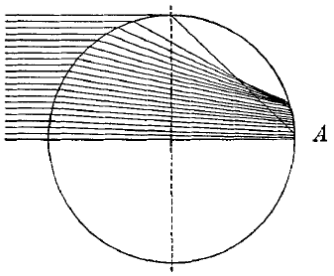
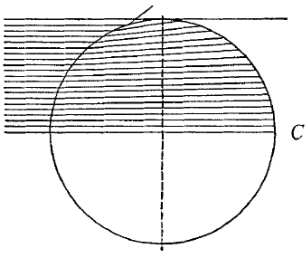


FIG. 12

The single-celled sporangiophore of *Phycomyces*, a fungus similar to *Pilobolus* acts like a light meter/converging lens that, when in air, focuses the light on the back side (A). When *Phycomyces* is grown in a medium that has the same refractive index as the cell, the light is not focused (C) and the sporangiophore does not bend (Castle, 1933)!







Earthworms are also capable of sensing light *without* eyes as reported by Charles Darwin (1881) in his book, *The Formation of Vegetable Mould, through the Action of Worms, with Observations of their Habits*. Earthworms have **light-sensitive photoreceptor cells in and under the skin** throughout their body although they are concentrated in the anterior portion (Hess, 1925). The earthworms are **photophobic** and move away from the light and towards the dark. At dawn, they crawl into their dark holes and stay there until dusk. I wonder if the birds know their schedule.



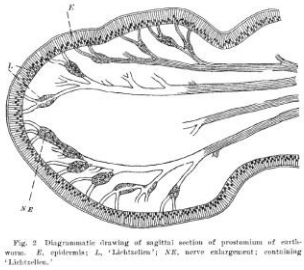


Fig. 2. Diagrammatic drawing of sagittal section of prostomium of earthworm. *E*, epidermis; *L*, 'Lichtzellen'; *NE*, nerve enlargement; containing 'Lichtzellen.'



Some animals have light meter-like “eyes” or **ocelli**, where photoreceptive cells that face the surface are arranged in **pits** or **cup-like patches**. **Pit** or **cup-like eyes** are found in the mollusc, *Patella vulgata*, which is a limpet that tenaciously attaches to rocks in the intertidal zone shown here on the **Hugh Miller** Trail near the Village of Cromarty Scotland.

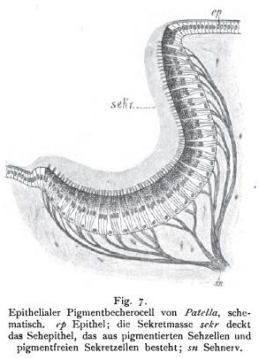
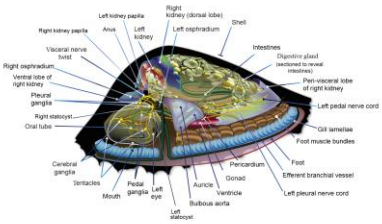


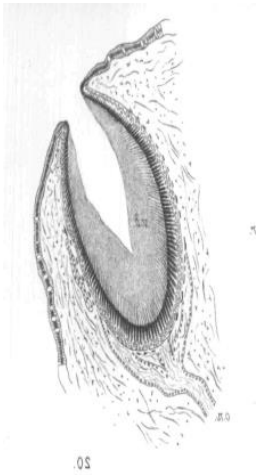
Fig. 7.
Epitheliales Pigmentbecherocell von *Patella*, schematisch. *ep* Epithel; die Sekretmasse *sekr* deckt das Sehepithel, das aus pigmentierten Sehzellen und pigmentfreien Sekretzellen besteht; *sn* Sehnerv.







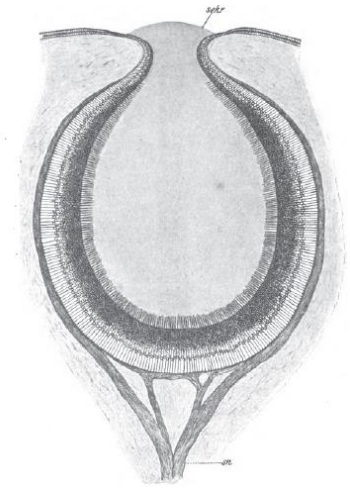
In the living fossil, *Pleurotomaria*, the small and inconspicuous eyes of this mollusc are more sunken. The photoreceptors face into the cavity that forms the optic cup and the ganglia are behind them. The cavity is open and sea water fills the upper portion of the cavity and a vitreous material fills the bottom of the optic cup. The **geometry** *almost* approaches that of a **pinhole camera**; however, with such a wide aperture relative to the image distance, any object would probably appear as a blob.







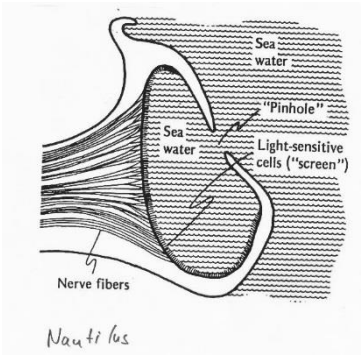
The geometry of the eye of the **iridescent** mollusc, *Haliotis* or abalone is more like a **pinhole camera**. The smaller **aperture** and more spherical retina would result in a relatively sharp image and relatively good **visual acuity**. The **tradeoff** of the smaller aperture is that the image will be **dimmer**.



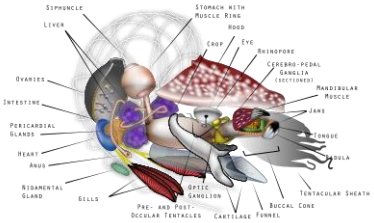




The geometry of the eye of the **cephalopod mollusc**, *Nautilus*, another living fossil, is even more like a **pinhole camera**. The smaller **aperture** and more spherical retina would result in a relatively sharp image and relatively good **visual acuity**. The **tradeoff** of the smaller aperture is that the image will be **dimmer**.









The **pinhole camera eye** of *Nautilus*, trades off dimness for visual acuity. Dimness can be overcome by the addition of a converging lens to make a **camera-like eye**, just as the *camera obscura* was improved by adding a converging lens.

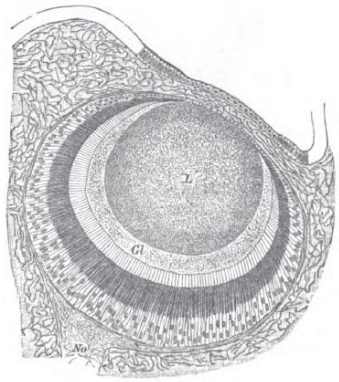


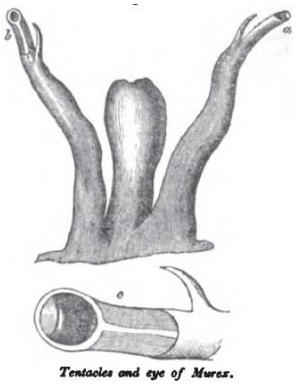


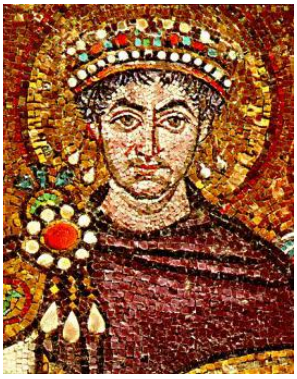


The gelatinous lenses of *Murex* and *Helix* that I will describe below do not have the refracting or dioptric power to produce a focused image on the retina.

Murex is a mollusc that lives in the intertidal zone. We will talk about *Murex* later in the semester when I talk about the dyes **Tyrian** (royal) **purple** and **Tekhelet**. *Murex* has a camera-like eye where the optic cup-like retina is filled with a gelatinous lens that captures a lot of light compared with a pinhole but it probably underfocuses and is not very effective in image formation. *Murex* does have a cornea that interfaces with salt water (n= 1.33-1.34) at times and air (n = 1) at other times, but because the cornea is so flat is does not have much refractive or dioptric power and does not participate much in image formation.

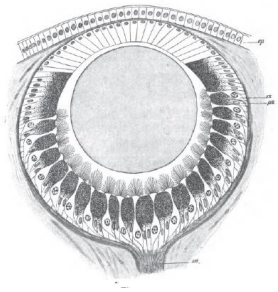




Other molluscs, such as land snail, *Helix*, have an eye like that of *Murex* that captures a lot of light but is also probably not very effective in image formation.



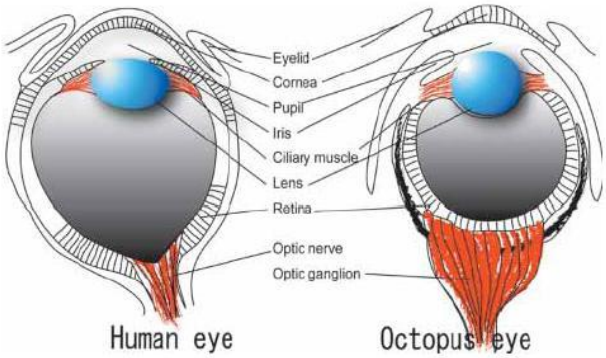
Going back to aquatic animals, some **predatory** animals, such as squid and octopus that live **in the sea** where **light may be limiting** have eyes with the ability to both capture light and to produce a focused image on the retina. A lens that has the ability of **accommodate** mitigates the tradeoff between brightness and visual acuity, although it does introduce aberrations.



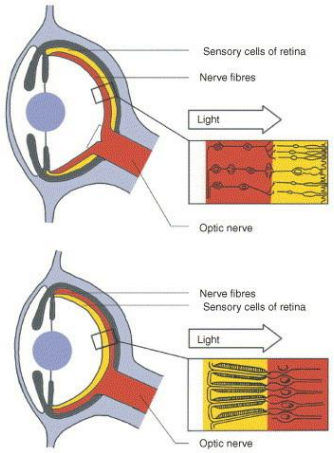



The eye of a **squid** or an **octopus** is similar to the human eye in that it has a **cornea** and a **crystalline lens** to refract light, an **iris** that surrounds a **pupil** that opens in dim light, a **retina** and an **optic nerve**. The visual system is also similar

in that a large part of the **brain** is involved in visual processing. The octopus and squid eyes differ in that the human eye **accommodates** by changing the shape of the **crystalline lens**, becoming more convex when focusing nearby objects whereas the octopus and squid eyes, like a camera, **accommodate** by moving the crystalline lens closer to the object when focusing nearby objects.



There is also a difference in the organization of the **retina** in the human and octopus eye. In the human retina, except at the fovea, the photoreceptor cells are at the far side of the incoming light and the neural cells are on the near side. This by necessity results in a blind spot. In the octopus, the photoreceptor cells are at the near side of the incoming light and the neural cells are on the far side. Consequently, there is no blind spot.



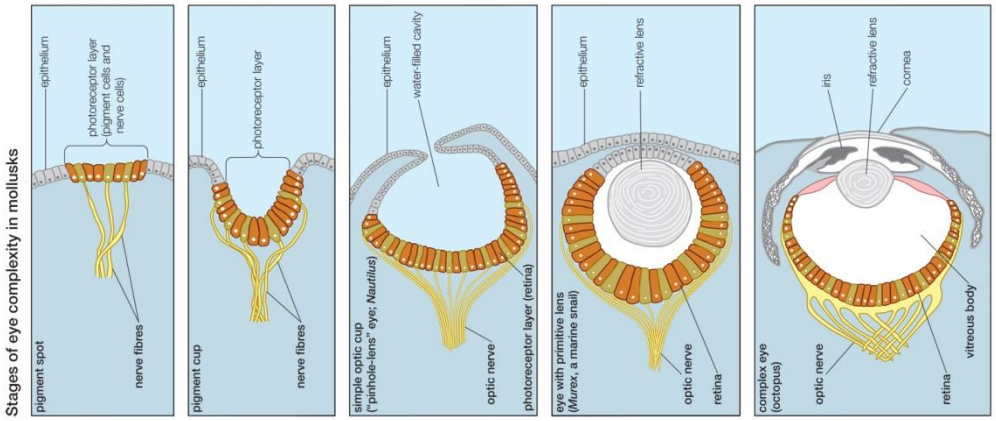
The giant or colossal squid is about 4.2 meters long and lives 1000 meters beneath the sea. The large soccer ball-sized eye, orange-sized lens, and its 8-9 cm in diameter pupil, results in a large light gathering capacity that helps the giant squid see in deep waters. Humans can only see in waters 500-600 meters down. The giant squid eye also has **photophores** that contain **bioluminescent bacteria**

help the giant squid to see in deep waters.

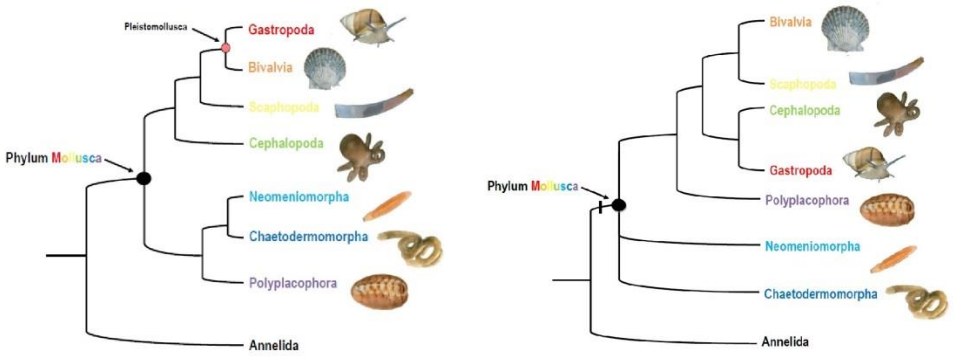
http://squid.tepapa.govt.nz/anatomy/article/the-eye-of-the-colossal-squid



The **levels of complexity** of the molluscan eye from a **light-meter eye**, through a **pinhole camera eye** to a **camera eye** are summarized in the figure below.

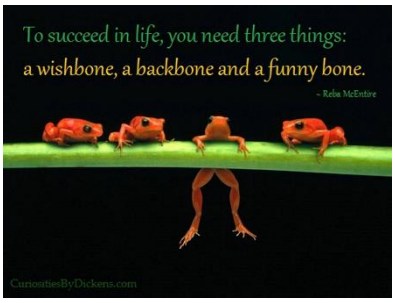


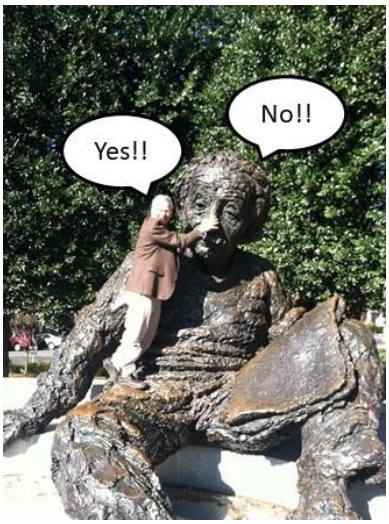
Potential evolutionary relationships between these organisms are given below:



Key

There are many potential synapomorphies (shared derived traits) between the two classes Bivalvia and Gastropoda which likely to have been present in last common ancestor of Gastropoda and Bivalvia. Both gastropods and bivalves have moved back into brackish and freshwater water habitats. The veliger larvae are very similar in gastropods and bivalves and both have larval retractor muscles and a velum muscle ring present (Wanninger & Haszprunar 2002). Both of these two classes have also lost their the anterior ciliary rootlet in locomotory cilia (which is found in most molluscs) (Lundin, Schander & Todt 2008).

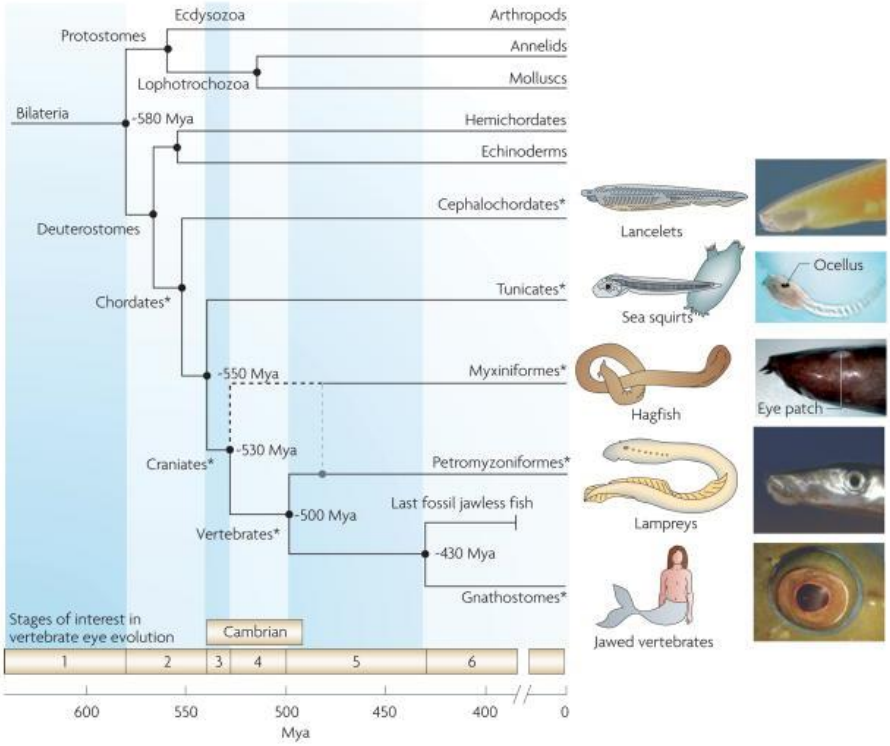




Let's look at the eyes of **chordates**, including hagfish, lampreys and other vertebrates, the ancestors of which existed at the time of the **Cambrian explosion** about 543 million years ago. Chordates are bilaterally symmetrical and possess a notochord, which is a support structure that develops into the backbone in vertebrates. During the Cambrian, diversification does not appear **gradual** as Darwinian theory assumes but **rapid**. A deep insight into the mystery of the Cambrian explosion can be obtained by reading *Darwin's Doubt* by Stephen C. Meyer (2014).

I am considering **time to be real and unidirectional**. This is not a common belief nowadays. To quote an anonymous reviewer of one of my recent papers (2/7/15): "*I'm worried that the author is addressing a non-problem. Even if time's arrow is not real, there still may be local time asymmetries – in the same way as organisms constitute local violations of the law of increasing entropy*."

In *In the Blink of an Eye: How Vision Sparked the Big Bang of Evolution* and *Seven Deadly Colours: The Genius of Nature's Palette and How it Eluded Darwin*, Andrew Parker suggests that the rapid diversification of animals that took place in the Cambrian was a result to the evolution of eyes which led to intense predation and the ability to escape it.



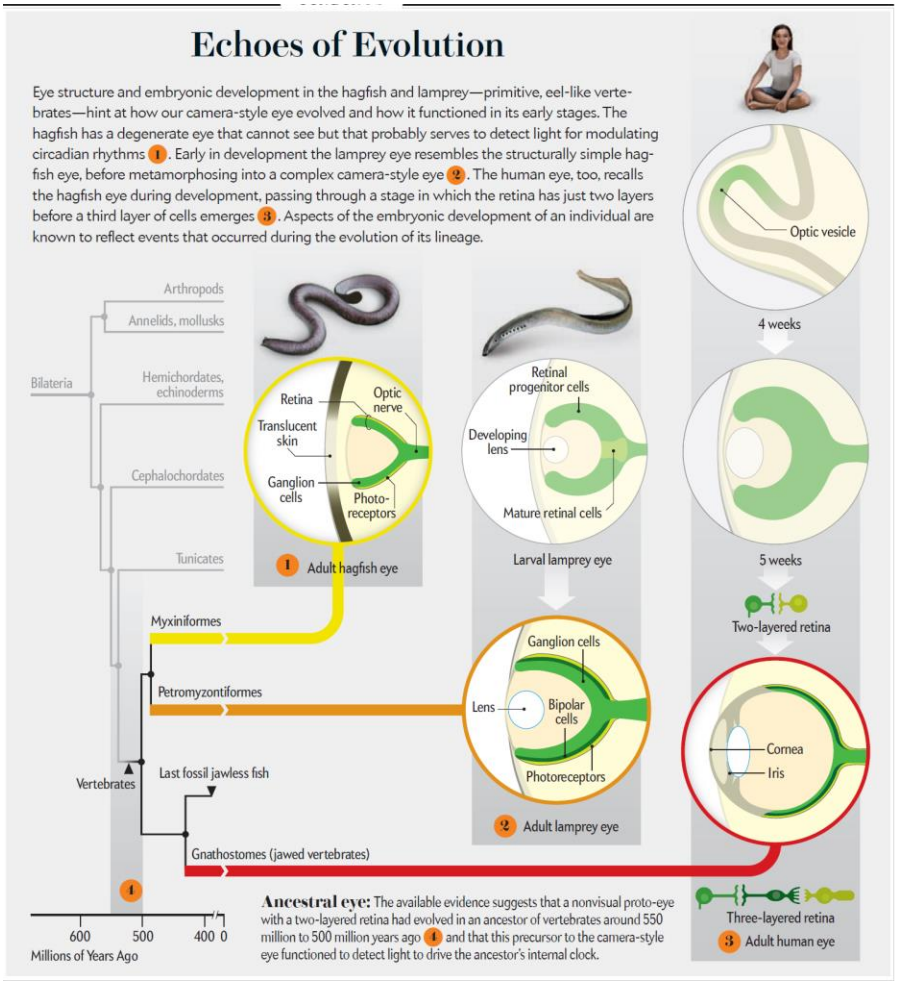


The **hagfish** is a slime secreting, jawless eel-like living fossil that has a notochord but lacks vertebrae. It may be more primitive than lampreys or may have degenerated from lampreys (Lamb et al, 2007). The hagfish eye is **small and buried behind a patch of translucent skin**. It cannot form an image since it lacks a cornea, an iris, a pupil (or pinhole), and a crystalline lens. Moreover, the photoreceptors in the retina do not connect to bipolar cells but

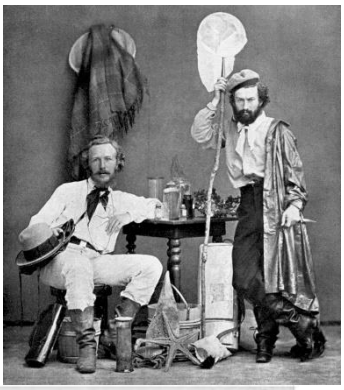
connect directly to ganglion cells, which go the hypothalamus, a part of the brain that is in part involved with circadian rhythms.



The **lamprey** is also an eel-like jawless fish that has a notochord and lacks vertebrae. Unlike the hagfish, the lamprey has large eyes. The **eyes** of the adult lamprey are similar to human eyes, while the eyes of the larvae are reminiscent of the hagfish eye, which is unable to produce an image. **Karl Von Baer** suggested that the **developmental stages through which the embryo passes** might reflect the **evolutionary history** of that organism. Even though natural selection could act on any stage of embryo development, it would be more life-threatening to change an earlier process than to add on a process later in development. Similar embryology may be a reflection of **common descent**.



See the illustration from **Ernst Haeckel**'s (l) (1874) book *Anthropogenie* showing very early, somewhat later, and still later stages of embryos of fish (F), salamander (A), turtle (T), chick (H), pig (S), cow (R), rabbit (K), and human (M)

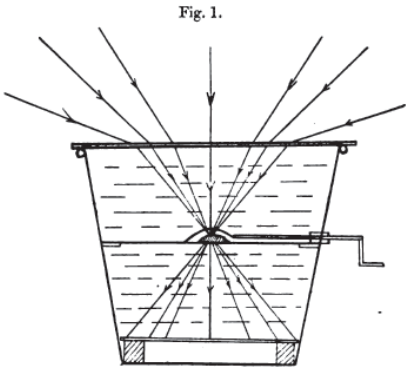






Fish are aquatic vertebrates whose eyes differ from eyes of terrestrial organisms because the **refractive index** of water differs from the refractive index of air. Compared to terrestrial vertebrates, fish lenses are denser and more **spherical**. This is because the refractive index of water is close to the refractive index of the cornea and consequently, the cornea has little refracting or dioptric power and the **crystalline lens provides the majority of the dioptric power of a fish eye**. Unlike human eyes, the crystalline lens in the eyes of fish is typically **spherical** with a **short focal length that focuses near objects on the retina when the muscles are relaxed**. When the inelastic, rigid fish eye **accommodate**s it does ***not*** change shape. The crystalline lens moves toward the retina so that distant objects become focused. The **size of the pupil** of a fish's eye is **fixed**.

James Clerk Maxwell (1854) contemplated the way the world would look to a fish based on the geometry of a fish's very short focal length crystalline lens and Robert Wood (1906) "*interested to ascertain how the external world looks to the fish*, created the first **fisheye camera** by putting a camera underwater (middle figure). He then created a horizontal water camera (figure on right) that "*gives us a good idea of how the visitors at an aquarium look to the fishes*." Lenses that capture rays coming from **ultra wide angles** are known as fisheye lenses.



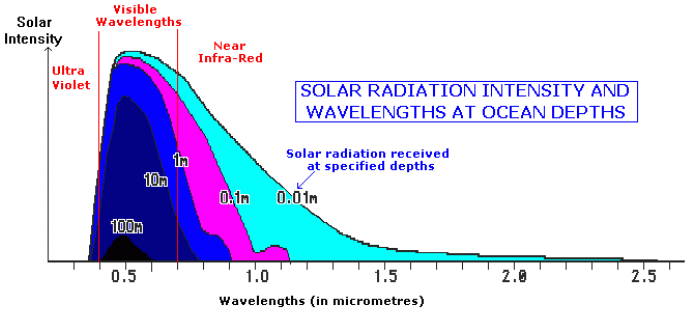


Fish-eye lenses are available for smart phones for less than ten dollars.





Sunlight traveling into water becomes bluer with depth since the longer (redder) wavelengths get **absorbed** by the water. Since water absorbs the redder wavelengths and scatters and reflects the shorter wavelengths, it appears blue. You can test this by throwing M&M's off the side of a boat into water and see which ones disappear first.

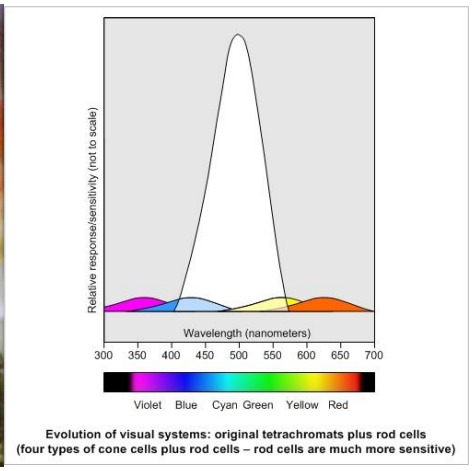


The solar radiation `envelope' penetrates the ocean to 100 metres at visible wavelengths but to much shallower depths as wavelength increases. Back radiation in the far infra-red from the Greenhouse Effect occurs at wavelengths centred around 10 micrometres, well off the scale of this chart, and cannot penetrate the ocean beyond the surface 'skin'.

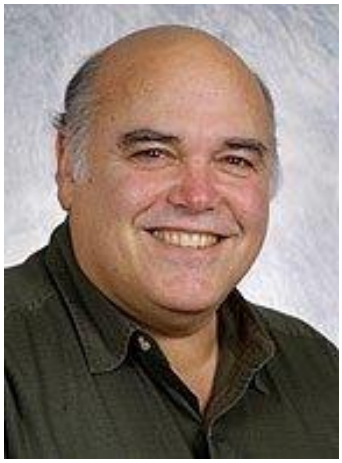


Consequently, while fish living in shallow water have **retinas** with mostly **cones** that give **photopic** color vision, fish living in deeper water have **retinas** with mostly **rods** that give **scotopic** vision. The retinas of fish living in shallow waters are also sensitive to **ultraviolet light**. **Goldfish** are **tetrachromats** with four different types of cones, including ultraviolet, blue, green, and red. Goldfish are able to see colors ranging from infrared through the visible range to the ultraviolet. Ellis Loew (Cornell) studies vision in fish.



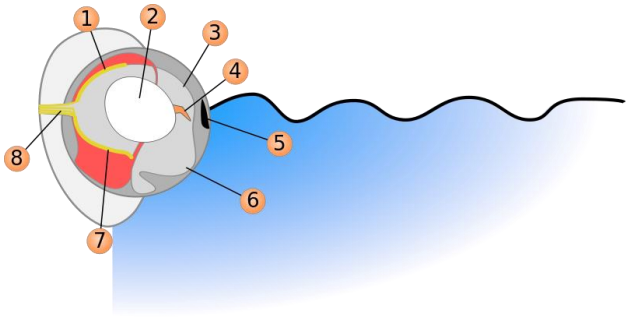


Evolution of visual systems: original tetrachromats plus rod cells
(four types of cone cells plus rod cells – rod cells are much more sensitive)



The **four-eyed fish** (*Anableps)* are visionaries among fish. They have eyes on each side of their head that are divided into two parts that can be used simultaneously. The top part of the eye is good for catching insects in the **air** to eat. The bottom part of the eye is good for looking for predators under **water**. A part of the retina is used for water vision (1) and another part is used for air vision (7). The curvature of the crystalline lens (2) is greater for light coming through the water pupil (6) than it is for the light coming through the air pupil (3) as a result of the need for greater refracting or dioptric power for focusing light rays coming from water (n = 1.333) compared with light rays coming from air (n = 1).

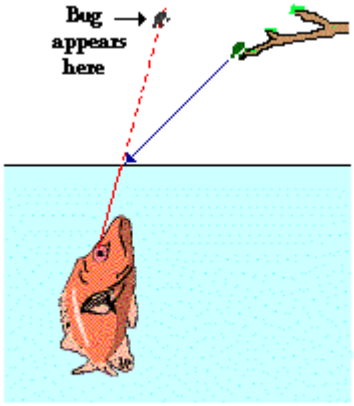




http://www.youtube.com/watch?v=ZPR7aqzvHtA

The **archerfish** (*Toxotes*) are the sharpshooters among fish. They are able to spit at insects up to three meters above the surface of the water and knock them into the water so they can eat them. This means that the archerfish is able to compensate for the bending of light that occurs at the air water interface and is described by the **Snel-Descartes Law**. The archerfish's brain fixes the refraction illusion unlike ours when we see a broken pencil at a water air interface! Unlike the archerfish, we are hard-wired to think that light travels in straight lines!

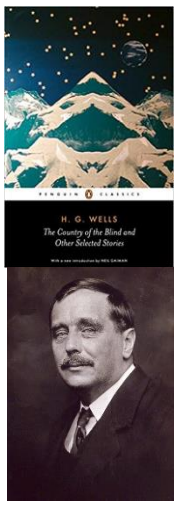




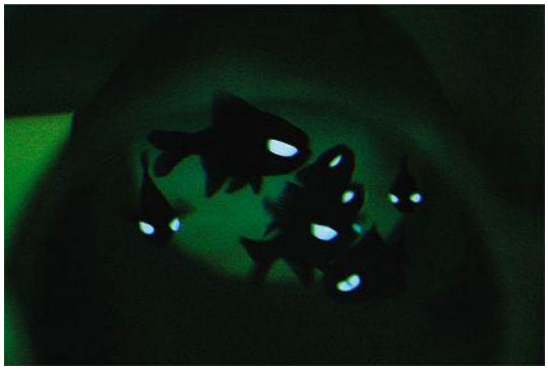


Cave fish (*Amblyopsis*) live in the dark and have no need for eyes. Some are completely blind and some can only detect the difference between light and dark. (Remember, "*In the Country of the Blind, the one-eyed man is king*."—a short story written by **H. G. Wells** in which Nuñez would rather see anywhere else than be king in the country of the blind.) Here is a radio play with Sir Laurence Olivier: https://www.youtube.com/watch?v=2Dy_qldjLJ4) It will remind you of **Plato's Allegory of the Cave**.





The eyes of **flashlight fish** light up as a result of symbiotic **bioluminescent bacteria** that are contained in **photophores** below each eye. The light is produced constantly but the fish flashes the light two to three times a minute by rotating the photophore in the eye socket. We will talk about deep ocean-dwelling fish that make use of bioluminescent bacteria for **camouflage**, communication, and for catching prey later this semester.



Frogs are **amphibians** that begin their life as tadpoles swimming with their **eyes underwater** and then spend most of their life with their **eyes above water**. During the metamorphosis, the **cornea** becomes **smoother** and **rounder** and **eyelids** and **tear ducts**, which keep the cornea clean and moist, form. These features that ***do not*** occur in fish eyes that are surrounded by water. The crystalline lens of frogs, like that of fish is rigid, and accommodation results from the back and forth movement of the lens and not from a change in its shape. During the metamorphosis, the eyes are positioned near the top of the head where they provide the s**tereo vision necessary for catching food** as well as **peripheral vision necessary for seeing predators**.





The red-eyed tree frog (*Agalychnis callidryas*) has a spectacular iris color. Red eyes also occur in albino frogs that lack pigmentation in the iris.





Reptiles, unlike fishes and amphibians have a retina with a **fovea** that allows them to **resolve fine details**. Reptilian eyes accommodate as a result of changing the shape of the crystalline lens. Unlike other animals, the **crystalline lens** of chameleons at rest is a **diverging lens** that reduces the refracting or dioptric power of the eye given by the **converging lens cornea** when a distant object is focused on the retina. Chameleon eyes are mounted on **turrets** on both sides of the head. The two eyes turn independently, allowing chameleons to see in two different directions at once. Diurnal reptiles that are active during the

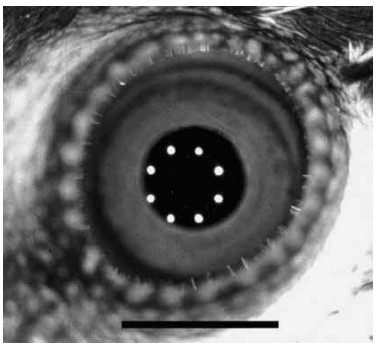
day have **cone-rich retinas** for **photopic color vision**, while nocturnal and burrowing reptiles have **rod-rich retinas** for **scotopic vision**.

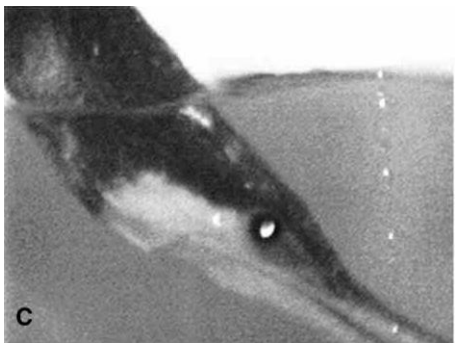


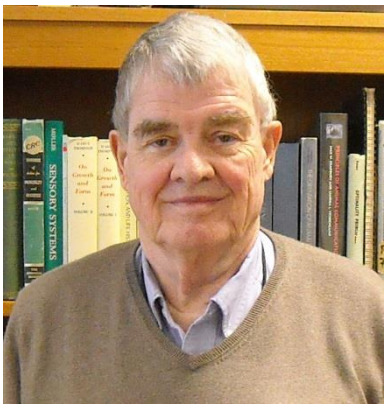
Birds have a variety of eyes that let them see with great acuity. The ostrich has the second largest (2 inches in diameter) eye among animals, second only to the giant squid. While a large eye is useful to a squid for its **light collecting ability** in dimly-lit habitats, the large eye is useful to an ostrich for the **better visual acuity** it provides.



Birds that need good vision when in air, with a refractive index of 1 and water with a refractive index of 1.33-1.34 have the ability to change the curvature of ***both*** their **cornea** and their **crystalline lens** when they **accommodate**. **Cormorants** (*Phalacrocorax carbo sinensis*) and **gannets** (*Morus serrator*) **accommodate** with their **corneas above water** where the refractive index of air is one and **accommodate** with their **crystalline lens** when they are **underwater** (n = 1.33-1.34) and the cornea no longer has much refractive or dioptric power. Howard Howland (Cornell) studies bird eyes.







Diurnal birds have cone-dominated retinas and excellent **photopic color vision** while **nocturnal birds**, such as **owls** have **rod-dominated retinas** and **scotopic vision**. In fact the fovea of owls is also rod-dominated. Owls also have large eyes with good light-capturing ability for hunting at night. They also have a **tapetum lucidum** for reflecting back to the photoreceptor pigments any light that had not been captured on the first pass. The two forward-facing eyes give them good stereo vision. Owls cannot move their eyes in their sockets, but they can see in many directions by turning their neck 270 degrees in either direction.



Raptors are birds of prey that can have a piercing stare are a result of the large eyebrow above their eye that shields the eye from the direct rays of the sun. **Raptors** also have great visual acuity compared with humans. Their greater visual acuity results from **cones** in the **fovea** that are **thinner** and **more numerous** than the cones of humans. In fact, raptors have two highly developed foveas in each retina. When a **bifoveate** raptor initially sees its prey it does not fly directly towards the prey, but spirals towards it, with its head straight relative to the body but at an angle to its prey. The position of the head reduces air resistance and puts the central fovea of one eye (**monocular vision**) in



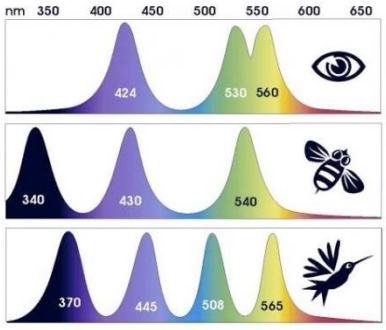


the line of sight. As the raptor approaches its prey, the flight path becomes more direct and the temporal foveas are used in order to enhance the **stereo vision** necessary for precision aim.

Predatory birds, such as the **peregrine falcon**, tend to have large forward facing eyes with a small field of view but **stereo vision** with good depth perception, while **prey species**, such as **pigeons**, have **small**, **flat**, **laterally-placed** eyes that are capable of **surveying a wide area**, but with monocular vision and little or no depth perception.



Birds that pollinate flowers are typically **tetrachromats** and have ultraviolet, blue, green, and red cones. These birds also have carotenoid pigment-containing oil droplets that act like filters in front of the cones, perhaps creating even more types of cones. Some birds may be **pentachromic** as a result of the differential filtering of the oil droplets over the four types of opsin photoreceptors. While the ability to **discriminate colors** may be an advantage, the downside is reduced visual acuity. Do you know why?



The **visual spectrum of diurnal bird pollinators** is enhanced in the **red** compared with the visual spectrum of bees. Consequently, red and orange flower are more likely to be pollinated by birds than by bees. (Some **butterflies** are tetrachromatic and also see in the red). We will talk about flower color and pollinator vision later in the semester.



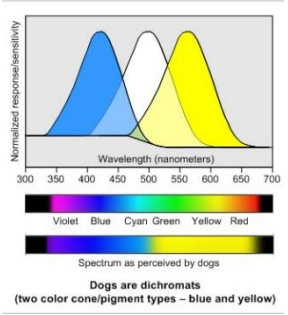
Predatory mammals, including **cheetahs**, **dogs** and **cats** have their camera eyes placed in the front of their head to give **binocular vision** with good **depth perception**. Predatory mammals also have retinas with **foveas** that give good **visual acuity**. **Accommodation** of mammalian eyes results from a change in the shape and a **decrease in the focal length** of the crystalline lens when viewing nearby objects.



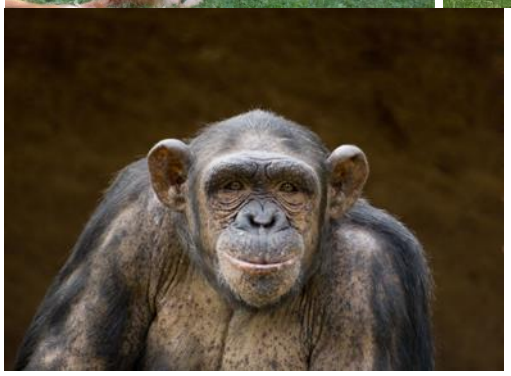
Grazing animals , such as a **horse** or antelope that might serve as a meal for predators, have camera eyes placed on the side of their heads to give a **wide field of view** (350º, 65 º of binocular vision and 285 º of monocular vision) with little depth perception. Horses have little power of accommodation.



Most terrestrial **mammals**, including **dogs**, **cats**, and **bulls** are **dichromats** and have poor color vision. Exceptions include monkeys, apes, and humans, which are all **trichromats**.





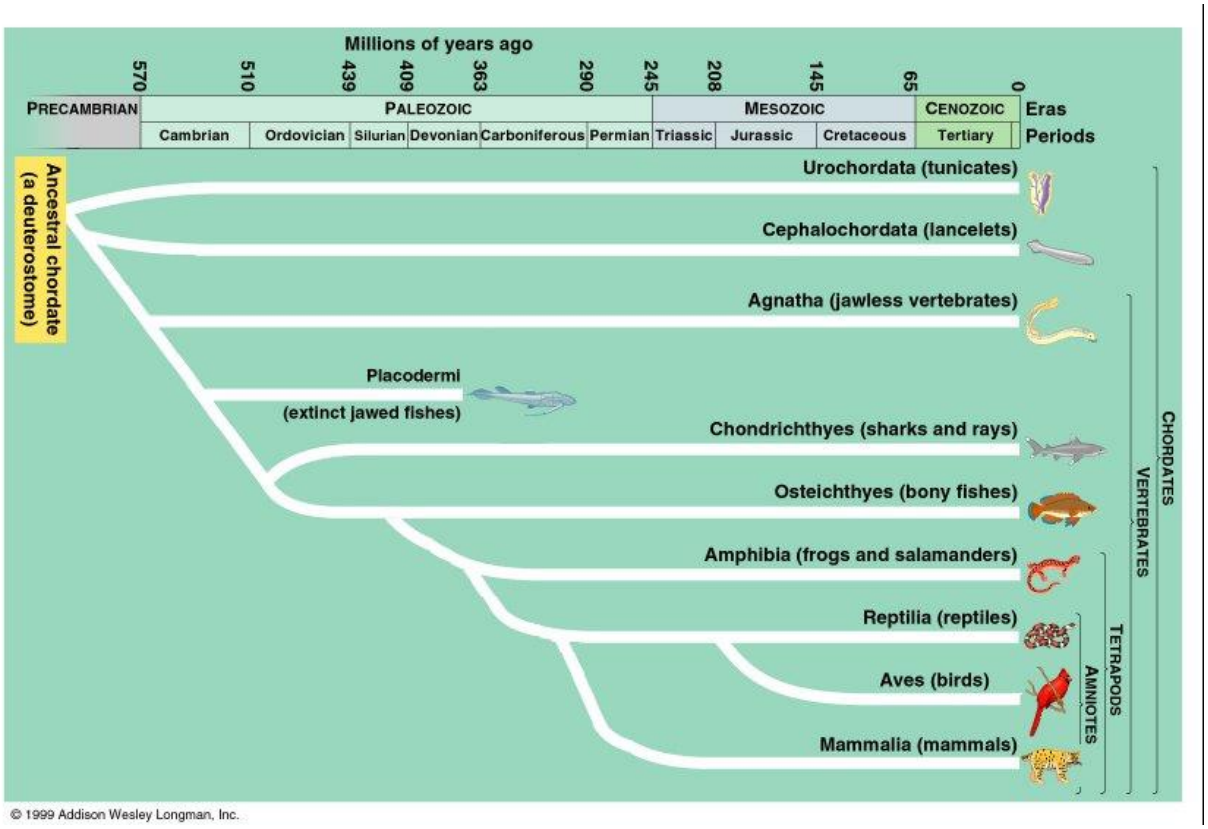


Nocturnal mammals have rod-rich retinas for scotopic vision and a **tapetum lucidum** to help them see in the dark. **Reflection** of light from the **tapetum lucidum** is the cause of **eyeshine** (in dogs, cats, and alligators).

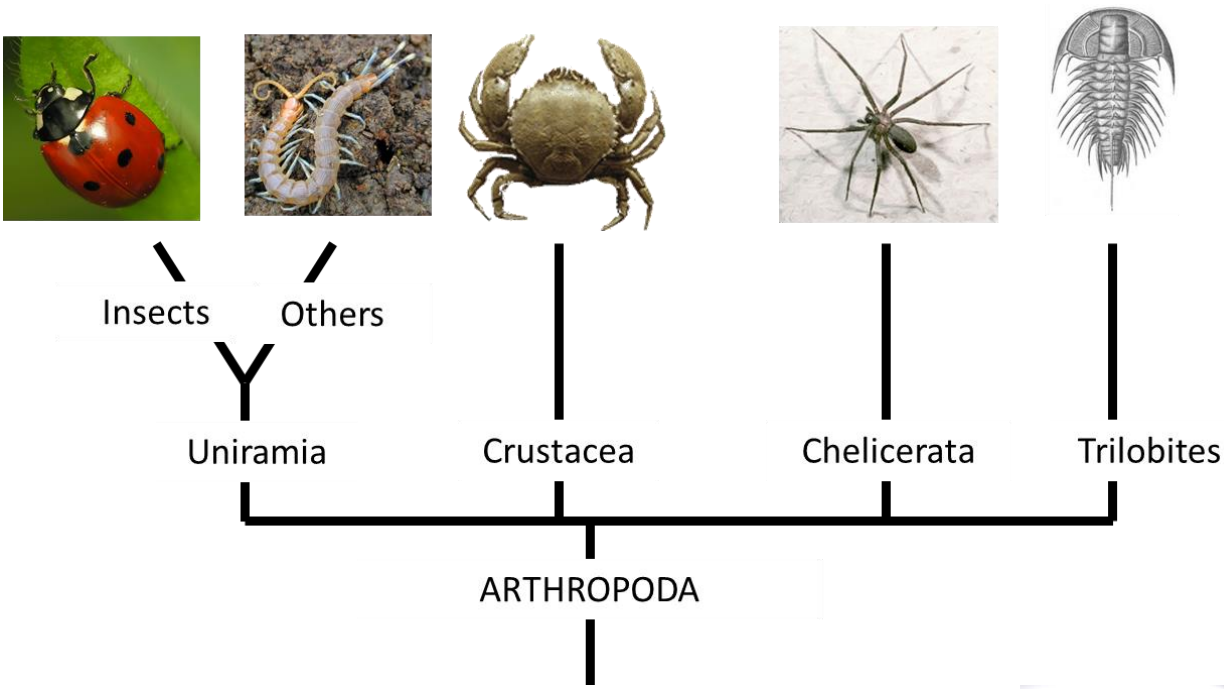




We see the **variation** in the placement of the eyes, the size of the eyes, the proportion of focusing that is due to the cornea and crystalline lens, the mechanism of accommodation, the ability of the pupil to contract and dilate, the ratio of rods (scotopic vision) to cones (photopic color vision) in the retina, and the spectral sensitivity of the cones. We can see that the eyes of fish, amphibians, reptiles, birds, and mammals have evolutionary adaptations and/or designs that **suit the life style of the beholder**. What are the **causes** of the diversity seen in the vertebrate eye?



Before answering that question, let's look at the **eyes** of the **arthropods** , which include the Trilobites, the Arachnids, the Crustaeceans, and the Insects.





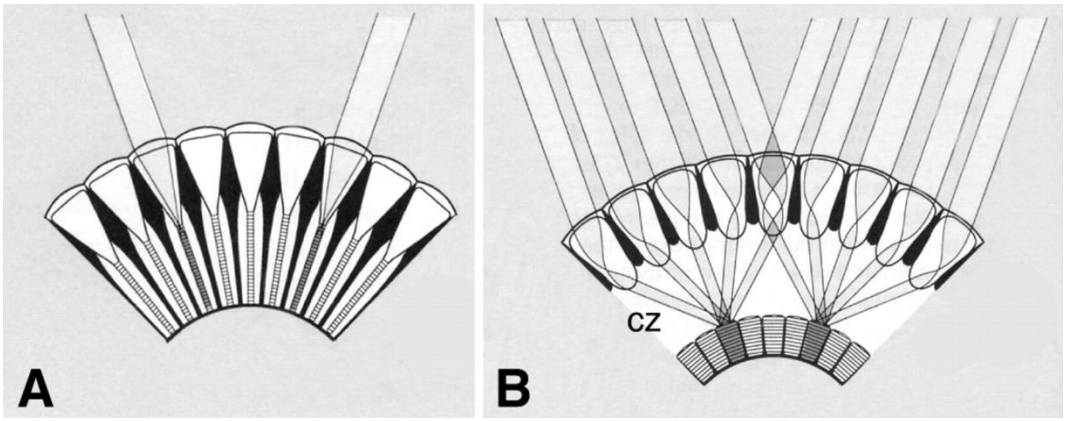
Five hundred and forty million years ago, in the **Cambrian**, the **trilobites** may have been the first animals to see the world. They had **compound eyes** like their relatives, the insects and crustaceans.



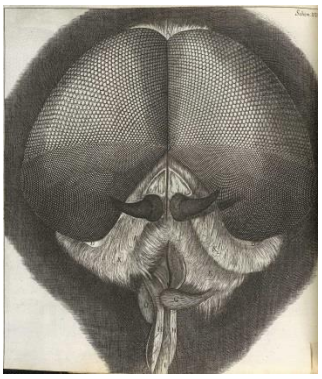
Compound eyes are made out of many units called **ommatidia**. They function to give a **wide field** and **rapid** responses, which is why it is hard to swat a fly. A compound eye typical of **diurnal insects** such as **houseflies**, **dragonflies,** and **butterflies** is of the **apposition type** (A) **where light reaches the photoreceptors exclusively from the small corneal lens located directly above**. Generally speaking, each cornea forms an inverted image of the object, but the photoreceptors at the base of each **ommatidium** measures only the brightness of the small region of space collected by the cornea. The erect image seen by the insect is a mosaic of the individual brightness levels of each field of view.

Nocturnal insects such as **cockroaches** and **moths** that live in limiting light conditions have a **superposition type** (B) of compound eye. The sensitivity to light is increased by having hundreds to thousands of corneal facets that collect and focus the light towards single photoreceptors in the retina.





Robert Hooke (1665) published his observation of the compound eyes of a grey drone fly and the eyes of other insects in his ***Micrographia***. We will see the *Micrographia* when we go to Kroch Library later this semester.



Demonstration: Observe a house fly's apposition type compound eye under the dissecting microscope.



Crustaceans, such as **lobsters**, shrimp, and crayfish also have **superposition type compound eyes**. However, in their case, the light is directed down the **ommatidium** according to the **law of reflection**, not the law of refraction.

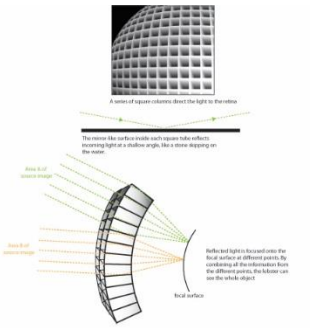
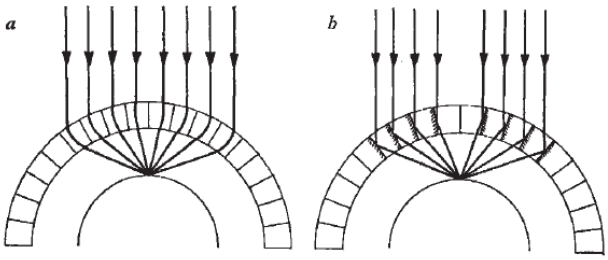
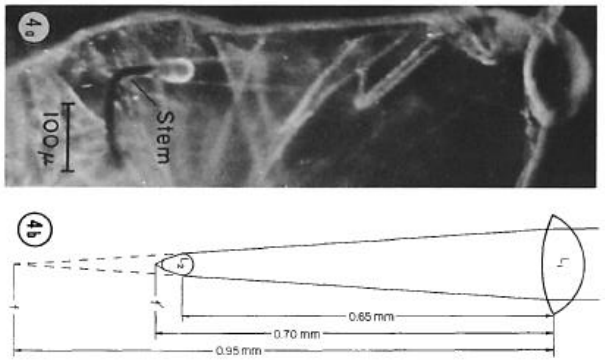


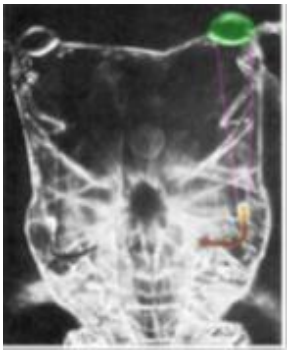
Fig. 1 Superposition image formation (*a*) by refraction (modified from Exner) and (*b*) by reflection.



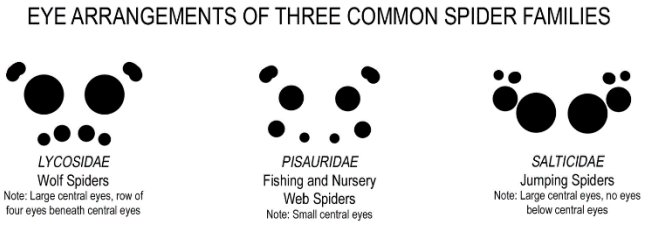


Some **copepods**, which are also crustaceans, can have eyes that can only be described as **telescopes**!



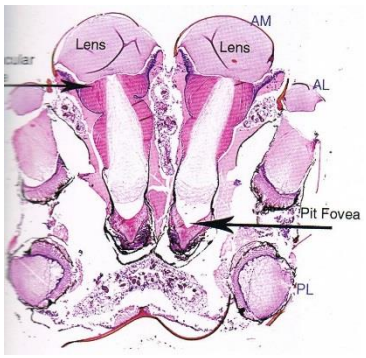


Spiders are **arthropods** that typically have eight simple eyes. Some of the eyes look forward, the rest scan the peripheries. As in other land animals, the



cornea is the main refracting system in spider eyes and the optical system is reminiscent of a **refracting telescope**.





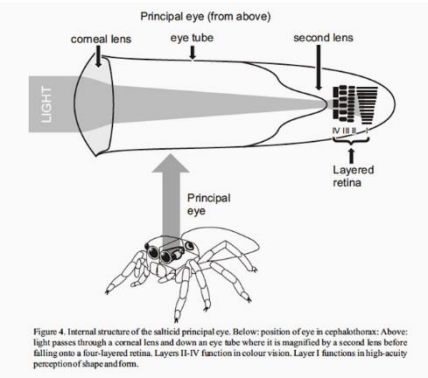


Figure 4. Internal structure of the salticid principal eye. Below: position of eye in cephalothorax: Above: light passes through a corneal lens and down an eye tube where it is magnified by a second lens before falling onto a four-layered retina. Layers II-IV function in colour vision. Layer I functions in high-acuity perception of shape and form.

The **jumping spider** (*Portia fimbriata*), which can jump twenty body lengths, and the **ogre-faced net-casting** spider (*Dinopis subrufa*) have very high resolution eyes with a limiting resolution only 2.4 arc minutes that allows them to hunt and successfully capture their prey. Some spiders are diurnal and others are nocturnal hunters. https://www.youtube.com/watch?v=Wt4LpZa3iFs





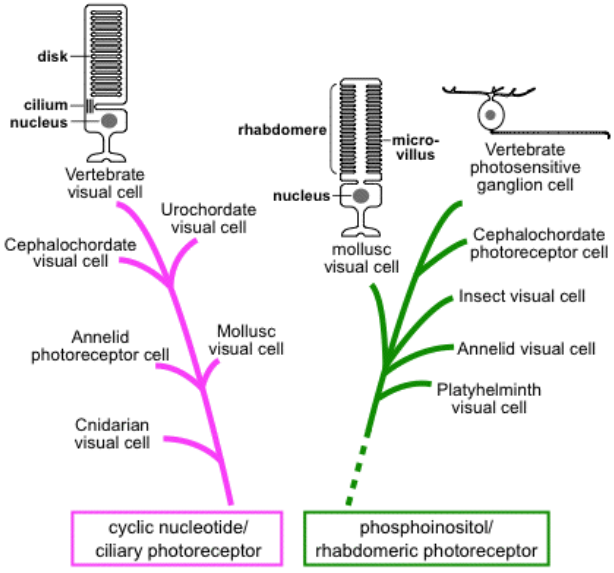
Nocturnal spiders have relatively large eyes and well developed tapeta to allow them to hunt at dusk and in moonlight. Here is a picture of eyeshine from a **wolf spider**.



Web-spinning spiders whose food comes to them, have eyes with low resolving power.



There is diversity in the type of cells that act as photoreceptors in animals. In the vertebrate line, the rods and cones are modified **cilia**. In all other animals, the photoreceptor cells can be either modified cilia or modified **microvilli**. Later in the semester we will talk about **melanopsin**, a pigment that is in the human eye that does not participate in image formation, but in sensing the light-dark cycle involved in out sleep-wake cycle. While the rod (**rhodopsin**) and cone (**photopsin**) pigments in humans are found in **ciliary**-like cells, the **melanopsin** is found in **microvilli**-like cells.

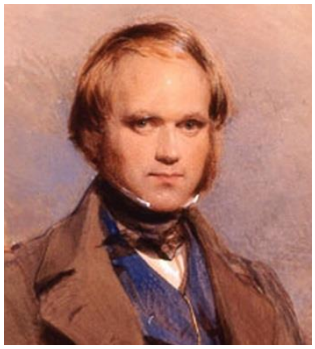


As we see there is a great diversity in eyes in the animal world and each form is suited to the life style of the beholder. Optically speaking, there are as many ways that animal eyes use light to form images as there are optical instruments. Animals use **pinholes**, **converging** and **diverging lenses**, and **mirrors** to produce images of the external world. We have discussed the eyes of diurnal and nocturnal animals as well as the eyes of aquatic and terrestrial animals and the design constraints. Amazed by the design of eyes, **William Paley**



(1802) wrote in ***Natural Theology***, "*every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature, of being greater and more, and that in a degree which exceeds all computation. I mean that the contrivances of nature surpass the contrivances of art, in the complexity, subtility, and curiosity of the mechanism; and still more, if possible, do they go beyond them in number and variety; yet, in a multitude of cases, are not less evidently mechanical, not less evidently contrivances, not less evidently accommodated to their end, or suited to their office, than are the most perfect productions of human ingenuity.*

I know no better method of introducing so large a subject, than that of comparing a single thing with a single thing; an eye, for example, with a telescope. As far as the examination of the instrument goes, there is precisely the same proof that the eye was made for vision, as there is that the telescope was made for assisting it. They are made upon the same principles; both being adjusted to the laws by which the transmission and refraction of rays of light are regulated. I speak not of the origin of the laws themselves; but such laws being fixed, the construction, in both cases, is adapted to them. For instance; these laws require, in order to produce the same effect, that the rays of light, in passing from water into the eye, should be refracted by a more convex surface, than when it passes out of air into the eye. Accordingly we find that the eye of a fish, in that part of it called the crystalline lens, is much rounder than the eye of terrestrial animals. What plainer manifestation of design can there be than this difference? What could a mathematical-instrument-maker have done more, to show his knowledge of his principle, his application of that knowledge, his suiting of his means to his end; I will not say to display the compass or excellence of his skill and art, for in these all comparison is indecorous, but to testify counsel, choice, consideration, purpose?"



Charles Darwin (1859) in *The Origin of Species* proposed that the eye did not need a creator, but evolved by natural selection. "*To suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree.* ***Yet reason tells me, that if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; if further, the eye does vary ever so slightly, and the variations be inherited, which is certainly the case; and if any variation or modification in the organ be ever useful to an animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, can hardly be considered real.*** *How a nerve comes to be sensitive to light, hardly concerns us more than how life itself first originated; but I may remark that several facts make me suspect that any sensitive nerve may be rendered sensitive to light, and likewise to those coarser vibrations of the air which produce sound.*

In looking for the gradations by which an organ in any species has been perfected, ***we ought to look exclusively to its lineal ancestors****; but this is scarcely ever possible, and* ***we are forced in each case to look to species of the same group, that is to the collateral descendants from the same original parent-form, in order to see what gradations are possible, and for the chance of some gradations having been transmitted from the earlier stages of descent, in an unaltered or little altered condition****. Amongst existing Vertebrata, we find but a small amount of gradation in the structure of the eye, and from fossil species we*

can learn nothing on this head. In this great class we should probably have to descend far beneath the lowest known fossiliferous stratum to discover the earlier stages, by which the eye has been perfected.

In the Articulata we can commence a series with ***an optic nerve merely coated with pigment****, and without any other mechanism; and from this low stage, numerous gradations of structure, branching off in two fundamentally different lines, can be shown to exist, until we reach a moderately high stage of perfection. In certain crustaceans, for instance, there is a double cornea, the inner one divided into facets, within each of which there is a lens-shaped swelling. In other crustaceans the transparent cones which are coated by pigment, and which properly act only by excluding lateral pencils of light, are convex at their upper ends and must act by convergence; and at their lower ends there seems to be an imperfect vitreous substance. With these facts, here far too briefly and imperfectly given, which show that t****here is much graduated diversity in the eyes of living crustaceans****, and bearing in mind how small the number of living animals is in proportion to those which have become extinct, I can see no very great difficulty (not more than in the case of many other structures) in believing that natural selection has converted the simple apparatus of an optic nerve merely coated with pigment and invested by transparent membrane, into an optical instrument as perfect as is possessed by any member of the great Articulate class.*

He who will go thus far, if he find on finishing this treatise that large bodies of facts, otherwise inexplicable, can be explained by the theory of descent, ought not to hesitate to go further, and to admit that a structure even as perfect as the eye of an eagle might be formed by natural selection, although in this case he does not know any of the transitional grades. His reason ought to conquer his imagination;

though I have felt the difficulty far too keenly to be surprised at any degree of hesitation in extending the principle of natural selection to such startling lengths.

It is scarcely possible to avoid comparing the eye to a telescope. We know that this instrument has been perfected by the long-continued efforts of the highest human intellects; and we naturally infer that the eye has been formed by a somewhat analogous process. But may not this inference be presumptuous? Have we any right to assume that the Creator works by intellectual powers like those of man? If we must compare the eye to an optical instrument, we ought in imagination to take a thick layer of transparent tissue, with a nerve sensitive to light beneath, and then suppose every part of this layer to be continually changing slowly in density, so as to separate into layers of different densities and thicknesses, placed at different distances from each other, and with the surfaces of each layer slowly changing in form. Further we must suppose that there is a power always intently watching each slight accidental alteration in the transparent layers; and carefully selecting each alteration which, under varied circumstances, may in any way, or in any degree, tend to produce a distincter image. ***We must suppose each new state of the instrument to be multiplied by the million; and each to be preserved till a better be produced, and then the old ones to be destroyed. In living bodies, variation will cause the slight alterations, generation will multiply them almost infinitely, and natural selection will pick out with unerring skill each improvement. Let this process go on for millions on millions of years; and during each year on millions of individuals of many kinds; and may we not believe that a living optical instrument might thus be formed as superior to one of glass, as the works of the Creator are to those of man?***

If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my

theory would absolutely break down. But I can find out no such case. No doubt many organs exist of which we do not know the transitional grades, more especially if we look to much-isolated species, round which, according to my theory, there has been much extinction. Or again, if we look to an organ common to all the members of a large class, for in this latter case the organ must have been first formed at an extremely remote period, since which all the many members of the class have been developed; and in order to discover the early transitional grades through which the organ has passed, we should have to look to very ancient ancestral forms, long since become extinct."

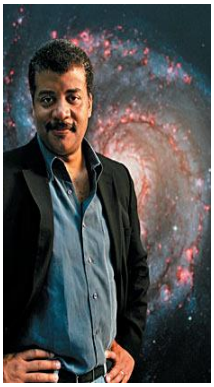


In the *Blind Watchmaker*, Richard Dawkins (1986) discounted Paley and supported Darwin, "*Paley's argument is made with passionate sincerity and is informed by the best biological scholarship of his day, but it is wrong, gloriously and utterly wrong. The analogy between telescope and eye, between watch and living organism, is false. All appearances to the contrary, the only watchmaker in nature is the blind forces of physics, albeit deployed in a very special way. A true watchmaker has* ***foresight****: he designs his cogs and springs, and plans their interconnections, with a future purpose in his* ***mind's eye****. Natural selection, the blind, unconscious, automatic process which Darwin discovered, and which we now know is the explanation for the existence and apparently purposeful form of all life, has no purpose in mind. It has no mind and* ***no mind's eye****. It does not plan for the future. It has* ***no vision****,* ***no foresight****,* ***no sight at all****. If it can be said to play the role of the watchmaker in nature, it is the* ***blind*** *watchmaker."* Dawkins wrote in the *New York Times* (April 9, 1989), "*It is absolutely safe to say that if you meet somebody who claims not to believe in evolution, that person is ignorant, stupid or insane (or wicked, but I'd rather not*

consider that)." Richard Dawkins demonstrates the evolution of the eye in this short video: http://www.youtube.com/watch?v=Nwew5gHoh3E

How will technology be involved in the evolution of the eye? Go to this website http://www.space-between.org/ and ask David Brewer, Senior Extension Associate at the K. Lisa Yang and Hock E. Tan Institute on Employment and Disability ILR School, 201 Dolgen Hall Cornell University.

Today, scientists are emphasizing the ***un-intelligent design*** of the eye as evidence for evolution by natural selection. Neil deGrasse Tyson (2009) wrote in *The Perimeter of Ignorance*, "*The eye is often held up as a marvel of biological engineering. To the astrophysicist, though, **it's only a soso detector**. A better one would be much more sensitive to dark things in the sky, and to all the invisible parts of the spectrum. How much more breathtaking sunsets would be if we could see ultraviolet and infrared. How useful it would be if, at a glance, we could see every source of microwaves' in the environment, or know which radio station transmitters were active. How helpful it would be if we could spot police radar detectors at night.*



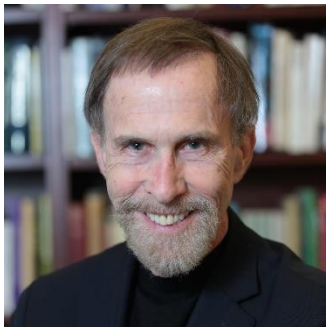
To deny or erase the rich, colorful **history** *of scientists and other thinkers who have invoked divinity in their work would be intellectually dishonest. Surely there's an appropriate place for intelligent design to live in the academic landscape. How about the* **history** *of religion? How about philosophy or psychology? The one place it doesn't belong is the science classroom."*

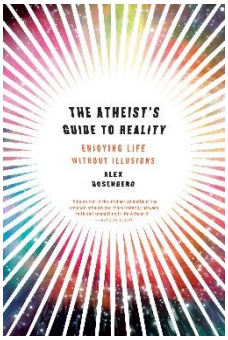
Trevor Lamb (2011) wrote in *The Evolution of the Eye*, "*For all the ingenious features evolution built into the vertebrate eye, there are a number of decidedly inelegant traits. For instance, the retina is inside out, so light has to pass through the whole thickness of the retina—through the intervening nerve fibers and cell bodies that scatter the light and degrade image quality—before reaching the light-sensitive photoreceptors. Blood vessels also line the inner surface of the retina, casting unwanted shadows onto the photoreceptor layer. The retina has a blind spot where the nerve fibers that run across its surface congregate before tunneling out through the retina to emerge behind it as the optic nerve. The list goes on and on.*



These defects are by no means inevitable features of a camera-style eye because octopuses and squid independently evolved camera-style eyes that do not suffer these deficiencies. Indeed, if engineers were to build an eye with the flaws of our own, they would probably be fired. ***Considering the vertebrate eye in an evolutionary framework reveals these seemingly absurd shortcomings as consequences of an ancient sequence of steps, each of which provided benefit to our long-ago vertebrate ancestors even before they could see. The design of our eye is not intelligent—but it makes perfect sense when viewed in the bright light of evolution****.*

Alex Rosenberg (2011) states in *The Atheist's Guide to Reality Enjoying Life Without Illusions*, that our sense of vision is so bad, as evidenced by our being deceived by **optical illusions** that you should "*Never Let Your Conscious Be Your Guide*." *He*





writes, "Ultimately, science and scientism are going to make us give up as illusionary the very thing conscious experience screams out at us loudest and longest: the notion that when we think, our thoughts are about anything at all, *inside or outside of our minds…Thinking about things is an overwhelmingly powerful illusion. Once we learn how this profound illusion is produced, we'll understand why it's hard to cast the illusions of consciousness aside for the real answers to the relentless questions about the self, mind, soul, free will, and the meaning of life*."

Here are some of Alex Rosenberg's answers to the relentless questions:
Is there a God? No.
What is the nature of reality? What physics says it is.
What is the purpose of the universe? There is none.
What is the meaning of life? Ditto.
Why am I here? Just dumb luck.
Does prayer work? Of course not.
Is there a soul? Is it immortal? Are you Kidding?
What is the difference between right and wrong, good and evil? There is no moral difference between them.

"*If you still can't sleep at night, even after accepting science's answers to the persistent questions, you probably just need one more little thing besides Epicurean detachment. Take a Prozac or your favorite serotonin reuptake inhibitor, and keep taking them till they kick in*."



More recently, Brian Ford (2013) wrote in *Debunking the Myth of Intelligent Design*, "*The structure of the eye is widely cited as an example of intelligent design because, say the proponents, until an eye has been fully formed it simply cannot function. Thus, evolution vaguely in the direction of a fully developed eye could not have taken place unless there were a designer at work, who envisaged what the final result might be. This does not stand scrutiny. First, there are eyes of every type in differing animals. Some are simple (like those of spiders) whereas others are complex (like those of flies). Some eyes (including ours) have lenses, whereas others, like those of a squid* [sic], *work wonderfully with no lens at all. Any designer, having worked out a perfect organ of sight, would install it in everything that needed an eye. Running countless different types of eyes in parallel is the height of inefficiency.*

It is the mammalian eye that provides unambiguous evidence. No designer could have made such a curious mistake than in contriving our eyes, They're assembled backwards, and afflict us all with inferior vision…. This all reveals to us that humans were not designed by some supreme being. As a product of design we are excruciating inefficient, metabolically muddled, functionally futile and conceptually confused. ***It would take a designer of unimaginable and perverse stupidity to make so many obvious mistakes. God is portrayed in many ways by world religions, but not one of them insists that their deity is an idiot….So we can see that the design of humans is idiotic and riddled with problems that make people suffer****. If you wish to seek intelligence in the way living systems work, then there is no point in seeking inspiration from God."*

What do ***you think***? Natural selection? Godly design?

The motto of the Royal Society of London is ***Nullius in Verba***, which roughly translates as "*take no one's word for it.*" The motto expresses the Society's belief in the importance of **seeing for one's self** and **not bowing to external authority**.



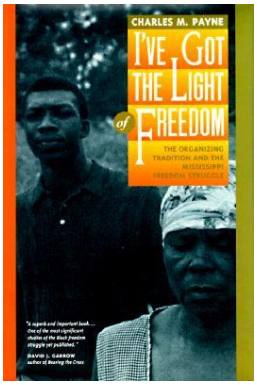


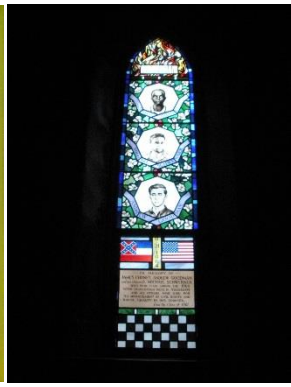
The Royal Society's motto 'Nullius in verba' roughly translates as 'take nobody's word for it'. It is an expression of the determination of Fellows to withstand the domination of authority and to verify all statements by an appeal to facts determined by experiment.



What are our eyes for? Jacob Helen Campbell (1892), author of *Darkness and Daylight*, and Jacob Riis (1890,1902,1903), author of *How the Other Half Lives* and *The Battle with the Slum*, used their eyes to see injustice. http://www.authentichistory.com/1898-1913/2-progressivism/2-riis/index.html They shared their sight with us by way of flashlight-lit photographic images that showed the **dark side** of affluent society. **Marilyn Van Derbur** told the story of being an incest survivor in *Darkness to Light* (https://www.youtube.com/watch?v=ALEfE3rNCqI). Likewise, people in the civil rights movement illuminated what was wrong with America with the light of freedom, and made it better. Hear Fannie Lou Hamer sing *This*







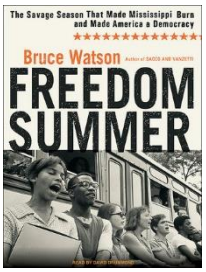
Little Light of Mine:

https://www.youtube.com/watch?v=zAjSlf3BDP8

and see a short documentary about her entitled,

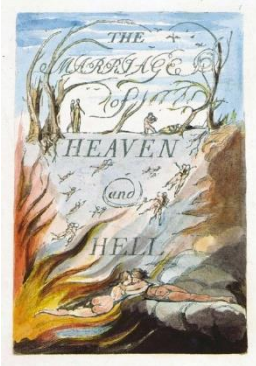
This Little Light of Mine:

https://www.youtube.com/watch?v=ZlTvXzxloCs





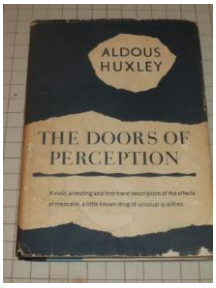
What do we learn about being human from studying eyes and vision?



William Blake (ca. 1790) wrote in *The Marriage of Heaven and Hell*:

"*If the **doors of perception** were cleansed everything would appear to man as it is, infinite.*

For man has closed himself up. Till he sees all things thro' narrow chinks of his cavern."



Remind you of **Plato's Allegory of the Cave**?

Aside: Aldous Huxley (1954) used *The Doors of Perception* as a title for a book about his experiences with mescaline.



Viktor Frankl (1955) wrote in *The Doctor and the Soul*:

"*If we present man with a concept of man which is not true, we may well corrupt him. When we present him as an automation of reflexes, as a mind-machine, as a bundle of instincts, as a pawn of drives and reactions, as a mere product of instincts, heredity, and environment, we feed the despair to which man is, in any case, already prone. I became acquainted with the last stages of corruption in my second concentration camp in Auschwitz. The gas chambers of Auschwitz were the ultimate consequence of the theory that man is nothing but the product of heredity and environment—or, as the Nazis liked to say, of 'Blood and Soil.' I am absolutely convinced that the*

gas chambers of Auschwitz, Treblinka, and Maidanek were ultimately prepared not in some Ministry or other in Berlin, but rather at the desks and in the lecture halls of nihilistic scientists and philosophers."

http://www.ted.com/talks/viktor_frankl_youth_in_search_of_meaning



Blowin in the Wind

by Bob Dylan (1962)

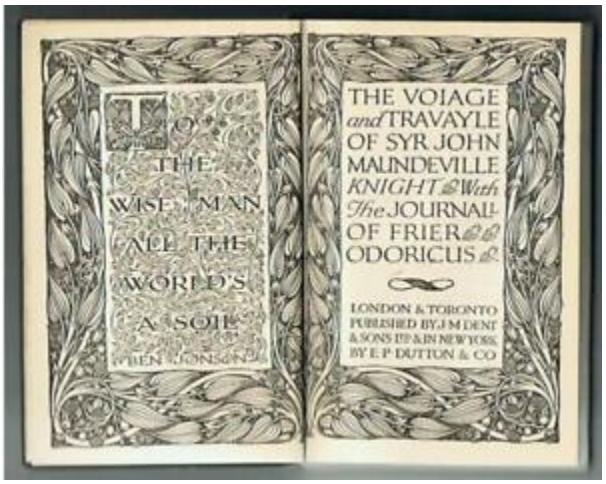
How many roads must a man walk down
Before you call him a man?
Yes, 'n' how many seas must a white dove sail
Before she sleeps in the sand?
Yes, 'n' how many times must the cannonballs fly
Before they're forever banned?
The answer, my friend, is blowin' in the wind
The answer is blowin' in the wind

How many years can a mountain exist
Before it's washed to the sea?
Yes, 'n' how many years can some people exist
Before they're allowed to be free?
Yes, 'n' how many times can a man turn his head
Pretending he just doesn't see?
The answer, my friend, is blowin' in the wind
The answer is blowin' in the wind

How many times must a man look up
Before he can see the sky?
Yes, 'n' how many ears must one man have
Before he can hear people cry?
Yes, 'n' how many deaths will it take till he knows
That too many people have died?
The answer, my friend, is blowin' in the wind
The answer is blowin' in the wind

Bob Dylan won the 2016 Nobel Prize in Literature:
https://www.nobelprize.org/nobel_prizes/literature/laureates/2016/dylan-speech.html

https://www.nobelprize.org/nobel_prizes/literature/laureates/2016/dylan-lecture.html



What about crocodile tears? In a book written around 1400 and entitled *The Voyage and Travel of Sir John Mandeville,* a description is given of the tears shed by crocodiles as they consume their prey. "*In that country and by all Ind be great plenty of cockodrills, that is a manner of a long serpent, as I have said before. And in the night they dwell in the water, and on the day upon the land, in rocks and in caves. And they eat no meat in all the winter, but they lie as in a dream, as do the serpents. These serpents slay men, and they eat them weeping; and when they eat they move the over jaw, and not the nether jaw, and they have no tongue*."

The idea that crocodiles shed tears while they eat their prey gave rise to the idea of "crocodile tears"—tears that are shed without remorse or sympathy.

George Johnson (1927) studied crocodiles but found that crocodile tears were a myth. He wrote:

"I *made the experiment of squeezing the juice of an onion mixed with common salt into the eyes of four species in order to ascertain whether this irritating solution would excite any flow of tears, but it had no effect in increasing the moisture beyond the slight normal secretion. To my mind this is conclusive that the popular notion of Crocodiles shedding tears is entirely a myth*."



Figure 1. Bubbles in the eyes of "Bomber," a 4.1-meter-long male American alligator. Bubbles formed as researchers approached the alligator with food. The photo was taken 2.75 minutes after the first feeding in the trial. Photograph: Kent A. Vliet.

However, Malcolm Shaner and Kent Vliet (2007) took movies of alligators eating and showed that

they do cry when they eat—perhaps because their tear ducts are activated serendipitously by the eating processes.

Fish Eye Lens



Charles Darwin, Samuel Wilberforce and How We See the Color of Ants

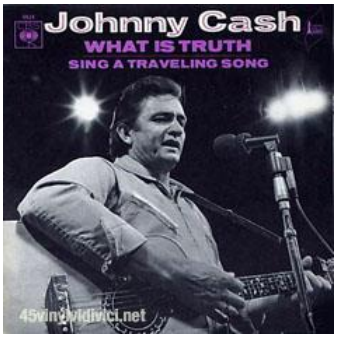
"We are not afraid to entrust the American people with unpleasant facts, foreign ideas, alien philosophies, and competitive values. For a nation that is afraid to let its people judge the truth and falsehood in an open market is a nation that is afraid of its people."



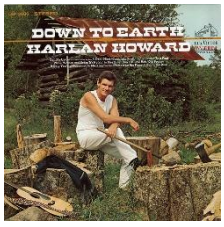
From "Remarks on the 20th Anniversary of the Voice of America," John F. Kennedy (2/26/62) http://www.jfklibrary.org/Asset-Viewer/Archives/JFKWHA-075-005.aspx

Likewise, in our personal struggle to keep what is good, bring in what is better, remove the bad, and keep out the worst, we should not be afraid to entrust students, including science students, with unpleasant facts, foreign ideas, alien philosophies, and competitive values in their own personal **search for truth**. After all, while I believe that truth exists, and that the truth will set you free (John 8:32), I also believe that none of us (including me) has a monopoly on the truth. Pilate asked (John 18:38) "'*What is truth?*'" More recently, Johnny Cash asked *What is Truth* and sang (https://www.youtube.com/watch?v=qO5z2xUNUpU; https://www.youtube.com/watch?v=pjBrbZ52544)





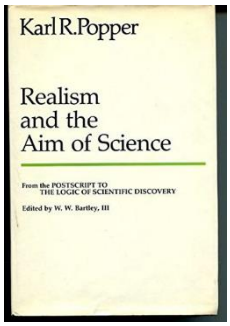
You better help the voice of youth find
"What is truth"
And the lonely voice of youth cries
"What is truth?"



According to Harlan Howard, "*Country music is three chords and the truth*."

In *A Few Good Men* Tom Cruise said "*I want the truth*." https://www.youtube.com/watch?v=9FnO3igOkOk We should all ask, in everything we study and do, *What is truth*?



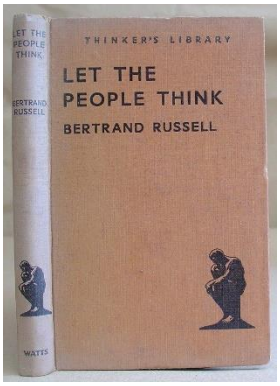


Karl Popper (1983), in *Realism and the Aim of Science*, considers the central problem in the philosophy of knowledge to be: "*How can we adjudicate or evaluate the far-reaching claims of competing theories and beliefs?*" Popper goes on to say, "*This problem has led, historically, to a second problem: How can we* justify *our theories or beliefs? And this second problem is, in turn, bound up with a number of other questions: What does a justification consist of? And, more especially: Is it possible to justify our theories or beliefs* **rationally***: that is to say, by giving reasons—'positive reasons' (as I shall call them), such as an appeal to observation; reasons, that is, for holding them to be true, or to be at least 'probable' (in the sense of the probability calculus)?*" Popper then introduces a third problem to consider. "*This third problem is the problem of whether one theory is* **preferable** *to another—and, if so, why. (I am speaking of a theory's being preferable in the sense that we think or conjecture that it is* **a closer approximation to the truth**, *and that we may even have reasons to think or to conjecture that it is so*.)"



On March 14, 2017, Professors Robert George, a conservative, and Cornel West, a radical, wrote, "[t]*he pursuit of knowledge and the maintenance of a free and democratic society require the cultivation and practice of* ***the virtues of intellectual humility, openness of mind, and, above all, love of truth…****Our willingness to listen to and respectfully engage those with whom we disagree (especially about matters of profound importance)*

*contributes vitally to the maintenance of a milieu in which people feel free to speak their minds, consider unpopular positions, and explore lines of argument that may undercut established ways of thinking. Such an ethos protects us against dogmatism and groupthink, both of which are toxic to the health of academic communities and to the functioning of democracies***.**"



Bertrand Russell (1941) states in *Let the People Think*, that one's philosophy has practical consequences for politics. He says that **relativism**, the idea that there is no such thing as objective truth, and **pragmatism**, the idea that what is useful is true, are closely linked with fascism. In *Conjectures and Refutations*, Karl Popper (1965) extends this sentiment to all authoritarian and totalitarian ideologies.

Pano Kanelos (November 8, 2021), president of the newly established University of Austin wrote in an article entitled, *We Can't Wait for Universities to Fix Themselves*, "*I left my post as president of St. John's College in Annapolis to build a new university dedicated to the fearless pursuit of truth…Much is broken in America. But higher education might be the most fractured institution of all. There is a gaping chasm between the promise and the reality of higher education. Yale's motto is Lux et Veritas, light and truth. Harvard proclaims: Veritas. Young men and women of Stanford are told Die Luft der Freiheit weht: The wind of freedom blows. These are soaring words. But in these top schools, and in so many others, can we actually claim that the pursuit of truth—once the central purpose of a university—remains the highest virtue? Do we honestly believe that the crucial means to that end—freedom of inquiry and civil discourse—prevail when illiberalism has become a pervasive feature of campus life?...This core purpose—the intrepid pursuit of truth—has been at the heart of education since Plato founded his Academy in 387 B.C. Reviving it would produce a resilient (or*

"antifragile") cohort with exceptional capacity to think fearlessly, nimbly, and inventively. Such graduates will be the future leaders best prepared to address humanity's challenges."



Leonhard Euler discussed the nature of truth and its discovery "*from our own experience, from reasoning, or from the report of others*." These are the "*sources laid open by the Creator for the discovery of truth*" in his *Letters to a German Princess, On Different Subjects in Physics and Philosophy* written to Princesses Charlotte and Louise from 1760-1762. These letters also address many of the aspects of optics, light, and colors we discuss in this class.

Vol I: https://archive.org/details/letterseulertoa00eulegoog

Vol II: https://archive.org/details/letterseulerond07brewgoog

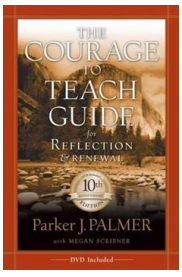
In Peter Kreeft's (1982) book *Between Heaven & Hell: A Dialog Somewhere Beyond Death*, John F. Kennedy, C. S. Lewis, and Aldous Huxley, who all died on November 22, 1963, discuss the nature and importance of **exo**teric (external), as opposed to **eso**teric (within), truth.

Lewis: *Because the one thing necessary for all true liberation is often very painful.*

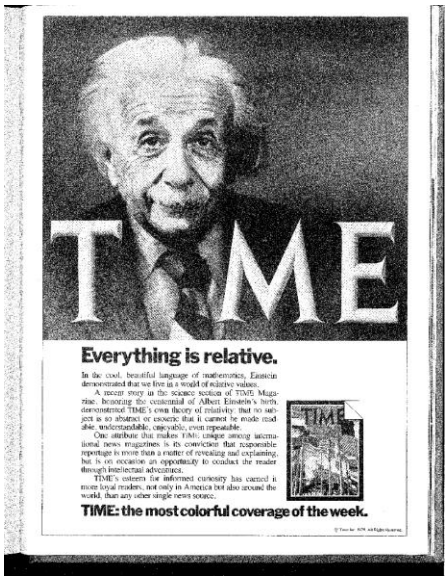
Kennedy: *What's that?*

Lewis: *Truth.*

Kennedy: *But truth is a primary human need.*



In *The Courage to Teach*, Parker J. Palmer (2007) notes that "*A mode of knowing arises from the way we answer two questions at the heart of the educational mission:* ***How do we know what we know? And by what warrant can we call our knowledge true?***"



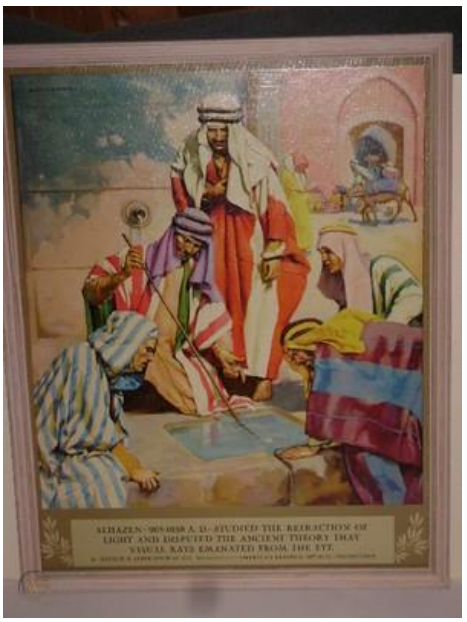
Or **is everything relative** in our **post-modern** world and there no such thing as absolute truth? *Time* magazine reported in 1979 (when they misrepresented Einstein's belief in absolutes), "*In the cool, beautiful language of mathematics, Einstein demonstrated that we live in a world of* ***relative values***."

According to **Noam Chomsky** (1967), "*It is the responsibility of intellectuals to speak the truth and to expose lies….If it is the responsibility of the intellectual to insist upon the truth, it is also his duty to see events in their historical perspective*." It is our responsibility to ask the intellectuals to state the **assumptions** and **line of reasoning** that led them to the truth. To ensure clarity of communication, it is also important for each of us to define the words we are using to make or refute our arguments.



According to **Karl Niklas**, "*The only think that stands in the way of communication is language*."





Abdelhamid I. Sabra (2003) tells us that **Alhazen wrote** in his book, *Aporias against Ptolemy*: "***Truth is sought for itself" but "the truths," he warns, "are immersed in uncertainties"*** *and the scientific authorities (such as Ptolemy, whom he greatly respected) are "not immune from error...." Nor, he said, is human nature itself: "Therefore, the seeker after the truth is not one who studies the writings of the ancients and, following his natural disposition, puts his trust in them, but rather the one who suspects his faith in them and questions what he gathers from them, the one who submits to argument and demonstration, and not to the sayings of a human being whose nature is fraught with all kinds of imperfection and deficiency.* ***Thus the duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency***."
https://www.harvardmagazine.com/2003/09/ibn-al-haytham-html

I realize that the claim, "*There is a Truth*" is not provable but the claim "*There is no Truth*" is self-defeating.



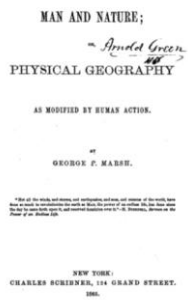
In this lecture it is my aim to stimulate, not to satisfy, curiosity, and it is no part of my object to save my students the labor of observation or of thought. For labor is life. These sentiments, and the words themselves come from **George P. Marsh**'s *Man and Nature; or, Physical Geography as Modified by Human Action* (1865) and *The Earth as Modified by Human Action* (1907):

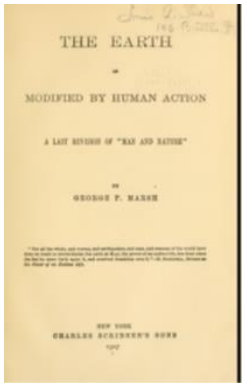
In these pages it is my aim to stimulate, not to satisfy, curiosity, and it is no part of my object to save my readers the labor of observation or of thought. For labor is life, and

*Death lives where power lives unused.**

Self is the schoolmaster whose lessons are best worth his wages; and since the subject I am considering has not yet become a branch of formal instruction, those whom it may interest can, fortunately, have no pedagogue but themselves. To the natural philosopher, the descriptive poet, the painter, the sculptor, and indeed every earnest observer, the power most important to cultivate, and, at the same time, hardest to acquire, is that of seeing what is before him. ***Sight is a faculty; seeing, an art.*** *The eye is a physical but not a self-acting apparatus, and in general it sees only what it seeks. Like a mirror, it reflects objects presented to it; but it may be as insensible as a mirror, and not consciously perceive what it reflects.*

It has been maintained by high authority, that the natural acuteness of our sensuous faculties can not be heightened by use, and hence, that the minutest details of the image formed on the retina are as perfect in the most untrained as in the most thoroughly disciplined organ. This may be questioned, and it is agreed on all hands that the power of multifarious perception and rapid discrimination may be immensely increased by well-directed practice. This exercise of the eye I desire to promote, and, next to moral and religious doctrine, I know no more important practical lessons in this earthly life of ours—which, to the wise man, is a school from the cradle to the grave—than those relating to the employment of the sense of vision in the study of nature.


MAN AND NATURE;
or
PHYSICAL GEOGRAPHY
AS MODIFIED BY HUMAN ACTION.
BY
GEORGE P. MARSH.
NEW YORK:
CHARLES SCRIBNER, 124 GRAND STREET.


THE EARTH
AS
MODIFIED BY HUMAN ACTION
A NEW REVISION OF "MAN AND NATURE"
BY
GEORGE P. MARSH
NEW YORK
CHARLES SCRIBNER'S SONS

Marsh quoted and translated Frederik Paludam Müller:

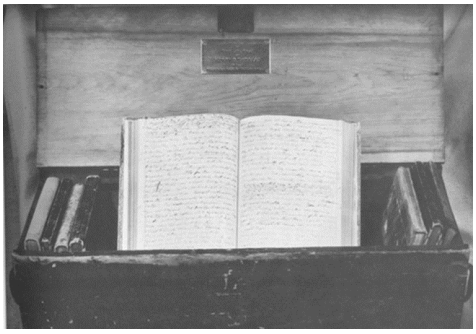
In the material eye, you think, sight lodgeth!

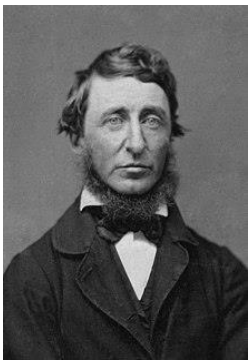
The eye is but an organ. Seeing streameth

From the soul's inmost depths. The fine perceptive

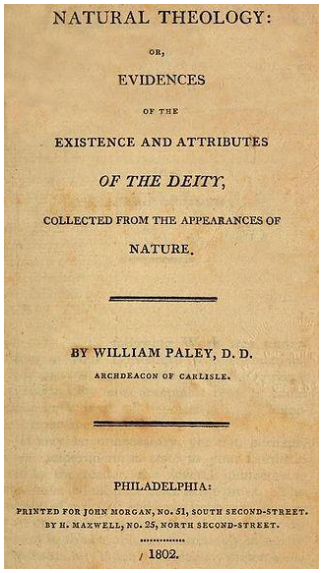
Nerve springeth from the brain's mysterious workshop.

On August 5, 1851, Henry David Thoreau wrote in his journal, "*The question is not what you look at, but what you see*." https://www.walden.org/wp-content/uploads/2016/02/Journal-2-Chapter-7.pdf





In the last lecture I talked about **eyes**, both human and animal, and the conditions and compromises that are necessary for seeing in **water and/or air**, seeing during **daytime and/or during the night**, and seeing for **predators and their prey**. Looking at the eye, **William Paley** concluded that the Creator must be good. Paley (1802) wrote, "*The proof of the divine goodness rests upon two propositions; each, as we contend, capable of being made out by observations drawn from the appearances of nature. The first is, 'that, in a vast plurality of instances in which contrivance is perceived, **the design of the contrivance is beneficial**.' The second, 'that the Deity has superadded pleasure to animal sensations, **beyond what was necessary for any other purpose**, or when the purpose, so far as it was necessary,' might have been effected by the operation of pain*."


NATURAL THEOLOGY:

OR,

EVIDENCES

OF THE

EXISTENCE AND ATTRIBUTES

OF THE DEITY,

COLLECTED FROM THE APPEARANCES OF

NATURE.

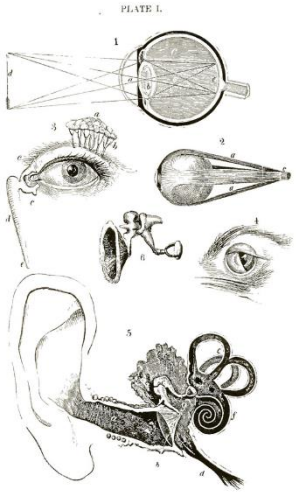
BY WILLIAM PALEY, D. D.

ARCHDEACON OF CARLISLE.

PHILADELPHIA:

PRINTED FOR JOHN MORGAN, NO. 51, SOUTH SECOND-STREET.
BY H. MAXWELL, NO. 25, NORTH SECOND-STREET.

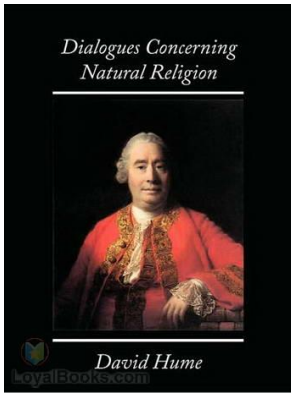
1802.



Nature is not simple and there are difficult questions for everyone to ask and answer. Paley saw nature in terms of evidence of the goodness of God. However, others, such as Augustin Pyramus de Candolle (1820) saw nature as war-like:

"*All the plants of a given country, all those of a given place, are* ***at war one with another****. The first which establish themselves by chance in a particular spot, tend, by the mere occupancy of space, to exclude other species—****the greater choke the smaller****, the longest livers replace those which last for a shorter period, the more prolific gradually make themselves* ***masters*** *of the ground, which species multiplying more slowly would otherwise fill.*"

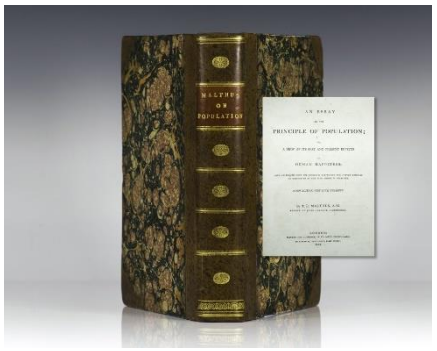




De Candolle's thinking about nature as a battlefield coincided with Hume's (1779) philosophy as expressed in *Dialogues Concerning Natural Religion*, in which he wrote:

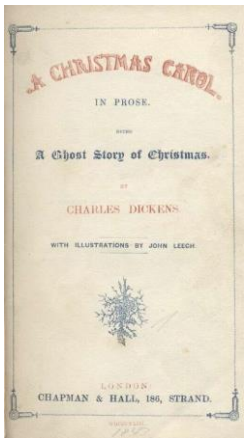
*And why should man, added he, pretend to an exemption from the lot of all other animals? The whole earth, believe me, PHILO, is cursed and polluted. **A perpetual war is kindled amongst all living creatures**. Necessity, hunger, want, stimulate the strong and courageous: Fear, anxiety, terror, agitate the weak and infirm. The first entrance into life gives anguish to the new-born infant and to its wretched parent: Weakness, impotence, distress, attend each stage of that life: and 'tis at last finished in agony and horror.*

*Observe too, says PHILO, the curious artifices of Nature, in order to imbitter the life of every living being. The stronger prey upon the weaker, and keep them in perpetual terror and anxiety. The weaker too, in their turn, often prey upon the stronger, and vex and molest them without relaxation. Consider that innumerable race of insects, which either are bred on the body of each animal, or flying about infix their stings in him. These insects have others still less than themselves, which torment them. And thus on each hand, before and behind, above and below, every animal is surrounded with **enemies**, which incessantly seek his misery and destruction.*



It also coincided with **Thomas Malthus**' (1798) thinking that there will not be enough food for a growing population of humans as expressed in *An Essay on the Principle of Population* became known in artistic circles. Malthus wrote, "*The power of population is so superior to the power in the earth to produce subsistence for man, that premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation. They are the precursors in the great army of destruction; and often finish the dreadful work themselves. But should they fail in this **war of extermination**, sickly seasons, epidemics, pestilence, and plague, advance in terrific array, and sweep off their thousands and ten thousands. Should*

success be still incomplete, gigantic inevitable famine stalks in the rear, and with ***one mighty blow levels the population with the food of the world****."* That is, the mighty blow decreases the surplus population.



Scrooge in **Charles Dickens'** (1843; Rare Books PR4572 .C55 1843b; https://www.npr.org/2004/12/13/4225458/jonathan-winters-a-christmas-carol) *A Christmas Carol* put it this way: "*I wish to be left alone," said Scrooge. "Since you ask me what I wish, gentlemen, that is my answer. I don't make merry myself at Christmas and I can't afford to make idle people merry. I help to support the establishments I have mentioned—they cost enough; and those who are badly off must go there."*

"Many can't go there; and many would rather die."

"If they would rather die," said Scrooge, "they had better do it, and ***decrease the surplus population****. Besides—excuse me—I don't know that."*

"But you might know it," observed the gentleman.

"It's not my business," Scrooge returned. "It's enough for a man to understand his own business, and not to interfere with other people's. Mine occupies me constantly. Good afternoon, gentlemen!"



Scrooge was reminded of his words in a conversation with The Ghost of Christmas Present: *"Spirit," said Scrooge, with an interest he had never felt before, "tell me if Tiny Tim will live."*

"I see a vacant seat," replied the Ghost, "in the poor chimney-corner, and a crutch without an owner, carefully preserved. If these shadows remain unaltered by the Future, the child will die."

"No, no," said Scrooge. "Oh, no, kind Spirit! say he will be spared."

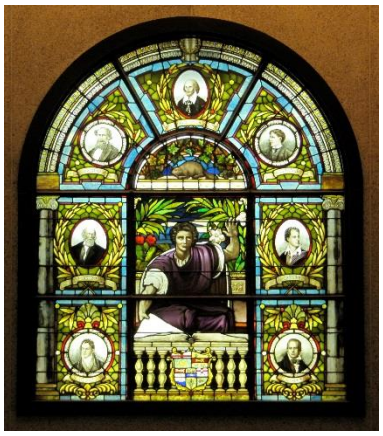
"If these shadows remain unaltered by the Future, none other of my race," returned the Ghost, "will find him here. What then? If he be like to die, he had better do it, and ***decrease the surplus population****."*

Scrooge hung his head to hear his own words quoted by the Spirit, and was overcome with penitence and grief.

"Man," said the Ghost, "if man you be in heart, not adamant, forbear that wicked cant until you have discovered What the surplus is, and Where it is. Will you decide what men shall live, what men shall die? It may be, that in the sight of Heaven, you are more worthless and less fit to live than millions like this poor man's child. Oh God! to hear the Insect on the leaf pronouncing on the too much life among his hungry brothers in the dust!"

Scrooge's partner, Jacob Marley, died the day before Christmas Eve, the same day as Thomas Malthus (December 23, 1834).

The poet, **Alfred, Lord Tennyson** (1849) wrote in *In Memoriam A.H.H.*, a poem about hope after great loss that took seventeen years to write: http://www.online-literature.com/tennyson/718/



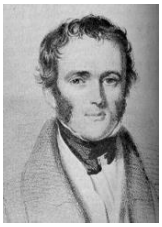
Are God and Nature then at strife,
That Nature lends such evil dreams?
So careful of the type she seems,
So careless of the single life;

Who trusted God was love indeed
And love Creation's final law
Tho' Nature, red in tooth and claw
With ravine, shriek'd against his creed

And the theme *red in tooth and claw* was taken up by Sting in *I was Brought to My Senses* (https://www.youtube.com/watch?v=QrLF4HymAs4)



De Candolle 's thinking was considered by scientists such as the geologist **Charles Lyell** (1832), the botanist **William Jackson Hooker** (1834), and the polymath **Herbert Spencer** (1852). Spencer wrote "*On contemplating its general circumstances, we perceive that any race of organisms is subject to two sets of conflicting influences. On the one hand by natural death, by enemies, by lack of food, by atmospheric changes, &c., it is constantly being destroyed. On the other hand, partly by the strength, swiftness, and sagacity of its members, and partly by their fertility, it is constantly being maintained.*" Spencer then uses physical analogy.







$$F_{preservative} - F_{destructive} = \frac{dp}{dt}$$

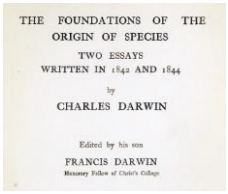
where $\frac{dp}{dt}$ is the change in population (rather than momentum) over time.

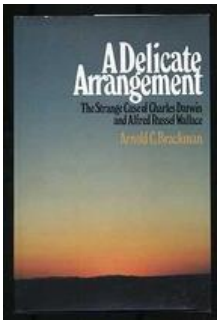
"*These conflicting sets of influences may be conveniently generalized as—the **forces destructive** of race, and the **forces preservative** of race. Whilst any race continues to exist, the forces destructive of it and the forces preservative of it must perpetually tend towards **equilibrium**. If the forces destructive of it decrease, the race must gradually become more numerous, until, either from lack of food or from increase of enemies, the destroying forces again balance the preserving forces. If, reversely, the forces destructive of it increase, then the race must diminish, until,*

either from its food becoming relatively more abundant, or from its enemies dying of hunger, the destroying forces sink to the level of the preserving forces. Should the destroying forces be of a kind that cannot be thus met (as great change of climate), the race, by becoming extinct, is removed out of the category. Hence this is necessarily the law of maintenance of all races; seeing that when they cease to conform to it they cease to be."



Charles Darwin also saw nature in terms of war and warfare. In June 1858, upon receiving a manuscript on evolution by natural selection written by Alfred Russel Wallace, Darwin stitched together unpublished essays he wrote in 1842 and 1844 and wrote a manuscript to **combat** Wallace's claims to the theory of evolution by natural selection (Brackman, 1980; Wolfe, 2016). In a "delicate arrangement," the two manuscripts were presented in alphabetical order (D before W) at the Linnean Society meeting on July 1, 1858, giving Darwin priority. Darwin began: "*De Candolle, in an eloquent passage, has declared that **all nature is at war**, one organism with another, or with external nature. **Seeing** the contented face of nature, this may at first well be doubted; but **reflection** will inevitably prove it to be true.*"





Charles Darwin went on to say that the war exists, in part, because each species has the ability to produce an exponentially increasing number of offspring: "*Nature may be compared to a surface on which rest ten thousand sharp wedges touching each other and driven inwards by incessant blows. Fully to realize these views much **reflection** is requisite. **Malthus on man** should be studied; and all such cases as the mice in La Plata, or of the cattle and horses when first turned out in South America, of the birds by our calculation, &c., should be well considered. **Reflect** on the **enormous multiplying power inherent** and annually in action in all animals; **reflect** on the countless seeds scattered by a hundred ingenious contrivances, year after year, over the whole face of the land;*"

Darwin built on Malthus' (1798), de Candolle's (1820), and Spencer's (1852) thinking. Darwin realized that even though species have the potential to increase exponentially, the number of individuals in that species tends to stay constant because there is a struggle for the limited amount of food: *"and yet we have every reason to suppose that the **average percentage of each of the inhabitants of a country usually remains constant**. Finally, let it be borne in mind that this average number of individuals (the external conditions remaining the same) in each country is kept up by **recurrent struggles** against other species or against external nature (as on borders of the Arctic regions, where the cold checks life), and that ordinarily **each individual of every species holds its place**, either by its **own struggle** and capacity of acquiring nourishment in some period of its life, from the egg upwards; or by the **struggle of its parents** (in short-lived organisms, when the main check occurs at longer intervals) **with other individuals of the same or different species**."*

$$F_{preservative} - F_{destructive} = \frac{dp}{dt} = 0$$

Darwin goes on to say that if conditions change and a certain variation in an individual gives it an advantage in the struggle for existence under the new conditions, and, if the adaptive trait is inherited, then the offspring that inherit the advantageous variation would have an advantage in the struggle for existence: "***Now, can it be doubted, from the struggle each individual has to obtain subsistence, that any minute variation in structure, habits, or instincts, adapting that individual better to the new conditions, would tell upon its vigour and health? In the struggle it would have a better chance of surviving; and those of***

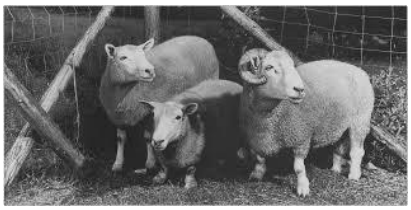
its offspring which inherited the variation, be it ever so slight, would also have a better chance."



How much of a difference in the advantage of a variation would determine the life or death of an individual? According to Darwin, "***Yearly more are bred than can survive; the smallest grain in the balance, in the long run, must tell on which death shall fall, and which shall survive***."

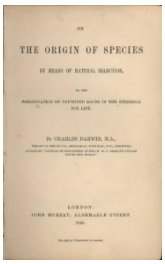
The greater the advantage, the shorter the time it should take for the individuals that inherited the advantageous variation to replace the individuals that do not have the advantageous variation. If a variation had such a small selective advantage, how long would it take to produce a new species that had the advantageous variation and for the old species that did not have the advantageous variation to die out? According to Darwin, "*Let the work of selection on the one hand, and death on the other, go on for a thousand generations, who will pretend to affirm that it would produce no effect, when we remember what, in a few years,* [Robert] *Bakewell effected in cattle, and Western in* [Ancon] *sheep, by this identical principle of selection?*"





https://www.ans.iastate.edu/about/history/people/robert-bakewell

In 1859, Darwin put his theory more succinctly in *On the Origin of Species*, "If during the long course of ages and under varying conditions of life, **organic beings vary at all in the several parts of their organisation**, and I think this cannot be disputed; if there be, owing to the **high geometrical powers of increase of each species**, at some age, season, or year**, a severe struggle for life,** and this certainly cannot be disputed; then, considering the infinite complexity of the relations of all organic beings to each other and to their conditions of existence,



causing an infinite diversity in structure, constitution, and habits, to be advantageous to them, I think it would be a most extraordinary fact if no variation ever had occurred useful to each being's own welfare, in the same way as so many variations have occurred useful to man**. But, if variations useful to any organic being do occur, assuredly individuals thus characterised will have the best chance of being preserved in the struggle for life**; and from the strong principle of inheritance they will tend to produce offspring similarly characterised. This principle of preservation, I have called, for the sake of brevity, Natural Selection."

Darwin (1859) ended the *Origin of Species*, like so: "In the distant future I see open fields for far more important researches. Psychology will be securely based on a new foundation, that of the necessary acquirement of each mental power and capacity of gradation. Light will be thrown on the origin of man and his history."

We will discuss Darwinian evolutionary theory in detail when we discuss the coloration of the peppered moth later this semester. For now, we will set the way-back machine to Oxford, England on the thirtieth of June in the year 1860 when there was a meeting of the British Association for the Advancement of Science (BAAS). This was the first meeting of the BAAS since the November 24, 1859 publication of Charles' Darwin's ***On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life***.

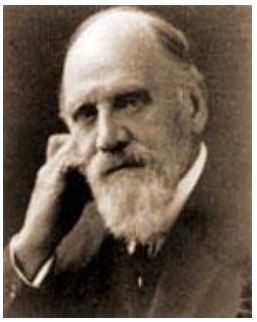






Legend has it that at this meeting, the young **Thomas Henry Huxley** debated the seasoned Bishop of Oxford, **Samuel Wilberforce** who had been elected to the **Royal Society of London** on December 18, 1845 and was vice president of the **British Association for Advancement of Science**, although the legend leaves out his scientific credentials. (The photograph of Samuel

Wilberforce was taken by his friend, Charles Lutwidge Dodgson, who is better known as Lewis Carroll).

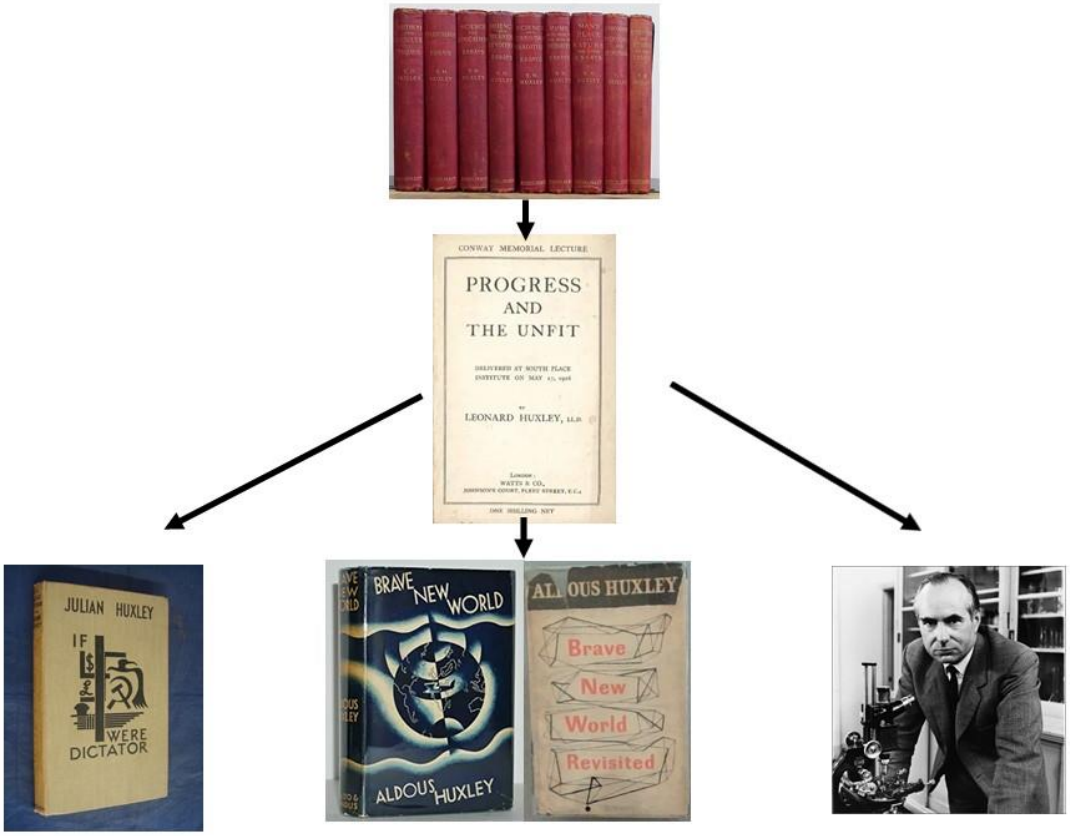


Accounts of the meeting were given in the *Athenaeum* and the *Oxford Chronicle and Berks and Bucks Gazette* of July 21, 1860 https://paulbraterman.wordpress.com/2017/11/06/tl-dr-wilberforce-huxley-encounter-oxford-chronicle-and-athenaeum-accounts/, but there was no mention of a debate. The first mention of the debate was given twenty-seven years later by **Francis Darwin** (1887) when he put the following description in volume II (pp. 321-323) of *The Life and Letters of Charles Darwin, including an Autobiographical Chapter*:

"The excitement was tremendous. The Lecture-room, in which it had been arranged that the discussion should be held, proved far too small for the audience, and the meeting adjourned to the Library of the Museum, which was crammed to suffocation long before the champions entered the lists. The numbers were estimated at from 700 to 1000. Had it been term-time, or had the general public been admitted, it would have been impossible to have accommodated the rush to hear the oratory of the bold Bishop. Professor Henslow, the President of Section D, occupied the chair, and wisely announced in limine that none who had not valid arguments to bring forward on one side or the other, would be allowed to address the meeting: a caution that proved necessary, for no fewer than four combatants had their utterances burked by him, because of their indulgence in vague declamation.

*"**The Bishop was up to time, and spoke for full half-an-hour with inimitable spirit, emptiness and unfairness. It was evident from his handling of the subject that he had been 'crammed' up to the throat, and that he knew nothing at first***

hand; in fact, he used no argument not to be found in his 'Quarterly' article (that was finished on May 20, 1860)***. He ridiculed Darwin badly, and Huxley savagely, but all in such dulcet tones, so persuasive a manner, and in such well-turned periods, that I who had been inclined to blame the President for allowing a discussion that could serve no scientific purpose, now forgave him from the***



bottom of my heart. Unfortunately the Bishop, hurried along on the current of his own eloquence, so far forgot himself as to push his attempted advantage to the verge of personality in a telling passage in which he turned round and addressed Huxley: I forget the precise words, and quote from Lyell. 'The Bishop asked whether Huxley was related by this grandfather's or grandmother's side to an ape.'* Huxley replied to the scientific argument of his opponent with force and eloquence, and to the personal allusion with a self-restraint, that gave dignity to his crushing rejoinder."

The legend of the Oxford Debate was also presented by **Leonard Huxley**, (1900) a writer, the son of T. H. Huxley, and the father of Julian Huxley, Andrew Fielding Huxley, and Aldous Huxley in *The Life and Letters of Thomas Henry Huxley* Volume 1 (pp. 192-204). Here is an excerpt:

*"**[The famous Oxford Meeting of 1860 was of no small importance in Huxley's career. It was not merely that he helped to save a great cause from being stifled under misrepresentation and ridicule—that he helped to extort for it a fair hearing; it was now that he first made himself known in popular estimation as a dangerous adversary in debate—a personal force in the world of science which could not be neglected. From this moment he entered the front fighting line in the most exposed quarter of the field….***

Then there were calls for the Bishop, but he rose and said he understood his friend Professor Beale had something to say first. Beale, who was an excellent histologist, spoke to the effect that the new theory ought to meet with fair discussion, but added, with great modesty, that he himself had not sufficient knowledge to discuss the subject adequately. Then the Bishop spoke the speech that you know, and the question about his mother being an ape, or his grandmother.



***From the scientific point of view, the speech was of small value. It was evident from his mode of handling the subject that he had been "crammed up to the throat," and knew nothing at first hand; he used no argument beyond those to be found in his "Quarterly" article, which appeared a few days later, and is now admitted to have been inspired by Owen. "He ridiculed Darwin badly and Huxley savagely;** *but," confesses one of his strongest opponents, "all in such dulcet tones, so persuasive a manner, and in such well turned periods, that I who*

had been inclined to blame the President for allowing a discussion that could serve no scientific purpose, now forgave him from the bottom of my heart."

The Bishop spoke thus "for full half an hour with inimitable spirit, emptiness and unfairness." "In a light, scoffing tone, florid and fluent, he assured us there was nothing in the idea of evolution; rock-pigeons were what rock-pigeons had always been. Then, turning to his antagonist with a smiling insolence, he begged to know, was it through his grandfather or his grandmother that he claimed his descent from a monkey?" *("Reminiscences of a Grandmother,"* [sic] *"Macmillan's Magazine," October 1898. Professor Farrar thinks this version of what the Bishop said is slightly inaccurate. His impression is that the words actually used seemed at the moment flippant and unscientific rather than insolent, vulgar, or personal. The Bishop, he writes, "had been talking of the perpetuity of species of Birds; and then, denying a fortiori the derivation of the species Man from Ape, he rhetorically invoked the aid of FEELING, and said,* ***'If any one were to be willing to trace his descent through an ape as his GRANDFATHER, would he be willing to trace his descent similarly on the side of his GRANDMOTHER?' His false humour was an attempt to arouse the antipathy about degrading WOMAN to the quadrumana.*** *Your father's reply showed there was vulgarity as well as folly in the Bishop's words; and the impression distinctly was, that the Bishop's party, as they left the room, felt abashed, and recognised the Bishop had forgotten to behave like a perfect gentleman.")*

This was the fatal mistake of his speech. Huxley instantly grasped the tactical advantage which the descent to personalities gave him. He turned to Sir Benjamin Brodie, who was sitting beside him, and emphatically striking his hand upon his knee, exclaimed,] "The Lord hath delivered him into mine hands." [The bearing of the exclamation did not dawn upon Sir Benjamin until after Huxley had completed

*his "forcible and eloquent" answer to the scientific part of the Bishop's argument, and proceeded to make his famous retort. (**The "Athenaeum" reports him as saying that Darwin's theory was an explanation of phenomena in Natural History, as the undulatory theory was of the phenomena of light. No one objected to that theory because an undulation of light had never been arrested and measured. Darwin's theory was an explanation of facts, and his book was full of new facts, all bearing on his theory. Without asserting that every part of that theory had been confirmed, he maintained that it was the best explanation of the origin of species which had yet been offered. With regard to the psychological distinction between men and animals, man himself was once a monad—a mere atom, and nobody could say at what moment in the history of his development he became consciously intelligent. The question was not so much one of a transmutation or transition of species, as of the production of forms which became permanent.***

***Thus the short-legged sheep of America was not produced gradually, but originated in the birth of an original parent of the whole stock, which had been kept up by a rigid system of artificial selection**.)*

Reminiscences of a Grandmother was actually entitled, A Grandmother's Tales, which states: "I was happy enough to be present on the incredible occasion at Oxford when Mr. Huxley bearded Bishop Wilberforce. There were so many of us that were eager to hear that we had to adjourn to the great library of the Museum. I can still hear the American accents of Dr. Draper's opening address, when he asked, "Air we a fortuitous concourse of atoms?" and his discourse I seem to remember as somewhat dry. Then the Bishop rose, and in a light scoffing tone, florid and fluent, he assured us there was nothing in the idea of evolution; rock-pigeons were what rock-pigeons had always been. Then, turning to his antagonist

with a smiling insolence, he begged to know, was it through his grandfather or his grandmother that he claimed his descent from a monkey? On this Mr. Huxley slowly and deliberately arose. A slight tall figure stern and pale, very quiet and very grave, he stood before us, and spoke those tremendous words,—words which no one seems sure of now, nor I think, could remember just after they were spoken, for their meaning took away our breath, though it left us in no doubt as to what it was. He was not ashamed to have a monkey for his ancestor; but he would be ashamed to be connected with a man who used great gifts to obscure the truth. No one doubted his meaning and the effect was tremendous. One lady fainted and had to be carried out: I, for one, jumped out of my seat; and when in the evening we met at Dr. Dubeney's, every one was eager to congratulate the hero of the day. I remember that some naïve person wished 'it could come over again:' and Mr. Huxley, with the look on his face of the victor who feels the cost of victory, put us aside saying, 'Once in a life-time is enough, if not too much.'"

Leonard Huxley ended his account by saying ***The importance of the Oxford meeting lay in the open resistance that was made to authority, at a moment when even a drawn battle was hardly less effectual than acknowledged victory. Instead of being crushed under ridicule, the new theories secured a hearing, all the wider, indeed, for the startling nature of their defence.]"***

Leonard Huxley's account of the so-called Oxford debate between Wilberforce and Huxley became standard reading for many as a result of its inclusion in ***The Norton Anthology of English Literature*** as an example of Victorian literature. A similar account presented by William Irvine (1955, 1963) in his book, *Apes, Angels, & Victorians* was endorsed by Julian Huxley, and the tradition continues in Ruth Moore's (1955) *Charles Darwin: A Great Life in Brief*

and Ian Hesketh's (2009), *Of Apes and Ancestors: Evolution, Christianity, and the Oxford Debate*.

Reginald G. Wilberforce (1881), Samuel's son, wrote in the *Life of the Right Reverend Samuel Wilberforce, D. D.*, "*the Bishop…made an eloquent speech condemning Mr. Darwin's theory as unphilosophical and as founded on fancy, and he denied that any one instance had been produced by Mr. Darwin which showed that the alleged change from one species to another had ever taken place. In the course of this speech, which made a great impression**, the Bishop said, that whatever certain people might believe, he would not look at the monkeys in the Zoological as connected with his ancestors, a remark that drew from a certain learned professor the retort, 'I would rather we descended from an ape than a bishop.***'"

Huxley's account became the standard story about Samuel Wilberforce. As Randy Moore and Mark Decker (2009) wrote, in *More than Darwin: The People and Places of the Evolution-Creationism Controversy*, "*The 'Huxley—Wilberforce debate' has become legendary, aided by the lack of a transcript of the proceedings… Whether these statements were actually said, and who 'won' the debate is unclear….**Although the 'debate' accomplished little for either science or religion, the event was significant because it was a public refusal by the scientific community to allow the Church to dictate matters of science*."

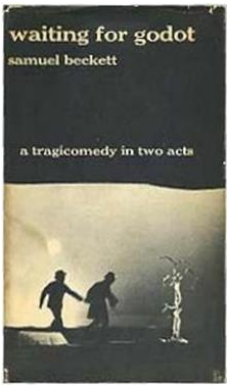


FIGURE 1.20. *Vanity Fair* magazine caricatures of Bishop Wilberforce (*left*), Thomas Henry Huxley (*middle*), and Charles Darwin (*right*). Wilberforce attacked Darwin's ideas at an 1860 British Association meeting, and Huxley—"Darwin's bulldog"—defended Darwin at this debate.

1.20, reprinted from Drawings by Ape from Vanity Fair (**left**) July 24, 1869, (**center**) January 28, 1871, (**right**) Sept. 30, 1871

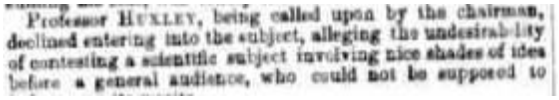
Evolution © 2007 Cold Spring Harbor Laboratory Press

Unfortunately, it is the only story that most scientists know; which reminds me of a few lines from *Waiting for Godot* by Samuel Beckett:



ESTRAGON:
Who believes him?
VLADIMIR:
Everybody. It's the only version they know.
ESTRAGON:
People are bloody ignorant apes.

Speaking of ignorance, according to the ***Oxford Chronicle*** of July 21, 1860, *Professor HUXLEY, being called upon by the chairman, declined entering into the subject, alleging the undesirability of contesting a scientific subject involving nice shades of idea before a general audience, who could not be supposed to judge upon its merits*.


Professor HUXLEY, being called upon by the chairman, declined entering into the subject, alleging the undesirability of contesting a scientific subject involving nice shades of idea before a general audience, who could not be supposed to

The BISHOP of OXFORD again rose and was received with cheers and laughter…He ridiculed Professor Huxley's ***appeal to authority*** *in connection with his remarks on amateurs in science. On which side lay the* ***authority***. *Sir B. Brodie, Professor Owen, and other eminent men were opposed to it, and how the Professor could talk as he had done about* ***authority*** *he did not know. (Laughter and cheers.) The Bishop then noticed the Professor's concluding remarks, denying the cogency of the illustrations, and after experiencing some interruptions in his scientific dicta, sat down amid loud cheers.*


The BISHOP of OXFORD, on rising, was loudly cheered. Having briefly noticed Professor Draper's arguments, and ridiculed his comparison of the marble and table, he proceeded to say he had given the theory advanced by Mr Darwin his most careful and anxious consideration. The conclusion he had come to was, that when tried by the principles of inductive science, philosophy, or logic, it entirely broke down. (Cheers.) And to come to facts, he maintained that those brought forward utterly failed to prove his theory. The permanence of specific forms was a fact confirmed by all observation, the few exceptions that existed being confined to a few cases in certain species of plants. Take, for instance, the remains of animals, plants, and man. Egyptian catacombs. Now, anatomists tell us that even in mummies, 4,000 years old, there is not the slightest physiological difference as compared with the race now—(hear, hear)—and so it was with animals and plants. All spoke of their identity with existing forms, and of the irresistible tendency of organised beings to assume an unalterable character. (Applause.) Glancing at Professor Huxley's remarks, on the previous day, in a discussion with Professor Owen, the Bishop facetiously asked if he had any particular predilection for a monkey ancestry, and, if so, on which side —whether he would prefer an ape for his grandfather, and a woman for his grandmother, or a man for his grandfather, and an ape for his grandmother. (Much laughter.) But to treat the subject seriously. (Hear, hear.) The line between man and the lower animals was distinct. There was no tendency on the part of the lower animals to become the self-conscious intelligent being, man; or, in man, to degenerate and lose the high characteristics of mind and intelligence. All experiments failed to show any tendency in one animal to assume the form of the other. Even in the great case of the pigeons, quoted by Mr. Darwin, he admitted that no sooner were these animals set free, than they returned to their primitive type. (Hear, hear.) Everywhere sterility attended hybridism, as was seen in the closely allied forms of the horse and the ass. Viewing the matter in another aspect, he did consider it a most degrading assumption—(hear, hear)—that man, who, in many respects, partook of the highest attributes of God —(hear, hear)—was a mere development of the lowest forms of creation. (Applause.) He could scarcely trust himself to speak upon the subject, so indignant did he feel at the idea. He did not desire timidity in scientific investigation. (Hear, hear.) Religion had nothing to fear. (Hear, hear.) But what he did protest against was the hasty adoption of unsound hypotheses and unproved assertions for the weighty realities of scientific truth. (Applause.) He did not believe that science and revelation were inimical to each other, but that what appeared irreconcileable in the present state of scientific knowledge would in the fulness of time be made manifest, and redound to the triumph of both. (Prolonged cheering.)

Professor HUXLEY followed. In reply to the Bishop's query he said that if the alternative were given him of being descended from a man conspicuous for his talents and eloquence, but who misused his gifts to ridicule the laborious investigations of science and obscure the light of scientific truth, or from the humble origin alluded to, he would far rather choose the latter than the former. (Oh, oh, and laughter and cheering.) He then defended Mr. Darwin's theory from the charge of being a mere hypothesis, and said it was an explanation of phenomena in natural history holding the same relation as the undulating theory to the phenomena of light. Did any one object to that theory because an undulation of light had

Professor HUXLEY rose in answer to calls for him, and said he was sure the Bishop could have no desire to mislead, but he thought he had misapprehended his remarks upon ***authority****. What he had deprecated was* ***authority*** *like the Bishop's, authority derived from a reputation acquired in another sphere. (Hear, hear, and laughter.)*


never been arrested and measured? His charge against Mr. Darwin's opponents was that they did not attempt to bring forward any important fact against his theory. That theory was an explanation of facts the result of laborious research, and abounded in new facts bearing upon it. Without asserting that every part of the theory had been confirmed, he maintained that it was the best explanation of the origin of species which had yet been offered—(hear, hear)—and he did protest against this subject being dealt with by amateurs in science, and made the occasion of appeals to passion and feeling. (Applause.) With regard to the psychological distinction between man and animals, it must be remembered man himself was once a nomad—a mere atom of matter—and who could say at what moment of his development he became consciously intelligent. (Hear, hear.) The question was not so much one of a transmutation or transition of species as of the production of forms which become permanent. In the course of an argument to support this position, he instanced the short-legged sheep of America, which were not produced gradually, but originated in the birth of an original parent of the whole stock, which had been kept up by a rigid system of artificial selection. (The Professor, on resuming his seat, was loudly applauded.)

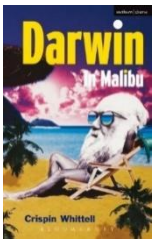
The BISHOP of OXFORD again rose and was received with cheers and laughter. He said he regretted that Professor Huxley had taken umbrage at what he had said. He did not know that he had said anything which could possibly give offence to Mr. Darwin's greatest friends, and as for his query to Professor Huxley he had been tempted to it by the merriment of the audience, and it was merely a passing allusion. He ridiculed Professor Huxley's appeal to authority in connection with his remarks on amateurs in science. On which side lay the authority. Sir B. Brodie, Professor Owen, and other eminent men were opposed to it, and how the Professor could talk as he had done about authority he did not know. (Laughter and cheers.) The Bishop then noticed the Professor's concluding remarks, denying the cogency of the illustrations, and after experiencing some interruptions in his scientific dicta sat down amid loud cheers.

Professor HUXLEY rose in answer to calls for him, and said he was sure the Bishop could have no desire to mislead, but he thought he had misapprehended his remarks upon authority. What he had deprecated was authority like the Bishop's, authority derived from a reputation acquired in another sphere. (Hear, hear, and laughter).

Indeed, according to **Tom Wolfe** (2016), "*Subscribing to Darwinism showed that one was part of a bright, enlightened minority who shone far above the mooing herd below*."



The debate that never happened continues in Crispin Whittell's 2003 play, *Darwin in Malibu*.



Aside: As a graduate student in the 1980s, studying how plant cells respond to light, I could see how the truly great natural laws, derived from physics, chemistry, and biology applied at every level to the world around us and I saw a logic and beauty in this design and it inspired in me a sense of wonder and gratitude and love for its creator.

Because of my love of science and how useful it was for understanding the world I lived in, I wrote a book entitled, *Plant Cell Biology: From Astronomy to Zoology* for Princeton University Press. As the title suggests, I include all disciplines to emphasize the unity of nature and the intricacy of the design at all

levels, as I describe and explain cells and how they make life possible. The book had several working titles, including *Molecular Theology of the Cell*.

In the 400 pages of text and 140 pages of references, I put in a section entitled, The Mechanistic Viewpoint and God. I wrote, "*In general, there seems to be a war between science and religion, but this does not need to occur. In studying mechanisms, one must deconstruct the whole into its parts and determine the relationships between the parts as well as the relationships between the parts and the whole. Each community has words to describe 'the whole'. Throughout civilization, Homo sapiens have strived to live up to our specific epithet by struggling to understand the relationship between the parts and the whole in terms of understanding, among other things, our place in the universe, our relation to other people, our relationship to other species, and our relationship to the environment. Science and religion have been our guides throughout this struggle to understand. Science and religion may be two sides of the same coin of understanding, each with a measure of truth, and each complementing the other….It is often thought that a mechanistic viewpoint excludes God. …In this book, I will not base any mechanisms on the existence of God, and at the same time, I will not conclude that the discovery of a mechanism precludes the existence of a God*."

While it was not OK to include God in a science book, it seemed like it was OK to dismiss God in a science book. In *DNA: The Secret of Life*, James Watson (2009) wrote*: Does life have some magical, mystical essence, or is it, like any chemical reaction carried out in a science class, the product of normal physical and chemical processes? Is there something divine at the heart of a cell that brings it to life? The double helix answered that question with a definitive No."* I did not

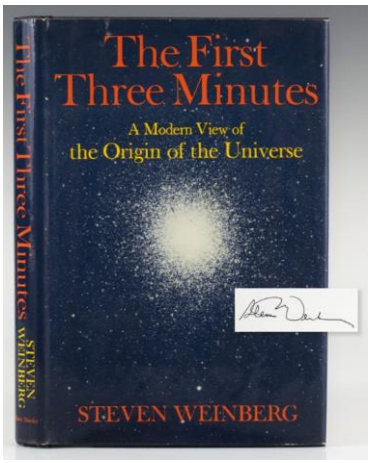
think the question of whether there was something divine at the heart of a cell was definitively solved.

My editor, Emily Wilkinson retired and Sam Elworthy, who became editor at Princeton University Press, told me that **God had no place in a science textbook**. I explained to him why it was important for *scientific completeness* in explaining the relationships between the parts and the whole. He wanted it out, and I said no and we cancelled the contract for that book and another one that I wrote on Light Microscopy that begins with, *And God said, Let there be light: and there was light*.

I had worked hard for almost 20 years on those books, and it wasn't for the money since the royalties had already been promised to the Profiles-in-Courage Award given by the JFK Library and to Habitat for Humanity. But I knew it was the right decision. A year or two later I got a call from Elsevier asking me whether they should publish a certain book. I raved about the book, saying that it was among the top three books written since the field of plant physiology was initiated 150 years ago, and definitely would be worth publishing…but it would not be a money maker because the perspective of the book was not fashionable enough and too few teachers would put in the work necessary to teach the material—even though the book was original, scholarly, and important. Good they said, since that is the kind of book they wanted to publish! They liked my way of looking at science. And they asked, "by the way do you have any books you'd like us to publish!" I said yes, and they published them.

I was surprised at the difference in perspectives between the nonprofit academic publisher, who should be my peeps, and the capitalist publisher. I started to wonder if we in academia are giving you the whole story.

My story is not unique: https://www.thegoodbook.com/blog/interestingthoughts/2019/01/09/the-time-john-lennox-was-pressured-to-give-up-his-/



Steven Weinberg (1993) wrote in *The First Three Minutes*, "*The more the universe seems comprehensible, the more it also seems pointless…The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy*."

The New York Times reported that at a conference entitled, "*Beyond Belief: Science, Religion, Reason and Survival*," Steven Weinberg said, "*Anything that we scientists can do to weaken the hold of religion should be done and may in the end be our greatest contribution to civilization*." https://www.nytimes.com/2006/11/21/science/21belief.html

Now let's discuss Samuel Wilberforce's **Review of Origin of Species.**

Samuel Wilberforce began his review by saying, "*Any contribution to our Natural History literature from the pen of Mr. C. Darwin is certain to command attention. **His scientific attainments, his insight and carefulness as an observer, blended with no scanty measure of imaginative sagacity, and his clear and lively style, make all his writings unusually attractive***.

*The essay is full of Mr. Darwin's characteristic excellences. It is a most readable book; full of facts in natural history, old and new, of his collecting and of his observing; and all of these are told in his own perspicuous language, and all thrown into **picturesque** combinations, and all sparkle with the **colours** of fancy and the **lights** of imagination. It assumes, too, the grave proportions of a sustained argument upon **a matter of the deepest interest, not to naturalists only, or even to***

men of science exclusively, but to every one who is interested in the history of man and of the relations of nature around him to the history and plan of creation. (pp. 52-53).

With Mr. Darwin's 'argument' we may ***say in the outset that we shall have much and grave fault to find***. ***But this does not make us the less disposed to admire the singular excellences of his work****; and we will seek* in limine *to give our readers a few examples of these. Here, for instance, is a beautiful illustration of the* ***wonderful interdependence of nature****—of* ***the golden chain of unsuspected relations which bind together all the mighty web which stretches from end to end of this full and most diversified earth***. *Who, as he listened to the musical hum of the great humble-bees*[1]*, or marked their ponderous flight from flower to flower, and watched the unpacking of their trunks for their work of suction, would have supposed that the multiplication or diminution of their race, or the fruitfulness and sterility of the red clover, depend as directly on the vigilance of our cats as do those of our well-guarded game-preserves on the watching of our keepers? Yet this Mr. Darwin has discovered to be literally the case:—*



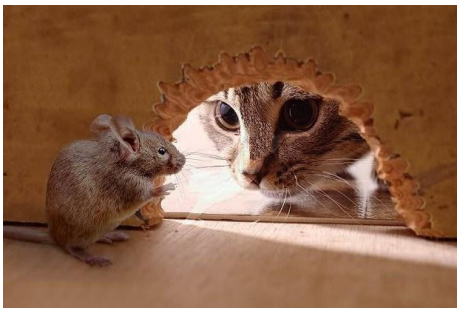
From experiments which I have lately tried, I have found that the visits of bees are necessary for the fertilisation of some kinds of clover; but humble-bees alone visit the red clover (Trifolium pratense), as other "bees cannot reach the nectar. Hence I have very little doubt, that if the whole genus of humble-bees became extinct or very rare in





[1] Humble bees, who were named after their hum, became known as bumble bees in Beatrix Potter's (1910) book *The Tale of Mrs. Tittlemouse*, in which she wrote, "Suddenly round a corner, she met Babbitty Bumble--"Zizz, Bizz, Bizzz!" said the bumblebee." Listen to a bumblebee inside a flower. The sound of their buzzing changes. When they are performing buzz pollination, the bees unhinge their wings from their wing muscles and vibrate their bodies, making that buzzing sound of middle C. The sound of the vibration causes the flower to explosively release pollen.

England, the heartsease and red clover would become very rare or wholly disappear. The number of humble-bees in any district depends in a great degree on the number of field-mice, which destroy their combs and nests; and Mr. H. Newman, who has long attended to the habits of humble-bees, believes that "more than two-thirds of them are thus destroyed all over England." Now the number of mice is largely dependent, as every one knows, on the number of cats; and Mr. Newman says, "near villages and small towns I have found the nests of humble-bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice." Hence, it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention, first of mice, and then of bees, the frequency of certain flowers in that district. (pp. 73-74).



Again, how beautiful are the experiments recorded by him concerning that wonderful relation of the ants to the aphides, which would almost warrant us in giving to the aphis the name of Vacca formicaria:—

One of the strongest instances of an animal apparently performing an action for the sole good of another with which I am acquainted is that of aphides voluntarily yielding their sweet excretion to ants. That they do so voluntarily the following facts will show. I removed all the ants from a group of about a dozen aphides on a dock plant, and prevented their attendance during several hours. After this interval, I





felt sure that the aphides would want to excrete. I watched them for some time through a lens, but not one of them excreted. I then tickled and stroked them with a hair in the same manner, as well as I could, as the ants do with their antennae, but not one excreted. Afterwards I allowed an ant to visit them, and it immediately seemed, by its eager way of running about, to be well aware what a rich flock it had discovered. It then began to play with, its antennae on the abdomen first of one aphis and then of another, and each aphis, as soon as it felt the antennae, immediately lifted up its abdomen and excreted a limpid drop of sweet juice, which was eagerly devoured by the ant. Even the quite young aphides behaved in this manner, showing that the action was instinctive, and not the result of experience. (pp. 210-211).

Or take the following admirable specimen of the union of which we have spoken, of the employment of the observations of others with what he has observed himself, in that which is almost the most marvelous of facts—the ***slave-making instinct*** *of certain ants. We say nothing at present of the place assigned to these facts in Mr. Darwin's argument, but are merely referring to the collection, observation, and statement of the facts themselves:*

Slave-making Instinct.—This **remarkable instinct** was first discovered in the Formica (Polyerges) rufescens by Pierre Huber, a better observer even than his celebrated father. This ant is absolutely dependent on its **slaves**; without their aid the species would certainly become extinct in a single year. The males and fertile females do no work. The workers or sterile females, though most energetic and courageous in capturing slaves, do no other work. They are incapable of making their own nests or of



feeding their own larvae. When the old nest is found inconvenient, and they have to migrate, it is the slaves which determine the migration, and actually carry their masters in their jaws. So utterly helpless are the masters, that when Huber shut up thirty of them without a **slave**, but with plenty of the food, which they like best, and with their larvae and pupæ to stimulate them to work, they did nothing; they could not even feed themselves, and many perished of hunger. Huber then introduced a single slave (F. fusca), and she instantly set to work, fed and saved the survivors, made some cells and tended the larvae, and put all to rights. What can be more extraordinary than these well-ascertained facts? If we had not known of any other slave-making ant, it would have been, hopeless to have speculated **how so wonderful an instinct could have been perfected**. Another species (Formica sanguinea) was likewise first discovered by P. Huber to be a **slave-making ant**. This species is found in the southern parts of England, and its habits have been attended to by Mr. F. Smith, of the British Museum, to whom I am much indebted for information on this and other subjects,— Although fully trusting to the statements of Huber and Mr. Smith, **I tried to approach the subject in a sceptical frame of mind, as any one may well be excused for doubting the truth of so extraordinary and odious an instinct as that of making slaves**. Hence I give the observations which I have myself made in some little detail. I opened fourteen nests of F. sanguinea, and found a few slaves in each. Males and fertile females of the slave-species (F. fusca) are found only in their own proper communities, and have never been observed in the nests of F. sanguinea. **The slaves are black**, and not above half the size of their **red masters**, so that **the contrast in their appearance is very great**. When the nest is slightly disturbed, the slaves





occasionally come out, and, like their masters, are much agitated, and defend the nest. When the nest is much disturbed, and the larvae and pupae are exposed, the slaves work energetically with their masters in carrying them away to a place of safety. Hence it is clear that the slaves feel quite at home. During the months of June and July, in three successive years, I have watched for many hours several nests in Surrey and Sussex, and never saw a slave either leave or enter a nest. As, during these months, the slaves are very few in number, I thought that they might behave differently when more numerous, but Mr. Smith informs me that he has watched nests at various hours during May, June, and August both in Surrey and Hampshire, and has never seen the slaves, though present in large numbers in August, either leave or enter the nest. Hence he considers them as **strictly household slaves**. The masters, on the other hand, may be constantly seen bringing in materials for the nest and food of all kinds. During the present year, however, in the month of July, I came across a community with an unusually large stock of slaves, and I observed a few slaves mingled with their masters leaving the nest, and marching along the same road to a large Scotch fir-tree, twenty-five yards distant, which they ascended together, probably in search of aphides or cocci. According to Huber, who had ample opportunities for observation, in Switzerland the slaves habitually work with their masters in making the nest, and they alone open and close the doors in the morning and evening; and, as Huber expressly states, their principal office is to search for aphides. This difference in the usual habits of the masters and slaves in the two countries probably depends merely on the slaves being captured in greater numbers in Switzerland than in England.



One day I fortunately witnessed a migration of F. sanguinea from one nest to another, and it was a most interesting spectacle to behold the masters carefully carrying (instead of being carried by, as in the case of F. rufescens) their slaves in their jaws.



Another day my attention was struck by about a score of the slave-makers haunting the same spot, and evidently not in search of food: they approached, and were vigorously repulsed by an independent community of the slave species (F. fusca), sometimes as many as three of these ants clinging to the legs of the slave-making F. sanguinea. The latter ruthlessly killed their small opponents, and carried their dead bodies as food to their nest, twenty-nine yards distant, but they were prevented from getting any pupæ to rear as slaves. I then dug up a small parcel of pupæ of F. fusca from another nest, and put them down on a bare spot near the place of combat; they were eagerly seized and carried off by the tyrants, who perhaps fancied that, after all, they had been victorious in their late combat….

Now I was curious to ascertain whether F. sanguinea could distinguish the pupæ of F. fusca, which they habitually make into slaves, from those of the little and furious F. flava, which they rarely capture, and it was evident that they did at once distinguish them, for we have seen that they eagerly and instantly seized the pupæ of F. fusca, whereas they were much terrified when they came across the pupæ or even the earth from the nest of F. flava, and quickly ran away; but in about a quarter of an hour, shortly after all the little yellow ants had crawled away, they took heart and carried off the pupæ.



One evening I visited another community of F. sanguinea, and found a number of these ants entering their nest, carrying the dead bodies of F. fusca (showing that it was not a migration) and numerous pupæ. I traced the returning file burthened with booty, for about forty yards, to a very thick clump of heath, whence I saw the last individual of F. sanguinea emerge, carrying a pupa; but I was not able to find the desolated nest in the thick heath. The nest, however, must have been close at hand, for two or three individuals of F. fusca were rushing about in the greatest agitation, and one was perched motionless with its own pupa in its mouth on the top of a spray of heath over its ravaged home. (pp. 219-223).

We can perhaps best convey to our readers a clear view of Mr. Darwin's chain of reasoning, and of our objections to it, if we set before them, first, the conclusion to which he seeks to bring them; next, the leading propositions which he must establish in order to make good his final inference; and then the mode by which he endeavours to support his proposition. Here is "*the theory which really pervades the whole volume.*" (p. 57).

Analogy would lead me one step further, namely, to the belief that all animals and plants have descended from some one prototype. But analogy may be a deceitful guide. Nevertheless all living things have much in common, in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction.…Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed [by the Creator]. (p. 484).

But we are too loyal pupils of inductive philosophy to start back from any conclusion by reason of its strangeness. ***Newton's patient philosophy*** *taught him*

to find in the falling apple the law which governs the silent movements of the stars in their courses; and if Mr. Darwin can with the same correctness of reasoning demonstrate to us our fungular descent, we shall dismiss our pride, and avow, with the characteristic humility of philosophy, our unsuspected cousinship with the mushrooms…. Now, the main propositions by which Mr. Darwin's conclusion is attained are these:- 1. That observed and admitted variations spring up in the course of descents from a common progenitor. 2. That many of these variations tend to an improvement of the parent stock. 3. That, by a continued selection of these improved specimens as the progenitors of future stock, ***its improvement may be unlimitedly increased****. 4. And, lastly, that there is in nature a power continually and universally working out this selection, and so fixing and augmenting these improvements.* (pp. 57-58).

What do you think is the strength of each of these propositions? Wilberforce concedes that "*The facts are all gathered from a true observation of nature, and from a patiently obtained comprehension of their undoubted and unquestionable relative significance. That such a struggle for life then actually exists, and that it tends continually to lead the strong to exterminate the weak, we readily admit…But before we can go a step further, and argue from its operation in favour of a perpetual improvement in natural types, we must be shown first that this law of competition has in nature to deal with such favourable variations in the individuals of any species, as truly to exalt those individuals above the highest type of perfection to which their least imperfect predecessors attained…and then, next, we must be shown that there is actively at work in nature, co-ordinate with the law of competition and with the existence of such favourable variations, a power of accumulating such favourable variation through successive descents.* (pp. 61-62).

Wilberforce admits that variation exists in a species and so does selection for superior traits. He wonders however, is there proof that nature has the power to fix this variation into a new and improved species? That is, why don't we see old species turn into new and improved species?

Wilberforce points out that in the past 4000 years of history, domestic pigeons, which are a race eminently subject to **variation** and have been **selected** to produce any given feather, beak, or head, all have identical major structures (e.g., **skeletal**) and all **interbreed**. Moreover, there is reversion of hybrids to the parental type. Consequently, there is more of a tendency for **variations to vanish** and for the hybrids to return or relapse to the parental type than for variations to **become fixed** and form new species. Consequently, Wilberforce considers all domestic pigeons one species. Are they **one diverse species with well-marked varieties** as Wilberforce suggests or are they **each incipient species** as Darwin asserts?










Wilberforce points out that the same is true of the hog, horse, ass, sheep, goat, cow, dog, cat, and chicken: when breeding is relaxed, they tend back to the **original type** without a **SPECIFIC change**. In fact, ever since the wandering Ulysses returned to Ithaca with his dog, **there has not been a SPECIFIC change in dogs** (e.g., no major difference in the skeletal structure or in the ability to breed). Consequently, according to Wilberforce, dogs are **one diverse species with well-marked varieties**. That is, there is an archetypical or Platonic dog with many varied representations.

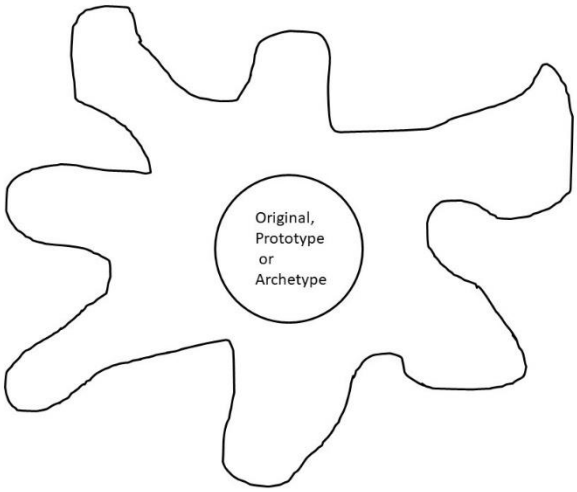


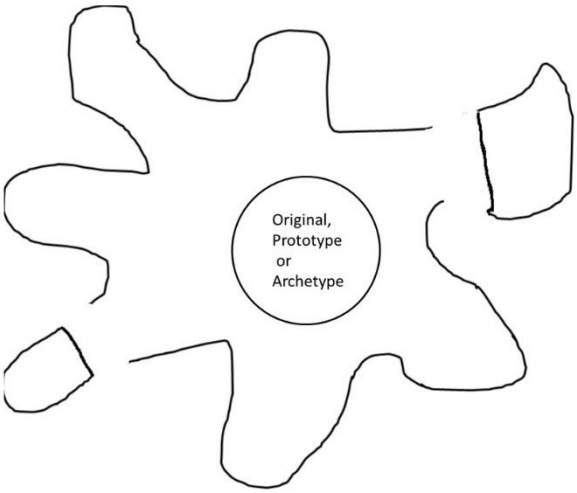
Cats were embalmed in Egypt 4000 years ago and, while there is a lot of variation, there appears to be no SPECIFIC change in cats in the past 4000 years and all cats are of **one diverse species with well-marked varieties**. That is, there is an archetypical or platonic cat with many varied representations.

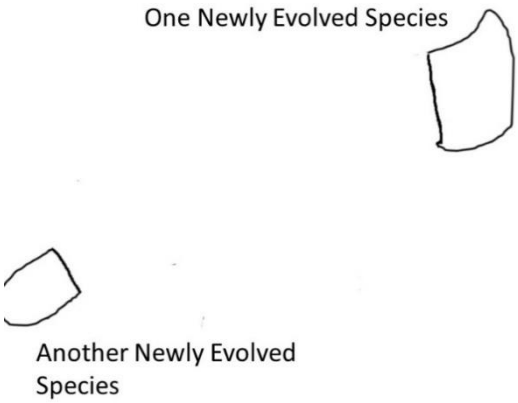


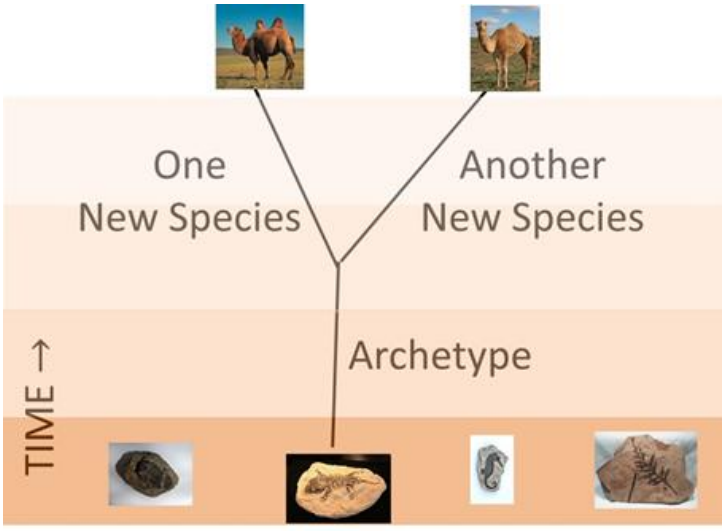


Darwin argues that **nature is a more powerful and continuous selector**, **working over vast expanses of time**, and can do more than man in selecting varieties…that is …can cause ***specific*** or ***species-inducing*** changes…(p. 67).







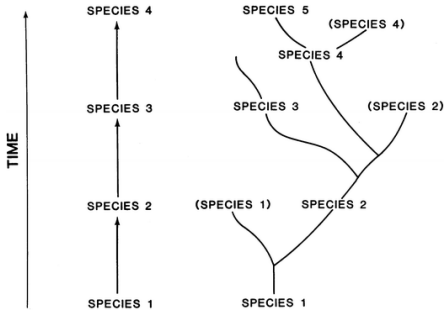


Wilberforce argues that man can only **select one part at the expense of another**…this is a LAW! The **bulldog gains in strength but loses in swiftness**… **the greyhound gains in swiftness but loses in strength**… Man's variations do not IMPROVE the character of an animal because something is lost and something is gained. **Nature tends to kill the monster and stabilize the type**. There is no evidence for accumulating and fixing **specific** variations. (p. 68).

Wilberforce asks, if new species were occurring **shouldn't we see at least one**? He also wonders why the closest microscopic observation has never detected the faintest tendency in the highest of the Algae to improve into the very lowest Zoophyte. (pp. 69-70).

Wilberforce concludes that there is ***no*** evidence for **speciation going on**. What about evidence from the fossil record?

Why then is not every geological formation and every stratum full of such intermediate links? Geology assuredly does not reveal any such finely graduated organic chain; and this, perhaps, is the most obvious and gravest objection which can be urged against my theory. The explanation lies, as I believe, in the extreme imperfection of the geological record. (p. 280).



Now Wilberforce asks, "*On what then is the new theory based? We say it with unfeigned regret, in dealing with such a man as Mr. Darwin, on the merest hypothesis, supported by the most unbounded assumptions. These are strong words, but we will give a few instances to prove their truth:*--" (p. 81).

All physiologists admit that the swim-bladder [in boney fish] is homologous or "ideally similar " in position and structure with the lungs of the higher vertebrate

animals; hence there **seems to me to be no great difficulty in believing** that natural selection has actually converted a swim-bladder into a lung, or organ used exclusively for respiration. (p. 191).

I can indeed hardly doubt that all vertebrate animals having true lungs have descended by ordinary generation from the ancient prototype, of which we know nothing, furnished with a floating apparatus or swim-bladder. (p. 191).

I see no difficulty in supposing that such links formerly existed, and that each had been formed by the same steps as in the case of the less perfectly gliding squirrels, and that each grade of structure was useful to its possessor. Nor **can I see any insuperable difficulty in further believing** it possible that the membrane-connected fingers and forearm of the galeopithecus [flying lemur] might be greatly lengthened by natural selection, and this, as far as the organs of flight are concerned, would convert it into a bat. (p. 181).

Wilberforce protests against the frequent occurrence of statements such as "***I can conceive***"… "***It is not incredible***"… "***I do not doubt***" … "***It is conceivable***" Wilberforce adds, "*In the name of all true philosophy we protest against such a mode of dealing with nature, as utterly dishonourable to all natural science, as reducing it from its present lofty level of being one of the noblest trainers of man's intellect and instructors of his mind, to being a mere idle play of the fancy, without the basis of fact or the discipline of observation."* (pp. 83-84). Is Wilberforce being fair here? Why and/or why not?

Why might someone have a hard time believing what Darwin asks us to believe? Darwin answers,

…the chief cause of our natural unwillingness to admit that one species has given birth to other and distinct species is that we are always slow in admitting any great change of which we do not see the intermediate steps. (p. 481).

But what is **belief** and what is **analysis**? What is **faith** and what is **reason**?

Wilberforce answers, *'Analysis,' says Professor Sedgwick, ' consists in making experiments and observations, and in drawing general conclusions from them by induction, and admitting of no objections against the conclusions but such as are taken from experiments or other certain truths; for hypotheses are not to be regarded in experimental philosophy.' ['A Discourse on the Studies of the University,' by A. Sedgwick, p. 102].*

Wilberforce also rejects Darwin's use of **time**. According to Wilberforce, *The other solvent which Mr. Darwin most freely and, we think, unphilosophically employs to get rid of difficulties, is his use of time. This he shortens or prolongs at will by the mere wave of his magician's rod. Thus the duration of whole epochs, during which certain forms of animal life prevailed, is gathered up into a point, whilst an unlimited expanse of years, impressing his mind with a sense of eternity, is suddenly interposed between that and the next series, though geology proclaims the transition to have been one of gentle and, it may be, swift accomplishment. All this too is made the more startling because it is used to meet the objections drawn from facts. 'We see none of your works,' says the observer of nature; ' we see no beginnings of the portentous change; we see plainly beings of another order in creation, but we find amongst them no tendencies to these altered organisms.' True says the great magician, with a calmness no difficulty derived from the obstinacy of facts can disturb; ' true, but remember the effect of time. Throw in a few hundreds of millions of years more or less, and why should not all these*

changes be possible, and, if possible, why may I not assume them to be real? (pp. 84-85).

Now I think we come to the crux of the matter. Wilberforce writes, "*There are no parts of Mr. Darwin's ingenious book in which he gives the reins more completely to his fancy than where he deals with* ***the improvement of instinct by his principle of natural selection***. *We need but instance his assumption, without a fact on which to build it, that the marvelous skill of the honey-bee in constructing its cells is thus obtained, and the* ***slave-making habits of the Formica Polyerges*** *thus formed. There seems to be no limit here to the exuberance of his fancy, and we cannot but think that we detect one of those hints by which Mr. Darwin indicates the application of his system from the lower animals to man himself,* ***when he dwells so pointedly upon the fact that it is always the black ant which is enslaved by his other coloured and more fortunate brethren. 'The slaves are black!' We believe that, if we had Mr. Darwin in the witness-box, and could subject him to a moderate cross-examination, we should find that he believed that the tendency of the lighter-coloured races of mankind to prosecute the negro slave-trade was really a remains, in their more favoured condition, of the 'extraordinary and odious instinct ' which had possessed them before they had been ' improved by natural selection ' from Formica Polyerges into Homo."*** (pp. 88-89).

Samuel Wilberforce, who obtained a first class in mathematics at Oxford, was a member of the Royal Society of London, and was vice president of the BAAS then states, "*Our readers will not have failed to notice that we have objected to the views with which* ***we have been dealing solely on scientific grounds***. *We have done so from our fixed conviction that it is thus that the truth or falsehood of such arguments should be tried.* ***We have no sympathy with those who object to any facts or alleged facts in nature, or to any inference logically deduced from them,***

***because they believe them to contradict what it appears to them is taught by Revelation**. We think that all such objections savour of a timidity which is really inconsistent with a firm and well-instructed faith:—*

***'Let us for a moment,' profoundly remarks Professor Sedgwick, 'suppose that there are some religious difficulties in the conclusions of geology. How, then, are we to solve them? Not by making a world after a pattern of our own—not by shifting and shuffling the solid strata of the earth, and then dealing them out in such a way as to play the game of an ignorant or dishonest hypothesis—not by shutting our eyes to facts, or denying the evidence of our senses—but by patient investigation, carried on in the sincere love of truth, and by learning to reject every consequence not warranted by physical evidence'** *[Wilberforce's note: 'A Discourse on the Studies of the University, p. 149].*

*He who is as sure as he is of his own existence that the **God of Truth is at once the God of Nature and the God of Revelation**, cannot believe it to be possible that His voice in either, rightly understood, can differ, or deceive His creatures. To oppose facts in the natural world because they seem to oppose Revelation, or to humour them so as to compel them to speak its voice, is, he knows, but another form of the ever-**ready feebleminded dishonesty of lying for God**, **and trying by fraud or falsehood to do the work of the God of truth**. It is with another and a nobler spirit that the true believer walks amongst the works of nature. The words graven on the everlasting rocks are the words of God, and they are graven by His hand. No more can they contradict His Word written in His book, than could the words of the old covenant graven by His hand on the stony tables contradict the writings of His hand in the volume of the new dispensation. There may be to man difficulty in reconciling all the utterances of the two voices.*

But what of that? He has learned already that ***here he knows only in part, and that the day of reconciling all apparent contradictions between what must agree is nigh at hand****. He rests his mind in perfect quietness on this assurance,* ***and rejoices in the gift of light without a misgiving as to what it may discover****:—*" (pp. 92-93).

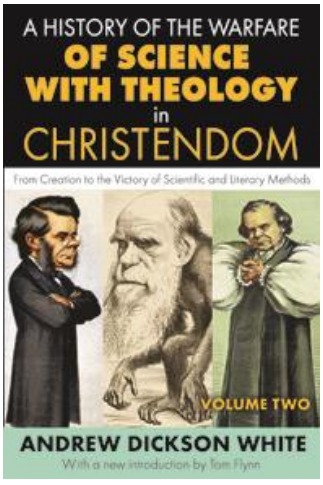
Darwin wrote to J. D. Hooker on July 20, 1860

P.S. I have just read Quarterly R. **It is uncommonly clever; picks out with skill all the most conjectural parts, & brings forwards well all difficulties.** It quizzes me quite splendidly by quoting the Anti-Jacobin versus my grandfather. You are not alluded to; nor, strange to say, Huxley, & I can plainly see here & there Owen's hand. The concluding pages will make Lyell shake in his shoes. By Jove if he sticks to us he will be a real Hero.

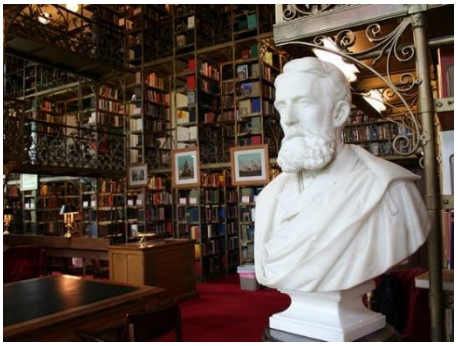
Good night—your well-quizzed, but not sorrowful & affectionate friend. C.D.

I can see there has been some queer tampering with the Review—for a page has been cut out & reprinted.

Harvard University was founded in 1636 and was affiliated with Calvinism. Yale University was founded in 1701 and was affiliated with Calvinism. The University of Pennsylvania was founded in 1740 and was nonsectarian. Princeton University was founded in 1746 and was nonsectarian. Columbia University was founded in 1754 and was affiliated with the Church of England. Brown University was founded in 1754 and was affiliated with Baptists. Dartmouth College was founded in 1769 and was affiliated with Calvinists and Cornell University was founded in 1865 and was nonsectarian.



Andrew Dickson White (1896), the first president of the nonsectarian Cornell University and a historian, wrote about Wilberforce's review of Darwin's Origin of Species and the Oxford debate in his *History of the Warfare of Science with Theology in Christendom* (pp. 70-86):



"Darwin's Origin of Species had come into the theological world like a ***plough into an ant-hill****. Everywhere those thus rudely awakened from their old comfort and repose had swarmed forth angry and confused. Reviews, sermons, books light and heavy, came flying at the new thinker from all sides.*

The keynote was struck at once in the Quarterly Review by Wilberforce, Bishop of Oxford. He declared that Darwin was guilty of "a tendency to limit God's glory in creation"; that "the principle of natural selection is absolutely incompatible with the word of God"; that it "contradicts the revealed relations of creation to its Creator"; that it is "inconsistent with the fulness of his glory"; that it is "a dishonouring view of Nature"; and that there is "a simpler explanation of the presence of these strange forms among the works of God": that explanation being—"the fall of Adam." Nor did the bishop's efforts end here; at ***the meeting of the British Association for the Advancement of Science*** *he again disported himself in the tide of popular applause. Referring to the ideas of Darwin, who was absent on account of illness, he congratulated himself in a public speech that he was not descended from a monkey. The reply came from Huxley, who said in substance: "If I had to choose, I would prefer to be a descendant of a humble monkey rather than of a man who employs his knowledge and eloquence in misrepresenting those who are wearing out their lives in the search for truth."*

This shot reverberated through England, and indeed through other countries.

Whatever additional factors may be added to natural selection—and Darwin himself fully admitted that there might be others—the theory of an evolution process in the formation of the universe and of animated nature is established, and the old theory of direct creation is gone forever. In place of it ***science*** *has given us*

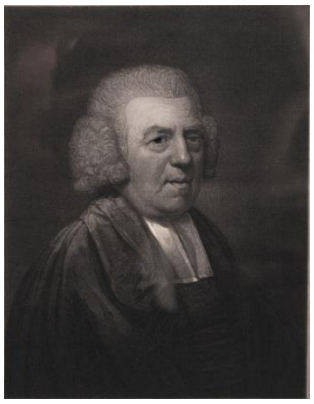
conceptions far more noble, and opened the way to an argument for design infinitely more beautiful than any ever developed by ***theology****."*

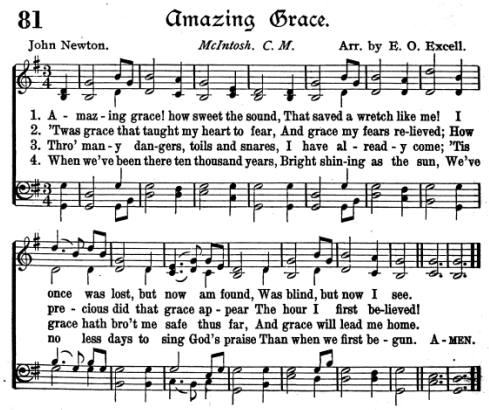
A. D. White, Francis Darwin, and Leonard Huxley never mentioned Wilberforce's scientific criticisms. **Were A. D. White, Francis Darwin, and Leonard Huxley promoting the questioning of authority as long as no one questioned their view of scientific authority**? I personally wonder if the way the scientific establishment, who became a "Darwinist mob," chose to argue or not argue the merits of the case between Wilberforce and Huxley set up the model for the **unquestioning authority of scientism**, the use of *ad hominin* remarks to the "deniers" and "contrarians," and the eventual marginalization of the unfit in the name of **eugenics**. Eugenics is a term that was coined by Darwin's cousin, Francis Galton (http://galton.org/eugenicist.html).

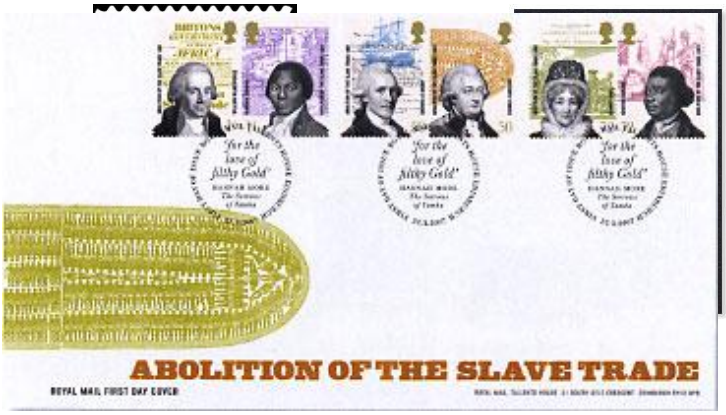


Why was Samuel Wilberforce so concerned about the slave-making instinct of ants and that this instinct may be inherited by humans? Samuel Wilberforce's father was **William Wilberforce**. William was influenced by his friend named **John Newton** (1788), the author of *Thoughts upon the African Slave Trade* and the hymn **Amazing Grace**. The autobiographical hymn is about Newton, who was a slave trader and realized that he was lost. He got William Wilberforce to become an abolitionist and Wilberforce spent the rest of his life to end the slave trade in the British Empire. http://www.amazinggracemovie.com/ William Wilberforce was well-known in the nineteenth century. He was mentioned by Harriet Beecher Stowe in *Uncle Tom's Cabin* published in 1852 and by Abraham Lincoln during a debate in 1858.







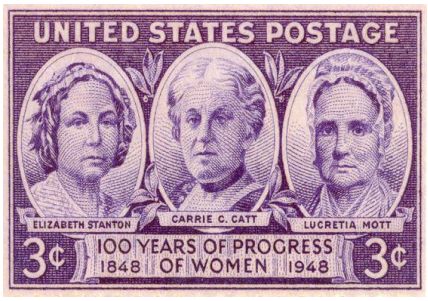


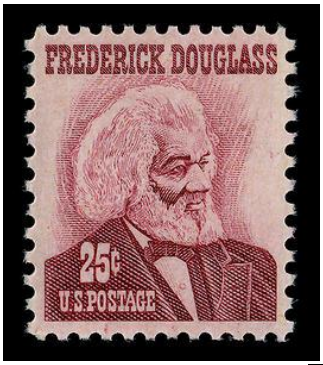
Do any of you know the name of William Wilberforce? If not, I bet you know the names of other freedom fighters such as Abraham Lincoln, Martin Luther King, Cesar Chavez, Mahatmas Gandhi, Frederick Douglass, Elizabeth Cady Stanton, Susan B. Anthony, and Nelson Mandela. William Wilberforce belongs with this group. Martin Luther King Jr. (1957) used the example of William Wilberforce as a way of "Conquering Self-centeredness" in a sermon delivered at Dexter Avenue Baptist Church: "*And the way to solve this problem is not to drown out the ego but to find your sense of importance in something outside of the self. And you are then able to live because you have given your life to something outside and something that is meaningful, objectified. You rise above this self-absorption to something outside. We look through history. We see that biography is a running commentary of this. We see a Wilberforce. We see him somehow satisfying his desire by absorbing his life in the slave trade, those who are victims of the slave trade. …And then we can even*



find Jesus totally objectifying himself when he cries out, 'Ye have done it unto the least of these my brethren, ye have done it unto me.'"

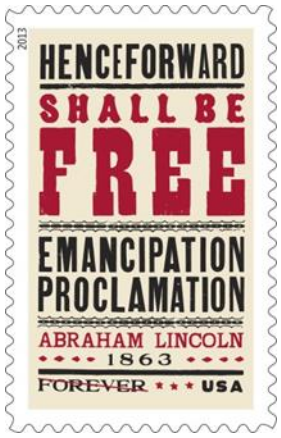










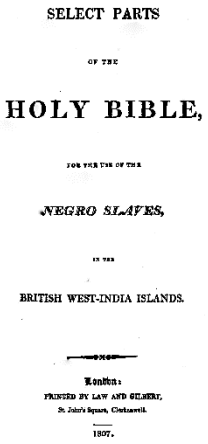






© Can Stock Photo - csp13383903

During the time William Wilberforce was working to end the slave trade and slavery, the Society for the Conversion of Negro Slaves (1807) had a Bible printed that could be used in the British West-India Islands. It was entitled, "*Select Parts of the Holy Bible for the use of the Negro Slaves in the British West-India Islands*." Exodus begins at Chapter 19. Passages such as "*There is neither Jew nor Greek, there is neither* ***bond nor free****, there is neither male nor female: for ye are all one in Christ Jesus*" (Galatians 3:28) were omitted while passages such as "*Servants, be obedient to them that are your masters according to the flesh, with fear and trembling, in singleness of your heart, as unto Christ*" (Ephesians 6:5) were kept. That is, passages that could incite rebellion were removed while those that promoted submission to authority were retained.


SELECT PARTS

OF THE

HOLY BIBLE,

FOR THE USE OF THE

NEGRO SLAVES,

IN THE

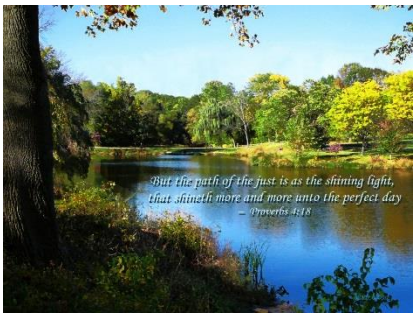
BRITISH WEST-INDIA ISLANDS.

London:
PRINTED BY LAW AND GILBERT,
St. John's Square, Clerkenwell.
1807.

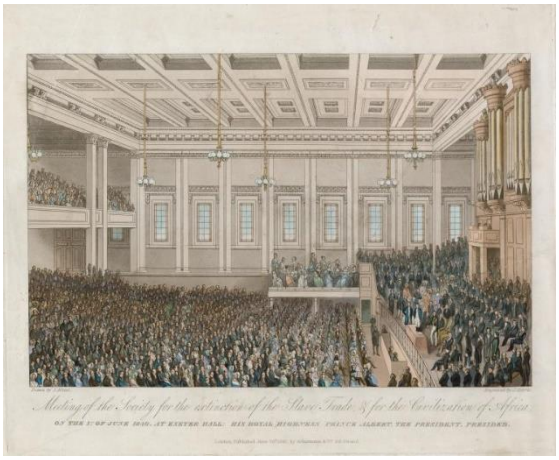
https://books.google.com/books/about/Select_parts_of_the_holy_Bible_for_the_u.html?id=e9gHAAAAQAAJ)

Samuel Wilberforce (1868) wrote a book about his father's life entitled, *Life of William Wilberforce*. He ended the book like so: "*A number of those who had been indebted to his kindness met after his funeral, 'with feelings almost as disconsolate as those of the bereaved apostles, to lament his loss.' 'Great part of our coloured population, who form here an important body,' writes a dignified clergyman from the West Indies, 'went into mourning at the news of his death.' The same honour was paid his by this class of persons at New York, where also an eulogium (since printed) was pronounced upon him by a person publicly selected for the task, and their brethren throughout the United States were called upon to pay the marks of external respect to the memory of their benefactor. For departed kings there are appointed honours, and the wealthy have their gorgeous obsequies: it was his nobler portion to clothe a people with spontaneous mourning, and go down to the grave amid the benedictions of the poor.*"

"*It is impossible to conclude this history without noting the truth of the inspired words: 'Godliness has the promise of the life that now is well as that which is yet to come.' If ever any man drew the lot of a happy life, he did so who has been described. Yet his Christian faith was from first to last the talisman of his happiness. Without it the buoyancy of his youthful spirits led to a frivolous and unsatisfying waste of life. With it came lofty conceptions—an energy which triumphed over sickness and languor, over the coldness of friends and the violence of enemies—a calmness not to be provoked—a perseverance which repulse could not baffle. To these virtues was owing the happiness of his active days.*

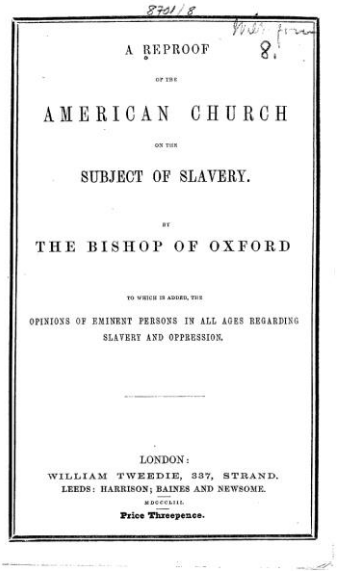


Through the power of the same sustaining principle, his affection towards his fellow-creatures was not dulled by the intercourse with the world, nor his sweetness of temper impaired by the irritability of age. A firm trust in God, an undeviating submission to His will, an overflowing thankfulness—these maintained in him to the last that cheerfulness which this world could neither give nor take away. They poured even upon his earthly pilgrimage the anticipated radiance of that brighter region, to which the servants of God are admitted, For 'the path of the just is like the ***shining light****, which* ***shineth*** *more and more unto the perfect day.'"*

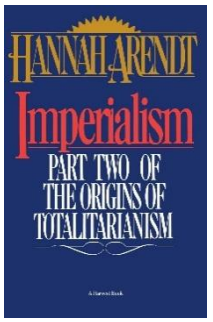


There was still more work to be done in endling slavery throughout the world. His Royal Highness Prince Albert presided over the Meeting of the **Society for the Extinction of the Slave Trade,** & for the Civilization of Africa on June 1, 1840. Hundreds of British and 50 Americans attended. Prince Albert said, "*I have been induced to preside at the Meeting of this Society, from a conviction of its paramount importance to the great interests of humanity and justice. I deeply regret that the benevolent and persevering exertions of England to abolish that atrocious traffic in human beings (at once the desolation of Africa and the blackest stain upon civilized Europe) have not as yet led to any satisfactory conclusion. But I sincerely trust that this great country will not relax in its efforts until it has finally, and for ever, put an end to a state of things so repugnant to the spirit of Christianity, and* ***the best feelings of our nature.*** *Let us therefore trust that Providence will prosper our exertions in so holy a cause, and that (under the auspices of our Queen and Her Government) we may at no distant period be*

rewarded by the accomplishment of the great and humane object for the promotion of which we have this day met."


A REPROOF
OF THE
AMERICAN CHURCH
ON THE
SUBJECT OF SLAVERY.
BY
THE BISHOP OF OXFORD
TO WHICH IS ADDED, THE
OPINIONS OF EMINENT PERSONS IN ALL AGES REGARDING SLAVERY AND OPPRESSION.
LONDON:
WILLIAM TWEEDIE, 337, STRAND.
LEEDS: HARRISON; BAINES AND NEWSOME.
Price Threepence.

After his father William Wilberforce brought a successful end to the slave trade and slavery in the British Empire, Samuel Wilberforce (1844,1853) fought to end slavery in America. "*Of the twenty-six states, thirteen are slave states; admitting, that is, within their own borders, the institution of Slavery as a part of their institutions; and of these, five—Maryland, Virginia, Kentucky, Missouri, and in part, Tennessee—are slave-selling, whilst those south of them are slave-buying states….Accordingly, the master-evil of the South is, that the slaves are not treated as having souls…. 'Let no man from henceforth,' said the Christian Council of London, in 1102, 'presume to carry on that wicked traffic, by which men in England have been hitherto sold like brute animals.' This must be the Church's rule on the banks of the Mississippi, as it was on those of the Thames."*



As described by Hannah Arendt (1976), in *The Origins of Totalitarianism*, in the 19th century, racism combined with bureaucracy allowed the seemingly endless expansion of the British Empire throughout the world. The *Great Game* of expansion for expansion's sake, is well

characterized by Cecil Rhodes, who said, "*The world is nearly all parcelled out, and what there is left of it is being divided up, conquered and colonised. To think of these stars that you see overhead at night, these vast worlds which we can never reach. I would annex the planets if I could; I often think of that. It makes me sad to see them so clear and yet so far*."

Wilberforce University, named after William Wilberforce, was the first predominantly African-American Private University in the United States. It was founded in 1856 by members of the Methodist Episcopalian Church. The Wilberforce School in Princeton, NJ, was also named after him.

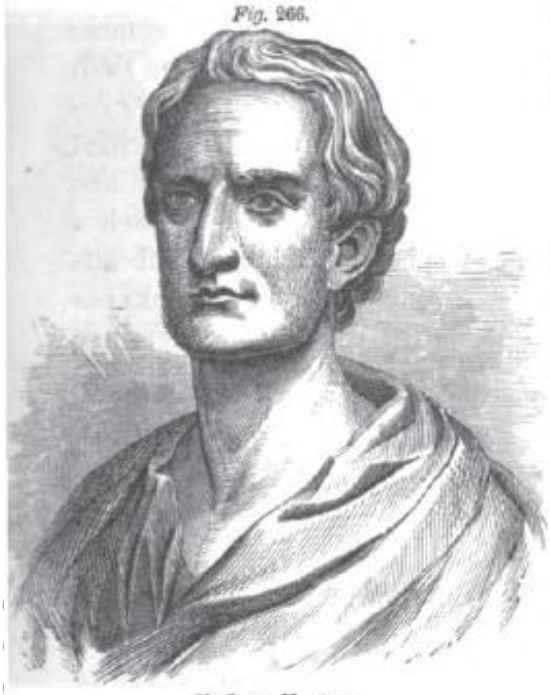
In May 1860, just a month before the meeting of the BAAS at Oxford, Samuel Wilberforce gave speeches on behalf of the Oxford and Cambridge Mission to Central Africa. He said, "*The Gospel must be brought from without from those who had now the **lamp of truth**, and who had it in order that they might **enlighten** others as well as themselves. The grounds which should induce us to make some great and hearty efforts to carry God's truth among His people were, that they need it greatly, that they are ready to receive it, that we are specially called to impart it from close connection with them, and because **as the children of slave traders we had to cut off the entail of curses by reversing the inheritance of wrong which the slave trade had inflicted upon Africa.**"*

I think that Samuel Wilberforce like Thomas Jefferson believed, "**We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness.** I think that Wilberforce would have accepted Darwinian Theory if the **evidence** from the **fossil record** was strong enough and if someone could show that a **new and improved species was differentiated from a pre-existing and less improved species.** That is **macroevolution** (which he rejected) as opposed to **microevolution** (which he accepted). But in the absence of that data, he would not accept the theory because the theory could serve as a **natural law justification** for a **slave-making instinct in humans** at a time when England was looking for **new colonies** to replace the lost American colonies. Science is often used to provide a natural law for justifying political, social, and economic policy. For example, **John Draper** (1861) wrote in *History of the Intellectual Development of Europe* that the "*Social advancement is as completely under the control of natural law as is bodily growth."* The page below is from Draper's book on *Human Physiology*, the same John Draper who was the keynote speaker in June 1860 at the BAAS meeting in Oxford.



THERE are great differences in the aspect of men.
The portrait of Newton is from the frontispiece of his immortal Prin-

Fig. 266.



Sir Isaac Newton.

cipia. "Does he eat, and drink, and sleep, like other people?" ask- Differences in form, color, and dispositions of men.

Fig. 267.



Australian.

ed the Marquis de l'Hôpital, himself a great contemporary French math-

ard has furnished. This man lives in a hollow tree, which he has in part excavated by fire, and obtains a precarious support from shell-fish, or bruised ants and grass. He can make a hook of a piece of oyster,

There was no "consensus" among great scientists regarding the value and the limitations of Darwin's theory of evolution by natural selection. Two Harvard scientists, **Asa Gray** (1860) and **Louis Agassiz** (1874) reviewed the *Origin of Species* in the *Atlantic Monthly*:

Louis Agassiz's review, like Wilberforce's, was critical: https://books.google.com/books/about/Evolution_and_Permanence_of_Type.html?id=wQVbAAAAQAAJ, writing, "*Darwin has placed the subject on a different basis from that of all his predecessors, and has brought to the discussion a vast amount of well-arranged, information, a convincing cogency of argument, and a*

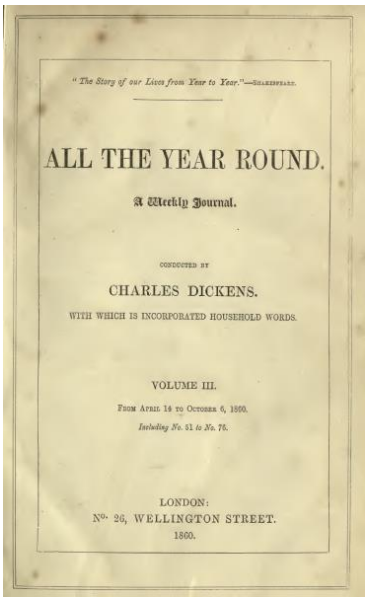
captivating charm of presentation. His doctrine appealed the more powerfully to the scientific world because he maintained it at first not upon metaphysical ground but upon observation. ***Indeed it might be said that he treated his subject according to the best scientific methods, had he not frequently overstepped the boundaries of actual knowledge and allowed his imagination to supply the links which science does not furnish.***

Asa Gray's review was more accepting: https://www.theatlantic.com/magazine/archive/1860/07/darwin-on-the-origin-of-species/304152/

When species, like individuals, were found to die out one by one, and apparently to come in one by one, a theory for what Owen sonorously calls "the continuous operation of the ordained becoming of living things" could not be far off… That all such theories should take the form of a derivation of the new from the old seems to be inevitable, perhaps from our inability to conceive of any other line of secondary causes, in this connection. Owen himself is apparently in travail with some [non gradual] *transmutation theory of his own conceiving, which may yet see the light, although Darwin's came first to the birth. Different as the two theories will probably be in particulars, they cannot fail to exhibit that fundamental resemblance in this respect which betokens a community of origin, a common foundation on the general facts and the obvious suggestions of modern science. Indeed,- to turn the point of a taking simile directed against Darwin,— the difference between the Darwinian and the Owenian hypotheses may, after all, be only that between homoeopathic and heroic doses of the same drug.* We will discuss Owen's theory in a later lecture.

Today, the Green New Deal is justified in the name of "Science" but what are the values and limitations of the evidence supporting the Green New Deal? https://ocasio-cortez.house.gov/sites/ocasio-cortez.house.gov/files/Resolution%20on%20a%20Green%20New%20Deal.pdf.

Charles Dickens (1842), who wrote ardently against slavery in *American Notes for General Circulation*, weighed in on Charles Darwin's Origin of Species in what may be called **A Tale of Two C.D.s**:


"The Story of our Lives from Year to Year."—SHAKESPEARE.

ALL THE YEAR ROUND.

A Weekly Journal.

CONDUCTED BY

CHARLES DICKENS.

WITH WHICH IS INCORPORATED HOUSEHOLD WORDS.

VOLUME III.

FROM APRIL 14 TO OCTOBER 6, 1860.

Including No. 51 to No. 76.

LONDON:
No. 26, WELLINGTON STREET.
1860.

In an article entitled *Natural Selection*, published in Dickens' magazine All the Year Round (3, 293-299; https://archive.org/details/allyearround03dick/page/n7), Dickens (1860) wrote about Darwin's theory of natural selection as applied to the evolution of structures and the evolution of instincts: *It is well for Mr. Charles Darwin, and a comfort to his friends, that he is living now, instead of having lived in the sixteenth century; it is even well that he is a British subject, and not a native of Austria, Naples, or Rome. Men have been kept for long years in durance, and even put to the rack and the stake, for the commission of offences minor to the publication of ideas less in opposition to the notions held by the powers that be.*

*But we have come upon more tolerant times. If a man can calmly support his heresy by reasons, the heresy will be listened to; and, in the end, will be either received or refuted, or simply neglected and forgotten. Mr. Darwin also enjoys the benefit of the bygone heresies of previous heretics; one heresy prepares the way for, and weakens the shock occasioned by, another. Astronomical and geological innovations render possible the acceptance of doctrines that would have made people's hair stand on end three centuries ago. This is an enormous progress; for what are three or four centuries in the history of the human race? What, in the history of the world? Truth is a bugbear which is fast losing its terrors: we are getting more and more accustomed to it, and are less and less afraid to look it in the face. But then comes the old question, "**What is Truth?**" Mr. Darwin believes he knows, or is on the way to know.*

Charles Darwin comes of a family renowned for close observation, intellectual ability, and boldness of speculation; he is gifted with clear and passionless judgment, and with an amiable and gentlemanly disposition; it is doubtful whether he have an enemy in the world; it is certain that he has, and deserves to have, many friends. He is blessed with a sufficiency of worldly riches, and has not strong health — the very combination to make a student. He is sincerity itself, thoroughly believing all he states, and daring to state what he believes. No mental reservation is employed to dissemble the tendency of his scientific views. He has circumnavigated the globe, and beheld the manners of many men, savage and civilised; of many birds, beasts, reptiles, and fishes. He has compared living forms with those which existed on the same spot of land ages and ages ago. In his Voyage with the Beagle he has delighted his readers with the simplicity and the clearness with which he has explained geological changes. For more than twenty years he has been patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on the origin of living things as we now behold them existing; regardless of expense and labour, he has long searched for the truth respecting this question. He believes he has found it, and he enunciates his creed in a book which is an abstract of a larger work that will take two or three more years to complete.

But, as the tolerant spirit of the age allows him to state and to hold his belief unmolested, it also allows dissenters from his novel doctrines to declare their unbelief of them, and to manifest the hardness of their hearts by utter deafness to Mr. Darwin's most persuasive attempts at conversion. The world in general is quite unprepared to hear his unaccustomed views propounded. The propositions are so unfamiliar, that, be they false or be they true, they are almost sure to meet with a flat denial. The dominant and fundamental idea may be grand, clear, and decided. ***As a theory, it is complete and harmonious in all its parts, regarded merely as a theory; but, as a history of the past, and as a statement of present and future facts, its authority must entirely rest on the reader's judgment whether the proofs and the reasoning are conclusive to his mind or not. It is a question of the interpretation to be given to certain appearances and occurrences; it is a matter of circumstantial evidence****. Mr. Darwin is already supported by a small party of disciples and fellow-labourers, who put faith in his inspiration; while the great majority shrink back in alarm at the boldness of his conclusions, and at the illimitable lapse of time which it unfolds before their wondering and bewildered gaze. He will*

hardly be surprised himself — nor will the reader — to find that the mass of his audience have ears but hear not, and eyes but see not — as he sees and understands the works of nature. ***Before accepting such a theory, we, the multitude, must think twice. Well, let us think twice; thinking twice never does harm****.*

The creed to which it is proposed to convert the world is as follows: Although much remains obscure, and will long remain obscure, Mr. Darwin entertains no doubt that the view which most naturalists entertain, and which he formerly entertained himself — namely, that each species has been independently created — is erroneous. ***He is fully convinced that species are not immutable****;* [* See "Species," in All the Year Round, No. 58, p. 174.]* ***but that those belonging to what are called the same genera are lineal descendants of some other and generally extinct species****.*

The modifications which species have undergone are mainly, but not exclusively, he believes, the result of a process called Natural Selection. He cannot doubt that ***the theory of descent, with modification****, embraces all the members of the same class. He believes that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number. Analogy would lead him one step further; namely, to the belief that, in the beginning, there arose some single, primitive, rudimentary, organised cell, or elementary being, which was the first parent of every living creature — that all animals and plants have descended from some one prototype. But* ***analogy****, he owns, may be a deceitful guide. Nevertheless,* ***all living things have much in common in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction****. We see this even in so trifling a circumstance as that the same poison often similarly affects plants and animals; or that the poison secreted by the gall-fly produces monstrous growths on the wild rose or oak-tree. Therefore, Mr. Darwin would* ***infer from analogy*** *that, probably, all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed by the Creator.*

Is it too much to say that, in the good old times, opinions like these would have been strongly redolent of fagot and flame?

Our philosophical reformer adduces numerous facts which he holds to be inexplicable on the theory of independent acts of creation. By the supposition of a migration, with subsequent modification, we can see why oceanic islands should be inhabited by few species, but, of these, that many should be peculiar. We can clearly see why those animals which cannot cross wide spaces of ocean, as frogs and terrestrial mammals, should not inhabit oceanic islands; and why, on the other hand, new and peculiar species of bats, which can traverse the ocean, should so often be found on islands far distant from any continent. The grand facts respecting the grouping of all organic beings on certain areas of the earth's surface — such as a predominance of monkeys with prehensile tails in one country, of ant-eaters and toothless animals in another, of pouched animals in another, of a peculiar modification of leaves in Australian shrubs, of peculiar aloes or agaves in America — are inexplicable on the theory of creation.

Glancing at instincts, marvellous as some are, they offer, it appears, no greater difficulty than does corporeal structure, on the theory of the Natural Selection of successive, slight, but profitable, modifications. We can thus understand why nature moves by graduated steps in endowing different animals of the same class with their several instincts. On the view of all the species of the same genus having descended from a common parent, and having inherited much in common, we can understand how it is that allied species, when placed under considerably different conditions of life, yet should follow nearly the same instincts; why the male wrens of North America, for instance, build "cock-nests" to roost in, like the males of our distinct kitty-wrens — a habit wholly unlike that of any other known bird. ***On the view of instincts having been slowly acquired through Natural Selection****, we need not marvel at some instincts being apparently not perfect, but liable to mistakes, as when blow-flies lay their eggs in the carrion-scented flowers of stapelias;* ***nor at many instincts causing other animals to suffer, as when ants make slaves of their fellow-ants****, when the larvae of ichneumon flies feed within the live bodies of caterpillars, and when the nestling cuckoo ungratefully ejects his legitimate foster-brethren out of the family nest.*

Instincts are as important as bodily structure for the welfare of each species*, under the conditions of life by which it happens to be surrounded. Under changed circumstances, it is possible that slight modifications of instinct might be profitable to a species; and if it can be shown that instincts do vary ever so little, then Mr. Darwin sees no difficulty in Natural Selection*

preserving and continually accumulating variations of instinct to any extent that may be profitable. His line of argument — ***and the whole volume is one long argument — may be summed up in this: give him an inch, and he takes an ell****. Instincts certainly do vary — for instance, the migratory instinct varies, both in extent and direction, and in its total loss. So it is with the nests of birds, which vary partly in dependence on the situations chosen and on the nature and temperature of the country inhabited, but often from causes wholly unknown to us. It is thus, he believes, that all the most complex and wonderful instincts have originated; although no complex instinct can possibly be produced except by the slow and gradual accumulation of numerous slight, yet profitable, variations, requiring ages upon ages, and tens of thousands, perhaps hundreds of millions, of generations to work them out. For Mr. Darwin assumes such an inconceivably vast period of lapsed time for the accomplishment of his theory, that it is simply not eternity, because it had beginning.*

Variations of instinct, thus acquired, become, in races, habitual and hereditary*. Habit and the selection of so-called accidental variations, have played important parts in modifying the mental qualities of our domestic animals. It cannot be doubted that young pointers will sometimes point, and even back other dogs, the very first time that they are taken out; retrieving is certainly in some degree inherited by retrievers; as is a tendency to run round, instead of at, a flock of sheep by shepherds' dogs. These actions do not differ essentially from true instincts; for the young pointer can no more know that he points to aid his master, than the white butterfly knows why she lays her eggs on the leaf of the cabbage. How strongly these habits and dispositions are inherited, and how curiously they become mingled, is well shown when different breeds of dogs are crossed. A cross with the greyhound has given to a whole family of shepherds' dogs, the lurchers, a tendency to hunt hares, rendering them invaluable to poachers. Le Roy describes a dog whose great-grandfather was a wolf, and this dog showed a trace of its wild parentage only in one way — by not coming in a straight line to his master when called.*

To understand how instincts in a state of nature have become modified by Natural Selection, let us consider the case of the cuckoo. It is commonly admitted that the more immediate and final cause of the cuckoo's instinct is that she lays her eggs, not daily, but at intervals of two or three days; so that, if she were to make her own nest and sit on her own eggs, those first laid would have to be left for some time unincubated, or there would be eggs, and

young birds of different ages in the same nest; which would make the process of laying, hatching, and rearing the young, inconveniently long and troublesome. The American cuckoo makes her own nest, and has eggs and young successively hatched, all at the same time.

Now, instances can be given of various birds which have been known occasionally to lay their eggs in other birds' nests. Let us suppose that the ancient progenitor of our European cuckoo had the habits of the American cuckoo, but that she occasionally laid an egg in another bird's nest by way of experiment. If the old bird profited by this occasional habit, or if the young were made more vigorous by the mistaken maternal instinct of another bird than by their own mother's care, encumbered as she can hardly fail to be by having eggs and young of different ages at the same time, then the old birds, or the fostered young, would gain an advantage. And analogy leads Mr. Darwin to believe that the young thus reared would be apt to follow, by inheritance, the occasional and aberrant habit of their mother, and in their turn would possibly lay their eggs in other birds' nests, and thus be successful in rearing their young. By a continued process of this nature, he believes that the strange instinct of our cuckoo could be, and has been, generated.

To Mr. Darwin, this explanation appears conclusive; other persons, less under the influence of a fixed idea, may observe that, ***with the help of an "if" and a "suppose," there is little difficulty in explaining anything***.

The occasional habit of birds laying their eggs in other birds' nests, either of the same or of a distinct species, is not very uncommon with the Gallinaceae; it is frequent with domestic hens; and this, perhaps, explains the origin of a singular instinct in the allied group of ostriches, for several hen ostriches, at least in the case of the American species, unite and lay, first a few eggs in one nest, and then the rest in another, and these are hatched by the males. This instinct may probably be accounted for by the fact of the hens laying a large number of eggs, but, as in the case of the cuckoo, at intervals of two or three days. The instinct, however, of the American ostrich has not as yet been perfected; for a surprising number of eggs lie strewed over the plains, so that in one day's hunting Mr. Darwin himself picked up no less than twenty lost and wasted eggs.

Many bees are parasitic, and always lay their eggs in the nests of bees of other kinds. This case is more remarkable than that of the cuckoo, for these bees have not only their instincts, but their structure also, modified in accordance with their parasitic habits: they do not possess the pollen-collecting apparatus which would be necessary if they had to store food for their own young. Some species likewise of Sphegidae (wasp-like insects) are parasitic on other species; and M. Fabre has lately shown good reason for believing that although the Tachytes nigia generally makes its own burrow and stores it with paralysed prey for its own larvae to feed on, yet that when this insect finds a burrow already made and stored by another sphex, it takes advantage of the prize, and becomes, for the occasion, parasitic. In this case, as with the supposed case of the cuckoo, Mr. Darwin can see no difficulty in Natural Selection making an occasional habit permanent, if, advantage to the species, and if the insect whose nest and stored food are thus feloniously appropriated, be not thus exterminated.

Such ideas are opposed to the belief of philosophers who hold that the various species of plants and animals have been independently created, and have been purposely fitted and adapted to the place in creation which they were intended to occupy by an Overruling Intelligence; for it is maintained that the more complex organs and instincts have been perfected, not at once in the first-created individual, by the Hand of the Maker, but by the accumulation of innumerable slight variations, each good for the individual possessor for the time being, during an exceedingly long succession of individuals from generation to generation.

The result is asserted to have been effected in this way: ***there can be no doubt that species give rise to minor varieties****; for no two individuals are exactly alike, but may be easily distinguished one from the other. A shepherd knows every sheep in his flock, a huntsman every hound in his pack, calling it by name; a busy-body knows every face in his village and its neighbourhood; probably a bee knows every bee belonging to its hive.* ***Variations are often hereditary****; red-haired parents will probably have a red-haired family. Varieties of talent and bodily strength are hereditary; diseases and defects are hereditary, as is every day seen with consumption and deafness. If any animal or plant in a state of nature be highly useful to man, or from any cause closely attract his attention, varieties of it will almost universally be found recorded.* ***Now, individual differences are considered by Mr. Darwin as the first step towards***

such slight varieties as are barely thought worth mentioning in works on natural history: varieties which are in any degree more distinct and permanent, are steps leading to more strongly marked and more permanent varieties; and these latter lead to sub-species, and to species. In short, all organised and animated forms are in a state of passage from one stage of difference to another; all nature is moving insensibly forwards up the slope of one vast sliding scale; the world is a never-ceasing workshop for the process of manufacturing new species of plants and animals.

Mr. Darwin believes that any well-marked variety may be called an incipient species; and herein lies the whole turning-point, the cornerstone, perhaps the stumbling-block, of his System of Nature; grant him that, and nothing can stop the career of his theory; give him that inch, and he may take, not an ell, but a hundred thousand miles of philosophical territory. ***Conscious of the importance of his postulate, he candidly observes: "Whether this belief" (that varieties are incipient species)" be justifiable, must be judged of by the general weight of the several facts and views given throughout this work***." *Achilles is a mighty man, but unfortunately he is afflicted with a vulnerable heel. Elsewhere he says: "It has often been asserted, but the assertion is quite incapable of proof, that the amount of variation under nature is a strictly limited quantity." But there's the rub. A mathematical demonstration may be impossible; but certain observers and experimenters say that their experiments and observations strongly tend to the belief that varieties do not vary beyond certain limits; that is the impression which their minds receive from what they see; just as Mr. Darwin's observations strongly tend to make him view all existing beings, not as special creations, but as the lineal descendants of some few beings which lived long before the first bed of the Silurian system was deposited, and to conclude thence that (as all the living forms of life are the lineal descendants of those which lived long before the Silurian epoch) we may feel certain that the ordinary succession by generation has never once been broken, that no cataclysm has desolated the whole world, and that we may look with some confidence to a secure future of equally inappreciable length.*

But no human intellect, unaided by revelation, is at present able to make such conclusions as these matters either of positive proof or of positive refutation. They must remain a question of opinion, a balancing of probabilities, in which each man judges according to his lights, the tone of his mind, and the inferences which his previous notions

lead him to draw from the premises before him. Two men may arrive at contrary opinions, both reasoning with perfect sincerity of heart and desire for truth, *For instance, while Mr. Darwin holds that the world has been desolated by no past cataclysm and need apprehend no future one (which is contrary to the universal tradition and belief of civilised nations), M. Boutigny, a savant, of high rank in his own country, asserts, with specious and plausible argument, not only that the moon was shot out by a convulsive explosion from the earth, but that our planet may any day be seized with the throes of a universal earthquake which shall end in the expulsion of a second satellite; in which case, every living thing must be destroyed by fire. No cataclysm! Why Messieurs Adhémar and Lehon, distinguished men of science, believe that they have proved that a grand deluge must inevitably devastate the globe every ten thousand five hundred years* [* See All the Year Round, No. 52, p. 40.]; that such deluges have regularly occurred during all previous time, and that such will recur again at their stated epochs; and that, although these grand deluges may not be so universal as to desolate the whole world, they are cataclysms sufficiently terrific to exterminate the great majority of existing creatures, and to render a fresh act of creation an event at least desirable and called for by circumstances.*

*To return to the theory by which independent creations are obviated. Nature is most prodigal in conferring life****. More individuals of every kind, both plants and animals, are produced than can possibly survive, and there must in every case be a contest for life; either between individuals of the same species, or between the individuals of distinct species.*** *It is* ***Malthus****'s doctrine applied to the whole animal and vegetable kingdoms, with increased force; for, in this case, there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing more or less rapidly in numbers, all cannot so increase, for the world would not hold them. There is no exception to the rule that every organic being naturally increases at so high a rate, that, if not destroyed, the earth would soon be covered by the progeny of a single pair.* ***Even slow-breeding man has doubled in twenty-five years; and at this rate, in a few thousand years there would literally not be standing-room for his progeny****. Linnaeus has calculated that if an annual plant produced only two seeds — and there is no plant so unproductive as this — and their seedlings next year produced two, and so on, then, in twenty years, there would be a million of plants.*

As a consequence, the weakest goes to the wall; it is a race for life, with the deuce taking the hindmost. A grain in the balance will determine which individual shall live and which shall die: which variety or species shall increase in number, and which shall decrease, or finally become extinct*. The slightest advantage in one being, at any age or during any season, over those with which it comes into competition, or any better adaptation in however slight a degree to the surrounding physical conditions, will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. This is Natural Selection — a power which acts during long ages, rigidly scrutinising the whole constitution, structure, and habits of each creature — favouring the good and rejecting the bad. Though nature grants vast periods of time for the work of natural selection, she does not grant an indefinite period; for as all organic beings are striving, it may be said, to seize on each place in the economy of nature, if any one species does not become modified and improved in a corresponding degree with its competitors, it will soon be exterminated.*

Cases of adaptation which have hitherto been attributed to design and contrivance are by this theory regarded as the result of natural selection only. When we see leaf-eating insects green, and bark-feeders mottled grey, the Alpine ptarmigan white in winter, the red grouse the colour of heather, and the black grouse that of peaty earth, we must believe that those tints are of service to these birds and insects in preserving them from danger. Grouse, if not destroyed at some period of their lives, would increase in countless numbers — they are known to suffer largely from birds of prey; and hawks are guided by eyesight to their prey — so much so, that on parts of the Continent persons are warned not to keep white pigeons, as being the most liable to destruction. Hence Mr. Darwin can see no reason to doubt that Natural Selection might be effective in giving the proper colour to each kind of grouse, and in keeping that colour, when once acquired, true and constant.

To make it clear how Natural Selection acts, an imaginary illustration is given. Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer, for instance, had from any change in the country increased in numbers, or that other prey had decreased in

numbers, during that season of the year when the wolf is hardest pressed for food. Under such circumstances, there is no reason to doubt that the swiftest and slimmest wolves would have the best chance of surviving, and so be preserved or selected — provided always that they retained strength to master their prey at this or some other period of the year, when they might be compelled to prey on other animals. There seems no more reason to doubt this, than that man can improve the fleetness of his greyhounds by methodical selection, or by that unconscious selection which results from each man trying to keep the best dogs without any thought of modifying the breed.

Even, without any change in the proportional numbers of the animals on which our wolf preyed, a cub might be born with an innate tendency to pursue certain kinds of prey. Nor can this be thought very improbable; for we often observe great differences in the natural tendencies of our domestic animals; one cat, for instance, taking to catching rats, another mice; one cat, according to Mr. St. John, bringing home winged game, another hares, or rabbits, and another hunting on marshy ground and almost nightly catching woodcocks or snipes. The tendency to catch rats rather than mice is known to be inherited. Now, if any slight innate change of habit or of structure benefited an individual wolf, it would have the best chance of surviving and of leaving offspring. Some of its young would probably inherit the same habits or structure, and by the repetition of this process, a new variety might be formed which would either supplant or coexist with the parent form of wolf. Or, again, the wolves inhabiting a mountainous district, and those frequenting the lowlands, would naturally be forced to hunt different prey; and from the continued preservation of the individuals best fitted for the two sites, two varieties might be slowly formed. According to Mr. Pierce, there are two varieties of the wolf inhabiting the Catskill Mountains in the United States; one with a light greyhound-like form, which pursues deer, and the other more bulky, with shorter legs, which more frequently attacks the shepherds' flocks.

The use and the disuse of particular organs combine their effects with those of natural selection, in the modification of species; use strengthens and enlarges certain parts, and disuse diminishes them. Such modifications are inherited. Many animals have structures which can be explained by the effects of disuse. As Professor Owen has remarked, there is no greater anomaly in nature than a bird that cannot fly; yet there are several in this state. Since the larger ground-

feeding birds seldom take flight except to escape danger, Mr. Darwin believes that the nearly wingless condition of several birds, which now inhabit or have lately inhabited several oceanic islands, tenanted by no beast of prey, has been caused by disuse. The ostrich, indeed, inhabits continents, and is exposed to danger from which it cannot escape by flight; but by kicking it can defend itself from its enemies, as well as any of the smaller quadrupeds. We may imagine that the early progenitor of the ostrich had habits like those of a bustard, and that as Natural Selection increased in successive generations the size and weight of its body, its legs were used more, and its wings less, until they became incapable of flight.

The eyes of moles and of some burrowing rodents are rudimentary in size, and in some cases are quite covered up by skin and fur. This state of the eyes is probably due to gradual reduction from disuse, but aided, perhaps, by Natural Selection. In South America, a burrowing rodent, the tuco-tuco, is even more subterranean in its habits than the mole; and the Spaniards, who often catch them, assert that they are frequently blind. One, which Mr. Darwin kept alive, was certainly in this condition, the cause, as appeared on dissection, having been inflammation of the nictitating membrane. As frequent inflammation of the eyes must be injurious to any animal, and as eyes are certainly not indispensable to animals with subterranean habits, a reduction in their size, with the adhesion of the eyelids and growth of fur over them, might, in such case, be an advantage; and if so, Natural Selection would constantly aid the effects of disuse. It is well known that several animals, belonging to the most different classes, which inhabit the caves of Styria and of Kentucky, are blind. In some of the crabs, the foot-stalk for the eye remains, though the eye is gone; the stand for the telescope is there, though the telescope with its glasses has been lost. As it is difficult to imagine that eyes, though useless, could be in any way injurious to animals living in darkness, Mr. Darwin attributes their loss wholly to disuse. Not a single domestic animal can be named which has not, in some country, drooping ears; and the view suggested by some authors, that the drooping is due to the disuse of the muscles of the ear from the animals not being much alarmed by danger, is accepted as probable.

Mr. Wollaston has discovered the remarkable fact that two hundred kinds of beetles, out of the five hundred and fifty inhabiting Madeira, cannot fly; and that of the twenty-nine endemic genera, no less than twenty-three genera have all their species in this condition. Several facts, namely, that beetles, in many parts of the world, are frequently blown to sea and perish; that the

beetles in Madeira, as observed by Mr. Wollaston, lie much concealed until the wind lulls and the sun shines; that the proportion of wingless beetles is larger on the exposed Desertas than in Madeira itself; and especially the extraordinary fact, so strongly insisted on by Mr. Wollaston, of the almost entire absence of certain large groups of beetles, elsewhere excessively numerous, and which groups have habits of life almost necessitating frequent flight;—these several considerations have made Mr. Darwin believe that the wingless condition of so many Madeira beetles is due mainly to the action of natural selection, but combined probably with disuse. For, during thousands of successive generations, each individual beetle which flew least, either from its wings having been ever so little less perfectly developed, or from indolent habit, will have had the best chance of surviving from not being blown out to sea; and, on the other hand, those beetles which most readily took to flight would oftenest have been blown to sea and thus have been destroyed. As with mariners shipwrecked near a coast, it would have been better for the good swimmers if they had been able to swim still further, whereas it would have been better for the bad swimmers if they had not been able to swim at all, and had stuck to the wreck.

The theory, of which a brief sample has been given, entails the vastest consequences. We are no longer to look at an organic being as a savage looks at a ship — as at something wholly beyond his comprehension; we are to regard every production of nature as one which has had a history; we are to contemplate every complex structure and instinct as the summing up of many contrivances, each useful to the possessor, nearly in the same way as when we look at any great mechanical invention as the summing up of the labour, the experience, the reason, and even the blunders, of numerous workmen*. The natural system of classification becomes a genealogical arrangement, in which we have to discover the lines of descent by the most permanent characters, however slight their vital importance may be; because the real affinities of all organic beings are due to inheritance or community of descent. Natural Selection can only act through and for the good of each being; acting by competition, it adapts the inhabitants of each country only in relation to the degree of perfection of their associates; so that we need feel no surprise at the inhabitants of any one country (although on the ordinary view supposed to have been specially created and adapted for that country) being beaten and supplanted by the naturalised productions from another land. Nor ought we to marvel if all the contrivances in nature be not, as far as we can judge, absolutely perfect; and if some of them be*

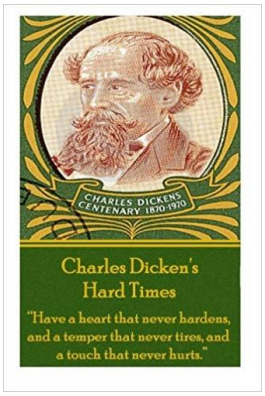
abhorrent to our ideas of fitness. We need not marvel at the sting of the bee causing the bee's own death; at the instinctive hatred of the queen bee for her own fertile daughters; and at other such cases.

Judging from the past, we are to infer that not one living species will transmit its unaltered likeness to a distant futurity. And, of the species now living, very few will transmit progeny of any kind to a far-distant futurity; for the manner in which all organic beings are grouped, shows that the greater number of species of each genus, and all the species of many genera, have left no descendants, but have become utterly extinct. We can so far take a prophetic glance into futurity as to foretell that it will be the common and widely-spread species, belonging to the larger and dominant groups, which will ultimately prevail and procreate new and dominant species. ***And as Natural Selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows****.*

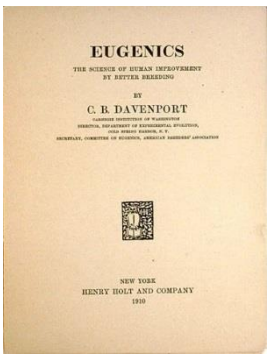


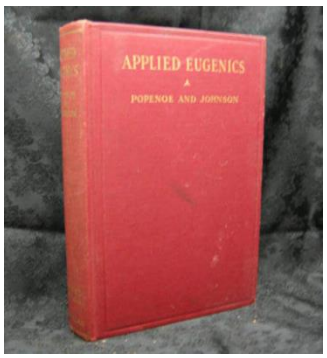
Timid persons, who purposely cultivate a certain inertia of mind, and who love to cling to their preconceived ideas, fearing to look at such a mighty subject from an unauthorised and unwonted point of view, may be reassured by the reflection that, ***for theories, as for organised beings, there is also a Natural Selection and a Struggle for Life****. The world has seen all sorts of theories rise, have their day, and fall into neglect.* ***Those theories only survive which are based on truth, as far as our intellectual faculties can at present ascertain****; such as the Newtonian theory of universal gravitation.* ***If Mr. Darwin's theory be true, nothing can prevent its ultimate and general reception, however much it may pain and shock those to whom it is propounded for the first time. If it be merely a clever hypothesis, an ingenious hallucination, to which a very industrious and able man has devoted the greater and the best part of his life, its failure will be nothing new in the history of science****. It will be a* ***Penelope's web****, which, though woven with great skill and art, will be ruthlessly unwoven, leaving to some more competent artist the task of putting together a more solid and enduring fabric.*

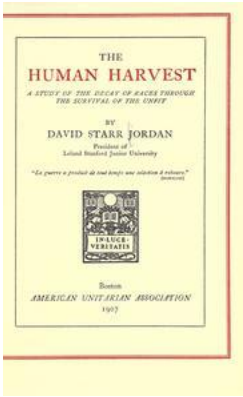
This article, like the others that appeared in *All the Year Round*, was written to be discussed around the breakfast table. Dickens' personal experiences and observations of instinct and human nature expressed in Victorian England, where technology, based on the steam engine driven by burning coal, rapidly transformed a rural agrarian society into an urban industrial society provided the foundational evidence for his novels. According to Tom Wolfe (1989), in Dickens' novels, the city of London was "*always in the foreground, exerting its relentless pressure on the souls of its inhabitants*." Had Dickens been a strict Darwinian when it came to materialism and the instincts of humans, in *A Christmas Carol*, there would have been no Christmas ghosts and **the Scrooge at the beginning of the story would have represented the survival of the fittest**. It may be no surprise to learn that the intelligentsia in Victorian England, according to Tom Wolfe (1989) and Arnold Hauser (1951), regarded Dickens as "*the author of the uneducated, undiscriminating public*."



Many scientists, including **David Starr Jordan**, a Cornell graduate and first president of Stanford University, Paul Popenoe, Luther Burbank, Charles Davenport, William Castle, and others began looking at human beings as predominantly a product of their genes and built up the **progressive science** of **eugenics**, the science of the improvement of the human race by better breeding. As **Charles B. Davenport** (1911), who we discussed in terms of eye color, wrote, "*The eugenical standpoint is that of the agriculturalist who, while recognizing the value of culture, believes that permanent*







advance is to be made only by securing the best 'blood.' Man is an organism—an animal; and the laws of improvement of corn and of race horses hold for him also. Unless people accept this simple truth and let it influence marriage selection human progress will cease."

William E. Castle (1921) wrote in *Genetics and Eugenics*: "*No one can deny that our country's population is increasing fast enough, the only danger is that the biologically poorest elements in the population may increase faster than any other. The declining birth rate is not itself serious, but the differential character of its decline is serious. The most intellectual and cultured elements in the population breed slowest. Professor Cattell says that a Harvard graduate has on the average three-fourths of a son and a Vassar graduate one-half of a daughter. If this continues college graduates may look forward to the early extinction of their line as an element of the American population*."

See the movie, *The Black Stork*, made in 1917 about Doctor **Harry J. Haiselden** and his quest to use his scientific and medical knowledge for human progress. https://www.youtube.com/watch?v=9m6OCT8YmfU *Tomorrow's Children* is another movie made in 1934 with the same theme. https://www.youtube.com/watch?v=yXQNU4IeO6Y

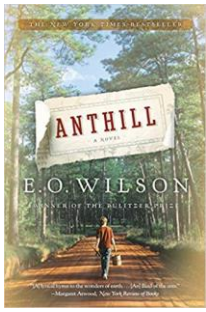


C. S. Lewis (1952) wrote in *Mere Christianity*, "*We all want progress. But progress means getting nearer to the place where you want to be. And if you have taken a wrong turning, then to go forward does not get you any nearer. If you are on the wrong road, progress means doing an about-turn and walking back to the right road; in that case the man who turns back soonest is the most progressive man*."

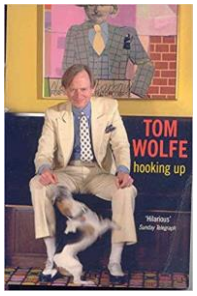
Taking a Cue From Ants on Evolution of Humans (https://www.nytimes.com/2008/07/15/science/15wils.html)



Edward O. Wilson is an expert in the study of ants and the author of *Anthill* and ***Sociobiology: The New Synthesis***. **The** New Synthesis (with "The" with a capital T) is based on his knowledge of the social behavior of ants, as well as genetics and evolution. Wilson (1975) states, "*the humanities and social sciences shrink to specialized branches of biology…*," that "*Scientists and humanists should consider together the possibility that the time has come for ethics to be removed temporarily from the hands of the philosophers and biologicized*" and that "*It seems that our autocatalytic social evolution has locked us onto a particular course which the early hominids still within us may not welcome.* ***To maintain the species indefinitely we are compelled to drive toward total knowledge, right down to the levels of the neuron and gene. When we have progressed enough to explain ourselves in these mechanistic terms, and the social sciences come to full flower, the result might be hard to accept***."



Are we merely products of natural selection and everything we do or think genetically determined? Is the soul dead? Is there no such thing as self-control and free will? Can we really explain ourselves or a man like Wilberforce in these materialistic and mechanistic terms? Some biologists, including Walter Gilbert who shared the 1980 Nobel Prize in Chemistry, think that once we know a person's genome, a computer with sufficient analytical power could predict the course of that person's life.



Tom Wolfe (2000) has written about E.O. Wilson, who he calls Darwin II in *Digibabble, Fairy Dust, and the Human Anthill* and *Sorry, but Your Soul Just Died*—two essays in the book, *Hooking Up.*

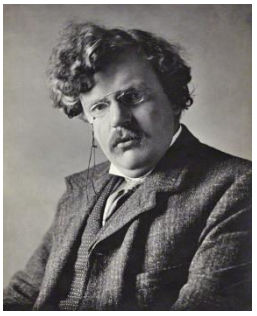
Viktor Frankl (1962), a survivor of Auschwitz, wrote in the *Doctor and the Soul*, "*Three factors characterize human existence as such: man's spirituality, his freedom, his responsibility*." Is it likely that these three factors arose by natural selection and that these three factors will be enhanced through a breeding program?



William Jennings Bryan (1925) began to question the value of the Darwinian war-like philosophy. At the Scopes Trial, he said, "*Let us, then, hear the conclusion of the whole matter. **Science is a magnificent material force, but it is not a teacher of morals. It can perfect machinery, but it adds no moral restraints to protect society from the misuse of the machine. It can also build gigantic intellectual ships, but it constructs no moral rudders or the control of storm-tossed human vessels. It not only fails to supply the spiritual element needed, but some of its unproven hypotheses rob the slip of its compass and thus endanger its cargo.***

In war, science has proven itself an evil genius; it has made war more terrible than it ever was before. Man used to be content to slaughter his fellowmen on a single plain - the earth's surface. Science has taught him to go down into the water and shoot up from below and to go up into the clouds and shoot down from above, thus making the battlefield three times as bloody as it was before. But science does not teach brotherly love. Science has made war so hellish that civilization was about to commit suicide; and now we are told that newly discovered instruments of destruction will make the cruelty of the late war seem trivial in comparison with

the cruelties of wars that may come in the future. If civilization is to be saved from the wreckage threatened by intelligence not consecrated by love, it must be saved by the moral code of the meek and lowly Nazarene. His teachings, and His teachings alone, can solve the problems that vex the heart and perplex the world."

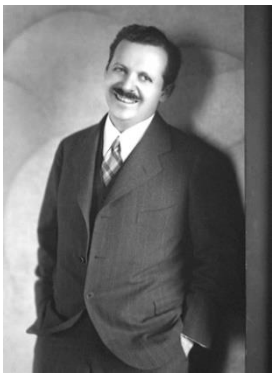


We hear all the time "*Science says*," but science does not say anything, scientists do. And scientists must make their case stating a **line of reasoning** rather than a **talking point** as much as anyone else. In seeing the gradual change from science as a method of inquiry to scientism, where the authority of science becomes unquestioned, **G. K. Chesterton** (1932) wrote in, *On the Intellect of Yesterday "Or take another test from another type of inquiry. When all the drawing-rooms began to buzz suddenly with the name of Einstein, some of us were enabled to guess that they must once have buzzed quite as abruptly with the name of Darwin. **Some of us are inclined to guess that Darwinism became a fashion long before anybody really thought it was a fact.** Doubtless any number of society ladies went about saying that Professor Darwin was really too wonderful, just as they afterwards went about saying that Professor Einstein was really too wonderful. But, when all is said, there is no comparison between the two cases. Any number of people did really attack the study of biology, in order to agree or disagree with Darwin. Hardly one person in a thousand thought of attacking the higher mathematics in order to agree with Einstein. People did talk about Darwinism as well as about Darwin. Most of those who talk about Einstein talk about Einstein. They know nothing but the name and the notion that something very important has happened in connexion with the name. The talk about Darwin may have been popular science, but it was science, and it was popular. The talk about Einstein may rather be called **popular nescience**. He has not made astronomy really popular, as the other made biology really popular. And I believe that the reason is a certain increased laziness of the intellect; that fewer*

people are ready for a long, sustained logical demonstration, quite apart from whether we think that the demonstration really demonstrates. In my boyhood there were any number of funny little atheists running about ready and eager to prove what they had learned from the work of Darwin. So there were any number of fanatical little Free-Traders eager to prove what they had learned from the speeches of Cobden. ***I do not find men now so eager to prove things; but, at the most, to assure me that they have been proved.***

One way of putting it is that this is a psychological age, which is the opposite of an intellectual age. It is not a question of persuading men, but of suggesting how they are persuaded. It is an age of Suggestion; that is, of appeal to the irrational part of man. Men discussed whether Free Trade was false or true; they do not so much discuss whether Empire Free Trade is false or true, as whether it is booming or slumping; whether it is based on an understanding of Mass Psychology, or whether its opponents or supporters have what Americans call Personality. It is all great fun, and there is doubtless a truth in it, as in other things. But, whatever else it is, it is not a mark of stronger mentality, and any old Scotch Calvinist farmer, who could follow his minister's desolate and appalling sermon to Seventeenthly and Lastly, had an immeasurably better brain."

In his essay, *Is Darwin Dead*?, Chesterton made very weak scientific arguments against Darwinism where he questioned "*the survival value of features in their unfinished state*." While his scientific critique is weak and flawed, his critique of scientism is strong and accurate.



Sigmund Freud's nephew**, Edward Bernays** (1928), who graduated from Cornell University in 1912, wrote in his book, *Propaganda*, "*Universal literacy was supposed to educate the common man to control his environment. Once he could read and write he would have a mind fit to rule. So ran the democratic doctrine. But instead of a mind,* ***universal literacy has given him rubber stamps, rubber stamps inked with advertising slogans, with editorials, with published scientific data, with the trivialities of the tabloids and the platitudes of history, but quite innocent of original thought****. Each man's rubber stamps are the duplicates of millions of others, so that when those millions are exposed to the same stimuli, all receive identical imprints. It may seem an exaggeration to say that the American public gets most of its ideas in this wholesale fashion. The mechanism by which ideas are disseminated on a large scale is propaganda, in the broad sense of an organized effort to spread a particular belief or doctrine….*"

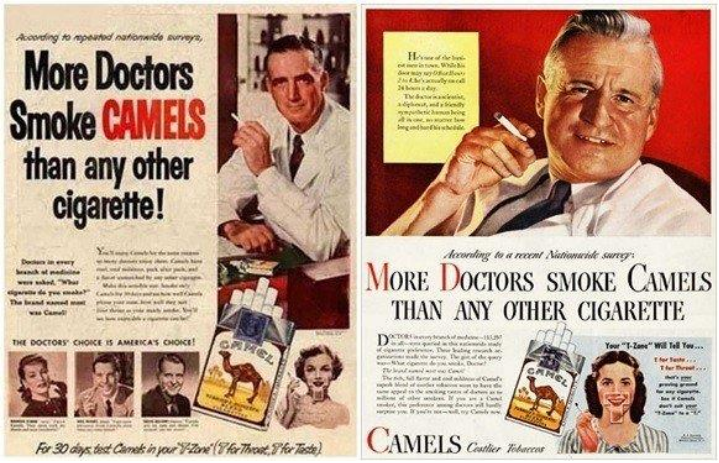
"*Trotter and Le Bon concluded that the* ***group mind*** *does not think in the strict sense of the word****. In place of thoughts it has impulses, habits and emotions****. In making up its mind its first impulse is usually to follow the example of a trusted leader* [or to know what answer will result in an "A"]. *This is one of the most firmly established principles of mass psychology. It operates in establishing the rising or diminishing prestige of a summer resort, in causing a run on a bank, or a panic on the stock exchange, in creating a best seller, or a box-office success* [or what is considered right or wrong on a test]."

"*But when the example of the leader is not at hand and the herd must think for itself, it does so by means of cliches, pat words or images which stand for a whole group of ideas or experiences. Not many years ago, it was only necessary to tag a political candidate with the word interests to stampede millions of people into voting against him, because anything associated with "the interests" seemed*

necessarily corrupt. Recently the word Bolshevik has performed a similar service for persons who wished to frighten the public away from a line of action."

"*The old propagandist based his work on the mechanistic reaction psychology then in vogue in our colleges. This assumed that the human mind was merely an individual machine, a system of nerves and nerve centers, reacting with mechanical regularity to stimuli, like a helpless, will-less automaton. It was the special pleader's function to provide the stimulus which would cause the desired reaction in the individual purchaser. It was one of the doctrines of the reaction psychology that a certain stimulus often repeated would create a habit, or that the mere reiteration of an idea would create a conviction. Suppose the old type of salesmanship, acting for a meat packer, was seeking to increase the sale of bacon. It would reiterate innumerable times in full-page advertisements: 'Eat more bacon. Eat bacon because it is cheap, because it is good, because it gives you reserve energy.'*"

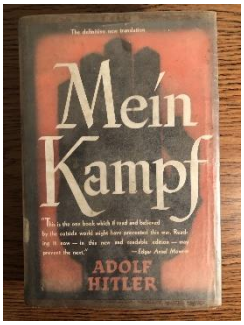
"*The newer salesmanship, understanding the group structure of society and the principles of mass psychology, would first ask: "Who is it that influences the eating habits of the public?" The answer, obviously, is: "The physicians." The new salesman will then suggest to physicians to say publicly that it is wholesome to eat bacon. He knows as a mathematical certainty, that large numbers of persons will follow the advice of their doctors, because he understands the psychological relation of dependence of men upon their physicians*."



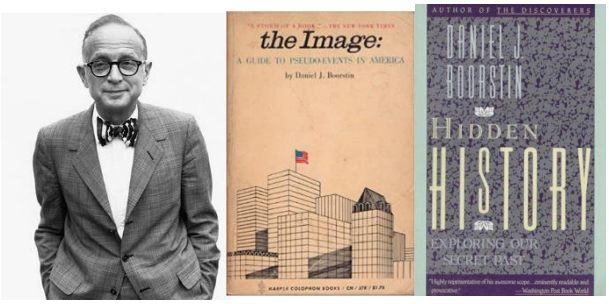


Public relations pioneer Edward Bernays, shown (L to R) from the late 1920s to early '30s, the mid- to late '40s and 1990. The Museum of Public Relations

Edward Bernays (1937) wrote in *The Minority Rules*, "*Thomas Jefferson said that the world was made, not for Caesar, but for the common man. The contemporary common man, however, shows no sign of giving three whoops in East New York whether it was made for him or not. Caesar leads him along by the nose. Universal literacy was supposed to educate the common mortal into control of his environment. Once he could read and write he would have a mind fit to rule. So ran the democratic doctrine. But* ***instead of a mind, universal literacy has given him a rubber stamp, a rubber stamp inked with advertising slogans, with editorials, with published scientific data, with the trivialities of the tabloids and the profundities of history, but quite innocent of original thought****. Each man's rubber stamp is the twin of millions of others, so that when these millions are exposed to the same stimuli, all receive identical imprints. It may seem a wild exaggeration to say that the American public gets most of its ideas in this wholesale fashion. But to say so is merely to state a fact that is as real as it is unrecognized. The mechanism by which it is done is propaganda—propaganda, that is, in its broad sense of an organized effort to spread a particular belief or opinion*." In his book entitled *Crystalizing Public Opinion*, Bernays (1923) wrote, "***The only difference between "propaganda" and "education," really, is in the point of view. The advocacy of what we believe in is education. The advocacy of what we don't believe in is propaganda****. Each of these nouns carries with it social and moral implications. Education is valuable, commendable, enlightening, instructive. Propaganda is insidious, dishonest, underhand, misleading*."



Adolf Hitler (1924) wrote in Mein Kampf, "*The function of propaganda is, for example,* ***not to weigh and ponder*** *the rights of different people, but exclusively to emphasize the one right which it has set out to argue for.* ***Its task is not to make an objective study of the truth****, in so far as it favors the enemy, and then set it before the masses with academic fairness; its task is to serve our own right, always and unflinchingly. …****But the most brilliant propagandist technique will yield no success unless one fundamental principle is borne in mind constantly and with unflagging attention. It must confine itself to a few points and repeat them over and over****. Here, as so often in this world, persistence is the first and most important requirement for success*." Ironically, this quote is often misattributed to Joseph Goebbels.

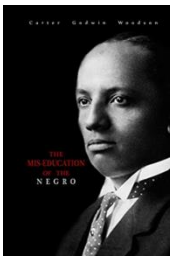


According to **Daniel Boorstin** (1961, 1987), "*propaganda substitutes opinion for facts*."

Is science ever presented as propaganda?

The National Center for Science Education (https://ncse.ngo/why-teach-evolution-0), staffed by experts in science education, states that "*Biological evolution is a scientifically settled theory. Among scientists, this means that its fundamental principle —the shared ancestry of living organisms —has overcome all scientific challenges. However, the general public is uncomfortable with evolution because of what some people perceive as the moral, or cultural implications of evolution*. The NCSE" is concerned with critical thinking about evolution: "*Critical thinking is an important component of a good education. Critical thinking about evolution must start with a solid understanding of what evolution is and how contemporary scientists understand it. 'Critical thinking'*

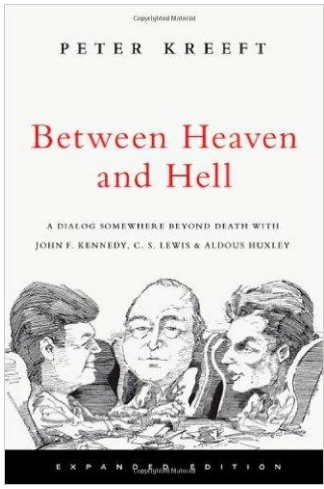
materials recently offered to school boards consist of misinterpretations of scientific research about biological evolution. They confuse an active discussion among scientists over the details of evolution with a disagreement about whether evolution has occurred. This is not critical thinking, but hucksterism." In teaching you about Wilberforce, have I misrepresented anything to you?



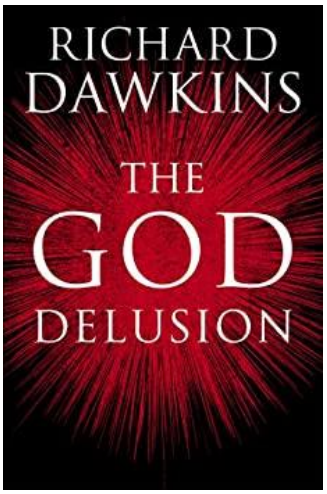
Mental slavery results when one cannot differentiate between education and indoctrination. **Carter Goodwin Woodson** (1933) wrote in ***The Mis-Education of the Negro,*** "*When you control a man's thinking you do not have to worry about his actions. You do not have to tell him to stand here or go yonder. He will find his 'proper place' and will stay in it*."

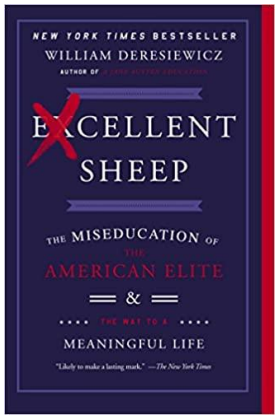
Viktor Frankl (1986) wrote in ***The Doctor and the Soul***, *"If we present a man with a concept of man which is not true, we may well corrupt him. When we present man as automaton of reflexes, as a mind-machine, as a bundle of instincts, as a pawn of drives and reactions, as a mere product of instinct, heredity and environment, we feed the nihilism to which modern man is, in any case, prone. I became acquainted with the last stage of that corruption in my second concentration camp, Auschwitz. The gas chambers of Auschwitz were the ultimate consequence of the theory that man is nothing but the product of heredity and environment – or, as the Nazi liked to say, of 'Blood and Soil.' I am absolutely convinced that the gas chambers of Auschwitz, Treblinka, and Maidanek were ultimately prepared not in some Ministry or other in Berlin, but rather at the desks and in the lecture halls of nihilistic scientists and philosophers.*"

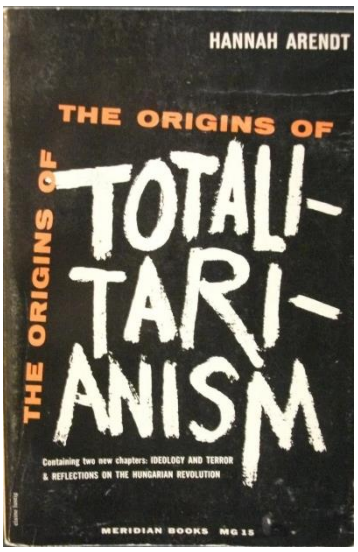
Professors and science books can also be salesmen…which is why I say—Think for yourself, observe and experiment, and use logic and reason—and do not believe anything I write or say! I do not want to teach you what I know but I want to teach you how to learn to know so that you don't just accept the *cliches, pat words or images* at a time as Kreeft describes, when we do get "*respect and acceptance by others…not by being different but by being the same*."



Richard Dawkins (2006) wrote in *The God Delusion*, "*A study in the leading journal Nature by Larson and Witham in 1998 showed that of those American scientists considered eminent enough by their peers to have been elected to the National Academy of Sciences…only about 7 per cent believe in a personal God. This overwhelming preponderance of atheists is almost the exact opposite of the profile of the American population at large, of whom more than 90 per cent are believers in some sort of supernatural being. The figure for less eminent scientists, not elected to the National Academy, in intermediate. As with the more distinguished sample, religious believers are in a minority, but a less dramatic minority of about 40 per cent. It is completely as I would expect that American scientists are less religious than the American public generally, and that the most distinguished scientists are the least religious of all. What is remarkable is the polar opposition between the religiosity of the American public at large and the atheism of the intellectual elite*." At an Ivy League University, do you feel any pressure to be part of the intellectual elite rather than the American public at large? Does the pressure lead in any way to becoming what **William Dereshwicz** calls, an excellent sheep?

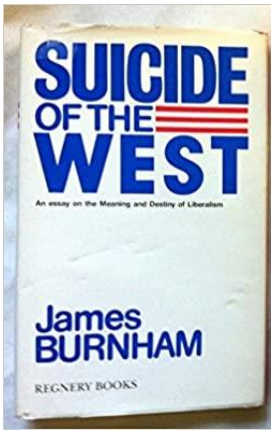






Aside: In *The Origins of Totalitarianism*, Hannah Arendt (1976) describes the role of elites historically as functionaries in totalitarian movements based upon "*the* [organizational] *principle that whoever is not included is excluded, whoever is not with me is against me,* [such that] *the world at large loses all the nuances, differentiations, and pluralistic aspects*". Arendt writes, "*The total responsibility for everything done by the movement and this total identification with every one if its functionaries have the very practical consequence that nobody ever experiences a situation in which he has to be responsible for his own actions or can explain the reasons for them*." How does the inability for the elites to explain their reasons even when calling for or implementing mandates come about? Arendt writes, "*The machine that generates, organizes, and spreads the monstrous falsehoods of totalitarian movements depends again upon the position of the Leader. To the propaganda assertion that all happenings are* ***scientifically predictable according to the laws of nature or economics****, totalitarian organization adds the position of one man who has monopolized this knowledge and whose principal quality is that he 'was always right and will always be right.'* ***To a member of a totalitarian movement this knowledge has nothing to do with truth and this being right nothing to do with the objective truthfulness of the Leader's statements which cannot be disproved by facts but only be future success or failure.*** *The Leader is always right in his actions and since these are planned for centuries to come, the ultimate test of what he does has been removed beyond the experience of his contemporaries*." How much trust should we put in our leaders and how much trust should we put in ourselves?

When I say, think for yourself, I am not suggesting that reality and truth are relative and that you should be a **post-modernist** who thinks that reality and truth are esoteric, relative concepts that are constructed by each individual. I am not a **post-modernist**. I am a dualist—a mixture of a **pre-modernist** and a **modernist**—perhaps what James Burnham (1964) in *Suicide of the West*, would call a conservative *and* a liberal.



PREMODERNISM	MODERNISM	POSTMODERNISM
Objective Ultimate Truth	Objective Ultimate Truth	Objective Ultimate Truth is Unknowable
Supernatural	Anti-Supernatural	Mystical
Authority from God (or gods)	Authority from Science & Human Reason	No Ultimate Authority

The founding document of the United States of America is the **Declaration of Independence**. It states that individual liberty is God-given and thus each person is free to choose his or her own philosophy and worldview. The first amendment of the Constitution states that *Congress shall make no law respecting an establishment of religion* [worldview], *or prohibiting the free exercise thereof*. That is final. Calvin Coolidge spoke on the 150th Anniversary of the Declaration of Independence, "*It is often asserted that the world has made a great deal of progress since 1776, that we have had new thoughts and new experiences which have given us a great advance over the people of that day, and that we may therefore very well discard their conclusions for something more modern. But that reasoning can not be applied to this great charter*. ***If all men are created equal, that is final. If they are endowed with inalienable rights, that is final.*** *If governments derive their just powers from the consent of the governed, that is*

final. No advance, no progress can be made beyond these propositions. If anyone wishes to deny their truth or their soundness, the only direction in which he can proceed historically is not forward, but backward toward the time when there was no equality, no rights of the individual, no rule of the people. Those who wish to proceed in that direction can not lay claim to progress. They are reactionary. Their ideas are not more modern, but more ancient, than those of the Revolutionary fathers."

What do we believe to be true? What do we know to be true? Whose authority do we accept and whose ideas do we believe and why? The 1619 Project and 1776 Report offer diametrically opposed views on freedom and slavery in America. Parents and educators also seem to have diametrically opposed views.

I think William and Samuel Wilberforce could be described as men who after learning from the slave trader John Newton that "*God created mankind in his own image*" (Genesis 1:27), followed the words of the prophet Micah (6:8) "*to do justice, to love kindness, And to walk humbly with your God*." If you think that God is "*arguably the most unpleasant character in all fiction: jealous and proud of it; a petty, unjust, unforgiving control-freak; a vindictive, bloodthirsty ethnic cleanser; a misogynistic, homophobic, racist infanticidal, genocidal, filicidal, pestilential, megalomaniacal, sadomasochistic, capriciously malevolent bully*" as Richard Dawkins wrote in *The God Delusion*, it makes no sense to give voice to William and Samuel Wilberforce, who were motivated by both faith in God and reason. According to Robert Fitch (1959), who wrote *The Obsolescence of Ethics*: "*Ours is an age where ethics has become obsolete. It is superseded by science, deleted by philosophy and dismissed as emotive by psychology*."

According to music and pop culture journalist **Steve Turner**, Darwin is part of the trinity *Marxfreudanddarwin* that is so important in today's culture. Turner wrote in *Creed*,

This is the creed I have written on behalf of all us.
We believe in Marxfreudanddarwin*…*

We believe that there is no absolute truth
excepting the truth that there is no absolute truth.

Xenophanes (570-478 BC) believed that there is an ultimate Truth, but no person has ever nor will ever know it. In fact, even if a person spoke the ultimate Truth, he would not even recognize it. Karl Popper (1963) quoted Xenophanes in *Realism and the Aim of Science*:


XENOPHANES.

But as for certain truth, no man has known it,

Nor will he know it; neither of the gods

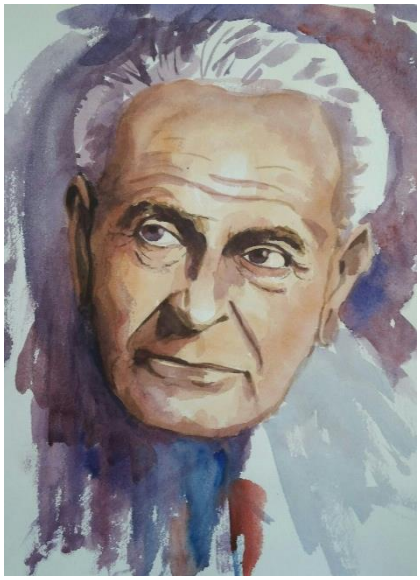
Nor yet of all the things of which I speak.

And even if by chance he were to utter

The perfect truth, he would himself not know it;

For all is but a woven web of guesses.

Guesses that Popper defined as **working hypotheses** in the search for truth. Popper wrote, "*I then suggested that the whole trouble was due to the mistaken belief that scientific knowledge was an especially strict or certain or august kind of knowledge. This statement met with the same reception as the first. I concluded with an attempt to explain that, in the usual sense of 'know',*



whenever I know that it is raining, it must be true that it is raining; for if it is not true, then I simply cannot know that it is raining, however sincerely I may believe that I know it. In this sense of the word, 'knowledge' always means 'true and certain knowledge'; and 'to know' means, in addition, to be in possession of sufficient reason *for holding that our knowledge is true and certain. But, I said, there was no such thing as scientific knowledge in this sense. If, nonetheless, we chose to label the results of our scientific endeavours with the customary name 'scientific knowledge', then we ought to be clear that scientific knowledge was not a species of knowledge; least of all, a species distinguished by a high degree of solidity or certainty. On the contrary, measured by the high standards of scientific criticism, 'scientific knowledge' always remained sheer guesswork—although guesswork controlled by criticism and experiment…Admittedly, I had attacked, by implication, Science with a capital 'S', and those of its devotees who were ready to take its pronouncements as gospel truth*."



In today's cancel culture, those who believe that they know the truths of science use it to cancel others. Herbert Marcuse (1969) wrote in Repressive Tolerance, "*Such indiscriminate tolerance is justified in harmless debates, in conversation, in academic discussion; it is indispensable in the* ***scientific enterprise****, in private religion****. But society cannot be indiscriminate where the pacification of existence, where freedom and happiness themselves are at stake: here, certain things cannot be said, certain ideas cannot be expressed, certain policies cannot be proposed, certain behavior cannot be permitted***

without making tolerance an instrument for the continuation of servitude." And, in today's cancel culture, when the happiness of some is at stake, tolerance in the scientific enterprise is no longer warranted.

Marcuse goes on to say, "*This pure toleration of sense and nonsense is justified by the democratic argument that nobody, neither group nor individual, is in possession of the truth and capable of defining what is right and wrong, good and bad. Therefore, all contesting opinions must be submitted to 'the people' for its deliberation and choice. But I have already suggested that the democratic argument implies a necessary condition, namely, that the people must be capable of deliberating and choosing on the basis of knowledge, that they must have access to authentic information, and that, on this. basis, their evaluation must be the result of autonomous thought*." This tolerance is not practiced by those who think that they are uniquely intelligent and in possession of authentic information, whereas the unwashed masses, the commonfolk, and the *hoi paloi*, are neither intelligent nor in possession of authentic information.



I think that the erasure of Wilberforce's name in academia is a modern instance of **cancel culture**, which is not unlike the example set by Theodosius I in 391, when he made pagan thought illegal and not unlike the example set by Pope Theophilus of Alexandria, when he ordered the burning of the last vestige of the great library in Alexandria. Questioning Darwin is not allowed in academia. Samuel Wilberforce questioned Darwinian evolution and instead of responding with reason, the response was to use *ad hominem* attacks and then to ostracize

Samuel Wilberforce and his whole family, including William Wilberforce. Yes, academia can be red in tooth and claw. In terms of what goes around comes around, T. H. Huxley's name was just removed from the Huxley College of the Environment at Western Washington University.





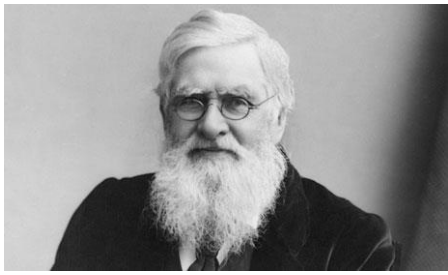
We have come a long way, although I would not say progressed, since September 14, 1859, when Prince Albert served as the President at the meeting of the British Association for the Advancement of Science, where he said, "*To return to ourselves, however: one part of the functions of the Association can receive no personal representation, no incarnation: I mean the very fact of meetings like that which we are at present inaugurating.* ***This is not the thoughtful direction of one mind over acquired knowledge, but the production of new thought by the contact of many minds, as the spark is produced by the friction of flint and steel; it is not the action of the monarchy of a paternal Government, but the republican activity of the Roman Forum****. These meetings draw forth the philosopher from the hidden recesses of his study, call in the wanderer over the field of science to meet his brethren, to lay before them the results of his labours, to set forth the deductions at which he has arrived, to ask for their examination, to maintain in the combat of debate the truth of his positions and the accuracy of his observations. These meetings, unlike those of any other Society, throw open the arena to the cultivators of all sciences, to their*

*mutual advantage: the geologist learns from the chemist that there are problems for which he had no clue, but which that science can solve for him; the geographer receives light from the naturalist, the astronomer from the physicist and engineer, and so on. And all find a field upon which to meet the public at large,—invite them to listen to their reports and even to take part in their discussions,—show to them that philosophers are not vain theorists, but essentially men of practice—**not conceited pedants, wrapped up in their own mysterious importance, but humble inquirers after truth**, proud only of what they may have achieved or won for the general use of man. Neither are they daring and presumptuous unbelievers—a character which ignorance has sometimes affixed to them—who would, like the Titans, storm heaven by placing mountain upon mountain, till hurled down from the height attained, by the terrible thunders of outraged Jove; but rather the pious pilgrims to the Holy Land, who toil on in search of the sacred shrine, in search of truth—God's truth—God's laws as manifested in His works, in His creation.*"



First Light: Big Bang Cosmology and the Origin of Life

Last time we discussed Samuel Wilberforce's (1860) scientific and critical review of Charles Darwin's ***On the Origin of Species by Means of Natural Selection: or The Preservation of Favoured Races in the Struggle for Life***. I also presented what I think was the unfair way Wilberforce was marginalized and forgotten by many in the scientific and academic communities. The marginalization of the whole Wilberforce family name may be a result of Samuel Wilberforce's rigorous criticism of the *Origin of Species*. Indeed, it is even possible that there is, according to Leon Wieseltier, a "*scientistic tyranny in American intellectual life*." Wieseltier realizes that "*The problem of the limits of science is not a scientific problem. It is also pertinent to note that the history of science is a history of mistakes, and so the dogmatism of scientists is especially rich*." https://newrepublic.com/article/112481/darwinist-mob-goes-after-serious-philosopher There is no reason why a free human being has to follow the consensus or authority mindlessly. *Emancipate yourself from mental slavery*!



I gave voice to Wilberforce in the last lecture because he has a lot to teach us, yet he has no voice in the modern world. We do hear about **Alfred Russel Wallace**, but only in terms of where he and Darwin agreed. Beyond that, biologists don't often give him a listen either. Wallace differed with Charles Darwin on the influence of natural selection on qualities in humans that in all honesty probably do not have a selective advantage in terms of producing more progeny.



For example, Wallace (1913) did not think that there was a slave making instinct. He wrote in *Social Environment and Moral Progress*, "*The belief was once prevalent, and is still held by many persons, that a knowledge of right and wrong is inherent or instinctive in everyone, and that the immoral person may be justly punished for such wrongdoing as he commits. But that this cannot be wholly, if at all, true is shown by the fact that in different societies and at different periods the standard of right and wrong changes considerably. That which at one time and place is held to be right and proper is, at another time or place, considered to be not only wrong, but one of the greatest of crimes. The most striking example of this change of opinion is that of* ***slavery****, which was held to be quite justifiable by the most highly civilized people of antiquity, and hardly less so by ourselves within the memory of persons still living*."

In a review of Lyell's books *Principles of Geology*, tenth edition and *Elements of Geology*, sixth edition, published in the *Quarterly Review* (April 1869), Wallace wrote, "*This subject is a vast one, and would require volumes for its proper elucidation, but enough, we think, has now been said, to indicate the possibility of a new stand-point for those who cannot accept the theory of evolution as expressing the* ***whole truth*** *in regard to the origin of man. While admitting to the full extent the agency of the same great laws of organic development in the origin of the human race as in the origin of all organized beings,* ***there yet seems to be evidence of a Power which has guided the action of those laws in definite directions and for special ends***. ***And so far from this view being out of harmony with the teachings of science, it has a striking analogy with what is now taking place in the world, and is thus strictly uniformitarian in character***. *Man himself guides and modifies nature for special ends. The laws of evolution alone would perhaps never have produced a grain so well adapted to his uses as wheat; such*

fruits as the seedless banana, and the bread-fruit; such animals as the Guernsey milch-cow, or the London dray-horse. Yet these so closely resemble the unaided productions of nature, that we may well imagine a being who had mastered the laws of development of organic forms through past ages, refusing to believe that any new power had been concerned in their production, and scornfully rejecting the theory that in these few cases a distinct intelligence had directed the action of the laws of variation, multiplication, and survival, for his own purposes. We know, however, that this has been done; and we must therefore admit the possibility, that in the development of the human race, a Higher Intelligence has guided the same laws for nobler ends.

Such, we believe, is the direction in which we shall find the true reconciliation of Science with Theology on this most momentous problem. *Let us fearlessly admit that the mind of man (itself the living proof of a supreme mind) is able to trace, and to a considerable extent has traced, the laws by means of which the organic no less than the inorganic world has been developed. But let us not shut our eyes to the evidence that an Overruling Intelligence has watched over the action of those laws, so directing variations and so determining their accumulation, as finally to produce an organization sufficiently perfect to admit of, and even to aid in, the indefinite advancement of our mental and moral nature.*"

Wallace had the same opinion in the twentieth century. In an interview with W. B. Northrop, Wallace (1913) said, "*I maintain that the theory of evolution does not account for many of the mental attributes of man. It does not account for our wonderful mathematical, musical, or artistic faculties. Who can claim that man has received these endowments from some lower animal which never possessed an inkling of them? Many of the lower animals, it is true, display a much finer physical and muscular development than man does. They are gifted with greater*

agility and endurance, and undoubtedly we have derived from them many of our physical attributes. But who can reasonably say that we are indebted to any of the lower animals for our high intellectual faculties? The gulf which separates the ant from Newton, the ape from Shakespeare, the parrot from Isaiah, cannot be bridged by the struggle for existence. To call the spiritual nature of man a 'by-product,' developed by us in our struggle for existence, is a joke too big for this little world. ***It was on this very point that I differed from Darwin, and it is on these points that I cannot meet the modern materialists who say that man is merely an animal and there is nothing for him beyond the grave****. It is very well for us to try to account for the material on a mere material basis, and it may be very satisfactory to some people who do not seriously consider the subject; but, if the soul has come into being from what is popularly termed 'the struggle for existence,' how is it that in this very struggle for existence we meet daily with people who are making self-sacrifices, exhibiting wonderful heroism and disinterested affection—live men and women of the day who are actually spending their existence for the sake of others? If every one were merely engaged in the desperate struggle for existence, why should any member of the human family try to help along or support anybody else?*

*"****Evolution can account well enough for the land-grabber, the company promoter, the trust, and the sweater, but it fails to account for Raphael and Wagner, Swedenborg, Newton, Florence Nightingale, or others of this character****. The world has been moved far more by spiritual forces than by material and selfish ones. Neither Darwin nor Moses has yet conquered mankind. Life, with its mysteries of consciousness and personality, is still the dumping-ground of theories and dreams. Until science has demonstrated the existence of the soul man approaches death with an open mind. I hold that the existence of the soul and the presence of consciousness beyond the grave have been already proved. It is*

because the scientific investigation of psychical matters has become confused in the popular mind with the imposture of charlatans that indiscriminating people regard Spiritualism as a fake. An honest and unbiased examination of all the facts gathered by modern psychologists would certainly open the eyes of even the most doubtful of all the Thomases. ***Truth is born into this world only with pangs and tribulations, and every fresh truth is received unwillingly. To expect the world to receive a new truth, or even an old truth, without challenging it, is to look for one of those miracles which do not occur***."

T. H. Huxley began to see the limits of the theory of evolution by natural selection when it came to the **ethical behavior of human beings.** In his Romanes Lecture of 1893, eleven years after Charles Darwin died, he said, "*The science of ethics professes to furnish us with a reasoned rule of life; to tell us* ***what is right action*** *and* ***why it is so***. *Whatever differences of opinion may exist among experts, there is a general consensus that* ***the ape and tiger methods of the struggle for existence are not reconcilable with sound ethical principles****... As I have already urged, the practice of that which is ethically best–what we call goodness or virtue–involves a course of conduct which, in all respects, is opposed to that which leads to success in the cosmic struggle for existence. In place of ruthless self-assertion it demands self-restraint; in place of thrusting aside, or treading down, all competitors, it requires that the individual shall not merely respect, but shall help his fellows; its influence is directed, not so much to the survival of the fittest, as to the fitting of as many as possible to survive. It repudiates the gladiatorial theory of existence. It demands that each man who enters into the enjoyment of the advantages of a polity shall be mindful of his debt to those who have laboriously constructed it; and shall take heed that no act of his weakens the*



fabric in which he has been permitted to live. Laws and moral precepts are directed to the end of curbing the cosmic process and reminding the individual of his duty to the community, to the protection and influence of which he owes, if not existence itself, at least the life of something better than a brutal savage."

T.H. Huxley went on to say, "***Let us understand, once for all, that the ethical progress of society depends, not on imitating the cosmic process, still less in running away from it, but in combating it. It may seem an audacious proposal thus to pit the microcosm against the macrocosm and to set man to subdue nature to his higher ends; but I venture to think that the great intellectual difference between the ancient times with which we have been occupied and our day, lies in the solid foundation we have acquired for the hope that such an enterprise may meet with a certain measure of success***."

In the third edition of *Darwinism* by Alfred Russel Wallace (1912), he wrote, "***I am glad to be able to quote the opinion of the late Professor Huxley in support of one of the more important arguments adduced in this chapter as to certain human faculties being such as could not have been developed by the agency of natural selection***. *Mr. Wilfred* [sic Wilfrid] *Ward (in the Nineteenth Century of August 1896) states, that Huxley once said to him: '****One thing which weighs with me against pessimism, and tells for a benevolent Author of the Universe, is, my enjoyment of scenery and music. I do not see how they can have helped in the struggle for existence. They are gratuitous gifts***.'"
https://mathcs.clarku.edu/huxley/comm/Books/Ward.html
https://books.google.com/books?id=k29JAAAAYAAJ&pg

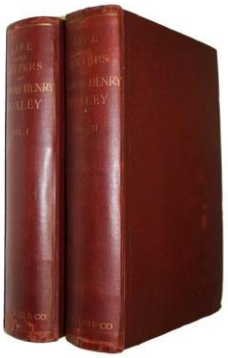
Charles Darwin disagreed with Wallace, writing to him, on March 27, 1869: "*I hope you have not murdered too completely your own & my child*." The editors (2007) of *Nature* identify with Darwin, writing "*the idea that human minds are the product of evolution is not atheistic theology. It is unassailable fact*." https://www.nature.com/articles/447753a

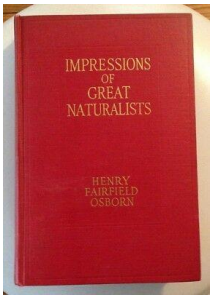


Aside: T. H. Huxley was not such a "**bulldog**" as his reputation suggests. In fact, he was never called Darwin's bulldog during his lifetime. The oft-repeated idea that he was Darwin's bulldog came about like so: In a lecture given in 1895, shortly after Huxley' death, **Henry Fairfield Osborn** described a day in 1879 when Darwin visited Huxley's anatomy class where Osborn was a student. According to Osborn, "*They came in together, Huxley leading slowly down the long, narrow room, pointing out the especial methods of teaching, which he had originated and which are now universally adopted in England and in this country. Darwin was instantly recognized by the class as he entered and sent a thrill of curiosity down the room, for no one present had ever seen him before. There was the widest possible contrast in the two faces. Darwin's grayish-white hair and bushy eyebrows overshadowed the pair of deeply set blue eyes, which seemed to image his wonderfully calm and deep vision of nature, and at the same time to emit benevolence. Huxley's piercing black eyes and determined and resolute face were full of admiration and at the same time protection of his older friend. He said afterwards: 'You know I have to take care of him—in fact, I have always been Darwin's bull-dog,' and this exactly expressed one of the many relations which existed so long between the two men*."

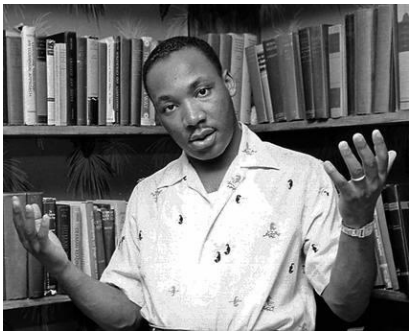


In *Life and Letters of Thomas Henry Huxley* (v. 1, p. 363), Leonard Huxley (1900), T. H. Huxley's son and PR man, changed Osborn's recollection to a direct quote having to do with the so-called Huxley-Wilberforce debate: "'*I am Darwin's bull-dog,' he once said, and the Quarterly Reviewer's treatment of Darwin, 'alike unjust and unbecoming,' provoked him into immediate action.*" Since then, Huxley's image as being a bull-dog stuck (https://www.linnean.org/news/2019/07/01/1st-july-2019-why-there-was-no-darwins-bulldog). Even Osborn eventually came to ape Leonard Huxley's misrepresentation of Osborn's earlier writing, changing "once" to "often." Osborn (1924) wrote that Huxley "*often alluded to himself as* "*Darwin's bull dog*." This is how scientific reputations are made. Science is not immune from the use of propaganda.

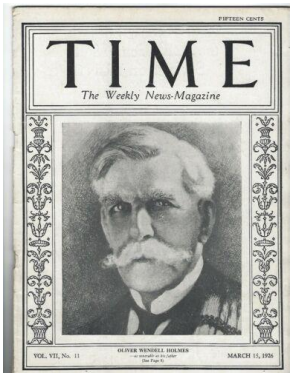


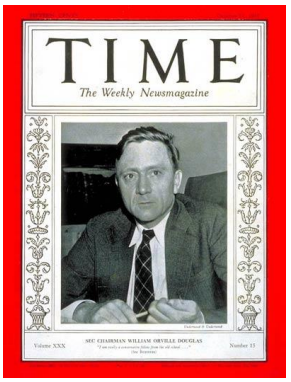


Martin Luther King (1947) wrote in "The Purpose of Education:" "*To think incisively and to think for one's self is very difficult. We are prone to let our mental life become invaded by legions of half truths, prejudices, and propaganda…. **To save man from the morass of propaganda, in my opinion, is one of the chief aims of education. Education must enable one to sift and weigh evidence, to discern the true from the false, the real from the unreal, and the facts from the fiction.***"



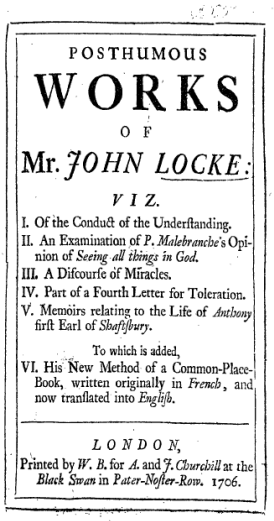
To be able to sift and weigh evidence at a university, a university must be what Justice **William O. Douglas** called, a "*marketplace of ideas*" where there must be, in Justice **Oliver Wendell Holmes** (1919)' words, a "*free trade in ideas*." Holmes went on to say, "*The best test of truth is the power of the*







thought to get itself accepted in the competition of the market." But this test is only valid when opposing evidence is freely available. As William Bragg (1933) wrote, "***From religion comes man's purpose; from science, his power to achieve it. Sometimes people ask if religion and science are not opposed to one another. They are: in the sense that the thumb and fingers or my hand are opposed to one another. It is an opposition by means of which anything can be grasped***."


POSTHUMOUS
WORKS
OF
Mr. JOHN LOCKE:
VIZ.
I. Of the Conduct of the Underſtanding.
II. An Examination of P. *Malebranche*'s Opinion of *Seeing all things in God.*
III. A Diſcourſe of Miracles.
IV. Part of a Fourth Letter for Toleration.
V. Memoirs relating to the Life of *Anthony* firſt Earl of *Shaftſbury.*
To which is added,
VI. His New Method of a Common-Place-Book, written originally in *French*, and now tranſlated into *Engliſh.*
LONDON,
Printed by *W. B.* for *A.* and *J. Churchill* at the *Black Swan* in *Pater-Noſter-Row.* 1706.

John Locke (1706) in **Of the Conduct of the Understanding**, wrote "***Every man carries about him a touchstone, if he will make use of it, to distinguish substantial gold from superficial glitterings, truth from appearances.*** *And indeed the use and benefit of this touchstone, which is natural reason, is spoiled and lost only by assumed prejudices, overweening presumption, and narrowing our minds*."



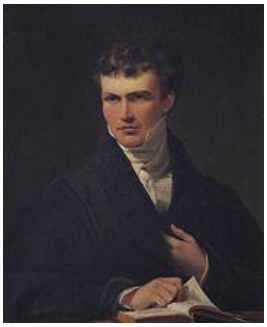
David Herbert Lawrence or **D. H. Lawrence**, as he is better known, wrote about the sense of truth in ***The Deepest Sensuality****:*

The profoundest of all sensualities
is the sense of truth
and the next deepest sensual experience
is the sense of justice.

Sense of Truth

You must fuse mind and wit with all the senses
Before you can feel truth.
And if you can't feel truth you can't have any other
Satisfactory sensual experience.

I believe that human beings have a "*sense of truth*." This sense helps to analyze phenomena, including scientific phenomena, when we have incomplete information. If you believe we have a sense of truth, could natural selection account for the development of a *sense of truth*?

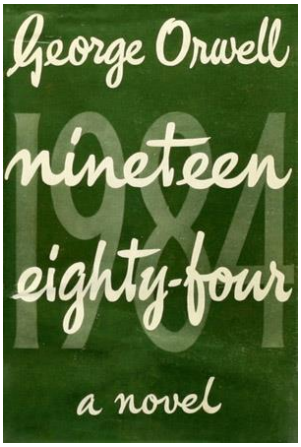


In a paper entitled, *On the fundamental antithesis of philosophy*, **William Whewell** discusses two kinds of truths: ***necessary truths*** and ***truths of experience***. Necessary truths, like 2 + 2 = 4, cannot be otherwise. On the other hand, we can imagine that the truths of experience, such as the earth orbits the sun in a year, the moon goes through its phases in a month, and the earth rotates in a day, could be otherwise. "*Necessary truths are formed from our thoughts, the elements of the world within us; and are established from definitions and axioms. The truths of experience, as they appear to us in the external world, we call Facts; and when we are able to find among our ideas a train which will conform themselves to the apparent facts, we call this a Theory. This distinction and opposition, thus expressed in various forms; as Necessary and Experiential Truth, Ideas and Senses, Thoughts and Things, Theory and Fact, may be termed* ***the Fundamental Antithesis of Philosophy****; for almost all the discussions of philosophers have been employed in asserting or denying, explaining or obscuring this antithesis.* ***No apprehension of things is purely ideal: no experience of external things is purely sensational…If we think of any thing, we must recognize the existence both of thoughts and things. The fundamental antithesis of philosophy is an antithesis of inseparable elements. We are often told that such a thing is a fact and not a Theory…Does the apprehension of the fact imply assumptions which may with equal justice be***

called a theory, and which are perhaps false theory? In which case, the fact is no fact."

We must take care and use our experience when it comes to what we accept as necessary truths. In *1984*, George Orwell (1949) wrote

"*'Do you remember,' he went on, 'writing in your diary, "**Freedom is the freedom to say that two plus two make four**"?'*



'Yes,' said Winston.

O'Brien held up his left hand, its back towards Winston, with the thumb hidden and the four fingers extended.

'How many fingers am I holding up, Winston?'

'Four.'

'And if the party says that it is not four but five—then how many?'

'Four.'

The word ended in a gasp of pain. The needle of the dial had shot up to fifty-five. The sweat had sprung out all over Winston's body. The air tore into his lungs and issued again in deep groans which even by clenching his teeth he could not stop. O'Brien watched him, the four fingers still extended. He drew back the lever. This time the pain was only slightly eased.

'How many fingers, Winston?'

'Four.'

The needle went up to sixty.

'How many fingers, Winston?'

'Four! Four! What else can I say? Four!'

The needle must have risen again, but he did not look at it. The heavy, stern face and the four fingers filled his vision. The fingers stood up before his eyes like pillars, enormous, blurry, and seeming to vibrate, but unmistakably four.

'How many fingers, Winston?'

'Four! Stop it, stop it! How can you go on? Four! Four!'

'How many fingers, Winston?'

'Five! Five! Five!'

'No, Winston, that is no use. You are lying. You still think there are four. How many fingers, please?'

'Four! five! Four! Anything you like. Only stop it, stop the pain!'

Abruptly he was sitting up with O'Brien's arm round his shoulders. He had perhaps lost consciousness for a few seconds. The bonds that had held his body down were loosened. He felt very cold, he was shaking uncontrollably, his teeth were chattering, the tears were rolling down his cheeks. For a moment he clung to O'Brien like a baby, curiously comforted by the heavy arm round his shoulders. He had the feeling that O'Brien was his protector, that the pain was something that came from outside, from some other source, and that it was O'Brien who would save him from it.

'You are a slow learner, Winston,' said O'Brien gently.

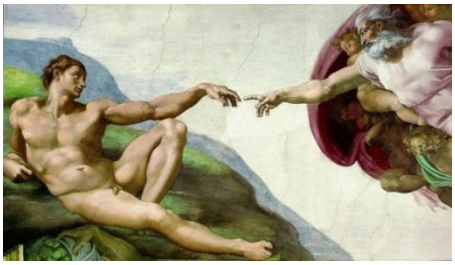
*'How can I help it?' he blubbered. '**How can I help seeing what is in front of my eyes**? Two and two are four.'*

'Sometimes, Winston. Sometimes they are five. Sometimes they are three. Sometimes they are all of them at once. You must try harder. It is not easy to become sane.'

Does the scientific establishment ever put us in the position of being a Winston?

https://www.youtube.com/watch?v=IyLfcNaeB7Y&feature=youtu.be

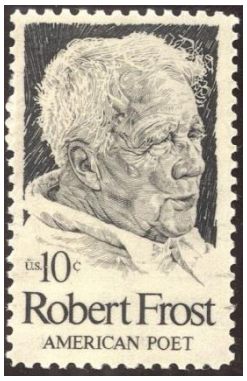
On February 10, 2014, The American Institute of Biological Sciences (http://ncse.com/news/2014/02/aibs-opposes-oklahomas-antiscience-bill-0015389 http://www.aibs.org/position-statements/20140210_ok_science_ed_act.html) wrote the following about a bill being considered by the Oklahoma Legislature: "*Advocates for this and similar legislation often assert that evolution and climate change are controversial subjects. Any controversy is purely political.* ***There is no legitimate scientific controversy about evolution or climate change****. Scientists have, and continue to, empirically test these concepts and with each test the evidence grows stronger and our understanding more thorough*." Similar bills are currently being debated in many states: https://ncse.com/news/2017.



Charles Darwin (1859) ended his *Origin of Species* like so: "*It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been* ***produced by laws acting around us****.* ***These laws, taken in the largest sense, being Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external*** *conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the* ***war of nature****, from famine and death, the most exalted object which we are capable of conceiving, namely, the*

production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."

Where did life come from?

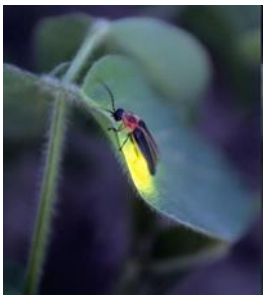




The Secret Sits

We dance round in a ring and suppose,
But the Secret sits in the middle and knows.

--Robert Frost



Aristotle (350 BC), who synthesized the teachings of the times into a theory of life that envisioned that living beings can ***either*** come from other living beings following the sexual union of male and female ***or*** if their type does not have sex, they can be formed **spontaneously**. It seemed to Aristotle that plants originated spontaneously from the earth; frogs sprang up from mud; fireflies came from the morning dew; and maggots, flies, fleas, and lice came from manure, decaying meat, and other filth. This conclusion, which Aristotle presented in *On the Generation of Animals*, is supported by **casual observations** of the world. (http://www.esp.org/books/aristotle/generation-of-animals/html/) Indeed Lucretius (50 BC) wrote *On the Nature of Things* that "*Earth, the all-mother, is beheld to be.*" (*http://classics.mit.edu/Carus/nature_things.mb.txt*)





Johannes Baptista van Helmont, a physician, natural philosopher, pious heretic, searcher for truth, child of the seventeenth century, discoverer of gases (from the Greek *Χαος*), and target of the Spanish Inquisition from 1625 to 1642, had a recipe for producing mice by combining human sweat with wheat germ and leaving them alone in a jar for 21 days. However, in 1668, **Francesco Redi**, a physician, natural philosopher and poet, saw things differently with regard to spontaneous generation. In his book, *Esperienze intorno alla Generazione degl'Insetti*, Redi showed that maggots did not appear in meat when he placed the meat in a jar, and carefully covered it with fine gauze. In fact, he noticed that maggots did not arise spontaneously, but only developed when flies were allowed to lay their eggs on the meat.



T. H. Huxley translated Redi's words (in an Address to the British Association at Liverpool in 1870): "*Here are dead animals, or pieces of meat. I expose them to the air in hot weather, and in a few days they swarm with maggots. You tell me that these are generated in the dead flesh; but if I put similar bodies, while quite fresh, into a jar, and tie some fine gauze over the top of the jar, not a maggot makes its appearance, while the dead substances, nevertheless, putrefy just in the same way as before. It is obvious, therefore, that the maggots are not generated by the corruption of the meat; and that the cause of their formation must be something which is kept away by gauze. But gauze will not keep away aëriform bodies, or fluids. This something must, therefore, exist in the form of solid particles too big to get through the gauze. Nor is one long left in doubt what these solid particles are;*


ESPERIENZE
Intorno alla Generazione
DEGL'INSETTI
FATTE
DA FRANCESCO REDI
CARLO DATI.



for the blowflies, attracted by the odour of the meat, swarm around the vessel and, urged by a powerful but, in this case, misleading instinct, lay eggs, out of which the maggots are immediately hatched, upon the gauze. The conclusion, therefore, is unavoidable; the maggots are not generated by the meat, but the eggs which give rise to them are brought through the air by the flies."

The belief in spontaneous generation of large plants and animals began to wane throughout the 17th and 18th centuries, due in part to observations on sperm by **Antony van Leeuwenhoek** and on embryo development by William Harvey. However, with the discovery of **animalcules** by Leeuwenhoek (1676), the belief in the spontaneous generation of microbes became the standard belief because the microbes **seemed to appear out of nothing**.



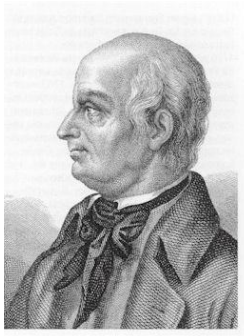
Leeuwenhoek was a draper and probably used a magnifying glass to inspect the quality of cloth. His curiosity and observational powers led to many discoveries. His interest in the cause of taste led to the discovery of bacteria: "*Having several times endeavoured to discover the cause of the pungency of Pepper upon our tongue, and that the rather, because it hath been found, that though Pepper had lain a whole year in vinegar, yet it retained still its pungency; I did put about 1/3 of an ounce of whole pepper in water, placing it in my Study, with the design, that the pepper being thereby rendred soft, I might be enabled the better to observe what I proposed to my self. This pepper having lain about 3 weeks in the water, to which I had twice added some Snowwater, the other water being in part exhaled; I looked upon it the 24. of April 1676. and discern'd in it, to my great wonder, an incredible number of very little animals of divers kinds….*"

Demonstration: Observe the presence of microbes in black pepper water that was not inoculated. Did they arise by spontaneous generation?

fig: G.



The apparent spontaneous generation of microorganisms was **confirmed experimentally** when **John Needham** (1749), a Catholic Priest, boiled mutton gravy, stoppered it, and found that microbes grew in the boiled broth.

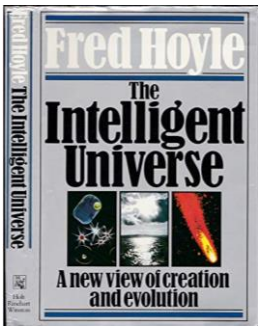


Lazzaro Spallanzani (1769, 1784), another Catholic Priest and natural philosopher, repeated Needham's experiment and showed that if you boiled chicken broth and the container it was in *extensively* before you stoppered it tightly, microbes would not appear in the broth. They only appeared after the stopper was opened. Thus, it appeared that microbes only seemed to arise spontaneously because they were ubiquitous. They were either already in any preparation that had not been properly sterilized or were capable of contaminating any preparation that they could enter. Spallanzani's supporters believed that he had shown that spontaneous generation was impossible, whereas Needham's supporters believed that Spallanzani had only shown that microbes need air.

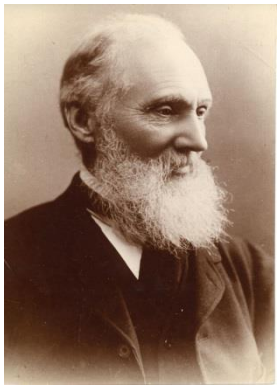


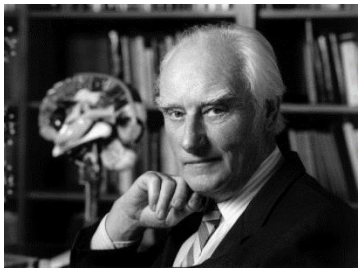
In the middle of the 19th century, **Louis Pasteur** performed the critical experiment. With his now-famous swan-shaped flasks that allowed air, but not microbes, to pass, Pasteur showed that as long as a solution is properly sterilized (e.g., **pasteurized**) and airborne contaminants excluded by cotton-wool, no microbes were generated in the broth, even when air was able to freely pass through the long neck. He concluded that there is no such thing as spontaneous generation of

microbes. In his Address to the British Association in Liverpool in 1870, T. H. Huxley traced "*the path of which has been followed by a scientific idea in its long and slow progress from the position of a probable hypothesis to that of an established Law of Nature."* That is, from Redi's hypothesis to the Law of Nature that ***all* life comes from pre-existing life**. The famous quote by T. H. Huxley, "*The great tragedy of Science—the slaying of a beautiful hypothesis by an ugly fact*" can be found in his Address to the British Association at Liverpool in 1870. https://archive.org/details/scientificmemoi01huxlgoog

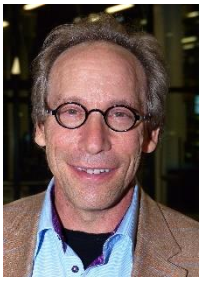


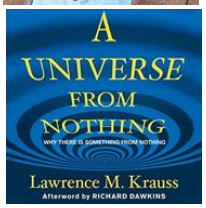
If living organisms cannot originate spontaneously, and the early earth was a molten ball incapable of supporting life, then how did they originate on earth? Some scientists, including Hermann Richter (1865), **Lord Kelvin (1871)**, **Hermann von Helmholtz** (1881), **Svante Arrhenius**, **Francis Crick** (1981), and **Fred Hoyle** realizing that no one has yet created life in the laboratory, suggested that life cannot be created, but must come from existing life. If life can only originate from life, then life on earth must have originated in outer space and come to earth on meteorites in the form of cosmozoa, microbes, spores, or seeds. This theory is called **panspermia**, which means seeds everywhere. Arrhenius (1908) wrote, "*The Universe in its essence has always been what it is now. Matter, energy, and life have only varied as to shape and position in space*."




Even if the panspermia theory is true, we are still faced with the question of how living organisms originated in the universe. So, although it is possible that life on Earth originated on another planet in another solar system or another galaxy, I will use **Occam's razor** and assume that **life on Earth originated from or was created from lifeless matter on Earth itself**. This does not mean that life did not also arise from lifeless matter elsewhere in the universe, and the arguments I make apply to the origin of life anywhere. Let us now start at the beginning, the origin of the universe.





According to Lawrence Krauss, there is no creator, and the universe came from nothing. (https://www.youtube.com/watch?v=7ImvlS8PLIo; https://www.youtube.com/watch?v=46sKeycH3bE; https://www.youtube.com/watch?v=MawwCJ5q-2Y; https://www.youtube.com/watch?v=vwzbU0bGOdc) This is contrary to the **first law of thermodynamics**, which states that energy cannot be created or destroyed except by the creator. It is consistent with **Heisenberg's uncertainty principle** that states that energy can be created for a period of time as long as the product of the energy and duration of time is equal to or less than Planck's constant. The two laws of nature **contradict** each other, and you can decide for yourself which is more fundamental.



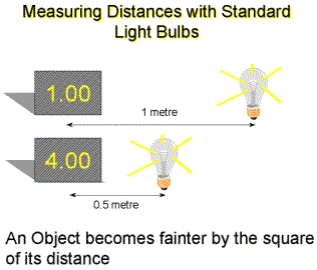
Demonstration: Have you ever seen matter create itself? Using only the objects in the empty tray in front of you, create a universe. Please raise your hand when you are finished. Do you think the results would be different if the experiment were repeated by each person on earth (http://www.worldometers.info/world-population/), every day for a year? Why or

why not? (I should give you six days and let you rest on the seventh). Out of curiosity, did anyone in this room give birth to themselves?

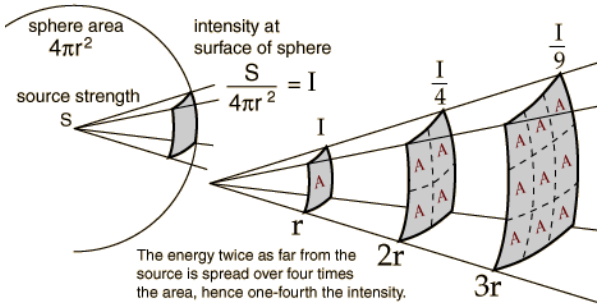


Demonstration: The transformation of energy and the **First Law of Thermodynamics**. Energy cannot be created or destroyed but it can be interconverted.

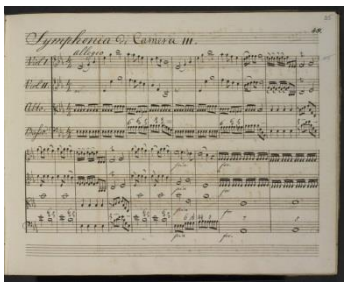
Our present idea of the origin of the universe is intimately connected with our concept of its **size**. In Ptolemy's time it was believed that earth was like a point in the center of a spherical universe. In the 17th century, **Christiaan Huygens** made attempts to measure the distance to the stars by using the **Principle of Uniformity of Nature** and provisionally assuming that the sun was a star and the distant stars had the same intrinsic brightness as the sun. Huygens assumed that the stars only appeared dimmer than the sun due to their distance. The sun served as a **standard candle**. Using the inverse square law, Huygens estimated that Sirius, the brightest star, is 28,000 times farther from earth than the sun is. The equation is: $S_{sun\ or\ star} = I_{sun} 4\pi r_{sun}^2 = I_{star} 4\pi r_{star}^2$.



An Object becomes fainter by the square of its distance



Throughout the 18th century, telescope designs improved, and **William Herschel** began to see the ***more distant stars*** which were dimmer and thus had not been seen with the older telescopes that had less light-gathering power. Herschel described light-gathering power as "*the power of*





penetrating into space." With each improvement of the telescope, the known universe became larger and larger. William Herschel did not start out as an astronomer but became interested in astronomy as a result of his interest in **music**, which led him to **mathematics**, having read Robert Smith's (1749, 1738) *Harmonics, or the Philosophy of Musical Sounds* and *A Compleat System of Opticks*, which led him to **optics** and the **design of telescopes**, which led him to astronomy. Herschel was indeed a polymath. He discovered many new double stars (1782, 1785, 1821), Uranus (which was originally called *Georgium Sidus* by Herschel in honor of George III in 1781), infrared radiation (1800), and he related the increased price of wheat to the paucity of sunspots (1801). His son was John Herschel.

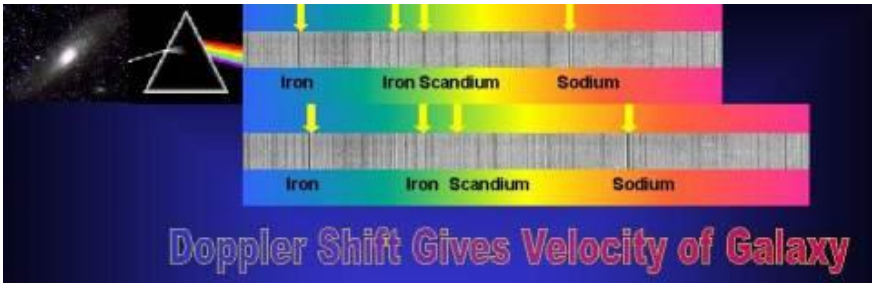


Using the giant telescopes at the Palomar and Harvard College observatories in the early 20th century, **Harlow Shapley** mapped the positions of spiral nebulae, which are now known as galaxies, using the intrinsic brightness of stars known as **Cepheids** as standard candles. While Shapley thought that the spiral nebulae were all within the Milky Way, he concluded that the Milky Way was much bigger than previously thought and therefore the universe too was ***even larger*** than his predecessors conjectured.

Meanwhile, **Vesto Slipher** measured the **red shifts** in the spectra of number of galaxies. Using the **Doppler Principle**, he concluded that, as a rule, the galaxies were receding from earth at tremendous velocities. We talked about Gregor

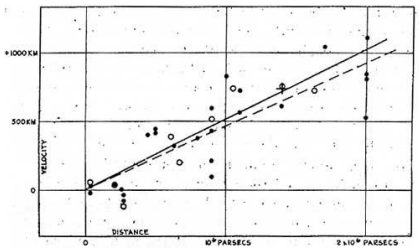
Mendel and Christian Doppler last week. We will talk more about spectral lines and red shifts next week.







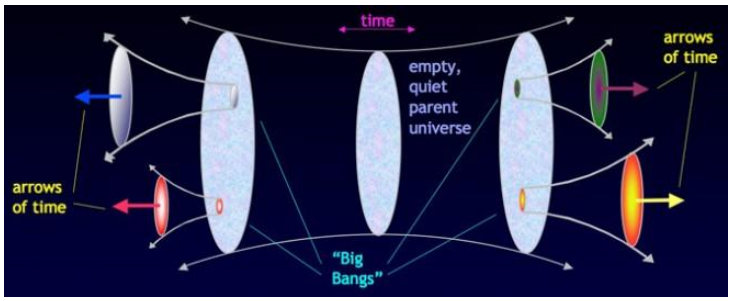
In the 1920s, **Edwin Hubble** noticed that the recession velocities determined by the **red shifts** of the spectra of galaxies were proportional to their distance from earth, and concluded that the universe was not only large but ***expanding***. Hubble determined the constant of proportionality between the recession velocity and the distance from earth. The proportionality constant is known as the *Hubble constant*. If we assume that prior to the large-scale expansion of the universe all the galaxies were clumped together, we can estimate the age of the universe from the reciprocal of Hubble's constant. The current best guess for **the age of the universe is 13.8 billion years.**



How was the universe formed? According to the thirteenth century thinking of **Robert Grosseteste** (Grandy, 2014), *God created a dimensionless point of light containing both form and matter. As the point expanded, differentiation ensued to produce the material multiplicity of the cosmos. The first moment of creation, the moment of first light, hence lives on in all later moments, and this fact expresses itself in the splendor of the physical universe.*



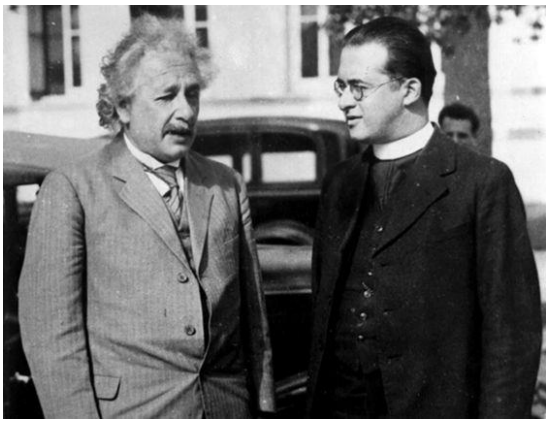
The current consensus among cosmologists is that 13.8 billion years ago, **space** and **time**, as well as all the **matter** and **energy** contained in the universe, came into being in one gigantic explosion. This theory proffered by **Georges Lemaitre** and made popular by **George Gamow** is called the **Big Bang Theory**, a moniker given by Fred Hoyle in order to mock this cosmological creation theory. Hoyle believed that the universe was eternal and thus could not have had a beginning. Although I will only discuss the Big Bang Theory since it is strongly supported by the discovery of the cosmic microwave background radiation, there is an alternative cosmological theory, known as the **Steady-State Theory**, based on the idea of continuous creation. Currently, cosmologists, including Brian Greene and Max Tegmark, believe that there is a **multiverse** and we live in only one of many universes that result from quantum fluctuations. I'll just discuss the one I live in, which I am happy to call the Luddite universe!









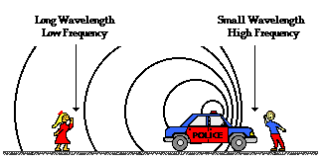


According to the modern version of the **Big Bang Theory**, at time zero, when exnihilation occurred, the universe exploded from an infinitesimally tiny and infinitely hot point. There was only **one** thing, and this force/particle had an energy equal to *kT*, where the temperature ***T* equals infinity**. According to **Albert Einstein's General Theory of Relativity**, this infinitesimally small point could not exist inside anything, because that would be something. So according to the Big Bang Theory, and *Genesis* for that matter, in the beginning there was a unity, a singularity, a **primeval atom**, as it was called by **Georges Lemaître**.



Demonstration: As the temperature (*T*) of a gas increases, it exerts more pressure (*P*) if the volume (*V*) is constant. The pressure is related to the temperature by the ideal gas law. If the container is allowed to expand and if the temperature is not held constant, the gas will cool. The ratio of the product of pressure and volume (*PV*) to temperature for a single particle is given by Boltzmann's constant (k), according to the **ideal gas law**. Imagine pumping up the sphere to such a high density, temperature and pressure and letting the walls dissolve. What would happen to the gas molecules? Would they move away from the sphere? Where would the translational kinetic energy originate?



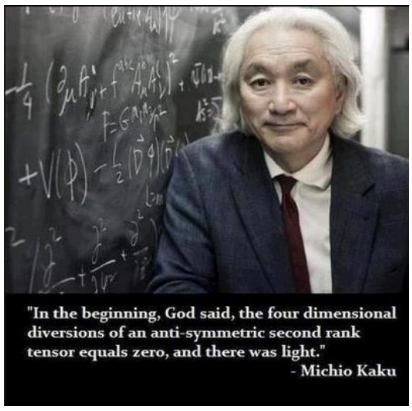


Demonstration: We will look at the acoustic **Doppler effect** which is more pronounced than the optical Doppler effect because the ratio of the speed of the object to the speed of the wave is greater for the acoustic Doppler effect. This is because the speed of sound (300 m/s) is so much less than the speed of

light (300×10^6 m/s). Taking the last demonstration into consideration, how would the Doppler effect influence the appearance of the gas molecules to an observer near the original position of the sphere or the appearance of the gas molecules to an observer towards which the gas molecules were moving?



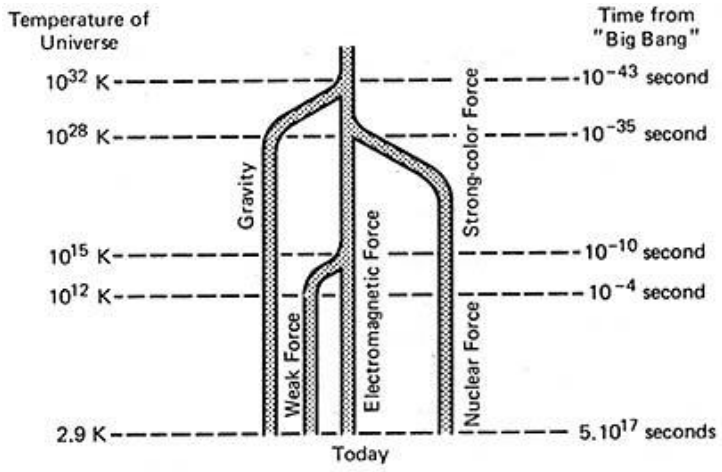
Some people may call what was **there at the beginning** *God*, others *love, intelligence, the spirit of life*, *logos*, or *consciousness*. **Michio Kaku**, a theoretical physicist, describes it in terms of a saying he saw on a tee shirt at Berkeley: "*In the beginning God said, the four-dimensional divergence of an antisymmetric, second rank tensor equals zero, and there was light, and it was good. And on the seventh day he rested*." Whatever we call what was there at the beginning, the violent explosion caused the universe to expand, and as a consequence of the **expansion**, the universe began to cool. As the universe **cooled**, the single particle in the universe no longer had enough energy to prevent its splitting into two particles, and when it split there was not enough energy (kT) to **fuse** the two split particles back together. The particles that carry the **gravitational force** separated from the particles that carry the **grand unified (GUT) force**. The energy of a given particle is typically expressed in electron volts (eV). The energy of a particle can be related to temperature (T) with the following identity:



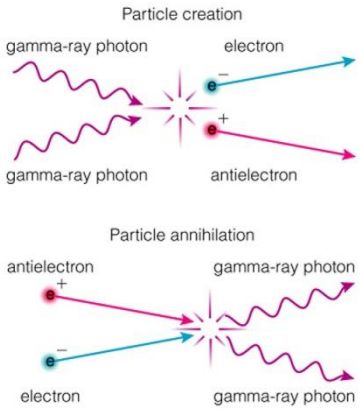
$$\text{electrical energy} = eV = kT = \text{thermal energy}$$

where e is the elementary charge (1.6×10^{-19} Coulombs), V is an electrical potential in Volts, and k is Boltzmann's constant (1.38×10^{-23} J/K).

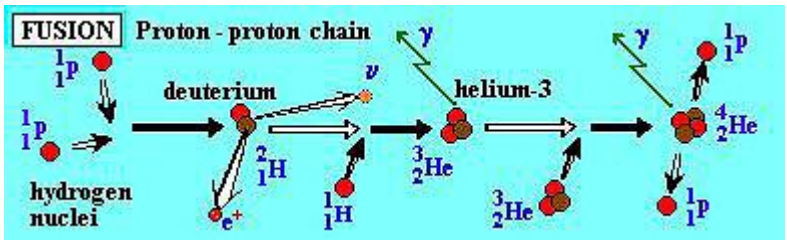
As the universe continued to expand, the temperature continued to cool, which resulted in the separation of the GUT particle into particles that carry the **electroweak** and the **strong force**. **Ten nanoseconds** after the creation of the universe, the particles that carry the electroweak force separated into particles that carry the weak force and **photons**, which are the particles that carry the **electromagnetic force**.



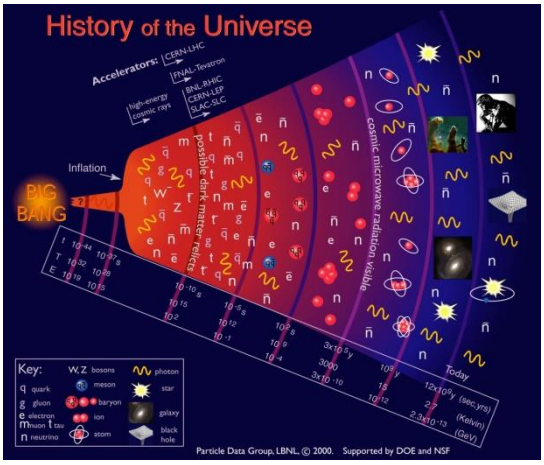
Approximately 1 millisecond after the creation of the universe, the temperature cooled enough so that electron-positron, proton-antiproton and other **matter-antimatter pairs** formed from photons and then annihilated each other to become photons again. As the universe continued to expand, particles made of matter, such as **electrons**, **protons**, and **neutrons** remained. The whereabouts of the antimatter is a mystery that cannot be accounted for by the standard model of physics. I think that it might be what others call **dark matter**.



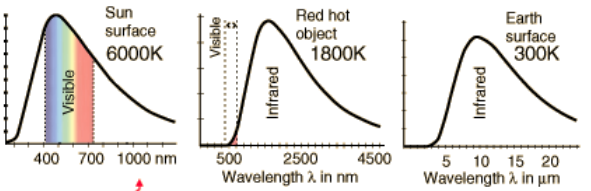
Three minutes after the big bang, the universe cooled enough to allow the formation of hydrogen and helium nuclei, in a process known as **nucleosynthesis**.

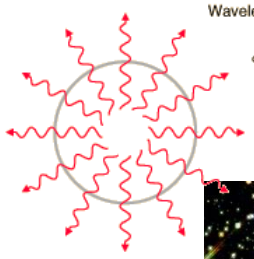


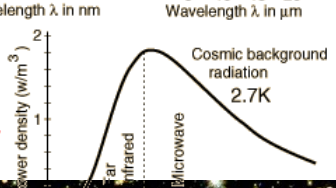
The nuclei and electrons collided with each other with energies that were too high to allow the formation of atoms. **Three hundred thousand years** after the creation of the universe, the universe cooled to about 3000 K, which is cool enough to allow the electrons to bind to the atomic nuclei and form **hydrogen atoms** and **helium atoms**.



When the charged nuclei and electrons that **interact with all wavelengths of light**, became **neutral atoms**, the universe changed from being mostly **opaque** to being **transparent**. As the transparent universe continued to expand, the wavelengths of the **ancient radiation** got longer and longer. The distribution of the wavelengths in the cosmic background radiation is now in the microwave range. This is consistent with the universe being a blackbody with a temperature of 2.7 K. The cosmic microwave background



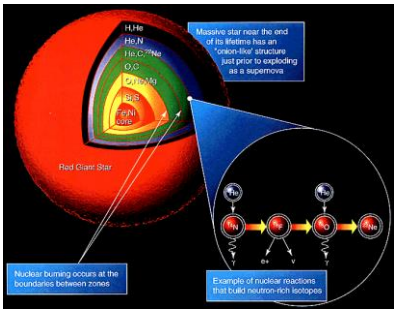






radiation is a relic of the **first light**, the **oldest light in our universe**, imprinted on the universe when it was just 300 thousand years old.

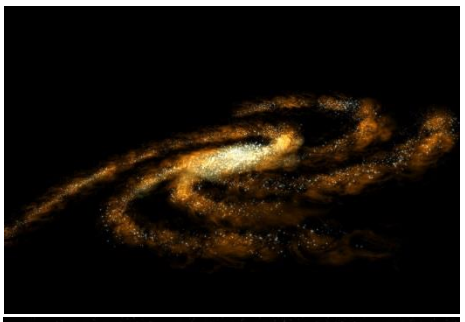
After a further **one** or **two billion years**, the atoms began to coalesce into dense areas as a result of **gravitational attraction**. The aggregation of these atoms gave rise to **stars**, including **quasars**, and collections of stars known as **galaxies**. As the atoms in the stars were pulled together as a result of gravitational attraction, the **gravitational energy** was transformed into **thermal energy**, and the masses of **hydrogen ignited** to become glowing stars. The **high temperatures and pressures** developed inside the stars provided the energy necessary for **thermonuclear fusion** that **fuses** the **hydrogen** nuclei into **helium** nuclei and other nuclei of light elements, including **carbon**, **nitrogen**, **oxygen**, **sulfur**, and **phosphorous**—the **elements so important for life**.

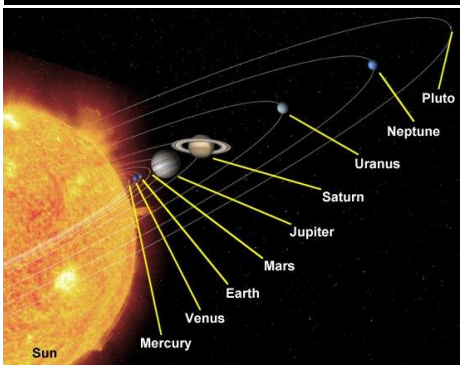


Eventually the **first-generation stars exploded**, sending fragments of dust into the universe. The energy of the explosion formed the heavier elements, including **sodium** (Na), **magnesium** (Mg), **calcium** (Ca), **iron** (Fe), and **cobalt** (Co), which were spread over the universe in the form of **cosmic dust**.

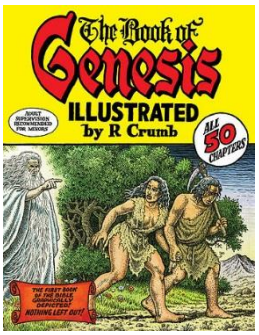


Approximately 4.6 billion years ago, on the edge of a **spiral galaxy** known as the **Milky Way**, a rotating cloud of gas and dust known as a **nebula** collapsed and began to spin faster and faster, just like a figure skater does, according to the **Law of Conservation of Angular Momentum**. The center of the cloud became so massive and dense; it **collapsed under gravitational pressure and ignited the gasses within it to form a glowing star**, which we call our **sun**. Around the sun, other dust particles clumped together into what we now call the **planets**. One of these clumps formed our home planet. And as Ptolemy wrote in the *Almagest* (Book I, sect 4), the earth is spherical.



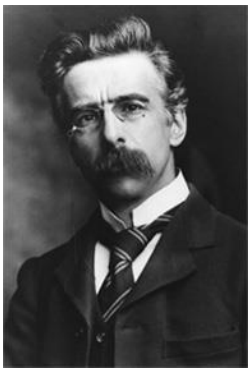


In the seventeenth century, the age of earth was determined by the theologians **James Ussher** and **John Lightfoot** by following "the begets" in the Bible. They estimated the creation of the earth to have occurred about 4000 BC. The polymath **Edmund Halley** (1715), who is well-known to you as the namesake of a comet he discovered, suggested that science may have a role to play in the determination of the age of the earth. Halley proposed that the age of the earth could be calculated from the saltiness of the sea. Halley suggested that the **sea was salty** because the water that gave rise to rivers dissolved salt out of the rocks and the rivers carried the salty water to the sea. Consequently, the sea became saltier with time.





Assuming that the primeval ocean was formed by the condensation of water upon the land, and thus did not contain as much salt as it now does, **John Joly** (1899), another polymath, estimated the age of the earth to be **90 million years old**. Joly estimated the age by guessing that the total mass of the oceans is 1.322×10^{18} tons. He then assumed that rain leached the sodium out of the rocks and into the rivers, the average concentration of sodium in rivers is about 24,106 tons per cubic mile, the mass of sodium in the oceans is one percent of the mass of the oceans or 1.415×10^{16} tons, and the average amount of river water reaching the ocean is 6524 cubic miles per year.

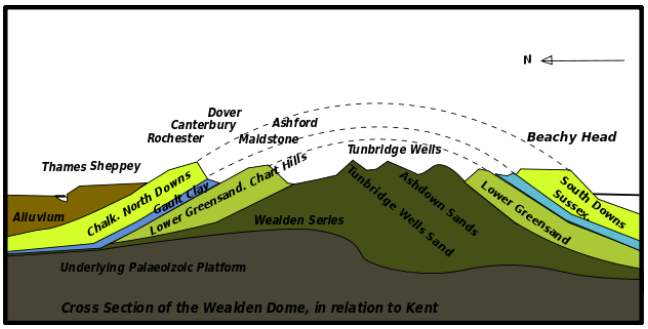


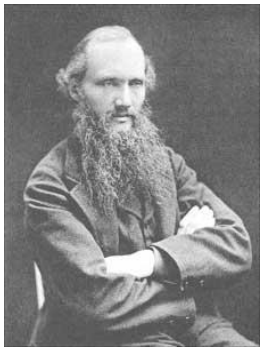
$$1.415 \times 10^{16} \times \frac{1}{6524} \times \frac{1}{24106} = 89.96 \times 10^{6} \text{ years}$$

In the first edition of *The Origin of Species*, **Charles Darwin** (1859) estimated that if the wave action of the sea **eroded** a 500-foot-high chalk cliff at a rate **of one inch per century**, then the denudation of a chalk deposit in England known as **the Weald** would have taken 306,662,400 years. Darwin revised his assumptions in the second edition (Darwin, 1860) and completely removed his estimate of the minimal age of the Weald from the third (Darwin, 1861) and later editions of the *Origin of Species* after having "*been convinced of its inaccuracy in several respects by an excellent article in the 'Saturday Review,' Dec. 24, 1859.*"

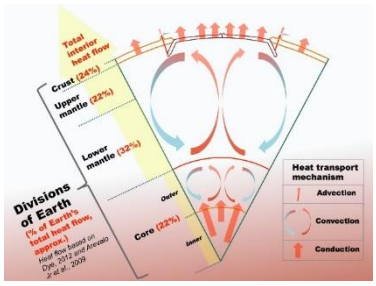




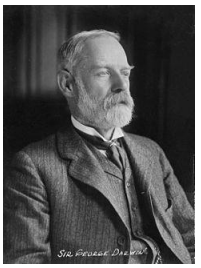




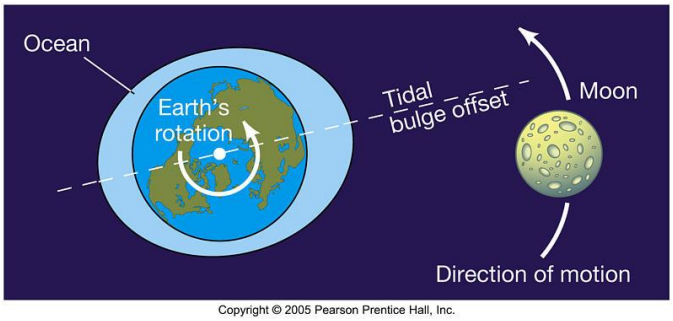
William Thomson (1864), another polymath, estimated the age of the earth from its thermal properties and his knowledge of heat flow. He knew that **temperature increases as one descends in a cave or a mine** and therefore the core of the earth must be hotter than its surface. He also knew that heat must move from the core to the surface by conduction. He also realized that since the surface of the earth does not become hotter from year to year, then there must also be a secular loss of heat from the surface. This one-way flow of heat was consistent with the Second Law of Thermodynamics that he cofounded. By estimating the current rate of heat flow and the current temperature of the core, Thomson concluded that "*it is quite certain that the solar system cannot have gone on even as at present, for a* ***few hundred thousand or a few million years***."



Aside: Rate of heat flow = (heat transfer coefficient) (surface area of earth) (temperature of core – temperature of surface) / (radius of the earth)



The age of the earth was estimated by **George Darwin**, Charles' son, from a determination of the present distance between the moon and the earth. Darwin assumed that initially the earth and the moon were one molten body and as a result of fission, they separated, with the moon revolving around the earth. As a result of **tidal friction**, the moon revolves more slowly over time and consistent with **conservation of angular momentum** ($L = mvr$), recedes from the earth over time. From the observed rate of recession, Darwin (1898) estimated the minimum age of the earth to be **50-60 million years** old when



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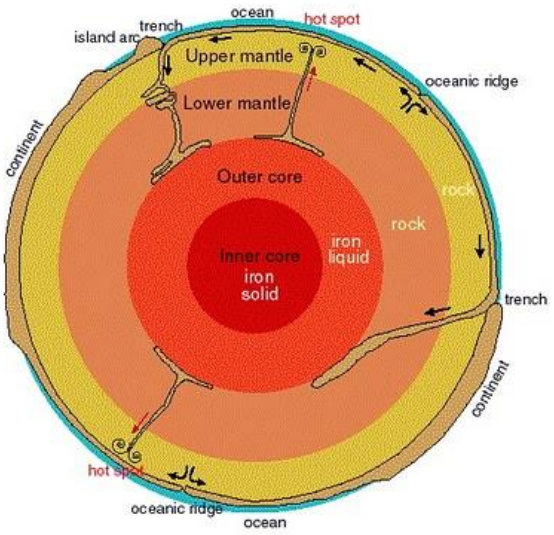
the earth and moon must have been in contact. According to George Gamow, given that the distance from the earth to the moon is about 239,000 miles and the moon recedes 5 inches (= 7.89×10^{-5} miles) per year, the moon and earth must have been in contact 3 billion years ago, making the earth even older. The actual rate of recession is about 3.8 cm/year (2.36121×10^{-5} miles/year), which would make the earth about 10 billion years old (239000 miles/2.36121×10^{-5} miles/year).

Aside: Note that the earth never had enough angular momentum to fission off the moon as George Darwin suggested and currently it is thought that soon after the earth was formed, a large body named **Theia** collided with the proto-earth blasting material into orbit that eventually accreted into the moon.

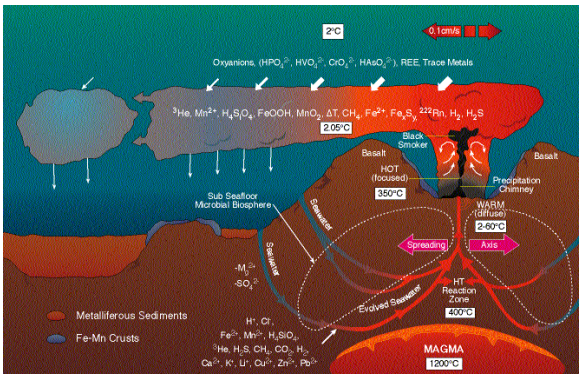


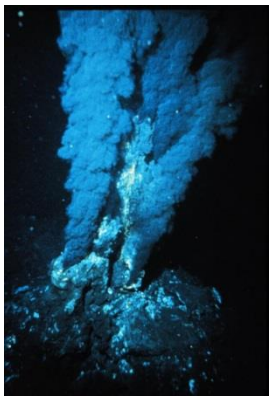
Each estimate of the age of the earth derived from scientific principles is greater than the age of the earth estimated by the theologians. Nevertheless, there is much variation as a result of the **incomplete knowledge that the assumptions** are based on. For example, the earth would be much older than William Thomson estimated from the temperature of the earth if there were a continuous source of heat generation in the core of the earth that he did not take into consideration. Indeed, such a heat source does exist. It results from **radioactivity**, which was not known until Henri Becquerel discovered it serendipitously in 1896. The age of the earth is currently determined using **radiometric dating**, which I will talk more about next week. Analysis of radioactive elements and their decay products indicates that earth and the rest of the solar system were formed between 4.5 and 4.6 billion years ago.

Four and a half billion years ago earth was becoming fully formed, although it was extremely hot and essentially **ocean-less** and **atmosphere-less**. Heat was primarily generated by radioactive decay in the core of the earth, although some heat may have been due to gravity pulling earth's components together. As a result of gravity, the dense metals such as iron sank to the core while the lighter rocky materials containing aluminum, silicon, calcium, magnesium, sodium, and potassium floated to the surface.



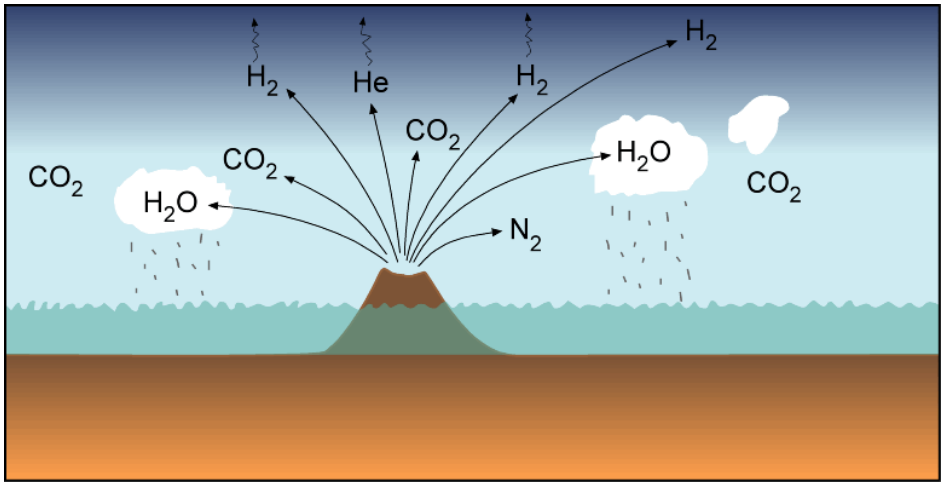
Hydrothermal vents, earthquakes, volcanism, and impacts caused gasses in rocks to be released, probably producing an atmosphere of H_2O, CO_2, N_2, as well as CO, CH_4, NH_3, and H_2S.

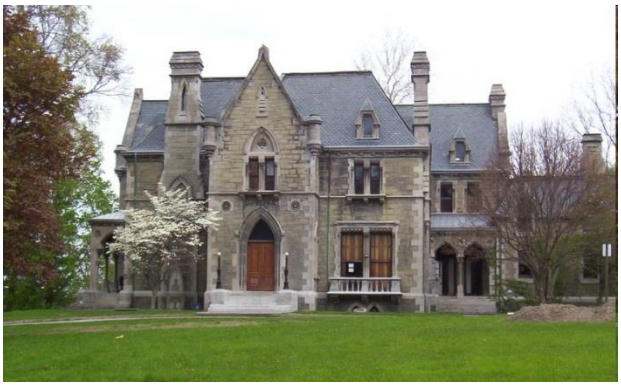






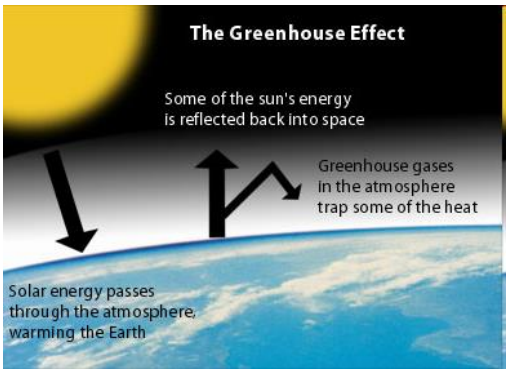
The gravitational attraction of earth was not great enough to hold onto the lightest elements, including H_2 and He_2, and thus most of the original atmosphere of hydrogen and helium was lost. The loss of hydrogen does not mean that the atmosphere became oxidizing, because there was no molecular oxygen in the atmosphere yet. The accumulation of **molecular oxygen (O_2)**, which happened during the **Precambrian**, approximately 3.4 to 2.7 billion years ago, only occurred after the origin of life and the introduction of **photosynthetic mechanisms**. It is still a mystery whether or not the early atmosphere was oxidizing, reducing, or, something in between.





Water from outgassing reacted with CO_2 in the air to produce carbonic acid. Returning to earth as **acid rain**, the carbonic acid probably leached Ca^{2+} and Mg^{2+} from rocks and formed **limestone** ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). **Llenroc** (Cornell spelled backwards) is formed from more recently formed limestone, most likely produced by the skeletal remains of corals.

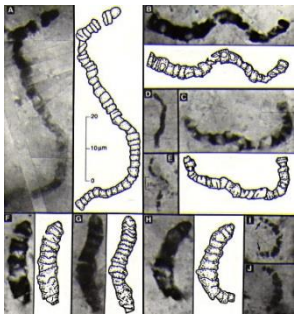
In this way, the **CO_2** was removed from the atmosphere and precipitated in sediments. Atmospheric CO_2 would have acted as a **greenhouse gas** to keep the **early earth warm**; thus knowledge of the CO_2 concentration would be useful in determining the climate of the early earth. While the actual CO_2 concentration during the formation of earth is not known, the amount of CO_2 in the atmosphere was determined by the balance between outgassing and precipitation.

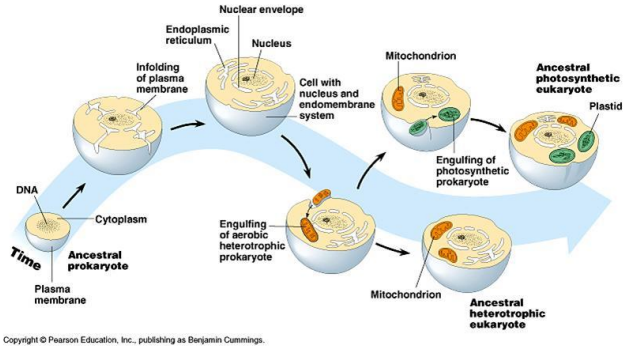


From the formation of earth 4.6 billion years ago until approximately 3.8 billion years ago, earth may have been **bombarded with meteorites or fragments of rocks** that were not included in the initial process of planet formation. Any one of these **impactors** may have hit with so much energy that it would have **vaporized** any organic molecules or living organism that may have already formed. Thus, from 4.6 to 3.8 billion years ago, attempts at the creation of life would have been **frustrated** by the enormous energy provided by the impactors, and life neither could have formed nor continued.



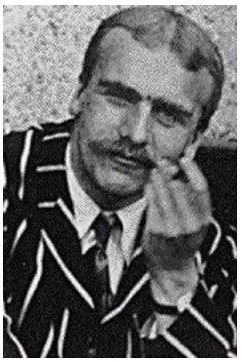
Some of the oldest known rocks, which are 3.5 billion years old, formed on earth, contain fossils that resemble cyanobacteria. Thus, **prokaryotic-like cells** appeared between **3.8 and 3.5 billion years ago**, only 300 million years after what may have been repeated sterilizations of the planet by impactors from space. **Eukaryotic cells** may have originated approximately **1.4 billion years ago** by engulfing other prokaryotic organisms in a process known as **endosymbiosis**.

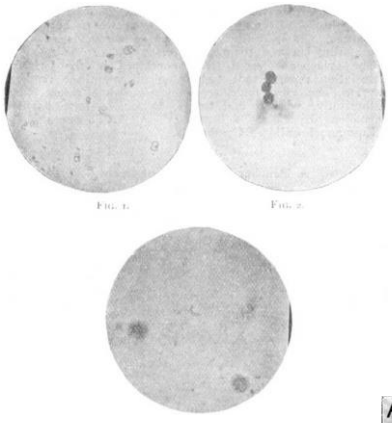


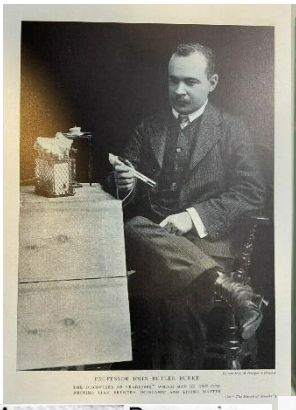


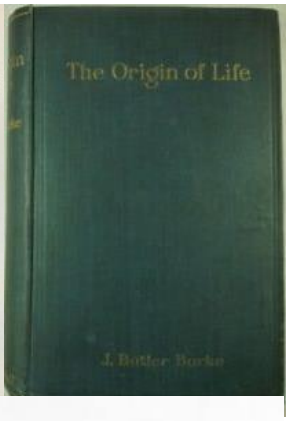
Life as we know it requires carbon-containing compounds, and we must ask: What was the **source of the organic compounds** that made up the first life on earth? It is possible that organic compounds, including urea, formaldehyde, amino

acids, purines, sugars, etc., came from asteroids, comets, or meteorites. These compounds have been found in meteorites and cyanide and acetylene have been found by NASA's Spitzer Space Telescope. However, according to **Charles Darwin**, it is likely that prebiotic chemical evolution took place on earth. Charles Darwin (1871) guessed that life began in a "**warm little pond**" when he wrote to his friend, Joseph Hooker, "*But if (and oh! What a big if!) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc. present, that a protein compound was chemically formed ready to undergo still more complex changes*." **John Burdon Sanderson Haldane** (1929) wrote, "*Now, when ultra-violet light acts on a mixture of water, carbon dioxide, and ammonia, a vast variety of organic substances, including sugars and … proteins are built up. … In this present world, such substances, if left about, decay—that is to say, they are destroyed by micro-organisms. But before the origin of life they must have accumulated till the primitive oceans had reached the consistency of hot dilute soup."*

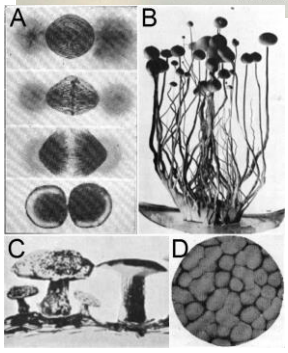








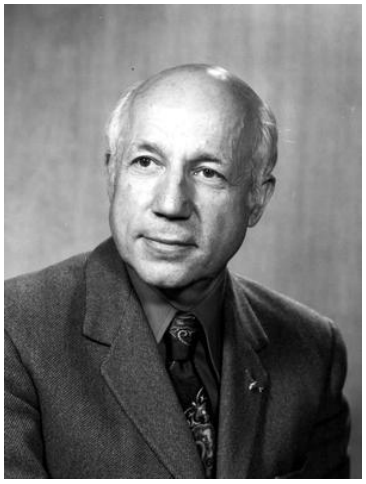
John Butler Burke (1905), working in the Cavendish Laboratory, tried to create life by exposing sterilized homemade beef bouillon to the radioactive rays of radium. The cells or "radiobes" he created seemed to grow and divide. However, Sir William Ramsay believed that the radiobes were nothing more than bubbles of oxygen and hydrogen produced when the radium rays decomposed water. The bubbles then got coated by the albumin in the bouillon so that the

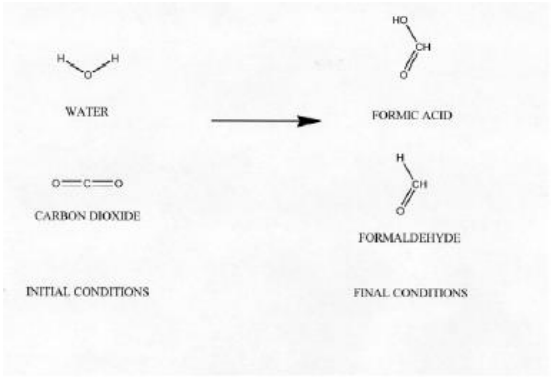




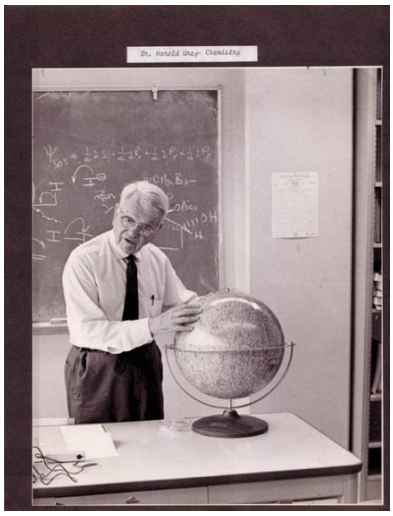
product looked like a cell, but its contents were nothing more than a mixture of oxygen and hydrogen.

In 1912, Stéphane Leduc created the term synthetic biology in his book, *La Biologie Synthétique* to describe the work he did to try to produce osmotically active life from nonlife in chemical gardens. Synthetic biology or "intentional biology" to create or modify life using DNA technology is currently very popular at many universities, including Cornell.





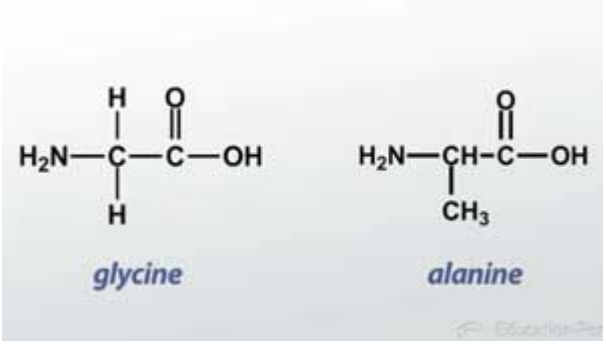
In 1951, **Melvin Calvin**, who we will encounter again when we talk about photosynthesis, conducted experiments on prebiotic evolution and succeeded in fixing carbon dioxide into a more reduced, organic form. They irradiated a **mixture of water and carbon dioxide** in a closed chamber with a **helium ion beam** from **Ernest Lawrence's cyclotron**. This resulted in the formation of **formic acid** and **formaldehyde**. Formic acid was first discovered by John Wray (1670) in ants (*Formica*).



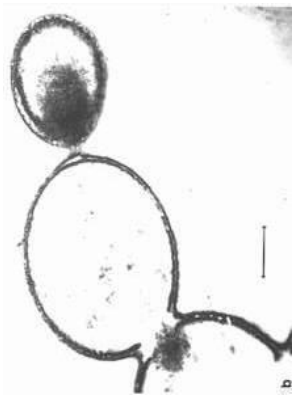
At about this same time, **Harold Urey**, who had been studying the atmosphere of Jupiter, wrote that the atmosphere of the early earth, like that of Jupiter's, may have been **reducing**, and thus may have consisted largely of hydrogen, methane, ammonia, and water. He suggested that Calvin's experiment be repeated using a **reducing**, not an oxidizing, **atmosphere**.



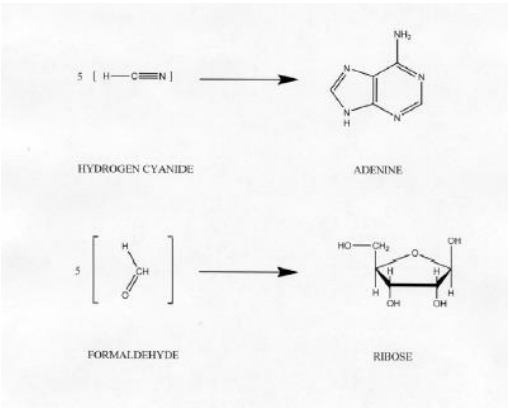
Stanley Miller, a graduate student of Urey's, created an apparatus designed to mimic this presumed early-earth condition. A gaseous mixture of methane, ammonia, hydrogen, and water was connected to a flask of boiling water. The steam created by the boiling water caused the gasses to move past electrodes, the electrical discharges of which simulated lightning in the atmosphere. A cold-water jacket caused molecules to condense and fall out of the "atmosphere." The reaction was allowed to run for a week, after which the solution, which had become deep red, was analyzed. Miller had succeeded in producing not only the formic acid and formaldehyde, but since he included **nitrogen**, he could also form **hydrogen cyanide**, which can combine with water and aldehydes to form the **amino acids**, glycine, and alanine.

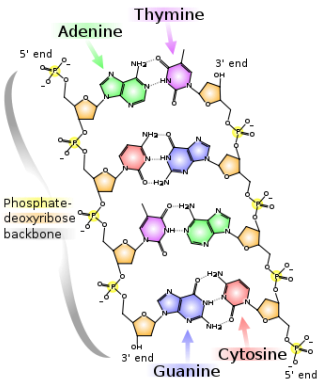


Under prebiotic conditions, amino acids can **polymerize into polypeptides** without the aid of enzymes or a template. The **peptide bonds** between the amino acids occur as a result of **dehydration reactions**. Even more complex structures like **proteinoid microspheres** can form under prebiotic conditions. Proteinoids are large, branched molecules produced when amino acid mixtures containing large amounts of aspartic acid, glutamic acid, or lysine are heated without water. When these dry proteinoids are placed in warm water and allowed to cool, microspheres are produced, and these proteinoid microspheres look similar to the microspheres found in rocks that are 3.8 billion years old.

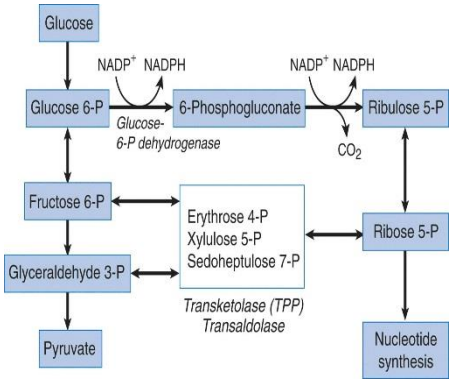


Nucleic acids can also be synthesized under early-earth conditions. Adenine can be formed from hydrogen cyanide. **Adenine** is made according to the simple overall reaction: **5 HCN ⇔ adenine**. **Ribose** and other sugars can also be made under similar conditions by the overall reaction: **5 formaldehyde (CH_2O) ⇔ ribose ($C_5H_{10}O_5$)**. The adenine and ribose can lose a single water molecule and form **adenosine**. By including phosphate in the presumed early-earth conditions, nucleoside monophosphates, including adenosine monophosphate, guanosine monophosphate, cytidine monophosphate, thymidine monophosphate, and uridine monophosphate, as well as adenosine trisphosphate (ATP) are formed. The polymerization of **deoxyribonucleotides** would result in **DNA**.

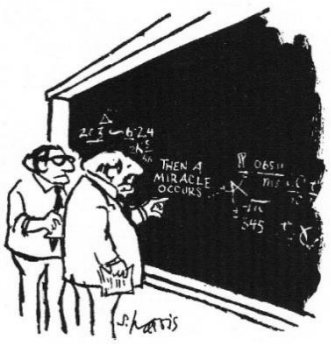


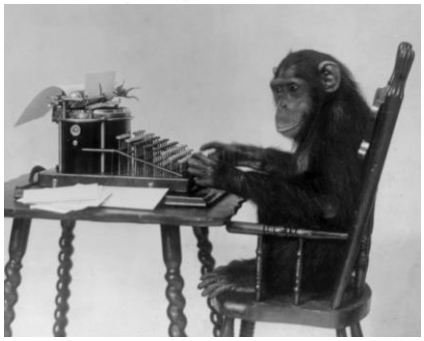


By adding **ferrous ions** (Fe^{2+}), which are enriched in early sediments, and simulating the conditions thought to resemble the primordial oceans, Keller et al. (2014, 2016) have been able to create the energy transforming **glycolytic** and nucleotide-synthesizing **pentose-phosphate pathways** without enzymes, suggesting that the origin of metabolic pathways may date back to the prebiotic world! These enzyme-free pathways can even be regulated. The Fe^{2+}-stimulated glycolytic reactions are favored at neutral pH while the Fe^{2+}-stimulated pentose phosphate reactions are favored at alkaline pH. The pathways themselves along with the Fe^{2+} **catalysts** may have been taken up by the cells that later evolved gene-encoded enzymes to facilitate theses metabolic processes.



In the experiments described above, which are performed under early-earth conditions, the **yields of organic molecules and macromolecules are extremely low**. The **yields depend greatly on the reducing power** of the atmosphere used. Reducing power is related to **chemical energy** and the greater the reducing power, the greater the yield. The **yields also depend on the other types of energy available** (e.g., light, heat, lightning, cosmic rays, etc.) and the availability of dehydrating conditions. While the **probability** of various molecules coming together to form a living organism is **infinitesimally low**, it only had to happen once. During a long enough time and with a large enough number of mixtures, every possible combination will eventually occur and improbable combinations eventually occur. As **Herodotus** (ca. 450 BC) said, "*If one is sufficiently lavish with time, everything possible happens*." And as **Émile Borel** suggested, with enough time, a



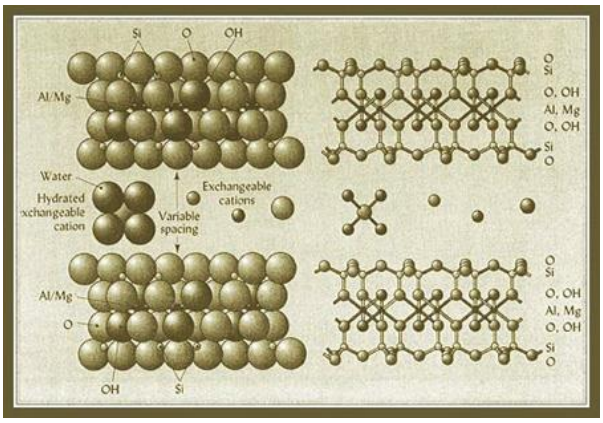


million monkeys could type all the volumes that exist in the British Museum. Yes, a miracle can occur. Michael Dowd (2007) wrote in *Thank God for Evolution*!, "*The evolutionary epic is first and foremost a celebration of the* ***arrow of time***." Although as I mentioned, Einstein wrote in a letter of condolence to Michele Besso's mother, "*People like us, who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion*." Is the arrow time fundamental or an illusion?—Your choice.

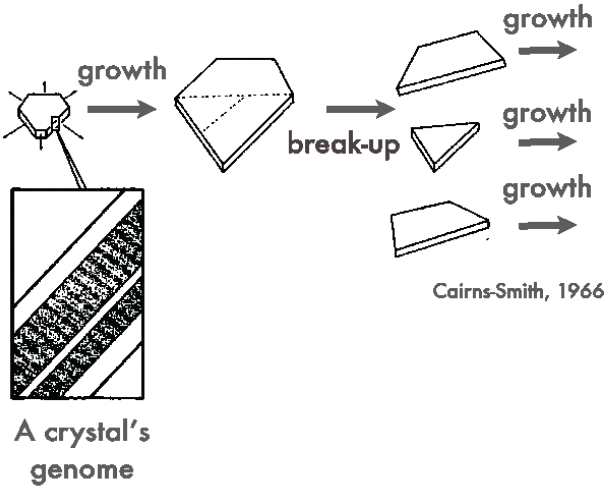


Stimulated by Charles Darwin's *Origin of Species*, **Ludwig Boltzmann** (1886), a strong proponent of the reality of atoms, combined his interests in physics and biology and proposed that **life began with the formation of self-replicating complexes of atoms**. In order for life to evolve, it must replicate with a high yet finite degree of fidelity. However, given the complexity of the current genetic apparatus, it is unlikely that the genetic apparatus arose all at once. How then did the first self-replicating molecular structure arise? One candidate for the earliest ancestor, alluded to in *Genesis* (2:7), is **clay**.

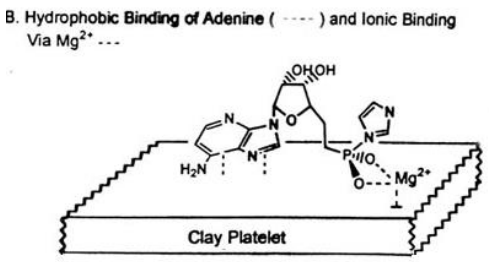
Clays are inorganic microcrystalline particles approximately 10 micrometers in diameter that are made out of hydrated aluminum silicates and other assorted cations and anions. As crazy as this idea sounds, **clays are capable of replicating themselves.**

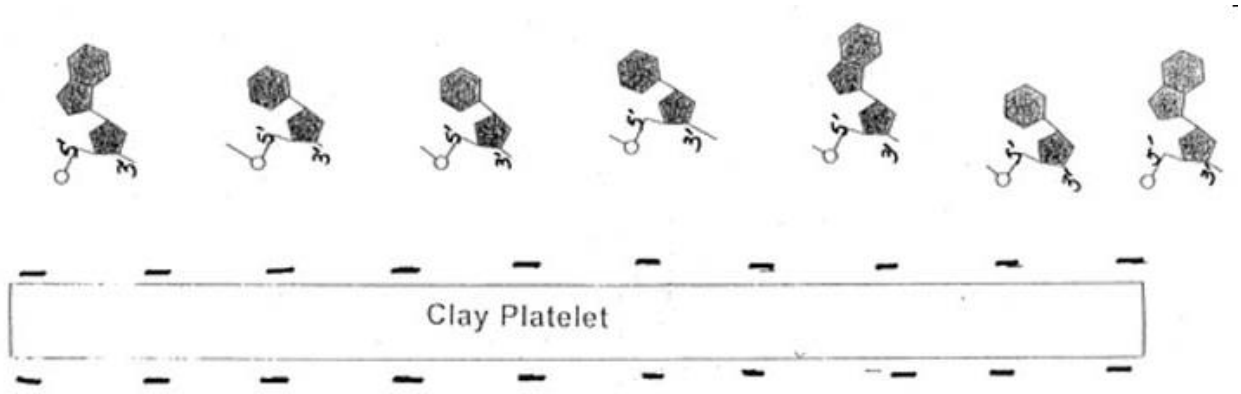


Normally, the composition of a clay crystal that forms *de novo* is determined by the relative abundance of ions in a solution. However, if a suspension of a given charge is seeded with crystals of differing charge, the **growing crystals** are typical of the **seeding clays** rather than the **suspension**.



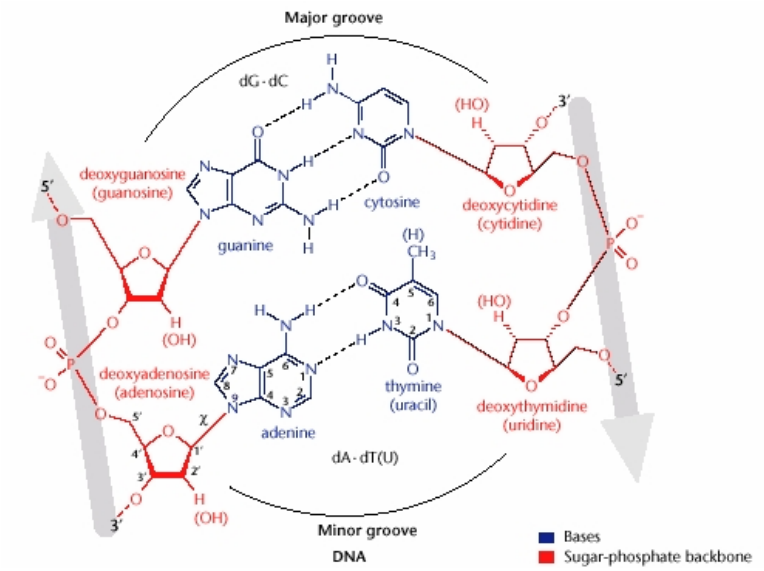
The clays may have facilitated the formation of organic molecules in prebiotic conditions. The clays may have bound nucleotides, including ATP. A given sequence of charge density on clay might have resulted in the binding and ordering of a particular linear sequence of nucleotides resulted in the performance of sequential reactions.



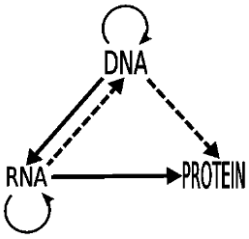


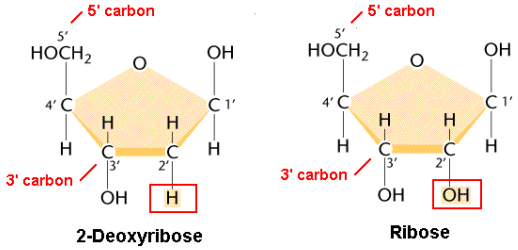
The sugar phosphates of closely bound nucleotides might have polymerized to form a backbone so that the macromolecular complex could have performed sequential reactions free in solution.

A s**equence of clay-bound nucleotides** might have contained the information necessary to **form a polymer** and to allow a **sequence of reactions**. As an added bonus, however, the nucleic acid polymer would have the ability to bind with a "**complementary nucleotide**" through the formation of hydrogen bonds and form an intermediate template so that it could **reproduce itself**. If nucleic acid could **reproduce faster** than the clays reproduced, the nucleic acids would outcompete the clays for the replicating function, in a process that Graham Cairns-Smith (1982) calls **genetic takeover**. Eventually the nucleotides left the evolutionarily-challenged clays behind, and the nucleotide-based genetic code went through its own evolutionary development.



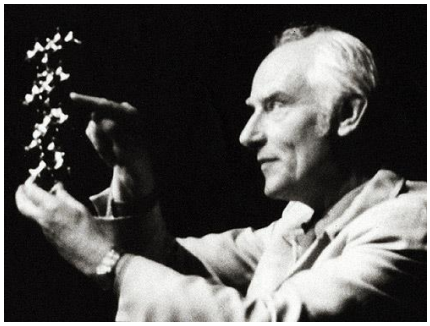
Whether clay was our ancestor, the genetic apparatus as we know it probably evolved from RNA alone, into the **trinity of molecules** that carry the **information of life**: **DNA**, **RNA**, and **protein**. DNA has an advantage over RNA as an informational molecule, in part, because its stability is greater than that of RNA due to the reduction of the 2'OH to 2'H.





(Klug & Cummings 1997)

Proteins, on the other hand, outperform RNA in **enzymatic functions** due perhaps to the variety of functional groups found in the **twenty amino acids** compared to the **four nucleotides**. Eventually, **RNA** provided the link between the **coding function of DNA** and the **catalytic function of proteins**.

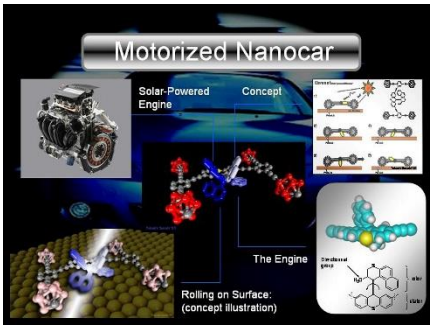


Francis Crick (1981) co-discoverer of the structure of DNA, wrote in *Life Itself: Its Origin and Nature*: "*An honest man, armed with all the knowledge available to us now, could only state that in some sense, the origin of life appears at the moment to be almost a miracle, so many are the conditions which would have had to have been satisfied to get it going*." He went on to say, "*But this should not be taken to imply that there are good reasons to believe that it could not have started on the earth by a perfectly reasonable sequence of fairly ordinary chemical reactions. The plain fact is that the time available was too long, the many microenvironments on the earth's surface too diverse, the various chemical possibilities too numerous and our own knowledge and imagination too feeble to allow us to be able to unravel exactly how it might or might not have*

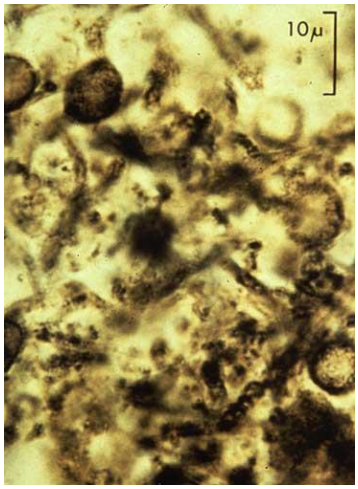
happened such a long time ago, especially as we have no experimental evidence from that era to check our ideas against."

The **National Academy of Sciences** (1999) notes that "*For those who are studying the origin of life, the question is no longer whether life could have originated by chemical processes involving nonbiological components. The question instead has become which of many pathways might have been followed to produce the first cells*." On the other hand, according to **James Tour** (2016), a synthetic chemist who makes chemical microcars, wrote in, *Animadversions of a Synthetic Chemist*, "*The basis upon which we as scientists are relying is so shaky that we must openly state the situation for what it is: it is a mystery*."





The similarities in molecules, mechanisms, metabolic pathways, and structures in living organisms point to a **single common ancestor**. Throughout history, the idea of common descent was espoused in one form or another by Empedocles, Pierre-Louis Moreau de Maupertuis (1753), Erasmus Darwin (1794–1796), Jean Lamarck (1809), and others. Matthias Schleiden (1853) wrote, "*This view, that the whole fullness of the vegetable world has been gradually developed out of a single cell and its descendants, by gradual formation of varieties, which became stereotyped into species, and then, in like manner, became the producers of new forms, is at least quite as possible as any other, and is perhaps more probable and correspondent than any other, since it carries back the Absolutely Inexplicable, namely the production of Organic Being, into the very narrowest limits which can be imagined."*



John Herschel wrote a letter to Charles Lyell on February 20, 1836, in which he called the way that one species replaced another, the **mystery of mysteries**. **Charles Darwin** (1859) presented evidence that since variation could be acted upon by artificial selection, evolution must take place over long periods of **time** as a **gradual** result of natural selection.

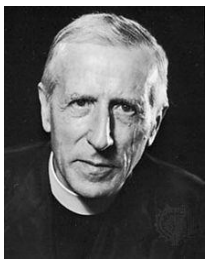
According to Darwin (1859), "*Although in many cases it is most difficult to conjecture by what transitions an organ could have arrived at its present state; yet, considering that the proportion of living and known forms to the extinct and unknown is very small, I have been astonished how rarely an organ can be named, towards which no transitional grade is known to lead. The truth of this remark is indeed shown by that old canon in natural history of '****Natura non facit saltum****.'* [Nature does not make a jump.] *We meet with this admission in the writings of almost every experienced naturalist; or, as Milne Edwards has well expressed it, nature is prodigal in variety, but niggard in innovation.* ***Why, on the theory of Creation, should this be so? Why should all the parts and organs of many independent beings, each supposed to have been separately created for its proper place in nature, be so invariably linked together by graduated steps?*** *Why should not Nature have taken a leap from structure to structure?* ***On the theory of natural selection, we can clearly understand why she should not; for natural selection can act only by taking advantage of slight successive variations; she can never take a leap, but must advance by the shortest and slowest steps.***

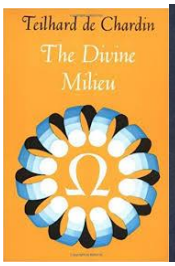
Darwin set up the dichotomy: The origin of species that were created by God would occur in **jumps** while the origin of species by natural selection would occur **gradually**.

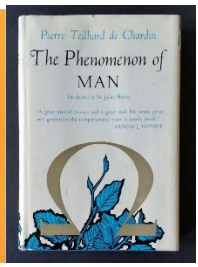


Richard Goldschmidt (1933) was skeptical of the well-established belief in Darwin's theory of the **gradual** origin of species by natural selection, and he offered an alternative theory for the origin of species. He proposed that new species evolve through **drastic changes** that result from a mutation in a gene that influences the relative rates of various developmental processes. Such a change would create "***hopeful monsters*** *which would start a new evolutionary line if fitting into some empty environmental niche*." A minute change in the DNA that encodes controlling elements such as a transcription factor, an element in a signal transduction cascade, or a regulatory RNA, may provide the mechanism that leads to such a drastic change and a new evolutionary line.

What is the relationship between the origin of life and the origin of consciousness (being aware of the external world) and the origin of a **conscience** (inner knowledge)? Is it best described by a gradual transition or by jumps? The former would imply a natural origin and the latter would imply a supernatural origin.



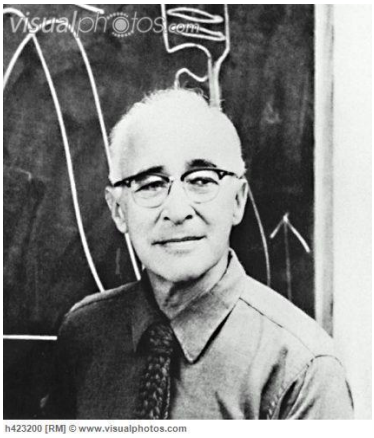




Pierre Teilhard de Chardin, a paleontologist and a priest put the two together and considered the theory of evolution by natural selection to be **God's first step** in a much grander design. To Teilhard de Chardin, creation was a God-driven purposeful teleological process acting on matter that led towards the omega point which is union with the Godhead.

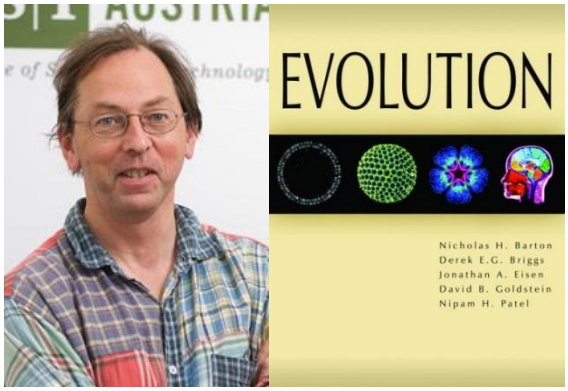


I have discussed how the **original quantum particle evolved into atoms**, how atoms gave rise to molecules, how molecules gave rise to self-replicating systems, and how self-replicating systems gave rise to cellular life. In each stage of the evolution of life in the universe, **new and surprising properties emerged** from the combination of previous entities. **Louis de Broglie** (1946) maintains that thought is an essential condition for the progressive evolution of the human race. Some cells may specialize in higher functions of thought and self-identity. A small group of **large spindle-shaped cells** has been discovered in the brains of humans and primates. These cells, which are also known as Von Economo neurons, may be involved in **self-identity** and **self-awareness**. When these cells are damaged, people become "vegetables." These cells are less active in depressed people, disappear in people afflicted with Alzheimer's disease, and are more active in people with manic disorders. These cells alone are probably not sufficient to make us human.



Although truly amazing, is it not possible that when you put together billions of cells that are specialized for communication that consciousness and a conscience is a natural outcome? **George Wald** (1963) captured this awe and rational thinking when he spoke in front of the president of the United States and said: "*We have been told so often and on such tremendous authority as to seem to put it beyond question, that the essence of things must remain forever hidden from us; that we must stand forever outside nature, like children with their noses pressed against the glass, able to look in, but unable to enter. This concept of our origins encourages another view of matter. We are not looking into the universe from outside. We are looking at it*

from inside. Its history is our history; its stuff, our stuff. From that realization we can take some assurance that what we see is real. Judging from our experience upon this planet, such a history that begins with elementary particles, leads perhaps inevitably toward a strange and moving end; a creature that knows, a science-making animal that turns back upon the process that generated him and attempts to understand it. Without his like, the universe could be, but not be known, and that is a poor thing. Surely this is a great part of our dignity as men, that we can know, and that through us matter can know itself; that beginning with protons and electrons, out of the womb of time and the vastness of space, we can begin to understand; that organized as in us, the hydrogen, the carbon, the nitrogen, the oxygen, those 16 to 20 elements, the water, the sunlight—all, having become us, can begin to understand what they are, and how they came to be."



According to Nicholas H. Barton et al. (2007), the authors of *Evolution* published by Cold Spring Harbor Laboratory Press, "*The exquisite biological devices that we now see appear as though carefully designed for their present purposes, and this appearance of design was long taken as evidence of an intelligent creator.* ***We now know that biological function is constructed and maintained by natural selection: the gradual accumulation of variations that arise by chance*** *and that are preserved because they* ***aid the survival and reproduction of their carriers****. The theory of evolution is a synthesis of Darwinian natural selection and Mendelian genetics. It allows us to ask not just how life evolved, but why it is as it is: Why do organisms develop from a single cell? Why is the genetic code as it is? Why is there sexual reproduction?*"

The view presented in the Cold Spring Harbor Laboratory book is the standard view of scientists. It is not the only reasonable view. What are the **assumptions** upon which the standard view and your view are based? What are the **values and limitations** of the **evidence** supporting the standard view and, if it differs, your view? It certainly differs from the view of Alfred Russel Wallace (1858), the original expositor of the theory of evolution by natural selection and of T. H. Huxley (1893) in his Romanes Lecture.



In his book, *Social Environment and Moral Progress*, **Alfred Russel Wallace** (1913) weighed in on the importance of variation to the purpose of life: "*One of the weakest and most foolish of all the objections to the Darwinian theory is, that it does not explain variation, and is therefore worthless. We might as well say that Newton's discovery of the laws of gravitation are worthless because its cause was not and has not yet been discovered, or that the undulatory theory of light and heat is worthless, because the origin of the ether, the thing that undulates, is not known, The beginnings of things can never be known, and, as Darwin well said, it is foolish to waste time in speculation about them. I think I have shown in my World of Life that infinite variability is a basic law of Nature and have suggested its probable purpose.* ***That purpose seems to have been the development of a life-world culminating in Man—a being capable of studying, and enjoying, and to some extent comprehending, the vast universe around him, from the microscopic life in almost every drop of water to the whirling nebulae of the glittering star-depths extending to almost unimaginable distances around him.***

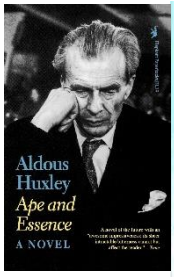
Looking at him thus, man is as much above, and as different from, the beasts that perish as they are above and beyond the inanimate masses of meteoritic

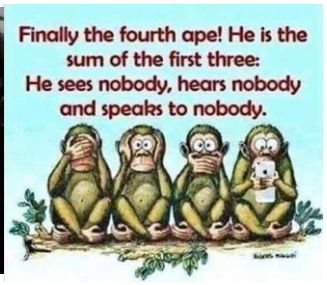
matter, which as we now know, occupy the apparently vacant spaces of our solar system, and from which comets and stars are in all probability the aggregations due to the action of the various cosmic forces which everywhere seem capable of producing variety and order out of a more uniform but less orderly chaos.

But besides this lofty intellect, man is gifted with what we term a moral sense: an insistent perception of justice and injustice, of right and wrong, of order and beauty and truth, ***which as a whole constitute his moral and esthetic nature****, the origin and progress of which I have endeavored to throw some light upon in the present volume. The long course of human history leads us to the conclusion that this higher nature of man arose at some far distant epoch, and through it has developed in various directions, does not seem yet to have elevated the whole race much above its earliest condition, at a time when, by the influx of some portion of the spirit of the Deity, man became 'a living soul'.*

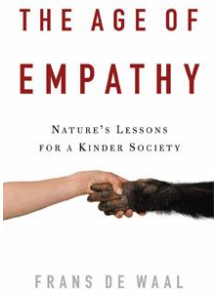
We will now consider some of the changes which this higher nature of man has produced in the action of the laws of variation and natural selection. These are very important and are so little understood that almost all popular writers on the subject of the future of mankind are led into stating as scientific conclusions what are wholly opposed to the actual teaching of evolution…

But if we…give due weight to the complete distinctness and enormous superiority of the mind of man as compared with that of other mammals, we shall be inclined to…[be] *almost certain when we realize the enormous effect his mind has produced, in modifying and almost neutralizing the action of that great law of natural selection which has held supreme sway in every other portion of the organic world.*"

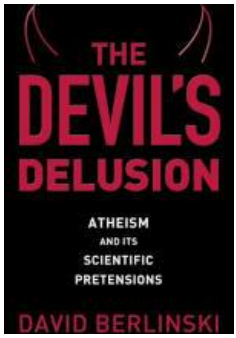


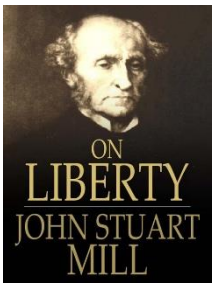


Do you define human beings, who have a material composition nearly identical to the material composition of the earth, bacteria, plants, and animals, no different in kind from those groups as the materialists do? Do you define human beings who have a skeletal structure nearly identical to that of monkeys and apes, no different in kind from those groups? Do you define human beings, who have a *moral and esthetic nature* no different or different in kind from monkeys and apes? Are we a mixture of *Ape and Essence*?

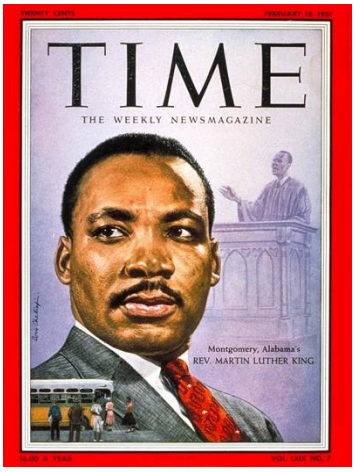


Frans de Waal (http://www.emory.edu/LIVING_LINKS/empathy/faq.html) posits: "*If an extraterrestrial were to visit earth, he would have a hard time seeing most of the differences we treasure between ourselves and the apes*." According to David Berlinski (2008), who wrote *The Devil's Delusion: Atheism and Its Scientific Pretensions*, "*The idea that human beings have been endowed with powers and properties not found elsewhere in the animal kingdom—or the universe, so far as we can tell—arises from a simple imperative:* ***Just look around***." Add up the similarities (e.g., skeletal structure and DNA sequence, being able to recognize ourselves in a mirror) and differences (e.g. musical, artistic, and architectural abilities, use of language in speaking, reading, and writing, ease in giving birth) between apes and human beings. How do you weigh the importance of each similarity and difference? If you believe that human beings and apes are different in kind, what is the cause of that difference? Natural selection? A quantum fluctuation? Chance? God?



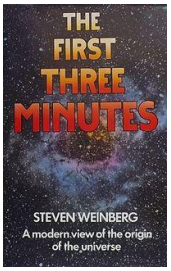


As John Stuart Mill (1859) wrote in On Liberty, "*He who knows only his own side of the case, knows little of that. His reasons may be good, and no one may have been able to refute them. But if he is equally unable to refute the reasons on the opposite side; if he does not so much as know what they are, he has no ground for preferring either opinion*."



Martin Luther King (1957) said in a sermon entitled, Overcoming an Inferiority Complex, "*Irreligion somehow leaves us standing in a blind universe. It says to us somehow that* ***human life is nothing but a cosmic accident on a minor planet, a sort of haphazard by-product of blind forces***. *Says to us somehow that* ***man is nothing but a tiny vagary of whirling electrons, a wisp of smoke from a limitless smoldering***. *But then religion comes over and says, 'Oh no,' that this* ***universe has meaning*** *and that* ***every individual in this universe counts and every individual in this universe has significance*** *because there is a God who guides the destiny of life. There is a God who stands at the center of the universe, and he who discovers this principle begins to live*." Martin Luther King (1953) also wrote in "*The False God of Science*" "*Let us notice this morning how modern man has made a god of science…Doubtless some one has been saying, but is it not right to devote ourselves to scientific adventure? Is not science important for the progress of civilization? To this I would answer yes. No person of sound intelligence could minimize science. It is not science in itself that I am condemning, {*but it is the tendency of projecting it to the status of God that I am condemning*}. We must come to see that science only furnishes us with the means by which we live, but never with the spiritual ends for which we live*."

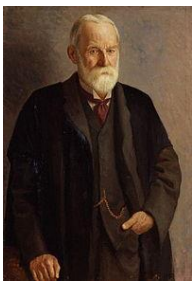




Martin Luther King was awarded the Nobel Peace Prize in 1964. His view contrasts with that of **Steven Weinberg**, who was an undergraduate at Cornell and was awarded the Nobel Prize in physics in 1979. Weinberg said at a meeting entitled, *Beyond Belief: Science, Religion, Reason and Survival*, "*Anything that we scientists can do to weaken the hold of religion should be done and may in the end be our greatest contribution to civilization*." (https://www.nytimes.com/2006/11/21/science/21belief.html) Weinberg (1993) wrote in his book, *The First Three Minutes*, "*The more the universe seems comprehensible, the more it also seems* ***pointless****…The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy*."

Here is an excerpt of review of Karl R. Popper's (1962) *Conjectures and Refutations. The Growth of Scientific Knowledge* by Paul Feyerabend: "*The theory of (scientific) knowledge which was developed in the thirties by Professor Karl Popper is the first example of what one might call a* ***non-authoritarian epistemology****. Ancient beliefs were based on personal authority. They were defended, or 'supported,' by reference to the dictum of such authority. The reform of the theory of knowledge that accompanied the rise of modern science eliminated the personal element, but it did not eliminate the appeal to authority, which returned in the more abstract and depersonalized form of various 'sources of knowledge,' such as Experience or Reason. Popper's contribution consists in eliminating the last element of authoritarianism, the idea that knowledge must have a foundation, and the correlated idea that its evaluation consists in investigating the manner in which it is related to this foundation. The evaluation of*

theories on the basis of an experience that is 'given' is now replaced by the competition of alternative ideas; the acceptance of a theory as being 'proven' by experience (or 'highly confirmed' by experience) is replaced by the acceptance of a theory that has eliminated its competitors because of its comprehensiveness, elegance, promise of future discovery, and has turned out to be the best-for the time being. In the present book, which contains articles previously published as well as some new material, Professor Popper applies this simple and revolutionary idea to a great variety of topics, ranging from scientific matters to politics…The power of Popper's nonauthoritarian point of view, its ability to throw new light upon, and perhaps to solve, problems which have arisen again and again in the history of thought becomes very evident from a perusal of these essays, which are a major contribution to philosophy and whose publication constitutes a major event in the history of this subject."




One more thought from **George Darwin** (1873), a son of Charles Darwin, who imagined a better world where **artificial selection** could be applied to human beings (eugenics). His essay is entitled, *On Beneficial Restrictions to Liberty of Marriage*, which was published in the Contemporary Review (22:412-426). Darwin wrote, "*It is in his own case alone that man ventures to neglect the knowledge he has acquired of the beneficial effects of careful breeding….And this neglect appears likely to continue so long as the pernicious idea generally prevails that man alone of all animals is under the personal and direct management of the Deity; and yet what believer in evolution can doubt that results as surprisingly might be effected in man, as now seen in our horses, dogs, and cabbages*?"

George Darwin is echoing the thoughts of his cousin, Francis Galton (1865), "*If a twentieth part of the cost and pains were spent in measures for the*

improvement of the human race that is spent on the improvement of the breed of horses and cattle, what a galaxy of genius might we not create! We might introduce prophets and high priests of civilization into the world, as surely as we can propagate idiots by mating crétins. Men and women of the present day are, to those we might hope to bring into existence, what the pariah dogs of the streets of an Eastern town are to our own highly-bred varieties."
http://galton.org/essays/1860-1869/galton-1865-macmillan-hereditary-talent.html



You can watch a debate between Lawrence Krauss and John Lennox (2013) on the question, *Does The Cosmos Leave Space For God?*
https://www.youtube.com/watch?v=B2eZA2kXpc0

Does the universe have a cause? Huxley and Darwin weighed in on the question:

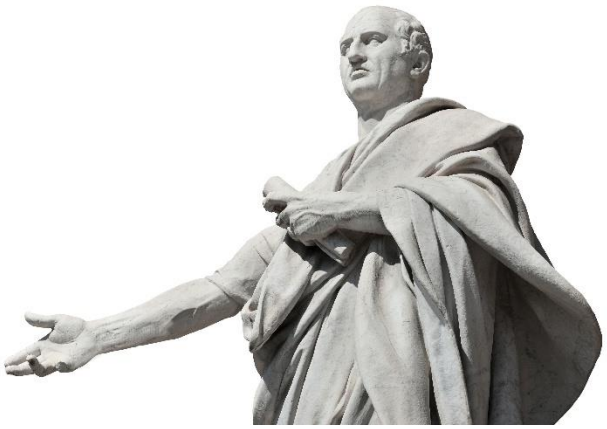
In *The Life and Letters of Charles Darwin*, T. H. Huxley (1888) wrote, "*Do they believe that anything in this universe happens without reason or without a cause? Do they really conceive that any event has no cause, and could not have been predicted by any one who had sufficient insight into the order of Nature?*" For that matter, Darwin wrote to J. D. Hooker on July 12, 1870, "*My theology is a simple muddle: I cannot look at the universe as a result of blind chance*". He went on to say, "*yet I can see no evidence of beneficent design, or indeed of design of any kind in the details.— As for each variation that has ever occurred having been preordained for a special end, I can no believe in it, than that the spot on which each drop of rain falls has been specially ordained*."



Charles S. Pierce (1878) wrote in *The order of Nature*, which appeared in *Popular Science Monthly*, "*The chance world shown to be so different from that in which we live would be one in which there were no laws, the characters of different things being entirely independent; so that, should a sample of any kind of objects ever show a prevalent character, it could only be by accident, and no general proposition could ever be established. Whatever further conclusions we may come to in regard to the order of the universe, this much may be regarded as solidly established, that the world is not a mere chance-medley*." How do you see the world—is it fundamentally governed by chance or by laws—or is this a false dichotomy? The choice is a matter of faith.

Thomas Reid's (1865) Essays on the Intellectual Powers of Man, gives an ancient and a modern view of the choice:

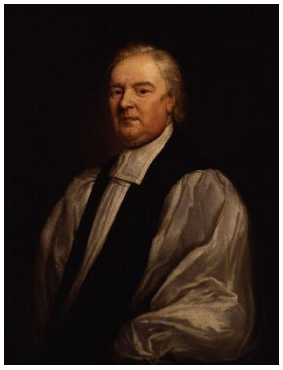
"*The first is **Cicero**, whose words, Lib. I., cap. xiii., De divinatione, may be thus translated:*



'Can anything done by chance have all the marks of design? Four dice may by chance turn up four aces; but do you think that four hundred dice, thrown by chance, will turn up four hundred aces? Colours thrown upon canvas without design may have some similitude to a human face; but do you think they might make as beautiful a picture as that of the Coan Venus? A hog turning up the ground with his nose may make something of the form of the letter A; but do you think that a hog might describe on the ground the Andromache of Ennius? Carneades imagined, that in the stone

quarries at Chios he found in a stone that was split a representation of the head of a little Pan, or sylvan deity. I believe he might find a figure not unlike; but surely not such a one as you would say had been formed by an excellent sculptor like Scopas. For so, verily, the case is, that chance never perfectly imitates design.' Thus Cicero.

Now, in all this discourse I see very good sense, and what is apt to convince every unprejudiced mind; ***but I see not in the whole a single step of reasoning. It is barely an appeal to every man's common sense****.*



Let us next see how the same point is handled by the excellent ***Archbishop Tillotson****, 1st Sermon, vol. i.:*

'For I appeal to any man of reason, whether anything can be more unreasonable than obstinately to impute an effect to chance which carries in the face of it all the arguments and characters of design? Was ever any considerable work, in which there was required a great variety of parts, and an orderly and regular adjustment of these parts, done by chance? Will chance fit means to ends, and that in ten thousand instances, and not fail in any one? How often might a man, after he had jumbled a set of letters in a bag, fling them out upon the ground before they would fall into an exact poem, yea, or so much as make a good discourse in prose? And may not a little book be as easily made as this great volume of the world? How long might a man sprinkle colours upon canvas with a careless hand before they would make the exact picture of a man? And is a man easier made by chance than his picture? How long might twenty thousand blind men, who should be sent out from the remote parts of England, wander up and down before they would all meet upon Salisbury plains, and fall into rank and file in the exact order of an army? And yet this is much more

easy to be imagined than how the innumerable blind parts of matter should rendezvous themselves into a world. A man that sees Henry the Seventh's chapel at Westminster might with as good reason maintain (yea, and much better, considering the vast difference between that little structure and the huge fabric of the world), that it was never contrived or built by any man, but that the stones did by chance grow into those curious figures into which we see them to have been cut and graven; and that upon a time (as tales usually begin), the materials of that building, the stone, mortar, timber, iron, lead, and glass, happily met together, and very fortunately ranged themselves into that delicate order in which we see them now so close compacted, that it must be a very great chance that parts them again. What would the world think of a man that should advance such an opinion as this, and write a book for it? If they would do him right, they ought to look upon him as mad. But yet he might maintain this opinion with a little more reason than any man can have to say that the world was made by chance, or that the first men grew out of the earth, as plants do now. For can anything be more ridiculous and against all reason, than to ascribe the production of men to the first fruitfulness of the earth, without so much as one instance or experiment in any age or history to countenance so monstrous a supposition? The thing is at first sight so gross and palpable, that no discourse about it can make it more apparent. And yet these shameful beggars of principles, who give this precarious account of the original of things, assume to themselves to be the men of reason, the great wits of the world, the only cautious and wary persons, who hate to be imposed upon, that must have convincing evidence for everything, and can admit nothing without a clear demonstration for it.'

In this passage, the excellent author takes what I conceive to be the proper method of refuting an absurdity, by exposing it in different lights, in which every man of

common understanding perceives it to be ridiculous. And although there is much good sense, as well as wit, in the passage I have quoted, ***I cannot find one medium of proof in the whole***."

So, there is no proof that the universe was created by chance (the view of the men of reason and the great wits of the world) or by a cause (the commonsense view). But do the great wits of the world rest on a scientific pillow?

The Concept of a Scientific Pillow



In his essay *Of Experience*, **Michel de Montaigne** starts out saying, "*There is no desire more natural than that of knowledge. We try all ways that can lead us to it; where reason is wanting, we therein employ experience, which is a means much more weak and cheap; but truth is so great a thing that we ought not to distain any mediation that will guide us to it*." Then he introduces the concept of a ***soft, easy, and wholesome pillow*** to describe our ***ignorance and incuriosity***, "*In this universality, I suffer myself to be ignorantly and negligently led by the general law of the world: I shall know it well enough when I feel it; my learning cannot make it alter its course; it will not change itself for me; 'tis folly to hope it, and a greater folly to concern one's self about it, seeing it is necessarily alike public and common. The goodness and capacity of the governor ought absolutely to discharge us of all care of the government: philosophical inquisitions and contemplations serve for no other use but to increase our curiosity. The philosophers; with great reason, send us back to the rules of nature; but they have nothing to do with so sublime a knowledge; they falsify them, and present us her face painted with too high and too adulterate a complexion, whence spring so many different pictures of so uniform a subject. As she has given us feet to walk with, so has she given us prudence to guide us in life:*

not so ingenious, robust, and pompous a prudence as that of their invention; but yet one that is easy, quiet, and salutary, and that very well performs what the other promises, in him who has the good luck to know how to employ it sincerely and regularly, that is to say, according to nature. The most simply to commit one's self to nature is to do it most wisely. ***Oh, what a soft, easy, and wholesome pillow is ignorance and incuriosity, whereon to repose a well-ordered head****!"*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PIERRE DELBET

La Science et la Réalité

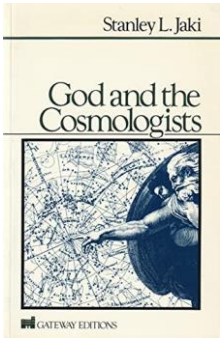
PARIS
ERNEST FLAMMARION, ÉDITEUR
26, RUE RACINE, 26

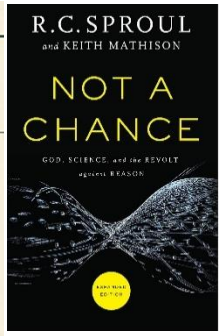
1913

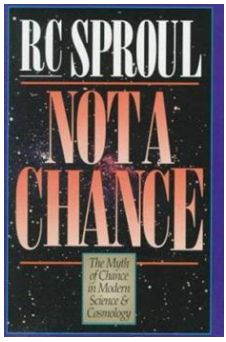
In *La science et la réalité*, ***Pierre Delbet*** (1913) realized that science makes use of soft pillows. He wrote, "*For a long time, all questions relating to chance caused me painful discomfort. In saying how I got out of this state of anxiety, I might free some unknown friends tortured by the same preoccupation that gripped me once. Chance appears to me today as a law, the most general of all laws. It became for me a soft pillow like the one Montaigne says only ignorance and incuriosity could provide; but it is a* ***scientific pillow***."



Chance cannot be a cause of anything. It describes the probability of an effect when we do not know the cause. **Aristotle** toyed with the idea of chance when it came to formal, efficient, and final causes in order to account for free will. However, he denied the role of chance as a material cause, otherwise something could come from nothing. For this reason, Aristotle assumed that the universe was eternal. Thomas Aquinas, believed that the only thing that was eternal was God, and only a creator God could create a universe from nothing. Somehow, in science, chance became an acceptable replacement for a cause—and for God.







Stanley Jaki (1989), in *God and the Cosmologists* and R. C. Sproul (1994, 2014) in *Not a Chance* lucidly argue why chance cannot be a cause. Jaki sees the word chance to indicate our ignorance of true causes. Jaki sees the assertion that chance is a cause to be "***the softest 'philosophical' pillow in all scientific history***." He asserts that "*once more, as so often in that history, most successful mathematical formulas served as magic tools for making shabby philosophizing a most respectable attitude*."

Stanley Jaki (1986) wrote in *Chance or Reality and Other Essays*, "*…during the half a dozen years that followed the enunciation by Heisenberg of the principle of uncertainty, almost immediately a drastic meaning was grafted on it, a meaning thoroughly philosophical…**reality's place was taken by chance, not the chance that stands for ignorance, but which stands for a philosophical ghost residing in the shadowy realm between being and non-being***."

Karl Popper considered himself "*the last laggard of the Enlightenment*." He had "*in mind the hope that inspired Pestalozzi, that knowledge may make us free...that we may rouse ourselves from our dogmatic slumber, as Kant called it."*

Newton's research on the physical universe inspired all. Here are two poems about Isaac Newton written by one scientist and one poet:

Ode to Isaac Newton

--Edmund Halley (1686)

Lo, for your gaze, the pattern of the skies!
What balance of the mass, what reckonings
Divine! ***Here ponder too the Laws which God,***

Framing the Universe, set not aside
But made the fixed foundations of his work.

The inmost place of the heavens, now gained,
Break into view, nor longer hidden is
The force that turns the farthest orb. The sun
Exalted on his throne bids all things tend
Toward him by inclination and descent,
Nor suffer that the courses of the stars
Be straight, as through the boundless void they move,
But with himself as centre speeds them on
In motionless ellipses. Now we know
The sharply veering ways of comets, once
A source of dread, nor longer do we quail
Beneath appearances of bearded stars.

At last we learn wherefore the silver moon
Once seemed to travel with unequal steps,
As if she scorned to suit her pace to numbers -
Till now made clear to no astronomer;
Why, though the Seasons go and then return,
The Hours move ever forward on their way;
Explained too are the forces of the deep,
How roaming Cynthia bestirs the tides,
Whereby the surf, deserting now the kelp
Along the shore, exposes shoals of sand
Suspected by the sailors, now in turn
Driving its billows high upon the beach.

Matters that vexed the minds of ancient seers,
And for our learned doctors often led
to loud and vain contention, now are seen
In reason's light, the clouds of ignorance
Dispelled at last by science*. Those on whom*
Delusion cast its gloomy pall of doubt,
Upborne now on the wings that genius lends,
May penetrate the mansions of the gods
And scale the heights of heaven. O mortal men,
Arise! And, casting off your earthly cares,
Learn ye the potency of heaven-born mind,

Its thought and life far from the herd withdrawn!

The man who through the tables of the laws
Once banished theft and murder, who suppressed
Adultery and crimes of broken faith,
And put the roving peoples into cities
Girt round with walls, was founder of the state,
While he who blessed the race with Ceres' gift,
Who pressed from grapes an anodyne to care,
Or showed how on the tissue made from reeds
growing behind the Nile one may inscribe
Symbols of sound and so present the voice
For sight to grasp, did lighten human lot,
Offsetting thus the miseries of life
With some felicity. But now, behold,
Admitted to the banquets of the gods,
We contemplate the polities of heaven;
Discern the changeless order of the world
And all the aeons of its history.

Then ye who now on heavenly nectar fare,
Come celebrate with me in song the name
Of Newton, to the Muses dear; ***for he***
Unlocked the hidden treasuries of Truth*:*
So richly through his mind had Phoebus cast
The radiance of his own divinity.
Nearer the gods no mortal may approach*.*

A poem sacred to the memory of Sir Isaac Newton

—James Thomson (1727).

Shall the great soul of Newton quit this earth,
To mingle with his stars; and every muse,
Astonish'd into silence, shun the weight
Of honours due to his illustrious name?
But what can man?--Even now ***the sons of light****,*
In strains high-warbled to seraphic lyre,
Hail his arrival on the coast of bliss.

Yet am not I deterr'd, though high the theme,
And sung to harps of angels, for with you,
Ethereal flames! ambitious, I aspire
In Nature's general symphony to join.

And what new wonders can ye show your guest!
Who, while on this dim spot, where mortals toil
Clouded in dust, from motion's simple laws,
Could trace the secret hand of Providence,
Wide-working through this universal frame.

Have ye not listen'd while he bound the suns
And planets to their spheres! th' unequal task
Of humankind till then. Oft had they roll'd
O'er erring man the year, and oft disgrac'd
The pride of schools, before their course was known
Full in its causes and effects to him,
All-piercing sage! who sat not down and dream'd
Romantic schemes, defended by the din
Of specious words, and tyranny of names;
But, bidding his amazing mind attend,
And with heroic patience years on years
Deep-searching, saw at last the system dawn,
And shine, of all his race, on him alone.

What were his raptures then! how pure! how strong!
And what the triumphs of old Greece and Rome,
By his diminish'd, but the pride of boys
In some small fray victorious! when instead
Of shatter'd parcels of this earth usurp'd
By violence unmanly, and sore deeds
Of cruelty and blood, Nature herself
Stood all subdu'd by him, and open laid
Her every latent glory to his view.

All intellectual eye, our solar-round
First gazing through, he by the blended power
Of gravitation and projection saw
The whole in silent harmony revolve.
From unassisted vision hid, the moons

To cheer remoter planets numerous pour'd,
By him in all their mingled tracts were seen.
He also fix'd the wandering Queen of Night,
Whether she wanes into a scanty orb,
Or, waxing broad, with her pale shadowy light,
In a soft deluge overflows the sky.
Her every motion clear-discerning, he
Adjusted to the mutual main, and taught
Why now the mighty mass of water swells
Resistless, heaving on the broken rocks,
And the full river turning; till again
The tide revertive, unattracted, leaves
A yellow waste of idle sands behind.

Then breaking hence, he took his ardent flight
Through the blue infinite; and every star,
Which the clear concave of a winter's night
Pours on the eye, or astronomic tube,
Far-stretching, snatches from the dark abyss,
Or such as farther in successive skies
To fancy shine alone, at his approach
Blaz'd into suns, the living centre each
Of an harmonious system: all combin'd,
And rul'd unerring by that single power,
Which draws the stone projected to the ground.

O unprofuse magnificence divine!
O wisdom truly perfect! thus to call
From a few causes such a scheme of things,
Effects so various, beautiful, and great,
An universe complete! and O belov'd
Of Heaven! whose well-purg'd penetrative eye,
The mystic veil transpiercing, inly scann'd
The rising, moving, wide-establish'd frame.

He, first of men, with awful wing pursu'd
The comet through the long elliptic curve,
As round innumerous worlds he wound his way,
Till, to the forehead of our evening sky
Return'd, the blazing wonder glares anew,

And o'er the trembling nations shakes dismay.

The heavens are all his own, from the wild rule
Of whirling vortices and circling spheres
To their first great simplicity restor'd.
The schools astonish'd stood; but found it vain
To keep at odds with demonstration strong,
And, unawaken'd, dream beneath the blaze
Of truth. At once their pleasing visions fled,
With the gay shadows of the morning mix'd,
When Newton rose, our philosophic sun!
Th' aërial flow of sound was known to him,
From whence it first in wavy circles breaks,
Till the touch'd organ takes the message in.
Nor could the darting beam of speed immense
Escape his swift pursuit and measuring eye.
Ev'n Light itself, which every thing displays,
Shone undiscover'd, till his brighter mind
Untwisted all the shining robe of day;
And, from the whitening undistinguish'd blaze,
Collecting every ray into his kind,
To the charm'd eye educ'd the gorgeous train
Of parent colours. First the flaming red
Sprung vivid forth; the tawny orange next;
And next delicious yellow; by whose side
Fell the kind beams of all-refreshing green.
Then the pure blue, that swells autumnal skies
Ethereal played; and then, of sadder hue,
Emerg'd the deepen'd indigo, as when
The heavy-skirted evening droops with frost;
While the last gleamings of refracted light
Died in the fainting violet away.
These, when the clouds distil the rosy shower,
Shine out distinct adown the wat'ry bow;
While o'er our heads the dewy vision bends
Delightful, melting on the fields beneath.
Myriads of mingling dyes from these result,
And myriads still remain--infinite source
Of beauty, ever flushing, ever new.

Did ever poet image aught so fair,
Dreaming in whisp'ring groves by the hoarse brook?
Or prophet, to whose rapture heaven descends?
Ev'n now the setting sun and shifting clouds,
Seen, Greenwich, from thy lovely heights, declare
How just, how beauteous the refractive law.

The noiseless tide of time, all bearing down
To vast eternity's unbounded sea,
Where the green islands of the happy shine,
He stemm'd alone; and, to the source (involv'd
Deep in primeval gloom) ascending, rais'd
His lights at equal distances, to guide
Historian wilder'd on his darksome way.

But who can number up his labours? who
His high discoveries sing? When but a few
Of the deep-studying race can stretch their minds
To what he knew--in fancy's lighter thought
How shall the muse then grasp the mighty theme?

What wonder thence that his devotion swell'd
Responsive to his knowledge? For could he,
Whose ***piercing mental eye*** *diffusive saw*
The finish'd university of things
In all its order, magnitude, and parts,
Forbear incessant to adore that Power
Who fills, sustains, and actuates the whole?

Say, ye who best can tell, ye happy few,
Who saw him in the softest lights of life,
All unwithheld, indulging to his friends
The vast unborrow'd treasures of his mind,
oh, speak the wondrous man! how mild, how calr
How greatly humble, how divinely good,
How firm establish'd on eternal truth;
Fervent in doing well, with every nerve
Still pressing on, forgetful of the past,
And panting for perfection; far above
Those little cares and visionary joys

That so perplex the fond impassion'd heart
Of ever-cheated, ever-trusting man.
This, Conduitt, from thy rural hours we hope;
As through the pleasing shade where nature pours
Her every sweet in studious ease you walk,
The social passions smiling at thy heart
That glows with all the recollected sage.

And you, ye hopeless gloomy-minded tribe,
You who, unconscious of those nobler flights
That reach impatient at immortal life,
Against the prime endearing privilege
Of being dare contend,--say, can a soul
Of such extensive, deep, tremendous powers,
Enlarging still, be but a finer breath
Of spirits dancing through their tubes awhile,
And then for ever lost in vacant air?

But hark! methinks I hear a warning voice,
Solemn as when some awful change is come,
Sound through the world--" 'Tis done!--the measure's full;
And I resign my charge."--Ye mouldering stones
That build the towering pyramid, the proud
Triumphal arch, the monument effac'd
By ruthless ruin, and whate'er supports
The worship'd name of hoar antiquity--
Down to the dust! What grandeur can ye boast
While Newton lifts his column to the skies,
Beyond the waste of time. Let no weak drop
Be shed for him. The virgin in her bloom
Cut off, the joyous youth, and darling child--
These are the tombs that claim the tender tear
And elegiac song. But Newton calls
For other notes of gratulation high,
That now he wanders through those endless worlds
He here so well descried, and wondering talks,
And hymns their Author with his glad compeers.

O Britain's boast! whether with angels thou
Sittest in dread discourse, or fellow-blest,

Who joy to see the honour of their kind;
Or whether, mounted on cherubic wing,
Thy swift career is with the whirling orbs,
Comparing things with things, in rapture lost,
And grateful adoration for that light
So plenteous ray'd into thy mind below
***From Light Himself**; oh, look with pity down*
On humankind, a frail erroneous race!
Exalt the spirit of a downward world!
O'er thy dejected country chief preside,
And be her Genius call'd! her studies raise,
Correct her manners, and inspire her youth;
For, though deprav'd and sunk, she brought thee forth,
And glories in thy name! she points thee out
To all her sons, and bids them eye thy star:
While, in expectance of the second life,
When time shall be no more, thy sacred dust
Sleeps with her kings, and dignifies the scene.



As long as we are discussing the creation of the universe, I would like to add a note about **creativity in science**. **Gerrit Verschuur** (1993), a radio astronomer wrote in Hidden Attractions, "*Perhaps modern university curricula should include exercises to facilitate the letting go of prejudice so as to encourage students to consider occasionally the impossible if not the incredible. Time and again significant breakthroughs in science are made by those ready and willing to take a completely different approach to a problem that has been unsuccessfully confronted by more conventional minds for years.* ***The creative approach requires that, for a while at least, someone be willing to climb out of the mainstream and take a look at the flow of ideas from the banks of the river. How else does one obtain a clear perspective? If you are up to your neck in the water it is difficult to see where you are, and impossible to perceive the world view that can be had from the bank.***"

We must all find **our place in the universe**, and each of us can do that by finding our own purpose—knowing ourselves and recognizing our own special strengths. There is a story:



A young student asked Mozart's advice on how to write a symphony. Mozart said: "*It is a difficult and complex form. I would suggest that you first write a few keyboard sonatas, and maybe a string quartet or two, before you start thinking about writing a symphony*."

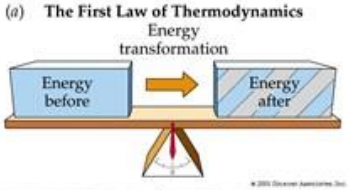
"*But Herr Mozart*," the student insisted, "*you were writing symphonies when you were far younger than I am*."

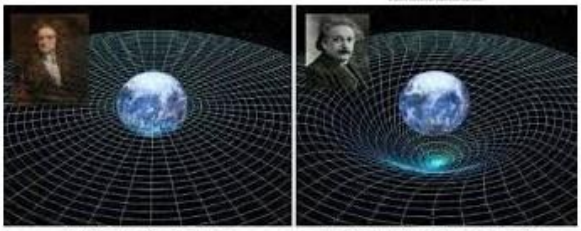
Mozart replied: "*I never asked how*."

Production of Sunlight and Chemical Spectroscopy

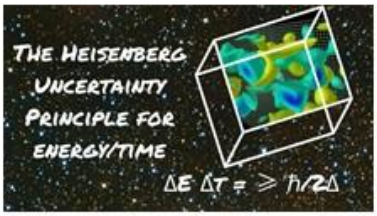
Review: Here are some of the big questions we have touched on so far:

Thermodynamics is fundamental:
A creator is necessary to create something.




Newton's fixed space Einstein's flexible space-time

Universe of **relative** spacetime created at the big bang and expanded into nothing; or energy and matter of Universe created in **absolute** space and time and expanded into absolute space over time.



Uncertainty Principle is fundamental:
Something comes from nothing.

Darwin's **Natural Selection** is fundamental and differential reproduction based on a nature that is red in tooth and claw is the whole story in explaining the origin of the bone structure and mind of human beings; or according to Alfred Russel Wallace and T. H. Huxley, natural selection is not the whole story.



There is a fundamental **truth** although because we see through a glass darkly, no one can know it completely. Faith, reason, and evidence-based science provide a way that leads to the truth; or all knowledge is socially constructed. Consequently, there is no absolute truth and nothing to have faith in.





Individual identity is fundamental because each person is created in the image of God; or group identity based on the melanin content of the skin is fundamental.

There is a close relationship between chemistry and light. **Phosphorus** is a chemical that can produce light. **Hennig Brand** in 1669 was an **alchemist** who thought that he might find the **Philosopher's Stone** (*lapis philosophorum*) or the secret for converting base or ignoble metals into gold in human urine. Perhaps he was inspired by urine's golden color (produced by urobilin, a breakdown product of heme). In the process of isolating different chemicals in the urine, probably at night, he serendipitously discovered a chemical that was capable of producing light. Consequently, he named the chemical **phosphorus**, meaning **light bearer**, from the Greek *Φωσφόρος*.





Nothing Gold Can Stay by Robert Frost

Nature's first green is gold,
Her hardest hue to hold.
Her early leaf's a flower;
But only so an hour.
Then leaf subsides to leaf.
So Eden sank to grief,
So dawn goes down to day.
Nothing gold can stay.

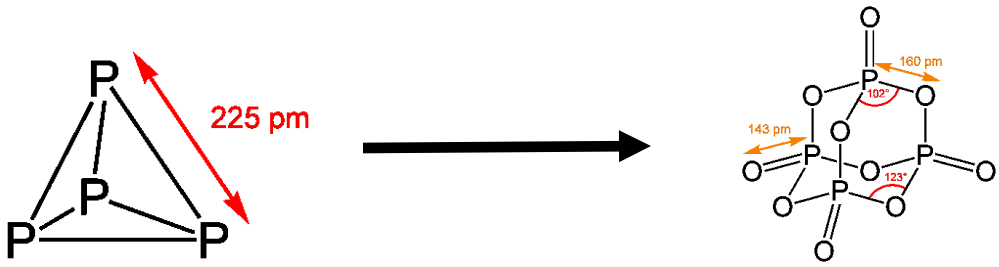


Aside: In 1980, Glenn Seaborg produced gold from bismuth using particle bombardment at the Lawrence Berkeley Laboratory at a cost of one quadrillion dollars per ounce (which at the time was worth $560/oz).



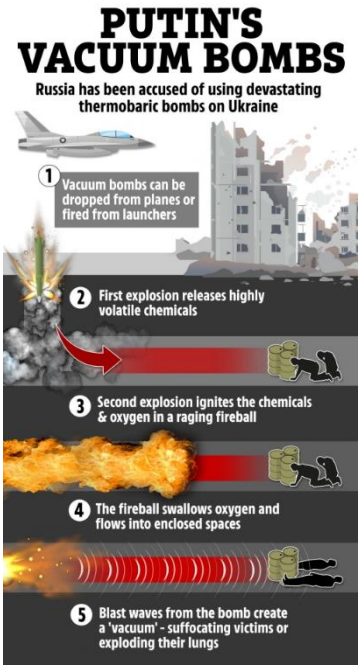
We now know that phosphorus in the form of pure white tetrahedral phosphorus (P_4) ignites spontaneously in the presence of oxygen to form phosphorus oxide, transforming chemical energy into radiant energy (light) in the process. The rearrangement of bonds results from the rearrangement of **electrons**.

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$





White phosphorus, which can be explosive, can be exposed to sunlight or heated to produce a ***polymerized form*** of phosphorus known as **red phosphorus**, which is more stable. Red phosphorus only gives off light when it is excited by friction (triboluminescence). For this reason, red phosphorus is used to produce **safety matches**.

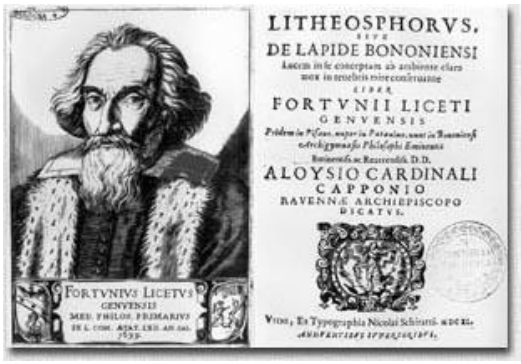


Aside: In a thermobaric or vacuum bomb, an initial anerobic explosive reaction releases tiny particles of B, Al, Mg, Si, Ti, Zr, and C into the atmosphere. Within a millisecond, these tiny aerosol particles with high surface-to-volume ratios combine with oxygen and burst into flames. They use up the oxygen in the atmosphere and because they combine with so much oxygen, a partial vacuum is created. The lack of oxygen prevents respiration and the decrease in air pressure causes lungs to collapse.



A light-emitting chemical reaction is known as **chemiluminescence**. Phosphorus is not phosphorescent, as it is defined today. **Phosphorescence**, which was named after phosphorus, is defined today as a **delayed re-emission of light that has already**

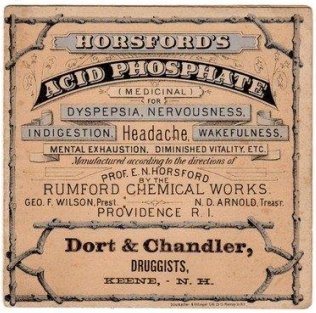
been absorbed. Chemiluminescent substances, such as white phosphorus, do ***not*** require pre-illumination to glow whereas phosphorescent substances, such as the **Bologna Stone**, by contrast, do.

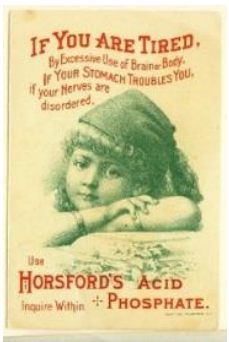


The **Bologna Stone**, or litheosphorus had recently been discovered in Bologna by Vincenzo Casciarolo in his search for the Philosopher's Stone. Casciarolo (1640) wrote in *Litheosphorus*, "*that the stone was most suitable for the production of gold by virtue of its notable weight and content of sulphur. After submitting the stone to much preparation, it was not the Pluto of Aristophanes that resulted; instead, it was the Luciferous Stone, which would not itself produce gold,* ***but which would absorb the golden light of the sun, like a new Prometheus stealing a Celestial Treasure****."* The Bologna Stone was later found to be composed of barium sulfate. **https://io9.gizmodo.com/the-bologna-stone-was-a-glowing-mystery-for-400-years-1724589932**

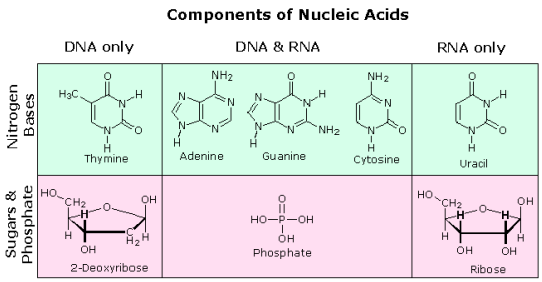


The phosphorous first isolated by Hennig Brand was, as we now know, of humble human origin. **Johann Kunckel** (1676) also figured out how to produce phosphorus from urine. It was a difficult process and Kunckel reasoned that anything that comes out of the human body (at a rate of 1.4 g P/day) must also go in. Consequently, he found that many foods of animal and plant origin, when heated in a furnace, produced phosphorous. Kunckel was able to turn phosphorus into gold in that he got rich performing spectacular shows for the nobility with the phosphorus he had created. He also sold phosphorus for medicinal purposes. Indeed, **phosphorus is essential for life** as

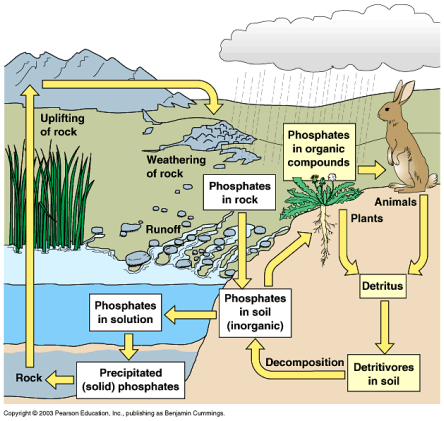


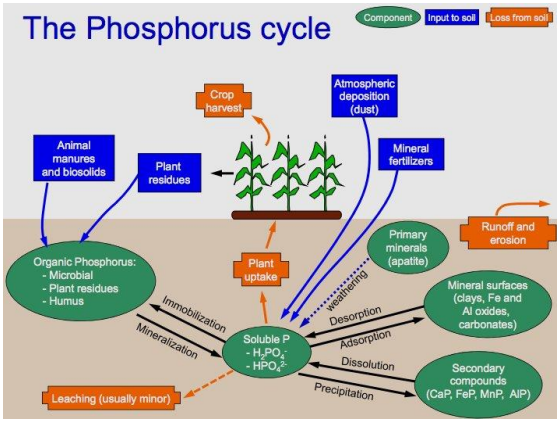


we know it as it is a constituent of all **nucleic acids**, including DNA, RNA, ATP, and the cGMP involved in vision.



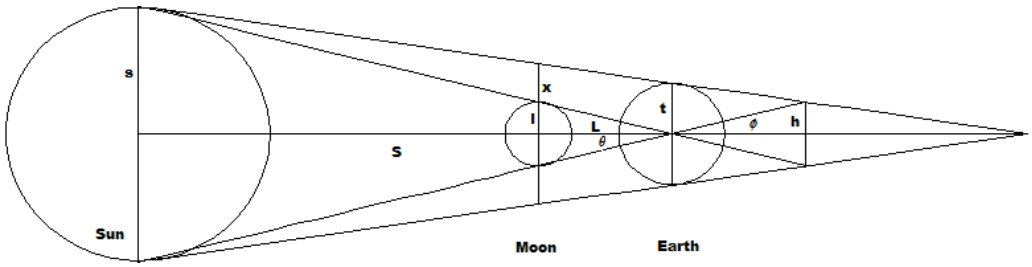
The phosphorus on earth, which was originally **produced in first generation stars**, circulates in the lithosphere (the rocky crust of the earth), the hydrosphere (the water on the surface of the earth), and the biosphere (the living organisms on earth).



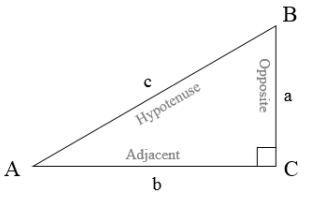




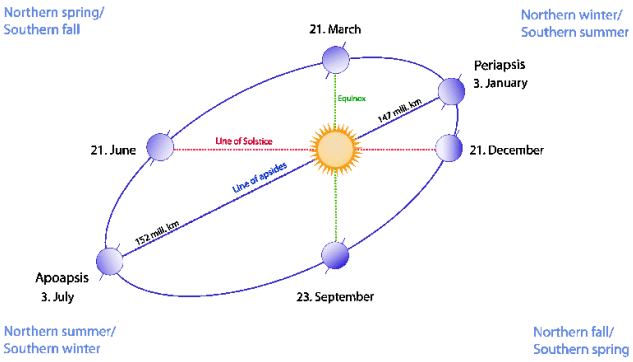
We are now going to discuss the **cause of sunlight**, but before we do, we have to understand a few facts about the sun, such as the **distance** between the sun and the earth and the **diameter** of the sun, so that we can make reasonable inferences about the cause of sunlight. **Hipparchus** (190-120 BC) estimated the mean **distance** from the earth to the sun by making measurements of the angles the edge of sun could be seen from different places on earth during a solar eclipse and used **trigonometry** to analyze the angles and lengths.



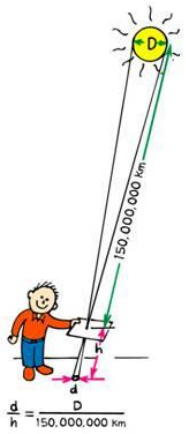
Trigonometry (from the Greek for measuring triangles (τρίγωνο)) was invented by Euclid and Archimedes in the third century BC and Hipparchus used it in the second century BC as a way of simplifying the application of **geometry** (from the Greek for measuring the earth (**γεω**)) to astronomy.



Today the **average** distance between the sun and the earth is defined as approximately **1.5×10^{11} m** (which is a distance of approximately **8.3 light-minutes**, given that the speed of light in the vacuum of space is about 3×10^8 m/s). This means that it takes sunlight approximately eight minutes to reach the earth and that we see the sun where it was eight minutes ago. The distance 1.5×10^{11} m from the earth to the sun is known as 1 **astronomical unit** (au). The astronomical unit is defined as "*the radius of an unperturbed circular Newtonian orbit about the sun of a particle having infinitesimal mass, moving with a mean motion of 0.01720209895 radians per day*." Note: $0.01720209895 \times 365.26 = 2\pi$.



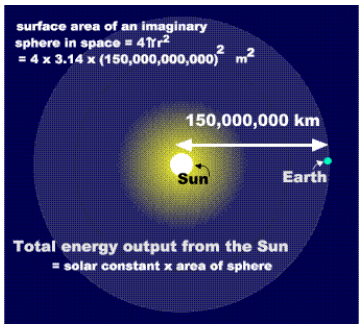
The **diameter of the sun** can be estimated using a **pinhole**. The pinhole will form an image of the sun on a piece of paper. The size of the image will depend on the distance between the image and the pinhole. Use a ruler to measure the diameter of the image (y_i) of the sun and the distance between the pinhole and the image (s_i). Using 1.5×10^{11} m as the distance to the sun (s_o), calculate the diameter of the sun (y_o) using the following formula based on the assumption that vertical angles are equal:



$$\frac{y_o}{y_i} = -\frac{s_o}{s_i}$$

The **diameter** of the sun is about **1.39×10^9 m**; the radius (r_s) is **0.7×10^9 m**.

We can measure the **luminosity** of the sun, which is the rate at which the sun is radiating energy, by measuring the **intensity** of sunlight at the earth's surface (I_{earth}), which is a distance r from the sun and, by assuming the sun to be a point source of light. We can then use the inverse square law to determine the power of the source (S, as we did in the second lecture) and the luminosity of the sun (L_{sun}, in Watts = Joules/second):



$$I_{earth} = \frac{L_{sun}}{4\pi r^2}$$

The average intensity of sunlight at the earth's surface is known as the **solar constant**. A term coined by **Claude Pouillet** in 1838. Pouillet measured the solar constant with a **pyrheliometer**, which at the time was a



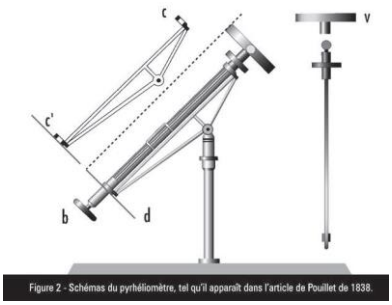
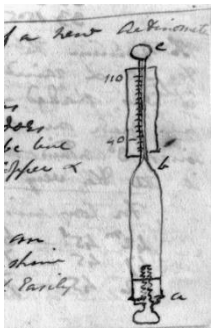


Figure 2 - Schémas du pyrhéliomètre, tel qu'il apparaît dans l'article de Pouillet de 1838.

thermometer placed in a cylinder of water whose blackened side faced the sun. He determined the solar constant by measuring the rate that the temperature of the water increased when the blackened side was in the sun. To compensate for the loss of heat from the thermometer to the environment, he added the rate of cooling determined when the blackened side was in the shade. Pouillet determined the solar constant to be 1.228×10^3 W/m^2.



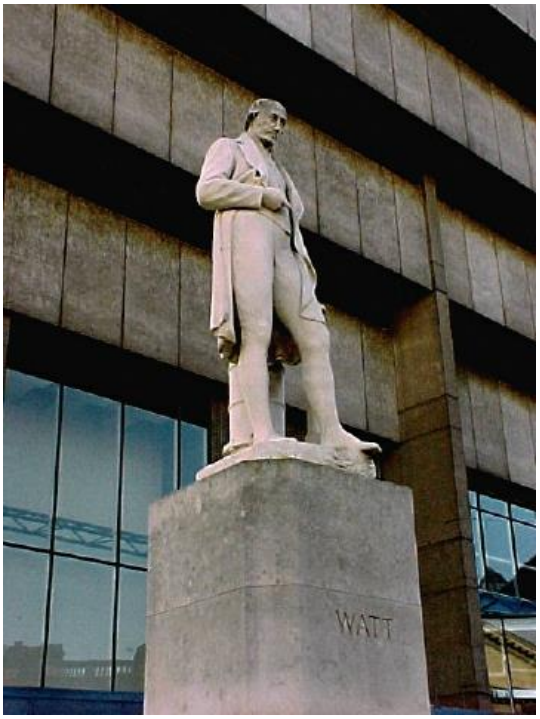
After traveling through the Alpine pass between France and Italy in 1824, **John Herschel**, William Herschel's son, got a sunburn, and unlike most others who get sunburned, he decided to design an instrument to measure the intensity of the sun. He wrote "*…the scorching effect of the Sun's rays upon every exposed part of the skin proved so severe as to excite in my mind a lively desire to subject to some precise means of measurement the cause of so disagreeable an effect.*"





John Herschel developed an **actinometer** that was in essence a thermometer placed in water in which black ink was dissolved to measure the light intensity. The light intensity was calculated from the difference between the temperature of the thermometer in the sunlight and in the shade. Herschel (1847) determined the solar constant to be 1.004×10^3 W/m^2.

Asides on the unit of luminosity or power known as the Watt (W), which was named after James Watt, and the Lunar Society of Birmingham. This marble statue of James Watt made by Alexander Munro in 1868 stands in Birmingham, England, the birthplace of the **industrial revolution** and the home of the **Lunar Society**. Watt is standing on a pedestal that is one square meter and the stature is known as **one Watt per meter squared**. Nowadays, only the pigeons come to visit him.





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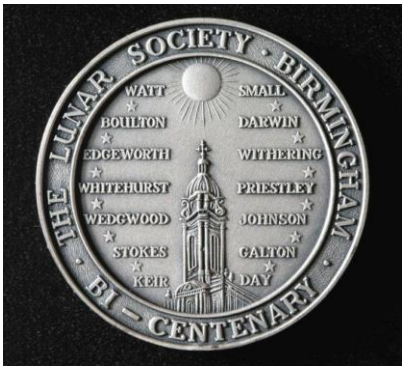
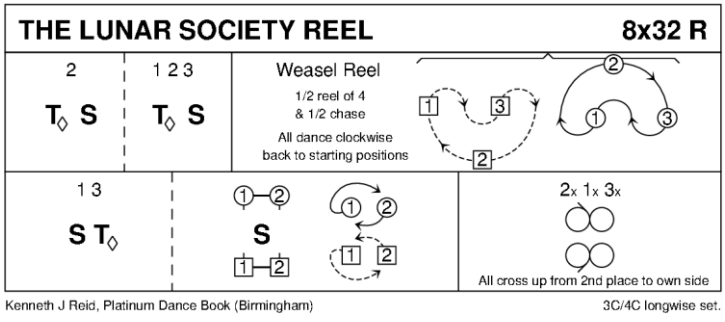




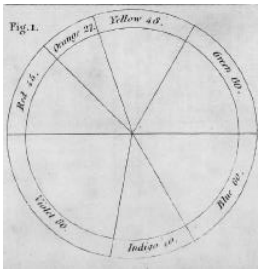


Gilded bronze statue of Matthew Boulton, **James Watt**, and William Murdoch looking at plans for a steam engine.

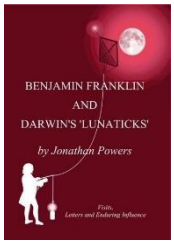


The rotund **Erasmus Darwin**, a physician, poet, and Charles Darwin's paternal grandfather, was also a member of the Lunar Society. Erasmus wrote, in *Zoonomia* (1796), "*Would it be too bold to imagine, that in the great length of time, since the earth began to exist, perhaps millions of ages before the commencement of the history of mankind, would it be too bold to imagine, that all warm-blooded animals have arisen from one living filament, which THE GREAT FIRST CAUSE endued with animality, with the power of acquiring new parts, attended with new propensities, directed by irritations, sensations, volitions, and associations; and thus possessing the faculty of continuing to improve by its own inherent activity, and of delivering down those improvements by generation to its posterity, world without end*." Sound familiar?

http://www.gutenberg.org/files/15707/15707-h/15707-h.htm



Samuel "John" Galton, a gun maker who made muskets that were given to local African chieftains in exchange for slaves and experimented with color mixing (Monthly Magazine 8, 509. 1799), was also a member of the Lunar Society. His son, Samuel, married Violetta Darwin, a daughter of Erasmus Darwin, and one of their sons was **Francis Galton**, who wrote *Hereditary Genius* and coined the word eugenics. **Josiah Wedgwood** and **Joseph Priestley** were members of the Lunar Society who were abolitionists.



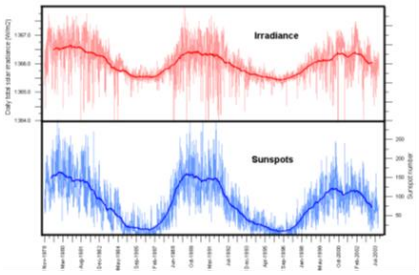
William Small, a member of the Lunar Society was one of **Thomas Jefferson**'s mathematics teachers in Williamsburg, Virginia; and **Benjamin Franklin** was a corresponding member of the Lunar Society. (I am an overseas member of the Lunar Society).



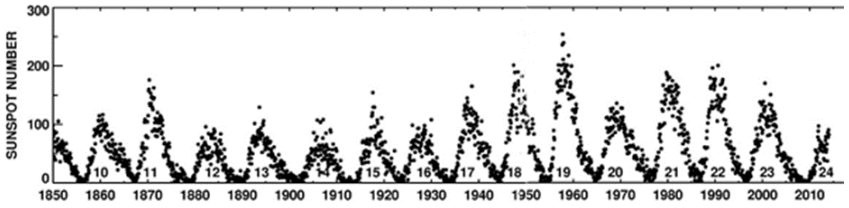
The **solar constant** is currently measured by satellite above the earth's atmosphere to be about $\mathbf{1.36 \times 10^3\ W/m^2}$. The actual solar intensity on earth varies with latitude due to the tilt of the earth. It also varies at a given spot on earth during the day due to the rotation of the earth and during the year due to the ellipticity of the earth's orbit. The solar constant in ***not constant*** but represents an average of these intensities in time and space. Moreover, the actual solar intensity on earth has varied historically since the tilt of the earth,

the rotation of the earth, and the ellipticity and precession of the earth's orbit change slowly over time. **Milutin Milanković** (1920) took into consideration such changes and proposed that there were long term cycles that affected the value of the solar intensity at a given spot on earth. The solar constant, which characterizes the greatest and most important source of energy available on earth, does not represent a static system, but the changing relationship between sun and the earth.

The solar constant also depends on changes in the physical processes that go on in the sun. The solar constant varies about **0.1%** cyclically with an eleven-year period that is correlated with sunspots, which are regions that are cooler than the rest of the sun. Faculae, which are associated with the sunspots are regions that are warmer than the rest of the sun. Since the greater intensity of faculae more than compensates for the lesser intensity of the sunspots, the magnitude of the solar constant is positively correlated with the number of sunspots.



The sun is a **plasma** composed of rapidly moving charged particles that generate magnetic fields. The **11-year sunspot cycle** is also correlated with an increased flux of charged particles known as the solar wind as well as with an increased magnetic field whose polarity reverses with a 22-year cycle. The earth's magnetic field deflects the electrons and protons in the solar wind from striking the earth, and thus minimizes the rate of cosmic ray-induced genetic mutations and variability.



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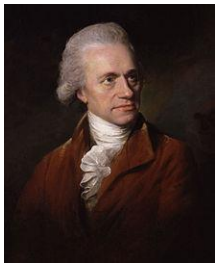
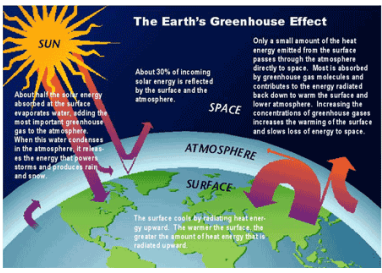
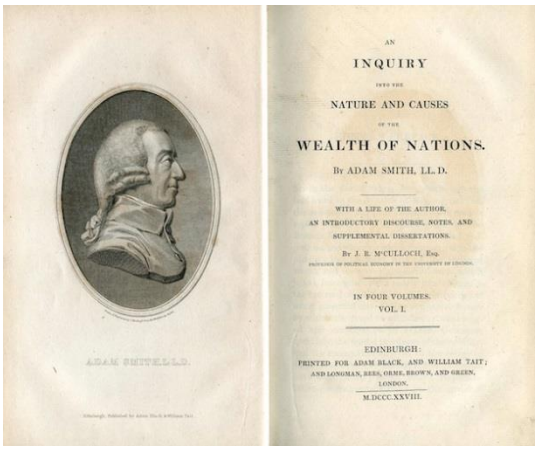


William Herschel (1801) realized that there was variability in the appearance of the sun and wrote "*The influence of this eminent body, on the globe we inhabit, is so great, and so widely diffused, that it becomes almost a duty for us to study the operations which are carried on upon the solar surface.* ***Since light and heat are so essential to our well-being, it must certainly be right for us to look into the source from whence they are derived, in order to see whether some material advantage may not be drawn from a thorough acquaintance with the causes from which they originate…..****We are not only in possession of photometers and thermometers, by which we can measure from time to time the light and heat actually received from the sun, but have more especially telescopes, that may lead us to a discovery of the causes which dispose the sun to emit more or less copiously the rays which occasion either of them. And, if we should even fail in this respect, we may at least succeed in becoming acquainted with certain symptoms or indications, from which some judgment might be formed of the temperature of the seasons we are likely to have."* William Herschel made the first attempt to relate the appearance and disappearance of sunspots to the temperature of the earth. He could not measure the intensity of light and heat everywhere and all the factors that control the temperature of the earth, such as the CO_2 concentration in the atmosphere, but his thinking is ingenious and worth knowing.



William Herschel (1801) wrote "*With regard to the contemporary severity and mildness of the seasons, it will hardly be necessary to remark, that nothing decisive can be obtained. But, if we are deficient here, an indirect source of information is opened to us, by applying to the influence of sun-beams on the vegetation of wheat in this country. I do not mean to say, that this is a real criterion of the quantity of light and heat emanated from the sun; much less will*

the price of this article completely represent the scarcity or abundance of the absolute produce of the country. For the price of commodities will certainly be regulated by the demand for them; and this we know is liable to be affected by many fortuitous circumstances. However, although an argument drawn from a well ascertained price of wheat, may not apply directly to our present purpose, yet, admitting the sun to be the ultimate fountain of fertility, this subject may deserve a short investigation, especially as, for want of proper thermometrical observations, no other method is left for our choice."

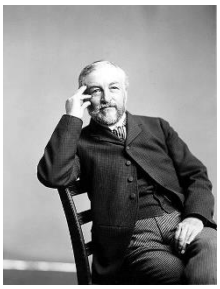


"Our historical account of the disappearance of the spots in the sun, contains five very irregular and very unequal periods. The first takes in a series of 21 years, from 1650 to 1670, both included. But it is so imperfectly recorded, that it is hardly safe to draw any conclusions from it; for we have only a few observations of one or two spots that were seen in all that time, and those were only observed for a short continuance. However, on examining the table of prices of the quarter of nine bushels of the best or highest prices wheat at Windsor, marked in ***Dr. Adam Smith's valuable Inquiry into the nature and causes of the wealth of nations****, we find that wheat, during the time of the 21 years above mentioned, bore a very high price; the average of the quarter being £2, 10s.* $5\frac{19}{21}d$*. This period is much too long compare it with a preceding or following one of equal duration. Besides, no particulars having been given of the time preceding, except that spots in the sun, a good while before, began to grow very scarce. There might be even fewer of them from the year 1650 to 1670. Of the 21 years immediately following, we know that they certainly comprehend two short periods, in which there were no spots on the sun; of these, more will be said*

hereafter; but, including even them, we have the average price of wheat, from 1671 to 1691, only £2, 4s. $4\frac{2}{3}$ d. The quarter. The difference, which is a little more than 9 to 8, is therefore still a proof of a temporary scarcity…. ***The result of this review of the foregoing five periods is, that, from the price of wheat, it seems probable that some temporary scarcity or defect of vegetation has generally taken place, when the sun has been without those appearances which we surmise to be symptoms of a copious emission of light and heat****. In order, however, to make this an argument in favor of our hypothesis, even if the reality of a defective vegetation of grain were sufficiently established by its enhanced price. It would still be necessary to shew that a deficiency of the solar beams had been the occasion of it. Now, those who are acquainted with agriculture may remark, that wheat is well known to grow in climates much colder than ours; and that a proper distribution of rain and dry weather, with many other circumstances which it will not be necessary to mention, are probably of much greater consequence that the absolute quantity of light and heat derived from the sun****. To this I shall only suggest, by way of answer, that those very circumstances of proper alternations of rain, dry weather, winds, or whatever else may contribute to favour vegetation in this climate, may possibly depend on a certain quantity of sun-beams, transmitted to us at proper times;*** *but, this being a point which can only be ascertained by future observations, I forbear entering farther into a discussion of it.*"

While I think that Herschel's thinking was ingenious and points to the fact that the net effect of dark-looking sunspots is to increase the intensity of sunlight, Herschel's thinking and analysis is currently pooh-poohed by those who think the human impact on climate far exceeds the astronomical impact on climate: **https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/grl.50846**

Aside: In May, 1921, the activity of sunspots was so intense that they caused damage to the **transatlantic cable**, **telegraph lines**, and also caused fires that engulfed the switchboard of the Central New England Railroad and the railroad control tower near **Grand Central Station**, is why the event is sometimes referred to as the "New York Railroad Superstorm." It also **dimmed the lights of Broadway**.



The **luminosity** or the rate in which the sun radiates energy at the sun's surface (L_{sun}) is given by $I_{earth} 4\pi r^2$, where I_{earth} is the measured intensity on earth and r is the distance between the sun and the earth. The luminosity or power is equal to about $\mathbf{3.8 \times 10^{26}}$ **W**. A Watt equals a Joule/second. The **luminosity** or power is given in **Watts** while the **intensity**, which is the **rate the sun radiates energy per unit area** is given in Watts per meter squared. The **spectral distribution** of sunlight (intensity vs. **wavelength**) was first measured quantitatively under the Allegheny sky by **Samuel Pierpont Langley** in 1881.

					mm.				
λ =	.00035	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011
					div.				
Defl.	12	55	207	246	198	129	80	58	41



Langley became the third **Secretary of the Smithsonian Institution** in 1887 and founder of the Smithsonian Astrophysical Observatory in 1890, which initially did research on solar radiation and the solar constant. Former Cornell University President Skorton was the thirteenth Secretary of the Smithsonian Institution.

Modern measurements ***above*** the atmosphere give the following somewhat **continuous spectral distribution**:

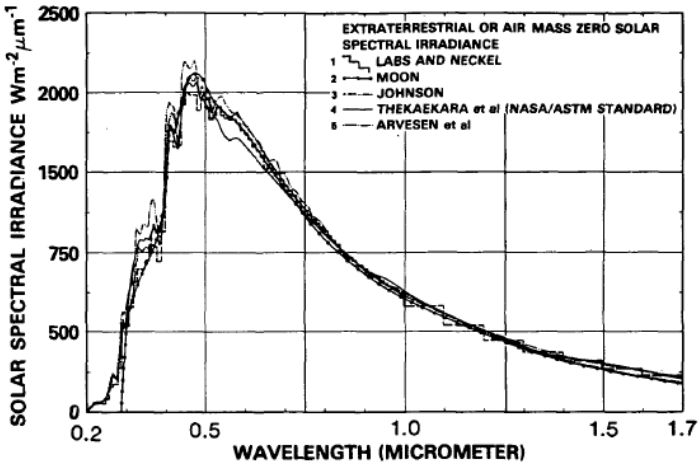


Figure 1. Solar Spectral Irradiance Outside the Atmosphere, 0.2 μm - 1.7 μm reported by: 1. Labs and Neckel, 2. P. Moon, 3. F.S. Johnson, 4. Thekaekara et al (NASA/ASTM Standard), 5. Arvesen et al.

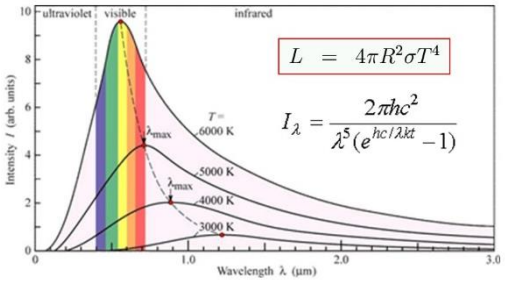
The **temperature (*T*) of the surface of the sun**, which is **5778 K** can be estimated from either the luminosity of the sun ($I_{earth} = \frac{L_{sun}}{4\pi r^2}$) using the **Stefan-Boltzmann law**:

$$L_{sun} = I_{earth} 4\pi r^2 = 4\pi r_s^2 \sigma T^4$$

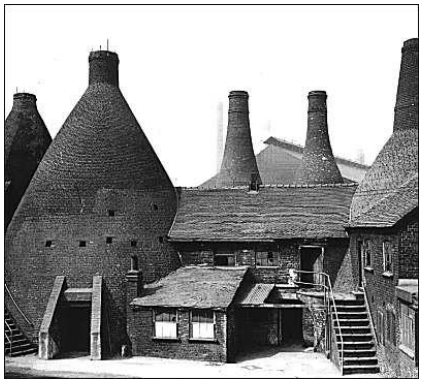
where r_s is the radius of the sun (in m) and σ is the Stefan-Boltzmann constant ($\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}), or it can be estimated from the continuous spectral distribution produced by a "hot" **incandescent body** using **Max Planck's blackbody radiation law**:

$$I(\lambda) = \frac{2\pi hc^2}{\lambda^5 (e^{hc/\lambda kT} - 1)}$$

where λ (in m) is the wavelength of light, k is the Boltzmann constant (k = 1.38 × 10^{-23} J/K), c is the speed of light (c = 2.99 x 10^8 m/s) and h is Planck's constant (h = 6.626 × 10^{-34} J s). The peak for the sun is in the yellow part of the spectrum which is why the sun looks yellow.

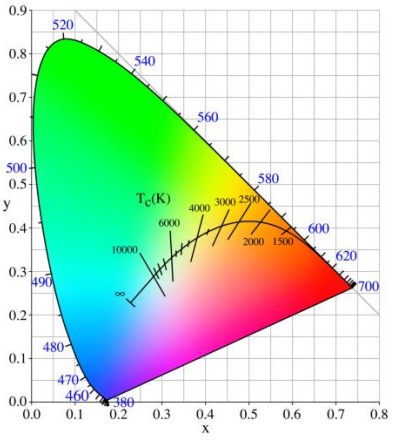


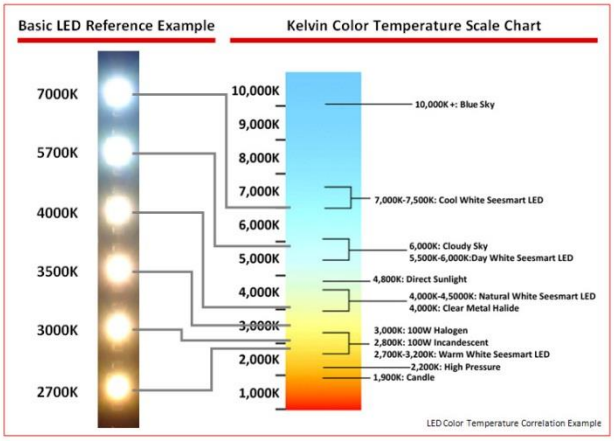
The Stefan-Boltzmann and Planck radiation laws were derived, in part, from measuring the intensity and color of radiated light from bodies of different temperatures (for example, **pottery in the kilns of Josiah and Thomas Wedgwood**). Josiah Wedgwood was a member of the Lunar Society, an abolitionist, and the grandfather of both Charles Darwin and of his wife, Emma.

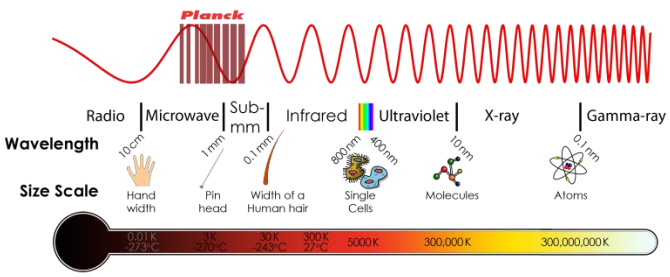




The commonly-observed relationship between the color (peak wavelength) and the temperature of a body are presented in various ways in the following figures:









The sun is a **star** and the relationship between the luminosity of a star and its temperature or spectral color class can be shown in a **Hertzsprung-Russell diagram**. $L/L_{\odot}$ is the ratio of the luminosity of a star to the luminosity of the sun. After the stars are assembled using gravitational energy, they spend most of their life on the main sequence (MS). The hot and luminous stars are in the upper left of the main sequence and the cool dim stars are on the bottom right. At the end of a star's life, it develops into a red giant and then into a white dwarf. The cool and brilliant red giants and hot and dim white dwarfs are shown above and below the main sequence, respectively. A star evolves onto a given place in the main sequence depending on the **initial mass** of the clump formed in a given nebula to form a **protostar**.

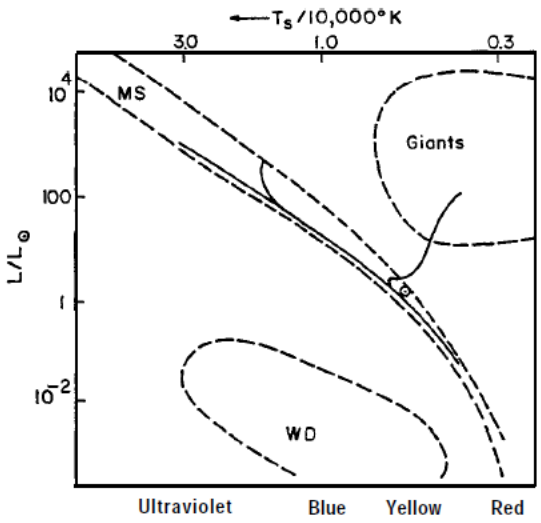


Fig.1. Hertzsprung-Russell diagram. From E.E.Salpeter, in *Apollo and the Universe*, Science Foundation for Physics, University of Sydney, Australia, 1967.

The **luminosity** of a star depends on its **mass**, which is a measure of the gravitational energy of the star and the fuel it has to burn. $M/M_{\odot}$ on the abscissa is the ratio of the mass of a star to the mass of the sun. The solar mass is calculated from the orbits of the planets using **Newton's Law of Universal Gravitation** and the stellar masses can be calculated from the orbits of binary stars.

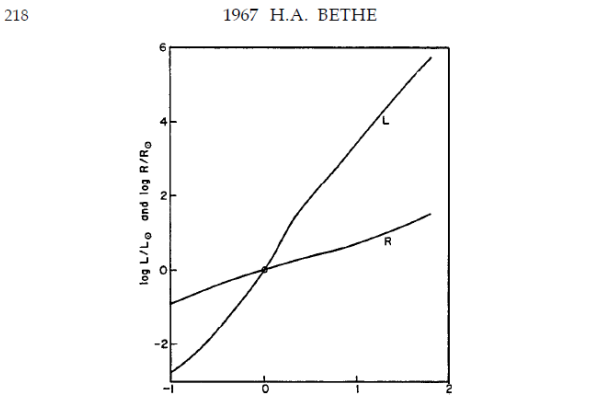
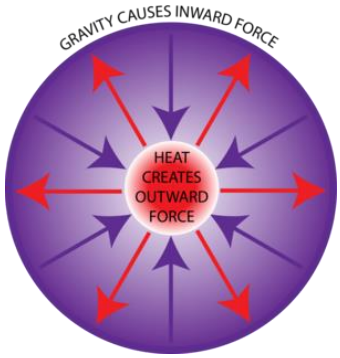


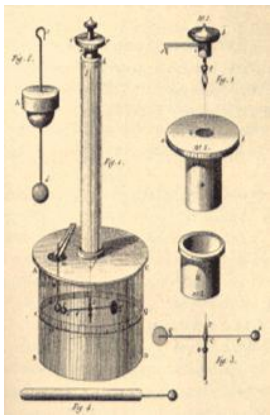
Fig. 2. Luminosity and radius of stars vs. mass. Abscissa is $\log M/M_{\odot}$. Data from C. W. Allen, *Astrophysical Quantities*, Athlone Press, 1963, p. 203. The curve for $\log L/L_{\odot}$ holds for all stars, that for $R/R_{\odot}$ only for the stars in the main sequence. The symbol ☉ refers to the sun.

The **most luminous** stars on the main sequence have the **greatest masses** (150 M_{sun}) and the least luminous stars on the main sequence have the smallest masses (0.08 M_{sun}, which is the ***minimal mass*** needed to ignite nuclear reactions).

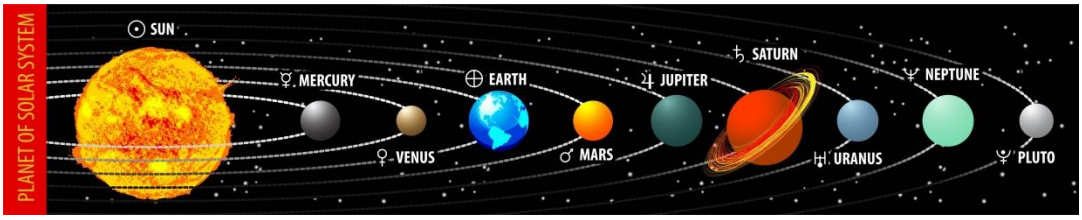
The mass of the sun (M_{sun}) can be estimated from Newton's Law of Universal Gravitation and Newton's Second Law:

$$mg = G\frac{M_{sun}m}{r^2} = \frac{mv^2}{r} \qquad M_{sun} = \frac{rv^2}{G}$$



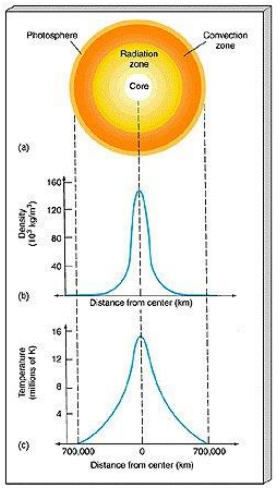


where g (in m s^{-2}) is the acceleration at which a planet with mass m is falling into the sun, G is the gravitational constant measured by Henry Cavendish in 1798 using the torsion balance and is equal to 6.67 × 10^{-11} m^3 kg^{-1} s^{-2}, and r is the distance between a planet and the sun. The velocity (v) of a planet is equal to the ratio of the circumference ($2\pi r$) of the orbit to its period. The acceleration is equal to the velocity squared divided by the radius of the orbit ($g = \frac{v^2}{r}$). From studying the orbits of the planets in the solar system around the sun, the **mass** of the sun has been determined to be **1.99 × 10^{30} kg**, which is about 300,000 times more massive than the earth.



If we plug in the **radius of the sun for r**, we get the gravitational force per unit mass upon any body at the **surface of the sun**. This gravitational force is so large that it could cause the gravitational collapse of the sun such that the sun would become approximately a point in approximately 30 minutes. The fact that

the radius of the sun seems to be **constant** indicates that the gravitational force must be **transformed into an opposing force** when it acts on the sun itself. Indeed, it is, the compression of the sun itself results in the production of heat inside the sun. The heat causes the **dissociation of the electrons** from the nuclei of atoms forming a **plasma**. The heat also causes the ionized nuclei and electrons to move very fast and act like an **expanding gas** that exerts a **pressure** that **balances the gravitational force**. As a consequence of the hydrostatic equilibrium, the **radius of the sun remains constant**. **Radiation pressure**, which is pressure due to the force exerted by light itself, also contributes, along with gas pressure, to balance the pressure due to gravitational contractions. The **average density** of the sun is estimated from its **mass** and **volume** ($V = \frac{4}{3}\pi r^3$) to be approximately **1.4 g/cc** and the density in the center which has to balance all of the gravitational force is approximately 150 g/cc. The density of water is approximately 1 g/cc. Although we have never sampled the inside of the sun directly, we just used the laws of nature and a little algebra to give us an idea of the internal conditions of the sun.



Hermann von Helmholtz (1856) proposed that **gravitational contraction** is the cause of the energy radiated by the sun. The gravitational energy (in Joules) of a spherical sun is related to the gravitational force per radial distance and is given by the following equation.

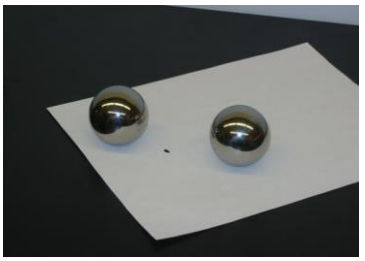


$$E_{gravitational} = -\frac{3GM_{sun}^2}{5r}$$

Demonstration: Observe the effect of gravity on two rolling objects—a double cone and a cylinder rolling down an inclined plane:



Demonstration: Converting mechanical energy into thermal energy (heat): Observe what happens to a piece of paper when you smash together the two chrome steel balls with a piece of paper in between.



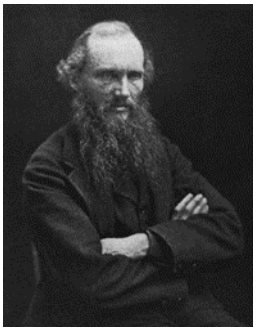
Demonstration: Converting mechanical energy into thermal energy (heat): Compress air with the fire syringe and observe what happens to the cotton.



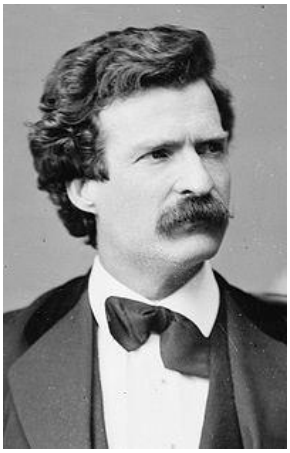
The ratio of the **gravitational energy (2.3×10^{41} J)** to the **luminosity** (**3.8×10^{26} W** = J/s) gives an estimate of the **time** in seconds that it would take to radiate the observed energy if the gravitational contraction served as the only source of energy. The ratio tells us that, if the conversion of gravitational energy into heat was the only source of energy in the sun, then **the age of the sun** would be about **20 million years**, which seemed reasonable in 1856. This would also give an estimate of the age of a habitable earth that depended on the light and heat of the sun. However, in **1859**, when **Charles Darwin** calculated the age of the earth to be greater than 300 million years, from the time it would take for erosion to denude the Weald, 20 million years seemed too short for the age of the sun. An old earth would be consistent with the **gradual origin of species by natural selection**. William Thomson, the



greatest living scientific authority at the time, who later became **Lord Kelvin**, argued against Darwin. This is why Darwin withdrew his estimate of the age of the earth. According to Thomson (1862), the sun, which is necessary for life on earth, and which derived its energy from gravity, could not have provided the needed sunlight for 300 million years of evolution by natural selection.



Mark Twain satirized the situation, and wrote, "*Some of the great scientists, carefully ciphering the evidences furnished by geology, have arrived at the conviction that our world is prodigiously old, and they may be right but Lord Kelvin is not of their opinion. He takes the cautious, conservative view, in order to be on the safe side, and feels sure it is not so old as they think. As Lord Kelvin is the* ***highest authority in science*** *now living, I think we must yield to him and accept his views."*

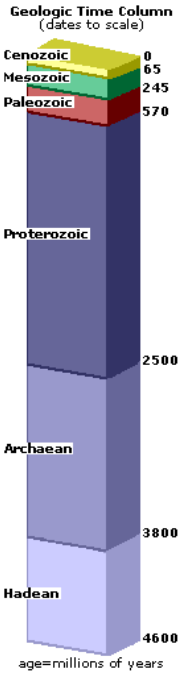


William Thomson could not have **foreseen** the possibility of thermonuclear transformation of nuclear mass into energy to produce sunlight as the temperature of the sun stayed constant.



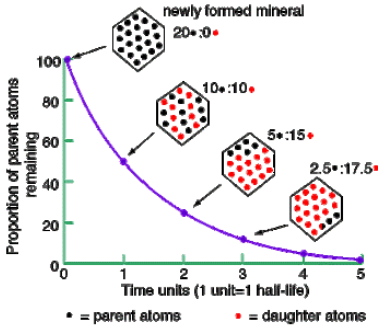


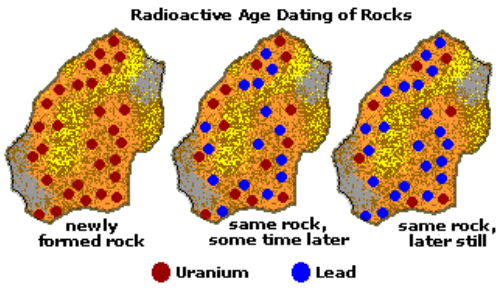




Henri Becquerel (1896), who was interested in what was called the **phosphorescence** of **uranium** at the time, **serendipitously** discovered **radioactivity**, which was due to the emission of electrons, when he noticed that uranium produced an **image** of itself on the photographic film it had been resting on in the **dark**. Radioactive elements are transformed into other elements during **radioactive decay** by **fission**, which was named after bacterial fission. Rutherford called the study of radioactive decay "***the new alchemy***" since radioactive decay resulted in the **transmutation of elements** for example uranium into lead. By measuring the ratio of the radioactive parent element to the stable element it transforms into in various ancient rocks, **Ernest Rutherford** and **Frederick Soddy** estimated the age of the earth. Current radiometric dating estimates the **age of the earth to be approximately 4.54 billion years old**.







Sometimes the greatest living scientific authority is *not* right. Frederick Soddy (1904) described the hullabaloo between **Lord Kelvin**, the physicist and **Charles**

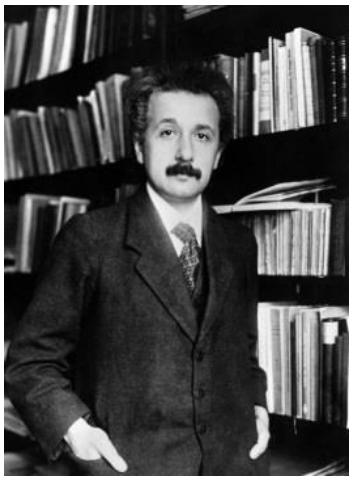
Darwin, the biologist concerning the age of the earth like so: "*Throughout the latter part of the last century a* ***controversy****, as to the possible age of the earth as a planet fitted for habitation, existed between two schools, represented by the physicists on the one side and the biologists on the other. Some of the arguments advanced by the former make strange reading at the present time.*"



In 1898, **Marie Curie**, who coined the term **radioactivity**, and her husband **Pierre Curie** isolated from uranium-rich pitchblende, polonium, named after Marie Curie's native country and **radium**, from the Latin word *radius*, which means ray. In 1903, Pierre Curie noticed that radium released heat but ***unlike*** other thermal processes (e.g. the radiation of heat by an iron rod), the radium did not cool down to the temperature of its surroundings. **Ernest Rutherford** and **Frederick Soddy** as well as **William Wilson**, **John Joly**, and **George Darwin**, one of Charles Darwin's sons, all proposed in 1903 that **radioactivity** might be the source of the sun's radiated energy. However, a spectroscopic study of the chemical composition of the sun revealed that the sun was composed primarily of hydrogen and helium and that there were little or no heavy radioactive chemicals in the sun.

In 1904, Mark Twain described the luminescence of lucifer in ***Sold to Satan***, as *a softly glowing, richly smoldering torch, column, statue of pallid light, faintly tinted with a spiritual green*, because he was made of radioluminescent radium.

In 1905, **Albert Einstein** proposed that mass is related to energy by the famous equation:

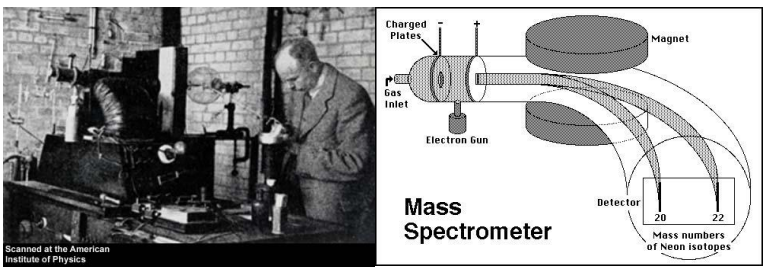


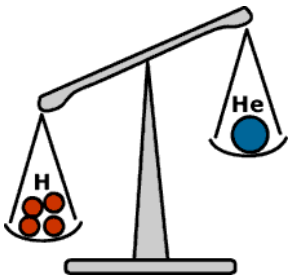
$$E = mc^2$$

In a paper entitled, *Does the inertia of a body depend upon its energy content*?, Einstein realized that because the speed of light *c* is so large (3×10^8 m/s) his equation meant that a **tiny bit of mass** could be transformed into an **enormous amount of energy**. He also realized that his theory could be tested with radium salts, since the emission of **energy** by radium may be correlated with a decrease in its **mass**.

Could Einstein's equation apply to **thermonuclear fusion** as well as nuclear fission? Could the source of the sun's energy be **thermonuclear fusion** as opposed to nuclear fission? **Thermonuclear fusion** results when protons, the charged nuclei of hydrogen atoms, smash into each other to form a deuteron. Under **ambient temperatures**, protons do not smash into each other because their **electric charge repels** them from other protons. However, by heating the protons to millions of degrees Kelvin, they would have enough **kinetic energy** to overcome the **electrostatic barrier** and could smash into each other.

Using a **mass spectrograph** that separates atoms and molecules according to their mass just as a spectrograph separates light according to its wavelengths, **Francis Aston** (1920) **serendipitously** discovered that one helium nucleus (with an atomic mass of 3.99 Daltons) has less mass than 4 hydrogen



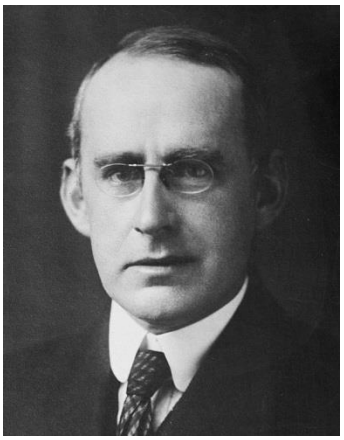


nuclei, each with an atomic mass of 1.008 Daltons. Aston, who was actually interested in looking for isotopes of neon, realized that the difference in mass between four hydrogen atoms and one helium atom is a source of a tremendous amount of energy.

Aston's experimental results gave the following masses for hydrogen and helium:

mass of 1 proton (p)	1.67358×10^{-27} kg
mass of 4 protons (4p)	6.6943×10^{-27} kg
mass of helium nucleus (He)	6.6466×10^{-27} kg
difference (4p – He)	0.0477×10^{-27} kg

Arthur Eddington suggested in his presidential address at the 1920 meeting of the British Association for the Advancement of Science that Aston's measurement of the 0.7% mass difference between four hydrogen atoms and one helium atom meant that, if the sun derived its energy from **thermonuclear fusion**, the sun could shine for billions of years by converting hydrogen atoms to helium.

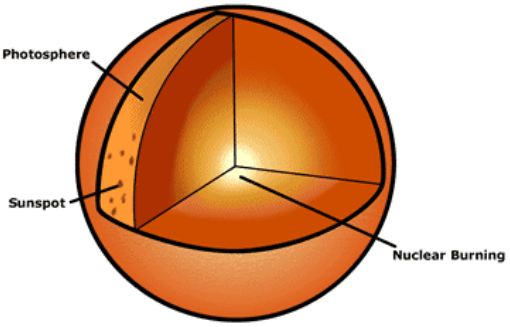


Applying Einstein's equation to the mass deficiency, we see that each fusion of **four hydrogen nuclei** (protons) into a **helium nucleus**, also known as an **alpha particle**, could result in 4.3×10^{-12} J.

$$E = 0.0477 \times 10^{-27} \text{ kg } (3 \times 10^{8} \text{ m/s})^2 = 4.3 \times 10^{-12} \text{ J}$$

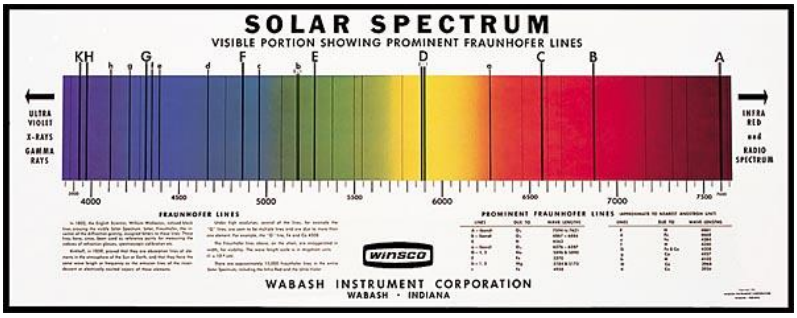
In order for fusion to yield the observed **luminosity** of 3.8×10^{26} W, 8.8×10^{37} helium nuclei would have to be formed from four hydrogen nuclei per second. This means that only 5.9×10^{11} kg, which is a trivial proportion of the sun's mass (1.99×10^{30} kg), would have to be burned per second and the sun would burn for

billions of years. The enormous amount of energy released from the **nuclear burning** of hydrogen into helium is nearly twenty million times ***greater*** than the amount of energy released by the **electron burning** of the same mass of hydrocarbon into carbon dioxide and water.



The sun, like most stars, is composed of hot gas that radiates energy into space. Heat always moves from hotter regions to cooler regions of matter, and, consequently, in the sun, the energy that is radiated from the **cooler surface** must come from a **hotter core** where it is generated. Charged particles as well as energy produced in the core also move to the surface where they are emitted.

Spectroscopic studies carried out during the 19th century showed that the sun was composed primarily of **hydrogen** (71%) and **helium** (27.1%), which was named after the sun (*Helios*) where it was first discovered. Oxygen (0.97%), carbon (0.4%), nitrogen (0.096%), silicon (0.099%), magnesium (0.0765), neon (0.058%), iron (0.14%), sulfur (0.04%), and a small amount of phosphorus make up the rest of the sun's mass.



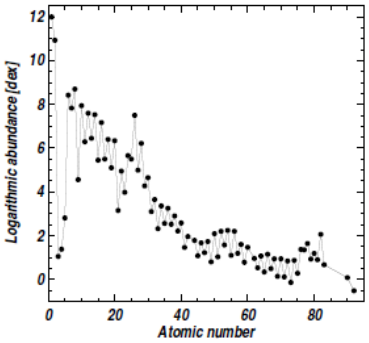


Figure 4: The present-day solar photospheric elemental abundances as a function of atomic number. As throughout this article, the logarithmic abundance of hydrogen is defined to be $\log \epsilon_H = 12.0$.

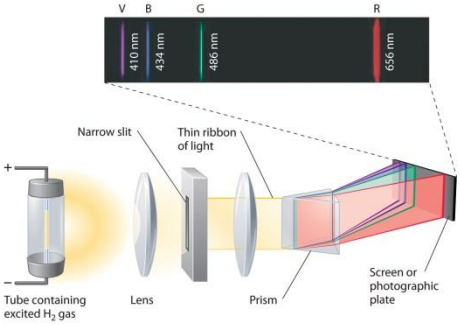
The elements in the sun's atmosphere are identified by **Fraunhöfer lines**, which are dark lines in the **continuous blackbody spectrum** produced by a

hot glowing or **incandescent body**. The dark lines are formed because each element in the sun's atmosphere absorbs certain wavelengths and re-emits them in all directions resulting in less light of those wavelengths coming to the earth. The darker the line, the greater is the abundance of the element that causes the line.

Demonstration: Observe the spectral lines of hydrogen with your spectroscopes.

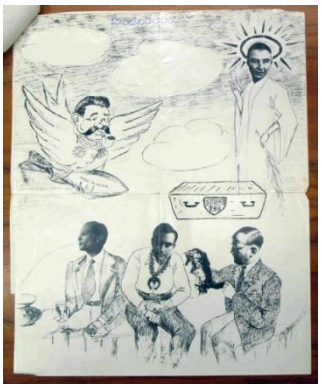


(a)



(b)

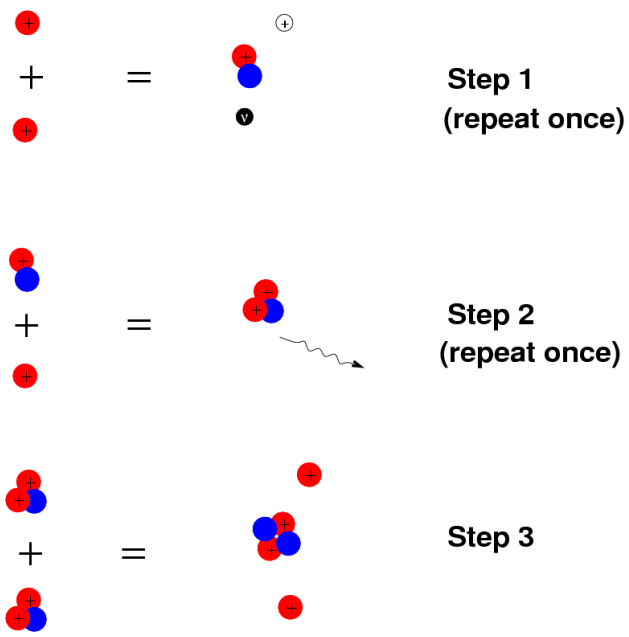
In 1938, **George Gamow** brought together astrophysicists and physicists at a meeting at George Washington University in Washington DC to exchange expertise in order to understand the sun and other stars. **Bengt Strömgren** asked the physicists there to find an explanation for the temperature, density, and chemical composition of the sun. **Hans Bethe** (Cornell), a nuclear physicist, looked at the various possible ways that nuclear reactions might occur in the sun. Bethe suggested that, if the **core of the sun were 16 million degrees Kelvin, the p—p** (proton-proton) **chain of nuclear reactions** would be the dominant source of energy production. Hans Bethe (1967) won the Nobel Prize for this work.



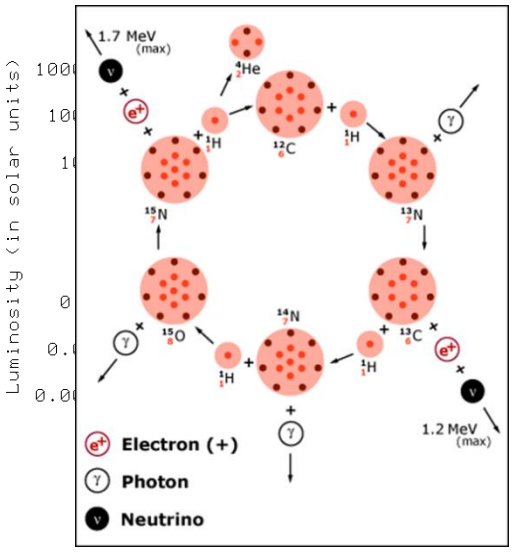




In the typical **p—p** nuclear reaction in the core of the sun (Step 1), two hydrogen nuclei (^{1}H, protons) are moving fast enough to overcome their electrostatic repulsion and they fuse to produce a heavy hydrogen nucleus (^{2}H = a deuteron = a proton and a neutron), and a positron and a neutrino are released. In Step 2, deuterons and protons are moving fast enough to overcome their electrostatic repulsion and fuse to produce a light element of helium (^{3}He) and a **gamma ray is released**. In Step 3, two light helium (^{3}He) nuclei are moving fast enough to overcome their electrostatic repulsion and fuse to form a normal helium ^{4}He nucleus and two hydrogen nuclei (^{1}H, protons), which will continue to participate in nuclear reactions, are released.

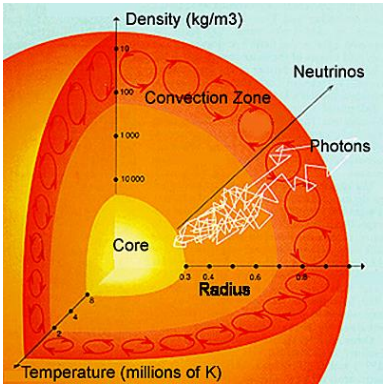


Only as small percentage of nuclei involved in the p—p nuclear reaction moves fast enough at the temperature of the core to overcome the electrostatic repulsion and fuse. At the temperature of the core of the sun, the percentage of heavier nuclei, including those of carbon, nitrogen, and oxygen that move fast enough to overcome the electrostatic repulsion is even smaller so only a small amount of fusion involving these elements take place in the sun's core. On the other hand, in stars that are more massive than the sun and closer to the top left corner of the main sequence in the **Hertzsprung-**

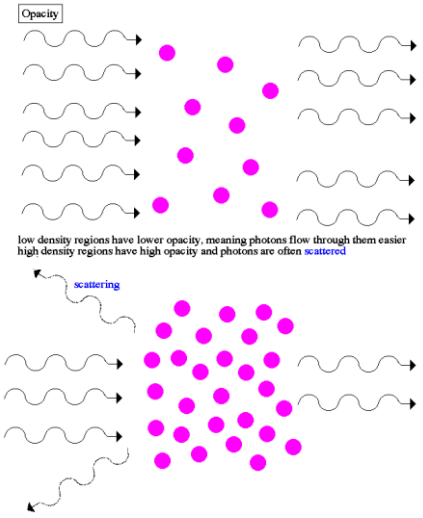


Russell diagram, the temperature is higher and the **carbon-nitrogen-oxygen (CNO) cycle** results in the fusion of four hydrogen nuclei (^{1}H, protons) into a single helium nucleus (^{4}He, alpha particle), using carbon as a catalyst, with the emission of energy from the core in the form of gamma rays.

Gamma rays that are released in the nuclear reactions taking place in the **core** travel about 500 micrometers before they strike a free electron and are scattered. The scattering process goes on and on as the gamma rays proceed in a **random walk** to the surface sharing their energy with the electrons. The ionized nuclei and electrons scatter the gamma rays so completely that the sun's interior is almost **opaque** to the gamma rays (just like the plasma, containing positively-charged nuclei and electrons that existed from three minutes after the **big bang** to 300,000 years after the big bang, was opaque to photons).

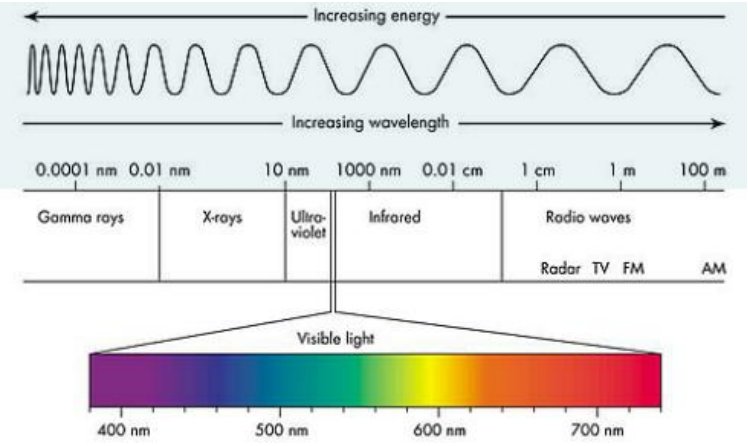


The **opacity** of the interior of the sun is due to the scattering of gamma rays by free electrons that takes place on its way from the core to the surface. With each scattering event, the energy of the gamma ray decreases so that eventually, the energy of radiation is reduced to energies in the **visible range**. As a result of numerous scattering events, it takes approximately **30 thousand years** for the photons formed in the nuclear reactions in the core to reach the surface. This is much longer than the two seconds it would take a photon at a velocity of 2.99×10^{8} m/s to move the same distance through free space. Radiation is not the only way that energy moves from the core to the surface. Near the surface, energy transfer is augmented by **convection**, where warmer plasma rises

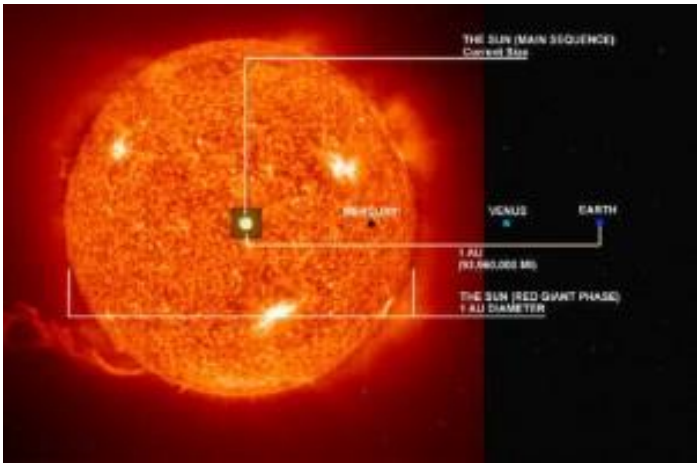


and cooler plasma falls in response to gravity. Given the radius of the sun, the "speed of light" or perhaps "the slowness of light" through the sun is approximately 7×10^{-4} m/s, far less than the 3×10^{8} m/s it travels from the sun to the earth's atmosphere.

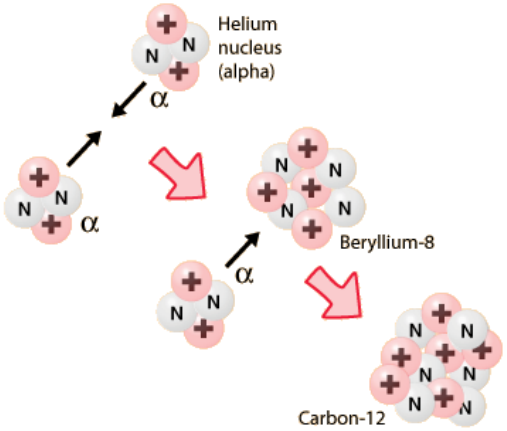
The sun was born approximately 4.6 billion years ago in the Milky Way galaxy when the **gaseous nebula**, which was composed primarily of hydrogen and helium and contained a smattering of dust, attracted itself gravitationally to form a spherical **protostar**. The gaseous **protostar** contracted as a result of the massive amount of **gravitational force** on itself. This compression resulted in the heating of the core and the eventual attainment of **hydrostatic equilibrium** where gravitational energy was balanced by thermal energy. Consequently, the diameter of the sun became stable. Given the temperature of the core, **alchemy** occurred, and hydrogen nuclei fused into helium in **thermonuclear reactions**. The alchemical transformation results in helium nuclei that have less mass than the four hydrogen nuclei that compose each one. The lost mass or 0.7% mass defect is radiated away, in part, as radiant energy that diffuses to the surface of the sun, losing energy at each scattering so that the photons are transformed from energetic gamma ray photons to photons of visible sunlight.

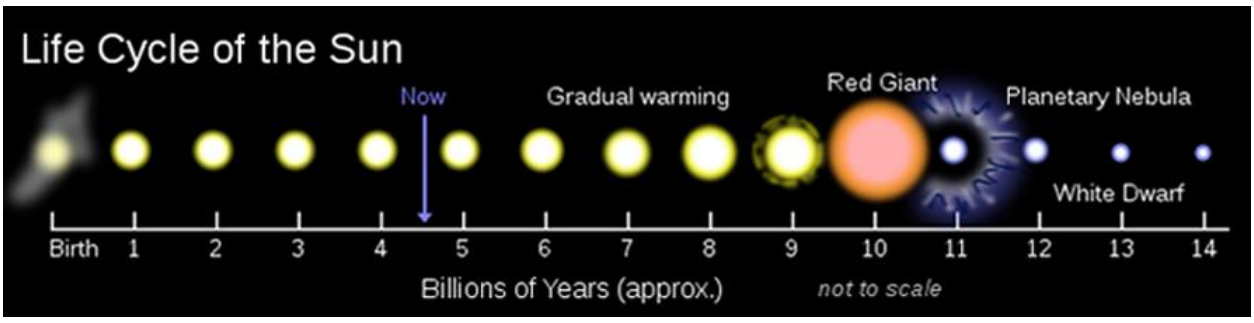


When the sun eventually consumes its supply of hydrogen, the core will be primarily composed of **helium**. No more nuclear reactions will take place in the core and it will cool and contract. However, the hydrogen outside the core will continue to burn and will expand. As the core contracts and as the hydrogen burning shell expands, the sun will move off the main sequence and become a **red giant**.



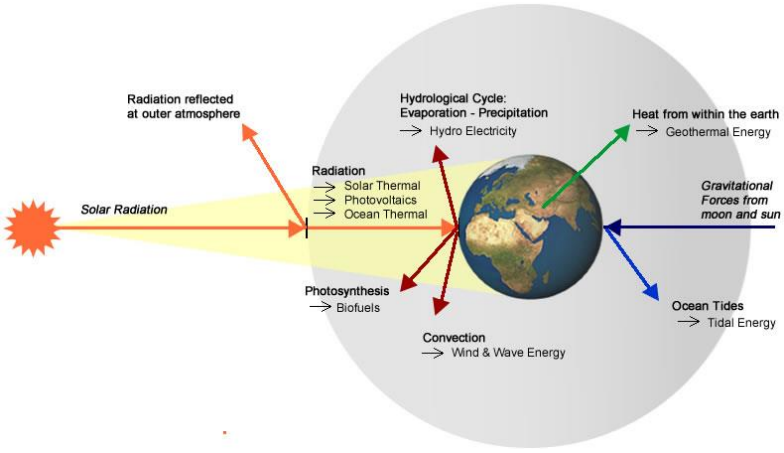
As the central core of the sun continues to contract, the density of helium will increase and the temperature of the core will rise. When the temperature of the core surpasses a threshold (100 million degrees), it becomes possible to burn helium into carbon in the **triple alpha process**. This burning, known as the **helium flash**, is explosive. During the explosion, the short-lived burning hydrogen envelope, known as a **planetary nebula**, is sloughed off and the bright core, now known as a **white dwarf**, is all that is left. The sun is currently about five billion years old; it will become a red giant and then a white dwarf when it is 10 and 11 billion years old, respectively.





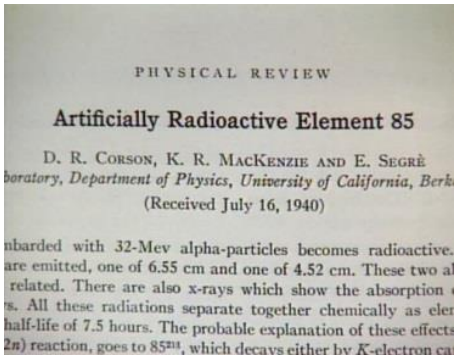
In general, the alchemical process of nuclear fusion results because the **kinetic energy** of the atomic nuclei is great enough to overcome **the electrostatic repulsion** that exists between positively-charged nuclei. As the size of the nucleus increases, it takes more and more energy to give the nuclei sufficient kinetic energy ($\frac{1}{2} mv^2$) to overcome the electrostatic energy ($\frac{q^2}{4\pi\varepsilon_o r}$) barrier. For this reason, the temperature of the star determines how heavy an element can be if it is to be burned. Hydrogen (1 Dalton) burns at 10^7 K, helium (4 Daltons) at 10^8 K, carbon (6 Daltons) at 5×10^8 K, oxygen (16 Daltons) at 2×10^9 K, and silicon (28 Daltons) at 3×10^9 K. The unit of atomic mass is named after the colorblind John Dalton.

The sun is **massive** in that it has a lot of fuel to burn, and **the nuclear reactions** yield far more energy per mass consumed than **chemical combustion reactions**, which involve the **rearrangement of electrons**. The sun, which is in some respects not a renewable resource, will provide the earth with energy for the next five billion years. The sun's radiant energy warms the earth, resulting in **wind** that transports the pollen of grasses. The warmth due to the sun's radiant energy also results in the **evaporation of water** from the sea that leads to **rain on land** that is necessary for the growth of trees, shrubs and herbs. The visible light from the sun provides the **energy for photosynthesis**, which is responsible for all the food we eat. The visible light from the sun provides information for seeing the **colors in the world** around us and for telling the **time of day**, the **season of the year**, and the **direction in space**.



President Emeritus **Dale Corson** designed a sundial so that we can tell the time.





PHYSICAL REVIEW

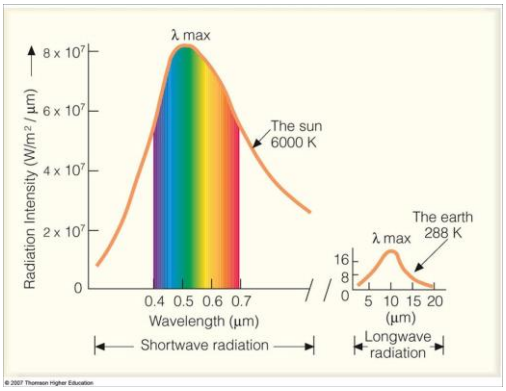
Artificially Radioactive Element 85

D. R. CORSON, K. R. MACKENZIE AND E. SEGRÈ
boratory, Department of Physics, University of California, Berk
(Received July 16, 1940)

nbarded with 32-Mev alpha-particles becomes radioactive.
are emitted, one of 6.55 cm and one of 4.52 cm. These two al
related. There are also x-rays which show the absorption
s. All these radiations separate together chemically as ele
half-life of 7.5 hours. The probable explanation of these effect
2n) reaction, goes to 85^{211}, which decays either by *K*-electron ca



Like the **average temperature** of the sun, the average temperature of the earth is also somewhat constant. As the sun can be considered to be an **incandescent black body** with an average temperature of about 6000 K, the earth can be considered to be a black body with an average temperature of about 288 K (58.73 F). The radiant energy of the sunlight entering the earth's atmosphere is radiated away from the earth as **mid infrared** (5 to (25-40) μm) radiation. That is, since the energy (E in J) of a photon is related to its wavelength (λ in m) by the product (hc = 6.6 × 10^{-34} Js · 3 × 10^{8} m/s) of Planck's constant and the speed of light, the average energy of photons leaving the earth is less than the average energy of photons entering the earth.



$$E = \frac{hc}{\lambda}$$

The **mid-infrared energy** radiated away from the earth, which originates from the **visible light energy** from the sun, will have little contribution to the enormous amount of cosmic **microwave** background radiation that reminds us of the first light, whether defined by Robert Grosseteste or by the Big Bang Theory.

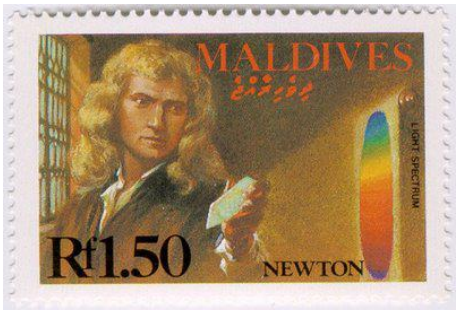
As you can see, we are able to get to know a fair amount about our sun through observation and theory. **Arthur Eddington** ended his 1920 presidential address by saying, " *In ancient days two aviators procured to themselves wings.* ***Daedalus*** *flew safely through the middle air across the sea, and was duly honoured on his landing. Young* ***Icarus*** *soared upwards towards the Sun till the wax melted which bound his wings, and his flight ended in fiasco. In weighing their achievments perhaps there is something to be said for Icarus. The classic authorities tell us that he was only 'doing a stunt,' but I prefer to think of him as the man who certainly brought to light a constructional defect in the flying-machines of his day. So, too, in Science. Cautious Daedalus will apply his theories where he feels most confident they will safely go; but* ***by his excess of caution their hidden weaknesses cannot be brought to light****. Icarus will strain his theories to the breaking-point till the weak joints gape. For a spectacular stunt? Perhaps partly; he is often very human. But if he is not yet destined to reach the Sun and solve for all time the riddle of its constitution, yet he may hope to learn from his journey some hints to build a better machine.*"



Science, when healthy, sees the values and limitations of both Daedelus and Icarus.

While the sun, like any other **incandescent body** emits a **continuous spectrum** of light with a **spectral distribution** defined only by its **temperature**, upon looking closely, the spectrum is **interrupted** by **dark lines**. These dark spectral lines were used by chemical spectroscopists to identify the chemicals present in the sun. Now I am going to discuss **chemical spectroscopy** itself.

Isaac Newton accomplished with a prism what Roger Bacon realized nature accomplishes with each water droplet in a rainbow. By passing a cylindrical beam of sunlight though a prism, **Isaac Newton** (1671) revealed that the white light from the sun was composed of a continuous spectrum of colors.



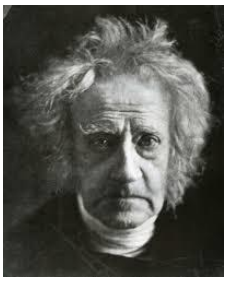
By replacing the round hole that admitted the sunlight into the laboratory with a **narrow slit**, **William Hyde Wollaston** (1802) became aware of the fact that the colors of the spectrum were not continuous but separated by a series of discrete black lines. **Joseph von Fraunhöfer** noticed that the ***black lines*** that were present in the spectra of sunlight were absent in the light from the flame of a lamp. In fact, he noticed that the light from a flaming or electrical lamp had ***bright lines*** in the spectrum that corresponded to the dark lines of the solar spectrum.







Thomas Mellvill (1756) discovered that when he added salts to the flame of a spirit lamp, the color constitution of the light was altered, and he wondered if sunlight might be composed of "*such colours and in such proportions as were seen in the lights of salts and burning spirits.*" **John Herschel** (1823) expanded Mellvill's line of investigation by soaking the wick of a spirit lamp in a solution of strontium chloride or copper chloride. Upon lighting the wick, he observed that the salt produced a characteristic color when heated—**strontium** produced a flame with a "*beautiful carmine-red colour*" and **copper** produced a flame with an "*emerald-green colour*." Realizing the importance of this discovery for chemistry, Herschel latter wrote, "*The colours thus communicated by the different bases to flame, afford in many cases a ready and neat way of detecting extremely minute quantities of them.*"



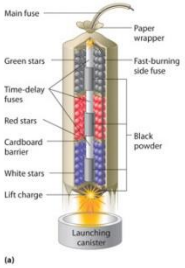
Demonstration: Observe the color of the flame of an alcohol lamp after adding strontium chloride and copper chloride individually using loops made from nichrome wire. Look at the flame with a spectroscope.



William Henry Fox Talbot (1826) came to the same conclusion as John Herschel while he was trying to develop a monochromatic lamp that would be useful for microscopy and for studying the properties of light. Talbot also suggested that "*whenever the prism shows a homogeneous ray of any colour to exist in a flame, this ray indicates the formation or the presence of a definite chemical compound.*"

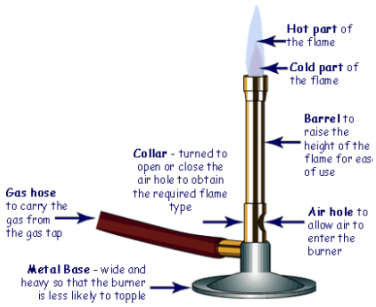


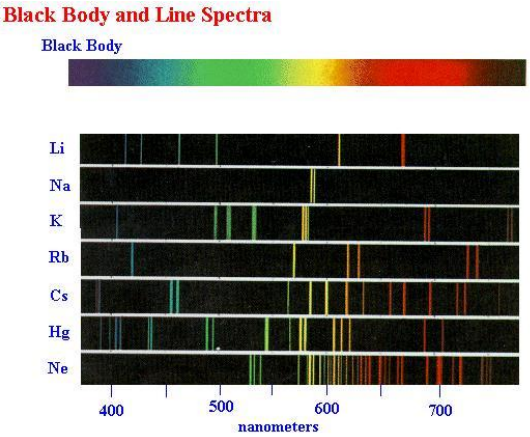
Every time we see a **fireworks** display, we are reminded of the relationship between the chemical elements and the color emitted.





Gustav Kirchhoff (1863), **Robert Bunsen**, and others using a **Bunsen burner**, firmly established that each **chemical element absorbed** and **emitted** light waves with **characteristic discrete wavelengths**. By meticulously comparing spectra, Kirchhoff in particular showed that the **emission** of light by a given element gave rise to the **bright lines** in the spectrum, and the **absorption** of light by the same element gave rise to the **dark lines** in the spectrum. The light or dark **spectral lines** could be used to **identify chemical elements**.





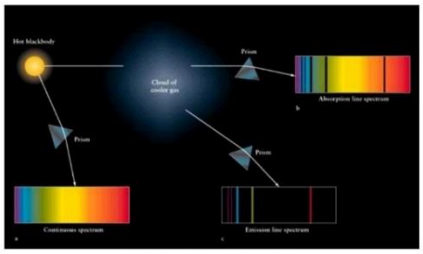
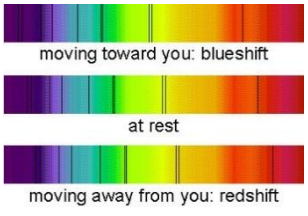


Fig: Emission & Absorption spectrum

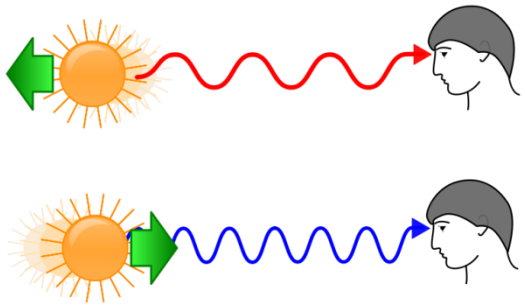
The field of **spectrum analysis** made it possible for Kirchhoff, Anders Ångstrom, Norman Lockyer (1887), William Huggins (1899), and others to **identify chemical elements** not only in terrestrial samples, but also in celestial bodies, including the sun.



The **identification of the chemical elements** by their **characteristic spectral lines** should ***not*** depend on the velocity of the observer. However, Ernst Mach (1860) and Hippolyte Fizeau (1870) suggested that as a result of the **Doppler effect**, there may be a **shift** in the position of the spectral bands emanating from the heavenly bodies that depended on their radial motion. If the atom were ***moving relative*** to the observer, the observer would reckon that the atom was absorbing or emitting light with a different wavelength than that which was expected. **Light** emitted by atoms



moving away from an observer would be **red shifted** and **light** emitted by atoms **moving towards** an observer would be **blue shifted**.

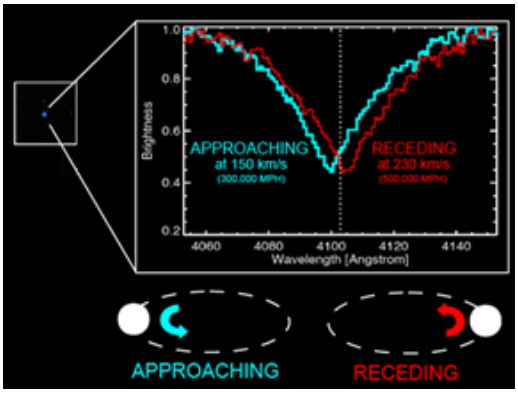


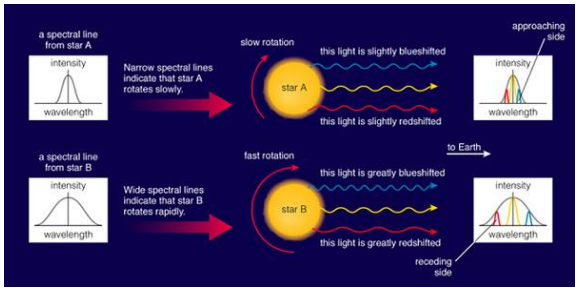
Thus, *prima facie*, it would seem that an observer at rest with respect to the atom and an observer moving relative to the atom would **identify it as an atom of a different element**. In order for the spectral line to be identified as one coming from a given element, **independent of the relative motion**, one would have to use an equation for the spectral lines that would allow any and all observers to agree on the chemical identity of the source of the emitted light. This is the principle of relativity applied to chemical identification. The transformation is:

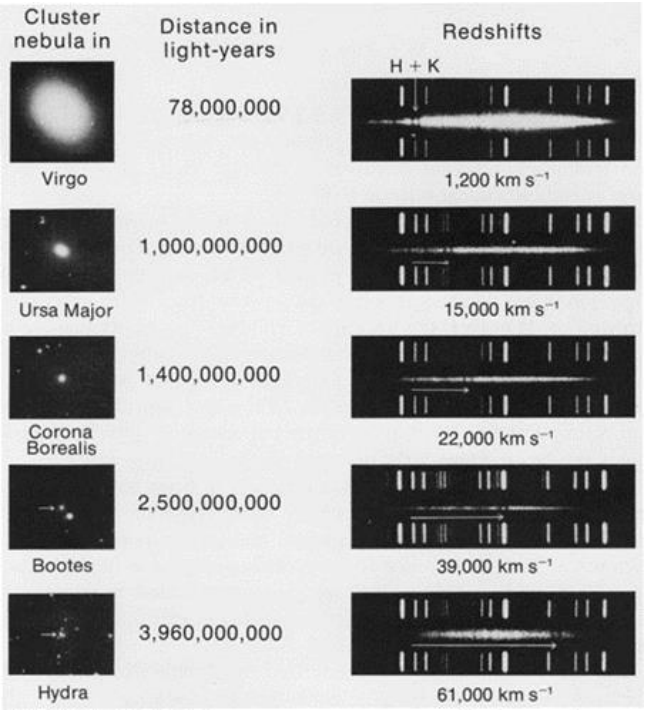
$$\lambda_{moving} = \lambda_{stationary}\left[\frac{1-\frac{v}{c}\cos\theta}{\sqrt{1-\frac{v^2 cos^2\theta}{c^2}}}\right]$$

Chemical elements **moving away** ($\theta = 180°$) from the observer would seem to be red shifted, with the **magnitude of the red shift related to the velocity**; and chemical elements **moving towards** ($\theta = 0°$) the observer would seem to be blue shifted, with the **magnitude of the blue shift related to the velocity**. Assuming that the chemicals in stars are identical with the chemicals on

earth, their Doppler-shifted spectral lines have been used to measure radial, rotational, and revolutionary motion.





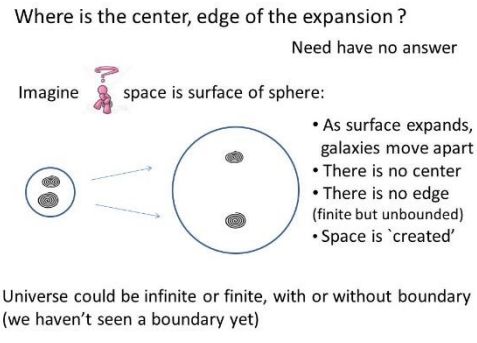


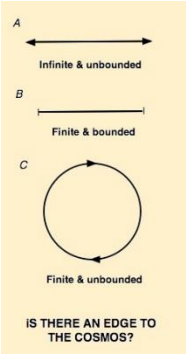
This is the same **red shift** based on the **Doppler effect** that allowed **Vesto Slipher** to measure the **radial velocities of the nearby spiral galaxies**, and given the extraordinary velocities that they were hurling through space, Slipher (1921) surmised, *"If the above swiftly moving nebula* [galaxy] *be assumed to have left the region of the sun at the beginning of the earth, it is easily computed, assuming the geologists' recent estimate for the earth's age, that the nebula* [galaxy] *now must be many millions of light years distant."*

This is the same **red shift** based on the **Doppler effect** that allowed **Edwin Hubble** (1929) to notice "***a linear correlation between distances and velocities***" and that the recession velocities of galaxies were proportional to their distance from the sun. Hubble (1937) pointed out that the "*velocity-shifts, on a microscopic*

scale, are familiar phenomena, and their interpretation is not to be questioned. Now the red-shifts observed in nebular [galactic] *spectra behave as velocity-shifts behave—the fractional shift dλ/λ is constant throughout a given spectrum—and they are readily expressed as velocities of recession. The scale is so convenient that it is widely used, even by those cautious observers who prefer to speak of 'apparent velocities' rather than actual motion….The law of red-shifts then reads: the nebulae* [galaxies] *are receding from the earth in all directions, with velocities that are proportional to their distances from the earth."*

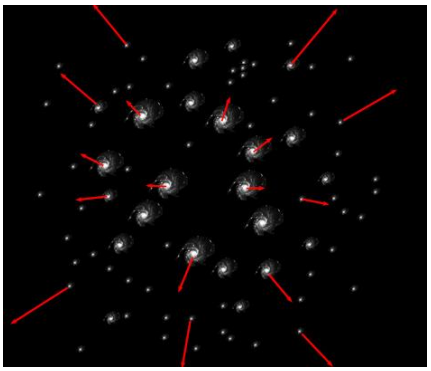
This is the same **red shift** based on the **Doppler effect** that allowed physicists who had been involved in radar during World War II to turn their instruments towards the heavens to study the cosmos at **radio wavelengths**. Astronomers at Cambridge University surveyed the sky for radio sources that produced electromagnetic radiation with a wavelength of about 1.8 m. These remote radio sources were identified with optical objects and they became known as quasi-stellar radio sources or **quasars**. These remote "radio stars" were among the first stars formed in the universe and exhibit **red shifts** that indicated that they had incredible velocities, such as 110,200 kilometers per second and greater.

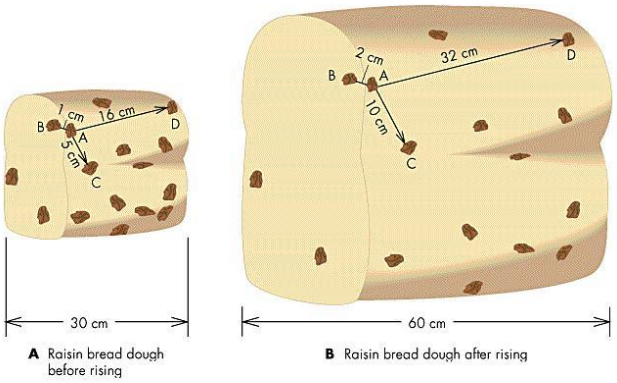




The theory of relativity is based on the assumption that there are no privileged observers. Einstein (1917,1920) extended this assumption to the whole universe and found the idea that the universe might have a center to be distasteful. Consequently Einstein (1920) came up with "***the possibility if a 'finite' and yet 'unbounded' universe***" to "***free ourselves from the distasteful conception that the material universe ought to possess something of the nature of a centre***." This is the origin on the

Cosmological Principle. According to Einstein (1931), "Alle Stellen des Universums sind gleichwertig," which translates to "*all parts of the universe are equivalent*." What I am calling Einstein's Cosmological Principle was first stated by Milne (1932,1933) to postulate that "*the moving picture of the world as made by any one observer is identical with that made by any other observer*," and "*the universe must appear the same to all observers*." De Sitter (1934) called the assertion "*that statistically the world pictures of two different observers must be the same*" the Cosmological Principle.

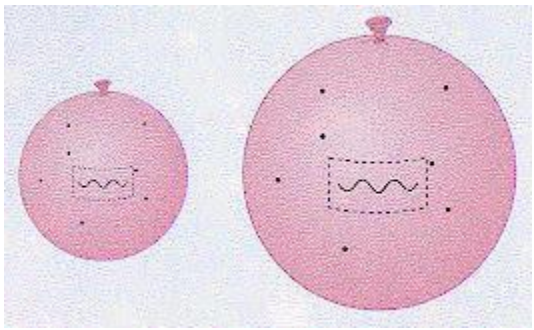




A Raisin bread dough before rising

B Raisin bread dough after rising

The Perfect Cosmological Principle proffered by Hermann Bondi and Thomas Gold (1948) states that the universe not only looks the same to any observer in space but to any observer in time. Belief in the Perfect Cosmological Principle caused them to postulate the **Steady State Universe**—a Universe where there is no sign of creation because it is postulated to exist eternally. In presenting the Perfect Cosmological Principle, Bondi and Gold (1948) stated that "*The unrestricted repeatability of all experiments is the fundamental axiom of physical science. This implies that the outcome of an experiment is not affected by the position and the time at which it is carried out*." However, experiments are as different from observations as the front end of a cow is different from the back end and the top of a leaf is different from the bottom of a leaf. While the various cosmological principles serve the principle



of the economy of thought, the assumptions, if too simplistic made lead to complications in the interpretations.

The **Cosmological Principle** is an **untested assumption** and as an untested assumption, it is open to questioning. The **cosmological principle** states that on a sufficiently large scale, all observers in the universe see the same thing no matter who or where they are. By **assuming** that we are ***not*** in a special place in the universe where the heavenly bodies are all moving away from us and that ***any observer*** in the universe would see similar red shifts, **these red shifts are considered by cosmologists to be a consequence of the expansion of space** using an expanding raisin bread as an analogy. I see things differently (which is not allowed by the cosmological principle)! I do not accept the **cosmological principle** as foundational and I do not accept the assumption that everyone no matter where they are will see red shifts, just like I believe that two observers can look at the southern sky and the northern sky and see different constellations. Therefore, I consider the red shifts to be a consequence of their **velocity *in* space** as opposed to the **velocity *of* the expansion of space**. This would make us near the center of the universe. You are free to make your own decisions. The figure below demonstrates my commonsense cosmological principle that a botanist (me) came up with: What you see depends on your position.



Jeffrey Buller (2015), author of *The Essential Academic Dean or Provost*, second edition states it this way: *It is a truism in higher education that what you see depends on where you sit.*

For what it is worth, **Aldous Huxley** wrote in Chapter II of *Brave New World* (**https://www.huxley.net/bnw/two.html**), about a method which would keep people safe from botany, which could lead to such commonsense thinking:

MR. FOSTER was left in the Decanting Room. The D.H.C. and his students stepped into the nearest lift and were carried up to the fifth floor.

INFANT NURSERIES. NEO-PAVLOVIAN CONDITIONING ROOMS, announced the notice board.

The Director opened a door. They were in a large bare room, very bright and sunny; for the whole of the southern wall was a single window. Half a dozen nurses, trousered and jacketed in the regulation white viscose-linen uniform, their hair aseptically hidden under white caps, were engaged in setting out bowls of roses in a long row across the floor. Big bowls, packed tight with blossom. Thousands of petals, ripe-blown and silkily smooth, like the cheeks of innumerable little cherubs, but of cherubs, in that bright light, not exclusively pink and Aryan, but also luminously Chinese, also Mexican, also apoplectic with too much blowing of celestial trumpets, also pale as death, pale with the posthumous whiteness of marble.

The nurses stiffened to attention as the D.H.C. came in.

"Set out the books," he said curtly.

In silence the nurses obeyed his command. Between the rose bowls the books were duly set out–a row of nursery quartos opened invitingly each at some gaily coloured image of beast or fish or bird.

"Now bring in the children."

They hurried out of the room and returned in a minute or two, each pushing a kind of tall dumb-waiter laden, on all its four wire-netted shelves, with eight-month-old babies, all exactly alike (a Bokanovsky Group, it was evident) and all (since their caste was Delta) dressed in khaki.

"Put them down on the floor."

The infants were unloaded.

"Now turn them so that they can see the flowers and books."

Turned, the babies at once fell silent, then began to crawl towards those clusters of sleek colours, those shapes so gay and brilliant on the white pages. As they approached, the sun came out of a momentary eclipse behind a cloud. The roses flamed up as though with a sudden passion from within; a new and profound significance seemed to suffuse the shining pages of the books. From the ranks of the crawling babies came little squeals of excitement, gurgles and twitterings of pleasure.

The Director rubbed his hands. "Excellent!" he said. "It might almost have been done on purpose."

The swiftest crawlers were already at their goal. Small hands reached out uncertainly, touched, grasped, unpetaling the transfigured roses, crumpling the illuminated pages of the books. The Director waited until all were happily busy. Then, "Watch carefully," he said. And, lifting his hand, he gave the signal.

The Head Nurse, who was standing by a switchboard at the other end of the room, pressed down a little lever.

There was a violent explosion. Shriller and ever shriller, a siren shrieked. Alarm bells maddeningly sounded.

The children started, screamed; their faces were distorted with terror.

"And now," the Director shouted (for the noise was deafening), "now we proceed to rub in the lesson with a mild electric shock."

He waved his hand again, and the Head Nurse pressed a second lever. The screaming of the babies suddenly changed its tone. There was something desperate, almost insane, about the sharp spasmodic yelps to which they now gave utterance. Their little bodies twitched and stiffened; their limbs moved jerkily as if to the tug of unseen wires.

"We can electrify that whole strip of floor," bawled the Director in explanation. "But that's enough," he signalled to the nurse.

The explosions ceased, the bells stopped ringing, the shriek of the siren died down from tone to tone into silence. The stiffly twitching bodies relaxed, and what had become the sob and yelp of infant maniacs broadened out once more into a normal howl of ordinary terror.

"Offer them the flowers and the books again."

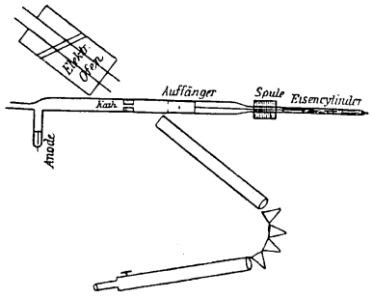
The nurses obeyed; but at the approach of the roses, at the mere sight of those gaily-coloured images of pussy and cock-a-doodle-doo and baa-baa black sheep, the infants shrank away in horror, the volume of their howling suddenly increased.

"Observe," said the Director triumphantly, "observe."

Books and loud noises, flowers and electric shocks–already in the infant mind these couples were compromisingly linked; and after two hundred repetitions of

the same or a similar lesson would be wedded indissolubly. What man has joined, nature is powerless to put asunder.

"They'll grow up with what the psychologists used to call an 'instinctive' hatred of books and flowers. Reflexes unalterably conditioned. They'll be safe from books and botany all their lives." *The Director turned to his nurses. "Take them away again."*



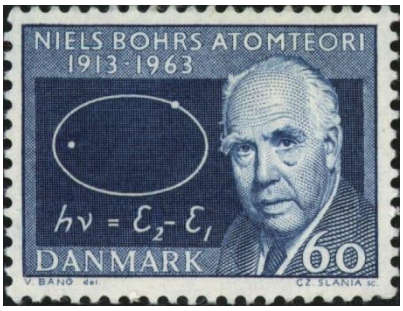
Johannes Stark (1902) realized that the **Doppler effect** would also apply to terrestrial light sources and consequently, a given chemical atom would have different characteristic spectra depending on its relative velocity. Using the positively-charged atoms that make up canal rays, Stark observed that, consistent with the Doppler effect, the positions of the spectral lines emitted from the atomic ions moving **towards** him were shifted towards the **blue end** of the spectrum and the positions of the spectral lines emitted from the atomic ions **moving away from** him were shifted towards the **red end** of the spectrum. Stark used the Doppler shift to determine the velocity of the positively-charged atoms that made up the canal rays.

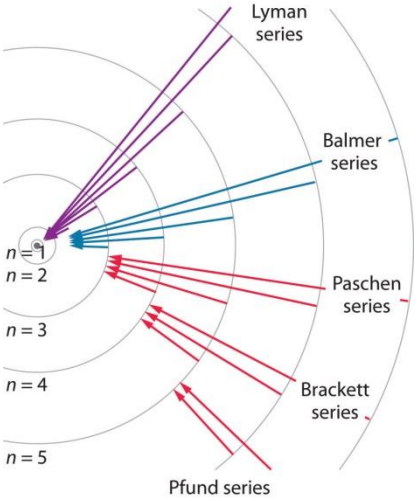
Demonstration: Observe the cathode rays (electrons) and anode or canal rays (protons). Observe the cathode rays (electrons) in the plasma globe





In 1913, **Niels Bohr** proposed a **model** of a stationary hydrogen atom based on the **discrete spectral lines** it **absorbs** or **emits**. Bohr proposed that the reason atoms emit discrete spectral lines is because the **electrons move around the nucleus in circular orbits that can have only certain allowed radii** characterized by an integer **(n = 1, 2, 3…)**. When a negatively-charged electron jumps from an orbit to one closer to the positively-charged nucleus, it **emits** light of a given spectral line, consistent with the **electrostatic energy lost** by an atom when opposite charges move closer together. When an electron **absorbs** light corresponding to a given spectral line, the electron overcomes the electrical attraction and moves from an orbit near the positively-charged nucleus to one farther away, consistent with the electrostatic energy gained by an atom when opposite charges move away from each other.





According to Bohr, the energy (E) of each orbit (n) is given by the following formula, where R represents a constant known as the Rydberg constant, which is equal to 1.097×10^7 m^{-1}.

$$E = \frac{Rhc}{n^2}$$

The energy (E) absorbed ($+Rhc$) or emitted ($-Rhc$) by an electron following from the initial orbit (n_i) to the final orbit (n_f) is given by:

$$E = \pm Rhc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

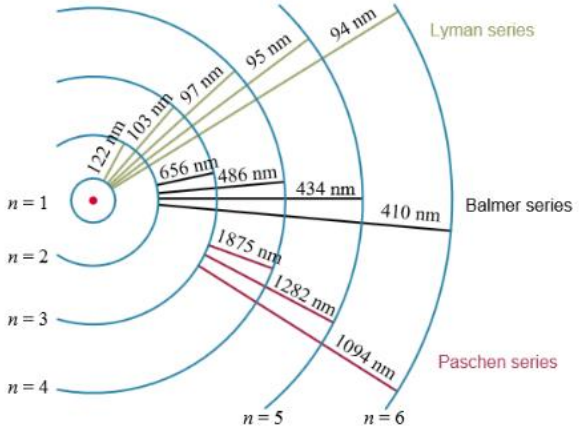
Since $E = \frac{hc}{\lambda}$, the wavelength of light that is emitted or absorbed by the transition from one orbit to another is given by:

$$E = \pm Rhc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = \frac{hc}{\lambda}$$

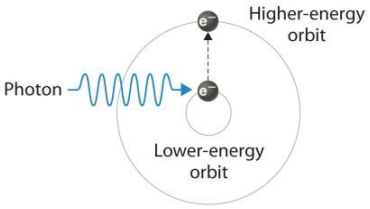
$$\frac{1}{\lambda} = \pm R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

What is the wavelength emitted by an electron jumping from orbit 2 to orbit 1, closer to the positively-charged nucleus? 121.54 nm.

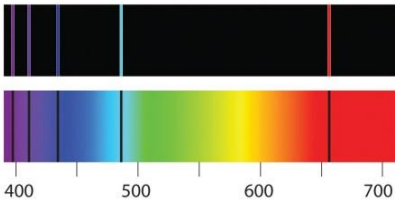
What is the wavelength emitted by an electron jumping from orbit 3 to orbit 2, closer to the positively-charged nucleus? 655.74 nm.



According to the Bohr model, the **absorption** of light by an atom and the dark band it produces can be pictured like so:

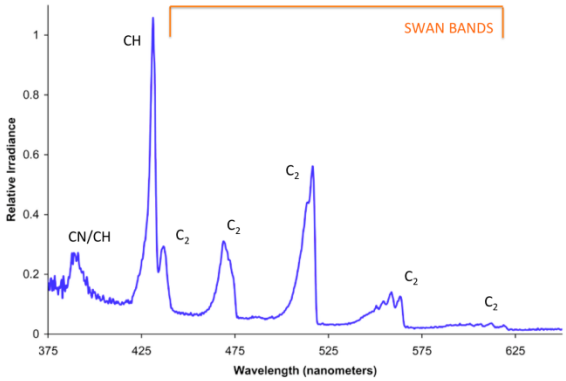


(a) Electronic absorption transition



(b) H_2 emission spectrum (top), H_2 absorption spectrum (bottom)

When atoms are bonded together into molecules, the molecules absorb and emit light in a manner that depends on their atomic composition and the type of bonds. When a **carbon** atom bonded to a **hydrogen** atom as **CH** cools, it emits light, when it is cooled, it absorbs light. When **two carbon** atoms, bonded together as **C_2** cool, it also emits light, but light of different wavelengths than CH. When the C_2 is cool, it absorbs light. These are the molecules that give rise to the **blue region of a flame**.

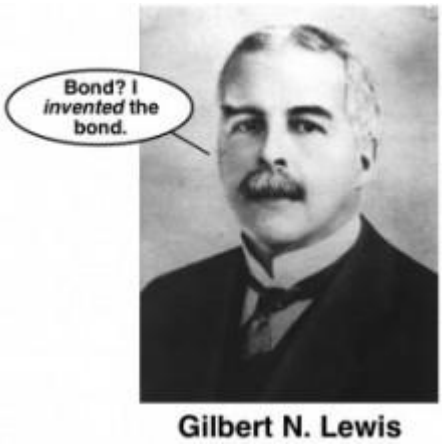




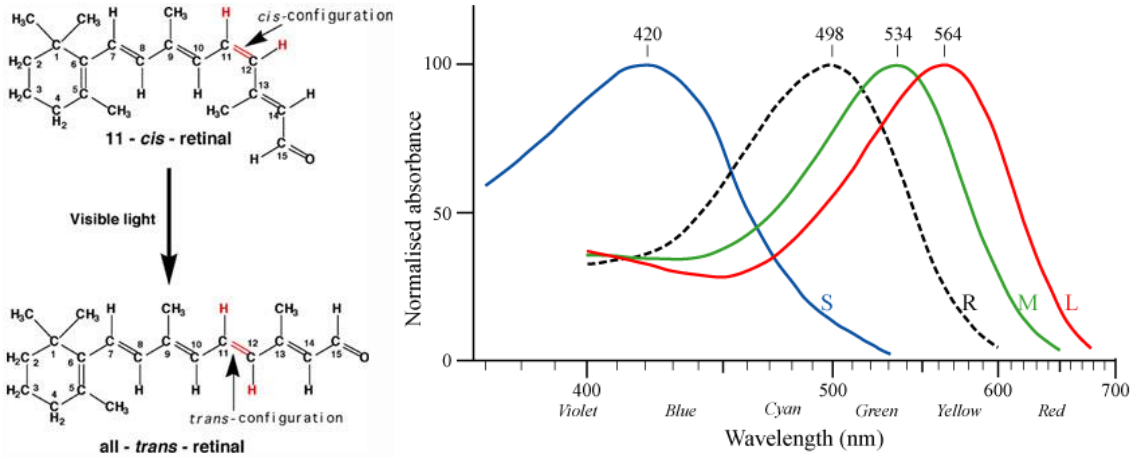
By analyzing the emission or absorption spectrum of light from a carbon-containing molecule, one can deduce its structure. Conversely, if one knows its structure, one can estimate its absorption or emission spectrum.

Below are the structures of various **pigments** that function in the absorption of sunlight that makes life possible and enjoyable. We will discuss these pigments and the processes they mediate over the semester.

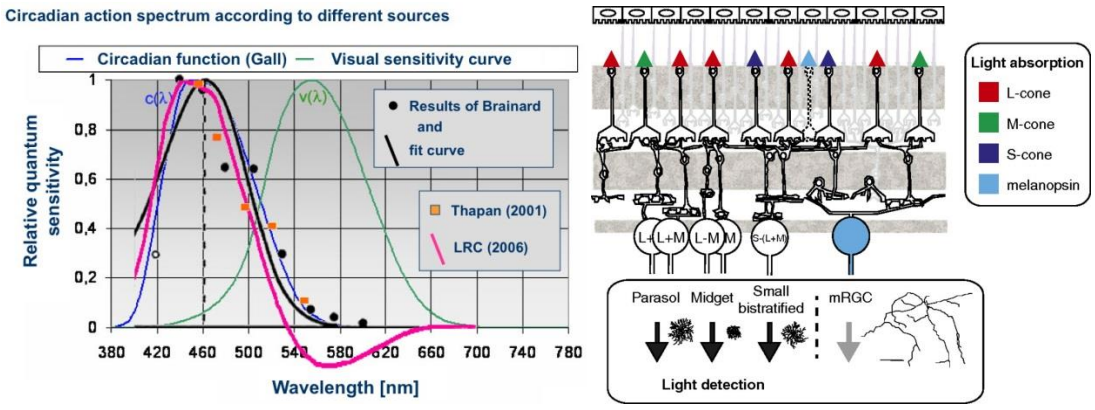
The **pigments** have much in common. Notice that they each have many **conjugated double bonds** (-C=C-C=C-). That is, **single bonds and double bonds alternate, resulting in delocalized electrons** that are not bound to a single positively-charged nucleus. Also notice that the **delocalized electrons** result in absorption spectra that are **more continuous** (less discrete) than those of **gaseous atoms** and **less continuous** (more discrete) that that of an **incandescent object**.



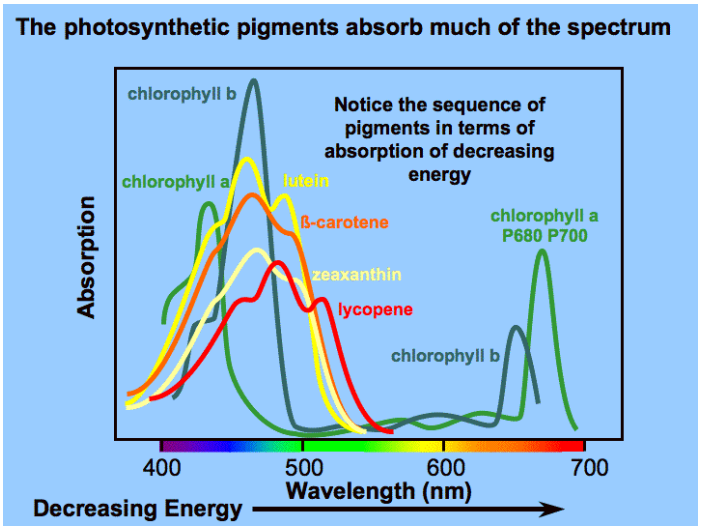
Rhodopsin and **photopsins** are **pigments** composed of **retinal** attached to different **opsin proteins** that make scotopic and photopic **vision** possible. Differences in the opsin proteins result in the differences in the peak spectral sensitivities.

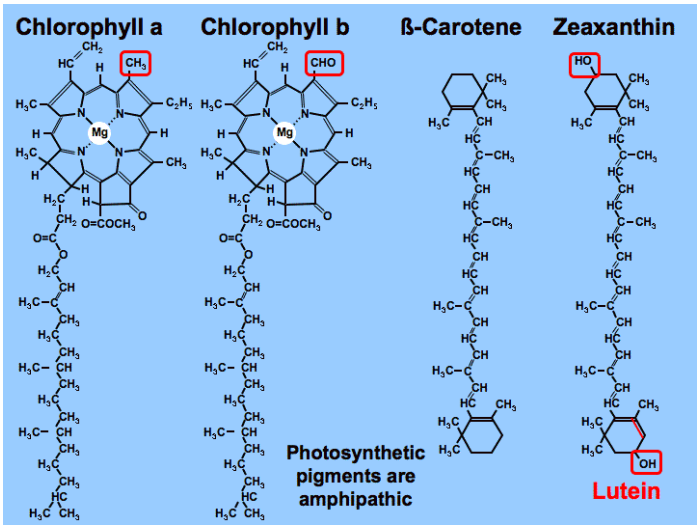


Melanopsin is another pigment found in 1-2% of the **ganglion cells** in the retina of the vertebrate eye. Melanopsin is also composed of **retinal** attached to an opsin protein. The opsin protein in human melanopsin is more similar to invertebrate opsins involved in vision than to the vertebrate opsins involved in vision. Melanopsin functions in the **pupillary light reflex response** and to **tell time** necessary to maintain **circadian rhythms** and synchronize our **sleep-wake cycle** with the natural **light-dark cycle**.

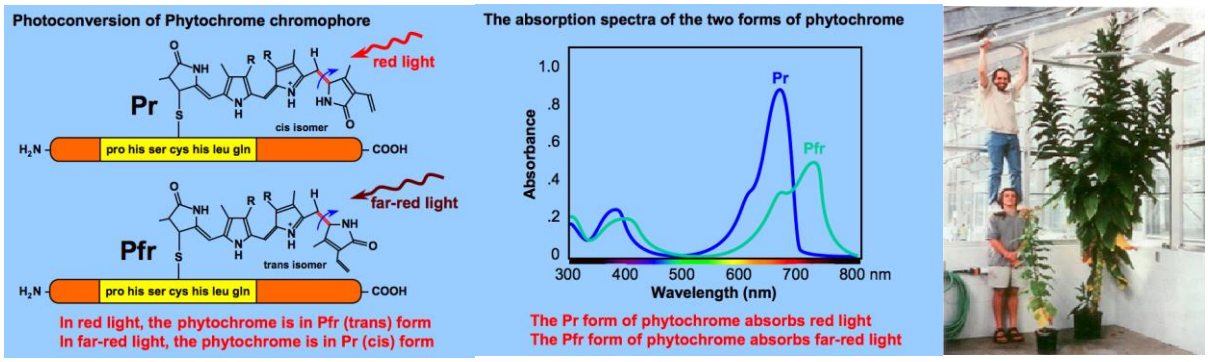


Chlorophylls, **carotenoids** and **zeaxanthin** are the **pigments** involved in **photosynthesis** in green plants.

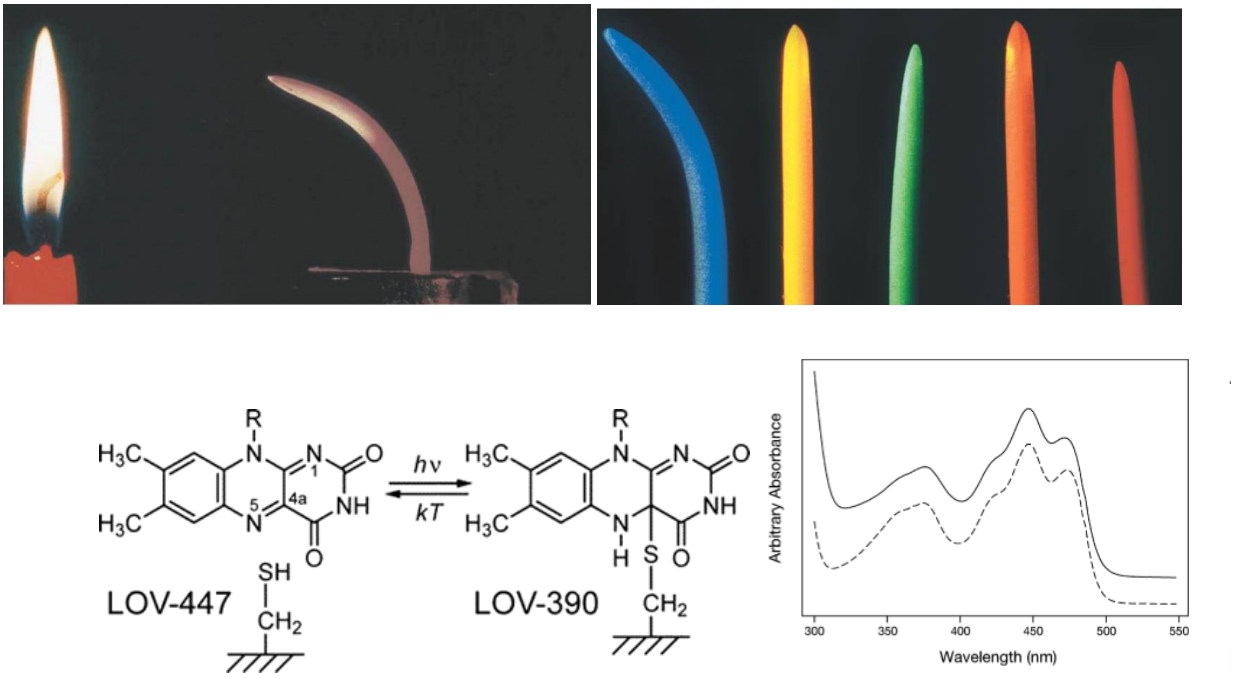




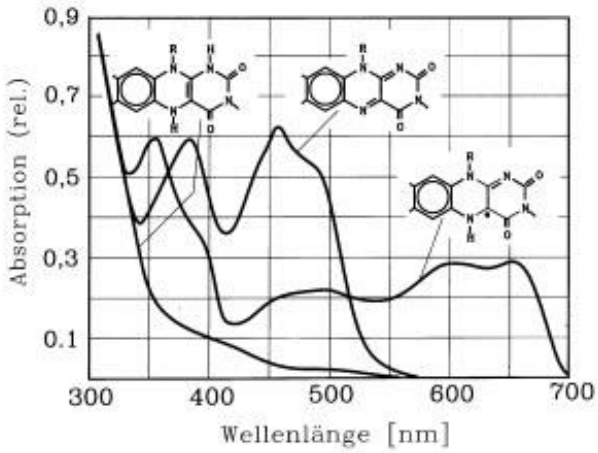
Phytochrome, **phototropin**, and **cryptochrome** are three **pigments** important for plants to respond to the environment. **Phytochrome** is a biliprotein that is involved in flowering, shade avoidance and seed germination.



Phototropin is a flavoprotein involved in phototropism, which is the bending response towards light.

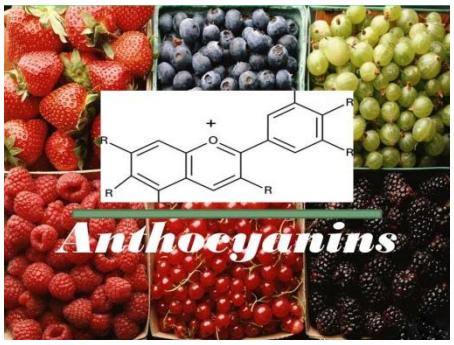


Cryptochrome, like phototropin, is another flavoprotein. It seems to be part of a light-regulated molecular clock involved in biological circadian rhythms in both plants and invertebrates.





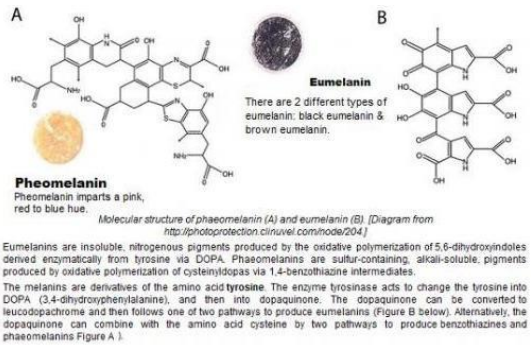
Anthocyanins are **pigments** that make the **attractive colors** of many **flowers** and **fruits**. The color depends on the acidity of the cell.



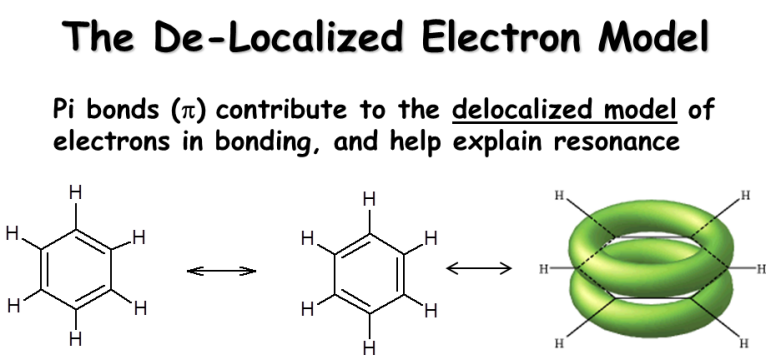


Eumelanin and **pheomelanin** are melanin pigments that color our eyes, skin and hair.

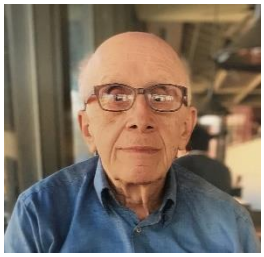




Tightly bound electrons interact with x-rays or ultraviolet light. The delocalized electrons which are far from any positively-charged nucleus, gives them the right energy to interact with visible light. The delocalized electrons are found in molecules with conjugated double bonds.



While we are talking about chemicals, I will tell you about **administratium**, an element discovered by **William DeBuvitz**, who came up with the idea in February 1988 while giving a physics exam at Middlesex County College in Edison, N.J. As he read a "*memo from the college administration about the latest reorganization, with its usual increase in vice presidents, assistants to the vice presidents, etc., looked over at a large periodic chart on the wall, and it all came together*:"



Administratium

New chemical Element Discovered

The heaviest element known to science was recently discovered by investigators at a major U.S. research university. The element, tentatively named administratium, has no protons or electrons and thus has an atomic number of 0. However, it does have one neutron, 125 assistant neutrons, 75 vice neutrons and 111 assistant vice neutrons, which gives it an atomic mass of 312. These 312 particles are held together by a force that involves the continuous exchange of meson-like particles called morons.

Since it has no electrons, administratium is inert. However, it can be detected chemically as it impedes every reaction it comes in contact with. According to the discoverers, a minute amount of administratium causes one reaction to take over four days to complete when it would have normally occurred in less than a second.

Administratium has a normal half-life of approximately three years, at which time it does not decay, but instead undergoes a reorganization in which assistant neutrons, vice neutrons and assistant vice neutrons exchange places. Some studies have shown that the atomic mass actually increases after each reorganization.

Research at other laboratories indicates that administratium occurs naturally in the atmosphere. It tends to concentrate at certain points such as government agencies, large corporations, and universities. It can usually be found in the newest, best appointed, and best maintained buildings.

Scientists point out that administratium is known to be toxic at any level of concentration and can easily destroy any productive reaction where it is allowed to accumulate. Attempts are being made to determine how administratium can be controlled to prevent irreversible damage, but results to date are not promising.

Sun Gods: Many cultures have sun deities. **Apollo** was the sun god of the ancient Greeks and Romans, and the subject of a ballet by **George Balanchine**.





Delphi is considered to be the place where Gaia or Mother Earth and the origin of all life lived with her son Python who was a snake. Delphi is also the place where the two eagles who were released by Zeus, one of which flew east and the other flew west, met. Consequently, Delphi was considered to be the center of the world. Around 1000 BC, Apollo the sun god and son of Zeus came to Delphi, killed Python, so he could rule Gaia and the earth. A Temple of Apollo, originally made of laurel leaves, was built over the dead snake. A priestess with prophetic powers lived in the cella of the temple. Apollo gave to the oracle of Delphi maxims such as **Know Yourself** and also helped her predict the future. Temples of Apollo, each with their own oracle, sprung up in many places. In 191 BC, the Romans took over Delphi. In 302 AD, Emperor Diocletian consulted the oracle of Apollo and was told that Christianity would lead to the destruction of the Empire. This led to

the persecution of Christians. Theodosius I retaliated and destroyed the Temple of Apollo in Delphi in 390 AD.



In Japan: **Amaterasu**, the sun god, emerges from a cave and brings sunlight back to the universe.





The **absorption of the various wavelengths** that compose sunlight and the **transmission** of others by inorganic pigments in or on glass can be appreciated when looking at the **image** of **Isaac Newton** in the chemically **stained glass window** of the Wren Library (Isaac Newton (1642-1727) being presented to George III (1738-1820) with Francis Bacon (1561-1626) looking on, designed by Giovanni Battista Cipriani, 1771); the chemically stained glass window of the Olney Parish Church that depicts the **image** of **John Newton**; the chemically stained glass window at the Fountain Street Church in Grand Rapids, Michigan that depicts the **image** of **Charles Darwin**; and the chemically stained glass window at the Grace Cathedral in San Francisco that depicts the **image** of **Albert Einstein** and his equation $\boldsymbol{E = mc^2}$**.**





Hans Bethe discovered how sunlight was generated by the sun. Silvan S. Schweber read a Stephen Spender (1955) poem at a celebration of Hans Bethe's Life:



I Think Continually of Those Who Were Truly Great

I think continually of those who were truly great.
Who, from the womb, remembered the soul's history
Through corridors of light, where the hours are suns,
Endless and singing. Whose lovely ambition
Was that their lips, still touched with fire,
Should tell of the Spirit, clothed from head to foot in song.
And who hoarded from the Spring branches
The desires falling across their bodies like blossoms.

What is precious, is never to forget
The essential delight of the blood drawn from ageless springs
Breaking through rocks in worlds before our earth.
Never to deny its pleasure in the morning simple light
Nor its grave evening demand for love.
Never to allow gradually the traffic to smother
With noise and fog, the flowering of the spirit.

Near the snow, near the sun, in the highest fields,
See how these names are fêted by the waving grass
And by the streamers of white cloud
And whispers of wind in the listening sky.
The names of those who in their lives fought for life,
Who wore at their hearts the fire's centre.
Born of the sun, they travelled a short while toward the sun
And left the vivid air signed with their honour.

And an excerpt from a poem by Philip Savage (**https://books.google.com/books?id=MnQ1AAAAMAAJ&pg=PA3#v=onepage&q&f=false**), written at another Ivy League college:

WHEN February sun shines cold
There comes a day when in the air

The wings of winter slow unfold
And show the golden summer there.

Dead ivy on the winter wall
Is glowing with an April light;
And all the wreckage of the fall
Above the snow comes into sight.

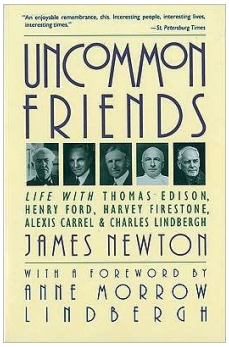
By a green rock beneath the pines
Are shadows blue along the snow.
Above the silent sun the lines
Of cloud in white procession go.

A bloom is on the forest tops
Of red light bursting through the brown.
The ice awakes, and silver drops
Come through the meadow stealing down.

The sky is hushed; beneath the trees
Where silentness and night have birth,
I heard the sunset whisper, Peace!
Peace, Peace! The gods are on the earth.

Don't forget *You are my Sunshine* performed by:

Jimmie Davis (**https://www.youtube.com/watch?v=ckKeQNCyPBU**)
The Pine Ridge Boys (**https://www.youtube.com/watch?v=xvPolI-pBCw**)
Gene Autry (**https://www.youtube.com/watch?v=1AhpWZjqMLI**)
Bing Crosby (**https://www.youtube.com/watch?v=zCUsvPgNi5Q**)
Doris Day (**https://www.youtube.com/watch?v=RUuCi4tOvQ8**)
Ricky Nelson (**https://www.youtube.com/watch?v=ZGSxj_V0uhA**)
Ray Charles (**https://www.youtube.com/watch?v=MvMl6MDjdak**)
Aretha Franklin (**https://www.youtube.com/watch?v=N3RthBGJL1s**)
Johnny Cash (**https://www.youtube.com/watch?v=cGa3zFRqDn4**)
Anne Murray (**https://www.youtube.com/watch?v=vHEaRFNx7tw**)
Carly Simon (**https://www.youtube.com/watch?v=8z6MQ7gMi_U**)
Miley Cyrus (**https://www.youtube.com/watch?v=xLQ8NOT8olk**)



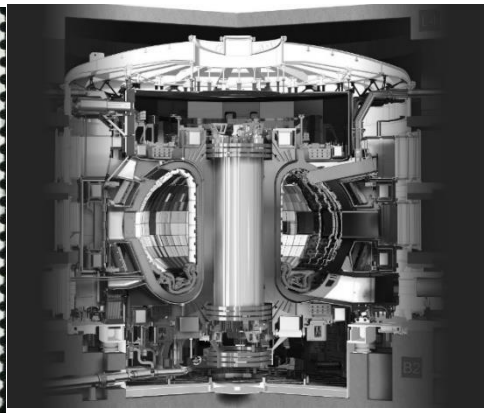
In 1931, Thomas Edison thought about renewable energies, including solar and wind energy. In the book, *Uncommon Friends: Life with Thomas Edison, Henry Ford, Harvey Firestone, Alexis Carrel, & Charles Lindbergh*, James D. Newton describes a conversation between Henry Ford, Thomas Edison, and Roger Firestone that took place in March 1931:

Sometimes the three looked into the future. After they'd been discussing problems at home and abroad, the old man said suddenly, We are like tenant farmers, chopping down the fence around out house for fuel, when we should be using nature's inexhaustible sources of energy—sun, wind, and tide.

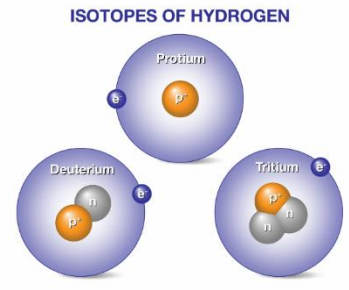
Firestone responded that oil and coal and wood couldn't last forever. They'd been tackling rubber. He wondered how much hard research was going into harnessing the wind, for example. Windmills hadn't changed much in a thousand years.

Ford said there were enormously powerful tides—for example, the Bay of Fundy. Scientists had only been playing with the question so far.
Edison said, I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait till oil and coal run out before that. I wish I had more years left.



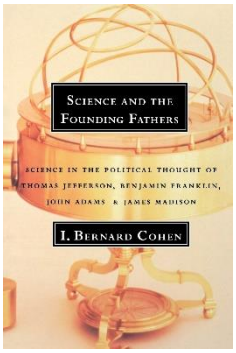


Hopefully, **fusion energy**, which occurs in the sun, will be used to make steam to drive turbines that will **produce clean electricity** on Earth. Thirty-five nations are collaborating to build a magnetic fusion device in France that will test the feasibility of fusion as a large-scale source of energy. The device is called TOKAMAK, which is Russian for toroidal chamber with axial magnetic field. The collaboration is known as **ITER**, which means, "*The Way*" in Latin. In the TOKAMAK, hydrogen nuclei exist as a plasma of charged deuterium nuclei (or deuteron—one proton and one neutron) and tritium nuclei (one proton and two neutrons). The plasma is contained by a magnet and heated to the point where the nuclei move fast enough to fuse into helium nuclei when they collide. These isotopes are used because they release more energy than p—p fusion and fuse at lower temperatures than

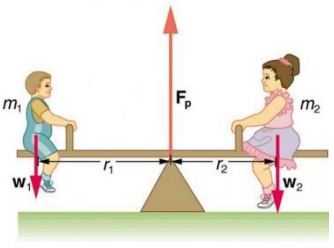


the nuclei of other elements with greater masses. The fusion of a deuterium and tritium nucleus releases 2.8×10^{-12} Joules, which is greater than the fusion of two protons, which releases 2.3×10^{-13} Joules. The larger isotopes require higher temperatures to heat them up so they fuse upon collision. Currently it takes more energy to heat up the deuterium-tritium plasma to the needed **100 million C**, which is hotter than the core of the sun, than is released by fusion.

A General Principle about Everything and Nothing



We can learn a lesson from hydrostatic equilibrium that when something is static, it is not necessarily due to the absence of causes or forces, but to the balance of causes or forces. Remember that the sum of all real numbers is zero, and sometimes everything is difficult to distinguish from nothing—just as **aught**, meaning everything can have the same meaning as naught, meaning nothing. The sun is one example, we also talked about Herbert Spencer's description of the destructive forces and preservative forces on race in maintaining stasis. The founders of the United States were well versed in Newton's Laws and designed the three branches of government in a way that the forces exerted by each branch would preserve individual liberty.



Thomas Jefferson wrote to Richard Price Paris on January 8, 1789, "*Bacon, Locke and Newton…I consider them as the three greatest men that have ever lived, without any exception, and as having laid the foundation of those superstructures which have been raised in the Physical & Moral sciences*."

When we see stasis, consider the benefit of opposing forces, for if there were no opposing forces ($F_2 = 0$) such as friction, the tiniest force (F_1) would cause a given mass (m), be it a golf ball or a country, to accelerate (a) to infinite velocity.

Newton's Second Law if often written as:

$$F = ma$$

But it is more realistic to write it like so:

$$F_1 - F_2 = ma$$

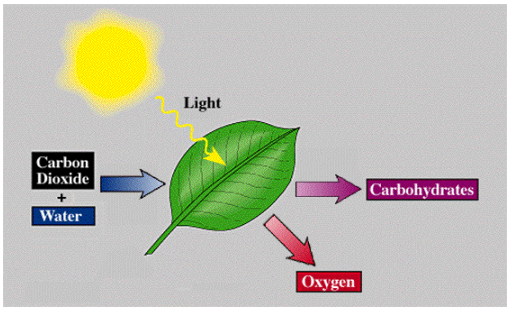
Photosynthesis: Converting Radiant Energy into Chemical Energy
Pigments and Leaves



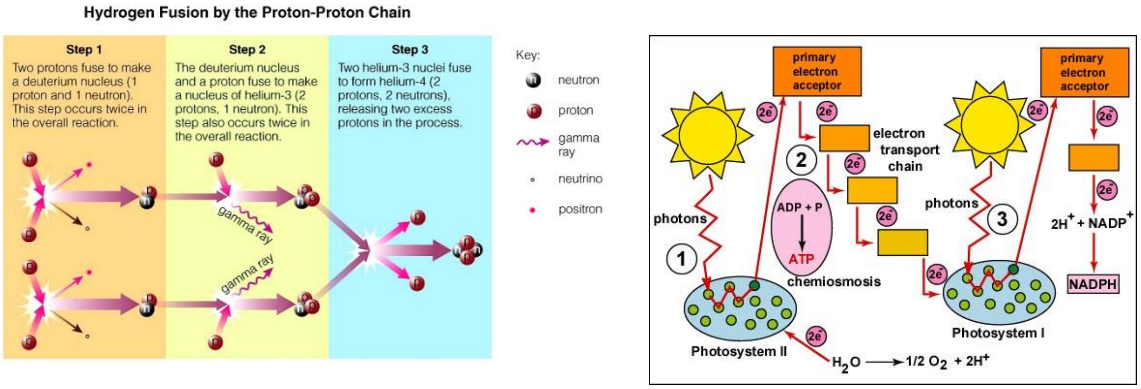
In a speech entitled, *What is Science?*, **Richard Feynman** (1969) said: "*As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts. When someone says, 'Science teaches such and such,' he is using the word incorrectly. Science doesn't teach anything; experience teaches it. If they say to you, 'Science has shown such and such,' you might ask, 'How does science show it? How did the scientists find out? How? What? Where?' It should not be 'science has shown' but 'this experiment, this effect, has shown.' And you have as much right as anyone else, upon hearing about the experiments--but be patient and listen to all the evidence--to judge whether a sensible conclusion has been arrived at.*" You can find the whole speech, which includes thinking about photosynthesis http://www.fotuva.org/feynman/what_is_science.html.

Photosynthesis is the **light (*hv*)-dependent chemical fixation** of gaseous **carbon dioxide** (CO_2) and liquid **water** (H_2O) into solid **carbohydrate** ($C(H_2O)$) with the evolution of **gaseous oxygen** (O_2).

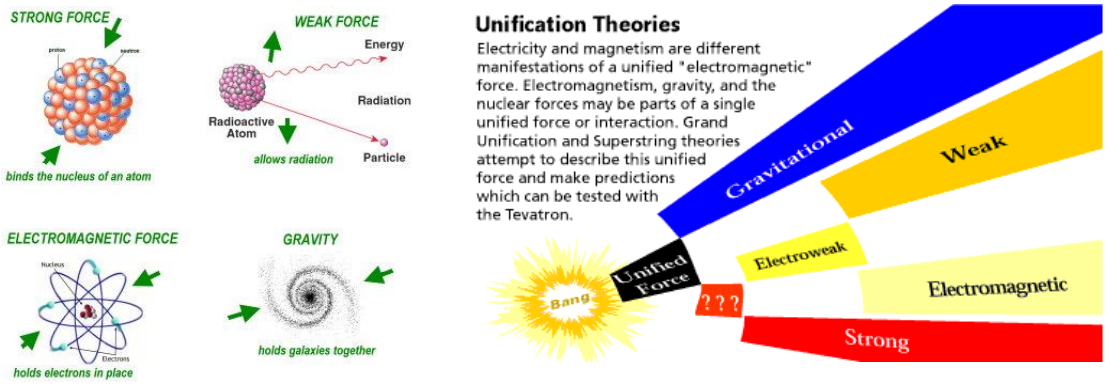
$$CO_2 + H_2O \xrightarrow{hv} C(H_2O) + O_2$$



The "***alchemical***" production of sunlight resulted from the rearrangement of four hydrogen nuclei, each of which consists of one **proton**, into **helium** nuclei, each of which consist of two protons and two neutrons. The chemical fixation of carbon dioxide into carbohydrate by photosynthesis results from the sunlight-powered rearrangement of the orbiting **electrons**.



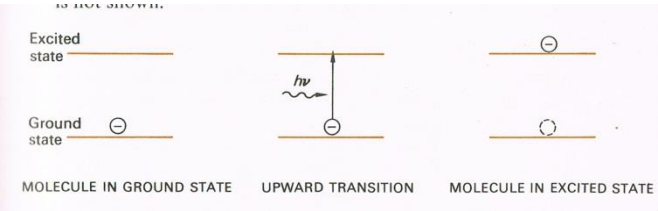
The alchemical production of sunlight involves the **weak and strong forces**. The **weak force** causes the transmutation of a proton into a neutron, a positron, and a neutrino. The **strong force** holds protons together in spite of their like charges. The photosynthetic fixation of carbon dioxide into carbohydrate involves the **electromagnetic force**.



The fixation of carbon dioxide into carbohydrate involves **the transfer of electrons** from water to carbon dioxide. The **L**oss of **E**lectrons is called **O**xidation and the **G**ain of **E**lectrons is called **R**eduction. I remember these definitions using

the phrase **LEO** the lion goes **GER**. The negatively-charged electrons (e^-) are followed by the positively-charged protons (H^+) so that there is a net transfer of 2H from each water molecule to carbon dioxide. This is an oversimplified and **simplistic** way of looking at the chemistry since the transfer takes place in many, many steps. However, this simplistic view leads us to look for a **pigment** that is able to **transfer electrons** in a **light-dependent** manner.

The absorption of light by a molecule such as **chlorophyll**, just like the **absorption** of light by an atom, results in the transfer of an electron from a lower energy **ground state** to a higher energy **excited state**.



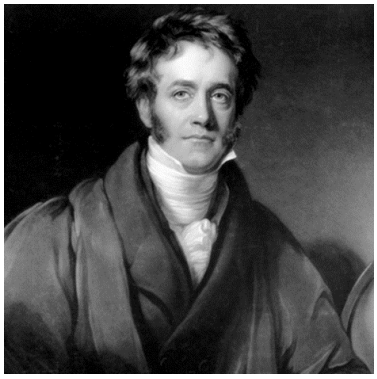
It is now a commonplace that in order to use the **radiant energy** $\left(E = h\nu = \frac{hc}{\lambda}\right)$ inherent in sunlight to fix carbon dioxide and water into carbohydrate, the radiant energy must be **absorbed** by a **pigment**. This is known as the **Grotthuss-Draper Law** or the **First Law of Photochemistry**. **John Draper** (1841,1872-73), who was the keynote speaker at the 1860 meeting of the British Association for the Advancement of Science at Oxford, stated: "*That the ray effective in producing chemical or molecular changes in any special substance is determined by the absorptive property of that substance*," "*that it depends on the chemical nature of the ponderable material what rays shall be absorbed*," and "*the*



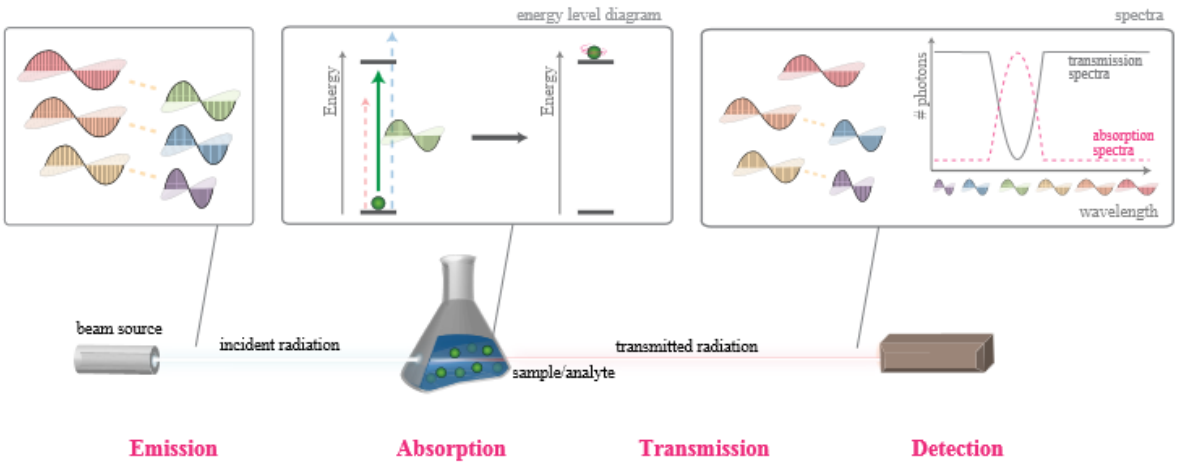
rays which are effective in the destruction of any given vegetable color are those which by their union produce a tint complementary to the color destroyed."

Theodor von Grotthuss (1819) performed the original experiments that led to the First Law of Photochemistry. Grotthuss noticed that an alcoholic solution of iron (III) thiocyanate, which is red, became decolorized when it was exposed to light. He also noticed that the rate of decolorization was proportional to the **intensity of the light** and the **duration of the exposure**. After seeing that other colored solutions behaved the same way, Grotthuss concluded that a photochemical reaction could be caused only by the light absorbed by the chemical substance and its **rate was proportional to the light intensity and the exposure time.** Grotthuss also noticed that green light was most effective in decolorizing iron (III) thiocyanate, which is red; blue light was most effective in decolorizing gold chloride which is yellow; and yellow light was most effective in decolorizing a starch iodide solution, which is blue. **John Herschel** (1842) discovered that paper treated with the pigments from flower petals were also decolorized by the **complementary** color of light. Grotthuss, Herschel, and Draper found that **each pigment absorbs the color of light that is complementary to its own color. Its own color is the color that the pigment transmits or reflects**.

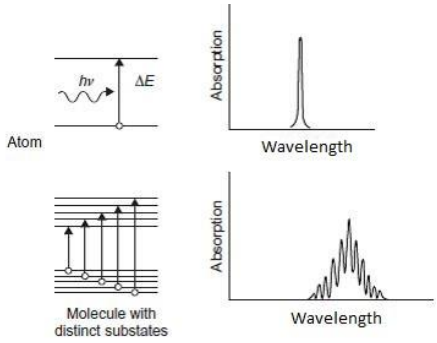




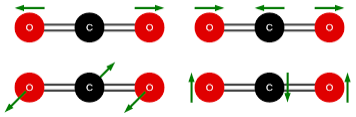
Absorption will (probably) occur if the pigment has a **transition energy** value where an **electron** can move from a **ground state** to an **excited state** that corresponds with the radiant energy of the **wavelength** of light.



An **absorption spectrum** of a given pigment is the **probability** that a **photon** with radiant energy $\left(E = h\nu = \frac{hc}{\lambda}\right)$ will be **absorbed** by that **pigment**. The probability depends primarily on the **chemical structure** of the pigment, although it also depends on the environment (i.e., acidic or basic; oily or aqueous) in which the pigment exists. Since a molecule is composed of many atoms, there are many more **energy states** that correspond to **vibrational states** and **rotational states** between the various **atoms and groups of atoms** that compose the molecule. Consequently, the **absorption spectra of molecules** are broader and more complicated than the **absorption spectra of atoms**. The allowed energy states of atoms, in which the electrons orbit the nucleus, are known as **orbits** and the allowed energy states of molecules, in which the electrons are shared with one or more atoms, are known as **orbitals**. The allowed states are where the atom or molecule change by **one unit of angular momentum** ($\hbar = \frac{h}{2\pi}$, in Joule seconds) during absorption or emission. This is because each photon, no matter what its wavelength, carries exactly one unit of angular momentum ($\hbar = \frac{h}{2\pi}$).



Demonstration: Using your spectroscope, compare the emission spectrum of **carbon dioxide** with the emission spectrum of hydrogen.



Gilbert N. Lewis and **Melvin Calvin** at Berkeley and later **Robert Woodwood** and **Louis Fieser** (who developed **napalm**, an incendiary weapon that is a modern form of **Greek fire**) at Harvard came up with a **set of rules** that generally predict the **absorption spectrum** of a chemical from the **number of conjugated double bonds that result in the delocalization of electrons**. Each added conjugated double bond shifts the peak of the absorption spectrum from approximately 230 **nm by 30 nm towards the red end of the spectrum**. This means the more conjugated double bonds, the more delocalized the electrons are from the nucleus of the atoms and the greater the probability that lower energy photons (i.e., with a long wavelengths) will be absorbed.

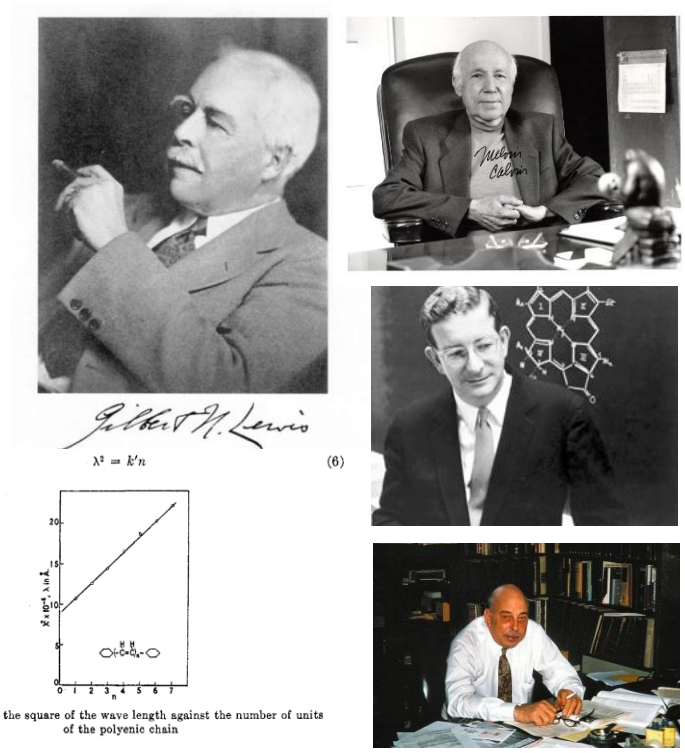
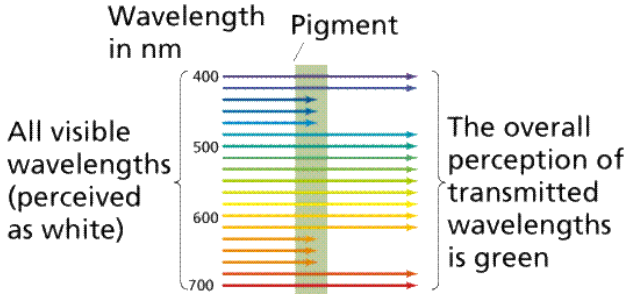


FIG. 11. Plot of the square of the wave length against the number of units of the polyenic chain

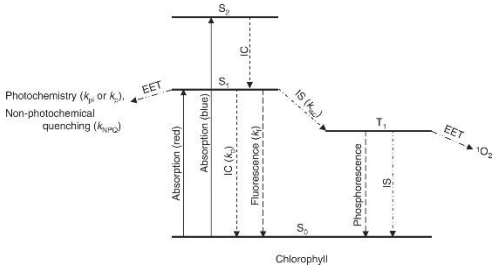


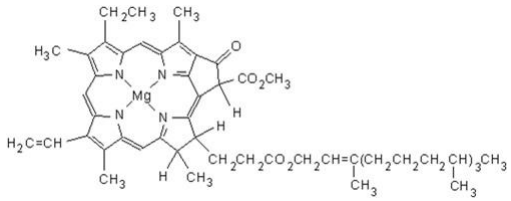
Demonstration: Extract chlorophyll from *Chara coralina* cells by grinding the cells with a mortar and pestle. Add a little isopropyl alcohol to dissolve the chlorophyll. Then pour off the green solution into a little test tube. Use your spectroscope to look at the spectrum of sunlight with and without the tube containing chlorophyll in front of the slit. Which color(s) do the chlorophyll

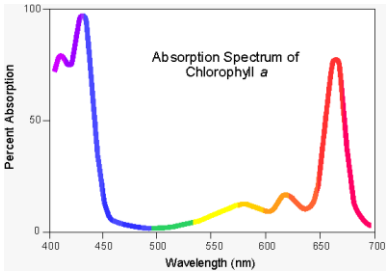
molecules absorb and which color(s) do the chlorophyll molecules transmit? Is your result consistent with those of Grotthuss and Herschel? Here is the spectrum of the juice of a green leaf obtained by David Brewster (1834):



The **energy levels** of electrons and the number of **conjugated double bonds** in the pigment can be deduced by looking at the **absorption spectrum**. The absorption spectrum and structure of chlorophyll *a* are given below.



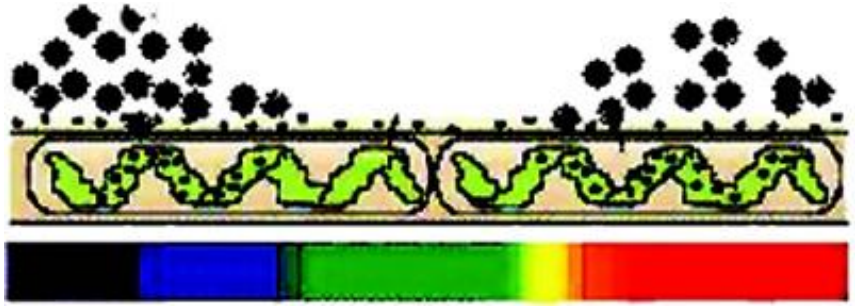




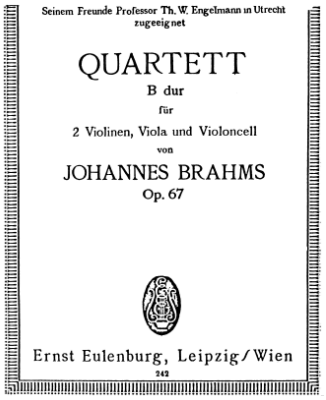


How do we know that chlorophyll *a* is involved in photosynthesis? We compare the **absorption spectrum** of the pigment with the **action spectrum** of photosynthesis. An action spectrum is a test to see which wavelengths of light are most effective in producing the desired response. We could measure the effect of each wavelength of light on **carbon dioxide fixation** using radioactive $^{14}CO_2$, or we could measure the effect of each wavelength of light on **oxygen evolution**. **Theodor Engelmann** determined the effectiveness of each wavelength of light in the 1880s, sixty years before the invention of $^{14}CO_2$, in a very clever way using a microscope. Engelmann projected a spectrum of light on an algal filament on a

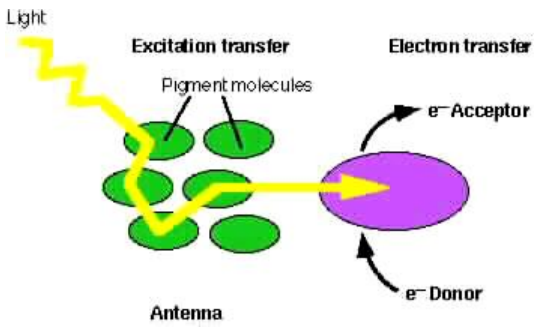
microscope slide. The most effective wavelengths would result in the greatest production of oxygen. Engelmann then put **oxytactic (oxygen-seeking) bacteria** onto the microscope slide and watched to see where they went. They went to either the blue irradiated region or the red irradiated region, but not to the green region, indicating that photosynthetic oxygen evolution was stimulated most by blue and red light absorbed by chlorophyll and least by green light, the color of chlorophyll.

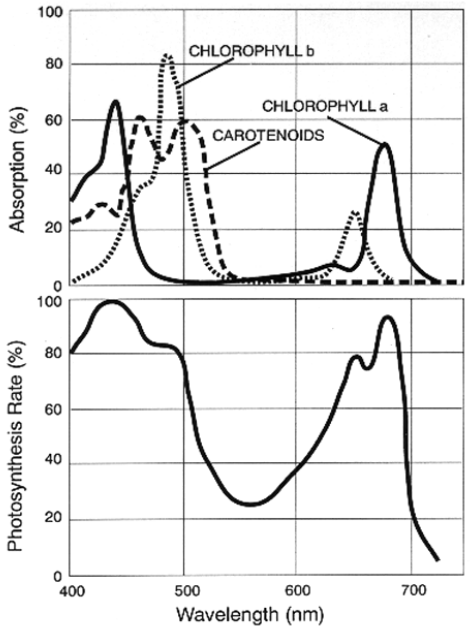


Thus the **action spectrum for photosynthetic oxygen evolution** determined by Engelmann matched the **absorption spectrum for chlorophyll *a***. This is strong evidence that chlorophyll *a* is the pigment responsible for photosynthesis. If you were wondering, this ***is*** the same Theodor Engelmann, who was also an amateur cellist, to whom **Johannes Brahms** dedicated Opus 67 for a String Quartet.



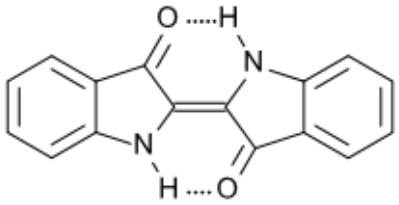
In detail, the action spectrum of photosynthesis does ***not*** perfectly match the absorption spectrum for chlorophyll *a*. This is because there are ***other*** pigments involved in photosynthesis that act as **antennae** that capture additional wavelengths of light and transfer the energy to chlorophyll *a*.



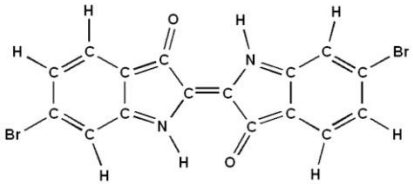


A **transparent molecule** is **transparent** because it does ***not*** absorb visible light. (Later in the semester we will talk about transparent animals). A **pigment** is a molecule that preferentially **absorbs** one or two colors of the spectrum and thus appears as the **complementary color** since the complementary color is **reflected** or **transmitted** to our eyes. Organic pigments used for dyeing textiles and as cosmetics such as **indigo**, **Tyrian purple**, and **cochineal** have been part of the human condition for millennia.

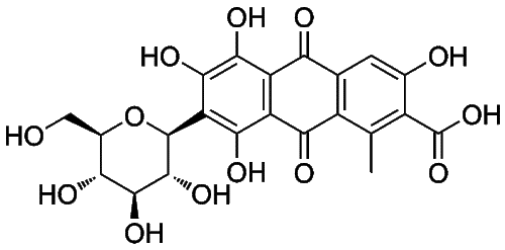




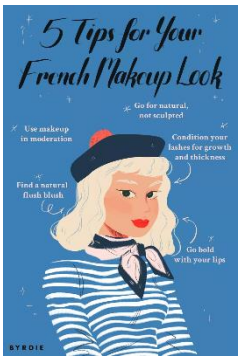












Note that these **pigments** look somewhat like each other and to **chlorophyll** in terms of having **many conjugated double bonds**. Unlike chlorophyll, the pigments in clothes and lipsticks re-radiate a larger proportion of the ***absorbed*** light as **infrared light (heat).** However, for a pigment to participate in a light-driven chemical reaction sequence, such as photosynthesis, where the **energy of light** is effectively transformed into the **energy of life**, the pigment must be capable of **transferring an electron** from the excited state of the pigment to an **acceptor** which becomes **reduced** and the pigment must also be capable of **replenishing** the lost electron in the pigment from a **donor**, which then becomes **oxidized**. During photosynthesis, chlorophyll participates in **oxidation-reduction** reactions.

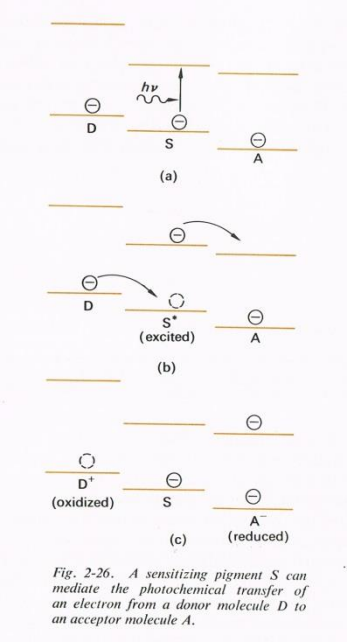
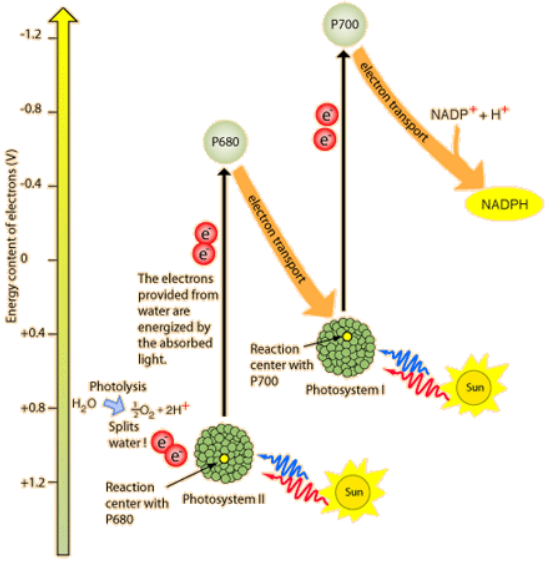


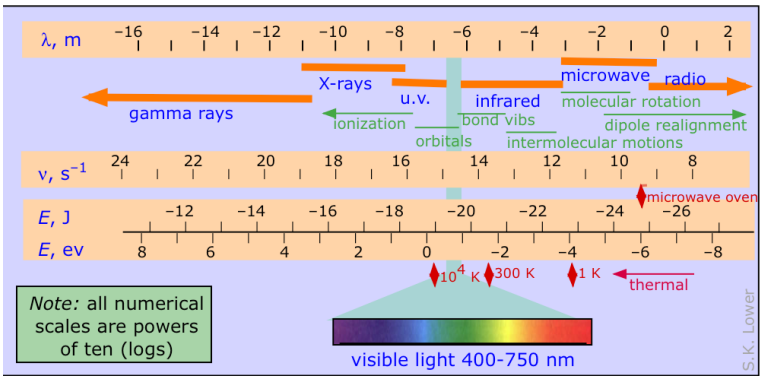
Fig. 2-26. A sensitizing pigment S can mediate the photochemical transfer of an electron from a donor molecule D to an acceptor molecule A.

Any molecule that is capable of gaining and losing electrons has what is called a **redox potential**. The redox potential is a measure of the **affinity of the molecule for electrons**. The more negative the redox potential, the more likely the molecule will donate an electron and the more positive the redox potential, the more likely the molecule will accept an electron. When two molecules with different redox potentials are next to each other, the electron is **spontaneously** or **passively** transferred ***from*** the molecule with the more negative redox potential ***to*** the molecule with the more positive redox potential and energy that can be harnessed to do the work of life is released in the process.



On the other hand, the transfer of an electron from a molecule with a more positive redox potential to one with a more negative redox potential **requires an input of energy**. Chlorophyll can **actively** transfer an electron from an electron donor with a positive redox potential to an electron acceptor with a more negative redox potential using the **radiant energy** of the **light** that it **absorbs**. The redox potential is given in Volts, but it can be converted into an energy unit in Joules by multiplying the redox potential by a constant known as the elementary charge of an electron (*ze*) and is equal to -1.6×10^{-19} Coulombs. The difference in the redox energy between the ground state of chlorophyll (1.0 V) and the excited state of chlorophyll (-0.7 V) in photosystem II is (-0.7 V – 1.0 V) × -1.6×10^{-19} Coulombs = 2.7×10^{-19} J. This is equal to the minimum energy of a photon needed to excite an electron in chlorophyll from the ground to the excited state. Given that $E = \frac{hc}{\lambda}$, what is the minimum wavelength of a photon necessary to raise an electron in chlorophyll from the ground to the excited state? Does 680 nm light have enough energy?



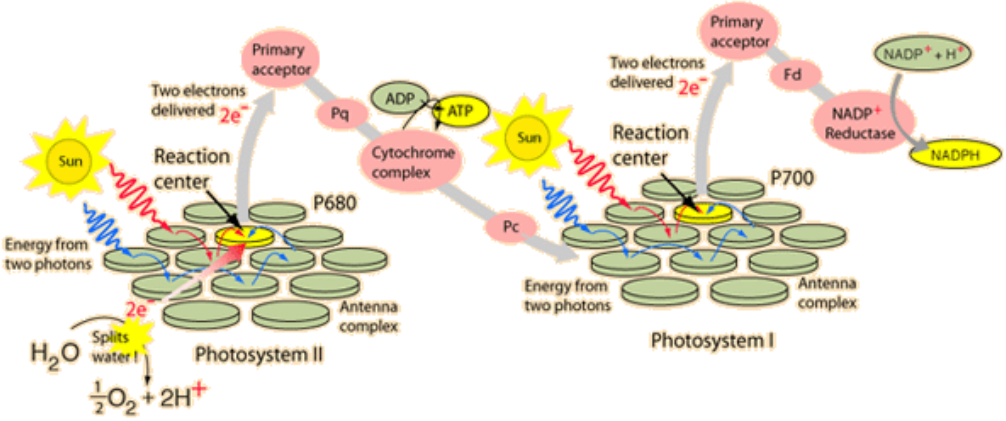


In the light reactions of photosynthesis, there are **two steps**; both involve chlorophyll acting as a light-activated **electron pump** that transfers an electron to an acceptor with a more negative redox potential. The two steps are known as **photosystem I** and **photosystem II**.

Aside: Robert Emerson, the great grandson of Ralph Waldo Emerson's brother, provided the first evidence of two photosystems using this equipment. Emerson

died in an airplane crash. The photographs are from his student mononymous Govindjee's photosynthesis museum https://news.illinois.edu/view/6367/801235 .





Each photon absorbed by photosystem I results in the transfer of an electron to $NADP^+ + H^+$ which eventually becomes reduced to **NADPH**. ***Two*** molecules of NADPH can provide two hydrogen atoms to reduce ***one*** molecule of carbon dioxide (CO_2) to carbohydrate ($C(H_2O)$). It takes two electrons and thus two

photons absorbed by photosystem I to reduce $NADP^+ + H^+$ to make one **NADPH**. Thus, it takes four electrons and **four photons** absorbed by photosystem I to produce two molecules of NADPH. In order to replenish the four electrons from the chlorophyll in photosystem I so that the process can repeat, the chlorophyll in photosystem II must absorb **four photons** and pass them on indirectly through an electron transfer chain to photosystem I. Thus it takes **eight photons** to make **two NADPHs** that are capable of reducing one molecule of carbon dioxide (CO_2) to the level of carbohydrate ($C(H_2O)$). The four electrons from the chlorophyll in photosystem II are replenished from water. When two water molecules are stripped of four electrons, an oxygen molecule (O_2) is evolved, and four protons are added to the lumen.

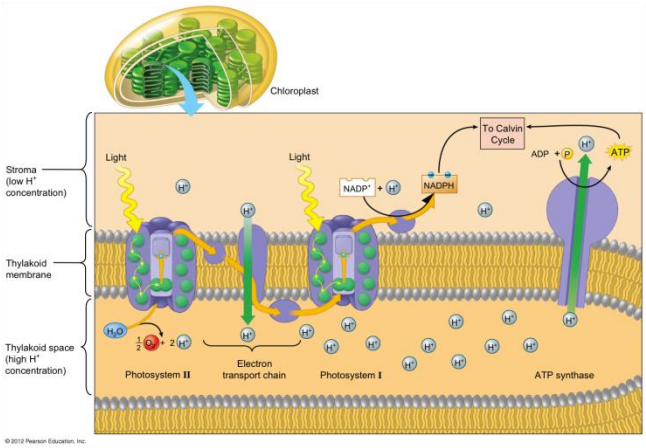
$$2H_2O \rightarrow O_2 + 2H^+ + 2e^-$$

The energy (E) of a photon of a given wavelength (λ) is given by the following equation:

$$E = \frac{hc}{\lambda}$$

where c is the speed of light (c = 2.99 x 10^8 m/s) and h is Planck's constant ($h = 6.626 \times 10^{-34}$ J s). How much energy is in a photon of 680×10^{-9} m light? How much energy is in the eight photons needed to reduce one carbon dioxide to carbohydrate? How much energy is in 48 photons needed to reduce six carbon dioxide molecules to make a six-carbon sugar like glucose? How much energy is in 96 photons needed to reduce twelve carbon dioxide molecules to make a 12-carbon sugar like sucrose?

The light reactions described above take place on the **thylakoid membranes** in the **chloroplast**. The hydrophobic thylakoid membranes composed in part of a lipid bilayer separate two aqueous compartments known as the stroma and the lumen. As the electrons are passed along the **electron transport chain** from photosystem II to photosystem I, they simultaneously transfer protons (H^+) from the **stroma** to the **lumen**. The buildup of protons in the lumen, including those that are produced by the splitting of water and the depletion of protons in the stroma result in the **separation of charge** that is used by a protein known as the coupling factor or **ATP synthase** as an energy source to synthesize **ATP** from ADP and Pi.

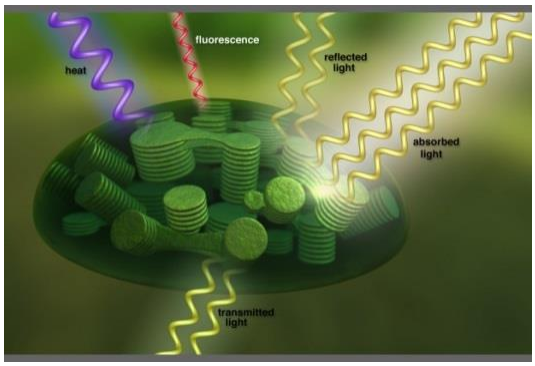


As you can see, the light-dependent **separation of charge**, whether the charges stem from electrons or from protons, provides **electrochemical energy** just like a **battery** that can be used to do the **work of life**. No work can be done without an energy input and the energy necessary for the work of life can come from various energy sources (electrical, chemical, gravitational, and radiant), all ultimately derived from the sun's gravitational and nuclear energy (and the initial big bang energy that gave rise to the hydrogen in the sun). This is **the First Law of Thermodynamics**—energy cannot be created or destroyed, but it can be interconverted. The electrochemical energy from the **charge separation of electrons** is used to **synthesize NADPH** and the electrochemical energy from the **charge separation of protons** is used to **synthesize ATP**. In the next lecture, I will tell you how the NADPH and ATP are

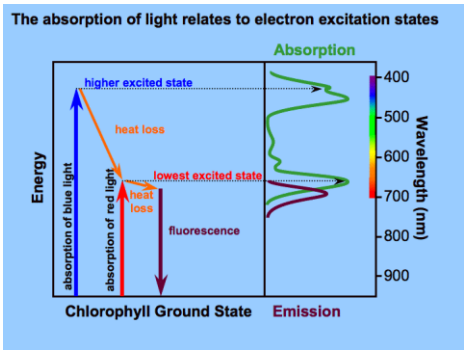


used in **light-independent reactions** to fix carbon dioxide (CO_2) to carbohydrate ($C(H_2O)$).

If the plant does ***not*** have the ability use the NADPH and ATP for fixing carbon in the light-independent reactions, the radiant energy absorbed by chlorophyll could be used to form **damaging free radicals**, which are molecules with an unpaired electron. Plants have several dissipation mechanisms to rid the plant of energy absorbed by the antenna complexes that is in excess of that used to drive the photochemical process of photosynthesis. One mechanism to reduce the production of free radicals is to re-emit the radiant energy as light in a process known as **fluorescence**.

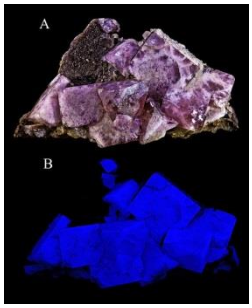


Some of the absorbed energy causes the chlorophyll molecule, which looks as flexible as chicken wire, to bend or vibrate a little. Thus some of the absorbed energy is transformed into kinetic energy and eventually emitted as heat (infrared wavelengths). Since some of the energy of the absorbed light is transformed into kinetic energy, the radiant energy of the light emitted as fluorescence must be less than the radiant energy of the light absorbed. Consequently, the wavelength of the light emitted as fluorescence is longer than the wavelength of the absorbed light.

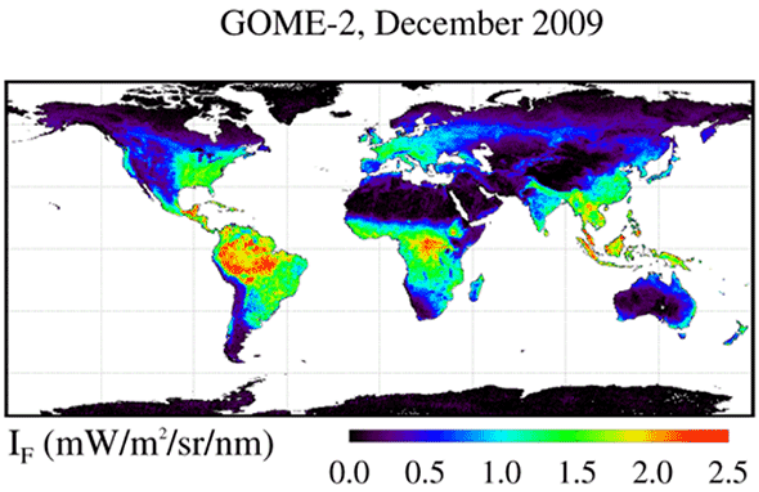


This is known as a **Stokes shift**, named after **George Stokes**, who coined the word fluorescence, named after the mineral **fluorspar** (calcium fluoride), which emitted longer wavelength blue light after it absorbed shorter wavelength invisible ultraviolet light. See the beautiful fluorescence of fluorspar in the **Timothy N. Heasley Museum** in Snee Hall (Cornell).

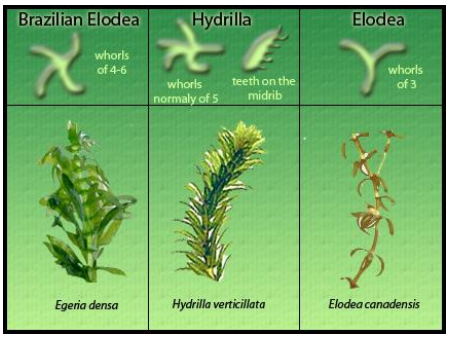




The red fluorescent light emitted by chlorophyll can be monitored by satellite. This **remote sensing** gives an estimate of the global distribution of photosynthesis.



Demonstration: Using a **fluorescence microscope**, observe the fluorescence of the chlorophyll in chloroplasts of *Elodea* (a relative of *Hydrilla*). What happens to the fluorescence after exposure to blue light?



In general, the **leaf** is the **organ** of plants that specializes in photosynthesis. In fact, the word **chlorophyll** comes from the Greek *kloros* and *phyllon* for **green leaf**. Leaves are green because the chlorophyll *a* in them reflects and transmits the wavelengths of light that it does not absorb. Leaves are ***not*** the only photosynthetic organ. Some epiphytic orchids growing in low light conditions have **green photosynthetic**



roots, cacti growing in dry deserts have no leaves, but do have **green photosynthetic stems**, some fruits and seeds, including **Mendel's culinary green peas**, and some flower parts, including the sepals of Cox's Orange and Pippin apples, are also photosynthetic.

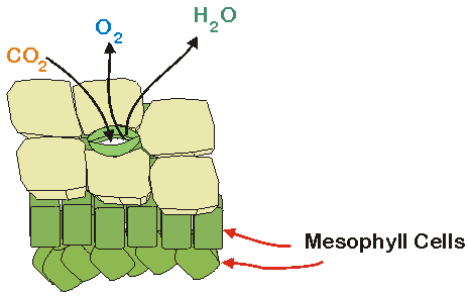




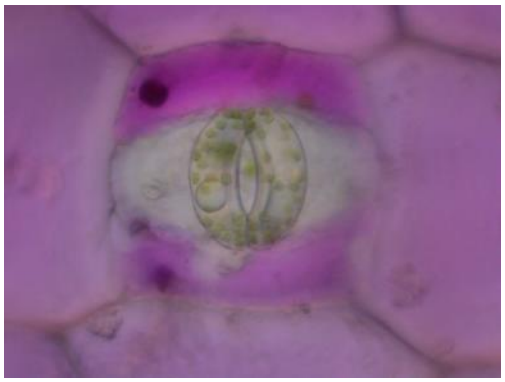
The **primary function** of a leaf is to **capture sunlight** and transform the radiant energy into chemical energy with as little as possible of the incident energy transformed into heat. Thus, the structure of the leaf **optimizes** photosynthesis under **various constraints**. Remember the tradeoffs of aperture size in the *camera obscura* and Samuel Wilberforce's discussion of compensation when selecting for one thing at the expense of another? (Wilberforce Falls on the Hood River in Canada is named after his father, William Wilberforce).



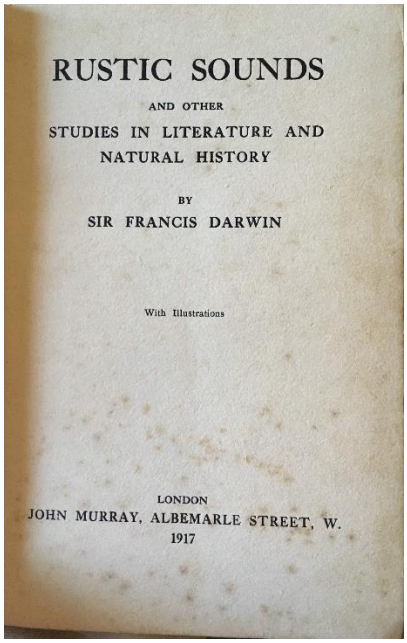
The **carbon dioxide** used for photosynthesis enters the leaf through valves in the leaf called **stomata**. When the valves are open, **carbon dioxide** can enter the leaf and can be converted into carbohydrate; however, at the same time, **water** that enters the leaf by way of the stem and the roots will be lost. If too much water is lost, the leaves will **wilt**, and photosynthesis as well as many other functions necessary for life will shut down.



Demonstration: Using a **bright field** or **differential interference contrast microscope**, observe the stomates of *Rhoeo spathacea*.



In an essay entitled, *Picturesque Experiments* in a book entitled, *Rustic Sounds and other Essays*, **Francis Darwin** (1917) presents a series of picturesque experiments that demonstrate photosynthesis. Here is one: "*There are other methods of demonstrating the movements of the stomata. Stahl had the happy inspiration of making use of the colour-changes of cobalt chloride. A piece of filter paper soaked in a 5 p.c. solution of this salt is blue when dried, and turns pink in damp air. A dry piece of this material, applied with proper precaution to the stomata-bearing surface of a leaf, rapidly changes to pink if the stomata are open. When, however, the same trial is made on the upper surface of a leaf, where stomata do not occur, no such change occurs. If two leaves are treated at the same time, one in the normal position and the other upside down, it is delightful to watch the appearance of a pink picture of that leaf whose stomatic surface is in contact with the paper, while no such change takes place over that which exposes no stomata to the tell-tale material*."


RUSTIC SOUNDS

AND OTHER

STUDIES IN LITERATURE AND NATURAL HISTORY

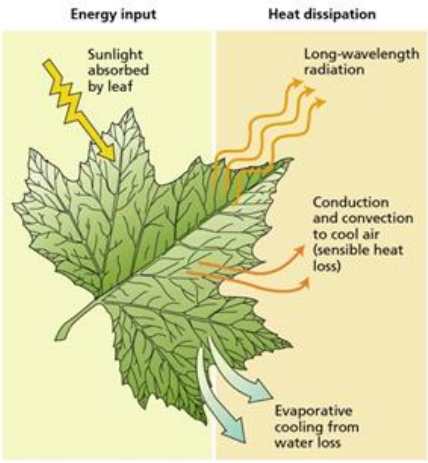
BY

SIR FRANCIS DARWIN

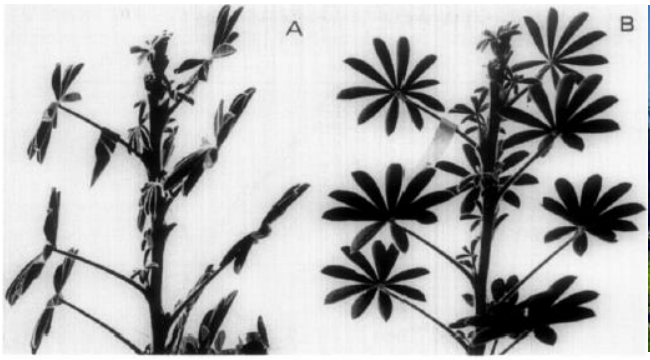
With Illustrations

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1917

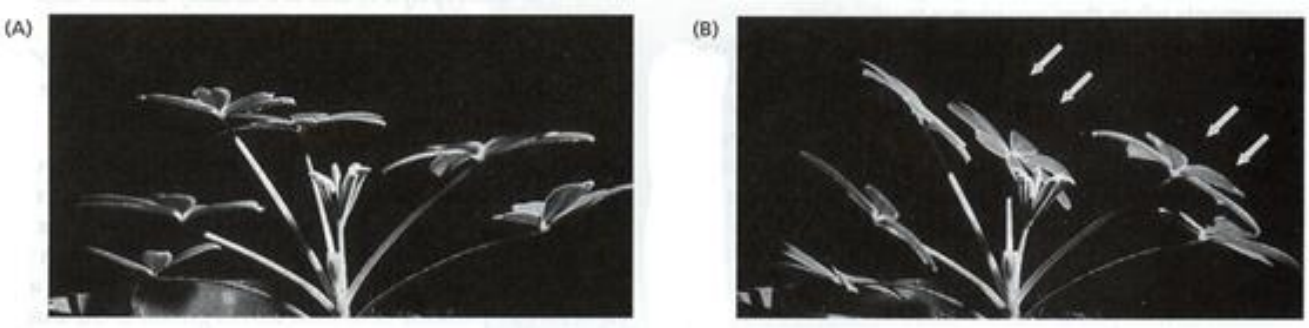
The bigger the leaf, the more sun it will capture but bigger is not always better since the bigger the leaf the more the leaf will be heated up by the sunlight. Too much heat will result in cooking the proteins in the leaf. Plants use the evaporation of water from the leaf to keep the leaf cool just like we use the evaporation of sweat to cool us. Evaporation and sweating cool the surface because it takes **heat energy to convert a liquid into a gas and the heat energy leaves with the gas**. The amount of carbon dioxide fixed by a leaf and the amount water lost by a leaf must be **balanced**.



Some plants optimize photosynthesis by tracking the position of the sun so that the leaves face the sun throughout the day. Lupin (*Lupinus pilosis*), malva, and sunflower (*Helianthus annuus*) are examples of plants that perform **solar tracking** or **heliotropism**.
http://plantsinmotion.bio.indiana.edu/plantmotion/movements/tropism/solartrack/solartrack.html







Some species are only heliotropic when they are **well watered**. In times of drought, the leaves close up to minimize the leaf area that captures the sun and results in leaf heating and/or water loss. *Eremalche rotundifolium* pictured on the left is tracking the sun. Water-stressed *Lupinus arizonicus* pictured on the right has minimized its solar exposure until its water status improves.



Let's look at a leaf that is growing where there is **plenty of sunlight** and **plenty of water**. This is the leaf of the water lily *Victoria regia* that lives in the still waters of the great rivers of the South America that flow into the Atlantic Ocean. In still waters there is a stunning way to collect light for photosynthesis and no plant does this in a more spectacular way than the *Victoria regia*. ***This is a leaf's leaf***. The six foot in diameter leaves float on the still water, supported from the bottom with **girder-like ribs** and **air spaces**.

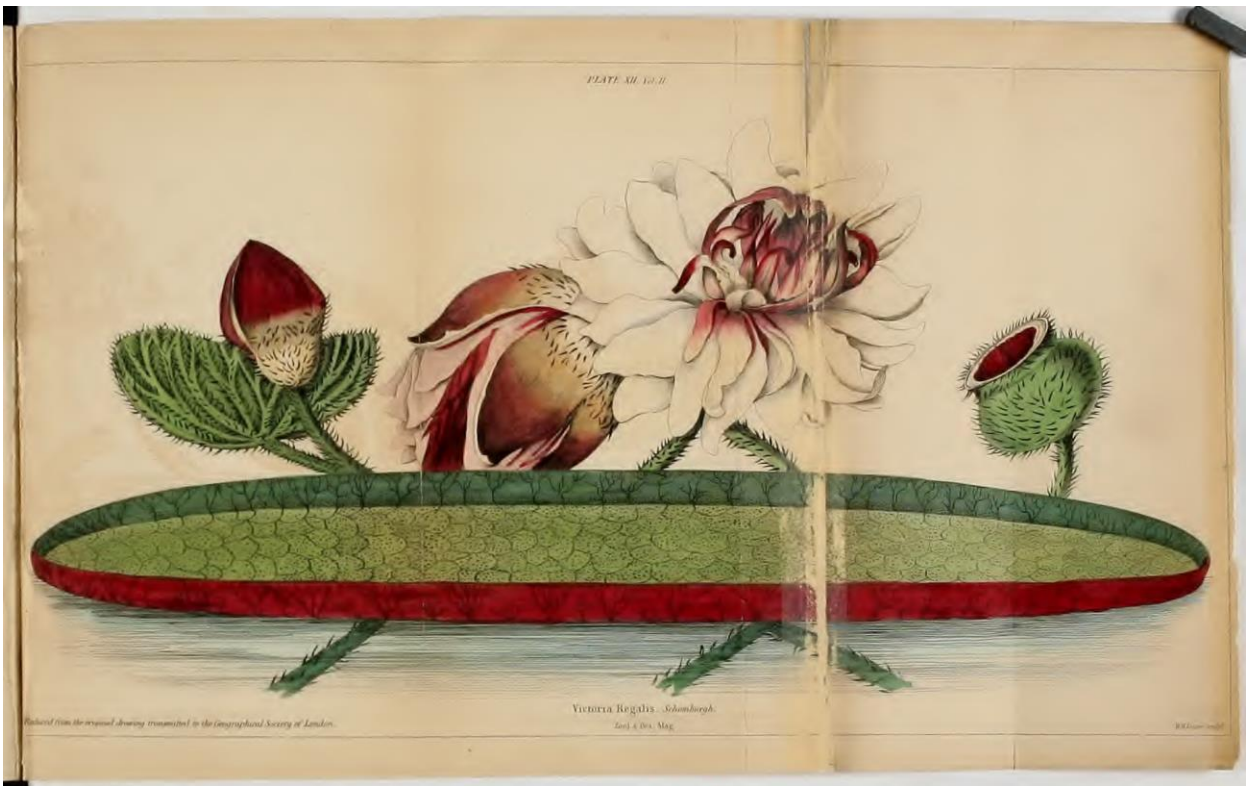


Robert Schomburgk discovered this water lily in British Guiana (Guyana) which was 'discovered" by Walter Rayleigh in his shipboard (as opposed to alchemical), search for Eldorado—gold. Robert Schomburgk sent a leaf of the water lily along with a description and two drawings back to England. In 1837, **John Lindley** privately published twenty-five copies of a pamphlet on the plant he named *Victoria regia*, which included Schomburgk's description of the plant. A month later, John Edward Gray (1837) published Schomburgk's description of the plant and a drawing in the form of an engraving in the more-widely read Magazine of Zoology and Botany. According to Schomburgk, *"Some object on the southern extremity of this basin attracted my attention. It was impossible to form any idea what it could be, and, animating the crew to increase the rate of their paddling, shortly afterwards we were opposite the object which had raised my curiosity. A vegetable wonder! all calamities were forgotten, I felt as botanist, and felt myself rewarded. A gigantic leaf, from 5 to 6 feet in diameter;*



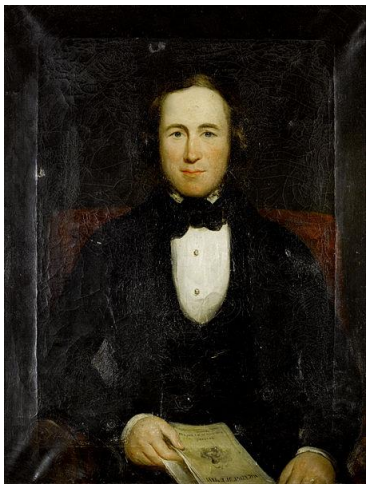
salver-shaped, with a broad rim of light green above, and a vivid crimson below, resting upon the water. Quite in character with the wonderful leaf was the luxuriant flower, consisting of many hundred petals, passing in alternate tints from pure white to rose and pink. The smooth water was covered with them, and I rowed from one to the other, and observed always something new to admire. The leaf on its surface is of a bright green, in form almost orbiculate, with this exception, opposite its axis, where it is slightly bent up. Its diameter measured from 5 to 6 feet; around the whole margin extended a rim about 3 to 5 inches high, on the inside light green, like the surface of the leaf, on the outside, like the leaf's lower part, of a bright crimson. ***The ribs are very prominent, almost an inch high, radiate from a common centre, and consist of eight principal ones, with a great many others branching off from them. These are crossed again by a raised membrane, or bands at right angles, which gives the whole the appearance of a spider's web****, and are beset with prickles;* ***the veins contain air cells*** *like the petiole and flower stem. The divisions of the ribs and bands are visible on the upper surface of the leaf….When it* [the flower] *first opens, it is white, with pink in*

the middle, which spreads over the whole flower, the more it advances in age, and it is generally found the next day of pink- colour."



In August 1846, fresh seeds of the Victoria water lily were collected in Bolivia by Thomas Bridges and brought to the **Royal Botanic Garden at Kew**. By October, two plants were thriving but by December 12th they died.





Other batches of seeds arrived at Kew beginning on February 18, 1849. By March 23, six seeds had germinated and by the end of the summer, fifty plants were thriving. Half of the plants were distributed to cultivators of rare plants, including **Joseph Paxton**, who got a plant on August 3rd.

Joseph Paxton, the head gardener for the **Duke of Devonshire**, was the first person to successfully nurture *Victoria regia* into bloom in England. The first flower fully opened on **November 9, 1849** in the great glass house he built especially for the water lily in the gardens of **Chatsworth House**.

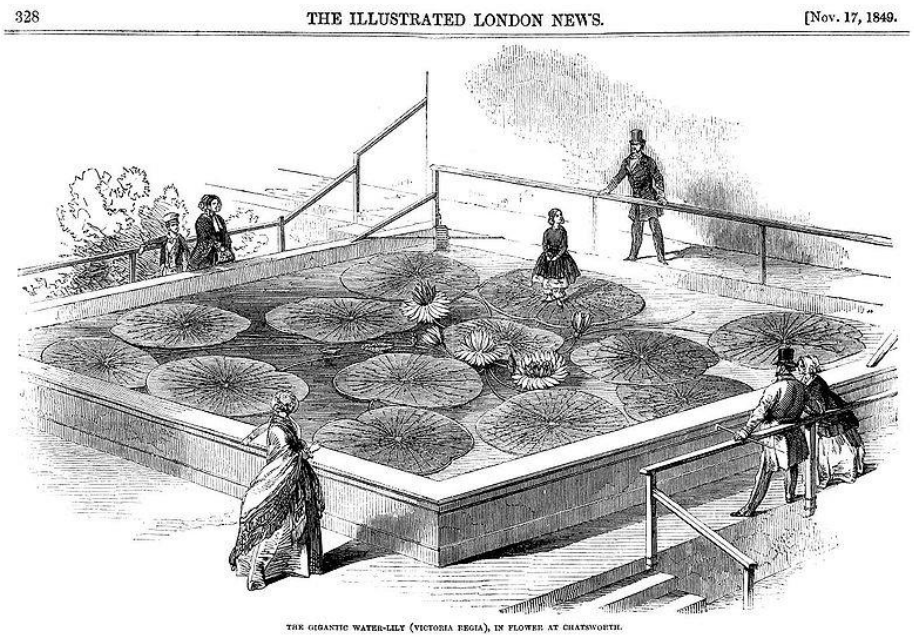


On November 13, 1849, Joseph Paxton went to **Windsor Palace** to present one of the first blossoms and a leaf to **Queen Victoria**, to whom the genus was dedicated.



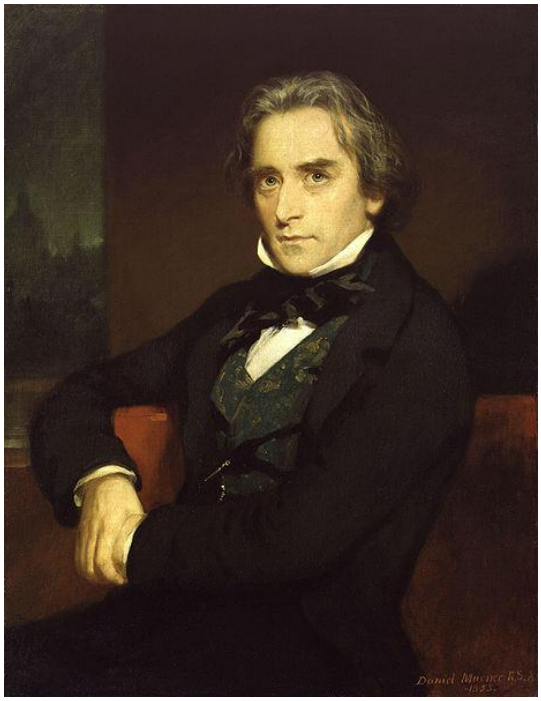
As reported in the Gardiner's Chronicle in 1850, "*Some of the more vigorous leaves are, at particular stages of their growth, recorded to have* ***increased in diameter at the remarkable rate of sixteen or eighteen inches within twenty-four hours****.... The largest flower produced at Chatsworth, of which we have any record, was* ***thirteen inches in diameter****....One curious fact connected with the Victoria Water Lily is* ***the extreme buoyancy of its large succulent foliage, occasioned by the presence of large air-cells in the thick ribs which cover like network the under surface, much aided no doubt by its large surface****, and the deep pit-like recesses formed between the interlacing veins. A child seven or eight years of age is said to have been supported by a leaf of the Chatsworth plant. The weight was, however, in this instance, distributed by means of a piece of board laid on the leaf, and on which the child stood.*"

According to an article published in 1885 by the Wisconsin State Horticultural Society (15: 143-146), "*The event brought together a distinguished concourse of visitors of the nobility and literati.* ***A novel event was the appearance, on the occasion, of little Miss Annie Paxton, who, dressed in costume of a fairy, took her place in one of the tray-like leaves, and, like a Naiad of the waters, presided as the fairy guardian of this beautiful floral queen.****"*


328 THE ILLUSTRATED LONDON NEWS. [Nov. 17, 1849.

THE GIGANTIC WATER-LILY (VICTORIA REGIA), IN FLOWER AT CHATSWORTH.

Douglas W. Jerrold wrote a poem for the occasion:



On unbent leaf, in fairy guise
Reflected in the water,
Beloved, admired by heart and eyes,
Stands Annie, Paxton's daughter.

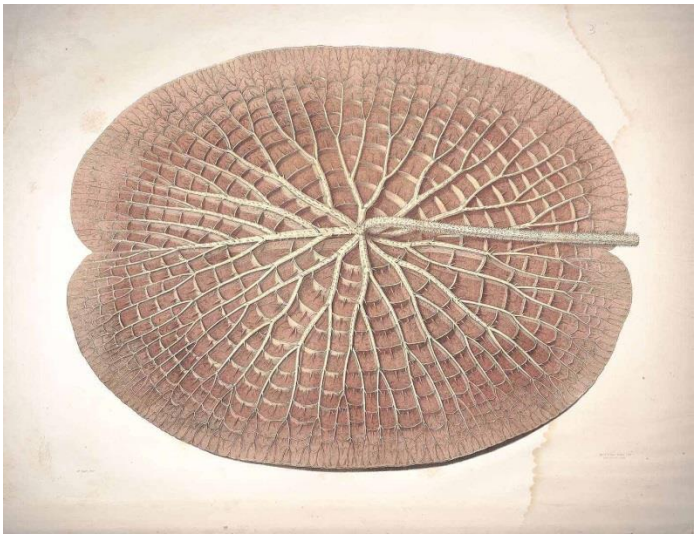
Accept a wish, my little maid,
Begotten at the minute,
That scenes so bright may never fade,
You still the fairy in it.

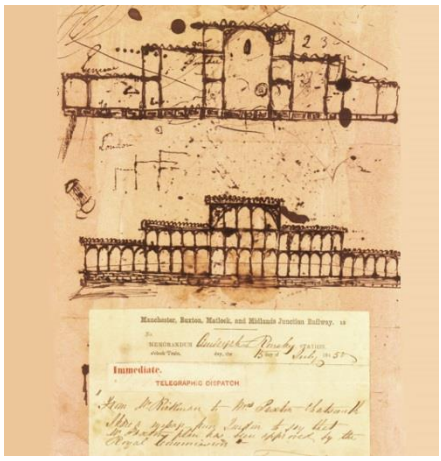
That all your life, nor care, nor grief
May load the winged hours
With weight to bend a lily's leaf,
But all around be flowers.

Joseph Paxton had been experimenting with building glass houses, but his interest in *Victoria regia* and the structure of the leaf of *Victoria regia* itself had inspired him to follow new lines in the construction of the building known as the **Lily House** that would house the *Victoria regia*. Paxton's granddaughter, **Violet Rosa Markham** (1935), wrote in *Paxton and the Bachelor Duke*, "*Victoria, amiable throughout her career, apart from her house, actually contributed some structural principles to the Exhibition building. In the paper describing his design, read by Paxton to the Fine Arts Society on November 13th, 1850, he exhibited one of the marvelous leaves five feet in diameter and pointed out that its* ***underside was a beautiful example of natural engineering***. *For it possessed ribs like levers radiating from the centre (where they were nearly two inches deep), with large bottom flanges, and very thin middle ribs with cross girders between each pair to keep the middle ribs from buckling.* *'**Nature was the engineer**,' said Paxton.* ***'Nature has provided the leaf with longitudinal and transverse girders and supports that I, borrowing from it, have adopted in this building**.'"*



The Victoria Regia.



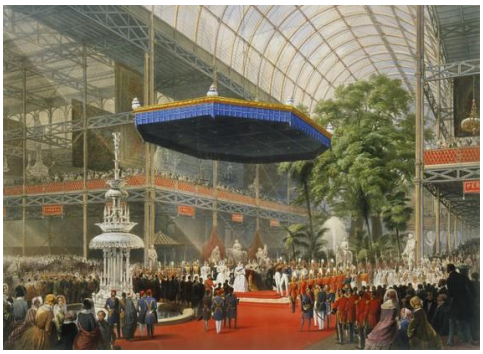


The Lily House was built entirely out of glass and cast iron. Everything used to build the building had **multiple roles**. The **roof** was a light and heat adjuster; the **supporting columns**, **rafters**, and **sash bars** were also drainpipes. The **floor** was a ventilator and a dust trap. The parts of the Lily house were **prefabricated** and **modular** and could be built **inexpensivel**y and the same modules could be used to construct variously-designed buildings. When it was time to design the Great Exhibition of 1851, he used the lessons he had learned from *Victoria regia*, beating out the 245 designs offered by professional architects from all over the world. Paxton's design was selected because it was **inexpensive**, did ***not*** use bricks and mortar, and could be built and dissembled **quickly**.

Joseph Paxton used the design principles he learned from *Victoria regia* and used to design the Lily House to design the building for the **Great Exhibition of the Works of Industry of all Nations** or the **Great Exhibition of 1851**. Douglas Jerrold, using the pseudonym "Mrs Amelia Mouser (July 13, 1850), described the building that Paxton proposed to build as the "*palace of the very crystal*" and from that time on it was known as the **Crystal Palace**, home of the Great Exhibition of 1851.



Using the principles of the **economy of nature** exhibited in the leaf of *Victoria regia*, Paxton built the Crystal Palace within nine months—on time and on budget!! **Prince Albert**, who was interested in science, trade, industry, and the arts saw the project through, and **Queen Victoria** opened the Great Exposition of 1851.















Anaglyph made from a **stereoscopic Daguerreotype** of the Crystal Palace that was taken on May 1, 1851. It gives a three-dimensional image when you view it with a red filter over the left eye and a blue filter over the right eye.



Paxton was knighted and became Sir Joseph Paxton in 1851. Paxton could not only assemble the Crystal Palace easily and quickly but he could also disassemble it easily and quickly so that he could return Hyde Park to the people.

In 1854, Paxton then moved the Crystal Palace from Hyde Park to Sydenham Hill, where it was used for many exhibitions, including a dinosaur exhibit. The Crystal Palace was destroyed in a fire on November 30, 1936. **Winston Churchill**, along with 100,000 people saw it burn. Churchill said, "*This is the end of an age*."





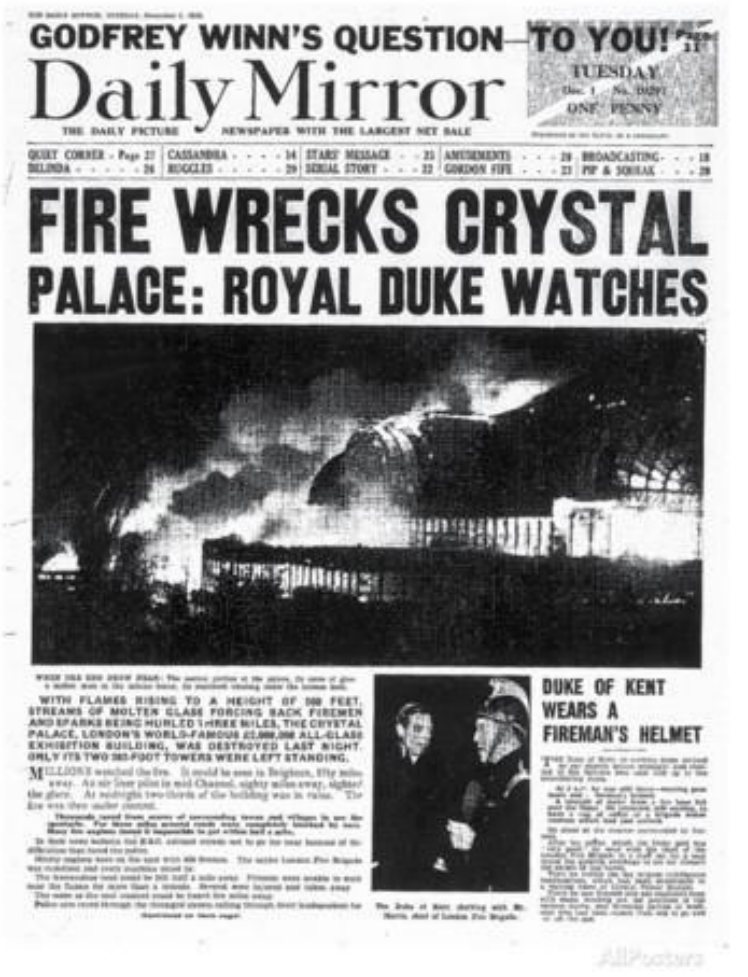
THE ILLUSTRATED LONDON NEWS

SATURDAY, DECEMBER 5, 1936.

THE DESTRUCTION OF ONE OF THE WORLD'S LANDMARKS: THE DRAMA OF THE CRYSTAL PALACE FIRE AT ITS HEIGHT—WATER JETS PLAYING NEAR THE SOUTH TOWER, WHICH THREATENED TO COLLAPSE.

The Crystal Palace on Sydenham Hill, a landmark famous not only to Londoners but throughout the world, was destroyed by fire on the night of November 30. Only the two great towers, 282 ft. high, one at each end, were eventually left standing above the ruins of the huge structure, which covered 25 acres.

The fire broke out about 8 p.m. and spread with astonishing rapidity. Some 500 firemen were engaged, with over ninety fire-fighting appliances—a record for a London fire. At one time it was feared the South Tower might collapse into streets crowded with spectators. Further photographs appear on later page.



GODFREY WINN'S QUESTION—TO YOU!

Daily Mirror

THE DAILY PICTURE NEWSPAPER WITH THE LARGEST NET SALE

TUESDAY

ONE PENNY

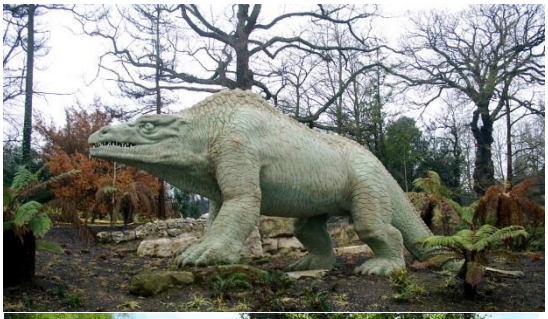
FIRE WRECKS CRYSTAL PALACE: ROYAL DUKE WATCHES

WITH FLAMES RISING TO A HEIGHT OF 100 FEET, STREAMS OF MOLTEN GLASS FORCING BACK FIREMEN AND SPARKS BEING HURLED THREE MILES, THE CRYSTAL PALACE, LONDON'S WORLD-FAMOUS £2,000,000 ALL-GLASS EXHIBITION BUILDING, WAS DESTROYED LAST NIGHT. ONLY ITS TWO 282-FOOT TOWERS WERE LEFT STANDING.

DUKE OF KENT WEARS A FIREMAN'S HELMET

On September 23, 1851, **T. H. Huxley** wrote to his future wife, Henrietta Anne Heathorn, "*The great Temple of England at present is the Crystal Palace—58,000 people worship these every day. They come up to it as the Jews came to Jerusalem at the time of the Jubilee.*" The Exhibition of 1851 at the Crystal Palace exhibited two specimens of the duck-billed platypus and a specimen of the giant ground sloth prepared by **Richard Owen**. When the Crystal Palace was moved to Sydenham, Prince Albert wanted to include life-sized models of dinosaurs, including the carnivorous Megalosaurus and the herbivorous Iguanodon. Richard Owen, who coined the word **dinosaur** in 1841, was the scientific consultant to the sculptor, Benjamin Waterhouse Hawkins. Over a million people a year came to this exhibit to learn about and enjoy natural history as a part of Victorian culture.





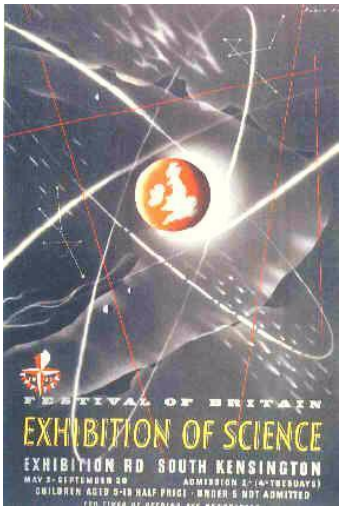


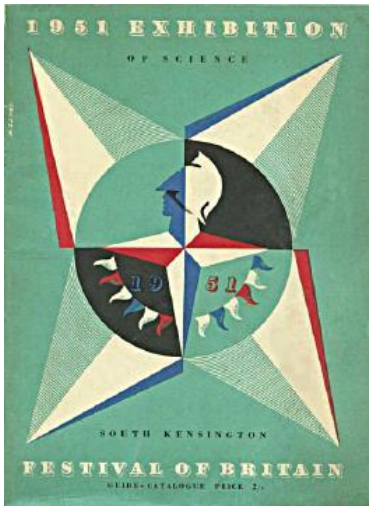


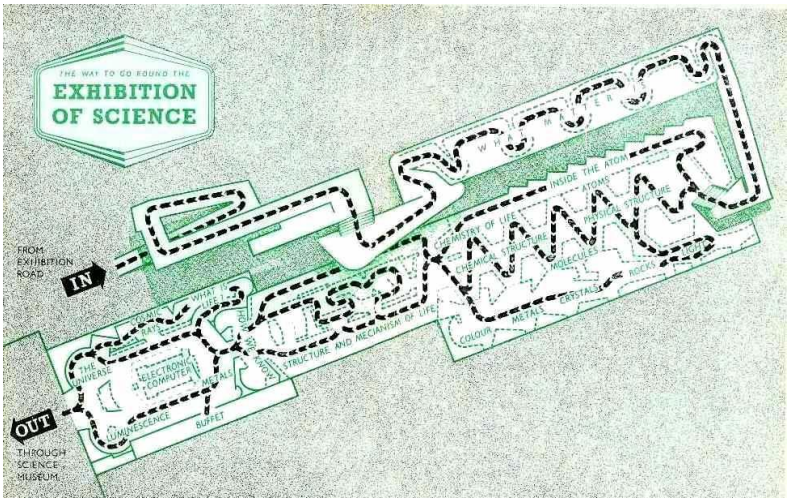
The 1951 ***Festival of Britain*** was originally planned to commemorate the Great Exhibition of 1851 but developed as a celebration of the post-WWII era of prosperity and progress guided by the transition from the old culture of art and literature to the new culture of science and technology as described in C. P. Snow's book, *The Two Cultures and the Scientific Revolution*.

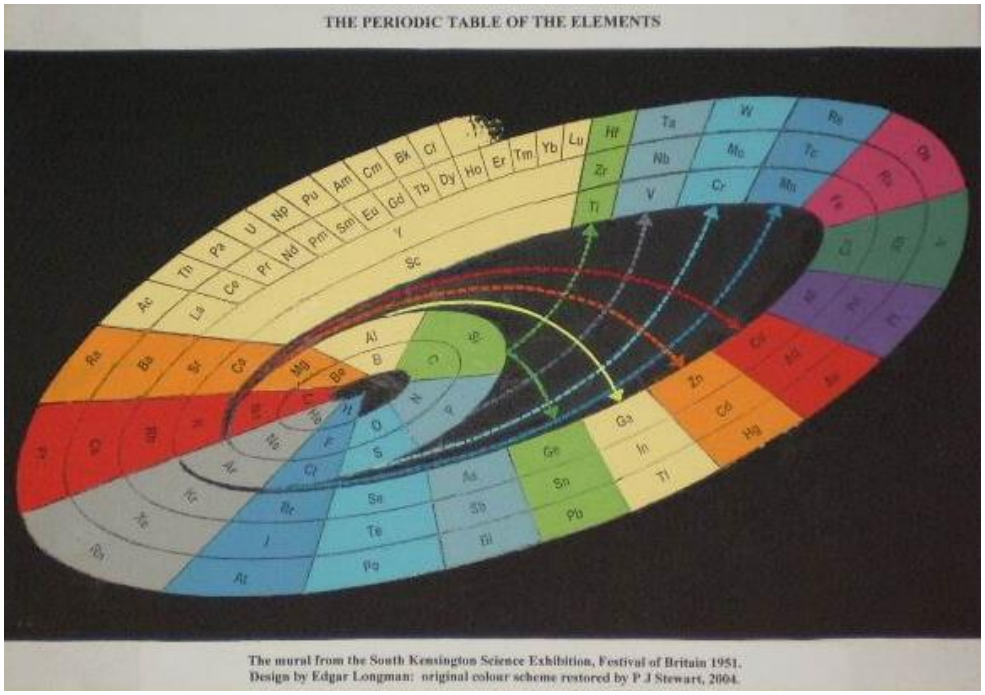
http://www.goodeveca.net/science1951/guide.html

http://www.goodeveca.net/nimrod/



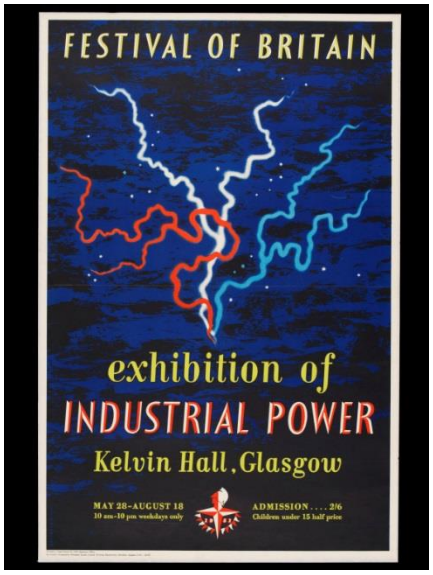




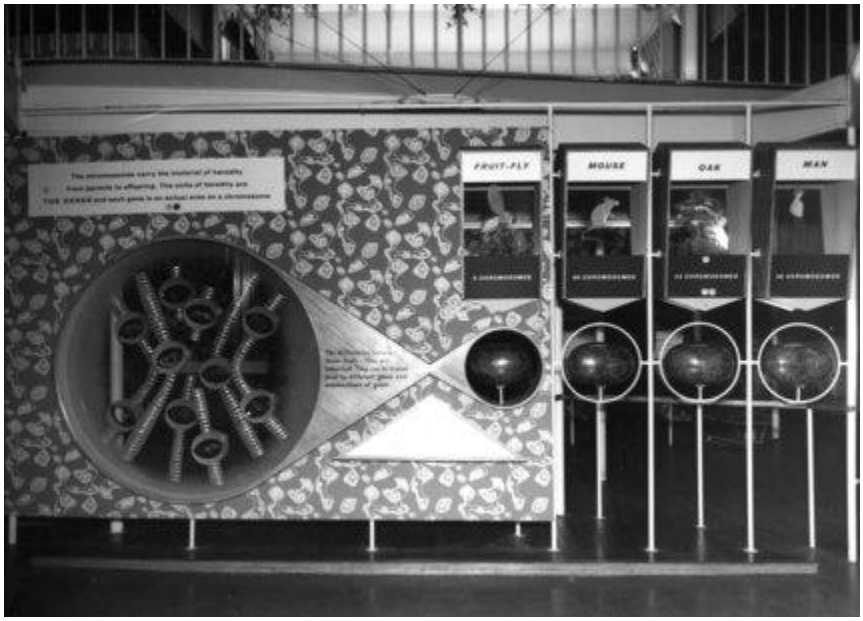


The mural from the South Kensington Science Exhibition, Festival of Britain 1951.
Design by Edgar Longman: original colour scheme restored by P J Stewart, 2004.





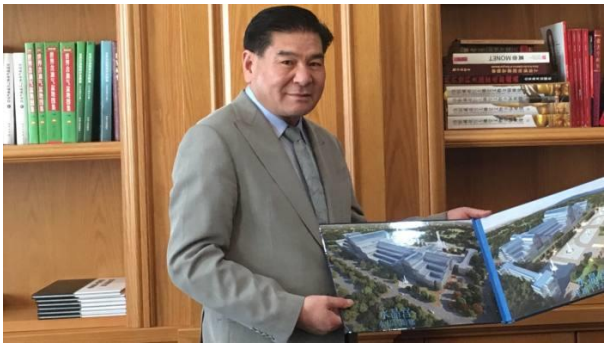




According to **Lisa Jardine**, who gave the 2009 C. P. Snow Lecture in Christ's College and daughter of Jacob Bronowski, "*There is a real reluctance to recognize the role pure science has played in the Allied victory, even as that science is hailed as the key to the future. As a consequence, science is celebrated as the source of emancipation, liberation and progress. But the context within which this is most clearly the case—the triumph of the Allies over the forces of Fascism—is left out. The omission is certainly a conscious one. Almost all those*

associated with the two Exhibitions had worked on wartime scientific developments, including radar, strategic bombing and ultimately the atomic bomb….There could hardly be a clearer example of deliberate amnesia….If science was to be represented as holding the key promises for Britain's future, he [Lord Ismay] *must surely have believed it ought to be a science which was not associated with the enormity of the unimaginable scale of human casualties and suffering of those final weeks of the war with Japan.*"

Real estate mogul **Ni Zhaoxing** thought about bringing the Crystal Palace back to life as a 21st century cultural attraction. However the deal fell through.





In the 19th century, *Victoria regia* came to the United States where its mechanical strength also caused a stir.



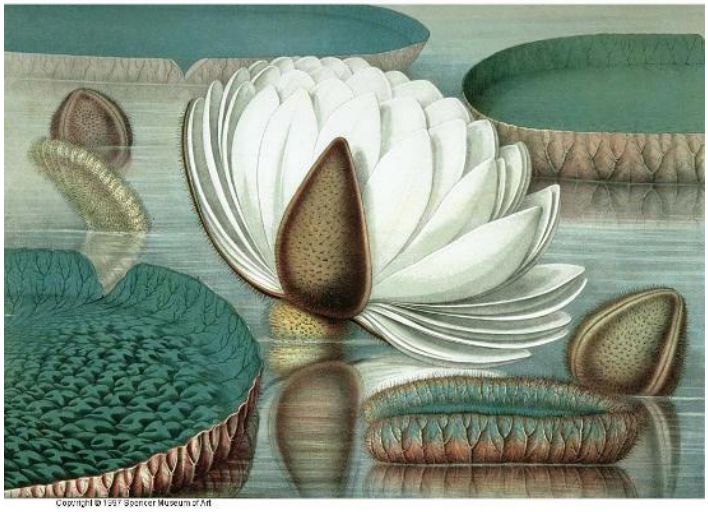




Karl Niklas (Cornell), Steven Vogel, and Park Nobel study the biomechanics and biophysics of plants and their leaves.



John Fisk Allen wrote and **William Sharp** illustrated *Victoria regia, or The Great Water Lily of America* in 1854. William Sharp drew the images on stones and printed them. Sharp was America's first **chromolithographic printer,** and this book is the earliest example of large scale color printing in the United States. We will see this book in the Rare and Manuscript Collections at Kroch Library.





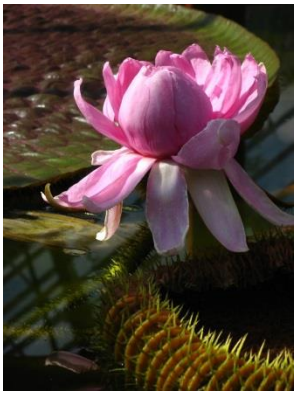




Pollination in *Victoria regia* is as interesting as the leaf. The flower of *Victoria regia* is originally white and **opens at night**. Only the female parts

(pistils) of the flower are fertile while the **petals are white**. While the flower is white, the core of the flower heats up to about 95 ºC. At this temperature, chemicals are volatized which gives the flower a butterscotch and pineapple scent. This scent attracts pollen-covered **scarab beetles** that will pollinate the flower. At **dawn**, the petals close around the beetle, and they stay closed for 24 hours while the beetle pollinates the pistil. Subsequently, the male parts of the flower (stamens) become fertile. At **dusk**, the petals turn pink and the flower opens to let out the pollen-covered beetle, which can now fly to a white flower, with fertile female parts.



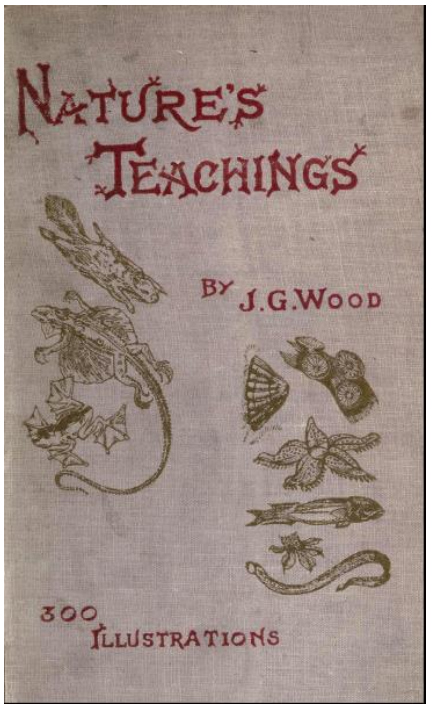


You can watch the lily grow and bloom and be pollinated in time lapse http://www.youtube.com/watch?v=igkjcuw_n_U

Mann Library Special Collections has *Victoria regia, or Illustrations of the Royal Water-Lily, in a Series of Figures Chiefly Made from Specimens Flowering at Syon and at Kew* by Sir William Jackson Hooker and Walter Hood Fitch printed by Bradbury & Evans for Reeve & Benham in 1851. (Call Number: QK495.N97 F5 Oversize)



In *Nature's Teachings*, the Reverend J. G. Wood (1858, 1907) wrote, "*The capabilities of the Crystal Palace had lain latent for centuries, but the generalising eye of genius was needed to detect it. A thousand men might have seen the Victoria Regia leaf, and not thought very much of it; but the right man came at the right time, the most wonderful building in the world sprang up like the creation of a fairy dream, and the obscure gardener became Sir Joseph Paxton. I have no doubt that thousands of similar revelations are at present hidden in Nature, awaiting the eye of their revealer*." You can learn a lot from botany and looking at a leaf, the organ that specializes in photosynthesis.



Botany

by Berton Braley (1929)



There should be no monotony
In studying your botany;
It helps to train
And spur the brain--
Unless you haven't gotany.

It teaches you, does Botany,
To know the plants and spotany,
And learn just why
They live or die--
In case you plant or potany.

You learn, from reading Botany,
Of wooly plants and cottony
That grow on earth,
And what they're worth,
And why some spots have notany.



You sketch the plants in Botany,
You learn to chart and plotany
Like corn or oats--
You jot down notes,
If you know how to jotany.

Your time, if you'll allotany,
Will teach you how and what any
Old plant or tree
Can do or be--
And that's the use of Botany!

Prince Albert described the nature of science in a speech he gave in front of the British Association for the Advancement of Science in 1859, "*To define the nature of Science, to give an exact and complete definition of what that Science, to whose service the Association is devoted, is and means, has, as it naturally must, at all times occupied the Metaphysician. He has answered the question in various ways, more or less satisfactorily to himself or others. To me, Science, in its most general and comprehensive acceptation, means the knowledge of what I know, the*

consciousness of human knowledge. Hence, to know is the object of all Science; and all special knowledge, if brought to our consciousness in its separate ***distinctiveness from****, and yet in its recognized* ***relation to the totality of our knowledge****, is scientific knowledge. We require, then, for Science—that is to say, for the acquisition of scientific knowledge—those* ***two activities of our mind*** *which are necessary for the acquisition of any knowledge—****analysis and synthesis****;* ***the first, to dissect and reduce into its component parts the object to be investigated, and to render an accurate account to ourselves of the nature and qualities of these parts by observation; the second to recompose the observed and understood parts into a unity in our consciousness, exactly answering to the object of our investigation****. The labours of the man of Science are therefore at once the most humble and the loftiest which man can undertake.* ***He only does what every little child does from its first awakening into life****, and must do every moment of its existence; and* ***yet he aims at the gradual approximation to divine truth itself. If, then, there exists no difference between the work of the man of Science and that of the merest child, what constitutes the distinction? Merely the conscious self-determination. The child observes what accident brings before it, and unconsciously forms its notion of it; the so-called practical man observes what his special work forces upon him, and he forms his notions upon it with reference to this particular work. The man of Science observes what he intends to observe, and knows why he intends it. The value which the peculiar object has in his eyes is not determined by accident, nor by an external cause, such as the mere connection with work to be performed, but by the place which he knows this object to hold in the general universe of knowledge, by the relation which it bears to other parts of that general knowledge****.*

To arrange and classify that universe of knowledge becomes therefore the first, and perhaps the most important, object and duty of Science. It is only when brought into a system, by separating the incongruous and combining those elements in which we have been enabled to discover the internal connection which the Almighty has implanted in them, that we can hope to grapple with the boundlessness of His creation, and with the laws which govern both mind and matter.

The operation of Science then has been, systematically to divide human knowledge, and raise, as it were, the separate groups of subjects for scientific consideration, into different and distinct sciences. The tendency to create new sciences is peculiarly apparent in our present age, and is perhaps inseparable from so rapid a progress as we have seen in our days; for the acquaintance with and mastering of distinct branches of knowledge enables the ***eye****, from the newly gained points of*

***sight**, to **see** the new ramifications into which they divide themselves in strict consecutiveness and with logical necessity. But in thus gaining new centres of **light**, from which to direct our researches, and new and powerful means of adding to its ever-increasing treasures, Science approaches no nearer to the limits of its range, although travelling further and further from its original point of departure. For God's world is infinite; and the boundlessness of the universe, whose confines appear ever to retreat before our finite minds, strikes us no less with awe when, prying into the starry crowd of heaven, we find new worlds revealed to us by every increase in the power of the telescope, than when the microscope discloses to us in a drop of water, or an atom of dust, new worlds of life and animation, or the remains of such as have passed away.*

Whilst the tendency to push systematic investigation in every direction enables the individual mind of man to bring all the power of which he is capable to bear on the specialities of his study, and enables a greater number of labourers to take part in the universal work, it may be feared that that consciousness of its unity which must pervade the whole of Science if it is not to lose its last and highest point of sight, may suffer. It has occasionally been given to rare intellects and the highest genius to follow the various sciences in their divergent roads, and yet to preserve that point of sight from which alone their totality can be contemplated and directed. Yet how rare is the appearance of such gifted intellects! and if they be found at intervals, they remain still single individuals, with all the imperfections of human nature.

*The only mode of supplying with any certainty this want, is to be sought in the combination of men of Science representing all the specialities, and **working together for the common object of preserving that unity** and presiding over that general direction. This has been to some extent done in many countries by the establishment of academies embracing the whole range of the sciences, whether physical or metaphysical, historical or political. In the absence of such an institution in this country, all lovers of Science must rejoice at the existence and activity of this Association, which embraces in its sphere of action, if not the whole range of the sciences, yet a very large and important section of them, those known as the inductive sciences, excluding all that are not approached by the inductive method of investigation. It has, for instance (and, considering its peculiar organization and mode of action, perhaps not unwisely), eliminated from its consideration and discussions those which come under the description of moral and political sciences. **This has not been done from undervaluing their importance and denying their sacred right to the special attention of mankind, but from a desire to deal with those subjects only which can be reduced to***

positive proof, and do not rest on opinion or faith. *The subjects of the moral and political sciences involve not only opinions but feelings; and their discussion frequently rouses passions. For feelings are 'subjective,' as the German metaphysician has it—they are inseparable from the individual being—an attack upon them is felt as one upon the person itself; whilst facts are 'objective' and belong to everybody—they remain the same facts at all times and under all circumstances: they can be proved; they have to be proved, and, when proved, are finally settled. It is with facts only that the Association deals. There may for a time exist differences of opinion on these also, but the process of removing them and resolving them into agreement is a different one from that in the moral and political sciences. These are generally approached by the deductive process; but if the reasoning be ever so acute and logically correct, and* ***the point of departure, which may be arbitrarily selected,*** *is disputed, no agreement is possible; whilst we proceed here by the inductive process, taking nothing on trust, nothing for granted, but reasoning upwards from the meanest fact established, and making every step sure before going one beyond it, like the engineer in his approaches to a fortress.* ***We thus gain ultimately a roadway, a ladder by which even a child may, almost without knowing it, ascend to the summit of truth and obtain that immensely wide and extensive view which is spread below the feet of the astonished beholder****. This road has been shown us by the great* [Francis] *Bacon; and who can contemplate the prospects which it opens, without almost falling into a trance similar to that in which he allowed his imagination to wander over future ages of discovery!*"



Maya Angelou saw more than leaves when looking at trees. When asked by *Life Magazine* (December 1988) about the meaning of life, she answered, "*And I am obliged to report that the answer changes from week to week. When I know the answer, I know it absolutely; as soon as I know that I know it, I know that I know nothing. About 70 percent of the time my conclusion is that there is a grand design. I believe that the force that created life is betting that human beings will do something quite wonderful—like live up to their potential. I am influenced largely by Blaise Pascal and his wager. Pascal advises us to bet on the toss of a coin that*

God is. If we win, we win eternity. If we lose, we lose nothing. ***I'm looking out a large window now and I see about 40 dogwood and maple and oak and locust trees and the light is on some of the leaves and it's so beautiful. Sometimes I'm overcome with gratitude at such sights and feel that each of us has a responsibility for being alive: one responsibility to creation, of which we are a part, another to the creator—a debt we repay by trying to extend our areas of comprehension***."

Back to the Crystal Palace. The United States of America contributed a statue to the Great Exhibition of 1851 entitled, "*The Greek Slave*," which celebrated the fact that Greece recently won its independence from the Ottoman Empire. The marble sculpture, carved by Hiram Powers, is an example of American neoclassical sculpture. It was the first American nude sculpture. It inspired many poems. Powers was motivated to make this sculpture when he "*remembered reading of an account of the atrocities committed by the Turks on the Greeks during the Greek revolution- ... During the struggle the Turks took many prisoners, male and female, and among the latter were beautiful girls, who were sold in the slave markets of Turkey and Egypt. These were Christian women, and it is not difficult to imagine the distress and even despair of the sufferers while exposed to be sold to the highest bidder*."





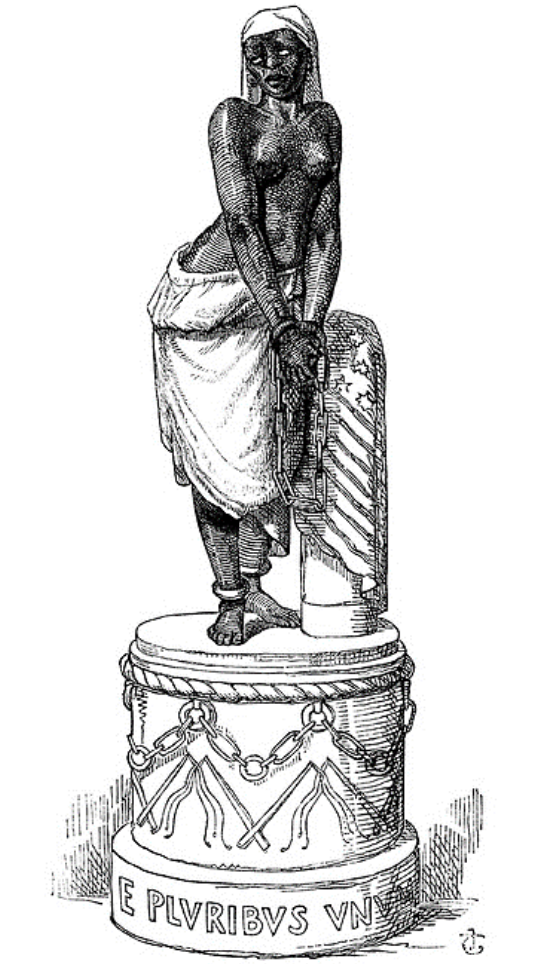
Elizabeth Barret Browning wrote poems to help abolish slavery. She saw the sculpture in Florence, Italy, and then wrote the sonnet "*Hiram Powers' Greek Slave*," which appeared in Charles Dickens' *Household Words* in 1850.



They say Ideal beauty cannot enter
The house of anguish. On the threshold stands
An alien Image with enshackled hands,
Called the Greek Slave! as if the artist meant her
(That passionless perfection which he lent her,
Shadowed not darkened where the sill expands)
To so confront man's crimes in different lands
With man's ideal sense. Pierce to the centre,
Art's fiery finger! and break up ere long
The serfdom of this world. Appeal, fair stone,
From God's pure heights of beauty against man's wrong!
Catch up in thy divine face, not alone
East griefs but west, and strike and shame the strong,
By thunders of white silence, overthrown.

Abolitionist demonstrations occurred at the statue. Recognizing the irony that the United States, who fought a war with England over freedom, still had slavery, *Punch* published a picture called, *The Virginian Slave,* by John Tenniel, which was intended as a companion to Powers' "*Greek Slave*." Together, the two pieces of art represent the inability of the United States to recognize its own tyranny while crying out against slavery elsewhere in the world.



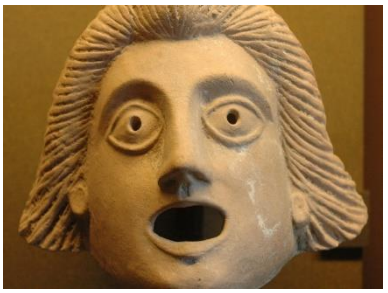


THE VIRGINIAN SLAVE.

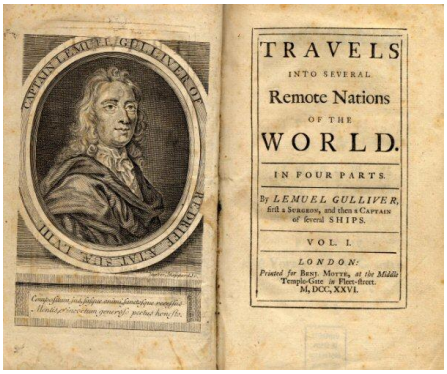
INTENDED AS A COMPANION TO POWER'S "GREEK SLAVE."



Hypocrisy never wears well. .Hannah Arendt (1963) wrote in *On Revolution*, "*As witnesses not of our intentions but of our conduct, we can be true or false, and the hypocrite's crime is that he bears false witness against himself.* ***What makes it so plausible to assume that hypocrisy is the vice of vices is that integrity can indeed exist under the cover of all other vices except this one.*** *Only crime and the criminal, it is true, confront us with the perplexity of radical evil; but only the hypocrite is really rotten to the core*."



The word hypocrite comes from the Greek word *hypokrites*, which means an actor. *Hypokrites* is a compound noun, made from Greek words that mean an interpreter from underneath, because the actors in ancient Greek theater wore masks, and so they interpreted the story from underneath their masks.



Can sunlight be extracted from plants? In ***Gulliver's Travels***, **Jonathan Swift** (1736) satirized his impression that scientists were high class beggars who used science to serve themselves rather than to improve the human condition. When Lemuel Gulliver visited the island of Laputa, he found a man who was working on the extraction of sunbeams from cucumbers:


"He had been eight years upon a project for extracting sunbeams out of cucumbers"

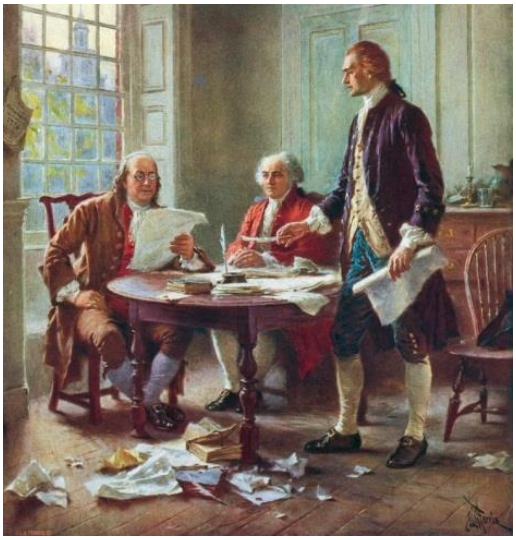
"*The first man I saw was of a meagre aspect, with sooty hands and face, his hair and beard long, ragged, and singed in several places. His clothes, shirt, and skin, were all of the same colour. He has been eight years upon a project for* ***extracting sunbeams out of cucumbers****, which were to be put in phials hermetically sealed, and let out to warm the air in raw inclement summers. He told me, he did not doubt, that, in eight years more, he should be able to supply the governor's gardens with sunshine, at a reasonable rate: but he complained that his stock was low, and entreated me 'to give him something as an encouragement to ingenuity, especially since this had been a very dear season for cucumbers.'* ***I made him a small present, for my lord had furnished me with money on purpose, because he knew their practice of begging from all who go to***

see them." http://www.shmoop.com/gullivers-travels/part-3-chapter-5-full-text.html

https://www.theguardian.com/science/the-h-word/2013/mar/14/science-history-satire-politics-swift-gulliver

Photosynthesis: Converting Radiant Energy into Chemical Energy
The Light-Independent Reactions

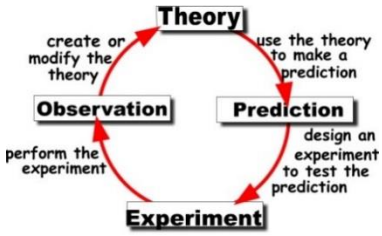
The **Laws of Nature describe**, **predict**, and **explain** how and why events occur in nature. The Laws of Nature serve as **summaries of a large number of observations and experimental results** that have taken place since the time humans began questioning. Once enounced and accepted, **the Laws of Nature seem right, true, self-evident**, and the **basis of building higher-level systems of reason**, whether scientific or political, based on the **always testable assumption that the law is true**. The Laws of Nature can be called **Principles**. Thomas Jefferson, John Adams, and Benjamin Franklin used the **Laws of Nature** to justify the separation of the American colonies from England in the **Declaration of Independence**:



"*When in the Course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume among the powers of the earth,* ***the separate and equal station to which the Laws of Nature and of Nature's God entitle them****, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.* ***We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness****....*"

The Laws of Nature are principles, but they may not *always* apply to *every* situation. In a healthy society, the application of the Laws of Nature is questioned. For example, does every conceived individual have a right to life or is life defined

by birth? Does every criminal have an unalienable right to his/her liberty? When does the liberty of society trump an individual liberty? Thomas Jefferson wrote to James Madison on January 30, 1787, "*I hold it that a little rebellion now and then is a good thing, and as necessary in the political world as storms in the physical... It is a medecine necessary for the sound health of government."* The application of the Laws of Nature is also questioned when science is healthy. Is the Special Theory of Relativity or the Doppler effect more fundamental for describing relative motion? Is the Uncertainty Principle or the First Law of Thermodynamics more fundamental when describing material processes? Is the Cosmological Principle or the Doppler Effect more fundamental when describing our place in the universe? Everyone has a right to examine the evidence and question the self-evident nature of any Law of Nature. **Science** ends and **Scientism** begins when the loop is broken, and questioning is forbidden.



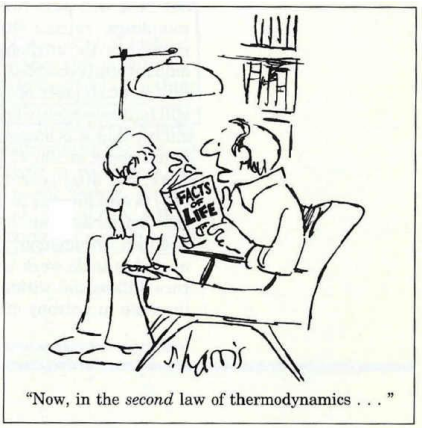
Biological processes and indeed **life itself** can be and has been described, predicted, and explained to a great degree by the **Laws of Nature**. The **First Law of Thermodynamics** is a **Law of Nature** that states that **energy** can be **interconverted** between different forms (e.g. gravitational, electrical, magnetic, chemical, radiant, and thermal) but not created or destroyed. For example, **radiant energy** is converted into **chemical energy** and **thermal energy** during vision by absorption of a photon by the 11-*cis* retinal of the rhodopsin and photopsins in our eyes.

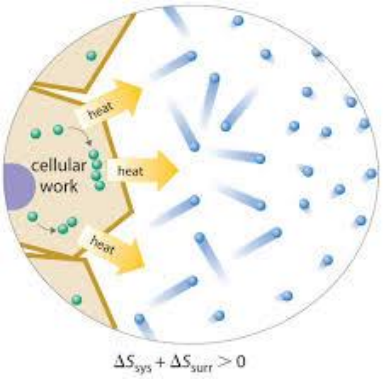
Demonstration: Connect the water electrolysis unit to the transformation of energy apparatus. Turn the crank and see how much energy it takes to split H_2O into $½O_2$ and H_2. Imagine how much energy it took to create an atmosphere composed of 21% oxygen on earth.

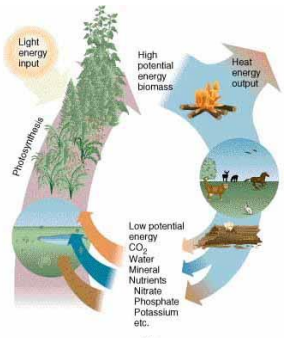


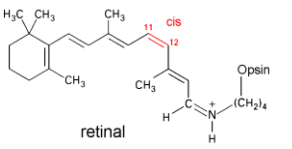


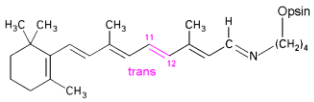
The **Second Law of Thermodynamics** is a **Law of Nature** that gives **directionality** in **time** to transformations by stating that while energy ***cannot*** be **destroyed** in an energy transformation, it ***can*** be **degraded into heat**, which at constant temperature is equivalent to **entropy**. Heat, which is also known as thermal energy is equal to the product of temperature (T) and entropy (S) where $heat = T\,S$. Moreover, transformations occur **passively** and **spontaneously** only in the **direction** that **gives rise to increased entropy**. For example, the absorption of light by the rhodopsin and photopsins not only results in the production of chemical energy in the transformation of 11-*cis* retinal to all-*trans* retinal but also results in the production of entropy or heat which is radiated away at the **speed of light** as **infrared wavelengths**. There is **directionality** to the transformation since the reconversion of all-*trans* retinal to 11-*cis* retinal cannot result in the emission of light. Another example of **directionality** stipulated by the **Second Law of Thermodynamics** that has to do with vision is the transformation of the chemical energy of ATP that results in **contraction** of the muscles that move the eyeball. Heat or entropy is produced at the same time. Again, there is **directionality** because the **relaxation** of the muscle does not result in the production of ATP in part because the increase in entropy or the energy converted to heat is **dispersed** at the **speed of light**. I believe that the Laws of Thermodynamics are the two most fundamental **Laws of Nature**. You are free to believe otherwise.

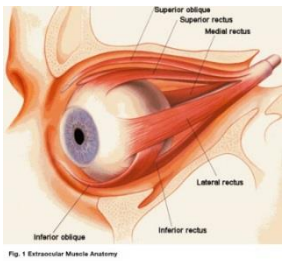


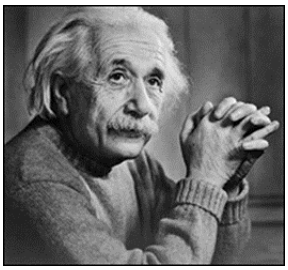






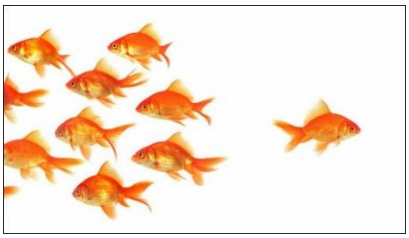








Albert Einstein (1949) wrote in his autobiographical sketch, "*A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts*." **Arthur Eddington** (1915) wrote in *The Nature of the Physical World*, "*The law that entropy always increases holds, I think, the supreme position among the laws of Nature.…if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."*



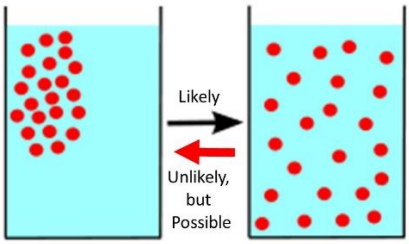
Although Albert Einstein, Max Planck, and Erwin Schrödinger did not agree with the majority of the physicists, it is conventional wisdom among physicists that **Heisenberg's uncertainty principle** is ***more*** fundamental than the First Law of Thermodynamics. Heisenberg's uncertainty principle states that energy (ΔE) can come from nothing but only for a limited period of time (Δt) according to the following equation (http://www.aip.org/history/heisenberg/p08.htm):



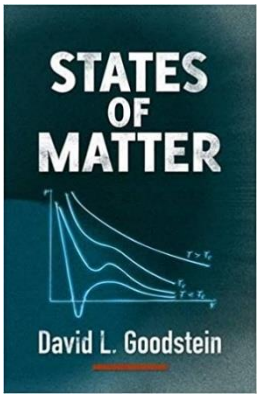
$$\Delta E\, \Delta t \geq \frac{\hbar}{2} = \frac{h}{4\pi}$$

How long would a photon with a wavelength of 500 nm exist if it popped out of the vacuum according to Heisenberg's uncertainty principle? If it takes approximately 10^{-15} seconds for rhodopsin to absorb the photon, would you be able to see it?



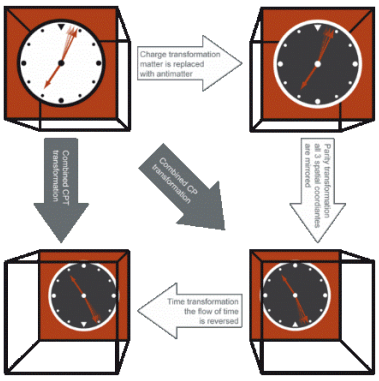


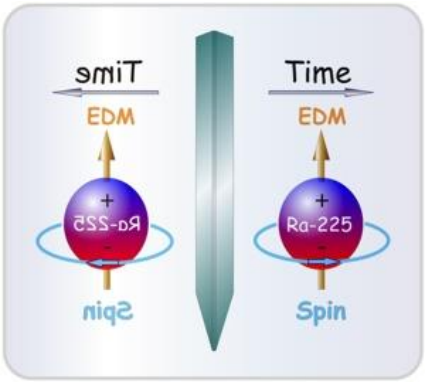
It is also conventional wisdom among physicists that **statistical mechanics**, based on the **reversibility of time**, is fundamental but the Second Law of Thermodynamics is ***not*** fundamental because it is based on the assumption that **time is irreversible**. Conventional wisdom states that **time itself is reversible**. According to conventional wisdom, **chance and statistics** give us the **illusion** that time is irreversible.



Perhaps I should mention that David Goodstein (1985) noted in his book *States of Matter* that "*Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906, by his own hand. Paul Ehrenfest, carrying on the work, died similarly in 1933. Now it is our turn to study statistical mechanics.*" Goodstein then suggests that "[p]*erhaps it will be wise to approach the subject cautiously*."

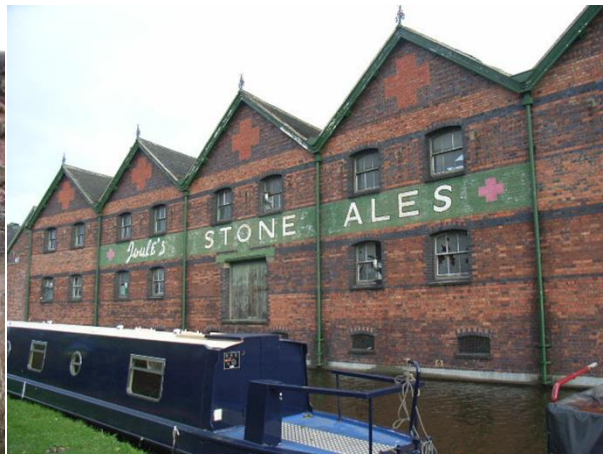
Quantum electrodynamics (QED) considers antimatter to be matter going backwards in time.





If you are unable to picture these descriptions of physical objects existing in the world, you are not alone. In *Natural Law and the Structure of Matter*, Werner Heisenberg (1981) described the physicists' view of the world: "*I think that modern physics has definitely decided in favor of Plato.* ***In fact the smallest units of matter are not physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language***."





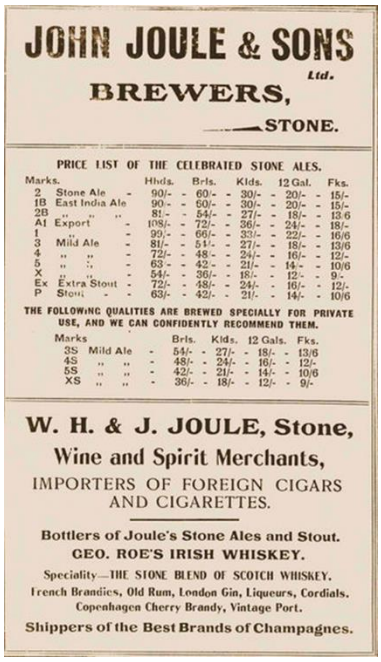


The **First Law of Thermodynamics**, which is also known as a statement of the **conservation of energy**, was discovered, in part, and first stated quantitatively in an English brewery. Since the 12th century, Augustinian monks **brewed beer** at the priory in Market Drayton, England. The monks blessed the brew in each barrel and put a cross on the barrels that contained the superior batches. This went on until **Henry VIII** ordered the **Dissolution of the Monasteries** in the 16th century. In the 18th century, two brothers William and Francis Joule became brewers, each opening their own brewery. John Joule, Francis's son and William's nephew, took over Francis's brewery in 1813 and adopted the red cross that the monk's used to signify a superior brew as a trademark. Joule's Brewery still exists today.



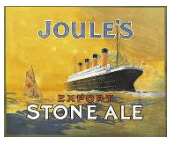


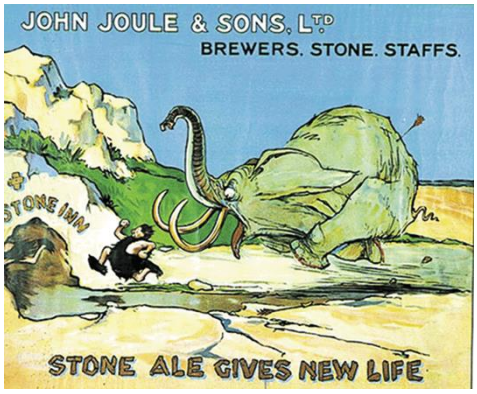


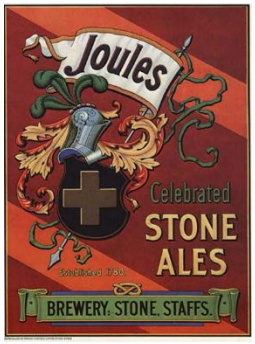


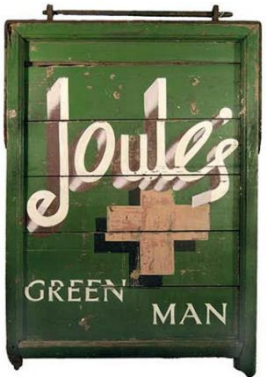




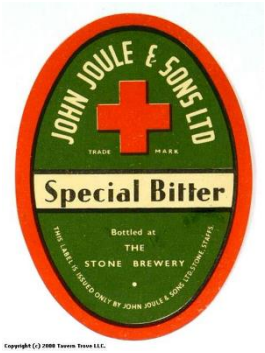






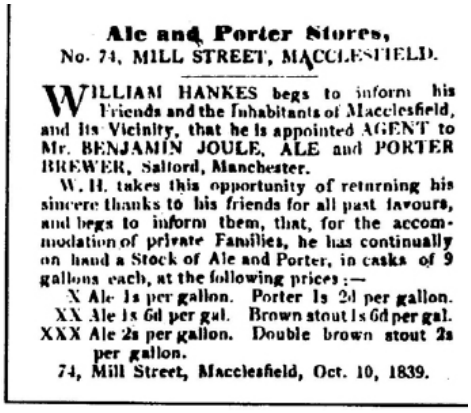








Around 1788, William Joule set up his brewery on New Bridge Street in Salford, England. **William** and his wife **Martha** had six children and all, but one died leaving **Benjamin** to run William Joule & Son brewery. In 1817, the brewery, which brewed ale and porter, became known as the Benjamin Joule brewery and on Christmas Eve, 1818 **James Prescott Joule** was ***born in the brewery*** to Benjamin and Alice Joule. James Joule, while a brewer too, became better known as one of the discoverers of the **First Law of Thermodynamics**.



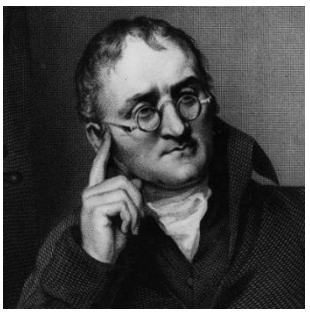
Ale and Porter Stores,
No. 74, MILL STREET, MACCLESFIELD.

WILLIAM HANKES begs to inform his Friends and the Inhabitants of Macclesfield, and its Vicinity, that he is appointed AGENT to Mr. BENJAMIN JOULE, ALE and PORTER BREWER, Salford, Manchester.

W. H. takes this opportunity of returning his sincere thanks to his friends for all past favours, and begs to inform them, that, for the accommodation of private Families, he has continually on hand a Stock of Ale and Porter, in casks of 9 gallons each, at the following prices;—

X Ale 1s per gallon. Porter 1s 2d per gallon.
XX Ale 1s 6d per gal. Brown stout 1s 6d per gal.
XXX Ale 2s per gallon. Double brown stout 2s per gallon.

74, Mill Street, Macclesfield, Oct. 10, 1839.



While James Joule was a teenager, he was fortunate to have **John Dalton**, who was **colorblind** and the founder of the **atomic theory**, as was one of his teachers. James Joule wrote, "*Dalton possessed a rare power of engaging the affections of his pupils for **scientific truth**; and it was from his instruction that I first formed a desire to increase my knowledge by original researches*."



George Harrison wrote the last verse to the song *Hurdy Gurdy Man* by **Donovan**:

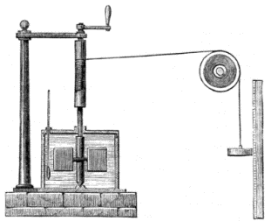
> *When the truth gets buried deep,*
> *beneath a thousand years of sleep,*
> *time demands a turn around,*
> *and once again the truth is found.*



James Joule was a **businessman** who ran the brewery every day from nine in the morning to six at night until the brewery was sold in 1854. He did; however, find time to do research before breakfast and in the evening.

James Joule wanted to quantify the relationship between motion and heat; that is, mechanical energy and thermal energy. He wrote in July 1843, "*I have lately proved experimentally that heat is evolved by the passage of water through narrow tubes. My apparatus consisted of a piston perforated by a number of small holes, working in a cylindrical glass jar containing about 7 lb. of water from a mechanical force capable of raising about 770 lb. to the height of one foot, a result which will be allowed to be very strongly confirmatory of our previous deductions. I shall lose no time in repeating and extending these experiments,*

being satisfied that ***the grand agents of nature are, by the Creator's fiat, indestructible; and that wherever mechanical force is expended, an exact equivalent of heat is always obtained***."





In order to obtain more **quantitative** results, Joule used a paddle wheel driven by **gravitational energy** to **heat** the water in a cylinder, and then he correlated the increase in the temperature of water with the energy used to turn the paddle wheel. Joule concluded, "1*st. That the quantity of heat produced by the friction of bodies, whether solid or liquid, is always proportional to the quantity of force expended. And, 2nd. That the quantity of heat capable of increasing the temperature of a pound of water (weighed in vacuo, and taken between 55º and 60º) by 1º Fahr. Requires for its evolution the expenditure of a mechanical force represented by the fall of 772 lb. through the space of one foot*."



Hermann von Helmholtz (1856) used James Joule's result to model the transformation of the sun's gravitational energy into thermal energy.

James Joule saw **conservation of energy** and the **First Law of Thermodynamics** as a way of seeing the **unity in the apparent diversity of causes and effects**. Not only did he ***not*** eliminate God from science with the law he helped found, but he saw the **First Law of Thermodynamics** as a manifestation of the will of God. James Joule wrote, "*Indeed the phenomena of nature, whether mechanical, chemical or vital, consist almost entirely in a continual conversion of attraction through space, living force* [kinetic energy] *and heat into one another….And though, as in the awful vision of Ezekiel, 'wheel may*

be in the middle of wheel', and everything may appear complicated and involved in the apparent confusion and intricacy of an almost endless variety of causes, effects, conversions, and arrangements, yet is the most perfect regularity preserved—the whole being governed by the sovereign will of God."

James Joule (1873) wrote, "*After the knowledge of, and obedience to, the will of God, the next aim must be to know something of His attributes of wisdom, power, and goodness as evidenced by His handiwork…. **It is evident that an acquaintance with natural laws means no less than an acquaintance with the mind of God therein expressed.***" Much of science relates the parts to the whole and it is ***not*** impossible that having such a wide view of the whole helps to make one a great scientist.

James Prescott Joule became famous as one of the discoverers of the **First Law of Thermodynamics**. The Joule family name also lives on in the brewing industry!



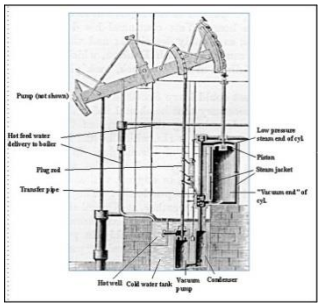


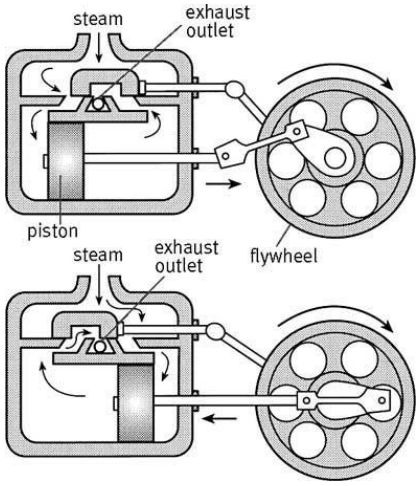


I will discuss Julius **Robert Mayer's** (1842) prior discovery of the First Law of Thermodynamics, when I discuss respiration.

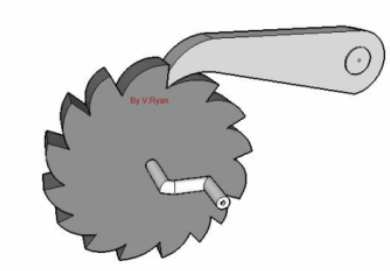


While Joule and Mayer studied the **transformation of gravitational or mechanical energy into thermal energy or heat**, **Sadi Carnot** (1824) studied the **motive power of heat**, which is the reverse process. **James Watt** patented the first **steam engine in** 1781 that could produce rotary motion to power looms, water pumps, ships, tractors, and locomotives. Sadi Carnot wanted to know how efficiently **steam engines** could transform the **energy of heat** into the **mechanical movement** of a piston. He realized that production of motive power in steam engines is due to the transportation of thermal energy from a warm body to a cold body and the greater the difference in temperature, the greater the motive force would be. The hot body causes the gas to **expand,** and the cold body causes the gas to **contract**. Alternating the expansion and contraction moves a piston that is connected to a wheel that can only rotate in one direction. The temperatures of the hot and cold bodies are T_2 and T_1, respectively. The efficiency of the Carnot engine driven by hot and cold bodies at T_2 and T_1 is:

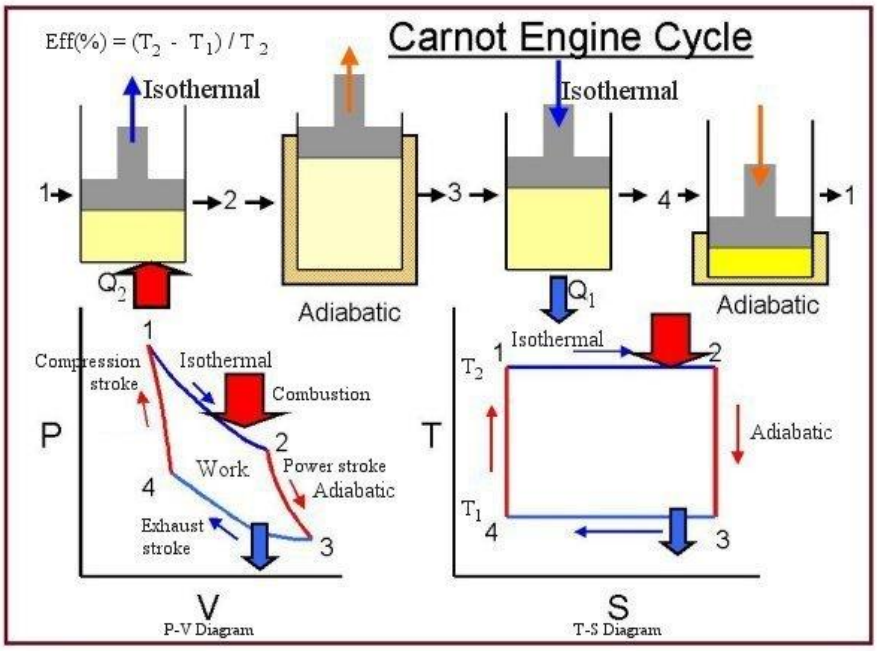


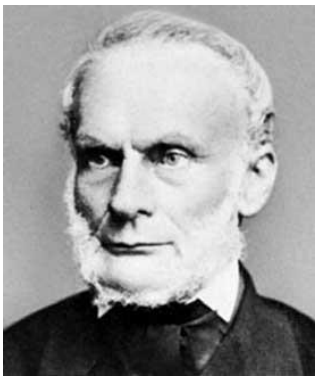


$$\text{Efficiency} = 100\% \left[\frac{T_2 - T_1}{T_2}\right] = 100\% \left[1 - \frac{T_1}{T_2}\right].$$

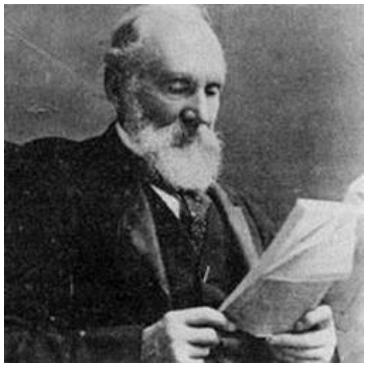


What are the conditions necessary to get an engine with 0% efficiency or with 100% efficiency and no energy lost as heat?





Around 1850, **Rudolf Clausius** and **Lord Kelvin** independently rediscovered Carnot's results and realized that the engine would only have one hundred percent efficiency if the cold body were at absolute zero. Consequently, they realized while **mechanical energy** could be ***completely*** converted into **thermal energy,** only a ***portion*** of the **thermal energy** could be converted into **mechanical energy**. Recognizing that the **complete reversibility** of energy transformations claimed by James Joule's First Law of Thermodynamics did not occur in nature, **Lord Kelvin** wrote, "...***if also the materialistic hypothesis of life were true, living creatures would grow backwards, with conscious knowledge of the future, but no memory of the past, and would come again unborn***. ***But the real phenomena of life infinitely transcend human science****; and speculation regarding consequences of their* ***imagined reversal*** *is*



utterly unprofitable. Far otherwise, however, it is in respect to the reversal of the motions of matter uninfluenced by life [i.e., the Carnot cycle], *a very elementary consideration of which leads to the full explanation of the theory of* ***dissipation of energy***." The **Second Law of Thermodynamics** was necessary not only to explain the **ubiquity** of **irreversibility** but even to explain the reversible Carnot cycle.

Lord Kelvin and **Rudolf Clausius** both articulated the **Second Law of Thermodynamics** that states that in any energy transformation, **useful energy** is **dissipated** or **degraded,** and **thermal energy** is generated in its place. **Thermal energy** is the product of **temperature** (K) and **entropy** (J/K), which comes from the Greek *η τρπή* meaning "in transformation." Therefore, **energy transformations** at constant temperature occur **spontaneously** and **passively** in the direction of **increased entropy** (which can be thought of generally as increased volume of matter or radiation). On the other hand, an **energy transformation** that **decreases entropy** is not spontaneous or passive but is **active** and **requires an input of energy**.

Lord Kelvin, like James Joule was not trying to eliminate God from science by creating a new **Law of Nature**. In fact, he felt the reverse, as he wrote to J. Helder on May 12, 1906, "*if you think strongly enough you will be forced by science to the belief in God, which is the foundation of all religion*."

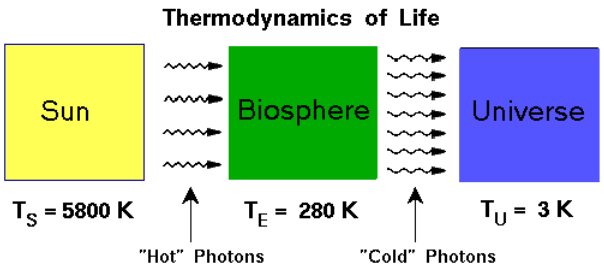


C. P. Snow (1961), both a writer and a physical chemist who studied the **photochemistry** of vitamins, lamented about the failure of education in *The Two Cultures and the Scientific Revolution*, "*A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought* ***highly educated***

and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: Have you read a work of Shakespeare's?"

I hope you can consider yourself to be highly educated people who could describe the Second Law of Thermodynamics. **Clausius** summarized the two laws of thermodynamics like so:

The energy of the universe is constant.
The entropy of the universe tends to a maximum.



Entropy is related to the **number** of entities. In terms of **photosynthesis**, in which sugar is synthesized, six molecules of carbon dioxide and six molecules of water have more entropy than one molecule of glucose and six molecules of oxygen. Therefore, in the following **photosynthetic reaction** where 12 molecules are reduced to 7, entropy decreases and the reaction will ***not*** be **passive** or **spontaneous**:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

The photosynthetic reaction will only occur if energy is added in the form of **radiant energy** (48*hv*):

$$6CO_2 + 6H_2O + 48hv \rightarrow C_6H_{12}O_6 + 6O_2 + \text{heat}$$

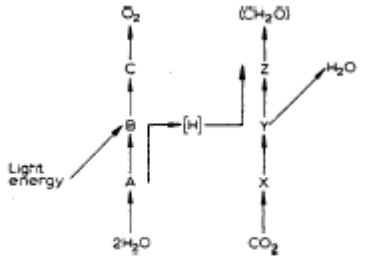
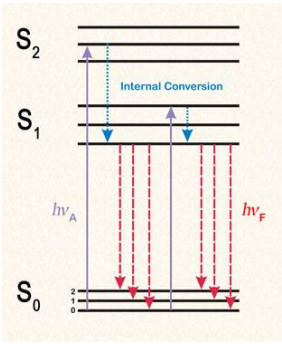


Fig.1. Elementary photosynthesis scheme.

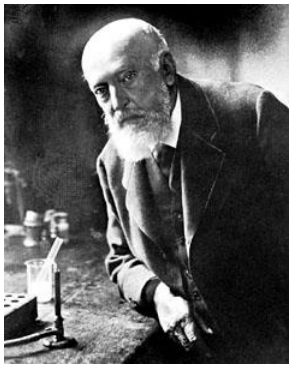
As I discussed last time, the **radiant energy** needed for this transformation is **absorbed** by **chlorophyll** in the **thylakoid membranes** which, in the **chloroplast**, results in **charge separation** of electrons (e^-) that reduce $NADP^+ + H^+$ to **NADPH** and the charge separation of protons (H^+) that result in the synthesis of **ATP** from ADP and Pi. The NADPH and ATP are used in the light-independent reactions to synthesize carbohydrates (sugars and starch). Some of the absorbed useful visible light energy is converted to **infrared heat energy** through **internal conversions.**

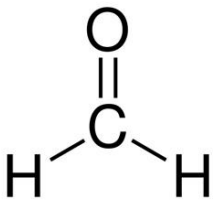


Burning one molecule of glucose releases 4.8×10^{-18} J of energy. The 48 photons of 680 nm light needed to synthesize one molecule of glucose have $48 \times 2.9 \times 10^{-19}$ J $= 1.4 \times 10^{-17}$ J of energy. What proportion of radiant energy is given off as heat? About 0.66 or 66%. Photosynthesis is about 34 percent efficient in terms of the radiation absorbed.

$$\text{Efficiency} = 100\% \left(\frac{48\frac{hc}{\lambda} - E_{glucose}}{48\frac{hc}{\lambda}}\right)$$

What is the mechanism that causes the formation of carbohydrate from CO_2? **Adolph von Baeyer** (1870) proposed that the carbohydrate formed by plants resulted from the direct light-mediated formation of formaldehyde (CH_2O), followed by the condensation of six formaldehydes to make sugar.

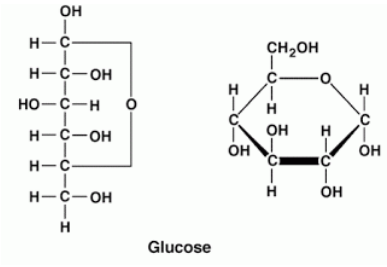




$$CO_2 + H_2O \longrightarrow HCHO + O_2$$

$$\times HCHO = (CH_2O) \times$$

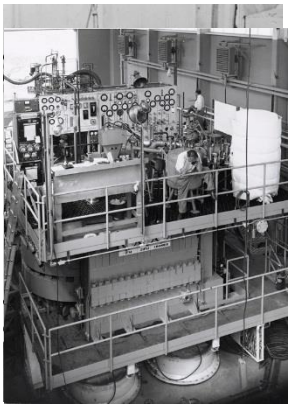
$$6(CH_2O) = C_6H_{12}O_6$$



We now know however that carbohydrate formation is the result of a light-independent **cyclic process** that takes place in the **stroma** of the **chloroplast**. The light-independent synthesis of carbohydrate involves the addition of a carbon dioxide to a five-carbon receptor molecule.



Using **radioactive $^{11}CO_2$**, which they made by bombarding boron ($_5B^{10}$) with deuterons ($_1D^2$) to yield $_6C^{11}$ and a neutron ($_0n^1$), **Samuel Ruben** and **Martin Kamen** (1939,1940) tried to **trace** the **pathway of carbon** in photosynthesizing barley plants and *Chlorella*, a single-celled alga that was more suited for quantitative experiments. They precipitated or centrifuged out the possible products of the photosynthetic reaction to see which molecules in the cells became radioactive first. Unfortunately, ^{11}C has a half-life of only 20 minutes, so much of the activity was gone by the time they could isolate the radioactive chemicals involved in carbon fixation. Harold Urey suggested that they make a biological tracer with a long half-life. In



1940, Samuel Ruben and Martin Kamen developed a method for producing large quantities of ^{14}C by bombarding ammonium nitrate with neutrons using the **cyclotron** in Ernest Lawrence's laboratory in order to trace the pathway of carbon and find the first products of photosynthesis. The ^{14}C they produced had a half-life of 5,730 years.

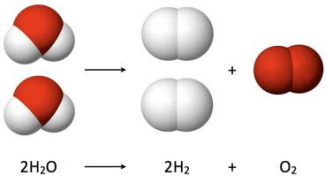
TABLE I

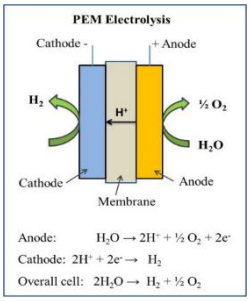
ISOTOPIC RATIO IN OXYGEN EVOLVED IN PHOTOSYNTHESIS BY *Chlorella*[a]

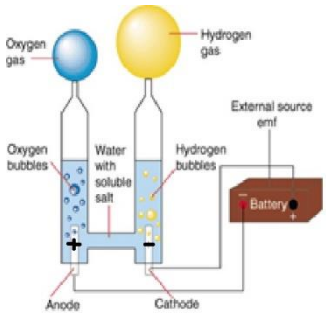
Expt.	Substrate	Time between dissolving $KHCO_3$ + K_2CO_3 and start of O_2 collection, minutes	Time at end of O_2 collection, minutes	Percent. O^{18} in H_2O	Percent. O^{18} in $HCO_3^- + CO_3^-$	Percent. O^{18} in O_2
1	0.09 *M*	0		0.85	0.20	..
	$KHCO_3$	45	110	.85	.41[b]	0.84
	+0.09 *M*	110	225	.85	.55[b]	.85
	K_2CO_3	225	350	.85	.61	.86
2	0.14 *M*	0		.20		..
	$KHCO_3$	40	110	.20	.50	.20
	+0.06 *M*	110	185	.20	.40	.20
	K_2CO_3					

While waiting for the chance to use ^{14}C to study carbon fixation in photosynthesis, Samuel Ruben, Merle Randall, Martin Kamen, and James Hyde used a **stable isotope of oxygen** (^{18}O) and a mass spectrometer to test whether oxygen evolved from $H_2{}^{18}O$ ***or*** $C^{18}O_2$ in **photosynthesizing *Chlorella*** cells. They found that the isotopic ratio ($^{18}O/^{16}O$) of the oxygen evolved was the same as the isotopic ratio of the oxygen in the water but different from the isotopic ratio of oxygen in the carbon dioxide. Thus, they concluded that oxygen evolution results from **the splitting of two water** molecules, which had been proposed by Cornelius van Niel (1935), and ***not*** from the splitting of carbon dioxide.

Demonstration: At the beginning of class I set up the demonstration of the First Law of Thermodynamics that we have seen before. This time I will also use the electrical energy of a battery to split water and show you how you can determine that the gases produced are hydrogen (it produces a very pale blue flame and pops when exposed to a lighted taper) and oxygen (causes a burning taper to burst into flame).







Sunday, **December 7, 1941**, the Japanese bombed Pearl Harbor and Ernest Lawrence's laboratory prepared to fight a war and any work that did not contribute to the war effort would be put on hold. This included Ruben and Kamen's work on photosynthesis using $^{14}CO_2$. Samuel Ruben began wartime research on **phosgene** ($COCl_2$), a poisonous gas and died September 28, 1943, in a lab accident with the poisonous gas. Phosgene had been discovered by John Davy in 1812 when he irradiated carbon monoxide and chlorine with **sunlight**. Phosgene ($COCl_2$) contains no phosphorous but gets its name from the method of production, which in Greek is *φως* for "light" and *γινομαι* "to produce".


SPECIAL War Edition

THE GETTYSBURG TIMES

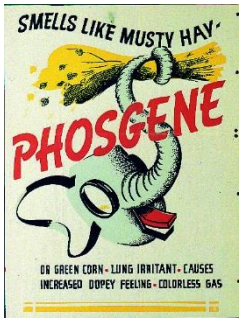
SPECIAL War Edition

Japan Attacks Pearl Harbor And Then Declares War on U. S.

Sea and Air Might Are Hurled Against England And U. S. by Japanese

Japan's Reply to U. S. Is Delivered 12 Minutes Before Bombing of Honolulu

Uncle Sam's Forces Are Fighting On Land, Sea And In Air To Halt Invasion Of Bases By Nipponese



As a part of his wartime activities, Martin Kamen occasionally went to **Oak Ridge National Laboratory** to do research on the enrichment of ^{235}U, which was necessary to build an atom bomb. Kamen knew but was not supposed to know that there was a neutron pile at





the **Clinton Works** in Oak Ridge. He asked **Charley Coryell** if it was possible to get some ^{24}Na for an experiment. After being escorted to a secret building a half hour away along a bumpy road in a car with closed blinds, Kamen received the radioactive sodium. When he opened the vial, he saw that it must be much more radioactive than anything he could have produced using the cyclotron since it **glowed purple**. He reasoned that the atomic reactor must produce a beam of millions more neutrons than the cyclotron could. Still in shock about the magnitude of radioactivity in the **glowing sample**, Martin Kamen told Ernest Lawrence about his realization. Ernest Lawrence seemed uninterested, but shortly afterwards an investigation was launched and concluded that Martin Kamen could not be trusted with classified information.

Martin Kamen realized that his **phone was tapped** and that his home on Buena Vista Way in Berkeley was being **watched by agents** who kept their cars running during a time of wartime rationing. Without revealing any secrets, Kamen reassured neighbors, including a woman seeking a divorce who thought the agents might have been detectives hired by her husband and a gay couple who worked for the civil defense and thought that ***they*** were not being spied on. Kamen believed that he had special troubles for security because he had "*such a wide circle of acquaintances and such varied social activities.*" He even socialized with "*leftist individuals and bons vivants*." He even went to benefits for the Anti-Fascist Refugee League and the Soviet-America Friendship Association.

When Martin Kamen, who was a son of a Russian immigrant, was at a party thrown by his friend **Isaac Stern**, the Russian-born violinist, to celebrate Isaac Stern's return from a USO tour, Kamen met the Russian consul and vice consul. **Gregory Kheifetz**, the vice consul asked Martin Kamen for help in contacting Ernest Lawrence's brother John to make an arrangement for treating an official in the Russian consulate in Seattle for leukemia. Martin Kamen contacted John Lawrence the next day.







APPETIZERS

COO-COO CLAM COCKTAIL (In Season)	1.00
COO-COO CLAMS, Half Shell (6) 1.00; (12)	1.95
BABY SHRIMP COCKTAIL	1.15
PRAWN COCKTAIL	1.25
CRAB MEAT COCKTAIL	1.25
CRAB LEG COCKTAIL	1.50
EASTERN OYSTER COCKTAIL	1.35
KING NEPTUNE JUMBO SEAFOOD COCKTAIL	2.50
EASTERN OYSTERS (6), On Shell	2.25
CRACKED CRAB . Whole 3.25; Half	1.75

NOW IN SEASON

SOUPS

	Bowl	Cup
OUR FAMOUS CLAM CHOWDER	.50	.35
CREAM STYLE CLAM CHOWDER	.50	.35
MOCK TURTLE SOUP	.50	.35
CLAM BROTH	.50	.35
CRAB GUMBO LOUISIANA	.50	.35

BREAD AND BUTTER SERVED WITHOUT ENTREE 15c

SALADS

"PIECES OF EIGHT" SALAD	3.10
Timbale of lobster, crab legs, shrimps, sliced avocado and tomato. Roquefort dressing. So different!	
DINNER SALAD	.50
MIXED GREENS IN BOWL	.75
WITH SHRIMP	1.50
WITH CRAB MEAT	1.75
CRAB, SHRIMP, or PRAWN LOUIE	2.35
FRUIT AND COTTAGE CHEESE	1.50
TOMATO, Filled with CRAB or SHRIMP	1.75
AVOCADO WITH CRAB or SHRIMP	2.00
HEARTS OF ROMAINE, Anchovy Strips	.95

OUR FAMOUS DE LUXE
COLD SEAFOOD PLATTER
A potpourri of delicacies from the sea and shore. Cold whole lobster, shrimps, crab legs, clams or oysters on the half shell. Served with special dressing.
GROTTO CHOWDER BEVERAGE
Service for Two $8.50

BLUE CHEESE DRESSING 25c EXTRA

VEGETABLE DU JOUR .45

Bernstein's Complete
GROTTO DINNERS
Choice of One:
Shrimp Cocktail
Grotto Clam Chowder
Mixed Green Dinner Salad
Blue Cheese Dressing 15c Extra

ENTREES

BAKED SEA BASS, ITALIENNE	3.15
REX SOLE or SAND DABS	3.15
GOLDEN FILET OF SOLE	2.95
ABALONE STEAK DORE	3.75
GOLDEN PRAWNS	3.50
DEEP FRIED SCALLOPS	3.35

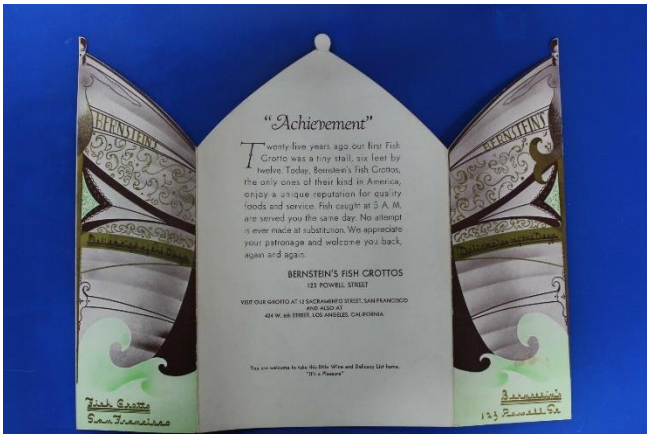
ICE CREAM or SHERBET
COFFEE TEA MILK

Specialties

CIOPPINO or BOUILLABAISSE	3.95
Lobster tail, Clams, Crab, Halibut and Salmon.	
STUFFED LOBSTER PRINCESS	4.65
COO-COO CLAMS, Steamed, Bordelaise	2.45
OYSTERS KIRKPATRICK	2.95
DEVIL CRAB	2.75
Baked in scallop shell! Served with bordure potatoes.	
BARBECUED COO-COO CLAMS	2.35
Served in shell with Bernstein's famous Penquin sauce.	
OYSTERS ROCKEFELLER	2.95
BONED SAND DABS, Saute Meuniere	2.45
BARBECUED PRAWNS, Penquin Sauce	2.50

Gregory Kheifetz (right) called Kamen to let him know that John Lawrence had contacted him and that he would like to take Martin Kamen out for dinner to thank him before he had to return to Russia. Kamen, Kheifetz, and his successor had dinner at **Bernstein's Fish Grotto**. But because Martin Kamen was under suspicion of being a security risk, FBI agents observed the dinner and Kamen was **fired** by the University of California at Berkeley and all academic positions were closed to him. G-2 was building a dossier on Martin Kamen that included innuendos of moral turpitude and leftist associations.

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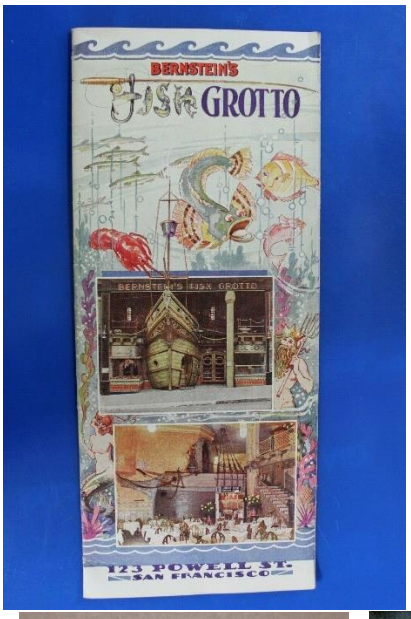
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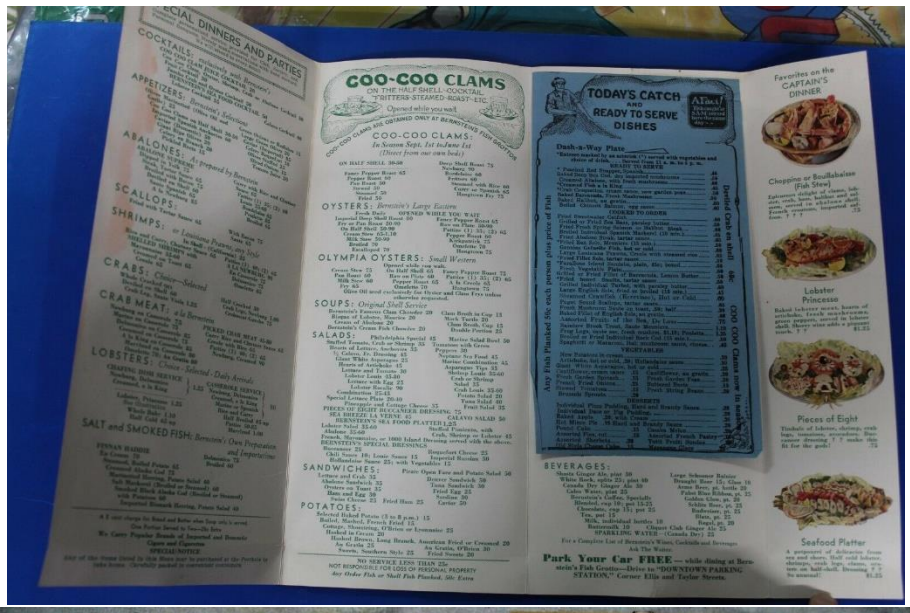
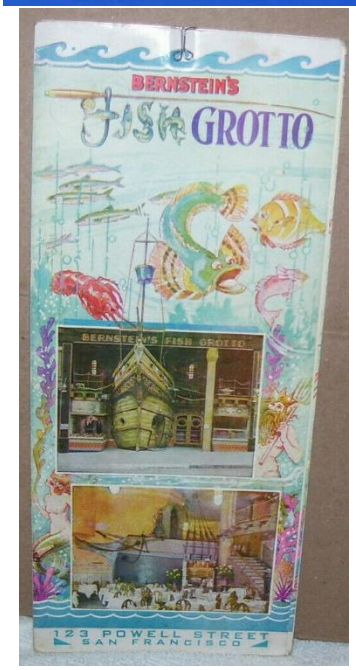

COCKTAILS:
APPETIZERS:
ABALONES:
SCALLOPS:
SHRIMPS:
CRABS:
CRAB MEAT:
LOBSTERS:
SALT and SMOKED FISH:
COO-COO CLAMS
ON THE HALF SHELL—COCKTAIL
"BITTERS-STEAMED-ROAST"-ETC.
Opened while you wait
COO-COO CLAMS:
OYSTERS:
OLYMPIA OYSTERS:
SOUPS:
SALADS:
SANDWICHES:
POTATOES:
TODAY'S CATCH
AND
READY TO SERVE
DISHES
Dash-a-Way Plate
BEVERAGES:
Park Your Car FREE
Favorites on the CAPTAIN'S DINNER
Chopping or Bouillabaisse (Fish Stew)
Lobster Princesso
Pieces of Eight
Seafood Platter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ENJOY A COCKTAIL BEFORE YOUR DINNER
MANHATTAN, MARTINI OR AN OLD FASHION 50c
OUR SPECIAL DINNERS
SERVED FROM 4:30 P.M. TO 8:30 P.M.
BERNSTEIN'S SPECIAL SALAD OF THE DAY
A TRULY GREAT BERNSTEIN VALUE
FRESHLY CAUGHT BROOK TROUT
Served Saute Meuniere
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$1.50
TODAY'S CATCH
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DISHES
SEA FOOD COCKTAILS AND APPETIZERS
SOUPS
COOKED TO ORDER
VEGETABLES IN SEASON
POTATOES
Coo-Coo Clams
Coo-coo Clam Broth
or
Coo-coo Clam Chowder
COO-COO CLAMS, STEAMED, FRIED
or IN THE HALF SHELL
Shoestring Potatoes
$1.50
FROM THE
Chef's Galley
EPICURE'S DELIGHT
DESSERTS AND FRUIT IN SEASON
CHEESE
BEVERAGES
Favorites on the CAPTAIN'S DINNER

Martin Kamen could not get a job in academia or industry. It turned out that military intelligence had placed his name on a "*master list of **unemployables** for the information of possible employers*." Even Linus Pauling and James Franck could not help him get a job. He finally did get a job as a welding inspector at the Kaiser shipyard in Richmond, California.



In 1945, with help from Arthur Compton and with a good recommendation from Ernest Lawrence, Martin Kamen became a professor of biochemistry at Washington University in St. Louis. Unfortunately, the FBI inherited from the military intelligence, the security file on Martin Kamen. In 1947, his passport was confiscated and in 1948, he was summoned to testify by the **House Un-American Activities Committee** (HUAC) chaired by **Representative J. Parnell Thomas** regarding the possibility that he had leaked atomic secrets to the Russians. Martin Kamen was questioned about the **Bernstein Fish Grotto dinner**. He was cleared by the HUAC on September 1948 but only got his passport back from the State Department on July 8, 1955, following his lawsuit against the Secretary of State, John Foster Dulles.

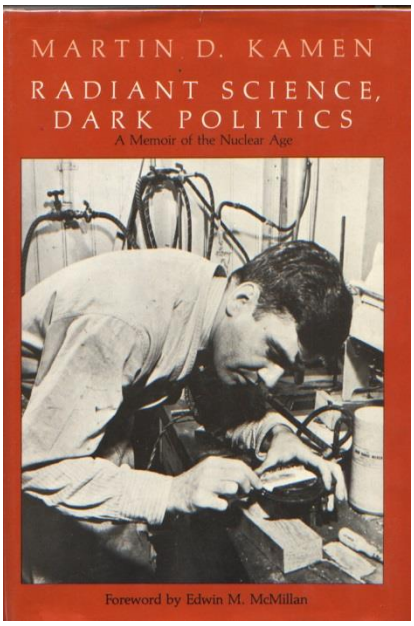


Cartoon by Dan Bishop in the *St. Louis Star-Times*, September 4, 1948.
Radiant Science, Dark Politics.

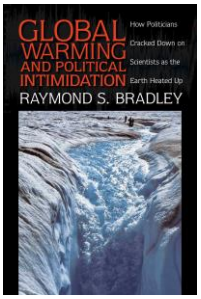


On the other hand, Rep. **J. Parnell Thomas** was **convicted of fraud**, served nine months in a federal penitentiary and resigned from Congress. Martin Kamen (1985) chronicled his life in ***Radiant Science, Dark Politics***. George B. Kauffman (1986) wrote, "*From the pages of this*

*book Kamen emerges as a **Mensch**-a multidimensional human being whose only "crime" was his gregariousness. It is not only a scientific document but also a tribute to the human spirit in its depiction of Kamen's triumph over adversity. It reads like a "Who's Who" in nuclear science and music, and it abounds with incisive character sketches of Kamen's scientific acquaintances. More than 200, including no less than 18 Nobel laureates, are mentioned, and an entire chapter is devoted to E. O. Lawrence and J. Robert Oppenheimer. As a cautionary tale, it recalls a shameful period in American history when political expediency aroused the anti-intellectualism latent in our society and an hysterical tide of anti-Communism swept the nation. For those too young to have experienced the McCarthy era and the early days of the Cold War, it will engender disbelief that such character assassinations of scientists on the basis of outright lies or the flimsiest of evidence could have been tolerated in a democracy.*"



Human nature is human nature and today, politics and science still make strange bedfellows:



In 1996, Martin Kamen won the **Enrico Fermi Award** given by the United States Department of Energy in recognition of lifetime achievements in energy research. According to the Department of Energy, "*During the war years Kamen's liberal ideas and outgoing personality caused him to be watched by government security, including the F.B.I. In 1944, he was declared security risk and dismissed from the Berkeley Radiation Lab. A few years later he was called before the House Un-American Activities Committee. Kamen fought in the courts for over*

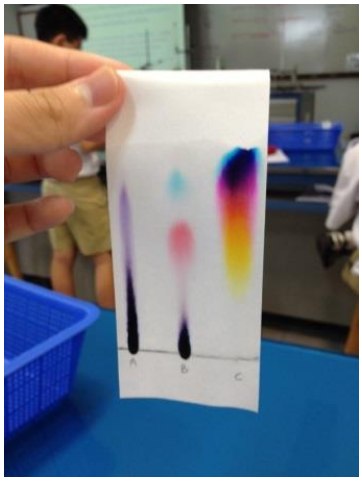


ten years to clear his name and to regain his passport, which had been denied whenever he had been invited to attend scientific meetings abroad."
http://science.energy.gov/fermi/award-laureates/1990s/kamen/

I have been teaching you that **science is a human endeavor** that involves the positive aspects and the negative aspects of being human. It also involves the positive and negative aspects of government, another human endeavor. Once Martin Kamen was eliminated from his research on photosynthesis, there was room for someone else to step in.



In 1945, Ernest Lawrence asked **Melvin Calvin**, who apparently had the "correct" political views, to continue the project initiated by Samuel Ruben and Martin Kamen. Calvin and his colleagues combined the **investigative power of ^{14}C** and the use of *Chlorella* a single-celled alga that could be easily cultivated and rapidly labeled with $^{14}CO_2$ with the newly developed technique of **paper chromatography** invented in 1944, in order to identify the first products of photosynthesis.

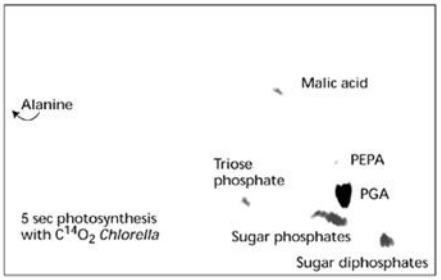


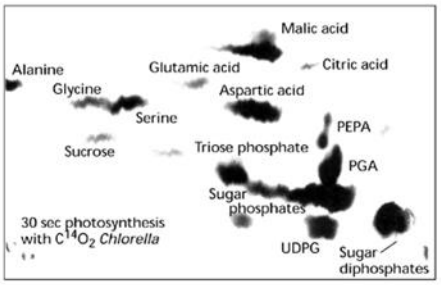
Paper chromatography had been invented to separate the amino acids in protein hydrolysates. It works by the same principle that a drop of ink on filter paper separates into a red, green, and blue band. On a paper chromatogram, each compound moves in a given solvent in a manner that depends on the affinity of the molecule for the polar water absorbed to the cellulose in the paper compared to the nonpolar solvent.

The photosynthetic reaction could be stopped rapidly by dropping the *Chlorella* cells in **boiling methanol**, which both killed the cells and extracted the products of photosynthesis.



The **extracts** were loaded onto a paper chromatogram. In this way, the products can be compared to authentic standards. It can also be determined if the products were phosphorylated by treating the extract chemically or enzymatically to remove the phosphate and seeing how they move on the chromatogram. In this way, Calvin and his colleagues discovered that **within 5 seconds**, 3-phosphoglyceric acid was labeled, and suggested that there was a **two-carbon acceptor for** CO_2. However, as soon as they **increased the temporal resolution** of their assay, they **guessed** that the first product labeled was a six-carbon molecule formed from the joining of CO_2 to a **five-carbon molecule known as ribulose bisphosphate (RuBP)**.





By following the position of the ^{14}C in the various products over time and analyzing the energetics of each step, Calvin and his colleagues came up with the complete pathway of the photosynthetic carbon-reduction cycle, which is known universally as the **Calvin cycle**.

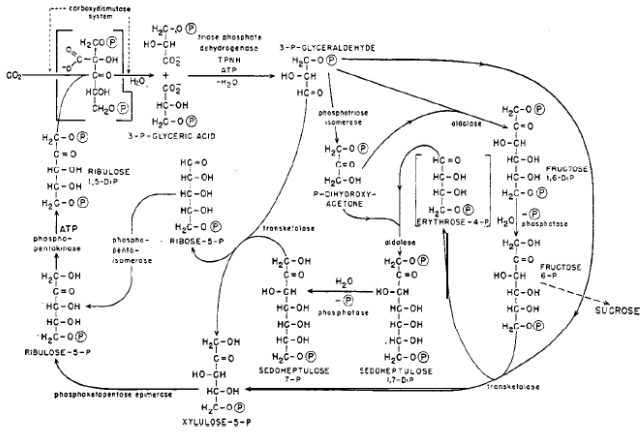
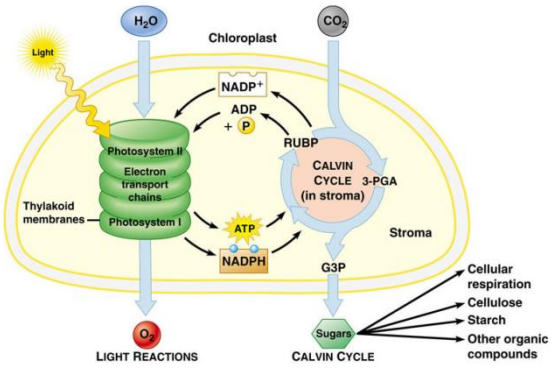


Fig. 18. The photosynthetic carbon cycle.



The ***NADPH*** formed in the light reactions is a **reducing agent** that **transfers the electrons (and protons)** necessary to reduce the CO_2 into energy-rich carbohydrate ($C(H_2O)$) in the light-independent reactions. The **ATP** is used as an **energy source** in the light-independent reactions to drive the Calvin cycle and regenerate the CO_2 receptor (RUBP). The sugar that is produced during photosynthesis is used by most organisms as an energy source and as a carbon source for synthesizing other carbohydrates, proteins, nucleic acids, lipids, and waxes. (Note that 1 Calorie = 4184 Joules).



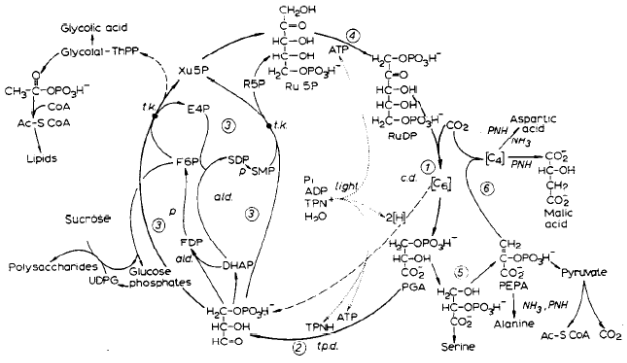
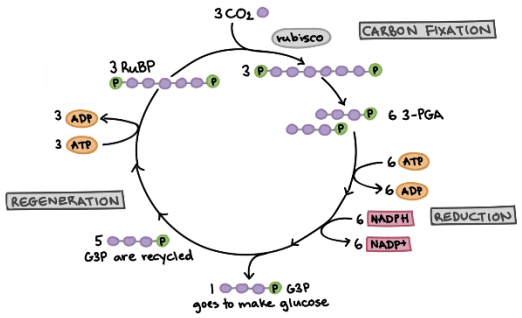
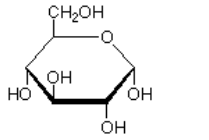


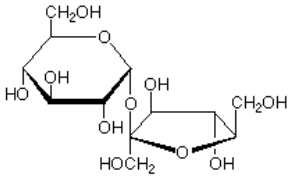
Fig. 20. The photosynthetic carbon cycle and its relation to quantum conversion and to succeeding biosynthesis.



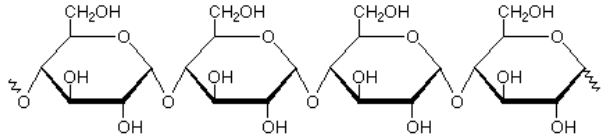
Carbohydrates (4 Calories/gram):



monosaccharide (glucose)

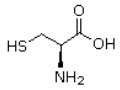
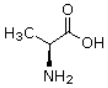
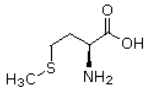
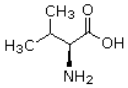
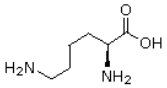
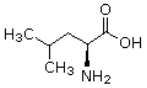
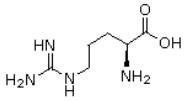
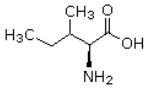
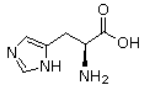
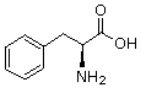
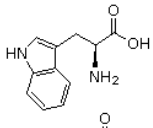
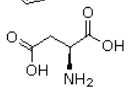
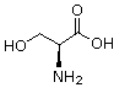
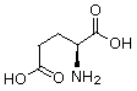
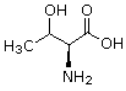
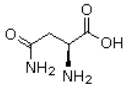
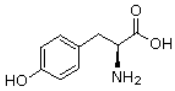
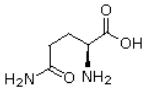


disaccharide (sucrose)

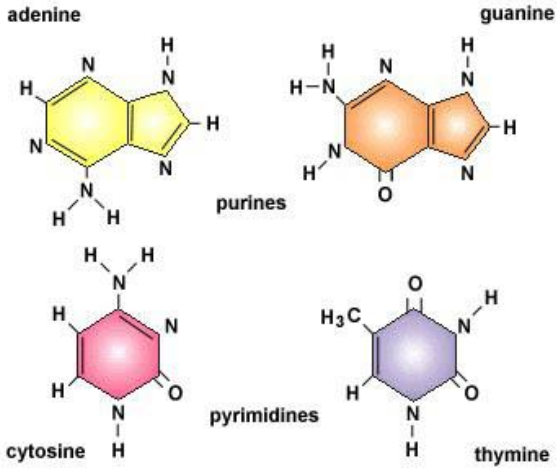


polysaccharide (amylose starch)

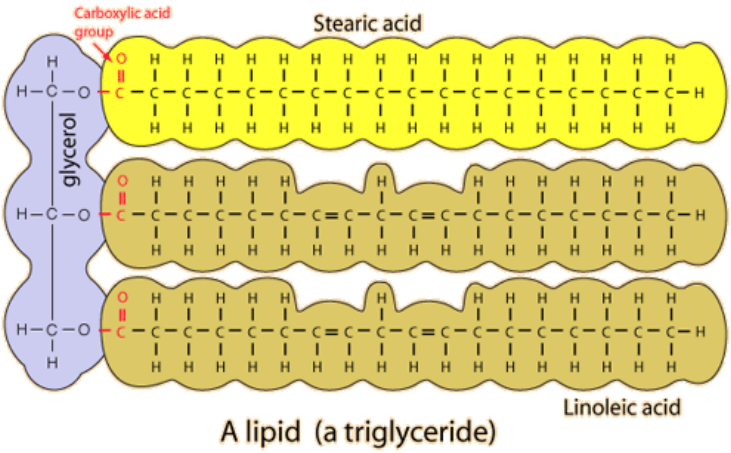
Amino acids (protein components; 4 Calories/gram):

Name	Formula	Abbreviations		Name	Formula	Abbreviations	
Glycine		Gly	G	Cysteine		Cys	C
Alanine		Ala	A	Methionine		Met	M
Valine		Val	V	Lysine		Lys	K
Leucine		Leu	L	Arginine		Arg	R
Isoleucine		Ile	I	Histidine		His	H
Phenylalanine		Phe	F	Tryptophan		Trp	W
Proline		Pro	P	Aspartic Acid		Asp	D
Serine		Ser	S	Glutamic Acid		Glu	E
Threonine		Thr	T	Asparagine		Asn	N
Tyrosine		Tyr	Y	Glutamine		Gln	Q

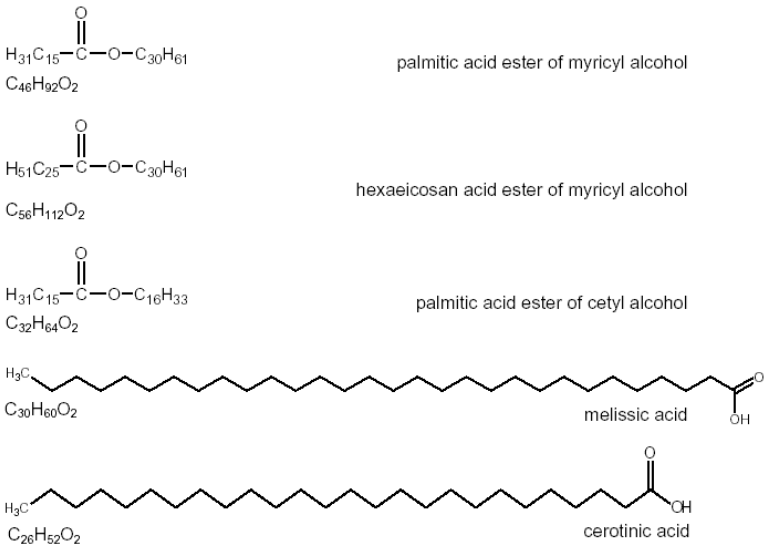
Nucleic acids components:



Lipids (9 Calories/gram):



Waxes:



Note the type of molecules that have the highest density of CH bonds. These are the hydrocarbons, including the lipids and the waxes. They will take the most energy to make, they will store the most energy, and they will make available the most energy. We will discuss them specifically in the next lecture on the chemical history of a candle.

The enzyme that is involved in the attachment of CO_2 to RuBP, resulting in the fixation of CO_2 is known as ribulose bisphosphate carboxylase/oxygenase or **Rubisco** for short. Rubisco is an **extremely slow enzyme** that performs about **three** carboxylations per second. **Typical enzymes** perform between **thousands** and **millions of reactions per second**. In order to compensate for this inefficiency, Rubisco is an abundant protein and represents 25-75 percent of the leaf protein. It is the most abundant protein on earth and thankfully, its inefficiency makes plants protein-rich and nutritious to eat.



Melvin Calvin won the **Nobel Prize in Chemistry** in 1961 for elucidating the path of carbon in photosynthesis, more commonly known as the **Calvin cycle**. Perhaps if the country were not on a witch hunt at that time, Martin Kamen would have won two Nobel Prizes—one for the invention of the method to make ^{14}C and the other for elucidating the path of carbon in photosynthesis. A *nearly* Kamen-less oral history of the Calvin group has been published. It does state that Calvin "*did not like very much (Martin) Kamen*."
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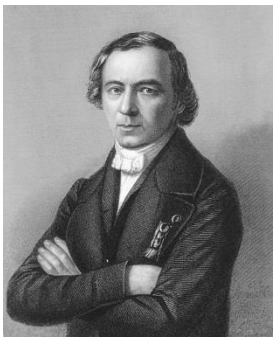
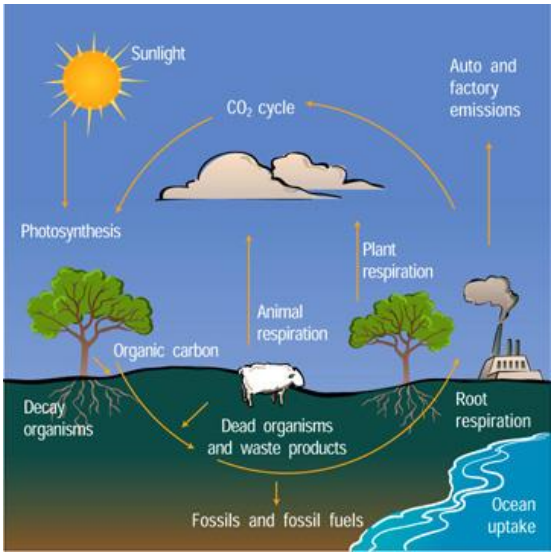
https://archive.org/details/thecalvinlaboral02moserich/page/n5/mode/2up



The **biotic carbon cycle** was understood by chemists in the mid-19th century. **Jean-Baptiste Dumas** wrote, "*... green plants constitute the great laboratory of organic chemistry. It is they which, with carbon, hydrogen, nitrogen, and ammonium oxide, slowly build the most complex organic materials. They received from the solar rays, in the form of heat or chemical radiation, the power needed for this work. Animals assimilate or absorb the organic materials made by plants. They change them bit by bit. ... They therefore decompose bit by bit these organic materials created by plants; they bring them back bit by bit toward the state of carbonic acid, of water, of nitrogen, of ammonia, the state that permits them to be restored in the air.*"



T. H. Huxley (1893) described the cycle by means of a sociological metaphor: "*Thus the plant is the ideal prolétaire of the living world, the worker who produces; the animal, the ideal aristocrat, who mostly occupies himself in consuming*."



Next, we will talk about how candles and cells combust the carbohydrates and hydrocarbons consistent with the **First and Second Laws of Thermodynamics** to yield light and the energy for life.

James Joule discovered the first law of thermodynamics in the basement of a brewery that fermented the starch—a product of photosynthesis, stored in **barley** seeds. In one respect, all beers are light beers! Fermenting glucose or **grape** sugar—also a product of photosynthesis results in the production of wine. Wine too, is captured light. The next time you drink a glass of wine, remember what Dante (*Purgatorio* 30:77) wrote,





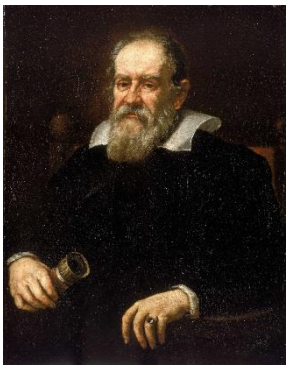
Behold the Sun's heat which becometh wine
Joined to the juice that from the vine distils.

And what Francesco Redi (*Bacco in Toscana*) wrote,



That blood so fine is a kindled ray
From the Sun, in heaven set,
Entangled and held a prey
By clustering grapes in their net.

And what Lorenzo Magalotti (1721; *Lettere Scientifiche ed Erudite*; Letters II and V) tells us what his friend Galileo believed:



Wine is a mixture of sap and of light.

According to Benjamin Franklin (1779), "[w]*e hear of the conversion of water into wine at the marriage in Cana as of a miracle. But this*

conversion is, through the goodness of God, made every day before our eyes. Behold the rain which descends from heaven upon our vineyards; there it enters the roots of the vines, to be changed into wine; a constant proof that God loves us, and loves to see us happy. The miracle in question was only performed to hasten the operation, under circumstances of present necessity, which required it."

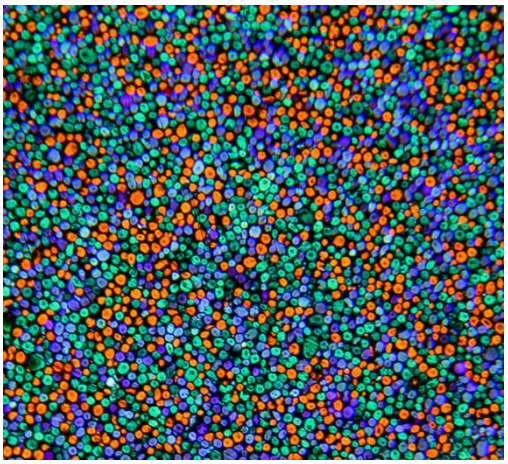


Starch, a carbohydrate formed in **chloroplasts** in the photosynthetic green part of plants or in **amyloplasts**, a type of non-green plastid found in the non-green parts of plants has been put to use in a very clever way by **Auguste and Louis Lumière** in 1904 to show the relation between light and life to make photographic images of plants, animals, people, and medical conditions. The technique is known as the **autochrome** process.

The New Lumiere Process of Color Photography by Dr. M. L. Hiedingsfeld (The Lancet-clinic (1908) v. 99, p. 785). *It affords me great interest this evening to present the latest scientific triumph in clinical and pathological photography, namely, the new Lumiere process of color photography. The first slide which I wish to present is a photograph of a variegated bouquet of flowers, which*





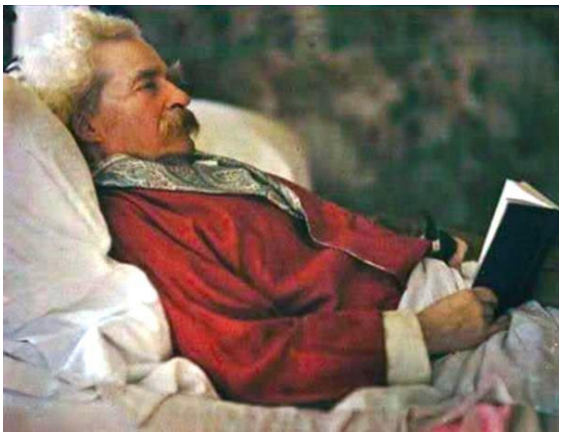


was taken with an indoor exposure of one minute, and which faithfully reproduces every variation in the shade of the original flowers; also one or two clinical photographs of patients taken under the same conditions, in which the color value of the skin lesions are also faithfully reproduced. The autochrome plates by this new process of color photography have made colored photography successful after experimentation at the hands ot numerous investigators, covering a period of almost twenty years. The process is exceedingly simple. The plate is first coated with starch granules, representing the three primary colors, orange, violet and green, and then coated with sensitized silver, the same as the ordinary photographic plate. The color value of any object which is photographed is reproduced on the plate by the fact that only that ray reaches the silver through the corresponding primary color or combination of primary colors which is interposed between it and the sensitized silver. After the plate is developed the sensitized silver will only allow the corresponding light to be returned through the plate which will bring out the same colors from the combination of starch granules which primarily reached the sensitized silver. The color value, therefore, is an absolutely accurate and perfect one, and the process will be invaluable for the preservation of faithful color records of pathological specimens and certain clinical conditions. It will also prove invaluable in color microphotography, and I herewith take pleasure in showing some microphotographs which are faithful reproductions in color value of the objects photographed. The process has one serious objection, and that is that the starch granules which carry the color in the autochrome plates are more or less opaque in character and interfere materially with the sharpness and definition of the photographic image. If these granules can be replaced with some translucent

substance like gelatine it will be come a highly perfected art and hold a correspondingly valuable and indispensable place in our clinical and laboratory methods.

Note that the plate was processed into a positive transparency. This is done by first developing it into a negative. Then the silver that formed the negative image is removed chemically. Then the remaining silver halide is exposed to light and developed to produce a positive image.

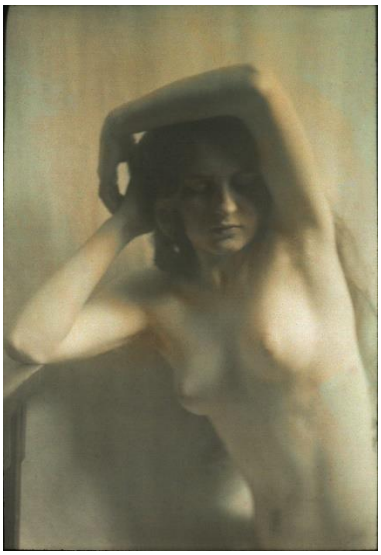
The **autochrome** process was incredible. Alfred Stieglitz wrote, "*The possibilities of the new process seem to be unlimited… soon the world will be color-mad, and Lumière will be responsible*."

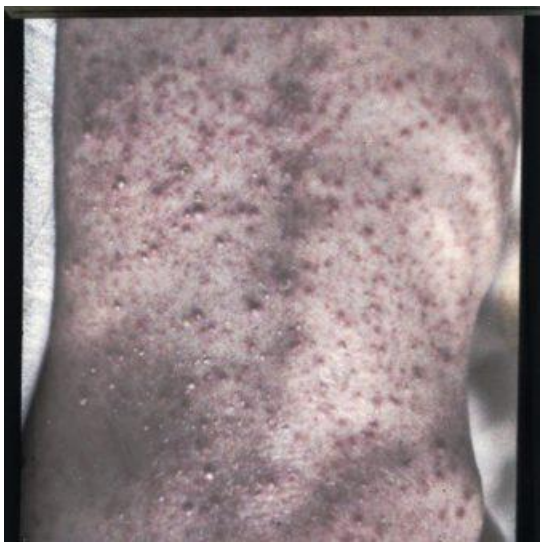




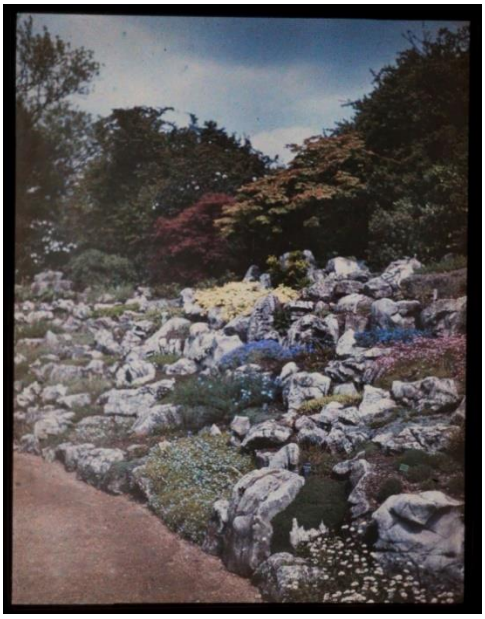






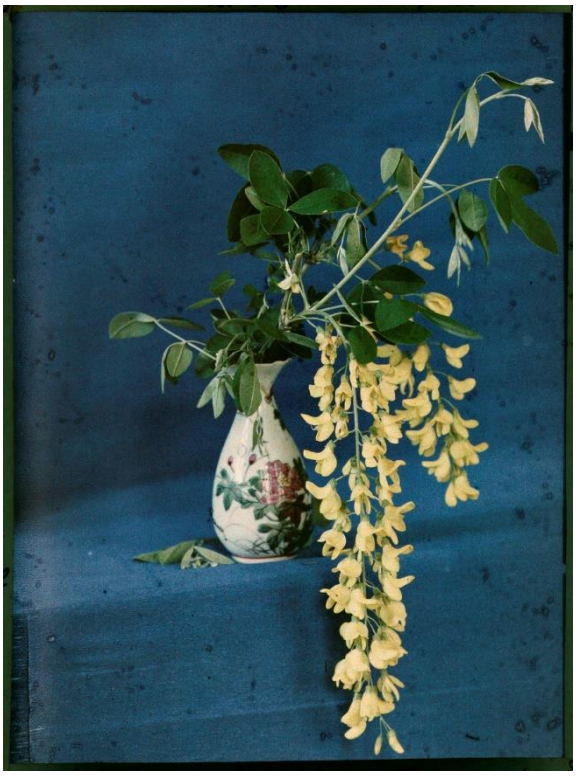














Here is a picture of an autochrome viewer:



http://www.luminous-lint.com/__phv_app.php?/f/_autochrome_examples_01/

https://dtculturalheritage.com/preserving-the-national-geographic-societys-autochrome-collection/

https://www.npr.org/sections/pictureshow/2010/05/25/127112999/autochromes

https://birdinflight.com/inspiration/experience/20200221-o-gorman.html

http://home.bway.net/jscruggs/auto.html

https://blog.scienceandmediamuseum.org.uk/autochromes-the-dawn-of-colour-photography/

https://books.google.com/books?id=8g8CAAAAYAAJ&pg=PA785&dq=Autochrome+Lumi%C3%A8re+orange+green+violet#v=onepage&q=Autochrome%20Lumi%C3%A8re%20orange%20green%20violet&f=false

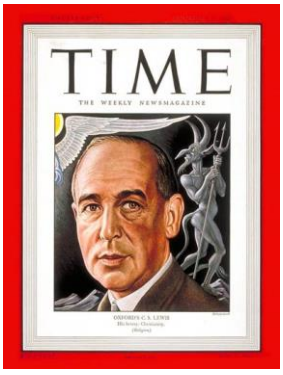
http://theimageworks.com/pdf/100years.pdf

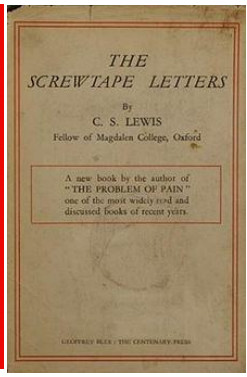
https://www.antiq-photo.com/en/collections/page/157/

http://www.earlyphotography.co.uk/site/entry_F76.html

https://www.europeana.eu/portal/en/explore/galleries/autochrome







Remember how the Deltas in **Aldous Huxley**'s (1932) *Brave New World* were behaviorally modified to hate books and nature? How often do you **read a book** for enjoyment and **take a walk through nature** during the day, enjoying the **sunlight** and its effects and using your **photopic** vision, or take a walk at night looking at the moon, stars, and planets with your photopic vision and the objects they illuminate with your **scotopic** vision? I hope that *Light and Life* **encourages** (puts in your heart) you to do just that! In The *Screwtape Letters*, **C. S. Lewis** (1942) warned against any activities in the battle between good and evil that **discourage** (take away from your heart) you from doing these two things:

My dear Wormwood,

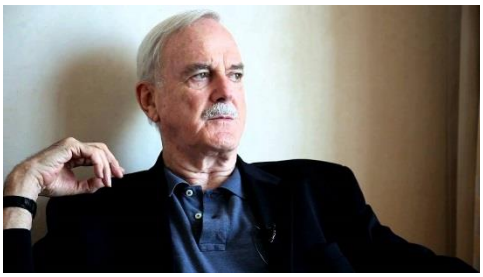
"*...And now for your blunders. On your own showing you first of all allowed the patient to read a book he really enjoyed, because he enjoyed it and not in order to make clever remarks about it to his new friends. In the second place, you allowed him to walk down to the old mill and have tea there—a walk through country he really likes, and taken alone. In other words you allowed him two real positive Pleasures. Were you so ignorant as not to see the danger of this?*

...How can you have failed to see that a real pleasure was the last thing you ought to have let him meet? Didn't you foresee that it would just kill by contrast all the trumpery which you have been so laboriously teaching him to value? And ***that the sort of pleasure which the book and the walk gave him was the most dangerous of all****? That it would peel off from his sensibility the kind of crust you have been forming on it....*

..The man who truly and disinterestedly enjoys any one thing in the world, for its own sake, and without caring twopence what other people say about it, is by that very fact fore-armed against some of our subtlest modes of attack. You should always try to make the patient abandon the people or food or books he really likes in favour of the "best" people, the "right" food, the "important" books. I have known a human defended from strong temptations to social ambition by a still stronger taste for tripe and onions....

Your affectionate uncle Screwtape"

You can hear John Cleese, the Provost's Visiting Professor and former A. D. White Professor-at-Large reading Letter 13 of *The Screwtape Letters*



https://www.youtube.com/watch?v=t8gWEZ1xJkY&list=PLA8BAC9375345E6C7&index=13

I am transcribing a handwritten notes on "The aims of science and true spirit of research". This may be a draft of Joule's presidential dress to the British Association meeting, Bradford 1873, which was not delivered due to Joule's ill-

health. The Aims of Science by James Joule gives us some insight to one of the discoverers of the first law of thermodynamics. I have only gotten this far so far:



"*The examination of the works of the Almighty is a source of pure delight to every man whose mind has not been debased. He loves to behold the beauty and order of nature and his intellectual faculties are occupied by and endeavor to obtain a more intimate acquaintance with the wonders of the creation. In this view natural philosophy may be considered second in importance to religion only; for surely after the knowledge of, and obedience to, the will of God, the next aim must be to know something of his attributes of wisdom, power, and goodness as evidenced by his handiwork.*

From the beginning intelligent minds have been thus occupied. When the cornerstone of the earth was laid the morning stars all sang together and all the sons of God shouted for joy. And although it is not given to mortals to know or to enjoy as do those exalted beings yet it is our high privilege to learn by patient search and so to acquire a body of truth perpetually increasing both in quantity and in kind and bringing us nearer and nearer to the fountain of all light.

He may therefore affirm that the study of nature and her laws is essentially a holy undertaking. Bearing this in mind we shall have no difficulty in showing the spirit in which it should be pursued, the great objects it has in view and its great importance and even absolute necessity in the education of youth.

One of the chief characteristics of the spirit in which science should be pursued is a love of the wisdom which it unfolds, a love of truth for its own sake independently of a regard to the advantages of whatever kind which are expected to be derived from it. The very name philosophy [love of wisdom] shows that this feeling has always been considered the leading one. The pleasure experienced in

contemplating the beautiful the harmonious the beneficent and the peace naturally produces love and this naturally leads us to seek a more intimate acquaintance with those beloved objects. Then there should be a certain inquisitiveness of mind to know that which is already unknown, a principle which is one of the most important that belongs to our nature and is in fact the philosophical cause which reconciles us to life which would be miserable indeed if it presented merely the recurrence of the same objects, and gave no hope of varied and fresh enjoyment. A third great requirement of him who pursues natural science is humility. Other acquirement may be compatible with pride of heart, to some it may be an essential qualification. A certain routine may be attained by pride, nay its votaries may be the most successful in obtaining wealth and honorable distinctions. But science will have none such. The state of mind of a proud man is wholly inimical to the success in the pursuit of truth, and invariably leads to the dark paths of error. In studying the works of nature a man should commence with the sentiment of his ignorance, that he knows nothing and has everything to learn, he ought to have modesty in stating his opinions and be always ready to modify or even to retract them. All this is odious to a proud man. He approaches the subject with his preconceived and worthless hypothesis, he proceeds to the profane attempt to twist and distort the laws of nature to adapt them to his hypothesis, he ends by accumulating a ---- of pretended facts and fallacious theories. Thus a humble and teachable spirit are necessary to everyone who wishes to pursue truth successfully. Other characteristics are diligence, effort, patience, these which are requisite for success in any walk of life and no less in that we are now considering. These latter receive a healthy stimulus from a well regulated love of approbation, and the high hope of success.

The great object which natural science has in view is to elevate man in the scale of intellectual creature by the exercise of the higher faculties of his nature in

developing the wonders of the glorious creation. The second and subsidiary object is to promote the well being and comfort of mankind & to increase his-----. These objects are done by ---- and should not be separated. The benefit to be attained is for the entire man for his soul his mind his body. The importance of each object is measured by the importance of that part of human nature which is beneficially affected. The first object therefore at least as much more important than the second as the intellect is more noble than the body. This, namely the raising man in the scale of intelligent creatures can hardly be mentioned without a rise of feeling of ourselves and even incredulity.

And yet it is evident that an acquaintance with natural laws means no less than an acquaintance with the mind of God therein expressed. This acquaintance brings us nearer to Him if such a term may be used in respect to the Infinite. One of the distinguishing features that separates us from the beasts is that the latter have no knowledge of the natural laws, a similar distinction doubtless separates us from beings of a higher order than ourselves whose range of vision and capacity of thought are more extensive. David seems to be impressed with this when he says "I will consider thy heavens, even the works of thy fingers: the moon and the stars, which thou hast ordained. What is man, that thou are mindful of him: and the son of man, that thou visitest him? Thou made him lower than the angels to crown him with glory and worship." No one can doubt that man's nature may be raised. Scripture teaches this and this, and this has been the pervading hope & belief of all ages and nations. And although the meaning may have been generally restricted to the change which must take place in his arrival to a --- separate state of existence, yet it is not necessarily confined thereto. On the contrary an improvement in the intellectual powers of man may be expected even in his mortal state. Experience shows that this is possible. There are classes of truths which are individual, or one community can not grasp as another individual or another community can. There

are truths which are readily held by the present generation which the most civilized of ancient nations were unable to comprehend as has been ably shown by Whewell in his history of the Inductive Sciences. If such a change has been wrought heretofore, what may not be expected for the future now that the sources of improvement are multiplied and deepened, and we possess the experience and the resources which have accumulated for four thousand years.

The second and subsidiary object of natural science is to promote the comfort and well being of man and to increase his luxuries. It is needless to attempt to enumerate the thousands of ways in which science ministers to this object for everywhere may we trace its beneficial influence. In the ----state of society the bare necessaries of life, food, ----and dwelling are obtained, but whenever comfort or beauty exists it is by an application of science. It assists and supplies our natural powers by calling in the forces of nature. Heat, magnetism, electricity, chemistry, geology, optics, mechanics enable man to centre in himself and in a far higher degree of naturally superior advantages, possessed by a variety of creatures such as strength, swiftness, extended vision. Natural history in all its branches gives him better food supplies him with medicine shields him from disease, and so tends materially to lengthen the span of his life.

Such are then the legitimate objects of science. It is deeply to be regretted that another and most unworthy object has been introduced and has gradually and alarmingly increased in prominence. This is the improvement of the art of war and the implements of mutual destruction. I know that there are those who think that these improvements will tend to put an end to war by making it more destructive. I cannot think that such as opinion is based on common sense. I believe war will not only be more destructive but be carried on with greater ferocity. Individual campaigns will doubtless be short as well as decisive, but this will necessarily cause that rapid rise and fall of states and unsettling of boundaries and

constitutions which must eventually deteriorate civilization itself and render peace impossible. And thus by applying itself to an improper object science may eventually fall by its own hand. In reference to this subject we must also deplore the prostitution of science for the aggrandisment of an individuals and nations, the result being that the weaker is destroyed and the stronger race is established on its ruins. In making the above remarks, I allude to war generally, I intend no disparagement of the efforts being made to secure the integrity and liberties of Great Britain. These have been forced upon us and it is matter of congratulation that we are not responsible for the present military attitude of Europe.

Such being the characteristics of the spirit fostered by the cultivation of natural science, and such being the great objects which are in view, it is almost incredible that anyone should be bold enough to deny its importance, nay its absolute necessity in education. Suppose a student to be thoroughly acquainted with every event which has occurred in the history of the world, suppose him to have a perfect knowledge of every language that has been spoken by man, suppose him to have an accurate perception of the most subtle questions of industrial arts, yet however important and essential all of these and much more may be he cannot be considered more than half educated if he does not know something of the objects of the material world, their history, their forces and the laws which keep in order what would be otherwise chaos."

And a final note about Lord Kelvin's visit to Cornell: While visiting Cornell on May 2, 1902, Lord Kelvin said, "***Glasgow University is one of the most picturesque in the world, but Cornell is by far the most picturesque, surpassing in this respect any he had seen in Europe, Asia, or America.***"
https://ecommons.cornell.edu/bitstream/handle/1813/25855/004_29.pdf?sequence=1&isAllowed=y

Chemical History of a Candle:

Converting Hydrocarbons into Light and Carbohydrates into ATP

Benjamin Franklin (January 17, 1706-April 17, 1790), like most other children in colonial Boston, only went to school for two years before he started work at the age of ten as an apprentice in his father's soap and **tallow candle** making shop. The tallow chandler had to boil the **suet** or **animal fat** in a vat of water to produce tallow and then pour the tallow that had been skimmed off the water into molds. We now know that tallow is primarily a mixture of the following fatty acids: palmitic acid (16:0), stearic acid (18:0) and oleic acid (18:1). Ben cut wicks, filled molds, tended the shop and went on errands, but he disliked the hot, smelly, and dirty work of a tallow chandler. His father, Josiah Franklin, not wanting Ben to run off to sea like Ben's oldest brother, Josiah Jr. had, took Ben to the shops of various craftsmen so that Ben could pick a trade more to his liking. The fact that Ben liked to read and could write and spell well, made printing seems like the ideal craft. At the age of twelve, Ben apprenticed as a printer with his brother James. While he was never to be a chandler, as a **writer and a printer**, he held the **light of liberty** high.



In *From Boyhood to Manhood. The Life of Benjamin Franklin*, William M. Thayer (1889) wrote, "*He believes that 'one to-day is worth two to-morrows'; and he acted accordingly, with the* ***candle-shop and printing office for his school-room****, and* ***Observation for his teacher****. His career furnishes one of the noblest*

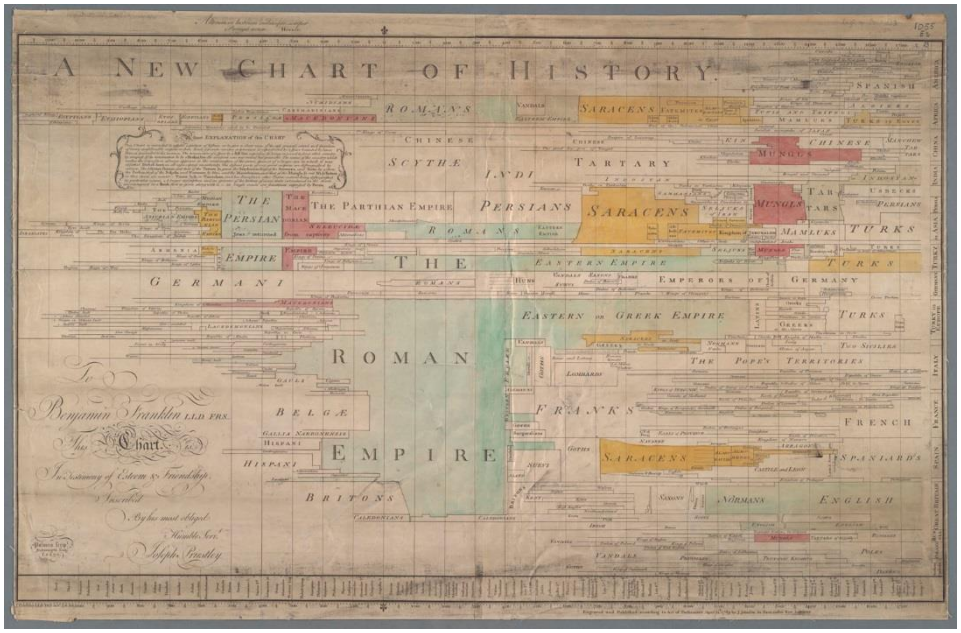
*examples of success for the young of both sexes to study. We offer his life as one of the **brightest** and best in American history to inspire young hearts with lofty aims*."



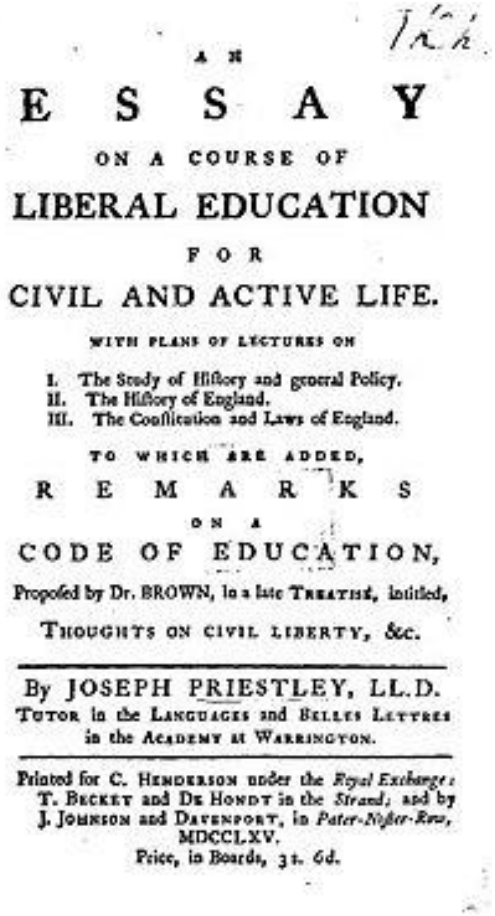
In fact, Ben Franklin, who had dinner with **William Wilberforce** at the Marquis de Lafayette's home on October 20, 1783, was the first of the founders to break the silence about slavery, Franklin petitioned Congress in 1790 to abolish slavery.
http://www.archives.gov/legislative/features/franklin/



Joseph Priestley met Benjamin Franklin in London in the 1760s and they became friends. Ben Franklin encouraged Priestley, who up until this time dedicated his life to the ministry and to teaching, to also pursue his scientific interests. Joseph Priestley was inspired and in addition to his theological and pedagogical writings, he wrote books on Electricity, Perspective, Vision, Light and Colours, and different kinds of Airs. As a teaching aid, Priestley had produced beautiful charts as a useful way of seeing the **unity in diversity**.



The English Parliament passed laws between 1660 and 1665 that prevented **dissenters** from holding political office, teach school, serve in the military, or attend Oxford and Cambridge unless they ascribed to the Articles of the Church of England. Priestley argued in these pamphlets that matters of private conscience such as education and religion and should not be controlled by the state. Moreover, he advocated that women should also be educated.



AN

ESSAY

ON A COURSE OF

LIBERAL EDUCATION

FOR

CIVIL AND ACTIVE LIFE.

WITH PLANS OF LECTURES ON

I. The Study of History and general Policy.
II. The History of England.
III. The Constitution and Laws of England.

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ON A

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Proposed by Dr. BROWN, in a late TREATISE, intitled,

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By JOSEPH PRIESTLEY, LL.D.
TUTOR in the LANGUAGES and BELLES LETTRES in the ACADEMY at WARRINGTON.

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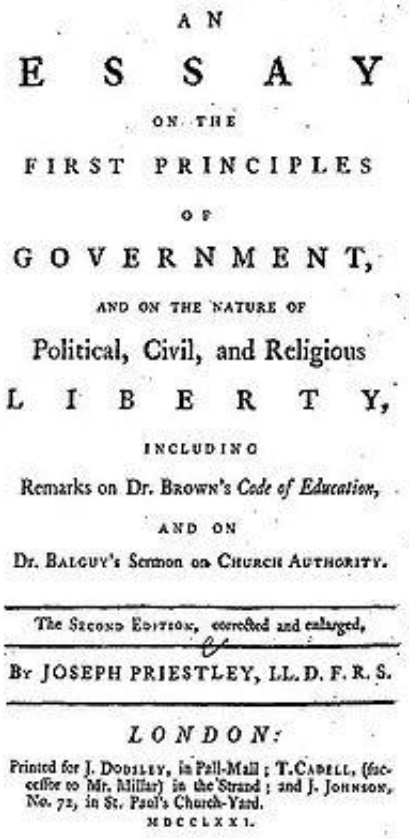

AN

ESSAY

ON THE

FIRST PRINCIPLES

OF

GOVERNMENT,

AND ON THE NATURE OF

Political, Civil, and Religious

LIBERTY,

INCLUDING

Remarks on Dr. BROWN's *Code of Education*,

AND ON

Dr. BALGUY's Sermon on CHURCH AUTHORITY.

The SECOND EDITION, corrected and enlarged,

By JOSEPH PRIESTLEY, LL.D. F.R.S.

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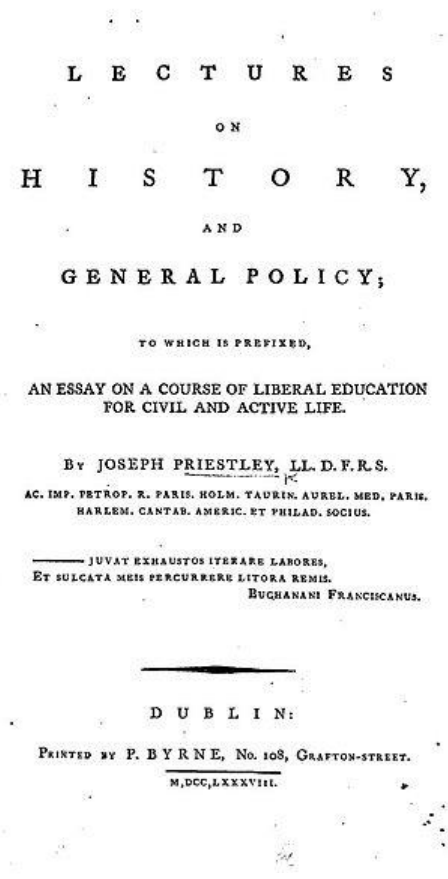
MDCCLXXI.



LECTURES

ON

HISTORY,

AND

GENERAL POLICY;

TO WHICH IS PREFIXED,

AN ESSAY ON A COURSE OF LIBERAL EDUCATION FOR CIVIL AND ACTIVE LIFE.

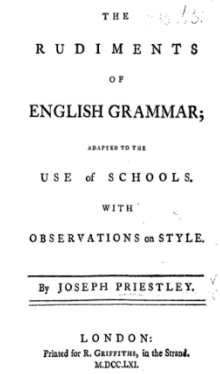
By JOSEPH PRIESTLEY, LL.D. F.R.S.

AC. IMP. PETROP. R. PARIS. HOLM. TAURIN. AUREL. MED. PARIS. HARLEM. CANTAB. AMERIC. ET PHILAD. SOCIUS.

——— JUVAT EXHAUSTOS ITERARE LABORES,
ET SULCATA MEIS PERCURRERE LITORA REMIS.
BUCHANANI FRANCISCANUS.

DUBLIN:

PRINTED BY P. BYRNE, No. 108, GRAFTON-STREET.
M,DCC,LXXXVIII.



THE

RUDIMENTS

OF

ENGLISH GRAMMAR;

ADAPTED TO THE

USE of SCHOOLS,

WITH

OBSERVATIONS on STYLE.

By JOSEPH PRIESTLEY.

LONDON:
Printed for R. GRIFFITHS, in the Strand.
M.DCC.LXI.

Ever wonder if you should say lie or lay? Here is a couplet from Priestley's (1833) *English Grammar; Lectures on the Theory of Language and Universal Grammar*:

Beneath this stone my wife doth lie:
She's now at rest, and so am I.



ENGLISH GRAMMAR;

LECTURES

ON THE

THEORY OF LANGUAGE AND UNIVERSAL GRAMMAR;

AND ON

ORATORY AND CRITICISM.

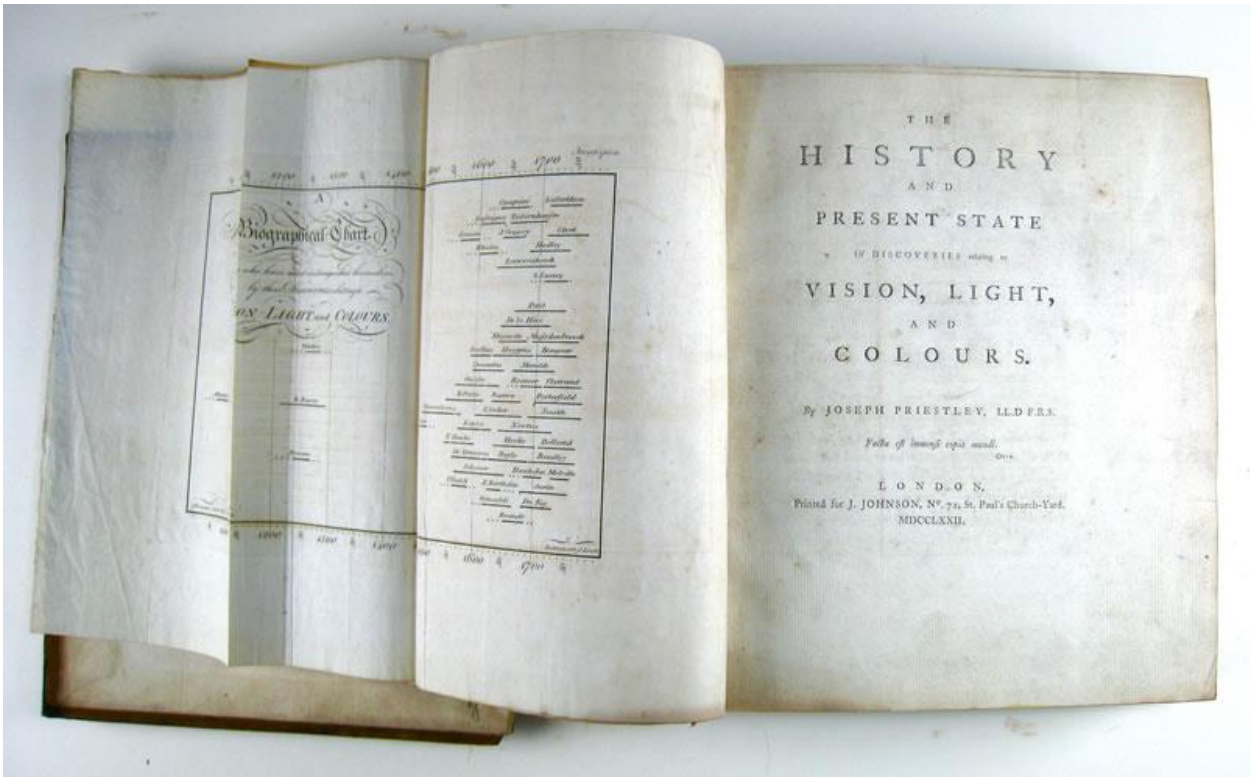
By JOSEPH PRIESTLEY, LL.D. F.R.S. &c.

WITH

NOTES AND AN APPENDIX,

BY

JOHN TOWELL HUTT.



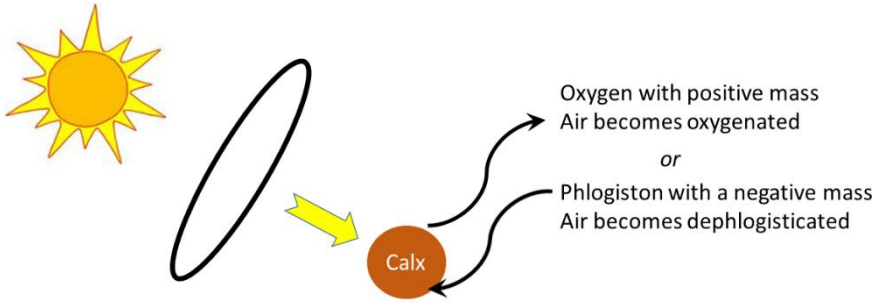
Priestley wrote in the preface to *The History and Present State of Electricity with Original Experiments*, "*Human happiness depends chiefly upon having some object to pursue, and upon the vigour with which our faculties are exerted in the pursuit.* ***And, certainly, we must be much more interested in pursuits wholly our own, than when we are merely following the track of others****."*





One way in which Priestley studied air on August 1, 1774 was to **focus sunlight** with a twelve-inch in diameter **converging or burning lens** onto orange mercuric calx. The mercury calx turned into liquid metallic mercury as if it captured **phlogiston** from the air so that the air became **dephlogisticated**. We now know that **mercuric calx** is **mercuric oxide** and the mercuric oxide releases oxygen in response to sunlight as opposed to gaining phlogiston from the air. That is, sunlight breaks the chemical bond

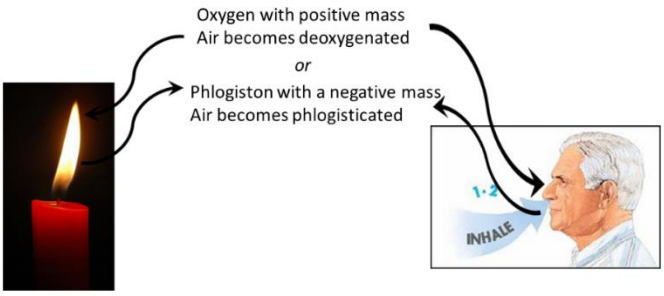
between mercury and oxygen. I will call what **Priestley studied oxygen**, although he went to his grave believing it was dephlogisticated air.



The **Gaussian lens equation** tells us that the image of the sun appeared at the focus of the lens, since the object distance, s_o is 1.5×10^{11} m, which made $\frac{1}{s_o}$ practically zero and thus made s_i practically equal to f.

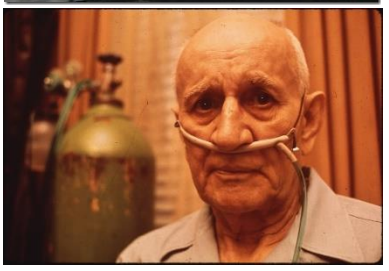
$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

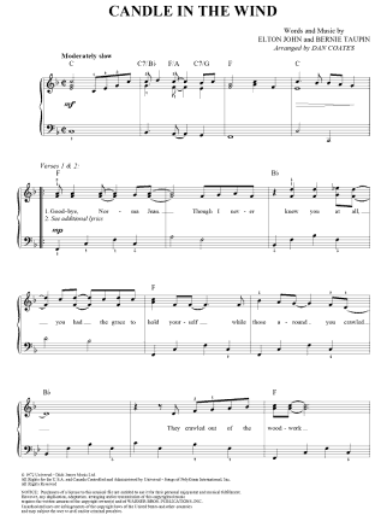
In order to test the nature of the **dephlogisticated air** or really the oxygen gas given off by the mercuric calx, Priestley collected it in a bottle. He then placed a candle in the bottle and saw that it burned with a "*remarkably vigorous flame*." Priestley also saw that a **mouse** would live longer in this **dephlogisticated air** than it would in **common air**, and he called dephlogisticated air, **vital air**.



Priestley wrote, "…*to complete the proof of the superior quality of this air, I introduced a mouse into it; and in a quantity in which, had it been common air, it would have died in about a quarter of an hour; it lived at two different times, a whole hour, and was taken out quite vigorous."* This was a special air. If this air was good for a candle and a mouse, could it be good for humans too? Priestley tried breathing the oxygen he produced and wrote, "*My reader will not wonder, that, after having ascertained the superior goodness of dephlogisticated air by mice living in it…,* ***I should have the curiosity****, by breathing it….The feeling of it to my lungs was not sensibly different from that of common air; but I fancied that my breast felt particularly light and easy for some time afterwards. Who can tell but that, in time, this pure air may become a fashionable article in luxury….From the greater strength and vivacity of the flame of a candle, in this pure air, it may be conjectured, that it might be particularly salutary to the lungs in certain morbid cases, when the common air would not be sufficient to carry off the putrid effluvium fast enough."* He also remarked, "*But, perhaps, we may also infer from these experiments, that though pure dephlogisticated air* [oxygen] *might be very useful as a medicine, it might not be so proper for us in the usual healthy state of the body; for, as a candle burns out much faster in*

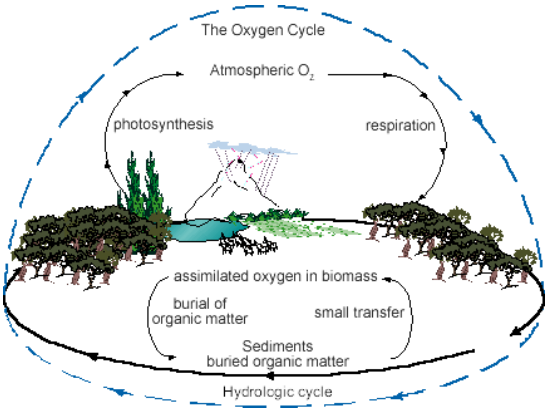


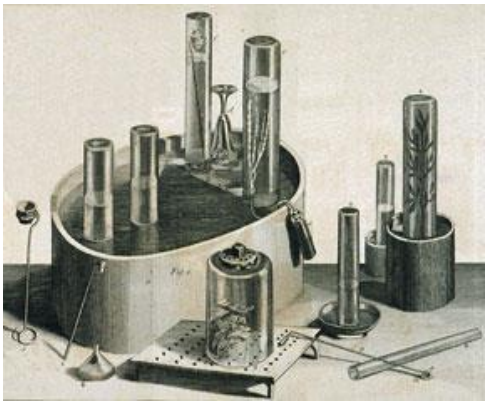




dephlogisticated than in common air, so we might, as may be said, live out too fast and the animal powers be too soon exhausted in this pure kind of air. A moralist, at least, may say, that the air which nature has provided for us is as good as we deserve." Otherwise, the candle burns out long before the legend does.

The figure below shows the global oxygen cycle that provides the "*air which nature has provided for us* [that] *is as good as we deserve*."





On August 17, 1771, Priestley found that if he put a **sprig of mint** in the jar, it **refreshed the air** so that a candle could burn, and a mouse could live. A sprig of groundsel, the worst smelling weed he could find, also refreshed the air. In fact, it was a **general property of plants** that they could refresh the air. We now know that plants evolve oxygen. Priestley's experiments were irreproducible because he never got the chance to discover that light was required for oxygen evolution.





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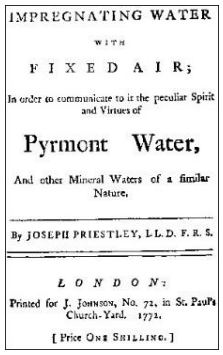
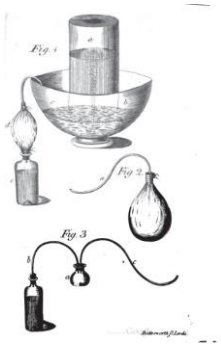
This is because his home, his lab, and the Unitarian Meeting House where he preached were burned down on July 14, 1791, the second anniversary of the storming of the Bastille, by a mob who did not agree with his **anti-authoritarian views** regarding church and king, specifically his Unitarian philosophy and his support of the American and French Revolutions. Veto power, whether exercised by mobs and monarchs, is still veto power. *Veto* is Latin for "*I forbid*."





Joseph Priestley was an original thinker and a remarkable chemist who discovered other gases in addition to oxygen, including nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), hydrogen chloride (HCl), carbon monoxide (CO), ammonia (NH_3), and sulfur dioxide (SO_2). Living near a brewery, he also did many experiments on the **carbon dioxide** gas that was given off by the brewery. Again we see the relationship between beer and science. One of the things Priestley (1772) did was to impregnate water with carbon dioxide to invent **seltzer water**. The seltzer water was similar to the mineral water from the German spa town Bad Pyrmont. Priestley generated CO_2 gas by adding sulfuric acid to chalk ($CaCO_3$) and bubbling the gas through water.


IMPREGNATING WATER
WITH
FIXED AIR;
In order to communicate to it the peculiar Spirit and Virtues of
Pyrmont Water,
And other Mineral Waters of a similar Nature,
By JOSEPH PRIESTLEY, LL.D. F.R.S.
LONDON:
Printed for J. JOHNSON, No. 72, in St. Paul's Church-Yard. 1772.
[Price One Shilling.]



$$CaCO_3 + H_2SO_4 \rightarrow H_2O + CaSO_4 + CO_2 \uparrow$$

In 1783, carbonated water was marketed by Joseph **Schweppe,** who kept the bottles horizontal to retain the carbonation because the cork stayed wet and expanded. Schweppes was the official



drink of the **Great Exposition of 1851** in the Crystal Palace, designed by Joseph Paxton, based on the architecture of the leaf of *Victoria regia*.



In 1794, Joseph Priestley emigrated to **Northumberland, Pennsylvania**, where his family would be safe, and he would be near his friends, Ben Franklin and Thomas Jefferson. There he helped found the Unitarian Church of America and continued to do experiments.



Joseph Priestley had shared his results on dephlogisticated air with **Antoine Lavoisier** over dinner in October 1774. **Antoine Lavoisier** questioned Priestley's interpretation and later **reinterpreted** Priestley's **dephlogisticated air** in terms of **oxygenated air**. Lavoisier coined the word oxygen in 1778 from the Greek *ὀξύς*, which means the sour taste of acids and *γενής*, which means "to produce." At the time, Lavoisier's proposal of the properties and existence of oxygen did not seem all that strong since hydrochloric acid (HCl), which was certainly an acid, had no oxygen at all. Humphry Davy (1812) later showed that acids were more correctly defined by the presence of hydrogen rather than oxygen.

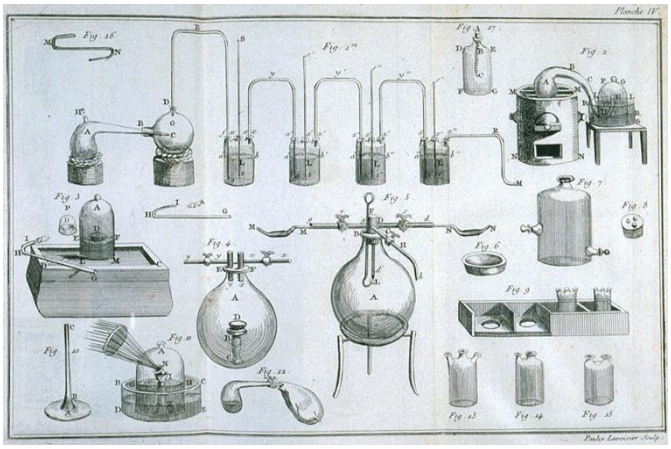
After weighing the reactants and products of various chemical reactions, Lavoisier proposed a chemical theory of the elements that stated all elements have a **positive mass** and thus calx was a combination of a metal and oxygen. When the calx was burned with a magnifying glass, it lost mass because it lost oxygen, not because it gained negative mass phlogiston. When a metal was heated, it gained mass as a result of combining with oxygen. Radiant energy provides the force to overcome the electrostatic attractive force between a positively-charged metal and

negatively-charged oxygen while thermal energy provides the force that allows a metal to **rust**, **burn**, or **combust** by combining with oxygen.

Lavoisier believed that **respiration** and **combustion** were **analogous** reactions in terms of chemistry. That is the **burning of food** is like the **burning of wood**. Lavoisier determined that in both cases, **combustion** results from the combination of **oxygen** with **carbon** and **hydrogen**.

Antoine Lavoisier relied on the relationship between light and life when he stated, *"In respiration, as in combustion, it is the atmospheric air which furnished oxygen…; but since in respiration it is…the blood, which furnishes the combustion matter, if animals did not regularly replace by means of food…that which they lose by respiration, **the lamp would soon lack oil**, and the animal would perish as a **lamp is extinguished** when it lacks nourishment."*

According to Antoine Lavoisier, "*The proofs of this **identity of effects** in respiration and combustion are immediately deducible from experiment. Indeed, upon leaving the lung, the air that has been used for respiration no longer contains the same amount of **oxygen**; it contains not only **carbonic acid gas** but also much more **water** than it contained before it had been inspired."*



That is, the formula for respiration of carbohydrate is:

$$C(H_2O) + O_2 \rightarrow CO_2 + H_2O + \text{heat}$$

Or in terms of glucose:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{heat}$$

During combustion, the chemical energy in the reduced CH bonds is transformed into thermal energy, heat, or the product of temperature and entropy. Originally, it was thought that food powered the body by producing heat. After all human life is associated with warm bodies and death is associated with cold bodies.

We will see that, according to the **First Law of Thermodynamics**, we can transform the chemical energy of the CH bonds into the chemical energy of ATP when we consider combustion during respiration, and we can transform the chemical energy of the CH bonds into radiant energy when we consider combustion in candles. According to the **Second Law of Thermodynamics**, both processes increase entropy. The so-called reverse reaction of photosynthesis that decreases the entropy of the chemicals involved, still increases entropy overall when you take into consideration the transformation of light energy in the visible range into thermal energy in the infrared range.

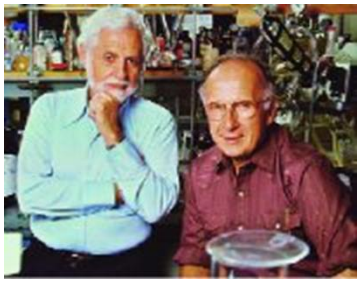


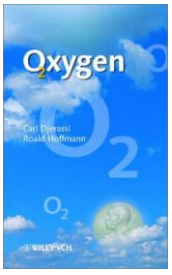
Antoine Lavoisier not only showed that **respiration** could be defined as a **combustion** process measured by the **uptake of O_2** and the **expulsion of CO_2 and H_2O**, but he and **Pierre Simon de Laplace** found using an **ice calorimeter**, that for equal outputs of CO_2, the same amount of heat was generated to melt the same amount of ice, by a respiring guinea pig and burning wood.

Like Joseph Priestley, Antoine Lavoisier never finished his experiments on respiration because he was "politically incorrect." Lavoisier, who owned shares in a tax collection business, lost his head in a **guillotine** on May 8, 1794, during the French Revolution. After Antoine's death, Madame Lavoisier married Count Rumford. We will see Antoine and Madame Lavoisier's own books and the copper plates **Madame Lavoisier** made to illustrate *Traité Élémentaire de Chimie* when we go the Rare and Manuscript Collections.



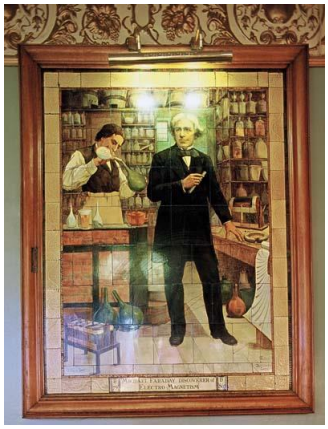
Roald Hoffmann (Cornell) and Carl Djerassi wrote a play about the nature of discovery in terms of the role of Joseph Priestley, Carl Scheele, Antoine Lavoisier, and their wives. Discovery in science is often a result of the work of many people over time. Scheele produced "fire air" before Priestley produced "dephogisticated air," but Priestley published first. Lavoisier had a better understanding of its chemistry and named it oxygen. Davy found that the chemistry of acids, was not given by the possession of oxygen, from which oxygen got is name, but was given by the possession of hydrogen. Just who did discover oxygen?





Michael Faraday, Humphry Davy's assistant, gave a series of lectures on chemistry to children at the Royal Institution at Christmas time. His most famous lecture series is on ***The Chemical History of a Candle,*** which he began by saying, *"I propose to bring before you, the Chemical History of a Candle….There is not* ***a law under which any part of this universe is governed which does not come into play****….There is no better, there is no more open door by which you can enter into the study of natural philosophy, than by considering the physical phenomena of a candle. I trust, therefore, I*





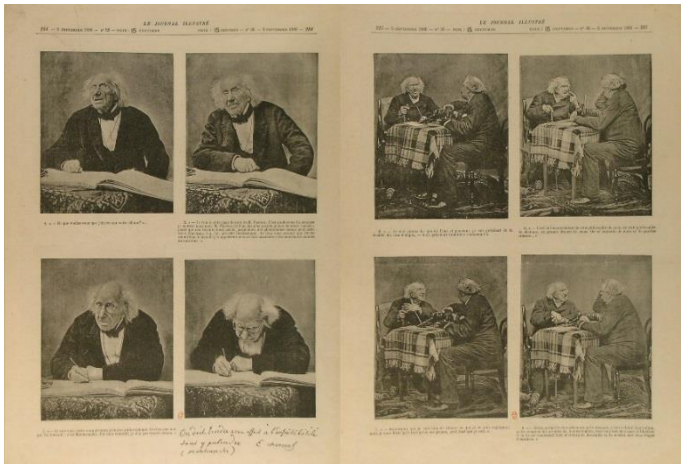
shall not disappoint you in choosing this for my subject rather than any newer topic, which could not be better, were it even so good." Today we will replicate to some degree his lecture series on ***The Chemical History of a Candle***. http://www.rigb.org/christmas-lectures http://www.rigb.org/visit-us/faraday-museum

Look at all the candles in the room. They are made of malleable solids composed of water-**insoluble hydrocarbons**, **rich in CH bonds**, that are in the form of **hard fats** (ester of fatty acids and glycerol) or **waxes** (esters of fatty acids and fatty alcohols). One is made from **tallow**, one is made from **spermaceti**, one is made from **beeswax**, one is made from **bayberry wax**, and one is made from **paraffin**. Each of them transforms the chemical energy of the hydrocarbon into radiant energy of light and heat after being ignited by a match. This **transformation**, which **disperses heat and gases** and thus **increases entropy**, is known as **combustion**. Consequently, the transformation is **irreversible** and must follow the **First and Second Laws of Thermodynamics.**



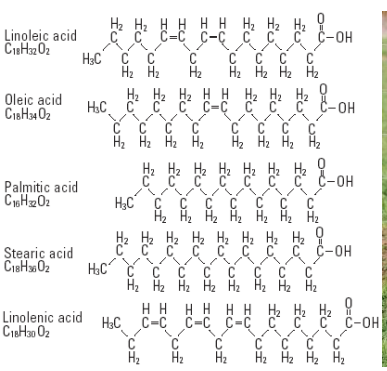
Fat is good in that it is a **very efficient form of energy storage** in warm- blooded animals since 1 gram of fat can store **9 Calories**, whereas 1 gram of carbohydrate or 1 gram of protein can only store 4 Calories. **One Calorie is equivalent to 4184 Joules**. If we stored the same amount of energy as carbohydrate (4 Calories/gram) or as protein (4 Calories/gram), we would weigh more than we do. Thus "*fat is good*!"

In the early 18th century, the photogenic **Michel Eugène Chevreul**, a chemist interested in the chemistry of soaps and candles, both of which were produced from natural products, determined that all fats are composed of glycerol and fatty acids. Fats, which were solid, had more stearic acid, and oils, which were liquid had more oleic acid. Stearic acid comes from *stear* (στέαρ), the Greek word for tallow, and oleic acid from the Latin cognate (*oliva*) of the Greek word *elaía* (ἐλαία) for olive. Palmitic acid comes from the word palm and was first isolated from palm oil.



We can use animal fat to make candles. Survivalists make candles out of tallow and they could eat them if it became necessary. Tallow rendered from beef suet is composed primarily of palmitic (16:0), stearic (18:0) and oleic (18:1) acids**.** **Tallow candles allow us to transform life into light**.

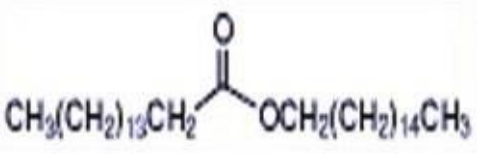






Spermaceti candles are made from a **wax** found in the heads of **sperm whales**. Spermaceti wax is composed primarily of the ester of **cetyl alcohol and palmitic acid** ($C_{15}H_{31}COO\text{-}C_{16}H_{33}$). **Spermaceti candles allow us to transform life into light**, and were the original candles used to define one **candlepower** in the British Metropolitan Gas Act of 1860. Whaling is outlawed and our spermaceti was made synthetically.







Bayberry candles are made from the green wax that is removed from the surface of the bayberry (*Myrica pensylvanica*). They have a wonderful smell. Bayberry wax is not actually a wax but more like plant tallow made of triglycerides, composed of lauric acid (12:0), myristic acid (14:0) and palmitic acid (16:0). A true wax is an ester of a long chain alcohol and a fatty acid. **Bayberry candles allow us to transform life into light**.





Beeswax is a true wax made from by **worker bees** by **chewing honey** made from **nectar**. In fact the burning candles smell like honey. The bees use the wax to build honeycomb cells in a hive which the young are raised. The fresh wax is

white, but it turns yellow when pollen oils and a resinous substance called propolis that is used to seal the hives is incorporated into the wax. Beeswax candles are chemically complex and are made of many components and allow us to **transform life into light**.





Historically or in parts of the world we do not see often, other organisms are used to turn life into light. For example, the **candlefish** (*Thaleichthys pacificus*) is composed of 15% fat. Indigenous people dry the fish and burn it as a candle!




Candle-wood or **bogwood** formed about 4500 years ago when the climate in Ireland and Scotland changed, perhaps as a result of volcanic dust, by becoming wetter and cooler. The cool water-loving bog plants, including sphagnum moss, heathers, grasses, and sedges encroached on





the oaks, pines, and yews. In the newly formed bogs, the trees died due to lack of oxygen. The lack of oxygen in acidic waterlogged peat provided a reducing atmosphere that prevented the decomposition of the dead trees. Candle-wood or **fatwood** is harvested from the stumps of long leaf pine in Honduras and the southern United States.

As long as the **proportion of hydrocarbons is high**, whether, tallow, spermaceti, bayberry, beeswax, candlefish, or candlewood, **the chemical energy produced by life can be transformed into the radiant energy of light**.

The word candle comes from the Latin word *candere* which means "to shine." Today we will study the **combustion process that occurs in a candle** and that gives rise to a **flame** in order to understand the chemistry of combustion and next time we will **compare and contrast** it to the **combustion process that takes place in living organisms**. Both combustion processes conform to the **First and Second Laws of Thermodynamics** in that **one form of energy is transformed into another** and that the **transformation only occurs in one direction**. In general, combustion processes ***out of the body*** are hot enough to boil water (> 100 C = 373 K) whereas the combustion processes that take place ***in the body*** do so at ambient temperature (37 C = 310 K). **Enzymes** make it possible to perform combustion reactions at ambient temperatures.

The **photosynthetic transformation of radiant energy into chemical energy** that ultimately gives rise to all our food, and to the fats and waxes used in candles, can be looked at as the **closest thing to the "reverse process" of combustion although it is clearly not a reversal of the combustion process** and candle light in not a result of light emission from chlorophyll (even in cucumbers). While the overall chemical formulae of combustion and photosynthesis make

photosynthesis and combustion look like two words for the same reversible process, clearly and consistently with the **Second Law of Thermodynamics**, they are not reversible processes but each **irreversible** and **directional in time**.

In order to understand the combustion process that occurs in a candle, let's first characterize the flame itself. The unknown intensity of the candle flame can be measured with **Rumford's photometer** that compares the darkness of the shadow produced by the light in question to a standard candle. The test light is moved forward or backward until the shadows are equally dark. The relative intensity is calculated from the distances of the two lights to the screen using the inverse square law.

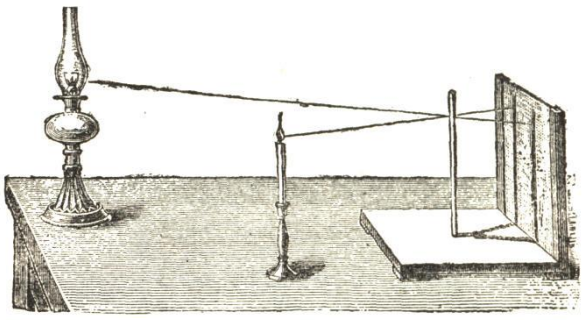


Fig. 262. RUMFORD'S SHADOW PHOTOMETER.

Intensity of unknown light = Intensity of standard light $\frac{d^2_{unknown}}{d^2_{standard}}$

The unknown intensity of a candle flame can also be measured with **Bunsen's Photometer** where the distance between an unknown light from a piece of white paper with a grease spot is varied until the grease spot seems to disappear because it is equally illuminated on both sides. Again, the inverse square law, which we learned from geometrical optics and used to estimate the luminosity of the sun, is useful.

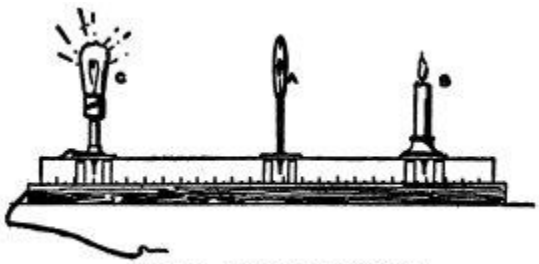
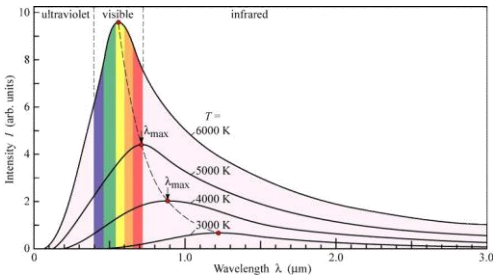


Fig. 82. Bunsen's photometer

Intensity of unknown light = Intensity of standard light $\frac{d^2_{unknown}}{d^2_{standard}}$

The **temperature** of the flame can be estimated from its luminosity or intensity at the surface of the flame using the formula: $I(r)4\pi r_{flame-sensor}^2 = L_{candle} = 4\pi r_{flame}^2 \sigma T^4$, where the Stefan-Boltzmann constant can be derived from other more basic constants: $\sigma = \frac{2\pi^5 k^4}{15c^2h^3}$. The measured **color temperature** of a candle flame is approximately **1850 K**.



Demonstration: Look at the flame through the spectroscope. Is the spectrum continuous or discrete? Although we cannot see the infrared wavelengths, the peak of the spectrum is closer to the red compared to the peak of the solar spectrum, which you can observe through the pinhole in the window. We can characterize the light emitted by the candle as a continuous spectral distribution produced by a "hot" **incandescent body** using **Max Planck's blackbody radiation law**:

$$I(\lambda) = \frac{2\pi hc^2}{\lambda^5\left(e^{hc/\lambda kT}-1\right)}$$

where λ (in m) is the wavelength of light, $I(\lambda)$ is the intensity of a given wavelength at the surface of the flame, k is the Boltzmann constant (k = 1.38 × 10^{-23} J/K), c is the speed of light (c = 2.99 x 10^8 m/s) and h is Planck's constant (h = 6.626 × 10^{-34} J s). Soon we will **identify the incandescent hot body** that gives rise to the continuous blackbody spectrum.



Look at the virtual image of the flame of a spermaceti candle through the 1 diopter (f = 1 m) and 2 diopter (f = 0.5 m) converging lenses aligned to form a 3-diopter compound lens (f = 0.333 m). A closer look shows that the flame consists of three parts, as described by Worthington Hooker. The **inner part** of the flame appears to be **dark and hollow. The wax is vaporized in the hollow, called region 3**, and passes into **region 2**, the borderland between the fuel in region 3 and the air in region 1.



The brightest part of the flame is caused by the **incandescence** of the **fine solid particles of carbon soot** in region 2. The **incandescent particles are also the cause of the black body spectral distribution**. This region is also very hot. As the carbon particles combine with oxygen, they move away from region 2 as carbon dioxide and water. As the soot particles turn to gas in region 1, the flame dims compared with region 2. The major locus of **heat** generation during the combustion process occurs in region 2 where **the fuel and the air come together**. The highest temperatures however are in the blue region, where the oxygen concentration is high and most of the chemical energy is converted to heat and not light.



What happens to the candle over time? Assuming time exists, the fact that candles get shorter over time as they use up their fuel source made possible **candle clocks**, which are among one of the most ancient timekeepers made by humans. The fact that candles get shorter over time also made **courting candles** possible. Legend has it that in the 16th -19th centuries, courting candles were lit by a girl's father to set a time limit on how long she could spend with a suitor. The suitor could stay until the courting candle burnt to the metal at the top of the candle holder—although the father could change the height of the candle based on how he felt about the suitor.



A candle gets shorter as the fuel gets used up. How does the fuel get to region 2 where it will combine with the air? In order to understand the passage of fuel to the combustion zone, let's look at the flame produced by olive oil burning lamps, which have been used at least since biblical times when the Israelites were commanded in Exodus 27:20 "*to bring you clear oil of pressed olives for the light so that the lamps may be kept burning*."





When we light the wick, the flame travels down the cotton to the olive oil, where the flame is put out. The **liquid oil** itself does ***not*** burn while the flame does continue to burn above the oil at the expense of the oil. The oil can only burn when it gets to the top of the wick where it is vaporized. While the oil is initially vaporized by the heat from the match, the flame of the lamp takes over the role of vaporizer for as long as the lamp is lit. That is, some of the energy of the oil must be used to vaporize the oil.

Heat + liquid → vapor

How does the oil get to the top of the wick? The oil gets to the top of the wick by **capillary attraction**. Capillary action is a result of **electrostatic attraction** that is stronger than the attractive **force of gravity** towards the earth.

The greater the surface area of the wick, the greater is the amount of electrostatic attraction and the greater the amount of capillary action. The surface area is increased by using many thin treads of cotton to form the wick. Multiple thin filaments are excellent at wicking and they can wick bacteria from a non-sterile area such as the vagina to an axenic area such as the uterus to cause pelvic inflammatory disease. This was the **unintended consequence** of the filaments attached to the Dalkon shield, an **intrauterine device**



(IUD) that caused pelvic inflammatory disease (PID). What is true and good for candles is true and bad for IUDs.

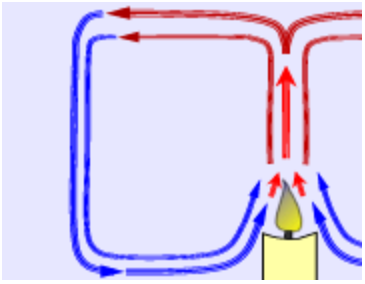
At the top of the wick of an oil lamp, the vaporized oil molecules collide with each other. If the molecules are hot enough, they break each other's bonds when they collide into each other and the molecules literally fragment. At the bottom of the flame, you will see a little blue that results from the chemiluminescence of the C_2 and CH fragments, which will combine with sufficient oxygen at the **bottom of the flame** to form invisible molecules of carbon dioxide and water without forming more complicated soot particles. The blue region is the hottest part of the flame. **Above the flame**, the fragments cannot become invisible quick enough because there is not enough available oxygen. Consequently, soot particles form. It is these soot particles that incandesce to turn the chemical energy of the CH bonds of olive oil into the radiant black body spectral distribution of lamp light. The soot molecules become invisible when they turn into carbon dioxide and water as they come in contact with oxygen in region 1.

Let's look at a candle, where the fuel is a solid. The flame melts the solid hydrocarbon into a cup-containing liquid. The transformation of solid fuel into a liquid fuel requires heat and some of the chemical energy of the solid fuel is used to drive this solid-to-liquid phase transition.

$$\text{Heat} + \text{solid} \rightarrow \text{liquid}$$

The flame also causes the current of air to move upward as a result of the flame heating the air since the heated air expands and becomes less dense. This results in

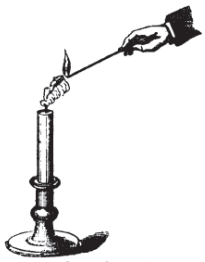
a low-pressure region above the flame and the air moves from regions of high pressure to regions of low pressure. The **upward flow of air cools the sides of the candle** and makes a cup to hold the melted wax that is not cooled by the air.



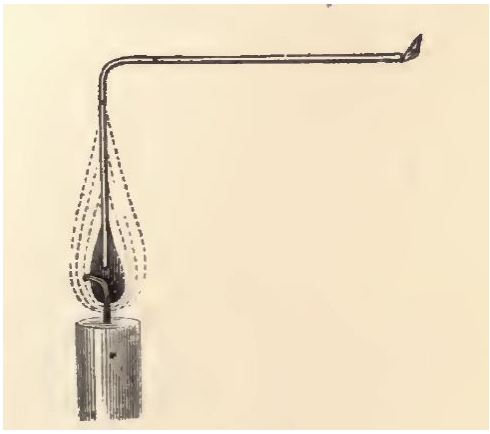
The candle flame, like the oil lamp flame, is separated from and is above the liquid wax. The temperature at which the candle wax melts (transformed from a solid to a liquid) is known as its **melt point**. The melted hydrocarbon, like the olive oil, also moves up the wick against the force of gravity to make a flame by **capillary action**. The greater the number of strands and the thinner they are in a wick, the greater the surface area, the greater the electrostatic attraction, and the greater the rate of ascent of the liquid. Lower molecules are attracted to the climbing molecules and also get pulled up to the flame where the liquid hydrocarbon is evaporated, vaporized and turned into a gas. The temperature at which the liquid wax is vaporized (transformed from a liquid to a gas) and it is able to ignite and burn is known as its **flashpoint**. The transformation of liquid fuel into vapor fuel requires heat and some of the chemical energy of the solid fuel is used to drive this liquid-to-vapor phase transition.

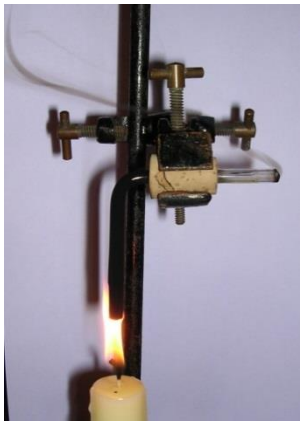
Wax	**Approx. formula**	**H/C**	**melt point (F)**	**flashpoint (F)**
Beef Tallow	$C_{16}H_{32}O_2$	2	104	512
Bayberry	$C_{12}H_{24}O_2$	2	118	230
Beeswax	$C_{15}H_{31}COOC_{30}H_{61}$	2	144-147	399.9
Paraffin	$C_{31}H_{64}$	2.06	115-154	395
Spermaceti	$C_{32}H_{64}O_2$	2	210	500

Vaporized hydrocarbon is a fuel that can burn. You can see this by blowing out the candle and looking at the vaporized fuel as a white smoke. You can light this smoke two or three inches above the wick. When the **vapor ignites it will cause the wick to relight**.



We can show that this **vaporized fuel** is in region 3, the **dark inner hollow of the flame**. We can examine the dark region 3 by inserting a bent glass tube into this region. The vapor that comes out of the end of the tube can be ignited and the flame of the candle can be produced at a distant place. When I raise the tube to **region 2**, t**he bright part of the flame, there is nothing to ignite.** In region 2, the vapor has already been burned and the result is the production of a black smoke that is composed of soot particles. Region 2 is where the combustible vapor and the oxygen in the air have combined to make incandescent light.







We can see where the soot particles that incandesce are localized in the flame in an unusual way. When the candle is illuminated by the lamp of a slide projector, one sees that the brightest region of the flame casts a shadow on the screen. Thus, **the soot particles, which are opaque and cast a shadow are in the brightest region of the flame**. Surrounding the dark shadow is a lighter shadow and surrounding that is a bright region that is a diffraction artifact resulting from the light that diffracts from the particles that make the shadow. (Next time you are

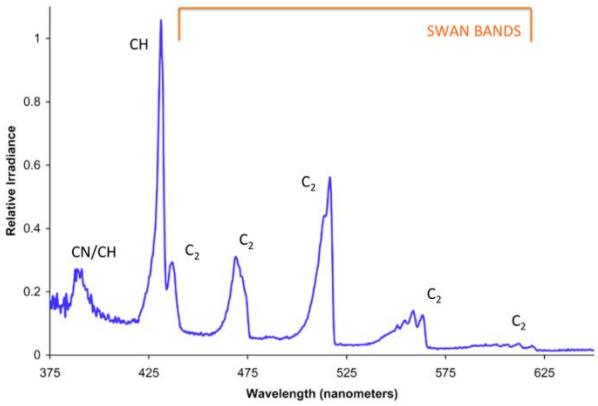


looking at your own shadow on a sunny day you will see that your shadow too is surrounded by a bright halo).

In the middle of the flame is the combustible vapor and on the outside of the flame is the oxygen that is necessary to combust the vapor. **In between these two regions is the reaction zone where the oxygen and the vapor interact to form incandescent soot particles and heat**. This is the hottest region of the flame above the wick. Region 2 can be visualized with a piece of paper because it is hot enough to produce a ring on a piece of paper that results from the caramelization of the top of the filter paper and soot deposited on the bottom of the filter paper.

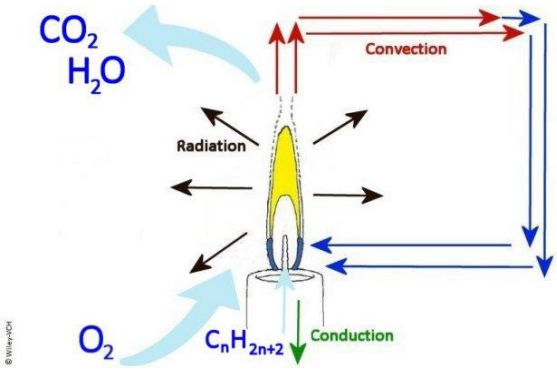


In region 3, where oxygen is limiting, the hot vaporized fuel molecules collide with each other and break into smaller molecules such as C_2 and CH. This **oxygen-limited process** is known as **pyrolysis**, which means heat-induced breakup in the absence of oxygen. It also results in the production of free radicals. The newly formed molecules transform some of their excitation energy into light energy in a process known as **chemiluminescence**. Chemiluminescence of C_2 and CH gives rise to the blue in the flame. **The blue exists throughout the flame** but is dimmer than the continuous spectral distribution of light resulting from **incandescence**. Below are pictures of a candle flame taken with quartz lens and a filter that only lets ultraviolet light pass (l), a filter that only lets visible light pass (c) and a filter that only lets infrared light pass (r).





In the absence of oxygen, the pyrolytic fragments get a chance to form complicated soot particles in region 2 that can incandesce. When these soot particles are exposed to enough oxygen as they reach region 1, they turn into the invisible molecules of carbon dioxide and water, causing region 1 to be less bright than region 2.



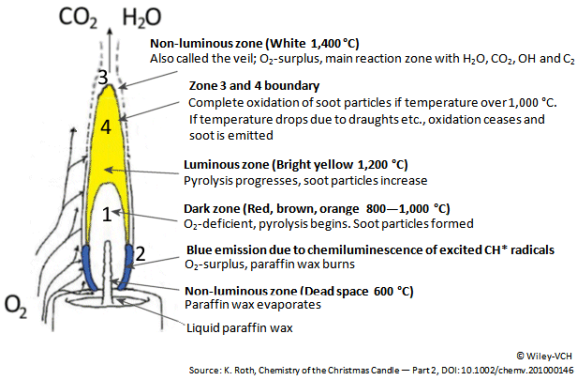
At the bottom of the flame, the pyrolytic fragments will quickly combine with the readily available oxygen to form invisible molecules of carbon dioxide and water without forming more complicated soot particles which would incandesce. Thus, the chemical energy is mostly converted into thermal energy. Above the flame, the pyrolytic fragments cannot become invisible quick enough because there is not enough available oxygen. Consequently, soot particles form. It is these soot particles that incandesce to turn the chemical energy of the CH bonds of the fuel into the radiant black body

spectral distribution of candlelight. The soot molecules become invisible when they turn into carbon dioxide and water as they come in contact with oxygen.

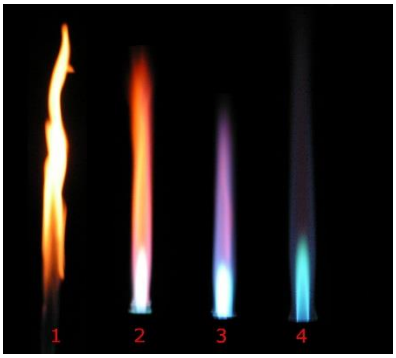


Fresh air is necessary for combustion to proceed. When we place a candle in a bell jar, the flame is extinguished after a minute or two.

Since the heat of the candle results in an upward draft of fresh oxygen-containing air, the **bottom of the reaction zone** has the most oxygen resulting in the complete combustion of the products of pyrolysis without the intermediate production of soot. In this region, **chemiluminescence** is ***not*** overwhelmed by the **incandescence of the soot particles** and the flame appears **blue**.



The flame in a **gas stove, propane torch or a Bunsen burner**, has sufficient oxygen for the oxidation of the products of pyrolysis without the intermediate formation of soot. **Under these conditions, more energy is emitted as heat than as visible light**. The flames shown on the right result from increasing availability of oxygen.



Complete combustion without producing sooty intermediates allows us to cook our food efficiently and cleanly, but there is not enough light produced by this process to provide light. Ever think that soot could be romantic?



Soot production occurs when there is not enough oxygen to burn the initial pyrolysis products directly into carbon dioxide and water. The perfect amount of

incomplete combustion produces a yellowish flame. The **wick** too is important in determining the quality of the flame. Too little combustion occurs when a wick is so big that it delivers too much fuel for the amount of oxygen available, and a black sooty smoke is produced. When the wick is too small, combustion is also limited because there is not enough fuel.

Incandescence results from the oxidation of soot particles produced by the incomplete combustion of the products of pyrolysis. **Any finely divided solid, which has a large surface to volume ratio, can incandesce.** Each *Lycopodium* spore vaporizes producing soot particles that become incandescent when they oxidize. **The large surface to volume ratio maximizes the amount of oxygen that can interact with the spore and minimizes the amount of heat that can be carried away**. **The result is the transformation of chemical energy into light**. The incandescence produced by ignited *Lycopodium* spores was used to produce a **flash of light by photographers** in the early days of photography. *Lycopodium* spores are used by magicians to create a clean-burning jet of fire known as dragon's breath.







Iron particles (Iron powder, but not iron oxide powder) also become **incandescent** when placed in a flame. Incandescence occurs because their large **surface to volume** ratio maximizes the amount of oxygen that can interact with the powered iron but minimizes the amount of heat that can be carried away. A **cast iron skillet** does not incandesce because it has a much smaller surface to volume ratio than the iron powder. Unlike the *Lycopodium* spores, the iron powder remains a solid and incandesces without vaporizing. Iron has a high affinity for oxygen. We often see rust. In order for iron to rapidly bind to oxygen though, it has to be **heated** to high temperatures or acted on **enzymatically** at ambient temperatures.

Incandescent iron can be seen when you hit a nail with a hammer. The nail becomes hot enough to combine with oxygen and bits of iron fly off due to the explosion. The spark is incandescent iron oxide formed by the burning of iron!



Electrical energy can be converted into thermal energy when a 9V battery is touched to the finely spun iron in **steel wool** that has been fluffed up. This can be used to make a fire when camping. https://www.youtube.com/watch?v=xbwNJhJwnSs



Likewise, on a camping trip, mechanical energy can be converted into thermal energy with a magnesium fire starter. https://www.youtube.**com**/watch?v=Cz7md8ArN60

Incandescent iron is formed by **flint and steel lighters**. The incandescent iron oxide particles produced by rubbing flint on steel can be used to ignite **charcloth** (pure carbon) and start a fire. The charcloth is made by heating cotton or linen in limited oxygen in a tinderbox for about five minutes. This lowers the ignition temperature of the fabric by eliminating the volatile components



that would drain away heat necessary for volatilizing these components from the fire.

This process of heating wood ($C_{42}H_{60}O_{28}$) in the absence of oxygen (**pyrolysis**) is used to make **charcoal** ($C_{16}H_{10}O_2$). The same process is used to make **biochar**, which can be used to amend soils.

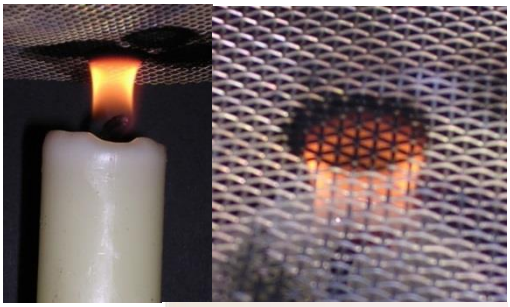
$$2C_{42}H_{60}O_{28} \rightarrow 3\ C_{16}H_{10}O_2 + 28\ H_2O + 5\ CO_2 + 3CO + C_{28}H_{34}O_9$$



The carbon-rich solid charcoal has too little oxygen to form a flame, which is why **charcoal glows or incandesces** while **wood burns or produces a flame**.

Approximately 30,000-32,000 years ago, Cro-magnon man used charcoal to produce beautiful drawings in the caves of Grotte Chauvet Pont d'Arc, which was rediscovered by moderns in 1996.





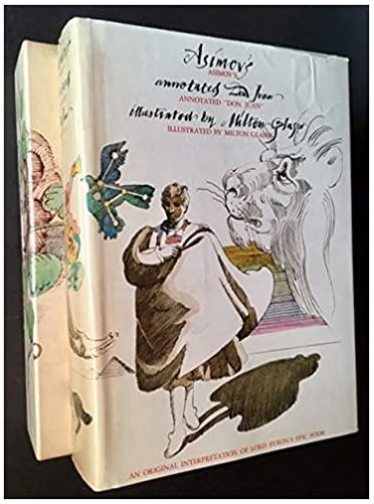
The surface to volume ratio of an **iron mesh** causes it to carry off the heat of a flame without incandescing white. The decrease in the temperature prevents the combustion of soot particles and the flame cannot go through the mesh and is quenched. This is why a wire mesh is placed in front of your fireplace and around a **Davy safety lamp** invented by **Humphry Davy**, Michael Faraday's predecessor at the Royal Institution and used by miners to see in coal mines.



Lord Byron wrote about Davy in his epic satire, *Don Juan* (*Canto I*):

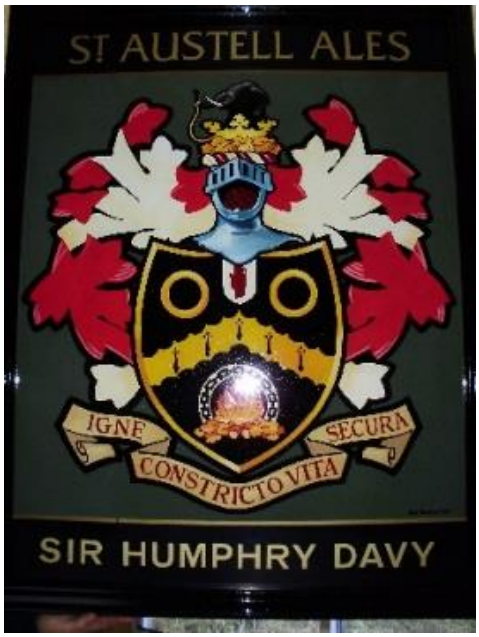
CXXXII

This is the patent age of new inventions
For killing bodies, and for saving souls,
All propagated with the best intentions;
Sir Humphry Davy's lantern, by which coals
Are safely mined for in the mode he mentions,
Tombuctoo travels, voyages to the Poles,
Are ways to benefit mankind, as true,
Perhaps, as shooting them at Waterloo.



Davy's Coat of Arms reads, *I constricted the fire: Life is safe*.
http://www.rigb.org/our-history/iconic-objects/iconic-objects-list/davy-lamp

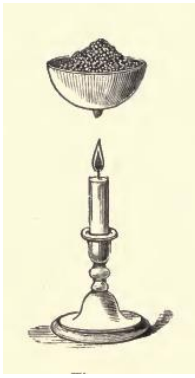




The products produced by a candle flame can be captured in a **fire balloon**. They are ***not*** sooty, but transparent or invisible. The soot particles are formed as a result of incomplete combustion. Incandescence does not continue when there is sufficient oxygen. So, when there is sufficient oxygen, as there is in region 1 at the margin of the flame, the carbon that makes up the soot is transformed into something else that is **gaseous and invisible**.

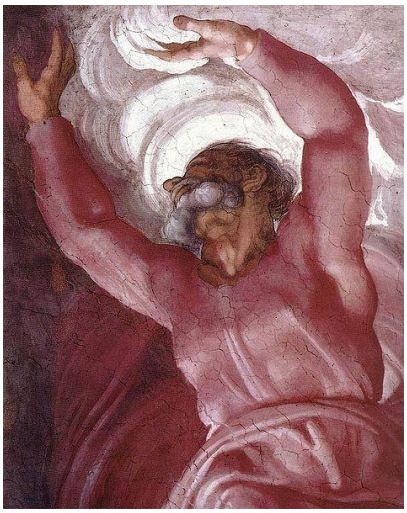


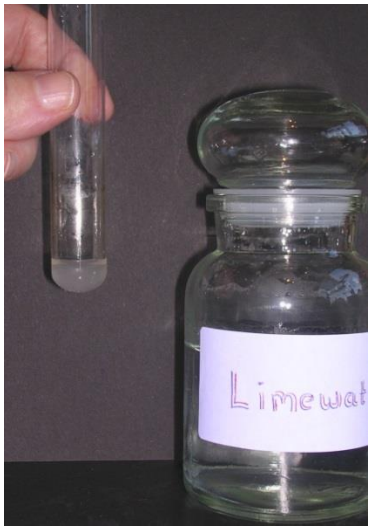
One of the products that formed in the flame is **water**. We can condense the gas produced by the candle flame (or from our breath) on the bottom of a dish containing ice and salt into a liquid to see if it is water. Water is the only gas that will become a liquid close to 0 C. Water is not initially in the candle. **The water formed by combustion is made of two substances, one provided by the candle and one provided by the air**.





The other product that is formed in the flame is **carbon dioxide**. Carbon dioxide can be tested with **limewater**, which is an aqueous solution of calcium hydroxide. Limewater was used as a whitewash in **buon fresco painting**. Historically, it is known as the paint whitewash. The chemical reaction of carbon dioxide gas with aqueous limewater results in the production of solid calcium carbonate and water. A cloudy appearance of the limewater solution caused by the calcium carbonate indicates that the sample gas, whether from the candle or our breath, contains carbon dioxide.





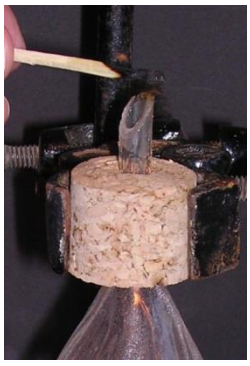


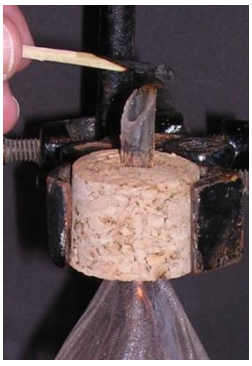
$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

Carbon dioxide is not initially in the candle. **The CO_2 formed by combustion is made of two substances, one provided by the candle and one provided by the air**.

Carbon dioxide can also be identified by testing a gas' ability to **extinguish fire**. The gas emitted by the candle flame is able to extinguish a match. Carbon dioxide acts a **fire extinguisher** by displacing oxygen and can be used in putting out fires where there is no source of oxygen.











Now I want to show you that an unsalted dry roasted peanut can be used for a fuel to make a flame. We can also estimate the amount of thermal energy it produces when it burns by placing the burning peanut under a tin can that has been filled with 0.1 kg of water (m). After weighing the peanut (0.5-1 gram), we measure the temperature of the water with an **infrared thermometer probe**. Then we light the peanut and measure the rise in the temperature (ΔT) of the water. The amount of heat produced by the peanut is given by the following formula:

$$\text{Thermal energy} = c\ m\ \Delta T$$

where c is the heat capacity of water and is equal to 4186 J/(kg C) or 1 Calorie/(kg C). The ratio of 4.186 to 1 is the ratio of the **mechanical equivalent of heat** to the specific heat determined by **James Joule** with his **paddle wheel** in the **basement of the brewery**. The thermal energy of a peanut measured in this crude way is about 4186 J or 1 Calorie. If the difference in the initial weight and final weight of the peanut was 0.5 g, then the energy content of the peanut would be about 2 Calories/gram. This is an underestimate since much of the heat is radiated away by the metal can. How could we be more accurate?

Next time we will look at **ancient fossils** found in the **coal beds** of America to get an idea of fossil fuels and of geological time. The plant fossils still contain the carbon that they fixed photosynthetically so many years ago. The fossil fuels are mostly and most likely hydrocarbon rich deposits of ancient organisms that we

combust to release thermal energy today. We will also discuss more about respiration in living organisms that occurs at ambient temperatures.

Michael Faraday ended his lecture series on *The Chemical History of a Candle* by saying, "*...you see the analogy between respiration and combustion is rendered still more beautiful and striking. Indeed, all I can say to you at the end of these lectures (for we must come to an end at one time or other) is to express a wish that you may, in your generation,* ***be fit to compare to a candle; that you may, like it, shine as lights to those about you; that, in all your actions, you may justify the beauty of the taper by making your deeds honourable and effectual in the discharge of your duty to your fellow-men****."*



John Ondrasik wrote a song about how Ukrainian President Zelenskyy shines like a flame and makes us think!

On May 28, 1850, Charles Dickens wrote to Michael Faraday:

"Dear Sir,

I take the liberty of addressing you as if I knew you personally; trusting that I may venture to assume that you will excuse that freedom.



It has occurred to me that it would be extremely beneficial to a large class of the public, to have some account of your late lectures on the breakfast-table, and of those you addressed, last year, to children. I should be exceedingly glad to have some papers in reference to them, published in my new enterprise "Household Words." May I ask you whether it would be agreeable to you,—and if so, whether you would favor me with the loan of your notes of those lectures for perusal?...

Your faithful Servant,

Charles Dickens."

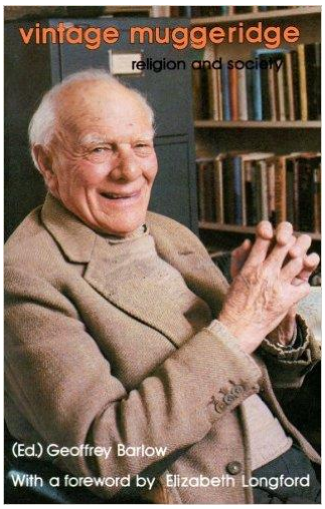
Dickens used Faraday's lecture notes to write a story called the *Chemistry of a Candle* for families to read around the breakfast table (http://www.victorianweb.org/authors/dickens/faraday3.html). Faraday's candlestick has been on exhibit at the Charles Dickens Museum. https://dickensmuseum.com/blogs/charles-dickens-museum/michael-faradays-candlestick



Light, to the **luminaries** who created the **Enlightenment** such as Thomas Jefferson, is freedom from ignorance. As **Thomas Jefferson** said in a letter to Tench Coxe in 1795, "***Light and liberty go together****"* and in a letter to Cornelius Camden Batchly in 1822, "***I look to the diffusion of light and education as the resource most to be relied on for ameliorating the condition, promoting the virtue, and advancing the happiness of man.***"



In an address entitled, *The Blessing of Liberty and Education*, given at the dedication of a school for black children in Manassas, Virginia, Frederick Douglass (1894) said, "***There is fire in the flint and steel, but it is friction that causes it to flash, flame and burn, and give light where all else may be darkness****. There is music in the violin, but the touch of the master is needed to fill the air and the soul with the concord of sweet sounds.* ***There is power in the human mind, but education is needed for its development***."

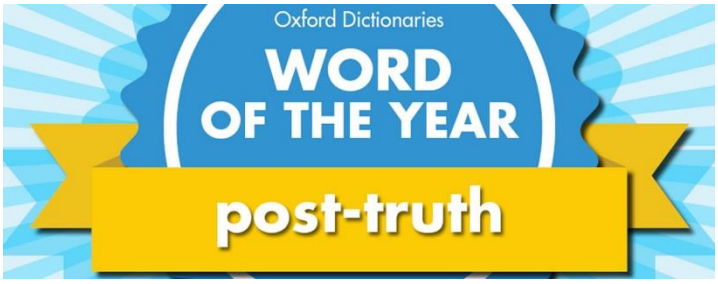


Education may not always be "*relied on for ameliorating the condition, promoting the virtue, and advancing the happiness of man*." According to **Malcolm Muggeridge**, "*So the final conclusion would surely be that whereas other civilizations have been brought down by attacks of barbarians from without, ours had the unique distinction of training its own destroyers at its own educational institutions, and then providing them with facilities for propagating their destructive ideology far and wide, all at the public expense. Thus did Western Man decide to abolish himself, creating his own boredom out of his own affluence, his own vulnerability out of his own strength, his own impotence out of his own erotomania, himself blowing the trumpet that brought the walls of his own city tumbling down, and having convinced himself that he was too numerous, labored with pill and scalpel and syringe to make himself fewer. Until at last,* ***having educated himself into imbecility****, and polluted and drugged himself into stupefaction, he keeled over—a weary, battered old brontosaurus—and became extinct*."



In a speech entitled, *Observation on Mental Education*, given by Faraday (May 6, 1854), who believed in one truth and that the God of the Bible was also the God of Nature wrote, "*I take courage, Sir, from your presence here this day, to speak boldly that which is upon my mind. I feared that it might be unpleasant to some of my audience, but as I know that your Royal Highness* [Prince Albert] *is a champion for and desires the truth, I will believe that all here are united in the same cause and therefore will give utterance, without hesitation, to what I have to say regarding the present*

condition of Mental Education… ***the book of nature, which we have to read, is written by the finger of God***."



In **post-modern** times, when objective truth no longer exists, the **Oxford English Dictionary** proclaimed "***post-truth***" to be the Word of the Year for 2016. Post-truth is "*an adjective defined as 'relating to or denoting circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief.*"
https://en.oxforddictionaries.com/word-of-the-year/word-of-the-year-2016

I worry about the slippage from the emphasis on ***lines of reasoning*** to get to the ***truth*** and ***talking points that substitute for the truth***. For example, in June 2020, Stephen Colbert asked Sen. Kamala Harris about what she said in a primary debate for president.

Colbert: *How do you go from being such a passionate opponent on such bedrock principles for you, and now you guys seem to be pals?*
Harris: *It was a debate.*
Colbert: *Not everyone landed punches like you did, though.*
Harris (laughing): *It was a debate.*
Colbert: ***So you didn't mean it***?
Harris: *It was a debate.*

In our post-truth world, let ***us*** go through life considering life to be meaningful and consequently, saying what we mean and meaning what we say.

In a post-truth world, as Karl Popper (1983) says in *Realism and the Aim of Science*, "[t]*here is no truth in science: there is only utility. Science is unable to enlighten our minds: it can only fill our bellies*."



Hans Christian Anderson wrote a fairy tale and a short story that relates to today's lecture. Hans Christian Anderson's first fairy tale, which was discovered in 2012, was entitled, ***The Tallow Candle*****.**

"*It sizzled and fizzled as the flames fired the cauldron. it was the Tallow Candle's cradle - and out of the warm cradle came a flawless candle; solid, shining white and slim it was formed in a way that made everyone who saw it believe that it was a promise of a bright and radiant future – promises that everyone who looked on believed it would really want to keep and fulfil.*

The sheep – a fine little sheep – was the candle's mother, and the melting pot its father. Its mother had given it a shiny white body and an inkling about life, but from its father it had been given a craving for the flaming fire that would eventually go through its marrow and bone and shine for it in life.

That's how it was born and had grown; and with the best and brightest anticipation cast itself into existence. There it met so many, many strange creations that it became involved with, wanting to learn about life – and perhaps find the place where it would best fit in. But it had too much faith in the world that only cared about itself, and not at all about the Tallow Candle. A world that failed to understand the value of the candle, and thus tried to use it for its own benefit, holding the candle wrongly; black fingers leaving bigger and bigger blemishes on its pristine white innocence which eventually faded away, completely covered by the dirt of a surrounding world that had come much too close; much closer than the candle could endure, as it had been unable to tell grime from purity – although it remained pristine and unspoiled inside.

False friends found they could not reach its inner self and angrily cast the candle away as useless.

The filthy outer shell kept all the good away – scared as they were to be tainted with grime and blemishes – and they stayed away.

So there was the poor Tallow Candle, solitary and left alone, at a loss at what to do. Rejected by the good, it now realised it had only been a tool to further the wicked. It felt so unbelievably unhappy, because it had spent its life to no good end – in fact it had perhaps sullied the better parts of its surroundings. It just could not determine why it had been created or where it belonged; why it had been put on this earth – perhaps to end up ruining itself and others.

More and more, and deeper and deeper, it contemplated – but the more it considered itself, the more despondent it became, finding nothing good, no real substance for itself, no real goal for the existence it had been given at its birth. As if the grimy cape had also covered its eyes.

But then it met a little flame, a tinder box. It knew the candle better than the Tallow Candle knew itself. It came closer and there was bright expectation in the candle – it lit and its heart melted.

Out burst the flame, like the triumphant torch of a blissful wedding. Light burst out bright and clear all around, bathing the way forward with light for its surroundings – its true friends – who were now able to ***seek truth in the glow of the candle****.*

The body too was strong enough to give sustenance to the fiery flame. One drop upon another, like the seeds of a new life, trickled round and chubby down the candle, covering the old grime with their bodies.

They were not just the bodily, but also the spiritual issue of the marriage.

And the Tallow Candle had found its right place in life – and shown that it was a real candle, and went on to shine for many a year, pleasing itself and the other creations around it."

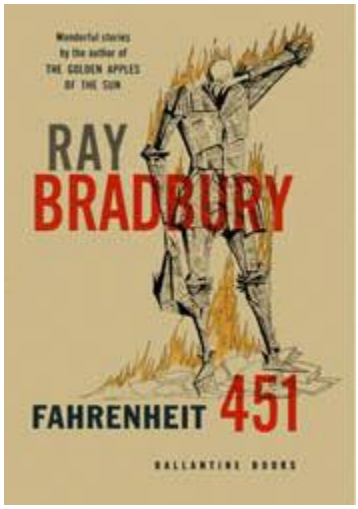
https://www.youtube.com/watch?v=lBk9qSxn390

Hans Christian Andersen's first short story was entitled, *The Tinder Box*.

https://www.youtube.com/watch?v=GFURBFg1VoA



Fires are not only illuminating, sometimes that can be obscuring, casting a dark shadow into the future. We discussed the burning of the Library in Alexandria. **Ray Bradbury** wrote about the burning of books. https://www.secret-satire-society.org/wp-content/uploads/2014/01/Ray-Bradbury-Fahrenheit-451.pdf



The temperature that paper burns is **451 degrees Fahrenheit**, which explains the title of Ray Bradbury's book (1953), ***Fahrenheit 451,*** which describes a dystopia where people stopped reading books for two reasons. One because they found lines in them offensive, and two because they didn't have a long enough attention span to read a book. Eventually books were outlawed and burned by the "firemen" who worked for the state. Bradbury wrote *Fahrenheit 451* to describe a world without books because he was afraid that television, which was the smartphone of 1953, would kill people's interest in reading books, turn them into morons, and substitute having knowledge with being bombarded with factoids. https://www.laweekly.com/news/ray-bradbury-fahrenheit-451-misinterpreted-2149125; http://www.raybradbury.com/images/video/about_freeDOM.html According to Bradbury, "*I am a preventor of futures, not a predictor of them. I wrote Fahrenheit 451 to prevent book-burnings, not to induce that future into happening, or even to say that it was inevitable*."

http://community.seattletimes.nwsource.com/archive/?date=19930312&slug=1689996



"***The problem in our country isn't with books being banned, but with people no longer reading. Look at the magazines, the newspapers around us - it's all junk, all trash, tidbits of news.***"

"***You don't have to burn books to destroy a culture. Just get people to stop reading them***."

Question: *How does the story of Fahrenheit 451 stand up in 1994?*

R.B.: *It works even better because we have political correctness now. Political correctness is the real enemy these days….*

Even more depressing is that I foresaw political correctness 43 years ago.

http://diginole.lib.fsu.edu/islandora/object/fsu:168044/datastream/PDF/view

Dr. Ben Carson wrote the following poem in response to the cancelling of six Dr. Seuss books:



I do not like to cancel books. I do not like how that looks.

I do not like it here, nor there, I do not like it anywhere.

I do not like it in the store, I do not want it anymore.

I do think it's time past, no longer to have thought a crime.

I do hope one day to see across my country 'tis of thee, books used to read and learn instead of set ablaze to burn.

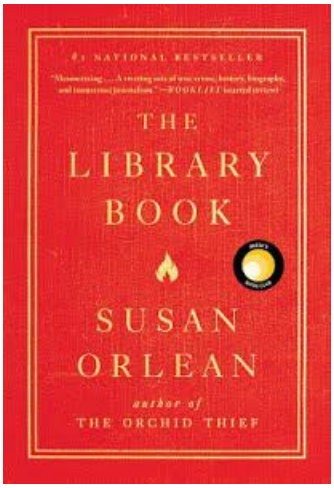


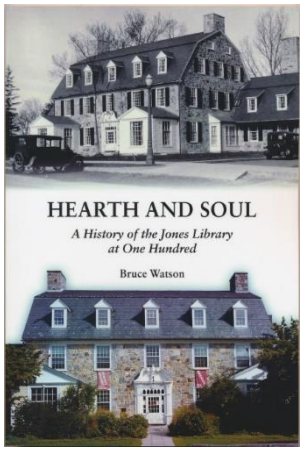
Our heritage for all to share, little patriots everywhere.

Our nation's story rich and vast, our true history taught in class.

A special place for all to be, a place known for its liberty.

Susan Orlean (2018) describes the fire in the Central Los Angeles Library in **The Library Book**. Due to the perfect ratio of fuel to oxygen, the fire burned clear. "*In the physics of fire, there is a chemical phenomenon known as a* ***stoichiometric condition****, in which the fire achieves the perfect burning ratio of oxygen to fuel—in other words, there is exactly enough air available for the fire to consume all of what is burning. Such a ratio creates an ideal fire situation, which results in total, perfect combustion. A stoichiometric condition is almost impossible to create outside of a laboratory. It requires such an elusive, precise balance of fuel and fire and oxygen that, in a sense, it is more theoretical than actual. Many firefighters have never seen such a blaze and never will. Not long ago, I had coffee with a man named Ron Hamel. He is now an arson investigator, but at the time of the library fire, Hamel was a captain in the fire department. Although over thirty years have passed, he remains awed by what he saw that day at the library. He talked about it like someone might talk about seeing a UFO. In his decades with the department, Hamel fought thousands of fires, but he said he never experienced another that was as exceptional as the fire at Central Library. Usually, a fire is red and orange and yellow and black. The fire in the library was colorless. You could look right through it, as if it were a sheet of glass. Where the flame had any color, it was pale blue. It was so hot that it appeared icy. Hamel said he felt like he was standing inside a blacksmith's forge. "We thought we were looking at the bowels of hell," he said, tapping his coffee mug. "Combustion that complete is almost impossible to achieve, but in this case, it was achieved. It was surreal*."





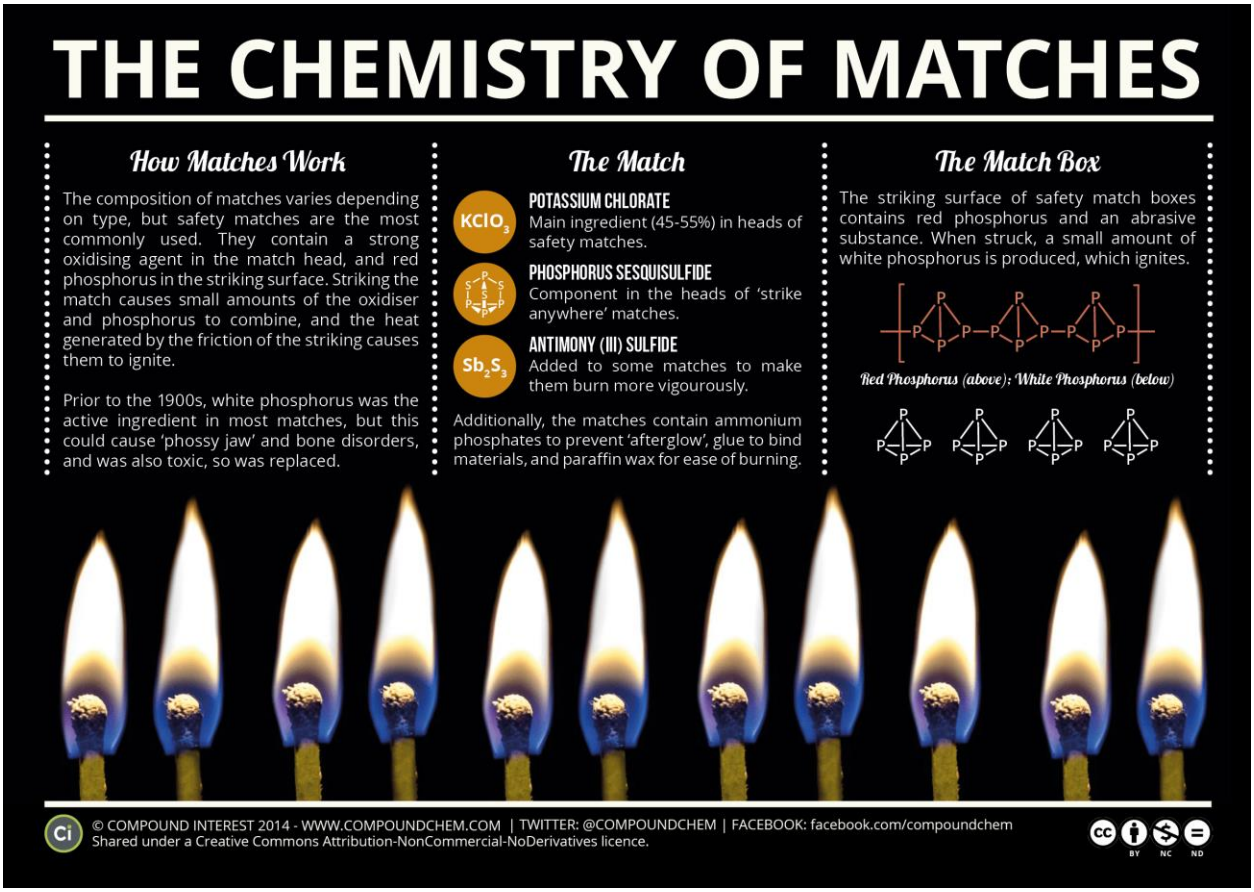
Bruce Watson (2019) wrote about the *Hearth and Soul* of the Jones Library in Amherst, MA that houses archival collections of works by Emily Dickinson, Robert Frost, Robert Francis, and Julius Lester. Here is a poem by Emily Dickinson—

The Poets light but Lamps

The Poets light but Lamps —
Themselves — go out —
The Wicks they stimulate
If vital Light

Inhere as do the Suns —
Each Age a Lens
Disseminating their
Circumference —





https://www.compoundchem.com/2014/11/20/matches/
https://www.youtube.com/watch?v=y2ErAPODA6U

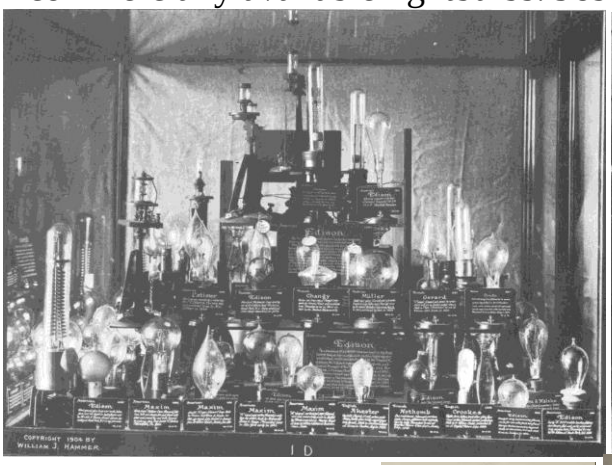
Switching the Light: From a Chemical Energy Source to an Electrical Energy Source

The invention of the lightbulb:

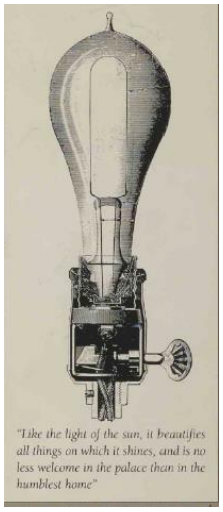
Humphry Davy (1802) connected a battery consisting of 2,000 cells to a thin strip of platinum. The platinum became incandescent without melting. Davy (1807-1809) also connected the battery to two pieces of charcoal which would cause bright sparks to jump across the gap—creating the first arc lamp. These lamps were neither bright enough nor long-lasting enough to be used as a lamp. **Warren de la Rue** (1840) put a coiled platinum filament in a **vacuum** tube and

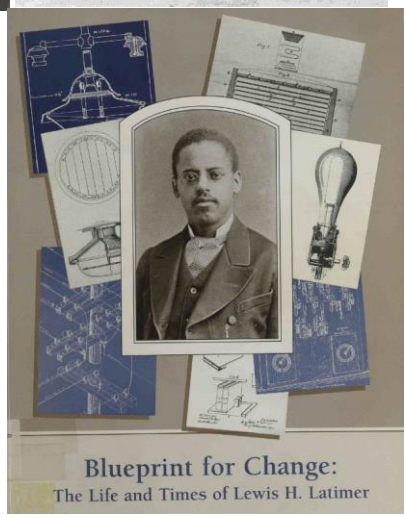
passed an electric current through it. In a vacuum, there were fewer gas molecules to react with the platinum, thus improving its longevity.

Because of the high cost of platinum, other materials were sought out to be filaments that could be used in commercially available lightbulbs. **Joseph Swan** (1850s) developed the carbon filament, which also has a high melting point. **Thomas Edison** (1879), filed for a US patent for an electric lightbulb using "*a carbon filament or strip coiled and connected ... to platina contact wires*." Edison (December 31, 1879) said, "*We will make electric light so cheap that only the rich will be able to burn candles*." **Lewis Latimer** (1882), whose parents, George and Rebecca (*née* Smith) Latimer, were runaway slaves, and who attended school up until fifth grade, and who, at age 15, fought in the Union Navy aboard the USS *Masasoit* during the Civil War, was one of the founding members of **Edison's Pioneers**. He developed an improved method of heat-treating carbon filaments in the absence of oxygen. Latimer's pyrolysis technique involved stuffing carbon filaments inside cardboard envelopes that were coated with a substance that kept the filaments from sticking before he exposed the filaments and cardboard envelopes to high temperature in the absence of oxygen. Since the envelopes expanded and contracted at the same rate as the filaments, the filaments kept their shape and no longer broke or became

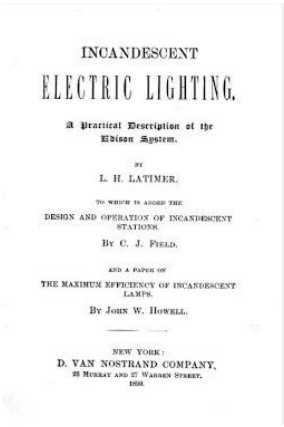


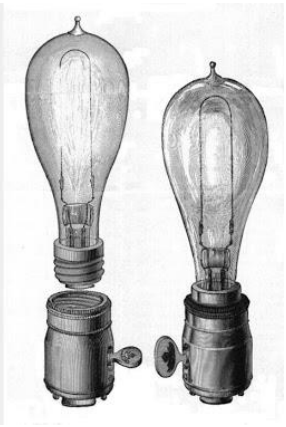






misshapen. Latimer's technique allowed him to produce a lightbulb with a longer life, making the electric lightbulb affordable so that middleclass families and small business could illuminate their homes and workplaces with electric lightbulbs. Latimer characterized the utility of the incandescent electric lightbulb like so: "*Like the light of the sun, it beautifies all things on which it shines, and is no less welcome in the palace than in the humblest home*."


INCANDESCENT
ELECTRIC LIGHTING.
A Practical Description of the Edison System.
BY
L. H. LATIMER.
TO WHICH IS ADDED THE
DESIGN AND OPERATION OF INCANDESCENT STATIONS.
BY C. J. FIELD.
AND A PAPER ON
THE MAXIMUM EFFICIENCY OF INCANDESCENT LAMPS.
BY JOHN W. HOWELL.
NEW YORK:
D. VAN NOSTRAND COMPANY,
23 MURRAY AND 27 WARREN STREET.
1890.



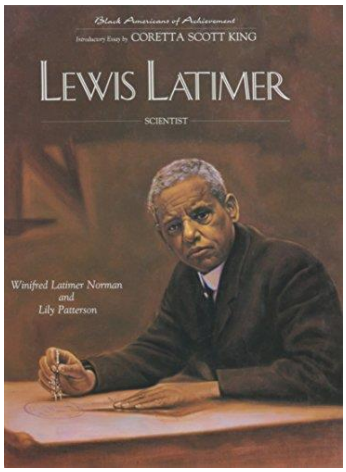
Latimer (1890) described the working of the lightbulb in his book *Incandescent Electric Lighting: A Practical Description of the Edison System* like so: "*If the electric current can be forced through a substance that is a poor conductor, it will create a degree of heat in the substance, which will be greater or less according to the quantity of electricity forced through it. Upon this principle of the heating effect of the electric current, is based the operation of the incandescent lamp…Where copper and platinum wires readily conduct the current, the carbon filament offers a great deal of resistance to its passage, and for this reason becomes very hot, in fact is raised to a white heat or incandescence, which gives its name to the lamp. You doubtless wonder why this thread of charcoal is not immediately consumed when in this state, but this is readily accounted for when you remember, that without the oxygen of the air, there can be no combustion, and that every possible trace of air has been removed from the bulb and it so thoroughly sealed up as to prevent the admission of the air about it; and yet the lamp does not last forever, for the reason that the action of the current upon the carbon has a tendency to divide up its particles and transfer them from one point to another so that, sooner or later, the filament gives way at some point. Yet most of these lamps are guaranteed to last a thousand hours, and this at*

from four to six hours a day gives the lamp a life of several months." Thus, the filament in an incandescent electric lightbulb and the soot produced when a candle burns produces illumination similarly.

Lewis Latimer was also active in civil rights. In a letter written to Richard Greener supporting the *National Conference of Colored Men,* whose goal was to draft a unified political platform for the 1896 Republican National Convention in Detroit, Lewis Latimer (1895) wrote, "*I am heart and soul in the movement (1) Because it is necessary that we should show the people of this country that we who have by our martyrdom under the lash; by our heroism on the battlefield; by our Christian forbearance beneath an overwhelming burden of injustice; and by our submission to the laws of the native land, proven ourselves worthy citizens of our common country. (2) Because there is no separation of the colored Americans from those of the white American, and it is our duty to show our country, and…the world that we are looking to the interests of the country at large, when we protest against the crime and injustice meted out to any class or conditions of our citizens. (3) Because the community which permits a crime against its humblest member to go unpunished is nursing into life and strength a power which will ultimately threaten its own existence. (4) Because our history conclusively proves that the attempt to degrade any portion, class, or race of our common people has always been fraught with more danger to the oppressor than the oppressed. (5) Because an evenhanded justice to all, under and through the law, is the only safe course to pursue for where might makes right, brute strength will supersede intelligence in the control of our communities.*

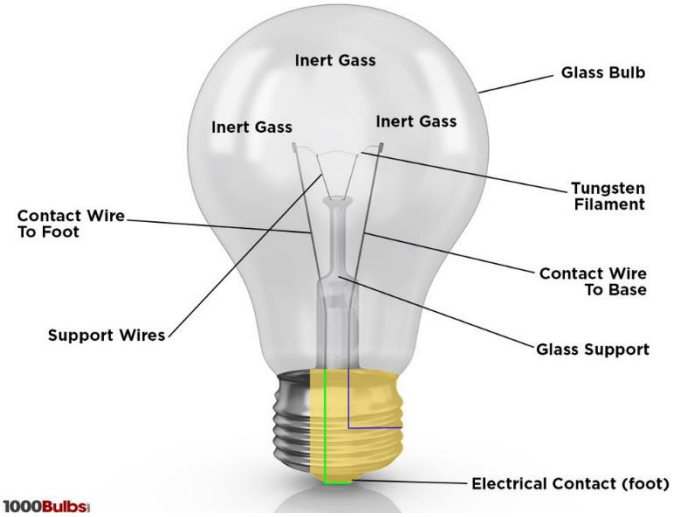
We should have a National Convention, forgetting all other considerations directs its energies to presenting its cause before the people, as it affects the people at large, presenting it as our fathers did the question of slavery, with facts and

figures, showing, as it can be shown, that where the Colored American is lynched, the white American is assassinated; that ignorance and crime go hand in hand with prejudice; that schools and churches multiply where there is neither class nor color distinctions in the law; that class legislation puts a premium on ignorance and illiteracy, in that it aids a man to think himself superior by accident of birth than by the achievements of merit and ability. ***If our cause be made the common cause, and all our claims and demands be founded on justice and humanity, recognizing that we must wrong no man in winning OUR rights, I have faith to believe that the Nation will respond to our plea for equality before the law, security under the law, and an opportunity, by and through maintenance of the law, to enjoy with our fellow citizens of all races and complexions the blessings guaranteed us under the Constitution of 'life, liberty and the pursuit of happiness****. "'*



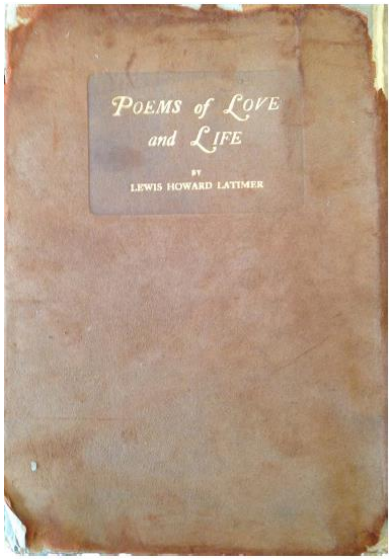
Sándor Just and **Franjo Hanaman** (1904) developed a tungsten filament that lasted longer and gave brighter light than the carbon filament. **Irving Langmuir** (1913) found that filling a lamp with inert gas such as argon or nitrogen instead of using a vacuum slows down the evaporation of the tungsten resulting in a longer filament life. He also developed the spiral tungsten filament. The result of the work of these and people is today's incandescent lamp.





Here are Poems by Lewis Latimer. His father also wrote poetry.

Friends



Friend of my childhood,

Of life's early days

When together we wandered

Through bright sunny ways

Each true to the other,

Till full manhood came,

And found the old friendship

As ever the same.

Came summer and winter,

Years waxed and waned.

Youth it had left us

But friendship remained

And now as with white locks

I bend o'er life's page,

The friend of my childhood

Is the friend of my age.

Ebon Venus (A tribute to his wife)

Let others boast of maidens fair,

Of eyes of blue and golden hair;

My heart like needles ever true

Turns to the maid of ebon hue.

I love her form of matchless grace,

The dark brown beauty of her face,

Her lips that speak of love's delight,

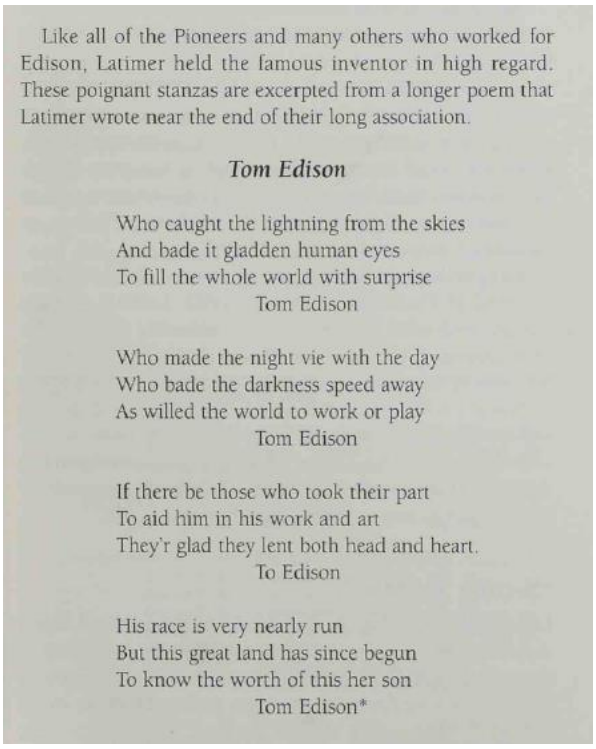
Her eyes that gleam as stars at night.

O'er marble Venus let them rage,

Who sets the fashions of the age;

Each to his taste, but as for me,

My Venus shall be ebony.



Like all of the Pioneers and many others who worked for Edison, Latimer held the famous inventor in high regard. These poignant stanzas are excerpted from a longer poem that Latimer wrote near the end of their long association.

Tom Edison

Who caught the lightning from the skies
And bade it gladden human eyes
To fill the whole world with surprise
Tom Edison

Who made the night vie with the day
Who bade the darkness speed away
As willed the world to work or play
Tom Edison

If there be those who took their part
To aid him in his work and art
They'r glad they lent both head and heart.
To Edison

His race is very nearly run
But this great land has since begun
To know the worth of this her son
Tom Edison*

And a poem written by John Greenleaf Whittier (1843) about George Latimer, Lewis' father:

From Massachusetts to Virginia

The blast from Freedom's Northern hills, upon its Southern way,
Bears greeting to Virginia from Massachusetts Bay.
No word of haughty challenging, nor battle bugle's peal,
Nor steady tread of marching files, nor clang of horsemen's steel.

No trains of deep-mouthed cannon along our highways go;
Around our silent arsenals untrodden lies the snow;
And to the land-breeze of our ports, upon their errands far,
A thousand sails of commerce swell, but none are spread for war.

We hear thy threats, Virginia! thy stormy words and high,
Swell harshly on the Southern winds which melt along our sky;
Yet, not one brown, hard hand foregoes its honest labor here,
No hewer of our mountain oaks suspends his axe in fear.

Wild are the waves which lash the reefs along St. George's bank;

Cold on the shore of Labrador the fog lies white and dank;
Through storm, and wave, and blinding mist, stout are the hearts which man
The fishing-smacks of Marblehead, the sea-boats of Cape Ann.

The cold north light and wintry sun glare on their icy forms,
Bent grimly o'er their straining lines or wrestling with the storms;
Free as the winds they drive before, rough as the waves they roam,
They laugh to scorn the slaver's threat against their rocky home.

What means the Old Dominion? Hath she forgot the day
When o'er her conquered valleys swept the Briton's steel array?
How side by side, with sons of hers, the Massachusetts men
Encountered Tarleton's charge of fire, and stout Cornwallis, then?

Forgets she how the Bay State, in answer to the call
Of her old House of Burgesses, spoke out from Faneuil Hall?
When, echoing back her Henry's cry, came pulsing on each breath
Of Northern winds, the thrilling sounds of "Liberty or Death!"

What asks the Old Dominion? If now her sons have proved
False to their fathers' memory, false to the faith they loved;
If she can scoff at Freedom, and its great charter spurn,
Must we of Massachusetts from truth and duty turn?

We hunt your bondmen, flying from Slavery's hateful hell;
Our voices, at your bidding, take up the bloodhound's yell;
We gather, at your summons, above our fathers' graves,
From Freedom's holy altar-horns to tear your wretched slaves!

Thank God! not yet so vilely can Massachusetts bow;
The spirit of her early time is with her even now;
Dream not because her Pilgrim blood moves slow and calm and cool,
She thus can stoop her chainless neck, a sister's slave and tool!

All that a sister State should do, all that a free State may,
Heart, hand, and purse we proffer, as in our early day;
But that one dark loathsome burden ye must stagger with alone,
And reap the bitter harvest which ye yourselves have sown!

Hold, while ye may, your struggling slaves, and burden God's free air

With woman's shriek beneath the lash, and manhood's wild despair;
Cling closer to the "cleaving curse" that writes upon your plains
The blasting of Almighty wrath against a land of chains.

Still shame your gallant ancestry, the cavaliers of old,
By watching round the shambles where human flesh is sold;
Gloat o'er the new-born child, and count his market value, when
The maddened mother's cry of woe shall pierce the slaver's den!

Lower than plummet soundeth, sink the Virginia name;
Plant, if ye will, your fathers' graves with rankest weeds of shame;
Be, if ye will, the scandal of God's fair universe;
We wash our hands forever of your sin and shame and curse.

A voice from lips whereon the coal from Freedom's shrine hath been,
Thrilled, as but yesterday, the hearts of Berkshire's mountain men:
The echoes of that solemn voice are sadly lingering still
In all our sunny valleys, on every wind-swept hill.

And when the prowling man-thief came hunting for his prey
Beneath the very shadow of Bunker's shaft of gray,
How, through the free lips of the son, the father's warning spoke;
How, from its bonds of trade and sect, the Pilgrim city broke!

A hundred thousand right arms were lifted up on high,
A hundred thousand voices sent back their loud reply;
Through the thronged towns of Essex the startling summons rang,
And up from bench and loom and wheel her young mechanics sprang!

The voice of free, broad Middlesex, of thousands as of one,
The shaft of Bunker calling to that of Lexington;
From Norfolk's ancient villages, from Plymouth's rocky bound
To where Nantucket feels the arms of ocean close her round;

From rich and rural Worcester, where through the calm repose
Of cultured vales and fringing woods the gentle Nashua flows,
To where Wachuset's wintry blasts the mountain larches stir,
Swelled up to Heaven the thrilling cry of "God save Latimer!"

And sandy Barnstable rose up, wet with the salt sea spray;

And Bristol sent her answering shout down Narragansett Bay
Along the broad Connecticut old Hampden felt the thrill,
And the cheer of Hampshire's woodmen swept down from Holyoke Hill.

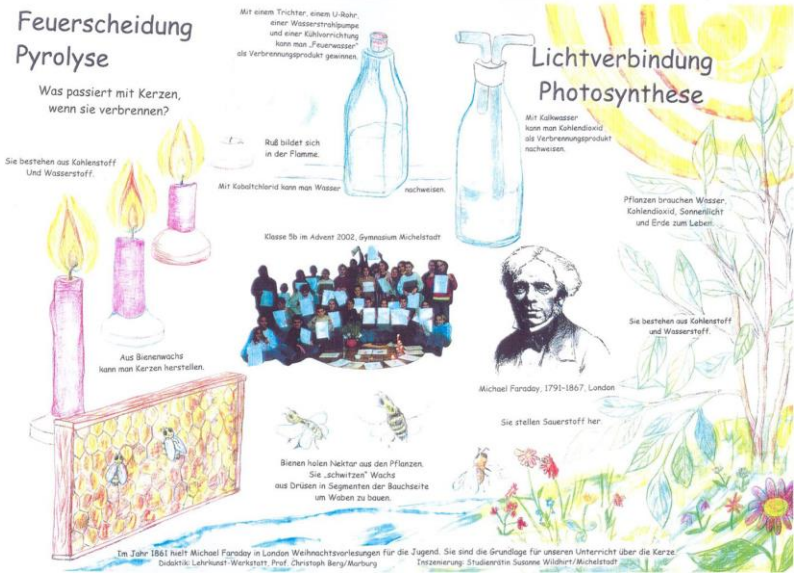
The voice of Massachusetts! Of her free sons and daughters,
Deep calling unto deep aloud, the sound of many waters!
Against the burden of that voice what tyrant power shall stand?
No fetters in the Bay State! No slave upon her land!

Look to it well, Virginians! In calmness we have borne,
In answer to our faith and trust, your insult and your scorn;
You've spurned our kindest counsels; you've hunted for our lives;
And shaken round our hearths and homes your manacles and gyves!

We wage no war, we lift no arm, we fling no torch within
The fire-clamps of the quaking mine beneath your soil of sin;
We leave ye with your bondmen, to wrestle, while ye can,
With the strong upward tendencies and godlike soul of man!

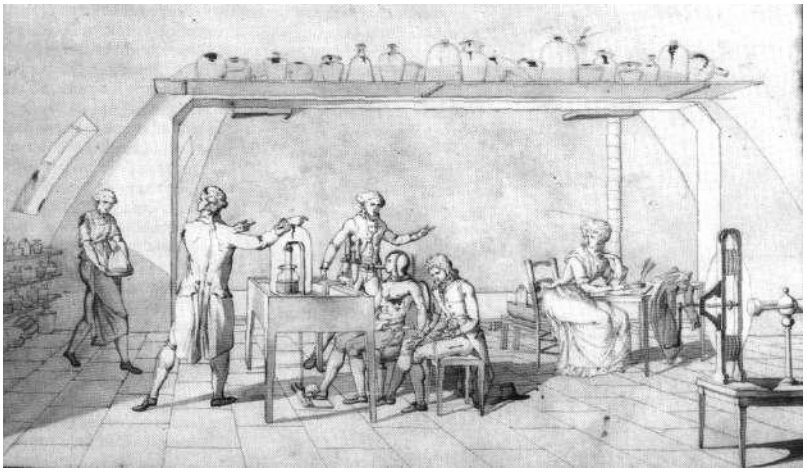
But for us and for our children, the vow which we have given
For freedom and humanity is registered in heaven;
No slave-hunt in our borders, and no pirate on our strand!
No fetters in the Bay State, and no slave upon our land!

A picture that shows how the chemical history of a candle relates to many of the topics that we will discuss this semester.



Cellular Respiration: Converting carbohydrate into chemical energy without emitting visible light

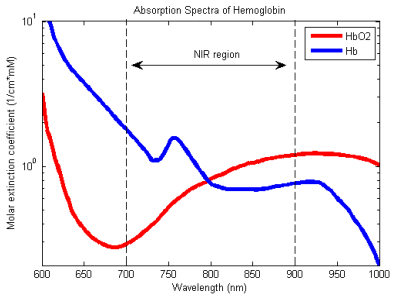
A knowledge of the relationship between light and the spirit is ancient. According to Proverbs (20:27), "*The spirit of man is the candle of the Lord, searching all the inward parts of his being*." The great chemist, **Antoine Lavoisier** was the first scientist to draw an analogy between respiration and the chemical process of combustion.



Although in 1789, he ended a memoir like so: "*One may say that this analogy between combustion and respiration has not escaped the notice of poets, or rather the philosophers of antiquity, and which they had expounded and interpreted. This **fire stolen from heaven**, this torch of **Prometheus**, does not only represent an ingenious and poetic idea, it is a faithful picture of the operations of nature, at least for animals that breathe; one may therefore say, with the ancients, that **the torch of life** lights itself at the moment the infant breathes for the first time, and it does not extinguish itself except at death. In considering such happy agreement, one might sometimes be tempted to believe that the ancients had indeed penetrated further than we think into the sanctuary of knowledge, and that the myth is actually nothing but an allegory, in which they hid the **great truths of medicine and physics**."*



J. Robert Mayer, a ship's physician, originally discovered the **First Law of Thermodynamics** when he noted in 1840 the color of venous blood is redder in people who live in the tropics than in people who live in colder climates. He wrote, "*Observations which I made in the Tropics taught me to recognize the role which the blood corpuscles play in the* ***combustion process in the body****. In a sea voyage of 100 days, out of a passenger list of 28 there occurred no serious incidence of sickness. However, a few days after the arrival in Batavia (Dutch East Indies) there broke out an epidemic of an acute catarrhal inflammatory affection of the lungs. In the ample blood-letting which I carried out, the blood from the veins in the arm had an unusually red color, so that if I had judged by color alone I might have thought I had struck an artery*….At this point Mayer realized that in **tropical climates** there was no need for **combustion to heat the body** as there is such a need in **colder climates**, and consequently, there is more unused oxygen in the blood of people who live in tropical climates compared with people who live in colder climates and this is why the venous blood is redder in people who live in tropical climates compared to people who live in colder climates. Mayer also realized that physical work generates heat and that it too must be powered by combustion. Although Mayer was not sure how heat itself caused the muscles to contract.

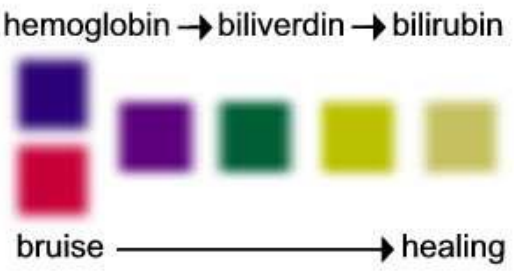


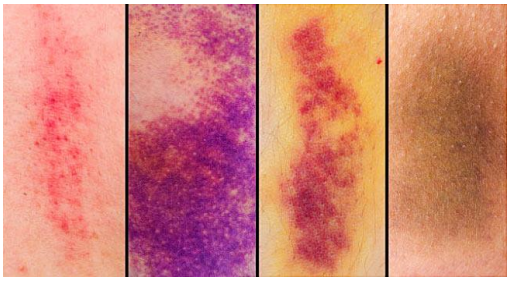
Demonstration: Measure the oxygen content of your blood using the oximeter, which transmits two wavelengths of light through the finger to a photodetector. It measures the changing ratio of the absorbances of the red (660 nm) to the infrared light (940 nm) in order to determine the percent saturation of the **oxygen-binding hemoglobin** in the **arterial blood**.



As an aside, a bruise is initially red due to oxygenated hemoglobin and then deep purple due to the breakdown of hemoglobin. Subsequently, the

hemoglobin breaks down into biliverdin, a green pigment, which breaks down into bilirubin, a yellow pigment. Bruises typically become red, purple, green, dark yellow, pale yellow, and then disappear.



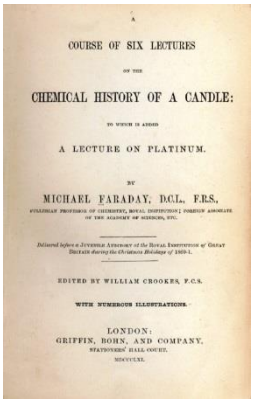


From his simple observation, Mayer realized that ***ex nihilo nihil fit. Nil fit ad nihilum***. That is, **nothing comes from nothing, every effect must be preceded by a cause, and the effect is equal to the cause**. He then applied the **First Law of Thermodynamics**, not only to heating the human body, but to gravitational energy, radiant energy, chemical energy, kinetic energy, electrical energy, and magnetic energy.



In *The Sound of Music*, Maria and Georg sang the song, *Something Good* which contains what I consider to be a truism, consistent with the First Law of Thermodynamics:

Nothing comes from nothing
Nothing ever could


COURSE OF SIX LECTURES
ON THE
CHEMICAL HISTORY OF A CANDLE:
TO WHICH IS ADDED
A LECTURE ON PLATINUM.
BY
MICHAEL FARADAY, D.C.L., F.R.S.,
EDITED BY WILLIAM CROOKES, F.C.S.
WITH NUMEROUS ILLUSTRATIONS.
LONDON:
GRIFFIN, BOHN, AND COMPANY,

Last time we reenacted to some degree **Michael Faraday's** lecture series on *The Chemical History of a Candle*. Faraday demonstrated the analogy between combustion and respiration by showing that they both produce carbon dioxide and water. Michael Faraday is another scientist who was not trying to replace God with science. In a lecture given at the Royal Institution entitled, *Observations on the Education of the Judgment*,

Faraday said, "*…the book of nature, which we have to read, is written by the finger of God*."

Last time we observed that the combustion process that occurs in a **candle** involves **pyrolysis**, which takes place in the dark hollow of the flame, **chemiluminescence**, which can be seen best in the blue region at the bottom of the flame, **incandescence**, which is seen in the brightest portion of the flame, and **oxidation**, which occurs at the outside of the flame (http://vimeo.com/40271657).

The **intracellular combustion process or the respiratory process**, unlike the burning of a candle, does not involve the transformation of chemical energy into radiant energy and the emission of visible light. So, **while the chemical analogy is good, there are limitations**. While **pyrolysis** involves the fragmentation of the fuel by exposing it to temperatures that are high enough to boil our blood, fuel fragmentation occurs very differently in intracellular combustion. How is the fuel fragmented at **ambient temperature** in living cells?

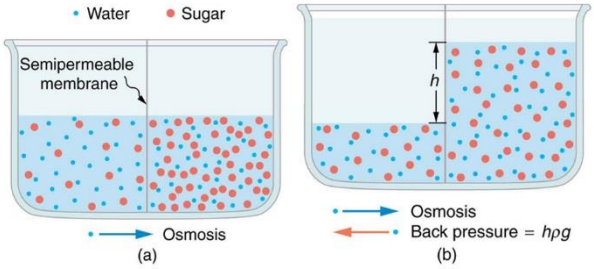


Louis Pasteur guessed that **fermentation** is respiration without air, and it not just a **chemical process** but a **vital process** that **requires living organisms**. He wrote, "*I am of the opinion that alcoholic fermentation never occurs without simultaneous organization, development and multiplication of cells....*" since he was never able to get fermentation to take place *in vitro* in the absence of living yeast. However, **Eduard Buchner** (1897) using a **German beer yeast** instead of a **French wine yeast** was able to obtain fermentation or **anaerobic respiration** *in vitro* when he added sugar to a yeast extract.

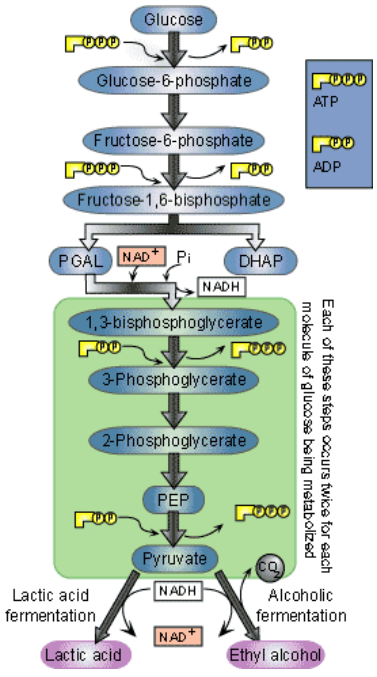




Actually, this was a **lucky** find, since Buchner was making a health tonic, and only added the sugar as a preservative, when the other antiseptics failed to keep the extract sterile. Buchner's wife made the suggestion based on her commonsense knowledge that fruit preserves are made by heating fruit in a sugar solution. The sugar acts as a preservative because bacteria cannot grow in high concentrations of sugar (or salt) because the high concentration of sugar draws water out of the bacteria by **osmosis** and they **dehydrate**.

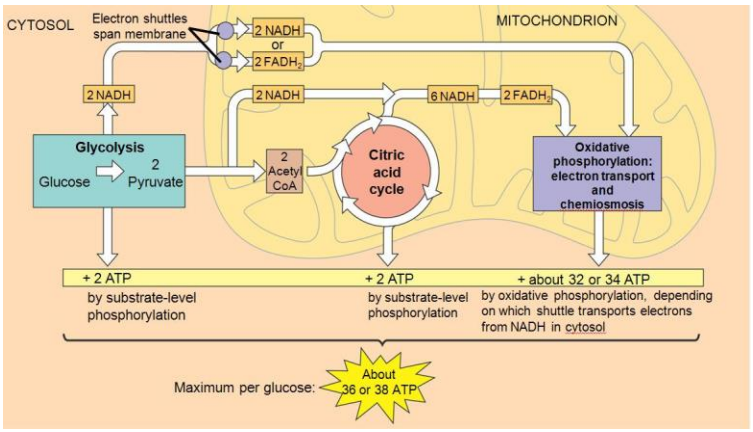


In this way, Buchner discovered the part of the yeast that caused the fermentation of sugar in the absence of air and named the extract **zymase,** from *zyme*, the Greek word for "**yeast**," and *diastasis*, the Greek word for "break apart." Willy Kühne named all biocatalysts, **enzymes**, from the Greek words, *en zyme*, which mean "**in yeast**".



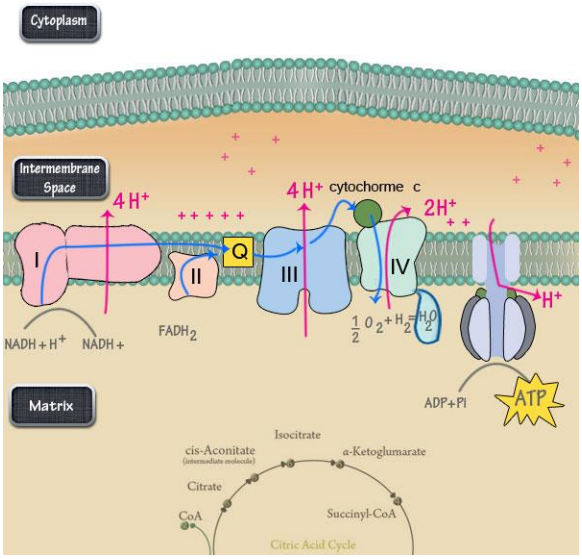
In the candle, the fuel is broken down in a couple of haphazard steps by heat in a process known as **pyrolysis**. In living cells, the fuel is not fragmented by heat but is broken down in **glycolysis** at **ambient temperatures** in about a dozen sequential and ordered steps as a result of the intervention of **enzymes**. In the process of fermentation, which takes place in the **cytosol**, **hydrogen atoms** in the form of electrons and protons, are removed from the sugar in a process of **oxidation (loss of electrons is oxidation).** During the **oxidation process**, a net production of **two molecules of ATP** is formed from each sugar molecule. Most of the chemical energy in the original sugar molecule fragmented in glycolysis is left unavailable as lactic acid or

ethanol, although we make use of these products in pickling, wine, and beer making.

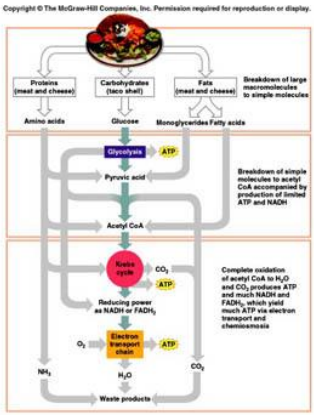


In the presence of **oxygen**, aerobic respiration takes place where the pyruvate is not turned into lactic acid or ethanol, but **fully oxidized** into **carbon dioxide** and **water**.

The second leg of the oxidation of glucose takes place in **mitochondria** and results in the production of approximately **38 molecules of ATP** per sugar molecule compared with two molecules produced by fermentation alone.



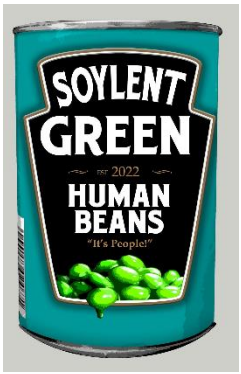
In **aerobic respiration**, the electrons that are removed from the molecules being oxidized are transferred to **NAD^+ to form NADH**, a molecule that is similar to NADPH, the hydrogen carrier that participates in photosynthesis. The NADH then passes its electrons to an **electron transport chain** composed of **iron-containing cytochromes**, which means "**cell color**." This too is similar to the electron transport chain of photosynthesis. After all both processes transform the chemical energy of reduced molecules by oxidizing them. Moreover, as the electrons move from an acceptor with a more negative redox potential to one with a more positive redox potential, they can use the redox



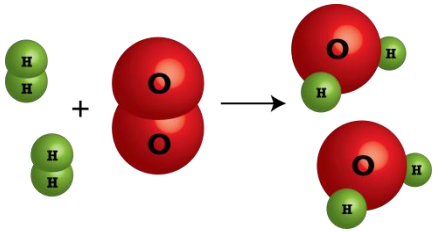
energy made available in the electron transfer to transfer protons from the matrix of the mitochondria to the intermembrane space. This **charge separation** is also similar to what happens during photosynthesis. The electrochemical energy of the proton gradient is then used by the coupling factor or ATP synthase to synthesize **ATP** from ADP and Pi.







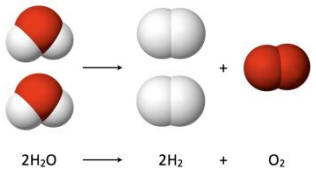
All foodstuffs, including carbohydrates, lipids, and proteins as well as mixtures such as Soylent, which is composed of soybean and lentil, and not to be confused with Soylent Green, are enzymatically combusted so that the energy in their CH bonds can be transformed into the energy of **ATP**. We now know that **ATP is the common intermediate that is used to energize all aspects of life,** including, **mechanical work**, like muscle contraction, **biosynthetic work** like sugar, protein, and lipid synthesis, and **electrical work**, like nerve transmission.



In aerobic respiration, the **oxygen** functions as the ultimate electron acceptor. It is transformed into two **water molecules** when it **gains four electrons** and four hydrogen ions (protons). The oxygen gains the electrons transferred to it by **cytochrome oxidase**, an **iron**-containing enzyme. This is equivalent to the outermost region of the flame.



The rapid binding of iron to oxygen that took place in the candle when we sprinkled iron powder (but not iron oxide) in the flame or when we struck the **flint** against the **steel** took place at a temperature high enough to result in **incandescence**. On the other hand, the binding of oxygen to iron-containing **cytochrome oxidase** takes place at **ambient temperatures**.

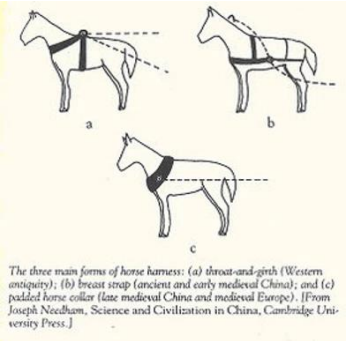


Chemically, the formation of water by cytochrome oxidase is a reversal of the oxygen splitting that occurred in Photosystem II of photosynthesis.

Aerobic respiration provides large quantities of energy to the cell. The many small steps involved in intracellular combustion allow some of the energy of combustion to be conserved as the chemical energy of ATP.



Aside: The original harness for horses was a **neck and girth** harness in which the straps were place around the horse's neck and girth. If the horse pulled too much weight, its windpipe would be squeezed, which restricted the ability of **oxygen** to get to the cells. About 100 B.C., the modern harness was invented in China. It put the force on the shoulders rather than the windpipe and allowed for the pulling of heavier loads with a single horse.



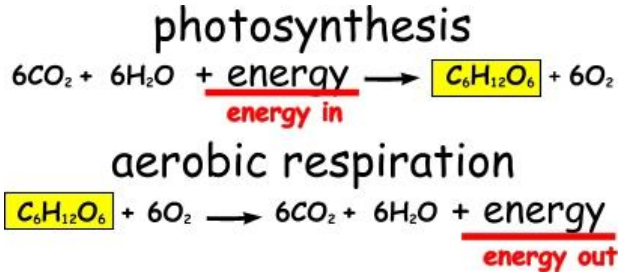
The three main forms of horse harness: (a) throat-and-girth (Western antiquity); (b) breast strap (ancient and early medieval China); and (c) padded horse collar (late medieval China and medieval Europe). [From Joseph Needham, Science and Civilization in China, Cambridge University Press.]

This harness arrived in Europe around 1000 A.D. By not restricting the flow of oxygen to the horse's cells, this harness allowed one man and a horse plowing the fields to do the work of 50 men. Due to the increased horsepower, food became more plentiful. The efficiency gained in the way humans could utilize horses,

resulted in increased productivity, and a surplus of food. This set the stage for the **Renaissance**.



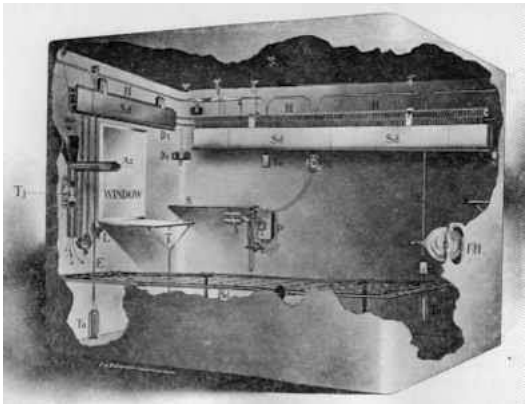
The overall equations of aerobic respiration and photosynthesis appear to represent the same reaction proceeding in reverse directions. While there are many similarities between the two reactions that take place in the mitochondria and chloroplasts in terms of generating and using charge separation of electrons and protons to synthesize ATP, respiration and photosynthesis are quite distinct and irreversible processes. The energy transducing processes of respiration and photosynthesis can be well understood in terms of the **First *and* Second Laws of Thermodynamics**.

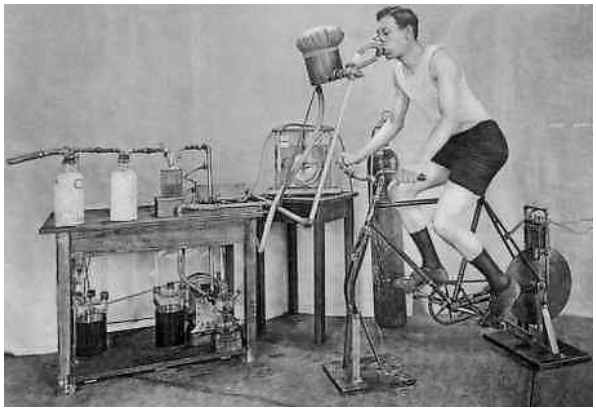


Photosynthesis requires an energy input in the form of light, to reduce the entropy of the chemicals involved in photosynthesis. Entropy increases overall however because a portion of the visible wavelengths of light is converted into infrared wavelengths, i.e., heat, thermal energy, or entropy. Aerobic respiration transforms some of the chemical energy of sugar to the chemical energy of ATP, the rest being given of a heat, thermal energy, or entropy.



Wilbur Olin Atwater treated the human body as a black box with inputs and outputs to gain insight into food, respiration, and mechanical work. In order to do this, he built in 1896 a respiration calorimeter room that measured the amount of **oxygen** taken up, the amount of **carbon dioxide** emitted, and the amount of **heat** generated when a person did any kind of **mechanical work**, for example, peddle a bicycle.



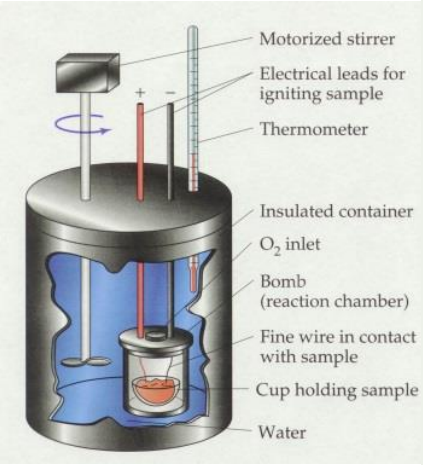


At the time Atwater did experiments, he did not know about how the energy derived by respiration was utilized by muscle contraction. He did not know about ATP and wondered, **could it be heat? Or could the electrons transferred from sugar to oxygen be used as an electric current**?

According to the First Law of Thermodynamics, to perform work, you have to ingest (at least) the same number of calories of food. Given the amount of work performed on a daily basis, Atwater recommended that active men and women eat approximately 2000-3000 Calories/day. However, "work" was typically more strenuous 100 years ago before there were cars, computers, smartphones, washers, dryers, or even Carvana, renttherunway.com, Uber, Lyft, DoorDash and Grubhub.

We measured the ability of a burning **peanut** to heat water. With a little more sophistication, Atwater burned thousands of foods in a bomb calorimeter to

determine their "**fuel value**." He found that in general, carbohydrates yield 4 Calories/gram, proteins yielded 4 Calories/gram, and fats yielded 9 Calories/gram. Atwater found that **meat** and **cereals** have a fuel value of approximately **1000 Calories/pound** whereas **fruits** and **vegetables** have a fuel value of approximately **250 Calories/pound** (= 0.55 Calories/gram). From the **calorimetry perspective alone**, fruits and vegetables did not seem to be very good foods. Modern nutrition theory at the turn of the 20th century based on the **fuel value of food** led to the "**typical American diet**" of white bread, muscle type of meat, potato, and sugar. A typical breakfast, lunch and dinner are shown below:



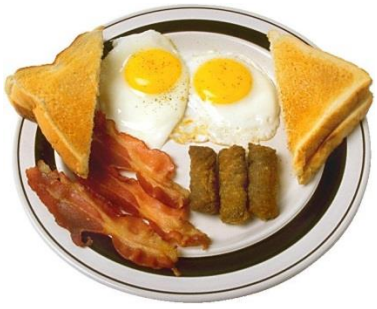
Nutrition Facts

Serving Size 1 peanut

Amount Per Serving	
Calories 11	Calories from Fat 8
	% Daily Values*
Total Fat 0.94g	1%
Saturated Fat 0.156g	1%
Polyunsaturated Fat 0.275g	
Monounsaturated Fat 0.467g	
Cholesterol 0mg	0%
Sodium 6mg	0%
Potassium 13mg	
Total Carbohydrate 0.27g	0%
Dietary Fiber 0.2g	1%
Sugars 0.08g	
Protein 0.5g	
Vitamin A 0%	Vitamin C 0%
Calcium 0%	Iron 0%

* Percent Daily Values are based on a 2000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Nutrition Values are based on USDA Nutrient Database SR18



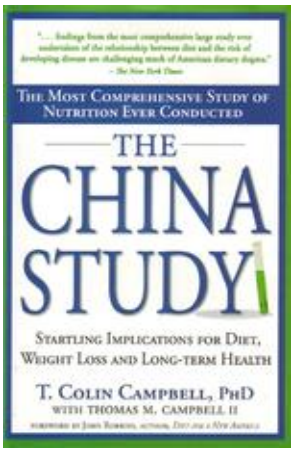


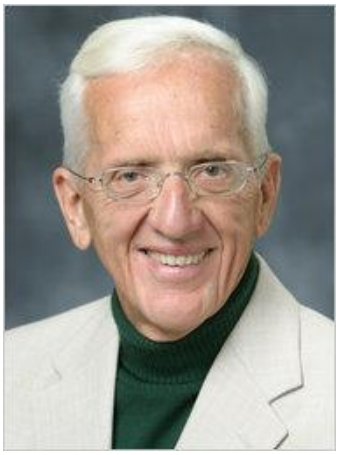
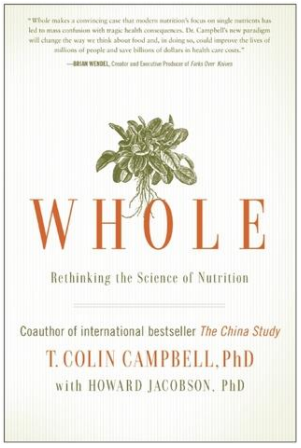


We now know that there are other things, such as **vitamins**, **minerals**, and **antioxidants** that are important in determining what good food is. We do not eat food for its fuel value alone.

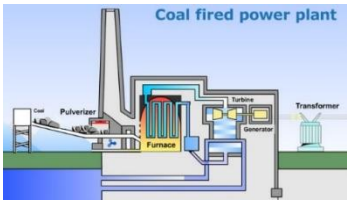


The China Study written by T. Colin Campbell (Cornell) presents the gold standard of evidence for the relationship between diet and health.



Thus ends the material for Prelim 1. (pre-omicron days)





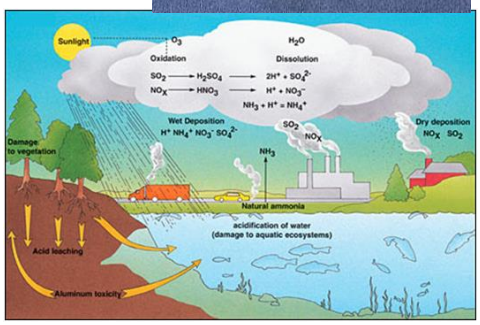


We have discussed how candles made of fats or wax can be burned for light. **Coal** is an organic rock produced from **plant products** that we use to generate steam to drive turbines that generate electricity. As a segue to describing coal balls, I will discuss coal itself. **Lignite** and **bituminous** coal are sedimentary rocks, produced from **peat** that grew in **bogs**. Lignite coal was produced during the Tertiary Period (66-2.58 million years ago). It has a high moisture and ash content, low **hydrocarbon** content, and thus low caloric value (60 Calories/gram). Bituminous coal is formed when a lignite-like coal has been subjected to high pressures. It has a higher fuel value than lignite (100 Calories/gram). Bituminous coal was produced about 100-300 million years ago. **Anthracite** coal has the lowest ash and moisture content, the highest hydrocarbon content, and thus the greatest caloric value (120 Calories/gram). This is because anthracite coal is a metamorphic rock that has been subjected to high temperatures and pressures that removed the volatile compounds that would have taken a portion of the thermal energy of the burning coal to volatilize them without producing heat. Anthracite coal was formed during the **Carboniferous Period,** about **359.2-299 million years ago**. Notice that

all of the coals, because of their high density, have a much higher fuel value than fat (9 Calories/gram).



Coal in relatively stable parts of the lithosphere that have been subjected to very high pressures (5000 MPa) but relatively low temperatures (900 -1300 C) can be transformed into **diamonds**.



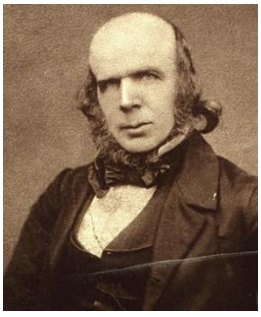
While it is the hydrocarbon portion of coal that is burned to turn water into steam, coal also contains other components, including **sulfur dioxide** (SO_2) that combines with oxygen and water in the atmosphere to cause **acid rain** (H_2SO_4). Acid rain devastates forests by damaging the leaves of trees and leaching the nutrients from the soil so the roots cannot mine them. Acid rain also dissolves buildings and monuments made from limestone ($CaCO_3$) and marble, which is composed of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). Marble is metamorphosed limestone.



$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2\uparrow$$



The effect of acid rain, resulting from the **industrial revolution**, was described by **Robert Angus Smith** (1872), a chemist who lived in the industrial city of Manchester, England, in his book, *Air and Rain: the Beginnings of a Chemical Climatology*. We will talk more about Manchester, England when we discuss the relationship between coal burning, the discoloration of tree bark, and the **evolution of the coloration of peppered moths**.







Here are some of Smith's measurements of oxygen and carbon dioxide that may be of interest to you. Note that **candles go out** when the oxygen concentration falls to 18.5%.

Oxygen in the Air.

(Per cent., or, if read as whole numbers, per million.)

	Volume per cent.
N.E. sea-shore and open heath (Scotland)	20·9990
Tops of hills (Scotland)	20·9800
In a suburb of Manchester in wet weather	20·9800
" " "	20·9600
St. John's, Antigua	20·9500
In the outer circle of Manchester, not raining	20·9470
Low parts of Perth	20·9350
Swampy places, favourable weather, France and Switzerland	20·9220 to 20·9500
In fog and frost in Manchester	20·9100
London, open places, summer	20·9500
In a sitting-room which felt close, but not excessively so	20·8900
In a small room with petroleum lamp	20·8400
Ditto, after six hours	20·8300
Pit of theatre, 11.30 p.m.	20·7400
Gallery, 10.30 p.m.	20·8600
About backs of houses and closets	20·7000
In large cavities in metalliferous mines (average of many)	20·7700
In currents	20·6500
Court of Queen's Bench, February 2, 1866	20·6500
Under shafts in metalliferous mines (average of many)	20·4240
In sumps or pits in a mine " "	20·1400
When candles go out	18·5000
The worst specimen yet examined in a mine	18·2700
Very difficult to remain in for many minutes	17·2000

Carbonic Acid in the Air.

(Per cent., or, if read as whole numbers, per million.)

	Volume per cent.
In mines—largest amount found in Cornwall	2·5000
Average of 339 analyses	·7850
In theatres, worst parts, as much as	·3200
In workshops, down to	·3000
About middens	·0774
During fogs in Manchester	·0679
Manchester streets, ordinary weather	·0403
Where fields begin	·0369
On the Thames at London	·0343
In the London parks and open places	·0301
In the streets	·0380
On hills in Scotland from 1,000 to 4,406 feet high	·0332
At the bottom of the same hills	·0341
Hills below 1,000 feet	·0337
" between 1,000 and 2,000 feet	·0334
" between 2,000 and 3,000 feet	·0332
" above 3,000 feet	·0336



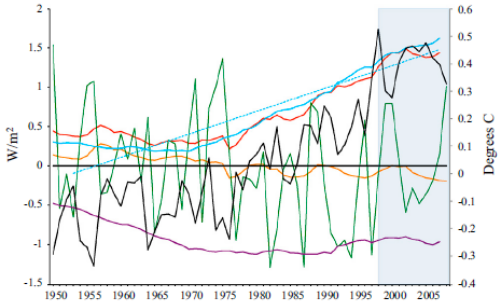
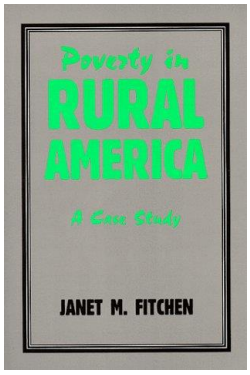


Fig. 1. Radiative forcing of anthropogenic sulfur emissions (purple line), net anthropogenic forcing (blue line), linear estimate of net anthropogenic forcing (blue dash), total radiative forcing (red line), radiative forcing of solar insolation (orange line), and observed temperature (black). The SOI (divided by 10) is given in green. SOI data are presented as annual mean sea level pressure anomalies at Tahiti and Darwin. Post-1998 period of interest (highlighted gray).

The sulfur emissions that are produced by burning coal also **scatter** the sun's rays just as volcanic dust scatters the sun's rays, resulting in less sun reaching the earth's surface and subsequent **global cooling**. Robert K. Kaufmann (2011) noticed that anthropogenic forcing of the global heat load was 0.13 W/m^2 between 2002 and 2007, which was smaller than the anthropogenic forcing (0.24 W/m^2) between 1997 and 2002. Were humans becoming better stewards of the planet? No. Kaufmann suggests that during the latter time period, some of the **global warming** caused by the anthropogenic rise in carbon dioxide (CO_2) was partially mitigated by the doubling of coal consumption in China between 2003 and 2007, which resulted in an increase in sulfur emissions, and a scattering away of incoming sunlight. The forcing coefficients are multiplied by the climate sensitivity factor to determine how the incoming heat changes the global temperature. I have no idea how to calculate the **climate sensitivity factor (**or if one can be calculated nearly as rigorously as the temperature changes that occur as a result of the absorption and scattering of radiation are calculated).



When it comes to green technologies, it is worth remembering that nothing is a renewable resource. It is also worth remembering to take into consideration the **mineral depletion of soil** that occurs by growing agricultural crops such as cotton, flax (linen), and the food for silkworms (silk) and sheep (wool) with the **depletion of fossil fuels** that occurs with the production of olefin, a fabric made from polypropylene. Olefin is lightweight, colorfast, and resistant to staining, mildew, and abrasion, however, it is not biodegradable.

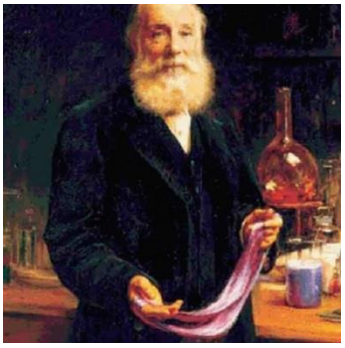


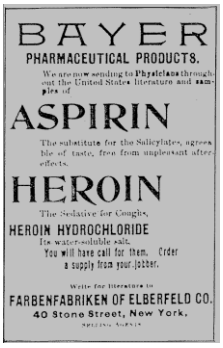
The influence of poor soils on multigenerational poverty in the Ithaca area was well documented by **Janet Fitchen**.

In the past, **coal gas** was distilled from **coal** to make **illuminating gas** and the residue, which is known as **coal tar**, was used as an inexpensive hydrocarbon source to make fabric dyes and pharmaceuticals.









Today we will have a chance to make **coal ball peels**. Coal balls are found in bituminous and anthracite coal seams. Coal balls are **concretions** made during the **Carboniferous Period**, 359.2-299 million years ago, when **calcium carbonate** infiltrated plant material and it **fossilized**. The calcium carbonate was probably dissolved from a layer of fossil shells in the strata above the coal. The fossilized

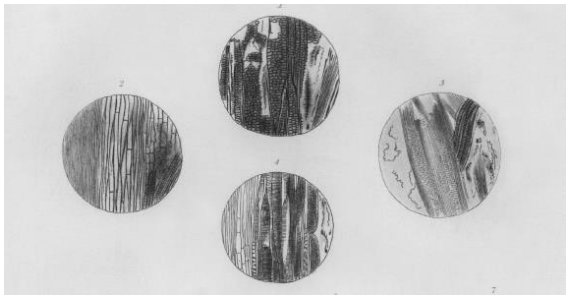
material is the same material that makes up the coal, although in the coal balls, its structure is preserved. The coal balls themselves are not coal, they are calcium carbonate rich (76.66%) but not carbon rich (4.95%) and are not burnable.

The coal beds are 10-12 meters thick and formed from many successive layers. Each **successive layer** represents an **individual flood** event in the **coal swamp**.

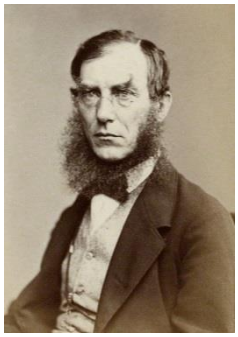




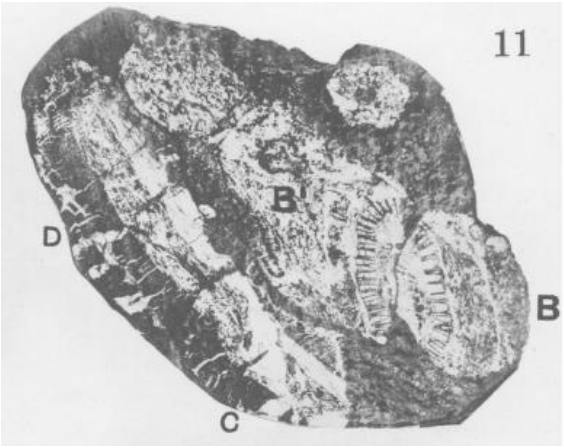
The flooding occurred during **interglacial periods** where the continental shelf was covered with shallow seas. During the flood periods, the dead plants did not completely decay but turned into **peat. Heat and pressure in the earth transformed the peat into coal**. The structures of the plants that were transformed into coal balls were preserved.



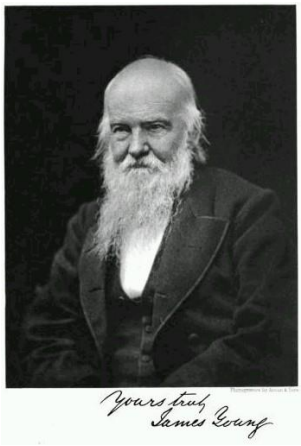
Limestone nodules or **coal balls**, found in the coal seams of Lancashire, were first described in 1855 by **Joseph Dalton Hooker** M. D., a friend of Charles Darwin, and **Edward William Binney** Esq., a friend of James Joule. They wrote, "*A section of any of these nodules shows a confused mass of decayed and apparently decaying vegetable remains; they present no appearance of these remains having been brought together by any mechanical agency; they appear to be associated together just as they fell from the plants that produced them, and to be rotting remains of a redundant and luxuriant vegetation*."



Mary Stopes and David Watson (1909) found continuity of plant stems that are continuous between two coal balls suggesting that the coal balls with the plants within them formed in situ and did not roll in from other places.



Binney was a partner in E. W. Binney & Co., who manufactured paraffin wax. In my **personal quest** to find the **connection between all things**, I am currently searching for a connection between E. W. Binney (1819-1881) and Binney & Smith, the company that makes **Crayola** crayons. Here is what I have so far.



E. W. Binney & Company was formed in 1851 by Edward William Binney, James Young and Edward Meldrum. **James Young** noticed that oil dripped from the roof of a coal mine. Guessing that the oil originated from coal that was exposed to heat, he treated coal with heat and distilled out paraffin oil. Light paraffin oil, also known as **kerosene** (a term coined by **Abraham Gesner**), is used for fuel for lamps and jets, heavy paraffin oil is used for making paraffin wax, which was used for candles. *Keros* (κηρός) is the Greek word for wax.



Joseph Walker Binney (born December 6, 1836), son of Richard and Elizabeth (Cowley) Binney, emigrated from England to upstate New York in 1860 and founded the Peekskill Chemical Works in 1864. I do not know his relationship to E. W. Binney or even if there is a relationship. Joseph Binney used **pyrolysis** techniques to manufacture charcoal from hardwoods and the **pigment lamp black** from animal fats and whale oil. In 1885, Joseph's son Edwin Binney and nephew C. Harold Smith became partners in Binney & Smith, who manufactured **carbon black pigment used for car tires** that previously were grayish white, and the **iron oxide pigment used to paint the red barns** seen throughout New York.



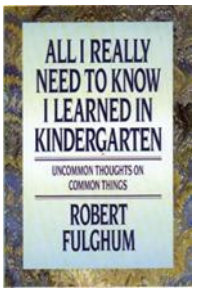




They used slate to make school pencils (1900) and paraffin to make Crayola crayons (1903). Crayola comes from the French words *craie* for chalk *oléagineux* for oily. In 1958 they introduced the box with 64 colors and a built-in sharpener. I wanted this box all my life. Amy gave me my first one along with the Robert Fulghum's book, "*All I Needed to Know I Learned in Kindergarten- Uncommon Thoughts on Common Things*," in which he wrote,







"*Crayolas plus imagination (the ability to create images) - these make for **happiness** if you are a child. Amazing thing Crayolas. Some petroleum-based wax, some dye, a little binder - not much to them. Until you add the imagination. The Binney Company in Pennsylvania makes about two billion of these oleaginous sticks of pleasure every year and exports them to every country in the United Nations. Crayolas are one of the few things the human race has in common. The green and yellow box hasn't changed since 1937. In fact the only change has been to rename the "flesh" color to "peach". That's a sign*

of progress.

The way I know about "flesh" and "peach is that when I bought my godson the trainer set, I indulged myself. Bought my very own set of sixty four. In the big four section box with the sharpener built right in. Never had my own set before. Seems like I was always too young or too old to have one. While I was at it, I bought several sets. Got one for the kid's mother and father and explained it was theirs, not his.

What I notice is that every adult or child I give a new set of Crayolas to goes a little funny. The kids smile, get a glazed look on their faces, pour the crayons out, and just look at them for a while. Then they go to work on the nearest flat surface and will draw anything you ask, just name it. The adults always get the most wonderful kind of sheepish smile on their faces - a mixture of delight and nostalgia and silliness. And they immediately start telling you about all their experiences with Crayolas. Their first box, using every color, breaking them, trying to get them in the box in order again, trying to use them in a bundle, putting them on hot things to see them melt, shaving them into waxed paper and ironing them into stained glass windows, eating them and on and on. If you want an interesting party sometime, combine cocktails and a fresh box of Crayolas for everybody.

When you think about it, for sheer bulk there's more art done with Crayolas than with anything else. There must be billions of sheets of paper in every country in the world, in billions of boxes and closets and attics and cupboards, covered with billions of pictures in crayon. Ronald Reagan and Mikhail Gorbachev used crayons, I bet. So did Fidel and the Emperor of Japan and Rajiv Gandhi and Mrs. Thatcher and Mr. Mubarak and maybe even the ayatollah. And just about everyone else you care to name.

Maybe we should develop a Crayola bomb as our next secret weapon. A happiness weapon. A beauty bomb. And every time a crisis developed, we would launch one. It would explode high in the air - explode softly - and send thousands, millions, of little parachutes into the air. Floating down to earth - boxes of Crayolas. And we wouldn't go cheap, either - not little boxes of eight. Boxes of sixty-four, with the sharpener built right in. With silver and gold and copper, magenta and peach and lime, amber and umber and all the rest. And people would smile and get a little funny look on their faces and cover the world with imagination.

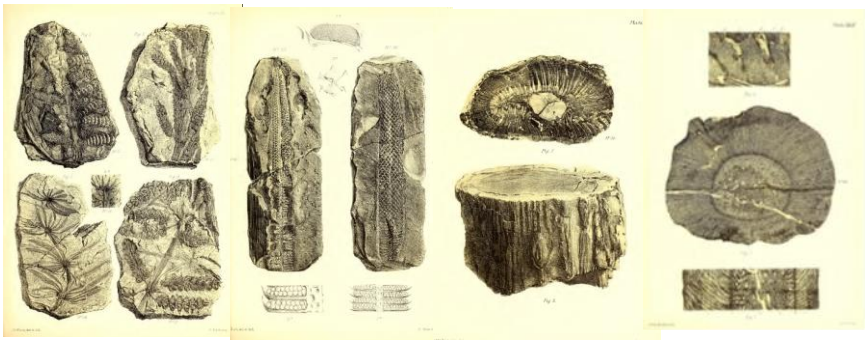
Guess that sounds absurd, doesn't it? A bit dumb. Crazy and silly and weird. But I was reading in the paper today how much money the Russians and our Congress

just set aside for weapons. And I think what those weapons will do. And I'm not confused about what's weird and silly and crazy and absurd. And I'm not confused about the lack of, or the need for, imagination in low or high places. Pass the crayons, please."

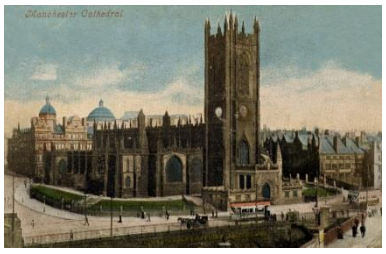
I never found a connection between Edward William Binney, son of Elizabeth (Cross) and Thomas Binney, who supplied Joule's grandfather with malt, and Binney & Smith Crayons. I did find the following anecdotes.

As reported in the Oxford Dictionary of National Biography, Edward William Binney learned of "***the destitution of some artisan mathematicians and botanists***" and tried to establish a public society for "***the relief and encouragement of scientific men in humble life***" (Manchester Guardian, 13 Dec 1843). However, Binney thought that the conditions imposed by Richard Parkinson, a clergyman concerned with the morality of the recipients, would ruin the proposed society's aims. Consequently, in 1844, Binney set up a private fund where he presented donations at an annual dinner he gave for scientific artisans. James Crowther, a porter, autodidact, and amateur botanist, and Richard Buxton, a shoemaker, autodidact, and amateur botanist were supported by Binney's fund.

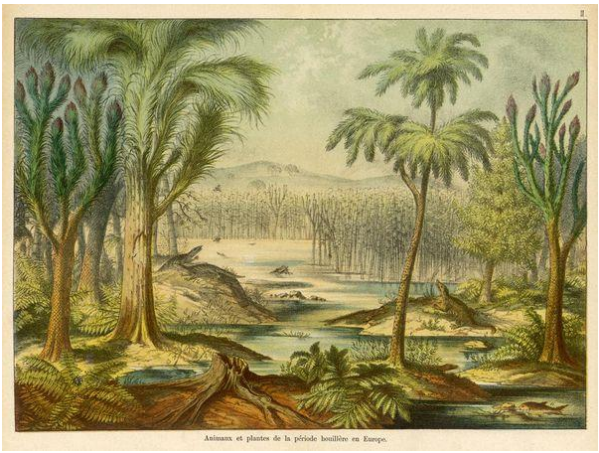
Edward William Binney, was, himself, an amateur botanist. Here are some pictures from Binney's book entitled, *Observations on the Structure of Fossil Plants Found in the Carboniferous Strata*.



The carboniferous sandstone known as **Binney's Sandstone**, was named in honor of Edward Binney by Broadhurst and Simpson (1999) to "*commemorate the work of a pioneer in the study not only of the geology of Manchester, but of its building stones as well*."



The carboniferous coal swamp, which included *Lepidodendron*, a tree-like fossil **lycopod**, *Calamites*, a tree-like fossil **horsetail**, and **seed ferns** may have looked like this:



I would like you to know the small living relatives of the tall tree-like plants that gave us coal.









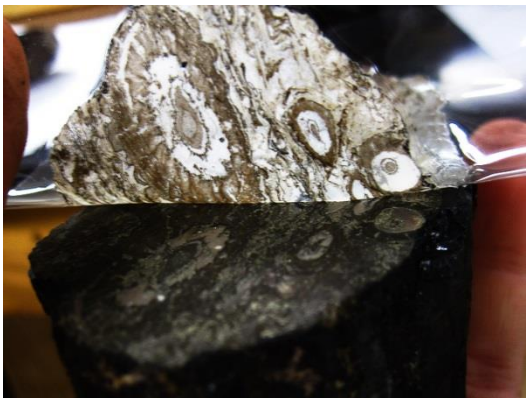


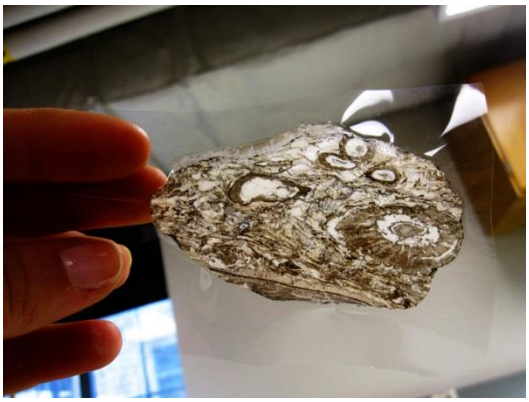




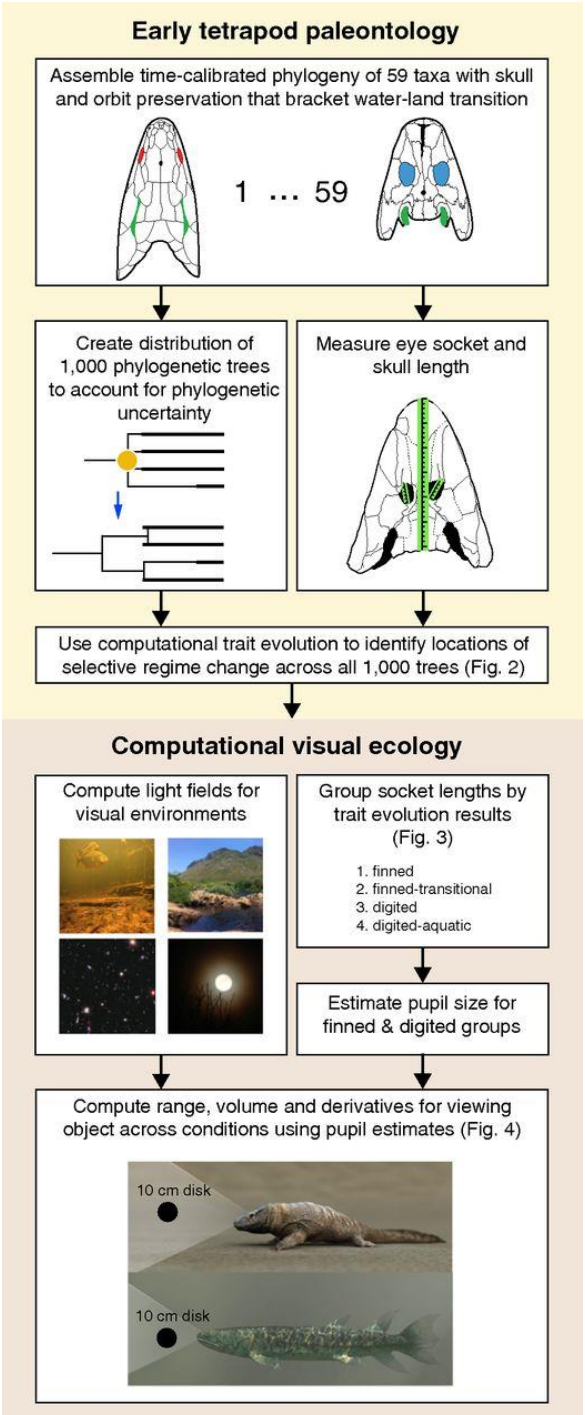
The **procedure to make coal ball peels**, given below, takes about 25+ minutes.

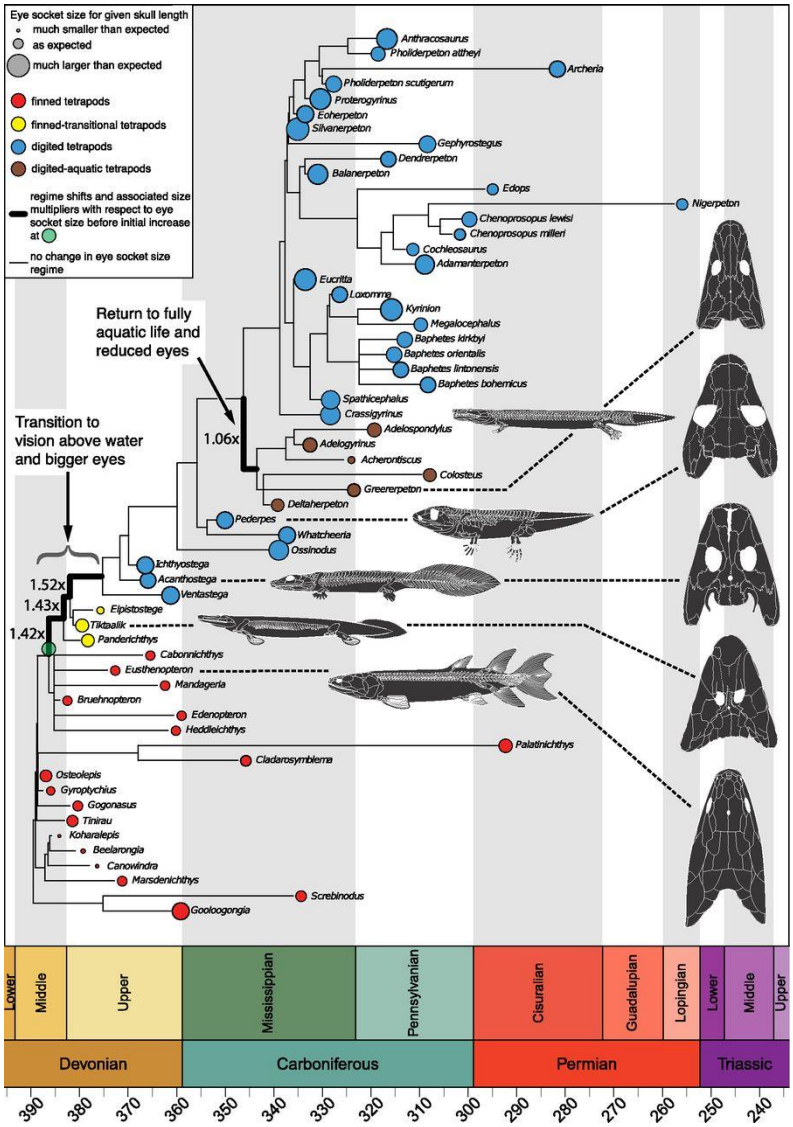
1. Polish the surface of the coal ball with carborundum (SiC), the second hardest material, for **30-60 seconds** using figure 8 motions.
2. Without touching the surface, rinse the surface with water (catching the carborundum in the tub).
3. Soak the shiny surface of the coal ball in 5% (v/v) hydrochloric acid (HCl) for **15 seconds** to dissolve the calcite without removing the organic matter that makes up the cell walls. The organic matter should turn white. Gently wash the surface with water (H_2O) at an angle.
4. Place the coal ball on its side under a heat lamp on tray of gravel until the water on the surface evaporates and the surface becomes a dull gray. The fan will speed up the evaporation process. This takes about **10 minutes**. Adjust polished surface so that it is horizontal.
5. Cover the surface (and not your clothes) liberally with acetone ($(CH_3)_2CO$) and then gently place an acetate sheet by slightly folding the acetate sheet and applying it from the center to the outside.
6. Wait **30** (15-40) **minutes** until the acetate is dry. Then peel the acetate sheet from the coal ball surface and view shiny-side-up with dissecting microscope and take pictures.



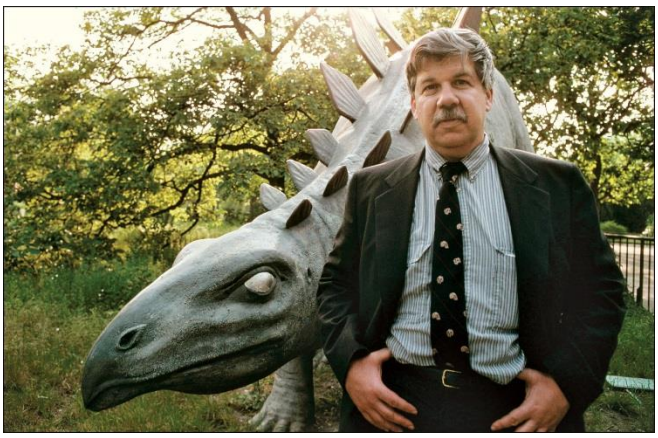


Fossil study shows that at approximately the same time the giant plants were growing, **fish** were evolving **larger and forward-facing eyes**—perhaps to see the insects living on land that would be delicious and nutritious enough to lead to the selective advantage of **limbs** that would allow the fish to walk out of the water and on to land (MacIver et al., 2017).



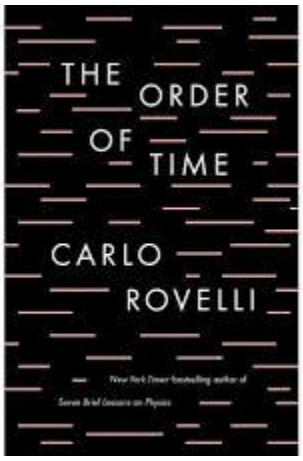


The concept of deep time influenced **Stephen Jay Gould**'s definition of the meaning of life. When asked about the meaning of life by *Life Magazine* (December 1988), the paleontologist answered, "*The human species has inhabited this planet for only 250,000 years or so-roughly .0015 percent of the history of life, the last inch of the cosmic mile. The world fared perfectly well without us for all but the last moment of earthly time—and this fact makes our appearance look more like an* ***accidental afterthought*** *than the culmination of a prefigured plan. Moreover, the pathways that have led to our evolution are* ***quirky***, ***improbable***, ***unrepeatable*** *and utterly* ***unpredictable***. *Human evolution is not random; it makes sense and can be explained after the fact. But wind back life's tape to the dawn of time and let it play again—and you will never get humans a second time.* ***We are here because one odd group of fishes had a peculiar fin anatomy that could transform into legs for terrestrial creatures****; because the earth never froze entirely during an ice age; because a small and tenuous species, arising in Africa a quarter of a million years ago, has managed, so far, to survive by hook and by crook.* ***We may yearn for a 'higher' answer—but none exists***. *This explanation, though superficially troubling, if not terrifying, is ultimately liberating and exhilarating.* ***We cannot read the meaning of life passively in the facts of nature. We must construct these answers ourselves—from our own wisdom and ethical sense. There is no other way***."



According to Vice President Kamala Harris, there is "great significance to the passage of time."

Of course, the whole idea of evolution itself is meaningless if **time is an illusion** as the theoretical physicist Carlo Rovelli (2018) claims in *The Order of Time*.



In an interview about his book, Rovelli states: "*We have learned that* ***time passes at different rates depending on altitude and on speed****. We have learned* ***that the fundamental equations of physics do not distinguish the past from the future****. And we have learned that our very strong intuition about the present is valid only in a relatively small bubble around us;* ***there is no objectively defined*** **present** ***in the large universe****. Those are not speculations.* ***They are established physics***." https://physicstoday.scitation.org/do/10.1063/PT.6.4.20190219a/full/

Again, we see that science does not say something unequivocally, but scientists in different fields disagree about what are established facts. You have every right to choose which theory seems more correct to you. If established physics is correct, then the theory of evolution is meaningless. If the theory of evolution is correct, then it is time to **disestablish** physics, although on this issue physicists seem to be **antidisestablishmentarians** in such a way as could be described as **antidisestablishmentarianism**. I never thought I'd be able to use that word in a sentence!

Luminescence and the Production of Light by Living Organisms



The term **luminescence** was coined by **Eilhard Wiedemann** (1888) to distinguish the **cold light** produced by x-rays, radioactivity, and "*all those phenomena of light which are not solely conditioned by the rise in temperature*" from **incandescence** or **hot light** that comes from **incandescent** sources such as the sun, an oil lamp, a candle, a gas lamp, and an electric lamp with a carbon or tungsten filament.

Wiedemann defined many kinds of luminescence, based upon the **type of energy transformed into light**. We have talked about **chemiluminescence**, in which light emission is the result of a chemical reaction (e.g., white phosphorous). We have talked about **photoluminescence**, in which light emission is a result of the absorption of light. When the emission is somewhat immediate and transient (10^{-8} s), photoluminescence is known as **fluorescence** (e.g., chlorophyll) and when the emission is delayed (1 millisecond) and long lasting (milliseconds to hours), photoluminescence is known as **phosphorescence** (e.g., Bologna stone). **Radioluminescence** is when light emission is a result of a material being bombarded by ionizing radiation (e.g., the purple glow of the ^{22}Na that caused a huge change in Martin Kamen's life). Soon after the discovery of radioactivity, Mark Twain (1904), in *Sold to Satan*, described Satan's look as not being red like a fire coal but as *a softly glowing, richly smoldering torch, column, statue of pallid light, faintly tinted with a spiritual green*, because he was made of radioluminescent radium.





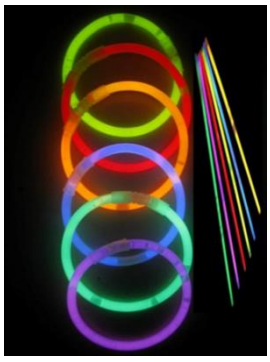
Triboluminescence is when light is emitted as a result of the mechanical breakage of bonds (e.g., flash rocks made of quartz, **Uncompahgre Ute Indian rattles**), which shoots out electrons that excite the nitrogen gas in the air and cause them to emit light. Francis Bacon (1620) wrote in Novum Organum, "*It is well known that all sugar, whether candied or plain, if it be hard, will sparkle when broken or scraped in the dark*." **Wint-O-Green life savers** glow even brighter than sugar because the spark of light given off by the electrons exciting the nitrogen gas of the air is absorbed by methyl salicylate and reemitted as fluorescent light. **Electroluminescence** is when light is emitted as a result of an electric field or the passage of an electric current through a gas (e.g., neon lights) or semiconductor (e.g., light emitting diode; **LED**), and **bioluminescence** is the emission of light by living organisms.

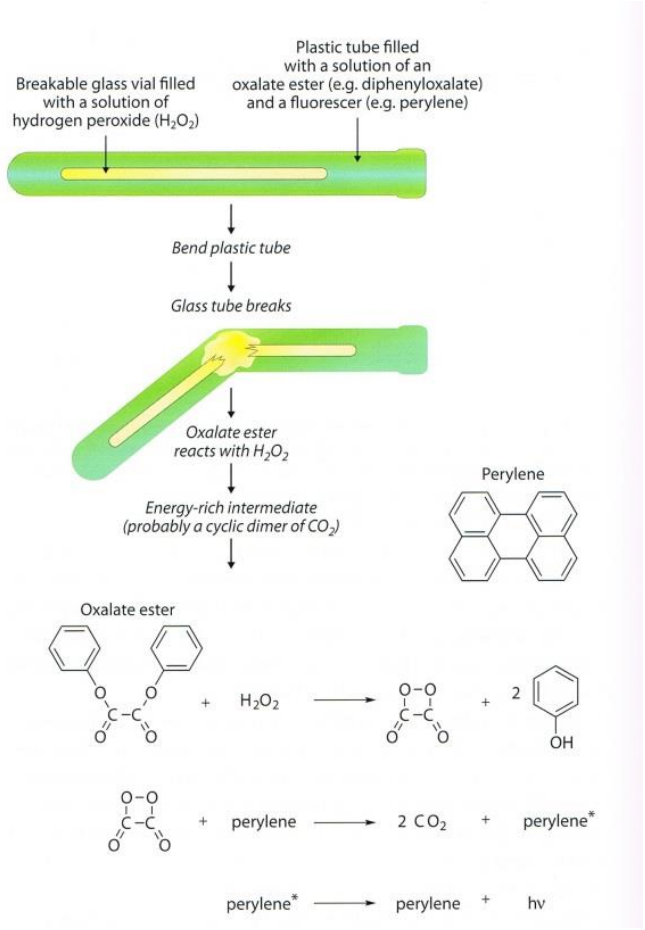
Demonstration of luminescence or cold light: Bioluminescent bacteria: *Vibrio*; bioluminescent fungi: (*Armarillia*, *Panellus*); bioluminescent dinoflagellates (*Pyrocystis*); bioluminescent sea fireflies (*Cypridina hilgendorfii*); photoluminescent Krypton (Europium) sheets and pellets; chemiluminescent glow sticks; and triboluminescent quartz "flash rocks."





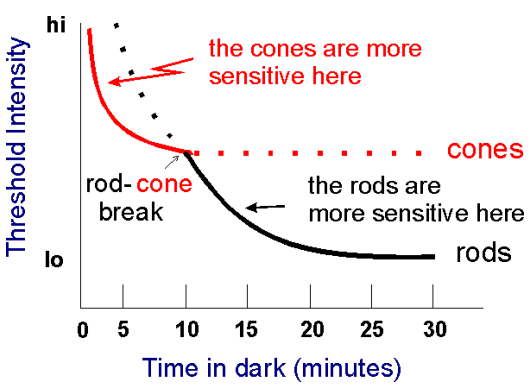


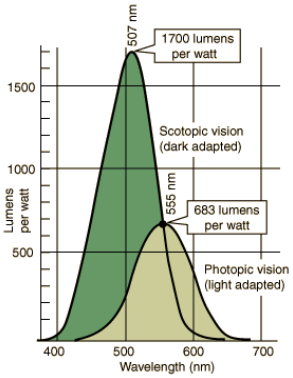






Luminescence is typically a very low light phenomenon that requires our dark-adapted, wide-open, dilated pupil, **rod-dominated**, **scotopic vision** to see. **Robert Boyle** had to do his experiments on luminescence at night and it is quaint how he described each experiment he did **yester-night**.

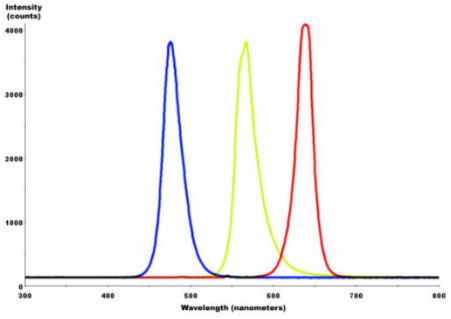


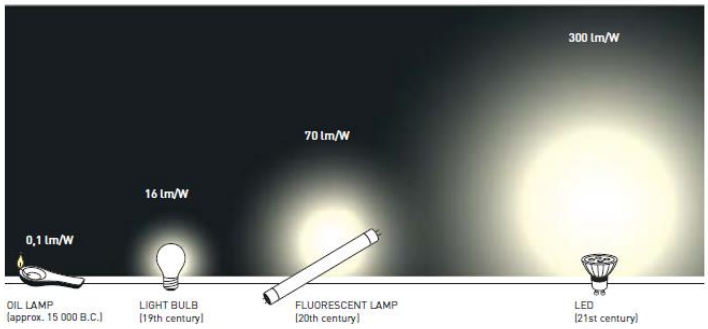




Currently work is being done which would allow the replacement of **incandescent light** with **electroluminescent light** produced by red-green-blue (RGB) light emitting diodes (LEDs) that minimize the amount of energy transformed into thermal energy but maximize the amount of energy transformed into white visible light that is seen by our **cone-dominated, photopic visual system**. The ratio of the



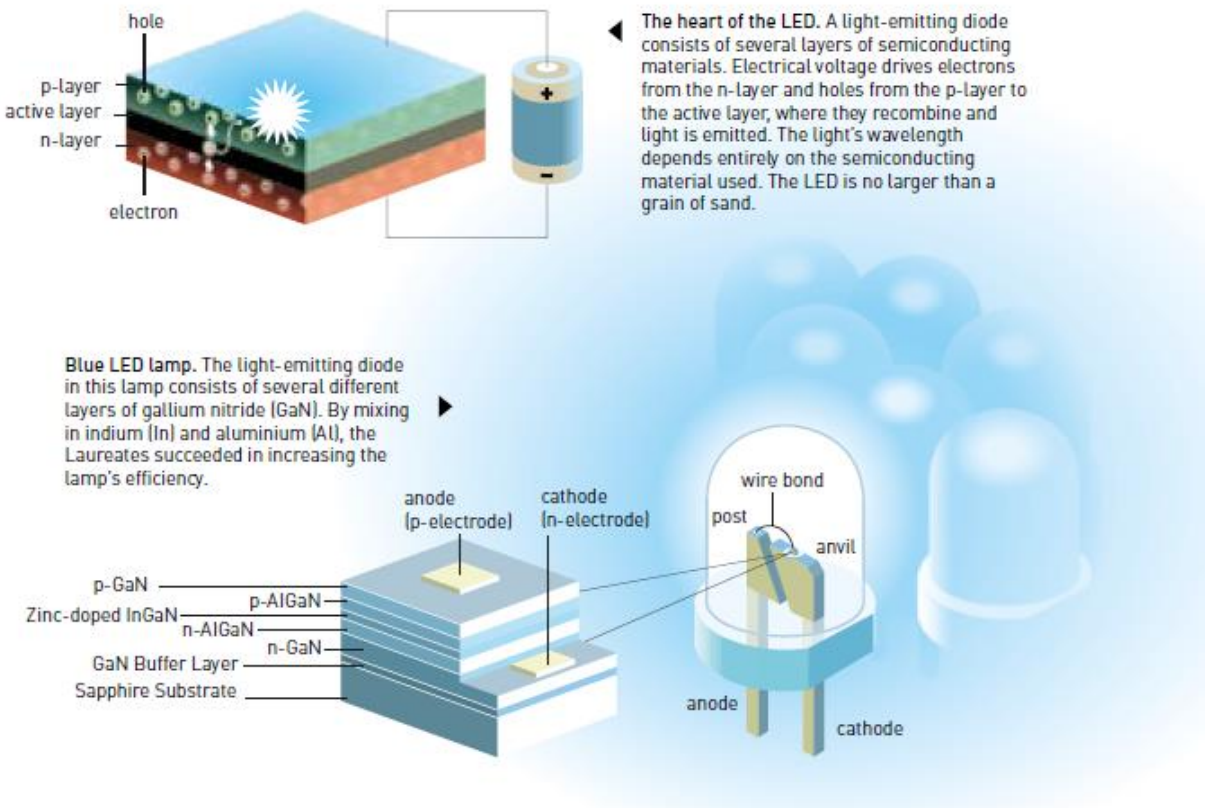




energy output (luminous flux in lumens) to the energy input (in Watts) is spectacular for LEDs. LEDs produce approximately 300 lumens/watt while tungsten lightbulbs produce about 16 lumens/watt. The 2014 Nobel Prize in Physics was awarded to Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura "*for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources.*" "*The Laureates challenged*

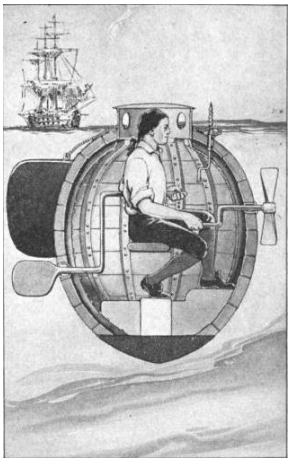
established truths; they worked hard and took considerable risks. They built their equipment themselves, learnt the technology, and carried out thousands of experiments. Most of the time they failed, but they did not despair; this was laboratory artistry at the highest level."
http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/presentation-speech.html

Since ancient times, Aristotle, Pliny the Elder, and others have noticed that rotten wood, fish, and meat emitted light. Using his vacuum pump, **Robert Boyle** (1667,1672) showed that the luminous emission of greenish-blue light from stinking fish, a rotting neck of veal, and rotten wood required **air** (which later was shown to contain **oxygen**). Clever people have used the luminescent light of rotting fish, wood, and tiny crustaceans to see at times and in spaces that that are not reached by sunlight or moonlight.



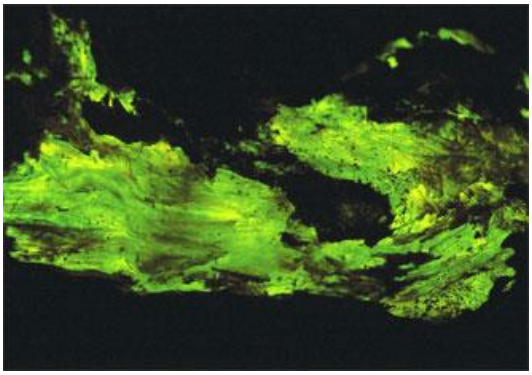
During the Revolutionary War, **David Bushnell**, while an undergraduate at Yale, designed the **Turtle**, so called because it resembled "*two upper tortoise shells of equal size, joined together*." The Turtle was about six feet high, three feet wide and four feet long with just enough space for one person. It could hold enough air for one person for about 30 minutes. The operator drove the Turtle about 3 mph by turning a propeller with a hand crank. On the top of the Turtle, a second propeller, also turned by a hand crank, moved the Turtle up and down. The Turtle had a rudder to steer it and a foot valve to let water into a ballast tank at the bottom to submerge the Turtle. The Turtle carried a **time bomb** also designed by David Bushnell that he made from a hollow log containing 150 pounds of gunpowder and a clock to ignite it. A barometer and the needles of the compass in the Turtle were illuminated with "***fox-fire, i.e. wood that gives light in the dark***."









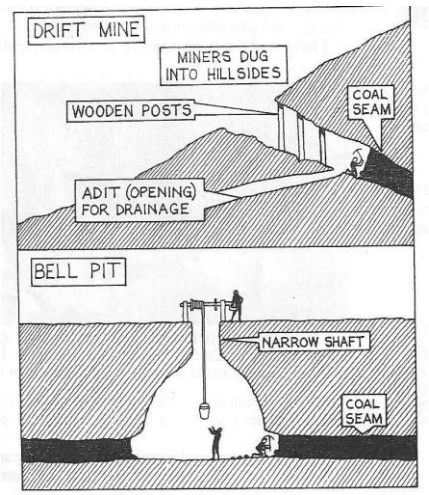


David Bushnell had built the Turtle to break the British blockade of Boston harbor. However, throughout the winter, it was so cold that the fox fire was not able to glow. He sent word to Benjamin Franklin asking, "*whether he knows of any*

kind of phosphorus which ***will give light in the dark and not consume the air***," noting that "*he has tried a candle, but that destroys the air so fast he cannot remain under water long enough to effect the thing*." On March 17, 1776, the British forces commanded by General William Howe evacuated Boston and the Turtle had lost its chance for action in Boston. Not wanting to miss his chance to fight in warmer weather, when the fox fire would glow, David Bushnell offered the Turtle to help George Washington defend New York City from the British. The Turtle, commanded this time by Ezra Lee, was transported to New York Harbor where the HMS Eagle, commanded by William Howe's brother, Richard Howe was moored. Unfortunately, the Turtle did not contain enough air to securely fasten the time bomb to the Eagle and move away safely. Thus, the Turtle never succeeded in helping win the Revolutionary War against the British. In this class, however, the Turtle is famous for its clever use of **bioluminescence**!

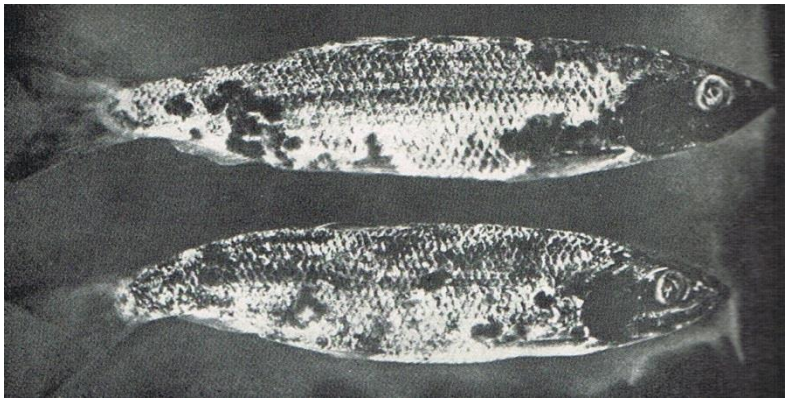
http://connecticuthistory.org/david-bushnell-and-his-revolutionary-submarine/

http://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/s/submarine-turtle-naval-documents.html#item10



Coal weaves a thread through many aspects of light and life. With the development of the **external combustion engines** that used coal to heat water to **steam** in the late 18th century, water-powered factories were replaced by steam-powered factories. This **industrial revolution** resulted in an increased demand for coal that was greater than that that could be extracted from **drift mines** and **bell pits**. Consequently, **deep mines** were dug. The deep mines were not only

dark but contained flammable gas and explosive coal dust. For this reason, miners would





bring **bioluminescent rotting fish** to see in the mine. Miners stopped using rotting fish to illuminate the mines after Humphry Davy discovered that flame cannot pass through a screen mesh and invented the vegetable oil burning **Davy safety lamp** in 1815. Since the flame could not pass through the **screen mesh** but gases could, the lamp could also be used as a gas detector. The presence of **methane (firedamp)** in the mine would cause the flame to burn **higher and bluer**. The presence of **carbon dioxide gas (chokedamp)** and not enough oxygen in the mine would cause the flame to **burn low**. The metal gauge along the side of the lamp was used to measure the height of the flame and thus the amount of methane or carbon dioxide in the mine.



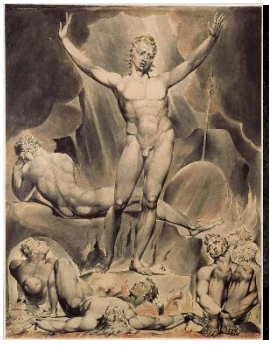
Eugene Petrov (1941), a Soviet writer, dramatist, and war correspondent wrote in his Front Diary, "*I observe many small and large **luminous blue grains** under foot. It is as though someone has trod ahead with magic **perpetual fire** trickling from his knapsack. It takes some time to realize that it is simply bits of **rotten wood** which a fatigue party has carefully collected in the forest and used to lay **luminous tracks** between the tents. Here such tracks are known as the 'Milky Way'.*"

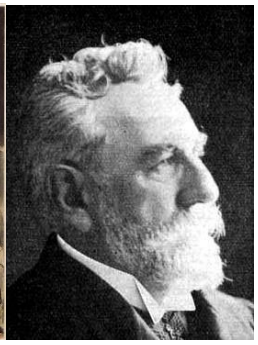
During World War II Japanese soldiers fighting in the Pacific theatre used dried ground *Cypridina* (= *Vargula*), a tiny **crustacean** mixed with water to produce weak but sufficient luminescent light to see on moonless nights. The soldiers would then rub small amounts of the solution on each other's back so that they could follow the soldier who was 15-20 feet in front of them. The soldiers may have also rubbed their hands with *Cypridina* to illuminate and read maps.





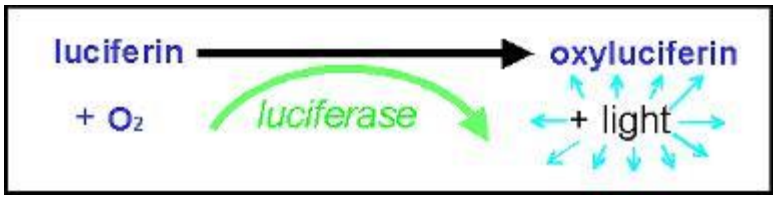
Demonstration: Observe luminescence in Sea Fireflies (*Cypridina hilgendorfii*).





Raphaël Dubois (1885) performed experiments with many bioluminescent taxa and discovered that the production of living light required **two separate water-soluble components**. The first one, which he extracted with hot water, was a heat-stable component that he called **luciferin**, after **Lucifer**, the Latin word for light-bearer. It may have come from the Hebrew word הֵילֵל (*heilel*) for morning star that appears in Isaiah 14:12 "*How you have fallen from heaven, morning star, son of the dawn! You have been cast down to the earth, you who once laid low the nations!"*

The second component, which Dubois extracted with cold water, was heat-labile and therefore an enzyme. He called the enzyme **luciferase**. The two components were **necessary and sufficient** to produce light in a test tube.

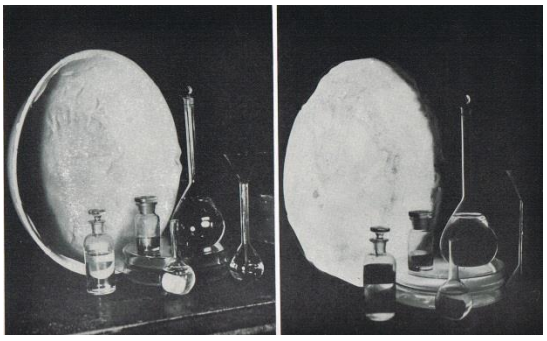


In 1896, Raphaël Dubois "*opened a new and promising field for future progress by showing the inferiority of these means [of artificial lighting] when compared with those of nature and by placing the question upon the ground of producing illumination by a new method*." In the **Paris International Exposition of 1900,** Raphaël Dubois showed the world that six one-gallon flasks of bioluminescent bacteria could light a room sufficiently for the visitors to read newspapers without any danger of fire or explosion.

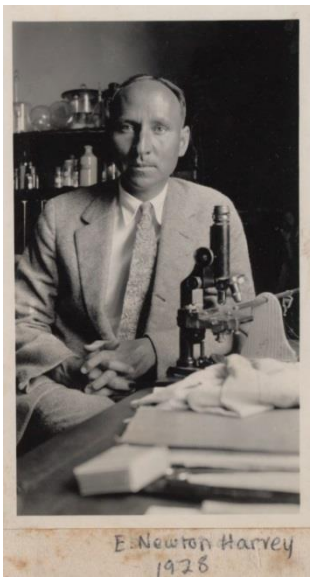
Human beings had made use of bioluminescence for light outside the home. Putting his research to practical use, Raphaël Dubois built a **bioluminescent lamp** for inside the home and created a photograph of paper lace using bioluminescent bacteria to expose the paper. E. Newton Harvey used bioluminescent bacteria to illuminate a still life.







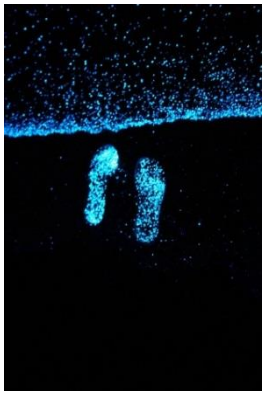
Like the 19th century naturalists, such as Charles Darwin and T. H. Huxley, at the beginning of the 20th century **E. Newton Harvey** made expeditions all over the world making observations and collecting animals. While on his honeymoon in 1916 and while he was swimming at night in the waters near the Misaki Laboratory Biological Station south of Tokyo, he became enamored by the blue bioluminescence of *Cypridina hilgendorfii*, known as the sea firefly or **Umihotaru** (海ほたる) in Japanese. *Cypridina* are scavengers that live on the ocean bottom waiting for fish to die and sink—at which time they rapidly consume the fish.



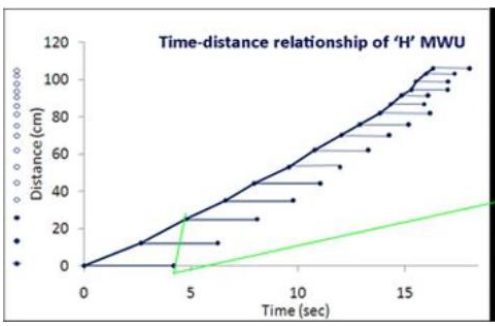
As **Jim Morin** (Cornell) observed, when the Caribbean Ostracodes like *Cypridina* are pursued by a predator, they emit clouds of blue bioluminescence as a means to escape the predator.

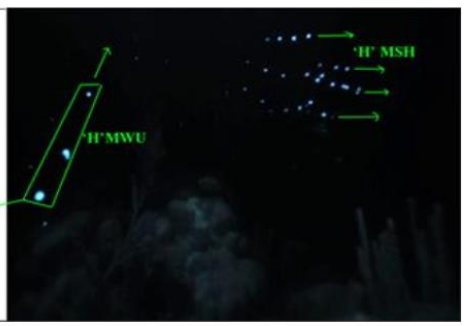


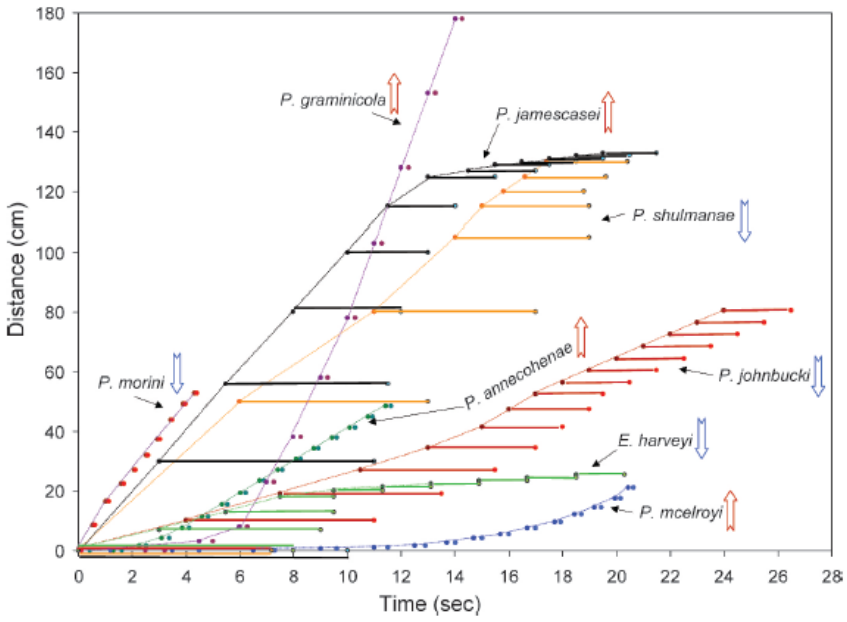


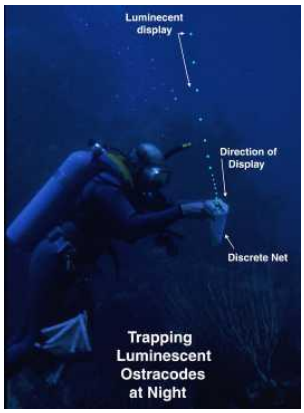








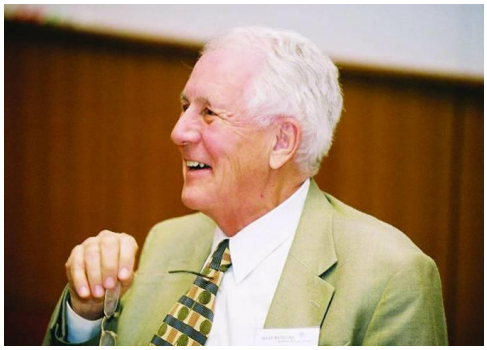




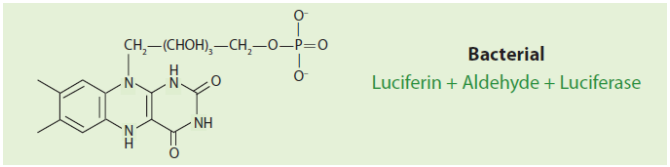
In their **courtship behavior**, which occurs on moonless nights, the males synchronously release pulses of blue bioluminescence in a species-specific manner to attract the females, who use the displays to orient and intercept the male producing it. The bioluminescence of Ostracodes is always extracellular. The courtship displays may be at risk as a result of **light pollution** coming from resorts built on the seashores where cypridinid Ostracodes live.

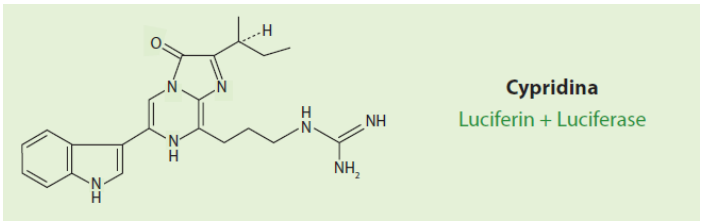
E. Newton Harvey caught *Cypridina* by suspending a large fish head by a string in shallow sandy water and waiting for swarms of *Cypridina* to eat it. After two hours, he lifted the fish head out of the water and picked off the *Cypridina*. E. Newton Harvey had a passion for bioluminescence and studied its physics, chemistry, and biology. E. Newton Harvey showed that the bioluminescent organisms all had the two components that Raphaël Dubois had discovered: a **luciferin** and a **luciferase**. However, the luciferin of one taxon would not necessarily interact with the luciferase of another. By discovering that the luciferins and luciferases from different taxa were ***not*** interchangeable, E. Newton Harvey learned that there was not just one kind of luciferin and just one kind of

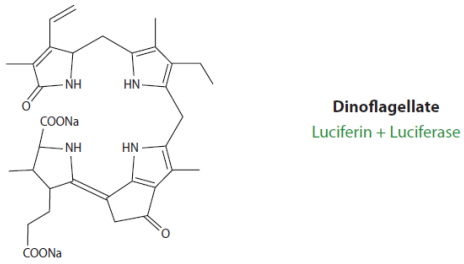
luciferase, but ***many*** kinds of luciferins and ***many*** kinds of luciferases. He found the **diversity in the apparent unity**.

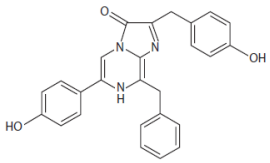


E. Newton Harvey found that **Charles Darwin's** idea that unity of function is a consequence of **common descent** does ***not*** apply to bioluminescence. According to **J. Woodland (Woody) Hastings** (1996), a graduate student of E. Newton Harvey, "*Many different organisms, ranging from bacteria and fungi to fireflies and fish, are endowed with the ability to emit light, but the bioluminescent systems are not evolutionarily conserved: genes coding for the luciferase proteins (Lase) are* ***not homologous****, and the luciferins are also different, falling into many unrelated chemical classes.*"







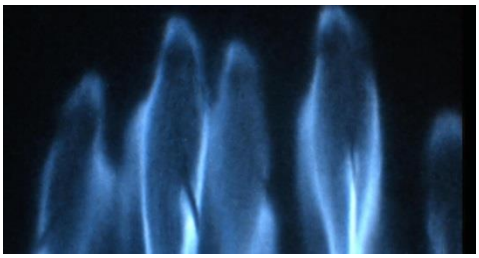


Coelenterazine

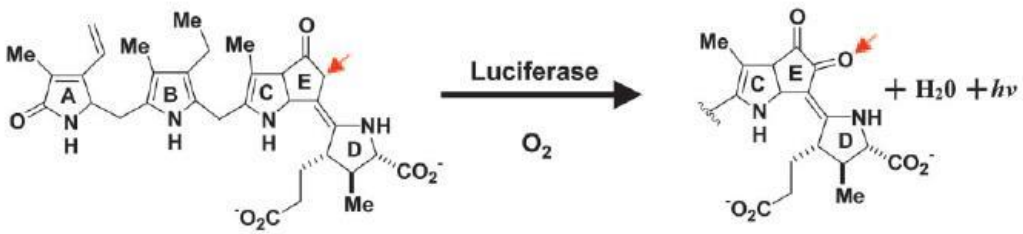
Luciferin + Luciferase
Photoprotein

While the **specific** chemical natures of luciferin and luciferase differ, the bioluminescence they generate all follow a **general rule**: A **high-energy molecule** containing a number of **conjugated double bonds** is converted to a **low-energy molecule** in an **oxygen-requiring enzymatic process** and in the process the **energy difference is released as visible light energy**. The oxygen is usually consumed in the form of **molecular oxygen** although some systems use the peroxide anion (O_2^{2-}).





For example, the **mechanically-induced bioluminescence of dinoflagellates**, which has been shown by Esaias and Curl (1972) to function as a burglar alarm to scare away predators, is described by the following reaction:



Luciferase binds **oxygen** and a reduced or high-energy form of luciferin. The luciferase functions as an **electron and proton pipe** that passes **two electrons**

and **two protons** from the high-energy form of **luciferin to oxygen**. This transfer results in the formation of **oxyluciferin**, a low-energy form of luciferin and water. In the process, the difference in the redox energy of the reduced luciferin and the oxyluciferin is transformed into visible light. In some respects, bioluminescence, where the **luciferase enzyme** acts as an **electron pipe**, is the **reverse of photosynthesis** where **chlorophyll** acts as an **electron pump**.

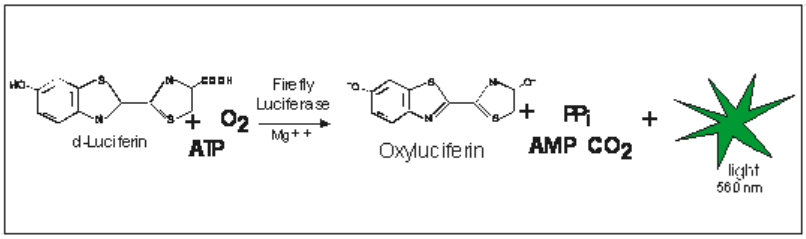


The mechanisms of bioluminescence in *Cypridina*, bacteria (*Vibrio*) and fungi (*Armillaria*, the honey fungus) share some similarities with dinoflagellates, although their luciferins and luciferases differ. While the function of bioluminescence in all fungi is not known, some suggest that bioluminescence in some fungi is a strategy to attract arthropods and insects that will disperse the spores. This may be true for fungi with bioluminescent fruiting bodies (e.g. *Omphalotus*, *Mycena*, *Panellus*, *Neonothopanus*; https://blog.mycology.cornell.edu/2010/04/12/this-bark-glows-in-the-dark-bioluminescence-in-mushrooms/), but cannot explain bioluminescence in *Armillaria*, whose underground mycelia are bioluminescent but its fruiting body (mushroom) is not. **Perhaps this is the fungal expression of 'art for art's sake.'**





In the case of **firefly bioluminescence**, like bioluminescence in dinoflagellates, a high-energy molecule that contains many conjugated double bonds is converted to a low-energy molecule in an oxygen-requiring enzymatic process and in the process the energy difference in released as visible light energy. In the case of fireflies, however, the high-energy form of luciferin requires supplementation by **ATP** which is converted to AMP and pyrophosphate (P_iP_i). The redox energy is the primary source of energy as the energy of ATP (8×10^{-20} J) is too little to produce a photon itself ($E = \frac{hc}{\lambda} \approx 4 \times 10^{-19}$ J).



In fireflies, bioluminescence is used in **courtship behavior.** In some taxa, the male fireflies (or beetles to an entomologist) produce a sequence of light flashes in a species-specific manner. The females recognize the flash sequence and flash back once. The males recognize the single flash by the amount of time elapsed between the end of the male's sequence of flashes and the female's single flash. Then the male flies to the female and mates with her.









Now, there is a complication involved in the courtship behavior. The females of one genus of fireflies (*Photurus*) are ***femme fatales*** and prey on the male fireflies of another genus (*Photinus*). The females of *Photurus* have two different light delays that that can use: one that matches their own genus and effects mating and one that matches the other genus and effects eating. **Tom Eisner** (Cornell), author of *For Love of Insects*, showed that the females of *Photurus* incorporate a chemical known as **lucibufagin** (*luci* from the Latin for light, *bu* from the genus of toad *Bufo* that produces a similar chemical named bufalin) when they eat the lucibufagin-producing males of *Photinus*.

Lucibufagin makes the *Photurus* females and their eggs **unpalatable** to predatory **jumping spiders**. When the female *Photurus* have not eaten *Photinus* males, they do not acquire the lucibufagins and are eaten by predatory spiders. The more *Photinus* males that the *Photurus* females eat, the more lucibufagins they acquire and the better the protection they have from predators.





There are some species of fireflies where the males all flash in synchrony. For example, *Photinus carolinus* males synchronously produce a series of 5-8

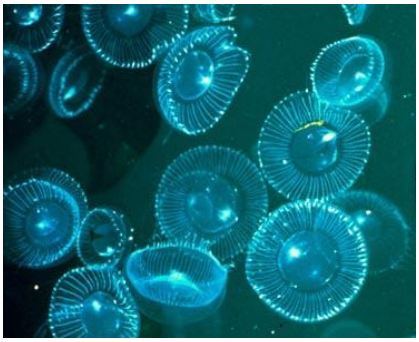
flashes followed by 8 s of darkness. They can be found in Allegany National Forest.



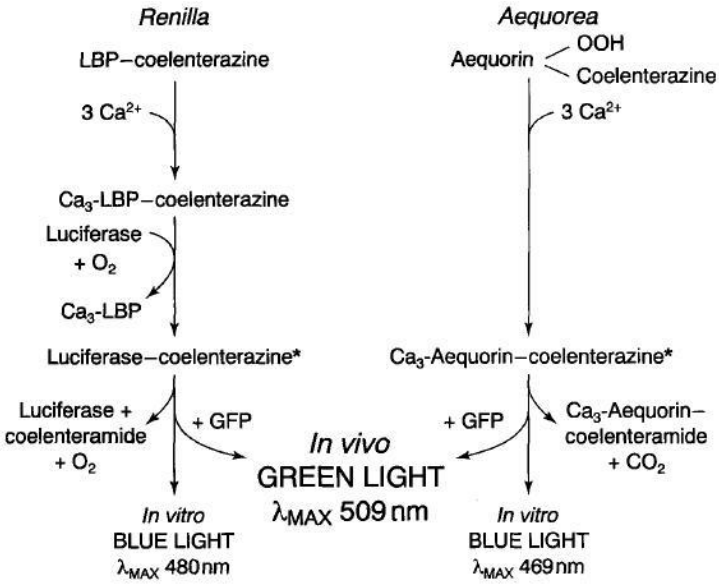
Synchronous fireflies are not so rare in Southeast Asia and species of the *Pteroptyx* genus can be seen lighting up mangrove trees!

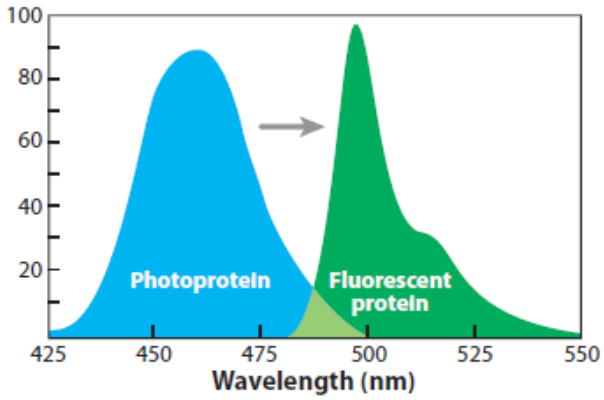


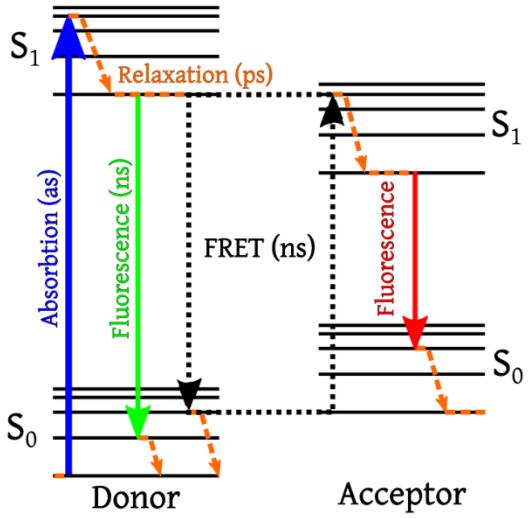
Another variation in the production of bioluminescence is found in jellyfish (*Aequorea*) and related hydroids (*Obelia* and *Renilla*) where the luciferin is a **coelenterazine** (that they probably ingest as part of their diet).











The green bioluminescence in these organisms is stimulated only when they are disturbed and perhaps it may have a defensive function. The luciferase of *Aequorea* is a protein called **aequorin**. The aequorin binds the luciferin, known as **coelenterazine** in an oxygen-dependent manner. The luciferin-luciferase complex does not emit light until it binds **calcium ions**. *Aequorea* emits blue light *in vitro*, but it emits green light *in vivo*. It emits green light *in vivo* because *Aequorea* contains a protein that fluoresces green after it absorbs blue light. When the aequorin and **green fluorescent protein** molecules are close enough (i.e., 5-10 nm) to each other, as they are in the living cell, the energy that would be emitted by aequorin after it binds calcium ions is transferred to the green

fluorescent protein by a process known as **resonance energy transfer** (RET) and the green fluorescent protein emits green light. I will talk about fluorescent proteins again when I discuss fluorescence microscopy.

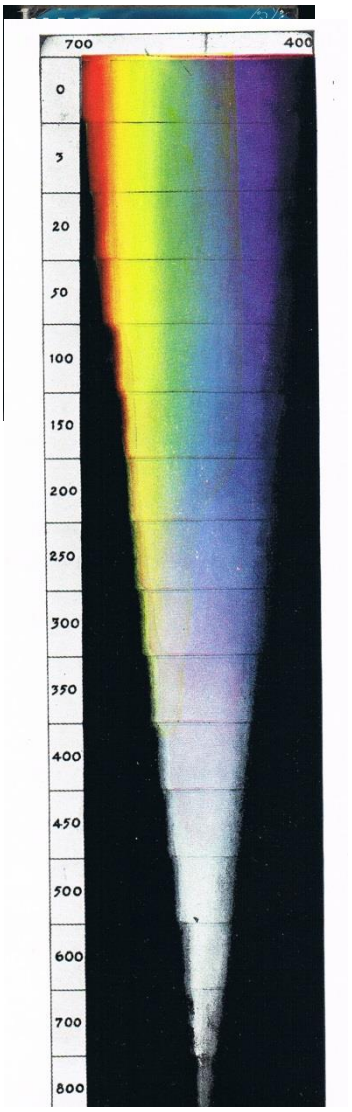
Genetically-engineered bacteria can produce the aequorin protein. This aequorin is sold as Prevagen.



Prevagen™ (aequorin)



Bioluminescence is ***rare*** in **terrestrial habitats** and nonexistent in fresh water. However, deep down in the ocean, deeper than where sunlight can reach, there is a world of **marine creatures** that **turn life into light** in order to create their own light **to see**, to **catch prey**, **to mate**, and to **confound predators**. **William Beebe** was a seasoned **explorer and a naturalist** who turned his attention from the jungles to the sea. He and **Otis Barton** built the **bathysphere** that allowed them to go into the depths and darkness in August 1934 where no living person had gone before, and to **discover a world of living light**.



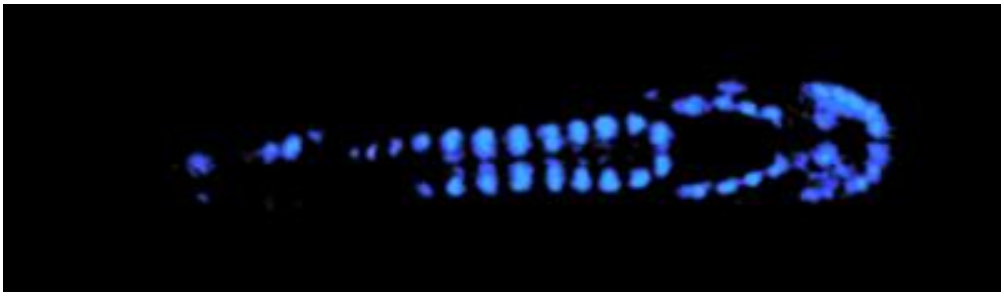
William Beebe wrote in ***Half Mile Down***, "*Ever since the beginnings of human history, when first the Phoenicians dared to sail the open sea, thousands upon thousands of human beings had reached the depth at which we were now suspended, and had passed on to lower levels. But all of these were dead, drowned victims of war, tempest, or other acts of God. We were the first living men to look out at strange illumination: And it was stranger than any imagination could have conceived. It was an* ***indefinable translucent blue*** *quite unlike anything I have ever seen in the upper world, and it excited our optic nerves in a most confusing manner. We kept thinking and calling it brilliant, and again and again I picked up a book to read the type, only to find that I could not tell the difference between a blank page and a colored plate. I brought all my logic to bear, I put out of mind the excitement of our position in watery space and tried to think sanely of comparative color, and I failed utterly. I flashed on the searchlight, which seemed the yellowest thing I have even seen, and let it soak into my eyes, yet the moment it was switched off, it was like the long vanished sunlight—it was as though it never had been—and* ***the blueness of the blue****, both outside and inside our sphere, seemed to pass materially through the eye into our very beings. This is all very unscientific; quite worthy of being jeered at by optician or physicist, but there it was."*

"*Here and at 800 feet a human being was permitted for the first time the sight of living, silver hatchet-fish,* ***heliographing****, their silver sides. I made Barton look quickly out so he could verify the unexpected sight.*"

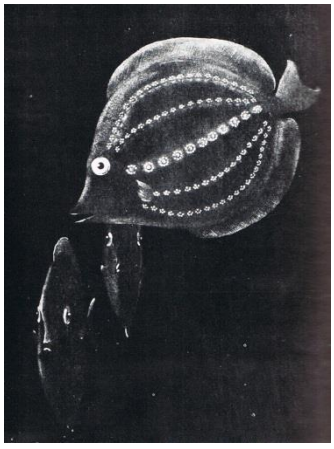
See a video that shows the effect of water depth on color:
https://www.rateyourdive.com/wiki/absorption/



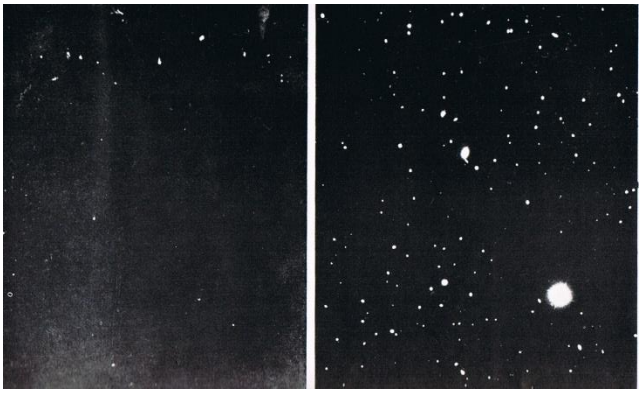
The **hatchet-fish** produce bioluminescence on their undersides as **counter illumination** to confound predators by eliminating their silhouettes that would be recognized by predators swimming beneath them. Because of the **counter illumination**, the hatchet-fish confound their predators by becoming **invisible from below**.



"*Life again became evident around 1300 feet and mostly luminous. After watching a dozen or more firefly-like flashes I turned on the searchlight and saw nothing whatsoever. These sparks, brilliant though they were, were kindled into conflagration and quenched in the same instant upon* ***invisible bodies***."

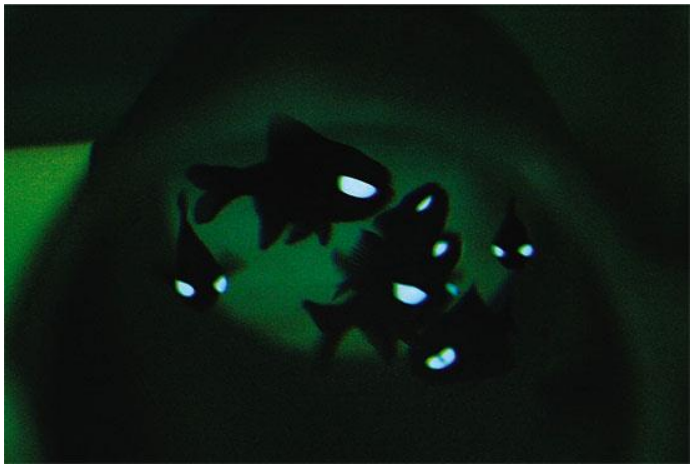


"*After these dives were past…, I would feel like an astronomer might who looks through his telescope after having rocketed to Mars and back, or like* ***a paleontologist who could suddenly annihilate time*** *and see his fossils alive.*" On the right is a picture of the luminous stars in the heavens and on the left is a picture of the luminous fish in the sea.



William Beebe estimated that at depths greater than 400 meters, ninety five percent of fish are bioluminescent.

Flashlight fish (*Kryptophanaron alfredi*; *Photoblepharon palpebratum; P. steinitzi* and *Anomalops katoptron*) and the giant squid farm bioluminescent bacteria in pockets near their eyes that act as **headlights** so that the hosts can see deep beneath the sea.







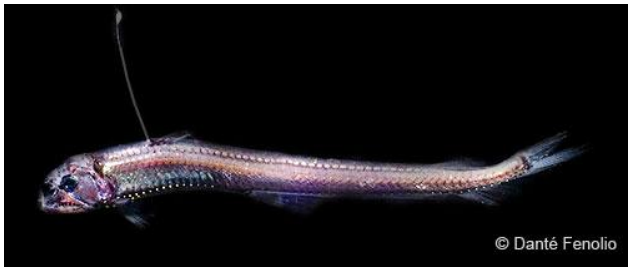
Dragonfish have **blue bioluminescent headlights** and **red bioluminescent headlights** that act as a **sniper scope**. The blue bioluminescent light can be seen with the **scotopic rod-dominated visual system of most deep-sea fishes**, but among the deep-sea fish, **only the dragonfish has the long wave photoreceptors** to see the red light that the photophores produce.



Like the Ostracodes discussed above, some deep-sea fish, crustaceans, and the **vampire squid** emit clouds of bioluminescent materials into the water to escape from predation.

Anglerfish, **viperfish** (*Chauliodus*), and **dragonfish** use **blue bioluminescent "lures"** to attract prey. Blue light travels in water farther than other colors that are absorbed more readily. The fish produce blue bioluminescent light in two different ways. The viperfish and dragonfish produce bioluminescence themselves while the anglerfish farms bioluminescent bacteria.



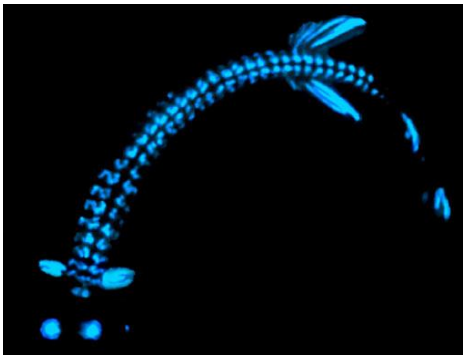




Anglerfish video: https://www.youtube.com/watch?v=XUVerZsbYiw

Viperfish video: https://www.youtube.com/watch?v=ZygDDhdI5do

Dragonfish video: https://www.youtube.com/watch?v=JZNHIqqa_FU

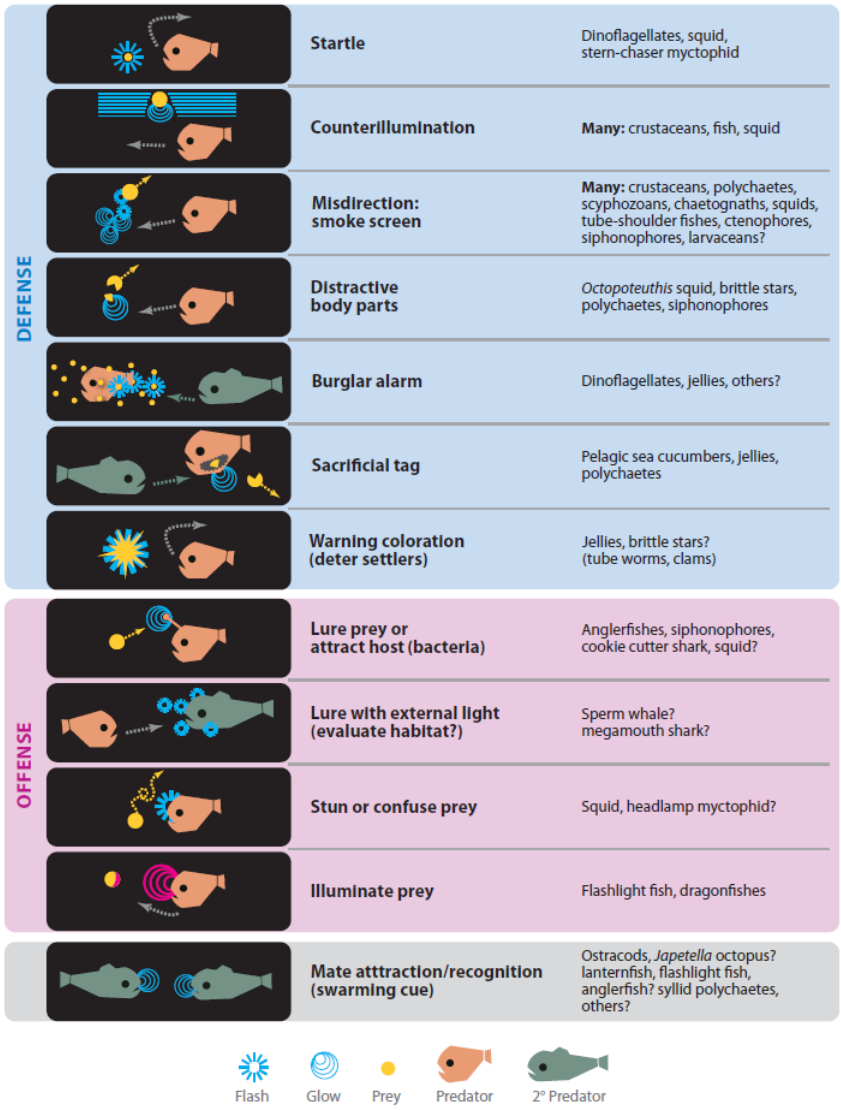


The **lanternfish** are undersea bioluminescent artists. They use bioluminescence for **vision**, **courtship** and **counter-illumination**. Let's now watch these deep sea marvels in the video entitled, "*Marine Bioluminescence: Secret Lights in the Sea*."



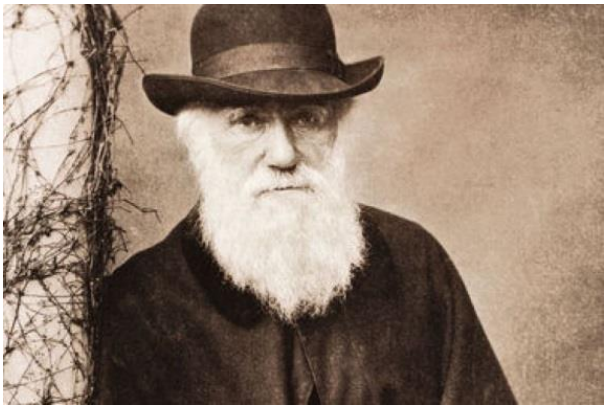
William Beebe wrote, "*In this kingdom most of the plants are animals, the fish are friends, colors are unearthly in their shift and delicacy; here miracles become marvels, and marvels recurring wonders. There may be a host of terrible dangers, but in hundreds of dives we have never encountered them. One thing we cannot escape—forever afterward, throughout all our life, the memory of the magic of water and its life, of the home which was once our own—this will never leave us."*

Here is a chart that summarizes marine organisms that are bioluminescent and the likely functions of the bioluminescence. But what are the functions of bioluminescence of the symbiotic bacterium *Vibrio* or the fungus, *Armillaria*?



Lars Olof Björn (1976) wrote in his book entitled, *Light and Life*, "*Even for a person with a vivid imagination there are many cases of bioluminescence left for which* ***no sensible purpose*** *can be invented. What use do bacteria and protozoans have for their light emission? To explain the many cases of seemingly useless bioluminescence, some scientists have assumed that the light is a by-product of biochemical processes serving a different purpose. But this does not seem very reasonable either. The emission of a photon requires the collection of a large amount of energy in a single molecule and this must be regarded as a remarkable biochemical feat which hardly occurs by accident.*" What is the **Law of Nature** that describes and explains the occurrence of bioluminescence?





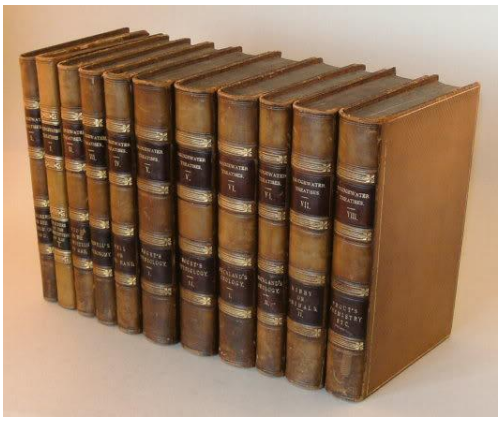
Can you explain the bioluminescence of the bacterium *Vibrio* or the fungus *Armillaria* in terms of the **Laws of Nature**? Charles Darwin (1859) had a hard time. He wrote, "*The electric organs offer another and even more serious difficulty; for they occur in only about a dozen fishes, of which several are widely remote in their affinities. Generally when the same organ appears in several members of the same class, especially if in members having very different habits of life, we may attribute its presence to* ***inheritance from a common ancestor****; and its absence in some of the members to its loss through disuse or natural selection. But if the electric organs had been inherited from one ancient progenitor thus provided, we might have expected that all electric fishes would have been specially related to each other. Nor does geology at all lead to the belief that formerly most fishes had electric organs, which most of their modified descendants have lost.* ***The presence of luminous organs in a few insects, belonging to different families and orders, offers a parallel case of difficulty****….In all these cases of two very distinct species furnished with apparently the same anomalous organ, it should be observed that, although* ***the general appearance and function of the organ may be the same****, yet some fundamental difference can generally be detected. I am inclined to believe that in nearly the same way as two men have sometimes independently hit on the very same invention, so* ***natural selection****, working for the good of each being* ***and taking advantage of analogous variations****, has sometimes modified in very nearly the same manner two parts in two organic beings,* ***which owe but little of their structure in common to inheritance from the same ancestor****.*

Although in many cases it is most difficult to conjecture by what transitions an organ could have arrived at its present state; yet, considering that the proportion of living and known forms to the extinct and unknown is very small, I have been astonished how rarely an organ can be named, towards which no transitional grade is known to lead. The truth of this remark is indeed shown by that old canon in natural history of 'Natura non facit saltum.' [Nature does nothing in jumps]. *We meet with this admission in the writings of almost every experienced naturalist; or, as Milne Edwards has well expressed it, nature is prodigal in variety, but niggard in innovation.* ***Why, on the theory of Creation, should this be so? Why should all the parts and organs of many independent beings, each supposed to have been separately created for its proper place in nature, be so invariably linked together by graduated steps? Why should not Nature have taken a leap from structure to structure? On the theory of natural selection, we can clearly understand why she should not; for natural selection can act only by taking advantage of slight successive variations; she can never take a leap, but must advance by the shortest and slowest steps***."

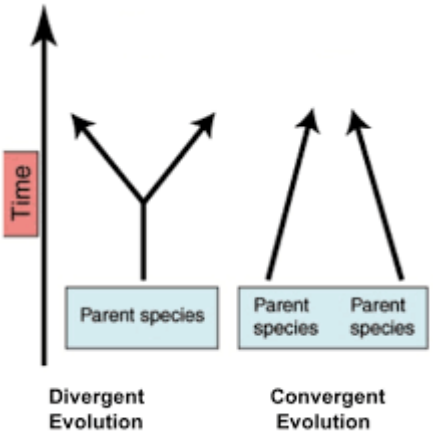


Is bioluminescence in these taxa better described and explained by Charles Darwin's theory of **natural selection** or by **congenital changes, mutations**, or **jumps**. Such jumps might give the appearance of **design** exhibiting "*the Power, Wisdom, and Goodness of God, as manifested in the Creation*." **Francis Henry Egerton**, the 8th Earl of Bridgewater who loved to give dinner parties for dogs commissioned the **Bridgewater Treatises** to present design in nature. As it says in Job 12:7-9, "*But ask the animals, and they will teach you, or the birds in the sky, and they will tell*

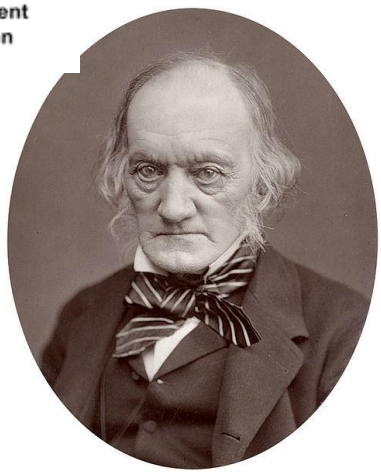
you; or speak to the earth, and it will teach you, or let the fish in the sea inform you. Which of all these does not know that the hand of the LORD *has done this*."



Back to natural selection. Is bioluminescence in *Vibrio* or the fungus *Armillaria* a **random variation** upon which **natural selection** could capitalize on if its **selective value** were greater than its **cost**, or eliminate if its cost were greater than its selective value? Could bioluminescence be a result of an ancient process that has been **lost** in most organisms but **repressed** and later **revived** in other unrelated taxa where it proved useful? What are the meanings of homologous processes derived by **evolution from common descent** (**divergent evolution**) and analogous processes derived by **convergent evolution**? How do you distinguish convergent evolution from design?



While I only pose these questions here, I want to mention **Richard Owen**, who coined the word **dinosaur** and was the scientific consultant to the sculptor Benjamin Waterhouse Hawkins, who produced the life-sized models of the dinosaurs for the **Crystal**

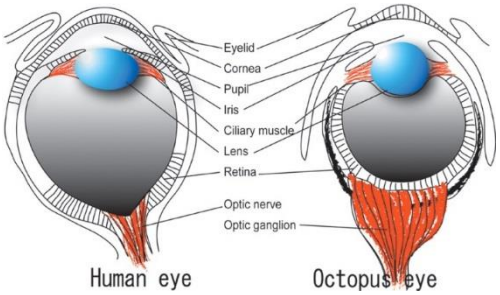




Palace after it was moved to Sydenham. Richard Owen is the 19th century scientist who introduced the terms **homology** and **analogy** in terms of **progressive evolution.**

After finishing grammar school, **Richard Owen** became an apprentice to Leonard Dickson, a local surgeon who performed post-mortems at a local prison. This led to a lifelong interest in anatomy, **comparative anatomy**, and fossil anatomy. Richard Owen studied hard tissue such as **teeth and bones** as well as soft tissue such as the brain.

In order to make sense of the basic **unity** (**archetype**) and **diversity** of organs, Richard Owen (1848) distinguished **homology** from **analogy**. If two or more parts are related by **common descent**, they are considered to be **homologous**. The wing of a bat and the forearm of a rat is an example of a homology. If two or more parts have some similarities in terms of **form or function**, but are not related by common descent, they are considered to be **analogous**. The wings of butterflies and bats or the **camera-like eyes** of cephalopods and vertebrates are examples of analogy. Analogous parts of organisms that are not related by common descent can be considered to be analogies that are the result of **convergent evolution** and/or **design**.



Using evidence of comparative anatomy, Richard Owen saw the **succession** of fossil organisms from the lower strata to the upper strata and the **progression** of simpler vertebrates such as fish to more advanced mammals to be a result of a "*continuous operation of the ordained becoming of living things*"—God was the **first cause** and a **number of possible second causes**, including **natural selection**

and more importantly **congenital changes** (e.g. mutations or jumps) resulted in the transformation of species. Owen did ***not*** believe in the immutability of species.

Based on his **personal philosophy** and his **scientific observations**, Richard Owen (1859) saw anatomical as well as spiritual distinctions between human(ity) and apes. At the **1860 meeting of the British Association for the Advancement of Science at Oxford**, Richard Owen proposed that there are sufficient differences in the brains of apes and human beings to set humans apart. Humans had a seahorse-shaped region of the brain known as the **hippocampus minor** and apes lacked a hippocampus minor. Could his **personal philosophy** have prejudiced his ability to objectively observe and interpret anatomical observations?

The young **Thomas H. Huxley**, on the other hand, made more accurate observations on the brains and did not see anatomical or any other differences to be significant enough to separate human beings struggling for existence from apes and monkeys. Then again, such a separation also went against Huxley's **personal philosophy**. Could Huxley's personal philosophy have prejudiced his ability to acknowledge the possibility that there may be more to being human than that which can be weighed, measured, and counted? Any challenge to Huxley's personal philosophy brought out the **firebrand** and **provocateur** in him. Although remember, as Huxley got older, he concluded in his Romanes Lecture that the ethical behavior of humans could not be simply a result of natural selection.

T. H. Huxley wrote to Frederick Dyster on January 30, 1859, "*both [Theology and Parsondom] are in my mind the natural and irreconcilable* ***enemies*** *of Science. … If I have a wish to live thirty years, it is that* ***I may see the foot of Science on the necks of her enemie****s*." In a review of *Origin of Species*, T. H. Huxley (1860) wrote, "*Extinguished theologians lie about the cradle of every*

science as the strangled snakes beside that of Hercules; and history records that whenever science and orthodoxy have been fairly opposed, the latter has been forced to retire from the lists, ***bleeding and crushed if not annihilated; scotched, if not slain***." On October 11, 1862, T. H. Huxley wrote to Frederick Dyster, about Richard Owen, "*Before I have done with that mendacious humbug I will nail him out, like a kite to a barn door, an example to all evil doers….*"

According to Huxley (1863), "*As if to demonstrate, by a striking example, the impossibility of erecting any cerebral barrier between man and the apes, Nature has provided us, in the later animals, with an* ***almost complete series of gradations*** *from brains little higher than that of a Rodent, to brains little lower than that of Man. And it is a remarkable circumstance, that though so far as our present knowledge extends, there is one true structural break in the series of forms of the Simian brains,* ***this hiatus does not lie between Man and the man-like apes, but between the lower and the lowest Simians****; or, in other words, between the old and new world apes and monkeys, and the Lemurs…. So far as cerebral structure goes, therefore, it is clear that Man differs less from the Chimpanzee or the Orang, than these do even from the Monkeys, and that the difference between the brains of the Chimpanzee and of Man is almost insignificant when compared with that between the Chimpanzee brain and that of a Lemur*."

T. H. Huxley (1861) had previously expanded on the series between humans of various races and apes, "*…the cerebral hemispheres of the Bosjesman (and to a certain extent of the negro), so far as the evidence before us goes, are different from those of the white man…the same nature as most of those which distinguish the ape's brain from that of man. In other words, if we place A, the European brain, B, the Bosjesman brain, and C, the orang brain, in a series, the differences between A and B, so far as they have been ascertained, are of the same nature as*

the chief of those between B and C….The brains of the lowest races of mankind have been hardly at all examined; and it would be a matter of great interest….Medical men living at the Cape of Good Hope, in Australia, and within reach of the Hill-men of India, will, it is to be hoped, some day solve these problems for the zoologist."

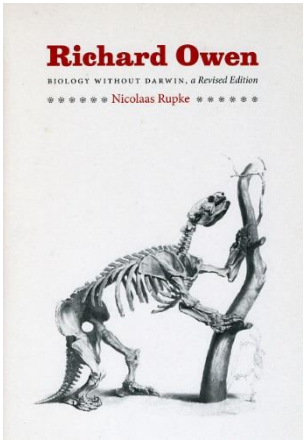
Realizing that brain size was a function of body size, but intelligence was not, Richard Owen (1862) wrote, "Al*though in most cases the Negro's brain is less than that of the European, Tiedemann and the author* [Richard Owen] *of the present paper had observed individuals of the Negro race in whom the brain was as large as the average one of the Caucasian;* ***and the author concurred with the great physiologist of Heidelberg in connecting with such cerebral development the fact that there had been no province of intellectual activity in which individuals of the pure Negro race had not distinguished themselves****. The contrast between the brains of the Negro and Gorilla, in regard to size, was still greater in respect of the proportional size of the brain to the body —the weight of a full-grown male Gorilla being one-third more than that of an average-sized Negro.*"

Charles Darwin (1839), on the other hand thought there were great differences between "savage and civilized man." Darwin wrote in the *Voyage of the Beagle*: "*In the morning the Captain sent a party to communicate with the Fuegians. When we came within hail, one of the four natives who were present advanced to receive us, and began to shout most vehemently, wishing to direct us where to land. When we were on shore the party looked rather alarmed, but continued talking and making gestures with great rapidity. It was without exception the most curious and interesting spectacle I ever beheld:* ***I could not***

have believed how wide was the difference between savage and civilized man*: it is greater than between a wild and domesticated animal, inasmuch as in man there is a greater power of improvement…. Viewing such men,* ***one can hardly make one's self believe that they are fellow-creatures, and inhabitants of the same world****. It is a common subject of conjecture what pleasure in life some of the lower animals can enjoy: how much more reasonably the same question may be asked with respect to these barbarians…. They cannot know the feeling of having a home, and still less that of domestic affection; for the husband is to the wife a brutal master to a laborious slave. Was a more horrid deed ever perpetrated, than that witnessed on the west coast by* ***Byron****, who saw a wretched mother pick up her bleeding dying infant-boy, whom her husband had mercilessly dashed on the stones for dropping a basket of sea-eggs! How little can the higher powers of the mind be brought into play: what is there for imagination to picture, for reason to compare, or judgment to decide upon? to knock a limpet from the rock does not require even cunning, that lowest power of the mind.* ***Their skill in some respects may be compared to the instinct of animals; for it is not improved by experience****: the canoe, their most ingenious work, poor as it is, has remained the same, as we know from Drake, for the last two hundred and fifty years."*
http://www.gutenberg.org/files/944/944-h/944-h.htm#link2HCH0010

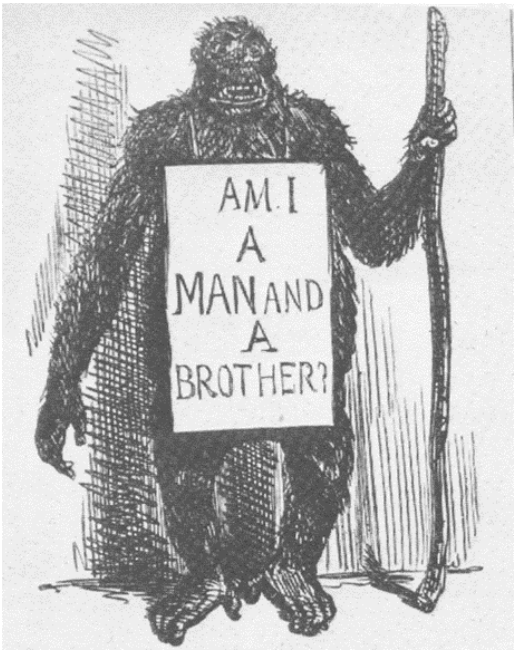
At the time, T. H. Huxley embraced **August Comte's materialist and positivist philosophy**. Huxley (1861) wrote, "***Theologians and moralists****, historians and poets, impressed by a sense of the infinite responsibilities of mankind, awed by a just prevision of the great destinies in store for the only earthly being of practically unlimited powers, or touched by the tragic dignity of the ever-recurring struggle of human will with circumstance, have always tended to conceive of their kind as something apart, separated by a great and impassible barrier, from the rest of the natural world. On the other hand, the* ***students of***

***physical science**, discovering as complete a system of law and order in the microcosm as in the macrocosm, incessantly lighting upon new analogies and new identities between life manifested by man, and life in other shapes,—have no less steadily gravitated towards the opposite opinion, and, as knowledge has advanced, have more and more distinctly admitted the closeness of the bond which unites man with his humbler fellows. A controversy has raged between these opposed schools…."*



There are significant **similarities** and **differences** between humans and apes and there is no reason for a thinking person to deny either the similarities or the differences. Moreover, one must decide which similarities (skeletal structure) and which differences (artistic ability) are important in distinguishing taxonomic groups. There are also significant differences between individuals, and one must make sure that sufficient evidence has been collected and covariant causes eliminated before making extrapolations from limited facts that may later be proven to be unjustified. I think Nicolaas Rupke (2009) gives a fair analysis of Owen and Huxley in *Richard Owen: Biology without Darwin*. The actual two year-long scientific rivalry between T. H. Huxley and Richard Owen (as opposed to the science versus religion rivalry between Huxley and Wilberforce fabricated in the histories told by Francis Darwin and Leonard Huxley and propagated to this day) became famous and was treated with humor in its time.

Punch published ***Monkeyana*** in May 1861.



Monkeyana

Am I satyr or man?
Pray tell me who can,
And settle my place in the scale.
A man in ape's shape,
An anthropoid ape,
Or monkey deprived of his tail?

The Vestiges taught,
That all came from naught
By "development," so called, "progressive;"
That insects and worms
Assume higher forms
By modification excessive.

Then Darwin set forth
In a book of much worth,
The importance of "nature's selection;"
How the struggle for life
Is a laudable strife,
And results in "specific distinction."

Let pigeons and doves
Select their own loves,
And grant them a million of ages,
Then doubtless you'll find
They've altered their kind,
And changed into prophets and sages.

Leonard Horner relates,
That Biblical dates
The age of the world cannot trace;
That Bible tradition,
By Nile's deposition,
Is put to the right about face.

Then there's Pengelly

Who next will tell ye
That he and his colleagues of late
Find celts and shaped stones
Mixed up with cave bones
Of contemporaneous date.

Then Prestwich, he pelts
With hammers and celts
All who do not believe his relation,
That the tools he exhumes
From gravelly tombs
Date before the Mosaic creation.

Then Huxley and Owen,
With rivalry glowing,
With pen and ink rush to the scratch;
'Tis Brain versus Brain,
Till one of them's slain,
By JOVE! it will be a good match!

Says Owen, you can see
The brain of Chimpanzee
Is always exceedingly small,
With the hindermost "horn"
Of extremity shorn,
And no "Hippocampus" at all.

The Professor then tells 'em,
That man's "cerebellum,"
From a vertical point you can't see;
That each "convolution"
Contains a solution
Of "Archencephalic" degree.

That apes have no nose,
And thumbs for great toes,
And a pelvis both narrow and slight;
They can't stand upright,
Unless to show fight,

With 'Du Chaillu,' that chivalrous knight!

Next Huxley replies,
That Owen he lies,
And garbles his Latin quotation;
That his facts are not new,
His mistakes not a few,
Detrimental to his reputation.

"To twice slay the slain,
By dint of the Brain,
(Thus Huxley concludes his review)
Is but labour in vain,
Unproductive of gain,
And so I shall bid you 'Adieu'!"

Punch also published ***The Gorilla's Dilemma*** in October 1862:

The Gorilla's Dilemma (Excerpt)

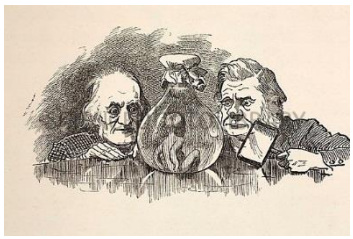
(To Professor Owen & Huxley)

SAY am I a man and a brother,
Of only an anthropoid ape?
Your judgment, be 't one way or 'tother,
Do *put into positive shape.*

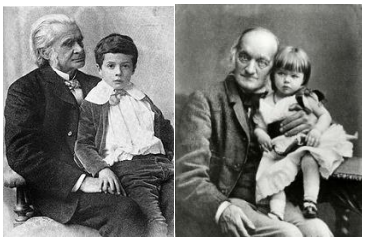
Must I humbly take rank as quadruman
As OWEN maintains that I ought:
Or rise into brotherhood human,
As HUXLEY has flatt'ringly taught?

For though you may deem a Gorilla
Don't think much of his rank in creation,
If of feeling one have a scintilla,
It glows to know "who's one's relation"—

Charles Kingsley (1863) wrote about the rivalry in his book, ***Water Babies***:



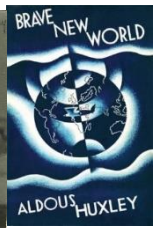
"*You may think that there are other more important differences between you and an ape, such as being able to speak, and make machines, and know right from wrong, and say your prayers, and other little matters of that kind; but that is a child's fancy, my dear. Nothing is to be depended on but* ***the great hippopotamus test****. If you have a hippopotamus major in your brain, you are no ape, though you had four hands, no feet, and were more apish than the apes of all aperies. But if a hippopotamus major is ever discovered in one single ape's brain, nothing will save your great- great- great- great- great- great- great- great- great- great- great- greater- greatest- grandmother from having been an ape too. No, my dear little man; always remember that the one, true, certain, final and all-important difference between you and an ape is, that you have a hippopotamus major in your brain, and it has none; and that to discover one in its brain will be a very wrong and dangerous thing, at which every one will be very much shocked.*"



What happened to T. H. Huxley and Richard Owen? They both became grandfathers. T. H. Huxley's grandchildren include Julian Huxley, **Aldous Huxley**, and Andrew Fielding Huxley.



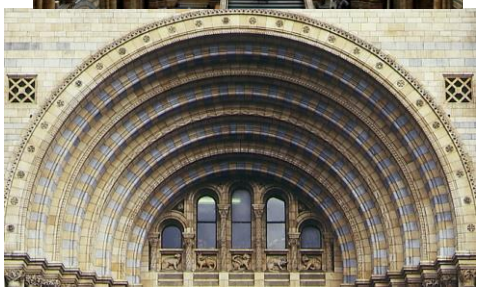




Richard Owen became the prime mover in establishing the **British Museum of Natural History** in 1881 in South Kensington, the former site of the **Crystal Palace** and Great Exposition of 1851. It was a museum for both the specialists and for the general population. The building, which was a **cathedral to nature** was designed by Alfred Waterhouse. It was a Romanesque **terracotta** building that produced a **romantic skyline**. It is an example of a work of art in the service of science. In contrast to the limestone that was typically used for buildings, the terracotta was resistant to acid rain and was also washable, two desirable characteristics in coal burning-Victorian London. The terracotta could also be inexpensively made and molded into decorative plants, animals, and gargoyles.
http://nhm.ac.uk/visit-us/history-architecture/index.html









The **British Museum of Natural History** houses collections of butterflies, beetles, fossils, plants and animals. http://www.nhm.ac.uk/nature-online/collections-at-the-museum/museum-treasures/charles-darwin-pigeons/index.html







The **British Museum of Natural History** houses Charles Darwin's pigeon collection. http://www.nhm.ac.uk/nature-online/collections-at-the-museum/museum-treasures/charles-darwin-pigeons/index.html



The **British Museum of Natural History** houses Alfred Russel Wallace's insect collection: : http://www.nhm.ac.uk/nature-online/collections-at-the-museum/museum-treasures/alfred-russel-wallace-insects/index.html



The **British Museum of Natural History** has also created an excellent and free online book about ***Slavery and the Natural World*** https://www.nhm.ac.uk/discover/slavery-and-the-natural-world.html You can see that the world was in need of **William Wilberforce's** and his son **Samuel Wilberforce's** vision for the right to liberty for all people no matter what their color. Oddly enough, William Wilberforce is mentioned only in terms of having correspondence with **Joseph Banks** and Samuel Wilberforce and the **slave-making instinct of ants** is not mentioned at all.



Joseph Banks was a botanist, who sailed with Captain James Cook, and gave advice to King George III on how to make plants profitable. Banks initially accepted slavery as necessary part of the global economy and suggested that William Bligh, Captain of the **HMS Bounty**, collect breadfruit plants from Tahiti and transport them to the Caribbean, where the trees would be a ready source of the carbohydrate-rich fruits that could be used to feed the slaves.

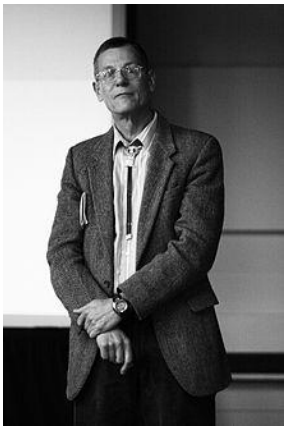


In 1868, in a letter to Charles Darwin, T. H. Huxley drew this sketch **elevating Darwin to Pope**. Since then, a part of biology could be looked at as **hagiology**, the study of the life of the saints. T. H. Huxley's son, Leonard Huxley (1903), a writer, wrote ***Life and Letters of Thomas Henry Huxley***. This book, along with ***The Life and Letters of Charles Darwin***, written by Francis Darwin (1887), Charles' son, became the official history. The Darwin-Huxley story is basically the only story that is told. The Owen-Wilberforce story has been so marginalized as to be nearly forgotten.



The hegemony of Darwin-Huxley versus Owen continues in terms of statuary. When the **British Museum of Natural History** opened, a statue of Richard Owen was placed below a stained-glass window in the Central Hall. When Charles Darwin died in 1882, his statue was also placed in the Central Hall. When T. H. Huxley died in 1899, his statue was placed near Owen's. In 1927, Darwin's statue was moved to the North Hall. In 2009, Owen's statue in the Central Hall was replaced by Darwin's.

There were many reasons behind the Darwin-Huxley and Owen-Wilberforce polarity. But I think **materialism or naturalism versus spiritualism** was a part of it. Richard Owen did not eliminate God from the evolutionary process, Darwin and Huxley seemed to. As scientists, we (including or perhaps especially me) bring our **personal philosophy** to bear on our science. For example, I see both the value and limitations of Charles Darwin's theory of natural selection. As someone that sees the limitations more so than most scientists, I have no problem in accepting the **existence of free will** and the **meaningfulness of life** and the observational evidence that they both exist.



Others disagree. For example, in response to an essay written by Phillip E. Johnson[1], **Will Provine** (1990; Cornell) wrote, "*Evolution produces two results that cry out for explanation adaptation and diversity. Sonar in bats, **eyesight in eagles**, **sunlight energy capture in plants**, and adaptations in general had only one kind of explanation before Darwin; the argument from design. The same argument explained the vast diversity of kinds of animals and plants. The greatest minds in*

[1] http://www.firstthings.com/article/1990/10/002-evolution-as-dogma-the-establishment-of-naturalism

the history of Western Civilization, from Plato and Aristotle to Augustine, St. Thomas Aquinas, Kepler, Galileo, Newton, and Boyle, all believed that the argument from design was the only reasonable explanation for adaptations in animals and plants. When they were alive, they were right.

As a young man, Charles Darwin was a creationist deeply impressed with William Paley's version of the argument from design. But after returning from the voyage of H.M.S. Beagle, reconsideration of what he had seen on the voyage convinced him that evolution had occurred. A short time later, when he deduced the theory of natural selection to explain the adaptations in which he had previously seen the handiwork of God, ***Darwin knew that he was committing cultural murder****. He understood immediately that if natural selection explained adaptations, and evolution by descent were true, then the argument from design was dead and all that went with it,* ***namely the existence of a personal god, free will, life after death, immutable moral laws, and ultimate meaning in life****. The immediate reactions to Darwin's On the Origins of Species exhibit, in addition to favorable and admiring responses from a relatively few scientists, an understandable fear and disgust that has never disappeared from Western culture.*

Johnson [author of *Evolution as Dogma: The Establishment of Naturalism*] *has excellent reasons for fearing and despising modern scientific conceptions of the evolutionary* ***process. He clearly wants animals and plants (humans in particular-he says nothing about disgusting parasites) to have been designed by divine purpose.*** *He wants to have free will and divinely inspired moral laws that last forever unchanged, and I suspect that he wants to have some kind of ultimate meaning in life coupled with life after death****.*** *If modern evolutionary biology is true, then all these lofty desires are hopeless*."
http://www.arn.org/docs/johnson/pjdogma2.htm

Question: Does the concept of democracy and voting have any meaning if there is no such thing as free will?

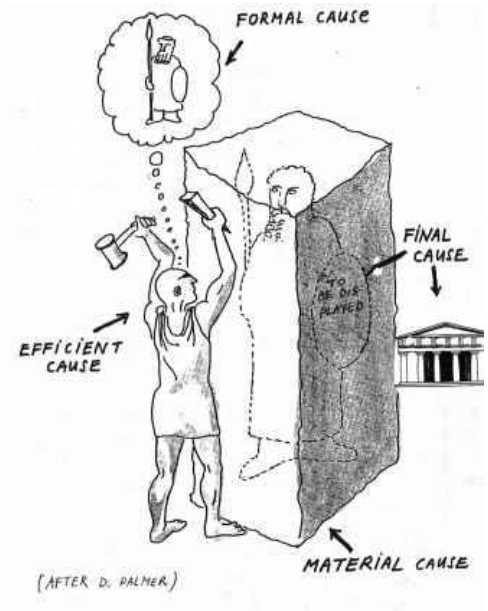


The movie "*Creation*" is a superbly done movie on Charles Darwin's personal struggles based on the book *Annie's Box: Darwin, His Daughter, and Human Evolution*, by Darwin's great, great grandson, Randal Keynes.

https://vimeo.com/71717324

Is there room for more than one cause in science? Must we accept unconditionally that the materialist theory of natural selection will describe and explain all aspects of life? Let's consider the story of **Theseus's Paradox**. According to Plutarch, "*The ship wherein Theseus and the youth of Athens returned from Crete had thirty oars, and was preserved by the Athenians down even to the time of Demetrius Phalereus, for they took away the old planks as they decayed, putting in new and stronger timber in their place, in so much that this ship became a standing example among the philosophers, for the logical question of things that grow; one side holding that the ship remained the same, and the other contending that it was not the same*." Thomas Hobbes wondered: What would happen if each of the original planks were collected after they were

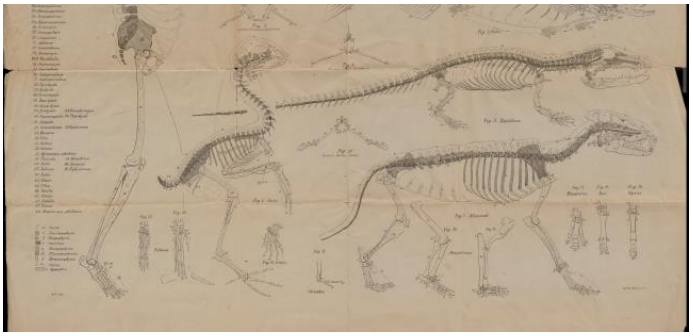


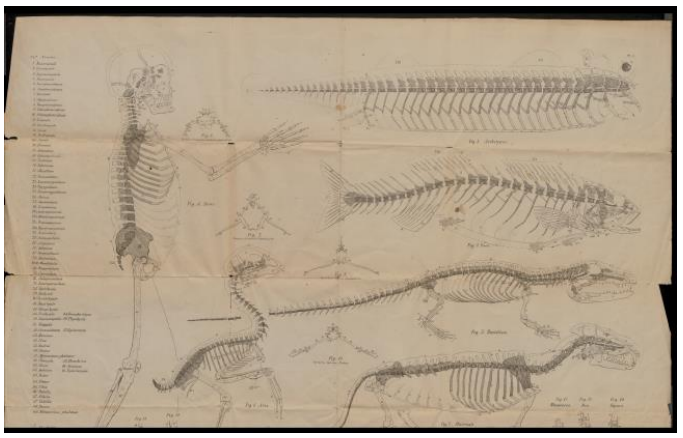


replaced and then were used to build a second ship? Which ship, if either one of them, is the original Ship of Theseus? I want to say, a reasonable person can hold more than one explanation for the same object or process. **Dualism** or even **quadrupleism** is not a bad thing.

Aristotle proposed **four causes** (or explanations) that are needed to describe an object such as Theseus's ship. The **formal cause** is the form of the object; the **material cause** is the matter that makes up the object; the **efficient cause** is the mechanism of how or by whom the object is made; and the **final cause**, is the intended purpose of the object. Taking the four causes into consideration, there is no single answer to Hobbes' question about which is the original ship. By reducing the question to a single cause, we can only get a partial, although dogmatic, answer. Is it possible that the young Thomas H. Huxley dismissed any potential causes too quickly? If we are to believe that he had not lost his mind when he gave the Romanes Lecture, then the answer is yes.

While Richard Owen's name has been lost, his theory of **analogy** and **homology**, which was presented in a lecture entitled *On the Nature of Limbs*, given at the Royal Institution in 1849, has become a cornerstone in all levels of biology. Although he was a comparative anatomist, Richard Owen realized that every grade of organization can be considered to have at least **two meaningful causes**: **form** that arises from an evolutionary and developmental plan, and **function** that



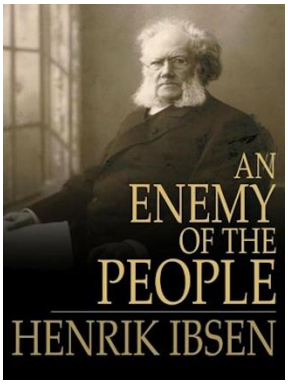


facilitates the processes, such as movement that are necessary for life.

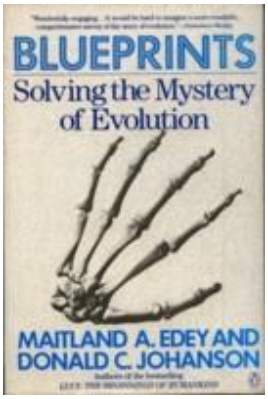


The concepts of **analogy** and **homology** can be applied to genes as well as limbs. If two or more objects are related by **common descent**, they are considered to be **homologous**. If two or more objects have some similarities in terms of form or function, but are not related by common descent, they are considered to be **analogous**. Without sufficient experimental evidence to support convergent evolution or design, gradual or saltational change, the **bioluminescent production of light** by organisms that are not related by common descent can be considered by reasonable people to be analogies that are the result of **convergent evolution** that results from **gradual natural selection**, **large congenital changes (e.g., genetic mutations or jumps) that have no selective advantage**, and/or **design**.

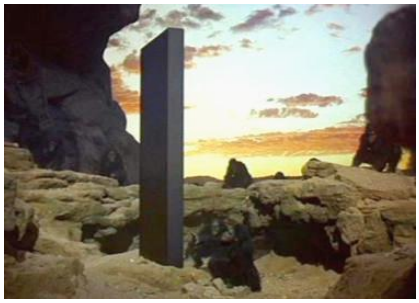
The **National Center for Science Education** defines anti-evolutionism in the classroom as teaching the strengths and weaknesses of evolution and teaching how to critically analyze evolution (http://ncse.com/evolution/education/anti-evolutionism-classroom). I obviously disagree and would not call myself an anti-evolutionist. I am just a strong believer that a healthy science demands questioning and believe that any consensus on any issue does not eliminate the possibility of questioning. **Henrik Ibsen** wrote in "*An Enemy of the People*," "*The majority is never right. Never, I tell you! That's one of these lies in society that no free and intelligent man can help rebelling against*." There is a trend however



that treats **science as a package deal** that has been packaged by the consensus. The trend suggests that you cannot choose for yourself those parts of science that you think have strong support and reject the other parts. In their book *Blueprints: Solving the Mystery of Evolution*, Maitland A. Edey and Donald C. Johanson (1989) write, "*You can`t accept one part of science because it brings you good things like electricity and penicillin, and throw away another part because it brings some ideas you don`t like about the origin of life*."

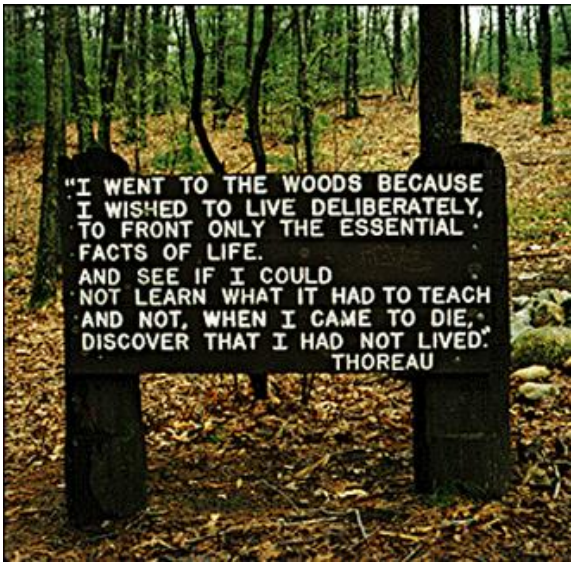


Science does not have to be **monolithic**. Use your own mind! Think for yourself! Make your own decisions! In *The Everlasting Gospel*, William Blake wrote about the importance of the mind/soul in seeing:



This life's five windows of the soul
Distorts the heavens from pole to pole
And leads you to believe a lie
When you see with, not through, the eye.

"*I know of no more encouraging fact than the unquestionable ability of man to elevate his life by a conscious endeavor. It is something to be able to paint a particular picture, or to carve a statue, and so to make a few objects beautiful; but it is far more glorious to carve and paint the very atmosphere and medium through which we look, which morally we can do. To affect the quality of the day, that is the highest of arts.*" -- Henry David Thoreau, in *Where I Lived and What I Lived For*

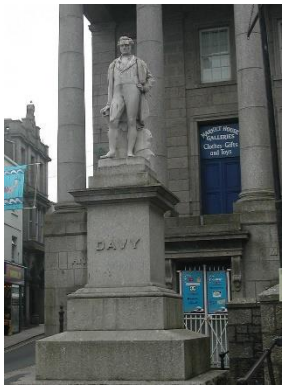


Some picture windows in the city are truly beautiful! Here's a ***trompe l'oeil* stained glass window** designed by Richard Morris Hunt for **Henry Gurdon Marquand's** New York City home.



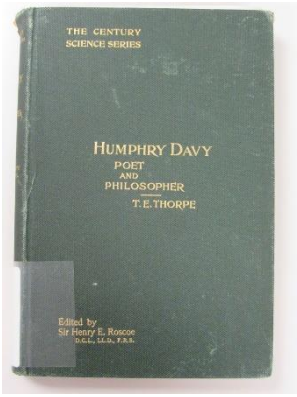


Humphry Davy, the inventor of the miner's safety lamp, the discoverer of sodium, potassium, calcium, magnesium, strontium, and barium, and the person who named N_2O laughing gas also was inspired by nature to write poetry about bioluminescence. He wrote a poem entitled, *To the Fire-flies*.



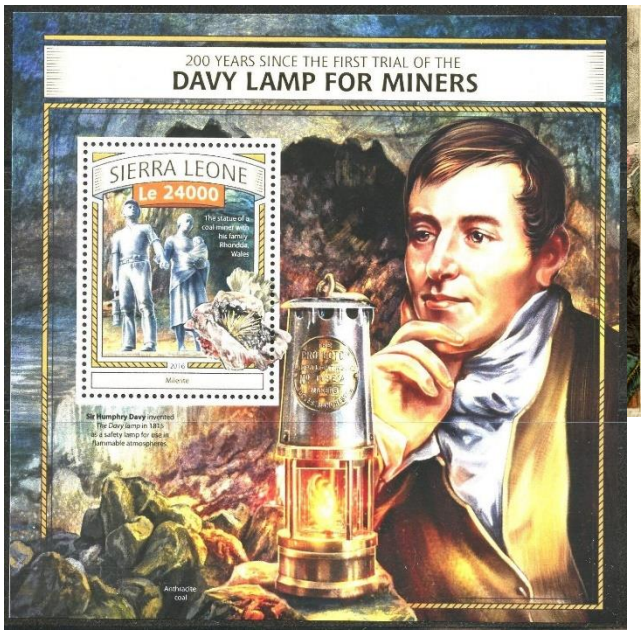
To the Fire-flies (1819)

Ye animated lamps that 'midst the shade
Of ancient chesnuts, and the lofty hills
Of Lusignana, by the foaming rills
That clothe the Serchio in the evening play!
So bright your light, that in the unbroken ray.

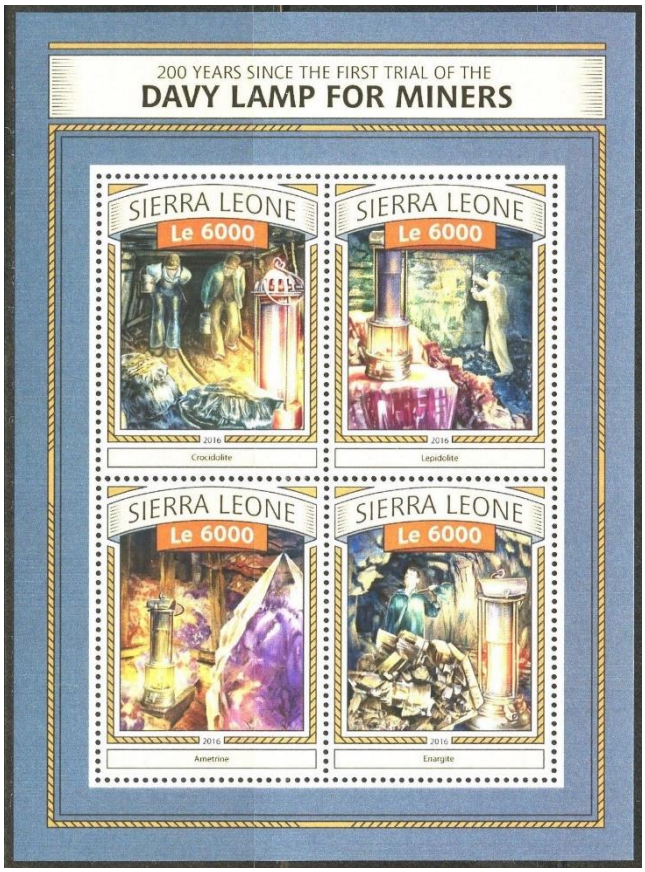


Which clothe the nearest slopes! how thro' the groves
Of Lucca do ye dance! The breeze that moves
Their silver leaves, a mountain zephyr's wing,
Has brought you here to cheer our tardy spring.
Oft had I seen ye 'midst thy orange bowers,

Parthenope! and where Velino pours
In thundering cataracts; but ne'er before
So high upon the mountains, where ye soar
E'en in mid air, leaving those halcyon plains
Where spring or summer everlasting reigns,
Where flowers and fruit mature together grow,
To visit our rude peaks, where still the snow
Glitters e'en in the genial month of flowers.
But brightly do ye move in fiery showers,
Seen like the falling meteor from afar,
Or like the kindred of the erring star.
May not the stars themselves in orbits whirl'd,
Be but a different animated world,
In which a high and lofty breath of life,
Of worlds and insects calms the wakening strife,
Commands the elements, and bids them move
In animation to the voice of Love!



Thou loveliest form of the celestial world,
When in the circle of thy brightness
Thou sheddest in the blue unclouded sky
All thy meridian lustre! in the north,
Above the heath-clad mountains have I seen
Thy clear and mellow light; and when the waves
Of the Atlantic raised their foaming surge
Against the eternal rocks, where fabled sleeps
The last of western Titans—then, when young
In mind, and light of heart, thy rays had power
To solemnize and tune to thoughts sublime
My vagrant spirit; now, in these fair climes,
Where in a purer and more balmy air,
And in a sky whose tints of ether seem
Giving a saint-like glory to thy rays,
Thy influence is e'en stronger in a heart
Wearied, but not yet broken or subdued.
Yet still my heart is sensible to thee,
As when it first received the flood of life
In youth's full spring-tide; and to me it seems
As if thou- wert a sister to my soul,
An animated being, carrying on



An intercourse of sweet and lofty thoughts,
Wakening the slumbering powers of inspiration
In their most sacred founts of feeling high.

The tempest gather'd on thy verdant hills,
0 Lusignano! The azure southern sky
Was dimm'd by fleeting mists. Soon the dark cloud
Form'd more compact, and to the zenith rose;
The bright blue of the northern distance then,
And all the mountains show'd their shaggy crests
Of ancient chesnuts, dark and deep in shade.
To the feverish flush of the meridian sun
Succeeded quick a damp and sudden chill;
The lightning flash'd. At first, a feeble light,
Scarce seen, even in the darkest part of heaven,
Succeeded by low murmurings; brighter gleam'd
Each flash that follow'd, and now louder roar'd
The thunder distant, but it soon became
The loudest burst of heaven's artillery.

— The whirlwind gone,
A calm, a soothing freshness soon succeed.
Thus in the mind springs new-born energy,
— Thoughts that were dead are roused,
And all the purer being wakes again.
The slime of foulness and impurity
Are borne into the ocean deep of reason,
And new creations dance upon its waves,
E'en as they purify—a thousand forms
Of beauty, and of goodness, and of grace.
The intellectual soul, freshen'd by dew
From heaven, enrich'd, is glad and green with life.

Again that lovely lamp from half its orb
Sends forth a mellow lustre, that pervades
The eastern sky, and meets the rosy light
The mountains all above are clear and bright,
Their giant forms distinctly visible,
Crested with shaggy chesnuts, or erect,

Bearing the helmed pine, or raising high
Their marble columns crown'd with grassy slopes.
From rock to rock the foaming Lima pours
Full from the thunder storm, rapid, and strong,
And turbid. Hush'd is the air in silence;
The smoke moves upwards, and its curling waves
Stand like a tree above. E'en in my heart,
By sickness weaken'd and by sorrow chill'd,
The balm of calmness seems to penetrate,—
Mild, soothing, genial in its influence.
Again I feel a freshness, and a power,
As in my youthful days, and hopes and thoughts
Heroical and high! The wasted frame
Soon in corporeal strength recruits itself,
And wounds the deepest heal; so in the mind,
The dearth of objects and the loss of hope
Are in the end succeeded by some births
Of new creative faculties and powers,
Brought forth with pain, but, like a vigorous child,
Repaying by its beauty for the pang.

According to J. Z. Fullmer (1960), "*Throughout all Davy's poetry, parallel with the theme of permanence and change runs the eternality aspect identified as light. Eventually light became for him synonymous with his personal God. In one sense, it is fair to say that the development of his poetry reflects the development within Davy of this equation:* ***God is Light****. The light may be sunlight, moonlight, light from the evening star, or the cold light of fireflies…. In the poetry of his second period…light is generally a manifestation of the 'One Intelligence,' while in poems written after 1812, Davy frequently made 'light' identical with the 'Intelligence'*"

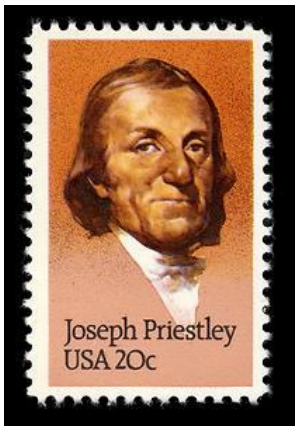
Humphry Davy, one of the world's greatest scientists, was not as dogmatic as the **National Center for Science Education** and some scientists or perhaps **scient(ism)ists** today who think that some aspects of science are beyond question and have been settled by the consensus for all time. Davy realized that indeed he was one of the men that must be careful of the idols of the Tribe, the Marketplace, the Theatre, and the **Cave**. In an address delivered to the Royal Society on November 30, 1825, he said:

"*Fortunately science, like that nature to which it belongs, is neither limited by time nor by space. It belongs to the world, and is of no country and of no age.* ***The more we know, the more we feel our ignorance; the more we feel how much remains unknown****; and in philosophy, the sentiment of the Macedonian hero can never apply, — there are always new worlds to conquer.*"

Davy also wrote in *Consolations in Travel: Or, The Last Days of a Philosopher*:

"*It is surely a pure delight to know, how and by what processes this earth is clothed with verdure and life, how the clouds, mists and rain are formed, what causes all the changes of this terrestrial system of things, and by what divine laws order is preserved amidst apparent confusion. It is a sublime occupation to investigate the cause of the tempest and the volcano, and to point out their use in the economy of things, — to bring the lightning from the clouds and make it subservient to our experiments, — to produce as it were a microcosm in the laboratory of art, and to measure and weigh those invisible atoms, which, by their motions and changes according to laws impressed upon them by the Divine Intelligence, constitute the universe of things. The true chemical philosopher sees good in all the diversified forms of the external world. Whilst he investigates the operations of infinite power guided by infinite wisdom, all low prejudices, all mean superstitions disappear from his mind. He sees man an atom amidst atoms fixed upon a point in space; and yet modifying the laws that are around him by understanding them; and gaining, as it were, a kind of dominion over time, and an empire in material space, and exerting on a scale infinitely small a power seeming a sort of* ***shadow*** *or* ***reflection*** *of a creative energy, and which entitles him to the distinction of being made in the* ***image*** *of God and animated by a spark of the divine mind. Whilst chemical pursuits exalt the understanding, they do not depress the imagination or weaken genuine feelings; whilst they give the mind habits of accuracy, by obliging it to attend to facts, they likewise extend its analogies; and, though conversant with the minute forms of things, they have for their ultimate end the great and magnificent objects of nature. They regard the formation of a crystal, the structure of a pebble, the nature of a clay or earth; and they apply to the causes of the diversity of our mountain chains, the appearances of the winds, thunder-storms, meteors, the earthquake, the volcano, and all those phenomena which offer the most striking images to the poet and the painter. They keep alive that inextinguishable thirst after knowledge, which is one of the greatest charactics of our nature; — for every discovery opens a new field for investigation of facts, shows us the imperfection of our theories****. It has justly been said, that the greater the circle of light, the greater the boundary of darkness by which it is surrounded***."

The last sentence is a paraphrase of a line written by **Joseph Priestley** (1790), a discoverer of oxygen in the Preface of his *Experiments and Observations on Different Kinds of Air*. Priestley too realized that he was a man who lived in a cave as described by Plato.



"***The greater is the circle of light, the greater is the boundary of the darkness by which it is confined***. *But, notwithstanding this, the more light we get, the more thankful we ought to be, for by this means we have the greater range for satisfactory contemplation. In time the bounds of light will be still farther extended; and from the infinity of the divine nature, and the divine works, we may promise ourselves an endless progress in our investigation of them: a prospect truly sublime and glorious.* ***The works of the greatest and most successful philosophers are, on this account, open to our complaints of their being imperfect***."

This way of thinking goes back to **Socrates**' Apology"

"*I dare say, Athenians, that some one among you will reply, 'Yes, Socrates, but what is the origin of these accusations which are brought against you; there must have been something strange which you have been doing? All these rumours and this talk about you would never have arisen if you had been like other men: tell us, then, what is the cause of them, for we should be sorry to judge hastily of you.' Now I regard this as a fair challenge, and I will endeavour to explain to you the reason why I am called wise and have such an evil fame. Please to attend then. And although some of you may think that I am joking, I declare that I will tell you the entire truth. Men of Athens, this reputation of mine has come of a certain sort of wisdom which I possess. If you ask me what kind of wisdom, I reply, wisdom such as may perhaps be attained by man, for to that extent I am inclined to believe that I am wise; whereas the persons of whom I was speaking have a superhuman wisdom which I may fail to describe, because I have it not myself; and he who says that I have, speaks falsely, and is taking away my character. And here, O men of Athens, I must beg you not to interrupt me, even if I seem to say something extravagant. For the word which I will speak is not mine. I will refer you to a witness who is worthy of credit; that witness shall be the God of Delphi—he will tell you about my wisdom, if I have any, and of what sort it is. You must have known Chaerephon; he was early a friend of mine, and also a friend of yours, for he shared in the recent exile of the people, and returned with you. Well, Chaerephon, as you know, was very impetuous in all his doings, and* ***he went to Delphi and boldly asked the oracle to tell him whether—as I was saying, I must beg you not to interrupt—he asked the oracle to tell him whether anyone was wiser than I was, and the Pythian prophetess answered, that there was no man***

wiser. *Chaerephon is dead himself; but his brother, who is in court, will confirm the truth of what I am saying.*

Why do I mention this? Because I am going to explain to you why I have such an evil name. When I heard the answer, I said to myself, What can the god mean? and what is the interpretation of his riddle? for I know that I have no wisdom, small or great. What then can he mean when he says that I am the wisest of men? And yet he is a god, and cannot lie; that would be against his nature. After long consideration, I thought of a method of trying the question. I reflected that if I could only find a man wiser than myself, then I might go to the god with a refutation in my hand. I should say to him, 'Here is a man who is wiser than I am; but you said that I was the wisest.' Accordingly I went to one who had the reputation of wisdom, and observed him—his name I need not mention; he was a politician whom I selected for examination—and the result was as follows: When I began to talk with him, I could not help thinking that he was not really wise, although he was thought wise by many, and still wiser by himself; and thereupon I tried to explain to him that he thought himself wise, but was not really wise; and the consequence was that he hated me, and his enmity was shared by several who were present and heard me. So I left him, saying to myself, as I went away: Well, although I do not suppose that either of us knows anything really beautiful and good, ***I am better off than he is,—for he knows nothing, and thinks that he knows****; I neither know nor think that I know. In this latter particular, then, I seem to have slightly the advantage of him. Then I went to another who had still higher pretensions to wisdom, and my conclusion was exactly the same. Whereupon I made another enemy of him, and of many others besides him.*

*Then I went to one man after another, being not unconscious of the enmity which I provoked, and I lamented and feared this: but necessity was laid upon me,—the word of God, I thought, ought to be considered first. And I said to myself, Go I must to all who appear to know, and find out the meaning of the oracle. And I swear to you, Athenians, by the dog I swear!—for I must tell you the truth—the result of my mission was just this****: I found that the men most in repute were all but the most foolish; and that others less esteemed were really wiser and better.*** *I will tell you the tale of my wanderings and of the 'Herculean' labours, as I may call them, which I endured only to find at last the oracle irrefutable. After the politicians, I went to the poets; tragic, dithyrambic, and all sorts. And there, I said to myself, you will be instantly detected; now you will find out that you are more ignorant than they are. Accordingly, I took them some of the most elaborate passages in their own writings, and asked what was the meaning of them—thinking that they would teach me something. Will you believe me? I am almost ashamed to confess the truth, but I must say that there is hardly a person present who would*

not have talked better about their poetry than they did themselves. Then I knew that not by wisdom do poets write poetry, but by a sort of genius and inspiration; they are like diviners or soothsayers who also say many fine things, but do not understand the meaning of them. ***The poets appeared to me to be much in the same case; and I further observed that upon the strength of their poetry they believed themselves to be the wisest of men in other things in which they were not wise. So I departed, conceiving myself to be superior to them for the same reason that I was superior to the politicians.***

At last I went to the artisans. I was conscious that I knew nothing at all, as I may say, and I was sure that they knew many fine things; and here I was not mistaken, for they did know many things of which I was ignorant, and in this they certainly were wiser than I was. ***But I observed that even the good artisans fell into the same error as the poets;—because they were good workmen they thought that they also knew all sorts of high matters, and this defect in them overshadowed their wisdom; and therefore I asked myself on behalf of the oracle, whether I would like to be as I was, neither having their knowledge nor their ignorance, or like them in both; and I made answer to myself and to the oracle that I was better off as I was.***

This inquisition has led to my having many enemies of the worst and most dangerous kind, and has given occasion also to many calumnies. And I am called wise, for my hearers always imagine that I myself possess the wisdom which I find wanting in others: but the truth is, O men of Athens, ***that God only is wise****; and by his answer he intends to show that the wisdom of men is worth little or nothing; he is not speaking of* ***Socrates****, he is only using my name by way of illustration, as if he said,* ***He, O men, is the wisest, who, like Socrates, knows that his wisdom is in truth worth nothing****. And so I go about the world, obedient to the god, and search and make enquiry into the wisdom of any one, whether citizen or stranger, who appears to be wise; and if he is not wise, then in vindication of the oracle I show him that he is not wise; and my occupation quite absorbs me, and I have no time to give either to any public matter of interest or to any concern of my own, but I am in utter poverty by reason of my devotion to the god.*

*There is another thing:—young men of the richer classes, who have not much to do, come about me of their own accord; they like to hear the pretenders examined, and they often imitate me, and proceed to examine others****; there are plenty of persons, as they quickly discover, who think that they know something,***

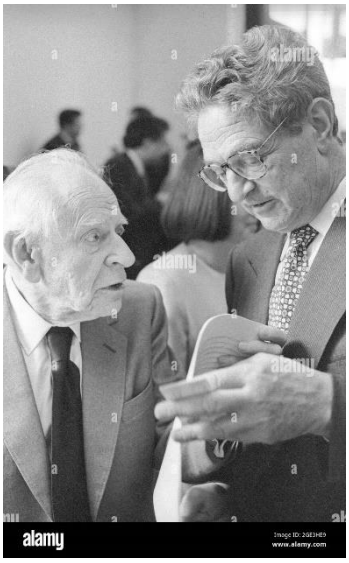
but really know little or nothing; and then those who are examined by them instead of being angry with themselves are angry with me: *This confounded Socrates, they say; this villainous misleader of youth!—and then if somebody asks them, Why, what evil does he practise or teach? they do not know, and cannot tell; but in order that they may not appear to be at a loss, they repeat the ready-made charges which are used against all philosophers about teaching things up in the clouds and under the earth, and having no gods, and making the worse appear the better cause; for they do not like to confess that their pretence of knowledge has been detected—which is the truth; and as they are numerous and ambitious and energetic, and are drawn up in battle array and have persuasive tongues, they have filled your ears with their loud and inveterate calumnies. And this is the reason why my three accusers, Meletus and Anytus and Lycon, have set upon me; Meletus, who has a quarrel with me on behalf of the poets; Anytus, on behalf of the craftsmen and politicians; Lycon, on behalf of the rhetoricians: and as I said at the beginning, I cannot expect to get rid of such a mass of calumny all in a moment. And this, O men of Athens, is the truth and the whole truth; I have concealed nothing, I have dissembled nothing. And yet**, ***I know that my plainness of speech makes them hate me, and what is their hatred but a proof that I am speaking the truth?****—Hence has arisen the prejudice against me; and this is the reason of it, as you will find out either in this or in any future enquiry*."





In 399 B.C., Socrates was found guilty of corrupting the youth, given poison hemlock to drink, and was thereby cancelled!

In *Realism and the Aim of Science*, Karl Popper (1983) describes our knowledge in terms of conscious (critical) and unconscious (uncritical) thought, when he writes, "*Most of us, especially most philosophers, hold a great number of theories consciously, and after critical examination; and we may be prepared both to defend these by argument and to give them up when good arguments are brought against them. But we all also hold theories which we take for granted more or less unconsciously and therefore uncritically; and these uncritically held theories often contain the strongest reason for continuing to hold those other theories consciously. This has been known for a long time….*"



Consider how circle of ignorance described by Socrates differs when it comes to Socrates' critical thinking that emphasizes the individual and today's Critical Theory that emphasizes intersectionality and the identity group. There is a difference between "know thyself", the command of the Delphic deity, and the postmodernist command of "know thy identity group."

Hear Bill Maher talk about cancel culture and indoctrination in elite schools.

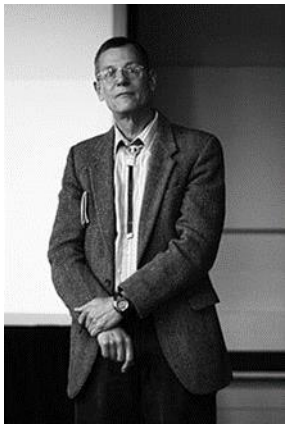


I will end this lecture with some pretty stamps of bioluminescent organisms:



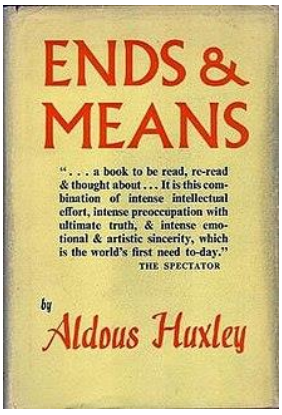
Using Light to Keep Track of Time and Determine Orientation in Space:

Photomorphogenesis in Plants



Last time I mentioned that Will Provine (1990, Cornell) wrote, "*As a young man, Charles Darwin was a creationist deeply impressed with William Paley's version of the argument from design. But after returning from the voyage of H.M.S. Beagle, reconsideration of what he had seen on the voyage convinced him that evolution had occurred. A short time later, when he deduced the theory of natural selection to explain the adaptations in which he had previously seen the handiwork of God,* ***Darwin knew that he was committing cultural murder. He understood immediately that if natural selection explained adaptations, and evolution by descent were true, then the argument from design was dead and all that went with it, namely the existence of a personal god, free will, life after death, immutable moral laws, and ultimate meaning in life***."

Provine's words represent the scientific consensus today (https://en.wikipedia.org/wiki/Scientific_consensus). But that does not mean that scientific knowledge leads to a comprehensive understanding of the fullness of life.



Remember what Aldous Huxley (1937), the grandson of T. H. Huxley, wrote in *Ends & Means*: "*No account of the scientific picture of the world and its history would be complete unless it contained a reminder of the fact, frequently forgotten by scientists themselves, that this picture does not even claim to be comprehensive. From the world we actually live in, the world that is given by our senses, our intuitions of beauty and goodness, our emotions and impulses, our moods and sentiments, the man of science abstracts a simplified private universe of things possessing only those*

qualities which used to be called 'primary.' Arbitrarily, because it happens to be convenient; because his methods do not allow him to deal with the immense complexity of reality, he selects from the whole of experience only those elements which can be weighed, measured, numbered, or which lend themselves in any other way to mathematical treatment. By using this technique of simplification and abstraction, the scientist has succeeded to an astonishing degree in understanding and dominating the physical environment. The success was intoxicating and, with an illogicality which, in the circumstances, was doubtless pardonable, many scientists and philosophers came to imagine that this useful abstraction from reality was reality itself. Reality as actually experienced contains intuitions of value and significance, contains love, beauty, mystical ecstasy, intimations of godhead. Science did not and still does not possess intellectual instruments with which to deal with these aspects of reality. Consequently it ignored them and concentrated its attention upon such aspects of the world as it could deal with by means of arithmetic, geometry and the various branches of higher mathematics. ***Our conviction that the world is meaningless is due in part to the fact (discussed in a later paragraph) that the philosophy of meaninglessness lends itself very effectively to furthering the ends of erotic or political passion; in part to a genuine intellectual error—the error of identifying the world of science, a world from which all meaning and value has been deliberately excluded, with ultimate reality****. It is worth while to quote in this context the words with which Hume closes his* Enquiry*: 'If we take in our hand any volume—of divinity, or school metaphysics, for instance—let us ask, Does it contain any abstract reasoning concerning quantity or number? No. Does it contain any experimental reasoning concerning matter of fact and existence? No. Commit it then to the flames; for it can contain nothing but sophistry and illusion.' Hume mentions only divinity and school metaphysics; but his argument would apply just as cogently to poetry,*

music, painting, sculpture and all ethical and religious teaching. Hamlet *contains no abstract reasoning concerning quantity or number and no experimental reason concerning evidence; nor does the Hammerklavier Sonata, nor Donatello's David, nor the* Tao Te Ching *nor* The Following of Christ. *Commit them therefore to the flames: for they can contain nothing but sophistry and illusion.*

We are living now, not in the delicious intoxication induced by the early successes of science, but in a rather grisly morning-after, when it has become apparent that what triumphant science has done hitherto is to improve the means for achieving unimproved or actually deteriorated ends. In this condition of apprehensive sobriety we are able to see that the contents of literature, art, music even in some measure of divinity and school metaphysics are not sophistry and illusion, but simply those elements of experience which scientists chose to leave out of account, for the good reason that they had no intellectual methods for dealing with them. In the arts, in philosophy, in religion men are trying—doubtless, without complete success—to describe and explain the non-measurable, purely qualitative aspects of reality. Since the time of Galileo, scientists have admitted, sometimes explicitly, but much more often by implication, that they are incompetent to discuss such matters. The scientific picture of the world is what it is because men of science combine this incompetence with certain special competences. They have no right to claim that this product of incompetence and specialization is a complete picture of reality. As a matter of historical fact, however, this claim has constantly been made. The successive steps in the process of identifying an arbitrary abstraction from reality with reality itself have been described, very fully and lucidly, in Burtt's excellent Metaphysical Foundations of Modern Science*; and it is therefore unnecessary for me to develop the theme any further. All that I need add is the fact that, in recent years, many men of science*

have come to realize that the scientific picture of the world is a partial one the product of their special competence in mathematics and their special incompetence to deal systematically with aesthetic and moral values, religious experiences and intuitions of significance. Unhappily, novel ideas become acceptable to the less intelligent members of society only with a very considerable time-lag. Sixty or seventy years ago the majority of scientists believed and the belief often caused them considerable distress that the product of their special incompetence was identical with reality as a whole. To-day this belief has begun to give way, in scientific circles, to a different and obviously truer conception of the relation between science and total experience. The masses, on the contrary, have just reached the point where the ancestors of to-day's scientists were standing two generations back. ***They are convinced that the scientific picture of an arbitrary abstraction from reality is a picture of reality as a whole and that therefore the world is without meaning or value****. But nobody likes living in such a world. To satisfy their hunger for meaning and value, they turn to such doctrines as Nationalism, Fascism and revolutionary Communism. Philosophically and scientifically, these doctrines are absurd; but for the masses in every community, they have this great merit: they attribute the meaning and value that have been taken away from the world as a whole to the particular part of the world in which the believers happen to be living.*

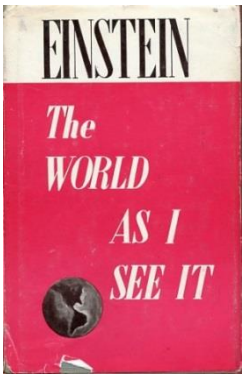
These last considerations raise an important question, which must now be considered in some detail. Does the world as a whole possess the value and meaning that we constantly attribute to certain parts of it (such as human beings and their works); and, if so, what is the nature of that value and meaning? This is a question which, a few years ago, I should not even have posed. For, like so many of my contemporaries, I took it for granted that there was no meaning.

This was partly due to the fact that I shared the common belief that the scientific picture of an abstraction from reality was a true picture of reality as a whole; partly also to other, non-intellectual reasons. I had motives for not wanting the world to have a meaning; consequently assumed that it had none, and was able without any difficulty to find satisfying reasons for this assumption.

Most ignorance is vincible ignorance. We don't know because we don't want to know. It is our will that decides how and upon what subjects we shall use our intelligence. ***Those who detect no meaning in the world generally do so because, for one reason or another, it suits their books that the world should be meaningless***."



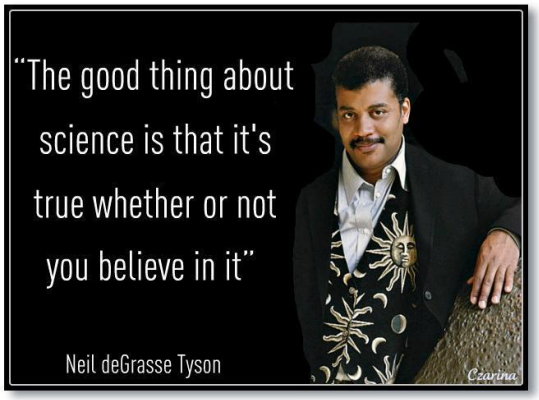
Aldous Huxley's (1937) reconsideration of the scientific picture presented here is not unlike T. H. Huxley's (1893) reconsideration described in his Romanes lecture.



Albert Einstein resisted the scientific consensus: "*What is the meaning of human life, or of organic life altogether? To answer this question at all implies a religion. Is there any sense then, you ask, in putting it? I answer, the man who regards his own life and that of his fellow-creatures as meaningless is not merely unfortunate but almost disqualified for life*." From *The World as I See It* by Albert Einstein (1949).

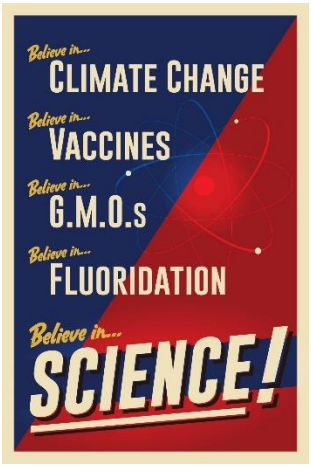
What does "***I believe in science***" mean?







https://www.youtube.com/watch?v=yRxx8pen6JY











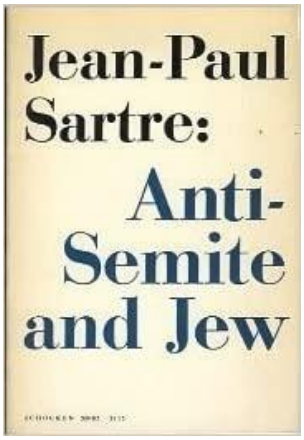


Imagine a society or even a university where people say "***I understand science***" and where leaders say with good faith, "*I understand the science and I can explain my analysis to you*."

Science should be done, and scientific statements should be made, in good faith.



Good faith (Latin: *bona fides*) is a sincere intention to be honest, open, and fair, regardless of the outcome. **Bad faith** (Latin: *mala fides*) is a sustained form of hypocrisy, deception, and even self-deception that is likely to occur when one believes that a problem is existential, and a certain outcome is so necessary because time will run out and one has no choice. This leads one to believe that there no need and no time to present a line of reasoning and craft a winning argument. In fact, someone who acts in bad faith "*has chosen to devaluate words and reasons*." **Jean-Paul Sartre** (1948) wrote in *Anti-Semite and Jew*, "*They delight in acting in **bad faith**, since they seek not to persuade by sound argument but to intimidate and disconcert. If you press them too closely, they will abruptly fall silent, loftily indicating by some phrase that the time for argument is past*." Sartre goes on to say, "*We have here a basic fear of oneself and of truth. What frightens them is not the content of truth, of which they have no conception, but the form itself of truth, that thing of indefinite approximation*."



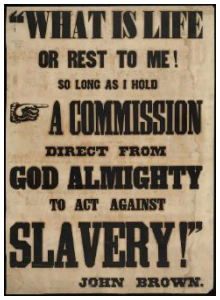
Bad faith becomes more common when one fears the uncertainties of the human condition, including the uncertainty of truth, which Sartre describes as *"that thing of indefinite approximation*". While science once aimed at minimizing fear through scientific explanation in the search for truth, it now seems to try to instill fear and foster an intolerance to those who do not perceive the same fear.

According to Uriel Abulof (Cornell), "*[t]he politics of bad faith prospers because it is effective: if there is 'no choice,' there is no need for justification, let*

alone the need for taking responsibility." As politics and science make more and more intimate bedfellows, the science of bad faith becomes more like the politics of bad faith, and scientists see no need to rigorously justify and take responsibility for their conclusions, but rather make an appeal to authority.

As human beings, we have the freedom to think critically or to be intellectually lazy. We also have the freedom to act in good faith or in bad faith. Authenticity describes the connection between conscious thinking and active doing. Jean-Paul Sartre (1948) writes, "*If it is agreed that man may be defined as a being having freedom within the limits of a situation, then it is easy to see that the exercise of this freedom may be considered as authentic or inauthentic according to the choices made in the situation.* ***Authenticity, it is almost needless to say, consists in having a true and lucid consciousness of the situation, in assuming the responsibilities and risks that it involves, in accepting it in pride or humiliation, sometimes in horror and hate. There is no doubt that authenticity demands much courage and more than courage***."

We have been speaking about human life and in order to know ourselves better, let's define life in general. There are similarities and differences between how human beings and plants sense and respond to situations. The most authentic, true, lucid, and courageous human beings show more differences than similarities when compared with plants. As a comparison, let's discuss the consciousness of plants and how they respond appropriately to the information they take in.



Life can be **operationally defined** by a biologist as 1) the ability to **assimilate sustenance** in the form of matter and energy from the environment; 2) the ability to **transform** this environmental input at **ambient temperature and pressure** into **usable energy** (chemical, electrical and

radiant) as well as the **common and unique molecules** (including pigments, luciferins and luciferases) that make up the body; 3) the ability to **expel any waste material** that would be toxic; 4) the **ability to move** using its own energy source; 5) the ability to **reproduce the information** in the form of DNA that directs all the above processes with **near perfect fidelity** such that the near-perfect reproduction gives rise to variation; and 6) the **ability to sense** and **respond** appropriately to the environment. This operational definition of life does not subsume the additional requirements that contribute to our own definition of **a good and well-lived life**.

Life is a Journey by Rabbi Alvin Fine (https://vimeo.com/42921067)

Birth is a beginning and death is a destination. And life is a journey.
From childhood to maturity and youth to age;
From innocence to awareness and ignorance to knowing;
From foolishness to discretion and then, perhaps, to wisdom;
From weakness to strength or strength to weakness. And often, back again;
From loneliness to love, from joy to gratitude, from pain to compassion,
From grief to understanding, from fear to faith,
From defeat to defeat to defeat. Until looking backward or ahead,
We see that victory lies not at some high place along the way,
But in having made the journey, stage by stage a sacred pilgrimage.
Birth is a beginning and death is a destination.
And life is a journey, a sacred pilgrimage—to life everlasting.



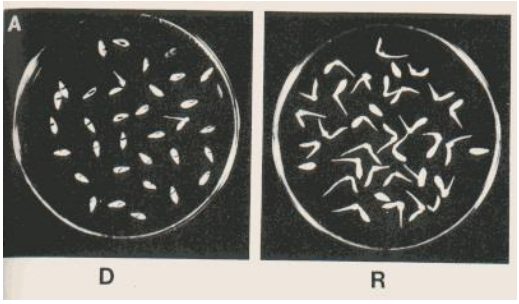
Consciousness, as defined as **an awareness of the external environment** is the first step in responding appropriately to the environment. It is a characteristic of life and may have begun with the first cell. Remember that Jerome Wolken described *Euglena* as a **photo-neurosensory cell**. Consciousness

differs from **conscience**, which means a **knowledge within oneself**, an inner sense of **right and wrong**, a **moral** sense, **intention**. Here we are touching on the origin of conciousness and the science that describes and explains it. Do animals, including, monkeys and apes have a conscience? A **Law of Nature** that describes the origin of conscience is still forthcoming and may be a place where science and theology meet.



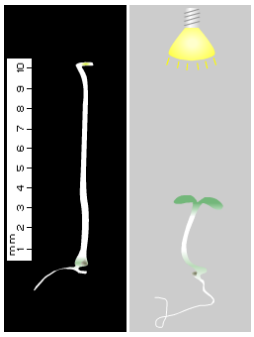
Plants do not have a conscience but are conscious in that they sense the external environment and respond appropriately to the sensations. If we were to ramble through a meadow, hike through the woods, walk along the seashore, climb a mountain, or walk quietly and observantly through a garden at the **Cornell Botanic Gardens**, it would become increasingly clear that it is a normal and ubiquitous property of plants to **sense** and **respond** to their environment.

Plants depend on sunlight to power photosynthesis, where **radiant energy acts as a substrate** that is transformed into chemical energy. However, plants also depend on the **information content of sunlight** to **catalytically** affect their structure and function.

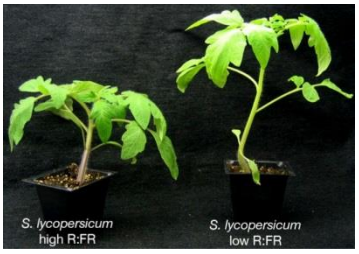


For example, some seeds, particularly those of weeds, do not **germinate** in the dark (D) but require a short burst of red light (R), given alone or as part of white light, to **germinate**.

Once the seeds germinate, many seedlings require light to retard stem growth and to promote leaf expansion and greening. Development in the dark, where the seedling appears pale and drawn out (**etiolated**) is known as **skotomorphogenesis**. Development in the light is known as **photomorphogenesis**.



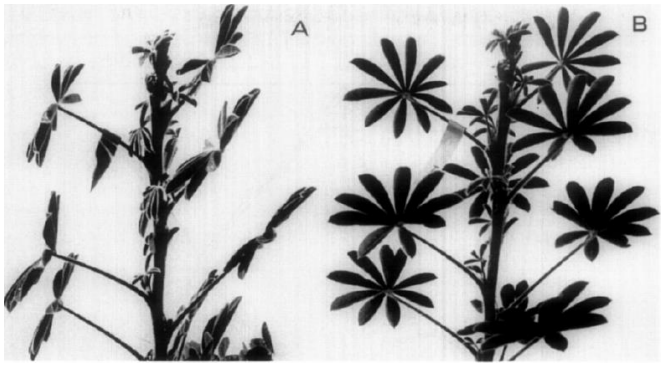
Plants also develop differently depending on whether they grow in the **shade** (where the red part of sunlight has been absorbed by the chlorophyll in the leaves above) or in **full sun** (which has plenty of red light). The **shade-avoidance response** involves stem elongation. Thinking of the etiolation response or the shade-avoidance response, we see the general biological principle of **compensatory growth**, **compensation**, or **variation on the archetype**. There is no single best way for a plant to grow because there is no single environment. In the real world, having a variety of good ways to respond to a variable environment leads to the successful life of a plant.



Some plants sense the **direction of light** and the whole plant bends or turns towards the light in a process known as **phototropism**.



The leaves of some plants can track the movement of the sun throughout the day. The process of **solar tracking** is known as **heliotropism**.



Some plants are also able sense the **duration of sunlight**, which is a measure of day length. The response to the duration of day length or **photoperiod** is known as **photoperiodism**. Plants respond differently to **day length**. For example, **skunk cabbage** flowers in the spring when the days are short, and **chicory** flowers in the summer when the days are long.





Many flowers, including the daylily and *Crocus*, can tell when the daylight begins and ends. They open in the morning and close at night. Perhaps they open for insect pollinators and close to protect the flowers from insect pests. Some leaves also change their position during the day and at night. They spread out in the day to catch the sunlight and close at night. Such daily responses may be part of a daily rhythm, known as a **circadian rhythm**, which will persist in continuous darkness, but which is reset each morning when the sun rises. **Circadian** means, about a day.



Noon



Midnight





Demonstration: Sensitive plant (*Mimosa*) and Venus' flytrap (*Dionea*). See the ant?



Roger Hangarter has captured many video clips that show "**plants in motion**" where many of the motions are responses to light (http://plantsinmotion.bio.indiana.edu/).

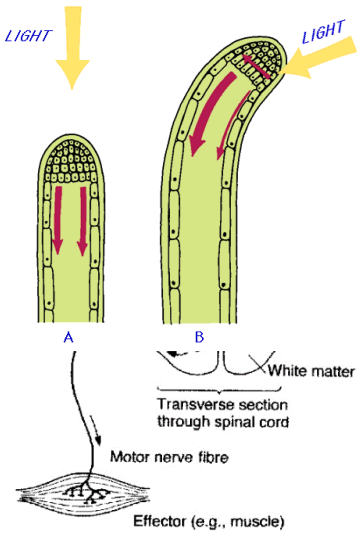




Plants are born to run!

https://canvas.cornell.edu/courses/12596/files/975457?module_item_id=295840

In order for plants to sense and respond to the **information** held by the environmental light, they must have **photoreceptor pigments**. When activated, these pigments must activate **signal transduction chains** (like the one we discussed that participated in vision) that lead to the **physical and/or chemical changes** that result in the appropriate **response.** Stimulus response coupling in plants has a surprising

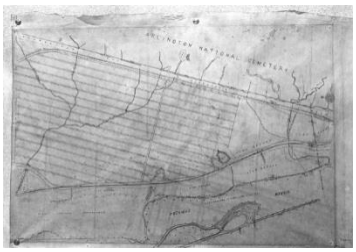


number of similarities with stimulus response coupling in humans.

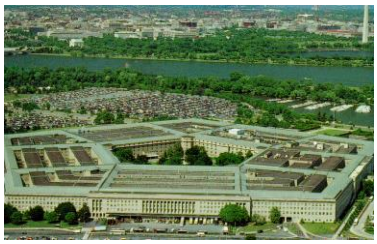
Raoul Francé (1905) wrote, *"What grander lesson could the speechless plants give than that which they have taught us: that their sense life is a primitive form, the beginning of the human mind... it tells us that after* ***all the living world is but mankind in the making****, and that we are but a part of all."*



I am now going to discuss the **discovery of photoperiodism**—something that occurred at the present location of the **Pentagon**. A **United States Department of Agriculture** research farm known as the **Arlington Experimental Farm** once stood where the South Parking Lot of the Pentagon now stands.

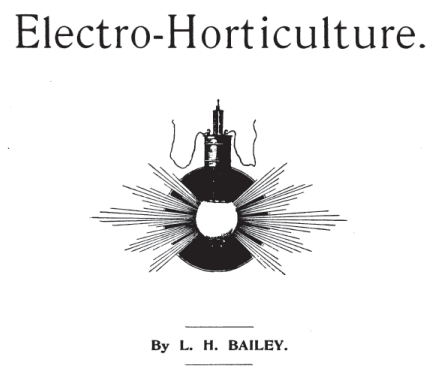




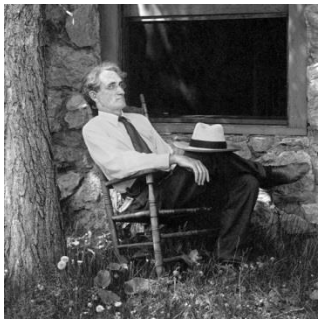


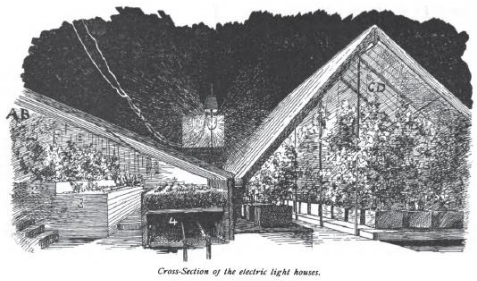
In order to make room for the military's growing needs during World War II, President Franklin D. Roosevelt signed an order to move the Experimental Farm to Beltsville, Maryland. Groundbreaking for the Pentagon occurred at the Arlington Experimental Farm site on September 11, 1941, and **Colonel Leslie Groves**, who would later oversee the Manhattan Project, oversaw the project. The **Pentagon** building was designed to have a pentagonal shape because the original Arlington Experimental Farm had a pentagonal shape.

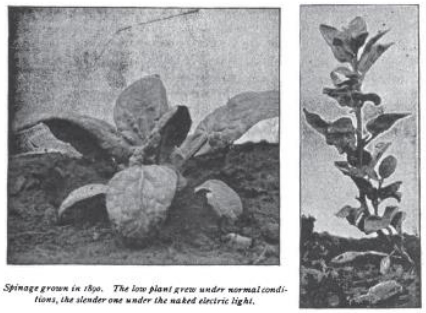
Photoperiodism is ***not*** primarily a response to the intensity of light or the total quantity of light but to the **duration** and **timing** of the light and dark conditions. **Liberty Hyde Bailey**'s (Cornell; 1892) use of artificial light in greenhouses led to an awareness that the **duration** of illumination has various effects on plant growth.


Electro-Horticulture.

By L. H. BAILEY.




Cross-Section of the electric light houses.


Spinage grown in 1890. The low plant grew under normal conditions, the slender one under the naked electric light.

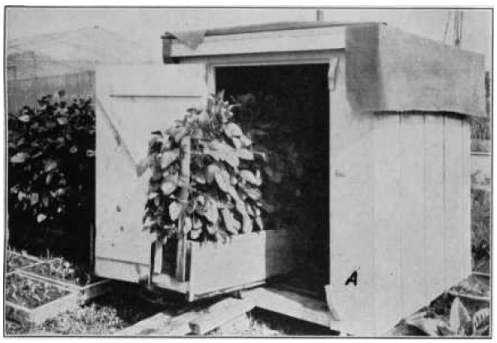


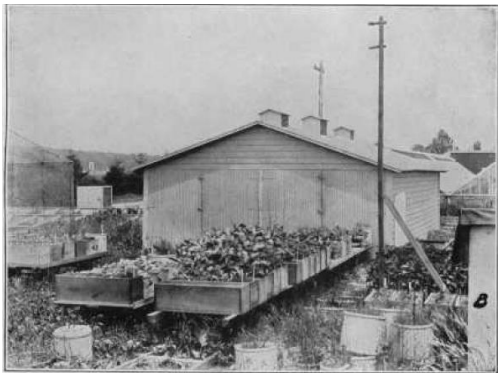
Very tall and leafy mutants of **tobacco** plants occasionally appeared in an experimental plot at the Arlington Experimental Farm. Getting seed to propagate one of these gigantic mutants, which was known as **Maryland Mammoth**, was difficult.

According to Harry Allard (1919), "*The great increase in number of leaves, together with a greatly elongated main stem, is accompanied by a period of vegetative vigor of such long duration that blossoming does not normally take place when the plants are growing in the field. In order to obtain seed from such plants, the usual practice has been to transplant the roots and stub, or even the plants entire, to the greenhouse in the fall, where vegetative vigor is resumed with the final production of normal blossoms and seed during the winter*."



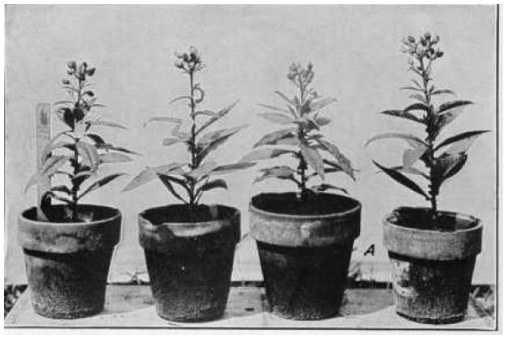
Wightman Garner and Harry Allard found that it did not matter what size pot they grew the Maryland Mammoth tobacco plants in or how well they were fertilized, the experimental plants, no matter what the treatment, would never flower in the summer even though they reached a height of 10-15 feet; and would all flower at the same time in the winter even though the plants were not yet 5 feet tall. Garner and Allard (1920) wrote, "*Obviously, then, **the time of year** in which the Mammoth tobacco develops determines whether the growth is of the giant character*."

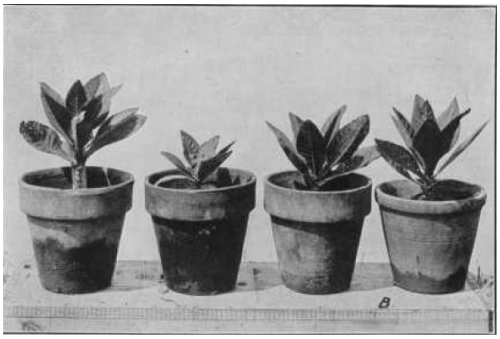




While the **difference in temperature** was an obvious potential cause of the difference between the behavior of plants in the summer and in the winter, the **length of daylight** could also be the cause of the difference in plant behavior in the summer and the winter. Garner and Allard (1920) could study the influence of day length in four different ways. They could compare the behavior of plants growing at different latitudes or at different seasons of the year; or they could supplement the daylight with artificial light or prevent the daylight from reaching the plant. They chose the latter experimental treatment. In the summer of 1918, they built a **dark chamber** to limit the length of daylight experienced by the Maryland Mammoth tobacco plants and in 1919 they expanded the experimental treatment by building a **dark house** to limit the length of daylight experienced by the plants. The plants could be moved in and out of the dark house every day with trucks on steel tracks.

The plants grown in 8-inch pots that were exposed to **seven hours of sunlight** from 9AM to 4PM and then wheeled into the dark house flowered by August 15, 1919. The control plants grown in 8-inch pots that were kept outdoors, exposed to the **long days** of summer, had not flowered by August 15, 1919.





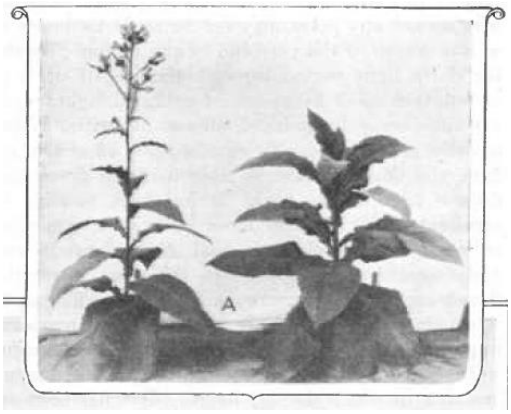
Likewise, Maryland Mammoth plants grown in 12-quart buckets that were exposed to **7 hours of sunlight** flowered and produced seeds by August 19, 1919, while the ones exposed to **12 hours of sunlight** or left outdoors did not.



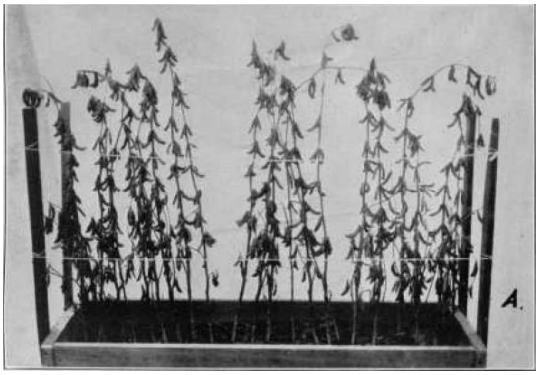




Garner and Allard had solved the problem of the Maryland Mammoth. Once they understood the role of **photoperiod**, they could get the plants to flower and set seed by growing them during the **long days of summer by using the dark house** or during the **short days of winter in a greenhouse**.

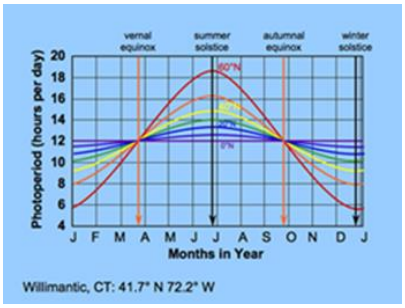


Garner and Allard experimented with many plants, including **Peking soybeans**. Peking soybeans exposed to **7½ hours of daylight** before being put in a dark house already had matured pods ready for harvest on September 13, 1919, while the control plants that had been left outside exposed to the **long days of summer** had seed pods that were still green and leaves that were just beginning to yellow.





Garner and Allard began to realize that each variety of soybean had its own "***critical length of day*** *required for furnishing the stimulus which brings into expression the processes of sexual reproduction*." Others would define **short-day plants** as plants that ***will not*** flower if the photoperiod is extended beyond the **critical photoperiod,** and they would define **long-day plants** as plants that ***will*** flower if the photoperiod is extended beyond the **critical photoperiod**.



These are convenient definitions for horticulturalists and plant physiologists. However, the distinction between short-day plants and long-day plants is based on whether or not flowering is promoted or inhibited by increasing the light period about a critical value and not based on the absolute day length as it would be defined by a naturalist, where short days occur in spring and fall and long days occur in summer. For example, *Xanthium* **(cocklebur)** is a **short-day plant with a critical photoperiod of 15½ hours** and will ***not*** flower if the light period is extended beyond the critical photoperiod. *Hyoscyamus* **(Henbane)** is a **long-day plant with a critical photoperiod of 11 hours** but ***will*** **flower when the photoperiod is extended beyond the critical photoperiod**.

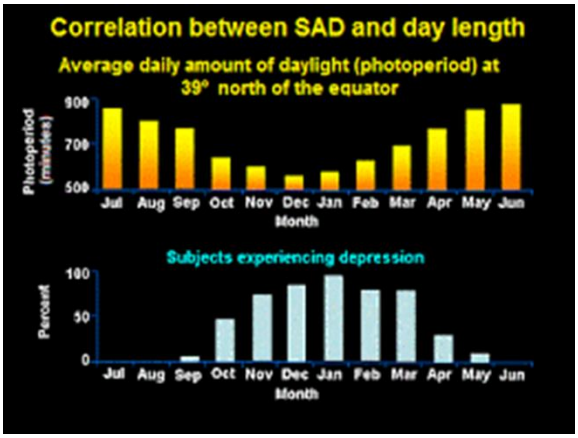




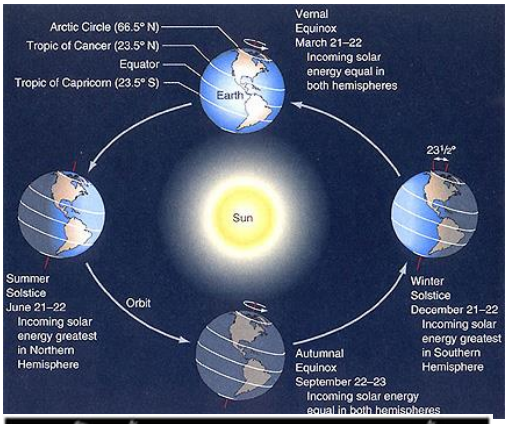
Garner and Allard (1920) ended their paper by coining the terms **photoperiod** "*to designate the favorable length of day for each organism*" and **photoperiodism** "*to designate the response of organisms to the relative length of day and night*." Furthermore, they wrote about the possibility of photoperiodism in animals, "*As to* ***animal life****, nothing definite can be said, but it may be found eventually that the animal organism is capable of responding to the stimulus of certain day lengths. It has occurred to the writers that possibly the* ***migration of*** *birds furnishes an interesting illustration of this response. Direct response to a stimulus of this character would seem to be more nearly in line with modern teachings of biology than are theories which make it necessary to assume the operation of instinct or volition in some form as explaining the phenomena in question*."

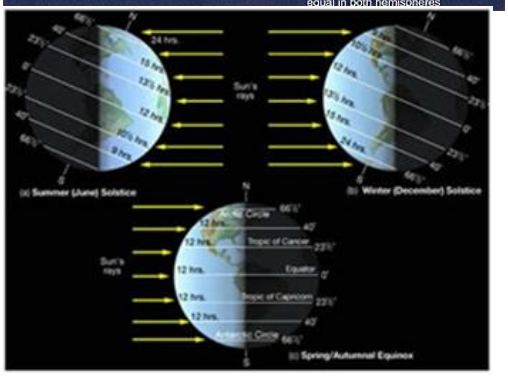
Humans are sensitive to photoperiod in terms of seasonal affective disorder (SAD).

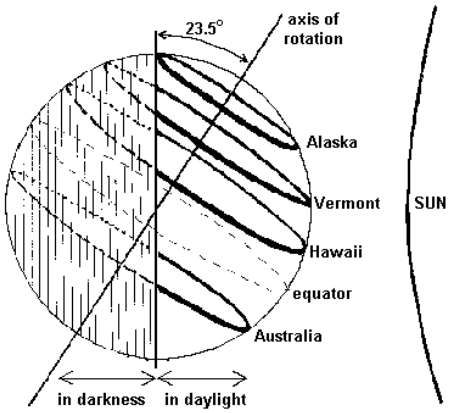


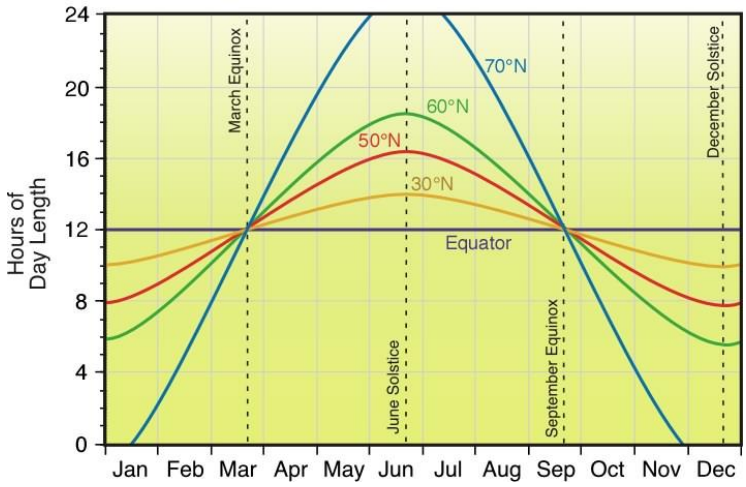


The **day lengths** of the growing regions of earth depend on **astronomical factors**. The **day length** or **photoperiod** in the temporal regions of earth changes seasonally as a result of the **23½ degrees tilt of the earth's axis**. During **summer** in the northern hemisphere, the earth is tilted toward the sun so that the days are longer than the nights. During **winter** in the northern hemisphere, the earth is tilted away from the sun, so the days are shorter than the nights. To get a real picture of the seasonal changes imagine what would happen if the axis were tilted 90 degrees.

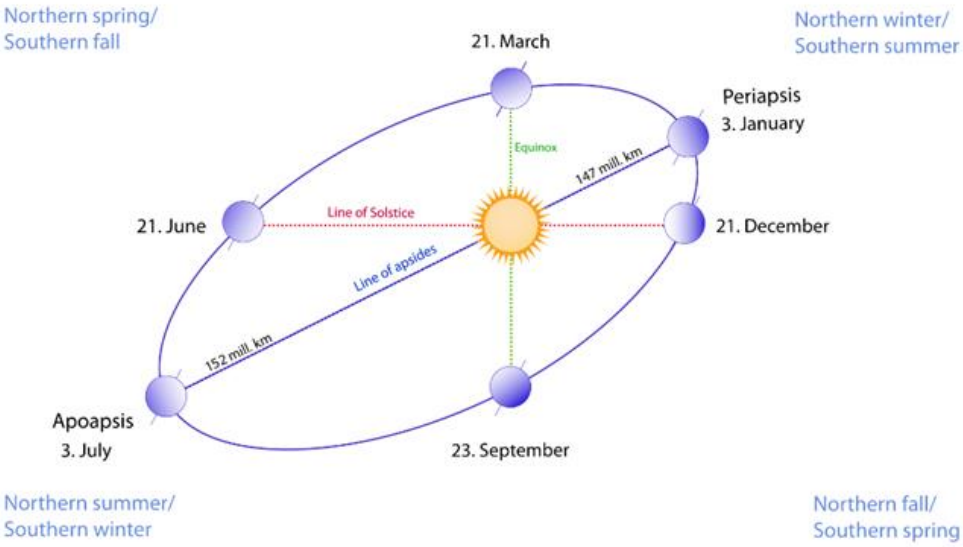






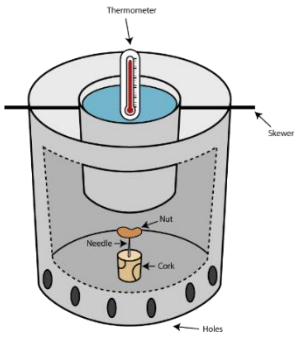


The latitude of Ithaca is 42.4440° N. The **summer solstice** (≈ June 21) marks the longest day of the year, and the **winter solstice** (≈ December 21) marks the shortest. On the **autumnal equinox** (≈ September 21) and **vernal equinox** (≈ March 21), the day lengths and night lengths are equal.

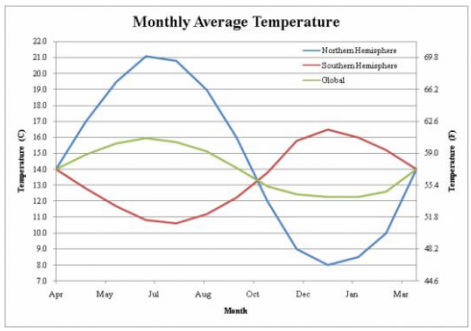


Even though the photoperiods in the northern and southern hemispheres are complementary during the year, the two hemispheres are not complementary in terms of solar radiation and temperature—two factors that also affect plant growth and development. Because the **earth's orbit** is **elliptical** and not a perfect circle, the northern hemisphere gets less solar radiation than the southern hemisphere.

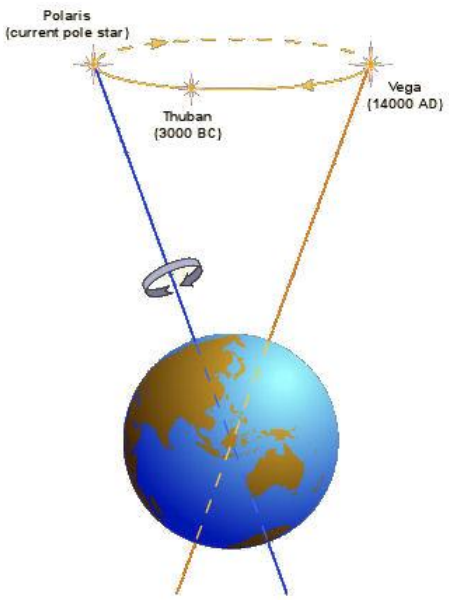
This is because the northern hemisphere tilts towards the sun when it is **farthest** from the sun during the long days of its summer and the southern hemisphere tilts towards the sun when it is **closest** to the sun during our winter and during its long days of its summer.

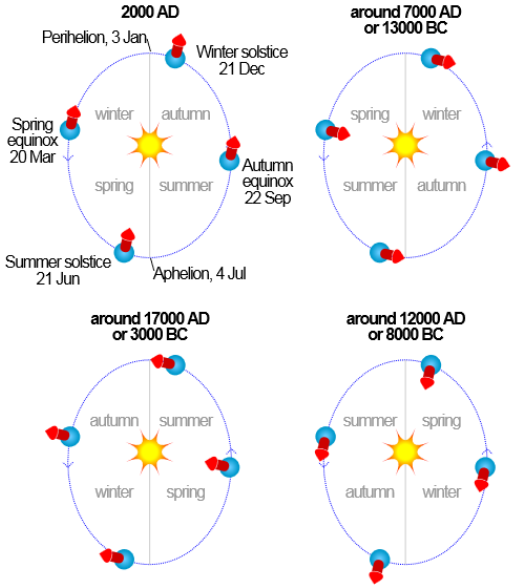


Because of the differences in the relative proportions of land, the northern hemisphere heats up and cools more quickly than the southern hemisphere. This is because the proportion of water to land is greater in the southern hemisphere than in the northern hemisphere and water has a greater **heat capacity** than land. Remember from our **calorimetry experiment with the peanut**, the change in temperature (ΔT) in response to an input of thermal energy (TE) depends in the heat capacity (c) and mass (m) of the water according to the following equation: $TE = c\ m\ \Delta T$. The northern hemisphere has an **ocean to land ratio** of 60.7% to 39.3% while the southern hemisphere has a ratio of 80.9% to 19.1%. Consequently, annual temperature variation is moderated in the southern hemisphere compared with the northern hemisphere. Because of the heat capacity of water, summer in the northern hemisphere is hotter than summer in the southern hemisphere even though the earth is closer to the sun during summer in the southern hemisphere than it is during summer in the northern hemisphere; and winter in the northern hemisphere is colder than winter in the southern hemisphere even though the earth is closer to the sun during winter in the northern hemisphere than it is during winter in the southern hemisphere. The heat capacity of water also explains why the average temperature of the earth is lowest when the earth is closest to the sun and warmest when the earth is farthest from the sun.



Water is important for plant growth in many ways!!!!!

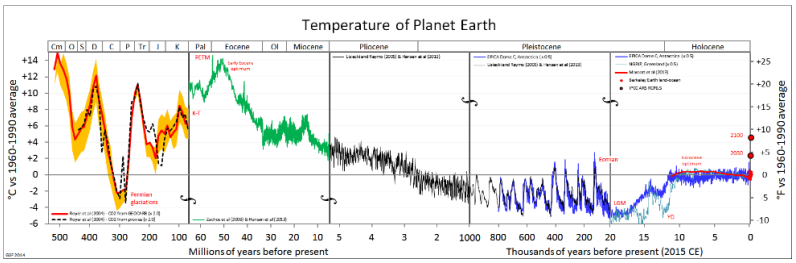




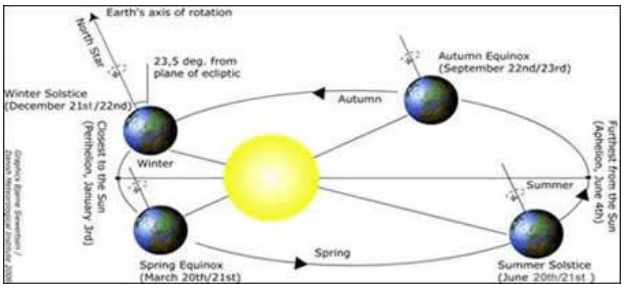
Because the earth is not a perfect sphere (the radius at the equator and the poles is 6378 km and 6357 km, respectively), the gravitational forces from the sun and the moon create a torque on the axis of the earth that causes the tilt to change. The change in tilt has a **period of 25,765 years** and results in a precession of the position of the sun on the first day of spring (vernal equinox). In other words, while winter currently occurs in the northern hemisphere when the earth is closest to the sun (**perihelion**), around 12000 AD, as a result of the **precession of the equinoxes**, winter will occur when the earth is farthest from the sun (**aphelion**).

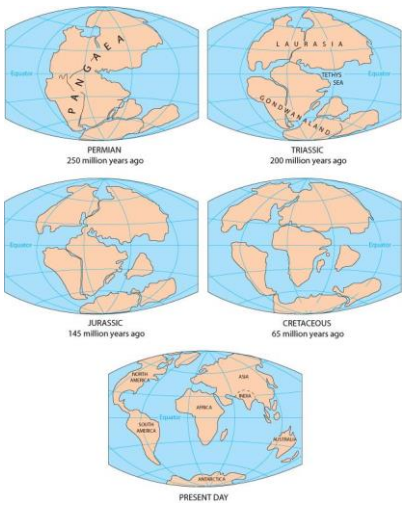
The **photoperiod** of a region, along with its temperature, water availability, and light intensity, are important factors in determining the **natural geographical distribution** or **biogeography** of plants in terms of their northward and southward distribution. Harry Allard (1948) realized that day length is a part of **climate change** that occurs over **geological time** when he wrote, "*Length of day must, therefore, always be a function of every climate. Geologists inform us that there have been great changes in world climate throughout all the great geological eras. Some climates have been characteristically warm and weakly zonal and others have been cool and strongly zonal.* ***That there have been profound local, regional and even world-wide changes in climate involving length of day as well as***

temperature cannot be denied. *The* ***astronomical relations*** *responsible for earth climate are very complex and involve many factors including the earth's obliquity, the rate of rotation, the distance and eccentricity of the path of revolution around the sun, the length of time required to complete the revolution, as well as various conditions pertaining to the intensity of the solar energy and many physical conditions obtaining upon the earth itself. The astronomer, on purely mathematical grounds, may theorize about changes in the obliquity of the axis. However, were this obliquity actually to approach zero, with the same daily rotation that we have at present, causing a uniform length of day of 12 hours to prevail over all the earth, accompanied by weak zonations of temperature, there is every reason to believe that profound changes would take place in the floristic life-form and vegetation of the earth."*

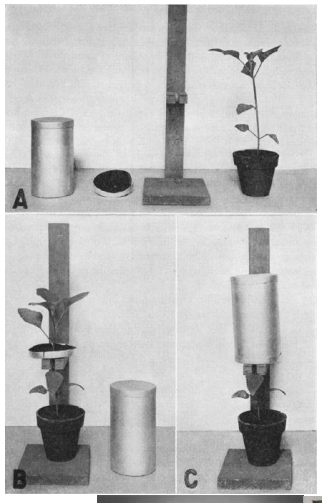


The **photoperiodic responses** of plants on earth are adapted to the **astronomical relations** between the earth and the sun. However, the profound changes that have occurred in the vegetation on earth over geological time are ***not*** due to a change in the obliquity of the axis, but due to other factors that have a major effect on climate such as meteorite impact and the movement of land masses proposed by **Alfred Wegener** (1915) and known as **plate tectonics**. Plate tectonics explains the shape of the continents and the similarities of fossils on different continents.





Working together for one summer, Karl Hamner and **James Bonner** (1938) found that the **leaves**, as opposed to the stems, are the organs of the *Xanthium* plant that sense the length of the day. When they removed all the leaves from a plant, the cocklebur would not flower under short days. It would flower under short days when they left one leaf. In fact, they could grow the plant under long days, slide a light-tight cylinder over one leaf so that only one leaf was exposed to short days. Even though only one leaf was exposed to short days, the whole plant flowered.



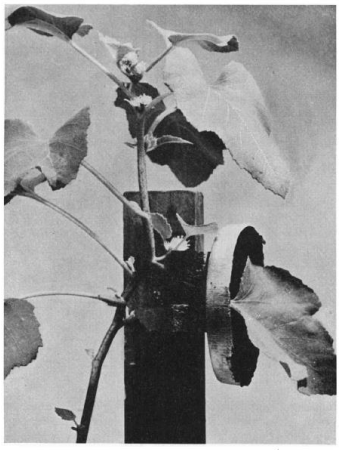


FIG. 5.—Development of flowers on a plant one leaf of which (shown at right o over) has been exposed to 20 short photoperiods; remainder subjected to long photo eriods only.

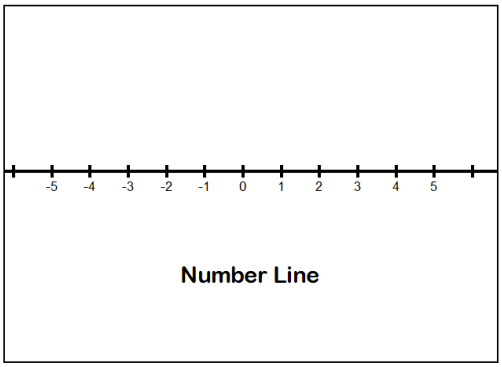




Karl Hamner and James Bonner (1938) exposed plants to various day lengths with a constant night length or to various night lengths with a constant day length and found that the length of the day was not very important for flowering in *Xanthium* but that it was essential that the **dark period exceeded 8½ hours**. They wrote that "*It seems probable that the manufacture of the substance or substances responsible for the initiation of the flowering condition in Xanthium is* ***not*** *primarily* ***a response to duration of the photoperiod, but rather a response to duration of the dark period***."

Indeed, realizing that the **photoperiod** and **dark period** are **complements** of each other, Vernon H. Blackman (1936) had already pointed out that, "*Duration of illumination rather than quantity of light is the important thing, and this is exceedingly difficult to interpret in terms of physiology. In the case of short-day plants there is some reason for believing that it is the* ***corollary of the period of***

illumination, namely the period of darkness*, to which attention should be directed.*"

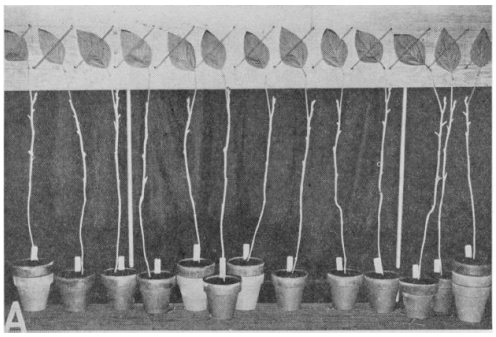


Remember the sum of real numbers equals zero and that helps you to remember that you may only be thinking of a solution to a problem in terms of the "positive" causes and not the "negative" causes.

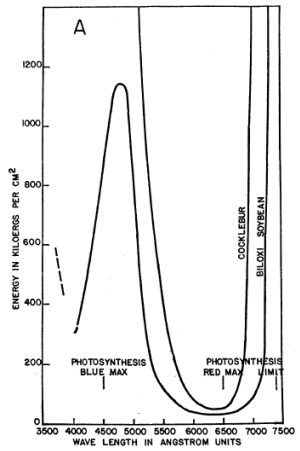
Then Karl Hammer and James Bonner serendipitously discovered that a ***single*** dark light period was enough to stimulate flowering when Edith Neidle, a graduate student of Karl Hamner's, went to the greenhouse and found that all the *Xanthium* plants were flowering. The greenhouse manager reluctantly told her that the power had been off for one night and consequently, all the plants had received a single long night. Building on this **lucky find**, Karl Hamner and James Bonner (1938) compared plants that had a 9-hour dark period with plants that experienced a one-minute flash of light 4.5 hours into the dark period. The plants that had a 9-hour dark period flowered (mac fl & fr = macroscopic flowers and fruits) as usual while the plants whose dark period was interrupted by a one-minute flash of light remained vegetative.

EFFECT OF INTERRUPTION OF DARK PERIOD BY VARYING EXPOSURES TO LIGHT ON FLOWERING OF XANTHIUM. EXPERIMENTS X-43, X-60, X-71; UNTREATED CONTROLS ALL VEGETATIVE

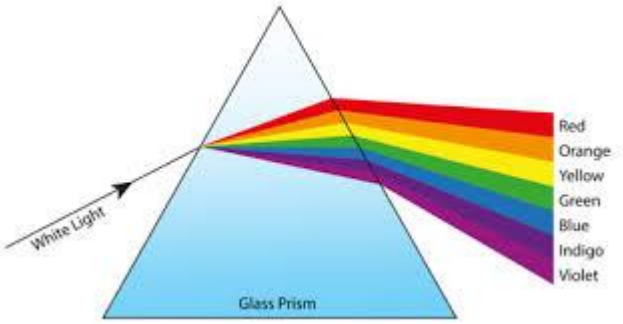
LENGTH OF PHOTOPERIOD (HOURS)	LENGTH OF DARK PERIOD (HOURS)	LIGHT EXPOSURE DURING DARK PERIOD	NO. OF PLANTS	CONDITION OF PLANTS AT END OF TREATMENT
15	9	None	12	mac fl & fr
15	4.5+4.5	1 minute after 4.5 hours	10	veg



What is the **photoreceptor** that **absorbs** the one-minute pulse of light that inhibits flowering? At the new USDA center in Beltsville that replaced the Arlington Experimental Farm where Garner and Allard discovered photoperiodism, **Harry Borthwick**, **Sterling Hendricks**, and Marion Parker built a **large spectrograph** to irradiate leaves of *Xanthium* or Biloxi soybean with a brief pulse of light with different wavelengths during the dark period and compare the ability of the pulse of light of a given wavelength to **inhibit** flowering. They used the large spectrograph to obtain an **action spectrum**. An action spectrum is a plot of the effectiveness or the amount of radiant energy of a given wavelength of light needed to cause a given response.



To construct the **large spectrograph**, Parker et al. (1946) used the prisms that **Samuel Pierpont Langley** used to measure the solar insolation and determine the solar constant, a carbon arc lamp that was cadged from a Baltimore movie theatre, and a large resistor that had been discarded from the Georgetown streetcar system. Admirably, this government-run spectrograph construction project had an outside cost of $50.



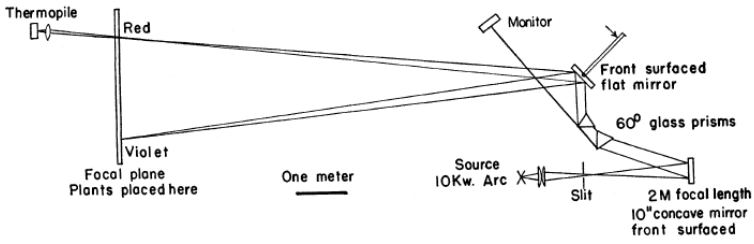


FIG. 1.—Diagram of optical path in spectrograph used for irradiation of plant leaves

The **Grotthuss-Draper Law** also known as the **First Law of Photochemistry** states that the radiant energy that causes a response must be absorbed by the pigment that mediates the response. Consequently, a **comparison** of the **action spectrum** for the inhibition of flowering with the **absorption spectrum** of known pigments would indicate which

pigment was involved in photoperiodism. Parker et al. (1946) found that blue light was not effective and that red light from 600-680 nm was most effective. This ***did not*** coincide with the absorption spectrum of any ***known*** pigment, including chlorophyll.

Borthwick et al. (1952) also found that when the pulse of red-light irradiation is followed by a pulse of far-red (722-745 nm) irradiation, the inhibiting pulse of red light is nullified and flowering occurs.

EFFECT OF VARIOUS WAVE-LENGTHS OF RADIATION ON PROMOTION OF FLOWERING OF *Xanthium saccharatum* PLANTS THAT HAD PREVIOUSLY RECEIVED RADIATION INHIBITORY TO FLOWERING

WAVE-LENGTH, Å	INCIDENT POWER (ERGS × 10^3/CM.^{2}/MIN.)	NUMBER OF FLOWERING PLANTS PER LOT OF 4 AFTER IRRADIATION FOR INDICATED TIME			
		16 MIN.	8 MIN.	4 MIN.	2 MIN.
6820–7020	87	0	0	0	0
7020–7215	93	1	3	0	0
7215–7450	99	3	3	3	1
7450–7700	102	1	1	1	0
7700–8010	105	0	0	0	0
8010–8300	111	0	0	0	0

Robert J. Downs (1956), also at Beltsville, showed that the pigment that inhibited flowering in *Xanthium* **could be turned on and off like a switch**. Flowering would be determined by the last irradiation. If the last irradiation was red light, flowering would be inhibited and if the last irradiation was far red light, flowering would occur.

TABLE III

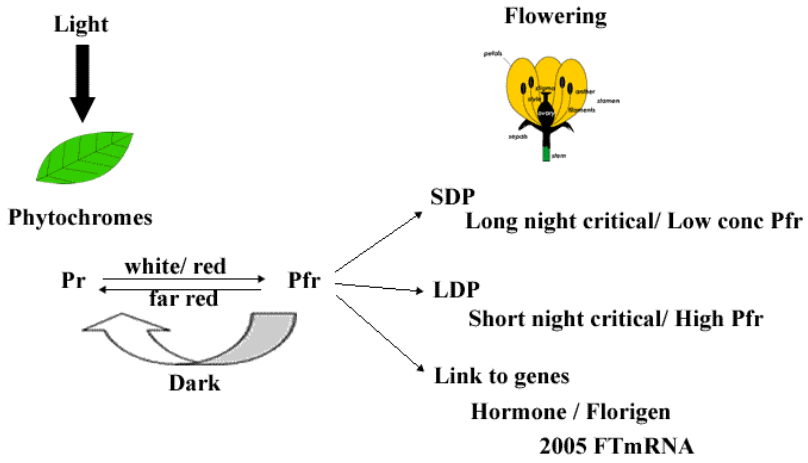
EFFECT OF DAILY INTERRUPTIONS OF THE DARK PERIOD WITH SEVERAL CONSECUTIVE IRRADIATIONS WITH RED AND FAR-RED IN SEQUENCE ON FLOWER INITIATION OF COCKLEBUR AND SOYBEAN

TREATMENT	MEAN STAGE OF FLORAL DEVELOPMENT IN COCKLEBUR *	MEAN NO. OF FLOWERING NODES IN BILOXI SOYBEAN **
Dark control	6.0	4.0
R	0.0	0.0
R, FR	5.6	1.6
R, FR, R	0.0	0.0
R, FR, R, FR	4.2	1.0
R, FR, R, FR, R	0.0	...
R, FR, R, FR, R, FR	2.4	0.6
R, FR, R, FR, R, FR, R	0.0	0.0
R, FR, R, FR, R, FR, R, FR	0.6	0.0

* Two min far-red from the sun. Values are for lots of 5 plants.

** Eight min of far-red from three 300-watt internal reflector flood lamps. Values are for lots of 4 plants.

According to Borthwick et al. (1952), reproduction in many plants is controlled by the length of the dark cycle and "*A dark reaction affords the measure of time and this reaction can be quickly stopped or reversed by light such as that from the rising sun.*" After reading about the **business cycle** in Arnold Tustin's (1953), *The Mechanism of Economic Systems*, Sterling Hendricks realized the importance of **connected linear systems that oscillate** and proposed that the pigment itself may be **photoreversible**. He also suggested that the **dark transformation** or **reversion** of the far red-absorbing form of the pigment to the red-absorbing form of the pigment may be the **basis of the timing mechanism** that enabled photoperiodic plants to measure the length of the dark period. During the light period, the red light-absorbing form of the pigment is converted to the far red light-absorbing form and at the onset of the dark period; the pigment begins to revert to the red light-absorbing form. A flash of red light during the dark period converts the pigment to the far-red light-absorbing form and the dark period has to start again. If the dark period does not last longer than the critical dark period, no flowering occurs. On the other hand, if the red-light flash is followed by a far red light flash, the pigment reverts to the red light-absorbing form and flowering results. Whereas short-day plants (long-night plants) require a **low concentration of the far-red light-absorbing form** of the pigment to trigger the plant to flower in response to the dark period, long-day plants (short-night plants) require **a high concentration of the far red light-absorbing form** of the pigment to trigger the plant to flower in response to the dark period.



Looking back, Harry Allard (1948) realized that "*So long as there is light, terrestrial rotation, the sun, cycles of length of day will continue to operate upon plant and animal life upon the earth*." On the other hand, the United Nations downplays the influence of astronomical factors that operate on animal and plant life, and it contends that the "[h]*uman influence on the climate system is clear*."



The plant leaves sense the day length with a photoreversible photoreceptor pigment. This pigment is involved in **photoperiodism** and many other red light-stimulated **photomorphogenetic responses**. Since the pigment absorbs reddish light, it probably reflects and transmits blue light and therefore looks blue. So the members of the Beltsville group, including Warren Butler, Karl Norris, Bill Siegelman, and Sterling Hendricks built a **special spectrophotometer** to assay the **photoreversible pigment**, and then extracted a red light-absorbing **photoreversible** blue pigment that could be transformed to a far red-absorbing greenish pigment.

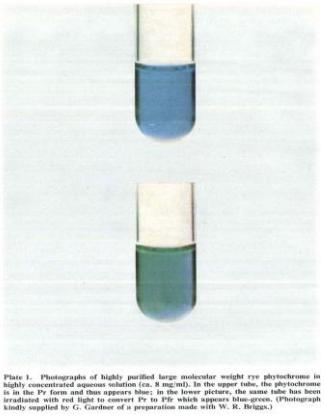
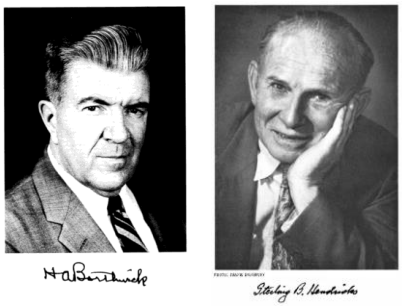


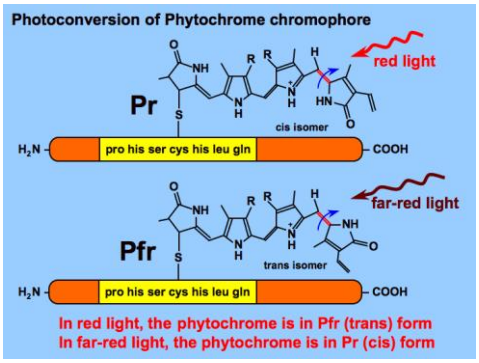
Plate 1. Photographs of highly purified large molecular weight rye phytochrome in highly concentrated aqueous solution (ca. 8 mg/ml). In the upper tube, the phytochrome is in the Pr form and thus appears blue; in the lower picture, the same tube has been irradiated with red light to convert Pr to Pfr which appears blue-green. (Photograph kindly supplied by G. Gardner of a preparation made with W. R. Briggs.)

Excited to show the photoreversible pigment at the Ninth International Botanical Congress in Montreal in the summer of 1959, Sterling Hendricks, Warren Butler, and Bill Siegelman drove from Beltsville, Maryland to Montreal. Every time they stopped for gas; they would check the pigment sample in the trunk. They did not realize that exposing the extracted pigment to light when they opened the trunk resulted in the conversion of the stable red light-absorbing form to the less stable far-red light-absorbing form. By the time they got to the meeting, the pigment sample had degraded, and the demonstration was a dud. The photoreversible pigment became known as "*the pigment of the imagination*."

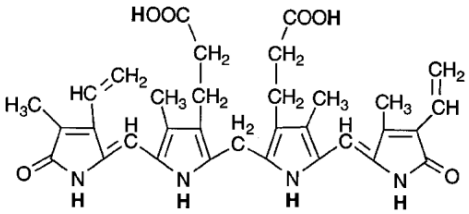
Following the suggestion by Warren Butler to call the yet unpurified photoreversible pigment **phytochrome** from the Greek for "plant color," **Harry Borthwick** and **Sterling Hendricks** named it in 1960. Phytochrome was finally purified in the 1980s.

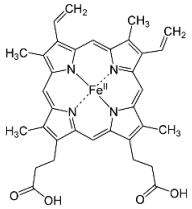


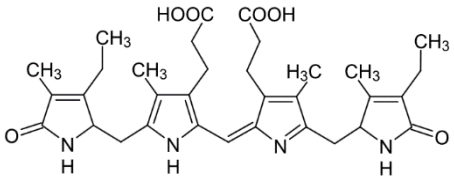
Phytochrome is a biliprotein with the following red-far red reversible structures:



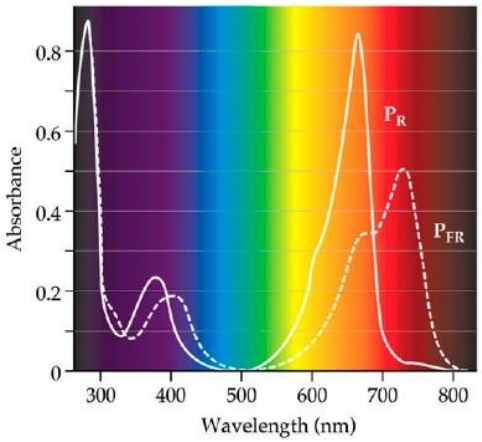
Biliprotein is named after **bilirubin** (l), which is a component of bile. Bilirubin is a breakdown product of the **heme** (c) from hemoglobin that is recycled from aged red blood cells. Bilibrubin gives the brown color to feces and is converted to urobilin (r) that gives urine its yellow color.



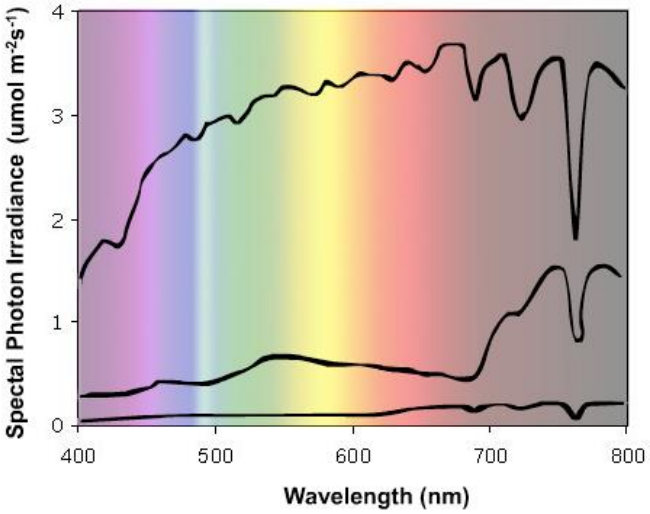


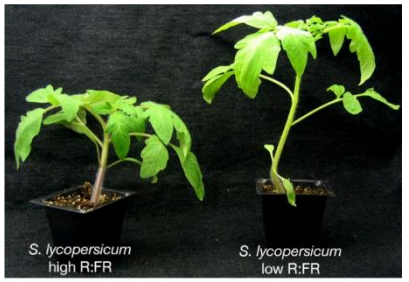


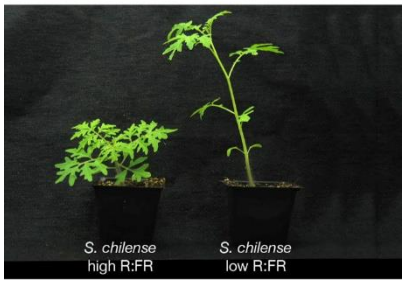
Isolated phytochrome is red-far red reversible and has **absorption spectra** that match the **action spectra** of the red-light inhibition of flowering and the far red light nullification of the red light inhibition.



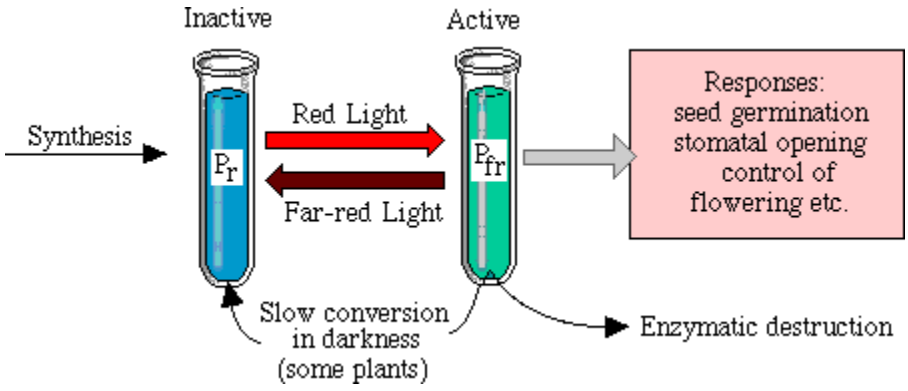
Phytochrome is involved in many other **photoresponses** in the **life cycle of plants** besides photoperiodism. These **photoresponses** include **seed germination**, the **de-etiolation response**, and the **shade-avoidance response**. The upper curve shows the spectral energy distribution of solar radiation at noon on a clear day. The ratio of red (660 nm) light to far red (730 nm) light is greater than unity. The middle curve shows the spectral energy distribution of solar radiation at noon after being filtered through a canopy of mustard seedlings. In this case the ratio of red light to far red light is less than unity. The ratio of red to far red-light inverses after the solar radiation is filtered through a canopy. Plants can sense the ratio of red light to far-red light and grow as a short sun plant or a tall shade.



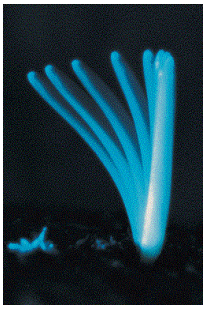




The participation of **phytochrome** in various **photoresponses** has been determined by **comparing** the **photoreversible action spectra** of these responses with the **photoreversible absorption spectra** of phytochrome. The participation of phytochrome in



these responses is also determined by comparing the **photoresponses** of **phytochrome mutants** with the **wild type**.

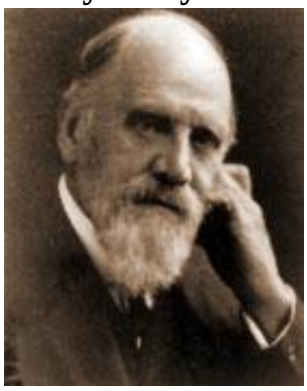


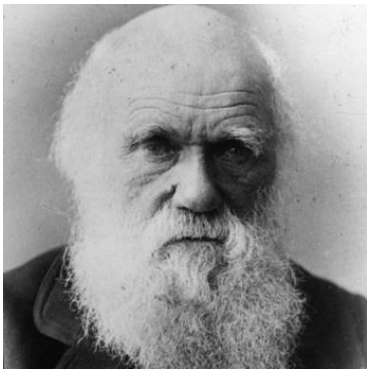
While the **photoperiodic response** helps plants to **orient in time**, the **phototropic response,** which is the **lateral bending of plants in the direction of light,** helps plants **orient in space**. Unlike the photoperiodic response, which is a response to **red light**, the phototropic response is a response to **blue light**.



Julius von Sachs (1864) determined that phototropism is a **blue light** response by passing light through **various colored filters** and seeing which colored light caused the plants to bend.

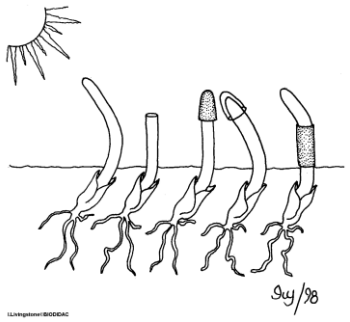
Charles Darwin (1880) and his son **Francis**, who studied *The Power of Movement in Plants*, realized that the **light acted catalytically and not as a substrate** since the light produced by the gas light, which was twelve feet from the seedlings, "*was so obscure that we could not see the seedlings themselves, nor read the large Roman figures on the white face of a watch, nor see a pencil line on paper, but could just distinguish a line made with Indian ink*." Even when the light was so dim, the seedlings bent towards the light in three hours and the curvature occurred about an inch below the tip. Remember that in photoperiodism, light also acted **catalytically**, and a one-minute pulse of light was sufficient to determine if the plant was to be vegetative or reproductive.



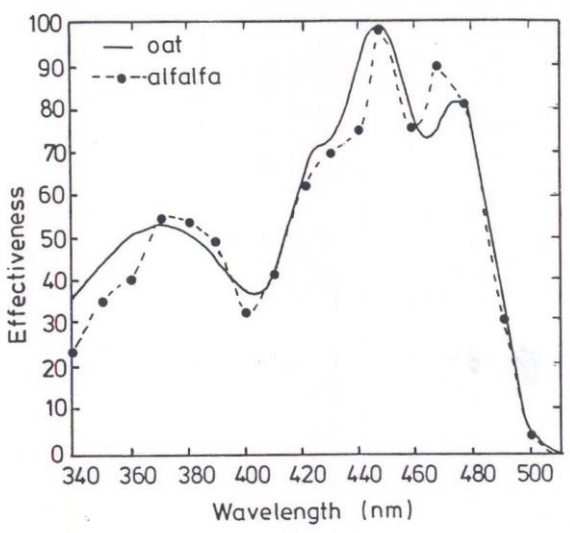




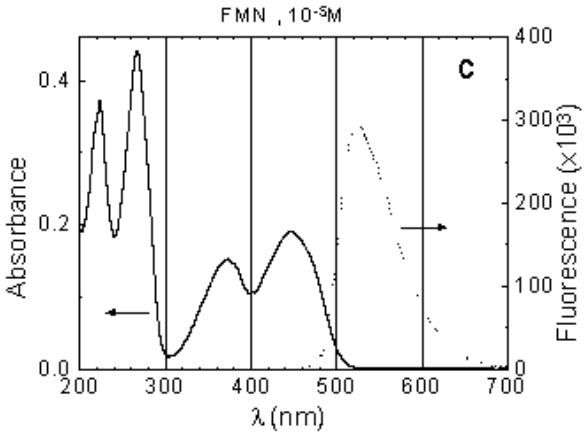
Charles and Francis Darwin determined the **site of light perception** for phototropism, by cutting off the tip, covering the tip with an opaque cap or transparent cap, or covering the middle with an opaque or transparent tube. As long as the tip was present or accessible to light, the seedling bent, indicating that the **tip of the seedling was the site of perception for phototropism**. The tip is the site of perception; it transmits a message to the middle of the seedling where the bending takes place. Remember that for photoperiodism, the leaves are the **site of perception**; they transmit a message to the buds of the plant which are the parts of the plant that flower.



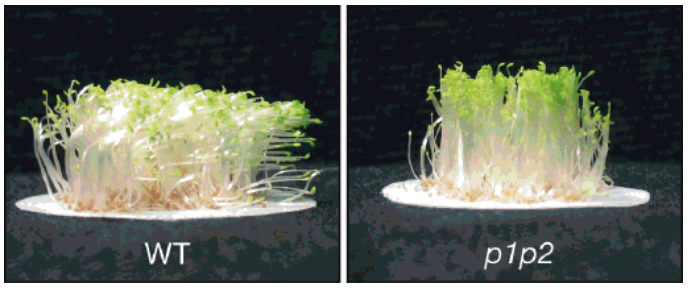
The **action spectrum** for phototropism, obtained by Kenneth Thimann and Curry (1960) shows a peak in the blue and another smaller peak in the ultraviolet region of the spectrum.

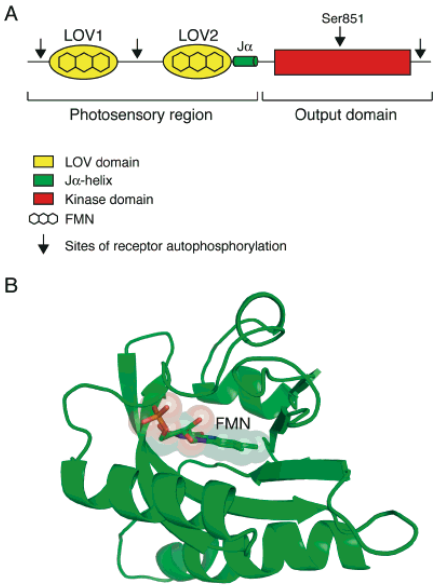


The **action spectrum** for phototropism is consistent with the **absorption spectrum** of an FMN (flavin mononucleotide)-containing flavoprotein.



Genetic studies showed that a certain **mutant** (p1p2) that lacks a **FMN-containing flavoprotein** is unable to sense blue light whereas the wild type is phototropic and bends towards the blue light. This is strong evidence that the FMN-containing flavoprotein, now known as **phototropin**, is the photoreceptor pigment that permits plants to **orient in space**. Remember that **phytochrome** is the photoreceptor pigment that permits plants to **orient in time** with the photoperiodic response.





Photobiology is the study of the effect of light on living organisms. It is fascinating from a theoretical, experimental, and applied point of view. For example, an understanding of photoperiodism has made it possible to **force plants** to flower out of season or for a specific holiday.



Figure 1. Scheduling Time Line for 6-inch Pinched Poinsettia

3-4 wks	1-2 wks	2-3 wks	1 wk	9 wks	
0	3-4	4-6	6-9	7-10	16-19
Stick Cuttings	Pot to final container	Pinch	Growth retardant (shoots 1½-2")	Natural SD Sep 21-27	Finish

Moreover, the discovery of photoperiodism in plants has led to the understanding of the effect of seasons on reproduction and migration in animals.



In this lecture I have been discussing the **consciousness of plants** in terms of how they sense the external world and respond in space and time appropriately to it. I started this lecture discussing the origin of consciousness in single-celled organisms such as *Euglena*. There are similarities and differences among all taxa. However, our consciousness, used in our attempt to understand truth and the **Laws of Nature** by which the universe is governed, is so much greater than the consciousness of *Euglena*, plants, and chimpanzees.

Understanding consciousness has been a goal of scientists—scientists as Aldous Huxley (1937) noted do not speak "[f]*rom the world we actually live in, the world that is given by our senses, our intuitions of beauty and goodness, our emotions and impulses, our moods and sentiments, the man of science abstracts a simplified private universe of things possessing only those qualities which used to be called 'primary.' Arbitrarily, because it happens to be convenient; because his methods do not allow him to deal with the immense complexity of reality, he selects from the whole of experience only those elements which can be weighed, measured, numbered, or which lend themselves in any other way to mathematical treatment*."

As I have told you, I am not a numeralologist, when it comes to describing complex and meaningful qualities with a number, such as a GPA. Here is an historical example where the science of intelligence may not have been that intelligent.

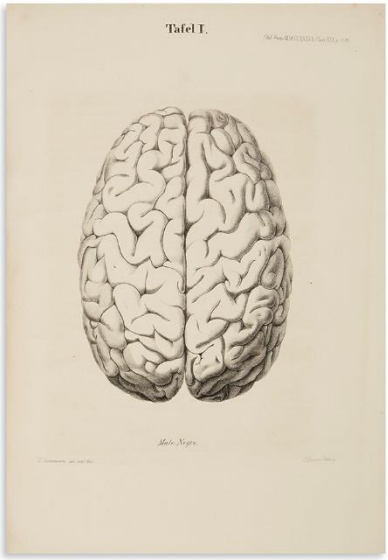


In a paper entitled, *On the Brain of the Negro, compared with that of the European and the Orang-Outang*, **Frederick Tiedemann** (1836) began by stating the then current conclusions of science that had political and legislative implications, "*I take liberty of presenting to the Royal Society a paper on a subject which appears to me to be of great importance in the*





natural history, anatomy, and physiology of Man; interesting also in a political and legislative point of view. Celebrated naturalists, Camper, Soemmerring, and Cuvier, look upon the Negroes as a race inferior to the European in organization and intellectual powers, having much resemblance to the monkey." It seemed like "**a belief in science**," at the *onset* of Tiedemann's anatomical work on the brain supported the institution of slavery. **A belief in science without understanding science is an a-theistic religion or scientism**.



Tiedemann did not believe in the science-based conclusions of his time. He realized that if the size of the brain was the best indicator of intelligence, then elephants would be more intelligent than human beings. He performed a study of the brain in which he took into consideration the size of the brain relative to the size of the person and drew a conclusion that was at odds with the current science and was more in line with William Wilberforce's thinking. Tiedemann concluded, "*The brain is undoubtedly the organ of the mind. It is the part of our body which gives us the consciousness of our own existence, and through which we receive the impressions made upon the external senses, conducted to the brain by the nerves. Here the perceptions are compared and combined so as to produce ideas. In this organ, we think, reason, desire, and will. In short, the brain is the instrument by which all the operations called intellectual are carried on. It is proved by facts and observations that animals partake of feelings, sensations, and intellectual faculties in a higher degree, and approach nearly to mankind in proportion as their brain resembles more the human brain.*

An intimate connexion between the structure of the brain and the intellectual faculties in the animal kingdom cannot be doubted. ***As the facts which we have advanced plainly prove that there are no well-marked and essential differences between the brain of the Negro and European, we must conclude that no innate difference in the intellectual faculties can be admitted to exist between them****. This has been denied by philosophers, naturalists, and travelers, who assert that the Ethiopian race is naturally inferior to the European in intellectual and moral powers. The data upon which such an opinion is based are either* ***erroneous suppositions*** *and* ***false deductions*** *from anatomy and physiology, or* ***superficial observations*** *on the intellectual and moral faculties of the Negroes, made by partial or prejudiced travelers. Very little value can be attached to these researches, when we consider that they have been made for the most part on poor and unfortunate Negroes in the Colonies, who have been torn from their native country and their families, and carried into the West Indies, and doomed there to a perpetual slavery and hard labour in the sugar plantations. Such is the nature of the researches of Thunberg, Long, Jefferson, Estwick, Chatelux, and others. Many of them deny that the Negro is a reasonable being, and they say that all Negroes are vicious, malignant, perverse, treacherous, and faithless. They observe, that the understanding of the Negro is not capable of improvement, that their temper and disposition are incorrigible, and that they are incapable of civilization.* ***Some have even believed the falsely supposed natural inferiority of the intellectual and moral faculties of the Ethiopian race, to be an excuse for slavery***."

"Science" has throughout history supported racist conclusions based on anatomy, genetics, and intelligence tests. However, there have also been scientists that have fought against scientific conclusions based on erroneous suppositions, false deductions, or superficial observations. We must use our intelligence and

critical thinking, not to "**believe the science**" but to **understand the science**. This is not always easy when being a believer is science gives you security in the world of the elites, and, in **Bernard Lazare**'s words, the status of a **parvenu** rather than a **pariah**, while being an understander of science gives no such guarantees.

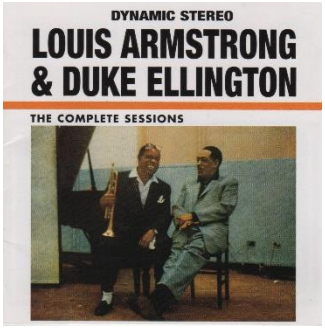


Einstein (1954) wrote in *Essays Presented to Leo Baeck on the occasion of his eightieth birthday*, "*Um ein tadelloses Mitglied einer Schafherde sein zu Können, muss man vor allem ein Schaf sen*," which means, "***To be an impeccable member of a flock of sheep, one must first of all be a sheep***."

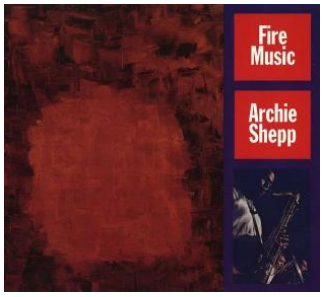


Cornel West provided examples of creative and inspiring people who even under difficult conditions were far better described as human beings than as sheep. West (1991) wrote in *Charlie Parker Didn't Give a Damn,* "***Jazz is the middle road between invisibility and anger***. ***It is where self-confident creativity resides***. *Black music is paradigmatic of how black persons have best dealt with their humanity, their complexity their good and bad, negative and positive aspects, without being excessively preoccupied with whites. Duke Ellington, Louis Armstrong, and Coltrane were just being themselves*." Another example of walking the middle road is the tenor saxophonist Archie Shepp. His 1965 album *Fire Music*, which is dedicated to Malcolm X, has the song *Malcolm, Malcolm, Semper Malcolm*, as well as *Prelude to a Kiss* by Duke Ellington. Shepp is a great example for anyone who does not aim to be an impeccable member of a flock of sheep.





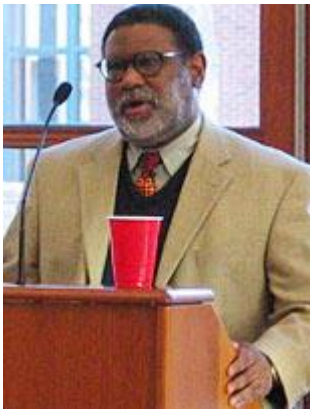




Indeed, jazz music itself depends on the balance between the soloist and the group, and many jazz musicians provide inspiring examples of how creative people can balance assimilation into society while maintaining cultural and personal identity.

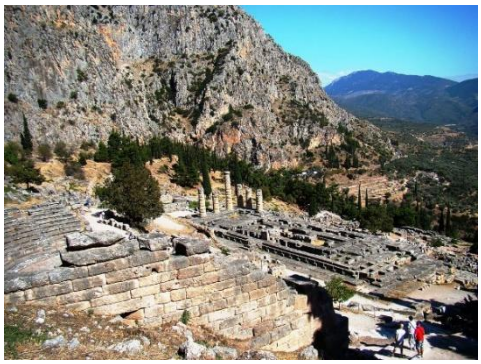
Archie Shepp was also a great and inspiring teacher to me. Here is an excerpt from an interview with him:

> I leave students on their own a lot. I expect a lot from them, but I don't demand much from them. In a world like ours where more and more young people are oriented to authoritarian, submissive control, my sort of education seems disorganized and strange, peculiar. If I don't tell them what to do they don't have a damned idea in the world what to think about. And even when I tell them, they don't do it. It's not as though they do it. It's just as though they feel that the job has been done because they've been told.



Inspired by Archie Shepp, who was a professor of African-American Studies at UMass/Amherst, John Calmore (1992), a law professor, wrote in *Critical Race Theory, Archie Shepp, and Fire Music: Securing an Authentic Intellectual Life in Multicultural a World*, "*In the mid-1960s, Archie Shepp took his "fundamentally critical" tenor saxophone and stepped outside the* ***commercially laden mainstream's musical community of assumptions and voiced his dissent beyond the ways it would be tolerated within the constraints of conventional jazz****. Twenty-five or so years later, some legal scholars of color, including myself, are voicing our dissent from many of the law's underlying assumptions. It is critical race theory's basic move from bit criticism to fundamental criticism that authenticates us as intellectuals of color and legitimatizes us as exemplars of oppositional cultural practice. We are grounding critical race scholarship in a sense of reality*

that reflects our distinctive experiences as people of color. Race-conscious experience is a springboard from which we engage in fundamental criticism."



I certainly believe in the concept of fundamental criticism, however, there is a difference between walking the middle road in academia and not being a sheep and walking the middle road in academia and demanding that everyone else becomes a sheep. When activism based on the foundation of postmodernism becomes so intwined with scholarship, critical thinking is replaced by critical theory, and education is replaced by indoctrination. Human intelligence based on free will, consciousness, and conscience, is more than stimulus-response coupling. It is *different in kind* from plant intelligence, monkey intelligence, or sheep intelligence for that matter. As *Homo sapiens*, we can do what was inscribed on the Temple of Apollo, "know thyself." Again, my view is not a fashionable view, and you are free to have your own view.

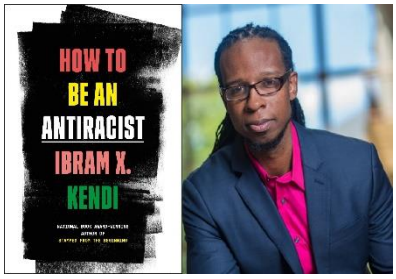


Consciousness and conscience together allow us to exercise **free will**, which I believe is a fundamental aspect of being human. According to Genesis 3, right from the beginning, human beings were endowed by the Creator with free will in terms of who we accept as knowledgeable and which stimuli we respond to: *[1] Now the serpent was more crafty than any of the wild animals the Lord God had made. He said to the woman, "Did God really say, 'You must not eat from any tree in the garden'?" [2] The woman said to the serpent, "We may eat fruit from the trees in the garden, [3] but God did say, 'You must not eat*

fruit from the tree that is in the middle of the garden, and you must not touch it, or you will die.'"

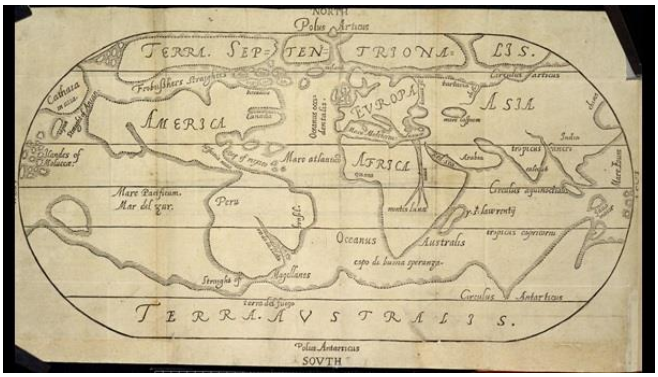
4 "You will not certainly die," the serpent said to the woman. 5 "For God knows that when you eat from it your eyes will be opened, and you will be like God, knowing good and evil."6 When the woman saw that the fruit of the tree was good for food and pleasing to the eye, and also desirable for gaining wisdom, she took some and ate it. She also gave some to her husband, who was with her, and he ate it…22 And the Lord God said, "The man has now become like one of us, knowing good and evil. He must not be allowed to reach out his hand and take also from the tree of life and eat, and live forever." 23 So the Lord God banished him from the Garden of Eden to work the ground from which he had been taken. 24 After he drove the man out, he placed on the east side of the Garden of Eden cherubim and a flaming sword flashing back and forth to guard the way to the tree of life.

There is value in this creation story. **Ibram X. Kendi** (2019) wrote in *How to Be an Antiracist*, "*Biological racism rests on two ideas: that the races are meaningfully different in their biology and that these differences create a hierarchy of value. I grew up believing the first idea of biological racial difference. I grew up disbelieving the second idea of biological racial hierarchy, which conflicted with the biblical creation story I'd learned through religious study, in which all humans descend from Adam and Eve. It also conflicted with the secular creed I'd been taught, the American creation story that 'all men are created equal.*'"

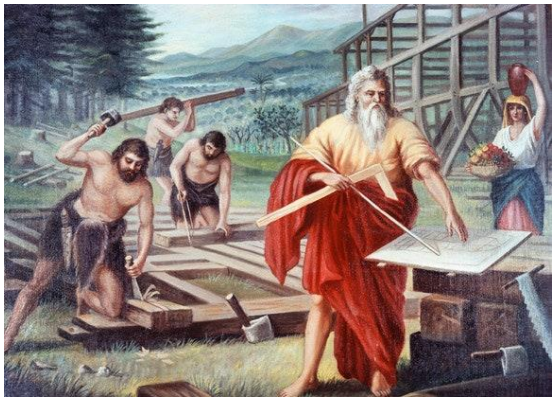


Kendi also rejected the value of religion in fighting racism when he learned that George Best (1578) interpreted in racial terms, the story of Noah and his son Ham, who was cursed and whose descendants were destined to be slaves. Best

wrote in *A True Discourse of the Late Voyages of Discoverie*, that Ham's "*sonne should be borne, whose name was Chus, who not only it selfe, but all his posteritie after him, should be so blacke & lothsome, that it might remaine a spectacle of disobedience to all the World. And of this blacke & cursed Chus came al these blacke Moores which are in Africa*." Kendi makes no mention of Wilberforce.



Aside: While we are talking about Noah, I want to mention a description of him given in Genesis 6:9 that relates to how we may want to judge the actions of historic characters: *Noah was a righteous man, blameless among the people of his time, and he walked faithfully with God*. Note that his blamelessness was considered relative to the people of *his* time, not the present time.



What do you do when the authorities disagree with your own intelligence? What do you do when you think that "*skin color is as meaningless to our underlying humanity as the clothes we wear over that skin*…[and t]*o be a antiracist is to also recognize the living, breathing reality of the racial mirage, which makes our skin colors more meaningful than our individuality*?" According to Kendi, a professor of history at Boston University, "[r]*acist ideas are not natural to the human mind*." Kendi realized that "*marginalization in academic thought did not mean marginalization in common thought, including the kind of common thinking that surrounded me as a child*."

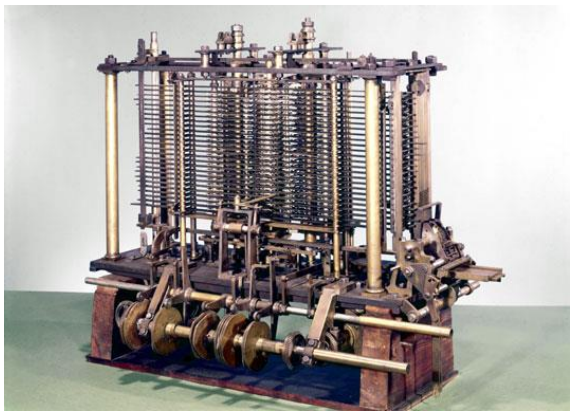
Remember that science, from *scientia*, the Latin word for knowledge, provides valuable yet incomplete information about the objective world. The motto of the Royal Society is *Nullius in verba*—take no one's word for it. If you believe that you have free will, nobody can tell you what to think—whether the authority is science, religion, or critical theory. If you believe that there is a Truth, even though you cannot know the whole truth—then nobody can make you accept their definition of truth without your consent. Authenticity is also key. You are an authentic human being when your actions are congruent with your beliefs, despite external pressures to conform.

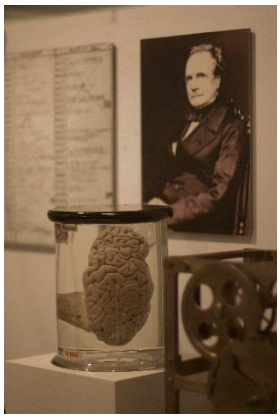




William Whewell (1837) ended his *History of the Inductive Sciences* like so "*The real philosopher, who knows that all the kinds of truth are intimately connected, and that all the best hopes and encouragements which are granted to our nature must be consistent with truth, will be satisfied and confirmed, rather than surprised and disturbed, thus to find the natural sciences leading him to the borders of a higher region.* ***To him it will appear natural and reasonable, that, after journeying so long among the beautiful and orderly laws by which the universe is governed we find ourselves at last approaching to a source of order and law, and intellectual beauty:--that, after venturing into the region of life and feeling and will, we are led to believe the fountain of life and will, not to be itself unintelligent and dead, but to be a living mind, a power which aims as well as acts****. To us this doctrine appears like the natural cadence of the tones to which we have so long been listening; and without such a final strain our ears would have been left craving and unsatisfied. We have been lingering long amid the harmonies of law and symmetry, constancy and development; and*

these notes, through their music was sweet and deep, must too often have sounded to the ear of our moral nature, as vague and unmeaning melodies, floating in the air around us, but conveying no definite thought, moulded into no intelligible announcement. But one passage which we have again and again caught by snatches, though sometimes interrupted and lost, at last swells in our ears full, clear, and decided; and the religious 'Hymm in honour of the Creator,' to which Galen so gladly lent his voice, and in which the best physiologists of succeeding times have ever joined, is filled into a richer and deeper harmony by the greatest philosophers of these later days, and will roll on hereafter, the 'perpetual song' of the temple of science."





Charles Babbage (1838), inventor of the mechanical computer, responded to **Whewell**'s claim that "*We may thus, with the greatest propriety, deny to the mechanical philosophers and mathematicians of recent times any authority with regard to their views of the administration of the universe; we have no reason whatever to expect from their speculations any help, when we ascend to the first cause and supreme ruler of the universe. But we might perhaps go farther, and assert that they are in some respects less likely than men employed in other pursuits, to make any clear advance towards such a subject of speculation*" by producing *A Fragment*, the Ninth and unauthorized Bridgewater Treatise. In the second edition, Babbage described the power of mathematics in understanding the Creator:

"*First, The truths of pure mathematics are* ***necessary truths****; they are of such a nature, that to suppose the reverse, involves a contradiction.*

Secondly, ***The laws of nature****, on which physical reasonings are founded, although some of them are considered as necessary truths, depend, in many instances, on the testimony of our senses. These derive their highest confirmation from the aid of pure mathematics, by which innumerable consequences, previously unobserved, are proved to result from them.*

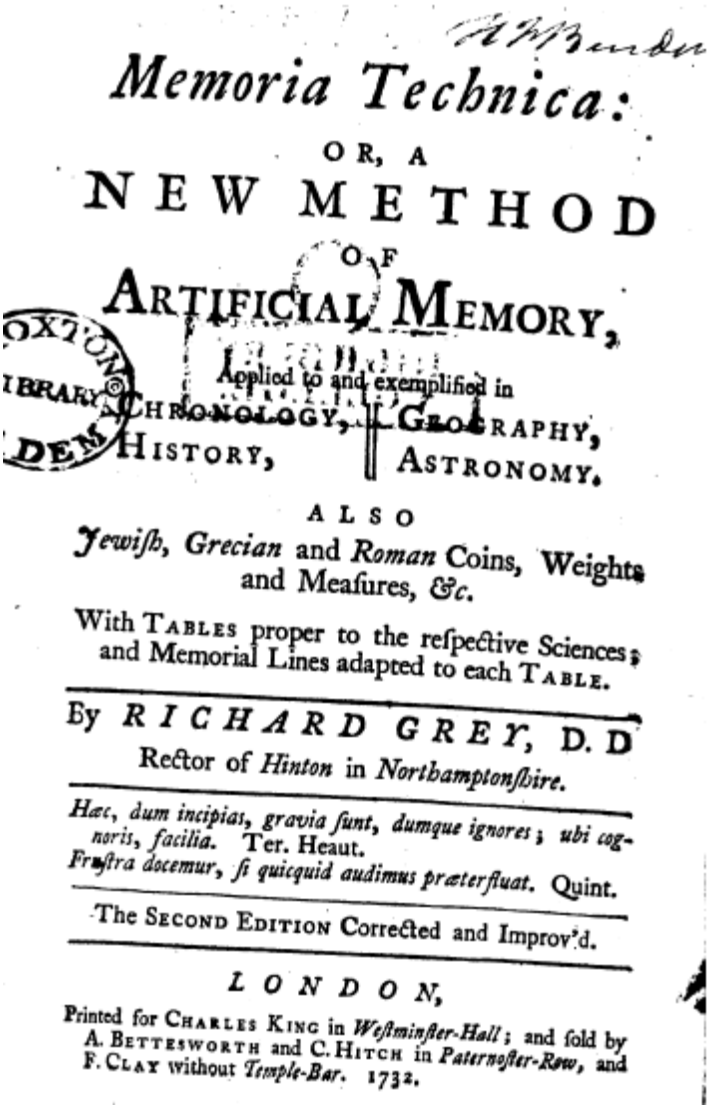
Thirdly, The truths of natural religion rest also on the testimony of our external senses, but united with that internal consciousness of intention or design which we experience in our own breast, and from which we infer similar powers in other beings. Many of the facts on which the conclusions of natural religion are founded, derive their chief importance from the aid supplied by the united power of the two former classes, and the amount and value of this support will be enlarged with the advance of those sciences.

Fourthly, Revealed religion rests on human testimony; and on that alone. Its first and greatest support arises from natural religion. I have endeavoured in one chapter of the present volume to show, that, notwithstanding the weakening effect of transmission upon testimony, a time may arrive when, by the progress of knowledge, internal evidence of the truth of revelation may start into existence with all the force that can be derived from the testimony of the senses.

The first class of truths then (those of Pure Mathematics) appears to rest on necessity. The second, (the Laws of Nature,) on necessity and our external senses. The third, (those of Natural Religion,) on our external senses and internal consciousness. The last, (those of Revelation,) on human testimony. If they admit of any classification, as subjects having a common resemblance, or as possessing different degrees of evidence, I have placed them in the only order which, in my

opinion, is consistent with truth; convinced that it is more injurious to religion to overrate, than to undervalue the cogency of the evidence on which it rests."

Having trouble with remembering things? We can learn from the plants. In this lecture I have shown you that **plants have a real notion of time and place**. Richard Grey (1732) wrote in the second edition of *Memoria Technica: or, a New Method of Artificial Memory, Applied to and exemplified in Chronology, Geography, History, Astronomy, Also Jewish, Grecian and Roman Coins, Weights and Measures, &c.*, "*I believe it will be agreed on all Hands, that, to instance in History only, **a Man who has an exact Notion of Time and Place**, finds incomparably more Pleasure, and make a speedier Progress in that Study, than he who has not.*"



Memoria Technica:

OR, A

NEW METHOD

OF

ARTIFICIAL MEMORY,

Applied to and exemplified in

CHRONOLOGY, GEOGRAPHY,

HISTORY, ASTRONOMY,

ALSO

Jewiſh, Grecian and Roman Coins, Weights and Meaſures, &c.

With TABLES proper to the reſpective Sciences; and Memorial Lines adapted to each TABLE.

By RICHARD GREY, D. D

Rector of *Hinton* in *Northamptonſhire.*

Hæc, dum incipias, gravia ſunt, dumque ignores; ubi cognoris, facilia. Ter. Heaut.

Fruſtra docemur, ſi quicquid audimus præterfluat. Quint.

The SECOND EDITION Corrected and Improv'd.

LONDON,

Printed for CHARLES KING in *Weſtminſter-Hall*; and ſold by A. BETTESWORTH and C. HITCH in *Paternoſter-Row*, and F. CLAY without *Temple-Bar*. 1732.

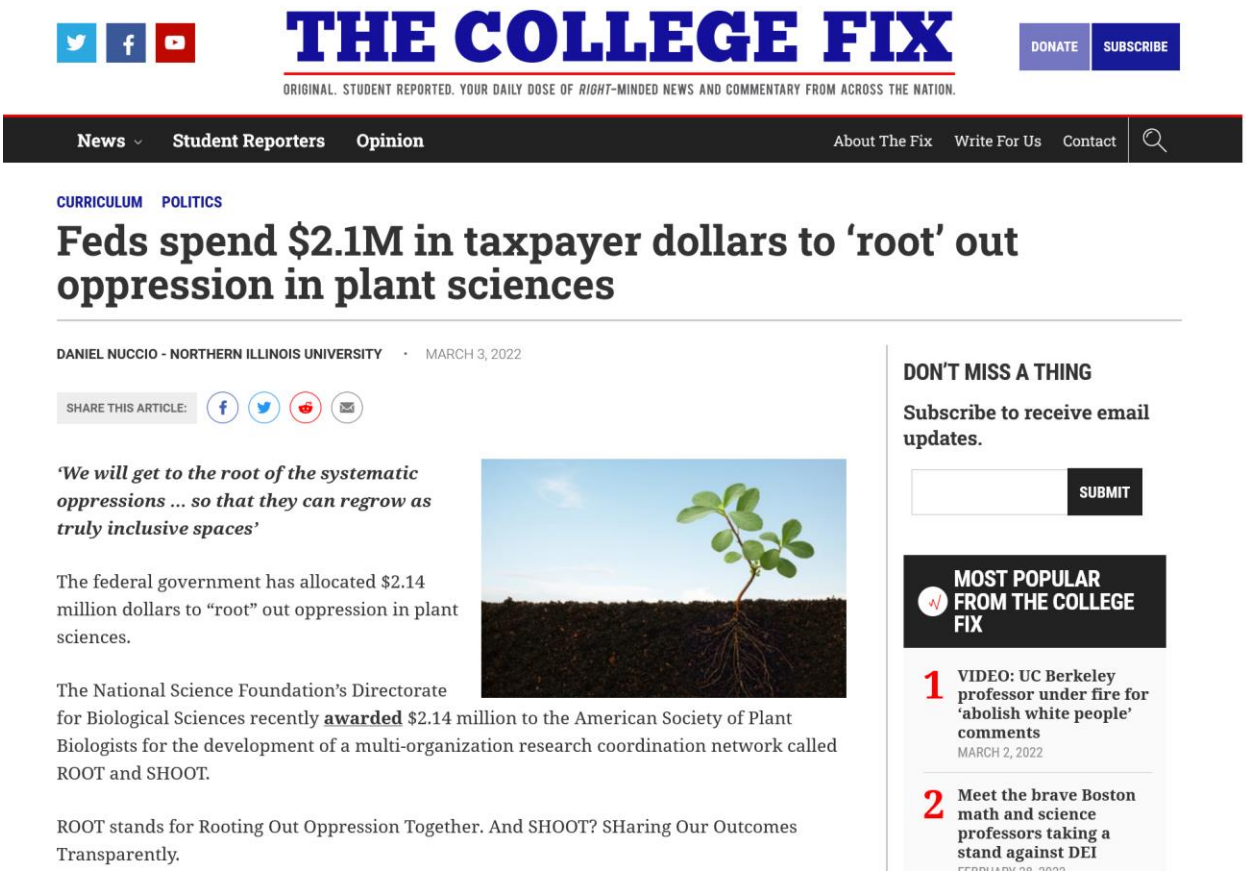
Plants have the ability to count. Watch this video.

Greg Gage
|
TED2017

Electrical experiments with plants that count and communicate

https://www.ted.com/talks/greg_gage_electrical_experiments_with_plants_that_count_and_communicate/discussion#t-4335

While we are talking about plants, I would be remiss not to mention the "roots" and "shoots" of oppression:



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CURRICULUM POLITICS

Feds spend $2.1M in taxpayer dollars to 'root' out oppression in plant sciences

DANIEL NUCCIO - NORTHERN ILLINOIS UNIVERSITY · MARCH 3, 2022

SHARE THIS ARTICLE:

'We will get to the root of the systematic oppressions ... so that they can regrow as truly inclusive spaces'

The federal government has allocated $2.14 million dollars to "root" out oppression in plant sciences.

The National Science Foundation's Directorate for Biological Sciences recently **awarded** $2.14 million to the American Society of Plant Biologists for the development of a multi-organization research coordination network called ROOT and SHOOT.

ROOT stands for Rooting Out Oppression Together. And SHOOT? SHaring Our Outcomes Transparently.

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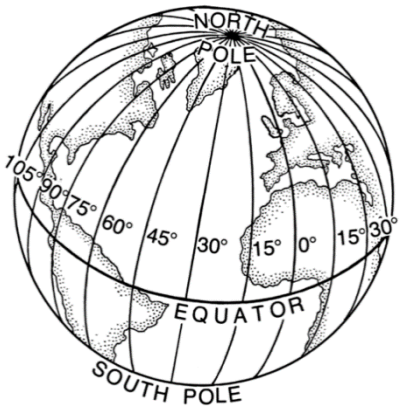


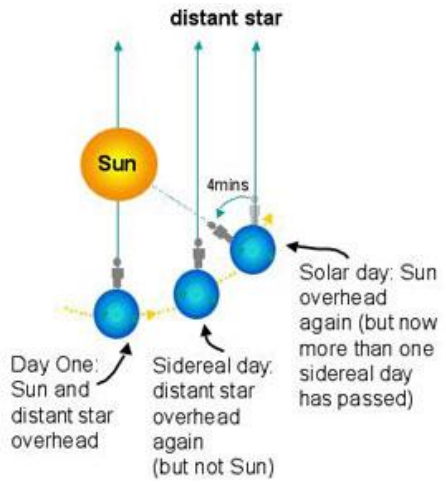
Living organisms from wildflowers to whales have **internal or endogenous biological clocks** that are normally synchronized with **the daily rotation of the earth upon its axis** that runs from the North Pole to the South Pole. The earth spins counterclockwise as viewed from the North Pole. Consequently, no matter which latitude one resides and how long the photoperiod is, the sun *appears* to rise in the east and set in the west.

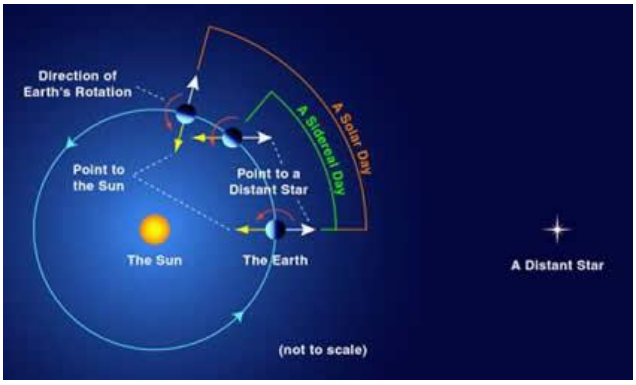


Photograph by George Rankin of the sun rise and set in the Arctic in January. Five exposures taken 1h apart.

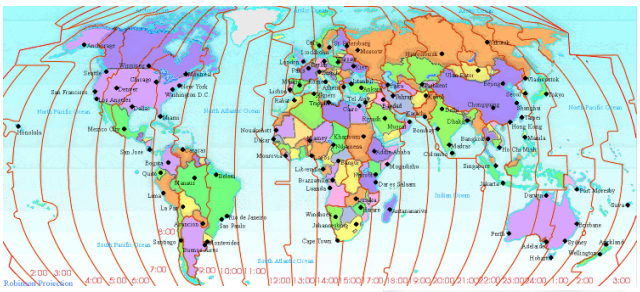
Experience the rotation of the earth through **time-lapse photography** by Shane Black https://www.youtube.com/watch?v=9d8wWcJLnFI, Michael Shainblum https://www.youtube.com/watch?v=vLUNWYt3q1w, Andrew Arthur Breese https://www.youtube.com/watch?v=R5LRpH62mss, Anna Possberg https://www.youtube.com/watch?v=8GpDXV9BfLU, Harley Grady https://www.youtube.com/watch?v=nam90gorcPs, and Dimitry Pisank https://www.theguardian.com/science/video/2015/jun/23/earth-international-space-station-timelapse-video

The period of earth's rotation, which is known as the **solar day**, is the time it takes for the sun to appear directly overhead at two successive noons. The solar day is approximately 24 hours. Because the earth **orbits** around the sun as it **rotates**, the solar day is actually a little longer than the actual rotation period of the earth, which is known as the **sidereal day**. Because the speed of the earth as it orbits the sun is not constant but faster at **perihelion** ($r = r_{min}$) than that **aphelion** ($r = r_{max}$), the average speed of the earth around the average position of the sun is used to determine the solar day. The **sidereal day**, which is 23 hours and 56 minutes, is the time it takes for the distant stars to appear in the same position. The four minute difference between a solar day and **sidereal day** means that a viewer will see the same stars "rise" above the horizon four minutes earlier each **solar day**.





Before the widespread use of railroad trains in the 1840's, each community had its own **local time**, where twelve o'clock noon on each day was defined as the time when the sun was at its **zenith** or highest point in the sky. However, when it became crucial to coordinate train schedules to minimize train crashes on single train tracks, **standard time zones** were created that closely aligned to lines of longitude separated by 10° and **Greenwich England**, where the famous observatory was that provided maps for navigation, became the **prime meridian**.





In 1918, the Standard Time Act became law in the U. S. The Official U. S. time can be found at http://www.time.gov/.

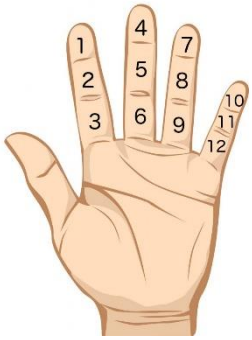






Currencies, temperature, lengths, mass, and even library books have been decimalized (Vera, 2009). Have you ever wondered why we never hear of **decimal time**? Decimal time was originally proposed by D'Alembert in 1754. On October 5, 1793, during the **French Revolution**, decimal time was introduced as part of its goal to decimalize everything that could be measured. Each day was divided into ten hours, each hour was divided into 100 minutes, and each minute was divided into 100 seconds. Decimal[1] time was never popular and was abandoned on April 7, 1795, the same day that the decimal system for length, volume, and mass began. At this time, the meter was defined as one ten millionth of the distance between the North Pole and the Equator along the line of longitude passing through Paris, and the gram was defined as the mass of a cubic centimeter of water. See the current time in decimal time at http://minkukel.com/scripts/metric-clock/.

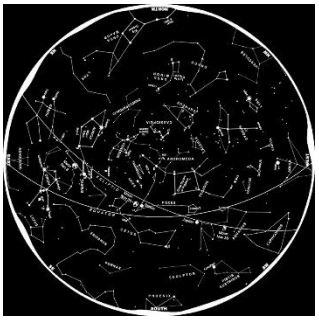


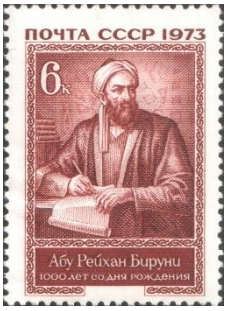


The oldest known **sundial** was found in Egypt's Valley of the Kings, and it dates from 1500 BC. We got the 24-hour day from the ancient Egyptians (2100 BC), who divided the day into 24 hours: 10 hours of daylight (when sundials could be used to tell time), 12 hours of nighttime (when constellations could be used to tell time), and two twilight hours, one at dawn and

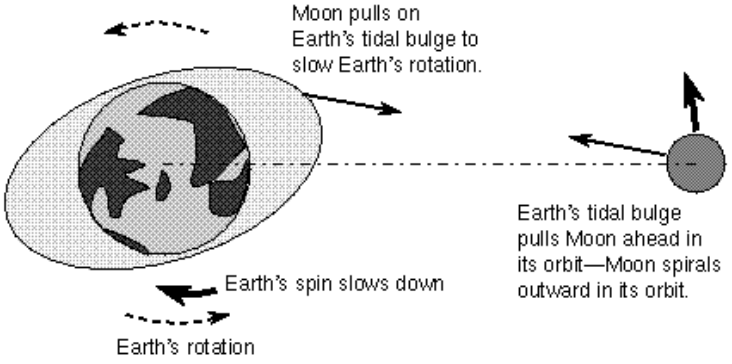
[1] The word decimation comes from the Roman times when one out of ten soldiers of an army were executed as a punishment for its cowardice.

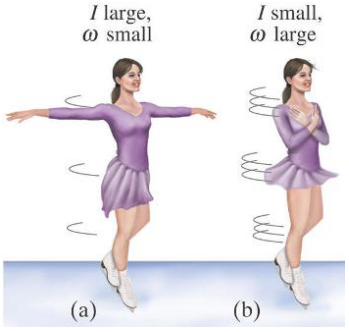
one at dusk (when neither sundial nor constellations could be used to tell time). The hours were of unequal duration probably based on different seasonal hours of light. **Hipparchus** (190–120 BC) suggested that a day be divided into twenty-four hours, based on the measurable twelve hours of daylight and twelve hours of darkness observed on **equinox** days. According to C. Edward Sachau (1879) who translated *The Chronology of Ancient Nations*, Al-Biruni (1000), an Iranian polymath, divided the hour into 60 minutes and the minute into 60 seconds.





The **day length** on earth has ***not*** been constant over geological time because the daily period of rotation of the earth has not been constant. The length of the day has grown longer by **2 seconds per 100,000 years** as a consequence of the **tidal friction** between the earth and the moon. Overall, because **angular momentum is conserved**, the total angular momentum of the earth and moon stays constant, but the tidal friction results in a decrease in the angular momentum of the earth and an increase in the angular momentum of the moon. The decrease in the angular momentum of the earth, means that the earth rotates more slowly on its axis and the increase in the angular momentum of the moon means that the moon orbits the earth more slowly now than it did in the past and its distance from the earth continues to increase.



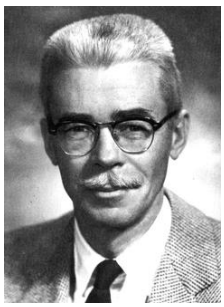


The increase in the length of the period of the earth's daily rotation is supported by diverse observations. For example, **historical records of solar eclipses over China**, from which the orbits of the sun and moon have been calculated, indicate that if the period of the earth's daily rotation were not increasing, then the reported shadows produced by the eclipsed sun would not be where they were recorded to be. Moreover, the moon's orbital radius as determined by the amount of time it takes laser light to travel from the earth to the **retro-reflector arrays placed on the moon** by Apollo 11, Apollo 14, Apollo 15, and Lunakhod 2, and back to earth again, has increased by 3.82 cm/year. This is consistent with the decrease in the daily period of rotation of the earth as a result of the transfer of angular momentum from the earth's rotation to the moon's orbital motion (Dickey et al. 1994). The increase in the moon's orbital radius also results in an increase in the period of the lunar month (Runcorn, 1966).





John Wells (1963), a geology professor at Cornell, used the relationship between light and life to discover the day length on earth hundreds of millions of years ago. Wells looked at **fossil corals** from the **Middle Devonian** (387 million years ago based on **radiometric dating**) and **Pennsylvanian** (307 million years ago based on **radiometric dating**) collected near Cornell University. The fossil corals show both **annual growth rings due to seasonal changes in temperature** and



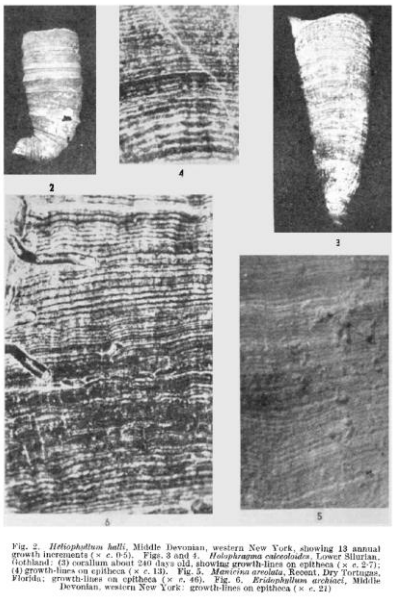


Fig. 2. *Heliophyllum halli*, Middle Devonian, western New York, showing 13 annual growth increments (× c. 0·5). Figs. 3 and 4. *Holophragma calceoloides*, Lower Silurian, Gotland: (3) corallum about 240 days old, showing growth-lines on epitheca (× c. 2·7); (4) growth-lines on epitheca (× c. 13). Fig. 5. *Manicina areolata*, Recent, Dry Tortugas, Florida; growth-lines on epitheca (× c. 46). Fig. 6. *Eridophyllum archiaci*, Middle Devonian, western New York: growth-lines on epitheca (× c. 21)

daily growth rings due to the **diurnal incorporation of calcium carbonate**.

The fossil corals from the Middle Devonian had more daily growth rings than the fossil corals from the Pennsylvanian that had more daily growth rings than the corals from the present. Wells (1963) concluded that there were about 400 days per year in the **Middle Devonian** about 387 days per year in the **Pennsylvanian** and about 365 days per year in the present.

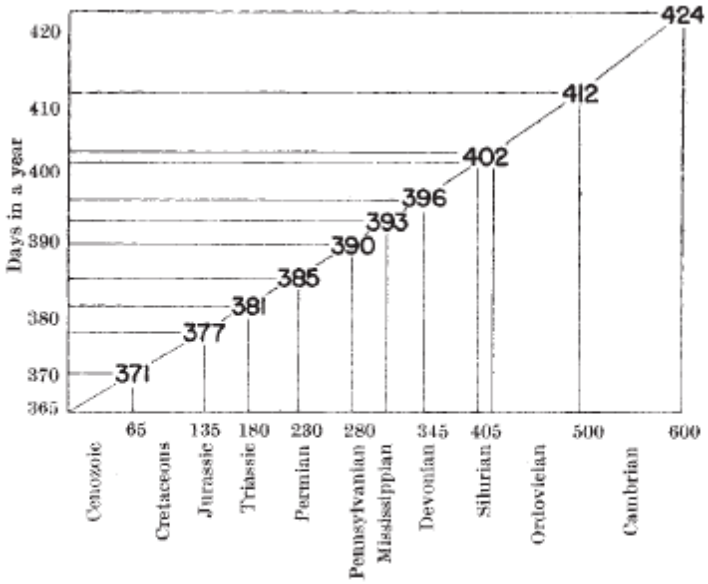


Fig. 1. Relation between days in each year and geological time (radioactive age data from Kulp, 1961)

By assuming that the period of the earth's orbit ($t = \frac{2\pi r\sqrt{r}}{\sqrt{GM_{sun}}}$ from Newton's law of gravitation) around the sun has been constant, Wells calculated the period of the daily rotation of the earth in various geological periods. He calculated that the daily rotation of the earth took about 21.9 hours in the **Middle Devonian**, 22.6 hours in the **Pennsylvanian**, and increased to its present value of about 24 hours.



In an article published in the *New York Times* on April 19, 1964, **John Burdon Sanderson Haldane** singled out John Wells as someone who could make great scientific strides with next to no money by using his visual system (eyes and mind) and a ten-dollar hand lens to measure the number of fifty micrometer daily growth rings in an annular ring. Haldane wrote, "*Professor Wells of Cornell University also has this quality. He collects ancient and modern coral. Those which grow in seas where the temperature varies much with the seasons often show annual growth*

rings like trees. Wells found that some also show daily ridges of growth, which can be counted with a good hand lens costing perhaps $10. Modern corals show about 365 ridges a year….Silurian corals show about 400 rings a year. As the year has probably changed little, therefore the days have been getting longer. (They are getting longer, as we know, from records of ancient eclipses, among other evidence. This is thought to be due to the braking action of the tides, both in the sea and in the earth, which is not quite rigid.) Ask anyone who does not know the answer how much the apparatus cost which proved that the number of days in the year has increased [*sic*; he meant decreased] *by 35 in 350 million years and he will probably guess at $10 million or so."*

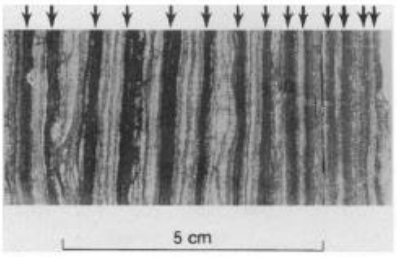
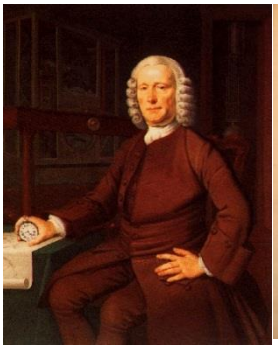
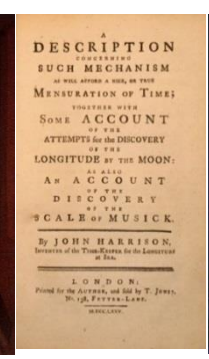


Fig. 1. Photograph of polished core of BCC tidalites. Laminae of coarse silt to fine-grained sand were transported only during the strongest spring tides. The thick dark bands (arrows) correspond to neap-tide deposition of fine-grained mud.

A more recent analysis of the laminated tidal sediments from the **Precambrian** indicates that **900 million years ago**, the length of a day on earth was approximately **18.2 hours** (Sonnett et al., 1996).

Now that we have a sense of the **astronomical** or environmental **clock**, independent of and **external** to our bodies, we will talk about the **endogenous biological clock** in plants, humans, and other mammals.




A
DESCRIPTION
CONCERNING
SUCH MECHANISM
AS WILL AFFORD A NICE, OR TRUE
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TOGETHER WITH
SOME ACCOUNT
OF THE
ATTEMPTS for the DISCOVERY
OF THE
LONGITUDE BY THE MOON:
AS ALSO
AN ACCOUNT
OF THE
DISCOVERY
OF THE
SCALE OF MUSICK.
By JOHN HARRISON,
Inventor of the Time-Keeper for the Longitude at Sea.
LONDON:
Printed for the Author, and sold by T. Jones,
No. 138, Fetter-Lane.
MDCCLXXV.



Like the accurate **chronometer** designed in the first half of the 18th century by **John Harrison** to determine **longitude**, biological clocks are relatively **temperature insensitive**. The daily **entraining** or **synchronizing** event (time-giver or ***zeitgeber*** in German) is a result of the **daily light-dark transition** that

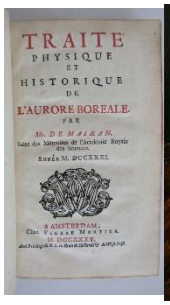
takes place everywhere on the surface of the earth except at the poles at certain times of the year.



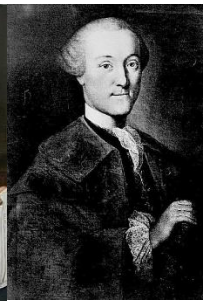


The **entrainment** of biological rhythms with the rotation of the earth was first noticed by observing plants. As he trekked across the known world in the fourth century BC, **Alexander the Great**, a student of Aristotle, was interested in the influence of climate on the variety of plants he saw. While on the Island of Tylos (Bahrain), one of Alexander's admirals, Androsthenes of Thasos, noticed that the leaflets of the **tamarind** showed sleep movements (*Botanische Forschungen des Alexanderszuges* by Bretzl, 1903). Theophrastus wrote about Androsthenes' observations in his *Historia Plantarum*: The tamarind was "*another tree with many leaves…that closes at night, but opens at sunrise, and by noon is completely unfolded; and at evening—again it closes by degrees and remains shut at night, and the natives say it goes to sleep*." That is, the leaflets opened during the day and closed at night. In 1729, the astronomer **Jean-Jacques d'Ortous de Mairan,** who studied the **Northern Lights**, also noticed this sleep behavior in the sensitive plant (***Mimosa***). He put the plants in constant darkness and noticed that the cyclic behavior persisted as if the plants could sense the sun without seeing it. In 1758 **Henri-Louis Duhamel du Monceau** put a *Mimosa* plant under a blanket and put it in a leather trunk in a wine cellar. The *Mimosa* continued its rhythmic leaflet movements indicating that the

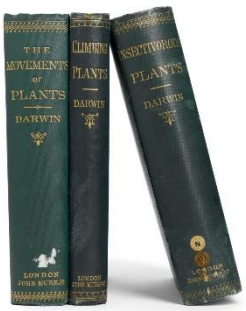


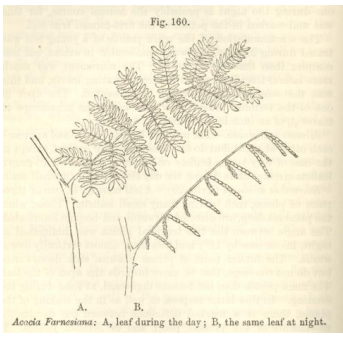






movements were independent of light and temperature changes. **Johann Gottfried Zinn** (1759) put bean (*Phaseolus*) plants in the dark and also saw that their rhythmic leaf movements occurred independent of light and temperature changes. In their book *The Power of Movement in Plants*, Charles and Francis Darwin (1880) reported their observations on many genera that show sleep movements.

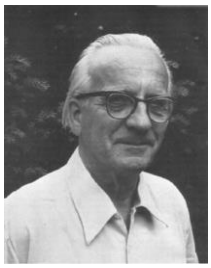




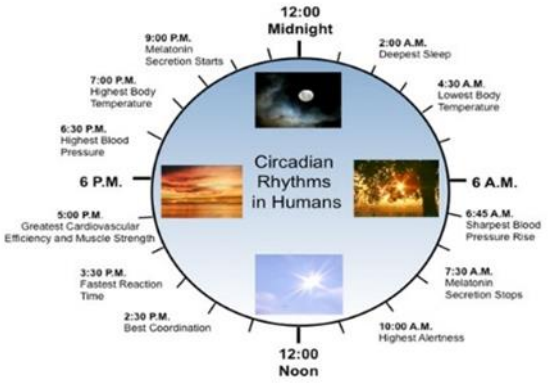


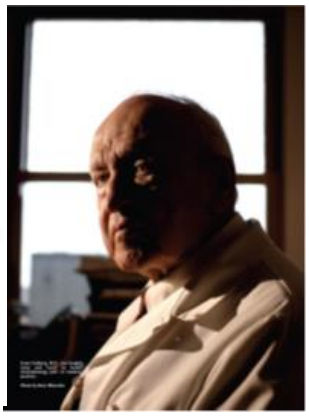


In 1832, **Augustin Pyramus de Candolle** (who saw nature as being at war) expanded on the previous work by measuring the **period** of *Mimosa* leaflet movements in the dark. He found the period to be 22–23 hours long. **Svante Arrhenius** (1898) suggested that atmospheric electricity triggered the movements. While testing Arrhenius' suggestion that atmospheric electricity triggered leaflet movements by adding charged particles or removing charged particle from the air, **Erwin Bünning** found that light was the factor that **synchronized** leaf movement in beans (*Phaseolus*). He also found that the period of rhythmic movement was temperature-insensitive—just like the chronometer designed by John Harrison. Soon research began on biological rhythms in animals. Measurements of biological rhythms with high temporal resolution provided evidence that the rhythms were less than 24 hours. These experiments supported the controversial and seemingly parapsychological and metaphysical idea at the time that the period of the rhythms was not based on 24 hour changes in the **exogenous physical cues** coming from the rotation of the earth as promoted by Frank A. Brown Jr. but on an **endogenous clock** promoted by Colin Pittendrigh. Bünning (1958) wrote a book about biological rhythms called *The Physiological Clock*.



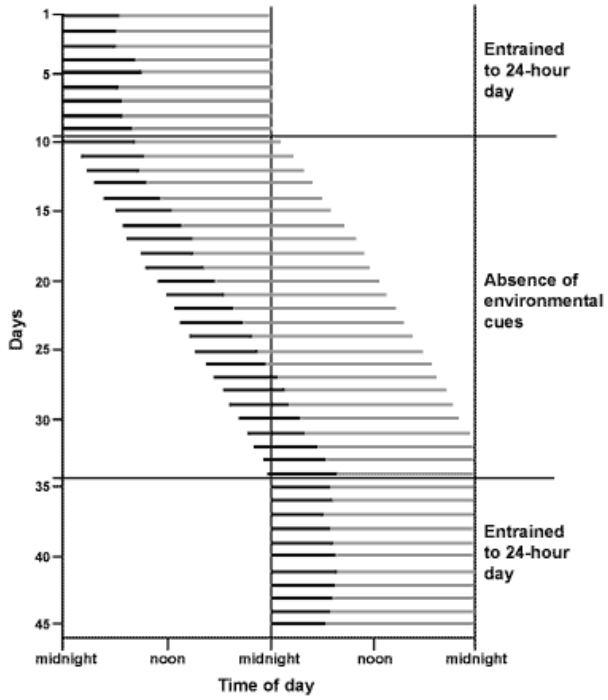
Aside: In his autobiography, Bünning (1977) wrote "*According to a long-lasting tradition in my country, every well-educated man was expected to have and to passionately defend his own '**Weltanschauung**.' This word cannot be translated by 'conception of the world' or 'world outlook.' 'Weltanschauung' means to combine everything from science, religion, politics, social life, etc into one whole concept. This explains why in my country, even though people are not as hot-blooded as many other nationalities, extreme positions in science or politics are often defended with fanatic obstinacy*." Bünning also wrote that "*certain people have a horizon with the radius r = 0, and this is what they call their standpoint*." Interestingly, Bünning's description is an apt way of describing postmodernist **standpoint theory**.





Studies of biological rhythms showed that in the absence of environmental cues, the biological clock is no longer synchronized with the daily light-dark period, however, the **free running** biological clock still runs with a **circadian rhythm** that is about or "*circa*" in Latin a day or "*dies*" in Latin. With the help of William McDonald, a professor of Classics, who was known to say that lectures were "*a means of getting information from a professor's notes to the students' notes without going through the heads of either*," the word **circadian** was coined by **Franz Halberg** in 1959. The study of biological rhythms in plants set the stage for the study of biological rhythms in humans—just in time for the cold war.

While we will only discuss circadian rhythms today, remember that living organisms also exhibit **monthly** (lunar), **annual,** or **seasonal** (solar) rhythms. In addition, animals that live in tidal zones have a **tidal** rhythm.



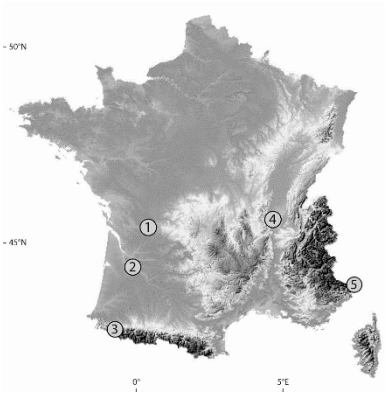
The figure below depicts the circadian **sleep-wake cycle** of one individual person. The black lines represent the periods in which the person slept, and the gray lines represent the periods in which the person was awake. During regular time periods of light and darkness, the sleep-wake cycle was **entrained** to a period of 24 hours. However, on days 10 through 34, when the person was isolated from any environmental cues or ***zeitgeber***, the person went to sleep one hour later each day and after 24 days, the person was again going to bed at midnight. While the sleep-wake cycle continued to oscillate in the absence of environmental cues, indicating that the sleep-wake cycle rhythm is **endogenous**, the period of the endogenous rhythm was greater than 24 hours. On day 35, when the person was subjected again to the ***zeitgeber*** or **normal environmental cues**, the **sleep-wake** cycle became **entrained** and **synchronous with the daily rotation of the earth**.

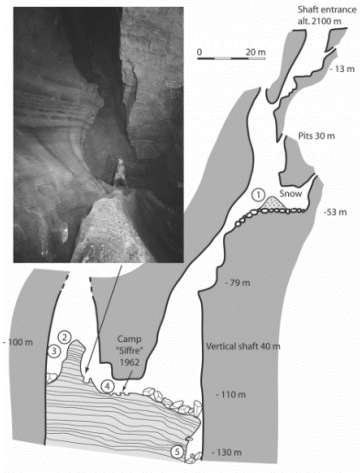
Determining the natural free-running period of the biological clock in humans began following the **Cuban Missile Crisis** in October 1962, when it seemed like people might have to live in isolation in space capsules and nuclear submarines or in underground bunkers or deep subterranean caves for a period of time during and after a nuclear war. It was discovered that the **natural, free-running period of the biological clock** of humans in **underground bunkers** or **deep subterranean caves**, where they were ***not*** exposed to the ***zeitgeber* or environmental cues that cause an entrainment or synchronization of the endogenous biological clock with the daily rotation of the earth**, is slightly ***greater than*** 24 h.





Michael Siffre loved geology, speleology, philosophy, and had a desire to investigate the mental and physical limits of human beings and our adaptive power by living for two months in **Scarasson Cavern**, which is located in the Provence-Alpes-Côte d'Azur in the southeast corner of France. In the cave, which was formed by water charged with carbonic acid (H_2CO_3) inside a subterranean glacier 375 feet underground, he was "*deprived of any points of reference in time and space.*" Siffre (1964) wrote, "*Living underground for a protracted period would mean being shut off from the daily cycle: there would be no setting sun to tell me that night was approaching.* ***I wondered to what extent*** *the* ***cosmic phenomena of night and day controlled our periods of sleep and activity****. In short, I wanted to investigate time—the most inapprehensible and irreversible thing. I wanted to investigate that*

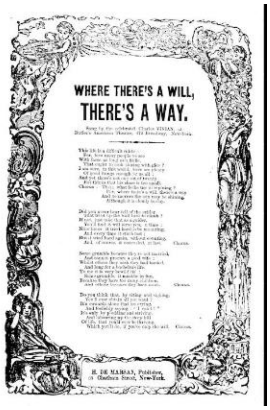




notion of time which has haunted humanity since its beginning. Perhaps time existed on three levels: that which is perceived, created by the brain, the result of conditioning to the twenty-four-hour cycle of night and day; biological time—a rhythm of activity-repose set up in the organism through the years; and objective time, measured by clocks." Siffre found that his **biological clock** continued to work in the absence of environmental cues, but psychologically, he broke down and became depressed.

Michael Siffre ended his book, *Beyond Time* with the following advice: "*As to what I learned personally from my experience, I can only repeat that if I survived the difficult conditions in which I voluntarily placed myself, it was mainly due to my* ***will power****, my passionate resolve to see the thing through, and not disappoint my collaborators not lose my self-respect. I was not out to break a record; it was not a physical exploit that I intended to bring off; it was an experiment with scientific aims that I wanted and was determined to perform, come what may. Years ago an American classmate ironically repeated a folk saying that children two generations ago were made to copy in their exercise books: '****Where there's a will, there's a way****.' I memorized it, for I sensed behind the words age-long experience. In my case, that simple truth was certainly proved more than once. And if other young fellows plan to embark upon an adventure such as mine, I can only advise them—at the risk of sounding like an old fogey—to school themselves daily in self control, which is a form of will power. Will power plays a part as important as, if not more important than, the careful choice of equipment and a rigorous course in physical training. I would tell young aspirants that, armed with this weapon, you can do a great deal; you can do anything*."

Where There's a Will There's a Way *by John Godfrey Saxe*



Is Learning your ambition?
There is no royal road;
Alike the peer and peasant
Must climb to her abode:
Who feels the thirst of knowledge
In Helicon may slake it,
If he has still the Roman will
"To find a way, or make it!"

Below are pictures of an older **Michel Siffre** in a cave in Texas, repeating and extending to six months, the experiment he performed in his twenties. (http://www.cabinetmagazine.org/issues/30/foer.php).



Another place where human beings are ***not*** exposed to any ***zeitgeber*** or environmental cues that cause an entrainment or synchronization of the endogenous biological clock with the daily rotation of the earth is the **Antarctic** in winter. During the autumn when the sun "rises" and "sets," the circadian rhythms of volunteers were entrained with the daily rotation of the earth and had a period of 24 hours. However, during the 126 days of winter that occurred between January 1987 and February 1988, the **natural, free-running periods** of the endogenous circadian clocks of four volunteers were 24 hours 29 minutes, 24 hours 45 minutes, 25 hours 7 minutes and 25 hours 14 minutes. The average **natural, free-running period** of the endogenous circadian clock was 24



hours 54 minutes, which is greater than the 24-hour daily rotation of the earth. (I will discuss the discovery of fossils in Antarctica in the next lecture.)



A Trident nuclear submarine such as the **USS Georgia** is another place where human beings are not exposed to the ***zeitgeber*** or environmental cues that cause an entrainment or synchronization of the endogenous circadian clock with the daily rotation of the earth. After submergence, synchronization of the endogenous clock, in terms of **salivary melatonin** levels, is lost. Here are data from two individuals, one with **a natural, free-running endogenous clock period** of 24.32 hours and one with **a natural, free-running endogenous clock period** of 24.75 hours. In both cases, there is a **phase shift,** and the peak of salivary **melatonin** occurs later and later. Again, the natural, free-running **period** of the endogenous biological clock is greater than 24 hours.

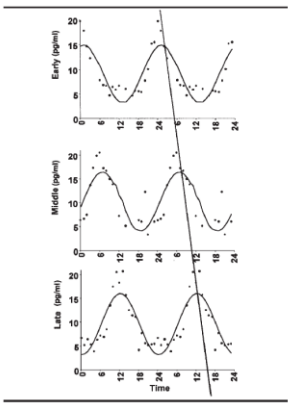


Figure 1. Double-plotted salivary melatonin data from a representative subject (105) working the 6/12 schedule. Top graph shows data collected at the start of the study, and the middle and lower graphs show data from about 3 weeks and 6 weeks later, respectively. The best-fitting cosinor is overlaid on each data set, and a line is drawn through the acrophases. Estimated tau = 24.32 h.

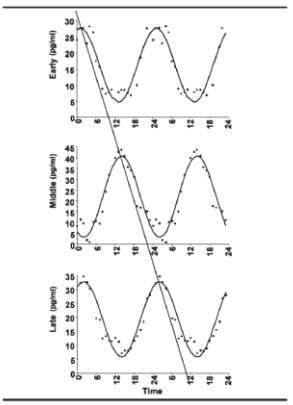


Figure 2. Double-plotted salivary melatonin data from a representative subject (110) working the 6/12 schedule. Top graph shows data collected at the start of the study, and the middle and lower graphs show data from about 3 weeks and 6 weeks later, respectively. The best-fitting cosinor is overlaid on each data set, and a line is drawn through the acrophases. Estimated tau = 24.75 h.



More recently, **Charles Czeisler** (left) et al. (1999) found that in humans living for one month in an environment free of any ***zeitgeber*** or environmental cues, the **natural, free-running period** of the endogenous circadian clock is typically **24 hours and 11 minutes**.

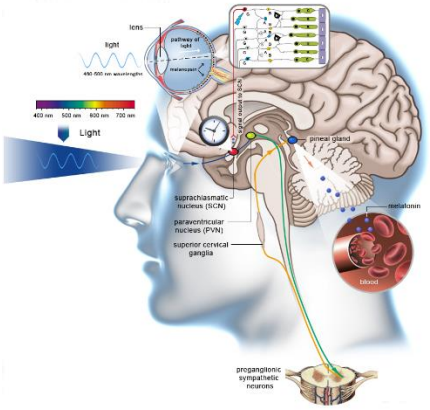
We have already seen that it was both **useful and simplistic** to consider eye color to be a dichotomous Mendelian trait that is controlled by one gene. Likewise, it is both **useful and simplistic** to consider the period of the endogenous biological clock to be identical among individuals.

Here is some actual data on the free-running period of the endogenous circadian clock determined from measurements of the rhythms of **core body temperature**, **melatonin levels in blood samples**, and **cortisol levels in blood samples** of individuals.

Table 1. Intrinsic periods of the temperature (τ_t), melatonin (τ_m), and cortisol (τ_c) rhythms (expressed as hours:minutes) in young and older subjects in the 28-hour forced desynchrony protocol. For each subject, the estimated period of each of the three rhythms lies within the 95% confidence interval of the other two rhythms. τ_t, τ_m, and τ_c were highly correlated [Pearson correlation: τ_t versus τ_m, $r = 0.951$; τ_t versus τ_c, $r = 0.982$; τ_m versus τ_c, $r = 0.984$ ($P < 0.0001$ in all cases)]. Our composite estimate of the intrinsic period for each subject (τ) was computed by averaging τ_t, τ_m, and τ_c, if available. Constraints on the total blood collection volume and vascular access limited the number of older subjects for whom cortisol and melatonin data were available; also, in two young subjects (1145 and 1257), an inadequate number of blood samples were collected and analyzed for cortisol concentrations to obtain a reliable estimate of circadian period.

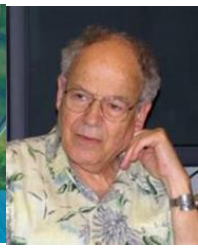
Subject	Age (years)	Sex	τ_t (±SD)	τ_m (±SD)	τ_c (±SD)	τ
Young subjects						
1105	25	M	24:16 ± :02	24:14 ± :05	24:17 ± :10	24:16
1106	21	M	24:14 ± :01	24:14 ± :02	24:18 ± :07	24:16
1111	22	M	24:17 ± :01	24:17 ± :03	24:19 ± :05	24:18
1120	25	M	24:08 ± :01	24:09 ± :01	24:10 ± :07	24:09
1122	23	M	24:09 ± :01	24:07 ± :02	24:08 ± :09	24:08
1133	23	M	23:53 ± :01	23:51 ± :03	23:52 ± :10	23:52
1136	22	M	24:09 ± :01	24:10 ± :04	24:13 ± :07	24:11
1144	23	M	24:15 ± :01	24:17 ± :01	24:18 ± :06	24:16
1145	30	M	24:09 ± :01	24:11 ± :04	–	24:10
1209	21	M	24:06 ± :01	24:05 ± :00	24:08 ± :01	24:07
1257	26	M	24:19 ± :02	24:23 ± :01	–	24:21
Range	21–30		23:53–24:19	23:51–24:23	23:52–24:19	23:52–24:21
Mean	23.7		24:10	24:11	24:11	24:11
±SD	2.7		00:07	00:08	00:09	00:08
±SEM	0.8		00:02	00:03	00:03	00:02
Older subjects						
1213	74	F	24:02 ± :02	–	–	24:02
1215	64	M	24:07 ± :07	24:01 ± :02	24:07 ± :08	24:05
1304	64	M	24:03 ± :03	24:09 ± :07	–	24:06
1319	67	F	24:10 ± :02	24:10 ± :04	–	24:10
1355	69	M	24:25 ± :02	24:25 ± :03	–	24:25
1366	66	M	24:28 ± :05	24:30 ± :03	–	24:29
1375	66	M	24:19 ± :02	24:20 ± :05	–	24:20
1458	67	M	24:09 ± :02	24:13 ± :03	–	24:11
1475	72	F	24:00 ± :03	24:04 ± :07	–	24:02
1485	65	M	24:06 ± :01	24:09 ± :05	–	24:07
1490	71	F	24:13 ± :02	–	–	24:13
14A6	65	M	24:04 ± :02	24:07 ± :02	–	24:05
1507	66	M	24:10 ± :03	–	–	24:10
Range	64–74		24:00–24:28	24:01–24:30		24:02–24:29
Mean	67.4		24:10	24:13		24:11
±SD	3.2		00:09	00:09		00:08
±SEM	0.2		00:02	00:03		00:02

Where is the endogenous biological clock? In mammals, probably including humans, the **primary** or **master** endogenous circadian biological clock is in the **suprachiasmatic nucleus (SCN)** of the **hypothalamus**.



The suprachiasmatic nucleus (SCN) is a group of about 50,000 cells in the **hypothalamus** of the brain that is dedicated to the time-keeping function (**nucleus**) above (**supra**) the **optic chiasm** where the optic nerves that come from both eyes cross.There are two suprachiasmic nuclei, one connected to each eye. The function of the suprachiasmic nucleus as the locus of the endogenous circadian clock has been demonstrated most conclusively with **ablation** (removal) and **transplantation** (replacement) experiments in **hamsters** performed by Martin Ralph and **Michael Menaker**.





Hamsters, like other rodents are **nocturnal**. They typically sleep during the day and are active at night. It is easy to measure the sleep-wake cycle of a hamster by connecting a monitor to an exercise wheel. Martin Ralph and Michael Menaker found that a typical hamster (A,B,C) has a sleep-wake cycle of 24.1 hours when it is exposed to a cycle of 14 hours of light and 10 hours of darkness. The active time on the wheel is during the dark period. They also found that when a typical hamster (A,B,C) is placed in continuous darkness, it more or less maintains its sleep-wake rhythm, with the active time on the wheel during the dark period. Then they found that abnormal hamsters (D,E,F) have a 22 hour sleep-wake cycle and ***cannot*** entrain or synchronize well with the light-dark cycle. They called the hamster with abnormal rhythm a *tau* (τ) mutant.

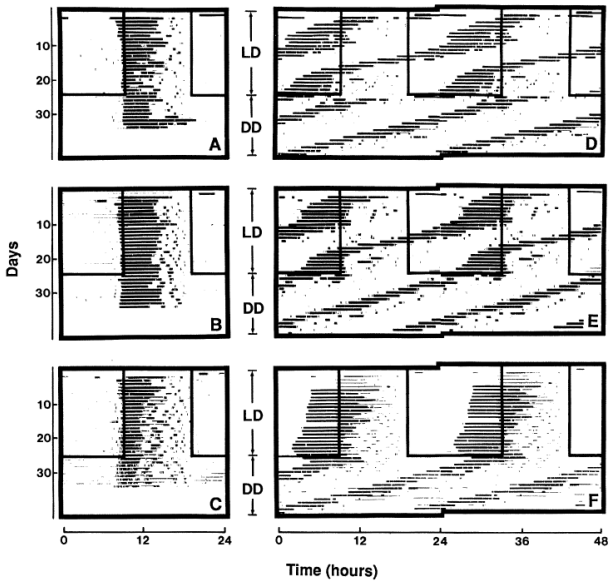


Fig. 1. Activity records (raw data) of six male F_1 littermates. Panels D to F are double plotted (as shown by the time axis). Boxes superimposed on each panel enclose the light portion (14 hours) of a light:dark cycle. LD, 14 hours of light in 100 lux; 10 hours of dark. DD, constant dark. Wheel running activity is indicated by the dark bands on each day.

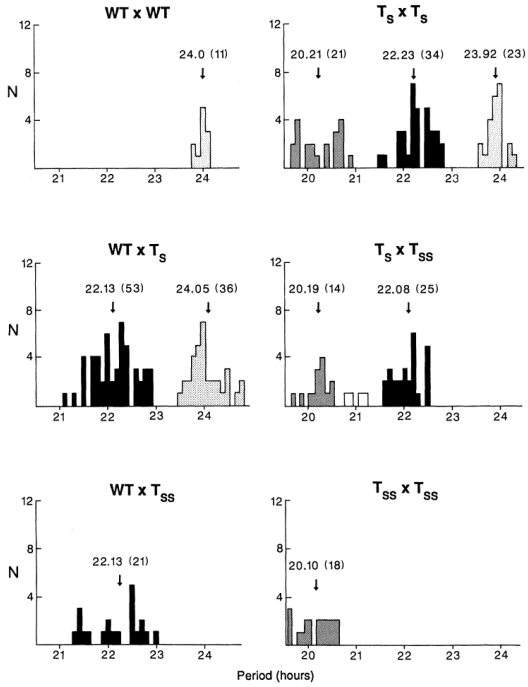


Fig. 2. Frequency distribution of τ from various crosses. After recording entrainment for 5 days, the animals were released into DD. Period was determined from the slope of a line fit by eye or regression analysis through the onsets of activity between day 4 and day 14 in DD. For statistical analysis, animals were assigned to particular groups on the basis of their phenotype: T_{ss} ($\tau \leq 21.00$ hours); T_s ($21.00 < \tau \leq 23.25$ hours); WT (23.25 hours $< \tau$). Our current data indicate that the ranges of the three groups do not overlap. Animals with τ values close to the extreme of the range for a group are routinely tested in backcrosses before genotype is inferred. Furthermore, many animals represented in this figure have been used in our breeding program, and in no case have the distributions of τ from their offspring indicated that we have been incorrect in assigning animals to a particular group. The four animals represented by the open histograms (in the $T_s \times T_{ss}$ panel) could not be assigned to a group based on phenotype alone and have not produced sufficient offspring to infer genotype; therefore, they have not been included in the statistical analysis. WT, wild type ($\tau \approx 24$ hours); T_s, putative heterozygote phenotype ($\tau \approx 22$ hours); and T_{ss}, putative homozygote mutant phenotype ($\tau \approx 20$ hours). Average τ for each group is indicated; number (n) of animals for each group is shown in parentheses; N is number of animals with a given free-running period.

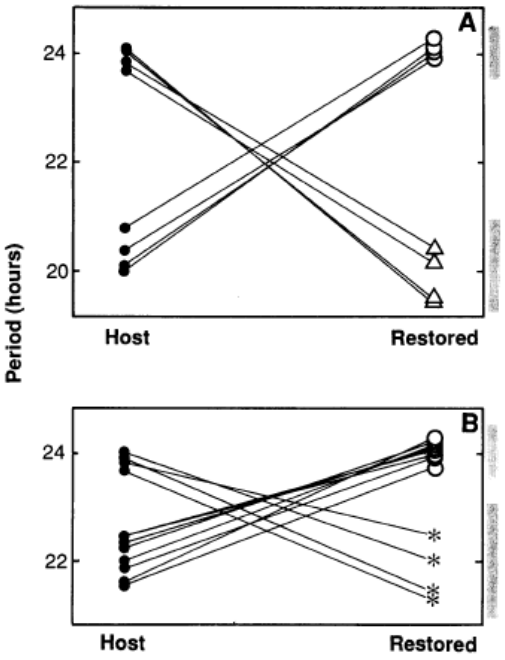
Martin Ralph and Michael Menaker also found that when a typical hamster is mated with an abnormal hamster, the ratio of hamsters with a 24.03 hour or a 22.31-hour sleep-wake cycle was 1:1, consistent with a mating of a wild type with a heterozygote if there is only a **single gene** that is not on an X chromosome that codes for the duration of the sleep-dark cycle. They also found that when two heterozygotes with 22.31-hour sleep-wake cycle were mated, the offspring were of three types: 24-hour, 22-hour and 20-hour

sleep-wake cycles, indicating that the abnormal hamsters with a 22-hour sleep-wake cycle have **one semi-dominant allele** at one locus and the abnormal hamsters with a 20-hour sleep-wake cycle have **two semi-dominant alleles** at that locus. Can you confirm Martin Ralph and Michael Menaker's conclusion using **Punnett squares**?

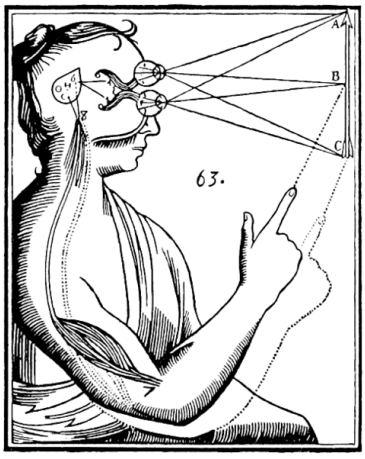
	W	W
W		
τ		

	W	τ
W		
τ		

The **suprachiasmatic nuclei** of a hamster can be ablated and replaced with the suprachiasmic nuclei of another hamster. **Reciprocal transplantion studies** between wild type hamsters with a sleep-wake cycle of 24 hours and homozygous tau hamsters (A) with a sleep-wake cycle of 20 hours, and reciprocal transplantation studies between wild type hamsters with a sleep-wake cycle of 24 hours and heterozygous tau hamsters (B) with a sleep-wake cycle of 22 hours show that the **sleep-wake cycle is controlled by the genetics of the cells of the suprachiasmatic nuclei**. This is good evidence that the suprachiasmic nuclei contains the circadian biological clock that regulates the sleep-wake cycle, but is the suprachiasmic nucleus the only biological clock in the hamster that regulates

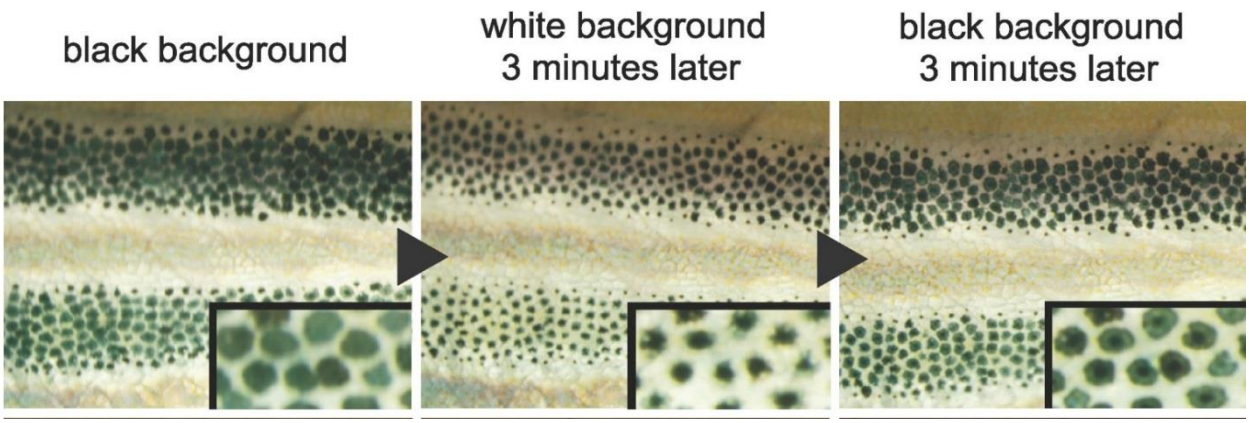


the sleep-wake cycle? Could there be other biological clocks in the hamster? Before we discuss other clocks, we will discuss how the endogenous biological clock in the suprachiasmic nuclei is entrained or synchronized by the daily **light-dark transition** with the 24-hour period of the daily rotation of the earth.



After more than two millenia of observations and research on vision and the eye, it was a surprise to learn in 1998 that **melanopsin**, a ***new*** photoreceptor pigment had been discovered in the retina. In order to follow the discovery of a new photoreceptor pigment, we have to take a detour and learn about the melanophores of cold-blooded animals. When we discussed eye color, we talked about the **melanocytes in the iris** that produced **melanin-containing melanosomes.** Melanin producing cells are now called **melanocytes in warm-blooded animals** and **melanophores in cold-blooded animals**. The melanophores in cold-blooded animals, including fish, reptiles, and amphibians allow the animals to **lighten or darken their skin tone** to **mimic** the **background** in order to **camouflage themselves**—a natural **optical illusion**.





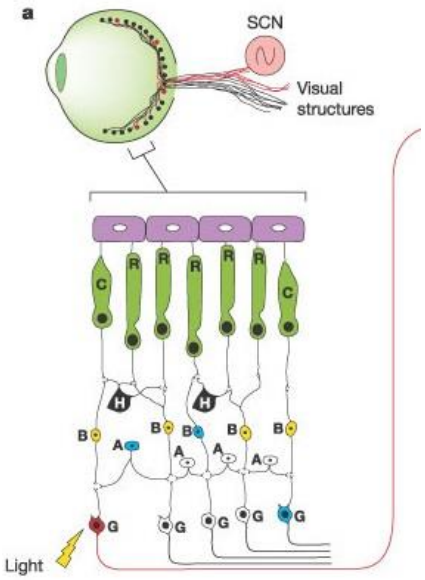


When the **melanosomes** in the **melanophores** in the skin of Zebrafish are **dispersed** throughout the cell, the melanophores in the **skin appear dark**. When the **melanosomes** in the **melanophores** in the skin of Zebrafish are aggregated in the cell, the melanophore in the **skin appears light** and the skin reflects the color of the cell beneath.

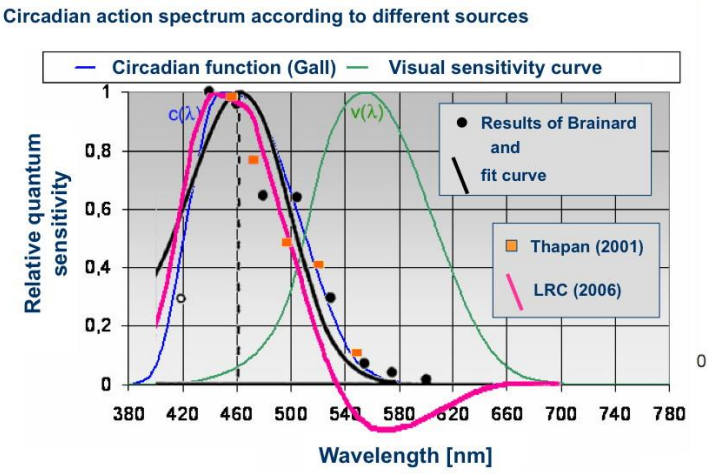
Ignacio Provencio discovered the gene for the **photoreceptor pigment** which he called **melanopsin** that controls the distribution of **melanin** in the **melanophores** of cold-blooded animals. Interestingly, a comparison of the amino acid sequence deduced from the nucleotide sequence of the melanopsin gene with the gene sequences of the visual opsins in rods (rhodopsin) and cones (photopsins) of vertebrates and the rhodopsins in invertebrates, including cephalopods and insects, shows that melanopsin of vertebrates is more closely related (**homologous**) to **invertebrate** rhodopsin (39% identity) than to **vertebrate** opsins (30% identity). How can you explain this in terms of the evolution of the eye? Common ancestry? Convergent evolution? Design?



Unexpectedly, Provencio et al. (1998) found messenger RNA transcripts that coded for melanopsin, not only in the **melanophores in the skin of tadpoles**, but also in the **suprachiasmic nuclei**, the **iris**, the **retinal pigment epithelium**, and in the **inner retina**. Two years later, Provencio et al. (2000) also discovered **melanopsin** in scattered cells in the **ganglion cell layer** of the **human retina**. The **intrinsically photosensitive retinal ganglion cells (ipRGC)**, which make up approximately 1-2% of the retinal ganglion cells, are connected directly through a bundle of neurons known as the **retinohypothalmic tract (RHT)** to the **suprachiasmatic nucleus (SCN)**. These clues suggest that light absorbed by **melanopsin** provides the ***zeitgeber*** to ensure the **endogenous biological clock** in the **suprachiasmic nuclei** is entrained by light, and thereby typically synchronized with the daily rhythm of the earth's rotation.



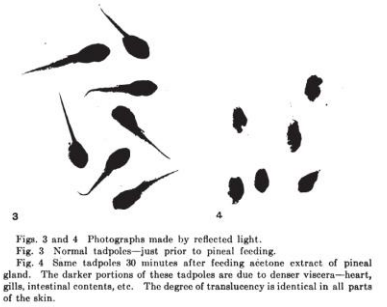
The **action spectrum** of the **synchronization signal** involved in synchronizing the endogenous biological clock with the daily rotation of the earth matches the **absorption spectrum of melanopsin** that has a peak around 460 nm and does ***not*** match the absorption spectrum of rhodopsin involved in rod-dominated scotopic vision, which has a peak around 498 nm, or the photopsins involved in cone-dominated photopic vision, which has a peak around 555 nm (S-420 nm, M-534 nm, L-564 nm).



How does the endogenous biological clock in the suprachiasmic nuclei regulate the sleep-wake cycle? How does light absorbed by melanopsin in the **intrinsically photosensitive retinal ganglion cells (ipRGC)** affect the sleep-wake cycle?

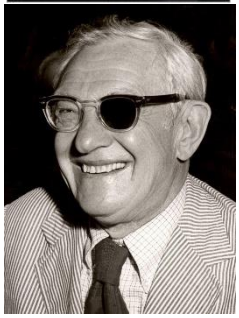
The **intrinsically photosensitive retinal ganglion cells (ipRGC)** are connected directly by the neurons in the **retinohypothalmic tract (RHT)** to the **suprachiasmatic nucleus (SCN)**. Likewise, the **suprachiasmatic nucleus (SCN)** is connected by neurons to the **pineal gland**, which secretes a **soporific known as melatonin** into the blood stream. In order to understand how melatonin got its name, we have to make another detour to discuss the melanophores in cold-blooded animals.

Melatonin got its name because it can cause the **melanosomes** in dermal **melanophores** of tadpoles to aggregate. Carey McCord and Floyd Allen (1917) fed **extracts of the pineal gland** of cows to tadpoles and found that thirty minutes later, the tadpoles became lighter in color. The extract had caused the aggregation of melanosomes in the dermal melanophores.



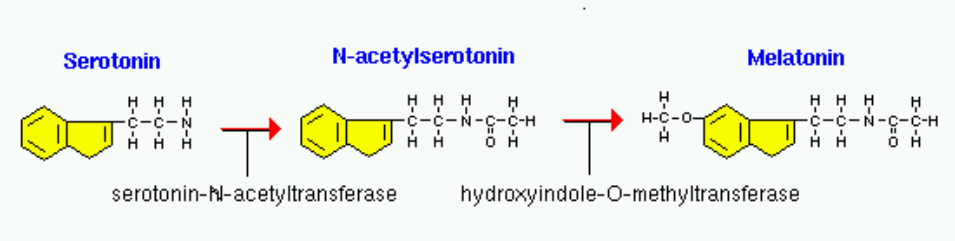
Figs. 3 and 4 Photographs made by reflected light.
Fig. 3 Normal tadpoles—just prior to pineal feeding.
Fig. 4 Same tadpoles 30 minutes after feeding acetone extract of pineal gland. The darker portions of these tadpoles are due to denser viscera—heart, gills, intestinal contents, etc. The degree of translucency is identical in all parts of the skin.





Noting that the **pineal extract** caused skin to lighten, **Aaron Lerner** (1958,1959,1960), a dematologist, and his colleagues repeated the work of McCord and Allen, isolated the chemical that lightened the frog's skin by causing the aggregation of melanosomes, determined the structure of the **frog skin-lightening chemical**, and named it **melatonin**. **Julian Axelrod**, who

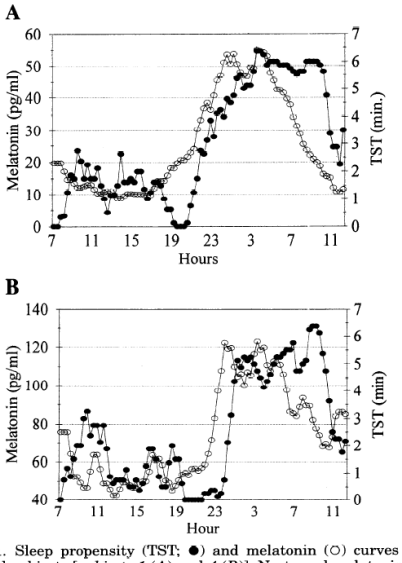
called himself a *late blooming biochemical neuroscientist*, discovered the enzymes that synthesized melatonin.





Unfortunately melatonin was not involved in causing skin-lightening conditions such as **vitiligo**. It does however seem to be involved in the **sleep-wake cycle** in humans, and melatonin had been given the nickname, the ***hormone of the darkness***. The levels of melatonin in the blood vary in a circadian fashion, **being low during daytime** and **high at night**. This rhythm persists for up to three weeks in individuals kept under very dim light conditions showing that **melatonin levels** in the blood are under the control of an **endogenous biological clock**.

Shochat et al. (1997) showed that an ***increase* in melatonin** in the blood **precedes sleepiness** as measured by a propensity to sleep and a ***decrease* in melatonin in the blood precedes wakefulness** as measured by a propensity not to sleep.



1. Sleep propensity (TST; ●) and melatonin (○) curves of 2 cal subjects [*subjects 1* (*A*) and *4* (*B*)]. Nocturnal melatonin rise decline precede the rise and decline in nocturnal sleep propen- Curves were smoothed by a 4-point moving average window.

Waldhauser et al. (1988) found that the **magnitude of the melatonin peak declines with age** which is correlated with the difficulty in sleeping that comes with aging.

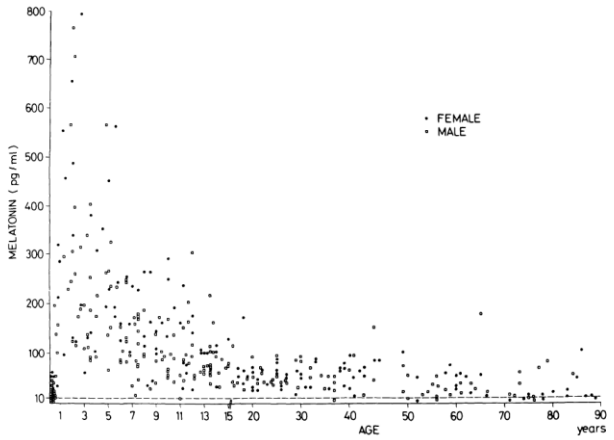


FIG. 1. Nightime serum MLT concentrations in 367 subjects (210 males and 157 females) aged 3 days to 90 yr. For conversion of MLT concentrations to SI units (nanomoles per L), multiply by 0.0043478.

Zeitzer et al. (2000) found that an 6.5 hour **exposure to as little as 106 lux of white light** during early biological night **delays the secretion of melatonin into the blood**. Higher intensities (9100 lux) suppress the secretion of melatonin into the blood during the exposure and delay it when the light is turned off. Rüger et al. (2013) found that as little as 11.2 lux of 480 nm **blue light** was as effective as 10,000 lux white light, indicating that the photoreceptor pigment responsible for melanin suppression and delay is sensitive to blue light, as is true of melanopsin. Here are examples of illuminance in lux under various conditions. 11.2 lux is ***about*** the brightness of twilight.

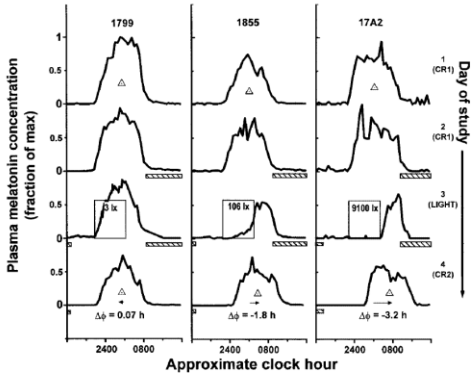
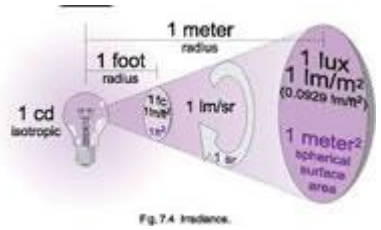


Figure 1. Phase shift of the human circadian pacemaker and acute suppression of plasma melatonin
Melatonin profiles during days on which the first constant routine (CR) (1 and 2), the single experimental light exposure 6·5 h in duration (3), and the second CR (4) occurred are shown for three representative subjects (1799, 1855, 17A2). In the dimmest light condition, exposure to the dim light stimulus (~3 lx) had little effect on either the phase of the melatonin rhythm (phase shift ($\Delta\phi$) 0·07 h) or concentration of plasma melatonin (suppression 11 %). In the brightest light condition (~9100 lx), light both shifted the rhythm ($\Delta\phi$ −3·2 h) and completely suppressed plasma melatonin (98 %). Exposure to dim room light (~106 lx) evoked more than half of the shift observed in the brightest light condition ($\Delta\phi$ −1·8 h compared with −3·2 h) and a nearly equal amount of suppression (88 %). During the CRs and day of experimental light exposure, subjects were exposed to no more than 5 lx in the horizontal angle of gaze at any time except during the scheduled sleep episodes (hatched bars < 0·03 lx) and the experimental light exposure (labelled open boxes, see Fig. 2). Individual subject data were plotted on a time scale in which their habitual wake time was assigned a reference value of 08.00 h. Phase of the melatonin maximum (midpoint of the upward and downward mean crossings) during each CR is noted as the △. For graphical purposes, ordinate values were normalized to each subject's absolute peak plasma melatonin concentration.

Condition	Illumination	
	(ftcd)	*(lux)*
Sunlight	10,000	107,527
Full Daylight	1,000	10,752
Overcast Day	100	1,075
Very Dark Day	10	107
Twilight	1	10.8
Deep Twilight	.1	1.08
Full Moon	.01	.108
Quarter Moon	.001	.0108
Starlight	.0001	.0011
Overcast Night	.00001	.0001

Lux is a **photometric unit** that measures the **brightness** of a light as perceived by the human eye with photopic cone-dominated vision. One lux is equal to **one lumen per meter squared**. Free apps are available to turn smartphones into lux meters (https://play.google.com/store/apps/details?id=com.notquitethem.android.luxmeter and https://itunes.apple.com/us/app/luxmeter/id526675593?mt=8).





Demonstration: Use the Digital Lux Meter to measure the brightness of the light in the classroom in foot candles or in lux and to get an idea of different brightnesses in terms of lux. One lux is equal to 0.0929 footcandles, the brightness of a standard spermaceti candle at one foot. Light meters that measure the brightness of light absorbed by melanopsin or **melanopic-lux** are being developed.

The timing of the light pulse, in addition to its spectral composition, its intensity, and its duration, is important to know. A light pulse given near the beginning of the sleep period **delays the phase** (starting point) of the sleep-wake cycle making you less sleepy while a light pulse near the end of the sleep period **advances the phase** (starting point) of the sleep-wake cycle making you more awake. This can be visualized in a **phase-response curve**. Our response to light does ***not*** only depend on the physical quantities of light but also on when the light is given relative to the phase of our endogenous biological clock.

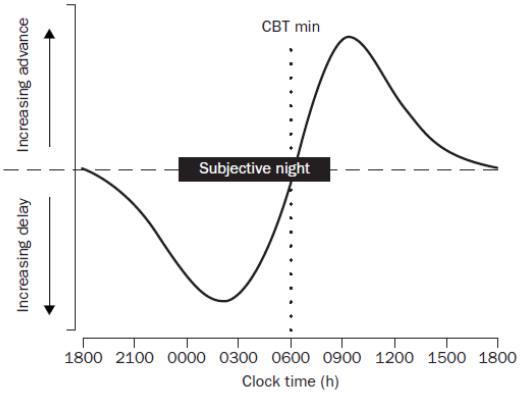
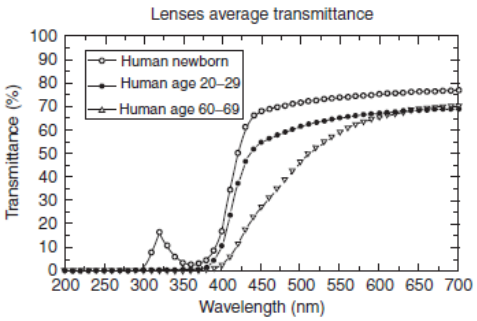


Figure 2: **Phase response curve (PRC) of a human being, in response to light**

Aside: Brainard et al. (1997) found that **aging** is also correlated with a **yellowing of the crystalline lens** which blocks the transmission of the blue light that suppresses melatonin.



Sleep disturbances that are associated with desynchronization of the melatonin rhythms with the daily rotation of the earth can sometimes be ameliorated by **taking exogenous melatonin at the correct time**. The effectiveness of melatonin treatment seems to be variable—perhaps as a result of individual variability in the cycles and in part due to the lack of attention paid to timing—when in an individual's cycle one should take exogenous melatonin. An awareness and understanding of our **biological time** is especially important in our **24-hour society** (Rajaratnam and Arendt, 2001). Josephine Arendt (2000) wrote in *The New England Journal of Medicine*, "*the true potential of melatonin is becoming evident, and* ***the importance of the timing of treatment is becoming clear. Our 24-hour society, with its chaotic time cues and lack of natural light, may yet reap substantial benefits***."



Perhaps instead of taking **exogenous melatonin**, we can control the light around us to modulate the production of **endogenous melatonin** so we can sleep better. **Amber** bulbs and nightlights, blue-blocking filters for smartphones and tablets, and glasses that block blue light may be helpful at bedtime (https://www.lowbluelights.com/index.asp; https://www.lowbluelights.com/media/19552.mp3; Burkhardt and Phelps, 2009). It is also possible to get a free app that adjusts the **color temperature** of the displays of smartphones and tablets to the time of day—warm at night, like sunlight during the day (http://justgetflux.com/).



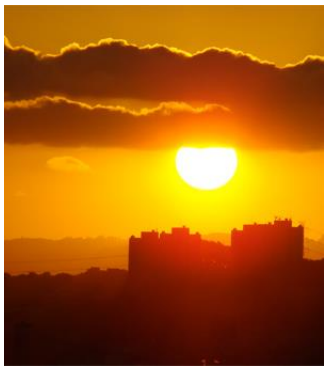
The **Yin-Yang** symbol, which shows the sun and moon embracing signifies opposites such as day and night, light and dark.







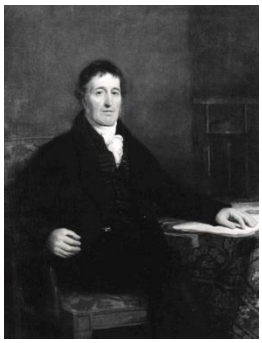
Eva Schernhammer and Abraham Haim have correlated **light at night** (LAN) that causes **circadian disruption** in the workplace and in the bedroom to increased risk of **breast cancer**.



Perhaps it is a good time to remember that throughout most of human history, **sunlight** (supplemented at night with firelight) was the ***zeitgeber*** that entrained and synchronized the sleep-wake cycle with the daily rotation of the earth. The firelight evolved into light from an **oil lamp** about 4500 BC and then light from a **candle** about 3000 BC. Although the technology of artificial light improved, there was a cost to using it and so it was used frugally. In London in 1417, in Paris in 1524, and in Dublin in 1616, it became required by law to put a candle in the window of houses facing the street. Then came gas steet lighting.

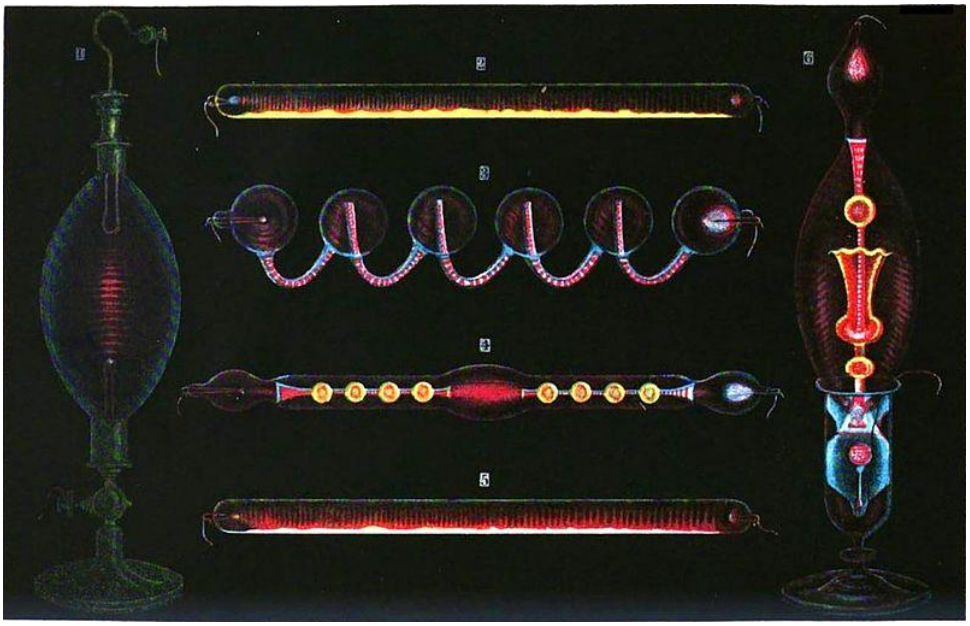
Up until 1802, coal had only been used to power steam engines. In 1802, **William Murdoch** used the coal gas produced by heating coal to produce the first outdoor gaslight. The streets of London were lit by gaslight in 1807; the streets of





Baltimore were lit by gaslight in 1816, the streets of Paris were lit by gaslight in 1829, and the streets of **Montreal** were lit in 1837.

Heinrich Geissler invented the electric arc lamp in 1857. It was a partially evacuated gas containing glass cylinder with a metal electrode at each end.When a high voltage was applied to the electrodes, an electrical current flowed through the tube, dissociating electrons from the gas molecules. When the electrons recombined with the ions, fluorescent light was emitted. The color of light depends on which atoms were in the tube.



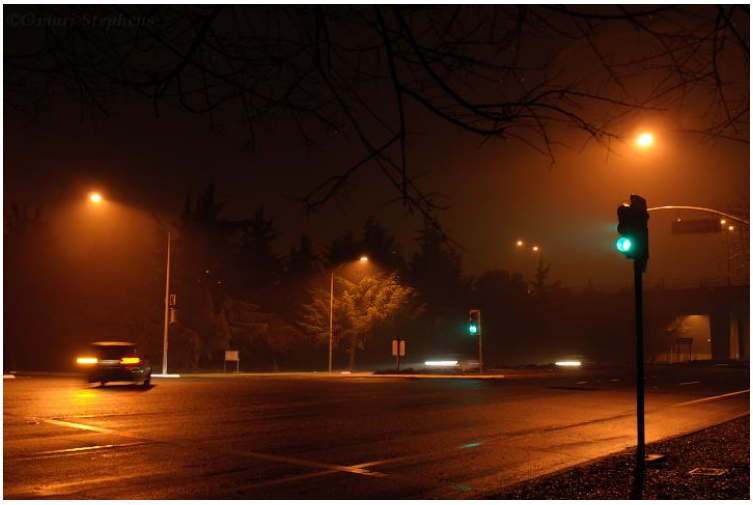
Electric arc lamps replaced gaslights along the streets of Paris and London in 1878 and incandescent electric street lights were intoduced along streets in Newcastle-upon-Tyne and in Cleveland, Ohio in 1879. Georges Calude invented the **neon light** in 1910 and since that time it has been used to illuminate colorfully



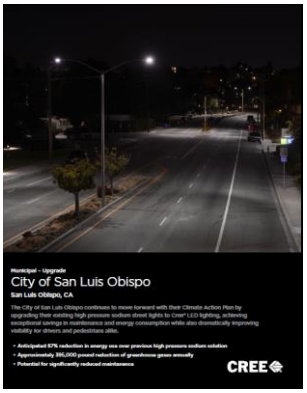


the streets in many cities, including **Times Square** in New York City and **Shibuya** in Tokyo Japan.

High Pressure Sodium vapor lamps that illuminate the streets monochromatically were introduced as street lights in 1964. The light spectrum of these lamps does ***not*** match the absorption spectrum of melanopsin and thus does not disrupt circadian rhythms.



Luminescent cold lights such as light emitting diode (LED) lamps are being introduced for street lights. They reduce the amount of energy needed to get a given amount of brightness, although the full spectrum LEDs are more disruptive to our circadian rhythms than the yellow high pressure sodium lights. Phosphorescent particles are being introduced into roads and paths.









This path, is inspired by Van Gogh's Starry Night
https://studioroosegaarde.net/project/van-gogh-path

Satellite images from space show that some regions of the world are exposed to perpetual daylight—a form of **light pollution**. Other regions experience **light poverty**.



Sara Pritchard (STS, Cornell) edited a special issue of Journal of Energy History on light and darkness, particularly as it relates to light pollution: https://energyhistory.eu/en/special-issue/lights-and-darknesses-looking-back-looking-forward



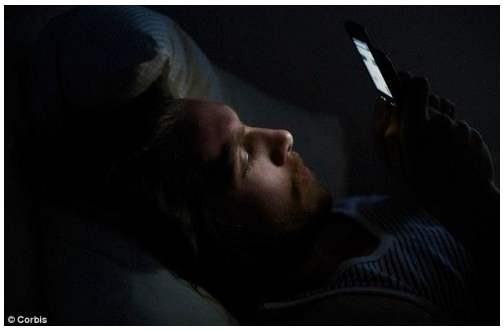
Light pollution makes it seem like the sky has become emptied of stars. Light out of place or glare due to misdirected light makes it difficult to see astronomical objects such as the **Milky Way** even in rural areas such as Ithaca.

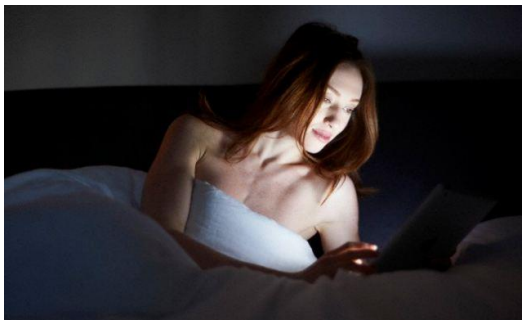


Intelligent street lighting, produced by Tvilight, uses motion sensors to brighten LED lamps only when they are needed. The use of intelligent street lighting saves energy and reduces light pollution.



And with our modern urbanized sleeping habitat, the perpetual daylight from artificial light came indoors:





And the light from smartphones and tablets at bedtime may reduce or delay the production of melatonin. Wood et al (2013) found that a two hour exposure to the blue light produced by an iPad reduces the salivary melatonin levels by 23%.

Table 1
Lighting conditions (photopic illuminance in lux and CL_A measured with the Dimesimeter), predicted melatonin suppression (CS) and measured melatonin suppression after 1-h and 2-h exposures. Mean ± standard error of the mean (SEM) values are shown.

		Photopic illuminance (lux)	CL_A	CS[b]	Measured suppression (%)
1 h	Tablet + blue LEDs	59 ± 5.0	648 ± 4.9	0.46 ± 0.0013	48 ± 4
	Tablet + orange-tinted glasses[a]	9.8 ± 1.9	1.5 ± 0.31	0.0017 ± 0.0004	NA
	Tablet-only	18 ± 3. 8	19 ± 4.6	0.03 ± 0.0066	7.0 ± 4
2 h	Tablet + blue LEDs	57 ± 3.8	645 ± 3.4	NA	66 ± 4
	Tablet + orange-tinted glasses[a]	9.9 ± 1.6	1.5 ± 0.29	NA	NA
	Tablet-only	16 ± 2.7	17 ± 3.51	NA	23 ± 6

NA: not applicable.
[a] The tablet with the orange-tinted glasses condition was used as the dark control.
[b] Based upon a 1-hr duration of light exposure and a 2.3 mm pupil diameter.

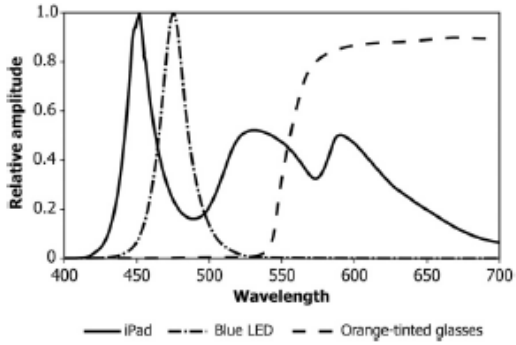
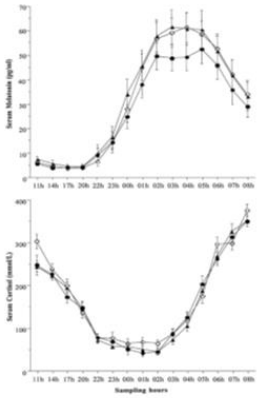


Fig. 1. Spectral transmittance of the orange-tinted glasses, the relative spectral power distribution (SPD) of a 470-nm (blue) LED, and the relative SPD of an iPad 1 (white screen, full brightness) used in the experiment.

Melatonin is not the only hormone whose levels in the blood change in a circadian manner. **Cortisol** levels also change in a circadian manner (Selmaoui and Touitou, 2003). While the levels of melatonin are correlated with sleepiness, the levels of cortisol are correlated with **wakefulness**. Since cortisol is also a hormone produced in stressful situations, **chronic stress** results in a constant production of cortisol and interferes with the ability to sleep.



Vitamin D, also known as the sunshine vitamin, is produced by the body in response to sunlight and is necessary for normal bone development. However, vitamin D is also a steroid **hormone** that can have significant effects on the body as a result of the variety of vitamin D receptors in the brain. As a result of spending less time in sunlight, more and more people are developing vitamin D deficiencies and the deficiencies are correlated with sleep disorders (Gominak and Stumpf, 2012). While studying people with headaches, Gominak serendipitously found that people who took vitamin D supplements were able to wake up rested. It seems that vitamin D reduces the level of melatonin in the body. The levels of vitamin D, like the levels of cortisol, are correlated with **wakefulness** and the **day-like physiological state**. Thus, when vitamin D supplements are taken at night,

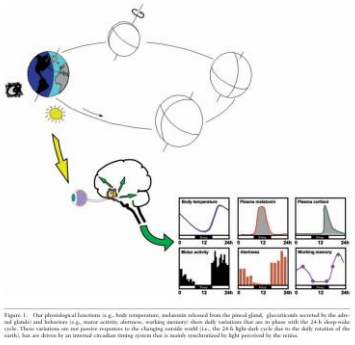
they prevent sleepiness while the same supplements taken in the morning increase wakefulness.

Anti-histamines often cause sleepiness, which led researchers to check if the hormone **histamine** changes in a circadian fashion (Brown et el. 2001). The levels of histamine, like the levels of cortisol, are correlated with **wakefulness** and the **day-like physiological state**.

Anti-diuretic hormone also varies in a circadian manner. It is highest at night so that our sleep in not interrupted by the urge to urinate.

The **Lighting Research Center at Rensselaer Polytechnic Institute** (http://www.lrc.rpi.edu/programs/lightHealth/index.asp) researches questions about light, health, and circadian rhythms.

Just as there is more than one chemical that regulates sleep, there may be **more than one endogenous biological clock**. Tosini and Menaker (1996) have shown that retinas isolated from hamsters have a circadian rhythm of melatonin synthesis and the period of the rhythm depends on the genotype. Retinas from wild type hamsters have a 24-hour period while retinas from homozygous tau mutants have a 21-hour period.



In conclusion, we have a **primary endogenous biological clock** in our brain and perhaps secondary endogenous biological clocks elsewhere that regulate the **sleep-wake cycle** by rhythmically releasing hormones such as **melatonin** and **cortisol** into our blood stream that affect when we go to sleep and wake up. Our endogenous biological clock can be naturally reset by sunlight as a ***zeitgeber*** so that it is entrained or synchronized with the daily rotation of the earth.

Melatonin does not induce sleepiness in all organisms since in **nocturnal** organisms the levels of melatonin also rise during the dark period, which is the active period in nocturnal organisms. In general, **melatonin signals the dark period**, and when the melatonin level is high, diurnal organisms get sleepy and nocturnal organisms awaken.

Exposure to bright light, particularly in the blue region of the spectrum, which is absorbed by **melanopsin** in the **intrinsically photoreceptive retinal ganglion cells (iPRGC)**, **resets the phase** of the endogenous clock, which regulates the timing of **melatonin** and **cortisol** release and the sleep-wake cycle so that they are no longer synchronized with the daily rotation of the earth. We can increase the amount of melatonin produced during the sleep period by avoiding bright blue light that acts as a ***zeitgeber*** before bedtime. On the other hand, bright blue light during the day increases our level of wakefulness.

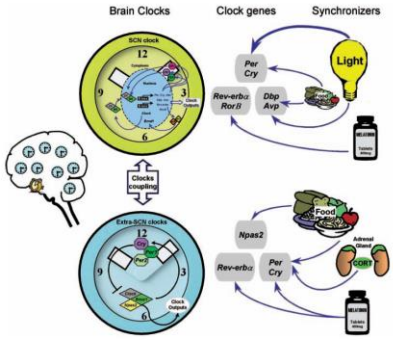
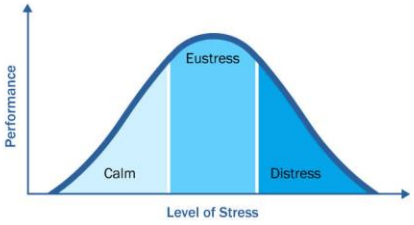


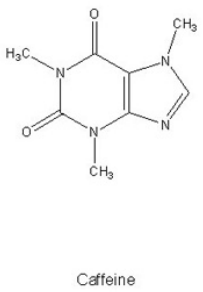
Figure 5. There are many cerebral clocks with diverse clockworks and synchronizers. Light is the major synchronizer for the SCN clock, leading to activation of transcription of *Per* genes. Other cues, such as food and melatonin, can also have synchronizing or modulating effects on the SCN clock. On the other hand, feeding cues are powerful synchronizers for most extra-SCN clocks via changes of *Per* and *Npas2* expression. Corticosterone (CORT) and other glucocorticoids secreted by the adrenal glands can affect the timing of brain oscillators expressing high density of glucocorticoid receptors like the amygdala or the hippocampus. Melatonin drives the rhythmic expression of clock genes in the pars tuberalis of the adenohypophysis.

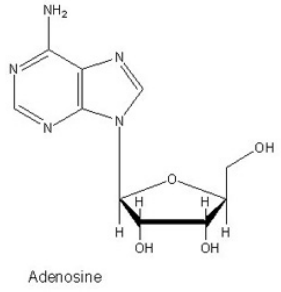
Cortisol levels are correlated with wakefulness, and we can decrease the nighttime levels of cortisol by managing our **stress levels** and quality of stress. We want no stress at night and **eustress** not **distress** during the day.

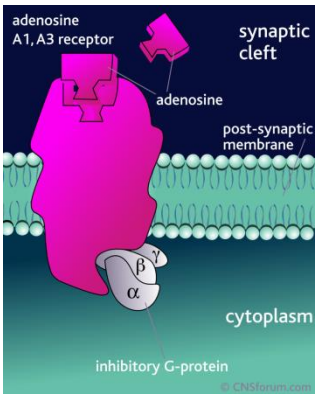


Coffee and **tea**, which contain caffeine, help make us alert during the day and make it harder to sleep at night. **Caffeine** increases our level of wakefulness not by interacting with the endogenous biological clock but by inhibiting the binding of **adenosine** to the **adenosine receptors** in the forebrain and hippocampus that when activated by adenosine, sedate the brain and cause sleepiness. When adenosine binds to the adenosine receptor, it sedates the brain by inhibiting the release of all neurotransmitters into the synapses.



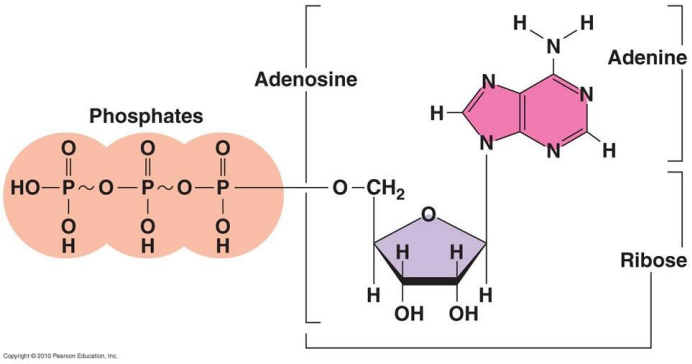








The buildup of adenosine comes from the breakdown of **adenosine triphosphate (ATP)** that occurs through **physical activity**. ATP is resynthesized from adenosine during sleep periods where the level of physical activity is low.



It is common sense and there is evidence from the National Sleep Foundation (http://sleepfoundation.org/) that the synchronization of the endogenous biological clock with the daily rotation of the earth results in a rested, happy, and healthy person. Indeed, **Benjamin Franklin** (1746), the son of a tallow chandler who would make money if people stayed up late, wrote, "*Early to bed and early to rise, makes a man healthy, wealthy, and wise.*" Christopher William Hufeland (1797) wrote in ***The Art of Prolonging Life***, "*That period of twenty-four hours, formed by the regular revolution of our earth, in which all its inhabitants partake, is particularly distinguished in the physical economy of man…It is, as it were, the unity of our natural chronology*."

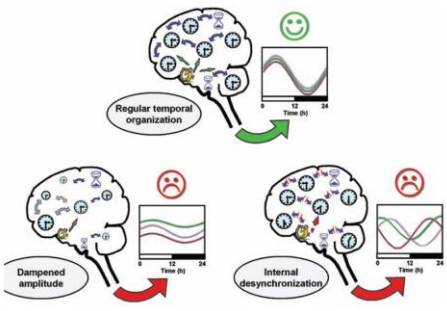


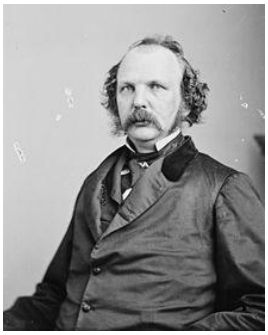
Figure 7. A regular 24-h temporal organization is thought to be important for good health. Dampening in the amplitude of circadian oscillations can affect the main SCN clock and/or some other brain clocks. Internal desynchronization can occur between brain oscillators and the SCN clock or between all of them. Dampened amplitude of circadian oscillations or internal desynchronization within the brain both lead to altered circadian organization that may have major impacts on health.





John Godfrey Saxe wrote, *Early Rising*.

"God bless the man who first invented sleep!"
So Sancho Panza said and so say I;
And bless him, also, that he didn't keep
His great discovery to himself, nor try
To make it,—as the lucky fellow might—
A close monopoly by patent-right.



T. Boone Pickens says, "*I try to live by one simple rule. Work eight hours and sleep eight hours, and make sure they are not the same eight hours*." Other Booneisms: https://boonepickens.com/?page_id=1283



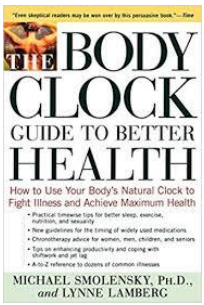
Isaiah (52:1) reminded the Hebrews to "*Awake, awake*", a theme that is repeated throughout the Bible.



Watch a great teaching movie on biorhythms made by Eric Bittman: https://srbr.org/about-chronobiology/chronohistory/a-teaching-video-on-biological- rhythms/



The human body varies throughout the day, and it is possible that the timing of some medical conditions and life-threatening emergencies may depend on the biological clock. Michael Smolensky (a student of Franz Halberg) and Lynne Lamberg (2000) tell us that like the crocodile in *Peter Pan*, we carry a clock around inside of us. They suggest that we become aware of our **body clock** or **body time**. It turns out that certain diseases and dysfunctional symptoms appear at specified times during the circadian cycle. Moreover, it may also be better to take some medications at certain times of day to increase effectiveness and reduce side effects. **Chronomedicine** takes the body clock into consideration.



In terms of our body clock, there are the best of times and the worst of times:

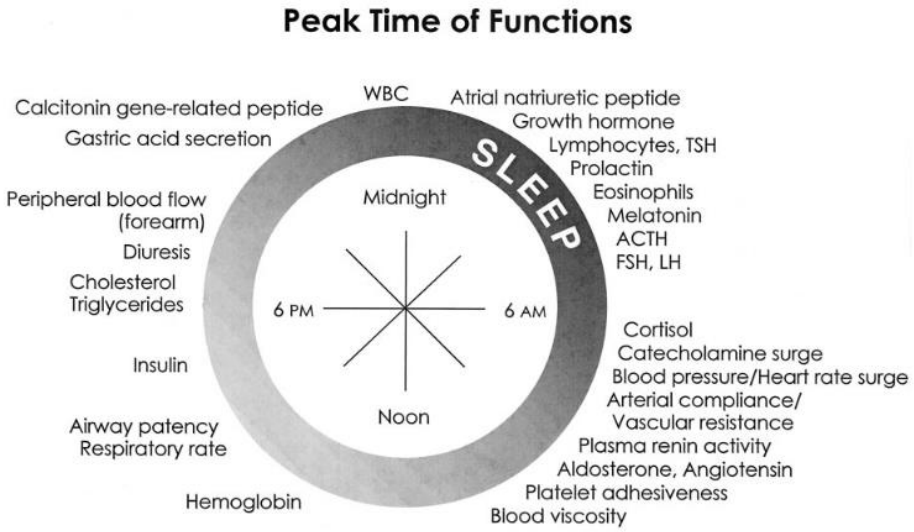
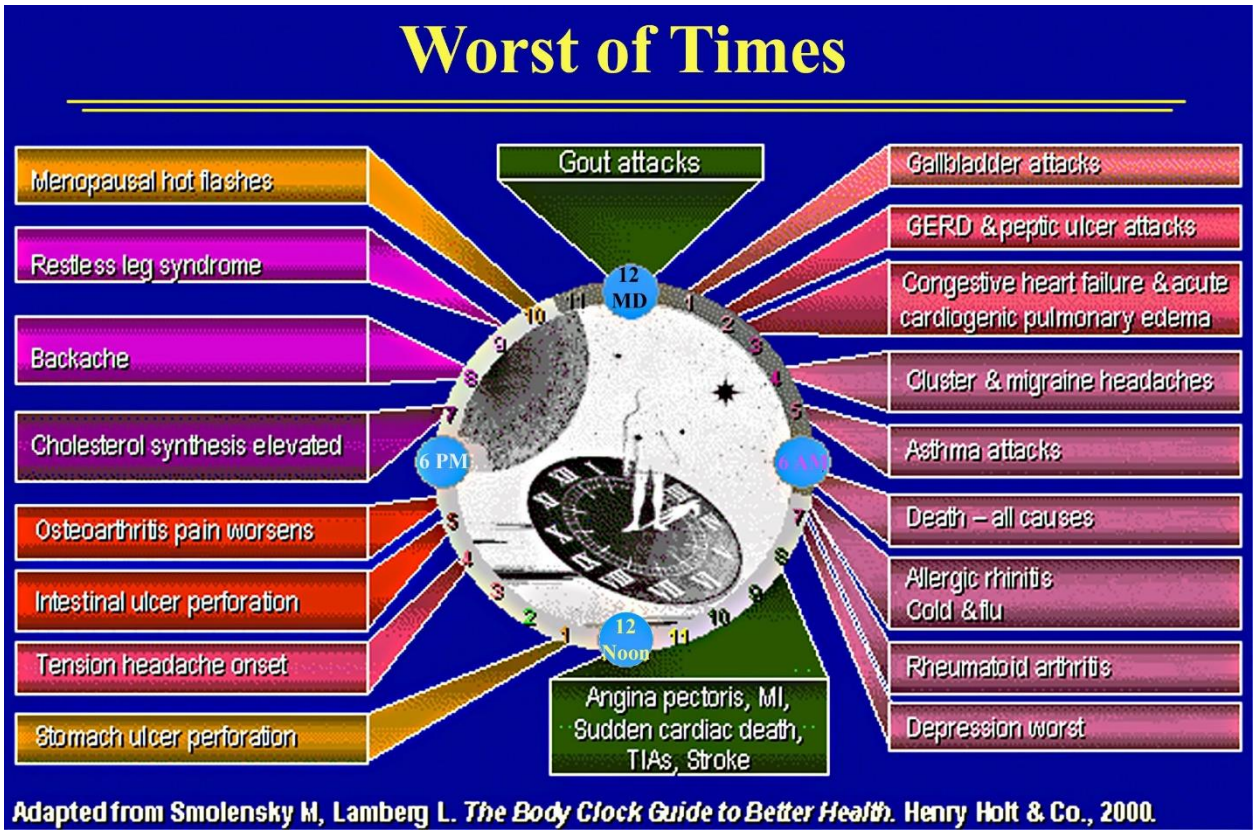
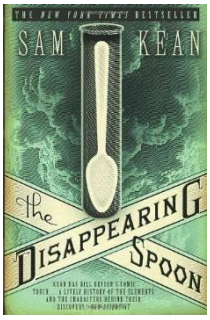


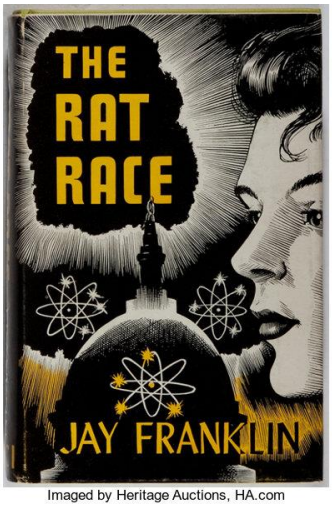
FIG. 1. Clock-like illustration of the organization of the circadian time structure shown by the peak time location of selected rhythms relative to the sleep (10:30 PM to 6:30 AM) activity (6:30 AM to 10:30 PM) routine of healthy persons. ACTH = adrenocorticotropic hormone; FSH = follicle stimulating hormone; LH = luteinizing hormone; TSH = thyroid stimulating hormone; WBC = white blood cells. Modified with permission from Patient Care. Medical Economics for Smolensky MH, Bing ML: Chronobiology and chronotherapeutics in primary care. Patient Care Clin Focus 1997;31(Summer Suppl):1–15.[19]





Bipolar disorder may in part be due to a disconnection from the circadian rhythm reset daily by the sun. As described by Sam Kean in *The Disappearing Spoon and other True Tales of Madness, Love, and the History of the World from the Periodic Table of the Elements*, **lithium** may treat bipolar disorder by synchronizing the various biological clocks in a person.

Thinking about time brings us the concept of "The Rat Race"



Imaged by Heritage Auctions, HA.com

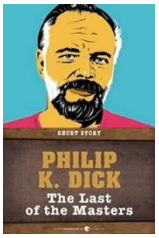
The Rat Race was used as a title for a novel written by Jay Franklin in 1947 for Colliers Magazine and first published in book form in 1950. It is dedicated *To those few rats in Washington who do not carry brief-cases.*



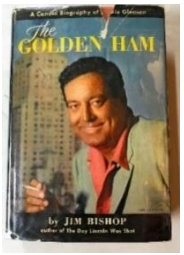
The term "rat race" was used in an article about Samuel Goudsmit published in 1953 entitled: *A Farewell to String and Sealing Wax~I* in which Daniel Lang wrote, *Sometimes when his sardonic mood is on him, he wonders whether the synchrotrons, the betatrons, the cosmotrons, and all the other contrivances physicists have lately rigged up to create energy by accelerating particles of matter aren't playing a wry joke on their inventors. "They are accelerating us too," he says, in a voice that still betrays a trace of the accent of his native Holland. In protesting against the speedup, Goudsmit can speak with authority, for in the course of only a few years, he, like many other contemporary physicists, has seen his way of life change from a tranquil one of contemplation to a rat race.*


Dr. Samuel A. Goudsmit

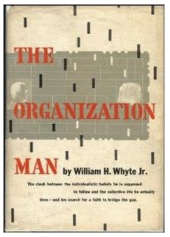
Philip K. Dick used the term in *The Last of the Masters* published in 1954: *"Maybe," McLean said softly, "you and I can then get off this rat race. You and I and all the rest of us. And live like human beings." "Rat race," Fowler murmured. "Rats in a maze. Doing tricks. Performing chores thought up by somebody else." McClean caught Fowler's eye. "By somebody of another species."*



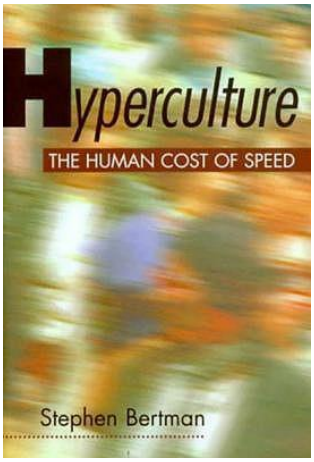
Jim Bishop used the term rat race in his book *The Golden Ham: A Candid Biography of Jackie Gleason.* The term occurs in a letter Jackie Gleason wrote to his wife in which he says: *Television is a rat race, and remember this, even if you win you are still a rat.*



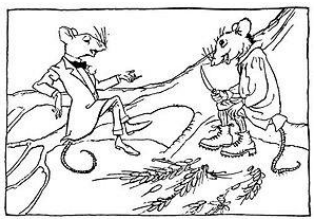
William H. Whyte used the term rat race in *The Organization Man*: "*The word collective most of them can't bring themselves to use—except to describe foreign countries or organizations they don't work for—but they are keenly aware of how much more deeply beholden they are to organization than were their elders. They are wry about it, to be sure; they talk of the "treadmill," the "rat race," of the inability to control one's direction*."



According to Stephen Bertman, in his *Satires* (II:6), Horace (1st century BC) compared citified life to a "rat race." Here is Horaces' retelling of Aesop's (620-564 BC) fable in *The Country Mouse and the Town Mouse*:

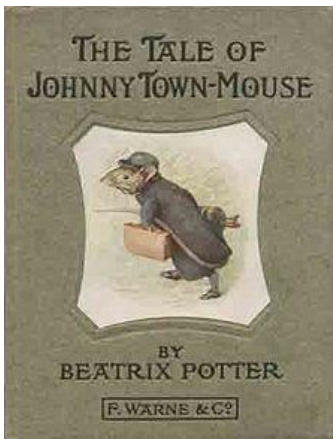


Now and then Cervius my neighbour spins us a yarn,
Some apt old woman's tale. So, if anyone praised
Arellius' wealth but ignored his cares, he'd begin:
'It's said a country mouse welcomed a town mouse once
To his humble hole, the guest and the host were old friends:
He lived frugally, and was careful, but his spirit
Was still open to the art of being hospitable.
In short, he never grudged vetch or oats from his store,
And he'd bring raisins or pieces of nibbled bacon
In his mouth, eager by varying the fare to please
His guest, whose fastidious tooth barely sampled it.
At last the town mouse asks: 'Where's the pleasure, my friend,
In barely surviving, in this glade on a steep ridge?
Wouldn't you prefer the crowded city to these wild woods?
Come with me, I mean it. Since all terrestrial creatures
Are mortal, and there's no escape from death for great
Or small, then live happily, good friend, while you may





Surrounded by joyful things: mindful while you live
How brief existence is.' His words stirred the country mouse,
Who scrambled lightly from his house: then the two
Took their way together as proposed, eager to scurry
Beneath the city walls in darkness. And now night
Occupied the zenith, as the pair of them made tracks
Through a wealthy house, where ***covers dyed scarlet***
Glowed on ivory couches, and baskets piled nearby
Held the remains of all the courses of a magnificent
Feast, that had been celebrated the previous evening.
Once the town mouse had seated the country mouse
Amongst the purple*, he rushed about like a waiter,*
The host serving course after course, performing the role
Himself, and not unlike a slave first tasting what he served.
The country-mouse at ease enjoyed the change of style,
Playing the contented guest amongst all the good things,
When suddenly a great crashing of doors, shakes them
From their places. They run through the hall in fear, stricken
By greater panic when the high hall rings to the barking
Of Molossian hounds. Then says the country-mouse: 'This
Life's no use to me: and so, farewell: my woodland hole,
And simple vetch, safe from such scares, they'll do for me.'



Remember talking about **heliotropism** in sunflower where the non-flowering plant faces the rising sun (east) in the morning, tracks the sun during the day, faces the setting sun (west) in the evening and then rotates to meet the rising sun (east) in the morning? Varying light direction is necessary to "train" the plants but the plants soon develop a "habit." That is, the direction they face is independent of the direction of the sun. Shibaoka and Yamaki (1959) and Atamian et al. (2016) found that when they rotated a plant 180° at noon (arrow) the plant faced east in the evening, and every other evening and west in the morning and every other morning for four days. Thus ,once the plant developed the "habit" the direction the plant faced depended on an entrained endogenous circadian rhythm and not on the direction of the sun.

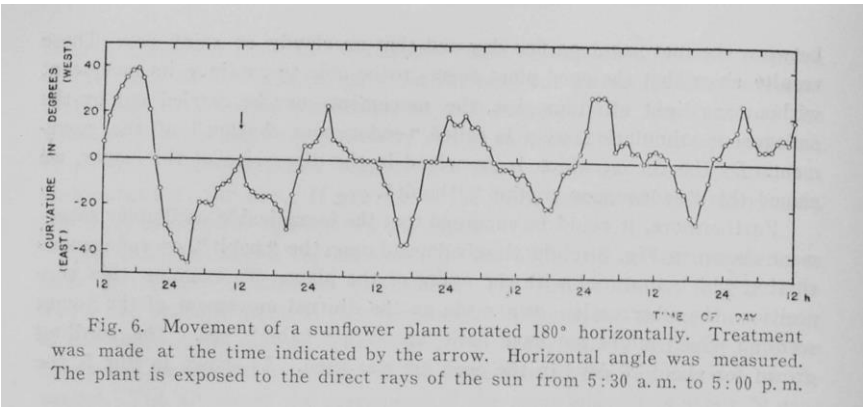


Fig. 6. Movement of a sunflower plant rotated 180° horizontally. Treatment was made at the time indicated by the arrow. Horizontal angle was measured. The plant is exposed to the direct rays of the sun from 5:30 a.m. to 5:00 p.m.

By the way, once the sunflower plant flowers, it no longer turns to face the sun, but remains facing east.

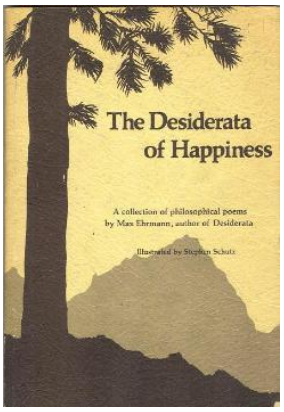


In this lecture, we have talked a lot about **time**. If time were an illusion, as the mathematical physicist's party line states, biological clocks would ***not*** be a fundamental scientific concept worthy of a lecture. Although I am in a minority of one, I think **time is real and absolute** and that biology with its **bio-logic** is more fundamental than current mathematical physics. See the following three videos for Brian Greene's, Michio Kaku's, and Julian Barbour's view of time:

Brian Greene in *Fabric of the Cosmos: The Illusion of Time*
https://www.youtube.com/watch?v=9Qu9XaF2K10
Michio Kaku in *The True Nature of Time*
https://www.youtube.com/watch?v=2TiQidGPHA4
Julian Barbour on *Does Time Exist?*

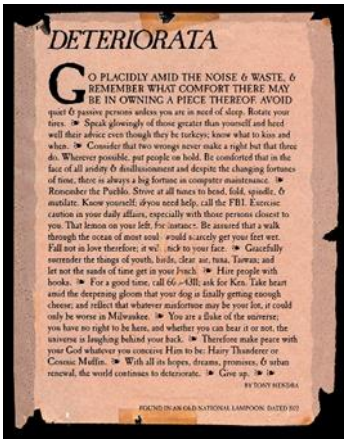
https://www.youtube.com/watch?v=KkjXuS_Z1ds





I think that the **present** or **now** is fleeting, but as a part of the **universe**, you are also connected to its **past**. You are stardust in that the material that makes up your body was synthesized by stars that exploded billions of years ago. The stardust provided the material from which the earth and all its creatures were and will be formed. All the food you eat is fundamentally synthesized using the radiant energy produced by the nuclear fusion reactions in the core of the sun. Our endogenous clocks are timed with the rotation of the earth on its axis and synchronized by the sunrise. You are, as **Max Ehrmann** (1927) wrote in the poem *Desiderata*, which is Latin for *desired things*, "*...**a child of the universe** no less than the trees and the stars; you have a right to be here*."

Desiderata: recited by Les Crane (1971), a radio and television personality, a civil rights activist mentioned in Phil Och's song *Love Me, I'm a Liberal*, and responsible for creating the Top 40:



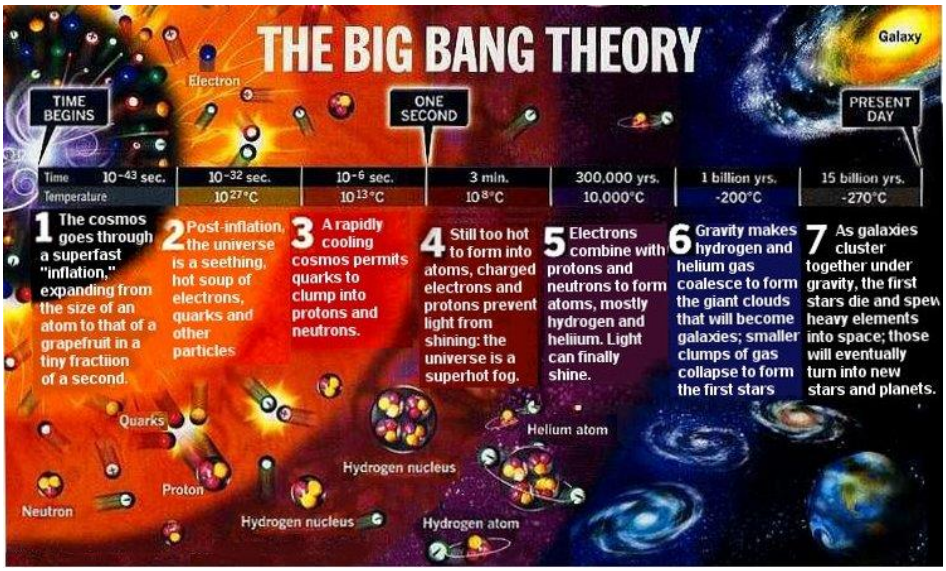
https://www.youtube.com/watch?v=398_oV5ovyw

Recited by Leonard Nimoy (Mister Spock):
https://www.youtube.com/watch?v=ZZJ1fJTezFE
Richard Burton: https://www.youtube.com/watch?v=GmHl0ZhhZLc
Deteriorata (1972): a Parody by National Lampoon:
https://www.youtube.com/watch?v=Ey6ugTmCYMk



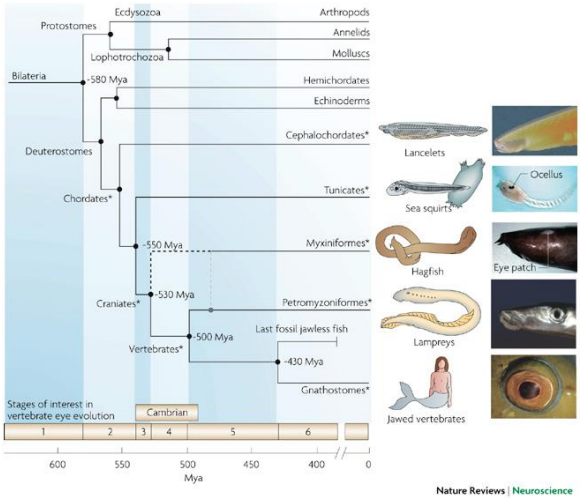
Over the semester we have considered time as an independent variable on which we could order various events. John F. Kennedy spoke about "our time" at the University of California at Berkeley on March 23, 1962:

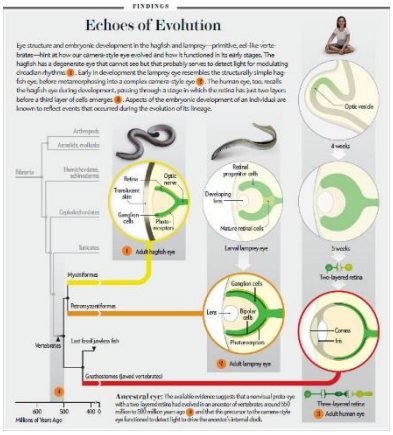
"*'Knowledge is the great sun of the firmament,' said Senator Daniel Webster. 'Life and power are scattered with all its beams.' In its light, we must think and act not only for the moment but for our time. I am reminded of the story of the great French Marshal Lyautey, who once asked his gardener to plant a tree. The gardener objected that the tree was slow-growing and would not reach maturity for a hundred years. The Marshal replied, 'In that case, there is no time to lose, plant it this afternoon.' Today a world of knowledge--a world of cooperation--a just and lasting peace--may be years away. But we have no time to lose. Let us plant our trees this afternoon.*"

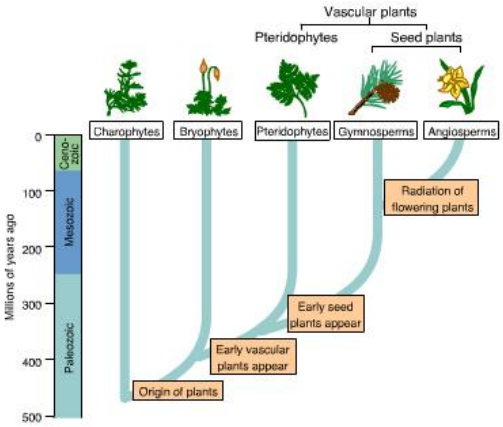


We have looked at the **big bang** in terms of astronomical time.

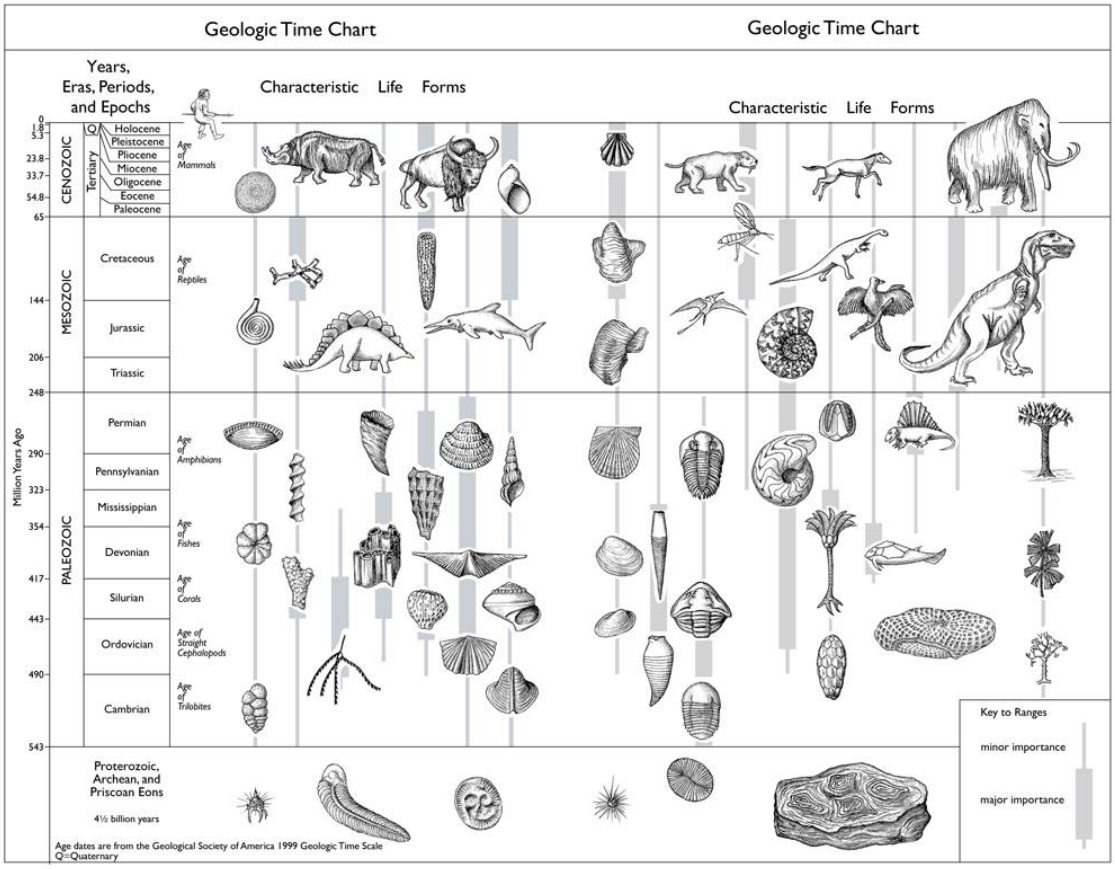
We have looked at the **biogenic origin of oxygen**, the **evolution of the eye**, and the **plants found in coal balls** in terms of geological time.



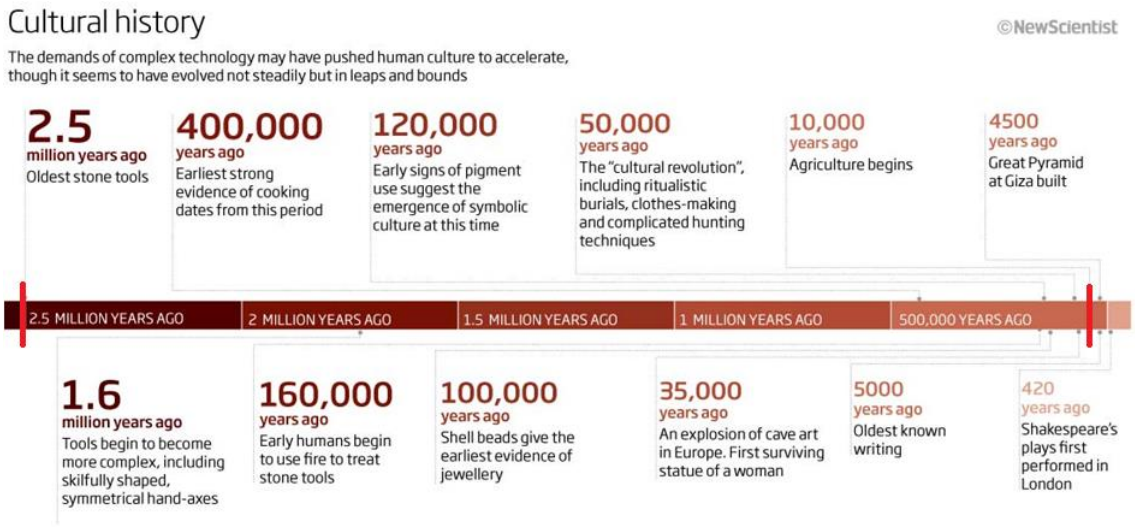




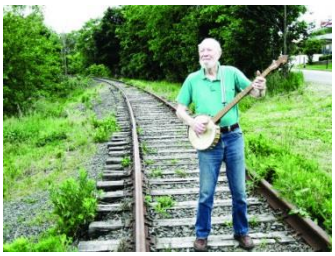
Below is a chart of geological time where the Carboniferous is split into the Mississippian and Pennsylvanian.



When we talked about the chemical history of a candle and charcoal, we considered our cultural history in terms of cave art produced 35,000 years ago:



In so many ways, time is necessary for musicians. Without time, there is no music. There are many songs about time:



Solomon (Ecclesiastes 3), and later **Pete Seeger** and all who covered his song, *Turn! Turn! Turn! (to Everything There Is a Season)* considered the nature of time and realized that "*There is a time for everything, and a season for every activity under the heavens: a time to be born and a time to die, a time to plant and a time to uproot, a time to kill and a time to heal, a time to tear down and a time to build, a time to weep and a time to laugh, a time to mourn and a time to dance, a time to scatter stones and a time to gather them, a time to embrace and a time to refrain from embracing, a time to search and a time to give up, a time to keep and a time to throw away, a time to tear and a time to mend, a time to be silent and a time to speak, a time to love and a time to hate, a time for war and a time for peace*."

Other songs about time:

As Time Goes By sung by Dooley Wilson:
https://www.youtube.com/watch?v=zaAqze81y4Y
As Time Goes By sung by Binnie Hale (1932) with original lyrics about Einstein:
https://www.youtube.com/watch?v=iBGDg9w5AtI
Time is on my Side sung by the Rolling Stones:
https://www.youtube.com/watch?v=XzcWwmwChVE
Time after Time sung by Cyndi Lauper:
https://www.youtube.com/watch?v=h0NkCvFD5r4
Rock Around the Clock sung by Bill Haley and the Comets:
https://www.youtube.com/watch?v=F5fsqYctXgM
Time sung by Pink Floyd:
https://www.youtube.com/watch?v=JwYX52BP2Sk
Does Anyone Really Know What Time It Is? Sung by Chicago:
https://www.youtube.com/watch?v=7uy0ldI_1HA
Time in a Bottle sung by Jim Croce:
https://www.youtube.com/watch?v=dO1rMeYnOmM
Time Warp from Rocky Horror Picture Show:
https://www.youtube.com/watch?v=tkplPbd2f60
Feels Like the First Time sung by Foreigner:
https://www.youtube.com/watch?v=qHDy_b33cCQ
The Longest Time sung by Billy Joel:
https://www.youtube.com/watch?v=a_XgQhMPeEQ
Now's the Time sung by The Hollies:
https://www.youtube.com/watch?v=WBfFrNpjZmc
Now's the Time played by Charlie Parker:
https://www.youtube.com/watch?v=ryNtmkfeJk4
The Times They Are a Changin' sung by Bob Dylan:
https://www.youtube.com/watch?v=e7qQ6_RV4VQ
Summertime Blues by Eddie Cochran:
https://www.youtube.com/watch?v=HWbXCz9UZYo
Wintertime sung by the Steve Miller Band:
https://www.youtube.com/watch?v=S_rZ7to0rqQ
Summertime sung by Ella FitzGerald and Louis Armstrong:
https://www.youtube.com/watch?v=lnXLVTi_m_M
Springtime for Hitler from The Producers:
https://www.youtube.com/watch?v=BCIHUmjKD9U
Funny How Time Slips Away sung by Willie Nelson:
https://www.youtube.com/watch?v=iZaZqx9v3dU
Night Time is the Right Time sung by Ray Charles:
https://www.youtube.com/watch?v=PuNzqDUvods

Blues in Time performed by Gerry Mulligan and Paul Desmond:
https://www.youtube.com/watch?v=nhMUnYM2UPg
Hard Time Killing Floor Blues from O Brother, Where Art Thou?
https://www.youtube.com/watch?v=fhRmCMWdRqM
Evening: The Sunset-Twilight Time sung by the Moody Blues:
https://www.youtube.com/watch?v=Bbs_EBRnuBw
Long Time Gone sung by Crosby, Stills & Nash:
https://www.youtube.com/watch?v=2DUqplxIcNk
Clocks sung by Coldplay:
https://www.youtube.com/watch?v=d020hcWA_Wg
Time After Time played by Miles Davis
https://www.youtube.com/watch?v=FpZHjvFXprk
100 Years by Five for Fighting
https://www.youtube.com/watch?v=tR-qQcNT_fY

The Poets also write about time:

Acquainted with the Night by Robert Frost

I have been one acquainted with the night.
I have walked out in rain --and back in rain.
I have outwalked the furthest city light.

I have looked down the saddest city lane.
I have passed by the watchman on his beat
And dropped my eyes, unwilling to explain.

I have stood still and stopped the sound of feet
When far away an interrupted cry
Came over houses from another street,

But not to call me back or say good-bye;
And further still at an unearthly height
One luminary clock against the sky

Proclaimed the time was neither wrong nor right.
I have been one acquainted with the night.

The Paradox of Time by Henry Austin Dobson

Time goes, you say? Ah no!
Alas, Time stays, we go;
Or else, were this not so,
What need to chain the hours,
For Youth were always ours?
Time goes, you say?-ah no!

Ours is the eyes' deceit
Of men whose flying feet
Lead through some landscape low;
We pass, and think we see
The earth's fixed surface flee:-
Alas, Time stays,-we go!

Once in the days of old,
Your locks were curling gold,
And mine had shamed the crow.
Now, in the self-same stage,
We've reached the silver age;
Time goes, you say?-ah no!

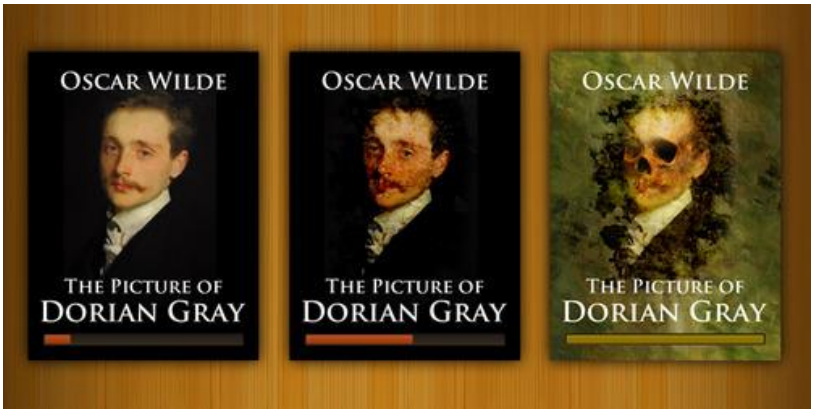
Once, when my voice was strong,
I filled the woods with song
To praise your 'rose' and 'snow';
My bird, that sang, is dead;
Where are your roses fled?
Alas, Time stays,-we go!

See, in what traversed ways,
What backward Fate delays
The hopes we used to know;
Where are our old desires?-
Ah, where those vanished fires?
Time goes, you say?-ah no!

How far, how far, O Sweet,

The past behind our feet
Lies in the even-glow!
Now, on the forward way,
Let us fold hands, and pray;
Alas, Time stays,-we go!

The Picture of Dorian Gray, written by Oscar Wilde (1891), gives an idea of what happens when we stay and time goes in the case of Dorian Gray.



Various ideas of time have been expressed by artists.

Engraved by Phillips Galle after Pieter Bruegel's (1574) "*The Triumph of Time*"

https://www.youtube.com/watch?v=Nl0RXP0YioM



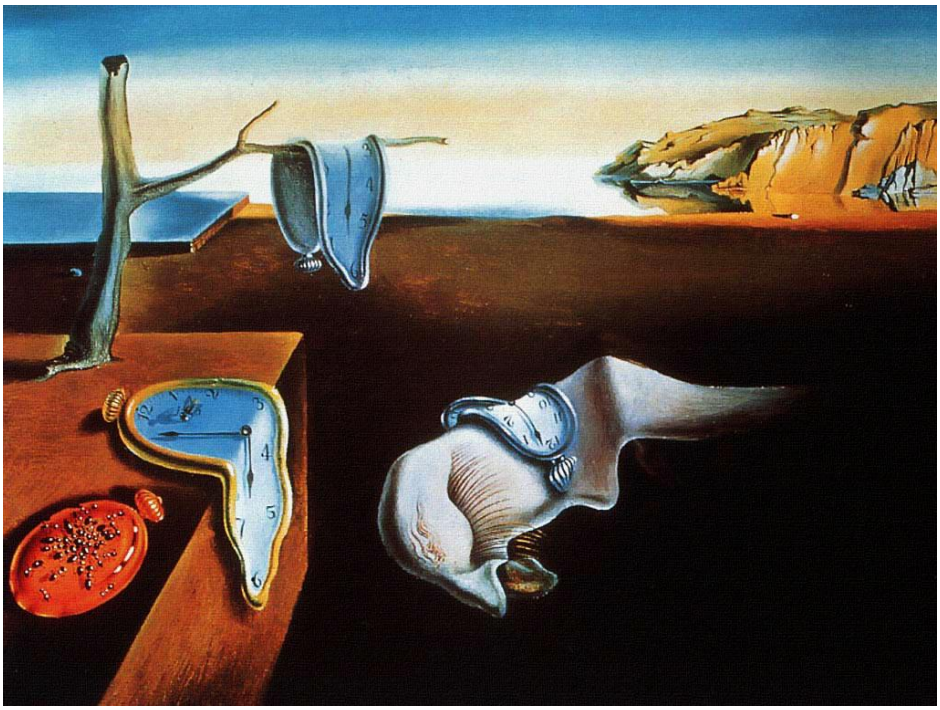
Agnolo Bronzino’s (1545) *Venus, Cupid, Folly and Time*



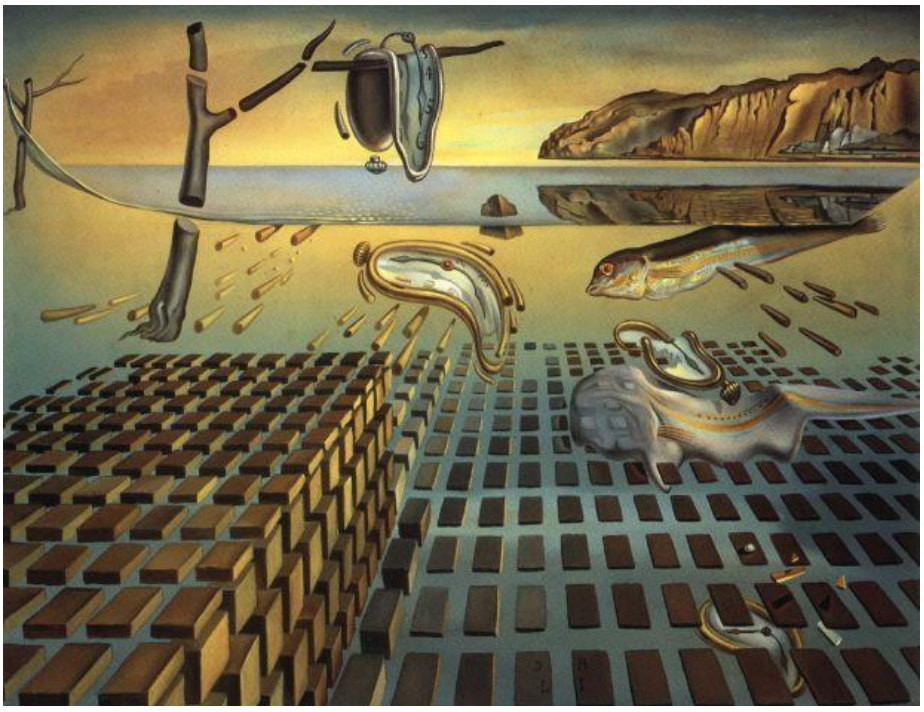
Antonio de Pereda's (1632-1636) *Allegory of Vanity*



Salvador Dali's (1931) *The Persistence of Memory*



And Salvador Dali's (1954) *The Chromosome of a Highly-coloured Fish's Eye Starting the Harmonious Disintegration of the Persistence of Memory*



Alighiero y Boetti's (1968) *Gemelli* where he is holding hands with himself.



Julie De Waroquier's (2011) *The Weight of Time*



And movies: Harold Lloyd hanging from a clock in *Safety Last* (1923)

https://www.youtube.com/watch?v=VFBYJNAapyk



This picture was also used in Christian Marclay's (2010) *The Clock*

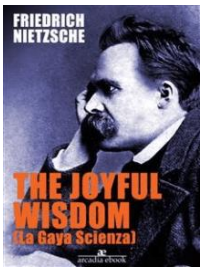
https://www.youtube.com/watch?v=BXbQw0rE5UE

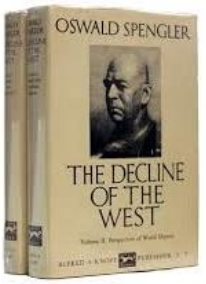
Harold "Doc" Edgerton captured an "instant of time" with a strobe light.



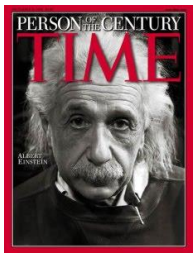
A secular world, from the Latin word *saecularis* meaning "temporal" should be a world that believes that time is fundamental. After all, if time is an illusion, the whole secular world is an illusion.

As a consequence of World War One (1914-1918), intellectuals and artists sought to return to another era characterized by **Johann Wolfgang von Goethe**'s holistic and romantic physics rather than Isaac Newton's classical physics based on logic, with the machine guns and airplanes it produced. It also shunned classical chemistry based on logic, along with the poison gas it produced. In fact, in this new era, anything that pointed to the classical, logical, and absolute was denigrated and anything that supported the fundamental nature of the relative was celebrated. The writings of **Friedrich Nietzsche** (*The Joyous Wisdom*) and **Oswald Spengler** (*The Decline of the West*) that **vilified the absolute and celebrated the relative** were widely read. Readers hoped that society would enter a period of rejuvenation while leaving the period of decay behind.





Following World War One, which underscored the decay of Western Civilization, the idea that time and space were **relative and interdependent** proposed earlier by Albert Einstein (1905) and Hermann Minkowski (1909) rather than **absolute and independent** as Isaac Newton assumed became accepted at the pinnacle of scientific thought and celebrated by the literati and other cognoscenti. The **idea of relativism** became the foundation of everything from quantum physics to morality. From 1919 on, Einstein came to be considered the smartest man on earth, and in 1999 *Time* Magazine named him Person of the Century. (In the last lecture of the semester, I will discuss how the concept of relativism influenced quantum mechanics).





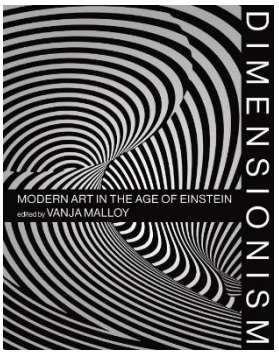




Although artists such as **Marcel Duchamp** (1911-1912; *Nude and Sad Young Man on a Train*; *Nude Descending a Staircase No. 2*; 1912; https://www.wikiart.org/en/marcel-duchamp/all-works#!#filterName:all-paintings-chronologically,resultType:masonry) and **Pablo Picasso** (1928, *Painter and Model*; https://www.pablopicasso.org/picasso-paintings.jsp) had already created art that questioned the common sense view of time and space, in 1936, the **Dimenionist Manifesto** was produced by Charles Sirató. It stated that avant-garde art should be based on Einstein and Minkowski's view of space-time (https://www.amherst.edu/amherst-story/today/amherst-in- pictures/dimensionism-modern-art-in-the-age-of-einstein).

THE DIMENSIONIST MANIFESTO

Paris, 1936



Dimensionism is a general movement of the arts. Its unconscious origins reaching back to Cubism and Futurism, it has been continuously elaborated and developed since then by all the peoples of Western civilization. ***Today the essence and theory of this great movement bursts with absolute self-evidence. Equally at the origin of Dimensionism are the European spirit's new conceptions of space-time (promulgated most particularly by Einstein's theories) and the recent technical givens of our age. The absolute need to evolve, an irreducible instinct, has sent***

the avant-garde on their way toward the unknown, leaving dead forms and exhausted essences as prey for less demanding artists. We must accept—contrary to the classical conception—that Space and Time are no longer separate categories, but rather that they are related dimensions in the sense of the non-Euclidean conception, and thus all the old limits and boundaries of the arts d i s a p p e a r. *This new ideology has elicited a veritable earthquake and subsequent landslide in the conventional artistic system. We designate the totality of relevant artistic phenomena by the term "DIMENSIONISM." / Tendency or Principle of Dimensionism****. Its formula: "N + 1." (A formula discovered in Planist theory and then generalized, reducing to a common law the seemingly chaotic and inexplicable artistic phenomena of our age.)***

ANIMATED BY A NEW CONCEPTION OF THE WORLD, THE ARTS, IN COLLECTIVE FERMENTATION (their interpenetration) HAVE BEEN SET INTO MOTION AND EACH HAS ABSORBED A NEW DIMENSION. EACH HAS FOUND A NEW FORM OF EXPRESSION INHERENT TO THE NEXT DIMENSION, OBJECTIFYING THE WEIGHTY INTELLECTUAL CONSEQUENCES OF THIS FUNDAMENTAL CHANGE. Thus, the Dimensionist tendency has led to:

I. ...L i t e r a t u r e leaving the line and entering the plane. Calligrammes. Typograms.

P l a n i s m . (preplanism)

Electric Poems.

II. ...P a i n t i n g quitting the plane and entering space. Painting in space

"Constructivism"

Spatial Constructions.

Poly-Material Constructions.

*III. …**S c u l p t u r e stepping out of closed, immobile, dead forms, that is, out of forms conceived of in three-dimensional Euclidean space—in order to appropriate for artistic expression Minkowski's four-dimensional space**. It has been, above all, "solid" sculpture (classical sculpture) that has opened itself up, first to inner space, then to movement, and is transformed into: Perforated Sculpture. Open Sculpture. Mobile Sculpture. Motorized Objects. And after this a completely new art form will develop: Cosmic Art (The Vaporization of Sculpture, Synos-Sense Theater, provisional denominations.) The artistic conquest of four-dimensional space / to date an artistic vacuum /. Rigid matter is abolished and replaced by vaporized materials. Instead of looking at objects of art, the person becomes the center and the subject of creation, and creation consists of sensorial effects operating in a closed cosmic space. This is how one would most concisely summarize the essence of Dimensionism: Deductive with respect to the past. Inductive with respect to the future. Alive in the present.*

Helen Lundeberg's (1935) *Double Portrait of the Artist in Time* captures the artist at different times (https://americanart.si.edu/artist/helen-lundeberg-3018).



Helen Lundeberg's (1944) *Self Portrait* captures warped space.



Dorothea Tanning's (1945) *The Truth about Comets* captures transformation in time (https://www.dorotheatanning.org/life-and-work/view/243/).



Alexander Calder created mobiles to capture four dimensions of objects: three dimension in space and one in time (http://www.calder.org/work/by-category/hanging-mobile). This one is called *Triple Gong* (1948).





Let’s unpack the meaning of 3 + 1 = 4-dimensionalism.

Four dimensionalism usually means that objects cannot be described simply in terms of absolute space, with its three dimensions and absolute and independent time, with its one dimension but must be described in terms of an interdependent space time relative to the observer. But it can also mean that objects can be described simply in absolute space and absolute time—but not in absolute three-dimensional space alone without any representation of time. The paintings and mobile above can be interpreted in terms of the relative interdependent or absolute independent conception of time and space.

Let’s return to the **Ship of Theseus**. When speaking in terms of three-dimensional space alone, we have to assume that objects such as the Ship of Theseus are eternally stable and unchanging. However, as long as the **temperature** is greater than **absolute zero**, this is in direct contradiction to the **second law of thermodynamics**, and thus to me untenable. Thus, even without replacing the wooden boards, the Ship of Theseus continually evolves and deteriorates, unless energy is added. This means that there is no single definition of the Ship of Theseus, and we must always define which Ship of Theseus we are talking about.

Aside: Remember that **statistical mechanics**, which is considered more fundamental than the second law of thermodynamics by the cognoscenti, also introduces time—but time that is reversible and there are no unique moments in time. Thus, statistical mechanics allows for the deteriorated Ship of Theseus to return to its original state in principle, although the chance of it is unlikely.

Let's not be too simplistic. Is the house we live in the same house as the one we bought? If not, do we still have to pay a mortgage on this house? If not, do we even own the house? Let's use **common sense**, in science as well as society.



Tom Stoppard was not too simplistic when he wrote about the importance of temperature in considering the irreversibility of time in his play *Arcadia* (Act II Scene 3).



Tom Stoppard's
ARCADIA
Directed by David Leveaux

ARCADIA opens at the Ethel Barrymore Theatre (243 W. 47th Street) on March 17, 2011.

Pictured (L-R): Bel Powley, Raúl Esparza, Lia Williams and Tom Riley

© Carol Rosegg, 2011

Hannah: What did she see?

Valentine: That you can't run the film backwards. Heat was the first thing which did not work that way. Not like Newton. A film of a pendulum, of a ball falling through the air—backwards, it looks the same.

Hannah: The ball would be going the wrong way.

Valentine: You'd have to know that. But with heat—friction—a ball breaking a window—

Hannah: Yes.

Valentine: It won't work backwards.

Hannah: Who thought it did?

Valentine: She saw why. You can put back the bits of glass but you can't collect up the heat of the smash. It's gone.

Septimus: So the Improved Newtonian Universe must cease and grow cold. Dear me.

Valentine: The heat goes into the mix.

Thomasina: Yes we must hurry if we are going to dance.

Valentine: And everything is mixing the same way, all the time, irreversibly—



Salvador Dali

As a result of differences between Christian and Aristotelian scholarship, Étienne Tempier (1277), The Bishop of Paris issued the Condemnations of 1277 on March 7, many of which dealt with the **nature of time**. For example, *Quod evum*

et tempus nichil sunt in re, Sed solum in apprehensione or "***It is heretical to maintain that the age and time do not exist in reality but only in the mind***."

George Santayana (1905) wrote in *The Life of Reason: Reason in Common Sense* (p. 284): "*Progress, far from consisting in change, depends on retentiveness. When change is absolute there remains no being to improve and no direction is set for possible improvement: and when experience is not retained, as among savages, infancy is perpetual.* ***Those who cannot remember the past are condemned to repeat it***."

The condemnations of 1277 were based on the **assumption** that the logic of the Catholic Church was infallible.

Condemnations of today are often based on the **assumption** that the logic of the scientific consensus is infallible.



Remember what **Richard Feynman** (1969) said in a speech entitled, *What is Science?:* "*As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts. When someone says, 'Science teaches such and such,' he is using the word incorrectly. Science doesn't teach anything; experience teaches it. If they say to you, 'Science has shown such and such,' you might ask, 'How does science show it? How did the scientists find out? How? What? Where?' It should not be 'science has shown' but 'this experiment, this effect, has shown.' And you have as much right as anyone else, upon hearing about the experiments--but be patient and listen to all the evidence--to judge whether a sensible conclusion has been arrived at.*"

To get to know Feynman a little better, here is a letter we wrote to his wife Arline who died very young.

October 17, 1946

D'Arline,

I adore you, sweetheart.

I know how much you like to hear that — but I don't only write it because you like it — I write it because it makes me warm all over inside to write it to you.

It is such a terribly long time since I last wrote to you — almost two years but I know you'll excuse me because you understand how I am, stubborn and realistic; and I thought there was no sense to writing.

But now I know my darling wife that it is right to do what I have delayed in doing, and that I have done so much in the past. I want to tell you I love you. I want to love you. I always will love you.

I find it hard to understand in my mind what it means to love you after you are dead — but I still want to comfort and take care of you — and I want you to love me and care for me. I want to have problems to discuss with you — I want to do little projects with you. I never thought until just now that we can do that. What should we do. We started to learn to make clothes together — or learn Chinese — or getting a movie projector. Can't I do something now? No. I am alone without you and you were the "idea-woman" and general instigator of all our wild adventures.

When you were sick you worried because you could not give me something that you wanted to and thought I needed. You needn't have worried. Just as I told you then there was no real need because I loved you in so many ways so much. And now it is clearly even more true — you can give me nothing now yet I love you so that you stand in my way of loving anyone else — but I want you to stand there. You, dead, are so much better than anyone else alive.

I know you will assure me that I am foolish and that you want me to have full happiness and don't want to be in my way. I'll bet you are surprised that I don't even have a girlfriend (except you, sweetheart) after two years. But you can't help it, darling, nor can I — I don't understand it, for I have met many girls and very nice ones and I don't want to remain alone — but in two or three meetings they all seem ashes. You only are left to me. You are real.

My darling wife, I do adore you.

I love my wife. My wife is dead.

Rich.

PS Please excuse my not mailing this — but I don't know your new address.

Earlier we talked about how the relationship between the earth and the moon affected the length of day over geological time. Here is a picture of *The Earth from the moon* from Le Monde Physique by Amédeé Guillemin (1882). This book also has many figures that review the optics that we have learned this semester.



Fig. 8. — Le clair de terre sur la Lune.

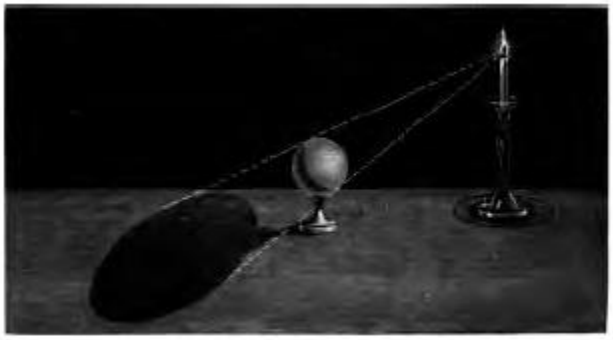


Fig. 9. — Cône d'ombre d'un corps opaque. Ombre portée.



Fig. 18. — Images produites à l'intérieur de la chambre obscure.



Fig. 39. — Formation des images vues par réflexion sur un miroir plan.



Fig. 49. — Miroir concave. Image renversée, plus petite que l'objet.

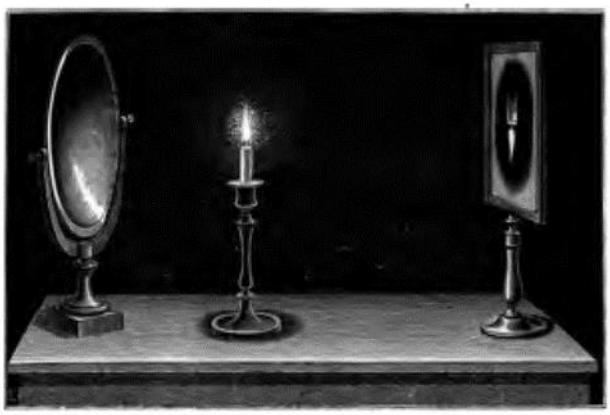


Fig. 50. — Miroir concave. Image renversée, plus grande que l'objet.



Fig. 16. — Image renversée d'une bougie.



Fig. 51. — Miroir concave. Image virtuelle, droite et plus grande que l'objet.



Fig. 58. — Image droite virtuelle dans les miroirs sphériques convexes.

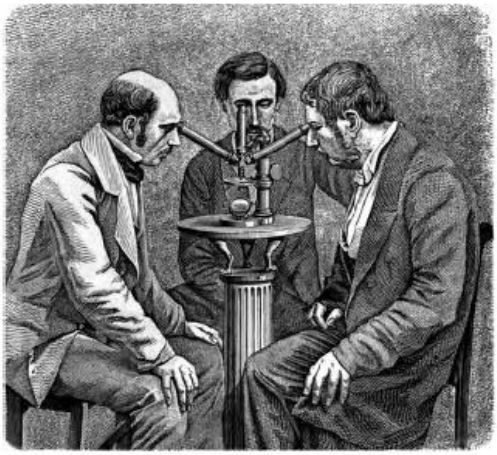


Fig. 287. — Microscope à trois corps pour les observations simultanées.

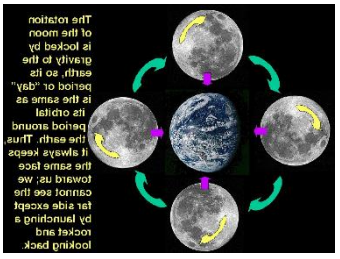


Fig. 78. — Phénomène de réflexion totale.



Fig. 149. — Structure de la flamme d'une bougie et coupe de la même flamme.

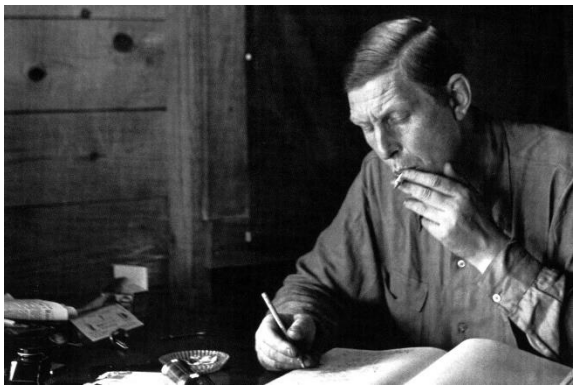
Aside: Since the period of rotation of the moon around its axis is 27 days and the period of the moon's orbit around the earth is also 27 days, the moon keeps the same side facing the earth and does not seem to rotate and the dark side of the moon does get illuminated by the sun!



According to Theophrastus (371- 287 BC): Συνεχές τε … πολυτελὲς ἀνάλωμα εἶναι τὸν χρόνον. *Time is the most valuable thing a man can spend*.

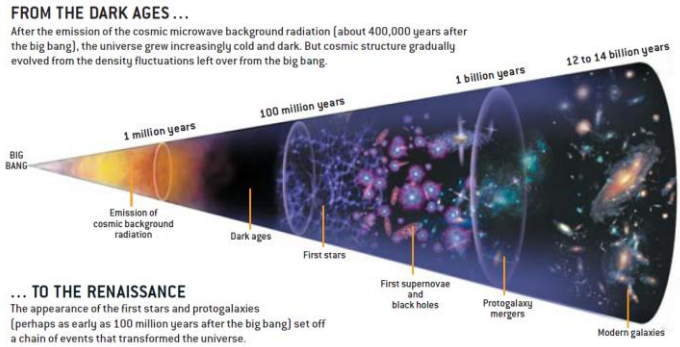


One more thing about sleep. According to **W. H. Auden**, a professor is "*one who talks in someone else's sleep*."



Ultraviolet Light: Ozone Layer, DNA Damage and Repair, Melanoma, Vitamin Synthesis and Breakdown, Vision, and Fluorescence

The **ultraviolet light** that reaches the earth is intimately dependent on the natural history of **oxygen**. The **oxygen** atoms found on earth were made in the fusion reactions that took place in the **carbon-nitrogen-oxygen (CNO) cycle** in the cores of massive first-generation stars that formed about **13.6 billion years ago** between 0.1 and 0.25 billion years after the big bang.



The earth's atmosphere had little or no **molecular oxygen** (O_2) before photosynthetic organisms inhabited the earth. In the **Precambrian** era, between **3.7 to 2.4 billion years ago**, oxygen was split from water (H_2O) by the first marine **photosynthetic cyanobacteria** and formed molecular oxygen. This molecular oxygen oxidized (loss of electron) dissolved ferrous (Fe^{2+}) iron to produce ferric (Fe^{3+}) iron in the forms of hematite (Fe_2O_3) and magnetite ($Fe_3O_4 = Fe^{2+}Fe_2^{3+}O_4$). These dense iron oxides precipitated out of solution and formed layers that resulted in sedimentary rock. The **layers of hematite and magnetite** alternated with layers of **shale** or **chert**, which was probably formed from **mud exposed to anoxic, anaerobic, or reducing conditions**. The mass rusting combined with the **cyclic variation in molecular oxygen** gave rise to **banded-iron formations.**



Because of the abundance of hematite, it is one of the most inexpensive paint pigments to produce. This makes **hematite-colored red paint** the logical choice for painting large structures, such as red barns and covered bridges.





The **sunlight-dependent** Precambrian photosynthetic reactions that evolved oxygen also produced carbohydrates ($C(H_2O)$) that were converted biosynthetically to many organic molecules, including porphyrins such as chlorophyll and heme.

$$CO_2 + H_2O + 8h\nu \rightarrow C(H_2O) + O_2 + \text{heat}$$

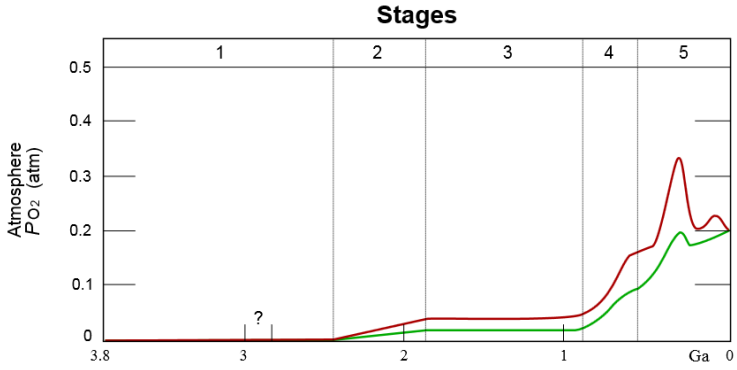
Vast deposits of dead Precambrian photosynthetic cyanobacteria and the organic matter that they contained, when subjected to anaerobic conditions and cooking due to the high temperatures inside the earth resulting from radioactive decay, may have given rise to the hydrocarbons found in the **Precambrian petroleum** (from the Greek *petra* (*πέτρα*) for rock and the Latin *oleum* for oil) **deposits** of **coal, oil, and natural gas** (Vassoyevich et al., 1971). Indeed Alfred Treibs (1934) found porphyrins in petroleum deposits. There are two schools of thought as to whether the Precambrian deposits are **biogenic** or **abiogenic**. The importance of life in the biogenic formation of the earth as we know it has been emphasized by **Eduard Suess**, who coined the word **biosphere**, and **Vladimir Vernadsky**. The importance of abiogenic processes in petroleum formation has been emphasized by **Tommy Gold** (Cornell) in his book, *The Deep Hot Biosphere*, where he



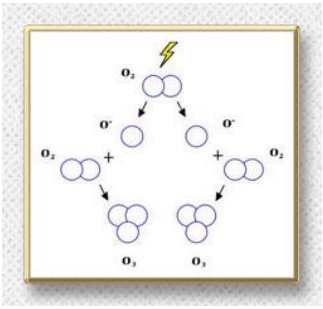


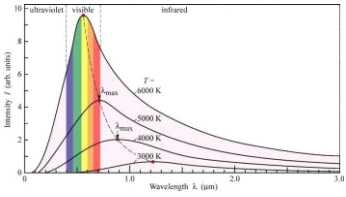


suggests that petroleum was formed from primordial hydrocarbons that may have been trapped during the formation of the earth.

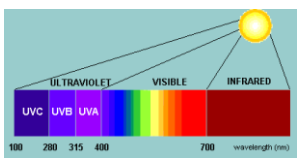


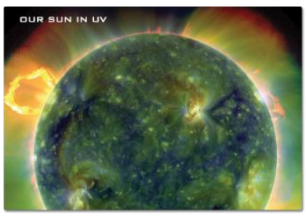
Approximately **2.4 billion years ago**, the amount of molecular oxygen produced by **photosynthetic cyanobacteria** overwhelmed the capacity of the ferrous iron to react with it and some of the molecular oxygen dissolved in the ocean and some rose to become part of the atmosphere. This is known as the **great oxygenation event**. Approximately **1.85-0.85 billion years ago**, the molecular oxygen started to outgas from the ocean. Some of this oxygen oxidized minerals on land and the rest entered the atmosphere where some of it reacted with **ultraviolet light** to form the **ozone layer**. Ozone comes from the Greek word, *ozein* (*ὄζειν*), which means "*to smell*." Ozone produced by **lightning**, which results when there is sufficient **charge separation** between the bottom of a cloud and the surface of the earth, giving rise to an electric field of about a million volts per meter, is what we smell during a thunderstorm.

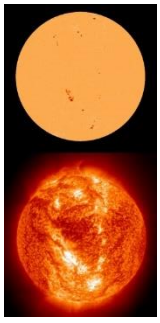




Consistent with the sun being an **incandescent blackbody radiator** with a surface temperature of about **6000 K** and a **spectral distribution** described by **Planck's blackbody radiation formula**, **sunlight** is composed of **ultraviolet light**, **visible light**, and **infrared light**.







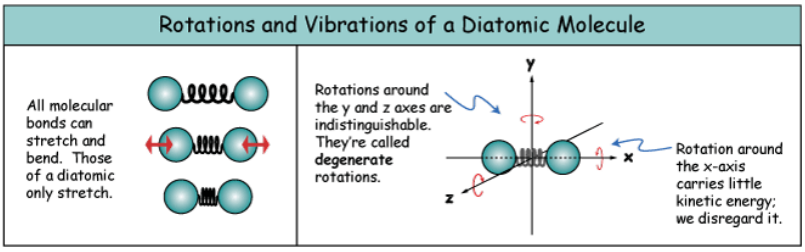
The ultraviolet light is further subdivided into **UVA** (315-400 nm), **UVB** (280-315 nm) and **UVC** (100-280 nm). The proportion of UVC transmitted to the earth increases in years when the sunspot activity is high. **Photons** of **ultraviolet light** ($h\nu_{uv}$) in the UVC range with wavelengths equal to and less than 240 nm coming from the **sun** transforms **molecular oxygen** (O_2) into **ozone** (O_3) according to the following formulae:

$$O_2 + h\nu_{uv} \rightarrow 2O$$

$$O + O_2 \rightarrow O_3 + \text{heat}$$

The energy (E) of a 240 nm photon is equal to $E = h\nu = \frac{hc}{\lambda} = 8.3 \times 10^{-19}$ J. Note that *hc*, the product of Planck's constant and the vacuum speed of light is approximately equal to 2×10^{-25} Jm.

Absorption is a process where the energy of a photon is transferred to matter consistent with the **First and Second Laws of Thermodynamics**. If the matter is a gas molecule, composed of more than one atom, the transfer of energy can happen in a number of ways.

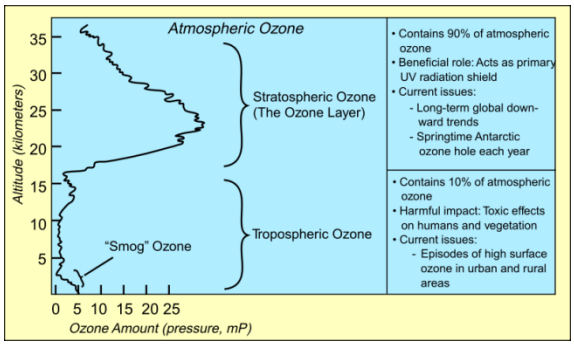


Light absorption can cause the gas molecule to **vibrate**, to **rotate**, or to **break** (dissociate). Each type of energy transfer occurs at a specific band of the solar spectrum. When an ultraviolet photon with a wavelength of longer than 240 nm is absorbed by molecular oxygen, the energy causes the bond between the two oxygen atoms to vibrate, and the photon is subsequently scattered. A portion of a molecule's translational energy may be released as heat, resulting in inelastic scattering and a small lengthening of the wavelength of the scattered light compared to the wavelength of the absorbed light.

When an ultraviolet photon with a wavelength of 240 nm is absorbed by molecular oxygen, the bond is broken, and the two atoms of oxygen are jettisoned off at high speeds with a kinetic energy equal to the difference in energy of the photon that broke the bond and the energy needed to just break the bond.



Most of the ozone formed from molecular oxygen is about 15-40 km above the surface of the earth in the **stratosphere**. The ozone in this layer, which is known as the **ozone layer**, breaks down into atomic oxygen (O) and molecular oxygen (O_2) when it absorbs a photon of ultraviolet light in the UVC and UVB ranges with a wavelength less than 290 nm.

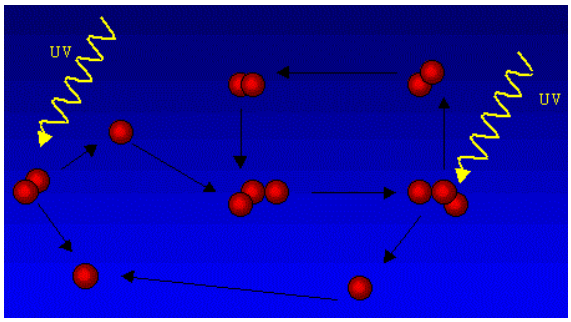


$$O_3 + h\nu_{uv} \rightarrow O + O_2 + \text{heat}$$

The energy (E) of a 290 nm photon is equal to $E = h\nu = \frac{hc}{\lambda} = 6.9 \times 10^{-19}$ J.

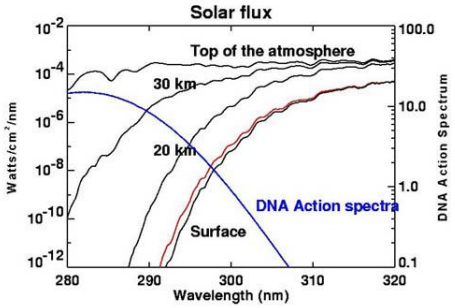
The above reactions that generate and break down **ozone** can be summarized by the following equation:

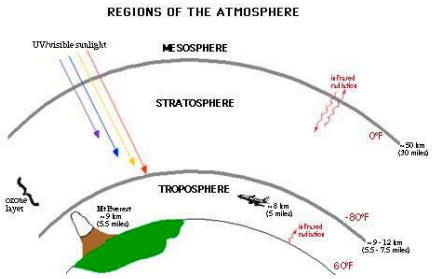
$$3\,O_2 \underset{h\nu_{uv\,(290,\,UVB)}}{\overset{h\nu_{uv\,(240,UVC)}}{\rightleftharpoons}} 2\,O_3$$



where the conversion between oxygen and ozone in both directions **suck up ultraviolet light in the UVC and UVB regions** and give off heat, which is thermal energy in the infrared range. Consequently, the **ozone layer filters out all**

of the ultraviolet photons in the UVC range and most of the ultraviolet photons in the UVB range. The complete filtering out of ultraviolet light in the **UVC range** is important for life since it is these wavelengths that are absorbed by DNA and could result in substantial **genetic damage** and/or **death**.





Ultraviolet light was discovered in 1801 by **Johann Wilhelm Ritter**, who was stimulated by William Herschel's (1800) then recent surprising discovery, made with the aid of a thermometer, of invisible heat rays beyond the red end of the spectrum. Ritter found invisible rays beyond the blue end of the spectrum by showing that these invisible rays were effective in blackening silver salts by converting silver ions (Ag^+) to metallic silver (Ag^o). Ritter called the invisible yet active rays, **deoxidizing rays** (i.e., reducing) to distinguish them from heat rays. The reaction, which became very important in making **light-sensitive film and paper for photography**, a word coined in 1839 by William Herschel's son John, is given by the following reaction.



$$Ag^+ + e^- \xrightarrow{h\nu_{uv}} Ag^o$$



In 1877, Arthur Downes and **Thomas Blunt** showed that **sunlight** had **bactericidal action** on cultures of *Bacillus anthracis*. Harry Marshall Ward repeated and extended the work of Downes and Blunt in 1892. He projected **sunlight** through the letter E and showed its **bactericidal** effect on a gelatin plate containing anthrax spores.

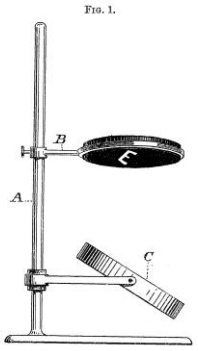
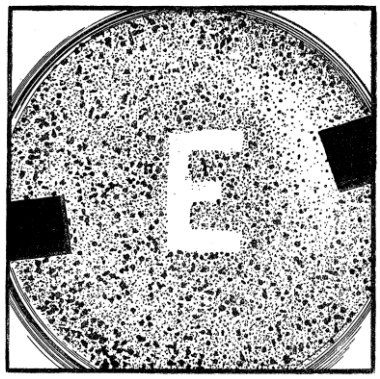


Fig. 1.



Ward then projected a **spectrum** produced by a naked **mercury vapor arc lamp** upon *Bacillus anthracis* on agar plates and found that the spores and colonies exposed to the violet and ultraviolet end of the spectrum did not grow while the colonies exposed to the visible and infrared portion of the spectrum grew normally. Notice in the spectrum on top, the transmission of ultraviolet light has been blocked by glass.

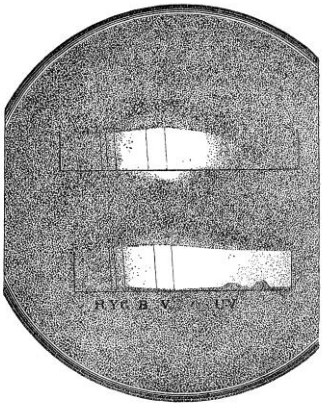
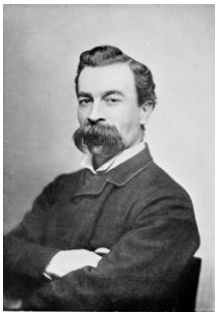


Fig. 2.—Plate similar to fig. 1, but exposed to the electric spectrum (obtained by means of quartz apparatus) for twelve hours, and incubated four days. The lower slot was covered with quartz only, the upper with a thin plate of glass. The base-line in each case gives length of exposed slot. In both cases the spores were uninjured in the infra-red, red (R), orange-yellow (Y), or green (G). The maximum effect was in the blue-violet, and it is interesting to see how the bactericidal action extended far into the ultra-violet (UV) in the case of the lower slot, where the light passed through quartz only. The two little protuberances over UV were due to two little overflows of burnt Canada balsam at the edge of the slot, cutting off light.



Ward also realized that. "*these results suggest evidently that the naked arc light may prove to be a very efficient* ***disinfecting agent*** *in hospital wards, railway carriages, or anywhere where the rays can be projected directly on to the organism*."

Niels Finsen suffered from Niemann–Pick disease and noticed that sunshine made him feel better. This got him interested in studying the effect of light in treating diseases. In 1895, he developed the Finsen lamp and used ultraviolet light to treat patients with *lupus vulgaris*.



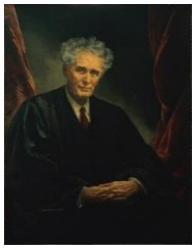


Lupus vulgaris is a form of tuberculosis that attacks the skin. Finsen won the Nobel Prize in Physiology and Medicine in 1904 for developing **phototherapy**, although his disease prevented him from attending the ceremony, and he died shortly afterwards. Antibiotic treatment has replaced UV phototherapy for the treatment of lupus.

Louis Brandeis (1913) wrote that *"Sunlight is said to be the best of disinfectants*" in an article entitled "*What Publicity Can Do*" aimed in remedying social and industrial diseases.

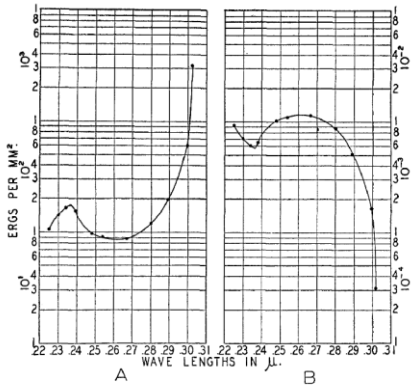


Publicity has already played an important part in the struggle against the money trust

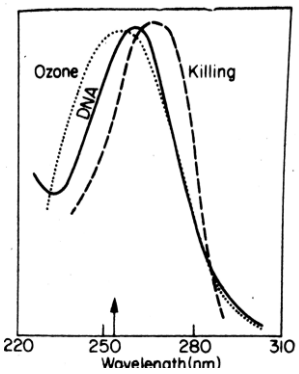


Frederick Gates (1930) performed **action spectroscopy** to determine the most effective wavelengths for the bactericidal action of ultraviolet light on *Staphylococcus aureus*, a bacterium that causes food poisoning. He found that the most effective wavelengths are **between 250 nm and 270 nm**. Gates suggested that the action spectrum indicated that there was a "*close relation to specific light absorption by some single essential substance in the cell*."



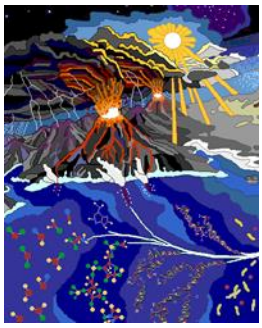


TEXT-FIG. 2. A. Curve of incident energies involved in the destruction of 50 per cent of *S. aureus*.
B. Curve of the reciprocals of 2A.

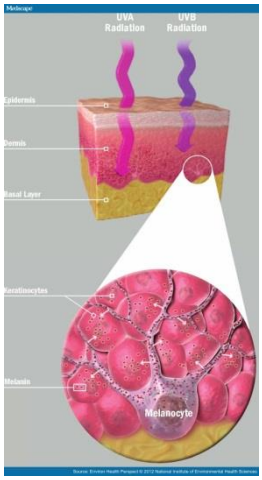


We now know that **DNA is the** "***single essential substance in the cell***" that has **the absorption spectrum** that matches **the action spectrum for the bactericidal and germicidal killing effect**. The **absorption spectrum** of the **oxygen and ozone present in the stratosphere** ensures that a large proportion of germicidal ultraviolet photons in the UVC range never reach the surface of the

earth. However, ***before*** the existence of atmospheric oxygen and ozone, any life on earth would have been exposed to the germicidal action that is caused by the ultraviolet photons in the UVC range that are present in sunlight.



As we will see, the transmission of ultraviolet light through the atmosphere has both **beneficial** and **harmful** effects. The most dangerous effect occurs when ultraviolet photons in the **UVB** and **UVA** ranges are absorbed by the **DNA** in the dendrite-like **melanocytes** in our skin.

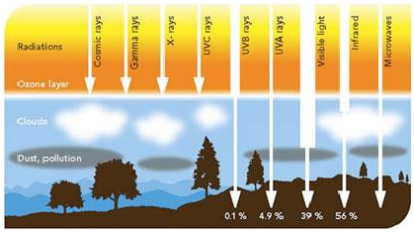


While ultraviolet photons in the UVC range are absorbed by DNA even better than ultraviolet photons in the UVB and UVA range, the ultraviolet photons in the UVC range are completely blocked by the oxygen and ozone in the stratosphere. Ultraviolet photons in the UVC range, produced artificially by **germicidal lamps**, should be avoided. Ultraviolet photons in the UVB range (3%) and UVA range (97%) produced by tanning beds have all the risks and benefits of the ultraviolet radiation in sunlight.

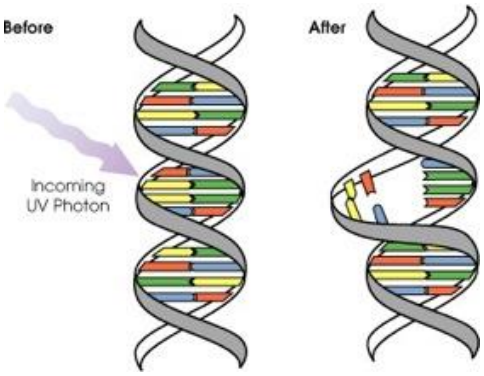


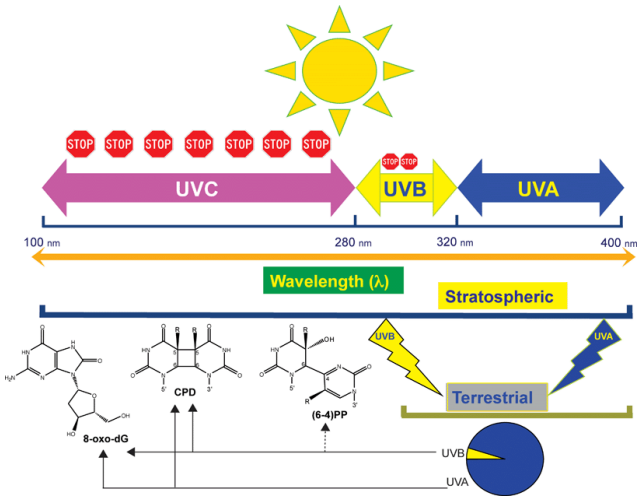


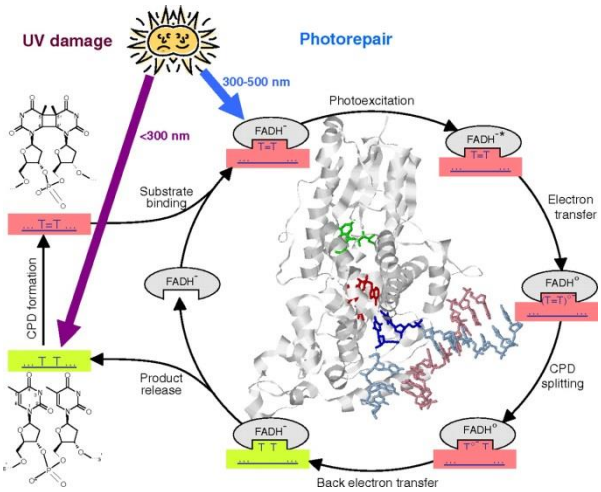
By sheer **numbers alone**, photons in the UVB and UVA range are the cause of **natural ultraviolet damage** to DNA on earth. When photons in the UVB and UVA range are absorbed by the DNA in the nucleus of the **melanocytes**, DNA damage can occur.



The absorption of a **UVB photon** by DNA typically produces a **cyclobutane pyrimidine dimer (CPD)** composed of thymine-thymine or it produces the **formation of oxidized DNA bases** such as 8-oxo-7,8-dihydro-2′-deoxyguanosine form. The absorption of **UVA photons** typically results in the production of reactive oxygen species (ROS) or free radicals that produce oxidized DNA bases.





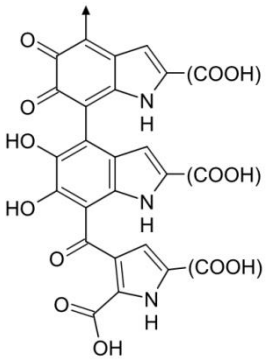


The nucleus has a number of systems that can **recognize and repair damaged DNA** resulting from a **cyclobutane pyrimidine dimer (CPD)**. We will only talk about one of them—the repair system that depends on an **enzyme** known as **photolyase**, which is a **flavoprotein** activated by **UV-blue light**. Photolyase works by temporarily transferring an excited electron from the FADH to the cyclopyrimidine dimer. The electron in the flavin is excited as a result of the absorption of UV-blue light. The temporary transfer to the cyclobutane pyrimidine dimer fixes the damage. **Riboflavin** (vitamin B2) is required for the function of flavoproteins, including photolyase. The diagram above emphasizes the **hurtful and helpful aspects** of ultraviolet light.

DNA damage caused by ultraviolet light ***can*** be repaired, but if it is not repaired, the DNA damage may result in a deletion, an insertion, or a chromosomal translocation. These "mutations" can result in **melanomas**, which are **malignant tumors of melanocytes**.



Melanin is a **large complex blobby wobbly flexible** polymer that contains many conjugated double bonds which absorb almost all wavelengths of light, including ultraviolet. Upon absorption of light, the flexible polymer flops around turning radiant energy into kinetic energy and eventually thermal energy (heat or infrared light). Melanin comes from the Greek μέλας which means black or dark.



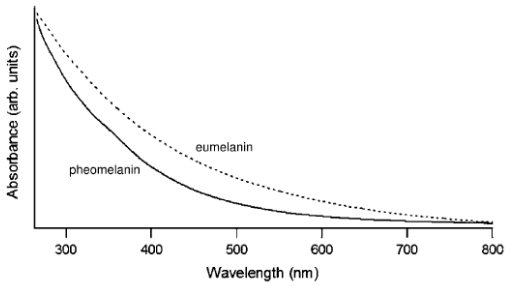
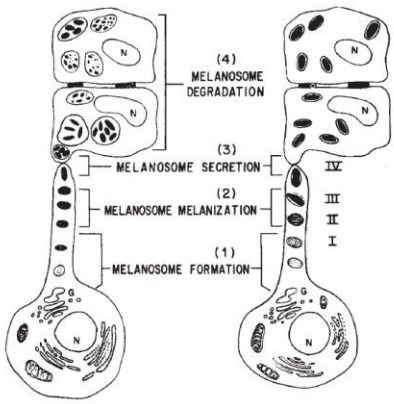
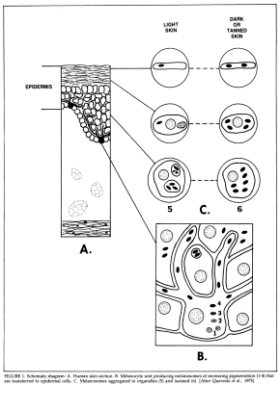


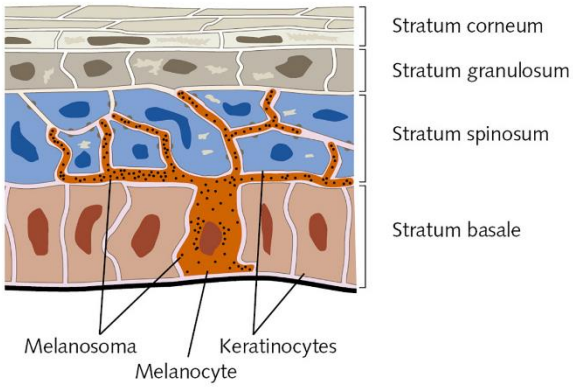
Fig. 2 The broad-band absorption spectra of eumelanin and pheomelanin.[6]

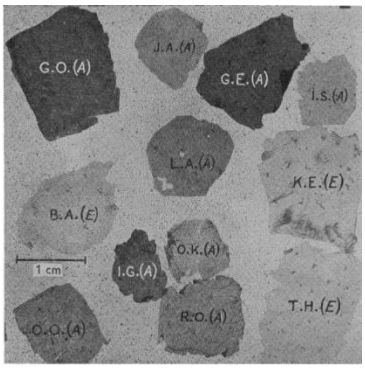
Melanin occurs in **melanosomes** that are produced in dendrite-like cells known as **melanocytes** which are **below the epidermis**. The **melanosomes** leave the **melanocytes** by exocytosis and are engulfed by endocytosis by the **keratinocytes** above in the **epidermal layer**.





On the extremes of **skin tone**, which is under both **genetic** and **environmental control**, **whiter skin tone** results from having fewer and smaller melanosomes that tend to be aggregated in the keratinocytes, and **darker skin tone** results from having more and larger melanosomes that tend to be dispersed in the keratinocytes.

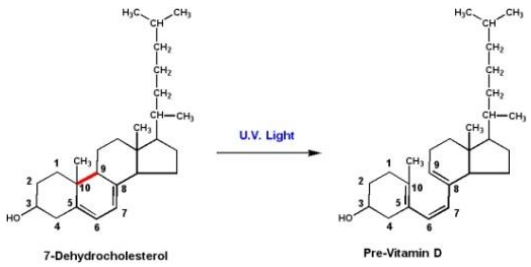




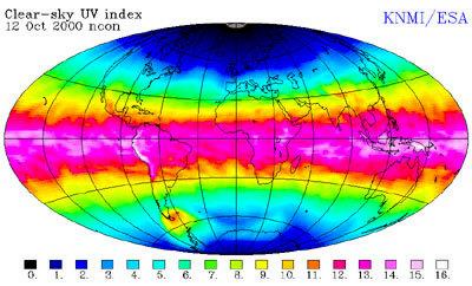
Macht, Anderson and Bell (1928) and Thomson (1955) showed that dark skin (A) **transmits** less ultraviolet light than light skin (E). Thus, skin tone can influence the **nutritional state of our bodies** in terms of the levels of **vitamin D** and **folate** by influencing the **transmission** of **ultraviolet light** through the **skin**.

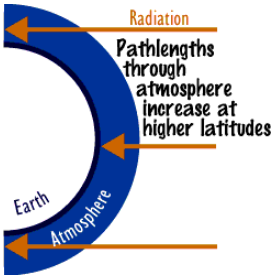


Vitamin D is responsible for the intestinal uptake of calcium and phosphate, two elements necessary for good **bones**. A **deficiency** in vitamin D results in the bone disease known as **rickets**. Hess and Unger (1921) showed that rickets can be prevented by exposure to sunlight. It turned out that the **biosynthesis of vitamin D** takes place in **the keratinocytes of the skin** and that one of the steps in the biosynthetic pathway of vitamin D **requires ultraviolet light** in the **UVB range**. The precursor of vitamin D, 7-dehydrochloresterol, is the **UVB photoreceptor pigment**.



The **melanin** in the keratinocytes ***competes*** with the **7-dehydrocholesterol**, a precursor of vitamin D, for the ultraviolet photons in the UVB range that are required for vitamin D biosynthesis. This can become a problem in **northern latitudes** where, as a result of the increased path length through the atmosphere, and the fact that **scattering** is inversely proportional to the fourth power of the wavelength, the incident level of **ultraviolet photons in the UVB range is low and limiting**, especially in the winter months. For the record, Ithaca is 42.4433° N latitude (76.5° W long).





In general, the incident level of ultraviolet photons in the UVB range is correlated with latitude, although this correlation breaks down in the southern hemisphere where there is a **hole in the ozone layer**. According to W. Farnsworth Loomis (1967) and Alain Corcos (1983), **the light skin tone of people living in northern latitudes may be a consequence of the requirement for vitamin D**.



Native people (**Inuit**) living in northern latitudes close to the Arctic Circle get along fine with dark skin as a result of a diet high in cold-water fatty fish that are rich in fat-soluble vitamin D.



Melanin, which can be **black or brown**, is not the only way to darken skin tone; increased amounts of **dietary carotene**, which is **yellow**, directed to the skin also gives a darker skin tone. The relative amounts of carotene and melanin we have in our skin give us our individual (Pantone-numbered) skin tone.









While ***too few*** ultraviolet photons may lead to a vitamin D deficiency, ***too many*** ultraviolet photons may lead to a **folate** (vitamin B9) deficiency. A deficiency in folate leads most notably to **birth defects**. Banda and Eaton (1978) found that exposure of people with light skin tones to ultraviolet photons in the **UVA** substantially lowered the levels of folate in their blood compared to the levels found in people with light skin tones that were ***not*** exposed to ultraviolet photons in the **UVA** range. Consequently, Banda and Eaton (1978) proposed that **the dark skin tone of people living near the equator may be a protection against the photolysis of folate**. Perhaps each of our skin tones came about as a ***balance*** between the **photosynthesis of vitamin D and the photolysis of folate**.

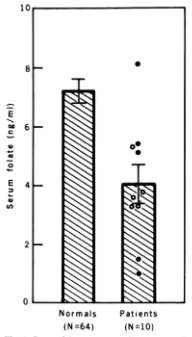
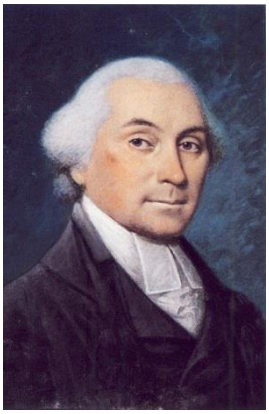


Fig. 1. Serum folate concentrations measured by radioassay (17) in ten patients receiving phototherapy (see text) and in 64 healthy individuals. All patients had received phototherapy for at least 3 months, and five patients had been exposed to UV light 9.5 to 13.5 months (open circles). The difference between the two groups was statistically significant ($P < .005$). Brackets represent the standard error of the mean.

Does **tanning** have a role in our vitamin content? In polar and temperate regions where there is a lot of sunlight in **summer** and a dearth of sunlight in winter, those people capable of tanning produce more melanin in the summer and the skin tans. This protects the folate. In the **winter**, less melanin is produced, the tan disappears and the body is in a position to produce more vitamin D.

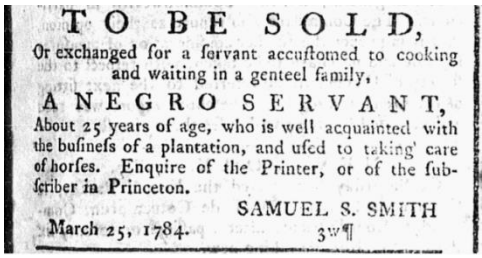


The correlation between skin tone, health, climate, and latitude was recognized long before the studies I just mentioned. In 1744, **John Mitchell** published a paper entitled, *An essay upon the causes of the different colours of people in different climates*, where he investigated the material, formal, and final causes of skin tone. As to final causes, John Mitchell (1744) wrote "*White People are most healthy in cold, and black or tawny People in hot Countries; each being Subject to Disorders, on a Removal to these respective Climes.... From what has been said about the Cause of the Colour of black and white People, we may justly conclude, that they might very naturally be both descended from one and the same Parents, as we are otherwise better assured from Scripture, that they are (a); which may remove the Scruples of some nice Philosophers on this Matter, who cannot or will not believe even the Scriptures, unless it be so far as they can be made agreeable to their Philosophy:* ***For the different Colours of People have been demonstrated to be only the necessary Effects, and natural Consequences, of their respective Climes****, and Ways of Life; as we may further learn from Experience, that they are the most suitable for the Preservation of Health, and the Ease and Convenience of Mankind in these Climes, and Ways of Living: So instead of being a Curse denounced on them, on account of their Forefather Ham, as some have idly imagined, is rather a Blessing, rendering their Lives, in that intemperate Region, more tolerable, and less painful…."*

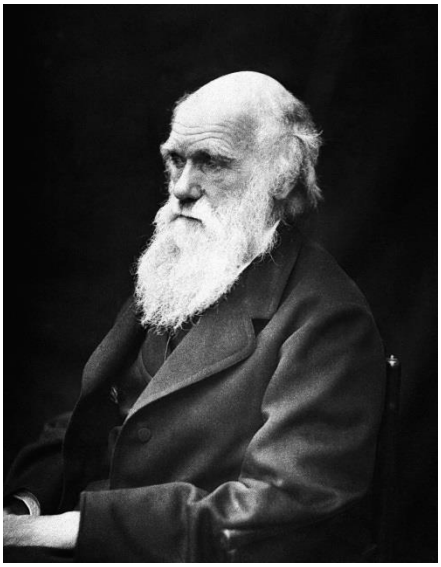


Likewise, **Samuel Stanhope Smith** (1787) wrote, in *An Essay on the Causes of the Variety of Complexion and Figure in the Human Species*, "*In tracing the globe from the pole to the equator, we observe a gradation in the complexion nearly in proportion to the latitude of the country….**Our experience verifies the power of climate on the complexion.** The heat of summer darkens the skin, the cold of winter chafes it, and excites a sanguine colour. These alternate effects in the temperate zone tend in some degree to correct one another. But when heat or cold predominates in any region, it impresses, in the same proportion, a permanent and characteristical complexion. The degree in which it predominates may be considered as a constant cause to the action of which the human body is exposed….Encircle the earth in every zone, and, making those reasonable allowances which have been already suggested, and which will afterwards be farther explained, you will see every zone marked by its distinct and characteristical colour. The black prevails under the equator; under the tropics, the dark copper; and on this side of the tropic of Cancer, to the seventieth degree of north latitude, you successively discern the olive, the brown, the fair and the sanguine complexion. Of each of these there are several tints and shades. And under the arctic circle, you return again to the dark hue. This general uniformity in the effect indicates an influence in the climate, that, under the same circumstances, will always operate in the same manner.*"

Samuel Stanhope Smith, the 7th President of Princeton (1795-1812), was an early defender of the unity of mankind—arguing that environment, not innate biological differences, determined one's race. His convictions, however, did not prevent him from owning slaves himself…."



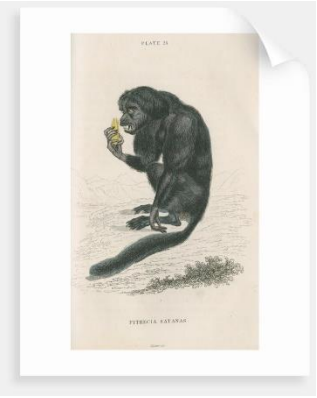
TO BE SOLD,
Or exchanged for a ſervant accuſtomed to cooking and waiting in a genteel family,
A NEGRO SERVANT,
About 25 years of age, who is well acquainted with the buſineſs of a plantation, and uſed to taking care of horſes. Enquire of the Printer, or of the ſubſcriber in Princeton.
SAMUEL S. SMITH
March 25, 1784. 3w¶



Interestingly, one particular scientist did not consider skin tone in terms of its contribution to **adaptation** to the environment, but only in terms of its **aesthetic** appeal in terms of **sexual selection**. In *The Descent of Man, and Selection in Relation to Sex*, **Charles Darwin** (1871) wrote, "*If, however, we look to the races of man, as distributed over the world,* ***we must infer that their characteristic differences cannot be accounted for by the direct action of different conditions of life****, even after exposure to them for an enormous period of time…. It is not improbable that the texture of the hair, which differs much in the different races, may stand in some kind of correlation with the structure of the skin; for the colour of the hair and skin are certainly correlated, as is its colour and texture with the Mandans. The colour of the skin and the odour emitted by it are likewise in some manner connected…. We have thus far been baffled in all our attempts to account for the differences between the races of man; but there remains one important agency, namely* ***Sexual Selection****, which appears to have acted as powerfully on man, as on many other animals.... It can further be shewn that the differences between the races of man, as in* ***colour****, hairyness, form of features, &c., are of the nature which it might have been expected would have been acted on by sexual selection* [different standards of beauty]."

Charles Darwin (1882) went on to say in the second edition, "*The best kind of evidence that in man the* ***colour of the skin*** *has been modified through sexual selection is scanty; for in most races* ***the sexes do not differ in this respec****t, and only slightly, as we have seen, in others. We know, however, from the many facts already given that* ***the colour of the skin is regarded by the men of all races as a***

highly important element in their beauty*; so that it is a character which would be likely to have been modified through selection, as has occurred in innumerable instances with the lower animals.* ***It seems at first sight a monstrous supposition that the jet-blackness of the negro should have been gained through sexual selection; but this view is supported by various analogies, and we know that negroes admire their own colour****. With mammals, when the sexes differ in colour, the male is often black or much darker than the female; and it depends merely on the form of inheritance whether this or any other tint is transmitted to both sexes or to one alone.* ***The resemblance to a negro in miniature of Pithecia satanas with his jet black skin, white rolling eyeballs, and hair parted on the top of his head, is almost ludicrous****.*



The colour of the face differs much more widely in the various kinds of monkeys than it does in the races of man; and we have some reason to believe that the red, blue, orange, almost white and black tints of their skin, even when common to both sexes, as well as the bright colours of their fur, and the ornamental tufts about the head, have all been acquired through sexual selection. ***As the order of development during growth, generally indicates the order in which the characters of a species have been developed and modified during previous generations****; and as the newly-born infants of the various races of man do not differ nearly as much in colour as do the adults, although their bodies are as completely destitute of hair,* ***we have some slight evidence that the tints of the different races were acquired at a period subsequent to the removal of the hair****, which must have occurred at a very early period in the history of man."*

Then Charles Darwin (1882) summarized his views, "*We may conclude that the greater size, strength, courage, pugnacity, and energy of man, in comparison*

with woman, were acquired during primeval times, and have subsequently been augmented, chiefly through the contests of rival males for the possession of the females. The greater intellectual vigour and power of invention in man is probably due to natural selection, combined with the inherited effects of habit, for the most able men will have succeeded best in defending and providing for themselves and for their wives and offspring. As far as the extreme intricacy of the subject permits us to judge, it appears that our male ape-like progenitors acquired their beards as an ornament to charm or excite the opposite sex, and transmitted them only to their male offspring. The females apparently first had their bodies denuded of hair, also as a sexual ornament; but they transmitted this character almost equally to both sexes. It is not improbable that the females were modified in other respects for the same purpose and by the same means; so that women have acquired sweeter voices and become more beautiful than men.

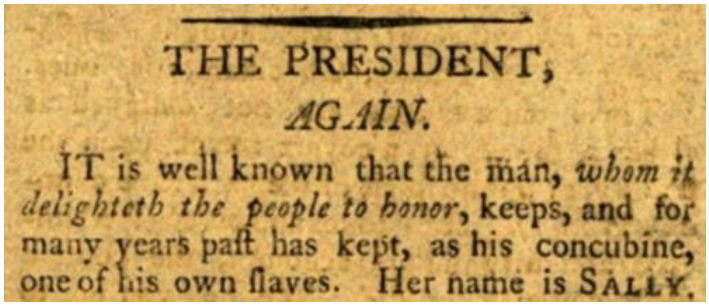
It deserves attention that with mankind the conditions were in many respects much more favourable for sexual selection, ***during a very early period, when man had only just attained to the rank of manhood****, than during later times.* ***For he would then, as we may safely conclude, have been guided more by his instinctive passions, and less by foresight or reason****. He would have jealously guarded his wife or wives. He would not have practised infanticide; nor valued his wives merely as useful slaves; nor have been betrothed to them during infancy. Hence we may infer that the races of men were differentiated, as far as sexual selection is concerned, in chief part at a very remote epoch; and this conclusion throws light on the remarkable fact that at the most ancient period, of which we have as yet any record, the races of man had already come to differ nearly or quite as much as they do at the present day.*

The views here advanced, on the part which sexual selection has played in the history of man, want scientific precision. He who does not admit this agency in the case of the lower animals, will disregard all that I have written in the later chapters on man. We cannot positively say that this character, but not that, has been thus modified; it has, however, been shewn that the races of man differ from each other and from their nearest allies, in certain characters which are of no service to them in their daily habits of life, and which it is extremely probable would have been modified through sexual selection. We have seen that with the lowest savages the people of each tribe admire their own characteristic qualities,—the shape of the head and face, the squareness of the cheek-bones, the prominence or depression of the nose, ***the colour of the skin****, the length of the hair on the head, the absence of hair on the face and body, or the presence of a great beard, and so forth. Hence these and other such points could hardly fail to be slowly and gradually exaggerated, from the more powerful and able men in each tribe, who would succeed in rearing the largest number of offspring, having selected during many generations for their wives the most strongly characterised and therefore most attractive women.* ***For my own part I conclude that of all the causes which have led to the differences in external appearance between the races of man, and to a certain extent between man and the lower animals, sexual selection has been the most efficient****.*" What do you think?

In *Darwin's Sacred Cause: How a Hatred of Slavery Shaped Darwin's Views on Human Evolution*, Adrian Desmond and James Moore (2009) applaud Charles Darwin's "*scientific support for racial unity, now detached from its religious roots* [as being] *inimical to the pluralistic pro-slavery message*" and virtually ignore Samuel Wilberforce's anti-slavery works and concerns. Charles

Darwin was not only a scientist, but a product of his times and his science must be interpreted with this in mind.

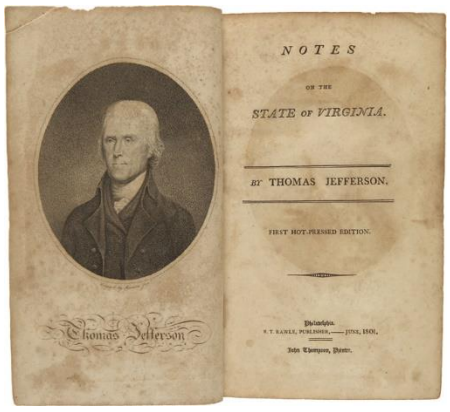
I wonder what Thomas Jefferson would think about Charles Darwin's arguments for the sexual selection of skin color?



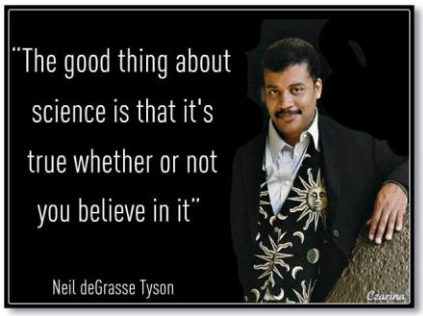
THE PRESIDENT,
AGAIN.

IT is well known that the man, *whom it delighteth the people to honor*, keeps, and for many years paft has kept, as his concubine, one of his own flaves. Her name is SALLY.

Thomas Jefferson (1787) was also a **scientist and a product of his times**. He wrote as a scientist in ***Notes on the State of Virginia***, "*Comparing them by their faculties of memory, reason, and imagination, it appears to me that in memory they are equal to the Whites, in reason much inferior, as I think one could scarcely be found capable of tracing and comprehending the investigation of Euclid; and that in imagination they are dull, tasteless, and anomalous*." **Again, it is more important to understand the science than to just believe it**.



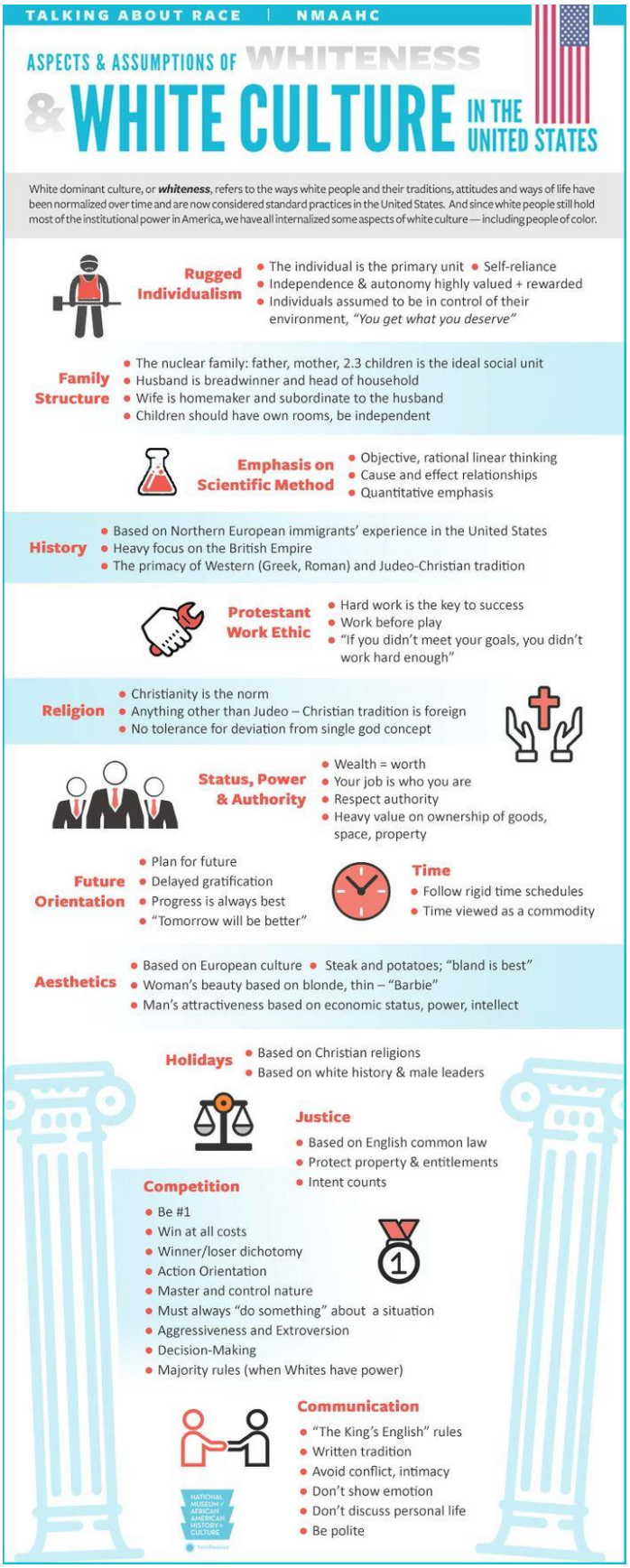
NOTES
ON THE
STATE OF VIRGINIA.
BY THOMAS JEFFERSON.
FIRST HOT-PRESSED EDITION.
Thomas Jefferson



Is there an association between skin color and values and does this lead to oppression by white people?

In the June 21, 1862 edition of Harper's Weekly it says, "*THERE is a lively piece of twaddle afloat. It is the ineffably and silly assertion that this is a nation of white men, or a white man's government. Of course it is only one of the mean appeals to the hate that people always feel for those they have injured. Its intention is to quench any sympathy for black men. It is the kind of argument that does duty in bar rooms, and is very effective in the mouths of politicians whose success depends upon the ignorance and not upon the intelligence of the people*."

Today, calling America a white nation is *in vogue*.



And Cornell University is in vogue, or should I say, woke.

Randy O. Wayne

From: bounce-126477827 -90823176@list.cornell.edu on behalf of Lori J. Sonken
Sent: Tuesday, April 12, 2022 8:40 AM
To: FACULTY-DEVELOPMENT-EVENTS-L
Subject: Register Now: How to Interrupt Inequality in Faculty Hiring (4/29)

Colleagues,

We are writing to invite you to an event hosted by the Faculty Advancement Network (FAN), the Ivy Plus consortium, organized to advance diversity and inclusion in the professoriate. Cornell is a founding member.

Ivy+ FACULTY ADVANCEMENT NETWORK



In this FAN workshop, Dr. Damani White-Lewis and Dr. Román Liera will present evidence that typical faculty hiring practices cement racial and ethnic inequalities in the professoriate. How do our perceptions of "fit", "niceness," and "whiteness" get in the way of racial equity, from before the ad to after the offer? We will be guided through strategies to assess hiring in different stages so that faculty, search committees, and academic leaders can make better decisions.

Click here to see the research

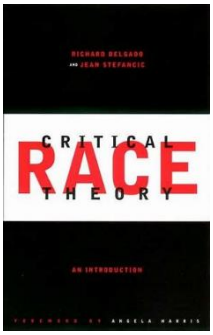
and to register for

Out of curiosity, what is "whiteness," and does it have anything to do with melanin concentration? Also, has anyone ever considered "fit" and "niceness" in terms of race—or is this "just academic"?



Judith H. Katz (1978) wrote in *White Awareness: Handbook for Anti-Racist Training*, "*White people do not see themselves as White. This is a way of denying responsibility for perpetuating the racist system and being part of the problem. By seeing oneself solely as an individual, one can disown one's racism*." I could not agree less. **Since I take the view that the heart, mind, and soul belong to an individual, not to an identity group, the only way for someone to think freely, and to take responsibility for their thoughts and actions is to see oneself primarily as an individual**. The importance of individual freedom and equality, the cornerstone of liberalism, is a product of the **Age of Enlightenment**. Critical race theory, on the other hand is a product of **Postmodernism**. According to **Richard Delgado and Jean Stefancic** (2001, 2017), the authors of *Critical Race Theory: An Introduction*, "[c]*ritical race theory scholars are* ***discontented with liberalism*** *as a framework for addressing America's racial problems*." To be more specific, "[u]*nlike traditional civil rights, which embraces incrementalism and step-by-step progress, critical race theory questions the very foundations of the liberal order, including* ***equality theory****, legal* ***reasoning****, Enlightenment* ***rationalism****, and neutral principles of constitutional law*."





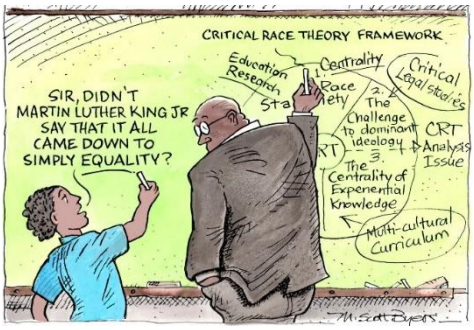
With critical theory, the identity of a group becomes more fundamental than the individual; discontinuous change is considered better than continual change, and Enlightenment rationalism and constitutional law, founded on the laws of nature and nature's God, are no longer considered to be fundamental. The tenets of critical theory have replaced the tenets of a liberal education. Indeed, Delgado and Stefancic (2001) stated, "*Many in the field of education consider themselves critical race theorists…* [and] critical *race theory*

contains an activist dimension. It not only tries to understand our social situation, but to change it; it sets out not only to ascertain how society organizes itself along racial lines and hierarchies, but to transform it for the better."

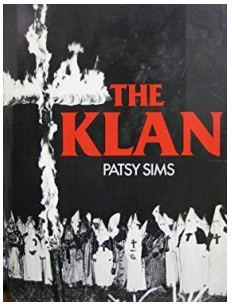


I have another issue with critical theory. According to Delgado and Stefancic (2001), "***For the critical race theorist, objective truth, like merit, does not exist, at least in social science and politics. In these realms, truth is a social construct created to suit the purpose of the dominant group***." I have the same problem with physical theories that posit that objective space and time do not exist.

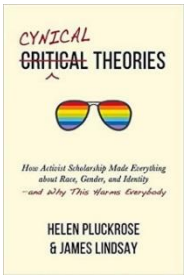
Aside: In my humble opinion, critical theory, based on the **postmodernist** foundational assumption that there is no Truth except the Truth that society is comprised of systems of power, privilege, and victimhood, and those in power and with privilege construct knowledge with the goal of victimizing those who are not in positions of power and privilege, does not describe what I believe to be an objectively real world. Critical theory states that there is no objective knowledge and anyone who claims to have objective knowledge is doing so to keep or to gain power. I have read many things on critical theory, and to me critical theory seems to be foundationless—as it must be if it is to be postmodern. I also think that it is more illiberal, authoritarian, and divisive than liberal philosophy, and is well characterized by the phrase "*Shut up and listen*." Using the R-word to refer to white people, where one can "at best" become an anti-racist



racist, is no different than using the N-word to refer to black people. According to Judith Katz, author of *White Awareness*, "*an anti-racist racist is a white person who understands his/her racism, understands as well that given the dynamics of racism in the U.S. today they will always be racist but takes action steps to try and combat it in situations where he/she has some power*."



To me, critical theory is reminiscent of the Inquisition, where one is not free to question the fundamental assumption that all knowledge and behavior is based on power, privilege, and victimhood. I believe that critical theory has more similarities with Jim Crow philosophy and the sentiment of the Ku Klux Klan than with the philosophy of the Civil Rights Movement. I believe that Critical Theorists create a certain group "*who desperately longed to be better than somebody*", as Patsy Sims described the Klan. I believe that Critical Theory leads less to social justice than to **universal mental slavery**. As Martin Luther King Jr. (1967) said in a speech entitled, *Where do we go from here?* to the Southern Christian Leadership Conference, "*As long as the mind is enslaved, the body can never be free*. "



Critical theory, which targets whiteness, is ***celebrated*** in academia, and is currently the pinnacle of academic scholarship and a research area that provides a sure way to get a job in the administration or in human resources in a corporation. Proponents of critical theory, which teaches one to search for minute details of culture that may result in identity-based microaggressions, power imbalances, and oppression, believe that critical theory should be a requirement for education; and opponents of critical theory, believe that it is more like propaganda, manipulation, and indoctrination, and as such is an anathema to the search for truth in a free society. Although this may seem extreme, in my experience, near universal celebration of critical theory is the academic equivalent to **pithing**, **a**



neurophysiological technique used to separate the spinal cord from the brain, so that simple reflexes that do not depend on the brain can still occur. Again, this is my opinion, and you are welcome to agree or disagree.

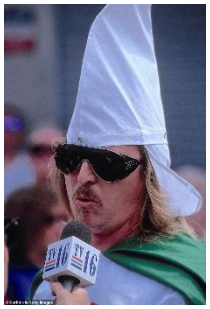
Helen Pluckrose and James Lindsay (2020) wrote in *Cynical Theories*, "*While scholars can, of course, be activists and activists can be scholars, combining these two roles is liable to create problems and,* ***when a political stance is taught at a university, it is apt to become an orthodoxy, which cannot be questioned****. Activism and education exist in a fundamental tension—activism presumes to know the truth with enough certainty to act upon it, while education is conscious that it does not know for certain what is true and therefore seeks to learn more.*"



There is racism, discrimination, bigotry, and inequality in America. But is America better defined by its racism or by its anti-racism? What are the historical and international standards by which it should be judged? Are the standards fair? Why are so many people, including people of color migrating to America? Kathleen Brush (2020) wrote in *Racism and anti-Racism in the World before and after 1945,* "[r]*ecently, thousands have said they were unproud to be American because of its Racism? I hope this book will show that America is an anti-racist leader, and this is something to be proud of*." Once historical and international standards are taken into consideration, you may see that critical theory is the opposite of critical thinking, and solutions for existing problems based on critical thinking look very different compared to solutions based on critical theory.

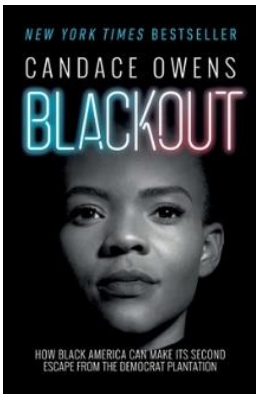
One can make a living in the race industry. In 1911, Booker T. Washington wrote in The Intellectuals and the Boston Mob, "[t]***here is another class of***

coloured people who make a business of keeping the troubles, the wrongs and the hardships of the Negro race before the publi*c. Having learned that they are able to make a living out of their troubles, they have grown into* ***the settled habit of advertising their wrongs—partly because they want sympathy and partly because it pays****. Some of these people do not want the Negro to lose his grievances, because they do not want to lose their jobs*." **Chester Doles**, a member of the Ku Klux Klan also wanted to make money in the grievance industry. He told Daryl Davis, the author of *Klan-Destine Relationships*, "*There's a lot of money to be made in racial politics for profit. I will follow in the steps of David Duke*." A lucrative grievance industry exists on the right and the left.





Candace Owens (2020), in her book *Blackout*, promotes questioning the assumptions of the academic orthodoxy. In a section entitled ***Allegory of the Democratic Cave***, she wrote, "*True freedom and real change are always possible. I awake every morning with a renewed sense of hope that we are moving closer and closer to dragging Plato's prisoners into the light. I have learned to practice patience, persistence, and optimism through my admiration of Frederick Douglass, who once wrote, 'I have seen how a man was made a slave.' His words ring like a timeless bell because I believe that I too have seen how men are made slaves. I have seen how black Americans have been enslaved by the debate of race. I have seen how liberals and leftists, under guidance from the Democratic establishment, have stripped us of our families, our faith, and our futures. But Douglass's quotation continues, with a promising forewarning: 'And now you shall see how a slave was made a man.' And so we shall."*





James Lindsay, Peter Boghossian and Helen Pluckrose believed that "[s]*omething has gone wrong in the university—especially in certain fields within the humanities. Scholarship based less upon finding truth and more upon attending to social grievances has become firmly established, if not fully dominant, within these fields, and their scholars increasingly bully students, administrators, and other departments into adhering to their worldview. This worldview is not scientific, and it is not rigorous. For many, this problem has been growing increasingly obvious, but strong evidence has been lacking. For this reason, the three of us just spent a year working inside the scholarship we see as an intrinsic part of this problem*." They created a hoax to show the similarity between critical theory and the ideas of intolerance against a given group expressed by Adolf Hitler in *Mein Kampf*. They submitted a paper entitled, **Our Struggle Is My Struggle: Solidarity Feminism as an Intersectional Reply to Neoliberal and Choice Feminism** to *Afflia: Journal of Women and Social Work* under the names of Maria Gonzales and Lisa A. Jones. When the editors found out that the paper was a hoax, they retracted it. In that paper, the authors paraphrased Chapter 12, in volume I of *Mein Kampf* and concluded that individuality is the enemy of identity:

The women's movement has long been pluralistic, yet in recent decades has diversified further along lines of ***individual choice*** *versus* ***collective action****. This has been enabled by new opportunities for women that were not universally accessible. As a result, a form of* ***choice feminism*** *has developed in some feminists, especially in contexts in which* ***neoliberalism*** *is dominant, while calls for intersectional allyship, inclusion, and solidarity have grown louder in others. Responding to this tension, many scholars, particularly those within the field of social work, have shown* ***that choice feminism is characterized by a number of problematic themes that can, paradoxically, reinforce oppression for marginalized people****. Particularly, it can offer a heuristic of choice that is used to justify feminist decisions that benefit a small set of women at the expense of standing in solidarity with others and remediating oppression. This complex*

problem may benefit from a detailed interrogation of allyship and its attendant repercussions. Consequently, this paper forwards a framework for ***solidarity feminism****—that is, an approach to feminism that centers solidarity against oppression by favoring* ***inclusive values-based allyship over choice feminism*** *as an intersectional means to address one aspect of the enduring universalism problem within the feminist movement.* I ask, who gets to choose the inclusive values?



Nikki Haley (2019) said at the Fall Convocation at Elon University, "*That lesson I learned on the playground has literally played out throughout my life. When you are faced with a challenge, if you first discuss what you have in common, and then get to the challenges, everyone lets their guard down and then you can have a discussion*."

On March 20, 2022, The New York Times editorial board published an editorial entitled, *America has a free speech problem*. Here is an excerpt. "*For all the tolerance and enlightenment that modern society claims, Americans are losing hold of a fundamental right as citizens of a free country: the right to speak their minds and voice their opinions in public without fear of being shamed or shunned.*

This social silencing, this depluralizing of America, has been evident for years, but dealing with it stirs yet more fear. It feels like a third rail, dangerous. For a strong nation and ***open society****, that is dangerous.*

How has this happened? In large part, it's because the political left and the right are caught in a destructive loop of condemnation and recrimination around cancel culture. Many on the left refuse to acknowledge that cancel culture exists at all, believing that those who complain about it are offering cover for bigots to peddle hate speech. Many on the right, for all their braying about cancel culture, have embraced an even more extreme version of censoriousness as a bulwark against a

rapidly changing society, with laws that would ban books, stifle teachers and discourage open discussion in classrooms.

Many Americans are understandably confused, then, about what they can say and where they can say it. ***People should be able to put forward viewpoints, ask questions and make mistakes and take unpopular but good-faith positions on issues that society is still working through - all without fearing cancellation****.*

However you define cancel culture, Americans know it exists and feel its burden. In a new national poll commissioned by Times Opinion and Siena College, only 34 percent of Americans said they believed that all Americans enjoyed freedom of speech completely. The poll found that 84 percent of adults said it is a 'very serious' or 'somewhat serious' problem that some Americans do not speak freely in everyday situations because of fear of retaliation or harsh criticism.

This poll and other recent surveys from the Pew Research Center and the Knight Foundation reveal a crisis of confidence around one of ***America's most basic values. Freedom of speech and expression is vital to human beings' search for truth and knowledge about our world. A society that values freedom of speech can benefit from the full diversity of its people and their ideas. At the individual level, human beings cannot flourish without the confidence to take risks, pursue ideas and express thoughts that others might reject.***

Most important, freedom of speech is the bedrock of democratic self-government. If people feel free to express their views in their communities, the democratic process can respond to and resolve competing ideas. Ideas that go unchallenged by opposing views risk becoming weak and brittle rather than being strengthened by tough scrutiny*.*

When speech is stifled or when dissenters are shut out of public discourse, a society also loses its ability to resolve conflict, and it faces the risk of political violence."



Free speech is an essential freedom in America. Three minutes ago, the *New York Times* posted this: Elon Musk Offers to Buy Twitter: Live Updates. His takeover bid at $54.20 a share comes just weeks after he became the company's largest shareholder. Musk wrote to Bret Taylor, the chair of the Twitter board, "*I invested in Twitter as I believe in its potential to be the platform for free speech around the globe, and I believe free speech is a societal imperative for a functioning democracy,*" he said in the letter to Twitter. *"However, since making my investment I now realize the company will neither thrive nor serve this societal imperative in its current form. Twitter needs to be transformed as a private company*."

I personally believe that universities are the breeding grounds of cancel culture, and moreover, that science is being used and abused as an intellectually lethal tool of cancel culture. This is why I teach *Light and Life* as I do. It is neither a popular nor an easy approach, but I cannot do otherwise. When he was more than four score and one year old, and his "*lamp of life*" was almost spent,





John Stark wrote a toast in a letter on July 31, 1809, in which he described the Revolutionary War soldiers he led at the Battle of Bennington, "*They were men that had not learned the art of submission, nor had they been trained to the art of war. But* ***our astonishing success taught the enemies of liberty that undisciplined***

freemen are superior to veteran slaves." The toast was, "***Live free, or die—Death is not the worst of evils***." This became the state motto of New Hampshire.

John Lennon's dream in *Imagine* contrasts with Stark's view.

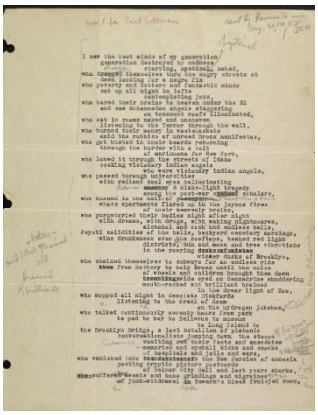


Imagine there's no countries
It isn't hard to do
Nothing to kill or die for
And no religion too
Imagine all the people
Living life in peace

You may say I'm a dreamer
But I'm not the only one
I hope someday you'll join us
And the world will be as one



I live every day for what I consider to be the best balance between individual freedom and societal freedom, although what I have written above is out of step with academia today. To use a line from Allen Ginsberg's *Howl*, "*I saw the best minds of my generation destroyed by madness*." Like always, you are free to have your own views. However, I do ask you to think critically about the value and limitations of critical theory, as you would for any theory, including my theories.



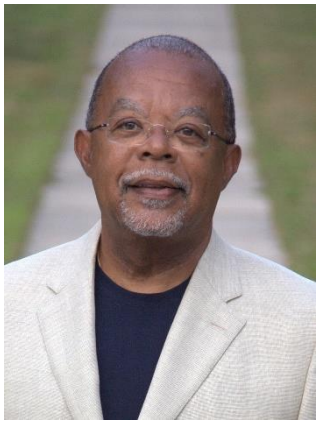
Do you have to be white to own or sell slaves? Nwaubani Ogogo Oriaku, the great grandfather of Nigerian journalist **Adaobi Tricia Nwaubani** was a slave seller and a product of his times.



https://www.bbc.com/news/world-africa-53444752
https://www.theguardian.com/world/2009/nov/18/africans-apologise-slave-trade



And now for another indication that one's identity defined by skin color is less of an indication of someone's view of freedom than one's individual character: Carter G. Woodson (1924) wrote in *Free Negro Owners of Slaves in the United States in 1830*, "*The aim of this report on the free Negro is to facilitate the further study of this neglected group. Most of these people have been forgotten, for persons supposedly well-informed in history are surprised to learn today that about a half million, almost one-seventh of the Negroes of this country, were free prior to the emancipation in 1865.* ***It is hardly believed that a considerable number of Negroes were owners of slaves themselves, and in some cases controlled large plantations***."



Henry Louis Gates Jr, a former Cornell Professor of English, Literature and Africana Studies from 1985 to 1990, wrote in an OpEd entitled, *Ending the Slavery Blame-Game*, "*Advocates of reparations for the descendants of those slaves generally ignore this untidy problem of the significant role that Africans played in the trade, choosing to believe the romanticized version that our ancestors were all kidnapped unawares by evil white men, like Kunta Kinte was in* 'Roots.' *The truth,*

however, is much more complex: slavery was a business, highly organized and lucrative for European buyers and African sellers alike."

I understand that my assumption of the fundamental nature of the individual versus the fundamental nature of identity based on skin color is not in line with critical theory. Everyone is free to choose the assumptions that they feel are closest to the truth. This is in line with the concept of diversity of thought.

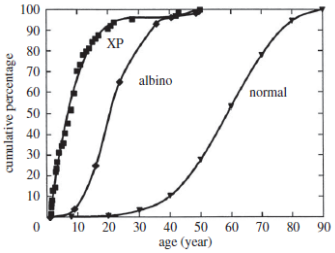
One more thing about the biological consequences of skin color.



Figure 2. Tanzanian African albino. Copyright Reuters.

Since albinos have a greater incidence of **skin cancer** compared to people with darker skin, Mel Greaves suggests that dark skin evolved as a protection against skin cancer. It is possible that the earliest humans had white skin covered by fur—similar to the skin color that occurs under the fur in **chimpanzees**. The skin of the hairless face and hands are also white in infant chimpanzees but becomes darker with age. The fur would protect the white skin from the sun's melanoma-causing and folate-degrading UV rays. As hair became thinner, the amount of melanin in the skin increased to protect us from the sun's ultraviolet rays. Some people in Africa even evolved dark black skin. The lighter soles and palms of dark-skinned people are more prone to skin cancer than the darker areas. (XP—individuals with a defect in DNA damage repair)





Greaves suggests that at first all proto-humans lost their fur and were white skinned, then all humans were black skinned. Eventually, once people migrated out of Africa approximately 50,000-80,000 years ago, they experienced a lot more variation in levels of sunlight—and consequently more variation in skin color evolved. For example, in Northern Europe, where there is little sunlight, a mutation that caused albinism emerged that allowed the carrier to

synthesize vitamin D in limited sunlight. Generally speaking, the variation in skin color then is a reflection of the variation in the intensity and duration of sunlight from the equator to the poles.



In general, people do not usually think of the **biological roles** of melanin and skin color, but the **socially-constructed roles** and politically-constructed roles. As an example of the politically-constructed roles, in 2020, when running for president, Joe Biden told Charlamagne Tha God on The Breakfast Club, "*If you have a problem figuring out whether you're for me or Trump then you ain't black*."

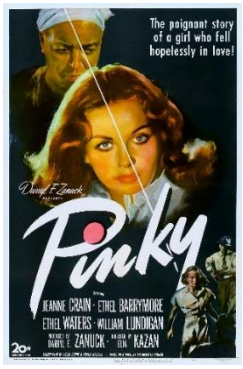


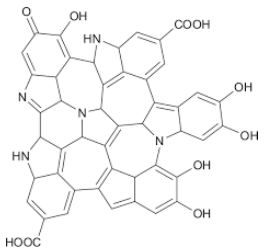
In order to get a feel for the socially-constructed roles based on melanin, the movies *Imitation of Life*, *I Passed for White*, *Lost Boundaries*, and *Pinky* show what happens when people have very light skin and are treated as being black or white at different times in their lives. Think of molecules as having both a scientific and social history. *Melanin: The Scientific and Social History of a Molecule*.



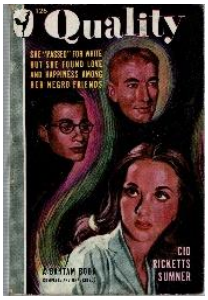


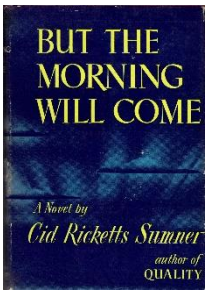




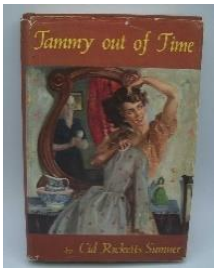


Aside: *Pinky* was the film version of *Quality* written in 1946 by (Bertha) Cid Ricketts Sumner, the former wife of Cornell's James B. Sumner, the one-armed biochemist who won the Nobel Prize for showing that enzymes are proteins. Cid Ricketts Sumner (1949) wrote in the pre-civil rights era. In *But the Morning Will Come* Sumner wrote about the complexities of individual people that academics, such as Miss Stockbridge, do not always understand. Philip tells her "*When you break a mob into individuals, it disintegrates. Give the victim a name and a place, no matter how lowly, in the community, and he is no longer an impersonal menace that must be destroyed*." Miss Stockbridge says, "*Well, I must say, it is most disturbing…I had my thesis so well planned, with all my facts and observations fitting neatly under my convictions. And now—*" Philip answers (describing the inductive scientific method of Francis Bacon), "***Perhaps it might be more logical and scientific to draw your convictions from your facts***." Jeff adds, "*Miss Stockbridge had said that the world must be changed all in a moment, by force of will and edict. I told her that any real and lasting change in human relations must come slowly and naturally, not from the outside, but from within*."





Sumner also wrote the Tammy series that was also made into movies, including *Tammy and the Bachelor*, *Tammy in Rome*, *Tammy Tell Me True*, and *Tammy and the Doctor*, and *Tammy and the Millionaire*.



Abel Meeropol wrote a song called *Strange Fruit* that was first sung by Billie Holiday (https://www.youtube.com/watch?v=-DGY9HvChXk). It was written in response to a lynching based on the melanin content of skin. The song was specifically written in response



to a photograph taken by Lawrence Beitler that portrayed the lynching of Thomas Shipp and Abram Smith that occurred on August 7, 1930 in Marion Indiana (https://www.npr.org/templates/story/story.php?storyId=129025516).

Strange Fruit

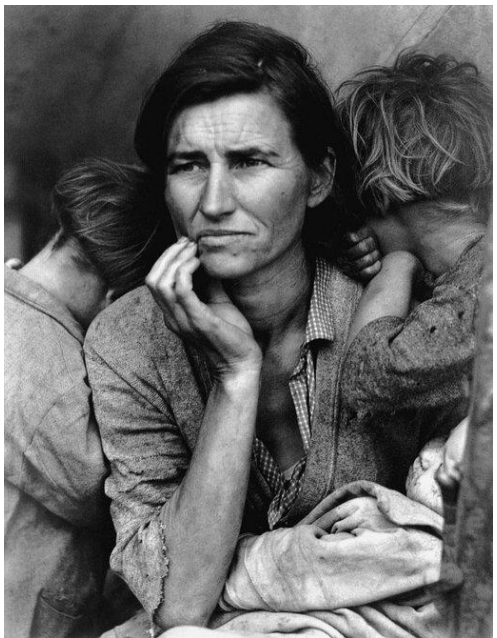


Southern trees bearing strange fruit
Blood on the leaves and blood at the roots
Black bodies swinging in the southern breeze
Strange fruit hanging from the poplar trees
Pastoral scene of the gallant south
Them big bulging eyes and the twisted mouth
Scent of magnolia, clean and fresh
Then the sudden smell of burning flesh
Here is fruit for the crows to pluck
For the rain to gather, for the wind to suck
For the sun to rot, for the leaves to drop
Here is a strange and bitter crop.



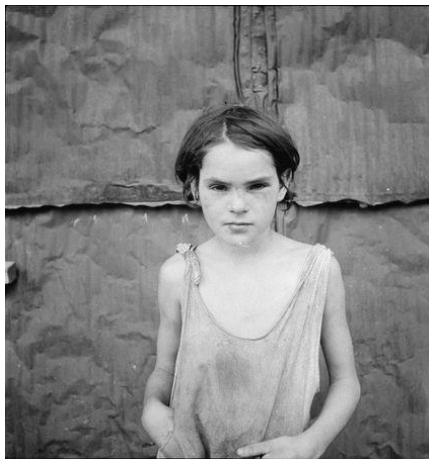
An individual's face is so much more than its melanin content. According to Dorothea Lange, "*The human face is the universal language. The same expressions are readable, understandable all over the world*." And I will add, no matter what the group identity or intersectionality. Here are some photographs taken by Dorothea Lange.

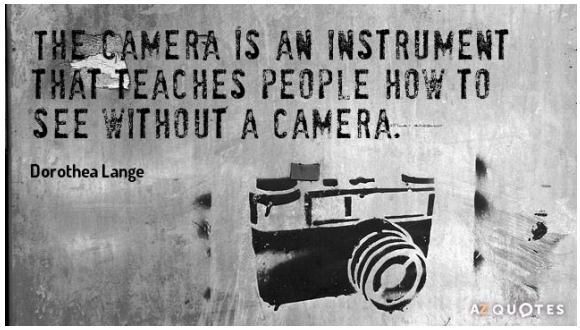




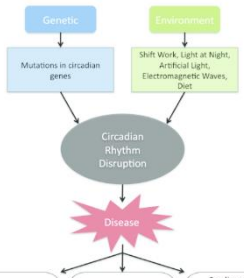




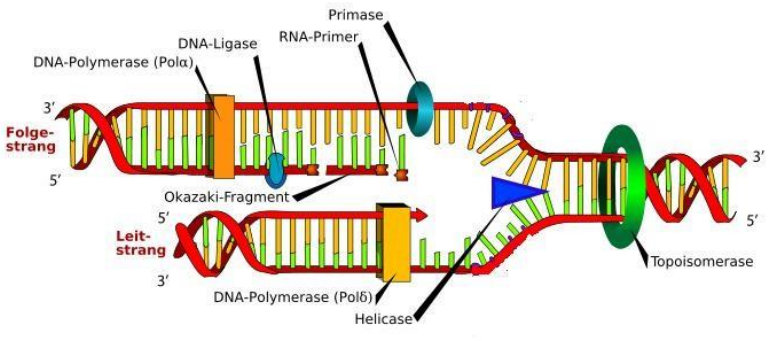



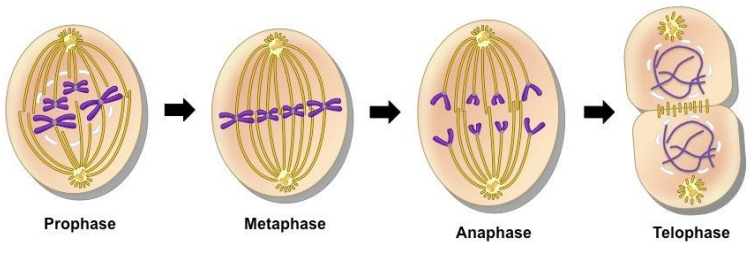


The synchronization of **circadian rhythms** with the normal day-night cycle established by the rotation of the earth is associated with a lower incidence of **cancer**. This may be because cells divide at night when the cancer-causing UV rays from the sun are on the other side of the earth (Bünning, 1953). Restricting **cell division** to the dark period is universal among organisms from cyanobacteria to humans.



Cell division that does not lead to evolution requires the perfect copying of the genes and the perfect distribution of those identical genes to the daughter cells. Both the copying (**DNA replication**) and the distribution





(**mitosis** and meiosis) are hypersensitive and vulnerable to UV damage. Disruption of these processes could result in cancer. Consequently, the timing of cell division, which includes DNA replication and chromosome movement typically occurs at night and is regulated by the circadian clock.

The selective value of avoiding UV light during cell division, especially on the early earth before the cyanobacteria produced the O_2 that shielded the planet from UV light, may have been the impetus for the evolution and/or design of the biological clock.

While we now know that UV radiation has both positive and negative effects, in hindsight we see that what is sold as science may appear to have been nothing more than propaganda or advertising, if we do not think critically and maintain a certain skepticism as long as we do not know the whole story. Based on the scientific study of UV light, at the time, UV bulbs were produced and sold that were "*as safe as the sun*," but if UV light could kill bacteria by damaging their DNA, was it not impossible that it could also damage our DNA?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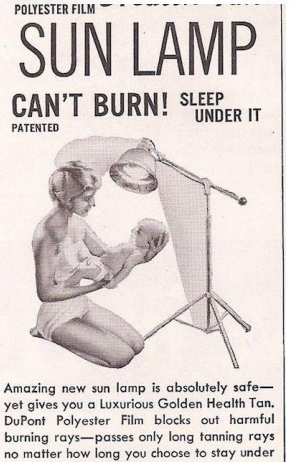
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Humans cannot see in the ultraviolet range, but some animals are able to **see ultraviolet light**. **John Lubbock**, Charles Darwin's neighbor and a banker by trade, first showed that some animals are able to see ultraviolet light. In his book entitled, *On the Senses, Instincts, and Intelligence of Animals; With Special Reference to Insects*, Sir John Lubbock (1889) wrote "*I HAVE elsewhere* [in *Ants, Bees, and Wasps*] *recorded a series of experiments on ants with light of different wave-lengths, in order, if possible, to determine whether ants have the power of distinguishing colors. For this purpose* ***I utilized the dislike which ants, when in their nest, have for light****. Not unnaturally, if a nest is uncovered, they think they are being attacked, and hasten to carry their young away to a darker and, as they suppose, a safer place. I satisfied myself, by hundreds of experiments, that if I exposed to light the greater part of a nest, but left any of it covered over, the young would certainly be conveyed to the dark part. In this manner I satisfied myself that the various rays of the spectrum act on them in a different manner from that in which they affect us; for instance, that ants are* ***specially sensitive to the violet rays****. But I was anxious to go beyond this, and to attempt to determine whether… their limits of vision are the same as ours. We all know that if a ray of white light is passed through a* ***prism****, it is broken up into a beautiful band of colors, known as the* ***spectrum****. To our eyes this spectrum, like the rainbow, which is, in fact, a spectrum, is bounded by red at the one end and violet at the other, the edge being sharply marked at the red end, but less abruptly at the violet. But a ray of light contains, besides the rays visible to our eyes, others which are called, though not with absolute correctness, heat-rays and* ***chemical rays****. These, so far from falling within the limits of our vision, extend far beyond it, the heat-rays at the red end, the chemical or* ***ultra-violet rays*** *at the violet end. I made a number of experiments which satisfied me that ants are sensitive to the* ***ultra-violet rays****,* ***which lie beyond the range of our vision****. I was also anxious to see how two colors identical to our eyes, but one of which transmitted and the other intercepted the* ***ultra-violet rays****, would affect the ants. Mr. Wigner was good enough to prepare for me a solution of iodine in bisulphide of carbon, and a second of indigo, carmine, and roseine mixed so as to produce the same tint. To our eyes the two were identical both in color and capacity; but of course the* ***ultra-***



violet rays *were cut off by the bisulphide-of-carbon solution, while they were, at least for the most part, transmitted by the other. I placed equal amounts in flat-sided glass bottles, so as to have the same depth of each liquid. I then laid them, as in previous experiments, over a nest of Formica fusca. In twenty observations the ants went seventeen times in all under the iodine and bisulphide, twice under the solution of indigo and carmine, while once there were some under each. These observations, therefore, show that the solutions,* ***though apparently identical to us, appeared to the ants very different****, and that, as before,* ***they preferred to rest under the liquid which intercepted the ultra-violet rays****....*"



In order to determine if the ants sensed the ultraviolet light with their eyes, **Auguste Forel** hoodwinked the ants by putting varnish over their eyes**.** While the **sighted ants avoided the region irradiated with ultraviolet light**, the **blinded ants** did not, indicating that the ants used only their eyes and not their whole body to see ultraviolet light.

Aside: Many people believe in science and ostracize others who they claim do not believe in science. I think this worldview is based on the belief that science is objective and based on facts that need not be questioned. Again, I am a minority of one who believes that **science is a human endeavor** and as such **individual philosophy permeates science**. As scientists, it is important that we state any assumptions we may hold that may influence what experiments we do, which observations we make, and how we interpret our results. It is just as important that the nonscientist consider these questions.

Our worldview influences our science just as our science influences our worldview. In the epilogue of his book, "*The Social World of Ants Compared with that of Man*" Auguste Forel (1928) wrote, "*The resemblance between a society of ants and a society of men is no mere matter of appearances, any more than the difference between them. Both depend on profound causes, hereditary or acquired,*

which we have now to analyse seriously;…there is 'a shifting of proclivities from the egocentric to the sociocentric plane.' The great variability of their instincts, the generally omnivorous capacities of their digestion, the multiplicity of their species…, their longevity, the relative stability of their colonies and their distribution over practically the whole world give the ants a great social force which other social insects possess in part only. According to Wheeler, both ants and mammals seem to have appeared during the period which we call Mesozoic or secondary, when life first began to blossom throughout the world in its full glory. As the same author shows, the formicary is a society of females and their polymorphous derivative forms, in which the stupid male plays but an accessory part as a humble follower. The two human sexes, on the other hand, are complementary to each other, their mental faculties being, generally speaking, equivalent. The hereditary social instinct of ants permits them to live without chieftains, guides, police of laws, in an admirably co-ordinated state of anarchy; human beings are absolutely incapable of doing this, and if they attempt as much they at once fall back into such a triumphant state of brigandage that they are compelled to submit once more to the rule of chieftains. Such is the ancient tragedy of humanity, a thousand times repeated throughout history….the social cosmos of a formicary is very much superior to our states, societies and federations, from the point of view of order, organization, and the social work of the united entity. Why so? Well, dear reader, it is because man's hereditary nature, deep-rooted in his brain, makes him an egoistic, individualistic, fierce, domineering, tyrannical, jealous, passionate and revengeful being, who wishes to enjoy liberty by the abuse of his neighbor's toil. For the slightest social defects possessed by this neighbour he is argus-eyed, but he unconsciously misinterprets or extenuates his own faults. For his personal satisfaction alone he chooses a few friends or companions and one or several sexual help-mates. It is comparatively rare for even his family to be

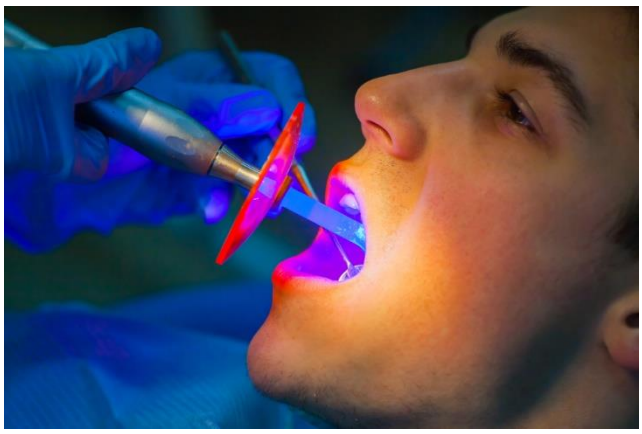
united. Yet there are some men, and more especially some women—though they are exceptional—it is true, who devote themselves to the social well-being of humanity and are perpetually denying themselves for the sake of their neighbours; but the masses misunderstand and persecute them. Moreover, when they attain 'power' success intoxicates them and turns their heads; rare indeed are whose who resist, keep their integrity and persevere to the end along the path of true social service. What must we do, then, to grow nearer to the ants and yet remain men?...One question takes precedence of all others: In the future society of the nations, what must be centralized and what decentralized? The first work of centralization should be brought to bear upon a great supernational army, which is absolutely necessary to subdue the present absolute rule of the fierce national groups of human wild beasts known as States….On the other hand we must decentralize the Universities and scholastic authorities if all ranks, in order to free them from every bureaucratic yoke and from the terror of examinations, at the same time organizing them on the model of the 'New Schools' with a minimum of obligatory instruction. We must in a general way disestablish all the autocracies and bureaucracies of States, provinces and even towns, and give normal individuals of both sexes a corresponding increase in freedom and responsibility, from youth upwards….Thus in a word the supernational authority, directly elected by the nations, will in no sense of the word oppress them and must be merely a federation so organized as to safeguard liberties and their truly national aspirations against the arbitrary tyranny of States."

In response, Horace Donisthorpe (1927) wrote in his book *British Ants: Their Life-History and Classification* about Auguste Forel's book, "*This, although in many ways is a fine work, is somewhat disappointing in that it is not up to date, and that the opportunity has been made for airing the author's socialistic views. I*

should wish in particular to protest against the ants being employed as a supposed weapon in political controversy. In my opinion an entomological work is not the appropriate means for the introduction of political theories of any kind, still less for their glaring advertisement. Let those, however, who are ready to set forth the social life of ants as a lesson to human beings, and as an argument favouring a socialistic community, reflect on the following facts: —To all intents and purposes the working classes of ants are sterile! They have no trade union rules; each worker does as much work as she can from early morn to dewy eve, and often during the hours of the night as well. All are willing to sacrifice their lives at a moment's notice for the good of the state, and are ever industrious and contented. In some of the harvesting ants the large workers possess enormously developed heads in order to contain the powerful muscles of the jaws with which they crush the hard seeds for food; but when these workers are no longer needed by the colony, the other ants cut off their heads and throw them on the refuse heap. This is a very drastic, but effective, method of getting rid of a superfluous working class."

In *Solomon's Little People: A story about the Ants*, James Crowther (1882) also compared people with ants, when he wrote, "*The ants are a people." Yes, just as there is the white man of Europe, and the black man of Africa, and the red and yellow men of Asia and America, so are there white ants, and black ants, and red ants, and yellow ants; and,* ***curious enough, just as in America the white people made slaves of the black, so too do the white ants make slaves of the black ones****; and just as both the white people as well as the black employ vast armies of soldiers in gratuitous, slaughter in war, so do the ants; —* ***did they learn the bad habit from us, or we from them, I wonder****?*"





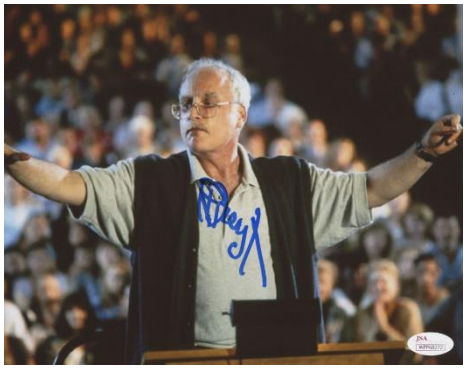
Ultraviolet light may be used by **dentists** to harden, cure, or polymerize the resin composite that is used to fill cavities. More recently, resins that polymerize under 400—500 nm blue light, which is less dangerous and penetrates deeper than UV light, is being used. When filling the cavity, the dentist switches from while light to amber light so the resin will not begin to harden while it is being applied.

What is Science? Should science be questioned? What are facts? Should facts be questioned?

I began this semester by saying: "*I love science and the ability of the scientific method for helping us to question, understand, and appreciate the world around us. I am a staunch supporter of questioning any and all authority in order to help us understand and appreciate the world around us. On that note, I will try to provide you with as much personal experience as possible concerning light and life so that you do not have to believe a single thing I say but have enough experience to trust your knowledge while understanding both the* ***value and limitations*** *of what you and others know. I want you to be able to say, 'I understand' before you say 'I agree,' 'I disagree,' or 'I suspend judgement' on any scientific issue.*"

Are we setting up a false dichotomy dividing people who believe in science on one side and people who do not believe in science on the other—without discussing an understanding of science? It is possible that the emphasis on **believing in science** is part of a non sequitur that actually undermines the civic values upon which the United States of America were founded? When I was a kid,

we would ask each other meaningless questions, "*Do you walk to school or carry a lunch?*" or "*Is it farther to school or by bus?"* To me, dividing the world into those who believe in science and those who do not is equally meaningless. The United States of America grew out of the Enlightenment values that emphasized the freedom to question and dissent. **Richard Dreyfuss** (Mr. Holland in *Mr. Holland's Opus*) started *The Dreyfuss Civics Initiative* (TDCI), which "*is a non-profit, non-partisan organization that aims to revive the teaching of civics in American public education to empower future generations with the critical-thinking skills they need to fulfill the vast potential of American citizenship*." The following is an excerpt from the Dreyfuss Civics Initiative https://thedreyfussinitiative.org/initiative/ .



What is Civic Education?

The Civic Education we strive to implement is the teaching of American history, government, and civic values through the prism of the Enlightenment Era, which introduced protection of the individual, the people of a nation being the highest political power, due process of law, equality of rights and opportunity, rights of freedom of expression and worship, that were revolutionary in history.

Civic values ***such as civility, clarity of thought, and the importance of dissent are not inherited at birth. The ideas must be taught, and the younger the better. In light of the changing demands on the education system due to an increasing focus on Science, Math and other academics, civics has seen its allocation of time greatly diminished resulting in younger generations having little connection to our founding documents and political system***.

In order for our children to be effective citizens, they must ***understand*** *the development of America so they know how our political structure is unique and exceptional.* ***Additionally, future generations must be taught how to understand all sides of an issue, thoughtfully develop an opinion, and discuss that opinion with civility and reason****.* ***We must not shy away from, but embrace teaching the controversial issues and events throughout our history that have shaped the current standing of America****. The Dreyfuss Civics Initiative plans to educate citizens on the power they have as well as giving future generations the skills they need to be intelligent citizens. Responsible citizenship is dangerous in its absence and unknowable unless taught."*

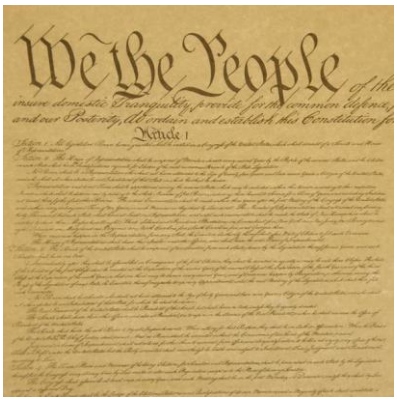
What Makes America Unique?

The United States of America was one of the first political bodies that gave its subjects distinct ***individual freedoms****, which are outlined in the Bill of Rights. Built from the ideas of the Enlightenment, America was constructed as a nation dependent on the sovereignty of the people, a breakthrough in a world full of monarchies and tyrannies. Our political system emphasizes the* ***power of the individual*** *by granting citizens the distinctive ability to be part of a sovereign body that elects representatives and impacts policies.*

How is America Not Fulfilling its Potential?

Despite having a political system that highlights ***individual freedom and responsibility****, we fail to provide individuals with the skills they need to successfully fulfill the role of citizenship. It is quite apparent that civic values have been absent in certain events of our country's recent history. We have experienced conflicting political parties unable to compromise, violent protests that have showcased a government unable to foster peace, and new generations that are*

falling behind its peers in education rankings. Extremism has plagued our government and caused shutdowns, fostered resentment between political parties, and generally caused inefficiencies. ***The lack of civility in debate that has been seen in our political bodies is destructive and needs to be addressed.*** *On top of that, the average American citizen has a poor understanding of civics and the nuances of our political structure. Civics must be taught so that our future leaders have the skills they need to run our country effectively, and future generations have the skills they need to be informed, active citizens. This foundation of properly educated students will help address the problems we are experiencing today and begin to create the successful future we desire for our posterity.*





Dreyfuss et el. (2015) wrote, "***We The People*** *may not survive beyond the next generation if the "**We**" as it was created through Enlightenment ideals, becomes "**them**" again as a pre-revolutionary status of rigid class* [or belief in science]- *based leadership. Therefore it is imperative that we ask if we are indeed educating our future generations in a way which will protect "We The People" as leaders.*"

The 10 guiding concepts for The Dreyfuss Civics Curriculum are:

1. Reason, 2. Logic, 3. Clarity of Thought, 4. Clarity of Expression, 5. Critical Analysis, 6. Values of Debate, Dissent and Civility, 7. Historical Context, 8. Rumination & Contemplation, 9. Agility of Mind, and 10. Ethics.

Each of the 10 concepts is defined within the context of civics, with the previous concept building into the next concept.

***Reason**: To think with a premise and in a formative way that leads to a honed and rational thought.*

***Logic**: The act of using reason in a step by step means that has valid and reliable principles, and facts, as a foundation.*

***Clarity of Thought**: The act of using logic to create ideas and beliefs about a specific occurrence that is not biased.*

***Clarity of Expression**: The act of using precise and accurate ideas to present clarity of thought.*

***Critical Analysis**: Judicious and significant evaluation of a specific situation that leads to valid and reliable outcomes, with thought for, and by, all sides.*

***Values of Debate, Dissent and Civility**: The freedom to present and consider different means of mediation and dialogue, with outcomes that range from disagreement to agreement, all in a professional manner.*

***Historical Context**: Chronological perspective of the most unique developments in human existence relating to Enlightenment ideas and freedom from class structure.*

***Rumination & Contemplation**: Within historical contextualization, reflection and deliberate consideration of significant differences in thought and positions to achieve reason.*

***Agility of Mind**: Skillful contemplation of thought and actions of others is using debate/dissent/context to achieve the highest level of precise propositions in all arts and sciences.*

***Ethics**: An aggregate of morals and civil interactions within a specific group that uses logic to solve conflicts and in a manner that reflects an agility of mind.*

The guiding concepts for the Dreyfuss Civics Curriculum are applicable to the study of "*Light and Life*" as well as any science curriculum.

Other animals besides ants see ultraviolet light. **Bees** are **trichromats** that have a **UVA-absorbing photoreceptor pigment** as part of their visual system and **pigeons** and **starlings** are **tetrachromats** that have a **UVA-absorbing photoreceptor pigment** as part of their visual system.

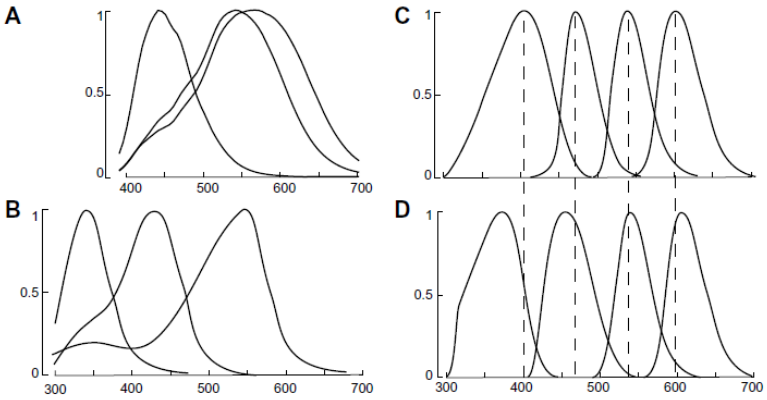
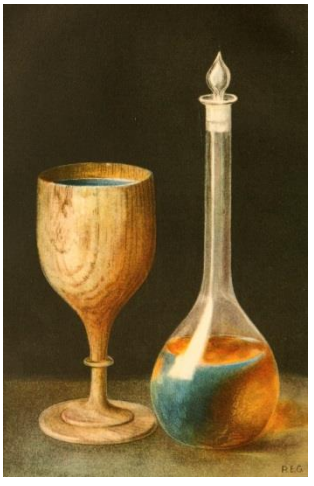


Fig. 1. Normalized photoreceptor spectral sensitivities of: (A) Human; (B) Honeybee; (C) Pigeon; (D) Starling.

Swallowtail butterflies, with as many as eight photoreceptor pigments, have a UVA-absorbing photoreceptor pigment. Are the UVA-absorbing photoreceptor pigments of insects and birds **homologous** and were they present in a **common ancestor** or are UVA-absorbing photoreceptor pigments **analogous** and a result of **convergent evolution** and/or **design**?



The ultraviolet photons in sunlight were instrumental in the discovery of **fluorescence**. Fluorescence was first noticed in the sixteenth century by the Bernadino de Sahagún, the Franciscan missionary who wrote the *Florentine Codex*, or Nicolo Monardes, the physician from Seville who wrote *Joyfull Newes Out of the Newe Founde Worlde.* The two books described the newly discovered medicinal plants from America. Monardes described what he saw when

he put thin pieces of the wood of *Lignum nephriticum* (*Eysenhardtia polystachya*) into clear fountain water, "*doeth beginne to chaunge it self into a blewe couller verie cleare…although that the woodde bee of a white couller*."

Demonstration: Fluorescence under penlight illumination of an extract of the wood of *Lignum nephriticum* (*Eysenhardtia polystachya*) in a wine glass.

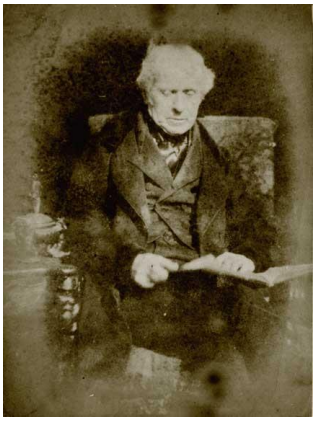


The extract of the wood, which emits blue light, was used, as the original specific name suggests, for "*them that doeth not pisse liberally*." The blue light emission was so spectacular, that the wood of *Lignum nephriticum* was carved into cups that were given to the royalty and visiting dignitaries.

A century after the discovery of the blue emission from *Lignum nephriticum*, Robert Boyle (1664) noted that adding vinegar to the extract of *Lignum nephriticum* decreased the amount of blue light emission, whereas adding basic solutions such as urine restored it. Boyle concluded that the color of the extract can be used to discern the **acidity** or **alkalinity** of a substance.

Throughout history, philosophers have thought about how the color of a body is related to its fundamental composition or structure. While experimenting with a prism and illuminating objects with monochromatic light, Newton (1730) showed that the color of an object was not an absolute property of the object itself, but depended on the color of the illuminating light. He noticed that if an object looked red when illuminated with white light, it looked black when illuminated with anything but red light, indicating that the color of an object was due to the

color of light that was reflected from the object. Newton thought about this relationship and proposed that, "*The bigness of the component parts of natural Bodies may be conjectured from their Colours*."

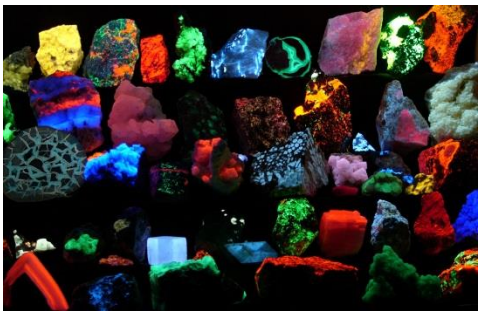


Sir **David Brewster** (1833) continued to study the cause of natural colors and **extracted chlorophyll** from many plants, including Laurel (*Prunus Lauro-cerasus*), which was one of the plants used for making laurel wreathes. He wrote, "*In making a strong beam of the sun's light pass through the green fluid, I was surprised to observe that its colour was a brilliant red, complementary to the green…. I have observed the same phenomenon in various other fluids of different colours, that it occurs almost always in vegetable solutions…. One of the finest examples of it which I have met with may be seen by transmitting a strong pencil of solar light through certain cubes of bluish fluor-spar. The brilliant blue colour of the intromitted pencil is singularly beautiful*."





Demonstration: Fluorescence of minerals, particularly Willemite & Calcite from Sterling Hill Mine in Ogdensburg, NJ under UVB illumination.



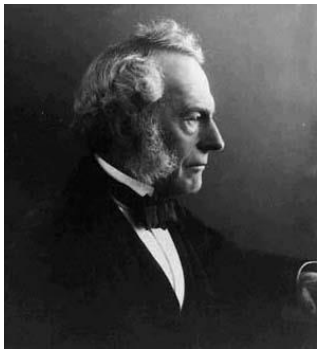
David Brewster concluded that the **absorption** of rays by the atoms of a substance must play some role in the change in color. He wrote: "*The true cause of the colours of natural bodies may be thus stated: When light enters any body, and it is either reflected or transmitted to the eye, a certain portion of it, of various refrangibilities, is lost within the body; and the colour of the body, which evidently arises from the loss of part of the*

intromitted light, is that which is composed of all the rays which are not lost; or, what is the same thing, the colour of the body is that which, when combined with that of all the rays which are lost, compose the light. Whether the lost rays are reflected or detained by a specific affinity for the material atoms of the body, has not been rigorously demonstrated…. it seems almost certain, that in all transparent bodies, and in that great variety of substances in which no reflected tints can be seen, ***the rays are detained by absorption***."

Even more puzzling than a green solution of chlorophyll that gave off red light was to find a colorless solution that gave off blue light when irradiated with invisible ultraviolet light. **John Herschel** (1845) observed a solution of **quinine sulphate** and found, "*Though perfectly transparent and colourless when held between the eye and the light, or a white object, it yet exhibits in certain aspects, and under certain incidences of the light, an extremely vivid and beautiful celestial blue colour, which from the circumstances of its occurrence, would see to originate in those strata which the light first penetrates in entering the liquid….*"

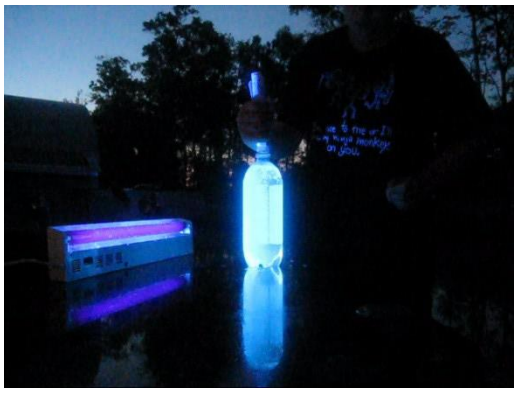


George Gabriel Stokes (1852) repeated Herschel's observation with **sulphate of quinine** and wrote "*It was certainly a curious sight to see the tube instantaneously lighted up when plunged into the invisible rays: it was* ***literally darkness visible****. Altogether the phenomenon had something of an unearthly appearance*." Stokes (1885) irradiated the solution with variously colored light obtained by passing sunlight through a prism. He noticed that the emitted light always had a longer wavelength than the incident light, and wrote

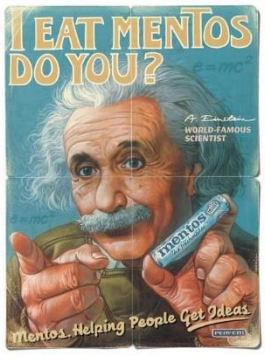


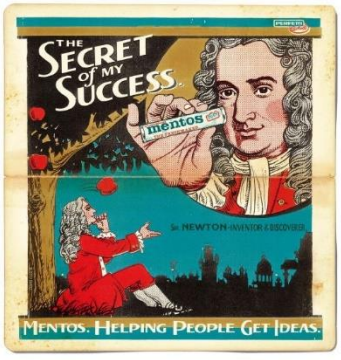
"*Perhaps the most striking feature in this phenomenon is the change in refrangibility of light which takes place in it, as a result of which* ***visible light can be got out of invisible light****, if such an expression may be allowed: that is, out of radiations which are of the same physical nature as light, but are of higher refrangibility than those that affect the eye; and in the same way light of one kind can be got out of light of another, as in the case for instance of an alcoholic solution of the green colouring matter of leaves, which emits a blood red light under the influence of the indigo and other rays. Observation shows that this change is always in the direction of a lowering*."

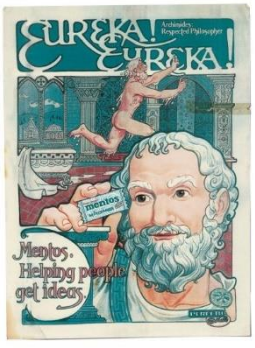
Demonstration: A fountain of quinine spraying from a bottle of tonic water to which a tube of Mentos candies has been quickly added makes a spectacular demonstration of fluorescence when viewed under blacklight (UVA) illumination.





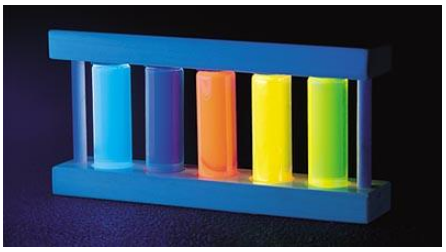






George Stokes called this phenomenon, where specimens absorb light of one wavelength and reemit it at a longer wavelength, **fluorescence**, after the mineral

fluor-spar, which shows the same phenomenon. **The phenomenon that the light emitted by fluorescent objects always has a longer wavelength than the light absorbed is now known as Stokes' Law**.



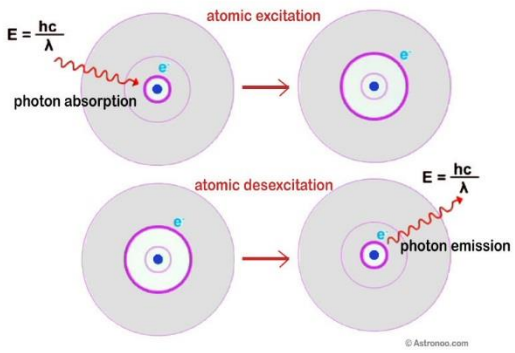
Demonstration: Observe the fluorescence of a variety of liquids viewed under ultraviolet (UVA) light.

George Stokes also postulated that fluorescence was related to **phosphorescence**. The only difference is that light given off by specimens that showed fluorescence stopped immediately after the incident light was shut off, whereas phosphorescent specimens continued to glow for relatively long periods of time after the incident light was removed. Indeed, with fluorescence, light emission stops almost immediately (within 10^{-8} s) after the cessation of the activating (or actinic) radiation, whereas with phosphorescence the emitted light persists for seconds, minutes, hours, days, or even months.

George Stokes (1852) tried to come up with a physical mechanism to describe how short wavelength light could turn into long wavelength light after it interacted with the fluorescent molecules. He weakly proposed that the incident light sent the atoms in a fluorescent molecule into a vibration and the light emitted from this vibration was of a longer wavelength. He did not like this conclusion and believed that his explanation made no physical sense since it was physically impossible, according to classical wave theory, to get a short wavelength wave to give rise to a long wavelength wave. A better explanation had to await Einstein's development of **quantum theory**.

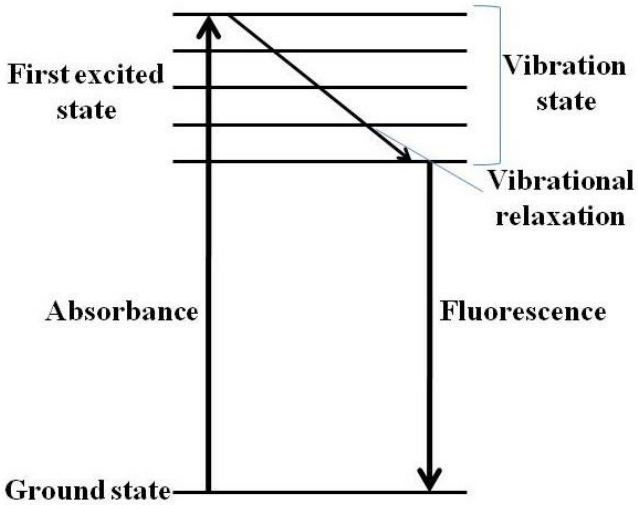
According to quantum theory, **atomic absorption** results in the transfer of an electron from a **low energy ground state** to a **higher energy excited state** in a

process that takes about one period of light vibration (10^{-15} s). **Atomic emission** occurs when an electron falls from the excited state to the ground state. The **absorption spectrum** and the **emission spectrum** of a gaseous atom are identical. The wavelength of emitted light gives a signature of the energy differences between electrons in the ground and excited states. The emitted wavelength (λ) depends on the energy difference (E) between the excited state and the ground state according to the following formula:

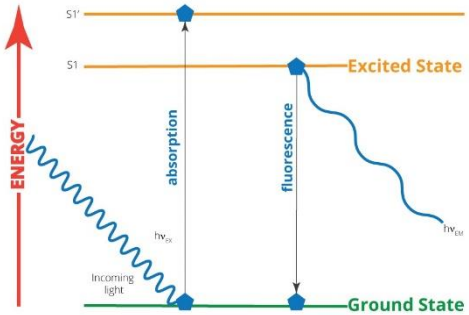


$$\lambda = \frac{hc}{E}.$$

A **flexible molecule** has many vibrational states and rotational states. As a result of the intramolecular movement, the excited state of a flexible molecule can **dissipate energy** in a variety of ways, which takes 10^{-15} to 10^{7} s. Initially, the electronic energy can be conserved within the molecule, in a process known as internal conversion, radiationless transfer, or vibrational relaxation, where the electronic energy is converted to kinetic energy, which accompanies the translational, intramolecular vibrational and rotational movement in the molecule. Eventually, the kinetic energy is completely lost to the surround through collisions or as emission of thermal energy with wavelengths in the infrared range.

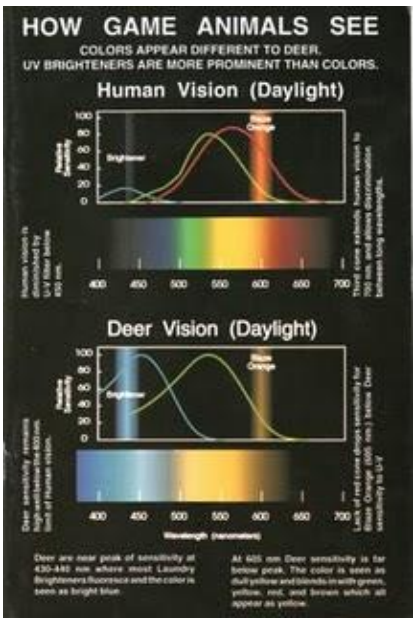


Once an electron reaches the lowest vibrational or



rotational level of the excited state, it can return to the ground state by emitting a photon in a process known as fluorescence, which takes about 10^{-8} s. Because some of the original radiant energy has been converted to kinetic energy, the energy of the emitted photon is less than the energy of the absorbed photon, and the wavelength of the emitted photon is longer than the wavelength of the absorbed photon. This is the reason behind Stokes' Law.

Fluorescent brighteners are often added to laundry detergents. The brighteners absorb ultraviolet light from sunlight and emit longer wavelength ultraviolet light. The fluorescent light emitted makes the clothes appear brighter. Since **deer can see in the ultraviolet**, hunters should be aware of the propertied of the detergent they use to wash their clothes.

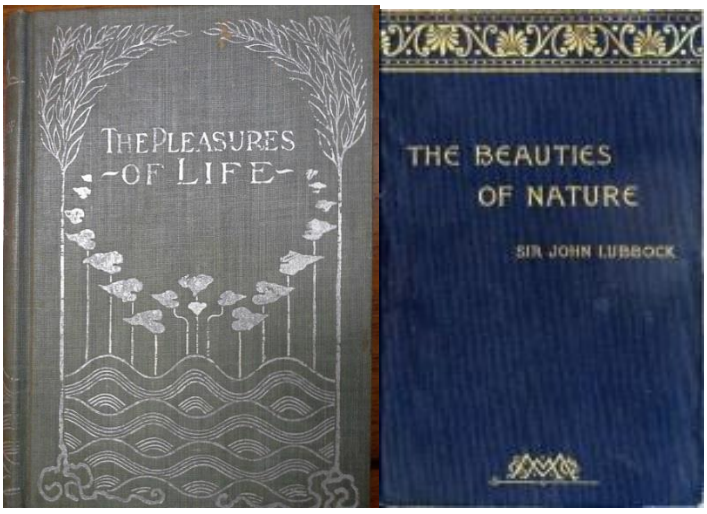




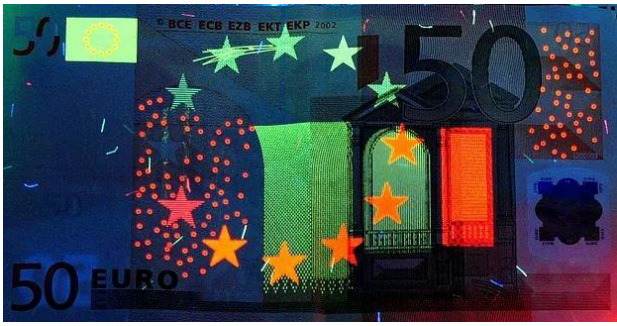
John Lubbock, Lord Avebury, who was the first person to observe that ants can sense ultraviolet light, discovered that **ants can see a world that is invisible yet assessable to humans.** In his book, *The Beauties of Nature*, John Lubbock wrote, "*The world we live in is a fairyland of exquisite beauty, our very existence is a miracle in itself, and yet few of us enjoy as we might, and none of us as yet appreciate fully, the beauties and wonders which surround us. The greatest traveler cannot hope even in a long life to visit more than a very small part of*

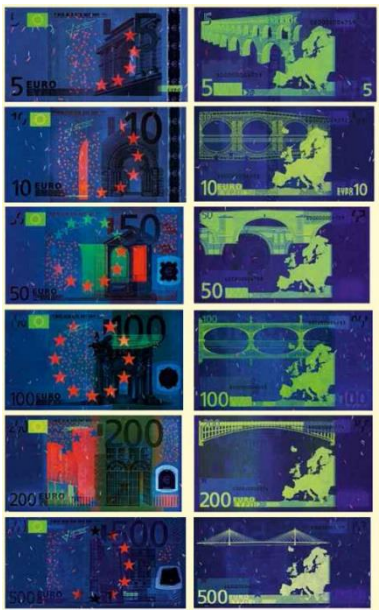


our earth, and even of that which is under our very eyes how little we see! What we do see depends mainly on what we look for. When we turn our eyes to the sky, it is in most cases merely to see whether it is likely to rain. In the same field the farmer will notice the crop, geologists the fossils, botanists the flowers, artists the colouring, sportsmen the cover for game. Though we may all look at the same things, it does not at all follow that we should see them. It is good, as Keble says, 'to have our thoughts lift up to the world where all is beautiful and glorious,'—but it is well to realize how much of this world is beautiful."

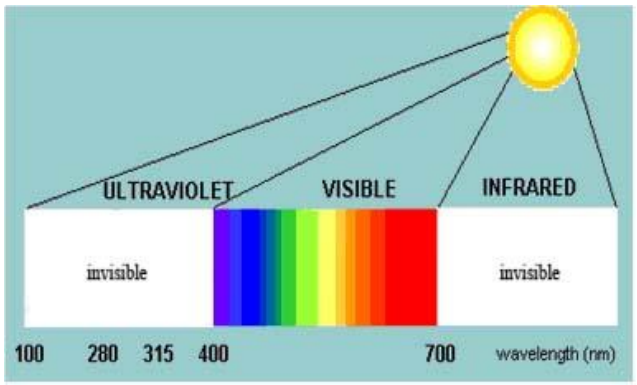


Speaking of John Lubbock, who was a banker, the **Euro** uses the UV-induced fluorescence of the element **Europium**, which appropriately has the symbol EU, to discourage counterfeiting. The fluorescent Europium is attached to various dyes. Under UV light, the paper itself is not fluorescent, but the inks are. On the front of the bill, the blue ink in the European flag and the signature becomes green and the yellow ink in the stars becomes orange. On the back of the bill, the map of Europe, the bridge, and the denomination becomes yellowish.

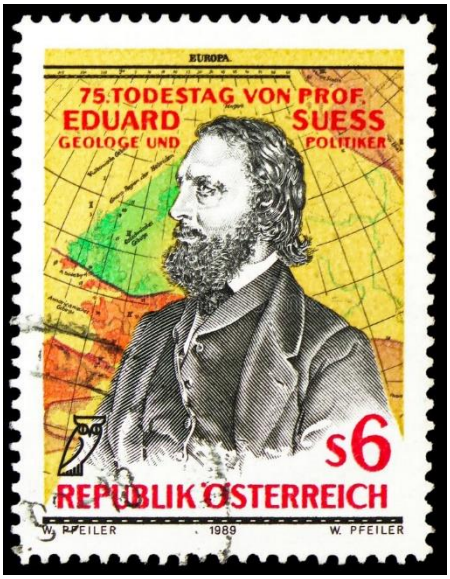




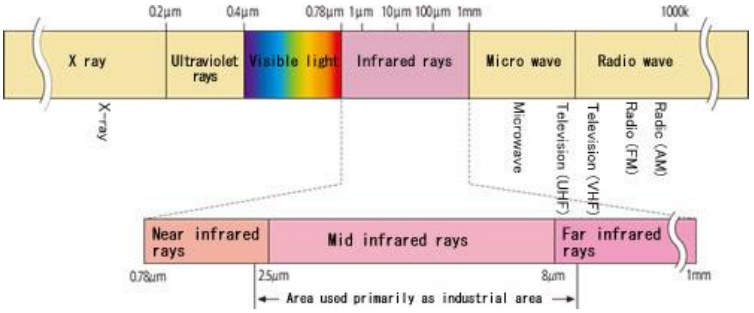
Ultraviolet (UV) light consists of electromagnetic radiation that has a higher frequency and shorter wavelength than visible light. For symmetry's sake, I will discuss **infrared (IR) radiation** that has a lower frequency and longer wavelength than visible radiation. Infrared radiation was discovered by **William Herschel** (1800) a year before Johann Ritter (1801) discovered ultraviolet radiation.



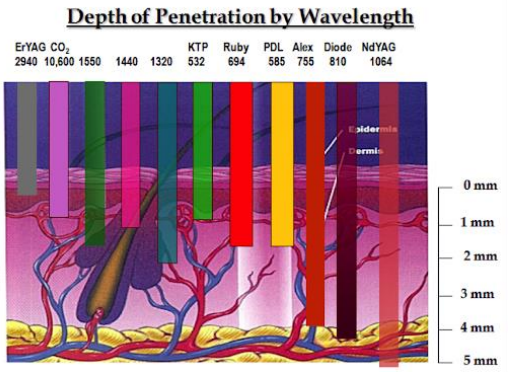
Of all the wavelengths of electromagnetic radiation, it is infrared radiation that is the most contentious because it is infrared radiation that is scattered by methane (CH_4) and carbon dioxide (CO_2) in the atmosphere. In the words of Eduard Suess (1906, II:2), "***Now, however, it is no longer to the mute eloquence of nature that we must lend an ear, but to the conflict of human opinion, sometimes loud-voiced enough***."

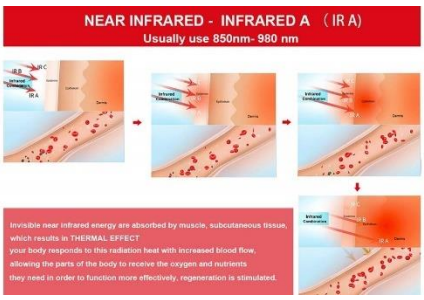


Before I discuss the relationship between infrared light and climate, I will quickly mention that studies are beginning that show the relationship between infrared light and wellness. The infrared region is divided by the CIE (International Commission on Illumination) into IR-A (700-1400 nm), IR-B (1.4-3 μm), and IR-C (3-1000 μm). The infrared region is divided by the ISO (International Organization for Standardization) into Near-IR (780-3000 nm), Med-IR (3-50 μm), and Far-IR (50-1000 μm).

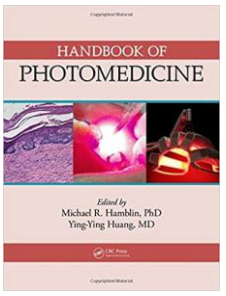


Low-level infrared light therapy is being used to improve wound healing and reduce pain, inflammation, and swelling (Chung et al., 2012; Mussttaf et al., 2019). The longer the wavelength, the less it is scattered according to **Rayleigh** and the deeper the light **penetrates**. Consequently, far infrared light penetrates into the body better than near infrared light, which penetrates the body more than red light (which is used to stimulate hair growth). The medical use of infrared light goes by the name of photomedicine, photobiomodulation, or phototherapy.

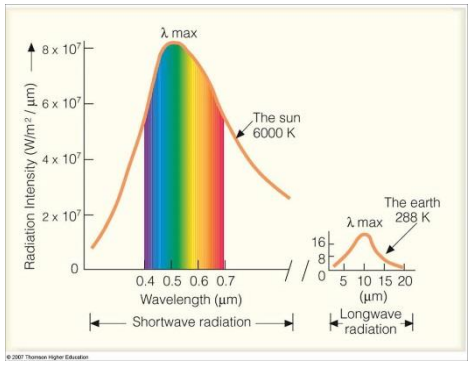








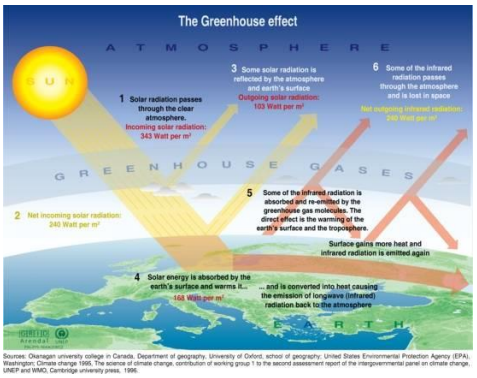
We have discussed the production of **infrared radiation** that occurs in every physico-chemical reaction according to the **Second Law of Thermodynamics**. As a result of the radiation of heat, the earth can be described as a blackbody radiator with an average temperature in 2015 of about 288.8 K (15°C or 59 °F). The peak wavelength (λ_{peak}) of the radiation emitted by a blackbody is given by **Wien's displacement law**:



$$\lambda_{peak} = \frac{2.989 \times 10^{-3}\ m\ K}{T}.$$

The peak wavelength for a blackbody radiator with a temperature of 288 K is **10 micrometers**.

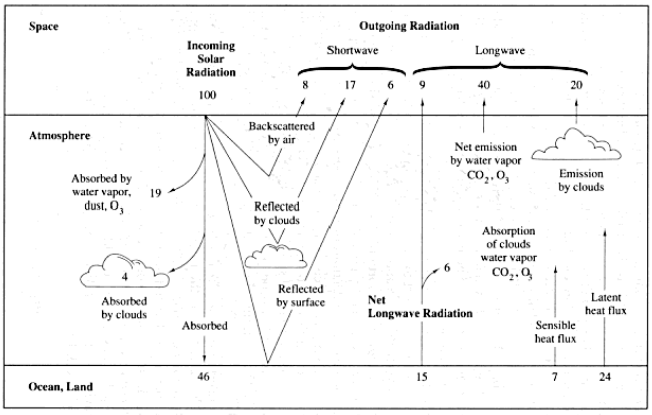
The amount of energy radiated from the earth with temperature (T) into space is given by the Stefan-Boltzmann law:



$$E = \frac{L_{earth}}{4\pi r^2} = \sigma T^4$$

where σ is the Stefan-Boltzmann constant ($\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^4) and the radiated energy is equal to about 390 W/m^2.

As a reference, the value of the solar constant is 1,360 W/m^2. However, this is a maximal value, calculated for a surface perpendicular to the sun's rays and above the atmosphere so that there are no losses due to absorption and scattering by the atmosphere.

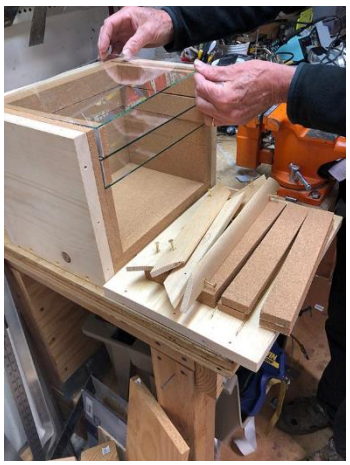


Joseph Fourier (1827), who studied heat, thought about the terrestrial temperature. He realized that the temperature of the surface of the earth would be affected by solar heating, heating from the center of the earth, and heat loss to space. He realized that since the temperature of the earth was relatively stable, the earth must be radiating as much heat as it absorbs.

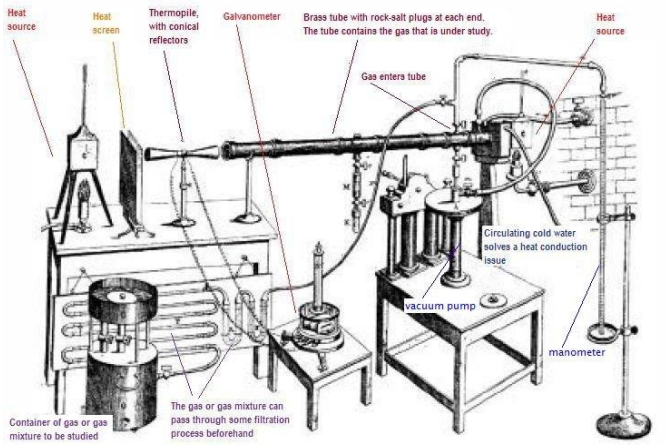


http://www.wmconnolley.org.uk/sci/fourier_1827/fourier_1827.html He also guessed that the gaseous atmosphere might act like the glass in **Horace-Bénédict de Saussure's helio-thermometer**, which let in visible rays which were absorbed by the black interior and trapped the emitted infrared rays. **De Saussure** (1743) built the helio-thermometer to measure the amount of insolation in the Alps. He put a blackened thermometer in a box with a wall of three layers of glass to allow the sun to reach the thermometer but to prevent the outside air from cooling the thermometer. The thermometer registered >100 F when the air was only 30 F. He realized that even though the intensity of light increased as he climbed the mountain the density of the heat particles decreased, and this was the cause of the paradoxical observed decrease of temperature with height. He wrote, "*The principal reason for the prevailing cold on high and isolated summits, is that they are surrounded by and chilled by air which is constantly cold. This air is cold because it cannot be strongly heated, neither by the rays of the sun, due to its transparency, nor by the surface of the earth due to the distance separating them*."





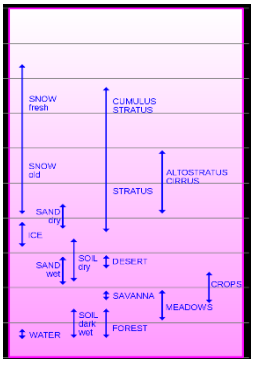
That is, it was the density of air molecules that have a capacity to hold heat that decreases with height.



John Tyndall noticed that a number of gases that were transparent to visible light were opaque when it came to infrared light. That is, gases such as water vapor, carbon dioxide, and water **absorb** infrared light and **scatter** it in all directions, including back to the earth. Tyndall realized that the atmospheric gases moderated the temperature changes that would occur at night compared to day. Tyndall (1863) realized, that "[t]*his aqueous vapor is a blanket more necessary to the vegetable life of England than clothing is to man. Remove for a single summer-night the aqueous vapor from the air which overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost. The aqueous vapor constitutes a local dam, by which the temperature at the earth's surface is deepened: the dam, however, finally overflows, and we give to space all that we receive from the sun*." **Svante Arrhenius** (1896) suggested that the atmospheric gases acted like the glass of a hothouse.



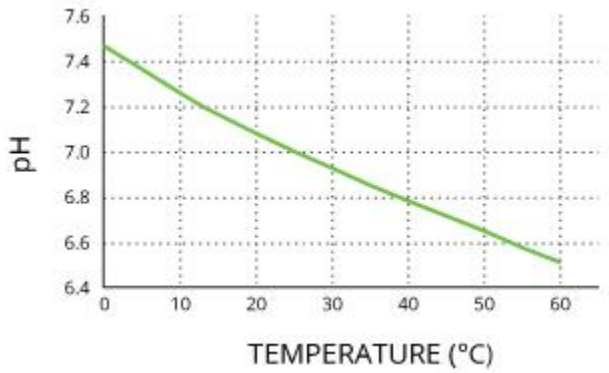
Aside: **Mount Tyndall** is a mountain in the Sierras that was first climbed on July 6, 1864, by Clarence King and Richard Cotter. It was named after John Tyndall.



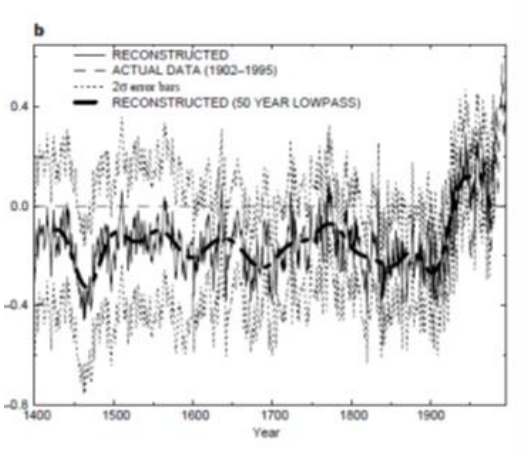
The earth and its atmosphere can reflect a portion of the incoming sunlight back into space. The sunlight reflected from the earth is known as **earthshine**. The reflectivity of the earth and its atmosphere is known as its

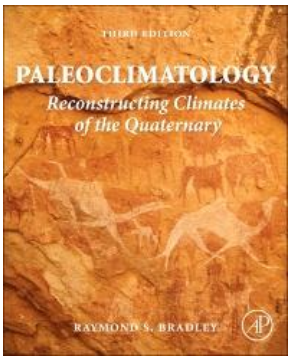
albedo from the Latin *albus*, which means white. Snow, ice, clouds, and volcanic dust increase the albedo. Thus, the albedo of the earth is not constant but depends on the amount and type of cloud cover, the amount and type of snow and ice, and volcanic activity. In round numbers, approximately 30% of the solar energy is **reflected** back into space and approximately 23% of the solar energy is **absorbed** by water vapor and clouds, which leaves 46% of the solar energy or about 626 W/m^2 to reach a perpendicular surface on earth. Since the earth is closer to a hemisphere than a disk, the solar energy reaching the surface is $\frac{2\pi r^2}{\pi r^2} = 2$ times less or about 313 W/m^2. If the net solar energy input (313 W/m^2) were smaller than the energy radiating from earth (390 W/m^2), then the earth would cool. Luckily, the earth is surrounded by a gaseous atmosphere that is nearly **transparent to visible light** yet **acts like a greenhouse** to return some of the infrared radiation radiated by the earth back to the earth. **Water vapor** and **carbon dioxide** make up the majority of the greenhouse gases that scatter infrared light back to the earth. Water accounts for 90% of the atmosphere's ability to intercept the heat radiated from the earth and carbon dioxide accounts for 7%.

The temperature of the earth is rising. Raymond Bradley testified before the Senate on May 17, 2000 (https://www.govinfo.gov/content/pkg/CHRG-106shrg81375/html/CHRG-106shrg81375.htm): According to Ray Bradley (2000), "*This conclusion is supported by numerous lines of environmental evidence, melting of glaciers, retreat of sea ice, changes in vegetation, rising of sea level, et cetera*." I agree with this. The increase in temperature also causes a decrease in the pH of water.

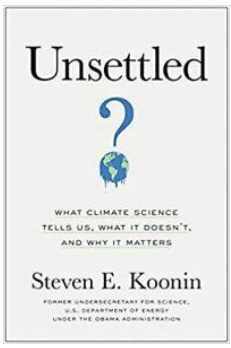


Ray Bradley went on to say, "…*the reconstructed record (of mean annual temperature for the northern hemisphere) shows that temperatures slowly declined over the millennium, with especially cold conditions in the 15th, 17th and 19th centuries. This colder period is generally referred to as the ``Little Ice Age,'' when glaciers advanced in most mountainous regions of the world*. ***However, the downward trend changed abruptly to a strong warming trend early in the 20th century and this rate of warming was unprecedented in the last 1000 years. The warming continued through the 1990s making that decade the warmest in at least 1000 years; indeed, 1998 was arguably the warmest year of the millennium, and 1999 was only slightly cooler***."

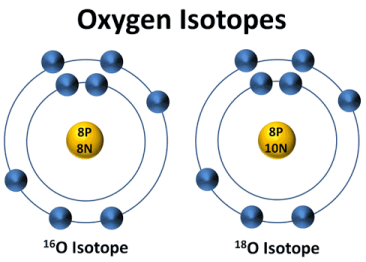


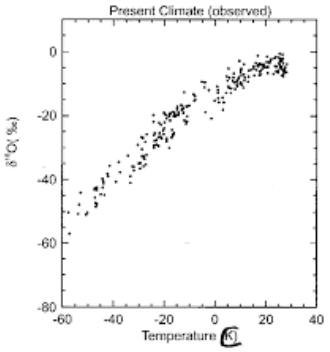


Since thermometers have only been around for a few hundred years, thanks to **Daniel Fahrenheit** (1686 – 1736) and **Anders Celsius** (1701 – 1744), the temperature of past climates cannot be measured directly. Instead, they are measured by **paleoclimatologists**, including Ray Bradley, through **temperature-dependent proxies** such as the thickness of annual rings of trees, the presence of pollen from plants that grow at different temperatures, and the oxygen isotope ratio of ice cores. For any *thermodynamic analysis*, temperatures should be calibrated in Kelvin. Thus, as stated by Steven Koonin in *Unsettled*, an increase in 3 C from 15 C to 18 C should not be looked at as 20% increase in temperature but as an increase from 273 + 15 = 288 K to 273 + 18 = 291 K should be looked as an 1% increase in temperature.

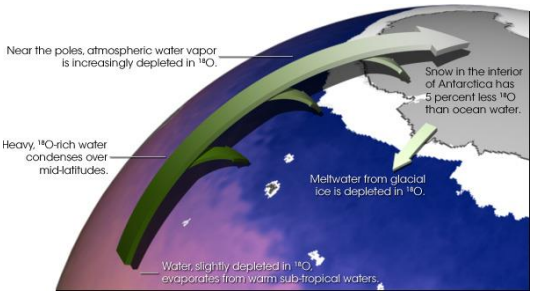


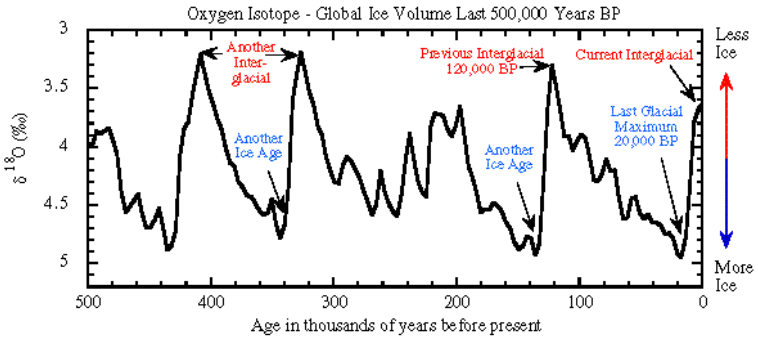
Oxygen isotopes with different numbers of **neutrons** have different physical properties. ^{18}O has 8 protons and 10 neutrons and is thus heavier than ^{16}O, which has 8 protons and 8 neutrons. Because of the greater mass, more energy is needed to vaporize $H_2{}^{18}O$ than $H_2{}^{16}O$. Thus, the greater the temperature of the air mass, the greater the $^{18}O/^{16}O$ ratio.



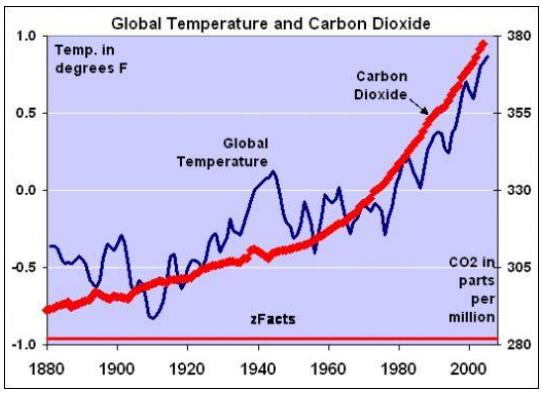


As a warm air mass containing water vapor moves from a warm region at the equator to a cold region at the poles, the water vapor condenses and precipitates out. $H_2{}^{18}O$ releases more energy than $H_2{}^{16}O$ when it condenses, therefore the $^{18}O/^{16}O$ ratio in precipitated water is a function of temperature. This means that the lower the temperature, the lower the ^{18}O content and the lower the $^{18}O/^{16}O$ ratio will be. Since the temperature decreases from the equator to the poles, the $^{18}O/^{16}O$ ratio of the precipitation gets lower and lower as the air travels from the equator to the poles. By the time the air gets to the poles, the precipitation from it has a very low $^{18}O/^{16}O$ ratio. However, as the temperature of the earth warms, the $^{18}O/^{16}O$ ratio of the precipitation increases. Consequently, the climate of the earth over geological time scales can be probed in ice cores a mile deep.





Bradley also testified: "*At the same time, concentration of greenhouse gases in the atmosphere increased to levels that were higher than at any time in the last 420,000 years. Carbon dioxide levels are now 35 to 40 percent higher than they were in the middle of the 19th Century. This change is largely the result of fossil fuel combustion*."



But how is the change in the CO_2 concentration related to temperature? I wrote to Ray Bradley on 3/29/20 to ask him about a figure in his book: Hello. How are you? I met you last semester when I was on sabbatical with Peter Hepler and I asked you about methane absorption relative to the earth's IR emission window. I am spending this time locked in place reading. I just finished your book, Global Warming and Political Intimidation. Great book! I wonder if you have done a cross correlation analysis on the data in Figure 3 to analyze the cause and effect relationship between CO2 and temperature.

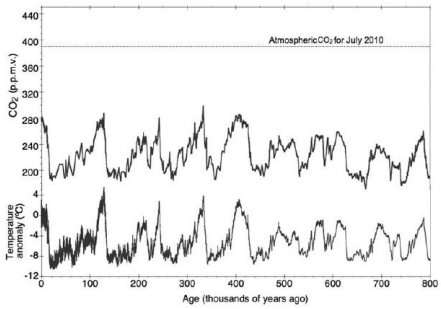


FIGURE 3. (top graph) Atmospheric carbon dioxide levels obtained from bubbles trapped in an ice core from Vostok in Antarctica (measured in parts per million by volume, or ppmv). The record extends back (from left to right) from the pre-industrial period to 800,000 years ago. Carbon dioxide levels reached 390ppmv in 2010.
(bottom graph) Estimates of temperature differences from today at Vostok, based on deuterium isotopes in the ice.
Source: Adapted from Dieter Lüthi et al., "High-Resolution Carbon Dioxide Concentration Record 650,000–800,000 Years before Present," Nature 453 (2008): 379–82.

Thanks,

Randy

On 4/14/22 I resent the email and got the following reply:

Hi Randy,

I'm glad you liked the book. I'm hoping somebody will ban it in order to revive sales...

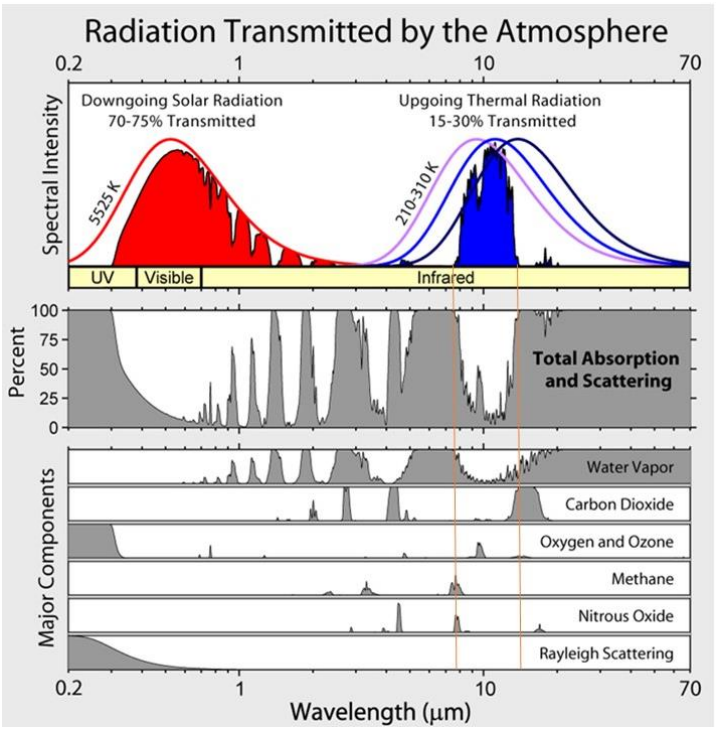
No, I have not done the correlation you suggest, but it is surely significant. There is a large set of papers that discuss that relationship and how it came about. The story (as far as I have kept up with it) relates to the role of the Southern Ocean sequestering CO2 at depth during the ice ages, and releasing it thereafter. The extent of sea-ice plays an important role in this. Working out the leads and lags is a complex game, given that the CO2 record itself is delayed within the ice due to the time it takes to "close off" the gas diffusion in firn as it transitions to ice.

I hope that gives you more to ponder on. I attach another book that gives you additional info, albeit a few years out of date now.

PALEOCLIMATOLOGY_3rd Edition.pdf

Cheers

ray



As a result of the earth being a blackbody radiator with a temperature of about 288 K, the wavelength of the infrared radiation that currently leaves the earth's atmosphere is between 8 and 13 μm (between the two vertical red lines). Anthropogenic greenhouse gases that absorb and scatter back infrared rays between 8 and 13 μm will heat up the earth. The question is how much? The answer comes from predictive modelling equations, but the thing about **equations** is that the left side must be **equal** to the right side. So the temperature change given by the left side of the equation must be equal to the numerical assumptions on the right side. **Models predict numbers but numbers are not observational or experimental data**. No one has been able to explain to me the assumptions that went into how the **Intergovernmental Panel on Climate Change** (IPCC) figured out the climate sensitivity factor and the radiative forcing for CO_2, never mind whether those assumptions are valid and reliable (Anyone who can explain it to me deserves an automatic A+). The climate sensitivity forcing equation as given by the IPCC is $\Delta T_s = \Lambda \Delta F$, where T_s is the steady-state surface **temperature** of the earth (in K), Λ is the **climate sensitivity factor** (in K/(W/m^2)), and ΔF (in W/m^2) is the **radiative forcing**. It seems to me that the Grotthuss-Draper Law applies. The law states that only light that absorbed

by a system can bring about a change. Therefore, in order to predict the effect of a changing concentration of a given greenhouse gas on temperature, they need to relate the area under the curve of the absorption spectrum of a particular greenhouse gas to the area under the curve of the emitted infrared light, and then calculate how the decrease in emission into space will give rise to a temperature increase on earth. Note that the atmosphere is already saturating for infrared radiation shorter than 8 μm and longer than 13 μm so that increasing the concentration of greenhouse gases will have no effect on wavelengths in this range. I want to **understand the science** not just **believe the science**!

The key factor on understanding the effect of CO_2 on global temperature comes from knowing the actual value of the **climate sensitivity factor** (Λ) that relates the change in global temperature to the change in the atmospheric CO_2 concentration:

$$\Delta T_s = T_2 - T_1 = \Lambda\, \Delta \ln[CO_2] = \Lambda \ln \frac{[CO_2]_2}{[CO_2]_1}$$

Gilbert Plass (1956), in The Carbon Dioxide Theory of Climate Change, modelled it to be 3.6 C; F. Möller (1963) in On the Influence of Changes in the CO_2 Concentration in Air on the Radiation Balance of the Earth's Surface and on the Climate, modelled it to be 1.5 C; L. D. Kaplan (1960) in The Influence of Carbon Dioxide Variations on the Atmospheric Heat Balance to be 1.8 C, Syukro Manabe and Anthony Broccoli (2020), in *Beyond Global Warming: How Numerical Models Revealed the Secrets of Climate Change* modelled it to be about 3.2 C.

As far as I can tell, the experiments necessary to determine Λ have not progressed in increasing our understanding the climate sensitivity factor and in

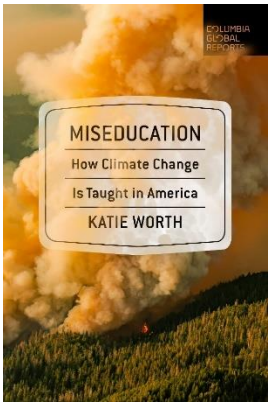
narrowing the estimate in a century.

https://www.aps.org/policy/statements/upload/climate-review-framing.pdf

Date	Source	Confidence in Attribution	Equilibrium Climate Sensitivity (C)
1896 & 1938	Arrhenius / Callendar	------	2 – 5.5
1979	Charney Report	------	1.5 – 4.5
1990	IPCC FAR	No quantification of anthropogenic contribution to warming	1.5 – 4.5 (best guess = 2.5)
1996	IPCC SAR	*The balance of evidence suggests a discernible human influence on climate.*	1.5 – 4.5 (best guess = 2.5)
2001	IPCC TAR	*Human-emitted greenhouse gases are likely (67-90% chance) responsible for more than half of Earth's temperature increase since 1951.*	1.5 – 4.5
2007	IPCC AR4	*Human-emitted greenhouse gases are very likely (at least 90% chance) responsible for more than half of Earth's temperature increase since 1951.*	2 – 5.5 (>66% chance correct)
2013	IPCC AR5	*Human-emitted greenhouse gases are extremely likely (at least 95% chance) responsible for more than half of Earth's temperature increase since 1951.*	1.5 – 4.5

The last column of the table above [see Nature Geosciences 1, 735 (2008)] shows successive IPCC estimates of the Equilibrium Climate Sensitivity[4], following first estimates more than a century ago. A factor-of-three uncertainty in the global surface temperature response to increased atmospheric CO_2 as expressed by ECS has persisted through the last three decades of research despite the significant intellectual effort that has been devoted to climate science.

The American Physical Society asks: 1) *What gives rise to the large uncertainties in this fundamental parameter of the climate system?* and 2) *How is the IPCC's expression of increasing confidence in the detection/ attribution/ projection of anthropogenic influences consistent with this persistent uncertainty? Wouldn't detection of an anthropogenic signal necessarily improve estimates of the response to anthropogenic perturbations?*



In Miseducation; How Climate Change is Taught in America, Katie Worth (2021) writes, "*On the whole, science remains one of the most trusted institutions in America, and the trust has remained relatively stable for the last forty years. Dig into these numbers, however, and patterns appear. Christians have less trust in science than nonreligious people, rural dwellers have less than urbanites, and Republicans less than Democrats. There have been times in the last forty years when these camps had equal confidence in science. Today, the space between them is as large as it's ever been.*

These patterns are no accident of history. Rather, they are the product of successful disinformation campaigns, animated not by science but by ideology."

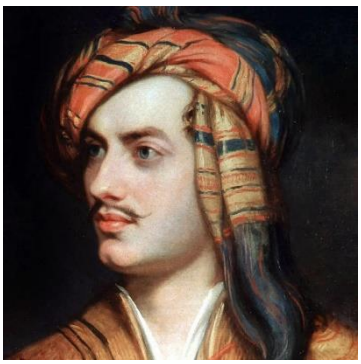
Could it be that there is far more agreement than Katie Worth believes on the **facts**, but far less agreement on the **rigor of the fact finding and the interpretation of the facts**?

Those who do not "believe" in the consensus interpretation are called deniers. To be absolutely clear, Katie Worth writes, "*A note on terminology: This book uses the term 'climate denier' to describe groups or people who know (or should know, based on their position or declared authority) that the conclusions of modern climate science are legitimate, but who nonetheless promote the idea that they are not. For members of the public who have been misled by the sources of information they trust, the term 'climate doubter' applies. Also, this book uses the terms 'climate change,' 'climate crisis,' and 'global warming' as shorthand for 'anthropogenic climate change,' the extraordinary transformations in our atmosphere and ecosystems that have occurred since industrialization. Any reference to natural climate change is described as such.*"

I believe that Katie Worth is playing fast and loose with words. **In order to use climate change as shorthand for anthropogenic climate change, one must present enough evidence to show unequivocally that humans are the major cause of climate change and that natural causes are negligible**. From my experience, I do not believe that this bar has been met.

I also believe that the phrase 'climate change' is often used as Mephistopheles advises in Goethe's *Faust* Part One, in which Mephistopheles

says, “[f]*or at the point where concepts fail, At the right time a word is thrust in there. With words we fitly can our foes assail*.” Until someone clearly quantifies the contributions of anthropogenic (and presumably gynogenic) climate change and natural climate change, and explains how the climate sensitivity factor is determined, I believe that the phrases climate change and climate denier are used as tools of propaganda rather tools of science. If I am right, then the groups and people described by Katie Worth may differ primarily in the *way they look at the incomplete knowledge* concerning climate change. The people who Katie Worth describe as those who do not trust the interpretation of scientific knowledge as defined by the consensus, may be in fact those who trust science as a **method** to investigate the natural world through questioning, observation, experiment, and analysis, and who believe that the individual has as much right to draw conclusions from the data as the consensus does, especially when the consensus resorts to *ad hominin* attacks on those who question their conclusions. The tyranny of the mob, like the tyranny of the monarch, is still tyranny. Remember what **Lord Byron** (George Gordon Byron) wrote in Canto XVII of *Don Juan*,



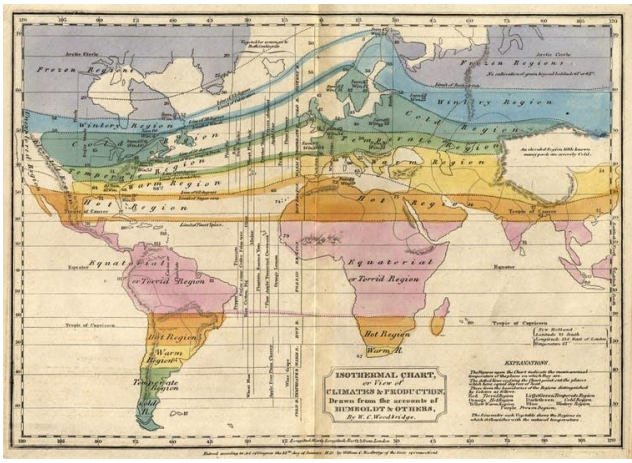
There is a commonplace book argument,
Which glibly glides from every vulgar tongue
When any dare a new light to present:
'If you are right, then everybody's wrong.'
Suppose the converse of this precedent
So often urged, so loudly and so long:
'If you are wrong, then everybody's right.'
Was ever everybody yet so quite?

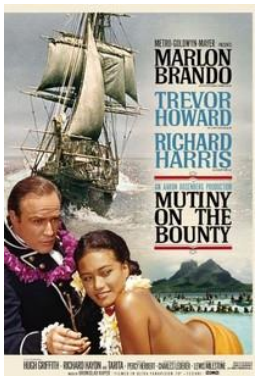


Now back to a little history that led scientists to conclude that the earth's climate changes. In 1492, **Christopher Columbus** traveled from Spain to the New World, where he found corn, potatoes, and squash. **The Golden Age of Botany** began when he brought them back to the Old World where they could be grown in regions that were climatically like those where they grew in the New World.



In the late 1700's, the Spanish Government authorized **Alexander von Humboldt and Aimé Bonpland** to explore the plants and the climate in which they grew in South America. Von Humboldt paid for the trip himself. **Humboldt concluded that climates depend largely on latitude, elevation, and proximity to water**. The fact that England is warmer than Hudson Bay Canada shows the importance of the proximity to water. Von Humboldt drew maps showing isothermal lines, where regions would support similar crops. The climates were **relatively stable** although they **changed in the past** as evidenced from **fossil seashells found on mountains** and **fossils of large trees and mammals found in the arctic. He also saw that through deforestation and filling in swamps, agriculture could have a warming effect on climate**.





During the Age of Botany, valuable crops such as coffee, tea and sugar were transplanted throughout the world. Many of the introductions, such as the transplantation of **breadfruit** from the South Pacific to the

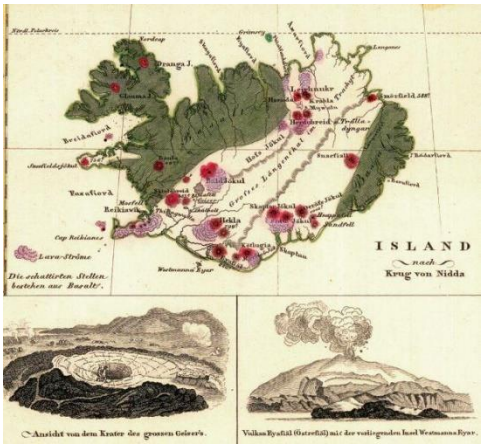
Caribbean to be used as a **food for the slaves**, became fodder for books and movies.



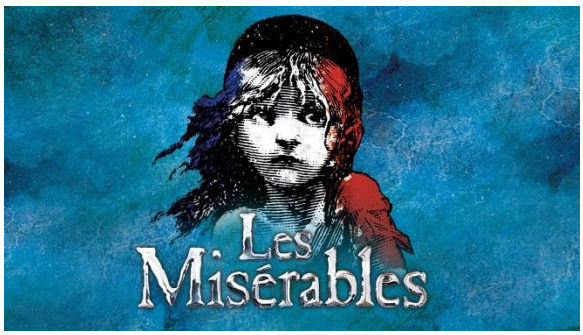
By recalling the story of Joseph told in Genesis 41 in which he interpreted **Pharoah's dreams** of seven fat cows and seven lean cows, and seven fat ears of grain and seven thin ones, we are reminded that there were seven good years for agriculture and seven years of drought. The climate is not always stable and thus we should always responsibly store food.

According to Proverbs (30:24-25) *Four things on earth are small, yet they are exceedingly wise: the **ants** are not a strong species, yet they store up their food in the summer*…. And Proverbs (6:6-8) "*Go to the ant, thou sluggard; consider her ways, and be wise: Which having no guide, overseer, or ruler, Provideth her meat in the summer, and gathereth her food in the harvest*."

In 1783, while **Ben Franklin** was in Paris, negotiating the Treaty that would end the Revolutionary War, **a volcano erupted in Iceland**. Ben Franklin realized that the **volcano** caused a fog that diminished the ability of the sunshine to penetrate the atmosphere. He wrote, "*During…the summer…of the year 1783…there existed a constant fog over all Europe, and a great part of North America…the rays of the sun were indeed rendered so faint in passing through it, that when collected in the focus of a burning glass they would scarce kindle brown paper. Of course, their summer effect in heating the Earth was exceedingly diminished. Hence the surface was early frozen…The cause of this universal fog…was the vast quantity of smoke, long continuing, to issue during the summer from…Iceland, and that other volcano which arose out of the sea near that island…*"

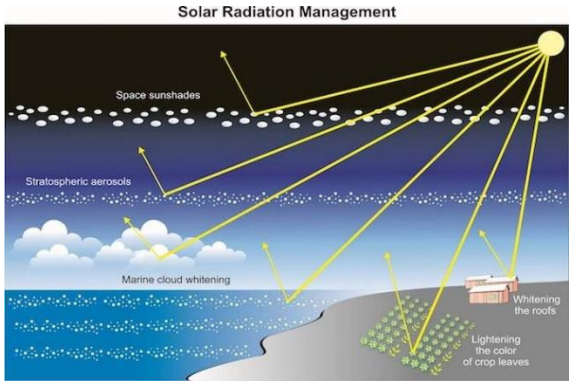


The lack of sunlight resulted in famine; and misery hit France. Was the **French Revolution** brought on by climate change or by an incompetent government, who responded to the misery of the French people by saying "*Let them eat cake*."



In 1815, **Mount Tambora** erupted in Indonesia. In 1816, it caused **the year without a summer** and a worldwide food shortage. It also caused the **Giétro Glacier** to advance, which blocked a river and formed an ice-dammed lake.









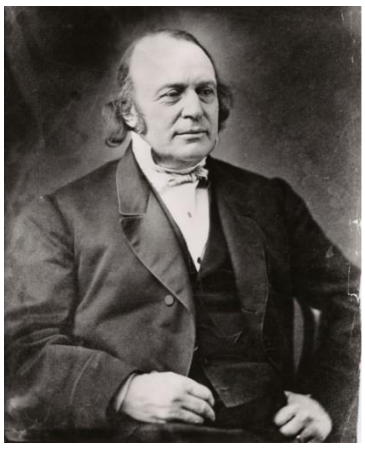
Ignaz Venetz, an engineer, tried to drain the lake; but in 1818, the ice dam failed and catastrophically flooded the village of Bagnes. In 1821, the Swiss Natural Science Society offered a prize for research that would address the then recent climate phenomena. Ignaz Venetz wrote the winning essay entitled *Mémoire sur les Variations de la température dans les Alpes de la Suisse*, **suggesting that climate change has always occurred** and proposed that much of Europe had at one point in the past been covered by glaciers. Venetz concluded that the climate change is the rule. He did so by reading reports that grape vines no longer could be grown in places they once flourished [in the 1200s

England had a thriving wine industry]; by seeing that mountain passes which were once open were now blocked and those that were once blocked were now open; and by seeing the ruins of ancient buildings, roads and forests that resulted from glacial advance or retreat [glaciers are like enormous plows that till the land]. The periodic advance and retreat of glaciers could also explain how giant boulders known as **erratics** became scattered throughout the hemisphere.



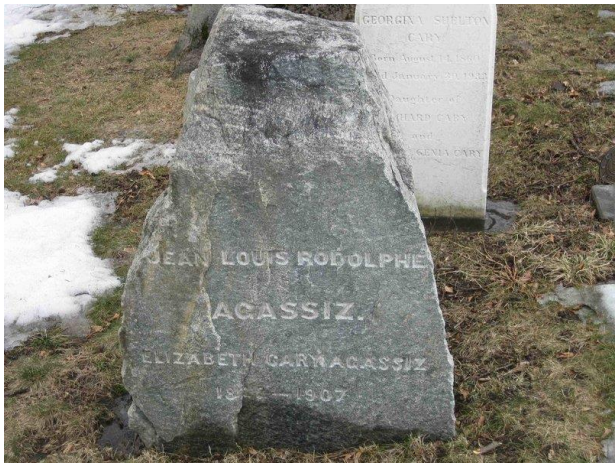
Today, Bill Gates would like to finance, in part, a solar geoengineering project called Stratospheric Controlled Perturbation Experiment (SCoPEx) that mimics the effects of volcanic action on dimming the solar radiation that reaches the earth by putting an aerosol made of $CaCO_3$ (and perhaps sulfuric acid) in the atmosphere. The Intergovernmental Panel on Climate Change suggests that the SCoPEx project could lower global temperatures by a full 1.5° C for no more than $1-10 billion a year. What could go wrong? If something does, *we could always eat cake!*

Louis Agassiz, who was also Swiss, studied glaciers. Agasssi had a great influence on American science. He became a lecturer at Cornell University and a professor at Harvard. A. D. White, the first President of Cornell, sought his advice on who to hire. Here is a statue of Agassiz at Stanford University. It fell during the earthquake of 1906. Stanford's President David Starr Jordan wrote, "Somebody—Dr. Angell, perhaps—remarked that '*Agassiz was great in the abstract but not in the concrete*.'"

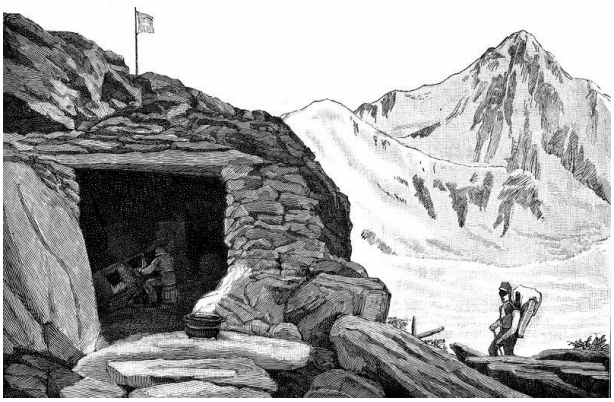




Here is Agassiz' gravestone [in Mount Auburn Cemetery, which is not far from Harvard], a stone cut by the glacier he studied so much in Switzerland.



While studying the movement of glaciers, he stayed each night at hotel with the pompous name, **Hôtel des Neuchâtelois**. It was built from the rocks broken and carried by the glacier, which are known as glacial till. He began each morning by bathing in a large tub of ice water, which made him feel warm the rest of the day as he traipsed around the glacier. He had a cup of hot chocolate for breakfast. He ended each day with mutton and rice for dinner, a cup of coffee, and a cigar.



Like Venetz, he concluded from the movements of the glaciers that all of Europe was once covered by glaciers and he traveled to **Scotland** to see if this land, which presently had no glaciers, showed evidence of glaciers being there in the past. He found evidence of rocks that had been polished and **scored** by the retreat of glaciers, and he found **moraines** composed of glacial till that indicated the farthest reach of the glaciers. This proved that the earth had experienced an **Ice Age**.

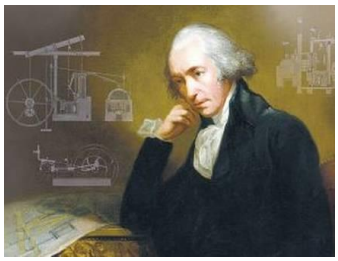




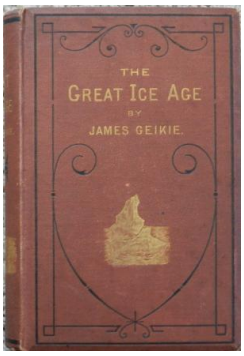
As an aside, **Long Island** is a pile of rocks [moraine] pushed by the glacier that tilled the land. The moraine indicates the farthest reach of glaciers in the last glacial period approximately 20,000 years ago.

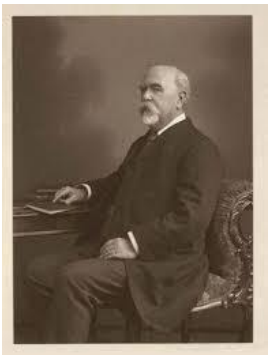


As a result of the development of the steam engine by **James Watt** in Scotland between 1763 and 1775, the mining of coal became necessary to power the industrial revolution. It was the **Golden Age of Geology**. Coal powered the Industrial Revolution and the digging of **coal**, and the **canals** used to transport it gave a peak into the past history of the earth. **Each layer indicated a different climate**. And the plants buried in it gave an indication of the nature of a climate. **Peat** indicates a cool and moist environment, fossil **ferns** indicate a moist climate (warm or cool depending on the type of fern), while fossil **oak** and **pine** trees indicate a drier temperate environment. By discovering alternating layers of glacial till and plant and animal remains, it became clear to **James Geike**, that there were **many Ice Ages**. The interglacial periods were not only warm, but very warm, as indicated by the finding of fossil bones and tusks of **elephants** throughout Europe.



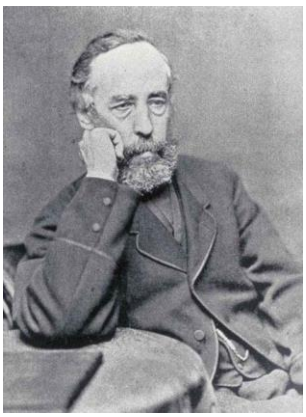


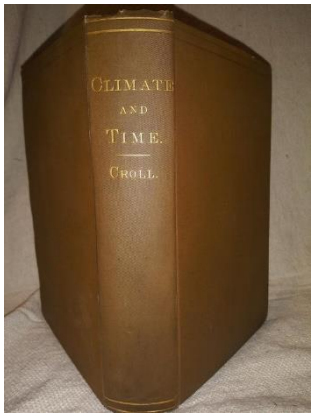


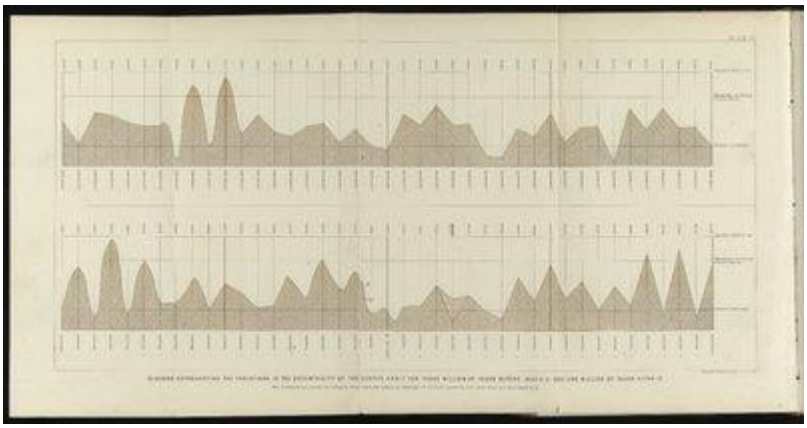




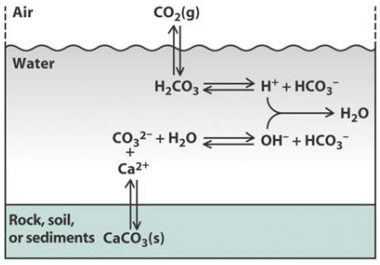
Interested in determining the cyclical cause of ice ages, **James Croll** (1885), a grounds keeper at the museum of the Andersonian University in Glasgow, went into the University library at night and read the astronomical works of Urban Le Verrier. Croll calculated the effect of the periodically changing **eccentricity of the orbit of the earth around the sun from elliptical to circular and the precession of the equinoxes** to retrodict the climate over the last 3 million years and to predict the climate for the next 1 million years. He presented his work in *Climate and Time in their Geological Relations: A Theory of Secular Changes of the Earth's Climate.* Croll's work suggests that there may be an astronomical cause that can result in the current global warming. The figure below shows the amount of ice, which is inversely proportional to the temperature.



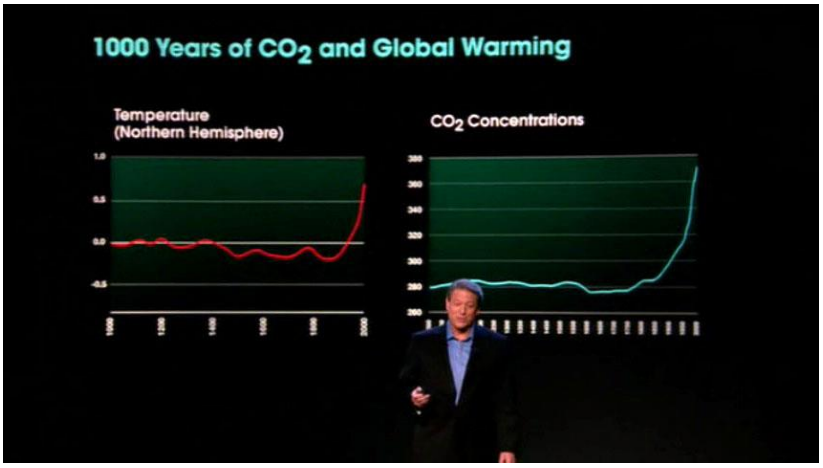




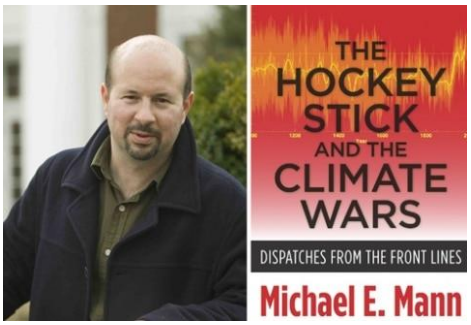




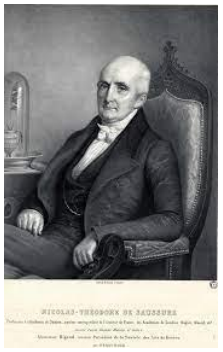
Carbon dioxide naturally enters the atmosphere as a result of **volcanic activity** and the decomposition of **calcium carbonate** in water. Could changes in the earth's temperature from astronomical causes result in an increase in atmospheric CO_2? Yes, if you ask me. A natural warming of the oceans would cause the outgassing of CO_2. So the question is, how much atmospheric CO_2 comes from anthropogenic sources and how much comes from outgassing of the oceans?



As long as the energy that reaches the earth as visible light equals the energy that leaves the earth as infrared light, the earth's temperature will be in balance. Too little carbon dioxide in the atmosphere would tend to push the earth into an ice age and too much carbon dioxide in the atmosphere would tend to push the earth into a warm or interglacial period. The more **fossil fuels** we burn on earth, the more carbon dioxide will go into the atmosphere, and it will be more likely that we will tip the balance toward **global warming**. There is a correlation between global temperature and atmospheric carbon dioxide that coincides with the **industrial revolution** (Hansen and Sato, 2001). But correlation does not mean causation. Is the increased anthropogenic CO_2 responsible for the increase in global temperature as the **hockey stick** graphs presented by the Nobel Peace Prize winning IPCC and Al Gore imply?







However, the hockey stick graph does not include the CO_2 measurements made by the de Saussures in the mountains of Switzerland in the eighteenth century. In 1796, **Horace de Saussure** measured the CO_2 concentration in the fresh air of the Swiss Alps, and his son Théodore published fuller accounts in 1828 and 1830. (**Théodore de Saussure** (1804), while unknown to climatologists, knew how to measure CO_2 concentration, and he is well-known for demonstrating that photosynthesis required the uptake of both CO_2 and H_2O). De Saussure found that the CO_2 concentration was higher in the town of Geneva (468 ppm) than outside in Chambeisy (437 ppm).

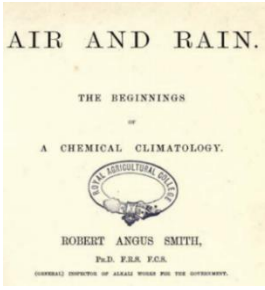
Date.	Time.	At Chambeisy.	In Geneva.
1827.			
February 12.	Mid-day	·0358	·0455
May 22		·0540	·0569
May 26		·0471	·0528
August 9		·0453	·0476
1828.			
January 28		·0426	·0427
February 19.		·0462	·0482
April 10		·0465	·05
July 25		·0390	·0445
July 1	Midnight	·0407	·0385
September 4	11 at night	·0441	·0439
September 5		·0382	·0420
October 1		·0414	·0423
October 2		·0367	·0405
	Mean	·0437	·0468

De Saussure also found that the CO_2 concentration was higher in the mountains than in the plains—probably because the nitrogen concentration in the air decreased with elevation. In general, de Saussure found that the average value of the CO_2 concentration was 490 ppm, where the minimum value was 370 ppm, and the maximum value was 620 ppm.

Name of mountain.	Height of mountain in mètres.	Carbonic acid in the air of the mountain.	Carbonic acid in the air of the plain.
La Dôle	1267	·0461	·0474
Grand Salève-sur-Crevin	877	·0557	·0482
Hermitage (Petit Salève)	331	·0544	·0482
La Dôle	1267	·0491	·0446
Vasserode-sous-la-Dôle	908	·0481	·0446
Grand Salève-sur-Grange-Tournier	945	·0413	·0367* ·0359†
Col de la Faucille	963	·0443	·0414
ditto	963	·0454	·0415
ditto		·0369	·0387
ditto		·0360	·0322
ditto		·0422	·0355
ditto		·0395	·0315



Moreover, the hockey stick graph for CO_2 does not include the higher values of CO_2 recorded by **Robert Angus Smith** (1872), another forgotten scientist, in *Air and Rain: The Beginnings of a Chemical Climatology*, where the average CO_2 concentration in the fresh air of Scotland was found to be **336 ppm**.


AIR AND RAIN.

THE BEGINNINGS

OF

A CHEMICAL CLIMATOLOGY.

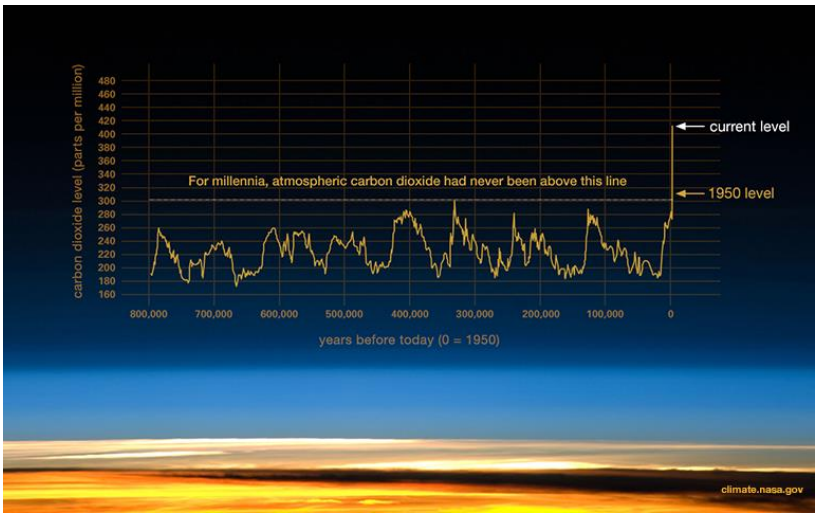
ROBERT ANGUS SMITH,

Carbonic Acid.

Places between 2,000 and 3,000 feet high.		Places above 3,000 feet high.	
Name of Place.	CO_2 in 100 pts.	Name of Place.	CO_2 in 100 pts.
Ben Lomond	·0339	Ben Muich Dhu	·0350
Ben-na-Board	·0337	Ben Nevis	·0327
Ben Voirlich	·0320	Ben Ledi	·0327
		Lochin-y-gair	·0335
Mean	·0332	Mean	·0336

Mean of all the foregoing in Scotland . . . ·0336

Yet NASA published the following graph:



NASA claims, "*During ice ages, CO_2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm (see fluctuations in the graph). In 2013, CO_2 levels surpassed 400 ppm for the first time in recorded history. This recent relentless rise in CO_2 shows a remarkably constant relationship with fossil-fuel burning, and can be well accounted for based on the simple premise that about 60 percent of fossil-fuel emissions stay in the air. Today, we stand on the threshold of a new geologic era, which some term the '**Anthropocene**', one where the climate is very different to the one our ancestors knew*." Did NASA do due diligence in investigating the scientific evidence that may not or even does not support the consensus? I have not yet met a climate scientist that knows the historical literature. Is there a **good reason** to neglect these data or is it **intellectual laziness** or **bad faith**?

As you can see, the hockey stick graph for CO_2 does not include the historical measurements presented by Angus Smith and Horace and Théodore de Saussure. It also does not include the historical data presented by Fonselius et al.

(1956), which is readily available online: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.2153-3490.1956.tb01208.x.

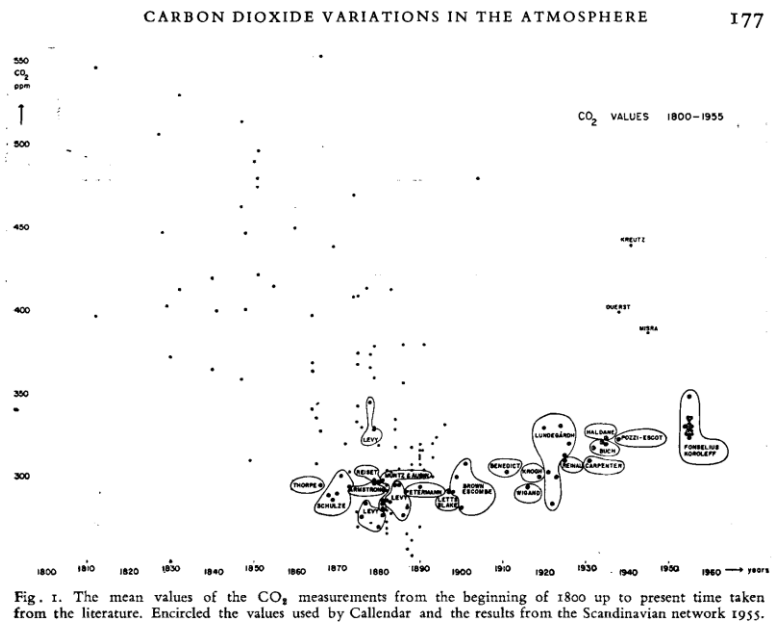
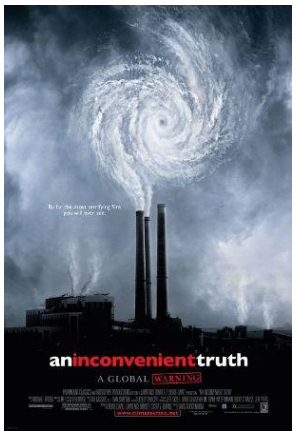


Fig. 1. The mean values of the CO_2 measurements from the beginning of 1800 up to present time taken from the literature. Encircled the values used by Callendar and the results from the Scandinavian network 1955.



In the movie, *An Inconvenient Truth*, former Vice President, co-founder (2004) and current Chairman of Generation Investment Management LLP, which integrates finance with sustainability (https://www.generationim.com/), Al Gore described the effect of anthropogenic carbon dioxide emission into the environment on global warming. http://an-inconvenient-truth.com/; https://www.youtube.com/watch?v=OcLG-tcMvyg The temperature trends based on various models can be found at: http://www.theconsensusproject.com/trend.php.



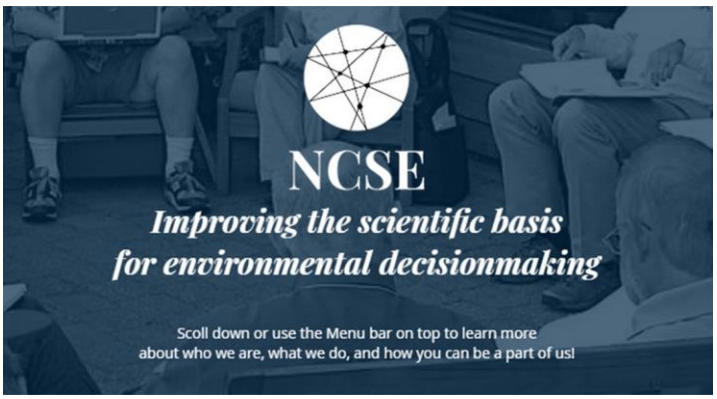
Steven Koonin (2021) tells a story in *Unsettled* that may emphasize the interest in non-experts (as opposed to experts?) trying

to understand the relationship between carbon dioxide and global temperature through questioning: "*In 2008, I was working as BP's chief scientist, focused on accelerating renewable energy technologies. I was invited to attend a small dinner hosted by Prince Philip at Buckingham Palace. I arrived in black tie at the palace courtyard via London cab; a quick security check and I was ushed into a reception room along with other guests. After predinner drinks and small talk, we, a group of about fourteen that included Prince Philip, Princess Anne, BP CEO John Browne, and other notables from UK academia, business, and government, moved into a grander room and settled around a large dining table.*

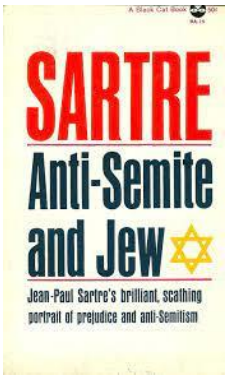


The chitchat among tablemates quieted as Prince Philip made his welcome and reminded us that the topic of the evening was climate and energy. ***He then opened the conversation by asking the group a question about the relationship between carbon dioxide emissions and rising global temperatures.*** *The prince's framing was sufficiently technical that there was awkward silence around the table—until yours truly, the cheeky American scientist, spoke up in a Brooklyn accent to deliver a mini-lecture on infrared-active molecules, the 'black window' effect, and the connection between atmospheric concentration and emissions. I earned an appreciative nod from the Duke of Edinburgh, whom I found to be quite knowledgeable.*

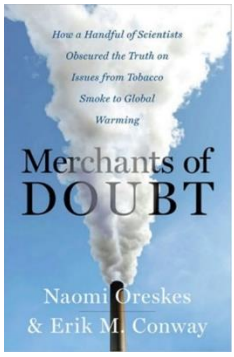
I suspect that the Duke already knew the answer to his conversation-starting question when he asked it. In any event, the lively discussion that followed over a fine dinner mirrored many others that I've been involved in—finding ***non-experts eager to understand*** *the complex and nuanced subjects of climate and energy, as well as a confusion about the nature and scale of the problems facing us*."



The National Center for Science Education (https://ncse.ngo/climate-change) states: "*The National Center for Science Education is the only national organization devoted to defending the teaching of climate change in public schools.* ***Human-caused climate change is not scientifically controversial****. Although most U.S. adults believe that the climate is changing, only about half know that human activities are* ***substantially*** *responsible. The polarized and politicized nature of the societal debate about climate change can make it challenging for teachers to present the science honestly, accurately, and completely. NCSE is committed to helping teachers gain the confidence and support they need to teach climate change right*."



According to The Consensus Project (http://theconsensusproject.com/), "***The debate is over****, there is an overwhelming and growing scientific consensus that global warming is real*." Remember what **Jean-Paul Sartre** (1948) wrote in *Anti- Semite and Jew*, "*They delight in acting in* ***bad faith****, since they seek not to persuade by sound argument but to intimidate and disconcert. If you press them too closely, they will abruptly fall silent, loftily indicating by some phrase that the time for argument is past*." Sartre goes on to say, "*We have here a basic fear of oneself and of truth. What frightens them is not the content of truth, of which they have no conception, but the form itself of truth, that thing of indefinite approximation*." People who question the **authority of the consensus** are called ***Merchants of Doubt***. But what if there are legitimate scientific questions?



The **New Green Deal** introduced by Representative **Alexandria Ocasio-Cortez** proposes a way to mitigate global warming https://web.archive.org/web/20190207191119/https:/ocasio-cortez.house.gov/media/blog-posts/green-new-deal-faq and https://ocasio-cortez.house.gov/sites/ocasio-cortez.house.gov/files/Resolution%20on%20a%20Green%20New%20Deal.pdf



John Kerry told the 2021 Climate Adaptation Summit: "*Three years ago, scientists gave us a pretty stark warning. They said we have 12 years within which to avoid the worst consequences of climate change. And now we have nine years left. And I regret that my country has been absent for three of those years*."

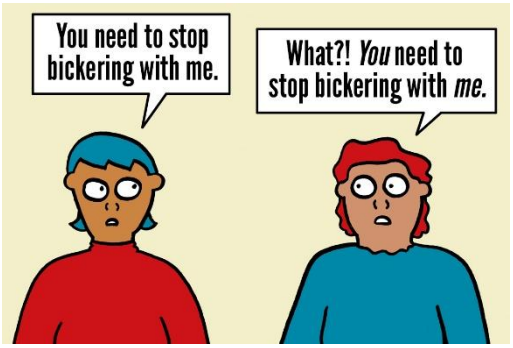


Whose responsibility is it to provide clear and convincing scientific evidence for anthropogenic climate change? Michael Mann (2012) wrote in The *Hockey Stick and the Climate Wars*, "[t]*he climate denial campaign seemed to enjoy the same advantage as the defense in a criminal trial. Those opposed to limiting carbon emissions recognized long ago they need only cast 'reasonable doubt' to convince members of the public that it is too expensive to take action. They need not present a logically consistent case. It suffices for them to attempt to simply pick holes in the scientific evidence, however inconsequential. The greater burden lies with those making the scientific case. They must present a case so persuasive that even the most skilled artists of sophistry cannot undermine it. Critics frequently argue that until science is able to offer proof of the reality of human-caused climate change, it is too early to act. Yet this is a red herring. Science can only*

ever offer weights of evidence, degrees of confidence, and estimated risk. 'Proof' is reserved for mathematical theorems and alcoholic beverages."

But I still have fundamental questions:

> What is the proportion of natural and anthropogenic causes to global warming?
> What is the proportion of natural and anthropogenic causes to the current atmospheric CO_2 increase?
> What is the effect of an increase in the atmospheric CO_2 concentration on scattering the wavelengths of infrared light emitted by the earth, and what effect does this difference in scattering have on the global temperature?
> How is the climate sensitivity factor calculated? What are the assumptions that underlie the equation?
> Shouldn't the science that is supporting policy change provide at least clear and convincing evidence if not being beyond a reasonable doubt?
> And most of all, why is there so much bickering on this issue?



Political Bickering Over Climate Change Reaches New Lows

https://www.cbsnews.com/news/political-bickering-over-climate-change-reaches-new-lows/

The **CO_2 Coalition** has a **view of science** that resonates with me because it tries to **understand science** by making inferences based on a **line of reasoning** that is based on **first principles** rather than based on what I consider to

be **talking points**. http://co2coalition.org/wp-content/uploads/2016/10/Carbon-Dioxide-Benefits-the-World-2.pdf In a paper entitled, ***Carbon Dioxide Benefits the World: See for Yourself***, they write, *This white paper summarizes the views of the CO_2 Coalition, a new and independent, non-profit organization that seeks to engage thought leaders, policy makers, and the public in an informed, dispassionate discussion of how our planet will be affected by CO_2 released from the combustion of fossil fuel. Available scientific facts have persuaded Coalition members that additional CO_2 will be a net benefit. Rather than immediately setting this document aside for promoting such a politically incorrect view, readers would do well to act on the ancient motto of Britain's prestigious Royal Society—**nullius in verba**, 'don't take anyone's word for it,' or more simply, 'see for yourself.'*

Claims that '97 percent of scientists' agree that a climate catastrophe is looming because of the emission of CO_2 should be greeted with skepticism. Traditional science has advanced by comparing observations or experiments with theoretical predictions. If there is agreement with theory, confidence in the theory is increased. If there is disagreement, the theory is abandoned or it is modified and tested again against observations.

***Scientific truth has never been established by consensus**, for example, by '97 percent agreement.' History reveals many instances when the scientific consensus of the day was later discredited. The widespread embrace and practice of eugenics in the early 1900s; opposition to the theory of plate tectonics in geology; and the dominance of Lysenkoist biology in the Soviet bloc, are a few recent examples. Given the frequency of mistaken consensus, citizens everywhere should heed the Royal Society's motto and learn as much as they can about how increasing CO_2 levels in the atmosphere will affect the planet.*

In a more recent paper, the CO_2 Coalition writes, *The public requires an informed, dispassionate discussion of how our planet will be affected by CO_2 released from the combustion of fossil fuel and other sources. In a white paper, entitled Carbon Dioxide Benefits the World; See for Yourself the CO_2 Coalition, a new and independent non-profit organization summarized the scientific case that additional CO_2 will be a net benefit for the world. Following the words of the United States Declaration of Independence, the Coalition believes that 'a* ***decent respect to the opinions of mankind' requires that they should declare the causes which impel them to this politically incorrect view****—and in more detail than is appropriate for a White Paper. That is the purpose of the present paper, A Primer on Carbon Dioxide and Climate.*

The CO_2 Coalition is **not trusted** by various groups:

http://polluterwatch.org/CO2-Coalition

https://www.desmogblog.com/co2-coalition

http://www.rightwingwatch.org/post/from-cpac-the-great-news-about-carbon-dioxide/

https://energydesk.greenpeace.org/2015/12/08/exposed-academics-for-hire/

https://www.dailykos.com/stories/2016/11/2/1590075/-The-Kochs-Doubt-Machine-and-WSJ-s-War-Against-CO2-Science?

https://insideclimatenews.org/news/06032017/climate-change-denial-scientists-richard-lindzen-mit-donald-trump



Faculty of the Program in Atmospheres, Oceans and Climate
Department of Earth, Atmospheric and Planetary Sciences

Massachusetts Institute of Technology
77 Massachusetts Avenue, Building 54
Cambridge, Massachusetts 02139–4307

March 2, 2017

President Donald Trump
White House
Washington, DC

Dear Mr. President:

It has come to our attention that our colleague Richard Lindzen, Professor Emeritus at MIT, has sent you a letter urging you to withdraw from the UN climate convention, claiming that actions with respect to global climate are not scientifically justified.

As his colleagues at MIT in the Program in Atmospheres, Oceans and Climate, all of whom are actively involved in understanding climate, we write to make it clear that this is not a view shared by us, or by the overwhelming majority of other scientists who have devoted their professional lives to careful study of climate science.

The risks to the Earth system associated with increasing levels of carbon dioxide are almost universally agreed by climate scientists to be real ones. These include, but are not limited to, sea level rise, ocean acidification, and increases in extreme flooding and droughts, all with serious consequences for mankind. Professional societies like the American Meteorological Society and the American Geophysical Union have released official statements on the concerns of their members about these risks. We owe it to future generations to remain engaged with the international community to seek the widest possible efforts to understand and mitigate those threats.

We hope this information is helpful to you in evaluating the true balance of expert opinion on this important issue.

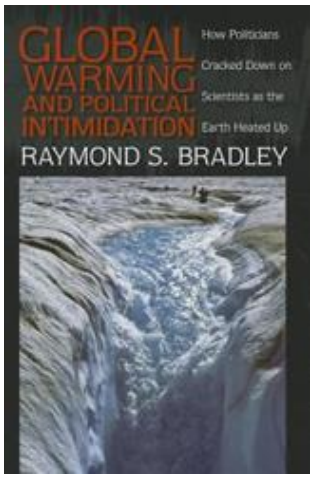
With Respect,

The faculty of the MIT Program in Atmospheres, Oceans and Climate

Andrew R. Babbin, Assistant Professor, MIT
Edward A. Boyle, Professor, MIT
Timothy Cronin, Assistant Professor, MIT
Daniel Cziczo, Associate Professor, MIT
Kerry A. Emanuel, Professor, MIT
Dara Entekhabi, Professor, MIT
Raffaele Ferrari, Professor, MIT
Glenn R. Flierl, Professor, MIT
Michael Follows, Professor, MIT
Colette L. Heald, Associate Professor, MIT
John Marshall, Professor, MIT
David McGee, Associate Professor, MIT
Paul O'Gorman, Professor, MIT
R. Alan Plumb, Professor Emeritus, MIT
Ronald G. Prinn, Professor, MIT
Paola Rizzoli, Professor, MIT
Daniel Rothman, Professor, MIT
Sara Seager, Professor, MIT
Noelle Eckley Selin, Associate Professor, MIT
Susan Solomon, Professor, MIT
Roger E. Summons, Professor, MIT
Carl Wunsch, Professor Emeritus, MIT

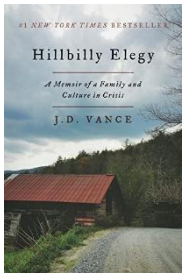
Although Climategate shows that there is distrust on both side: https://www.theguardian.com/environment/2010/jul/07/hacked-climate-emails-analysis

Raymond Bradley testified before the Senate on May 17, 2000 (https://www.govinfo.gov/content/pkg/CHRG-106shrg81375/html/CHRG-106shrg81375.htm). In a prepared statement, he wrote:



"*We are living in unusual times. The climate of the twentieth century climate was dominated by universal warming; almost all parts of the earth had temperatures at the end of the century that were higher than when it began.* ***At the same time, the concentration of greenhouse gases in the atmosphere increased to levels that were higher than at any time in at least the last 420,000 years. These observations are incontrovertible***." Are these observations really incontrovertible?

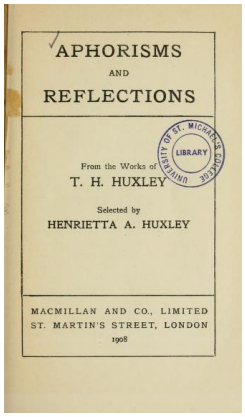
You decide!

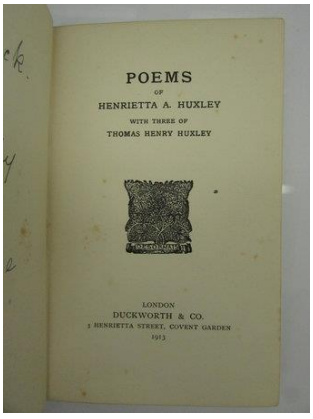


Coal miners are people and the coal miners have quite a culture, encompassing food, music, and worker's rights. I wouldn't call them privileged. Do you know about the 1920 miner's strike in Matewan?

In science, it is healthy to have diverse points of view. It says in a book entitled, *Aphorisms and Reflections*, complied by T. H. Huxley's wife **Henrietta**, "***There is assuredly no more***





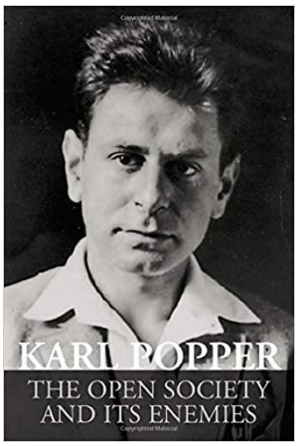


effectual method of clearing up one' s own mind on any subject than by talking it over, so to speak, with men of real power and grasp, who have considered it from a totally different point of view."

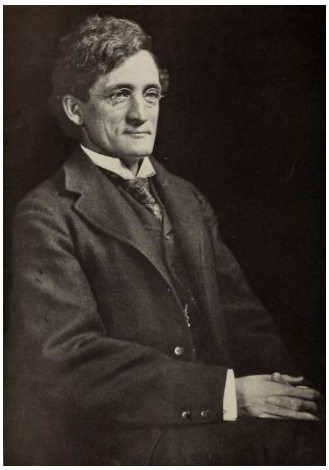
Let me repeat:

"***There is assuredly no more effectual method of clearing up one' s own mind on any subject than by talking it over, so to speak, with men of real power and grasp, who have considered it from a totally different point of view***."

As it says in Proverbs 27:17, *As iron sharpens iron, so one person sharpens another*.



Opponents help you see where you have to gather more facts, sharpen your arguments, and perform better research to answer those uncomfortable questions that may come from an over-representation of facts. **Karl Popper** wrote in ***The Open Society and its Enemies: Hegel and Marx,*** "*… a rationalist, even if he believes himself to be intellectually superior to others, will reject all claims to authority since he is aware that, if his intelligence is superior to that of others (which is hard for him to judge), it is only in so far as he is capable of learning from criticism as well as from his own and other people's mistakes, and one can learn in this sense only if one takes others and their arguments seriously.* ***Rationalism is therefore bound up with the idea that the other fellow has a right to be heard, and to defend his arguments.*** *It thus implies the recognition of the claim to tolerance, at least of all those who are not intolerant themselves*."



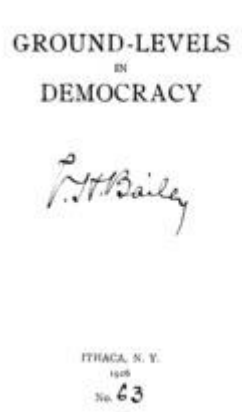
Liberty Hyde Bailey (1916), the founder and first dean of the College of Agriculture and Life Sciences at Cornell, begins his book *Ground-Levels in Democracy* like so: "*TO FIND the fact and to know the truth, this is the purpose of the quest of science. If the truth can be applied to the arts of life, the gain is good; but the truth is valuable on its own account, and for the range and reach that it imparts to the mind. As the truth is of itself, as it knows no person and no condition, so is its application impartial and so is its effect on the mind uncompromising.*

One never makes the quest with success unless the mind is open at the start. The quest is to find out, always to discover, never to prove a thesis or to demonstrate an assumed position. ***Herein does this mind differ from that of the advocate who must merely prove a case,*** *or from that of the preacher who must support a dogma, or from that of the politician who must defend a party.*

Science cannot be dogmatic, if it is science; it cannot be partisan if its judgment is that of the open mind, seeking. Our policies are largely controlled by the partisan, and by the publicist who endeavors to support his argument. Science is not argumentative: the whole statement of its case is merely the statement of the fact and its significance. There is no taking of sides to truth. The prejudiced mind — the mind that prejudges — is never the scientific mind. Therefore does the science- spirit introduce a modern element into society; and in the end it will reshape our political philosophy.

Science is never partial to any set of facts. It weighs all facts, giving to each its due place and import. It is easy enough to show that the moon exerts powerful influence on the work of the planter if we choose certain coincidences and ignore

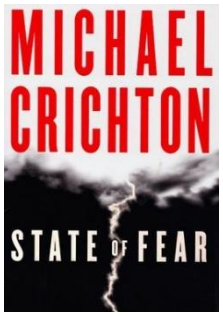
all the exceptions. ***This is the political method,—to remember the facts that support our own argument and forget those that have an opposite or a different significance.*** *Most persons in all the daily relations of life see only one side of a situation, which means that they do not see at all but only follow a chosen and blind course, consciously or subconsciously.*" Bailey goes on to say, "*The science-spirit removes at once the fear of truth and the fear of dogma and the fear of nature. Ignorance is always bondage, and it is the truth that shall make you free*." If you think that Liberty Hyde Bailey's view in 1916 is refreshing and would still be valuable today, I highly recommend that you read this short book.



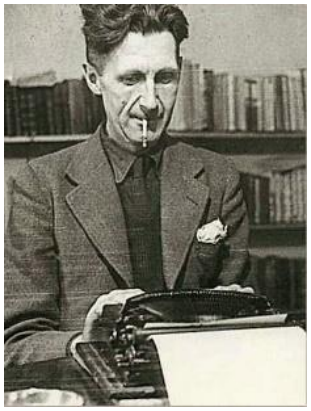
In an interview with Grist Magazine, Al Gore (2006) http://grist.org/article/roberts2/ was asked, "***There's a lot of debate right now over the best way to communicate about global warming and get people motivated. Do you scare people or give them hope? What's the right mix?*** **He answered, "*I think the answer to that depends on where your audience's head is*.** *In the United States of America, unfortunately we still live in a bubble of unreality. And the Category 5 denial is an enormous obstacle to* any *discussion of solutions. Nobody is interested in solutions if they don't think there's a problem. Given that starting point, I believe it is appropriate to have an over-representation of factual presentations on how dangerous it is, as a predicate for opening up the audience to listen to what the solutions are, and how hopeful it is that we are going to solve this crisis.*"



https://www.algore.com/



Michael Crichton (2004) wrote a techno-thriller in which he warns both sides of the climate change debate against the politicization of science. He presents many references so readers can assess his thinking and arrive at their own conclusions.



George Orwell wrote in *1984*, "***The Party told you to reject the evidence of your eyes and ears***. *It was their final, most essential command. His heart sank as he thought of the enormous power arrayed against him, the ease with which any Party intellectual would overthrow him in debate, the subtle arguments which he would not be able to understand, much less answer. And yet he was in the right! They were wrong and he was right. The obvious, the silly, and the true had got to be defended.* ***Truisms are true****, hold on to that! The solid world exists, its laws do not change. Stones are hard, water is wet, objects unsupported fall towards the earth's center. With the feeling that he was speaking to O'Brien, and also that he was setting forth an important axiom, he wrote:*

Freedom is the freedom to say that two plus two make four. *If that is granted, all else follows"*



Here is a story from the July 4, 1949, issue of *Life* magazine about Orwell's *1984*. It was illustrated by Abner Dean (neé Epstein), the cousin of Jacob Epstein, the sculptor, and **Howie Evans** (neé Epstein), who is an emeritus professor in the Vet School at Cornell. Dean's cartoons were described by Clifton Fadiman like so: "*His pictures are trick mirrors in which we catch sight of those absurd fragments of ourselves that we never see in the smooth glass of habit*."



LONDON IN 1984, as described by Novelist Orwell, is a dreary mass of wartime rubble through which Party members, in uniforms resembling overalls, move warily under the watchful eyes of the Thought Police and of their leader Big Brother. People in ordinary dress are *proles*, or non-Party members, who are kept in ignorance and are regarded simply as animals. Building at center with the Party's three slogans, which sound absurd but are actually believed by members, is Ministry of Truth. To the right is windowless Ministry of Love, a monument of cruelty where victims of the Thought Police are tortured out of their heretical notions.

ILLUSTRATIONS FOR LIFE
BY ABNER DEAN

THE STRANGE WORLD OF 1984

AN ENGLISHMAN WRITES A FRIGHTENING SATIRE ABOUT THE CRUEL FATE OF MAN IN A REGIMENTED LEFT-WING POLICE STATE WHICH CONTROLS HIS MIND AND SOUL



NOVELIST ORWELL

British Novelist George Orwell, 46, who fought in the Spanish Civil War, saw firsthand what the Communists were up to and has since devoted all his talents to warning the world of the fate which awaits it if it confuses liberalism with regimentation. His *Animal Farm* (1946) was a deft satire of what happened to a group of barnyard animals who, in the delusion that living standards can be raised by surrendering freedom, placed their affairs in the hands of a dictatorial pig named Napoleon. His new novel, *Nineteen Eighty-four* (Harcourt, Brace and Company, $3), is a terrifying forecast of what the world of human beings may be like 35 years hence. Al-



though it is not funny, like *Animal Farm*, it is even more effective. It is a July selection of the Book-of-the-Month Club and will be condensed in the September *Reader's Digest*. It is guaranteed to make the flesh creep on anything except brass monkeys and commissars.

In the year 1984 left-wing totalitarianism rules the world. England, the scene of the novel, is known as Airstrip One, a province of a vaguely Anglo-American world power known as Oceania. The prevailing philosophy is *Ingsoc* (a perverted English socialism); the dictator is a Stalinlike character known as Big Brother, who is never seen in person and is perhaps actually a myth. Even in its physical aspects Oceania is a horrible place. The standard of living is pitiably low —in the first place the factories cannot be run efficiently under regimentation, and in the second place it is a cardinal principle of Ingsoc to wage constant war to shoot away the products of the machine and keep the world in poverty and ignorance. London is mostly a mass of rubble left over from the wars which finally created the world of 1984; the only handsome buildings are those where Party members conduct the government. One is the Ministry of Truth, busy manufacturing the lies that are fed to the populace. There are also the Ministry of Love (home of the brutal secret police), the Ministry of Peace (which wages war) and the Ministry of Plenty (which is chiefly concerned with new ways of cutting rations).

The London masses, 85% of the population, are now known as proles; they live in abject poverty and ignorance and their only function is to work, eat, breed and die. Party members are distinguished from the proles by their uniforms, a kind of suit of overalls. (In the case of women the uniform is usually set off by the red sash of the Junior Anti-Sex League; pleasure in sex is frowned on by Big Brother—as is any form of human emotion which might make Party members less frustrated and thus less amenable to discipline.) The members are also distinguished by the drab unhappiness which Artist Abner Dean has depicted in these drawings, and by the constant struggle to keep out of the toils of the Thought Police, whose methods of terror are shown on the following pages. Ingsoc's dictators have finally learned the technique of perpetuating a regimentation forever—they have learned to control, in fact to eliminate, the mind and soul of man.

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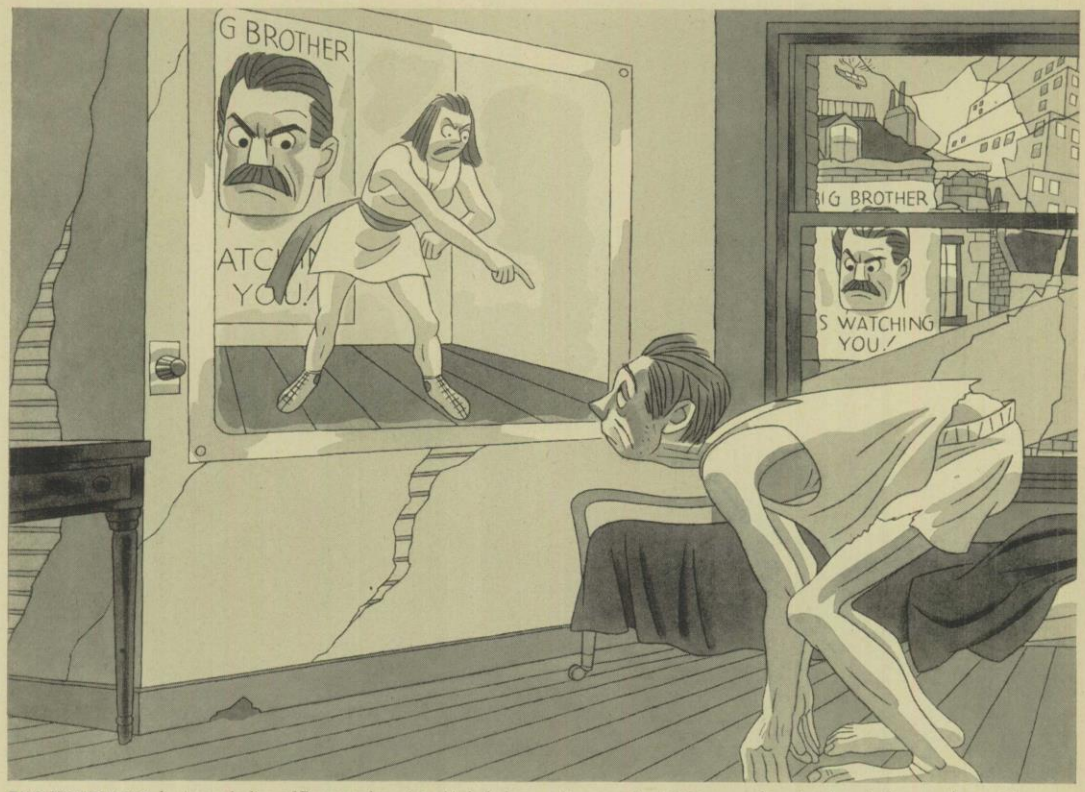

THE TELESCREEN dominates the lives of Party members; it is a kind of television set which can never be turned off, and which can pick up as well as receive images. Over it the members hear what they are supposed to do and believe—and from the other end the dreaded Thought Police can see everything they do and hear everything they say. Here Party Member Winston Smith, serial number 6079, the hero of Orwell's novel, stands before the telescreen, which has awakened him promptly at 7:15 a.m., and is going through the compulsory setting-up exercises known as the Physical Jerks. At the other end the instructress has noted that he is not touching his toes, and she is barking, "Smith! 6079 Smith W! Yes, *you*! Bend lower, please. You can do better than that. You're not trying. Lower please! That's better, comrade. . . . We don't all have the privilege of fighting in the front line, but at least we can all keep fit!" Winston is trying to conceal his distaste.

BOY MEETS GIRL: 1984 STYLE



A LOVE AFFAIR leads Winston first to happiness, inevitably to tragedy. One morning, in a hallway of the Ministry of Truth the dark-haired girl, Julia, pretends to fall and thus manages to hand Winston a note. Since any strange experience is frightening in Oceania, Winston expects some kind of sinister message; instead he is amazed to find the three words, "I love you." Love, of course, is a forbidden emotion in Oceania; so he quickly throws the note down the office *memory hole*, a kind of automatic incinerator system used to destroy historical documents which the Party wants to forget. He then arranges to meet Julia in the midst of a crowd in Victory Square, where they elude the telescreens just long enough for her to whisper instructions for reaching a hiding place she has found in the country. Up to this point Winston, 39, once married but quickly separated from an intense Party woman whom he despised, has been terribly



TWO MINUTES HATE is a daily institution designed to keep Party members in a frenzy of excitement and rage against the Party's enemies. Here Winston Smith and his fellow workers hiss the telescreen image of Emmanuel Goldstein (who is to Ingsoc what Trotsky is to Communism, except that he is a complete myth invented by the Party leaders). Smith is secretly a rebel against Ingsoc, but he finds himself as emotional as the rest: "The horrible thing about the Two Minutes Hate was that it was impossible to avoid joining in. Within 30 seconds any pretense was always unnecessary. A hideous ecstasy of fear and vindictiveness, a desire to kill, to torture, to smash faces in with a sledge hammer, seemed to flow through the whole group of people like an electric current." It is on this morning that Winston notices that a girl with dark hair is watching him; he fears that she is a member of the Thought Police. For her real reason, see the drawings below.



lonely. Now, in a trysting place beneath the trees he finds a kindred soul in the rebellious Julia; she removes the hateful sash of the Anti-Sex League and they enter upon one of the most furtive and pathetic little love affairs in all literature. For a time they find occasional sanctuary in a room Winston has rented over the store of a prole shopkeeper. Julia is good at smuggling forbidden pleasures; they have real coffee (not the ersatz "Victory" mixture) and chocolate, and Julia adorns herself with cosmetics and perfumes which no Party member is ever supposed to use. But eventually, of course, the Thought Police catch up with them; they discover that even the shopkeeper's room was a trap where they were watched by a hidden telescreen and all their conversations were recorded. For the unspeakable crime of indulging in a human emotion they are arrested and hauled away to repent their sins in the horrible confines of the Ministry of Love.

CONTINUED ON NEXT PAGE



"Ah don't need no shootin' iron, son. Ah'm totin' mah cash in American Express Travelers Cheques."

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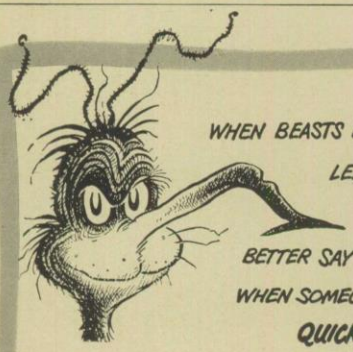

WHEN BEASTS LIKE THIS WON'T LEAVE THEIR LAIRS

MERE INSECTS BETTER SAY THEIR PRAYERS—

WHEN SOMEONE SAYS:

QUICK, HENRY, THE

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Famous FLIT HOUSEHOLD SPRAY is powerfully effective against roaches, flies, mosquitoes, moths, bugs, ants, gnats and many other common household pests! FLIT contains active ingredients for *fast* knockdown — *sure kill.* It's by far the finest household spray ever manufactured by FLIT! Keep it handy — use it often for more pleasant and comfortable living.

SAY IT! SPRAY IT! SLAY IT!



BUY LOW COST FLIT TODAY!

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"FACECRIME"—such as the unorthodox look of sly satisfaction on the man at the center—is a terrible word in Newspeak and a terrible offense in 1984. The Thought Police will have this man before he knows it.

THE LANGUAGE IS CALLED "NEWSPEAK"

Newspeak is the official language of Oceania in 1984. It is a kind of staccato verbal shorthand, designed to enable human beings to communicate with the minimum possible number of words. As Orwell explains it, "Any word could be negatived by adding the affix *un-*, or could be strengthened by the affix *plus-*, or, for still greater emphasis, *doubleplus-*. Thus, for example, *uncold* meant 'warm,' while *pluscold* and *doublepluscold* meant, respectively, 'very cold' and 'superlatively cold.' Given the word *good*, there was no need for such a word as *bad*, since the required meaning was better expressed by *ungood*." The ultimate aim of Newspeak was to reduce the vocabulary until it would be impossible to think a heretical thought—there would be just no words for disliking Ingsoc.

Some of the strange Newspeak words which crop up frequently in *Nineteen Eighty-four:*

Crimethink—to think anything not approved by Ingsoc.
Facecrime—looking as if you are thinking wrong.
Goodthink—to think in strict Ingsoc dialectics.
Duckspeak—to utter Party beliefs with such automatic, unthinking speed as to sound like a duck's irrational quacks.
Doublethink—ability to believe absolutely in a deliberate lie.

EVERYBODY CONFORMS OR ELSE

Most readers of Nineteen Eighty-four *will find that the thing which chills them most is the terrible urgency under which Oceania's citizens dwell. Big Brother permits no deviations, not even the faintest suspicion that man deserves a better fate than Ingsoc. As Orwell describes it:*

A Party member lives from birth to death under the eye of the Thought Police. Even when he is alone he can never be sure that he is alone. Wherever he may be, asleep or awake, in his bath or in bed, he can be inspected without warning and without knowing he is being inspected. His friendships, his behavior toward his wife and children, the words he mutters in sleep, are all jealously scrutinized. Any eccentricity, however small, any change of habits, any nervous mannerism that could possibly be the symptom of an inner struggle, is certain to be detected. He has no freedom of choice in any direction whatever.

A Party member is expected to have no private emotions and no respites from enthusiasm. He is supposed to live in a continuous frenzy of hatred of foreign enemies and internal traitors, of triumph over victories, and of self-abasement before the power and wisdom of the Party. The discontents produced by his bare, unsatisfying life are deliberately turned outward and dissipated by such devices as the Two Minutes Hate, and the speculations which might possibly induce a skeptical or rebellious attitude are killed in advance by his early acquired inner discipline. The first and simplest stage in the discipline is called, in Newspeak, *crimestop*. Crimestop means the faculty of stopping short, as though by instinct, at the threshold of any dangerous thought. It includes the power of not grasping analogies, of failing to perceive logical errors, of misunderstanding the simplest arguments if they are inimical to Ingsoc. Crimestop, in short, means protective stupidity.

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Goodbye itch! Goodbye flea!
With Sergeant's that's how it can be!

He gives so much, and asks so little. It's a good idea to check up now and then and sort of balance the score! One way is to have safe, quick-acting Sergeant's Dog Care Products always on hand to help keep him in fine fettle. There's one for almost every canine trouble. Science and research create these products—veterinarians test them thoroughly. Behind each one is 74 years' devotion to dogs. Keep the following items on hand. You'll find them at your drug or pet store.

FOR FLEAS—**Sergeant's SKIP-FLEA* Soap for the bath—Sergeant's SKIP-FLEA Powder dusted on regularly between baths. Both kill and repel fleas.**

FOR THAT ITCHING SKIN **irritation sometimes called "summer eczema," soothing Sergeant's Skin Balm brings quick, healing relief.**

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One of America's Leading Manufacturers of Sun Glasses, Combs, Toys and Housewares

INGSOC CATCHES THEM YOUNG

In Oceania even the children are a kind of Thought Police; the Party catches them young, gets them to join the "Spies" and intoxicates them with banners, rifle drills and the yelling of slogans until they become Big Brother's most frantic claque. Winston learns about the Spies in a conversation with his ebullient acquaintance Parsons, who has sired two of them:

"Mischievous little beggars they are," [says Parsons] "but talk about keenness! All they think about is the Spies. D'you know what that little girl of mine did last Saturday, when her troop was on a hike out Berkhampstead way? She got two other girls to go with her, slipped off from the hike, and spent the whole afternoon following a strange man. They kept on his tail for two hours, right through the woods, and then, when they got into Amersham, handed him over to the patrols."

"What did they do that for?" said Winston, somewhat taken aback. Parsons went on triumphantly:

"My kid made sure he was some kind of enemy agent—might have been dropped by parachute, for instance. She spotted he was wearing a funny kind of shoes—said she'd never seen anyone wearing shoes like that before. So the chances were he was a foreigner. Pretty smart for a nipper of seven, eh?"

"What happened to the man?" said Winston.

"I wouldn't be altogether surprised if!" Parsons made the motion of aiming a rifle, and clicked his tongue for the explosion.

"Did I ever tell you, old boy," [Parsons went on] "about the time when those two nippers of mine set fire to the old market woman's skirt because they saw her wrapping up sausages in a poster of B.B.? Sneaked up behind her and set fire to it with a box of matches. Burned her quite badly, I believe. Little beggars, eh? But keen as mustard! That's a first-rate training they give them in the Spies nowadays—better than in my day, even. What d'you think the latest thing they've served them out with? Ear trumpets for listening through keyholes! Of course it's only a toy, mind you. Still, gives 'em the right ideas, eh?"

But of course Parsons' queer pride in his two little beasts, like everything else in Oceania, ends in tragedy. After Winston is jailed by the Thought Police, who should be hauled into his cell but Parsons! In amazement Winston asks, "What are you in for?" This conversation follows:

"Thoughtcrime!" said Parsons, almost blubbering. "Thoughtcrime is a dreadful thing, old man. It's insidious. It can get hold of you without your even knowing it. Do you know how it got hold of me? In my sleep! Yes, that's a fact. There I was, working away, trying to do my bit—never knew I had any bad stuff in my mind at all. And then I started talking in my sleep. Do you know what they heard me saying? 'Down with Big Brother!' Yes, I said that! Said it over and over again, it seems."

"Who denounced you?" said Winston.

"It was my little daughter," said Parsons with a sort of doleful pride. "She listened at the keyhole. Heard what I was saying, and nipped off to the patrols the very next day. Pretty smart for a nipper of 7, eh? I don't bear her any grudge for it. In fact I'm proud of her. It shows I brought her up in the right spirit, anyway."



JUNIOR "SPIES," taught from the cradle to be full of love for Big Brother and hate for heretics, trail a market woman whom they suspect of deviationism. For what happens to the poor woman, see text above.

THE SECRET OF DOUBLETHINK

The most important word in Newspeak is doublethink, meaning a queer mental process which makes the Ingsoc philosophy possible. Orwell describes it in these words:

Doublethink means the power of holding two contradictory beliefs in one's mind simultaneously, and accepting both of them. The Party intellectual knows in which direction his memories must be altered; he therefore knows that he is playing tricks with reality; but by the exercise of doublethink he also satisfies himself that reality is not violated. Doublethink lies at the very heart of Ingsoc, for the secret of rulership is to combine a belief in one's own infallibility with the power to learn from past mistakes. The Party rejects and vilifies every principle for which the Socialist movement originally stood, and it chooses to do this in the name of Socialism. It preaches a contempt for the working class unexampled for centuries, and it dresses its members in a uniform which was at one time peculiar to manual workers and was adopted for that reason. These contradictions are not accidental; they are deliberate exercises in doublethink. For it is only by reconciling contradictions that power can be retained indefinitely.

THE BOOT ON THE HUMAN FACE

The terrible climax of Nineteen Eighty-Four *takes place in the Ministry of Love, where Winston Smith is finally broken into accepting the basic philosophy of Ingsoc. He had written in his diary, "Freedom is the freedom to say that two plus two make four." Now he learns on the torture table that two and two are whatever the Party says—three, five or nothing at all. There can be no truths in Ingsoc, only doctrines. Nor can there be any happiness, or kindness, or humanity. The sole goal of a totalitarianism is power—sheer, naked and brutal power. Now that Winston is broken, his tormentor talks to him frankly, in words that summarize the end stages of the totalitarian philosophy:*

"Power is in inflicting pain and humiliation. Power is in tearing human minds to pieces and putting them together again in new shapes of your own choosing. Do you begin to see, then, what kind of world we are creating? It is the exact opposite of the stupid hedonistic Utopias that the old reformers imagined. The old civilizations claimed that they were founded on love or justice. Ours is founded upon hatred. In our world there will be no emotions except fear, rage, triumph, and self-abasement. Everything else we shall destroy—everything. In the future there will be no wives and no friends. Children will be taken from their mothers at birth, as one takes eggs from a hen. There will be no loyalty, except loyalty toward the Party. There will be no love, except the love of Big Brother. There will be no laughter, except the laugh of triumph over a defeated enemy. There will be no art, no literature, no science. There will be no curiosity, no enjoyment of the process of life. But always there will be the intoxication of power, constantly increasing and constantly growing subtler. Always, at every moment, there will be the thrill of victory, the sensation of trampling on an enemy who is helpless. If you want a picture of the future, imagine a boot stamping on a human face—forever."



TORTURE TABLE on which Winston is placed by Thought Police in the Ministry of Love is a racklike invention which administers any desired degree of pain, without killing or maiming, at mere flick of a dial.

UNBURN SUNBURN



Get soothing relief from pain

You may not realize it right away, but when you're sunburned you're *burned*. You need a real *burn* remedy. Many doctors and nurses—and millions of users—recommend Unguentine, because it works *three ways:*



1. Relieves the pain of sunburn.
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NOTE: Unguentine is *antiseptic* as well as soothing. That's why it comes in handy for many other summer "skinjuries"—scratches, scrapes, scuffs and skin irritations. At all drug stores, in tubes and jars. *Get Unguentine today.*

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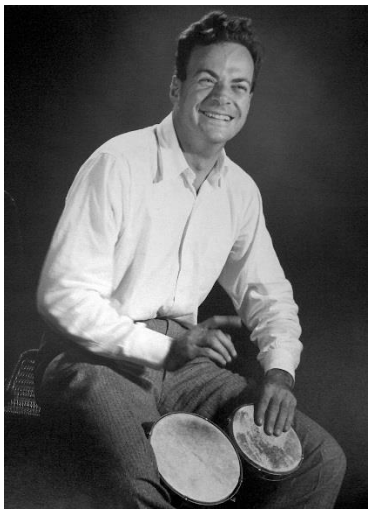
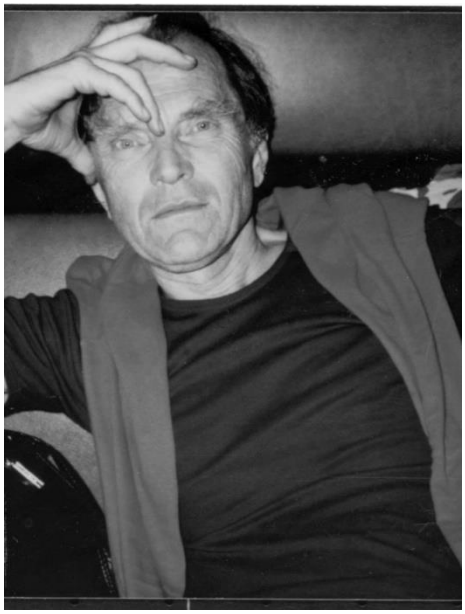
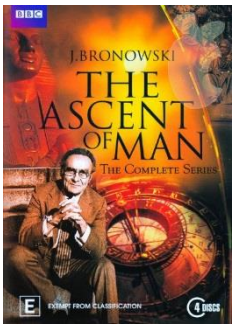
I want to remind you of the importance of making up your own mind as to what are the laws of nature. According to **Richard Feynman** (1965), "*... possibly the chance is high that the truth lies in the fashionable direction. But, on the off-chance that it is in another direction — a direction obvious from an unfashionable view… — who will find it? Only someone who has sacrificed himself by teaching himself … from a peculiar and unusual point of view; one that he may have to invent for himself. I say sacrificed himself because he most likely will get nothing from it, because the truth may lie in another direction, perhaps even the fashionable one.*"



Paul Feyerabend writes about **the place and misplace of authority in science**—whether the authority is a monarch or a mob—in *Science in a Free Society* (1978), *The Tyranny of Science and Knowledge* (1996), *Science and Relativism* (1999). Feyerabend suggests that John Stuart Mill's essay on "*On the Liberty of Thought and Discussion*" is the best description of how to do science well and is consistent with how messy science (like any other human endeavor) really is. Feyerabend and Mill show that even when every scientist except one believes a certain thing, why it is important to listen to the questions and answers of the one.



What is the place of science in supporting political power? **Jacob Bronowski** (1974) wrote in *The Ascent of Man*, "*There is an age-old conflict between intellectual leadership and civil authority. How old, how*



bitter, came home to me when I came up from Jericho on the road that Jesus took, and saw the first glimpse of Jerusalem on the skyline as he saw it going to his certain death. Death, because Jesus was then the intellectual and moral leader of his people, but he was facing an establishment in which religion was simply an arm of government. And that is a crisis of choice that leaders have faced over and over again: Socrates in Athens; Jonathan Swift in Ireland, torn between pity and ambition; Mahatma Gandhi in India; and Albert Einstein, when he refused the presidency of Israel.

I bring in the name of Einstein deliberately because he was a scientist, and the intellectual leadership of the twentieth century rests with scientists. ***And that poses a grave problem, because science is also a source of power that walks close to government and that the state wants to harness. But if science allows itself to go that way, the beliefs of the twentieth century will fall to pieces in cynicism.*** *We shall be left without belief, because no beliefs can be built up in this century that are not based on science as the recognition of the uniqueness of man, and a pride in his gifts and works. It is not the business of science to inherit the earth, but to inherit the moral imagination; because without that man and beliefs and science will perish together*."

"*…Johnny von Neumann was in love with the* ***aristocracy of intellect****. And that is a belief which can only destroy the civilization that we know.* ***If we are anything, we must be a democracy of the intellect****. We must not perish by the distance between people and government, between people and power, by which Babylon and Egypt and Rome failed. And that distance can only be conflated, can only be closed, if knowledge sits in the homes and heads of people with no ambition to control others, and not up in the isolated seats of power.*

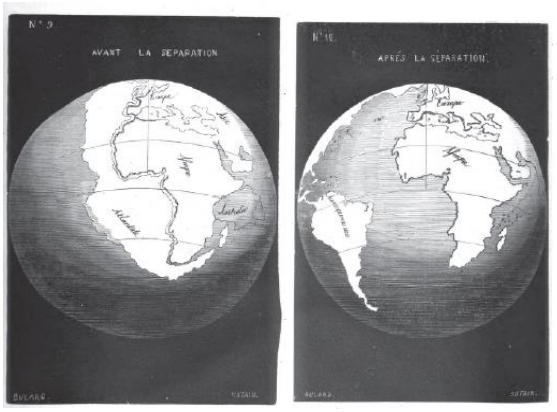
That seems a hard lesson. After all, this is a world run by specialists: is not that what we mean by a scientific society? No, it is not. A scientific society is one in which specialists can indeed do the things like making the electric light work. ***But it is you, it is I, who have to know how nature works, and how (for example) electricity is one of her expressions in the light and in my brain***."
https://www.dailymotion.com/video/x20p9h4_bbc-ascent-of-man-13-the-long-childhood_tv



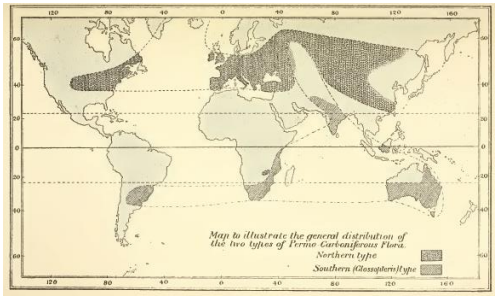
As long as we are discussing the influence of carbon dioxide produced by the burning of fossil fuels on climate, I thought I would mention the **discovery of coal** in the Beardmore Glacier in **Antarctica** by explorers **Frank Wild** and **Ernest Shackleton** (*The Heart of the Antarctic* V.2, 1909) during the **Nimrod Expedition**. **The discovery of coal in Antarctica meant that the climate on Antarctica was once mild enough to support the growth of photosynthetic plants that captured the radiant energy of the sun**, used it to convert carbon dioxide and water into plant structures that were later turned into coal by the heat and pressure generated by the earth. What can the dead remains of plants tell us about previous climate changes, and what can the death of the explorers who found them tell us about what it means to be human?



Aside: On Saturday March 5, 2022, the 100th anniversary of Sir Ernest Shackleton's funeral, his ship Endurance was discovered 3,008 meters below the surface in the icy waters of Antarctica. The wrecked ship was in pristine condition because no wood-eating microorganisms live in it.



Eduard Suess' (1885) postulated that the continents in the Southern hemisphere were once connected into a large landmass known as **Gondwanaland**, named after a coal locality, studied by Henry Benedict Medlicott (1864). In this locality in India, fossil *Glossopteris* was found. Others described *Glossopteris* from regions in the Southern Hemisphere, including South Africa, New Zealand, and South America. Thus it seemed possible that the reason that the similar fossil plants were found in such disparate places is because in the past, the now disconnected places were attached together.



Suess' idea was based on **Abraham Ortelius'** (1596) and **Theodor Christoph Lilienthal's** (1756) proposal that the South America and Africa fit look like they would fit together and **Antonio Snider-Pellegrini's** (1858) proposal that all the continents were once connected based on his discoveries of identical plants in the Carboniferous coal deposits in Europe and the United States.

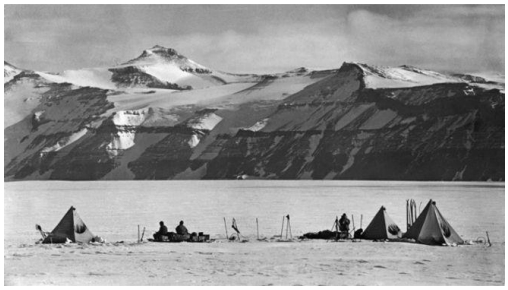
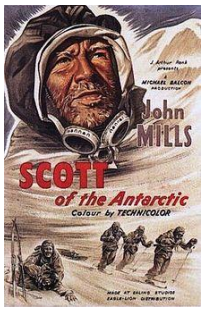


Marie Stopes (1910) was a paleobotanist who studied fossils in coal and **coal balls** at **Manchester** University. She met **Robert Falcon Scott** when he was in Manchester, but she could not convince him to let her join his expedition to Antarctica. However, Scott promised to bring back the fossils she wanted.



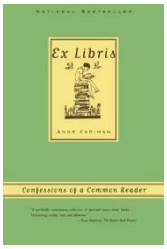



Scott (right) lost the race to the South Pole to **Roald Amundsen** (left; whom Roald Hoffmann is named after) but he kept his promise to Marie Stopes. In his diary, Scott (1912) wrote that he spent "*the rest of the day geologising … under cliffs of Beacon sandstone, weathering rapidly and carrying veritable coal seams. From the last, Wilson, with his sharp eyes, has picked several plant impressions, the last a piece of coal with beautifully traced leaves in layers, also some excellently preserved impressions of thick stems, showing cellular structure….*"

Scott died without throwing away the 16 kg of fossils, which would have lightened his load and perhaps allowed him to live. The fossils collected by Scott can be found at the British Museum of Natural History http://nhm.ac.uk/nature-online/earth/fossils/glossopteris/index.html. Frank Debenham, who survived the expedition, wrote (in *Scott's Last Expedition*, v.2; arranged by Leonard Huxley) that the 300-250-million-year-old *Glossopteris* fossils collected at the Beardmore Glacier by Dr. Wilson and Lieutenant Bowers "*are perhaps the most important of all the geological results. The plant fossils collected by this party are the best preserved of any in this quadrant of the Antarctic, and are of the character best suited to settle a long-standing controversy between geologists as to the nature of the former union between Antarctica and Australasia*." **Anne Fadiman** (1998), daughter of Clifton Fadiman mentioned above, wrote in *Ex Libris*, "*When I think of the causes for which people more commonly give up their lives—nationalism, religion, ethnicity—it seems to*





me that a thirty-five pound bag of rocks, and the lost world it represents, is not such a bad thing to die for."



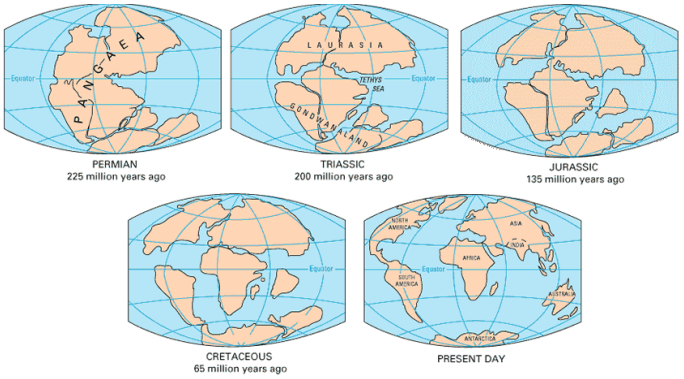
There is a has a stained-glass window commemorating Robert Falcon Scott's fatal expedition to the South Pole St Peter's Church in Binton, Warwickshire, UK. The Rector of the church, Lloyd Bruce, who commissioned the window, was Scott's brother-in-law. The window was built in 1915.

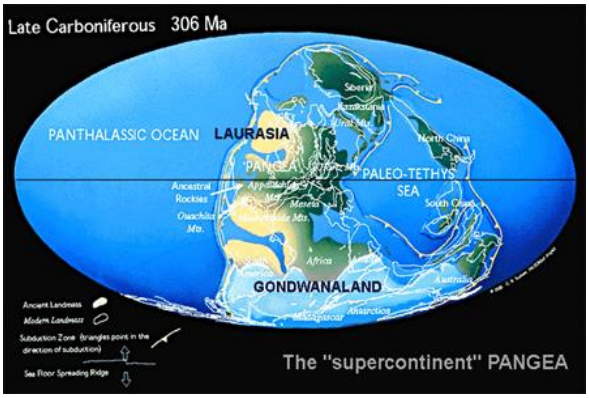
The four panes show the explorers bidding their families goodbye; their disappointment at discovering Amundsen's flag; Oates' self-sacrifice, choosing to meet death in a blizzard rather than slow the others; the cairn erected over the bodies of Bowers, Wilson, and Scott.

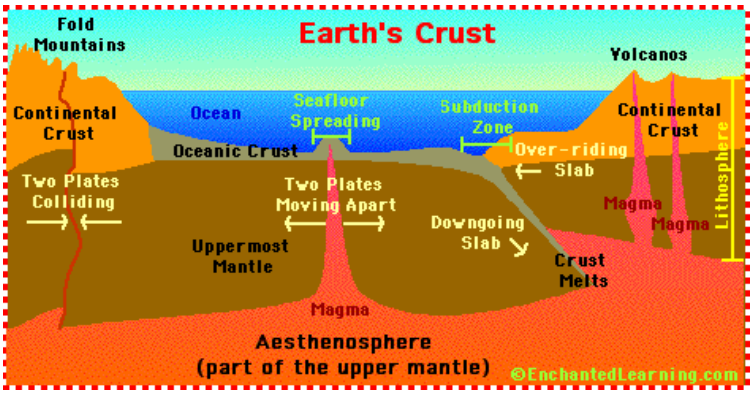




Alfred Wegener (1924) proposed the theory of continental drift or **plate tectonics**, which with the help of others described and explained how hot magma coming from deep in the earth can produce the force to push land masses around the globe over geological time.







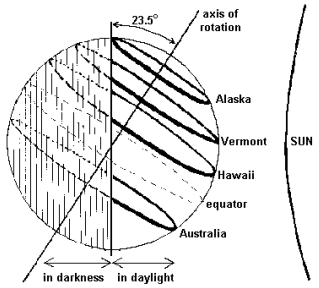
Continental drift was not accepted until after Wegener's death.

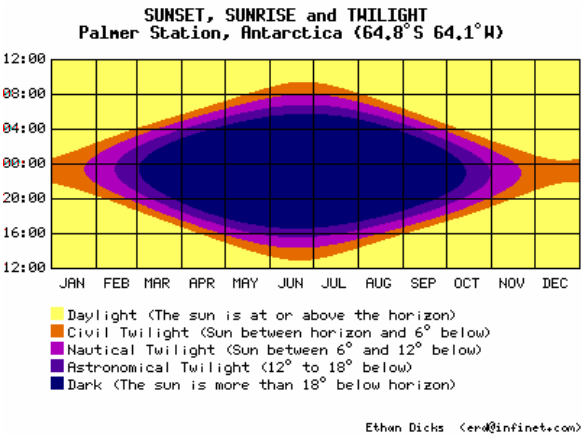
https://www.youtube.com/watch?v=PKBttUMKND4

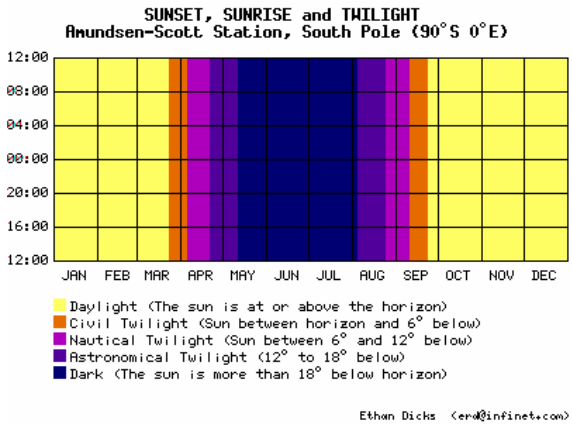
See the position of your address over geological time:

http://dinosaurpictures.org/ancient-earth#750

How has the movement of Antarctica to the South Pole from being closer to the equator 300 million years ago affected the **photoperiod** experienced by life on that continent? When the continent of Antarctica was closer to the equator, it had four seasons, got more solar irradiation, the continent was warmer, and forests could thrive.







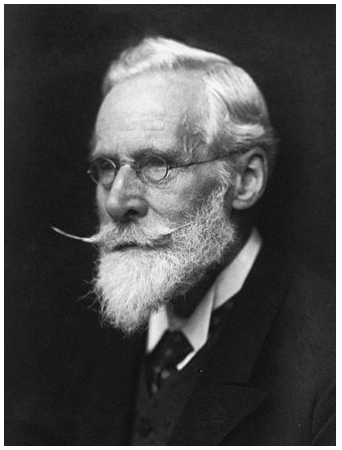
Invention of sunglasses to protect eyes from UV and IR light:



The industrial revolution resulted in some dangerous jobs, and legislation, such as the Workman's Compensation Act, was passed in 1897. It financially compensated workers who were injured. This act did not include **cataracts** in the classification of industrial diseases. The Royal Society set up the Glass Worker's Cataract Committee in 1908.



William Crookes knew of work done by Widmark, Hess, and Birch-Hirschfeld on the destructive effect of ultraviolet light on the lens and the protective effect of UV blockers such as "**Euphosglas**." Crookes took photographs of molten glass in the white-hot (~1500 C) furnaces and realized that in addition to the infrared heat rays, a substantial amount of ultraviolet light was emitted by the hot furnaces. Crookes mixed various metals to create a glass that was transparent to visible rays but opaque to UV and IR rays. The best formulation was Crookes 158 that included cerium borate and ferric and chromium oxides. It blocked all the **UV ligh**t shorter than 370 nm and sixty three percent of the **infrared rays**, while transmitting fifty four percent of the visible rays. Such a glass worn as spectacles would allow the glassworkers to see clearly while preventing glassworker's cataract. In 1912, E. K. Martin showed that UV irradiation produced by a mercury vapor lamp can produce cataracts, and in 1915, Hamilton Hartridge and Archibald Hill showed that IR radiation also caused cataracts. Workers began





to wear Crookes glasses, while those who had gotten cataracts from their job were eligible for compensation.

Crookes realized that his UV blocking glass would be useful for more people than glassworkers. "*When glasses are required which are restful to the eyes in the glare of the sun on chalk cliffs, expanses of snow, or reflected from the sea, Glasses 249, 197, 252, 165, 210, and 248 are most suitable, the tints being yellow, green, and neutral. Moreover, they have the advantage of cutting off practically all the ultra-violet rays and also a considerable amount of the heat radiation*." The best formulation for sunglasses turned out to be Crookes 249 that included cerium nitrate, ferric oxide, and cobalt sulphate. It had a pale blue tint and was almost opaque to the ultra-violet rays. It cut off half of the infrared radiation and transmitted 63 percent of the visible rays. Chance Brothers began producing sunglasses from Crookes glass in 1914.









Sam Foster, the founder of Foster Grant, which was in the Plastics Pioneer City (Leominster, MA—home of Earl Tupper's Tupperware and the pink flamingo lawn ornament) sold ladies hair accessories made of plastic. However, when short hair became stylish,





the bottom fell out of the hair accessory business, and he had to find something else to sell. Foster began to make plastic sunglasses. He sold his first pair of sunglasses in Atlantic City in 1929. In 1937, Bausch & Lomb began selling teardrop shaped green glass lenses in plastic frames as aviation sunglasses that knocked out glare. A year later, Bausch & Lomb switched to metal frames and created the Ray-Ban Aviator sunglasses. Sunglasses instantly became popular and by 1938, Life Magazine reported that "*Dark Glasses are New Fad for Wear on City Streets.*"

Study Question

How does the self-gravitational energy of the sun cause skin cancer (Melanoma)?

Gravitational energy of the sun upon itself is transformed into thermal energy that ionizes the hydrogen atoms into rapidly moving protons and electrons. The rapidly moving protons fuse together in the core of the sun to form helium nuclei, gamma ray photons and neutrinos. Due to all the free electrons in the sun, the sun is almost opaque to the gamma ray photons. After about 30,000 years, the gamma ray photons work their way to the surface of the sun, but have transferred much of their energy to the electrons that scattered them so they become ultraviolet photons. The ultraviolet photons are emitted by the sun and travel 8.3 minutes through the near vacuum of space to the stratosphere of the earth. Here most of the ultraviolet photons will be absorbed by reactions involving molecular oxygen and ozone. The ultraviolet photons that pass through the stratosphere will enter the troposphere where many of them will be Rayleigh scattered by nitrogen molecules. The ultraviolet photons that pass through the troposphere and then pass through the melanin in the keratinocytes enter the melanocytes in the skin of a person. Many of

the ultraviolet photons will be absorbed by the melanin in the keratinocytes and transformed into heat (infrared radiation). The ultraviolet photons that are transmitted through or around the melanin will be absorbed by the DNA in the melanocyte. The absorption of an ultraviolet photon may produces a cyclobutane pyrimidine dimer (CPD) composed of thymine-thymine. If the DNA damage is not repaired, genetic changes caused by deletions, insertions and chromosomal translocations may occur. These genetic changes may result in a melanoma, which is a malignant tumor of melanocytes.



To study for this class, think of other questions that "**connect the dots**" with regards to topics that we have covered this semester.



I sent this email to Katie Worth, the author of *Miseducation*:

Dear Ms Worth,

I just finished reading "Miseducation". I would like to present my take on the book to you before I present it to my class so you can tell me where I have gone wrong:

In Miseducation; How Climate Change is Taught in America, Katie Worth (2021) writes, “On the whole, science remains one of the most trusted institutions in America, and the trust has remained relatively stable for the last forty years. Dig into these numbers, however, and patterns appear. Christians have less trust in science than nonreligious people, rural dwellers have less than urbanites, and Republicans less than Democrats. There have been times in the last forty years when these camps had equal confidence in science. Today, the space between them is as large as it’s ever been.

These patterns are no accident of history. Rather, they are the product of successful disinformation campaigns, animated not by science but by ideology.”

Could it be that there is far more agreement than Katie Worth believes on the facts, but far less agreement on the rigor of the fact finding and the interpretation of the facts?

Those who do not “believe” in the consensus interpretation are called deniers. To be absolutely clear, Katie Worth writes, “A note on terminology: This book uses the term ‘climate denier’ to describe groups or people who know (or should know, based on their position or declared authority) that the conclusions of modern climate science are legitimate, but who nonetheless promote the idea that they are not. For members of the public who have been misled by the sources of

information they trust, the term ‘climate doubter’ applies. Also, this book uses the terms ‘climate change,’ ‘climate crisis,’ and ‘global warming’ as shorthand for ‘anthropogenic climate change,’ the extraordinary transformations in our atmosphere and ecosystems that have occurred since industrialization. Any reference to natural climate change is described as such.”

I believe that Katie Worth is playing fast and loose with words. In order to use climate change as shorthand for anthropogenic climate change, one must present enough evidence to show unequivocally that humans are the major cause of climate change and that natural causes are negligible. From my experience, I do not believe that this bar has been met.

I also believe that the phrase ‘climate change’ is often used as Mephistopheles advises in Goethe’s Faust Part One, in which Mephistopheles says, “[f]or at the point where concepts fail, At the right time a word is thrust in there. With words we fitly can our foes assail.” Until someone clearly quantifies the contributions of anthropogenic (and presumably gynogenic) climate change and natural climate change, and explains how the climate sensitivity factor is determined, I believe that the phrases climate change and climate denier are used as tools of propaganda rather tools of science. If I am right, then the groups and people described by Katie Worth may differ primarily in the way they look at the incomplete knowledge concerning climate change. The people who Katie Worth describe as those who do not trust the interpretation of scientific knowledge as defined by the consensus, may be in fact those who trust science as a method to investigate the natural world through questioning, observation, experiment, and analysis, and who believe that the individual has as much right to draw conclusions from the data as the consensus does, especially when the consensus resorts to ad hominin attacks on those who question their conclusions. The tyranny of the mob,

like the tyranny of the monarch, is still tyranny. Remember what Lord Byron (George Gordon Byron) wrote in Canto XVII of Don Juan,

> There is a commonplace book argument,
>
> Which glibly glides from every vulgar tongue
>
> When any dare a new light to present:
>
> 'If you are right, then everybody's wrong.'
>
> Suppose the converse of this precedent
>
> So often urged, so loudly and so long:
>
> 'If you are wrong, then everybody's right.'
>
> Was ever everybody yet so quite?

Where have I gone wrong?

Thanks,

Randy

Katie wrote back on 3/23/22: Thanks for your message, Randy. I would be very curious to hear what your students think of both my analysis and yours. What class are you teaching it in?

Respectfully,

Katie

I wrote back on 3/23/22

Dear Katie,

Thanks for your email. I teach a course called light and life. It is a nonmajors biology or physics course that covers almost anything you could imagine that falls under the two umbrellas. I tell the students

from the beginning that I do not want them to believe anything I say, and I hope to give them enough personal experience and textual evidence to come to their own conclusions. Here are my 2022 lecture notes so far: http://labs.plantbio.cornell.edu/wayne/pdfs/Incomplete2022.pdf

I ask them to read the notes before the lecture and then write a one page dinner conversation with one of the people who I will talk about in the lecture. I will talk about your book in a few weeks in lecture 17 when I cover UV light and IR light. I will suggest that the students, who come into my class knowing the party line an Ivy League University has on climate change, write a dinner conversation with you!!! I will ask those students to send their conversations to you.

I have a pretty good knowledge of thermodynamics and optics but I still have no idea how the climate sensitivity factor is calculated. This is important since it is the fundamental equation upon which the climate models are based. I ask everyone I know who works on climate change: How is the climate sensitivity factor calculated? What are the assumptions that underlie the equation? So far, no one seems to know. Do you know?

Again, thanks for your email, and I hope you will get some dinner conversations from my students.

Thanks,

Randy

I hope that some of you write a dinner conversation with Katie Worth.

I want to remind you that Xenophanes (570-478 BC) believed that there is an ultimate Truth, but no person has ever nor will ever know it. In fact, even if a person spoke the ultimate Truth, he would not even recognize it. Karl Popper (1963) quoted Xenophanes in Realism and the Aim of Science:

> *But as for certain truth, no man has known it,*
> *Nor will he know it; neither of the gods*
> *Nor yet of all the things of which I speak.*
> *And even if by chance he were to utter*
> *The perfect truth, he would himself not know it;*
> *For all is but a woven web of guesses.*

Guesses that Popper defined as working hypotheses in the search for truth. Popper wrote, "*I then suggested that the whole trouble was due to the mistaken belief that scientific knowledge was an especially strict or certain or august kind of knowledge. This statement met with the same reception as the first. I concluded with an attempt to explain that, in the usual sense of 'know', whenever I know that it is raining, it must be true that it is raining; for if it is not true, then I simply cannot know that it is raining, however sincerely I may believe that I know it. In this sense of the word, 'knowledge' always means 'true and certain knowledge'; and 'to know' means, in addition, to be in possession of sufficient reason for holding that our knowledge is true and certain. But, I said, there was no such thing as scientific knowledge in this sense. If, nonetheless, we chose to label the results of our scientific endeavours with the customary name 'scientific knowledge', then we ought to be clear that scientific knowledge was not a species of knowledge; least of all, a species distinguished by a high degree of solidity or certainty. On the contrary, measured by the high standards of scientific criticism, 'scientific knowledge' always remained sheer guesswork—although guesswork controlled by criticism and experiment…Admittedly, I had attacked, by implication, Science with a capital 'S', and those of its devotees who were ready to take its pronouncements as gospel truth*."



The Torah or Old Testament uses the word *yada* to mean "know" or "knowledge" 950 times. To know is not just to be intellectually informed about some abstract principle like memorizing a bullet point on a PowerPoint slide for an exam, but to apprehend and experience reality. Knowledge is not the possession of information, but rather its exercise or actualization in the form of wisdom.

When a **believer in the scientific consensus** calls someone a **denier**, there is an assumption that the believer *knows* the Scientific Truth, and that that Scientific Truth has been established beyond all *reasonable doubt*. When it is raining, ***knowing*** that it is raining, is ***knowing*** something beyond a reasonable doubt. Someone who stands in the rain and denies that it is raining could fairly be defined as a denier. However, someone who does not think that the consensus has presented evidence beyond a reasonable doubt is not denying reality but disagreeing with an interpretation of reality. It does not mean that that person who disagrees with the consensus is disagreeable, delusional, evil, or a patsy—just like any person who believes the interpretation of the consensus is not necessarily pleasant, rational, virtuous, and speaking truth to power.

I hope that in this class, you have learned about searching for objective truth even though we never and probably will never know the complete objective truth. As I discussed in terms of ultraviolet and infrared radiation, the search for the objective truth requires civil conversations involving questioning, reflection, free speech, and free thought. As Henri Poincaré (1901) said, "*To doubt everything or to believe everything are two equally convenient solutions; both dispense with the necessity of reflection*."



Plant and Animal Coloration: Pigments, Attraction, Inbreeding and Outbreeding, Camouflage, and Mimicry



Bacteria, fungi, protists, and animals may be colored as a result of being **self-luminous**, producing variously colored light in a process known as **bioluminescence**. However, most colored organisms are not self-luminous. **Coloration** of **nonluminous** organisms may result from **pigments**, which cause color due to the **differential absorption** of the spectral colors of sunlight, or it may result from striated or lamellar structural specializations, which impart color due to **differential diffraction** or **interference** of the spectral colors of sunlight. This lecture will cover the **biology of coloration due to pigments** and the next lecture will primarily cover coloration due to striated or lamellar structural specializations.

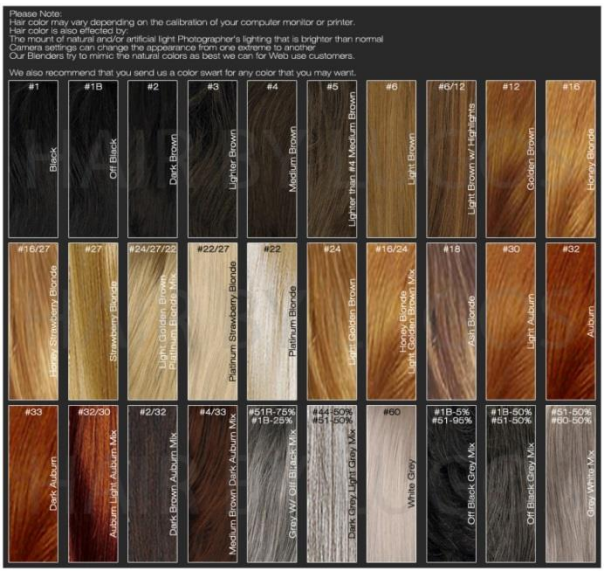
Melanins are commonly occurring **pigments.** Melanins are **pigments** involved in human eye, skin, lip (phaeomelanin), and hair color. We have talked about the importance of **eumelanin** and **pheomelanin** in producing our individual skin color, and **eumelanin** and **pheomelanin** in producing our individual eye color. Now I will talk about the contributions of **eumelanin** and **pheomelanin** in producing our individual hair color, including the colors of **eyelashes** and **eyebrows** that protect the eyes from debris and perspiration. **Eumelanin** can be either a black or a brown pigment. **Pheomelanin** can be either a reddish, orange, or yellow pigment. It is also found in the redder areas of the skin (e.g., lips).

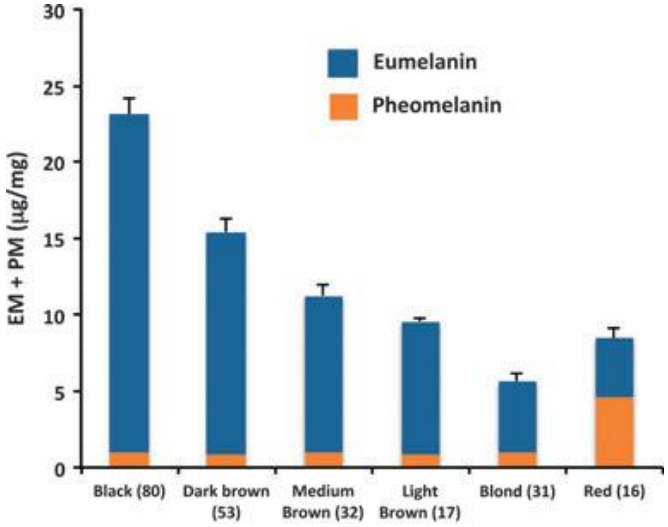


The concentration of eumelanin determines how dark the hair is. **High concentrations** of **brown eumelanin** result in brown hair and **low concentrations** result in blonde (female) or blond (male) hair. When combined with a high concentration of brown eumelanin, small amount of phaeomelanin makes the hair

lighter or reddish brown. When combined with a low concentration of brown eumelanin, phaeomelanin gives golden blonde or strawberry blonde hair.

High concentrations of **black eumelanin** result in black hair and low concentrations result in ash blonde hair. **High concentrations of phaeomelanin** result in red or orange hair.







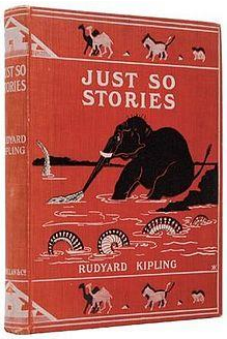
We discussed Charles Darwin's theory of **sexual selection** in terms of human skin color. **Peter Frost** (2006) **suggests** that the blonde-dark dichotomy in human hair color **may** also be the result of **sexual selection** among **hunter gatherers** in **Northern Europe**. *The London Times* on February 26, 2006, reported "*The modern gentleman may prefer blondes. But new research has found that it was cavemen who were the first to be lured by flaxen locks. According to the study, north European women evolved blonde hair and blue eyes at the end of the Ice Age to make them stand out from their rivals at a time of fierce competition for scarce males. The study argues that* ***blond hair*** *originated in the region because of* ***food shortages*** *10,000-11,000 years ago. Until then, humans had the dark brown hair and dark eyes that still dominate in the rest*

of the world. Almost the only sustenance in northern Europe came from roaming herds of mammoths, reindeer, bison and horses. Finding them required long, arduous hunting trips in which numerous males died, leading to a high ratio of surviving women to men. Lighter hair colours, which started as rare mutations, became popular for breeding and numbers increased dramatically, according to the research, published under the aegis of the University of St Andrews. 'Human hair and eye colour are unusually diverse in northern and eastern Europe (and their) origin over a short span of evolutionary time indicates some kind of selection,' says the study by Peter Frost, a Canadian anthropologist. Frost adds that the high death rate among male hunters 'increased the pressures of sexual selection on early European women, one possible outcome being an unusual complex of colour traits.' Frost's theory, to be published this week in Evolution and Human Behavior, the academic journal, was supported by Professor John Manning, a specialist in evolutionary psychology at the University of Central Lancashire. 'Hair and eye colour tend to be uniform in many parts of the world, but in Europe there is a welter of variants,' he said. 'The mate choice explanation now being put forward is, in my mind, close to being correct.' Frost's theory is also backed up by a separate scientific analysis of north European genes carried out at three Japanese universities, which has isolated the date of the genetic mutation that resulted in blond hair to about 11,000 years ago. The hair colour gene MC1R has at least seven variants in Europe and the continent has an unusually wide range of hair and eye shades. In the rest of the world, dark hair and eyes are overwhelmingly dominant. Just how such variety emerged over such a short period of time in one part of the world has long been a mystery. According to the new research, if the changes had occurred by the usual processes of evolution, they would have taken about 850,000 years. But modern humans, emigrating from Africa, reached Europe only 35,000-40,000 years ago. Instead, Frost attributes the

rapid evolution to how they gathered food. In Africa there was less dependence on animals and women were able to collect fruit for themselves. In Europe, by contrast, food gathering was almost exclusively a male hunter's preserve. The retreating ice sheets left behind a landscape of fertile soil with plenty of grass and moss for herbivorous animals to eat, but few plants edible for humans. Women therefore took on jobs such as building shelters and making clothes while the men went on hunting trips, where the death rate was high. The increase in competition for males led to rapid change as women struggled to evolve the most alluring qualities. Frost believes his theory is supported by studies which show blonde hair is an indicator for high oestrogen levels in women."



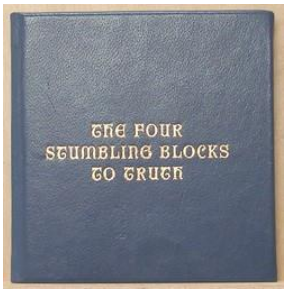
I assume that the warming period following the ice age can be considered to be ***natural climate change***, not to be confused with ***climate change***.

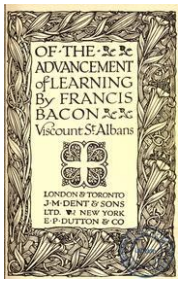


Do you consider this scientific evolutionary explanation a **fact,** a **hypothesis**, a **theory**, a law of nature, or a **just so story** (Gould, 1978)? At this juncture, I would like to remind you of the letter written on February 10, 2014 by the American Institute of Biological Sciences (AIBS) (http://www.aibs.org/position-statements/20140210_ok_science_ed_act.html) concerning an anti-evolution bill in Oklahoma (http://webserver1.lsb.state.ok.us/cf_pdf/2013-14%20INT/SB/SB1765%20INT.PDF). It states "*Advocates for this and similar legislation often assert that evolution and climate change are controversial subjects. Any controversy is purely political.* ***There is no legitimate scientific controversy about evolution*** *or climate change. Scientists have, and continue to, empirically test these concepts and with each test the evidence grows stronger and our understanding more thorough."*



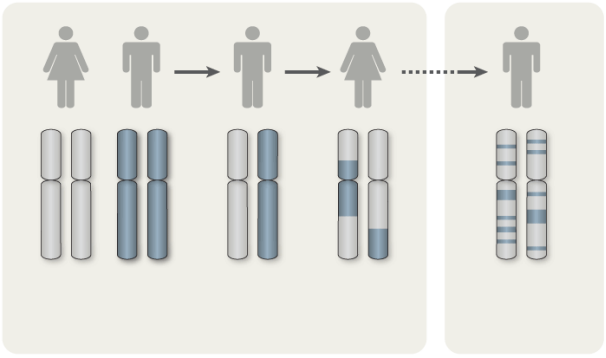
If you ask me, legitimate controversy always exists when science is healthy. **Albert Szent-Györgyi** (1972), who won the Nobel Prize in Physiology or Medicine for his discovery of vitamin C, and who is one of my scientific heroes. He realized that "*a discovery must be, by definition, at variance with existing knowledge*," and divided scientists into two categories: the Apollonians and the Dionysians. He called **scientific dissenters**, who explored "**the fringes of knowledge**," Dionysians. He wrote, "*In science the Apollonian tends to develop established lines to perfection, while the Dionysian rather relies on intuition and is more likely to open new, unexpected alleys for research...The future of mankind depends on the progress of science, and the progress of science depends on the support it can find. Support mostly takes the form of grants, and the present methods of distributing grants unduly favor the Apollonian*."

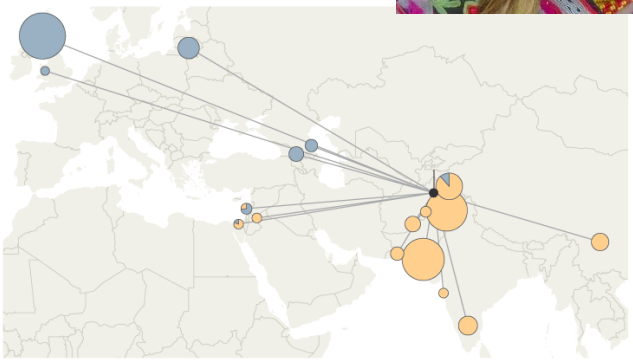




Hair that is low in eumelanin, e.g., blonde, is not limited to Europe. European-type DNA for blond hair entered the gene pool of the **Kalash people** of Pakistan sometime between 990 and 210







B.C. This could reflect the invasion of India by **Alexander the Great** in 326 B.C.

As the number of generations increase, the DNA in the chromosomes inherited from the original European blond-haired parent gets chopped into smaller and smaller pieces as a result of crossing over during meiosis. It is possible to estimate how many generations have passed since the introduction of DNA that codes for blond hair by measuring the average size of the original DNA fragments. Statistical analysis suggests that the two populations mixed before 210 B.C. http://www.admixturemap.paintmychromosomes.com/

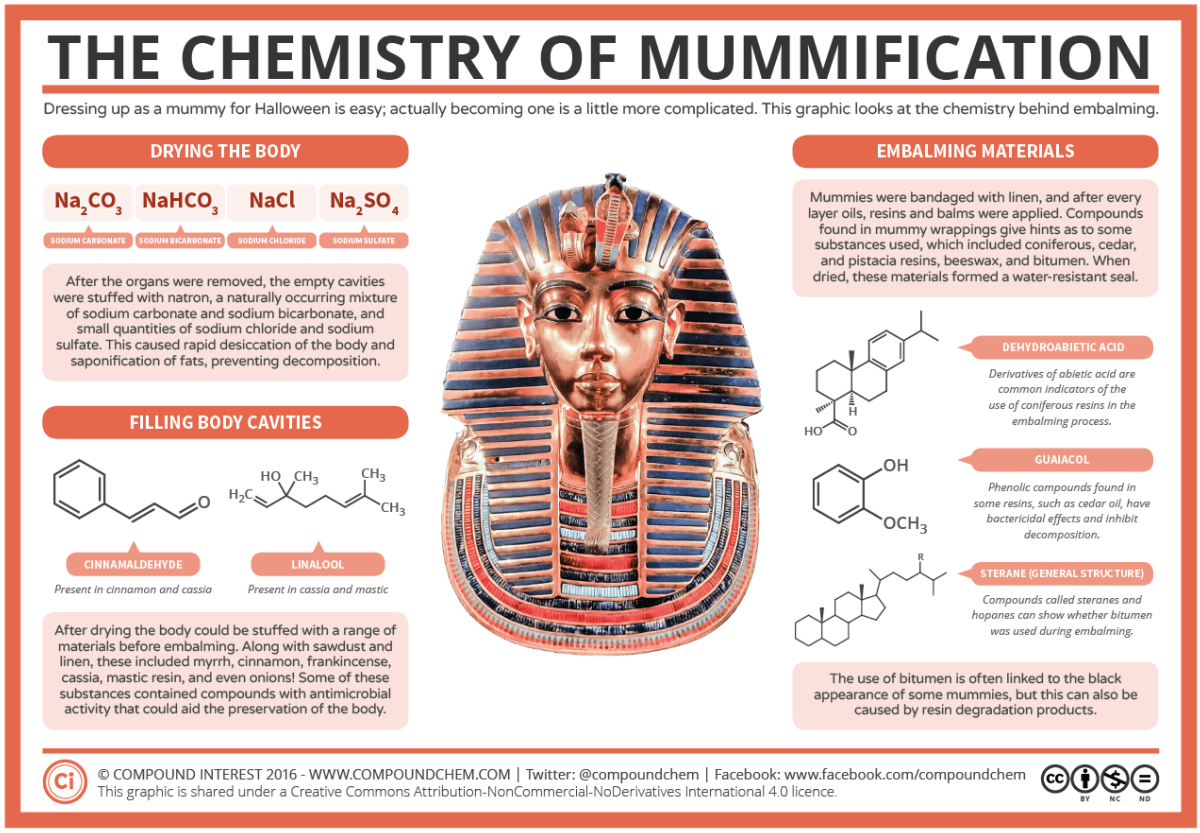
Indeed, some blond hair genes also existed in Egypt as early as 1375 BC. The evidence is that the mummified Tjuyu, who died in 1375 BC and was the great grandmother of Pharaoh Tutankhamun, was a strawberry blonde.



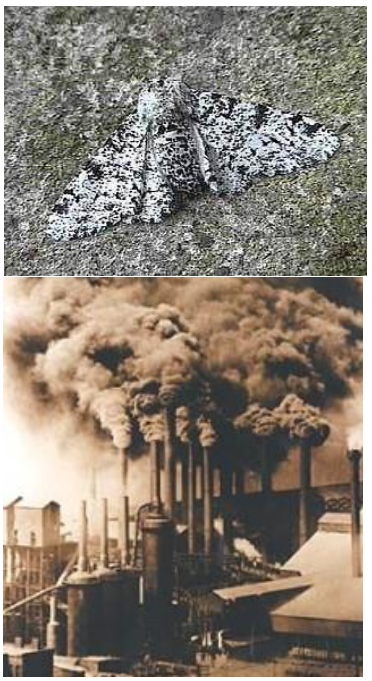
While most Egyptians had and have dark hair, Kerry Muhlestein, Cannon Fairbairn, and Ronald Harris found cemeteries used from 1st - 7th century AD during Roman rule in Fag el-Gamous, Egypt where mummies seem to be clustered together by hair color where those with blond hair are located in one area of the cemetery and those with red hair in another.



The Egyptians developed the chemistry of mummification (https://www.compoundchem.com/2016/10/27/mummification/):



Now we will discuss **peppered moths** that have either high or low concentrations of melanin.



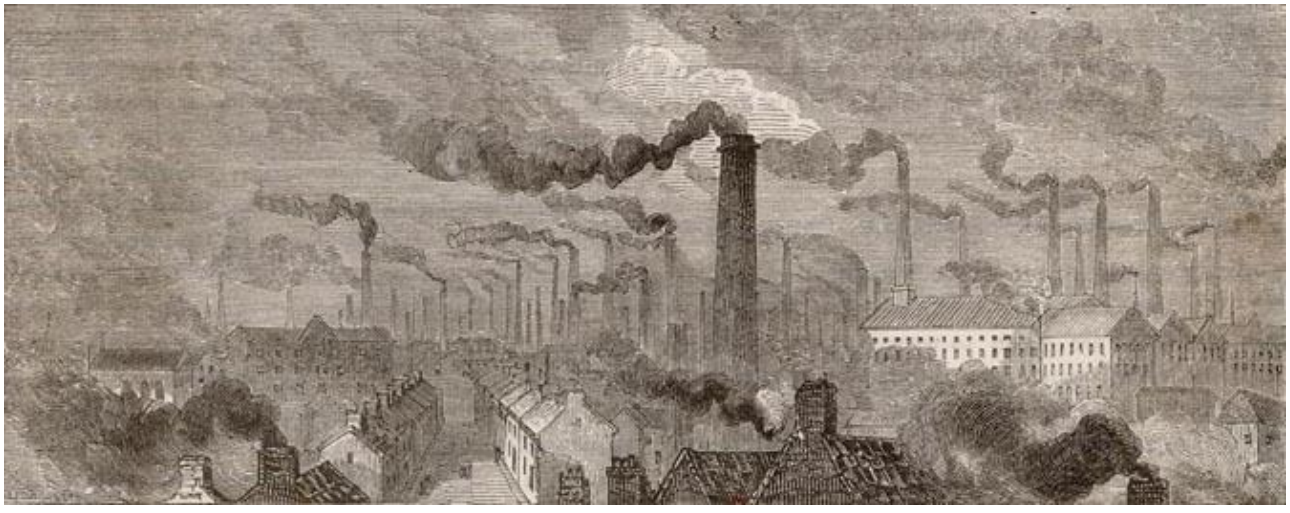
Peppered moths contain melanin and a demonstration that their **melanin content** has a naturally (but not sexually) **selective advantage** tied in with the **industrial revolution** was suggested in a letter written to Charles Darwin by A. B. Farn on November 18, 1878. Prior to the industrial revolution, the air in London and Manchester (where James Joule was taught by John Dalton, Edward Binney provided "*the relief and encouragement of scientific men in humble life*," and Marie Stopes taught paleobotany) was clean and clear and during the day light-colored peppered moths (*Biston betularia*) rested on trees that were covered with light-colored

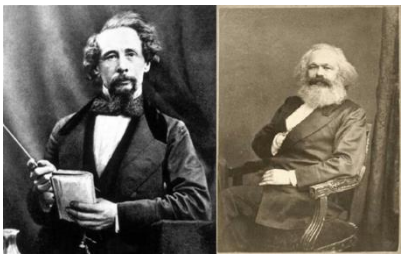
lichens. Since the peppered moths did not produce much melanin, they blended in with the lichens. Their natural **camouflage** made it difficult for **avian predators** to find and eat them.

However, with the increased burning of **coal** brought on by the **industrial revolution**, the atmospheric concentration of **sulfur dioxide** (SO_2) increased and killed the pollution-sensitive lichens as the **soot** also darkened the tree bark.

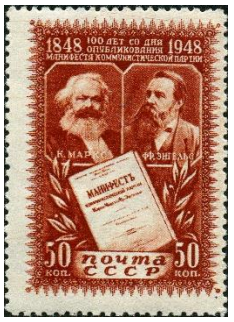
Manchester, which was close to coal deposits and the shipping port of Liverpool, became the first modern industrial city. **Charles Dickens** (1854) called Manchester "***Coketown***." In *Hard Times*, he wrote, "*It was a town of red brick, or a brick would have been red if the* ***smoke and ashes*** *would have allowed it; but as matters stood it was a town of unnatural red and black, like the painted face of a savage. It was a town of machinery and tall chimneys, out of which interminable serpents of* ***smoke*** *trailed themselves forever and ever, and never got uncoiled. It had a* ***black canal*** *in it, and a river that ran* ***purple with some ill-smelling dye****, and vast piles of building full of windows where there was a rattling and a trembling all day long, and where the piston of the steam-engine worked monotonously up and down, like the head of an elephant in a state of melancholy madness*."


HOUSEHOLD WORDS.
A WEEKLY JOURNAL.
CONDUCTED BY CHARLES DICKENS.
HARD TIMES.





Charles Dickens (February 7, 1812 – 9 June 9, 1870) and **Karl Marx** (May 5, 1818 – March 14, 1883) wrote at the same time and the same place (London), and it is interesting to compare the different ways that Charles Dickens and Karl Marx responded to the downsides of the imbalance of power between capitalists and workers caused by the **Industrial Revolution**. Charles Dickens wrote about ***small changes that needed to be made in the hearts of individual***s, while Karl Marx wrote about ***revolutionary changes that needed to be made to the state***.



Friedrich Engels lived in Manchester, England where he observed the horrors of the industrial revolution, including, in addition to the pollution, the **cruelty of child labor**, and the **poor living conditions of the working class**. This led him to write *The Condition of the Working Class in England*. Soon afterwards, he wrote *The Communist Manifesto* with Karl Marx (1848) which stated that "[t]*he history of all hitherto existing society is the history of class struggles*" and the solution is the "*forcible overthrow of all existing social conditions*."

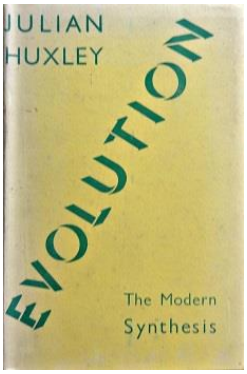
The Communist Manifesto ends with these words: "*The Communists disdain to conceal their views and aims. They openly declare that their ends can be attained only by the* ***forcible overthrow of all existing social conditions****. Let the ruling classes tremble at a Communistic revolution. The proletarians have nothing to lose but their chains. They have a world to win.* ***Working Men of All Countries, Unite!****"*

Marx's "scientific law" of history describes the cause of progressive historical change in terms of a never-ending class struggle between the class of people who create the wealth of society (proletariat) and those who own the means

of production of the wealth (bourgeoisie). The ultimate goal is a communist society of producers and consumers operating on the premise that "[f]*rom each according to his ability, to each according to his needs*." According to Engels, the introduction of new technologies that reduce the need for manual labor while increasing production that results in ***surplus product*** is the impetus for political crises that result in a revolutionary change.

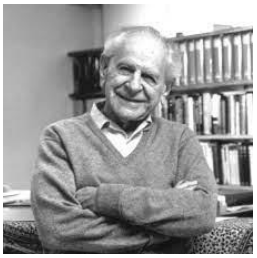
Marx's "scientific" law of history, like Darwin's law of nature is a law of motion, where change assumed to represent progress, is the natural state. Both laws are laws of becoming rather than laws of being. They are laws of dynamics rather than laws of statics. According to the law of history, the dying classes are eliminated while according to the law of nature the unfit are eliminated. They are in opposition to the ideas of stability that underlie constitutional governments and special creation. Being *laws of motion*, they provide a natural framework for *movements.* Marx's law of history has provided the scientific foundation for socialist movements and Darwin's law of nature provided the scientific foundation for the Nazi movement. In his funeral speech for Marx on March 17, 1883, Engels said, "***Just as Darwin discovered the law of development of organic life, so Marx discovered the law of development of human history***: *the simple fact, hitherto concealed by an overgrowth of ideology, that mankind must first of all eat, drink, have shelter and clothing, before it can pursue politics, science, art, religion, etc.; that therefore the production of the immediate material means, and consequently the degree of economic development attained by a given people or during a given epoch, form the foundation upon which the state institutions, the legal conceptions, art, and even the ideas on religion, of the people concerned have been evolved, and*





in the light of which they must, therefore, be explained, instead of vice versa, as had hitherto been the case."

It is important to realize that "progress" is the *not* only direction that Darwinian evolution can take. Julian Huxley (1942) wrote in *Evolution: A Modern Synthesis*, "***Evolution*** *in biology is a loose and comprehensive term applied to cover* ***any and every change occurring****: in the constitution of systematic units of animals and plants, from the formation of a new subspecies or variety to the trends, continued through hundreds of millions of years, to be observed in large groups. The main processes covered by the term are as follows. (1) Long-continued trends, as revealed by indirect evidence and in some cases by the immediate data of fossils. These are for the most part towards specialization (p. 486), a number of them towards that peculiar form of specialization called* ***degeneration*** *(p. 558), and a few towards that all-round biological improvement. which may be styled evolutionary progress (p. 559), All these are essentially adaptive, or, if you prefer it, functionally guided. In addition, certain trends occur which cannot be interpreted adaptively, at least in the light of present knowledge, such as that of various lines of ammonites to greater complexity followed by progressive unrolling of the spiral and by other simplifications (p. 506)."*



Karl Popper (1961), in a book dedicated to the "*memory of the countless men and women of all creeds or nations or races who fell victims to the fascist and communist belief in Inexorable Laws of Historical Destiny*", declares that since the course of human history is strongly influenced by human knowledge and we cannot predict scientifically the growth of human knowledge, scientific or otherwise, then there is no scientific basis for predicting the "*future course of history*" just as there is no scientific basis for reliably predicting the future course of evolution.

Besides being laws of motion, Marx's law of history and Darwin's law of nature have another aspect in common. The goal of these laws of motion is not the welfare of the individual but the welfare or survival of the species, human or otherwise. **In both laws of motion, with the fabrication of an identity group, each individual becomes equally superfluous—thus reducing the distinction between the living and the nonliving.**



After the fall of the Soviet Union on December 31, 1991, Phil Collins, an artist, discovered a Soviet-era statue of Engels in a dump in **Ukraine**. The statue had been cut in half at the waist and had patches of blue and yellow paint on it, which are the national colors of Ukraine. In 2017, Collins repaired the statue and erected in Manchester.



Another aside: Despite suffering personal hardships, the textile mill workers of Manchester decided to not use any cotton from America that was picked by slaves. On December 31, 1862, the day before the Emancipation Proclamation went into effect, they sent a letter to **Abraham Lincoln** stating, "*As citizens of Manchester, assembled at the Free-Trade Hall, we beg to express our fraternal sentiments toward you and your country. We rejoice in your greatness as an outgrowth of England, whose blood and language you share, whose orderly and legal freedom you have applied to new circumstances, over a region immeasurably greater than our own. We honor your Free States, as a singularly happy abode for the working millions where industry is*

*honored. One thing alone has, in the past, lessened our sympathy with your country and our confidence in it—we mean the ascendency of politicians who not merely maintained negro slavery, but desired to extend and root it more firmly. Since we have discerned, however, that the victory of the free North, in the war which has so sorely distressed us as well as afflicted you, will strike off the fetters of the slave, you have attracted our warm and earnest sympathy. We joyfully honor you, as the President, and the Congress with you, for many decisive steps toward practically exemplifying your belief in the words of your great founders: '**All men are created free and equal**'…*[t]*he vast progress which you have made in the short space of twenty months fills us with hope that **every stain on your freedom** will shortly be removed, and that the erasure of that foul blot on civilisation and Christianity – chattel slavery – during your presidency, will cause the name of Abraham Lincoln to be honoured and revered by posterity. We are certain that such a glorious consummation will cement Great Britain and the United States in close and enduring regards*." On January 19, 1863, Abraham Lincoln wrote to the workingmen of Manchester, "*I cannot but regard your decisive utterances upon the question as an instance of sublime Christian heroism which has not been surpassed in any age or in any country. It is indeed an energetic and re-inspiring assurance of **the inherent power of truth**, and of the ultimate and universal triumph of justice, humanity, and freedom*." A statue of Abraham Lincoln stands in Manchester, which is dedicated to, "*the support that the working people of Manchester gave in their fight for the abolition of slavery during the American Civil War.....By supporting the union under President Lincoln at a time when there was an economic blockade of the southern states the Lancashire cotton workers were denied access to raw cotton which caused considerable unemployment throughout the cotton industry*."

By this time in Manchester, the trunks of the trees were becoming darker, and the light-colored peppered moths (*Biston betularia typica*) were no longer camouflaged when they rested on tree trunks during the day, and thus, they became vulnerable to predation by birds.



In 1864, R. S. Edleston noticed that a **dark variant** of the peppered moth (*Biston betularia carbonaria*) was becoming common in Manchester, while only sixteen years before, it was almost unknown. In his book entitled, *British Moths*, **James Tutt** (1896) wrote the light-colored moth "*as it rests on a trunk in our southern woods, is not at all conspicuous, and looks like a natural splash or scar, or a piece of lichen, and this is its usual appearance and manner of protecting itself. But near our large towns where there are factories, and where* ***vast quantities of soot*** *are day by day poured out from countless chimneys,* ***falling and polluting the atmosphere with noxious vapours and gases****, this Peppered Moth has,* ***during the last fifty years****, undergone a remarkable change.* ***The white has entirely disappeared, and the wings have become totally black****, so black that it has obtained the cognomen* [nickname] *'negro' from naturalists. As the manufacturing centres have spread more and more, so the 'negro' form of the Peppered Moth has spread at the same time and in the same districts. Let us see whether we can understand how this has been brought about! Do you live near a large town? Have you a greenhouse which you have tried to keep clean and beautiful with white paint? If so, what is the result? The paint is put on, all is beautifully white, but a little shower comes and the beauty is marred for ever. But in country places, though white paint has showers frequently falling on it, it is not spoilt like yours. No! near large towns, when the rain falls it brings down with it the impurities, the*

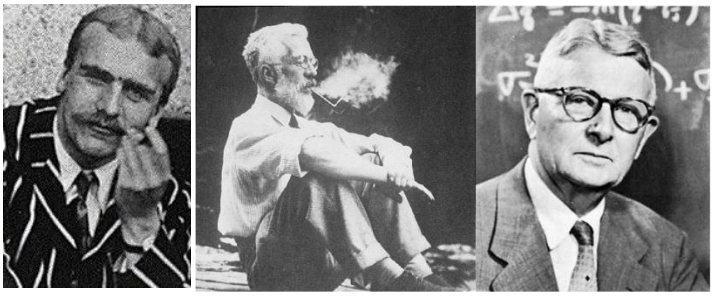


smoke and dirt, hanging in the air. The rain does no damage, it is the 'blacks' which it brings down that spoil everything, for when the water evaporates these dirty remnants are left behind. A few showers, and your white paint is a mass of filth and blackness. And this is going on all around our large cities and towns, not only in but for miles outside them, and, in our manufacturing districts, where the quantity of impurities is much greater, the result is also more intense, and we find fences, trees, walls, etc., getting black with the continual deposit on them. A small proportion of rain with a large quantity of smoke will produce as decided a result as a larger quantity of rain with a smaller quantity of smoke, but under both conditions the darkening goes on. Ah! You understand that! Don't you? Now let us go back to our Peppered Moth. ***In our woods in the south the trunks are pale and the moth has a fair chance of escape, but put the Peppered Moth with its white ground colour on a black tree trunk, and what would happen? It would, as you say, be very conspicuous, and would fall prey to the first bird that spied it out. But some of these Peppered Moths have more black about them than others, and you can easily understand that the blacker they are the nearer they will be to the colour of the tree trunk, and the greater will become the difficulty of detecting them. So it really is; the paler ones the birds eat, the darker ones escape. But then, if the parents are the darkest of their race, the children will tend to be like them, but inasmuch as the search by birds gets keener and keener, only the very blackest will be likely to escape. Year after year, this has gone on, and the selection has been carried to such as extent by Nature that no real black and white Peppered Moths are found in these districts, but only the black kind. This blackening we call 'melanism,'*** *and the Peppered Moth is by no means the only kind of insect which this melanic change has been brought about in recent times. Many others are becoming jet black in these districts, and some of the Yorkshire naturalists*

have made many remarkable discoveries in this direction. But, of course, only those species whose habit it is to hide on fences, trees, stones, etc., in such districts, i.e., on surfaces, which are blackened by smoke and damp, are liable to the changes which we have just mentioned."

According to James Tutt (1896), the observed change in the proportion of white and black peppered moths was a natural consequence of the change in the color of the environment as described by Charles Darwin's theory of natural selection. That is, during the times that the air was clear and clean, the light-colored peppered moths were **camouflaged** and safe from predatory birds. Therefore, they could reproduce and have light-colored offspring. However, with the darkening of the trees, the light-colored peppered moths were no longer camouflaged. Consequently, they were more likely to be eaten by predator birds and would not be able to reproduce. This would be considered **incipient speciation** by Charles Darwin and **variation on a type** by Samuel Wilberforce. Charles Darwin would see this as **progressive evolution**; Samuel Wilberforce would wonder if melanization was a variation that came at the expense of another variation.

John Burdon Sanderson Haldane (1924) reported that by 1901, the light-colored peppered moths had disappeared and that he could make a **mathematical model** that described the rapid disappearance as a result of **natural selection**.



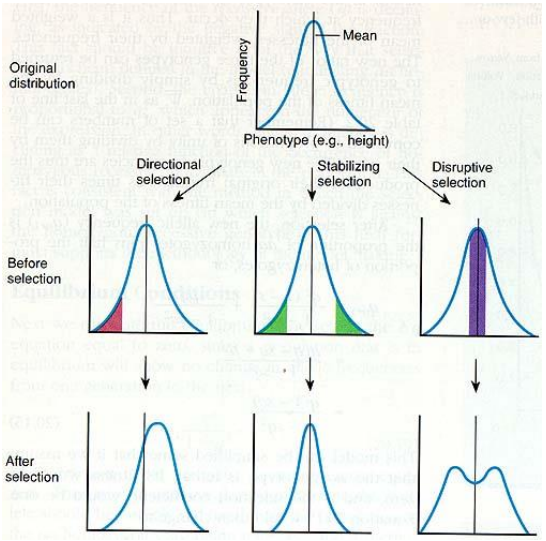
The **mathematical models** that **J. B. S. Haldane**, **Ronald Fisher**, and **Sewell Wright** produced in the 1920s and 1930s united **Gregor Mendel's mathematical laws of inheritance** with **Charles Darwin's theory of natural selection**. **Julian**

Huxley (1943), a grandson of T. H. Huxley, called the marriage of Mendel and Darwin, "***The Modern Synthesis***" and he became the mathematical geneticists' bulldog and the leading champion of the idea that natural selection was the primary if not the only cause of evolution.

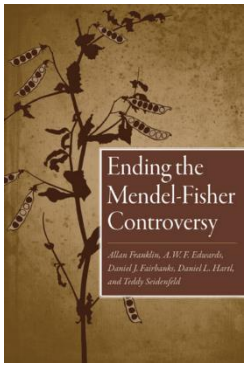




The Modern Synthesis involved incorporating the probabilities with which each genotype produced offspring (i.e., **fitness**) as a result of natural selection into the probabilities of offspring predicted by Mendelian factors alone. The fittest survive and fitness is defined by the proportion of progeny that survives. J. B. S. Haldane, Ronald Fisher, and Sewell Wright initiated the field of **population genetics**, which reduced the natural complexity of each organism to a single gene or two, the variability in which were mathematically tractable. Let's add back a little complexity. How would the above theoretical graphs look if we simultaneously took into consideration the **positive and negative effects** of a new trait? For example, selection for one of two complementary traits (speed or strength) in a dog.

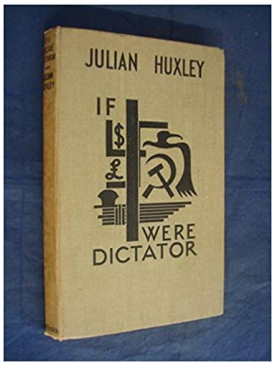


In this day and age when more people are looking at **Big Data** from the perspective of **computation** and I would say fewer people know how to obtain quantitative, meaningful, and insightful experimental data in a way that Gregor Mendel could, I want to mention a ***rumor*** that was started by R. A. Fisher, the Galton Professor of Eugenics at University College, London in a paper entitled, "*Has Mendel's work been rediscovered?*" (Ann. Sci. 1: 115–137 (1936)). Fisher uses his chi squared test to show that given the sample



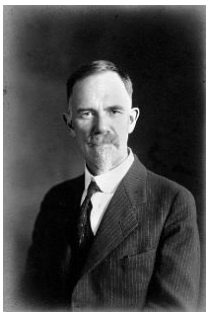
sizes used, the values that Mendel observed were too close to the expected values. According to Fisher, "*in one series of results the numbers observed agree excellently with the two to one ratio, which Mendel himself expected, but differ significantly from what should have been expected had his theory been corrected to allow for the small size of his test progenies. To suppose that Mendel recognized this theoretical complication, and adjusted the frequencies supposedly observed to allow for it, would be to contravene the weight of the evidence supplied in detail by his paper as a whole. Although no explanation can be expected to be satisfactory, it remains a possibility among others that Mendel was deceived by some assistant who knew too well what was expected. This possibility is supported by independent evidence that the data of most, if not all, of the experiments have been falsified as to agree closely with Mendel's expectations*."

I see in Mendel's work, the results of a great scientist, who simultaneously and interactively combined theory with the improvement of experimental protocol to get the most accurate, honest, and meaningful data. I see in Fisher's work, the view of a statistician, who specializes in analyzing but not obtaining the data and who was unable to recognize the brilliance of a scientific person who could best be described as a statistical outlier and not just average.

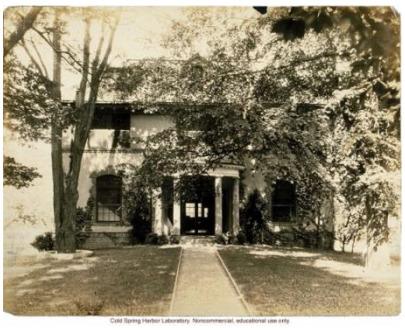


Julian Huxley was interested in applying the **progressive ideals** of the Modern Synthesis to human beings. In a book entitled, *If I Were Dictator*, Julian Huxley (1934) described what he would do if he were the scientific dictator in charge of the scientific planning of society imagined by his brother Aldous (1932) in *Brave New World*. Julian Huxley (1944) wrote in an essay entitled, *The Uniqueness of Man*:

"*…we must plan our **eugenic policy** along some such lines as the following:... **The lowest strata, allegedly less well-endowed genetically, are reproducing relatively too fast**. Therefore birth-control methods must be taught them; they must not have too easy access to relief or hospital treatment lest the removal of the last check on natural selection should make it too easy for children to be produced or to survive; long unemployment should be a ground for sterilization, or at least relief should be contingent upon no further children being brought into the world; and so on. That is to say, **much of our eugenic programme will be curative and remedial merely, instead of preventive and constructive**.*" Huxley was not the only scientist interested in creating a better society through better genes. Before Hitler's program, many geneticists in the United States and England were actively creating a better society through better genes.




Since the rediscovery of Gregor Mendel's work in 1900, geneticists such as **Charles Davenport** and **Edward East** have been open to reduce human characteristics from **eye color** to **genius and criminality** to one to several dichotomous Mendelian traits.



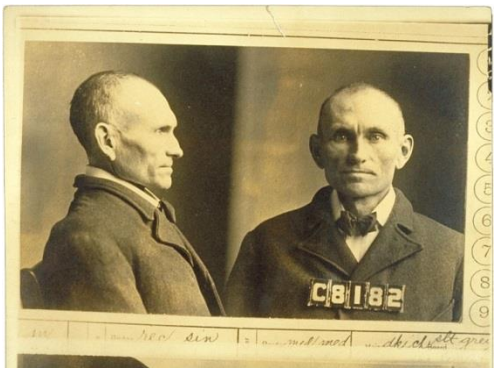
According to Charles Davenport, who worked at the **Eugenics Record Office** at **Cold Spring Harbor** *"**Eugenics is the science of the improvement of the human race by better breeding**…. The eugenical standpoint is that of the agriculturalist who, while recognizing the value of culture, believes that permanent advance is to be made only by securing the best 'blood'. Man is an organism—an animal; and the laws of improvement of corn and of race horses hold true for him also."*

Charles Davenport (1911) realized that *"The human babies born each year constitute **the world's most valuable crop.** Take the population of the globe to be one and one-half billion, probably about 50 million children are born each year….It is a reproach to our intelligence that we as a people, **proud in other respects of our control of nature**, should have to support about half a million insane, feeble-minded, epileptic, blind and deaf, 80,000 prisoners and 100,000 paupers at a cost of over 100 million dollars a year."*

To Davenport, genetic diversity provided the basis for improving the human harvest. *"**It is just the fact of diversity of characteristics of people that gives basis for the belief in the practicability of improving the qualities of the 'human harvest'….**The element of inheritance is not the individual as a whole or even, in many cases, the traits as they are commonly recognized but, on the contrary, certain unit characters. What are, indeed, units and what are complexes it is not always easy to determine and it can be determined only by the results of breeding."*

Moreover, to Davenport, marriage was an experiment in human breeding. He wrote "*To get at the facts it is necessary to study the progeny of human marriages. Now marriage can be and is looked at from many points of view. In novels, as the climax of human courtship; in law, largely as a union of two lines of property-descent; in society, as fixing a certain status; but in eugenics, which considers its biological aspect, **marriage is an experiment in breeding; and the children, in their varied combinations of characters, give the result of the experiment. That marriage should still be only an experiment in breeding, while the breeding of many animals and plants has been reduced to a science, is ground for reproach***."

With these assumptions, Charles Davenport expressed his hopes: "*Surely the human product is superior to that of poultry; and as we may now predict with precision the characters of the offspring of a particular pair of pedigreed poultry so may it sometime be with man. As we now know how to make almost any desired combination of the characters of guinea-pigs, chickens, wheats, and cottons so may we hope to do with man*." Now Charles Davenport had to identify the good or **eugenic traits** and the bad or **dysgenic traits**. According to Davenport (1911), ***poverty is a bad genetic (dysgenic) hereditable trait***.





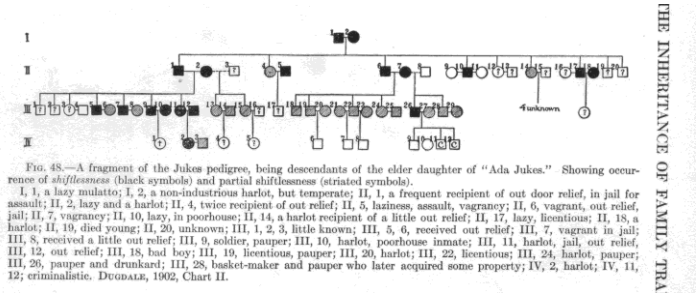


FIG. 48.—A fragment of the Jukes pedigree, being descendants of the elder daughter of "Ada Jukes." Showing occurrence of *shiftlessness* (black symbols) and partial shiftlessness (striated symbols).

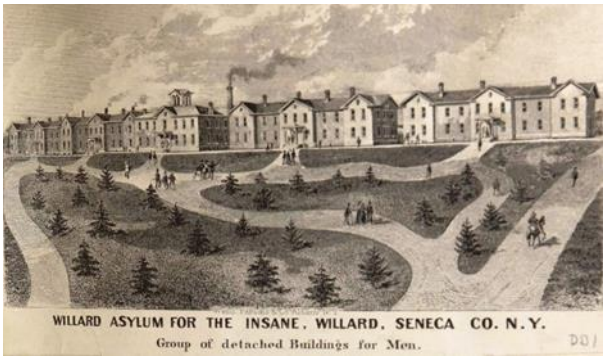
I, 1, a lazy mulatto; I, 2, a non-industrious harlot, but temperate; II, 1, a frequent recipient of out door relief, in jail for assault; II, 2, lazy and a harlot; II, 4, twice recipient of out relief; II, 5, laziness, assault, vagrancy; II, 6, vagrant, out relief, jail; II, 7, vagrancy; II, 10, lazy, in poorhouse; II, 14, a harlot recipient of a little out relief; II, 17, lazy, licentious; II, 18, a harlot; II, 19, died young; II, 20, unknown; III, 1, 2, 3, little known; III, 5, 6, received out relief; III, 7, vagrant in jail; III, 8, received a little out relief; III, 9, soldier, pauper; III, 10, harlot, poorhouse inmate; III, 11, harlot, jail, out relief, III, 12, out relief; III, 18, bad boy; III, 19, licentious, pauper; III, 20, harlot; III, 22, licentious; III, 24, harlot, pauper; III, 26, pauper and drunkard; III, 28, basket-maker and pauper who later acquired some property; IV, 2, harlot; IV, 11, 12; criminalistic. DUGDALE, 1902, Chart II.

THE INHERITANCE OF FAMILY TRA

Charles Davenport also worried about the effect of **immigration** on the quality of the human harvest writing, "*There is no question that, taken as a whole, the hordes of Jews that are now coming to us from Russia and the extreme southeast of Europe, with their intense individualism and ideals of gain at the cost of any interest, represent the opposite extreme from the*



early English and the more recent Scandinavian immigration with their ideals of community life in the open country, advancement by the sweat of the brow, and the uprearing of families in the fear of God and the love of country....it appears certain that, unless conditions change of themselves or are radically changed, the population of the United States will, on the account of the great influx of blood from South-eastern Europe, ***rapidly become darker in pigmentation****.... Since of the insane in [public] hospitals there are relatively more foreign-born than native it seems probable that, under present conditions, the ratio of insanity in the population will rapidly increase.*" Perhaps it is possible that the native-born went to private hospitals.


WILLARD ASYLUM FOR THE INSANE. WILLARD. SENECA CO. N.Y.
Group of detached Buildings for Men.

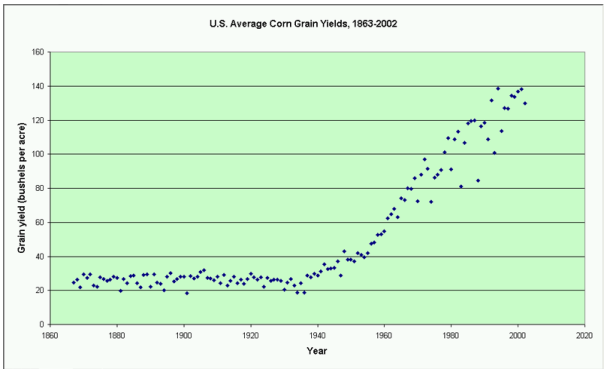
Edward East was a geneticist. He found that when a corn plant is self- pollinated, all the progenies resemble that plant, although they all differ from each other to some extent. He also noticed that after **seven** (the number of completion) seasons of self-pollination, a plant known as an ***inbred*** or ***pure-breeding strain*** is produced (0,1,2,2). That is, all of the progenies will be genetically identical to each other and to the inbred parent. Unfortunately, while inbreeding **brings together desirable genes and fixes them**, it also results in ***loss of vigor***.

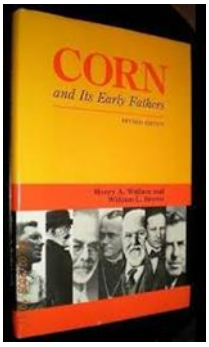


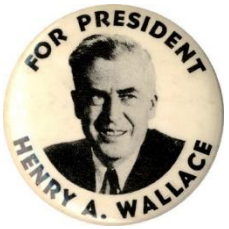
When the **self-pollinated** or **inbred** plants (l,m) are **cross-pollinated** or **outbred** to produce hybrid progeny (r), these plants are even more vigorous than the plants from which the inbreds had been developed. This phenomenon is called ***hybrid vigor***.



From Edward East's time to the present, hybrid corn has been important in so many ways. With the introduction of hybrid corn, yield increased. **Henry Wallace** (1932), the Progressive Party nominee in 1948, wrote that "*The best hybrids of the future will be so much better than the best hybrids of today….*"







Hybrid corn was as American as apple pie. **Roswell Garst** recognized that the United States' biggest agricultural problem was its surpluses and the USSR's biggest problem in agriculture was scarcity. Garst believed that the U.S. surpluses could be used as a "*weapon for peace*." When **Soviet Premier Nikita Khrushchev** came to the United States in September 1959, he wanted to see two things: **Disneyland** and **hybrid corn**. Khrushchev was touring the heart of the Midwest corn belt to see for himself why "*agriculture, America's biggest success, [was] communism's biggest failure*." Khrushchev bought hybrid corn seed in Iowa, which made him happy, but was not allowed to go to Disneyland for security reasons. This made Khrushchev blow his top!







See how Roswell Garst drilled a hole in the iron curtain with his "***Peace through Corn***" approach. https://www.youtube.com/watch?v=ucqxsWmmfJE

Although **Edward East** (1919) did critical work in establishing the **value of outcrossing and hybridization**, he also read books such as *Hereditary Genius* written by Francis Galton (1869), Charles Darwin's cousin, *British Men of Genius*

by Havelock Ellis (1904), and *Heredity in Royalty* by F.A. Woods (1906) all of which indicated that success ran in families—without taking **nepotism** into consideration. In his book entitled, *Inbreeding and Outbreeding: Their Genetic and Sociological Significance*, Edward East (1919) also asked if his conclusions regarding corn extended to humans. Edward East (1919) wrote, "*If we examine carefully the genealogical records of such families, marriage of near relatives is found to be a common occurrence. Would it not be wise to* ***do away with statutes against the marriage of first cousin****s such as are laid down in the laws of nearly half our States, even though the argument on the other side, as we shall show, is just as great? If such laws had been followed in every mating the world would have lost an Abraham Lincoln and have been compelled to punish a* ***Charles Darwin***."

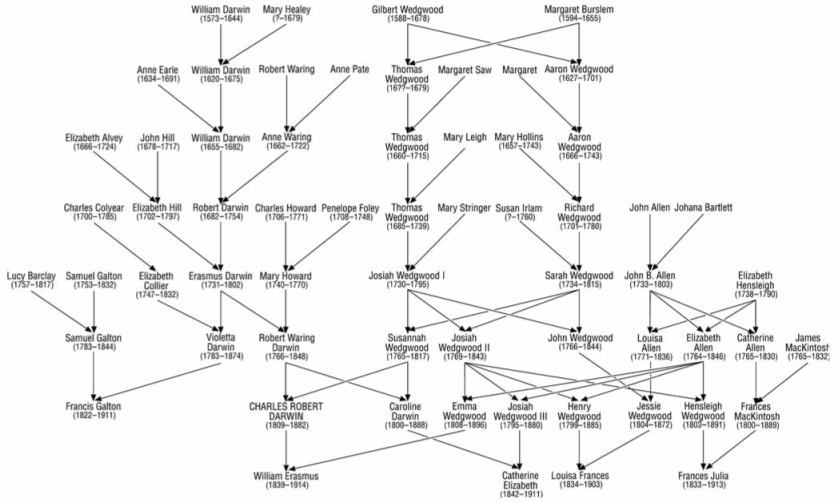
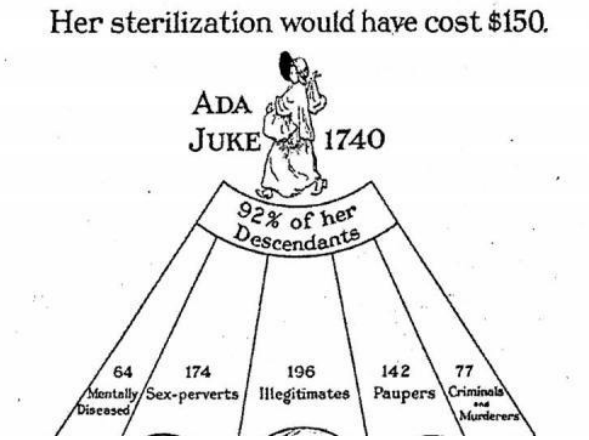


Figure 1. Pedigree of the Darwin/Wedgwood dynasty represented as chains of descent.



As we saw with corn, there are values and limitations to inbreeding as there is to outbreeding. Charles Darwin worried that his daughter **Annie** (1841-1851) may have died so young because Charles and his wife Emma were related—both having **Josiah Wedgwood** as a grandfather. (I can find no evidence that there was inbreeding in Abraham Lincoln's family).

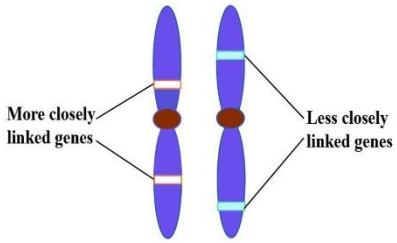
Edward East (1919) saw that in humans, inbreeding, "*given the possession of desirable characteristics on which to base selection, could hardly fail to bring results…..the reverse is not so pleasing. Dreary histories have been written of consistently degenerate families with such a monotonously infamous record they are known throughout the world. These are the* ***Jukes****, an* ***inbred family*** *whose record of pauperism, prostitution and crime has been traced for six generations.*"



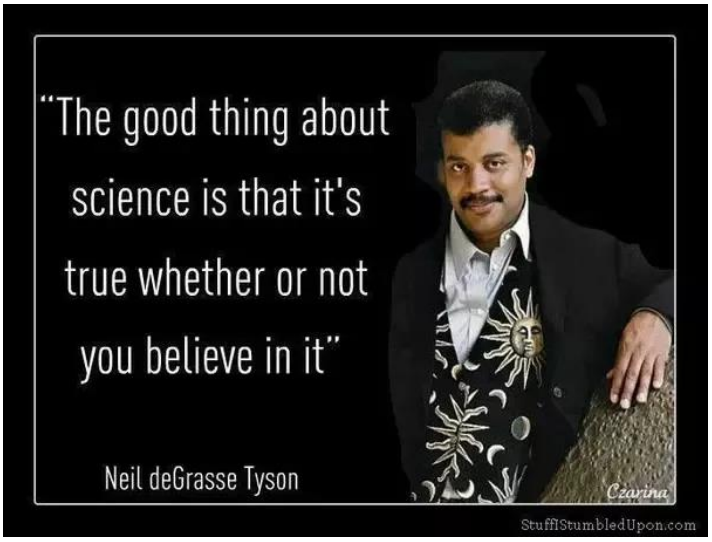
"*…does anyone believe that these families would have been a credit to the communities harboring them if the environment were changed. It was tried many times and failed. No! What happened in these cases was the establishment of near-homogeneous races having a bad heredity. The result of inbreeding where the germ plasm is bad stands forth as a terrible example. What would have happened had there been no isolation would have been the contamination of good blood lines*."

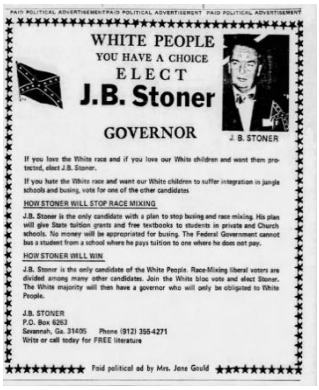


What did Edward East (1919) have to say about breeding between "whites" and "negroes?" "*The races differ by so many transmissible factors, factors which are probably linked in various ways, that there is, practically speaking, no reasonable chance of such breaks in linkage occurring as would bring together only the most desirable features.... The real result of such a wide racial cross, therefore, is to break apart those compatible*



physical and mental qualities which have established a smoothly operating whole in each race by hundreds of generations of natural selection [i.e., linked genes]. *If the two races possessed equivalent physical characteristics and mental capacities, there would still be this valid genetical objection to crossing, as one may readily see. But in reality the negro is inferior to the white.* ***This is not hypothesis or supposition; it is a crude statement of actual fact.***"





Although rare, this sentiment existed in my lifetime. When I lived in Georgia in 1977-1978, J. B. Stoner was running for Governor on this platform. J. B. Stoner, was a member of the Ku Klux Klan and the National States Rights Party, was the man who bombed the Bethel Baptist Church in Birmingham Alabama, and was an attorney for James Earl Ray, who assassinated Martin Luther King. He was also a died-in-the-wool racist who thought that both Adolf Hitler and the Ku Klux Klan were "*too moderate*." I could not disagree more with the way critical theory redefines words to label every person with the same melanin content as J. B. Stoner as a racist. In systematics, there are lumpers and splitters, I guess in this case I am a splitter.



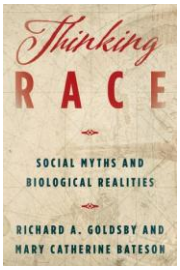
Also in Georgia, in 1973, on St. Simons Island, my friend Ric and I got to stay with Bessie Jones, the granddaughter of a slave, who taught the songs, riddles, and games, she learned from her grandfather to the younger generations. She transferred her love of her culture.

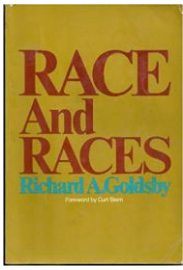




Richard Goldsby, who was a graduate student with Melvin Calvin (of Calvin cycle fame), has written intelligently about the relationship between genetics and race (vimeo.com/230150268). He recently coauthored a book entitled, *Thinking Race* with Mary Catherine Bateson, the daughter of anthropologists, Margaret Mead and Gregory Bateson, and the granddaughter of **William Bateson**, who coined the term, genetics.

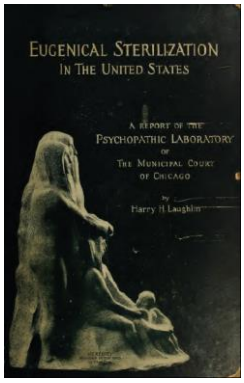






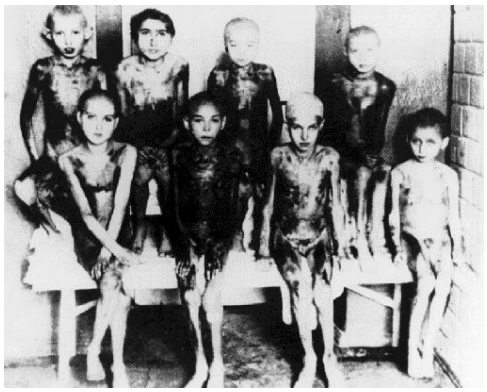
Harry Laughlin, the Director of the Eugenics Record Office at Cold Spring Harbor, testified to the Congressional Committee on Immigration and Naturalization in 1922, ***"The character of a nation is determined primarily by its racial qualities; that is, by the hereditary physical, mental and moral or temperamental traits of its people."***







When testifying as an expert witness to the committee that crafted the ***Immigration Act of 1924***, Laughlin recommended that the US return to the same racial composition as that which existed in 1890, before there was a large influx of immigrants. In 1934, Congress was considering the possibility of increasing the quotas to allow in the Jewish refugee children who were fleeing from Hitler's Nazi Regime. The Committee again called upon Harry Laughlin, since "*Mr. Laughlin is beyond doubt the* ***foremost authority*** *in the United States.*" Laughlin testified that *"The Jews are no exception…."* and the refugee boats were sent away from the ports. In 1936, Laughlin was awarded an honorary Doctor of Medicine from the University of Heidelberg, the intellectual seat of the Nazi regime.





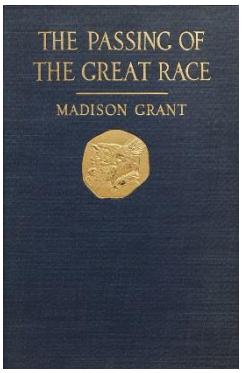
During the **Progressive Era** (1900-1930), the new science of genetics was being applied in many ways to make what the geneticists considered to promote progress and produce a better society.

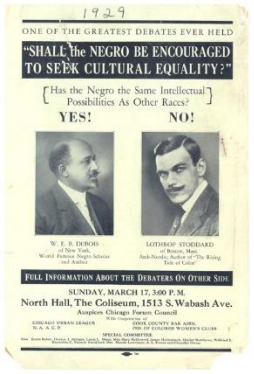


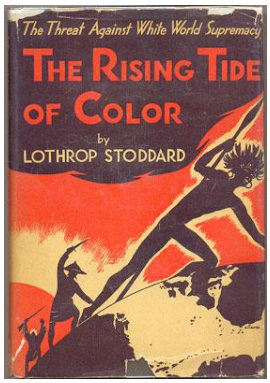
The **American Breeder's Association** was founded in 1906 by Charles Davenport to "*investigate and report on heredity in the human race, and emphasize the value of superior blood and the menace to society of inferior blood*." **Luther Burbank**, the renowned horticulturalist was made an honorary member of the association. **The Galton Society** was founded in

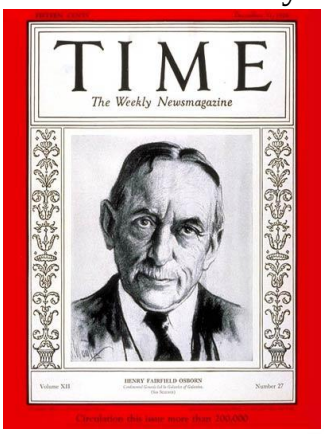
1918 by **Madison Grant**, a conservationist, Trustee of the American Museum of Natural History, and author of *The Passing of the Great Race*, **Henry Fairfield Osborn**, a student of T. H. Huxley who first described *Tyrannosaurus rex* and who was President of the American Museum of Natural History, **Lothrop Stoddard**, who wrote *The Rising Tide of Color: The Threat Against White World-Supremacy*, embryologist Ed**win G. Conklin**, and Charles Davenport, who became the first president of the Galton Society. The Galton Society promoted the sterilization of the unfit. The **American Eugenics Society** was founded in 1922 by Henry Fairfield Osborn, Madison Grant, Harry Laughlin, John Kellogg, and **Margaret Sanger**. It existed until 1972 when it was renamed "The Society for the Study of Social Biology." It is currently known as The Society for Biodemography and Social Biology. Plant breeders, including **David Starr Jordan**, a Cornell graduate and First President of Stanford University and **Paul Popenoe**, famous for introducing dates into California, served on the board of the **Human Betterment Foundation** that from 1928-1942 promoted sterilization to prevent undesirables from breeding. Plant breeders knew that to produce a successful variety, you have to make many crosses and throw away all progeny



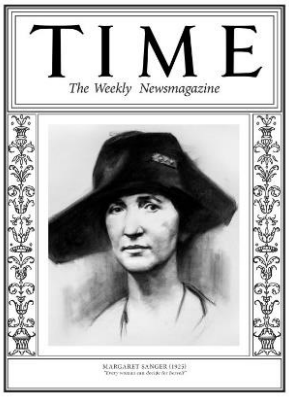




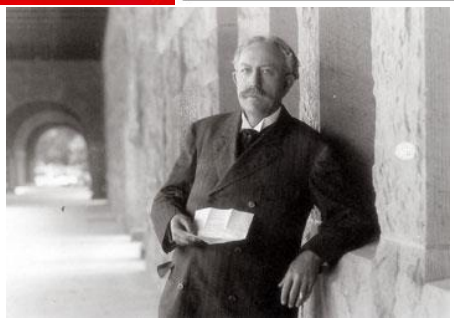




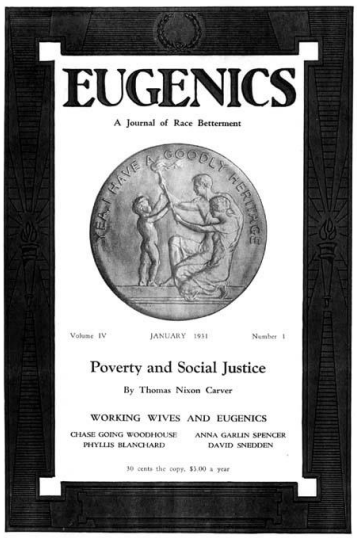


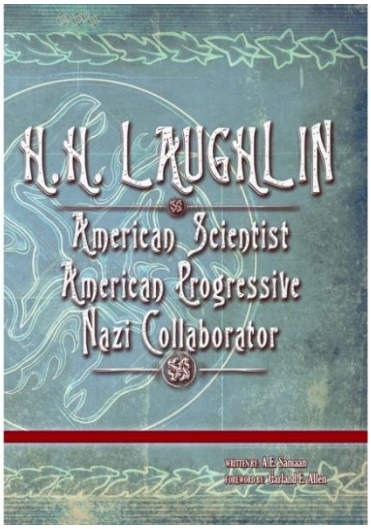



Paul Popenoe

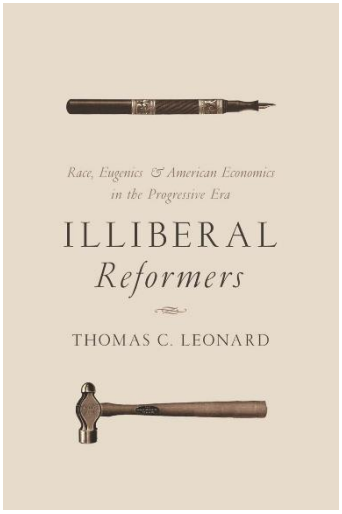


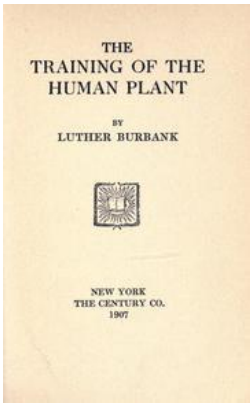
except those with the desired traits. In the Progressive Era, eugenics was the cutting edge of science.











Luther Burbank (1909) wrote in *The Training of the Human Plant*, "*It would, if possible, be best absolutely to prohibit in every State in the Union the marriage of the* ***physically, mentally and morally unfit****. If we take a plant which we recognize as poisonous and cross it with another which is not poisonous and thus make the wholesome plant evil, so that it menaces all who come in contact with it, this is criminal enough. But suppose we blend together two poisonous plants and make a third even more virulent, a vegetable degenerate, and set their evil descendants adrift to multiply over the earth, are we not distinct foes to the race? What, then, shall we say of two people of absolutely defined physical impairment who are allowed to marry and rear children? It is a crime against the state and every individual in the state. And if these physically degenerate are also morally degenerate, the crime becomes all the more appalling.*"

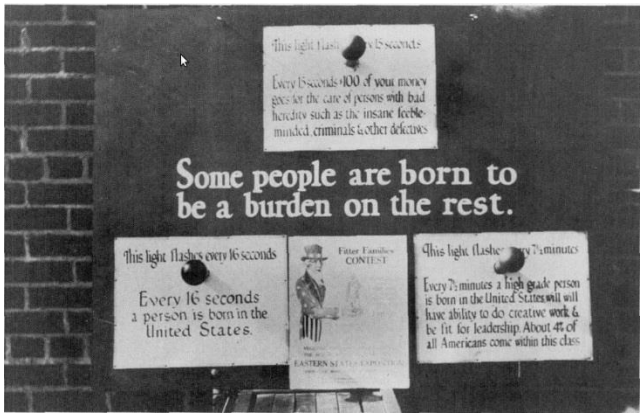


Leonard Huxley (1926), T. H. Huxley's son and Julian's father, wrote in *Progress and the Unfit*, "*Progress is not inevitable as society evolves; the hope of ensuing progress is to make certain that the evolutionary material, moral and intellectual as much as physical, is* ***not unfit*** *for this purpose. To make no effort towards this difficult end is to abandon reasonable hope for the future of mankind.*"

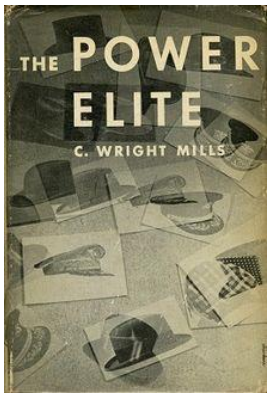


Marie Stopes, the paleobotanist who studied **coal balls**, the author of *Ancient Plants* (1910), and who asked Robert Falcon Scott to collect fossils on his expedition to Antarctica was also a eugenicist. Stopes (1920) after suggesting that Parliament craft acts that "*deal with the terrible debasing power of the inferior, the depraved and feeble-minded, to whom reason means nothing and can mean nothing, who are thriftless, unmanageable and appallingly prolific. Yet if the good in our race is not to be swamped and destroyed by the debased as the fine tree by the parasite, this prolific depravity must be curbed*." She ended *Radiant Motherhood* like so: "*…the fine and splendid race which to-day, as God's prophet, I see in a vision and which might so speedily be materialized on earth*." Stopes was serious about eliminating the unfit from the human race and thus opposed the marriage of her son Harry to Mary because Mary was near-sighted. In spite of his mother's opposition, Harry married Mary, and so Marie Stopes cut Harry out of her will, bequeathing her fortune to the Eugenics Society.

The science of genetics had a reasonable, rational, scientific, and evidence-based foundation. It was supported by the scientific luminaries or prophets who saw people as living organisms essentially equivalent to plants and animals. Consequently, genetics seemingly had unlimited value in improving the human condition just like it improved domestic animals and crop plants—until one asks, **When it comes to human beings, who gets to choose who is fit and who is unfit?** (Anyone can weigh up the criteria on which someone calls themselves fit or in today's jargon, elite. Why are they elite? Are they wise? Athletic? Creative? Wealthy? Beautiful? Educated? Connected?)



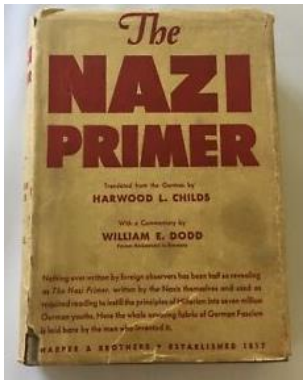
The Latin word *eligere* means to choose. From this word comes the French word *élite*, meaning a selection or choice. From this word comes the English word *elite*, meaning a choice or select body, the best part. C. Wright Mills (1956) wrote about the elite in *The Power Elite*: "*It is a well-regulated existence where education plays a critical role. Youthful upper-class members attend prominent preparatory schools, which not only open doors to such elite universities as Harvard, Columbia, Dartmouth College, Yale, and Princeton, but also to the universities' highly exclusive clubs. These memberships in turn pave the way to the prominent social clubs located in all major cities and serving as sites for important business contacts*." Should the elite not only be the fit chosen to reproduce but also be the choosers of who is fit enough to reproduce?



Ironically, those who graduate from elite colleges and universities are the least likely to produce enough children to reproduce their "good" genes. As Irving

Fisher (1921) stated in his Presidential Address entitled, *Impending Problems of Eugenics*, "*Professor McDougall has given reason to believe, that the present occupational stratification of society corresponds roughly to the stratification of intelligence; that the four classes, (1) professional men, and business executives, (2) other business men, (3) skilled work- men and (4) unskilled workmen represent on the whole four classes of human beings graded as to innate mental ability. The college graduate means the professional man and business executive. Cattell finds that* ***the average Harvard graduate is the father of three-fourths of a son and the average Vassar graduate the mother of one-half of a daughter*** *and that the average family of American men of science is only 2.22 as compared with an average of 4.66 for the country. Popenoe and Johnson give similar results summarizing many statistical studies of Yale, Harvard, and other educational institutions.* ***At present, then, our educational system seems to be destroying the very material on which it works! Colleges seem to be engines for the mental suicide of the human race! Are the colleges, of to-day sterilizing our scholars as did the monasteries and nunneries of the middle ages? Such race suicide of scientific and educated men and of the well- to-do classes means that their places will speedily be taken by the unintelligent, uneducated and inefficient***."

The Nazis had the same worry: "*The less worthy multiply without restraint and are continually spreading their hereditary sufferings abroad. We see that from the fact that in Germany the average number of children amounts to*



2.2 in the case of sound families

3.5 in the case of weak minded families

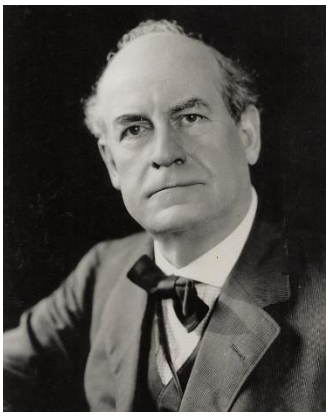
4.9 in the case of criminal families."



Margaret Sanger had definite views on who was fit and unfit and promoted birth control as a remedy to reduce the number of unfit. In *Why Not Birth Control Clinics in America*?, Sanger (1919) wrote, "*In conclusion, I am going to make a statement which may at first seem exaggerated, but which is nevertheless carefully considered.* ***The effort toward racial progress that is being made to-day by the medical profession, by social workers, by the various charitable and philanthropic organizations and by state institutions for the physically and mentally unfit is practically wasted****. All these forces are in a very emphatic sense marking time. They will continue to mark time until the medical profession recognizes the fact that the ever-increasing tide of the unfit is overwhelming all these agencies are doing for society. They will continue to mark time until they get at the source of these destructive conditions and apply a fundamental remedy. That remedy is birth control*."

Margaret Sanger (1923) promoted birth control as a "*a practical and powerful weapon against national and racial decadence*." She wrote in *High Lights in the History of Birth Control*, "*The results of the intelligence tests, the menace of indiscriminate immigration, the fertility of the unfit, and the increasing burden upon the healthful and vigorous members of American society of the delinquent and dependent classes, together with the growing danger of the abnormal fecundity of the feeble-minded, all emphasize the necessity of clear-sightedness and courage in facing the problem, and throw new light on the possibilities of Birth Control as a practical and powerful weapon against national and racial decadence*." Sanger (1920) also noted in her book, *Woman and the New Race*, "[i]*t is apparent that nothing short of contraceptives can put an end to the*

horrors of abortion and infanticide." "*The question that society must answer is this: Shall family limitation be achieved through birth control or abortion*?"



William Jennings Bryan, who, as a result of the **Scopes trial** that took place in July 1925, has been ridiculed as a fool because he openly opposed the scientific establishment. As a Christian, three-time Democrat presidential nominee, and a **populist** who advocated for the common folk against the pressures of the bankers of 1896 or the scientists of 1925, and questioned theories and policies that would serve the elite at the expense of the common folk, "***the great commoner***" saw the downside of a scientific theory applied to a democratic people by the scientific elite. He saw the elite as people who "***assume an intellectual superiority and often take little pains to conceal the assumption***." In his *The Prince of Peace* speech, Bryan (1904) explained why he rejected Darwinism. "***The Darwinian theory represents man as reaching his present perfection by the operation of the law of hate—the merciless law by which the strong crowd out and kill off the weak. If this is the law of our development then, if there is any logic that can bind the human mind, we shall turn backward toward the beast in proportion as we substitute the law of love. I prefer to believe that love rather than hatred is the law of development. How can hatred be the law of development when nations have advanced in proportion as they have departed from that law and adopted the law of love?***" In *The Menace of Darwinism*, Bryan (1921) worried that the acceptance of evolutionary theory would suggest that the only way to progress was "*the life and death struggle from which sympathy and the spirit of brotherhood are eliminated*." The text of the speech Bryan intended to give at the Scopes trial can be found on page 1 of the *New York Times* (July 29, 1925). His speech includes Darwin's (1871) ideas from *The Descent of Man* that

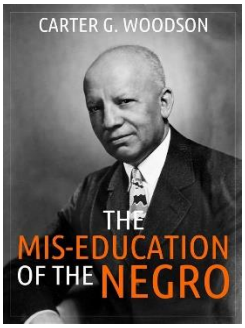
he objected to such as: "*With savages, the weak in body or mind are soon eliminated; and those that survive commonly exhibit a vigorous state of health. We civilised men, on the other hand, do our utmost to check the process of elimination; we build asylums for the imbecile, the maimed, and the sick; we institute poor-laws; and our medical men exert their utmost skill to save the life of every one to the last moment. There is reason to believe that vaccination has preserved thousands, who from a weak constitution would formerly have succumbed to small-pox.* ***Thus the weak members of civilised societies propagate their kind. No one who has attended to the breeding of domestic animals will doubt that this must be highly injurious to the race of man. It is surprising how soon a want of care, or care wrongly directed, leads to the degeneration of a domestic race; but excepting in the case of man himself, hardly any one is so ignorant as to allow his worst animals to breed***.

The aid which we feel impelled to give to the helpless is mainly an incidental result of the instinct of sympathy, which was originally acquired as part of the social instincts, but subsequently rendered, in the manner previously indicated, more tender and more widely diffused. Nor could we check our sympathy, if so urged by hard reason, without deterioration in the noblest part of our nature. The surgeon may harden himself whilst performing an operation, for he knows that he is acting for the good of his patient; but if we were intentionally to neglect the weak and helpless, it could only be for a contingent benefit, with a certain and great present evil. Hence we must bear without complaining the undoubtedly bad effects of the weak surviving and propagating their kind; [*but there appears to be at least one check in steady action, namely the weaker and inferior members of society not marrying so freely as the sound; and this check might be indefinitely increased, though this is more to be hoped for than expected, by the weak in body*

or mind refraining from marriage.]" Bryan worried that the teaching of the evolutionary theory of the origin of man [as opposed to animals] would eliminate love.

Bryan, like Alfred Russel Wallace, and Prometheus for that matter saw something immaterial and divine in human beings. Unlike Darwin, they saw human beings as having characteristics that were unique to human beings and different in kind to animals. Darwin saw these characteristics of human beings as being improvements on animal characteristics based on the survival of the fittest. Darwin (1874) wrote in the *Descent of Man*, "*Man in the rudest state in which he now exists is the most dominant animal that has ever appeared on this earth. He has spread more widely that any other highly organised form: and all others have yielded before him. He manifestly owes this immense superiority to his intellectual faculties, to his social habits, which lead him to aid and defend his fellows, and to his corporeal structure. The supreme importance of these characters has been proved by the final arbitrament of the battle for life. Through his powers of intellect, articulate language has been evolved; and on this his wonderful advancement has mainly depended. As Mr. Chauncey Wright remarks: 'a psychological analysis of the faculty of language shews, that even the smallest proficiency in it might require more brain power than the greatest proficiency in any other direction.' He has invented and is able to use various weapons, tools, traps, &c., with which he defends himself, kills or catches prey, and otherwise obtains food. He has made rafts or canoes for fishing or crossing over to neighbouring fertile islands. He has discovered the art of making fire, by which hard and stringy roots can be rendered digestible, and poisonous roots or herbs innocuous.* ***This discovery of fire, probably the greatest ever made by man, excepting language, dates from before the dawn of history.*** *These several*

inventions, by which man in the rudest state has become so pre-eminent, are the direct results of the development of his powers of observation, memory, curiosity, imagination, and reason. ***I cannot, therefore, understand how it is that Mr. Wallace maintains, that 'natural selection could only have endowed the savage with a brain a little superior to that of an ape****."*"

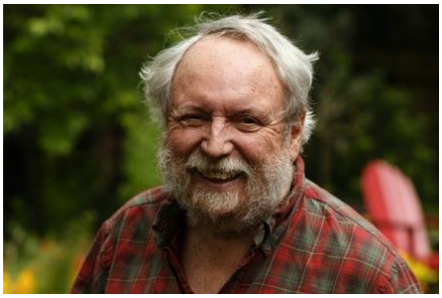


Carter G. Woodson (1933) wrote in *The Mis-Education of the Negro*, "*The old worn-out theories as to man's relation to God and his fellowman, the system of thought which has permitted one man to exploit, oppress, and exterminate another and still be regarded as righteous must be discarded for the thought of men as brethren and the idea of God as the lover of all mankind*."

Surely in its search for a biological theory of everything, the genetic view abstracted the reality of humanity to such an extent that what it meant to be human was no different than what it meant to be a plant or an animal. Races within the human race were treated the same way.

Now I ask you, has **science** turned into **scientism** and has **evolution** become a **religion**? In an article entitled *How evolution became a religion: creationists correct?* which was published in the *National Post* (Saturday, May 13, 2000), **Michael Ruse**, a philosopher of science, wrote,





I still remember arguing in the Arkansas court house with one of the most prominent of the literalists (now generally known as creationists). ***Duane T. Gish****, author of the best-selling work, "Evolution: The Fossils Say No!," resented bitterly what he felt was an unwarranted smug superiority assumed by us from the side of science.*

*"Dr Ruse," Mr. Gish said, "****the trouble with you evolutionists is that you just don't play fair. You want to stop us religious people from teaching our views in schools. But you evolutionists are just as religious in your way.***

Christianity tells us where we came from, where we're going, and what we should do on the way. I defy you to show any difference with evolution. It tells you where you came from, where you are going, and what you should do on the way. You evolutionists have your God, and his name is Charles Darwin*.''*

At the time I rather pooh-poohed what Mr. Gish said, but I found myself thinking about his words on the flight back home. And I have been thinking about them ever since. Indeed, they have guided much of my research for the past twenty years. Heretical though it may be to say this—and many of my scientist friends would be only too happy to chain me to the stake and to light the faggots piled around—I now think the Creationists like Mr. Gish are absolutely right in their complaint.

Evolution is promoted by its practitioners as more than mere science. Evolution is promulgated as an ideology, a secular religion—a full-fledged alternative to Christianity, with meaning and morality*. I am an ardent evolutionist and an ex-Christian, but I must admit that in this one complaint—and Mr. Gish is but one of many to make it—the literalists are absolutely right. Evolution is a religion. This was true of evolution in the beginning, and it is true of evolution still today.*

One of the earliest evolutionists was the eighteenth-century physician Erasmus Darwin, grandfather of Charles. He was no atheist, believing rather in God as "Unmoved Mover": a being who decides right at the beginning on the future course of nature, lays down unbreakable laws, and never acts again.

Rightly, Erasmus Darwin saw this "deism" as challenging Christian theism, which takes God as ready always to intervene miraculously in His creation. For Erasmus Darwin, evolution was simply confirmation of his commitment to a law-bound process of creation set down by a non-interventionist God. It was part and parcel of his alternative religion.

To this vision, Darwin's grandfather added an ***enthusiasm for social progress—as embodied by the Industrial Revolution****—which progress he then read right into his science. Erasmus saw* ***social progress as a rise from a simple village-based society to the complexity of the modern city****, and analogously he thought evolution rises progressively from the simple, the undifferentiated blobs of the first life forms (known as "monads"), to the apotheosis of organic complexity, the human race.*

In his progressivism—especially in his belief that we humans ourselves can and do improve our overall well-being—Erasmus clearly stood in yet another way against Christianity, which stresses that salvation can come only through God. For the Christian, our greatest gains "count for naught."

Evolution therefore came into being as a kind of secular ideology, an explicit substitute for Christianity. It stressed laws against miracles and, by analogy, it promoted progress against providence.

And so things continued. In 1859, Charles Darwin, the father of modern evolutionary thought, published his great work On the Origin of Species. With this book, Darwin hoped to change things and make a less ideological system of evolution. He offered a systematic survey of the biological world, showing how many different factors—the fossil record, the geographical distributions of organisms, the discoveries from embryology—point to evolution. At the same time, he proposed his celebrated mechanism of natural selection: thanks to population pressures, some creatures flourish and have offspring and some do not and, over the ages, this "survival of the fittest" leads to full-blown change.

But almost at once Darwin's efforts were frustrated by (of all people) his greatest supporter, his famous "bulldog," Thomas Henry Huxley.

When Jesus died he left no functioning religion. This was the work of his supporters, especially Saint Paul, and as we all know the Christianity of Saint Paul was not exactly identical to the Christianity of Jesus. Like the great apostle and Christianity, Huxley—one of the most prominent scientists and greatest educators and social reformers of his day—had begun by denying evolution, and when converted had the same enthusiasm as Paul.

But like Paul also, for all that Huxley venerated Charles Darwin, he could see in the master's writings only a glimpse of what he himself needed for his own purposes. And in working to his own ends, Huxley was led to the same consequences as Paul: a functioning system, but not that of the man in whose name he worked and preached.

Origin appeared at just that time in Victorian Britain when it was necessary to transform the country from a rural-based, near-feudal society and to fit it for an

urbanized, industrialized future. *There was need for reform everywhere: in the civil service, merit had to count, not connection. In medicine, doctors had to stop killing patients and start curing them.* ***In education, learning had to be for today and not to glorify the past***. *Huxley and his fellow reformers were in the thick of all this—Huxley himself was a college dean, served as a member of the new London School Board and on numerous royal commissions looking into the state of things.*

Correctly, Huxley saw Christianity—the established Anglican Church particularly—as allied with the forces of reaction and power. He fought it vigorously, most famously when he debated Samuel Wilberforce, the Bishop of Oxford. (Supposedly, on being asked whether he was descended from monkeys on his grandfather's side or his grandmother's side, Huxley replied he had rather be descended from an ape than from a bishop of the Church of England.)

As a social reformer therefore, Huxley, known in the papers as "Pope Huxley", was determined to find a substitute for Christianity. Evolution, with its stress on unbroken law—which could be used to reflect messages of social progress—was the perfect candidate. Life is on an upwardly moving escalator. It has reached Victorian Britain. Who knows what glories and triumphs might lie ahead? Thus the vision of Saint Thomas—something to be preached far and wide. Working men's clubs, popular scientific congresses, debating societies, university convocations were Huxley's Corinthians and Galatians.

Indeed, recognizing that a good religion needs a moral message as well as a history and promise of future reward, Huxley increasingly turned from Darwin (who was not very good at providing these things) toward another English evolutionist.

Herbert Spencer—prolific writer and immensely popular philosopher to the masses—shared Huxley's vision of evolution as a kind of metaphysics rather than a straight science. He was happy to insist that even moral directives come from the evolutionary process itself.

*"**Social Darwinism**" (more accurately, Social Spencerianism) took evolution to entail struggle and success for the few, and so the moral message was understood as enthusiasm for laissez-faire individualism. The state should stay out of the*

running of society, and the best should be allowed to rise to the top. Failures deserve their fates.

Of course, there were differences between Social Darwinians. Socialists, Marxists and anarchists also justified their beliefs in the name of Darwin. The point is that the harnessing of evolution to ends that were explicitly moral, even political, went on right through the nineteenth century.

The even greater point is that it continued to go on right through the twentieth century. ***Evolutionary ideas were to undergo a great transformation in the 1930s and 1940s, when a professional science of evolutionary studies was developed—a professional science which stood on its own legs by its own merits, having no need for an alternative career as secular ideology. But this secular ideology or religion hardly folded its tents and crept away. One of the most popular books of the era was Religion without Revelation, by evolutionist Julian Huxley, grandson of Thomas Henry****. First published in 1927, the book was revised (for a second time) and reissued in the 1950s.*

"All thought and emotion," Huxley wrote, "even the highest, spring from natural mind, whose slow development can be traced in life's evolution, so that life in general and man in particular are those parts of the world substance in which the latent mental properties are revealed to their fullest extent." As always, evolution was doing everything expected of religion, and more.

Today, professional evolution thrives. But the old religion survives and thrives right alongside it. Evolution now has its mystical visionary, its Saint John of the Cross. ***Harvard entomologist and sociobiologist Edward O. Wilson tells us that we now have an "alternative mythology" to defeat traditional religion****. "Its narrative form is the epic: the evolution of the universe from the big bang of fifteen years ago through the origin of the elements and celestial bodies to the beginnings of life on earth."*

Faithful to the oldest tradition of evolutionary theorizing—reading his morality and politics into his science and then reading it right back out again*—Mr. Wilson warns us that we have evolved in symbiotic relationship with the rest of living nature, and lest we cherish and preserve biodiversity we will all perish. Drawing on the dispensationalism of his Southern Baptist childhood, with the*

eloquence and moral fervour of Billy Graham, ***Mr. Wilson begs us to repent, to stand up and acknowledge our sins and to walk forward in the ways of evolution. We have but a short time, else moral darkness will fall on us al****l.*

The language of Stephen Jay Gould is hardly more tempered. We learn that evolution "liberates the human spirit," that for sheer excitement evolution "beats any myth of human origins by light years," and that we should "praise this evolutionary nexus—a far more stately mansion for the human soul than any pretty or parochial comfort ever conjured by our swollen neurology to obscure the source of physical being."

Mr. Gould ultimately rejects traditional readings of evolution for a more inspiring, liberating version: "We must assume that consciousness would not have evolved on our planet if a cosmic catastrophe had not claimed the dinosaurs as victims. In an entirely literal sense, we owe our existence, as large and reasoning mammals, to our lucky stars." If this is not to rival traditional Judaeo-Christian teaching—with its central belief that we humans are not just random happenstances, but a major reason why God created heaven and earth—I do not know what is.

What is the moral to be drawn from all of this? You might think that the time has come to save evolution from the evolutionists*.*

Darwinism is a terrific theory that stimulates research in every area of the life sciences. In the human realm, for instance, discoveries in Africa trace our immediate past in ever greater detail, while at the same time the Human Genome Project opens up fascinating evolutionary questions as we learn of the molecular similarities between ourselves and organisms as apparently different as fruit flies and earthworms. Surely this is enough.

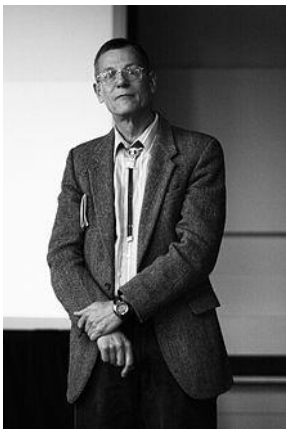
There is no need to make a religion of evolution. On its own merits, evolution as science is just that—good, tough, forward-looking science, which should be taught as a matter of course to all children, regardless of creed*.*

But, let us be tolerant. If people want to make a religion of evolution, that is their business. Who would deny the value of Mr. Wilson's plea for biodiversity? Who would argue against Mr. Gould's hatred of racial and sexual prejudice, which he has used evolution to attack?

The important point is that we should recognize when people are going beyond the strict science, moving into moral and social claims, thinking of their theory as an all-embracing world picture. All too often, there is a slide from science to something more, and this slide goes unmentioned—unrealized even.



For pointing this out we should be ***grateful for the opponents*** *of evolution. The Creationists are wrong in their Creationism, but they are right in at least one of their criticisms. Evolution, Darwinian evolution, is wonderful science. Let us teach it to our children. And, in the classroom, let us leave it at that. The moral messages, the underlying ideology, may be worthy. But if we feel strongly, there are other times and places to preach that gospel to the world.*



According to **William Provine** (Cornell, 1973), "*In the mid-1930s, geneticists' published statements about the effects of race crossing changed from condemnation to agnosticism. In part this change came from biological evidence. In the late 1920's and early 1930's geneticists experienced a growing realization that human heredity was more complex than they had previously thought….More important than new biological evidence as a factor prompting geneticists to publically reevaluate their theories of race mixture was the application of Nazi race doctrines before World War II. The Nazi doctrines resembled those of* ***Madison Grant****, who had declared that 'the cross between any of the three European races and a Jew is a Jew'….* [T. H. Huxley's grandson, Julian] *Huxley and Haldane attacked Nazi race doctrines with vigor, but they stopped short of denying hereditary mental differences or condoning all racial intermingling. The genetic evidence about race mixture was simply nonexistent, they said, and that situation should be remedied. Haldane wrote…'I would urge the extraordinary importance of a scientific study of*

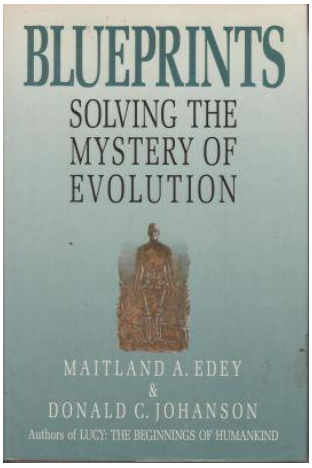
the effects of racial crossing for the future of the British Commonwealth'…. Huxley's view was similar…'The question whether certain race crosses produce 'disharmonious' results needs more adequate exploration.'"

Following World War II and the obvious consequences of Adolf Hitler's racial cleansing policy, as quoted by William Provine (1973), Leslie C. Dunn, and Theodosius Dobzhansky (1946) wrote in their book, *Heredity, Race, and Society*, "*Contrary to opinion vociferously expressed by some sincere but misguided people,…a trend* [towards race fusion] *is not biologically dangerous. Mixing of closely related races may even lead to increased vigor. As for the most distantly separated races, there is no basis in fact to think that either biological stimulation or deterioration follows crossing. The widespread belief that human race hybrids are inferior to both their parents and somehow constitutionally unbalanced must be counted among the superstitions.*"

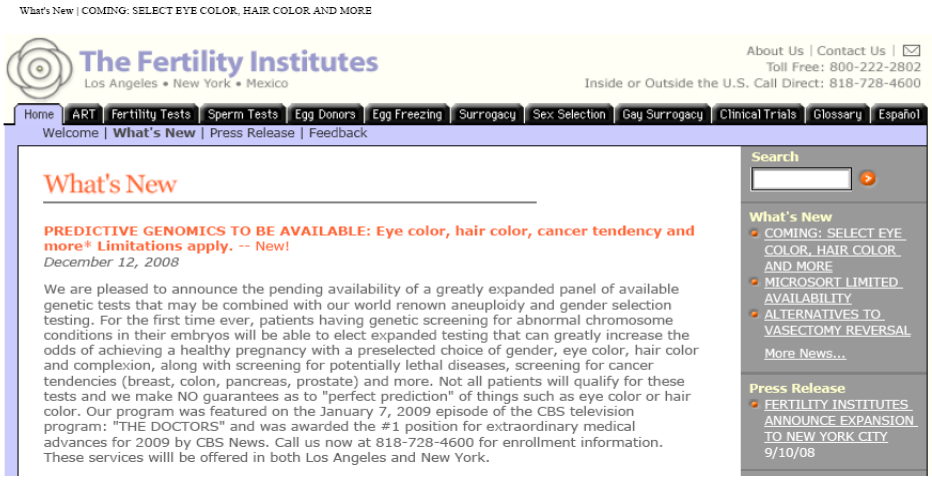
William Provine (1972) ended his paper on *Geneticists and the Biology of Race* Crossing like so: "*I am not condemning geneticists because social and political factors have influenced their scientific conclusions about race crossing and race differences. It is necessary and natural that changing social attitudes will influence areas of biology where little is known and the conclusion are possibly socially explosive.* ***The real danger is not that biology changes with society, but that the public expects biology to provide the objective truth apart from social influences. Geneticists and the public should realize that the science of genetics is often closely intertwined with social attitudes and political considerations."***

The science of human genetics in the 1920's and 1930's was known as **eugenics**. Eugenics, under the name of applied genetics is with us today. Maitland Edey and Donald Johanson (1989) write about the survival of the human race in

Blueprints: Solving the Mystery of Evolution: "*There is a way out of this. It is not more weapons, more treaties, more garbage, more chemicals, or more smog. It is* ***better people****. Perhaps the next step in our evolution as a species will be for us to recognize that natural selection of our emotions has been too slow and that we must speed things up, to keep pace with our culture, through* ***applied genetics****….For we are now on the verge of having the scientific skills to do something about it*."



Today's science, based on the Human Genome Project and the HapMap Project, is known by some as **Newgenics**. Newgenics allows the selection of embryos for the desired genetic traits, including **eye color** and **hair color**. The Fertility Institutes hope to make this a reality.



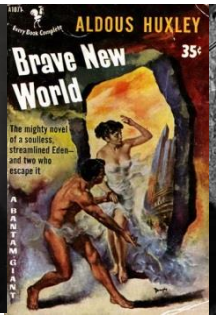


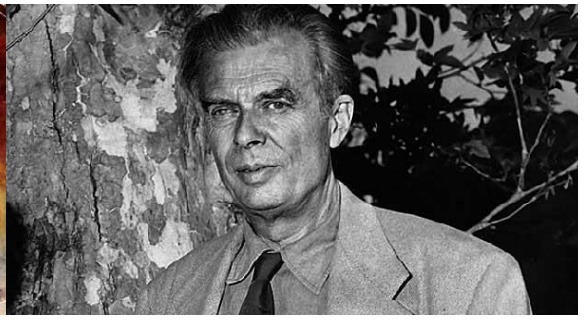


In the postmodernist world, is it possible to select the gender that a gender-fluid baby will choose once it decides on its gender? The Fertility Institutes actually selects for sex, as they test for XX and XY chromosomes.

Crispr technology could be used to engineer the individual and/or his/her progeny. On November 26, 2018, Dr. He announced that he had edited the genomes of twin girls to make them resistant to H.I.V. While this technique may prevent disease and make babies prettier, smarter, and more athletic, will it take away something that makes us human. To quote John Pierce (Can Science do without sentiment?), an engineer at Bell Labs, "*I am afraid that there will be little tangible left in a later age to remind our heirs that we were men rather than cogs in a machine*."

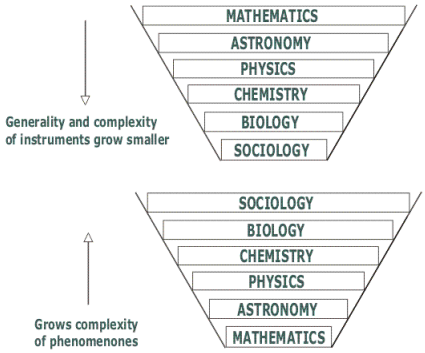






Aldous Huxley (1932), the author of *Brave New World*, was the grandson of **T. H. Huxley**, the son of Leonard Huxley, the brother of **Julian Huxley**, and the half-brother of Andrew Fielding Huxley. He knew where science was going. In a book review of *Brave New World* for *The Daily Telegraph* in 1932, **Rebecca West**, who had a **relationship** and a son with Huxley criticized him because *"he does not explain to the reader in a preface or footnotes how much solid justification he has for his horrid visions."*

Given that the dominant philosophy of scientists is the **positivist philosophy** of **Auguste Comte**, the mathematical formulation of life processes becomes the epitome of biological thought and the mathematicians become the prophets. Philip M. Sheppard (1954) wrote "*The great advances in understanding the process of evolution, made during the last thirty years, have been a direct result of the mathematical approach to the problem adopted by R. A. Fisher, J. B. S. Haldane, Sewell Wright, and others….The hypotheses derived by mathematicians have given a great impetus to experimental work on the genetics of populations*." I ask you to ask yourself who will question the mathematicians? Who will admit that they cannot understand nor do the math?

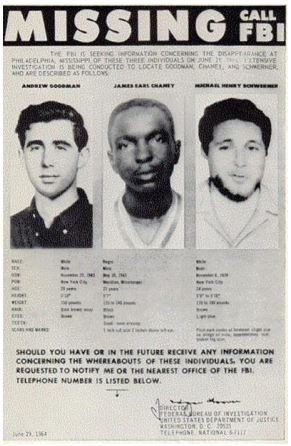


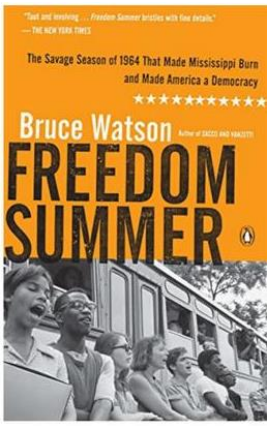
The **inherent value** in mathematizing nature is the reduction of complexity to the lowest common denominator in order to test stringently the effect of a given factor. The **inherent risk** in mathematizing nature is the elimination of unwanted factors or factors that may be **meaningful** and **valued** but cannot be **measured** and **quantified**. The real risk is when we the people ***blindly*** accept what the experts say. **Think for yourself** and **question authority** (including me)! William Provine (1973) quoted Reginald Punnett (1907) as saying "*Education is to a man what manure is to the pea*." Let's make sure that education like manure acts as a nutrient and not as a waste. In his book "*Tools for Thought: How to Understand and Apply the Latest Scientific Techniques of Problem Solving*," Conrad Waddington (1977) coined the term **COWDUNG** to represent the **co**nventional **w**isdom of the **d**ominant **g**roup.



The conventional wisdom of the dominant group is not necessarily rational. In his book ***Freedom Summer***, Bruce Watson (2010) describes the vision of **Robert Moses**, "*Only when blacks in Mississippi were joined by whites, he* [Moses] *argued, would civil rights be no longer a question of skin color but a '**question of rational people against irrational people** ...I always thought that the one thing we can do for the country that no one else could do is to be above the race issue.*'"







The Black Power Mixtape 1967-1975 is a great movie documenting the Black Power movement. Bill Cosby made a movie in 1968 entitled, Black History: Lost, Stolen, or Strayed.



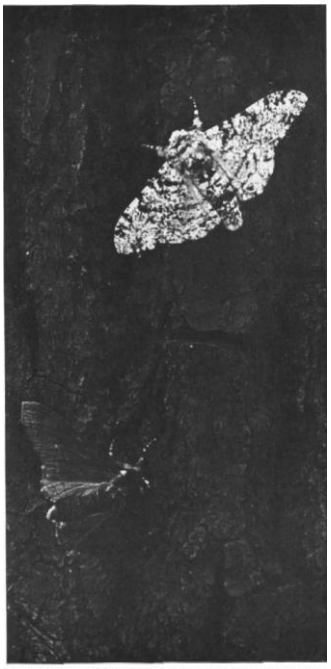


Now back to **peppered moths** and how the increased burning of **coal** as a result of the **industrial revolution**, served as an environmental **natural color selection** factor that resulted in an increase in the proportion of dark-colored peppered moths and a decrease in the proportion of the light-colored peppered moths.





On the one-hundred-year anniversary of the publication of *On the Origin of Species by Means of Natural Selection, Or the Preservation of Favoured Races in the Struggle for Life* by Charles Darwin, **H. B. D. Kettlewell** (1959) published a paper in *Scientific American* titled, *Darwin's Missing Evidence*, in which he extended James Tutt's work on peppered moths and other moths that fly at night and rest on tree trunks or on the underside of branches during the day. Bernard Kettlewell documented that in England, over seventy species of light-colored moths also became darker and that the trend extended to other industrialized countries including France, Germany, Poland, Czechoslovakia, Canada, and the United States.



DARK AND LIGHT FORMS of the peppered moth were photographed on the trunk of a oak blackened by the polluted air of the English industrial city of Birmingham. The lig form (*Biston betularia*) is clearly visible; the dark form (*carbonaria*) is well camouflage

Bernard Kettlewell (1955) marked and released light-colored, intermediate-colored, and dark-colored peppered moths in a **polluted forest in the Christopher Cadbury Bird Reserve near the manufacturing city of Birmingham England**. Birds such as the Robin, Hedge Sparrow, and Great Tit preyed on the peppered moths. After a couple of days, Bernard Kettlewell recaptured more than twice as many dark-colored peppered moths as intermediate-colored or light-colored peppered moths, suggesting that the dark-colored peppered moths were better **camouflaged** and could hide from the predatory birds better than the lighter colored peppered moths, and they could **produce more offspring** that were also **camouflaged** and could hide from the predatory birds. In polluted environments, the dark-colored peppered moths **survive because they are**

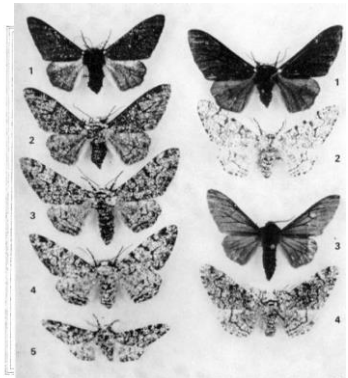
the fittest and are defined as the fittest because they survive in the greatest proportion.

Then Kettlewell (1955) marked and released light-colored, intermediate-colored, and dark-colored peppered moths near Dorset England in "*Deanend Wood, an unspoilt relict part of an ancient deciduous forest."* Birds such as the Robin, Song Thrush, Yellowhammer, Nuthatch, and Spotted flycatcher preyed on the peppered moths. After a couple of days, Kettlewell recaptured three times as many light-colored peppered moths as dark-colored peppered moths, suggesting that the light-colored peppered moths were better **camouflaged** and could hide from the predatory birds better than the darker colored peppered moths and **produce more offspring** that were also **camouflaged** and could also hide from the predatory birds. In unpolluted environments, the light-colored peppered moths **survive because they are the fittest** and are defined as the fittest because they survive in the greatest proportion.



SAME TWO FORMS of the peppered moth were photographed against the lichen-encrusted trunk of an oak in an unpolluted area. Here it is the dark form which may be clearly seen. The light form, almost invisible, is just below and to the right of the dark form.

Amateur entomologists studied the forests throughout Great Britain and found that the proportion of dark variants of the peppered moths was greater in woods near industrialized cities in the south of England and the proportion of light-colored pepper moths was greater throughout the rest of Great Britain in the more pristine areas. The intermediate-colored peppered moths (*Biston betularia insularia*) were more prevalent in the in the semi-polluted areas. These data indicate that the predominant color of peppered moths in a given environment is determined by the ability of the peppered moth to hide from



PROPORTION OF FORMS of the peppered moth at various locations in the British Isles is indicated on this map. The open area within a colored circle represents the proportion of the light form *Biston betularia* recorded; the solid colored area, the proportion of the dark form *carbonaria*; the hatched colored area, the proportion of another dark form, *insularia*. Small black circles on the map indicate the location of major industrial centers.

predatory birds long enough to reproduce and pass on their genes that control melanism.

Kettlewell (1959) ended his paper celebrating the centennial of the publication of *On the Origin of Species by Means of Natural Selection, Or the Preservation of Favoured Races in the Struggle for Life* with "*Melanism is not a recent phenomenon but a very old one. It enables us to appreciate the vast reserves of genetic variability which are contained within each species, and which can be summoned when the occasion arises.* ***Had Darwin observed industrial melanism he would have seen evolution occurring not in thousands of years but in thousands of days-well within his lifetime. He would have witnessed the consummation and confirmation of his life's work***."

However, the three-color variants of the peppered moth all interbreed and are thus considered to be variants of a single species. While Charles Darwin would consider this **incipient speciation** and evidence for the **origin of species**, Samuel Wilberforce would consider this to be **variation on an archetype**. Is there any scientific basis for choosing one interpretation over the other? It is worth asking to what extent the gradual mechanism of evolution by natural selection applies to variation, speciation, generiation, familiation, orderization, classization and kingdomization? To what extent does Richard Owen's idea of discontinuous congenital changes apply to these processes?

In England, the proportion of light-colored peppered moths surviving predation is greater than the proportion of dark-colored peppered moths surviving predation as a result of the **air getting cleaner**. Cook et al.

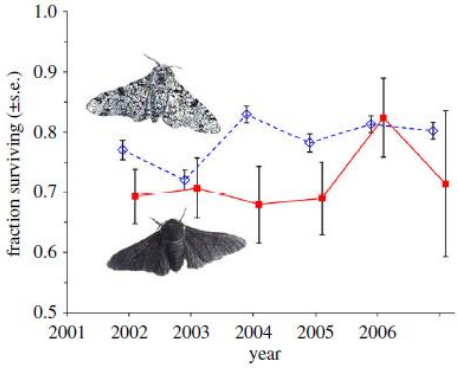


Figure 1. Survival of moths (±s.e.) over the course of the predation experiment. Unfilled diamonds with dashed lines, non-melanic; filled squares with solid lines, melanic.

(2012) write, "***The new data, coupled with the weight of previously existing data convincingly show that 'industrial melanism in the peppered moth is still one of the clearest and most easily understood examples of Darwinian evolution in action'***."

How well does the example of the changing characteristics of the peppered moths account for T. H. Huxley's thought that, "*One thing which weighs with me against pessimism, and tells for a benevolent Author of the Universe, is, my enjoyment of scenery and music. I do not see how they can have helped in the struggle for existence. They are gratuitous gifts*"?



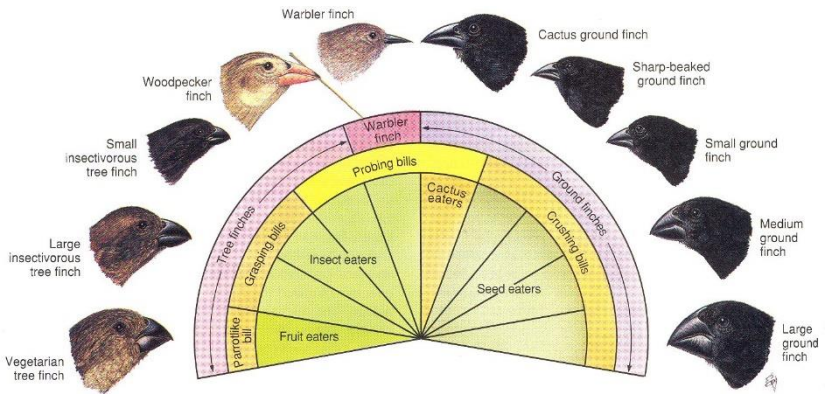




Further evidence for Darwinian evolution came from the study of birds and tortoises living on the Galapagos Islands. While on the Beagle, Darwin visited an archipelago of volcanic islands known as the **Galapagos Islands** where he noticed that there were a group of **finches** whose melanin-containing black to greyish brown plumage was unremarkable and whose songs were simple and unmelodious. However, their **beaks** were noteworthy in terms of the variety of sizes and shapes. Darwin (1845) wrote, "*Seeing this gradation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for*

different ends." Indeed, this kind of variation gave Darwin the idea that **species may not be immutable, and this variation may lead to the appearance of new species**. He went on to write in *The Voyage of the Beagle*, "*The natural history of these islands is eminently curious, and well deserves attention. Most of the organic productions are aboriginal creations, found nowhere else; there is even a difference between the inhabitants of the different islands; yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean, between 500 and 600 miles in width. The archipelago is a little world within itself, or rather a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions. Considering the small size of the islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth.*"

Darwin brought the birds back to England where John Gould classified them as a new group of related species. David Lack (1947) showed that each type of beak was specialized to make use of a different food sources (fruit, insect, cactus, and seeds). The finches that ate seeds required heavy beaks to crack them open, the finch that drank nectar required a long, curved beak, the finches that ate insects from a tree required a sharp pointed beak



like that of a woodpecker. They also use a twig or a cactus spine as a tool to pry out insects. In addition, experiments and observations done by Lack show that the finches recognize members of their own species by their beaks. According to Lack, the beak shapes and sizes evolved as a result of natural selection, the birds with the most adapted beak for the food available on the island would leave the most offspring and therefore be the fittest.

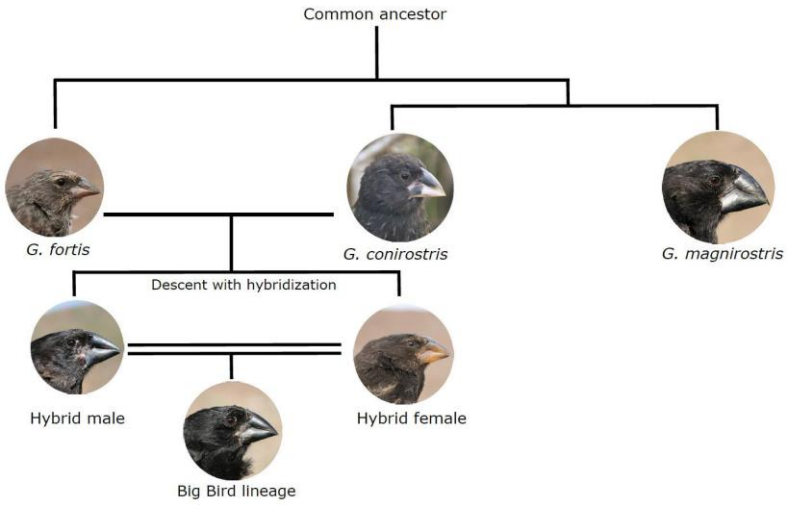


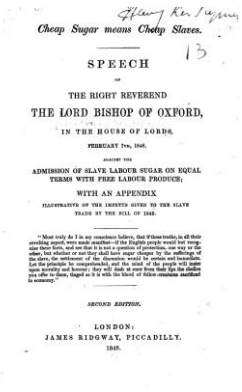




Update from the Galapagos Islands: Here is the best evidence so far on the origin of species: (https://www.nytimes.com/2014/08/05/science/in-darwins-footsteps.html) **Peter and Rosemary Grant** spent 40 years on **Daphne Island** in the Galapagos. In 1981, a hybrid of the medium-beaked ground finch and the cactus finch arrived on the island. They called him **Big Bird**. Big Bird had a different song compared to the other finches. He could also eat large tough seeds, small soft seeds, and nectar from the cactus. Was Big Bird's appearance best described as gradual or saltational?

Big Bird mated with a medium-beak female. Their children, grandchildren, and great-grandchildren breed only among their kind, and all sing his unusual song. Has this inbred population become a new species? According to the Grants, "*It is highly unlikely that we have witnessed the origin of a long-lasting species, but not impossible*."




Cheap Sugar means Cheap Slaves.

SPEECH

OF

THE RIGHT REVEREND

THE LORD BISHOP OF OXFORD,

IN THE HOUSE OF LORDS,

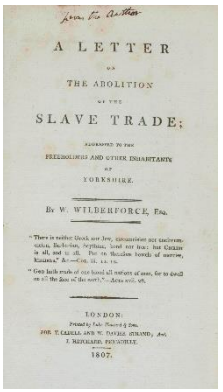
ADMISSION OF SLAVE LABOUR SUGAR ON EQUAL TERMS WITH FREE LABOUR PRODUCE;

WITH AN APPENDIX

SECOND EDITION.

LONDON:

JAMES RIDGWAY, PICCADILLY.


A LETTER

ON

THE ABOLITION

OF THE

SLAVE TRADE;

ADDRESSED TO THE

FREEHOLDERS AND OTHER INHABITANTS

OF

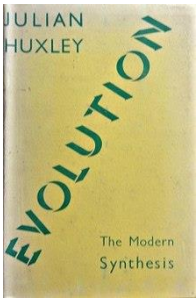
YORKSHIRE.

By W. WILBERFORCE, Esq.

LONDON:

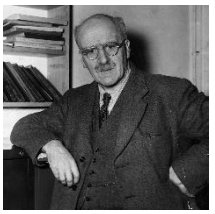
1807.

The peppered moths and Galapagos finches provide clear evidence in support of Darwinian evolution, but is there such clear evidence that supports the origin of reason, conscience, self-reflection, writing, speaking, and mathematical ability, and moral reasoning by natural selection in humans? What are the values and limitations of Darwin's theory of evolution by natural selection when it comes to humans? What does it mean to leave the most offspring and be defined evolutionarily as being the fittest? How does evolution by natural selection define what it means to be human?

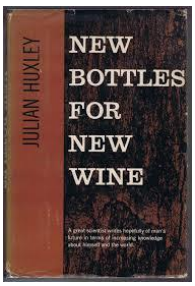


Julian Huxley (1942), T. H. Huxley's grandson, put together Mendelian genetics, which had not been rediscovered until after T. H. Huxley's death, with Darwinian evolution to get "*The Modern Synthesis*." According to the modern Synthesis, life coded by genes evolved gradually, somewhat erratically but steadily from unicellular organisms through fish, amphibians, reptiles, birds, and mammals to humans in an **upward progression that is characterized by the use of mental ability to yield greater and greater control over and even independence of the external environment**.

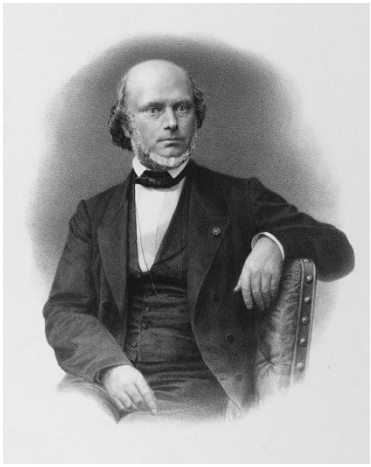
For Julian Huxley to be consistent with the principles of Darwinian evolution, those humans who had **more offspring** would have to be the **fittest** and it is they who should affect **human progress**. Yet Huxley (1944) took an about face when he realized that "***the lowest strata, allegedly less well-endowed genetically, are reproducing relatively too fast***." This led him to propose "***something in the nature of a religion***" that he called **evolutionary humanism** that promoted **eugenic** policies, particularly birth control with its ability **to separate love, sex**, **and reproduction**, to right this wrong (https://ia801605.us.archive.org/9/items/in.ernet.dli.2015.280031/2015.280031.Evolution-The.pdf; https://www.nytimes.com/1975/02/16/archives/julian-huxley-scientist-and-writer-dies-julian-huxley-scientist-and.html). In the *something in the nature of a religion* of evolutionary humanism, the genetically well-endowed scientific elite would decide who reproduces and who does not. According to Huxley (1957), "*The working out of an effective and acceptable eugenic policy will be seen as not only an urgent but an inspiring task, and its political or theological obstruction as immoral*." **J. B. S. Haldane** (1932) realized that in the shift from biological evolution to progress, "*we are already leaving the relatively firm ground of scientific objectivity for the shifting morass of human values*."



There is a contradiction between Darwinian evolution and progressivism. You must decide which is the most fundamental definition of human fitness—Darwin's biological definition of having the most offspring or another definition that defines human fitness in another non-Darwinian way—as T. H. Huxley (1893) realized late in life when he wrote, "***the ape and tiger methods of the struggle for existence are not reconcilable with sound ethical principles***…."



In his essay on *Evolutionary Humanism*, Julian Huxley (1957) stated, "*The main difference is that whereas T. H. Huxley never quite rid himself of the* ***dualistic*** *premiss of his age, we are perforce* ***monists****, in the sense of* ***believers*** *in the oneness of things, the unitary nature of reality; we see ourselves, together with our* ***science and our beliefs****, as an integral part of the cosmic process instead of somehow outside of it*." According to Julian Huxley, "*the crux of the so-called conflict between science and religion…should more properly be described as a conflict between the progress of established knowledge and a particular type of religious hypothesis*." I ask, isn't established knowledge based on assumptions and isn't it worthy of being questioned? How else does one develop a deep relationship with knowledge...whether it be a knowledge of God or a knowledge of science? In Julian Huxley's Progressive view, established Science and a faithful belief in it in the twentieth century replaces God and the "*repugnant and indeed intellectually immoral*" belief in God in the nineteenth period. Huxley further states that "*the advance of knowledge is making supernaturalism in general, and the god hypothesis in particular, untenable for an increasing number of educated people…religion must now ally itself wholeheartedly with science* [with its] *disinterested devotion to truth*." What assumptions does Huxley make about who is educated (and who should be allowed to reproduce)? What is your own Weltanschauung or worldview that both depends upon and guides your line of reasoning?



There is a lot that comes with the scientific and religious view of the origin of human beings. Jean-Louis-Armand de Quatrefages de Breau looked at the data and concluded that he would maintain an open mind regarding the question of the origin of species. Robert E. Stebbins (1988) captured the thought of Jean-Louis-

Armand de Quatrefages de Breau when it came to the difference between the origin of species and variations on a type:

In contrast to Flourens's critical, naive, and bitter attacks were the fair and ubiquitous writings of ***Jean-Louis-Armand de Quatrefages de Breau*** *(1810-1892), professor at the Sorbonne in 1847, professor of anthropology at the Museum of Natural History in 1855, elected to the Academy of Sciences in 1852, president of the academy in 1873. De Quatrefages was almost universally respected as a gentleman and as a scientist. His scientific interests and knowledge ranged widely, and his numerous publications included many articles and two most important books on Darwin: Darwin et ses precurseurs frangais: Etude sur le transformisme (1870 and 1892) and Les Ejnuies de Darwin (1894).*

Darwin had very high respect for de Quatrefages. He had sent him a prepublication copy of the Origin of Species, realizing that de Quatrefages would be a very important man to have on his side. Considering de Quatrefages's many writings and his stature among French scientists, it is tempting to suggest that the conversion of no other single man could have been more important for the French reception of Darwin. There is a striking parallel between Huxley's statement that Darwinism's 'logical foundation was insecure so long as experiments in selective breeding had not produced varieties which were more or less infertile' and de Quatrefages's assertions of the current lack of proof. Huxley made his 'act of philosophical faith,' but de Quatrefages did not.

De Quatrefages's interest in the species question and his intellectual honesty can perhaps be indicated best by a paragraph appearing in the fourth of five articles he wrote for the Revue des Deux Mondes in 1869:

Such is the last word of this long study. It is not without regret that I write it. I would not be of my own time, if I did not understand and share the anxious curiosity with which so many educated or common intelligences today question the creation on the secrets of its origin and of its end in the name of science. To avow that human knowledge cannot even yet approach these problems is as painful to me as to any other person. However, one thought sweetens this otherwise galling feeling of impotence. I like to believe that we are opening out the happier route, and we are perhaps preparing the distant solution of these questions which are unfathomable for us. As humble as it may appear to certain minds, this task abundantly has its grandeur and its charms. It is that which our fathers have accomplished for us; let us accomplish it for our sons; but if we want to leave them

a genuine inheritance, let us not dream about that which can be, but let us look for that which is.

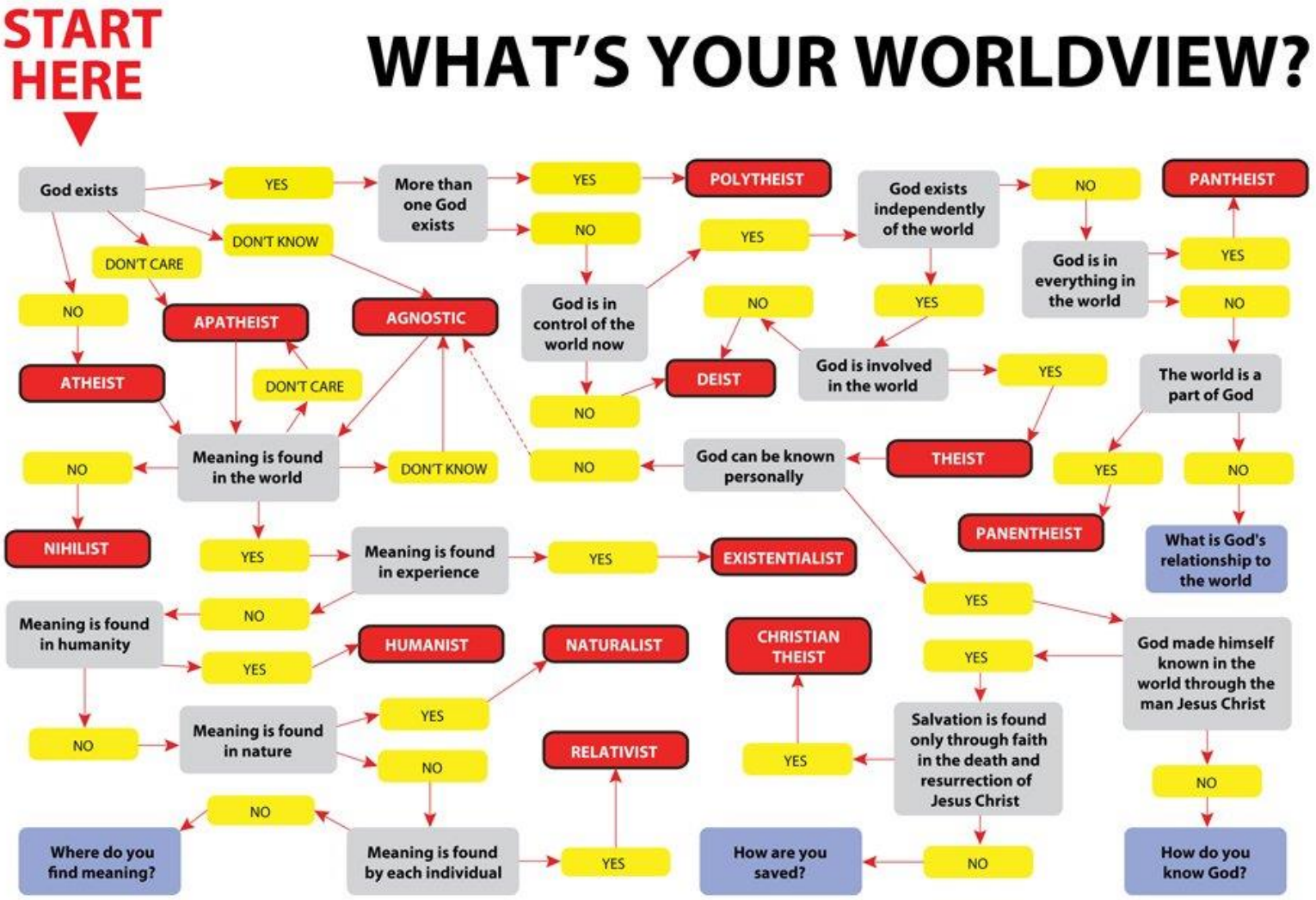
De Quatrefages's consistency of argument over more than thirty years is remarkable. He saw the arguments for evolution as clearly as any person could. It was even claimed that he presented Darwin's arguments better than Darwin himself did. He deeply respected Darwin's empirical work and even saw a remarkable correspondence between Darwin's theories and reality. He certainly saw much value in the ideas of natural selection, struggle for existence, many types of adaptation to the environment, etc. He was pleased that Darwin's later works allowed for factors in addition to natural selection. ***Nevertheless, Darwin had not demonstrated a single change from one species to another, and de Quatrefages adamantly withheld assent to transformism pending such empirical demonstration.*** *In his last book, published posthumously, he said in a mood of at least mild disappointment: 'Each day, in the crowd of publications of many sorts and on the most diverse subjects, it is affirmed that transformism presently reigns as master in science, and that it has the assent of all somewhat well informed minds and those of all savants truly worthy of the name.' He seemed to suggest that the idea of transformation of species would probably be accepted in the future on the basis of more knowledge than was yet available, but such commitment would be premature at the time he wrote.*

He explicitly defended the right and necessity for propounding theories, but said that, in the very important question of evolution, the matter should be kept much more open than either the pro-Darwinists or the anti-Darwinists wanted. While the evolutionists insisted on more variation than could be substantiated by the facts, the antievolutionists were too dogmatic and went beyond the facts in denying any change. In contrast, de Quatrefages underlined the fact of human ignorance. Toward transformism he remained agnostic and was critical of the true believers on either side of him."

Charles Darwin sent a letter to Quatrefages on May 28, 1870, saying

"*Dear Sir*

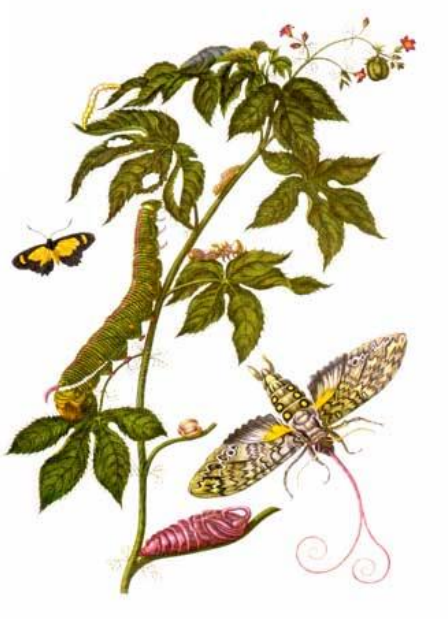
I have received and read your volume & am much obliged for your present.[2] *The whole strikes me as a wonderfully clear & able discussion, & I was much interested by it to the last page. It is impossible that any account of my views could be fairer, or as far as space permitted fuller, than that which you have given. The way in which you repeatedly mention my name is most gratifying to me. When I finished the second part, I thought that you had stated the case so favourably that you would make more converts on my side than on your own side. On reading the subsequent parts I had to change my sanguine view. In these latter parts many of your strictures are severe enough, but all are given with perfect courtesy & fairness.*[3] ***I can truly say I would rather be criticised by you in this manner than praised by many others****. I agree with some of your criticisms, but differ entirely from the remainder; but I will not trouble you with any remarks*."


START HERE
WHAT'S YOUR WORLDVIEW?
God exists
YES
More than one God exists
YES
POLYTHEIST
DON'T KNOW
NO
DON'T CARE
NO
APATHEIST
AGNOSTIC
God is in control of the world now
YES
God exists independently of the world
NO
PANTHEIST
NO
DEIST
YES
God is in everything in the world
YES
ATHEIST
DON'T CARE
God is involved in the world
YES
NO
NO
The world is a part of God
Meaning is found in the world
DON'T KNOW
NO
God can be known personally
THEIST
YES
NO
NO
NIHILIST
YES
Meaning is found in experience
YES
EXISTENTIALIST
PANENTHEIST
What is God's relationship to the world
YES
NO
Meaning is found in humanity
HUMANIST
NATURALIST
CHRISTIAN THEIST
YES
God made himself known in the world through the man Jesus Christ
YES
NO
Meaning is found in nature
YES
NO
RELATIVIST
YES
Salvation is found only through faith in the death and resurrection of Jesus Christ
NO
NO
Where do you find meaning?
Meaning is found by each individual
YES
How are you saved?
NO
How do you know God?

Going back to moths, Maria **Sibylla Merian** (1705), who was an exceptional illustrator of nature, was the first to distinguish the moths from the butterflies. "*I created the first classification for all the insects which had chrysalises, the* ***daytime butterflies*** *and the* ***nighttime moths***." (See *Metamorphosis insectorum Surinamensium at* [*https://gdz.sub.uni-goettingen.de/id/PPN477653782?tify={%22pages%22:[11],%22view%22:%22toc%22*](https://gdz.sub.uni-goettingen.de/id/PPN477653782?tify={%22pages%22:[11],%22view%22:%22toc%22)) This distinction tells us something about their vision. **Scotopic** for moths and **photopic** for butterflies.

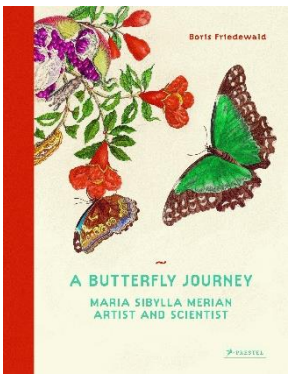












Melanin is a common pigment in the animal kingdom. Melanin produced by the melanophores of other cold-blooded animals, including **toads** and **tadpoles** is a pigment that allows for both **static** and **dynamic camouflage**.





The paucity of melanin produced by the melanocytes in **polar bears** compared with the related **brown Kodiak bears** allows for **static camouflage** in the arctic ice. Although polar bears and brown bears are considered to be different species, they can breed and produce hybrids known as pizzly bears, prizzly bears or grolar bears.







The **arctic fox** produces melanin in its hair in the summer but not in the winter allowing for seasonal dynamic camouflage.





Crows, which are smaller, and ravens, which are larger, are famous for their feathers, made jet black by melanin (although the raven's feathers have a greater bluish iridescence produced by structure not by pigment than the crow's feathers). I do not know the function of the melanin in crows and ravens.



Cormorants also have black feathers. Unlike other water birds, they have less developed preen oil glands. While this may make it easier for them to swim underwater with speed and agility, their feathers will be waterlogged on land or in the air. The black color of their feathers makes it quicker for them to dry out their feathers in the sunlight.



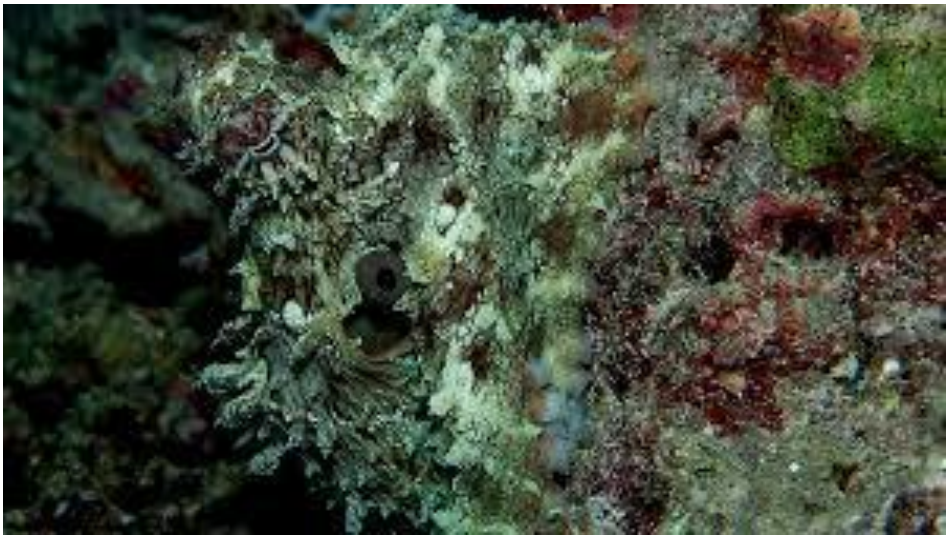


Cephalopods, including octopus and squid secrete black, blue-black or brown **ink** that is colored with melanin to avoid capture.

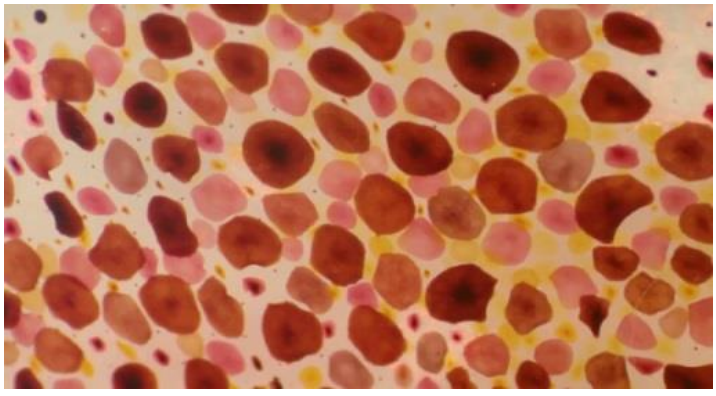




Cephalopods are the masters of camouflage. Can you see the octopus in this picture?



Cephalopods have yellow, red, and brown **chromatophores** that give them dynamic camouflage (http://www.youtube.com/watch?v=eS-USrwuUfA). A chromatophore is multicellular and consists of a single chromatophore cell that contains pigment granules that are enclosed in a sacculus, and muscle, and nerve cells. Unlike melanophores in cold-blooded animals



where the melanosomes aggregate or disperse as a result of intracellular motors, the chromophores of cephalopods change color when the surrounding muscle squeezes the chromatophore cell and changes the size and shape of the sacculus.

Here are some animals that use camouflage to look like or **mimic** plants. The **dead leaf butterfly** looks like a dead leaf.



The **Malaysian orchid mantis** looks like a part of the flower.



The **stick insects** look like twigs and the **leaf insects** or **walking leaves** look like leaves.





Plants also produce melanin, which is known as **phytomelanin**. It is thought to serve as mechanical protection against predators.



While it is rare for animals to be green, most plants have **green leaves** and **stems** due to the **reflectance and transmittance of sunlight** from and through the **chlorophyll** (from the Greek *chloros χλωρός* and *phyllon φύλλον* which means green and leaf) molecules in the **chloroplasts**. In **variegated leaves**, some cells in the leaves do not produce chloroplasts with chlorophyll.





The chloroplasts also contain **carotenoids** which have a dual role in photosynthesis—they act as **accessory antenna pigments** that capture blue light and transfer the radiant energy to chlorophyll. They also have a **protectant function** being able to safely dissipate excess radiant energy and damaging chemical energy under high light conditions.

The carotenoids in the chloroplasts include yellow **xanthophylls** (from the Greek *xanthos ξανθός* and *phyllon φύλλον*, which means yellow and leaf) and red, orange, or yellow **carotenes** (from the Latin *carota* which means carrots), both of which absorb blue light. The **kelp** that lives in the ocean where **blue light penetrates** best rely on a xanthophyll known as **fucoxanthin** to capture light and transfer the energy to chlorophyll. The fucoxanthin gives the brown algae their brown color.









The carotenoids in the leaves become visible in the fall and color the **fall foliage** yellow and orange.

Carotenoids are nutritious in that they provide us with molecules that we cannot synthesize ourselves. Because of their role in photosynthesis, carotenoids are found in dark green leaves. They are also found in other organs that have been bred to be yellow, orange, or red.

Carotenoids of the carotene group such as carotene and lycopene are necessary for vision, yet they are not produced in the human body. We must eat plants that contain carotenes that act as **precursors to vitamin** A, which is necessary for the formation of rhodopsin, the photopsins, and melanopsin. Sweet

potato, carrots, and broccoli are plants rich in carotenes that act as precursors to vitamin A.





Carotenoids of the xanthophyll group such as **lutein** and **zeaxanthin *cannot*** act as **precursors to vitamin A,** but they are found in the **macula lutea** and may be useful in protecting the eyes from photodamage. Dark green leafy vegetables and yellow corn are a rich source of these carotenoids. Chickens eat plants that produce xanthophylls and lay eggs that have yolks rich in xanthophylls.







Carotenes are also responsible for the coloring of **pink flamingos**. The carotenes that are responsible for the pink and orange color comes from the phytoplankton they eat and/or the phytoplankton-eating brine shrimp that they eat.



Likewise, the pink and orange color of **salmon** flesh comes from the phytoplankton they eat and/or the phytoplankton-eating brine shrimp that they eat.



Live lobsters can be blue, yellow, greenish, or orange—almost any color but red. The various colors are a result of the xanthophylls that are in the lobster's diet. The lobsters convert the plant xanthophylls into **astaxanthin**, a xanthophyll that when bound to a protein gives each lobster its characteristic color.

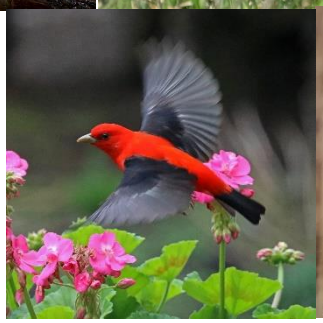


When any **lobster is cooked** in steaming water, the **astaxanthin** separates from the protein and gives its characteristic red color to the shell, no matter which color the living lobster was. The red color of **cooked crabs and shrimp** is also due to **astaxanthin**.



Male cardinals and other red (Scarlet Tanager, Red-Winged Blackbird), orange (Baltimore Oriole), or yellow (American Goldfinch) birds also owe their bright coloration to the carotenoids in their diet.




A diet rich in carotenoids imparts a **yellow tone** to **human skin**. The healthy glow that comes from eating a diet rich in carotenoids (e.g., carrot juice) may also protect the skin from oxidative damage caused by ultraviolet light.



Carotenes are important components of flowers. Carotenes give the yellow color to buttercups, the orange color to daffodils (*Narcissus*), and the red color to red hot poker flowers (*Kniphofia*).



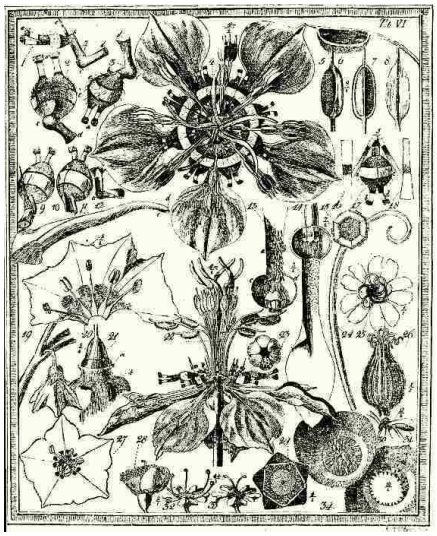


Before we discuss the color of flowers, let's ask, why do plants have such beautiful, showy, and colorful flowers? Leigh Hunt (1878) wrote in his book *The Seer or, Common-Places Refreshed*, "*We feel as if there were a moral as well as a material beauty in color, --an inherent gladness,--an intention on the part of Nature to share with us a pleasure felt by herself.* ***Colors are the smiles of Nature****. When they are extremely smiling, and break forth into other beauty besides, they are her laughs; as in the flowers. The '****laughing flowers.****' Says the poet* [Shelley]*; and it is* ***the business of the poet to feel truths beyond the proof of the mechanician****. Nature at all events, humanly speaking, is manifestly very fond of color; for she has made nothing without it. Her skies are blue; her fields green; her waters vary with her skies; her animals, minerals, vegetables, are all colored. She paints a great many of them in apparently superfluous hues, as if to show the dullest eye how she loves color.*"



The beauty of flowers is not primarily for our pleasure but to attract pollinators. In his book, *Insects and Flowers: The Biology of a Partnership*, **Friedrich Barth** calls flowers the "*masterpieces of biological adaptation. We cannot really understand flowers unless we know something about the insects that visit them. What is happening between them is a trade: food in exchange for pollination. The* ***kaleidoscope*** *of flower shapes, the* ***rainbow of brilliant colors****, the bouquet of scents—all these evolved because it was advantageous to give some guidance to insects searching for nectar and pollen*."





As documented in his book *The Secret of Nature in the Form and Fertilisation of Flowers Discovered,* **Christian Konrad Sprengel** (1793) first realized the importance of the relationship between flowers and insects. He wrote, "*My studies convinced me more and more that many—indeed, perhaps all—flowers with juice are fertilized by the insects that feed on this juice, and hence that although from the insects' point of view this feeding is the ultimate goal, from that of the flowers it is only a means, and in fact the only means, to a particular end: their pollination*."



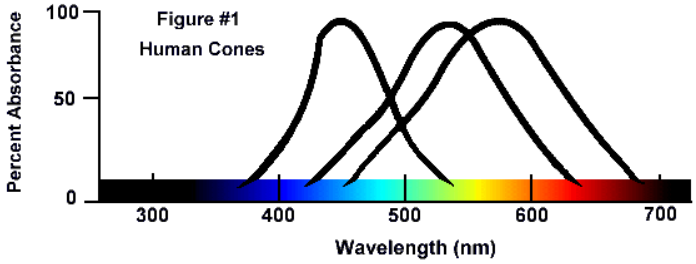
While looking at the hairs that cover the nectar on the inner portion of the petals of **cranesbill**, Sprengel (1793) realized "*That most flowers secrete nectar, and that this nectar which is protected from the rain, would be of no help to the insects if there were not some means of ensuring that they can easily find this food intended for them. Nature, which does nothing by halves, in this case again has found the most effective devices. First she has made sure that the insects discern the flowers from afar, either by sight or by smell or by both senses together. All nectar flowers are therefore decorated with a corolla, and very many emit a scent that to humans is in many cases pleasant, often unpleasant, sometimes unbearable—but always pleasant for the insect for which the nectar is intended. The corolla (except in a very few species) is colored—that is,* ***colored other than green****—so* ***that it stands out clearly against the green color of the plants***."



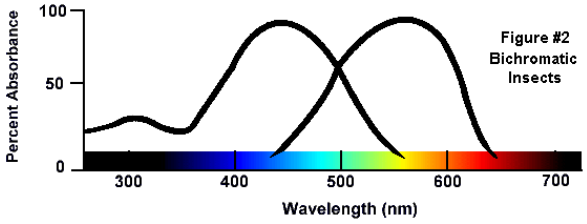
While looking at the yellow ring of the **forget-me-not flower**, Sprengel (1793) realized that "*when an insect attracted to a flower, whether by the beauty of its corolla or by its pleasant smell, alights: it will either detect the nectar immediately or it will not, because the nectar is located in a hidden place. In the later case Nature comes to its aid, with the* ***nectar guide****. This consists of one or more spots, lines, dots, or figures of a color different from that of the corolla as a whole, so that it stands out more or less strongly against the color of the corolla. It is always just where the insects must crawl in if they want to reach the nectar*."



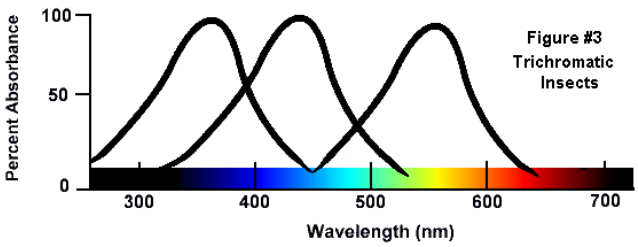
Humans see the **nectar guides** or **pathfinders** with our trichromatic cone-dominated photopic vision, but what do insects see? In the nineteenth century, John Lubbock and later Frank Lutz and Floyd Richtmyer (Cornell, 1922) in the twentieth century showed that ants and fruit flies, respectively, could see in the ultraviolet range that was invisible to humans.



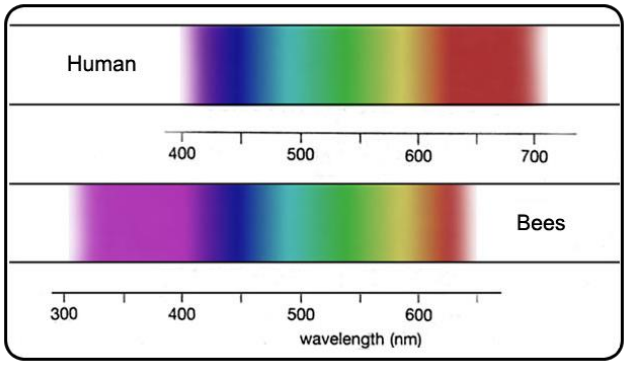
Most insects are bichromats that can see in the ultraviolet but cannot see red. Note that the combination of 370 nm + 600 nm light would appear to be the same as 500 nm light. Thus, the color of a flower that reflects ultraviolet and orange might look like the color of the leaves to a bichromatic insect.



Honeybees, humble- or bumblebees, and diurnal butterflies that play a large role in pollination have trichromatic vision. Unlike humans, they can perceive ultraviolet light but not red light. The trichromats see 300 nm + 560 nm light as a unique color "**bee-purple**" and not as blue green since the mid-wavelength photoreceptor is not stimulated. (http://www.cals.ncsu.edu/course/ent425/tutorial/colorvision.html). We do not know what bee-purple looks like to the bee, but we can know that it is a unique color.



Thus, vision in flower-visiting insects is shifted about 100 nm towards the short wavelengths compared with human vision.



Consequently, bees and other insect pollinators see the nectar guides in the flowers differently than we do. According to Frank Lutz (1924), "*The well known and widely accepted theory of the origin of conspicuous floral colors, that they have evolved by natural selection because they facilitate the visits of pollen-carrying insects, was propounded and has continued to be discussed on the basis of the colors as man sees them and with the*





assumption that the vision of insects is like that of man. Not only are floral colors not what they seem to us to be, but the vision of insects is quite different from normal human vision. It is therefore desirable, quite apart from any theory that may be involved, to get a better knowledge of the facts." So, after testing the ability of flower-visiting insects to go to ultraviolet light, Frank Lutz (1924) photographed flowers under ultraviolet light using a **pinhole camera** which transmits all wavelengths of light equally. He and others have shown the nectar guides that are invisible to the human eye but visible to the insect pollinators.

Tom Eisner (Cornell, 2001) has shown that flowers have **flavonoids** and other compounds that **absorb ultraviolet light** and act as **nectar guides** for insects.

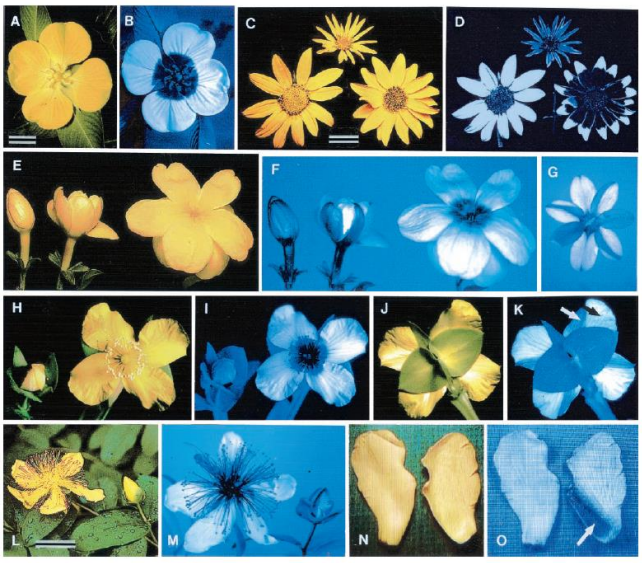


Fig. 1. Floral images in visible and UV light (the UV images are transduced into blue). (*A* and *B*) *Ludwigia peruviana*. (*C* and *D*) *Chrysopsis villosa* (*Left*), *Helianthella quinqueneris* (*Top*), and *Viguiera multiflora* (*Right*). (*E* and *F*) *J. primulinum*; bud opening into blossom. (*G*) Same, pressed flower in abaxial view. (*H–K*) *H. edisonianum* in frontal view beside bud and in abaxial view (arrows in *K*; white, portion of petal exposed in bud; black, portion of petal exposed in blossom). (*L* and *M*) *H. calycinum* flower, beside mature bud. (*N* and *O*) *H. calycinum* petals in frontal and abaxial view (the arrow in *O* points to the UV-absorbent zone on abaxial surface of petal). [Bars: *A* and *C* (1 cm); *L* (2 cm); *E* and *H* are slightly larger than natural size; *N* is at natural size.]



In most cases, flowers that attract insects have a showy corolla to attract the insects from afar. They also have nectar guides to help the insects find the nectar that would be difficult to find because it is covered in order for it to be protected from the rain. **Why do flowers go through so much trouble to attract insects**?

Christian Konrad Sprengel (1793) began to answer this question, when he noticed that "*Since many flowers are of one sex only, and probably as many more are dichogamous* [the stigma and anthers do not develop simultaneously], *nature seems to intend that no flower shall be fertilized by means of its own pollen*." He then showed that in **daylily**, the pistil cannot produce fertile seeds when it is pollinated with pollen from the same plant.





Thomas Andrew Knight (1799), who was interested in improving food plants, provided evidence about the value of outcrossing in plants that helped make Sprengel's (1797) conjecture that "*nature seems to intend that no flower shall be fertilized by means of its own pollen*" intelligible. Knight (1799) noticed that the pea plants that had been growing in his garden year after year had ceased to be productive. However, when he crossed the peas with another variety, the plants "*rose with excessive luxuriance*." Knight (1799) wrote "*I had, in this experiment, a striking instance of* ***the stimulative effects of crossing the breeds****; for the smallest variety, whose height rarely exceeded two feet, was increased to six feet; whilst the height of the large and luxuriant kind was very little diminished. By this process, it is evident, that any number of new varieties may be obtained; and it is highly probable, that many of these will be found better calculated to correct the defects of different soils and situations, than any we have at present; for I imagine that all we now possess, have in a great measure been the produce of accident; and it will rarely happen, in this or any other case, that accident has done all that art will be found able to accomplish.*"

Then **Charles Darwin** (1859) "*collected so large a body of facts, showing, in accordance with the almost universal belief of breeders, that with animals and plants a cross between different varieties, or between individuals of the same variety but of another strain,* ***gives vigour and fertility to the offspring****; and on the other hand, that* ***close interbreeding diminishes vigour and fertility****; that these facts alone incline me to believe that it* ***is a general law of nature*** *(utterly ignorant though we be of the meaning of the law)* ***that no organic being self-fertilises itself for an eternity of generations; but that a cross with another individual is occasionally—perhaps at very long intervals—indispensable****."*

In *The Variation of Animals and Plants under Domestication* (v. 2), Charles Darwin (1868,1875) presented the large body of facts and concluded "*The gain in constitutional vigour, derived from an occasional cross between individuals of the same variety, but belonging to distinct families, or between distinct varieties, has not been so largely or so frequently discussed, as have the evil effects of too close interbreeding. But the former point is the more important of the two, inasmuch as the evidence is more decisive.* ***The evil results from close interbreeding are difficult to detect, for they accumulate slowly****, and differ much in degree with different species;* ***whilst the good effects which almost invariably follow a cross are from the first manifest****.* ***It should, however, be clearly understood that the advantage of close interbreeding, as far as the retention of character is concerned, is indisputable, and often outweighs the evil of a slight loss of constitutional vigour****. In relation to the subject of domestication, the whole question is of some importance, as too close interbreeding interferes with the improvement of old races*."

Since most **mutations** are **deleterious** and **recessive**, outbreeding resulting from **cross-pollination has the advantage of suppressing the expression of a**

deleterious trait. On the other hand, it has the disadvantages of suppressing the very rare recessive advantageous trait.

By taking into consideration the general **value and limitations** of **inbreeding** resulting from **self-pollination** and **outbreeding** resulting from **cross-pollination**, we can understand the great lengths that flowers go to in order to **attract insects that will perform the cross-pollinations between different individuals of the same species**.

As an example of the great lengths that flowers will go to in order to attract a particular wasp, the parts of the **orchid flower mimic a female wasp**. To ensure pollination between individuals of the same species, each species has a flower that mimics a specific female wasp. While the wasp copulates with the flower, pollen gets attached to the wasp which eventually flies to another flower where it deposits the pollen on the stigma as it copulates with another female wasp mimic.





Here is a picture of a wasp copulating with an orchid flower:



DECEIVED BY physical and chemical cues, the wasp *Campsoscolia ciliata* tries to mate with the orchid *Ophrys speculum*. The labellum, or lower lip, of the flower has roughly the size, shape and fuzziness of a female wasp; male wasps apparently cannot distinguish between them. As a result the orchid is pollinated by wasps that visit one flower after another searching for a mate.

(http://www.youtube.com/watch?v=-h8I3cqpgnA).

Another example of a **close and specific relationship between a flower and a pollinator** is **Darwin's orchid**. Seeing that the spur of this orchid is about a foot long, Charles Darwin **predicted** in 1862 that a moth will be discovered that has a foot-long proboscis that will get the nectar at the bottom of the spur and pollinate the orchid. In 1903, such a moth, known as Morgan's Sphinx moth was (actually re-)discovered. It was actually first described by F .Walker in 1856.





Watch a video of Darwin's orchid being pollinated (http://www.youtube.com/watch?v=OMVN1EWxfAU).

The **value and limitations of inbreeding and outbreeding** was known to the **eugenicists of the 20th century**, yet it was not reflected in their interpretations and recommendations concerning the mating of diverse human beings. It is always important to question the experts. Nowadays, people who question the experts are often labeled "**deniers**" or "**contrarians**", but a justified scientific conclusion should be able to withstand scrutiny without resorting to name calling.

The **red**, **blue,** and **purple** colors of flowers are typically due to **anthocyanins**. In fact, the same flower can change color during its life. In bud, the color of the corolla of the **Japanese morning glory** is purple but when it opens up in the morning and is ripe to be pollinated, the corolla turns blue. The anthocyanin pigment is the same, but its color changes as a result of the change in the cell's pH—being red when the cell is acidic and blue when it is alkaline. By the afternoon, the flower wilts.

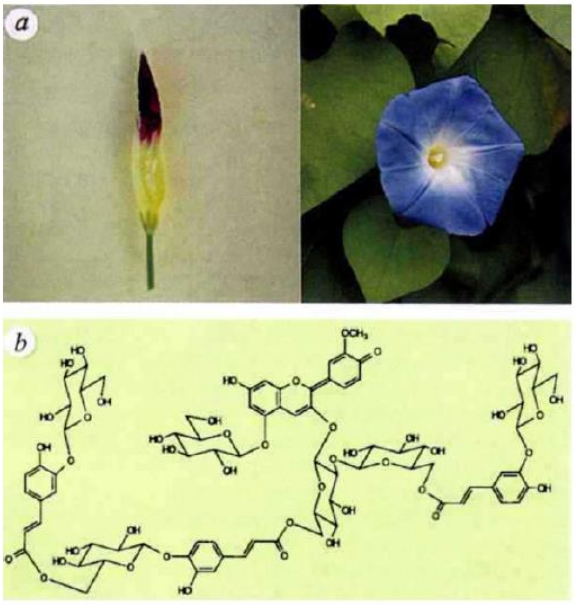


FIG. 1*a*, Blue blooming flower (right) and the bud (left) of *Ipomoea tricolor* cv. heavenly blue. *b*, Structure of heavenly blue anthocyanin (HBA)[9].

The colors of the corollas of some plants such as lantana change to a color that is less attractive to the pollinator after the flower has been pollinated and there is no longer any nectar for the pollinator.



The pH of the cells of **Hydrangea** determines the color of the anthocyanins within.

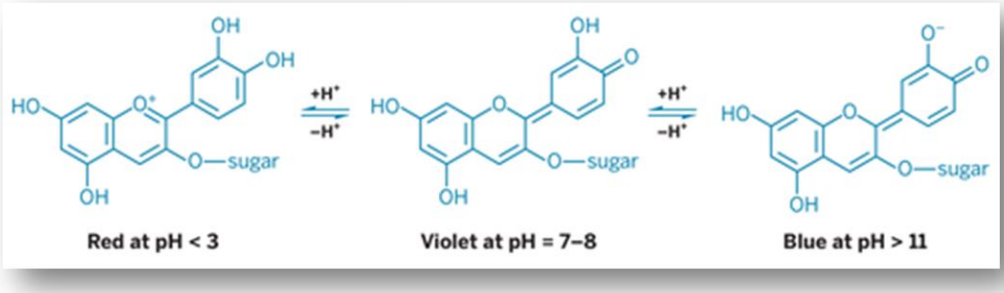




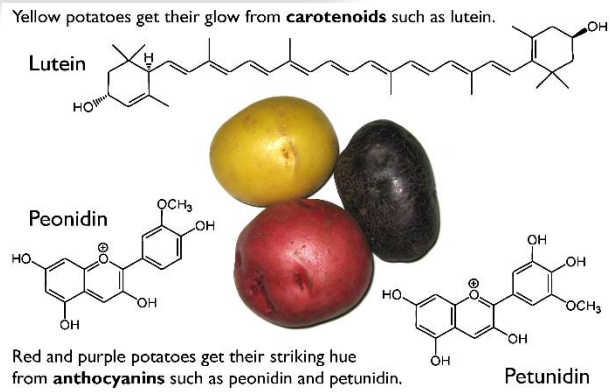
Anthocyanins, extracted from red cabbage, can be used as a **pH indicator**.







Red and purple potatoes, originally from the mountains of Bolivia and Peru, get their color from **anthocyanins.**



Fruits often contain **anthocyanins** that produce colors that **attract animals** that will **disperse the seeds** within the **fruits.**




The red color in apple skin is due to light-induced anthocyanin formation. Lailiang Cheng (Cornell, 2013) showed that the anthocyanins are produced where the apple gets sufficient sunlight.



During autumn in New England, as the chlorophyll in the leaves breaks down to recycle the nitrogen, and the yellow xanthophylls and orange carotenes become more visible, the cells also synthesize anthocyanins during this time that give the beautiful reds and purples to **fall foliage**.

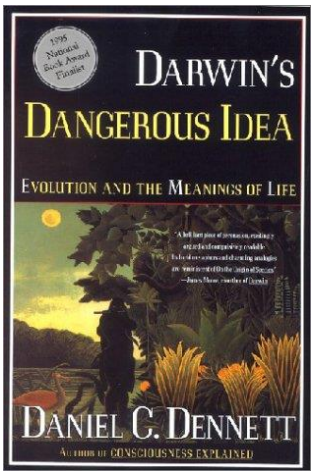


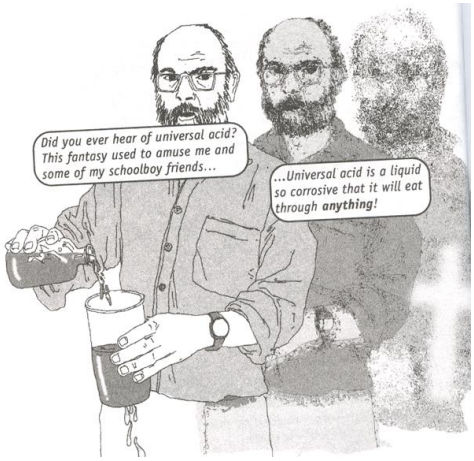

Nobody really knows the adaptive value of the beautiful fall colors. However, in the *Finest Show on Earth*, Edwin Matzke (1942) wrote about fall foliage, "'*Infinite shades of color,' says the artist; 'gradual changes in acidity.' Says the scientist*." He ended the article with this: "*Perhaps this is the botanical expression of 'art for art's sake.' In any event, it is a gracious way of saying good-bye*."



As we think about the beauty of nature, its reality, and the reality of ourselves who are part of nature, we can also think about **Daniel Dennett's** view of the evolution of this beauty out of chaos and his assertion that design does not need a designer. Daniel Dennett (1995) wrote in *Darwin's Dangerous Idea*, "*Did you ever hear of universal acid? This fantasy used to amuse me and some of my schoolboy friends—I have no idea whether we invented or inherited it, along with Spanish fly and saltpeter, as part of underground youth culture. Universal acid is a liquid so corrosive that it will eat through anything! The problem is: what do you keep it in? It dissolves glass bottles and stainless-steel canisters as readily as*

paper bags. What would happen if you somehow came upon or created a dollop of universal acid? Would the whole planet eventually be destroyed? What would it leave in its wake? After everything had been transformed by its encounter with universal acid, what would the world look like? Little did I realize that in a few years I would encounter an idea—Darwin's idea—bearing an unmistakable likeness to universal acid: it eats through just about every traditional concept, and leaves in its wake a revolutionized world-view, with most of the old landmarks still recognizable, but transformed in fundamental ways. Darwin's idea had been born as an answer to questions in biology, but it threatened to leak out, offering answers—welcome or not—to questions in cosmology (going in one direction) and psychology (going in the other direction). If redesign could be a mindless, algorithmic process of evolution, why couldn't that whole process itself be the product of evolution, and so forth all the way down? And if mindless evolution could account for the breathtakingly clever artifacts of the biosphere, how could the products of our own 'real' minds be exempt from an evolutionary explanation? ***Darwin's idea thus also threatened to spread all the way up, dissolving the illusion of our own authorship, our own divine spark of creativity and understanding***."





Considering humans as nothing more than mindless atoms and the divine spark within each individual as just an illusion can have the effect of a universal acid. Read the words of **Paul Popenoe** (1934), published in the Journal of Heredity (26(7):257-260): "***The policy of the present German government is therefore to***

gather about it the recognized leaders of the eugenics movement, and to depend largely on their counsel in framing a policy which will direct the destinies of the German people, as Hitler remarks in Mein Kampf, 'for the next thousand years.' *Whether this policy will be carried through successfully, of course remains to be seen. At best, mistakes will be inevitable. But the Nazis seem, as this scientific leadership becomes more and more prominent in their councils, to be avoiding the misplaced emphasis of their earlier pronouncements on questions of race, and to be proceeding toward a policy that will accord with the best thought of eugenicists in all civilized countries.* ***In any case, the present German government has given the first example in modern times of an administration based frankly and determinedly on the principles of eugenics.*** *It has thus posed the question in a way that no other people can ignore.*"





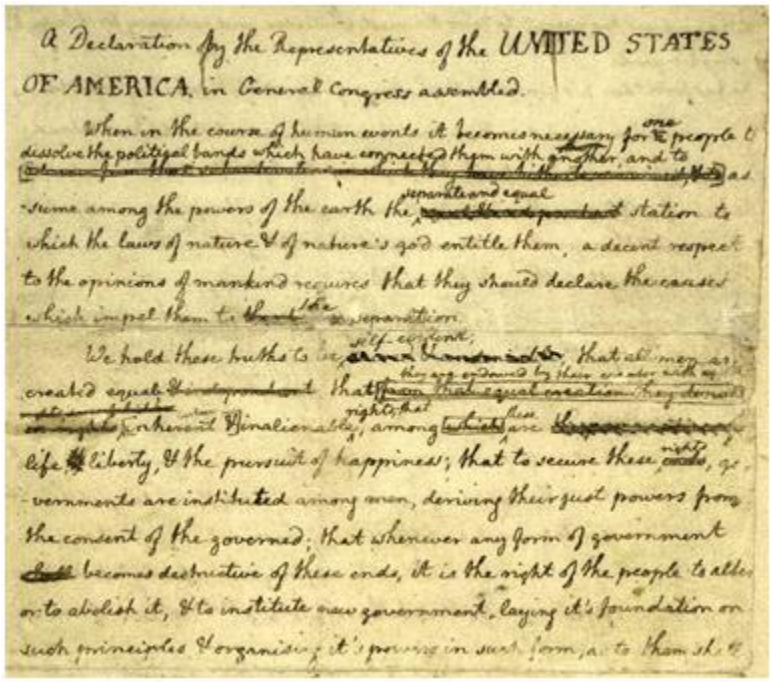
In "*The Suicide of Thought*," **G. K. Chesterton** describes the philosophic evolutionist as someone who reverses and negatives René Descartes epigram, "*I think; therefore I am*" by saying, "***I am not; therefore I cannot think***."

Chesterton goes on to say, "*In case the point is not clear, an historic example may illustrate it. The French Revolution was really an heroic and decisive thing, because the Jacobins willed something definite and limited.* ***They desired the***

freedoms of democracy, but also all the vetoes of democracy. They wished to have votes and NOT to have titles. *Republicanism had an ascetic side in Franklin or Robespierre as well as an expansive side in Danton or Wilkes. Therefore they have created something with a solid substance and shape, the square social equality and peasant wealth of France. But since then the revolutionary or speculative mind of Europe has been weakened by shrinking from any proposal because of the limits of that proposal. Liberalism has been degraded into liberality. Men have tried to turn "revolutionise" from a transitive to an intransitive verb. The Jacobin could tell you not only the system he would rebel against, but (what was more important) the system he would NOT rebel against, the system he would trust. But the new rebel is a Sceptic, and will not entirely trust anything. He has no loyalty; therefore he can never be really a revolutionist. And the fact that he doubts everything really gets in his way when he wants to denounce anything.* ***For all denunciation implies a moral doctrine of some kind; and the modern revolutionist doubts not only the institution he denounces, but the doctrine by which he denounces it.*** *Thus he writes one book complaining that imperial oppression insults the purity of women, and then he writes another book (about the sex problem) in which he insults it himself. He curses the Sultan because Christian girls lose their virginity, and then curses Mrs. Grundy because they keep it.* ***As a politician, he will cry out that war is a waste of life, and then, as a philosopher, that all life is waste of time.*** *A Russian pessimist will denounce a policeman for killing a peasant, and then prove by the highest philosophical principles that the peasant ought to have killed himself. A man denounces marriage as a lie, and then denounces aristocratic profligates for treating it as a lie. He calls a flag a bauble, and then blames the oppressors of Poland or Ireland because they take away that bauble.* ***The man of this school goes first to a political meeting, where he complains that savages are treated as if they were***

beasts; then he takes his hat and umbrella and goes on to a scientific meeting, where he proves that they practically are beasts. In short, the modern revolutionist, being an infinite sceptic, is always engaged in undermining his own mines. *In his book on politics he attacks men for trampling on morality; in his book on ethics he attacks morality for trampling on men. Therefore the modern man in revolt has become practically useless for all purposes of revolt. By rebelling against everything he has lost his right to rebel against anything*."

When developing our thoughts, it is important to know what are the **first principles, foundations, or cornerstones upon which our worldview rests**. Thomas Jefferson (1776) wrote in the **Declaration of Independence**, "*We hold these **truths** to be self-evident, that all men are created equal, that they are **endowed by their Creator** with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness*." Change the word Creator to yesterday's, today's, or tomorrow's scientists (or any other group of people) and then ask, what would our worldview be? What would our unalienable rights be? What would be the role of government in protecting these rights? Whose rights would be protected? What has been and what is the role of **melanin** in debating these rights?


A Declaration by the Representatives of the UNITED STATES OF AMERICA, in General Congress assembled.

When in the course of human events it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume among the powers of the earth the separate and equal station to which the laws of nature & of nature's god entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.

We hold these truths to be self-evident, that all men are created equal that from that equal creation they derive rights inherent & inalienable, among which are life, liberty, & the pursuit of happiness; that to secure these ends, governments are instituted among men, deriving their just powers from the consent of the governed; that whenever any form of government becomes destructive of these ends, it is the right of the people to alter or to abolish it, & to institute new government, laying it's foundation on such principles & organising it's powers in such form, as to them shall

grounded in the unique, Judeo-Christian concept of man's inherent dignity as a creature made in God's image, endowed with reason, free will, and an eternal soul. The Founders understood that one of Government's primary tasks is to preserve the freedom for each person to follow his own conscience, so they enshrined certain fundamental rights in our nation's constitution to guarantee this freedom."



Calvin Coolidge (1926) spoke the following words on the 150th anniversary of the Declaration of Independence: *"About the Declaration there is a finality that is exceedingly restful. It is often asserted that the world has made a great deal of progress since 1776, that we have had new thoughts and new experiences which have given us a great advance over the people of that day, and that we may therefore very well discard their conclusions for something more modern. But that reasoning can not be applied to this great charter.* ***If all men are created equal, that is final. If they are endowed with inalienable rights, that is final. If governments derive their just powers from the consent of the governed, that is final. No advance, no progress can be made beyond these propositions.*** *If anyone wishes to deny their truth or their soundness, the only direction in which he can proceed historically is not forward, but backward toward the time when there was no equality, no rights of the individual, no rule of the people. Those who wish to proceed in that direction can not lay claim to progress. They are reactionary. Their ideas are not more modern, but more ancient, than those of the Revolutionary fathers….No other theory is adequate to explain or comprehend the Declaration of Independence. It is the product of the spiritual insight of the people. We live in an* ***age of science*** *and of abounding accumulation of material things.*

These did not create our Declaration. Our Declaration created them. The things of the spirit come first. Unless we cling to that, all our material prosperity, overwhelming though it may appear, will turn to a barren sceptre in our grasp. If we are to maintain the great heritage which has been bequeathed to us, we must be like-minded as the fathers who created it. We must not sink into a pagan materialism. We must cultivate the reverence which they had for the things that are holy. We must follow the spiritual and moral leadership which they showed. We must keep replenished, that they may glow with a more compelling flame, the altar fires before which they worshiped."
https://teachingamericanhistory.org/library/document/speech-on-the-occasion-of-the-one-hundred-and-fiftieth-anniversary-of-the-declaration-of-independence/

In the *Descent of Man*, Darwin (1877) wrote, *The main conclusion arrived at in this work, namely, that man is descended from some lowly organised form, will, I regret to think, be highly distasteful to many. But there can hardly be a doubt that we are descended from barbarians. The astonishment which I felt on first seeing a party of Fuegians on a wild and broken shore will never be forgotten by me, for the reflection at once rushed into my mind--such were our ancestors. These men were absolutely naked and bedaubed with paint, their long hair was tangled, their mouths frothed with excitement, and their expression was wild, startled, and distrustful. They possessed hardly any arts, and like wild animals lived on what they could catch; they had no government, and were merciless to every one not of their own small tribe. He who has seen a savage in his native land will not feel much shame, if forced to acknowledge that the blood of some more humble creature flows in his veins. For my own part I would as soon be descended from that heroic little monkey, who braved his dreaded enemy in order to save the life of his keeper, or from that old baboon, who descending from the mountains,*

carried away in triumph his young comrade from a crowd of astonished dogs—as from a savage who delights to torture his enemies, offers up bloody sacrifices, practices infanticide without remorse, treats his wives like slaves, knows no decency, and is haunted by the grossest superstitions.

Man may be excused for feeling some pride at having risen, though not through his own exertions, to the very summit of the organic scale; and the fact of his having thus risen, instead of having been aboriginally placed there, may give him hope for a still higher destiny in the distant future. But we are not here concerned with hopes or fears, only with the truth as far as our reason permits us to discover it; and I have given the evidence to the best of my ability. We must, however, acknowledge, as it seems to me, that man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his god-like intellect which has penetrated into the movements and constitution of the solar system—with all these exalted powers—Man still bears in his bodily frame the indelible stamp of his lowly origin.

And slavery existed in the first civilizations in Sumer and Babylon. The Sumerian Code of Ur-Nammu, written ca. 2100-2050 B. C., and the Babylonia Code of Hammurabo, written ca. 1700, distinguish slaves from free persons. Prisoners of war were enslaved rather than killed, criminals were enslaved as punishment for crimes, and people who were in debt were enslaved, either voluntarily or involuntarily, to pay off their debts. Today, slavery still exists in the form of human trafficking, including child sex trafficking. Today, the smuggler-migrant connection is the most visible form of what Darwin calls the "slave-making instinct."



Leonard Cohen (1992) on the meaning of *Anthem*,



That is the background of the whole record, I mean if you have to come up with a philosophical ground, that is "Ring the bells that still can ring". It's no excuse...the dismal situation…and the future is no excuse for an abdication of your own personal responsibilities towards yourself and your job and your love. "Ring the bells that still can ring": they're few and far between but you can find them. "Forget your perfect offering" that is the hang-up that you're gonna work this thing out. Because we confuse this idea and we've forgotten the central myth of our culture which is the expulsion from the garden of Eden. This situation does not admit of solution of perfection. This is not the place where you make things perfect, neither in your marriage, nor in your work, nor anything, nor your love of God, nor your love of family or country. ***The thing is imperfect. And worse, there is a crack in everything that you can put together, physical objects, mental objects, constructions of any kind. But that's where the light gets in, and that's where the resurrection is and that's where the return, that's where the repentance is. It is with the confrontation, with the brokenness of things.***

Historically, people have recognized the importance of the cracks or chinks. Bishop **Joseph Hall** (1574-1656) wrote in a commentary on Absalom's return and conspiracy (2 Samuel 14:1-4), "***Good eyes see light though the smallest chinks***."



And **Edmund Waller** (1606–1687) wrote about light coming through the chinks in *Old Age and Death*,

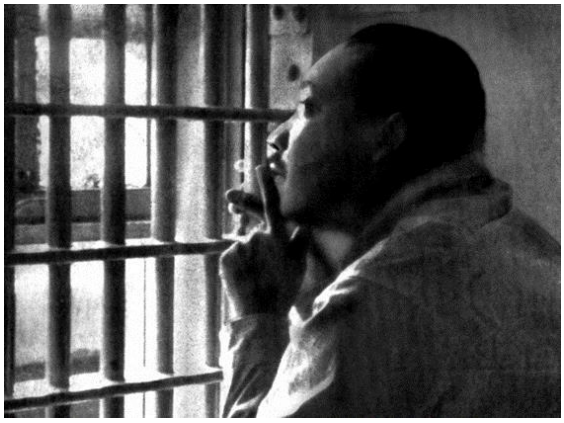


THE SEAS are quiet when the winds give o'er;
So calm are we when passions are no more.
For then we know how vain it was to boast
Of fleeting things, too certain to be lost.
Clouds of affection from our younger eyes
Conceal that emptiness which age descries.

The soul's dark cottage, battered and decayed,
Lets in new light through chinks that time has made:
Stronger by weakness, wiser men become,
As they draw near to their eternal home.
Leaving the old, both worlds at once they view,
That stand upon the threshold of the new.

Throughout this lecture and this course, I have discussed that there are contradictions in the "fundamental laws of nature." Thus, one must use their own sense of truth to weigh the evidence for each law in a contradictory pair of laws after examining the assumptions and the lines of reasoning upon which the laws are based. This allows one to conditionally choose which one of a contradictory pair of laws is really fundamental. **Martin Luther King Jr**. pointed out in his ***Letter from a Birmingham Jail*** written on April 16, 1963, that when it comes to society "*there are two types of laws: just and unjust…Now, what is the difference*

between the two? How does one determine whether a law is just or unjust?" Again, choosing the just laws mean ever-questioning and choosing conditionally the best fundamental assumptions and lines of reasoning.



"Letter from a Birmingham Jail"

My Dear Fellow Clergymen:

While confined here in the Birmingham city jail, I came across your recent statement calling my present activities "unwise and untimely." Seldom do I pause to answer criticism of my work and ideas. If I sought to answer all the criticisms that cross my desk, my secretaries would have little time for anything other than such correspondence in the course of the day, and I would have no time for constructive work. But since I feel that you are men of genuine good will and that your criticisms are sincerely set forth, I want to try to answer your statement in what I hope will be patient and reasonable terms.

I think I should indicate why I am here in Birmingham, since you have been influenced by the view which argues against "outsiders coming in." I have the honor of serving as president of the Southern Christian Leadership Conference, an organization operating in every southern state, with headquarters in Atlanta, Georgia. We have some eighty five affiliated organizations across the South, and one of them is the Alabama Christian Movement for Human Rights. Frequently we share staff, educational and financial resources with our affiliates. Several months ago the affiliate here in Birmingham asked us to be on call to engage in a nonviolent direct action program if such were deemed necessary. We readily consented, and when the hour came we lived up to our promise. So I, along with

several members of my staff, am here because I was invited here. I am here because I have organizational ties here.

But more basically, I am in Birmingham because injustice is here. Just as the prophets of the eighth century B.C. left their villages and carried their "thus saith the Lord" far beyond the boundaries of their home towns, and just as the Apostle Paul left his village of Tarsus and carried the gospel of Jesus Christ to the far corners of the Greco Roman world, so am I compelled to carry the ***gospel of freedom*** *beyond my own home town. Like Paul, I must constantly respond to the Macedonian call for aid.*

Moreover, I am cognizant of the interrelatedness of all communities and states. I cannot sit idly by in Atlanta and not be concerned about what happens in Birmingham. Injustice anywhere is a threat to justice everywhere. We are caught in an inescapable network of mutuality, tied in a single garment of destiny. Whatever affects one directly, affects all indirectly. Never again can we afford to live with the narrow, provincial "outside agitator" idea. Anyone who lives inside the United States can never be considered an outsider anywhere within its bounds.

You deplore the demonstrations taking place in Birmingham. But your statement, I am sorry to say, fails to express a similar concern for the conditions that brought about the demonstrations. I am sure that none of you would want to rest content with the superficial kind of social analysis that deals merely with effects and does not grapple with underlying causes. *It is unfortunate that demonstrations are taking place in Birmingham, but it is even more unfortunate that the city's white power structure left the Negro community with no alternative.*

In any nonviolent campaign there are four basic steps: collection of the facts to determine whether injustices exist; negotiation; self purification; and direct

action. We have gone through all these steps in Birmingham. There can be no gainsaying the fact that racial injustice engulfs this community. Birmingham is probably the most thoroughly segregated city in the United States. Its ugly record of brutality is widely known. Negroes have experienced grossly unjust treatment in the courts. There have been more unsolved bombings of Negro homes and churches in Birmingham than in any other city in the nation. These are the hard, brutal facts of the case. On the basis of these conditions, Negro leaders sought to negotiate with the city fathers. But the latter consistently refused to engage in good faith negotiation.

Then, last September, came the opportunity to talk with leaders of Birmingham's economic community. In the course of the negotiations, certain promises were made by the merchants--for example, to remove the stores' humiliating racial signs. On the basis of these promises, the Reverend Fred Shuttlesworth and the leaders of the Alabama Christian Movement for Human Rights agreed to a moratorium on all demonstrations. As the weeks and months went by, we realized that we were the victims of a broken promise. A few signs, briefly removed, returned; the others remained. As in so many past experiences, our hopes had been blasted, and the shadow of deep disappointment settled upon us. We had no alternative except to prepare for direct action, whereby we would present our very bodies as a means of laying our case before the conscience of the local and the national community. Mindful of the difficulties involved, we decided to undertake a process of self purification. We began a series of workshops on nonviolence, and we repeatedly asked ourselves: "Are you able to accept blows without retaliating?" "Are you able to endure the ordeal of jail?" We decided to schedule our direct action program for the Easter season, realizing that except for Christmas, this is the main shopping period of the year. Knowing that a strong

economic-withdrawal program would be the by product of direct action, we felt that this would be the best time to bring pressure to bear on the merchants for the needed change.

Then it occurred to us that Birmingham's mayoral election was coming up in March, and we speedily decided to postpone action until after election day. When we discovered that the Commissioner of Public Safety, Eugene "Bull" Connor, had piled up enough votes to be in the run off, we decided again to postpone action until the day after the run off so that the demonstrations could not be used to cloud the issues. Like many others, we waited to see Mr. Connor defeated, and to this end we endured postponement after postponement. Having aided in this community need, we felt that our direct action program could be delayed no longer.

You may well ask: "Why direct action? Why sit ins, marches and so forth? Isn't negotiation a better path?" You are quite right in calling for negotiation. Indeed, this is the very purpose of direct action. Nonviolent direct action seeks to create such a crisis and foster such a tension that a community which has constantly refused to negotiate is forced to confront the issue. It seeks so to dramatize the issue that it can no longer be ignored. My citing the creation of tension as part of the work of the nonviolent resister may sound rather shocking. But I must confess that I am not afraid of the word "tension." I have earnestly opposed violent tension, but there is a type of constructive, nonviolent tension which is necessary for growth. ***Just as Socrates felt that it was necessary to create a tension in the mind so that individuals could rise from the bondage of myths and half truths to the unfettered realm of creative analysis and objective appraisal, so must we see the need for nonviolent gadflies to create the kind of tension in society that will help men rise from the dark depths of prejudice and racism to the majestic heights of understanding and brotherhood****. The purpose of*

our direct action program is to create a situation so crisis packed that it will inevitably open the door to negotiation. I therefore concur with you in your call for negotiation. Too long has our beloved Southland been bogged down in a tragic effort to live in monologue rather than dialogue.

One of the basic points in your statement is that the action that I and my associates have taken in Birmingham is untimely. Some have asked: "Why didn't you give the new city administration time to act?" The only answer that I can give to this query is that the new Birmingham administration must be prodded about as much as the outgoing one, before it will act. We are sadly mistaken if we feel that the election of Albert Boutwell as mayor will bring the millennium to Birmingham. While Mr. Boutwell is a much more gentle person than Mr. Connor, they are both segregationists, dedicated to maintenance of the status quo. I have hope that Mr. Boutwell will be reasonable enough to see the futility of massive resistance to desegregation. But he will not see this without pressure from devotees of civil rights. My friends, I must say to you that we have not made a single gain in civil rights without determined legal and nonviolent pressure. ***Lamentably, it is an historical fact that privileged groups seldom give up their privileges voluntarily. Individuals may see the moral light and voluntarily give up their unjust posture; but, as Reinhold Niebuhr has reminded us, groups tend to be more immoral than individuals****.*

We know through painful experience that freedom is never voluntarily given by the oppressor; it must be demanded by the oppressed. Frankly, I have yet to engage in a direct action campaign that was "well timed" in the view of those who have not suffered unduly from the disease of segregation. For years now I have heard the word "Wait!" It rings in the ear of every Negro with piercing familiarity.

This "Wait" has almost always meant "Never." We must come to see, with one of our distinguished jurists, that "justice too long delayed is justice denied."

We have waited for more than 340 years for our constitutional and God given rights. The nations of Asia and Africa are moving with jetlike speed toward gaining political independence, but we still creep at horse and buggy pace toward gaining a cup of coffee at a lunch counter. *Perhaps it is easy for those who have never felt the stinging darts of segregation to say, "Wait." But when you have seen vicious mobs lynch your mothers and fathers at will and drown your sisters and brothers at whim; when you have seen hate filled policemen curse, kick and even kill your black brothers and sisters; when you see the vast majority of your twenty million Negro brothers smothering in an airtight cage of poverty in the midst of an affluent society; when you suddenly find your tongue twisted and your speech stammering as you seek to explain to your six year old daughter why she can't go to the public amusement park that has just been advertised on television, and see tears welling up in her eyes when she is told that Funtown is closed to colored children, and see ominous clouds of inferiority beginning to form in her little mental sky, and see her beginning to distort her personality by developing an unconscious bitterness toward white people; when you have to concoct an answer for a five year old son who is asking: "Daddy, why do white people treat colored people so mean?"; when you take a cross county drive and find it necessary to sleep night after night in the uncomfortable corners of your automobile because no motel will accept you; when you are humiliated day in and day out by nagging signs reading "white" and "colored"; when your first name becomes "nigger," your middle name becomes "boy" (however old you are) and your last name becomes "John," and your wife and mother are never given the respected title "Mrs."; when you are harried by day and haunted by night by the fact that you are*

a Negro, living constantly at tiptoe stance, never quite knowing what to expect next, and are plagued with inner fears and outer resentments; when you are forever fighting a degenerating sense of "nobodiness"--then you will understand why we find it difficult to wait. There comes a time when the cup of endurance runs over, and men are no longer willing to be plunged into the abyss of despair. I hope, sirs, you can understand our legitimate and unavoidable impatience. You express a great deal of anxiety over our willingness to break laws. This is certainly a legitimate concern. Since we so diligently urge people to obey the Supreme Court's decision of 1954 outlawing segregation in the public schools, at first glance it may seem rather paradoxical for us consciously to break laws. One may well ask: "How can you advocate breaking some laws and obeying others?" The answer lies in the fact that ***there are two types of laws: just and unjust****. I would be the first to advocate obeying just laws. One has not only a legal but a moral responsibility to obey just laws. Conversely, one has a moral responsibility to disobey unjust laws. I would agree with St. Augustine that "****an unjust law is no law at all****."*

Now, what is the difference between the two? How does one determine whether a law is just or unjust? A just law is a man made code that squares with the moral law or the law of God. An unjust law is a code that is out of harmony with the moral law. To put it in the terms of St. Thomas Aquinas: An unjust law is a human law that is not rooted in eternal law and natural law. Any law that uplifts human personality is just. Any law that degrades human personality is unjust. All segregation statutes are unjust because segregation distorts the soul and damages the personality. It gives the segregator a false sense of superiority and the segregated a false sense of inferiority. Segregation, to use the terminology of the Jewish philosopher Martin Buber, substitutes an "I it" relationship for an "I thou" relationship and ends up relegating persons to the

status of things. Hence segregation is not only politically, economically and sociologically unsound, it is morally wrong and sinful. Paul Tillich has said that sin is separation. Is not segregation an existential expression of man's tragic separation, his awful estrangement, his terrible sinfulness? Thus it is that I can urge men to obey the 1954 decision of the Supreme Court, for it is morally right; and I can urge them to disobey segregation ordinances, for they are morally wrong.

Let us consider a more concrete example of just and unjust laws. An unjust law is a code that a numerical or power majority group compels a minority group to obey but does not make binding on itself. This is difference made legal. By the same token, a just law is a code that a majority compels a minority to follow and that it is willing to follow itself. This is sameness made legal. *Let me give another explanation. A law is unjust if it is inflicted on a minority that, as a result of being denied the right to vote, had no part in enacting or devising the law. Who can say that the legislature of Alabama which set up that state's segregation laws was democratically elected? Throughout Alabama all sorts of devious methods are used to prevent Negroes from becoming registered voters, and there are some counties in which, even though Negroes constitute a majority of the population, not a single Negro is registered. Can any law enacted under such circumstances be considered democratically structured?*

Sometimes a law is just on its face and unjust in its application. For instance, I have been arrested on a charge of parading without a permit. Now, there is nothing wrong in having an ordinance which requires a permit for a parade. But such an ordinance becomes unjust when it is used to maintain segregation and to deny citizens the First-Amendment privilege of peaceful assembly and protest.

I hope you are able to see the distinction I am trying to point out. In no sense do I advocate evading or defying the law, as would the rabid segregationist. That would lead to anarchy. One who breaks an unjust law must do so openly, lovingly, and with a willingness to accept the penalty. I submit that an individual who breaks a law that conscience tells him is unjust, and who willingly accepts the penalty of imprisonment in order to arouse the conscience of the community over its injustice, is in reality expressing the highest respect for law*.*

Of course, there is nothing new about this kind of civil disobedience. It was evidenced sublimely in the refusal of Shadrach, Meshach and Abednego to obey the laws of Nebuchadnezzar, on the ground that a higher moral law was at stake. It was practiced superbly by the early Christians, who were willing to face hungry lions and the excruciating pain of chopping blocks rather than submit to certain unjust laws of the Roman Empire. ***To a degree, academic freedom is a reality today because Socrates practiced civil disobedience.*** *In our own nation, the Boston Tea Party represented a massive act of civil disobedience.*

We should never forget that everything Adolf Hitler did in Germany was "legal" and everything the Hungarian freedom fighters did in Hungary was "illegal." It was "illegal" to aid and comfort a Jew in Hitler's Germany. Even so, I am sure that, had I lived in Germany at the time, I would have aided and comforted my Jewish brothers. If today I lived in a Communist country where certain principles dear to the Christian faith are suppressed, I would openly advocate disobeying that country's antireligious laws.

I must make two honest confessions to you, my Christian and Jewish brothers. First, I must confess that over the past few years I have been gravely disappointed with the white moderate. I have almost reached the regrettable

conclusion that the Negro's great stumbling block in his stride toward freedom is not the White Citizen's Counciler or the Ku Klux Klanner, but the white moderate, who is more devoted to "order" than to justice; who prefers a negative peace which is the absence of tension to a positive peace which is the presence of justice; who constantly says: "I agree with you in the goal you seek, but I cannot agree with your methods of direct action"; who paternalistically believes he can set the timetable for another man's freedom; who lives by a ***mythical concept of time*** *and who constantly advises the Negro to wait for a "more convenient season." Shallow understanding from people of good will is more frustrating than absolute misunderstanding from people of ill will. Lukewarm acceptance is much more bewildering than outright rejection.*

I had hoped that the white moderate would understand that law and order exist for the purpose of establishing justice and that when they fail in this purpose they become the dangerously structured dams that block the flow of social progress. I had hoped that the white moderate would understand that the present tension in the South is a necessary phase of the transition from an obnoxious negative peace, in which the Negro passively accepted his unjust plight, to a substantive and positive peace, in which all men will respect the dignity and worth of human personality. Actually, we who engage in nonviolent direct action are not the creators of tension. We merely bring to the surface the hidden tension that is already alive. We bring it out in the open, where it can be seen and dealt with. Like a boil that can never be cured so long as it is covered up but must be opened with all its ugliness to the natural medicines of air and light, injustice must be exposed, with all the tension its exposure creates, to the light of human conscience and the air of national opinion before it can be cured.

In your statement you assert that our actions, even though peaceful, must be condemned because they precipitate violence. But is this a logical assertion? Isn't this like condemning a robbed man because his possession of money precipitated the evil act of robbery? Isn't this like condemning Socrates because his unswerving commitment to truth and his philosophical inquiries precipitated the act by the misguided populace in which they made him drink hemlock? Isn't this like condemning Jesus because his unique God consciousness and never ceasing devotion to God's will precipitated the evil act of crucifixion? We must come to see that, as the federal courts have consistently affirmed, it is wrong to urge an individual to cease his efforts to gain his basic constitutional rights because the quest may precipitate violence. Society must protect the robbed and punish the robber. I had also hoped that the white moderate would reject the myth concerning time in relation to the struggle for freedom. I have just received a letter from a white brother in Texas. He writes: "All Christians know that the colored people will receive equal rights eventually, but it is possible that you are in too great a religious hurry. It has taken Christianity almost two thousand years to accomplish what it has. The teachings of Christ take time to come to earth." Such an attitude stems from a ***tragic misconception of time, from the strangely irrational notion that there is something in the very flow of time that will inevitably cure all ills***. ***Actually, time itself is neutral; it can be used either destructively or constructively. More and more I feel that the people of ill will have used time much more effectively than have the people of good will.*** *We will have to repent in this generation not merely for the hateful words and actions of the bad people but for the appalling silence of the good people.* ***Human progress never rolls in on wheels of inevitability; it comes through the tireless efforts of men willing to be co workers with God, and without this hard work, time itself becomes an ally of the forces of social stagnation. We must use time creatively, in the knowledge***

that the time is always ripe to do right. Now is the time to make real the promise of democracy and transform our pending national elegy into a creative psalm of brotherhood. Now is the time to lift our national policy from the quicksand of racial injustice to the solid rock of human dignity.

You speak of our activity in Birmingham as extreme. At first I was rather disappointed that fellow clergymen would see my nonviolent efforts as those of an extremist. I began thinking about the fact that I stand in the middle of two opposing forces in the Negro community. One is a force of complacency, made up in part of Negroes who, as a result of long years of oppression, are so drained of self respect and a sense of "somebodiness" that they have adjusted to segregation; and in part of a few middle-class Negroes who, because of a degree of academic and economic security and because in some ways they profit by segregation, have become insensitive to the problems of the masses. The other force is one of bitterness and hatred, and it comes perilously close to advocating violence. It is expressed in the various black nationalist groups that are springing up across the nation, the largest and best known being Elijah Muhammad's Muslim movement. Nourished by the Negro's frustration over the continued existence of racial discrimination, this movement is made up of people who have lost faith in America, who have absolutely repudiated Christianity, and who have concluded that the white man is an incorrigible "devil."

I have tried to stand between these two forces, saying that we need emulate neither the "do nothingism" of the complacent nor the hatred and despair of the black nationalist. For there is the more excellent way of love and nonviolent protest. I am grateful to God that, through the influence of the Negro church, the way of nonviolence became an integral part of our struggle. If this philosophy had not emerged, by now many streets of the South would, I am convinced, be flowing

with blood. And I am further convinced that if our white brothers dismiss as "rabble rousers" and "outside agitators" those of us who employ nonviolent direct action, and if they refuse to support our nonviolent efforts, millions of Negroes will, out of frustration and despair, seek solace and security in black nationalist ideologies--a development that would inevitably lead to a frightening racial nightmare.

Oppressed people cannot remain oppressed forever. The yearning for freedom eventually manifests itself, and that is what has happened to the American Negro. Something within has reminded him of his birthright of freedom, and something without has reminded him that it can be gained. Consciously or unconsciously, he has been caught up by the Zeitgeist, and with his black brothers of Africa and his brown and yellow brothers of Asia, South America and the Caribbean, the United States Negro is moving with a sense of great urgency toward the promised land of racial justice. If one recognizes this vital urge that has engulfed the Negro community, one should readily understand why public demonstrations are taking place. The Negro has many pent up resentments and latent frustrations, and he must release them. So let him march; let him make prayer pilgrimages to the city hall; let him go on freedom rides -and try to understand why he must do so. If his repressed emotions are not released in nonviolent ways, they will seek expression through violence; this is not a threat but a fact of history. So I have not said to my people: "Get rid of your discontent." Rather, I have tried to say that this normal and healthy discontent can be channeled into the creative outlet of nonviolent direct action. And now this approach is being termed extremist. But though I was initially disappointed at being categorized as an extremist, as I continued to think about the matter I gradually gained a measure of satisfaction from the label. Was not Jesus an

extremist for love:""Love your enemies, bless them that curse you, do good to them that hate you, and pray for them which despitefully use you, and persecute you." Was not Amos an extremist for justice: "Let justice roll down like waters and righteousness like an ever flowing stream." Was not Paul an extremist for the Christian gospel: "I bear in my body the marks of the Lord Jesus." Was not Martin Luther an extremist: "Here I stand; I cannot do otherwise, so help me God." And John Bunyan: "I will stay in jail to the end of my days before I make a butchery of my conscience." And Abraham Lincoln: "This nation cannot survive half slave and half free." And Thomas Jefferson: "We hold these truths to be self evident, that all men are created equal . . ." ***So the question is not whether we will be extremists, but what kind of extremists we will be. Will we be extremists for hate or for love? Will we be extremists for the preservation of injustice or for the extension of justice?*** *In that dramatic scene on Calvary's hill three men were crucified. We must never forget that all three were crucified for the same crime--the crime of extremism. Two were extremists for immorality, and thus fell below their environment. The other, Jesus Christ, was an extremist for love, truth and goodness, and thereby rose above his environment.* ***Perhaps the South, the nation and the world are in dire need of creative extremists***.

I had hoped that the white moderate would see this need. Perhaps I was too optimistic; perhaps I expected too much. I suppose I should have realized that few members of the oppressor race can understand the deep groans and passionate yearnings of the oppressed race, and still fewer have the vision to see that injustice must be rooted out by strong, persistent and determined action. I am thankful, however, that some of our white brothers in the South have grasped the meaning of this social revolution and committed themselves to it. They are still all too few in quantity, but they are big in quality. Some -such as Ralph McGill, Lillian Smith,

Harry Golden, James McBride Dabbs, Ann Braden and Sarah Patton Boyle--have written about our struggle in eloquent and prophetic terms. Others have marched with us down nameless streets of the South. They have languished in filthy, roach infested jails, suffering the abuse and brutality of policemen who view them as "dirty nigger-lovers." Unlike so many of their moderate brothers and sisters, they have recognized the urgency of the moment and sensed the need for powerful "action" antidotes to combat the disease of segregation. Let me take note of my other major disappointment. I have been so greatly disappointed with the white church and its leadership. Of course, there are some notable exceptions. I am not unmindful of the fact that each of you has taken some significant stands on this issue. I commend you, Reverend Stallings, for your Christian stand on this past Sunday, in welcoming Negroes to your worship service on a nonsegregated basis. I commend the Catholic leaders of this state for integrating Spring Hill College several years ago.

But despite these notable exceptions, I must honestly reiterate that I have been disappointed with the church. I do not say this as one of those negative critics who can always find something wrong with the church. I say this as a minister of the gospel, who loves the church; who was nurtured in its bosom; who has been sustained by its spiritual blessings and who will remain true to it as long as the cord of life shall lengthen.

When I was suddenly catapulted into the leadership of the bus protest in Montgomery, Alabama, a few years ago, I felt we would be supported by the white church. I felt that the white ministers, priests and rabbis of the South would be among our strongest allies. Instead, some have been outright opponents, refusing to understand the freedom movement and misrepresenting its leaders; all too many

others have been more cautious than courageous and have remained silent behind the anesthetizing security of stained glass windows.

In spite of my shattered dreams, I came to Birmingham with the hope that the white religious leadership of this community would see the justice of our cause and, with deep moral concern, would serve as the channel through which our just grievances could reach the power structure. I had hoped that each of you would understand. But again I have been disappointed.

I have heard numerous southern religious leaders admonish their worshipers to comply with a desegregation decision because it is the law, but I have longed to hear white ministers declare: "Follow this decree because integration is morally right and because the Negro is your brother." In the midst of blatant injustices inflicted upon the Negro, I have watched white churchmen stand on the sideline and mouth pious irrelevancies and sanctimonious trivialities. In the midst of a mighty struggle to rid our nation of racial and economic injustice, I have heard many ministers say: "Those are social issues, with which the gospel has no real concern." And I have watched many churches commit themselves to a completely other worldly religion which makes a strange, un-Biblical distinction between body and soul, between the sacred and the secular.

I have traveled the length and breadth of Alabama, Mississippi and all the other southern states. On sweltering summer days and crisp autumn mornings I have looked at the South's beautiful churches with their lofty spires pointing heavenward. I have beheld the impressive outlines of her massive religious education buildings. Over and over I have found myself asking: "What kind of people worship here? Who is their God? Where were their voices when the lips of Governor Barnett dripped with words of interposition and nullification? Where

were they when Governor Wallace gave a clarion call for defiance and hatred? Where were their voices of support when bruised and weary Negro men and women decided to rise from the dark dungeons of complacency to the bright hills of creative protest?"

Yes, these questions are still in my mind. In deep disappointment I have wept over the laxity of the church. But be assured that my tears have been tears of love. There can be no deep disappointment where there is not deep love. Yes, I love the church. How could I do otherwise? I am in the rather unique position of being the son, the grandson and the great grandson of preachers. Yes, I see the church as the body of Christ. But, oh! ***How we have blemished and scarred that body through social neglect and through fear of being nonconformists***.

There was a time when the church was very powerful--in the time when the early Christians rejoiced at being deemed worthy to suffer for what they believed. ***In those days the church was not merely a thermometer that recorded the ideas and principles of popular opinion; it was a thermostat that transformed the mores of society.*** *Whenever the early Christians entered a town, the people in power became disturbed and immediately sought to convict the Christians for being "disturbers of the peace" and "outside agitators."* But the Christians *pressed on, in the conviction that they were "a colony of heaven," called to obey God rather than man. Small in number, they were big in commitment. They were too God-intoxicated to be "****astronomically intimidated****." By their effort and example they brought an end to such ancient evils as infanticide and gladiatorial contests. Things are different now. So often the contemporary church is a weak, ineffectual voice with an uncertain sound. So often it is an archdefender of the status quo. Far from being disturbed by the presence of the church, the power*

structure of the average community is consoled by the church's silent--and often even vocal--sanction of things as they are.

But the judgment of God is upon the church as never before. If today's church does not recapture the sacrificial spirit of the early church, it will lose its authenticity, forfeit the loyalty of millions, and be dismissed as an irrelevant social club with no meaning for the twentieth century. Every day I meet young people whose disappointment with the church has turned into outright disgust.

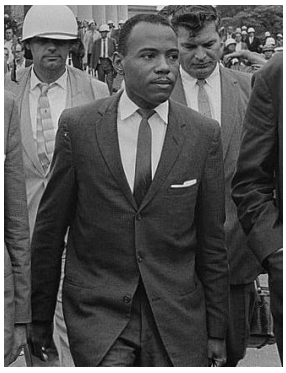
Perhaps I have once again been too optimistic. Is organized religion too inextricably bound to the status quo to save our nation and the world? Perhaps I must turn my faith to the inner spiritual church, the church within the church, as the true ekklesia and the hope of the world. But again I am thankful to God that some noble souls from the ranks of organized religion have broken loose from the paralyzing chains of conformity and joined us as active partners in the struggle for freedom. They have left their secure congregations and walked the streets of Albany, Georgia, with us. They have gone down the highways of the South on tortuous rides for freedom. Yes, they have gone to jail with us. Some have been dismissed from their churches, have lost the support of their bishops and fellow ministers. But they have acted in the faith that right defeated is stronger than evil triumphant. Their witness has been the spiritual salt that has preserved the true meaning of the gospel in these troubled times. They have carved a tunnel of hope through the dark mountain of disappointment. I hope the church as a whole will meet the challenge of this decisive hour. But even if the church does not come to the aid of justice, I have no despair about the future. I have no fear about the outcome of our struggle in Birmingham, even if our motives are at present misunderstood. We will reach the goal of freedom in Birmingham and all over the nation, because the goal of America is freedom. Abused and scorned though we

may be, our destiny is tied up with America's destiny. Before the pilgrims landed at Plymouth, we were here. Before the pen of Jefferson etched the majestic words of the Declaration of Independence across the pages of history, we were here. For more than two centuries our forebears labored in this country without wages; they made cotton king; they built the homes of their masters while suffering gross injustice and shameful humiliation -and yet out of a bottomless vitality they continued to thrive and develop. If the inexpressible cruelties of slavery could not stop us, the opposition we now face will surely fail. We will win our freedom because the sacred heritage of our nation and the eternal will of God are embodied in our echoing demands. Before closing I feel impelled to mention one other point in your statement that has troubled me profoundly. You warmly commended the Birmingham police force for keeping "order" and "preventing violence." I doubt that you would have so warmly commended the police force if you had seen its dogs sinking their teeth into unarmed, nonviolent Negroes. I doubt that you would so quickly commend the policemen if you were to observe their ugly and inhumane treatment of Negroes here in the city jail; if you were to watch them push and curse old Negro women and young Negro girls; if you were to see them slap and kick old Negro men and young boys; if you were to observe them, as they did on two occasions, refuse to give us food because we wanted to sing our grace together. I cannot join you in your praise of the Birmingham police department.

It is true that the police have exercised a degree of discipline in handling the demonstrators. In this sense they have conducted themselves rather "nonviolently" in public. But for what purpose? To preserve the evil system of segregation. Over the past few years I have consistently preached that nonviolence demands that the means we use must be as pure as the ends we seek. I have tried to make clear that it is wrong to use immoral means to attain moral ends. But now I must affirm that it is just as wrong, or perhaps even more so, to use moral means to preserve immoral ends. Perhaps ***Mr. Connor*** *and his policemen have been rather nonviolent in public, as was Chief Pritchett in Albany, Georgia, but they have used the moral means of nonviolence to maintain the immoral end of racial injustice. As T. S. Eliot has said: "The last temptation is the greatest treason: To do the right deed for the wrong reason."*



I wish you had commended the Negro sit inners and demonstrators of Birmingham for their sublime courage, their willingness to suffer and their amazing discipline in the midst of great provocation. One day the South will recognize its real heroes. They will be the ***James Meredith****s, with the noble sense of purpose that enables them to face jeering and hostile mobs, and with the agonizing loneliness that characterizes the life of the pioneer. They will be old, oppressed, battered Negro women, symbolized in a seventy two year old woman in Montgomery, Alabama, who rose up with a sense of dignity and with her people decided not to ride segregated buses, and who responded with ungrammatical profundity to one who inquired about her weariness: "My feets is tired, but my soul is at rest." They will be the young high school and college students, the young ministers of the gospel and a*



host of their elders, courageously and nonviolently sitting in at lunch counters and willingly going to jail for conscience' sake. One day the South will know that when these disinherited children of God sat down at lunch counters, they were in reality standing up for what is best in the American dream and for the most sacred values in our Judaeo Christian heritage, thereby bringing our nation back to those great wells of democracy which were dug deep by the founding fathers in their formulation of the Constitution and the Declaration of Independence.

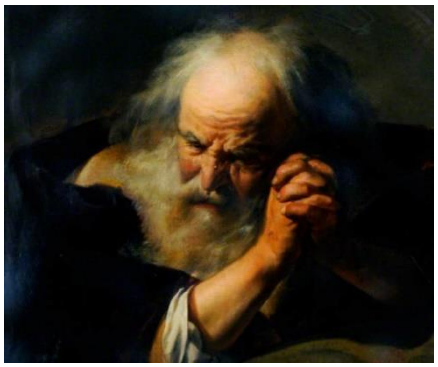
Never before have I written so long a letter. I'm afraid it is much too long to take your precious time. I can assure you that it would have been much shorter if I had been writing from a comfortable desk, but what else can one do when he is alone in a narrow jail cell, other than write long letters, think long thoughts and pray long prayers?

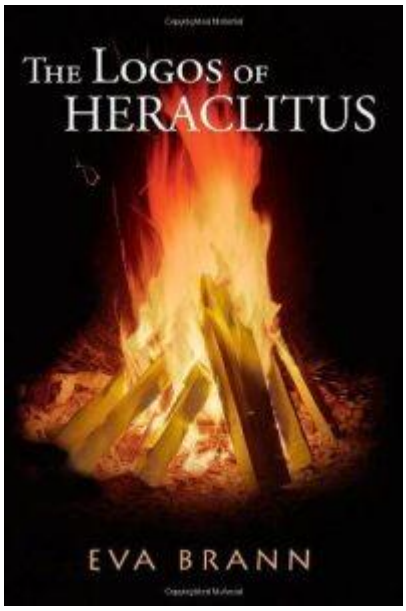
If I have said anything in this letter that overstates the truth and indicates an unreasonable impatience, I beg you to forgive me. If I have said anything that understates the truth and indicates my having a patience that allows me to settle for anything less than brotherhood, I beg God to forgive me.

I hope this letter finds you strong in the faith. I also hope that circumstances will soon make it possible for me to meet each of you, not as an integrationist or a civil-rights leader but as a fellow clergyman and a Christian brother. Let us all hope that the dark clouds of racial prejudice will soon pass away and the deep fog of misunderstanding will be lifted from our fear drenched communities, and in some not too distant tomorrow the radiant stars of love and brotherhood will shine over our great nation with all their scintillating beauty.

Yours for the cause of Peace and Brotherhood, Martin Luther King, Jr.

King, Martin Luther Jr.





Heraclitus (535 – 475 BC) called the underlying principle of order and knowledge, **logos**. Logos can mean "ground," "word," "speech," and "reason." In Greek, the word **Λόγος** has so many meanings that Eva Brann suggests that the word "logos" be added to our lexicon. Logos is the root of all the "-ology" words we have and is used to describe not only knowledge *of* nature but knowledge *in* nature—the underlying fundamental principles and laws. According to John 1, *In the beginning was the Word, and the Word was with God, and the Word was God. He was with God in the beginning. Through him all things were made; without him nothing was made that has been made. In him was life, and that life was the light of all mankind. The light shines in the darkness, and the darkness has not overcome it*. That is John 1:1 states: In the beginning was **Λόγος**.

It makes sense why someone who acts in bad faith, according to Sartre (1948) "*has chosen to devaluate words and reasons*."

Variegated comes from the Latin word *variare* which means change, alter, make different and the Proto-Indo-European root *ag* which means to drive, draw out or forth, move. The Oxford English Dictionary defines variegated as *Marked with patches or spots of different colours; varied in colour; of diverse or various colours; many-coloured, vari-coloured; spec. in Botany*. Variegated was first used in 1662 by Thomas Fuller in his book "***The history of the worthies of England who for parts and learning have been eminent in the several counties : together with an historical narrative of the native commodities and rarities in each county***"

https://quod.lib.umich.edu/e/eebo/A40672.0001.001/1:24.4.1.1?rgn=div4;view=fulltext Fuller wrote, "*Great the Art in meliorating of flowers, and the Rose of Roses [Rosa Mundi] had its first being in this City. As Jacob used an ingenious* invention to make Laban's cattle speckled or ring-straked, so, much the skil in making Tulips feathered and variegated, with stripes of divers colours*."

See Robert John Thornton's (1799) ***The temple of Flora or, Garden of nature, being picturesque botanical plates of the new illustration of the sexual system of Linnaeus*** or Robert Furber's (1730) book ***Twelve Months of Flowers***.

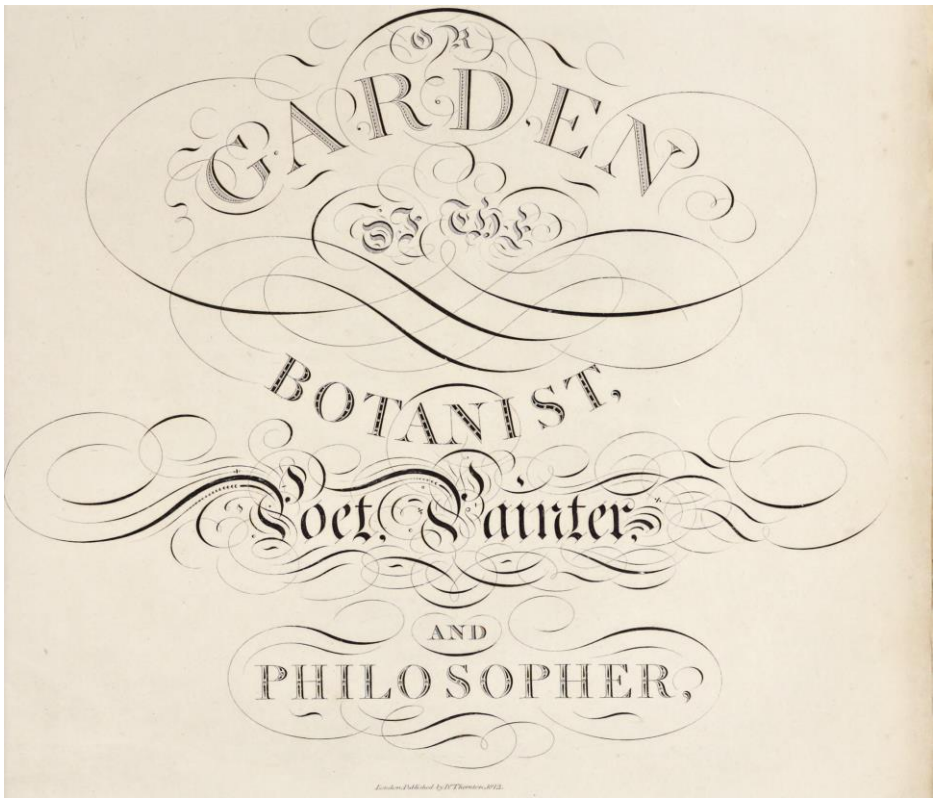




https://publicdomainreview.org/collection/plates-from-robert-thornton-s-temple-of-flora-1807 https://collections.mfa.org/objects/261904

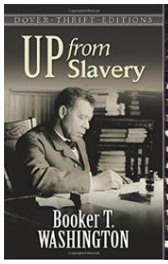

Flora dispensing Her Favours on the Earth


Temple of Flora,


OR
GARDEN
OF THE
BOTANIST,
Poet, Painter
AND
PHILOSOPHER,

A metaphor for the relationship between the parts to the whole: Booker T. Washington (1895) said in his Atlanta Exposition Address, "[i]*n all things that are purely social* ***we can be as separate as the fingers, yet one as the hand*** *in all things essential to mutual progress*."





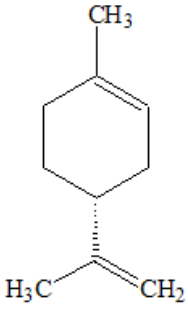


An aside on the smell of lemons and oranges.

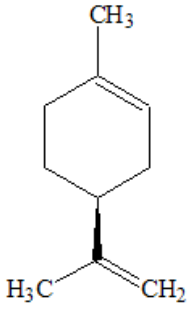
Limonene is colorless at room temperature and provides the smell of oranges and lemons. Limonene is a chiral molecule, so it may **rotate polarized light** to the **right** (D or dextrorotatory, which comes from the Latin for turns to the right (*dexter*) or R, which is Latin for right (*rectus*) or **left** (L or levorotatory, which is from the Latin for turns to the left (*laevus*) or S, which is from the Latin for left (*sinister*). The R enantiomer smells like orange and the S enantiomer smells like lemon.

Morrison and Boyd, the authors of *Organic Chemistry*, remind us that "[w]*e must remember that everything* ***(except, of course, a vampire)*** *has a mirror image, including all molecules. Most molecules, however, are superimposable on their mirror images, as, for example, bromochloromethane, and do not show this mirror-image isomerism*."





(R)



(S)



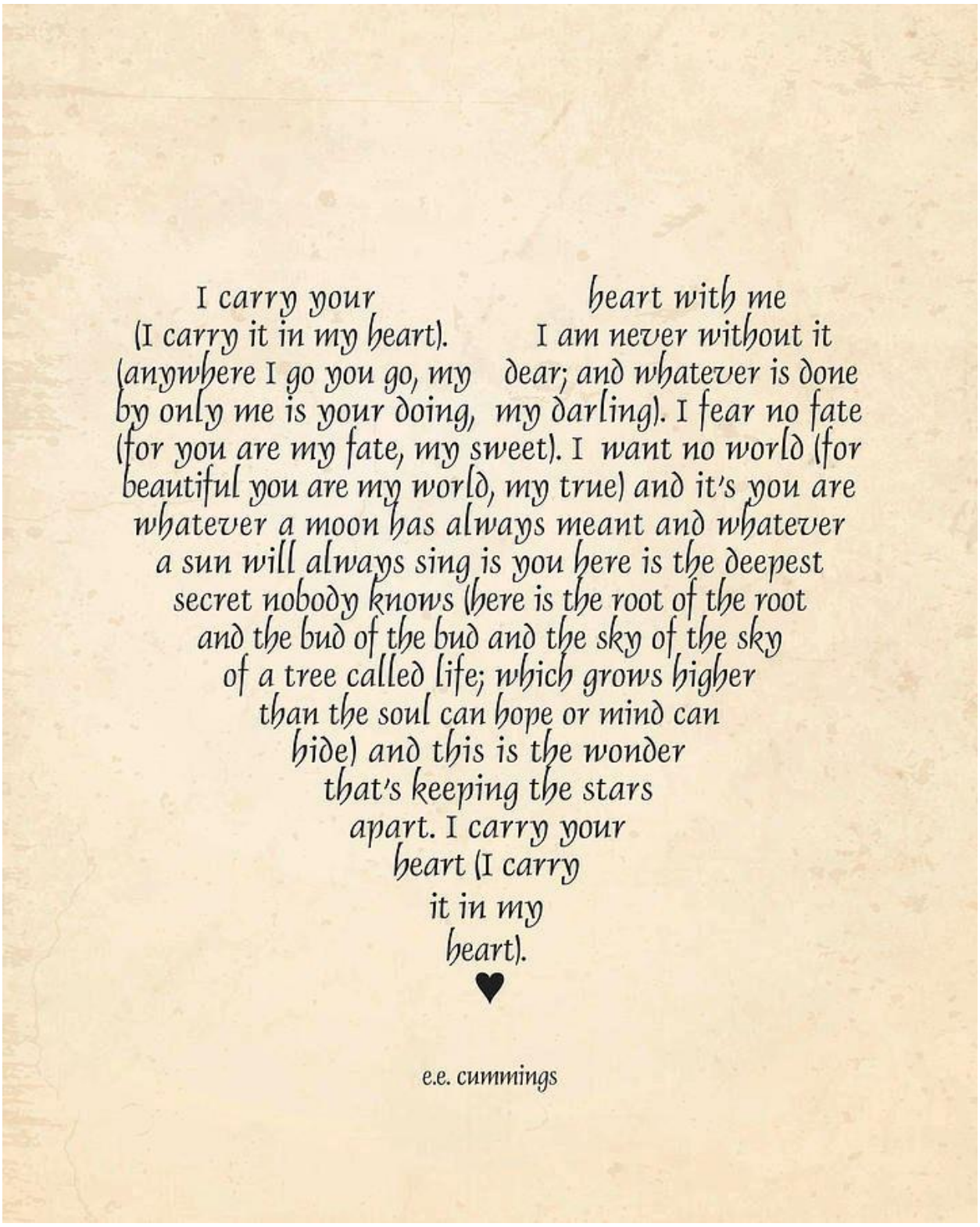
When the elected officials of the government consider themselves to be the Elite or the Elect, they may lose confidence in the commoners, as Bertolt Brecht (1953) told us in *The Solution*:

The Solution

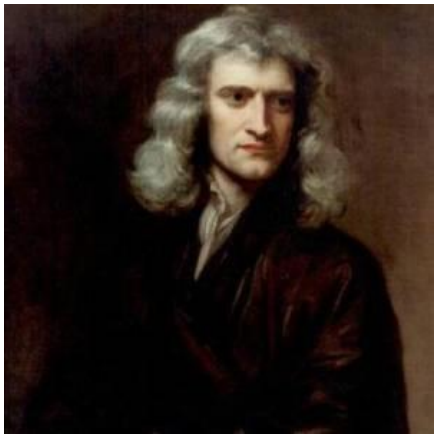
After the uprising of the 17th of June
The Secretary of the Writers' Union
Had leaflets distributed on the Stalinallee
Stating that the people
Had forfeited the confidence of the government
And could only win it back
By increased work quotas. Would it not in that case be simpler
for the government
To dissolve the people
And elect another?

The commoners are the salt of the earth. Jesus (Matthew 5:13) said in the *Sermon on the Mount*, "*You are the salt of the earth. But if the salt loses its saltiness, how can it be made salty again?*" Commonsense can instill life with abundant flavor!

I want to say that all my lectures carry the knowledge, love, and inspiration I get from Amy. This poem by e. e. cummings captures how I feel:



Plant and Animal Colorations: Iridescence, Warning Coloration, Sexual Selection, and the Wave Nature of Light



Sometimes ***less is more***, and it is really pretty amazing how transparent objects such as a solution of soap or gasoline become colored when it becomes thin enough. Isaac Newton (1730) wrote, "*It has been observed by others, that transparent Substances, as Glass, Water, Air, &c. when made* ***very thin*** *by being blown into* ***Bubbles****, or otherwise formed into* ***Plates****, do* ***exhibit various Colours according to their various thinness, altho' at a greater thickness they appear very clear and colourless*****."**



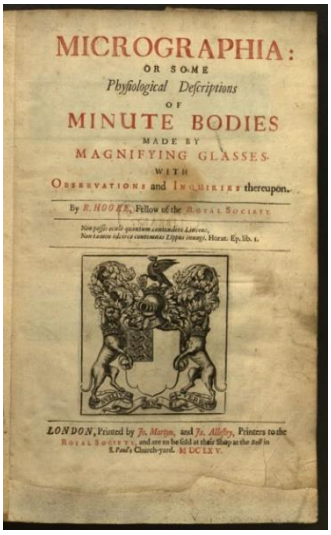
Demonstration: Blow soap bubbles and observe and describe the colors and order of colors on the top, bottom, and the rest of the surface of the bubble. How does the angle you view the soap bubble affect the colors that you see?



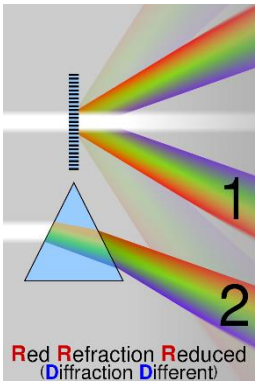
Demonstration: Look at the transparent mica (muscovite, Muscovy glass), then peel off a thin sheet and observe the colors and the order of colors. Are the colors more intense at the torn edges? How does the angle you view a thin sheet of mica affect the colors that you see?

How is it possible that a transparent soap solution or a transparent thin piece of mica can produce colors at all—never mind such vibrant and beautiful colors? Is this a case where we are producing something out of nothing?

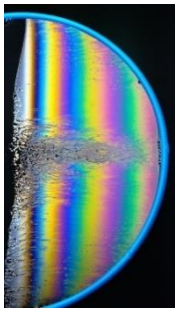
The observation of colors produced by thin plates of mica was first reported by **Robert Hooke** (1665) in his book ***Micrographia***: "*Moscovy-glass, or lapis specularis, is a Body that seems to have as many curiosities in its fabrick as any common mineral I have met with: for first, it is transparent to a great thickness: next, it is compounded of an infinite number of thin flakes joyned or generated one upon another so close & smooth, as with many hundreds of them to make one smooth and thin plate of a transparent flexible substance….This stone…exhibits…all the colours of the rainbow…but the order of the colours…was quite contrary to the primary or innermost rainbow, and the same with those of the secondary or outermost rainbow…….the phenomena of colours…I had often observed in those* ***bubbles which children use to make soap-water****,…I was able to produce the same phenomena in thin bubbles made with any other transparent substance.* "









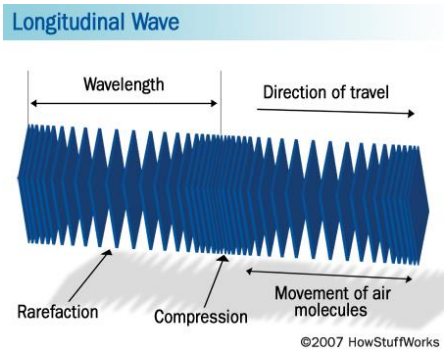




Robert Hooke (1665) observed similar colors in animal bodies such as pearls, **mother of pearl** shells, oyster shells, and concluded, "*wheresoever you meet with a* ***transparent body thin enough****, that is terminated by* ***reflecting*** *bodies of different* ***refractions*** *from it, there will be a production of these pleasing and lovely bodies.*" With his **microscope**, Robert Hooke could see that the colorful parts of these objects, as well as the **fantastical** and colorful regions of peacock and duck feathers, like the mica, also consisted of thin plates or lamina.



From his observations of thin plates of mica, soap bubbles, the feathers of peacocks and ducks, the spark from flint and steel, the luminescence of rotten wood and fish, the thermoluminescence of the Bologna stone, the triboluminescence of a diamond, the bioluminescence of sea water, the light reflected from cats' eyes, and the light coming from the bellies of glowworms, Robert Hooke (1665) tried to **understand the properties of light itself**. Hooke (1665) concluded that the motion of light was "***exceedingly quick****, such as those motions of* ***fermentation and putrifaction****, whereby, certainly, the parts are* ***exceedingly nimbly and violently mov'd****; and that, because we find* ***those motions are able more minutely to shatter and divide the body****, then the most violent heats menstruums we yet know. And that fire is nothing else but such a dissolution of the Burning body, made by the most universal menstruum of all sulphurous bodies, namely, the Air* …. And that, in all extremely hot shining bodies, there is a very quick motion that causes Light, as well as a more robust that causes Heat, may be argued from the celerity wherewith the bodies are dissolv'd. *Next, it must be a* ***vibrative motion****. And for this the newly mention'd diamond affords us a good argument; since if the motion of the parts did not return, the diamond must after many rubbings decay and be wasted…. And thirdly, that it is a* ***very short vibrating motion****….for a diamond being the hardest body we yet know in the world, and consequently the least apt to yield or bend, must consequently also have its vibrations exceeding short.* ***And these*** [Rapid, short, and vibrational motions], ***I think, are the three principle properties of a motion, required to produce the effect call'd light in the object.***"



Demonstration: Turn the crank of the wave demonstration apparatus to see both **transverse waves** and **longitudinal waves**. Although Robert Hooke did not clarify the type of vibration he thought light was, he was probably thinking of a sound wave analogy and sound waves are longitudinal waves that compress and rarefy the medium through which they travel.



Aside: The Great Fire of London occurred the year following the publication of Robert Hooke's *Micrographia*. Robert Hooke was a polymath who helped **Christopher Wren** design some of the monuments and buildings, including the **Monument to the Fire**, the **Royal Greenwich Observatory**, and **Bethlem** (known as Bedlam) **Royal Hospital** that would be built following the fire.

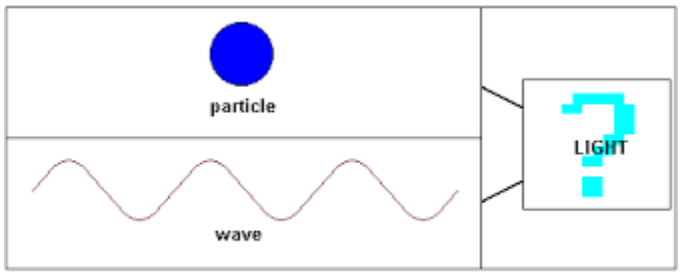




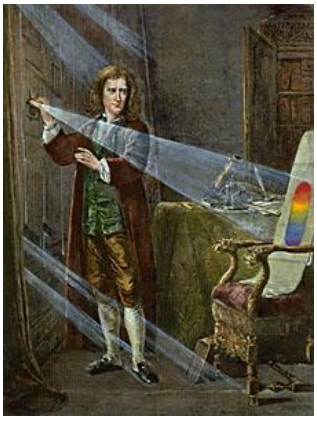


As we see, Robert Hooke (1665) considered light to be **vibrations with very short periods**. On the other hand, when we discussed color vision, we learned that **Isaac Newton** (1675) considered light to be composed of corpuscles and that a prism separated sunlight into corpuscles of "***unequal bignesses****…the largest beget a sensation of a red colour; the least, or shortest, of a deep violet; and the intermediate ones, of* ***intermediate colours….****"*

Here we see the origin of the **wave-particle duality of light.**

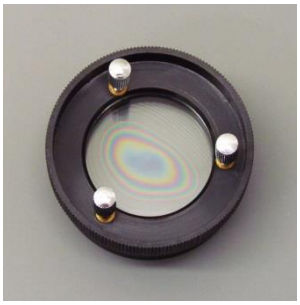


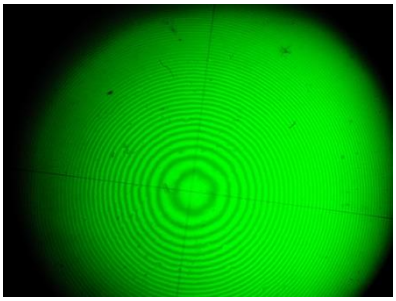
How to imagine the wave-particle duality.

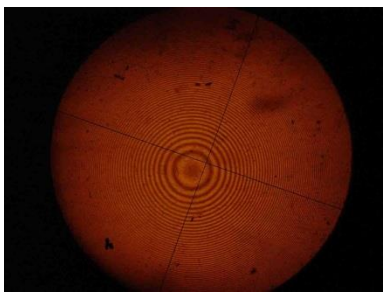


Isaac Newton was able to turn qualitative observations like we all make when we see the colors generated by soap bubbles into **quantitative experimental observations**. According to Isaac Newton (1730), "*If a Bubble be blown with Water first made tenacious by dissolving a little Soap in it, 'tis a common Observation, that after a while it will appear tinged with a great variety of Colours. As soon as I had blown any of them I cover'd it with a clear Glass, and by that means its Colours emerged in a very regular order, like so many concentrick Rings encompassing the top of the Bubble. And as the Bubble grew thinner by the continual subsiding of the Water, these Rings dilated slowly and overspread the whole Bubble, descending in order to the bottom of it, where they vanished successively. In the mean while, after all the Colours were merged at the top, there grew in the center of the Rings a small round black Spot*."

Demonstration: Observe **Newton's rings** using the Newton's ring apparatus on a light table using a measuring loupe. What happens to the position of the rings when you filter the light with various colored filters?



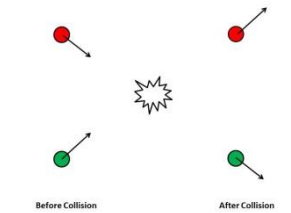




Throughout this semester, we have assumed that light is **absorbed** and **emitted** by atoms and molecules as **infinitesimally small corpuscles** that travel between the emitter and absorber along infinitesimally thin rays. This hypothesis has been very productive; having allowed us to predict, using **geometrical optics** and the laws of **reflection** and **refraction**, the position, orientation, and magnification of images formed by the ***camera obscura***, **mirrors**, and **lenses**. In the words of **Christiaan Huygens** (1690): "*As happens in all the sciences in which Geometry is applied to matter, the demonstrations concerning Optics are founded on truths drawn from experience. Such are that the rays of light are propagated in straight lines; that the angles of reflexion and of incidence are equal; and that in refraction the ray is bent according to the law of sines, now so well known, and is no less certain than the preceding laws*."



However, **Christiaan Huygens** (1690) not only saw the **value** of the corpuscular theory of light, but he also saw its **limitations**. He realized that if light were composed of material particles then the corpuscles composing a light ray crossing the corpuscles composing an intersecting light ray would **collide** with each other, causing each one to scatter and making it difficult for two people to see two different objects and even difficult for two people to see each other.



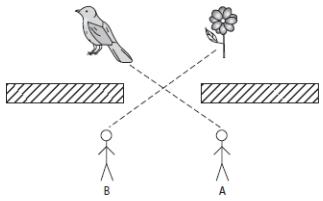


FIGURE 3.1 If light were composed of Newtonian corpuscles, corpuscles propagating from the bird to observer A should make it more difficult for observer B to see the flower, since the corpuscles from the flower will cause the corpuscles coming from the bird to scatter.

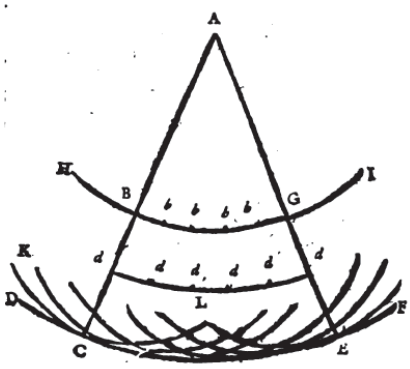
Christian Huygens (1690) wrote in his *Treatise on Light*, "*I do not find that any one has yet given a probable explanation of the first and most notable phenomena of light, namely why is it not propagated except in straight lines, and how visible rays, coming from an infinitude of diverse places, cross one another without hindering one another in any way*."

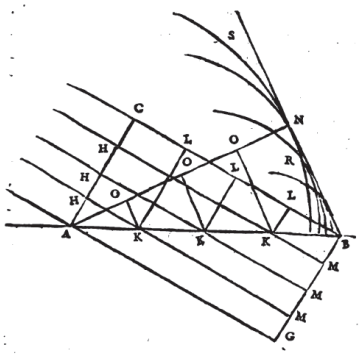


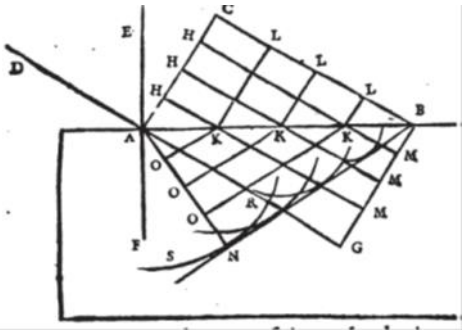
Christian Huygens decided that since particulate light corpuscles would collide with each other and interfere with each other's propagation, light must be **immaterial and consist of the motion of an ethereal medium**. Here is how he came to the conclusion that light is the motion of the ether. Fire produces light, and likewise, light, collected by a concave mirror, is capable of producing fire. Fire is capable of melting, dissolving, and burning matter, and it does so by disuniting the particles of matter and sending them in motion. According to the mechanical philosophy of nature championed by **René Descartes**, **anything that causes motion must itself be in motion**, and therefore, **light must be motion**. Since two beams of light crossing each other do not hinder the motion of each other, the components of light that are set in motion must be immaterial and imponderable. According to Huygens, light impels the so-called luminous ether through which the light propagates into motion. Then the motion of the ether causes an impression on our retina; resulting in vision much like vibratory motion of the air causes an impression on our eardrum; resulting in hearing.

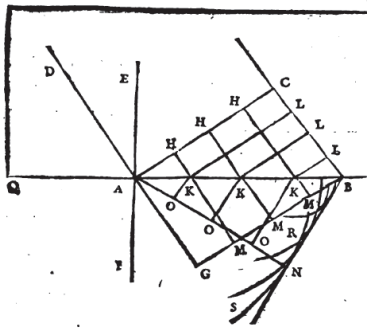


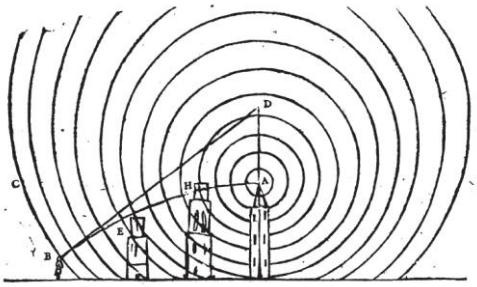
Christian Huygens (1690) explained the inverse square law, reflection, refraction, and even some atmospheric optical illusions with his wave theory of light. Notice that the prominent wave fronts and rays are related in that the prominent wave fronts are perpendicular to the rays.

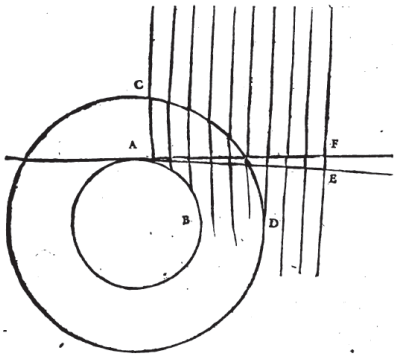








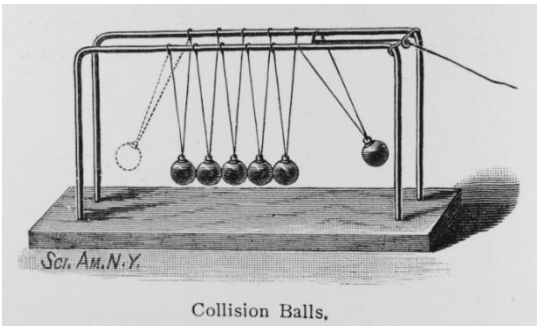




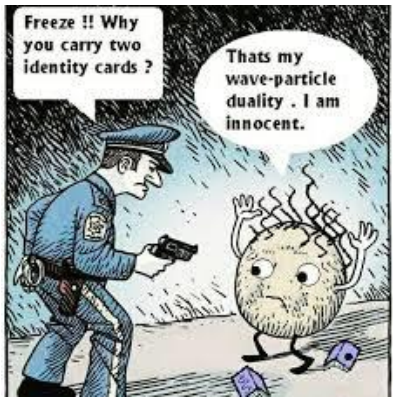
Interestingly, in order for the wave theory of light to explain the rapidity of light propagation and the fact that you can see very tiny things, Christian Huygens had to postulate that the ether itself was **particulate**.



Demonstration: Newton's Cradle shows the transfer of energy through elastic particles that mimic Huygens' particulate ether.



Collision Balls.



Again, we see the **wave-particle duality of light**. While Christian Huygens **chose** to see light as waves traveling through a particulate ether, Isaac Newton chose to see light as corpuscles traveling through a waving ether whose periodic density variation resulted in the colors of thin plates. Isaac Newton (1730, Query 3) asked, "*Are not rays of light in passing by the edges and sides of bodies, bent several times backwards and forwards, with a motion like that of an eel? And do not the three fringes of colour'd light above-mention'd arise from three such bendings*?"

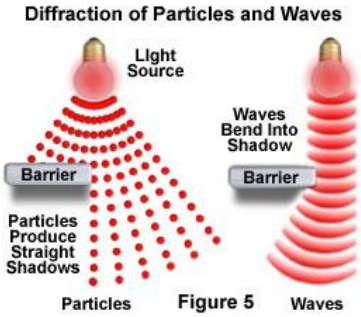


Figure 5

Isaac Newton considered light itself to be particulate because, if light indeed were primarily a wave, he should have seen light **bend behind an obstruction** the way sound waves and water waves bend around an obstruction. He did not see any light behind a small obstruction.

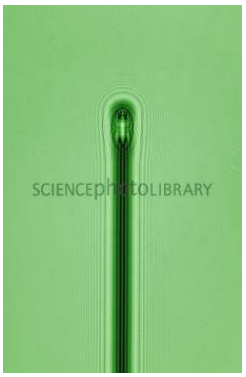


However, the bending of light by an obstruction had already been observed by **Francesco Maria Grimaldi** in 1665. He called this phenomenon **diffraction**, from the Latin words *dis* and *frangere* which mean "apart" and "to break." Unfortunately, Francesco Maria Grimaldi's observation that light does not always travel in straight lines in a single medium was lost to obscurity.

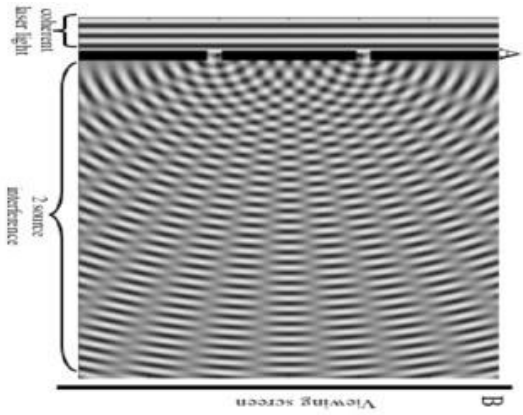


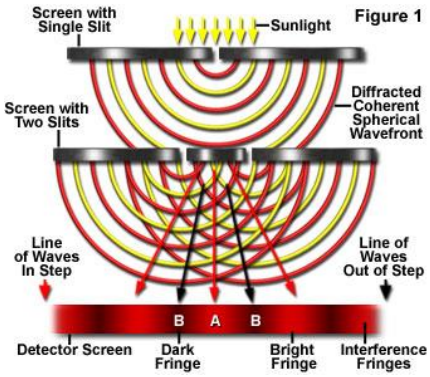
As a consequence of the great achievements of Isaac Newton and the hagiographic attitude and less than critical thoughts of the followers of this great man, the corpuscular theory of light predominated, and Robert Hooke's and Christiaan Huygens' wave theory of light lay fallow for about a century until it was revived by

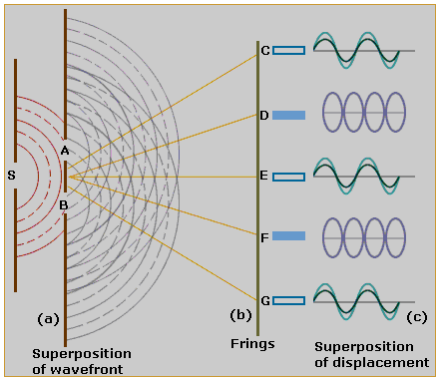
Thomas Young, a botanist, a translator of the Rosetta stone, and a physician who was trying his hand at teaching Natural Philosophy at the Royal Institution. While preparing his lectures, Thomas Young reexamined the objections that Isaac Newton had made to the wave theory of light. Thomas Young, **who studied the master, not the followers, apes, epigones, imitators, or votaries**, concluded that the wave theory in fact could describe what happens to light when it undergoes diffraction as well as reflection and refraction. Here is how Thomas Young (1804) came to this conclusion: "*I made a small hole in a window-shutter, and covered it with a piece of thick paper, which I perforated with a fine needle. For greater convenience of observation, I placed a small looking glass without the window-shutter, in such a position as to reflect the sun's light, in a direction nearly horizontal, upon the opposite wall, and to cause the cone of diverging light to pass over a table, on which were several little screens of card-paper. I brought into the sunbeam a slip of card, about one-thirteenth of an inch in breadth, and observed its shadow, either on the wall, or on other cards held at different distances. Besides the fringes of colours on each side of the shadow, the shadow itself was divided by similar parallel fringes, of smaller dimensions, differing in number, according to the distance at which the shadow was observed, **but leaving the middle of the shadow always white***."



Thomas Young observed something that the great Newton had missed. Young noticed that the light in fact did bend into the geometrical shadow of the slip of card. According to Thomas Young (1804), "*It was in May of 1801, that I discovered, by reflecting on the beautiful experiments of Newton, a law which appears to me to account for a greater variety of interesting phenomena than any other optical principle that has yet been made known. I shall endeavour to explain this law by a comparison:* ***Suppose a number of equal waves of water to move upon the surface of a stagnant lake, with a certain constant velocity, and to enter a narrow channel leading out of the lake; suppose, then, another similar cause to have excited another equal series of waves, which arrive at the same channel with the same velocity, and at the same time with the first. Neither series of waves will destroy the other, but their effects will be combined****; if they enter the channel in such a manner that the elevations of the one series coincide with those of the other, they must together produce a series of greater joint elevations; but if the elevations of one series are so situated as to correspond to the depressions of the other, they must exactly fill up those depressions, and the surface of the water must remain smooth; at least, I can discover no alternative, either from theory or from experiment.* ***Now, I maintain that similar effects take place whenever two portions of light are thus mixed; and this I call the general law of interference of light****.*"





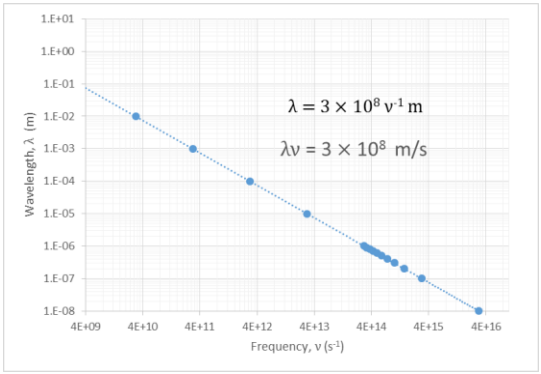


Demonstration: Look at the interference pattern in the mini ripple tank of water waves generated by two point sources.



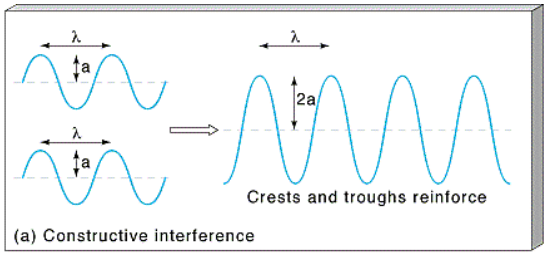


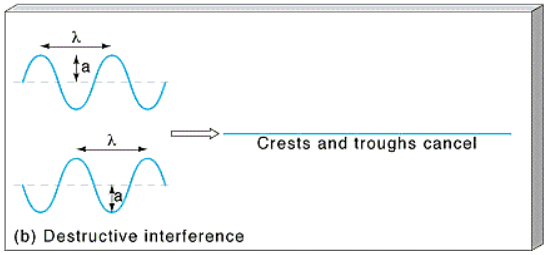
Let's look at the interference of light waves. Note that just like the mathematical waves we used to describe **circadian rhythms**, a light wave has a **phase** relative to a reference, an **amplitude**, a **period** and its inverse (a frequency), and a **wavelength**. The product of the frequency (ν) and the wavelength (λ) is the **speed of the wave**. For light, the speed in a vacuum is called c, which is 3×10^8 m/s. The relation between the speed and wavelength of light in a single inertial frame, that is, when the source of light and observer are not moving relative to each other, is given by the **dispersion relation**:



$$\nu\lambda = c$$

When two nearby waves have the **same phase**, they **constructively interfere** to produce a resultant wave that has twice the amplitude. Since the **intensity** (I) of the resultant is proportional to the square of the **amplitude** (a), the resultant intensity ($I = (2a)^2 = 4a^2$) is greater than the intensity of the individual waves that make up the resultant wave ($I = a^2 + a^2 = 2a^2$). **That is, the square of the sum is greater than the sum of the squares.**

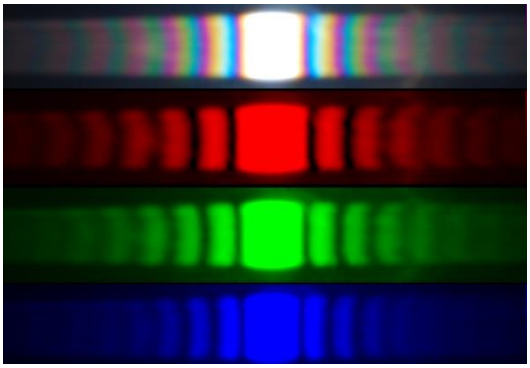




When **the peaks of one wave line up with the troughs of a nearby wave**, they **destructively interfere** to produce a resultant wave that has zero amplitude. Since the intensity (I) of the resultant is proportional to the square of the amplitude (a), the resultant intensity ($I = (a\text{-}a)^2 = (0a)^2 = 0$) is less than the intensity of the individual waves that make up the resultant wave ($I = a^2 + a^2 = 2a^2$). **That is, the square of the sum is less than the sum of the squares.** The averaged intensity of the waves that constructively and destructively interfere is equal to the intensity of the individual input waves, consistent with the **First Law of Thermodynamics**. That is, consistent with the first law of thermodynamics, **diffraction** does not lead to a change in the amount of energy, but it results in the **redistribution of energy in space**.

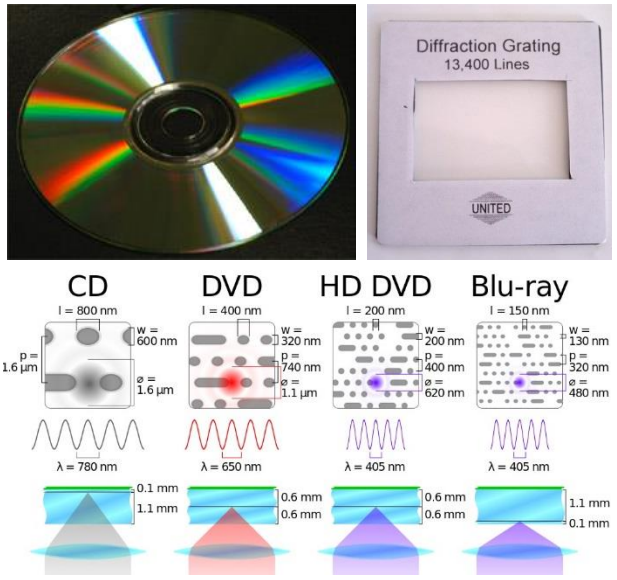
Thomas Young (1804) went on to say, "*The observations on the effects of diffraction and interference, may perhaps sometimes be applied to a practical purpose, in making us cautious in our conclusions respecting the appearances of* ***minute bodies viewed in a microscope.*** *The shadow of a fibre, however opaque, placed in a pencil of light admitted through a small aperture, is always somewhat less dark in the middle of its breadth than in the parts on each side. A similar effect may also take place, in some degree, with respect to the image on the retina, and impress the sense with an idea of a transparency which has no real existence: and, if a small portion of light be really transmitted through the substance, this may again be destroyed by its interference with the diffracted light, and produce an appearance of partial opacity, instead of uniform semitransparency. Thus, a central dark spot, and a light spot surrounded by a darker circle, may respectively be produced in the images of a semitransparent and an opaque corpuscle; and impress us with an idea of a complication of structure which does not exist*." We

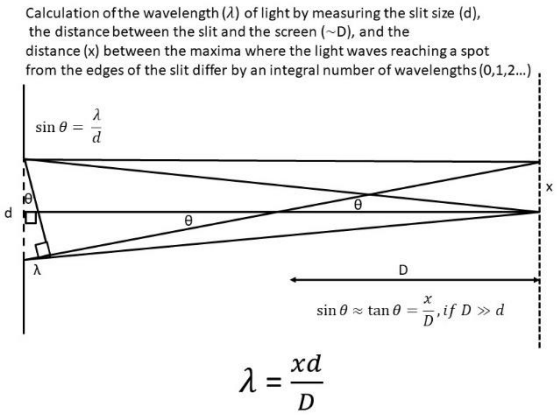
will repeat Thomas Young's experiments next lecture when we talk about microscopy.



Thomas Young found that the position of the bright and dark bands depended on the color of light. By measuring the distances between the bright bands of each color, he determined the **wavelength** of each color that makes up the **spectrum** of visible light.

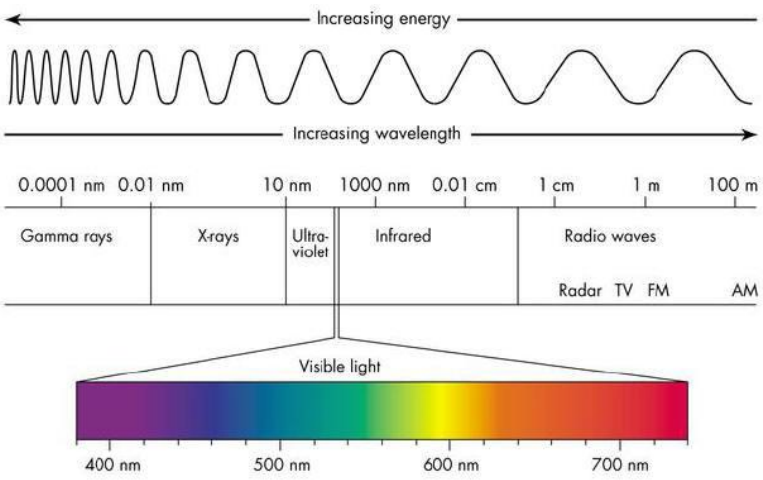
Demonstration: Look at the sunlight through your transmission diffraction grating and see how a transparent object with structures with a size on par with the wavelength of light can differentially diffract the spectral colors of sunlight. The lines on a compact disc (**CD**) are also sufficiently close and regular to act as a reflection diffraction grating that differentially diffracts the spectral colors of sunlight. Digital video discs (**DVD**) have closer lines and **blu-ray discs** have even closer lines.



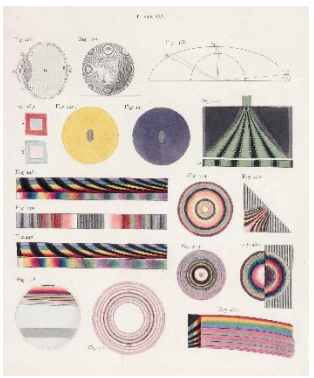


$$\lambda = \frac{xd}{D}$$

Thomas Young's work led to the description of the **spectrum** that we have alluded to all semester.



The colors produced by **thin film interference** of light waves and the **diffraction** of light waves are known as **structural colors**. Because the **colors we see vary** as we change our position of view, structural colors produce **iridescence**. That is, these structures with sizes close to the wavelength of light have the potential to produce all the colors of the rainbow. Iridescence is named after the Greek goddess **Iris**.



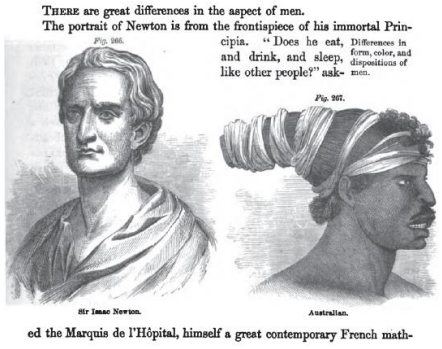


Despite or perhaps because of Thomas Young's accomplishments, he became a *persona non grata*, since he did not accept the corpuscular nature of light proffered a century before by his fellow Englishman Isaac Newton. Isaac Newton, is interred in **Westminster Abbey** with the following inscription on his monument, "*Here is buried Isaac Newton, Knight, who by a **strength of mind almost divine**, and mathematical principles peculiarly his*

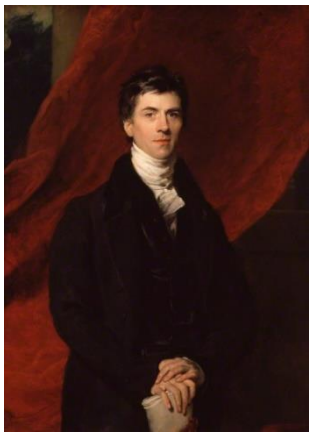




own, explored the course and figures of the planets, the paths of comets, the tides of the sea, the ***dissimilarities in rays of light****, and, what no other scholar has previously imagined, the* ***properties of the colours*** *thus produced. Diligent, sagacious and faithful, in his* ***expositions of nature, antiquity and the holy Scriptures, he vindicated by his philosophy the majesty of God mighty and good****, and expressed the simplicity of the Gospel in his manners. Mortals rejoice that there has existed such and so great an ornament of the human race! He was born on 25th December 1642, and died on 20th March 1726*." Newton was held in high regard in England as can be seen by the epitaph written in 1727 by **Alexander Pope**: "*Nature and Nature's laws lay hid in night: God said, 'Let Newton be!' and all was light*." **Edmund Halley** also wrote glowingly about Newton: "*So near the gods—man cannot nearer go*." **John Draper** (1861) put a picture of Newton in his book, *Human Physiology*. The **Marquis de L'Hôpital** glorified Newton thusly, "*Does he eat, and drink, and sleep, like other people? I represent him to myself as a celestial genius entirely disengaged from matter*."


THERE are great differences in the aspect of men.
The portrait of Newton is from the frontispiece of his immortal Principia. "Does he eat, and drink, and sleep, like other people?" asked the Marquis de l'Hôpital, himself a great contemporary French mathematician. Differences in form, color, and dispositions of men.
Fig. 266.
Sir Isaac Newton.
Fig. 267.
Australian.

Isaac Newton was beatified by the scientific community and Thomas Young was viciously attacked for being "**Anti-Newtonian."** (They did not use the terms denier and contrarian then). An anonymous reviewer, most likely **Lord Brougham**, wrote in the Edinburgh Review about Young's lecture on the wave theory of light, "***A mere theory is in truth destitute of all pretensions to merit of every kind, except that of a warm and misguided imagination. It demonstrates neither patience of investigation, nor rich resources of skill, nor vigorous habits of attention, nor powers of abstracting and comparing, nor extensive acquaintance with nature. It***



is the unmanly and unfruitful pleasure of a boyish and prurient imagination, or the gratification of a corrupted and depraved appetite." The anonymous reviewer went on to say: "*We take our leave of this paper with recommending it to the Doctor to do that which he himself says would be very easy; namely, to invent various experiments upon the subject. As, however, the season is not favourable for optical observation, we recommend him to employ his winter months in reading the "Optics", and some of the plainer parts of the "Principia", and then to begin his experiments by repeating those which are to be found in the former of these works*."



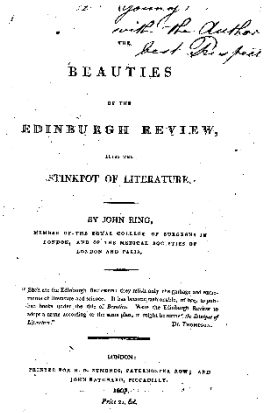


While Thomas Young is buried in St. Giles the Abbot Churchyard in Farnborough, London, England, a tablet was erected in his honor in Westminster Abbey. It reads, "*Sacred to the memory of Thomas Young M.D. Fellow and Foreign Secretary of the Royal Society Member of the National Institute of France. A man alike eminent in almost every department of human learning. Who, equally distinguished in the most abstruse investigations of letters and of science, first established the* ***undulatory theory of light*** *and first penetrated the obscurity which had veiled for ages the hieroglyphicks of Egypt. Endeared to his friends by his domestic virtues, honoured by the World for his unrivalled acquirements, he died in the hopes of the Resurrection of the just. Born at Milverton in Somersetshire June 13th 1773, died in Park Square London May 10th 1829, in the 56th year of his age.*"



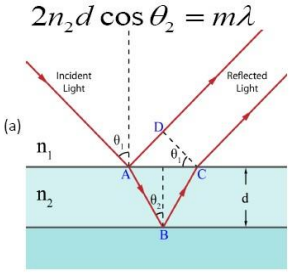
In science, there are stages in the acceptance of truth. According to J. B. S. Haldane (1963), the stages are: 1) *This is worthless nonsense*; 2) *This is an interesting, but perverse point of view;* 3) *This is true, but quite unimportant*; and 4) *I always said so*."

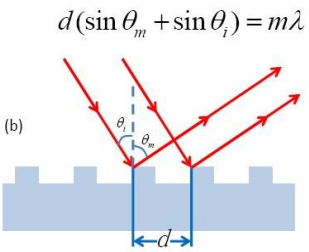
Approximately a half century after Young espoused his wave theory of light, his theory was shown to be so useful that it was finally accepted. And the Edinburgh Review became known as the ***Stinkpot of Literature***.

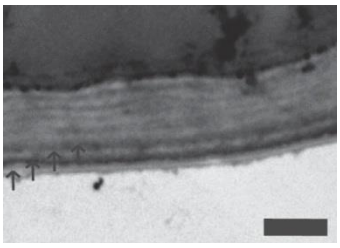

BEAUTIES
OF THE
EDINBURGH REVIEW,
STINKPOT OF LITERATURE.
BY JOHN RING,
LONDON:

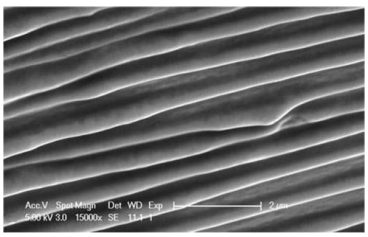
We will use Thomas Young's wave theory of light to understand coloration in nature. **Structural colors** can result from the interference of light produced by both closely-spaced **striated** structures and **thin layered** lamellar structures.

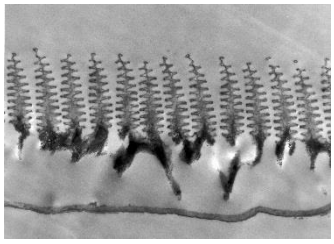
The structures that give rise to structural colors have dimensions close to the wavelength of light. Electron microscopy is typically used to determine the spacing of transparent striated structures and the thicknesses of

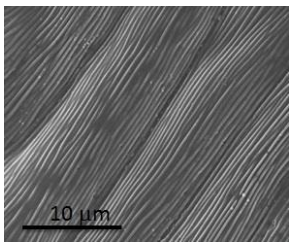












transparent lamella structures that give rise to the colors. The alternating layers of cellulose gives *Selaginella willdenowii* its blue color, alternating layers of chitin and air that look like a tree from the side give the Morpho butterfly its blue color, and striations in the cuticle of the Queen of the Night tulip give its purple color. Many structural colors also depend on melanin layers to give a **black background** so that the color is even **more vibrant**. Remember that the **blue of the sky** can be so vibrant and **saturated** because it set against the blackness of space and the **blue eyes** can be so vibrant because the scattering of light is set against the melanin in

the posterior pigment epithelium of the **iris**.

While the **differential absorption** of **pigments** is the most prevalent cause of coloration in plants and animals, coloration can result from the **differential interference of the spectral colors of sunlight that result from lamellar or striated structural specializations**. The structures are **inherently transparent** and the colors result from differences in the **refractive indices** of the layers, or of the striations. The brilliant colored light produced by structural specializations is known as **iridescence**. Robert Hooke (1665) called colors that were due to structural elements and not to pigments, **fantastical colors** and he could distinguish these colors from those produced by pigments with the following test: "*Now, that these colours are only fantastical ones, that is, such as arise immediately from the refractions of the light, I found by this, that water wetting these colour'd parts, destroy'd their colours, which seem'd to proceed from the alteration of the reflection and refraction*." Now we will apply the concept of interference to understand the colors of thin plates.

When light strikes a thin film some of it is reflected and some of it is refracted. The reflected light follows the **law of reflection** and the refracted light follows the **Snel-Descartes Law**. Some of the refracted light will reflect off the next surface and some of it will be refracted. The splitting between the reflected light and the refracted light occurs at each interface. The phase of the light that is reflected from the first interface will be retarded relative to the phase of the light that is reflected from the second interface. The amount of retardation will depend on two things—the length of the path in the refractive layer and the refractive index of this layer. Remember from our discussion of geometrical optics, the greater the refractive index of a transparent medium, the slower the light will propagate through that medium. The product of the geometric length and the

refractive index is known as the **optical path length**.

As long as the film is thin enough, the wave that is reflected from the top surface will be close enough to the wave that is reflected from the bottom surface and they will interfere with each other. If the two waves are in phase, the waves will constructively interfere and the reflection will be bright. If the two waves are one-half wavelength out of phase, the two waves will destructively interfere and the reflection will be black. The distance each wave travels through the thin film is independent of wavelength. However, the distance, in proportion to the wavelength of each spectral color, will be different. When sunlight impinges on the thin film, the **color of the reflected light is most similar to the color of the wavelength that undergoes complete constructive interference and is the complementary color** of **the color of the wavelength that undergoes complete destructive interference**. The wavelength that undergoes complete destructive interference depends on the **thickness** and **refractive index** of the film which determine the **optical path length**. Since the optical path length increases as the angle of viewing increases, the color of the reflected light changes with the viewing angle. The color of the reflected light stabilizes with respect to color as the number of thin layers gets large.

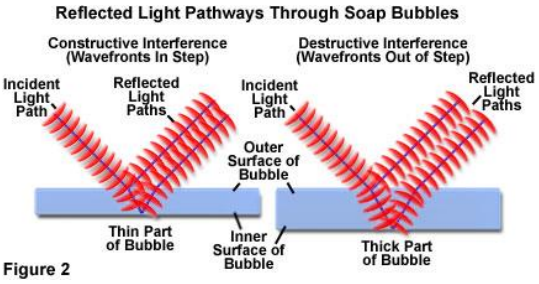
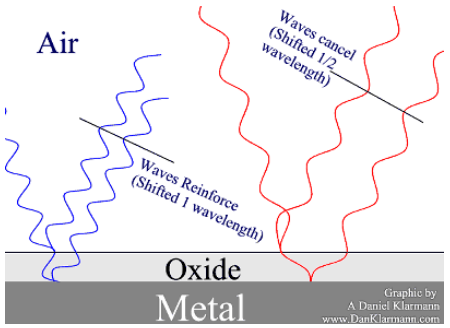
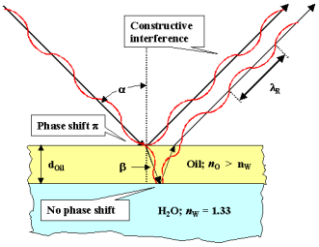


Figure 2



Optional: There is an added phase shift of one half wavelength when the reflection occurs at an interface where the light goes from a medium of lower refractive index to a medium of higher refractive index. There is no added phase shift of one half wavelength when the reflection occurs at an interface where the light goes from a



medium of higher refractive index to a medium of lower refractive index. These properties are important for determining the effectiveness of anti-reflection coats for lenses and the colors of jewelry made from metal oxides.

Jewelery that is based on structural colors made by thin layers of metal oxides:









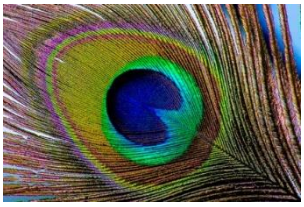
Demonstration: Look at the **male blue *Morpho* butterfly**. Describe the colors you see. How does the angle you view the butterfly wings affect the colors that you see?



Demonstration: Look at the colors of the exoskeletons of various **insects**.



Demonstration: Look at the peacock feather. Describe the colors you see. How does the angle you view the feather affect the colors that you see?



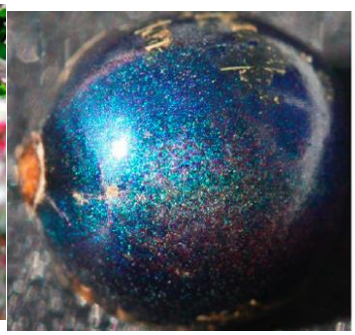
Isaac Newton (1730) wrote, "*The finely colour'd Feathers of some Birds, and particularly those of* ***Peacocks Tails****, do, in the very same part of the Feather, appear of several Colours in several Positions of the Eye, after the very same manner that thin Plates were found to do….*" Indeed, **thin layer interference** is responsible for the **iridescent blue and green colors** of the **tail feathers of male peacock**.



Thin layer interference is responsible for the **iridescent blue color** of the feathers of the **blue jay** and **indigo bunting males**. It is also responsible for the **iridescent blue color** of the fruit of the marble berry (***Pollia***).









Thin layer interference is responsible for the **iridescent green color** of the feathers of the hummingbirds and exoskeleton of insects, including tiger beetles and crysomelids.





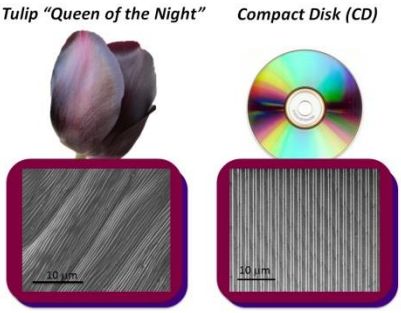


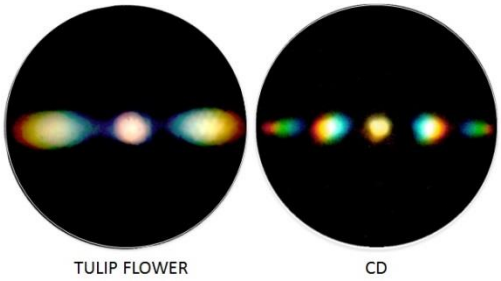
Thin layer interference is responsible for the **iridescent blue color** of *Selaginella willdenowii*. The function of iridescence in this plant is unknown.



Interference of **diffracted waves** gives the Queen of the Night tulip its purple color (http://www.colours.phy.cam.ac.uk/ferns-and-butterflies/).







Iridescent blue feathers in **male parrots** and **parakeets** are due to **thin layer interference**. The **green** color of parrots and parakeets results from the combination of **blue** structural colors and **yellow carotenoid pigments**. The carotenoids produce many colors of bird feathers depending on the dietary source and the protein attachment. Deep red feathers are due to rhodoxanthin, golden-yellow feathers are due to zeaxanthin, lemon-yellow feathers are due to lutein, scarlet red feathers are due to canthaxanthin, orange-red feathers are due to phoenicoxanthin, pale yellow to pale







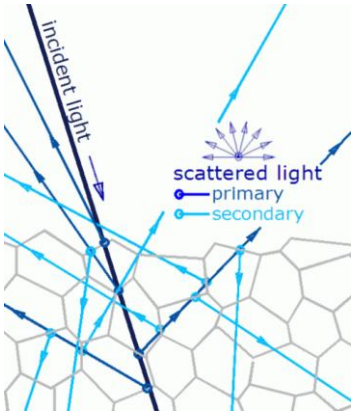
orange feathers are due to beta carotene, and salmon pink feathers are due to astaxanthin. The **white** is due to reflection from numerous air pockets.





As long as I am talking about white as a color, the white color of snow comes from the reflections of all wavelengths of sunlight **from air sandwiched between the layers of transparent snowflakes**. This **random sandwich-like structure** reflects all the wavelengths of sunlight because none of the wavelengths are differentially scattered or absorbed. Ice and water are not white because they are homogeneous and transmit all the *visible* wavelengths almost equally. While a snowball is white, it becomes transparent as it melts and loses it sandwich-like structure. When you crush or shave ice, it forms air pockets and appears white. http://www.weather.com/storms/winter/video/why-is-snow-white









A Patch of Old Snow by Robert Frost

There's a patch of old snow in a corner
That I should have guessed
Was a blow-away paper the rain
Had brought to rest.

It is speckled with grime as if
Small print overspread it,
The news of a day I've forgotten—
If I ever read it.

Stopping by Woods on a Snowy Evening by Robert Frost

Whose woods these are I think I know.
His house is in the village though;
He will not see me stopping here
To watch his woods fill up with snow.

My little horse must think it queer
To stop without a farmhouse near
Between the woods and frozen lake
The darkest evening of the year.

He gives his harness bells a shake
To ask if there is some mistake.
The only other sound's the sweep
Of easy wind and downy flake.

The woods are lovely, dark and deep,
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep.

Dust of Snow by Robert Frost

The way a crow
Shook down on me
The dust of snow
From a hemlock tree

Has given my heart
A change of mood
And saved some part
Of a day I had rued

Likewise, the white color of hair comes from the reflections of sunlight from air sandwiched between the keratin layers of hair. I do not know any more details than this.



Likewise reflection of sunlight from air trapped between cells is also responsible for the silver white color of the aluminum plant.



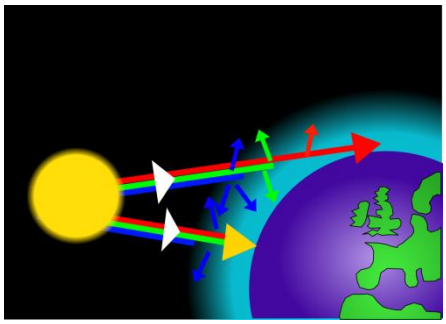
Structural colors can also be caused by **Rayleigh scattering (also known as Tyndall scattering)**. The grayish to bluish appearance of some leaves, including **blue spruce**, and **Atlas blue cedar**, probably results from the scattering of sunlight from the wax molecules that coat the epidermal surface of the leaves.





The **blue-eared glossy starling** provides one example in birds where the blue color of the feathers is generated by **Rayleigh or Tyndall scattering** in the same way that the **blue color of the eye** and the **blue color of the sky** are generated.





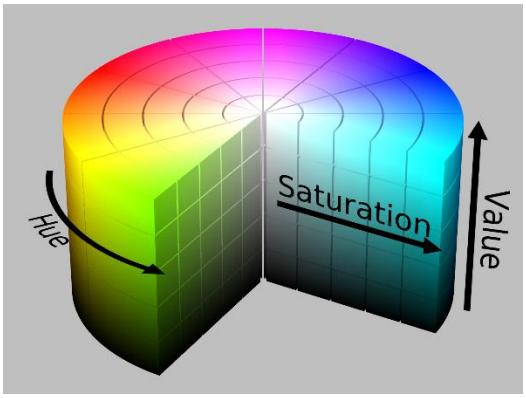


Structural colors may be a means to an end. What are the functions of the vibrant structural colors? It is possible that some animals use vibrant colors to **warn predators** that they are **poisonous** and do not taste good so that they will not be eaten and will be able to leave more offspring. Another function may be for **sexual selection**, since the males but not the females are typically brightly colored. The bright coloration of the males may make them more attractive to females making it possible for them to leave more offspring. I will discuss **warning coloration** first.



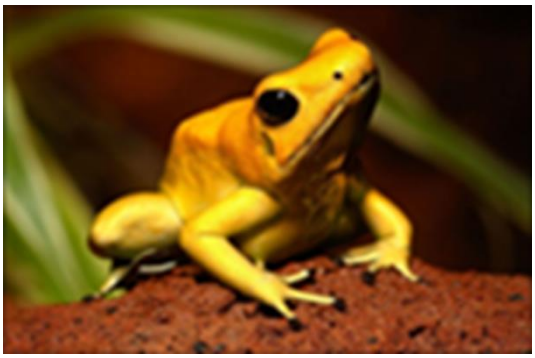
Poison frogs are brightly colored to warn their predators to leave them alone. The colors result from a combination of the **differential absorption of the spectral colors of sunlight by pigments** and the **differential interference of the spectral colors of sunlight that result from lamellar structural specializations**. In general the bright skin colors

result from three color influencing layers. The top layer contains **chromatophores** that contain **carotenoids or pteridine**. The middle layer contains **iridophores** containing thin plates of crystallized **guanine** that produce **structural blue**, and the bottom layer contains **melanin**-containing chromatophores to ensure that the colors are **not unsaturated because of reflected light** but saturated.











The poison dart frogs in Panama are very brightly colored and there seems to be a slight correlation ($r^2 = 0.61$) between color brightness and toxicity, especially considering the color brightness that the predatory birds see (Maan and Cummings, 2012).



Figure 1: Sampled populations of *Dendrobates pumilio* in the Bocas del Toro Archipelago, Panama. From Isla Bastimentos, two *D. pumilio* color morphs were collected (green and orange), as well as four individuals of the closely related but nontoxic control species *Allobates talamancae.*

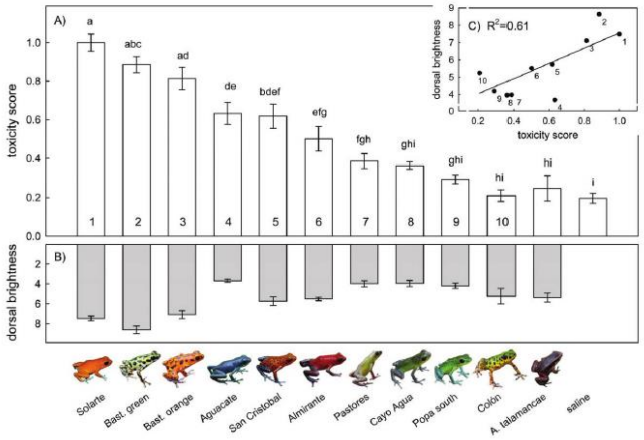
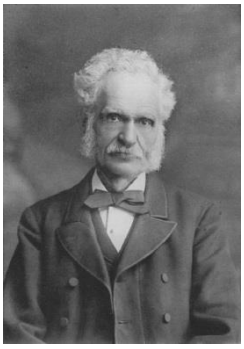


Figure 2: Toxicity scores and coloration brightness in *Dendrobates pumilio*. *A*, Open bars indicate toxicity scores with standard errors. Different letters above the bars indicate statistically significant differences; numbers are population numbers referred to in *C* and in subsequent figures. *Allobates talamancae* (a closely related Dendrobatid frog) and saline solution served as toxicity measure controls. *B*, Gray bars indicate the overall brightness of dorsal coloration (total reflectance flux, Σ*R*, in arbitrary units) for the 11 frog taxa. *C*, The inset gives the correlation between toxicity and dorsal brightness for the 10 *D. pumilio* populations. Numbers refer to the population labels in *A*.



From 1849 to 1860, **Henry Bates** wandered through the Amazon collecting butterflies. Bates grouped together the butterflies that looked similar but on close inspection he saw that many of the similarly looking butterflies were only distantly related.

Bates (1862) realized that the **Heliconiidae** butterflies resembled each other as would be expected of closely related species. The typical Heliconiidae are vibrantly colored with a **pattern of warning coloration** that communicates to their predators to leave them alone, because they are poisonous.



Bates noticed that the Heliconiidae butterflies flew around at a leisurely pace and were not eaten by birds, dragonflies, lizards, or robber-flies. He surmised that they could be so leisurely because they were care-free because they were **unpalatable**. The butterflies are poisonous as a result of eating and accumulating the chemicals produced by plants that are poisonous to most organisms but not to the butterflies. Bates then guessed that the nearby palatable Pieridae butterflies **evolved by natural selection** to look like or **mimic** the Heliconiidae butterflies.

The typical Pieridae butterflies are not very vibrant and do not have much of a pattern. In fact the name butterfly may have come from the name of a yellow member of this group (***Gonepteryx rhamni***) that was known as the **butter-coloured fly** by British Lepidopterists.







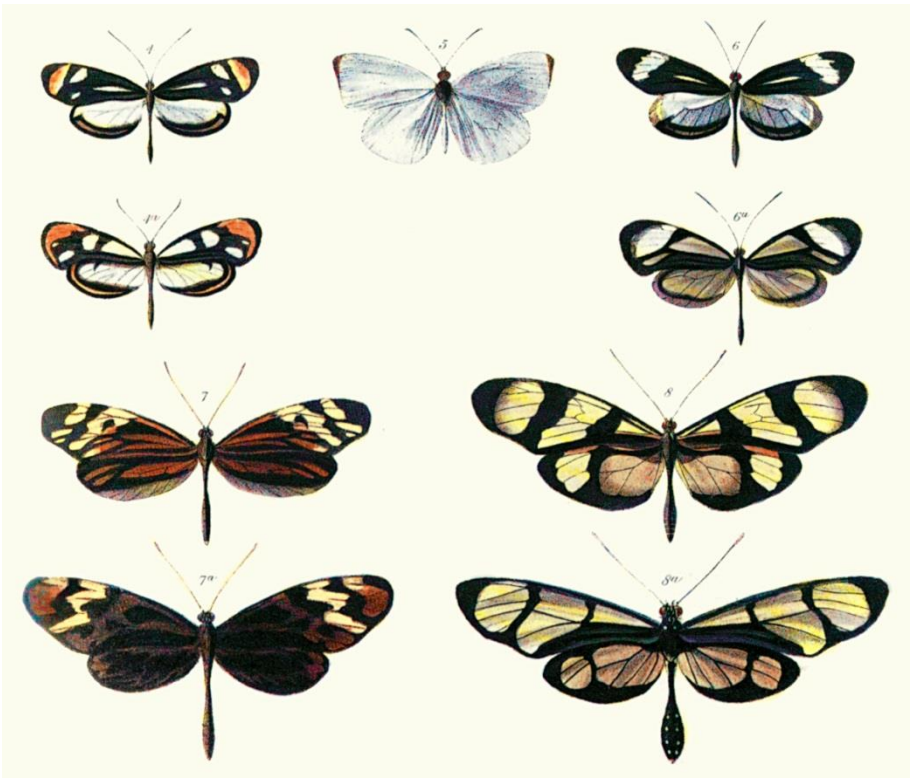


However, Bates noticed that the **Pieridae** butterflies that lived near the Heliconiidae butterflies did not look very much like the typical Pieridae but looked like the Heliconiidae. These Pieridae were vibrantly colored with a warning coloration pattern that communicated to their predators to leave them alone, even though they were not poisonous. According to Bates, they "played a part" or mimicked like a mime the poisonous Heliconiidae.

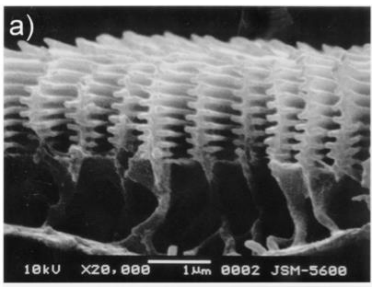


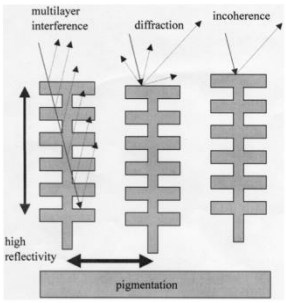
A palatable species that comes to look like an unpalatable and unrelated species is called a **Batesian mimic** and the strategy is known as **Batesian mimicry**. According to Bates, the variants of a palatable species that come to look like an unrelated unpalatable species have a selective advantage in that the predators learn not to eat the palatable butterflies that look most like the unpalatable butterflies. In this way, a palatable species develops a similar pattern of warning coloration as a poisonous species and the best mimics avoid predation and produce the most offspring. **It is a case of evolution by natural selection**. I do not know if there is or isn't direct evidence for speciation by natural selection.

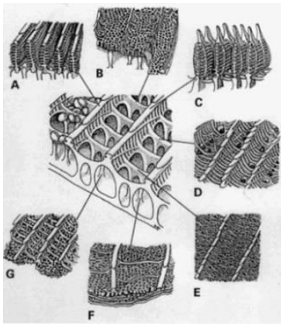
Here is a plate of **Batesian mimicry** from an 1862 publication of Bates himself. The butterflies (*Ithomiini*) in the second and fourth row are poisonous and unpalatable members of the Nymphalidae. The butterflies (*Dismorphia*) in the top and third row are the palatable mimics from the Pieridae.



The vibrant **iridescent** colors of butterfly wings are **structural colors**. The forms of the transparent structures, which are on the scale of the wavelengths of light, are both simple and complicated. Thus the spectral colors of butterfly wings are caused by a combination of **thin film interference** and **diffraction**.







Some snakes, including the Rainbow Boa, the White Lipped Python, Boelen's Python, and the Sunbeam Snake are also iridescent.

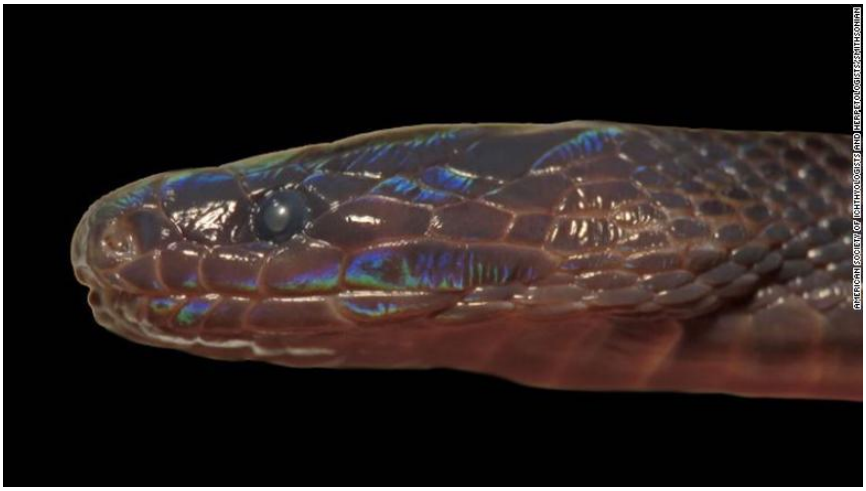








Achalinus zugorum, an iridescent snake was just discovered:



Snakes also exhibit **warning coloration**. Poisonous snakes, like the coral snakes of North America, may have **vibrant red, black and yellow warning colors** that let their predators know that they are poisonous and do not taste good. **We can tell the poisonous snakes because the yellow band meets both the red and black bands in the poisonous snakes**.



The blacks are produced by **melanins**, made by the snakes, the reds are produced by red **pteridines**, made by the snakes, and the yellows are produced by **carotenoids** that come from the snakes' food.

The harmless milk snake may gain some protection by mimicking the red, black, and yellow warning coloration of the poisonous coral snake. We can tell that it is not poisonous because the yellow band only touches the black bands.



Vibrant coloration may also be a result of **sexual selection**. According to **Charles Darwin** (1871), in humans, the males choose the females with whom they want to mate. In other animals, by contrast, it is the females who choose their mates. Consequently, in animals, the males have developed either weapons such as the **antlers of deer** and **horns of beetles** to chase off their competition and/or ornate displays such as the plumage of the peacock to attract the females. Interestingly, longer horns on beetles or giant hissing cockroaches may come at the expense of smaller testes. (http://www.bu.edu/phpbin/news-cms/news/?dept=1127&id=41428&template=226) Samuel Wilberforce



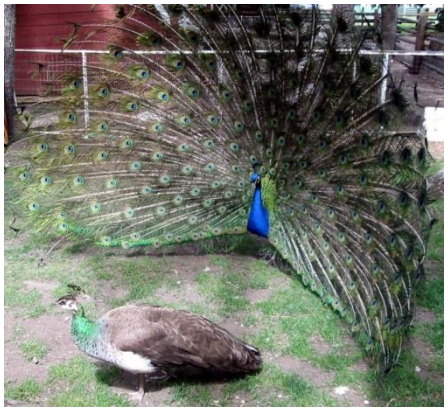


would smile.

In *On the Origin of Species by Means of Natural Selection, Or the Preservation of Favoured Races in the Struggle for Life*, Charles Darwin (1859) wrote, "*Inasmuch as peculiarities often appear under domestication in one sex and become hereditarily attached to that sex, the same fact probably occurs under nature, and if so, natural selection will be able to modify one sex in its functional relations to the other sex, or in relation to wholly different habits of life in the two sexes, as is sometimes the case with insects. And this leads me to say a few words on what I call* ***Sexual Selection****. This depends, not on a struggle for existence, but on a* ***struggle between the males for possession of the females; the result is not death to the unsuccessful competitor, but few or no offspring****. Sexual selection is, therefore, less rigorous than natural selection. Generally, the most vigorous males, those which are best fitted for their places in nature,* ***will leave most progeny****. But in many cases, victory will depend not on general vigour, but on having special weapons, confined to the male sex. A* ***hornless stag or spurless cock*** *would have a poor chance of leaving offspring. Sexual selection by always allowing the victor to breed might surely give indomitable courage, length to the spur, and strength to the wing to strike in the spurred leg, as well as the brutal cock-fighter, who knows well that he can improve his breed by careful selection of the best cocks. How low in the scale of nature this law of battle descends, I know not; male alligators have been described as fighting, bellowing, and whirling round, like Indians in a war-dance, for the possession of the females; male salmons have been seen fighting all day long; male stag-beetles often bear wounds from the huge mandibles of other males. The* ***war*** *is, perhaps, severest between the males of polygamous animals, and these seem oftenest provided with special* ***weapons****. The males of carnivorous animals are already* ***well armed****; though to them and to others, special means of*

defence may be given through means of sexual selection, as ***the mane to the lion****, the shoulder-pad to the boar, and the hooked jaw to the male salmon; for the shield may be as important for victory, as the sword or spear.*

*Amongst birds, the contest is often of a more peaceful character. All those who have attended to the subject, believe that there is the severest rivalry between the males of many species to attract by singing the females. The rock-thrush of Guiana, birds of Paradise, and some others, congregate****; and successive males display their gorgeous plumage and perform strange antics before the females, which standing by as spectators, at last choose the most attractive partner****. Those who have closely attended to birds in confinement well know that they often take individual preferences and dislikes: thus Sir R. Heron has described how one pied peacock was eminently attractive to all his hen birds. It may appear childish to attribute any effect to such apparently weak means: I cannot here enter on the details necessary to support this view; but if man can in a short time give elegant carriage and beauty to his bantams, according to his standard of beauty, I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their* ***standard of beauty****, might produce a marked effect. I strongly suspect that some* ***well-known laws*** *with respect to the plumage of male and female birds, in comparison with the plumage of the young, can be explained on the view of* ***plumage having been chiefly modified by sexual selection****, acting when the birds have come to the breeding age or during the breeding season; the modifications thus produced being inherited at corresponding ages or seasons, either by the males alone, or by the males and females; but I have not space here to enter on this subject.*



Thus it is, as I believe, that when the males and females of any animal have the same general habits of life, but differ in structure, colour, or ornament, such differences have been mainly caused by sexual selection; that is, individual males have had, in successive generations, some slight advantage over other males, in their weapons, means of defence, or charms; and have transmitted these advantages to their male offspring. *Yet, I would not wish to attribute all such sexual differences to this agency: for we see peculiarities arising and becoming attached to the male sex in our domestic animals (as the wattle in male carriers, horn-like protuberances in the cocks of certain fowls, &c.), which we cannot believe to be either useful to the males in battle, or attractive to the females. We see analogous cases under nature, for instance, the tuft of hair on the breast of the turkey-cock, which can hardly be either useful or ornamental to this bird;—indeed, had the tuft appeared under domestication, it would have been called a monstrosity*."

In his *The Descent of Man, and Selection in Relation to Sex*, Charles Darwin (1871) expanded on his ideas concerning sexual selection. He notes the sexual dimorphism in the amount of adornment—the males being more lavishly adorned than the females.



Charles Darwin discussed the "*care male birds display their various charms, and this they do with the utmost skill. Whilst preening their feathers, they have frequent opportunities for admiring themselves and of studying how best to exhibit*

their beauty. But as all the males of the same species display themselves in exactly the same manner, it appears that actions, at first perhaps intentional, have become instinctive. If so, we ought not to accuse birds of conscious vanity; yet when we see a peacock strutting about, with expanded and quivering tail-feathers, he seems the very emblem of pride and vanity."

Charles Darwin then discussed the **costs and benefits** of the adornment: "*The various ornaments possessed by the males are certainly of the highest importance to them, for they have been acquired in some cases at the expense of greatly impeded powers of flight or of running….. Nor can we doubt that the long train of the peacock and the long tail and wing-feathers of the Argus pheasant must render them a more easy prey to any prowling tiger-cat than would otherwise be the case. Even the bright colours of many male birds cannot fail to make them conspicuous to their enemies of all kinds…. What then are we to conclude from these facts and considerations? Does the male parade his charms with so much pomp and rivalry for no purpose? Are we not justified in believing that the female exerts a choice, and that she receives the addresses of the male who pleases her most? It is not probable that she consciously deliberates; but she is most excited or attracted by the most beautiful, or melodious, or gallant males. Nor need it be supposed that the female studies each stripe or spot of colour; that the peahen, for instance, admires each detail in the gorgeous train of the peacock—she is probably struck only by the general effect."*

After noting that in various species of peacocks there are gradations in the degree of adornments of the tail, Darwin suggested a mechanism as to how the peacock obtained his magnificent train **gradually** through **sexual selection**: "*As far, then, as the principle of gradation throws light on the steps by which the magnificent train of the peacock has been acquired, hardly anything more is*

needed. We may picture to ourselves a progenitor of the peacock in an almost exactly intermediate condition between the existing peacock, with his enormously elongated tail-coverts, ornamented with single ***ocelli****, and an ordinary gallinaceous bird with short tail-coverts, merely spotted with some colour; and we shall then* ***see in our mind's eye****, a bird possessing tail-coverts, capable of erection and expansion, ornamented with two partially confluent ocelli, and long enough almost to conceal the tail-feathers,—the latter having already partially lost their ocelli; we shall see in short, a Polyplectron. The indentation of the central disc and surrounding zones of the ocellus in both species of peacock, seems to me to speak plainly in favour of this view; and this structure is otherwise inexplicable. The males of Polyplectron are no doubt very beautiful birds, but their beauty, when viewed from a little distance, cannot be compared, as I formerly saw in the Zoological Gardens, with that of the peacock. Many female progenitors of the peacock must, during a long line of descent, have appreciated this superiority; for they have unconsciously, by the continued preference of the most beautiful males, rendered the peacock the most splendid of living birds*."

Sexual selection can be experimentally tested by mechanically reducing the number of eyespots in the peacock feathers and counting the number of copulations. When the eyespots are removed, the males have fewer copulations, indicating that the females may favor males with greater adornments with more eyespots. Ornate plumage gives the male an advantage in attracting females which supports Charles Darwin's theory of sexual selection (Dakin and Montgomerie, 2011). This experiment may have been flawed in that the peacocks may have been mangy and less attractive due to the cutting.

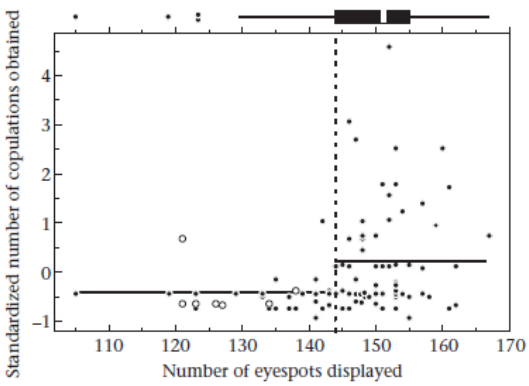


Figure 4. Relation between the number of copulations obtained (standardized by population–year) and the number of eyespots displayed on a peacock's train ($N = 102$). Data are from four studies (Petrie et al. 1991; Petrie & Halliday 1994; Loyau et al. 2005a; this study). The seven open circles are from the removal experiment in this study. Vertical dotted line is at the 25th percentile of displayed eyespot number shown in the main graph; horizontal solid lines are mean values for trains below and above that 25th percentile. Tukey box plot above graph shows the distribution of total number of eyespots displayed per train.

When the tail feathers remained intact, but the colored eyespots were covered with white or black stickers, the copulations per hour decreased. Ornate plumage gives the male an advantage in attracting females which supports Charles Darwin's theory of sexual selection (Dakin and Montgomerie, 2013).

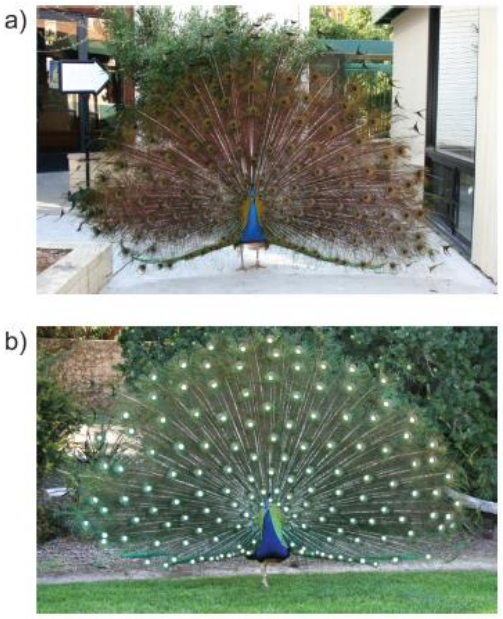
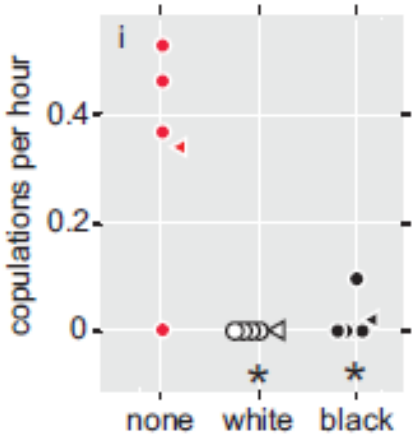


Figure 3
Experimental manipulation of peacock eyespot colors. Experimental males had either (a) black or (b) white stickers masking the purple-black and blue-green patches on all of the eyespot feathers in their train ornament.



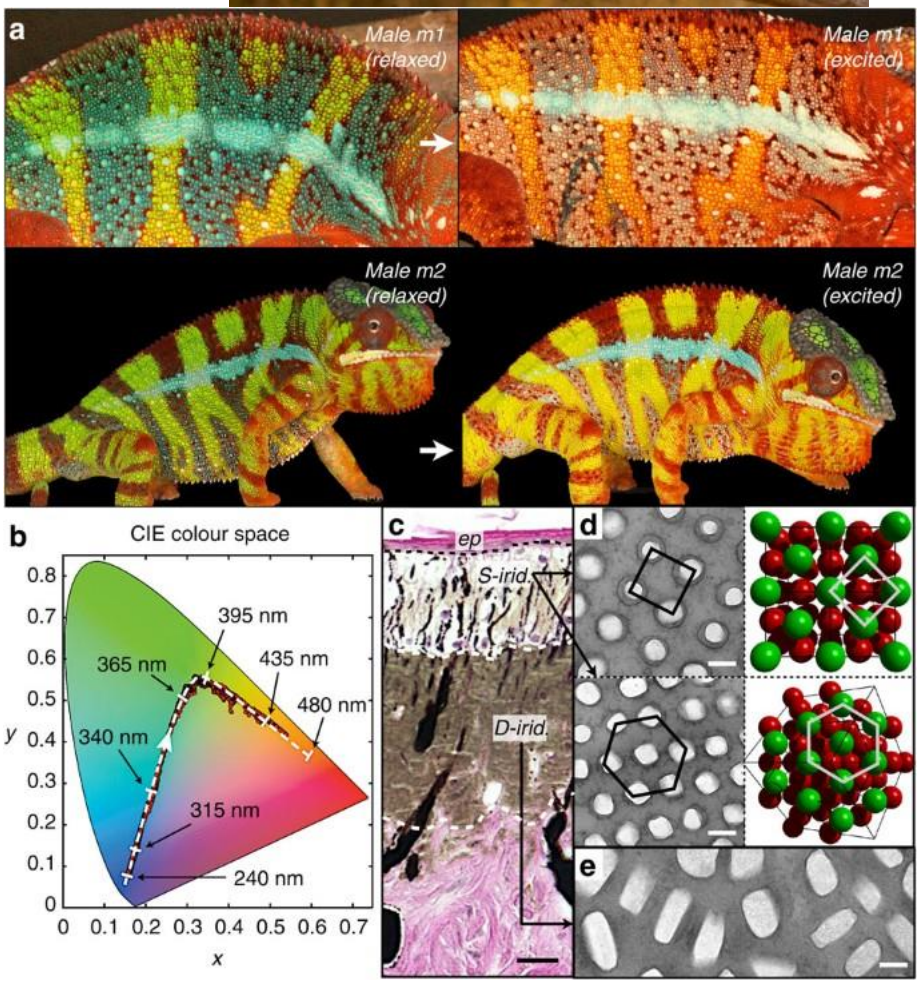
By the way, we have been talking about males and females as if those were the only two choices. Indeed **gyandromorph** cardinals, in which one half is male and one half is female, exist.





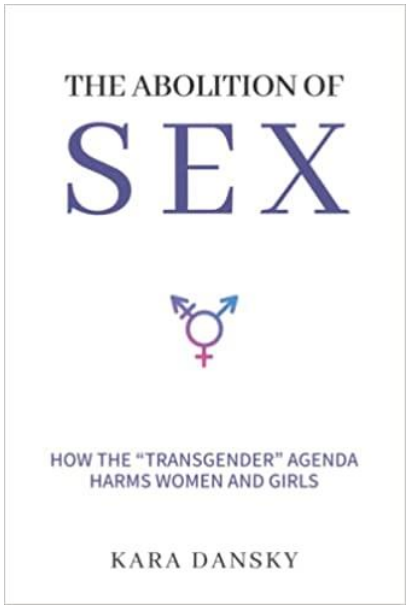
Females and young **chameleons** are dull-colored while adult male chameleons **change color when they see a rival male they want to chase away or a female they want to attract**. The adult males have two layers of iridophore cells in their skin. **Iridophores** are cells that contain transparent guanine crystals that diffract light. When the chameleon is in the relaxed state, the crystals in the iridophore cells are close together and as a consequence of diffraction and interference, they diffract short wavelengths. The diffracted blue wavelengths mix with yellow wavelengths reflected from pigments to make green—a color that is good for **camouflage**. When the cameleon becomes excited, the distance between the





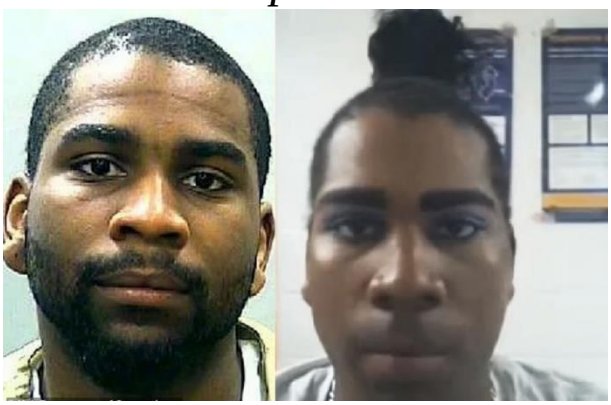
neighboring crystals increases, and as a consequence of diffraction and interference, each iridophore cell diffracts longer wavelengths. The longer wavelengths diffracted result in the chameleon turning yellow, orange, or red. The reversible color changes take only a few minutes.

In order for sexual selection to occur in males and females, sex must be **real**. Today many people are interested in abolishing **the biological concept of sex** and replacing it with the postmodern concepts of gender, gender fluidity, and gender identity, which are socially constructed through critical theory.



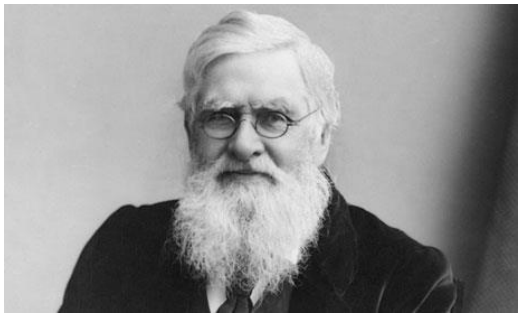


Transgender woman impregnates fellow inmates in US prison



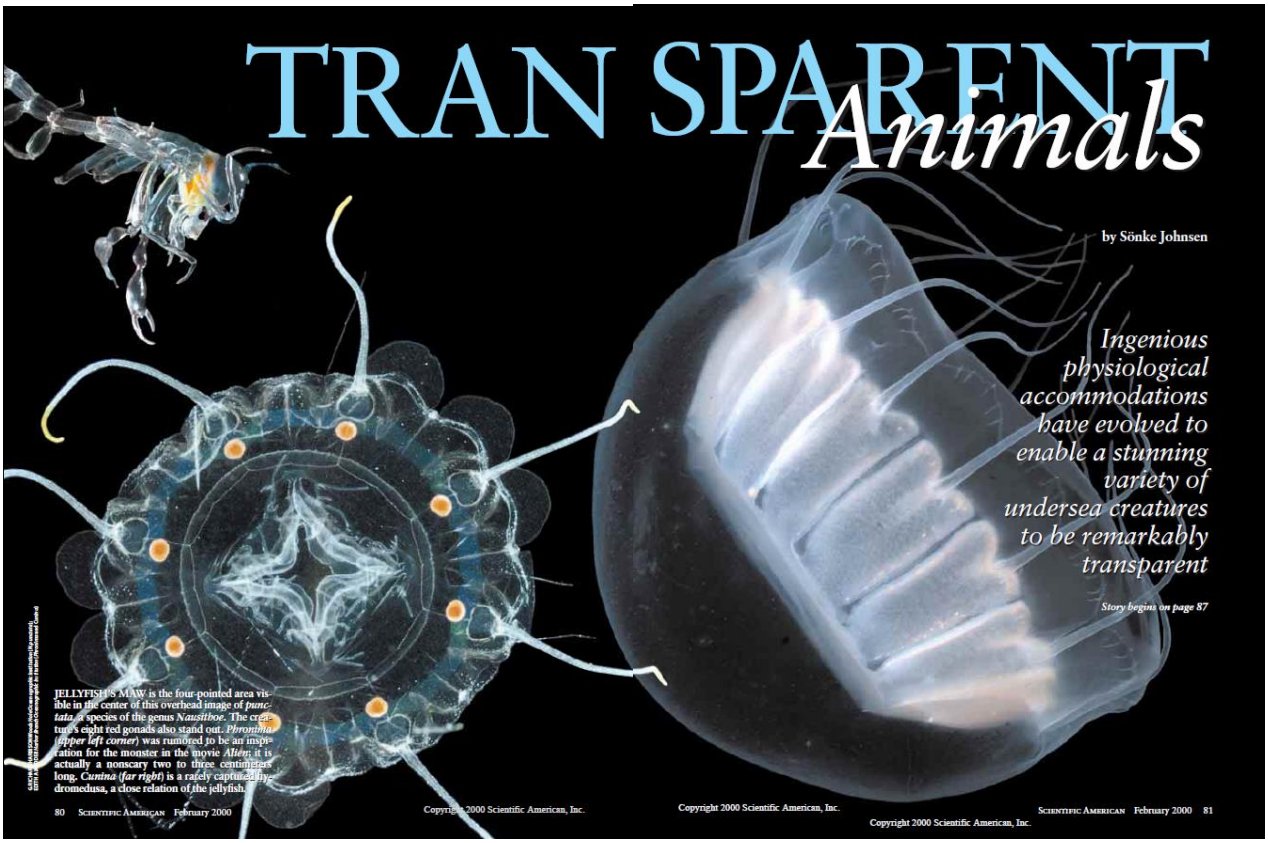
April 16, 2022: A transgender woman serving time in the Edna Mahan Correctional Facility in New Jersey has impregnated two female inmates at an all- women prison.

How often do we even consider the **colors of nature?** Eighteenth and nineteenth century naturalists, including Christian Konrad Sprengel, Charles Darwin, Henry Bates, and Alfred Russel Wallace have helped us to notice, think about, and appreciate the colors of nature, and the importance of color in the life of plants and animals. The role of these naturalists in developing our appreciation and understanding is clear from reading the following two paragraphs. Alfred Russel Wallace (1879) began his essay on *The Protective Colours of Animals* like so: "*To the ordinary observer the colours of the various kinds of molluscs, insects, reptiles, birds, and mammals, appear to have no use, and to be distributed pretty much at random. There is a general notion that in the tropics everything—insects, birds, and flowers especially—is much more brilliantly coloured than with us; but the idea that we should ever be able to give a satisfactory reason why one creature is white and another black, why this caterpillar is green and that one brown, and a third adorned with stripes and spots of the most gaudy colours, would seem to most persons both presumptuous and absurd. We propose to show, however, that* ***in a large number of cases the colours of animals are of the greatest importance to them, and that sometimes even their very existence depends upon their peculiar tint****s."* Alfred Russel Wallace ended the essay like so: "*We must now conclude this very brief outline of one of the most curious chapters in natural history. We have shown how varied and how widespread are protective colours among animals; and, if we add to these the cases in which conspicuous colours are useful, sometimes to* ***warn enemies*** *from such as are distasteful or are possessed of dangerous weapons, at other times to aid wandering species to* ***recognise their companions or to find their mates****, we shall become satisfied that we have a clue to much of the varied coloration and*



singular markings throughout the animal kingdom, which at first sight seem to have no purpose but variety and beauty."

Some animals are **transparen**t. For example jellyfish are made out gelatinous materials that have a **refractive index** so close to that of sea water that they are invisible—like the Pyrex glass rod in Wesson (soybean) oil.



TRAN SPARENT Animals

by Sönke Johnsen

Ingenious physiological accommodations have evolved to enable a stunning variety of undersea creatures to be remarkably transparent

Story begins on page 87

JELLYFISH'S MAW is the four-pointed area visible in the center of this overhead image of *punctata*, a species of the genus *Nausithoe*. The creature's eight red gonads also stand out. *Phronima* (*upper left corner*) was rumored to be an inspiration for the monster in the movie *Alien*; it is actually a nonscary two to three centimeters long. *Cunina* (*far right*) is a rarely captured hydromedusa, a close relation of the jellyfish.

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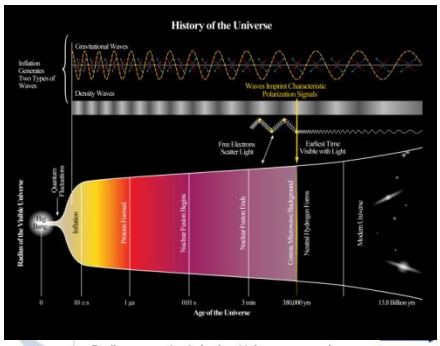
One last thing about the wave theory of light—the wave theory of light helps astrophysicists understand the wavelength of the cosmic background radiation and the **expansion of space**. Since I am a minority of one who doesn't think that space itself expands but that the universe expands in space, I see the red shift of the

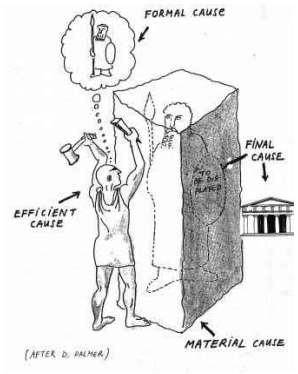


Radio waves stretched as Universe expands

Galaxy moving away with the expansion of the Universe

galaxies as a result of the Doppler effect and not from the expansion of space. I also see the wavelength distribution of the cosmic microwave background, not as a consequence of the expansion of space, but as the result of light undergoing billions of years of collisions which dissipate energy much like the energy of the gamma ray photons produced by fusion in the core of the sun is dissipated as they collide with electrons over the 100,000 year journey they make to the surface of the sun.

Study Questions



Let's answer some questions taking into consideration the **four Aristolean causes**: **the material, the formal, the efficient and the final**? We discussed Aristotles four causes when we talked about the **Ship of Theseus** in the luminescence lecture.

Why are leaves green? The material cause is chlorophyll. The formal cause is the arrangement of conjugated double bonds around the magnesium ion in the porphorin group on chlorophyll. The efficient cause is the reflection and transmission of light that is not absorbed by the chlorophyll. And the final cause is that the red and blue portions of the spectrum that are not reflected provide radiant energy that the plant transforms into the chemical energy of food.

Now you try—you may not be able to give all four causes in each case (at least I can't).

Why is human skin colored the way it is?

Why are forget-me-nots colored blue and yellow?

Why does foxfire glow in the dark?

Why do fireflies glow in the dark?

Why are peppered moths either light or dark?

Why are palatable butterflies patterned after unpalatable butterflies?

Why are tadpoles invisible sometimes?

Why are male peacocks so colorful?

Why is human skin tone lighter or darker?

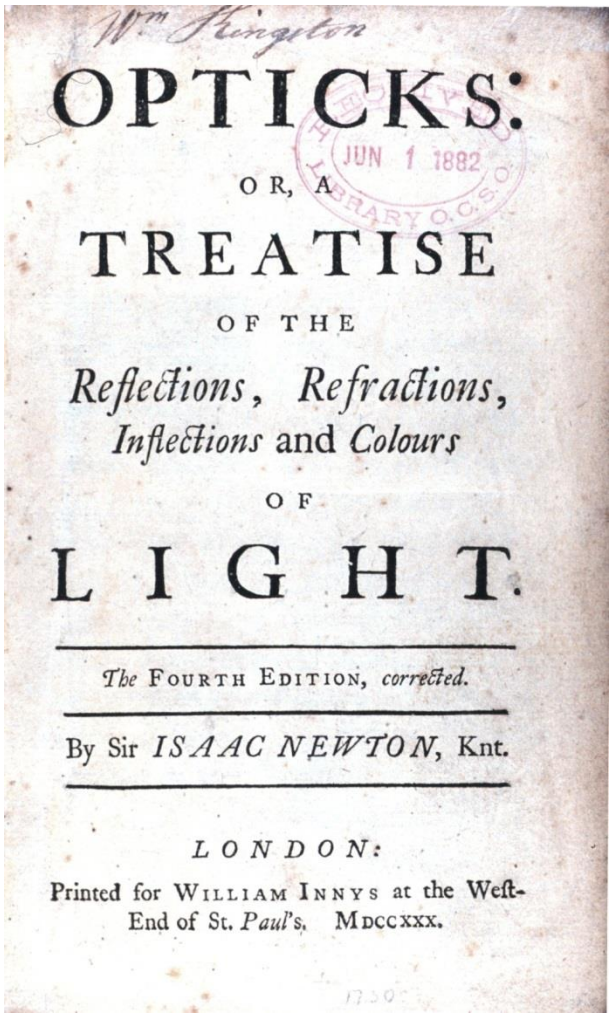
Why are human eyes the color they are?

Why do the endogenous clocks of humans synchronize with the daily rotation period of the earth?

Why do plants measure the lengths of the light and dark periods of a day?

Why is the snow white, the sky blue and the sun yellow-white?

What about a first cause? In Query 28 of his ***Opticks: or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light***, Isaac Newton (1730) reflected on the First Cause, when he wrote "*Whereas the main business of natural philosophy is to argue from phenomena without feigning hypotheses, and to deduce causes from effects, til we come to the very first cause, which certainly is not mechanical; and not only to unfold the mechanism of the world, but chiefly to resolve these and such like questions. What is there in places almost empty of matter, and whence is it that the sun and planets gravitate towards one another, without dense matter between them? Whence is it that nature doth nothing in vain; and whence arises all that order and beauty which we see in the world? To what end are comets, and whence is it that planets move all one and the same way in orbs concentrick, while comets move all manner of ways in orbs very excentrick; and what hinders the fix'd stars from falling upon one another? How came the bodies of animals to be contrived with so much art, and for what ends were their several parts****? Was the eye contrived without skill in opticks****, and the ear without knowledge of sounds? How do the motions of the body follow from the will, and whence is the instinct in animals? Is not the sensory of animals that place to which the sensible species of things are carried through the nerves and brain, that there they may be perceived by their immediate presence to that substance? And these things being rightly dispatch'd, does it not appear from phanomena that there is a being incorporeal,*


Wm Kingston

OPTICKS:

OR, A

TREATISE

OF THE

Reflections, Refractions, Inflections and *Colours*

OF

LIGHT.

The FOURTH EDITION, *corrected.*

By Sir *ISAAC NEWTON*, Knt.

LONDON:

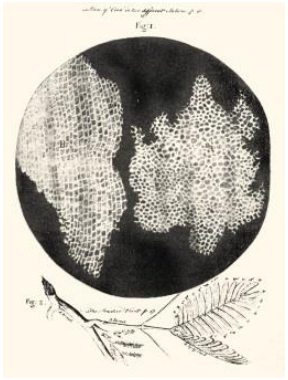
Printed for WILLIAM INNYS at the West-End of St. *Paul's*. MDCCXXX.

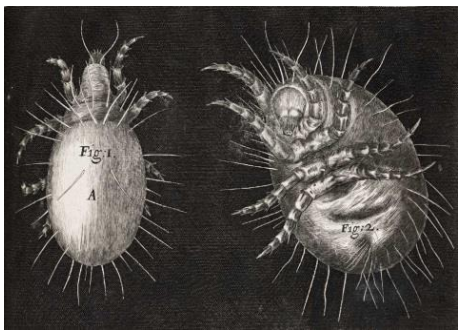
living, intelligent, omnipresent, who in infinite space, as it were in his sensory, sees the things themselves intimately, and thoroughly perceives them, and comprehends them wholly by their immediate presence to himself: Of which things the images only carried through the organs of sense into our little sensoriums, are there seen and beheld by that which in us perceives and thinks. And though every true step made in this philosophy brings us not immediately to the ***knowledge of the first cause****, yet it brings us nearer to it, and on that account it is to be highly valued."*

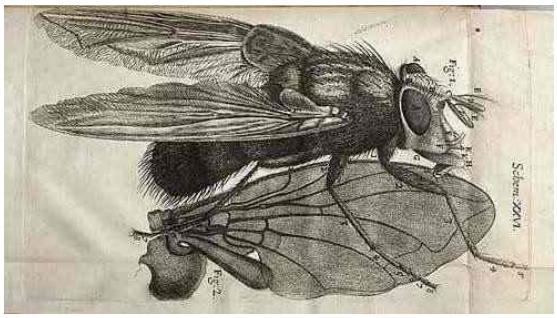
Newton ended the *Opticks* with Query 31. "*Now by the help of these principles, all material things seem to have been composed of the hard and solid particles above-mention'd, variously associated in the first creation by t****he counsel of an intelligent agent****. For it became him who created them to set them in order. And if he did so, it's unphilosophical to seek for any other origin of the world, or to pretend that it might arise out of a chaos by the mere laws of nature; though being once form'd, it may continue by those laws for many ages. For while comets move in very excentrick orbs in all manner of positions, blind fate could never make all the planets move one and the same way in orbs concentrick, some inconsiderable irregularities excepted, which may have risen form the mutual actions of comets and planets upon one another, and which will be apt to increase, till this system wants a reformation. Such a wonderful uniformity in the planetary system must be allowed the effect of choice. And so must the uniformity in the bodies of animals, they have generally a right and a left side shaped alike, and on either side of their bodies, two legs behind, and either two arms or two legs, or two wings before upon their shoulders, and between their shoulders a neck running down into a back-bone, and a head upon it; in in the head two ears, two eyes, a nose, a mouth, and a tongue, alike situated…****can be the effect of nothing else than the wisdom and skill of a powerful ever-living agent****…."*

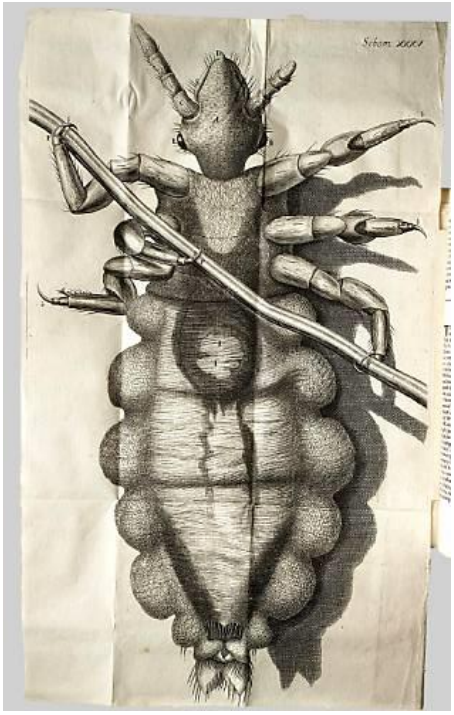
Seeing the Invisible: Using the Properties of Light and Pigments to Make Microscopic Organisms, including Germs, Visible

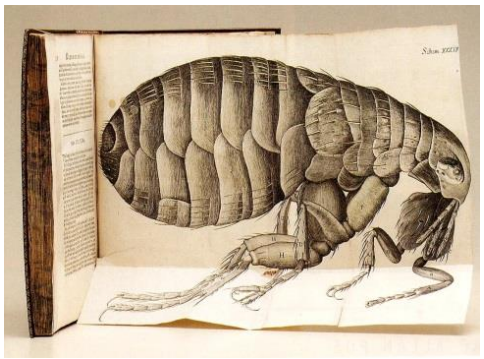
In 1665, **Robert Hooke** published a stunning book entitled, ***Micrographia****: or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries thereupon* that was illustrated with engravings of the objects he saw with his microscope. He saw the cells that composed cork, and the hairs of a blue fly, a flea, mites, a louse, and stinging nettle.

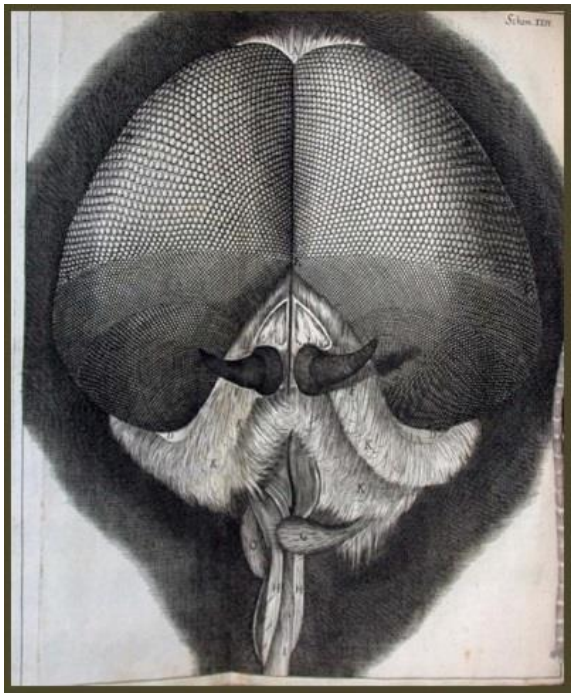


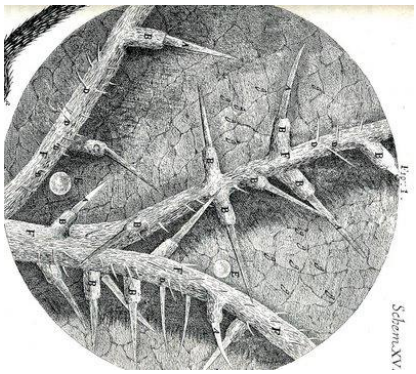




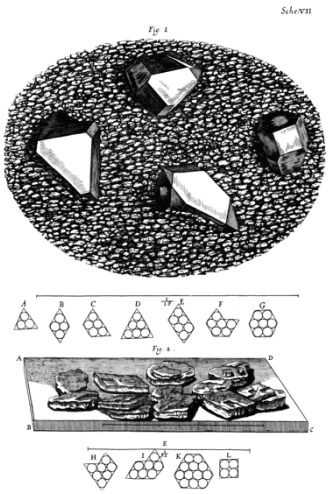




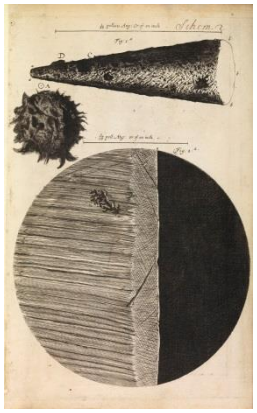




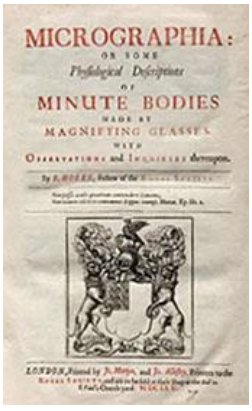
Robert Hooke also observed shards of flint, crystals in urine, and the eye of a grey drone-fly with his microscope. He saw beauty in works of nature; and the microscope revealed to him that "*the deepest discoveries shew us the greatest excellencies. An evident argument, that he that was the author of all these things, was no other than omnipotent; being able to include as great a variety of parts and contrivances in the yet smallest discernable point, as in those vaster bodies (which comparatively are also called points) such as the earth, sun, or planets*."



Robert Hooke came to these conclusions about the author of all things after comparing the form of nature's lowest accomplishments with man's finest technological accomplishments, such as the point of a needle or the edge of a razor, where "*the more we see of their shape, the less appearance will there be of their beauty*."



Robert Hooke intended to share his newly discovered world with anyone who was interested and the ***Micrographia*** became the first scientific bestseller—even though it was expensive, selling at a price of 30 shillings (~ $200). Robert Hooke wrote in the preface, "*by the means of **telescopes**, there is nothing so far distant but may be represented to our view; and by the **microscopes**, there is nothing so small, as to escape our inquiry; hence there is a new visible world discovered to the understanding. By this means the heavens are open'd, and a vast number of new stars, and new motions, and new productions appear in them, to which all the ancient astronomers were utterly strangers. By this the earth it self, which lyes so neer us, under our feet, shews quite a new thing to us, and in every little particle of its matter, we now behold almost as great a variety of creatures, as we were able before to reckon up in the whole universe it self…. I here present to the world my*



imperfect indeavours' which though they shall prove no other way considerable, yet, I hope, they may be in some measure useful to the main design of a reformation in philosophy, if it be only by shewing, that there is not so much requir'd towards it, any strength of imagination, or exactness of method, or depth of contemplation (though the addition of these, where they can be had must needs produce a much more perfect composure) as a ***sincere hand****, and a* ***faithful eye****,* ***to examine****, and to record, the things themselves as they appear*."

In inviting us to travel through the newly discovered microscopic world, **Robert Hooke** gives us some advice: "*The truth is, the science of nature has been already too long made only of work of the brain and the fancy: It is now high time that is should return to the plainness and foundations of observations on material and obvious things.* ***It is said of great empires, that the best way to preserve them from decay, is to bring them back to the first principles, and arts, on which they did begin. The same is undoubtedly true in philosophy, that by wandring far away into invisible notions, has almost quite destroy'd it self, and it can never be recovered, or continued, but by returning into the same sensible paths, in which it did at first succeed…..true philosophy…is to begin with the hands and eyes, and to proceed on through the memory, to be continued by the reason; nor is it to stop there, but to come about to the hands and eyes again….*"



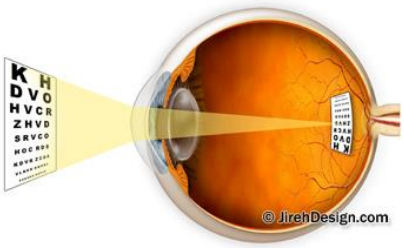
According to Heinrich Pestalozzi (1825), "[t]*he nature of these faculties within each person drives him to use them. The eye wants to see, the ear to hear, the foot wants to walk and the hand to grasp. And, equally, the heart wants to believe and love, the mind wants to think. There is in every faculty of human nature an urge to rise from its inert, unskilled state to become a trained power*." Pestalozzi, classifies these into the trinity of hand, heart, and mind, the training of which is the aim of education.

Today, someone who **works with their hands and eyes** would not be celebrated as being elite.

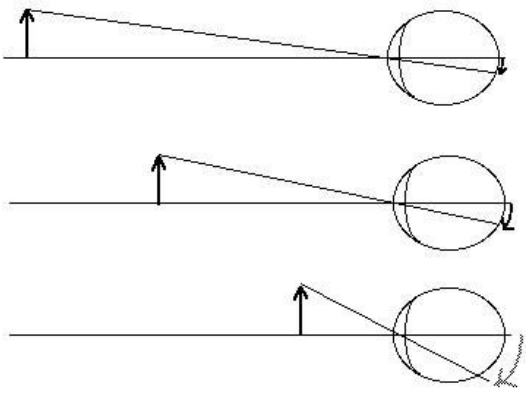




The microscope facilitates our journey into the microscopic world because it can **resolve two points separated by a distance that is smaller than the wavelength of visible light (400-700 nm).** By contrast, the human eye is only able to resolve two separate points that are greater than **70,000 nm** or 0.07 mm from each other. This is equivalent to one minute of arc. The **acuity** of the human eye is limited by the diameters of the **cones**, which are about 2 μm, in the **fovea** of the **retina**. The **cornea** and **crystalline lens** act together as a **converging lens** that produces a real, minified, inverted image of the object on the retina.

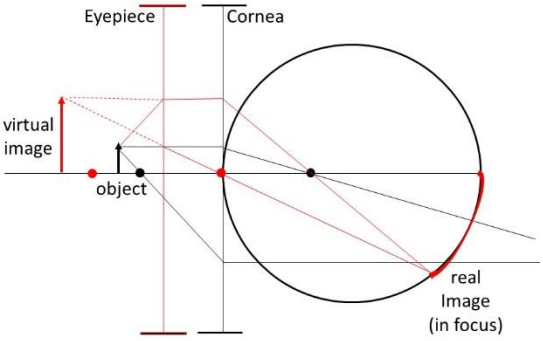


If light from two nearby points on an object fall on the same cone, the two points will appear to **our mind's eye** as one. If light from the two points fall on two separate cones separated by a third cone, the two points will be clearly resolved. The resolving power of the eye can be increased slightly by eye movements that vary the position of the cones.



In order for two points to appear as separate points, light from those points must enter the eye forming an angle greater than one minute of arc. This can be done by bringing the object very close to the eye. However, due to the limitation of our eye to focus at close distances, a specimen can be brought up only to the **near point of the eye**, which is about 25 cm from our eye. A microscope is a compound magnifying glass that makes it possible to increase the visual angle, so that light, emanating from two near but separate points, can enter the eye, forming an angle that subtends more than one minute of arc such that the light from the two separate points fall on separate cones.





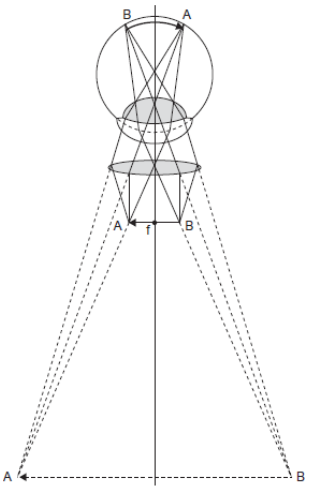
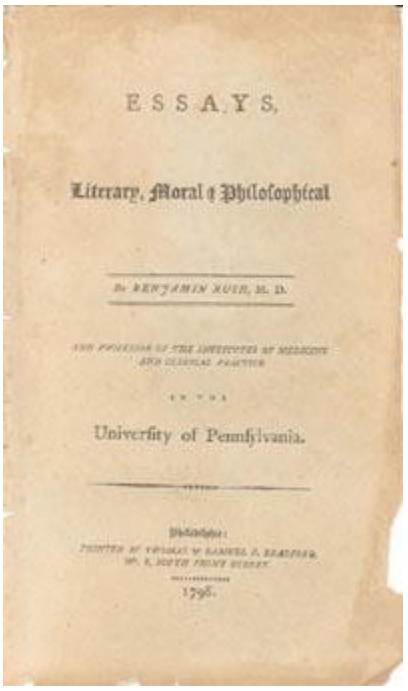


FIGURE 4.1 A simple microscope placed in front of the eye increases the visual angle, thus producing an enlarged image of a microscopic specimen on the retina. The specimen appears to be located at the near point of the relaxed eye and magnified.

In his *Thoughts on Common Sense,* **Benjamin Rush** (1798) wrote, "*...the most acceptable men in practical society, have been those who have never shocked their cotemporaries, by opposing popular or common opinions. Men of opposite characters,* ***like objects placed too near the eye****, are seldom seen distinctly by the age in which they live. They must content themselves with the prospect of being useful to the distant and more enlightened generations which are to follow them. Galileo, who asked pardon of the Pope, on his knees, for contradicting the common sense of the, church, respecting the revolution of the earth, and Dr. Harvey, who lost all his business by refuting the common sense of former ages, respecting the circulation of the blood, now enjoy a reputation for their opinions and discoveries, which has in no instance ever been given to the cold blood of common sense*."


ESSAYS,

Literary, Moral & Philosophical

By BENJAMIN RUSH, M. D.

AND PROFESSOR OF THE INSTITUTES OF MEDICINE AND CLINICAL PRACTICE IN THE

University of Pennsylvania.

Philadelphia:

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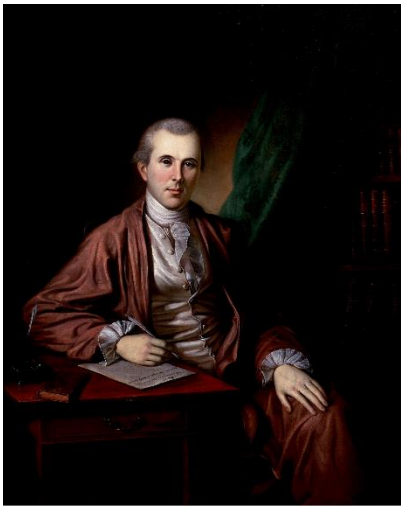
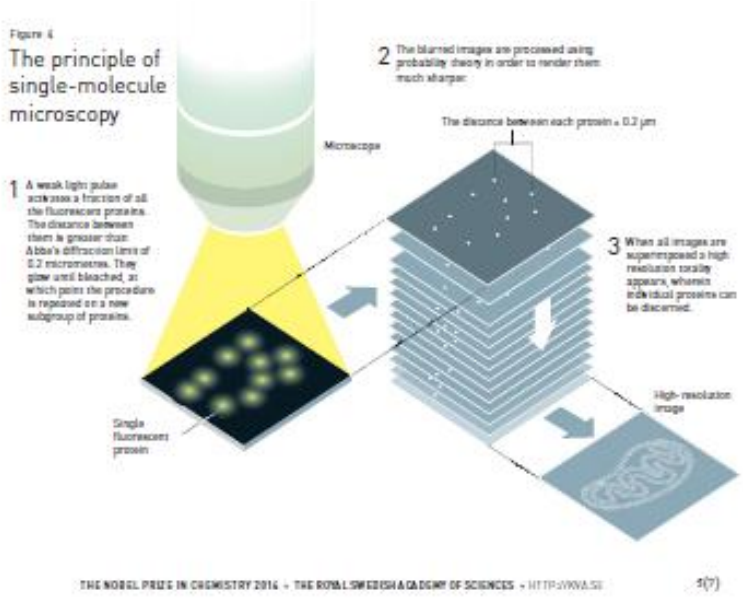
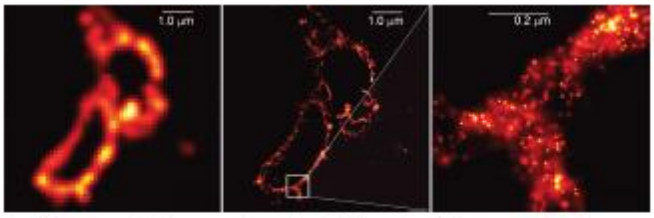
1798.



The 2014 Nobel Prize in Chemistry was awarded to Eric Betzig (Cornell), Stefan Hell, and William Moerner "*for the development of super-resolved fluorescence microscopy*" that can image individual molecules. They turned **microscopes** into **nanoscopes**!

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2014/popular-chemistryprize2014.pdf

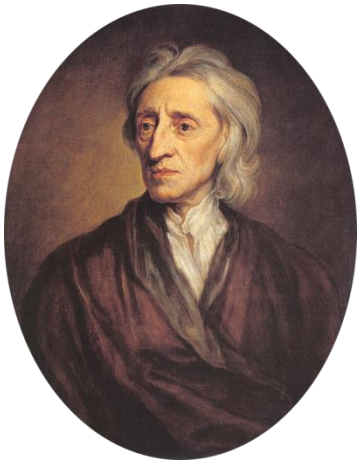






Neil deGrasse Tyson (2009) lamented the limitations of the eye in *The Perimeter of Ignorance*: "*The eye is often held up as a marvel of biological engineering. To the astrophysicist, though, **it's only a soso detector**. A better one would be much more sensitive to dark things in the sky, and to all the invisible parts of the spectrum. How much more breathtaking sunsets would be if we could see ultraviolet and infrared. How useful it would be if, at a glance, we could see every source of microwaves' in the environment, or know which radio station transmitters were active. How helpful it would be if we could spot police radar detectors at night*."

On the other hand, in *An Essay Concerning Human Understanding*, **John Locke** (1690) indicated that we might be fortunate to have eyes with limited acuity. John Locke (1690) wrote, "*We are able, by our senses, to know and distinguish things....if that most instructive of our senses, seeing, were in any man a thousand or a hundred thousand times more acute than it is by the best microscope, things several millions of times less than the smallest object of his sight now would then be visible to his naked eyes, and so he would come nearer to the discovery of the texture and motion of the minute parts of corporeal things; and in many of them, probably get ideas of their internal constitutions: but then he would be in a quite different world from other people: nothing would appear the same to him and others: the visible ideas of everything would be different. So that I doubt, whether he and the rest of men could discourse concerning the objects of sight, or have any communication about colours, their appearances being so wholly different. And perhaps such a quickness and tenderness of sight could not endure bright sunshine, or so much as open daylight; nor take in but a very small part of any object at once, and that too only at a very near distance. And if by the help of such* ***microscopical eyes*** *(if I may so call them) a man could penetrate further than ordinary into the secret composition and radical texture of bodies, he would not make any great advantage by the change, if such an acute sight would not serve to conduct him to the market and exchange; if he could not see things he was to avoid, at a convenient distance; nor distinguish things he had to do with by those sensible qualities others do. He that was sharp-sighted enough to see the configuration of the minute particles of the spring of a clock, and observe upon what peculiar structure and impulse its elastic motion depends, would no doubt discover something very admirable: but if eyes so framed could not view at once the hand, and the characters of the hour-plate, and thereby*

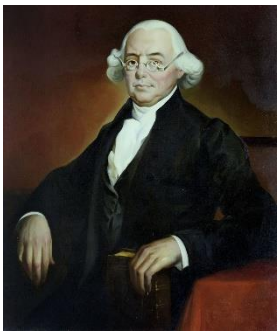


at a distance see what o'clock it was, their owner could not be much benefited by that acuteness; which, whilst it discovered the secret contrivance of the parts of the machine, made him lose its use."

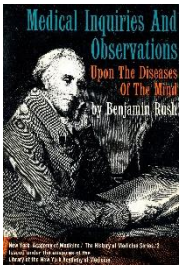


In *An Essay on Man*, **Alexander Pope** (1745) considered the same question:

> *Why has not Man a microscopic eye?*
> *For this plain reason, Man is not a Fly.*
> *Say what the use, were finer optics given,*
> *T'inspect a mite, not comprehend the heaven.*



The phrase "*microscopic eye*" was use again in November, 1787, while the Pennsylvania convention was debating whether they should refer the U. S. Constitution to a committee of the whole, James Wilson made the following observation: "*Shall we, Sir, while we contemplate a great and magnificent edifice, condescend like a fly, with its **microscopic eye**, to scrutinize the imperfections of a single brick?*"



The phrase was used again by Benjamin Rush (1812) in his book, *Medical Inquiries and Observations Upon the Diseases of the Mind*, "*The reader will excuse my frequent references to the poets for facts to illustrate the history of madness. They view the human mind in all its operations, whether natural or morbid, with a **microscopic eye**; and hence many things arrest their attention, which escape the notice of physicians*."

Given the limitations of the human eye, microscopes are necessary to see the invisible in the microscopic world. **Augustus de Morgan** (1872), the mathematician, wrote this couplet about the microscopic world seen by the seventeenth- and eighteenth-century microscopists.



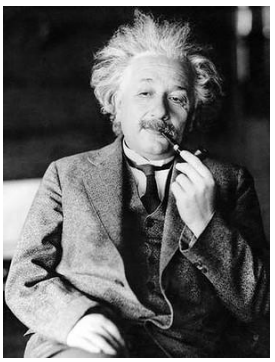
> *Great fleas have little fleas upon their backs to bite e'm,*
> *And little fleas have lesser fleas, and so on ad infinitum.*

The word microscope, which was coined by Giovanni Faber on April 13, 1625, comes from the Greek words *mikrós μικρός* and *skopeîn σκοπεῖν*, which mean "small" and "to see." Microscopes, known as **flea glasses**, for obvious reasons, were used for decades before Hooke made his observations. The bright-field microscope is, perhaps, one of the most elegant instruments ever invented, and the first microscopists used the technologically advanced increase in the resolving power of the human eye to reveal that the workmanship of the Creator can be seen at the most minute dimensions. The bright-field microscope made it possible to reveal the cell as the basic unit of life in the early 17th century, the structural basis for the transmission of inherited characteristics and the microscopic basis of infectious diseases in the late 19th century, and the reality of molecules in the 20th century.



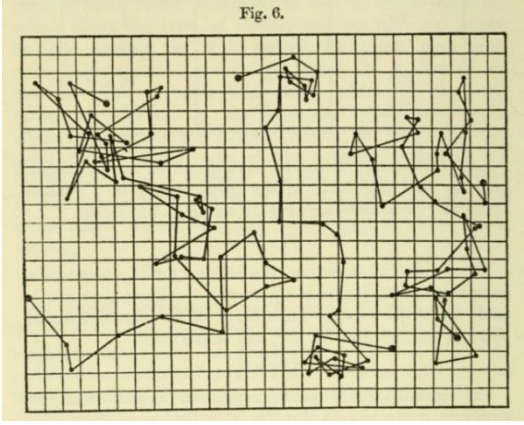






While studying pollination in plants, **Robert Brown** (1828, 1829) serendipitously discovered the incessant movement of living and nonliving particles, now known as **Brownian motion** with his simple botanical bright-field microscope. In 1905, **Albert Einstein** analyzed Brownian motion and concluded that the movement occurred as a result of the statistical distribution of forces exerted by the water molecules surrounding the particles. **Jean Perrin** (1909) confirmed Einstein's hypothesis by observing Brownian motion under the microscope and used his observations, along with Einstein's theory, to calculate Avogadro's number, the number of molecules in a mole. Ernst

Mach and Wilhelm Ostwald, who were the last holdouts to accept the **reality of atoms and molecules**, became convinced in the reality of molecules from the work done on Brownian motion. These influential scientists were held back from accepting the evidence of the existence of molecules from other kinds of physicochemical data because of their **positivist philosophy**, which could be summed up by the phrase "seeing is believing."



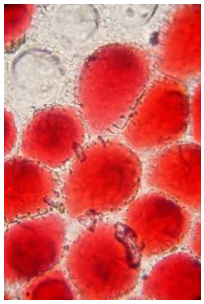
Demonstration: Carefully use the replica of **Leeuwenhoek's microscope** to see the hairs on the wing of a house fly. This is a simple microscope; meaning that it only has one converging lens that produces a virtual, magnified, erect image of the specimen. If the light source or better yet for this microscope, the sun is directly behind the specimen, you will have bright-field illumination, is the light source is perpendicular to the specimen, you will have dark-field illumination and if the light source is at a forty-five-degree angle to the specimen, you will have oblique illumination. Each type of illumination produces a different kind of image.



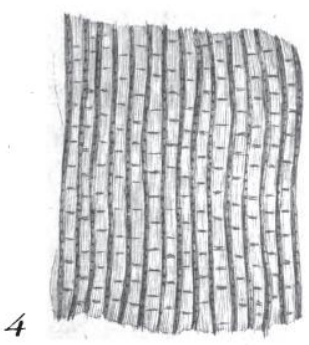
The bright-field microscope provides the best contrast when viewing **colored objects**. Plant cells can be naturally colored with anthocyanins, carotenoids and chlorophyll. Cells also can be colored with natural and artificial dyes.

Demonstration: Put a thin piece of a **flower petal** on a drop of water on a glass slide. The cells of the petals are colored with **anthocyanins**. The red anthocyanins attract hummingbirds, sunbirds, and butterflies that have a long





wavelength photopsin in their retina and are sensitive to red light.





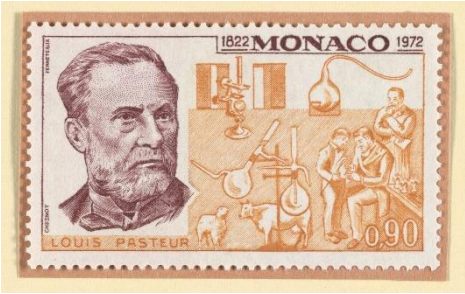
Natural dyes used to color fabrics were employed by **John Hill** (1770) to demonstrate the path that water took through the stem of the tree. By adding the **cochineal dye**, John Hill saw that "*the course of the vessels, is very distinctly and beautifully seen by it; for they only are crimson*." This was most likely the first use of dyes to selectively stain tissues. As we will discuss next week, cochineal is the dye that had been used to color the robes of **Catholic Cardinals** and the dye that would be used to color the uniforms of the British officers during the Revolutionary War giving them the name, **redcoats**. **Dyes became very important for elucidating the germ theory of disease**.

The microscope made it possible to discover invisible living organisms such as bacteria that can cause **disease**. Antony van Leeuwenhoek (1684) discovered bacteria living between his teeth: "*Tho my teeth are kept usually very clean, nevertheless when I view them in a magnifying glass, I find growing between them a little white matter as thick as wetted flower: in this substance tho I could not perceive any motion, I judged there might probably be living creatures. I therefore took some of the flower and mixt it either with pure rain water wherin were no animals; or else with some of my spittle (having no air bubbles to cause motion in it) and then to my great surprise perceived that the aforesaid matter contained very* ***many small living animals****, which moved themselves very extravagantly.*

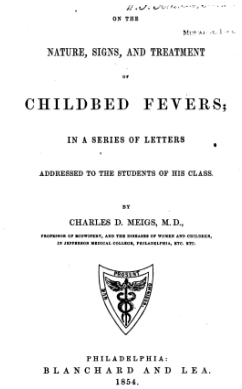


The biggest sort had the shape of A. their motion was strong and nimble, and they darted themselves thro the water or spittle, as a Jack or Pike does thro the water."





Alexander Gordon (1795), Oliver Wendell Holmes Sr. (1843), **Ignaz Semmelweis** (1844; https://www.youtube.com/watch?v=XCao_79drM4; https://www.youtube.com/watch?v=KDcAXdqkFks; https://www.youtube.com/watch?v=BxA-a4_SPME; https://www.youtube.com/watch?v=PlIYg6ApCx0) and **Louis Pasteur** (1856; https://www.youtube.com/watch?v=gcMBpKp8jcQ) among others proposed that diseases, such as puerperal fever or **childbed fever,** were caused by **germs** that had been transferred from the cadavers upon which autopsies were performed to the pregnant women who were delivering. Unbelievably, the doctors actually delivered babies without **washing their hands** after they performed autopsies. However, it was the consensus of the medical profession that the germ theory of disease was just silly; the obstetrician Charles Meigs, said, "*Doctors are gentlemen, and gentlemen's hands are clean*."



NATURE, SIGNS, AND TREATMENT

OF

CHILDBED FEVERS;

IN A SERIES OF LETTERS

ADDRESSED TO THE STUDENTS OF HIS CLASS.

BY

CHARLES D. MEIGS, M.D.,

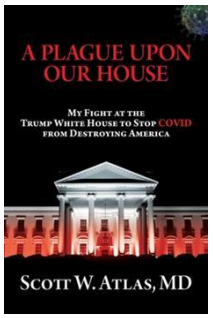
PHILADELPHIA:
BLANCHARD AND LEA.
1854.

cases as he did. I visited in consultation with him some of the very worst of the cases, and touched the patients, and was as liable to imbibe, or to be clothed with the effluvia from their bodies as he was; nevertheless, I did not carry any poison, or other cause of disease, to any patient of mine; and if not I, then how should he become capable of doing so? He is a gentleman who is scrupulously careful of his personal appearance, of great experience as a practitioner, and well informed as to modern opinions on the contagion of childbed fever. Still, those of you who are contagionists will say that he carried the poison from house to house; and if so, then you ought to give some rationale of the fact. Did he carry it on his hands? But a gentleman's hands are clean. Did he carry a nebula or halo about him? Then why not I also? If the nebula adhered to his clothing, it might as well have adhered to mine.



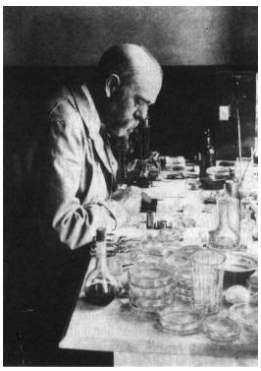
The medical profession, with its consensus, was wrong. **Kurt Vonnegut** (1981), a Cornellian, tells about this time in history in a commencement address he gave to the graduating class of Southampton College. He told them: "***My hero is Ignaz Semmelweis. I will go on to***

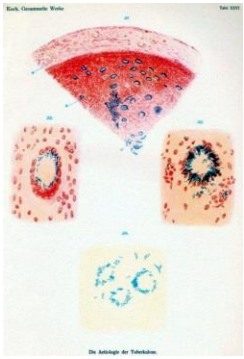
recommend to those graduating from colleges everywhere in the world this spring that their hero be Ignaz Semmelweis*."* I have appended an excerpt of Kurt Vonnegut's speech to these lecture notes and you can find the entire speech here (http://www.nytimes.com/books/97/09/28/lifetimes/vonnegut-commencement.html).



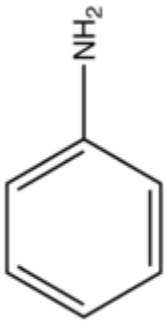
In his book, *A Plague Upon Our House*, a memoir that describes his time on the White House Coronavirus Task Force, Scott Atlas (2021) reminds us that "[a] *scientific truth is not declared by consensus. It arises from research, critical thinking, and debate, not groupthink and censure of alternative views*." Atlas, along with Jay Bhattacharya, and Martin Kulldorff (December 20, 2021) wrote in an article entitled, *America Needs a Rebirth of Science*, "[t]ruth-*seeking itself relies on an evidence-based process of debate free from fear of censorious ramifications. Yet now, anyone who dares to speak out against the "accepted" conclusions of America's self-designated scientific priestly class is marginalized. Declarations of false consensus have worked as intended (to intimidate alternative views), and scientists have silenced themselves to guard their careers…Science must once again be seen as a vibrant method that tends toward truth but that's always at risk of being overturned by the next discovery. Right now, the public is not getting from the scientific community what it needs, what it deserves, and what it pays for*." To this end, Hillsdale College just established The Academy for Science and Freedom to "*To educate the American people about the free exchange of scientific ideas and the proper relationship between freedom and science in the pursuit of truth*."

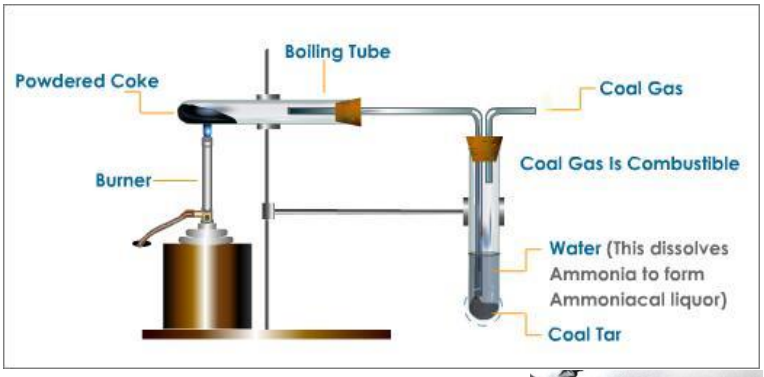
Ancient wisdom can be found in Psalm 24 (3-4): *Who may ascend the mountain of the Lord? Who may stand in his holy place? The one who has* ***clean hands*** *and a pure heart….*

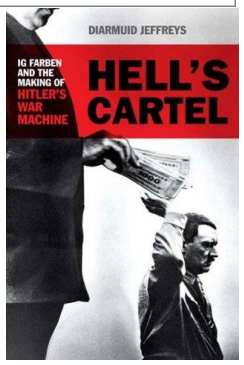




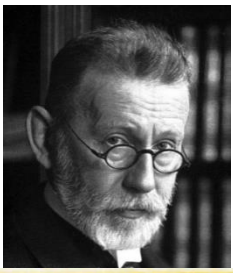
It became **Robert Koch's** (1877) job to prove beyond a shadow of a doubt that bacteria were the cause of many **infectious diseases**, including **tuberculosis** and **anthrax**. The first thing Robert Koch had to do was to develop staining procedures that would allow the bacteria to be visualized in blood smears and in tissues. Robert Koch made use of the new **aniline dyes**, including methyl violet, fuschin, and aniline brown that had been developed by the **German dye industry** to **stain the bacteria**. As we will discuss next week, the aniline dyes were produced from **coal tar**, the residue from the production of **coal gas** used for street lighting. The companies, including Agfa, BASF, Bayer, and Hoechst that produced the aniline dyes became part of **I. G. Farben** that built the concentration camp at **Auschwitz** where prisoners made rubber from coal.







Paul Ehrlich (1878) further developed the technique of **biological staining** using the **aniline dyes**. Paul Ehrlich was interested in combining chemistry and histology to study human cells and wrote a thesis entitled, *Chemical and Histological Staining Principles Using Aniline Dyes*. After hearing Robert Koch speak about germs, Paul Ehrlich noticed that some **dyes selectively bound to germs** but not to the cells they infected. Paul Ehrlich then realized that it would be possible to find a drug that directly targeted the germ (parasitotropic) without





targeting the human host cells (organotropic). Such a drug would act as a **magic bullet** against germs. Paul Ehrlich's first success in **chemotherapy**, a word he coined, was **Salvarsan**—the arsenic that saves. Salvarsan cured syphilis by selectively targeting the spirochete that caused it. Seeing more than the light coming through the eyepieces of his microscope, Paul Ehrlich founded the life-saving field of chemotherapy (https://vimeo.com/155189041).



Dyes are chemicals with several **conjugated double bonds** that absorb certain regions of the spectrum and reflect or transmit others. They only bind to the parts of the specimen that have certain chemical characteristics, particularly in terms of charge. When the specimen is illuminated with white light, the **amplitudes of the waves** with wavelengths that are absorbed by the dye are diminished. The amplitudes of the waves with wavelengths that are not absorbed by the dye pass through unchanged, resulting in a **differentially colored specimen**. The reduction of the amplitude of a wave when light passes through a dye is equivalent to the absorption of photons by the dye.

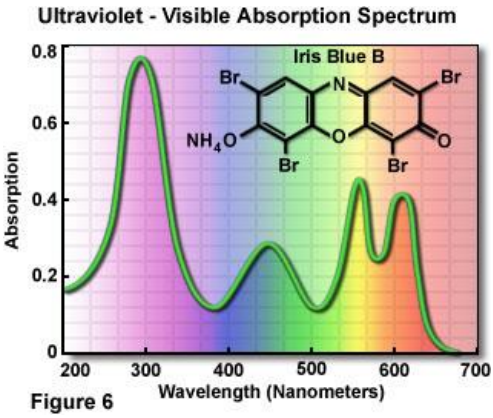
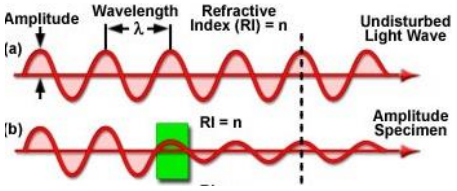
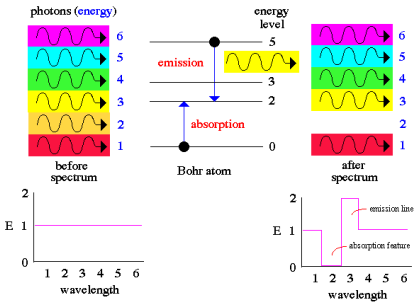
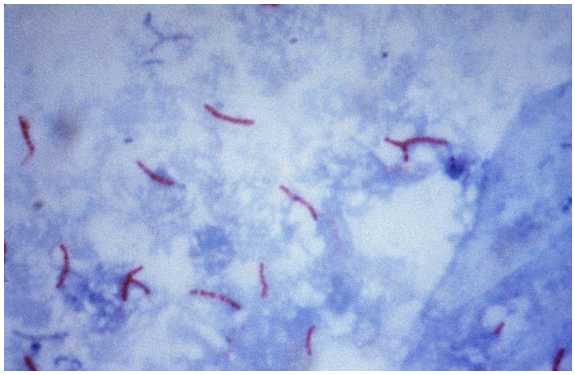


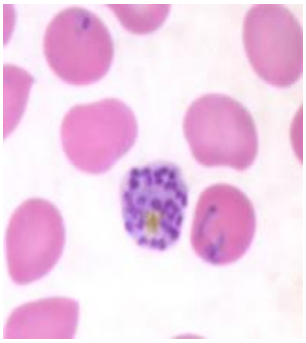
Figure 6

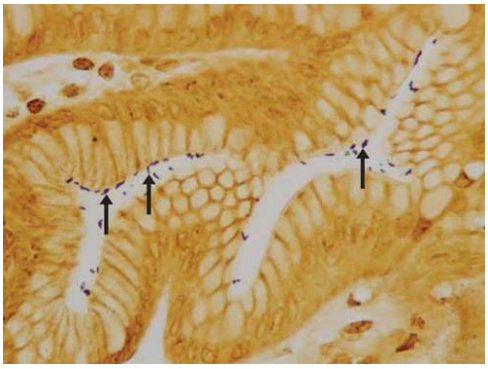




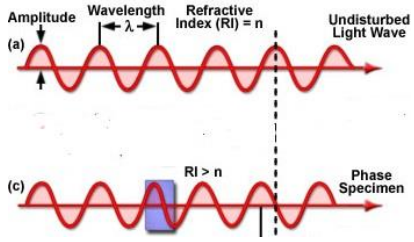
Better stains and specific staining methods allows the identification of specific disease-causing germs so that the diseases can be identified. The Ziehl-Neelsen stain colors the tuberculosis bacterium red, Giemsa stain colors malaria parasite blue, and the Warthin-Starry stain colors *Helicobacter pylori* black.

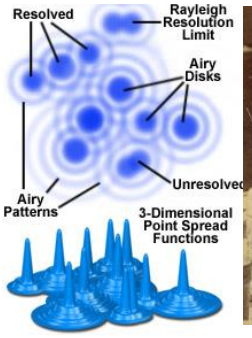


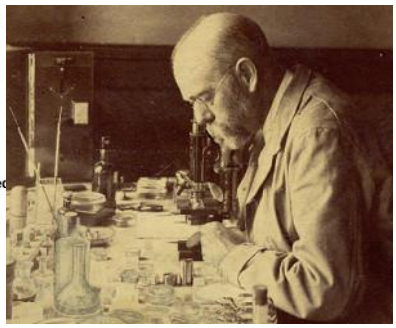


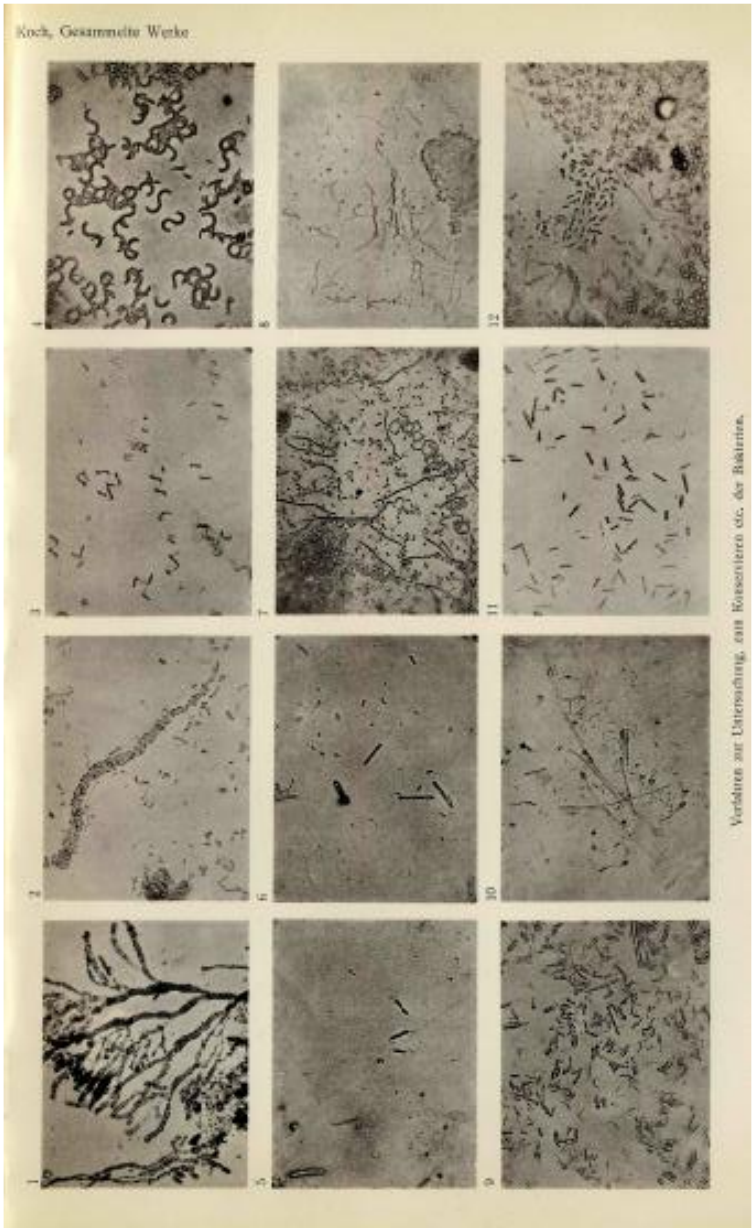


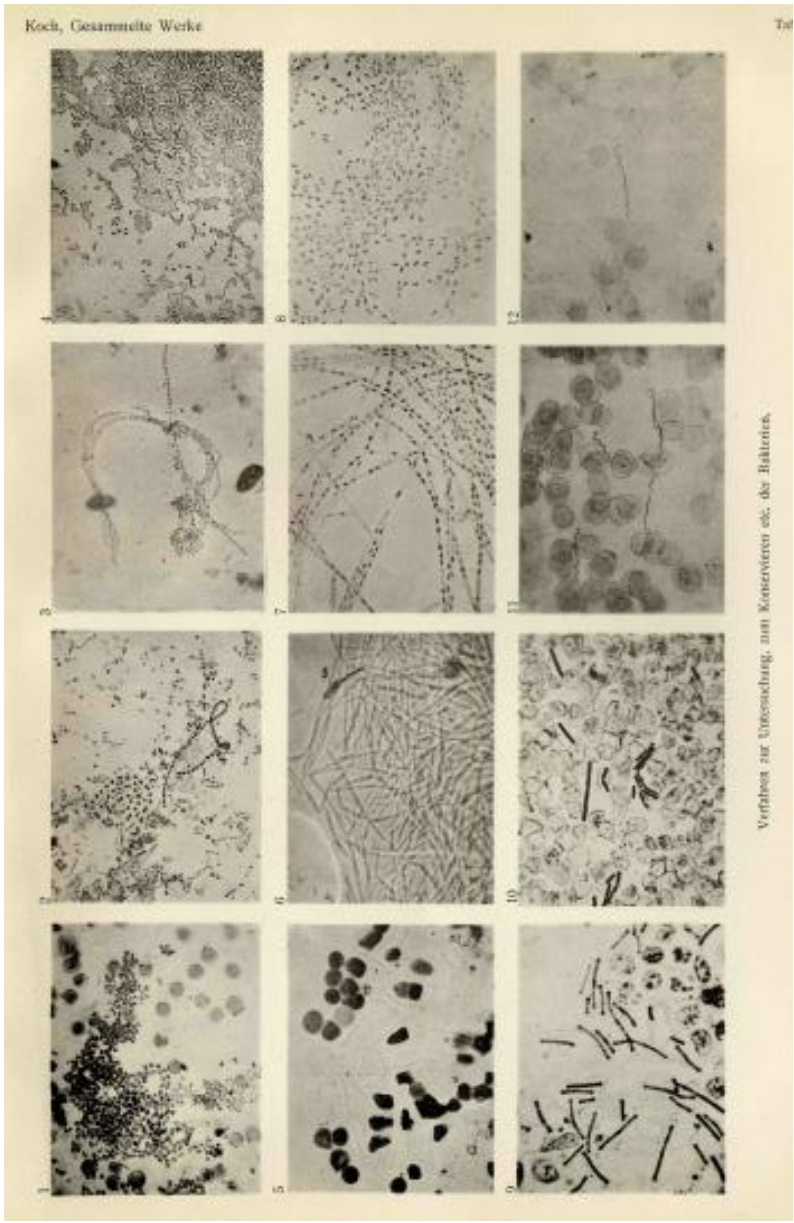
Thomas Young predicted that an understanding of the interference of waves caused by small objects would be important for microscopists in order to know **which parts of the image were actually parts of the object** and which ones were introduced by the **wave nature of light**. Contrast in transparent objects that introduce a change in the phases of the light waves result from destructive and constructive interference of the light waves. The trick is to know which dark and bright spots are true to the object and which are unfaithful. **Robert Koch** (1877) realized that when bacteria were observed with axial light, they seemed to have a capsule around them and realized that the capsule did not exist in the object itself but resulted from the **dark and light rings caused by diffraction**. He could eliminate this diffraction artifact by illuminating the object with a wide cone of light.








Koch, Gesammelte Werke
Verfahren zur Untersuchung, zum Konservieren etc. der Bakterien.

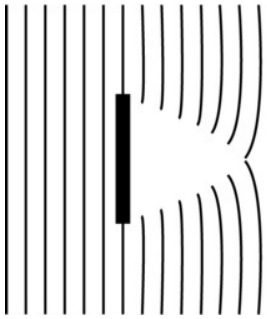

Koch, Gesammelte Werke
Verfahren zur Untersuchung, zum Konservieren etc. der Bakterien.



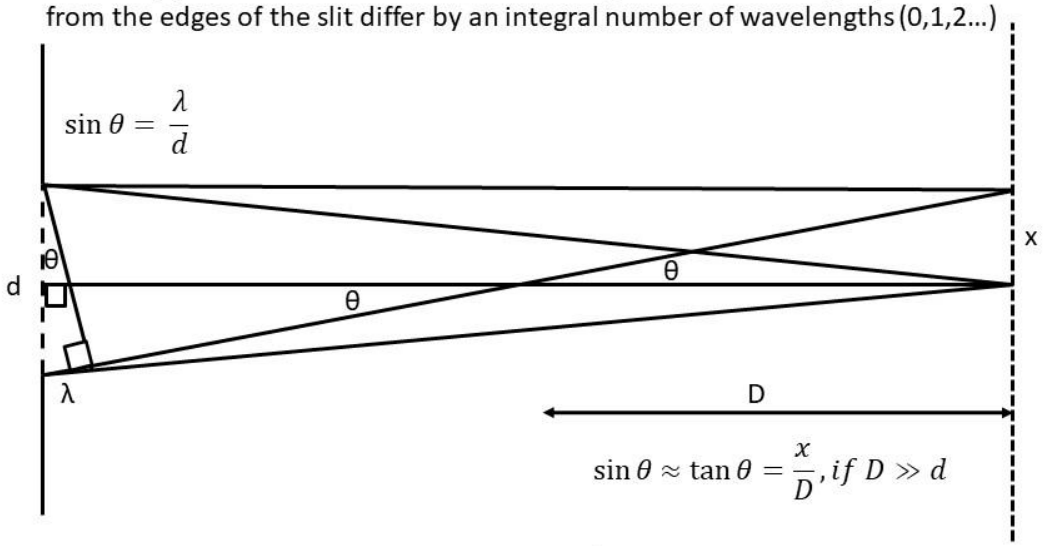
An example of Diffraction and Reflection

Demonstration: Repeat the experiment performed successfully by Thomas Young and unsuccessfully by Isaac Newton. Illuminate a slip of card using axial laser light and observe the image. Notice how the light bends behind the card and produces an image that is ***not*** a faithful representation of the object. This is a result of **diffraction produced by the wave nature of light**. This demonstration requires axial light. Perhaps Isaac Newton missed seeing this result because he performed the experiment on a day when the sun's rays were too diffuse.





Calculation of the wavelength (λ) of light by measuring the slit size (d), the distance between the slit and the screen (~D), and the distance (x) between the maxima where the light waves reaching a spot from the edges of the slit differ by an integral number of wavelengths (0,1,2...)

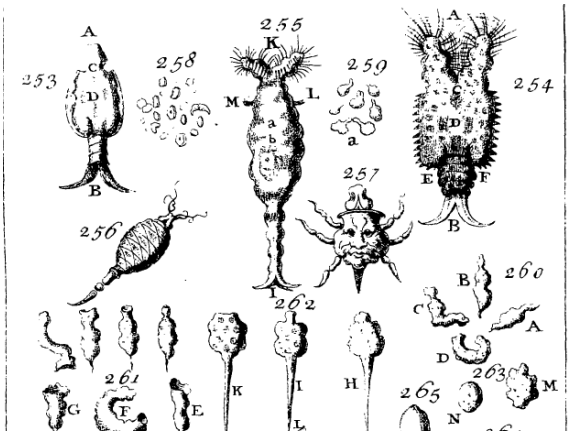


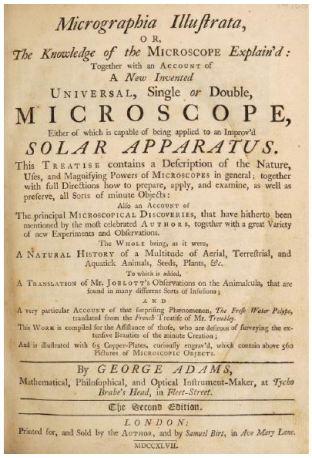
$$\lambda = \frac{xd}{D}$$

A quantum mechanical view of diffraction:

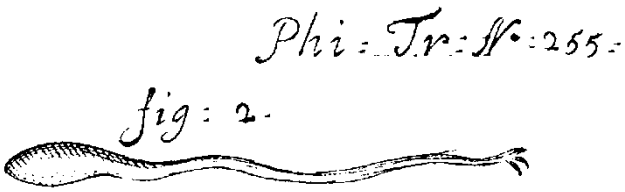


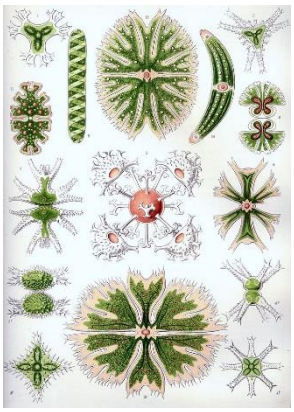
A lack of knowledge of the wave nature of light and the unfaithful images it may produce probably explains the observation of the **homunculus** by Nicolas Hartsoeker (1694) and of the **human-looking animalcule** (#257) by George Adams (1747).

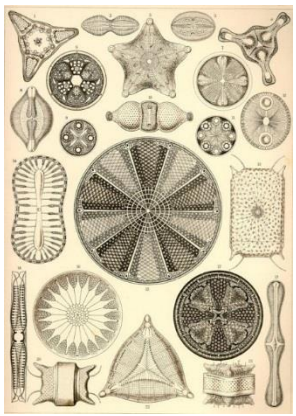


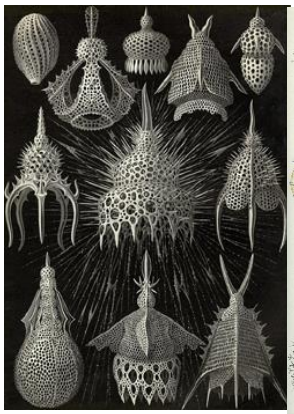

Micrographia Illuſtrata,
OR,
The Knowledge of the MICROSCOPE *Explain'd:*
Together with an ACCOUNT of
A *New Invented*
UNIVERSAL, Single *or* Double,
MICROSCOPE,
Either of which is capable of being applied to an Improv'd
SOLAR APPARATUS.
By *GEORGE ADAMS,*
Mathematical, Philoſophical, and Optical Inſtrument-Maker, at *Tycho Brahe's Head,* in *Fleet-Street.*
The Second Edition.
LONDON:
MDCCXLVII.

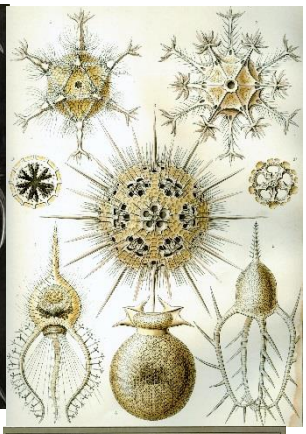
Even **Antony van Leeuwenhoek** (1699) could see something that may not have been there: *"I have in fact imagined that I could say as I beheld the animalcules in the semen of an animal that there lies the head and there as well the shoulders and there the hips; but since these notions have not the slightest shred of certainty,* ***I will not yet put forward such a claim, but hope that we may have the good fortune to find an animal whose male seed will be so large that we will recognize within it the figure of the creature from which it came****."*



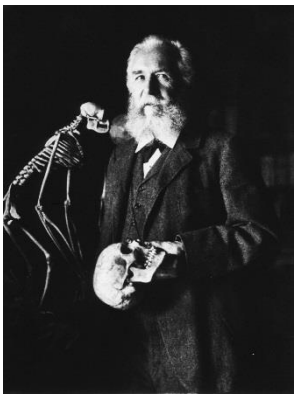


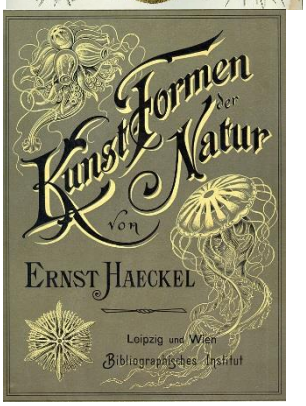




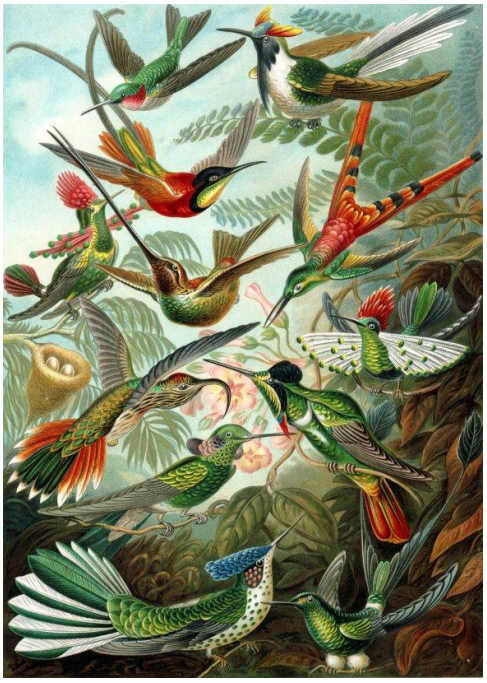


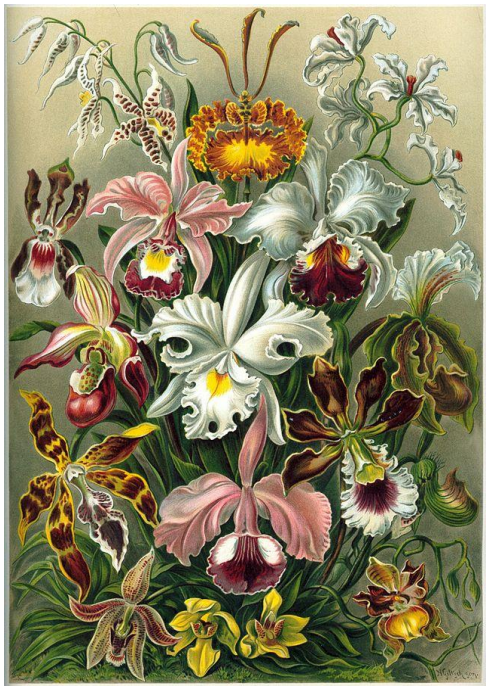
I want to give a short aside on **Ernst Haeckel**. **Poets** and **painters** have always been able to share the beauty of the natural world with others. Like Robert Hooke, **Ernst Haeckel** (1899-1904) wanted to share the beauty of the natural world that was invisible to most people but visible to him. He published a series of books entitled, ***Art Forms in Nature***, so that he could share with others the world that was made visible with the microscope. Haeckel also shared his



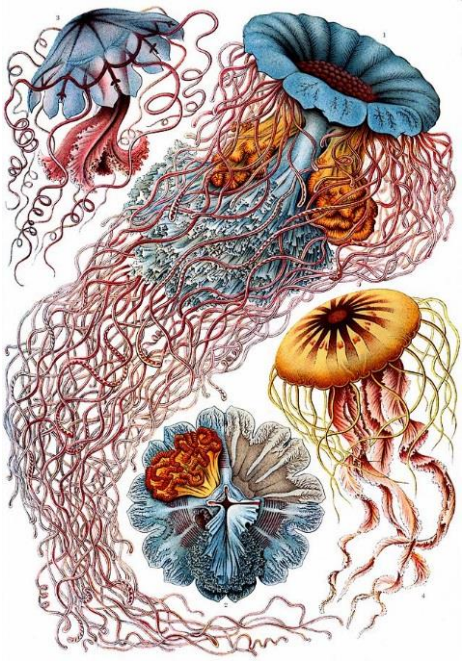


vision of the **color and form** of larger organisms that we have discussed this semester.

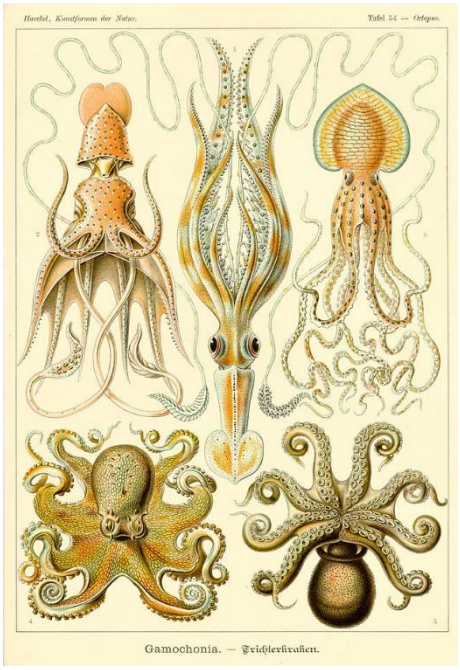






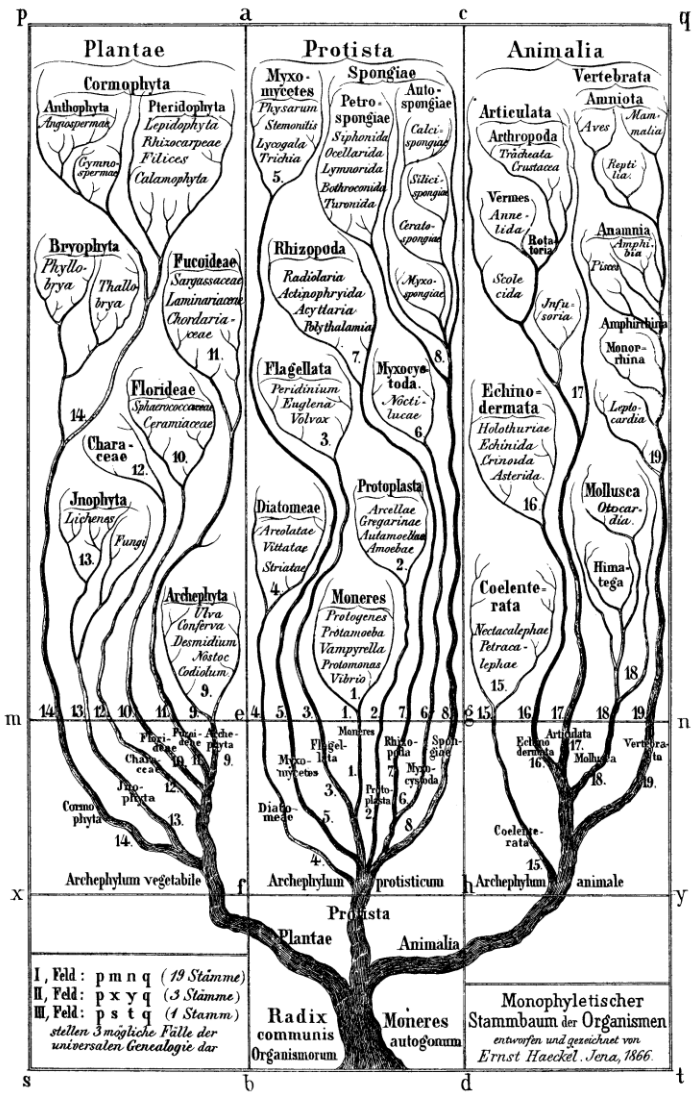


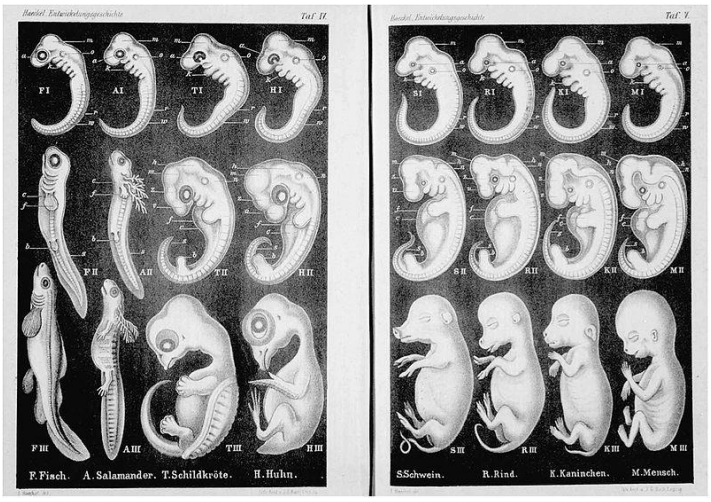




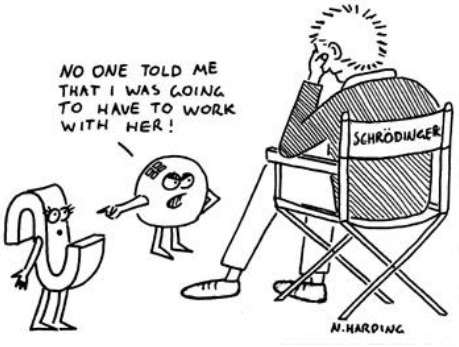
http://commons.wikimedia.org/wiki/Kunstformen_der_Natur

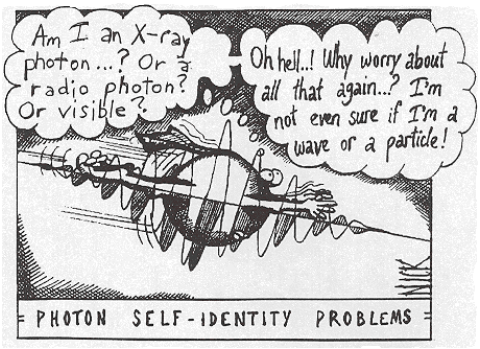
Haeckel (1866) also produced a tree that showed the evolutionary relationships between the various taxa. He coined the terms **phylogeny** and **ontogeny** to differentiate the evolutionary relationships between organisms and the developmental relationships. He noted that **ontogeny recapitulates phylogeny**, something that we saw in the evolution of the eye of hagfish, lamprey, and the vertebrates. The original proposal of ontogeny recapitulates phylogeny—that during development, the embryo of higher taxa proceed through embryonic stages that resemble the adult states of the lower taxa that evolved into the higher taxa, has been shown to be of limited value. However, among major taxa, there are similarities between the early stages of embryos which can be used to determine the relatedness of different taxa. In fact, the embryos are so similar that it is difficult to determine if it is an embryo of a pig, cow, rabbit, or human. Haeckel popularized evolutionary thinking in *The History of Creation* (1876), *The Riddle of the Universe* (1901), and *The Evolution of Man* (1879-1920).





We have now seen that the **wave-like** and **particle-like** properties of light are useful **models** in describing the absorption, emission, reflection, refraction, diffraction, and interference of light in the natural world. In the last lecture I will describe my model of the **photon** and I hope to make the photon, with both particle-like and wave-like properties, completely understandable for you.





Demonstration: In 1929, **Barbara McClintock** (Cornell) visualized and identified the individual **chromosomes** of maize, and it is still thrilling to see the **physical basis of heredity** standing out in red against a relatively clear cytoplasm. We will see the colored bodies or **chromo-somes** by putting undehisced anthers dissected from small flower buds in a drop of **acetocarmine** on a slide. We will then tease the anthers apart with **rusty iron** needles; perhaps even ones that belonged to Barbara McClintock, to free the microspores. We will then remove the empty anthers and **gently heat** the slide for about one second with an alcohol lamp until just before the stain bubbles. We will repeat this step four or five times. Then we will cover the preparation with a cover glass; press on the cover glass in order to flatten the cells; and view the preparation with a bright field microscope. *Mirabile dictu*, it never fails, we will literally see the invisible and, at





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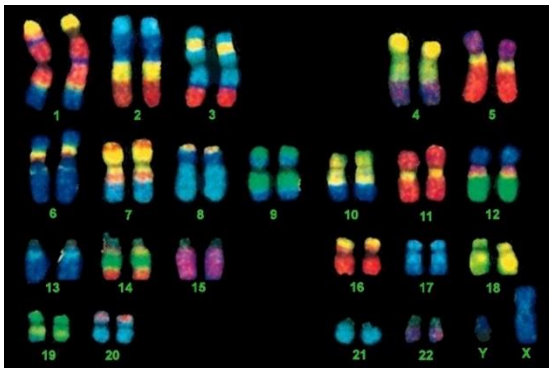
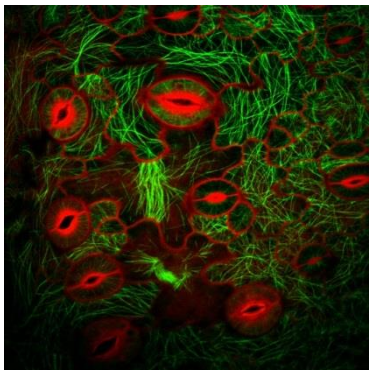
that instant, we will see chromosomes—the physical basis of heredity. Cell division often occurs at nighttime, which minimizes the chance of mutagenesis due to UV irradiation when the chromatin is most vulnerable.

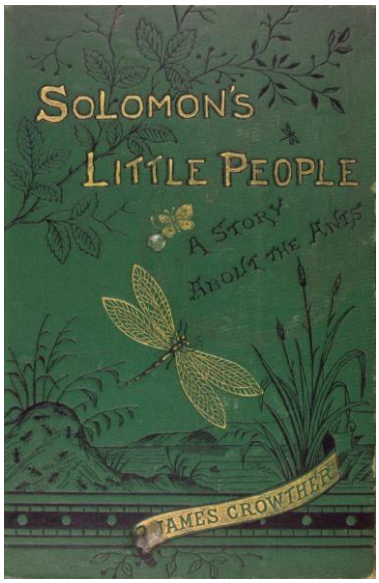


Today, light microscopes can be used to look at chromosomes that have been stained with **fluorescent probes** that identify specific sequences of DNA. This is called **chromosome painting**.

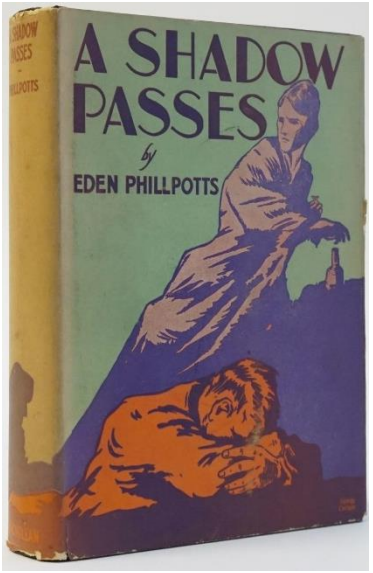


Cells can also be transformed with DNA that encodes any given protein plus a **green fluorescent protein**, a protein naturally involved in jellyfish **bioluminescence**, to show the spatial distribution of the given protein in a naturally non-luminescent cell. The microtubules that are composed of the tubulin protein are green and, as a consequence of the fluorescence of chlorophyll, the chloroplasts are red.

The microscope has made the invisible world visible. Paul wrote in Romans 1:20, "***For since the creation of the world God's invisible qualities—his eternal power and divine nature—have been clearly seen, being understood from what has been made, so that people are without excuse***." James Crowther expanded on this in *Solomon's Little People: A Story about the Ants*, "*What is the logic of this divine philosophy? This: that* ***we are to understand the things which we cannot see by the things that we can see, because everything in nature is a symbol of what is above and beyond nature***. *True it is that we are surrounded by the supernatural: it needs spiritual eyes to see the spiritual things, I know, because spiritual things can only*

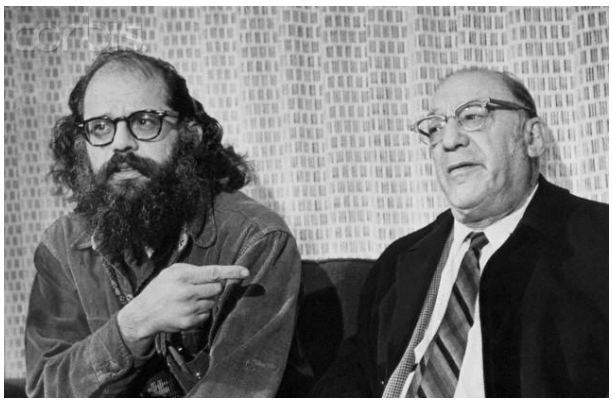


be discerned by spiritual sight. Have you spiritual eyes?—that is, have you 'the secret of wisdom' spoken of in the oldest poem in the world? If not, why not?"



Eden Phillpotts (1918) wrote in *A Shadow Passes*, "*In the marshes the buckbean has lifted its feathery mist of flower spikes above the bed of trefoil leaves. The fimbriated flowers are a miracle of workmanship and every blossom exhibits an exquisite disorder of ragged petals finer than lace.* ***But one needs a lens to judge of their beauty: it lies hidden from the power of our eyes****, and menyanthes must have bloomed and passed a million times before there came any to perceive and salute her loveliness.* ***The universe is full of magical things patiently waiting for our wits to grow sharper***."

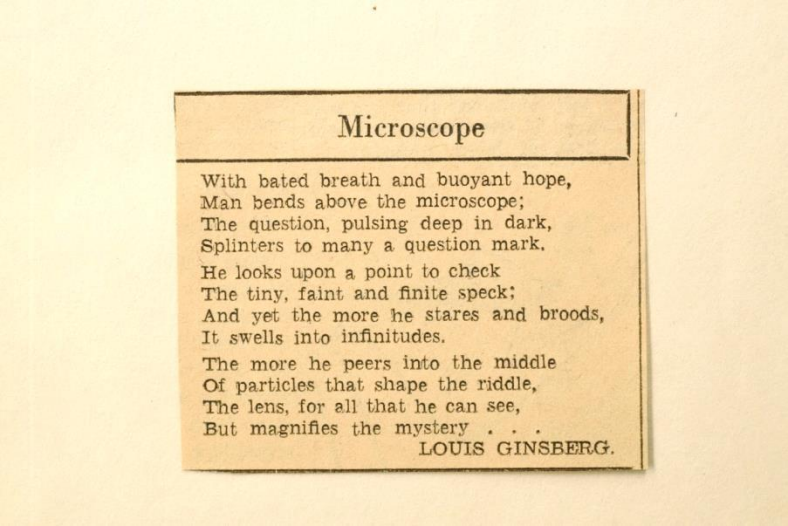
Microscopes have been inspirational to poets. **Louis Ginsberg**, Allen Ginsberg's father, wrote two poems about the microscope. The second one was discovered in Kroch Library!



Microscope

The more man delves
Into the dark,
The more he enlarges
A question-mark.

Bent like a question
And wonder-eyed,
Man peers at himself,
Magnified.



Microscope

With bated breath and buoyant hope,
Man bends above the microscope;
The question, pulsing deep in dark,
Splinters to many a question mark.

He looks upon a point to check
The tiny, faint and finite speck;
And yet the more he stares and broods,
It swells into infinitudes.

The more he peers into the middle
Of particles that shape the riddle,
The lens, for all that he can see,
But magnifies the mystery . . .

LOUIS GINSBERG.

For as little as $4 to as much as $200, you can turn your smartphone into a light microscope. This is becoming common among health care workers who can use their cell phone and a little dye to diagnose diseases far away from hospitals.

http://www.bhphotovideo.com/bnh/controller/home?O=&sku=970621&gclid=CP6Tz5fc6r0CFUuXOgodqHoA3A&Q=&is=REG&A=details

http://www.newegg.com/Product/Product.aspx?Item=9SIA2C00X84456&nm_mc=KNC-GoogleMKP&cm_mmc=KNC-GoogleMKP-_-pla-_-Camera+Flashes-_-9SIA2C00X84456&ef_id=UmPFEgAAADmFJyib:20140418190402:s

http://the-gadgeteer.com/2014/11/08/attach-this-100x-microscope-to-your-iphone-6-and-become-a-super-hero-scientist/

James Cybulski, James Clements, and Manu Prakash (http://www.foldscope.com/#/globalhealth/) developed the **Foldscope**, an origami-based paper microscope that cost's less than a dollar to make and that can be used in the field as "*an integral part of frugal science and engineering*."

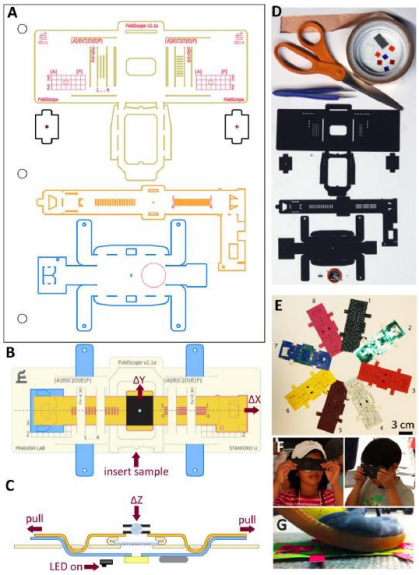


Figure 1. Foldscope design, components and usage. (A) CAD layout of Foldscope paper components on an A4 sheet. (B) Schematic of an assembled Foldscope illustrating panning, and (C) cross-sectional view illustrating flexure-based focusing. (D) Foldscope components and tools used in the assembly, including Foldscope paper components, ball lens, button-cell battery, surface-mounted LED, switch, copper tape and polymeric filters. (E) Different modalities assembled from colored paper stock. (F) Novice users demonstrating the technique for using the Foldscope. (G) Demonstration of the field-rugged design, such as stomping under foot.

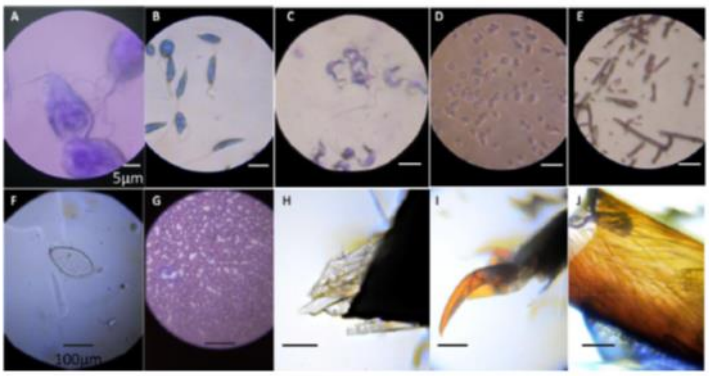
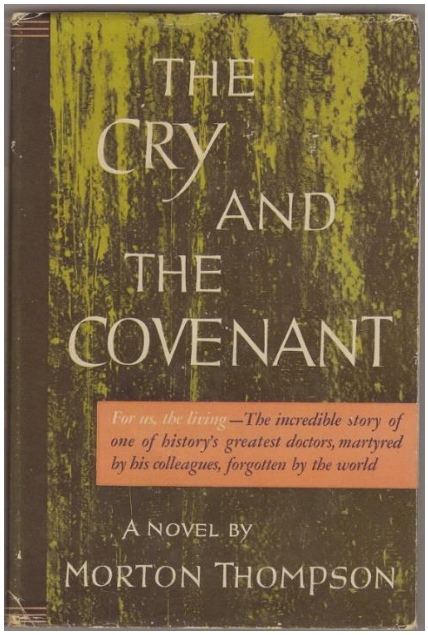


Figure 5. Mosaic of Foldscope Images. Bright field images of (A) *Giardia lamblia* (2,180X), (B) *Leishmania donovani* (1,450X), (C) *Trypanosom Cruzi* (1,450X), (D) gram-negative *Escherichia Coli* (1,450X), (E) gram-positive *Bacillus cereus* (1,450X), (F) *Schistosoma haematobium* (140X), and (G) *Dirofilaria immitis* (140X). Unstained (H) leg muscles and (I) tarsi of an unidentified ladybug (genus *Coccinella*). (J) Unstained leg muscles (fixed in formaldehyde) of an unidentified red ant (genus *Solenopsis*). An LED diffuser (Roscolux #111) was added for (A) and an LED condenser (2.4mm borosilicate ball lens) was used for (C). Images (H-J) were taken by novice user using a self-made Foldscope (140X). See table 2 for ball lenses used for specific magnifications. White scale bar: 5µm; black scale bar: 100µm.

We have come a long way since Ignaz Semmelweis' time in seeing the invisible.





June 7, 1981 New York Times

Graduates Hear Vonnegut On When It's Honorable To Be A 'Wise Guy'

A (Real) Commencement Address

The following remarks are (excerpted) from a speech at the Southampton College commencement last month by the writer Kurt Vonnegut Jr., who has a home on the East End.

"This speech conforms to the methods recommended by the United States Army Manual on how to teach. You tell people what you're going to tell them. Then you tell them, then you tell them what you told them.

Now we'll first discuss honorable behavior, especially in peacetime, and we'll then comment on the information revolution - the astonishing fact that human beings can actually know what they're talking about in case they want to try it. From there, I will go on to recommend to those graduating from colleges everywhere in the world this spring that their hero be **Ignaz Semmelweis**.

You may laugh at such a name for a hero, but you will become most respectful, I promise you, when I tell you how and why he died.

After I describe Ignaz Semmelweis a little, I will ask if he might not represent the next stage of human evolution. I will conclude that he had better be. If he doesn't represent what we're going to become next, then life is all over for us and for the cockroaches and the dandelions too.

I will give you a hint about him. He saved the lives of many women and children. If we continue on our present course there will be less and less of that going on. O.K…..

The thing I give you to cling to is a poor thing, actually. Not much better than nothing, and maybe it's a little worse than nothing. I've already given it to you. It is the idea of a truly modern hero. It is the bare bones of the life of Ignaz Semmelweis. My hero is Ignaz Semmelweis. You may be wondering if I'm going to make you say that out loud again. No, I'm not, you've heard it for the last time.

He was born in Budapest in 1818. His life overlapped with that of my grandfather and with that of your great-grandfathers and it may seem a long time ago to you, but actually he lived only yesterday.

He became an obstetrician, which should make him modern hero enough. He devoted his life to the health of babies and mothers. We could use more heroes like that. There's damn little caring for mothers or babies or old people or anybody physically or economically weak these days as we become ever more industrialized and militarized with the guessers in charge.

I have said to you how new all this information is. It is so new that the idea that many diseases are caused by germs is only about 120 years old.

The house I own out here in Sagaponack is twice that old. I don't know how they lived long enough to finish it. I mean the germ theory is really recent. When my father was a little boy, Louis Pasteur was still alive and still plenty controversial. There were still plenty of high-powered guessers who were furious at people that would listen to him instead of to them. Yes, and Ignaz Semmelweis also believed that germs could cause diseases. He was horrified when he went to work for a maternity hospital in Vienna, Austria, to find out that one mother in 10 was dying of childbed fever there.

These were poor people - rich people still had their babies at home. Semmelweis observed hospital routines, and began to suspect that doctors were bringing the infection to the patients. He noticed that the doctors often went directly from dissecting corpses in the morgue to examining mothers in the maternity ward. He suggested as an experiment that the doctors wash their hands before touching the mothers.

What could be more insulting. How dare he make such a suggestion to his social superiors. He was a nobody, he realized. He was from out of town with no friends and protectors among the Austrian nobility. But all that dying went on and on and Semmelweis, having far less sense about how to get along with others in this world than you and I would have, kept on asking his colleagues to wash their hands.

They at last agreed to do this in a spirit of lampoonery, of satire, of scorn. How they must have lathered and lathered and scrubbed and scrubbed and cleaned under their fingernails. The dying stopped - imagine that! The dying stopped. He saved all those lives.

Subsequently, it might be said that he has saved millions of lives - including quite possibly yours and mine. What thanks did Semmelweis get from the leaders of his profession in Viennese society, guessers all? He was forced out of the hospital and out of Austria itself, whose people he had served so well. He finished his career in a provincial hospital in Hungary. There he gave up on humanity, which is us, and our knowledge, which is now yours, and on himself.

One day in the dissecting room, he took the blade of a scalpel with which he had been cutting up a corpse, and he stuck it on purpose into the palm of his hand. He died, as he knew he would, of blood poisoning soon afterward.

The guessers had had all the power. They had won again. Germs indeed. The guessers revealed something else about themselves too, which we should duly note today. They aren't really interested in saving lives. What matters to them is being listened to -as however ignorantly their guessing goes on and on and on. If there's anything they hate, it's a wise guy or a wise girl.

Be one anyway. Save our lives and your lives too. Be honorable. I thank you for your attention."

I want to tell a few stories about **Diseases caused by Germs**.

Germs in Ithaca: The 1903 Typhoid Fever Epidemic

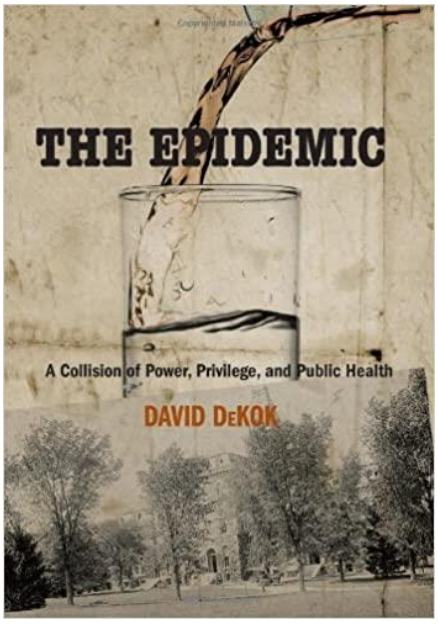
THE EPIDEMIC OF TYPHOID FEVER AT ITHACA, N. Y.

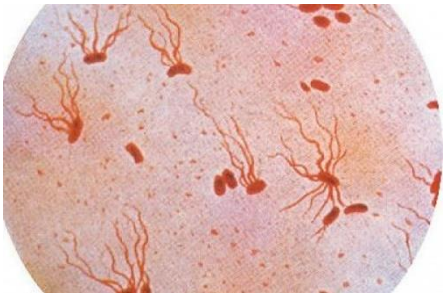
BY GEORGE A. SOPER, PH.D., CONSULTING ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Presented September 16, 1904.*]

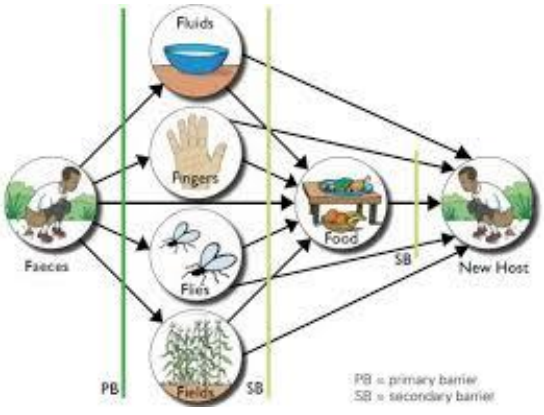
Mr. President, Ladies and Gentlemen of the New England Water Works Association, — The epidemic of typhoid fever which broke out at Ithaca in the winter of 1903 deserves to be regarded as one of the greatest outbreaks of this preventable disease which ever occurred in New York State. In the typhoid history of the whole country there have been few epidemics which have exhibited a larger number of cases.

Sanitary experts who visited Ithaca at the time of the epidemic were unanimous in their opinion as to its cause. Many who are familiar with the epidemiology of typhoid have said that seldom, if ever, has the danger of an epidemic been so unmistakably in evidence beforehand. Speaking now, more than a year after the outbreak, and with an intimate knowledge of the situation, it is difficult to understand why the city was not alive to the necessity of taking steps which would have rendered life and health secure. Apparently the people of this university town neither knew nor cared any more about the teachings of sanitary science than do the inhabitants of the scores of other cities in which epidemics occur. They were blinded to the dangers of the situation by the seeming healthfulness of the city's site, and so failed to establish those sanitary safeguards which are indispensable to every growing community.

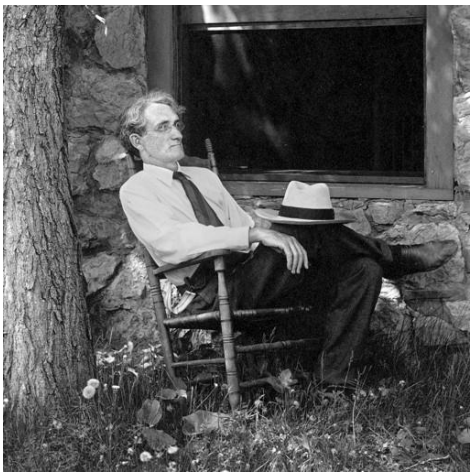




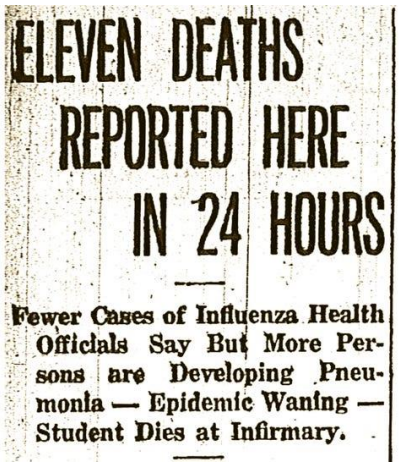
Typhoid fever is caused by being infected with the bacterium *Salmonella typhi*. You can get it through the **fecal-oral transmission route** by ingesting food or water that had been contaminated with feces or urine from an infected person. The **5 Fs** involved in transmission of the bacterium are: **fingers, flies, fields, fluids, and food**. Within 1-3 weeks, a patient may exhibit high fever, headache, constipation, diarrhea, rose-colored spots on the chest, and an enlarged liver or spleen, although it is possible to be a carrier without showing symptoms, like **Typhoid Mary**. In Ithaca, the 1903 typhoid epidemic was due to a contaminated water supply.



Liberty Hyde Bailey (1916) mentioned in his book, *Ground-Levels in Democracy*, "[i]*f science is not dogmatic or partial, so is it not disputatious. A few weeks ago a great meeting was held to discuss a difficult public situation, involving disease. There were violent opinions and strong parties for and against. One man read a paper giving the facts, without argument. The facts, not the arguments or the heated debates, finally determined the procedure.* ***No species of argument can influence a micro -organism***."



The 1918 Spanish Flu in Ithaca


ELEVEN DEATHS REPORTED HERE IN 24 HOURS

Fewer Cases of Influenza Health Officials Say But More Persons are Developing Pneumonia — Epidemic Waning — Student Dies at Infirmary.

A story on the 1918 Spanish Flu in Ithaca: https://www.ithaca.com/news/outbreak-ithaca-and-the-flu-epidemic/article_854e6bfa-0207-11e8-b816-338345014cef.html and information from the Cornell Alumni News: https://ecommons.cornell.edu/handle/1813/26498

https://ecommons.cornell.edu/handle/1813/26501

https://ecommons.cornell.edu/handle/1813/26503

https://ecommons.cornell.edu/handle/1813/26496

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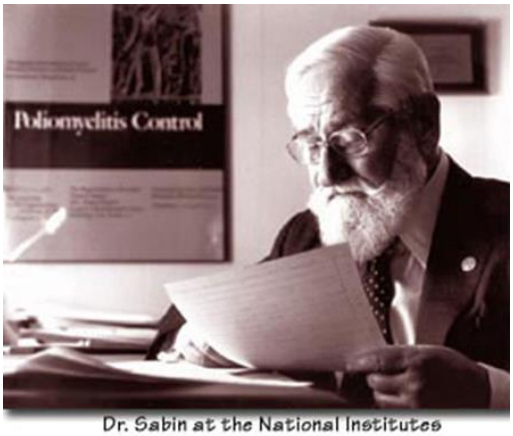
https://ecommons.cornell.edu/handle/1813/26496

Polio, a disease of the clean



Polio is an infectious viral disease that causes paralysis of the limbs. A mother's antibodies, but not her lymphocytes, are passed through the placenta from mother to child. Her antibodies and macrophages are passed through her breast milk. These antibodies provide a child with immunity to many germs, including polio.



Dr. Sabin at the National Institutes of Health, Ca. mid-1980's

While the child is immune, he/she can come in contact with these germs and build up his/her own **acquired immunity**, so that an infection will be fought in the child for the rest of his/her life by the powerful secondary immune response and he/she would not even realize they were infected.



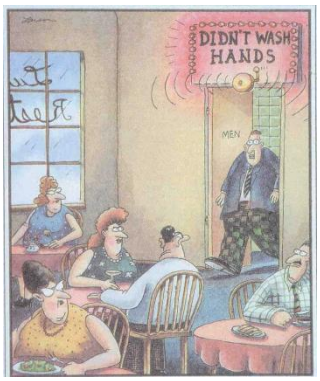
Exposure to some amount of dirt and germs during childhood primes the immune system so that the secondary immune response is armed and ready. Antibacterial soaps kill germs, but they also slow down the priming of the immune system.

Polio became a "disease of the clean."

Polio is a contagious disease. The polio virus enters the body through the mouth and leaves the body in the feces. By not flushing the toilet or washing one's hands, the polio virus can be transferred between infected and uninfected people by the fecal-oral route.

There was a polio epidemic in the United States in the 1950s. Consequently, health officials and scientists recommended good sanitary practices to prevent the spread of polio.





However, the recommended sanitary measures, including washing one's hands, cleaning one's house, and ensuring a polio virus-free water supply, prevents a child from developing acquired immunity to the polio virus while still being protected by his/her mother's antibodies. Consequently, a child or an adult, who has lost the protection of the maternal antibodies, but had not developed his/her own acquired immunity, could easily come down with polio. **Consequently, polio predominantly infected those who followed the new sanitary guidelines**.

The Global Polio Eradication Initiative's goal is to ensure that no child will ever again know the crippling effects of polio. **Polio vaccines have virtually eradicated polio**. **Jonas Salk** found that humans became immune to the polio virus when they were injected with a "formaldehyde-killed" virus.



Albert Sabin found that people became immune to the polio virus after eating a lump of sugar containing a weak variety of the virus. The dead virus vaccine could be prepared quickly, but it took a while to find the conditions that would yield a live virus that could enter the body through

the digestive system by itself and was safe. Moreover, there was no need for a shot!

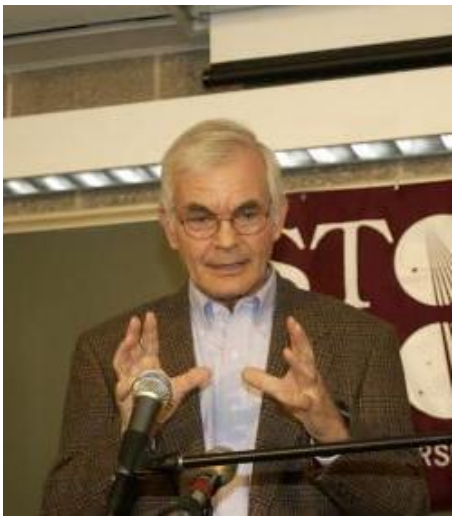


The live-attenuated virus has an advantage in that it easily passes from the immunized person to his/her family and friends by the fecal-oral route resulting in the immunization of many people.

Jonas Salk said, "*As a child I was not interested in science. I was merely interested in things human, the human side of nature, if you like, and I continue to be interested in that. That's what motivates me. And in a way, it's the human dimension that has intrigued me…I was curious from the earliest age on….I have the suspicion that this curiosity was very much a part of my early life: asking questions about unreasonableness. I tended to observe, and reflect and wonder. That sense of wonder, I think, is built into us.*"



According to **Eckard Wimmer** (2002), "*Research on viruses is driven not only by an urgent need to understand, prevent, and cure viral disease. It is also fueled by a strong curiosity about the minute particles that we can view both as chemicals and as 'living' entities*." Eckard Wimmer created a synthetic poliovirus:



Step 1. Obtain the published sequence of the genetic material (RNA) from the web.

Step 2. Send the sequence to a biotech company and receive in the mail DNA that will encode the genetic material of the virus.

Step 3. Add the synthetic DNA to an extract of human cells. The viruses form and assemble in this solution.

Step 4. Test the virus for pathogenicity by seeing if it can form plaques in (i.e. kill) cultured human cells.

The artificial polio virus is identical to the natural polio virus, and it causes paralysis and/or death in mice.



Bubonic Plague in Galveston

In 1920, rats infected with the bacterium that carries the bubonic plague arrived on Galveston Island. There was an immediate "*War on Rats*," rat trappers were sent out, and 46,623 rats were captured and fumigated.





Quarantine

I learned the word quarantine, which comes from the Italian word *quarantina*, which means forty days, when the Apollo astronauts returned from th eMoon. Apollo 11, 12, 13, and 14 astronauts were placed in the mobile quarantine facility (a converted Airstream trailer) after splashdown. Once the astronauts reached land, they spent 21 days quarantined in the Lunar Receiving Laboratory. The quarantine prevented the spread of any germs from the Moon. The quarantine requirement was eliminated after Apollo 14 once it was clear that the Moon was sterile.



Covid in Ithaca (2020-2021, 2022):



I thank you all for working together to ensure we can all be safe while making possible the university's primary mission, education. Since I am interested in fundamentals, I am very interested to learn about the origin of the virus in humans so we will be smarter next time one comes into being. The origin could be due to direct zoonotic (bat) transmission; introduction through an intermediate host (bat) followed by zoonotic transmission (e.g., mink); introduction through the cold/food chain, and introduction through a laboratory incident. According to the World Health Organization (2021) "*As far as WHO is concerned, all hypotheses remain on the table. This report is a very important beginning, but it is not the end. We have not yet found the source of the virus, and we must continue to follow the science and leave no stone unturned as we do," said Dr Tedros. "Finding the origin of a virus takes time and we owe it to the world to find the source so we can collectively take steps to reduce the risk of this happening again. No single research trip can provide all the answers*."

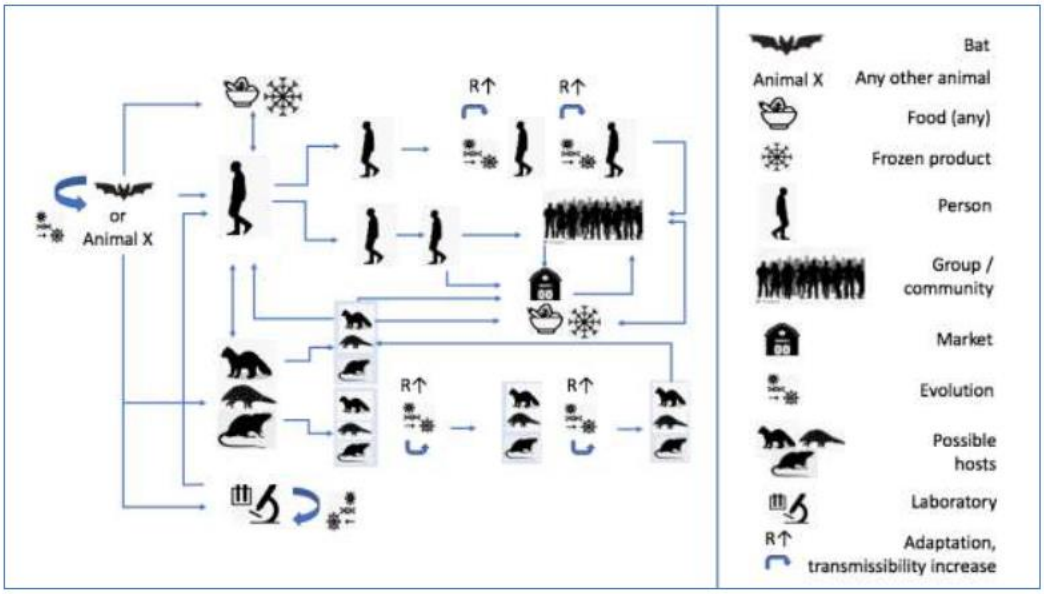


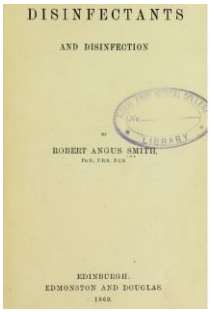
Fig. 1. Overall schema for possible pathways of emergence, providing a conceptual framework for possible routes for SARS-CoV-2 emergence. The icons are meant to be interpreted in a generic manner and the location and timing is not stated. The animals depicted reflect animal species that have been discussed in relation to potential infection but can be replaced by other species as well. Arrows indicate directions of possible transmission. The symbols indicating "evolution" are meant to reflect any mutations, recombination, variant selection leading to enhanced ability to infect other species and/or transmit.

Could there possibly be a link between WHO's scientific conclusions and politics?



Nicholas Wade presents in-depth reports in the *Bulletin of Atomic Scientists* about the origin of covid. Wade published an opinion piece on March 22, 2022 entitled, *Despite a manipulated media, the COVID lab leak has not been 'debunked'* in which he states, "*the science writers' section of the press corps has proved strangely incapable of telling the story straight*." As a result of his analysis, Nicholas Wade has become a *persona non grata* among scientists and other journalists. You have

to use ***critical thinking skills*** to analyze the story told by Nicholas Wade or by the consensus of science writers in the press corps to come closest to the truth.



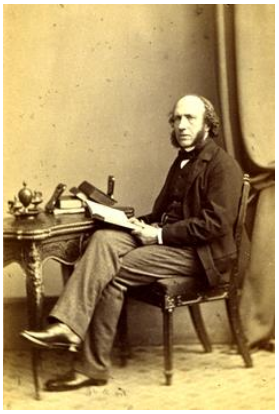
Antiseptics and **disinfectants** were discovered through trial and error in the ancient world. The production of ***coal tar*** allowed the discovery of carbolic acid by Friedlieb Ferdinand Runge in the nineteenth century, its use as a general antiseptic by Robert Angus Smith and William Crookes, and its use as an antiseptic in surgery by Joseph Lister.



Sprayer

Carbolic acid (phenol) had been used to deodorize sewage and Lister tried it as an antiseptic. Lister reduced infection when he used it to clean the patient's wounds, the dressings, the instruments, and his surgical hands. In 1867, Lister published "Antiseptic Principle of the Practice of Surgery" in the *Lancet*. But surgeons and physicians were set in their ways and ignored his writings. They probably saw Lister's excessive cleanliness and his carbolic acid (phenol) sprays during surgery as a waste of time and effort. In addition, the spray probably burnt their hands and eyes. Unfortunately, since Lister's ideas were greeted with such skepticism, it took nearly 30 years for "Listerism" to be universally accepted by medical practitioners and from then on, the sterilization of surgical instruments caused a dramatic fall in post-operative deaths from infection.





Understanding science usually means understanding its value and limitations, and the risks and benefits of applying science. When writing about preventing infection by germs, **Robert Angus Smith** (1869) states the evidence that each cure has value and limitations, and that one must weigh the risks and benefits. He emphasizes that one should use ***reason*** and never be ***one-sided***, writing, "*If we do not utter contradictions, we become one-sided, nature is full of them*", "[t]*his book is not intended to solve the great problem of purifying towns, but to collect some information useful in that direction. But I believe that we shall never see the extinctions of either middens or water-closets.* ***We must not be one-sided***", and "[w]***e see then that it is***

a very complicated problem. Disinfection is not a magic act performed by a small piece of some substance which removes all evils at once. There are many evils in various conditions, and each must be attacked in its own peculiar mode. People must use their reason."



How refreshing to hear that "science" was not used as a polarizing one-sided political tool. I want to mention that it is not impossible to use "science" during a pandemic for any party to gain political power. Just read the Rockefeller Foundation report written in 2010 that predicts how a pandemic could be used to increase ***authoritarian*** government control. I think that you will see what the futurists predicted in 2010 was what happened during the covid pandemic twenty years later. Use your critical thinking skills to decide what are the values of the political approach to a pandemic and what are the downsides. According to the prediction:

"*The pandemic blanketed the planet — though disproportionate numbers died in Africa, Southeast Asia, and Central America, where the virus spread like wildfire in the absence of official containment protocols. But even in developed countries, containment was a challenge. The United States's initial policy of 'strongly discouraging' citizens from flying proved deadly in its leniency, accelerating the spread of the virus not just within the U.S. but across borders. However, a few countries did fare better — China in particular. The Chinese government's quick imposition and enforcement of* ***mandatory quarantine*** *for all citizens, as well as its instant* ***and near-hermetic sealing off of all borders****, saved millions of lives, stopping the spread of the virus far earlier than in other countries and enabling a swifter postpandemic recovery.*

China's government was not the only one that took extreme measures to protect its citizens from risk and exposure. ***During the pandemic, national leaders around the world flexed their authority and imposed airtight rules and restrictions,*** *from the mandatory wearing of face masks to body-temperature checks at the entries to communal spaces like train stations and supermarkets.* ***Even after the pandemic faded, this more authoritarian control and oversight of citizens and their activities stuck and even intensified.*** *In order to protect themselves from the spread of increasingly global problems — from pandemics and transnational terrorism to environmental crises and rising poverty —* ***leaders around the world took a firmer grip on power.***

At first, the notion of a ***more controlled world*** *gained wide acceptance and approval.* ***Citizens willingly gave up some of their sovereignty — and their privacy — to more paternalistic states in exchange for greater safety and stability****.* ***Citizens were more tolerant, and even eager, for top-down direction and oversight, and national leaders had more latitude to impose order in the ways they saw fit.*** *In developed countries, this heightened oversight took many forms: biometric IDs for all citizens, for example, and tighter regulation of key industries whose stability was deemed vital to national interests. In many developed countries, enforced cooperation with a suite of new regulations and agreements slowly but steadily restored both order and, importantly, economic growth.*

Across the developing world, however, the story was different — and much more variable. Top-down authority took different forms in different countries, hinging largely on the capacity, caliber, and intentions of their leaders. In countries with strong and thoughtful leaders, citizens' overall economic status and quality of life increased. In India, for example, air quality drastically improved after 2016, when the government outlawed high emitting vehicles. In Ghana, the

introduction of ambitious government programs to improve basic infrastructure and ensure the availability of clean water for all her people led to a sharp decline in water-borne diseases. But ***more authoritarian leadership*** *worked less well — and in some cases tragically — in countries run by irresponsible elites who used their increased power to pursue their own interests at the expense of their citizens.*

There were other downsides, as the rise of virulent nationalism created new hazards: spectators at the 2018 World Cup, for example, wore bulletproof vests that sported a patch of their national flag. Strong technology regulations stifled innovation, kept costs high, and curbed adoption. In the developing world, access to 'approved' technologies increased but beyond that remained limited: the locus of technology innovation was largely in the developed world, leaving many developing countries on the receiving end of technologies that others consider 'best' for them. Some governments found this patronizing and refused to distribute computers and other technologies that they scoffed at as 'second hand.' Meanwhile, developing countries with more resources and better capacity began to innovate internally to fill these gaps on their own. ***Meanwhile, in the developed world, the presence of so many top-down rules and norms greatly inhibited entrepreneurial activity****.* ***Scientists and innovators were often told by governments what research lines to pursue and were guided mostly toward projects that would make money*** *(e.g., market-driven product development)* ***or were 'sure bets'*** *(e.g., fundamental research),* ***leaving more risky or innovative research areas largely untapped.*** *Well-off countries and monopolistic companies with big research and development budgets still made significant advances, but the IP behind their breakthroughs remained locked behind strict national or corporate protection. Russia and India imposed stringent domestic standards for supervising and certifying encryption-related products and their suppliers — a category that in*

reality meant all IT innovations. The U.S. and EU struck back with retaliatory national standards, throwing a wrench in the development and diffusion of technology globally.

Especially in the developing world, acting in one's national self-interest often meant seeking practical alliances that fit with those interests — whether it was gaining access to needed resources or banding together in order to achieve economic growth. In South America and Africa, regional and sub-regional alliances became more structured. Kenya doubled its trade with southern and eastern Africa, as new partnerships grew within the continent. China's investment in Africa expanded as the bargain of new jobs and infrastructure in exchange for access to key minerals or food exports proved agreeable to many governments. Cross-border ties proliferated in the form of official security aid. While the deployment of foreign security teams was welcomed in some of the most dire failed states, ***one-size-fits-all solutions yielded few positive results****.*

By 2025, people seemed to be growing weary of so much top-down control and letting leaders and authorities make choices for them.

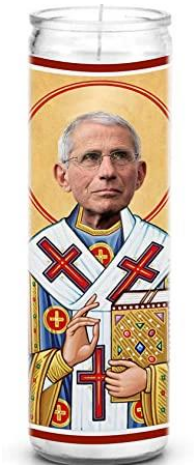
Wherever national interests clashed with individual interests, there was conflict. Sporadic pushback became increasingly organized and coordinated, as disaffected youth and people who had seen their status and opportunities slip away — largely in developing countries — incited civil unrest. In 2026, protestors in Nigeria brought down the government, fed up with the entrenched cronyism and corruption. Even those who liked the greater stability and predictability of this world began to grow uncomfortable and constrained by so many tight rules and by the strictness of national boundaries. The feeling lingered that sooner or later,

something would inevitably upset the neat order that the world's governments had worked so hard to establish."



On November 28, 2021, **Anthony Fauci** said on Face the Nation, "*Anybody who is looking at this carefully realizes there is a distinct anti-science flavor to this. If they get up and criticize science nobody is going to know what they are talking about. But if they get up and really aim their bullets at Tony Fauci, well people can recognize there is a person there. It is easy to criticize but they are really criticizing science because I* ***represent science****, that is dangerous.*"

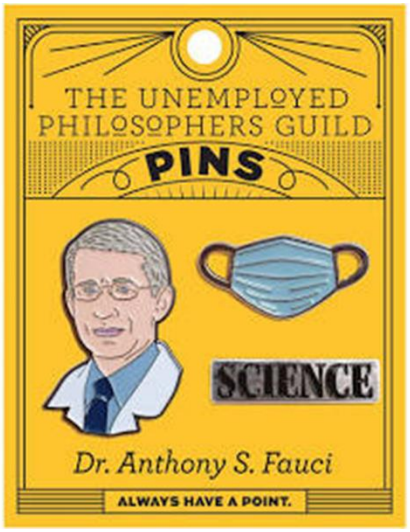
I would agree that Anthony Fauci ***represents science today***, and as its most public scientist, he is worshipped. However, I would also say that Anthony Fauci does not represent the big picture idea of Science with a capital S that we have discussed all semester. Have you ever heard Anthony Fauci present and critically analyze evidence—the real backbone of science—or does he just give recommendations without stating evidence and analysis? We live in a free country in which we can use **critical thinking skills** to analyze his recommendations. In a free country we are also free to worship Anthony Fauci for any reason we like.





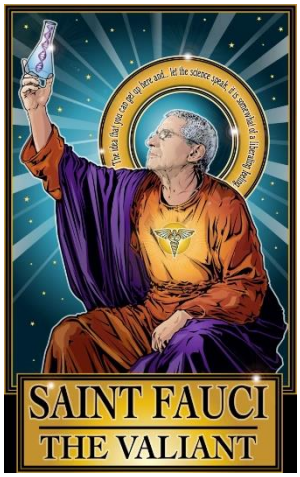












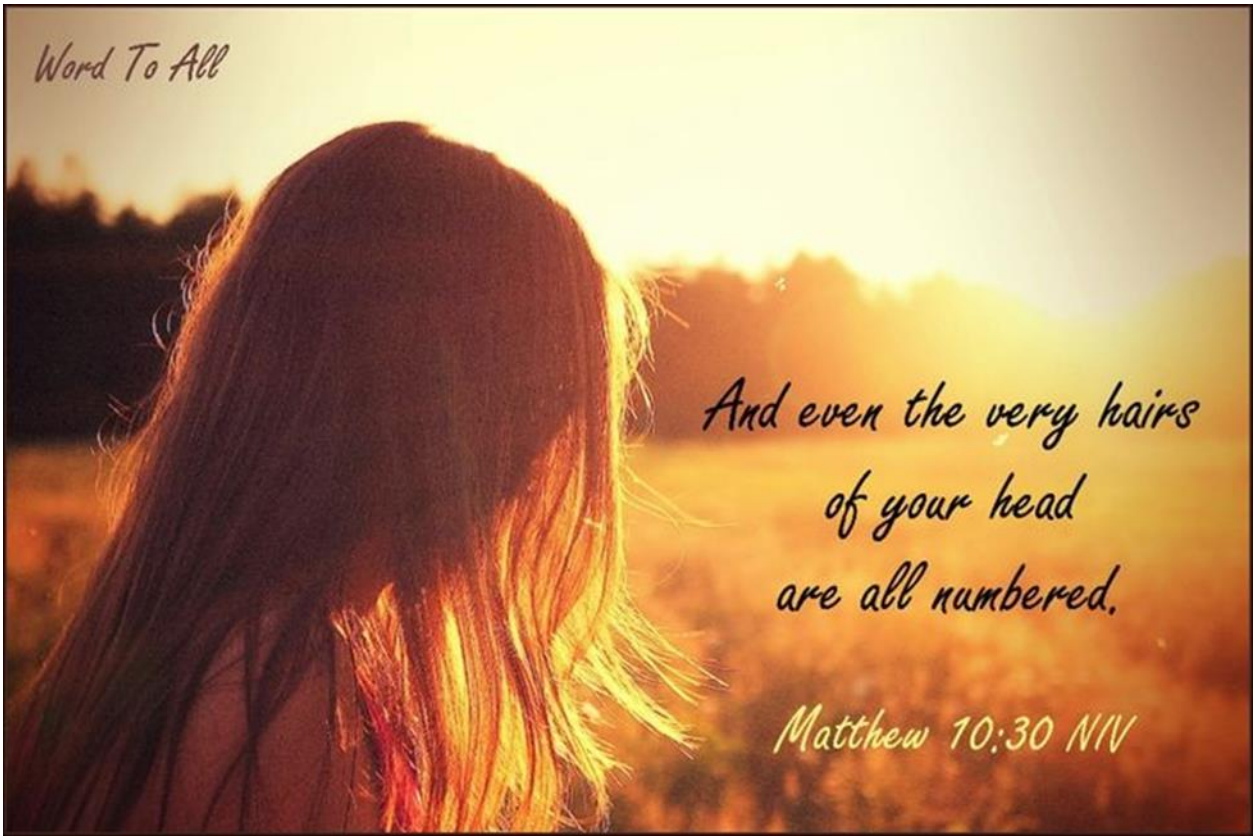


A story about the microscope

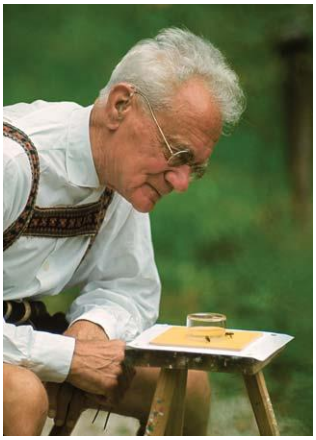


J. J. Thomson (1936), who discovered the electron, wrote, "*Another occasion, when I got some fun as well as instruction from my excursions into science, was once when a friend came in and as I was using a microscope my father had given me, I showed it to him, plucked a hair from my head and put it on the slide and told him to look at it; her did and seemed very much interested, much more than I had expected, for he was not very intelligent. He kept screwing it up and down. I thought perhaps the hair had blown*

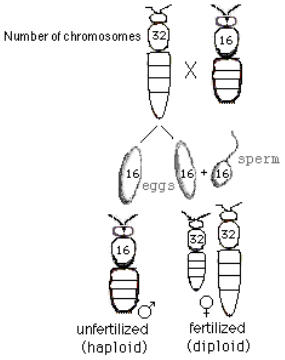
away. So I said, "Can you see it?" "Oh yes," he said, "I can see it." "Doesn't it look very big?" "It looks big enough, but I can't see the number on it." "Number," I said, "what number?" "Well," he said, "it says in the Bible that the hairs of our head are all numbered, but I can't find any number on this."



Polarized Light and Bee Vision: Sweetness and Light

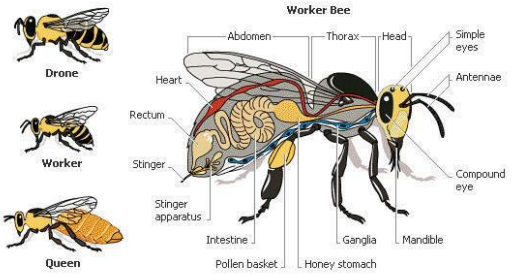




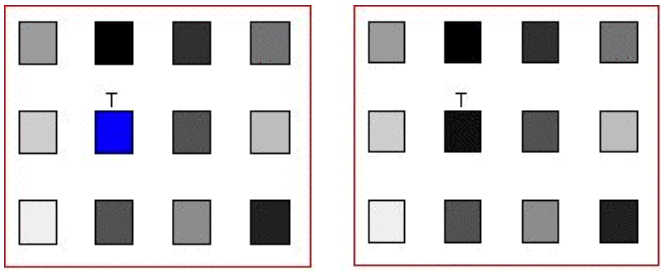


Karl von Frisch (1914) knew that the bright colors of bee-pollinated flowers would only make sense if the bees had color vision. That is, he realized that the flowers were communicating with the bees. From this initial insight, von Frisch elucidated the **language of bees** and found that the bees were also communicating with each other. When a worker honeybee finds flowers that contain nectar, **she** (all worker bees are female and diploid) returns to the hive to give the nectar to the young worker bees. The young worker bees suck the nectar from the forager and then convert it to honey in a process that involves regurgitation and dehydration. Then the foraging worker bee performs a special dance that enlightens the worker bees as to where the nectar is. It turns out that the original forager is able to communicate the direction of the food source in relation to the sun by means of **analyzing polarized ultraviolet light** from the sky. Generally, humans cannot perceive ultraviolet wavelengths or the polarization of the waves. The bees however can see what is invisible to us.

The initial experiments that were aimed at testing whether or not bees had **color vision** were done by von Frisch who put a dish of sugar solution over a piece of blue paper. The bees would drink the sugar solution until their **crops** or **honey-stomachs** were full and then they would fly back to the hive. After the bees repeated this behavior a few times, von Frisch put out two pieces of paper—a red one and a blue one but neither of them had a sugar solution on them. The bees



paid no attention to the red paper and flew to the blue paper even though it had no sugar on it. From these kinds of experiments, von Frisch concluded that **bees have color vision and can distinguish blue from red**.



In order to make sure that the bees were not sensing blue as being brighter than red, von Frisch placed a blue square without sugar water in the midst of many shades of gray guessing that if the bees that were **previously fed on blue paper** did not really have color vision but were only sensing the brightness monochromatically, then the bees would go to the blue card and a shade of gray that matched the brightness of the blue. Since the bees always fly towards the blue and never go to any shades of gray, the bees must be able to distinguish blue from every possible shade of gray.

Von Frisch (1915) trained the bees to **recognize blue** by putting sugar water, which has no scent, on a dish over the blue square and putting dishes without sugar over the gray squares. When he moved around the position of the blue square, the bees would always fly directly towards the blue square. In the same manner, von Frisch could also train the bees to **recognize an orange square, a yellow square, a green square, a violet or a purple square**, but he **could *not* train them to go exclusively to the red square**. When he tried to train bees to go to the red square, they would also go to the black square, indicating that they could not see red as a color. In order to test all the colors, including ultraviolet, Alfred Kühn (1927) extended von Frisch's experiments by irradiating the squares with various colors split by a prism and assayed which ones the bees would fly towards. Below is von Frisch's summary of the **comparison between bee and human vision**:

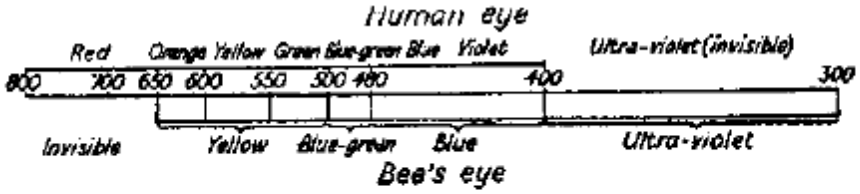


Fig. 19. The colours of the spectrum. Above: as they appear to the human eye; below: to the bee's eye. The numbers indicate the wave lengths of the beams of light (in thousandths of a thousandth millimetre) at given points of the spectrum.





Note that just because a flower looks red to us does not mean that bees see it as red and do not pollinate it. Bees will pollinate red flowers such as poppies or *Silene dioica*, but ***only*** if they also have ultraviolet reflectance that the bees can see. We see the flowers as being red or reddish while the bees see them as being ultraviolet (http://www.naturfotograf.com/UV_flowers_list.html).

Von Frisch (1915) also found that bees could be taught to **distinguish** drawings of shapes with different **forms**, and they do it best when the forms look like the flowers that they would likely visit.

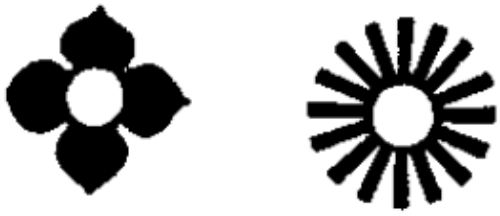


Fig. 24. Shapes that can be distinguished easily and certainly by bees.

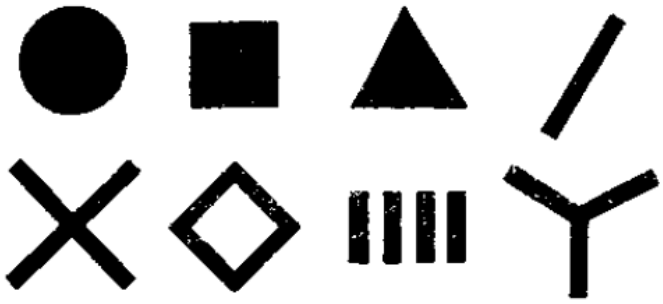


Fig. 25. Bees cannot distinguish between the shapes in the top row, nor between those in the bottom row. But they can distinguish those in the top from those in the bottom.

The ability to distinguish shapes depends on the **visual acuity** of the bee's eyes. Insects have compound eyes and the acuity depends on the size and number

of wedge-shaped **ommatidia**. The acuity of a worker honeybee is about **one degree of arc**. This is because a worker honeybee has about 5,500 ommatidia in each eye where the diameter of the lens of each ommatidium is about 20 μm.

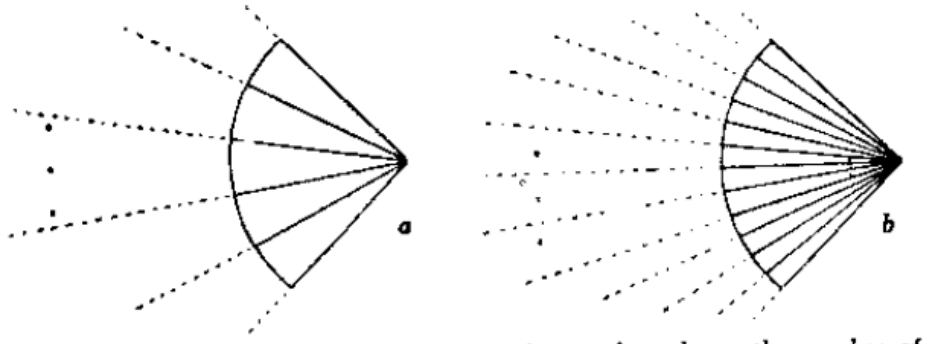
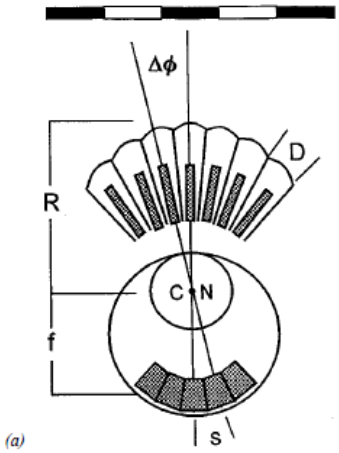


Fig. 23. Sharpness of vision of the insect's eye depends on the number of wedge-shaped sections.

By contrast, the human eye is able to resolve two separate points that are greater than **70 μm** or 0.07 mm from each other, which is equivalent to **one minute of arc**. The **acuity** of the human eye is limited by the diameters of the **cones**, which are about 2 μm, in the **fovea** of the **retina**. The acuity of the human eye is sixty times better (60' = 1°) than that of the honeybee eye, indicating that things look a little fuzzier to the bee than they do to us.



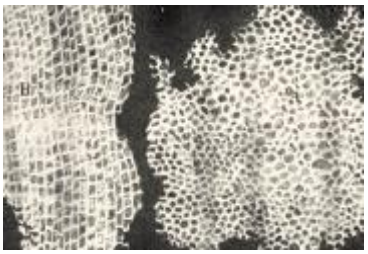
The nectar and pollen produced by the flowers will serve as a make-your-own room and board for the honeybees. The foraging worker honeybees leave the hive to look for flowers that contain pollen and nectar. Once they frenetically fill their pollen sacs and honey-stomachs with pollen and nectar, respectively, they fly back to the hive with a mass of pollen and nectar that is equivalent to their own





mass. The young worker bees in the hive use the nectar to make honey to feed the young, and they also use the honey to make scales of wax that are used to build the honeycomb. **A worker bee forages for about ten hours a day for nectar and pollen. It takes nectar from about 5 million flowers to make one pound of honey and one pound of honey to make about two ounces of wax**. Two ounces of wax consist of about 100,000 scales. Now you know what it means to be as busy as a bee!!





Each unit of the honeycomb is known as a **cell**, which inspired **Robert Hooke** (1665) to call the component parts of cork—cells. The cork, according to Hooke, was "*all perforated and porous, much like a honey-comb….walls (as I may so call them) or partitions of those pores were neer as thin in proportion to their pores, as those thin films of wax in a honey-comb (which enclose and constitute the hexangular **cells**) are to theirs*." The hexagonal shape of honeycomb cells is the most efficient design for filling a given volume with the least amount of material. It is known as **hexagonal close packing**.

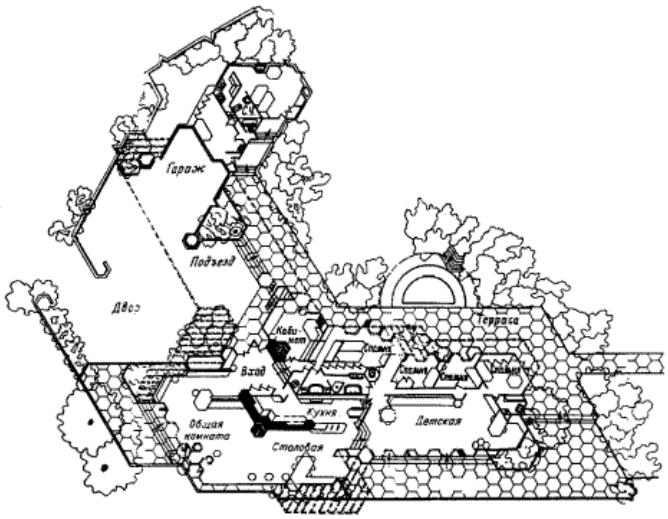




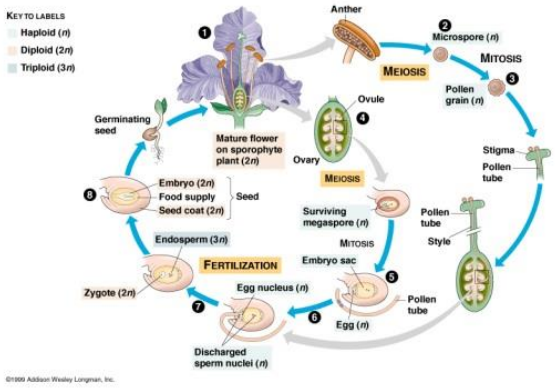
The design of an observational beehive where the honeycomb is placed between two pieces of glass was used by L**udwig Mies van der Rohe** (1921) for his submission of the "Honeycomb" to a high-profile competition to build Berlin's first skyscraper at Friedrichstraße railway station. In this design, an internal steel load-bearing structure would support the outside plate glass walls. https://www.bauhaus100.com/the-bauhaus/works/architecture/honeycomb-berlin/

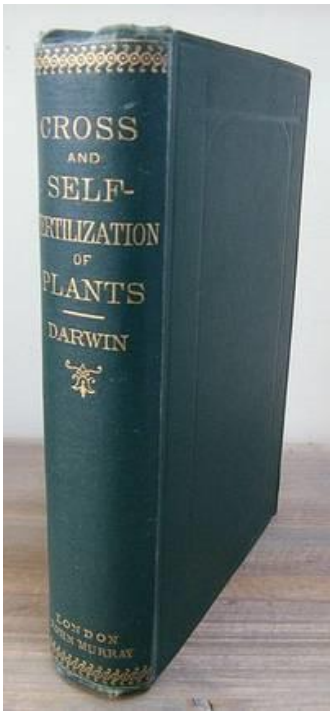
https://www.phaidon.com/agenda/architecture/articles/2014/march/19/how-mies-invented-modern-architecture/ https://www.moma.org/collection/works/787 (I wonder if Lugwig Mies van der Rohe knew about Joseph Paxton?)

Frank Lloyd Wright (1936) was also inspired by the efficiency of the hexagonal close packing of cells in the honeycomb when he designed the **Hanna-Honeycomb House**. This is the first and best example of Wright's hexagonal design where the house is based on a six-sided honeycomb pattern with 120-degree angles. https://www.nps.gov/places/hanna-honeycomb-house.htm https://franklloydwright.org/site/hanna-house/



The **angiosperms** or flowering plants gain from attracting the bees by becoming **cross pollinated** so that the next generation enjoys **hybrid vigor** and avoids **inbreeding depression**. The bees also gain from this **symbiotic relationship** by collecting nectar and pollen. When foragers return to the hive, they communicate to the worker bees the type of flower the nectar came from, the amount of nectar, its distance, and its direction.





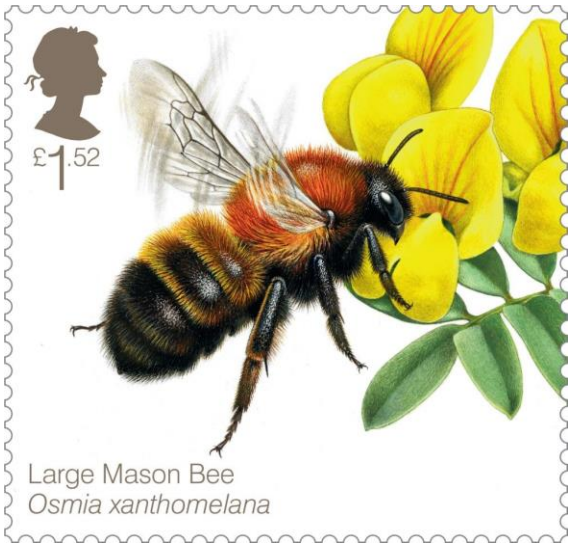
Charles Darwin (1876) commented on the fact that bees are good botanists when it comes to the ability to recognize flower types in ***The Effects of Cross and Self Fertilisation in the Vegetable Kingdom***. He wrote "*Bees and various other insects must be directed by* ***instinct*** *to search flowers for nectar and pollen, as they act in this manner without instruction as soon as they emerge from the pupa state. Their instincts, however, are not of a specialised nature, for they visit many exotic flowers as readily as the endemic kinds, and they often search for nectar in flowers which do not secrete any; and they may be seen attempting to suck it out of nectaries of such length that it cannot be reached by them.* ***All kinds of bees and certain other insects usually visit the flowers of the same species as long as they can, before going to another species***. *This fact was observed by* ***Aristotle*** *with respect to the hive-bee more than 2000 years ago, and was noticed by Dobbs in a paper published in 1736 in the Philosophical Transactions. It may be observed by any one, both with hive and humble-bees, in every flower-garden; not that the habit is invariably followed. Mr. Bennett watched for several hours many plants of Lamium album, L. purpureum, and another Labiate* [mint family] *plant, Nepeta glechoma, all growing mingled together on a bank near some hives; and he found that each bee confined its visits to the same species. The pollen of these three plants differs in colour, so that he was able to test his observations by examining that which adhered to the bodies of the captured bees, and he found one kind on each bee.*

Humble and hive-bees are good botanists, for they know that varieties may differ widely in the colour of their flowers and yet belong to the same species. *I have repeatedly seen humble-bees flying straight from a plant of the ordinary red*

Dictamnus fraxinella to a white variety; from one to another very differently colored variety of Delphinilum consolida and of Primula veris; from a dark purple to a bright yellow variety of Viola tricolor; and with two species of Papaver, from one variety to another which differed much in colour; but in this latter case some of the bees flew indifferently to either species, although passing by other genera, and thus acted as if the two species were merely varieties." Darwin, did not realize that bees may see the color of flowers differently than we see the color of flowers!



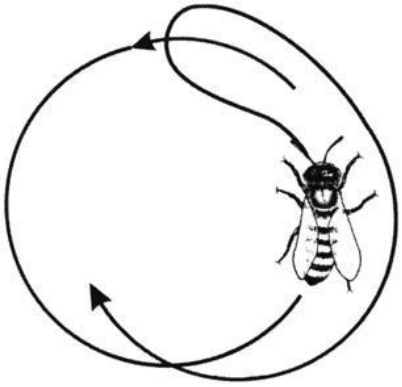




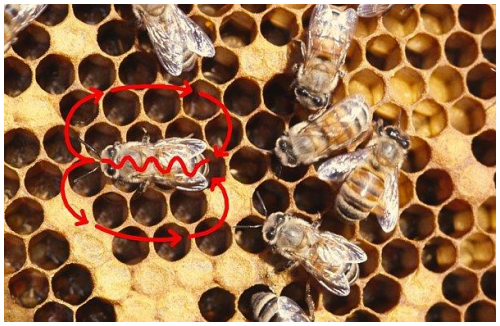




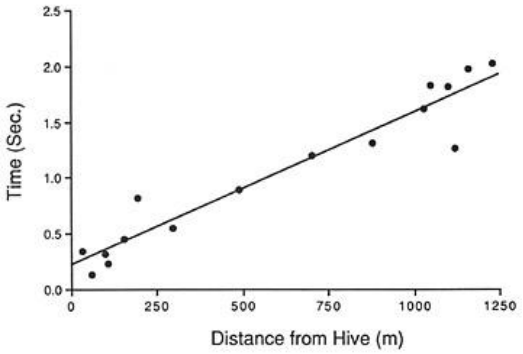
If the nectar-containing flowers are **nearby** to the hive, say **ten to fifteen meters** away—the definition of nearby depending on species, the forager will perform a **round dance** on the vertical side of the honeycomb when she returns to the hive. She will run in circles for several seconds to minutes around a single cell on the comb—reversing direction every one or two laps. If the scent on the pioneering foraging bee is the same as that which some bees have collected before, they will follow the foraging bee in her dance with their antennae close to her body and then follow her out of the hive to the flowers. But if her scent is different from that which the bees collected before they will stay in the hive. It seems like there are groups in the hive that become flower-specific **loyalists** or specialists. This loyalty ensures that the bees will **cross pollinate** flowers of the **same** species. The strength of the scent of the foraging bee alerts the worker bees in the hive as to the amount of nectar at the foraging site about which the foraging bee is communicating. As the sugar content of the nectar decreases, the bees dance less enthusiastically—that is for shorter times and less vigorously and they attract or enlist fewer bees to go to that foraging site. At this point, the worker bees change their flower scent loyalty and are attracted to the scent—for example *Phlox* v. *Cyclamen*—that is associated with more sugar and longer and more vigorous dancing.



Von Frisch found that when the nectar-containing flowers are **50 -100 meters** away from the hive, the round dance begins to morph into another dance, known as the **waggle dance**. When the food is still farther from the hive, even as far as 15 km, the



forager performs a **waggle dance** upon returning to the hive. The forager dances in figure eights on a vertical surface of the comb. In moving through the figure eight, the bee moves straight ahead for a short distance while waggling her body and then returns to the starting point by way of a semicircle. Then the bee again moves the same distance along the straight path while waggling her body and returns again to the starting point along a semicircle—but this time moving in the opposite sense as she did in the prior semicircle.

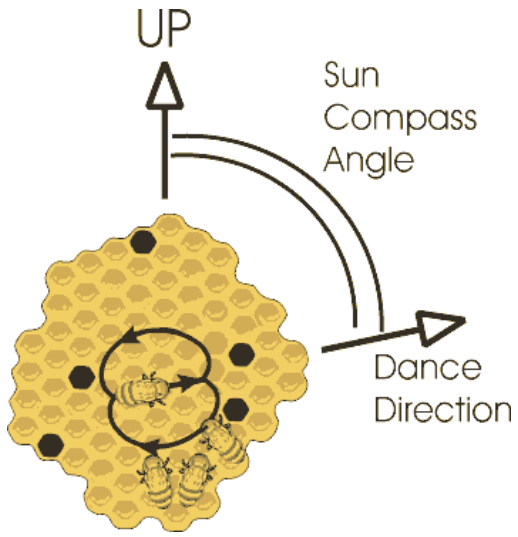


The waggle dance communicates both the **distance** to and the **direction** of the flower. By moving a feeding site to greater and greater distances from the hive, von Frisch found that the **distance** from the nectar-containing flowers to the hive is communicated by the **duration of the wagging part of the dance**. Although the actual relationship between dance duration and distance to the nectar-containing flowers depends on the species of honeybee, in general, the wagging lasts for about one second for every 500 meters between the hive and the nectar-containing flowers.



Want to hear something amazing? If the bee is subjected to a **headwind** or has to fly uphill, her dance overestimates the distance to the nectar-containing flowers. This is because she measures distance by how much **fuel** she uses to fly between the nectar-containing flowers and the hive. Scholze et al. (1964) found that the fuel the foraging worker bee is measuring is her **blood sugar**. The lower her blood sugar when she returns to the hive, the longer she estimates the distance to be.

Von Frisch noticed that the straight part of the waggle dance performed by bees that returned from a food source 200 meters **south** of the hive was always **tilted left** and that the straight part of the waggle dance performed by bees that returned from a food source 200 meters **north** of the hive was always **tilted right**. Von Frisch concluded that the **direction of the straight part of the waggle dance was somehow correlated with the direction of the nectar-containing flowers**.



Then von Frisch noticed that even if the position of the nectar-containing flowers remained constant and the duration of the waggle dance was constant, **the direction of the straight part of the dance shifted during the day**. Von Frisch guessed that the direction of the straight part of the dance was correlated with both the constant position of the nectar-containing flowers and the diurnally-varying position of the sun. The **direction** of the nectar-containing flowers is communicated by the angle from the vertical of the straight path along which the bee waggles. That is, the bee can sense both light and gravity and she converts the angle with respect to the sun to an angle with respect to the gravitational field of the earth. This conversion is

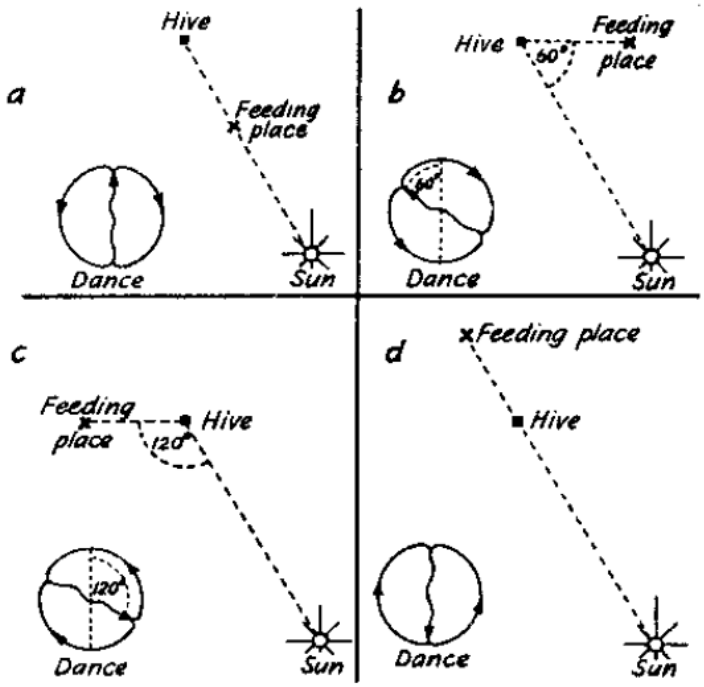


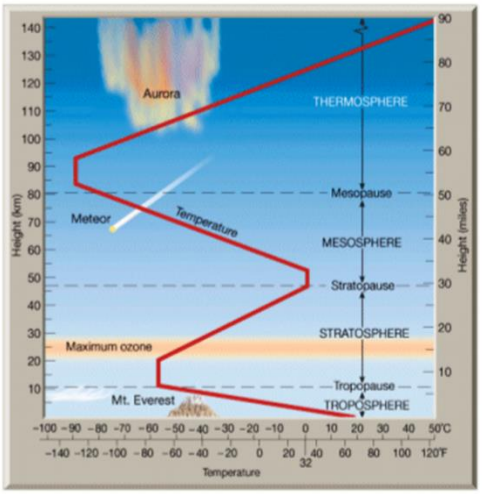
Fig. 44. Giving the sun's bearing in a dance on a vertical comb surface. The little diagrams on the left of each drawing show the dance as it appears on the vertical comb.

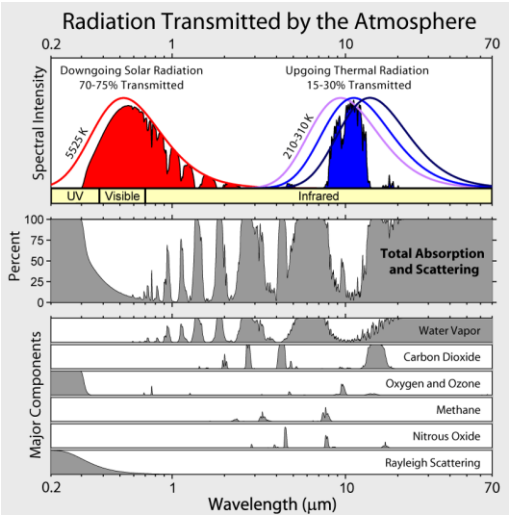
important since the inside of the hive is dark and the sun is not visible. Waggling while moving upward communicates "*fly towards the sun*" and waggling while moving downward communicates "*head away from the sun*." https://www.youtube.com/watch?v=bFDGPgXtK-U

If the nectar-containing flowers are sixty degrees anticlockwise relative to the direction of the sun, then the direction of the straight part of the waggle dance will be sixty degrees anticlockwise relative to up. If the nectar-containing flowers are one hundred twenty degrees clockwise relative to the direction of the sun, then the direction of the straight part of the waggle dance will be one hundred twenty degrees clockwise relative to up. By performing the waggle dance, the position of nectar-containing flowers within 360° degrees and 15 km can be communicated from the forager to the rest of the worker bees in the hive. The bees communicate a **vector quantity** that has both magnitude (distance) and direction.

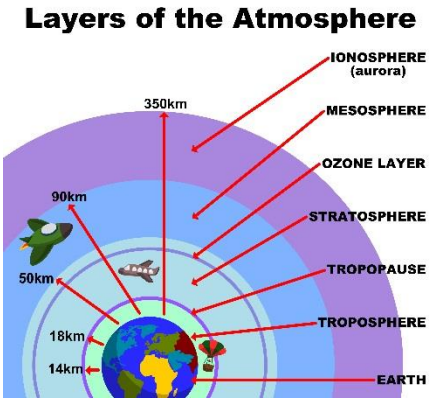
Von Frisch showed that even on a **cloudy day**, the dancing bees can still communicate the direction of the nectar-containing flowers. How do they (have sunshine on a cloudy day) and know where the sun is?

To answer this question, we will begin by reviewing what we know about **sunlight and the atmosphere**. The sunlight has a **blackbody distribution** or **color**

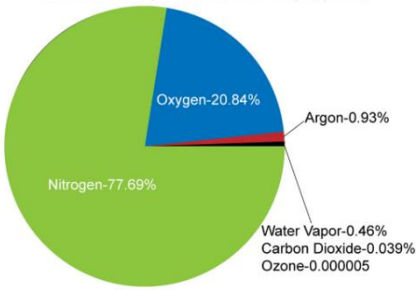




temperature that is a function of the temperature of the surface of the sun. As the sunlight enters the earth's atmosphere, the **ultraviolet** (all UVC and some UVB) rays are absorbed in the ozone layer by O_2 and O_3 and converted to heat (IR) that warms up the **stratosphere** where the **ozone layer** occurs.

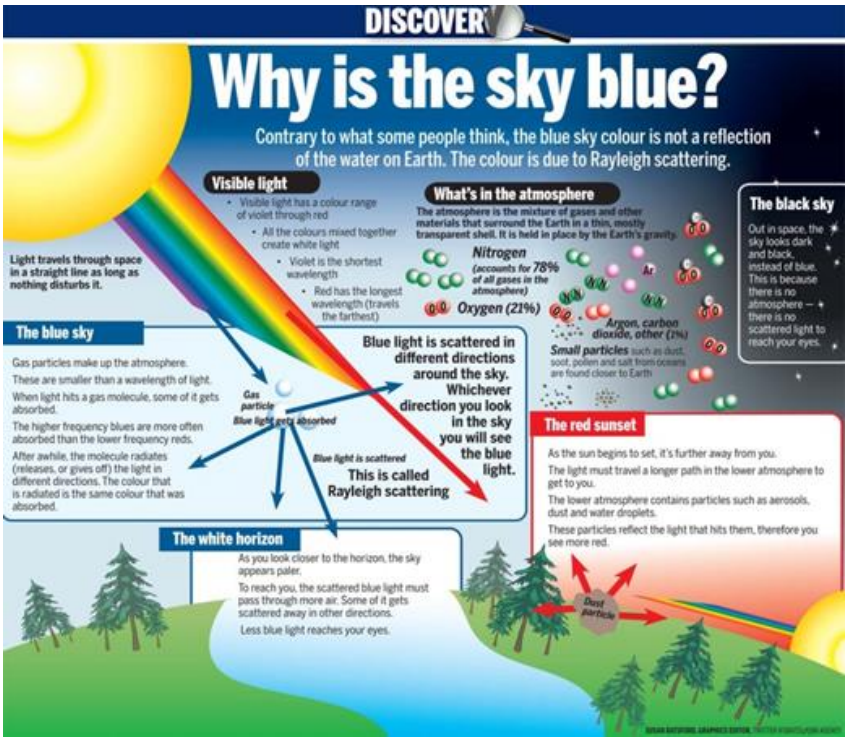


Below the stratosphere layer is the **troposphere** layer. The troposphere contains N_2, O_2, Ar, H_2O, CO_2, and O_3, **colorless** molecules that **scatter** the sunlight in a manner that is inversely proportional to the fourth power of the wavelength. The CO_2 and H_2O in the troposphere also **absorb and scatter** the incoming infrared radiation of the sun and the outgoing radiation from the earth (Tyndall, 1861; Arrhenius, 1896). Johann Lambert's (1760) law states that absorption is proportional to the thickness and August Beer's (1852) law states that the absorption is proportional to the concentration. The Beer-Lambert law states that the absorbance (A) of a given wavelength (λ) of light is proportional to both the thickness (d) and concentration (c) and the proportionality constant is called the **extinction coefficient** (ϵ_λ):

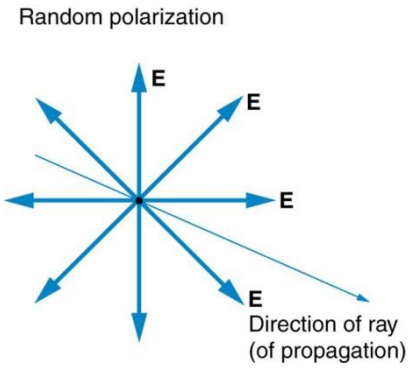


$$A = \epsilon_\lambda c d$$

This **Rayleigh scattering** is why the sky is blue. It is also why blue eyes, and the blue-eared glossy starling are blue.

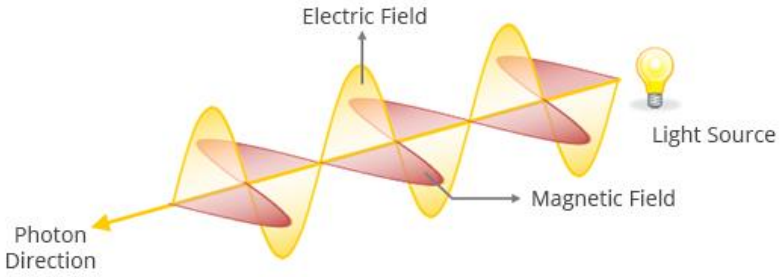


What I have not told you is that the scattered light is **polarized** (Arago, 1809, Tyndall, 1869). What is polarized light? The amplitudes of the wave in natural light vibrate in all azimuths (angles) around the axis of propagation of the light. Linearly polarized light is when light vibrates in one azimuth (angle) relative to the axis of propagation.

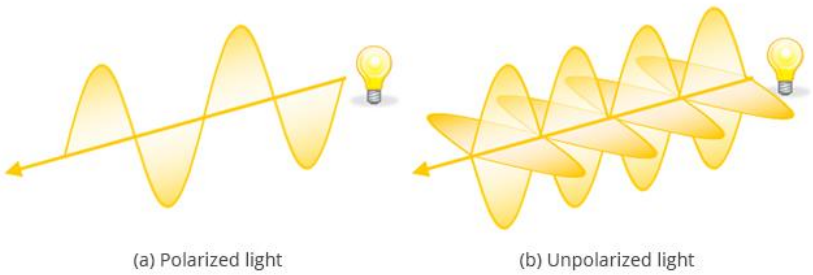


I also did not tell you that thanks to the theoretical treatment of many experiments done in the study of electricity and magnetism, **James Clerk Maxwell** (1865) determined that the light wave can be considered as an electromagnetic light wave with **vibrating electric and magnetic fields**.

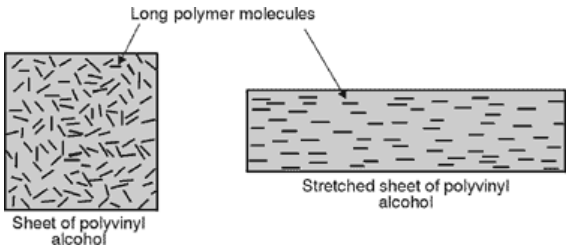




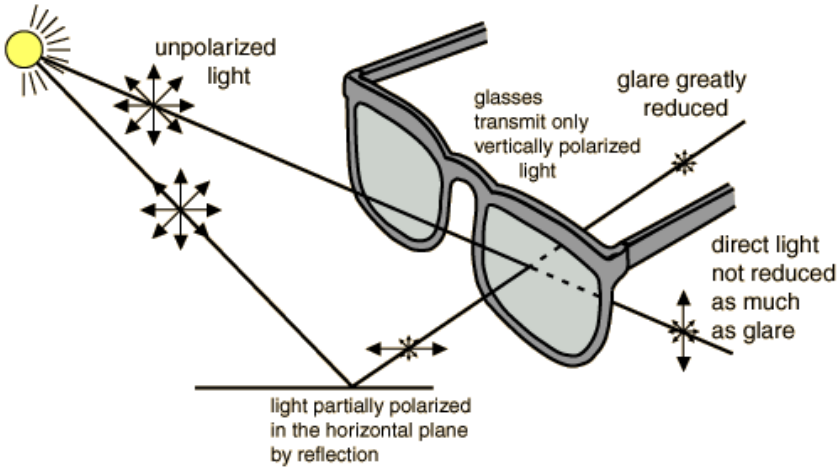
With linearly polarized light, the electric field of all the waves vibrate in one azimuth (angle) relative to the axis of propagation and with natural or unpolarized light, all the electric fields vibrate in each and every azimuth (angle).

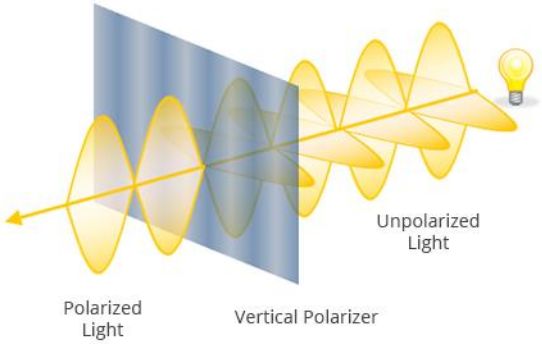


Whether or not light is linearly polarized can be determined with an **analyzer**. A **Polaroid** is an **analyzer** that **absorbs** all the light that is linearly polarized parallel to the long axis of the aligned bonds of the molecules of **polyvinyl alcohol impregnated with iodine** that make up the Polaroid. A Polaroid **transmits** all the light or the components of the light that is not linearly polarized parallel to the **aligned bonds** of **polyvinyl alcohol impregnated with iodine**.



When direct sunlight passes through Polaroid sunglasses, only light whose electric field is **perpendicular** to the aligned bonds of **polyvinyl alcohol impregnated with iodine** is transmitted through the glasses. Thus, when natural sunlight reaches Polaroid sunglasses, the light that is transmitted is linearly polarized light. On the other hand, **glare** which is caused by the **reflection of sunlight** from a dielectric or non-conducting surface is not transmitted at all. This is because **reflected light is linearly polarized with an azimuth parallel to the surface producing the glare**. Polaroid sunglasses work because glare is linearly polarized **parallel** to the surface causing the glare and the molecules in the Polaroid are aligned horizontally which is parallel





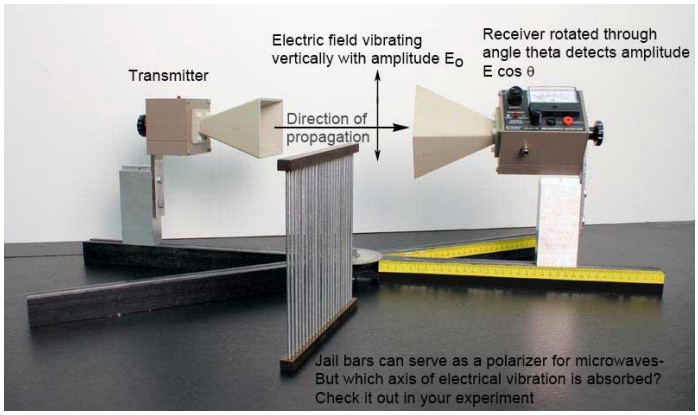
to most glaring surfaces. This is how Polaroid sunglasses work.

A Polaroid is similar to a prism in **that a prism resolves natural light into each wavelength while a Polaroid resolves natural light into each azimuth of polarization**.

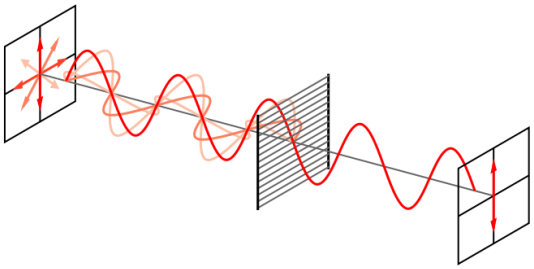
Demonstration: Observe glare through a Polaroid. Rotate the Polaroid to find the position of maximal and minimal transmission of glare. At the position of minimal transmission, the aligned molecules of **polyvinyl alcohol impregnated with iodine** will be **parallel** to the surface producing the glare**.**

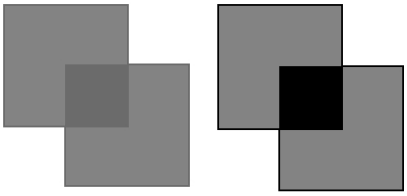


Demonstration: We can use **microwaves** that have a **wavelength of three centimeters** to understand polarization of waves. The transmitter is an antenna that transmits microwaves that are linearly polarized in the **vertical direction** (0°). The antenna of the transmitter uses electrical energy to move electrons up and down and the moving electrons emit electromagnetic waves with vertical polarization. The antenna of the receiver uses the electromagnetic wave to move electrons up and down and the moving electrons create an electric field in the antenna which is given by the meter. The receiver maximally absorbs the microwaves if its antenna is oriented in the **vertical direction**. It does ***not*** absorb any microwaves if the azimuth of the antenna is **perpendicular** to the azimuth of polarization. We can put an analyzer between the



transmitting antenna and the receiving antenna. When the wire grid is oriented with the bars **horizontally**, the microwaves are transmitted through it, as measured by the meter. When the wire grid is oriented with the bars **vertically**, the microwaves are not transmitted to the receiver as measured by the meter. This is because the **microwaves interact with the free electrons in the bar** and are in part reflected back to the transmitter. In addition, the energy of the microwaves is absorbed as it is converted into the kinetic energy of the electrons and is thus dissipated. The wire polarizer is used for centimeter long microwaves just as a Polaroid is used for 400-700 nm visible light waves. The polarizer in the figure on the right can represent the orientation of wire bars or the alignment of iodine in a polyvinyl alcohol sheet.





Demonstration: Each Polaroid filter transmits linearly polarized light. Use the overhead projector to see what is transmitted through two Polaroid filters when their axes of transmission are parallel and when their axes of transmission are perpendicular.

Demonstration: Look though a Polaroid at the skylight through the window. Rotate the Polaroid. What happens to the brightness of the skylight?

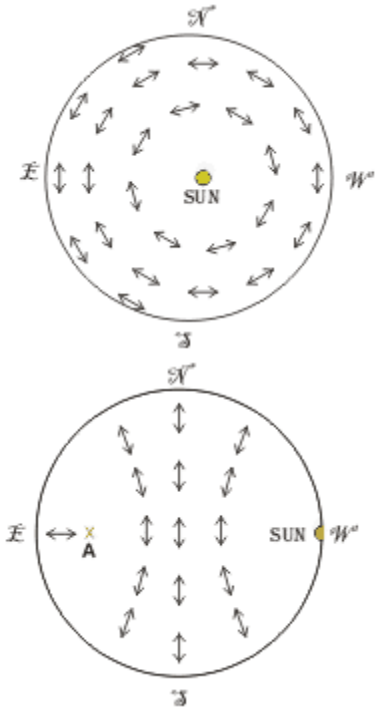


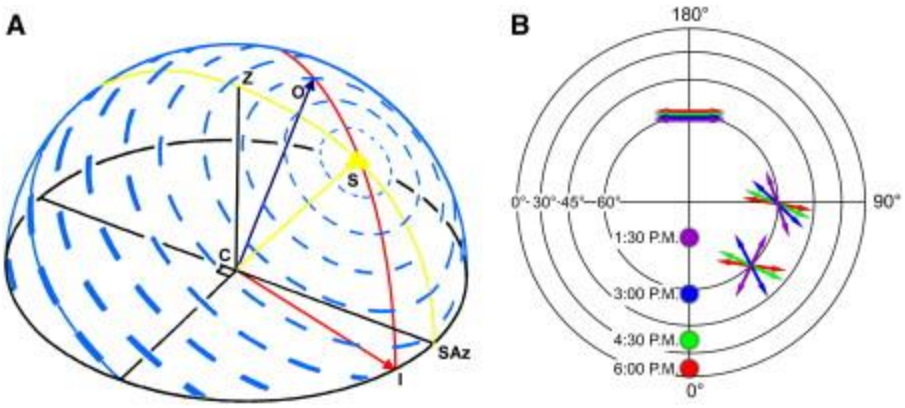


Now that we know how to analyze polarized light, let's turn our Polaroids towards the sky. A Polaroid, turned to a certain azimuth, reduces the amount of skylight. Photographers use a Polaroid filter (right) in front of the lens to increase the contrast of pictures that have a lot of sky.

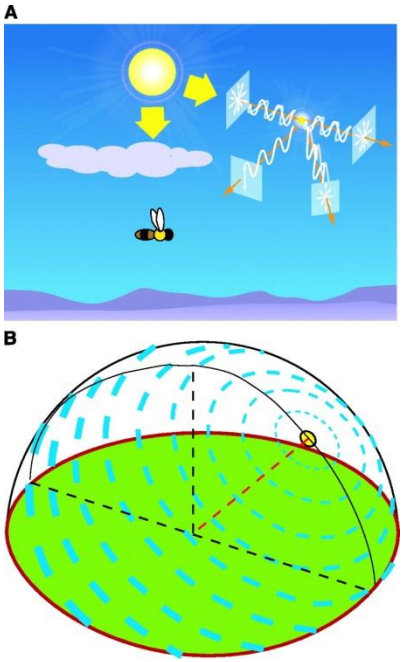


The above photographs demonstrate that the blue skylight is linearly polarized as a result of scattering by atmospheric molecules. **The azimuth of polarization of sunlight is a function of the position of the sun**. The degree of polarization increases as the angle made with the observer at the vertex by the sun and the position of the sky increases up until 90° from the sun. When the sun is at its **zenith** (maximal height), light at the horizon is maximally polarized and the azimuth of polarization is parallel to the horizon. When the sun is either rising or **setting**, the light along the **meridian** (the circular path along which the sun appears to travel) is maximally polarized and the azimuth of polarization is perpendicular to the meridian.





The pattern of polarization not only changes throughout the day but also throughout the year since the meridian is higher in the summer and lower in the winter. The amount of polarization at any point in the sky can be estimated by looking at the sky at that point through a linear polarizer. If there is a large intensity change when rotating the polarizer 90°, then there is a substantial amount of polarization. If the intensity change is small, then the amount of polarization is small too. It is generally true that where the skylight is polarized, the azimuth of polarization is perpendicular to the plane made up of three points—the position of the sky, the position of the sun, and the position of the observer.



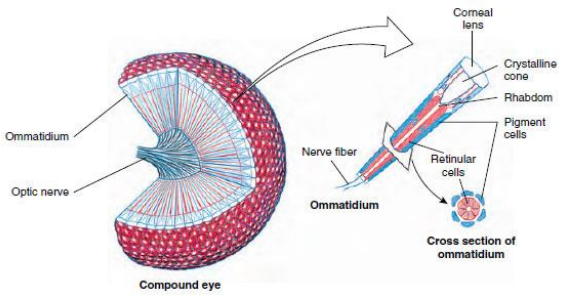
Von Frisch showed that the honeybees were able to tell the direction of nectar-containing flowers relative to the sun by analyzing the azimuth of polarization of light waves scattered by the gas molecules in the atmosphere. He did this first by determining the **action spectrum** of light that would cause the bees to perform the correct **waggle dance**. He put filters that transmitted a small part of the skylight spectrum around an enclosure. He found that the bees could communicate the correct position of the nectar-containing flowers relative to the sun only when the filter passed **ultraviolet light**. Therefore the bees were

using **ultraviolet wavelengths** (300-400 nm) to determine the position of the nectar-containing flowers relative to the sun. This action spectrum correlated with the ability of the bees to see in the ultraviolet.

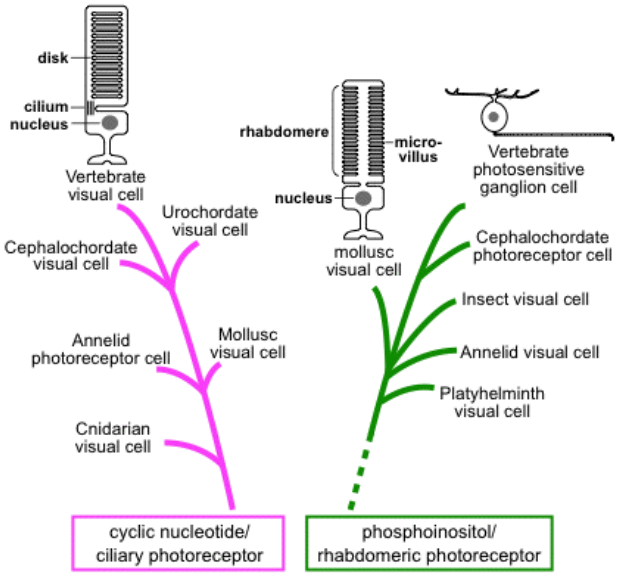
Next, von Frisch put a large Polaroid filter over the bees so that he could arbitrarily introduce polarized light with a given azimuth from the blue sky to the bees in a hive that was exposed to sunlight. Von Frisch rotated the polarizer to the right or to the left. Von Frisch (1971) wrote "*Never shall I forget the joy with which I saw the dancers react to it at once and shift the line of their wagging runs in the direction of rotation. Without exception the dances pointed farther toward the right after a rotation to the right, and farther toward the left after a rotation to the left. This of itself demonstrated that they orient with reference to the polarization of the blue sky….But they did not always shift their indication of direction by precisely the angle through which I had rotated the polaroid sheet. For example, it sometimes happened that after a rotation of 30 degrees the line of dancing was shifted in the same direction, but by 35 degrees. In order to comprehend this we need more intimate knowledge about the polarized light in the blue vault of heaven and about its analysis by the eye of the bee.*"

The polarized ultraviolet light is sensed by the two large compound eyes of a honeybee.

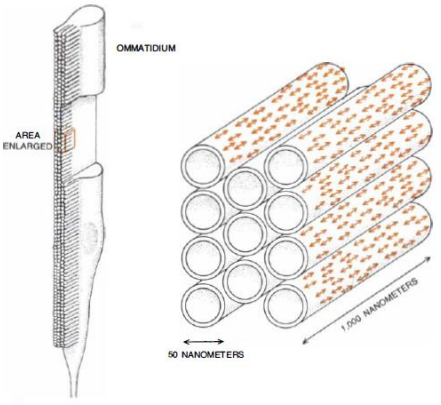




The honeybee eye must have an analyzer composed of a pigment that will absorb polarized ultraviolet light as a function of its azimuth. **Is there anything in the insect eye that looks like an analyzer**?



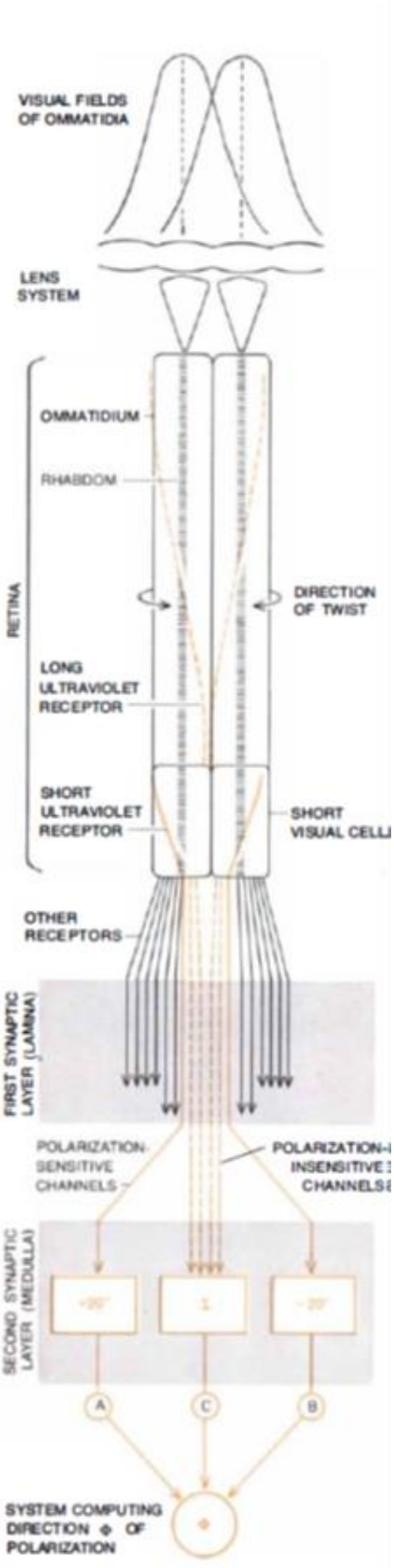
The structure of the visual cells in the retina of insects differ in the structure visual cells in the retina of humans and are similar to the melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGC). The visual cells of insects have parallel microvilli that contain the photoreceptor pigment. The 11-cis retinal of the photoreceptor pigment is a **dipolar molecule** that maximally absorbs polarized light whose azimuth is oriented **parallel** to the molecule and does not absorb polarized light whose azimuth is perpendicular to the molecule.



VISUAL CELLS of vertebrates (*top*) and invertebrates (*bottom*) differ in arrangement of photoreceptor membrane and orientation of molecules of visual pigment rhodopsin within membrane. In vertebrates axes of rhodopsin molecules (*color*) are randomly oriented; in insects they are parallel to long axis of tubelike microvilli. This maximizes absorption of polarized light.

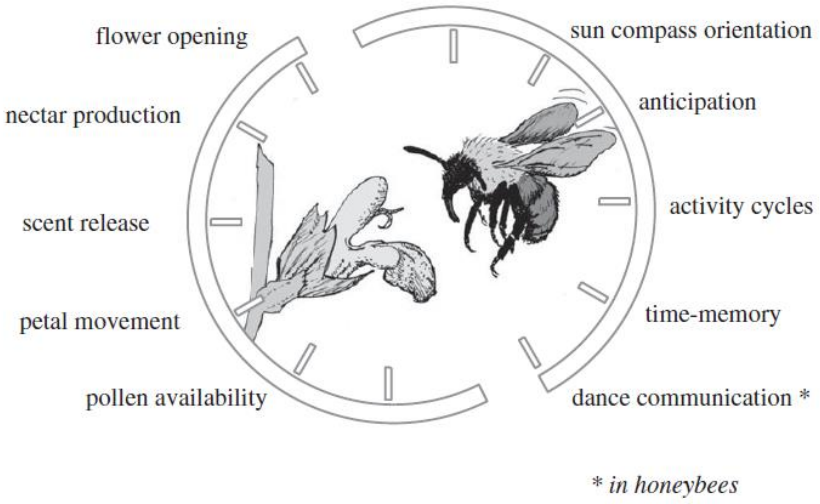
Rüdiger Wehner and Timothy Goldsmith measured the absorption of ultraviolet light with varying azimuths. If the photoreceptor molecules were **randomly** oriented in the visual cells, the amount of absorption would be **independent** of the azimuth of the ultraviolet light. If the photoreceptor molecules were not randomly oriented, the amount of absorption would depend on the azimuth of ultraviolet light. They found that the amount of absorption was maximal when the azimuth of polarized ultraviolet light was parallel to the microvilli, indicating that the **photoreceptor pigments are oriented parallel to the microvilli**. In humans, the photoreceptor molecules are randomly arranged in the visual cells, which is why we cannot detect the azimuth of polarization with our naked eyes.

There are about 5,500 **ommatia** in each eye of a honeybee and each ommatium contains nine visual cells. In each ommatidium, there are **two types of visual cells that contain UV-absorbing photoreceptor pigments.** One of the UV-absorbing visual cells is long, and it is twisted 180° throughout its length, meaning that it will absorb any and all azimuths of UV light equally. The other type of UV-absorbing visual cell, which is a **short cell**, is only twisted 40° and thus retains its sensitivity to polarized light. In each eye, half of the ommatidia have UV-absorbing visual cells are twisted **clockwise** and half have UV-absorbing cells that are twisted **anticlockwise**. The detection of the azimuth of polarization requires a pair of clockwise and anticlockwise ommatidia. Rüdiger Wehner (1976) has suggested "*a simple model explaining how the insect analyzes the direction of skylight polarization. In brief, the model indicates that if two polarization analyzers of opposite twist work together with at least one long ultraviolet-sensitive cell that is insensitive to the polarization of the skylight polarization anywhere overhead can be determined unambiguously. Hence any two adjacent ommatidia of opposite twist are equipped with all three of the necessary cells and will provide the analyzing system with all three of the necessary signals: two independent signals that are modulated by polarized skylight and one signal that is not*."



Polarized light whose azimuth is the same as the azimuth of maximal absorption of the pigment will be maximally absorbed and a message will be sent to the brain. Polarized light whose azimuth is perpendicular to the azimuth of maximal absorption of the pigment will not be absorbed and no message will be sent to the brain. The brain is necessary to decode the polarization of skylight to use the sun as a compass.

Since the pattern of polarization of skylight varies during the day and the season, bees must be able to **keep track of time** in order to use the sun as a compass. Von Frisch (1971) that bees "*have an excellent memory for time*" after all their foraging has to be **synchronized** with the **flower clock** that controls the blooming of as well as the opening and closing of flowers. "***Only connect***."



When Therese von Oettingen-Spielberg (1949) put a beehive containing bees that had never visited flowers in a screened-in courtyard that contained colored paper without scent and scented flowers that could not be seen she was surprised to find that only one or two bees visited the color displays or the scented but covered flowers. Von Frisch, who won the Nobel Prize for his work, described her findings like so: "*As with human beings, pioneers seem to be rare in the beehive. Most individuals prefer to wait for the discoveries of a few scouts in order to find food by following their instructions*."

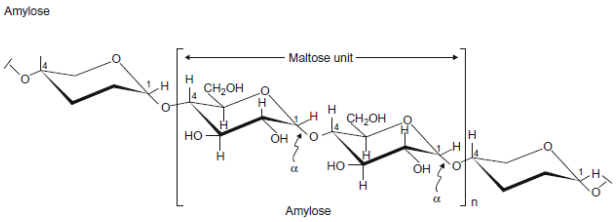
In *Ends and Means*, **Aldous Huxley** described different types of individuals from a historical perspective: "*At this point it becomes necessary to say something about that ideal individual into whom the changers of heart desire to transform themselves and others. Every age and class has had its ideal. The ruling classes in Greece idealized the magnanimous man, a sort of scholar and gentleman. Kshatriyas in early India and feudal nobles in mediaeval Europe held up the ideal of the chivalrous man. The honnête homme* [honest man] *makes his appearance as the ideal of seventeenth-century gentlemen; the philosophe* [philosopher], *as the ideal of their descendants in the eighteenth century. The nineteenth century idealized the respectable man. The twentieth has already witnessed the rise and fall of the liberal man and* ***the emergence of the sheep-like social man and the god-like Leader****. Meanwhile the poor and downtrodden have always dreamed nostalgically of a man ideally well-fed, free, happy and unoppressed*." Have humans evolved to become like bees? https://archive.org/stream/endsandmeans035237mbp/endsandmeans035237mbp_djvu.txt

See the waggle dance (http://video.nationalgeographic.com/video/weirdest-bees-dance and http://www.pbs.org/wgbh/nova/nature/waggle-dance.html).

In order for a material to respond to be sensitive to the polarization of light, it has to have some kind of **asymmetry**—such as an asymmetry in absorption or an asymmetry in refraction. The refractive index (n_i) of a material is a measure of the speed of light through the material. The refractive index is the ratio of the speed of light in a vacuum (c) to the speed of light in the material (v_i) according to the following equation.

$$n_i = \frac{c}{v_i}$$

It is the **electrons in the bonds** that interact with and that slow down the light. If the bonds are randomly arranged, then linearly polarized light of any azimuth will be slowed down equally. However, if the bonds are not randomly arranged, then polarized light with an azimuth that is parallel to the bonds will be slowed down more than polarized light with an azimuth perpendicular to the bonds. Such material will have two refractive indices, one for light that is parallel to the bonds and one for light that is perpendicular to the bonds. The refractive index parallel to the bonds will be greater than the refractive index perpendicular to the bonds. Substances with two refractive indices are **birefringent**. Amylose is birefringent having two indices of refraction. The index of refraction parallel to the long axis of the molecule is greater than the refractive index perpendicular to the long axis of the molecule. **Refractive index is all about the interaction of electromagnetic waves in the visible light range with electrons in the bonds of molecules**.



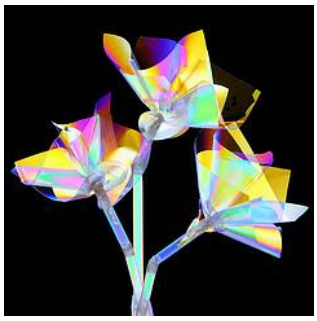
Birefringent substances will become colored when put between two Polaroids whose axes of transmission are perpendicular to each other. These **crossed polars** normally pass no light through them. They pass no light when a substance with one refractive index such as glass is put between them. They pass light when a birefringent substance is put between them. They also pass light when a substance with one refractive index that has been subjected to **stress** which **aligned the bonds** is put between them. This technique, known as **photoelastic stress analysis**, can be used by architects and engineers to visualize and measure the effect of stress in materials (http://flickrhivemind.net/Tags/birefringence/Interesting).





When molecules are not randomly arranged or symmetrical, then the electrons in the bonds interact with polarized light in a way that depends on the azimuth of polarization of the light. If the azimuth of polarization is parallel to the bonds the light will interact longer with the bonds than if the azimuth of polarization is perpendicular to the bonds. If the azimuth of polarization is at a forty five degree angle to the bonds, half of the light will interact parallel to the bond and half of the light will interact perpendicular to the bond. The way the two components recombine in the analyzer will result in the generation of colors.

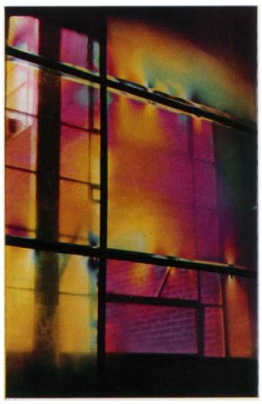
Demonstration: Observe crossed polarizers. What happens when you put thin sheets of mica or cellophane (plant cell walls) between them? You can arrange the pieces in more or fewer layers and with different orientations to get the desired color.



The principles of polarized light can be applied to art. **Joe Burns** (Cornell) **and his wife Judith** have done art using polarized light and **photoelastic stress**.







Top: *Louis Cork Marcheschi. 'For Marcel', 1972. The 500 watt incandescent lamp is activated by electricity provided by a high-voltage high-frequency generator.* (Photo: W. Young, Minneapolis, Minn., U.S.A.) (Fig. 7, cf. page 296.)

Bottom left: *Richard Bowman. 'Kinetograph, 6', oil on canvas,* 40 × 60 in., 1950. (Collection of Mr. and Mrs. D. Hurt, Mountain View, California, U.S.A.) (Fig. 3, cf. page 291.)

Bottom right: *Joseph A. Burns and Judith Klein Burns. View of a portion of the kinetic mural of stressed photoelastic material and light polarizers.* (Fig. 3, cf. page 325).

Chrono Art is the transformation of time into art. They make clock faces that get their colors based on polarized light.

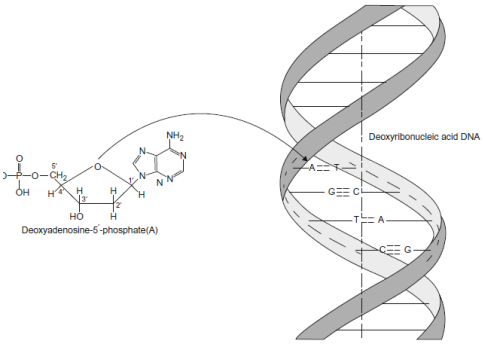
http://www.chronoart.com/index.html

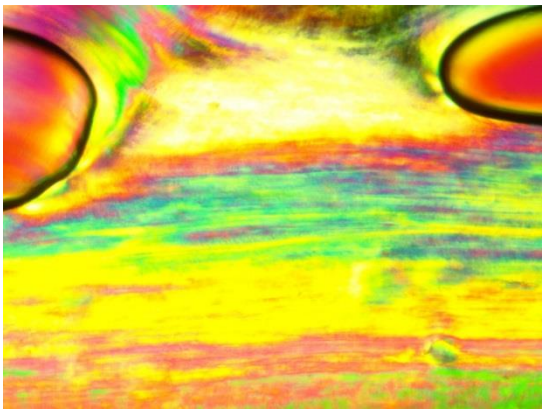






Demonstration: Polaroids can be used with a microscope to do **polarized light microscopy**. Since the bonds in DNA are nonrandom and linearly polarized





light with its azimuth perpendicular to the long axis of the is slowed down more than linearly polarized light with its azimuth parallel to the long axis of the molecule, DNA is birefringent. DNA, the chemical basis of heredity, is beautiful when visualized in a polarizing light microscope.

Demonstration: **Calcite or Icelandic spar** is birefringent and it resolves one beam of natural light into two beams of polarized light, each one with a polarization perpendicular to the other.



Lars Chittka, a behavioral ecologist, and Julian Walker (2006), an installation artist, wanted to show people, who were obviously attracted to flowers, that they should think about the "*fundamental philosophical issue of whether perception reflects reality, about the nature of the image as object, and about the biological meaning of colour for different receivers*." Lars Chittka and Julian Walker presented paintings to bumble (humble) bees that had never seen flowers before. The paintings included Vincent van Gogh's *Sunflowers*, Paul Gauguin's *A Vase of Flowers*, Patrick Caulfield's *Pottery*, and Fernand Léger's *Still Life with Beer Mug.*



Fig. 2. Paintings used: (a) Vincent Van Gogh (1853–1890) *Sunflowers* (1888). The original is in the National Gallery, London. The copy was painted by J. Walker (acrylic on canvas-board 45.5 × 35.5 cm). (b) Poster of Paul Gauguin (1848–1903). *A Vase of Flowers* 1896; oil on canvas 64 × 74 cm (copyright: The National Gallery, London). (c) Poster of Patrick Caulfield (b. 1936) *Pottery* 1969; oil on canvas 213.4 × 152.4 cm. Presented by Mrs. H. K. Morton through the Contemporary Art Society; Tate Gallery, London; (copyright: Patrick Caulfield 2004. All rights reserved, DACS, London). (d) Fernand Léger (1881–1955). *Still Life with Beer Mug* 1921–1922, oil on canvas 92.1 × 60 cm; purchased with assistance from the Friends of the Tate gallery 1976; Tate Gallery, London; Copyright: ADAGP, Paris and DACS, London 2004. Posters of (a) and (b) are available in The National Gallery shop, posters of (c) and (d) are available in Tate Modern's shop.



Fig. 3. Bees exploring paintings: (a) *Bombus terrestris* worker exploring Van Gogh's "Sunflowers". Some bees bear number plates on their backs to allow for individual recognition, (b) a *Bombus terrestris* male is landing on the edge of a blue flower of Gauguin's "A Vase of Flowers" (the most attractive portion of the painting for bees, (c) a worker bee hovering over Caulfield's "Pottery", and (d) another worker landing on a high contrast edge in Léger's "Still Life with Beer Mug".

They found that the bees were most attracted to Van Gogh's painting and the flowers on the paintings were the most common target where they landed. It was not just the flowers that attracted the bees since two other paintings—Caulfield's *Pottery* and Léger's *Still Life with Beer Mug*, which do not have flowers attracted more bees than *A Vase of Flowers*. Chittka and Walker want us to know that the colors we see, although related to what is really there, also depends on the biology of our species. That is, "***colour is neither firmly physics nor a domain of the arts: it is, to a large extent, biology***."

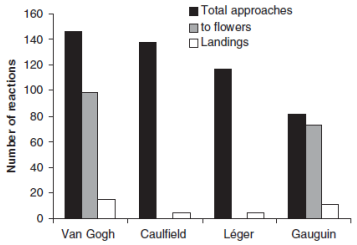


Fig. 4. Bees' reactions to the four paintings (arranged from left to right in decreasing order of popularity). Twelve minutes of observation time were evaluated for each painting.

This is something we all know from studying the diversity of photoreceptors in various organisms and the diversity of colors outside the visible spectrum!



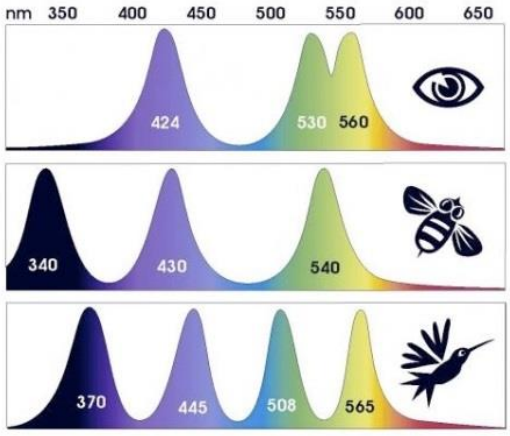


Fig. 1. A flower of *Iris pseudacorus* photographed in the visible (left) and in the ultraviolet (centre panel). The centre of the flower is strongly UV absorbing and appears as black, whereas the periphery reflects UV light. Right panel: a bumblebee worker probes the boundary between the two areas with her antennae. Photos by Prof. K. Lunau, with permission.



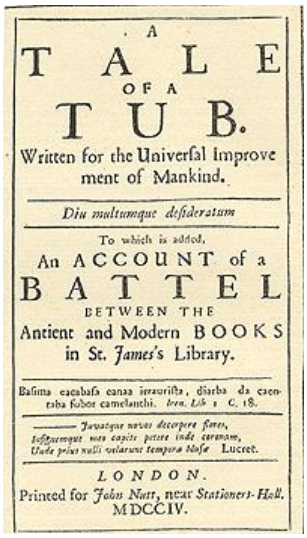
We began this semester looking at the real and virtual images of beeswax candles from Monticello, the home of Thomas Jefferson. On October 21, 1822, Thomas Jefferson wrote in a letter to Cornelius Camden Blatchly: *"I look to the diffusion of light and education as the resource to be relied on for ameliorating the condition, promoting the virtue, and advancing the happiness of man."*



All types of candles were burned at Monticello, including spermaceti, **beeswax**, bayberry, and tallow. We now have a great store of knowledge about how the candles come about. We know about how the colorful flowers on photosynthesizing plants attract the bees that carry the nectar, a product of photosynthesis and of sunlight, back to the hive where it is turned into honey and then beeswax. We know a lot about how the candle converts

the chemical energy of wax into the radiant energy of the flame—sweetness and light!

Actually, Thomas Jefferson preferred to use expensive spermaceti candles, because they burned so cleanly. According to one of Jefferson's granddaughters, "*When the candles were brought, all was quiet immediately, for he took up his book to read, and we would not speak out of a whisper lest we should disturb him, and generally we followed his example and took (up) a book…"*

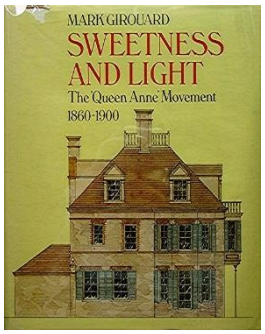

A
TALE
OF A
TUB.
Written for the Universal Improvement of Mankind.
Diu multumque desideratum
To which is added,
An ACCOUNT of a
BATTEL
BETWEEN THE
Antient and Modern BOOKS
in St. *James's* Library.
Basima cacabasa canaa irrauricta, diarba da caentaba fobor camelanthi. *Iren. Lib* 1 C. 18.
Juvatque novos decerpere flores,
Insignemque meo capite petere inde coronam,
Unde prius nulli velarunt tempora Musæ Lucret.
LONDON.
Printed for *John Nutt*, near *Stationers-Hall*.
MDCCIV.

There is an age old battle between those who take a **conservative** view of culture and society and those who take a **progressive** view. **Jonathan Swift** (1704) brings up this dichotomy in *An Account of a Battel between the Antient and Modern Books in St. James's Library* in which he tells the story of **Aesop**, an ancient book that heard an argument between a wandering **bee** who just barely escaped being trapped by a cobweb and a big fat spider who thought he was better than the bee. The progressive spider pointed out that the conservative bee creates nothing of its own, whereas he, the mathematically accomplished spider, is a creator who "*spins and spits wholly from himself*." The bee points out that the spider's web is spun from digested flies and that all the spider really adds of himself is his poison. By contrast, the bee "*with long search, much study, true judgment, and distinction of things, brings home honey and wax*" without doing the flowers harm, while the spider moves only inches and feeds on the "*vermin of the age*." Aesop saw the bees as being like the ancient writers who provided culture with delight (sweetness) and moral wisdom (light). The bees pretend to nothing of their own beyond their wings and voice: that is to say, their flights and language. And instead of working with dirt and poison, they have filled their hives with

honey and **wax**; thus, furnishing mankind with the two noblest of things, which are **sweetness and light**." http://www.gutenberg.org/files/623/623-h/623-h.htm



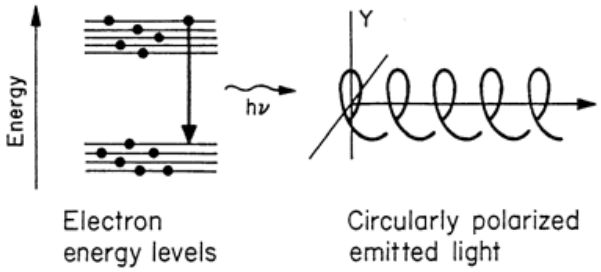
Matthew Arnold (1869), Aldous Huxley's maternal, great uncle, wrote in *Culture and Anarchy: An Essay in Political and Social Criticism*, "*it is not at this moment true, what the majority of people tell us, that the world wants* ***fire and strength*** *more than* ***sweetness and light****, and that things are for the most part to be settled first and understood afterwards*."https://www.bartleby.com/library/prose/369.html



The term *Sweetness and light* was used by Mark Girouard to describe the "Queen Anne Movement" (1860-1900).

Here is a paper entitled, **One Culture: Two Methods** that I wrote: http://labs.plantbio.cornell.edu/wayne/pdfs/OneCulture.pdf

Each **photon** emitted by the candle is **polarized**. I believe that the electric field is linearly polarized, and the magnetic field is circularly polarized. However, the standard interpretation of quantum mechanics says that each photon is circularly polarized, half are polarized clockwise and half are polarized anticlockwise.



We can learn a lot about light and life from watching the honeybees and follow all the **connections**. It is as true today as it was in 1792, when **Johann Wolfgang von Goethe** wrote in an essay entitled, *The Experiment as Mediator of Object and Subject* "*In living nature nothing happens that is not* ***in connection with a whole****….Since everything in nature, especially the more common forces and*



elements, is in eternal action and reaction, we can say of every phenomenon that it is connected to countless others, just as a radiant point of light sends out its rays in all directions."

T. H. Huxley admired Goethe immensely and collected and translated many of Goethe's aphorisms on nature for the first issue of the journal Nature (Nov 4, 1869).

Goethe: Aphorisms on Nature

T. H. Huxley

NATURE! We are surrounded and embraced by her: powerless to separate ourselves from her, and powerless to penetrate beyond her.

Without asking, or warning, she snatches us up into her circling dance, and whirls us on until we are tired, and drop from her arms.

She is ever shaping new forms: what is, has never yet been; what has been, comes not again. Everything is new, and yet nought but the old.

We live in her midst and know her not. She is incessantly speaking to us, but betrays not her secret. We constantly act upon her, and yet have no power over her.

The one thing she seems to aim at is Individuality; yet she cares nothing for individuals. She is always building up and destroying; but her workshop is inaccessible.

Her life is in her children; but where is the mother? She is the only artist; working-up the most uniform material into utter opposites; arriving, without a trace of effort, at perfection, at the most exact precision, though always veiled under a certain softness.

Each of her works has an essence of its own; each of her phenomena a special characterisation: and yet their diversity is in unity.

She performs a play; we know not whether she sees it herself, and yet she acts for us, the lookers-on.

Incessant life, development, and movement are in her, but she advances not. She changes for ever and ever, and rests not a moment. Quietude is inconceivable to her, and she has laid her curse upon rest. She is firm. Her steps are measured, her exceptions rare, her laws unchangeable.

She has always thought and always thinks; though not as a man, but as Nature. She broods over an all-comprehending idea, which no searching can find out.

Mankind dwell in her and she in them. With all men she plays a game for love, and rejoices the more they win. With many, her moves are so hidden, that the game is over before they know it.

That which is most unnatural is still Nature; the stupidest philistinism has a touch of her genius. Whoso cannot see her everywhere, sees her nowhere rightly.

She loves herself, and her innumberable eyes and affections are fixed upon herself. She has divided herself that she may be her own delight. She causes an endless succession of new capacities for enjoyment to spring up, that her insatiable sympathy may be assuaged.

She rejoices in illusion. Whoso destroys it in himself and others, him she punishes with the sternest tyranny. Whoso follows her in faith, him she takes as a child to her bosom.

Her children are numberless. To none is she altogether miserly; but she has her favourites, on whom she squanders much, and for whom she makes great sacrifices. Over greatness she spreads her shield.

She tosses her creatures out of nothingness, and tells them not whence they came, nor whither they go. It is their business to run, she knows the road.

Her mechanism has few springs — but they never wear out, are always active and manifold.

The spectacle of Nature is always new, for she is always renewing the spectators. Life is her most exquisite invention; and death is her expert contrivance to get plenty of life.

She wraps man in darkness, and makes him for ever long for light. She creates him dependent upon the earth, dull and heavy; and yet is always shaking him until he attempts to soar above it.

She creates needs because she loves action. Wondrous! that she produces all this action so easily. Every need is a benefit, swiftly satisfied, swiftly renewed.— Every fresh want is a new source of pleasure, but she soon reaches an equilibrium.

Every instant she commences an immense journey, and every instant she has reached her goal.

She is vanity of vanities; but not to us, to whom she has made herself of the greatest importance. She allows every child to play tricks with her; every fool to have judgment upon her; thousands to walk stupidly over her and see nothing; and takes her pleasure and finds her account in them all.

We obey her laws even when we rebel against them; we work with her even when we desire to work against her.

She makes every gift a benefit by causing us to want it. She delays, that we may desire her; she hastens, that we may not weary of her.

She has neither language nor discourse; but she creates tongues and hearts, by which she feels and speaks.

Her crown is love. Through love alone dare we come near her. She separates all existences, and all tend to intermingle. She has isolated all things in order that all may approach one another. She holds a couple of draughts from the cup of love to be fair payment for the pains of a lifetime.

She is all things. She rewards herself and punishes herself; is her own joy and her own misery. She is rough and tender, lovely and hateful, powerless and omnipotent. She is an eternal present. Past and future are unknown to her. The present is her eternity. She is beneficient. I praise her and all her works. She is silent and wise.

No explanation is wrung from her; no present won from her, which she does not give freely. She is cunning, but for good ends; and it is best not to notice her tricks.

She is complete, but never finished. As she works now, so can she always work. Everyone sees her in his own fashion. She hides under a thousand names and phrases, and is always the same. She has brought me here and will also lead me away. I trust her. She may scold me, but she will not hate her work. It was not I who spoke of her. No! What is false and what is true, she has spoken it all. The fault, the merit, is all hers.

So far Goethe.

When my friend, the Editor of NATURE, asked me to write an opening article for his first number, there came into my mind this wonderful rhapsody on "Nature," which has been a delight to me from my youth up. It seemed to me that no more fitting preface could be put before a Journal, which aims to mirror the progress of that fashioning by Nature of a picture of herself, in the mind of man, which we call the progress of science.

A translation, to be worth anything, should reproduce the words, the sense, and the form of the original. But when that original is Goethe's, it is hard indeed to obtain this ideal; harder still, perhaps, to know whether one has reached it, or only added another to the long list of those who have tried to put the great German poet into English, and failed.

Supposing, however, that critical judges are satisfied with the translation as such, there lies beyond them the chance of another reckoning with the British public, who dislike what they call "Pantheism" almost as much as I do, and who will certainly find this essay of the poet's terribly Pantheistic. In fact, Goethe himself almost admits that it is so. In a curious explanatory letter, addressed to Chancellor von Muller, under date May 26th, 1828, he writes:

"This essay was sent to me a short time ago from amongst the papers of the ever-honoured Duchess Anna Amelia; it is written by a well-known hand, of which I was accustomed to avail myself in my affairs, in the year 1780, or thereabouts.

"I do not exactly remember having written these reflections, but they very well agree with the ideas which had at that time become developed in my mind. I might term the degree of insight which I had then attained, a comparative one, which was trying to express its tendency towards a not yet attained superlative.

"There is an obvious inclination to a sort of Pantheism, to the conception of an unfathomable, unconditional, humorously self-contradictory Being, underlying the phenomena of Nature; and it may pass as a jest, with a bitter truth in it."

Goethe says, that about the date of this composition of "Nature" he was chiefly occupied with comparative anatomy; and, in 1786, gave himself incredible trouble to get other people to take an interest in his discovery, that man has a intermaxillary bone. After that he went on to the metamorphosis of plants, and to the theory of the skull; and, at length, had the pleasure of seeing his work taken up by German naturalists. The letter ends thus:—

"If we consider the high achievements by which all the phenomena of Nature have been gradually linked together in the human mind; and then, once more, thoughtfully peruse the above essay, from which we started, we shall, not without a smile, compare that comparative, as I called it, with the superlative which we have now reached, and rejoice in the progress of fifty years."

Forty years have passed since these words were written, and we look again, "not without a smile," on Goethe's superlative. But the road which led from his comparative to his superlative, has been diligently followed, until the notions which represented Goethe's superlative are now the commonplaces of science — and we have super-superlative of our own.

When another half-century has passed, curious readers of the back numbers of NATURE will probably look on our best, "not without a smile;" and**, it may be, that long after the theories of the philosophers whose achievements are recorded in these pages, are obsolete, the vision of the poet will remain as a truthful and efficient symbol of the wonder and the mystery of Nature.**

"*The history of honey goes with the history of mankind*." Bees, as producers of honey and beeswax have been connected to human culture for approximately 8000-9000 years as depicted in a **cave painting** of honey hunting found in Cuevas de la Araña in Valencia, Spain by Hernández Pacheco in 1924. Medicinal uses of honey are described in Sumerian clay tablets from 3000 BC and before the development of writing, a honey jar depicted "sweetness." **Hieroglyphics** from the tombs in ancient Egypt

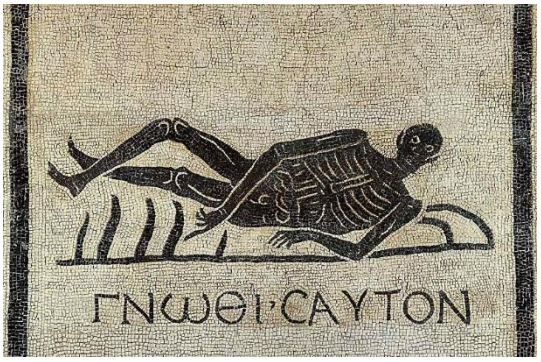








(2400 BC) depict beekeeping. The Smith papyrus (1550 BC), the oldest Egyptian medical literature contains 900 prescriptions using honey to treat wound healing, eye disease, ulcers, constipation, urinary problems, and inflammation of the knees and feet. Honey that was still edible was found in the **King Tutankhamen's** tomb, indicating that honey never spoils.



My goal for this course has been to **connect** the science of light and life to an understanding of the human condition and in so doing, encouraging you to **know yourself** (γνῶθι σεαυτόν), your own uniqueness, your origins, your purpose, your relationship to the universe, others, God, and the meaning of it all. E. M. Forster, like Goethe, emphasized the **importance of connections** in seeing the relationships of the parts to the whole. In *Howard's End* (1910) "*Margaret greeted her lord with peculiar tenderness on the morrow. Mature as he was, she might yet be able to help him* ***to the building of the rainbow bridge that should connect the prose in us with the passion***. ***Without it we are meaningless fragments, half monks, half beasts, unconnected arches that have never joined into a man***. *With it love is born, and alights on the highest curve, glowing against the grey, sober against the fire. Happy the man who sees from either aspect the glory of these outspread wings. The roads of his soul lie clear, and he and his friends shall find easy-going…. It did not seem so difficult. She need trouble him with no gift of her own. She would only point out the salvation that was latent in his own soul, and in the soul of every man.* ***Only***





connect! That was the whole of her sermon. Only connect the prose and the passion, and both will be exalted, and human love will be seen at its height. Live in fragments no longer. Only connect, and the beast and the monk, robbed of the isolation that is life to either, will die."

Look at all the connections between light and life in ***The Birds and the Bees*** by Herbert Newman: https://www.youtube.com/watch?v=umyl-wWRkJ4



Let me tell ya 'bout the birds and the bees
And the flowers and the trees
And the moon up above
And a thing called 'Love'

Let me tell ya 'bout the stars in the sky
And a girl and a guy
And the way they could kiss
On a night like this

When I look into your big brown eyes
It's so very plain to see
That it's time you learned about the facts of life
Starting from A to Z

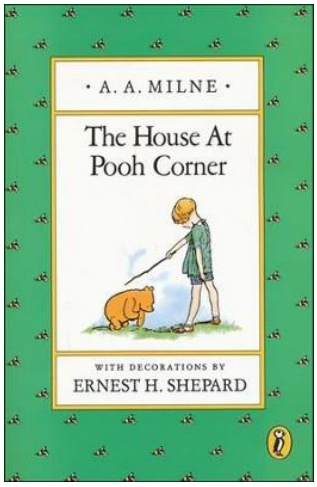
Or as Thomas Carew wrote in "A Rapture"

Then, as the empty bee that lately bore
Into the common treasure all her store,
Flies 'bout the painted field with nimble wing,
Deflow'ring the fresh virgins of the spring,

You can buy polarizers for your smartphones.

https://www.youtube.com/watch?v=VFLLP9gnZlg

A. A. Milne (1928) wrote in The House at Pooh Corner,



So they began going there, and after they had walked a little way Christopher Robin said:

"What do you like doing best in the world, Pooh?"

"Well," said Pooh, "what I like best?" and then he had to stop and think. Because although Eating ***Honey*** *was a very good thing to do, there was a moment just before you began to eat it which was better than when you were, but he didn't know what it was called.*

Kenny Loggins wrote the songs**: House at Pooh Corner** (https://www.youtube.com/watch?v=uqJptJEgICU; https://www.youtube.com/watch?v=fGTO-_hpnEc) and **Return to Pooh Corner** (https://www.youtube.com/watch?v=_iV4mol-Otw).

THE HUMBLE-BEE.

By Ralph Waldo Emerson

BURLY, dozing, humble-bee,
Where thou art is clime for me.
Let them sail for Porto Rique,
Far-off heats through seas to seek;
I will follow thee alone,
Thou animated torrid-zone!
Zigzag steerer, desert cheerer,
Let me chase thy waving lines;
Keep me nearer, me thy hearer,
Singing over shrubs and vines.

Insect lover of the sun,
Joy of thy dominion!
Sailor of the atmosphere;
Swimmer through the waves of air;
Voyager of light and noon;
Epicurean of June;
Wait, I prithee, till I come
Within earshot of thy hum,—
All without is martyrdom.

When the south wind, in May days,
With a net of shining haze
Silvers the horizon wall,
And, with softness touching all,
Tints the human countenance
With a color of romance,
And, infusing subtle heats,
Turns the sod to violets,
Thou, in sunny solitudes,
Rover of the underwoods,
The green silence dost displace
With thy mellow, breezy bass.

Hot midsummer's petted crone,
Sweet to me thy drowsy tone
Tells of countless sunny hours,
Long days, and solid banks of flowers;
Of gulfs of sweetness without bound
In Indian wildernesses found;
Of Syrian peace, immortal leisure,
Firmest cheer, and bird-like pleasure.

Aught unsavory or unclean
Hath my insect never seen;
But violets and bilberry bells,
Maple-sap, and daffodels,
Grass with green flag half-mast high,
Succory to match the sky,
Columbine with horn of honey,

Scented fern, and agrimony,
Clover, catchfly, adder's tongue,
And brier roses, dwelt among;
All beside was unknown waste,
All was picture as he passed.

Wiser far than human seer,
Yellow-breeched philosopher!
Seeing only what is fair,
Sipping only what is sweet,
Thou dost mock at fate and care,
Leave the chaff, and take the wheat.
When the fierce north-western blast
Cools sea and land so far and fast,
Thou already slumberest deep;
Woe and want thou canst outsleep;
Want and woe, which torture us,
Thy sleep makes ridiculous.

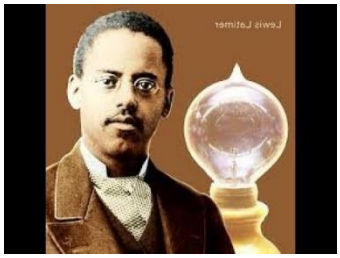
Churchill's Secret War: The British Empire and the Ravaging of India during World War II.
Lindemann believed that science could produce a race of humans blessed with "*the mental make-up of the worker bee*," without the ability to suffer or to feel ambition. Instead of being chained to "*the fetish of equality*," human differences should be accepted and even enhanced by means of science. With science, there was no need to wait for "*the haphazard process of natural selection to ensure that the slow and heavy mind gravitates to the lowest form of activity*."

The Pedigree of Honey
By Emily Dickinson



The pedigree of honey
Does not concern the bee;
A clover, any time, to him
Is aristocracy.

The Love is Like by Lewis Latimer



The love is like the cooling shade of trees
Or like the fragrant breath of flowers
My thoughts fly to thee as the wayward bees
Return to seek again the honeyed flowers.



In *Leviathan*, Thomas Hobbs (1651) states that since human beings are not bees not ants, it is not appropriate for them to live in insect-like societies.

Men naturally love liberty, and dominion over others; so what is the final cause or end or design they have in mind when they introduce the restraint upon themselves under which we see them live in commonwealths? It is the prospect of their own preservation and, through that, of a more contented life; i.e. of getting themselves out of the miserable condition of war which (as I have shown) necessarily flows from the natural passions of men when there is no visible power to keep them in awe and tie them by fear of punishment to keep their covenants and to obey the laws of nature set down in my chapters 14 and 15.

For the laws of nature—enjoining justice, fairness, modesty, mercy, and (in short) treating others as we want them to treat us—are in themselves contrary to our natural passions, unless some power frightens us into observing them. *In the absence of such a power, our natural passions carry us to partiality, pride, revenge, and the like. And covenants without the sword are merely words, with no strength to secure a man at all. Every man has obeyed the laws of nature when he has wanted to, which is when he could do it safely; but if there is no power set up, or none that is strong enough for our security, ·no-one can safely abide by the laws; and in that case· every man will and lawfully may rely on his own strength*

and skill to protect himself against all other men. In all places where men have lived in small families with no larger organized groupings·, the trade of robber was so far from being regarded as against the law of nature that ·it was outright honoured, so that the greater spoils someone gained by robbery, the greater was his honour. The only constraints on robbery came from the laws of honour, which enjoined robbers to abstain from cruelty and to let their victims keep their lives and their farm implements. These days cities and kingdoms (which are only greater families) do what small families used to do back then: for their own security they enlarge their dominions, on the basis of claims that they are in danger and in fear of invasion, or that assistance might be given to invaders ·by the country they are attacking·. They try as hard as they can to subdue or weaken their neighbours, by open force and secret manoeuvres; and if they have no other means for their own security, they do this justly, and are honoured for it in later years.

Nor can the joining together of a small number of men give them this security that everyone seeks; because when the numbers are small, a small addition on the one side or the other makes the advantage of strength so great that it suffices to carry the victory, and so it gives encouragement for an invasion. How many must we be, to be secure? That depends not on any particular number, but on comparison with the enemy we fear. We have enough if the enemy doesn't outnumber us by so much that that would settle the outcome of a war between us, which would encourage the enemy to start one.

And however great the number, if their actions are directed according to their individual wants and beliefs, they can't expect their actions to defend or protect them against a common enemy or against injuries from one another.

For being drawn in different directions by their differing opinions concerning how best to use their strength, they hinder rather than help one another, and by quarrelling among themselves they reduce their strength to nothing. When that happens they are easily subdued by a very few men who agree together; and when there's no common enemy they make war on each other for their particular interests. For if we could suppose a great multitude of men to agree in the observation of justice and other laws of nature, without a common power to keep them all in awe, we might as well suppose all mankind to do the same; and then there would not be—and would not need to be—any civil government or commonwealth at all, because there would be peace without subjection.

For the security that men desire to last throughout their lifetimes, it's not enough that they be governed and directed by one judgment for a limited time—e.g. for one battle, or one war. For in that case, even if they obtain a victory through their unanimous efforts against a foreign enemy, yet afterwards—when they have no common enemy, or when some of them regard as an enemy someone whom the others regard as a friend—the difference of their interests makes it certain that they will fall apart and once more come to be at war amongst themselves.

It's true that certain living creatures, such as bees and ants, live sociably with one another (which is why Aristotle counts them among the 'political' creatures, although each of them is steered only by its particular judgments and appetites, and they don't have speech through which one might indicate to

another what it thinks expedient for the common benefit. You may want to know why mankind can't do the same. My answer to that has six parts.

(1) Men continually compete with one another for honour and dignity, which ants and ***bees*** *do not; and that leads men, but not those other animals, to envy and hatred and finally war.*

(2) Among those lower creatures, the common good of all is the same as the private good of each; and being naturally inclined to their private benefit, in procuring that they also procure the common benefit. But a man's biggest pleasure in his own goods comes from their being greater than those of others!

(3) ***Bees*** *and ants etc. don't have the use of reason (as man does), and so they don't see—and don't think they see—any fault in how their common business is organized; whereas very many men think themselves wiser than the rest, and better equipped to govern the public. These men struggle to reform and innovate, one in this way and another in that, thereby bringing the commonwealth into distraction and civil war.*

(4) These creatures, though they have some use of voice in making known to one another their desires and other affections, don't have that skill with words through which some men represent good things to others in the guise of evil, and evil in the guise of good, and misrepresent how great various goods and evils are. These activities enable their practitioners to make men discontented, and to disturb their peace, whenever they feel like doing so.

(5) Creatures that lack reason don't have the notion of being insulted or wronged as distinct from being physically damaged; so as long as they are at ease physically they are not offended with their fellows; whereas man is most

troublesome when he is most at ease, for that is when he loves to show his wisdom and to control the actions of those who govern the commonwealth.

(6) The agreement of these creatures is natural, whereas men's agreement is by covenant only, which is artificial; so it's no wonder if something besides the covenant is needed to make their agreement constant and lasting, namely a common power to keep them in awe and direct their actions to the common benefit.

The only way to establish a common power that can defend them from the invasion of foreigners and the injuries of one another, and thereby make them secure enough to be able to nourish themselves and live contentedly through their own labours and the fruits of the earth, is to confer all their power and strength on one man, or one assembly of men, so as to turn all their wills by a majority vote into a single will. That is to say: to appoint one man or assembly of men to bear their person; and everyone to own and acknowledge himself to be the author of every act that he who bears their person performs or causes to be performed in matters concerning the common peace and safety, ***and all of them to submit their wills to his will, and their judgments to his judgment****. This is more than mere agreement or harmony; it is a real unity of them all. They are unified in that they constitute one single person, created through a covenant of every man with every other man, as though each man were to say to each of the others:*

I authorize and give up my right of governing myself to this man, or to this assembly of men, on condition that you surrender to him your right of governing yourself, and authorize all his actions in the same way.

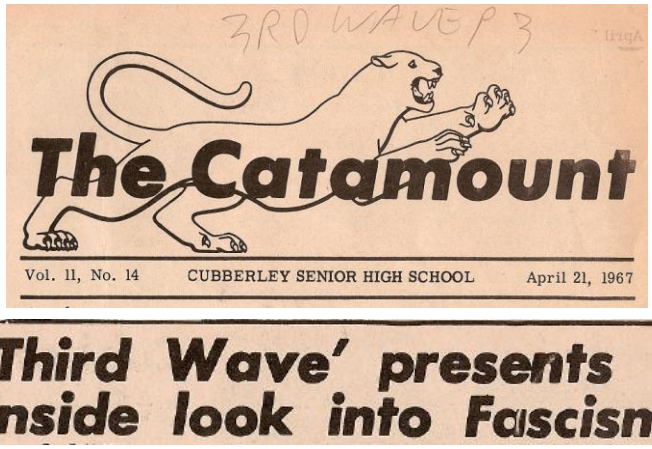
When this is done, the multitude so united in one person is called a COMMONWEALTH, in Latin CIVITAS. This is the method of creation of that great ***LEVIATHAN****, or rather (to speak more reverently) of that mortal god to*

which we owe, under the immortal God, our peace and defence. For by this authority that has been given to 'this man' by every individual man in the commonwealth, he has conferred on him the use of so much power and strength that people's fear of it enables him to harmonize and control the wills of them all, to the end of peace at home and mutual aid against their enemies abroad. He is the essence of the commonwealth, which can be defined thus:

A commonwealth is one person of whose acts a great multitude of people have made themselves the authors (each of them an author), doing this by mutual covenants with one another, so that the commonwealth may use the strength and means of them all, as he shall think appropriate, for their peace and common defence. He who carries this person is called SOVEREIGN, and said to have 'sovereign power', and all the others are his SUBJECTS.

Sovereign power can be attained in two ways. One is by natural force, as when a man makes his children submit themselves and their children to his government, by being able to destroy them if they refuse, or subdues his enemies to his will by war, sparing their lives on condition that they submit their wills to his government. The other is when men agree amongst themselves to submit to some one man or assembly of men, doing this voluntarily in the confidence that this man or assembly will protect them against all others. This latter, may be called a political commonwealth, or commonwealth by institution, and the former a commonwealth by acquisition. I shall speak first of a commonwealth by institution, turning to commonwealth by acquisition.

Lastly, since we are talking about the **wave nature of light**, I want to talk about a social experiment related to waves. **Ron Jones**, in 1967, created a classroom experiment for his Contemporary World class to show how it was possible for the people of Germany to allow the rise of National Socialism that led to fascism. One of the students, Steve Coniglio said that "*It was probably the most interesting unit I've had. It was successful in its goal to achieve the emotions of the Germans under the Nazi reign*." The experiment, involving his students, showed how a movement aimed at eliminating democracy, which "*has many unnatural aspects since the emphasis is on the individual instead of a disciplined and involved community*," could easily start here in America. You can see a made for TV movie called "*The Wave*" on YouTube.



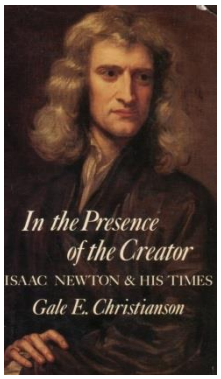


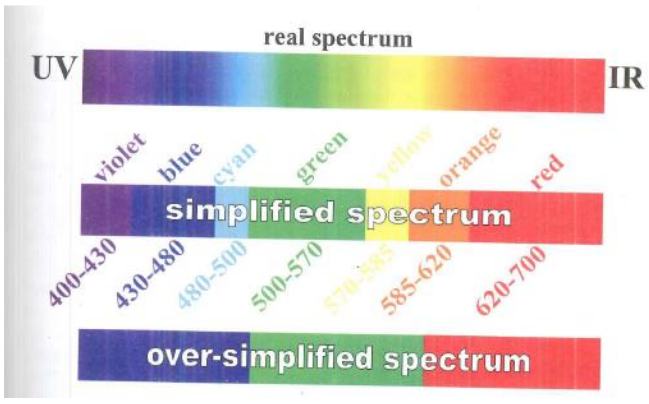
Purple, Blue, and Red Dyes

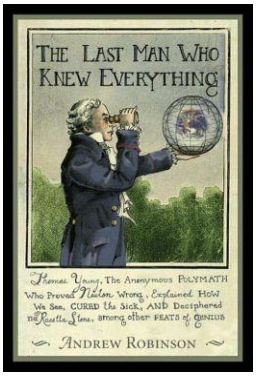


We have discussed the vibrant colors of **flowers**, the somber colors of **ants**, the happy colors of **leaves** throughout their lifespan, the iridescent colors of **butterflies**, **beetles**, and **birds**, the attractive and functional colors of **human eyes**, **skin**, and **hair**, the warm colors of **candlelight**, the inherited colors of **Mendel's peas**, the informative colors of stained **chromosomes**, and stained **germs**, the bioluminescent colors of **fireflies** and **dragonfish**, and the abiotic colors of **rainbows**, the **galaxies**, the **sun**, and the **sky**. The **natural world** is a wonderful world of color!

The **infinite number of colors** in the solar spectrum was divided into seven colors by **Isaac Newton**—perhaps for theological reasons. While there is no ***scientific*** reason to divide the **spectral colors** into **seven colors**, there is a natural reason to divide the spectral colors into **three primary colors**. Thomas Young (1802), who was belittled as an "Anti-Newtonian" for speaking out about the wave nature of light, predicted that ***if*** the human eye had **three photoreceptor pigments**, we could perceive all the colors of the rainbow. He was right.



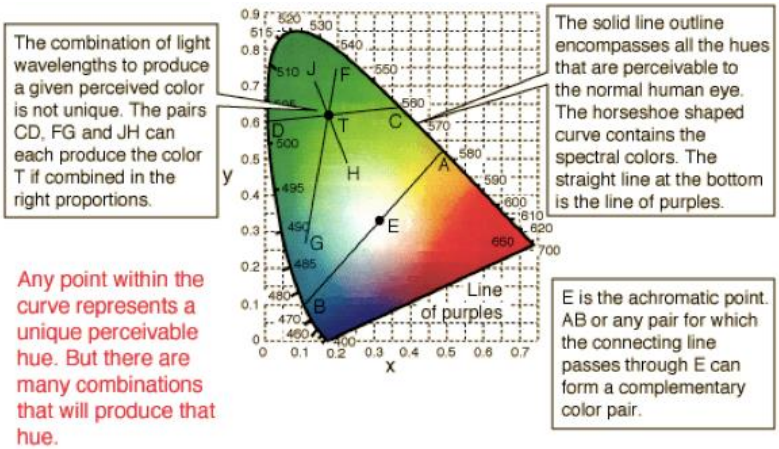




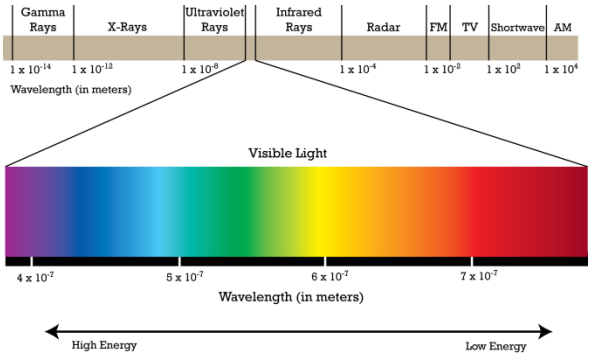


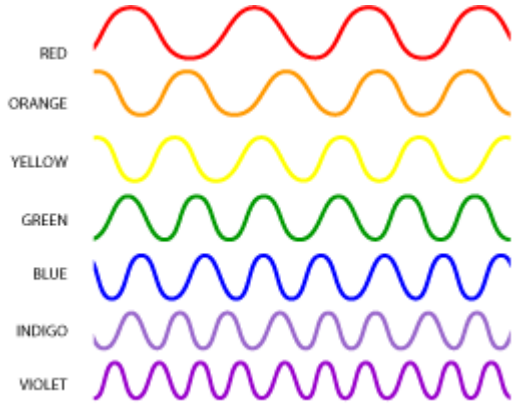
Thomas Young (1802) wrote "*Since, for the reason assigned by NEWTON, it is probable that the motion of the retina is rather of a vibratory* [longitudinal] *than of an undulatory* [transverse] *nature, the frequency of the vibrations must be dependent on the constitution of this substance. Now, as it is almost impossible to conceive each sensitive point of the retina to contain an infinite number of particles, each capable of vibrating in perfect unison with every possible undulation, it becomes necessary to suppose the number limited, for instance, to the* ***three principal colours****, red, yellow, and blue, of which the undulations are related in magnitude nearly as the numbers, 8, 7, and 6; and that each of the particles is capable of being put in motion less or more forcibly, by undulations differing less or more from a perfect unison; for instance, the undulations of green light being nearly in the ratio of 6½, will affect equally the particles in unison with yellow and blue, and produce the same effect as light composed of those two species:* ***and each sensitive filament of the nerve may consist of three portions, one for each principal colour***."

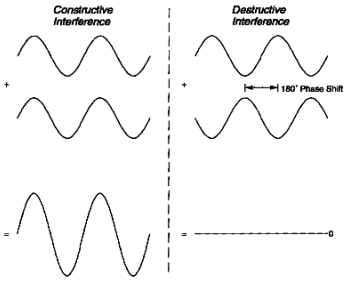
Below is a figure showing how the "*three portions*" can be combined to sense any spectral color or color that can be produced by combining the three primary colors.



Many of the wave properties of light can be described by the following diagrams:







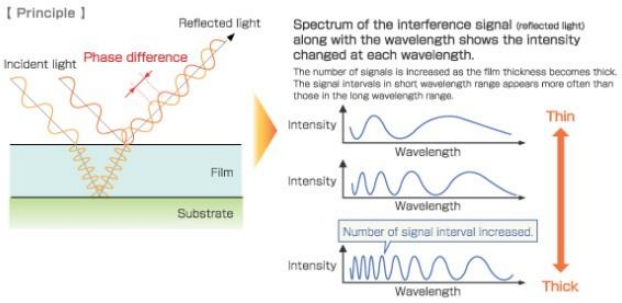
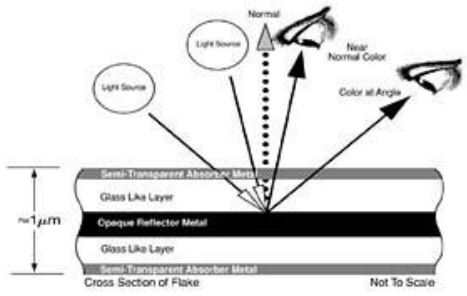


Figure 1 / Thin film interference pigment flake cross-section



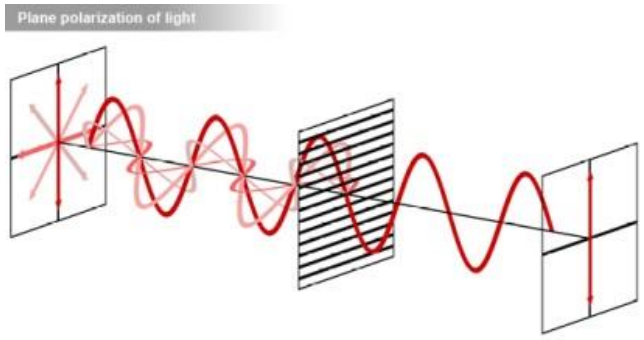
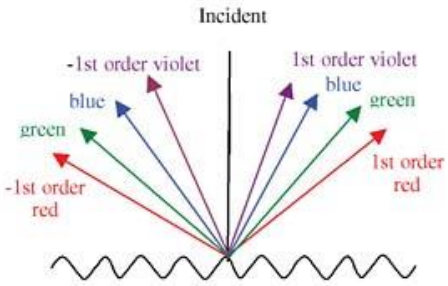
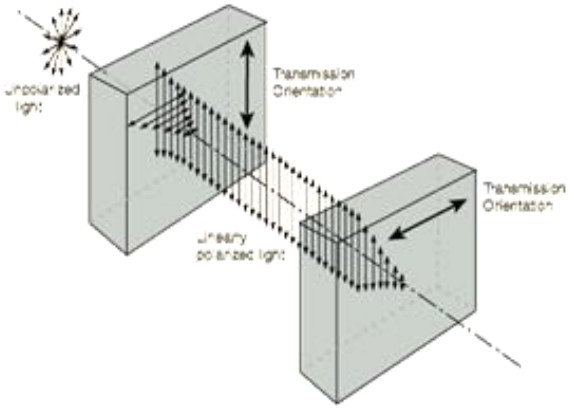


Figure 2 / Incident white light and resulting spectral distribution





We have discussed the value of the **wave theory of light** for understanding the **blue structural colors** of frogs, butterflies, and birds, as well as the ability of a foraging honeybee to use the **linearly polarized ultraviolet light scattered** by the gases in the atmosphere to communicate where the nectar-containing flowers are to the other worker bees in the hive. Now I want to discuss how Thomas Young simply and elegantly calculated the wavelength of a given spectral color of light from his theory. In a lecture series founded by **Henry Baker**, author of *The Microscope Made Easy* and *The Universe, a Poem intended to restrain the Pride of Man*, Thomas Young (1802) said, "*Whatever opinion may be entertained of the theory of light and colours which I have lately had the honour of submitting to the Royal Society, it must at any rate be allowed that it has* ***given birth to the discovery of a simple and general law****, capable of* ***explaining*** *a number of the phenomena of coloured light, which, without this law, would remain* ***insulated*** *and* ***unintelligible****. The law is, that 'wherever two portions of the same light arrive at the eye by different routes, either exactly or very nearly in the same direction, the light becomes most intense when the difference of the routes is* ***any multiple of a certain length****, and least intense in the intermediate state of the interfering portions; and* ***this length is different for light of different colors****.'"*

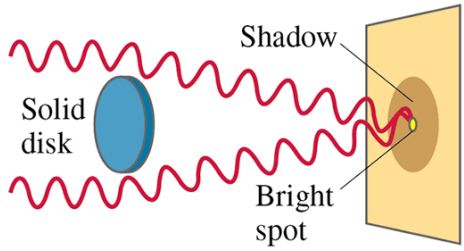


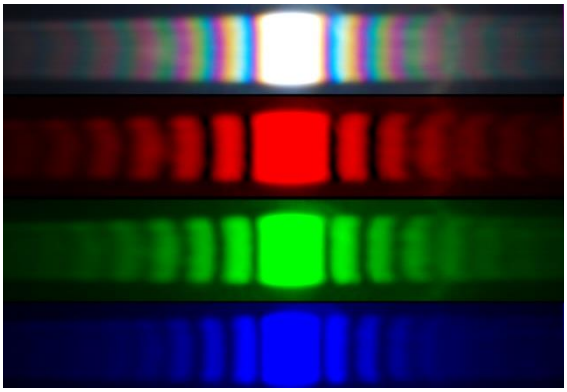




In another **Bakerian Lecture** entitled, *Experiments and Calculations Relative to Physical Optics*, Thomas Young (1804) talked about the wave theory of light: "*In making some experiments on the fringes of colours accompanying shadows, I have found so simple and so demonstrative a proof of* ***the general law of the interference of two portions of light****, which I have already endeavoured to establish, that I think it is right to lay before the Royal Society, a short statement of the* ***facts which appear to me decisive****. The proposition on which I mean to insist at present, is simply this, that* ***fringes of colours*** *are produced by the* ***interference of two portions of light****; and I think it will not be denied by the most prejudiced, that the assertion is proved by the experiments I am about to relate, which may be* ***repeated with great ease, whenever the sun shines, and without any other apparatus than is at hand to every one***."

Thomas Young then proceeded with his calculations of wavelength of light from the readily measured distances: "*If we now proceed to examine the* ***dimensions of the fringes****, under different circumstances, we may calculate the* ***differences of the lengths of the paths*** *described by the portions of light* [i.e. wavelength], *which have thus been proved to be concerned in producing those fringes; and we shall find, that where the* ***lengths are equal****, the light always remains white* [m = 0 and all spectral colors constructively interfere]*; but that, where either the brightest light* [i.e. maxima], *or the light of any given colour, disappears* [i.e. minima], *and reappears* [i.e. maxima], *a first* [m = 1], *a second* [m = 2], *or a third* [m = 3] *time, the differences of the lengths of the paths of the two portions are in arithmetical*





progression [i.e. constant difference], *as nearly as we can expect experiments of this kind to agree with each other*."

Thomas Young's results are shown below. The values are in inches. By converting inches to meters, you will see that his intervals are consistent with the currently measured wavelengths of light. Note that one inch = 0.0254 meters = 2.54×10^7 nm.

TABLE I. *Obs.* 9. N.

Distance of the knives from the aperture						101.
Distances of the paper from the knives	$1\frac{1}{2}$,	$3\frac{1}{3}$,	$8\frac{3}{5}$,	32,	96,	131.
Distances between the edges of the knives, opposite to the point of concourse	.012,	.020,	.034,	.057,	.081,	.087.
Interval of disappearance	.0000122,	.0000155,	.0000182,	.0000167,	.0000166,	.0000166.

TABLE II. *Obs.* 3. N.

Breadth of the hair		$\frac{1}{280}$.
Distance of the hair from the aperture		144.
Distances of the scale from the aperture	150,	252.
(Breadths of the shadow	$\frac{1}{34}$,	$\frac{1}{9}$.)
Breadth between the second pair of bright lines	$\frac{2}{47}$,	$\frac{4}{47}$.
Interval of disappearance, or half the difference of the paths	.0000151,	.0000173.
Breadth between the third pair of bright lines	$\frac{4}{73}$,	$\frac{3}{100}$.
Interval of disappearance, $\frac{1}{4}$ of the difference	.0000130,	.0000143.

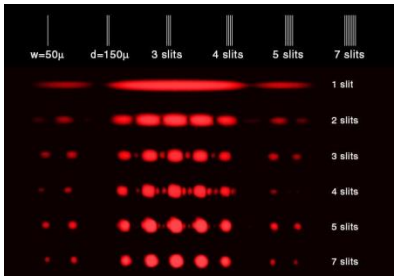
TABLE III. *Exper.* 3.

Breadth of the object	.434.
Distance of the object from the aperture	125.
Distance of the wall from the aperture	250.
Distance of the second pair of dark lines from each other	1.167.
Interval of disappearance, $\frac{1}{3}$ of the difference	.0000149.

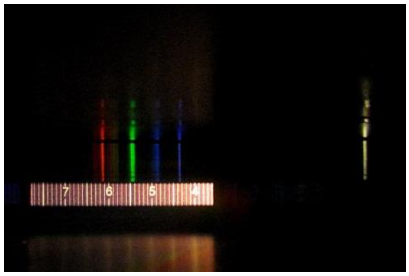
Exper. 4.

Breadth of the wire	.083.
Distance of the wire from the aperture	32.
Distance of the wall from the aperture	250.
(Breadth of the shadow, by three measurements	.815, .826, or .827; mean, .823.)
Distance of the first pair of dark lines	1.165, 1.170, or 1.160; mean, 1.165.
Interval of disappearance	.0000194.
Distance of the second pair of dark lines	1.402, 1.395, or 1.400; mean, 1.399.
Interval of disappearance	.0000137.
Distance of the third pair of dark lines	1.594, 1.580, or 1.585; mean, 1.586.
Interval of disappearance	.0000128.

Thomas Young used the diffraction of light by a single object to calculate the wavelength of light. The sharpness of the maxima can be increased by increasing the number of closely spaced objects (e.g., thin lines). The spectroscope we have been using all semester has many closely spaced lines that diffract the light. The closely spaced lines make a **diffraction grating**.



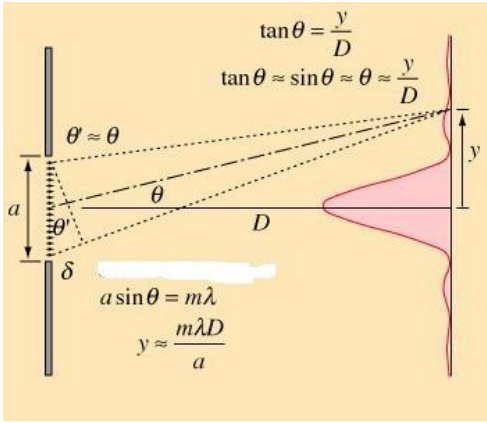




By measuring 1) the width (a) of the object or slit that diffracts the light, 2) the distance (D) between the object or slit and the wall where the diffraction pattern can be observed and 3) the distance (y) between each maximum (m) for any color of light, Thomas Young could calculate the wavelength (λ) of light:

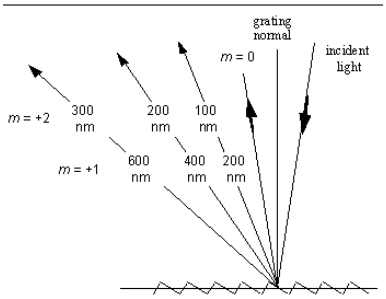
$$\lambda = a\ \frac{y}{mD}$$

Thomas Young's method of calculations can be used for objects or gratings with more than one slit. In these cases, a represents the distance between each ridge, groove or slit in a grating.



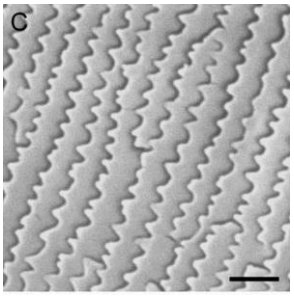
Trigonometry can be used to solve this equation since $\frac{y}{D}$ is equal to the $\tan\theta$, and for small angles, $\tan\theta = \sin\theta$, consequently, Thomas Young's calculations are often presented like so:

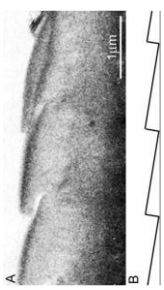
$$m\lambda = a \sin\theta$$



After accounting for the angle of the incident light, this formula can also be applied to **reflection diffraction gratings**. When the incident light is perpendicular to the grating, it can be applied as is.

Since this is a course on light and life, we will use a **scarbaeid beetle** to calculate the wavelength of the colored light observed at a given position. **Parallel ridges or grooves on the cuticle** of some scarabaeid beetles act as a **reflection diffraction grating**. Indeed, Thomas Young (1802) suggested that "*It is not improbable that the colours of the integuments of some insects, and of some natural bodies, exhibiting in different lights the most beautiful versatility, may be found to be of this description* [diffraction as a result of parallel lines], *and not to be derived from thin plates. In some cases, a single scratch or furrow may produce similar effects, by the reflection of its opposite sides*." The distance between the ridges is approximately 1500 nm, depending on species. To make the calculations independent of distance (D) from the beetle, we will use angular measurements, and we will only calculate the first order (m = 1) spectrum.







With ***almost*** infinite precision, we can associate the infinite number of first order (m = 1) colors with a wavelength calculated to a ***nearly*** infinite number of decimal points. We can predict the wavelength of the colors reflected from the striated cuticle of the scarabaeid beetle at any azimuth (θ) perpendicular to the plane of the **striated surface** using the following equation:

$$\lambda = a \sin\theta$$

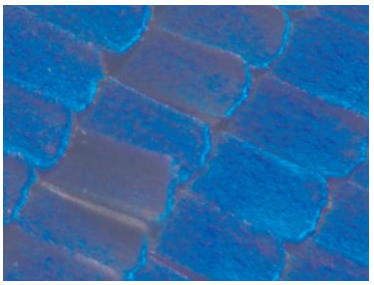
Problem: Given that the distance (a) between the ridges and grooves is approximately 1500 nm, and that sin 10° = 0.17, sin 20° = 0.34, sin 30° = 0.5, calculate the wavelength of the first order colored light observed at these three angles when the beetle is irradiated with a full spectrum of white light. Answer: 255 nm, 510 nm, and 750 nm. Which one will be visible to you and what color will it be?

The scarabaeid beetle uses the above equation every day to produce its iridescent colors, and now it is happy that you can use it too. The color also depends on the azimuth of the observer and without any relative motion between the scarabaeid beetle and the observer, it would not be iridescent because its color only changes as a result of the relative motion of the beetle and observer. Well, this is only approximately true for short time periods, because as the sun moves, the angle of incidence (θ_i) will change and we will have to use the more complicated form of the equation, with which of course the scarabaeid beetle is also facile:

$$m\lambda = a(\sin\theta_i \pm \sin\theta)\ .$$

where all angles are defined as positive, and the ***positive*** sign is used when the incident and diffracted light are on the same side of the normal to the grating and the ***negative*** sign is used when the incident and diffracted light are on opposite

sides of the normal to the grating. This equation transforms into the law of reflection when $m = 0$.



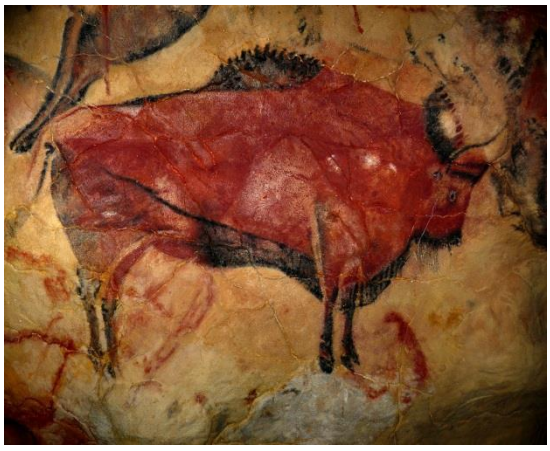
We will use a ***simplistic*** model of the wing of a **Blue Morpho butterfly** whose scales we will assume to be composed of a 184 nm thick (a) layer of chitin with a refractive index (n) of 1.56 surrounded by air spaces to calculate approximately the wavelength of light that undergoes **complete destructive interference** so that we see its **complementary color** seen perpendicular to the wing.

$$\lambda \approx n2a$$

The incident light is split up by the chitin layer in the scale into two portions—one that reflects off the top surface of the chitin and one that reflects off the bottom surface of the chitin. The portion that reflects off the bottom surface travels an additional **optical path length** ($n2a$) that depends on both the distance ($2a$) and the refractive index (n) of the chitin layer. The wavelength that undergoes complete destructive interference as it reflects off the top and bottom layer of chitin is 574 nm. This wavelength represents yellow-orange light, and its complement is blue. Consequently, the *Morpho* butterfly looks blue. Since the optical path length through the chitin increases as you increase the angle you look at the butterfly, a wavelength that represents more orange light will completely destructively interfere and the *Morpho* butterfly will appear blue green.

In addition to the **geometrical factors** given above, how we **perceive a given wavelength of light** depends on our **species** and **our individual genetic constitution**.

Speaking of our species, human beings love to produce and use colors. According to François Delamare and Bernard Guineau (2010) who wrote *Colours: Making and Using Dyes and Pigments*, "***Color is the child of light, the source of all life on earth***." In the ancient world, the vast richness of human-made color did not exist. The colors in the **cave paintings** produced over 40,000 years ago in Spain and over 30,000 years ago in France were limited to natural **earth tones** such as reds (hematite: Fe_2O_3), yellows ($FeO(OH)\cdot nH_2O$), browns, and blacks (C = charcoal). The pigments came from ground up (literally) minerals. The paintings had to be made in caves; otherwise, they would have been washed away by rain. Perhaps this partially explains the lack of blues (azurite: $Cu_3(CO_3)_2(OH)_2$) and greens (terre verte: iron silicate) in the cave paintings which would have appeared black by the yellow-orange light of a torch or a fire.







In the dry and bright climate of Egypt, stucco painters in 1400 BC used ground **lapis lazuli** to make **blue** and ground **malachite** to make **green**.





While the **lithosphere** yielded its colors to early humans, it was not easy to isolate and obtain the vibrant colors of the **biosphere** to color fabric for clothes and other uses. It would have been impossible to extract the iridescent blue structural colors from peacock feathers or *Morpho* butterflies, and the pigments obtained from extracts of the colorful leaves and flowers did not give permanent colors. These pigments were **stains not dyes**; meaning that they were **not color-fast or permanent,** and they would rapidly **fade away** with sunlight and water, whether the water came from rain, washing, or sweat. Unlike stains, **dyes are color-fast or permanent**. Before the invention of color-fast dyes, people probably wore drab clothes that were the color of the sheep or goats that provided the wool.



But it seems that humans have a desire if not a need to wear colorful clothes. If, as it says in Genesis 37:3, **Joseph**, who lived around 600-475 BC, had a **coat of many colors**, then there must have been a way to create color around us by dyeing fabric. From ancient times to the present, the production and use of beautiful and lasting colors have been a calling of humankind. Pliny the Elder, writing in 1 AD, reported that the Egyptians used color-fast fabric dyes. Red dye was made from the insect **kermes**, the **lichen** archil, or the herb **alkanet**; yellow dye from **saffron** or **buckthorn berries**, and purple dye was made from **mulberries**.











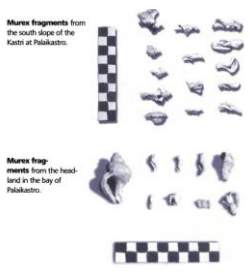
In ancient times, somebody discovered that a **snail** that lived in the Mediterranean Sea produced a **purple dye**—not a stain—but a dye that was color-fast. According to Greek legend, painted by Peter Paul Rubens (1636), **Herakles** discovered the dye when his sheep dog chewed a ***Murex*** snail and Herakles saw the color of his dog's mouth turn purple!






Murex is an **edible snail**, and it is also possible that a **Minoan fisherman discovered** the dye the same way as Herakles' legendary dog discovered it and according to my friend Allan Witztum, the fisherman may have accidentally discovered its value as a fabric dye when he wiped his hands on his shirt. A small number of shells found in a village probably indicates a refuse area for the shells of *Murex* that have been eaten. However, mounds consisting of many *Murex* shells would indicate a possible dye industry. Such a site, which also included a well, stone basins, and clay vats, was found by Robert Stieglitz (1994) in Knossos, Crete, indicating that by **1750 BC**, which is in the **Bronze Age**, the Minoans produced the dye from the *Murex* snails. The maritime merchants from Phoenicia may have learned from the Minoans who lived in Crete about the manufacture of the purple dye from *Murex* and about the legend of Herakles, which was depicted on a Phoenician coin.





Murex fragments from the south slope of the Kastri at Palaikastro.

Murex fragments from the headland in the bay of Palaikastro.


Remains of stone basins and well, near the shore on Kouphonisi.



A large mound of *Murex* was also discovered in the city of **Al Khor in Qatar**. Radiodating of this site suggests that dye production took place there by 1400 BC. (http://www.qatarvisitor.com/qatar-history/al-khor-island).

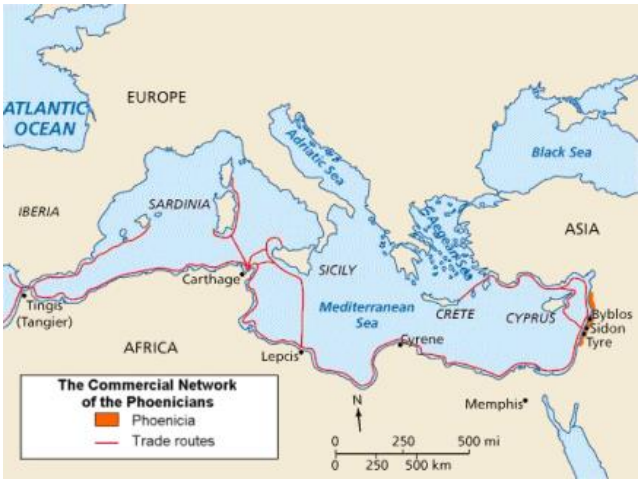


The *Murex* dye industry must have been up and running on the mainland by the 15th century BC. Two dyes made from *Murex*—one **blue**, known as ***tekhelet*** and one **purple**, known as ***argamman*** in Hebrew were offerings to God that were mentioned in the Bible in the telling of the exodus which took place around 1446 BC. It is written in Exodus 25:1-8 and 26:1: "*And the LORD spake unto Moses, saying, Speak unto the children of Israel, that they bring me an offering: of every man that giveth it willingly with his heart ye shall take my offering. And this is the offering which ye shall take of them; gold, and silver, and brass,* ***and blue, and purple,*** *and scarlet, and fine linen, and goats' hair, and rams' skins dyed red, and badgers' skins, and shittim wood, oil for the light, spices for anointing oil, and for sweet incense, onyx stones, and stones to be set in the ephod, and in the breastplate. And let them make me a sanctuary; that I may dwell among them… Make the tabernacle with ten curtains of finely twisted linen and* ***blue, purple*** *and scarlet yarn, with cherubim woven into them by a skilled worker."*



The blue dye known as ***tekhelet*** that came from *Murex* was especially important to the Israelites. It was written in Numbers (15:38-39) that Moses was told to "***Speak to the Israelites and tell them that throughout their generations they are to make tassels for the corners of their garments, and put a blue cord on the tassel at each corner. These will serve as tassels for you to look at, so that you***

may remember all the LORD's commands and obey them and not become unfaithful by following your own heart and your own eyes."

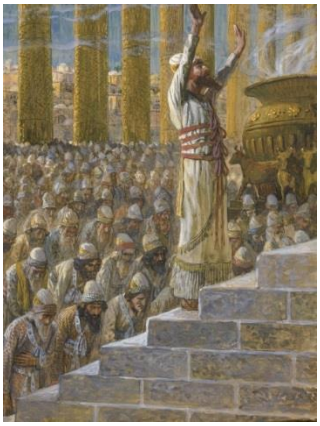


The Israelites may have obtained the ***tekhelet*** from the Phoenicians. The **Phoenicians** were maritime traders from 1550 BC-300 BC who became expert craftsmen in all things, including making dyes. The purple dye made from *Murex* became known as **Tyrian purple** after **Tyre**, the capital of Phoenicia. It states in 2 Chronicles (2:7) that Solomon (970 BC- 931 BC) needed craftsmen to help him build the Temple, and he asked the **Phoenician King Hiram of Tyre** (980 BC-947 BC) to "*Send me now therefore a man cunning to work in gold, and in silver, and in brass, and in iron, and in **purple**, and crimson, and **blue**, and that can skill to grave with the cunning men that are with me in Judah and in Jerusalem, whom David my father did provide*."



King Hiram responded (2 Chronicles 2:13-14) to **Solomon**, "*I am sending you Huram-Abi, a man of great skill, whose mother was from Dan and whose father was from Tyre. He is trained to work in gold and silver, bronze and iron, stone and wood, and with **purple and blue** and crimson yarn and fine linen. He is experienced in all kinds of engraving and can execute any design given to him. He will work with your skilled workers and with those of my lord, David your father*." The Phoenicians were known to the ancient Greeks as "***traders in purple***" and it is said that the name Phoenicia came from the Greek *phoenix* (*φοϊνιξ*), meaning **Tyrian purple**.





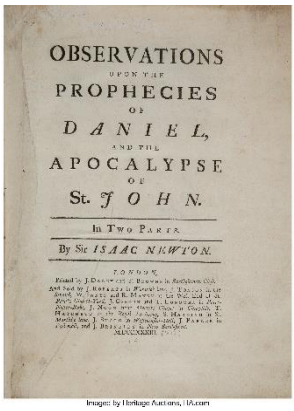
Seven years later, in 957 BC, Solomon's Temple was built (1 Kings 6-38). Solomon had great wisdom, wealth and power and may have written Proverbs, Ecclesiastes, and Song of Solomon. Wise or not, his wives turned his heart after other gods and Solomon built temples to their gods. Thus the Lord said to Solomon (1 Kings 11:11-12): "*Forasmuch as this hath been in thy mind, and thou hast not kept My covenant and My statutes, which I have commanded thee, I will surely rend the kingdom from thee, and will give it to thy servant* [Jeroboam]. *Notwithstanding in thy days I will not do it, for David thy father's sake; but I will rend it out of the hand of thy son* [Rehoboam]."





Following the death of Solomon, ten of the twelve tribes of the United Kingdom of Israel who felt that they had been taxed enough, formed the **Northern Kingdom of Israel**, leaving behind the **Southern Kingdom of Judah**. The Kingdom of Israel was taken by Sargon II of Assyria in 720 BC. In 605 BC, the **Babylonians** fought a great war against the **Assyrians**, which resulted in the Babylonian Empire expanding from being in the Fertile Crescent between the Tigris and Euphrates rivers in the Near East to the Mediterranean Sea in the Middle East. A rebellion against the **Babylonians** by the Phoenicians in Tyre and the Jews in Judah was unsuccessful and the Phoenicians and Jews, including **Daniel**, **Shadrach**, **Meshach**, and **Abednego** were subjugated by **Nebuchadnezzar** and brought to **Babylon**. (Isaac

Newton, 1733 wrote about the prophesies of Daniel http://www.newtonproject.ox.ac.uk/view/texts/normalized/THEM00197). The Temple of Solomon, with its *Murex* purple and blue fabric was pillaged and destroyed in 596 BC. **Babylon** was 1000 miles from the Mediterranean Sea—too far to obtain *Murex* to make ***tekhelet*** so that all the Jews could "***put a blue cord on the tassel at each corner. These will serve as tassels for you to look at, so that you may remember all the LORD's commands and obey them and not become unfaithful by following your own heart and your own eyes***."


OBSERVATIONS
UPON THE
PROPHECIES
OF
DANIEL,
AND THE
APOCALYPSE
OF
St. JOHN.
In Two Parts.
By Sir ISAAC NEWTON.
LONDON,
Images by Heritage Auctions, HA.com

Somewhere between 740 BC and 686 BC, Isaiah (45:1) prophesied that someone named Cyrus would save the Jews. In 539 BC, Babylon fell to **Cyrus the Great** of Persia who allowed the Jews to return to Jerusalem under the leadership of **Zerubbabel** to **rebuild the temple**. Some established Jews stayed in Babylon and during the rule of Xerxes (485 BC-465 BC), wealthy Jews such as Esther's adopted father **Mordechai** still had access to ***tekhelet*** and ***argamman*** as told in the Book of Esther (8:15): "*When Mordecai left the king's presence, he was wearing royal garments of **blue** and white, a large crown of gold and a **purple** robe of fine linen. And the city of Susa held a joyous celebration.*"











The **second temple** was built by **Zerubbabel** in Jerusalem, which was under Persian Rule, in 516 BC (Ezra 3). Following the conquest of **Darius III**, leader of the Persian Empire, by Aristotle's student **Alexander the Great** in 331 BC, the Jews came under the rule of the **Ptolemaic Empire**. Following the beheading of Pompey, the guardian of **Cleopatra** and her siblings, **Julius Caesar** conquered the Ptolemaic Empire in approximately 48 BC and the Jews became part of the Roman Republic. (Julius Caesar inserted three extra months into the calendar in 46 BC to synchronize the calendar with the seasons.) The Romans called the region, which included Judah, *Syria Palestina*, a name that was derived from the name of the area used by the ancient Greeks, Herodotus and Aristotle. As the Caesars gained power, the Roman Republic would become the Roman Empire.



During the years of the Roman Republic (40-39 BC), **King Herod** was declared the King of the Jews by the Roman Senate. During his reign, King Herod enlarged the second temple in 20-18 BC, creating the Wailing Wall. In the year 3, Jesus' parents brought him to this temple to be consecrated to God and to offer a sacrifice of a pair of doves or two young pigeons (Luke 2:21-24).

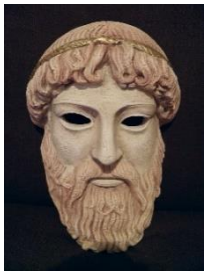


In 30-33, Jesus went back to this temple as an adult, overturned the tables of the money changers and those selling sacrificial animals (John 2:15; Matthew 21:12; El Greco, 1570), declared that the Sadducees and the Pharisees were hypocrites (Matthew 23), and taught the Gospel (John 7:14; 8:2; Luke 20:1), saying (John 8:12; William Holman Hunt,

1850s) "***I am the light of the world. Whoever follows me will never walk in darkness, but will have the light of life.***" Jesus then said to his disciples (Matthew 24:2; Mark 13:2; Luke 21:6), "*not one stone here will be left on another*."

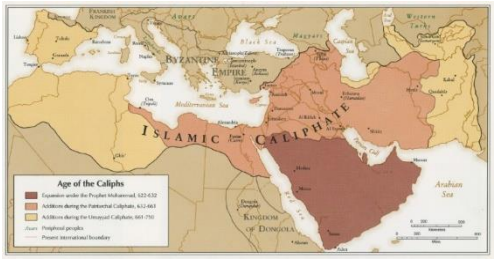


The word **hypocrite** is a word that comes from the Greek word *hypokrites*, which means an actor. It is translated literally as **an interpreter from underneath since ancient Greek actors wore masks and the actor spoke from underneath that mask**. It is translated figuratively as someone who wears a figurative mask and pretends to be someone who they are not.



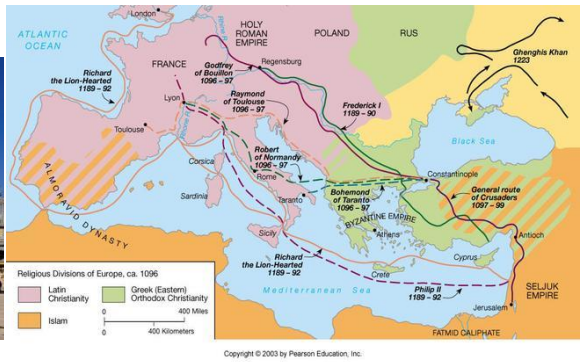
The second temple stood until 70, when it was **razed by the Roman army** led by Emperor Vespasian's son, **Titus**, leaving only the Temple Mount. In 136, Emperor Hadrian erected the **Temple of Jupiter** on the Temple Mount. In 614 the Persian Army led by **General Shaharbaraz** conquered what came to be called Palestine. The Romans regained control in 629 only to lose it in 638 to **Caliph Umar**, a companion of Muhammad, and his second religious and political successor. The **Dome of the Rock** shrine, erected in 671, marks the spot where Muslims believe is the farthest spot **Muhammad** (570-632) traveled from Mecca before he, according to the *Hadith*, ascended through the seven heavens to meet Allah. This is the time when the Sunni and











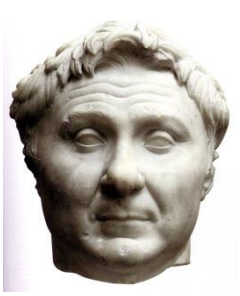
Shiite Muslims diverged due to a dispute on who would succeed Muhammad. (The Sunnis believed that Abu Bakr was the true successor, and the Shiites believed that Ali ibn Abi Talib was the true successor.) Jews believe it marks the spot where the **Ark of the Covenant**, the Holy of Holies, stood, and where the Third Temple will be built as described in Ezekiel 40-43. The **Al-Aqsa Mosque**, which means the farthest Mosque, was erected on the Temple Mount in 700 as the Caliphate was expanding. The **Crusades** (1095-1291) were aimed at gaining Christian control of the Temple Mount held by the Muslims.

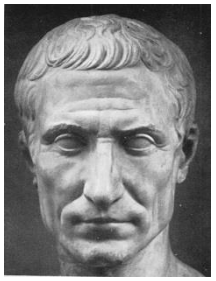


The Arab Conquest of Palestine also resulted in the destruction of anything associated with Roman rulers such as the **dye factories** used to make the **Royal purple dye**. Throughout the turbulent, tumultuous, and tempestuous history of the Jews, the knowledge needed to make ***tekhelet*** in Palestine, which was needed to make a blue cord for every pious man, was lost.



On the other side of the Mediterranean Sea, during much of the same period, magistrates of the Roman Republic (509 BC-44 BC) were expected to wear togas bordered with ***Murex* purple** at official functions. As victorious commanders or imperators of the Roman Republic, **Pompey and Julius Caesar** wore **pure *Murex* purple** togas. During the Roman Empire, the status of a person could be discerned immediately by the color of his clothing. Augustus Caesar (27 BC-14 AD) restricted the use of the *Murex* purple dyes to the governing classes. Men who belonged to the senatorial or equestrian classes could wear a tunic with two vertical purple stripes—the wider the stripe, the higher the status. A





pure purple toga could only be worn by the emperor, which gave rise to the phrase, "***to don the purple***," which meant to become emperor. **John Belushi** (1978) did not don the purple at the toga party at **Animal House**.



https://www.youtube.com/watch?v=I1X1uOUBZOs

To ensure that they were not outclassed by the status symbols worn by anyone, emperors **Caligula** (37-41) and **Nero** (54-68) made it illegal for anyone but the emperor to wear clothes dyed with the **Royal purple** dye from *Murex*. Nero had a bizarre interest in "light and life." Tacitus, a Roman senator and historian, recorded in his *Annals* (15:44) and Henryk Siemiradzki (1877) depicted in a painting, that **Nero burned Christians at night for illumination**. In 383, when **Theodosius I** turned a blind eye to the destruction of pagan culture, eliminated the Olympics, and made Christianity the official religion of the Roman Empire, he also made the manufacture of the purple dyes a monopoly of the state and a capital offence for those who manufactured the dye illegally.



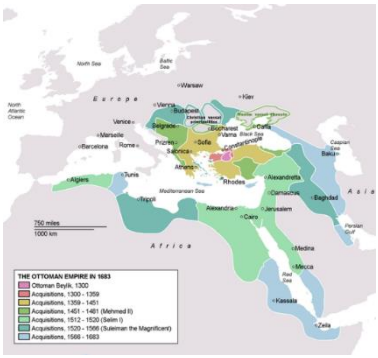
The *Murex* purple dye works in Tyre were included in this edict. Approximately 1000 years later, on May 29, 1453, In Constantinople, **Constantine XI** discarded his **purple cloak** and led his soldiers into a final attack against the Ottoman Caliphate in which he was killed by the 21year old **Sultan Mehmed II**.





Consequently, the ***Murex* purple dye manufacturing industry** along with the Byzantine Empire was demolished. As a result, the western knowledge necessary for manufacturing purple dye (***argamman***) from *Murex*, just as the Middle Eastern knowledge necessary for manufacturing blue dye (***Tekhelet***) from *Murex*, was lost. **Selim I**, who was the Ottoman sultan from 1512-1520, did not limit his rath to Christians, having said "*the killing of one Shia had as much otherworldly reward as the killing of seventy Christians*." At nearly the same time, **Shah Ismail I**, who became the Shah of Iran from 1501 to 1524, built the Safavid empire where the Shia could pray in peace. However, he executed any Sunnis who did not convert.



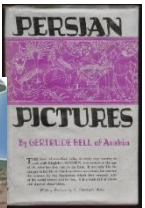


Led by the elite Sunni Muslim descendants of Osman I, the Ottoman Empire, which reached its greatest extent in 1683, slowly declined until World War I, when France and Britain conquered it and the Turks sought independence, in a war in which **T. E. Lawrence** (of Arabia) participated on the side of the Arabs. With the help of **Gertrude Bell**, the **League of Nations** partitioned the Ottoman Empire, creating Turkey for the Turks who were the peasants in the Ottoman Empire, and giving Syria and Lebanon to France and Mesopotamia (Iraq and Trans-Jordan) as well as Palestine to Britain.

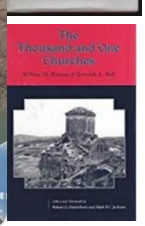


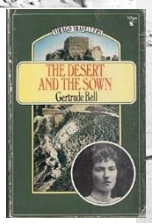


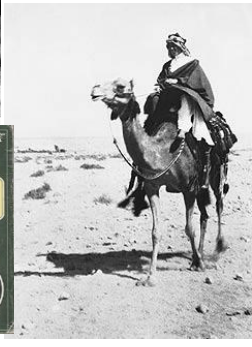


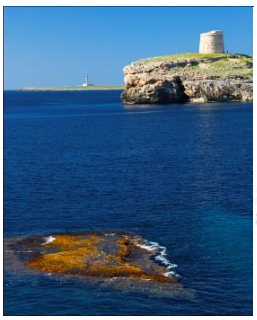














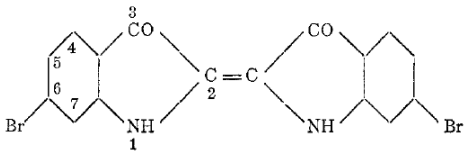
Meanwhile, in 1858, when **Henri de Lacaze-Duthiers** was collecting marine animals in Minorca, he noticed a fisherman who was painting yellow streaks on his shirt with the juice of a snail that he had broken open. When the streaks turned red-purple in the sunlight, Henri de Lacaze-Duthiers realized that the **shellfish**, *Thais haemastoma*, may be the source of the long lost **Tyrian purple**. Henri de Lacaze-Duthiers showed that three molluscs that lived in the Mediterranean Sea, including *Murex brandaris*, *Thais haemastoma*, and *Murex trunculus* produced Tyrian purple.



Rabbi Isaac Herzog (1913), who later became the chief Rabbi of Ireland, the British Mandate of Palestine, and Israel, wrote his doctoral thesis on the identity of the marine animal that produced ***tekhelet***. From his biblical and historical studies, Rabbi Herzog concluded that "*Of the species known to have been used by the Phoenicians in purple-dyeing, the one which furnishes a dye answering at least to some extent to the tradition of the* ***tekhelet*** *nuance is none other than the Murex trunculus*."



Paul Friedlaender (1909) isolated a dye from another *Murex* species, *Murex (Bolinus) brandaris*—but the dye was purple. In fact, it was **Tyrian purple** or ***argamman*** and it took 12,000 snails for Paul Friedlaender to make 1.4 grams of the dye—which made the great expense of the dye understandable. Chemically, the dye isolated from the *Murex* snail was 6,6-dibromoindigo.



6,6-Dibromindigo

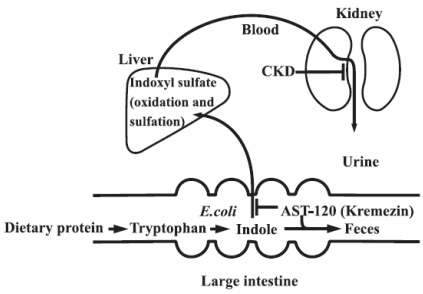
Thus, the structure of ***argamman***, the purple dye from *Murex*, was solved; but what about ***tekhelet***? According to Baruch Sterman (2012), who wrote *The Rarest Blue*, ***tekhelet*** is blue not purple. The Talmud states that the color of ***tekhelet*** is **similar to the sky or sea**; the *Septuagint*, the oldest translation of the Bible states that it is *Iakinthos*, which means **blue**; Saadiah (882) states that it is *asma'ngon*, which means "***like the color of the clear sky***;" and Maimonides (1135) states that "***it is the color of the clear sky visible near the sun*.**" The shade of blue of ***tekhelet*** can also be gleaned from the Talmudic warning not to use an otherwise indistinguishable counterfeit dye known as *kala ilan* that is made from a plant. The plant-based dye is most likely indigo from the leaves of the Indian plant, *Indigofera tinctoria*.



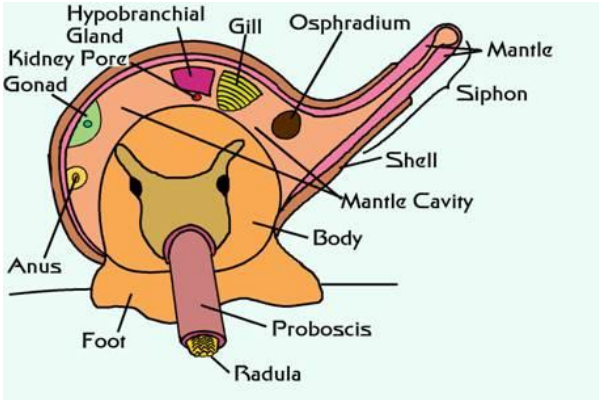


Then, in the 1980's, after leaving a reduced solution of the dye from *Murex* in a window on a sunny day, **Otto Elsner** found that the yellow-green solution produced a bright blue dye instead of a purple dye. Elsner serendipitously discovered the secret of producing a pure blue color from the *Murex trunculus* snail. **Otto Elsner then realized that wool dyed on cloudy days in the *Murex trunculus* extract was purple (*argamman*) while wool dyed on sunny days in the *Murex* extract was blue (*tekhelet*).**

To understand the effect of sunlight on the color of the dye, we have to understand the synthesis of the dye. In ***most*** organisms, **indole** is a colorless and toxic molecule produced by the body when it metabolizes **tryptophan** in the intestine. The indole passes from the intestine to the blood stream to the liver, where it is detoxified by being



converted into **indoxyl sulfate**, which travels to the kidney and is excreted in the urine.



While in most animals, only sulfur is added to the indole so that it can be safely excreted by the kidney, in the *Murex* snail, **bromine** and potassium are also added to the indole. This occurs in the **hypobranchial gland**, which functions to secrete mucus containing trapped particles inadvertently sucked in through the gills.

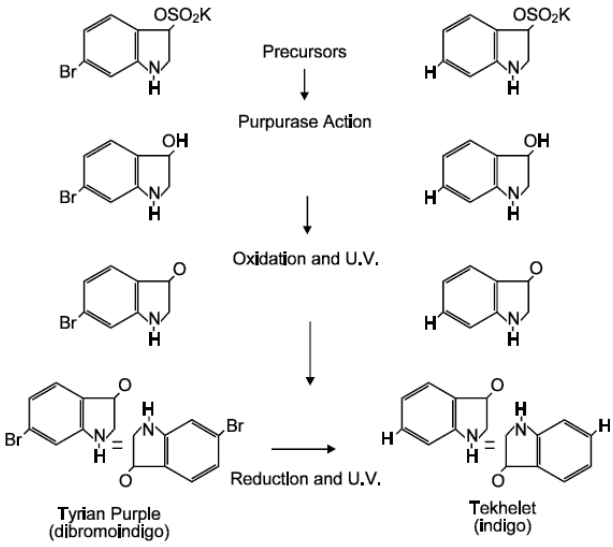


When the **hypobranchial gland,** which contains the **enzyme purpurase,** is removed from the snail and exposed to air, the clear indole-S-Br-K, which is stored in the gland, is hydrolyzed by the enzyme and **oxidized** by the air and sunlight—turning **purple**. Purpurase quickly decomposes, and consequently, the gland must be taken from the live snail. This would have eliminated the possibility of the ***tekhelet*** being made one thousand miles from the Mediterranean Sea in Babylon.

Movie: https://www.youtube.com/watch?v=kYoiEOpvB_w

The purple **oxidized** dye must then be **reduced** to form a **soluble** dye in order to bind to wool. In ancient times, the purple solution in a **vat** became reduced to a **yellow-green** solution when the **bacteria** that putrefied the snail parts that were part of the mixture **used up all the oxygen.** When the mixture was sufficiently **reduced**, it was ready to dye wool. In modern times, dyers use sodium

dithionite to reduce the dye. Wool is dipped into the reduced dye and the dye binds the wool. When the wool is removed from the dye solution, the bound dye is oxidized by the air and turns purple (*argamman*).



Serendipity plays a role in science. Otto Elsner left a solution of reduced yellow-green dye on the windowsill on a sunny day and found that when the dye is **reduced**, exposure to the **ultraviolet light** of sunlight converts the yellow-green dye, not to a purple dye (Tyrian purple or ***argamman***) upon oxidation but to a blue dye (***tekhelet***) upon oxidation. When wool is dipped into the reduced dye that has been exposed to the ultraviolet light of the sun, and then removed from the dye solution, the bound dye is oxidized by the air and turns blue (*tekhelet*).



Otto Elsner, Ehud Spanier, and John Edmonds and independently Zvi Koren found that the **ultraviolet light** causes the bromine bonds in **dibromoindigo** to break. This results in the formation of **indigo**, which is identical to the indigo dye produced by the plant, *Indigofera tinctoria*. As a result of the chemical effects of ultraviolet light, dibromoindigo (*argamman*) is converted to indigotin (*tekhelet*).

There **indole** precursors vary in the various species of snail and with the sex of the snail. Consequently, some snails produce ***tekhelet*** directly without irradiation by the ultraviolet rays of sunlight while others produce ***argamman*** directly and only produce ***tekhelet*** after irradiation with sunlight. *Murex trunculus*

typically gives a bluish-purple dye and *Murex brandaris* typically gives a red-purple dye. Males typically give a bluish-purple dye and females typically give a red-purple dye.



You can see **Roald Hoffmann** (Cornell) take part in the rediscovery of the process of producing *tekhelet* in the second part of the movie entitled "*The Mystery of Tekhelet*."

https://www.youtube.com/watch?v=8aAJgB4xAIw

https://www.youtube.com/watch?v=kYoiEOpvB_w

https://www.youtube.com/watch?v=NyKgow6WUFs

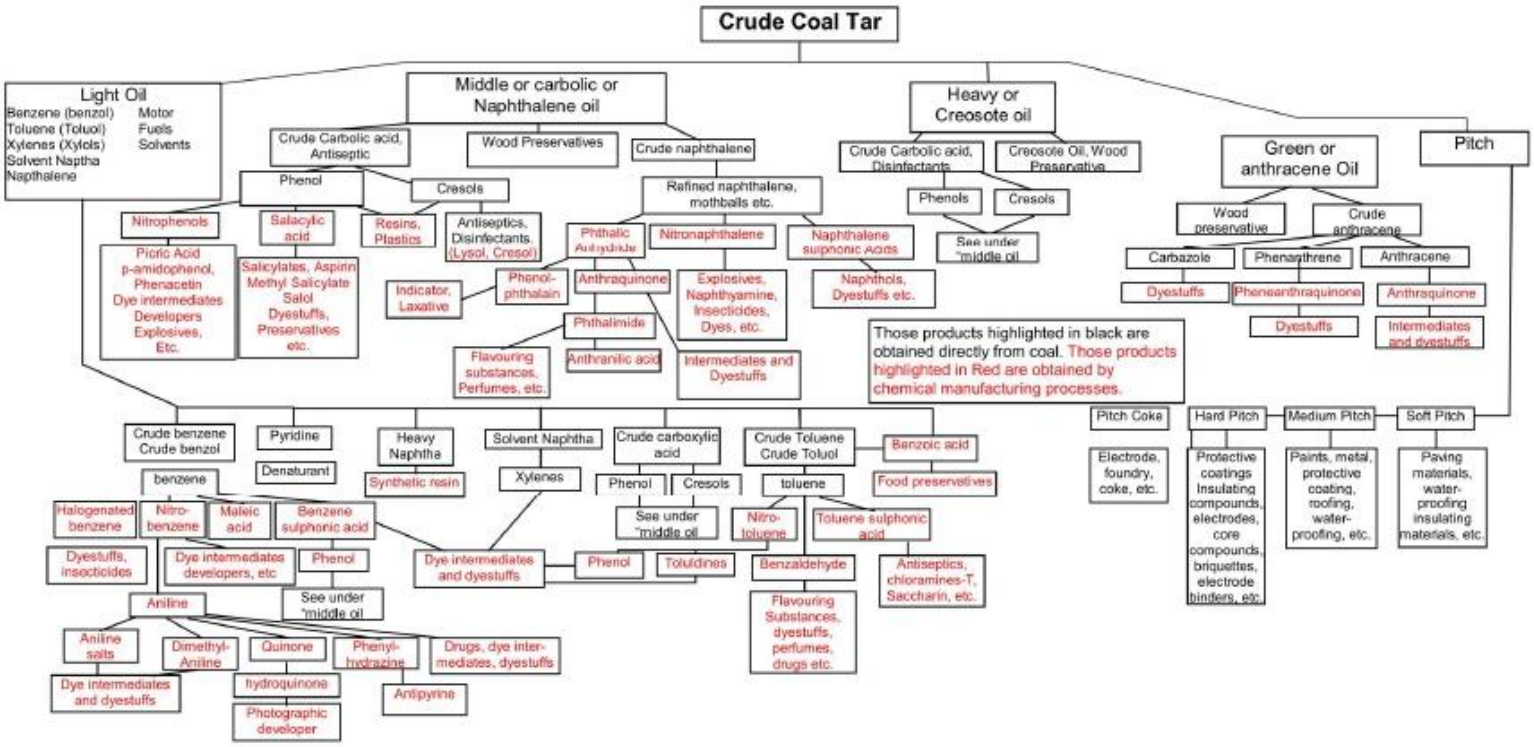


In March of 1856, approximately 400 years after the fall of Constantinople and the loss of knowledge about *Murex* dyes, and just ***before*** Henri de Lacaze-Duthiers showed that *Murex* produces Tyrian purple, **William Henry Perkin**, an 18-year-old student, was trying to make inexpensive **synthetic quinine** from derivatives of **coal tar**, which was the **waste product** from **coal gas production** from **bituminous coal**. Natural quinine, which was used to fight malaria, had to be extracted from the bark of *Chichona*, the Peruvian fever bark tree, which were grown on plantations in Southeast Asia, and was very expensive.



When coal is **combusted** in the **presence of oxygen**, water vapor, carbon dioxide, and ash are formed. However, when coal is burned in the **absence of oxygen** (**pyrolysis** or destructive distillation), a wide range of products that collectively form coal tar are formed. While the crude coal tar, a deep black, syrupy liquid with an unpleasant odor, was initially a nuisance, it soon became clear that the

coal tar contained chemicals such as benzene and phenol (also known as carbolic acid) that could be directly or indirectly converted into valuable and desirable products, including drugs, dyes, saccharine, antiseptics, insecticides, perfumes, food flavoring and preservatives, and photographic chemicals.



In trying to produce synthetic quinine, **William Henry Perkin** noticed a black residue on the bottom of a flask. The possibility of discovering a new dye was already in his mind. Friedlieb Ferdinand Runge (1834) had shown that a chemical that he distilled from coal tar would give a blue color after it was treated with chloride of lime ($Ca(ClO)_2$), and he named it cyanol; Carl Julius Fritzsche (1840) obtained an oily substance after he treated the colorful dye indigo with caustic potash (KOH) and named the oily substance **aniline**, after the Arabic word for indigo, ***añil***; and Perkin's teacher, **August von Hofmann** (1843) had shown



that cyanol and aniline, which were produced in different ways, were the same thing.





Instead of throwing the residue away which he intended to do after he cleaned the flask with alcohol, Perkin noticed that the black precipitate turned into a beautiful purple solution. The solution readily dyed silk and was color-fast—resistant to fading due to sunlight or washing. **Knowing the potential value of a color-fast purple dye**, he secretly continued work in his home and filed for a patent in August 1856. Perkin called the dye he synthesized, **Tyrian purple**, to emphasize the status and luxury classically associated with the color purple—and to be able to charge buyers more than they wanted to spend.





However, William Henry Perkin realized that historical references were not always the way to separate fashionistas from their money, so he renamed the dye, **mauve** (pronounced morve in the 19th century) after the French word for the color of the flowers of the mallow plant (*Malva sylvestris*) and it became known as **mauveine**. Mauveine became a very popular color when **Queen Victoria** appeared at the 1862 **International Exposition** in a silk gown colored with mauveine. The popularity of **crinoline dresses** worn by **Empress Eugénie**, the

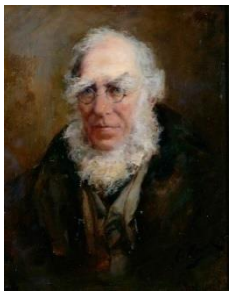


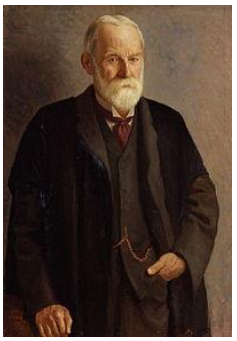


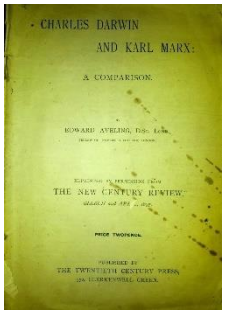


wife of Napoleon III, meant that even more mauveine was needed to dye the large surface of the crinoline gowns.









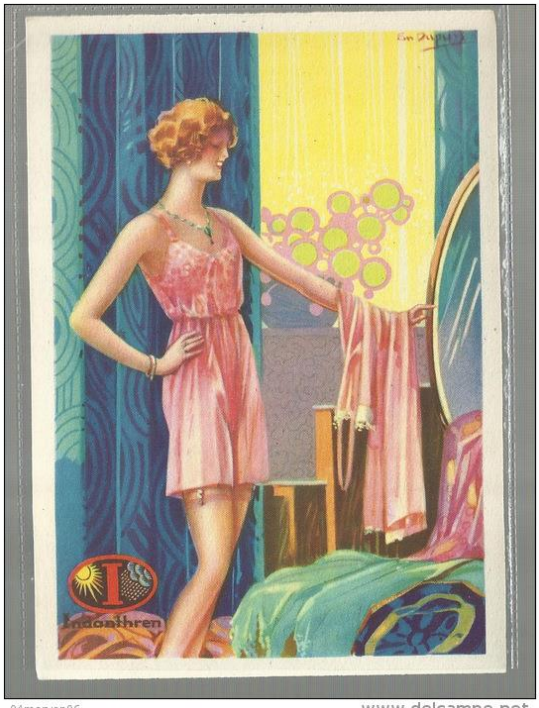
Royal purple plays a role in the **scientific royalty**. T. H. Huxley's son, Leonard Huxley (1918) wrote in the *Life and Letters of Sir* ***Joseph Dalton Hooker***, "*The story of Joseph Hooker's life-work is, in one aspect, the history of the share taken by botany in establishing the theory of evolution and the effect produced upon it by acceptance of that theory. He began with unrivalled opportunities, and made unrivalled use of them.* ***As a botanist, he was born in the purple, for in the realm of botany his father, Sir William Hooker, was one of the chief princes****, and he had at hand his father's splendid herbarium and the botanic garden which he had made one of the scientific glories of Glasgow University.*" A review of the book (Nature 101:481) states that "*We learn from this work how deeply Hooker was indebted to his distinguished father. If not exactly* ***born in the purple****, he certainly was* ***made to that purple*** *he wore so worthily*." An obituary for **George Howard Darwin**, the second son of Charles Darwin, and an astronomer who worked on the tidal friction between the earth and the moon, stated, "*Seldom can a scientific career have been set in more appropriate surroundings that that which has just closed: '****Born****,' to use a happy phrase coined for one of his brothers, '****in the scientific purple****,' Sir George Darwin not only proved worthy of his imperial descent, but capable of extending the boundaries of Empire in new directions."*

In *Charles Darwin and Karl Marx: A Comparison*, Edward Aveling (1897) wrote, "*Thus far I have pointed out resemblances between these two great men. I have now to not one of two points of difference between them. Darwin had the good fortune to be a man of means. Marx was all his life a poor man.* ***Darwin was born in the purple of wealth****. He had never to trouble about bread-and-*

cheese. He was saved from the carking cares that eat into life and make your best work impossible."

The dye industry made dyes that were inexpensive enough that throughout the world, middle class people could buy colored clothing.

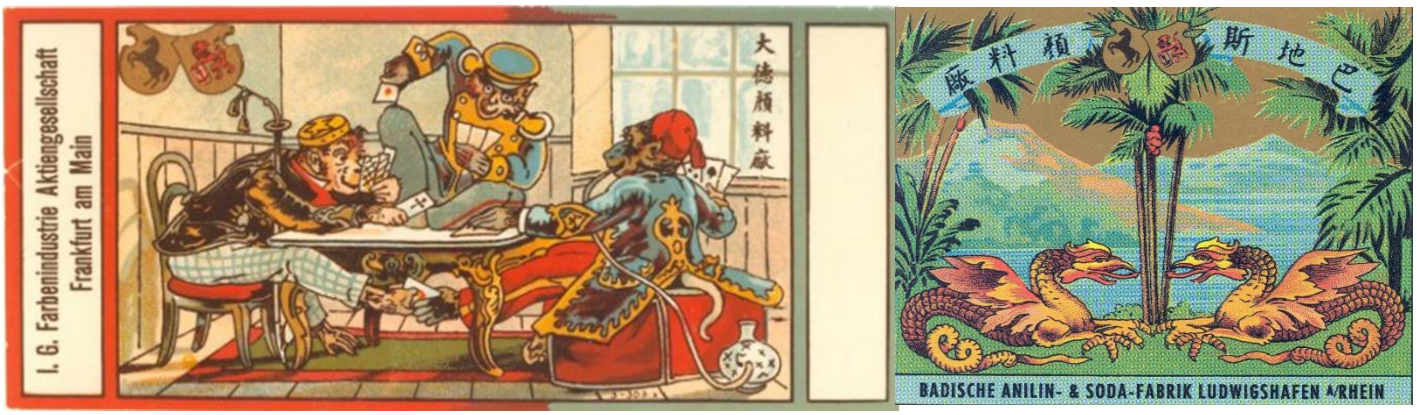


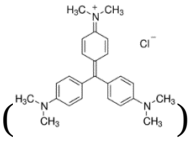
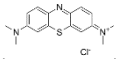
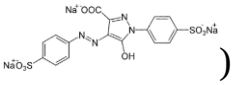
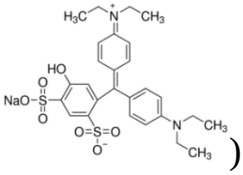
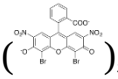
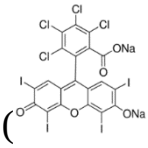










Coal tar dyes were used by the Lumière brothers to color the **starch grains** used to make **autochromes**. Crystal violet () and methylene blue () were used to color the starch grains violet, tartrazine () and Patent Blue () were used to color the starch grains green, and tartrazine, eosin (), and rose Bengal () were used to color the starch grains orange.





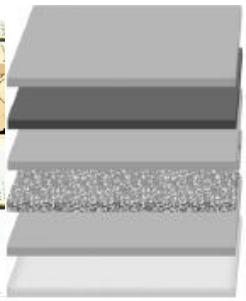
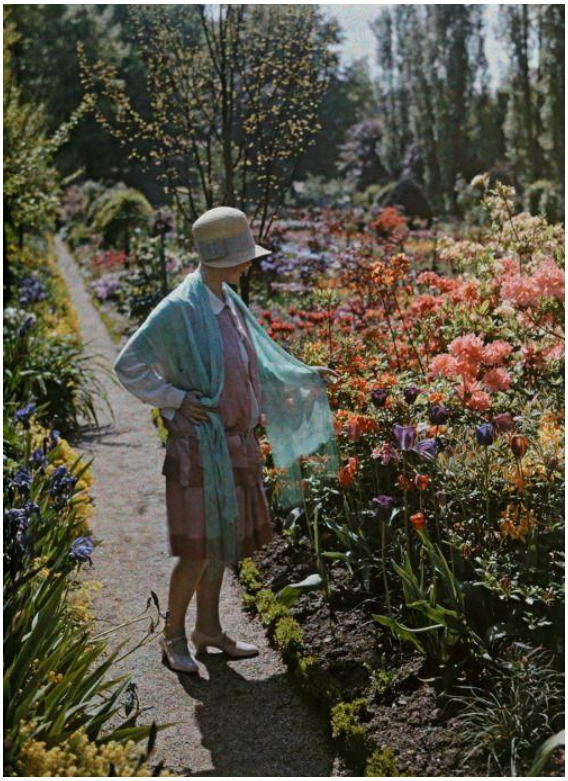
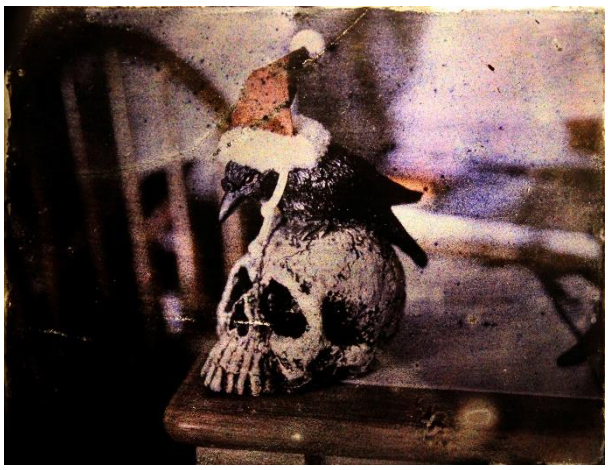


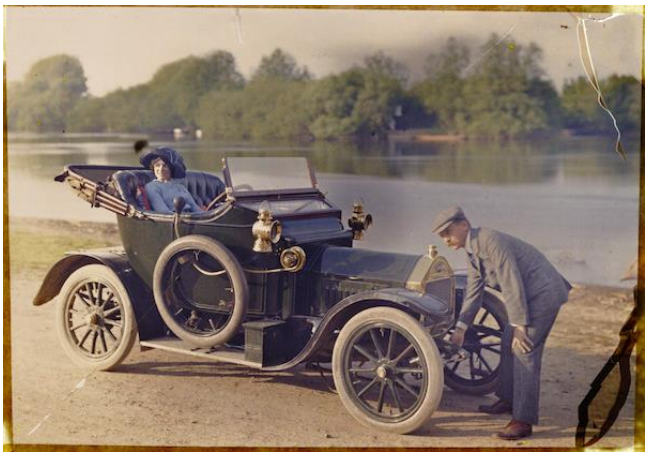
Illustration: Guida Casella

Fig.1. Autochrome layered structure

https://www.lensrentals.com/blog/2019/05/how-potatoes-and-gelatin-created-color-photography/

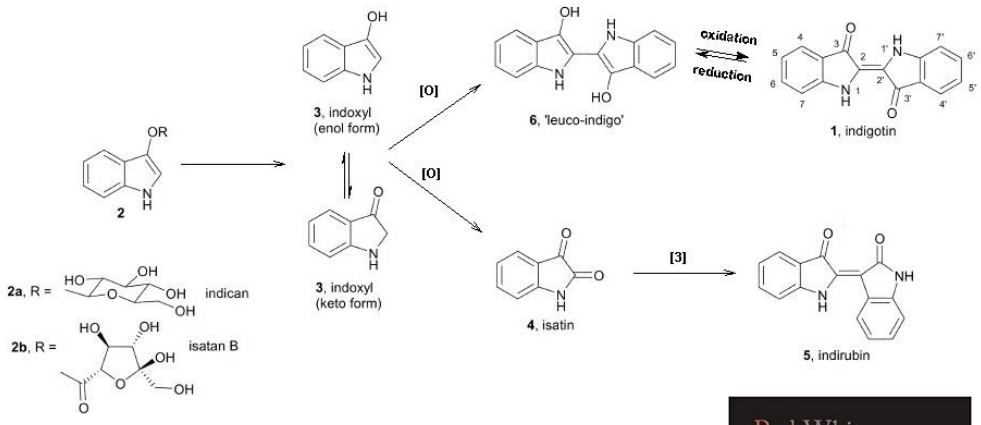






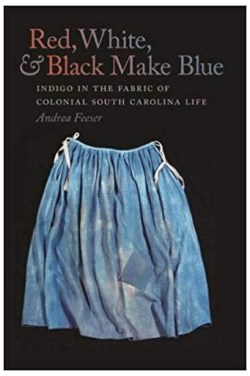


Other natural dyes, for example **indigo from *Indigofera tinctoria* in India**, were, like the *Murex* dyes, also labor intensive to make. Soaking indigo leaves in water, urine, and potash initiates **fermentation** which causes the **enzymatic conversion** of **indican** to **indoxyl** and glucose. The fermentation results in the **depletion of oxygen** from the solution which causes the indoxyl to be converted to soluble leuco-indigo. After all the leuco-indigo has been solubilized from the leaves, the solution is rapidly and constantly whipped to introduce oxygen, and to **oxidize** the leuco-indigo to **insoluble** indigotin. The indigotin is then dried and sold as a powder.

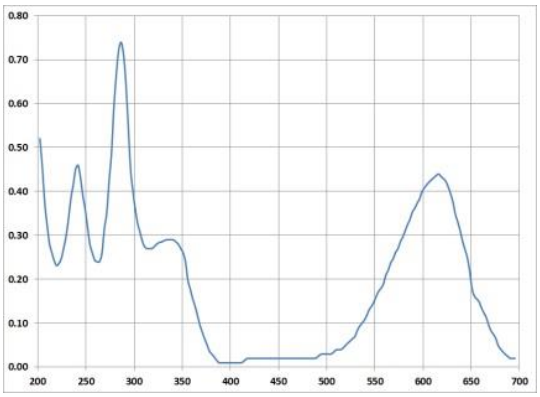


To be used, the indigotin must be **reduced** so it will be **soluble**. The fabric to be dyed is then dipped in the **reduced** yellow green indigotin (=leuco-indigo) solution and removed to the air so that the dye attached to the material will be **oxidized** and returned to the blue-colored indigotin. The more dips, the more saturated the color will be. Andrea Feeser (2013), author of *Red, White and Black Make Blue* that describes the role of red and black slaves in producing indigo for white plantation owners in South Carolina, describes the dyeing process like so: "*In the final stage of dyeing with indigo, a dyer pulls the cloth from an indigo bath, exposing the material to oxygen and setting off a chemical reaction that changes the cloth from yellowish-green to*





blue. Watching the transformation is not unlike watching time-lapse photography of a flower blossoming one thing becomes another slowly enough to mesmerize and quickly enough to thrill. In short, it seems magical." By the way, the color of the flag of South Carolina is indigo.



Here is the **absorption spectrum** of indigotin:

Indigo is blue because yellow and orange–red is **absorbed** by indigotin, and **blue**, the complementary color is **reflected**.

Indigotin can be obtained from many different plants from many plant families besides *Indigofera tinctoria*. One such plant is *Isatis tinctoria* or woad (http://www.woad.org.uk/index.html).

Demonstration: See the living plants of the pea family *Indigofera tinctoria* (indigo) and the mustard family *Isatis tinctoria* (woad).

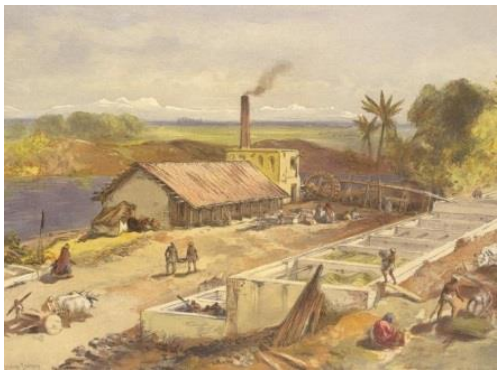




Demonstration: See the indigo powder and some indigo-dyed fabric from Japan.

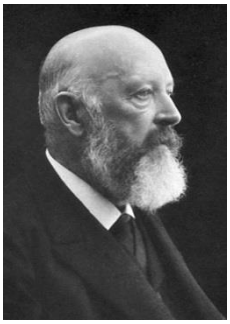




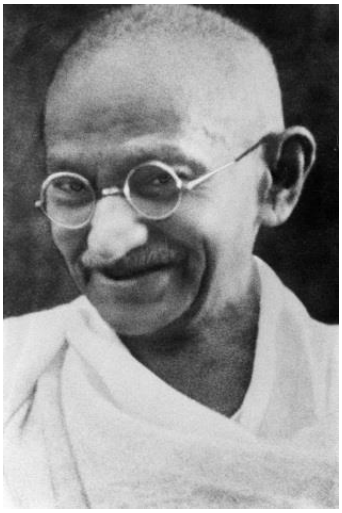


Most of the southern part of India had been under British rule since 1764; and in 1859, the farmers in Bengal revolted against the brutal treatment they were getting from the British colonialists. **Samuel Wilberforce** did have something to worry about in **1859**, which was the year the ***On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*** was published. The farmers in Bengal refused to plant even a single indigo plant, saying that they would rather beg than sow indigo. The revolt was eventually suppressed by the British Government and an "Indigo Commission" was appointed that reported that "*not a chest of Indigo reached England without being stained with human blood*."





Then in 1878, **Adolf von Baeyer** synthesized indigo from the **coal tar-derived aniline,** and **Badische Anilin- und Soda-Fabrik** (BASF), a part of the German dye Industry, began marketing it in 1897. As a result of the synthetic dye coming on the market, production of indigo in India dropped from 19,000 tons/year in 1856 to 1100 tons/year in 1914 and the price also fell. The poor farmers got even poorer and in **Champaran**, they revolted in 1914 and 1916. Raj Kumar Shukla, an indigo farmer, asked **Mahatma** (which is an honorific meaning high-souled) **Gandhi** to visit Champaran.



As soon as **Mahatma Gandhi** arrived in Champaran, the *satyagraha* or non-violent civil disobedience began, and the British Government ordered Mahatma Gandhi to leave. Mahatma Gandhi refused and the British Government rescinded its order. In March 1918, the Champaran Agraria Law was passed which gave the poor farmers more control over and compensation for the indigo. Because of the production of German synthetic dyes, however, there was no longer any need to grow indigo; nevertheless, the **Indian Independence Movement** had begun.

We see indigo every day and can appreciate its history, chemistry, and interaction with light.





After the fall of Constantinople, it was hard for the ruling classes in Europe to get striking purple dyes for their robes that would distinguish them from the riff raff. So, they switched to **scarlet** or **crimson red**, a color that had been worn by the European Kings who could not obtain *Murex* purple. The Catholic Cardinals wore robes dyed

with **Cardinal Red**, a dye made from the **scale insect** (*Kermes vermilio*) that attacked Mediterranean oak trees. The scale insect was called a ***grain*** and since the dye became fixed to the fabric and stably bound, the ability to hold on to anything tightly and without changing became known as ***ingrained***.



The monetarily successful people wanted to show off their taste in luxury items and their ability for conspicuous consumption. The **wealthy** obtained their red from the **scale insect** that attacked Mediterranean oaks. The **wealthier** used a more vivid red dye made from a scale insect from Poland (*Porphyrophora polonica*). The **wealthiest** used an even more vivid dye made from an Armenian scale insect (*Porphyophora hameli*), an insect that attacked certain herbs. The **wealthiest of the wealthiest** used the finest and most expensive red dye in Europe called Venetian red that contained **arsenic**, the secret ingredient that brightened the shade of red.



The **least wealthy** could get red dyes extracted from **plants** including **madder**, whose dye is known as **Turkey red**. Turkey red was good for dyeing indoor **rugs** but faded too quickly in the sunshine and rain to be valuable for red clothes. Likewise, red dyes from **logwood** (*Haematoxylum* [blood-wood] *campechianum*) and **brazilwood** faded in the sun like Turkey red. **Brasil** is what the Portuguese called the red dye from the sappanwood (*Caesalpinia sappan*) tree from Asia. When they found a tree (*Caesalpinia echinata*) that produced the same dye in South America, they called the place they found it, Brasil. None of these plant-derived dyes were durable enough to produce bright red clothes that would not fade in the sunlight and in water. Nevertheless, before they faded, clothes dyed with the costly scarlet and crimson dyes showed higher status than clothes dyed with the orange-red dyes.



I bet that someone back then said, "*I have a dream that one day people not be judged by the* ***color of their clothes*** *but by the content of their character*."



Demonstration: Living plant of madder (*Rubia tinctorum*). Look at the **roots**. You would never guess from the flowers that the roots produce such a pretty dye. It is a wonder how artisans figured out how to use the roots of madder to make a red dye and the leaves of indigofera and woad to make a blue dye.

Demonstration: Red dyes: madder, logwood, brazilwood.

The brightest red dye could get even brighter than anyone could have imagined. The Europeans discovered a new and striking red dye on the other side of the world that was so bright that would make it possible to differentiate many shades of color and thus classes of people.

The new scarlet and crimson **red dye**, known as **cochineal**, had been produced since 1000 BC by the people of South and Central America from the wingless females of a scale insect (*Dactylopius coccus*) which is similar to the scale insects of Europe but lives on the *Opuntia* cactus. The cochineal dye was generally produced for local use for cosmetics and to dye fabric and food. After Montezuma (1502-1520) conquered various groups to build the **Aztec Empire**, the conquered people used the cochineal and products dyed with cochineal to pay tribute or taxes to Montezuma.







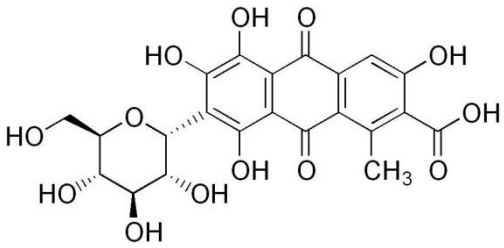
Conquerors are usually conquerors no matter where they come from. The **Spanish Conquistadors** arrived in Mexico in 1519, and within a few years they took over the local cochineal industry—not by farming the scale insect themselves but by taxing the local farmers. After all, farming the scale insects was labor-intensive and the ruling class would rather wear red than bleed red by working too close to the cactus.



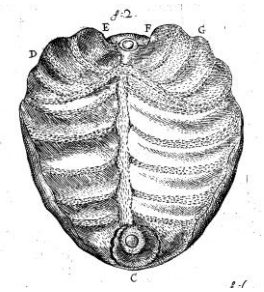


In order to produce cochineal dye, the farmers collect the **female scale insects, which are full of eggs** by hand using a feather, a paintbrush, or a pin. Squeezing a live insect releases the dye. To make the dye, the harvested insects are dried in the sun for about two weeks and then collected and ground.

The dye is then extracted from the ground dried insects that contain approximately 20% **carminic acid** by dry weight. It takes approximately 100,000 insects to make 1 kg of dye, making cochineal farming and dye production labor intensive.



The Spaniards brought 50-150 tons/year of cochineal grains, which amounts to **several trillion grains/year**, back to Europe where the Spaniards kept the source of cochineal a secret and others were not sure whether the **grain** was a **seed**, a **berry**, or an **insect**. With his microscope, **Antony van Leeuwenhoek** (1704) showed that cochineal was an insect.



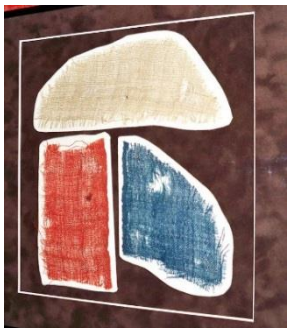
Demonstration: See the cochineal under the dissecting microscope.

The Aztecs taught the Spaniards that the carmine dye that has been extracted from the scale insects is not color-fast, and that the dye must be mixed with alum (hydrated potassium aluminum sulfate; $KAl(SO_4)_2 \cdot 12H_2O$) which is a **mordant** that bites on to the dye to make it color-fast.

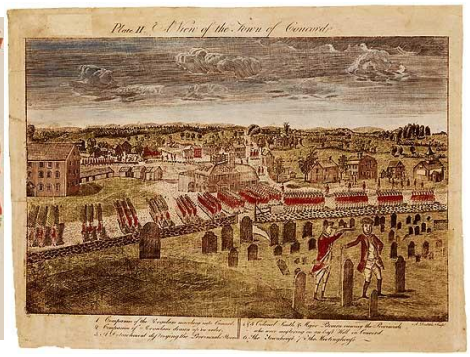
Sometime around 1606 or 1607, **Cornelis Drebbel**, a polymath who may have invented the microscope (*lunette de Dreubells*), was boiling an aqueous solution of cochineal to color the solution in a thermometer. Cornelis put the bright scarlet solution, which was similar to every cochineal solution made, and brighter than any other red dye, in the window to cool. When he returned to the cochineal solution, Drebbel noticed that the cochineal solution was the brightest shade of red he or anyone had ever seen. It turned out that the cause of the reddest of red dyes was due to a bottle containing a mixture of nitric acid and hydrochloric acid, known as *aqua regia*, breaking, and dissolving the tin in the window frame above the cochineal solution so that the **tin** dripped into it. Drebbel started a dye works himself to sell the **perfect red**. The **guilds** in the dye industry had always kept

things secret and Drebbel and his son-in-laws were no exception in that they too did not share their secret on how to produce such luminous reds with anyone. Eventually though, through independent research or espionage, others learned the secret of using **tin** to produce the **perfect red**.

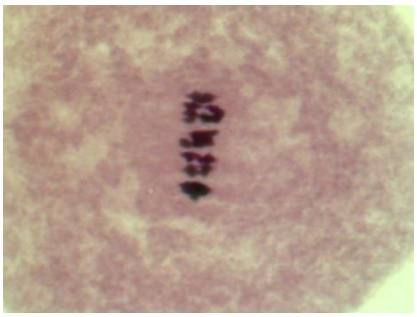
Oliver Cromwell ordered that the English officers' coats be dyed with the **perfect red**, while the lower ranks wore redcoats dyed with **madder**. During the American Revolution, the British were known as the redcoats. In the War of 1812, the red stripes in the flag that flew over Fort McHenry—the flag that inspired the Star-Spangled Banner, written by Francis Scott Key on September 14, 1814—were dyed with the **perfect red**.







John Hill (1770) used cochineal dye as a biological stain to see "*the course of the vessels… for they only are crimson*." Lord Osborne used alkaline carmine to show that there was one **nucleus** in each plant cell and Barbara McClintock (Cornell) used acid carmine to stain the **chromosomes** of maize.



We already discussed the reason that the *Murex* snails produce the precursors to *argamman* and *tekhelet*, and **Tom Eisner** (Cornell) learned the reason that scale insects produce carminic acid. Eisner put carminic acid at the concentration that is present in the scale insect into sugar solutions. He then allowed **ants** to eat the control sugar solutions or the sugar solutions containing carminic acid. The ants avoided the sugar solutions containing carminic acid and

they did so in the light and the dark, indicating that it is not the color of the chemical that deters the ants but the chemical itself.



Eisner also found that a **caterpillar** of a moth *Laetilia coccidivora* that was originally described by John Comstock (Cornell) feeds on the scale insects. The caterpillar stores the carminic acid in its crop at a higher concentration than is present in the scale insect. When the caterpillar is **attacked by ants**, the caterpillar vomits on the ants, covering them with the red dye. The ants then run away from the caterpillar, wiping their bodies against the ground to remove the cochineal such that they leave a red streak behind them.





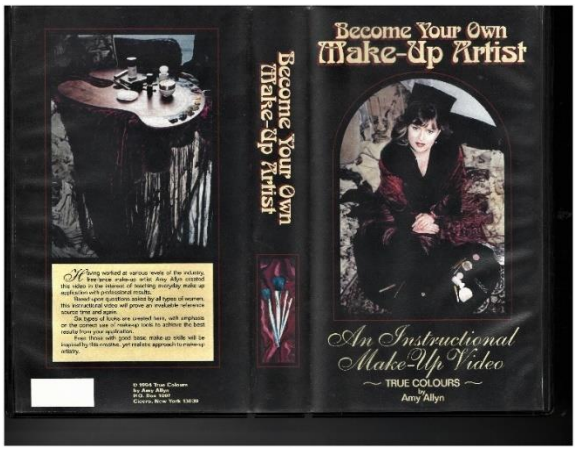


Throughout history and throughout the world, human beings have discovered ways to utilize animals, including snails and scale insects, and plants, such as indigo, woad, and madder to produce **pigments** that color the manufactured world using processes that make use of chemical processes of **fermentation**, **oxidation and reduction**, and **photochemistry**. We also discovered ways to color ourselves with natural pigments from plants. I have already mentioned cochineal being used for makeup. Henna was too. Henna has been found on the fingers and toes of the mummy of Ramses II and in the hair of the mummy of Queen





Hatshepsuth showing that henna has been used as a skin and hair dye hair for 6000 years. Native Americans used Bloodroot to produce red, Virginia creeper to produce pink, Annatto to produce orange yellow, and Coneflowers and Blueberries to produce purple war paint.



Since ancient times, colored cosmetics have been used. By 4000 BC, Egyptian women painted their faces with **galena mesdemet** (from copper and lead), **malachite** (from copper), and other naturally occurring colors (e.g. paprika). These colors signified their class. Henna dyes or rice powders were used in China, Japan, India, and North Africa. By the 1500s, European women lightened their skin with **white lead paint**. This practice may have led to the death of Queen Elizabeth I of England. By the 1800s, lead oxide was replaced by zinc oxide. Soon government regulation protected the consumer by prohibiting the use of deadly color additives.

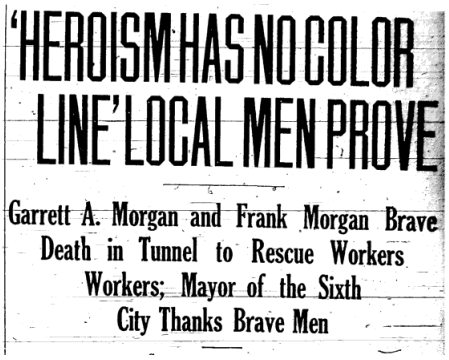




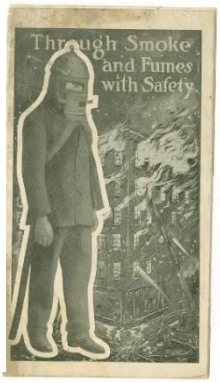


Cosmetics have also been made especially for African American hair and skin. **Garrett Morgan**, a child of slaves and an elementary school-educated inventor and entrepreneur, developed a hair-straightening solution in 1905 that he discovered by accident when he figured out that the soap solution made with excess lye, he invented to reduce friction and prevent sewing machine needles from burning the wool as it sewed, could also be used as a **relaxer** to straighten hair. He discovered this accidentally when Mary, his wife, called him for dinner, and he wiped his hands on a piece of pony-fur cloth. Later that night, he noticed that the fuzzy area of the cloth where he wiped his hands straightened out. He then tried the formula on the

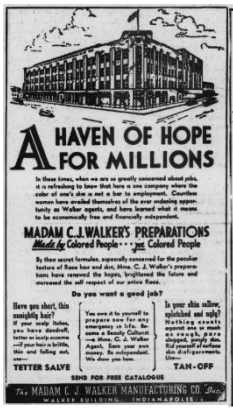
hair of a neighbor's Airedale dog, and then on his own hair. In 1910, Morgan also invented a black oil hair dye and a curved tooth comb that could be used to straighten hair. He started the G. A. Morgan Hair Refining Company in 1913. He used the profits to invent life-saving devices, such as the tri-color traffic light and the gas mask, which he used to save lives threatened by the Lake Erie Tunnel disaster on July 24, 1916. The G. A. Morgan Hair Refining Company was bought by *Proline*, the manufacturers of *Dark and Lovely*.


'HEROISM HAS NO COLOR LINE' LOCAL MEN PROVE

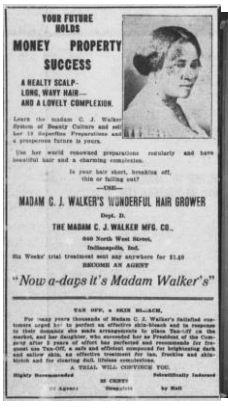
Garrett A. Morgan and Frank Morgan Brave Death in Tunnel to Rescue Workers Workers; Mayor of the Sixth City Thanks Brave Men



Madam C. J. Walker, whose parents were slaves, also developed and sold "*highly recommended*" and "*scientifically indorsed*" cosmetics and hair products "*made by colored people for colored people.*" As the founder of *Madam C. J. Walker Manufacturing Company*, she became the first female self-made millionaire.







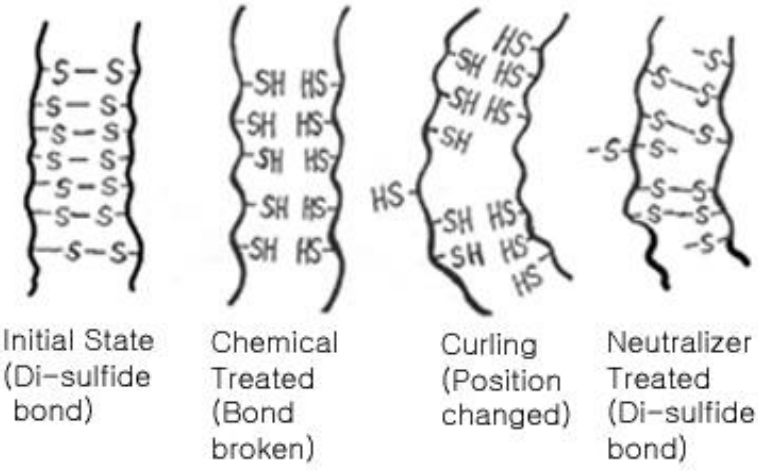


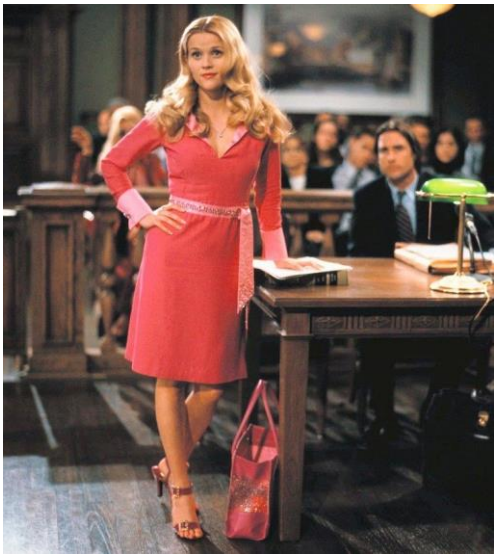


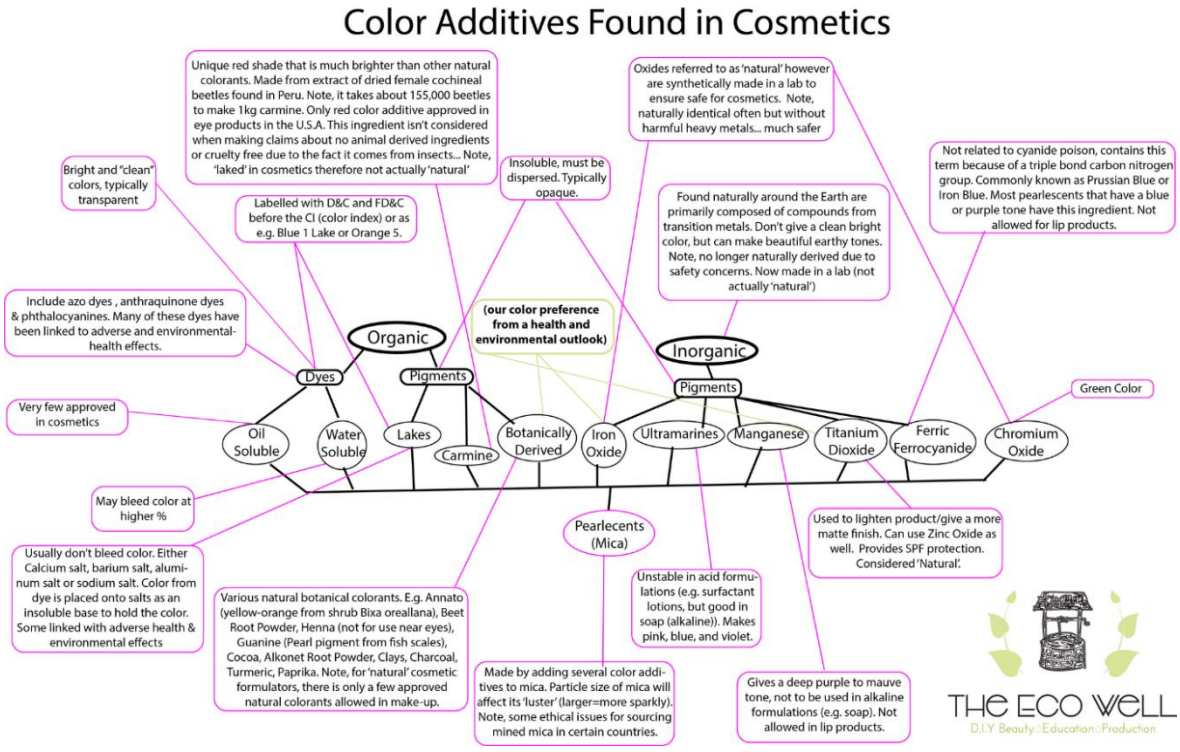


In 1930, David Goddard and Leonor Michaelis found that reducing the S-S bonds to SH between cysteines with **thioglycolic acid** relaxes the keratin molecules that make up hair. This discovery formed the basis of making permanent waves which requires the reoxidation of the cysteines to S-S, as told by Elle in *Legally Blonde*.









The color additives that are used in cosmetics and are approved by the Food and Drug Administration fall into two groups. The color additives in the first group are not made from coal tar and exempt from batch certification. While most of these color additives are pigments that produce color by differential **absorption**, mica produces **structural colors** as a result of **interference**, and zinc sulfide produces a yellow-green color due to **phosphorescence**. The color additives in the second group are made from coal tar or other petroleum products are given numbers and require batch certification. The "C" in FD & C or D & C stands for cosmetic.

Color Additives Approved for Use in Cosmetics
Part 73, Subpart C: Color additives exempt from batch certification

21 CFR Section	Straight Color	Year[2] Approved	Uses and Restrictions
§73.2030	Annatto	1977	Cosmetics generally[5] including eye area use.
§73.2085	Caramel	1981	Cosmetics generally[5] including eye area use.
§73.2087	**Carmine**	1977	Cosmetics generally[5] including eye area use.
§73.2095	**ß-Carotene**	1977	Cosmetics generally[5] including eye area use.
§73.2110	Bismuth citrate[3]	1978	Cosmetics intended for coloring hair on the scalp only NTE[7] 0.5 percent.
		2010	Cosmetics intended for coloring hair on the scalp only NTE[7] 2.0 percent.
§73.2120	Disodium EDTA-copper	1974	Coloring of shampoos that are cosmetics.
§73.2125	Potassium sodium copper **chlorophyllin** (chlorophyllin copper-complex)	1969	Coloring dentifrices that are cosmetics NTE[7] 0.1% in combination with a list of substances.
§73.2150	Dihydroxyacetone	1973	Externally applied cosmetics[6] intended solely or in part to impart color to the human body.
§73.2162	Bismuth oxychloride	1977	Cosmetics generally[5] including eye area use.
§73.2180	Guaiazulene	1977	Externally applied cosmetics[6].

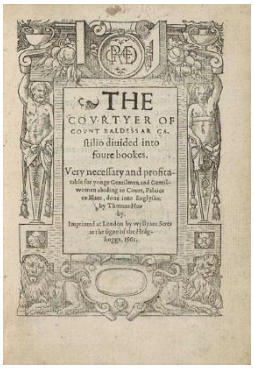
§73.2190	Henna[3]	1965	Coloring hair but not eyelashes, eyebrows, or eye area.
§73.2250	**Iron oxides**	1977	Cosmetics generally[5] including eye area use.
§73.2298	Ferric ammonium ferrocyanide	1977	Externally applied cosmetics[6] including eye area use.
§73.2299	Ferric ferrocyanide	1978	Externally applied cosmetics[6] including eye area use.
§73.2326	Chromium hydroxide green	1977	Externally applied cosmetics[6] including eye area use.
§73.2327	Chromium oxide greens	1977	Externally applied cosmetics[6] including eye area use.
§73.2329	**Guanine**	1977	Cosmetics generally[5] including eye area use.
§73.2396	Lead acetate[3]	1981	Cosmetics intended for coloring hair on the scalp only, NTE[7] 0.6 percent Pb (weight/volume).
§73.2400	Pyrophyllite	1973	Externally applied cosmetics[6].
§73.2496	**Mica**	1977	Cosmetics generally[5] including eye area use.
§73.2500	Silver [3]	1979	Coloring fingernail polish NTE[7] 1% of final product.
§73.2575	Titanium dioxide	1973	Cosmetics including eye area use.
§73.2645	Aluminum powder	1977	Externally applied cosmetics[6] including eye area use.
§73.2646	Bronze powder	1977	Cosmetics generally[5] including eye area use.
§73.2647	Copper powder	1977	Cosmetics generally[5] including eye area use.
§73.2725	Ultramarines	1976	Externally applied cosmetics[6] including eye area use.
§73.2775	Manganese violet	1976	Cosmetics generally[5] including eye area use.
§73.2991	Zinc oxide	1977	Cosmetics including eye area use.
§73.2995	Luminescent zinc sulfide [3]	2000	Nail polish and externally applied facial makeup[6] NTE[7] 10% of final product for limited, occasional use.

Color Additives Approved for Use in Cosmetics
Part 74, Subpart C: Color additives subject to batch certification[4]

21 CFR Section	Straight Color	Year[2] Approved	Uses and Restrictions
§74.2052	D&C Black No. 2	2004	Eyeliner, brush-on-brow, eye shadow, mascara, lipstick, blushers and rouge, makeup and foundation, and nail enamel.
§74.2053	D&C Black No. 3 [3]	2007	Eyeliner, eye shadow, mascara, and face powder.
		1982	Cosmetics generally[5].
§74.2101	FD&C Blue No. 1	1993	Allows MnO_2 in manufacture.
		1994	Eye area use (includes lake).
§74.2104	D&C Blue No. 4	1977	Externally applied cosmetics[6] .
§74.2151	D&C Brown No. 1	1976	Externally applied cosmetics[6] .
§74.2203	FD&C Green No. 3	1982	Cosmetics generally [5].
§74.2205	D&C Green No. 5	1982	Cosmetics generally[5].
		1994	Eye area use.
§74.2206	D&C Green No. 6	1982	Externally applied cosmetics[6] .
§74.2208	D&C Green No. 8	1976	Externally applied cosmetics[6] (NTE[7] 0.01% (by wt) of finished cosmetic product).
§74.2254	D&C Orange No. 4	1977	Externally applied cosmetics[6] .
		1984	Externally applied cosmetics[6] .
§74.2255	D&C Orange No. 5	1982	Mouthwashes, dentifrices, lipsticks, and other lip cosmetics NTE[7] 5 percent.
§74.2260	D&C Orange No. 10	1981	Externally applied cosmetics[6] .
§74.2261	D&C Orange No. 11	1981	Externally applied cosmetics[6] .
§74.2304	FD&C Red No. 4	1976	Externally applied cosmetics[6] .
		1983	Cosmetics generally [5].
§74.2306	D&C Red No. 6	2012	Ether-soluble matter specification changed to 1-[(4-methylphenyl)azo]-2-naphthalenol, not more than 0.015 percent.
		1983	Cosmetics generally [5].
§74.2307	D&C Red No. 7	2012	Ether-soluble matter specification changed to 1-[(4-methylphenyl)azo]-

			2-naphthalenol, not more than 0.015 percent.
§74.2317	D&C Red No. 17	1976	Externally applied cosmetics[6] .
§74.2321	D&C Red No. 21	1982	Cosmetics generally [5].
§74.2322	D&C Red No. 22	1982	Cosmetics generally [5].
§74.2327	D&C Red No. 27	1982	Cosmetics generally [5].
§74.2328	D&C Red No. 28	1982	Cosmetics generally [5].
§74.2330	D&C Red No. 30	1982	Cosmetics generally [5].
§74.2331	D&C Red No. 31	1976	Externally applied cosmetics[6] .
§74.2333	D&C Red No. 33	1988	Externally applied cosmetics[6] ; mouthwashes, dentifrices; cosmetic lip products (NTE[7] 3% (by wt) of finished cosmetic product).
§74.2334	D&C Red No. 34	1976	Externally applied cosmetics[6] .
§74.2336	D&C Red No. 36	1988	Externally applied cosmetics[6]; cosmetic lip products (NTE[7] 3% (by wt) of finished cosmetic product).
§74.2340	FD&C Red No. 40[3]	1975	Cosmetics generally[5].
		1994	Eye area use (includes Al lake). No oxidizing or reducing agents that may affect integrity.
§74.2602	D&C Violet No. 2	1976	Externally applied cosmetics[6] .
§74.2602a	Ext. D&C Violet No. 2	1976	Externally applied cosmetics[6] .
§74.2705	FD&C Yellow No. 5	1985	Cosmetics generally[5].
		1994	Eye area use (includes Al lake).
§74.2706	FD&C Yellow No. 6	1986	Cosmetics generally [5].
§74.2707	D&C Yellow No. 7	1976	Externally applied cosmetics[6].
§74.2707a	Ext. D&C Yellow No. 7	1976	Externally applied cosmetics[6].
§74.2708	D&C Yellow No. 8	1976	Externally applied cosmetics[6].
§74.2710	D&C Yellow No. 10	1983	Cosmetics generally [5].
		1984	Modification of uses and restrictions.
§74.2711	D&C Yellow No. 11	1976	Externally applied cosmetics[6].

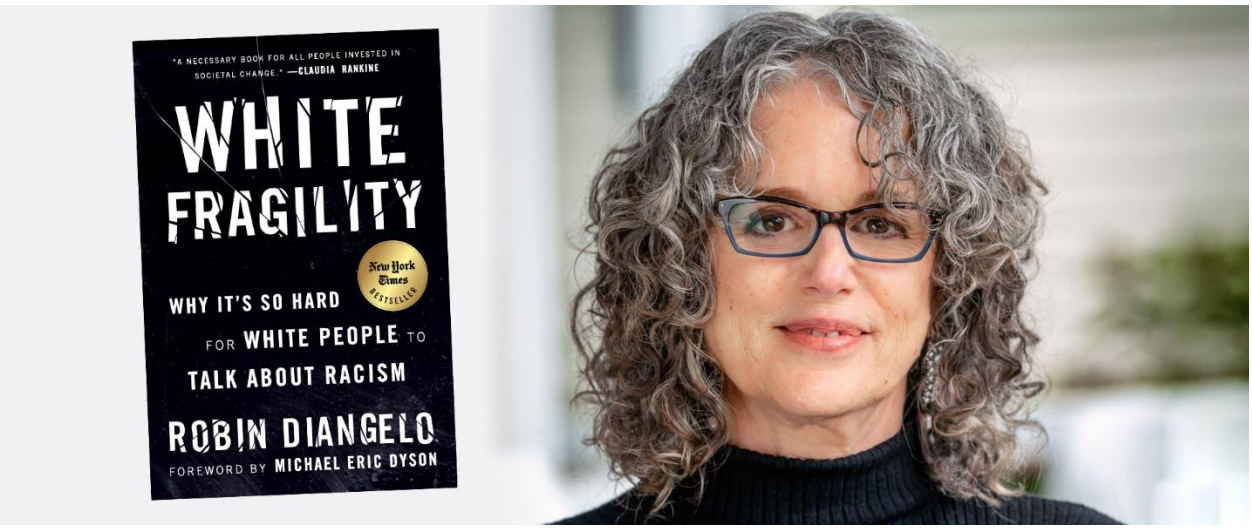
The labor-intensive natural dye industries were made redundant by the production of the artificial dyes. But as the dangers of artificial dyes became known, the labor-intensive natural dye industry began to grow again. You see natural cochineal from the scale insect instead of **alizarin**, the coal tar derivative, when you see **bright red lipstick**!


THE
COVRTYER OF
COVNT BALDESSAR CA.
stilio diuided into
foure bookes.
Very necessary and profita-
ble for yonge Gentlemen, and Gentil-
women abiding in Court, Palace
or Hall, done into English
by Thomas Hoby.
Imprinted at London by William Seres
at the signe of the Hedge-
hogge. 1561.

Sprezzatura is a word originating from Baldassare Castiglione's (1561) *The Book of the Courtier*. Sprezzatura symbolizes "***a certain nonchalance, so as to conceal all art and make whatever one does or says appear to be without effort and almost without any thought about it.***" It is the ability to accomplish difficult things as if they did not require any effort—or perhaps to use cosmetics to create a natural look that appears to have effortlessly sprung up from nature and truth.

A word about words: We have been talking about color-fast dyes. The word ***fast*** in this case means tightly bound, just like the word ***fast*** in fast friends.

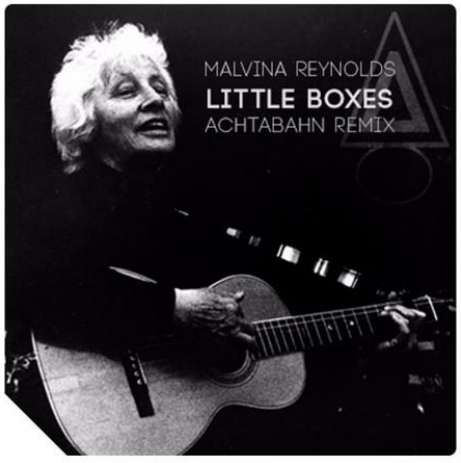
A word about the stability of colors: If you were to travel very fast ***away*** from a person wearing clothes dyed with dyes such as *argamman*, *tekhelet*, or cochineal, how would the colors look to you as compared to if you were to travel very fast ***towards*** the same person wearing clothes dyed with dyes such as *argamman*, *tekhelet*, or cochineal? Would the colors remain **stable,** or would they **change**? If so, would they change as a result of the Doppler effect or would they change as a result of time dilation as Einstein, and everyone but me thinks.



Since cosmetics are used to enhance natural skin color, I'll mention the word **"whiteness."** In the foreword to Robin DiAngelo's book *White Fragility*, Michael Eric Dyson (2018), wrote, "***To be sure, like the rest of race, whiteness is a fiction, what in the jargon of the academy is termed a social construct, an agreed-on myth that got empirical grit because of its effect, not its essence***." By design, *White Privilege* and Critical Theory in general is based on fictional foundations. According to me, the effect of Critical Theory based on postmodernism, which is based on the assertion that there is no truth, is to abolish critical thinking based on reasoning from clearly stated assumptions (postulated truth claims), and to establish mental slavery—separating the brain from the spinal cord. This semester I have done my best to present the world of light and life in a manner that empowers you to choose for yourself the fundamental laws that underlie your Weltanschauung or worldview. When choosing to build a worldview on a fundamental law that is a fiction, then that worldview will also most likely be a fiction. This describes the current academic worldview that cannot be understood, at least by me, in terms of its essence, but only by its effect. Robin DiAngelo, "*believe*[s] *that* ***white progressives cause the most daily damage to people of***

color. She "*define[s] white progressives as white people who think they are not racist, or are less racist, or in the 'choir,' or already 'get it.*'" Ironically, the alternative to the progressive academic social-science based postmodern worldview, like the progressive academic natural-science based eugenic worldview is the nonprogressive, liberal/conservative commonsense worldview held by William and Samuel Wilberforce, Benjamin Franklin, Thomas Jefferson, Abraham Lincoln, Frederick Douglass, William Jennings Bryan, Martin Luther King, and presidential candidate Barack Obama that is based on the fundamental law that all people are created equal in the image of God, or as it is stated in Galatians (5:14) "***For the entire law is fulfilled in keeping this one command: 'Love your neighbor as yourself.***"

A word about my mother: After dinner, my mother would play the piano for us. One of her regular songs was ***Little Boxes*** by Malvina Reynolds. It is a song about conformity or as we took it—nonconformity.
https://www.youtube.com/watch?v=2_2lGkEU4Xs



Little boxes on the hillside,
Little boxes made of ticky tacky,
Little boxes on the hillside,
Little boxes all the same.
There's a green one and a pink one
And a blue one and a yellow one,
And they're all made out of ticky tacky
And they all look just the same.

And the people in the houses
All went to the university,
Where they were put in boxes
And they came out all the same,
And there's doctors and lawyers,
And business executives,

And they're all made out of ticky tacky
And they all look just the same.

And they all play on the golf course
And drink their martinis dry,
And they all have pretty children
And the children go to school,
And the children go to summer camp
And then to the university,
Where they are put in boxes
And they come out all the same.

And the boys go into business
And marry and raise a family
In boxes made of ticky tacky
And they all look just the same.
There's a green one and a pink one
And a blue one and a yellow one,
And they're all made out of ticky tacky
And they all look just the same.



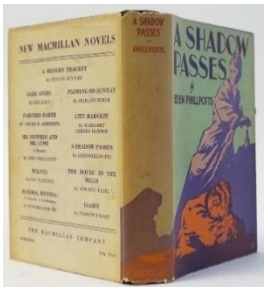
According to Nancy Reynolds Schimmel, Malvina Reynolds' daughter, "*My mother and father were driving South from San Francisco through Daly City when my mom got the idea for the song. She asked my dad to take the wheel, and she wrote it on the way to the gathering in La Honda where she was going to sing for the Friends Committee on Legislation. When Time Magazine (I think, maybe Newsweek) wanted a photo of her pointing to the very place, she couldn't find those houses because so many more had been built around them that the hillsides were totally covered*."

There is a difference between light and darkness, and each has its value. But, in this post-truth era, calling darkness light and light darkness is another thing. According to Isaiah (5:20-21), "*Woe to those who call evil good and good evil, **who put darkness for light and light for darkness**, who put bitter for sweet and sweet for bitter. Woe to those who are wise in their own eyes and clever in their own sight*."



Robert Aris Willmott (1858) wrote in *Summer Time in the Country*, "*Lord* [Francis] *Bacon considered it necessary to **contract and dilate the mind's eye-sight**; regarding the interchange of **splendour and gloom** as essential to the health of the organ. The reader may test the rule by trying it on his natural eyes. In a gorgeous summer day, let him come suddenly from a thick screen of branches, turning his face towards the sun, and then to the grass. Every blade will be reddened, as if a fairy procession had gone by. The colour is not in the grass, but in the eye; as that contracts, the glare vanishes. Subject the mental sight to a similar experiment. After wandering in the dim recesses of history or metaphysics, let the **inward eye** be lifted to the broad, central, glowing orbs of Shakspere* [sic]*, Milton, or Hooker, and then immediately cast down upon the common surface of daily life. Objects become hazy and discoloured; the dilation of the nerve of thought dazzles and bewilders the vision. It is wise, therefore, to familiarize the seeing faculty of the understanding to different degrees of luster. **Sunshine and twilight should temper one another***."





Eden Phillpotts (1918) wrote in *A Shadow Passes*, "*Light and shade both play their part in revelation of realities; and while most men and women steadfastly suppose that only the light of success is needful to*

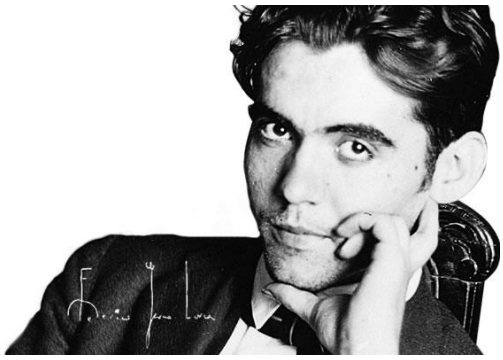
uncover the beautiful truth of them, it may be that they are mistaken and the shadow of failure would better do so."



Duende is a Spanish word that encompasses **darkness and light**. "*All that has black sounds has duende*." Duende describes a certain spirit that complements joy—it describes the "*bitter root*" of human existence, "*the pain which has no explanation*" that comes with the creativity that is necessary to grasp and to illuminate deep truths about the world—using the spoken word, the written word, dance, or, if you ask me, a scientific experiment.



In an essay entitled, *The Scientific Use of the Imagination*, John Tyndall describes the "***period of doubt and discomfort, of gloom and ennui***" as well as the "***pain of conflict and the debility of indecision***" that comes with looking for the next opening of scientific discovery. According to **Federico Garía Lorca**, duende involves risk—"*Seeking the duende, there is neither map nor discipline….The duende does not come at all unless he sees that death is possible*." The duende is neither an angel that illuminates nor a muse that provides form.



Federico Garía Lorca (1933) developed the aesthetics of duende in a lecture entitled, "*Juego y teoria del duende*" or Play and Theory of the Duende and describes duende as "*A mysterious force that everyone feels and no philosopher has explained*" and "*a power, not a work. It is a struggle, not a thought.*"

Brook Zern recognizes duende because "***it dilates the mind's eye****, so that the intensity becomes almost unendurable…. There is a quality of first-timeness, of reality so heightened and exaggerated that it becomes unreal…."*



William Cowper, an abolitionist, and associate of John Newton, with whom he wrote *Olney Hymns*, wrote a poem entitled, ***Light Shining out of Darkness***

God moves in a mysterious way,
His wonders to perform;
He plants his footsteps in the sea,
And rides upon the storm.

Deep in unfathomable mines
Of never-failing skill,
He treasures up his bright designs,
And works his sov'reign will.

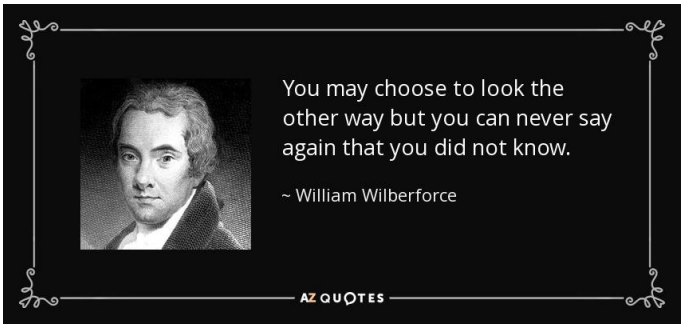
Ye fearful saints, fresh courage take,
The clouds ye so much dread
Are big with mercy, and shall break
In blessings on your head.

Judge not the Lord by feeble sense,
But trust him for his grace;
Behind a frowning providence
He hides a smiling face.

His purposes will ripen fast,
Unfolding ev'ry hour;
The bud may have a bitter taste,
But sweet will be the flow'r.

Blind unbelief is sure to err,
And scan his work in vain;

God is his own interpreter,
And he will make it plain.



Cowper also wrote a *Sonnet to* ***William Wilberforce****, Esq.*

Thy country, Wilberforce, with just disdain,
Hears thee, by cruel men and impious, call'd
Fanatic, for thy zeal to loose th' enthrall'd
From exile, public sale, and slav'ry's chain.
Friend of the poor, the wrong'd, the fetter-gall'd,
Fear not lest labour such as thine be vain!
Thou hast achiev'd a part; hast gain'd the ear
Of Britain's senate to thy glorious cause;
Hope smiles, joy springs, and tho' cold caution pause
And weave delay, the better hour is near,
That shall remunerate thy toils severe
By peace for Afric, fenc'd with British laws.
Enjoy what thou hast won, esteem and love
From all the just on earth, and all the blest above!

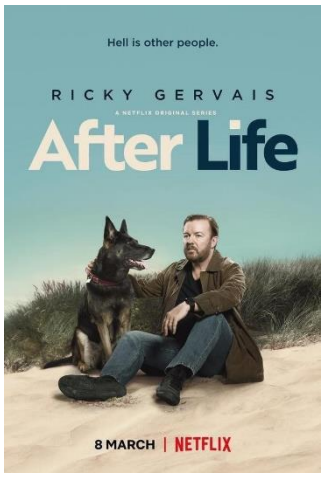
Johnny Cash wrote a song called, *Man in Black*, in which he sings,



Ah, I'd love to wear a rainbow every day,
And tell the world that everything's OK,
But I'll try to carry off a little darkness on my back,
'Till things are brighter, I'm the Man In Black

https://www.youtube.com/watch?v=1Okt0-Y38Pc

The series *After Life*, which was written and directed by **Ricky Gervais**, is a great example of duende. Ricky Gervais also stars in it.



This story about clothes, color, and seeing has very broad implications.

THE EMPEROR'S NEW CLOTHES

by Hans Christian Andersen

Many years ago there was an Emperor so exceedingly fond of new clothes that he spent all his money on being well dressed. He cared nothing about reviewing his soldiers, going to the theatre, or going for a ride in his carriage, except to show off his new clothes. He had a coat for every hour of the day, and instead of saying, as one might, about any other ruler, 'The King's in council,' here they always said. 'The Emperor's in his dressing room.'

In the great city where he lived, life was always gay. Every day many strangers came to town, and among them one day came two swindlers. They let it be known they were weavers, and they said they could weave the most magnificent fabrics imaginable. ***Not only were their colors and patterns uncommonly fine, but clothes made of this cloth had a wonderful way of becoming invisible to anyone who was unfit for his office, or who was unusually stupid.***

'Those would be just the clothes for me,' thought the Emperor. 'If I wore them I would be able to discover which men in my empire are unfit for their posts. And I could tell the wise men from the fools. Yes, I certainly must get some of the stuff woven for me right away.' He paid the two swindlers a large sum of money to start work at once.

They set up two looms and pretended to weave, though there was nothing on the looms. All the finest silk and the purest old thread which they demanded went into their traveling bags, while they worked the empty looms far into the night.

'I'd like to know how those weavers are getting on with the cloth,' the Emperor thought, but he felt slightly uncomfortable when he remembered that those who were unfit for their position would not be able to see the fabric. It couldn't have been that he doubted himself, yet he thought he'd rather send someone else to see how things were going. The whole town knew about the cloth's peculiar power, and all were impatient to find out how stupid their neighbors were.

'I'll send my honest old minister to the weavers,' the Emperor decided. 'He'll be the best one to tell me how the material looks, for he's a sensible man and no one does his duty better.'

So the honest old minister went to the room where the two swindlers sat working away at their empty looms.

'Heaven help me,' he thought as his eyes flew wide open, 'I can't see anything at all'. But he did not say so.

Both the swindlers begged him to be so kind as to come near to approve the excellent pattern, the beautiful colors. They pointed to the empty looms, and the poor old minister stared as hard as he dared. He couldn't see anything, because there was nothing to see. 'Heaven have mercy,' he thought. 'Can it be that I'm a fool? I'd have never guessed it, and not a soul must know. Am I unfit to be the minister? It would never do to let on that I can't see the cloth.'

'Don't hesitate to tell us what you think of it,' said one of the weavers.

'Oh, it's beautiful -it's enchanting.' The old minister peered through his spectacles. 'Such a pattern, what colors! I'll be sure to tell the Emperor how delighted I am with it.'

'We're pleased to hear that,' the swindlers said. They proceeded to name all the colors and to explain the intricate pattern. The old minister paid the closest attention, so that he could tell it all to the Emperor. And so he did.

The swindlers at once asked for more money, more silk and gold thread, to get on with the weaving. But it all went into their pockets. Not a thread went into the looms, though they worked at their weaving as hard as ever.

The Emperor presently sent another trustworthy official to see how the work progressed and how soon it would be ready. The same thing happened to him that had happened to the minister. He looked and he looked, but as there was nothing to see in the looms he couldn't see anything.

'Isn't it a beautiful piece of goods?' the swindlers asked him, as they displayed and described their imaginary pattern.

'I know I'm not stupid,' the man thought, 'so it must be that I'm unworthy of my good office. That's strange. I mustn't let anyone find it out, though.' So he praised the material he did not see. He declared he was delighted with the beautiful colors and the exquisite pattern. To the Emperor he said, 'It held me spellbound.'

All the town was talking of this splendid cloth, and the Emperor wanted to see it for himself while it was still in the looms. Attended by a band of chosen men, among whom were his two old trusted officials-the ones who had been to the weavers-he set out to see the two swindlers. He found them weaving with might and main, but without a thread in their looms.

'Magnificent,' said the two officials already duped. 'Just look, Your Majesty, what colors! What a design!' They pointed to the empty looms, each supposing that the others could see the stuff.

'What's this?' thought the Emperor. 'I can't see anything. This is terrible!'

'Am I a fool? Am I unfit to be the Emperor? What a thing to happen to me of all people! - Oh! It's very pretty,' he said. 'It has my highest approval.' And he nodded approbation at the empty loom. Nothing could make him say that he couldn't see anything.

His whole retinue stared and stared. One saw no more than another, but they all joined the Emperor in exclaiming, 'Oh! It's very pretty,' and they advised him to wear clothes made of this wonderful cloth especially for the great procession he was soon to lead. 'Magnificent! Excellent! Unsurpassed!' were bandied from mouth to mouth, and everyone did his best to seem well pleased. The Emperor gave each of the swindlers a cross to wear in his buttonhole, and the title of 'Sir Weaver.'

Before the procession the swindlers sat up all night and burned more than six candles, to show how busy they were finishing the Emperor's new clothes. They

pretended to take the cloth off the loom. They made cuts in the air with huge scissors. And at last they said, 'Now the Emperor's new clothes are ready for him.'

Then the Emperor himself came with his noblest noblemen, and the swindlers each raised an arm as if they were holding something. They said, 'These are the trousers, here's the coat, and this is the mantle,' naming each garment. 'All of them are as light as a spider web. One would almost think he had nothing on, but that's what makes them so fine.'

'Exactly,' all the noblemen agreed, though they could see nothing, for there was nothing to see.

'If Your Imperial Majesty will condescend to take your clothes off,' said the swindlers, 'we will help you on with your new ones here in front of the long mirror.'

The Emperor undressed, and the swindlers pretended to put his new clothes on him, one garment after another. They took him around the waist and seemed to be fastening something - that was his train-as the Emperor turned round and round before the looking glass.

'How well Your Majesty's new clothes look. Aren't they becoming!' He heard on all sides, 'That pattern, so perfect! Those colors, so suitable! It is a magnificent outfit.'

Then the minister of public processions announced: 'Your Majesty's canopy is waiting outside.'

'Well, I'm supposed to be ready,' the Emperor said, and turned again for one last look in the mirror. 'It is a remarkable fit, isn't it?' He seemed to regard his costume with the greatest interest.

The noblemen who were to carry his train stooped low and reached for the floor as if they were picking up his mantle. Then they pretended to lift and hold it high. They didn't dare admit they had nothing to hold.

So off went the Emperor in procession under his splendid canopy. Everyone in the streets and the windows said, 'Oh, how fine are the Emperor's new clothes! Don't they fit him to perfection? And see his long train!' Nobody would confess that he

couldn't see anything, for that would prove him either unfit for his position, or a fool. No costume the Emperor had worn before was ever such a complete success.

'But he hasn't got anything on,' a little child said.

'Did you ever hear such innocent prattle?' said its father. And one person whispered to another what the child had said, 'He hasn't anything on. A child says he hasn't anything on.'

'But he hasn't got anything on!' the whole town cried out at last.

The Emperor shivered, for he suspected they were right. But he thought, 'This procession has got to go on.' So he walked more proudly than ever, as his noblemen held high the train that wasn't there at all.



Be the child, don't lose your ability to observe, see the truth, trust your senses, and have the courage to freely speak it. Free speech means that you are not a free person unless you can freely say what you think!

Free speech is a foundation of a university. The University of Chicago (2014) put out a statement on free speech saying, "*In a word, the University's fundamental commitment is to the principle that debate or deliberation may not be*

suppressed because the ideas put forth are thought by some or even by most members of the University community to be offensive, unwise, immoral, or wrong-headed. It is for the individual members of the University community, not for the University as an institution, to make those judgments for themselves, and to act on those judgments not by seeking to suppress speech, but by openly and vigorously contesting the ideas that they oppose. Indeed, fostering the ability of members of the University community to engage in such debate and deliberation in an effective and responsible manner is an essential part of the University's educational mission."

While free speech is allowed at Cornell, many people do not feel comfortable in expressing their first amendment rights here. In a survey done by the Foundation for Individual Rights in Education (FIRE) Cornell received 15.1 out of 25 points in the comfort students feel in expressing their own thoughts to peers and professors. The Cornell Free Speech Alliance, is an independent organization advocating for free expression, viewpoint diversity, and academic freedom at Cornell University.



Let's not only look at the story of the *Emperor's New Clothes* in terms free speech but also in terms of "information," "misinformation", "disinformation", and "malinformation", as defined by the Cybersecurity & Infrastructure Security Agency on April 12, 2022.

Disinformation Stops With You

Bad actors spread disinformation to undermine democratic institutions and the power of facts. False or misleading information can evoke a strong emotional reaction that leads people to share it without first looking into the facts for themselves, polluting healthy conversations about the issues and increasing societal divisions.

Do your part to stop the spread of disinformation by practicing and sharing these tips.

Share

Recognize the Risk
Understand how bad actors use disinformation to shape the conversation and manipulate behavior.

Question the Source
Check who is really behind the information and think about what they gain by making people believe it.



Investigate the Issue
Search reliable sources to see what they are saying about the issue.

Think Before You Link
Take a moment to let your emotions cool and ask yourself whether your feelings about the content are based on fact.



Talk With Your Circle
Talk with your social circle about the risks of disinformation and how to respond when you see it.

Learn more at **www.cisa.gov/mdm-resource-library**

Who to follow

Trusted Sources Follow

Rely on official websites and verified social media for authoritative information.

Types of false info

Misinformation
is false, but not created or shared with the intention of causing harm.

Disinformation
is deliberately created to mislead, harm, or manipulate a person, social group, organization, or country.

Malinformation
is based on fact, but used out of context to mislead, harm, or manipulate.

Who spreads disinfo?

- Foreign States
- Scammers
- Extremist Groups

The Cybersecurity and Infrastructure Security Agency (CISA) produced this graphic to highlight tactics used by disinformation campaigns that seek to disrupt critical infrastructure in the United States. CISA's publication of information materials about this issue are intended for public awareness, and are not intended to restrict, diminish, or demean any person's right to hold, express, or publish any opinion or belief, including opinions or beliefs that align with those of a foreign government, are expressed by a foreign government-backed campaign, or dissent from the majority.

Disinformation Stops With You



Disinformation Stops with You | Recognize the Risk | Question the Source | Investigate the Issue | Think Before You Link | Talk With Your Circle

Recognize the Risk

Understand how malicious influencers use disinformation to shape the conversation and manipulate behavior. Once they've built an online presence, they start to post false or misleading content that steers their audience to more extreme positions and spreads to a bigger audience.

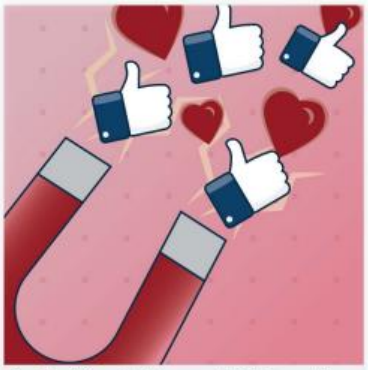
Learn more at www.cisa.gov/mdm-resource-library



Divide Us Bad actors use divisive societal issues to polarize Americans and push us into echo chambers that further amplify disinformation and obstruct healthy conversations about the issues.



Build a Following They may start to attract followers by posting entertaining, non-controversial content that appeals to their audience and builds trust before sharing disinformation.



Go Viral They'll often post disinformation as fun memes that are easy to share and get high engagement on social media, like captioned photos and GIFs. It may appear next to other entertaining content.



Amplify Coordinated campaigns spread disinformation across social media platforms, state-funded communication channels, and sometimes even official accounts, reaching far beyond the bad actor's immediate followers.



Make It Mainstream Even disinformation originally shared to a small audience can do huge damage when it is amplified, sometimes gaining mainstream media coverage that may lend it further credibility and a bigger audience.



Real World Effects Bad actors use online disinformation to affect our real-world behavior, like trying to influence how we vote, inciting physical confrontations, and disrupting healthy democratic discussions and participation.

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Disinformation Stops With You





Question the Source

Check who is really behind the information and think about what they gain by making people believe it. Disinformation is often designed to look authentic. Critically evaluate content to discern whether it's trustworthy.

Learn more at www.cisa.gov/mdm-resource-library



Check the Author Research the author's credentials. What else have they published? Are they qualified to cover the topic? If the content doesn't include an author's name, it might be disinformation.



Check the Date When was it published? Outdated content can lack important context, making it irrelevant to current events and misleading to someone reading it in the present.



Check the Message What is the content really saying? Disinformation often pushes a single viewpoint, takes an emotional tone, and uses attention-grabbing headlines that may not match the actual content.



Check for Facts Consider how the author supports their arguments and whether they address counterarguments. Opinions without evidence may not be accurate. Trustworthy fact-checking sites can help evaluate claims.



Check the Sources Credible content will cite supporting sources and provide additional resources for more information. Click on source links to make sure they work and support the content.



Check the Quality Disinformation is often hosted on low-quality websites. Look for signs, such as many ads; questionable sponsors; poor spelling, grammar, and punctuation; and suspicious URLs that mimic legitimate news sites.

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Disinformation Stops With You



Investigate the Issue

Search other reliable sources to see what they are saying about the issue. A thorough search will help make sure you that you are sharing accurate information. Don't share content if it isn't from a credible source or you can't find another credible source to confirm it.

Learn more at www.cisa.gov/mdm-resource-library



Is the Source Credible? Look at the site's "About" page to see whether it includes detailed information, such as its values, ownership, location, funding, and contact information.



What are Credible Sources Saying? Search the issue on trustworthy sites. If the facts reported by credible sources don't align with the content you're reviewing, don't share it.



What are Fact Checkers Saying? It's easy to believe things that confirm our views. If a claim seems too good to be true, see whether a trustworthy fact-checking organization has evaluated it and provided additional context.



Is Your Investigation Neutral? Make sure you are using unbiased search language and remain open-minded to evidence that might contradict your beliefs.



Does it Acknowledge Other Perspectives? Most hot-button issues are complicated. Although all authors have their own viewpoint, credible sources will recognize other perspectives and provide factual context around the issue.



Does it Provoke a Strong Reaction? If the content makes you feel shocked, angry, or sad, consider that its purpose may be to get you to respond emotionally and share it without confirming its accuracy.

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Disinformation Stops With You



Disinformation Stops with You



Recognize the Risk



Question the Source



Investigate the Issue



Think Before You Link



Talk With Your Circle



Think Before You Link

Take a moment to let your emotions cool and ask yourself whether your feelings about the content are based on fact. Disinformation is designed to evoke a strong emotional reaction that bypasses your critical thinking. You can interrupt the cycle of disinformation by taking time to research the content and reflect on whether sharing it would benefit the conversation.

Learn more at www.cisa.gov/mdm-resource-library



Know the Risk Sharing something you see online can seem harmless in the moment, but spreading disinformation can damage our ability to have meaningful conversations.



Know the Content Headlines and captions are often exaggerated to get an emotional response. Take time to read the entire post and determine whether they accurately reflect the content.



Know the Facts Investigate the issue being discussed. Check with trustworthy sources and fact checkers to verify the claims and make sure that they have not been taken out of context.



Know the Source Question who is really behind the content. Critically evaluate the credibility of the author and the legitimacy of the outlet by checking for facts, sources supporting the claims, and quality of the site.



Know Why You're Seeing It Social media algorithms promote content they think you will engage with, sometimes through specific targeting. If it was shared by a friend, make sure you trust the original source as much as the friend.



Know Yourself Ask yourself why you are sharing the content. People often share content that confirms their beliefs, even if it is untrue. If you wouldn't share it in person, don't share it online.



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Disinformation Stops With You



Talk With Your Circle

Talk with your social circle about the risks of disinformation and how to respond when you see it. It's probably not worth engaging with every piece of disinformation, but speaking up can help stop the spread. Do your research and share what you know with friends and family.

Learn more at www.cisa.gov/mdm-resource-library



Come Prepared Make sure you've done your homework and know the facts before starting a conversation. Even if you're sure it's disinformation, brush up on the latest evidence to be safe.



Decide If It's Worth It Once you have the facts, evaluate whether it's worth weighing in. Will your response help the conversation or cause conflict?



Respond Privately If you decide to respond, try doing so via direct message or even an offline conversation. Public comments can give disinformation more visibility and make discussions more confrontational.



Focus on the Facts If you do respond publicly, lead with the truth and don't repeat the false claim. Provide links to neutral, credible sources with more information about the issue.



Be Respectful Try to understand the beliefs of the person you're speaking with so you will be heard in return. It can be hard to change attitudes, but stay calm, positive, and empathetic to get your message across.



Be a Resource Stopping disinformation when you see it is important, but you can help friends and family build resilience to disinformation by proactively sharing resources and tips for doing their own fact-checking.

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Worried about disinformation? The Department of Homland Security is setting up a Disinformation Governence Board, and Nina Jankowicz has advice.

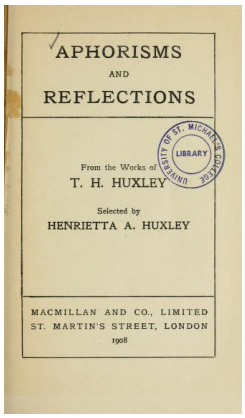
> — DHS is standing up a new Disinformation Governance Board to coordinate countering misinformation related to homeland security, focused specifically on irregular migration and Russia. **Nina Jankowicz** will head the board as executive director. She previously was a disinformation fellow at the Wilson Center, advised the Ukrainian Foreign Ministry as part of the Fulbright Public Policy Fellowship and oversaw Russia and Belarus programs at the National Democratic Institute. (h/t Daniel Lippman)

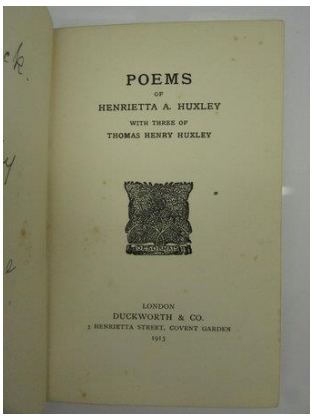


While the CISA recommends talking with your social circle to discern the difference between information, misinformation, disinformation, and malinformation, I recommend that you speak to people who do ***not*** think like you.

As I have said all semester, in science, it is healthy to have diverse points of view. It says in a book entitled, *Aphorisms and Reflections*, complied by T. H. Huxley's wife **Henrietta**, "***There is assuredly no more effectual method of clearing up one' s own mind on any subject than by talking it over, so to speak, with men of real power and grasp, who have considered it from a totally different point of view***."







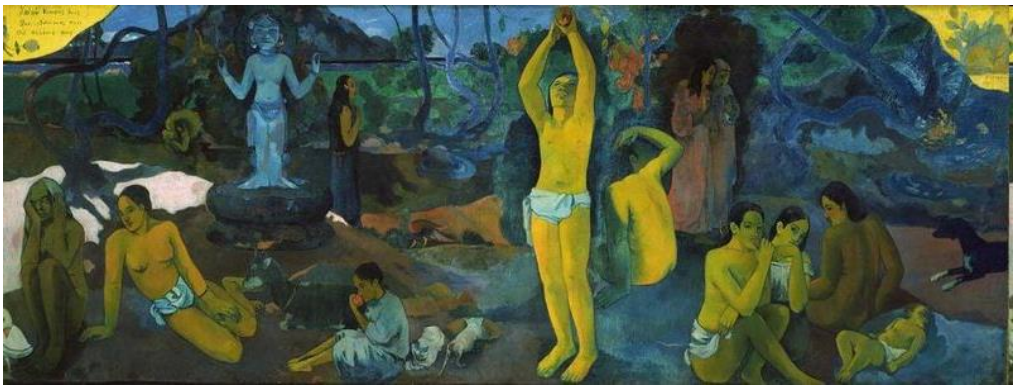
Let me repeat:

"***There is assuredly no more effectual method of clearing up one' s own mind on any subject than by talking it over, so to speak, with men of real power and grasp, who have considered it from a totally different point of view***."

As it says in Proverbs 27:17, ***As iron sharpens iron, so one person sharpens another***.

Think Critically and make your arguments in ***good faith***!

What is Life? and What is Light?



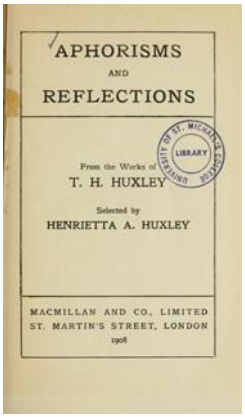


Science is a way of looking at the world around us in order to make sense of who we are, where we came from, and to help us understand and plan where we are going. **Erwin Schrödinger** stated that the value of natural science "*is the command of the Delphic deity…get to know yourself."* The science of biology is an analysis of the question, **what is life?** The science of physics is to a large extent an analysis of the question, **what is light?** We will look at these two questions to see the value as well as the limitations of the **scientific method** in understanding the true nature of the world around us and our place in that world.

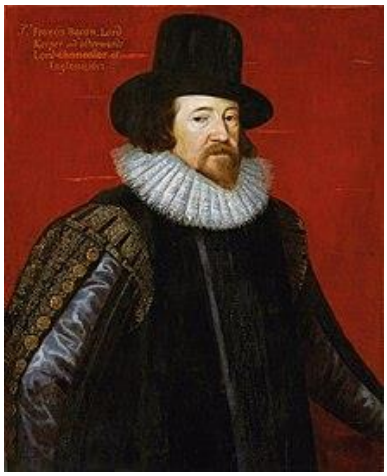


Science was never meant to ***replace*** the truth. Science is a ***method*** to ***search*** for the truth, while recognizing that knowing the complete, absolute, and objective truth is something that can never be obtained. The never-ending pursuit of truth requires courage. "*Courage*," according to Atticus Finch in Harper Lee's (1960) *To Kill a Mockingbird*, "*is when you know you're licked before you begin but you begin anyway and you see it through no matter what. You rarely win, but sometimes you do*."

Since the whole objective truth is never known, ***misinformation*** is mixed in with correct information and scientists of ***good faith*** must describe the ***limitations*** as well as the ***value*** of the ***evidence***, the ***analysis***, the ***interpretations***, and the ***conclusions***. ***Disinformation***, on the other hand, is when someone of ***bad faith*** who according to Sartre (1948) "*has chosen to devaluate words and reasons*" presents the science as the absolute, objective truth. Since science is presented to us in good faith and in bad faith, we need to live up to our specific epithet, *Homo sapiens*, and be wise. ***Wisdom*** is the ability to discern the true from the false—even without a misinformation governance board whose executive director is a great singer!

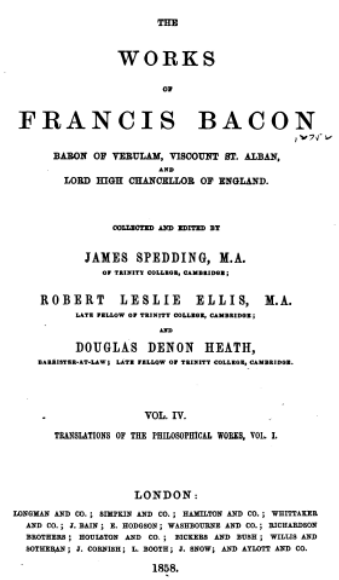


In science, it is healthy to have ***diverse points of view*** and ***groupthink*** leads to pathologies. It says in a book entitled, *Aphorisms and Reflections*, complied by T. H. Huxley's wife Henrietta, "***There is assuredly no more effectual method of clearing up one' s own mind on any subject than by talking it over, so to speak, with men of real power and grasp, who have considered it from a totally different point of view***."



Francis Bacon (1620), the counsel to Queen Elizabeth and a person who was known as the "father of experimental philosophy," if you do not count Robert Grosseteste and Roger Bacon, wrote a book entitled, *Novum Organum Scientiarum* (The New Instrument of Science), which presented the **inductive method**, as opposed to the deductive method, as the **scientific method** that provided the best way to **interpret nature** and find the truth about the natural world (http://www.sirbacon.org/baconidols.htm). Here is an excerpt.

Man, being the servant and interpreter of nature, can do and understand so much and so much only as he has ***observed in fact*** *or in* ***thought*** *of the course of nature: beyond this he neither knows anything nor can do anything.*


THE
WORKS
OF
FRANCIS BACON
BARON OF VERULAM, VISCOUNT ST. ALBAN,
AND
LORD HIGH CHANCELLOR OF ENGLAND.

COLLECTED AND EDITED BY
JAMES SPEDDING, M.A.
OF TRINITY COLLEGE, CAMBRIDGE;
ROBERT LESLIE ELLIS, M.A.
LATE FELLOW OF TRINITY COLLEGE, CAMBRIDGE;
AND
DOUGLAS DENON HEATH,
BARRISTER-AT-LAW; LATE FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

VOL. IV.
TRANSLATIONS OF THE PHILOSOPHICAL WORKS, VOL. I.

LONDON:
LONGMAN AND CO.; SIMPKIN AND CO.; HAMILTON AND CO.; WHITTAKER AND CO.; J. BAIN; R. HODGSON; WASHBOURNE AND CO.; RICHARDSON BROTHERS; HOULSTON AND CO.; BICKERS AND BUSH; WILLIS AND SOTHERAN; J. CORNISH; L. BOOTH; J. SNOW; AND AYLOTT AND CO.
1858.

Human knowledge and human power meet in one; for where the ***cause*** *is not known the* ***effect*** *cannot be produced. Nature to be* ***commanded*** *must be* ***obeyed****; and that which in contemplation is as the cause is in operation as the rule.*

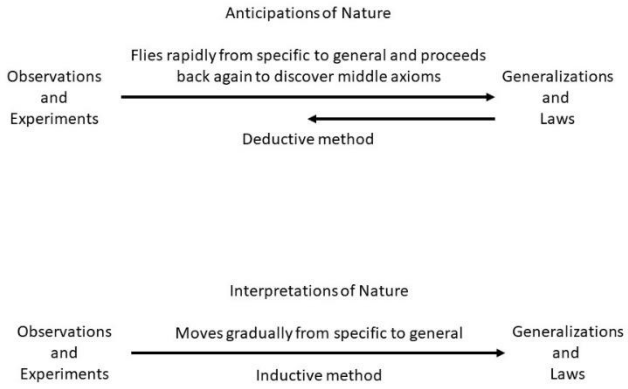
There are and can be only ***two ways*** *of* ***searching into and discovering truth. The one flies from the senses and particulars to the most general axioms, and from these principles, the truth of which it takes for settled and immovable proceeds to judgment and to the discovery of middle axioms! And this way*** [Deduction] ***is now in fashion. The other derives axioms from the senses and particulars, rising by a gradual and unbroken ascent, so that it arrives at the most general axioms last of all. This is the true way*** [Induction]***, but as yet untried****.*

The understanding left to itself takes the same course (namely, the former) which it takes in accordance with logical order. For the mind longs to spring up to positions of higher generality, that it may find rest there; and so after a little while wearies of ***experiment****. But this evil is increased by* ***logic****, because of the order and solemnity of its disputations.*

The understanding left to itself, in a sober, patient, and grave mind, especially if it be not hindered by received doctrines, tries a little that other way, which is the right one, but with little progress; since the understanding, unless

directed and assisted, is a thing unequal, and quite unfit to contend with the obscurity of things.

Both ways set out from the senses and particulars, and rest in the highest generalities; but the difference between them is infinite. For the one just ***glances*** *at* ***experiment and particulars*** *in passing, the other* ***dwells duly and orderly*** *among them. The one, again,* ***begins at once by establishing certain abstract and useless generalities****, the other* ***rises by gradual steps to that which is prior and better known in the order of nature****.*



The axioms now in use, having been suggested by a scanty and manipular [handful of] *experience and a few particulars of most general occurrence, are made for the most part just large enough to fit and take these in: and therefore it is no wonder if they do not lead to new particulars. And if some opposite instance, not observed or not known before, chance to come in the way, the axiom is rescued and preserved by some frivolous distinction; whereas the truer course would be to correct the axiom itself.*

The conclusions of human reason as ordinarily applied in matter of nature, I call for the sake of distinction ***Anticipations of Nature*** *(as a thing rash or premature). That reason which is elicited from facts by a just and methodical process, I call* ***Interpretation of Nature****.*

Anticipations are a ground sufficiently firm for consent; for even if men went mad all after the same fashion, they might agree one with another well enough [consensus].

For the winning of assent, indeed, ***anticipations*** *are far more powerful than* ***interpretations****; because being collected from a few instances, and those for the most part of familiar occurrence, they straightway touch the understanding and fill the imagination; whereas interpretations on the other hand, being gathered here and there from very various and widely dispersed facts, cannot suddenly strike the understanding; and therefore they must needs, in respect of the opinions of the time, seem harsh and out of tune; much as the mysteries of faith do.*

In sciences founded on opinions and dogmas, the use of anticipations and logic is good; for in them the object is to command assent to the proposition, not to master the thing.

Though all the wits of all the ages should meet together and combine and transmit their labours, yet will no great progress ever be made in science by means of anticipations; because ***radical errors in the first concoction of the mind*** [assumptions] *are not to be cured by the excellence of functions and remedies subsequent* [e.g., epicycles].

It is idle to expect any great advancement in science from the superinducing and engrafting of new things upon old. ***We must begin anew from the very foundations****, unless we would* ***revolve forever in a circle*** *with mean and contemptible progress.*

The honour of the ancient authors, and indeed of all, remains untouched; since the comparison I challenge is not of ***wits or faculties****, but of* ***ways and methods****, and the part I take upon myself is not that of a* ***judge****, but of a* ***guide****.*

This must be plainly avowed: no judgment can be rightly formed either of my method or of the discoveries to which it leads, by means of anticipations (that is to say, of the reasoning which is now in use); since I cannot be called on to abide by the sentence of a tribunal which is itself on its trial.

Even to deliver and explain what I bring forward is no easy matter; for things in themselves new will yet be apprehended with reference to what is old.

It was said by Borgia of the expedition of the French into Italy, that they came with chalk in their hands to mark out their lodgings, not with arms to force their way in. I in like manner would have my doctrine enter quietly into the minds that are fit and capable of receiving it; for confutations cannot be employed, when ***the difference is upon first principles*** *and very notions and even upon forms of demonstration.*

One method of delivery alone remains to us; which is simply this: we must lead men to the particulars themselves, and their series and order; while men on their side must force themselves for awhile to lay their notions by and begin to familiarise themselves with facts.

The doctrine of those who have denied that certainty could be attained at all, has some agreement with my way of proceeding at the first setting out; but they end in being infinitely separated and opposed. For the holders of that doctrine assert simply that nothing can be known; I also assert that not much can be known in nature by the way which is now in use. ***But then they go on to destroy the***

authority of the senses and understanding [not so different from Orwell's 1984]***; whereas I proceed to devise and supply helps for the same***.

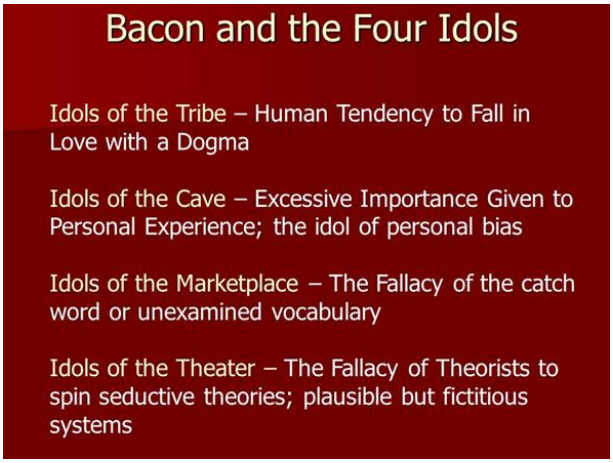
The idols and false notions which are now in possession of the human understanding, and have taken deep root therein, not only so beset men's minds that truth can hardly find entrance, but even after entrance obtained, they will again in the very instauration of the sciences meet and trouble us, unless men being forewarned of the danger fortify themselves as far as may be against their assaults.

There are four classes of Idols which beset men's minds. To these for distinction's sake I have assigned names,—calling the first class ***Idols of the Tribe****; the second,* ***Idols of the Cave****; the third,* ***Idols of the Market-place****; the fourth,* ***Idols of the Theatre****.*

The formation of ideas and axioms by true induction is no doubt the proper remedy to be applied for the keeping off and clearing away of idols. [See for yourself] *To point them out, however, is of great use; for the doctrine of Idols is to the Interpretation of Nature what the doctrine of the refutation of Sophisms is to common Logic.*

The Idols of the Tribe *have their foundation in* ***human nature*** *itself, and in the tribe or race of men. For it is a false assertion that* ***the sense of man is the measure of things****. On the contrary, all perceptions as well of the sense as of the mind are according to the* ***measure of the individual*** [which is why I teach you who said what] *and not according to the* ***measure of the universe****. And the human understanding is like a* ***false mirror****, which,* ***receiving rays irregularly, distorts and discolours*** *the nature of things by mingling its own nature with it.*

The Idols of the Cave *are the idols of the individual man. For every one (besides the errors common to human nature in general) has a cave* [Plato's Allegory of the Cave] *or den of his own, which* ***refracts and discolours the light of nature****; owing either to his own proper and peculiar nature; or to his* ***education*** *and conversation with others; or to the* ***reading of books****, and the* ***authority*** *of those whom he esteems and admires; or to the differences of impressions, accordingly as they take place in a mind preoccupied and predisposed or in a mind indifferent and settled; or the like. So that the spirit of man (according as it is meted out to different individuals) is in fact a thing variable and full of perturbation, and governed as it were by chance.* ***Whence it was well observed by Heraclitus that men look for sciences in their own lesser worlds, and not in the greater or common world****.*

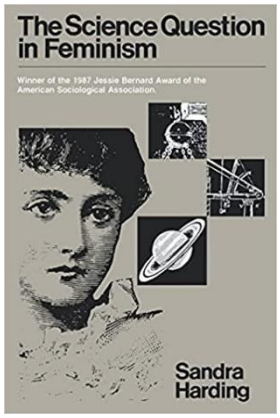


There are also Idols formed by the intercourse and association of men with each other, which I call ***Idols of the Market-place****, on account of the commerce and consort of men there. For it is by discourse that men associate; and words are imposed according to the apprehension of the vulgar* [Are terms such as time, space, species, origin of species, evolution, creation, chaos, life, racist, etc. used by scientists and Critical Theorists in the same way the public understands them?]. *And therefore* ***the ill and unfit choice of words wonderfully obstructs the understanding****. Nor do the definitions or explanations wherewith in some things learned men are wont to guard and defend themselves, by any means set the matter right. But words plainly force and overrule the understanding, and throw all into confusion, and lead men away into numberless empty controversies and idle*

fancies. [In Goethe's (1808) *Faust Part One*, Mephistopheles says, "*For at the point where concepts fail, At the right time a word is thrust in there. With words we fitly can our foes assail.*"]

Lastly, there are Idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call ***Idols of the Theatre****; because in my judgment all the received systems are but so many stage-plays, representing worlds of their own creation after an* ***unreal*** *and scenic fashion. Nor is it only of the systems now in vogue, or only of the ancient sects and philosophies, that I speak; for many more plays of the same kind may yet be composed and in like artificial manner set forth; seeing that errors the most widely different have nevertheless causes for the most part alike. Neither again do I mean this only of entire systems, but also of many principles and axioms in science, which by tradition, credulity, and negligence have come to be received.*

Psalm 115 describes and warns us about idols: "*But their idols are silver and gold, made by human hands. They have mouths, but cannot speak, eyes, but cannot see. They have ears, but cannot hear, noses, but cannot smell. They have hands, but cannot feel, feet, but cannot walk, nor can they utter a sound with their throats.* ***Those who make them will be like them, and so will all who trust in them***."

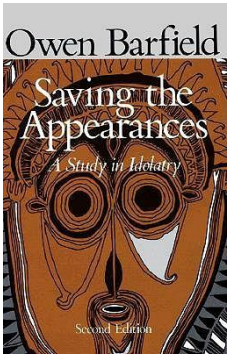


While I think that Francis Bacons' scientific method is important to understand what is true knowledge, Sandra Harding (1986), in *The Science Question in Feminism*, interprets Francis Bacon's scientific method as misogynistic or even that of a rapist. Harding writes, "*In a passage address to his monarch, Bacon uses bold sexual imagery to explain key features of the experimental method as the inquisition of nature:* 'For you have but to follow and as it were hound nature in her wanderings, and you will be able when you like to **lead and drive her afterward to the same place again….those holes and corners**, when the inquisition of truth is his whole object—as your majesty has shown in your own example'. *It might not be immediately obvious to the modern reader that this is Bacon's way of explaining the necessity of aggressive and controlled experiments in order to make the results of research replicable!...**There does, however, appear to be reason to be concerned about the intellectual, moral, and political structures of modern science when we think about how, from its very beginning, misogynous and defensive gender politics** and the abstraction we think of as scientific method have provided resources for each other. The severe hypotheses through controlled manipulations of nature, and the necessity of such controlled manipulations if experiments are to be repeatable, are here formulated by the father of scientific method in clearly sexist metaphors. **Both nature and inquiry appear conceptualized in ways modeled on rape and torture—on men's most violent and misogynous relationships to women—and this modeling is advanced as a reason to value science. It is certainly difficult to imagine women as an enthusiastic audience for these interpretations of the new science**."



According to me, this interpretation, like other post-modern interpretations based on the idea that there is no objective truth, and all knowledge is created by those in power to victimize others, is not true. You can read Bacon and Harding and make your own decisions.





Owen Barfield, a member of the Inklings along with C.S. Lewis, J. R. R. Tolkien, and others, reminds us to be aware of **idols** and to recognize the difference between nature itself and models of nature. We use our senses and indeed our common sense when we have direct **original participation** with nature**,** and we use our higher-level thinking when we see with the mind's eye nature in terms of models that cannot be directly experienced but render the observed phenomena calculable and predictable. Direct participation applies to the **appearances** of nature and the geometrical or mathematical models account for or "**save the appearances**" of nature. The observations (e.g., a rainbow or the positions of the planets) and models (e.g., water drops, refraction, and reflection, or the shapes and causes of the orbital motion) are both **figurations** that can be considered real or unreal, and, most importantly, the idea of which figuration is true is subject to change.



Most famously, **George Box** and Norman Draper (1987) wrote in *Empirical Model-Building and Response Surfaces*, "*... all models are approximations. **Essentially**, **all models are wrong, but some are useful**. However, the approximate nature of the model must always be borne in mind….*"

Barfield also reminds us that scientists often claim that the mathematical formulations are *merely tools* to account for or "save the appearances," yet they also claim that these tools provide the only valid description of reality. Barfield

(1957) writes in *Saving the Appearances: A study in Idolatry*, "***a representation, which is collectively mistaken for an ultimate—ought not to be called a representation. It is an idol***." Evolutionary theory, relativity theory, and quantum mechanics save the appearances, but are they representations of the ultimate truth?

According to Barfield, "*There is no 'science of sciences'; no unity of knowledge. There is only an accelerating increase in that pigeon-holed knowledge by individuals of more and more about less and less, which if persisted in indefinitely, can only lead mankind to a sort of '**idiocracy**' (in the original sense of the word)—a state of affairs, in which fewer and fewer representations will be collective, and more and more will be private, with the result that there will in the end be no means of communication between one intelligence and another*."

Barfield describes two coherent yet incompatible ways of thinking about the world, "*the familiar world which we see and know around us—the blue sky with white clouds in it, the noise of a waterfall or a motor-bus, the shapes of flowers and their scent, the gesture and utterance of animals and the faces of our friends—the world too, which (apart from the special inquiry of physics) experts of all kinds methodically investigate—is a system of collective representations. **The time comes when one must either accept this as the truth about the world or reject the theories of physics as an elaborate delusion. We cannot have it both ways***."

With a foundation of how to make sense of nature, let me ask, is it possible to come up with a **coherent** as opposed to a **discordant** theory of light and life within our scientific culture that brings enlightenment to the core existential questions?



Daniel Bell defines culture as "*the set of answers, **coherent** or discordant, the anguished responses to the significant questions of human existence*." "*Religion is a set of coherent answers to the core existential questions that confront every human group*." Should the set of answers presented as science be coherent or discordant? That is, would you prefer that science provide a **coherent set** or a **discordant set** of answers about the world in which we exist?

https://www.jstor.org/stable/pdf/20024766.pdf?refreqid=excelsior%3Acbff787f7409887eff7adf0a36f2e3d7

https://www.jstor.org/stable/pdf/589420.pdf?refreqid=excelsior%3Aeda16304640db31e8525f3713e8c2f91



Ravi Zacharias told the following story: "*In the early 1980s, sociologist Daniel Bell defined culture as 'the effort to provide a coherent set of answers to the existential questions that confront all human beings in the passage of their lives.' From what we cherish to what we abhor, from how we live to how we die, from what is sacred to what is profane, in each decision we try to make sense out of our lives. And culture is that sort of glue that holds our common values together.*

*Strangely, nowadays to understand culture even in those terms may well be outdated. I recall, for example lecturing at a university when a student stormed up to the microphone and bellowed, '**Who told you culture is a search for coherence?** Where do you get that idea from? This idea of coherence is a Western idea.'*

Rather surprised, I replied by reminding her that all I had done was present a sociologist's definition. 'Ah! Words! Just words!' she shouted back.

*'Let me ask you this then,' I pleaded with her. '**Do you want my answer to be coherent**?' At that moment, laughter rippled through the auditorium. She herself was stymied for a few moments. 'But that's language, isn't it?' she retorted.*

*So I asked her if language had anything to do with reality. 'Don't words refer to something?' I asked her. '**If you are seeking an intelligible answer from me, mustn't there be correspondence between my words and reality? How then can this basic requirement be met in our culture**?'*

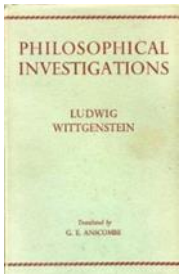
*Of course, this student is only reflecting **the spirit of thought among us today—no truth, no meaning, no certainty**. We now hear that language is detached from reality and truth detached from meaning. What we are left with is a way of thinking basically shaped by our appetites and by our proclivities, which is how life has become defined by our untamed passions. **Hence, incoherence is now normal**.*"

https://www.rzim.org/read/a-slice-of-infinity/words-bodies-and-spirit

https://www.rzim.org/listen/let-my-people-think/lifes-inescapable-questions-part-1

Aside: Ravi Zacharias has another great response to a philosophical question: He tells of a classic interaction between a student and a professor in a philosophy class. The student asks, **"How do I know I exist?"** and the professor answers, **"And whom shall I say is asking?"** By being able to ask a question and expect an answer from the person asked, the existence of the student is undeniable.

Remember what Ludwig Wittgenstein (1953) wrote about words that are used independent of their context, "For philosophical problems arise when language goes on holiday."



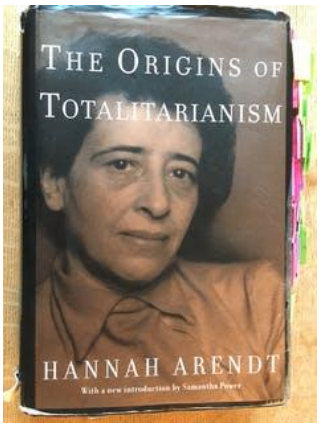
In the play, *The Whipping Man*, Mathew Lopez (2011) has Simon, a Jewish, Afro- American slave, say during Passover, a holiday that commemorates the escape of the Jews from Egyptian slavery, "*We talk with God, we wrestle with Him. Sometimes we even argue with Him. But we never stop asking, looking, hoping for answers. You don't lose your faith by not getting answers.* ***You lose your faith by not asking questions at all***."



Imagine you were wearing a **blue shirt** one day and each one of your five professors told you differently that your shirt was **red, orange, yellow, green, or violet**. Imagine also that each of them was going to give you a test with one question on it, "***What color is your shirt?***" Imagine how tiring it would be to remember the five incoherent and truthless answers that would be required for five different exams. It would be like wearing five yokes that were pulling you in different directions. Wouldn't it be more restful and meaningful to just wear the **yolk of truth**—where the yoke is easy, and the burden is light?



I remind you that **Hanna Arendt** (1996), wrote in *The Origins of Totalitarianism*, "***The ideal subject of totalitarian rule*** *is not the convinced Nazi or the convinced communist, but people for whom the distinction between fact and fiction (i.e., the reality of experience) and the distinction between true and false (i.e., the standards of thought) no longer exists*."

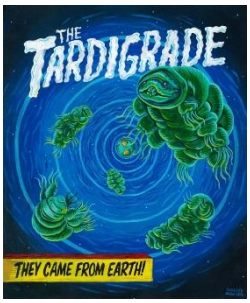


Let's come up with a coherent, meaningful, and scientific definition of life. **Life** can be **operationally defined** by a biologist as 1) the ability to **assimilate** matter and energy from the environment; 2) the ability to **transform** the environmental input into **usable energy** and **molecules**; 3) the ability to **expel toxic waste**; 4) the **ability to move**; 5) the **ability to sense** and **respond** appropriately to the environment, and 6) the ability to **reproduce hereditary** information with only **near perfect fidelity** so that species are able to **evolve** gradually by **natural selection** or in jumps by other mechanisms.

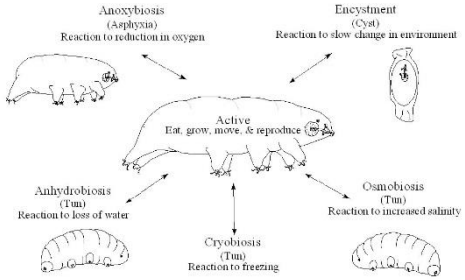


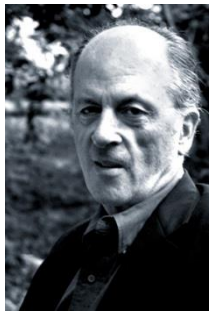
Note that each of these characteristics of life require **energy**. The relationship between the life processes and the immediate and ultimate sources of energy can be described by the **laws of thermodynamics**, which invokes a creator or by **Heisenberg's uncertainty principle**, which does not.

An operational definition is a suite of **measurable** quantities associated with a **meaningful** phenomenon, such as life, that cannot itself be directly measured *in toto*. The operational definition of life is **valuable** in that it is **general** and applies to almost any living creature and excludes most nonliving objects. It is also **valuable** in that it **reduces** the complexity of life into six essential processes—each of which can be studied based on the **assumption of materialism** and quantified using the laws of **physics** and **chemistry**.



However, there are **limits** as well as **value** to any operational scientific definition. If we do not see the limits of the current definition, we may conclude that an extremophile such as a **tardigrade** is not alive when it is in the midst of an extremely long period of dormancy during which it does not eat, does not grow, does not expel toxins, does not respond to the environment, and does not reproduce or evolve. There are intellectuals who I know that are so concerned with **accurately defining life** that they are not sure if they themselves are alive or not! When we sit with them for dinner, my wife Amy wonders, "*as long as they do not believe they are alive, why she can't have their dessert!"*





If something is not fundamentally real, it cannot be fundamentally meaningful. Norman Robert Campbell (1920), a physicist who was interested in the truth and meaning of science, reminds us in *The Philosophy of Theory and Experiment (Physics: The Elements)* that "*The meaning of a proposition—a phrase which I have often used without explaining it—is simply* ***the set of thoughts which it calls to mind****; the meaning of two propositions is different if they call up different thoughts. Now* ***it is meaning in this sense which alone is important to science****, and since it will be readily admitted that meaning in this sense has little or nothing to do with logical form, such form is of very little importance for science*."

Dismissing the reality of life because we cannot form a perfect and infallible mathematized or logical definition of life is acknowledging **the importance of the measurable over the meaningful** and an inability to recognize that we never have **complete information**, whether theoretical or observational, before we have to

make a decision. In my opinion, dismissing the reality of life is truly **missing the big picture**, **not seeing the forest for the trees**, and **throwing out the baby with the bathwater**. It also leads to an **incoherent** description of life. **Ferris Jabr** (http://ferrisjabr.com/Welcome.html), a science writer for *Scientific American* and *The New York Times*, two reputable outlets, captured the intellectual view:

The Opinion Pages | Op-Ed Contributor SCIENTIFIC AMERICAN™

Why Nothing Is Truly Alive **Why Life Does Not Really Exist**

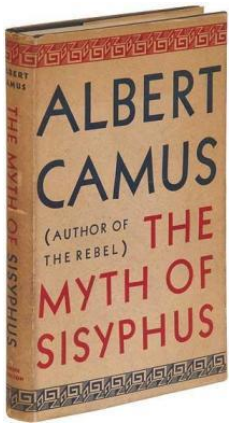
"*Recently, however, I had an epiphany that has forced me to rethink why I love living things so much and reexamine what life is, really. For as long as people have studied life they have struggled to define it.* ***Even today, scientists have no satisfactory or universally accepted definition of life****. While pondering this problem, I remembered my brother's devotion to K'Nex roller coasters and my curiosity about the family cat. Why do we think of the former as inanimate and the latter as alive? In the end, aren't they both machines? Granted, a cat is an incredibly complex machine capable of amazing behaviors that a K'Nex set could probably never mimic.* ***But on the most fundamental level, what is the difference between an inanimate machine and a living one? Do people, cats, plants and other creatures belong in one category and K'Nex, computers, stars and rocks in another? My conclusion: No. In fact, I decided, life does not actually exist***." http://blogs.scientificamerican.com/brainwaves/2013/12/02/why-life-does-not-really-exist/ Likewise, in a *New York Times* article, Zabr concludes "*Why is it so difficult for scientists to cleanly separate the living and nonliving and make a final decision about ambiguously animate viruses? Because they have been trying to define something that never existed in the first place. Here is my conclusion:* ***Life***

is a concept, not a reality*….****We must accept that the concept of life sometimes has its pragmatic value for our particular human purposes, but it does not reflect the reality of the universe outside the mind."***
http://www.nytimes.com/2014/03/13/opinion/why-nothing-is-truly-alive.html?_r=0

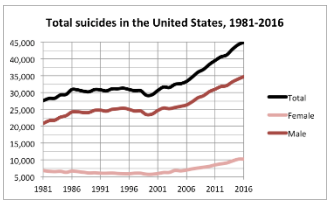
I wonder if Zabr, who assumes that George Berkeley's (1710) dictum, "ESSE is PERCIPI," to *be is to be perceived* even if it is not real is true, has life insurance.

If human life is not real, how can it possibly have meaning as an essential quality? If a life is not essentially meaningful and we exist, as atoms do, without being alive, why do we all agree that it is wrong to dismember a child but OK to take apart a K'Nex project? According to **existentialism**, **existence is prior to essence**. Consequently, **Søren Kierkegaard** (1813-1855) states that there is no eternal or external source of meaning and each individual is responsible for giving meaning to life and to live it in a way that does justice to the given meaning.

Absurdism is taking existentialism to the extreme in declaring that the world is **fundamentally meaningless and unintelligible**—devoid of eternal truths or values. Consequently, the search for meaning is futile and the only real problem, according to **Albert Camus** (1955), is whether or not to commit suicide. Camus concludes *The Myth of Sisyphus* like so: "*This universe henceforth without a master* ***seems*** *to him* [Sisyphus] *neither sterile nor futile. Each atom of that stone, each mineral flake of that night-filled mountain, in itself forms a world. The struggle itself toward the heights is enough to fill a man's heart. One must imagine Sisyphus happy.*"



Is it possible that the current increase in **suicides** has to do with the promotion of this philosophy?

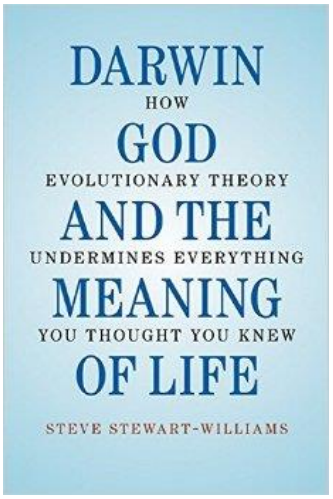


Evolutionary humanism also rejects the idea of the absolute and embraces the supremacy of the individual's mind. According to **Julian Huxley** (1961; *The Humanist Frame*), evolutionary humanism has "***nothing to do with Absolutes, including absolute truth, absolute morality, absolute perfection and absolute authority***," however, "*the evolution of mind or sentiency is an extremely* ***rare event in the vast meaninglessness of the insentient universe****, and man's particular brand of sentiency may well be unique. But in any case he* ***is highly significant****. He is a reminder of the existence, here and there, in the quantitative vastness of cosmic matter and its energy-equivalents, of a trend towards mind, with its accompaniment of quality and richness of existence; and, what is more, a proof of the importance of mind and quality in the all-embracing evolutionary process.*"



See the evolution of the Humanist Manifesto (I, II, and III): http://americanhumanist.org/Humanism/Humanist_Manifesto_III

Evolutionary humanism, which is existential, has evolved to a form of **nihilism**—the personal philosophy that existence has no meaning at all. According to Steve Stewart-Williams (2010) "*Darwin showed us that there is no reason to think that there is a teleological explanation for life. We are here because we evolved, and evolution occurred for no particular reason. Thus on a Darwinian view, not only is our species not as special as we had once thought, but* ***our lives are ultimately without purpose or meaning****. Life just winds on aimlessly, a*



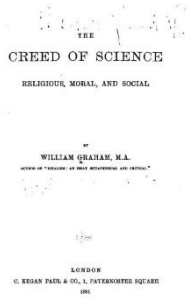
***pointless**, meandering sequence of events. Sometimes it's pleasant, sometimes not, but it lacks any overall purpose or goal or destination*."



It is understandable that Charles Darwin saw no meaning and purpose in life, especially after his beloved ten-year old daughter Annie, perhaps due to inbreeding depression, died on April 26, 1851, of scarlet fever. Here is an excerpt from a letter from Charles Darwin to Asa Gray (May 22, 1860); https://www.darwinproject.ac.uk/letter/DCP-LETT-2814.xml):

With respect to the theological view of the question; this is always painful to me.— I am bewildered.— I had no intention to write atheistically. ***But I own that I cannot see, as plainly as others do, & as I shd wish to do, evidence of design & beneficence on all sides of us. There seems to me too much misery in the world****. I cannot persuade myself that a beneficent & omnipotent God would have designedly created the Ichneumonidæ with the express intention of their feeding within the living bodies of caterpillars, or that a cat should play with mice. Not believing this, I see no necessity in the belief that the* ***eye*** *was expressly designed. On the other hand I cannot anyhow be contented to view this wonderful universe & especially the nature of man, & to conclude that everything is the result of brute force.* ***I am inclined to look at everything as resulting from designed laws, with the details, whether good or bad, left to the working out of what we may call chance.*** *Not that this notion at all satisfies me. I feel most deeply that the whole subject is too profound for the human intellect. A dog might as well speculate on the mind of Newton.— Let each man hope & believe what he can.—*

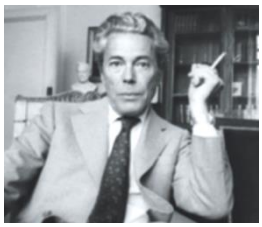
Certainly I agree with you that my views are not at all necessarily atheistical. The lightning kills a man, whether a good one or bad one, owing to the excessively complex action of natural laws,—a child (who may turn out an idiot) is born by action of even more complex laws,—and I can see no reason, why a man, or other animal, may not have been aboriginally produced by other laws; & that all these laws may have been expressly designed by an omniscient Creator, who foresaw every future event & consequence. But the more I think the more bewildered I become; as indeed I have probably shown by this letter.


THE
CREED OF SCIENCE
RELIGIOUS, MORAL, AND SOCIAL
BY
WILLIAM GRAHAM, M.A.
LONDON
C. KEGAN PAUL & CO., 1, PATERNOSTER SQUARE
1881

William Graham (1881) wrote in *The Creed of Science*, "*We repeat—the fatal defect in Darwinism, and in all the more or less systematic presentments that have lately been given of the whole doctrine of Evolution, whether by Spencer, Haeckel, Huxley, or Straub, is the* ***denial, express or by implication, of all and any purpose*** *or Final Cause in the universe.*"

Charles Darwin questioned whether a mind evolved by natural selection from the mind of lower organisms could be trustworthy. He wrote to **William Graham** on July 3, 1881: "*I hope that you will not think it intrusive on my part to thank you heartily for the pleasure which I have derived from reading your admirably written '****Creed of Science****,' ...You would not probably expect anyone fully to agree with you on so many abstruse subjects; and there are some points in your book which I cannot digest. The chief one is that the existence of so-called natural laws implies purpose. I cannot see this. Not to mention that many expect that the several great laws will some day be found to follow inevitably from some one single law, yet taking the laws as we now know them, and look at the moon, where the law of gravitation—and no doubt of the conservation of energy—of the*

atomic theory, &c. &c. hold good, and ***I cannot see that there is then necessarily any purpose.*** *Would there be purpose if the lowest organisms alone destitute of consciousness existed in the moon? But I have had no practice in abstract reasoning and I may be all astray.* ***Nevertheless you have expressed my inward conviction, though far more vividly and clearly than I could have done, that the Universe is not the result of chance. But then with me the horrid doubt always arises whether the convictions of man's mind, which has been developed from the mind of the lower animals, are of any value or at all trustworthy. Would any one trust in the convictions of a monkey's mind, if there are any convictions in such a mind?***"



Jacques Monod (1972) wrote in *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology*, "***Man at last knows that he is alone in the unfeeling immensity of the universe, out of which he emerged only by chance***. *Neither his destiny nor his duty have been written down. The kingdom above or the darkness below: it is for him to choose*."



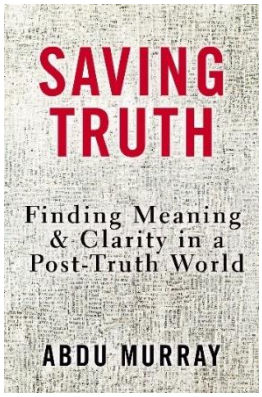
Scientists use **Occam**'s razor to justify the fundamental assumption of **scientism**, which is there is no God, and that **reality** consists only of matter and energy following the laws of **chance**. Ironically, for William of Occam, the only truly necessary entity was God, and everything else in the whole creation was contingent on Him (https://plato.stanford.edu/entries/ockham/).

Eric Voegelin (1948) describes the **scientistic creed** in his paper entitled, *The Origins of Scientism*. The scientific creed "*is characterized by three principle dogmas: (1) the assumption that the mathematized science of natural phenomena is a model science to which all other science ought to conform; (2) that all realms of being are accessible to the methods of the sciences of phenomena; and (3) that* ***all reality which is not accessible to sciences of phenomena is either irrelevant or, in the more radical form of the dogma, illusionary***."

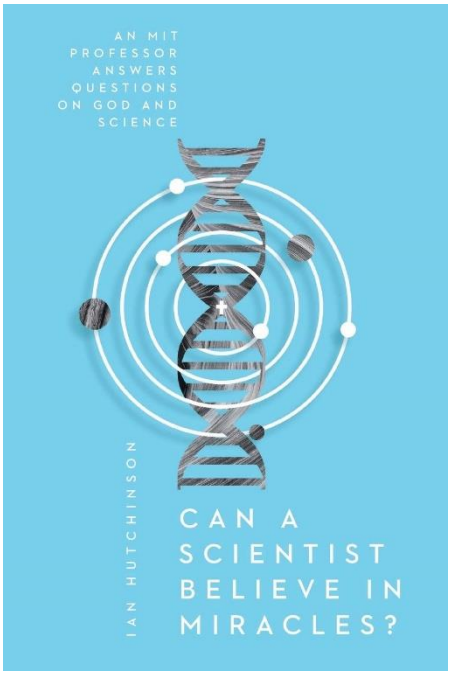


In her book, *Why I am an Atheist*, **Madalyn O'Hair** summed up the fundamental decision each person must make: "***Mind or matter, which came first?***" That is, is the mind of God the necessary cause of creation or is matter primary and our mind and the idea of God is just an **emergent property** of brain—matter; matter that came into being on its own. She went on to say, "*An A-theist is a materialist, a person who, simply is free from theism (religion)*." For me, the preponderance of the scientific evidence points to the Mind of God being prior to matter. Thus, I am not a materialist nor an atheist. You may weigh the evidence differently.

Abdu Murray (2018) wrote in ***Saving Truth***, "*Philosopher Alvin Plantinga brilliantly points out that belief in God isn't the enemy of science—naturalistic evolutionary theism is. He explains that* ***naturalistic evolution entails that our beliefs aren't based on whether they're true, but on how they help us survive and propagate our species. Thus, the truth or falsity of our beliefs, including those derived through science, is irrelevant. But science is supposed to be about the pursuit of truth. And if***



truth doesn't matter in atheistic evolution, then science isn't even possible. *Thus, we can't scientifically prove or rationally conclude that evolution actually happened*."

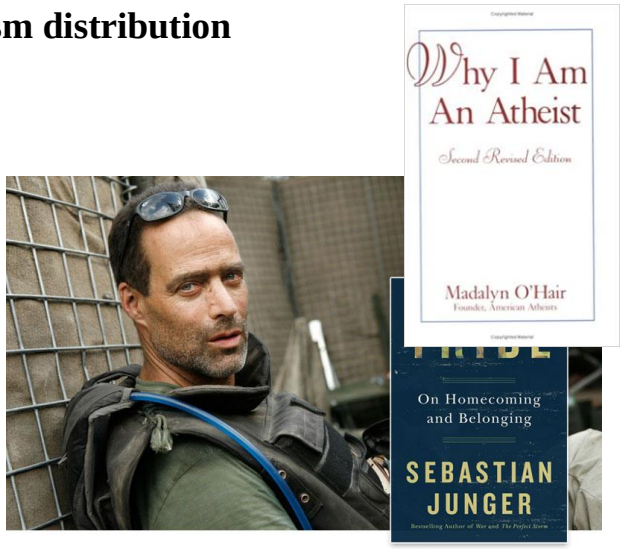


Ian Hutchinson (2018) wrote in *Can a Scientist Believe in Miracles?*, "*Essentially none of these academic believers seemed to feel compelled to contradict the scientific understanding of the universe with which I was familiar, and who details I was studying to master. It was not, therefore, that Christianity was agreed to be contradicted by science. If it had once been at war with science, science seemed to have won. Rather, the self-congratulatory attitude among the enlightened (including me) was that Christianity had been discovered to be irrelevant and outdated. Its commitment to past ideas was its problem, and those ideas had proven to be ineffective. Those of us who had escaped the religious trammels were free thinkers, finding out by our own efforts and intelligence what was really going on, not only in natural science but also across all academic disciplines.*

But I had as much difficulty with the enlightened attitude as I did with Christianity. ***It seemed pretty obvious that, despite the material benefits of science and technology, the secular society and academy was, if anything, doing a worse job at developing and sustaining the virtues that I valued: truth, integrity, rationality, compassion***."

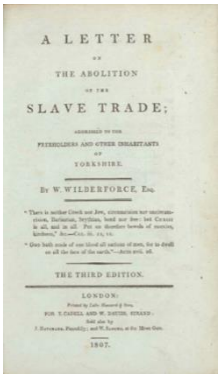
I want to emphasize that I have no doubt that each student is inherently special and has a life with meaning and purpose. I teach Light and Life as a course that fulfills a **science distribution requirement** that will enhance the virtues I

value not as one that would fulfill a **would-be scientism distribution requirement** that would diminish the virtues I value.



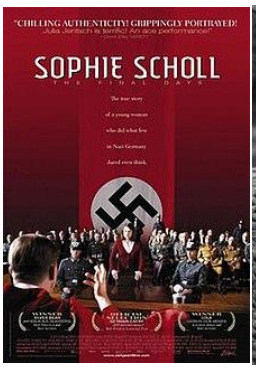
Sebastian Junger has an important perspective on the effect of returning to a society without purpose or meaning for a vet who has experienced purpose and meaning while watching out for and being watched out for by his or her fellow soldiers in war. https://www.vanityfair.com/news/2015/05/ptsd-war-home-sebastian-junger; https://www.ted.com/talks/sebastian_junger_why_veterans_miss_war/up-next





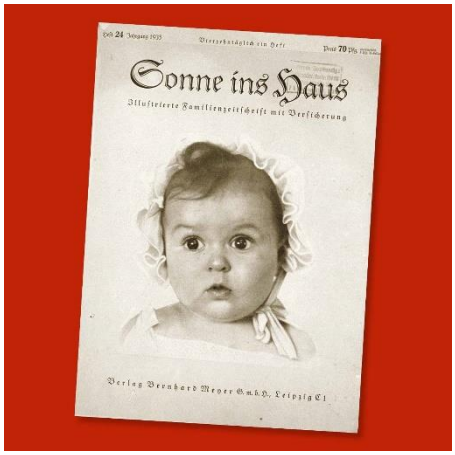
Is the meaning of life summarized by the *Struggle for Existence*, the title of the third chapter in Charles Darwin's (1859) book ***On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life***? I believe that human life has meaning beyond that of existence as **John Newton** acknowledged when he realized that (Genesis 1:26-27) "*God said, 'Let us make mankind in our image, in our likeness'….God created mankind in his own image, in the image of God he created them; male and female he created them*." With this realization, John Newton ceased to be a slave trader, wrote *Amazing Grace*, and influenced **William Wilberforce** to tirelessly shepherd two bills through Parliament—one that outlawed the slave trade and another that outlawed slavery itself in the British Empire.

What causes a man such as William Wilberforce to fight for the freedom of genetically unrelated people? What causes a biology major at the University of Munich like **Sophie Scholl** to speak freely, fight against the Nazis and defy Hitler, and "*not betray others to save her own **skin***" even if it meant that she would lose her head in a guillotine on February 22, 1943 when she was 21 years old?

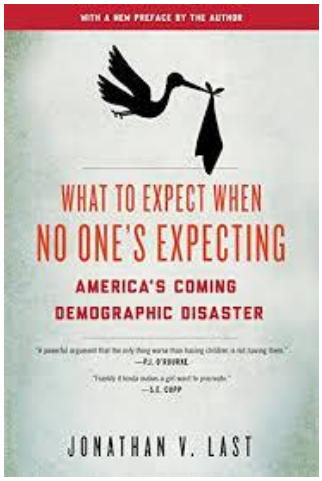




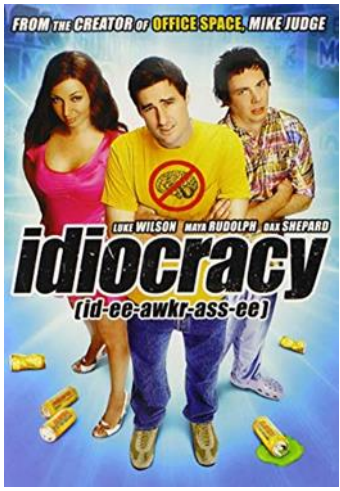
Aside: *Sonne ins Haus* ("Sun in the Home"), the Nazi family magazine held a competition that was arranged by Joseph Goebbels to find the perfect Aryan child, and on Jan. 24, 1935, they published a photograph of the winner on the front page. The judges didn't realize that the baby was Jewish. The photographer who submitted the picture wanted to make the Nazi's look foolish.



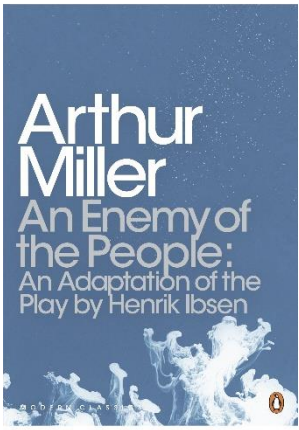
How does evolutionary theory that posits that the **purpose of life** is limited to the transmission of as many of our genes as possible to the next generation explain the actions of Wilberforce or Scholl? According to evolutionary theory, **fecundity is the most important indicator of fitness**. Is this part of a coherent theory? If so, why would people choose to go to college when, according to William E. Castle (1921), college-educated people are less evolutionarily fit than people who don't go to college? In his book entitled, *What To Expect When No One's Expecting: America's Coming Demographic Disaster*, Jonathan Last (2013) wrote, "*What we have, then, is a picture of an American middle class that is surprisingly*



barren ... Women who go to college or graduate school are unlikely to have even two children. ... It's a kind of ***reverse Darwinism*** *where the traditional markers of success make one less likely to reproduce*." While this statistic is a result of striving for gender equality (https://www.theatlantic.com/sexes/archive/2013/02/lets-not-panic-over-women-with-more-education-having-fewer-kids/273070/), could it lead to an **idiocracy** (https://archive.org/details/Idiocracy_201507)?



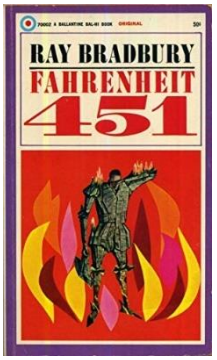
Who is the most fit to make the important decisions in society? Hendrik Ibsen (1882) wrote in *An Enemy of the People*:



> Dr. Stockmann: ***The worst enemy of truth and freedom in our society is the compact majority. Yes, the damned, compact, liberal majority….***
>
> Aslaksen: *As Chairman, I must request the speaker to withdraw his wild remarks.*
>
> Dr. Stockmann: *Not on your life…It is the* ***majority*** *here which is robbing me of my* ***freedom*** *and is trying to prevent me from* ***speaking the truth****.*
>
> Hovstad: ***The majority is always right!***
>
> Billing: *And it damn' well always stands for the truth too!*
>
> Dr. Stockmann: ***The majority is never right.*** *Never, I tell you! That's one of these lies in a society that no free and intelligent man can help rebelling against. Who are the people that make up the biggest proportion of the population—the intelligent ones or the fools?*



Is the minority the most fit to make decisions? Ironically, the **Chinese Communist Party** recently cancelled (https://www.nytimes.com/2018/09/13/world/asia/china-ibsen-play.html) a production of Ibsen's *An Enemy of the People*, reportedly because there was a hole in the stage. There may be a hole in the reasoning between an elite totalitarian government and the masses whose best interests it thinks it serves by limiting free, unofficial, and unsanctioned thought.



Ray Bradbury (1979) wrote in the Coda to *Fahrenheit 451*, "***There is more than one way to burn a book…****Fire-Captain Beatty, in my novel* Fahrenheit 451, *described how the books were burned first by minorities, each ripping a page or a paragraph from this book, then that, until the day came when the books were empty and the minds shut and the libraries closed forever*."

It has long been known how important reading is to freedom:

A Bill to Prevent All Persons from Teaching Slaves to Read or Write, the Use of Figures Excepted (1830)

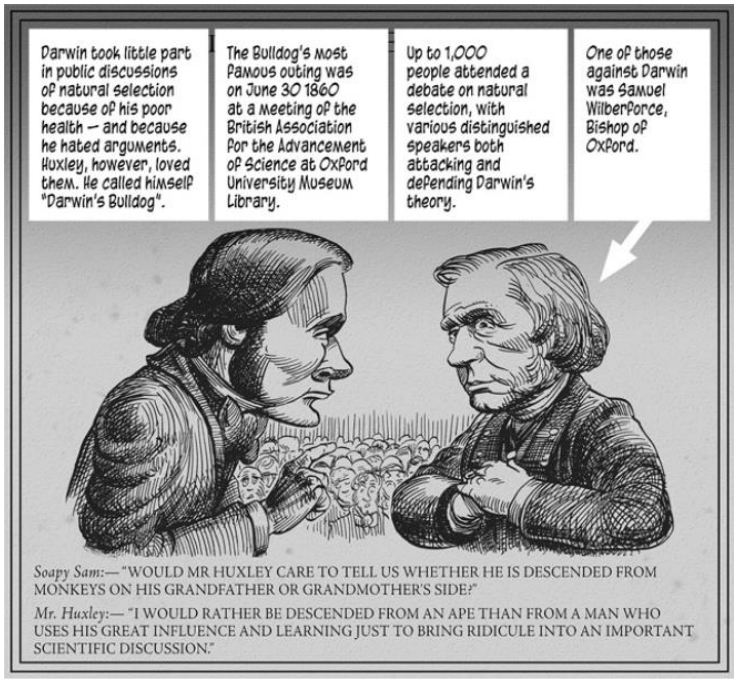
Whereas the teaching of slaves to read and write has a tendency to excite dissatisfaction in their minds and to produce insurrection and rebellion to the manifest injury of the citizens of this state: Therefore

Be it enacted by the General Assembly of the State of North Carolina, and it is hereby enacted by the authority of the same, that any free person who shall hereafter ***teach or attempt to teach any slave within this State to read or write,*** *the use of figures excepted, Shall be liable to indictment in any court of record in the State having jurisdiction thereof, and upon conviction shall at the discretion of the court if a white man or woman be fined not less than one hundred dollars nor more than two hundred dollars or imprisoned and if a free person of colour shall be*

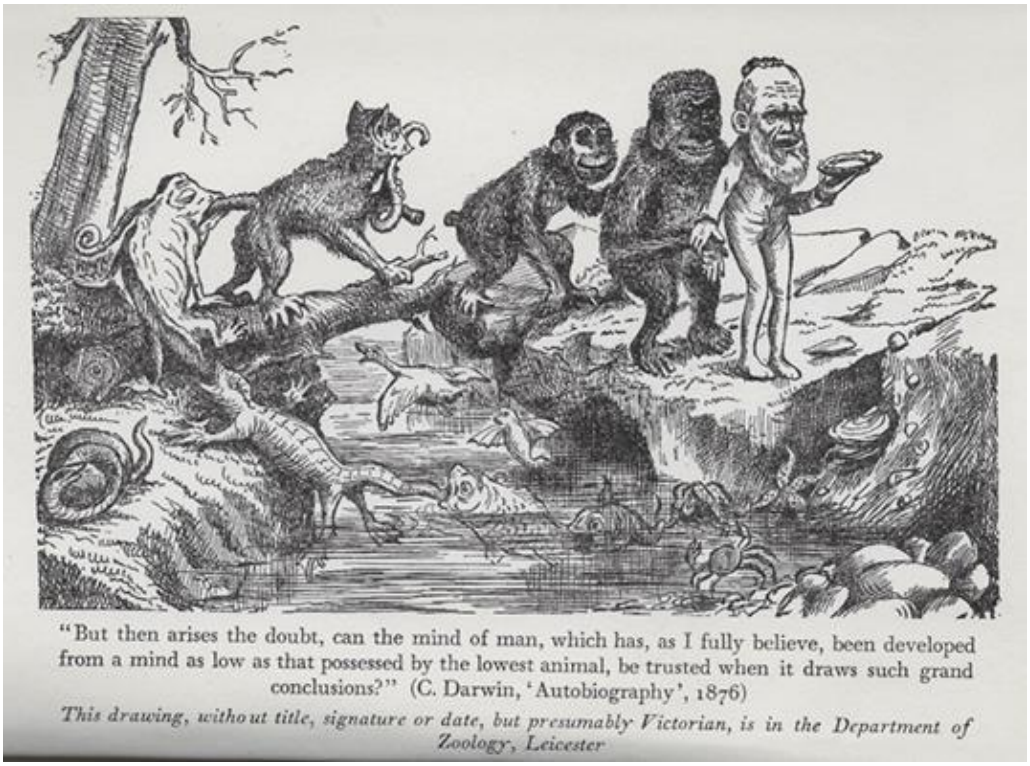
whipped at the discretion of the court not exceeding thirty nine lashes nor less than twenty lashes.

Be it further enacted that if any slave shall hereafter teach or attempt to teach any other slave to ***read or write*** *the use of figures excepted, he or she may be carried before any justice of the peace and on conviction thereof shall be sentenced to receive thirty nine lashes on his or her bare back.*

Could evolutionary theory, with its concept or concepts of fitness, be limited or incomplete? Could it explain what Francis Hutcheson called, the *Publick Sense* or human nature? Could there be something more than evolutionary theory in crafting a coherent theory of life? According to Julian Huxley (1960), No! However, **I offer William Wilberforce and Sophie Scholl as examples that there is a teleological explanation for life**. Samuel Wilberforce, William's son, who has been reduced by evolutionary biologists to "**Soapy Sam**," continued to fight against slavery in America and pointed out the relationship between slavery and evolutionary theory. Samuel Wilberforce (1860), who grew up with the responsibility to fight for the freedom of others wrote, "*man's gift of reason; man's free-will and responsibility; man's fall and man's redemption; the incarnation of the Eternal Son; the indwelling of the Eternal Spirit,—all are equally and utterly irreconcilable with the degrading notion of the brute origin of him who was created in the image of God*" in his review of ***On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life***.



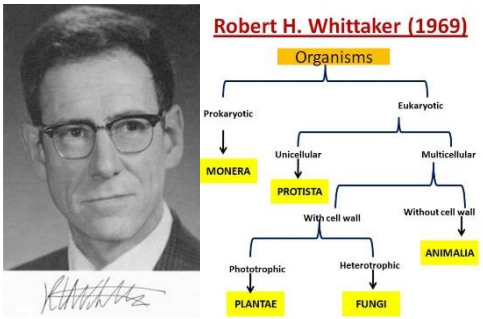
In his book, *Evolutionary Theory and Christian Belief: The Unresolved Conflict*, **David Lack** (1957) put together a Victorian pen and ink drawing found in the Department of Zoology, University College, Leicester with a sentence from Charles Darwin's (1876) autobiography that thoughtfully weighs the value of a theory developed by the mind of man that has evolved from the mind of the lowest animal.



"But then arises the doubt, can the mind of man, which has, as I fully believe, been developed from a mind as low as that possessed by the lowest animal, be trusted when it draws such grand conclusions?" (C. Darwin, 'Autobiography', 1876)

This drawing, without title, signature or date, but presumably Victorian, is in the Department of Zoology, Leicester

In the third edition of *Darwinism*, Alfred Russel Wallace (1912) wrote, "*I am glad to be able to quote the opinion of the late Professor Huxley in support of one of the more important arguments adduced in this chapter as to certain human faculties being such as could not have been developed by the agency of natural selection. Mr. Wilfred* [sic Wilfrid] *Ward (in the Nineteenth Century of August 1896) states, that Huxley one said to him: '**One thing which weighs with me against pessimism, and tells for a benevolent Author of the Universe, is, my enjoyment of scenery and music. I do not see how they can have helped in the struggle for existence. That are gratuitous gifts.***'"



I believe that bacteria (monera), protists, fungi, plants, animals, and human beings are alive—and the diversity between these groups requires different meanings of life in terms of **consciousness** and **conscience**. For example, plants are **conscious** in that they sense the environment (from the French *environer*, meaning to circle, to enclose, to surround) and use the information content of the environmental light to respond appropriately. There is a **unity** of life and Raoul Francé (1905) described plants as "*mankind in the making*." There is also a **diversity** in life and a difference between living plants and living humans is that living humans have a greater **consciousness** and strive **to understand** the external world and our place in that world.



Humans also have a **conscience—**a knowledge **within** oneself, an **inner light**, an **inner sense** of right and wrong, good and evil, a moral sense, **in**tegrity**, in**tention. Living humans also strive to understand our inner world—our "**invironment**." The **c**haracter of a human being is defined by a person's **c**onsciousness, **c**onscience, **c**redibility, and **c**ourage of **c**onvictions, and the natural state of a person is to be free to make **c**hoices—to live and let live.



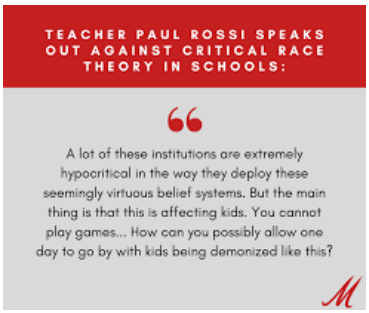
Aleksandr Solzhenitsyn (1973) wrote about the individual's conscience—the arbiter of good and evil as opposed to a group's conscience, which does not exist, in *The Gulag Archipelago*, "***If only there were evil people somewhere insidiously committing evil deeds, and it were necessary only to separate them from the rest of us and***

destroy them. But the line dividing good and evil cuts through the heart of every human being. And who is willing to destroy a piece of his own heart?

During the life of any heart this line keeps changing place; sometimes it is squeezed one way by exuberant evil and sometimes it shifts to allow enough space for good to flourish. One and the same human being is, at various ages, under various circumstances, a totally different human being. At times he is close to being a devil, at times to sainthood. But his name doesn't change, and to that name we ascribe the whole lot, good and evil."

Solzhenitsyn went on to say, "*Looking back, I saw that for my whole conscious life I had not understood either myself or my strivings. What had seemed for so long beneficial now turned out in actuality to be fatal, and I had been striving to go in the opposite direction to that which was truly necessary to me. But just as the waves of the sea knock the inexperienced swimmer off his feet and keep tossing him back on to the shore, so also was I painfully tossed back on dry land by the blows of misfortune. And it was only because of this that I was able to travel the path which I had always really wanted to travel.* ***It was granted me to carry away from my prison years on my bent back, which nearly broke beneath its load, this essential experience: how a human being becomes evil and how good. In the intoxication of youthful successes I had felt myself to be infallible, and I was therefore cruel. In the surfeit of power I was a murderer and an oppressor. In my most evil moments I was convinced that I was doing good, and I was well supplied with systematic arguments. And it was only when I lay there rotting on prison straw that I sensed within myself the first stirrings of good. Gradually it was disclosed to me that the line separating good and evil passes not through***

states, nor between classes, nor between political parties either - but right through every human heart - and through all human hearts. This line shifts. Inside us it oscillates with the years. And even within the hearts overwhelmed with evil, one small bridgehead of good is retained. And even in the best of all hearts, there remains…an un-uprooted small corner of evil. Since then I have come to understand the truth of all the religions on the world. They struggle with the evil inside a human being (inside every human being). It is impossible to expel evil from the world in its entirety, but it is possible to constrict it within each person*. And since that time I have come to understand the falsehood of all the revolutions of history: they destroy only those carriers of evil contemporary with them (and also fail, out of haste, to discriminate the carriers of good as well). And they take to themselves as their heritage the actual evil itself, magnified still more*."

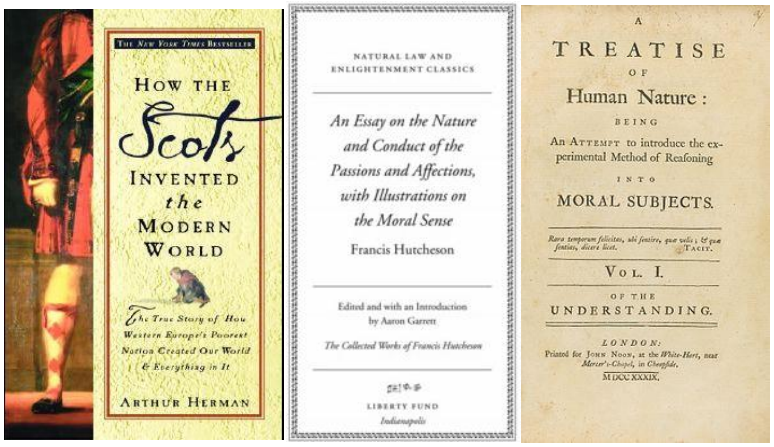


Critical Theory based on the **postmodernist** denial of Truth prioritizes group identity over individuality, and **impact** over **intent**—the external over the internal of the doer. It states that "*the impact of words and images perceived as racist — regardless of intent — is akin to 'using a gun or a knife to kill or injure someone.'*" Really? However, not saying or doing something when you thoughtfully and sincerely believe it to be true, and just going along to get along without being guided by one's conscience is soul destroying, encourages hypocrisy and performative cowardice instead of integrity and self-confidence. It prioritizes conformity to external pressure over individuality, prioritizes virtue signaling over character, and is an abdication of one's own moral agency.



Cornell likes to call itself the first American University, but in this *era* (which I see as an *error*) of critical theory, we have repudiated the concept of the American melting pot where individual ethnic, racial, and religious identity mix in a pluralistic society where each individual could find his or her uniqueness between the half-truth of pluralism and the half-truth of unity (*E pluribus unum*, the traditional motto of the United States). We have celebrated the concept of constructing two separate and unequal groups identified by critical theory as privileged and victimhood. Gone too is the sentiment of the modern motto of the United States, "*In God We Trust*". It is as if the motto of the postmodern or what Erwin Chargaff calls the post-rational university is "*In No Truth We Trust*". Is this the educational foundation of truth-lessness that we will use to teach students how to build bridges, treat disease, do scientific research, and solve mathematical problems?

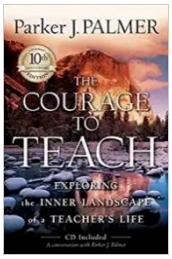
Psalm 15:1-2 asks and answers, "*O LORD, who shall sojourn in Your tent? Who shall dwell on your holy hill? He who walks blamelessly and does what is right and speaks the truth in his heart*."



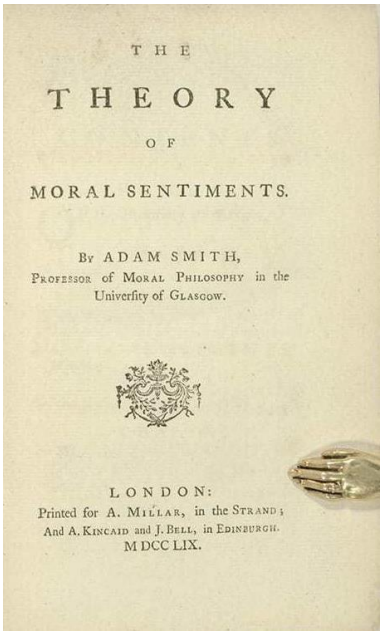
Two figures of the 18th century Scottish Enlightenment, **Francis Hutchison** and **David Hume**, proffered opposing views as to the source of morality. Hutchison believed that morality was an **inborn** gift from God, while Hume believed that there was a perpetual struggle between individual liberty and civil authority and consequently,

morality had to be **imposed by an outside authority** using a system of rewards and punishments. Hume but not Hutchison would be comfortable with Critical Theory and the new Disinformation Governance Board.

Here I want to distinguish between ***authority*** and ***power***—words that are easy to confuse, but they do not mean the same thing. According to Parker J. Palmer (2007) "***Power is no substitute for authority…The clue is in the word itself, which has* author *at its core. Authority is granted to people who are perceived as* authoring *their own words, their own actions, their own lives, rather than playing a scripted role at great remove from their own hearts. When teachers depend on the coercive powers of law or technique, they have no authority at all***."



In his *Theory of Moral Sentiments*, **Adam Smith** (1759) considered moral human beings to be by nature a divided self—the **spectator** and the **agent**—both inborn. Smith wrote, "*When I endeavor to examine my own conduct, when I endeavor to pass sentence upon it, and either to approve or condemn it, it is evident that, in all such cases, I divide myself, as it were, into two persons; and that I, the* ***examiner and judge****, represent a different character from that other I, the person whose conduct is examined into and judged of. The first is the judge; the second the person judged of. But that the judge should, in every respect, be the same with the person judged of, is as impossible, as that the cause should, in every respect, be the same with the effect.*"


THE
THEORY
OF
MORAL SENTIMENTS.

By ADAM SMITH,
Professor of Moral Philosophy in the
University of Glasgow.

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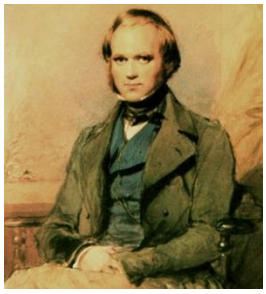
And A. Kincaid and J. Bell, in Edinburgh.
M DCC LIX.

Smith found common ground between Hutchison and Hume, writing, "*The wisdom of every state or commonwealth endeavours, as well as it can, to employ the force of the society to restrain those who are subject to its authority, from hurting or disturbing the happiness of one another. The rules which it establishes for this purpose, constitute the civil and criminal law of each state or country. The principles upon which those rules either are, or ought to be founded, are the subject of a particular science, of all sciences by far the most important, but hitherto, perhaps, the least cultivated, that of natural jurisprudence, concerning which it belongs not to our present subject to enter into any detail.* ***A sacred and religious regard not to hurt or disturb in any respect the happiness of our neighbour, even in those cases where no law can properly protect him, constitutes the character of the perfectly innocent and just man;*** *a character which, when carried to a certain delicacy of attention, is always highly respectable and even venerable for its own sake, and can scarce ever fail to be accompanied with many other virtues, with great feeling for other people, with great humanity and great benevolence. It is a character sufficiently understood, and requires no further explanation*." Smith attributes this character of the perfectly innocent and just man to the sacred. Could it be produced by natural selection?

Immanuel Kant (1788) wrote in ***The Critique of Practical Reason***, "***Two things fill the mind with ever new and increasing admiration and awe, the oftener and the more steadily we reflect on them: the starry heavens above and the moral law within***. *I have not to search for them and conjecture them as though they were veiled in darkness or were in the transcendent region beyond my horizon;* ***I see them before me and connect them directly with the consciousness of***



***my existence**. **The former begins from the place I occupy in the external world of sense, and enlarges my connection therein to an unbounded extent with worlds upon worlds and systems of systems, and moreover into limitless times of their periodic motion, its beginning and continuance. The second begins from my invisible self, my personality, and exhibits me in a world which has true infinity, but which is traceable only by the understanding, and with which I discern that I am not in a merely contingent but in a universal and necessary connection, as I am also thereby with all those visible worlds**. The former **view of a countless multitude of worlds annihilates as it were my importance as an animal creature**, which after it has been for a short time provided with vital power, one knows not how, must again give back the matter of which it was formed to the planet it inhabits (a mere speck in the universe). The second, on the contrary**, infinitely elevates my worth as an intelligence by my personality, in which the moral law reveals to me a life independent of animality and even of the whole sensible world**, at least so far as may be inferred from the destination assigned to my existence by this law, a destination not restricted to conditions and limits of this life, but reaching into the infinite.*"



I believe that it is reasonable to question the completeness of Charles Darwin's (1859, 1872) strictly **materialist** theory of evolution by **natural selection** or the **survival of the fittest** that states that **nature is red in tooth and claw** and that the **incessant and perpetual struggle for existence** gave rise **gradually** to the characters of human beings.

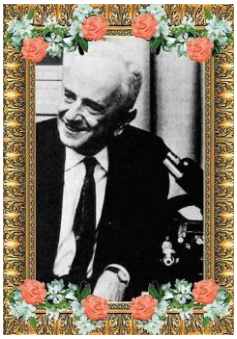


Alfred Russel Wallace (1869), cofounder of the theory of evolution by natural selection wrote, "*This subject is a vast one, and would require volumes for its proper elucidation**, but enough, we think, has now been said, to indicate the possibility of a new stand-point for those who cannot accept the theory of evolution as expressing the whole truth in regard to the origin of man**. While admitting to the full extent the agency of the same great laws of organic development in the origin of the human race as in the origin of all organized beings, there yet seems to be evidence of **a Power** which has guided the action of those laws in definite directions and for special ends. **And so far from this view being out of harmony with the teachings of science, it has a striking analogy with what is now taking place in the world, and is thus strictly uniformitarian in character.** Man himself guides and modifies nature for special ends. The laws of evolution alone would perhaps never have produced a grain so well adapted to his uses as wheat; such fruits as the seedless banana, and the bread-fruit; such animals as the Guernsey milch-cow, or the London dray-horse. Yet these so closely resemble the unaided productions of nature, that we may well imagine a being who had mastered the laws of development of organic forms through past ages, refusing to believe that any new power had been concerned in their production, and scornfully rejecting the theory that in these few cases a distinct intelligence had directed the action of the laws of variation, multiplication, and survival, for his own purposes. **We know, however, that this has been done; and we must therefore admit the possibility, that in the development of the human race, a Higher Intelligence has guided the same laws for nobler ends**.*

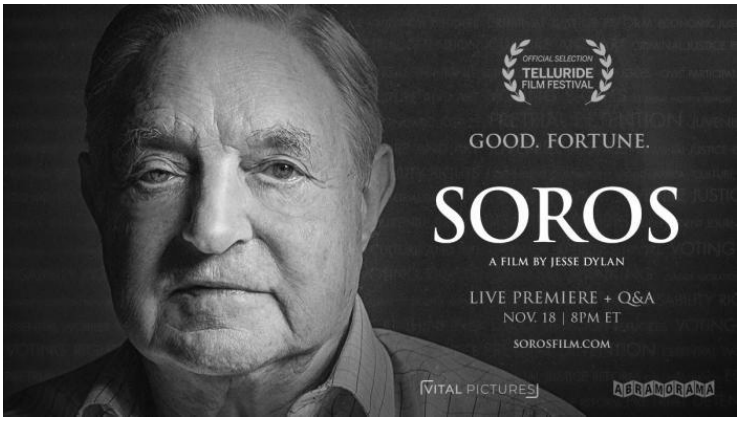
Such, we believe, is the direction in which we shall find the true reconciliation of Science with Theology on this most momentous problem. Let us

fearlessly admit that the mind of man (itself the living proof of a supreme mind) is able to trace, and to a considerable extent has traced, the laws by means of which the organic no less than the inorganic world has been developed. ***But let us not shut our eyes to the evidence that an Overruling Intelligence has watched over the action of those laws, so directing variations and so determining their accumulation, as finally to produce an organization sufficiently perfect to admit of, and even to aid in, the indefinite advancement of our mental and moral nature***."

Alfred Russel Wallace (1913) also said, "***Evolution can account well enough for the land-grabber, the company promoter, the trust, and the sweater, but it fails to account for Raphael and Wagner, Swedenborg, Newton, Florence Nightingale, or others of this character***." According to **Theodosius Dobzhansky** (1977), "*Altruism and heroism are possible only in a being which is free to choose a course of action…*. ***There is no way, at least no simple way, for natural selection to promote true altruism which is a freely elected way of behavior that benefits others at a detriment to the individual's own behavior***."

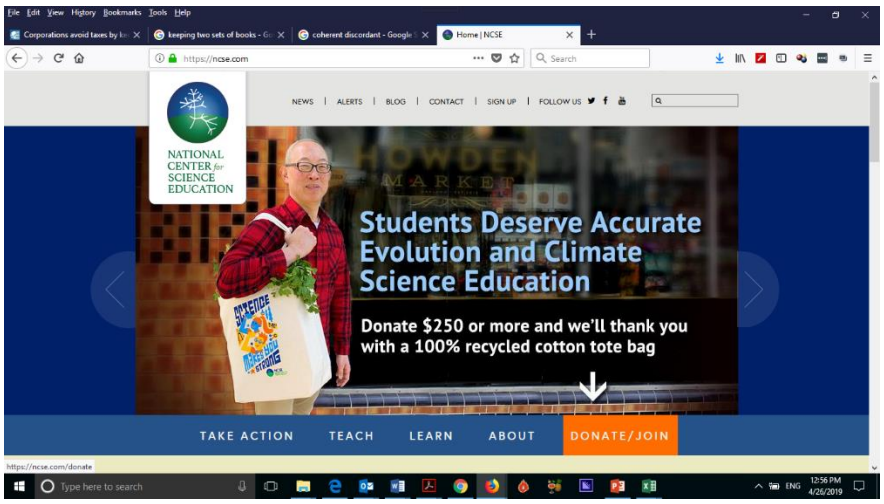


Read or watch an interview with **George Soros** to see how he wants to protect the world from people like George Soros. He describes how his "*character was made*" as a 14-year-old Jew posing as a Christian confiscating property from Jews in Nazi-occupied Budapest. He describes his adult character like so: "*I am basically there to—to make money. I cannot and*

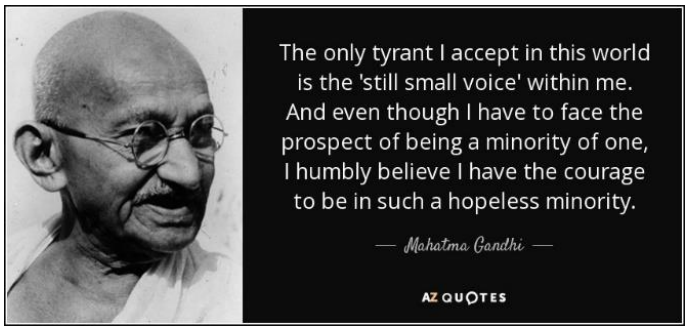


do not look at the social consequences of—of what I do." He sees himself as an altruist who sees laissez faire capitalism revered by the elite as a failed way of serving the public interest. Although according to him, money plays too big a role in politics and the world can be saved by Soros himself, who is ironically the man he wants to protect the world from.

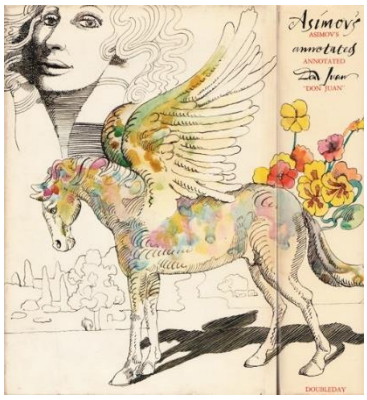
Samuel Wilberforce (1860) questioned whether Darwin's claims were supported by sufficient evidence; and Richard Owen (1860) questioned whether the gradualism that characterized Darwin's theory of the origin of species was sufficient for speciation. Is it good teaching practice to follow the recommendations of the **National Center for Science Education** (http://ncse.com/evolution/education/anti-evolutionism-classroom): "*A science teacher's professional responsibility is to teach science. Denigrating evolution or stating that 'some scientists reject evolution' misrepresents the mainstream, **consensus** view of the scientific community.*" This may be a condemnation of the mainstream consensus view, but I doubt it, since the NCSE (http://ncse.com/evolution/education/teach-controversy) believes that "*evolution should not be treated as controversial within a science class**. It is not scientifically controversial**, nor are resources for each side of comparable quality – evidence for evolution comes from peer-reviewed literature whereas evidence against evolution is built on flawed assumptions and popularized misconceptions*."



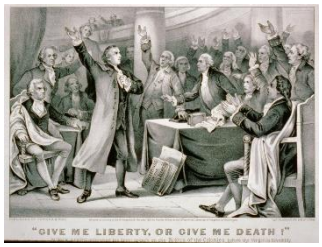
Likewise, based on a 1987 decision made by the U. S. Supreme Court in Edwards v. Aguillard, the *National Academy of Science* believes that Creation is a religious view and should not be taught in a science class (https://www.nap.edu/catalog/5787/teaching-about-evolution-and-the-nature-of-science; https://www.nap.edu/catalog/6024/science-and-creationism-a-view-from-the-national-academy-of; https://www.nap.edu/catalog/11876/science-evolution-and-creationism). I hope you don't mind that I, as a minority of one, made a scientific argument for creation based on the first law of thermodynamics. Therefore, I think that nonmaterialistic views can be discussed in a science class just as I think that science can discussed in classes that focus on the arts and humanities. After all, by definition, a **university** encompasses all **diversity** into **one unity**!!!!



Lord (George Gordon) Byron wrote in Canto XVII of **Don Juan**:



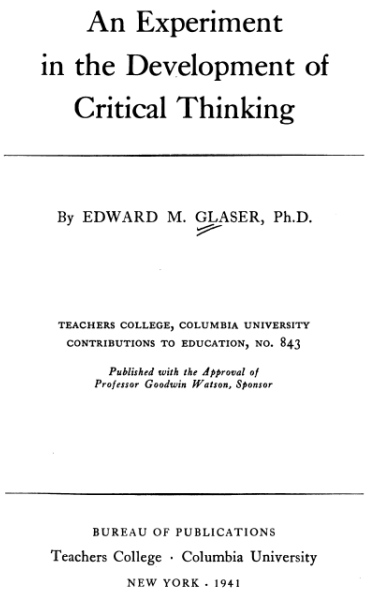
There is a commonplace book argument,
Which glibly glides from every vulgar tongue
When any dare a new light to present:
'If you are right, then everybody's wrong.'
Suppose the converse of this precedent
So often urged, so loudly and so long:
'If you are wrong, then everybody's right.'
Was ever everybody yet so quite?



Patrick Henry (March 23, 1775) in his *Give me Liberty or Give Me Death* speech stated that the "*freedom of the debate*" should be "*in proportion to the magnitude of the subject*." He went on to say, "*It is only in this way that we can hope to arrive at truth, and fulfill the great responsibility which we hold to God and our country*."

I believe that **defining evolution** and then teaching the **limitations** as well as the **value** of evolution helps develop critical thinking skills and a more coherent and penetrating science.

Edward M. Glaser (1941) wrote in *An Experiment in the Development of Critical Thinking*, "[t]*he ability to think critically…involves three things: (1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it and the further conclusions to which it tends. It also generally requires ability to recognize problems, to find workable means for meeting those problems, to gather and marshal pertinent information, to recognize unstated assumptions and values, to comprehend and use language with accuracy, clarity, and discrimination, to interpret data, to appraise evidence and evaluate arguments, to recognize the existence (or non-existence) of logical relationships between propositions, to draw warranted conclusions and generalizations, to put to test the conclusions and generalizations at which one arrives, to reconstruct one's patterns of beliefs on the basis of wider experience, and to render accurate judgments about specific things and qualities in everyday life.*


An Experiment
in the Development of
Critical Thinking

By EDWARD M. GLASER, Ph.D.

TEACHERS COLLEGE, COLUMBIA UNIVERSITY
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The development of ability to think critically, it should be noted, is not limited to cultivation of better methods for finding and testing evidence and meanings, and arriving at well-founded conclusions. Knowledge of the methods of logical inquiry is important. ***Even more important for the everyday practice of democracy, however, are the attitudes involved in critical thinking. Persons who have acquired a disposition to want evidence for beliefs, and who have acquired***

an attitude of reasonableness have also acquired some thing of a way of life which makes for more considerate and humane relationships among men."

Our **personal philosophy**, **worldview**, or **Weltanschauung** may determine how much evidence we require from science to explain the fundamental nature of the world we live in. Is the world a gift and "*the meek shall inherit the earth; and shall delight themselves in the abundance of peace*" as David wrote in Psalm 37 or is it better described by Charles Darwin who wrote to Joseph Hooker on July 13, 1856, "*What a book a devil's chaplain might write on the clumsy, wasteful, blundering low & horridly cruel works of nature!*"

David Gelernter (2019) wrote a thoughtful piece on questioning the worldview of Darwinism: https://www.claremont.org/crb/article/giving-up-darwin/.



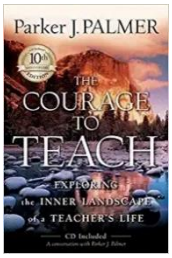
It is not easy or even profitable to think for yourself and not be compliant to the views of the elite. **Socrates** was put to death in 399 BC for being **politically incorrect**. His crime was that he thought for himself and encouraged others to do the same. Socrates said in the *Apology*, "***I must be frank with you…it seemed to me… that the people with the greatest reputations were almost entirely deficient, while others who were supposed to be their inferiors were much better qualified in practical intelligence***."

According to Brett Stephens (*Race and the Coming Liberal Jolt*, NYT April 27, 2021), "*Morally and philosophically, liberalism believes in* ***individual***

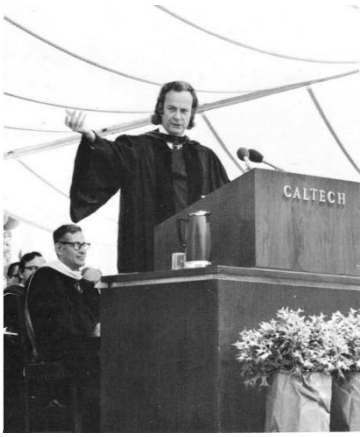
***autonomy**, which entails a concept of **personal responsibility**. The current model of anti-racism scoffs at this: It divides the world into racial identities, which in turn are governed by systems of privilege and powerlessness*."



If you ask me, for one to have a meaningful adult life, one must have purpose, love, integrity, courage and a thick **skin**, humility, perhaps a sense of humor, and the will to take personal responsibility for one's life. I think that one is defined more by one's individual character, defined by purpose, love, integrity, courage, and the way one handles personal responsibility that couples one's actions to one's beliefs. One's group identity or intersectionality is secondary at most to individuality, and virtue signaling, is a sign of cowardice.



According to Parker J. Palmer (2007), one's "[i]*dentity lies in the intersection of the diverse forces that make up* [one's] *life, and integrity lies in relating those forces in ways that bring* [one] *wholeness and life rather than fragmentation and death*."



Richard Feynman said in a [1974 commencement address] entitled ***Cargo Cult Science***, "*I have just one wish for you—the good luck to be somewhere where you are free to maintain the kind of integrity I have described, and where you do not feel forced by a need to maintain your position in the organization, or financial support, or so on, to lose your integrity. May you have that freedom*."

In response to the question "*What's the point of living with what we're going through here—having one war after another?*" from Marion Block, a freshman at Oberlin College (http://www.dbanderson.com/blog/MarionAnderson.pdf), Albert Einstein (1951) answered that in the human sphere, the answer is easy—"*to create satisfaction for ourselves and for other people*." He also said, that for the "*extra-human sphere the question has no meaning*."



April 28,1951

Miss Marion Block
May Cottage
Oberlin,Ohio

Dear Miss Block:

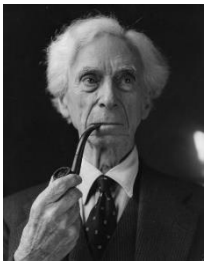
The question "Why" in the human sphere is easy to answer: to create satisfaction for ourselves and for other people. In the extra-human sphere the question has no meaning. Also the belief in God is no way out for in this case you may askä "Why God".

Sincerely yours,

A. Einstein.

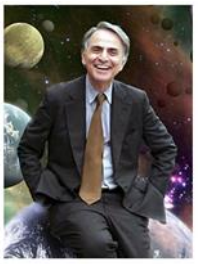
Albert Einstein.

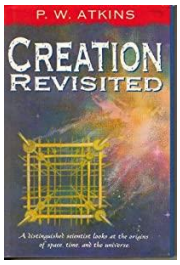
Is it meaningless to ask what is **the source** of the meaningful and defining characteristics of humans such as **conscience**—**the inner light**? Just because science can be used to create radios, TVs, nuclear bombs, smartphones, and genetically modified organism (GMOs) does not mean that science provides all the answers to all the questions. After all, whenever there is heartbreak or a disaster, we ask the artists and the clergy, not necessarily the scientists, to comfort us. Is this fact an ingredient in putting together a coherent theory of life? Artists and the clergy have provided us with meaning and value at a time when scientists have told us that **human beings are so insignificant**. While ordinary citizens are told by **Bertrand Russell** (1952) in an essay entitled, *Is there a God?* that "*If the universe had a Creator, it is hardly reasonable to suppose that He was specially interested in our little corner*;" by **Julian Huxley** (1960) in a paper entitled *Evolution in the High-School Curriculum* that we have "*been ousted from* [our] *self-imagined centrality in the universe to an infinitesimal location in a peripheral position in one of a million of galaxies*;" by **Carl Sagan** (1980) in his book *Cosmos*, that





we sit "*on an insignificant planet of a hum-drum star lost in a galaxy tucked away in some forgotten corner of a universe*;" by **Peter Atkins** (1992) in his book *Creation Revisited*, that "*man is not intrinsically significant…We live near a rather ordinary star which is a member if a rather ordinary galaxy somewhere insignificant in the puff of dust*;" and by **Lawrence Krauss** (2009; https://www.youtube.com/watch?v=7ImvlS8PLIo) that "*Our new picture of cosmology is that we live in a universe dominated by nothing…This tells us that we are more insignificant than we ever imagined…**We constitute a 1% bit of pollution** in a universe that is 30% dark matter and 70% dark energy. We are completely irrelevant*," in our secular society scientists have a **privileged position** and a special seat at the table—where the scientific answers that make up the tenets of **scientism** are considered to be **beyond question**.







Compare this sentiment with that of the **Apollo 8** astronauts, William Anders, James Lovell, and Frank Borman when they rounded the dark side of the moon and were the first humans to see the earth rise. William Anders said, "*We are now approaching lunar sunrise, and for all the people back on Earth, the crew of Apollo 8 has a message that we would like to send to you. In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light. And God saw the light, that it was good: and God divided the light from the darkness*."

James Lovell said: "*And God called the light Day, and the darkness he called Night. And the evening and the morning were the first day. And God said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were*

under the firmament from the waters which were above the firmament: and it was so. And God called the firmament Heaven. And the evening and the morning were the second day."

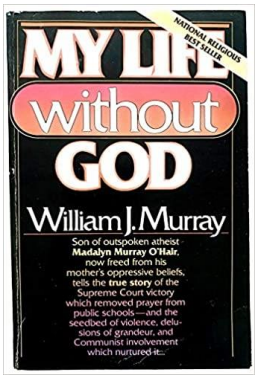




Frank Borman said: "*And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so. And God called the dry land Earth; and the gathering together of the waters called the Seas: and God saw that it was good. And from the crew of Apollo 8, we close with good night, good luck, a Merry Christmas – and God bless all of you, all of you on the good Earth*."



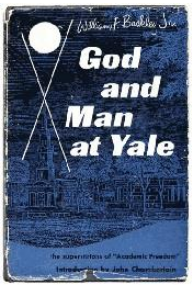
The sentiment was shared by King David when he wrote in Psalm 8, "*When I consider your heavens, the work of your fingers, the moon and the stars, which you have set in place, what is mankind that you are mindful of them, human beings that you care for them*?"



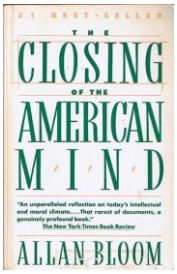
On the other hand, **Madalyn Murray O'Hair**, the founder of the American Atheists who successfully fought to have prayer removed from schools, sued to prevent NASA "*from doing any act whatsoever which restricts or abridges plaintiffs' freedom from religion and specifically enjoining NASA and its administrator and personnel from further directing or permitting religious activities, or ceremonies and especially the reading of the sectarian Christian religion Bible and from prayer recitation in space and in relation to all future space flight activity*." The US District Court for the Western

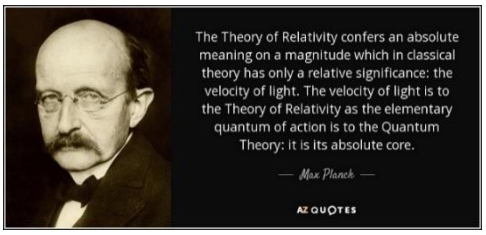
District of Texas (1969), as well as the U.S. Supreme Court (1970) dismissed the suit, but NASA was pressured to make space free from religion.

Students are typically taught scientism based upon the **false dichotomy** that science and the belief in God are mutually exclusive. But remember, scientists including, Robert Grosseteste, Roger Bacon, Galileo, Johannes Kepler, Isaac Newton, Robert Boyle, Joseph Priestley, Antoine Lavoisier, John Michell, Michael Faraday, James Clerk Maxwell, George Stokes, Lord Kelvin, James Joule, and Gregor Mendel did not find science and a belief in God mutually exclusive. Julian Huxley did away with absolutes, and his influence has had a profound and lasting effect on our culture.



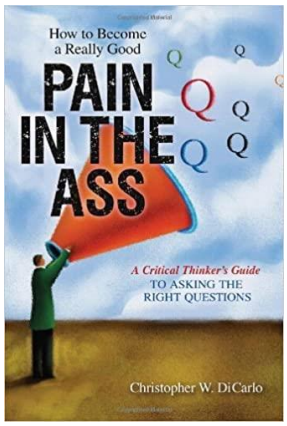
William F. Buckley Jr. (1951) wrote about this in *God and Man at Yale: The Superstitions of "Academic Freedom."* Buckley wrote, "*And there is surely not a department at Yale that is uncontaminated with* ***the absolute that there are no absolutes, no intrinsic rights, no ultimate truths***. *The acceptance of these notions…makes impossible any intelligible conception of an omnipotent, purposeful, and benign Supreme Being who has laid down immutable laws, endowed his creatures with inalienable rights, and posited unchangeable rules of human conduct*." In the *Closing of the American Mind*, **Allan Bloom** (1987; Cornell) wrote, "*There is one thing a professor can be absolutely certain of: almost every student entering the university believes, or says he believes, that* ***truth is relative***."

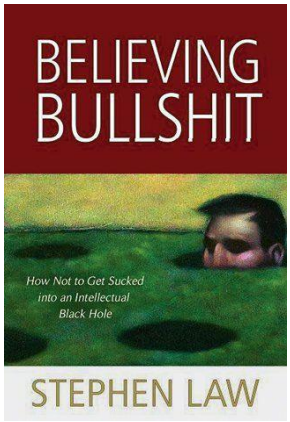




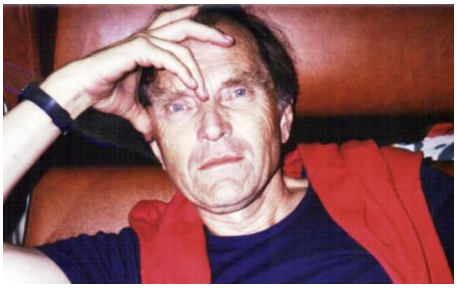
Is the speed of light in a vacuum (and perhaps other physical constants) the only things that are not relative?

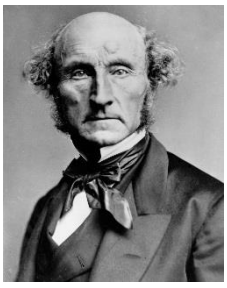
How to Become a Really Good Pain in the Ass: A Critical Thinker's Guide to Asking the Right Questions by Christopher DiCarlo (2011) and *Believing Bullshit* by Stephen Law (2011) are two books that are based on the assumption that science and a belief in God are mutually exclusive. Based on this assumption they teach one how to be "**unbiased**" and "**think critically**" by using scientific reasoning that they claim is not based on faith and authority. Read these books and ask yourself what fundamental assumptions are they basing their critical thinking upon? Are they unbiased? Can their views stand up to their own demands? I would say that they have dismissed a faith in Truth with a capital T for a fundamentalist's faith in Science with a capital S. Moreover, it is my impression that this faith in science may be based on Scientism and their faith in the authority of Scientists.



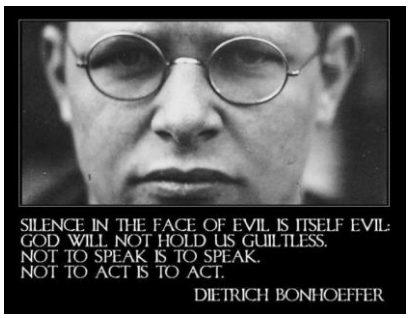


John Stuart Mill (1859) in "*On the Liberty of Thought and Discussion*" and **Paul Feyerabend** in "*How to Defend Society against Science*" remind us how important it is for a healthy science to ensure that nothing and no one is **beyond question**.





If we honestly look broadly and deeply at the great accomplishments of science, as I think we have in this course, it becomes clear that there are many places where there are gaps not only at the cutting edge, but also in the foundations of our scientific knowledge. **Henry Drummond** (1907) wrote in the *The Ascent of Man*, "*There are reverent minds who ceaselessly scan the fields of Nature and the books of Science in search of gaps—**gaps which they will fill up with God**. **As if God lives in gaps?....Nature is God's writing, and can only tell the truth; God is light, and in Him is no darkness at all***." Likewise, in a letter to Eberhard Bethge, **Dietrich Bonhoeffer** (1944) wrote, "*how wrong it is to use God as a stop-gap for the incompleteness of our knowledge. If in fact the frontiers of knowledge are being pushed further and further back (and that is bound to be the case), then God is being pushed back with them, and is therefore continually in retreat. We are to **find God in what we know, not in what we don't know***."

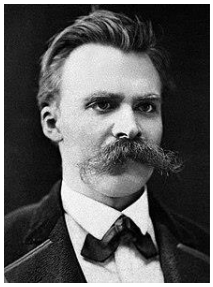


Charles Coulson (1958) wrote in *Science and the Idea of God*, "*The Christian God, at any rate, is no **God of the gaps**, though we have often been tempted to make Him so*."

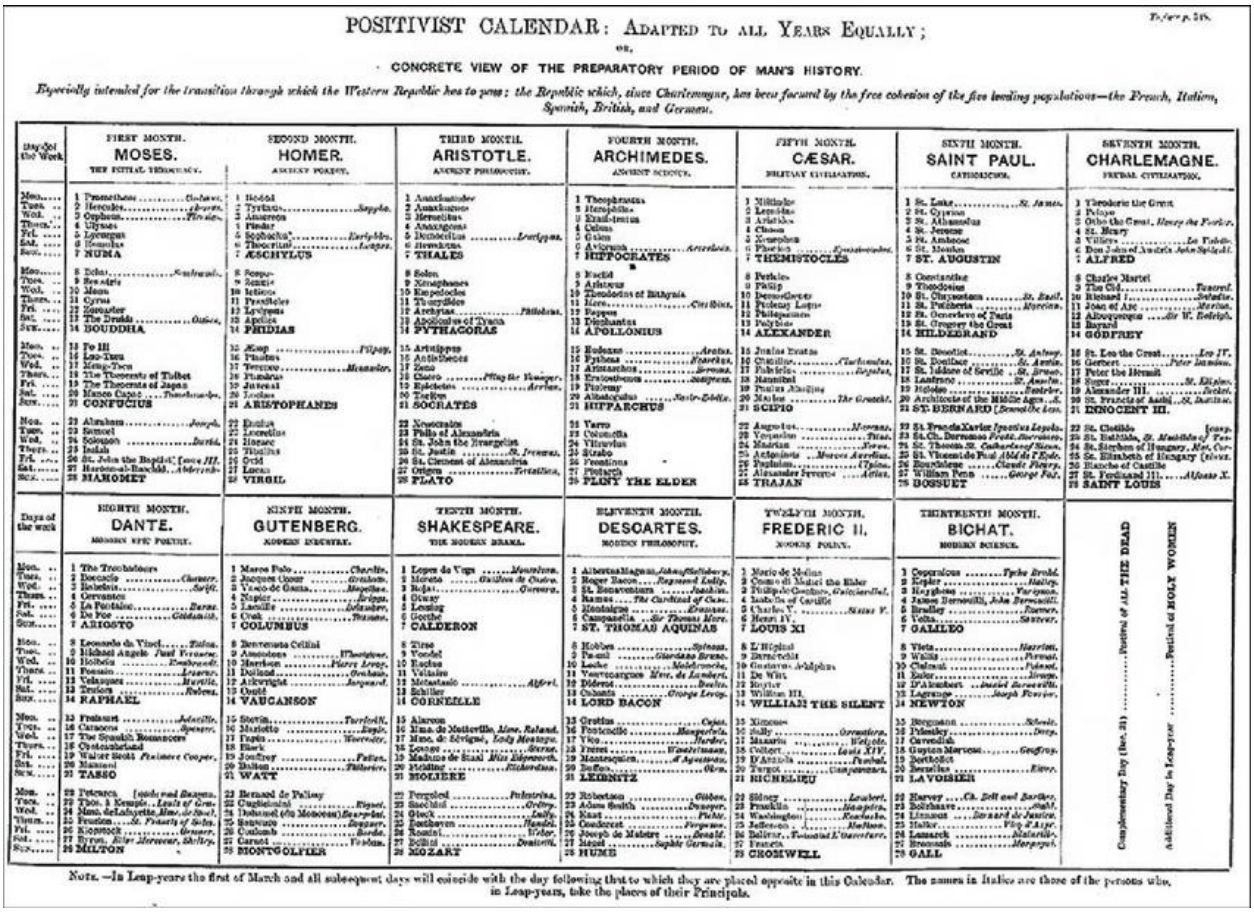


Auguste Comte and **Friedrich Nietzsche** have foundational roles in the development of the **scientism** accepted today where **materialism** and **relativism** are **celebrated** and the **supernatural** and **absolute** are **marginalized or eliminated** from so-called rational thinking. **Auguste Comte** believed that "*the discovery, or rather the proof, of the double movement of the earth constitutes the most important revolution in science belonging to the preliminary stage of human reason…it is by virtue of the earth's motion that the **Positive doctrine has come to***





be directly incompatible with all theological doctrine by making our largest speculations relative, whereas previously they had an absolute character."
Consequently, with such a relative world, **man became the measure of all things**.
Auguste Comte's (1848) **positivism** was a philosophical worldview that sought to improve social conditions necessary for the industrial society that formed in the aftermath of the French Revolution by creating a religion of humanity that replaced God with mathematical scientific formulas. Like any religion, the **Positivist Religion** would have a doctrine (*dogmé*), a moral code (*régime*), and a system of worship (*culte*) that would promote **altruism** (*altrusime*), a word coined by Comte. Scientists would be the spiritual authorities. Comte even produced a positivist calendar with 13 28-day months a year celebrating secular saints of philosophy and science:



POSITIVIST CALENDAR: ADAPTED TO ALL YEARS EQUALLY;

OR,

CONCRETE VIEW OF THE PREPARATORY PERIOD OF MAN'S HISTORY.

Especially intended for the transition through which the Western Republic has to pass: the Republic which, since Charlemagne, has been formed by the free cohesion of the five leading populations—the French, Italian, Spanish, British, and German.

Days of the Week	FIRST MONTH. MOSES. THE INITIAL THEOCRACY.	SECOND MONTH. HOMER. ANCIENT POESY.	THIRD MONTH. ARISTOTLE. ANCIENT PHILOSOPHY.	FOURTH MONTH. ARCHIMEDES. ANCIENT SCIENCE.	FIFTH MONTH. CÆSAR. MILITARY CIVILISATION.	SIXTH MONTH. SAINT PAUL. CATHOLICISM.	SEVENTH MONTH. CHARLEMAGNE. FEUDAL CIVILISATION.
Mon.	1 Prometheus	1 Hesiod	1 Anaximander	1 Theophrastus	1 Nitimbin	1 St. Luke	1 Theodoric the Great
Tues.	2 Hercules	2 Tyrtæus	2 Anaximenes	2 Heraclitus	2 Leonidas	2 St. Cyprian	2 Pelayo
Wed.	3 Orpheus	3 Anacreon	3 Heraclitus	3 Druid-Institu	3 Aristides	3 St. Athanasius	3 Otho the Great
Thurs.	4 Ulysses	4 Pindar	4 Anaxagoras	4 Celsus	4 Cimon	4 St. Jerome	4 St. Henry
Fri.	5 Lycurgus	5 Sophocles	5 Democritus	5 Galen	5 Xenophon	5 St. Ambrose	5 Villiers
Sat.	6 Hermilus	6 Thucydides	6 Herodotus	6 Archimedes	6 Phocion	6 St. Monica	6 Don John of Austria
Sun.	7 NUMA	7 ÆSCHYLUS	7 THALES	7 HIPPOCRATES	7 THEMISTOCLES	7 ST. AUGUSTIN	7 ALFRED
Mon.	8 Ichi	8 Sappo	8 Solon	8 Euclid	8 Pericles	8 Constantine	8 Charles Martel
Tues.	9 Sesostris	9 Sonnet	9 Xenophanes	9 Aristæus	9 Philip	9 Theodosius	9 The Cid
Wed.	10 Menu	10 Ictinus	10 Empedocles	10 Theodorius of Bithynia	10 Demosthenes	10 St. Chrysostom	10 Richard I
Thurs.	11 Cyrus	11 Pyrrhelyx	11 Thucydides	11 Hero	11 Ptolemy Lagus	11 St. Patricius	11 Joan of Arc
Fri.	12 Zoroaster	12 Lysippus	12 Archytas	12 Pappus	12 Philopœmen	12 St. Genevieve of Paris	12 Albuquerque
Sat.	13 The Druids	13 Apelles	13 Abolitionist of Tyrants	13 Diophantus	13 Polybius	13 St. Gregory the Great	13 Bayard
Sun.	14 BOUDDHA	14 PHIDIAS	14 PYTHAGORAS	14 APOLLONIUS	14 ALEXANDER	14 HILDEBRAND	14 GODFREY
Mon.	15 Fo Hi	15 Æsop	15 Aristippus	15 Hudoxus	15 Justus Erastus	15 St. Benedict	15 St. Leo the Great
Tues.	16 Leo Tseu	16 Phædrus	16 Antisthenes	16 Pythias	16 Cinnelius	16 St. Boniface	16 Gerbert
Wed.	17 Meng-Tseu	17 Terence	17 Zeno	17 Eudoxus	17 Fabricius	17 St. Isidore of Seville	17 Peter the Hermit
Thurs.	18 The Theorists of Tsi-Iet	18 Plautus	18 Cicero	18 Eratosthenes	18 Hannibal	18 Lanfranc	19 Roger
Fri.	19 The Theorists of Japan	19 Juvenal	19 Epicharis	19 Ptolemy	19 Pirrhus Xanthus	19 Ildefonso	20 Alexander III.
Sat.	20 Manco Capac	20 Lucian	20 Aristarchus	20 Athanasius	20 Marius	21 Archbishops of the Middle Ages	21 INNOCENT III.
Sun.	21 CONFUCIUS	21 ARISTOPHANES	21 SOCRATES	21 HIPPARCHUS	21 SCIPIO	22 ST. BERNARD	
Mon.	22 Abraham	22 Ennius	22 Xenocrates	21 Varro	22 Augustus	23 St. Francis Xavier	22 St. Clotilda
Tues.	23 Samuel	23 Lucretius	23 Philo of Alexandria	23 Columella	23 Vitruvius	24 St. Ch. Borromeo	23 St. Mathilda
Wed.	24 Solomon	24 Horace	24 St. John the Evangelist	24 Strabo	24 Mœcenas	25 St. Theresa	24 St. Stephen of Hungary
Thurs.	25 Indah	25 Tibullus	25 St. Justin	25 Frontinus	25 Antipatris	26 St. Vincent de Paul	25 St. Elizabeth of Hungary
Fri.	26 St. John the Baptist	26 Ovid	26 St. Clement of Alexandria	26 Pomponius	26 Paganism	27 Bourdaloue	26 Blanche of Castile
Sat.	27 Hariem-al-Raschid	27 Lucan	27 Origen	27 Plutarch	27 Alexander Severus	28 Claude Fleury	27 St. Ferdinand III.
Sun.	28 MAHOMET	28 VIRGIL	28 PLATO	28 PLINY THE ELDER	28 TRAJAN	29 BOSSUET	28 SAINT LOUIS

Days of the Week	EIGHTH MONTH. DANTE. MODERN EPIC POESY.	NINTH MONTH. GUTENBERG. MODERN INDUSTRY.	TENTH MONTH. SHAKESPEARE. THE MODERN DRAMA.	ELEVENTH MONTH. DESCARTES. MODERN PHILOSOPHY.	TWELFTH MONTH. FREDERIC II. MODERN POLITY.	THIRTEENTH MONTH. BICHAT. MODERN SCIENCE.	
Mon.	1 The Troubadours	1 Marco Polo	1 Lopez de Vega	1 Albertus Magnus	1 Mario de Molina	1 Copernicus	Festival of ALL THE DEAD
Tues.	2 Boccacio	2 Jacques Cœur	2 Moreto	2 Roger Bacon	2 Cosmo di Medici the Elder	2 Kepler	
Wed.	3 Beloheim	3 Vasco de Gama	3 Rojas	3 St. Bonaventura	3 Philippe de Comines	3 Hooghens	
Thurs.	4 Cervantes	4 Napier	4 Otway	4 Ramus	4 Isabella of Castile	4 James Bernoulli	
Fri.	5 La Pucelle	5 Lanskie	5 Lessing	5 Montaigne	5 Charles V.	5 Bradley	
Sat.	6 De Foe	6 Cook	6 Goethe	6 Campanella	6 Henri IV.	6 Vethe	
Sun.	7 ARIOSTO	7 COLUMBUS	7 CALDERON	7 ST. THOMAS AQUINAS	7 LOUIS XI	7 GALILEO	
Mon.	8 Leonardo da Vinci	8 Benvenuto Cellini	8 Tirso	8 Hobbes	8 L'Hopital	8 Vieta	
Tues.	9 Michael Angelo	9 Amontones	9 Vondel	9 Pascal	9 Barneveldt	9 Wallis	
Wed.	10 Holbein	10 Harrison	10 Racine	10 Locke	10 Gustavus Adolphus	10 Cassini	
Thurs.	11 Poussin	11 Dollond	11 Voltaire	11 Vauvenargues	11 De Witt	11 Euler	
Fri.	12 Velasquez	12 Arkwright	12 Metastasio	12 Diderot	12 Royer	12 D'Alembert	
Sat.	13 Teniers	13 Ouvid	13 Schiller	13 Chiarita	13 William III.	13 Lagrange	
Sun.	14 RAPHAEL	14 VAUCANSON	14 CORNEILLE	14 LORD BACON	14 WILLIAM THE SILENT	14 NEWTON	
Mon.	15 Poussin	15 Storin	15 Alarcon	15 Grotius	15 Ximenes	15 Bergmann	
Tues.	16 Canaletto	16 Mariotte	16 Lima de Mattercille	16 Fontenelle	16 Sully	16 Pylenkey	
Wed.	17 The Spanish Bourbons	17 Tapia	17 Mme. de Sévigné	17 Vico	17 Maurice	17 Cavendish	
Thurs.	18 Switzerland	18 Black	18 Lessay	18 Fenes	18 Colbert	18 Guyton Morveau	
Fri.	19 Walter Scott	19 Jouffroy	19 Madame de Staël	19 Montesquieu	19 D'Aranda	19 Berthollet	
Sat.	20 Manzoni	20 Dalton	20 Molière	20 Buffon	20 Turgot	20 Berzelius	
Sun.	21 TASSO	21 WATT	21 MOLIERE	21 LEIBNITZ	21 RICHELIEU	21 LAVOISIER	
Mon.	22 Petrarca	22 Bernard de Palissy	22 Pergolesi	22 Robertson	22 Sidney	22 Harvey	
Tues.	23 Thos. à Kempis	23 Cugliolmi	23 Bacchini	23 Adam Smith	23 Franklin	23 Dolebarre	
Wed.	24 Mme. de Lafayette	24 Mme. de Staël	24 Gluck	24 Kant	24 Washington	24 Linnæus	
Thurs.	25 Fenelon	25 Fenimore	25 Beethoven	25 Condorcet	25 Jefferson	25 Haller	
Fri.	26 Klopstock	26 Coulomb	26 Handel	26 Joseph de Maistre	26 Bolivar	26 Lamarck	
Sat.	27 Byron	27 Carnot	27 Bellini	27 Hegel	27 Broussais	27 Bichat	
Sun.	28 MILTON	28 MONTGOLFIER	28 MOZART	28 HUME	28 CROMWELL	29 GALL	Additional Day in Leap-year — Festival of HOLY WOMEN

NOTE.—In Leap-years the first of March and all subsequent days will coincide with the day following that to which they are placed opposite in this Calendar. The names in Italics are those of the persons who, in Leap-years, take the places of their Principals.

In *The Gay Science*, **Friedrich Nietzsche** (1882), who was influenced by Comte's positivist philosophy, wrote the **parable of the madman** who announced that **God is dead**:

"*Have you not heard of that madman who lit a lantern in the bright morning hours, ran to the market place, and cried incessantly: 'I seek God! I seek God!'—As many of those who did not believe in God were standing around just then, he provoked much laughter. Has he got lost? asked one. Did he lose his way like a child? asked another. Or is he hiding? Is he afraid of us? Has he gone on a voyage? emigrated? –Thus they yelled and laughed.*

The madman jumped into their midst and pierced them with his eyes. 'Whither is God?' he cried; 'I will tell you. We have killed him—you and I. All of us are his murderers. But how did we do this? How could we drink up the sea? Who gave us the sponge to wipe away the entire horizon? What were we doing when we unchained this earth from its sun? Whither is it moving now? Whither are we moving? Away from all suns? Are we not plunging continually? Backward, sideward, forward, in all directions? Is there still any up or down? Are we not straying, as through an infinite nothing? Do we not feel the breath of empty space? Has it not become colder? Is not night continually closing in on us? Do we not need to light lanterns in the morning? Do we hear nothing as yet of the noise of the gravediggers who are burying God? Do we smell nothing as yet of the divine decomposition? Gods, too, decompose. God is dead. God remains dead. And we have killed him.

*'How shall we comfort ourselves, the murderers of all murderers? What was holiest and mightiest of all that the world has yet owned has bled to death under our knives: who will wipe this blood off us? What water is there for us to clean ourselves***? What festivals of atonement, what sacred games shall we have to invent? Is not the greatness of this deed too great for us? Must we ourselves not become gods simply to appear worthy of it?** *There has never been a greater deed; and whoever is born after us—for the sake of this deed he will belong to a higher history than all history hitherto.'*

Here the madman fell silent and looked again at his listeners; and they, too, were silent and stared at him in astonishment. At last he threw his lantern on the ground, and it broke into pieces and went out. 'I have come too early,' he said then; 'my time is not yet. This tremendous event is still on its way, still wandering;

it has not yet reached the ears of men. Lightning and thunder require time; the light of the stars requires time; deeds, though done, still require time to be seen and heard. This deed is still more distant from them than most distant stars—and yet they have done it themselves.

It has been related further that on the same day the madman forced his way into several churches and there struck up his requiem aeternam deo. Led out and called to account, he is said always to have replied nothing but: 'What after all are these churches now if they are not the tombs and sepulchers of God?'"

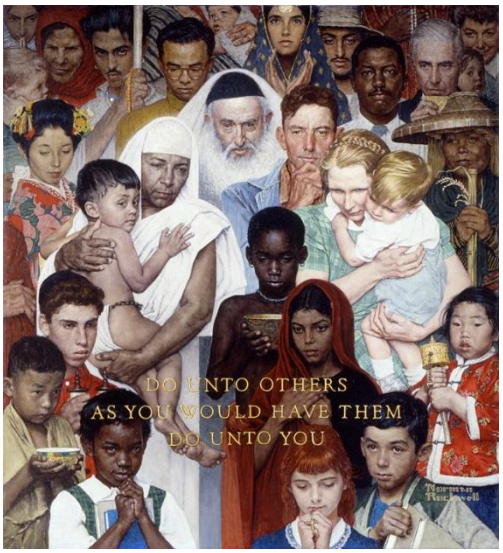
In science we fill the gaps with "**convenience unknowns**" and we have enough faith in the foundational "convenience unknowns" that we build a scientific edifice that is based on the assumption that the "convenience unknowns" are true and not just accepted by faith. Then scientists such as **Richard Dawkins**, author of *The God Delusion*, **Lawrence Krauss**, anti-theist and author of *A Universe from Nothing: Why There Is Something Rather Than Nothing* and *Why all scientists should be militant atheists*, **Stephen Hawking**, author of *The Grand Design*, Peter Atkins, author of *Creation Revisited*, **Victor Stenger**, author of *God: The Failed Hypothesis*, **Sam Harris**, author of *Letter to a Christian Nation* and *Free Will*, and many others (https://en.wikipedia.org/wiki/List_of_atheists_in_science_and_technology) tell us that not only is **science proof that God does not exist**, but having a faith in God is evil.



In an article entitled, *Is Science a Religion?* Dawkins declared, "***I think a case can be made that faith is one of the world's great evils, comparable to the smallpox virus but harder to eradicate***." Let's give value to science where it is due but let's also recognize its limitations—especially when there is **no need to mock** someone for their worldview when that worldview is based on faith as opposed to "convenience unknowns." Speaking of convenience unknowns, the electron is a convenience unknown. Has anyone ever seen an electron? The acceptance of the reality of an electron requires both **faith and reason**.

https://web.archive.org/web/20121030144700/
http://www.thehumanist.org/humanist/articles/dawkins.html

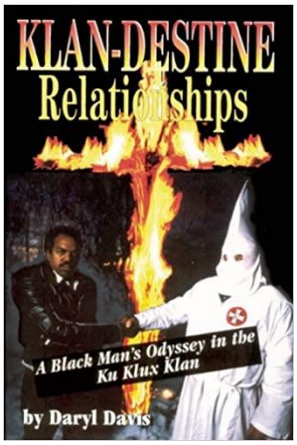




I believe that our behavior and the quality of our life depends on what we consider to be real and what we consider to be an illusion. I believe **freedom**—rights with responsibility—is real and that we live our lives differently if we think that our life is an illusion—equivalent to a "life" in a video game or *The Matrix*. In deciding what makes a good life, each one of us has the **right and responsibility** to choose which scientific answers are valuable and which answers are limited or perhaps even wrong. I think that ***noblesse oblige*** is foundational and "*from everyone who has been given much, much will be demanded; and from the one who has been entrusted with much, much more will be asked* (Luke 12:48)" and that real freedom comes from making personal decisions about our responsibilities. I think that **the golden rule** should be the foundation for each of us when we decide

what our rights are and what our responsibilities are. **Norman Rockwell** wrote, "*I'd been reading up on comparative religion. The thing is that all major religions have the Golden Rule in Common. 'Do unto others as you would have them do unto you.' Not always the same words but the same meaning*."

Science is not enough to provide a coherent theory of life because it does not provide us with good foundational principles that can describe a Wilberforce or a Scholl as well as a land-grabber. Science is enough to derive the law of reflection, but can evolutionary theory express the fundamental importance of love as well as 1 Corinthians 13:12-13: "***For now we see only a reflection as in a mirror; then we shall see face to face. Now I know in part; then I shall know fully, even as I am fully known. And now these three remain: faith, hope and love. But the greatest of these is love***." http://www.ccel.org/d/drummond/greatest/cache/greatest.pdf



Daryl Davis, a black man, has spent his life trying to understand why people hate him without even knowing him. In promoting the Gospel of Love, he met the people who seemed to be the most hateful racists—members of the Ku Klux Klan. By spending time one-on-one listening and talking with Klan members, the Klan members saw Daryl Davis as a man of character, realized that Daryl Davis' skin color no longer had the meaning it initially had for them, and over 200 members quit the Klan. Daryl Davis is a great boogie-woogie piano player. Daryl Davis' advice? "*Establish dialogue. When two enemies are talking, they're not fighting*."



Compare the "law of love" worldview presented in 1 Corinthians 13:12-13 with the "law of hate" worldview presented in *A Civic Biology* by George Hunter (1914), the book that instigated the **Scopes Monkey Trial** that pitted **Clarence Darrow** and **William Jennings Bryant** against each other. This trial was popularized by the book and movie ***Inherit the Wind*** (which was actually written in response to Joseph McCarthy). The text of *A Civic Biology* states:

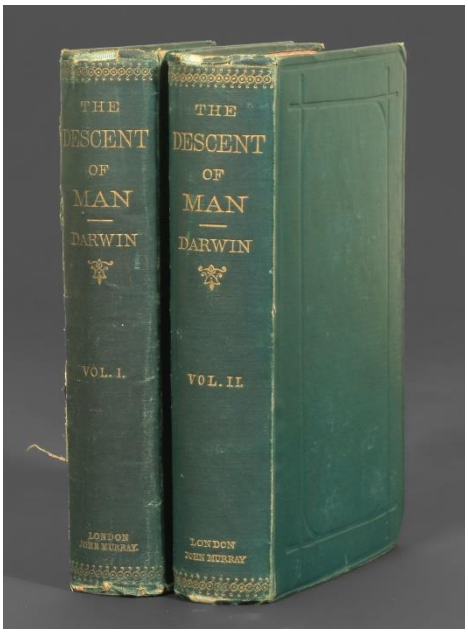
The Races of Man. - *At the present time there exist upon the earth five races or varieties of man, each very different from the other in instincts, social customs, and, to an extent, in structure. These are the Ethiopian or negro type, originating in Africa; the Malay or brown race, from the islands of the Pacific; the American Indian; the Mongolian or yellow race, including the natives of China, Japan, and the Eskimos; and finally,* ***the highest type of all****, the Caucasians, represented by the civilized white inhabitants of Europe and America.*

Eugenics. — *When people marry there are certain things that the individual as well as the race should demand. The most important of these* ***is freedom from germ diseases*** *which might be handed down to the offspring. Tuberculosis, that dread white plague which is still responsible for almost one seventh of all deaths, epilepsy, and feeble-mindedness are handicaps which it is not only unfair but criminal to hand down to posterity.* ***The science of being well born is called eugenics***.

Parasitism and its Cost to Society. — *Hundreds of families such as those described above exist to-day, spreading disease, immorality, and crime to all parts of this country.* ***The cost to society of such families is very severe. Just as certain animals or plants become parasitic on other plants or animals, these families have become parasitic on society. They not only do harm to others by corrupting,***

stealing, or spreading disease, but they are actually protected and cared for by the state out of public money. Largely for them the poorhouse and the asylum exist. They take from society, but they give nothing in return. They are true parasites.

The Remedy. — ***If such people were lower animals, we would probably kill them off to prevent them from spreading***. *Humanity will not allow this, but we do have the remedy of separating the sexes in asylums or other places and in various ways preventing intermarriage and the possibilities of perpetuating such a low and degenerate race. Remedies of this sort have been tried successfully in Europe* [http://eugenicsarchive.ca/discover/connections/5233e5175c2ec500000000e1] *and are now meeting with success in this country.*



This was progressive science! And science it was. Compare it to Darwin's (1871) thoughts in ***The Descent of Man***, "*With savages, the weak in body or mind are soon eliminated; and those that survive commonly exhibit a vigorous state of health. We civilized men, on the other hand, do our utmost to check the process of elimination. We build asylums for the imbecile, the maimed and the sick; we institute poor-laws; and our medical men exert their utmost skill to save the life of every one to the last moment. There is reason to believe that* ***vaccination*** *has preserved thousands, who from a weak constitution would formally have succumbed to small-pox. Thus the weak members of civilized societies propagate their kind.* ***No one who has attended to the breeding of domestic animals will doubt that this must be highly injurious to the race of man***."

Bad Genes and Marriage

By BARBARA YUNCKER

Persons who carry the recessive genes of severe inheritable disease should probably not have children, two famed scientists advised today in order not to increase the bad-gene load of the race.

The two are Nobel laureates Sir Peter Medawar of London and Dr. Linus Pauling, who holds the prize both for chemistry and for peace efforts. They were in town to participate in the dedication of the new Mount Sinai School of Medicine and inauguration of its president and dean, Dr. George James.

Sir Peter, whose prize honored pioneer work in the understanding of immunology and tissue rejection, said two carriers of the same defective gene—for Cooley's anemia or the retardation deficiency PKU, for example—"should be discouraged from marrying each other" because half their children will be carriers and a quarter of their children will be victims.

"It is humbug to say that such a policy violates an elementary right of human beings," Medawar said. "No one has conferred upon human beings the right knowingly to bring maimed or biochemically crippled children into the world."

Genetic Inflation

Even with such limitations, he said, "The frequency of the malignant gene will steadily rise . . . We are dealing here with a genetic equivalent of inflationary economics; we seem to be getting on all right, but the currency is deteriorating."

Countries to this he said, could come through medical advances such as direct genetic repair which he called "not likely, but not inconceivable . . . or, more likely, very early embryonic diagnosis of gross derangements of the chromosomal apparatus"—presumably with therapeutic abortion.

Pauling, speaking later at the "Future of Medicine" session at City College, said: "I agree we should keep these carriers from marrying one another. I have advised, not entirely joking, that individuals should have tattooed on their foreheads swmbols for the defective genes they carry . . .

"Because of certain objections which might be raised, a ribald friend suggests it would be better to tattoo the symbols n Braille on their abdomens.

Carriers who marry normals, he said, can produce carriers, so they "have an obligation to produce a decreased number of children, at least."

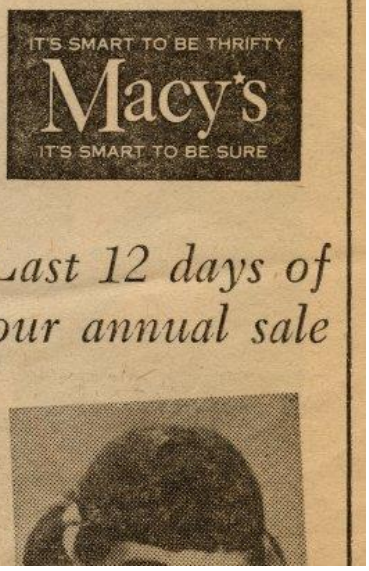
Dr. Francis H. C. Crick of Cambridge, who won a Nobel for his share in deciphering the structure of DNA, the basic genetic material, predicted the new area of ferment in medicine would be in study of the nervous system.

"f all the things we know about man, compared to what we would like to know, the nervous system is the one we know least . . . It is complex and we are complex for that reason."

The fourth Nobelist on the panel, Dr. George W. Beadle, now president of the University of Chicago, who elucidated how genes direct production of enzymes, stressed social responsibility of medical schools, particularly in urban centers, as his own and Sinai are. He warned that "black separatism may counteract and even reverse the trend . . . to [help] disperse, dilute and cure the concentrated social and medical ills" of urban slum areas in cooperative programs with their residents.

James in his inaugural address stressed the need to "redefine the very concept of medical care. The tenfold higher tuberculosis rates in certain areas of our city do not mean that the tuberculosis organism is more virulent there or that our drugs are any less effective in such areas. It must be the poverty and all that accompanies this which is responsible."

Govc. Rockefeller, in closing the day-long celebration of the new school affiliated with the City University of New York, praised it as proof hat "private citizens and private instituion citizens and private initiative and private enterprise can do a large job on a large scale."



Is this progressive science worthy of a free people? Is there value in the non-progressive or Luddite view that has been mocked? Just asking.



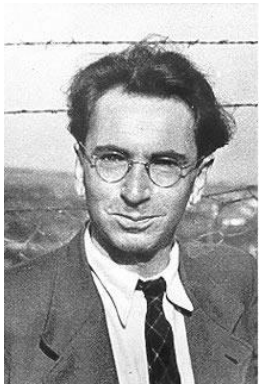


In the State of the Union Address given on January 6, 1941, Franklin D. Roosevelt defined human rights or freedoms when he said, "*In the future days, which we seek to make secure, we look forward to a world founded upon four* ***essential human freedoms***.



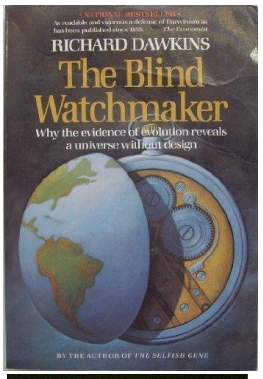
The first is ***freedom of speech and expression****—everywhere in the world. The second is* ***freedom of every person to worship God in his own way****—everywhere in the world. The third is* ***freedom from want****—which, translated into world terms, means economic understandings which will secure to every nation a healthy peacetime life for its inhabitants—everywhere in the world. The fourth is* ***freedom from fear****—which, translated into world terms, means a world-wide reduction of armaments to such a point and in such a thorough fashion that no nation will be in a position to commit an act of physical aggression*

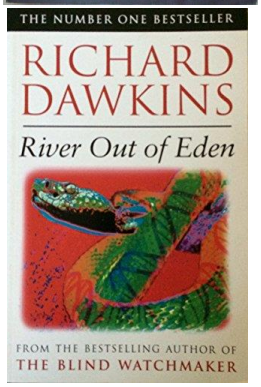
against any neighbor—anywhere in the world. That is no vision of a distant millennium. It is a definite basis for a kind of world attainable in our own time and generation. That kind of world is the very antithesis of the so-called new order of tyranny which the dictators seek to create with the crash of a bomb."

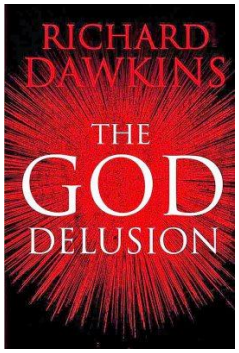


Viktor Frankl (1959), who was **Number 119,104**, wrote in *Man's Search for Meaning*, "*We who lived in the concentration camps can remember the men who walked through the huts comforting others, giving away their last piece of bread. They may have been few in number, but they offer sufficient proof that everything can be taken from a man but one thing: the last of the human freedoms — to* ***choose*** *one's attitude in any given set of circumstances, to* ***choose*** *one's own way….I became acquainted with those martyrs whose behavior in camp, whose suffering and death, bore witness to the fact the last inner freedom can't be lost. It can be said that they were worthy of their sufferings; the way they bore their suffering was a genuine inner achievement.* ***It is this spiritual freedom — which cannot be taken away — that makes life meaningful and purposeful****….The way in which a man accepts his fate and all the suffering it entails, the way in which he takes up his cross, gives him ample opportunity—even under the most difficult circumstances—****to add a deeper meaning to his life****. It may remain* ***brave, dignified and unselfish****. Or in the bitter fight for self preservation he may forget his* ***human dignity*** *and become* ***no more than an animal****.*"

Richard Dawkins wrote in *The Blind Watchmaker* (1986) "*Natural selection, the blind, unconscious, automatic process which Darwin discovered, and which we now know is the explanation for the existence and apparently purposeful form of all life,* ***has no purpose in mind***. ***It has no mind and no mind's eye***. *It does not plan for the future*. ***It has no vision, no foresight, no sight at all***. *If it can be said to play the role of watchmaker in nature, it is the blind watchmaker*" and he wrote in *River Out of Eden (1995)*, "*The universe we observe has precisely the properties we should expect if there is, at bottom, no design,* ***no purpose****, no evil and no good, nothing* ***but blind, pitiless indifference***. *DNA neither knows nor cares. DNA just is. And we dance to its music*." And "*This is one of the hardest lessons for humans to learn. We cannot admit that things might be neither good nor evil, neither cruel nor kind, but simply callous – indifferent to all suffering, lacking all purpose*" and *The God Delusion* (2006) "***There is something infantile in the presumption that somebody else (parents in the case of children, God in the case of adults) has a responsibility to give your life meaning and point***."



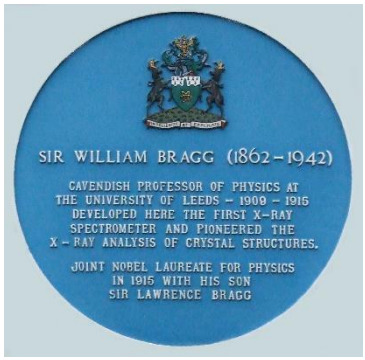




To me, it is a fundamental fact of life that life is fundamentally meaningful or purposeful, and we have the freedom and responsibility to decide for ourselves what is meaningful and purposeful and what is not. Neil deGrasse Tyson (https://www.youtube.com/watch?v=7pL5vzIMAhs), Richard Dawkins (https://www.youtube.com/watch?v=SIfMuSpwfBQ), Daniel Dennett (https://www.youtube.com/watch?v=ayJH0HSmlSQ), Lawrence Krauss (https://www.youtube.com/watch?v=yotpTOKLZ00; https://www.youtube.com/watch?v=B2eZA2kXpc0;

https://www.youtube.com/watch?v=q0mljE9K-gY), Peter Atkins (https://www.youtube.com/watch?v=g6MrktRKfJU; https://www.youtube.com/watch?v=TSZlPZvIOC0), and Christopher Hitchens (https://www.youtube.com/watch?v=bx1yXvcT2kw) believe that **chance and chaos are fundamental** but human beings are capable of creating meaning and purpose, particularly through science, in the fundamentally chaotic world.

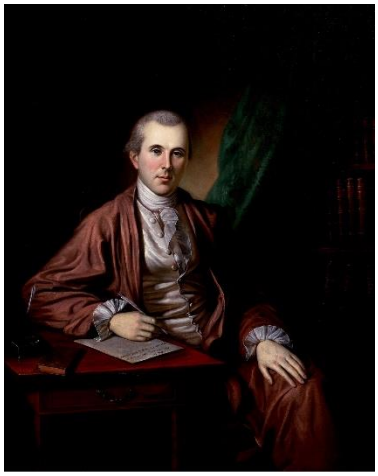
Believing in the fundamental nature of chance and chaos requires just as much faith as believing in the fundamental nature of truth and meaning requires faith. Both views are founded on assumptions that can be supported but not rigorously tested. Modern academia and intellectuals embrace science that supports the idea that chance and chaos are fundamental. Science that questions the idea that chance and chaos are fundamental is typically ridiculed, marginalized, or silenced.





In the words of **William Bragg** (1933), "*It is the fact that in our lives, in all that we work at and strive for, it is of first importance to know as much as we can about what we are doing, to learn from the experience of others, and, not stopping at that, to find out more for ourselves, so that our work may be the best of which we are capable. That is what science stands for. It is only half the battle, I know. There is also the great driving force which we know under the name of religion.* ***From religion comes man's purpose; from science, his power to achieve it. Sometimes people ask if religion and science are not opposed to one another. They are: in the sense that the thumb and fingers or my hand are opposed to one another. It is an opposition by means of which anything can be grasped****. It is*

right, therefore, with all our heart to learn what will help us in the work we want to do, and that when the call comes we can say, 'I am here and ready; I want to play my part, and I have tried to for myself to play it well.'"



Benjamin Rush, the other founder from Philadelphia named Benjamin, promoted the relationship between science and religion in the nascent United States. He addressed the people at the Young Ladies' Academy in Philadelphia on July 28, 1787, saying, "*I cannot help remarking in this place, that Christianity exerts the most friendly influence upon science, as well as upon the morals and manners of mankind. Whether this be occasioned by the* ***unity of truth****, and the mutual assistance which truths upon different subjects afford each other, or whether the faculties of the mind be sharpened and corrected by embracing the truths of revelation, and thereby prepared to investigate and perceive truths upon other subjects, I will not determine, but it is certain that the greatest discoveries in science have been made by Christian philosophers, and that there is the most knowledge in those countries where there is the most Christianity. By knowledge I mean truth only;* ***and by truth I mean the perception of things as they appear to the divine mind****. If this remark be well founded, then those philosophers who reject Christianity, and those Christians, whether parents or schoolmasters, who neglect the religious instruction of their children and pupils, reject and neglect the most effectual means of promoting knowledge in our country*."

Science is a human endeavor that is based on our diverse personal philosophies and worldviews. On the other hand, **scientism** states that the scientific method based on reductionism and materialism that will eventually reduce all phenomena to particle physics or mathematics is the **only valid method** of gaining knowledge about the world. **Julian Huxley** (1927) wrote in his book *Religion without Revelation*, "*What the sciences discover about the natural world and about the origins, nature and destiny of man is the truth for religion.* ***There is no other kind of valid knowledge****. This natural knowledge, organized and applied to human fulfilment, is the basis of the new and permanent religion*." In *Surprised by Joy*, **C. S. Lewis** (1955) tells us how scientism was his religion until he was thirty years old. "***You will understand that my rationalism was inevitably based on what I believed to be the findings of the sciences; and those findings, not being a scientist, I had to take on trust—in fact, on authority***."





I want you to think critically about issues and develop a conditional certainty (***thatige skepsis***), as described by Goethe and T. H. Huxley, without relying on any authority. There is no absolute unassailable proof for the fundamental meaning and purpose of life or for the fundamental nature of chance and chaos. They both take a leap of faith. I think that a healthy science would have room for both views and that you would be free in a democratic society founded on the Declaration of Independence and the Constitution to choose yours. Scientism only allows one view. Ray Bradbury's dystopia could last "[s]*o long as the vast population doesn't wander about quoting the Magna Carta and the Constitution*."

So, are we merely a collection of atoms in a meaningless universe formed out of chaos as many spokespersons of science tell us, or are we souls in bodies composed of atoms in a universe with purpose and meaning? W. H. F. A. wrote in *The British Friend* (p. 157) of 1892, "*'Never tell a child, said George Macdonald, 'you have a soul. Teach him, you are a soul; you have a body.'*" [George MacDonald (1867) actually wrote, in *Annals of a Quiet Neighbourhood*, "*And here let me interrupt the conversation to remark upon the great mistake of teaching children that they have souls. The consequence is, that they think of their souls as of something which is not themselves. For what a man HAS cannot be himself. …They ought to be taught that they have bodies*."]

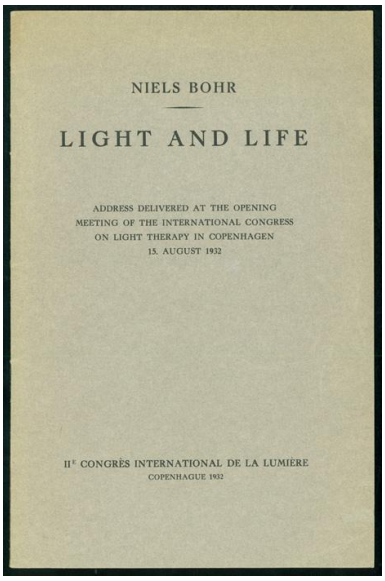
I believe that there is a downside to the materialistic view of humans. **Viktor Frankl** (1965) wrote in *The Doctor & the Soul*, "*If we present man with a concept of man which is not true, we may well corrupt him. When we present man as an* ***automaton of reflexes****, as a mind-machine, as a bundle of instincts, as a pawn of drives and reactions, as a mere product of instinct, heredity, and environment, we feed the nihilism to which modern man is, in any case, prone.*



I became acquainted with the last stage of that corruption in my second concentration camp, ***Auschwitz****. The gas chambers of Auschwitz were the ultimate consequence of the theory that man is nothing but the product of heredity and environment—or, as the Nazi liked to say, of 'Blood and Soil.'* ***I am absolutely convinced that the gas chambers of Auschwitz, Treblinka, and Maidanek were ultimately prepared not in some Ministry or other***

in Berlin, but rather at the desks and in the lecture halls of nihilistic scientists and philosophers."

Niels Bohr (1932) toyed with the idea that life itself may not be reducible to atomic physics. Speaking at the International Congress of Light Therapists, he said, in a talk entitled, *Light and Life*, "*Thus, we should doubtless kill an animal if we tried to carry the investigation of its organs so far that we could describe the role played by single atoms in vital functions. In every experiment on living organisms, there must remain an uncertainty as regards the physical conditions to which they are subjected, and the idea suggests itself that the minimal freedom we must allow the organism in this respect is just large enough to permit it, so to say,* ***to hide its ultimate secrets from us***."


NIELS BOHR

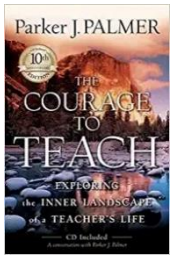
LIGHT AND LIFE

ADDRESS DELIVERED AT THE OPENING MEETING OF THE INTERNATIONAL CONGRESS ON LIGHT THERAPY IN COPENHAGEN 15. AUGUST 1932

IIe CONGRÈS INTERNATIONAL DE LA LUMIÈRE COPENHAGUE 1932



Personally, I believe that the **conveyor belt philosophy of education** today that celebrates the measurable (e.g., highest GPA for the least amount of work) and discounts the meaningful (finding a means to a free and responsible soul-satisfying life) goes a long way to create automatons of reflexes or perhaps worse. According to Parker J. Palmer (2007), "[t]*o educate is to guide students on an inner journey toward more truthful ways of seeing and being in the world*." The paths for the journey are intellectual, emotional, and spiritual, and this requires the full participation of the mind, the soul, and the spirit.





In a speech given in Nova Scotia, Marcus Garvey (1937) said, "***We are going to emancipate ourselves from mental slavery because whilst others might free the body, none but ourselves can free the mind***. *Mind is your only ruler, sovereign.* ***The man who is not able to develop and use his mind is bound to be the slave of the other man who uses his mind***, *because man is related to man under all circumstances for good or for ill. If man is not able to protect himself from the other man he should use his mind to good advantage. The fool will always carry the heavy burden. The fool will always be crushed without a tear from God or man because God Almighty never made a fool. God is all wise.* ***When God Almighty made man in His own image and likeness, it wasn't the physical, it was the mind that was like God***. ***Every man represents God in his unitary intelligence. When man abuses that intelligence he lowers himself***. *God has given you intelligence to take care of you. He hasn't repeated Himself yet. God was so thoughtful of man and his progeny that he made a variety of things so as to pander to the taste of the Adams that would come after the first. When God made you He made you the masters of the world, not serfs and slaves, but your mind must be developed intelligently.* ***It is your mind that rules the body. You cannot go further than that mind to seek truth and to know truth and to re-act to truth***. *That is the only way you will be able to protect your group. The white man is still doing research work with his mind. It has taken him to the bowels of the earth to extract what nature placed there for him. On that same intelligence he has gone into Heaven. What you see in Sydney, in Nova Scotia is only the fringe of the white man's intelligence. Everything that you see that is methodical is the product of the white man's mind.*

He visualizes nations and kingdoms and he has them. There is nothing spiritual around his materialism. They are all objective things realized, dreamt and thought out. Sydney is only what men have visualized to a greater extent. The British Empire was the visualization of men like Raleigh, and Drake, who seeing things of value, attached them to the mother country. If places are not well protected then men take them and add them to their Empires. The U.N.I.A. is dreaming of a day when the Negro will possess himself of a homeland, when he will build for himself. The man who cannot build for himself is not only a poor fish in the sea, but ultimately will be a dead fish, plodding for himself. Nobody wants to die except the fool, because ***life is a worth-while thing****. It is only people who are together can survive now-a-days. It is only by organising that we can get anywhere, as the Mayor told you. We are looking for the* ***redemption*** *and the* ***freedom*** *of our homeland*."

In the words of **Bob Marley**'s ***Redemption Song***:



Old pirates, yes, they rob I;
Sold I to the merchant ships,
Minutes after they took I
From the bottomless pit.
But my hand was made strong
By the 'and of the Almighty.
We forward in this generation
Triumphantly.
Won't you help to sing
These songs of freedom?
'Cause all I ever have:
Redemption songs;
Redemption songs.

Emancipate yourselves from mental slavery;
None but ourselves can free our minds*.*

Have no fear for atomic energy,
'Cause none of them can stop the time.
How long shall they kill our prophets,
While we stand aside and look? Ooh!
Some say it's just a part of it:
We've got to fulfill the book.

Won't you help to sing
These songs of freedom?
'Cause all I ever have:
Redemption songs;
Redemption songs;
Redemption songs.

Emancipate yourselves from mental slavery;
None but ourselves can free our mind.
Wo! Have no fear for atomic energy,
'Cause none of them-a can-a stop-a the time.
How long shall they kill our prophets,
While we stand aside and look?
Yes, some say it's just a part of it:
We've got to fulfill the book.

Won't you help to sing
These songs of freedom?
'Cause all I ever had:
Redemption songs
All I ever had:
Redemption songs:
These songs of freedom,
Songs of freedom.

https://www.youtube.com/watch?v=OFGgbT_VasI

https://www.youtube.com/watch?v=FPg_eu9_-OA

https://www.youtube.com/watch?v=xrYP2QqQ5wo

https://www.youtube.com/watch?v=55s3T7VRQSc

https://www.youtube.com/watch?v=hwNlQRvV-b4

Ever hear of George Johnson? He was a slave. Here is an actual recording of his voice. Ever hear of Fountain Hughes? He was a slave. Here is an actual recording of his voice.

Or instead of abolishing slavery and emancipating ourselves from **mental slavery**, we may be enslaving ourselves and our **unfreedom** by celebrating postmodern Critical Theory based on the assumption that there is no Truth and all truth is socially constructed. Denying the truth is equivalent to **amusing ourselves** with modern forms of **soma**. **Patrick Henry** (1775), who knew that "*it is natural to man to indulge in the illusions of hope… shut our eyes against a painful truth, and listen to the song of that siren till she transforms us into beasts. Is this the part of wise men, engaged in a great and arduous struggle for liberty? Are we disposed to be of the number of those who,* ***having eyes, see not, and, having ears, hear not,*** *the things which so nearly concern their temporal salvation? For my part, whatever anguish of spirit it may cost, I am willing to know the whole truth; to know the worst, and to provide for it. I have but one lamp by which my feet are guided, and that is the lamp of experience."* asked and answered, "***Is life so dear, or peace so sweet, as to be purchased at the price of chains and slavery? Forbid it, Almighty God! I know not what course others may take; but as for me, give me liberty or give me death!***"



Personal liberty was fundamental to the founders of America. Benjamin Franklin, the would be chandler, wrote on November 11, 1755, "*Those who would give up essential Liberty, to purchase a little temporary Safety, deserve neither Liberty nor Safety*."

Thomas Jefferson wrote to Charles Yancey on January 6, 1816 *"if a nation expects to be ignorant & free, in a state of civilisation, it expects what never was & never will be. the functionaries of every government have propensities to command at will the liberty & property of their constituents. there is no safe deposit for these but with the people themselves; nor can they be safe with them without information. where the press is free and every man able to read, all is safe*."



Declaration of INTERdependence

HUMAN PROGRESS having reached a high level through respect for the liberty and dignity of men, it has become desirable to re-affirm these evident truths:

That differences of race, color and creed are natural, and that diverse groups, institutions, and ideas are stimulating factors in the development of man;

That to promote harmony in diversity is a responsible task of religion and statesmanship;

That since no individual can express the whole truth, it is essential to treat with understanding and good will those whose views differ from our own;

That by the testimony of history intolerance is the door to violence, brutality, and dictatorship; and

That the realization of human interdependence and solidarity is the best guard of civilization.

Therefore, we solemnly resolve, and invite everyone to join in united action,

To uphold and promote human fellowship through mutual consideration and respect;

To champion human dignity and decency, and to safeguard these without distinction of race or color or creed;

To strive in concert with others to discourage all animosities arising from these differences, and to unite all groups in the fair play of civilized life.

Rooted in freedom, children of the same Divine Father, sharing everywhere a common human blood, we declare again that all men are brothers, and that mutual tolerance is the price of liberty.

Please sign, DETACH STUB, and return it to us. Retain Declaration and show it to others.
I hereby sign the Declaration of INTERdependence.

Signature_____

Name (Please Print)_____ Date_____

Address_____

Occupation_____ Phone_____

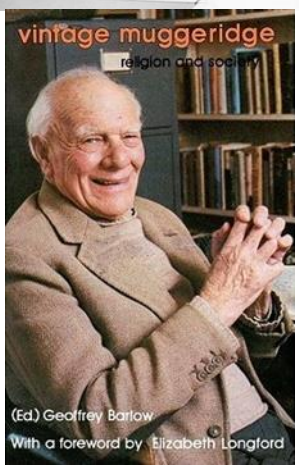
(No financial obligation is assumed by signing the Declaration)

Declaration of INTERdependence, Inc., 112 South La Brea Avenue, Los Angeles 36, California

To complement the Declaration of Independence, Will Durant wrote a **Declaration of INTERdependence**.



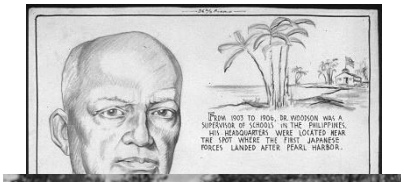
The late Democrat Senator from New York, Daniel Patrick Moynihan said, "*Am I embarrassed to speak for a less than perfect democracy? Not one bit. Find me a better one. Do I suppose there are societies which are free of sin? No, I don't. Do I think ours is, on balance, incomparably the most hopeful set of human relations the world has? Yes, I do*."



According to **Malcolm Muggeridge**, [i]*t has become abundantly clear in the second half of the twentieth century that Western Man has decided to abolish himself.* ***Having wearied of the struggle to be himself****, he has created his own boredom out of his own affluence, his own impotence out of his own erotomania, his own vulnerability out of his own strength; himself blowing the trumpet that brings the walls of his own city tumbling down, and, in a process of auto-genocide, convincing himself that he is too numerous, and labouring accordingly with pill and scalpel and syringe to make himself fewer in*

order to be an easier prey for his enemies; ***until at last, having educated himself into imbecility****, and polluted and drugged himself into stupefaction, he keels over a weary, battered old brontosaurus and becomes extinct.*

Dylan Thomas (1947) wrote, "*Do not go gentle into that good night. Rage, rage against the dying of the light*."





Carter G. Woodson asks if it is better to be "*un-educated*" than "*mis-educated*?"

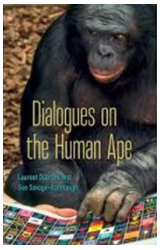
To paraphrase Ray Bradbury (1979), Do not go gently onto a shelf, degutted, to become a non-book.



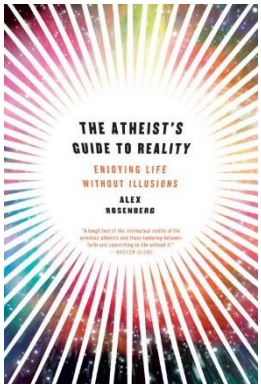
We have made quite a lot of use of language in this course, and soon you will be passing in your creative writing projects. A. N. Wilson wrote, "*Do materialists really think that language just "evolved", like* ***finches' beaks****, or have they simply never thought about the matter rationally? Where's the evidence? How could it come about that human beings all agreed that particular grunts carried particular connotations? How could it have come about that groups of anthropoid apes developed the amazing morphological complexity of a single sentence, let alone the whole grammatical mystery which has engaged Chomsky and others in our lifetime and linguists for time out of mind?* ***No, the existence of language is one of the many phenomena -***

of which love and music are the two strongest - which suggest that human beings are very much more than collections of meat*. They convince me that we are spiritual beings, and that the religion of the incarnation,* ***asserting that God made humanity in His image, and continually restores humanity in His image, is simply true. As a working blueprint for life, as a template against which to measure experience, it fits****."*

https://www.newstatesman.com/religion/2009/04/conversion-experience-atheism

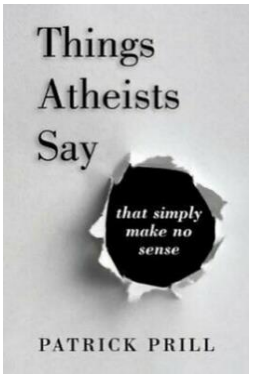


Or, is being human just an epigenetic phenomenon that influenced a few bonobos or chimps? (I have not read this book yet).



Alex Rosenberg (2011) wrote in a chapter entitled, *Never Let Your Conscious be Your Guide* in **The *Atheist's Guide to Reality***, "*Science provides clear-cut answers to all of the questions on the list: there is no free will, there is no mind distinct from the brain, there is no soul, no self, no person that supposedly inhabits your body, that endures over its lifespan, and that might even outlast it.* ***So, introspection must be wrong***."

Patrick Prill (2021) responded in ***Things Atheists Say that Simply Make No Sense***, "*The first big challenge with the idea we don't have a soul, as Alex Rosenberg points out, is that our own minds tell us we do. Our thoughts tell us that we have individual identity, unique ideas and perspectives, self-awareness, introspection, intent, self-direction, the ability to control our bodies and the ability to affect the things around us. Our thoughts tell us our 'self' is in charge. But, because this disagrees with what* Rosenberg *says science tells us, he claims our '*introspection must be wrong*'—what our thoughts tell us about ourselves can't be trusted.*



This is some concept. If what Rosenberg says is true, how could you trust your own thoughts about anything? Now that would be a problem, Also, the examples Rosenberg gives to support his claim have primarily to do with perception rather than introspection.

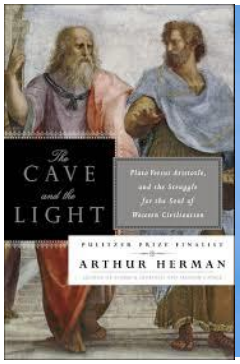
Yet we know that a straw only appears to bend when inserted into a glass of water. Our conscious thoughts are logical enough to figure this out and they can be trusted."

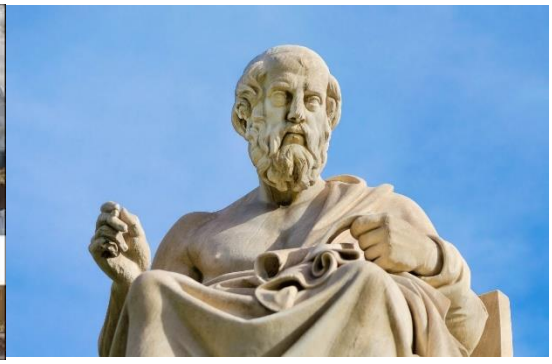
If we take Alex Rosenberg's advice and *Never Let Your Conscious be Your Guide*, then we will let someone else be the guide over our own life. Trust yourself!

Life can be defined by the **operational definition** of life I gave above but the **meaning of life** requires more. Human beings are able to assimilate matter and energy, move, and reproduce but we can choose to do these in a meaningful and loving way. This meaningfulness and origin of this choice is outside of evolutionary theory, but just because it is outside of evolutionary theory does not mean that meaning and origin do not exist. **Monists** believe that there is only one fundamental basis of reality (matter, energy, or spirit). **Dualists** believe that there are two (mass-energy and spirit). This also applies to the **mind-body duality**. Is the mind more than the brain, which is composed of matter?

In the story of the **Ship of Theseus** we learned that Aristotelian theory states that there is more than one reason or cause that something exists. The material cause, the formal cause, the efficient cause, the first cause, and the final cause. **Many intellectuals do not see the limits of evolutionary theory and extrapolate from its value to the idea that anything that cannot be explained by**

evolutionary theory is not real. My commonsense logic tells me that all theories are approximate, simplifications, and incomplete. Thus, they cannot undermine the existence of those things that they cannot explain.





I believe that each of us has a **sense of truth** and using that sense, you get to choose for yourself which Laws (νομός or *nomos*) of Nature are fundamental and true. Plato, whose given name was Aristocles (which means broad or wide), wrote in *The Republic*, "***The soul is like an eye: when it sees that on which truth and Being shine, the soul perceives and understands. And is radiant with intelligence***."



D. H. Lawrence wrote about the sense of truth in two poems:

The Deepest Sensuality*:*

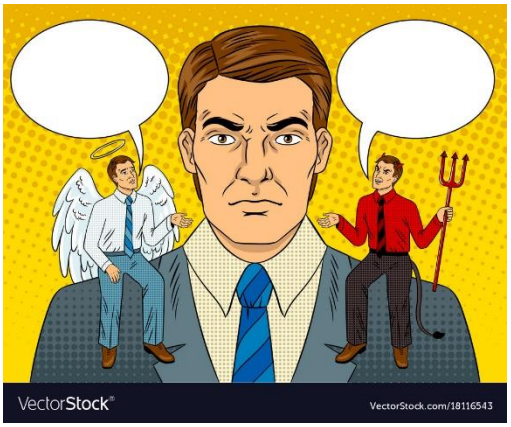
The profoundest of all sensualities
is the sense of truth
and the next deepest sensual experience
is the sense of justice.

Sense of Truth

You must fuse mind and wit with all the senses
Before you can feel truth.
And if you can't feel truth you can't have any other
Satisfactory sensual experience.

Our **sense of truth** helps us to decide the relationship between science and reality. Science is based on personal philosophy and you get to use your sense of

truth to choose if **reality is merely a fabrication of the conscious mind** and the theories of biology are eternal and true; or **if there is a true and fundamental reality** that is consistent with your own experience and observations, and it is the biological theories that approximate reality that are fabrications of the mind.

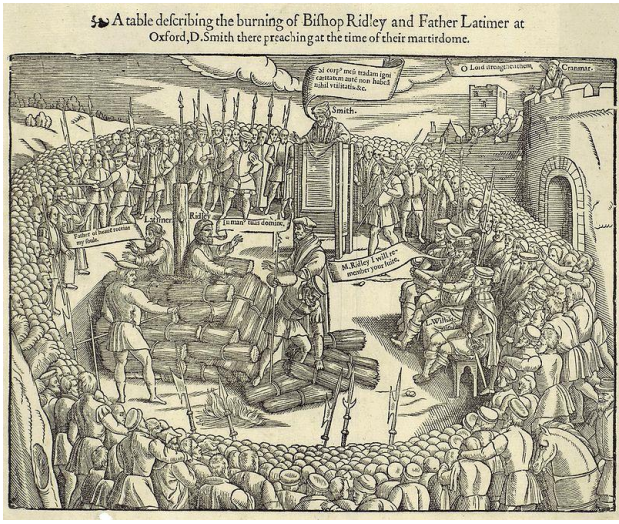


Is it possible that some human beings have a sense of truth and other human beings have a sense of untruth? If so, what are the causes of the sense of truth and the sense of untruth? Are the causes material or nonmaterial? Are the causes discoverable through scientific exploration, religious exploration, neither, or both?



Remember what Richard Feynman (1969) said in a speech entitled, *What is Science?*: "*As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts. When someone says, 'Science teaches such and such,' he is using the word incorrectly. Science doesn't teach anything; experience teaches it. If they say to you, 'Science has shown such and such,' you might ask, 'How does science show it? How did the scientists find out? How? What? Where?' It should not be 'science has shown' but 'this experiment, this effect, has shown.**' And you have as much right as anyone else, upon hearing about the experiment—but be patient and listen to all the evidence—to judge whether a sensible conclusion has been arrived at***." (http://www.fotuva.org/feynman/what_is_science.html)

Stand out like a candle:

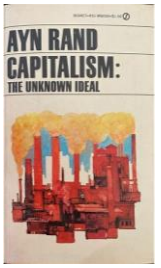


On 16 October 1555, **Nicholas Ridley and Hugh Latimer** were burned at the stake for heresy. Before the fires were lit Latimer shouted to Ridley: "*Play the man Master Ridley, we shall this day light a candle, by God's Grace, in England, as I trust shall never be put out*". In *The Chemical History of a Candle*, Michael Faraday reminded us to "*be fit to compare to a candle; that you may, like it, shine as lights to those about you; that, in all your actions, you may justify the beauty of the taper by making your deeds honourable and effectual in the discharge of your duty to your fellow-men*." Ray Bradbury wrote about Ridley and Latimer in *Fahrenheit 451*.

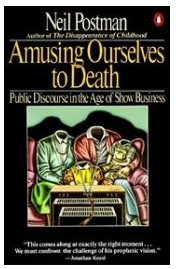


Aldous Huxley (1960) predicted in ***Brave New World Revisited*** the kind of dehumanization of scientists that is being caused by the massive advances in organization that have accompanied the advances in science spurred by the human genome project, "*During the past century the successive advances in technology have been accompanied by corresponding advances in organization. Complicated machinery has had to be matched by complicated social arrangements, designed to work as smoothly and efficiently as the new instruments of production.* ***In order to fit into these organizations, individuals have had to deindividualize themselves, have had to deny their native diversity and conform to a standard pattern, have had to do their best to become automata***." I have written about the same thing in a chapter

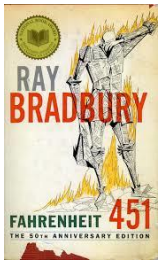
on Omic Science in the second edition of *Plant Cell Biology: From Astronomy to Zoology*.



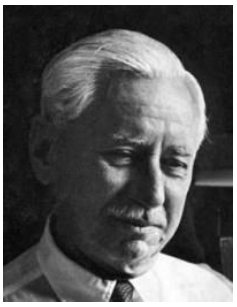
Ayn Rand (1966) wrote in *Capitalism: The Unknown Ideal*, "***Remember also that the smallest minority on earth is the individual. Those who deny individual rights, cannot claim to be defenders of minorities***."



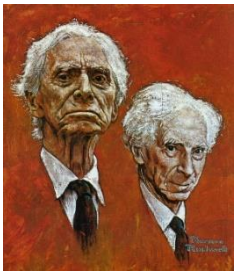
Neil Postman (1985) ends his book, *Amusing Ourselves to Death*, with a way of telling whether or not we have become automatons: "***For in the end, he [Aldous Huxley] was trying to tell us what afflicted the people in Brave New World was not that they were laughing instead of thinking, but they did not know what they were laughing about and why they had stopped thinking***."



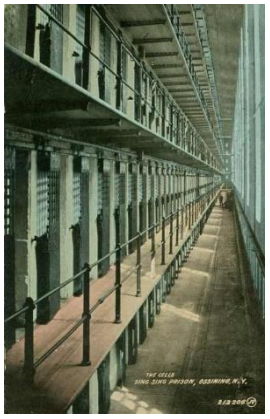
In *Fahrenheit 451*, Ray Bradbury (1953) described what it was like to live in a world without books: "***thinking little at all about nothing in particular***."



The philosopher **Will Durant** wrote a book entitled, *On the Meaning of Life*, where he wrote to many people asking them, *What is the meaning or worth of human life?* **Bertrand Russell**, certainly a member of the intellectual elite wrote back, "***I am sorry to say that at the moment I am so busy as to be convinced that life has no meaning whatever….I do not see that we can judge what would be the result of the discovery of truth, since none has hitherto been discovered***."



Owen C. Middleton, Life-Term Convict 79206 in Sing Sing Prison in Ossining, New York answered:



An eminent author and philosopher seeks an answer to that age-old question: ***What is the meaning or worth of human life?*** *An equally eminent publisher asked me how I manage to bear it in my present position. To the philosopher, I, a man serving a life term behind prison walls, answer that* ***the meaning life has for me depends upon, and is only limited by, my ability to recognize its great truths*** *and to learn and profit by the lessons they teach me. In short, life is worth just what I am willing to strive to make it worth.*

To the publisher, I say that life, even from within prison walls, can be as intensely interesting, as vitally worth-while as it is to any man on the outside. It all depends upon the faith one has in the soundness of his philosophy.

My philosophy of life is a homely one, compounded of many simple beliefs of which truth is the guiding star. Upon my ability to see life in its true aspect, ***I depend for that mental equilibrium without which I find myself drifting in a welter of conjecture and contradictory speculation****.*

'We are driven to conclude,' argues the philosopher, 'that the greatest mistake in human history was the discovery of truth. It has not made us happy, for it is not beautiful. It has not made us free, except from delusions that comforted us and restraints that preserved us. It has taken from us every reason for existence except the moment's pleasure and tomorrow's trivial hope.' If our happiness and our reason for existence depended upon our inherent tendency to seek comfort in delusions, false tradition and superstition, then I could agree. We should be unhappy when truth deprived us of their questionable consolation, but they do not.

Truth is not beautiful, neither is it ugly. Why should it be either? Truth is truth, just as figures are figures. When a man wishes to learn the exact condition of his business affairs, he employs figures and, if these figures reveal a sad state of his affairs, he doesn't condemn them and say that they are unlovely and accuse them of having disillusioned him. Why then condemn truth, when it only serves him in this enterprise of life as figures serve him in his commercial enterprises? That idol-worshipping strain in our natures has visioned a figure of Truth draped in royal raiment and, when truth in its humble form, sans drapery, appears to us, we cry, 'Disillusionment.'

Custom and tradition have caused us to confuse truth with our beliefs. Custom, tradition and our mode of living have led us to believe we cannot be happy, save under certain physical conditions possessed of certain material comforts. This is not truth, it is belief. Truth tells us that happiness is a state of mental contentment. Contentment can be found on a desert island, in a little town, or the tenements of a large city. It can be found in the palaces of the rich or the hovels of the poor.

Confinement in prison doesn't cause unhappiness, else all those who are free would be happy. Poverty doesn't cause it, else the rich all would be happy. Those who live and die in one small town are often as happy, or happier than many who spend their entire lives in travel. ***I once knew an aged negro who could not tell the meaning of one letter from that of another, yet he was happier than the college professor for whom he worked.*** *Hindus are happy, so are the Chinese, the Africans, the Spaniards, and the Turks. The North, the South, the East and the West all contain happy persons. There are celebrities who are happy, and there are many happy people living obscure lives. Happiness is neither racial, nor financial,*

nor social, neither is it geographical. What then can it be, and from what deep well does it spring?

Reason tells us that it is a form of mental contentment and— if this be true —its logical abode must be within the mind. The mind, so we are told, is capable of rising above matter. Can we be wrong then in assuming that mental contentment may be achieved under any condition, even in prison?

There are some who would have us believe that thought, discovery and invention have revealed life as a rather hopeless venture, and mankind a helpless pawn doomed to go down to defeat and oblivion, and from this gloomy prospect man turns and exclaims, 'What's the use?'

Natural history teaches us that in the great scheme of evolution, which is the only true and not comparative progress, certain forms of life, unable to adjust themselves to evolutionary changes, have been entirely blotted out. These were devoid of that constructive instinct we call invention. Life is in a constant state of change, and the development of thought and invention enables us to adjust ourselves to these changes. In fact our very fitness, our only hope of survival, depends upon the fertility of our inventiveness.

The prehistoric fish, when it developed legs with which to climb from its then native habitat or element, was as much of an inventor as were the Wright brothers. T. S. Eliot draws us a very convincing picture of a chaotic world in 'The Waste Land,' but I dare to question the premise upon which he paints his picture. Science, discovery, thought and deduction all tell me that the world is a living symbol of orderliness, that evolution is blind only according to man's standards of blindness, that chaos exists only in the minds of men. Reason will not permit me to

see life in any other aspect. To me, life is like a river, moving ever forward. There are eddies and crosscurrents, but the main stream sweeps onward.

Life cannot retrogress, neither can man. He is an integral part of the universe in which he lives, that universe which is ever moving forward to some appointed destiny. That life was accidental is a theory I am willing to accept, but it doesn't follow that it need be meaningless. ***Any man who has thought deeply enough to arrive at the conclusion that life is without meaning must surely be an intelligent man. Intelligent persons do not do meaningless things, yet these exponents of this doctrine continue to live. I am forced to conclude from this that they do not feel entirely in sympathy with their doctrine. Each time I pick up a newspaper and read of some man committing suicide, I say, 'There was a man who truly believed that life was without meaning.'***

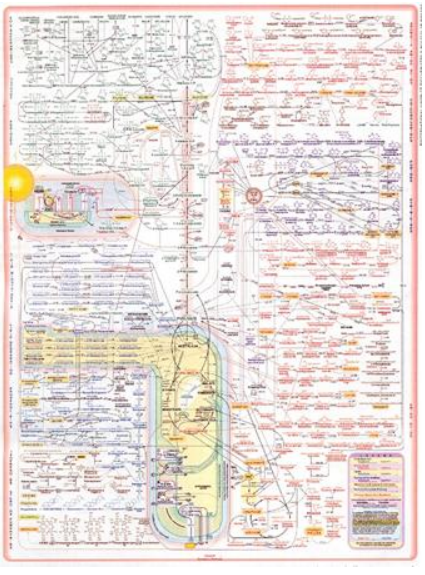
Those who decry the machine age as heralding the decadence of the race, do not stop to consider that manual labor is not a natural but an acquired habit of man. It was a crude means by which primitive man sought to adjust himself, sought to survive, a method for accomplishing those tasks and overcoming those obstacles which life presents. The machine is simply a quicker, more efficient means to the same end: Man's struggle to keep abreast, to survive. Just as man has changed his mode of living, so must he change his thoughts, his habits, and perhaps even his form. Back in the dim eons of time man has made several physical changes, why not in the far-distant future toward which we are traveling? Up from the deeps of the sea to the shallows came life, up from the shallows to the land.

This evening I stood in the prison yard amid other prisoners, with eyes lifted aloft, gazing at that great, beautiful sight, the airship Los Angeles *as it sailed majestically over our heads. Into my mind came the thought that, just as that*

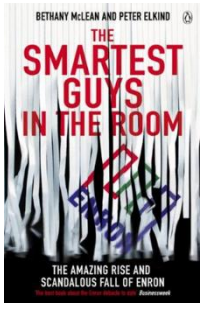
prehistoric creature struggled up out of the sea to the land, so is man struggling up from the land into the air. Who dare deny that, some day, up, ever up he will struggle through the great reaches of interstellar space to wrest from it the knowledge which will enable him to lift his life to a plane as high above this, our present one, as it is above that of prehistoric man?

I do not know to what great end Destiny leads us, nor do I care very much. Long before that end, I shall have played my part, spoken my lines, and passed on. How I play that part is all that concerns me. ***In the knowledge that I am an inalienable part of this great, wonderful, upward movement called life, and that nothing, neither pestilence, nor physical affliction, nor depression, nor prison, can take away from me my part, lies my consolation, my inspiration, and my treasure.***

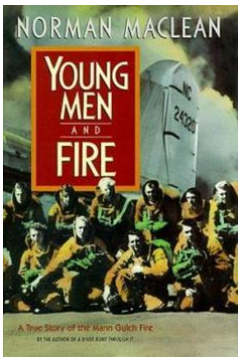
Now, I am not saying go to prison to find wisdom, but I am saying use your discernment when elites or what John McWhorter calls in *The New Religion*, "The Elect," present you with truths based on the foundation that there is no Truth. After all, physical incarceration is not as confining as mental slavery.



So, **what is life?** To me, life is **fundamentally real** and **fundamentally meaningful**, and **mental and physical freedom** is the natural state of a human being. The scientific method is a way to understand the real world and get to **know ourselves and help us live better**. Otherwise, what is the use of even studying life and the details of glycolysis, the Krebs cycle, and DNA replication? Remember, sometimes the smartest guys in the room—aren't!



Norman Maclean (1992), the author of *Young Men and Fire*, wrote about life: "*Far back in the impulses to find this story is a storyteller's belief that at times* ***life takes on the shape of art and that the remembered remnants of these moments are largely what we come to mean by life. The short semihumours comedies we live, our long certain tragedies, and our springtime lyrics and limericks make up most of what we are. they become almost all of what we remember of ourselves***."



Science has also a way to alleviate fear by increasing our understanding of the world, although recently it seems to me that science has been used to instill fear.



Today climate scientists warn us that life as we know it will end in the next decade and there is no time to persuade skeptics with evidence and reason. They claim that skeptics are not really skeptics but rather deniers of reality and contrarians when it comes to reason. Instead of answering the questions of skeptics, they label any questioning as **disinformation** or **misinformation**—as if they know the truth and there is no question. They also imply that any questioning is motivated by politics or profit. **Michael Mann** (2012) wrote in *The Hockey Stick and the Climate Wars*,

The Role of the Scientist

What is the proper role for scientists in the societal discourse surrounding climate change? Should they remain ensconced in their labs, with their heads buried in their laptops? Or should they engage in vigorous efforts to communicate their findings and speak out about the implications? I once subscribed to the former point of view. As a graduate student and then a beginning postdoctoral researcher in the mid-1990s, I wanted nothing more than to be left alone analyzing data, constructing and

running theoretical climate models, and pursuing curiosity-driven science. When we first published our hockey stick work in the late 1990s, I was of the belief that ***the role of a scientist was, simply put, to do science****. Others, I felt, should be left to assess and publicize any implications of the science.* ***Taking anything even remotely resembling a position regarding climate change policy was, to me, anathema. Doing so, I felt, would compromise the authority of my science. I felt that scientists should take an entirely dispassionate view when discussing matters of science—that we should do our best to divorce ourselves from all of our typically human inclinations—emotion, empathy, concern.*** *In the interviews I conducted with reporters, I was careful not to wade into the dangerous waters of expressing a personal opinion and to avoid entirely the subject of policy implications.*

*Everything I have experienced since then has gradually convinced me that my former viewpoint was misguided. I became a public figure involuntarily when our work was thrust into the public spotlight in the late 1990s. I have remained a public figure since, but I have come to embrace, rather than eschew, that role. Despite the battle scars I've suffered from having served on the front lines in the climate wars—and they are numerous—****I remain convinced that there is nothing more noble than striving to communicate, in terms that are simultaneously accurate and accessible, the societal implications of our scientific knowledge.*** *Indeed, much of my time and effort over the past decade has been dedicated to doing so.*

I can continue to live with the cynical assaults against my integrity and character by the corporate-funded denial machine. ***What I could not live with is knowing that I stood by silently as my fellow human beings, confused and misled by industry-funded propaganda, were unwittingly led down a tragic path that would mortgage***

future generations. How could we explain to our grandchildren that we saw the threat coming, but did not do all we could to ensure that humankind took the necessary precautions? Scientists who study climate change and its potential impacts understand better than anyone the nature of the climate change threat. It would, in my view, be irresponsible for us to silently stand by while industry-funded climate change deniers succeed in confusing and distracting the public and dissuading our policy makers from taking appropriate actions. *If climategate and the other related attacks against climate science have served no purpose other than to* ***awaken the scientific community to the reality that we are in a war*** *and to move some of my colleagues off the fence, then they will have served a purpose.*

The challenge climate scientists face remains monumental. Scientists understand the processes that lead to scientific consensus because these processes are intrinsic to the culture of science. They involve a good faith give-and-take of scientific ideas, through publication in the peer reviewed literature, the exchanges that take place at scientific meetings, and the participation in scientific assessments that attempt to characterize our collective knowledge. The processes that lead to a public consensus, however, are different, and by contrast are generally foreign to most scientists.

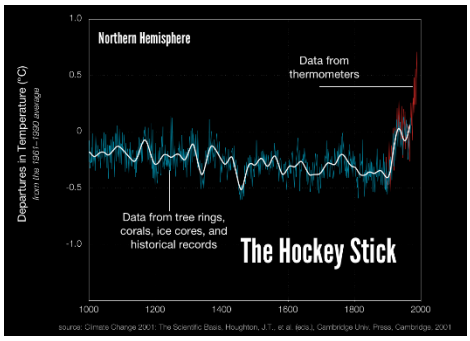
Scientific truth alone is not enough to carry the day in the court of public opinion. *The effectiveness of one's messaging and the resources available to support and amplify it play a far greater, perhaps even dominant role.* ***And here, as we have seen, the scientific community and those seeking to communicate its message are greatly outmatched by a massive disinformation campaign funded by powerful vested interests driven by a single goal.*** *That goal is to thwart efforts to regulate*

carbon emissions—a necessary step if we are to stabilize greenhouse gas concentrations below dangerous levels.

Foes of emissions limits have been able to exploit deficiencies in the public's understanding of the problem: the reality of the problem, the risks it presents, an honest accounting of the economic and environmental costs, and the ethical quandaries of inaction. These deficiencies are inextricably linked to the willingness—indeed, the inclination—of our mass media ***to present the views of a small number of mavericks, iconoclasts, and even crackpots as being on a par with those of the world's leading scientists.*** *While there are mavericks in every field, only in areas like climate science—where they are funded heavily and there are both* ***personal and economic interests in denying mainstream science****—are plain-old* ***charlatans so readily presented as credible voices in the public debate****, used to* ***advance the policy agenda of inaction favored by powerful economic interests and the politicians in their pocket****. As atmospheric scientist Kerry Emanuel eloquently put it during testimony he gave at a March 2011 congressional hearing, 'mavericks are indispensible to the progress of science, but politicians who make mascots out of mavericks are invariably engaging in advocacy.*'

Looking Ahead

In the end, what are the larger lessons to be taken away from my story? One lesson, I suppose, is a familiar one: Change is not easy. Rightly or wrongly, the ***hockey stick*** *was a game-changer in the climate change debate. It was a powerful, easily digestible icon, enough so that the* ***forces of climate change denial*** *saw the need to employ their full arsenal of resources in an attempt to destroy it—and, indeed, my collaborators and me. They supported scientific hired guns to assail us with a constant barrage of* ***specious criticisms and attacks****. They found ideologically sympathetic politicians, including powerful Senate and House committee chairs and state attorneys general, who were willing to* ***sponsor inquisitions of climate science and climate scientists.*** *They used stolen private e-mails to find material to misrepresent and smear us and other climate scientists. And they made use of their access to an array of media outlets to issue attack after vitriolic attack against us, the hockey stick, and the work of other scientists around the world. The assaults were in a sense the logical continuation of corporate-funded campaigns to attack* ***inconvenient scientific findings*** *that had begun decades ago.*



There are other sobering lessons that might be taken away as well. It is clear that the scientific community is, at present, ill-equipped to deal with direct assaults upon its integrity. ***A fundamental principle of scientific inquiry is the honest exchange of ideas, the communication of caveats and uncertainty. Without a science-literate and politically aware populace, there can be no match against well-funded, well-organized groups that place little value on honesty or integrity, that cleverly masquerade denialism as skepticism, and that are more than willing to state their own positions in the most absolute of terms, while exploiting and indeed***

misrepresenting the frank admissions of uncertainty by those they view as their opponents.

As Nature put it in editorial in the wake of the CRU e-mail hack in March 2010, climate scientists must acknowledge that 'they are in a street fight.' Nature went on to assess the predicament:

Climate scientists are on the defensive, knocked off balance by a re-energized community of global-warming ***deniers*** *who, by dominating the media agenda, are* ***sowing doubts about the fundamental science****. Most researchers find themselves completely out of their league in this kind of battle because it's only superficially about the science. The real goal is to stoke the angry fires of talk radio, cable news, the blogosphere and the like, all of which feed off of* ***contrarian*** *story lines and seldom make the time to assess facts and weigh evidence. Civility, honesty, fact and perspective are irrelevant.*

All is not lost, however. When scientists are willing to fight for their cause—in this case, communicating the potential climate change threat—there are many good men and women who will not simply stand by and do nothing. There were politicians of principle on both sides of the aisle, such as Democrat Henry Waxman and Republican Sherwood Boehlert, who were willing to stand up to McCarthyist attacks against me and my coauthors. There were reporters and editors who displayed thoughtfulness and sanity in their coverage of events even during the height of the media feeding frenzy. Dan Vergano and Brian Winter of USA Today, Seth Borenstein of the AP, and the BBC's Richard Black stand out as shining examples, as do the editorial boards of the Washington Post, the New York Times, and numerous smaller

newspapers around the country. Nongovernmental organizations such as the Union of Concerned Scientists, the Natural Resources Defense Council, and the oft-criticized but ever-gutsy Greenpeace all rose to the occasion. Many fellow scientists, academics, and other citizens did as well.

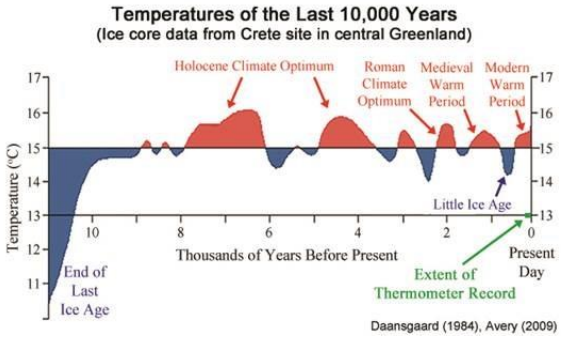
Yes, ***the public discourse has been polluted now for decades by corporate-funded disinformation****—not just with climate change, but with a host of health, environmental, and societal threats. Public perception is fickle. Things could change quickly with a concerted effort to improve the public's understanding of climate change risks and what's likely to be lost by not addressing them. Such an effort would of necessity require scientists to work closely with social scientists and with public policy and communication experts. It would require the financial support of foundations and private sector interests that genuinely care about Earth and its future. It would need to take full advantage of Internet-age organizing opportunities, using social media and online networking tools, to build a true grassroots movement that can go toe-to-toe with the massively-funded 'Astroturf' campaigns. And it would certainly need to work toward a dramatic improvement in the accuracy and objectivity of mainstream media coverage of the climate change issue. Only an* ***informed electorate*** *can hold our policy makers accountable to represent our interests and values and insist on the development of a sensible climate change strategy. Fortunately, there is evidence that some prominent media outlets are awakening to this reality and are willing to do their part.*

So there is reason for hope. I will end with a personal story that conveys my cautious optimism. At the height of the climategate assault, just after New Year's Day 2010, I was on a brief family vacation in the Florida Keys, a good opportunity, I felt, to

get away from it all, at least for a short while. It was just my luck that Key West was experiencing its most severe cold snap in decades. I was subjected to more than one local resident who, when informed that I was an atmospheric scientist, skeptically inquired something akin to, "So what about this supposed global warming?" I was happy to explain the difference between weather and climate, the fact that El Niño years tend to be cold in the southeastern United States, that other regions such as the tropics, the Arctic, and the Pacific Northwest were unusually warm, that 2009 had just gone down as one of the warmest years globally, and that the decade that had just ended was the warmest we had yet witnessed. Nonetheless, it was all a bit dispiriting, as if Mother Nature herself had decided to kick me while I was down.

But there was something more here. My four-year-old daughter was entranced by the Keys—the mangrove forests, the sonorous birds, the leaping dolphins, the coral reefs with their exotic and colorful fish. It was unlike anything she had ever seen. In fact, three generations of my family—my parents, my wife and me, and our daughter—were all sharing this mutual opportunity to enjoy one of Earth's true wonders—and authentic key lime pie. I didn't have the heart to tell our daughter that this island paradise was under assault—by us. That the warming and increasingly acidic ocean was slowly killing the reefs, that increasingly destructive hurricanes would subject them to further insult, and that projected sea level rise over the next few decades under "business as usual" emissions would literally submerge vast regions of the Florida Keys, including the wildlife refuges home to so many of its unique species. Nor do I have the heart to tell her now that the majestic scene of giraffes and elephants looming in the foreground of Ernest Hemingway's Snows of Kilimanjaro may soon become a casualty of our warming of the planet.

I am determined to do whatever I can to make sure that it will be possible for us to return decades from now—my wife and me, our daughter, her children, and perhaps theirs—to again marvel at these natural wonders. While slowly slipping away, that future is still within the realm of possibility. It is a matter of what path we choose to follow. I hope that my fellow scientists—and concerned individuals everywhere—will join me in the effort to make sure we follow the right one.



I want to be part of an informed electorate and on 4/21/22 I wrote to Michael Mann to get information on the relationship between contemporary tree ring data and instrumental temperature records to help me understand the tree ring data he used to determine that the ***global*** **temperatures** he deduced for the past 1000 years which yielded the hockey stick graph, indicating that climate change in the past 1000 years barely existed:

Dear Dr Mann,

I just finished reading your book, The Hockey Stick and the Climate Wars, and I wondered if you or others have compared tree ring data of trees growing over the past several decades with the instrumental measurements of temperature? If so, would you provide a reference for me?

My interest in this comes from the fact that I teach a course called Light and Life, and I give a lecture on IR light where I talk about global warming.

Thanks,

randy

I got an automated reply:

Your email has been received. Due to the high volume of emails received, however, I cannot promise that all messages will be read and/or replied to.

For publicity-related matters (interview requests, etc.) please contact Brooke Parsons of Public Affairs: brooke.parsons@hbgusa.com

For prospective speaking engagements, please contact Jodi Solomon Speakers: jodi@jodisolomonspeakers.com

For matters relating to *The Tantrum that Saved the World*, please contact our publicist Emily Shapiro:
eshapiro@northatlanticbooks.com

Like climate scientists, critical theorists do not see the need to answer questions and convince skeptics to change their minds by presenting clear and convincing evidence, logic, and analysis beyond a reasonable doubt. Again, this could not be more different than Popper's view of **debate in an open society**, where the search for truth to effect **gradual** policy change rather than gaining power itself to evoke **revolutionary** policy change is the goal. As Ibram X. Kendi (2019) wrote in *How to be an Antiracist*, "*An activist produces power and policy change, not mental change*." Kendi goes on to say, "*Educational and moral suasion is not only a failed strategy. It is a suicidal strategy…I had to forsake the suasionist bred into me, of researching and educating for the sake of changing minds*."

And frankly "*because science*" is not a good enough explanation:

From: Union of Concerned Scientists <action@ucsusa.org>
Sent: Monday, May 3, 2021 10:10 AM
To: Randy O. Wayne
Subject: Why stay masked? Because science



Why stay masked? Because science!

With the arrival of spring and the increasing availability of vaccines, hope is in the air. Also still in the air: COVID-19.

The pandemic isn't over yet, and we need to stay vigilant and keep masking up—especially if you're not 100 percent vaccinated yet. Tell everyone it's ***because science*** with your **UCS face mask**, $10 plus shipping at the UCS store.

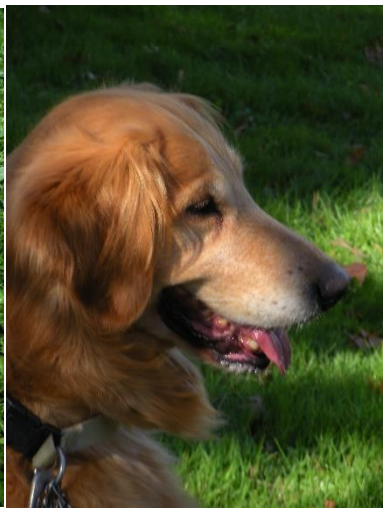


Nor is dismissing debate because one is a scientist, as **Nicholas Wade** courageously reported in an article published on May 5, 2021 in the *Bulletin of Atomic Scientists*. It is a good time to remember the statue of George Orwell that stands in front of the BBC.

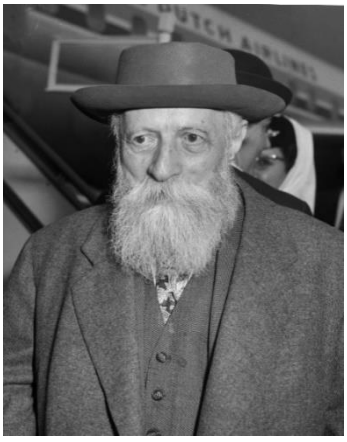


As an aside. What is the place of **pets** in a real and meaningful world? When we think of our pets, we appreciate the importance of both **inbreeding and outbreeding to preserve desirable characteristics and minimize inbreeding depression**. We think about our pets much like **Samuel Wilberforce** thought about breeds of pigeons, cats, and dogs—each has a unique set of qualities. We do not think about the survival of the fittest, in terms of defining the most fit dog as the one that leaves the most offspring. Quite the opposite, we value pets because they teach us about the **meaningful though unmeasurable qualities of gratitude, caring for others, and unconditional love**.

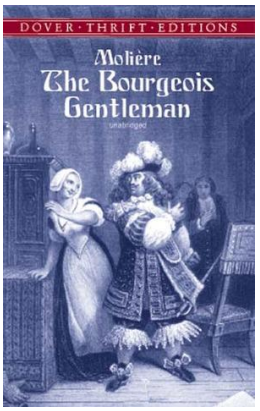




Martin Buber (1923) wrote in *I and Thou*, "***An animal's eyes have the power to speak a great language***. *Independently, without needing co-operation of sounds and gestures, most forcibly when they rely wholly on their glance, the eyes express the mystery in its natural prison, the anxiety of becoming. This condition of the mystery is known only by the animal, it alone can disclose it to us — and this condition only lets itself be disclosed, not fully revealed. The language in which it is uttered is what it says — anxiety, the movement of the creature between the realms of vegetable security and spiritual venture. This language is the stammering of nature at the first touch of spirit, before it yields to spirit's cosmic venture that we call man.* ***But no speech will ever repeat what that stammering knows and can proclaim***."



Speaking of speech, there are two kinds: Poetry and Prose. Have you read ***Le Bourgeois Gentilhomme*** by MOLIÈRE (Jean-Baptiste Poquelin, 1670)?



MONSIEUR JOURDAIN: Please do. But now, I must confide in you. I'm in love with a lady of great quality, and I wish that you would help me write something to her in a little note that I will let fall at her feet.

PHILOSOPHY MASTER: Very well.

MONSIEUR JOURDAIN: That will be gallant, yes?

*PHILOSOPHY MASTER: Without doubt. Is it **verse** that you wish to write her?*

*MONSIEUR JOURDAIN: No, no. No **verse**.*

*PHILOSOPHY MASTER: Do you want only **prose**?*

*MONSIEUR JOURDAIN: No, I don't want either **prose or verse**.*

PHILOSOPHY MASTER: It must be one or the other.

MONSIEUR JOURDAIN: Why?

*PHILOSOPHY MASTER: Because, sir, there is no other way to express oneself than with **prose or verse**.*

*MONSIEUR JOURDAIN: There is nothing but **prose or verse**?*

*PHILOSOPHY MASTER: No, sir, everything that is not **prose is verse**, and everything that is not **verse is prose**.*

MONSIEUR JOURDAIN: And when one speaks, what is that then?

*PHILOSOPHY MASTER: **Prose**.*

*MONSIEUR JOURDAIN: What! When I say, 'Nicole, bring me my slippers, and give me my nightcap,' that's **prose**?*

PHILOSOPHY MASTER: Yes, Sir.

MONSIEUR JOURDAIN: By my faith! ***For more than forty years I have been speaking prose without knowing anything about it****, and I am much obliged to you for having taught me that. I would like then to put into a note to her: 'Beautiful marchioness, your lovely eyes make me die of love,' but I want that put in a gallant manner and be nicely turned.*

Socialism enlists science in the battle against religion. V. I. Lenin (1905) wrote in *Socialism and Religion* (https://www.marxists.org/archive/lenin/works/1905/dec/03.htm#bkV10E036)

"*But a slave who has become conscious of his slavery and has risen to struggle for his emancipation has already half ceased to be a slave. The modern class-conscious worker, reared by large-scale factory industry and enlightened by urban life, contemptuously casts aside religious prejudices, leaves heaven to the priests and bourgeois bigots, and tries to win a better life for himself here on earth. The proletariat of today takes the side of socialism, which enlists* ***science in the battle against the fog of religion****, and frees the workers from their belief in life after death by welding them together to fight in the present for a better life on earth*."

"*Our Programme is based entirely on the* ***scientific****, and moreover the* ***materialist, world-outlook****. An explanation of our Programme, therefore, necessarily includes an explanation of the true historical and economic roots of the religious fog.* ***Our propaganda necessarily includes the propaganda of atheism****;* ***the publication of the appropriate scientific literature****, which the autocratic feudal government has hitherto strictly forbidden and persecuted, must now form one of the fields of our Party work. We shall now probably have to follow the advice Engels once gave to*

the German Socialists: to translate and widely disseminate the literature of the eighteenth-century French Enlighteners and atheists."

"*That is the reason why we do not and should not set forth our atheism in our Programme; that is why we do not and should not prohibit proletarians who still retain vestiges of their old prejudices from associating themselves with our Party.* ***We shall always preach the scientific world-outlook****, and it is essential for us to combat the inconsistency of various "Christians". But that does not mean in the least that the religious question ought to be advanced to first place, where it does not belong at all; nor does it mean that we should allow the forces of the really revolutionary economic and political struggle to be split up on account of third-rate opinions or senseless ideas, rapidly losing all political importance, rapidly being swept out as rubbish by the very course of economic development*."

Lenin shared his views on the danger of religion to the Communist Party with Maxim Gorky in a letter written on Nov. 13 or 14, 1913 (http://www.marx2mao.com/PDFs/Lenin%20CW-Vol.%2035.pdf), "*Just because any religious idea, any idea of any god at all, any flirtation even with a god, is the most inexpressible foulness, particularly tolerantly (and often even favourably) accepted by the democratic bourgeoisie—for that very reason it is the most dangerous foulness, the most shameful '****infection****.' A million physical sins, dirty tricks, acts of violence and infections are much more easily discovered by the crowd, and therefore are much less dangerous, than the subtle, spiritual idea of god, dressed up in the most attractive 'ideological' costumes*."

On January 20, 2021, at the Inauguration of President Joseph Biden, Amanda Gorman recited, actually danced and sang, her exceptional poem"

***The Hill We Climb* by Amanda Gorman**



"*When day comes we ask ourselves, where can* ***we find light in this never-ending shade****? The loss we carry, a sea we must wade. We've braved the belly of the beast, we've learned that quiet isn't always peace and the norms and notions of what just is, isn't always justice. And yet the dawn is ours before we knew it, somehow we do it, somehow we've weathered and witnessed a nation that isn't broken but simply unfinished.*

We, the successors of a country and a time where a skinny black girl descended from slaves and raised by a single mother can dream of becoming president only to find herself reciting for one. And, yes, we are far from polished, far from pristine, but that doesn't mean we are striving to form a union that is perfect, we are ***striving to forge a union with purpose****, to compose a country committed to all cultures, colors, characters and conditions of man.*

So we lift our gazes not to what stands between us, but what stands before us. We close the divide because we know to put our future first, we must first put our differences aside. We lay down our arms so we can reach out our arms to one another, we seek harm to none and harmony for all.

Let the globe, if nothing else, say this is true: that even as we grieved, we grew, even as we hurt, we hoped, that even as we tired, we tried, that we'll forever be tied together victorious, not because we will never again know defeat but because we will never again sow division.

Scripture tells us to envision that everyone shall sit under their own vine and fig tree and no one should make them afraid. If we're to live up to our own time, then victory won't lie in the blade, but in in all of the bridges we've made.

That is the promise to glade, the hill we climb if only we dare it because being American is more than a pride we inherit, it's the past we step into and how we repair it. We've seen a force that would shatter our nation rather than share it. That would destroy our country if it meant delaying democracy, and this effort very nearly succeeded. But while democracy can periodically be delayed, but it can never be permanently defeated.

In this truth, in this faith, we trust, for while we have our eyes on the future, history has its eyes on us, this is the era of just redemption we feared in its inception we did not feel prepared to be the heirs of such a terrifying hour but within it we found the power to author a new chapter, to offer hope and laughter to ourselves, so while once we asked how can we possibly prevail over catastrophe, now we assert how could catastrophe possibly prevail over us.

We will not march back to what was but move to what shall be, a country that is bruised but whole, benevolent but bold, fierce and free, we will not be turned around or interrupted by intimidation because we know our inaction and inertia will be the inheritance of the next generation, our blunders become their burden. But one thing is certain: if we merge mercy with might and might with right, then love becomes our legacy and change our children's birthright.

So let us leave behind a country better than the one we were left, with every breath from my bronze, pounded chest, we will raise this wounded world into a wondrous one, we will rise from the golden hills of the West, we will rise from the windswept

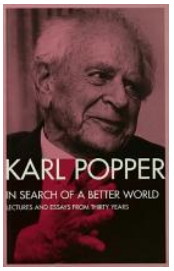
Northeast where our forefathers first realized revolution, we will rise from the lake-rimmed cities of the Midwestern states, we will rise from the sunbaked South, we will rebuild, reconcile, and recover in every known nook of our nation in every corner called our country our people diverse and beautiful will emerge battered and beautiful, when the day comes we step out of the shade aflame and unafraid, the new dawn blooms as we free it, ***for there is always light if only we're brave enough to see it, if only we're brave enough to be it****."*

Karl Popper (1965) wrote in *Conjectures and Refutations: The Growth of Scientific Knowledge*, "*THE ESSAYS and lectures of which this book is composed are variations upon one very simple theme—****the thesis that we can learn from our mistakes.*** *They develop a theory of knowledge and of its growth. It is a theory of reason that assigns to rational arguments the modest and yet important role of criticizing our often mistaken attempts to solve our problems. And it is a theory of experience that assigns to our observations the equally modest and almost equally important role of tests which may help us in the discovery of our mistakes. Though it stresses our fallibility it does not resign itself to scepticism, for it also stresses the fact that knowledge can grow, and that science can progress--just because we can learn from our mistakes.*

The way in which knowledge progresses, and especially our scientific knowledge, is by unjustified (and unjustifiable) anticipations, by guesses, by tentative solutions to our problems, by conjectures. These conjectures are controlled by criticism; that is, by attempted refutations, which include severely critical tests. They may survive these tests; but they can never be positively justified: they can neither be established as certainly true nor even as 'probable' (in the sense of the probability calculus). Criticism of our conjectures is of decisive importance: by bringing out our mistakes it makes us understand the difficulties of

the problem which we are trying to solve. This is how we become better acquainted with our problem, and able to propose more mature solutions: ***the very refutation of a theory—that is, of any serious tentative solution to our problem—is always a step forward that takes us nearer to the truth. And this is how we can learn from our mistakes***."

Popper ends the preface with a definition of liberal that has nothing to do with politics: "*To avoid misunderstandings I wish to make it quite clear that I use the terms 'liberal', 'liberalism', etc., always in a sense in which they are still generally used in England (though perhaps not in America):* ***by a liberal I do not mean a sympathizer with any one political party but simply a man who values individual freedom and who is alive to the dangers inherent in all forms of power and authority***."



Popper considered himself "***the last laggard of the enlightenment***." Me too!



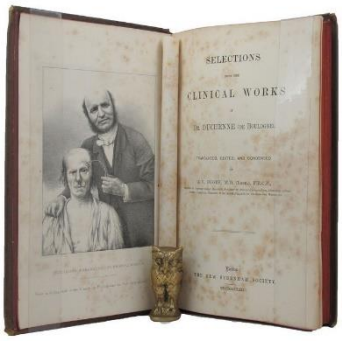
Finding the truth in science requires freedom of speech. We live in a country where free speech is paramount. The First Amendment of the Constitution states: *Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof; or abridging the* ***freedom of speech****, or of the press; or the right of the people peaceably to assemble, and to petition the Government for a redress of grievances.* Today the words **misinformation** and **disinformation** are thrown around by the **intellectually lazy** instead of using reason to answer the questions of those who do not agree with the statements presented. If you ask me, a real intellectual would

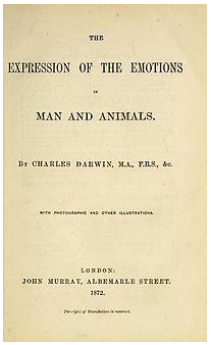
explain using evidence and reason why something is misinformation or disinformation.

One last thing about smiling eyes:









Guillaume Duchenne studied the physiology of facial expressions by stimulating facial muscles with electrodes and photographing the resultant facial expressions. In doing so, he identified two kinds of smiles based on the muscles used to effect them. One kind, now known as the **Duchenne smile**, involves the contraction of both the *zygomatic major* muscle, which raises the corners of the mouth and the *orbicularis oculi* muscle, which raises the cheeks and forms crow's feet around the eyes. The Duchenne smile is known as **smiling with the eyes**. According to Charles Darwin, who used Duchenne's photographs in his book, **The Expression of the Emotions in Man and Animals**, a real smile also requires the contraction of the *malaris* muscle that pulls the upper lip up.



A fake smile, which is the other kind of smile observed by Duchenne, only involves the *zygomatic major* muscle, and the eyes are not affected. This was known as the "*Pan Am smile*," and is now known as the "*Botox smile*," in part because Pan Am went out of business and Botox has become popular. The Pan Am smile is named

after the smile that flight attendants flashed as they said "*buh-bye*" to every passenger as they left the plane.

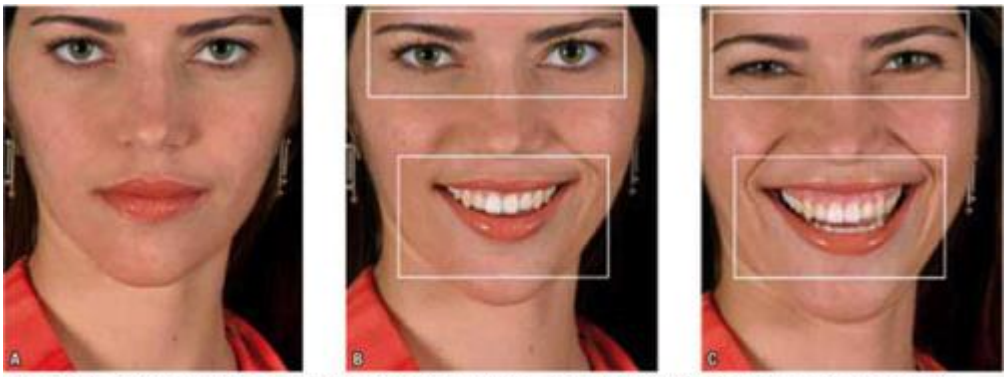
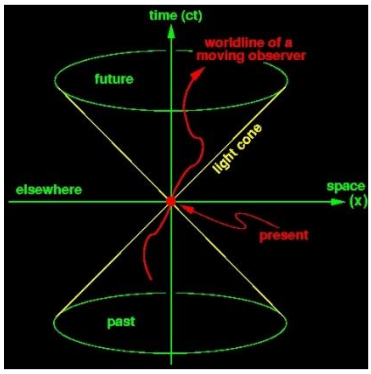
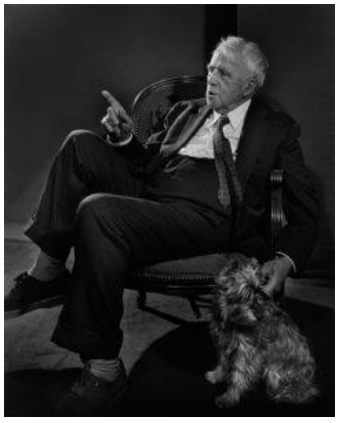


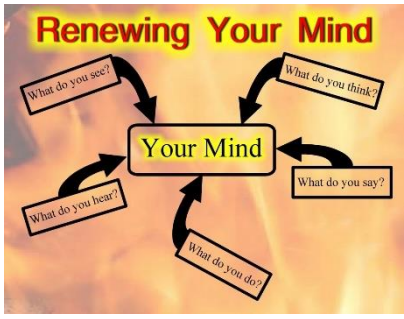
FIGURE 16 - Resting position (**A**). First stage of the smile – Social smile (**B**). Second stage of the smile – Spontaneous smile. Notice that in this stage the patient's eyes are half-shut. (**C**).



As intellectuals were using biology to tell us that life is neither real nor meaningful, **they were also using physics to tell us that space and time are illusions** held by those who cannot imagine traveling at speeds close to the speed of light. **Hermann Minkowski** (1908) wrote in a lecture entitled, *Space and Time*, "*The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.*"

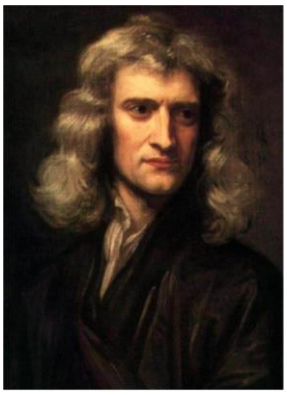


Robert Frost wrote in Notebook 22[49v], "*Einstein has done nothing but harm with the idea that time is nothing but a fourth dimension of space and so keeps space from having any fixed points to work from. Nothing abides long enough to own it or love it.* ***The worst of it is he sets up to speak with the authority of one too mathematical for us to try him. He is merely one more speculator in the realm of the metaphysical he despises.*** *I am glad to hear from behind the curtain he is not a good mathematician*." (in: *The Notebooks of Robert Frost,* Edited by Robert Faggen Belknap Press, Cambridge, MA. pp. 317-318).



It might be worthwhile to remember what Paul wrote in Romans 12:2 "*Do not be conformed to this world, but be transformed by the renewal of your mind…*"

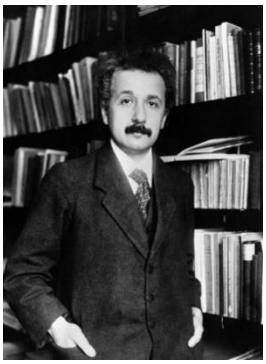
The intellectuals' idea of relative space-time depends on their understanding of the **physics of light**. Here I will discuss the physics of light and offer evidence against the relativity of an interdependent space-time and for the reality of the commonsense notion of **absolute** Newtonian time and Euclidean space.



What is light? Isaac Newton considered light in terms of its physical nature and in terms of "*Light—for the glory, truth and knowledge wherewith great and good men shine and illuminate others*."

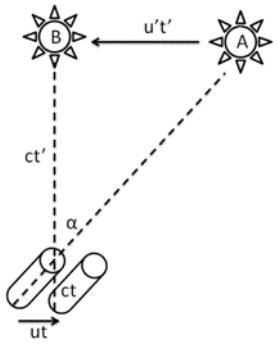


Speaking of truth, on the memorial to Albert Einstein at the National Academies of Science in Washington D.C., there is a quote from Einstein: "*The right to search for truth implies also a duty; one must not conceal any part of what one has recognized to be true*." The search for truth underlies both science and democracy. Allan Bloom (1982; Cornell) wrote, "[o]***nly democracy traces all its authority to reason****; other kinds of regimes can more or less explicitly appeal to other sources. When we talk about the West's lack of conviction or lack of will, we show that we are beginning to recognize what has happened to us. Exhortations to believe, however, are useless.* ***It is only by thinking ideas through again that we can determine whether our reason can any longer give assent to our principles***." Here, I will talk about the physical nature of light, and the importance of understanding light in terms of the **Laws of Thermodynamics**.



In the paper describing the research for which he explicitly got the Nobel Prize, **Albert Einstein** (1905) wrote, "*the energy of a light ray spreading out from a point is not continuously distributed over an increasing space, but consists of a finite number of* ***energy quanta which are localized at points in space****, which move* ***without dividing, and which can only be produced and absorbed as complete units***." These energy quanta became known as **photons**.

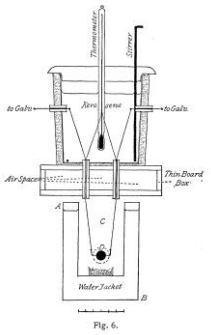
While I admire Albert Einstein, I believe that it is still rational to question his conclusions. I am going to show you why I think that the photon is **not a point** in space, but it has extension or "bigness" as Isaac Newton would say; and why I think that the photon **is not an elementary particle** but is divisible and composed of **two component parts**. But first I will present to you the widely accepted quantum mechanical model of the photon as a point-like elementary particle.



The **quantum mechanical photon** is a **mathematical point** characterized by the following four quantities: **speed**, **energy**, **linear momentum**, and **angular momentum**. The speed (c) of a photon in free space is currently defined as a constant equal to 2.99792458×10^8 m/s. The speed was first estimated by **James Bradley** (1729) who noticed that the apparent position of stars depended on which direction the earth was moving as it orbited the sun. From this "aberration," Bradley concluded that light travels 10,210 times faster than the earth in its orbit. This meant that "*one Particle of Light*" would take 8' 12" to propagate from the sun to the earth.

The **energy** of light was measured by **Ernest F. Nichols** (Cornell) and Hull (1903) by irradiating a blackened disc of silver, obtained from Tiffany & Co. and measuring its rate of temperature increase. The First Law of Thermodynamics was used to convert heat energy to radiant energy.



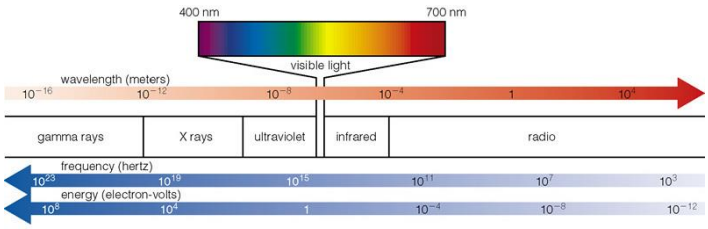


The **energy** (E) of a single photon could be determined by dividing the total energy of light by the number of photons that make up the light. But how do you express the energy of a photon? According to the wave theory of light, the energy is related to the amplitude of a wave. However, as we will see, the energy of a photon is related to its wavelength and is given by the following equation:

$$E = \frac{hc}{\lambda}$$

where h is Planck's constant ($6.62606957 \times 10^{-34}$ J s) and λ is the wavelength of the photon.

The wavelength of a photon represents its **wave-like properties**. Since the **frequency** (ν) of a wave is equal to the ratio of its speed to its wavelength $\left(\nu = \frac{c}{\lambda}\right)$, the energy of a photon in free space that is traveling at a speed c is also given by:

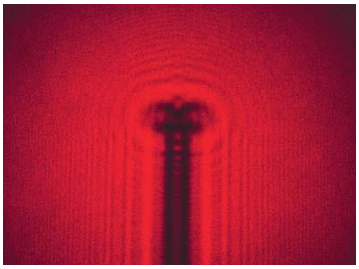


$$E = h\nu.$$

High energy photons such as photons in the X-ray (0.01 nm-10 nm) and UVC (100-280 nm) ranges have **short wavelengths** and low energy photons such as photons in the infrared (700 nm-1 mm) and microwave (1 mm-1 m) ranges have **long wavelengths**. The wavelength of photons is necessary to explain their ability to **interfere** in order to produce the beautiful iridescent colors observed in thin plates and in the tail feathers of a peacock. The wavelength of photons is also necessary to explain the **diffraction of light by small** and **microscopic objects**.







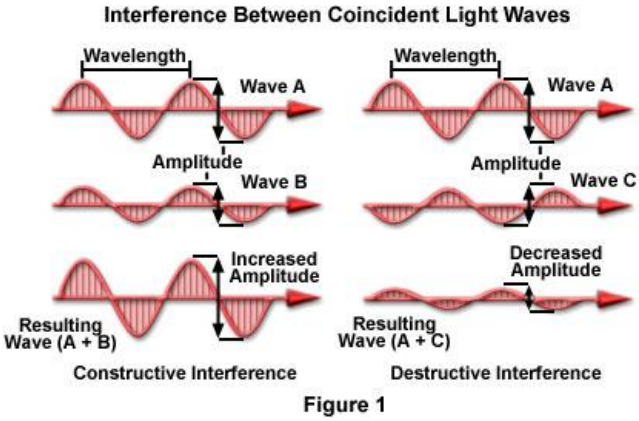
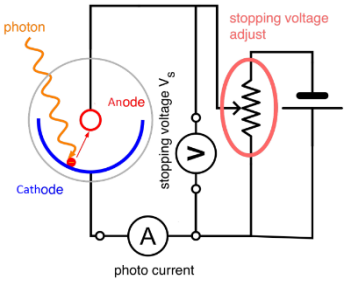


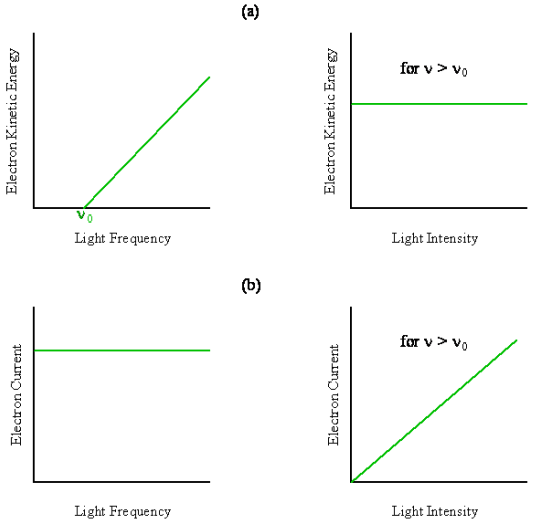
Figure 1

The explanation of interference demands that the energy or intensity of light depends on the **amplitude** of the light wave—being proportional to the **square of the amplitude** and not related to the **wavelength** or **frequency**. However, experiments performed in the later part of the 19th century by Philipp Lenard led to the idea that the energy of light is a function of the wavelength or frequency of light.

Philipp Lenard (1900,1902) showed that in a vacuum, the **photoelectrons** ejected from a metal by **ultraviolet light** could be accelerated or retarded by an electric field. The greater the electric field needed to retard the electrons, the greater the kinetic energy of those electrons must have been. Philipp Lenard showed that the **kinetic energy** of the ejected **photoelectrons** was related to the **frequency** of the incident light and not to its **intensity**. The **light intensity** however determined the amount of current generated by the incident light. Since the current is a measure of the number of electrons propelled from the metal, the **number of electrons** ejected from the metal is related to the light intensity.







Albert Einstein (1905) presented an equation to describe the photoelectric effect. The modern form of Einstein's equation for the kinetic energy ($KE = \frac{1}{2}mv^2$) of the electron becomes:

$$KE = hv - W$$

where W is the work function or the amount of energy it takes to release the electron from an atom.



Robert Millikan (1915, 1924) provided the experimental proof that confirmed the validity of Albert Einstein's equation "*after ten years of testing and changing and learning and sometimes blundering*." The **slope** of the line that related the kinetic energy of the photoelectrons ejected from a metal to the frequency of the incident light was equal to Planck's constant, and the product of the x-intercept and Planck's constant was equal to the **work function**.

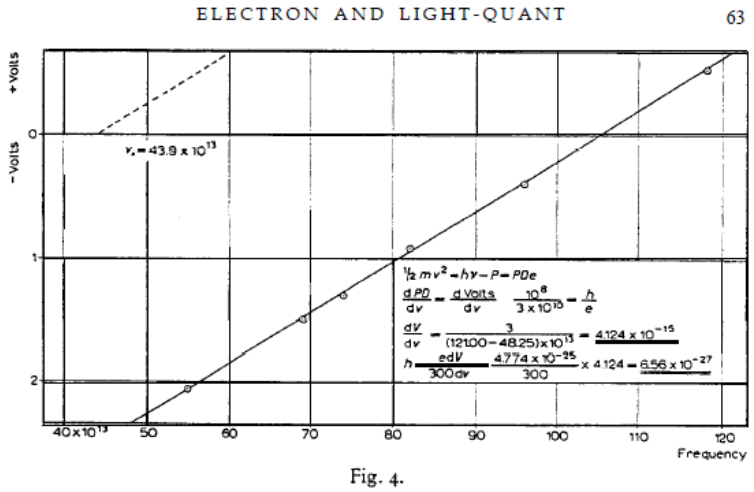


Fig. 4.

These experimental confirmations of Albert Einstein's heuristic proposal that the energy of a photon was related to its wavelength or frequency, but not its amplitude was quite a blow to the wave theory of light. However, Robert Millikan said in his Nobel lecture, "*…the general validity of Einstein's equation is, I think, now universally conceded, and to that extent the reality of Einstein's light-quanta may be considered as experimentally established. But the conception of* ***localized*** [point-like] ***light-quanta out of which Einstein got his equation must still be regarded as far from being established****…It may be said then without hesitation that it is not merely the Einstein equation which is having extraordinary success at the moment, but the Einstein conception as well. But* ***until it can account for the facts on interference and the other effects which have seemed thus far to be irreconcilable with it, we must withhold our full assent***."

Energy is a **scalar quantity** that only has **magnitude** and was easy to work with algebraically, while linear momentum is a **vector quantity**, with direction and magnitude, and was more difficult to work with, especially in the fledgling field of quantum theory. Nichols and Hull (1901,1903) measured the linear momentum of light (actually the radiation pressure) by shining light on a mirror hung on a fiber made of quartz and silk and measuring its deflection.

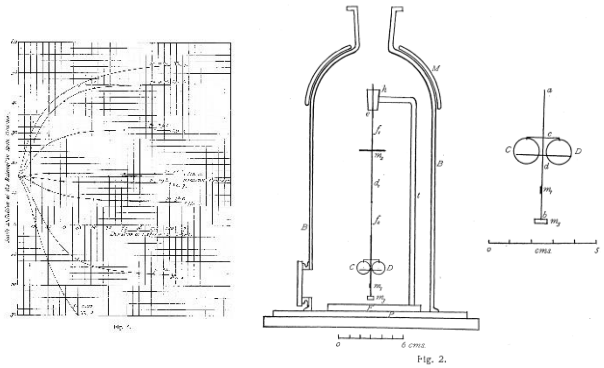
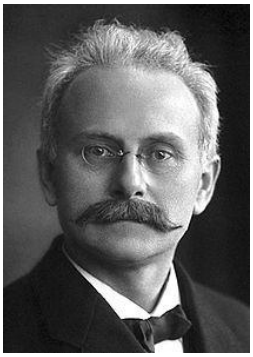


Fig. 2.



Johannes Stark (1909) also took into consideration the unidirectional nature of light propagation and related the linear momentum of a photon to its energy. The linear momentum (p) of a photon is related to its energy (E) by:

$$p = \frac{E}{c}$$

and since $E = \frac{hc}{\lambda}$,

$$p = \frac{h}{\lambda}.$$



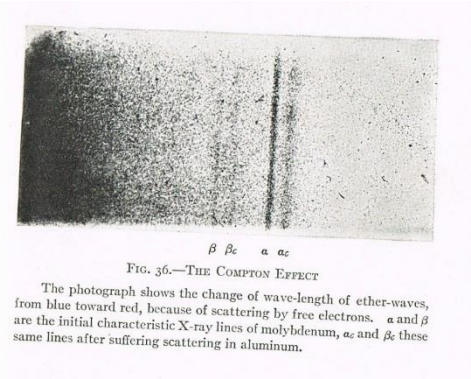

β β_c α α_c

FIG. 36.—THE COMPTON EFFECT

The photograph shows the change of wave-length of ether-waves, from blue toward red, because of scattering by free electrons. α and β are the initial characteristic X-ray lines of molybdenum, α_c and β_c these same lines after suffering scattering in aluminum.

Since the linear momentum of a photon is inversely proportional to its wavelength, photons with very short wavelength such as photons in the X-ray range (0.01-10 nm) will have very large linear momenta. **Arthur Compton** (1923) scattered X-rays from the electrons of graphite (carbon) and measured the

wavelength of the scattered X-rays with a diffraction grating spectrometer. He discovered that the wavelength of the scattered X-rays was longer than the wavelength of the incident X-rays.

Arthur Compton realized that the wavelength of the X-rays would get longer if X-rays were considered to be particles with energy and linear momentum; and that both energy and linear momentum were **conserved in a collision**. If the X-ray photon had enough linear momentum to cause the electron to recoil, then the scattered X-ray photon should have a smidgen less momentum than the incident X-ray photon. Arthur Compton found that the red shift in the wavelength of the scattered radiation was perfectly consistent with the **Doppler effect**, which was a wave-like phenomena, since the recoiling electron was actually moving away from the incident and scattered X-ray photons.

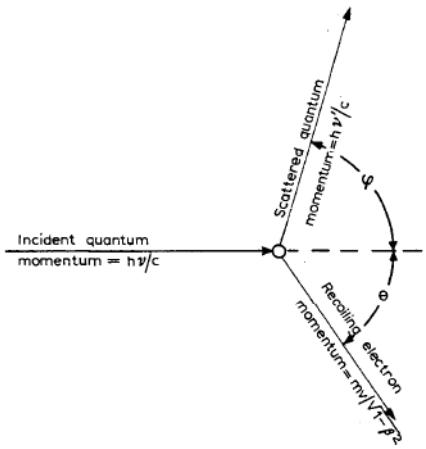


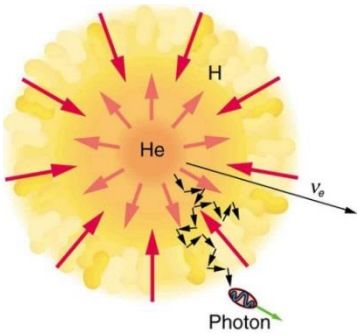
Fig. 9. An X-ray photon is deflected through an angle φ by an electron, which in turn recoils at an angle θ, taking a part of the energy of the photon.

The fact that energy and linear momentum are conserved in collisions between photons and electrons supports the **particulate nature of the photon** and also suggests that the photon has some kind of mass associated with it. Since photons propagate at the speed of light, the momentum (mv) is given by the following equation:

$$p = mc$$

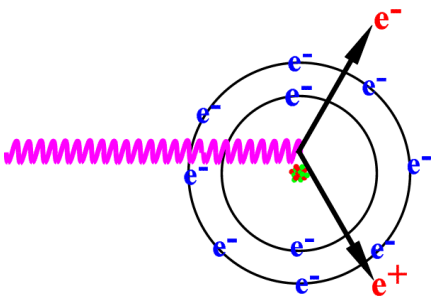
And since $E = pc$;

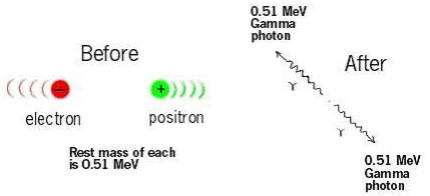
$$E = mc^2.$$



This equation states that mass and energy are transformable and that a small decrease in mass like that which occurs in the **core of the sun when four protons are fused into a helium nucleus**, results in a large release of energy.

The relationship between energy and mass comes from the definitions of a photon's energy and linear momentum. In fact, when a photon with a very short wavelength enters the strong electric field of an atom, the photon is transformed into an **electron** (e^-), which is a particle and a **positron** (e^+), which is an antiparticle in a process known as **pair production**. Conversely, when an antiparticle such as a positron collides with a particle such as an electron, they annihilate each other and are transformed into photons in a process known as **pair annihilation**.



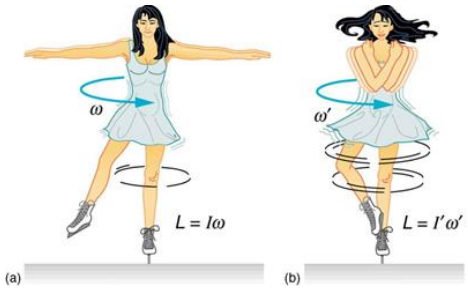


If the photon is a mathematical point, it cannot be composed of a particle and an antiparticle, but transforms into a particle and an antiparticle, the identities of which depend on the energy of the photon. If the photon has extension, it can be composed of a particle and an antiparticle, the identities of which depend on the energy of the photon.



The annihilation of electrons and positrons take place every day in hospitals that perform **PET (positron emission tomography) scans** to look for cancerous cells.

The First Law of Thermodynamics states that energy is conserved. There are other **conservation laws** that are equally important. These include the **conservation of linear momentum** and the **conservation of angular momentum**. Richard Beth (1936) showed that light has mechanical angular momentum using a torsion balance. He shined polarized light through a transparent birefringent disc suspended on a quartz fiber and measured the amount of rotation of the disk for light with a given polarization.



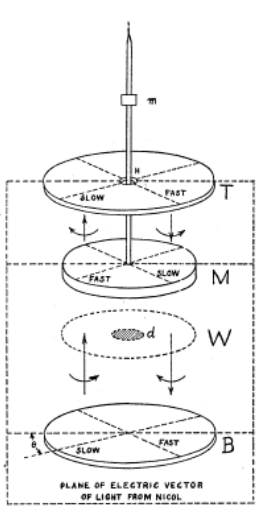


FIG. 3. Wave plate arrangement.

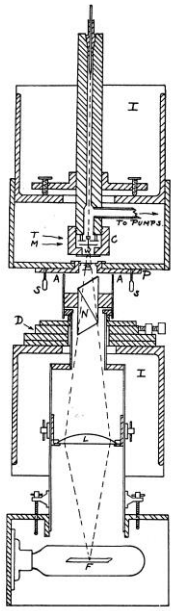
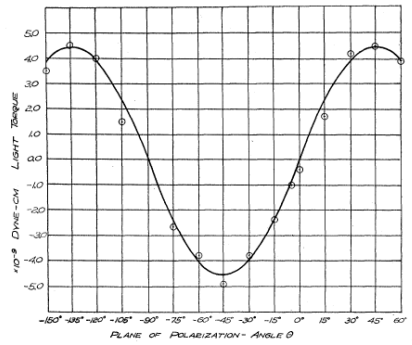


FIG. 1. Diagram of apparatus.

The **spin angular momentum** (L) for each and every photon given by the following equation:

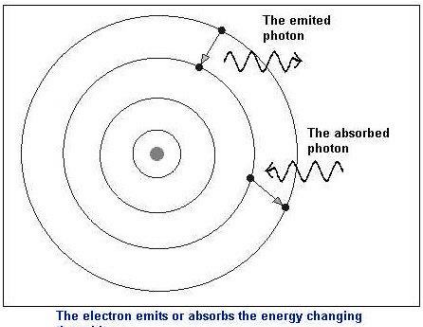
$$L = \frac{h}{2\pi} = \hbar$$

where ħ is known as h-bar. Interestingly, the spin angular momentum, which is a vector quantity, is unique in terms of conserved quantities in that it is the only property shared by all photons, independent of their frequency and wavelength.

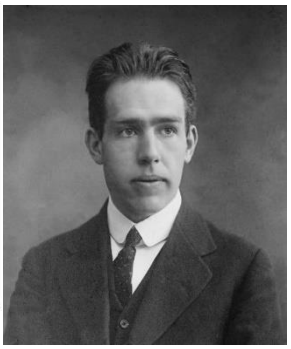


We have discussed the energy, linear momentum, and angular momentum of a photon. The fact that these are **conserved quantities** means that following an interaction of a photon with an object such as a gas molecule, a metal or a pigment, the energy, the linear momentum, and the angular momentum of the photon and the object must be the same as it was before the interaction.

Niels Bohr (1913) used the idea of quantized angular momentum to describe the planetary model of the atom and wrote, "*In any molecular system consisting of positive nuclei and electrons in which the nuclei are at rest relative to each other and the electrons move in circular orbits, the angular momentum of every electron round the centre of its orbit will in the permanent state of the system be equal to h/2π, where h is Planck's constant*."



The electron emits or absorbs the energy changing the orbits.

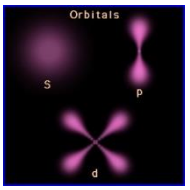


Arnold Sommerfeld (1923) suggested that **angular momentum**, which was then known as the moment of momentum, must not only characterize the atomic system but must be **conserved** when it emits a photon. Arnold Sommerfeld wrote, "*…in the process of emission…, we demanded…the conservation of energy. The energy that is made available by the atom should be entirely accounted for in the energy of radiation ν, which is, according to the quantum theory of the oscillator, equal to hν. With the same right, we now demand the* ***conservation of momentum and of moment of momentum: if in a change of configuration of the atom, its momentum or moment of momentum alters, then these quantities are to be reproduced entirely and unweakened in the momentum and moment of momentum of the radiation***."



While the idea that **energy, linear momentum, and angular momentum are conserved** during an interaction is consistent with the **first law of thermodynamics**, according to the **Copenhagen interpretation of quantum mechanics**, which is the consensus view, when these "laws" are applied to elementary particles, they are subordinate to the uncertainty principle, which states that the values of these quantities are uncertain over space and time. This is

because the Copenhagen interpretation demands that **conjugate properties** like energy and time, linear momentum and space, and angular momentum and direction **must be measured simultaneously**. This is ridiculous. For example, how can you measure the position of a particle or a car and its change in position, which gives its momentum, **simultaneously**? The uncertainty that comes from this ridiculous demand underlies all the unintuitive interpretations that come from quantum mechanics.

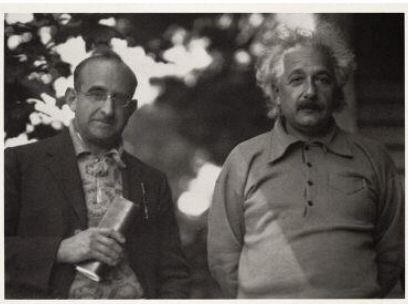


One of the unintuitive interpretations that come from the Copenhagen interpretation of quantum mechanics, which is the consensus view, is that the elementary particles, such as an electron that makes up a part of atoms, is not really there and has **no independent existence in space and time until it is measured**. Until it is measured, it exists in many possible states described by the wave functions. The orbitals in quantum mechanics indicate the most probable places that an electron may show up when measured. In *Introduction to Quantum Mechanics*, a standard textbook in quantum mechanics, David Griffiths (2005) describes: "***The orthodox position: The particle wasn't really anywhere***. *It was the act of measurement that forced the particle to 'take a stand' (though how and why it decided on the point C we dare not ask).* [Pascual] ***Jordan*** [1934] *said it most starkly, '****Observations not only disturb what is to be measured, they produce it****.... We compel (the particle) to assume a definite position.' This view (the so-called Copenhagen interpretation), is associated with Bohr and his followers. Among physicists it has always been the most widely accepted position.*"



Einstein, never believed that quantum mechanics was a complete theory of nature, and one moonlit night as Einstein walked with Abraham Pais in Princeton, Einstein asked Pais, "***Do you really believe the moon is not there when you are not looking at it?"***

The idea that conjugate properties must be measured simultaneously came from Einstein's theory of relativity that promoted the importance of taking simultaneity into consideration when making measurements in a universe where space and time were relative and absolute space and absolute time were illusions. But, did quantum mechanics take the idea of simultaneity too far? Werner Heisenberg (1983) and Philipp Frank (1947) present the following story:



Einstein: "*A new fashion has now arisen in physics. By means of ingeniously formulated theoretical experiments it is proved that physical magnitudes cannot be measured, or, to put it more precisely, that* ***according to accepted natural laws the investigated bodies behave in such a way as to baffle all attempts at measurement. From this the conclusion is drawn that it is completely meaningless to retain these magnitudes*** [energy and time; linear momentum and position, angular momentum and direction] ***in the language of physics.*****"**
Philipp Frank: "*But the fashion you speak of was invented by you in 1905*!"
Einstein: "***A good joke should not be repeated too often***."






By assuming that absolute space and time were illusions, and thus that conjugate properties had to be measured simultaneously, the idea of **complementarity** supplanted the classical concept of **causality** in modern physics. **Max Born and Werner Heisenberg** declared at the 1927 Solvay Conference, "*By way of summary, we wish to emphasise that while we consider the last mentioned enquiries, which relate to a quantum mechanical treatment of the electromagnetic field,* ***as not yet completed****,* ***we consider quantum mechanics to be a closed theory [geschlossene Theorie], whose fundamental physical and mathematical assumptions are no longer susceptible of any modification****…****On the question of the 'validity of the law of causality' we have this opinion: as long as one takes into account only experiments that lie in the domain of our currently acquired physical and quantum mechanical experience, the assumption of indeterminism in principle, here taken as fundamental, agrees with experience****. The further development of the theory of radiation will change nothing in this state of affairs, because the dualism between corpuscles and waves, which in quantum mechanics appears as part of a contradiction-free, closed theory, holds in quite a similar way for radiation****. The relation between light quanta and electromagnetic waves must be just as statistical as that between de Broglie waves and electrons****. The difficulties still standing at present in the way of a complete theory of radiation thus do not lie in the dualism between light quanta and waves—which is entirely intelligible—instead they appear only when one attempts to arrive at a relativistically invariant, closed formulation of the electromagnetic laws…."*

While the majority of physicists accepted Born and Heisenberg's claims, a few, including Planck, Einstein, and Schrödinger challenged what Schrödinger

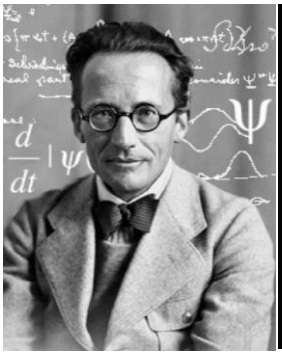
called "*the orthodox creed*." Max Planck and Albert Einstein saw the accommodation of acausality as a betrayal of the culture of physics whose aim had been to establish the relationship between cause and effect.



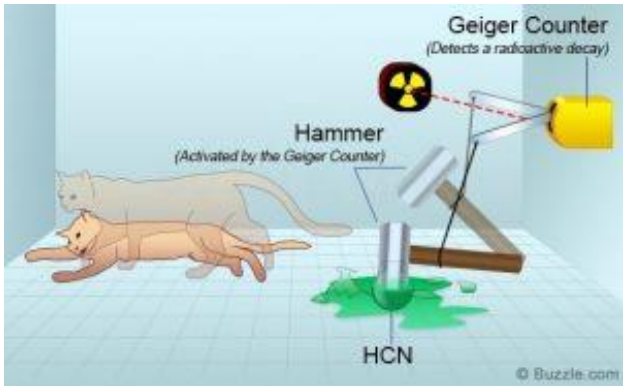
Max Planck (1932) thought that it was "premature" to raise the assumption of indeterminism to the principle of indeterminism. Planck wrote: "*The so-called principle of uncertainty, discovered and formulated by Heisenberg, is characteristic of quantum physics. It states that of two canonically conjugated quantities, such as position and momentum…only one can be measured with absolute accuracy, and that only by the sacrifice of accuracy in the other.,,Hence, if one of the two is determined with absolute accuracy, the other remains absolutely undetermined*."

"*It stands to reason that this statement makes it on principle impossible to transfer with any accuracy into the world of the senses the simultaneous values of coordinates and momenta which play the predominant part in the world of classical physics. For the strictly causal view of the world this fact raises a difficulty, which has already led some indeterminists to affirm that the law of causality in physics is definitely disproved. However, on closer consideration this conclusion, which is due to confusion of the world-picture with the world of sense, must be called at least premature. For there is at hand, for overcoming this difficulty, a means which has often done excellent service in similar cases. It is the assumption that the question as to the simultaneous values of the coordinates and of the momenta of a particle has no meaning in physics. The law of causality must not be blamed for the impossibility of answering a meaningless question. The blame must rather be laid on the assumption which have led to putting of that question, that is to say on the assumed structure of the physicist's world-picture*."

"*In conclusion we may therefore say: the law of causality is neither right nor wrong, it can be neither generally proved nor generally disproved. It is rather a heuristic principle, a sign-post (and to my mind the most valuable sign-post we possess) to guide us in the motley confusion of events and to show us the direction in which scientific research must advance in order to attain fruitful results*."

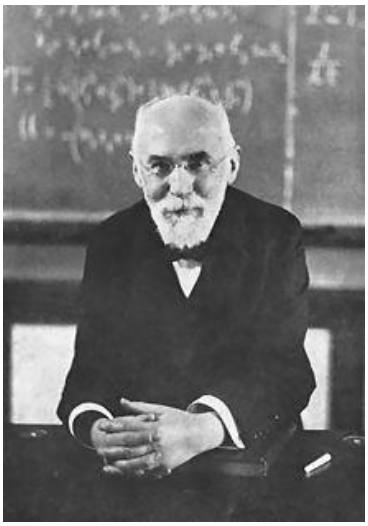






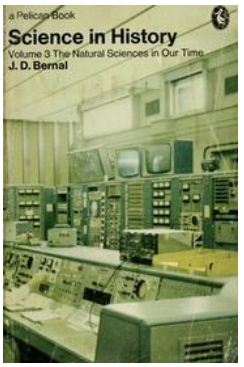
Erwin Schrödinger suggested that if the Copenhagen interpretation of quantum mechanics were true, then a cat could be dead and alive at the same time. Schrödinger (1935; Trimmer, 1980) wrote, "*One can even set up quite ridiculous cases. A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in a Geiger counter, there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer that shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The psi-function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts. It is typical of these cases that an indeterminacy originally restricted to the atomic domain becomes transformed into macroscopic indeterminacy, which can then be resolved by direct observation. That prevents us from so naively accepting as valid a "blurred model" for representing reality*."

According to Heisenberg "*All the opponents of the Copenhagen interpretation do agree on one point.* ***It would, in their view, be desirable to return to the reality concept of classical physics or, more generally expressed, to the ontology of materialism; that is, to the idea of an objective real world, whose smallest parts exist objectively in the same way as stones and trees, independently of whether or not we observe them***." But perhaps the atoms that make up stones and trees and cats are as real as the stones and trees and cats themselves.

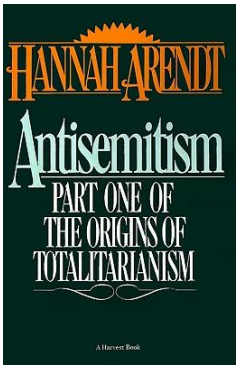


Hendrik Lorentz (1927) didn't like the idea of eliminating an objective real world from physics. When Born and Heisenberg presented their paper he responded with, "***We wish to make a representation of the phenomena, to form an image of them in our minds***. *Until now, we have always wanted to form these images by means of the ordinary notions of time and space. These notions are perhaps innate; in any case, they have developed from our personal experience, by our daily observations. For me, these notions are clear and I confess that I should be unable to imagine physics without these notions.* ***The image that I wish to form of phenomena must be absolutely sharp and definite, and it seems to me that we can form such an image only in the framework of space and time***. *For me, an electron is a corpuscle that, at a given instant, is present at a definite point in space, and if I had the idea that at a following moment the corpuscle is present somewhere else, I must think of its trajectory, which is a line in space. And if the electron encounters an atom and penetrates it, and after several incidents leaves the atom, I make up a theory in which the electron preserves its individuality; that is to say, I imagine a line following which the electron passes through the atom. Obviously, such a theory may be very difficult to develop, but a priori is does not seem to me impossible…I am ready to accept other theories, on condition that one is able to*

*re-express them in terms of clear and distinct images…**Could one not keep determinism by making it an article of faith? Must one necessarily elevate indeterminism to a principle?***"**



The crystallographer **J. D. Bernal** (1965) wrote that "*the* [indeterminacy] *construction put on the quantum theory is altogether* ***arbitrary and uncalled for***." The dissenting views were not taken seriously by the consensus.

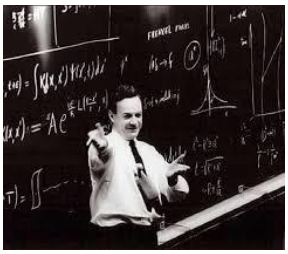


Whether based on reason or not, the separation of people into cliques is one aspect of being human. Quoting Marcel Proust, Hannah Arendt (1951) wrote in *The Origins of Totalitarianism*, "*The need to belong existed in other members of society too—'the question is not as for Hamlet,* ***to be or not to be, but to belong or not to belong.***'"

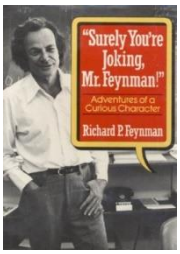
For the champions of the Copenhagen interpretation, a reality that assumed the truth of the law of causality was a free creation of the imagination but the laws of physics (e.g., the uncertainty principle) were eternal and true. **For Einstein, it was not reality that was a free creation of the imagination but the laws of physics**. How do these interpretations square with Francis Bacon's idea that **science meant connecting a cause to an effect**?

According to Frank (1947), "*In the name of progress in physics he* [Einstein] *claims the right to create any system of formulations and laws that would be in agreement with new observations…. **For Einstein the basic theoretical laws are a free creation of the imagination**, the product of the activity of an inventor who is restricted in his speculation by two principles: an empirical one, that the*

conclusions drawn from the theory must be confirmed by experience, and a half-logical, half aesthetic principle, that the fundamental laws should be as few in number as possible and logically compatible."

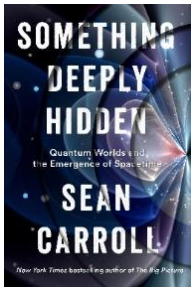


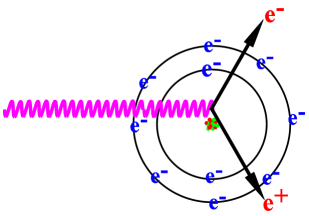
Quantum mechanics is unintelligible even to its most famous advocates. Richard Feynman (1965) said, "***I think I can safely say that nobody understands quantum mechanics***." If quantum mechanics describes the microscopic world of atoms that are the building blocks of the material world, it follows that causality in the macroscopic world is an illusion, and no one, even theoretical physicists, can understand the natural world.



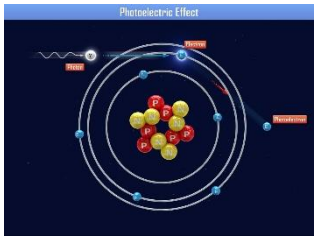


According to Sean Carroll (https://www.nytimes.com/2019/09/07/opinion/sunday/quantum-physics.html), "***If nobody understands quantum mechanics, nobody understands the universe***." Isn't science supposed to be a way of understanding the world?

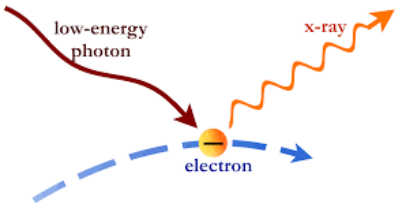




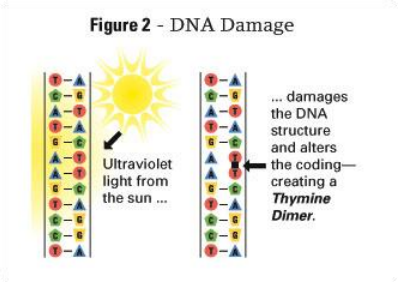
The quantum mechanical photon is a mathematical point that is characterized by four numbers that represent **speed**, **energy**, **linear momentum**, and **angular momentum**. Such a photon with the short wavelength of gamma rays may transform into an electron positron pair. Such a photon with the slightly longer wavelength of X-rays may collide with an electron and cause it to recoil. In the process, the wavelength of scattered light will be longer than the wavelength of incident light. Such

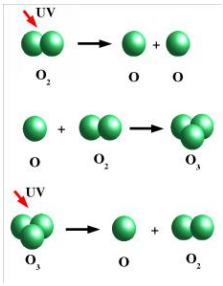


a photon with the longer wavelength of ultraviolet light will propel an electron from a metal in a phenomenon known as the photoelectric effect.

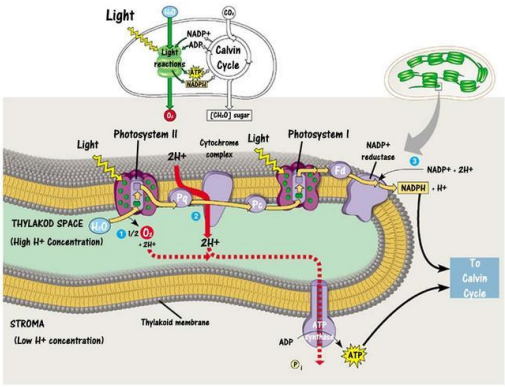


Such an ultraviolet photon could also **split a diatomic oxygen molecule or an ozone molecule in the stratosphere** or the hydrogen bonds of two **adjacent thymine bases in DNA** so that they form a TT dimer. It is intuitive to visualize the quantum mechanical photon participating in the above-mentioned processes.

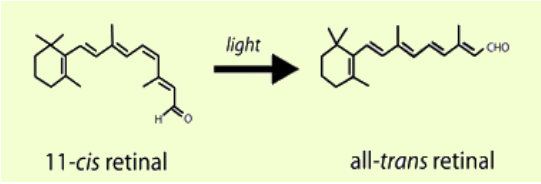




Likewise, a photon of visible light could be absorbed by a **chlorophyll molecule** in the chloroplast of a mesophyll cell in the leaf of a plant and transform the radiant energy of an absorbed photon into redox energy when an electron in the reaction center is propelled away from the positively charged nuclei of the atoms that make up the reaction center chlorophyll to an acceptor in the **photosynthetic** process. It is intuitive to visualize the quantum mechanical photon absorbed in this process as a particle.



A **spinning** photon of visible light could be **absorbed** by the 11-*cis* retinal of rhodopsin and photopsins and induce a **rotation** of a bond to form all *trans* retinal in the **visual process**. It is almost intuitive to visualize the spinning quantum mechanical photon absorbed in this process as a particle, although to induce rotation, the spinning photon really has to have **extension**.

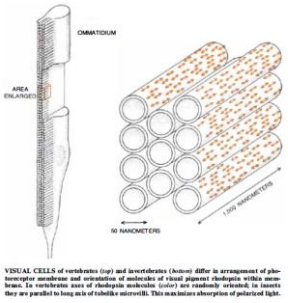


But when we consider the interaction of visible light with the molecules that make up the **thin layers** in the **blue feathers of a blue jay** or the **diffraction grating** in the exoskeleton of a scarabaeid beetle, it is impossible to visualize how the quantum mechanical **point-like** photon could produce the iridescent colors as a result of **thin film interference** and **diffraction**.





It is also impossible to visualize how the **absorption** of a quantum mechanical photon would make it possible for a honeybee to detect the **linear polarization of the skylight** in order to do the waggle dance and inform the other honeybees which direction the plants rich in nectar are.



VISUAL CELLS of vertebrates (*top*) and invertebrates (*bottom*) differ in arrangement of photoreceptor membrane and orientation of molecules of visual pigment rhodopsin within membranes. In vertebrate axes of rhodopsin molecules (*color*) are randomly oriented; in insects they are parallel to long axis of tubelike microvilli. This maximizes absorption of polarized light.

Neither the quantum mechanical model of a photon nor the classical wave model of light is sufficient on their own to explain all the observable interactions of light with matter. The quantum mechanical model assumes that a monochromatic photon is a mathematical point, and the wave theory assumes that a monochromatic photon is an infinite plane wave.

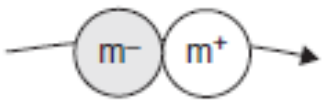
According to **Hendrik Lorentz** (1923) "*The discrepancy between these estimates of the size of a quantum, according to which it would be too big to enter our eye, and, on the other hand, the notion that it is small enough to be captured by a single electron, is certainly very wide. Yet the laws of the two classes of phenomena about which we have reasoned, the phenomena of interference and those of photo-electricity, are so well established that there can be no real contradiction between what we deduce from one class and from the other; it must after all be possible to reconcile the different ideas. Here is an important problem*

for the physics of the next future. ***We cannot help thinking that the solution will be found in some happy combination of extended waves and concentrated quanta, the waves being made responsible for interference and the quanta for photo-electricity***." I will show that it is possible to take the best parts of both theories to get a **pictorial and realistic model of a photon that will describe photons from gamma rays through radio waves** and will be approximated by the quantum mechanical photon in the gamma ray region and by the wave theory in the radio wave region of the spectrum.



To quote **C. S. Lewis** (1952; in *Mere Christianity* https://www.fadedpage.com/showbook.php?pid=20150620),

"*We all want progress. But progress means getting nearer to the place where you want to be.* ***And if you have taken a wrong turning, then to go forward does not get you any nearer***. ***If you are on the wrong road, progress means doing an about turn and walking back to the right road****; and in that case the man who turns back soonest is the most progressive man. We have all seen this when doing arithmetic. When I have started a sum the wrong way, the sooner I admit this and go back and start over again, the faster I shall get on. There is nothing progressive about being pigheaded and refusing to admit a mistake. And I think if you look at the present state of the world, it is pretty plain that humanity has been making some big mistake. We are on the wrong road. And if that is so, we must go back. Going back is the quickest way on*."



I start with the **assumption** that the photon may ***not*** be an elementary particle, but a **binary structure** consisting of a particle of matter and an antiparticle of antimatter. The **particle** and **antiparticle** have equal and opposite mass (M), charge (C) and sense of rotation (P). The sum of two masses or two charges that

are equal in magnitude but opposite in sign is **zero**. Thus, a photon in free space, where it does not interact with anything and cannot be measured, is **massless** and **charge neutral**. Because both the sense of rotation and the mass are opposite, the angular momentum of the two particles do not cancel each other but add to each other such that the binary photon has angular momentum. I define the conjugate particles of matter and antimatter as differing in charge, sense of rotation, and ***mass*** which gives **CPM symmetry** (Wayne, 2012). The **standard model of physics** defines the conjugate particles of matter and antimatter as differing in charge, sense of rotation, and ***direction in time*** which gives **CPT symmetry**. According to **Richard Feynman** (Cornell, 1988), "*Every particle in nature has an amplitude to move backwards in time, and therefore has an anti-particle…"*

Charge	*Parity*	*Time*
C (+ or -)	*P* (clockwise, left-handed, -1) or (anticlockwise, right-handed, +1)	*T* (+, forwards) or (–, backwards)

Charge	*Parity*	*Mass*
C (+ or -)	*P* (clockwise, left-handed, -1) or (anticlockwise, right-handed, +1)	*M* (+ or -)

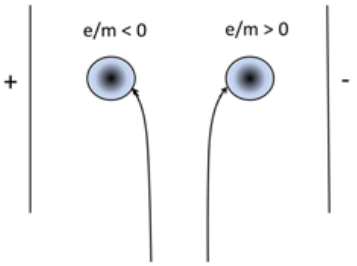
The two systems of symmetry are mathematically similar and can be considered to be two different bookkeeping systems that keep track of the same thing. Whereas in business, one bookkeeping system may be better for the IRS and the other is better for the investors, here one bookkeeping system is better for the

smartest guys in the room who make use of **relativity and quantum mechanics** as foundational principles to describe the world, and the other is better for those Luddites who use the law of causality and the laws of thermodynamics as foundational principles to describe the world.



Newton's Second Law was written only for bodies with positive mass which was reasonable because no other substance besides matter was known. I have generalized **Newton's Second Law** to include masses that are positive and negative—just as the laws of electricity and magnetism include positive and negative charges and north and south poles. Negative mass is a legitimate although an unwelcomed concept in physics and the cosmologist **Hermann Bondi** (1957) characterized many of its properties. I have defined matter as having a positive mass and antimatter as having a negative mass. According to the Newton's generalized Second Law, the ratio of force (F) to acceleration (a) of a body is given by:

$$m = \frac{F}{a}$$



where mass is a scalar quantity with sign and magnitude and force and acceleration are vector quantities with magnitude and direction in space. For positive mass, the vector of acceleration is **parallel** to the force vector, and for negative masses, the two vectors are **antiparallel**. A positive mass will accelerate toward an attractive force ($qq < 0$) and a negative mass will accelerate away from an attractive force. A positive mass will accelerate away from a repulsive force ($qq > 0$) and a negative mass will accelerate toward a repulsive force.

How do particles of negative and positive mass interact with themselves and with each other? At the onset, if we consider the particles to have mass but not

charge then we can use **Newton's Law of Gravitation** in a generalized version to describe the causal force and **Isaac Newton's (1687) Second Law** in a generalized version to determine how any two particles, with masses of arbitrary sign, respond to the causal force and accelerate relative to each other.

By equating the gravitational force (F_g) to the inertial force (F_i) we get:

$$\frac{G}{r^2} m_1 m_2 = F_g = F_i = m_2 g$$

where r is the distance between the two masses, G is the gravitational constant ($6.673003 \times 10^{11}\ m^3\ kg^{-1}\ s^{-2}$), m_1 is the mass of a large body like the earth or the sun, m_2 is the test mass, and g is the acceleration due to gravity of the test mass relative to the large body. The test mass accelerates toward the large body when $g > 0$, and the test body accelerates away from the large body when $g < 0$. The direction of the force and the acceleration for any combination of masses can be obtained by plugging masses of various signs into the above equation.

For example, when the mass of a large body is positive, there will be an attractive force ($F_g > 0$) between it and a positive test mass. Consequently, the positive test mass will accelerate toward the large positive mass ($g > 0$). When the mass of a large body is positive, there will be a repulsive force ($F_g < 0$) between it and a negative test mass. Consequently, the negative test mass will accelerate toward the large positive mass ($g > 0$).

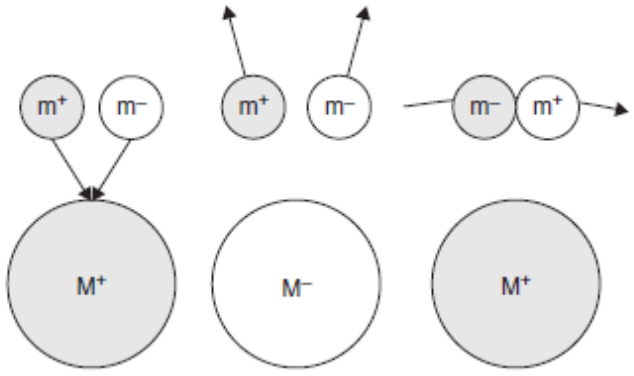
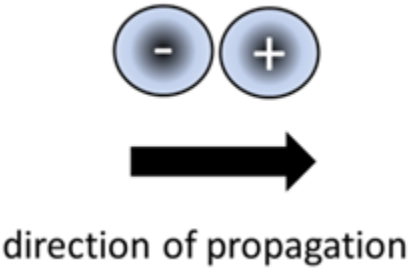


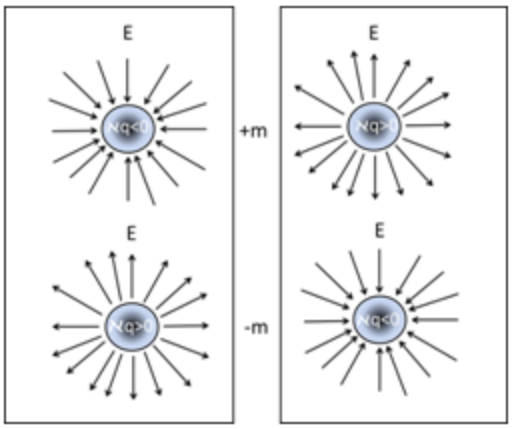
FIGURE A.1 Direction of acceleration between a large body mass and test masses.

When the mass of a large body is negative, there will be a repulsive force (F_g < 0) between it and a positive test mass. Consequently, the positive test mass will accelerate away from the large negative mass (g < 0). When the mass of a large body is negative, there will be an attractive force (F_g > 0) between it and a negative test mass. Consequently, the negative test mass will accelerate away from the large negative mass (g > 0).

Now for the interesting part that is relevant for the binary photon. If the magnitudes of the masses of a negative mass particle and a positive mass particle are the same, the positive mass particle will accelerate away from the negative mass particle ($g < 0$) and the negative mass particle will accelerate toward the positive mass particle ($g > 0$). Consequently, the negative mass particle will chase the positive mass particle.



I suggest that the gravitational force between the two conjugate semi-photons that make up the binary photon provides the motive force that causes a photon to move. While this is the only dynamic answer I know of to the question "**what causes light to move**?" it contradicts the widely held assumption that the gravitational force, which is the weakest of the four fundamental forces (e.g., strong, weak, electromagnetic, gravitational), is unimportant when it comes to subatomic distances. The proposed involvement of the gravitational force in binding the two conjugate semi-photons of the binary photon together and in propelling the binary photon through Euclidean space and Newtonian time may provide insight to explore the connection sought by Faraday (1846), Maxwell (1865), and Einstein (Pais 1982) between the gravitational and electromagnetic fields.

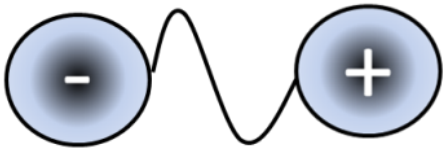


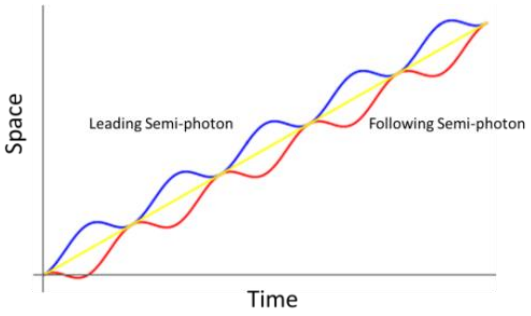
If the conjugate semi-photons that constitute the binary photon only had the properties of mass, the binary photon would accelerate to infinite velocity. Consequently, the conjugate particle and antiparticle that make up the binary photon must also have charge that could interact with the electric permittivity (ε_o) and magnetic permeability (μ_o) of the vacuum in order to constrain the velocity of the photon to the speed of light. The existence of charge within a photon seems reasonable since the **photon is the carrier of the electromagnetic force**. However, the electric field radiating from the charges of the particle and antiparticle must be equal in magnitude and opposite in sign to ensure that **the charge of the binary photon is neutral overall**. The direction of the electric field that radiates from a charge depends on both the sign of the charge and the sign of the mass. The gravitational force-induced movement of the charged particles causes a magnetic field according to Ampere's Law and an oppositely directed electromotive force according to Faraday's and Lenz's Laws that is responsible for reducing the velocity of the binary photon to the speed of light ($c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$).



Michael Faraday (1846) wrote: "*Neither accepting nor rejecting the hypothesis of an ether, or the corpuscular, or any other view that may be entertained of the nature of light; and, as far as I can see, nothing being really known of a ray of light more than of a line of magnetic or electric force, or even a line of gravitating force.*"

I assume that the center of gravity of the binary photon, which can be considered to be its rest frame, propagates at the speed of light c along the *z-axis* as a function of time. As a result of the gravitational force on a moving charge inducing an oppositely-directed electromotive force, the binary photon may have internal longitudinal motions that were predicted by Wilhelm Röntgen (1896) and George FitzGerald (1896) and consistent with Einstein's (1909a) "*oscillation energy of frequency v* [that] *can occur only in quanta of magnitude hv*." Indeed, de Broglie (1924) wrote, "*Naturally, the light quantum must have an internal binary symmetry corresponding to the symmetry of an electromagnetic wave*...." I have described the predicted sinusoidal oscillations with an antisymmetric normal mode using wave functions. The positions of the leading ($\phi_{leading}$) and following ($\phi_{following}$) semi-photons travelling through a medium of refractive index n along the *z axis* as a function of time and given by the following formulae:





$$\begin{bmatrix} \phi_{leading}(t) \\ \phi_{following}(t) \end{bmatrix} = \begin{bmatrix} \frac{c}{n}t + \frac{\lambda}{2\pi^2}(\cos^2 2\pi\nu t) \\ \frac{c}{n}t - \frac{\lambda}{2\pi^2}(\cos^2 2\pi\nu t) \end{bmatrix} [\hat{\boldsymbol{z}}]$$

In order for the semi-photons with mass ($\frac{\hbar\omega}{2c^2} = \frac{hc}{2\lambda c^2}$) to oscillate in a sinusoidal manner with angular frequency ($\omega = 2\pi\nu$), there must be a restoring force characterized by a spring constant (K in N/m). The frequency (ν) of the oscillator is related to the spring constant according to the following formula:

$$\nu = \frac{1}{2\pi}\sqrt{\frac{K}{m}}.$$

Solving for K, we find that the spring constant that provides the restoring force to the semi-photon is equal to the ratio of a constant ($4\pi^2 hc$) to the cube of the wavelength:

$$K = \frac{4\pi^2 hc}{\lambda^3}$$

The longer the wavelength, the lesser is the spring constant, and the more the binary photon approaches a **floppy wave**. On the other hand, the shorter the wavelength, the greater is the spring constant, and the more the binary photon approaches a **"hard" mathematical point**.

The velocities of the leading ($v_{leading}$) and following ($v_{following}$) semi-photons along the direction of propagation as a function of time are obtained by differentiating the positions of the semi-photons with respect to time:

$$\begin{bmatrix} v_{leading}(t) \\ v_{following}(t) \end{bmatrix} = \begin{bmatrix} \frac{c}{n} - \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t) \\ \frac{c}{n} + \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t) \end{bmatrix} [\hat{\boldsymbol{z}}]$$

The linear momentum would be the product of the mass of the semiphotons and their velocities:

$$\begin{bmatrix} p_{leading}(t) \\ p_{following}(t) \end{bmatrix} = \begin{bmatrix} m^+\left[\frac{c}{n} - \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t)\right] \\ m^-\left[\frac{c}{n} + \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t)\right] \end{bmatrix} [\hat{\boldsymbol{z}}]$$

The constant components of the linear momentum cancel, and the oscillating components of the linear momentum add. Thus, the linear momentum varies over a period of oscillation and is only constant when averaged over a wavelength.

Heretofore, the wave-particle duality of the quantum mechanical photon has been unintuitive. Friedrich Hund (1974) wrote "*one way of explaining quantum theory in physical terms these days consists in regarding it as* ***a completely non-intuitive unification or two intuitive pictures, i.e., classical particles and classical waves of fields***." William Bragg (1922) described the situation like so: "***On Mondays, Wednesdays and Fridays, we use the wave theory; on Tuesdays, Thursdays and Saturdays we think in streams of flying quanta or corpuscles…. Some day we shall piece all the maps together***." By considering the photon to be a binary photon composed of two conjugate particles, instead of an elementary particle, a *détente* is reached between the opposing views of the wave theory and particle theory so that it becomes possible to visualize simultaneously the wave and particle nature of the photon or what Arthur Eddington (1928) and Charles Galton Darwin, Charles Darwin's grandson, called "*wavicles*."

The longitudinal wave propagating along the *z axis* is possible if the photon is composed of two particles as opposed to one. Consequently, the binary photons that make up radio waves (1 m – 100 km) and microwaves (1 mm – 1 m) are predicted to be very long and binary photons that make up gamma rays (<0.01 nm) and X-rays (0.01-10 nm) are predicted to be very short—approximating a mathematical point. The binary photons that make up the visible light effective in photosynthesis and vision are predicted to be intermediate in length.

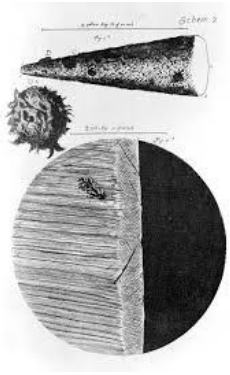


The possibility that a real photon has **transverse extension** in addition to **longitudinal extension** comes from an intuitive and mechanical understanding of angular momentum as a mechanical property that means something more than just a number. What would the radius of the binary photon be in order for it to have its

observed angular momentum of h-bar? While this question cannot be answered using current quantum mechanics (Landau and Lifshitz 1958), to answer this question, I went back to Niels Bohr's **Correspondence Principle** which **sets a classical quantity equal to a quantum quantity**.

In the point-like quantum mechanical photon, the **angular momentum** and **spin** are just numbers without any mechanical analog such as rotational kinetic energy. There is an explanation of what is spinning since a mathematical point cannot spin. According to Landau and Lifshitz (1958), "*in quantum mechanics, some 'intrinsic' angular momentum must be ascribed to an elementary particle, regardless of its motion in space. This property of elementary particles is peculiar to quantum theory…, and hence is essentially incapable of a classical interpretation. In particular**, it would be wholly meaningless to imagine the 'intrinsic' angular momentum of an elementary particle as being the result of its rotation about 'its own axis', if only because we cannot ascribe any finite dimensions to an elementary particle***."

If you start with **meaninglessness** you end with **meaninglessness**. Thus, I am assuming that the numerical quantum definitions of angular momentum and spin have outlived their usefulness and are now **too simplistic**. Remember that when **Robert Hooke** (1665) observed the point of a needle and the line of a straightedge razor with his microscope, he realized that the point was not a mathematical point, and the line was not a straight line. Hooke wrote, "*As in Geometry, the most natural way of beginning is from a Mathematical point; so is the same method in Observations and Natural history the most genuine, simple, and instructive. We must first endevour to make letters, and draw single strokes true, before we venture to write whole Sentences, or to draw large Pictures. And in Physical Enquiries, we must*



endevour to follow Nature in the more plain and easie ways she treads in the most simple and uncompounded bodies, to trace her steps, and be acquainted with her manner of walking there, before we venture our selves into the multitude of meanders she has in bodies of a more complicated nature; lest, ***being unable to distinguish and judge of our way, we quickly lose both Nature our Guide, and our selves too, and are left to wander in the labyrinth of groundless opinions****; wanting both judgment, that* ***light, and experience****, that clew, which should direct our proceedings.*

We will begin these our Inquiries therefore with the Observations of Bodies of the most simple nature first, and so gradually proceed to those of a more compounded one. In prosecution of which method, we shall begin with a ***Physical point****; of which kind the Point of a Needle is commonly reckon'd for one; and is indeed, for the most part, made so sharp, that the naked eye cannot distinguish any parts of it: It very easily pierces, and makes its way through all kind of bodies softer then it self: But if view'd with a very good Microscope, we may find that the top of a Needle (though as to the sense very sharp) appears a* ***broad****,* ***blunt****, and very irregular end; not resembling a Cone, as is imagin'd, but onely a piece of a tapering body, with a great part of the top remov'd, or deficient. The Points of Pins are yet more blunt, and the Points of the most curious* ***Mathematical Instruments*** *do very seldome arrive at so great a sharpness; how much therefore can be built upon demonstrations made onely by the productions of the* ***Ruler*** *and* ***Compasses****, he will be better able to consider that shall but view those points and lines with a Microscope.*

Now though this point be commonly accounted the sharpest (whence when we would express the sharpness of a point the most superlatively, we say, As sharp as a Needle) yet the Microscope can afford us hundreds of Instances of Points many thousand times sharper*: such as those of the hairs, and bristles, and*

claws of multitudes of Insects; the thorns, or crooks, or hairs of leaves, and other small vegetables; nay, the ends of the stiriæ or small parallelipipeds of Amianthus, and alumen plumosum; of many of which, though the Points are so sharp as not to be visible, though view'd with a Microscope (which magnifies the Object, in bulk, above a million of times) yet I doubt not, but were we able practically to make Microscopes according to the theory of them, we might find hills, and dales, and pores, and a sufficient bredth, or expansion, to give all those parts ***elbow-room****, even in the blunt top of the very Point of any of these so very sharp bodies. For certainly the quantity or extension of any body may be Divisible in infinitum, though perhaps not the matter.*" http://www.gutenberg.org/files/15491/15491-h/15491-h.htm

Since the binary photon is allowed to have extension or elbow-room, we can calculate its radius (r) to get an idea of what is spinning. If the binary photon has angular momentum and spin, what would the radius of the binary photon be in order for it to have its observed angular momentum ($\hbar$) and spin (± 1) of a boson? To answer this question, I have used Niels Bohr's **Correspondence Principle** which sets a classical quantity equal to a quantum quantity. Classically, the angular momentum of a particle is equal to mvr, where m is the mass of body, v is its angular velocity, and r is its radius.

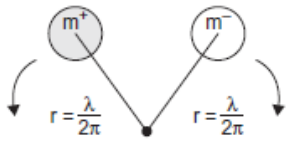


FIGURE A.2 The radius of a rotating mass with angular momentum of $\hbar/2$.

The mass of each semi-photon that composes the binary photon is one-half of the total mass of the binary photon, and using the equation $E = mc^2$, is given by:

$$m = \frac{h\nu}{2c^2}$$

Using the Correspondence Principle where v is the angular velocity and r is the radius of each semi-photon that composes the binary photon, we get:

$$L = \frac{\hbar}{2} = \frac{h}{4\pi} = mvr$$

for a semi-photon with angular momentum equal to $\frac{\hbar}{2}$. We can calculate the radius of the semi-photon by letting $v = 2\pi\nu r$ and inserting the mass $m = \frac{h\nu}{2c^2}$ of that semi-photon to get:

$$\frac{h}{4\pi} = \frac{h\nu}{2c^2} 2\pi\nu r^2$$

After cancelling and rearranging, we get:

$$r^2 = \frac{c^2}{(2\pi)^2 \nu^2}$$

Since according to the dispersion relation $\lambda\nu = c$, $\frac{c^2}{\nu^2} = \lambda^2$, we get:

$$r^2 = \frac{\lambda^2}{(2\pi)^2}$$

And after taking the square root of both sides, we get:

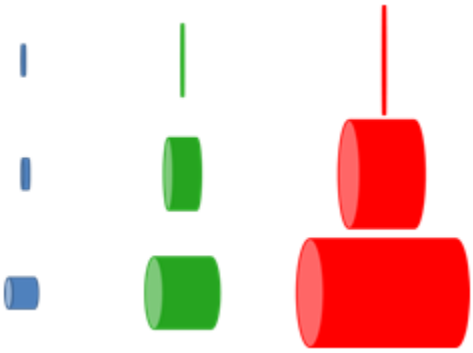
$$r = \frac{\lambda}{2\pi}$$

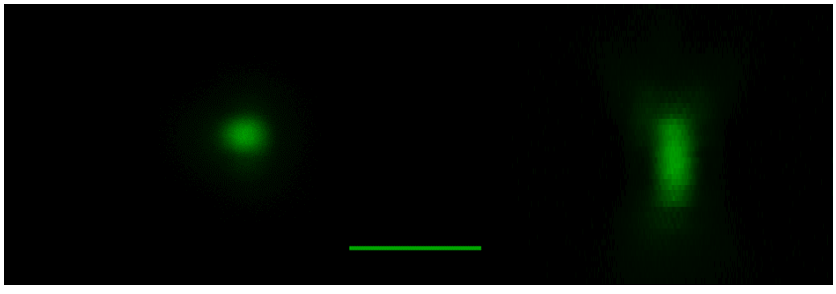
That is, **the radius of the binary photon is equal to the wavelength of light divided by 2π and the circumference ($2\pi r$) is equal to the wavelength**.

The radius of the binary photon is identical to the radius of the semi-photon, since for the binary photon, the angular momentum is equal to $\hbar = \frac{h}{2\pi}$ and the mass is equal to $\frac{h\nu}{c^2}$. The diameter (d) of a cylinder-like binary photon is approximately equal to one-third of its wavelength.

$$d = 2r = \frac{\lambda}{\pi} = 0.32\,\lambda$$

This equation, which is based on the assumptions that the binary photon has mechanical energy, and mechanical angular momentum, describes the "bigness" of a binary photon with a given wavelength. **When the wavelength of a binary photon approaches zero**, so does its diameter and the "bigness" of the binary photon approaches the size of a mathematical point. **When the wavelength of a binary photon approaches infinity**, so does its diameter and the "bigness" of the binary photon approaches infinity. A propagating binary photon of monochromatic 500 nm light has a wavelength of 500 nm and a diameter of 160 nm. **The lateral extension is why two "close" binary photons can interfere** at the surface of a thin film to cause the iridescent colors of **frogs**, **butterflies**, and **birds**; and **interfere** at the surface of the striations to cause the iridescent colors of **scarabaeid beetles**. It also explains why a 170 nm spherical bead observed in a confocal microscope looks like a **spheroid** that has a **length to width ratio equal to π**. The "bigness" of a binary photon with a wavelength of 400 nm is smaller; and the





"bigness" of a binary photon with a wavelength of 600 nm is larger than the bigness of a binary photon with a wavelength of 500 nm.

In order for the binary photon to have a non-vanishing angular momentum that is equal to $\frac{h}{2\pi}$, the two semi-photons, with masses of opposite signs, have to rotate perpendicular to the axis of propagation with opposite senses. Using the calculated radius, I have incorporated the rotation of the two semi-photons that make up the binary photon into the wave function that describes the time-varying positions (ϕ) of the two semi-photons:

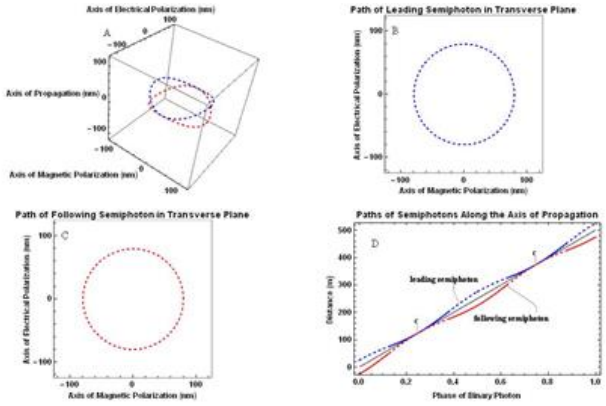
$$\begin{bmatrix} \phi_{leading}(t) \\ \phi_{following}(t) \end{bmatrix} = \begin{bmatrix} \frac{\lambda}{2\pi}\cos(2\pi\nu t) & -\frac{\lambda}{2\pi}\sin(2\pi\nu t) & \frac{c}{n}t + \frac{\lambda}{2\pi^2}(\cos^2 2\pi\nu t) \\ -\frac{\lambda}{2\pi}\cos(2\pi\nu t) & -\frac{\lambda}{2\pi}\sin(2\pi\nu t) & \frac{c}{n}t - \frac{\lambda}{2\pi^2}(\cos^2 2\pi\nu t) \end{bmatrix} \begin{bmatrix} \hat{\boldsymbol{x}} \\ \hat{\boldsymbol{y}} \\ \hat{\boldsymbol{z}} \end{bmatrix}$$

The velocities of the two particles can also be modeled by taking the derivative of the predicted positions of the semi-photons with respect to time.

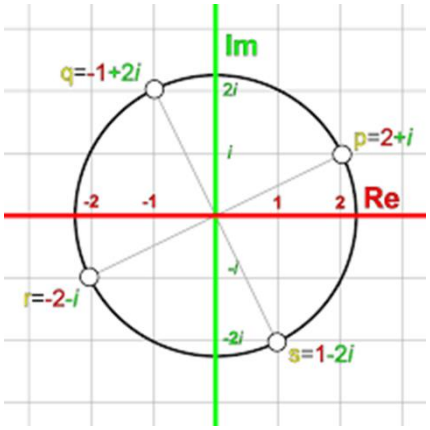
$$\begin{bmatrix} v_{leading}(t) \\ v_{following}(t) \end{bmatrix} =$$

$$\begin{bmatrix} -\frac{c}{n}\sin(2\pi\nu t) & -\frac{c}{n}\cos(2\pi\nu t) & \frac{c}{n} - \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t) \\ \frac{c}{n}\sin(2\pi\nu t) & -\frac{c}{n}\cos(2\pi\nu t) & \frac{c}{n} + \frac{2c}{\pi n}\sin(2\pi\nu t)\cos(2\pi\nu t) \end{bmatrix} \begin{bmatrix} \hat{\boldsymbol{x}} \\ \hat{\boldsymbol{y}} \\ \hat{\boldsymbol{z}} \end{bmatrix}$$

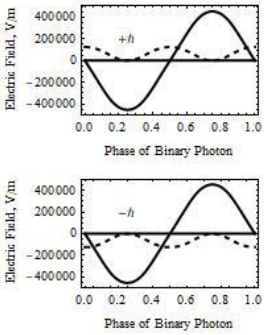
The three-dimensional internal movements of the binary photon look like so:



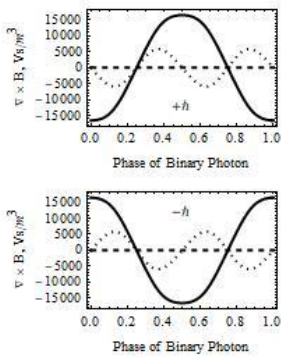
The two-dimensional movement of the semiphotons along **paths** or **trajectories** in the transverse plane perpendicular to the axis of propagation can be described by **Schrödinger's equation**, the fundamental equation of quantum mechanics, in terms of real and absolute Euclidean space and Newtonian time as opposed **configuration** or **phase space** (proposed by Max Born) and **imaginary time** (proposed by Wolfgang Pauli).



The **spinning and oscillating masses** of a binary photon not only allow us to visualize what is spinning and **why nearby photons can interfere**, but once we take the charges of the spinning masses into consideration we can also visualize and understand the **electromagnetic wave-like property of polarization**. Using a form of **Coulomb's Law** that has been generalized for positive and negative masses, we find that the electric field vectors from a positive mass with a positive charge points away from the mass and the electric field vectors from a negative mass with a negative charge points towards the mass.



As the two conjugate particles of the binary photon rotate, their electric fields are **superimposed**. At 0 (N) and 180 (S) degrees, the electric field vectors **destructively interfere** and at 90 (E) and 270 (W) degrees, the electric field vectors **constructively interfere** to give a linearly polarized wave. The azimuth of polarization of the binary photon depends on the azimuth of the line between the two particles of the binary photon when they are maximally separated. The **electric fields** are obtained using Coulomb's law from the **position vectors** of the semi-photons and the **magnetic fields** are obtained using the Biot-Savart law from their **velocity vectors**.



The **longitudinal electric field** can also be presented in terms of the distance between the semi-photons and the **longitudinal magnetic field** can also be presented as the product of the masses and velocities (i.e., linear momentum) of the semi-photons.

The relationship between the electric field and the magnetic field are described by Faraday's law and the Ampere-Maxwell law. By taking into consideration the equal and opposite charges that make up the electrically neutral binary photon, the two fields are out-of-phase with each other.

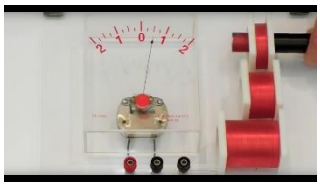
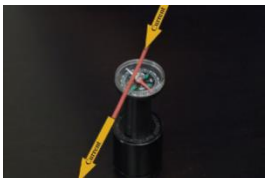
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

Demonstration: Faraday's law, Ampere's law, and Lenz's law.



While the **energy** and **angular momentum** of the photon must be constant in three dimensions, the product of the time-varying longitudinal linear momentum

(p) and the position of the center of gravity of the binary photon is also constant. The time-varying linear momentum of the binary photon may provide the **hidden variable** that allows the complete description of optical processes that was heretofore enshrouded in a mathematical point. A precisely defined state of the linear momentum and the position of the binary photon can be calculated in principle. The time-varying linear momentum varies by $\pm\frac{h}{\lambda}$ over one half of a wavelength. The product of the time-varying linear momentum $\frac{2h}{\lambda}$ and $\frac{\lambda}{2}$ along the axis of propagation results in an equation comparable to the **uncertainty relation**:

$$\left(\frac{\lambda}{2}\right)\left(\frac{2h}{\lambda}\right) = h$$

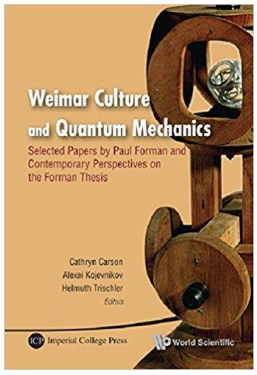
This is exactly the form and the result introduced by Heisenberg to describe the reciprocal relationship between momentum and position. Heisenberg called the relationship the **Principle of *Umbestimmtheit***, which could stand for the **Principle of Indeterminacy, Indefiniteness**, **or Uncertainty** in the following equation:

$$\Delta p \Delta z = h$$

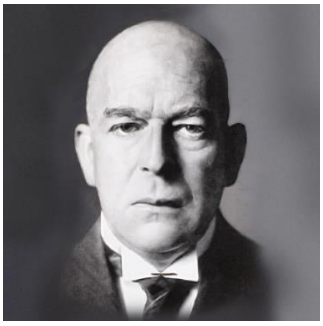
where Δ represents the uncertainty due to the wave nature of light. After multiplying by $1 = \frac{c}{c}$, we get: $\Delta pc\Delta\frac{z}{c} = \Delta E\Delta t = h$, which is interpreted by the consensus to mean that energy (ΔE), even of a universe in a multiverse, can be **created out of nothing** for a short time (Δt) as long as the product of energy and time is equal to Planck's constant. This is how the universes in a multiverse are created.

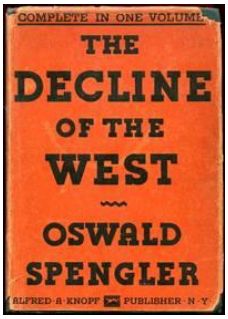
I told you that Lorentz, Planck, Einstein, and Schrödinger believed that the Copenhagen interpretation of quantum mechanics was not necessary According to **Paul Forman**, the orthodox view of quantum mechanics given by the **Copenhagen** interpretation and the Principle of Uncertainty were not required by the physics itself but grew out of the **cultural values** at the time in Weimar Germany as described by **Oswald Spengler**, which rejected the idea of causality and determinism. I agree wholeheartedly with the Forman thesis.





From Oswald Spengler's (1918) *The Decline of the West: Outlines of a Morphology of World History*





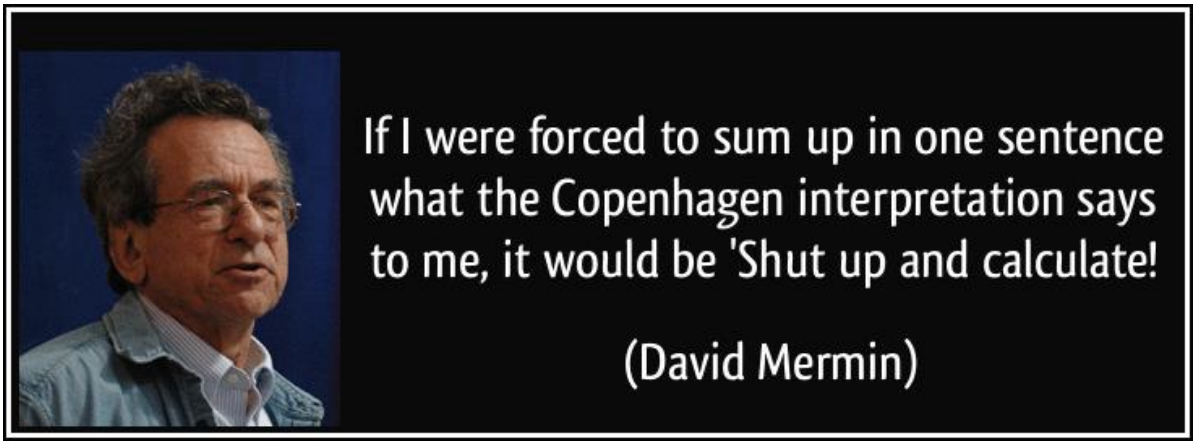
The optical theories of Anaxagora and Democritus are far from allowing human activity for sensory perception. Plato never perceives the self as the center of a transcendent sphere of activity, as Kant felt an inner need. The prisoners in his famous cave are really prisoners, slaves of external impressions, not their masters, illuminated by the general sun, not themselves suns that shine through everything. The physical concept of space energy - the completely unanticipated idea that spatial distance is already a form of energy, even the archetype of all energy, because that is the basis of the terms capacity and intensity - illuminates the relationship of the will to the imaginary soul space. We feel that both the dynamic worldview of Galileo and Newton and the dynamic soul image with the will as the focus and center of relationships mean one and the same thing. They are both Baroque phenomena, symbols of the Faustian culture that has reached full maturity.

Nothing justifies giving this spiritual world of form priority over others. Every science, like every myth, every religious belief in general rests on an inner certainty; their formations are of a different structure and sound, without being fundamentally different. All objections that natural science has against religion are met by it itself. It is a great prejudice to ever be able to put the truth in the place of

anthropomorphic ideas. There are no other anthropomorphic ideas at all. Man created God in his image - as certain as it is true of every historical religion, as it is certain of every physical theory that is supposed to be well founded. Each is itself a myth and preformed anthropomorphically in each of its traits. There is no such thing as pure science, there is not even a science that could be described as generally human.

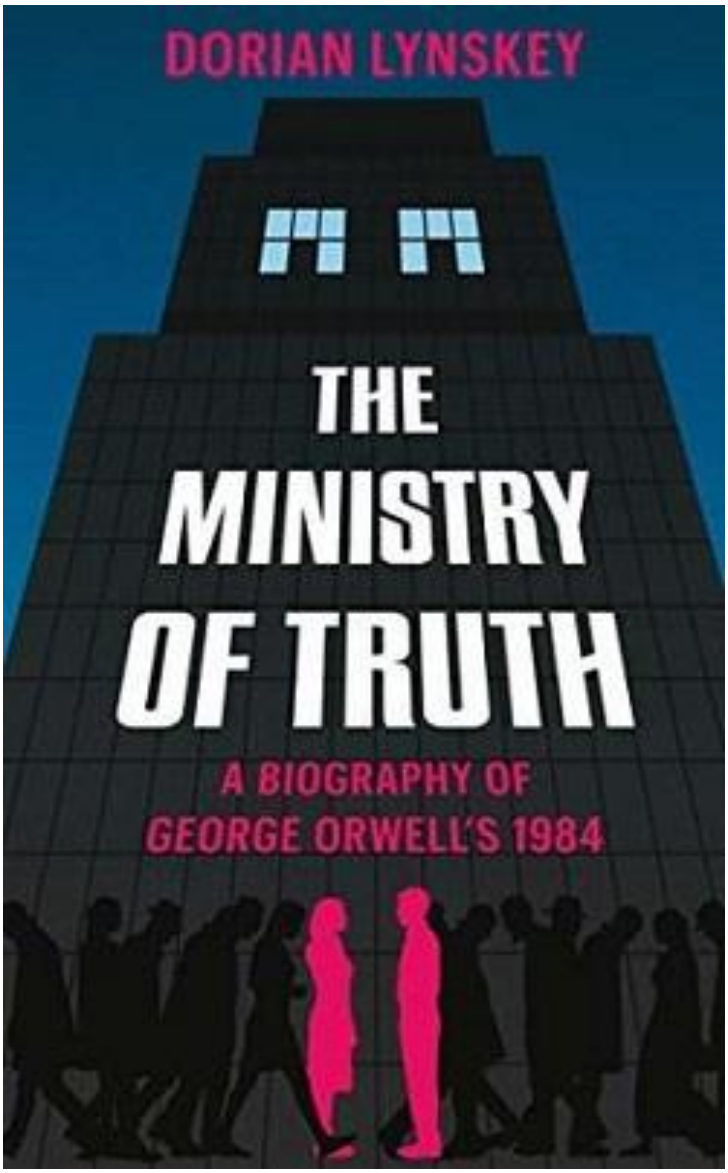
Each culture has developed its own, which is true for it alone and only remains as long as the culture is alive and in the realization of its inner possibilities. Once a culture has ended and the creative element, the visual power, and the symbolism have expired, empty formulas, skeletons of dead systems remain, which are literally perceived as meaningless and worthless, mechanically retained or despised and forgotten. Think of the sciences of the latest antiquity. Numbers, formulas, laws mean nothing, are nothing. They must have a body that a living human being gives them by expressing themselves in and through them, expressing them, taking possession of them internally. And that is why there is no absolute physics, only individual, emerging and dwindling physics within individual cultures.

The Principle of Uncertainty has led to the counterintuitive elevation of chance and the promotion of paradoxical interpretations of reality supported by the maxim "***shut up and calculate***," pronounced by Cornell's **David Mermin** (1989).



David Mermin, who is part of the third generation of quantum physicists (see below), tells us that quantum mechanics tells us "**about the limitations in**

how we think and how we are capable of apprehending the world." I think that it tells us about the limitations of the third generation of quantum physicists. Later we will hear that the *New York Times* will use the theory of relativity to make the point that in order to understand the world you will have to learn the theory of relativity. I am reminded of what **George Orwell** (1949) wrote in *1984*, "*The Party told you to reject the evidence of your eyes and ears. It was their final, most essential command*."





WHAT'S WRONG WITH THIS PILLOW?

N. David Mermin

Attitudes toward quantum mechanics differ interestingly from one generation of physicists to the next. The first generation are the founding fathers, who struggled through the welter of confusing and self-contradictory constructions to emerge with the modern theory of the atomic world and supply it with the "Copenhagen interpretation." On the whole they seem to have taken the view that while the theory is extraordinarily strange (Bohr is said to have remarked that if it didn't make you dizzy then you didn't really understand it), the strangeness arises out of some deeply ingrained but invalid modes of thought. Once these are recognized and abandoned the theory makes sense in a perfectly straightforward way. The word "irrational," which appears frequently in Bohr's early writings about the quantum theory, is almost entirely absent from his later essays.

The second generation, those who were students of the founding fathers in the early postrevolutionary period, seem firmly—at times even ferociously—committed to the position that there is really nothing peculiar about the quantum world at all. Far from making *bons mots* about dizziness, or the opposite of deep truths being deep truths, they appear to go out of their way to make quantum mechanics sound as boringly ordinary as possible.

The third generation—mine—were born a decade or so after the revolution and learned about the quantum as kids from popular books like George Gamow's. We seem to be much more relaxed about it than the other two. Few of us brood about what it all means, any more than we worry about how to define mass or time when we use classical mechanics. In contemplative moments some of us think the theory is wonderfully strange and others think it isn't; but we don't hold these views with great passion. Most of us, in fact, feel irritated, bored or downright uncomfortable when asked to articulate what we *really* think about quantum mechanics.

I'm one of the uncomfortable ones. If I were forced to sum up in one sentence what the Copenhagen interpretation says to me, it would be "Shut up and calculate!" But I won't shut up. I would rather celebrate the strangeness of quantum theory than deny it, because I believe it still has interesting things to teach us about how certain powerful but flawed verbal and mental tools we once took for granted continue to infect our thinking in subtly hidden ways. I don't think anybody, even Bohr, has done an adequate job of extracting these lessons. From this point of view the problem with the second generation's ironfistedly soothing attitude is that by striving to make quantum mechanics appear so ordinary, so sedately practical, so benignly humdrum, they deprive us of the stimulus for exploring some very intriguing questions about the limitations in how we think and how we are capable of apprehending the world.

I would guess that an unvoiced reason for such efforts to render quantum mechanics uninterestingly bland is the desire to counter the kind of dumb postquantum anti-intellectualism that says that even the physicists now know that everything is uncertain, leading to the disastrous corollary: Anything goes. It is indeed important to emphasize to those who would go from quantum mechanics to know-nothingism that the quantum theory, far from filling us with paralyzing (or liberating) uncertainty, now permits us to make the most accurate quantitative calculations in the history of science. We must certainly speak up against "the general antirationalist atmosphere which has become a major menace of our time, and which to combat is the duty of every thinker who cares for the traditions of our civilization."

On the other hand it's important in combat to shoot at the right target. The above quotation is from Karl Popper and is directed against the writings of Heisenberg and Bohr. Physicists in the second generation certainly have a much better sense of where to direct their fire; but in sanitizing the quantum theory to the point that nothing remarkable sticks out above the surface you run the risk that if you go inside and look around you won't find anything left to make it hang together anymore.

Thus although it is a fact about the quantum theory of paramount importance that it permits us to calculate measurable quantities with unprecedented precision, it does not follow from this that statements that the quantum theory is not deterministic but acausal are vast exaggerations—that the theory has little to do with whether or not nature is a game of probability. Yet it has been argued in this context[1] that even radioactive decay—the very paradigm of acausal discontinuous quantum behavior—appears as probabilistic and abrupt only when an inappropriate question is asked: If a particle is in a state of very well-defined energy, then it is inappropriate to ask for the exact time of its decay, and the answer is probabilistic only because the question is not appropriate to the experimental situation.

Now to be sure I can, at least in principle, produce at noon a particle that will decay as the clock is striking midnight, provided I make it in some tricky superposition of energy eigenstates for which asking when the particle decays *is* the appropriate

David Mermin is a professor at Cornell University and director of the Laboratory of Atomic and Solid-State Physics. He has worked in low-temperature physics, statistical physics, foundations of quantum mechanics and, most recently, quasicrystallography.

1989 American Institute of Physics

The Uncertainty Principle has also replaced the **Principle of Causality** and led to the Copenhagen interpretation of quantum mechanics. On the other hand, science sometimes follows a dead end and I, as a minority of one, think that the **rejection of causality** and the **promotion of paradoxes** is one such dead end.

The binary photon fulfills the hope of Louis De Broglie (1957) who wrote "*It is possible that looking into the future to a deeper level of physical reality we will be able to interpret the laws of probability and quantum physics as being the statistical results of the development of* ***completely determined values of variables which are at present hidden from us***." The motions that take place in the binary photon may provide the hidden variable that will result in a return to the Principle of Causality. Could the binary photon lead to the **real thing** that Einstein referred to when he wrote to Born on December 4, 1926: "***Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the 'old one'. I, at any rate, am convinced that He is not playing at dice***." The lack of causality that quantum mechanics brought to physics worried Einstein for the rest of his life. On December 22, 1950, we wrote to Schrödinger:

Dear Schrödinger,
You are the only contemporary physicist besides Laue, who sees that one cannot get around ***the assumption of reality****—if only one is honest. Most of them simply do not see what sort of risky game they are playing with reality—if only one is honest. Most of them simply do not see what sort of risky game they are playing with reality—****reality as something independent of what is experimentally established****. They somehow believe that the quantum theory provides a description of reality, and even a complete description; this interpretation is, however, refuted,*

most elegantly by your system of radioactive atom + Geiger counter + amplifier + charge of gun powder + cat in a box, in which the ψ-function of the system contains the cat both alive and blown to bits. Is the state of the cat to be created only when a physicist investigates the situation at some definite time? Nobody really doubts that the presence or absence of the cat is something independent of the act of observation. But then the description by means of the ψ-function is certainly incomplete, and there must be a more complete description. If one wants to consider the quantum theory as final (in principle), then one must believe that a more complete description would be useless because there would be no laws for it….But it seems certain to me that ***the fundamentally statistical character of the theory is simply a consequence of the incompleteness of the description****. This says nothing about the deterministic character of the theory; that is a thoroughly nebulous concept anyway, so long as one does not know how much has to be given in order to determine the initial state….*

Best regards! Yours,

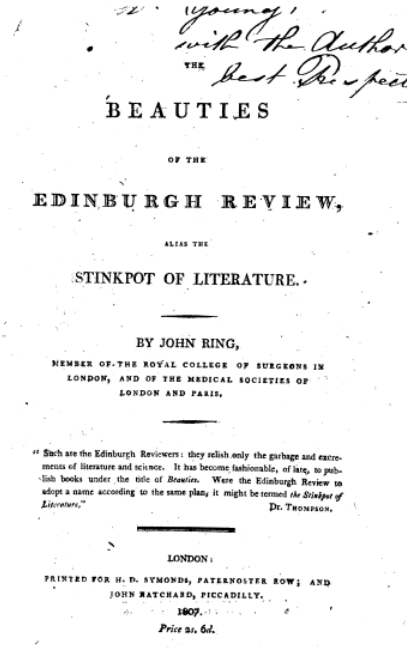
A. Einstein



Richard Feynman (1982) wrote in an article entitled, *Simulating physics with computers*, "*Turning to quantum mechanics, we know immediately that here we get only the ability, apparently, to predict probabilities. Might I say immediately, so that you know where I really intend to go, that* ***we always have had (secret, secret, close. the doors!) we always have had a great deal of difficulty in understanding the world view that quantum mechanics represents****. At least I do, because I'm an old enough man that I haven't*

got to the point that this stuff is obvious to me. Okay, I still get nervous with it. And therefore, some of the younger students ... you know how it always is, every new idea, it takes a generation or two until it becomes obvious that there's no real problem. It has not yet become obvious to me that there's no real problem. I cannot define the real problem, therefore I suspect there's no real problem, but I'm not sure there's no real problem. So that's why I like to investigate things."

The particle and wave-like character of light are both necessary to understand optical phenomena and the colors of nature (chromatics). Not realizing that **Newton**, himself, postulated the **duality** of light in terms of corpuscles that propagated through a wave-like ether and that **Huygens** also postulated the **duality** of light in terms of waves that propagated through a particulate ether, the **Edinburgh Review ridiculed Thomas Young** for even considering the wave-like nature of light and used invective to attack his character. In response to the *ad hominem* attack against Thomas Young published in the Edinburgh Review, the surgeon **John Ring**, who was famous for his early and courageous support of vaccinations, called the Edinburgh Review **The Stinkpot of Literature** and an anonymous critic wrote in the British Critic of January 1805, "To all this we can only say, *Tantaene animis caelestibus irae*? [[Is there] such great anger [belonging to] the heavenly spirits?—a quote from Virgil's *Aneid*]. For it would be a mere waste of time to search after any reasonable explanation of such a paroxysm of anger. Sir Isaac Newton, as we all know, was of the opinion, that light was propelled from the sun, as a projectile, in straight lines; Huygens and Hook (whose conjecture is supported by Dr. Young) supposed it to consist in a tremulous or undulatory motion; and there the matter rested.



BEAUTIES

OF THE

EDINBURGH REVIEW,

ALIAS THE

STINKPOT OF LITERATURE.

BY JOHN RING,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS IN LONDON, AND OF THE MEDICAL SOCIETIES OF LONDON AND PARIS.

"Such are the Edinburgh Reviewers: they relish only the garbage and excrements of literature and science. It has become fashionable, of late, to publish books under the title of *Beauties*. Were the Edinburgh Review to adopt a name according to the same plan, it might be termed *the Stinkpot of Literature*."

Dr. THOMPSON.

LONDON:

PRINTED FOR H. D. SYMONDS, PATERNOSTER ROW; AND JOHN HATCHARD, PICCADILLY.

1807.

Price 2*s.* 6*d.*

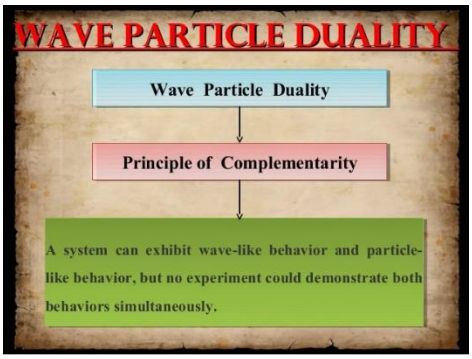


Cucumbers have continued to ripen, without waiting for the legal establishment of either hypothesis; and no succeeding philosopher, whether within or without the walls of **Bedlam**, had imagined that it was necessary to establish, by the authority of the Royal Society, a Catholic faith on the subject. But we must suppose that, as there are persons who "*when the bag pipes sings i'the nose, cannot contain their urine*" [from Shakespeare's Merchant of Venice], so the mention of the word *optics* has the power of irritating to frenzy the nerves of our brother critics in Edinburgh. This indeed is rendered quite evident by the strictures on Mr. Woods optics, and by those on Dr. Woollaston, which are contained in other parts of the same journal."

As a botanist, somewhat familiar with cucumbers, I see the possibility that the cucumbers ripen without waiting for an authority to decide whether light is a particle or a wave, because they photosynthesize, grow, respond to the light environment including the photoperiod, and flower, as if light is both particle-like and wave-like at the same time as described by the model of the binary photon. The **cucumber** is not a detector that senses either the **complementary** particle-like properties ***or*** the wave-like properties of light as required by the Copenhagen interpretation of quantum mechanics but a detector that senses the true **wave-like and particle-like duality** of the binary photon.

I want to distinguish between wave-particle **duality** and **complementarity**. Wave-particle duality means that the photon can be considered to have wave-like and particle-like aspects **simultaneously**. The principle of **complementarity** assumes that the characterization of a photon cannot be separated from the description given by the measuring instruments that measure either the particle-like

behavior or the wave-like behavior of the photon. Bohr's principle of **complementarity** states that it is only possible to observe complementary properties of the photon and impossible to observe the complementary wave-like and particle-like properties simultaneously. Bohr extends this principle to infer that there is no single picture of reality that unifies the complementary results obtained by different measuring instruments.



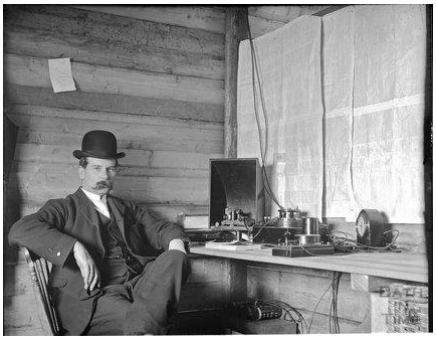
The binary photon model describes and explains **why light moves**, why electromagnetic radiation shows the **wave-particle duality** (as opposed to **complementarity**), why **short wavelength** light behaves more like a **particle** and why **long wavelength** light behaves more like a **wave**, the ability of light to interfere, and why light is **polarized,** and it provides a path to the **Principle of Causality** from the **Uncertainty Principle**. I agree completely with Einstein's view that the uncertainty principle is not fundamental, and the laws of quantum mechanics are incomplete. However, unlike Einstein, I also believe that the Special Theory of Relativity is not fundamental, as I will describe below. The wave-like nature of the binary photon is also subject to the **Doppler effect** discovered by **Christian Doppler**, Johann **(**Gregor) Mendel's physics teacher.



Curiously, even though the Doppler effect is readily perceived when there is relative motion, whether one is looking at the water waves produced by a swimming swan, the water waves striking a cattail, the sound waves produced by the siren on a fire truck, or the light coming from a distant galaxy, standard theories rarely, if ever, include the Doppler effect as a primary consideration in the study and description of relative motion. The analyses done by my colleagues and me (Maers and Wayne, 2011; Maers et al., 2013) are unique in that we incorporate

the Doppler effect expanded to the second order from the beginning (Wayne, 2010).

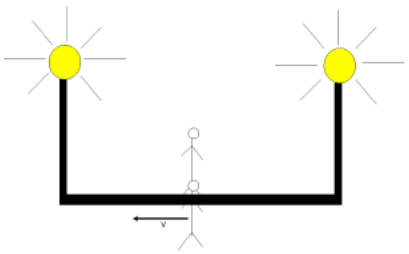






Albert Einstein lived at a time when **fast moving coal-powered trains** and **telegraphic communication based on electromagnetic waves that traveled at the speed of light** made time seem as if **time were relative**. Imagine someone living at that time who was one thousand miles away telling you that their train or a telegram was going to arrive at 12 o'clock noon. Which 12 o'clock noon, the noon of the person telling you or the noon of the person waiting for the train or the telegram? Even worse, imagine two trains running towards each other on a single track without realizing that they could crash because they both thought the other would be there at a different time. The confusion led to the creation of **standard time**, based on astronomical time reckoned at the Greenwich Observatory.

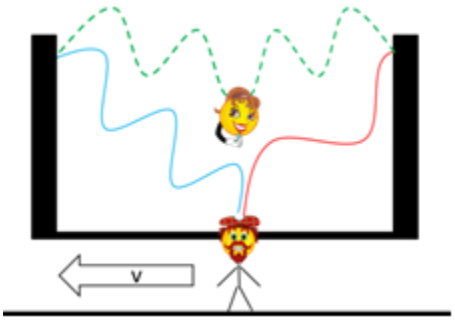
In his book *Relativity: The Special and the General Theory*, Albert Einstein (1920) used a **train analogy** to describe the foundations of the Special Theory of Relativity to a general audience in an intuitive nonmathematical way.



According to the **Special Theory of Relativity** time is relative. This was demonstrated by **Albert Einstein** by comparing the observations of a person on "*a very long train travelling along the rails with the constant velocity v*" with the

observations made by a person on a "*railway embankment*." Suppose that the observer in a railroad car midway between a lamp mounted on the back of the railroad car and an identical lamp mounted on the front of the railroad car saw the two lamps come on **simultaneously**, then the observer standing on the railway embankment, who is moving backwards at velocity *v* relative to the train would see the lamp on the back of the railroad car come on before the lamp on the front of the railroad car comes on. Since there was only one simultaneous event observed by the person on the train, but two non-simultaneous events observed by the person on the embankment, Albert Einstein concluded that time was relative and depended on the relative velocity of the observer.

Working at a time when transformations between local times and standard time were being made by engineers and telegraph operators, Albert Einstein was immersed in the relativity of time. Combined with the fact that he considered light to be a mathematical point where wavelength was just a number, Albert Einstein considered the **relativity of time** to be a more reasonable explanation than the **relativity of color** due to the Doppler effect. By contrast, I am immersed in a time of Doppler radar, Doppler weather, Doppler ultrasound, and Doppler MRI. How could I not look at the train metaphor in terms of the Doppler effect and the relativity of color?



According to my theory (Wayne, 2010), if the person in the railroad car midway between the lamps on the back and front of the railway car sees the lamps come on simultaneously, he or she would see them to be the same color. By contrast the person on the embankment would see the lamp on the back of the train to be bluer and the lamp on the front of the train to be redder as a result of the Doppler effect and the relative motion between the

train and the person on the railway embankment. While the velocities of the blue-shifted and red-shifted light are the same and equal to *c*, the speed of light in free space, the amplitude of the blue-shifted wave arrives at the observer before the amplitude of the red-shifted wave arrives at the observer. Consequently, the person on the platform would not observe the two lamps coming on simultaneously, but because of the difference in the wavelengths that results from the Doppler effect, the person on the railway embankment would observe the blue-shifted light from the lamp at the back before observing the red-shifted light from the lamp at the front.

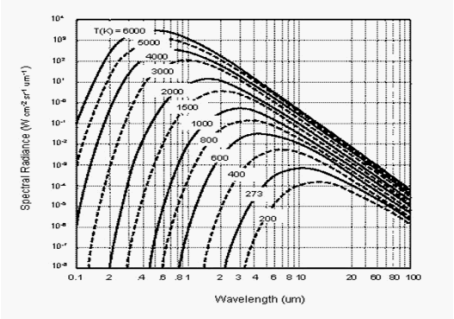


By considering the Doppler effect as a fundamental consideration in deriving the **Laws of Nature**, I have described the relativity of simultaneity in absolute Newtonian time. My understanding of the **geological record** as well as my observations on the dependability of time for the **entrainment of flowering** in plants to the revolution of the earth around the sun, for the **honeybees' clocks to synchronize with the flowers' clocks**, and for entraining the **sleep-wake cycle** to the rotation of the earth makes me think that time is not fundamentally relative but would exist even if there were no person to measure it. On the other hand, Albert Einstein, and most physicists since, considered the relativity of time to be a fundamental consideration in deriving the Laws of Nature and the **relativity of color due to the Doppler effect** to be a triviality.





The Doppler shift can be experienced everywhere. I bet you can tell the direction the elephant is walking from the Doppler shift in the water waves. The Doppler effect experienced by the binary photon can also be used to describe and explain why particles with a charge and/or a magnetic moment cannot go faster than the speed of light (Wayne, 2010). In order to calculate the number of Doppler-shifted photons that will collide with or scatter from the moving particle, we have to remember Max Planck's blackbody radiation law.

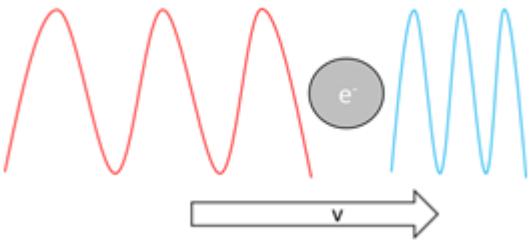


Max Planck discovered the function or law that related the **spectral distribution of light** emitted by a blackbody to its **temperature** and in doing so discovered the constant now known as Planck's constant.

According to **Max Planck's blackbody radiation law**, the greater the temperature of a cavity, the greater the number of photons in the cavity and the shorter their wavelength. This means that at any temperature greater than absolute zero, which according to the **Third Law of Thermodynamics** developed by **Walther Nernst**, is unattainable, there will be photons. This means that there will be binary photons in any space through which a particle with charge and/or magnetic moment moves.



If a particle is moving through a sea of photons, often called a **photon gas**, then the binary photons that collide with (particle terminology) or scatter from (wave terminology) the front of the moving particle will be **blue shifted** as a result of the



Doppler effect and the binary photons that collide with or scatter from the back of the moving particle will be **red shifted** as a result of the **Doppler effect**. Since the energy (E) and linear momentum (p) of the binary photons depend on their wavelength according to the familiar equations:

$$E = \frac{hc}{\lambda} \qquad\qquad p = \frac{h}{\lambda}$$

the blue-shifted binary photons that collide with or scatter from the front of a moving particle will push the particle backwards more than the red-shifted binary photons that collide with or scatter from the back of the moving particle will push the particle forwards. The faster the particle moves the greater is the **opto-mechanical counterforce** provided by the binary photons through which the particle moves. **This means light itself prevents a particle with charge and/or magnetic moment from moving faster than the speed of light.** This is why the limiting speed for particles with a charge and/or a magnetic moment is the vacuum speed of light. The speed of light is set by the electric permittivity (ε_o) and magnetic permeability (μ_o), the electrical and magnetic constants of the vacuum:

$$c = \sqrt{\frac{1}{\varepsilon_o \mu_o}}.$$

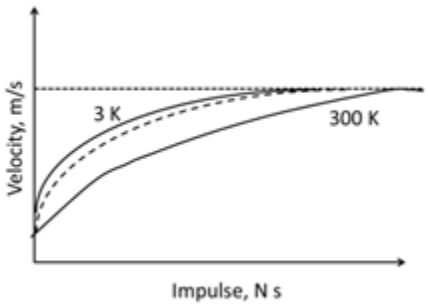
A biologist knows that anything that moves has to move through some resistive medium whether it is a *Euglena* swimming, a substrate diffusing towards an enzyme or a chloroplast moving towards the brighter part of a cell. By considering the Doppler effect and the **radiation friction** that results from it to be fundamental in deriving the laws of physics, I have been able to describe and explain the opto-mechanical counterforce that prevents particles with a charge and/or magnetic moment from exceeding the speed of light in absolute Newtonian time.

Einstein considered the relativity of time to be more fundamental to relative motion than the Doppler effect with its relativity of color. Consequently, by not considering the possibility that a moving particle must by necessity move through Doppler-shifted photons, Einstein concluded that particles do not go faster than the speed of light because time is relative. According to Einstein, the faster a particle goes, the shorter is the time it reckons the motive force to be accelerating it and the less it accelerates. The fact that the limiting speed of a particle is the same as the speed of light is not explained but given by fiat.



I have just provided you with the theory of the binary photon that eliminates the need to assume the **relativity of time and space as a fundamental truth** but requires you to assume the primacy of the Doppler effect along with the **relativity of color,** occurring in absolute Newtonian time and Euclidean space as a fundamental truth.

According the **opto-mechanical model** of how binary photons limit the speed of a moving particle to that of light, the greater the **temperature** of the space through which the particle moves, the greater the **number of binary photons** and the greater is the **opto-mechanical counterforce,** the **radiation friction**, or the **resistance** to acceleration. Consequently the opto-mechanical counterforce hypothesis is a testable hypothesis since the counterforce exerted on the moving particle increases with temperature. If the speed in which a particle is accelerated by a force ***is not*** temperature dependent, then the Special Theory of Relativity gives a better explanation of the limiting speed of particles. If the speed in which a particle is accelerated by a force ***is*** temperature dependent, then my theory of the

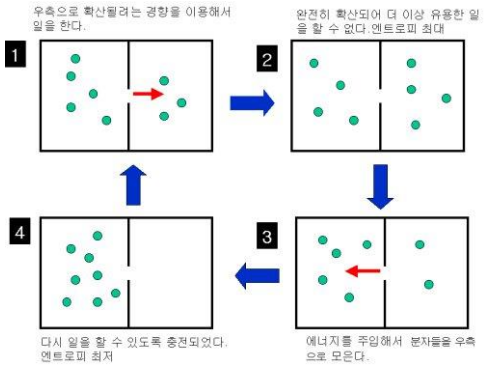


opto-mechanical counterforce provided by binary photons gives a better explanation of the limiting speed of particles. I really look forward to someone measuring the impulse-velocity relationship at 3 K and 300 K in a linear accelerator. According to the opto-mechanical counterforce theory, the force needed to accelerate a particle to a given velocity should be 10,000 times greater at 300 K than at 3 K.

There seems to be an undeniable **arrow of time** when we look at the geological record and the development of plants and animals, yet according to the standard model of physics, **time is an illusion** because the fundamental equations of physics do not have an arrow of time.



According to **Brian Greene** (2004), "*Even though experience reveals over and over again that there is an arrow of how events unfold in time,* ***this arrow seems not to be found in the fundamental laws of physics****.*" This is because the reversibility of time is the foundational assumption and ***only*** equations which are quadratic in time (t^2) are allowed to be called fundamental. This means that the fundamental equations also **assume that friction does not exist** and this is why the Second Law of Thermodynamics, which according to me foundationally describes and explains the observed unidirectional arrow of time, is not considered to be a fundamental law of physics. Statistical mechanics, which allows reversibility, is considered to be fundamental by the consensus.



By including the opto-mechanical counterforce produced by Doppler-shifted binary photons that affects any object composed of particles with a charge (e.g., electrons, protons) and/or a magnetic moment (e.g., neutrons), I have been able to combine **Newton's Second Law of Motion** with the **Second Law of Thermodynamics** to produce a fundamental, relativistic, and irreversible law of motion (Wayne, 2012). It states that **processes are irreversible** because of the opto-mechanical Doppler force that radiates away binary photons, particularly in the infrared that had collided with or were scattered by any moving object. These binary photons cannot be rounded up to reverse the natural process.

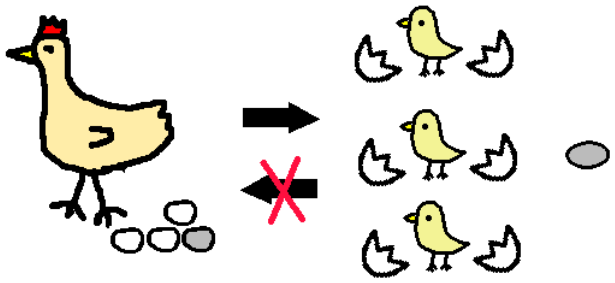
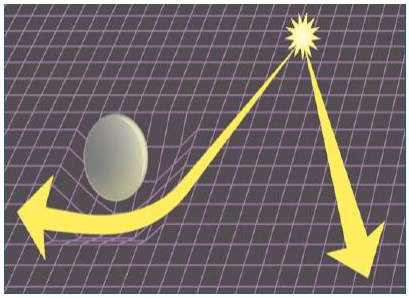
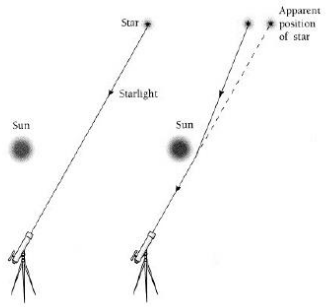


Figure 3

Since the Doppler effect was so useful as an alternative explanation of the kinematics of the relativity of simultaneity, and the Dopplerized binary photon was so useful as an alternative description and explanation of the dynamics involved in the limiting speed of light and why natural processes show an arrow of time even though the fundamental equations of physics do not, I put the model of the binary photon to a test by describing and explaining the observed magnitude of the **gravitational deflection of starlight**—the ***experimentum crucis*** in favor of the General Theory of Relativity, in terms of the binary photon.

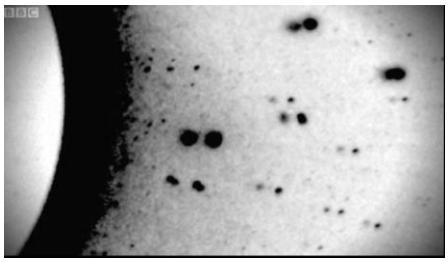
By assuming that the gravity was not a Newtonian force that influenced massive objects directly, but that gravity influenced the movement of mathematical point-like objects by **warping an interdependent space-time**, through which they moved, Albert Einstein predicted that starlight would be bent by the sun twice as much as was predicted by Johann von Soldner (1801) using the Newtonian Model that gravity is a force that interacts with massive particles and that light itself was corpuscular.





World War I prevented the planned **tes**t of the two models. Almost immediately after the armistice, **Arthur Eddington** turned his telescope towards the heavens and measured the deflection of sunlight by comparing the positions of stars near the sun made visible during the day as a result of a solar eclipse with the positions of the same stars at night.







Arthur Eddington measured that the deflection of sunlight was exactly what Albert Einstein had predicted and this led to the acceptance of the General Theory of Relativity that was based on the assumption that space and time are interdependent and relative. Arthur Eddington (1919) wrote to Albert Einstein "*...all of England has been taken by your theory. It has made a tremendous sensation. It is the best possible thing that could have happened for scientific relations between England and Germany*. " **John Burdon Sanderson Haldane** (1924), of peppered moth fame, wrote "*I do not doubt that he* [Einstein] *will be believed**. A prophet who can give signs in the heavens is always believed**....Einstein has told us that space, time, and matter are shadows of the fifth dimension, and the heavens have declared their glory.*" ***The New York Times*** covered the news:

The New York Times.

VOL. LXIX...No. 22,370. ... NEW YORK, MONDAY, NOVEMBER 10, 1919. THIRTY-TWO PAGES. TWO CENTS

LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

A BOOK FOR 12 WISE MEN

No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.

Thompson states that the difference between theories of Newton and those of Einstein are infinitesimal in a popular sense, and as they are purely mathematical and can only be expressed in strictly scientific terms it is useless to endeavor to detail them for the man in the street.

"What is easily understandable," he continued, "is that Einstein predicted the deflection of the starlight when it passed the sun, and the recent eclipse has provided a demonstration of the correctness of the prediction.

The New York Times.

VOL. LXIX...No. 22,369. .... NEW YORK, SUNDAY, NOVEMBER 9, 1919. 138 PAGES, In Eleven Parts,

ECLIPSE SHOWED GRAVITY VARIATION

Diversion of Light Rays Accepted as Affecting Newton's Principles.

HAILED AS EPOCHMAKING

British Scientist Calls the Discovery One of the Greatest of Human Achievements.

Copyright, 1919, by The New York Times Company.

Special Cable to THE NEW YORK TIMES.

LONDON, Nov. 8.—What Sir Joseph Thomson, President of the Royal Society, declared was "one of the greatest—perhaps the greatest—of achievements in the history of human thought" was discussed at a joint meeting of the Royal Society and the Royal Astronomical Society in London yesterday, when the results of the British observations of the total solar eclipse of May 29 were made known.



The New York Times.

NEW YORK, TUESDAY, NOVEMBER 25, 1919. THIRTY-TWO PAGES.

A NEW PHYSICS, BASED ON EINSTEIN

Sir Oliver Lodge Says It Will Prevail, and Mathematicians Will Have a Terrible Time.

SPACE OF FOUR DIMENSIONS

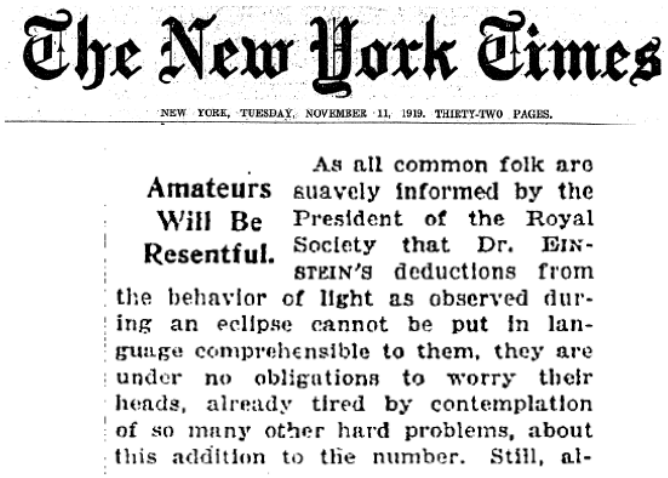
In Which Gravity Ceases to be a Force and Becomes a Quality.

ATTEMPT TO MEASURE IT

Its Radius Put at 16,000,000 Light-Years, or 80 Times the Distance to Farthest Star Cluster Known.

So complicated has this revolutionary theory proved that even some of the most learned have been confounded.

Hence the new physics, declared Sir Oliver, required our co-ordinates, not merely length, breadth, and thickness, but time. Gravity, too, ceases to become a force but becomes a quality in a fourth dimensioned space.



The New York Times

NEW YORK, TUESDAY, NOVEMBER 11, 1919. THIRTY-TWO PAGES.

Amateurs Will Be Resentful.

As all common folk are suavely informed by the President of the Royal Society that Dr. EINSTEIN'S deductions from the behavior of light as observed during an eclipse cannot be put in language comprehensible to them, they are under no obligations to worry their heads, already tired by contemplation of so many other hard problems, about this addition to the number. Still, al-



The New York Times.

NEW YORK, SUNDAY, NOVEMBER 16, 1919. In Eleven Parts.

JAZZ IN SCIENTIFIC WORLD

Prof. Charles Lane Poor of Columbia Explains Prof. Einstein's Astronomical Theories.

"'I have read various articles on the fourth dimension, the relativity theory of Einstein and other psychological speculation on the constitution of the universe; and after reading them I feel as Senator Brandegee felt after a celebrated dinner in Washington. 'I feel,' he said, 'as if I had been wandering with Alice in Wonderland and had tea with the Mad Hatter.'"



The New York Times.

NEW YORK, SUNDAY, DECEMBER 7, 1919. In Twelve Parts.

GIVEN THE SPEED, TIME IS NAUGHT

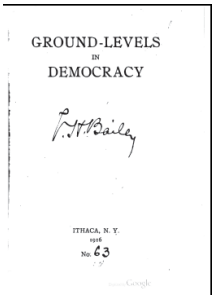
If Man Moved with the Velocity of Light He Might Remain Unchanged for 1,000 Years.

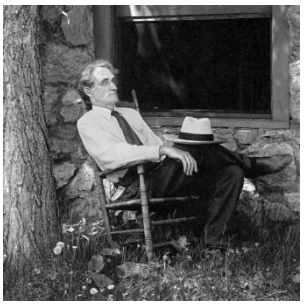
THE THEORY OF RELATIVITY

Among Other Things, It Makes Simultaneity of Two Widely Separated Events Impossible.

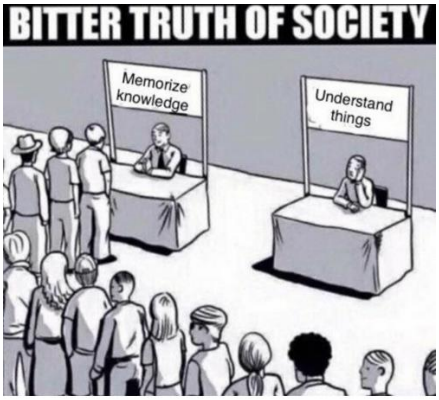
clearly. We shall find it leads to a world confused with a certain topsy-turviness; but if those English scientists are right in feeling that the theory is strongly supported we may be forced to conclude after all that our world is in just such a topsy-turvy condition, and that we must learn the theory of relativity in order to understand it.

The ***New York Times*** reported that "*if those English scientists are right in feeling that the theory is strongly supported* ***we may be forced to conclude after all that our world is in just a topsy-turvy condition, and that we must learn the theory of relativity to understand it***." Unfortunately, they also reported that "***As all common folk are suavely informed by the President of the Royal Society that Dr. Einstein's deductions from the behavior of light observed during an eclipse***





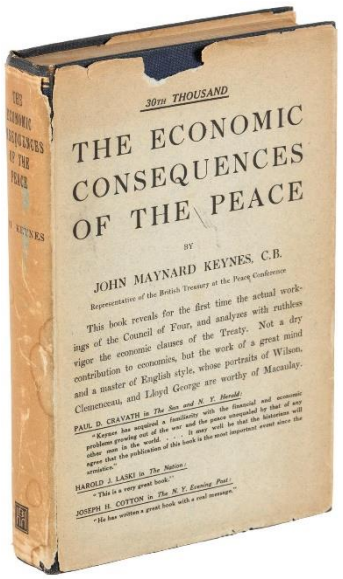
cannot be put in language comprehensible to them, they are under no obligation to worry their heads, already tired by contemplation of so many other hard problems*....”* It seemed that the common folk would never again be able to understand the world unless they were “*to reject the evidence of your eyes and ears*” and join the 12 wise men who could understand the Theory of General Relativity. This ***elitist attitude*** was quite a change from **Liberty Hyde Bailey’s** (1916) attitude who promoted ***the people’s understanding of science and the scientific spirit as a way to promote democracy***. Currently when STEM is king, are we teaching students to **understand things** or to **memorize science**?





According to **Subramanya Chandrasekhar**, Ernest Rutherford told him on May 29, 1919, “*The war had just ended, and the complacency of the Victorian and Edwardian times had been shattered. The people felt that all their values and all their ideals had lost their bearings. Now, suddenly, they learnt that an astronomical prediction by a German scientist had been confirmed…by British astronomers. Astronomy had always appealed to public imagination; and* ***an astronomical discovery, transcending worldly strife, struck a responsive chord****. The meeting of the Royal Society, at which the results of the British expeditions were reported, was headlined in all the British papers: and the typhoon of publicity crossed the Atlantic. From that point on, the American press played Einstein to the maximum*.” **Paul Dirac** (1977) came to a similar conclusion—relativity was “*an escape from the war*.”

In *The Economic Consequences of the Peace*, **John Maynard Keynes** (1920) described the postwar situation like so: "*In this autumn of 1919, in which I write, we are at the dead season of our fortunes. The reaction from the exertions, the fears, and the sufferings of the past five years is at its height. Our power of feeling or caring beyond the immediate questions of our own material well-being is temporarily eclipsed…We have been moved already beyond endurance, and need rest. Never in the lifetime of men now living has the universal element in the soul of man burnt so dimly*."



Do the eclipse results show unequivocally that "*space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.*" Could a rational person still believe that time and space are absolute and independent? I will show you that the model of the binary photon moving through absolute Newtonian time and Euclidean space predicts the **double deflection**—**the same observed result** predicted by Albert Einstein's General Theory of Relativity using an interdependent space-time.

Since the binary photon has angular momentum and radial extension, then it must have rotational motion, which means rotational energy. Thus, I applied the **equipartition theory** which was originally introduced by **Rudolf Clausius** to explain the specific heat of diatomic gasses to the binary photon.

I assume that the total energy of the photon is **equally partitioned** between the **translational energy** and the **rotational energy**.

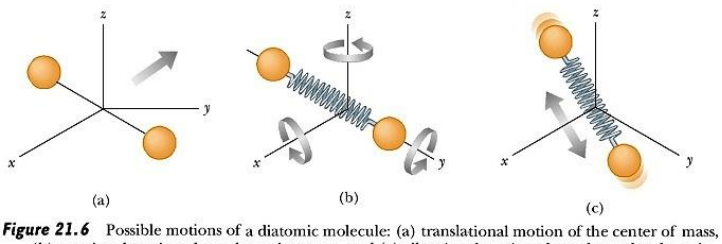
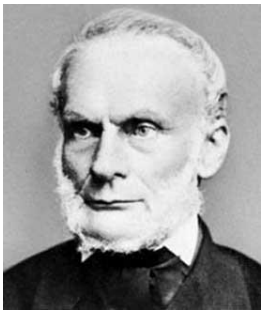
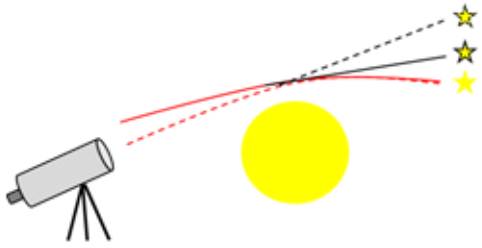


Figure 21.6 Possible motions of a diatomic molecule: (a) translational motion of the center of mass, (b) rotational motion about the various axes, and (c) vibrational motion along the molecular axis.



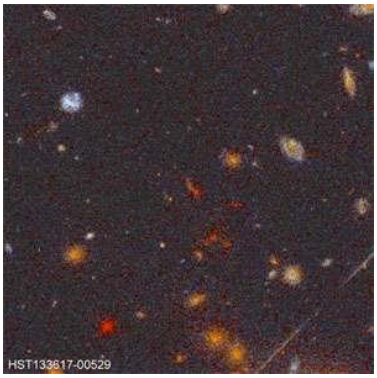
If the total energy of a binary photon is equipartitioned between the translational energy and the rotational energy, then the binary photon would have one-half of the expected translational energy. If a binary photon had **infinite translational energy**, it would not bend. If a binary photon had **zero translational energy**, it would fall into the sun. If a binary photon had **one-half the expected translational energy** because half of its total energy is partitioned into rotational energy, it would bend twice as much in a gravitational field and exhibit a double deflection—consistent with observation.



That is, my model of the binary photon that travels through **absolute space and time** gives the same prediction as Albert Einstein's General Theory of Relativity which assumes that mathematical point-like photons travel through an interdependent and relative space-time. Thus there is no need to assume that space-time is relative, and the universe is finite in size and unbounded, of which Bertrand Russell (April, 1955) warned us in a radio broadcast on *The Greatness of Albert Einstein*, "*Do not attempt to understand this unless you have studied non-Euclidean geometry*." The binary photon leads to a **more coherent** and less discordant **theory of light and life**. It saves the appearances, while being physically intelligible. It also does not demand a finite universe that has no room for an infinite God.

The complexity of a space-time that cannot be pictured resulted from a simplistic version of light that did not take the Doppler effect expanded to second order into consideration and considered the angular momentum to be merely a number. **The General Theory of Relativity, as complicated as the mathematics**

is, skimped on the assumptions. The simplistic assumptions led to complications in the results and made a pictorial understanding of the results impossible. According to the General Theory of Relativity and the Cosmological Principle, the universe is space-time and red-shifted galaxies are moving away from us because the space-time of the universe is expanding. Expanding into what, I ask.



Was the universe created in absolute space and time, with the galaxies shooting out from the explosive center red-shifted by the Doppler effect; or was the universe's origin and the origin of space-time itself a result of Heisenberg's Uncertainty Principle and the red-shift of the galaxies due to the expansion of space-time based on the Cosmological Principle?

Again, you get to choose what you consider reality to be and choose which Laws of Nature you think approximate reality better. And remember what **Lorentz** (1923) said in a lecture given at the Royal Institution, "*One of the lessons which this history of science teaches us is surely this, that we must not too soon be satisfied with what we have achieved.* ***The way of scientific progress is not a straight one which we can steadfastly pursue***. ***We are continually seeking our course, now trying one path and then another, many times groping the dark, and sometimes even retracing our steps***. ***So it may happen that ideas, which we thought could be abandoned once for all, have again to be taken up and come to new life***."

The Blind Man and The Elephant

by John Godfrey Saxe

It was six men of Indostan, to learning much inclined,
who went to see the elephant (Though all of them were blind),
that each by observation, might satisfy his mind.

The first approached the elephant, and, happening to fall,
against his broad and sturdy side, at once began to bawl:
"God bless me! but the elephant, is nothing but a wall!"

The second feeling of the tusk, cried: "Ho! what have we here,
so very round and smooth and sharp? To me tis mighty clear,
this wonder of an elephant, is very like a spear!"

The third approached the animal, and, happening to take,
the squirming trunk within his hands, "I see," quoth he,
the elephant is very like a snake!"

The fourth reached out his eager hand, and felt about the knee:
"What most this wondrous beast is like, is mighty plain," quoth he;
"Tis clear enough the elephant is very like a tree."

The fifth, who chanced to touch the ear, Said; "E'en the blindest man

can tell what this resembles most; Deny the fact who can,

This marvel of an elephant, is very like a fan!"

The sixth no sooner had begun, about the beast to grope,

than, seizing on the swinging tail, that fell within his scope,

"I see," quothe he, "the elephant is very like a rope!"

And so these men of Indostan, disputed loud and long,

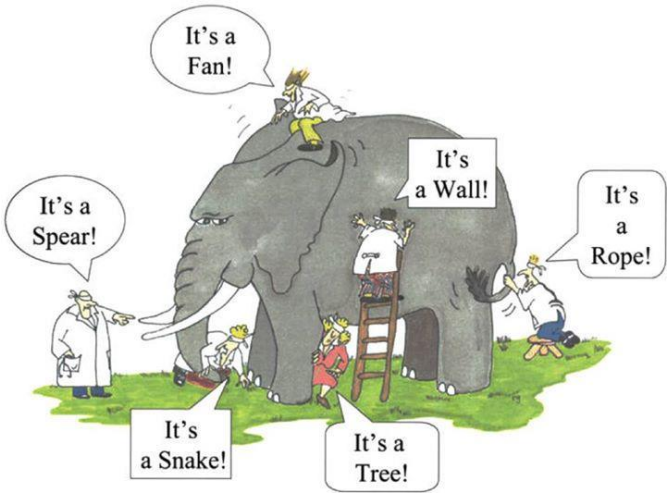
each in his own opinion, exceeding stiff and strong,

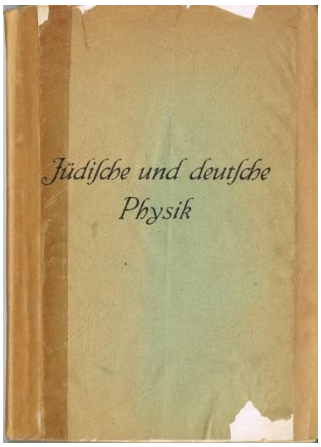
Though each was partly in the right, and all were in the wrong!

So, oft in theologic wars, the disputants, I ween,

tread on in utter ignorance, of what each other mean,

and prate about the elephant, not one of them has seen!





One more complication. The old idea of linear momentum of the photon was developed by **Johannes Stark** and the old idea of the Doppler effect as it was applied to was developed by **Philipp Lenard**. These two became horrible **Nazis** who persecuted Jewish scientists. Together (1924) they wrote, *The Hitler Spirit and Science*, in which they discussed the unique spirit carried in the Aryan-German blood—the "*spirit of total clarity, of honesty towards the outer world, and at the same time inner uniformity; that spirit which hates any compromising activity because it is insincere. But we have already recognized early on and revered this—to us exemplary—spirit in the great scientists of the past as well: in Galileo, Kepler, Newton, and Faraday. We admire and revere it in the same way also in Hitler….*" Lenard (1935) wrote in the *Forward* to his *German Physics*, "*In reality, as with everything that man creates,* ***science is determined by race or by blood****….It is important to examine the 'physics' of the Jewish people a bit here, because it stands as a conspicuous counterpart to German physics, and because for many, the latter will only be brought into the right light by identifying its opposite. As with everything Jewish, Jewish physics also only recently came under some unbiased public scrutiny. It has remained hidden for a long time and developed haltingly. At the end of the war when Jews in Germany began to dominate and to set the tone, the full force of its characteristics suddenly burst like a flood. It then promptly found avid supporters even among many authors of non-Jewish or of not really pure Jewish blood. To characterize it briefly, let me best refer you simply to the activities of its undoubtedly most prominent representative, to the unquestionably pure-blooded Jew A. Einstein. His 'relativity theories' attempted to transform and dominate the whole of physics; but they have now already completely played themselves out against reality. Apparently they never were even intended to be* ***true****. The Jew conspicuously lacks any understanding of* ***truth*** *beyond a mere*

superficial ***agreement with reality, which is independent of human thought. This is in contrast to the Aryan scientist's drive, which is as obstinate as it is serious in its quest for truth. The Jew has no noticeable capacity to grasp reality in any form other than as it appears in human activity and in the weaknesses of his host nation. Astonishingly, truth and reality do not appear to be anything at all special or different from untruth to Jews, but are equivalent to any one of the many different theoretical options available. It is obvious that this attitude is thus totally inappropriate for science; yet this fact was concealed through computational tricks…. Jewish 'physics' is therefore only an illusion and a degenerate manifestation of fundamental Aryan physics***."

Should I drop my research because it follows in the footsteps of Nazis—something that is definitely not politically correct? Do Lenard's words have both value and limitations? Is the search for the truth about light more or less important than the politics of science? Would the success of my work denigrate Jews and justify Nazis? Wait a minute, I am Jewish, and I believe that the Nazis were the epitome of evil on earth.

I believe that the sciences of relativity and quantum mechanics have a philosophical basis in the philosophy of **Friedrich Nietzsche**, who wrote about science in his book ***The Will to Power***, written in the 1880s. Tell me what you think. Here are some excerpts from *The Will to Power*:

594 Science— this has been hitherto a way of putting an end to the complete confusion in which things exist, by hypotheses that "explain" everything—so it has come from the intellect's dislike of chaos.— This same dislike seizes me when I consider myself: I should like to form an image of the inner world, too, by means of

*some schema, and thus triumph over intellectual confusion. Morality has been a simplification of this kind: it taught that men were known, familiar.— **Now we have destroyed morality—we have again become completely obscure to ourselves! I know that I know nothing of myself. Physics proves to be a boon for the heart: science (as the way to knowledge) acquires a new charm after morality has been eliminated— and because it is here alone that we find consistency, we have to construct our life so as to preserve it.** This yields a sort of practical reflection on the conditions of our existence as men of knowledge.*

*595 Our presuppositions: **no God: no purpose: finite force. Let us guard against thinking out and prescribing the mode of thought necessary to lesser men!***

596 No "moral education" of the human race: but an enforced schooling in [scientific] errors is needed, because "truth" disgusts and makes one sick of life— unless man is already irrevocably launched upon his path and has taken his honest insight upon himself with a tragic pride.

597 The presupposition of scientific work: belief in the unity and perpetuity of scientific work, so the individual may work at any part, however small, confident that his work will not be in vain.

*598 **A philosopher recuperates differently and with different means: he recuperates, e.g., with nihilism. Belief that there is no truth at all, the nihilistic belief, is a great relaxation for one who, as a warrior of knowledge, is ceaselessly fighting ugly truths. For truth is ugly**.*

*602 **This perspective world, this world for the eye, tongue, and ear, is very false**, even if compared for a very much more subtle sense-apparatus. **But its intelligibility, comprehensibility, practicability, and beauty begin to cease if we refine our senses; just as beauty ceases when we think about historical processes; the order of purpose is already an illusion**. It suffices that the more*

superficially and coarsely it is conceived, the more valuable, definite, beautiful, and significant the world appears. ***The deeper one looks, the more our valuations disappear— meaninglessness approaches! We have created the world that possesses values! Knowing this, we know, too, that reverence for truth is already the consequence of an illusion—and that one should value more than truth the force that forms, simplifies, shapes, invents. "Everything is false! Everything is permitted!" Only with a certain obtuseness of vision, a will to simplicity, does the beautiful, the "valuable" appear: in itself, it is I know not what.***

603 That the destruction of an illusion does not produce truth but only one more piece of ignorance, an extension of our "empty space," an increase of our "desert."

604 "Interpretation," the introduction of meaning—not "explanation" (in most cases a new interpretation over an old interpretation that has become incomprehensible, that is now itself only a sign). ***There are no facts, everything is in flux, incomprehensible, elusive;*** *what is relatively most enduring is— our opinions.*

608 ***The development of science resolves the "familiar" more and more into the unfamiliar:—it desires, however, the reverse, and proceeds from the instinct to trace the unfamiliar back to the familiar. In summa, science is preparing a sovereign ignorance, a feeling that there is no such thing as "knowing," that it was a kind of arrogance to dream of it, more, that we no longer have the least notion that warrants our considering "knowledge" even a possibility—that "knowing" itself is a contradictory idea. We translate a primeval mythology and vanity of mankind into the hard fact: "knowledge-in-itself" is as impermissible a concept as is "thing-in itself." Seduction by "number and logic," seduction by "laws." "Wisdom" as the attempt to get beyond perspective valuations (i.e., beyond the "will to power"): a principle hostile to***

life and decadent, a symptom as among the Indians, etc., of the weakening of the power of appropriation.

609 It is not enough that you understand in what ignorance man and beast live; ***you must also have and acquire the will to ignorance****. You need to grasp that without this kind of ignorance life itself would be impossible, that it is a condition under which alone the living thing can preserve itself and prosper: a great, firm dome of ignorance must encompass you.*

616 That the value of the world lies in our interpretation (— that other interpretations than merely human ones are perhaps somewhere possible—); that previous interpretations have; been perspective valuations by virtue of which we can survive in life, i.e., in the will to power, for the growth of power; that every elevation of man brings with it the overcoming of narrower interpretations; that every strengthening and increase of power opens up new perspectives and means believing in new horizons— this idea permeates my writings. ***The world with which we are concerned is false, i.e., is not a fact but a fable and approximation on the basis of a meager sum of observations; it is "in flux," as something in a state of becoming, as a falsehood always changing but never getting near the truth: for—there is no "truth."***

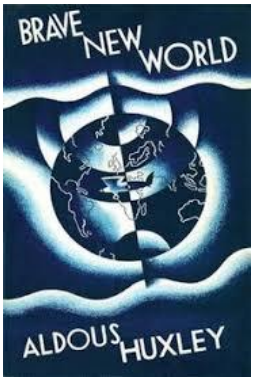
617 To impose upon becoming the character of being— that is the supreme will to power. Twofold falsification, on the part of the senses and of the spirit, to preserve a world of that which is, which abides, Which is equivalent, etc. ***That everything recurs is the closest approximation of a world of becoming to a world of being****:—high point of the meditation. From the values attributed to being proceed the condemnation of and discontent with becoming, after such a world of being had first been invented. The metamorphoses of what has being (body, God, ideas, laws of nature, formulas, etc.) "Beings" as appearance; reversal of values; appearance was that which conferred value—* ***. Knowledge-in-itself in a world of***

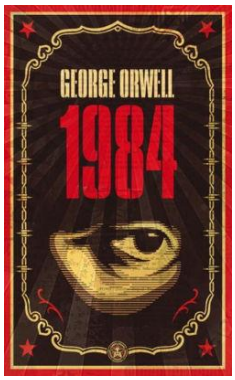
becoming is impossible; so how is knowledge possible? As error concerning oneself, as will to power, as will to deception.

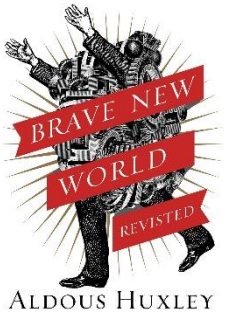
Becoming as invention, willing, self-denial, overcoming of oneself: no subject but an action, a positing, creative, no "causes and effects." Art as the will to overcome becoming, as "eternalization," but shortsighted, depending on the perspective: repeating in miniature, as it were, the tendency of the Whole. Regarding that which all life reveals as a diminutive formula for the total tendency; hence a new definition of the concept "life" as will to power. Instead of "cause and effect" the mutual struggle of that which becomes, often with the absorption of one's opponent; the number of becoming elements not constant. Uselessness of old ideals for the interpretation of the totality of events, once one knows the animal origin and utility of these ideals; all, moreover, contradictory to life. Uselessness of the mechanistic theory—it gives the impression of meaninglessness. The entire idealism of mankind hitherto is on the point of changing suddenly into nihilism—into the belief in absolute worthlessness, i.e., meaninglessness. The destruction of ideals, the new desert; new arts by means of which we can endure it, we amphibians. Presupposition: bravery, patience, no "turning back," no haste to go forward.

I see no reason to accept the pronouncements based on Comte's positivism, Nietzsche's nihilism, Huxley's scientism, Einstein's relativity, and Born and Heisenberg's quantum mechanics, which together have produced black holes into which reason and faith have both disappeared (to use an image invented by Andrew Wernick (2001) in Auguste *Comte and the Religion of Humanity: The Post-Theistic Program of French Social Theory*.) The fact that my model of the binary photon is consistent with physical observations and the biological understanding of time satisfies me.

I teach the **value of questioning authority** and fight with the spirit of Aldous Huxley and George Orwell against any form of totalitarianism that turns human beings into compliant automatons.









The culture of science, a according to Bruce Alberts, Marc Kirschner, Shirley Tilghman, and Harold Varmus (2014) "*now favors those who can guarantee results rather than those with potentially path-breaking ideas that, by definition, cannot promise success. Young investigators are discouraged from departing too far from their postdoctoral work, when they should instead be posing new questions and inventing new approaches. Seasoned investigators are inclined to stick to their tried-and-true formulas for success rather than explore new fields*."

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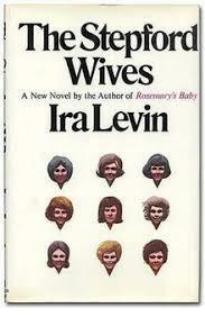
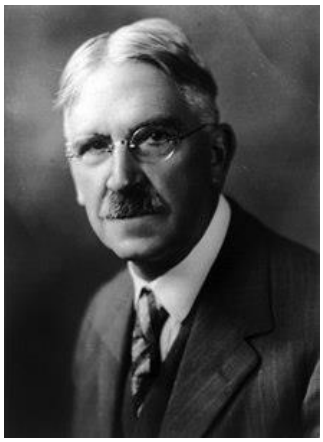
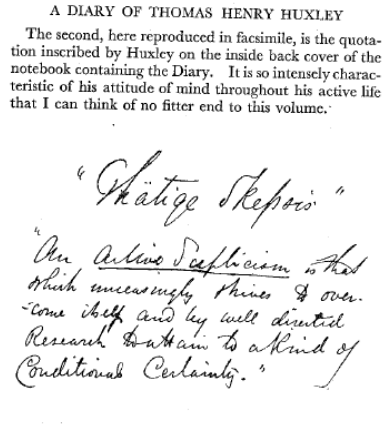


Where is the freedom to think? Not only are trained scientists working like automatons but also being replaced by automatons. According to Cornell's Steve Strogatz (Manjoo, 2011), "*Our time is limited. As thinking machines, they have a lot of advantages over us—this is obvious…We're not going to be the best players in town. I do think we'll be put out of business. This is really going to happen*."

More importantly, I'd like to ask the question: What are the goals of science? Are the goals best done by computers? Or should the goals be based on the proposition that science is a field of human endeavor that promotes freedom by training people to think. John Dewey (1910) realized, "***Genuine freedom, in short, is intellectual****; it rests in the trained power of thought, in ability to 'turn things over,' to look at matters deliberately, to judge whether the amount and kind of evidence requisite for decision is at hand, and if not, to tell where and how to seek such evidence. If a man's actions are not guided by thoughtful conclusions, then they are guided by inconsiderate impulse, unbalanced appetite, caprice, or the circumstances of the moment.* ***To cultivate unhindered, unreflective external activity is to foster enslavement****, for it leaves the person at the mercy of appetite, sense, and circumstance*."



In the first lecture I also told you that I love science and the ability of the scientific method for helping us question, understand, and appreciate the world around us. I am a staunch supporter of questioning any and all authority in order to help us understand and appreciate the world around us (and prevent totalitarianism). **I told you that I would try to provide you with as much personal experience as possible concerning light and life so that you do not have to believe anything I say but have enough experience to trust your knowledge while understanding both the value and limitations of what you know**. I then presented Goethe's phrase, ***Thatige Skepsis***, which was defined by **T. H. Huxley** as "***An Active Skepticism in what which unceasingly strives to overcome itself and by well directed Research to attain to a kind of Conditional Certainty***." On the right is a



A DIARY OF THOMAS HENRY HUXLEY

The second, here reproduced in facsimile, is the quotation inscribed by Huxley on the inside back cover of the notebook containing the Diary. It is so intensely characteristic of his attitude of mind throughout his active life that I can think of no fitter end to this volume.

"Thätige Skepsis"

"An active Scepticism is that which unceasingly thines & overcome itself and by well directed Research to attain to a kind of Conditional Certainty."

reproduction of Huxley's quote on the inside back cover of the notebook that contained his diary. It can be found in the book, *T. H. Huxley's Diary of the Voyage of H.M.S. Rattlesnake*, edited by his grandson, Julian Huxley.



SCIENCE

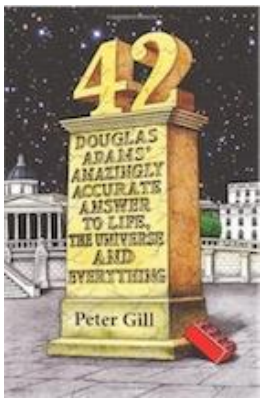
America's Smug Elite Is Harming Our Kids

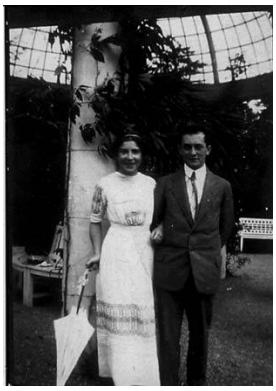
The push to decouple skepticism from science turns schoolchildren into victims

BY JACOB HALE RUSSELL AND DENNIS PATTERSON

Unfortunately today, according to Jacob Hale Russell and Dennis Patterson (2021), there is considerable evidence of a "*push to decouple skepticism from science*" by the "*smug elite*." Moreover, the scientific questions being asked or avoided have become linked to one's political affiliations.

We have to be aware of the difference between reality and the Laws of Nature that describe reality. We also have to be aware of the simplifications used to derive the Laws of Nature when we apply them to our lives. This reminds me of a story from *The Ultimate Hitchhiker's Guide to the Galaxy* by Douglas Adams: *"**Forty-two**!" yelled Loonquawl. "Is that all you've got to show for seven and a half million years' work?" I checked it very thoroughly," said the computer, "and that quite definitely is the answer. **I think the problem, to be quite honest with you, is that you've never actually known what the question is**." "But it was the Great Question! The Ultimate Question of Life, the Universe and Everything," howled Loonquawl.*





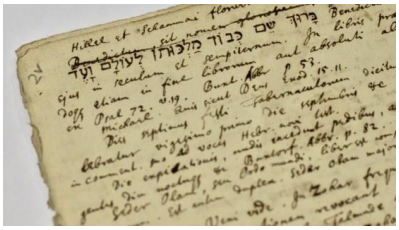
This quantative answer is too reductionist and unsatifying for me. Which reminds me of another story. When Max Born's wife Hedwig asked Einstein, "*Do you believe that everything can be pictured in a scientific* [mathematical] *manner?"* Einstein answered, "***Yes, it is conceivable but it would be of no use. It would be an inadequate means of expression—like representing a Beethoven symphony in terms of curves of air pressure****"* (Born 1965).

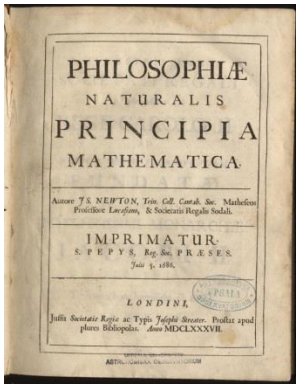


Perhaps the answer to the ultimate question is a little more subtle and close to home as Victor Frankl (1959) wrote about his time in Auschwitz when he connected light and life: "*Another time we were at work in a trench. The dawn was grey around us; grey was the sky above; grey the snow in the pale light of dawn; grey the rags in which my fellow prisoners were clad, and grey their faces. I was again conversing silently with my wife, or perhaps I was struggling to find the reason for my sufferings, my slow dying****. In a last violent protest against the hopelessness of imminent death, I sensed my spirit piercing through the enveloping gloom. I felt it transcend that hopeless, meaningless world, and from somewhere I heard a victorious 'Yes' in answer to my question of the existence of ultimate purpose.*** *At that moment a light was lit in a distant farmhouse, which stood on the horizon as if painted there, in the midst of the miserable grey of a dawning morning in Bavaria. 'Et lux tenebris lucet'—and the light shineth in the darkness. For hours I stood hacking on the icy ground. The guard passed by, insulting me, and once again I communed with my beloved. More and more I felt that she was present, that she was with me; I had the feeling that I was able to touch her, able to stretch out my hand and grasp hers. The feeling was very strong: she was there. Then, at that very*

moment, a bird flew down silently and perched just in front of me, on the heap of soil which I had dug up from the ditch, and looked steadily at me."

In the first lecture we also discussed the historical and cultural relationship between light and truth. **Isaac Newton** wrote in ***The First Book Concerning the Language of the Prophets***, "*Light—for the glory, truth and knowledge wherewith great and good men shine and illuminate others*." What kind of knowledge did Newton illuminate? Newton (1687) wrote in the General Scholium of his ***Principia***, "*This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful being…and from his true dominion it follows that God is a living, intelligent, and powerful being.*"





Thomas Jefferson, who along with the other founders used the Laws of Nature crafted by Isaac Newton to craft a government, wrote *"The most effectual means of preventing the perversion of power into tyranny are to* ***illuminate****, as far as practicable, the minds of the people . . . .* ***Light and liberty*** *go together. I look to the diffusion of* ***light*** *and education as the resource most to be relied on for ameliorating the condition, promoting the virtue, and advancing the happiness of man.* ***Enlighten*** *the people generally, and tyranny and oppressions of body and mind will vanish like evil spirits at the dawn of day."*



I hope that my lectures have fulfilled James Clerk Maxwell's goal as a teacher. In his inaugural lecture at King's College, the 29-year-old **James Clerk**

Maxwell (1860) said "*In this class, I hope you will learn not merely results, or formulae applicable to cases that may possibly occur in our practice afterwards, but the* ***principles*** *on which those formulae depend, and without which the formulae are mere mental rubbish. I know the tendency of the human mind is to do anything rather than think. But mental labour is not thought, and those who have with labour acquired the habit of application often find it much easier to get up a formula than to master a principle….****My duty is to give you the requisite foundation and to allow your thoughts to arrange themselves freely****. ****It is best that every man should be settled in his own mind, and not be led into other men's ways of thinking under the pretence of studying science****. ****By a careful and diligent study of natural laws I trust that we shall at least escape the dangers of vague and desultory modes of thought and acquire a habit of healthy and vigorous thinking which will enable us to recognise error in all the popular forms in which it appears and to seize and hold fast truth whether it be old or new***."

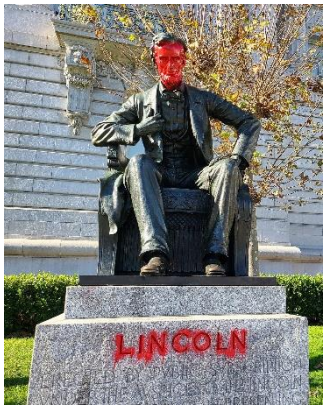


In this class, I have tried to teach you ***how*** to think not ***what*** to think by providing you with observational evidence, historical and textural evidence, and mathematical evidence to help you critically think about light and life so that **you can define a set of Laws of Nature that you as a unique individual believe to be true in describing and explaining light and life**.

I think the historical approach to science gives the context necessary to think critically and independently about the material. This goes against the idea of eliminating any evidence of the past to promote a new culture. We have seen the use of this method by Pope Theophilus of Alexandria, who destroyed the last

vestiges of the library in Alexandria to the removal of historical statues of Thomas Jefferson, Abraham Lincoln, and Frederick Douglass that we see today.

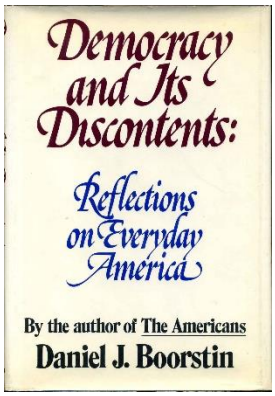








Henry Ford (Chicago Tribune, May 25, 1916) said, "*History is more or less bunk. It's tradition. We don't want tradition. We want to live in the present and the only history that is worth a tinker's damn is the history we make today*." Ford (New York Times, October 29, 1921) also said more succinctly, "*History is bunk*." Aldous Huxley (1932) incorporated Ford's thinking in ***Brave New World***, "*You all remember," said the Controller, in his strong deep voice, "you all remember, I suppose, that beautiful and inspired saying of Our Ford's: History is bunk. History," he repeated slowly, "is bunk."* George Orwell's (1945) *Animal Farm* begins with the animals destroying the evidence of political incorrectness found in the human culture. https://www.youtube.com/watch?v=h1DcWw9geig



In [t]*he Prison of the Present*, Daniel Boorstin (1974) reminds us of the perspective we lose when we do not have a historical basis to understand things that "*not yet gone through the formality of taking*

place." According to Boorstin, who was a librarian of Congress, "*Education is learning what you didn't even know you didn't know*."

John Keats worried that science destroyed our appreciation of the beauty in the world:

Lamia (excerpt from Part II)





Do not all charms fly
At the mere touch of cold philosophy?
There was an awful rainbow once in heaven:
We know her woof, her texture; she is given
In the dull catalogue of common things.
Philosophy will clip an Angel's wings,
Conquer all mysteries by rule and line,
Empty the haunted air, and gnomed mine -
Unweave a rainbow, as it erewhile made
The tender-person'd Lamia melt into a shade.

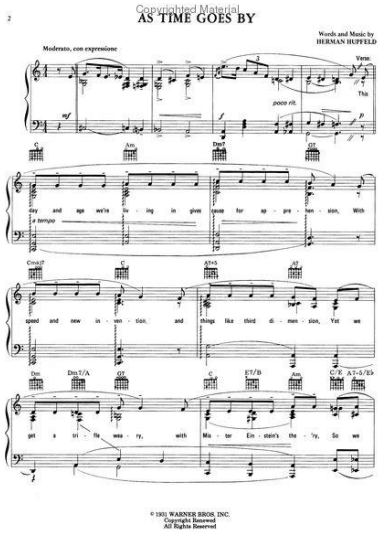
I hope that the science I have taught you has enhanced your appreciation of the beauty, design, and meaning found in the real and natural world. And I believe that the natural world that exists in real space and real time is real.

I want you to know the prelude to the song, *As Time Goes By* written by Herman Hupfeld in 1931. Unfortunately, the prelude is not well known since it was left out of the most famous version of *As Time Goes By* sung by Dooley Wilson in *Casablanca*. The prelude reminds us that, when it comes to time, biology trumps physics and "***The simple facts of life are such They cannot be removed...*****"**

As Time Goes By (Words and Music by Herman Hupfeld)

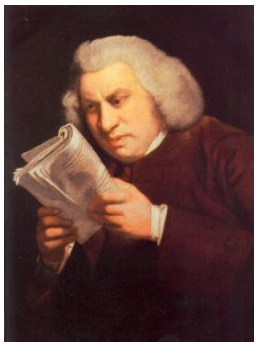
This day and age we're living in
Gives cause for apprehension
With speed and new invention
And things like fourth dimension.
Yet we get a trifle weary
With Mr. Einstein's theory.
So we must get down to earth at times
Relax relieve the tension

And no matter what the progress
Or what may yet be proved
The simple facts of life are such
They cannot be removed...



It can be heard in other versions sung by Mavis Rivers https://www.youtube.com/watch?v=B2WwilQbRZM, Binnie Hale (1932) https://www.youtube.com/watch?v=kx_hBIHoIaw, Rudy Vallee https://www.youtube.com/watch?v=vm-vwjnUNmo, Tony Bennett https://www.youtube.com/watch?v=qi_EEZHaMEQ and Johnny Mathis https://www.youtube.com/watch?v=7-v1N8MAe84.

Bishop Berkeley (1710) wrote "*But, say you, surely there is nothing easier than for me to imagine trees, for instance, in a park… and nobody by to perceive them….* ***The objects of sense exist only when they are perceived; the trees therefore are in the garden…no longer than while there is somebody by to perceive them***."



James Boswell (1833) told the following story in *Life of Samuel Johnson*: "*After we came out of the church, we stood talking for some time together of Bishop Berkeley's ingenious sophistry to* ***prove the non-existence of matter, and that every thing in the universe is merely ideal***. *I observed, that though we are satisfied his doctrine is not true, it is impossible to refute it. I never shall forget the alacrity with which Johnson*

*answered, striking his foot with mighty force against a large stone, till he rebounded from it, '**I refute it THUS.**"*

I agree, and contrary to the **Copenhagen interpretation of quantum mechanics**, an electron is there whether someone is there to measure it, the moon is there whether someone is there to see it, and a tree does make a noise when it falls whether someone is there to hear it or not. **Ronald Knox** provided an answer to why objects, such as electrons, the moon, and trees exist in space and time, even if there is no ***human*** observer.

God in the Quad by Ronald Knox

There was a young man who said, "God
Must think it exceedingly odd
If he finds that this tree
Continues to be
When there's no one about in the Quad."

REPLY
Dear Sir:
Your astonishment's odd:
I am always about in the Quad.
And that's why the tree
Will continue to be,
Since observed by
Yours faithfully,
GOD.



The term, ***solvitur ambulando*** is a Latin phrase that means, "*it is solved by walking*." Diogenes Laertius (3rd century A.D. *Lives of Eminent Philosophers*, VI. 39) reported that **Diogenes the Cynic** (4th century B.C.) answered Zeno's (5th century B.C.) paradoxes on the unreality of motion by standing up and walking away.

From Randy (who wonders how the universe began according to the Copenhagen interpretation of quantum mechanics if there were no one there to observe it). I asked Lawrence Krauss:

On May 8, 2019, at 12:59 PM, Randy O. Wayne <row1@cornell.edu> wrote:

Dear Professor Krauss,

This is a serious question from one who does not subscribe to the Copenhagen interpretation of quantum mechanics. If the Copenhagen interpretation of quantum mechanics is correct, how could the universe come into existence if no one was there to observe it? I look forward to your answer.

Sincerely,

Randy Wayne

From: Lawrence Krauss <lkrauss@asu.edu>
Sent: Wednesday, May 8, 2019 5:52 PM
To: Randy O. Wayne <row1@cornell.edu>
Subject: Re: Copenhagen Interpretation of the big bang

Quantum mechanics doesn't depend on or need human observers.

Typed on my iPhone, which sometimes has a mind of its own.

On May 8, 2019, at 3:03 PM, Randy O. Wayne <row1@cornell.edu> wrote:

Dear Professor Krauss,

Thank you for your answer, but doesn't the Copenhagen interpretation require that a measurement is made before a particle is commanded into existence? If not, please let me know. If so, how was the measurement made or what kind of nonhuman observer could make the measurement?

Thank you again,

Randy

From: Lawrence Krauss <lkrauss@asu.edu>
Sent: Wednesday, May 8, 2019 7:01 PM
To: Randy O. Wayne <row1@cornell.edu>
Subject: Re: Copenhagen Interpretation of the big bang

No it doesn't.

Typed on my iPhone, which sometimes has a mind of its own.

On May 8, 2019, at 6:22 PM, Randy O. Wayne <row1@cornell.edu> wrote:

Dear Professor Krauss,

Again, thank you for your response. You wrote in the New Yorker that "quantum mechanics tells us that, until we measure the position of either electron, we cannot say for certain where it is located. It can be, in some sense, everywhere at once." Are the particles formed in the big bang actually "everywhere at once" or is it that we just do not have knowledge of the particles until someone or something like a machine makes a measurement and collapses the wave function?

Thanks again,

Randy

Thu 5/9/2019 12:27 AM

Lawrence Krauss lkrauss@asu.edu

Re: Copenhagen Interpretation of the big bang

particles can be 'measured' by other particles.. via strong or violent interactions.. The system is quantum mechanical but on large scales evolves classically.

sorry.. really busy.. that will have to be it.



In the movie, ***Dead Poets Society*** (1989), **Robin Williams**, as John Keating, said, "*We don't read and write poetry because it's cute. We read and write poetry because we are members of the human race. And the human race is filled with passion. And medicine, law, business, engineering, these are noble pursuits and necessary to sustain life. But poetry, beauty, romance, love, these are what we stay alive for. To quote*

from Whitman, "O me! O life!.. of the questions of these recurring; of the endless trains of the faithless... of cities filled with the foolish; what good amid these, O me, O life?" Answer. ***That you are here - that life exists, and identity; that the powerful play goes on and you may contribute a verse****. That the powerful play *goes on* and you may contribute a verse. What will your verse be?"*



John Lubbock (1893) began his essay on *The Beauties of Nature* with "*We are told in the first chapter of Genesis that at the close of the sixth day 'God saw every thing that he had made, and, behold, it was very good.' Not merely good, but very good.*" **Louis Armstrong** (1967) sang it like this:

"What a Wonderful World"



By George David Weiss and Bob Thiele (as George Douglas).

I see trees of green, red roses, too,
I see them bloom, for me and you
And I think to myself
What a wonderful world.

I see skies of blue, and clouds of white,
The bright blessed day, the dark sacred night
And I think to myself
What a wonderful world.

The colors of the rainbow, so pretty in the sky,
Are also on the faces of people going by.
I see friends shaking hands, sayin', "How do you do?"
They're really sayin', "I love you."

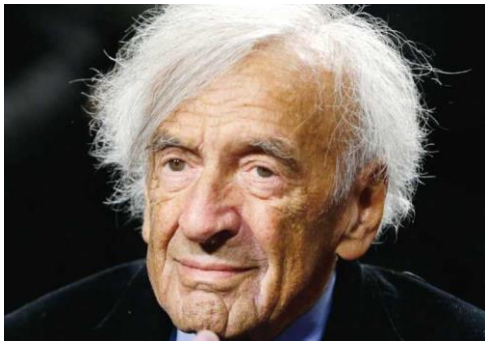
I hear babies cryin'. I watch them grow.
They'll learn much more than I'll ever know
And I think to myself
What a wonderful world

Yes, I think to myself
What a wonderful world

Oh yeah.

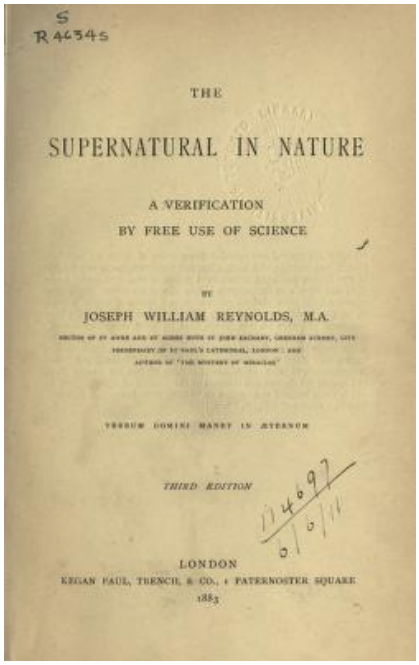
https://www.youtube.com/watch?v=E2VCwBzGdPM&feature=kp
https://www.youtube.com/watch?v=2nGKqH26xlg



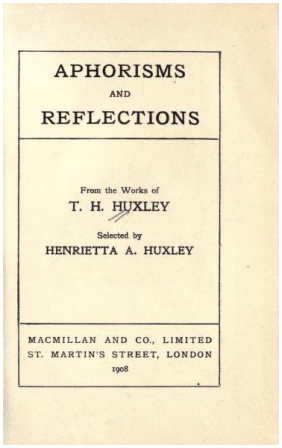


Elie Wiesel told *Life Magazine* (December, 1988), "*I've built my entire work on questions, not answers. It's important not to accept easy answers. Easy answers are always the wrong answers.* ***Questions remain, answers change****. Sometimes the answer changes more than once in a generation. And* ***"Why are we here?" is the most important question a human being has to face. Our obligation is to give meaning to life and in doing so to overcome the passive, indifferent life.*** *A person who is indifferent is dead without knowing it. I believe that life has meaning in spite of the meaningless death I have seen. Death has no meaning, life has. We must make every minute rich and enriching, not for oneself, but for someone else, and thereby create a bridge between beings that limits the domain of nothingness.* ***Life is a gift and meaning is its reward****. The meaning of life is to be found in every encounter. Every moment is a moment of grace*."

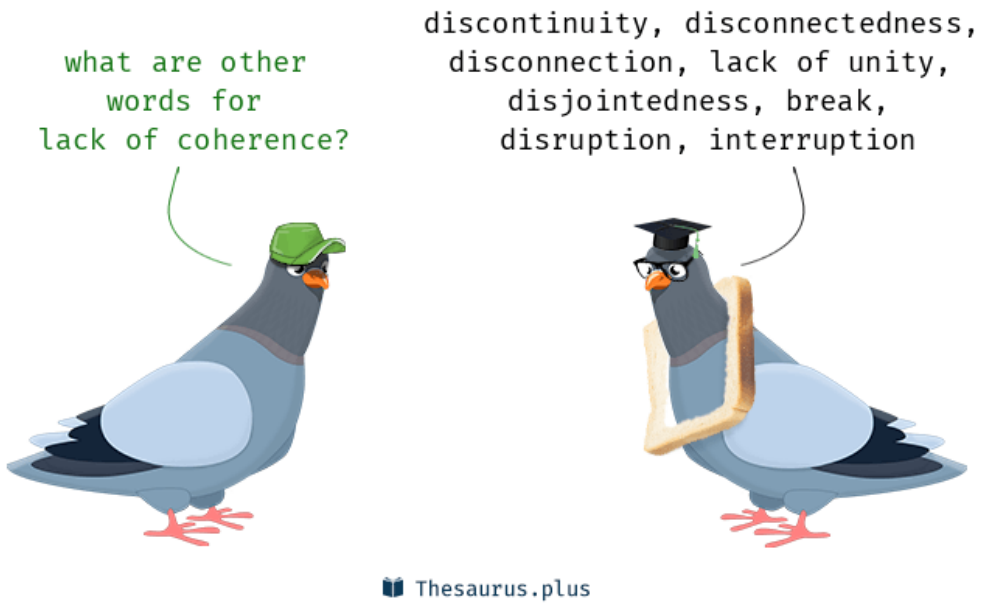
Joseph William Reynolds (1880) wrote, "*A clear thinker, listening to the eloquence, acknowledging the skill, and honouring the zeal of those who exhibit their stores, is sadly conscious that—though, after all, science is simply common sense applied to somewhat recondite matters—**scientific eyesight is not always scientific insight**. Men of scientific research often neglect scientific thought; a neglect more sure to bring heartache than blossom to bring fruit.*"



In the Preface to a collection of her husband's writings entitled *Aphorisms and Reflections*, **Henrietta Huxley** (1907) wrote, "*I hope that these selections may attract the attention of the working man, whose cause my husband so ardently espoused, and to whom he was the first to reveal, by his free lectures, **the loveliness of Nature, the many rainbow-coloured rays of science, and to show forth to his listeners how all these glorious rays unite in the one pure white light of holy truth***." I strove in these lectures to do the same.



There are two words that have been used to describe the world: **chaos and cosmos**. *Chaos* comes from the Greek word *khaos* which means abyss, that which gapes wide open and is vast and empty. Hesiod (700 BC) in his *Theogony* used *khaos* to describe the primeval emptiness of the Universe. Ovid (8 AD) in his *Metamorphoses*, compared *Khaos* to *Kosmos*, which is the Greek word for order, good order, orderly arrangement to describe the ordered Universe. Which does best describe our world?



At the end of the movie *Edison the Man* (1940), Spencer Tracey, who played Thomas A. Edison, gave the following speech, "*Mr. Toastmaster. Ladies and Gentlemen, To be told by the outstanding men and women of our time that you have contributed a great deal to human betterment. Very pleasant. Very pleasant. I'd hardly be human if my heart did not feel from such magnificent compliment. But somehow I have not achieved the success I want. Early this evening, I talked with two school children. Tomorrow, the world will be theirs. A troubled world, full of doubt and uncertainties. You say that we men of science have been helping it. Are those children and their children going to approve of what we have done? Or will you discover too late that they have relied too heavily on science and that this has become a monster whose final triumph is man's own destruction. Some of us are already beginning to feel that danger. But it can be avoided. I had once two dynamos. They needed regulating.* ***It was a problem of balance and adjustment****. And I feel that the confusion in the world today, presents much the same problem. But the dynamo of man's God given ingenuity is running away with the dynamo of his equally God given humanity. I'm too old now to do much more than to say Put*

those dynamos in balance. Make them work in harmony as the great designer intended they should. It can be done. What man's mind can see man's character can control. Man must learn that. And then we won't need to be afraid of tomorrow. ***And man will go forward, toward more light****.*"

https://www.springfieldspringfield.co.uk/movie_script.php?movie=edison-the-man

A Reminder

Excerpts from Aldous Huxley's (1932) ***Brave New World***:

MR. FOSTER was left in the Decanting Room. The D.H.C. and his students stepped into the nearest lift and were carried up to the fifth floor.

INFANT NURSERIES. NEO-PAVLOVIAN CONDITIONING ROOMS, announced the notice board.

The Director opened a door. They were in a large bare room, very bright and sunny; for the whole of the southern wall was a single window. Half a dozen nurses, trousered and jacketed in the regulation white viscose-linen uniform, their hair aseptically hidden under white caps, were engaged in setting out bowls of roses in a long row across the floor. Big bowls, packed tight with blossom. Thousands of petals, ripe-blown and silkily smooth, like the cheeks of innumerable little cherubs, but of cherubs, in that bright light, not exclusively pink and Aryan, but also luminously Chinese, also Mexican, also apoplectic with too much blowing of celestial trumpets, also pale as death, pale with the posthumous whiteness of marble.

The nurses stiffened to attention as the D.H.C. came in.

"Set out the books," he said curtly.

In silence the nurses obeyed his command. Between the rose bowls the books were duly set out–a row of nursery quartos opened invitingly each at some gaily coloured image of beast or fish or bird.

"Now bring in the children."

They hurried out of the room and returned in a minute or two, each pushing a kind of tall dumb-waiter laden, on all its four wire-netted shelves, with eight-month-old babies, all exactly alike (a Bokanovsky Group, it was evident) and all (since their caste was Delta) dressed in khaki.

"Put them down on the floor."

The infants were unloaded.

"Now turn them so that they can see the flowers and books."

Turned, the babies at once fell silent, then began to crawl towards those clusters of sleek colours, those shapes so gay and brilliant on the white pages. As they approached, the sun came out of a momentary eclipse behind a cloud. The roses flamed up as though with a sudden passion from within; a new and profound significance seemed to suffuse the shining pages of the books. From the ranks of the crawling babies came little squeals of excitement, gurgles and twitterings of pleasure.

The Director rubbed his hands. "Excellent!" he said. "It might almost have been done on purpose."

The swiftest crawlers were already at their goal. Small hands reached out uncertainly, touched, grasped, unpetaling the transfigured roses, crumpling the illuminated pages of the books. The Director waited until all were happily busy. Then, "Watch carefully," he said. And, lifting his hand, he gave the signal.

The Head Nurse, who was standing by a switchboard at the other end of the room, pressed down a little lever.

There was a violent explosion. Shriller and ever shriller, a siren shrieked. Alarm bells maddeningly sounded.

The children started, screamed; their faces were distorted with terror.

"And now," the Director shouted (for the noise was deafening), "now we proceed to rub in the lesson with a mild electric shock."

He waved his hand again, and the Head Nurse pressed a second lever. The screaming of the babies suddenly changed its tone. There was something desperate, almost insane, about the sharp spasmodic yelps to which they now gave utterance. Their little bodies twitched and stiffened; their limbs moved jerkily as if to the tug of unseen wires.

"We can electrify that whole strip of floor," bawled the Director in explanation. "But that's enough," he signalled to the nurse.

The explosions ceased, the bells stopped ringing, the shriek of the siren died down from tone to tone into silence. The stiffly twitching bodies relaxed, and what had become the sob and yelp of infant maniacs broadened out once more into a normal howl of ordinary terror.

"Offer them the flowers and the books again."

The nurses obeyed; but at the approach of the roses, at the mere sight of those gaily-coloured images of pussy and cock-a-doodle-doo and baa-baa black sheep, the infants shrank away in horror, the volume of their howling suddenly increased.

"Observe," said the Director triumphantly, "observe."

Books and loud noises, flowers and electric shocks–already in the infant mind these couples were compromisingly linked; and after two hundred repetitions of the same or a similar lesson would be wedded indissolubly. What man has joined, nature is powerless to put asunder.

"They'll grow up with what the psychologists used to call an 'instinctive' hatred of books and flowers. Reflexes unalterably conditioned. They'll be safe from books and botany all their lives." The Director turned to his nurses. "Take them away again."

Still yelling, the khaki babies were loaded on to their dumb-waiters and wheeled out, leaving behind them the smell of sour milk and a most welcome silence.

****

Every discovery in pure science is potentially subversive; even science must sometimes be treated as a possible enemy. Yes, even science."

Science? The Savage frowned. He knew the word. But what it exactly signified he could not say. Shakespeare and the old men of the pueblo had never mentioned science, and from Linda he had only gathered the vaguest hints: science was something you made helicopters with, some thing that caused you to laugh at the Corn Dances, something that prevented you from being wrinkled and losing your teeth. He made a desperate effort to take the Controller's meaning.

"Yes," Mustapha Mond was saying, "that's another item in the cost of stability. It isn't only art that's incompatible with happiness; it's also science. Science is dangerous; we have to keep it most carefully chained and muzzled."

"What?" said Helmholtz, in astonishment. "But we're always saying that science is everything. It's a hypnopædic platitude."

"Three times a week between thirteen and seventeen," put in Bernard.

"And all the science propaganda we do at the College …"

"Yes; but what sort of science?" asked Mustapha Mond sarcastically. "You've had no scientific training, so you can't judge. I was a pretty good physicist in my time. Too good–good enough to realize that all our science is just a cookery book, with an orthodox theory of cooking that nobody's allowed to question, and a list of recipes that mustn't be added to except by special permission from the head cook. I'm the head cook now. But I was an inquisitive young scullion once. I started doing a bit of cooking on my own. Unorthodox cooking, illicit cooking. A bit of real science, in fact." He was silent.

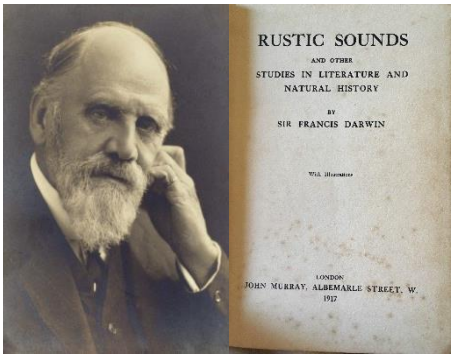
"What happened?" asked Helmholtz Watson.

The Controller sighed. "Very nearly what's going to happen to you young men. I was on the point of being sent to an island."

Or should it be called ***Cowardly New World***?

The movie *Brave New World* (https://www.youtube.com/watch?v=BCV03eKS6qU), released in 1980 has the following lines about the elite alphas:

As select Alphas, conditioned to ***believe without knowing and to know without believing****, you have been chosen to view the surrogate revelations and synthetic mysteries upon which all perfect 'assemblific' believe is founded. Here before you are sacred Teletime-plex relics of the sanctified life, thought and Holy Works of our Ford. From whose divine inspiration came the ultimate perfection of the endless assembly line.*



Science is what you know and understand. Francis Darwin (1917) wrote in *Rustic Sounds and other Studies in Literature and Natural History*, "*The word 'science' simply means knowledge, but it is usually applied to knowledge that can be verified. Thus we learn by heart that Queen Anne died in 1714. I believe this to be a fact, but I have no means of verifying it.* ***But if I am told that putting chalk into acid will produce a heavy gas having the quality of extinguishing a lighted match, I can verify it. I can do the thing and see the results. I am now equal to my teacher; I know it in the same way that he does. It has become my very own fact, and it seems to have the satisfactory quality that possession gives.*** *This characteristic of scientific knowledge is not always recognized. I mean the profound difference between what we know and what we are told. When science began to flourish at Cambridge in the 'seventies, and the University was asked to supply money for buildings, an eminent person objected and said, 'What do you want with their laboratories?—why can't they believe their teachers, who are in most cases clergymen of the Church of England?' This person had no conception of what the word 'knowledge' means as understood in science*."

Or as it says in Job 12:7-10:

But ask the animals, and they will teach you,

or the birds in the sky, and they will tell you;

or speak to the earth, and it will teach you,

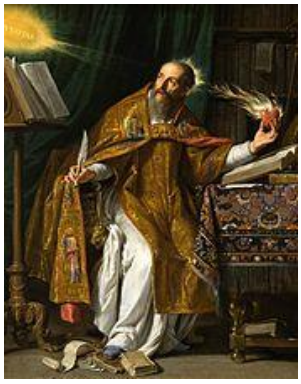
or let the fish in the sea inform you.

Which of all these does not know

that the hand of the Lord has done this?

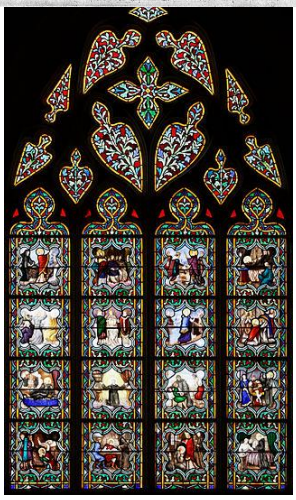
In his hand is the life of every creature

and the breath of all mankind.





Belief and understanding oppose each other like a thumb opposes the fingers. If you ask me, both are necessary to gain wisdom and a knowledge of the truth. It is also important to differentiate, when we have incomplete information, what beliefs we assume to be true and self-evident, what facts are in evidence, and what assumptions do we use to interpret the facts. Peter Abelard said, *by doubting we question and through questioning we perceive the truth*. There is an element of truth in the saying, *Seeing is believing*, and there is also an element of truth in the saying *Believing is seeing* and we must always question our faith and reasoning. Saint Augustine (354-430) and **Saint Anselm** (1033-1109) took belief in self-evident assumptions fundamental to understanding when they said, I believe in order to understand. **Peter Abelard** (1079-1142) took the obverse approach, saying, no one can believe something which he has not first understood. I believe and understand Augustine, Anselm, and Abelard.

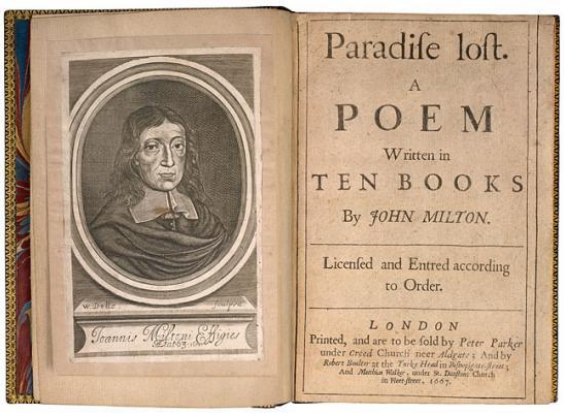


John Locke (1690) wrote about civility in contending with a diversity of opinions in *An Essay Concerning Human Understanding*, "*The right use of it, mutual charity and forbearance, in a necessary* ***diversity of opinions****. Since, therefore, it is unavoidable to the greatest part of men, if not all, to have several opinions, without certain and indubitable proofs of their truth; and it carries too great an imputation of ignorance, lightness, or folly for men to quit and renounce their former tenets presently upon the offer of an argument which they cannot immediately answer, and show the insufficiency of: it would, methinks, become all men to maintain peace, and the common offices of humanity, and friendship, in the* ***diversity of opinions****; since we cannot reasonably expect that any one should readily and obsequiously quit his own opinion, and embrace ours,* ***with a blind resignation to an authority which the understanding of man acknowledges not****. For however it may often mistake, it can own no other guide but reason, nor blindly submit to the will and dictates of another. If he you would bring over to your sentiments be one that examines before he assents, you must give him leave at his leisure to go over the account again, and, recalling what is out of his mind, examine all the particulars, to see on which side the advantage lies: and if he will not think our arguments of weight enough to engage him anew in so much pains, it is but what we often do ourselves in the like case; and we should take it amiss if others should prescribe to us what points we should study. And if he be one who takes his opinions upon trust, how can we imagine that he should renounce those tenets which time and custom have so settled in his mind, that he thinks them self-evident, and of an unquestionable certainty; or which he takes to be impressions he has received from God himself, or from men sent by him? How can we expect, I say, that opinions thus settled should be given up to the arguments or authority of*



a stranger or adversary, especially if there be any suspicion of interest or design, as there never fails to be, where men find themselves ill treated? We should do well to commiserate our mutual ignorance, and endeavour to remove it in all the gentle and fair ways of information; and not instantly treat others ill, as obstinate and perverse, because they will not renounce their own, and receive our opinions, or at least those we would force upon them, when it is more than probable that we are no less obstinate in not embracing some of theirs. For where is the man that has incontestable evidence of the truth of all that he holds, or of the falsehood of all he condemns; or can say that he has examined to the bottom all his own, or other men's opinions? The necessity of believing without knowledge, nay often upon very slight grounds, in this fleeting state of action and blindness we are in, should make us more busy and careful to inform ourselves than constrain others. At least, those who have not thoroughly examined to the bottom all their own tenets, must confess they are unfit to prescribe to others; and are unreasonable in imposing that as truth on other men's belief, which they themselves have not searched into, nor weighed the arguments of probability, on which they should receive or reject it. Those who have fairly and truly examined, and are thereby got past doubt in all the doctrines they profess and govern themselves by, would have a juster pretence to require others to follow them: but these are so few in number, and find so little reason to be magisterial in their opinions, that nothing insolent and imperious is to be expected from them: and there is reason to think, that, if men were better instructed themselves, they would be less imposing on others."

John (1:4) wrote, "*In him was life, and that life was the light of all mankind*" and I will end the way John Milton (1667) began *Paradise Lost*:



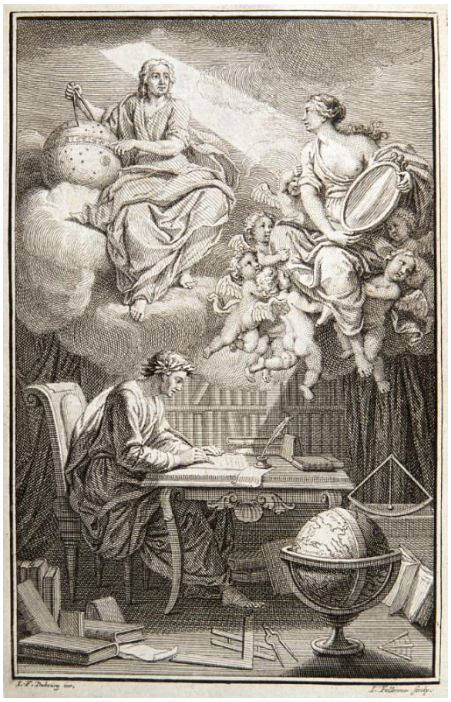
Illumine, what is low raise & support;
That to the highth of this great argument
I may assert eternal Providence,
And justifie the wayes of God to Men.

Illumine appears in science:

In the frontispiece to Newton's *Principia* (1729) Newton sits in the heavens, in midst of clouds accompanied by the naked truth as a light shines from behind him. As the clouds dissipate, the orbits of the planets around the sun become revealed.



Newton remains in the heavens in the frontispiece of Voltaire's *Elements of the Philosophy of Newton* (1738).



Illumine appears in the frontispiece of George Adams (1787), *Essays on the Microscope*:



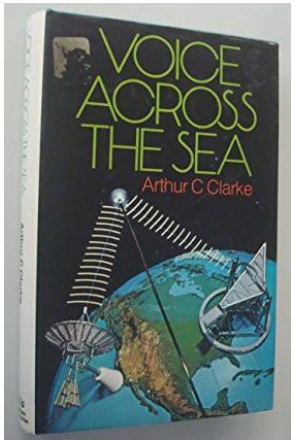
See the microscope along with Illumine, in the frontispiece of Diderot and D'Alembre's *Encyclopédie*.



I have digressed many times. Ray Bradbury (1979) wrote, "*For, let's face it, digression is the soul of wit. Take the philosophic asides away from Dante, Milton or Hamlet's father's ghost and what stays is dry bones. Laurence Sterne said it once: Digressions, incontestably, are the sunshine, the life, the soul of reading! Take them out and one cold eternal winter would reign in every page*."

But I digress…

Arthur C. Clarke (1974) wrote in *Voices Across the Sea*, "*I would also like to emphasise that this is not a history of submarine communications. As far as it goes it is, I believe, accurate, but it makes no attempt to be complete. My object has been frankly, to entertain as much as to instruct, and as a result* ***I have wandered down some odd by-ways whenever the scenery has intrigued me.*** *It will contribute little to anyone's understanding of telegraphy to know how Oliver Heaviside made tea, why Lord Kelvin's monocle revolutionized electrical measurements, what a Kentucky colonel was doing in Whitehall, how Western Union lost $3,000,000 in Alaska, and what unlikely articles the Victorians made*



from gutta-percha. ***Yet it is precisely such trivia that make history three-dimensional, and I do not apologise for including them***." Clarke, along with Stanley Kubrick, wrote the screenplay for *2001: A Space Odyssey*—either an apocalyptic or optimistic statement about humanity and who we each choose to be. Indeed, Clarke's three-dimensional presentation in *Voices Across the Sea*, helps us to "know ourselves."

I started the semester by saying:

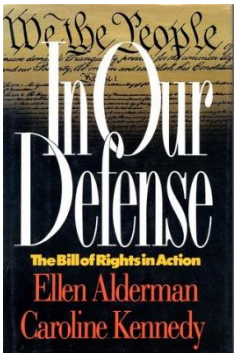
"I *love science and the ability of the scientific method for helping us to question, understand, and appreciate the world around us. I am a staunch supporter of questioning any and all authority in order to help us understand and appreciate the world around us. On that note, I will try to provide you with as much personal experience as possible concerning light and life so that you do not have to believe a single thing I say but have enough experience to trust your knowledge while understanding both the* ***value and limitations*** *of what you and others know. I want you to be able to say, "I understand" before you say "I agree," "I disagree," or "I suspend judgement" on any scientific issue."*

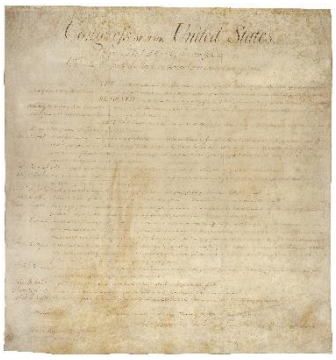
Learning Outcome for PL BIO 1130: **Emancipate yourself from mental slavery & other light topics**. Remember, the majority is sometimes right, and the minority is sometimes right. Have the courage to be a free person who is able to make your own judgements and utter your own thoughts and opinions in your never-ending search for truth.



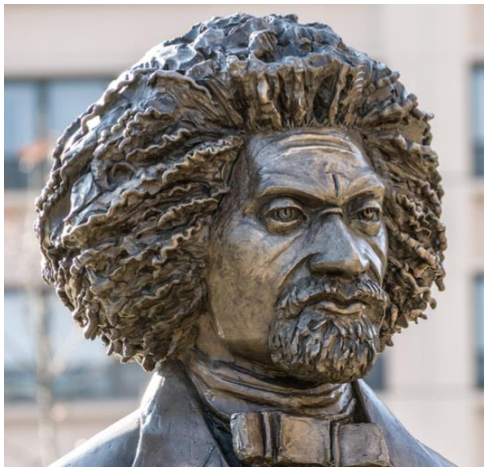
Benjamin Franklin (1722), writing as Silence Dogood, wrote "***WITHOUT Freedom of Thought, there can be no such Thing as Wisdom; and no such Thing as publick Liberty, without Freedom of Speech****; which is the Right of*

every Man, as far as by it, he does not hurt or control the Right of another. And this is the only Check it ought to suffer, and the only bounds it ought to know."



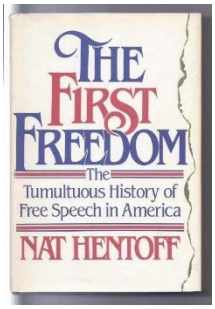


The **First Amendment** of the Constitution of the United States assures every citizen that "*Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof; or abridging the* ***freedom of speech****, or of the press; or the right of the people peaceably to assemble, and to petition the Government for a redress of grievances*."



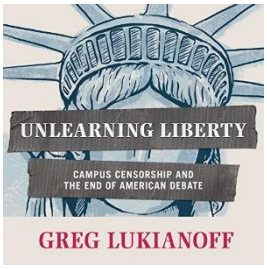
Remember the words of **Frederick Douglass**, who said in his Plea for Freedom of Speech in Boston, on December 9, 1860, "*No right was deemed by the fathers of the Government more sacred than the right of speech. It was in their eyes, as in the eyes of all thoughtful men, the great moral renovator of society and government. Daniel Webster called it a homebred right, a fireside privilege.* ***Liberty is meaningless where the right to utter one's thoughts and opinions has ceased to exist. That, of all rights, is the dread of tyrants. It is the right which they first of all strike down.*** *They know its power. Thrones, dominions, principalities, and powers, founded in injustice and wrong, are sure to tremble, if men are allowed to reason of righteousness, temperance, and of a judgment to come in their presence. Slavery cannot tolerate free speech. Five years of its exercise would banish the auction block and break every chain in the South. They will have none of it there, for they have the power. But shall it be so here?... There can be no right of speech where any*

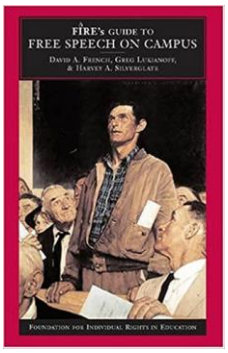




man, however lifted up, or however humble, however young, or however old, is overawed by force, and compelled to suppress his honest sentiments.

Equally clear is the right to hear. To suppress free speech is a double wrong. It violates the rights of the hearer as well as those of the speaker*. It is just as criminal to rob a man of his right to speak and hear as it would be to rob him of his money*."





Free speech is being threatened in universities. Nat Hentoff, Alan Dershowitz, and Greg Lukianoff, the President and CEO of the Foundation for Individual Rights in Education (FIRE), are outspoken and modern defenders of free speech. Lukianoff produced a list of 12 Bad Anti-Free Speech Arguments, and answers to them!

U.S. News: Alumni Yank Funds Over Free Speech --- Would-be donors with moderate, conservative views say diversity of thought isn't fostered Belkin, Douglas . Wall Street Journal , Eastern edition; New York, N.Y. [New York, N.Y]. 03 Dec 2021: A.7.

"Two years ago Cornell University asked a California real-estate developer and longtime donor for a seven-figure contribution. Carl Neuss didn't write the check immediately, saying he was worried about what he saw as liberal ***indoctrination*** *on campus and* ***declining tolerance toward competing viewpoint****s. To allay Mr. Neuss's concerns, the development office introduced him to some politically moderate professors, he said. The attempt backfired. The professors, he said, told him they felt humiliated by the diversity training they were required to attend and perpetually afraid they would say something factual -- but impolitic. '****If you say the wrong words, you could lose your position or be shunned****,' said Mr. Neuss.*

*Joel Malina, Cornell's vice president for university relations, said '**robust debate and a discussion of all views remain hallmarks of the Cornell experience**.' Mr. Neuss, who graduated from Cornell in 1976, withheld his donation and then helped start the Cornell Free Speech Alliance. It is one of about 20 such dissident alumni organizations that have taken root on college campuses over the last couple of years -- including several this fall.*"

As to the value of science, Cornell professor Robert Rathburn Wilson, was asked by then-senator John Pastore (RI) about the proposed Fermilab, "*Is there anything connected with the hopes of this accelerator that in any way involves the security of the country?*" *Wilson, to his credit, answered just as bluntly: "No sir, I don't believe so." "Nothing at all?" Pastore asked. "Nothing at all." Pastore pressed further: "It has no value in that respect?" And then Wilson knocked it out of the park. "**It has only to do with the respect with which we regard one another, the dignity of man, our love of culture. It has to do with: Are we good painters, good sculptors, great poets? I mean all the things we really venerate in our country and are patriotic about. It has nothing to do directly with defending our country except to make it worth defending**."*

Martin Heidegger wrote in *What Is Called Thinking?*, "[i]n joy, thinking becomes a gracious thanking." Indeed, *think* and *thank* are etymologically related words. They both come from the Proto-Indo- European root "*tong*", which means to feel or to think.



Allan Boom (1982; Cornell) recognized that universities may not be the place where students come for the purpose of being liberally educated, to study how to be free, and to learn to think for themself. Bloom wrote, "*Today a young person does not generally go off to the university with the expectation of having an*

intellectual adventure, of discovering strange new worlds, of finding out what the comprehensive truth about man is. This is partly because he thinks he already knows, partly because he thinks such truth unavailable. And the university does not try to persuade him that he is coming to it for ***the purpose of being liberally educated, at least in any meaningful sense of the term–to study how to be free, to be able to think for himself****. The university has no vision, no view of what a human being must know in order to be considered educated. Its general purpose is lost amid the incoherent variety of special purposes that have accreted within it. Such a general purpose may be vague and undemonstrable, but for just this reason it requires the most study. The meaning of life is unclear, but that is why we must spend our lives clarifying it rather than letting the question go. The university's function is to remind students of the importance and urgency of the question and give them the means to pursue it. Universities do have other responsibilities, but* ***this should be their highest priority***."

In an age when scientific knowledge is defined by the end (consensus) rather than the means (an understanding of how we know what we know using scientific methods), it is worthwhile to consider the words of Karl Popper (1964) in *The Poverty of Historicism*, "*Science, and more especially scientific progress, are the results not of isolated efforts but of the free competition of thought. For science needs ever more competition between hypotheses and ever more rigorous tests*."



Thank you for your time this semester. I hope that the learning objectives have been met.



