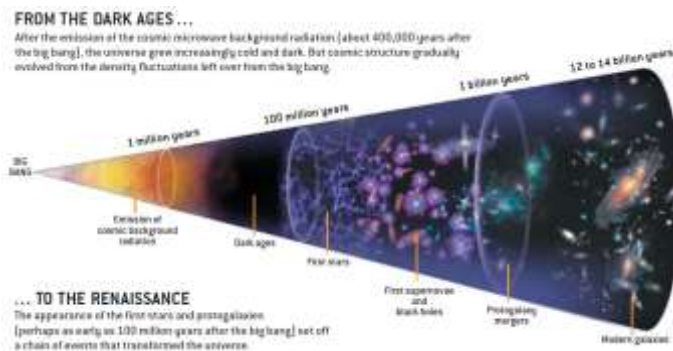


Ultraviolet Light: Ozone Layer, DNA Damage and Repair, Melanoma, Vitamin Synthesis and Breakdown, Vision and Fluorescence

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.



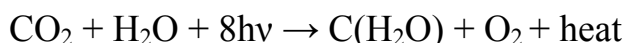
The earth's atmosphere had little or no **molecular oxygen (O₂)** before photosynthetic organisms inhabited the earth. In the **Precambrian** era, between **3.7 to 2.4 billion years ago**, oxygen was split from water (H₂O) by the first marine **photosynthetic cyanobacteria** and formed molecular oxygen. This molecular oxygen oxidized (loss of electron) dissolved ferrous (Fe²⁺) iron to produce ferric (Fe³⁺) iron in the forms of hematite (Fe₂O₃) and magnetite (Fe₃O₄ = Fe²⁺Fe³⁺O₄). 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**.



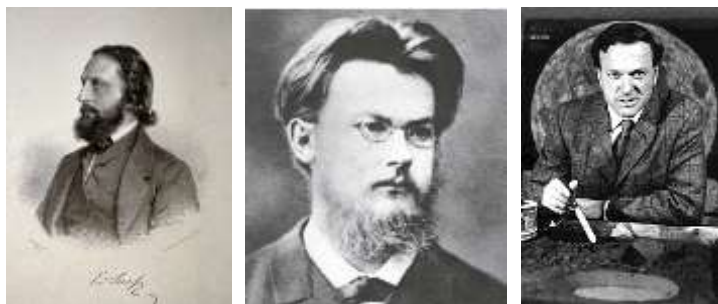
Because of the abundance of hematite, it is one of the most inexpensive paint colors to produce. This makes **hematite-colored red paint** the logical choice for painting large structures, such as red barns and covered bridges.



The **sunlight-dependent** Precambrian photosynthetic reactions that evolved oxygen also produced carbohydrates (C(H₂O)) that were converted biosynthetically to many organic molecules, including porphyrins such as chlorophyll and heme.



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.

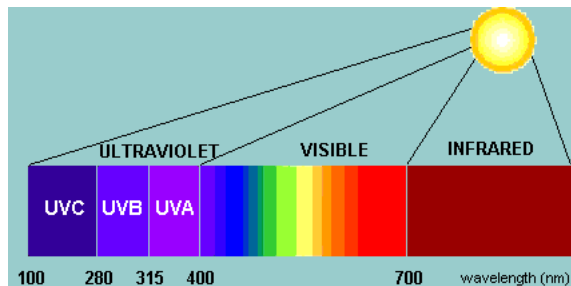
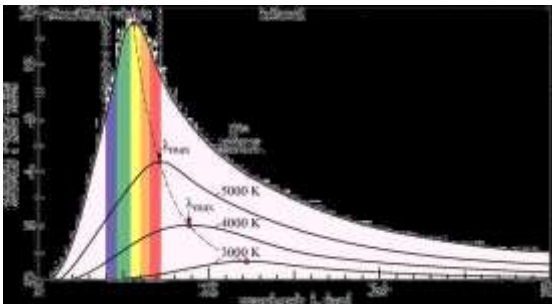
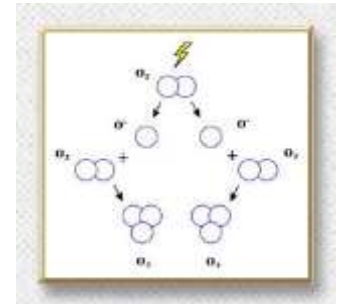
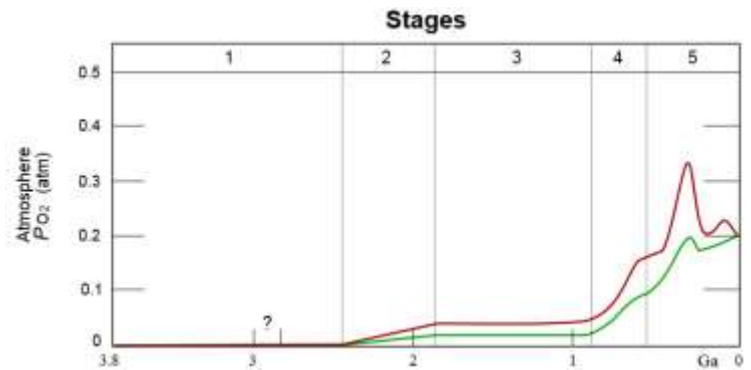
Approximately **2.4 billion years ago**, the amount of molecular oxygen produced by **photosynthetic cyanobacteria** overwhelmed the capacity of the ferrous iron to react with it and some of the molecular

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

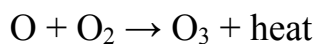
of it reacted with **ultraviolet light** to form the **ozone layer**. Ozone comes from the Greek word, *ozein* (*ὄζειν*), which means “to smell.” Ozone produced by **lightning**, which results when there is sufficient **charge separation** between the bottom of a cloud and the surface of the earth to make 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:

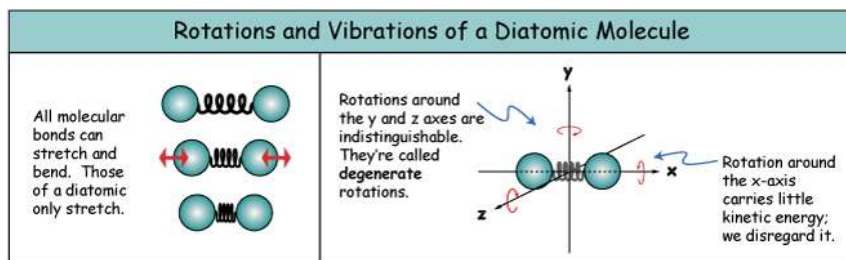


The energy (E) of a 240 nm photon is equal to $E = h\nu = \frac{hc}{\lambda} = 8.3 \times 10^{-19}$ J. Note that hc , the product of Planck's constant and the vacuum speed of light is approximately equal to 2×10^{-25} Jm.

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.

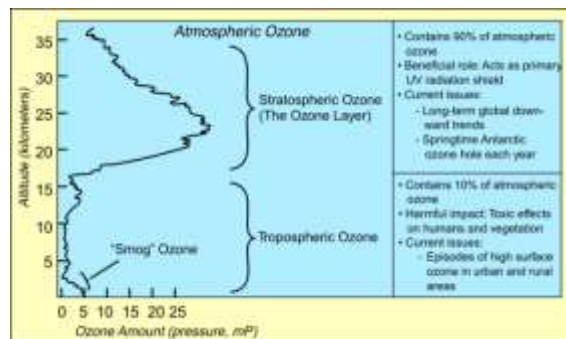


A portion of a molecule's translational energy may be released as heat, resulting in inelastic scattering and a small lengthening of the wavelength of the scattered light compared to the wavelength of the absorbed light.

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.

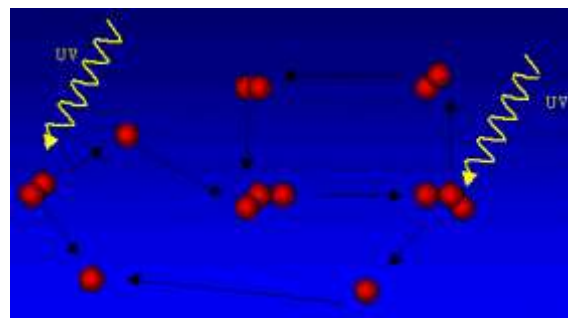
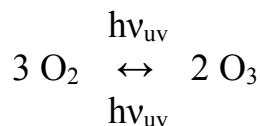


Most of the ozone formed from molecular oxygen is about 15-40 km above the surface of the earth in the **stratosphere**. The ozone in this layer, which is known as the **ozone layer**, breaks down into atomic oxygen (O) and molecular oxygen (O₂) when it absorbs a photon of ultraviolet light in the UVC and UVB ranges with a wavelength less than 290 nm.



The energy (E) of a 290 nm photon is equal to $E = h\nu = \frac{hc}{\lambda} = 6.9 \times 10^{-19} \text{ J}$.

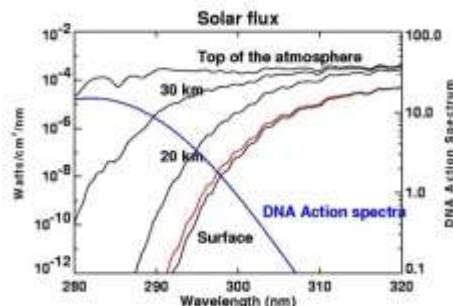
The above reactions that generate and break down **ozone** can be summarized by the following equation:



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

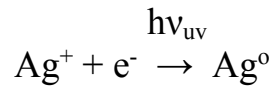
important for life since it is these wavelengths that are absorbed by DNA and could result in substantial **genetic damage** and/or **death**.



Ultraviolet light was discovered in 1801 by **Johann Wilhelm Ritter**, who was stimulated by William Herschel's (1800) then recent surprising discovery 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^0). Ritter called the invisible yet active rays, **deoxidizing rays** to distinguish them from heat rays. The reaction, which became very important in making **light-sensitive film and paper**



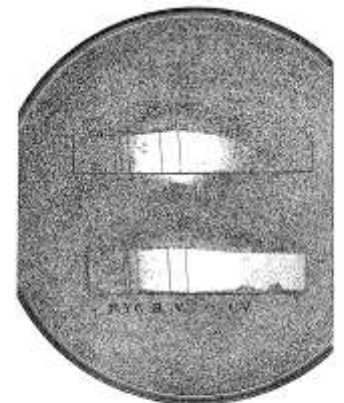
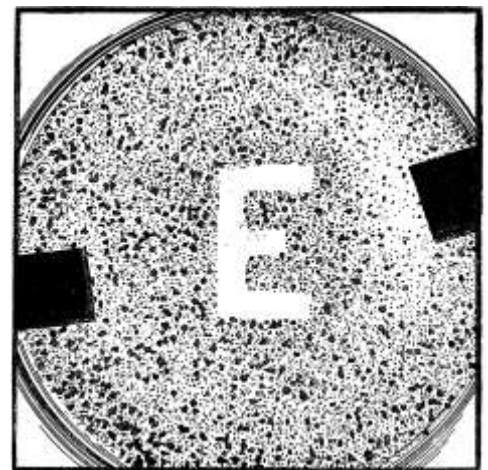
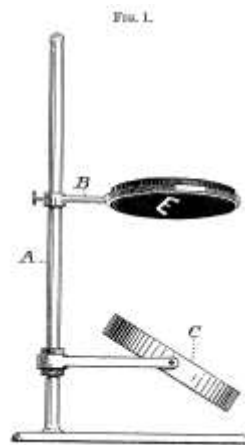
for **photography**, a word coined in 1839 by William Herschel's son John, is given by the following reaction.



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.



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.



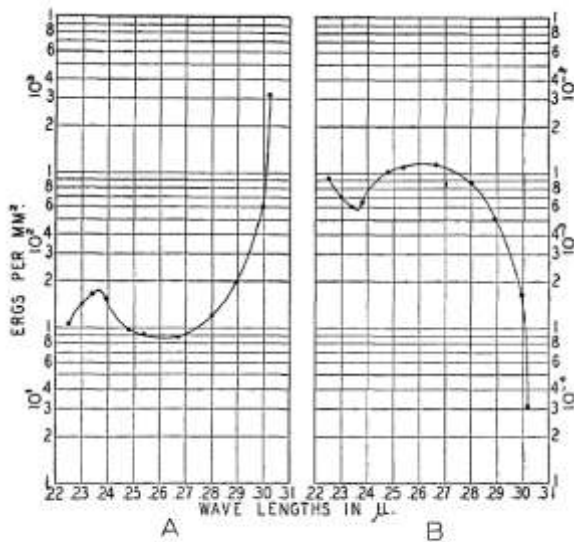
Ward also realized that. *“these results suggest evidently that the naked arc light may prove to be a very efficient **disinfecting agent** in hospital wards, railway carriages, or anywhere where the rays can be projected directly on to the organism.”*

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 slit was covered with quartz only, the upper with a thin plate of glass. The line-line in each case gives length of exposed slit. 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 slit, where the light passed through quartz only. The two little protuberances over UV were due to two little streaks of burnt Canada balsam at the edge of the slit, emitting off light.

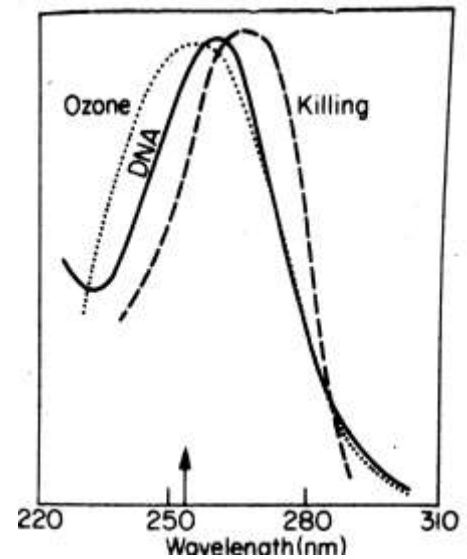
Louis Brandeis (1913) wrote that “*Sunlight is said to be the best of disinfectants*” in an article entitled “*What Publicity Can Do*” aimed in remedying social and industrial diseases.



Frederick Gates (1930) performed **action spectroscopy** to determine the most effective wavelengths for the bactericidal action of ultraviolet light on *Staphylococcus aureus*. 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

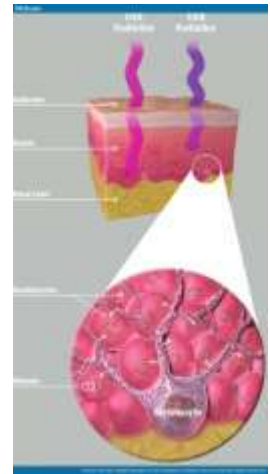


oxygen and ozone, any life on earth would have been exposed to the germicidal action that is caused by the ultraviolet photons in the UVC range that are present in sunlight.

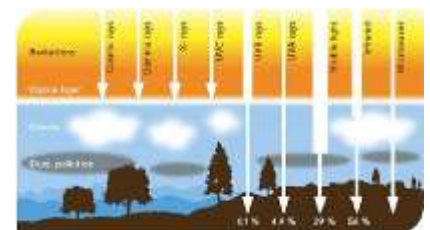
As we will see, the transmission of ultraviolet light through the atmosphere has both **beneficial** and **harmful** effects. The most dangerous effect occurs when ultraviolet photons in the **UVB** and **UVA** ranges are absorbed by the **DNA** in the dendrite-like **melanocytes** in our skin.

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.

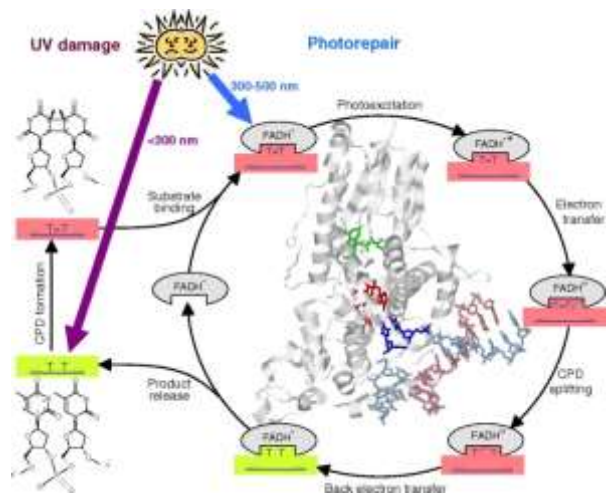
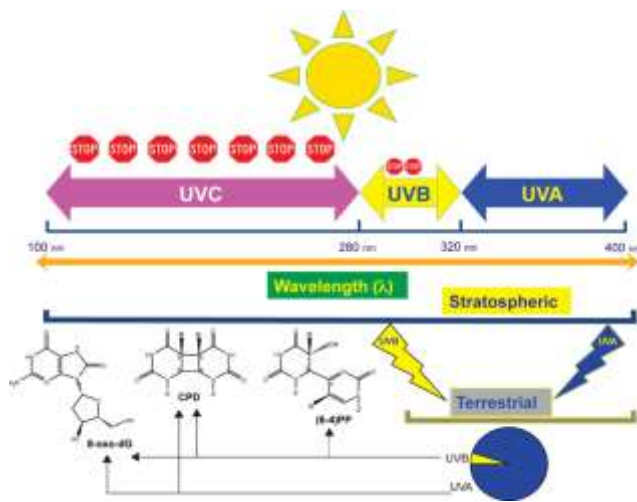
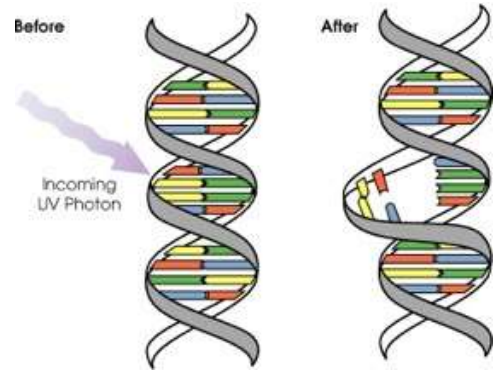
Ultraviolet photons in the UVB range (3%) and UVA range (97%) produced by tanning beds have all the risks and benefits of the ultraviolet radiation in sunlight.



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 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 cyclopurimidine 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).

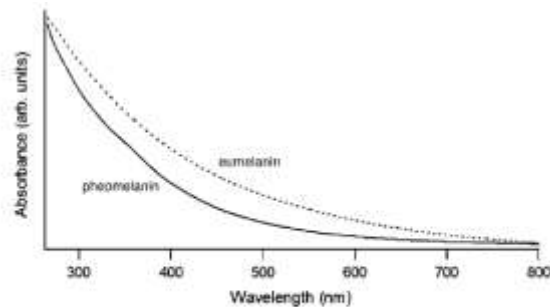
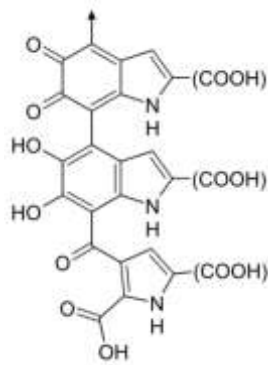
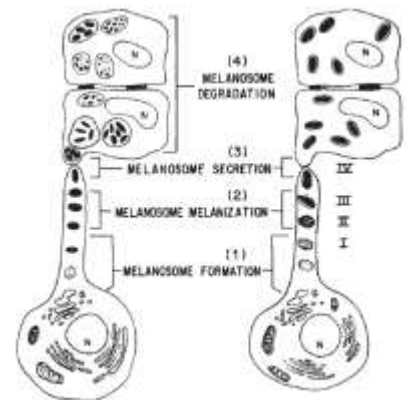
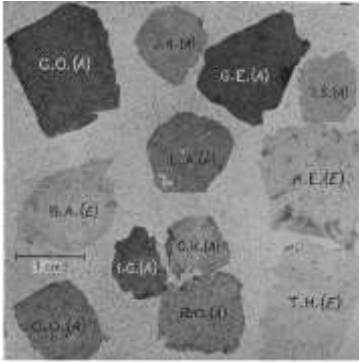
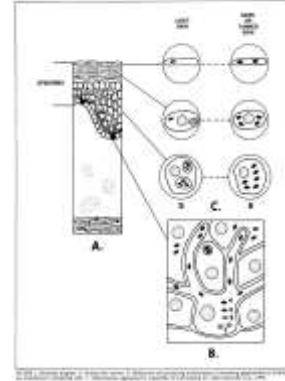


Fig. 2 The broad-band absorption spectra of eumelanin and pheomelanin.⁶

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**.

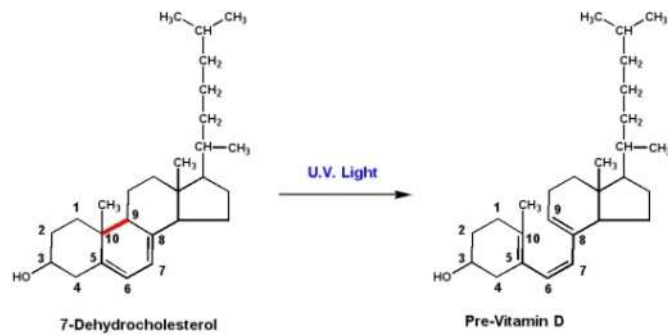


On the extremes of **skin tone**, which is under both **genetic** and **environmental control**, **whiter skin tone** results from having fewer and smaller melanosomes that tend to be aggregated in the keratinocytes, and **darker skin tone** results from having more and larger melanosomes that tend to be dispersed in the keratinocytes.

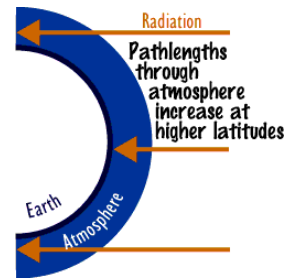
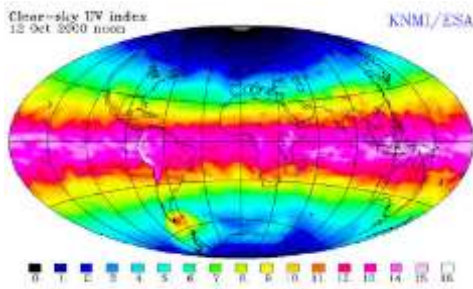


Macht, Anderson and Bell (1928) and Thomson (1955) showed that dark skin (A) **transmits** less ultraviolet light than light skin (E). Thus, skin tone can influence the **nutritional state of our bodies** in terms of the levels of **vitamin D** and **folate** by influencing the **transmission of ultraviolet 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-dehydrocholesterol, 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, the incident level of **ultraviolet photons in the UVB range is 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 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 is **black**, 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**.

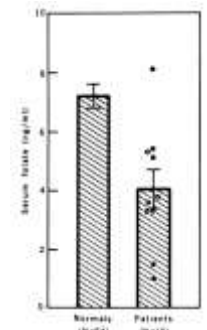


Fig. 1. Serum folate concentrations measured by radioassay (RIA) in two patients receiving phototherapy (see text) and in 94 healthy individuals. All patients had received phototherapy for at least 1 month, and five patients had been exposed to UV light 12 to 13.5 months before studies. The difference between the two groups was statistically significant ($p < .001$). Error bars represent the standard error of the mean.

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*



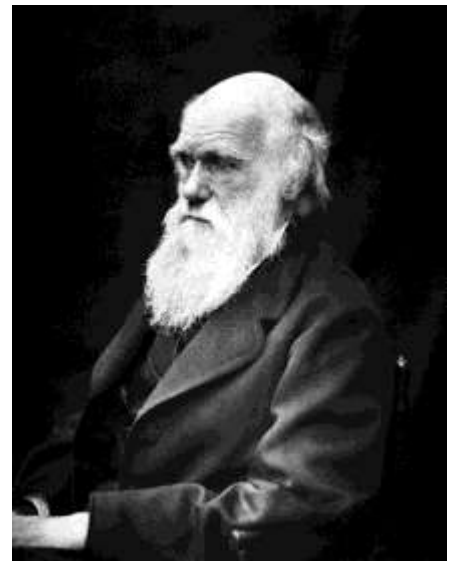
are most healthy in cold, and black or tawny People in hot Countries; each being Subject to Disorders, on a Removal to these respective Climes.... From what has been said about the Cause of the Colour of black and white People, we may justly conclude, that they might very naturally be both descended 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 characteristic 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 characteristic 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.”

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 respect, 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.

Some animals are able to **see ultraviolet light**. **John Lubbock**, 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: 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. 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 those 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 if 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.”

After reading Auguste Forel’s and Horace Donisthorpe’s views on ants, how do you interpret 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.”*

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.

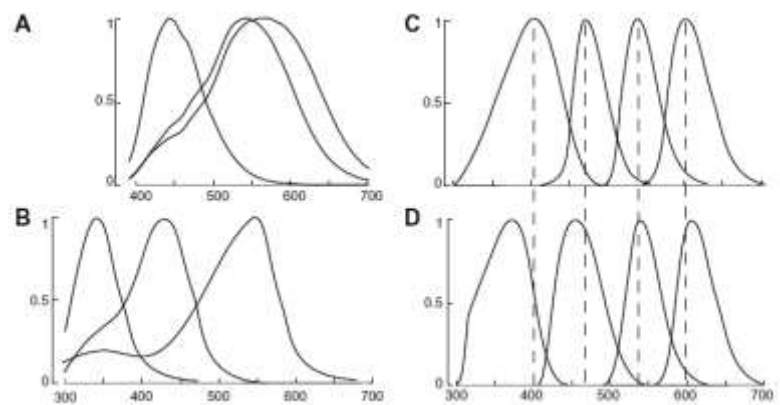


Fig. 1. Normalized photoreceptor spectral sensitivities of: (A) Human; (B) Honeybee; (C) Pigeon; (D) Starling.

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 UVA illumination of thin pieces of wood of *Lignum nephriticum* (*Eysenhardtia polystachya*).



The extract of the wood, which also emitted the 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.

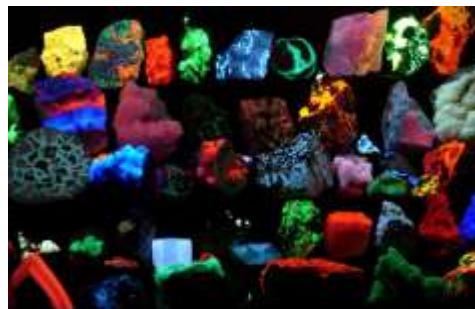
Throughout history, philosophers have thought about how the color of a body is related to its fundamental composition or structure. While experimenting

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.



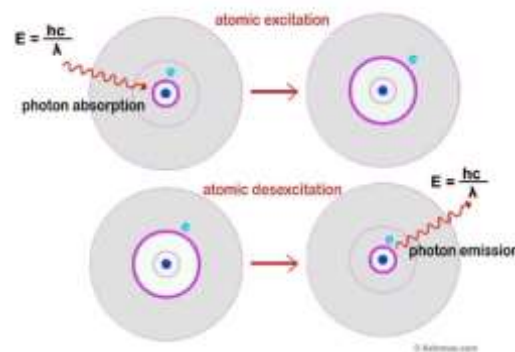
George Stokes also postulated that fluorescence was related to **phosphorescence**. The only difference is that light given off by specimens that showed fluorescence stopped immediately after the incident light was shut off, whereas phosphorescent specimens continued to glow for relatively long periods 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 the development of **quantum theory**.

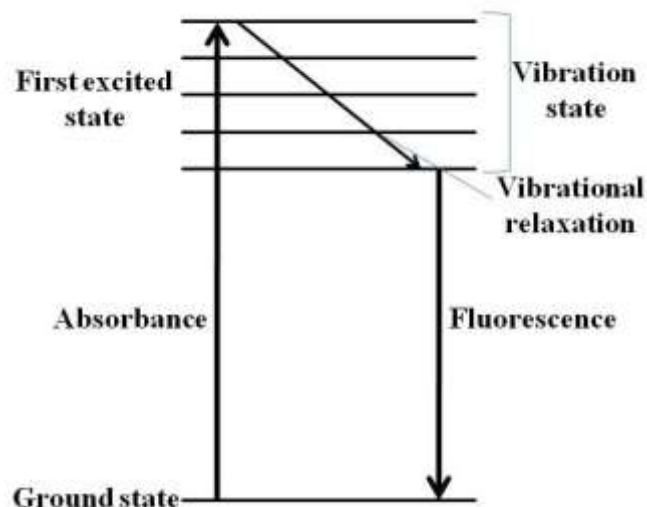
According to quantum theory, **atomic absorption** results in the transfer of

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:

$$\lambda = \frac{hc}{E}$$

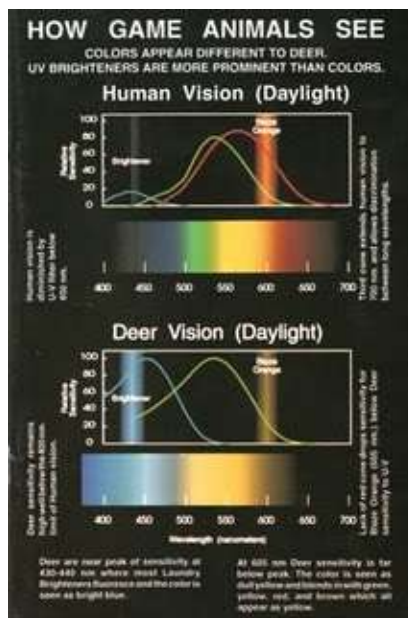


A **flexible molecule** has many vibrational states and rotational states. As a result of the intramolecular movement, the excited state of a flexible molecule can **dissipate energy** in a variety of ways, which takes 10^{-15} to 10^7 s. Initially, the electronic energy can be conserved within the molecule, 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 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 wavelength of the emitted photon is greater than the wavelength of the absorbed photon. This is the reason behind Stokes' Law.

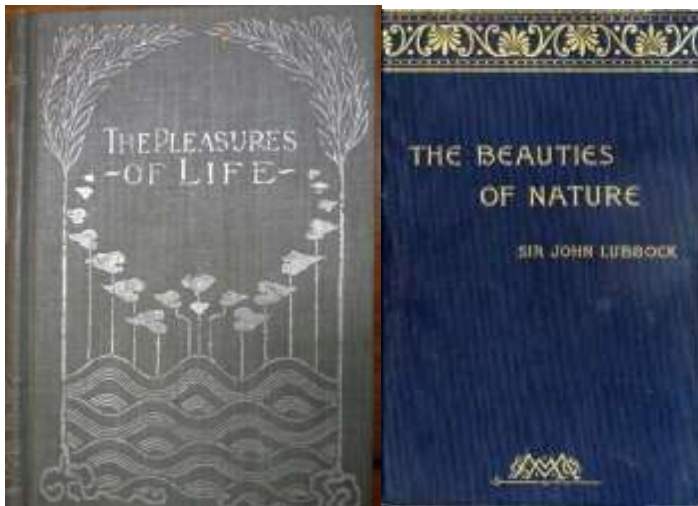
Fluorescent brighteners are often added to laundry detergents. The brighteners absorb ultraviolet light from sunlight and emit longer wavelength ultraviolet light. The fluorescent light emitted makes the clothes appear brighter. Since **deer can see in the ultraviolet**, hunters should be aware of the detergent they use to wash their clothes.



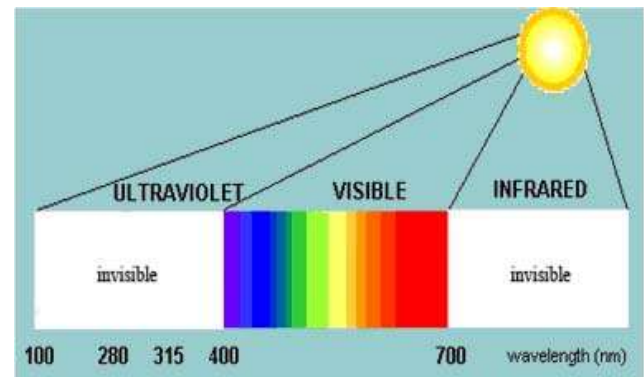
John Lubbock, Lord Avebury, was the first person to observe that ants can sense ultraviolet light. That is, John Lubbock discovered that **ants can see a world that is invisible yet assessable to humans**. In his book, *The Beauties of Nature*, John Lubbock wrote, “*The world we live in is a fairyland 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."



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. 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."*



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. The peak wavelength (λ_{peak}) of the radiation emitted by a blackbody is given by **Wien's displacement law**:

$$\lambda_{peak} = \frac{2.989 \times 10^{-3} \text{ m K}}{T}$$

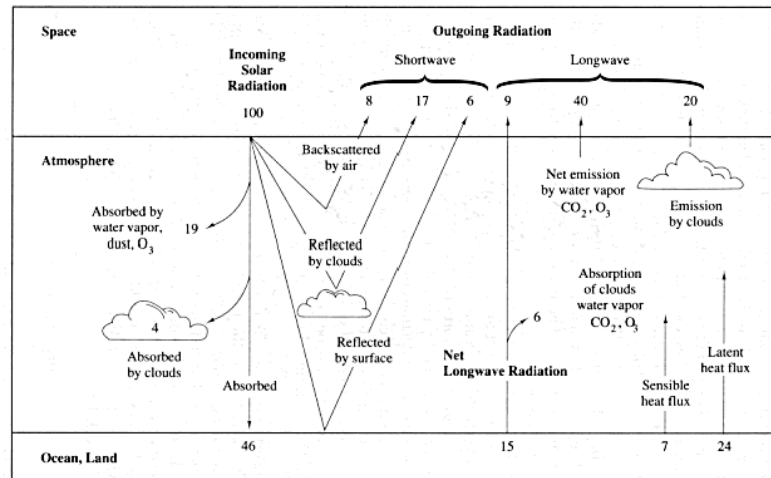
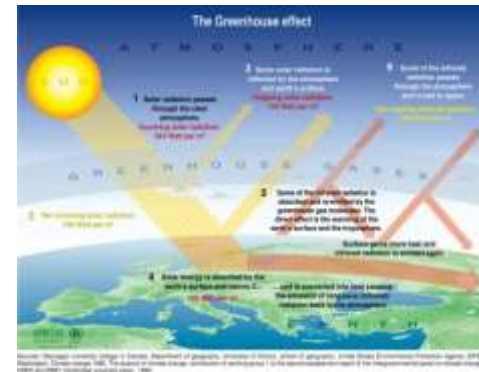
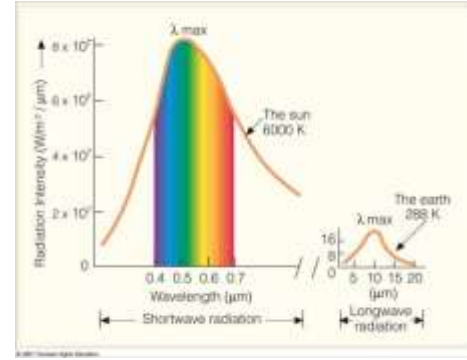
The peak wavelength for a blackbody radiator with a temperature of 288 K is 10 micrometers.

The amount of energy radiated from the earth with temperature (T) into space is given by the Stefan-Boltzmann law:

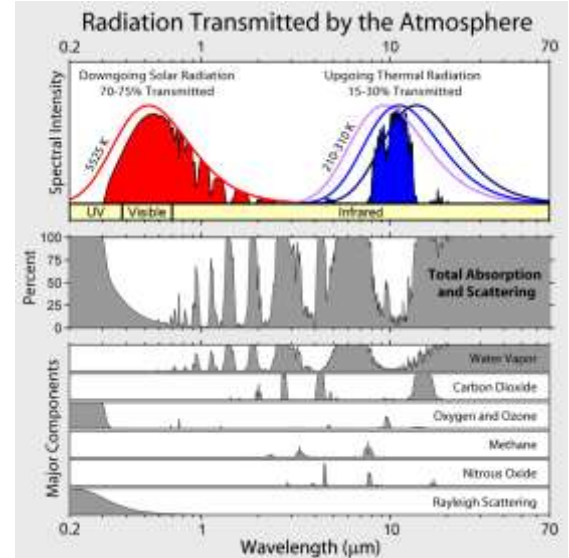
$$E = \frac{L_{earth}}{4\pi r^2} = \sigma T^4$$

where σ is the Stefan-Boltzmann constant ($\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^4$), and is equal to about 390 W/m².

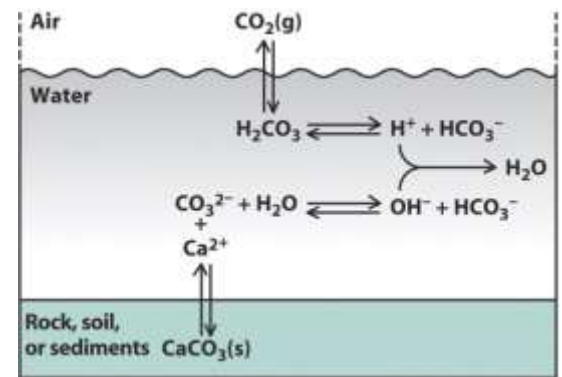
As a reference, the amount of solar constant is 1,360 W/m². However, this is a maximal value, calculated for a surface perpendicular to the sun's rays and above the atmosphere so that there are no losses due to absorption and scattering by the atmosphere.



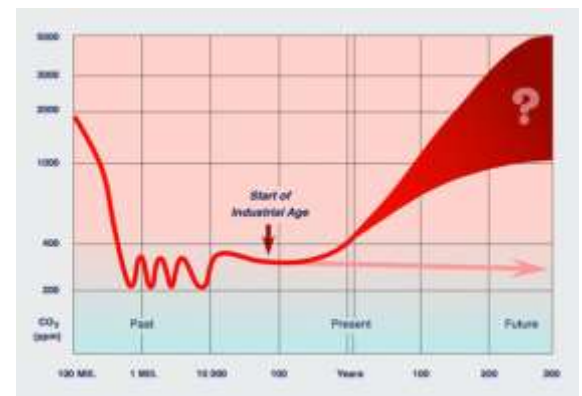
Approximately 30% of the solar energy is **reflected** back into space and approximately 23% of the solar energy is **absorbed** by water vapor and clouds, leaving 46% of the solar energy or about 626 W/m² to reach a perpendicular surface on earth. Since the earth is closer to a hemisphere than a disk, the solar energy reaching the surface is $\frac{2\pi r^2}{\pi r^2} = 2$ times less or about 313 W/m².



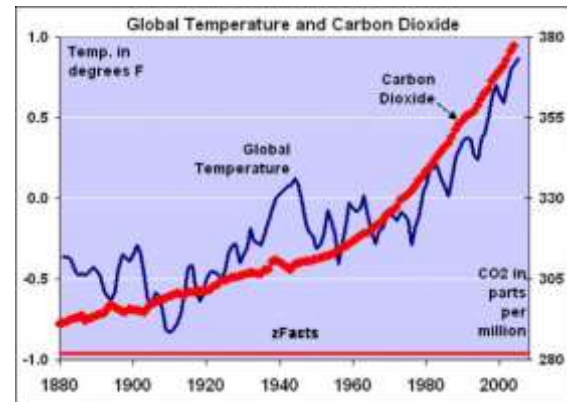
If the net solar energy input (313 W/m²) were smaller than the energy radiating from earth (390 W/m²), then the earth would cool. Luckily, the earth is surrounded by a gaseous atmosphere that is nearly **transparent to visible light** yet acts like a greenhouse to return some of the infrared radiation 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. Carbon dioxide naturally enters the atmosphere as a result of **volcanic activity** and as a result of the decomposition of **calcium carbonate**.



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).



In the movie, *An Inconvenient Truth*, Vice President 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>. 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.*”



In science, it is always good to have opponents. 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. 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.”

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.”

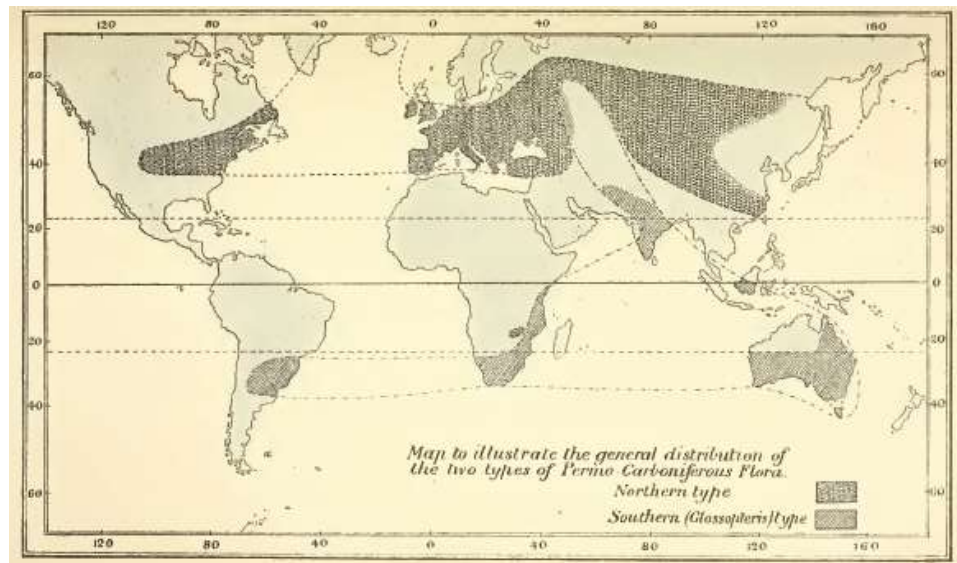


Paul Feyerabend writes about the place and misplace of authority in science—whether the authority is a monarch or a mob—in *Science in a Free Society* (1978), *The Tyranny of Science and Knowledge* (1996), *Science and Relativism* (1999). Feyerabend suggests that John Stuart Mill’s essay on “*On the 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.

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 the death of the explorers who found them tell us about what it means to be human?



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; who 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*



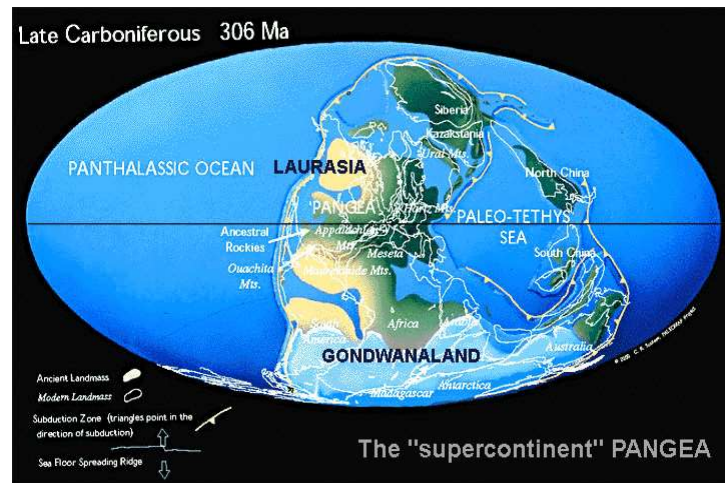
last a piece of coal with beautifully traced leaves in layers, also some excellently preserved impressions of thick stems, showing cellular structure....”



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.”



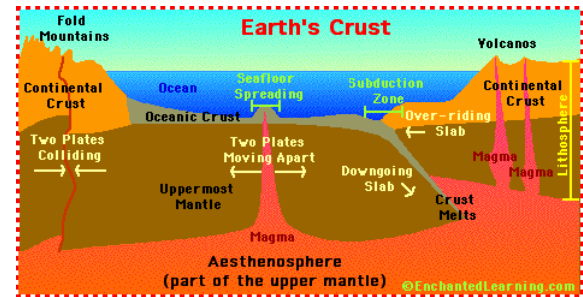
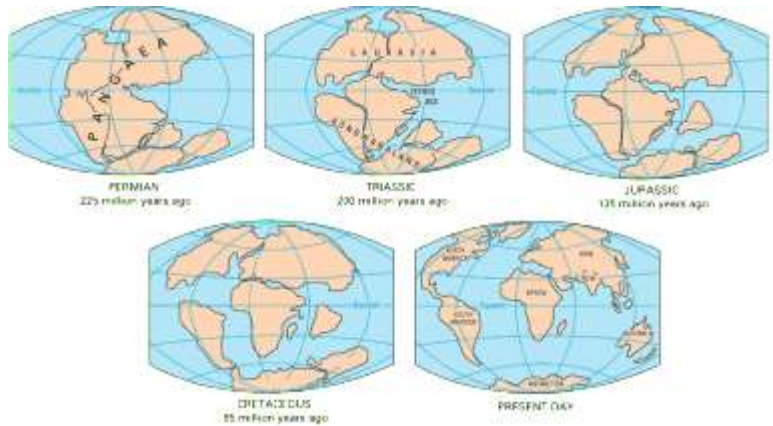
Anne Fadiman (1998) wrote in *Ex Libris*, “When I think of the causes for which people more commonly give up their lives—nationalism, religion, ethnicity—it seems to me that a thirty-five pound bag of rocks, and the lost world it represents, is not such a bad thing to die for.”



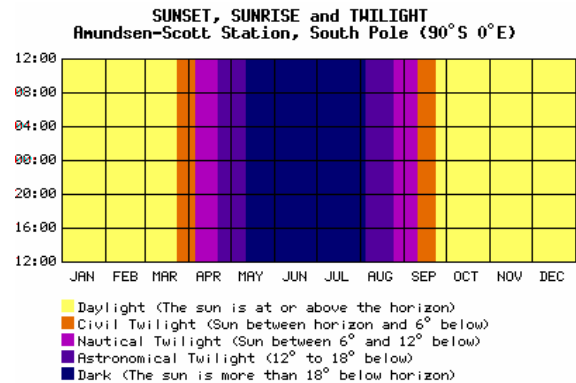
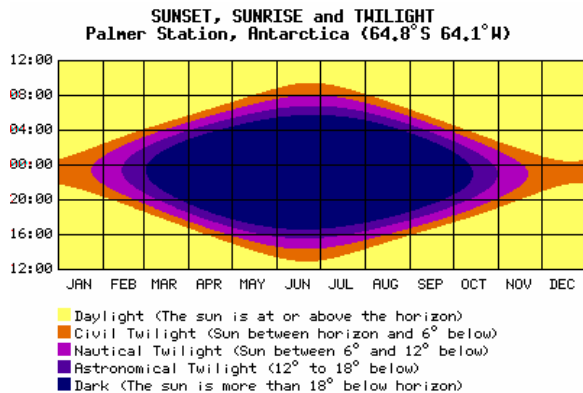
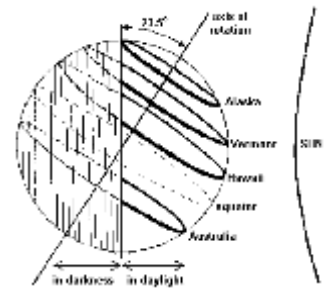
Alfred Wegener (1924)

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>



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 seasonal variation, got more solar irradiation, the continent was warmer, and forests could thrive.



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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. 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 produce 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.



Think of other questions that “connect the dots” with regards to topics that we have covered this semester.

