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.

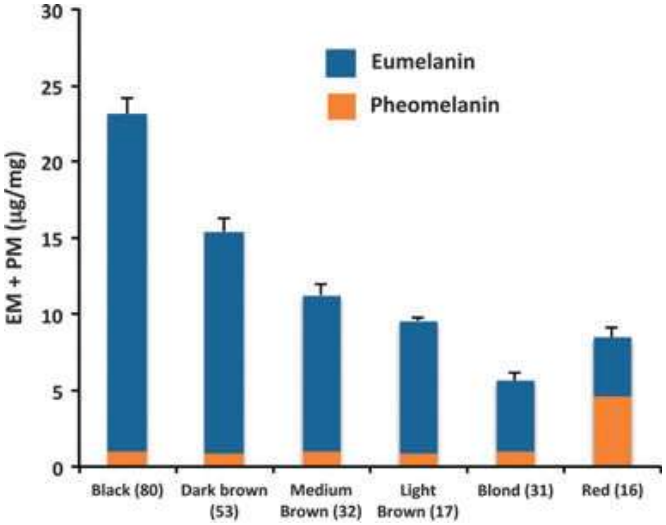
Melanins are commonly-occurring **pigments.** Melanins are **pigments** involved in human eye, skin and hair color. We have talked about the importance of **eumelanin** and **pheomelanin** in producing our individual skin color, and **eumelanin** and **pheomelanin** in producing our individual eye color. 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.

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.

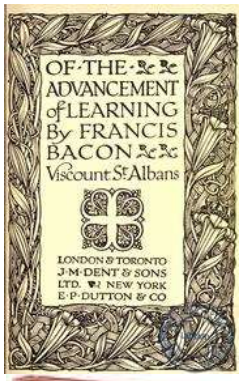
High concentrations of **black eumelanin** result in black hair and low concentrations result in ash blonde hair. **High concentrations of phaeomelanin** result in red or orange hair.

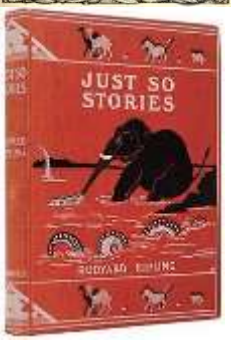


We discussed Charles Darwin's theory of **sexual selection** in terms of human skin color. **Peter Frost** (2006) **suggests** that the blonde-dark dichotomy in human hair color **may** also be the result of **sexual selection** among **hunter gatherers**. *The London Times* on February 26, 2006 reported "*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."





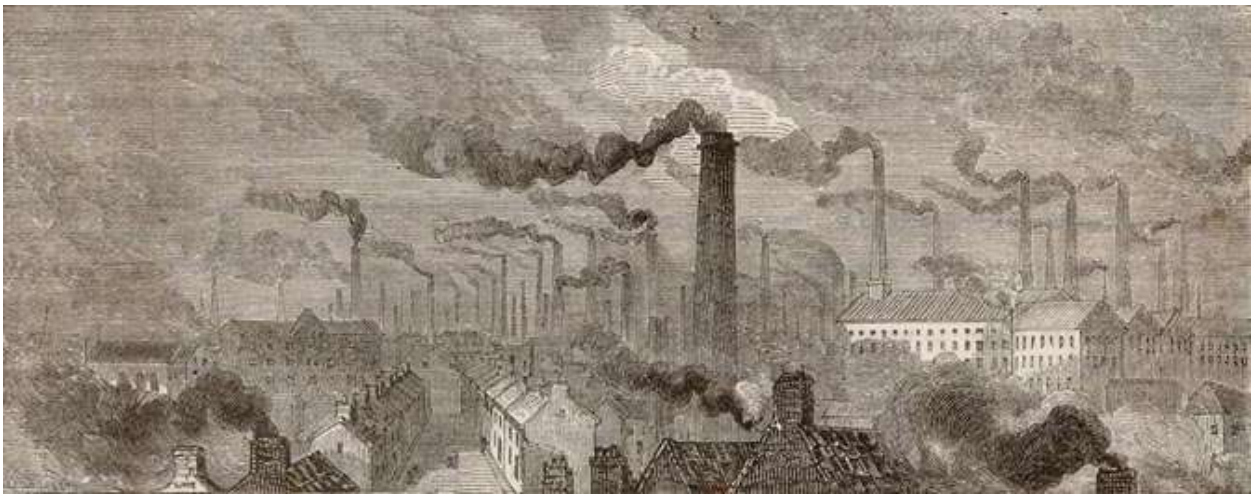
Do you consider this scientific evolutionary explanation a **fact,** a **hypothesis**, a **theory**, a law of nature, or a **just-so story**? At this juncture, I would like to remind you of the letter written on February 10, 2014 by the American Institute of Biological Sciences (AIBS) (http://www.aibs.org/position-statements/20140210_ok_science_ed_act.html) 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."*

Peppered moths also 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.

Since the trunks of the trees became darker, the light colored peppered moths (*Biston betularia typica*) were no longer camouflaged when they rested on tree trunks during the day and 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***

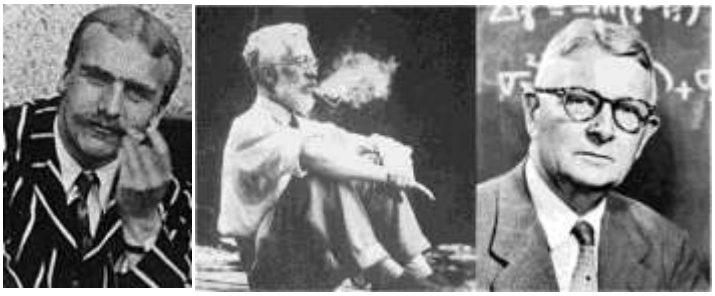


wings have become totally black*, so black that it has obtained the cognomen* [nickname] *'negro' from naturalists. As the manufacturing centres have spread more and more, so the 'negro' form of the Peppered Moth has spread at the same time and in the same districts. Let us see whether we can understand 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*

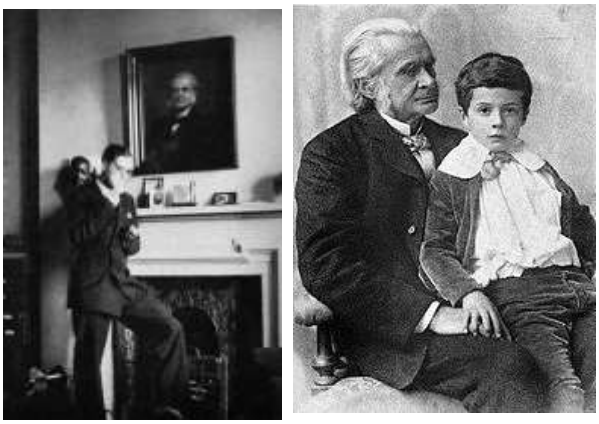
outside them, and, in our manufacturing districts, where the quantity of impurities is much greater, the result is also more intense, and we find fences, trees, walls, etc., getting black with the continual deposit on them. A small proportion of rain with a large quantity of smoke will produce as decided 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.

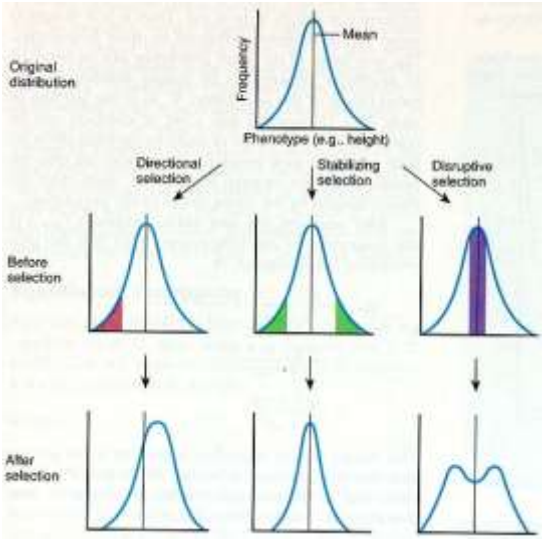
John Burdon Sanderson Haldane (1924) reported that by 1901, the light colored peppered moths had disappeared and that he could make a **mathematical model** that described the rapid disappearance as a result of **natural selection**.



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 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.

Julian Huxley was interested in applying the **progressive ideals** of the Modern Synthesis to human beings. 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.

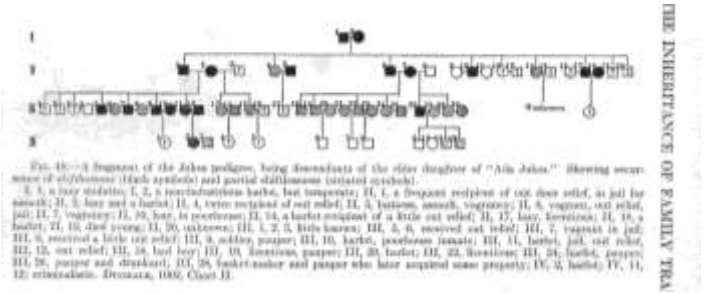
According to Charles Davenport, who worked at the **Eugenics Record Office** at **Cold Spring Harbor** *"**Eugenics is the science of the improvement of the human race by better breeding**.... The eugenical standpoint is that of the agriculturalist who, while recognizing the value of culture, believes 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."*

Also 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***.

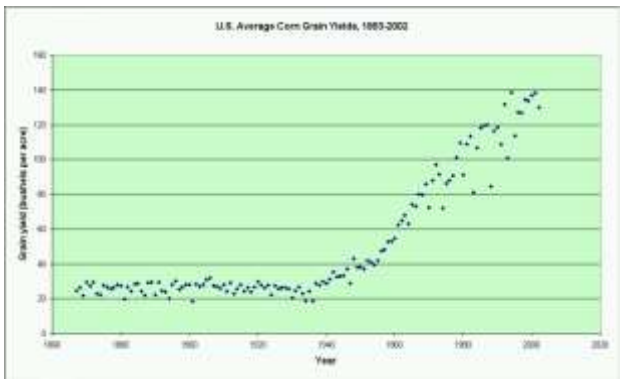


Charles Davenport also worried about the effect of **immigration** on the quality of the human harvest writing, "*There is no question that, taken as a whole, the hordes of Jews that are now coming to us from Russia and the extreme southeast of Europe, with their intense individualism and ideals of gain 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."

Edward East was a geneticist. He found that when a corn plant is self-pollinated, all the progeny resemble that plant, although they all differ from each other to some extent. He also noticed that after seven 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 progeny 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) 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 extended to humans. Edward East (1919) wrote, "*If we examine carefully the geneological 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 cousins 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***."

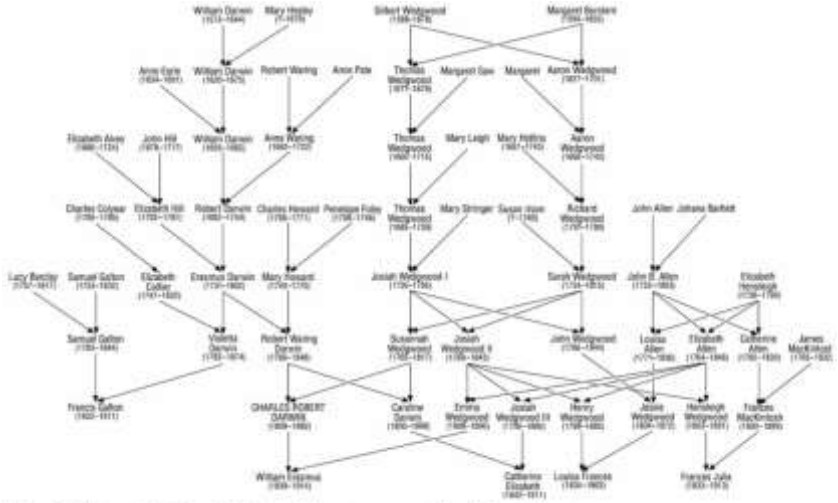


Figure 1. Pedigree of the Darwin/Wedgwood dynasty represented as chains of descent.

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 Thomas Wedgwood as a grandfather.

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. 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.***"

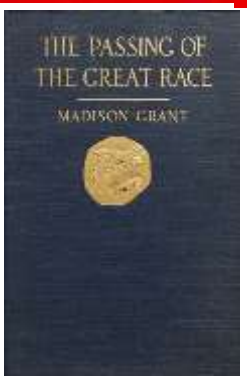
Harry Laughlin, the Director of the Eugenics Record Office at Cold Spring Harbor, testified to the Congressional Committee on Immigration and Naturalization in 1922, *"**The character of a nation is determined primarily by its racial***

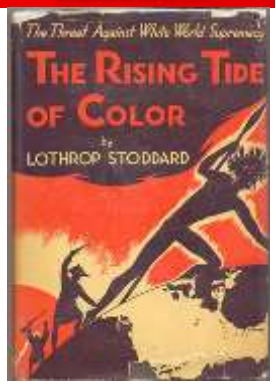
qualities; that is, by the hereditary physical, mental and moral or temperamental traits of its people."

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 doctorate 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.

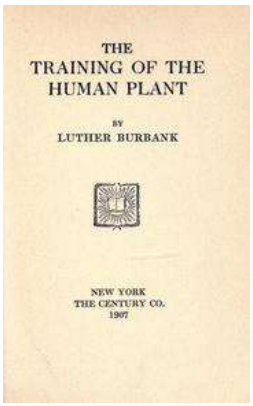
The **American Breeder's Association** was founded in 1906 by Charles Davenport to "*investigate and report on heredity in the human race, and emphasize the value of superior blood and the menace to society of inferior blood*." **Luther Burbank**, the renowned horticulturalist was made an honorary member 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, who first described *Tyrannosaurus rex* and 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 Edwin 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 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






Paul Popenoe

prevent undesirables from breeding. Plant breeders knew that to produce a successful variety, you have to make many crosses and throw away all progeny except those with the desired traits. In the Progressive Era, eugenics was the cutting edge of science.



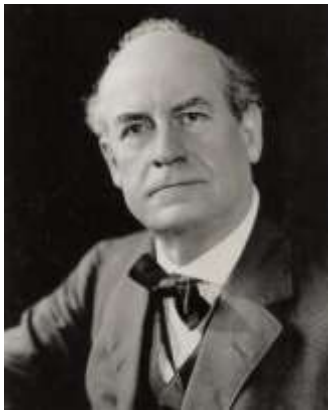
Luther Burbank (1909) wrote in *The Training of the Human Plant*, "*It would, if possible, be best absolutely to prohibit in every State in the Union the marriage of the physically, mentally and morally unfit. If we take a plant which we recognize as poisonous and cross it with another which is not poisonous 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, author of *Ancient Plants* (1910) and the paleobotanist 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*," 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.

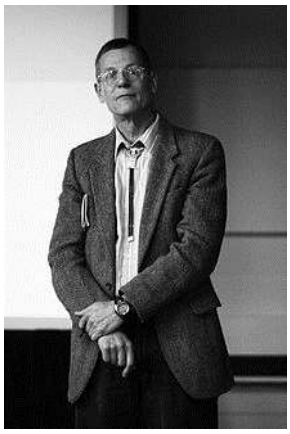
The science of genetics had a reasonable, rational, scientific and evidence-based foundation. It was supported by the scientific luminaries or prophets who saw people as living organisms essentially equivalent to plants and animals. Consequently, genetics seemingly had unlimited value in improving the 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?"**



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 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*."

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.

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 vorciferously expressed by some sincere but misguided people,…a trend* [toward 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*

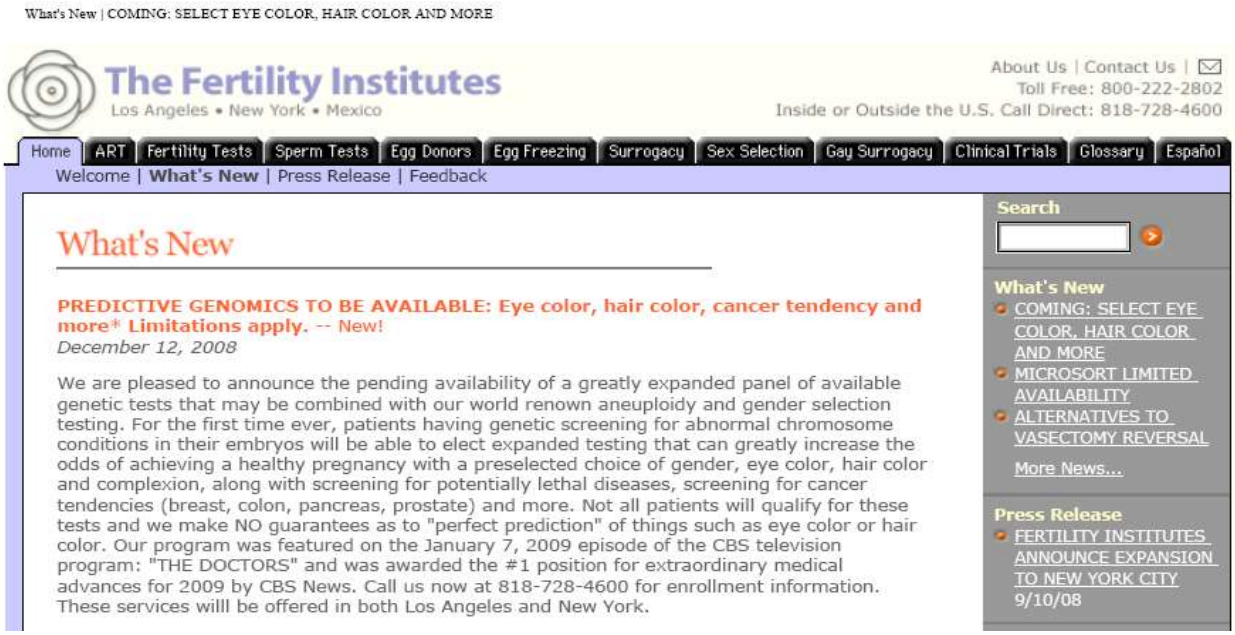
or deterioration follows crossing. The widespread belief that human race hybrids are inferior to both their parents and somehow constitutionally unbalanced must be counted among the superstitions."

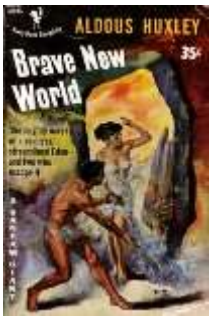
William Provine (1972) ended his paper on *Geneticists and the Biology of Race* Crossing like so: "*I am not condemning geneticists because social and political factors have influenced their scientific conclusions about race crossing and race differences. It is necessary and natural that changing social 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."***

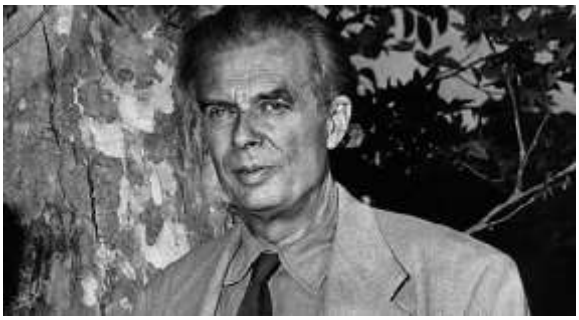
The science of human genetics in the 1920's and 1930's was known as **eugenics**. Eugenics, under the name of applied genetics is with us today. Maitland Edey and Donald Johanson (1989) write about the survival of the human race in *Blueprints: Solving the Mystery of Evolution*: "*There is a way out 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

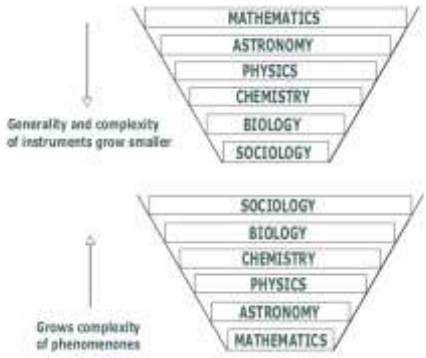
embryos for the desired genetic traits, including **eye color** and **hair color**. The Fertility Institutes hope to make this a reality by late 2015.







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.

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.

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 **produce more offspring** that were also **camouflaged** and could also 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.

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 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 Samuel Wilberforce would consider this to be **variation on a type**, 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?

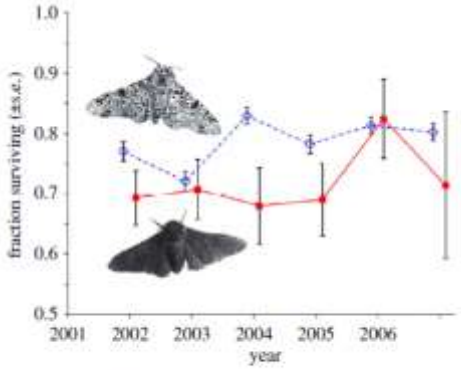


Figure 1. Survival of moths (±s.e.) over the course of the predation experiment. Unfilled diamonds with dashed lines, non-melanic; filled squares with solid lines, melanic.

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. (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'***."

Speaking of 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.*" 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.

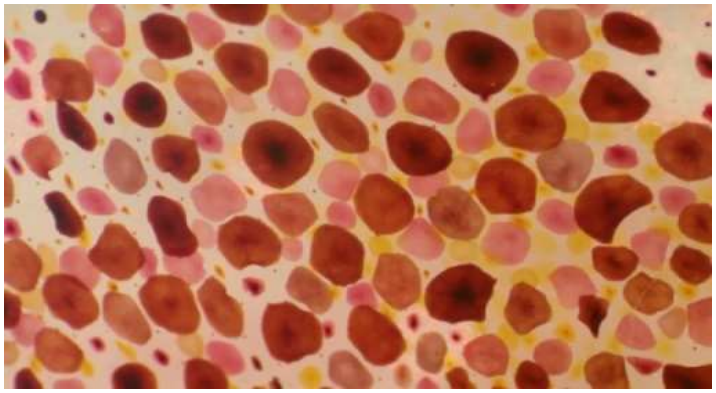
The **arctic fox** produces melanin in its hair in the summer but not in the winter allowing for seasonal dynamic camouflage.

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.

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.

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 live 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 or orange birds also owe their bright coloration to the carotenoids in their diet.

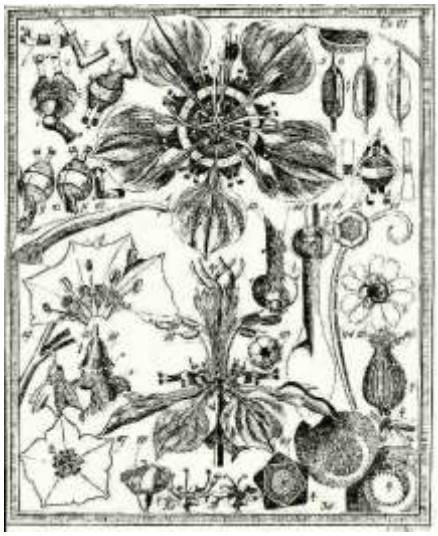
A diet rich in carotenoids imparts a **yellow tone** to **human skin**. The healthy glow that comes from eating a diet rich in carotenoids may also protect the skin from oxidative damage caused by ultraviolet light.

Carotenes are important components of flowers. Carotenes give the yellow color to buttercups, the orange color to daffodils (*Narcissus*), the red color to red hot poker flowers (*Kniphofia*) carrots.

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*

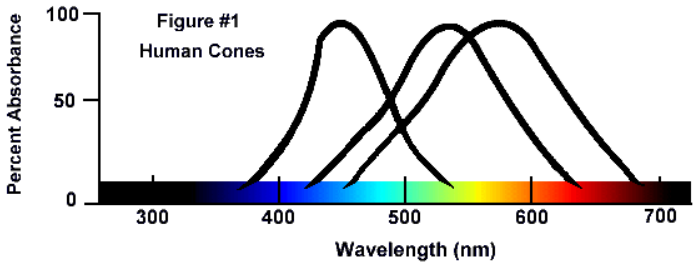
flowers it is only a means, and in fact the only means, to a particular end: their pollination."

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***."

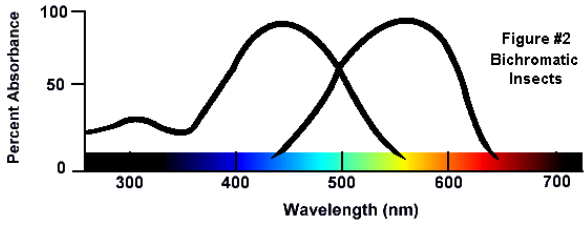
While looking at the yellow ring of the **forget-me-not flower**, Sprengel (1793) realized that "*when an insect attracted to a flower, whether by the beauty of its corolla or by its pleasant smell, alights: it will either detect the nectar immediately or it will not, because the nectar is located in 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."

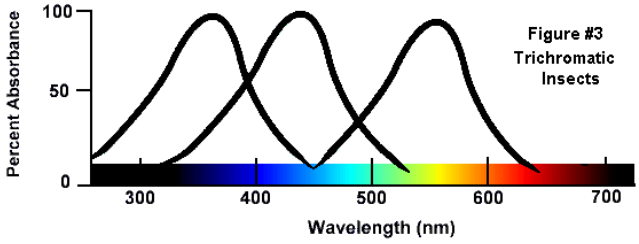
Humans see the **nectar guides** or **pathfinders** with our trichromatic cone-dominated photopic vision, but what do insects see? In the nineteenth century, John Lubbock and later Frank Lutz and Floyd Richtmyer (Cornell, 1922) showed that ants and fruitflies, respectively, could see in the ultraviolet range that was invisible to humans.



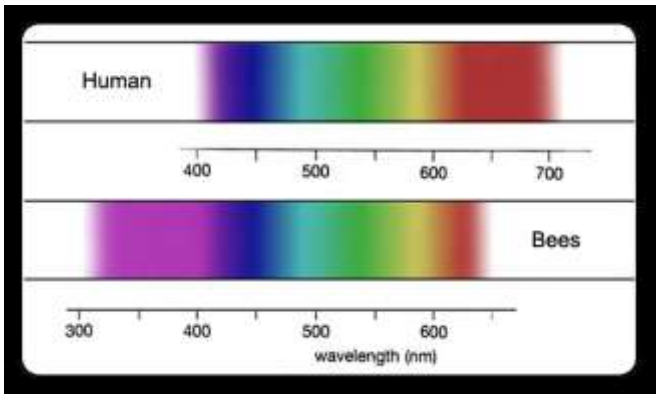
Most insects are bichromats that can see in the ultraviolet but cannot see red. Note that the combination of 370 nm + 600 nm light would appear to be the same as 500 nm light. Thus the color of a flower that reflects ultraviolet and orange might look like the color of the leaves to a bichromatic insect.



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.

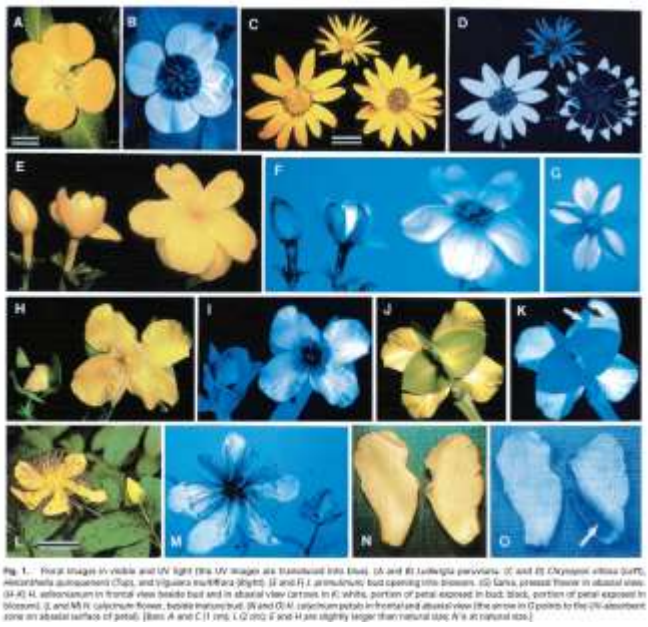


Thus vision in flower-visiting insects is shifted about 100 nm towards the short wavelengths compared with human vision.

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. 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.



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:

(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 discovered.

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.

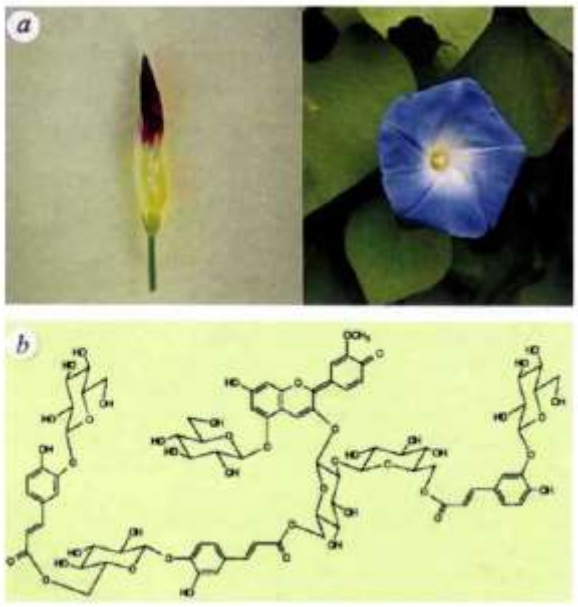
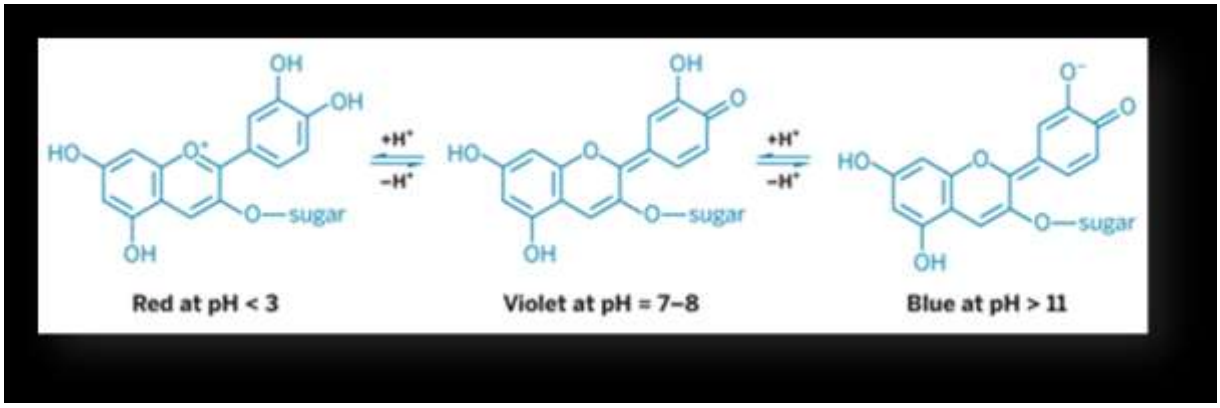


FIG. 1a, Blue blooming flower (right) and the bud (left) of *Ipomoea tricolor* cv. heavenly blue. *b*, Structure of heavenly blue anthocyanin (HBA)[9].

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** determine the color of the anthocyanins within.

Anthocyanins, extracted from red cabbage, can be used as a **pH indicator**.



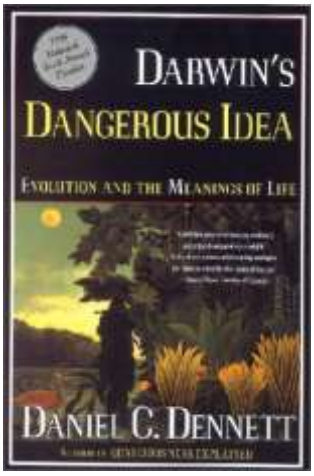
Fruits often contain **anthocyanins** that produce colors that **attract animals** that will **disperse the seeds** within the **fruits.**


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?"

Yes, it can be 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."