# Pre-Darwinian Theories

The acceptance of biological evolution is an essential part of the modern scientific explanation of the natural world. Most scientists and major religions in the Western World have long since incorporated it into their understanding of nature and humanity. However, some churches still maintain that there was a special and independent creation of every species and that life forms do not change through time from generation to generation. These "creationists" often share beliefs about the Judeo-Christian Bible that were widely held, even by scientists, during the early 19th century and before.

James Ussher
1581-1656

The traditional Judeo-Christian version of creationism was strongly reinforced by **James Ussher**, a 17th century Anglican archbishop of Armagh in Northern Ireland. By counting the generations of the Bible and adding them to modern history, he fixed the date of creation at October 23, 4004 B.C. During Ussher's lifetime, debate focused only on the details of his calculations rather than on the approach. Dr. Charles Lightfoot of Cambridge University in England had the last word. He proclaimed that the time of creation was 9:00 A.M. on October 23, 4004 B.C.

This belief that the earth and life on it are only about 6000 years old fit neatly with the then prevalent theory of the "Great Chain of Being." This held that God created an infinite and continuous series of life forms, each one grading into the next, from simplest to most complex, and that all organisms, including humans, were created in their present form relatively recently and that they have remained unchanged since then. Given these strongly held beliefs, it is not surprising that 17th and 18th century European biology consisted mainly of the description of plants and animals as they are with virtually no attempt to explain how they got to be that way.

Carolus Linnaeus
1707-1778

The leading biological scientist of the mid 18th century was the Swedish botanist Karl von Linné (**Carolus Linnaeus** in Latin). His 180 books are filled with precise descriptions of nature, but he did little analysis or interpretation. This is to be expected since Linnaeus apparently believed that he was just revealing the unchanging order of life created by God. The goal of documenting change in nature would not have made sense to him. Late in his life, however, he was troubled by the fact that plant hybrids could be created by cross pollination. These were varieties that had not existed before. Linnaeus stopped short of concluding that these plants had evolved.

Despite his limiting research bias, Linnaeus was a first class scientist. His most important contribution to science was his logical classification system for all living things which he proposed in his book *Systema Naturae*, first published in 1735. In this and subsequent works, he described plants and animals on the basis of physical appearance and method of reproduction. He classified them relative to each other according to the degree of their similarities. He used a binomial nomenclature in naming them. That is to say, organisms were given

two Latin names--genus and species . Each genus could have many related species. Each genus was also part of larger categories of living things.

John Ray
1627-1705

The concept of genus and species was actually developed in the late 1600's by **John Ray**, an English naturalist and ordained minister. However, it was Linnaeus who used this system to name us *Homo sapiens* (literally, "wise men"). He also placed us in the order *Primates* (a larger, more inclusive category than our genus) along with all of the apes, monkeys, and prosimians. This was very controversial at the time since it implied that people were part of nature, along with other animals and plants. In addition, it meant that we were biologically closer to the other primates than to all other animals.

Comte de Buffon
1707-1788

Late in the 18th century, a small number of European scientists began to quietly suggest that life forms are not fixed. The French mathematician and naturalist, George Louis Leclerc, Comte de **Buffon** , actually said that living things do change through time. He speculated that this was somehow a result of influences from the environment or even chance. He believed that the earth must be much older than 6000 years. In 1774, in fact, he speculated that the earth must be at least 75,000 years old. He also suggested that humans and apes are related. Buffon was careful to hide his radical views in a limited edition 44 volume natural history book series called *Histoire Naturelle* (1749-1804). By doing this, he avoided broad public criticism.

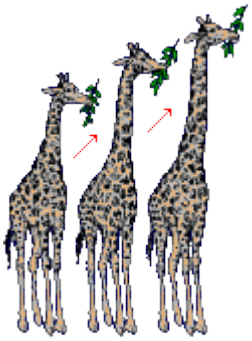
Buffon was a quiet pioneer in asserting that species can change over generations. However, he publicly rejected the idea that species could evolve into other species. One of his most significant contributions to the biological sciences was his insistence that natural phenomena must be explained by natural laws rather than theological doctrine.

Erasmus Darwin
1731-1802

Another late 18th century closet-evolutionist was **Erasmus Darwin** , the grandfather of the well known 19th century naturalist, Charles Darwin. Erasmus was an English country physician, poet, and amateur scientist. He believed that evolution has occurred in living things including humans, but he only had rather fuzzy ideas about what might be responsible for this change. He wrote of his ideas about evolution in poems and a relatively obscure two volume scientific publication entitled *Zoonomia; or, the Laws of Organic Life* (1794-1796). In this latter work, he also suggested that the earth and life on it must have been evolving for "millions of ages before the commencement of the history of mankind."

The first evolutionist who confidently and very publicly stated his ideas about the processes leading to biological change was a French protégé of the Comte de Buffon. He was Jean-Baptiste Chevalier de **Lamarck** . Unfortunately, his theory about these processes was incorrect.

Lamarck believed that microscopic organisms appear spontaneously from inanimate materials and then transmute, or evolve, gradually and progressively into more complex forms through a constant striving for perfection. The ultimate product of this goal-oriented evolution was thought by Lamarck to be humans. He believed that evolution was mostly due to the **inheritance of acquired characteristics** as creatures adapted to their environments. That is, he believed that evolution occurs when an organism uses a body part in such a way that it is altered during its lifetime and this change is then inherited by its offspring. For example, Lamarck thought that giraffes evolved their long necks by each generation stretching further to get leaves in trees and that this change in body shape was then inherited. Likewise, he believed that wading birds, such as herons and egrets, evolved their long legs by stretching them to remain dry. Lamarck also believed that creatures could develop new organs or change the structure and function of old ones as a result of their use or disuse.



Lamarck's incorrect idea of the cause of evolution

Jean-Baptiste Lamarck
1744-1829

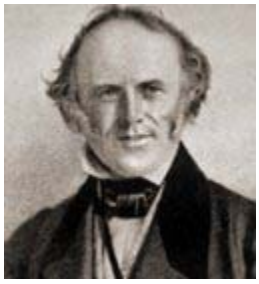
Lamarck did not invent the idea of inheritance of acquired characteristics but stated it clearly and publicly in an 1809 publication entitled *Philosophie Zoologique.* It was relatively easy for the French scientist, **George Cuvier** , and other critics of Lamarck to discredit his theory. If it was correct, the children of cowboys who have developed bowed legs as a result of a lifetime of riding horses would be born with bowed legs as well. That, of course, does not occur. Likewise, the children of professional weight lifters are not born with enlarged muscles.

While Lamarck's explanation of evolution was incorrect, it is unfair to label him a bad scientist. In fact, he was at the cutting edge of biological research for his time. He and George Cuvier were largely responsible for making biology a distinct branch of science.

Despite his criticism of Lamarck, Cuvier did not reject the idea that there had been earlier life forms. In fact, he was the first scientist to document extinctions of ancient animals and was an internationally respected expert on dinosaurs. However, he rejected the idea that their existence implied that evolution had occurred--he dogmatically maintained the "fixity" of species.

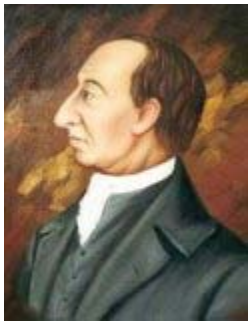
George Cuvier
1769-1832

Cuvier advocated the theory of **catastrophism** , as did most other leading scientists of his day. This held that there have been violent and sudden natural catastrophes such as great floods and the rapid formation of major mountain chains. Plants and animals living in those parts of the world where such events occurred were often killed off according to Cuvier. Then new life forms moved in from other areas. As a result, the fossil record for a region shows abrupt changes in species. Cuvier's explanation relied solely on scientific evidence rather than biblical interpretation.



Charles Lyell
1797-1875

A careful examination of European geological deposits in the early 19th century led the English lawyer and geologist, **Charles Lyell** , to conclude that Cuvier's catastrophism theory was wrong. He believed that there primarily have been slower, progressive changes. In his three volume *Principles of Geology* (1830-1833), Lyell documented the fact that the earth must be very old and that it has been subject to the same sort of natural processes in the past that operate today in shaping the land. These forces include erosion, earthquakes, glacial movements, volcanoes, and even the decomposition of plants and animals.



James Hutton
1726-1797

Lyell provided conclusive evidence for the theory of **uniformitarianism**, which had been developed originally by the late 18th century Scottish geologist, **James Hutton**. This held that the natural forces now changing the shape of the earth's surface have been operating in the past much the same way. In other words, the present is the key to understanding the past.

This revolutionary idea was instrumental in leading Charles Darwin to his understanding of biological evolution in the 1830's. However, it was not until the late 19th century that most educated people in the Western world finally rejected the theory of catastrophism in favor of uniformitarianism.

Today, we know that our planet has been shaped by occasional catastrophic events, such as bombardment of large meteors, in addition to the comparatively slower natural processes suggested by uniformitarianism. All of these events have potentially affected the rate and direction of biological evolution.

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# *Darwin and Natural Selection*

Most educated people in Europe and the Americas during the 19th century had their first full exposure to the concept of evolution through the writings of **Charles Darwin** . Clearly, he did not

invent the idea. That happened long before he was born. However, he carried out the necessary research to conclusively document that evolution has occurred and then made the idea acceptable for scientists and the general public. This was not easy since the idea of evolution had been strongly associated with radical scientific and political views coming out of post-revolutionary France. These ideas were widely considered to be a threat to the established social and political order.

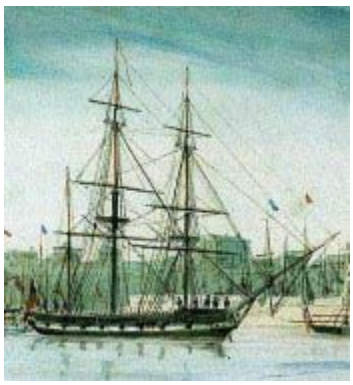
Charles Darwin was born into a moderately wealthy family in Shrewsbury, England. His father, Robert, had the largest medical practice outside of London at the time and his mother, Susannah Wedgwood, was from a family of wealthy pottery manufacturers. She died when Charles was only 8 years old. Thereafter, he was raised mostly by his father and older sisters. Charles grew up in comparative luxury in a large house with servants. However, this was a socially very conservative time in England that set narrow limits on a young man's behavior and future possibilities. The constraints on women in Darwin's social class were even greater. Most were given only enough education to efficiently manage the homes of their future husbands and raise their children. Young men were expected to go to university in order to prepare themselves to become medical doctors, military officers, or clerics in the Church of England. Most other occupations were considered somewhat unsavory.

Charles Darwin
1809-1882

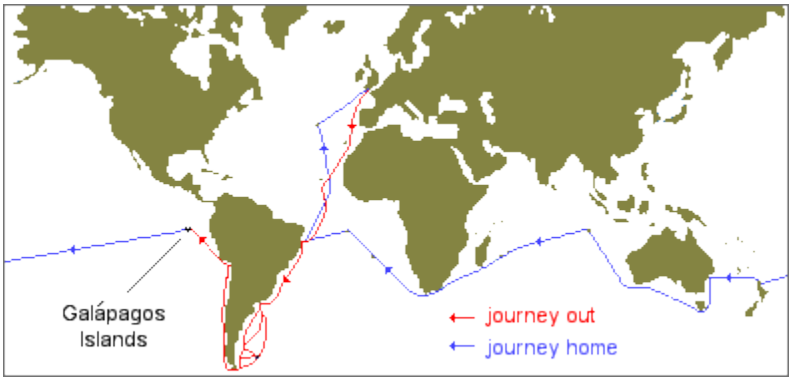
At his father's direction, Charles Darwin started university at 16 in Edinburgh, Scotland as a medical student. He showed little academic interest in medicine and was revolted by the brutality of surgery. He dropped out after two years of study in 1827. His father then sent him to Cambridge University in 1828 to study theology. It was there that his life's direction took a radical change. He became very interested in the scientific ideas of the geologist Adam Sedgwick and especially the naturalist John Henslow with whom he spent considerable time collecting specimens from the countryside around the university. At this time in his life, Darwin apparently rejected the concept of biological evolution, just as his mentors Sedgwick and Henslow did. However, Darwin had been exposed to the ideas of Lamarck about evolution earlier while he was a student in Edinburgh.

Following graduation from Cambridge in 1831 with a degree in theology, Darwin was clearly more interested in biology than he was in a clerical career. Fortunately, John Henslow was able to help him secure a berth on a British Navy mapping expedition that was going around the world on what would ultimately become a five year long voyage. Initially, Darwin's father refused to allow him to go but was eventually persuaded by Charles and even agreed to pay for his passage and for that of his man servant on the journey. They sailed two days after Christmas in 1831 aboard the survey ship H.M.S. Beagle with Darwin acting as an unpaid naturalist and gentleman companion for the aristocratic captain, Robert Fitzroy. Darwin was only 22 years old at the time. The Beagle was a compact 90 foot long ship with a crew of 74. There was little space, even for the captain. Because of its small size, it was generally thought by naval men that the Beagle was ill suited for the rough seas it would encounter, especially at the southern tip of South America. Darwin frequently suffered from sea sickness on the voyage.

It was during the beginning of the voyage that Darwin read the early books of Charles Lyell and became convinced by his proof that uniformitarianism provided the correct understanding of the earth's geological history. This intellectual preparation along with his research on the voyage were critical in leading Darwin to accept evolution. Especially important to the development of this understanding was his 5 weeks long visit to the Galápagos Islands in the Eastern Pacific Ocean. It was there that he began to comprehend what causes plants and animals to evolve, but he apparently did not clearly formulate his views on this until 1837.

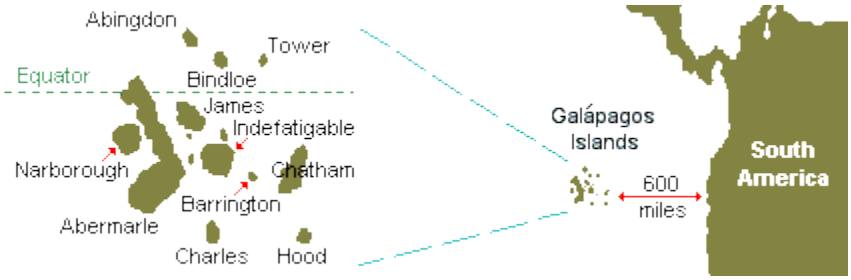


H.M.S. Beagle




Five year voyage of H.M.S. Beagle (1831-1836)

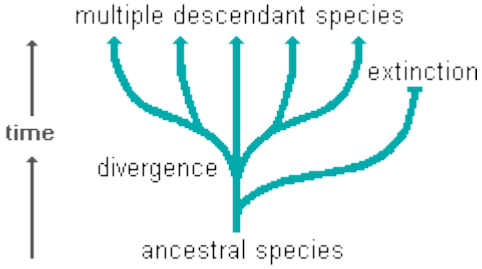
The Galápagos Islands have species found in no other part of the world, though similar ones exist on the west coast of South America. Darwin was struck by the fact that the birds were slightly different from one island to another. He realized that the key to why this difference existed was connected with the fact that the various species live in different kinds of environments.




Darwin identified 13 species of finches in the Galápagos Islands. This was puzzling since he knew of only one species of this bird on the mainland of South America, nearly 600 miles to the east, where they had all presumably originated. He observed that the Galápagos species differed from each other in beak size and shape. He also noted that the beak varieties were associated with diets based on different foods. He concluded that when the original South American finches reached the islands, they dispersed to different environments where they had to adapt to different conditions. Over many generations, they changed anatomically in ways that allowed them to get enough food and survive to reproduce.

Finches from the Galápagos Islands

Today we use the term **adaptive radiation** to refer to this sort of branching evolution in which different populations of a species become reproductively isolated from each other by adapting to different ecological niches and eventually become separate species.




Darwin came to understand that any population consists of individuals that are all slightly different from one another. Those individuals having a variation that gives them an advantage in staying alive long enough to successfully reproduce are the ones that pass on their traits more frequently to the next generation. Subsequently, their traits become more common and the population evolves. Darwin called this "descent with modification."

The Galápagos finches provide an excellent example of this process. Among the birds that ended up in arid environments, the ones with beaks better suited for eating cactus got more food. As a result, they were in better condition to mate. Similarly, those with beak shapes that were better suited to getting nectar from flowers or eating hard seeds in other environments were at an advantage there. In a very real sense, nature selected the best adapted varieties to survive and to reproduce. This process has come to be known as **natural selection**.

Darwin did not believe that the environment was producing the variation within the finch populations. He correctly thought that the variation already existed and that nature just selected for the most suitable beak shape and against less useful ones. By the late 1860's, Darwin came to describe this process as the "survival of the fittest." This is very different from Lamarck's incorrect idea that the environment altered the shape of individuals and that these acquired changes were then inherited.

Thomas Malthus
(1766-1834)

Nineteenth century critics of Darwin thought that he had misinterpreted the Galápagos finch data. They said that God had created the 13 different species as they are and that no evolution in beak shape has ever occurred. It was difficult to conclusively refute such counter arguments at that time. However, 20th century field research has proven Darwin to be correct.

In 1798, **Thomas Malthus**, an English clergyman and pioneer economist, published *Essay on the Principles of Population*. In it he observed that human populations will double every 25 years unless they are kept in check by limits in food supply. In 1838, Darwin read Malthus' essay and came to realize that all plant and animal populations have this same potential to rapidly increase their numbers unless they are constantly kept in check by predators, diseases, and limitations in food, water, and other resources that are essential for survival. This fact was key to his understanding of the process of natural selection. Darwin realized that the most fit individuals in a population are the ones that are least likely to die of starvation and, therefore, are most likely to pass on their traits to the next generation.

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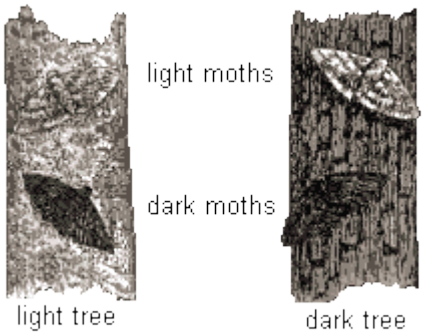
An example of evolution resulting from natural selection was discovered among "peppered" moths living near English industrial cities. These insects have varieties that vary in wing and body coloration from light to dark. During the 19th century, sooty smoke from coal burning furnaces killed the lichen on trees and darkened the bark. When moths landed on these trees and other blackened surfaces, the dark colored ones were harder to spot by birds who ate them and, subsequently, they more often lived long enough to reproduce. Over generations, the environment continued to favor darker moths. As a result, they progressively became more common. By 1895, 98% of the moths in the vicinity of English cities like Manchester were mostly black. Since the 1950's, air pollution controls have significantly reduced the amount of heavy particulate air pollutants reaching the trees, buildings, and other objects in the environment. As a result, lichen has grown back, making trees lighter in color. In addition, once blackened buildings were cleaned making them lighter in color. Now, natural selection favors lighter moth varieties so they have become the most common. This trend has been well documented by field studies undertaken between 1959 and 1995 by Sir Cyril Clarke from the University of Liverpool. The same pattern of moth wing color evolutionary change in response to increased and later decreased air pollution has been carefully documented by other researchers for the countryside around Detroit, Michigan. While it is abundantly clear that there has been an evolution in peppered moth coloration due to the advantage of camouflage over the last two centuries, it is important to keep in mind that this story of natural selection in action is incomplete. There may have been additional natural selection factors involved.




Dark moths on light colored bark are easy targets for hungry birds but are hidden on pollution darkened trees.

Darwin did not rush his ideas about natural selection into print. He first concentrated his efforts on writing the account of his voyage on the Beagle and analyzing the specimens that he brought back with him. An additional factor was the widespread Christian evangelical fervor in England during the 1830's and 1840's. He could have been charged with sedition and blasphemy for widely publishing his unpopular theory. After returning from the voyage around the world on H.M.S. Beagle, he settled down in England, married Emma Wedgwood (his wealthy first cousin), raised a large family, and quietly continued his research at his newly purchased country home 16 miles south of London. In 1842 and 1844, he wrote relatively short summaries of his theory, but they were not widely read outside of British scientific circles. It was not until he was 50 years old, in 1859, that he finally published his theory of evolution in full for his fellow scientists and for the public at large. He did so in a 490 page book entitled *On the Origin of Species*. It was very popular and controversial from the outset. The first edition came out on November 24, 1859 and sold out on that day. It went through six editions by 1872. The ideas presented in this book were expanded with examples in fifteen additional scientific books that Darwin published over the next two decades.

Down House--Charles and Emma Darwin's country home where he wrote his major publications and their family lived contentedly for 40 years.

Emma Darwin
1808-1896

Alfred Wallace
1823-1913

What finally convinced Darwin that he should publish his theory in a book for the general educated public was the draft of an essay that he received in the summer of 1858 from a younger British naturalist named **Alfred Wallace**, who was then hard at work collecting biological specimens in Southeast Asia for sale to museums and private collectors. Darwin was surprised to read that Wallace had come upon essentially the same explanation for evolution. Being a fair man, Darwin later insisted that Wallace also get credit for the natural selection theory during debates over its validity that occurred at a meeting of the British Association for the Advancement of Science at Oxford University in 1860. We now know that Darwin deserves most of the credit. In 1837, one year after he returned from the voyage on the Beagle, he made detailed notes on the idea of evolution by means of natural selection. At that time Wallace was

only 14. In addition, it was Darwin's book, rather than Wallace's essay, that had the most impact on the Victorian public. Darwin not only described the process of natural selection in more detail, but he also gave numerous examples of it. It was his *On the Origin of Species* that convinced most scientists and other educated people in the late 19th century that life forms do change through time. This prepared the public for the acceptance of earlier human species and of a world much older than 6000 years.


Gregor Mendel
1822-1884

Both Darwin and Wallace failed to understand an important aspect of natural selection. They realized that plant and animal populations are composed of individuals that vary from each other in physical form. They also understood that nature selects from the existing varieties those traits that are most suited to their environment. If natural selection were the only process occurring, each generation should have less variation until all members of a population are essentially identical, or clones of each other. That does not happen. Each new generation has new variations. Darwin was aware of this fact, but he did not understand what caused the variation. The first person to begin to grasp why this happens was an obscure Central European monk named **Gregor Mendel**. Through plant breeding experiments carried out between 1856 and 1863, he discovered that there is a recombination of parental traits in offspring. Sadly, Darwin and most other 19th century biologists never knew of Mendel and his research. It was not until the beginning of the 20th century that Mendel's pioneer research into genetic inheritance was rediscovered. This was long after his death. He never received the public acclaim that was eventually showered on Darwin during his lifetime.

Charles Darwin's convincing evidence that evolution occurs was very threatening to many Christians who believed that people were created specially by God and that they have not changed biologically since that creation. The idea that there could have been prehistoric humans who were anatomically different from us was rejected for similar reasons. However, Charles Lyell's geological evidence that the earth must be much older than 6,000 years along with the rapidly accumulating fossil record of past evolution convinced educated lay people in the 1860's to think what had been unthinkable earlier.


Boucher de Perthes
(1788-1868)

Archaeological confirmation of the existence of prehistoric Europeans had been accumulating since the 1830's. However, until the late 1850's, it had been widely rejected or misinterpreted. Much of this evidence had been collected by Jacques **Boucher** Crèvecoeur **de Perthes** , a customs officer in northern France during the early 1800's. His hobby was collecting ancient stone tools from deep down in the Somme River gravel deposits. Since he found these artifacts in association with the bones of extinct animals, he concluded that they must have been made at the time that those animals lived.

Boucher de Perthes tried to publish his findings in 1838. They were rejected by all important scientists and scientific journals. The prehistoric stone tools usually were dismissed as being only "lightning stones" (i.e., the remnants of lightning bolts). However, by 1858, his claims were beginning to be accepted by some enlightened Western European scientists. Darwin's publication of *On the Origin of Species* the following year convinced even more educated people that Boucher de Perthes had been right.

Prehistoric artifact incorrectly thought to be a "lightning bolt remnant"

Darwin's popularizing the idea of evolution also made it possible for scientists to begin to accept that some of the makers of Boucher de Perthes' prehistoric tools had already been discovered and that their bones were in museums. These bones had been found in several Western European countries during the first half of the 19th century. However, they had all been dismissed as being from odd looking modern people. During the 1860's, some were correctly determined to be from an earlier species or variety of people who had lived during the last ice age--i.e., long before recorded history. We now know that these ancient people were mostly Neandertals, who lived about 150,000-28,000 years ago.

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# *Evidence of Evolution*

The Nobel Prize winning scientist Linus Pauling aptly described science as the search for truth. Science does this by continuously comparing its theories objectively with evidence in the natural world. When theories no longer conform to the evidence, they are modified or rejected in favor of new theories that do conform. In other words, science constantly tries to prove its assumptions to be false and rejects implausible explanations. In this way, scientific knowledge and understanding grow over time. Religious explanations for the order of things are not science because they are based primarily on faith and do not subject themselves to be objectively falsified. Because of this fundamental difference in the approach to understanding our natural world, the U.S. Supreme Court in effect decided in 1987 that the Biblically based "creation science" is not a science and cannot be taught as such in public schools as an alternative or in addition to the mainstream evolutionary theory of the biological sciences. However, religious creation stories and the idea of "intelligent design" can be taught in philosophy, religion, or history courses. Religion and Science provide different approaches to knowledge. It is important to understand both.

### What is Evolution?

Biological evolution is genetic change in a population from one generation to another. The speed and direction of change is variable with different species lines and at different times. Continuous

evolution over many generations can result in the development of new varieties and species. Likewise, failure to evolve in response to environmental changes can, and often does, lead to extinction.

When scientists speak of evolution as a theory they do not mean that it is a mere speculation. It is a theory in the same sense as the propositions that the earth is round rather than flat or that our bodies are made of atoms are theories. Most people would consider such fundamental theories to be sufficiently tested by empirical evidence to conclude that they are indeed facts. As a result of the massive amount of evidence for biological evolution accumulated over the last two centuries, we can safely conclude that evolution has occurred and continues to occur. All life forms, including humans, evolved from earlier species, and all still living species of organisms continue to evolve today. They are not unchanging end-products.

For those who have difficulty in accepting evolution because of what they perceive as contradictions with their fundamental religious beliefs, it may be useful to distinguish the ultimate origin of life from its later evolution. Many, if not most, biological scientists accept that primordial life on earth began as a result of chance natural occurrences 3.5-4 billion years ago. However, it is not necessary to believe in that view in order to accept that living creatures evolved by natural means after the origin of the first life. Charles Darwin modified his religious beliefs, as did many others, as a result of the discovery of convincing proof of evolution. Darwin's religious faith was also severely challenged by the death of his 10 year old daughter Annie in 1851. Apparently, he came to believe that his God created the order of the universe including the rules of nature that result in biological evolution. His famous book, *On the Origin of Species*, was not a denial of his God's existence. However, he did reject a literal interpretation of the Judeo-Christian Bible. His religious beliefs were probably very similar to those who advocate "theistic evolution" today.

We now understand that there are a number of different natural processes that can cause evolution to occur. These are presented in a later tutorial of this series (*Synthetic Theory of Evolution*).

## How Do We Know That Evolution Has Occurred?

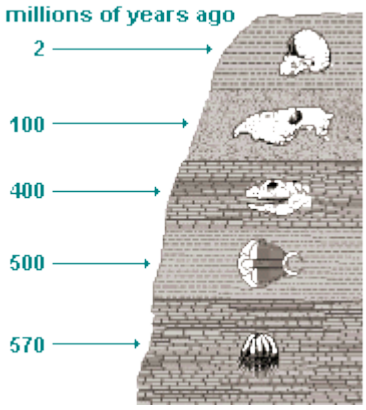
The evidence for evolution has primarily come from four sources:

1. the fossil record of change in earlier species
2. the chemical and anatomical similarities of related life forms
3. the geographic distribution of related species
4. the recorded genetic changes in living organisms over many generations

## The Fossil Record

Remains of animals and plants found in sedimentary rock deposits give us an indisputable record of past changes through time. This evidence attests to the fact that there has been a tremendous variety of living things. Some extinct species had traits that were transitional between major groups of organisms. Their existence confirms that species are not fixed but can evolve into other species over time.

The evidence also shows that what have appeared to be gaps in the fossil record are due to incomplete data collection. The more that we learn about the evolution of specific species lines, the more that these so-called gaps or "missing links in the chain of evolution" are filled with transitional fossil specimens.



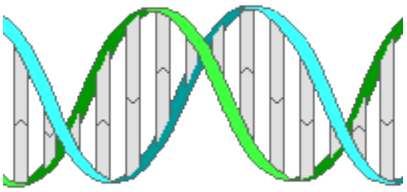

Geological strata containing an evolutionary sequence of fossils

## Chemical and Anatomical Similarities

Living things on earth are fundamentally similar in the way that their basic anatomical structures develop and in their chemical compositions. No matter whether they are simple single celled protozoa or highly complex organisms with billions of cells, they all begin as single cells that reproduce themselves by similar division processes. After a limited life span, they also all grow old and die.

All living things on earth share the ability to create complex molecules out of carbon and a few other elements. In fact, 99% of the proteins, carbohydrates, fats, and other molecules of living things are made from only 6 of the 92 most common elements. This is not a mere coincidence.

All plants and animals receive their specific characteristics from their parents by inheriting particular combinations of genes. Molecular biologists have discovered that genes are, in fact, segments of DNA molecules in our cells.



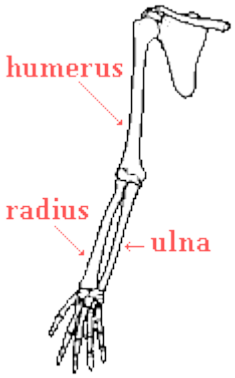
section of a DNA molecule

These segments of DNA contain chemically coded recipes for creating proteins by linking together particular amino acids in specific sequences.


simple protein molecule

All of the tens of thousands of types of proteins in living things are made of only 20 kinds of amino acids. Despite the great diversity of life on our planet, the simple language of the DNA code is the same for all living things. This is evidence of the fundamental molecular unity of life.

In addition to molecular similarities, most living things are alike in that they either get the energy needed for growth, repair, and reproduction directly from sunlight, by photosynthesis , or they get it indirectly by consuming green plants and other organisms that eat plants.




Human arm bones
(typical vertebrate pattern)

Many groups of species share the same types of body structures because they inherited them from a common ancestor that had them. This is the case with the vertebrates , which are the animals that have internal skeletons. The arms of humans, the forelegs of dogs and cats, the wings of birds, and the flippers of whales and seals all have the same types of bones (humerus, radius, and ulna) because they have retained these traits of their shared common ancient vertebrate ancestor.

All of these major chemical and anatomical similarities between living things can be most logically accounted for by assuming that they either share a common ancestry or they came into existence as a result of similar natural processes. These facts make it difficult to accept a theory of special and independent creation of different species.

## Geographic Distribution of Related Species

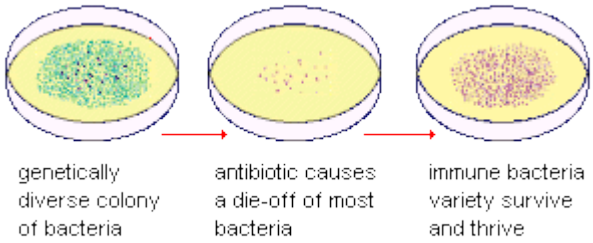
Another clue to patterns of past evolution is found in the natural geographic distribution of related species. It is clear that major isolated land areas and island groups often evolved their own distinct plant and animal communities. For instance, before humans arrived 60-40,000 years ago, Australia had more than 100 species of kangaroos, koalas, and other marsupials but none of the more advanced terrestrial placental mammals such as dogs, cats, bears, horses. Land mammals were entirely absent from the even more isolated islands that make up Hawaii and New Zealand. Each of these places had a great number of plant, insect, and bird species that were found nowhere else in the world. The most likely explanation for the existence of Australia's, New Zealand's, and Hawaii's mostly unique biotic environments is that the life forms in these areas have been evolving in isolation from the rest of the world for millions of years.

## Genetic Changes Over Generations

The earth's environments are constantly changing, usually in subtle and complex ways. When the changes are so great as to go beyond what most members of a population of organisms can tolerate, widespread death occurs. As Charles Darwin observed, however, not all individuals always perish. Fortunately, natural populations have genetic diversity. Those individuals whose characteristics allow them to survive an environmental crisis likely will be the only ones able to reproduce. Subsequently, their traits will be more common in the next generation--evolution of the population will have occurred.

This process of natural selection resulting in evolution can be easily demonstrated over a 24 hour period in a laboratory Petri dish of bacteria living in a nutrient medium. When a lethal dose of antibiotic is added, there will be a mass die-off. However, a few of the bacteria usually are immune and survive. The next generation is mostly immune because they have inherited immunity from the survivors. That is the case with the purple bacteria in the Petri dishes shown below--the bacteria population has evolved.

Evolution of antibiotic resistant bacteria




This same phenomenon of bacteria evolution speeded up by human actions occurs in our own bodies at times when an antibiotic drug is unable to completely eliminate a bacterial infection. That is the reason that medical doctors are sometimes hesitant to recommend an antibiotic for their patients and insist that the full dosage be used even if the symptoms of illness go away. They do not want to allow any potentially antibiotic resistant bacteria to survive.

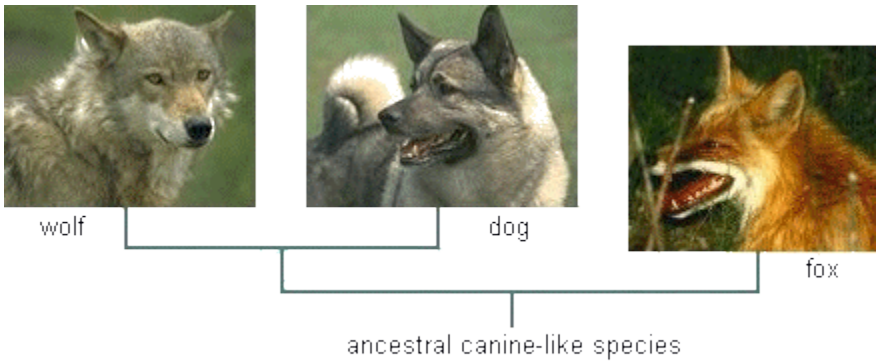
Dog variety resulting from selective breeding over many generations

People have developed many new varieties of plants and animals by selective breeding. This process is similar to the bacteria experiment described above. Selection of specimens to breed based on particular traits is, in effect, changing the environment for the population. Those individuals lacking the desirable characteristics are not allowed to breed. Therefore, the following generations more commonly have the desired traits.

Species that mature and reproduce large numbers in a short amount of time have a potential for very fast evolutionary changes. Insects and microorganisms often evolve at such rapid rates that our actions to combat them quickly lose their effectiveness. We must constantly develop new pesticides, antibiotics, and other measures in an ever escalating biological arms race with these creatures. Unfortunately, there are a few kinds of insects and microbes that are now significantly or completely resistant to our counter measures, and some of these species are responsible for devastating crop losses and deadly diseases.

Insect with a high reproductive potential

If evolution has occurred, there should be many anatomical similarities among varieties and species that have diverged from a common ancestor. Those species with the most recent common ancestor should share the most traits. For instance, the many anatomical similarities of wolves, dogs, and other members of the genus *Canis* are due to the fact that they are descended from the same ancient canine species. Wolves and dogs also share similarities with foxes, indicating a slightly more distant ancestor with them.




Given the abundant evidence supporting the theory of biological evolution, it is highly probable that evolution has occurred and is still occurring today. However, there remains speculation in regards to the specific evolutionary path of some species lines and the relative importance of the different natural processes responsible for their evolution.

Much has been added to our understanding of the nature of evolution since the 19th century. It is now known that there are six different processes that can operate independently or in consort to bring about evolution. The understanding of these processes has become the basis for an overall synthetic theory of evolution . This theory encompasses multiple causes, including Charles Darwin's concept of natural selection, Gregor Mendel's experimental results concerning genetic inheritance, as well as a number of crucial 20th century discoveries. The synthetic theory of evolution will be revisited with more detail in the 6th tutorial of this biological anthropology series.

## The Public Perception of Evolution in the United States

Biological evolution is far from being universally accepted by Americans. Annual national polls carried out since the mid 1980's by the Center for Biomedical Communication at Northwestern

University School of Medicine indicate that the percentage of Americans who accept evolution has dropped from 45% to 40%. Curiously, the number who reject evolution have also dropped from 48% to 39% over the same time period. Those who are uncertain about whether evolution occurs or not have increased from 7% to 21%. While it is encouraging that fewer people are now hostile to the idea of biological evolution, the U.S. still has a higher percentage of its population who hold this view than 33 of the 34 European nations and Japan. This is very likely a consequence of the relative emphasis placed on teaching science in public schools in the different countries. In addition, anti-evolution sentiment is far stronger in American national politics, especially in the Republican Party.