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Evolution

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People have always wondered how life originated and how so many different kinds of plants and animals arose. Stories of a supernatural creation of life developed among many peoples. The Bible, for example, tells of God's creation of humans and other higher animals over several days. Many people also believed that insects, worms, and other lower creatures spontaneously generated from mud and decay. Long after these stories became rooted in tradition, scientists began to question them.

Theories of special creation usually hold that life retains its original God-created form; it is immutable, or unchangeable. By contrast, theories of organic **evolution** state that all organisms, including humans, are mutable; that is, they respond dynamically over time to changes in the environment.

Although the **theory of organic evolution** is accepted by the overwhelming majority of the scientific community, this **theory** has aroused controversy since the middle of the 19th century. Most objections have come from religious groups that support special creation, or the **theory** they term creationism, or creation science. Individuals and organizations that support this concept defend the belief that all beings were created by God. Fundamentalist Christians and others feel that the premise that species are continually changing conflicts with literal interpretations of the Bible. They have fought, sometimes successfully, to prevent the use of biology textbooks that teach **evolution**; or they have insisted that creation science be presented as an alternative **theory**. (For an extensive discussion of human **evolution**, see [Human Origins](#).)

The Origin of Life

The first serious attack on the idea of spontaneous generation of life was made in 1668 by Francesco Redi, an Italian physician, who proved that maggots did not arise spontaneously in decaying matter, as commonly believed, but from eggs deposited there by flies. Proof that microorganisms are not generated spontaneously came in the 1860s, when Louis Pasteur, a French scientist, showed that they, too, develop from preexisting life (see [Pasteur, Louis](#)).

Many theories have been developed to explain how life first originated on Earth. Some people theorize that microorganisms reached Earth from another planet. Most scientists discount this idea, called panspermia, because the radiation in space would kill cells or spores before they reached Earth. Instead, they believe that terrestrial life evolved from nonliving matter on the primitive Earth. The way in which life first formed may always remain a mystery, but the following explanation is likely. (See also [Extraterrestrial Life](#).)

In the 1980s scientists discovered fossil remains of microorganisms resembling cyanobacteria (formerly known as blue-green algae) in rocks that were about 3 billion years old. Since Earth is thought to be about 4.5 billion years old, the first living things probably evolved within a billion years of Earth's formation. In the 1920s Aleksandr Oparin, a Soviet biochemist, pointed out that the atmosphere of the primitive Earth was probably very different from today's. A so-called reducing

atmosphere-one with much more hydrogen than oxygen-probably existed then. It also probably contained methane, other hydrocarbons, water vapor, and ammonia. Oparin suggested that the organic compounds in the first organisms could have been formed by the action of sunlight and the heat from volcanoes or lightning on the reducing atmosphere of the primitive Earth.

Oparin's **theory** can be supported by the fact that all living things are alike in some respects. For example, they all consist of cells that must have enzymes to catalyze, or speed up, the biochemical reactions of life (see [Cell](#); [Enzymes](#)). Enzymes are proteins, and consist of about 20 kinds of amino acids, nitrogen-containing organic molecules found in the proteins of all organisms. Also, all cells transmit hereditary traits through nucleic acids (see [Genetics](#)).

In 1953 Stanley Miller, then a young graduate student at the University of Chicago, passed an electric spark through an experimental atmosphere containing the chemical elements suggested by Oparin. A mixture of organic chemicals resulted, including several of the vital amino acids. Since Miller's pioneering work, other scientists have produced many naturally occurring amino acids and nucleic acid components in the laboratory under prebiological conditions. Radio astronomers have discovered related molecules in dust clouds far from our solar system.

Scientists think that simple prebiological organic chemicals concentrated in lakes and tidal pools, forming a rich primordial 'soup.' Influenced by ultraviolet light and mild heating, the simple molecules then condensed into more complex ones resembling proteins and nucleic acids. This might have taken place on the surface of minerals or in oily colloidal droplets called coacervates floating in the mix (see [Colloid](#)).

The next stage in the formation of life is the vaguest. For life to persist after becoming established, there must have been polymers (long-stranded molecules) capable of replicating, or making copies of, themselves. Presumably these first self-replicating polymers were like nucleic acids. Once polymers could replicate, those best able to cope with their surroundings survived. After certain other basic adaptations were achieved, the most primitive cells arose. From then on, only natural selection was needed to give rise to the many species that would inhabit Earth.

Natural Selection Directs Evolution

Fossils clearly show that various living things once existed that no longer do. Fossils of animals that no longer exist puzzled the early 19th-century naturalists. Georges Cuvier, a French scientist, believed that the fossil sequence resulted from a series of recurring catastrophes, followed by creation of new plants and animals. Charles Lyell, an English geologist, saw instead that the fossil sequences in progressively younger rock layers substantiated the notion that living things experience gradual body changes over the years. Moreover, changes can be demonstrated in living things today, which prompts scientists to believe that **evolution** occurs through change.

Around 1800 Jean-Baptiste Lamarck, a French naturalist, suggested that **evolution** resulted from the use or nonuse of body structures. Lamarck knew that a structure grows through use, just as the muscles of a weight lifter grow larger through exercise. He assumed that a parent's enlarged structures would be inherited by its offspring, and that structures that were not used would eventually degenerate and become lost. Thus, an almost infinite number of structural developments or losses would lead to evolutionary change. Lamarck's idea, known as the **theory of the inheritance of acquired characteristics**, was disproved in the 20th century.

Charles Darwin, a 19th-century English naturalist, argued that natural selection guides evolutionary change (see [Darwin, Charles](#)). Darwin's contemporary Alfred Russel Wallace, another English naturalist, stated a similar **theory of evolution** independently of Darwin. The **theory of natural selection** is based on the idea that living things are in constant competition for limited but essential resources in their environment, such as food and shelter. Organisms with traits that help them or their offspring survive, which are known as adaptations, have an advantage over those with harmful or less

useful traits (see [Adaptation](#)). In the struggle for existence, the better-adapted organisms are selected and thrive at the expense **of** their competition. The more successful animals reproduce and pass their adaptive traits to their offspring while those that are not as well adapted have fewer offspring and eventually die out.

In 1859 Darwin published his views in 'On the Origin **of** Species by Means **of** Natural Selection', sparking a major controversy between theologians and scientists. Even scientists argued with each other over how the traits Darwin thought were subject to natural selection could be inherited. Ironically, an Austrian priest, Gregor Mendel, published genetic principles in 1866 that could have settled the problem. But Mendel's work was not appreciated until 1900. (See also [Genetics](#).)

Zoologists today divide all living things into a hierarchy **of** taxonomic categories. The species level in this hierarchy groups together those individuals that are the most similar to one another. Populations **of** the same species can interbreed, exchange genes, and pass on traits to their offspring. Amoebas and some other species do not reproduce sexually, but they still resemble their fellow species members.

Extinct and recent species in an evolutionary line share structural similarities as a result **of** natural selection. The ancestors **of** all living species were the best-adapted individuals **of** their day, just as future beings will evolve from the best-adapted individuals **of** today if natural selection is allowed to run its course. Body makeup or behavioral patterns gave these ancestors some survival benefit, and their ability to develop key structures or behave in the selectively valuable way was passed on to their descendants.

However, changes in those inherited traits might be valuable, too, if the environment changed. A muscular fin, for example, would be **of** great value in enabling a lunged fish to crawl out **of** a drying pond. After generations, the selectively valuable structure might no longer look like the original. Nonetheless, the underlying 'raw material' could be recognized. The main limbs **of** whales, mice, bats, and humans have similar components. Regardless **of** their function, they are homologous structures—that is, they have a common origin. By contrast, structures with the same function but different evolutionary origin, such as the wings **of** insects and those **of** birds, are analogous structures.

Geographic barriers are the best stimulants **of evolution**. Formation **of** a mountain range, for example, can divide a species into isolated units and thus block gene exchange. Also, a few members **of** a species might wander across a mountain chain and establish an isolated population. Eventually, the mountains might erode enough for descendants **of** the isolates to regain contact with descendants **of** the parent group. If they diverged too much genetically but still interbred, most **of** their offspring would be infertile hybrids.

Organisms from different evolutionary lines may independently evolve similar traits because **of** similar ecological circumstances. This is known as convergent, or parallel, **evolution**. For example, the colobine monkeys **of** Africa and Asia have multichambered stomachs similar to those **of** cattle and other ruminants that allow for the digestion **of** leaves. In the forechambers **of** the gut in both groups, bacteria break down, or degrade, the cellulose in the plant cell walls, enabling the animal to digest the plant material. The specialized stomachs and the adaptation **of** producing the cellulose-degrading bacteria arose independently in these two groups because they are selective advantages in their respective habitats. The traits were then retained and passed on to the offspring. A similar example **of** convergent **evolution** can be found in the emerald tree boa and the green tree python, which share certain aspects **of** coloring and behavioral traits though they developed in different parts **of** the world..

Genetic Factors in Evolution

If all members **of** a species were genetically identical, there would be no natural selection. There must be some genetic variation within a species so that the fittest may be selected. An individual's shape, size, color, and other readily observable features, called phenotypes, are controlled by that individual's genotype, or genetic makeup. Those individuals whose genotypes produce the best-

adapted phenotypes are most likely to reproduce and to pass on their genes.

Mutations are the primary source **of** genetic variation and have a strong influence on **evolution**. If by altering a genotype a mutation provides a phenotype with a selective advantage, this trait stands a good chance **of** being passed on to the offspring. Then the new genotype would be more frequent in the population. However, some mutations are so harmful that they raise the population's death rate. Although they are not always lethal, some mutations reduce survival potential. Ordinarily, natural selection would eliminate mutant genes with no selective value. Among human cultures with a high regard for life, however, people with less well-adapted genes can live a full life and pass on their genes to future generations.

Variation may also stem from gene frequency. The frequency **of** any gene in a population is an indication **of** its selective value, and gene frequency rests on certain genetic factors. Most organisms, for example, carry two genes, called alleles, for any trait (see [Genetics](#)). Sometimes one allele dominates the other. The dominating allele is called the heterozygous dominant; the allele being dominated is called the heterozygous recessive. If an identical pair **of** alleles-both **of** which are either recessive or dominant-occurs on a chromosome, the alleles are called homozygotes because neither one **of** the pair dominates the other. A hidden pool **of** variation lies in a population's alleles. If a recessive allele has a selective advantage then the recessive homozygotes would leave more offspring than the dominants. Eventually, any expression **of** the dominant allele would be eliminated. On the other hand, if the recessive allele hinders survival, the recessive homozygotes would leave few or no offspring. These genes would not be lost from the gene pool, however. Instead, they would be maintained in low frequency for generations through the heterozygotes, in whom only the dominant genes are expressed. Then someday those recessive genes might have some survival value if the natural environment undergoes changes.

Rates of Evolutionary Change

In 1977 a group **of** scientists set out to examine the process **of** extinction by transplanting a group **of** lizards to a lizardless island in the Bahamas, fully expecting that the lizards would eventually die out in the foreign environment. Much to the scientists' surprise, the lizards did not die out, but instead displayed a remarkable ability to adapt and prosper. While the experiment to trace the process **of** extinction proved a failure, it prompted other researchers to adapt the experiment to test the process **of** evolution.

Six years later, both groups **of** scientists began a study **of** the evolutionary patterns among lizard groups introduced to nonnative environments by replicating the initial experiment. The scientists transplanted a species **of** lizard, *Anolis sagrei*, which had been collected from thickly wooded islands in the Bahamian region onto 14 different lizardless islands in the Bahamas. The long legs **of** *A. sagrei* made it particularly well-suited for the tree-lined environment from which they were taken, but they were transplanted to small islands-some **of** them barely 100 yards (91 meters) wide-chosen for their sparse vegetation and lack **of** large trees. The biologists predicted that the lizards, over the course **of** a relatively short span **of** time, would begin to differentiate themselves biologically in order to adapt to the variations in vegetation, and that the lizards would adapt to their new island homes by developing shorter legs which would allow them to maneuver more quickly on the relatively barren islands. Fourteen years after the lizards were dispersed throughout the Bahamian archipelago, the biologists announced that the lizards adapted to their environment exactly as predicted.

The lizards had developed, over the course **of** 14 years, physical changes in the length **of** their limbs. Through the process **of** natural selection, lizards with shorter legs proved more adept at catching food on the islands they inhabited, as their shorter limbs allowed them to move more quickly than their long-legged competitors. The scientists noted that the magnitude **of** the physical changes in the lizards corresponded to the degree **of** difference between the vegetation pattern **of** the island from which the lizards were originally taken and the island to which they were transported.

The lizard evolutionary study was hailed as a major breakthrough by evolutionary biologists, as it seemed to support the argument that environmental factors can promote evolutionary changes, as

Charles Darwin observed in his famous treatise on bird differentiation in the Galapagos Islands. The study also shed considerable light on the question of whether species evolve in the same manner on a small- and large-scale basis. Numerous examples of small-scale, or microevolutionary, change in natural environments have been recorded by scientists since the process of evolution was first suggested in the 19th century. These changes tended to be of a biochemical nature, as species adapt to new biological challenges which threaten their existence. Macroevolution, on the other hand, measures the evolution of species by utilizing fossil records in an attempt to discern major physical changes over millions of years. Many evolutionary biologists argued that macroevolutionary change occurs only as the result of cataclysmic environmental changes, and that species, once they have evolved to adapt to the new environment, remain relatively static until the next major cataclysmic event forces evolutionary change to resume. If such a theory were proved correct, it would mean that organisms might experience minor evolutionary fluctuations over a limited term, but that these changes would be decidedly different from tremendous leaps in physical characteristics that produce entirely new species.

The results of the lizard study seemed to indicate that little difference existed in the process of microevolutionary and macroevolutionary change. Changes in physical characteristics are measured by biologists with a unit called a darwin, which corresponds to the degree of physical change judged in relation to the amount of time that the change took to manifest itself; barring cataclysmic occurrences, most significant evolutionary changes recorded in fossil beds occurred over millions of years, but, because of the slow rate of change, amount to a measurement of roughly 1 darwin. The changes that occurred among the lizard population examined during the study evolved at the extraordinary rate of nearly 2,000 darwins over the 14-year period of the study. Scientists argued that the process of change witnessed in the lizards on a microevolutionary scale was akin to the macroevolutionary pattern of change that had led to the creation of more than 150 species of lizard throughout the Bahamas, prompting the hypothesis that macroevolution may just be microevolution on a large scale. (See also [Biochemistry](#); [Biology](#); [Ecology](#); [Heredity](#).)