The theory of organic 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 hold 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 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 protein enzymes to catalyze, or speed up, the biochemical reactions of life (see Cell; Enzymes). Enzymes 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 chemicals 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 prebiological " 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 prebiological soup (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 occurred 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 theories, however, were 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, places to hide, and opportunities to breed. Accordingly, natural selection favors any trait that helps an organism or its offspring survive.

For example, the daring shown by birds in the face of a predator near the nest involves the risk of death. Nonetheless, natural selection compensates the risk by increasing the offspring’s chances of survival. In 1859 Darwin published his views in ‘ On the Origin of Species by Means of Natural Selection’, and a major controversy was immediately sparked 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. 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, or gene changes, are a source of 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, most 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.