Biology




Biology (from Greek: βίος, *bio*, "life"; and λόγος, *logos*, "knowledge"), more specifically referred to as the **biological sciences**, is the branch of science that studies life. This broad spectrum of empirical fields studies and classifies living organisms and biological phenomena.

Biology as a whole, which is a vast field, examines the structure, function, growth, origin, evolution, and distribution of living things both past and present. It classifies and describes the various forms of organisms, how organisms function, how species come into existence, and the interactions they have with each other and with the natural environment.

Many of the biological sciences are highly specialized disciplines. Traditionally, the specific fields within biology are very broadly grouped by the basic type of organisms being studied:

- botany, the study of plants:
- zoology, the study of animals, and
- microbiology, the study of microorganisms.

The fields within biology are further divided based on the scale at which organisms are studied and the methods used to study them:

- biochemistry examines the fundamental chemistry of life;
- cellular biology examines the basic building block of all life, the cell;
- physiology examines the physical and chemical functions of the tissues and organ systems of an organism; and
- ecology examines how various organisms interrelate.

In addition to all of the basic groupings and specialized fields within biology, many applied fields of biology such as medicine and genetic research are more complex and involve many additional specialized sub-disciplines.

Biology as a unified science was first developed in the nineteenth century, as scientists discovered that all living things shared certain fundamental characteristics and were best studied as a whole. Today, biology is a standard subject of instruction at schools and universities around the world, and over a million papers are published annually in a wide array of biology and medicine journals.

Foundations of modern biology

For

Biology is a branch of science that characterizes and investigates living organisms utilizing the scientific method. There are four broad unifying principles of biology:

- Cell theory. All living organisms are made of at least one cell, the basic unit of function in all organisms. In addition, the core mechanisms and chemistry of all cells in all organisms are similar, and cells emerge only from preexisting cells that multiply through cell division.

- Evolution. Through natural selection and genetic drift, a population's inherited traits change from generation to generation.

- Gene theory. A living organism's traits are encoded in their DNA, the fundamental component of genes. In addition, traits are passed on from one generation to the next by way of these genes. All information flows from genes to the phenotype, the observable physical or biochemical characteristics of the organism. Although the phenotype expressed by the gene may adapt to the environment of the organism, that information is not transferred back to the genes. Only through the process of evolution do genes change in response to the environment.

- Homeostasis. The physiological processes that allow an organism to maintain its internal environment notwithstanding its external environment.

Cell Theory

Main article: Cell theory

The cell is the fundamental unit of life. Cell theory states that all living things are composed of one or more cells, or the secreted products of those cells, for example, shell and bone. Cells arise from other cells through cell division, and in multicellular organisms, every cell in the organism's body is produced from a single cell in a fertilized egg. Furthermore, the cell is considered to be the basic part of the pathological processes of an organism.

Evolution

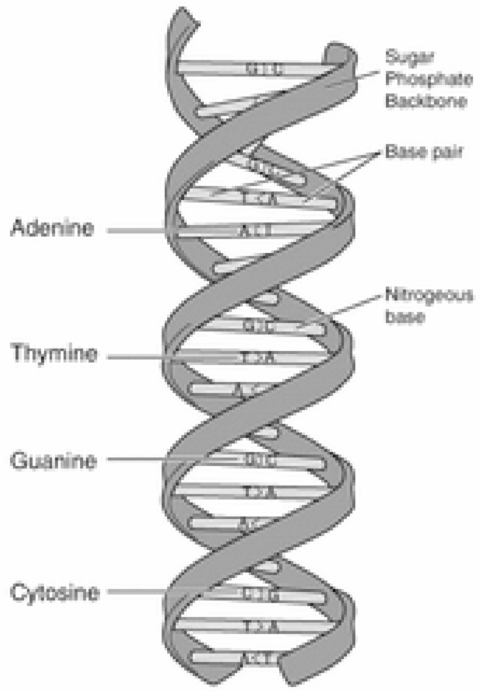
A central organizing concept in biology is that all life has a common origin (see Common descent) and has changed and developed through evolution. This has led to the striking similarity of units and processes discussed in the previous section. Charles Darwin established evolution as a viable theory by articulating its driving force, natural selection (Alfred Russel Wallace is recognized as the co-discoverer of this concept). Darwin theorized that species and breeds developed through the processes of natural selection as well as by artificial selection or selective breeding. Genetic drift was embraced as an additional mechanism of evolutionary development in the modern synthesis of the theory.

The evolutionary history of a species— which describes the characteristics of the various species from which it descended— together with its genealogical relationship to every other species is called its phylogeny. Widely varied approaches to biology generate information about phylogeny. These include the comparisons of DNA sequences conducted within molecular biology or genomics, and comparisons of fossils or other records of ancient organisms in paleontology. Biologists organize and analyze evolutionary relationships through various methods, including phylogenetics, phenetics, and cladistics. For a summary of major events in the evolution of life as currently understood by biologists, see evolutionary timeline.

Up into the 19th century, it was commonly believed that life forms could appear spontaneously under certain conditions (see spontaneous generation). This misconception was challenged by William Harvey's diction that "all life [is] from [an] egg" (from the Latin "Omne vivum ex ovo"), a foundational concept of modern biology. It simply means that there is an unbroken continuity of life from its initial origin to the present time.

A group of organisms shares a common descent if they share a common ancestor. All organisms on the Earth both living and extinct have been or are descended from a common ancestor or an ancestral gene pool. This last universal common ancestor of all organisms is believed to have appeared about 3.5 billion years ago. Biologists generally regard the universality of the genetic code as definitive evidence in favor of the theory of universal common descent (UCD) for all bacteria, archaea, and eukaryotes (see: origin of life).

Gene theory



Schematic representation of DNA, the primary genetic material.

Biological form and function is created from and is passed on to the next generation by genes, which are the primary units of inheritance. Physiological adaption to an organism's environment cannot be coded into its genes and cannot be inherited by its offspring (see Lamarckism). Remarkably, widely different organisms, including bacteria, plants, animals, and fungi, all share the same basic machinery that copies and transcribes DNA into proteins. For example, bacteria with inserted human DNA will correctly yield the corresponding human protein.

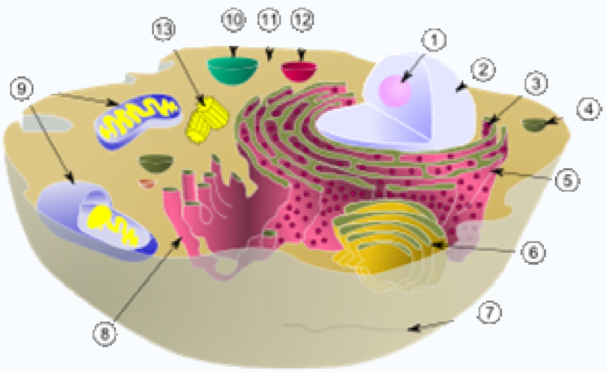
The total complement of genes in an organism or cell is known as its genome which is stored on one or more chromosomes. A chromosome is a single, long DNA strand on which thousands of genes, depending on the organism, are encoded. When a gene is active, the DNA code is transcribed into an RNA copy of the gene's information. A ribosome then translates the RNA into a structural protein or catalytic protein.

Homeostasis

Homeostasis is the ability of an open system to regulate its internal environment to maintain a stable condition by means of multiple dynamic equilibrium adjustments controlled by interrelated regulation mechanisms. All living organisms, whether unicellular or multicellular, exhibit homeostasis. Homeostasis exists at the cellular level, for example cells maintain a stable internal acidity (pH); and at the level of the organism, for example warm-blooded animals maintain a constant internal body temperature. Homeostasis is a term that is also used in association with ecosystems, for example, the atmospheric concentration of carbon dioxide on Earth has been regulated by the concentration of plant life on Earth because plants remove more carbon dioxide from the atmosphere during the daylight hours than they emit to the atmosphere at night. Tissues and organs can also maintain homeostasis.

Research

Structural



Schematic of typical animal cell depicting the various organelles and structures.

Main articles: Molecular biology, Cell biology, Genetics, and Developmental biology

Molecular biology is the study of biology at a molecular level. This field overlaps with other areas of biology, particularly with genetics and biochemistry. Molecular biology chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interrelationship of DNA, RNA, and protein synthesis and learning how these interactions are regulated.

Cell biology studies the physiological properties of cells, as well as their behaviors, interactions, and environment. This is done both on a microscopic and molecular level. Cell biology researches both single-celled organisms like bacteria and specialized cells in multicellular organisms like humans.

Understanding cell composition and how they function is fundamental to all of the biological sciences. Appreciating the similarities and differences between cell types is particularly important in the fields of cell and molecular biology. These fundamental similarities and differences provide a unifying theme, allowing the principles learned from studying one cell type to be extrapolated and generalized to other cell types.

Genetics is the science of genes, heredity, and the variation of organisms. Genes encode the information necessary for synthesizing proteins, which in turn play a large role in influencing (though, in many instances, not completely determining) the final phenotype of the organism. In modern research, genetics provides important tools in the investigation of the function of a particular gene, or the analysis of genetic interactions.

Within organisms, genetic information generally is carried in chromosomes, where it is represented in the chemical structure of particular DNA molecules.

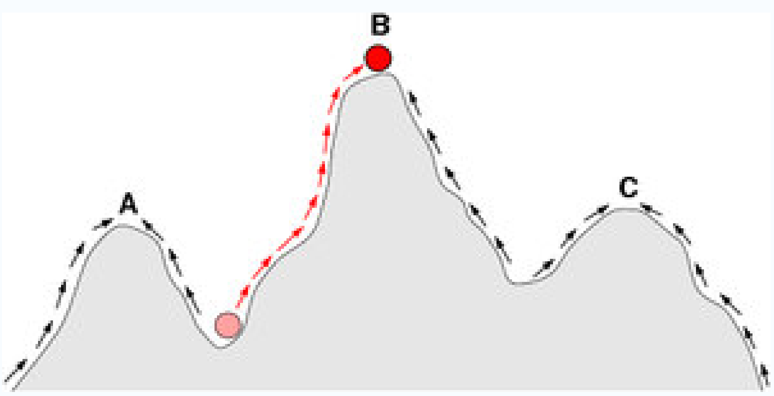
Developmental biology studies the process by which organisms grow and develop. Originating in embryology, modern developmental biology studies the genetic control of cell growth, differentiation, and "morphogenesis," which is the process that gives rise to tissues, organs, and anatomy. Model organisms for developmental biology include the round worm *Caenorhabditis elegans*, the fruit fly *Drosophila melanogaster*, the zebrafish *Brachydanio rerio*, the mouse *Mus musculus*, and the weed *Arabidopsis thaliana*.

Physiological

Physiology studies the mechanical, physical, and biochemical processes of living organisms by attempting to understand how all of the structures function as a whole. The theme of "structure to function" is central to biology. Physiological studies have traditionally been divided into plant physiology and animal physiology, but the principles of physiology are universal, no matter what particular organism is being studied. For example, what is learned about the physiology of yeast cells can also apply to human cells. The field of animal physiology extends the tools and methods of human physiology to non-human species. Plant physiology also borrows techniques from both fields.

Anatomy is an important branch of physiology and considers how organ systems in animals, such as the nervous, immune, endocrine, respiratory, and circulatory systems, function and interact. The study of these systems is shared with medically oriented disciplines such as neurology and immunology.

Evolution



In population genetics the evolution of a population of organisms is sometimes depicted as if travelling on a fitness landscape. The arrows indicate the preferred flow of a population on the landscape, and the points A, B, and C are local optima. The red ball indicates a population that moves from a very low fitness value to the top of a peak.

Evolution is concerned with the origin and descent of species, as well as their change over time, and includes scientists from many taxonomically-oriented disciplines. For example, it generally involves scientists who have special training in particular organisms such as mammalogy, ornithology, botany, or herpetology, but use those organisms as systems to answer general questions about evolution. Evolutionary biology is mainly based on paleontology, which uses the fossil record to answer questions about the mode and tempo of evolution, as well as the developments in areas such as population genetics and evolutionary theory. In the 1990s, developmental biology re-entered evolutionary biology from its initial exclusion from the modern synthesis through the study of evolutionary developmental biology. Related fields which are often considered part of evolutionary biology are phylogenetics, systematics, and taxonomy.

Up into the 19th century, it was believed that life forms were being continuously created under certain conditions (see spontaneous generation). This misconception was challenged by William Harvey's diction that "all life [is] from [an] egg" (from the Latin "Omne vivum ex ovo"), a foundational concept of modern biology. It simply means that there is an unbroken continuity of life from its initial origin to the present time.

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The two major traditional taxonomically-oriented disciplines are botany and zoology. Botany is the scientific study of plants. Botany covers a wide range of scientific disciplines that study the growth, reproduction, metabolism, development, diseases, and evolution of plant life. Zoology involves the study of animals, including the study of their physiology within the fields of anatomy and embryology. The common genetic and developmental mechanisms of animals and plants is studied in molecular biology, molecular genetics, and developmental biology. The ecology of animals is covered under behavioral ecology and other fields.

Taxonomy

A phylogenetic tree of all living things, based on rRNA gene data, showing the separation of the three domains bacteria, archaea, and eukaryotes as described initially by Carl Woese. Trees constructed with other genes are generally similar, although they may place some early-branching groups very differently, presumably owing to rapid rRNA evolution. The exact relationships of the three domains are still being debated.

Classification is the province of the disciplines of systematics and taxonomy. Taxonomy places organisms in groups called taxa, while systematics seeks to define their relationships with each other. This classification technique has evolved to reflect advances in cladistics and genetics, shifting the focus from physical similarities and shared characteristics to phylogenetics.

Traditionally, living things have been divided into five kingdoms:

> Monera -- Protista -- Fungi -- Plantae -- Animalia

However, many scientists now consider this five-kingdom system to be outdated. Modern alternative classification systems generally begin with the three-domain system:

> Archaea (originally Archaebacteria) -- Bacteria (originally Eubacteria) -- Eukaryota

These domains reflect whether the cells have nuclei or not, as well as differences in the cell exteriors.

Further, each kingdom is broken down continuously until each species is separately classified. The order is:

1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. Genus
7. Species

The scientific name of an organism is obtained from its genus and species. For example, humans would be listed as *Homo sapiens*. *Homo* would be the genus and *sapiens* is the species. Whenever writing the scientific name of an organism, it is proper to capitalize the first letter in the genus and put all of the species in lowercase; in addition the entire term would be put in italics or underlined. The term used for classification is called taxonomy.

There is also a series of intracellular parasites that are progressively "less alive" in terms of metabolic activity:

Viruses -- Viroids -- Prions

The dominant classification system is called Linnaean taxonomy, which includes ranks and binomial nomenclature. How organisms are named is governed by international agreements such as the International Code of Botanical Nomenclature (ICBN), the International Code of Zoological Nomenclature (ICZN), and the International Code of Nomenclature of Bacteria (ICNB). A fourth Draft BioCode was published in 1997 in an attempt to standardize naming in these three areas, but it has yet to be formally adopted. The Virus cInternational Code of Virus Classification and Nomenclature (ICVCN) remains outside the BioCode.

Environmental

Main articles: Ecology, Ethology, Behavior, and Biogeography

Ecology studies the distribution and abundance of living organisms, and the interactions between organisms and their environment. The environment of an organism includes both its habitat, which can be described as the sum of local abiotic factors such as climate and ecology, as well as the other the organisms that share its habitat. Ecological systems are studied at several different levels, from individuals and populations to ecosystems and the biosphere. As can be surmised, ecology is a science that draws on several disciplines.

Ethology studies animal behavior (particularly of social animals such as primates and canids), and is sometimes considered a branch of zoology. Ethologists have been particularly concerned with the evolution of behavior and the understanding of behavior in terms of the theory of natural selection. In one sense, the first modern ethologist was Charles Darwin, whose book "The Expression of the Emotions in Man and Animals" influenced many ethologists.

Biogeography studies the spatial distribution of organisms on the Earth, focusing on topics like plate tectonics, climate change, dispersal and migration, and cladistics.

Every living thing interacts with other organisms and its environment. One reason that biological systems can be difficult to study is that so many different interactions with other organisms and the environment are possible, even on the smallest of scales. A microscopic bacterium responding to a local sugar gradient is responding to its environment as much as a lion is responding to its environment when it searches for food in the African savannah. For any given species, behaviors can be co-operative, aggressive, parasitic or symbiotic. Matters become more complex when two or more different species interact in an ecosystem. Studies of this type are the province of ecology.

History

Although the concept of ***biology*** as a single coherent field arose in the 19th century, the biological sciences emerged from traditions of medicine and natural history reaching back to Galen and Aristotle in ancient Greece. During the Renaissance and early modern period, biological thought was revolutionized by a renewed interest in empiricism and the discovery of many novel organisms. Prominent in this movement were Vesalius and Harvey, who used experimentation and careful observation in physiology, and naturalists such as Linnaeus and Buffon who began to classify the diversity of life and the fossil record, as well as the development and behavior of organisms. Microscopy revealed the previously unknown world of microorganisms, laying the groundwork for cell theory. The growing importance of natural theology, partly a response to the rise of mechanical philosophy, encouraged the growth of natural history.

Over the 18th and 19th centuries, biological sciences such as botany and zoology became increasingly professional scientific disciplines. Lavoisier and other physical scientists began to connect the animate and inanimate worlds through physics and chemistry. Explorer-naturalists such as Alexander von Humboldt investigated the interaction between organisms and their environment, and the ways this relationship depends on geography—laying the foundations for biogeography, ecology and ethology. Naturalists began to reject essentialism and consider the importance of extinction and the mutability of species. Cell theory provided a new perspective on the fundamental basis of life. These developments, as well as the results from embryology and paleontology, were synthesized in Charles Darwin's theory of evolution by natural selection. The end of the 19th century saw the fall of spontaneous generation and the rise of the germ theory of disease, though the mechanism of inheritance remained a mystery.

In the early 20th century, the rediscovery of Mendel's work led to the rapid development of genetics by Thomas Hunt Morgan and his students, and by the 1930s the combination of population genetics and natural selection in the "neo-Darwinian synthesis". New disciplines developed rapidly, especially after Watson and Crick proposed the structure of DNA. Following the establishment of the Central Dogma and the cracking of the genetic code, biology was largely split between *organismal biology*—the fields that deal with whole organisms and groups of organisms—and the fields related to *cellular and molecular biology*. By the late 20th century, new fields like genomics and proteomics were reversing this trend, with organismal biologists using molecular techniques, and molecular and cell biologists investigating the interplay between genes and the environment, as well as the genetics of natural populations of organisms.