Text For Biology at Roxbury Community College

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Welcome

This Is A Text For The Introductory Biology Courses (SCI103 And SCI104) at RCC.

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Acknowledgements

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Chapter 1

Biology

Biology is the natural science that studies living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development and evolution. Despite the complexity of the science, certain unifying concepts consolidate it into a single, coherent field. Biology recognizes the cell as the basic unit of life, genes as the basic unit of heredity, and evolution as the engine that propels the creation and extinction of species. Living organisms are open systems that survive by transforming energy and decreasing their local entropy to maintain a stable and vital condition defined as homeostasis.

Sub-disciplines of biology are defined by the research methods employed and the kind of system studied: theoretical biology uses mathematical methods to formulate quantitative models while experimental biology performs empirical experiments to test the validity of proposed theories and understand the mechanisms underlying life and how it appeared and evolved from nonliving matter about 4 billion years ago through a gradual increase in the complexity of the system.

Biology derives from the Ancient Greek words of □□□□; romanized bíos meaning "life" and -□□□□□; romanized logía (-logy) meaning "branch of study" or "to speak". Those combined make the Greek word □□□□□□□□; romanized biología meaning biology. Despite this, the term □□□□□□□□ as a whole didn't exist in Ancient Greek. The first to borrow it was the English and French (biologie). Since the advent of the scientific era, reanalyzable as a compound using the combining forms bio + logy.[clarification needed]

The Latin-language form of the term first appeared in 1736 when Swedish scientist Carl Linnaeus (Carl von Linné) used biologi in his Bibliotheca Botanica. It was used again in 1766 in a work entitled Philosophiae naturalis sive physicae: tomus III, continens geologian, biologian, phytologian generalis, by Michael Christoph Hanov, a disciple of Christian Wolff. The first German use, Biologie, was in a 1771 translation of Linnaeus' work. In 1797, Theodor Georg August Roose used the term in the preface of a book, Grundzüge der Lehre van der Lebenskraft. Karl Friedrich Burdach used the term in 1800 in a more restricted sense of the study of human beings from a morphological, physiological and psychological perspective (Propädeutik zum Studien der gesammten Heilkunst). The term came into its modern usage with the six-volume treatise Biologie, oder Philosophie der lebenden Natur (1802–22) by Gottfried Reinhold Treviranus, who announced:

The objects of our research will be the different forms and manifestations of life, the conditions and laws under which these phenomena occur, and the causes through which they have been effected. The science that concerns itself with these objects we will indicate by the name biology [Biologie] or the doctrine of life [Lebenslehre].

Although modern biology is a relatively recent development, sciences related to and included within it have been studied since ancient times. Natural philosophy was studied as early as the ancient civilizations of Mesopotamia, Egypt, the Indian subcontinent, and China. However, the origins of modern biology and its approach to the study of nature are most often traced back to ancient Greece. While the formal study of medicine dates back to Pharaonic Egypt, it was Aristotle (384–322 BC) who contributed most extensively to the development of biology. Especially important are his History of Animals and other works where he showed naturalist leanings, and later more empirical works that focused on biological causation and the diversity of life. Aristotle's successor at the Lyceum, Theophrastus, wrote a series of books on botany that survived as the most important contribution of antiquity to the plant sciences, even into the Middle Ages.

Scholars of the medieval Islamic world who wrote on biology included al-Jahiz (781–869), Al-Dīnawarī (828–896), who wrote on botany, and Rhazes (865–925) who wrote on anatomy and physiology. Medicine was especially well studied by Islamic scholars working in Greek philosopher traditions, while natural history drew heavily on Aristotelian thought, especially in upholding a fixed hierarchy of life.

Biology began to quickly develop and grow with Anton van Leeuwenhoek's dramatic improvement of the microscope. It was then that scholars discovered spermatozoa, bacteria, infusoria and the diversity of microscopic life. Investigations by Jan Swammerdam led to new interest in entomology and helped to develop the basic techniques of microscopic dissection and staining.

Advances in microscopy also had a profound impact on biological thinking. In the early 19th century, a number of biologists pointed to the central importance of the cell. Then, in 1838, Schleiden and Schwann began promoting the now universal ideas that (1) the basic unit of organisms is the cell and (2) that individual cells have all the characteristics of life, although they opposed the idea that (3) all cells come from the division of other cells. Thanks to the work of Robert Remak and Rudolf Virchow, however, by the 1860s most biologists accepted all three tenets of what came to be known as cell theory.

Meanwhile, taxonomy and classification became the focus of natural historians. Carl Linnaeus published a basic taxonomy for the natural world in 1735 (variations of which have been in use ever since), and in the 1750s introduced scientific names for all his species. Georges-Louis Leclerc, Comte de Buffon, treated species as artificial categories and living forms as malleable—even suggesting the possibility of common descent. Although he was opposed to evolution, Buffon is a key figure in the history of evolutionary thought; his work influenced the evolutionary theories of both Lamarck and Darwin.

Serious evolutionary thinking originated with the works of Jean-Baptiste Lamarck, who was the first to present a coherent theory of evolution. He posited that evolution was the result of environmental stress on properties of animals, meaning that the more frequently and rigorously an organ was used, the more complex and efficient it would become, thus adapting the animal to its environment. Lamarck believed that these acquired traits could then be passed on to the animal's offspring, who would further develop and perfect them. However, it was the British naturalist Charles Darwin, combining the biogeographical approach of Humboldt, the uniformitarian geology of Lyell, Malthus's writings on population growth, and his own morphological expertise and extensive natural observations, who forged a more successful evolutionary theory based on natural selection; similar reasoning and evidence led Alfred Russel Wallace to independently reach the same conclusions. Although it was the subject of controversy (which continues to this day), Darwin's theory quickly spread through the scientific community and soon became a central axiom of the rapidly developing science of biology.

The discovery of the physical representation of heredity came along with evolutionary principles and population genetics. In the 1940s and early 1950s, experiments pointed to DNA as the component of chromosomes that held the trait-carrying units that had become known as genes. A focus on new kinds of model organisms such as viruses and bacteria, along with the discovery of the double-helical structure of DNA in 1953, marked the transition to the era of molecular genetics. From the 1950s to the present times, biology has been vastly extended in the molecular domain. The genetic code was cracked by Har Gobind Khorana, Robert W. Holley and Marshall Warren Nirenberg after DNA was understood to contain codons. Finally, the Human Genome Project was launched in 1990 with the goal of mapping the general human genome. This project was essentially completed in 2003, with further analysis still being published. The Human Genome Project was the first step in a globalized effort to incorporate accumulated knowledge of biology into a functional, molecular definition of the human body and the bodies of other organisms.

1.1 Foundations of modern biology

1.1.1 Cell theory

Cell theory states that the cell is the fundamental unit of life, that all living things are composed of one or more cells, and that all cells arise from pre-existing cells through cell division. In multicellular organisms, every cell in the organism's body derives ultimately from a single cell in a fertilized egg. The cell is also considered to be the basic unit in many pathological processes. In addition, the phenomenon of energy flow occurs in cells in processes that are part of the function known as metabolism. Finally, cells contain hereditary information (DNA), which is passed from cell to cell during cell division. Research into the origin of life, abiogenesis, amounts to an attempt to discover the origin of the first cells.

1.1.2 Evolution

A central organizing concept in biology is that life changes and develops through evolution, and that all life-forms known have a common origin. The theory of evolution postulates that all organisms on the Earth, both living and extinct, have descended from a common ancestor or an ancestral gene pool. This universal common ancestor of all organisms is believed to have appeared about 3.5 billion years ago. Biologists regard the ubiquity of the genetic code as definitive evidence in favor of the theory of universal common descent for all bacteria, archaea, and eukaryotes (see: origin of life).

The term "evolution" was introduced into the scientific lexicon by Jean-Baptiste de Lamarck in 1809, and fifty years later Charles Darwin posited a scientific model of natural selection as evolution's driving force. (Alfred Russel Wallace is recognized as the co-discoverer of this concept as he helped research and experiment with the concept of evolution.) Evolution is now used to explain the great variations of life found on Earth.

Darwin theorized that species flourish or die when subjected to the processes of natural 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 the species—which describes the characteristics of the various species from which it descended—together with its genealogical relationship to every other species is known as its phylogeny. Widely varied approaches to biology generate information about phylogeny. These include the comparisons of DNA sequences, a product of molecular biology (more particularly genomics), and comparisons of fossils or other records of ancient organisms, a product of 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.)

Evolution is relevant to the understanding of the natural history of life forms and to the understanding of the organization of current life forms. But, those organizations can only be understood in light of how they came to be by way of the process of evolution. Consequently, evolution is central to all fields of biology.

1.1.3 Genetics

Genes are the primary units of inheritance in all organisms. A gene is a unit of heredity and corresponds to a region of DNA that influences the form or function of an organism in specific ways. All organisms, from bacteria to animals, share the same basic machinery that copies and translates DNA into proteins. Cells transcribe a DNA gene into an RNA version of the gene, and a ribosome then translates the RNA into a sequence of amino acids known as a protein. The translation code from RNA codon to amino acid is the same for most organisms. For example, a sequence of DNA that codes for insulin in humans also codes for insulin when inserted into other organisms, such as plants.

DNA is found as linear chromosomes in eukaryotes, and circular chromosomes in prokaryotes. A chromosome is an organized structure consisting of DNA and histones. The set of chromosomes in a cell and any other hereditary information found in the mitochondria, chloroplasts, or other locations is collectively known as a cell's genome. In eukaryotes, genomic DNA is localized in the cell nucleus, or with small amounts in mitochondria and chloroplasts. In prokaryotes, the DNA is held within an irregularly shaped body in the cytoplasm called the nucleoid. The genetic information in a genome is held within genes, and the complete assemblage of this information in an organism is called its genotype.

1.1.4 Homeostasis

Homeostasis is the ability of an open system to regulate its internal environment to maintain stable conditions by means of multiple dynamic equilibrium adjustments that are controlled by interrelated regulation mechanisms. All living organisms, whether unicellular or multicellular, exhibit homeostasis.

To maintain dynamic equilibrium and effectively carry out certain functions, a system must detect and respond to perturbations. After the detection of a perturbation, a biological system normally responds through negative feedback that stabilize conditions by reducing or increasing the activity of an organ or system. One example is the release of glucagon when sugar levels are too low.

1.1.5 Energy

The survival of a living organism depends on the continuous input of energy. Chemical reactions that are responsible for its structure and function are tuned to extract energy from substances that act as its food and transform them to help form new cells and sustain them. In this process, molecules of chemical substances that constitute food play two roles; first, they contain energy that can be transformed and reused in that organism's biological, chemical reactions; second, food can be transformed into new molecular structures (biomolecules) that are of use to that organism.

The organisms responsible for the introduction of energy into an ecosystem are known as producers or autotrophs. Nearly all such organisms originally draw their energy from the sun. Plants and other phototrophs use solar energy via a process known as photosynthesis to convert raw materials into organic molecules, such as ATP, whose bonds can be broken to release energy. A few ecosystems, however, depend entirely on energy extracted by chemotrophs from methane, sulfides, or other non-luminal energy sources.

Some of the energy thus captured produces biomass and energy that is available for growth and development of other life forms. The majority of the rest of this biomass and energy are lost as waste molecules and heat. The most important processes for converting the energy trapped in chemical substances into energy useful to sustain life are metabolism and cellular respiration.

1.2 Areas And Levels of Study And Research in Biology

1.2.1 Structural

Molecular biology is the study of biology at the molecular level. This field overlaps with other areas of biology, particularly those of genetics and biochemistry. Molecular biology is a study of the interactions of the various systems within a cell, including the interrelationships of DNA, RNA, and protein synthesis and how those interactions are regulated.

The next larger scale, cell biology, studies the structural and physiological properties of cells, including their internal behavior, interactions with other cells, and with their environment. This is done on both the microscopic and molecular levels, for unicellular organisms such as bacteria, as well as the specialized cells of multicellular organisms such as humans. Understanding the structure and function of cells is fundamental to all of the biological sciences. The similarities and differences between cell types are particularly relevant to molecular biology.

Anatomy is a treatment of the macroscopic forms of such structures organs and organ systems.

Genetics is the science of genes, heredity, and the variation of organisms. Genes encode the information needed by cells for the synthesis of proteins, which in turn play a central role in influencing the final phenotype of the organism. Genetics provides research tools used in the investigation of the function of a particular gene, or the analysis of genetic interactions. Within organisms, genetic information is physically represented as chromosomes, within which it is represented by a particular sequence of amino acids in particular DNA molecules.

Developmental biology studies the process by which organisms grow and develop. Developmental biology, originated from embryology, studies the genetic control of cell growth, cellular differentiation, and "cellular morphogenesis," which is the process that progressively 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 Danio rerio, the mouse Mus musculus, and the weed Arabidopsis thaliana. (A model organism is a species that is extensively studied to understand particular biological phenomena, with the expectation that discoveries made in that organism provide insight into the workings of other organisms.)

1.2.2 Physiological

Physiology is the study of the mechanical, physical, and biochemical processes of living organisms 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 some 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 borrows techniques from both research fields.

Physiology is the study the interaction of how, for example, the nervous, immune, endocrine, respiratory, and circulatory systems, function and interact. The study of these systems is shared with such medically oriented disciplines as neurology and immunology.

1.2.3 Evolutionary

Evolutionary research is concerned with the origin and descent of species, and their change over time. It employs scientists from many taxonomically oriented disciplines, for example, those with special training in particular organisms such as mammalogy, ornithology, botany, or herpetology, but are of use in answering more general questions about evolution.

Evolutionary biology is partly based on paleontology, which uses the fossil record to answer questions about the mode and tempo of evolution, and partly on the developments in areas such as population genetics. In the 1980s, developmental biology re-entered evolutionary biology after its initial exclusion from the modern synthesis through the study of evolutionary developmental biology. Phylogenetics, systematics, and taxonomy are related fields often considered part of evolutionary biology.

1.2.4 Systematic

Multiple speciation events create a tree structured system of relationships between species. The role of systematics is to study these relationships and thus the differences and similarities between species and groups of species. However, systematics was an active field of research long before evolutionary thinking was common.