new dictionary of the history of ideas

maryanne cline horowitz, editor in chief

volume 1

Abolitionism to Common Sense

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(both oral and written). In the early twenty-first century, as a result of these trends, biography is an increasingly global art, evidenced by the diversity in its subjects and forms.

See also ***Autobiography; Genre; Literature.***

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Frederick Liers

BIOLOGY. *Biology* comes from the Greek word for life, *bis,* and the Greek word for thought or reasoning, *logos.* It denotes the science that studies life, the properties and processes that sustain life, the evolutionary history of life, and particular living organisms. It is a science of enormous diversity, breadth, and heterogeneity unified only by the conceptual framework provided by the theory of evolution. Indeed, as famously noted in 1973 by the Russian evolutionary geneticist Theodosius Dobzhansky (1900–1975), "Nothing in biology makes sense except in the light of evolution"—a quote now replicated in so many university-level textbooks that it is almost a dictum in modern biology.

One reason for the diversity of biology comes from the staggering diversity of organisms that can be considered living. These range from viruses, bacteria, and fungi to plants and animals, including humans. Another reason is that life can be studied on various levels in a hierarchy that ranges from the organic-macromolecular level to genes, cells, tissues, organs, and entire organisms. Furthermore, organisms interact in, and can be organized into, families, communities, societies, species, populations, biomes or biota, and perhaps even the global systems (as in the controversial Gaia hypothesis, which postulates that the earth itself is a living organism). To a large extent, biological subdisciplines are organized around each of these levels of activity or organization. Thus, for example, cellular biology, or cytology (coming from the Greek word *cyto* for cell), deals specifically with the study of cells, while ecology (coming from the Greek word *oikos* for habitat) deals with interactions between populations, species, communities, and biomes and the processes that sustain them. Since biology deals immediately with living organisms and processes, it has a large applied component. It touches on medical and health-related areas, pharmacy, agriculture, forestry, and biological oceanography. In contemporary society, the promises and problems associated with applications of biology are staggering. They range from stem-cell research, the development and use of genetically modified organisms, and the use of biological tools as identity markers (as in DNA "fingerprinting") to the possibility of designer babies and human cloning. Whereas the physical sciences and their applications dominated science for much of the history of science, the biological sciences now dominate both popular and scientific discussions, especially after the discovery of the structure of DNA in 1953. Viewing the revolution precipitated by the applications of biology to society at the closing of the twentieth century, many commentators anticipate that the new century will be the century of biology.

The Origins of Biology

Though biology is generally regarded as a modern science with late origins in the early to mid-nineteenth century, it drew on varied traditions, practices, and areas of inquiry beginning in antiquity. Traditional histories of biology generally target two areas that merged into modern biological science: medicine and natural history. The tradition of medicine dates back to the work of ancient Greek medical practitioners such as Hippocrates of Kos (b. 460 B.C.E.) and to figures such as Galen of Pergamum (c. 130–c. 200), who contributed much to early understanding of anatomy and physiology. The tradition of natural history dates back to the work of Aristotle (384–322 B.C.E.). Especially important are his *History of Animals* and other works where he showed naturalist leanings. Also important is the work of Aristotle's student Theophrastus (d. 287 B.C.E.), who contributed to an understanding of plants. Aristotle and Theophrastus contributed not only to zoology and botany, respectively, but also to comparative biology, ecology, and especially taxonomy (the science of classification).

Both natural history and medicine flourished in the middle ages, though work in these areas often proceeded independently. Medicine was especially well studied by Islamic scholars working in the Galenic and Aristotelian traditions, while natural history drew heavily on Aristotelian philosophy, especially in upholding a fixed hierarchy of life. The Roman naturalist Caius Plinius Secundus (23–79), known as Pliny, also had a major influence on natural history during the middle ages, notably through his compendium *Natural History* (later shown to be rife with errors of fact). Without doubt the most outstanding contributor to natural history in the middle ages is Albertus Magnus (1206–1280), recognized for his superb botanical studies and for his work in physiology and zoology. A lesser known figure is Holy Roman Emperor Frederick II (1194–1250), whose treatise *The Art of Falconry* is one of the first serious accounts of ornithology.

Though animals traditionally drew the attention of many naturalists, the study of zoology remained underdeveloped during the middle ages, relying heavily on illustrated books of animals modeled on medieval bestiaries. Botany, on the other hand, flourished in the Renaissance and early modern period. The study of plants was important in medicine, as well as natural history (and in fact constituted one of the few early points of common focus in the two areas), because plants were regarded as *materia medica,* substances with noted medicinal properties. These medicinal properties drew medical attention to plants. Hence it became standard practice to plant gardens next to primary centers of medical instruction, and professors of medicine were very often experts in *materia medica* and served as garden curators. Indeed, noted taxonomists of the early modern period—individuals such as Andrea Cesalpino (1519–1603) and Carl Linnaeus (1707–1778), both of whom are considered fathers of modern botany for their work in reforming taxonomy—were simultaneously physicians and botanists. An exception was John Ray (1627–1705), an English taxonomist who also worked with animals.

Also leading to the growing interest in and need for taxonomy and to an unprecedented development of natural history were the voyages of exploration associated with the establishment of colonies from the late fifteenth century. Largely to meet the demand to classify the collections made by explorers and travelers in order to exploit these natural commodities, gardens and museums of natural history were created in European centers associated with colonial conquests, especially Madrid, Paris, and London. A new period of scientific exploration dawned with the first voyage of Captain James Cook, whose expeditions included not only astronomers and artists but also botanists, such as Joseph Banks (1743–1820). On returning to London, Banks was instrumental in helping to found the Royal Institution of Great Britain, as well as in continuing to expand Kew Garden and the Royal Society. He also encouraged these institutions to serve the interests of both natural history and the expanding British Empire in the late eighteenth and early nineteenth centuries.

While botany and medicine were closely linked, anatomy and physiology followed other trajectories. After Galen, the next major figure in the history of anatomy is Andreas Vesalius (1514–1564) of Belgium. Unlike many anatomists (such as Galen, who relied on dissections of animals such as pigs and Barbary apes), Vesalius drew his knowledge of the human body from detailed dissections on human cadavers. He was unusual for his time in believing that the authority of nature should supercede the authority of ancient texts. His seven-volume atlas of human anatomy, *De Humani Corporis Fabrica* (On the fabric of the human body), covered skeletal and muscular anatomy as well as the major organ systems of the body. Skillfully illustrated by some of the leading Renaissance artists, the atlas was considered a work of art as well as of anatomical science. Although Vesalius challenged many of tenets held by Galen and his numerous commentators, he nonetheless retained some erroneous conventions present in Galen's anatomy, such as the existence of pores in the septum of the heart and "horned" appendages in the uterus (present in the pig uterus but not in the human uterus). Vesalius's work was shortly followed by the work of anatomical specialists such as Bartolomeo Eustachio (1510–1574) and Gabriele Falloppio (1523–1562). Eustachio specialized in the anatomy of the ear, and Falloppio specialized in the female reproductive tract.

Developments in anatomy that turned interest to the parts and organs of the body were accompanied by questions dealing with organ function. In the sixteenth century, physiology, the science that deals specifically with the functioning of living bodies, began to flourish. The major animal physiologist of this period was William Harvey (1578–1657). Harvey performed numerous dissections and vivisections on a range of animals to determine that blood circulates through the body and is not manufactured *de novo,* as Galenic tradition had dictated. Harvey's influence was felt not only in medicine, but also in comparative physiology and comparative biology, since he performed his experiments on diverse animal systems. His experiments and major treatise, *An Anatomical Disputation concerning the Movement of the Heart and Blood in Living Creatures* (1628), are considered one of the first demonstrations of the method of hypothesis testing and experimentation. While Harvey frequently drew analogies between the pumping action of the heart and mechanical pumps, he resisted the idea that the body entirely obeyed mechanistic principles. Unlike his contemporary René Descartes (1596–1650), who held mechanistic theories of the functioning of animal bodies, Harvey maintained that some kind of nonmechanistic special forces, later called "vitalistic," were responsible for the life processes of animate matter.

The mechanical philosophy—the belief that the universe and its constituent parts obeyed mechanical principles that could be understood and determined through reasoned observation and the new scientific method—thus made its way into the history of biology. This engendered a lively discussion between mechanism and vitalism, between the idea that life obeyed mechanistic principles and the idea that life depended on nonmechanistic "vital" principles or somehow acquired "emergent properties." The debate cycled on and off for much of the subsequent history of biology, up to the middle decades of the twentieth century.

During the Renaissance, the mechanical philosophy did gain some proponents in anatomy and physiology, the most notable figure being Giovanni Borelli (1608–1679), who sought to understand muscle action in animal bodies in terms of levers and pulleys. Some early embryologists, as followers of Descartes, espoused the belief that development too followed mechanistic principles. In what came to be known as preformation theory or "emboitement," the seeds of mature but miniaturized mature adult forms or *homunculi* were thought to be embedded entirely intact in mature organisms (as though they were encased in a box within a box, hence the name "emboitement"). Prominent advocates of this view included Marcello Malpighi (1628–1694) and Jan Swammerdam (1637–1680). This stood in contrast to the idea of "epigenesis," the belief dating back to Aristotle and his commentators that development began from initially undifferentiated material (usually the ovum) and then followed an epigenetically determined path of development after fertilization. One of the more prominent proponents of this theory was Pierre Louis Maupertuis (1698–1759), who argued that preformationist theories could not explain why offspring bore characteristics of both parents.

In the seventeenth and eighteenth centuries, theories of embryology and development were superimposed with theories of sexual reproduction, along with a number of theories on the origins of life, most of which upheld the idea of spontaneous generation. During this period debates raged over spontaneous generation, the idea that life was spontaneously created out of inanimate matter. The popular belief that living organisms propagated from mud in streams, dirt and detritus, or environments such as rotting meat was supported by a number of scholars from antiquity on. William Harvey's research into reproduction, published in 1651 as *Exercitationes de Generatione Animalium* (Essays on the generation of animals), began to cast doubt on spontaneous generation. Harvey believed that all life reproduced sexually, a view he pithily stated with his famous dictum *Ex ovo omnia* ("Everything comes from the egg"). In 1668 the Italian physician Francesco Redi (1626–1697) performed a famous experiment that further detracted from the theory of spontaneous generation. By carefully covering rotting meat so that it was not accessible to flies, he showed that maggots did not spontaneously emerge. The idea that sexual reproduction characterized much of life was further reinforced when Nehemiah Grew (1641–1711) demonstrated sexuality in plants in 1682. Later, in 1768, the Italian physiologist Lazzaro Spallanzani (1729–1799) offered additional evidence disproving spontaneous generation, and in 1779 he gave an account of the sexual function of ovum and sperm. Despite this accumulating experimental evidence against spontaneous generation, new developments continued to fuel belief in spontaneous generation. In 1740, for example, Charles Bonnet (1720–1793) discovered parthenogenesis ("virgin birth"—an asexual form of reproduction) in aphids, and in 1748 John Turberville Needham (1731–1781) offered evidence of what he thought were spontaneously generated microbes in a sealed flask of broth (this was later challenged by Pierre-Louis Moreau de Maupertuis [1698–1759]). Finally, the discovery of microbial life supported the idea that living organisms spontaneously emerged from natural environments such as pond water. The seventeenth and eighteenth centuries thus witnessed a number of debates that were only resolved much later in the late nineteenth century when distinctions were made between the very different processes associated with reproduction, the origins of life, and embryological or developmental unfolding. Belief in spontaneous generation was finally put to rest in 1860 by the celebrated "swan-necked flask" experiments of Louis Pasteur (1822–1895).

Other notable developments in the origins of biology came as the result of new instruments and technologies, the most important of which was the microscope. Developed independently by Robert Hooke (1635–1703) in England and Antony Van Leeuwenhoek (1632–1723) in the Netherlands, the microscope revealed a previously unseen and entirely unimagined universe of life. Robert Hooke first observed repeating units he described as "cells" in his *Micrographia* (1665), while Leeuwenhoek observed varied motile organisms he described as "animalcules." While the microscope opened up cytological and microbiological explorations, it also shattered Aristotle's notion that life is organized along a *scala naturae* (ladder of nature), since new and minute animal forms were not easily located on the ladder of creation. It also fueled the belief in spontaneous generation. Pioneering the use of the microscope and its application to anatomy, Marcello Malphighi (1628–1694), Italian professor of medicine and personal physician to Pope Innocent XII, drawing on the previous work of Andrea Cesalpino and William Harvey, studied the circulatory and respiratory systems of a range of animals (especially insects). He was one of the first to study major organ groups such as the brain, lungs, and kidneys in diverse organisms.

Modern Biology

Though there is some disagreement among historians of biology about the precise origins, the transition to modern biology appears to have occurred from the late eighteenth century to the early nineteenth century. A confluence of developments brought about this transition. In France naturalists reformed taxonomy and began to recognize the extinction of life forms. This progress resulted from the work of natural historians such as the Compte de Buffon (1707–1788), Georges Cuvier (1769–1832), Étienne Geoffroy de Saint Hilaire (1772–1844), and Jean-Baptiste de Lamarck (1744–1829) at institutions such as the Jardin du Roi. New sciences emerged, including comparative anatomy and paleontology, areas in which Cuvier is still recognized as the founding father. French anatomists such as Xavier Bichat (1771–1802) and physiologists such as François Magendie (1783–1855), by experimenting on animal systems (sometimes to questionable excess in the case of Magendie), refined and enhanced understanding of fundamental physiological processes, and thereby revolutionized physiological understanding of life. In Germany the insights of natural philosophers such as Johann Wolfgang von Goethe (1749–1832) and Lorenz Oken (1779–1851) began to generate a serious interest in a unified science of life.

All of this activity was echoed by a number of early references to biology in a number of obscure German contexts beginning in the late eighteenth century. Traditional histories generally pinpoint the first general use of the term *biology* at 1800 in the medical treatise *Prapädeutik zum Studium der gesammten Heilkunst* (Propaedeutic to the study of general medicine) by Karl Friedrich Burdach (1776–1847), who used it mostly for the study of human morphology, physiology, and psychology. It appeared again in 1802 in the work of the German naturalist Gottfried Treviranus (1776–1837) and in the work of Jean-Baptiste de Lamarck, the French botanist and early proponent of transmutationism. Although the word gained some currency by the 1820s, especially in the English language, it was largely through the efforts of August Comte (1798–1857), the French social philosopher, that the term gained its most widespread currency. For Comte, biology, one of the "higher sciences" in his philosophy of positivism, was the discipline of knowledge that organized the study of life and sought the principles of life.

Especially critical to the development of modern biology was the period between 1828, when Friedrich Wöhler (1800–1882) artificially synthesized the organic compound urea in the laboratory (fueling the debate between mechanism and vitalism), and 1866, the year Gregor Mendel (1822–1884) published his theory of heredity. During this time the conceptual foundations of the new science were laid, and many of the defining criteria of nearly all the major subdisciplines of biology were established.

The first areas for which groundwork was laid were cytology (now part of the more general discipline of cell biology) and histology (the study of tissues). Advances in optics in the 1830s by workers such as Giovanni Battista Amici (1784–1863) significantly enhanced the resolving power of the microscope and diminished or entirely eliminated such disruptive phenomena as chromatic aberration. Techniques for selectively dyeing and staining cellular components and enhancements in sectioning that led to thinner and thinner sections further enabled researchers to see more clearly increasingly finer structures. As a result of improvements in microscope technology, a series of plant and animal observations from 1833 led to recognition of a number of cellular structures, beginning with the nucleus, first observed in orchid cells by the English microscopist Robert Brown (1773–1858). Observations on the cells of plants and animals culminated in the establishment of the cell theory in the late 1830s, the recognition that cells were the basic unit of organization in all living tissues. The establishment of the cell theory resulted from observational work by the botanist Matthias Schleiden (1804–1881) and by the animal physiologist Theodor Schwann (1810–1882). Rudolf Virchow (1821–1902) extended this theory in 1840 to include the observation that all cells come from cells, and in 1858, in his *Cellular Pathology,* he provided new foundations for understanding disease in terms of cellular disruption. The germ theory of disease, a theory that Louis Pasteur proposed in the 1860s as a result of his work in microscopy, suggested that microorganisms were the causes of infectious diseases. Advances in microscopy in the nineteenth century thus laid the foundations not only of cytology and histology but also of the new science of microbiology (the study of microbial life), which continued to explore smaller and smaller life forms well into the twentieth century.

Yet another area that drew heavily on microscopy was knowledge of heredity (later designated as the science of genetics), especially in the late nineteenth century after structures such as chromosomes were first observed and cellular reproduction was understood in terms of meiosis and mitosis. The chromosome theory of heredity, first proposed by Walter Sutton (1877–1916) and Theodor Boveri (1862–1915), largely integrated knowledge of the fine structure and behavior of chromosomes with Mendelian genetics to suggest that chromosomes were the material carriers of heredity. This theory was not articulated until early in the twentieth century, between 1902 and 1903. This development occurred so late because Gregor Mendel's experimental insights into the process of heredity, which had been published in 1866, was not appreciated until its rediscovery in 1900. The modern science of heredity, which William Bateson (1861–1926) designated as genetics, began in the early years of the twentieth century, with initial inquiry determining the extent to which Mendelian principles operated in the natural world. The second area of interest sprung from the pioneering research of the American geneticist Thomas Hunt Morgan (1866–1945) and his laboratory on Mendelian genetics in the fruit fly, *Drosophila melanogaster.* Beginning roughly in the 1910s and peaking in the 1930s, this classic school of genetics worked on the transmission of a number of characteristics by studying mutant forms of *Drosophila.*

Microscopic techniques also played an active role in other important areas of nineteenth-century biology, areas such as embryology, and brought into relief the interplay between heredity, development, cytology, and evolution. By the late nineteenth century, persistent questions of biological development were being tackled with techniques and insights gleaned from cytology and cellular physiology, leading to a renewal of the debate between mechanism and vitalism. Just when figures such as August Weismann (1834–1914) had articulated mechanistic theories linking heredity with development and evolution, leading to movements such as developmental mechanics, individuals such as Hans Driesch (1867–1961) challenged strict mechanism in biology by experimentally demonstrating that almost any part of the cellular constituents of embryonic tissues had the potential to develop into mature forms. Driesch's experimental efforts were rivaled by those of Wilhelm Roux (1850–1924), the leading advocate of developmental mechanics.

The middle decades of the nineteenth century also witnessed improvements in animal physiology, especially through the efforts of the German school associated with Johannes Müller (1801–1858) and later through the pioneering efforts of Hermann von Helmholtz (1821–1894). Increasingly, work in physiology, especially that of Helmholtz, drew heavily on the physical sciences. This research further supported the view that life obeys mechanistic principles and is reducible to such sciences as chemistry and physics. Proponents of this view increasingly dominated physiology, an arch example being Jacques Loeb (1859–1924), the German-American biologist most associated with mechanistic and reductionistic approaches to biology. His essays in *The Mechanistic Conception of Life* (1912) summarized this point of view.

Unquestionably, a major development in the critical early period of modern biology was the articulation and acceptance of evolution as based largely on the mechanistic process of natural selection. Drawing on a number of transmutation theories

PROPERTIES OF LIVING ORGANISMS

A capacity for evolution

A capacity for self-replication

A capacity for growth and differentiation via a genetic program

A capacity for self-regulation, to keep the complex system in a steady state (homeostasis, feedback)

A capacity (through perception and sense organs) for response to stimuli from the environment

A capacity for change at the level of phenotype and of genotype

SOURCE: Ernst Mayr, *This is Biology: The Science of the Living World* (1997).

(especially those of Buffon, Lamarck, and Robert Chambers [1802–1871]), Charles Darwin (1809–1882) and Alfred Russel Wallace (1823–1913) independently formulated similar theories of species change through the mechanism of natural selection, jointly publishing their insights in a paper read to the Linnaean Society in 1858. Darwin articulated his theory more fully in his celebrated work *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (1859). Though the mechanism of evolutionary change continued to resist full understanding by scientists, the fact that life on earth had had an evolutionary history became widely accepted by the late nineteenth century. Because the mechanism remained uncertain, evolutionary theory remained controversial in the closing decades of the nineteenth century. Suggested alternative mechanisms included neo-Lamarckism, directed evolution, aristogenesis, and mutation theory—an entirely new theoretical formulation that drew on the new experimental science of genetics. The turn of the twentieth century is frequently known as the "eclipse of Darwin," not so much because he fell into disfavor, but because alternatives to his theory of natural selection were being favored instead.

Between 1930 and 1950 scientists became certain about the mechanism of natural selection by integrating insights into heredity from Mendelian genetics with insights from traditional natural-history-oriented areas such as systematics, botany, and paleontology to formulate what has been called the "synthetic theory of evolution." At this time evolutionary biology was organized as a discipline, in order to study the process of evolution from a range of perspectives. This "evolutionary synthesis"—an integration of Darwinian selection theory with the newer Mendelian genetics—is generally recognized as a major event in the history of twentieth-century biology. With the establishment of the synthetic theory of evolution, scientists began to feel that a mature, unified, modern science of biology had emerged. Theodosius Dobzhansky, whose own work in evolutionary genetics served as catalyst for this synthesis, has maintained that evolution went a long way toward unifying biology.

Much of the work of twentieth-century biologists served to integrate biology. In addition, new technologies (such as the first electron microscopes in the 1930s), as well as developments and refinements in existing technologies, led to a staggering range of new discoveries in the twentieth century. In 1895 the Dutch biologist Martinus Beijerinck (1851–1931) designated what is known now as viruses—tiny living aggregations of protein and nucleic acid—as "filterable agents" because they passed through fine filters that could contain bacteria. It was known that these filterable agents could induce disease, but their structure was unknown until 1935, when W. M. Stanley (1904–1981) first crystallized the tobacco mosaic virus. This opened up further inquiry into viruses as disease-causing agents, into proteins and nucleic acids as the sole components of this very simple form of life, and into biochemical techniques instrumental for carrying out this research. By the late 1930s molecular biology and biochemistry were gaining traction. The reductionistic, mechanistic approaches of these sciences further pushed biological thinking about life in those directions. There was acute interest in the molecular structure of important proteins such as insulin, whose structure was determined in 1955 by Frederick Sanger (b. 1918), and in the role played by proteins and nucleic acids in reproduction and genetics.

In 1953 vitalistic approaches and philosophies received two body blows. First, the discovery of the structure of DNA (deoxyribonucleic acid), by Rosalind Franklin (1920–1958), Maurice Wilkins (b. 1916), James D. Watson (b. 1928), and Francis Crick (1916–2004) made the mechanism of the replication of genetic material understandable at the macromolecular level and moved genetics in the direction of molecular genetics. More than any discovery in recent biology, the discovery of the structure of DNA brought forth a revolution in biology, not just because of the theoretical knowledge gleaned, but also because of the potential applications of this knowledge.

EARLY DEFINITIONS OF BIOLOGY

From Lamarck, 1802: Biology: this is one of the three divisions of terrestrial physics; it includes all which pertains to living bodies and particularly to their organization, their developmental processes, the structural complexity resulting from prolonged action of vital movements, the tendency to create special organs and to isolate them by focusing activity in a center, and so on.

From Treviranus, 1802: The objects of our research will be the different forms and phenomena of life, the conditions and laws under which they occur and the causes whereby they are brought into being. The science which concerns itself with these objects we shall designate Biology or the Science of Life.

SOURCE: As translated by William Coleman in *Biology in the Nineteenth Century: Problems of Form, Function, and Transformation* (1971), p. 2.

The second body blow to vitalism was delivered in the same year by news of the celebrated experiment simulating the origins of life under early conditions on earth by Stanley Miller (b. 1930) and Harold C. Urey (1893–1981) at the University of Chicago. Miller and Urey enclosed the constituents of the early atmosphere of earth (methane, ammonia, and hydrogen gas) in a glass vessel and applied a high-energy electrical discharge to it, "sparking" it to simulate lightning. A container of boiling water constantly supplied water vapor and heat. The cooling and condensing water vapor simulated rain. After letting the apparatus run for a number of hours and eventually weeks, Miller and Urey collected a brown-red pastelike substance and chemically analyzed it to reveal a number of amino acids, the building blocks of proteins, and other macromolecules usually associated only with living organisms. The Miller-Urey experiment thus provided evidence that the basic building blocks for life could be generated by the kinds of conditions present in the early atmosphere of the earth. Subsequent experiments simulating conditions on other planets supported the view that life may also have originated in space, on other planets, or wherever similar conditions are found. For this area of study integrating research on the origins of life on earth with research on the existence and specific character of life on other planets, the molecular geneticist Joshua Lederberg (b. 1925) coined the term "exobiology," the biology of organisms outside earth. Its sibling science is esobiology, or earth-based biology.

After World War II, biology boomed, and with it emerged new societies and institutions to organize the growing science. In 1947 the first umbrella organization for the biological sciences, the American Institute of Biological Sciences, was created in the United States. Other institutions, such as the National Science Foundation in the United States, established large divisions (and budgets) to fund research in the biological sciences. Both trends helped shape the direction and character of subsequent biological research. As with many other sciences in the postwar period, the dominant site of activity in the biological sciences had shifted from its older European centers in Germany, France, and England to the United States. At the height of the Cold War, the Soviet launch of the Sputnik satellite drove a panicked U.S. government to offer even stronger support of scientific research. The biological sciences, too, benefited from this turn of events and received generous funding for research and biological instruction. Textbooks such as the popular Biological Sciences Curriculum Study drew on a virtual industry of biologists and educators to produce a series of widely read and influential textbooks for American high school students. Research in the United States continued at specialized research centers such as that at Cold Spring Harbor (in 2004 a center for molecular biology) and more traditional research settings including public and private universities, land-grant colleges, hospitals and medical centers, museums and gardens. In university education, biology as a subject area is considered so vital that it has become a requirement for general education programs. It is rapidly becoming one of the most popular majors for university students not just in the United States but worldwide.

Despite arguments for the unity of the increasingly diverse biological sciences, controversies and debates erupt between biologists about fundamental concepts in the biological sciences. Differences are especially pronounced between more reductionistic, physicalist, laboratory-driven, and experimental sciences such as molecular biology and biochemistry and more integrative, field-oriented, observational, and historical sciences such as evolutionary biology and ecology. In the mid-1960s, university biology departments became divided over differences in conceptual foundations, goals, methodology, philosophy, and scientific style. As a result, at locations such as Harvard University, departments of biology formally divided into departments of molecular biology and organismic biology, an area defined as an integrative approach to the biological sciences that includes a strong historical and ecological component. Roughly at this time ecology—a science of enormous heterogeneity drawing on a range of approaches, practices, and methodologies and rooted in questions pertaining to adaptive responses to varying environments—became integrated with evolutionary approaches and instituted in departments of ecology and evolution. Often located within ecology and evolution departments are systematics and biodiveristy studies, a newer area concerned with biodiversity, including classification and conservation.

In 1961 the evolutionary biologist, historian, and philosopher Ernst Mayr, reflecting on some of these growing differences between biologists, provocatively suggested that biology in fact comprises two sciences. The first is a biology based on proximate causes that answers questions of function (molecular biology, biochemistry, and physiology). The second is a biology based on ultimate causes that seeks historical explanation (evolutionary biology, systematics, and the larger discipline of organismic biology). While the biology of proximate causes is reductionistic and physicalist, the biology of ultimate causes is historical and is characterized by emergent properties. Much of Mayr's reflections on the structure of the biological sciences has formed the backbone of the history and philosophy of biology and has made its way into some textbooks in the biological sciences. While vitalism is no longer tenable in biology, there is considerable support for the belief that complex properties emerge from simpler strata in biology and for the idea that such emergent properties are useful in explaining life.

See also ***Evolution; Genetics; Life.***

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BIOMETRY. *See* Evolution.

BIRTH CONTROL AND ABORTION. *See* Family Planning.

BLACK ATLANTIC.

In writing *The Black Atlantic: Modernity and Double Consciousness* (1993), Paul Gilroy sought to devise a theoretical approach to understanding race that encompassed three crucial elements. First, the idea of race as fluid and ever-changing, rather than static; second, the idea of race as a transnational and intercultural, rather than strictly national, phenomenon; third, the focus on analyzing resistance to racism as a phenomenon that emerged transnationally and diasporically.

Gilroy seeks to provide a theoretical rendering of race that bridges the hemispheres. To this end he takes the Atlantic as his preferred unit of analysis and uses it to ground his transnational perspective on race. In Gilroy's analysis the black Atlantic represents the history of the movements of people of African descent from Africa to Europe, the Caribbean, and the Americas and provides a lens through which to view the ways that ideas about nationality and identity were formed. Thus, in *Black Atlantic* the focus is on intercontinental trade and travel as well as on processes of conversion and conquest and the resultant forms of creolization and hybridization that occur.