




<p> See the Online Learning Center for a chapter summary, chapter outline and learning objectives</p>	<p><b>Chapter Outline</b></p> <p><b>The World of Physical Anthropology</b>  <i>Studies of Physical Anthropology</i>  <i>Physical Anthropology in the World of Anthropology</i>  <i>Conclusion</i></p> <p><b>The Nature of Science</b>  <i>The Many Aspects of Science</i>  <i>Scientific Thinking</i>  <i>Science as a Creative Process</i>  <i>Applying Scientific Thinking to Anthropological Problems</i>  <i>Science and Religion</i>  <i>Summary</i></p> <p><b>Views on the Essence of Humans, Nature, and Time</b>  <i>Questioning the Old Ideas</i>  <i>Early Evolutionary Ideas</i>  <i>What Is the Age of the Earth?</i>  <i>Humans before Adam and Eve?</i>  <i>Darwin's Voyage of Discovery</i>  <i>Darwinian Natural Selection</i>  <i>Evolution and Creationism</i>  <i>Summary</i></p>
	<p>The ideas embodied in the opening quotation, taken from Charles Darwin's <i>The Descent of Man</i>, were revolutionary for their time. Darwin's message was that humans, like all animals, were not specially created and that human characteristics arise from the actions of the same natural forces that affect all life.</p> <p>Darwin is thought to have been a great discoverer of new facts and ideas, and indeed he was. On the other hand, Darwin's ideas, like all ideas, were formed, nurtured, and brought to maturity in the context of particular intellectual backgrounds. The things we think, the relationships we see, and the very process of creativity are determined, in part, by our cultural environment. The knowledge that a person has at any one time represents the accumulation of information and ideas from his or her whole lifetime. The theory of evolution was not developed by one person. It was part of a chain of intellectual events, each link being necessary to the continuity of that chain.</p> <p>One of the disciplines that studies the theory of evolution is physical anthropology. We will begin our voyage of discovery by exploring the field of physical anthropology and its place in the world of anthropology.</p> <p><b>THE WORLD OF PHYSICAL ANTHROPOLOGY</b></p> <p><b>anthropology</b>  The broad-scope scientific study of people from all periods of time and in all areas of the world. Anthropology focuses on both biological and cultural characteristics and variation as well as biological and cultural evolution.</p> <p><b>physical anthropology</b>  A branch of anthropology concerned with human biology and evolution.</p> <p>The anthropologist is an explorer in pursuit of answers to such questions as: What is it to be human? How did humans evolve? What is the nature of humankind? <b>Anthropology</b> is such a broad discipline, however, that it is divided into several subfields or branches. One of the oldest subfields is that of <b>physical anthropology</b>, which includes the study of human biological evolution, the process of biological change by which populations of organisms come to differ from their ancestral populations.</p> <p><b>Studies of Physical Anthropology</b></p> <p>Physical anthropology is a very diverse field. Some areas of interest lie within the realm of biology and medical science; others are more tuned to cultural anthropology and archaeology.<sup>1</sup> Anthropologists who specialize in the study of growth and development and anatomy often are found in departments of anatomy and health sciences and schools of medicine. These</p> <p><sup>1</sup> For further information about the diversity of disciplines within physical anthropology, see C. W. Wienker and K. A. Bennett, "Trends and Developments in Physical Anthropology," <i>American Journal of Physical Anthropology</i> 87 (1992), pp. 383–393. (See also Table 18–3.)</p>

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**FIGURE 1-1**



investigators frequently conduct research on human populations in various parts of the world, allowing them to compare different modern populations. For example, physical anthropologists might study the growth patterns of children growing up at high altitude in the Peruvian Andes Mountains. Other anthropologists study a wide range of health-related topics such as nutrition, disease, and aging.

A focal area of study in physical anthropology is the study of evolution. Anthropologists join with their colleagues in biology in the study of evolutionary theory. Anthropologists are particularly interested in the reconstruction of human and nonhuman primate evolution. Key evidence in these studies is the evidence provided through the fossil record (paleontology) and through analysis of cultural remains (archaeology). Paleontology and archaeology join to create the study of paleoanthropology (Figure 1-1).

A major key in understanding evolutionary processes is an understanding of the mechanisms of heredity—the field called genetics. Many anthropologists are active in studying topics in many subfields of genetics, including human and primate genetics. More recently the comparative study of protein molecules and DNA, the heredity material, has created the field of molecular evolution, which has brought forth new understandings about the relationships among contemporary organisms.


As we will see later, the critical unit of evolution is the population, a group of closely related organisms. Anthropologists carefully document the characteristics of extant human populations in a number of ways. From these studies, we can learn about how different human populations adapt to their environments. The study of human variation is especially important in our shrinking world as more and more people from diverse parts of the world become economically and politically influenced by one another.

Many physical anthropologists specialize in the study of the fossil record or in skeletal remains found in an archaeological context. For these reasons, anthropologists have become very interested in the biology of the skeleton. As a result, some anthropologists are employed in forensic anthropology, a branch of forensic science. Often found in coroner offices, forensic anthropologists analyze skeletal remains from criminal scenes to determine biological factors about the individual, such as sex and age at death, as well as to determine the probable cause of death.

The members of the animal kingdom most closely related to humans in an evolutionary sense are the primates, a group of animals that include the living prosimians, monkeys, apes, and humans in addition to a wide variety of now-extinct forms. Many anthropologists are in the field studying primate behavior and ecology while others are in the lab working on problems in primate anatomy and evolution (Figure 1-2).

### **Physical Anthropology in the World of Anthropology**

Physical anthropology is one of four main branches of the study of people; the others are cultural anthropology, archaeology, and linguistics. Many anthropologists see applied anthropology as a fifth field. While traditionally anthropologists are trained in all of the four main fields and see anthropology as a holistic discipline, in recent years, the discipline of

 See the Online Learning Center for an Internet Activity on the American Anthropological Association

**FIGURE 1-2****The Study of Primates**

Primatologist Dian Fossey discusses the fine points of photography with some of her subjects. Her life is recounted in the book and the movie *Gorillas in the Mist*.

**cultural anthropology**

The study of the learned patterns of behavior and knowledge characteristic of a society and of how they vary.

**culture**

Learned, nonrandom, systematic behavior and knowledge that can be transmitted from generation to generation.

**archaeology**

The scientific study of the past and current cultures through the analysis of artifacts and the context in which they are found.

**anthropological linguistics**

The study of language in cross-cultural perspective; the origin and evolution of language.

**applied anthropology**

A branch of anthropology devoted to applying anthropological theory to practical problems.

anthropology has become more and more diverse and specialized, and many new anthropologists are given minimal training outside their own specializations. This has become very much the case in physical anthropology.

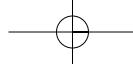
**Cultural anthropology** is the study of human social organization and culture. A central concept in cultural anthropology is that of **culture**. Culture is learned, transmittable behavior that employs the use of symbols, such as words. Cultural behavior, the focus of Chapter 10, is the main way by which humans adjust to their environments.

**Archaeology** is the study of the material remains of human activity, artifacts, and the context in which they are found. Both artifacts and their context are used to reconstruct how different cultures have adjusted to varying situations through time and to explain stability and change. Although some archaeologists study contemporary societies, most archaeologists study the cultures of the past. **Anthropological linguistics** examines the history, function, structure, and physiology of one of a people's most definitive characteristics—language. **Applied anthropology** is concerned with the application of anthropological ideas to current human problems (Box 1-1).

While many physical anthropologists work closely with biologists and other related specialists, physical anthropologists are keenly aware of the special nature of the human species. Herein lie the special emphasis and approach of the physical anthropologist. For example, the biologist who is studying human populations may note that one population has a higher frequency of dark skin than another. The biologist's approach is to describe this variation, perhaps by investigating the genetic mechanisms that led to the differentiation. The anthropologist goes one step further: he or she attempts to discover cultural conventions that may be keeping the dark-skinned populations from interbreeding with the light-skinned ones. For instance, cultural conventions involving concepts of beauty, class distinctions, kinship considerations, economic relationships, and so on all affect breeding patterns. In other words, the physical anthropologist takes note of the fact that culture both builds upon and modifies biology.

**Conclusion**

This text deals with many issues about the nature of humanity, a very complex and difficult topic. There are no simple answers to the many questions that are raised in this book. The purpose of the book is to provide a basic understanding of humans, their development, and



## Box 1-1 The Branches of Anthropology

### PHYSICAL ANTHROPOLOGY

The study of human biological evolution with an interest in the interaction between human behavior, the physical environment, and biology.

#### Some Areas of Concentration within Physical Anthropology

**Human genetics:** The study of the processes of inheritance and inherited variation.

**Primate paleontology:** The search for and study of the fossil evidence of primate (humans are primates) evolution. The term **paleoanthropology** is used when the emphasis is strictly on humans and human ancestors. Paleoanthropology also includes the study of archaeological evidence.

**Primatology:** The study of the living nonhuman primates that includes lemurs, monkeys, and apes.

**Human biological variation:** The study of the genetic and other biological variation among different groups of people.

**Human growth and development:** The study of gender and group differences in growth and development and the study of how patterns of growth and development have changed over time.

**Human ecology:** The study of peoples' relationships to their environments.

**Osteology:** The study of the skeleton.

**Forensic anthropology:** The application of anthropological knowledge, especially of the skeleton, to criminal investigations. Such knowledge, popularized recently on such television programs as *CSI* and *The New Detectives* is used for identifying bodies and determining the cause of death.

### CULTURAL ANTHROPOLOGY

The study of all aspects of human behavior from a comparative perspective.

#### Some Areas of Concentration within Cultural Anthropology

**Ethnography:** The study of an individual culture that results in a written description of that culture.

**Ethnology:** The cross-cultural study of culture. Although cultural anthropologists study individual cultures, the focus of cultural anthropology is to develop a broad understanding of human nature through the analysis and comparison of individual ethnographies. The goal is to discover human universals and the range of human behavior variation.

Cultural anthropologists believe in a holistic approach, that is, in order to know about any subsystem of a culture, say religion, you need to know about all areas of that culture (kinship, politics, economics, concepts of health and disease, and so on). Yet, many cultural anthropologists keeping holism in mind spe-

cialize in a subsystem of human behavior. So within cultural anthropology some of the specializations are:

**Comparative religion:** The study of magic, witchcraft, and religion.

**Kinship studies:** The study of how people see themselves as related to others.

**Economic anthropology:** The study of how goods and services are distributed within and between societies.

**Political anthropology:** The study of the distribution and use of power and authority within and between societies.

**Medical anthropology:** The study of attitudes and practices dealing with health and illness.

**Urban anthropology:** The study of city life from an anthropological prospective.

### ARCHAEOLOGY

Although some archaeologists study contemporary cultures, most attempt to reconstruct and describe cultures of the past. Archaeologists study artifacts, the manufactured objects made by humans to perform a variety of tasks, the context in which the artifacts are found, and the physical environment.

#### Some Areas of Concentration within Archaeology

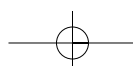
**Area-of-the-world emphasis:** Some archaeologists are interested in a particular area of the world. This includes New World archaeology and Old World archaeology. Yet, within these two broad areas, there might be more specific interest. A New World archaeologist, for instance, might specialize in the Southwest United States.

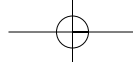
**Time-period emphasis:** Some archaeologists are interested in studying the recent past, say Native American culture of a hundred or so years ago. Others are interested in the remote past, such as the first stone tools that were produced more than two million years ago.

**Cultural resource management (CRM):** Today, in many government jurisdictions, an environmental impact study is required before any construction can begin. Usually an element of such a study is an archaeological survey of the proposed construction site. If archaeological evidence is found, excavation of the site might have to be completed before construction proceeds. More than 40 percent of archaeologists in the United States do cultural resource management studies.

**Underwater archaeology:** The study of shipwrecks and other underwater sites.

Archaeologists who deal with cultures that did not have writing are called **prehistoric archaeologists**, whereas those that supplement their research with written records are called **historical archaeologists**. **Classical archaeologists** specifically study Old World civilizations and often are trained in the area of art, the classics, or Near Eastern studies.





## Box 1–1 (continued)

### ANTHROPOLOGICAL LINGUISTICS

Anthropological linguistics is the comparative study of the structure of and relationship between world languages. It also is concerned with the evolution of the human language capacity and the role of language in the general evolution of the human species.

#### Some Areas of Concern within Anthropological Linguistics

**Ethnolinguistics:** The study of the interrelationship of language to the general culture. Ethnolinguists are interested in such questions as: Does the language one speaks influence thought? If it does, to what degree does that influence extend? How does language encode and transmit cultural, emotional, and symbolic meaning and values?

**Sociolinguistics:** Sociolinguistics is the study of the degree and form of social variation in the use of language between different genders, age groups, ethnic groups, occupation groups, and other social classifications.

**Language acquisition studies:** The study of how children spontaneously learn language.

**The study of the structure of language:** Some anthropological linguists emphasize the study **phonology** (the sound systems of language), **morphology** (words, their structure and history), **syntax** (structures larger than words, such as clauses, phrases, and sentences), or **semantics** (the study of meaning).

**Historical linguistics:** This is the study of language change and the relationship of one language to another.

### APPLIED ANTHROPOLOGY

Applied anthropology is the practical application of anthropological knowledge from any subfield of anthropology to real-world concerns. Within physical anthropology, forensic investigation would be an example of applied physical anthropology. Some cultural anthropologists work for international development agencies with the goal of using funds for such development in an efficient and humane way based on anthropological knowledge of the population that is being helped. Environmental impact studies would be an example of applied anthropology done by archaeologists. Anthropological linguists might help with the development of language teaching programs. These are just a few examples of applied anthropology.

their place in nature. We cannot promise that all your questions about people will be answered; in fact, we can promise that they will not. A great deal has been learned about human nature over the centuries, especially in the last century-and-a-half, yet anthropology is still a dynamic subject. With each publication of a research project, new information is added to our knowledge of humanity. In other words, data that are needed to answer crucial questions about the human species are still being uncovered.

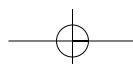
Why study anthropology? Because anthropology provides empirical knowledge about the human condition. On one level, this serves to feed our curiosity about ourselves. However, anthropological studies also provide data useful to the fields of medicine, environmental maintenance, urban planning, education, and so forth. Anthropology also attempts to provide a profile of human potentials and limitations. For instance, it explores the question of whether or not humans are violent by nature.

### THE NATURE OF SCIENCE

The physicist investigating the relationship between time and space, the chemist exploring the properties of a new substance, the biologist probing the mysteries of the continuity of life, and the anthropologist searching for human origins share a common trait—curiosity. This is not to say that nonscientists are not curious; most people possess curiosity. The scientist, however, uses scientific reasoning as a specific method to delve into enigmatic problems.

Unfortunately, science often is misunderstood. The multiplication of our knowledge in medicine and technology has led to the idea that science can cure all and explain all and that only enough time, money, and intelligence are needed. In truth, science cannot provide all the answers. In fact, many phenomena are not even subject to scientific explanations.

Science also has been attacked as a cause of most contemporary problems. It is said to be responsible for depersonalizing the individual, for stripping creativity from human behavior, and for creating massive threats to the species through the development of nuclear power, insecticides, and polluting machinery. If we analyze the situation, we can see that the



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<p><b>science</b> A way of learning about the world by applying the principles of scientific thinking, which includes making empirical observations, proposing hypotheses to explain those observations, and testing those hypotheses in valid and reliable ways; also refers to the organized body of knowledge that results from scientific study.</p> <p><b>reliable</b> Predictable.</p> <p><b>empirical</b> Received through the senses (sight, touch, smell, hearing, taste), either directly or through extensions of the senses (such as a microscope).</p> <p><b>variable</b> Any property that may be displayed in different values.</p> <p><b>hypothesis</b> An informed supposition about the relationship of one variable to another.</p>	<p>people who developed computers did not intend to debase humankind, nor did those who introduced mass production wish to crush creativity. It is what society, policy makers especially, does with scientific achievements that makes them social or antisocial. There is nothing inherently good or bad about science.</p> <h3>The Many Aspects of Science</h3> <p>Just what is <b>science</b>? Here is where the dictionary fails, for science is not something that can be easily defined. It is an activity, a search, and a method of discovery that results in a body of knowledge.</p> <p>Science is the activity of seeking out <b>reliable</b> explanations for phenomena. <i>Reliable</i> here means “predictable.” <i>Predictability</i> does not mean “assurance”; it simply may indicate the percentage of cases in which, under a given set of conditions, a particular event will occur.</p> <p>Science is also a search for order. Nature does not categorize; people do. Through classifications, systematic similarities and differences can be found. This display of ordered relationships allows for discoveries that might otherwise never be made.</p> <h3>Scientific Thinking</h3> <p>The first step in scientific studies is to make an observation. Scientific observations are <b>empirical</b> observations, observations based upon information received through the senses (seeing, touching, smelling, hearing, tasting). The information can be received directly through the senses or indirectly through an instrument that enhances the senses, such as a microscope or telescope. Some observations are accidental; some are deliberate, such as when a paleontologist goes to a specific geological formation to look for a specific fossil; and some are the results of an experiment.</p> <p>Next, a question is asked about the observation. For instance, one might observe that the brain size of a series of fossils ancestral to humans become larger through time. The question might then be asked: “What advantages might increasing brain size have had in the pre-human and human evolutionary line?”</p> <p>The next step is to identify the variables to be studied. A <b>variable</b> is any property that may be displayed in different forms. For example, the volume of the brain case, that part of the skull that houses the brain, is a variable; it may measure 400 cubic centimeters in one fossil and 1600 cubic centimeters in another. In order for a variable to be the subject of a scientific study, we must be able to measure it precisely. Different people measuring the same variable should arrive at the same measurement.</p> <p>The next step in scientific studies is proposing a hypothesis. A <b>hypothesis</b> is a tentative answer to a question posed about the relationship of one variable to another. Is one variable independent of the other variable, or does one variable cause another variable to occur? For example, one might hypothesize that among the ancestors of modern humans, as the average size of the brain case increases, so does the ability of the population to manufacture tools. Brain case size is one variable, and the number of tools found in association with the skull is a second variable. The hypothesis proposes a direct relationship between the two variables: as one increases, so does the other. While this particular hypothesis proposes a relationship between two variables, it does not propose that one variable causes the other to occur.</p> <p>Once proposed, the hypothesis must be tested against reality. In the above example, we could measure brain case size in fossil skulls and count the number of stone tools found in association with each skull. If, upon analysis, we find that as the average size of the brain case increases, so does the number of tools, then we have identified one line of evidence that supports the validity of the hypothesis.</p> <p>Evidence is not necessarily absolute proof. There could be unknown factors responsible for the observed correlation of the variables. For instance, an increase in the population density at a series of sites might influence the number of stone tools found. Perhaps some habitats are more easily exploited with simpler technologies than are others. In other words, the</p>
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<p><b>theory</b> A step in the scientific method in which a statement is generated on the basis of highly confirmed hypotheses and used to generalize about conditions not yet tested.</p>	<p>relationship between the variables in the hypothesis may turn out to be accidental or to be the result of a variable or variables not identified in the original hypothesis.</p> <p>After a number of studies exploring the relationships of all the variables have been completed, we might develop some generalizations. We might suggest that an increase in the volume of the brain case is correlated with a whole range of behaviors that differentiate earlier humanlike organisms from later ones. Each of these new hypotheses would then have to be tested by some research design. Each test might reveal hidden variables that will either disprove or modify the original and related hypotheses. This hypothesis-test-hypothesis-test cycle is a self-corrective feature of science. Scientists realize that results are never final.</p> <p>Science is cumulative. It is constantly open to repeated criticism and testing by other scientists. Experiments performed in one lab must yield the same results when duplicated in another lab, and new discoveries must be consistent with previous ones.</p> <p><b>Theory</b></p> <p>After many tests have been conducted on a set of similar hypotheses with confirming results, a <b>theory</b> may be proposed: A statement based upon highly confirmed hypotheses that generalizes about conditions not yet tested. For example, the testing of thousands of hypotheses on the reasons for change in anatomy and behavior has led to great confidence in the theory of evolution.</p> <p>A theory shows the relationship among scientific facts. It explains how data are related to each other. For instance, facts derived from the study of anatomy, physiology, genetics, and paleontology show that evolution has occurred.</p> <p>There are more components to scientific thinking than we can discuss in this book. The main point is that scientific thinking is a way to test one's ideas against the real world in a disciplined way. Each step in the process must be made clear so that the procedure can be repeated and yield the same results.</p> <p><b>Science as a Creative Process</b></p> <p>Science is a creative process. The scientist must be a keen observer, possess a questioning mind, and ask unique, nonstereotyped questions. The scientist must be clever in suggesting possible answers to his or her own queries. Above all, the scientist must be innovative in designing experiments that will test the validity of the hypothesis. However, it is a mistake to believe that intuition and passion are absent from science. A hunch, along with persistence, has more than once led to a revolutionary discovery. This happened when Mary Leakey and her husband, Louis Leakey, found evidence of early humans in an area that they had been combing for 28 years.</p> <p>The passion involved in the search for a new truth or simply a new fact can be as intense as that of the artist attempting to create a masterpiece. From Copernicus's calculations to modern methods of charting the entire human genetic system, the scientist displays an ability to see unique solutions to problems that most people do not even recognize as problems.</p> <p><b>Applying Scientific Thinking to Anthropological Problems</b></p> <p>In many instances, it is difficult to apply the experimental method to the investigation of humans. For one thing, physical scientists, such as physicists and chemists, can design experiments that can be repeated—in many cases, as many times as desired. The physical anthropologist is often limited in the degree and manner in which the phenomena being studied can be repeated for the sake of experimentation. For instance, how does one repeat the past in an attempt to test hypotheses on early human ancestors?</p> <p>To explore hypotheses about fossil populations, physical anthropologists might use various methods of comparison. For instance, a series of fossils from older to younger could be compared to determine relationships among anatomical structures. Comparative research also can involve the study of living organisms through comparing embryological development, as well as molecular similarities and differences. These studies are used to determine the</p>
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unknown, is dangerous and is considered a male activity. Since shallow fishing is undertaken with regularity, time is spent making observations of fish behavior and experiments are performed on how best to catch the prey. Nothing is done religiously or magically to protect the fishing party or to ensure a catch. The story is different with deep-sea fishing. Men occasionally do not return from the expeditions, so elaborate rituals are performed in order to appease or appeal to the gods of the unpredictable seas.

In conclusion, a scientific statement asserts the natural causality of phenomena. One thing happens because of preceding events that led up to it. Things happen and conditions exist because of the physical, chemical, biological, behavioral, and/or cultural and social characteristics of the thing in question and the context in which it is found. Religious or magical statements assert causality beyond the natural; when natural causality cannot be determined or is not sought, spiritual causality is often assumed.


### Summary

Science is the activity of seeking out reliable explanations for phenomena. Science is also the search for order and a method for discovery. The result of the activity of science is a body of empirical knowledge that can be used to understand the universe better and to predict the processes, structure, form, and function of natural occurrences. Scientific thinking provides a systematic way of investigation and includes the identification of variables, hypothesis formation, and tests of the validity of the hypothesis, and of postulating theories. Scientific thinking also includes the comparative method. All scientific statements are tentative. It is because new evidence is always possible that a scientific statement can never be completely proved.

Science is not a mere mechanical pursuit for knowledge but involves creativity and the passion of discovery and accomplishment. Many breakthroughs, as well as more mundane discoveries, have resulted from a hunch followed by long years of persistent examination.

The scientist and the theologian are both interested in giving answers. However, the scientist proceeds by testing questions about the nature of empirical observation, whereas the theologian consults the philosophy of his or her particular religion and interprets the meaning of that philosophy for a particular situation. Scientific statements are never considered absolute, but at any one time religious doctrine is. All people have a body of scientific knowledge, but for the things they fear or cannot understand in an empirical way, religion and magic provide a measure of comfort and assurance.

## VIEWS ON THE ESSENCE OF HUMANS, NATURE, AND TIME

 See the Online Learning Center for an Internet Activity on the history of evolutionary theory

### anthropocentricity

The belief that humans are the most important elements in the universe.

### spontaneous generation

An old and incorrect idea that complex life forms could be spontaneously created from nonliving material.

### immutable

Unchanging.

Although there were many variations in the early ideas about the universe, they were often the opposite of those embodied in present evolutionary theory. These old ideas had to be challenged before a new concept of reality could arise.

First among the early views was the idea of human superiority, or **anthropocentricity**. This belief was that the earth is the center of the universe and that all the celestial bodies revolve around it. Humans placed themselves on a pedestal, believing that God provided the animals and plants for people's use and fancy. The similarities that people observed between humans and animals and among various animal species were seen as reflecting the design of the Creator. Many people believed that certain shapes and forms are pleasing to God and that God therefore used these as models for all creations.

People of that era, as well as many people today whose beliefs are based upon a literal interpretation of the Bible, thought that life had been formed from nonlife at the will of the Creator. Some believed that this process of creation continued even after the original six days of Genesis. This concept is known as **spontaneous generation**, whereby living organisms could arise from nonliving material. People also believed that once a type of organism is created, its descendants will remain **immutable**, in the same form as the original, from generation to generation.

## Box 1–2 Science, Religion, and Political Intrigue—The Trial of Galileo



In 1633, the Roman Inquisition found Galileo Galilei (1564–1642), at the age of 69, guilty of supporting the Copernican view that the sun, not the earth, is at the center of the universe. In 1616, the Catholic Church had condemned this sun-centered (**heliocentric**) view of the universe as “false and opposed by the Holy Scripture.” In 1600, even before this official condemnation, Giordano Bruno had been burned at the stake for his support of the Copernican view. Galileo was saved from that fate and was instead put under “house arrest” for the last nine years of his life.

Pietro Redondi, an Italian historian of science, has proposed another account of the trial of Galileo. He believes he has uncovered an ancient case of plea bargaining.

Redondi believes that a Jesuit named Orazio Grassi wrote the note, indirectly accusing Galileo of heresy. In 1623, Galileo had professed his belief that all matter consists of small, unchangeable atomic particles. The letter suggested that this view contradicted the idea that the bread and wine of communion could be transformed into the body and blood of Christ. It would have been extreme heresy to suggest such a thing.

Pope Urban VIII, a personal friend of Galileo, had given Galileo permission to publish his ideas on Copernicanism. In 1632, the Copernican idea was not as controversial as it had been in 1600 and 1616, but the Jesuits, who wished to control the Vatican, knew that the atomic theory was a much more profound contradiction of church doctrine. They continued to place pressure

on the Pope by attempting to discredit his friend Galileo. In 1624, nothing was done about the Jesuit attack on Galileo; the Jesuits did not have enough influence at that time. However, developments in the European Thirty Years’ War had made Pope Urban VIII more politically vulnerable, so, in the 1630s, the Jesuits attempted to reopen their attack. The Pope now, for political reasons, had to pay attention to the Jesuits or be discredited himself.

The Pope defused the situation by allowing Galileo to plead guilty to supporting the Copernican theory. In return, the Inquisition would not charge Galileo for promoting the atomic theory. Galileo agreed to cooperate. In this way, Galileo was saved from burning at the stake, and the Pope showed he still had control.

In 1984, Galileo was given a full pardon by the Catholic Church. And, in 1996, Pope John Paul II, in a message to the Pontifical Academy of Science, indicated that he believed that there was no necessary contradiction between evolutionary theory and Christian beliefs.<sup>1</sup>

<sup>1</sup> “The Truth Cannot Contradict Truth,” Address to the Pontifical Academy of Science, October 22, 1996, reprinted at <http://www.newadvent.org/docs/jpoactc.htm>.

**Source:** D. Dickson, “Was Galileo Saved by Plea Bargain?” *Science* 233 (1986), pp. 612–613; and L. S. Lerner and E. A. Gosselin, “Galileo and the Spector of Bruno,” *Scientific American* 255 (November 1986), pp. 126–133.

The original creation, as described in Genesis, supposedly took place a few thousand years before the Greek and Roman empires. Archbishop James Ussher of Armagh, Ireland (1581–1656), used the generations named in the Bible to calculate that the earth’s creation took place at noon on October 23, 4004 B.C. The idea of a spontaneously created and static life, a life brought into being only 6000 years ago, is directly counter to modern evolutionary theory. The development of evolutionary theory depended upon an increasing disbelief in these old ideas.

### Questioning the Old Ideas

What a shock it must have been to European scholars of the sixteenth century when Nicolaus Copernicus (1473–1543) showed conclusively that the earth was not the center of the universe and was not even the center of the solar system! This was but one of a series of revelations that were to bombard the old ideas.

A tired, lost sea captain, who was fearful that he was going to fall off the edge of the earth, might have been both elated and confused at the greeting he received from an exotic people living on a shore that he thought could not possibly exist. The Age of Exploration, which began for Europeans in the late 1400s with the voyages of explorers such as Christopher Columbus, revealed variations of life not dreamed of before. By 1758, 4235 species of animals were cataloged. Today, about 1,032,000 species are known. During the Age of Exploration, strange animals never mentioned in the Bible were seen by Europeans for the first time. Naturalists were overwhelmed by the quantity of new discoveries and the problems of organizing this rapidly growing wealth of data.

**FIGURE 1-3****Carolus Linnaeus  
(1707–1778)**

Portrait of Carolus Linnaeus painted in 1737 in a Lapp costume. A Swedish naturalist and botanist, he established what became the modern method of naming the living world.

***Carolus Linnaeus's Classification***

Although all cultures classify plants and animals into some kind of scheme, it was not until the seventeenth and eighteenth centuries that comprehensive written classifications were made. The Swedish naturalist Carolus Linnaeus (1707–1778) succeeded in classifying every animal and plant known to him into a system of categories (Figure 1–3). This type of classification is absolutely necessary for a scientific understanding of the relationship of one plant or animal to the next. Yet at first it reinforced traditional ideas. Linnaeus saw each category as fixed and immutable, the result of divine creation.

Linnaeus's scheme became important to modern biological sciences for many reasons. First, it imposed order upon nature's infinite variation. Linnaeus saw that the analysis of anatomical structures could be used to group plants and animals into categories. The most specific groups included organisms that were very much alike, whereas the more general levels encompassed the specific groups, thereby representing a wider range of variation. Linnaeus wrote that the first order of science is to distinguish one thing from the other; his classification helped do just that.

Second, although Linnaeus considered organisms to be immutable, paradoxically his classification provided a means for "seeing" changes and possible ancestral relationships. Scientists wondered if similar organisms were related by common ancestry. If two or more types had a common origin but were now somewhat different, it followed that evolution must have occurred. Linnaeus, who had been so emphatic about the idea of unchanging species, began in later life to question this concept of fixity. He had observed new types of plants resulting from crossbreeding, and he had decided that perhaps all living things were not immutable.

Third, Linnaeus included people in his classification. Although he did not contend that humans are related to other animals, his placement of humans in this scheme was sure to raise the question.

***Could Nature Be Dynamic?***

Many people of the eighteenth century were intrigued with the rapidly increasing information brought to the fore by exploration. Not only were new varieties of plants and animals

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being discovered, but so were new people. Who were the Native Americans, the Polynesians, the Africans? Were they human, or were they part human and part ape? Credible answers to these and other questions could not be supplied by traditional explanations.

The effect of exploration in guiding people to new realities was intensified by the great revolutions of the eighteenth and nineteenth centuries. These revolutions included technological changes in the industrial age as well as political upheavals, such as the American and French revolutions. Technological and political developments that brought about major social changes created an atmosphere in which the idea of immutability could be questioned. If people could change their social systems so rapidly, if human life could be so dynamic, then perhaps so was nature. It was in the late eighteenth century that the first modern theories of organic evolution emerged.

### Early Evolutionary Ideas

Georges-Louis Leclerc Comte de Buffon (1707–1788), a contemporary of Linnaeus, proposed many major points that Darwin would later include in *On the Origin of Species*. Buffon recognized the tendency of populations to increase at a faster rate than their food supply, hence the struggle for survival. He noted the variations within species and speculated on methods of inheritance. He questioned spontaneous creation. He also challenged the church's dating of the earth, proposing that the earth is much older than 6000 years. Buffon's importance was diminished by his lack of conciseness, but he might have been vague and apologetic about his thoughts for fear of being considered a heretic.

Although Buffon was one of the first people to scientifically investigate evolution, it was left to Jean-Baptiste de Lamarck (1744–1829) to articulate a systematic theory of evolution as an explanation of organic diversity. Lamarck used the previous nonevolutionary idea that organisms could be ranked in a progressive order, with humans at the top. He envisioned evolution as a constant striving toward perfection and believed deviations were due to local adaptations to specific environments.

Lamarck is remembered by many for his explanation of the cause of these deviations. He again used an idea that had been around for centuries. He proposed that an organism acquired new characteristics in its lifetime by virtue of using or not using different parts of its body and that these newly acquired characteristics could then be inherited by the individual's offspring. For instance, if an animal constantly had to stretch its neck to get at food in the branches of a tree, its neck would get longer. If the trees were to get taller, the animal would then have to stretch more, and its neck would get longer still. This was Lamarck's explanation of the giraffe. He believed that a trait, once acquired, would be passed on to the next generation. This concept is known as the **theory of acquired characteristics**.

Lamarck's importance lies in his proposal that life is dynamic and that there is a mechanism in nature that promotes ongoing change. The method of change he suggested, however, is incorrect. Acquired characteristics are not transmitted to offspring. A person who is very muscular as a result of lifting weights will not be more likely to have a muscle-bound child (Figure 1–4).

Lamarck, like so many famous people of science, was a synthesizer. He combined previously existing notions (such as Linnaean classification and the idea of acquired characteristics) into a new system with new meaning. Although the details of his ideas are incorrect, his emphasis on change gave support to the thoughts of those investigators who would ultimately discover accurate explanations for the changes he proposed.

### Catastrophism

The work of Lamarck and other early evolutionists, along with increasing evidence that changes had occurred in the living world, prompted thinkers to attempt to reconcile the traditional view of a divinely created changeless world with new evidence and ideas. The French scholar Georges Cuvier (1769–1832) is known for developing the idea called the theory of **catastrophism**. Cuvier recognized the fact that as we dig down into the earth, we see different assemblages of plants and animals. In many cases, specific layers of flora and fauna

#### theory of acquired characteristics

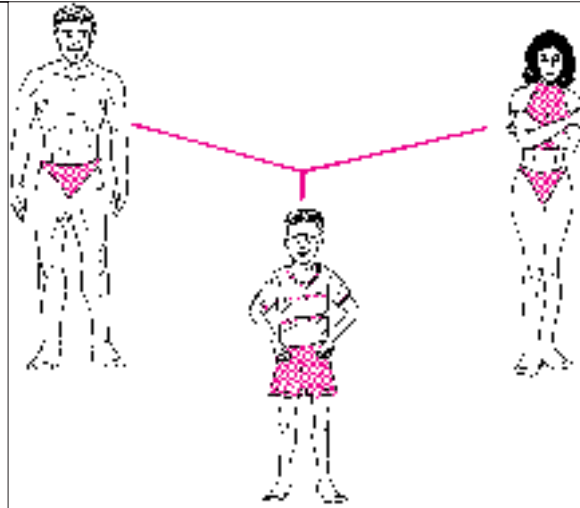
Concept, popularized by Lamarck, that traits gained during a lifetime can then be passed on to the next generation by genetic means; considered invalid today.

#### catastrophism

Idea that the earth has experienced a series of catastrophic destructions and creations and that fossil forms found in each layer of the earth are bounded by a creation and destruction event.

**FIGURE 1-4****Inheritance of Acquired Characteristics**

Today, biologists do not believe that the increase or decrease in the size or strength of parts of the body due to use or disuse is transmitted to offspring. For example, if a couple lift weights and become muscular, their newly acquired physical condition will not be passed on genetically to their offspring.



seem to be almost totally replaced by new types overlying them. Cuvier believed that the living organisms represented in each layer were destroyed by a catastrophic event and that the next set of plants and animals represented a new creation event. Although Cuvier did not construct his ideas to bolster a literal interpretation of the Bible, others saw the last catastrophic event as the biblical flood.

According to the proponents of catastrophism, not all plants and animals need be destroyed by a cataclysmic event. For instance, the animals that were collected by Noah survived the flood. Also, Cuvier believed that catastrophes could be localized. Organisms that survived in an area not affected by the cataclysm could then migrate into the areas left vacant by the catastrophe.

Today, evolutionists reject the ideas of divinely created organisms and divinely orchestrated catastrophes. However, just as Linnaeus's classification, originally conceived to explain traditional religious concepts, has become a major tool for modern biologists, some of Cuvier's ideas are still present in the work of some modern evolutionary theorists. As with Linnaeus's ideas, Cuvier's ideas have been expanded upon and reinterpreted in nonreligious terms. For instance, some modern researchers see catastrophic events, such as the effects of meteorites that hit the earth, as the catalysts of major evolutionary events, such as mass extinctions of plants and animals and ensuing rapid evolutionary changes in some of the surviving populations. However, other evolutionists do not view catastrophic events as primary causes of evolutionary change. They see large-scale evolution as the result of the gradual accumulation of small changes over time. This idea of gradual modification of a species is the basic thesis of Darwin's model of evolution. Before we discuss Darwin, however, we turn to a scientist who directly influenced him.

### What Is the Age of the Earth?

By the early nineteenth century, masses of new data had been gathered that threw doubt on traditional interpretations. Charles Lyell (1797–1875) synthesized this new information in a textbook, *Principles of Geology*, the first of three volumes being published in 1830 (Figure 1-5). In it he popularized the principle of **uniformitarianism**, first proposed by James Hutton (1726–1797), which was a main prerequisite to the development of a credible evolutionary theory. The principle of uniformitarianism states that physical forces, such as wind, rain, heat, cold, moving water, volcanism, and earthquakes, that are at work today altering the earth were also in force, working in the same way, in former times. Therefore, “the present is the key to the past.”

Lyell also realized that, as they operate today, the processes resulting in physical alteration of the earth would require very long periods of time to form the layers of the earth

#### **uniformitarianism**

Principle that states that physical forces working today to alter the earth were also in force and working in the same way in former times.

**FIGURE 1-5****Charles Lyell  
(1797–1875)**

The main purpose of his book, *Principles of Geology*, was to establish the principle of uniformitarianism, as the book's subtitle indicates: "Being an attempt to explain the former changes of the earth's surface, by reference to causes now in operation."

**strata**

Layers of sedimentary rocks.

known as **strata** (Figure 1-6). Therefore, it could be inferred that the large number and often great thickness of strata formed in the past must have taken a long time to develop. This inference also challenged biblical chronology because it showed that the earth's age was many times greater than previously thought. In popularizing the theory of uniformitarianism, Lyell also was setting the stage for a theory of the evolution of the living world.

William Smith (1769–1839), who was nicknamed "Strata Smith," had found that each stratum was characterized by distinct fossils that could be used to indicate the age of strata. In 1815, he released the first geological maps of English strata.

Charles Lyell also studied fossil plants and animals that were embedded in the various strata. These and other similar investigations suggested that the earth is extremely old and that life had existed in various forms, some now extinct, for hundreds of centuries. Lyell, himself, did not become convinced of the antiquity of living things until later in his life when, in his text *The Antiquity of Man* (1863), he supported Charles Darwin's theory of natural selection.

**Humans before Adam and Eve?**

Fossils of extinct forms of plants and animals had been known long before Lyell's time, and many valid interpretations had been made. However, as often happens, the evidence was more frequently viewed in terms of predispositions and the special interests of the observer; it was not analyzed critically. For instance, early proponents of catastrophism believed that extinct animals were creatures "who did not make the Ark." After Lyell's systematic investigation, some scientists began at last to speculate on the idea of a more dynamic world. Yet the notion of prehistoric people was still heresy. Were not all people descendants of Adam and Eve?

In the early 1800s, Jacques Boucher de Crèvecœur de Perthes (1788–1868) made a systematic attempt to demonstrate the existence of a prehistoric period. While digging on the banks of the Somme River in southwestern France, he discovered that many stones were not made of the same material as the walls of the pit in which they were uncovered. In addition, the stones had obviously been shaped into specific forms (Figure 1-7). Other people also

**FIGURE 1-6**

**Stratigraphy**

The Grand Canyon shows the various strata that have accumulated over millennia.



**FIGURE 1-7**

**Lightning Stone**

This is an example of a hand ax from the Lower Paleolithic of southwestern France.



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See the Online Learning Center for an Internet Activity on Charles Darwin

had observed these types of rocks. They considered them to be “figured stones” of an unknown origin or “lightning stones,” petrified lightning cast to the earth by God during thunderstorms. Boucher de Crèvecoeur de Perthes was convinced that they were made by ancient people. To back up this conviction, he collected what he thought was an immense amount of evidence to support his case. He submitted his report in 1838 to various scientific societies, where it was rejected. Not until 20 years later, a year before the publication of Darwin’s *On the Origin of Species*, were his conclusions accepted.

By the time of Darwin, the notions of anthropocentrism, immutability, and a date of 4004 B.C. for the earth’s origin had been altered or reversed. For most of the scientific community, the final discrediting of spontaneous creation would have to wait until the time of the French chemist Louis Pasteur (1822–1895). Pasteur, who had developed the pasteurization process and vaccinations against anthrax and rabies, also disproved spontaneous creation.

### Darwin’s Voyage of Discovery

It was Charles Darwin (1809–1882) who proposed a compelling theory for the mechanism of organic evolution that accurately synthesized the available evidence (Figure 1–8). At the age of 22, Darwin was invited to accompany a scientific investigation on the ship *HMS Beagle*. On December 27, 1831, the *Beagle* sailed from Plymouth, England, on what was to be a five-year voyage of discovery (Figure 1–9). Darwin spent much of the five years confined on the small ship, which measured 90 feet in length and less than 25 feet at the widest point. He was one of 74 aboard.

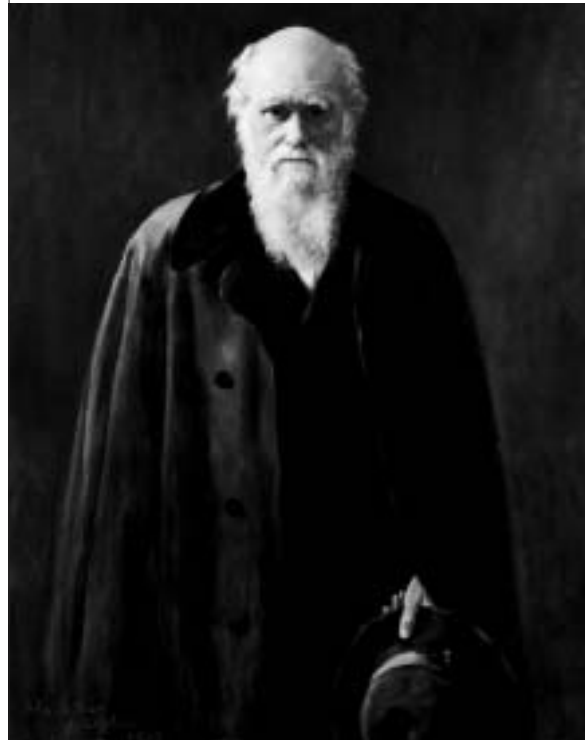
The purpose of the voyage was to chart the southeastern coast of South America and to calculate an accurate fixing of longitude around the world. It was the role of the voyage in Darwin’s life, however, that made it one of the most famous journeys in history. On this voyage, Darwin gained new insights into the origin of coral reefs, described in detail fauna and flora, and studied fossilized animals.

In the Andes, Darwin found seashells in rocks at 3962 meters (13,000 feet), and in Valdivia, Chile, he personally experienced a devastating earthquake that elevated the shore by several feet. These and other experiences showed how dynamic the earth is. He realized that

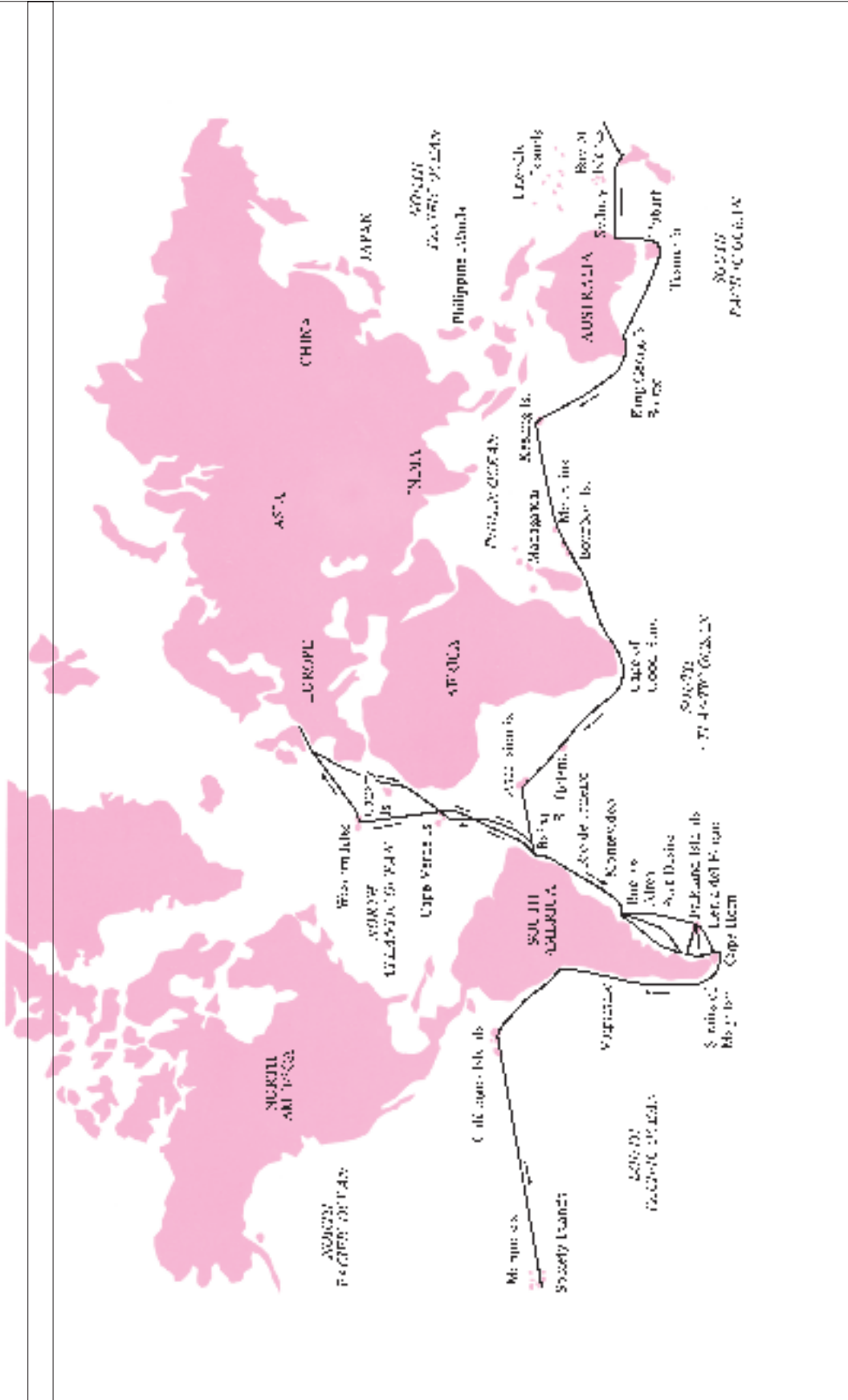
#### FIGURE 1–8

##### Charles Darwin (1809–1882)

The 1250 copies of the first printing of his book *On the Origin of Species* sold out on the day of its issue in 1859. Darwin’s concept of natural selection has been firmly established as a hallmark of modern biological science.



**FIGURE 1-9 The Voyage of Charles Darwin**  
This map traces the voyage of *HMS Beagle* (December 1831–October 1836), during which the young Charles Darwin gathered data that he would use to formulate the theory of natural selection.



the tops of mountains once had been under the sea and that coastlines could be significantly altered by earthquakes.

Throughout his trip, Darwin witnessed the great diversity in nature. His five-week visit to the Galápagos Islands, a volcanic group of islands some 965 kilometers (600 miles) west of Ecuador, possibly provided a major stimulus for his most famous contribution to science: the concept of natural selection. It was there that he observed giant tortoises, seagoing lizards, ground finches, and other animals that showed variations related to differences in the different island habitats. Ultimately he hypothesized that environmental forces acted to weed out those individuals whose characteristics were not as well-suited to a particular situation.

Darwin was not the only person who was developing a theory of evolution based on species adaptation to the environment. As often happens in science, two or more people came up with basically the same conclusion simultaneously. In the summer of 1858, Darwin must have got quite a jolt when he received an essay from Alfred Russell Wallace (1823–1913), another naturalist, with whom he had been corresponding (Figure 1–10). Wallace had come up with basically the same ideas that Darwin had been working on for two decades. Both men received credit for their work at a meeting of the Linnaean Society in 1858. Because Darwin was the first to publish his work, in his book *On the Origin of Species* in 1859, he has since received most of the credit for modern evolutionary theory.

### Darwinian Natural Selection

The concept of **natural selection** emerged from the analysis of the observations made and specimens collected by Charles Darwin on his voyage. Natural selection is the process of favoring or weeding out individuals with different characteristics from a population. Those individuals that are well-suited for their environment will be “favored” in the sense that they

#### natural selection


Differential fertility and mortality of genotypes within a population.

#### FIGURE 1–10

##### Alfred Russell Wallace (1823–1913)

Darwin was about halfway through writing *On the Origin of Species* in 1858 when he received an essay from Wallace that outlined Darwin’s ideas. Darwin published an extract of his book along with Wallace’s essay later in 1858. Neither piece received much attention at the time.



 See the Online Learning Center for an Interactive Exercise on natural selection

will pass on their heritable attributes to the next generation at a higher rate than individuals not as well-suited to the environment.

Darwin noted that within any group of plants or animals there existed much variability. With very few exceptions, each offspring of a pair of sexually reproducing adults is unique. (The exceptions include identical twins and the results of cloning.) While the majority of organisms resemble some type of average or norm, there will always be individuals that are smaller or larger, lighter or darker, or possess some unique features when compared with the average.

Darwin also realized that all living creatures have the capacity to reproduce in great numbers. For example, if one pair of houseflies bred in April and all eggs hatched and in turn lived to reproduce, by August the total number of houseflies descending from the original pair would be 191,010,000,000,000,000. Of course, in real life, not all eggs do hatch, and not all individuals that are born live to reproduce. However, the numbers of individuals born or hatched tend to be vast.

This capacity for organisms to rapidly increase in number was noted by Thomas R. Malthus (1766–1834) in his *Essay on the Principles of Population*. Malthus wrote that the human population is growing at a faster rate than food production, and famine and economic chaos would result as the population grew and food resources dwindled. In general, populations have the potential of dramatically increasing in numbers. However, such growth is limited by such factors as space, food, predators, and disease.

Because of limitations in population growth, Darwin concluded that only a proportion of animals that are born live to reproduce. Since individuals differ from one another, those individuals who possess features that increase the chance of surviving are likely to pass on these features to the next generation. On the other hand, organisms with traits that reduce the chance of successfully reproducing are less likely to pass on these traits. Thus, populations of organisms changed through time as those features that contribute to survival are inherited by future generations.

#### ***Darwin's Finches: A Case of Natural Selection***

Darwin believed that natural selection operated over extremely long periods of time. Therefore, natural selection could not be directly observed, although it could be deduced through the study of the end products or through individuals that have been fossilized. Darwin believed that his logic was sound—natural selection had to be occurring—but at a pace that was impossible to observe within the human life span.

Contemporary field biologists, however, have discovered many situations where natural selection is operating on a time scale that can be observed during the professional lifetime of the investigator. One such case involves the finches found on the Galápagos Islands. These birds, studied by Charles Darwin on his voyage, are today called Darwin's finches.

Finches are songbirds that belong to the same family as sparrows and canaries. Darwin observed several species of finches that had beaks of different sizes and shapes and generally ate different foods. Finches with large, powerful beaks could break open hard seeds that other finches could not. One variety of finch had a short, thick beak; its diet consisted mainly of leaves, buds, blossoms, and fruits. Another finch had a long, straight beak; it subsisted mainly on nectar from the prickly pear cactus.

Darwin believed that competition led to diversity in animal and plant types. For example, the small-beaked birds could not compete for hard seeds with the birds that had more powerful beaks. Unless the birds with smaller beaks possessed characteristics that would allow them to exploit a different segment of the habitat, they might become extinct.

Darwin was impressed by the fact that animals on the Galápagos Islands had “cousins” on the South American mainland. He postulated that since these volcanic islands were younger than the mainland, the animals must have originated on the mainland. He then reasoned that as members of the original population became isolated from each other, they evolved differently, depending on the local environment.

In 1973, biologists Peter and Rosemary Grant arrived on the very small island of Daphne Major in the Galápagos where they began a study that would involve several of their students

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**FIGURE 1-11****Darwin's Finches**

(a) The medium ground finch, *Geospiza fortis*, and (b) the cactus finch, *Geospiza scandens*.



(a)



(b)

and would last over two decades. Out of this work would come direct proof that natural selection did indeed occur in a real-life situation.<sup>2</sup>

Daphne Major is a small island of about 100 acres, small enough to be studied intensively. The Grants studied two species of finch that lived on the island, the medium ground finch and the cactus finch (Figure 1-11). Eventually all of the finches on the island were captured and released. They were carefully weighed and measured, and photographed; colored rings placed on their legs ensured that the investigators were able to identify each and every bird in the field. Newborn chicks were examined and banded before they left the nest. Their habitats were also carefully studied and available food supplies were quantified.

No rain fell on Daphne Major between mid-1976 and early 1978. Because of the lack of water, fewer seeds were produced and the small, soft seeds that were the preferred food for the ground finches soon disappeared. What was left were the larger, harder seeds that were very difficult to eat. In this situation, birds with larger and more powerful beaks had a distinct advantage. For example, it is very difficult to reach the four to six seeds within the hard fruit of *Tribulus*. On the average, the large ground finch is able to crack the fruit in about 2 seconds and within an additional 7 seconds is able to eat all of the seeds. On the other hand, the smaller ground finch takes about 7 seconds to get into the fruit and another 15 seconds to eat the one or two seeds it can wrestle out of the shell. The smaller bird is using more energy to get less food than the larger bird.

These estimates of time illustrate differences between species. Similar differences are found between birds of different sizes within the same species. Those animals with larger

<sup>2</sup> P. R. Grant, *Ecology and Evolution of Darwin's Finches* (Princeton, NJ: Princeton University Press, 1986); J. Weiner, *The Beak of the Finch* (New York: Knopf, 1994).

beaks expend less time and energy to more successfully exploit the large tough seeds that are left at the height of the drought.

Not surprisingly, a large number of birds died as a result of the drought. Of the 1200 medium ground finches living on the island at the beginning of 1977, only 180 remained at the end of that year—only 15 percent of the birds survived. The rest had died primarily of starvation. However, when the Grants measured the beaks of the surviving medium ground finches, they discovered that the survivors had an average beak size that was 4 percent greater than the size found before the start of the drought. Since beak size is to a large extent inherited, this increased beak size also characterized the new generation of birds born after the end of the drought. Clearly, natural selection had produced an increase in average beak size.

### Evolution and Creationism

On departing from Plymouth in 1831, the captain of the *Beagle*, Robert Fitzroy, presented Charles Darwin with a gift. That gift, a copy of the newly published *Principles of Geology* by Charles Lyell, influenced the development of Darwin's ideas and was the source of some heated debates between Darwin and Fitzroy, a religious fundamentalist. Had Fitzroy read the book, he may never have given it to Darwin.

After the voyage, Lyell became Darwin's friend. In 1859, Lyell recommended that a partial disclaimer of sorts be added to *On the Origin of Species*, one that would recognize the role of the "Creator" in evolution. The book was first published on November 24, 1859, with no disclaimer; it sold out its first printing that same day. *On the Origin of Species* became the focus of a controversy between those who believed in the divine creation of life (creationists) and those who believed in a natural origin of life (evolutionists).

#### "Creation-Science"

Darwin's concept of natural selection has survived the scrutiny of over 140 years of biological study to become one of the foundations of modern biological science. Yet there are those who, for various reasons that lie outside of science, feel that the concept of evolution must be disproved in favor of a creationist interpretation. In recent times, creationists modified an old strategy. They called the concept of the divine creation of life a scientific view, and the term **creation-science** was born. Even creationists of the nineteenth century had used the argument that the biblical account of creation could be scientifically proved. Creation-science advocates began to sue teachers and school districts to force them to teach creation-science alongside evolutionary theory. They also put pressure on publishers to de-emphasize evolution in biology textbooks.

Under such pressure, several states passed balanced-treatment acts, which required that teachers present "scientific" evidence for creation concurrent with the teaching of evolution. Because it ultimately came before the U.S. Supreme Court, the 1981 Balanced Treatment Act of Louisiana became one of the most important of these acts. On June 19, 1987, the Supreme Court, by a vote of 7 to 2, declared the Louisiana act, and therefore all others like it, unconstitutional on the same grounds that Clarence Darrow had argued 62 years before (Box 1–3). The court agreed that the act

advanced a religious doctrine by requiring either the banishment of the theory of evolution from public classrooms or the presentation of a religious viewpoint that rejects evolution in its entirety.

The Court ruled that the Louisiana act violated the First Amendment's prohibition of the state's promotion of religious beliefs. Although many biologists believed that creation-science advocates had been dealt a coup de grace to their legal battle over establishing laws that prohibit or cripple the teaching of evolution, creationists developed other strategies.

A school teacher named Ray Webster attempted to teach "creation-science" in an Illinois public school. In the 1990 case, *Webster v. The New Lenox School District*, the Seventh Circuit Court of Appeals found that creation-science was religious advocacy. They further ruled

#### creation-science

The idea that scientific evidence can be and has been gathered for creation as depicted in the Bible. Mainstream scientists, many religious leaders, and the Supreme Court discount any scientific value of "creation-science" statements.



## Box 1-3 The Scopes Trial

By the 1920s, many Western theologians, as well as much of the public, had reconciled the concept of natural selection and organic evolution with their religious beliefs. Yet, in some quarters, there was still strong opposition to Darwinism. This opposition had its most dramatic airing in the summer of 1925 in a public spectacle called the “Scopes trial.”

John T. Scopes was a high school teacher in Dayton, Tennessee, who decided to challenge that state’s new law, the Butler Act, which prohibited the teaching of evolution. After teaching evolution in the classroom, Scopes was arrested. The trial focused national attention on the controversy. Clarence Darrow helped defend Scopes; William Jennings Bryan, the Democratic nominee

for president in 1896, 1904, and 1908, worked for the prosecution.

Darrow argued the case on the basis that Scopes’s academic freedom had been violated and that Scopes also had the constitutional guarantee of the separation of church and state. Bryan, an old man by 1925, did not argue well and was severely embarrassed by the defense. Yet Scopes *had* broken the state law and was fined \$100. The conviction was later overturned on a technicality. It was not the conviction that was important but the fact that the publicity over the trial acted to increase public acceptance of evolution and to discourage many states from enacting so-called monkey laws.




Clarence Darrow (left circle) defends high school science teacher John T. Scopes (right circle) in 1925 for teaching evolution in the state of Tennessee.

that the school district did not violate Webster’s rights to free speech by prohibiting him from teaching religion in his social science classes.

In 1999, the Kansas state school board created a media uproar by voting to reject parts of the national teaching standard dealing with evolution and other scientific principles. The

### intelligent design theory

An essentially religious explanation of the world that assumes the existence of a supernatural force that is responsible for the great complexity of life on earth today.

 See the Online Learning Center for an Interactive Activity on intelligent design and the evolution of the eye

school board did not ban the teaching of evolution, but it removed it as a topic in state competency tests. The implication was that evolution should not be considered a fact. This decision received both media ridicule and criticism from scientific organizations including the National Academy of Sciences, which had issued the national teaching standard. The voters in Kansas elected a new school board, and on February 14, 2001, the board restored evolution as a central part of the curriculum and rejected all suggestions to decrease and degrade the coverage of evolutionary theory in the classroom.

### **Intelligent Design**

Today, the battleground has shifted away from “creation-science” to a new approach called “**intelligent design theory.**” It is an attempt to present a more scientific-appearing alternate to evolution. Although there is some variation in its presentation, proponents of intelligent design theory appear to be willing to accept a long history of life on earth and some operation of some evolutionary processes, particularly microevolution. Although disguised as a scientific alternate to evolution, it predicates the existence of a supernatural force—the designer—who is responsible for the great complexity of life on earth today. Because of its reliance on a supernatural or divine power, it is essentially a religious, and not a scientific, explanation.

The core idea of intelligent design theory is that the great complexity of structure and biochemical and physiological processes found in living organisms cannot be explained on the basis of the natural process of evolution. We can infer that there exists an intelligent designer who is responsible for the purposeful complexity of nature.

Natural selection is based upon incremental changes over time, which assumes the presence of several intermediate steps, each step the result of selection for randomly produced variation. Proponents of intelligent design theory argue that if each of these intermediate steps was selected for, each intermediate step would have to be fully functional and operational, which is an impossible situation. Therefore, an alternative to natural selection is the existence of an intellectual designer who is responsible for the complexity of living organisms either through creation or through a divinely guided progressive unfolding of a grand plan through time.

In response to this concept, evolutionary biologists point out that simply because biological processes appear to be unexplainable in terms of today’s scientific knowledge, we do not have to assume the presence of a supernatural designer as the logical alternative. Science is progressive, and scientific explanations for biological and physical complexity have and will continue to reveal themselves over time. After all, many scientific problems solved today were overwhelming and unknowable to scientists working at the start of the twentieth century.

Evolutionary biologists also point out that many complex biological systems exhibit major imperfections or design flaws that should not be present if a divine intelligence were responsibility for that design. Design flaws can best be explained as the natural outcome of gradual modification through time through natural selection rather than as the handiwork of a divine force. One example of such a design flaw is the fact that the retina of the human eye is constructed with blood vessels and nerve fibers overlaying the surface that receives the light, so that light that enters the eye must pass through these structures before hitting the retina. The passage of these nerves through the retina to the optic nerve on the backside of the retina results in a blind spot.

### **Evolutionary Theory after Darwin: The Synthetic Theory**

The basic concepts of Darwin’s theory of evolution remain the cornerstone of modern evolutionary theory, yet much has been added to this base. Darwin, Wallace, and other naturalists of their day did not have an accurate picture of inheritance. They therefore were not sure of how characteristics were passed on from generation to generation or how new characteristics might arise. Progress in this area began to be made by Gregor Mendel, who will be discussed in the next chapter. Mendel discovered the basic laws of heredity, which he published in 1868.

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**synthetic theory of evolution**

The theory of evolution that fuses Darwin's concept of natural selection with information from the fields of genetics, mathematics, embryology, paleontology, animal behavior, and other disciplines.

Mendel's work began to answer basic questions of inheritance. Since Mendel's time, our knowledge of genetics has grown enormously. In the 1930s, population geneticists began to explain, in mathematical and statistical terms, how evolution could be seen as a change in the genetic composition of populations. From the 1970s through the 2000s, dramatic new discoveries about the genetic material (DNA and RNA) have allowed us to see evolutionary processes that occur at the molecular level. In addition, advances in the study of embryology, paleontology, animal behavior, and other disciplines all have contributed to a modern understanding of evolution. Because this understanding is based on a synthesis of information from diverse fields, it is sometimes called the **synthetic theory of evolution**.


**Summary**

Evolutionary theory has been shown to be a valid and reliable explanation of basic questions about life. Modern evolutionary theory grew out of a European intellectual climate. Before the nineteenth century, most Europeans saw humans as the superior center of a world populated by spontaneously created organisms that did not change once created. Each of these ideas fell in the light of new knowledge gathered by hundreds of scholars, including Copernicus, Linnaeus, Buffon, Lamarck, Lyell, Boucher de Crèvecoeur de Perthes, Darwin, Wallace, and Mendel. Darwin's concept of natural selection has fused with Mendel's concept of genetics; to this mixture new ingredients continue to be added, including concepts about the genetics of populations. Also, ideas of what embryos, fossils, and animal behavior can tell us about the past have become part of what is called the synthetic theory of evolution.

**Key Terms**

anthropocentricity, 00	culture, 00	science, 00
anthropological linguistics, 00	empirical, 00	spontaneous generation, 00
anthropology, 00	hypothesis, 00	strata, 00
applied anthropology, 00	immutable, 00	synthetic theory of evolution, 00
archaeology, 00	intelligent design theory, 00	theory, 00
catastrophism, 00	monocausal explanation, 00	theory of acquired characteristics, 00
control, 00	multicausal explanation, 00	uniformitarianism, 00
creation-science, 00	natural selection, 00	variable, 00
cultural anthropology, 00	physical anthropology, 00	
	reliable, 00	

**Study Questions**

 See the Online Learning Center for additional study questions

1. The development of the evolutionary concept was part of the general changes that were occurring in Western society from the fifteenth through nineteenth centuries. How were such historical events as the discovery of North America and the American Revolution related to the development of the theory of evolution?
2. What were some of the concepts about human nature and the relationship between humans and nature that had to change before an evolutionary concept could develop?
3. How does the idea of "catastrophism" differ from Darwin's concept of natural selection?
4. Who were some of the scholars who contributed to the development of evolutionary ideas? What did each contribute to that development?
5. Darwin, Wallace, and other naturalists of the nineteenth century did not have an accurate notion of one aspect of modern evolutionary theory. What element of modern theory was missing from their writings? Who began to provide accurate analyses of this missing element?
6. What is meant by the phrase "the synthetic theory of evolution"?
7. Many antievolutionists believe that since science does not have answers for all questions, scientific conclusions are not necessarily correct. This attitude reflects a failure to understand

## Critical Thinking Questions

- the nature of science. What is the general nature of scientific thinking? In what way is science “self-correcting”?
8. In what way does a scientific statement differ from a doctrine?
1. One of the criticisms levied against evolution is that no one has ever seen one kind of animal evolve into another. Although natural selection has been seen to occur in a small-scale situation, such as the case of the finches of Daphne Major, the time frame for the evolution of new species is far greater than the human life span. However, it is possible to infer the evolutionary history of living species using facts of anatomy, DNA analysis, and the fossil record. We make conclusions as to facts from inference everyday in our normal, everyday activities. Give some examples.
  2. The development and acceptance of evolutionary theory in the nineteenth century was very much a product of the political, economic, and intellectual changes of the time. Discuss how the development of the industrial revolution set the stage for the development and acceptance of the concept of evolution.
  3. Scientific thinking is based on the application of the scientific method of empirical observation and experimentation to formulate ideas about reality. Religion is generally based on the acceptance of ideas based on faith found in religious writings and the interpretations made by religious practitioners. Do you think that there is any possibility of a philosophical combination of science and religion into one concept of reality?

## Suggested Readings

Darwin, C. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life*. London: J. Murray, 1859. Many editions have been produced of this classic, including a 1967 facsimile of the first edition.

Desmond, A., and J. Moore. *Darwin: The Life of a Tormented Evolutionist*. New York: Warner, 1991. This biography of Darwin makes use of newly available sources and places Darwin and his ideas in the context of Victorian science and society.

Edey, M., and D. C. Johanson. *Blueprints: Solving the Mystery of Evolution*. New York: Penguin, 1989. This volume is a fascinating survey of the “evolution” of the theory of evolution. It gives interesting biographical portraits of the main figures in the development of evolutionary theory.

Eldredge, Niles. *The Triumph of Evolution and the Failure of Evolution*. New York: Freeman, 2000. Niles Eldredge, of the American Museum of Natural History, presents a well-thought-out discussion of evolutionary theory and how evolution successfully by accounts for the diversity of life on our planet.

Futuyma, D. J. *Science on Trial: The Case for Evolution*. Sunderland, ME: Sinauer Publishing, 1995. This volume is an interesting overview of the conflict between evolutionary teaching and fundamentalist ideas.

Giere, R. N. *Understanding Scientific Reasoning*, 4th ed. Fort Worth: Holt, Rinehart and Winston, 1996. This book explains scientific thinking using examples of scientific discoveries and everyday events.

Gould, S. J. *Time's Arrow Time's Cycle*. Cambridge, MA: Harvard University Press, 1987. The author discusses the historical development of the concept of deep time in geology, including a discussion of Charles Lyell's contributions.

Lyell, C. *Principles of Geology*, 3 vols. London: J. Murray, 1830–1833; rpt. New York: Johnson Reprint, 1969. This was the first geology “textbook,” and it influenced Darwin's perceptions of nature.

Mayr, E. *The Growth of Biological Thought: Diversity, Evolution, and Inheritance*. Cambridge, MA: Harvard University Press, 1985. This is an award-winning book on the history and development of modern biology.

Milner, R. *The Encyclopedia of Evolution*. New York: Facts on File, 1990. This is a very useful encyclopedia with entries on important people and concepts.

Pennock, Robert T. *Towel of Babel: The Evidence against the New Creationism*. Cambridge, MA: MIT Press, 1999. Philosopher Robert Pennock explores and critiques the ideas of creationism.

Pennock, Robert T. *Intelligent Design and Its Critics: Philosophical, Theological, and Scientific Perspectives*. Cambridge, MA: MIT Press, 2002. This sequel to *Towel of Babel* is an anthology of articles by creationists and responses by their critics. Pennock concludes with an essay on why creationism should not be taught in schools.

Rudwick, M. J. S. *Georges Cuvier, Fossil Bones, and Geological Catastrophes: New Translations and Interpretations of Primary Text*. Chicago: University of Chicago Press, 1997. This volume includes a translation of Cuvier's papers and corrects misconceptions about his ideas and motivations.

*Scientific Genius and Creativity: Readings from Scientific American*. San Francisco: Freeman, 1987. This book includes biographies of 10 great scientists and explores the role of genius and creativity in scientific discoveries.

Simpson, G. G. (ed.). *The Book of Darwin*. New York: Washington Square Press, 1982. The great biologist George Gaylord Simpson presents selections from the writings of Charles Darwin with insightful commentary.

Young, D. *The Discovery of Evolution*. Cambridge, England: Cambridge University Press, 1991. Richly illustrated by many historical photographs and drawings, this volume traces the development of evolutionary theory. It is an excellent introduction to evolution for the new student.

In addition to books, the journals and magazines listed below consistently have materials useful to physical anthropology students.

The following are popular magazines:

*American Scientist*  
*Archaeology*  
*BioScience*  
*Discover*  
*National Geographic*  
*Natural History*  
*Science News*  
*Scientific American*  
*Smithsonian*

The following are scientific journals:

*American Anthropologist*  
*American Journal of Human Biology*  
*American Journal of Physical Anthropology*  
*American Journal of Primatology*  
*Annals of Human Biology and Human Ecology*  
*Current Anthropology*  
*Evolutionary Anthropology*  
*Human Biology*  
*Human Evolution*  
*Journal of Animal Behavior*  
*Journal of Forensic Science*  
*Journal of Human Evolution*  
*Nature*  
*Science*

**Suggested  
Websites**

American Anthropological Association:

<http://www.aaanet.org>

The Charles Darwin Foundation for the Galápagos Islands:

<http://darwinfoundation.org>

History of evolutionary theory from the University of California Museum of Paleontology:

<http://www.ucmp.berkeley.edu/history/evolution.html>

Online Literature Library—Charles Darwin:

<http://www.literature.org/authors/darwin-charles>