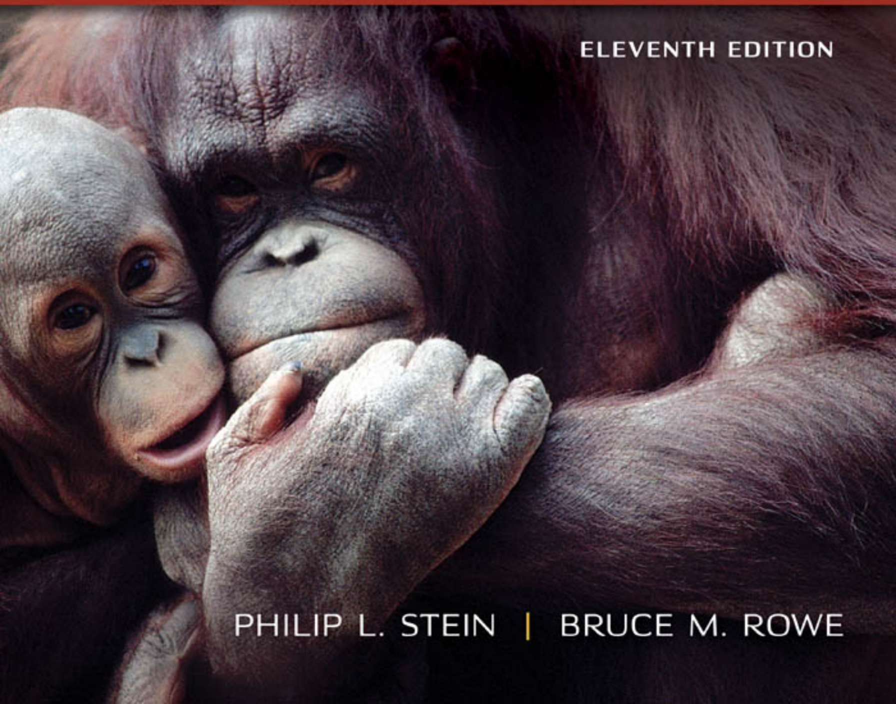
PHYSICAL ANTHROPOLOGY



ELEVENTH EDITION

PHILIP L. STEIN | BRUCE M. ROWE

Physical Anthropology

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Physical Anthropology

Eleventh Edition

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PHYSICAL ANTHROPOLOGY, ELEVENTH EDITION

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To our families and in the memory of

Eleanor Frances Blumenthal

Barbara Stein Akerman

Arnold L. Freed, M.D.

Sidney G. Stein

Rae Stein

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Preface

WHAT IS NEW IN THE ELEVENTH EDITION?

Physical anthropology is a dynamic field. We have updated the entire book on the basis of new information. This is seen most clearly in the chapters on the fossil record of human evolution (Chapters 12–15). As the last edition of this book was being prepared, a 47-million-year-old fossil, *Darwinius massillae,* which was nicknamed "Ida," was touted as "the missing link" in human evolution. The Internet and print media were full of claims and speculation, much of which either was not true or played on the public's misunderstanding of evolution, especially the misconception of a "missing link." Ida has little significance to the understanding of human evolution. We hope that after students complete a course in Physical Anthropology, they will recognize illogical or factually incorrect statements made in the name of evolutionary theory in the popular media. (*D. massillae* is discussed in the chapter on early primate evolution, along with a photograph.) Since we published the last edition of this book there have been numerous new fossil finds relevant to the study of human evolution as well as new analyses based on genetics that have shed light on human evolution and new insights on primate evolution and behavior based on the study of living primates.

In addition to updating the contents, the following are more-specific changes in this edition:

Chapter 1—Investigating the Nature of Humankind. The recently rehabilitated peppered moth example of natural selection was added to this chapter.

Chapter 2—The Study of Heredity. A new box was added on solving genetic problems using Punnett squares.

Chapter 3—The Modern Study of Human Genetics. We have added information on the 1000 Genome Project, predictive and preventive medicine, and caretaker genes.

Chapter 4—Population Genetics. New material on the bottleneck effect, the synergetic effect of the forces of evolution, and epigenetics as it relates to evolution has been included.

Chapter 5—The example of Darwin's finches was moved to Chapter 5 and used to further illustrate the concepts of selective agent, selective pressure, fitness, and adaptive radiation.

Chapter 6—We have added a new section "Similarities in Organisms" that includes a discussion of the concept of the Last Universal Common Ancestor (LUCA), evolutionary developmental biology, and Hox genes.

Chapter 7—The Living Primates. New topics include lemurs as the most endangered primate species, possible transmission of SIV from monkeys to humans that mutated into the HIV virus, and the tapetum lucidum.

Chapter 8—Comparative Studies: Anatomy and Genetics. New information on the function and variations of the inner ear in primates in relationship to primate communication and movement was added, as was a new box on aye-aye dentition and diet.

Chapter 9—Nonhuman Primate Behavior. We updated the case studies of the geladas and gibbons.

Chapter 10—Human Behavior in Perspective. A box on the evolution of cooperative behavior and networking has been added.

Chapter 11—The Record of the Past. The section "What Can Fossils Tell Us?" was rewritten and a box on the Anthropocene added.

Chapter 12—The Early Primate Fossil Record and the Origins of the Hominins. We have provided new information on the earliest primates.

Chapter 13—The Early Hominins. New information includes new material on *Australopithecus sediba,* the Afar of Ethiopia, locomotor patterns of early hominins, new evidence for early tool use, and the effects of climate change on hominin evolution.

Chapter 14—Early Species of the Genus *Homo*. We've added material on the significance of cooking, life in the Lower Paleolithic, taxonomic difficulties in defining the genus *Homo,* new information on *Homo antecessor,* what happened to the Neandertals, interpretation of Neandertal burials, the evolution of language including the FOXP2 gene, and the gestural hypothesis on the evolution of speech.

Chapter 15—The Evolution of *Homo Sapiens.* We have rewritten much of this chapter with new information on the origin of anatomical modern *Homo sapiens* in Africa and genetic admixture with earlier populations, the Denisovans, the Flores island fossils, the Red Deer Cave People, earliest cave art, and the peopling of the New World, with a box discussing the pros and cons of a European origin for some Native American populations.

Chapter 16—The Biology of Modern *Homo sapiens*. A new section on forensic anthropology has been added.

Chapter 17—The Analysis of Human Variation. We've introduced new material on human variation and intelligence and on the use of the concept of race in medicine.

Chapter 18—The Modern World. This chapter has been extensively updated and the material on forensic anthropology moved to Chapter 16.

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SUPPLEMENTS

For the Student

Student's Online Learning Center—This free Web-based student supplement features the following helpful tools at www.mhhe.com/stein11:

- Chapter objectives, outlines, and overviews.
- Self-quizzes (multiple choice and true/false questions with feedback indicating why an answer is correct or incorrect).
- Essay questions.
- Key terms.

FOR THE INSTRUCTOR

Instructor's Manual/Test Bank—This indispensable instructor supplement features chapter outlines, chapter summaries, learning objectives, discussion launchers, media and film suggestions, other resources including resources for distance learning, and a complete and extensive test bank with over 1200 test questions.

Instructor's Online Learning Center—Password-protected access to important instructor support materials and downloadable supplements such as

- The instructor's manual.
- PowerPoint lecture slides.

PowerWeb: Anthropology—A password-protected website that offers professors a turnkey solution for adding the Internet to a course. It includes current articles from *Annual Editions,* curriculum-based materials, weekly updates with assessment, informative and timely world news, refereed Web links, research tools, student study tools, interactive exercises, and much more.

As a full-service publisher of quality educational products, McGraw-Hill does much more than just sell textbooks. The publisher has created and published an extensive array of print, video, and digital supplements for students and instructors. This edition of *Physical Anthropology* includes an exciting supplements package. Orders of new (versus used) textbooks help us defray the cost of developing such supplements, which is substantial. Please consult your local McGraw-Hill representative for more information on any of the supplements.

Philip L. Stein
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About the Authors

Philip L. Stein

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Philip L. Stein has been teaching continuously at Pierce College since 1964. He received his BA in Zoology and MA in Anthropology from UCLA in 1961 and 1963, respectively. He has held a variety of positions at Pierce College, both as an instructor and as an administrator. He has contributed articles and chapters and has made presentations on the teaching of physical anthropology, including "The Teaching of Physical Anthropology," in C. Kottak et al. (eds.), *The Teaching of Anthropology: Problems, Issues, and Decisions* (Mountain View, CA: Mayfield, 1996), pp. 183–188; and "Teaching Anthropology in the Community College," in A. S. Ryan (ed.), *A Guide to Careers in Physical Anthropology* (Westport, CT: Bergin & Garvey, 2002), pp. 43–51. He has written the third edition of *The Anthropology of Religion, Magic, and Witchcraft* (Prentice Hall, 2011) with his daughter, Rebecca Stein, an instructor at Los Angeles Valley College. Professor Stein is a fellow of the American Anthropological Association and a member of the American Association of Physical Anthropologists and other professional organizations. He is active in the Society for Anthropology in Community Colleges, in which he served as President in 1995–96.

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Bruce M. Rowe is Professor of Anthropology at Los Angeles Pierce College, where he has taught since 1970. In addition to teaching physical and cultural anthropology courses, he teaches sociology and linguistics classes. He has coauthored the ten previous editions of *Physical Anthropology* and two editions of *Physical Anthropology: The Core.* Professor Rowe also has authored four editions of *The College Survival Guide: Hints and References to Aid College Students* and *The College Awareness Guide: What Students Need to Know to Succeed in College.* He is the coauthor of three editions of *A Concise Introduction to Linguistics* (with Diane P. Levine) and has contributed articles to two editions of *Strategies in Teaching Anthropology.* Professor Rowe has received numerous awards for teaching. He is a fellow of the American Anthropological Association and a member of the American Association of Physical Anthropologists and the Society for Anthropology in Community Colleges.

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A textbook in Physical Anthropology is full of bones, fossils, stones, and other physical things, in addition to important, complex concepts. This was a grand undertaking, and we were assisted by many exceptionally talented people. We want to thank these people here: Managing editor Penina Braffman; project manager Erin Melloy; designer Margarite Reynolds; director of content production Terri Schiesl; media project manager Sridevi Palani; and marketing manager specialist Alexandra Schultz.

Special appreciation goes to our families—especially Carol Stein and Christine L. Rowe, for their encouragement and help.

List of Boxes

Chapter 1

Investigating the Nature of Humankind

Evolution is not merely an idea, a theory, or a concept, but is the name of a process in nature, the occurrence of which can be documented by mountains of evidence that nobody has been able to refute. . . . It is now actually misleading to refer to evolution as a theory, considering the massive evidence that has been discovered over the last 140 years documenting its existence. Evolution is no longer a theory, it is simply a fact.

—*Ernst Mayr (1904–2005)*[1]

Chapter Outline

See the Online Learning Center for a chapter summary, chapter outline, and learning objectives.

After Reading This Chapter, You Should Be Able to Answer These Questions:

1. What are the main areas of interest in physical anthropology, and how does physical anthropology relate to the other subfields of anthropology?
2. What is meant by the term *scientific thinking,* and how does scientific thinking differ from religious thinking?
3. Generally speaking, the average European before the fifteenth century viewed the world much differently than does a modern person employing scientific thinking. In what ways were earlier views of the world different from those of most people in the scientific community today?
4. What are the historical events mentioned in this chapter that led to the changing view of the world? Specifically, what were the contributions of Nicolaus Copernicus, Carolus Linnaeus, Georges-Louis Leclerc de Buffon, Jean-Baptiste de Lamarck, Charles Lyell, William Smith, Jacques Boucher de Crèvecoeur de Perthes, Louis Pasteur, Charles Darwin, and Alfred Russel Wallace?
5. What is the concept of intelligent design, and what are the arguments against it?

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[1] E. Mayr, *What Evolution Is* (New York: Basic Books, 2001), p. 275.

"We have now seen that man is variable in body and mind; and that the variations are induced, either directly or indirectly, by the same general causes; and obey the same general laws, as with the lower animals."[2] These words were revolutionary for Charles Darwin's 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.

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 and from the people who lived in times past. 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.

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.

THE WORLD OF PHYSICAL ANTHROPOLOGY

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? **Anthropology** is such a broad discipline, however, that it is divided into several subfields or branches. One of the oldest subfields is that of **physical anthropology,** 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.

anthropology 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.

physical anthropology A branch of anthropology concerned with human biology and evolution.

Studies of Physical Anthropology

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.

Many anthropologists specialize in the study of human biology, and anthropologists are often found on the faculty of schools and departments of biology, public health, medicine, and dentistry. Many specialize in the study of anatomy, physiology, growth and development, aging, nutrition, health, and other related fields. Forensic anthropologists apply this knowledge to the analysis of skeletal remains from crime scenes to determine biological factors about the victim, such as sex and age at death, as well as to determine the probable cause of death.

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 DNA, the heredity material, has become one of the focuses of the field of comparative genomics, the comparison of all of the genetic information gathered on one species with other species. This has brought forth new understandings about the relationships among contemporary organisms and the relationship of extinct species to living species.

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

[2] C. Darwin, *The Descent of Man,* 2nd rev. ed. (London: J. Murray, 1874), p. 47.

Figure 1.1 The Study of the Fossil Record Paleoanthropologist David Lordkipanidze excavates an early hominin site at Dmanisi, Republic of Georgia.

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.

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 economically and politically influence one another.

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

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.* The Dian Fossey Gorilla Fund International.

situations through time and to explain stability and change. Although some archaeologists study contemporary societies, most archaeologists study the cultures of the past. **Linguistic anthropology** examines the history, function, structure, and physiology of one of people's most definitive characteristics—language. **Applied anthropology** is concerned with the application of anthropological ideas to current human problems.

linguistic anthropology 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.

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 evolution, and 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 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.

So just what is **science?** 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. Scientific investigations are based on observations. These observations may be the results of an experiment or simply an observation of something in nature, like a fossil tooth. The observations that we make must be **empirical.** By *empirical* we mean that we must be able to experience the object of study through our senses, although instruments, such as a microscope or an electronic scanning device, may be used to extend our senses.

Such empirical observations lead to the formation of questions about our world. However, scientific investigations can deal only with questions that are capable of being answered. Thus science cannot answer questions about morality or the supernatural.

science 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.

empirical Received through the senses (sight, touch, smell, hearing, taste), either directly or through extensions of the senses (such as a microscope).

Hypotheses and Testing Hypotheses

A **hypothesis** is a tentative answer to a question posed about an observation. A hypothesis, however, is not any explanation. It must be logical and testable; that is, there must be an objective way to find out if the hypothesis is correct or incorrect. Another way of stating this is that there must be some way to prove that the hypothesis is not true, although the result may show that the hypothesis is indeed correct.

In testing a hypothesis, one looks at the factors that characterize the observation; these factors are called **variables.** A variable is any factor or property of a phenomenon that may

hypothesis An informed supposition about the relationship of one variable to another.

variable Any property that may be displayed in different values.

be displayed in different ways or values. For example, the volume of the brain case, the part of the skull that houses the brain, is a variable. It may measure 400 cubic centimeters in one animal and 1300 cubic centimeters in another—it can vary. For a variable to be the subject of a scientific study, we must be able to measure it precisely. And different people measuring the same variable must arrive at the same value.

A hypothesis can be a statement about the relationship of one variable to another. Is one variable independent of the other variable, does one variable cause another variable to change, or does a third variable cause the two variables to change in a systematic way? For example, one might hypothesize that as the average size of the human brain increased through time, so did the complexity of technology. Brain size is one variable, and technological complexity 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.

Once proposed, the hypothesis must be tested against reality. One way to do this is to test the predictive value of the hypothesis by comparing it to all known data gathered from nature. In the previous example, we could measure brain case size in fossil skulls and count the number of certain types 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 tool types, we have identified one line of evidence that supports the validity of the hypothesis. New discoveries will either support the hypothesis or contradict it.

A second way to test a hypothesis is through experimentation. An **experiment** compares one situation with a second situation in which one variable has been altered by the experimenter. For instance, a geneticist could formulate a hypothesis about the function of a specific unit of inheritance. The geneticist could then conduct an experiment that rendered that unit inactive in one group of test subjects and left it alone in another group of test subjects. Analysis of the resulting data (observations) provides evidence of the validity of the hypothesis, disproves the hypothesis, or leads to a modification of the hypothesis. Experiments must be repeatable, and the validity of the original experiment depends on whether, when repeated, it yields the same results as did the initial experiment.

experiment A test of the predictive value of a hypothesis. A controlled experiment compares two situations in which only one variable differs.

A third possible way to test a hypothesis is to compare one phenomenon to other phenomena to determine relationships between them. The phenomena can be just about anything—rocks, stars, languages, living organisms. Although we cannot experiment directly with things that existed only in the past, we can compare living organisms to each other and look for patterns that indicate past evolutionary events and relationships. Comparative studies of anatomy have shown that chimpanzees and humans are more closely related to each other than humans are to monkeys. However, humans and monkeys are anatomically more closely related to each other than humans are to dogs. In Chapter 8, we will discuss comparative studies of genetics and biological molecules. In Chapters 9 and 10, we will talk about comparative behavioral studies.

After a number of studies exploring the relationships of all the variables have been completed, we might develop some generalizations. For instance, 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 populations from later ones. Each of these new hypotheses would have to be tested by some research design. Each test might reveal hidden variables that will 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.

Theory Science is cumulative. After many tests have been conducted on a set of similar hypotheses with confirming results, a **theory** may be proposed. For example, the testing of thousands of hypotheses on the reasons for progressive change in anatomy and behavior has led to great confidence in the theory of evolution.

theory 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.

Theory is a frequently misunderstood term. Many nonscientists equate theory with *hypothesis* or *speculation.* In popular usage, to say that something is "just a theory" means that it is just a vague and possibly erroneous sort of fact.

In reality, a scientific theory is a statement of extremely high validity—usually some general law or principle. The distinction between fact and theory is often subtle. For example, that evolution has occurred is a fact. The mechanisms, such as natural selection, that explain how and why evolution has occurred constitute a theory. The validity of evolution as a fact has not been an issue in science for well over 100 years, but the theories that explain the mechanisms of evolutionary change are still very much discussed and are important areas of ongoing research. So, when we refer to evolutionary theory, we are referring to the mechanisms that are responsible for evolutionary change.

Science and Religion

The theologian deeply involved in an interpretation of scriptures, the bereaved individual looking to scripture to explain death, and the shaman dancing for rain are putting their trust in traditional doctrines that, for the most part, they do not question. In contrast, the biologist examining cell structure, the anthropologist studying death rituals, and the meteorologist investigating the weather rely on methods and techniques that are aimed at producing new information and validating or correcting old explanations. Thus, they build a body of knowledge from which accurate predictions about natural occurrences can be made. The credibility of scientific conclusions is based on the concepts of accuracy, validity, and reliability; belief in religious doctrines is based on faith.

Scientists can attempt to answer only some questions; others cannot be subjected to scientific inquiry and are therefore not in the domain of empirical or objective research. For example, science cannot deal with the question of the existence of an omnipotent force. In order for an experiment to be carried out, a **control,** a situation that differs from the situation being tested, must be possible. If a phenomenon is present always and everywhere, how can its absence be tested?

control In the experimental method, a situation in which a comparison can be made between a specific situation and a second situation that differs, ideally, in only one aspect from the first.

Scientists do not claim that their conclusions are final. They realize that their statements are only as good as the data they have and that new information may alter their concepts. A religious belief can change in response to personal interpretation and public opinion, but such interpretation or new information is not necessarily linked to new empirical facts. To a believer, his or her religious belief or faith is taken as being absolutely true, whereas at no time is a scientific statement considered totally and irrefutably correct.

The scientific approach has been consciously and consistently used in Western societies since the 1600s; however, it is not just the industrial societies that practice science. All people make conclusions on the basis of experiments and observations. The phenomena that they can treat in this way make up their objective knowledge; the more mysterious facets of life are treated religiously or magically. For example, the Trobriand Islanders of the Pacific do two types of fishing: one in the shallow coastal pools and the other far out at sea. The first type is safe and is undertaken by men, women, and children; the second, filled with the 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. The story is different with deep-sea fishing. Men occasionally do not return from the expeditions, and so elaborate rituals are performed 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 better understand the universe and to predict the processes, structure, form, and function of natural occurrences. Scientific thinking provides a systematic method of investigation and includes the identification of variables, hypothesis formation, and tests of the validity of the hypothesis and of postulating theories. All scientific statements are tentative. It is because new evidence is always possible that a scientific statement can never be completely proved.

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

There were many variations in the early ideas about the universe. Biological evolutionary thought goes back to ancient times with some Greek, Roman, Chinese, and medieval Islamic scholars proposing ideas about how species change over time. However, many of the ideas held by people in Europe up until relatively recent times were the opposite of those embodied in present evolutionary thinking. These ideas had to be challenged before a new concept of reality could arise.

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

First among these views was the idea of **anthropocentricity,** the belief 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.

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

People of earlier times, as well as many people today whose beliefs are based on 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.

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

immutable Unchanging.

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 on the night before 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 on 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 that the earth was not the center of the universe; it is not even the center of the solar system! This was but one of a series of revelations that were to bombard the old ideas.

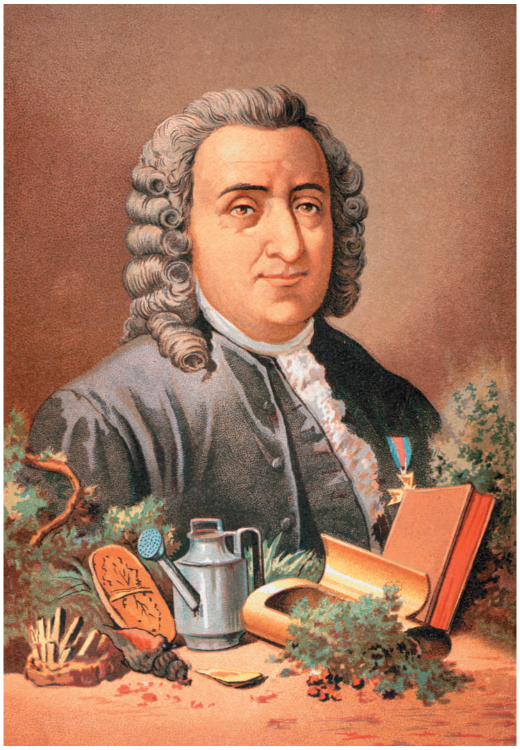

Figure 1.3 Carolus Linnaeus (1707–1778) Portrait of Carolus Linnaeus. A Swedish naturalist and botanist, he established what became the modern method of naming the living world.

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 and Vasco de Gama, revealed variations of life not dreamed of before. By 1758, 4235 species of animals were cataloged. Today, almost 2 million species have been formally described. This is only a small percentage of the estimated number of living species of animals thought to exist. 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.

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 kind of 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 on 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 categories included organisms that were very much alike, whereas the more general levels encompassed these 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 in 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 being discovered, 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.

A Brief History of the Development of Modern Evolutionary Theory

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, who coined the word *biology,* 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 proposed that an organism acquired new characteristics in its lifetime by virtue of using or not using different parts of its body. Lamarck believed that frequent use of a part of the body improved it whereas the lack of use of a body part weakened it, in some cases to the point where it disappeared altogether. This is called the **principle of use and disuse.** 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 **principle 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. However, there are some circumstances whereby environmental influences on an individual might be transmitted to the next generation and we will talk about those in Chapter 2. Yet, acquired characteristics are generally 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).

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 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 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.

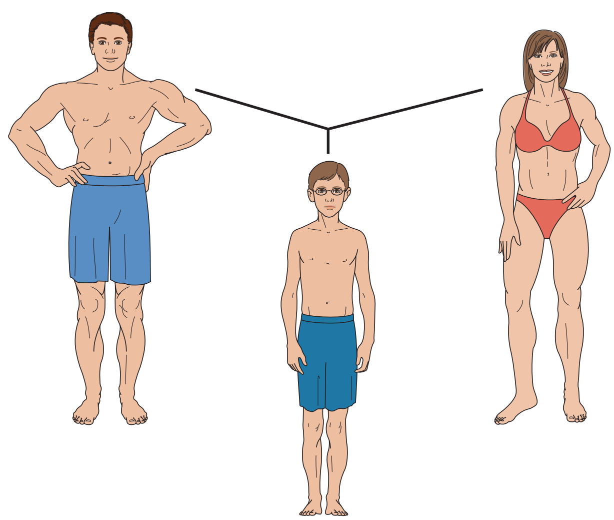

Figure 1.4 Inheritance of Acquired Characteristics
Today biologists do not believe that the increase or decrease in the size or strength of parts of the body due to use or disuse is transmitted to offspring. For example, if a couple lift weights and become muscular, their newly acquired physical condition will not be passed on genetically to their offspring.

principle of use and disuse Concept popularized by Lamarck that proposes that parts of the body that are used are often strengthened and improved, whereas parts of the body that are not used become weak and ultimately may disappear.

principle 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.

great chain of being (*scala naturae*) The idea that organisms are arranged in a hierarchy from lesser to greater state of perfection.