Science, Evolution, and Creationism
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CHAPTER ONE

EVOLUTION AND THE NATURE OF SCIENCE

The scientific evidence supporting biological evolution continues to grow at a rapid pace.

For more than a century and a half, scientists have been gathering evidence that expands our understanding of both the fact and the processes of biological evolution. They are investigating how evolution has occurred and is continuing to occur.

In 2004, for example, a team of researchers made a remarkable discovery. On an island in far northern Canada, they found a four-foot-long fossil with features intermediate between those of a fish and a four-legged animal. It had gills, scales, and fins, and it probably spent most of its life in the water. But it also had lungs, a flexible neck, and a sturdy fin skeleton that could support its body in very shallow water or on land.

Earlier scientific discoveries of fossilized plants and animals had already revealed a considerable amount about the environment in which this creature lived. About 375 million years ago, what is now Ellesmere Island in Nunavut Territory, Canada, was part of a broad plain crossed by many meandering streams. Trees, ferns, and other ancient plants grew on the banks of the streams, creating a rich environment for bacteria, fungi, and simple animals that fed on decaying vegetation. No large animals yet lived on the land, but Earth's oceans contained many **species** of fish, and some of those species fed on the plants and animals in shallow freshwater streams and swamps.

[**Species:** *In sexually reproducing organisms, species consist of individuals that can interbreed with each other.*]

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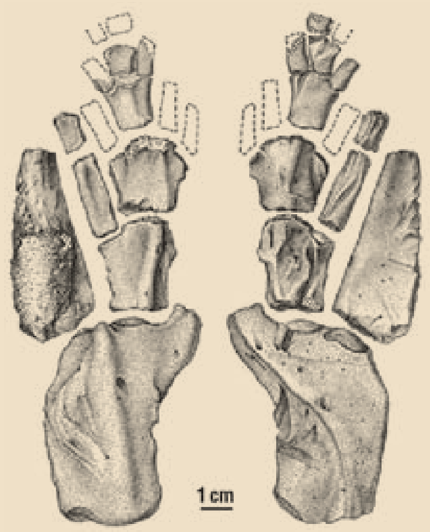
Paleontologist: *A scientist who studies fossils to learn about ancient organisms.*

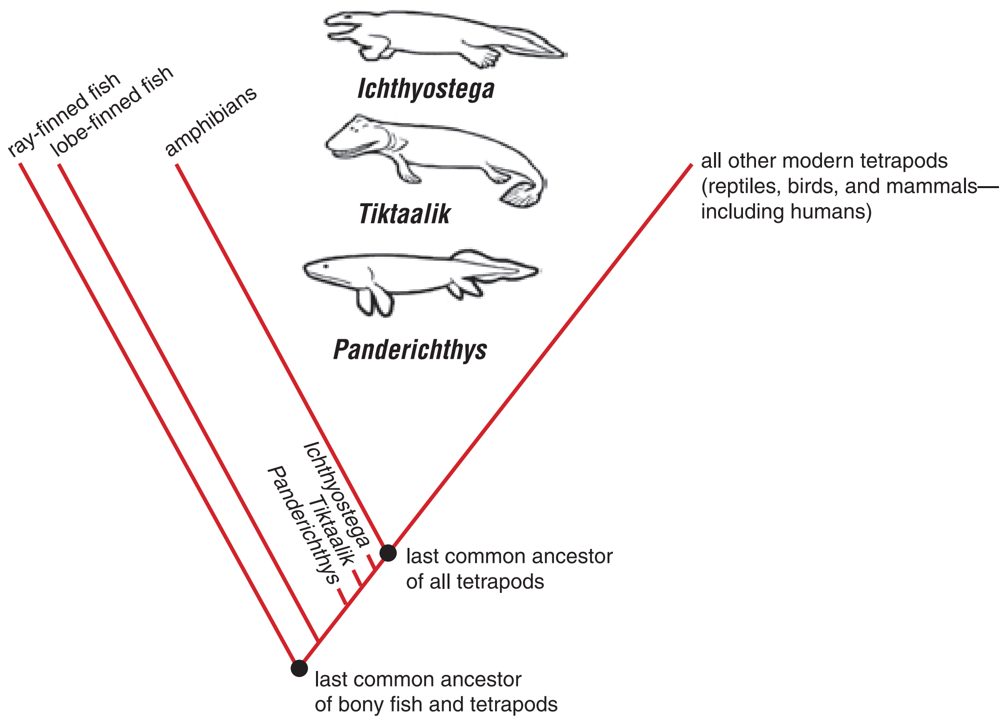
Paleontologists searched this valley in Nunavut, near the Arctic Circle in north central Canada, for fossils when they learned that it contained sedimentary rocks deposited during the period when limbed animals were first starting to live on land. Fossils of *Tiktaalik* were discovered on the dark outcropping of rock on the right side of this photograph.

Paleontologists had previously found the fossils of some of these shallow-water fishes. The bones in their fins were sturdier and more complex than in other fish species, perhaps allowing them to pull themselves through plant-filled channels, and they had primitive lungs as well as gills. Paleontologists had also found, in somewhat younger sediments, fossils of fishlike animals that likely spent part of their time on land. Known as early tetrapods (a word referring to their four legs), they had modified front and back fins that resembled primitive legs and other features suited for life out of the water. But paleontologists had not found fossils of the transitional animals between shallow-water fishes and limbed animals.

The team that discovered the new fossil decided to focus on far northern Canada when they noticed in a textbook that the region contained sedimentary rock deposited about 375 million years ago, just when shallow-water fishes were predicted by evolutionary science to be making the transition to land. The team had to travel for hours in planes and helicopters to reach the site, and they could work for just a couple of months each summer before snow began to fall. In their fourth summer of fieldwork they found what they had predicted they would find. In an outcropping of rock on the side of a hill, they uncovered the fossil of a creature that they named *Tiktaalik.* (The name means "big freshwater fish" in the language of the Inuit of northern Canada.) *Tiktaalik* still had many



Tiktaalik's left and right fins had a single upper bone (the large bone at the bottom of each of these drawings) followed by two intermediate bones, giving the creature an elbow and a wrist, as in more recent organisms.



Tiktaalik lived during the period when freshwater fishes were evolving the adaptations that enabled four-legged animals to live out of water. *Tiktaalik* may have lived somewhat before or somewhat after the ancestral species that gave rise to all of today's limbed animals, including humans. The evolutionary lineage that contained *Tiktaalik* may have gone extinct, as shown in this diagram by the short line branching from the main evolutionary lineage, or it may have been part of the evolutionary line leading to all modern tetrapods (animals with four legs). The last common ancestor of humans and all modern fishes also gave rise to evolutionary lineages that led to modern lobe-finned fishes (represented today by the coelacanth). In this and succeeding figures, time is represented by the lengths of the lines; modern groups of organisms are listed at the top of the figure.

of the features of fish, but it also had traits characteristic of early tetrapods. Most important, its fins contained bones that formed a limb-like appendage that the animal could use to move and prop itself up.

A prediction from more than a century of findings from evolutionary biology suggests that one of the early species that emerged from the Earth's oceans about 375 million years ago was the ancestor of amphibians, reptiles, dinosaurs, birds, and mammals. The discovery of *Tiktaalik* strongly supports that prediction. Indeed, the major bones in our own arms and legs are similar in overall configuration to those of *Tiktaalik.*

The discovery of *Tiktaalik*, while critically important for confirming predictions of evolution theory, is just one example of the many findings made every year that add depth and breadth to the scientific understanding of biological evolution. These discoveries come not just from paleontology but also from physics, chemistry, astronomy, and fields within biology. The theory of evolution is supported by so many observations and experiments that the overwhelming majority of scientists no longer question whether evolution has occurred and continues to occur and instead investigate the processes of evolution. Scientists are confident that the basic components of evolution will continue to be supported by new evidence, as they have been for the past 150 years.

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Biological evolution is the central organizing principle of modern biology.

[**Trait:** *A physical or behavioral characteristic of an organism.*]

[**DNA:** *Deoxyribonucleic acid. A biological molecule composed of subunits known as nucleotides strung together in long chains. The sequences of these nucleotides contain the information that cells need in order to grow, to divide into daughter cells, and to manufacture new proteins.*]

[**Protein:** *A large molecule consisting of a chain of smaller molecules called amino acids. The sequence of amino acids and the molecule's three-dimensional structure determine a protein's specific function in cells or organisms.*]

[**Mutation:** *A change in the sequence of nucleotides in DNA. Such changes can alter the structure of proteins or the regulation of protein production.*]

[**Population:** *A group of organisms of the same species that are in close enough proximity to allow them to interbreed.*]

The study of biological evolution has transformed our understanding of life on this planet. Evolution provides a scientific explanation for why there are so many different kinds of organisms on Earth and how all organisms on this planet are part of an evolutionary lineage. It demonstrates why some organisms that look quite different are in fact related, while other organisms that may look similar are only distantly related. It accounts for the appearance of humans on Earth and reveals our species' biological connections with other living things. It details how different groups of humans are related to each other and how we acquired many of our **traits.** It enables the development of effective new ways to protect ourselves against constantly evolving bacteria and viruses.

Biological evolution refers to changes in the traits of organisms over multiple generations. Until the development of the science of genetics at the beginning of the 20th century, biologists did not understand the mechanisms responsible for the inheritance of traits from parents to offspring. The study of genetics showed that heritable traits originate from the **DNA** that is passed from one generation to the next. DNA contains segments called genes that direct the production of **proteins** required for the growth and function of cells. Genes also orchestrate the development of a single-celled egg into a multicellular organism. DNA is therefore responsible for the continuity of biological form and function across generations.

However, offspring are not always exactly like their parents. Most organisms in any species, including humans, are genetically variable to some extent. In sexually reproducing species, where each parent contributes only one-half of its genetic information to its offspring (the offspring receives the full amount of genetic information when a sperm cell and an egg cell fuse), the DNA of the two parents is combined in new ways in the offspring. In addition, DNA can undergo changes known as **mutations** from one generation to the next, both in sexually reproducing and asexually reproducing organisms (such as bacteria).

When a mutation occurs in the DNA of an organism, several things can happen. The mutation may result in an altered trait that harms the organism, making it less likely to survive or produce offspring than other organisms in the **population** to which it belongs. Another possibility is that the mutation makes no difference to the well-being or reproductive success of an organism. Or the new mutation may result in a trait that enables an organism to take better advantage of the resources in its environment, thereby enhancing its ability to survive and produce offspring. For example, a fish might appear with a small modification to its fins that enables it to move more easily through shallow water (as occurred in the lineage leading to *Tiktaalik*); an insect might

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acquire a different shade of color that enables it to avoid being seen by predators; or a fly might have a difference in its wing patterns or courtship behaviors that more successfully attracts mates.

If a mutation increases the survivability of an organism, that organism is likely to have more offspring than other members of the population. If the offspring inherit the mutation, the number of organisms with the advantageous trait will increase from one generation to the next. In this way, the trait — and the genetic material (DNA) responsible for the trait — will tend to become more common in a population of organisms over time. In contrast, organisms possessing a harmful or deleterious mutation are less likely to contribute their DNA to future generations, and the trait resulting from the mutation will tend to become less frequent or will be eliminated in a population. Evolution consists of changes in the heritable traits of a population of organisms as successive generations replace one another. *It is populations of organisms that evolve, not individual organisms.*

The differential reproductive success of organisms with advantageous traits is known as **natural selection**, because nature "selects" traits that enhance the ability of organisms to survive and reproduce. Natural selection also can reduce the prevalence of traits that diminish organisms' abilities to survive and reproduce. Artificial selection is a similar process, but in this case humans rather than the environment select for desirable traits by arranging for animals or plants with those traits to breed. Artificial selection is the process responsible for the development of varieties of domestic animals (e.g., breeds of dogs, cats, and horses) and plants (e.g., roses, tulips, corn).

[**Natural selection:** *Differential survival and reproduction of organisms as a consequence of the characteristics of the environment.*]

Evolution in Medicine: Combating New Infectious Diseases

In late 2002 several hundred people in China came down with a severe form of pneumonia caused by an unknown infectious agent. Dubbed "severe acute respiratory syndrome," or SARS, the disease soon spread to Vietnam, Hong Kong, and Canada and led to hundreds of deaths. In March 2003 a team of researchers at the University of California, San Francisco, received samples of a virus isolated from the tissues of a SARS patient. Using a new technology known as a DNA microarray, within 24 hours the researchers had identified the virus as a previously unknown member of a particular family of viruses — a result confirmed by other researchers using different techniques.

Immediately, work began on a blood test to identify people with the disease (so they could be quarantined), on treatments for the disease, and on vaccines to prevent infection with the virus.

An understanding of evolution was essential in the identification of the SARS virus. The genetic material in the virus was similar to that of other viruses because it had evolved from the same ancestor virus. Furthermore, knowledge of the evolutionary history of the SARS virus gave scientists important information about the disease, such as how it is spread. Knowing the evolutionary origins of human pathogens will be critical in the future as existing infectious agents evolve into new and more dangerous forms.

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Evolution in Agriculture: The Domestication of Wheat

When humans understand a phenomenon that occurs in nature, they often gain increased control over it or can adapt it to new uses. The domestication of wheat is a good example.

By recovering seeds from different archaeological sites and noticing changes in their characteristics over the centuries, scientists have hypothesized how wheat was altered by humans over time. About 11,000 years ago, people in the Middle East began growing plants for food rather than relying entirely on the wild plants and animals they could gather or hunt. These early farmers began saving seeds from plants with particularly favorable traits and planting those seeds in the next growing season. Through this process of "artificial selection," they created a variety of crops with characteristics particularly suited for agriculture. For example, farmers over many generations modified the traits of wild wheat so that seeds remained on the plant when ripe and could easily be separated from their hulls. Over the next few millennia, people around the world used similar processes of evolutionary change to transform many other wild plants and animals into the crops and domesticated animals we rely on today.

In recent years, plant scientists have begun making hybrids of wheat with some of their wild relatives from the Middle East and elsewhere. Using these hybrids, they have bred wheat varieties that are increasingly resistant to droughts, heat, and pests. Most recently, molecular biologists have been identifying the genes in the DNA of plants that are responsible for their advantageous traits so that these genes can be incorporated into other crops. These advances rely on an understanding of evolution to analyze the relationships among plants and to search for the traits that can be used to improve crops.

Evolution can result in both small and large changes in populations of organisms.

Evolutionary biologists have discovered structures, biochemical processes and pathways, and behaviors that appear to have been highly conserved within and across species. Some species have undergone little overt change in their body structure over many millions of years. At the level of DNA, some genes that control the production of biochemicals or chemical reactions that are essential for cellular functioning show little variation across species that are only distantly related. (See, for example, the DNA sequences for two different genes that are conserved in closely related as well as more distantly related species that are described on pages 30 and 31.)

However, natural selection also can have radically different evolutionary effects over different timescales. Over periods of just a few generations (or,

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in some documented cases, even a single generation), evolution produces relatively small-scale **microevolutionary** changes in organisms. For example, many disease-causing bacteria have been evolving increased resistance to antibiotics. When a bacterium undergoes a genetic change that increases its ability to resist the effects of an antibiotic, that bacterium can survive and produce more copies of itself while nonresistant bacteria are being killed. Bacteria that cause tuberculosis, meningitis, staph infections, sexually transmitted diseases, and other illnesses have all become serious problems as they have developed resistance to an increasing number of antibiotics.

[**Microevolution:** *Changes in the traits of a group of organisms that do not result in a new species.*]

Another example of microevolutionary change comes from an experiment on the guppies that live in the Aripo River on the island of Trinidad. Guppies that live in the river are eaten by a larger species of fish that eats both juveniles and adults, while guppies that live in the small streams feeding into the river are eaten by a smaller fish that preys primarily on small juveniles. The guppies in the river mature faster, are smaller, and give birth to more and smaller offspring than the guppies in the streams do because guppies with these traits are better able to avoid their predator in the river than are larger guppies. When guppies were taken from the river and introduced into a stream without a preexisting population of guppies, they evolved traits like those of the stream guppies within about 20 generations.

Studies of guppies in Trinidad have demonstrated basic evolutionary mechanisms.

Incremental evolutionary changes can, over what are usually very long periods of time, give rise to new types of organisms, including new species. The formation of a new species generally occurs when one subgroup within a species mates for an extended period largely within the subgroup. For example, a subgroup may become geographically separated from the rest of the species, or a subgroup may come to use resources in a way that sets them apart from other members of the same species. As members of the subgroup mate among themselves, they accumulate genetic differences compared with the rest of the species. If this reproductive isolation continues for an extended period,

How long could it take to produce 1,000 generations?
How many generations might occur in a million years?

	1 Generation	1,000 Generations	Generations per 1 million years
Bacteria	1 hour to 1 day	1,000 hours (42 days) to 2.7 years	8.7 billion to 370.4 million
Pets: dog/cat	2 years	2,000 years	500,000
Humans	22 years	22,000 years	45,000

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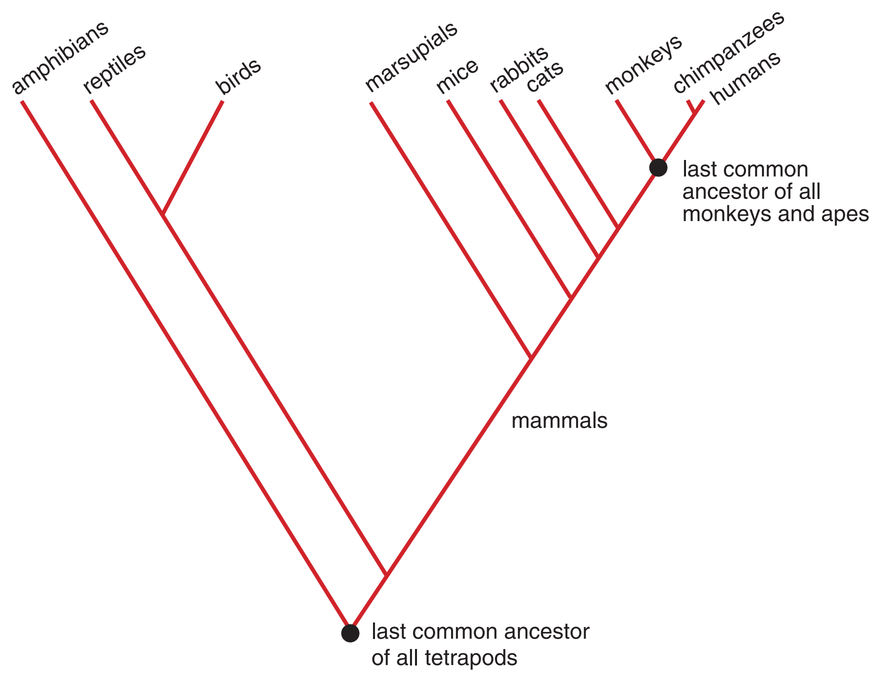
members of the subgroup may no longer respond to courtship or other signals from members of the original population. Eventually, genetic changes will become so substantial that the members of different subgroups can no longer produce viable offspring even if they do mate. In this way, existing species can continually "bud off" new species.

Over very long periods of time, continued instances of speciation can produce organisms that are very different from their ancestors. Though each new species resembles the species from which it arose, a succession of new species can diverge more and more from an ancestral form. This divergence from an ancestral form can be especially dramatic when an evolutionary change enables a group of organisms to occupy a new habitat or make use of resources in a novel way.

When tetrapods (such as this sea turtle laying its eggs on a coastal beach) evolved the ability to lay hard-shelled eggs, they no longer had to return to the water to reproduce.

Consider, for example, the continued evolution of the tetrapods after limbed animals began living on land. As new species of plants evolved and covered the Earth, new species of tetrapods appeared with features that enabled them to take advantage of these new environments. The early tetrapods were amphibians that spent part of their lives on land but continued to lay their eggs in the water or in moist environments. The evolution about 340 million years ago of amniotic eggs, which have structures such as hard or leathery shells

The last common ancestor of the four-legged animals living today gave rise to amphibians and was the predecessor of reptiles. Birds and mammals evolved from different lineages of ancient reptiles.



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Evolution in Industry: Putting Natural Selection to Work

The concept of natural selection has been applied in many fields outside biology. For example, chemists have applied principles of natural selection to develop new molecules with specific functions. First they create variants of an existing molecule using chemical techniques. They then test the variants for the desired function. The variants that do the best job are used to generate new variants. Repeated rounds of this selection process result in molecules that have a greatly enhanced ability to perform a given task. This technique has been used to create new enzymes that can convert cornstalks and other agricultural wastes into ethanol with increased efficiency.

and additional membranes that allow developing embryos to survive in dry environments, was one of the key developments in the evolution of the reptiles.

The early reptiles split into several major lineages. One lineage led to reptiles, including dinosaurs, and also to birds. Another lineage gave rise to mammals between 200 million and 250 million years ago.

The evolutionary transition from reptiles to mammals is particularly well documented in the fossil record. Successive fossil forms tend to have larger brains and more specialized sense organs, jaws and teeth adapted for more efficient chewing and eating, a gradual movement of the limbs from the sides of the body to under the body, and a female reproductive tract increasingly able to support the internal development and nourishment of young. Many of the biological novelties seen in mammals may be associated with the evolution of warm-bloodedness, which enabled a more active lifestyle over a much larger range of temperatures than in the cold-blooded reptilian ancestors.

Then, between 60 million and 80 million years ago, a group of mammals known as the primates first appeared in the fossil record. These mammals had grasping hands and feet, frontally directed eyes, and even larger and more complex brains. This is the lineage from which ancient and then modern humans evolved.

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Scientists seek explanations of natural phenomena based on empirical evidence.

Advances in the understanding of evolution over the past two centuries provide a superb example of how science works. Scientific knowledge and understanding accumulate from the interplay of observation and explanation. Scientists gather information by observing the natural world and conducting experiments. They then propose how the systems being studied behave in general, basing their explanations on the data provided through their experiments and other observations. They test their explanations by conducting additional observations and experiments under different conditions. Other scientists confirm the observations independently and carry out additional studies that may lead to more sophisticated explanations and predictions about future observations and experiments. In these ways, scientists continually arrive at more accurate and more comprehensive explanations of particular aspects of nature.

In science, explanations must be based on naturally occurring phenomena. Natural causes are, in principle, reproducible and therefore can be checked independently by others. If explanations are based on purported forces that are outside of nature, scientists have no way of either confirming or disproving those explanations. Any scientific explanation has to be *testable* — there must be possible observational consequences that could support the idea *but also ones that could refute it*. Unless a proposed explanation is framed in a way that some observational evidence could potentially count against it, that explanation cannot be subjected to scientific testing.

Definition of Science

The use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process.

Because observations and explanations build on each other, science is a cumulative activity. Repeatable observations and experiments generate explanations that describe nature more accurately and comprehensively, and these explanations in turn suggest new observations and experiments that can be used to test and extend the explanation. In this way, the sophistication and scope of scientific explanations improve over time, as subsequent generations of scientists, often using technological innovations, work to correct, refine, and extend the work done by their predecessors.

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Is Evolution a Theory or a Fact?

It is both. But that answer requires looking more deeply at the meanings of the words "theory" and "fact."

In everyday usage, "theory" often refers to a hunch or a speculation. When people say, "I have a theory about why that happened," they are often drawing a conclusion based on fragmentary or inconclusive evidence.

The formal scientific definition of theory is quite different from the everyday meaning of the word. It refers to a comprehensive explanation of some aspect of nature that is supported by a vast body of evidence.

Many scientific theories are so well established that no new evidence is likely to alter them substantially. For example, no new evidence will demonstrate that the Earth does not orbit around the Sun (heliocentric theory), or that living things are not made of cells (cell theory), that matter is not composed of atoms, or that the surface of the Earth is not divided into solid plates that have moved over geological timescales (the theory of plate tectonics). Like these other foundational scientific theories, the theory of evolution is supported by so many observations and confirming experiments that scientists are confident that the basic components of the theory will not be overturned by new evidence. However, like all scientific theories, the theory of evolution is subject to continuing refinement as new areas of science emerge or as new technologies enable observations and experiments that were not possible previously.

One of the most useful properties of scientific theories is that they can be used to make predictions about natural events or phenomena that have not yet been observed. For example, the theory of gravitation predicted the behavior of objects on the Moon and other planets long before the activities of spacecraft and astronauts confirmed them. The evolutionary biologists who discovered *Tiktaalik* (see page 2) predicted that they would find fossils intermediate between fish and limbed terrestrial animals in sediments that were about 375 million years old. Their discovery confirmed the prediction made on the basis of evolutionary theory. In turn, confirmation of a prediction increases confidence in that theory.

In science, a "fact" typically refers to an observation, measurement, or other form of evidence that can be expected to occur the same way under similar circumstances. However, scientists also use the term "fact" to refer to a scientific explanation that has been tested and confirmed so many times that there is no longer a compelling reason to keep testing it or looking for additional examples. In that respect, the past and continuing occurrence of evolution is a scientific fact. Because the evidence supporting it is so strong, scientists no longer question whether biological evolution has occurred and is continuing to occur. Instead, they investigate the mechanisms of evolution, how rapidly evolution can take place, and related questions.

In science it is not possible to prove with absolute certainty that a given explanation is complete and final. Some of the explanations advanced by scientists turn out to be incorrect when they are tested by further observations or experiments. New instruments may make observations possible that reveal the inadequacy of an existing explanation. New ideas can lead to explanations that reveal the incompleteness or deficiencies of previous explanations. Many scientific ideas that once were accepted are now known to be inaccurate or to apply only within a limited domain.

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However, many scientific explanations have been so thoroughly tested that they are very unlikely to change in substantial ways as new observations are made or new experiments are analyzed. These explanations are accepted by scientists as being true and factual descriptions of the natural world. The atomic structure of matter, the genetic basis of heredity, the circulation of blood, gravitation and planetary motion, and the process of biological evolution by natural selection are just a few examples of a very large number of scientific explanations that have been overwhelmingly substantiated.

Science is not the only way of knowing and understanding. *But science is a way of knowing that differs from other ways in its dependence on empirical evidence and testable explanations.* Because biological evolution accounts for events that are also central concerns of religion — including the origins of biological diversity and especially the origins of humans — evolution has been a contentious idea within society since it was first articulated by Charles Darwin and Alfred Russel Wallace in 1858.

Acceptance of the evidence for evolution can be compatible with religious faith.

Today, many religious denominations accept that biological evolution has produced the diversity of living things over billions of years of Earth's history. Many have issued statements observing that evolution and the tenets of their faiths are compatible. Scientists and theologians have written eloquently about their awe and wonder at the history of the universe and of life on this planet, explaining that they see no conflict between their faith in God and the evidence for evolution. Religious denominations that do not accept the occurrence of evolution tend to be those that believe in strictly literal interpretations of religious texts.

Science and religion are based on different aspects of human experience. In science, explanations *must* be based on evidence drawn from examining the natural world. Scientifically based observations or experiments that conflict with an explanation eventually *must* lead to modification or even abandonment of that explanation. Religious faith, in contrast, does not depend only on empirical evidence, is not necessarily modified in the face of conflicting evidence, and typically involves supernatural forces or entities. Because they are not a part of nature, supernatural entities cannot be investigated by science. In this sense, science and religion are separate and address aspects of human understanding in different ways. Attempts to pit science and religion against each other create controversy where none needs to exist.

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Excerpts of Statements by Religious Leaders Who See No Conflict Between Their Faith and Science

Many religious denominations and individual religious leaders have issued statements acknowledging the occurrence of evolution and pointing out that evolution and faith do not conflict.

"[T]here is no contradiction between an evolutionary theory of human origins and the doctrine of God as Creator."

— General Assembly of the Presbyterian Church

"[S]tudents' ignorance about evolution will seriously undermine their understanding of the world and the natural laws governing it, and their introduction to other explanations described as 'scientific' will give them false ideas about scientific methods and criteria."

— Central Conference of American Rabbis

"In his encyclical *Humani Generis* (1950), my predecessor Pius XII has already affirmed that there is no conflict between evolution and the doctrine of the faith regarding man and his vocation, provided that we do not lose sight of certain fixed points. . . . Today, more than a half-century after the appearance of that encyclical, some new findings lead us toward the recognition of evolution as more than an hypothesis. In fact it is remarkable that this theory has had progressively greater influence on the spirit of researchers, following a series of discoveries in different scholarly disciplines. The convergence in the results of these independent studies — which was neither planned nor sought — constitutes in itself a significant argument in favor of the theory."

— Pope John Paul II, Message to the Pontifical Academy of Sciences, October 22, 1996.

Excerpts of Statements by Religious Leaders Who See No Conflict Between Their Faith and Science

(continued)

"We the undersigned, Christian clergy from many different traditions, believe that the timeless truths of the Bible and the discoveries of modern science may comfortably coexist. We believe that the theory of evolution is a foundational scientific truth, one that has stood up to rigorous scrutiny and upon which much of human knowledge and achievement rests. To reject this truth or to treat it as 'one theory among others' is to deliberately embrace scientific ignorance and transmit such ignorance to our children. We believe that among God's good gifts are human minds capable of critical thought and that the failure to fully employ this gift is a rejection of the will of our Creator. . . . We urge school board members to preserve the integrity of the science curriculum by affirming the teaching of the theory of evolution as a core component of human knowledge. We ask that science remain science and that religion remain religion, two very different, but complementary, forms of truth."

—"The Clergy Letter Project" signed by more than 10,000 Christian clergy members. For additional information, see http://www.butler.edu/clergyproject/clergy_project.htm.

Excerpts of Statements by Scientists
Who See No Conflict Between Their Faith and Science

Scientists, like people in other professions, hold a wide range of positions about religion and the role of supernatural forces or entities in the universe. Some adhere to a position known as scientism, which holds that the methods of science alone are sufficient for discovering everything there is to know about the universe. Others ascribe to an idea known as deism, which posits that God created all things and set the universe in motion but no longer actively directs physical phenomena. Others are theists, who believe that God actively intervenes in the world. Many scientists who believe in God, either as a prime mover or as an active force in the universe, have written eloquently about their beliefs.

"Creationists inevitably look for God in what science has not yet explained or in what they claim science cannot explain. Most scientists who are religious look for God in what science does understand and has explained."

— Kenneth Miller, professor of biology at Brown University and author of *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Religion*. Quote is excerpted from an interview available at http://www.actionbioscience.org/evolution/miller.html.

"In my view, there is no conflict in being a rigorous scientist and a person who believes in a God who takes a personal interest in each one of us. Science's domain is to explore nature. God's domain is in the spiritual world, a realm not possible to explore with the tools and language of science. It must be examined with the heart, the mind, and the soul."

— Francis Collins, director of the Human Genome Project and of the National Human Genome Research Institute at the National Institutes of Health. Excerpted from his book, *The Language of God: A Scientist Presents Evidence for Belief* (p. 6).

"Our scientific understanding of the universe . . . provides for those who believe in God a marvelous opportunity to reflect upon their beliefs."

— Father George Coyne, Catholic priest and former director of the Vatican Observatory. Quote is from a talk, "Science Does Not Need God, or Does It? A Catholic Scientist Looks at Evolution," at Palm Beach Atlantic University, January 31, 2006. Available at http://chem.tufts.edu/AnswersInScience/Coyne-Evolution.htm.