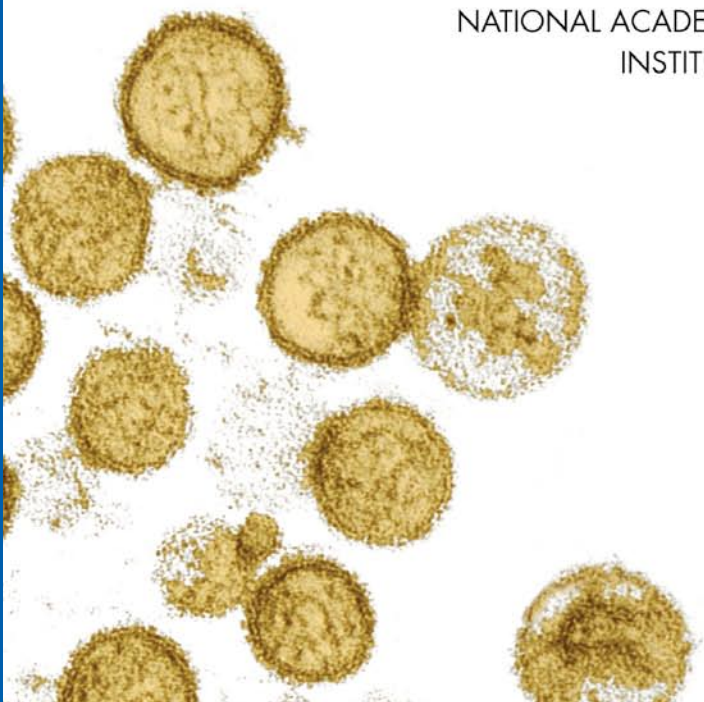
SCIENCE, EVOLUTION, AND CREATIONISM

NATIONAL ACADEMY OF SCIENCES
INSTITUTE OF MEDICINE



Why Is Evolution Important?

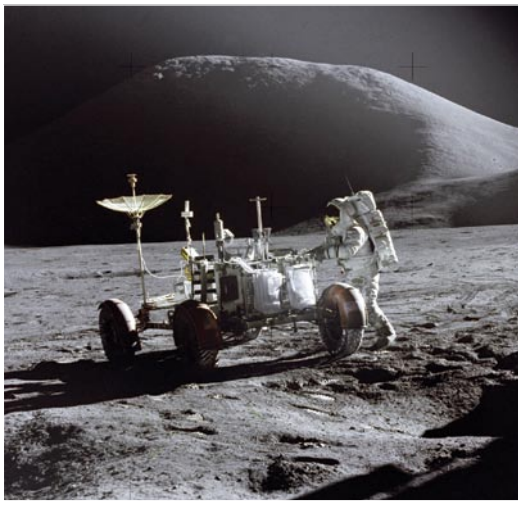
The discovery and understanding of the processes of evolution represent one of the most powerful achievements in the history of science. Evolution successfully explains the diversity of life on Earth and has been confirmed repeatedly through observation and experiment in a broad spectrum of scientific disciplines.

Evolutionary science provides the foundation for modern biology. It has opened the door to entirely new types of medical, agricultural, and environmental research, and has led to the development of technologies that can help prevent and combat disease. Regrettably, effective science education in our schools is being undermined by efforts to introduce non-scientific concepts about evolution into science classrooms.

How Science Works

The study of evolution provides an excellent example of how scientists go about their work. They observe nature and ask testable questions about the natural world, test those questions through experiment and new observations, and construct explanations of evolution based on evidence. As scientists gather new results and findings, they continue to refine their ideas. Explanations are altered or sometimes rejected when compelling contradictory evidence comes to light.

Some scientific explanations are so well established that no new evidence is likely to alter them. The explanation becomes a scientific theory. In everyday language a theory means a hunch or speculation. Not so in science. In science, the word theory refers to a comprehensive explanation of an important feature of nature that is supported by many facts gathered over time. Theories also allow scientists to make predictions about as yet unobserved phenomena.



A good example is the theory of gravity. After hundreds of years of observation and experiment, the basic facts of gravity are understood. The theory of gravity is an explanation of those basic facts. Scientists then use the theory to make predictions about how gravity will function in different circumstances. Such predictions have been verified in countless experiments, further confirming the theory. Evolution stands on an equally solid foundation of observation, experiment, and confirming evidence

The Theory of Evolution Has Been Repeatedly Tested and Confirmed

We all know from our experience that biological traits pass from parents to offspring. This is the basis of evolution.

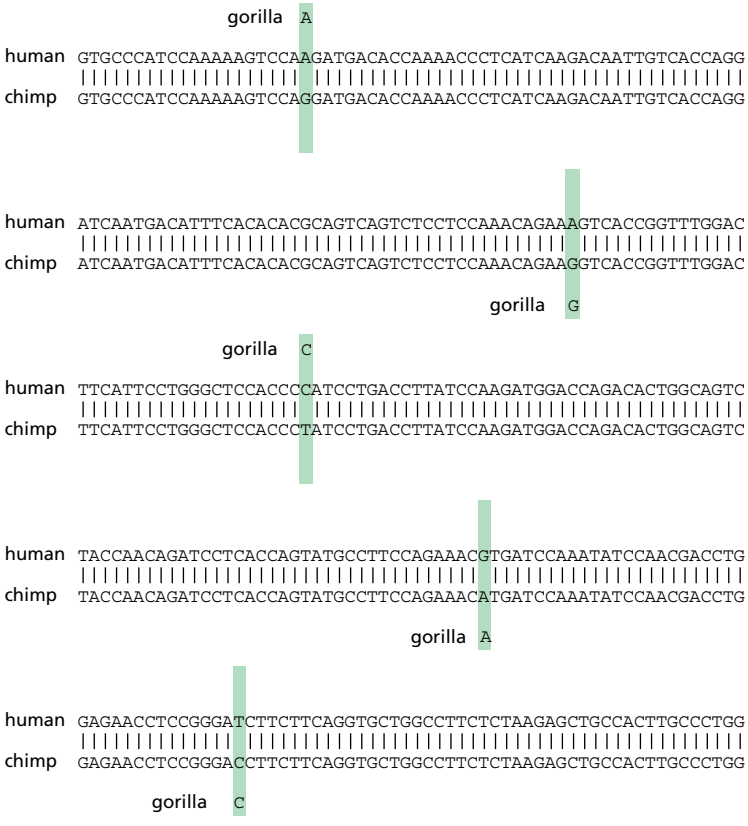
Sometimes traits change between generations. If a new trait results in an offspring doing better in its natural surroundings and producing more offspring that also inherit the trait, that trait will become more widespread over time. If the new trait makes the offspring less able to survive and thus leave fewer offspring, the trait will tend to fade from existence. Natural selection is the process by which some traits succeed and others fail in the environment where the organism lives. For every type of life we see today, there were many other types that were unsuccessful and became extinct.

Scientists no longer question the basic facts of evolution as a process. The concept has withstood extensive testing by tens of thousands of specialists in biology, medicine, anthropology, geology, chemistry, and other fields. Discoveries in different fields have reinforced one another, and evidence for evolution has continued to accumulate for 150 years.

The Fossil Record The concept of evolution is supported by fossil findings in rock layers from different ages of Earth's history. In general, fossils that more closely resemble today's life forms are found in younger rock layers, while many fossils that only distantly resemble life today occur in older layers. Based on such findings, naturalists proposed that species change, or evolve, over time. Natural selection has been identified as a driving force behind these changes. Since then, scientists have found an overwhelming number of fossils in rock layers of different ages that repeatedly confirm the changes in life forms that are predicted by the theory of evolution.

A near complete skeleton of a transitional bird-like fossil that was discovered in China and reported in 2006.

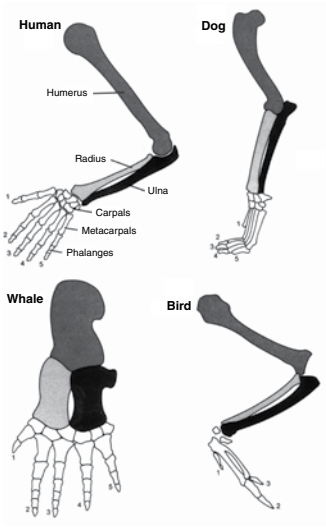
DNA Research Molecular biology and genetics have revealed how evolution works at the level of molecules. Unknown when evolution and natural selection were first proposed in 1859, genetics has shown that traits are passed from parent to offspring through DNA, a molecule in all living things that directs how cells grow and reproduce. DNA studies support findings from other branches of science. For example, species that appear to be more distantly related from their positions in the fossil record are found to have correspondingly greater differences in their DNA than species that appear more closely related in the fossil record.



Comparison of the human and chimp DNA sequences for the gene that encodes the hormone leptin (which is involved in the metabolism of fats) reveals only five differences in 250 nucleotides. Where the human and chimpanzee sequences differ, the corresponding nucleotide in the gorilla (shaded bars) can be used to derive the nucleotide that likely existed in the common ancestor of humans, chimpanzees, and gorillas. In two cases, the gorilla and human nucleotides match, while in the other three cases, the gorilla and chimpanzee sequences are the same. The common ancestor of the gorilla, chimpanzee, and human is most likely to have had the nucleotide that is the same in two of the three modern-day organisms because this would require just one DNA change rather than two

Common Ancestry There are common structures and behaviors among many species. A person writes, a cow walks, a whale swims, and a bat flies with structures built of bones that are different in detail but also remarkably similar to each other. When fossils are compared to one another in structure and in age, it becomes clear that an ancestral species gave rise to an array of successor species with the same basic arrangement of limb bones. As new findings have repeatedly demonstrated, for any two species living today, their evolutionary lines can be traced back in time until the two lines intersect in a common ancestor.

The fossil record, DNA research, the evidence that species have common ancestors, and other findings add up to overwhelming evidence that evolution by natural selection is how life on Earth arose and became diverse.



The bones in the forelimbs of terrestrial and some aquatic vertebrates are remarkably similar because they have all evolved from the forelimbs of a common ancestor.

Nature imposes a direction to evolutionary development. Though dolphins (left) are more closely related to humans than they are to sharks, they have evolved bodies adapted to an aquatic environment.

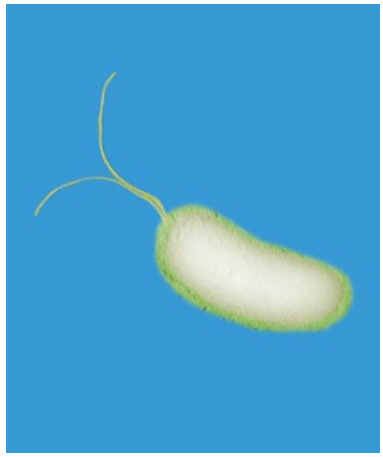
Creationism Does Not Belong in the Science Classroom

Some people argue that the diversity of life did not evolve through natural processes. They advocate that creation be added to the school science curriculum alongside biological evolution.

But creationism is not science. Creationist arguments are based on beliefs about an entity outside the natural world. But science can only investigate naturally occurring phenomena. In fact, the many questions about evolution raised by creationists are readily answered by available and accumulating scientific evidence. For example --

• Creationists argue that the theory of evolution is faulty because of gaps in the fossil record (creationists identify as gaps those situations where intermediate fossil forms between two related species are as yet undiscovered). But an increasing number of intermediate forms have been and continue to be found. Even without actual fossils in hand, scientists can use modern techniques

in molecular biology and genetics along with the principles of evolution to infer what forms of life existed and predict where and what kinds of fossils will likely be found.



Electron micrograph of a bacterial flagellum.

• Some creationists claim that certain features of living beings are too complex to have evolved through natural processes. They claim that structures such as a bacterium's flagellum (the hair-like part that gives the bacterium motion) , the human eye, or the immune system are "irreducibly complex" and must have been created intact by an "intelligent designer." But biologists have discovered that components of the flagellum have their own individual functions and also have found intermediate forms of flagella. Both of those findings support the idea of the flagellum evolving from existing structures over time. Also, the creationist argument that such features "must" have been designed is based on their preconceived idea of a Creator, while the scientific position is based on observable facts and falsifiable explanations.

• Some creationists argue based on scripture that the Earth cannot be old enough for the diversity of life to have emerged through evolution. Yet measurements from geology, astronomy, and other fields have repeatedly confirmed the ancient age of the Earth (approximately 4.5 billion years).

Because science has no way to accept or refute creationists' assertions, creationist beliefs should not be presented in science classrooms alongside teaching about evolution. Teaching non-scientific concepts in science class will only confuse students about the processes, nature, and limits of science.

Science and Religion Offer Different Ways of Understanding the World

Science and religion address separate aspects of human experience.

Many scientists have written eloquently about how their scientific studies of biological evolution have enhanced rather than lessened their religious faith. And many religious people and denominations accept the scientific evidence for evolution.

Our education system and our society as a whole are best served when we teach science, not religious faith, in science classrooms.

EVOLUTION IN ACTION

Medicine's Challenge in Countering Resistant Strains of Harmful Bacteria

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, the researchers compared the genetic material of the unknown virus with that of known viruses. Within 24 hours, they assigned the virus to a particular family based on its evolutionary relationship to other 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.

Understanding the evolutionary origins of human pathogens will become increasingly important as new threats to human health arise. For example, many people have suffered from severe medical problems as bacteria have evolved 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 non-resistant bacteria are being killed. Bacteria that cause tuberculosis, meningitis, staph infections (sepsis), sexually transmitted diseases, and other illnesses have evolved resistance to an increasing number of antibiotics and have become serious problems throughout the world. Knowledge of how evolution leads to increased resistance will be critical in controlling the spread of infectious diseases.

TIKTAALIK

A Case Study in Scientific Prediction

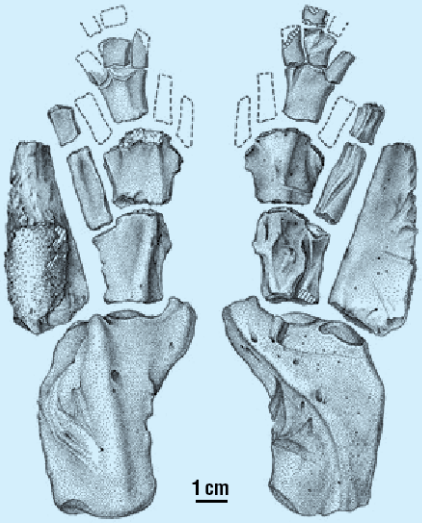
Using the principles of evolution, scientists have been able to predict what new fossils might be discovered. For example, scientists had found fossils of ancient fish that lived in shallow waters in earlier times and fossils of four-limbed land dwellers that appeared later in time. What happened in between?

Evolutionary theory predicts that there would be one or more creatures with characteristics of both the ancient fish and the later land-dwellers. A team of scientists decided to look in sedimentary rock in northern Canada that was deposited about 375 million years ago, about the time these intermediate species were thought to have lived, based on other evidence from the fossil record.

In 2004, the team found what they had predicted: the fossil of a creature with features of fish (scales and fins) and features of land-dwellers (simple lungs, flexible neck, and fins modified to support its weight). The bones in the limbs of this fossil, named *Tiktaalik*, resemble the bones in the limbs of land-dwelling animals today.

By understanding evolution, scientists were able to predict what type of creature existed and in what geologic layer it would be found. The discovery of *Tiktaalik* fills another gap in the fossil record.

Paleontologists searched this remote valley in north central Canada for a species intermediate between fish and limbed animals capable of living on land because they knew the sedimentary rocks there were deposited during the period when such a transition had taken place.



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 *and other fossil intermediates between fish and tetrapods. These fossils represent an assortment of species that lived between 385 and 359 million years ago, spanning the evolution of fish to amphibians.*

The content of this informational brochure was adapted from the full-length, 88-page version of *Science, Evolution, and Creationism* (2008), produced by a committee of the National Academy of Sciences and the Institute of Medicine. This brochure and the full-length report on which it is based are available for downloading in pdf format at http://www.nap.edu/catalog.php?record_id=11876.

AUTHORING COMMITTEE

FRANCISCO J. AYALA, *Chair*, University of California, Irvine*

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