

# Evolution and Creationism: A Guide for Museum Docents



## Museum of the Earth, Ithaca NY

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### 1. Introduction

This brief guide is intended to help you, the volunteer docent, understand and explain the basics of evolutionary biology to Museum of the Earth visitors. It is also intended to help prepare you to answer some of the most frequently asked questions about evolution, and to refer visitors to sources of additional information. Finally, it is intended to equip you with some tools that you can use to respond to challenges from Museum visitors to the ideas presented in the Museum exhibits.

This guide is intended for your use in conjunction with the permanent Museum exhibits. It is therefore very useful for you to become familiar with the content of the exhibits, especially the Evolution area in the Triassic-Jurassic World. In the pages that follow, look for the heading In the Museum for specific comments about the content of the exhibits in the Museum of the Earth.

## 2. Background

### A. Evolution and science

*Science* is an approach to explaining the natural world. It uses observations about the natural world and the rules of logic to test hypotheses that explain natural phenomena. Hypotheses that pass these tests are accepted, but such acceptance is always provisional; that is, any hypothesis can be overturned by sufficient credible contrary evidence. Science does not deal with the supernatural or with questions or issues for which no material or physical evidence exists; it is about seeking material causes for material phenomena.

*Evolution* is the idea that all organisms are connected by genealogy and have changed through time. Evolution is probably driven by several processes, the most important of which is natural selection. Natural selection is a process in which some individuals survive and reproduce better than others because they have inherited characteristics that help them do so. These characteristics are passed on to their descendants, who are more numerous than those of individuals lacking the characteristics, and so the whole population changes over time as these characteristics come to dominate.

Evolution is one of the most well supported ideas in science; that is, there is abundant evidence that it is true, so much that it would be irrational to reject it. Although all ideas in science are provisional, and potentially can be overturned by sufficient contrary evidence, evolution is as close to being a “fact” as any widely accepted scientific hypothesis, such as the heliocentric solar system or atomic theory. To achieve this status as a theory or fact, evolution has withstood rigorous scientific testing.

Evolution is a, perhaps the, fundamental idea of modern biology. Essentially every field of biology concerned with whole organisms, including ecology, behavior, and systematics (the study of biodiversity) is based on evolution. Essentially all practicing professional biologists who work on whole organisms accept evolution as an adequate explanation for the order, history, and diversity of life they observe. There is no serious disagreement among such professional biologists about whether evolution is “true.” Although it is possible to pursue fields of so-called “sub-organismal” biology, such as genetics, physiology, medicine, and biochemistry, without thinking about evolution, it is not possible to connect these areas to the biology of organisms without considering evolution.

But evolution is about far more than biology. Evolution is also central to many areas of the Earth sciences, such as stratigraphy (the study of the layering of rocks), geochronology (geological dating), tectonics (the study of mountain building and other major Earth movements), and paleontology (the study of the history of life as revealed by fossils). The assumptions and conclusions that underlie evolution, furthermore, such as the great age of the universe, the solar system, and the Earth; the continuity of past and present processes; and the constancy of physical law in time and space are shared with and essential to other fields of science such as astronomy, physics, and chemistry. Every major organization of professional scientists in the United States has endorsed the teaching of evolution and the rejection of the teaching of creationism as science. If the fundamental assumptions of evolutionary biology are incorrect, so are the fundamental assumptions of many other fields of science that we trust every day.

A fundamental tool of all science is *extrapolation*. For example, if we drop a ball, we can measure how fast it falls. We can then use this result to apply to other falling objects. Scientific ideas and theories are essentially about applying what is known to what is unknown. Science does not only deal with phenomena that can be observed directly. Indeed, the essence of science is to make an observation or experiment, and then use the results to predict what we will see in another instance. If we had to observe everything in science to be certain of it, we would never get anywhere.

## **B. Creationism**

*Creationism* is the belief that the Earth and its life were created by a supernatural power. Modern creationism is actually quite diverse; it includes people who think the Earth is 10,000 years old, and those who believe it is much older; people who believe that the Biblical flood explains all of the geological record, and those who accept a more complex history. Most importantly, creationists believe in the action of divine or supernatural forces in shaping the natural world on a regular basis. Almost all individuals who consider themselves creationists reject evolution as a general explanation for the order, history and diversity of life.

By this definition, most people in the United States are creationists. They do not believe in evolution; that is, they do not think that evolution happened or that evolution explains the natural world. Public opinion polls have been consistent over more than 20 years in reporting that at least half of Americans do not think evolution occurs. Almost 50% of those surveyed, for example, think that “God created human beings pretty much in their present form at one time within the last 10,000 years or so”, and almost 70% of those surveyed support teaching creationism in schools. Only about half of the respondents to one survey answered “false” to the statement, “The earliest humans lived at the same time as the dinosaurs;” less than half responded “true” to the statement “Human beings, as we know them today, developed from earlier species of animals” (Alters and Alters, 2003; see “Sources of more information” below). Although people with less education tend to accept evolution in smaller numbers, this pattern appears to cut across lines of education, class, and socio-economic status. Cornell Professor William Provine has polled students in the course he teaches on evolution for more than a decade, and finds that Cornell undergraduates accept or reject evolution in proportions approximately equal to national opinion polls.

On the other hand, a large majority in several recent polls say that they think evolution should be taught in public schools and some polls suggest that a majority of Americans may prefer that creationism be taught, but not as science.

Some of the disagreement between these results may be due to widespread public misunderstanding of evolution. Polls suggest that Americans do not really know much about it. Roughly a third of poll respondents think that “evolution means human beings have developed from apes” (which is such a dramatic oversimplification as to be incorrect); three quarters agree that “evolution is commonly referred to as they theory of evolution because it is not yet proven scientifically” (Alters and Alters, 2003). Most respondents to a 2000 poll admit they don't really know what the theory of evolution is.

Modern creationism frequently focuses on what its advocates describe as scientific evidence for creationist interpretations, labeled most often as “creation science” or, most recently,

“intelligent design theory.” Despite years of effort, however, creationists have produced no objective empirical evidence in favor of their hypotheses. Creationists therefore usually tend to focus not on evidence for their view, but on “problems” or objections to evolution and/or natural selection. For example:

- **There are no intermediates in the fossil record.** Untrue. There are thousands of known fossils that are intermediate in form between older and younger fossils.

In the Museum: You can see examples such as the early tetrapod *Acanthostega* in the Devonian life on land exhibit, mammal-like reptiles in the Carboniferous-to-Triassic theater, and the oldest known bird, *Archeopteryx*, in the Jurassic-to-Quaternary theater.

- **The fossil record is filled with gaps.** True, but the record is also good enough to show clear evidence of change with continuity, of descent with modification.
- **Small-scale change is one thing, but no one ever turned a dog into a cat.** True, but irrelevant. Reasonable extrapolation – of the type used by all scientists – from all available observations argues strongly for a view that all organisms share a common ancestor and have changed through time.
- **Evolution cannot be directly observed or experimented on. Unique, nonrepeatable historical events cannot be studied scientifically and depend on faith just as much as religion does.** Even unique, nonrepeatable events, which cannot be experimentally manipulated or observed directly, leave material results that can be studied scientifically. Crimes are not literally repeated and yet investigators use material evidence to solve them. Human history cannot be repeated, and yet we use written and other records to decipher what events occurred when. We observe the present and extrapolate what we see to the past.

### C. Intelligent Design

*Intelligent design* (ID) is the idea that features of the Earth or life can be best explained by reference to the conscious action of an intelligent agent, rather than to an undirected natural process or a material mechanism. Modern ID argues that it is a scientific and non-religious alternative to Darwinian evolution, and many of its advocates resist being grouped with creationists. Some proponents of ID accept an ancient age of the Earth, whereas others do not; some accept common ancestry of humans and apes but others reject evolution altogether.

Advocates of ID argue that there are features of organisms that are “irreducibly complex,” that is, they would not function if one element was removed. They argue that such features could not be produced by incremental additions via natural selection because intermediate stages would not be viable. They favor “teaching the controversy” between ID and evolution in science classrooms.

Despite its claims to scientific credibility, ID is a completely non-scientific, religious movement. Major problems with ID as a scientific theory include:

- Although advocates of ID state that it is based upon positive evidence and not just “gaps” in our understanding, they do not present clear criteria by which this evidence can be recognized.
- ID advocates have proposed no objective definition of “irreducible complexity” or method for testing for its existence. ID advocates, furthermore, ignore hypotheses that features of organisms may change their function as evolution proceeds, and thus that intermediate forms can be highly functional, which has long been a theme in evolutionary biology.
- ID arguments focus on our current inability to propose adequate evolutionary explanations for particular features of organisms, and thus on the extent of scientific knowledge at the time, ignoring the obvious fact that scientific knowledge and understanding are continuously growing.
- Advocates of ID maintain that their view does not require God to be the designer, but this is ingenuous. A supernatural creator/designer of the sort they need is a god in all but name, and the roots and background of the movement are clearly religious.
- ID is part of a larger movement, the stated goal of which is to fundamentally alter the nature of science and society by removing materialism and making supernaturalism and religion legitimate parts of science. ID is not science as we know and have used it for the past five centuries; it is religion.

### 3. Evolution: A quick overview

#### A. Evidence vs. mechanism

*Evolution* is the idea that all organisms are connected by genealogy and have changed through time. The question of *whether* evolution occurs is separate and different from the question of *how* evolution occurs. The evidence is overwhelming that evolution occurs, and that it is a satisfactory explanation for the observations we make about the history, order, and diversity of life.

In the Museum: The Evolution exhibit divides the evidence for evolution into six categories: biogeography, the fossil record, classification, comparative anatomy, observable small-scale changes, and genetics. No serious biologist or geologist has seriously questioned whether evolution occurs since the late nineteenth century. There is *no* significant evidence that it does not. Exhibits elsewhere throughout the rest of the Museum provide abundant additional examples of evidence for evolution in the fossil record.

Ideas become widely accepted in science because they are useful for explaining observations about the physical world, because they help us make predictions about natural occurrences,

and because they provide logically consistent explanations for what we see and answers to questions we ask.

Evolution is a widely accepted idea in science because it answers questions. Indeed, evolution was adopted almost immediately after the publication of Charles Darwin's book *On the Origin of Species* in 1859 because it appeared to provide logical and consistent answers to questions that had troubled scientists for generations. Evolution is an attempt by science to explain why things are the way they are.

In the Museum: The exhibits in the Museum of the Earth, especially the exhibit on Evolution, are based on the enormous usefulness of evolution as a theory of biological change and source of fundamental understanding about the natural world and how it came to be as we see it.

Even while scientists agree that evolution occurs, very energetic debate continues about the mechanisms by which it occurs. The exhibits in the Museum of the Earth present what most scientists believe is the most important evolutionary mechanism, natural selection, but they also touch on other mechanisms that various scientists seriously consider today, such as genetic drift and higher-level sorting of species. The evidence for natural selection is abundant and compelling and few scientists doubt that it occurs; the question is whether it is able to explain most or all of the changes that have occurred. These are areas of very active scientific research and a great deal remains to be learned.

Questions or debates about evolutionary mechanism have nothing to do with our confidence in whether evolution occurred. Evolution is probably driven by several processes, the most important of which is natural selection.

In the Museum: The Evolution exhibit area features displays that emphasize variation as one of the central observations about living things. Variation is the raw material of natural selection (see below) and it can be clearly seen in the groups of sparrows, snails, and fossil brachiopods in the exhibit, as well as in our everyday lives. Also in the Evolution exhibit area is a computer game that simulates natural selection. The visitor is an imaginary predator on moths of two colors. The more the visitor "catches" of one color in a generation, the smaller the contribution of that color to the next generation.

## **B. Natural selection**

*Natural selection* is a process proposed by Charles Darwin in his book *On the Origin of Species* in 1859 to account for evolutionary change – it is a potential mechanism for evolution. Like Darwin, most evolutionary biologists today think that natural selection is the most important mechanism by which evolution occurs.

Natural selection is a surprisingly simple concept. It is the idea that some individuals survive and reproduce better than others (due perhaps to variation, luck, disasters, and the influence of the environment). The characteristics of the parental generation are passed to their descendants (including those genetic traits which favored survival of the parents). Therefore, descendants of successful parents tend to be successful, or as evolutionary biologist Richard Dawkins puts it, "we are winners descended from a long line of winners." Through time, successful individuals produce more, and/or healthier offspring than unsuccessful individuals. Unsuccessful organisms produce fewer or no offspring on average and therefore, their contribution to the future of a species is limited. As a result of this differential reproductive success, individuals who have a genetic predisposition to survive and reproduce in their specific habitat will predominate as long as environmental conditions remain stable. If the environment changes, so does its pressure on organisms and their reproduction. The environment changes slightly over time, so change in species is also continuous, even if barely detectable to our eyes.

Natural selection depends on *genetic variation*. That is, no two individual organisms are identical, because of some combination of genetic differences and the effects of the environment. Those differences that are genetic or inherited are the "raw material" for natural selection. Ultimately, these differences originate by mutation in the genes (DNA), but many other genetic processes also affect variability. The environment "selects" from among the variants presented to it by every generation; those that do better and/or leave more offspring will deliver more of their genes to the next generation. Thus the environment, not the underlying genetic variation, determines the direction (e.g. whether horses get bigger, birds get bluer, or shells get thicker) of evolution by natural selection. When the environment changes, according to this view, so will the population, or it will become extinct.

Strictly speaking, "Darwinism" or "Darwinian evolution" refers only to evolution by natural selection, not to evolution in general. Thus, when evolutionary biologists debate whether "Darwinism" is an accurate or adequate view, they are talking about to what degree natural selection can account for evolutionary change, not whether evolution itself is valid.

In the Museum: The Museum exhibits on natural selection emphasize the existence of variation within species with displays of birds, snails, and brachiopods. The exhibit also includes a computer game that simulates the process of natural selection using moths of different colors in which the visitor is an imaginary "predator."

**Helpful hint:** A key point about situations such as that simulated by this computer game is the idea of *extrapolation*. Scientists examine a particular instance of apparent natural selection in nature, such as birds eating moths over a year or two, and then extrapolate to much longer time spans. This approach is not unique to evolutionary biology; all science is based on examining particular cases or a sample of data and then inferring from this basis what is happening in the larger world.

## C. Speciation

Not only has life changed over time, it has diversified into an amazing array of species and body types. This diversity, sometimes called *biodiversity*, is one of the most conspicuous characteristics of life on Earth: there have been and are millions of different species, and any theory of evolution must explain this. *Speciation* is the process or set of processes by which new species arise during evolution. Speciation is a very complex phenomenon, which is only partly understood. What seems clear, however, is that the origin of new species requires that an *ancestral* (sometimes called “parental”) population be divided into subpopulations by some event, such as the formation of a new island or mountain range, or a sudden change in behavior. The resulting *descendant* (sometimes called “daughter”) populations then diverge genetically – by chance or by natural selection – because they cannot interbreed. Eventually, they diverge so much that they would or could not interbreed successfully even if they lived together, and we say that a new species has formed.

In the Museum: The Museum exhibits explore speciation mainly from the point of view of a paleontologist, someone who tries to figure out how species formed in the past based on the fossils they leave behind. This is difficult to do, and the exhibit discusses and encourages visitors to think about how it can be accomplished. The exhibit focuses on the work of Cornell Professor Amy McCune and her work on fossil fish from the Triassic and Jurassic rocks of the Connecticut and Newark Valleys in the northeastern U.S. These are the same rocks that contain the abundant fossil dinosaur footprints that are displayed near the Evolution exhibit in the Triassic-Jurassic World.

## D. Extinction

*Extinction* – the disappearance of a species – is an important part of the evolutionary process and the history of life on Earth. Indeed, the vast majority of species that have ever existed on Earth are extinct.

In the Museum: Throughout the exhibits in the Museum of the Earth are panels marking the occurrence of episodes of “mass extinction,” when large numbers of species became extinct relatively suddenly.

## 4. Frequently Asked Questions

### What is evolution?

Organic evolution is the idea that all organisms are connected by genealogy and have changed through time.

### **How does evolution happen?**

Evolution is probably driven by several processes, the most important of which is natural selection.

### **Is evolution “just a theory”?**

A “theory” in science is a structure of related ideas that explains one or more natural phenomena and that is supported by observations from the natural world; it is not something less than a “fact.” Theories actually occupy the highest, not the lowest, rank among scientific ideas; they are systems of explanation that unite many different kinds of data and observations. They can be modified when new information becomes available, and they can be overturned or discarded when evidence to the contrary becomes so overwhelming that it can no longer be explained away. Evolution is a “theory” in the same way that the idea that matter is made of atoms is a theory, that bacteria cause disease is a theory, that the sun being the center of the solar system is a theory. Any of these theories might be incorrect (and good scientists must always consider that possibility), but scientists accept all of them as provisionally “true” because there is so much evidence to support them.

### **Is evolution “random”?**

No. Evolution is often clearly highly directional – that is, there are clear trends such as clam shells getting thicker or horses having fewer toes – and not random at all. But neither is any particular end-result expected or anticipated. Darwin’s hypothesis of natural selection states that the environment, which “selects” variants that do better at surviving and reproducing in their local circumstances, produces directionality in evolution. The underlying genetic variation, according to this theory, is “random” only in the sense that it is not in any preferred direction relative to the direction of eventual evolutionary change. Variation, in Darwin’s view, is in all directions, and then the environment steers it down only one or a few routes.

Furthermore, natural selection “builds” on previous generations; it does not start from scratch every generation. Thus statements such as “the chances of assembling a human being by chance are astronomical” are irrelevant; change by natural selection happens incrementally, generation by generation.

In the Museum: You can demonstrate this with the natural selection computer game. In the game, a population of moths changes color over time because one color is more visible to predators. This change is not random; it is directed by the moths’ environment.

### **Is it true that there is lots of evidence against evolution?**

No. Essentially all available data and observations from the natural world support the theory of evolution. No serious biologist or geologist today doubts whether evolution occurred; debate continues, however, among scientists about the mechanisms by which evolution occurred.

### **How do you know evolution has occurred?**

By examining fossils and comparing them to organisms alive today.

In the Museum: For example, a short film about Cornell professor Amy McCune shows how she uses fossil fish to study how evolution happened in what is now the Connecticut River Valley around 200 million years ago. She collects fossils from different layers and compares them to fish alive today and tries to conclude how evolution may have produced the patterns of similarity and difference she observes.

### **How do we know how old all this stuff is?**

Strictly speaking, the age of the Earth (or its rocks or fossils) in years isn't really relevant to whether or how evolution occurred. As long as the Earth is very old (more than a few hundred million years), evolution by natural selection could have occurred. But the process by which geologists determine the age of rocks and fossils is very important because fossils provide some of the best evidence for evolution.

The most important principle for studying evolution in the geological record using fossils is superposition – the idea that older layers of rock are below younger layers. This principle is coupled with the observation that different fossils occur in different rock layers. Application of this principle and these observations tells us that considerable time has passed and that the Earth and its life have changed enormously over time.

In the Museum: Superposition is explained in the stratigraphy exhibit in the Devonian World. Radiometric dating tells us that the Earth and its rocks are in fact very old, thereby providing long stretches of time for evolution to occur. This is explained in the Geological Time exhibit in the Devonian World.

### **Doesn't the complexity/design of nature imply an intelligent designer?**

Science deals only with material causes of material phenomena. Nothing we can observe in nature *requires* a supernatural designer; we therefore defer to observable, measurable processes to explain the patterns we see in nature.

### **Is evolution against religion?**

No. The most often-cited evidence for this is the fact that there are many evolutionary biologists and paleontologists who profess to be somewhat or very religious. More generally, it is possible to hold the view (as many practicing scientists do) that science and religion need not be in conflict with each other, because they address fundamentally different aspects of human experience. Science deals only with material reality; religion deals with the spiritual, the moral, and the ethical. Many scientists profess that science cannot ever answer ultimate questions such as “why are we here,” “what was the beginning of everything,” or “how should we live our lives.” According to this view, these questions very properly belong in the realm of religion.

## **What's wrong with teaching creationism and/or intelligent design in public school science classes?**

Both creationism and intelligent design have been tested as scientific hypotheses in the past, and both completely failed. There is no evidence that they are valid scientific ideas. In the absence of such evidence, they are clearly religious ideas, and as such have no place in the science classroom.

## **5. Helpful hints**

### **When talking to visitors about evolution:**

- Don't avoid using the word.
- Practice. Your credibility is higher, and you'll be more comfortable, when you sound like you know what you're talking about. Rehearse answers to the most frequently asked questions: *definitions for evolution and natural selection*, the *difference between evidence and mechanisms*, and *does evolution challenge religion*.
- Be honest and helpful, but not defensive. If you don't know the answer to a visitor's question, say so. And tell them you'll be glad to try to find out and to tell them the next time they're in the Museum.

### **If a visitor challenges you:**

- Listen. Be respectful. It enhances the credibility of your answers.
- Be polite but firm. Use the suggested answers above.

### **If a visitor is extremely argumentative or confrontational:**

Try one of the following:

- Hand them a comment card.
- Say: "These exhibits reflect the state-of-the-art in scientific knowledge. Like all scientific conclusions, they might change someday, but right now these statements are very well supported."
- "I'm not familiar with that information. I'll have to learn more about that."
- "I respect your perspective. Mine is different. And we'll have to leave it at that."
- "This is a place to talk about science, not philosophy, religion, or politics. This isn't the place to discuss the issues you're bringing up."

### **You cannot "win" against a convinced creationist.**

The most you can hope for is a respectful exchange of views, in which you both learn something. Sometimes that happens and it can be a very enlightening experience for both parties. Sometimes, however, they are looking for confrontation rather than an honest discussion and will try to lure you into a debate, in which their rhetorical devices will be an advantage. Don't be frustrated.

## 6. Sources of more information

### Books:

Alters, Brian J., and Sandra M. Alters, 2003, *Defending evolution. A guide to the creation/evolution controversy.* Jones and Bartlett, Boston, 261 pp.

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Pojeta, John, Jr., and Dale Springer, 2001, *Evolution and the fossil record.* American Geological Institute, Alexandria, VA, 27 pp.

Scott, E., 2004, *Evolution vs. Creationism. An introduction.* Greenwood Press, 296 p.

### Websites:

**The National Center for Science Education.** The NCSE is a clearing house and advocacy organization that monitors creationist activity around the country and provides information for educators at all levels. Their website is full of timely information and links to additional on-line resources: [www.ncseweb.org](http://www.ncseweb.org).

**University of California Museum of Paleontology.** One of the first and best sites on the web, and an excellent source of information on all aspects of evolution and paleontology: [www.ucmp.berkeley.edu](http://www.ucmp.berkeley.edu)

## **7. Acknowledgements**

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