Evolution and Creationism:
A Guide for Museum Docents

Museum of the Earth, Ithaca NY

By Warren D. Allmon
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Contents

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, some of them potentially hostile, from Museum visitors to the ideas presented in the Museum exhibits.

This guide is intended for your use in conjunction with the actual 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 that 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 they can be overturned by sufficient credible contrary evidence. Science does not deal with 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 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.

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 many fields of so-called "suborganismal" 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 o f 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 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 suchas 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.

Put simply, evolution is the result of the application of principles of scientific logic and reasoning to questions about the history, diversity, and order we observe in living things. 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.

B. Creationism.

Creationism is the belief that the Earth and its life were created, essentially in their modern forms, 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, and creationists reject evolution as an 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 it happened or that it 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% 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% 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-econonmic status. Cornell Professor William Provine has polled students in the course he teaches on evolution for more 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 sponsored by People for the American Way 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". Although it is perfectly legitimate for a person to hold and promote creationist beliefs, there is no scientific evidence for such beliefs, and they are not scientific by any reasonable definition of science, a point repeatedly affirmed by state and federal courts, as well as the U.S. Supreme Court.

3. Evolution answers questions

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 source of answers - of fundamental understanding about the natural world and how it came to be as we see it.

4. Why is evolution important?

Evolution is important for at least three reasons:

A. It is the central idea of modern biology.

It is accepted by essentially every modern, practicing biologist, and has been since around 1870. It forms the basis for almost everything we think we know about life and its history. An understanding of evolution is therefore very important for an understanding of all of biology.

B. It is central to our understanding of ourselves.

Evolution has implications for our conceptions of humanity's place in nature. The widespread acceptance of evolution by most educated people in the nineteenth century played a crucial role in the emergence of the modern world view in which dynamic change and scientific methods play such central roles. Understanding evolution is important for understanding modern world history as well as for a critical and informed examination of human's place in the world.

C. It is scientifically valid.

Evolution challenges some people's views of religion, morality, and ethics. This is not because evolution is contrary to religion in general, but because it is contrary to *some* religious views. Because of these objections, evolution - almost uniquely among scientific ideas - is often the subject of passionate public, political, and legal debates. Evolution is as well supported as *any* scientific idea, such as atomic theory, gravity, or the heliocentric solar system. Discarding or diluting the teaching or public discussion of evolution is thus a challenge to *all* science, and therefore a fundamental intellectual issue for society.

5. Evolution: A quick overview

A. Evidence vs. mechanism.

The question *of whether* evolution occurs is separate and different from the question of *how* evolution occurs. The evidence is overwhelming that evolution has occurred - 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.

Very energetic debate continues, however, about the mechanisms by which evolutionary change 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 in evolution. 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.

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. 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 because they have inherited characteristics that help them do so. These characteristics are passed on to their descendants, which are more numerous than those of individuals lacking the characteristics, and so the whole population changes over

time as these characteristics come to dominate.

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 of the genes (DNA), but variability is also affected by many other genetic processes. 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 direction of evolution (e.g., whether horses get bigger, birds get bluer, or shells get thicker) by natural selection is provided by the environment, not the underlying genetic variation. 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 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 on this basis what is happening in the larger world.

C. Speciation.

Not only has life changed over time; it has diversified. That is, it comes in many different kinds. This diversity is one of the most conspicuous characteristics of life on Earth — there have been and are millions of species — and any theory of evolution must explain it. 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, that is 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 hi 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.

6. 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 clearly highly directional, and not random at all. Darwin's hypothesis of natural selection states that this directionality is provided by the environment, which "selects" variants that do better at surviving and reproducing. 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 imposed by the environment of the moths.

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

No. Essentially all available data and observations from the natural world support the hypothesis 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 happened a long time ago?

By examining fossils and comparing them to organisms alive today. In the Museum exhibits, 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. 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. Application of this principle tells us that considerable time has passed and that conditions on Earth have changed enormously.

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. In the Museum, 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 material processes to explain what 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.

7. 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:

"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."

"Please excuse me. I have to go to the restroom."

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.

8. 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.

Futuyma, Douglas J., 1995, Science on trial. The case for evolution. 2nd edition. Sinauer Associates, Sunderland, MA, 287 pp.

Kelley, Patricia H., Jonathan R. Bryan, and Thor A. Hansen, editors, 1999, The evolution-creation controversy II: perspectives on science, religion, and geological education. The Paleontological Society Papers, volume 5, The Paleontological Society, 242 pp.

National Academy of Sciences, 1999, Science and creationism. A view from the National Academy of Sciences. Second Edition. National Academy Press, Washington, DC, 35 pp.

National Academy of Sciences, 1998, Teaching about evolution and the nature of science. National Academy Press, Washington, DC, 150 pp.

Pennock, Robert T., 1999, Tower of Babel. The evidence against the new creationism. MIT Press, Cambridge, MA, 429 pp.

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

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.natcenscied. or g