1. Evolution, Science, and the Discovery Science Place

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 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 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 as correct and factual science.

Put simply, the theory of 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.

2. 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.

3. 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.

4. 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. 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.

Very energetic debate continues, however, about the mechanisms by which evolutionary change occurs. At the DSP we strive to present what most scientists believe based on evidence- that the most important evolutionary mechanism is natural selection, but we 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.

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 overtime 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.

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.

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.

5. 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 driven by several processes, the most important of which is natural selection (others include sexual selection, genetic drift, etc.).

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.

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 or is currently occurring; 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 genetic data and comparing them to organisms alive today.

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, although there is enormous evidence for the currently accepted age of approximately 4.5 billion years. 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.

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" or "how should we live our lives". According to this view, these questions very properly belong in the realm of religion or philosophy.

Sources of more information

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