Big Ideas

Like all scientific disciplines, the field of evolutionary biology continually evolves over time. New discoveries fuel new ideas, providing an ever-increasing understanding of how populations and species change over time in response to a changing Earth. But of the overwhelming number of observations and principles that form the foundation of evolutionary biology, what is essential for every person to understand? All too often, curricula are too ambitious and, as a result, risk failing to cover topics in any substantial depth. An alternative approach is to build one's curriculum upon a foundation of focused, interconnected "Big Ideas." A well-designed set of Big Ideas can provide an all-encompassing conceptual framework for any discipline, including evolutionary biology. Developed by scientists and biology teachers, here is a set of Big Ideas that illuminates what is fundamental to the study of evolution:

- **Big Idea I:** Evolution is inherited change within a lineage.
- **Big Idea II:** Evolution is a scientific theory, subject to testing and revision.
- **Big Idea III:** Evolution by natural selection is key to understanding life on Earth.
- **Big Idea IV:** Many scientific fields contribute evidence for evolution.
- **Big Idea V:** Evolution happened and continues to happen.

These ideas are designed to cover the breadth of any evolutionary biology curriculum, but they require elaboration to build deep understanding. Each idea is essentially bottomless; that is, although a meaningful understanding of these ideas is readily attainable, the details contained within are endless. Each of the ideas can be understood, but the depth of understanding can vary greatly.

Introduction of these Big Ideas also invites discussion of the nature of science. As curricula are designed and implemented, the traditional topics of evolutionary biology should be complemented with ideas on how we come to know what we know about the natural world.

Each of these ideas are explained briefly in the pages that follow, and are discussed in detail later on in this *Guide*.

Big Idea I: Evolution is inherited change within a lineage.

To most people, the term "evolution" means change over time. This is a correct definition when discussing non-biological evolution such as the evolution of the solar system or the evolution of computers. It is also correct in this context, but more is necessary. The biological definition of evolution is *inherited change within a lineage*.

To fully understand the biological definition of evolution, it helps to consider each part separately.

- ***Inherited***. All organisms reproduce and pass their genes to their offspring. Each new generation inherits their genes and associated traits from their parents.

- ***Change***. The new generation is not an exact replica of the parental generation. Sexually reproducing organisms get half of their genome from each parent, so the result in each offspring is a combination. Parents that are most successful at reproducing contribute more offspring to the next generation, so their genes claim a higher percentage of the new generation. In addition, random genetic mutations occur that change the genetic composition of the next generation and introduce variation among individuals.

- ***Lineage***. As each generation reproduces it creates an uninterrupted chain of genetic inheritance from ancestors to descendants.

All together, these three concepts detail the biological definition of evolution. If you follow any lineage of organisms from ancestor to descendant, you will find inherited changes, in other words, evolution.

Bivalves have been evolving for over 500 million years. The bivalves alive today have some similarities but also many differences from those discovered in the fossil record. The similarities between modern and ancient bivalves provide evidence of their common lineage. The differences are evidence of their evolution over time.

For more discussion on this topic, see the sections **Why Study Evolution?: Defining "Evolution"** and **How Evolution Works**.

Big Idea II: Evolution is a scientific theory, subject to testing and revision.

It is often easy for students and even teachers to dismiss the theory of evolution as "just a theory." However, such a statement stems from a fundamental misunderstanding of the scientific process and the rank of scientific theories within it.

The term "theory" in everyday language means a mere guess or speculation. In scientific language, however, theories are the highest order of scientific explanation and are generally accepted to be true by the scientific community as a whole. A scientific theory is a synthesis of a large number of accepted and highly tested hypotheses. Scientists continue to test, refine, and add additional hypotheses to make a theory more concise, but it is highly unlikely that the whole theory will ever be replaced. In physics, a similarly supported theory is gravity; in chemistry, a good example is the atomic theory (that all matter is made up of particles called atoms).

There is no ongoing current debate among knowledgeable biologists about *whether* evolution occurs or has occurred. There is still vigorous debate about the details of *how* it occurs.

For more discussion on this topic, see the section **Why Study Evolution?: Defining "Science."**

Big Idea III: Evolution by natural selection is key to understanding life on Earth.

Harvard professor E.O. Wilson (1929-) proposed a two-idea suggestion for understanding biology.

(1) All organic processes are ultimately obedient to the Laws of Physics and Chemistry.

(2) Most scientists believe that all living systems and processes evolved by natural selection.

This emphasizes the importance of evolution and natural selection to understanding life on Earth today. Natural selection is based upon the principles that (1) organisms produce more offspring than can survive, (2) individuals compete for resources, (3) individuals have variations that could make them better (or less) able to survive and reproduce, and (4) the individuals that reproduce contribute to the next generation. The process of natural selection through time can be easily observed through the fossil record and by observing the adaptations, complexity, and diversity of living species.

For more discussion on this topic, see the section **How Evolution Works: Natural Selection**.

Big Idea IV: Many scientific fields contribute evidence for evolution.

Evidence for evolution has been supplied by many fields of scientific study. Paleontologists study the fossil record and the evolution of prehistoric life. Ecologists study the complexity and diversity of living species and their interactions with the environment. Anatomists study living species and the complexity, diversity, and similarities of their bodies. Developmental biologists study the embryology, growth, and aging of living species and compare the differences and similarities. Geneticists and molecular biologists study the DNA, RNA, and proteins of living species and compare the differences and similarities. Evolutionary biologists study the origins of species and synthesize information from other fields into an understanding of how evolution occurs on Earth. No other subject cuts across more fields of study than evolution.

For more discussion on this topic, see the section **The Evidence for Evolution**.

Big Idea V: Evolution happened and continues to happen.

Studying the fossil record is the easiest way to observe that evolution happened in the past. Evolution is still occurring today, but it is more difficult to observe. The minor changes from generation to generation can take thousands or millions of years to accumulate before they are noticeable or result in a distinctly new species. Organisms with very short generation times, however, can provide evidence that evolution is still occurring today. The Fruit Fly, *Drosophila melanogaster*, is one of the most commonly used model organisms in biology because it is easy to care for, breeds quickly, lays many eggs, and has a generation time of only 10 days. Its genes are easily manipulated through embryological techniques; it is a perfect organism for studying "artificial selection" (human-induced natural selection, used widely in animal husbandry). As a second example from human medicine, the common flu virus changes (evolves) enough every year that a new flu vaccine must be produced to protect us from repeat infection. In addition, the emergence of antibiotic-resistant bacteria is evidence that bacteria have evolved to survive the human-devised drugs that previously would have killed them.

For more discussion on this topic, see the section **Evolution in Everyday Life**.

The Teacher-Friendly Guide to Evolution

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By Paula M. Mikkelsen & Robin Henne

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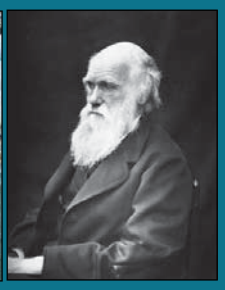

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