13.1 Evidence for Evolution

Imagine going back in time 50 million years. You see a horse about the size of a cat. Would you believe you are looking at an ancestor of the modern horse (Figure 13.1)? *Eohippus* was only 20 cm tall at the shoulders and had five toes. A modern horse is about 150 cm tall at the shoulders and has only one toe. A scientific theory states that newer species have descended from older species through a process called *evolution*. What is evolution and what is the evidence that supports it as a theory?

Figure 13.1: *Eohippus is an ancestor of the modern horse.*

What is evolution?

Adaptation and evolution

An **adaptation** is an inherited trait that helps an organism survive. Adaptations include body structures that help an organism feed, move around, and protect itself. **Evolution** is the process of how organisms acquire adaptations over time.

A moth and a bird

Through evolution, the structures of organisms become adapted for their functions. Look at the organisms below. The one on the left is a sphynx moth (an insect). The one on the right is a hummingbird. Both species have evolved similar adaptations for feeding on flower nectar. Can you identify how they are similarly adapted for feeding? How are they different?

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adaptation - an inherited trait that helps an organism survive.

evolution - the process of how organisms acquire adaptations over time.

Evolution is a branching process

All life forms had a common beginning

There is great diversity in living species. *Diversity* means variety. Scientists estimate that there are between 5 and 50 million living species. Among those species are single-celled bacteria that lack cell nuclei, single-celled eukaryotes that have cell nuclei, and multicellular fungi, plants, and animals. Where did all of these different species come from? Scientists hypothesize that **all life forms evolved from a common ancestor and new species branch off from earlier species.** An **ancestor** is an organism from which others have descended.

Cell evidence

You have learned that all living things are made of cells. There are many similarities among *all* cells. For example, all cells have a similar cell membrane. Many cells have the same type of cellular respiration. Also, all cells have DNA as their hereditary material. Similarities among all cells support the hypothesis that all life evolved from a common ancestor.

Bacteria were the first living things

Earlier, you learned that bacteria were the first organisms on Earth. Evidence for this comes from fossils of single-celled prokaryotes found in rocks that are more than 3 billion years old. Scientists hypothesize that all species evolved from a single prokaryotic cell such as a bacteria. Eukaryotic cells evolved from bacteria. Multicellular organisms followed. From there, more and more species branched off through the process of evolution.

Branching diagrams

A **cladogram** displays evolutionary relationships among living species and their ancestors. A cladogram resembles a branching tree. Each branch represents a different evolutionary path. The point where two branches come together represents a common ancestor that shares evolved characteristics with the species that branch off from it. Figure 13.2 shows a simple cladogram.

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ancestor - an organism from which others have descended.

cladogram - a tree-like diagram that displays evolutionary relationships among living species and their ancestors.

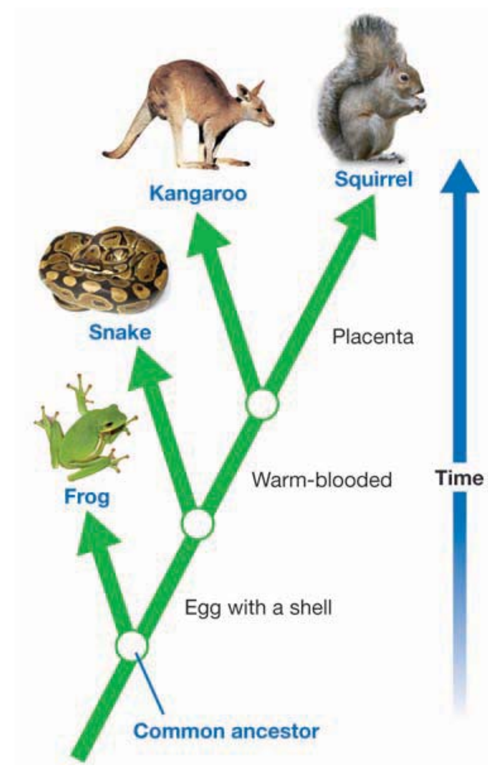
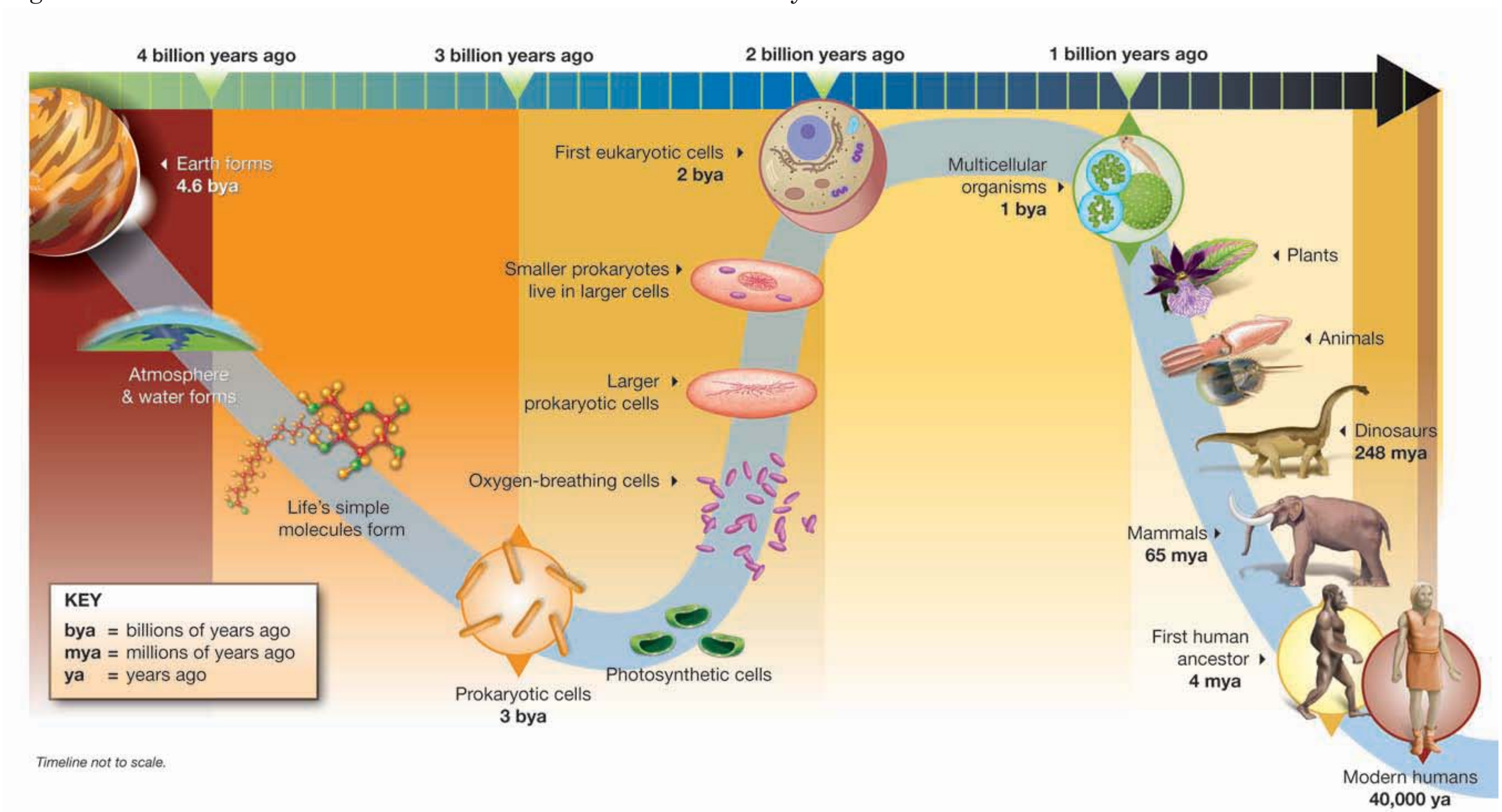


Figure 13.2: *An example of a cladogram.*

An evolutionary timeline

Scientists believe that Earth is about 4.6 billion years old. The first life appeared over 3 billion years ago in the form of tiny, single-celled prokaryotes. About 2 billion years ago, those cells evolved into larger cells with a nucleus. Smaller prokaryotic cells took up residence inside the larger cells and eventually evolved into organelles like mitochondria. Multicellular organisms appeared about a billion years ago. Larger animals and plants have been evolving for the past 500 million years. The diagram below shows a theoretical timeline of how the diversity of life evolved.



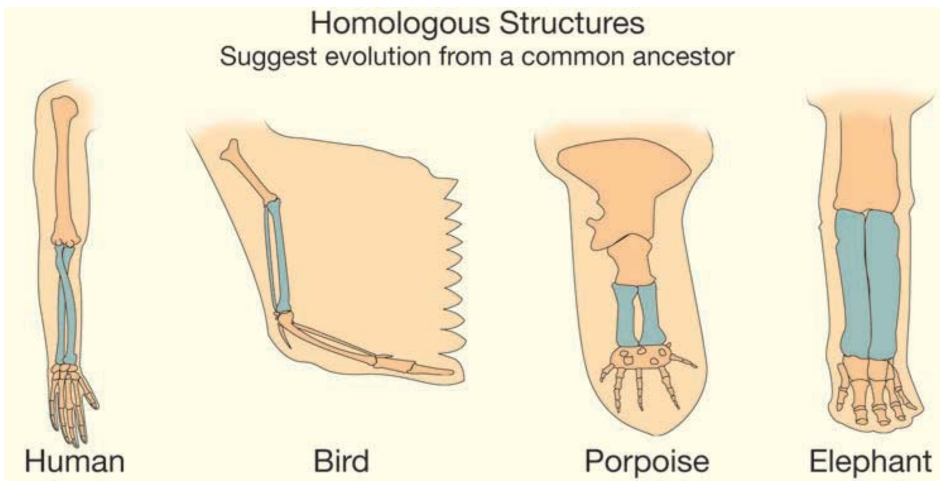
Lines of evidence

Three major lines of evidence

Evolution is a scientific theory that explains how life changes through time. A theory is based on scientific evidence gathered from data and observations. **Many lines of evidence provide the basis for the theory of evolution. These include comparative anatomy, DNA analysis, and the fossil record.**

Comparative anatomy

Comparative anatomy is the study of anatomical similarities and differences among species. For example, what does your arm have in common with the wing of a bird, the flipper of a porpoise, and the forelimb of an elephant? The diagram below shows that each has a similar bone structure. **Homologous structures** have a common origin, but do not necessarily perform the same function. The structures in the limbs below indicate that the organisms are related by a common ancestor.



Analogous structures

Analogous structures serve the same function but come from different origins. Though structurally similar, they do not arise from a common ancestor. An example of analogous structures is the wing of an insect and the wing of a bird (Figure 13.3).

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> **homologous structures** - body structures that have a common origin but do not necessarily perform the same function.

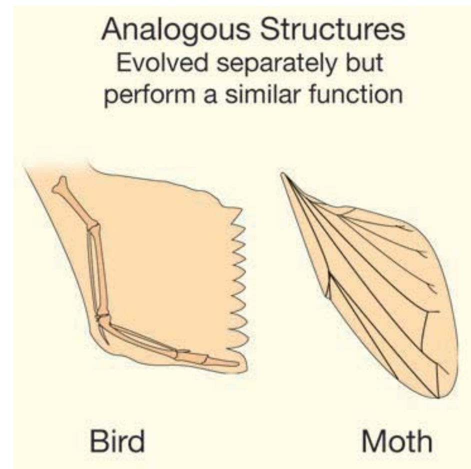
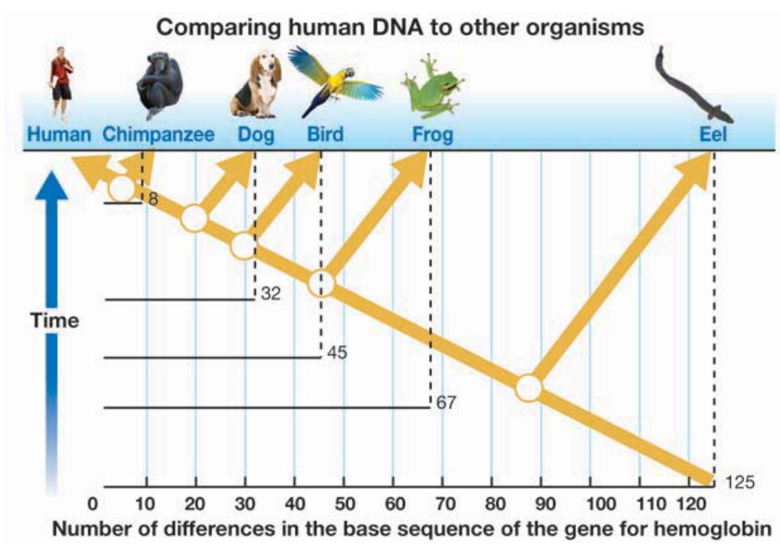


Figure 13.3: *An insect wing and the wing of a bird are both similar in function but do not come from a common ancestor.*

Comparing embryos Another way to compare the anatomy of different species is to compare their embryos. Scientists have discovered similarities in embryos of vertebrates (Figure 13.4). **Vertebrates** are animals with a backbone. You are a vertebrate. So are other mammals, birds, reptiles, and fish. Adult vertebrates also share many similarities in their skeletons and muscles. This is evidence that all vertebrates descended from a common ancestor.

DNA evidence All species of organisms have DNA as their hereditary material. Scientists compare the DNA base sequences of different species to determine evolutionary relationships. **Species that share more similarities in their DNA base sequences are more closely related than those that share fewer similarities.** Scientists hypothesize that if two species have similarities in their base sequences, they share a common ancestor. The diagram compares the DNA base sequences in the gene that codes for hemoglobin in vertebrates. The greater the number of differences in base sequences, the farther the evolutionary distance from humans.



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vertebrates - animals with a backbone.

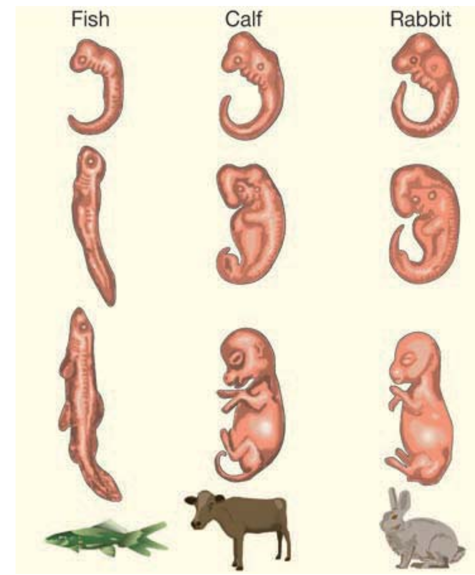


Figure 13.4: *Comparing the embryos of different vertebrates.*

Fossils

What are fossils?

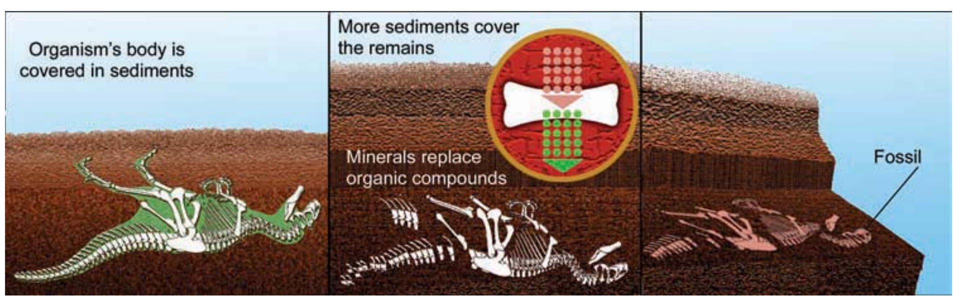
Much of the evidence for evolution comes from studying fossils. A **fossil** is a remnant or trace of an organism from the past, such as a skeleton or leaf imprint, embedded and preserved in Earth's crust. Earth's crust is its outermost layer made of rock.

Sedimentary rock

Most fossils are dug up from sedimentary rock layers. *Sedimentary rock* is rock that has formed from *sediments*, like sand, mud, or small pieces of rock. Over long periods of time, sediments are squeezed together as they are buried under more and more layers that pile up. Eventually, those sediments are compressed into sedimentary rock. The layers that are farther down in Earth's crust are older than the upper layers. Figure 13.5 shows layers of sedimentary rock that have been exposed along a river. Each layer contains fossils. Which fossils are oldest?

How fossils are formed

Many fossils are formed from the hard parts of an organism's body like bones and teeth. Fossil formation begins when an organism's body is quickly covered in sediments from an event like a mudslide or a sand storm. Over time, more and more sediments cover the remains. The body parts that do not rot are buried under layers of sediments. After a long time, the organic compounds in the body parts are replaced with rock-like minerals. This process results in a heavy, rock-like copy of the original object—a fossil.



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fossil - a remnant or trace of an organism from the past, such as a skeleton or leaf imprint, embedded and preserved in Earth's crust.

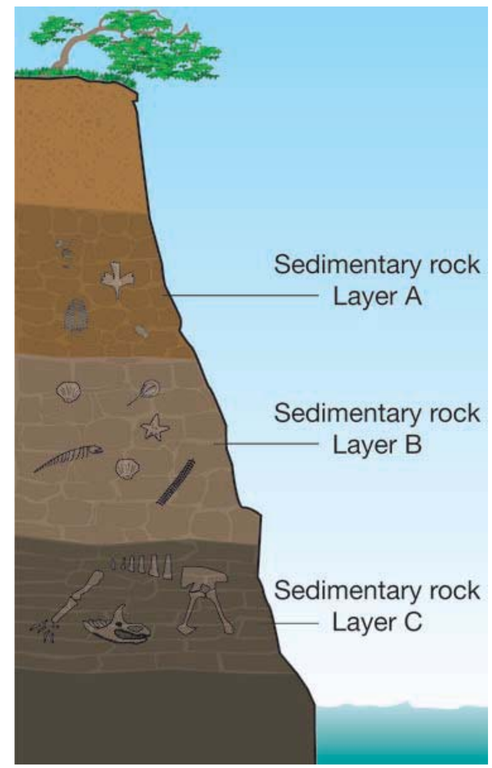


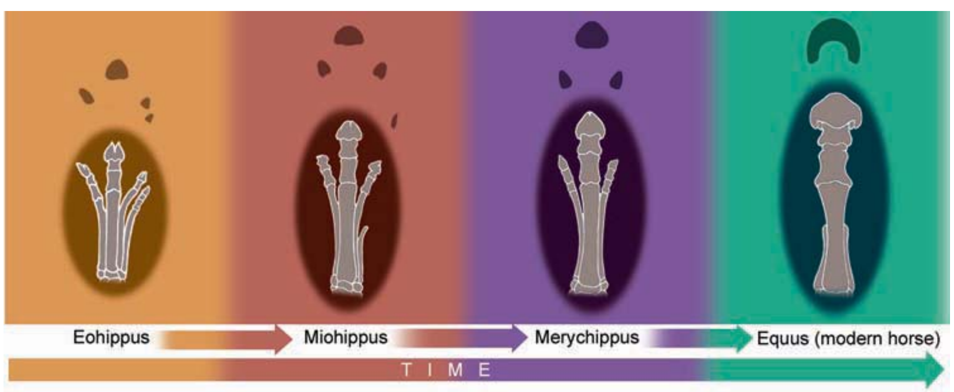
Figure 13.5: *Which fossils are oldest? Which are youngest?*

The fossil record

What is the fossil record? Fossils provide a historical sequence of life on Earth known as the **fossil record**. Fossils found in the upper (newer) sedimentary layers more closely resemble present-day organisms than fossils found in deeper (older) layers. Through that information, scientists have been able to piece together parts of the fossil record. Scientists use the fossil record to trace the order in which evolutionary changes occurred.

Gaps in the fossil record Although scientists have collected thousands of fossils, there are many gaps in the fossil record. That is because most ancient species did not fossilize. They simply decayed and were lost from the fossil record. Scientists estimate that only a small percentage of past organisms have been (or will be) found as fossils.

Using the fossil record A good example of how scientists use the fossil record to trace evolution is the horse. Scientists have found many fossils of horse ancestors. Figure 13.6 shows how some of the horse's ancestors may have looked. Below are the limb bones of horse ancestors and the modern horse. The evolution of a species takes millions of years and does not occur in a straight line. There are many branches that lead to different species with different adaptations.



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fossil record - a historical sequence of life on Earth based on the sequence of fossils.

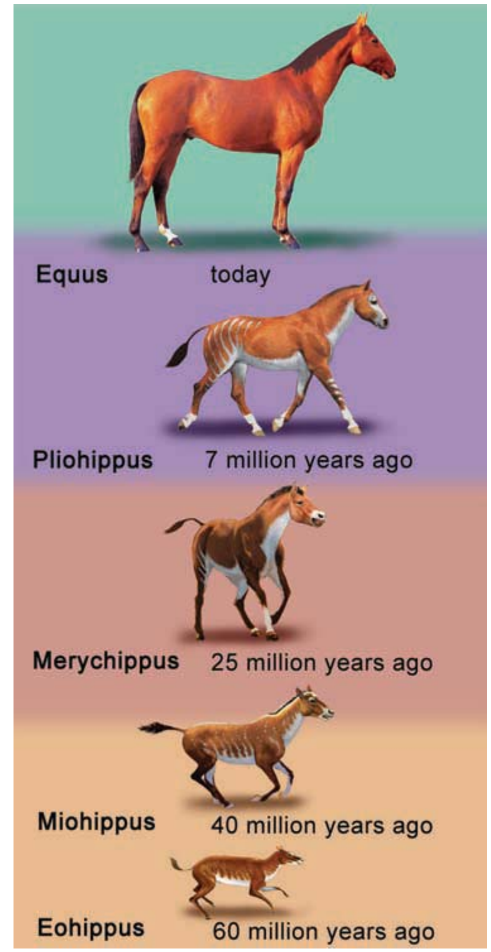

Figure 13.6: *Ancestors of the modern horse.*