Section 1

# Change Over Time

### Terms to Learn

adaptation
species
evolution
fossil
fossil record
vestigial structure

### What You'll Do

- Explain how fossils provide evidence that organisms have evolved over time.
- Identify three ways that organisms can be compared to support the theory of evolution.

If someone asked you to describe a frog, you might say that a frog has long hind legs, eyes that bulge, and a habit of croaking from time to time. Then you might start to think about some of the differences among frogs—differences that set one kind of frog apart from another. Take a look at **Figures 1, 2,** and **3** on this page. These frogs look different from each other, yet they all inhabit a tropical rain forest.

**Figure 1** *The red-eyed tree frog hides among a tree's leaves during the day and comes out at night.*

**Figure 2** *The smoky jungle frog blends into the forest floor.*

**Figure 3** *The strawberry dart-poison frog's bright coloring warns predators that it is poisonous.*

## Differences Among Organisms

As you can see, these three frogs have different adaptations that enable them to survive. An **adaptation** is a characteristic that helps an organism survive and reproduce in its environment. Adaptations can include structures and behaviors for finding food, for protection, and for moving from place to place.

Living things that share the same characteristics and adaptations may be members of the same species. A **species** is a group of organisms that can mate with one another to produce fertile offspring. For example, all red-eyed tree frogs are members of the same species and can mate with one another to produce more red-eyed tree frogs.


Native tribes in Central America rub the poison from the strawberry dart-poison frog on their arrow tips before hunting. The poison helps to paralyze their prey.

**Do Species Change over Time?** These frogs are just a few of the millions of different species that share the Earth with us. The species on Earth today range from bacteria that lack cell nuclei to multicellular fungi, plants, and animals. Have these same species always existed on Earth?

Earth is a very old planet. Scientists estimate that it is 4.6 billion years old. The planet itself has changed a great deal during that long period of time. Fossil evidence shows that living things have changed as well. Since life first appeared on Earth, a great number of species have died out and have been replaced by newer species. **Figure 4** shows some of the different life-forms that have existed during Earth's history.

What causes species to change? Scientists think that newer species have descended from older species through the process of evolution. **Evolution** is the process by which populations accumulate inherited changes over time. Because of evolution, scientists think that all living things, from daisies to crocodiles to humans, share a common ancestor.

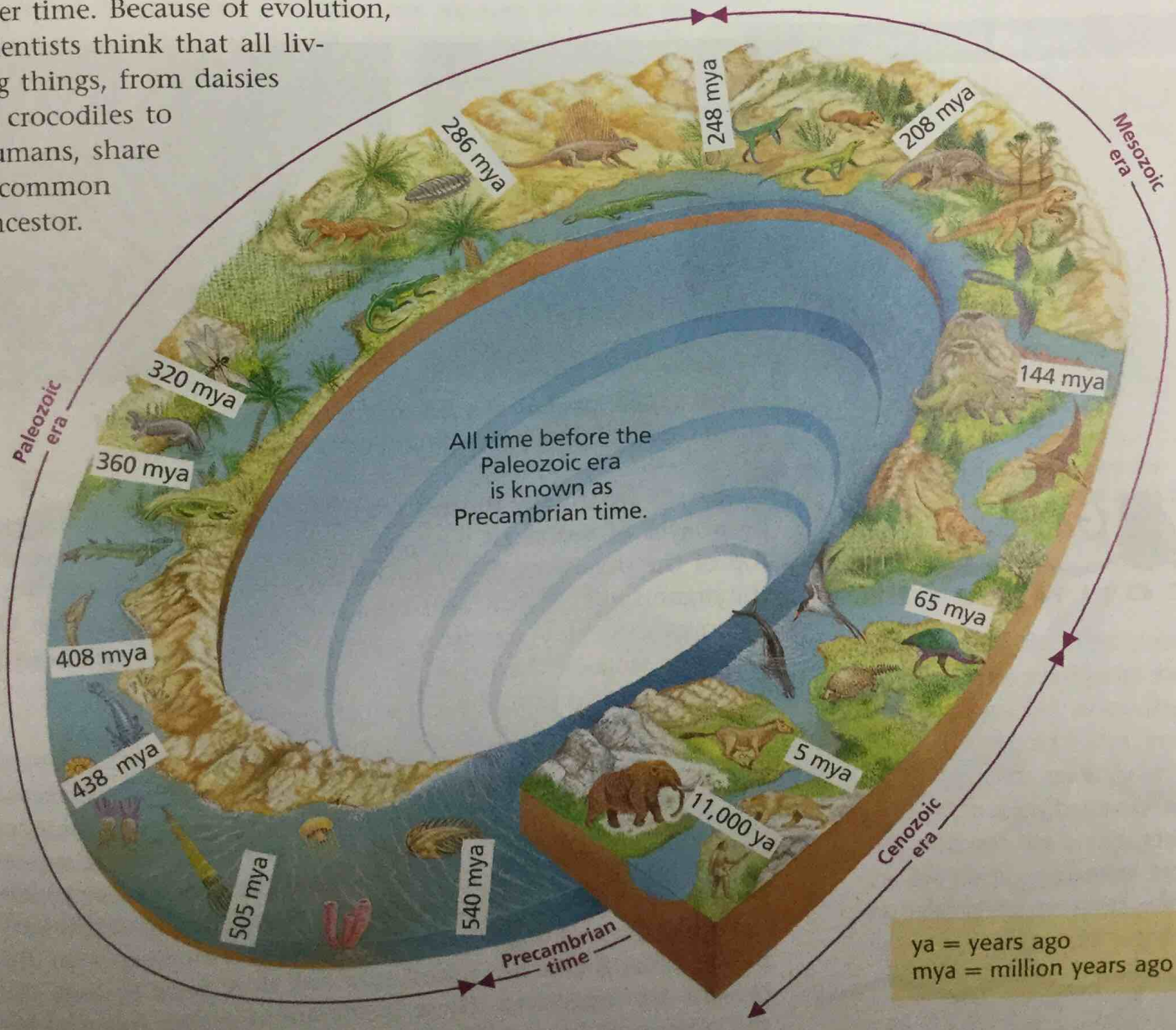



**Figure 4** *This spiral diagram represents many changes in life on Earth since the formation of the planet 4.6 billion years ago.*

## Evidence of Evolution: The Fossil Record

Evidence that living things evolve comes from many different sources. This evidence includes fossils as well as comparisons among different groups of organisms.

**BRAIN FOOD**

To date, scientists have described and named about 300,000 fossil species.

**Fossils** The Earth's crust is arranged in layers, with different kinds of rock and soil stacked on top of one another. These layers are formed when sediments, particles of sand, dust, or soil are carried by wind and water and are deposited in an orderly fashion. Older layers are deposited before newer layers and are buried deeper within the Earth. **Fossils,** the solidified remains or imprints of once-living organisms, are found in these layers. Fossils, like those pictured in **Figure 5,** can be of complete organisms, parts of organisms, or just a set of footprints.

**Figure 5** *The fossil on the left is of a trilobite, an ancient aquatic animal. The fossils on the right are of seed ferns.*

**Geology CONNECTION**

Fossils are usually found in layered rock called sedimentary rock. Sedimentary rock usually forms when rock is broken into sediment by wind, water, and other means. The wind and water move the sediment around and deposit it. Over time, layers of sediment pile up. Lower layers are compressed and changed into rock.

Fossils are usually formed when a dead organism is covered by a layer of sediment. Over time, more sediment settles on top of the organism. Minerals in the sediment may seep into the organism, gradually replacing the organism with stone. Or the organism may rot away completely after being covered, leaving a hole in the rock called a *mold*.

**Reading the Fossil Record** Fossils provide a historical sequence of life known as the **fossil record.** The fossil record supplies evidence about the order in which evolutionary changes have occurred. Fossils found in the upper, or newer, layers of the Earth's crust tend to resemble present-day organisms. This similarity indicates that the fossilized organisms were close relatives of present-day organisms. The deeper in the Earth's crust fossils are found, the less they tend to look like present-day organisms. These fossils are of earlier forms of life that may now be extinct.

**Gaps in the Fossil Record** If every organism that lived left an imprint behind, the fossil record would resemble a very large evolutionary family tree. **Figure 6** shows a hypothetical fossil record in which all relationships between organisms are clearly mapped.

Although scientists have collected thousands of fossils, gaps remain in the current fossil record, as shown in **Figure 7.** This is because specific conditions are necessary for fossils to form. The organism must be buried in very fine sediment. Also, oxygen—which promotes decay—cannot be present. However, very few places are free of oxygen. Because the conditions needed for fossils to form are rare, fossils are often difficult to find. Nevertheless, scientists have identified some fossils that complete sections of the fossil record.

**Vestigial Structures** Whales are similar in shape to fish. Yet whales are *mammals*—animals that breathe air, give birth to live young, and produce milk. Although modern whales do not have hind limbs, there are remnants of hind-limb bones inside their bodies, as shown in **Figure 8.** These remnants of once-useful structures are known as **vestigial** (ves TIJ ee uhl) **structures.** Scientists think that over millions of years, whales evolved from doglike land dwellers into sea-dwelling organisms. But scientists have not had the fossil evidence to support their ideas—until now. Read the following case study to learn the story of whale evolution.

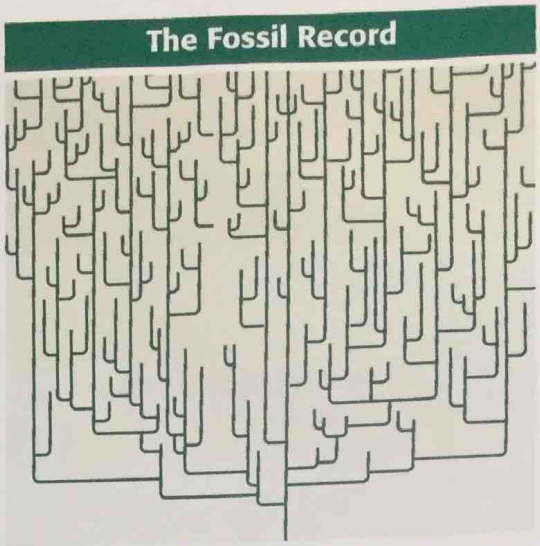



**Figure 6** *This is the way the fossil record might appear if fossils from every species had been found.*

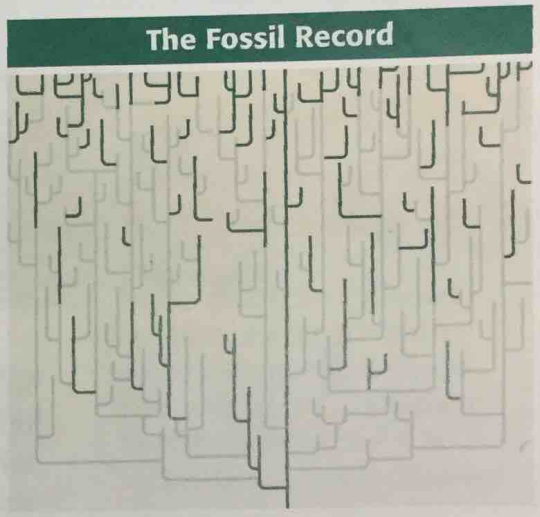



**Figure 7** *This diagram illustrates the many gaps in the existing fossil record.*

**Figure 8** *Remnants of hind-limb bones are embedded deep inside the whale's body.*

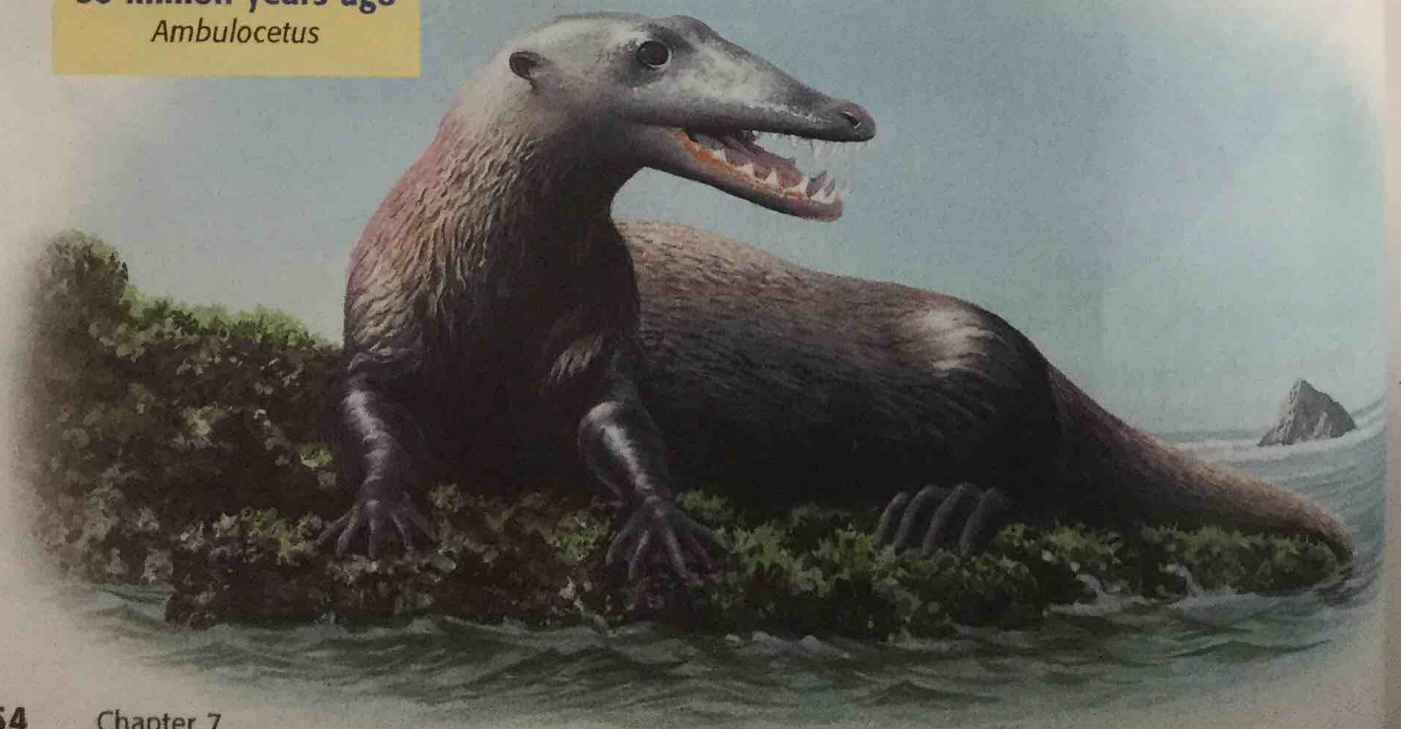
## Case Study: Evolution of the Whale

Scientists hypothesize that whales evolved from land-dwelling mammals like *Mesonychid* (muh ZOH ni kid), shown below, which returned to the ocean about 55 million years ago. During the 1980s and 1990s, several fossils of whale ancestors were discovered. These discoveries support a theory of whale evolution.

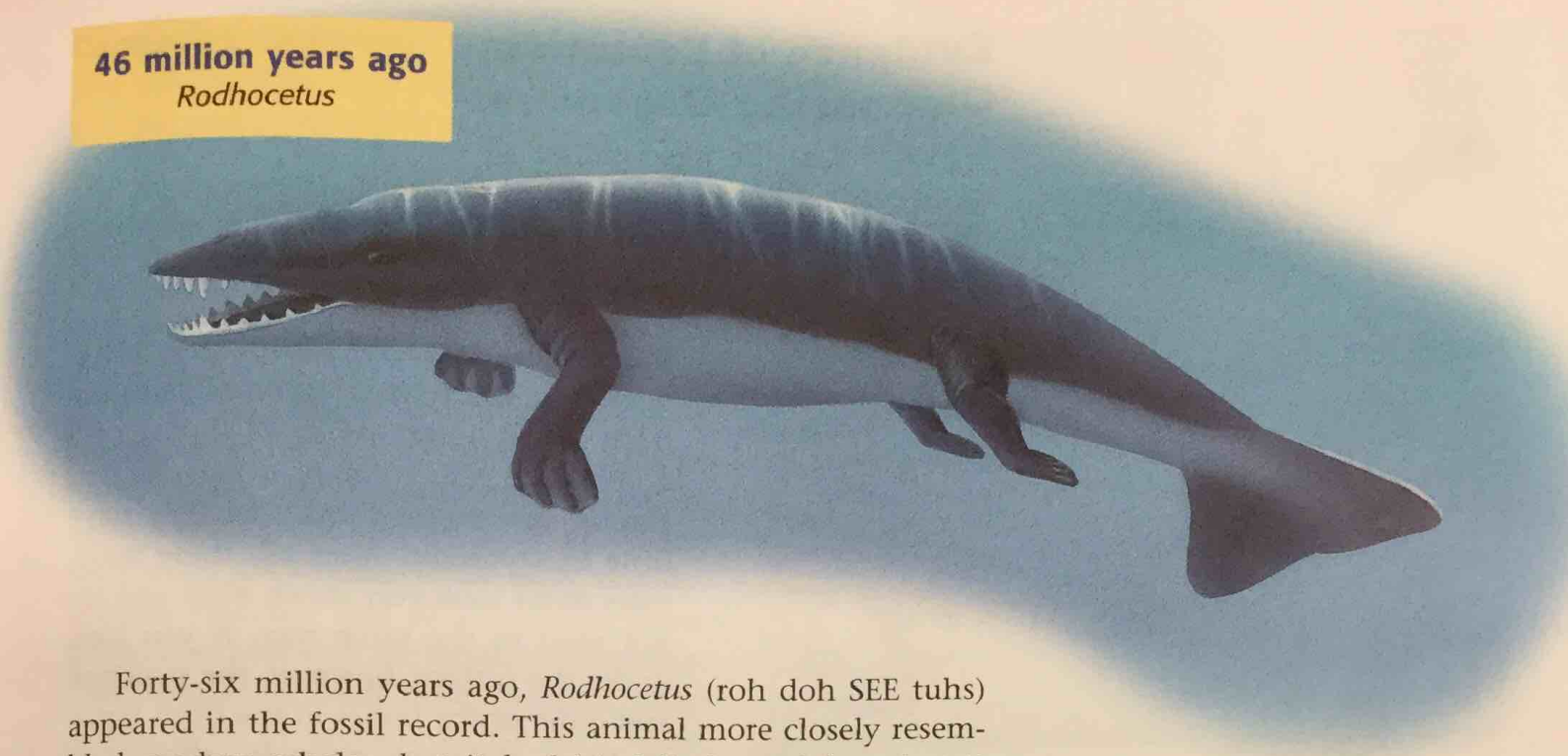
**55 million years ago**
*Mesonychid*

*Ambulocetus* (AM byoo loh SEE tuhs), pictured below, lived in coastal waters. *Ambulocetus* had shorter legs than *Mesonychid*, but it still had feet and toes that could support its weight on land. Although *Ambulocetus* had a tail, scientists think it kicked its legs like an otter in order to swim and used its tail for balance.

**50 million years ago**
*Ambulocetus*



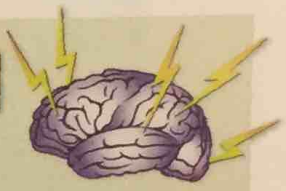
**46 million years ago**
*Rodhocetus*



Forty-six million years ago, *Rodhocetus* (roh doh SEE tuhs) appeared in the fossil record. This animal more closely resembled modern whales, but it had hind limbs and feet that it retained from its land-dwelling ancestor. Because of its short legs, *Rodhocetus* was restricted to a crocodile-like waddle while on land. Unlike the legs of *Ambulocetus*, these legs were not necessary for swimming. Instead, *Rodhocetus* depended on its massive tail to propel it through the water. While *Ambulocetus* probably pulled itself onto land every night, *Rodhocetus* probably spent most of its time in the water.

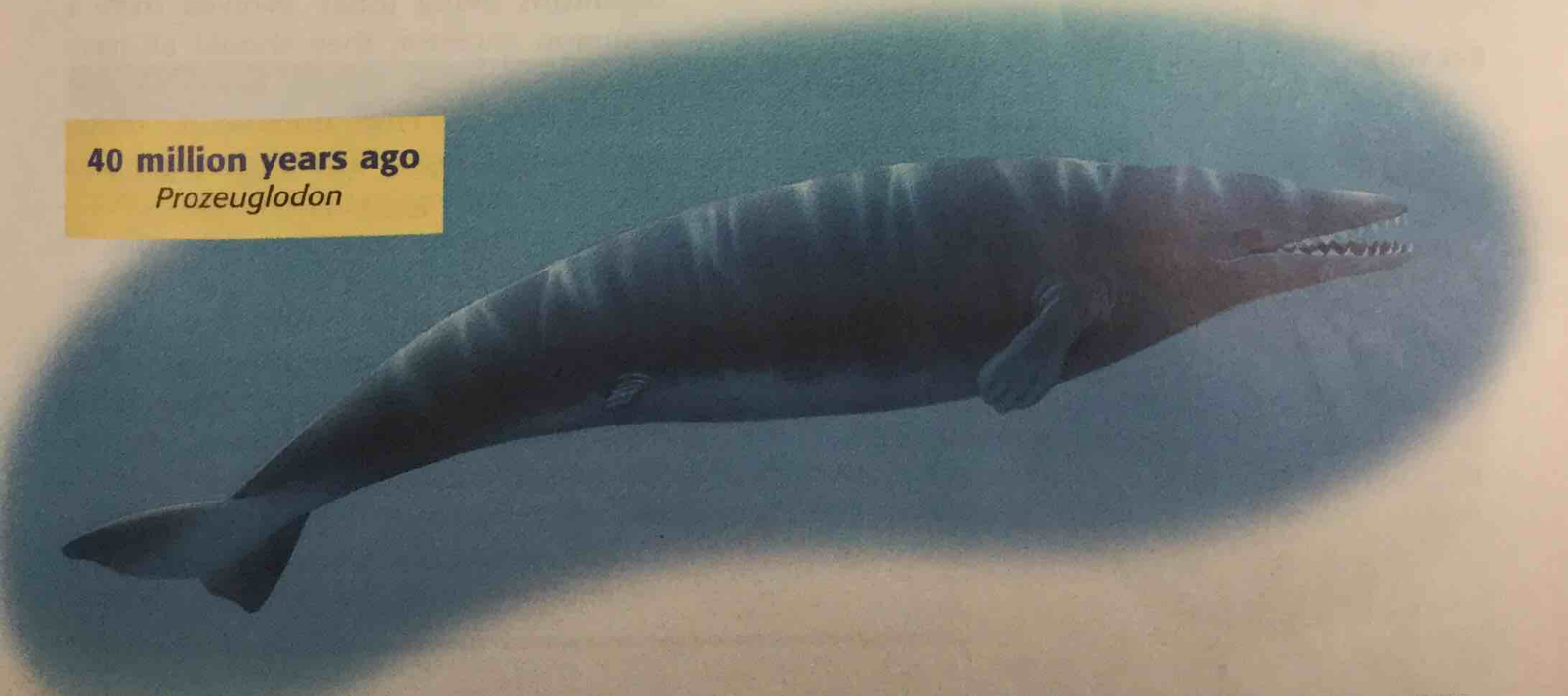
*Prozeuglodon* (pro ZOO gloh dahn), which appeared in the fossil record 6 million years after *Rodhocetus*, was well adapted for life at sea. Although it still had a pair of very small legs, *Prozeuglodon* lived only in the water.

**BRAIN FOOD**



During their early development, modern whale embryos have four limbs. The rear limbs disappear before birth, and the front limbs develop into flippers.

**40 million years ago**
*Prozeuglodon*



## Evidence of Evolution: Comparing Organisms

Evidence that life has evolved also comes from comparisons of different groups of organisms. On the following pages, the different kinds of evidence that support the theory of evolution are discussed in greater detail.

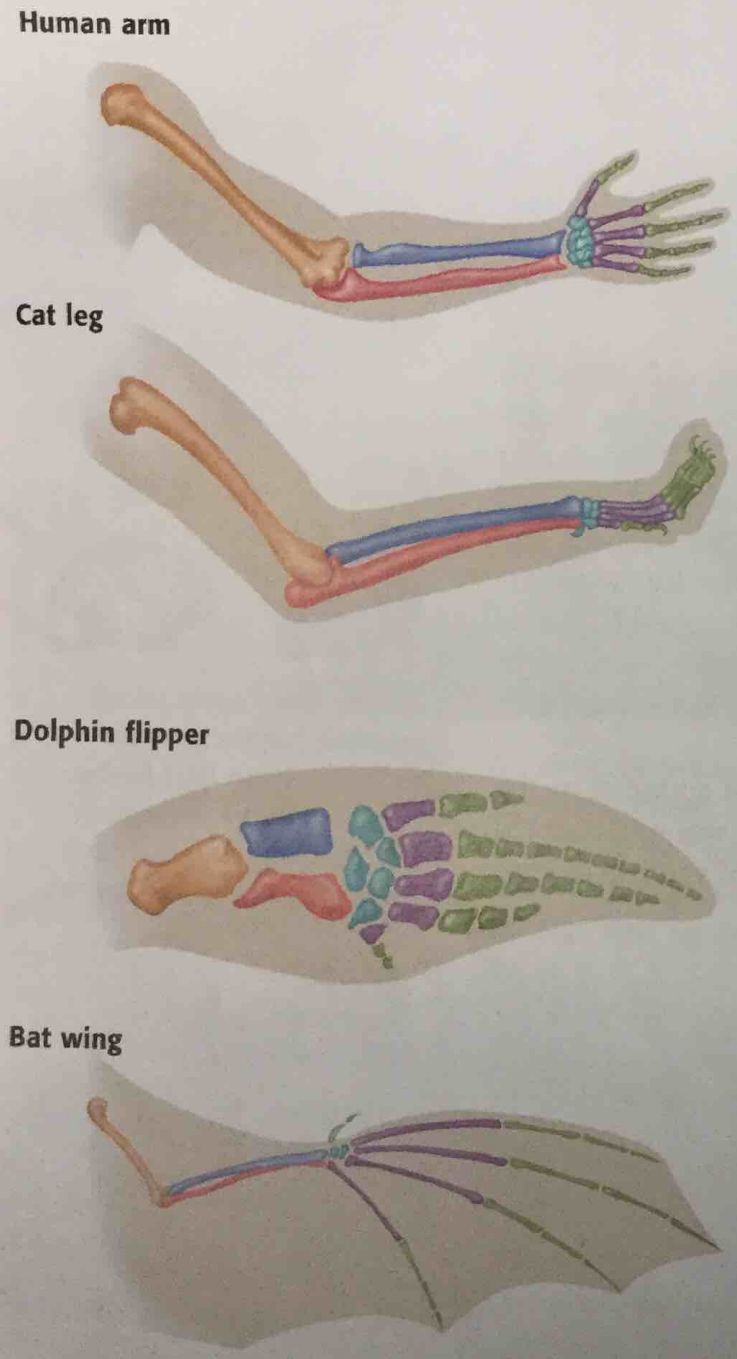



**Figure 9** *The bones in the front limbs of these animals are similar, even though the limbs are used in different ways. Similar bones are shown in the same color.*

**Comparing Skeletal Structures** What does your arm have in common with the front leg of a cat, the front flipper of a dolphin, or the wing of a bat? At first glance, you might think that they have little in common. After all, these structures don't look very much alike and are not used in the same way. If you look under the surface, however, the structure and order of the bones in the front limbs of these different animals, shown in **Figure 9,** are actually similar to the structure and order of the bones found in your arm.

The similarities indicate that animals as different as a cat, a dolphin, a bat, and a human are all related by a common ancestor. The evolutionary process has modified these bones over millions of years to perform specific functions.

**Comparing DNA from Different Species** Scientists hypothesize that if all organisms living today evolved from a common ancestor, they should all have the same kind of genetic material. And in fact they do. From microscopic bacteria to giant polar bears, all organisms share the same genetic material—DNA.

In addition, scientists hypothesize that species appearing to be close relatives should have greater similarities in their DNA than species appearing to be distant relatives. For example, chimpanzees and gorillas appear to be close relatives. Chimpanzees and toucans appear to be distant relatives. The DNA of chimpanzees is, in fact, more similar to the DNA of gorillas than to the DNA of toucans.

**Comparing Embryonic Structures** Can you tell the difference between a chicken, a rabbit, and a human? It's pretty easy when you compare adults from each species. But what about comparing members of these species before they are born? Look at the left side of **Figure 10,** which depicts the very early embryos of a chicken, a rabbit, and a human.

All the organisms shown in the figure are *vertebrates*, or animals that have a backbone. Early in development, human embryos and the embryos of all other vertebrates are similar. These early similarities are evidence that all vertebrates share a common ancestor. Although the embryos look similar to each other in very early stages, none of them look like their adult forms. Embryo development has evolved over millions of years, causing the embryonic structures to grow into many different species of vertebrates. The changes in the process of embryo development therefore produce animals as different as a chicken and a human.

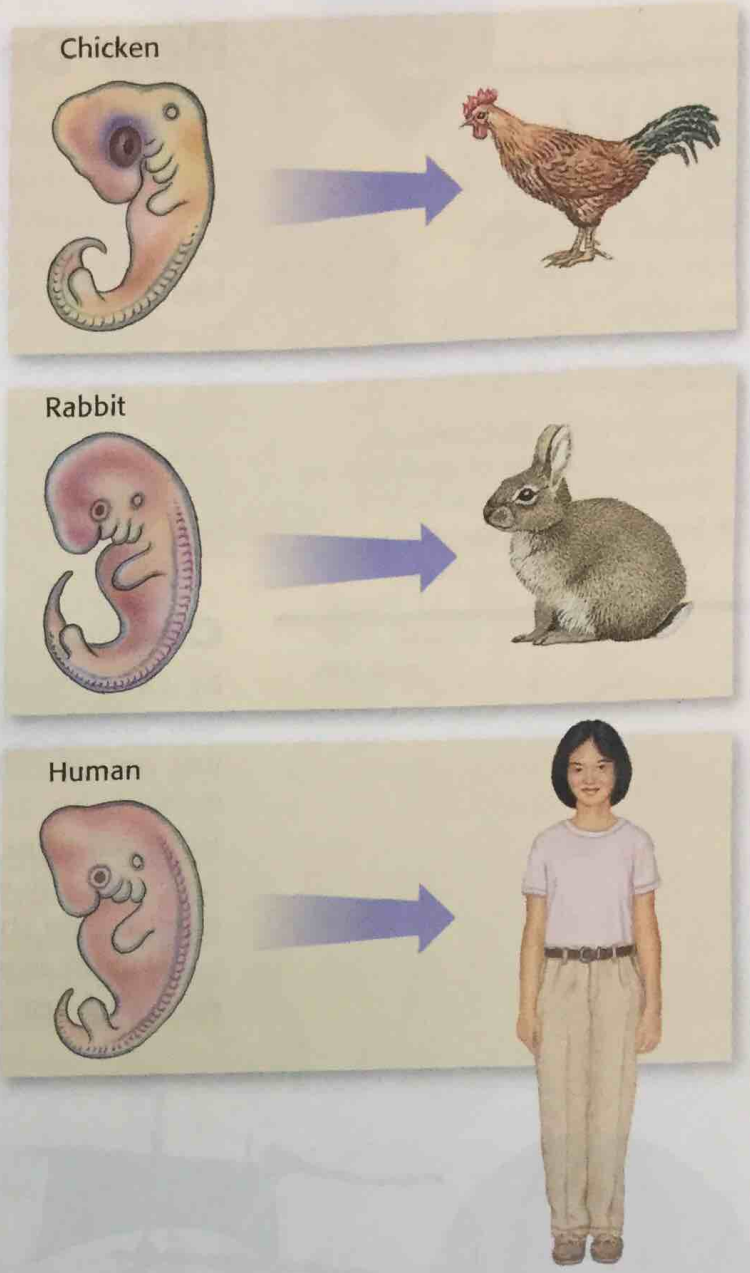



**Figure 10** *The embryos of different vertebrates are very similar during the earliest stages of development.*

## REVIEW

1. How does the fossil record suggest that species have changed over time?
2. How do the similarities in the fore-limb bones of humans, cats, dolphins, and bats support the theory of evolution?
3. **Interpreting Graphics** The photograph at right shows the layers of sedimentary rock exposed during the construction of a road. Imagine that a species which lived 200 million years ago is found in the layer designated as **b**. Its ancestor, which lived 250 million years ago, would most likely be found in which layer, **a** or **c**? Explain your answer.