SECTION 1

Change over Time

If someone asked you to describe a frog, you might say that a frog has long hind legs, has bulging eyes, and croaks. But what color skin would you say that a frog has?

Once you start to think about frogs, you realize that frogs differ in many ways. These differences set one kind of frog apart from another. The frogs in **Figures 1, 2,** and **3** look different from each other, yet they may live in the same areas.

READING WARM-UP

Objectives

- Identify two kinds of evidence that show that organisms have evolved.
- Describe one pathway through which a modern whale could have evolved from an ancient mammal.
- Explain how comparing organisms can provide evidence that they have ancestors in common.

Terms to Learn

adaptation
species
evolution
fossil
fossil record

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Differences Among Organisms

As you can see, each frog has a different characteristic that might help the frog survive. A characteristic that helps an organism survive and reproduce in its environment is called an **adaptation.** Adaptations may be physical, such as a long neck or striped fur. Or adaptations may be behaviors that help an organism find food, protect itself, or reproduce.

Living things that have the same characteristics 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 strawberry poison arrow frogs are members of the same species and can mate with each other to produce more strawberry poison arrow frogs. Groups of individuals of the same species living in the same place make up a *population*.

Reading Check **How can you tell that organisms are members of the same species?** *(See the Appendix for answers to Reading Checks.)*

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

Figure 2 The bright coloring of the strawberry poison arrow frog warns predators that the frog is poisonous.

Figure 3 The smoky jungle frog blends into the forest floor.

Do Species Change over Time?

In a single square mile of rain forest, there may be dozens of species of frogs. Across the Earth, there are millions of different species of organisms. The species that live on Earth today range from single-celled bacteria, which lack cell nuclei, to multicellular fungi, plants, and animals. Have these species always existed on Earth?

Scientists think that Earth has changed a great deal during its history, and that living things have changed, too. Scientists estimate that the planet is 4.6 billion years old. Since life first appeared on Earth, many species have died out, and many new species have appeared. **Figure 4** shows some of the species that have existed during Earth's history.

Scientists observe that species have changed over time. They also observe that the inherited characteristics in populations change over time. Scientists think that as populations change over time, new species form. Thus, newer species descend from older species. The process in which populations gradually change over time is called **evolution.** Scientists continue to develop theories to explain exactly how evolution happens.

adaptation a characteristic that improves an individual's ability to survive and reproduce in a particular environment

species a group of organisms that are closely related and can mate to produce fertile offspring

evolution the process in which inherited characteristics within a population change over generations such that new species sometimes arise

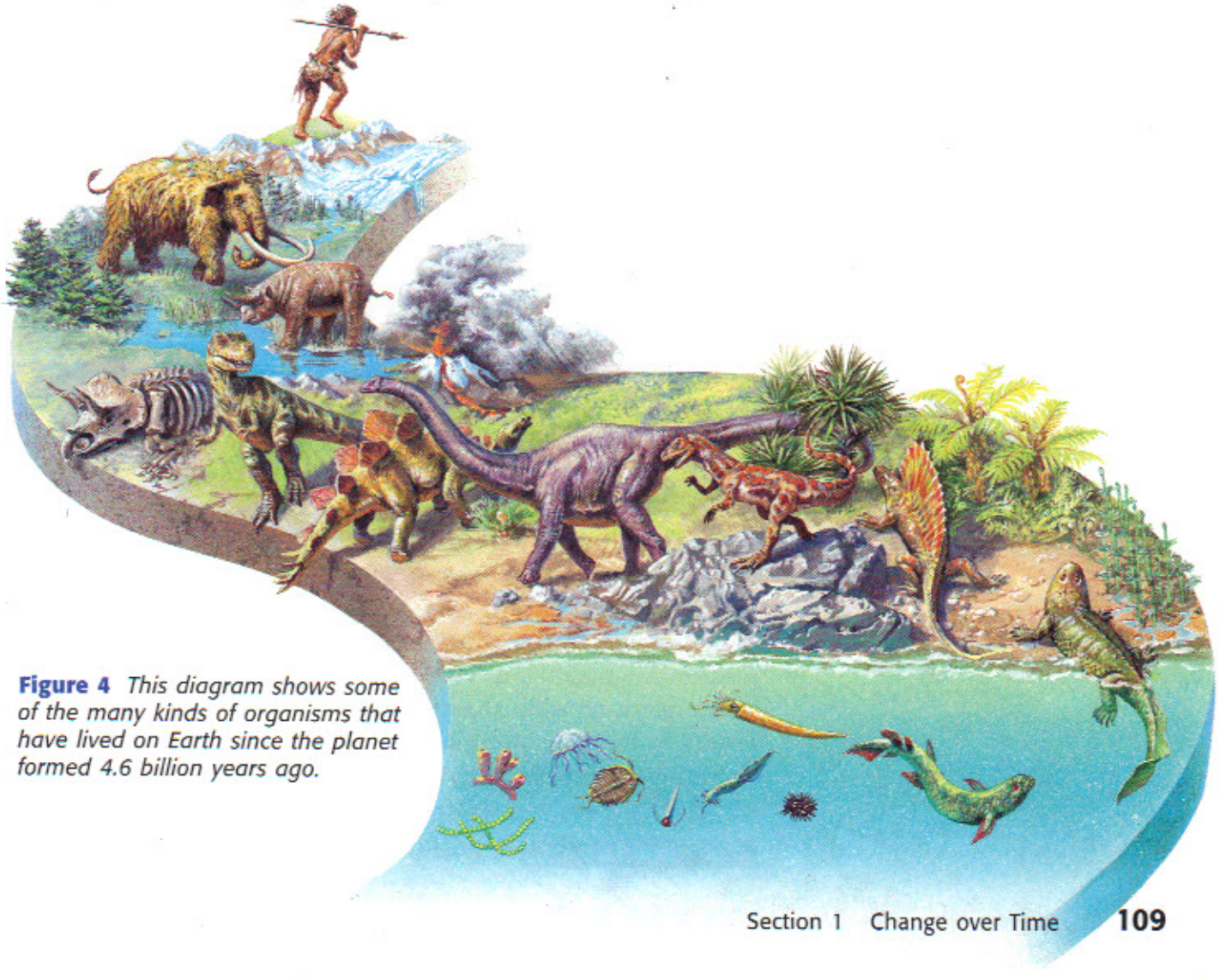


Figure 4 *This diagram shows some of the many kinds of organisms that have lived on Earth since the planet formed 4.6 billion years ago.*

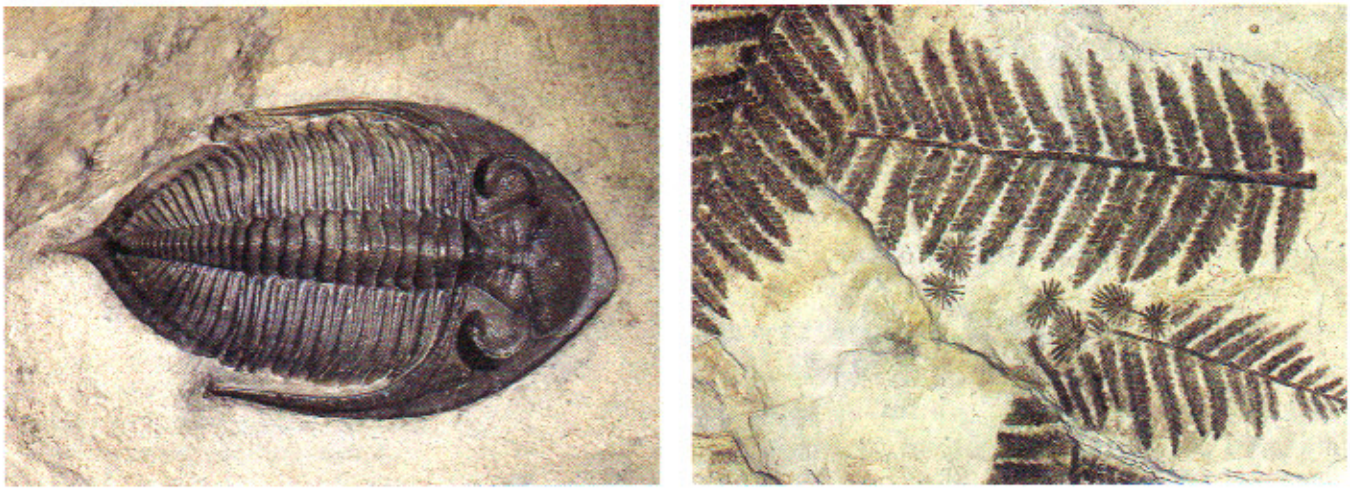


Figure 5 *The fossil on the left is of a trilobite, an ancient aquatic animal. The fossils on the right are of seed ferns.*

Evidence of Changes over Time

Evidence that evolution has happened is buried within Earth. Earth's crust is arranged in layers. These layers are made up of different kinds of rock and soil stacked on top of each other. These layers form 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 Earth.

Fossils

fossil the remains or physical evidence of an organism preserved by geological processes

fossil record a historical sequence of life indicated by fossils found in layers of the Earth's crust

Sometimes, the remains or imprints of once-living organisms are found in the layers of rock. These remains are called **fossils.** Examples of fossils are shown in **Figure 5.** Fossils can be complete organisms, parts of organisms, or just a set of footprints. Fossils usually form 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 and gradually replace the organism with stone. If the organism rots away completely after being covered, it may leave an imprint of itself in the rock.

The Fossil Record

By studying fossils, scientists have made a timeline of life that is known as the **fossil record.** The fossil record organizes fossils by their estimated ages and physical similarities. Fossils found in newer layers of Earth's crust tend to be similar to present-day organisms. This similarity indicates that the fossilized organisms were close relatives of present-day organisms. Fossils from older layers are less similar to present-day organisms than fossils from newer layers are. The older fossils are of earlier life-forms, which may not exist anymore.

Reading Check How does the fossil record organize fossils?

Evidence of Ancestry

The fossil record provides evidence about the order in which species have existed. Scientists observe that all living organisms have characteristics in common and inherit characteristics in similar ways. So, scientists think that all living species descended from common ancestors. Evidence of common ancestors can be found in fossils and in living organisms.

Drawing Connections

Scientists examine the fossil record to figure out the relationships between extinct and living organisms. They draw models, such as the one shown in **Figure 6,** that illustrate their hypotheses. The short horizontal line at the top left in the diagram represents a species that lived in the past. Each branch in the diagram represents a group of organisms that descended from that species.

As shown in **Figure 6,** scientists think that whales and some types of hoofed mammals have a common ancestor. This ancestor was probably a mammal that lived on land between 50 million and 70 million years ago. During this time period, the dinosaurs died out and a variety of mammals appeared in the fossil record. The first ocean-dwelling mammals appeared about 50 million years ago. Scientists think that all mammal species alive today evolved from common ancestors.

Scientists have named and described hundreds of thousands of living and ancient species. Scientists use information about these species to sketch out a "tree of life" that includes all known organisms. But scientists know that their information is incomplete. For example, parts of Earth's history lack a fossil record. In fact, fossils are rare because specific conditions are necessary for fossils to form.

CONNECTION TO Geology

Sedimentary Rock Fossils are most often found in 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. Find out if your area has any sedimentary rocks that contain fossils. Mark the location of such rocks on a copy of a local map.

ACTIVITY

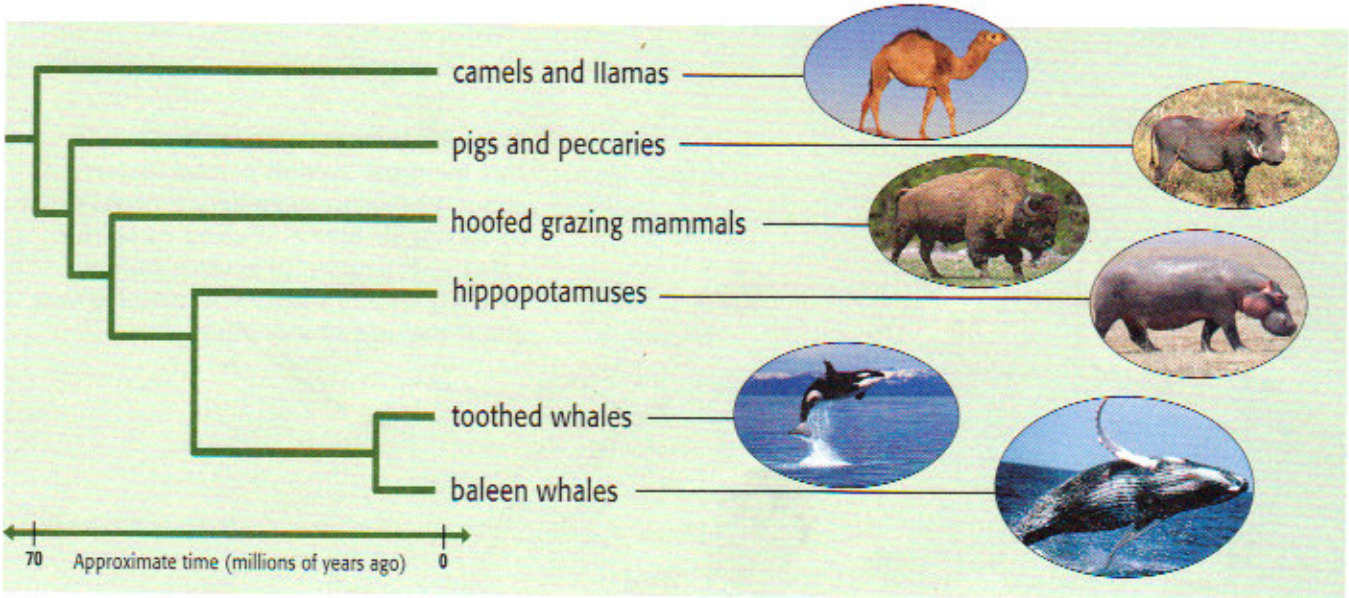


Figure 6 *This diagram is a model of the proposed relationships between ancient and modern mammals that have characteristics similar to whales.*

Examining Organisms

Examining an organism carefully can give scientists clues about its ancestors. For example, whales seem similar to fish. But unlike fish, whales breathe air, give birth to live young, and produce milk. These traits show that whales are *mammals*. Thus, scientists think that whales evolved from ancient mammals.

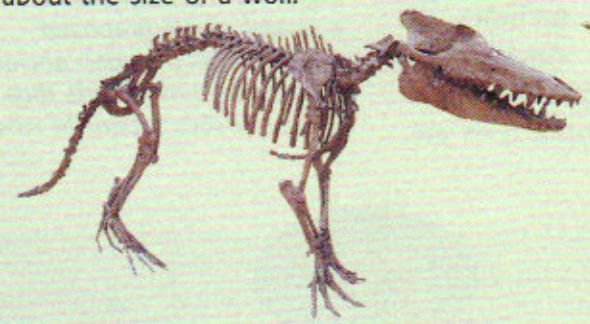
Case Study: Evolution of the Whale

Scientists think that the ancient ancestor of whales was probably a mammal that lived on land and that could run on four legs. A more recent ancestor was probably a mammal that spent time both on land and in water. Comparisons of modern whales and a large number of fossils have supported this hypothesis. **Figure 7** illustrates some of this evidence.

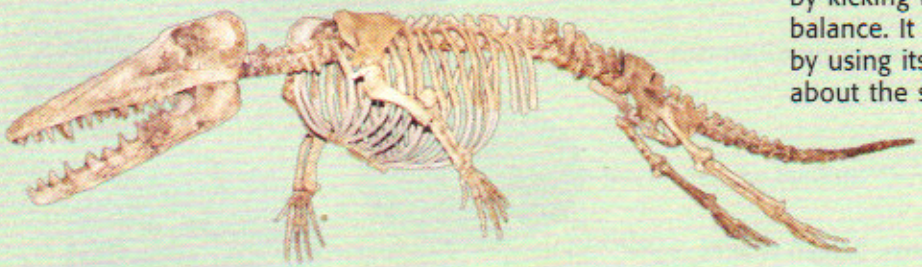
Reading Check What kind of organism do scientists think was an ancient ancestor of whales?

Figure 7 Evidence of Whale Evolution

a ***Pakicetus*** (PAK uh SEE tuhs)
Scientists think that whales evolved from land-dwelling mammals that could run on four legs. One of these ancestors may have been *Pakicetus,* which lived about 50 million years ago. The fossil skeleton and an artist's illustration of *Pakicetus* are shown here. *Pakicetus* was about the size of a wolf.



b ***Ambulocetus*** (AM byoo loh SEE tuhs)
This mammal lived in coastal waters about 49 million years ago. It could swim by kicking its legs and using its tail for balance. It could also waddle on land by using its short legs. *Ambulocetus* was about the size of a dolphin.



Walking Whales

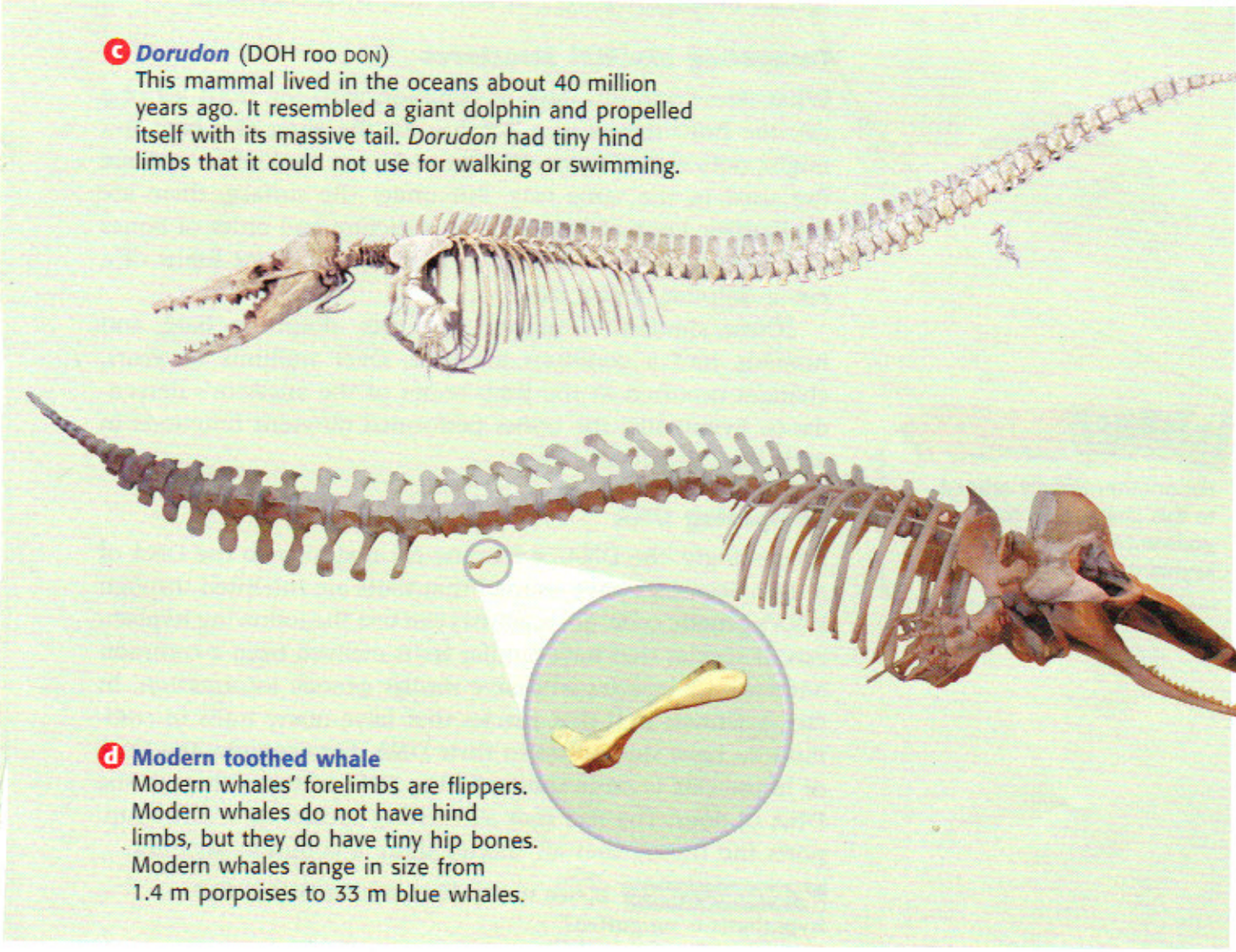
The organisms in **Figure 7** form a sequence between ancient four-legged mammals and modern whales. Several pieces of evidence indicate that these species are related by ancestry. Each species shared some traits with an earlier species. However, some species had new traits that were shared with later species. Yet, each species had traits that allowed it to survive in a particular time and place in Earth's history.

Further evidence can be found inside the bodies of living whales. For example, although modern whales do not have hind limbs, inside their bodies are tiny hip bones, as shown in **Figure 7.** Scientists think that these hip bones were inherited from the whales' four-legged ancestors. Scientists often look at this kind of evidence when they want to determine the relationships between organisms.

MATH PRACTICE

The Weight of Whales

Whales are the largest animals ever known on Earth. One reason whales can grow so large is that they live in water, which supports their weight in a way that their bones could not. The blue whale—the largest type of whale in existence—is about 24 m long and has a mass of about 99,800 kg. Convert these measurements into feet and pounds, and round to whole numbers.



c ***Dorudon*** (DOH roo DON)
This mammal lived in the oceans about 40 million years ago. It resembled a giant dolphin and propelled itself with its massive tail. *Dorudon* had tiny hind limbs that it could not use for walking or swimming.

d **Modern toothed whale**
Modern whales' forelimbs are flippers. Modern whales do not have hind limbs, but they do have tiny hip bones. Modern whales range in size from 1.4 m porpoises to 33 m blue whales.

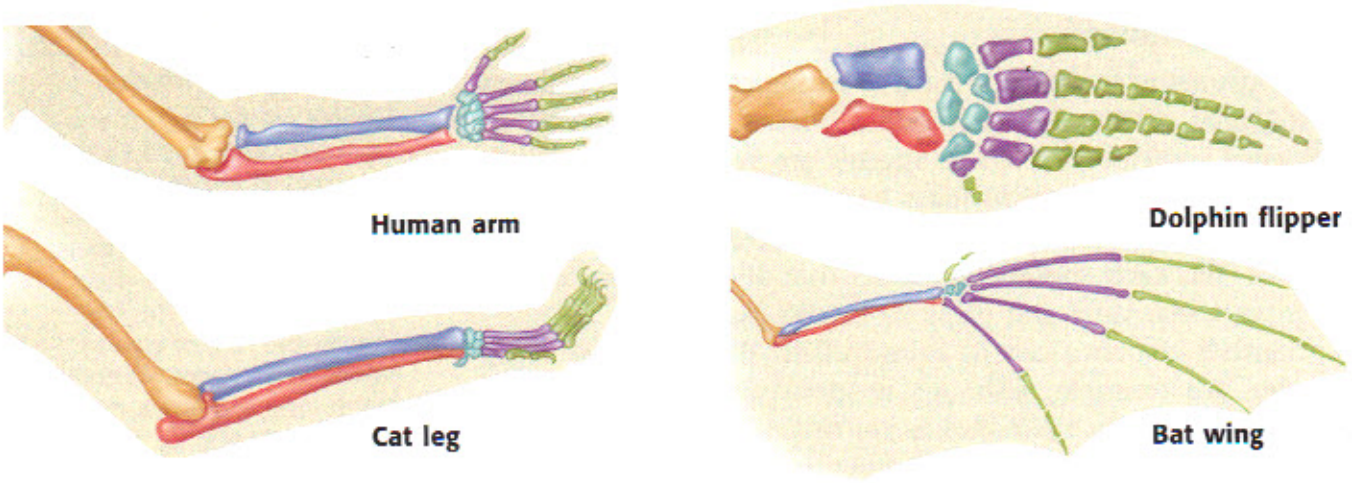


Figure 8 *The bones in the front limbs of these animals are similar. Similar bones are shown in the same color. These limbs are different sizes in life.*

Comparing Organisms

Evidence that groups of organisms have common ancestry can be found by comparing the groups' DNA. Because every organism inherits DNA, every organism inherits the traits determined by DNA. Organisms contain evidence that populations and species undergo changes in traits and DNA over time.

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? You might notice that these structures do not look alike and are not used in the same way. But under the surface, there are similarities. Look at **Figure 8.** The structure and order of bones of a human arm are similar to those of the front limbs of a cat, a dolphin, and a bat.

These similarities suggest that cats, dolphins, bats, and humans had a common ancestor. Over millions of years, changes occurred in the limb bones of the ancestor's descendants. Eventually, the bones performed different functions in each type of animal.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5EVOW.**

Comparing DNA

Interestingly, the DNA of a house cat is similar to the DNA of a tiger. Scientists have learned that traits are inherited through DNA's genetic code. So, scientists can test the following hypothesis: If species that have similar traits evolved from a common ancestor, the species will have similar genetic information. In fact, scientists find that species that have many traits in common do have similarities in their DNA. For example, the DNA of house cats is more similar to the DNA of tigers than to the DNA of dogs. The fact that all existing species have DNA supports the theory that all species share a common ancestor.

Reading Check **If two species have similar DNA, what hypothesis is supported?**

SECTION Review

Summary

- Evolution is the process in which inherited characteristics within a population change over generations, sometimes giving rise to new species. Scientists continue to develop theories to explain how evolution happens.
- Evidence that organisms evolve can be found by comparing living organisms to each other and to the fossil record. Such comparisons provide evidence of common ancestry.
- Scientists think that modern whales evolved from an ancient, land-dwelling mammal ancestor. Fossil organisms that support this hypothesis have been found.
- Evidence of common ancestry among living organisms is provided by comparing DNA and inherited traits. Species that have a common ancestor will have traits and DNA that are more similar to each other than to those of distantly related species.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

adaptation	species
fossil	evolution

1. Members of the same ___ can mate with one another to produce offspring.
2. A(n) ___ helps an organism survive.
3. When populations change over time, ___ has occurred.

Understanding Key Ideas

4. A human's arm, a cat's front leg, a dolphin's front flipper, and a bat's wing
   - **a.** have similar kinds of bones.
   - **b.** are used in similar ways.
   - **c.** are very similar to insect wings and jellyfish tentacles.
   - **d.** have nothing in common.
5. How does the fossil record show that species have changed over time?
6. What evidence do fossils provide about the ancestors of whales?

Critical Thinking

7. **Making Comparisons** Other than the examples provided in the text, how are whales different from fishes?
8. **Forming Hypotheses** Is a person's DNA likely to be more similar to the DNA of his or her biological parents or to the DNA of one of his or her cousins? Explain your answer.

Interpreting Graphics

9. The photograph below shows the layers of sedimentary rock exposed during the construction of a road. Imagine that a species that lived 200 million years ago is found in layer **b**. Would the species' ancestor, which lived 250 million years ago, most likely be found in layer **a** or in layer **c**? Explain your answer.