SECTION 1

Change over Time

Key Concept Independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.

What You Will Learn

- The fossil record provides evidence that species have changed over time.
- Fossils support the hypothesis that modern whales evolved from land mammals.
- Comparing the anatomy and DNA of organisms provides evidence that organisms have common ancestors.

Why It Matters

The theory of evolution is a good example of how scientists develop and use scientific theories.

Vocabulary

- adaptation
- fossil
- species
- fossil record
- evolution

READING STRATEGY

Graphic Organizer In your **Science Journal,** create a Concept Map by using the terms *fossils, sediment, sand, dust, soil, fossil record, estimated ages, physical similarities,* and *branching diagrams*.

What makes a frog a frog? Is it a frog's bulging eyes, its long hind legs, its croak, or the color of its skin?

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 **Figure 1** look different from each other, yet they may live in the same area.

Differences Between Organisms

As you can see, each frog has different characteristics that may help the frog survive. A characteristic that helps an organism survive and reproduce in its environment is called an **adaptation.** Some adaptations, such as a long neck or striped fur, are physical. Other adaptations are 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 frogs are members of the same species. Therefore, strawberry poison frogs can mate with each other to produce fertile strawberry frogs. A group of individuals of the same species living in the same place is a *population*.

Figure 1 **Adaptations in Species of Frogs**

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

The **smokey jungle frog** blends into the forest floor.

The bright coloring of the **strawberry poison frog** warns predators that the frog is poisonous.

Do Species Change over Time?

In a single square mile of rain forest, there may be dozens of species of frogs. Across Earth, there are millions of different species of organisms. The species that live on Earth today range from single-celled bacteria and archaea 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. They 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 2** 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 may form. Thus, newer species descend from older species. The process in which populations change over time is called **evolution.**

7.3.c Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.
7.3.d Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.

adaptation (AD uhp TAY shuhn) a characteristic that improves an individual's ability to survive and reproduce in a particular environment

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

evolution (EV uh LOO shuhn) the process in which inherited characteristics within a population change over generations such that new species sometimes arise

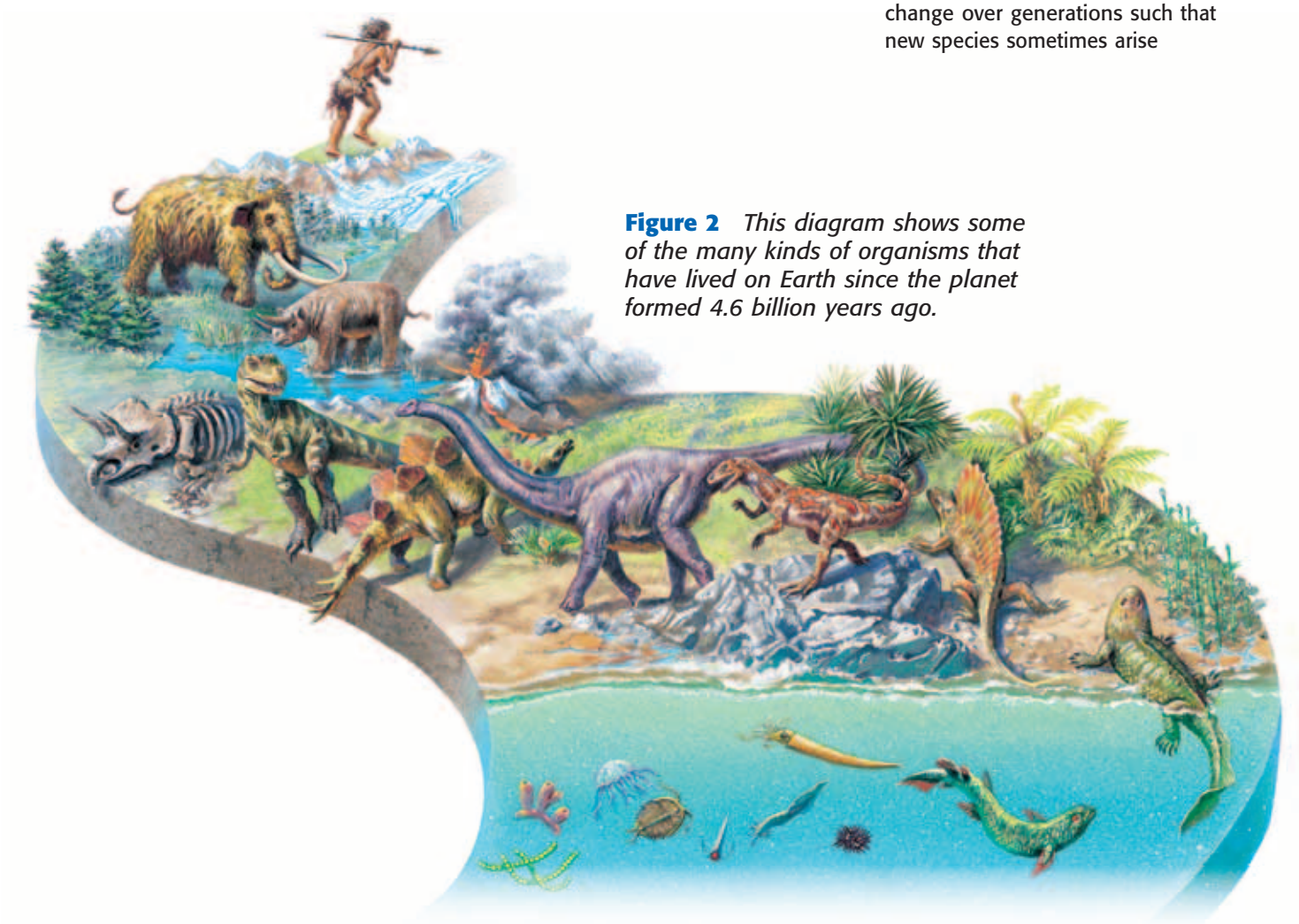


Figure 2 *This diagram shows some of the many kinds of organisms that have lived on Earth since the planet formed 4.6 billion years ago.*

Figure 3 *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

The layers of Earth's crust are made up of different kinds of rock and soil stacked on top of each other. Evidence that organisms have changed over time is buried in sedimentary rock. *Sedimentary* rock is formed when particles of sand, dust, or soil, are deposited in horizontal layers. After a rock layer forms, newer rock layers form on top of it. So, older layers are found below younger rock layers.

Wordwise **sedimentary**
The root *sed-* means "to sit" or "to settle." The suffix *-ment* means "result of."

Fossils

fossil (FAHS uhl) the trace or remains of an organism that lived long ago, most commonly preserved in sedimentary rock

fossil record (FAHS uhl REK uhrd) the history of life in the geologic past as indicated by the traces or remains of living things

The remains or imprints of once-living organisms found in layers of rock are called **fossils.** Examples of fossils are shown in **Figure 3.** 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

All of the fossils that have been found make up the **fossil record.** By examining the fossil record, scientists can learn about the history of life on Earth. 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. Comparing organisms in the fossil record provides evidence for how organisms have changed over time.

Standards Check **What is the fossil record?** 7.3.c

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, they think that all living species descended from common ancestors. Evidence of common ancestors is found in fossils and in living organisms.

Drawing Connections

As scientists analyze fossils and living organisms, they develop hypotheses about how species are related. Scientists draw *branching diagrams* that illustrate their hypotheses. A branching diagram, such as the one shown in **Figure 4,** shows the relationships between species. 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.

Scientists think that whales and some types of hoofed mammals have a common ancestor, as **Figure 4** shows. This ancestor was probably a land mammal that lived between 50 million and 70 million years ago. The fossil record shows that many mammals appeared during this time period. The first ocean-dwelling mammals appeared about 50 million years ago. Scientists think whales evolved from these ocean-dwelling mammals.

Scientists use information about organisms to sketch a "tree of life" that includes all known living things. As scientists gather new information, they reexamine how all organisms are related.

Standards Check **How do scientists use branching diagrams to show how all organisms are related?** 7.3.d

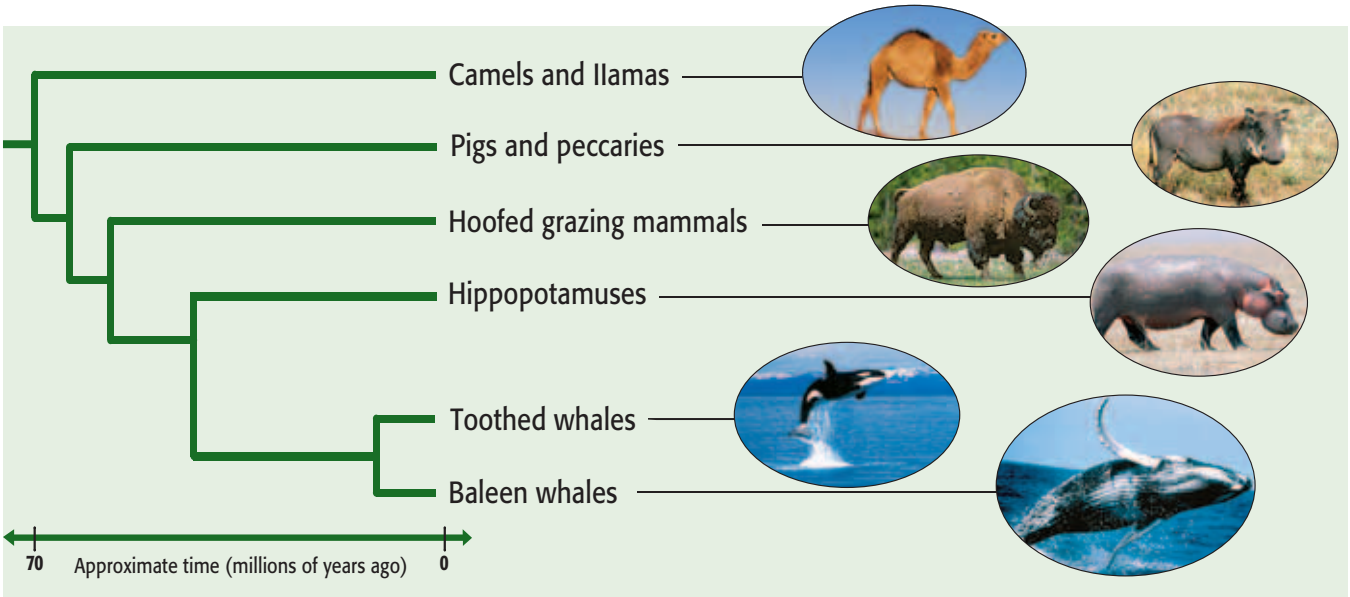


Figure 4 *This diagram is a model of the proposed relationships between some modern mammals.* ***According to the diagram, which animals share the closest common ancestor with whales?***

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 between modern whales and a large number of fossils support this hypothesis. **Figure 5** shows some of this evidence.

Standards Check **What evidence supports the hypothesis that the ancient ancestor of whales was a land mammal?** 7.3.c

Figure 5 **Evidence of Whale Evolution**

a ***Pakicetus*, 50 Million Years Ago**
Scientists think that whales evolved from land-dwelling mammals that could run on four legs. One of these ancestors may have been *Pakicetus* (PAK uh SEE tuhs), 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*, 49 Million Years Ago**
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* (AM byoo loh SEE tuhs) was about the size of a dolphin.

Walking Whales

The organisms in **Figure 5** 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. Some species had new traits that were shared with later species. Each species had traits that allowed it to survive in a particular time and place in Earth's history.

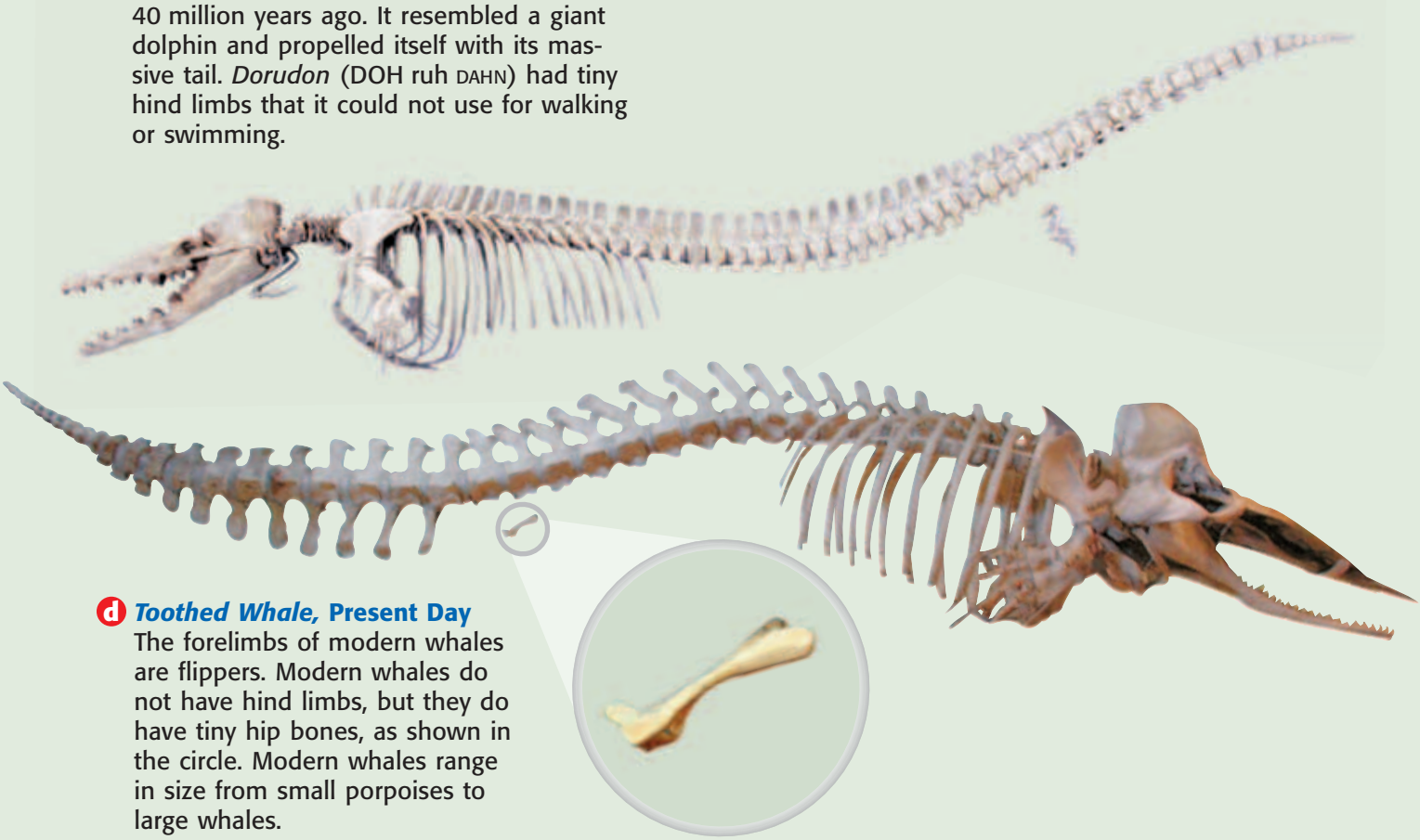
Further evidence can be found inside the bodies of living whales. For example, although modern whales do not have hind limbs, they have tiny hip bones, as **Figure 5** shows. Scientists think that these hip bones were inherited from the whales' four-legged ancestors. Scientists often look at this kind of evidence when trying to determine the relationships between organisms.

MATH PRACTICE

Whale Measurements

Blue whales are the largest animals known to have lived on Earth. Adult blue whales can grow to be 90 ft long. Calves, or young whales, are born large. Blue whale calves are about 23 ft long at birth. Convert the lengths of blue whale adults and calves into meters. Record your work in your **Science Journal.**

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



d ***Toothed Whale,* Present Day**
The forelimbs of modern whales are flippers. Modern whales do not have hind limbs, but they do have tiny hip bones, as shown in the circle. Modern whales range in size from small porpoises to large whales.

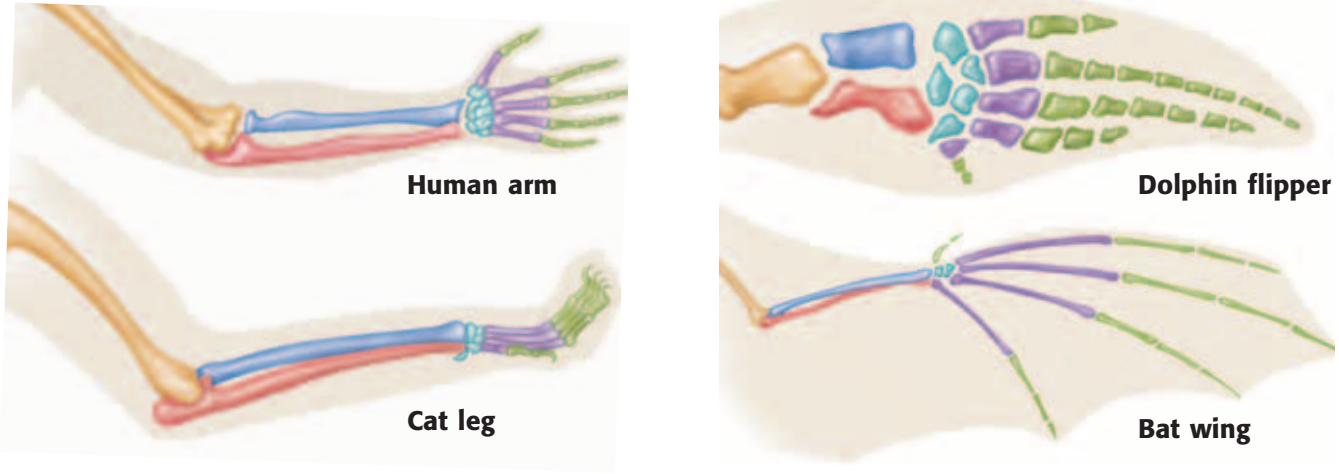


Figure 6 *The bones in the front limbs of humans, cats, dolphins, and bats are similar. Similar bones are shown in the same color. These limbs are not shown to scale.*

Quick Lab

Similarities in Anatomy

7.3.c

1. Each member of a group should select one of the bone arrangements in **Figure 6.**
2. On a piece of **paper,** draw an outline of your selected animal's limb.
3. Shape **modeling clay** into the limb bones. Position the model bones within the outline. If possible, use colors that are consistent with the illustration. Otherwise, decide as a group which colors will be used for specific bones.
4. Compare the shape of each bone as it appears in different limbs. Discuss how the size and shape of each bone relates to its function.

15 min

Comparing Organisms

The scientific fields of comparative anatomy and molecular biology provide evidence that organisms share common ancestors. Comparative anatomy is the study of the physical similarities and differences between organisms. Molecular biology is the study of the molecules found in living things.

Comparing Anatomy

When scientists study the anatomy, or structure, of different organisms, they find that related organisms share many traits. The arm of a human, the front leg of a cat, the front flipper of a dolphin, and the wing of a bat do not look alike and are not used in the same way. But under the surface, they are similar. Look at **Figure 6.** The bones of a human arm are similar in structure and order to the bones in 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. Eventually, the bones performed different functions in each type of animal.

Comparing DNA Molecules

The genetic information stored in an organism's DNA determines the organism's traits. DNA, along with RNA and proteins, are important molecules found in all living things. Scientists compare many organisms' DNA, RNA, proteins, and other molecules. The greater the number of similarities between the DNA of any two species, the more recently the two species shared a common ancestor. Scientists use molecular data, comparative anatomy, and fossils to support the theory that populations change over time and sometimes give rise to new species.

Standards Check **If two species have similar DNA, what would you infer about their ancestry?** 7.3.c