

Section 4

The Cycling of Matter

Key Concept Over time, matter such as rock, water, carbon, and nitrogen is transferred between organisms and the physical environment.

What You Will Learn

- The rock cycle is the series of processes in which rock changes from one form to another.
- In the water cycle, water condenses, precipitates, and evaporates through the various spheres of Earth.
- Nitrogen, carbon, and phosphorus cycle between Earth's spheres.

Why It Matters

The cycling of matter is important to many Earth processes and to the survival of organisms.

You probably know people who recycle paper, plastic, and aluminum. But did you know that Earth also recycles? Very little new matter enters the Earth system. So, existing matter must cycle continuously for this planet to support life. Water, carbon, nitrogen, phosphorus, and even rocks move through cycles. If these materials did not cycle, Earth could not support life.

The Changing Earth

As matter cycles through the Earth system, the matter changes. Earth's surface also changes. Some of the processes that cause change may take millions of years. For example, mountains that are thousands of meters high form at rates of only a few centimeters per year. Over time, this slow rate of change adds up to big changes. Many changes have taken place on Earth over a long period of time. As **Figure 1** shows, Earth's history spans 4,600 million (4.6 billion) years!

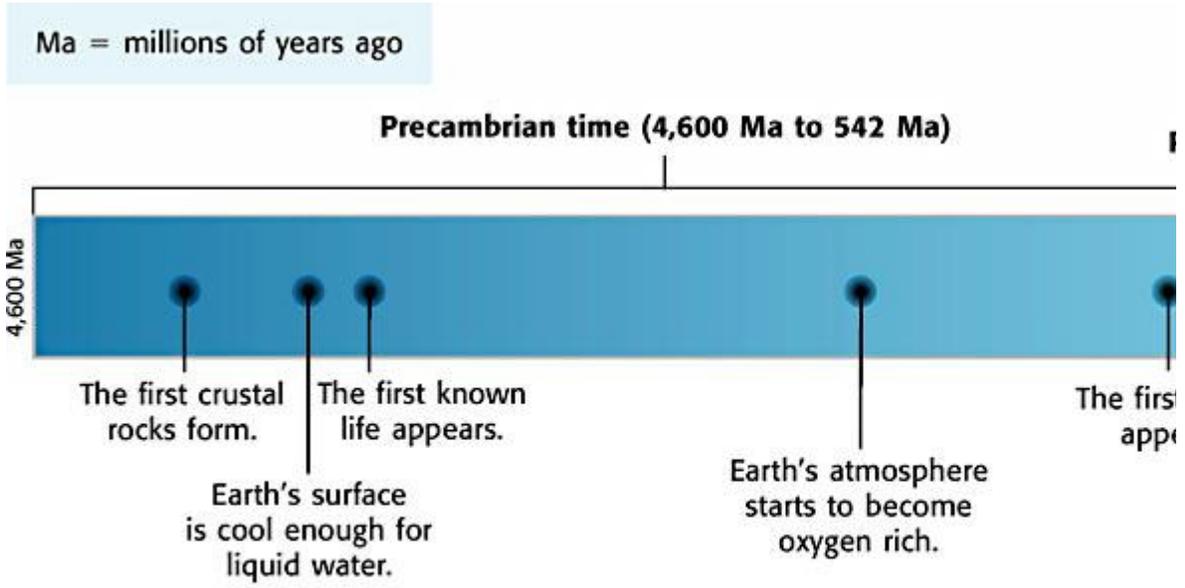


Figure 1 It has taken 4.6 billion years for Earth to become the way we know it today. **How many millions of years ago did the first life appear?**

Some changes happen very quickly. You may see them take place in a single day. For example, the weather may change from one hour to the next. Some cycles include steps that take millions of years and steps that take days or hours. All of the steps of all of these cycles constantly change Earth's surface.

The Rock Cycle

One cycle that takes millions of years is the rock cycle. The rock cycle consists of the processes by which rocks change from one form to another. Several geologic processes can change rock from one type to another. These processes include melting, cooling, cementation, heat, pressure, weathering, and erosion. *Weathering* is the process by which rock is broken down by wind, water, and temperature changes. *Erosion* is the process by which wind, water, ice, or gravity transport parts of the weathered rock from one location to another. A diagram of these

processes is shown in **Figure 2**.

Figure 2 The Rock Cycle



Pathways in the Rock Cycle

Rocks may follow a number of pathways in the rock cycle. For example, if it is exposed to weathering and erosion, igneous rock may become sedimentary rock. But under intense pressure and heat, igneous rock may become metamorphic rock. The pathway that a rock follows in the rock cycle is determined by the forces that act on the rock.

Forces That Change Rock

A rock's location determines the forces that will act on the rock. At Earth's surface, rock exposed to agents of weathering and erosion, such as wind and water, may become sedimentary rock. But deep inside Earth, rock exposed to high heat and pressure may become igneous rock or metamorphic rock.



Classes of Rocks

Geologists place all rocks into three major classes. These classes are based on how the rocks form. The three major classes of rocks are sedimentary, igneous, and metamorphic. *Sedimentary rocks* form when rocks break into smaller pieces and those pieces become cemented together. *Igneous rocks* form when hot, liquid rock—called *magma*—cools and becomes solid. *Metamorphic rocks* form when rock is changed because of chemical processes or changes in temperature and pressure. **Figure 3** shows examples of the three major classes of rocks. Each class of rock can be further classified into rock types based on composition and texture.

Figure 3 Classes of Rocks



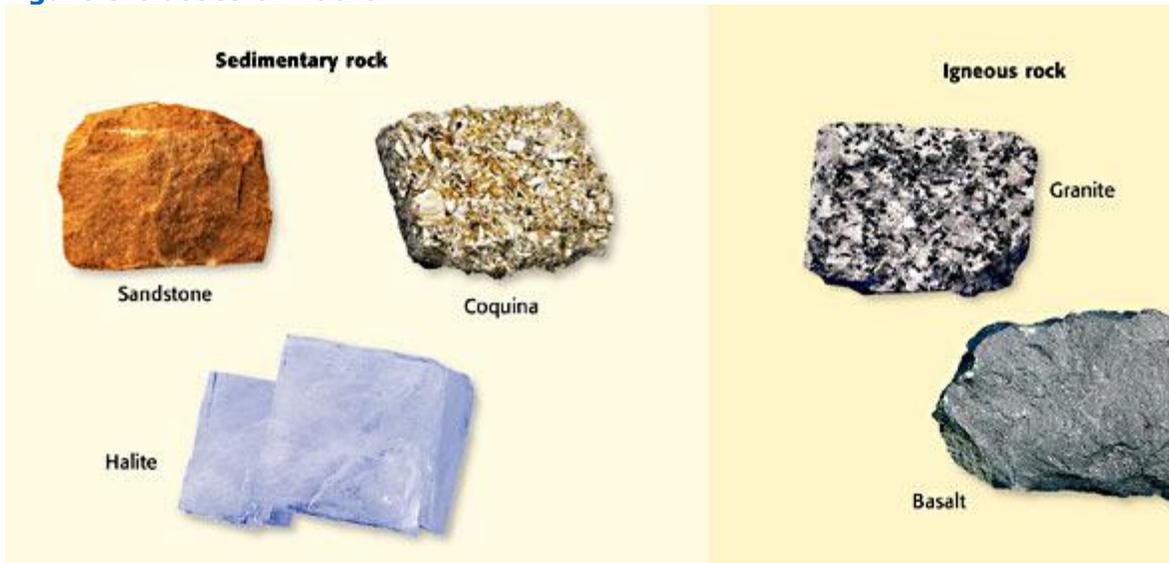
Sedimentary Rocks

Sedimentary rocks are divided into three types: *clastic*, *chemical*, and *organic*. Clastic sedimentary rocks are made of fragments of rock or minerals. Before they are cemented together, these fragments of rock or minerals are called *sediment*. Clastic sedimentary rocks form when sediments are buried, put under pressure, and cemented by minerals such as calcite and quartz. Chemical sedimentary rocks form when minerals crystallize from a solution, such as ocean water. The minerals are buried, put under pressure, and cemented together. Organic sedimentary rocks form when the shells and skeletons of dead marine animals are buried and cemented by calcite or quartz.

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The Water Cycle

The [water cycle](#) is the continuous movement of water between the atmosphere, the land, and the oceans, as shown in **Figure 4**. The sun is the major source of energy that powers the water cycle. Energy from the sun heats the water on Earth. This heating of water causes water to change states. For example, liquid water changes to water vapor.

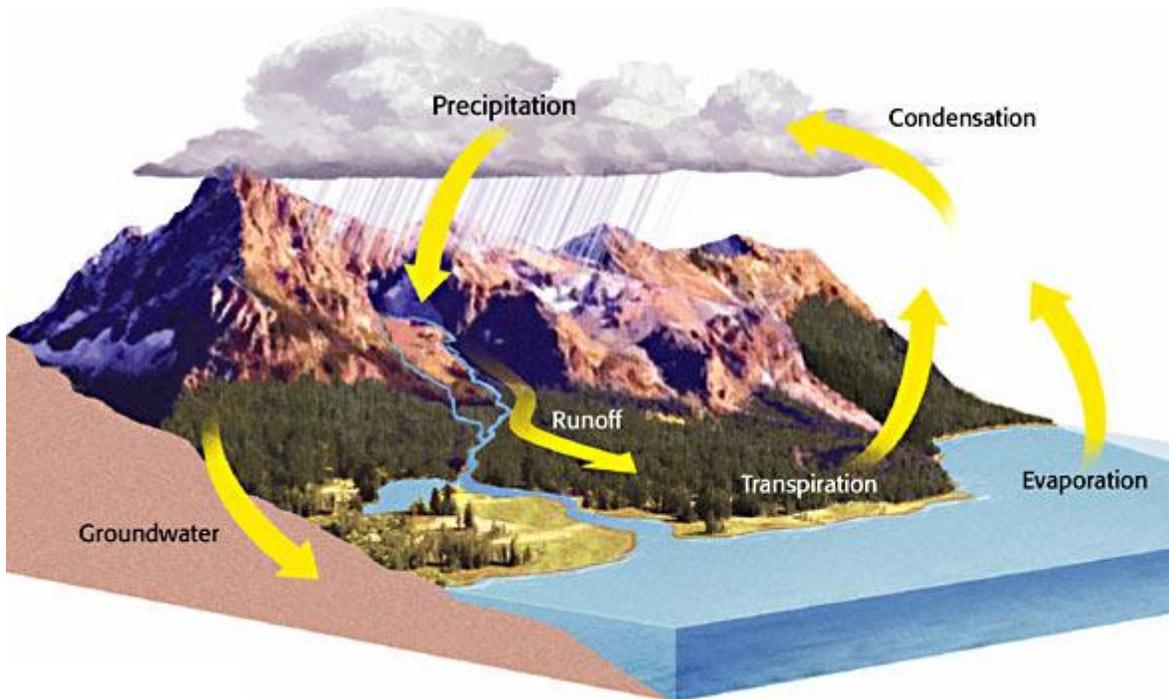


Figure 4 Water cycles from the ocean, into the air, onto land, and back into the ocean in the water cycle.

Steps of the Water Cycle

Evaporation is the process in which liquid water changes into gaseous water vapor. Water vapor is also released into the air through pores on the leaves of plants. This process is known as *transpiration*. If air that contains water vapor cools, the water vapor turns into liquid water droplets and forms clouds. The change from a gas to a liquid is called *condensation*. When water droplets become large enough, they fall back to Earth as *precipitation*, such as rain.

Pathways of the Water Cycle

Most precipitation falls directly into the ocean and never reaches the land surface. Precipitation that does reach the land surface may fill lakes, streams, and rivers and

eventually return to the ocean. Water moving over the land surface is called *runoff*. Gravity may move the water downward through spaces in rock or soil, where the water becomes groundwater.

Standards Check What is the major source of energy for the water cycle?

□

The Carbon Cycle

Carbon is an important element that cycles through the Earth system. Carbon is part of the proteins, fats, and carbohydrates in living things. But carbon is not only in living things. Carbon is also in the atmosphere, the water, the land, and the remains of living things. The cycling of carbon between Earth's spheres is called the **carbon cycle**, as shown in **Figure 5**.

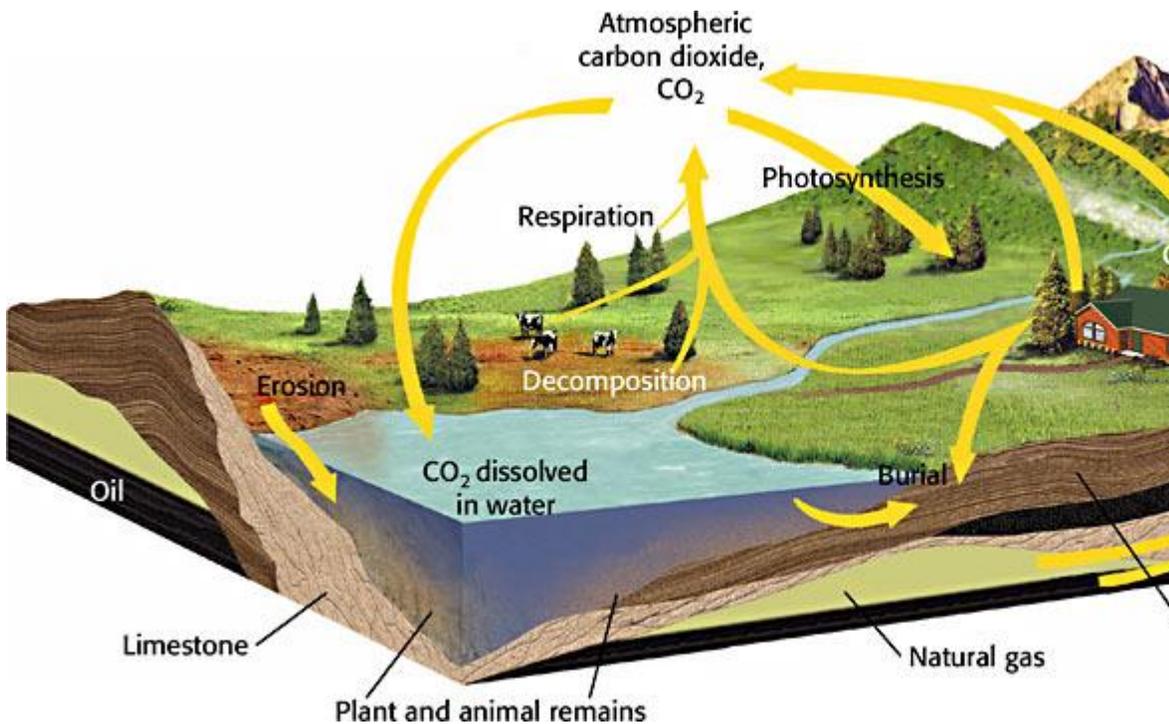


Figure 5 Carbon cycles through the Earth system in both rapid and slow processes.

Short-Term Processes

Parts of the carbon cycle are relatively rapid processes. To build plant material, plants use energy from the sun; from carbon dioxide, CO_2 ; and from water. When animals eat the plants, the energy in the plants is transferred to the animals. When the animals break down food to release energy, carbon is returned to the air as CO_2 . Then, the CO_2 is reused by plants. When a living thing dies, other organisms break down the remains. This process, called *decomposition*, releases the carbon from the dead organism back into the cycle.

Long-Term Processes

Other parts of the carbon cycle are much slower processes. In some cases, dead organisms are buried before they decompose. Their bodies chemically change as they are compacted for millions of years. This process forms rock, such as limestone, or fossil fuels, such as coal, gas, and oil. When humans burn these fuels, carbon returns to the atmosphere as carbon dioxide. This process of burning fuel is called *combustion*.

The Nitrogen Cycle

The circulation of nitrogen among Earth's spheres is called the [nitrogen cycle](#). This cycle is shown in **Figure 6**. Nitrogen is an important nutrient for all living things. Certain bacteria in soil change atmospheric nitrogen, N_2 , into forms of nitrogen that plants can use. Other organisms get the nitrogen that they need by eating plants. When organisms die, decomposers release nitrogen from the dead organisms back into the soil. Then, plants use some of this nitrogen. Some bacteria in soil change this nitrogen into atmospheric nitrogen, which returns to the air.

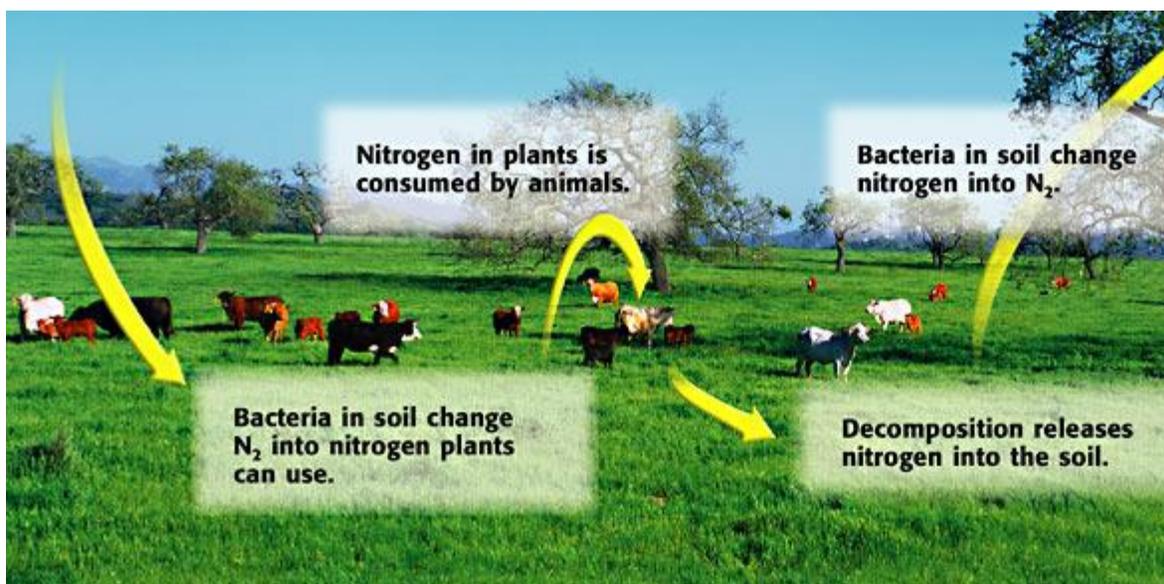


Figure 6 The nitrogen cycle includes bacteria, plants, and animals.

The Phosphorus Cycle

Like carbon and nitrogen, phosphorus is found in living things. Phosphorus is also found in soil, rock, and water. The roots of plants absorb phosphorus from the soil. Then, animals obtain phosphorus when they eat the plants. When the animals die, the phosphorus returns to the soil through decomposition.

Other Cycles in Nature

Other forms of matter on Earth also pass through cycles. Many of the minerals that living things need, such as the mineral calcium, are cycled through the environment. When a living thing dies, every substance in its body is recycled.

Each cycle is connected to other cycles in many ways. Some forms of nitrogen and

carbon are carried through the environment by water. Many nutrients pass from soil to plants to animals and back. Living things play an important part in each of the cycles and depend on the cycles for survival.

Standards Check How is matter passed from one living thing to another?



Section Summary

- The processes that cycle matter in the Earth system can be relatively rapid or may take millions of years.
 - The rock cycle is the series of processes in which rock changes from one form to another by geologic processes.
 - The three major classes of rocks are sedimentary, igneous, and metamorphic.
 - Water moves continuously from the ocean, to the atmosphere, to land, and back to the ocean through the water cycle.
 - In the carbon cycle, carbon is cycled in both rapid processes and slow processes.
 - Types of matter that are cycled through the Earth system include carbon, phosphorus, and nitrogen.
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Chapter Summary

The Big Idea

Many phenomena on Earth's surface are affected by the transfer of energy through Earth's systems.

Section 1 The Earth System

Key Concept Earth is a complex system made up of many smaller systems through which matter and energy are continuously cycled.

- Energy and matter flow through Earth's four spheres: the geosphere, atmosphere, hydrosphere, and biosphere.
- Energy flows through the atmosphere and hydrosphere mostly by convection.



The global ocean covers 71% of Earth's surface.

Section 2 Heat and Energy

Key Concept Heat flows in a predictable way from warmer objects to cooler objects until all of the objects are at the same temperature.

- Temperature is a measure of the average kinetic energy of particles in an object.
- Heat is energy that is transferred between objects.

- Heat flows by conduction, convection, and radiation.



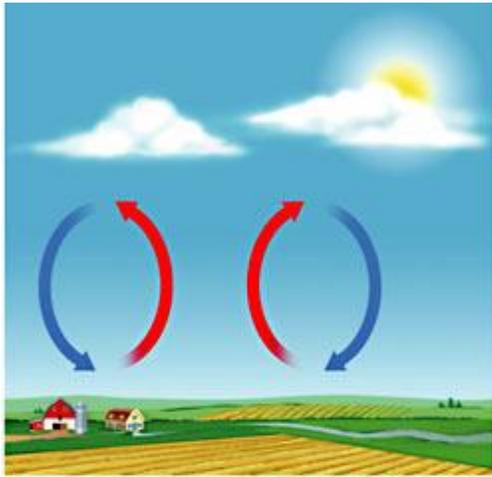
Convection currents transfer heat through a fluid.

Section 3

The Cycling of Energy

Key Concept Various heat-exchange systems work in the Earth system and affect phenomena on Earth's surface.

- Heat flow is the transfer of energy from a warmer object to a cooler object.
- Energy from the sun, the major source of energy for phenomena on Earth's surface, is transmitted to Earth by radiation.
- Heat from Earth's interior reaches the surface mostly by convection.



Heat is transferred in the atmosphere by convection.

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Sandstone is an example of a sedimentary rock.

