by flowing over the surface as run-off or under it as groundwater. When the water returns to the oceans, one turn of the water cycle is complete. The water cycle is driven by the energy of the Sun. All Earth's water, whether fresh or salt, has moved through this water cycle millions of times, over millions of years. Water is never created or destroyed, only changed.

The Carbon Cycle

In a biogeochemical cycle, a chemical element or compound is changed as it moves through the Earth system. The **carbon cycle** is a biogeochemical cycle involving the element carbon (C). Carbon has been called the building block of life. It is present in all organic material and in materials (such as coal and oil) that are derived from organisms that once lived. You may think of carbon as primarily a solid, but it can also be a component of certain gases, such as methane (CH_4) and carbon dioxide (CO_2).

Carbon enters the atmosphere in several different ways as carbon dioxide. Living things, such as animals, breathe it out. Organisms that break down decaying organic matter give off CO_2. When carbon-based materials burn—for example, when trees are consumed in a forest fire—they release CO_2 into the atmosphere. Volcanic eruptions release CO_2 from inside the Earth. Carbon dioxide diffuses out of the ocean waters in which it is dissolved.

Carbon is also removed from the atmosphere. Plants remove carbon dioxide from the atmosphere during photosynthesis and convert it into complex chemical compounds such as glucose (sugar). In doing so, they produce oxygen (O_2) and release it into the environment. The carbon is stored in the plants' tissues as carbohydrates and is passed on to animals that eat the plants.

Phytoplankton also plays an important part in the carbon cycle. Like land plants, these tiny oceanic organisms conduct photosynthesis. During photosynthesis, they take in carbon in the form of carbon dioxide and then release oxygen, which diffuses out of the water. Most phytoplankton is eaten by marine animals. However, a small percentage of dead phytoplankton settles on the floor of large bodies of water. As these organisms become part of the sediment, the carbon within them is stored. A place that stores carbon, such as an ocean, is called a **carbon sink**.

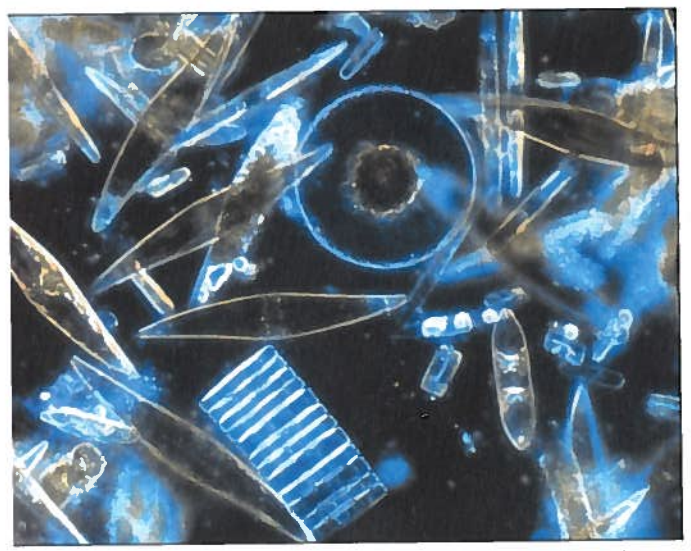

Figure 1.5.8 Phytoplankton. Why is protecting the phytoplankton population important to all life on Earth?

The action of the ocean waves dissolves carbon dioxide in seawater. There, it is converted into bicarbonate and carbonate compounds, such as calcium carbonate (or lime), the major component of seashells. Through wave action and through photosynthesis by phytoplankton, the ocean removes about 40 percent of the carbon that is released into the atmosphere by the burning of fossil fuels.

Once removed from the atmosphere, carbon can be stored for long periods of time. In some cases, it is stored only for the lifespan of the plant or animal whose tissues contain it. When this plant or animal dies,

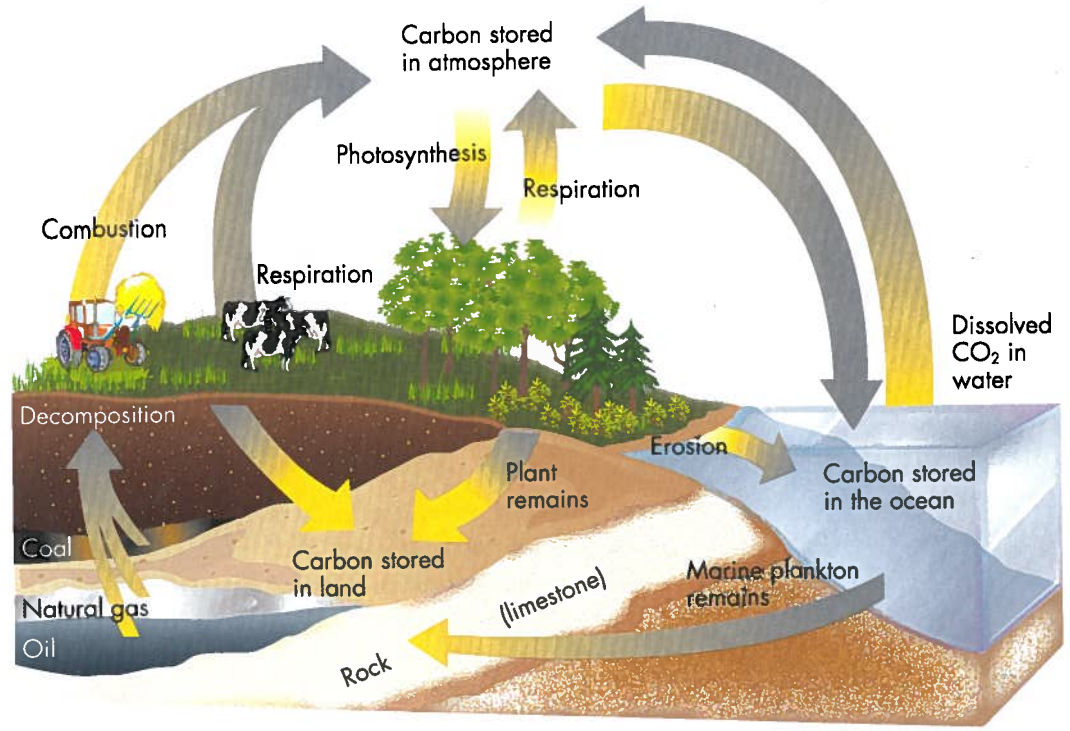

Figure 1.5.9 The carbon cycle. What happens within the carbon cycle if there are significant increases in combustion activities, or if large numbers of trees are cut down?

its tissues are decomposed by bacteria. The decomposition process changes the carbon compounds in the tissues into carbon dioxide and methane.

Some parts of the carbon cycle do not take long: organisms live, die, and decay in a short period of time. Other parts of the cycle take longer, such as the formation of fossil fuels. If a plant or animal dies and is engulfed by a low-oxygen environment, such as a marshland, the carbon in its tissues can change into fossil fuels such as coal and oil. When burned, these fossil fuels release the stored carbon back into the atmosphere. Carbon, like water, is never destroyed; it only changes from one form into another.

The Nitrogen Cycle

Nitrogen is both the most abundant element in the atmosphere and, as a building block of proteins and nucleic acids such as DNA, a crucially important component of all biological life. The **nitrogen cycle** is a complex biogeochemical cycle in which nitrogen is converted from its inert atmospheric form (N_2) into a form that is useful in biological processes. There are five steps in the nitrogen cycle, whereby nitrogen gas is converted into compounds that plants can use.

1. The nitrogen cycle starts with nitrogen fixation, a process that converts atmospheric nitrogen (N_2) into ammonia (NH_3). This conversion is done mostly by nitrogen-fixing bacteria such as cynobacteria and rhizobia. Ammonia is also found in organic nitrogen contained in plant and animal tissue. The most important pathway for plants to acquire nitrogen is through the cycling of organic nitrogen from dead plant matter into