

Lesson Overview

3.4 Cycles of Matter

THINK ABOUT IT

A handful of elements combine to form the building blocks of all known organisms.

Organisms cannot manufacture these elements and do not “use them up,” so where do essential elements come from?

How does their availability affect ecosystems?

Recycling in the Biosphere



How does matter move through the biosphere?

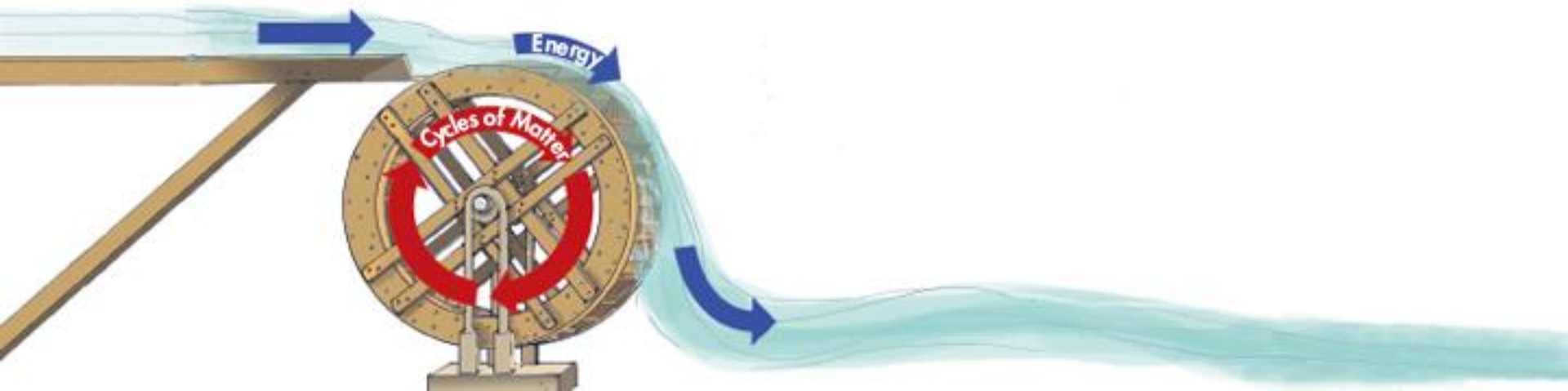


Unlike the one-way flow of energy, matter is recycled within and between ecosystems.

Recycling in the Biosphere

Unlike the one-way flow of energy, matter is recycled within and between ecosystems.

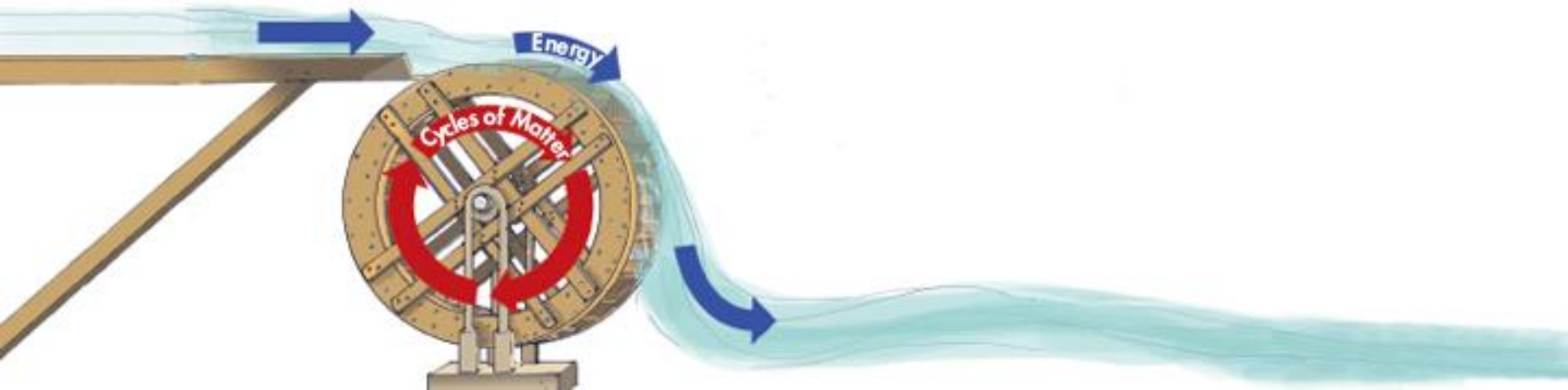
Elements pass from one organism to another and among parts of the biosphere through closed loops called **biogeochemical cycles**, which are powered by the flow of energy.



Recycling in the Biosphere

Biogeochemical cycles of matter involve *biological* processes, *geological* processes, and *chemical* processes.

As matter moves through these cycles, it is never created or destroyed—just changed.



Biological Processes

Biological processes consist of any and all activities performed by living organisms.

These processes include eating, breathing, “burning” food, and eliminating waste products.

Geological Processes

Geological processes include volcanic eruptions, the formation and breakdown of rock, and major movements of matter within and below the surface of the earth.

Chemical and Physical Processes

Chemical and physical processes include the formation of clouds and precipitation, the flow of running water, and the action of lightning.

Human Activity

Human activities that affect cycles of matter on a global scale include the mining and burning of fossil fuels, the clearing of land for building and farming, the burning of forests, and the manufacture and use of fertilizers.

Recycling in the Biosphere

Biogeochemical cycles of matter pass the same atoms and molecules around again and again.

The Water Cycle



How does water cycle through the biosphere?

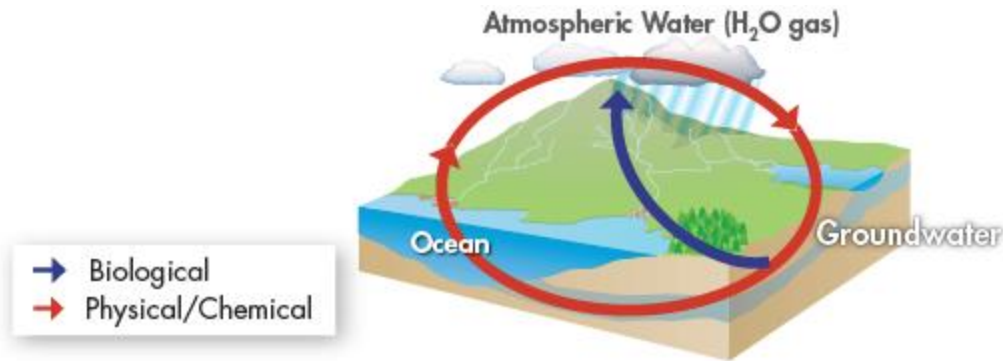


Water continuously moves between the oceans, the atmosphere, and land—sometimes outside living organisms and sometimes inside them.

The Water Cycle

Water molecules typically enter the atmosphere as water vapor when they evaporate from the ocean or other bodies of water.

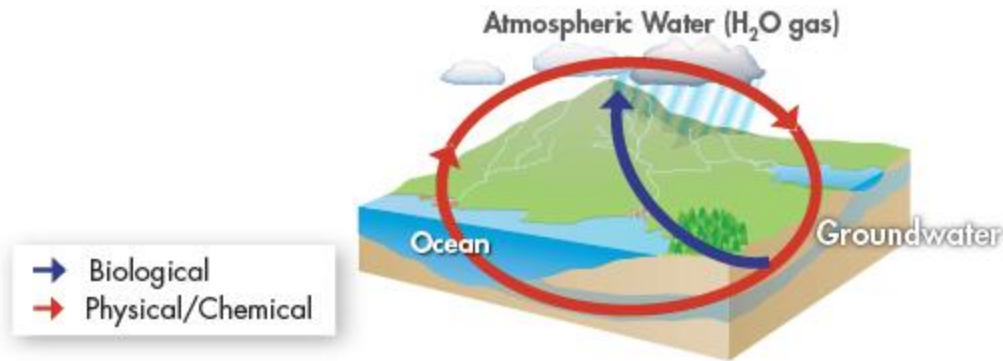
Water can also enter the atmosphere by evaporating from the leaves of plants in the process of transpiration.



The Water Cycle

If the air carrying it cools, water vapor condenses into tiny droplets that form clouds.

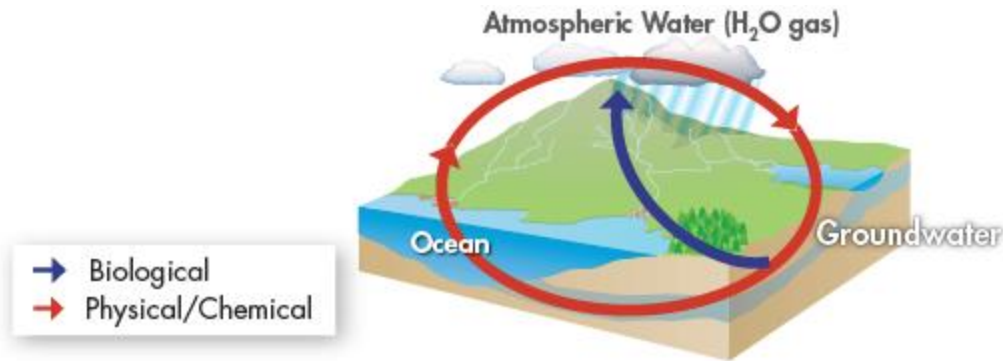
When the droplets become large enough, they fall to Earth's surface as precipitation in the form of rain, snow, sleet, or hail.



The Water Cycle

On land, some precipitation flows along the surface in what scientists call runoff, until it enters a river or stream that carries it to an ocean or lake.

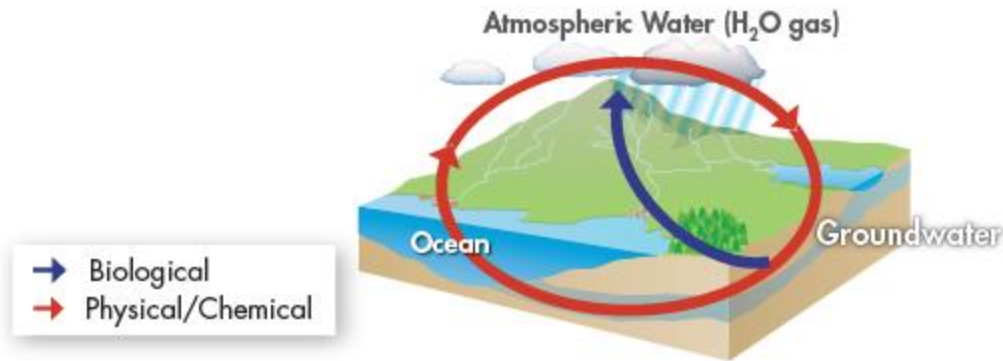
Precipitation can also be absorbed into the soil, and is then called groundwater.



The Water Cycle

Groundwater can enter plants through their roots, or flow into rivers, streams, lakes, or oceans.

Some groundwater penetrates deeply enough into the ground to become part of underground reservoirs.



Nutrient Cycles



What is the importance of the main nutrient cycles?



Every organism needs nutrients to build tissues and carry out life functions. Like water, nutrients pass through organisms and the environment through biogeochemical cycles.



The three pathways, or cycles, that move carbon, nitrogen, and phosphorus through the biosphere are especially critical for life

Nutrient Cycles

The chemical substances that an organism needs to sustain life are called **nutrients**.

Every organism needs nutrients to build tissues and carry out life functions.

Nutrients pass through organisms and the environment through biogeochemical cycles.

Nutrient Cycles

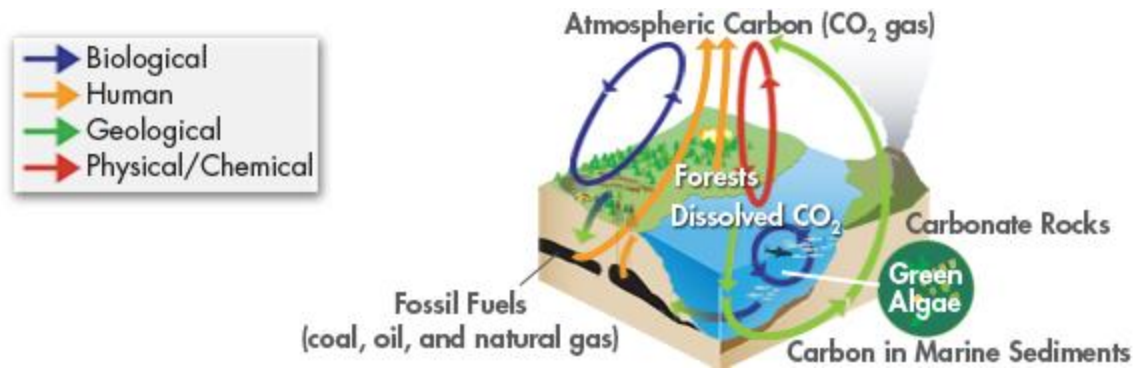
Oxygen participates in parts of the carbon, nitrogen, and phosphorus cycles by combining with these elements and cycling with them through parts of their journeys.

Oxygen gas in the atmosphere is released by one of the most important of all biological activities: photosynthesis.

Oxygen is used in respiration by all multicellular forms of life, and many single-celled organisms as well.

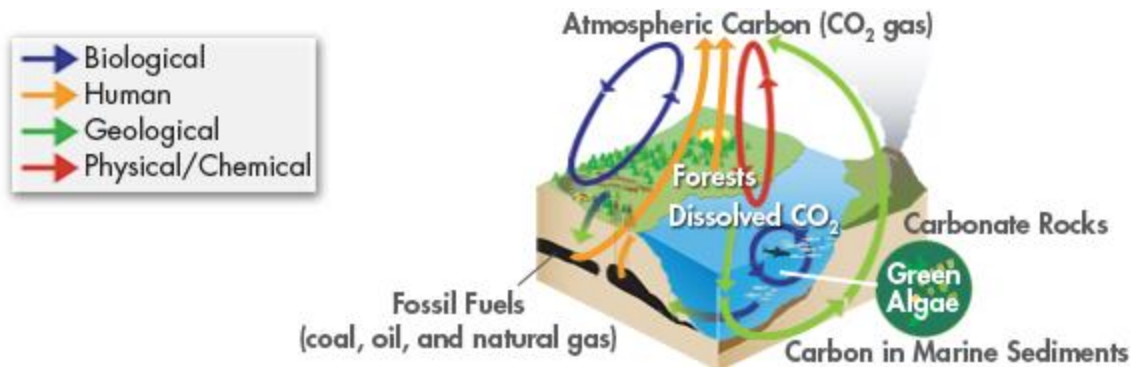
The Carbon Cycle

Carbon is a major component of all organic compounds, including carbohydrates, lipids, proteins, and nucleic acids.



The Carbon Cycle

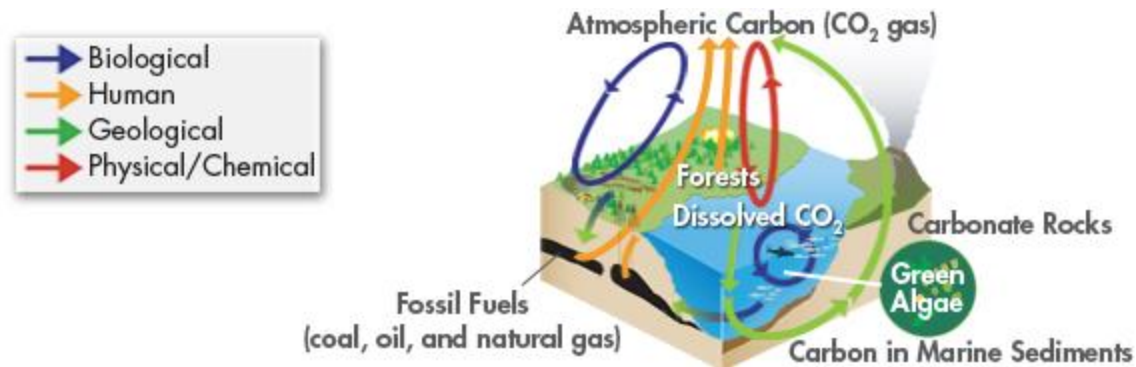
Carbon dioxide is continually exchanged through chemical and physical processes between the atmosphere and oceans.



The Carbon Cycle

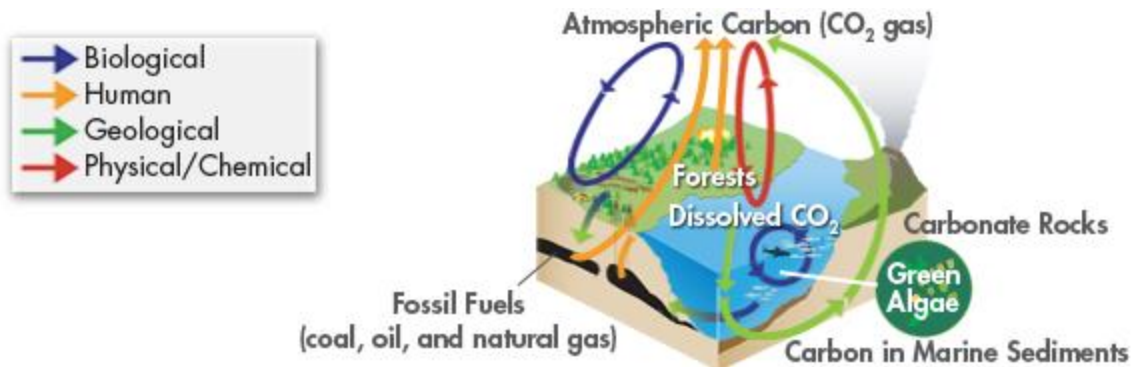
Plants take in carbon dioxide during photosynthesis and use the carbon to build carbohydrates.

Carbohydrates then pass through food webs to consumers.



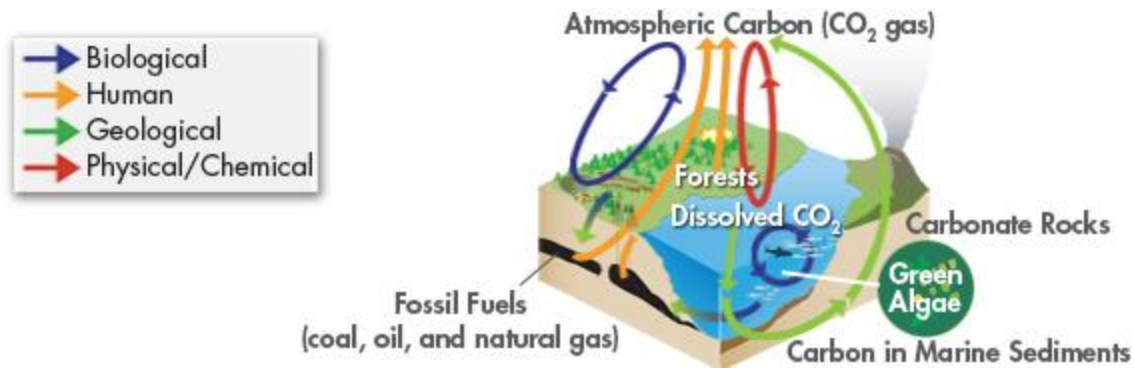
The Carbon Cycle

Organisms release carbon in the form of carbon dioxide gas by respiration.



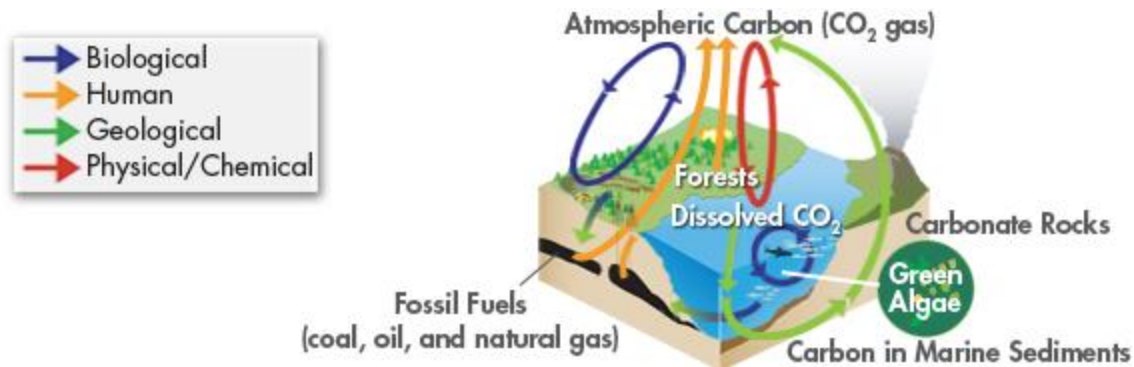
The Carbon Cycle

When organisms die, decomposers break down the bodies, releasing carbon to the environment.



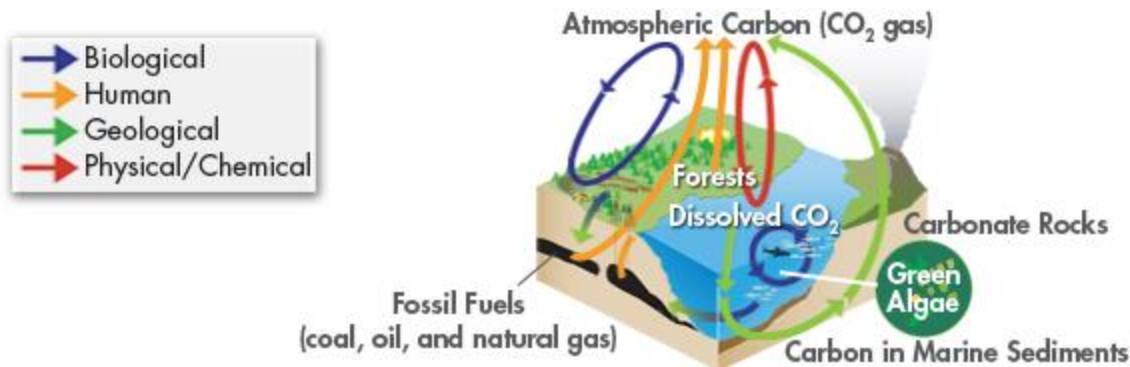
The Carbon Cycle

Geologic forces can turn accumulated carbon into carbon-containing rocks or fossil fuels.



The Carbon Cycle

Carbon dioxide is released into the atmosphere by volcanic activity or by human activities, such as the burning of fossil fuels and the clearing and burning of forests.

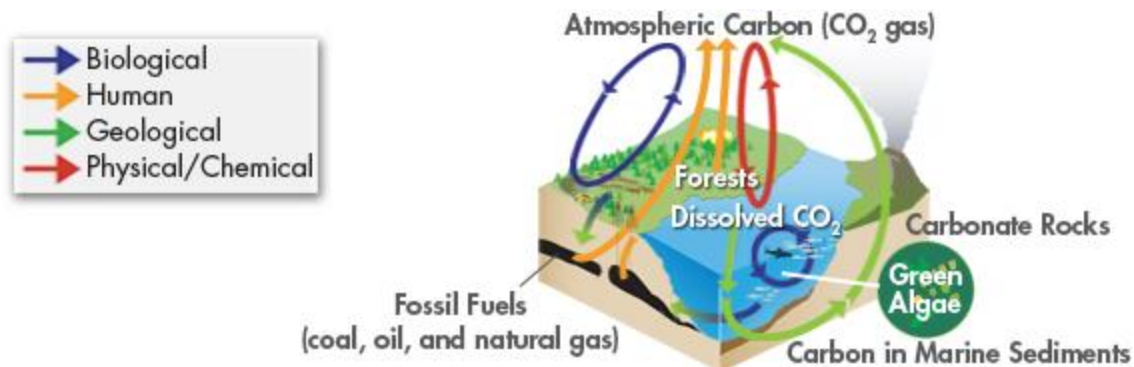


The Carbon Cycle

Important questions remain about the carbon cycle.

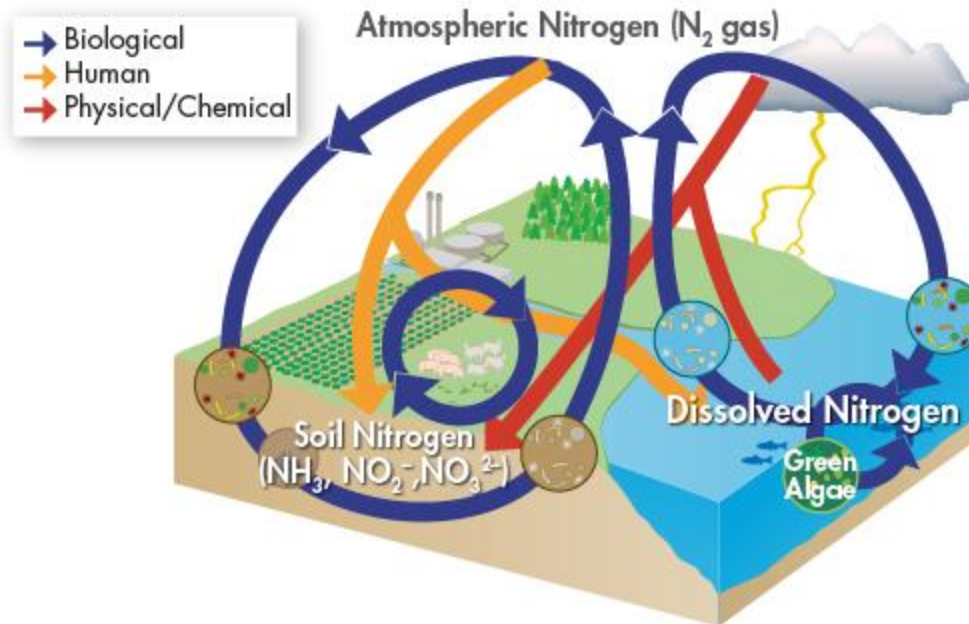
How much carbon moves through each pathway?

How do ecosystems respond to changes in atmospheric carbon dioxide concentration?



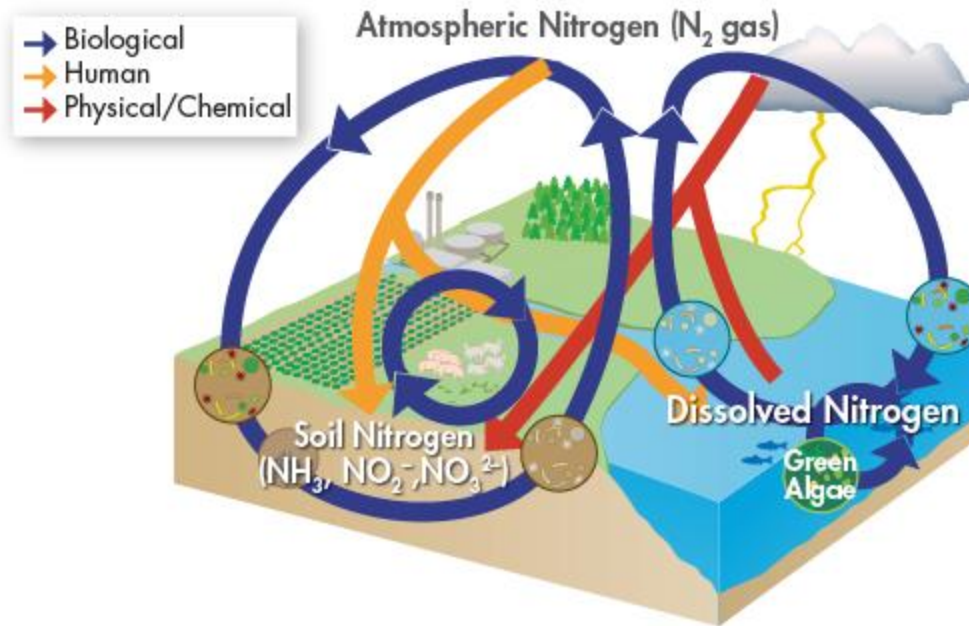
The Nitrogen Cycle

All organisms require nitrogen to make amino acids, which are used to build proteins and nucleic acids, which combine to form DNA and RNA.



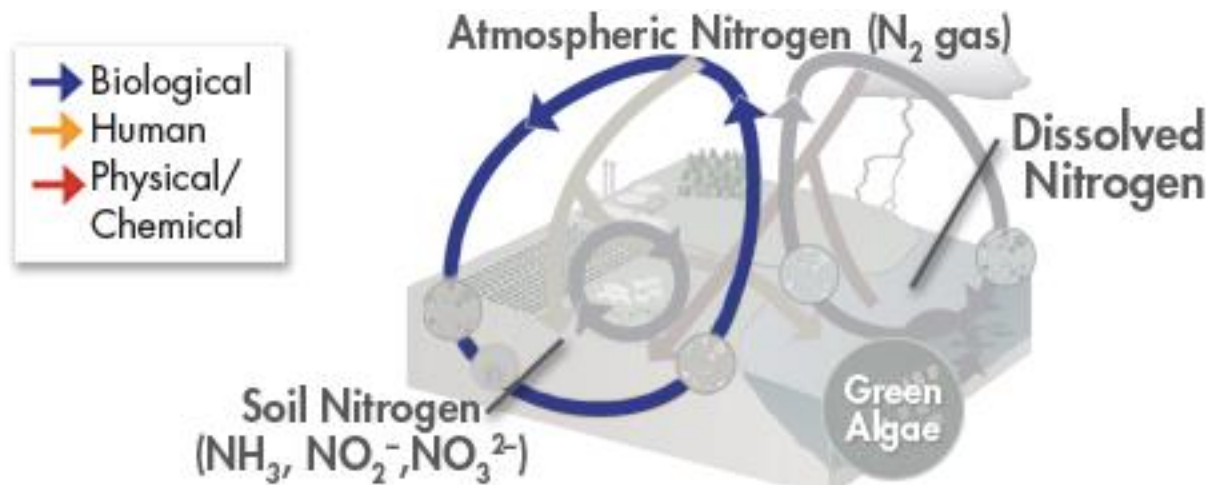
The Nitrogen Cycle

Nitrogen gas (N_2) makes up 78 percent of Earth's atmosphere.



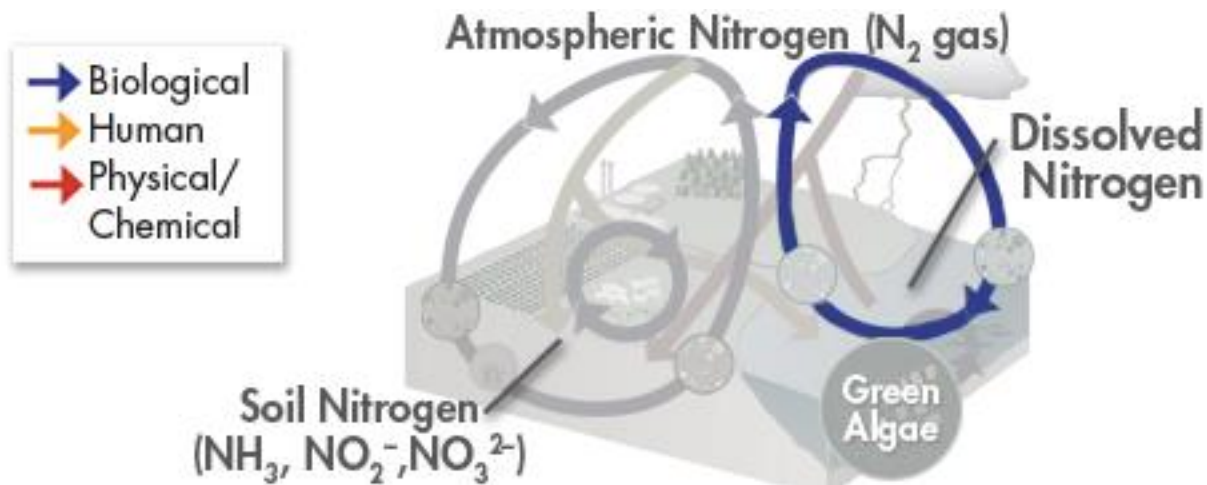
The Nitrogen Cycle

Nitrogen-containing substances such as ammonia (NH_3), nitrate ions (NO_3^-), and nitrite ions (NO_2^-) are found in soil, in the wastes produced by many organisms, and in dead and decaying organic matter.



The Nitrogen Cycle

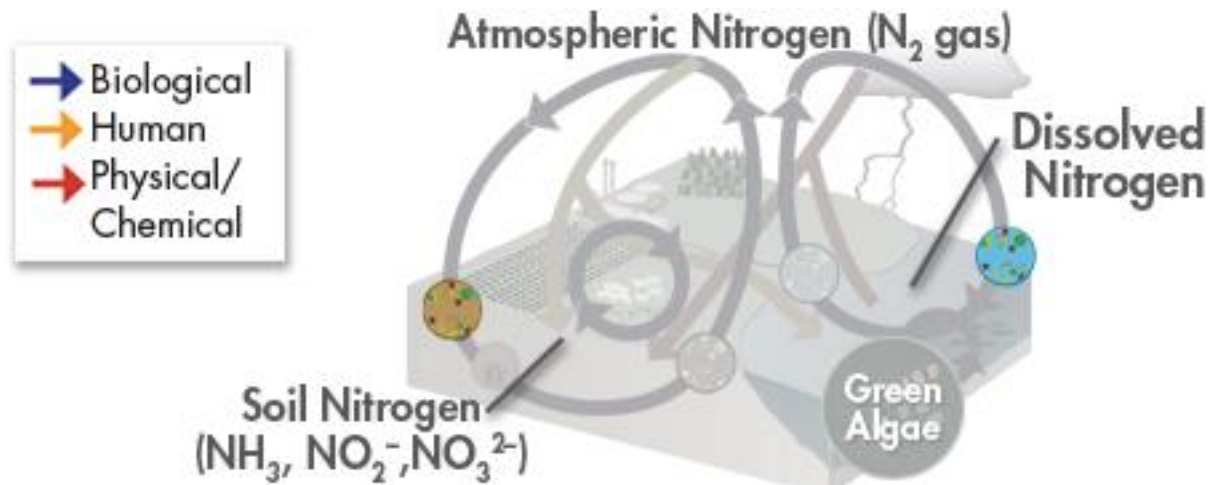
Dissolved nitrogen exists in several forms in the ocean and other large water bodies.



The Nitrogen Cycle

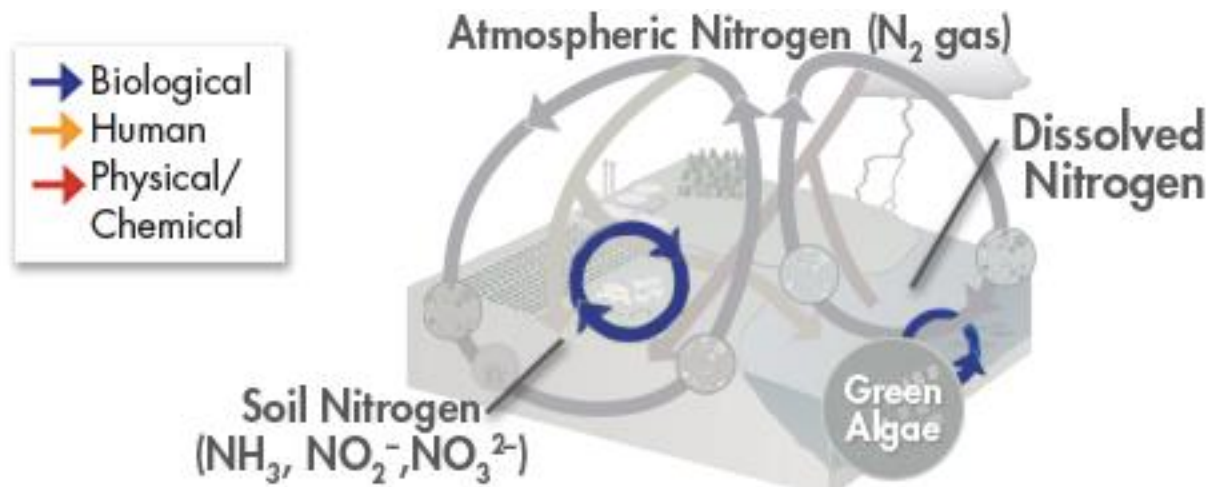
Although nitrogen gas is the most abundant form of nitrogen on Earth, only certain types of bacteria that live in the soil and on the roots of legumes can use this form directly.

The bacteria convert nitrogen gas into ammonia, in a process known as **nitrogen fixation**.



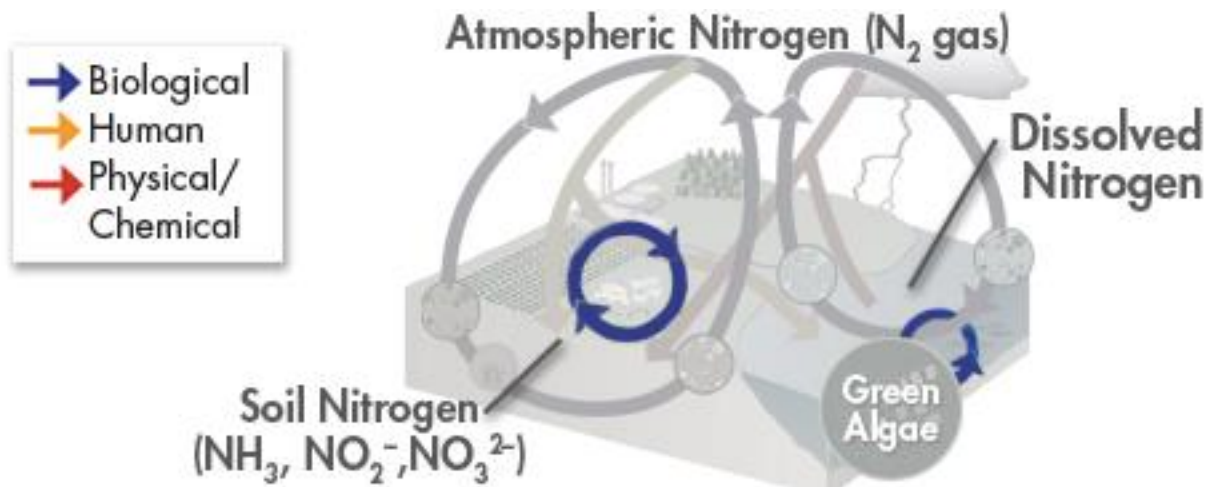
The Nitrogen Cycle

Other soil bacteria convert fixed nitrogen into nitrates and nitrites that primary producers can use to make proteins and nucleic acids.



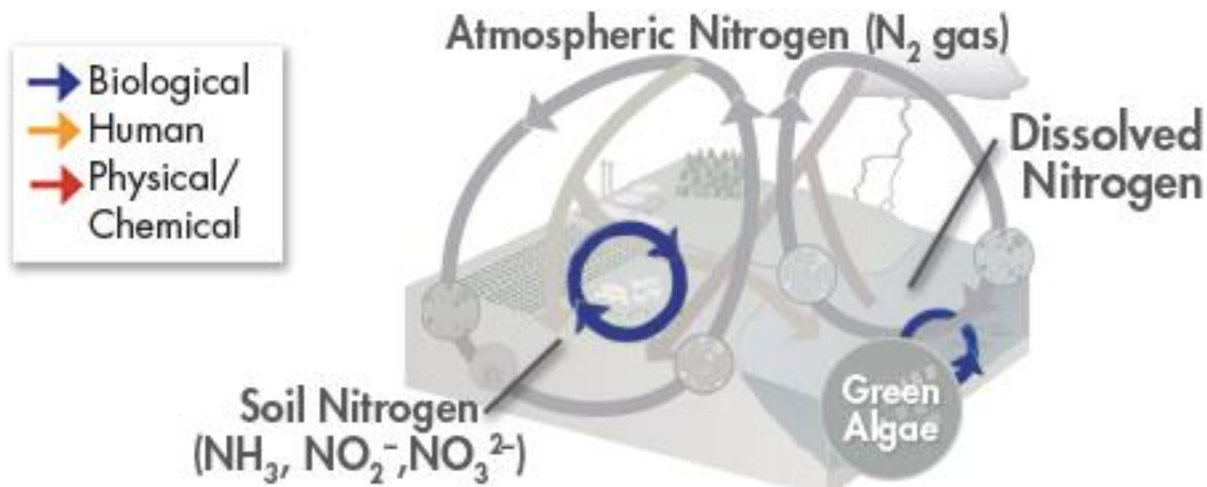
The Nitrogen Cycle

Consumers eat the producers and reuse nitrogen to make their own nitrogen-containing compounds.



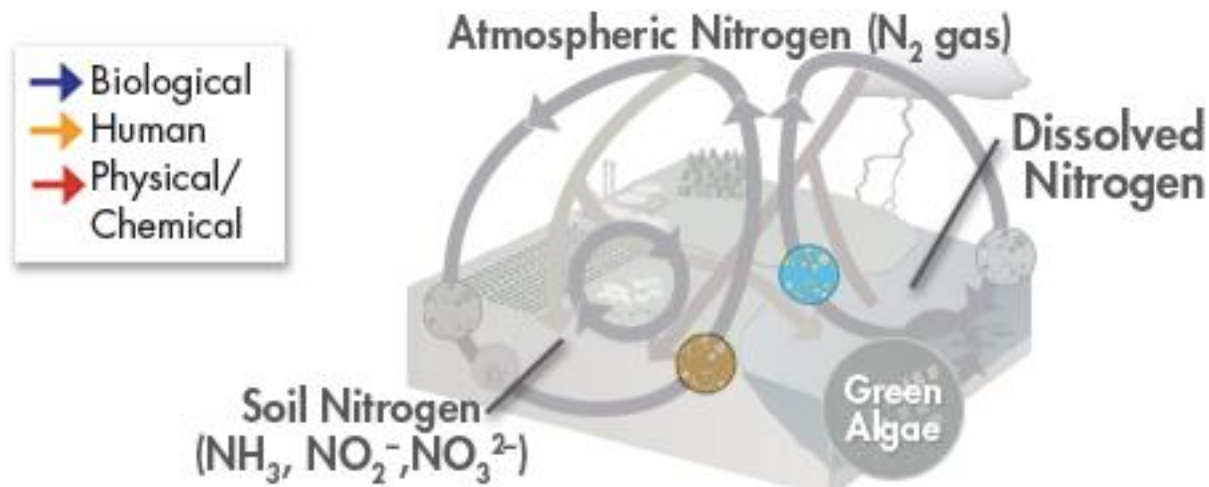
The Nitrogen Cycle

Decomposers release nitrogen from waste and dead organisms as ammonia, nitrates, and nitrites that producers may take up again.



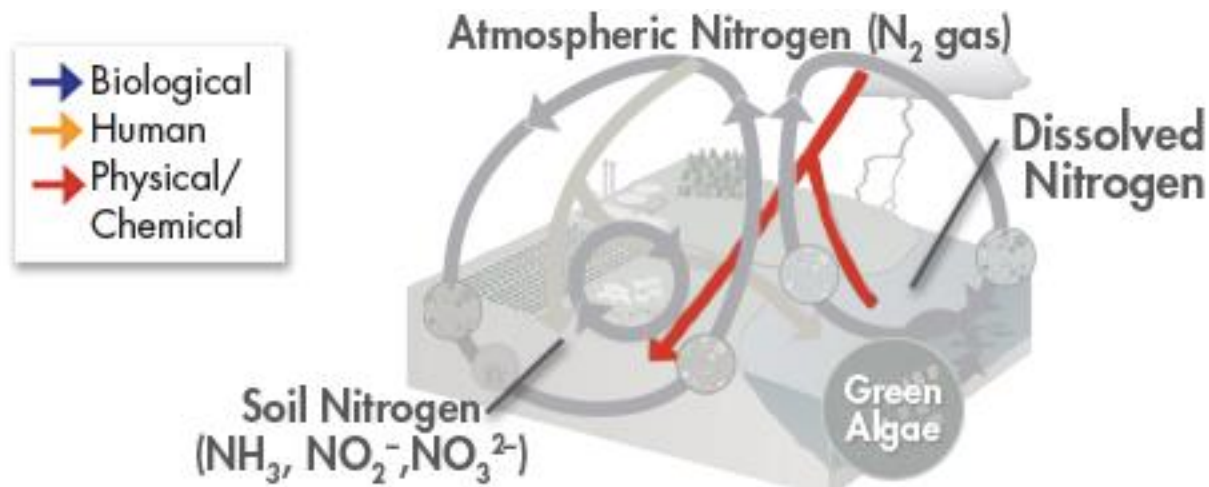
The Nitrogen Cycle

Other soil bacteria obtain energy by converting nitrates into nitrogen gas, which is released into the atmosphere in a process called **denitrification**.



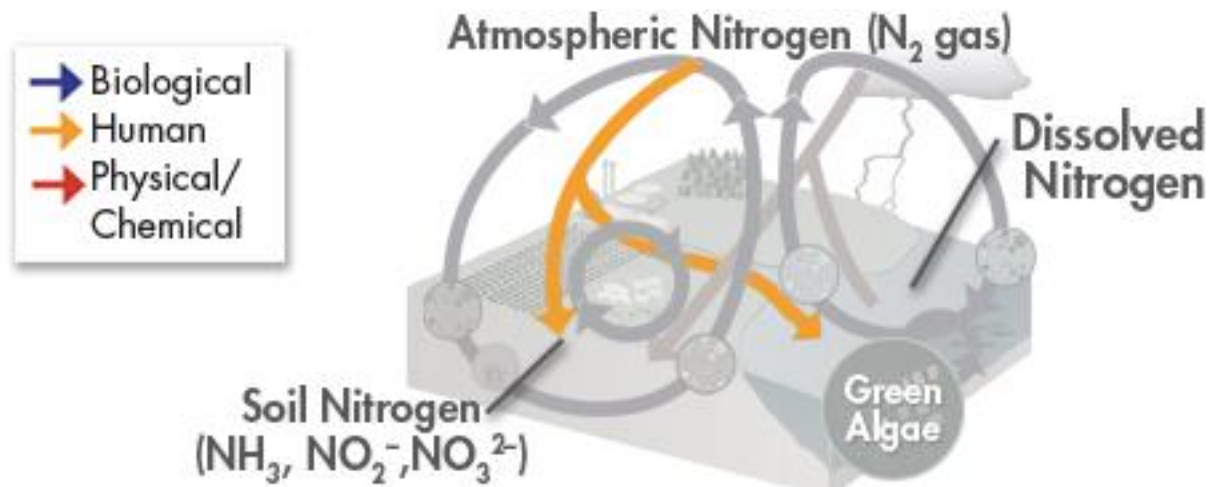
The Nitrogen Cycle

A small amount of nitrogen gas is converted to usable forms by lightning in a process called atmospheric nitrogen fixation.



The Nitrogen Cycle

Humans add nitrogen to the biosphere through the manufacture and use of fertilizers. Excess fertilizer is often carried into surface water or groundwater by precipitation.



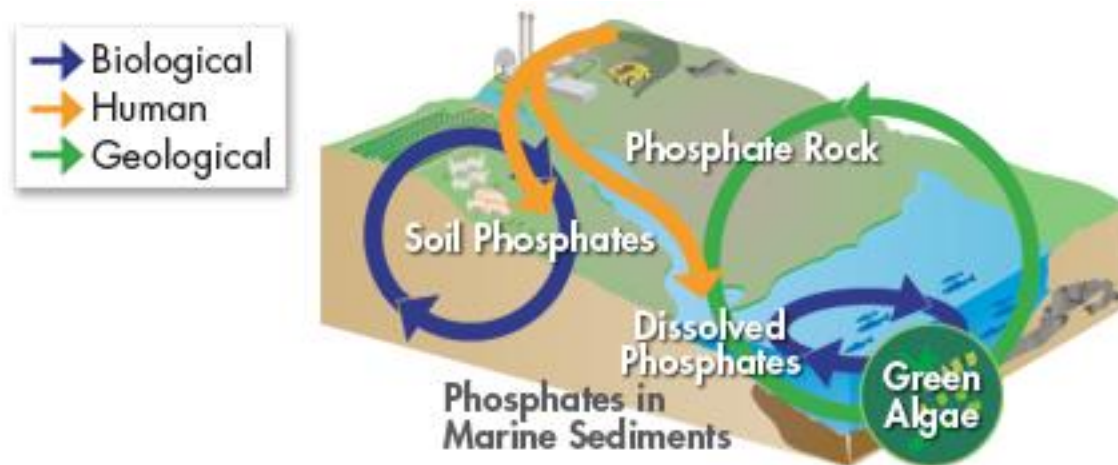
The Phosphorus Cycle

Phosphorus forms a part of vital molecules such as DNA and RNA.

Although phosphorus is of great biological importance, it is not abundant in the biosphere.

The Phosphorus Cycle

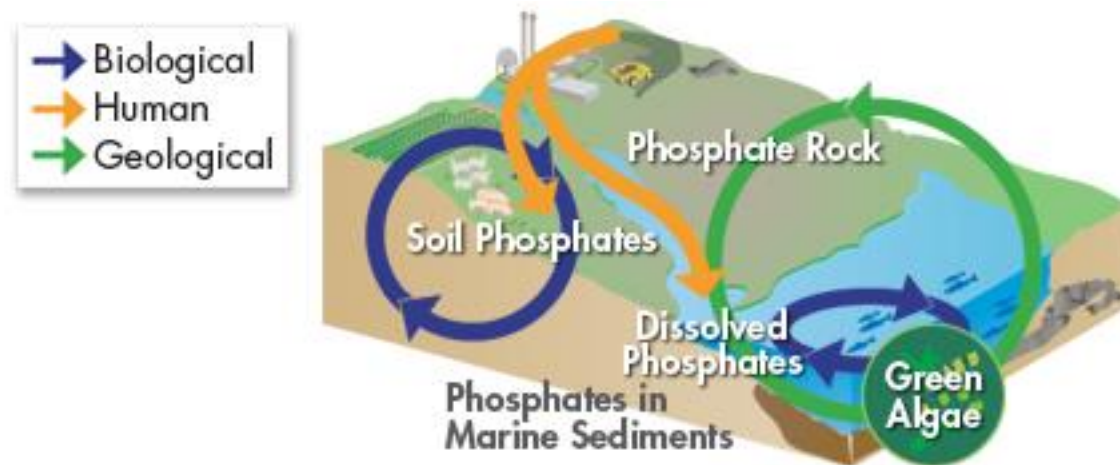
Phosphorus in the form of inorganic phosphate remains mostly on land, in the form of phosphate rock and soil minerals, and in the ocean, as dissolved phosphate and phosphate sediments.



The Phosphorus Cycle

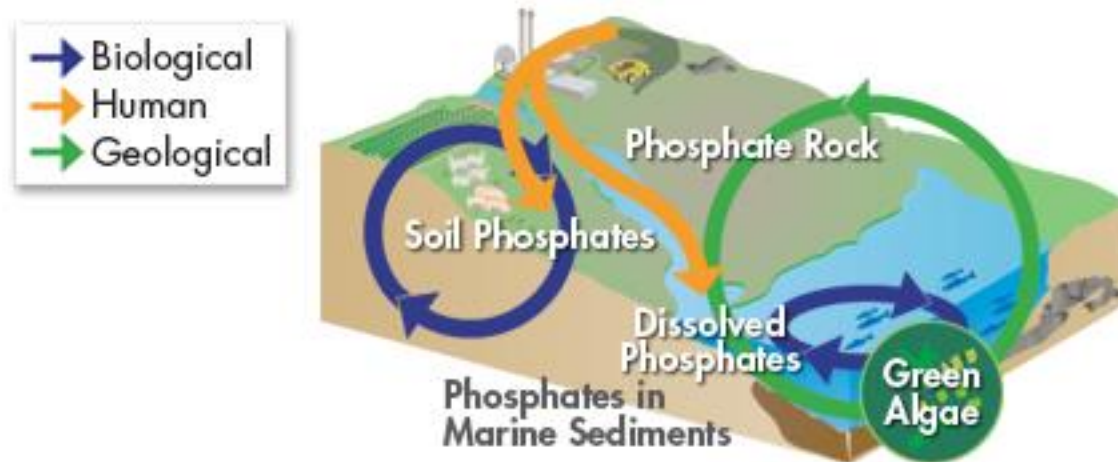
As rocks and sediments wear down, phosphate is released.

Some phosphate stays on land and cycles between organisms and soil.



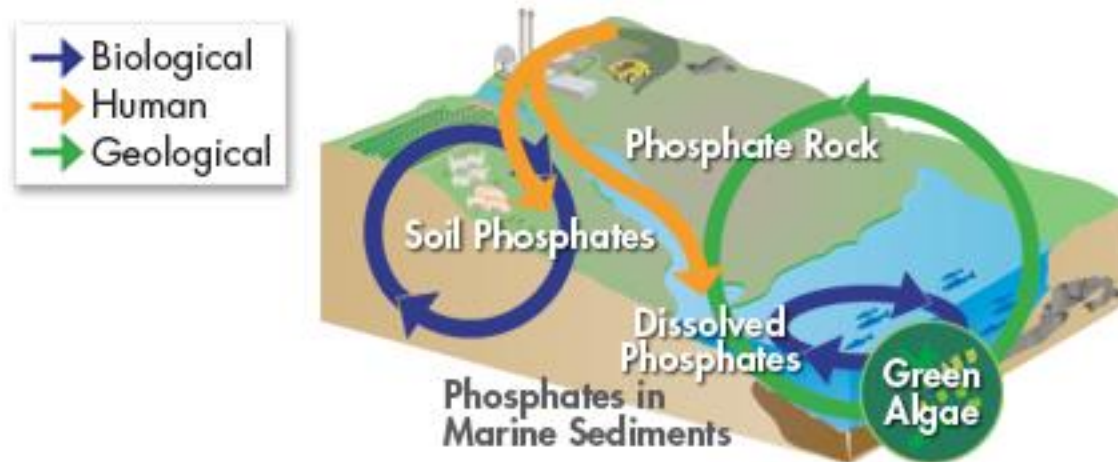
The Phosphorus Cycle

Plants bind phosphate into organic compounds when they absorb it from soil or water.



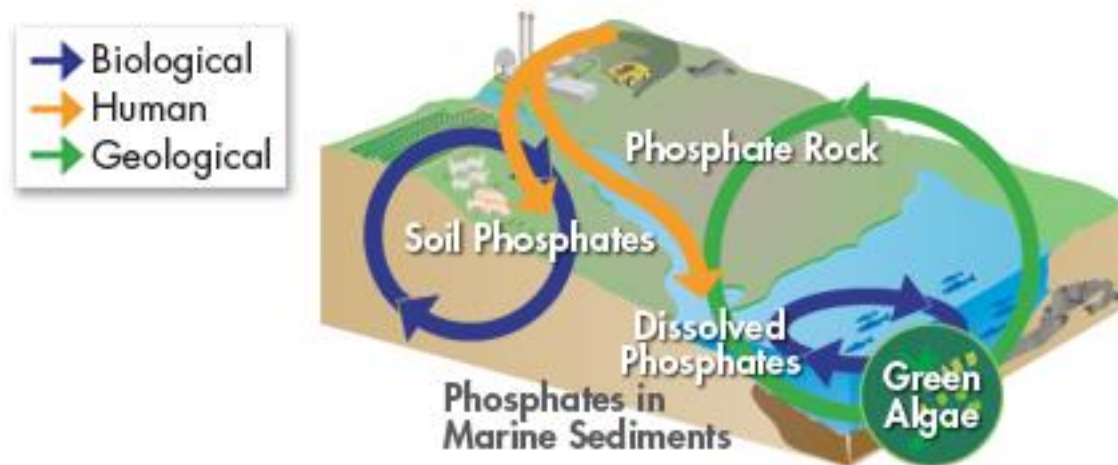
The Phosphorus Cycle

Organic phosphate moves through the food web, from producers to consumers, and to the rest of the ecosystem.



The Phosphorus Cycle

Other phosphate washes into rivers and streams, where it dissolves. This phosphate eventually makes its way to the ocean, where marine organisms process and incorporate it into biological compounds.



Nutrient Limitation



How does nutrient availability relate to the primary productivity of an ecosystem?



If ample sunlight and water are available, the primary productivity of an ecosystem may be limited by the availability of nutrients.

Nutrient Limitation

Ecologists are often interested in an ecosystem's primary productivity—the rate at which primary producers create organic material.

If an essential nutrient is in short supply, primary productivity will be limited.

The nutrient whose supply limits productivity is called the **limiting nutrient**.

Nutrient Limitation in Soil

The growth of crop plants is typically limited by one or more nutrients that must be taken up by plants through their roots.

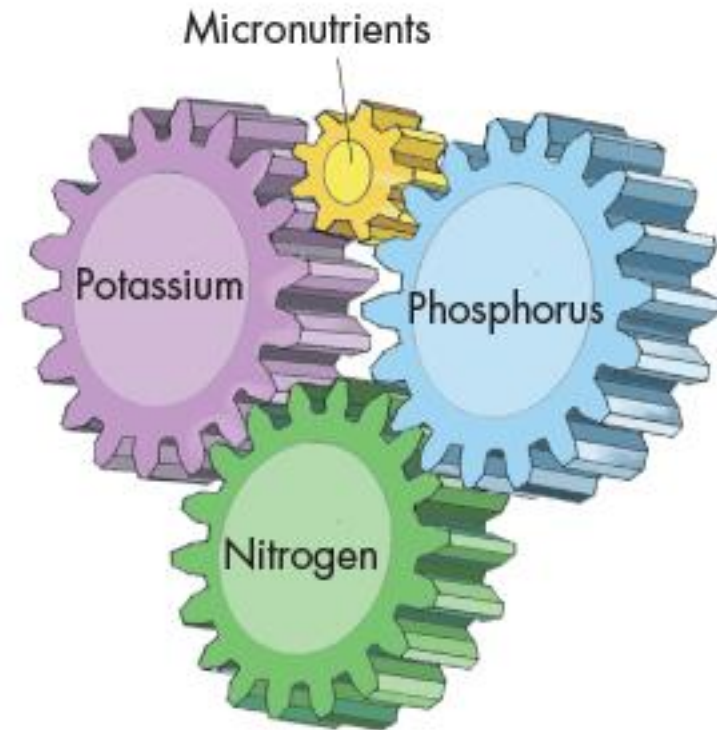
Most fertilizers contain large amounts of nitrogen, phosphorus, and potassium, which help plants grow better in poor soil. Carbon is not included in chemical fertilizers because plants acquire carbon dioxide from the atmosphere.

Micronutrients such as calcium, magnesium, sulfur, iron, and manganese are necessary in relatively small amounts, and are sometimes included in specialty fertilizers.

Nutrient Limitation in Soil

All nutrient cycles work together like the gears shown.

If any nutrient is in short supply—if any wheel “sticks”—the whole system slows down or stops altogether.



Nutrient Limitation in Aquatic Ecosystems

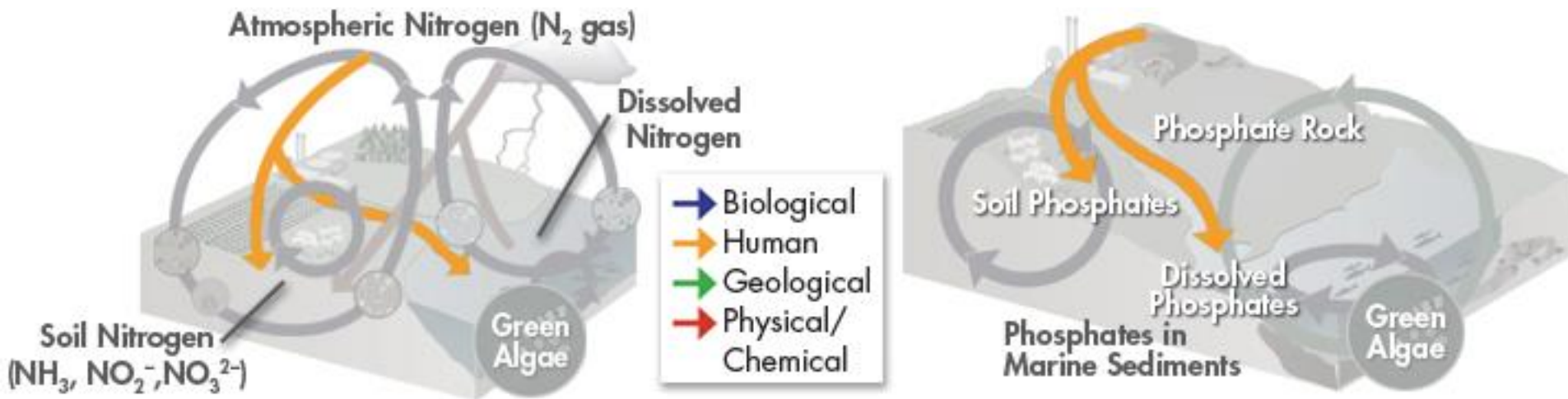
Oceans are nutrient-poor compared to many land areas.

In the ocean and other saltwater environments, nitrogen is often the limiting nutrient.

In streams, lakes, and freshwater environments, phosphorus is typically the limiting nutrient.

Nutrient Limitation in Aquatic Ecosystems

Sometimes an aquatic ecosystem receives a large input of a limiting nutrient—for example, runoff from heavily fertilized fields.



Nutrient Limitation in Aquatic Ecosystems

The result of this runoff can be an algal bloom—a dramatic increase in the amount of algae and other primary producers due to the increase in nutrients.

If there are not enough consumers to eat the algae, an algal bloom can cover the water's surface and disrupt the functioning of an ecosystem.

