46.4 Other Biogeochemical Cycles

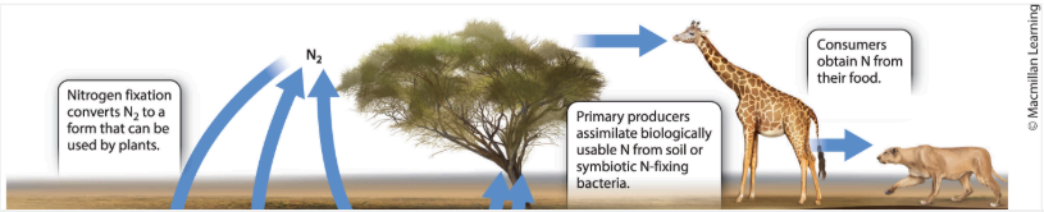
Until now, we have focused on carbon, and for good reason. Carbon atoms form the backbone of molecules in cells (other than water molecules), and carbon compounds such as fatty acids and sugars are the principal means through which energy is transferred from consumed to consumer. However, while carbon and energy dictate the biological structure of ecosystems, other nutrients, principally nitrogen (N) and phosphorus (P), determine how much carbon and energy move through ecosystems on land and in the sea. Because these elements commonly determine the rate of primary production within ecosystems, they are often termed **limiting nutrients**.

Proteins, nucleic acids, lipids, and other biological molecules contain nitrogen and phosphorus, so as organisms cycle carbon through ecosystems, they also cycle nitrogen, phosphorus, and other elements. The primary producers that fix CO_2 into carbohydrates also take up nitrogen and phosphorus from the environment and use those nutrients to synthesize amino acids, nucleic acids, and membranes. Consumers depend on primary producers not only for carbon and energy but also for nitrogen and phosphorus, which consumers need to synthesize their own organic molecules. Along the way in these biogeochemical cycles, metabolic wastes, including excess nitrogen and phosphorus, as well as carbon dioxide, are for nitrogen and phosphorus, which consumers need to synthesize their own organic molecules. Along the way in these biogeochemical cycles, metabolic wastes, including excess nitrogen and phosphorus, as well as carbon dioxide, are passed back to the environment through excretion and gas exchange.

In most ecosystems, nitrogen and phosphorus occur in limited supply, and this limits the amount of organic carbon that primary producers introduce into food webs and the amount of energy available to support trophic pyramids. For this reason, the long-term maintenance and functioning of ecosystems require that organisms actively cycle not only carbon but also nitrogen, phosphorus, and other elements critical for life.

The nitrogen cycle is closely linked to the carbon cycle.

Fig. 46.13 illustrates the same terrestrial ecosystem as shown in Fig. 46.12a but highlights the cycling of nitrogen. The primary producers, consumers, and decomposers linked in the carbon cycle also cycle nitrogen. Indeed, the biological carbon and nitrogen cycles are closely connected by both ecology and metabolism.



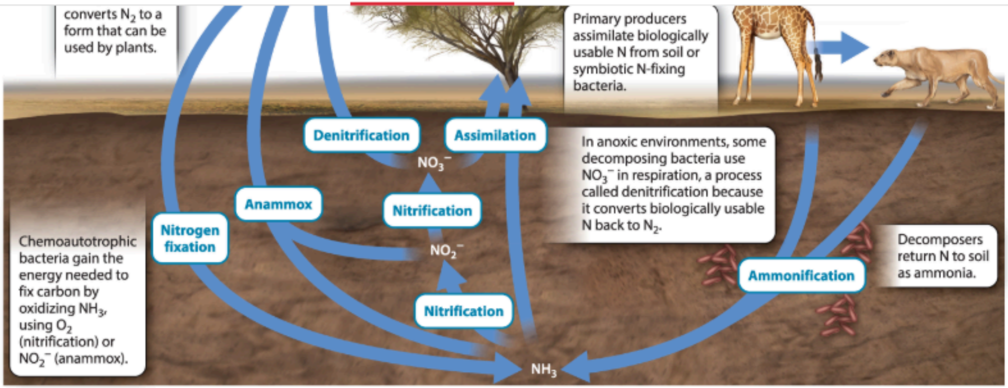


FIG. 46.13 The nitrogen cycle. The nitrogen cycle also links metabolism and ecology, governing the availability of nitrogen for primary producers and thereby exerting a strong influence on the biological carbon cycle.

Primary producers need nitrogen as well as carbon. While they fix into organic molecules by photosynthesis or chemosynthesis, primary producers generally obtain the nitrogen they require by taking up biologically usable nitrogen found as nitrate , ammonia , or ammonium ion in soil or water, a process called **assimilation**. Primary consumers obtain nitrogen from the primary producers they consume, just as they obtain carbon from these organisms. Through such consumption, both nitrogen and carbon travel across food webs. Decomposers return nitrogen to the environment as ammonia, a process termed **ammonification**.

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As shown in Fig. 46.13, a number of bacteria and archaea use nitrate or ammonia to generate energy, releasing nitrogen gas to the atmosphere. These processes include **denitrification** (a form of anaerobic respiration in which nitrate, rather than oxygen, serves as the terminal electron acceptor), **nitrification** (a chemoautotrophic process that uses energy gained from the oxidation of ammonia or nitrite, , by oxygen), and **anammox** (a form of chemoautotrophy, with energy gleaned from the reaction of ammonia and nitrite). Because of these processes, the amount of biologically usable nitrogen in communities would decline through time to very low levels were it not for **nitrogen fixation**, the process by which some bacteria and archaea reduce nitrogen gas to biologically usable ammonia (Chapter 24). Nitrogen fixation, then, is the process by which nitrogen enters food webs.

In the oceans, nitrogen cycling works much as outlined in the preceding paragraph: microorganisms fix , decomposers return biologically usable nitrogen compounds to the water, primary producers assimilate this nitrogen, and consumers cycle nitrogen even as they move carbon and energy through ecosystems. Eventually, as on land, microbes convert biologically usable nitrogen compounds back to .

The continual generation of biologically usable nitrogen compounds by nitrogen-fixing bacteria is fundamental not only to the nitrogen cycle but also to the carbon cycle, as it supplies critical nutrients for the primary producers at the base of an ecosystem's trophic pyramid and food web. As we discuss in Chapter 48, humans now fix a great deal of nitrogen through industrial processes, altering the balance

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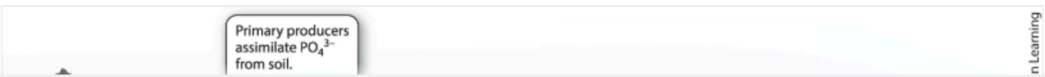
Phosphorus cycles through ecosystems, supporting primary production.

Like nitrogen, phosphorus is a key element needed for growth; this nutrient is incorporated into the nucleic acids and membranes found in all organisms as well as into ATP, the universal energy currency of life. The phosphorus cycle, however, is quite different from the nitrogen cycle. Whereas nitrogen is found largely in the atmosphere, phosphorus is mostly present in rocks. In addition, although nitrogen and phosphorus are both assimilated by primary producers, phosphorus does not provide electron donors or electron acceptors for energy metabolism. It simply enters the food web as phosphate ions (PO_4^{3-}) released from rocks by chemical weathering, is taken up — or assimilated — by primary producers, and then is transferred from one organism to another through cycles of consumption and decomposition, eventually returning to its geologic reservoir by accumulation in sediments (Fig. 46.14).



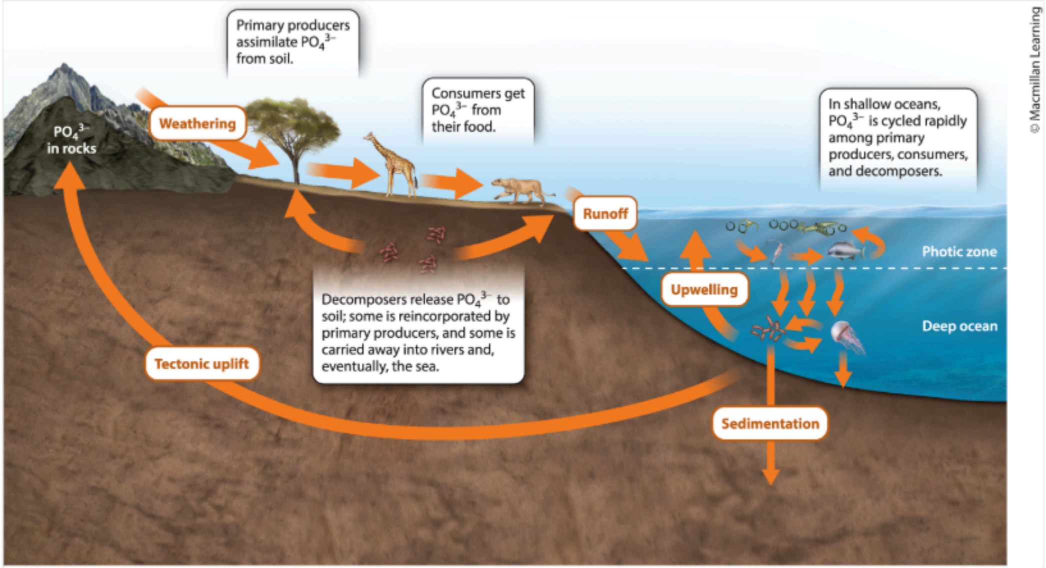
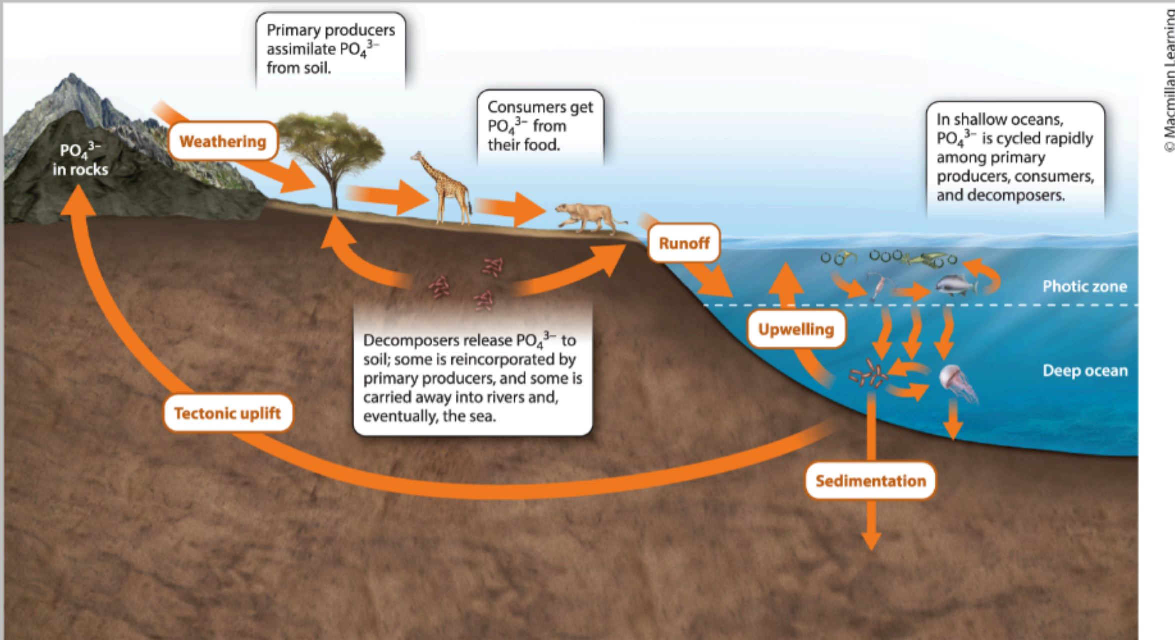


FIG. 46.14 The phosphorus cycle. Phosphorus, another key nutrient, is weathered from rocks and eventually returns to its geologic reservoir through deposition in sediments. Before it does, organisms repeatedly cycle phosphorus through ecosystems.

In the long term, phosphorus-containing sediments will be uplifted by tectonic processes to form mountains, making the phosphorus available again for release by chemical weathering. As is the case for nitrogen, humans have greatly accelerated phosphorus cycling through the mining of phosphate ores for fertilizer (Chapter



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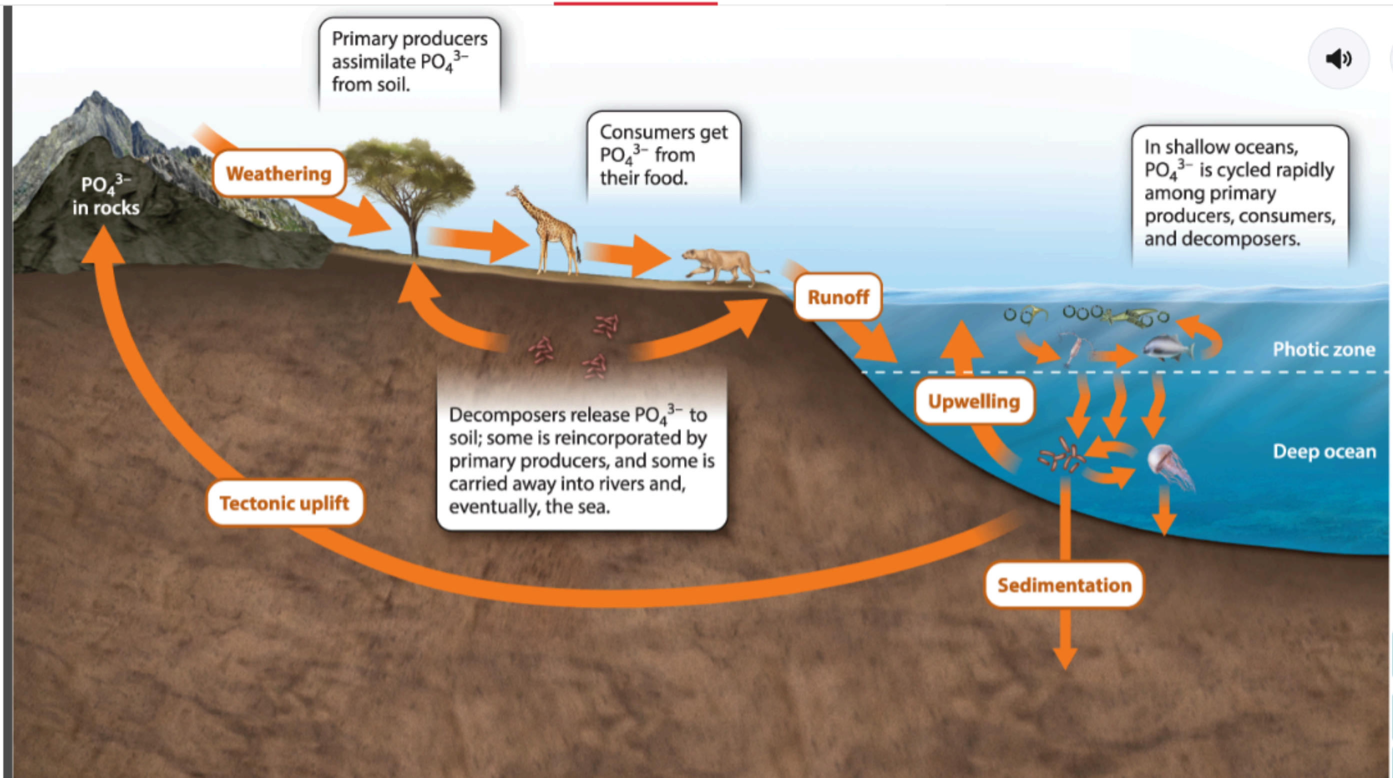

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