8.5: The Biosphere

Composed of living organisms and the materials and structures that they produce, the **biosphere** is one of the five major environmental spheres. The nature of the biosphere and its essential role in sustainability are the topics of Chapter 13. **Biochemistry**, the chemistry that occurs in the biosphere, is discussed in Chapter 7. The biosphere is of obvious importance to the discussion of soil and agriculture in Chapter 12. Aspects of the biosphere are important in sustainability covered in other chapters of the book.

The living organisms that compose the biosphere are the topic of the science of **biology**. The classes of biomolecules that make up these organisms are outlined in Chapter 7. They include proteins that are the basic building blocks of organisms, carbohydrates made by photosynthesis and metabolized by organisms for energy, lipids (fats and oils), and the all-important nucleic acids(DNA, RNA), genetic materials which define the essence of each individual organism and act as codes to direct protein biosynthesis and reproduction. Hierarchical organization is a characteristic of living organisms in the progression of biomolecules < living cells < organs < organisms < the biosphere, itself. Organisms carry out metabolic processes in which they chemically alter substances to obtain energy and to synthesize new biomass. An essential function of organisms is reproduction, and their young undergo various stages of development. Through their DNA organisms express heredity, and modifications of DNA cause mutations.

Although an imperfect system of classification, organisms are regarded as belonging to several kingdoms. Three of these are organisms capable of existing as single cells, but often occurring in colonies of undifferentiated cells clumped together: (1) Archaebacteria without defined cell nuclei that do not require oxygen or light and often exist in extreme environments such as hot springs; (2) eubacteria without defined cell nuclei including heterotrophs that metabolize organic material, cyanobacteria that obtain energy through photosynthesis, and members that obtain their energy by mediating reactions of inorganic matter; and (3) protists consisting of single-celled organisms that have defined cell nuclei enclosed by a nuclear membrane and often have animal-like features, such as moveable hair-like flagella that enable the organisms to move in water. At more complex levels are generally multicelled plantae (plants) and animalia (animals), as well as fungi including yeasts, molds, and mushrooms.

Several terms are used to describe organisms and their place in ecosystems. A **population** of organisms consists of a group of the same species. Groups coexisting in the same location makeup a **community**. Interacting communities and their physical environment make up an **ecosystem**, all of which grouped together constitute the entire biosphere. The basis of any ecosystem is its **productivity**, the ability to produce biomass, usually through photosynthesis in which organisms remove carbon dioxide from the atmosphere and fix it in the form of organic matter that is further converted by biochemical processes to proteins, fats, DNA, and other life molecules. These biomolecules constitute the basis of the whole ecosystem food chain upon which the remainder of the organisms in the food chain depend for their existence. In water, the most biomass at the base of the food chain is produced by algae, photosynthetic phytoplankton growing suspended in water. Some protozoa and some bacteria also have photosynthetic capabilities. The major photosynthetic organisms in terrestrial ecosystems are plants growing in soil.

The outline of the main features of the biosphere are shown in Figure 8.6. For the most part the biosphere is anchored by dominant plant species that are the major producers of biomass. The dominant plant species may also modify the physical environment in ways that facilitate the existence of other species. The big trees dominant in a rain forest obviously form an environment to which other organisms adapt, for example, by providing safe nesting places for birds. The shade provided by the trees makes up a microclimate and a degree of shelter at ground level in which certain kinds of organisms can thrive. Lichen, a synergistic combination of fungi and photosynthetic algae that grow on the surface of rocks weather the rocks to eventually produce soil in which other plants can grow.

The biosphere has undergone massive evolutionary and climate-related changes over millions of years. Much more rapid and sometimes dramatic changes have been caused by human influences. Arguably the most notable of these took place after Columbus discovered the Americas in 1492. Separated by vast oceans, the biospheres of the Eastern and Western hemispheres had evolved largely independent of each other. As humans introduced organisms from one hemisphere to the other an often spectacular phenomenon called ecological release took place as populations of some species exploded when they were introduced into regions free of their natural predators. The Bluegrass State of Kentucky got its name from the prolific growth of this grass introduced from Europe; clover from Europe also grew rapidly in the New World. Newly introduced peachtrees grew so well in the Carolinas and Georgia that fears were expressed over the potential development of a “peach tree wilderness.” Some regions of Peru were inundated with newly introduced mint. It is possible that a human population explosion in parts of Africa was made possible by productive corn from the Western Hemisphere enabling the removal of millions of people from the continent into slavery without depleting Africa’s population. Originating in the Andes Mountains of South America, the potato became a staple of the diet in

Ireland. When the catastrophic *Phytophthora infestans* fungal blight decimated the crop in the 1840s, Ireland lost half its population to starvation and emigration. Tragically, smallpox introduced to North America by Europeans decimated Native American populations, reducing populations of some tribes by 90%.

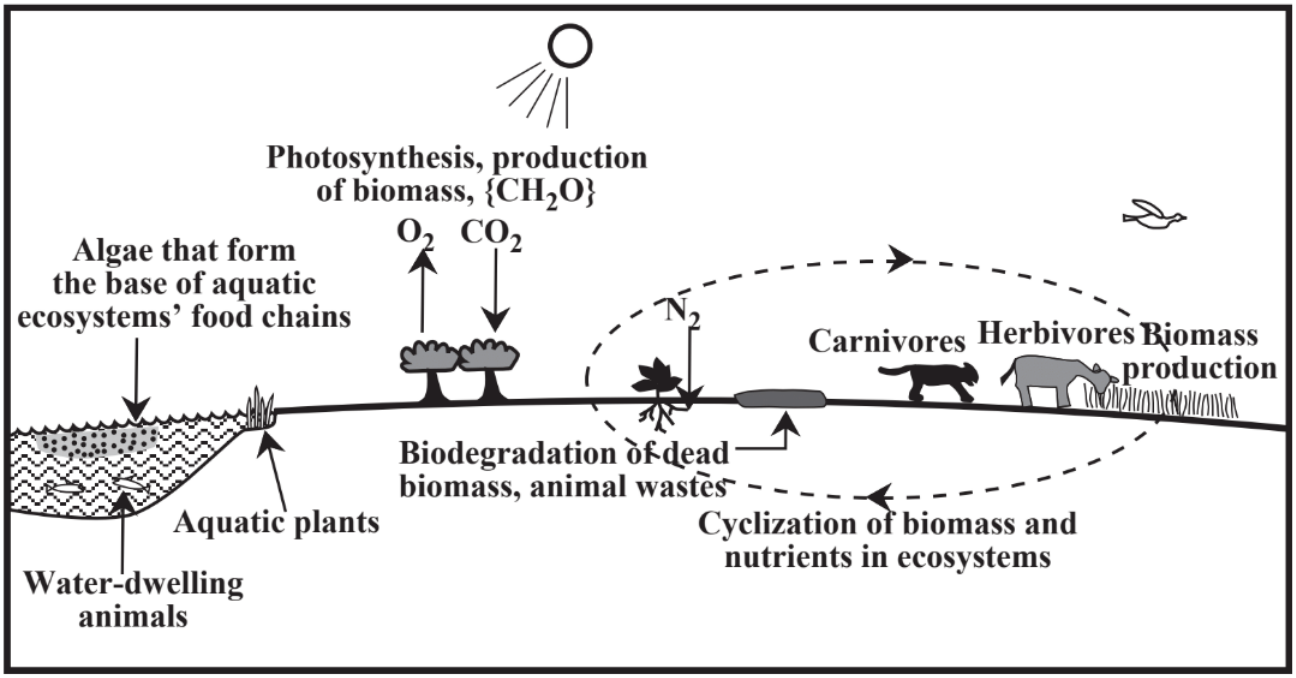

Figure 8.6. Organisms occur within ecosystems in the biosphere where they interact with each other and their enviroment. Ecosystems have evolved in a manner that enables the most efficient utilization of energy and matter with complete recycling of biomass and nutrients. Ecosystems are based upon photosynthetic plants and algae that produce the biomass that anchors the ecosystems, in the process removing carbon dioxide from the atmosphere and returning oxygen. Nitrogen-fixing bacteria, such as those that grow on the roots of leguminous plants, convert elemental nitrogen from the atmosphere to biochemically bound nitrogen. Fungi and bacteria degrade dead biomass, a process that returns nutrients to the ecosystem.

The biosphere has significant effects on the other environmental spheres and *vice versa*. Materials generated in the biosphere are used in the anthrosphere; wood is one such material. Biological productivity is largely determined by conditions of geospheric soil. The availability of the hydrosphere's water largely determines kinds and populations of organisms. Fertilizers and pesticides produced in the anthrosphere have a strong influence on biological productivity in agriculture. Shielding organisms from pollutants, wastes, and toxic substances generated in the anthrosphere is a high priority in environmental protection. The design and operation of the anthrosphere strongly influence the nature of the biosphere and its productivity, especially in the agricultural sector.

The biosphere largely determines Earth's environment. The atmosphere's oxygen was generated by photosynthetic bacteria eons ago. Lichen communities of synergistically growing algae and fungi act upon geospheric rock forming soil that supports plant life. The anthrosphere of less industrialized societies has been largely a product of the biosphere in which the human residents have existed. Massive herds of bison provided food, robes, and the material for the teepee dwellings of North American Plains Native Americans. The availability and kinds of wood have largely determined the nature of dwellings constructed in many societies. More than 2000 years ago, domesticated animals harnessed to carts, wagons, and plows provided humans with mobility and the source of power used to cultivate soil. Many societies, including the Amish farmers in the U.S., still use horses, donkeys, mules, oxen, and water buffalo for land cultivation and transport of goods. One of the basic tenets of green chemistry and sustainability is the use of materials from the biosphere to replace those produced from scarce, expensive petroleum.

In achieving sustainability humans have much to learn from the organisms in the biosphere which over millions of years have developed essential tools of survivability. An important aspect is the ability to thrive and be productive under the mild, safe conditions under which organisms may exist, conditions which are most desirable for green chemical synthesis and other sustainable activities. Even the conditions under which some thermophilic bacteria thrive in the thermal hot springs of Yellowstone National Park are mild compared to the much higher temperature, high-pressure conditions required in many chemical syntheses. The intolerance of living organisms to toxic substances provides valuable lessons regarding which substances should be avoided in the practice of green chemistry.

Important lessons in the development of sustainable systems of industrial ecology (Chapter13) are provided by the biosphere. Over hundreds of millions of years of evolution organisms in the biosphere have had to evolve sustainable ecosystems for their own survival, completely recycling materials and enhancing their environment. In contrast, humans have behaved in ways that are unsustainable with respect to their own existence, exploiting nonrenewable resources and fouling the environment upon which they depend for their own survival. The complex, sustainable ecosystems in which organisms live sustainably in relationships with each other and their surroundings serve as models for anthropogenic systems. By taking lessons from the biosphere and its long-established ecosystems, humans can develop much more sustainable systems of industry and commerce.

A crucial respect in which the biosphere is a key to achieving sustainability is its ability to perform photosynthesis and synthesis of specialized materials. Using carbon dioxide from the atmosphere and energy from the sun, organisms produce biogenic materials in a much greener, safer, more sustainable manner than the manner in which materials are produced in the anthrosphere. Furthermore, organisms are particularly well adapted to make a variety of complex and specialized materials that are very difficult or impossible to make by purely chemical means.
