12.2: The Biosphere

The **biosphere** consists of all living organisms and the materials and structures produced by living organisms. There is a very close connection between the biosphere and green chemistry including the following:

- Living organisms produce a wide range of materials that are used by humans for a variety of purposes.
- Large quantities of substances including pesticides and fertilizers are generated in the anthrosphere for use to control pests and enhance the growth and health of organisms in the biosphere.
- Reduction of the use and generation of toxic substances in the anthrosphere is designed to prevent harm to humans and other organisms in the biosphere.
- Environmental conditions largely determined by anthrospheric activities strongly affect organisms in the biosphere

Individual organisms in the biosphere and organisms interacting in ecosystems can teach humans a lot about how to apply green chemistry. One important respect in which this is done is by the mild conditions under which organisms carry out complex chemical syntheses. Living organisms can function only within narrow temperature ranges that are close to those that humans find comfortable. (Even the 90-100° C temperatures under which thermophilic bacteria function in hot springs and similar locations are not very far from room conditions.) Therefore, the enzyme-catalyzed reactions that organisms carry out occur under much milder conditions than the often high-temperature, high-pressure conditions of conventional chemical synthesis. Furthermore, organisms cannot tolerate highly toxic substances that are often used in chemical synthesis, the elimination of which is a primary objective of the practice of green chemistry.

Another lesson that living organisms provide for an efficiently operating anthrosphere is in the relationships between organisms with each other and with their environment in biological ecosystems. The wide variety of such ecosystems that have evolved over hundreds of millions of years of evolution have had to be sustainable to survive, completely recycling materials and preserving and enhancing their environment. This is in contrast to the way in which anthrospheric systems have evolved, especially during the last two centuries of the industrial revolution. In general, humans and their industrial systems have exploited nonrenewable resources and have polluted water, air, and land in a manner that simply cannot be sustained. Humans have a lot to learn from the biosphere regarding how to operate the anthrosphere sustainably (see the discussion of industrial ecology in Chapter 13) in which various enterprises compose sustainable industrial ecosystems analogous to ecosystems in the biosphere.

Biology

Biology is the science of life and the organisms that comprise life. So what is life? Biologists define living organisms as those that share (1) constitution by particular classes of life molecules,(2) hierarchical organization, (3) capability to carry out metabolic processes, (4) ability to reproduce, (5) development, and (6) heredity

The kinds of molecules that comprise living organisms were discussed in Chapter 7. Recall that these are *proteins* composed of polymers of nitrogen-containing amino acids, *carbohydrates* consisting of small molecules and polymers with an approximate simple formula of CH_2O, *lipids* defined by their property of solubility in organic solvents, and *nucleic acids* that are long polymers of sugars, nitrogen-containing bases, and phosphate. Two of these kinds of materials are often bonded together as hybrid molecules. Along with water and some kinds of salts they make up the matter in living organisms. Literally thousands of kinds of structural and functional characteristics are possible with the four kinds of molecules mentioned above. For example, proteins comprise muscle tissue and make up the enzyme molecules that act as catalysts to enable biochemical reactions to occur. A simple carbohydrate, glucose, $C_6H_{12}O_6$, is the primary organic product generated by plant photosynthesis and is present in animal bloodstreams. Large numbers of glucose molecules bonded together make up polymeric cellulose that is the structural material in plants. Lipids make up the crucial membranes that enclose living cells. And nucleic acids compose the genetic material that regulate cell function and reproduction.

Hierarchical organization applies to living organisms from the level of atoms all the way to the biosphere as a whole. Proteins, carbohydrates, lipids, and nucleic acids in living organisms are organized into distinct microscopic bodies contained in cells and called **organelles**. Cells are bodies of several micrometers (μm) in size that are the basic building blocks of organisms in that they are the smallest bodies of organisms that can exist independently (even cells of humans can be grown in cell cultures outside the body, given the appropriate nutrients and conditions). In higher organisms cells with similar functions comprise **tissues** and tissues in turn make up **organs**, which may be organized into whole systems of organs. An **organism** is a collection of organs and organ systems. Organisms from the same species assembled in a group comprise a **population** and a cluster of populations existing in the

same place makes up a **community**. Numerous communities living in a particular environmental area, interacting with each other and with their environment, make up an **ecosystem**. Finally, all Earth's ecosystems comprise the entire **biosphere.**

The process of **metabolism** is what occurs when organisms mediate chemical (biochemical)processes to get energy, make raw materials required for tissues in organisms or modify raw materials for this purpose, and reproduce. Although there are thousands of different metabolic reactions, two stand out. The first of these is *photosynthesis* shown in Reaction 12.3.1 in which plants use light energy to convert inorganic CO_2 and H_2O to glucose sugar, $C_6H_{12}O_6$. The second major type of metabolic reaction is the mirror image of photosynthesis, **cellular respiration** in which glucose is oxidized to CO_2 and H_2O, yielding energy that is used by the organism. An interesting aspect of the conversion and utilization of energy in metabolism is that all organisms use the high-energy chemical species **adenosine triphosphate**, **ATP**, (structural formula shown in Chapter 7, Section 7.8) to transfer, convert, and store energy.

All organisms undergo **reproduction** to produce offspring to continue the species. In addition to continuing a species, reproduction enables evolution to occur that results in new species.

Development is the process that occurs as an organism progresses from a fertilized egg to a juvenile and on to adulthood. Development occurs in higher forms of life (obvious in human babies) and even single-celled bacteria that reproduce by cell division undergo development as the cells grow and produce additional organelles prior to further division.

Heredity refers to the process by which traits characteristic of a species of organism are passed on to later generations. Heredity occurs through the action of DNA. Heredity is the mechanism by which organisms have undergone evolution and adaptation to their environment.

Organisms that comprise living beings in the biosphere range in size and complexity from individual bacterial cells less than a micrometer in dimensions up to giant whales and human beings capable of thought and reasoning and may be divided into several kingdoms. **Archaebacteria** and **Eubacteria** are generally single-celled organisms without distinct, defined nuclei. **Protists** are generally single-celled organisms that have cell nuclei and may exhibit rather intricate structures. The three other kingdoms are **Plantae**(plants), **Animalia** (animals), and **Fungi** typified by molds and mushrooms.

Organisms are classified according to their food and energy sources and their utilization of oxygen. **Autotrophs** synthesize their food and biomass from simple inorganic substances, usually using solar energy to perform **photosynthesis**. **Chemautotrophs** mediate inorganic chemical reactions for their energy. **Heterotrophs**, including humans, derive their energy and biomass from the metabolism of organic matter, usually biomass from plants. **Oxic** (aerobic) organisms require oxygen, whereas **anoxic** (anaerobic) organisms use alternate sources of oxidants. **Facultative** organisms can use oxygen or other oxidants depending upon conditions.

The biosphere is greatly influenced by the other environmental spheres. In an environment where temperatures are moderate, sunshine abundant, and nutrients readily available, the biosphere consists of diverse groups of organisms interacting and codependent within thriving ecosystems. Under extreme conditions, there may be only a few organisms composing the localized biosphere, specialized for existence at extreme temperatures, high acidities, high levels of pollutants, or other conditions that make life impossible for most organisms.

Just as the biosphere is strongly influenced by the environment in which the organisms are found, it has a strong influence upon its surroundings. Organisms act to break down inhospitable rock to form soil that supports a variety of plants. The oxygen in the atmosphere, upon which we all depend for our existence, was put there by photosynthesis performed by bacteria capable of photosynthesis. The nature of the anthrosphere that humans have constructed is influenced by the biosphere; examples include dwellings constructed of wood, and shelters and clothing used by Plains Native Americans made from bison hides.
