CHAPTER 48 ECOSYSTEMS AND HUMAN INTERFERENCES

Chapter Outline

48.1 The Nature of Ecosystems

A. The Earth
   1. The **hydrosphere** is the zone of water that covers over three-quarters of the earth.
      a. The oceans take up a great amount of heat and then release it slowly to the atmosphere.
      b. The ability of water to absorb and release great quantities of heat keeps our earth's climate within a livable range.
   2. The **atmosphere** is the gaseous layer near the earth.
      a. The atmosphere is concentrated in the lowest 10 kilometers but it extends thinly out to 1,000 km.
      b. The major atmospheric gases are nitrogen, oxygen and carbon dioxide.
      c. Carbon dioxide is necessary for photosynthesis.
      d. Oxygen is necessary for cellular respiration, and oxygen makes up the protective ozone (O_3) in the upper atmosphere.
   3. The **lithosphere** is the rocky substratum that extends from the surface about 100 kilometers deep.
      a. The weathering of rocks supplies minerals to plants and eventually forms soil.
      b. Soil contains decayed organic material (humus) that recycles nutrients to plants.
   4. The **biosphere** is the thin layer where life is possible between the outer atmosphere and the lithosphere.
   5. **Ecosystems** are characterized by one-way flow of energy through the biotic community and a cycling a materials from the abiotic environment to the biotic community and back.

B. Biotic Components of an Ecosystem
   1. Living things are organized in an ecosystem by how they secure their food: autotrophs or heterotrophs.
   2. Autotrophs
      a. Autotrophs capture energy (e.g., sunlight) and incorporate it into organic compounds; therefore they are also called **producers**.
      b. Photosynthetic organisms possess chlorophyll and carry on photosynthesis.
         1) Algae are the main producers in freshwater and marine environments.
         2) Green plants are main land photosynthesizers.
      c. **Chemoautotrophs** are bacteria that obtain energy from the oxidation of inorganic compounds such as ammonia, nitrites, and sulfides; they synthesize carbohydrates and are found in cave communities and ocean depths.
   3. Heterotrophs
      a. **Heterotrophs** need a source of preformed nutrients and consume tissues of other organisms.
      b. **Herbivores** are animals that feed directly on green plants.
      c. **Carnivores** are animals that eat other animals.
      d. **Omnivores** can feed upon a variety of organisms, including plants and animals; humans are omnivores.
   4. **Decomposers** are nonphotosynthetic bacteria and fungi that extract energy from dead matter, including animal wastes in the soil, and make nutrients available.
   5. Some animals (e.g., earthworms) feed on **detritus**—the decomposing products of organisms.

C. Energy Flow and Chemical Cycling
   1. All ecosystems are dependent upon solar energy flow and finite pools of nutrients.
   2. Most ecosystems cannot exist without a continual supply of solar energy.

3. Energy flow in an ecosystem is a consequence of two fundamental laws of thermodynamics:
    a. **First law of thermodynamics** states energy can neither be created nor destroyed; it can only be changed from one form of energy to another.
    b. **Second law of thermodynamics:** when energy is transformed from one form to another, there is always some loss of energy from the system, usually as low grade heat.

48.2 Energy Flow

A. Food Webs
1. The complex feeding relationships that exist in nature are called **food webs**.
2. A **grazing food web** begins with leaves, stems and seeds eaten by herbivores and omnivores.
3. A **detrital food web** begins with detritus, followed by decomposers (including bacteria and fungi).
4. Detrital food chains are connected to a grazing food chain when consumers of a grazing food chain feed on the decomposers of the detrital food chain.
5. In some ecosystems, more energy may move through the detrital food web than moves through the detritus food web.

B. Trophic Levels
1. A **food chain** represents a single path sequence of organisms that form links.
2. A **trophic level** is a feeding level of one or more populations in a food web; those organisms in an ecosystem that are the same number of food chain steps from the energy input into the system:
    a. **first trophic level—**primary producers,
    b. **second trophic level—**all the primary consumers,
    c. **third trophic level—**all the secondary consumers, etc.

C. Ecological Pyramids
1. About 10% of the energy at a particular trophic level is incorporated into the next trophic level.
    a. Thus, 1,000 kg (or kcal in an energy pyramid) of plant material converts to 100 kg of herbivore tissue, which converts to 10 kg of first carnivores, which can support 1 kg of second level carnivores.
    b. This rapid loss of energy is the reason food chains have from three to four links, rarely five.
    c. This rapid loss of energy is also the reason there are few large carnivores.
2. An **ecological pyramid** shows this trophic structure of an ecosystem as a graph representing biomass, organism number, or energy content of each trophic level in a food web.
3. The base of the pyramid represents the producer trophic level, and from there the consumer trophic level is stacked, with the apex representing the highest consumer trophic level.
4. A **pyramid of numbers** is based on the number of organisms in each trophic level.
5. A **pyramid of biomass** is based on the weight (biomass) of organisms at each trophic level at one time.
    a. Usually a large mass of plants supports a medium mass of herbivores and a small mass of carnivores.
    b. However, at one point in time at seashores, herbivores can have greater biomass feeding on algae that reproduce fast but are eaten, producing an inverted pyramid; over long time periods, the biomass is a normal pyramid.
6. One problem is where to fit in the decomposers; a large portion of energy becomes detritus in many ecosystems.

48.3 Global Biogeochemical Cycles

A. Biogeochemical Cycles
1. All organisms require a variety of organic and inorganic nutrients.
2. **Biogeochemical cycles** are the pathways by which chemicals circulate through the biotic and abiotic components of an ecosystem.
3. A **reservoir** is that portion of the earth that acts as a storehouse for the element.
4. An **exchange pool** is the portion of the environment from which producers take chemicals, such as the atmosphere or soil.
5. The **biotic community** is the pathway through which chemicals move through food chains.
6. Some cycles are primarily **gaseous cycles** (carbon and nitrogen); others are **sedimentary cycles**, (phosphorus).

B. The Water Cycle
1. In the **water** or **hydrologic cycle**, freshwater evaporates and condenses on the earth.
2. The evaporation of water from the oceans leaves behind salts.

3. Rainfall that percolates into the earth forms a water table at the surface of the groundwater.
4. An **aquifer** is an underground storage of fresh water in porous rock trapped by impervious rock.
5. Freshwater makes up about 3% of the world's supply of water and is considered a renewable resource.
6. However, freshwater becomes unavailable when consumption exceeds supply or is so polluted that it is not usable.

C. The Carbon Cycle
1. Both terrestrial and aquatic organisms exchange carbon dioxide with the atmosphere.
2. On land, photosynthesis removes CO_2 from the atmosphere; respiration then returns CO_2 to the atmosphere.
3. CO_2 from the air combines with water to produce bicarbonate (HCO_3), which is a source of carbon for aquatic producers, primarily protists.
4. Similarly, when aquatic organisms respire, the CO_2 they release combines with water to form bicarbonate ions (HCO_3^-).
5. The reservoir for the carbon cycle is largely composed of organic matter, calcium carbonate in shells, and limestone, as well as fossil fuels.

D. Carbon Dioxide and Global Warming
1. A **transfer rate** is the amount of a nutrient moving from one part of the environment to another in a specified time period.
2. The transfer rates between photosynthesis and respiration (including decay) are about even.
3. Because we burn fossil fuels and forests, there is now more CO_2 entering the atmosphere than is removed.
4. In 1850, atmospheric carbon dioxide was about 280 ppm; today it is about 350 ppm.
5. CO_2, nitrous oxide, and methane are **greenhouse gases** that contribute to the rise in atmospheric temperature.
6. The above gases and water vapor increase the greenhouse effect that holds heat next to the earth.
7. The increased heat may cause more clouds that in turn increase global warming.
8. Computer models cannot incorporate all variables; predictions are for 1.5–4.5^{o}C increase by 2100.
9. Possible results may include glaciers melting, sea levels rising, a redistribution of dry and wet regions, and an increase in species extinctions.

E. The Nitrogen Cycle
1. Nitrogen gas (N_2) is 78% of the atmosphere, yet nitrogen deficiency can limit plant growth.
2. In the **nitrogen cycle**, plants cannot incorporate N_2 into organic compounds and they therefore depend on the various types of bacteria to make nitrogen available to them.
3. Nitrogen Gas Becomes Fixed
   a. **Nitrogen fixation** occurs when N_2 is converted to a form that plants can use.
   b. Other nitrogen-fixing bacteria, living in nodules on the roots of legumes, make reduced nitrogen and organic compounds available to a host plant.
   c. Some cyanobacteria in water and the free-living bacteria in soil are able to reduce N_2 to ammonium (NH_4^+).
   d. Plants take up both NH_4^+ and nitrate (NO_3^-) from the soil.
   e. After plants take up NO_3^-, it is enzymatically reduced to NH_4^+ that is then used to synthesize amino and nucleic acids.
4. Nitrogen Gas Becomes Nitrates
   a. **Nitrification** is the production of nitrates (NO_3^-).
   b. Nitrogen gas is converted to NO_3^- in the atmosphere when cosmic radiation, meteor trails, and lightning provide the high energy for nitrogen to react with oxygen.
   c. Nitrifying bacteria convert NH_4^+ to NO_3^-.
   d. Ammonium in the soil is converted to NO_3^- by nitrifying bacteria in the soil in a two-step process that does not depend on nitrogen gas.
      1) First, nitrite-producing bacteria convert NH_4^+ to nitrite (NO_3^-).
      2) Then, nitrate-producing bacteria convert NO_2^- to NO_3^-.
   e. **Denitrification** is conversion of NO_3^- to nitrous oxide (N_2O) and N_2.
   f. There are denitrifying bacteria in both aquatic and terrestrial ecosystems.
   g. Denitrification counterbalances nitrogen fixation, but not completely; more nitrogen fixation occurs.

5. Nitrogen and Air Pollution
    a. Production of fertilizers and burning of fossil fuels adds three times the nitrogen oxides to the atmosphere as normal.
    b. **Acid deposition** occurs when nitrogen oxides and sulfur oxides combine with water vapor in the atmosphere.
    c. **Photochemical smog** results when nitrogen oxides and hydrocarbons react in presence of sunlight; smog contains ozone (O_3) and peroxyacetylnitrate (PAN) and causes respiratory problems.
    d. Air pollutants, that might otherwise escape, are trapped near the ground by **thermal inversions** where cold air is trapped near the ground by warm air above.

F. The Phosphorus Cycle
1. In the **phosphorus cycle**, weathering makes phosphate ions (PO_4 and HPO_4^{2-}) available to plants that take up phosphate from the soil.
2. Some of this phosphate runs off into aquatic ecosystems where algae incorporate it into organic molecules before it is entrapped in sediments.
3. Phosphate that is not taken up by algae is incorporated into sediments in the oceans.
4. Sediment phosphate only becomes available when geological upheaval exposes sedimentary rocks.
5. Phosphate taken up by producers is incorporated into a variety of organic compounds.
6. Animals eat producers and incorporate some of the phosphate into phospholipids, ATP, and nucleotides of DNA; however what is in teeth, bones, and shells does not decay for long periods.
7. Decay of organisms and decomposition of animal wastes eventually makes phosphate ions available again.
8. Available phosphate is generally taken up quickly; it is usually the limiting nutrient in most ecosystems.
9. Phosphorus and Water Pollution
    a. Humans boost the supply of phosphate by mining phosphate ores for fertilizers, detergents, etc.
    b. Run-off of animal wastes from livestock feedlots and commercial fertilizers from cropland as well as discharge of untreated and treated municipal sewage can all add excess phosphate to nearby waters.
    c. **Eutrophication** is the name of this over-enrichment that leads to algal blooms; when the algae die off, decomposers use up all of the oxygen and this can cause a massive fish kill.
    d. **Biological magnification** is the concentration of non-degraded chemicals as they move up the food chain; DDT is a classic example.
    e. Oil spills add over 5 million metric tons of oil a year to oceans.
    f. Human activities including pollution and fishing have exploited ocean resources to the brink of extinction.