Chapter 3

Ecosystems: What Are They and How Do They Work

Summary

1. Ecology is the study of connections in nature.

2. Life on earth is sustained by the one-way flow of high-quality energy from the sun, by the cycling of matter, and by gravity.

3. Matter, energy, and life are the major components of an ecosystem.

4. Energy in an ecosystem decreases in amount to each succeeding organism in a food chair or web.

5. Soil is a complex mixture of eroded rock, mineral nutrients, water, air, decaying organic matter, and billions of living organisms. It covers most of the earth and provides nutrients for plant growth. Soils are formed by a breaking down of rock, decomposing surface litter and organic matter. Bacteria and other decomposer microorganisms break down some of soil's organic compounds into simpler inorganic compounds.

6. Matter is recycled through the earth's ecosystem of air, land, water, and living organisms. This vast global recycling system is composed of nutrient cycles.

7. Scientists study ecosystems through the use of aquarium tanks, greenhouses, and controlled indoor and outdoor chambers. Specific variables are carefully controlled, like temperature, light, carbon dioxide, and humidity.

8. Two principles of sustainability found from learning how nature works are the law of conservation of matter and the two laws of thermodynamics.

Outline

3-1 What keeps us and other organisms alive?

A. Earth's life support system consists of four main systems: atmosphere (air), hydrosphere (water), geosphere (earth) and the biosphere (living things).
   1. Atmosphere contains many layers:
      a. The troposphere extends 17 km up and contains the air we breathe. About 1% is composed of greenhouse gases (water vapor, methane and carbon dioxide), which absorb energy to warm the lower atmosphere.
      b. The stratosphere lies 17–50 km above the troposphere and filters the sun's harmful radiation.
      c. The hydrosphere consists of earth's water, found in liquid water, ice, and water vapor.
      d. The geosphere consists of the earth's core, mantle, and crust.
      e. The biosphere is where life is found.

B. Life on earth depends on three interconnected factors
   1. The one-way flow of high-quality solar energy.
   2. The cycling of nutrients.
   3. Gravity.

C. Solar energy reaches earth as electromagnetic waves in the form of visible light, UV radiation and heat.

D. As solar radiation interacts with the earth, infrared radiation is produced. Greenhouse gases trap the heat and warm the troposphere. This natural greenhouse effect makes the planet warm enough to support life.
   1. Human activities add greenhouse gasses to the atmosphere, intensifying the greenhouse effect.

3-2 What are the major components of an ecosystem?

A. Ecology is the study of connections in the natural world.
   1. There are five levels of study: organisms, populations, communities, ecosystems and the biosphere.

   2. Ecosystems are comprised of living (biotic) and non-living (abiotic) components.

   3. Every organism occupies a trophic (feeding) level.
      a. Producers, or autotrophs, make their own food from compounds in the environment. Photosynthesis is the process by which plants take solar energy, carbon dioxide and water to form energy rich sugars. Chemosynthesis is the process by which some organisms can use geothermal energy to produce complex nutrient compounds.

4. Consumers, or heterotrophs, feed on other organisms.
    a. Herbivores (primary consumers) feed on plants.
    b. Carnivores feed on animals.
    c. Secondary consumer feed on herbivores
    d. Tertiary consumers feed on other carnivores.
    e. Omnivores feed on both plants and animals.
    f. Decomposers break down organic detritus (bacteria/fungi) into simpler inorganic compounds.
    g. Detritivores feed on dead organic matter and break it down into smaller molecules.

5. Glucose and other organic compounds are broken down and energy is released by the process of aerobic respiration, the use of oxygen to convert organic matter back to carbon dioxide and water.

6. Some decomposers are able to break down organic compounds without using oxygen. This process is called anaerobic respiration, or fermentation.

SCIENCE FOCUS: Microbes are pivotally important in terms of cycling matter, providing oxygen and regulating the earth's temperature by removing carbon dioxide.

3-3 What happens to energy in an ecosystem?

A. Food chains and food webs help us understand how eaters, the eaten, and the decomposed are interconnected in an ecosystem.

B. Energy flow in a food web/chain decreases at each succeeding organism in a chain or web.

C. The dry weight of all organic matter within the organisms of a food chain/web is called biomass.

D. The greater number of trophic levels in a food chain, the greater loss of usable energy.

F. The pyramid of energy flow visualizes the loss of usable energy through a food chain. The lower levels of the trophic pyramid support more organisms.

G. Production of biomass takes place at different rates among different ecosystems.
    1. The rate of an ecosystem's biomass production is the gross primary productivity (GPP).
    2. Some of the biomass must be used for the producers' own respiration. Net primary productivity (NPP) measures how fast producers can provide biomass needed by consumers in an ecosystem.
    3. Ecosystems and life zones differ in their NPP.

H. The planet's NPP limits the numbers of consumers who can survive on earth.

3-4 What happens to matter in an ecosystem?

A. Nutrient cycles/biogeochemical cycles are global recycling systems that interconnect all organisms.
    1. These cycles include the carbon, oxygen, nitrogen, phosphorus, and water cycles.

B. The water/hydrologic cycle collects, purifies, and distributes the earth's water in a vast global cycle.
    1. Solar energy evaporates water, and the water returns as rain/snow.
    2. Some water becomes surface runoff, returning to streams/rivers.
    3. Water is the major form of transporting nutrients within and between ecosystems.
    4. Many natural process purify water

C. The water cycle is altered by man's activities.
    1. We withdraw large quantities of fresh water.
    2. We clear vegetation and increase runoff, reduce filtering and increase flooding.
    3. We increase flooding as we drain and alter wetlands.

D. The carbon cycle circulates through the biosphere.
    1. CO_2 gas is an important temperature regulator on earth.
    2. Photosynthesis and aerobic respiration circulates carbon in the biosphere.
    3. Fossil fuels contain carbon.
    4. Excess carbon dioxide in the atmosphere has contributed to global warming.

E. Nitrogen is recycled through the earth's systems by different types of bacteria.

1. The nitrogen cycle converts nitrogen (N_2) into compounds that are useful nutrients for plants and animals.
2. The nitrogen cycle includes these steps:
   a. Specialized bacteria convert gaseous nitrogen to ammonia in nitrogen fixation.
   b. Special bacteria convert ammonia in the soil to nitrite ions and nitrate ions; the latter is used by plants as a nutrient. This process is nitrification.
   c. Decomposer bacteria convert detritus into ammonia and water-soluble salts in ammonification.
   d. In denitrification, nitrogen leaves the soil. Anaerobic bacteria in soggy soil and bottom sediments of water areas convert NH_3 and NH_4^+ back into nitrite and nitrate ions, and then nitrogen gas and nitrous oxide gas are released into the atmosphere.

3. Human activities affect the nitrogen cycle.
   a. In burning fuel, we add nitric oxide into the atmosphere; it can be converted to NO_2 gas and nitric acid, and it can return to the earth's surface as acid rain.
   b. Nitrous oxide that comes from livestock, wastes, and inorganic fertilizers we use on the soil can warm the atmosphere and deplete the ozone layer.
   c. We destroy forest, grasslands, and wetland and, thus, release large amounts of nitrogen into the atmosphere.
   d. We pollute aquatic ecosystems with agricultural runoff and human sewage.
   e. We remove nitrogen from topsoil with our harvesting, irrigating, and land-clearing practices.

F. The phosphorus cycle does not include the atmosphere. The major reservoir is terrestrial rock formations.
   1. Most soils contain little phosphate, and it is often the limiting factor for plant growth.
   2. Phosphorus is used as a fertilizer to encourage plant growth.
   3. Phosphorus also limits growth of producers in freshwater streams and lakes due to low solubility in water.

G. Humans interfere with the phosphorous cycle in harmful ways.
   1. We mine phosphate rock to produce fertilizers and detergents.
   2. We cut down tropical forests and, thereby, reduce the phosphorus in tropical soils.
   3. Eroding topsoil moves large quantities of topsoil to aquatic systems, where it stimulates growth in algae.

H. Sulfur cycles through the biosphere and much of it is stored underground in rocks and minerals.
   1. Natural sources of sulfur are hydrogen sulfide, released from volcanoes, swamps, bogs, and tidal flats where anaerobic decomposition occurs.
   2. Particles of sulfate, such as ammonium sulfate, enter the atmosphere from sea spray, dust storms and forest fires.
   3. Some marine algae produce dimethyl sulfide (DMS). DMS acts as nuclei for condensation of water found in clouds. This can affect the cloud cover and climate.
   4. Sulfur compounds can be converted to sulfuric acid, which falls as acid deposition.
   5. Burning coal and oil, refining oil, and the production of some metals from ores all add sulfur to the environment.

3-5 How do scientists study ecosystems?

A. Ecologists do field research, observing and measuring the ecosystem structure and function.

B. New technologies such as remote sensing and geographic information systems (GISs) gather data that is fed into computers for analysis and manipulation of data.

C. Ecologists use tanks, greenhouses, and controlled indoor and outdoor chambers to study ecosystems (laboratory research). This allows control of light, temperature, CO_2, humidity, and other variables.

D. Field and laboratory studies must be coupled together for a more complete picture of an ecosystem.

E. Systems analysis develops mathematical and other models that simulate ecosystems that are large and very complex and can't be adequately studied with field and laboratory research. This allows the analysis of the effectiveness of various alternate solutions to environmental problems and can help anticipate environmental surprises.

SCIENCE FOCUS: The use of satellites as remote sensing devises and tools such as Google Earth provide for a powerful new approach to understanding the environment and conducting research.

Key Terms

abiotic
aerobic respiration
anaerobic respiration
atmosphere
autotrophs
biogeochemical cycles
biomass
biosphere
biotic
carbon cycle
carnivores
chemosynthesis
community
consumers
decomposers
detritivores
ecology
ecosystem
fermentation
food chain
food web
greenhouse gases
gross primary productivity (GPP)
herbivores
heterotrophs
hydrologic (water) cycles
hydrosphere
natural greenhouse effect
net primary productivity (NPP)
nitrogen cycle
nutrient (biogeochemical) cycles
omnivores
organisms
photosynthesis
phosphorus cycle
population
primary consumers
producers
pyramid of energy flow
secondary consumers
stratosphere
sulfur cycle
tertiary consumers
trophic level
troposphere