ECOSYSTEMS: CONCEPTS AND FUNDAMENTALS

The Ecosystem: Sustaining Life on Earth

- **ECOSYSTEM**: Life is sustained by the interactions of many organisms functioning together, interacting through their physical and chemical environments.
- Sustained life on Earth is a characteristic of **ecosystems**, not of individual organisms or populations.

Basic Characteristics of Ecosystems

Ecosystem Structure

- **An ecosystem has two major parts: living and nonliving.**

Ecosystem Processes

- **Two basic kinds of processes must occur in an ecosystem: a cycling of chemical elements and a flow of energy.**

- **These processes are necessary for all life, but no single species can carry out all necessary chemical cycling and energy flow alone.**

- **Chemical elements recycled and converted to a reusable form by several different organisms.**

Ecological communities and food chains

Ecological community can be defined in two ways.

1. A set of interacting species found in the same place and functioning together, thus enabling life to persist.

- **PROBLEM** **it is often difficult in practice to know the entire set of interacting species.**

2. A practical or an operational definition, in which the community consists of all the species found in an area, whether or not they are known to interact.

PROBLEM **Animals in different cages in a zoo could be called a community according to this definition.**

- **One way that individuals in a community interact is by feeding on one another.**
- **Energy, chemical elements, and some compounds are transferred from creature to creature along food chains, the linkage of who feeds on whom.**
- **The more complex linkages are called FOOD WEBS.**

- **Ecologists group the organisms in a food web into TROPHIC LEVELS.**

A trophic level consists of all organisms in a food web that are the same number of feeding levels away from the original energy source.

- The original source of energy in most ecosystems is the **SUN**. In other cases, it is the energy in certain inorganic compounds.

- Green plants, algae, and certain bacteria produce sugars through the process of **PHOTOSYNTHESIS**, using only energy from the sun and carbon dioxide from the air. They are called **AUTOTROPHS** and are grouped into the**FIRST TROPHIC LEVEL.**

- All other organisms are called **HETEROTROPHS**.
  - **HERBIVORES**— organisms that feed on plants, algae, or photosynthetic bacteria—are members of the second trophic level.

- **CARNIVORES**, or meat-eaters, that feed directly on herbivores make up the third trophic level.

- **DECOMPOSERS**, those that feed on dead organic material,

  are classified in the highest trophic level in an ecosystem.

- Food chains and food webs are often quite complicated and thus not easy to analyze. The number of trophic levels differs among ecosystems.

One of the simplest natural ecosystems is a hot spring, such as those found in geyser basins in Yellowstone National Park, Wyoming. They are simple because few organisms can live in these severe environments.

Ecosystems as Systems

- **Ecosystems are open systems:** Energy and matter flow into and out of them.
- **An ecosystem is the minimal entity that has the properties required to sustain life.** However, ecosystems vary greatly in structural complexity and in the clarity of their boundaries.

- What all ecosystems have in COMMON is the flOW OF ENERGY and THE CYCLING OF CHEMICAL ELEMENTS, which give ecosystems the ability to sustain life.

Biological Production and Ecosystem Energy Flow

- **Ecosystem energy flow is the movement of energy through an ecosystem from the external environment through a series of organisms and back to the external environment.**
- **The fundamental processes common to all ecosystems.**

- **Energy enters an ecosystem by two pathways**:

    1. energy fixed by organisms and moving through food webs within an ecosystem;
    2. heat energy that is transferred by air or water currents or by convection through soils and sediments and warms living things. For instance, when a warm air mass passes over a forest, heat energy is transferred from the air to the land and to the organisms.

The Laws of Thermodynamics and the Ultimate Limit on the Abundance of Life

- What ultimately limits the amount of organic matter in living things that can be produced anywhere, at any time, forever on the Earth or anywhere in the universe?
- We ask this question when we are trying to improve the production of some form of life.

- **The answers to these questions lie in the laws of thermodynamics.**

- **The first law of thermodynamics**, known as the law of conservation of energy states that in any physical or chemical change, **energy is neither created nor destroyed but merely changed from one form to another.**
- Why can't energy be recycled in ecosystems and in the biosphere?

- Physicists have discovered that no use of energy in the real (not theoretical) world can ever be 100% efficient.
- Whenever useful work is done, some energy is inevitably converted to heat. Collecting all the energy dispersed in this closed system would require more energy than could be recovered. Our imaginary system begins in a highly organized state, with energy compacted in the coal. It ends in a less organized state, with the energy dispersed throughout the system as heat. The energy has been degraded, and the system is said to have undergone a decrease in order.

- The measure of the decrease in order (the disorganization of energy) is called **ENTROPY**.
- The second law of thermodynamics gives us a new understanding of a basic quality of life. It is the ability to create order on a local scale that distinguishes life from its nonliving environment. Energy must continually be added to an ecological system in a usable form. Energy is inevitably degraded into heat, and this heat must be released from the system. If it is not released, the temperature of the system will increase indefinitely. The net flow of energy through an ecosystem, then, is a one-way flow.

- The ecosystem is said to be an intermediate system between the energy source and the energy sink. The energy source, ecosystem, and energy sink together form a thermodynamic system.
- Producing organic matter requires energy; organic matter stores energy.

Biological Production and Biomass

- The total amount of organic matter in any ecosystem is called its

  BIOMASS.

- Biomass is increased through biological production (growth).

- Change in biomass over a given period is called **production**.

- Biological production is the capture of usable energy from the environment to produce organic matter (or organic compounds). This capture is often referred to as energy "**fixation**," and it is often said that the organism has "**fixed**" energy.

There are two kinds of production, gross and net.

- **GROSS PRODUCTION** is the increase in stored energy before any is used
- **NET PRODUCTION** is the amount of newly acquired energy stored after some energy has been used.
- When we use energy, we "burn" a fuel through respiration. The difference between gross and net production is like the difference between a person's gross and net income. Your gross income is the amount you are paid. Your net income is what you have left after taxes and other fixed costs. Respiration is like the expenses that are required in order for you to do your work.

- **PRIMARY PRODUCTION**: The production carried out by autotrophs
- **SECONDARY PRODUCTION**: The production carried out by heterotrophs
- Most autotrophs do photosynthesis.
- Some autotrophic bacteria can derive energy from inorganic sulfur compounds; **CHEMOAUTOTROPHS**. Mostly extremophiles

- **RESPIRATION** is the use of biomass to release energy that can be used to do work.

Energy Efficiency and Transfer Efficiency

- **How efficiently do living things use energy?**

- According to the second law of thermodynamics, no system can be 100% efficient.
- As energy flows through a food web, it is degraded, and less and less is usable.
- Generally, the more energy an organism gets, the more it has for its own use. However, organisms differ in how efficiently they use the energy they obtain. A more efficient organism has an advantage over a less efficient one.

- Efficiency can be defined for both artificial and natural systems: machines, individual organisms, populations, trophic levels, ecosystems, and the biosphere.
- Energy efficiency is defined as the ratio of output to input, and it is usually further defined as the amount of useful work obtained from some amount of available energy.

- A common ecological measure of energy efficiency is called **FOOD-CHAIN EFFICIENCY**, or **TROPHIC-LEVEL EFFICIENCY**, which is the ratio of production of one trophic level to the production of the next-lower trophic level.
- This efficiency is never very high.
- Green plants convert only 1–3% of the energy they receive from the sun during the year to new plant tissue.
- The efficiency with which herbivores convert the potentially available plant energy into herbivorous energy is usually less than 1%, as is the efficiency with which carnivores convert herbivores into carnivorous energy.

- The rule of thumb for ecological trophic energy efficiency is that more than 90% (usually much more) of all energy transferred between trophic levels is lost as heat. Less than 10% (approximately 1% in natural ecosystems) is fixed as new tissue.

Ecological Stability and Succession

- **Ecosystems are dynamic**: They change over time both from external (environmental) forces and from their internal processes.
- Ecosystems, however, not only change but also then recover and overcome these changes, and life continues on.

- When disturbed, ecosystems can recover through ecological succession if the damage is not too great.
- **Primary succession** is the establishment and development of an ecosystem where one did not exist previously. Coral reefs that form on lava emitted from a volcano and cooled in shallow ocean waters are examples of primary succession.

- **Secondary succession** is reestablishment of an ecosystem after disturbances. In secondary succession, there are remnants of a previous biological community, including such things as organic matter and seeds. A coral reef that has been killed by poor fishing practices, pollution, climate change, or predation, and then recovers, is an example of secondary succession. Forests that develop on abandoned pastures or after hurricanes, floods, or fires are also examples of secondary succession.