The Living Environment

The field of **environmental studies** uses knowledge from a wide variety of sciences and other disciplines to understand the functioning of the Earth's environment and to understand and address current environmental problems.
The **environment** consists of all the living and nonliving components that affect all forms of life on Earth.

Ecology

Ecology is the study of the interactions between and among organisms and their environment. An **organism** is any form of life.
Organisms are broken into two major types:

- **Prokaryotes:** Organisms whose cells lack nuclei
- **Eukaryotes:** Organisms whose cells have nuclei

Traditionally, taxonomists classified organisms in five **kingdoms.** Recent evolutionary research, however, has led to a new classification system that places organisms in three **domains.**

- **Archaea:** Prokaryotic, single-celled organisms that exist in harsh environments, such as oxygenless swamps, very salty bodies of water, and near deep-sea vents and sulfur springs
- **Bacteria:** Includes all other prokaryotes
- **Eukarya:** Encompasses all eukaryotic organisms, including all members of kingdoms Protista, Fungi, Plantae, and Animalia

Biomes and Ecosystems

A **biome** is a large region characterized by certain forms of life. Most biomes are determined by their characteristic weather pattern or **climate.**

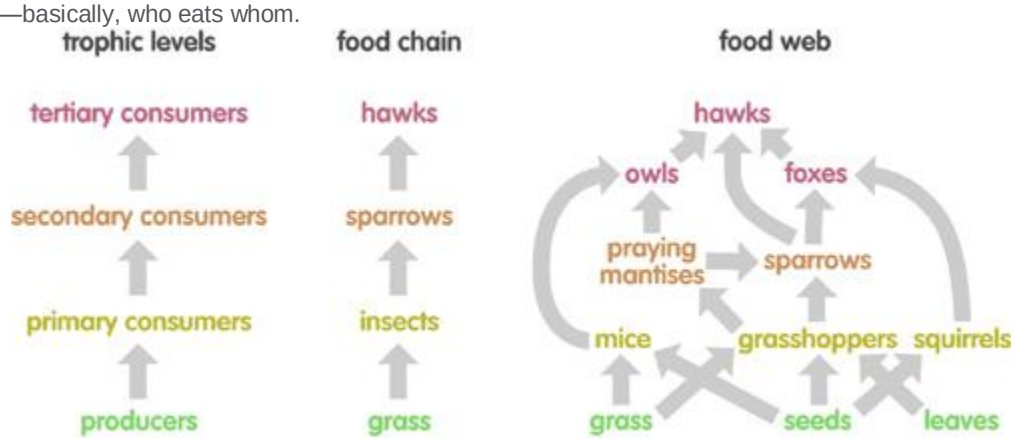
- Major **terrestrial biomes** include:
  - **Tropical rain forest:** Infertile soil but heavy rainfall; dense vegetation; greatest biodiversity of any land biome
  - **Savannah:** Open grassland with scattered trees; transitional between rain forest and desert
  - **Desert:** Minimal precipitation; sparse vegetation; extreme daily temperature fluctuation
  - **Chapparal:** Coastal area with short evergreen shrubs; mild, rainy winter; hot, dry summer
  - **Temperate grassland:** Abundant precipitation; rich soils; agriculturally productive
  - **Temperate deciduous forest:** Deciduous trees (have leaves that drop every winter); warm, rainy summer; cool winter
  - **Temperate coniferous forest:** Coniferous trees (have year-round needles); warm, rainy summer; cool winter
  - **Taiga:** Northern coniferous forest; long, cold winter
  - **Tundra:** Cold; little precipitation or vegetation; permafrost exists near the surface
- Major **aquatic biomes** include:
  - **Intertidal (littoral):** Shorelines and coasts; subject to periods of wet and dry
  - **Neritic:** Shallow waters to the continental shelf
  - **Oceanic (pelagic):** Surface layers of the open ocean
  - **Aphotic (abyssal):** Deep-water areas where no sunlight penetrates
  - **Freshwater:** Ponds, lakes, rivers, etc.; tied closely to surrounding terrestrial biomes

Every biome is home to a number of **ecosystems.** An ecosystem is a characteristic community of **abiotic** (nonliving) elements and **biotic** (living) organisms and the interactions between them. The **ecosphere** consists of all the Earth's ecosystems and is defined as all the living organisms and the nonliving elements with which they interact.
Ecosystems may be broken down in a number of ways. A **community**consists of all of the species living in an area; a **population** consists of all the organisms of one species living in an area.

- Communities are not static but change over time through a process of**ecological succession** or **community development.**
  - **Primary succession:** Colonization of an abiotic area by organisms for the first time.
  - **Secondary succession:** Recolonization of an area that has been seriously disturbed (e.g. by a forest fire) by new organisms.
  - **Pioneer species:** The first organisms to enter (in either primary or secondary succession).
- **Restoration:** The recovery of a site that was disturbed by humans. Restoration may rely on natural succession processes or may utilize more active management.

The Food Chain

In any ecosystem, matter and energy are transferred between organisms: some organisms produce energy themselves, while others obtain it by feeding on or decomposing other organisms. Organisms thus are classified according to their **trophic level**—the step that they occupy in their ecosystem's **food chain** or **food web.** A food chain or web details the order of trophic interactions in an ecosystem, showing how energy is transferred between organisms—basically, who eats whom.



Producers (autotrophs): Organisms that can make **organic** (carbon-containing) energy resources (e.g., sugar) from abiotic, **inorganic** (non-carbon-containing) components of the environment. Producers are considered to be in the first trophic level.

- **Biomass:** The organic material that plants produce.
- **Primary productivity:** The rate at which an ecosystem's producers create biomass.
- **Photosynthesis:** The process by which a producer converts energy from the sun, along with carbon dioxide (CO_2) and water (H_2O), to sugar (glucose) and oxygen (O_2). Photosynthesis is the primary means of production in most ecosystems.
- **Chemosynthesis:** Another, less common form of production that relies on energy from chemicals, rather than solar energy, to create organic energy resources.

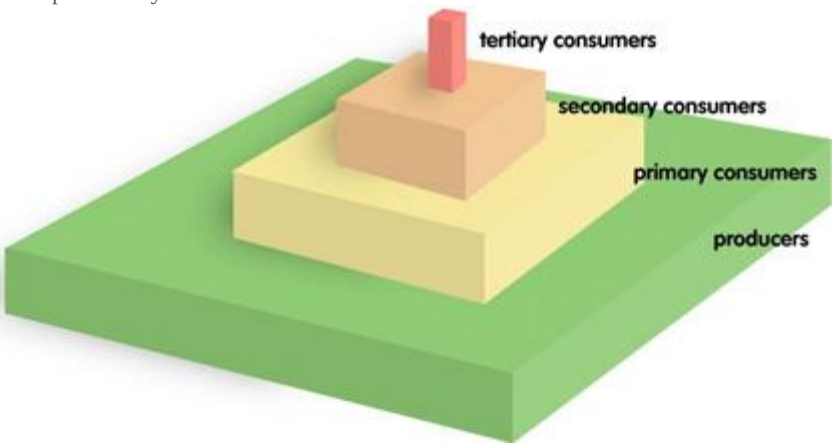
Consumers (heterotrophs): Organisms that gather energy by consuming organic material from other organisms. Rather than perform photosynthesis or chemosynthesis, consumers perform **aerobic respiration,** which converts sugar (glucose) and oxygen into carbon dioxide and water to give them energy. Consumers are considered to be in the second or higher trophic level.

- **Primary consumers:** Organisms that consume mainly producers. Primary consumers are also known as herbivores because they consume mainly plants.
- **Secondary consumers:** Organisms that consume mainly primary consumers. Secondary consumers are also known as **carnivores** because they consume mainly animals.
- **Tertiary consumers:** Organisms that consume secondary consumers. Like secondary consumers, tertiary consumers are carnivores.
- Some organisms cannot be classified in one trophic level because they consume organisms from multiple trophic levels.
  - **Omnivores:** Organisms that consume both producers and other consumers. Omnivores may be in the second and higher trophic levels depending on their level of consumption.
  - **Detritovores:** Organisms that consume **detritus** (the tissues of dead organisms, either producers or consumers) and organic waste.
  - **Decomposers:** Organisms that break down detritus through digestion.

Energy is lost during each energy transfer from one trophic level to the next, so more energy is needed to support higher trophic level feeders.

- As a result of energy loss, there is less biomass at high trophic levels than at low trophic levels.

- **Biomass pyramid:** A graphical representation of biomass in an ecosystem at various trophic levels. The pyramid shows that most of the Earth's biomass exists in producers, less in primary consumers, and increasingly less in higher trophic levels. In some circumstances the pyramid shape can vary.



Carrying capacity: The number of organisms that can be supported by the resources available within a given area. Carrying capacity is determined by the level of primary productivity and other factors.

- **Overshooting:** A situation in which the number of organisms in an area exceeds the area's carrying capacity.
- **Dieback:** The death of many individual organisms in an area, which occurs if carrying capacity is exceeded. Dieback continues until the area is returned to carrying capacity.

Many types of **species interactions** may occur within an ecosystem.

- **Mutualism:** Interaction between two species in which both species benefit.
- **Commensalism:** Interaction between two species in which one species benefits while the other experiences neither harm nor benefit.
- **Predation:** Interaction between two species in which one species preys upon or consumes the other.
- **Parasitism:** Interaction between two species in which one species (the**parasite**) uses or consumes part of another organism (the **host**) over a period of time, harming the host but not necessarily killing it.
- **Interspecific competition:** Competition among organisms of different species for some of the same resources. Both species suffer from this competition.
  - **Competitive exclusion:** Principle stating that no two species will use exactly the same resources, as the superior competitor will always outcompete and eventually kill off the inferior competitor.
  - **Niche:** A species' specific habitat, lifestyle, and resource usage habits. As a result of competitive exclusion, each species must occupy its own niche.

Evolution and Speciation

Species, interactions, and communities change over time, just as ecosystems do. Species change through the processes of **natural selection**and **evolution.**

Natural selection: First described by **Charles Darwin** in the mid-1800s, the process by which some genes within a population are selected to be replicated more frequently within a population. Those individuals possessing favorable genes—those that allow them to survive the best and reproduce the most—produce more offspring. Therefore, those favorable genes (and the associated traits) are represented in future populations more so than unfavorable genes. Natural selection is often termed the "survival of the fittest" principle.

Evolution: The process by which populations are changed through natural selection.

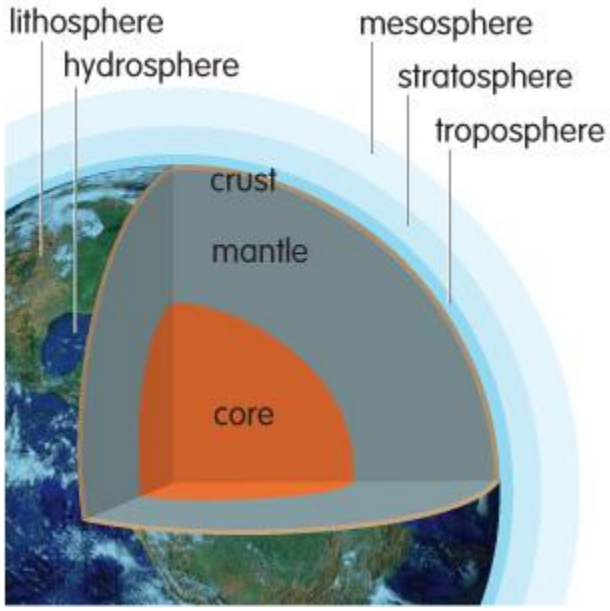
- **Coevolution:** The evolutionary change of two species together. Because species interact with one another, the evolution of one species may affect the evolution of another.
- **Speciation:** The formation of an entirely new species as a result of evolution. As populations of species evolve, they may become sufficiently different from their ancestors to be considered a new species. Speciation also can occur when geographic boundaries split populations from one another.

The Nonliving Environment

Environmental studies also takes into account the nonliving components of the Earth's environment, from the geology of the Earth itself to chemical and meteorological cycles taking place on the Earth's surface and in its atmosphere.

The Earth and Its Surroundings

The Earth formed 4.5 billion years ago. Since then, it has developed and modified four main physical environments that interact strongly with one another.



Atmosphere: The layer of gases surrounding the Earth. The atmosphere is divided into several levels:

- **Mesosphere:** The outermost layer of the atmosphere, extending from about 50–85km above the Earth's surface.
- **Stratosphere:** The middle level of the atmosphere, extending from about 13–50km above the Earth's surface.
- **Troposphere:** The lowest level of the atmosphere, extending from the Earth's surface to approximately10–13km above the surface.

Hydrosphere: The cumulative water supply in and on the Earth, including liquid water, frozen water, and water in gaseous form.

Biosphere: The approximately 12-mile-thick area of the Earth in which life exists, on and around its surface. The biosphere includes parts of the atmosphere, hydrosphere, and lithosphere.

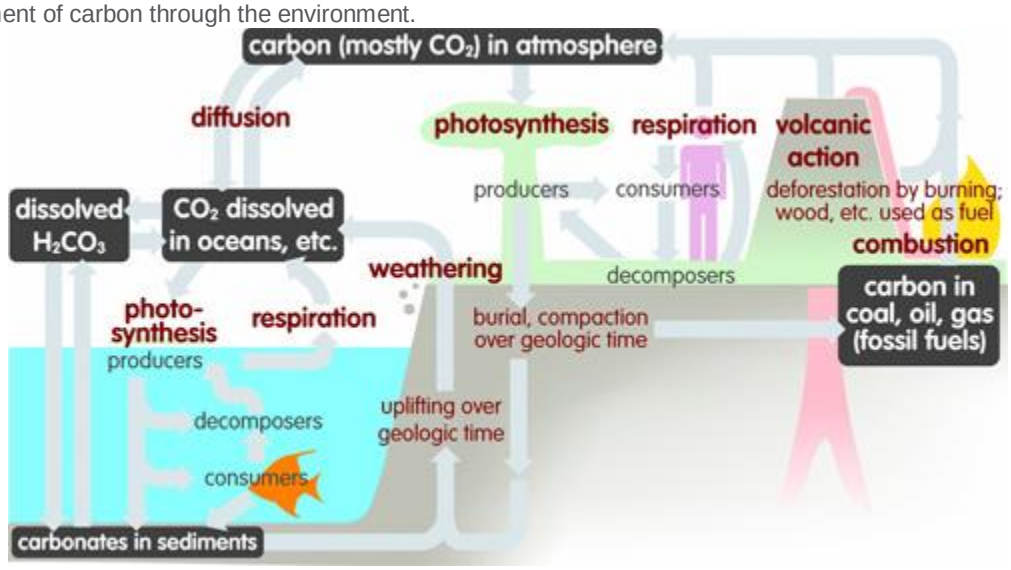
Lithosphere (geosphere): The solid portion of the Earth, which contains several layers:

- **Crust:** The outermost layer of the Earth, which makes up only about 2% of the Earth's volume. The crust is composed of eight principal elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. It is the only part of the lithosphere that humans have explored.
- **Mantle:** The largest layer of the lithosphere, located beneath the crust. The mantle is composed of a mix of solid and liquid metal and nonmetal elements, such as oxygen, iron, magnesium, and silicon.
- **Core:** The innermost central layer of the Earth. The core is composed of metals—mainly iron and some nickel—at very high temperatures.

Important Cycles in the Environment

A number of important **biogeochemical cycles** are constantly at work in the biosphere, recirculating nutrients and other elements through both the biotic and abiotic portions of ecosystems.

Carbon cycle: Carbon is the primary element of life and is found in all living organisms. The carbon cycle describes the movement of carbon through the environment.



- Carbon is found in the atmosphere (primarily as CO_2) and is also found dissolved in water.
- Producers convert carbon dioxide, through **photosynthesis,** to organic (carbon-containing compounds) that store energy.
- Consumers and decomposers use these carbon compounds to produce energy, breaking them down through **respiration,** thereby returning them to the atmosphere or to the water in the form of carbon dioxide.
- Carbon also can be **stored** in organic material, such as trees or fossil fuels.
  - The process of taking carbon from the environment and storing it in another form is known as **carbon sequestration.**
  - **Fossil fuels,** such as coal, oil, and natural gas, are partially broken-down plant or animal tissues that have been stored and transformed in the Earth's surface for long periods of time under high levels of heat or pressure.
- Carbon can then be released from the above stored forms through**combustion,** or burning.

Nitrogen cycle: Nitrogen is an important nutrient commonly found as a gas in the atmosphere.

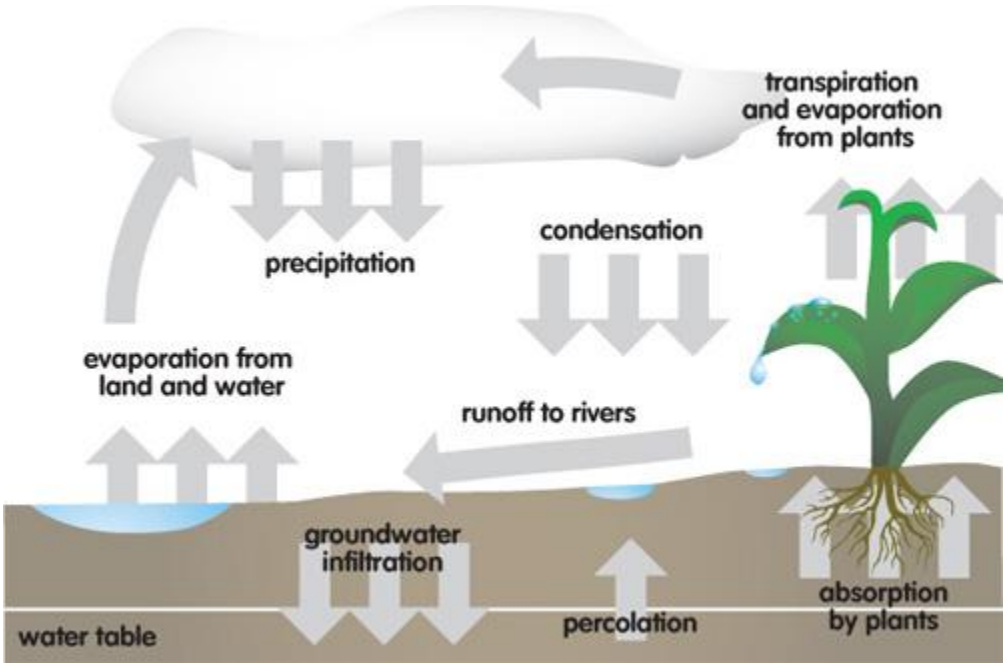
- Because plants and animals cannot use the gaseous form of nitrogen easily, it must first be converted to other usable forms by bacteria through**nitrogen fixation.**
- Some plants, called **legumes,** have nitrogen-fixing bacteria known as**rhizobium** in their roots. These plants take up the converted nitrogen and use it to form organic compounds, and then animals obtain these compounds by consuming the plants.
- After the plant or animal tissue dies or is discarded, the remaining nitrogen, usually in simple forms, is converted back into atmospheric form by specialized bacteria.

Phosphorus cycle: Phosphorus is a crucial element required for energy transfer in organisms, but much of the Earth's phosphorus is contained in rocks.

- When rocks containing phosphorous break down because of erosion or other factors, plants then take up this phosphorus directly, and animals consume the plants.
- Dissolved phosphorus and phosphorus waste eventually settles back to the ocean floor to become rock again.

Sulfur cycle: Another mineral, sulfur, is cycled in a manner similar to phosphorus.

Hydrologic cycle (water cycle): Water, the most vital requirement for most organisms, cycles through liquid, solid, and gaseous states throughout the Earth.



- Water **evaporates** (changes from liquid to gas) from surface water on the Earth and is taken into the atmosphere.
- It then **condenses** (changes from gas to liquid or solid) and falls down as**precipitation** (rain, snow, or ice) to the Earth's surface.
- Some of this precipitated water ends up as **runoff** (moving from the land back into water bodies), while some is taken up by plants.
- Plants may either **transpire** the water (pass it out through their pores back into the atmosphere), or the plants may die or be consumed, passing that water onto higher level organisms, detritovores, or back onto land.
- In addition to being stored in surface water, much of the Earth's water exists as **groundwater,** below the Earth's surface.