Ecosystems and Biomes

Ecologists categorize significant factors in an ecosystem as either abiotic (non-living) or biotic (living). Biogeochemical cycles show how nutrients are recycled through an ecosystem, while an energy pyramid demonstrates the flow of energy through organisms in an ecosystem.
Food chains and food webs help illustrate the specific means by which nutrients and energy are transferred between organisms in an ecosystem. On a larger scale, biomes represent the collection of many different, interrelated ecosystems that have characteristic inhabitants and typical climatic patterns. Terrestrial biomes are much better described and understood than aquatic ecosystems.

SECTION 1 - Ecosystems

Recall that an ecosystem is an assemblage of all of the organisms making up the biological communities in a designated environment, as well as the abiotic factors present. Certain geochemical cycles link all ecosystems and explain the means by which essential nutrients are effectively recycled as they are passed between organisms.

Biogeochemical Cycles

Four major biogeochemical cycles are of significance to ecologists, namely the carbon, water, nitrogen, and phosphorus cycles.

1. The *carbon* cycle is central to biology given that organisms are built from and dependent on carbon. The primary way in which carbon is transferred between organisms is through the dual gas exchange processes involved within photosynthesis and cellular respiration. As autotrophs absorb carbon dioxide (CO_2) to build glucose, they remove the same waste product that heterotrophs release into the atmosphere through cell respiration. When heterotrophs consume the autotrophs, they gain access to carbon for their own metabolism. Today's carbon cycle on Earth is vastly out of balance, as combustion of fossil fuels and other products of human industry introduce more CO_2 into the atmosphere, while through deforestation, humans remove organisms that absorb CO_2.
2. The *water* cycle is also important in understanding how organisms have ready access to that ever-important inorganic resource. Organisms give off water vapor through many processes (consider transpiration in plants or respiratory condensation in animals) and also lose liquid water through evaporative cooling (sweating) or excretion of nitrogenous wastes in urine. Animals obtain water through drinking and eating, as well as by creating it metabolically during anabolism. Plants and fungi obtain it through absorption from the roots and hyphae, respectively.
3. The *nitrogen* cycle helps scientists understand how organisms recycle the necessary nitrogen for proteins and nucleic acids. Soil bacteria are primarily responsible for most conversions within the cycle, as they initially convert atmospheric nitrogen gas into an ionic form such as a nitrate (NO>) or a nitrite (NO>) that a plant can then absorb as it takes up water through its roots. Other nitrogenous waste products from excretion and decomposition are returned to the soil as well, and other bacteria participate in converting them to the ammonium ion (NH_4).
4. The *phosphorus* cycle similarly helps explain how the phosphorus that is so crucial for nucleic acid structure is recycled through an ecosystem. It involves more geologic processes (such as the weathering of rocks) than biological ones (predominantly decomposition) that produce the phosphate ion (PO_4). This ionic form is then readily absorbed by plants and fungi and ingested by the animals that consume them.

Trophic Levels and the Energy Pyramid
Organisms within an ecosystem are organized energetically into trophic levels by their positions within the larger energy transfer process. The *primary producers* are placed at the bottom of the pyramid; they are usually photosynthetic (although chemosynthetic bacteria may constitute this level in specialized ecosystems) and possess the most biomass of any of the trophic levels overall. The next trophic level is made up of *primary consumers* (mainly herbivores) that have less biomass than the producers on which they depend. As the primary consumers eat the producers, they obtain energy and nutrients. The pattern continues with subsequent trophic levels (secondary consumers, tertiary consumers, and so on). Nutrients are passed efficiently from organism to organism, but a great deal of energy is lost in the process, meaning that limited sequential transfers can occur. When trophic levels are placed on top of each other in order of energetic dependence, they taper with each level, creating an energy pyramid. Due to the 10 percent rule, which states that the maximum level of net energy transferred to the next trophic level is 10 percent, the highest level of consumer possible (but not always present) in any natural ecosystem
is typically quaternary (fourth level).

Food Chains and Food Webs
A food chain is a specific sequence of energy transfer steps that are possible between successive trophic levels within a given ecosystem. It begins with a primary producer (such as a lava cactus) and ends with a top-level carnivore (such as a Galapagos hawk). When the intersection of the various food chains within an ecosystem is examined in its composite form, it is called a *food* web.

** When studying the concept of the energy pyramid, it is easy to assume that the trophic level just above the primary producers comprises the secondary consumers because of the sequential-sounding nature of their names. Remember that there is only one level of producers, and it is always situated on the bottom of the pyramid. The next level up must then be the first-order, or primary, consumers. Secondary consumers and so on follow.*
** In attempting to keep track of the mechanisms and significance of each of the biogeochemical cycles, it is helpful to remember the CHON elements and their significance in the different organic macromolecules. The CHO elements (carbon, hydrogen, and oxygen) are fundamental to all four of the macromolecule types, from carbohydrates and lipids to proteins and nucleic acids. Nitrogen (N) is common only in proteins and nucleic acids. Phosphorus is much less common in organic molecules overall, although it is abundant in nucleic acids as a fundamental part of each monomer (the phosphate group).*

SECTION 2 – Biomes
Terrestrial and Aquatic Biomes
Recall that biomes are large geographic ranges with characteristic climatic patterns and biodiversity. Terrestrial biomes, like the deciduous forests and savannas, are well described; aquatic biomes, especially the marine biomes and the deep sea in particular, are less so. Until recently, when deep-sea submersible technology became available for research, biologists knew very little about what existed far out of the reach of scuba divers and traditional submarines.

Tundra
The *tundra* is the northernmost biome, characterized by very low annual temperatures and relatively little precipitation. In terms of biotic composition, it typically has sparse, small vegetation and no large shrubs or trees. This is in large part due to its permanently frozen soil called *permafrost* that lies just beneath the upper soil.

Taiga *(or* **Coniferous Forest**)
The biome just to the south of the tundra is typically taiga, or coniferous forest. It is characterized by low temperatures and significant precipitation. The dominant plant species are usually conifers, trees bearing cones and needle like leaves. These are well adapted for the nutrient-poor soil and the large amounts of snow that would potentially collect on broad leaves.

Deciduous Forest (**or Temperate Broadleaf Forest**)
The deciduous forest often borders the taiga just to the south. Its soil is richer in nutrients, and it experiences more distinct seasons. A moderate amount of rainfall is typical in the deciduous forest, as are broadleaf trees that lose their leaves in the winter when the sun's intensity is not enough to support them. Conifers and evergreens are also common there.

Grasslands
Different grassland biomes exist, including temperate grasslands, savannas, and chaparrals. The *temperate grasslands* typically grow at the same latitude as the deciduous forests, but they are located toward the interior of continents instead of near the coastlines. The relatively low levels of precipitation do not support tall trees, so thick grasses and shrubs dominate instead.
In the *savannas,* some tall trees and large shrubs are scattered throughout the grassland, supported by the annual rainy season. The grasses of both temperate grasslands and savannas support large herds of grazing animals. *Chaparral* is a grassland-desert hybrid biome that is limited to the coastal regions of the Mediterranean and Southern California and characterized by a very mild climate.

Deserts
Deserts are well known for their very low levels of annual precipitation. Although often assumed to be hot, many deserts experience extremes in temperature, with relatively low temperatures at night. Desert vegetation is typically sparse and rich with species, such as fleshy cacti and succulents, that have specially adapted for such an extreme climate.

Rain Forests
Tropical rain forests are often described as the most biodiverse terrestrial biome. Positioned near the equator, they are characterized by warm temperatures, consistent sunlight intensity, and high levels of precipitation throughout the year. They are known for the thick canopy of tall trees that results, many of which are coated in smaller plants called *epiphytes,* which have adapted to grow in the upper branches without ever rooting into the soil.

Aquatic Biomes
While ecologists are more familiar with terrestrial biomes, aquatic biomes cover a much larger proportion of the Earth's surface (approximately 70 percent). The extreme depths of the ocean (average depth is more than 3.5 kilometers) also contribute to a massive volume of space within which marine organisms can live. Marine ecologists divide the oceans into zones; both the distance from the shore and the distance beneath the ocean's surface are significant in describing the zone. Generally speaking, organisms that occupy the upper levels of the water table and have access to the sun's radiant energy inhabit the *photic zone.* Those living beneath that level occupy the *aphotic zone.* Organisms living on the ocean floor, whether photic or aphotic, are called benthic.
The photic zone that is nearest the shoreline and is partially exposed to air on a daily basis with the ebb and flow of the tides is called the *intertidal zone.* Just past the intertidal zone is the *neritic zone,*

which stretches out as far as does the continental shelf. It is the most productive part of the ocean, rich in nutrients and home to coral reefs. Past the continental shelf lies the pelagic *zone*, or open ocean. The aphotic depths of the open ocean are called the *oceanic zone.* Some of the least understood biomes exist here, including deep-sea vent communities that are ultimately supported by chemosynthetic bacteria.

Main Ocean Zones

Freshwater biomes include moving bodies of water like rivers and streams, sedentary bodies like lakes and ponds, and transitory bodies like freshwater estuaries. Rivers and streams are bodies of freshwater that move down a slope toward a mouth. Murky, slow-moving rivers tend to be richer in nutrients and are thus more supportive of life than rocky, fast-moving rivers with clear water. Most lakes are described as *eutrophic*, also murky in appearance due to the lush vegetation and nutrient-rich waters. Fewer lakes are characterized as *oligotrophic*, possessing clear waters with rocky bottoms and supporting relatively little organic matter.

** Benthic does not necessarily imply aphotic, although this is an easy mistake.*

** Remember that benthic just means "bottom-dwelling." Tide pool communities in the intertidal zone and coral reef communities are examples of areas that are both benthic and photic.*

** It can sometimes seem overwhelming to keep track of the various ocean zones. There are a few conditions to keep in mind. First, does the zone receivesunlight (that is, is it photic)? If so, it may be intertidal if it's at the shoreline, neritic if it's above the continental shelf, or pelagic if it's part of the openocean. If the zone does not receive sunlight (that is, it's aphotic), then it's likely part of the oceanic zone.*

ASSESSMENT QUESTIONS

1. Which of the following trophic levels is mismatched to its description?
    a. Secondary consumer — carnivore
    b. Primary producer —au totroph
    c. Tertiary consumer — carnivore
    d. Primary producer — omnivore
2. Which of the following cycles is primarily responsible for recycling nutrient components of proteins?
    a. Phosphorus cycle
    b. Nitrogen cycle
    c. Carbon cycle
    d. Both a and c
3. Use the theme of continuity and variation to describe the current imbalance of the carbon cycle on Earth.
4. Which of the following terrestrial biornes is matched with the *incorrect* characteristic?
    a. Taiga — cone-bearing trees
    b. Temperate grassland — epiphytes
    c. Deciduous forest — broadleaf trees
    d. Tundra — permafrost
5. Which terrestrial biome is characterized as having the highest degree of species richness?
    a. Tundra
    b. Temperate grassland
    c. Tropical rain forest
    d. Desert
6. Use the theme of the relationship between structure and function to describe the concept of eutrophic lakes and slow-moving rivers.