BIOL 300 – Foundations of Biology
Summer 2017 – Telleen
Lecture Outline

Ecology and Ecosystems

I. What is **ecology**?

A. Derived from the Greek:
   1. *oikos* – house
   2. *logos* – study of
   3. study of the house in which we live

B. A more specific definition is this:

   The study of how organisms that live in a particular place interact with each other and their physical habitat.

II. Levels of ecological organization

A. Ecology looks at various levels of complexity that are hierarchical.

B. We have already talked about genes, individuals, and populations. Basically ecology starts at the level of populations. Here are the levels of organization:
   1. **Populations** – Individuals of the same species that live together, potentially interbreed, share the same habitat, and use the same pool of resources
   2. **Communities –** Populations of different species that live together in a particular habitat. Different species typically use different resources in the habitat.
   3. **Ecosystems –** A community and the non-living factors which it interacts with. Ecosystems are affected by the flow of energy and the cycling of nutrients
   4. **Biomes –** Major assemblages of plants/animals/microbes that occur over wide geographic areas with distinct physical characteristics. These can be terrestrial (land-based), aquatic (freshwater), or marine (salt water). Examples of biomes: desert, tropical rainforests, tundra, grassland, etc.
   5. **Biosphere –** All the Earth's biomes, which are interconnected and interacting.

III. A closer look at ecosystems

A. Ecosystems are the most complex biological system a biologist can study

B. Consists of a biological community and it's physical environment

C. Energy flows through ecosystems via a food chain (or food web)

D. All energy in ecosystems is ultimately derived from the sun (via photosynthetic organisms)

E. Organisms can be grouped based on how they acquire energy:
   1. **Producers**, also called **autotrophs**, are photosynthetic organisms
   2. **Consumers**, also called **heterotrophs**, consist organisms that feed from other organisms.
   3. There are different kinds of consumers:

        a. **Herbivores**, also called primary consumers, eat the producers
        b. **Carnivores** eat other animals. They are usually secondary, tertiary, or quaternary consumers.
        c. **Omnivores** are animals that eat both producers and other animals
        d. **Detritivores**, also called scavengers, are animals that eat dead organisms
        e. **Decomposers**, which are usually bacteria or fungi, break down and live off of organic substances and make the nutrients available to other organisms
    4. Detritivores and/or decomposers are present in every ecosystem.
F. Energy flows through **trophic levels**
    1. **Trophic levels** are composed of organisms whose energy source is the same number of consumption steps away from the sun.
    2. This means that the primary producers have trophic level of 1, because they derive their energy from the sun.
    3. Herbivores are the primary consumers and have a trophic level of 2, because they consume the producers
    4. Carnivores would have a trophic level of 3 or more
    5. Decomposers and detritivores are not typically assigned a trophic level because they feed from almost all levels
G. **Biomass** is a measure of the total weight of all organisms
    1. e.g. an ecosystems biomass is the weight of all organisms in it
    2. the biomass of the primary producers is the weight of all the photosynthetic organisms, etc.
H. Energy is lost as it flows through an ecosystem. Each organisms uses some of the energy for growth and cellular respiration and excretes some of it. For example, there might be 1000 calories (a measure of energy) captured by the producers, but only 150 of those calories gets passed on to the herbivores that eat them. When a carnivore eats the herbivore, only 30 of the 150 calories is passed along, and so on.
I. **Ecological pyramids** show how the biomass and energy are distributed to different trophic levels in an ecosystem. Typically (in terms of biomass, number of individuals, and energy): producers > herbivores (1^{o} consumers) > carnivores (2^{o} consumers) > 3^{o} consumers, and so on. The biomass of decomposers varies, but is usually less than all the other non-producers combined.
J. The loss of energy puts limits on the number of top-level carnivores a community can support.

IV. Nutrient Cycles

A. Unlike energy, the physical components of ecosystems are passed around and reused within ecosystems (and sometimes throughout biomes and the biosphere).
B. This reuse is often called recycling, or more commonly: **cycling**

C. Materials that are constantly recycled include all the chemicals that make up the soil, water, and air.
D. While many others are important, we will only discuss the cycling of several materials that are of critical importance to healthy ecosystems:
    1. Water
    2. Carbon
    3. Nitrogen
    4. Phosphorus

A. The Water Cycle

1. The availability of water and the way it cycles has the largest influence of any non-living component on the health on an ecosystem. A diagram of an example water cycle is shown in the textbook.
2. There are two ways that water cycles in an ecosystem:
    a. The **environmental water cycle**: This occurs as water in the environment **evaporates** as it is heated by the sun. After the water vapor enters the atmosphere, it condenses and falls as rain or snow.
    b. The **organismic water cycle**: Water does not return directly to the atmosphere. Instead, it is taken up by the roots of plants. After passing through the plants to the leaves, water evaporates into the atmosphere in a process called **transpiration**. Once the water is returned to the atmosphere it enters the environmental water cycle
3. The water cycle can be broken, which leads to significant impacts on the ecosystem involved. For example, very dense forest ecosystems cycle most their water through transpiration. However, clear cutting of large areas of forest break the water cycle because ground water no longer enters the atmosphere via the trees. This causes the excess groundwater to flow away from the ecosystem toward the sea leading to a net loss of water, which can turn a lush tropical rainforest into a semi-arid desert.

B. The Carbon Cycle

4. The Earth's atmosphere contains lots of carbon in the form of carbon dioxide (CO_2), which cycles between the atmosphere and living organisms
5. The cycle is started by plants (and other photosynthetic organisms) that fix the carbon to make organic molecules, essentially trapping the carbon in the living sphere
6. Carbon is returned to the atmosphere (in the form of CO_2) through **respiration, combustion, and erosion**
7. Respiration (as we discussed in the first part of the course) is the extraction of energy from organic molecules. Almost all living organisms respire (even plants). This process uses up oxygen (O_2) and produces CO_2
8. Lots of carbon is trapped in the form of wood (and other forms of dead material), where it can remain for many years. This carbon can be

released by burning, or combustion. Fossil fuels, for example, are dead organic material that becomes buried in sediment and is gradually transformed into coal or oil and is only released back into the atmosphere when it is burned

9. CO_2 is also dissolved in sea water. Large amounts of carbon are bound up in the calcium carbonate shells of marine organisms. The discarded shells eventually sink and are covered with sediments and become limestone. As oceans recede, the limestone is exposed and will erode allowing the carbonate to wash back into the oceans and re-enter the cycle.

G. The cycling of other chemicals

1. The **Nitrogen cycle**
    a. Nitrogen is present in large amounts in living organisms (particularly in amino acids and proteins), as well as in the atmosphere (in the form N_2)
    b. Most living organisms cannot use N_2, so they rely on certain organisms to convert N_2 to ammonia/ammonium (NH_3/NH_4^+), which can be used. This process is called **nitrogen fixation**.
2. The **Phosphorus cycle**
    a. Phosphorus is an essential element because it is a key component of DNA/RNA and ATP.
    b. P is often in very limited supply in the soil because it cannot form a gas so it is not available in the atmosphere.
    c. P exists in the soil and rock as calcium phosphate
    d. Phosphate is taken up from the soil by plants and then passed to other organisms. When organisms die, the organic P is converted back into phosphorus ions, which completes the cycle
    e. Excess phosphorus in some aquatic and marine ecosystems can cause significant problems because low phosphorus levels are often the limiting factor for algal growth. Pollution with fertilizers can sometimes cause algal blooms which use up all the oxygen in the ecosystem and kill off other organisms leaving behind a dead zone with no oxygen or living organisms. This process is called **eutrophication**.
3. Other chemicals cycle as well and can sometimes cause damage as they move through an ecosystem (even though many are absolutely essential for life). For example, acid rain is caused by excess sulfur in the atmosphere, while heavy metals such as cadmium, mercury, and lead can accumulated in higher organisms as they move through the trophic levels in a process called **biological magnification**.

V. Populations and Communities
   A. Population Growth
      1. **Population size**, which is the number of individuals in a population, is a critical property of any population. If a species consists of only small populations, it is often susceptible to environmental changes and extinction
      2. **Population density**, the number of individuals that occur in a unit of area, is also a critical factor.
      3. **Population dispersion**, the distribution of individuals within the populations range, is also significant
      4. **Population growth**, the increase in size of a population, is key, as are the factor in nature which limit such growth
      5. The rate of actual population growth is the difference between the birthrate and the death rate corrected for the movement of individuals into or out of the population.
      6. Populations will eventually stabilize at a certain size due to limitations of the environment such as space, light, nutrients, water, etc. The size of a population when it stabilizes is called the **carrying capacity**, the maximum number of individuals that an area can support. This is dynamic and can change as the environment does, and populations will tend to grow to the carrying capacity of their environment.
      7. Growth curves represent models of population growth. If there was no competition for resources and no limiting factors, populations would grow exponentially. However, most natural populations exhibit **logistic growth**, which produces a sigmoidal growth curve.
   B. **Population Demography** is the statistical study of populations
      1. Age structure
         a. Annual plant and insect populations who reproduce in one season and then die contain members who are all the same age.
         b. However, perennial plants and longer-lived animals contain individuals of various ages in the population
         c. A group of individuals of the same age are called a **cohort**
         d. Each cohort has a characteristic birthrate, called **fecundity**, and a characteristic death rate, called **mortality**. The difference between these two is the growth rate (as we already discussed)
         e. The relative number of individuals in each cohort is called the age structure
      2. **Sex ratio** is the proportion of males and females in a population
      3. Populations tend to stabilize in a constant environment, resulting in a particular **age distribution** (proportion of individuals in each cohort) within the population. This can be represented in a **survivorship curve**, which shows the likelihood of mortality at different ages.
   C. Communities and interaction between species
      1. Within a community, each organism occupies a particular biological role, or **niche**. A niche is the total of all the ways an organism uses its

resources (including food, space, etc), thus it is essentially a pattern of living.

2. Situations where two different organisms attempt to use the same resource are called **competition**. Competition can be between members of the same species or of different species and is usually greatest between organisms that obtain food in similar ways.
3. Competition usually favors the organism that can use the resource most efficiently. When niches overlap one of two things can happen:
    a. **competitive exclusion**: one organism wins and the other is driven out
    b. **resource partitioning**: dividing up of the resources two create two realized niches
4. Usually, competition is not too persistent in nature: Either one of the two species will go extinct or natural selection will reduce the competition by changes in the characteristics of the species.

D. Coevolution, Symbiosis, and Parasitism

1. Not all interactions between species are competitive
2. Organisms that live together in communities have adjusted to living with each other over millions of years. This is called **coevolution**. For example, many features of flowering plants have evolved in relation to the dispersal of seeds or gametes by animals. These animals also evolve other traits to help them obtain food, etc. from the plants they visit. Another example is to think of humans as coevolving with all of our agricultural plants and animals.
3. **Symbiosis** is two or more kinds of organisms living together in more or less permanent relationships. An example is lichens, which are a symbiosis between fungi and either algae or cyanobacteria. Another example is the leaf cutter ants, who use the leaf cuttings to cultivate fungal gardens, which are their primary food source.
4. Symbioses come in three flavors:
    a. **Mutualism**, in which both participating species benefit
    b. **Parasitism**, in which one species benefits at the expense of the other
    c. **Commensalism**, in which one species benefits, while the other neither benefits nor suffers.
5. Predator-Prey interactions can affect the sizes of populations, resulting in a **predator-prey cycle**. Predation can reduce competition and prevent certain species from completely dominating the ecosystem

E. **Ecological succession** refers to the changes in communities that occurs through competition and cooperation

1. Succession occurs because species alter the habitat and the resources available in it, often in ways that favor other species, but may be detrimental to the species itself.
2. Communities evolve to have greater total biomass and **species richness**, the number of total species in an ecosystem.