Notes

Biology 101, Fall 2007
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Topic: How do ecosystems work?

Reading: Chapter 28

Main concepts:

- Energy travels straight through an ecosystem. It can be transformed (light energy to chemical energy, chemical energy to motion, etc.), but most will be lost as heat with each transformation and with each transfer from organism to organism (through predation). Potentially, all energy that enters an ecosystem can leave that ecosystem as heat. Energy is not recycled.
- Materials cycle through an ecosystem. Small amounts may enter as particles from space, or leave as lost gasses to space, but most is conserved on the earth. Materials may take on different chemical forms (different compounds of nitrogen, for example), and can be transferred from organism to organism without loss.

Energy transfer

- In most natural communities on earth, energy enters the system as sunlight (exceptions include communities in deep sea ocean trenches which are powered by chemosynthesis). Photosynthetic organisms capture sun energy in order to power photosynthesis: the process of taking carbon from the atmosphere and making carbon compounds. Plants make these for their own use: as an energy source, and as material for building tissue.
- A trophic level is a feeding level.
  - Producer: Autotrophs. These organisms "produce" energy-rich organic compounds from inorganic molecules. They produce these molecules for their own use.
  - Primary consumer: Herbivores. Organisms that subsist on producers to get their energy and materials.
  - Secondary consumers: Carnivores. Organisms that feed on other heterotrophs to get their energy and materials.
  - Tertiary consumers, quaternary consumers, etc: Carnivores that consume an organism just below them on the food chain.
- Many organisms feed on several trophic levels. For example, an omnivore such as a human will be acting as a primary consumer when eating plants (such as fruits, vegetables, bread, etc.), as a primary consumer if eating herbivores (such as cows, chickens, etc.), and a higher level consumer if eating carnivores (such as salmon, tuna, etc.).
- Energy is passed from one trophic level to the next through herbivory and predation. Most of the transferred energy is used by the consumer and lost as heat and motion. Some is stored in the organism's tissues.
- Because energy is lost at each step of the food chain, organisms that are high on the chain require a much broader base of producers to support the chain that supports them than do organisms lower on the chain.

Material cycling

- Materials are also passed from one trophic level to the next through herbivory and predation. Heterotrophs must consume in order to get materials for building their tissues.
- Some materials, particularly environmental toxins, can accumulate in body tissues. For example, the now-illegal pesticide DDT accumulated in the environment. Insects that ate DDT-sprayed plants accumulated the toxin in their tissues. Birds that ate the insects were eating concentrated DDT, and as a consequence, stored even higher levels in their own tissues. Falcons that preyed on these birds accumulated even higher levels, to the point that they were poisoned by it, or laid thin-shelled eggs that broke easily.
- The carbon cycle is operated largely by chloroplasts (and cyanobacteria) which fix carbon dioxide into carbon compounds, and mitochondria (and heterotrophic bacteria) which break apart carbon compounds for energy, releasing carbon dioxide. Carbon can also be sequestered (stored) in the tissues of living organisms, in soil humus, in bodies of water, and may be stored for millions of years in layers of old swamps that over millions of years become peat, coal beds, petroleum, and other fossil fuels.
- The nitrogen cycle is operated largely by soil bacterial. Some fix atmospheric nitrogen into nitrogen compounds, which plants then absorb. Others break nitrogen compounds apart and release nitrogen gas. Many of the nitrogen-fixing bacteria have a relationship with plant roots, especially with plants in the pea and bean family.

- The phosphorous cycle includes weathering of phosphate-rich rock, which releases phosphorous compounds into the soil. Plants absorb phosphates, which they use in their tissues (DNA and cell membrane lipids both require phosphorous). Decaying organisms return phosphorous to the soil, and some is deposited in marine sediments that may eventually be compressed into rock.
- Humans have created an acid rain problem by increasing levels of nitrogen and sulfur in the atmosphere at rates higher than nature can cycle them.
- Nitrogen compounds uses as fertilizers on farms, gardens, lawns, and golf courses run off into surface water, causing overgrowth of algaes in aquatic environments.
- Humans have increased phosphates in the waterways by using detergents that contain phosphates, and through dumping of wastes of certain industrial processes. Phosphates in the waterways can cause overgrowth of algaes in aquatic environments.
- Humans are contributing to global climate change by burning fossil fuels for energy. While nature took hundreds of millions of years to store carbon as fossil fuel, humans have used nearly half of the known oil, coal, and natural gas reserves in less than 200 years, releasing large quantities of carbon dioxide into the atmosphere at rates much higher than nature can cycle the carbon, while at the same time engaging in land use practices that reduce carbon fixing. Carbon dioxide and other greenhouse gases affect the ways in which heat from the sun in retained in the oceans and atmosphere. Levels of these gases in the atmosphere have been linked to changes in global oceanic and atmospheric temperatures. While it is certainly possible that the earth is natural warming trend, human activity has been strongly linked to an acceleration in global climate change beyond what is known about natural cycles. Effects of global climate change vary from one part of the planet to another, depending on topography, and nearness to certain major oceanic currents, since ocean currents affect local climates.

Common misconceptions:

- Students often draw food webs with arrows traveling from predator to prey, indicating the action of predator pouncing on prey. The arrows should show in which direction energy flows: from that which is eaten to those that eat it.
- Students sometimes try to draw energy flow as a cycle. Energy may be transferred, but it is not recycled. Is source is the sun, and energy that is lost to the atmosphere as heat does not return to the sun.
- Some students believe that energy accumulates in the food chain, and believe this is why a pound of meat has more energy (calories) than a pound of vegetables. The opposite is true: energy is lost at each step of the food chain. Organisms eat to satisfy their own energy needs: they *use* the energy they consume. They do not consume it to “store” it for the next consumer. A piece of chicken that supplies 300 calories required 3000 calories or more of grain and other chicken food to create.
- The news media create an impression that scientists are evenly divided in a debate over whether humans contribute to global climate change or not. In truth, the vast majority of oceanographers, climatologists, and glaciologists who spend their lives studying the earth’s climate agree that 1) the earth’s oceans and atmosphere are warming, 2) human activity has greatly accelerated what might otherwise be a slow, natural warming trend, 3) human activity may cause warming beyond what would be caused by a normal warming trend, 4) negative consequences of this warming trend have already been observed, and 5) if human activity caused this to happen, human choices can slow or reverse the effect. Global warming has been known about and studied since the 1950’s.

Reading notes:

- What is the source of energy for most ecosystems on Earth?
- Define “trophic level.” List and define the different trophic levels. What are the relationships between the following terms? Producer, autotroph; consumer, heterotroph; primary consumer, herbivore; secondary consumer; carnivore. Is it possible for an organism to feed on several different trophic levels?
- Define “food chain” and “food web.” How are they similar, and how are they different? What do the arrows in a food web represent?
- Describe the energy pyramid. What do the levels of the pyramid represent? Why does the pyramid get smaller for each trophic level?
- Define the following and state their importance in food webs: detritus feeders, decomposers, scavengers. How are they similar, and how are they different?

- Create an annotated diagram of the carbon cycle, noting what happens at each step. Lewis Thomas, a famous science writer, once noted that mitochondria and chloroplasts (cell organelles) "run the place." In light of what you know about the carbon cycle, what does this mean?
- Create an annotated diagram of the nitrogen cycle, noting what happens at each step. Why are bacteria so important in this cycle? If a gardener used heat or a chemical to sterilize the soil, what would happen to the nitrogen cycle in the garden? If farming practices that rely on chemical fertilizers reduce the humus that feeds the soil microbial food chain, what does this do to the nitrogen cycle on farms?
- Create an annotated diagram of the phosphorous cycle, noting what happens at each step.
- Explain the effects of carbon dioxide in the atmosphere on global climate. What evidence shows that the earth is in a warming trend? What evidence shows that humans are accelerating global warming? What are some of the predicted consequences of global climate change?

Useful websites:

- "Food Chain Quick Flick" (http://magma.nationalgeographic.com/ngexplorer/0309/quickflicks/index.html) is a short animation for kids on the food chain principle.
- "Food Chain as a System" (http://www.physicalgeography.net/fundamentals/4e.html) is a short tutorial on energy loss at each step of the chain.
- "The Carbon Cycle" (http://www.purchon.com/ecology/carbon.htm) is an animation that operates by dragging your cursor over the words that describe the processes in the cycle.
- "The Nitrogen Cycle" (http://www.biology.ualberta.ca/facilities/multimedia/index.php?Page=280) is one of several ecology animations on this website.
- "RealClimate" (http://www.realclimate.org/) is a forum where climate scientists discuss climate research and climate news.
- "National Oceanic and Atmospheric Association" (http://www.noaa.gov/) has information on the atmosphere, world's oceans, and global climate change.