Energy and Nutrient Relations

Chapter 7

This diagram illustrates the flow of energy and nutrient relations in an ecosystem. It shows the different trophic levels:

- **Primary Consumers (Herbivores)**: These are the first level of consumers, feeding on producers (plants).
- **Secondary Consumers (Small Carnivores)**: Feed on primary consumers.
- **Tertiary Consumers (Large Carnivores)**: Feed on secondary consumers.

The diagram also indicates two types of nutritional sources:

- **Autotrophic**: Producers (plants) that can produce their own food via photosynthesis.
- **Heterotrophic**: Organisms that cannot produce their own food and must consume other organisms.

Energy and heat energy lost from the system are also depicted in the diagram.
Energy Sources

- Organisms can be classified by trophic (feeding) levels.
  - **Autotrophs** use inorganic sources of carbon and energy.
    - **Photosynthetic**: Use CO\(_2\) as carbon source, and sunlight as energy.
    - **Chemosynthetic**: Use inorganic molecules as source of carbon and energy.
  - **Heterotrophs** use organic molecules as sources of carbon and energy.
<table>
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<th></th>
<th>Heterotrophic</th>
<th>Photosynthetic</th>
<th>Chemosynthetic</th>
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<tr>
<td><strong>Prokaryotes</strong></td>
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<tr>
<td>(Bacteria, Archaea)</td>
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<tr>
<td><strong>Protists</strong></td>
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<tr>
<td><strong>Plants</strong></td>
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<td><strong>Fungi</strong></td>
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<td><strong>Animals</strong></td>
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- Prokaryotes draw on a greater variety of energy sources than any other group of organisms.

- Protists include many heterotrophic and photosynthetic species.

- Plants are mainly photosynthetic, with a few heterotrophic species.

- Fungi and animals are all heterotrophic.
Photosynthesis

- The synthesis of organic molecules using CO$_2$ as a source of carbon and light as the energy source
  - Light travels in waves in particles called photons
  - Photosynthetically Active Radiation (PAR)
    - Wavelengths of light used in photosynthesis (approx. 400-700 nm)

Photosynthesis converts CO$_2$ to Glucose!
Photosynthesis

• Chlorophyll absorbs photons.
  • Landscapes, water, and organisms can all change the amount and quality of light reaching an area.

There are different ways that photosynthesizers do it!
Photosynthetic Pathways

- Three different pathways
  - $\text{C}_3$ Photosynthesis
  - $\text{C}_4$ Photosynthesis
  - CAM Photosynthesis
Photosynthetic Pathways - $C_3$ Photosynthesis

- Used by most plants and algae.
- $CO_2 +$ ribulose bisphosphate (5 carbon sugar) = phosphoglyceric acid (3 carbon acid)
  - To fix carbon, plants must open stomata to let in $CO_2$.

- Water gradient may allow water to escape.

Where would you expect to find $C_3$ plants?
Some C₃ Plants

Wheat, rice, potatoes
Photosynthetic Pathways - $C_4$ Photosynthesis

- Reduces internal $CO_2$ concentrations.
  - Increases rate of $CO_2$ diffusion inward.
  - Need fewer stomata open – **conserves water**!

- Photosynthesis separated in space – $C_4$ molecule formed in mesophyll, then photosynthesis occurs in bundle sheath cell.

Where would you expect to find $C_4$ plants?
Some $C_4$ plants

Corn, sugarcane
Photosynthetic Pathways

• CAM Photosynthesis
  ❖ (Crassulacean Acid Metabolism)
  ❖ Photosynthesis separated in time
  ❖ Found mainly in succulent (water-storing) plants in arid environments
    ▪ Carbon fixation takes place at night – greatly reduced water loss
    ▪ Low rates of photosynthesis.
Results from the 3 photosynthetic pathways

- $C_3$ plants lose 380-900 g water for every gram of dry tissue produced
- $C_4$ plants lose 250-350 g water per gram of tissue produced
- CAM plants lose 50 g water per gram of tissue produced
Chemosynthetic Autotrophs

• Synthesize organic molecules using CO$_2$ as a carbon source and inorganic molecules as an energy source.
• Discovered in 1977
  ♦ nutrients discharged through oceanic rift.
    • Chemosynthetic bacteria are the autotrophs that the communities depend on.
      ➢ Free-living forms.
      ➢ Living within tissue of invertebrates.

http://www.youtube.com/watch?v=AlHJqA8YkoI
Heterotrophs

- Need to eat other things – source of carbon and energy
- Three Feeding Methods of Heterotrophs:
  - **Herbivores**: Feed on plants.
  - **Carnivores**: Feed on animal flesh.
  - **Detritivores**: Feed on non-living organic matter.

**Match ‘em!**
Chemical Composition and Nutrient Requirements

- Five elements make up 93-97% of biomass of plants, animals, fungi and bacteria:
  - Carbon
  - Oxygen
  - Hydrogen
  - Nitrogen
  - Phosphorus
It be dangerous to eat sometimes!!!

Herbivores

- Must overcome plant physical and chemical defenses.
  - Physical
    - Cellulose; lignin; silica
  - Chemical
    - Toxins
    - Digestion Reducing Compounds
Prey Defenses:

- Aposematic Coloring - Warning colors.
- Mullerian mimicry: Comimicry among several species of noxious organisms.
- Batesian mimicry: Harmless species mimic noxious species.

http://www.youtube.com/watch?v=lXi1fQ50Bc8
Predators & Prey

- Predators are usually selection agents for prey
  - Usually eliminate more conspicuous members of a population (less adaptive).
- Predator and prey species are engaged in a co-evolutionary race.
How do organisms choose to eat?
Optimal Foraging Theory – Feeding is an optimizing process!

- Natural selection favors individuals within a population that are more effective at acquiring energy.
- More abundant/larger prey yields larger energy return.
  - Must consider costs!

http://www.youtube.com/watch?v=d7avgPOIdPQ
Optimal Foraging By Plants???

• Is this possible??? How so???

Plants in environments with abundant nutrients but little light will spend less energy on root growth.

Plants in environments with abundant light but poor nutrients will spend less energy on stem and leaf growth.