Lecture: Energy Flow and Food Webs

Energy (E) is defined as the capacity to do work.

- **Potential Energy** - stored energy (example:)
  - elastic (as the energy in a stretched spring or rubber band)
  - gravitational (as in the attraction between earth and everything surrounding it)
  - chemical (the energy in the bonds that hold atoms together as molecules)

- **Kinetic Energy** - the energy of movement (example:)
  - motion (the energy of a moving object)
  - heat (the energy of atomic vibration)
  - sound (the energy of sound waves traveling through liquid, solid, or gas)
  - electromagnetic radiation (the energy of quanta, the smallest particles of energy, from cosmic rays to radiowaves)

**First Law of Thermodynamics**: Energy cannot be created or destroyed; it can only change in form.

**Second Law of Thermodynamics**: All systems in the universe tend to go from a state of order to a state of chaos (entropy; chaos). Entropy is energy unavailable to do work.

Energy is measured in units called Joules (J).

One J = about 1/4 calorie

One calorie is the amount of energy needed to raise the temperature of 1 gram of water by 1°C (Celsius).

The sun emits units of energy called quanta (singular = quantum).

A quantum has properties of both a particle (it bounces off solid matter, and its path can be bent if it travels through liquid) and a wave (It travels through space in a wave form):

![Wave Illustration]

**Wavelength**

**Amplitude**

<table>
<thead>
<tr>
<th>Wavelength (meters)</th>
<th>Radio</th>
<th>Microwave</th>
<th>Infrared</th>
<th>Visible</th>
<th>Ultraviolet</th>
<th>X-ray</th>
<th>Gamma Ray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^3$</td>
<td>$10^{-2}$</td>
<td>$10^{-5}$</td>
<td>$.5 \times 10^{-6}$</td>
<td>$10^{-8}$</td>
<td>$10^{-10}$</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>

About the size of...

- Buildings
- Humans
- Honey Bee
- Pinpoint
- Protozoans
- Molecules
- Atoms
- Atomic Nuclei
What is Light?

- Visible quanta are called **photons**
- All photons travel at the speed of light (299,792,458 meters per second!), but individual photons making up the light around us travel at different **wavelengths** or at different **frequencies**.
- Photons of different wavelengths interact with matter in different ways.
- The human visible spectrum of photons lies between 380 nm to about 580 nm
- A photon will be perceived by your brain as a particular **color** depending on its wavelength.
- The **frequency** of a photon is the number of waves it travels per unit of time.
- We usually measure frequency in **hertz (Hz)**, named for German physicist Heinrich Hertz.
- 1 Hz means that an event repeats once per second. (= one cycle per second)
- The **longer** the wavelength, the **lower** the frequency and energy.
- The **shorter** the wavelength, the **higher** the frequency and energy.

The highest energy photons are perceived by the human eye as violet; the lowest energy photons are perceived as red. (Other animals may see colors differently.)

![Graph showing the spectrum of light with increasing energy and wavelength, and different types of waves like Gamma rays, X-rays, Ultra-violet, Infrared, and Radio waves with additional labels for Radar, TV, FM, and AM.]

Photons can be
- **transmitted** (pass through matter)
- **reflected** (bounce off matter and change direction)
- **absorbed** (photon energy is converted into the energy of the molecule it hits)

Only absorbed photons have biological activity, because only those are giving up their energy to the matter that has absorbed them.
Photosynthesis

Plants have special pigments (light-absorbing molecules) called chlorophylls that absorb photons only in the red and blue/violet regions of the spectrum. These wavelengths drive photosynthesis, the conversion of light energy into chemical energy. All other wavelengths (yellow/green) are reflected, which is why plants look green. Plants reflect green light, and do not use it to make sugar.

Overall, the chemical reactions of photosynthesis can be represented as:

\[
\text{Light energy + plant enzymes} \\
6\text{CO}_2 + 12\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}
\]

...which means that it takes
- six molecules of carbon dioxide plus
- 12 molecules of water
in the presence of light and the proper enzymes in the cell, to make
- one molecule of glucose (energy is stored in its chemical bonds)
- 6 molecules of oxygen
- 6 molecules of water

Plants link sugars to form carbohydrate polymers called starch to store energy.

The plant uses starch to build its body and to store energy for later use.

Autotroph - (auto = "self"; "troph" - feeding) an organism that captures energy and stores it in the chemical bonds of organic molecules that it manufactures from inorganic molecules. (a.k.a. - producers) (Autotrophs that convert light energy to chemical energy are called photoautotrophs.)

Heterotroph - (hetero = "other"; "troph" - feeding) an organism that eats other organisms to obtain energy. (a.k.a. - consumer; decomposers are also heterotrophs)

Cellular Respiration: Opposite of Photosynthesis

All living organisms—including photoautotrophs—break down energy storage molecules (e.g., starch, fat) to release energy and use it to do work. The process living organisms use to release the energy stored in sugar is called cellular respiration.

The overall chemical equation for cellular respiration is exactly the opposite of photosynthesis:

\[
\text{about 16 enzymatic rxns} \\
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O} \rightarrow 6\text{CO}_2 + 12\text{H}_2\text{O} + \text{ENERGY}
\]
...which means that
  • one molecule of glucose in the presence of
  • six molecules of oxygen and
  • six molecules of water
can be "burned" to release stored energy and waste products of
  • 6 molecules of carbon dioxide and
  • 12 molecules of water

**Food Webs move Energy and Nutrients through Ecosystems**

Organisms either capture energy via photosynthesis, or they eat other organisms for energy. These feeding interactions among species in an ecosystem make up its **food web**.

The food web is created by organisms at different feeding levels or **trophic levels**:

  • **primary (1°)producers** - organisms that can perform photosynthesis.
  • **primary (1°)consumers** - organisms that eat primary producers.
  • **secondary (2°)consumers** - organisms that eat primary consumers.
  • **tertiary (3°)consumers** - organisms that eat secondary consumers.
  • **quaternary (4°)consumers** - organisms that eat tertiary consumers

**Decomposers** are a special type of consumer that can eat dead, organic matter (**detritus, carrion**) and break it back down into its original inorganic building blocks.

We can categorize animals by type of food they eat. You all have heard of...
  • **carnivore** - animal that eats meat
  • **herbivore** - animal that eats plant matter
  • **omnivore** - animal that eats a variety of things (plant and animal)

But don’t forget others such as…
  • **detritivore** - eats dead, organic matter (**detritus**), but does not decompose it
  • **insectivore** - eats insects
  • **frugivore** - eats fruits
  • (Insert your own favorite "-vore" here.)

Consider each of the following ecosystems in southern Florida, and try to imagine the animals, plants, fungi, protists, and bacteria that form the food webs within them.

  • Everglades Sawgrass marsh
  • Everglades Hardwood Hammock
  • Pine Rockland
  • Coastal Dunes
  • Coastal Hardwood Hammock
  • Mangrove Forest
  • Coral Reef
  • Estuary (where a river empties into the sea)

Your team will choose one of the ecosystems listed here and **CREATE A FOOD WEB DIORAMA** to amaze and educate your colleagues!