What is energy?

- The conventional definition of energy is the ability to do work. Work is equal force times distance. Much like mass or volume, energy is a property of an object. Since energy is a property of matter, it can be measured and quantified. Measuring energy helps one understand how it is used, how it changes form, and even how to increase energy efficiency.

Energy can be in any of several different forms: thermal energy, chemical energy, radiant energy, nuclear energy, etc. These forms of energy can be grouped into two broad categories (states of energy): kinetic energy and potential energy.

- **Kinetic energy** is motion energy or energy of a moving object. The faster an object moves, the more kinetic energy. Kinetic energy = \( \frac{1}{2}mv^2 \).

- **Potential energy** is energy stored in matter or the energy in matter due to its position or the arrangement of its parts. Potential energy appears in many different forms: gravitational, elastic, chemical, and electrical potential energy.

Energy Transfer

- The transfer of energy can take various forms; familiar examples include work, heat (mechanisms include conduction, convection, and radiation) which we have discussed in previous class meetings.

- Energy can be transferred from one object to another by doing work (work = force x distance). When work is done on an object, it results in a change in the object’s energy (kinetic or potential).

- Heat is the flow or transfer of energy between two objects of differing initial temperatures (from a hot object to one that is cooler) as we defined and observed in class last week.

Energy Conversion

- Keep in mind, from the first law of thermodynamics: energy can neither be created nor destroyed. Any energy that is lost by the system is gained by the surroundings, and vice versa. Although energy is conserved, not all of the energy is converted into the desired form, some of the energy becomes unavailable for further use (2nd law of thermodynamics). Although the quantity of energy is the same before and after conversion, the quality is different.

Measuring and Quantifying Energy

- Units of energy: the SI unit of energy is the joule \( \text{kg-m}^2/\text{s}^2 \), which is the amount of energy required to lift an object that weighs one Newton a one meter distance (along the direction of the force). A more familiar unit of energy is the calorie, which is defined as the amount of energy needed to raise the temperature of 1 gram of water.
of water 1°C. One calorie equal 4.184 joules. A related energy unit is the nutritional Calorie (1 Cal = 1000 cal = 1 kcal).

- The methods for the measurement of energy often deploy methods for the measurement of still more fundamental concepts of science (e.g., mass, distance, temperature, etc).
- In thermodynamics, the technique most often employed is calorimetry, which relies on the measurement of temperature.


Materials (per group):
Homemade calorimeter
  Small metal (soda) can
  Larger metal (soup) can
  Glass rod
Digital thermometer
Lighter
Graduated cylinder (100 ml)
Aluminum weighing boats
Ring stand
Scale
Food (cashews, marshmallows, popcorn, chips)
Safety glasses
Bucket w/ water (safety)

Experiment:
1. Of the 4 food items you will be testing, hypothesize which one will have more Calories (energy). Record your prediction in your journal.
2. Obtain a weigh boat and determine its weight. Place food item in the same weigh boat and record the initial weight \( W_i \) of the food item (subtract weight of weigh boat).
3. In a graduated cylinder, measure out 100 ml of water and pour it into the small (soda) can. Slide the glass rod through the tab in the soda can and carefully rest it on the ring stand. Measure the initial temperature of the water \( T_i \).
4. Place the weigh boat containing the food item on a non-flammable surface. Put on your safety goggles and ignite the food item. Some food items may require multiple attempts before they catch fire (if it goes out quickly, in less that a minute, relight it).
5. After the food item has finished burning, use the thermometer to carefully stir the water and measure the final temperature \( T_f \). Caution! The can and water will be hot!
6. After the burnt food item has cooled, weigh the remnants \( W_f \).
7. Repeat steps 1-7 for each food item. Make sure you use a new soda can and fresh water for each repetition of the experiment. Record data in your journal.

Determine Calories of the food items:
By measuring the change of temperature of a known volume of water, you can calculate the amount of energy in the food because the heat gained by the water will equal the heat lost by the food item (assuming no losses from the system).

\[ Q_{\text{heat lost by food}} = Q_{\text{heat gained by water}} \]

\[ Q_{\text{water}} = (m)(c)(\Delta T); \ m = \text{mass of water (grams; } 1g = 1ml) \]
\[ c = \text{specific heat capacity of water (1 calorie/g } ^\circ\text{C)} \]
\[ \Delta T = \text{change in temperature (} ^\circ\text{C)} \]

Questions:
I. Based on the results of your experiment, how many Calories per gram (Cal/g) were in each food item? Did your predictions in (1) hold true?

II. How well does the Calorie content you calculated compare to what is listed on the package? Were you able to determine the entire Calorie content of each item? If differences exist, what may account for these differences? How could you improve the experimental design so the results would be more consistent with the packaged values?

III. To which biological processes can this demonstration be related?
II. Class Demonstration – Virtual Bomb Calorimeter

(http://web.umr.edu/~gbert/animation.html)
(http://www.chm.davidson.edu/ronutt/che115/Bomb/Bomb.htm)

1. Visit the websites above and explore the bomb calorimeter animation and simulated experiment.
2. Evaluate the websites. Were they appropriate and useful teaching/learning tools? Address the content, authenticity, learning strategies, navigation, graphics, appeal, etc.

FOOD WEBS:

Movement of Energy Through Ecosystems (food chains and food webs)

- Food chain – is a single pathway of energy transfer through an ecosystem as organisms eat one another. The arrow show the direction of energy flow (biomass transfer), not the direction of eating. Trophic pyramids describe the linear flow of energy (biomass or productivity) from lower to higher trophic levels.
- Food web – a complex set of many interconnected food chains in a system.
- Both (graphically) describe the feeding relationships (transfer of energy and material) between organisms in an ecological community.

Organisms Represented in a Food Chain

- Each “link” in a food chain is a trophic level (feeding level), starting with:
  - Primary producers, or autotrophs – organisms that are capable of producing complex organic substances from an energy source and inorganic materials (photoautotrophs or chemoautotrophs).
  - Organisms that get their energy by consuming organic substances are called heterotrophs.
    - Herbivores - obtain their energy by consuming live plants.
    - Carnivores - obtain energy from consuming live animals.
    - Detritivores, scavengers and decomposers, which all consume dead biomass.
    - Mixotrophs?

Energy Efficiency

- In terms of energy, efficiency means how much of a given amount of energy can be converted from one form to another useful form (i.e., how much of the energy is used to do what is intended compared to how much is lost or “wasted” as heat).
- Efficiency = useful energy output/ energy input. No energy conversion is 100 percent efficient.
- Most food chains only have a few links in them because energy is lost at each level.
• In general, we assume a 10% efficiency from one trophic level to the next, meaning that 10% of the energy (material) is transferred, 90% goes back to the environment (lost as heat, used for metabolic activities of the ‘food item’).

III. Class Activity – Energy Transfer in Ecosystems
(modified after “The Root Beer Activity from the Utah State Office of Education http://www.usoe.k12.ut.us/curr/science.sciber00/8th/energy/sciber/ecosys.htm)

Materials:
Candy (1000g to demonstrate 3 trophic levels/organisms + the sun)
4 large beakers
Scale

Instructions:
1. Put 1000g of candy in the first beaker, this represents the amount of available energy from the sun. Note: the teacher can either use this as a demonstration in front of the class, or use students as volunteers (represent each trophic level or organisms in a food chain).
2. Now pass 10% or 1/10 of the candy (hint: use the scale) or “available energy from the sun” to the first trophic level or empty beaker. What trophic level does this represent?
3. Repeat the process for the remaining trophic levels.
4. Why aren’t there food chains that support an infinite number of links?