Teacher Notes for Food, Energy and Body Weight

by Dr. Ingrid Waldron, University of Pennsylvania, 2011[1]

Background. Before students begin this activity, they should learn basic concepts about food and cellular respiration, including the following.

Our bodies use food molecules to provide

- atoms and molecules needed for growth and repair of our bodies (e.g. calcium, vitamins, amino acids to synthesize proteins)
- energy for body processes, as described below

All organisms use a two-step process to provide the energy needed for most of their biological processes:

1. Chemical energy from organic molecules such as glucose or fatty acids is used to make ATP in a process called cellular respiration.
2. ATP provides the energy required for many biological processes.

Additional needed information about ATP and cellular respiration is reviewed in our activity "How Biological Organisms Use Energy" (available at http://serendip.brynmawr.edu/exchange/bioactivities).

Discussion of Questions in Student Handout

Question 1. Students should recognize that the energy needed for muscles to move comes from chemical energy in organic molecules from our food. To use this energy, our cells carry out cellular respiration which transfers energy from these organic molecules to ATP. ATP provides energy in a form that our cells can use for body activities such as muscle contraction. (Student answers or your discussion may also include a necessary step between food molecules and cellular respiration, namely, digestion of large organic food molecules such as starch and triglycerides to produce small organic molecules such as glucose and fatty acid that can travel in the blood and serve as input for cellular respiration.)

Question 2. For the top part of the chart, students need to recognize that energy can be transformed from one type to another; e.g. chemical energy in organic molecules can be converted to the kinetic energy of movement and heat. (In accord with the Second Law of Thermodynamics, heat is produced whenever energy is transformed from one type to another.) The transformation of chemical energy to kinetic energy and heat is accomplished by a series of complex molecular processes that transfer energy from organic molecules such as glucose to ATP to muscle proteins that produce muscle contraction. These molecular processes include the chemical reactions of cellular respiration during which the atoms in the input molecules (glucose, fatty acids, O_2) are reorganized into atoms in the output molecules (CO_2 and H_2O which leave the body via breathing and urination). Students may also include food molecules such as sugars, starch, and triglycerides as matter inputs. I would not be inclined to include ATP in the chart, because ATP is constantly recycled within cells as the reaction ATP --> ADP + phosphate

[1] These teacher notes, the related student handout, and other activities for teaching biology are available at http://serendip.brynmawr.edu/exchange/bioactivities. Hands-on, minds-on activities for teaching biology are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

provides energy for muscle contraction and cellular respiration reconstitutes ATP by the reaction ADP + phosphate --> ATP.

Discussion of this question can be used to emphasize the important point that energy can be converted to other forms of energy and the atoms in molecules can be arranged into other molecules, but energy can not be converted to matter or vice versa in biological processes (in accord with the First Law of Thermodynamics). This point is also important for question 4.

Question 3. Students can use their answer to question 2 to recognize that cellular respiration converts many of the molecules in food to CO_2 and H_2O which leave the body via breathing, urination and sweating. In addition, beverages and some foods (e.g. fruits and vegetables) contain a lot of H_2O; the body retains only enough H_2O to replace the H_2O lost by breathing, sweating, etc. Also, some food molecules are not absorbed from the digestive system and leave the body in feces. Since the average American consumes more calories than needed for body activities, some of the weight of the food is retained, as discussed in the next question.

Estimated annual food consumption in the US includes 75 pounds of added fats and oils, 152 pounds of caloric sweeteners, 195 pounds of meat and fish, 200 pounds of grains, 593 pounds of dairy, and 708 pounds of fruits and vegetables (http://www.usda.gov/factbook/chapter2.pdf). Notice that the types of foods at the beginning of this list have high calorie density; foods in the last two categories weigh substantially more per calorie consumed, in large part because they contain a lot of water.

Question 4. This question provides the opportunity to discuss the relationships and distinctions between food, calories and energy -- concepts that students often confuse. Food contains organic molecules which have chemical energy stored in the bonds between atoms. There are many other types of energy, including the kinetic energy of moving muscles and heat (the kinetic energy in the random motion of atoms and molecules). In addition to energy, food provides atoms and molecules needed for growth and repair of our bodies. A calorie is a unit of measure of energy; we use the lower case calories throughout because it is more familiar to students, even though we are actually referring to Calories or kilocalories.

If a person eats food with more calories than needed for body activities, some of the organic molecules contained in the food will not be used for cellular respiration, so the atoms in these molecules will not be given off as CO_2 and H_2O. The body uses surplus organic molecules to synthesize triglycerides which are stored in fat cells in our adipose tissue and glycogen (a polymer of glucose) which is stored in the liver and muscles. Less than a day's worth of energy is stored in the form of glycogen (~800 calories). In contrast, a normal weight person has enough stored fat to provide energy for about two months (~140,000 calories). Fat provides more energy per gram than carbohydrates or proteins (9 calories per gram vs. 4) and our fat stores also have less associated water; given the mobility of animals, this greater energy density is an important advantage for fat as the main energy storage molecule in animals.