

Teacher Notes for Food, Energy and Body Weight¹

This analysis and discussion activity helps students to understand the relationships between food, energy, cellular respiration, and changes in body weight. Analysis of a representative scenario helps students to understand how challenging it is to prevent weight gain by exercising to offset what seems to be a relatively modest lunch. In an optional research project, each student asks an additional question and prepares a report based on recommended reliable internet sources.

Before students begin this activity, they should have a basic understanding of biological molecules and cellular respiration. A helpful introductory activity is "How do organisms use energy?" (<http://serendipstudio.org/exchange/bioactivities/energy>).

Learning Goals

In accord with the Next Generation Science Standards², this activity:

- helps students to prepare for Performance Expectation HS-LS1-7, "Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy."
- reinforces student understanding of the Disciplinary Core Idea LS1.C: "... amino acids and other carbon-based molecules can be assembled into larger molecules ... Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken", carbon dioxide and water are formed, and the energy released is used in the production of ATP from ADP and P. Then, the hydrolysis of ATP provides the energy needed for many biological processes.
- engages students in the recommended Scientific Practice, "Constructing Explanations: Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena."
- can be used to illustrate the Crosscutting Concept:
 - "Energy and matter: Flows, cycles and conservation: Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system."
 - "Cause and Effect: Mechanism and Prediction: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system."

Students learn that food, calories and energy are not equivalent concepts.

- Food contains organic molecules which can be used for cellular respiration which produces ATP; hydrolysis of ATP provides the energy for the processes of life. Food also provides molecules that can be used for growth and repair of body tissues.
- Energy is a property of all sorts of biological and non-biological systems (e.g. the chemical energy available from cellular respiration of food molecules or the kinetic energy of moving muscles or cars).
- A calorie is a unit of measure of energy, in this context the energy available from oxidation of a food.³

¹ By Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania, 2020. These Teacher Notes and the related Student Handout are available at <https://serendipstudio.org/exchange/bioactivities/foodenergy>.

² <http://www.nextgenscience.org/sites/default/files/HS%20LS%20topics%20combined%206.13.13.pdf>

³ In this activity I use the lower case "calories" because this usage of nutritional calories is more familiar to students, even though technically I am referring to Calories = kilocalories.

Instructional Suggestions and Background Information

To maximize student participation and learning, I suggest that you have your students work in pairs or individually to complete groups of related questions and then have a class discussion after each group of related questions. In each discussion, you can probe student thinking and help them develop a sound understanding of the concepts and information covered before moving on to the next group of related questions.

If your students are learning online, we recommend that they use the Google Doc version of the Student Handout available at <https://serendipstudio.org/exchange/bioactivities/foodenergy>. To answer question 2, students can either print the relevant page, draw on it and send a picture to you, or they will need to know how to modify a drawing online. To answer online, they can double-click on the relevant drawing in the Google Doc to open a drawing window. Then, they can use the editing tools to answer the questions.⁴ If you prepare a revised version of the Student Handout Word document, please check the format by viewing the PDF.

A key is available upon request to Ingrid Waldron (iwaldron@upenn.edu). Additional background information and instructional suggestions are included in the paragraphs below.

Estimated annual per capita 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>; accessed in 2016). Notice that the types of foods at the beginning of this list have high calorie density; dairy and fruits and vegetables weigh substantially more per calorie consumed, in large part because they contain a lot of water.

The flowchart in question 2 summarizes how our bodies use food to provide (1) energy for body processes and (2) atoms and molecules needed for growth and repair of our bodies. This flowchart is obviously a very simplified version of the complex metabolism of macronutrients. Additional information is provided in the figure below.

⁴To draw a line

1. At the top of the page, find Select line and pick the type of line you want.
2. Place the line on your drawing:
 - Line, Elbow Connector, Curved Connector or Arrow: Click to start, then drag across the canvas.
 - Curve or Polyline: Click to start, then click at each point you want the line to bend. Double-click or complete the shape to finish.
 - Scribble: Click to start, then drag across the canvas.

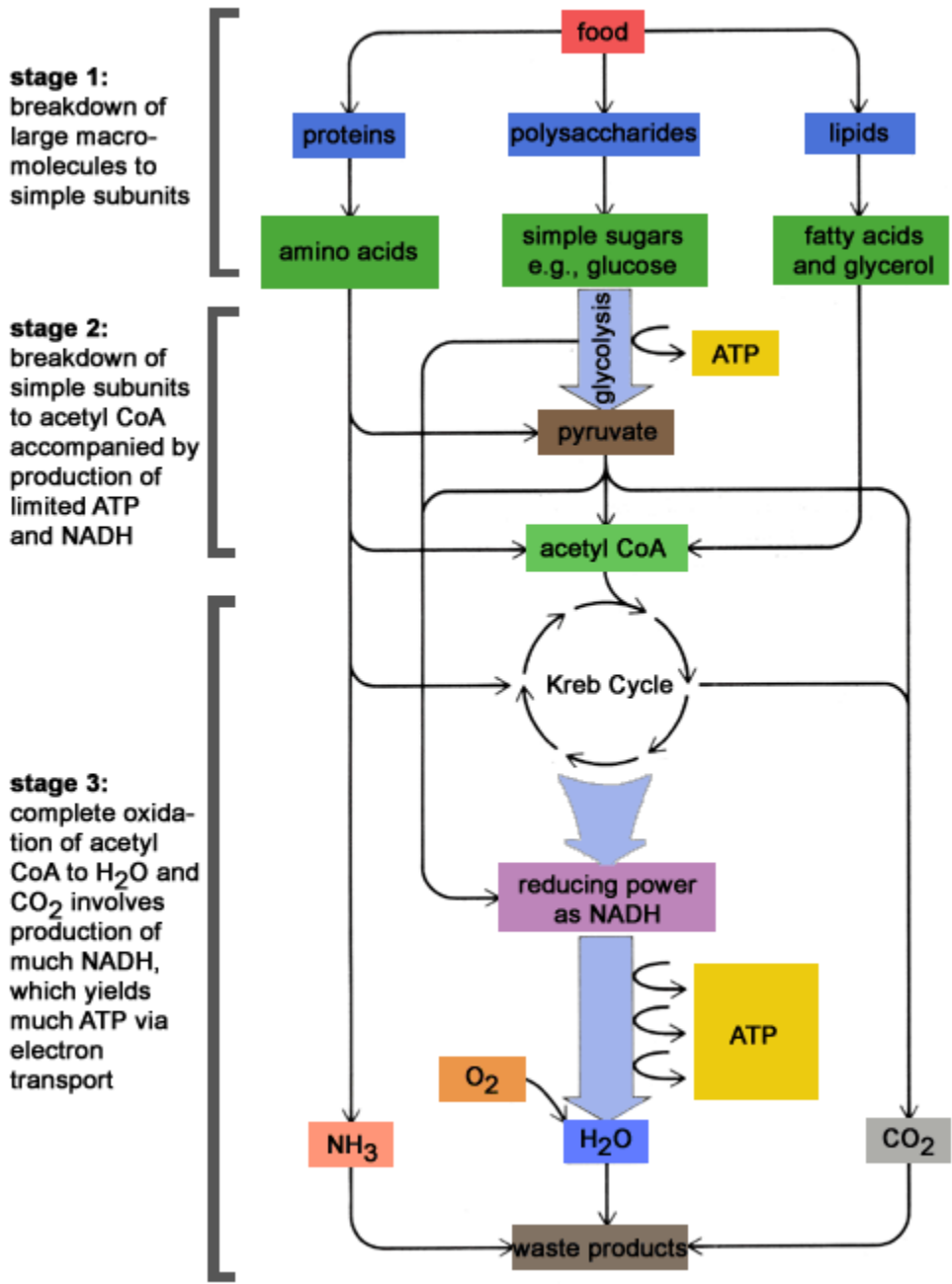
To draw a shape

1. At the top of the page, find and click Shape.
2. Choose the shape you want to use.
3. Click and drag on the canvas to draw your shape.

To insert text

1. At the top of the page, click Insert.
 - To place text inside a box or confined area, click Text Box and drag it to where you want it.
2. Type your text.
3. You can select, resize and format the word art or text box, or apply styles like bold or italics to the text.

When you are done, click Save and Close.



<https://schoolworkhelper.net/wp-content/uploads/2010/07/catabolism.gif>

The conservation of matter is an important principle that you can emphasize in discussing questions 1, 3 and 4. In discussing question 4, you will want to emphasize the important points that, although energy can be converted to other forms of energy and the atoms in reactant molecules can be reorganized into atoms in different product molecules, energy can *not* be converted to matter or vice versa.

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 CO₂ and H₂O. The body uses surplus organic molecules to synthesize:

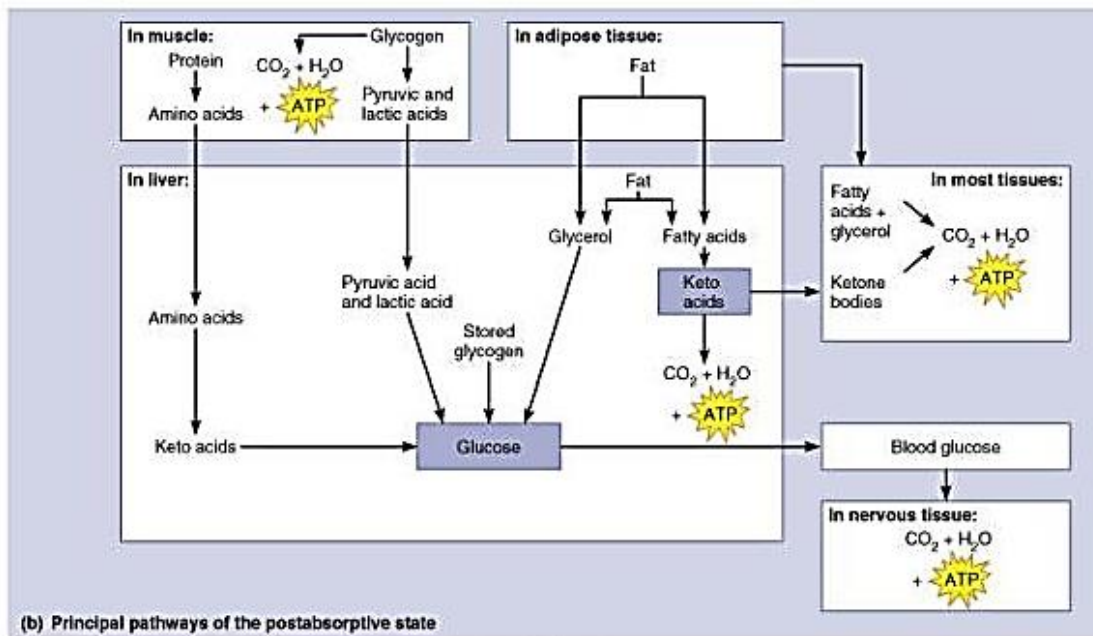
- triglycerides which are stored in fat cells in our adipose tissue and

- 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 fat stores also have less associated water. For both reasons, fat requires less weight per calorie, and this is a major advantage of fat as the main type of energy storage in animals.

Question 6 discusses one aspect of metabolism in the post-absorptive state, which can occur when there is a long interval between meals or when a person is eating food with fewer calories than required for the person's metabolism (dieting or famine). The figure below provides additional information.

Pathways of the Postabsorptive state



(b) Principal pathways of the postabsorptive state
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(<https://www.slideserve.com/atira/metabolism>)

The section on Eating and Exercising is based on a case study for teaching nutrition, "A Light Lunch? A Case in Calorie Counting". Additional information is available at http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=460&id=460. The table below gives the estimated calories for each food item.

Alicia		Maria	
Food Item	Calories	Food Item	Calories
Two slices of cheese pizza	280	Two slices of pepperoni pizza	358
Garden salad	38	Taco salad	284
Iced tea	88	Grape soda	166
Total calories	406	Total calories	808

The number of calories used during physical activity depends on the intensity of the exercise, which for walking depends on body weight and walking speed. A person who weighs 150 pounds typically uses ~240 calories per hour when walking at the rate of 2 miles per hour (http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=460&id=460). A person who weighs 125 pounds typically uses ~240 calories per hour when walking at the rate of 3.5 miles per hour (<https://www.health.harvard.edu/diet-and-weight-loss/calories-burned-in-30-minutes-of-leisure-and-routine-activities>; this source gives typical caloric expenditures for many different types of physical activity and body weights of 125, 155 or 185 pounds).

Current research suggests that an hour a day of moderate intensity aerobic exercise can contribute to weight loss and three or more hours per week of moderate intensity aerobic exercise can contribute to maintenance of weight loss (<https://spectrum.diabetesjournals.org/content/30/3/157>). However, it appears that, for some individuals, these amounts of physical activity do not contribute to weight loss.

The Student Handout omits many aspects of the complex physiology of weight gain and weight loss. For example, this activity does not discuss the hormonal and metabolic changes which make it difficult to maintain weight loss after obesity (<https://www.health.harvard.edu/blog/why-its-so-hard-to-lose-excess-weight-and-keep-it-off-the-biggest-losers-experience-2018031213396>). Substantial evidence indicates that regular aerobic exercise results in multiple health benefits (e.g. reduced risk of heart disease and diabetes) (<https://www.cdc.gov/nccdphp/sgr/chapcon.htm>).

Optional Research Project

This section invites students to explore their questions related to obesity or physical activity and provides the URLs for informative and reliable sources. If your students want to explore additional resources, you may want to use the resources available at <http://www.library.georgetown.edu/tutorials/research-guides/evaluating-internet-content> and <http://www.virtualsalt.com/evalu8it.htm> to help them learn about how to evaluate the reliability of different sources. This research project can be used to engage your students in the NGSS-recommended science practice of "Obtaining, Evaluating, and Communicating Information" (<https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf>).

Related Activities

“How do muscles get the energy they need for athletic activity?”

(<https://serendipstudio.org/exchange/bioactivities/energyathlete>)

In this analysis and discussion activity, students learn how muscle cells produce ATP by aerobic cellular respiration, anaerobic fermentation, and hydrolysis of creatine phosphate. They analyze the varying contributions of these three processes to ATP production during athletic activities of varying intensity and duration. Students learn how multiple body systems work together to supply the oxygen and glucose needed for aerobic cellular respiration. Finally, students use what they have learned to analyze how athletic performance is improved by the body changes that result from regular aerobic exercise.

“Photosynthesis and Cellular Respiration – Understanding the Basics of Bioenergetics and Biosynthesis”

(<https://serendipstudio.org/exchange/bioactivities/photocellrespir>)

In this minds-on activity, students analyze how photosynthesis, cellular respiration, and the hydrolysis of ATP provide energy for biological processes. Students learn that sugar molecules produced by photosynthesis are used for cellular respiration and for the synthesis of other organic molecules.⁵ Thus, photosynthesis contributes to plant energy metabolism and plant growth. The optional final section challenges students to explain observed changes in biomass for plants growing in the light vs. dark.

"Cellular Respiration and Photosynthesis – Important Concepts, Common Misconceptions, and Learning Activities" (<https://serendipstudio.org/exchange/bioactivities/cellrespiration>) provides an overview of energy, ATP, cellular respiration, and photosynthesis. This overview summarizes important concepts and common misconceptions and suggests a sequence of learning activities designed to develop student understanding of these concepts and overcome any misconceptions.

⁵ This parallels the dual uses of food molecules discussed in the current activity.