Category IV Life Science Examples

Representing ideas effectively

Food, Energy, and Growth - Example 1
The material provides several representations to clarify the key ideas about matter transformation. For example, the material uses a screen to model the role of the gut lining in letting digested, but not undigested, material pass through. Students use the screen to see that only digested protein (gelatin treated with meat tenderizer) can pass through (p. **29s**). The text presents an analogy between the process of digestion and reassembly of components in the body and the process of disassembling a house into its bricks and using the bricks to build a new building (p. **33s**). To represent the process of respiration, the text provides a diagram showing glucose and oxygen as inputs and carbon dioxide and water as outputs (p. **42s**). To represent digestion, the text uses a word equation and indicates that the arrow means “break down into” (pp. **25–26s**).

Think, write, and discuss

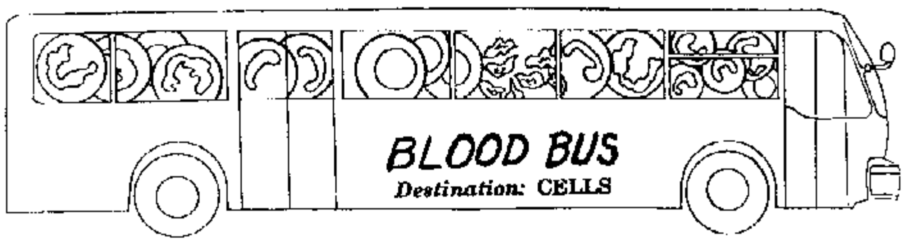
3. a) How is crushing or chopping the gelatin similar to what happens to the food we eat?

   b) If physically crushed gelatin can't get through the screen, what else could be done to it to get it through?

4. You probably noticed that not all the gelatin passes through the screen. Why do you think that is?

You already know that enzymes in your small intestine chemically change proteins into smaller, simpler "building block" molecules—just like meat tenderizer changes gelatin into different, smaller pieces. **The gelatin may not seem to have changed into a new substance, but it has.** The meat tenderizer chemically changed the gelatin into different molecules, smaller than the original gelatin protein molecules. As a new substance, it could fit through the screen.

Here's what happens after food is chemically changed into different, simpler molecules: ***The new molecules pass through very small openings in the wall of the small intestine and enter the bloodstream.*** They've made it onto the "blood bus"!



5. a) If the gelatin in our experiment represented the food you eat, what did the meat tenderizer represent?

   b) What did the screen represent?

6. Write a few sentences about what the wall of the small intestine might be like so the digested food can pass through it and into the bloodstream.

3. a) It is similar to breaking food by chewing and churning in the stomach.
   b) The food needs to be chemically broken down by an enzyme.

4. The particles that have not been "digested" (broken down) are too big to get through the holes in the screen. Students may refer to the substance as being too thick or say that it didn't turn into a liquid. If they say this, they are probably not thinking of the substance as made of tiny molecules. Remind them that even liquids are made up of molecules. This idea of food being composed of molecules is essential to students understanding how digested food passes through the intestinal wall.

5. a) Enzymes.
   b) The walls of the intestine.

6. Following the sand/screen analogy, the walls of the small intestine might have little openings or holes in it that allow the simpler, digested food particles to move through, big enough to let digested food out, but not big enough to let any undigested food out. **See comment below.**

Food movement from the small intestine into the blood stream: The molecular-level picture we're developing of food movement across the small intestine wall is simplified for the purposes of teaching at this grade level. Actually, there are several mechanisms at work here: Small molecules can pass through the small intestine wall and dissolve into the blood stream, but they have to be soluble to do this. Fats are not soluble, but fatty acids are. Also, there are molecular "carriers" that help transport molecules of digested food across this interface. The central idea for this unit is that the process of digestion is a chemical one, resulting in simpler, new "building block" molecules and glucose. It is these new, simpler molecules that pass into the blood, to be transported to cells.

Lesson 7

Let's review what we've talked about so far:

Think, write, and discuss

1. Create a table in your journal that tells what substance each component of the food you eat changes into when it is digested.
2. What has to happen to food so that it can make the trip out of the small intestine and into the cells?
3. a) Was all of the food able to get out of the small intestine? Why or why not?

   b) What happens to the particles that don't get out?
4. **Speculate:** Why must new materials be assembled inside of the cells rather than being assembled and then transported?
5. a) The picture you have assembled shows only one specific cell of the organism. How many other kinds of cells can you imagine there must be in your body?

   b) Name at least ten kinds of cells that need to get food.

Brick by Brick: Digestion is like taking a building apart, brick by brick, so you can use the bricks to build (and power) a new building. During the process of digestion, the large molecules of the food we eat, like the building, are torn down and chemically changed into simpler molecules—the bricks. These bricks are then carried to another location, where they are used to build a different building.

The bloodstream (the bus) is what carries the simpler molecules to all the cells of your body. The cells then use the "building block" molecules to make the exact proteins or fats they need to grow, to repair damaged parts, or to store energy for later use. And they use the glucose molecules for the fuel needed by the cell for powering everything that cells do.

Exactly what goes on in cells with the digested food—how cells extract the energy stored in glucose, and how they use amino acids to grow and repair themselves—is discussed in Cluster 3!

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1. Proteins change into amino acids, carbohydrates into glucose, and fats into fatty acids.

2. It has to be chemically changed (digested) into new molecules that can pass through the small intestine wall.

3. a) No, some of the food molecules were too big to get through the openings, like the fiber molecules. If students say "there weren't enough enzymes," make sure they know what the function of the enzymes is—to break down the parts of the food that are digestible—and that they aren't just parroting back a key word without understanding what enzymes do.

b) They move from the small intestine to the large intestine and out of the body as feces.

4. We begin to answer this question on the bottom of this page ("Brick by Brick"); a more-complete answer is developed in Cluster 3. It is interesting to listen to students' speculations, though, and you should encourage this. We are referring to amino acids as "building blocks" because they are re-assembled into different proteins in the cells, depending on the individual cell's need. Each cell is responsible for synthesizing its own proteins (following directions in its DNA). The purpose (function) of digestion, then, is to take apart the food we eat, (which has been built up in other organisms into their "body parts") into the amino acids, fatty acids, and glucose we need for making new body parts and storing and releasing energy.

5. a) Answers will vary.

b) Additional cells mentioned might include skin, blood (red and white), brain, nerve, liver, muscle, egg, sperm, etc.

What's feces? Indigestible food (like fiber), bacteria, mucus, dead cells, and food that just didn't get digested; and 75% water. It's the bacteria that produce the odor; as they feed on leftover and indigestible food, they produce gas. Some foods (notably beans and cabbage) are for a large part not digested, leaving lots for bacteria to eat, and producing lots of gas.

Lesson 8

Cellular respiration is a chemical reaction—actually a series of complex chemical reactions summarized by the equation shown here—that essentially rearrange the atoms of the reactant substances (glucose and oxygen) to form *new* substances (carbon dioxide and water), and in this case, release energy. Burning butter is a chemical reaction which requires oxygen (so is burning wax in a candle, or burning wood or paper.)

No matter is lost in this or any chemical reaction: the mass of water and carbon dioxide produced is exactly the same as the mass of glucose and oxygen that react together. You can see this by noticing that the equation is balanced: all the atoms that go into the reaction come out again. The energy stored in the original molecules is released for use in cell processes.

You may wish to discuss with students what happens when one is deprived of oxygen, as in carbon monoxide poisoning. Actually, death is caused because cells are not getting the oxygen they need. The first cells to be effected are usually brain cells and people become light-headed and pass out very quickly. Cells are deprived of oxygen because carbon monoxide will attach itself to the hemoglobin of the red blood cells 250 times faster than oxygen will. Also, it attaches more strongly than oxygen so it does not exchange with oxygen. As a result, the oxygen-carrying capacity of blood is drastically reduced and cells are no longer getting the oxygen they need—thus dying of asphyxiation.

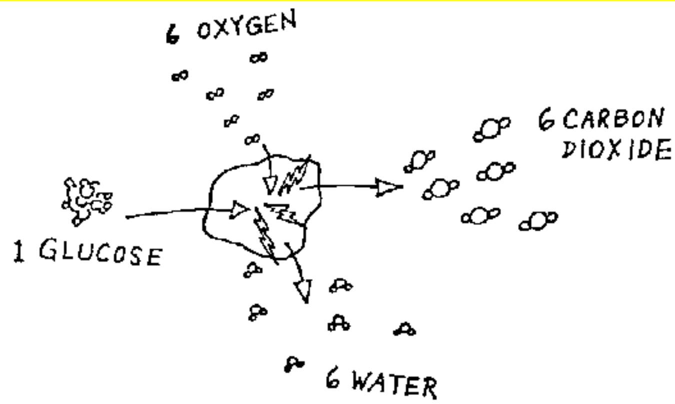
Building on your conclusions

Yes, a very complex set of chemical reactions is going on in cells that release the stored energy from glucose. Oxygen is needed to make these reactions occur, and carbon dioxide (and also water) is what's left after the reactions occur. To simplify these reactions, scientists write one equation:

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,H_2O + 6\,CO_2 \quad \textit{releasing energy}$$

glucose + oxygen ⟶ water vapor + carbon dioxide

What this looks like in a cell is this:



The glucose and oxygen molecules react, and the stored energy is released! The chemical reaction produces water and carbon dioxide, which leave the cell.

This process that cells use to get energy from food is called cellular respiration. It is the reason why you can't live more than a few minutes if you stop breathing. If cells can't get oxygen, they can't get the energy out of food, and they die very quickly. What would happen to you if your brain cells couldn't get oxygen?

* * *

What's the difference between a burning butter candle and what goes on in your cells?

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Lesson 11

many of your students think, then point out to them that the candle burns much longer than the match, indicating that there must be some additional energy (lots, actually) in the butter itself. If they believe that it is only the wick that is burning, have them try burning a wick by itself along side the candle: Which burns longer?

You may need to use an analogy for chemical energy changing into heat or light energy, such as in a light bulb or electric stove, where electrical energy is changed into heat and light energy; or in a fan, where electrical energy is changed into mechanical energy.

A scientific explanation of digestion

So far in this cluster, you have explored the digestion of two substances, starch (one type of carbohydrate) and protein. During the digestive process, starches (and other **carbohydrates**) are chemically broken down into simpler particles—molecules—called **glucose** (one type of sugar.) Glucose is a very small, simple sugar molecule. You may remember that it is the same sugar that plants form during the process of photosynthesis. All the starch and other carbohydrates that you eat in your food (including table sugar) are chemically broken down into glucose.

This breakdown begins in your mouth and continues in your small intestine. Chemicals, called enzymes, which cause this breakdown, are in saliva and in digestive juices found in your small intestine.

Protein in your food does not begin to be digested until it reaches the stomach. There, the enzymes in the stomach begin reacting with the protein to break it into simpler molecules called **amino acids**. Only part of the protein is digested in the stomach. Most of it passes, undigested, into the small intestine where more enzymes are produced for breaking down rest of the protein into amino acids.

$$\text{Carbohydrates} \xrightarrow{\text{break down into}} \text{glucose (simple sugar)}$$
$$\text{Proteins} \xrightarrow{\text{break down into}} \text{amino acids}$$

Glucose from carbohydrates is used mostly for energy.

Amino acids are the building materials used for making new cell parts and repairing old ones. Amino acids make **new** proteins that become parts of new cells when your body is growing. Skin, muscle, blood, and hair, and even enzymes all contain proteins.

The digestive tract is actually over 10 meters (approx. 30 feet) long. Over half of it is the small intestine. The esophagus (throat) and small intestine help move the food along by contractions of the muscles in their walls. Muscle contractions—churning—also help combine the food thoroughly with digestive enzymes. Food remains in the stomach for 2 to 3 hours, and in the small intestine for 8 to 12 hours.

Lesson 6

What about fats? We haven't done an activity that shows how fats are digested, but it's the same idea. In the small intestine, more digestive enzymes break **fat** into simpler "building block" molecules called **fatty acids**.

fats —break down into→ fatty acids

These fatty acids get *rebuilt* in the cells into new fats. Some of these new fats store energy until the cells need it (that's what body fat is, a place to store food for when you need energy), and some fatty acids are used in making amino acids—for making proteins that help make new cells and repair damaged cells.

10. Using the second drawing that you started earlier in this lesson, check it to make sure that it includes a mouth, stomach and small intestine. Use arrows and labels to show on the diagram where fats, proteins, and carbohydrates begin the processes of digestion. (Save the drawing.)

Where are we now on the food trip? We're somewhere in the small intestine. The food has been chemically changed into new substances—amino acids, glucose, and fatty acids.

Has the food finished its job at this point? Or is there still more to this story of the food trip?

Fatty acids can be changed into glucose if needed for energy, or into amino acids for building new proteins. Fatty acids are also important for several uses in the body, including making cell membranes, protecting nerve cells in the brain, making hormones, etc.

10. **Important points** to show on diagram include:

- **starches** are partially digested in the mouth but most of the digestion takes place in the small intestine; they become simple sugars called glucose.
- **proteins** are partially digested in the stomach but most of the digestion takes place in the small intestine; they become amino acids.
- **fats** are digested in the small intestine; they become fatty acids.

You may want to pose this last question to your students, either at the end of this lesson or the beginning of the next, to help them uncover any prior knowledge they may have about the circulatory system. Check their responses to see if they talk about "cells."

Lesson 6