Category II Summaries for Life Science Examples

Alerting teacher to commonly held ideas

Food, Energy, and Growth

Research indicates that students typically have several misconceptions about key ideas treated in the unit. Students think that

- food is whatever nutrients that organisms must take in if they are to grow and survive, rather than those substances from which organisms derive the energy they need to grow and the material of which they are made (American Association for the Advancement of Science [AAAS], 1993, pp. 120, 342; Driver et al., 1994, p. 27).
- food is a requirement for growth rather than a source of matter for growth (AAAS, 1993, p. 343; Driver et al., 1994, p. 60).
- food that is eaten and used as a source of energy belongs to a food chain, while the food that is incorporated into the body material of eaters is often seen as something different and is not recognized as the material which is the food at the next level (Driver et al., 1994, p. 35).
- organisms and materials in the environment are very different types of matter. For example, animals are made of bone, muscle, skin, etc.; plants are made of leaves, stems, and roots; and the nonliving environment is made of water, soil, and air. Students see these substances as fundamentally different and not transformable into each other (Smith & Anderson, 1986).

The module alerts teachers to several commonly held student ideas that are reported in the research literature, typically in brief sidebars accompanying the student text or content summaries in appendices. For example, in the context of describing cellular respiration, sidebars note the several common misconceptions (**Appendix 3**). Also noted are primitive notions students have about what food is and where it is used (pp. **4t**, **13t**). Student difficulties understanding the source of energy released by a burning butter “candle” or glucose are also described and contrasted with the scientific ideas (pp. **41–42t**).

In some places teacher notes contrast the student difficulty/misconception with the relevant scientific idea (e.g., pp. **16t**, **44t**). Still, it would have been helpful if the material had some introductory discussion of student difficulties/misconceptions so that teachers would be able to prepare themselves appropriately.

your body normally stores from excess food.

Also during exercise, the production of water and carbon dioxide increases. The increased heart and breathing rate is the body's way of delivering and removing these extra materials to and from the cells during this increased activity.

When students have heard of respiration before, they usually think of it simply as breathing.

Some of the energy released in cells is heat energy, which maintains your body temperature or heats you up when you exercise. But most of it (about 60%) remains as chemical energy, transferred to many special molecules (called ATP) in the cell, each of which can store the energy in very small usable quantities. These energy-rich ATP molecules move around the cell, supplying the energy needed by cells for life processes. The chemical energy in ATP molecules can be changed to motion in muscle cells, to light in the light-producing cells of the firefly, or to electrical signals in brain cells. It is used to move blood, repair wounds, move the lungs to breathe, and make new cells.

Students easily associate the need for energy with motion or exercise but seldom associate it with other cellular processes.

Growth and repair (protein synthesis)

Now the next question is, what happens with food to help people grow and repair damaged tissues? Again, this happens at the cell level.

We grow by adding new cells to our bodies, new muscle cells, new skin cells, new heart cells, new blood cells, new blood vessel cells, etc. etc. Where do these new cells come from? They are made out of the materials in food: the building blocks of fatty acids and amino acids.

Students don't usually recognize that new body growth requires new materials that have to come from somewhere. In other words, they don't apply any knowledge they may have of conservation of matter in this context of eating and growing.

Fatty acids are the building blocks for new fats and oils, which primarily make up cell membranes. Amino acids (along with nitrates and other minerals) are used for making specific new proteins, different from the ones in the plant and animal materials we eat. Some of these proteins are used for the inside components of new cells—the structures that allow nerve cells, for example, to pass electrical signals, or that allow muscle cells to contract. Some are exported out of certain cells to play important roles in fighting off disease (antibodies), or to regulate the action of organs (hormones) by acting as messengers or message receptors between cells. Some are used for the material that makes up hair, nails and teeth. Also, perhaps most importantly, protein is used to make enzymes. Enzymes are all over the body, not just in the digestive tract. They are needed to make many chemical reactions occur in cells.

The process of building new molecules is a critical function of cells. It uses the building blocks supplied by food, it requires

Discuss the Key Questions; perhaps write various answers on the board, brainstorming; or have students write their own answers. The purpose is to make students aware of the beliefs that they presently hold, and get them to begin to reflect on their adequacy. More-complete answers will be developed as the unit progresses.

Many students will say, at this point in the unit, that we need to eat healthful foods "because they help us grow," without giving any explanation of what they do inside our bodies (how we use food.) As the unit progresses, they need to improve their explanations to include the functions of food in our bodies.

WHAT IS IN VARIOUS FOODS?

Lesson 2

You probably know that children and young people need to eat healthful foods so that they will grow. But what are healthful foods? Is pizza healthful? Are hamburgers healthful? People have many different opinions about which foods are healthful. But there's one way to know for sure. Ask yourself two questions: Is this food a good source of energy? Is this food made up of the things that will help me grow?

But how can you know if a food is a good source of energy, or is made of the things you need to grow?

Key Questions	What's the difference between good foods and "junk" food? How could you find out which is which?

If you said that good foods help you grow big and strong, and junk foods don't, that's OK. But don't you want to know *why*?

If you said that we can't eat only junk foods like candy bars or cookies because they are mostly sugar and can cause cavities or because they have too much fat and that's bad for us—don't you want to know *why*? If you said that we can't eat just fruit because we won't get enough protein, or because maybe there's not enough of something in it that we need—don't you want to know *why* we need protein?

That's what this unit is about: finding out why we need to eat healthful foods.

The short answer is: **It's important to eat different kinds of foods because they contain different kinds of materials our bodies need for energy and for growing.**

What are these different kinds of materials? What are foods made of? We don't mean like a pizza is made of cheese, bread dough, tomato sauce and toppings, or like bread dough is made of flour, salt, sugar, baking soda, oil and yeast. But what are the components of flour, what are the components of cheese, what are the components of the basic foods we eat?

Lesson 2

Lesson Statement: Students identify the appropriate test for each of four food components (sugar, starch, protein and fat) by testing samples that are clearly either starch, sugar, protein, or fat, and then use these tests to decide which of these components are present in various foods. The last page of the lesson presents the idea that only small quantities of some of these components (sugar and fat) are needed in our diet.

Purpose: To discover how a chemical test can show the presence of certain nutrients in food; to learn to use proper controls when designing their own tests for food components;

So why is it important to know what's in foods?

Now that you have completed your food tests, you know that some foods have only protein, some have only fats, some have only starch or sugar, but most have combinations of two or more of these components.

In order to grow and obtain energy, your body must have all of these substances. Your body uses mainly carbohydrates and fats for their stored energy. Your body uses proteins to build new body parts when it grows or when it repairs itself. The materials in food actually become part of our bodies when we grow and gain weight.

But your body doesn't need each of these components in equal amounts! Many of us tend to eat too many foods with lots of sugar and fat (which we need only in limited quantities) and not enough of the starches and protein (which we need more of!)

19. a) Use what you have learned to write answers to the two key questions at the beginning of Lesson 2:

What's the difference between good foods and "junk" foods?

How could you find out which is which?

b) How are your answers different now than when you first thought about these questions at the beginning of the lesson?

It is important to understand that some of these food components are used mainly for energy and some mainly to help us grow. Cluster 2 will go into more detail about what happens to these components inside your body, and Cluster 3 will go into more detail about how the body uses food for energy and growth.

The last lesson in this cluster explains *where* food is used in our bodies. Where do you think?

We also use proteins for energy if we need energy beyond our carbohydrate and fat supplies. See note on p. TG 48 about **vitamins and minerals.**

19. a) Students should include the following key points: Foods that help you grow must have the proper nutrients for growth. "Junk foods" have too much of some nutrients that we only need in small amounts and not enough of the others. Many students associate fat and sugar with "junk food" and think that all sugar and fat is bad for you. Since each is a nutrient, your body needs it—but in smaller quantities than most people eat.

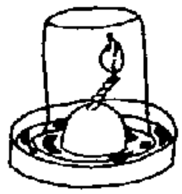
You could determine which componenets are present in any particular food by performing the food test on the food.

b) Answers vary

Where is food used in our bodies? Many students believe that food is used in our stomachs. They have very little notion of the cellular nature of organisms, and that nutrients from food are needed by cells. If students suggest that food is used in our stomachs, you might get them to think more deeply about this by asking: If energy is released from food, and if your muscles need energy when they work, how does the energy get to your muscles. Students answers to this question are interesting. Some might picture the human body like a giant electrical circuit, with the stomach being the battery, sending energy out to muscles over wires. The idea that this unit develops is that the "energy" goes around the body as digested food (glucose), to be released as needed for various cell activities.

Lesson 2

E. While the candle is still burning, test the air around it by pouring a little BTB into the Petri dish around the base of the butter candle. Cover the candle and Petri dish with a 250 ml beaker, so the spout on the beaker is under the BTB. Let it continue until the flame goes out. Then swirl the Petri dish, candle and beaker slightly and look for any color change in the BTB. Record your observations.



Think, write, and discuss

1. What evidence do you have that the burning butter candle is like whatever is going on inside your body when you use food. Think about Lesson 1. Describe your evidence in terms of *energy* and *substances*.

2. When the butter candle burned, it released light and heat—both forms of energy. Where do you think that energy was before the butter burned?

3. a) When you watched the butter candle, you saw it *burn* and *melt*. Which of these changes do you think caused the carbon dioxide to form?

   b) Do you think that what happens to the butter you eat is a chemical or physical change? Why?

4. What do you think would happen if you let the butter candle continue to burn with the beaker over the Petri dish? Do you know what substance in the air is needed for paper, wood, or even butter to burn?

Summarizing what you know

So what might be going on inside your cells when you need energy? What do we know so far? From Clusters 1 and 2, we know that

- Digested food goes to your cells.
- Oxygen goes to your cells.

So far in Cluster 3, we know that more carbon dioxide comes out of our body when we exercise, so can we conclude that

- Carbon dioxide is produced in cells when food is used for energy.

Also, from the difference between burning and melting, we know that

- Whatever is happening in your cells is a chemical process.

1. releases energy; produces carbon dioxide.

2. stored in the butter. Some students may suggest that the energy was in the flame that lit the candle — see comment below.

3. a) Burn

b) It's interesting to listen to students' views on this. Allow them to debate it for awhile. Ask them whether gas is given off when other things melt, like ice. We're trying to establish the important idea that this process of releasing energy involves a chemical change (actually many chemical changes.) Melting is only a change in state and, in fact, the butter **absorbs** energy from the burning process as it melts. Burning is a chemical process that changes the butter into new chemical substances.

4. Oxygen is needed. Eventually, the oxygen under the beaker would all be used up and the candle would go out.

As the candle burns under the beaker, students may notice the level of BTB inside the beaker going up. This is not the crucial observation (the color of the BTB, indicating released CO_2, is) but some students might ask about this. It is because there is more oxygen used by this chemical reaction than carbon dioxide produced, reducing the number of molecules inside the beaker, and therefore reducing the pressure. The outside air pushes up the water from the outside.

Lesson 11

Where does the energy come from? Energy released by the butter, both in the candle and inside one's body, is stored as chemical energy in food—a type of potential energy. The energy released is not produced by changing matter into energy. Instead, you can think of energy as being "locked up" in the glucose when it is made by plants—this energy originally coming from the sun—and unlocked in cellular respiration. Students may understand this from their earlier studies of photosynthesis or energy flow in ecosystems.

But the concept of potential energy is still often vague. Sometimes students believe that the energy they see in the candle simply came from the match that was used to light it. If this is what

(continued on next page)

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.

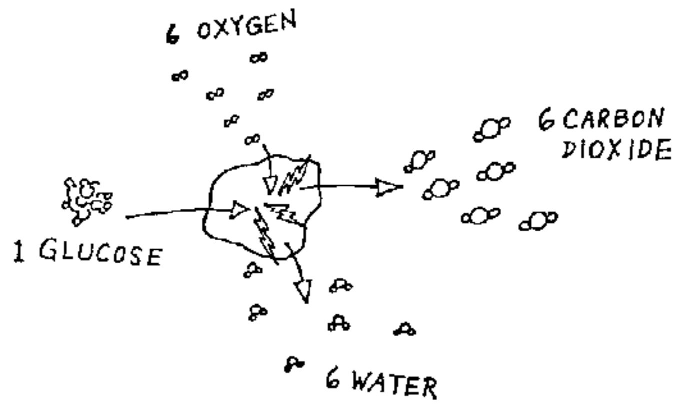
Building on your conclusions

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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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.

Lesson 11

At first, students may feel insulted by the level of this activity, but usually they will get into the sculpture part of it quickly. Be sure, however, that they realize why they are doing this--that they understand the similarity between grains of sand of their sculpture and cells of all living things. Also, help them realize that just as grains of sand come in different sizes, shapes and colors, so do cells in all living things. Heart cells are different from skin cells, and different again from blood cells, etc.

Their sculpture is different from living organisms in several ways. The most important way is that the "cells" in their sculpture are not organized into tissues and organs, like the heart, the liver, bones, muscles, the brain, etc.

3. By now students are beginning to construct the idea that food has to travel to every place in our bodies--to all cells--to be used for energy and growth. They might ask some questions like "Does food go to the end of your fingers?" or "Does food go into your brain?"

But they also might still be thinking that food needs to travel only to those places where you are growing, or only to those places that obviously need energy, like muscles. They should develop an understanding that every cell in our bodies has a place in making our bodies work correctly, and each cell needs energy.

Try This

A. **Take a cup full of wet sand.** Mold and shape it to look like a living organism of some kind: a person, a plant, an animal. Describe in your journal how the sculpture resembles a real person, plant or animal. Think about what each grain of sand represents. Also describe how this sand model is different from a living organism.

All of your body's cells are living. They need food and oxygen just like all living things do. They get rid of waste products, just like all living things do. They're busy all the time, doing all different kinds of things. You'd be surprised at the different activities that go on in cells.

So now the question is, does the food you eat go to your stomach, get used somehow in your stomach, and then go straight out through the other end?

Or does the food you eat perhaps just get *changed* somehow in your stomach, and then move to your cells, to be used in your cells? Choose one of these two possibilities that you think makes the most sense to you at this time. To make this choice, think about this: Where does your body need fuel for energy? Where does your body need "raw materials" for building new muscles, skin, blood, etc. as you grow?

We'll continue to talk about where food is used as the unit goes on.

* * *

Does this discussion make you think of other questions about food, energy, and cells?

3. Write any other questions you would like to find answers to in your journal.

Cluster 2 covers where your food goes after you chew it. You may be surprised!

Lesson 3

If you said you get tired when you exercise because you run out of food in your body, that would be a good guess, but most people have extra food—energy-rich fat—stored in their bodies just in case their glucose gets used up. (This is one way that exercise helps people lose weight, by using extra fat.)

What happens if your breathing can't keep up with your exercise?

But your body can't store extra oxygen. You get whatever you need by breathing. When you exercise, do you need more oxygen? Well, if your muscles need more energy to move fast during exercise, then you'll need more oxygen to release that energy from glucose. But if your muscle cells need energy faster than oxygen can be supplied to the cells by breathing, what happens?

Your muscle cells can't use glucose the same way if they don't have 6 oxygen molecules for every glucose molecule. Instead, a different chemical reaction takes place, one that releases *much* less energy than the cellular respiration reaction with 6 oxygen molecules does. And this different chemical reaction also produces an additional by-product (just like when a candle is short of oxygen, it can produce more smoke.) Because this by-product is produced faster than your blood can carry it away, it begins to build up in your muscles, causing pain and fatigue. That's why your muscles ache and you get cramps!

Some forms of exercise automatically rest your muscles after each time you use them. Cross-country skiing is one example. During the normal motion of push-glide, you use your muscles when you push. During this time, your cells release and use energy. Then you rest the muscles while you glide. This allows your body to continue to supply enough oxygen for the amount of energy required. Normal cross-country skiing along flat ground is good exercise for your heart, but doesn't necessarily wear you out!

Think, write, and discuss

5. Please explain in your own words why you need to eat. Don't forget to talk about cells in your explanation.

6. What happens to the air you breathe in?

7. Where does the carbon dioxide in your exhaled breath come from?

On to the next lesson...

Other "real-world" contexts of respiration include yeast in bread-making (as yeast consumes the sugar in the dough, its cellular respiration produces carbon dioxide, making bubbles that make the dough rise) and fermentation.

The by-product is lactic acid, which changes the pH in the muscles and keeps the muscle fibers from relaxing after they contract.

5. Answers will vary but the following key points should be included:

- food supplies the substances needed by the cells for making new materials and for producing energy. (Be sure students include both uses.)
- glucose and oxygen are chemically changed in cells into carbon dioxide and water vapor, releasing energy.
- the process is called cellular respiration.

6. The oxygen from the air you breathe is carried to cells where it is used to release the energy from glucose.

7. It comes from all the cells of the body. It is produced by the cells when glucose and oxygen react chemically to form carbon dioxide and water, releasing energy.

processes, and we hope that the knowlegde students construct as they search for answers to these questions will be retained by more students into their futures.

Lesson 11

Students' conception of respiration: If students have heard the word "respiration" before, they generally think of it only as breathing. This is where the common confusion about oxygen turning into carbon dioxide in the lungs comes from. With this naive view of respiration, they miss the essential connection between oxygen and *food*, and that a chemical reaction is needed for the production of carbon dioxide.