Category II Summaries for Life Science Examples

Addressing commonly held ideas

Food, Energy, and Growth

The material addresses several important commonly held student ideas, typically by challenging students to compare predictions based on a commonly held idea with what actually occurs. For example, teacher notes suggest what to do if students think that the energy they see in a burning candle comes only from the match used to light the candle (p. **42t**).

Another activity focuses students' attention on the necessity of transforming what they eat into what they are, which can help address the misconceptions that food is used in the stomach or just helps us grow, or that new body growth doesn't require new materials that have to come from somewhere (lesson 12, pp. 45–48s). Questions are used to focus students' attention on the problem. (pp. **45–46s**).

Students then use geometric models to show how the digested food is broken down into sub-units that are then reassembled into different structures (p. **46s**). And in the next lesson, students use the ideas of transformation and conservation to explain various phenomena involving weight gain and weight loss (pp. **49–51s**).

However, students are not typically asked to contrast scientific ideas with commonly held ideas. For example, the material does not employ the strategy of asking students to write a response to a hypothetical friend or younger sibling who holds a misconception. And while students are sometimes asked how their answers at the end of the lesson are different from their ideas at the beginning of the lesson (e.g., p. **13s**), this may or may not involve students in contrasting scientific ideas with commonly held ideas.

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.

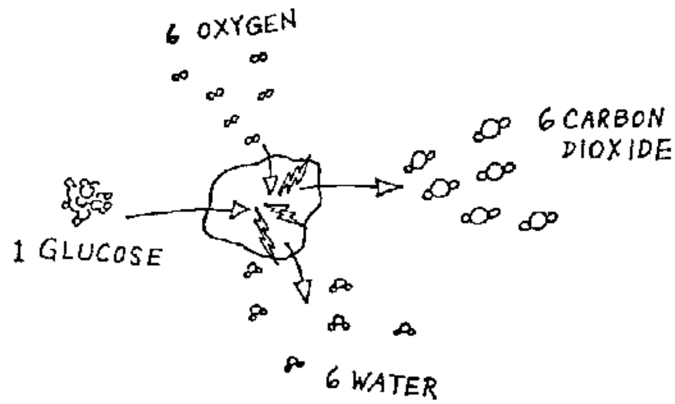
Building on your conclusions

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:

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

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?

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?

Lesson 11

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.

GROWING — *Lesson 12*

Most people know that you need to eat well to grow well. But just what does this mean? And how does food help a person grow?

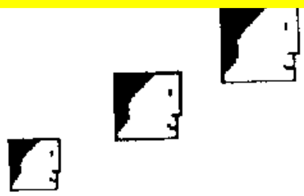
Throughout this unit we've said that food does two important things for living organisms (yes, not only humans, but dogs, cats, insects, bacteria, even plants!) It provides the energy they need for all of their body's activities, and it provides the raw materials needed for growing and repairing damaged body parts. But what does it mean to say that food provides raw materials for growing?

Key Question	
	How does food help a teenager get taller?
	How does food help a lizard regenerate a tail that gets torn off?
	How does food help a plant increase its size?

This key question, which will be examined as this lesson continues, assumes that students realize that when they grow, they actually have more material in their body than before—it's not a case of getting larger like a balloon expanding. The questions that follow the key questions are intended to help students recognize this.

The important idea for this lesson is that some material from food gets incorporated into bodies (cells) as we grow.

As you grow between the ages of 5 and 15,
you get much bigger and your weight increases.



Your bones get longer.
Your muscles get longer.
Do they just stretch?

As your bones and muscles get longer, you **need more skin to cover them**. Your body needs more blood to move food and oxygen to all of its cells.

Does your skin just stretch to cover your larger body? Does your blood just "thin out" to move over longer distances?

Let's think about one muscle as it grows:
As it gets longer, does it weigh more?
Is there more muscle material in it if it weighs more?
Do you think that your body adds more muscle material to the growing muscle?
Where do you think that extra muscle material comes from?

* * *

Yes, it comes from food. But the tricky problem is: **Since you don't eat human muscle material, how do you get it?** How do the animal and plant parts you eat become part of you? How can food materials that come from animals and

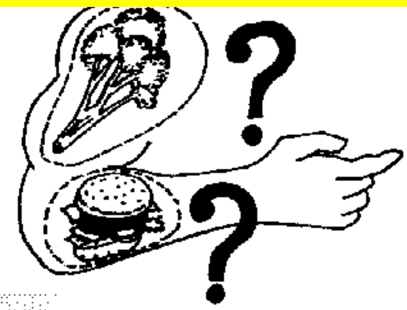
Lesson Statement: Students go back to the model of the digestive system they made in Cluster 2 and use the amino acids from digested fodds to make new protein. They make different arrangements of various numbers of objects to simulate they sythensis of proteins from amino acids.

Purpose: To understand how our bodies grow by adding new materials to cells.

Approximate Time: 1 or 2 class periods

Lesson 12

plants be changed into human body parts—human muscle material, new human blood, new human skin, and so on?



Try This

You will need:
- model from Cluster 2, Lesson 8
- "molecules" of protein, fat, and carbohydrate
- pins

Get out the model of the human digestive and circulatory systems you made in Cluster 2. Find the piece of different shaped paper that represent each of the basic components of food—the carbohydrates, the proteins, and the fats.

A. Place these pieces in the small intestine. They will represent, say, some broccoli and hamburger you just ate (plant and animal parts.)

B. Then pretend that the food is being digested: Separate the food particles into their digested products, showing that proteins are digested into ______, carbohydrates are digested into _____, and fats are digested into ______.

C. Move these digested particles through the wall of the small intestine into the blood stream, and give them a ride to, say, a muscle cell in your forearm.

What happens to them in the cell?

This is the big question. We already know what happens to glucose in the cell (what?) But what happens to amino acids?

Think this through for a minute. If your body needs new material to add to muscles as they grow, but you can't add the cow muscle materials in hamburger to your own muscles, where could this new material come from? From these amino acids? Yes. Just as proteins are broken down into amino acids, amino acids can be built back up into new proteins, the exact ones you need to make new muscle material! Your cells are tiny architects, building new muscle structures from the raw materials—the building blocks—of amino acids.

D. Use the amino acid pieces of paper in your model to build new proteins by taping them together in new ways. In your model, these new proteins can be thought of as new muscle material.

Lesson 12

The role of vitamins and minerals in growth: Vitamins and minerals are essential for making the chemical reactions occur that combine amino acids into new proteins. They are not incorporated into the new proteins, but are co-factors with enzymes to make these reactions occur. Vitamins cannot be produced by the body, so they have to be eaten; and some are not stored in the body for very long, so they have to be eaten every day. Certain minerals have other functions also, such as calcium in the production of bone matter, iron in the production of blood hemoglobin, and phosphorus for nerve firings.

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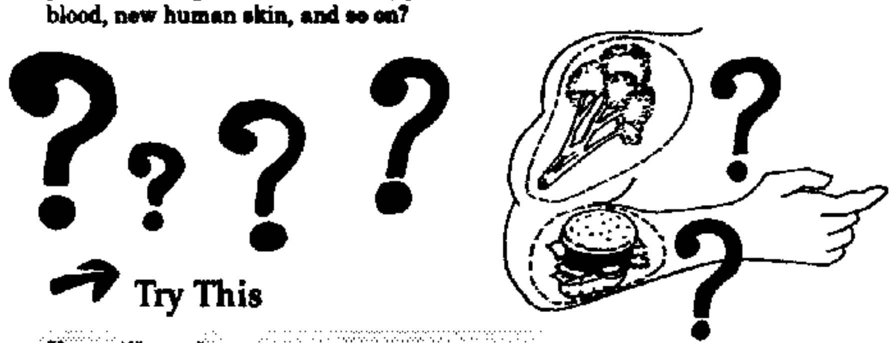

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WEIGHT GAIN AND WEIGHT LOSS

Lesson 13

All living things undergo continuous change during their brief span of life on earth. Fish get bigger, trees add new branches, crayfish regenerate damaged or lost parts, and people increase in size. In this lesson, you will use what you learned earlier in this cluster to help you understand the balance in your body between what goes in and what comes out.

Key Questions	Why does the food you eat make you grow and gain weight sometimes but not other times? What role does exercise play in weight gain and weight loss?

Allow students to speculate about these key questions, without providing answers at this point in the lesson.

Imagine two identical twins, Emily and Felicia. Each weighs 120 pounds. Emily is thirsty and so she drinks a pound (about a pint) of water. Felicia is very hungry so she eats a pound of spaghetti. For the purposes of this activity, consider all other food, water and activities of Emily and Felicia to be exactly the same unless indicated otherwise. Here is what happens to the weights of the two girls:

	Weight before eating or drinking	*Weight right after eating or drinking*	*Weight after one day*
Emily (water)	120 lb.	121 lb.	120 lb.
Felicia (spaghetti)	120 lb.	121 lb.	120.2 lb.

In answering questions 1-4, students are asked to do more than compare the effects of eating and drinking. They should speculate about what actually happens to food and water inside the girls' bodies. Most answers will probably be incomplete at this point. Note where students difficulties are.

Do you notice any pattern here? Both girls gained weight right away but lost most of that weight within a day. Felicia, though, didn't lose quite *all* of the weight she had gained.

1. Why do you think Emily did not show any weight gain after one day? Explain what Emily's body did with the water.

2. Why do you think Felicia showed a slight weight gain after one day? Explain what Felicia's body did with the spaghetti.

On a different day, Emily and Felicia both decided that they want to lose weight. Emily sat in a sauna for half an hour. She perspired a lot. Felicia ran for half an hour. She perspired a lot too. Here is what happened to their weights:

1. Emily's body used the water to help remove waste products through urine and feces; she lost the water in these ways over the long term, and returned to her original weight.

2. Felicia's body used some of the spaghetti (the protein) to build new body cells, adding to her weight. Most of the spaghetti, however, was used for energy, and the products of cellular respiration (carbon dioxide and water) were exhaled and excreted.

Lesson Statement: Students analyze several hypothetical cases of weight gain and weight loss and decide what factors caused each effect. They make predictions for specific situations and write a plan by which they can attain their own goals. They explore the weight balance of all things that go into one's body and come out.

Purpose: To help students understand weight gain and weight loss both with regard to short term effects and long term effects.

Approximate Time: 2 class periods

Lesson 13

	Weight before sauna or running	*Weight right after sauna or running*	*Weight after one day*
Emily (sauna)	120 lb.	118 lb.	120 lb.
Felicia (running)	120 lb.	118 lb.	119.9 lb.

3. How did the two girls gain back the weight they had lost?

4. **Notice that Felicia didn't quite gain all her weight back. Why? What happened to that weight?**

Both girls lost weight shortly after their activities by losing mostly water due to perspiration. They gained it back by drinking. Felicia, though, also used some *stored* food for energy needed for running. Through cellular respiration, it changed into water and carbon dioxide, and left her body, reducing her weight.

In general, you can do many different things that can cause you to gain or lose weight. Some of them make you gain or lose weight only in the short term. Others cause long term or permanent weight gain or loss. Let's try to sort out which activities have which sorts of effects.

5. Look at the activities listed in the table below. Think about what things cause only short-term weight gain or loss and what things cause long term weight gain or loss. Then copy the following table and fill in each space with one of the following: weight gain, weight loss, no effect or not sure.

Activity	*Short term effect*	*Long term effect*
Eating tuna fish	[weight gain]	[weight gain]
Eating french fries	[weight gain]	[weight gain]
Eating pasta	[weight gain]	[weight gain]
Drinking skim milk	[weight gain]	[weight gain]
Drinking water	[weight gain]	[no effect]
Playing basketball	[weight loss]	[weight loss]
Sitting in the sun (& perspiring)	[weight loss]	[no effect]
Sleeping	[weight loss]	[weight loss or no effect]
Going to the bathroom	[weight loss]	[no effect]

6. a) Study your answers and make a statement about what sorts of activities lead to long term weight gain or weight loss.

   b) What sorts of activities have no long term effect?

3. Mostly by drinking water to replenish what they lost through perspiration—our bodies demand this from us after we exercise!

4. She needed extra energy to make her body work faster than normal, so she used some of her stored body fat for that energy. It was changed to carbon dioxide and water, and exhaled. She actually lost weight by exhaling CO_2!

5. (see table)

6. Long term weight gain: eating food that helps build new cells (proteins) or that can be stored as body fat. This food intake has to be beyond what the body requires for energy.

Long term weight loss: exercise that uses stored body fat for its energy content, changing it into carbon dioxide and water. The carbon dioxide is exhaled, losing its weight.

b. ones that only involve water intake or loss

Calories: We deliberately have not talked about calories in this lesson, allowing the idea of calories to come up as a question from students instead. Many students are familiar with the idea of "counting calories" for dieting, or have seen the caloric value of a serving of food on package labeling. "Calorie" (with a capital C) is a common unit of energy that refers to the amount of energy released from the food when it is oxidized in the body—one Calorie is equal to the amount of energy needed to raise one kilogram of water one degree Celsius. In dieting, people often try to restrict the amount of calories (Calories) they eat, which is not the same, of course, as restricting only the quantity of food eaten, since some foods have more calories per ounce (or

Lesson 13

7. How can you explain long-term weight gain in terms of how our bodies use food? Use the concepts of digestion and cellular respiration in your answer.

8. Explain, in terms of energy, how you can control how much long-term weight you gain or lose?

9. Why does eating sugar result in weight gain if it is stored as fat, but not if it is used in cellular respiration.

10. Tell what kind of diet would be good for each of the following situations. Explain how you made your choice.

a) You are a body builder and want to add muscle to your body.

b) You want to gain weight.

c) You are planning an expedition to the Arctic and want to get your body ready for the trip.

d) What does a bear need to eat as it prepares for hibernation?

Body fat is not a bad thing. If you were exploring in the Arctic, you might have to go without food for several days. Excess food stored by your body as fat can be converted to glucose and used for energy when your body needs it. In times past, people might use body fat if crops failed or hunting was bad; body fat was important. In those situations, some people without some stored energy would weaken and perhaps die. Today, for people who never go hungry, the excess fat their bodies store is no longer useful. Because fat can cause serious health problems such as heart disease and high blood pressure, we need to keep our bodies from storing too much fat.

* * *

11. What do you want for yourself—weight gain, weight loss or just maintain your current weight? Write a plan that will help you achieve your goal. Tell why you think your plan will work.

7. Digested food (primarily amino acids and fatty acids) can be used for growth or for storage of fat; both result in weight gain. If digested food is used for repair or for cellular respiration, there will not be any long-term effect.

8. If you want to gain weight, take in more food for energy than what your body needs. It will be stored as body fat, adding to your weight.

If your body needs more energy than what's stored in the food you eat every day, it will use stored body fat for that extra energy, changing it to carbon dioxide and water, and exhaling the carbon dioxide.

9. When it is stored as fat, it adds to the weight of the body. When it is used in cellular respiration, it is changed into carbon dioxide and water vapor, and expelled from the body.

10. a) A diet rich in protein will provide amino acids needed for building muscle.

b) A diet high in carbohydrates and especially fat will provide the excess needed to gain weight.

c) Fats have twice as much available energy as carbohydrates (that's why they taste so good.) Eat lots of carbohydrates and fat to store up extra energy.

d) Lots of fat to store up extra energy for the body to keep warm and function during the long winter (Although bears don't actually hibernate—their body temperature does not drop significantly—they are much less active because food is much less available. In the same way, plants store food in the form of starch in the roots for use during the spring, before their leaves begin producing their own food.)

11. Answers vary

gram) than others. Generally foods high in calories (by weight) contribute more to body fat than those low in calories. But energy is needed by all people, even if they are dieting, so they have to maintain some minimal caloric intake—this is why bulimia or other forms of not eating are dangerous: Without any food, our bodies have no energy and no materials for growth and repair. New dietary guidelines recognize that foods high in saturated fats contribute more to body fat (and heart disease) than those of similar calorie content that are low in saturated fats.

Lesson 13

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!)

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) 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?

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

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?

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