Category II Summaries for Life Science Examples

Alerting teacher to commonly held ideas

Food for Plants

Research indicates that students typically have several misconceptions about key ideas on the photosynthesis topic. 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).
- plants get their food from the environment (mainly from the soil) rather than manufacture it themselves (AAAS, 1993, p. 342; Driver et al.,1994, p. 30).
- plants have multiple sources of food rather than that plants make food from water and carbon dioxide in the air and that this is their only source of food (AAAS, 1993, p. 342; Driver et al., 1994, pp. 31, 60).

Food for Plants alerts the teacher to all these student difficulties and commonly held ideas and represents research findings in an accurate way. The *Teacher's Guide* provides elaborate descriptions of four "Critical Barriers to Understanding Plants and their Food" (Teacher Introduction, pp. **5-7**). It also provides a chart of "conceptual contrasts" that compares the scientific view with students' misconceptions on the key ideas on this topic (Teacher Introduction, pp. **8-9**). The contrast between the student ideas and the scientific ideas makes it likely that teachers will better understand where the problem lies in student ideas.

B. Critical Barriers to Understandings Plants and Their Food

Four general issues are particularly difficult for most students when learning about how plants make their own food. These issues and the reasons for their importance from the students' points of view are as follows:

1. Food.

This word is rarely used with precision by either students or biologists. When talking about the food made by plants during photosynthesis, however, biologists are more consistent. In this context, biologists use the word "food" to refer to organic compounds with high-energy molecular bonds that organisms can use for growth and metabolism. Other substances that organisms need, such as water, oxygen, and minerals are inorganic and do not contain high-energy bonds in their molecules. These substances are NOT considered *food* by this scientific definition. It is this distinction that makes the statement "plants make their own food" meaningful. The process of photosynthesis provides the only bridge by which inorganic matter can be transformed into organic matter.

The biological distinction between energy-supplying substances (food) and non-energy-supplying substances (not food) is critical to understanding the significance of photosynthesis. Plants and other organisms convert glucose into the millions of other organic compounds (proteins, fats, hormones, enzymes, etc.) that make up the bodies of living things. However, all of those compounds (in other words, all food) are ultimately derived from a single source: glucose made during photosynthesis.

The distinction between plants as producers and animals as consumers in ecosystems cannot be meaningful to students who do not understand that the food made during photosynthesis is different in a very important way from other nutrients such as water and minerals. After all, what is it that plants produce and animals consume?

Students do not think about food in these ways, however. To them, food is whatever plants or animals take in to keep them alive and growing. From this perspective, it is easy to see how they could misunderstand or distort instruction about photosynthesis. Their definition of food is sensible, but it misses the essential distinction between energy-containing and non-energy-containing matter.

2. Energy.

The significance of the distinction between energy-containing and non-energy-containing substances lies primarily in energy relationships. Photosynthesis captures energy from sunlight and converts it to chemical potential energy stored in organic compounds (food).

Energy, however, is an abstract and difficult concept for most students. They tend to think about energy in vague terms, as part of everything that plants or people need. In order to appreciate the significance of energy in photosynthesis, they must learn to follow the path that energy takes and the changes it undergoes. Energy can change form. For example, light energy can be transformed into heat energy (notice the heat near a light bulb or the

sun's light energy being changed into heat energy which warms the earth). Students must appreciate the critical importance photosynthesis plays in changing energy from light energy into another form -- chemically stored energy -- that is usable by living things.

3. Matter.

Biologists' conceptions of photosynthesis also depend on a chemical understanding of the nature of matter. Biologists make a distinction between energy (light, heat, chemically stored energy, sound, etc.) and matter. Photosynthesis is seen as a process by which light energy is used to change matter chemically -- a chemical change or chemical reaction. The substances involved are characterized as chemical compounds. In these chemical reactions, matter is changed but conserved. Scientists think of these chemical reactions as involving rearrangements of molecules which result in the formation of new compounds. Water molecules and carbon dioxide molecules are rearranged to form sugar molecules and oxygen molecules.

Most students, however, are not used to thinking about molecules, chemical formulas, or chemical reactions. In fact, they do not typically think about things they cannot see -- such as the idea that things are happening inside of plants other than water being sucked into the plant by the roots. These invisible things and processes seem very mysterious to them and only vaguely understandable.

4. The Functional Nature of Scientific Explanations.

Consider these answers that students gave to another question about food for plants:

Question:	**Do plants need food? Why or why not?**
Susan:	Yes. They need sun, fertilizer, water, and soil.
Brooks:	Yes. It's like people, they can't live without food.
Ryan:	Yes. Because plants have to eat or they would die.

It is notable that the students' explanations of "why" don't really explain anything. Susan and Ryan's explanations are essentially circular; they restate in different words that plants need food. Brooks appeals to an analogy between plants and humans.

Scientists, on the other hand, strive for **functional** explanations (for example, "Plants need food because their cells use food as a source of energy.") Biologists think about the function that each substance plays in the internal workings of the plant. They seek to understand not just whether or not a plant needs a particular substance to stay alive; they want to know what happens to that substance inside a plant. How does the plant use it? Thus, an essential part of

learning about photosynthesis is learning to develop appropriate functional explanations and definitions.

We have chosen to emphasize these four issues because the concepts they involve are absolutely essential for students to make real sense of photosynthesis. Unfortunately, most textbooks and courses fail to treat these concepts adequately, forcing students to memorize more technical vocabulary and advanced concepts before they have struggled with these fundamental ideas.

To help students understand the central ideas, we have carefully limited the amount of scientific terminology introduced, we have not discussed photosynthesis at a molecular level, and we have omitted discussions of the light and dark phases of photosynthesis. The production of oxygen in photosynthesis is de-emphasized in order to emphasize food production. In earlier research, we found that emphasis on these ideas often served only to distract students from the central issues.

COMPARING STUDENT CONCEPTIONS AND WAYS OF THINKING WITH SCIENTISTS' CONCEPTIONS AND WAYS OF THINKING...
ABOUT PLANTS AND THEIR FOOD

ISSUE	GOAL CONCEPTIONS	NAIVE CONCEPTIONS
Plants' source of food	Plants make their own food internally using carbon dioxide, water, and sun in a process called photosynthesis.	Plants take in their food from the outside environment.
	This is plants' only source of food.	Plants have multiple sources of food.
Nature of food	Food made by green plants is matter that organisms can use as a source of energy. It is an energy-containing material.	Food is the stuff that organisms eat, chew, take into their bodies.
Function of food in plants	Food supplies the energy that each cell of a plant needs for internal life processes (functional explanation).	Food is need to keep plants alive, to grow (nonfunctional explanation).
Matter transformation (chemical change)	Water and carbon dioxide taken into plants is changed into new matter as a result of a chemical reaction. In this chemical change, nonenergy-containing matter (carbon dioxide and water) is rearranged and recombined to make energy-containing food (glucose).	Water and carbon dioxide taken into plants are not changed. They are used unchanged to support two separate life processes -- drinking/eating the water and breathing the carbon dioxide.
Movement of matter	Water and carbon dioxide travel to cells in the leaf where they are involved in one process -- photosynthesis.	Water and carbon dioxide travel throughout the plant where they are used for two separate processes -- eating/drinking the water and breathing the carbon dioxide.

Energy transformation	During photosynthesis, light energy from the sun is changed into chemical energy stored in the food that plants make.	Plants need sun to live, grow, to be green. (No notion of energy being absorbed, needed, or changed) OR Plants get their energy directly from the sun -- this is their food. (No notion of light energy being transformed into food energy)
Importance of food-making process for plants	Most important product is food. This food is the plant cells' only source of energy.	The food-making process in plants is something they do for the benefit of people/animals. Plants are important because they give us oxygen and food.
Importance of food-making process for people/animals	Animals depend on plants for food as well as oxygen. Only green plants can change light energy from sun into chemical energy stored in food. Thus, only green plants can make energy-containing food that all living things need.	Plants are important because they make oxygen for people and animals to breathe. (Focus on oxygen production, not food production) Plants are also an important source of food for animals, but they are not the only source.