5.3: How do Plants Use Food to Grow? Reading

Purpose for Reading: *As you read this text, work to make sense of how plant systems build up matter so that plants are able to grow.*

Zooming into Growing

Scientists work to explain things we can observe—like plants growing—by "zooming in" to the smaller systems that plants are made of—cells—as well as the molecules that make up cells. Let's zoom into an plant to figure out how in grows.

Macroscopic scale: We observe plants growing at the macroscopic scale. Materials are moving inside a growing plant:

- During photosynthesis, the cells of the leaf convert carbon dioxide and water into glucose and oxygen. Glucose is absorbed by the phloem to be sent to the rest of the cells in the plant.
- Water and dissolved minerals such as nitrogen and phosphorous come into the plant through the roots and travel (through vessels called the xylem) to all the cells of the plant.

The cells use these essential materials—glucose, minerals, and water—to grow larger and divide. What is happening inside the potato at the microscopic and atomic-molecular scales to allow the potato to grow?

Cellular scale: Every cell in a potato plant takes in glucose, water, and minerals. They use these materials to grow larger and divide. How do cells produce the matter—mostly large organic molecules—that they are made of? This is a puzzling question since only small molecules can get out of the phloem and through the cell membrane.

Atomic-molecular scale: Some of the glucose molecules and minerals are combined into large organic molecules (biosynthesis) in the plant's cells. This building of large organic molecules in all kinds of cells is how the potato grows.

Using Four Steps to Explain Biosynthesis

We can explain biosynthesis—the building up of materials in a living organism—by answering the four numbered questions on the Three Questions handout:

1. How do molecules move to the location of the chemical change?

Small organic molecules in: Glucose molecules move out of the phloem and into cells all over the potato. Minerals such as nitrogen also enter the cells dissolved in water.

2. How are atoms in molecules being rearranged into different molecules?

Plant cells are made mostly of water and large organic molecules—carbohydrates such as starch and cellulose, proteins, and fats. They make those large organic molecules with two kinds of chemical changes.

- First, the cells make all the different small organic molecules that they need from glucose and minerals. This is a complicated process. There is a little more about this process in the section on multiple pathways, below.
- Then the cells combine the small organic molecules to make large organic molecules such as starch, cellulose, fats, and proteins. The chemical change also produces water molecules.

3. What is happening to energy?

The chemical energy stored in the high energy bonds (C-C and C-H) in the small organic molecules remains in the bonds when they are combined into large organic molecules since the bonds are not changed. (The chemical reaction to bond together the small organic molecules requires a little bit of energy, which the cells get from cellular respiration.)

4. How do molecules move away from the location of the chemical change?

Cells grow and water out: Cells grow bigger and may eventually divide as more large organic molecules are made. Water leaves the cells.

Biosynthesis & Feeding the World

Most of the time, we want to maximize biosynthesis in crops. The more biosynthesis occurs, the more food that is produced by a crop. However, sometimes more biosynthesis can cause problems, such as the problem that an agricultural scientist named Normal Borlaug encountered in his research in the late 1940s. By preventing disease and using fertilizers, Borlaug and his team were able to maximize wheat production. However, they were so successful in maximizing wheat biosynthesis that the seed heads of the wheat plants became too heavy for the plant to support, causing the wheat plants to collapse and fail.

To address this problem, Borlaug and his team found a strain of wheat (called *semi-dwarf wheat*) with an unusual trait – short, stubby stems. By combining the genetics of the highly-productive wheat plants with the short-stemmed wheat, Borlaug was able to create varieties that could produce six times as much grain. Borlaug's work occurred as populations around the planet skyrocketed after World War II, and he is credited with preventing *billions* of deaths from starvation and malnutrition. Today, about half the world's population consumes grain from strains of plants developed by Normal Borlaug. Due to the extensive benefits of his scientific research for global populations, Borlaug was awarded the Nobel Peace Prize in 1970.

Multiple Pathways

You have modeled and explained a few examples of biosynthesis in plants. However, there are many other pathways that change small organic molecules into the large organic molecules that plants need to grow, move, and function. Some of these pathways have multiple steps, some can happen in both forward and reverse, some have parts that happen in different cells before the products are combined, and some pathways are cyclical.

For example, you can go online and look at a metabolic pathways poster: http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Sigma/General_Information/metabolic_pathways_poster.pdf.

As you can see, biochemists have found many different ways that cells can change molecules through chemical reactions. Note that this poster shows *just the small organic molecules.* A poster that shows how all these small organic molecules are made into large organic molecules would have to be many times larger.