Reference 3

Cellular Respiration

Cellular respiration is a critical biochemical process for life on Earth. All cells require a continuous supply of energy to maintain order, build organic molecules, grow, and carry on all their other activities. Plants and other organisms can recover the solar energy stored in the molecular bonds of glucose by breaking down the sugar. Energy can then be stored in the bonds of ATP, which is used for a variety of processes that a cell must carry out to live. Cellular respiration is the most efficient way that glucose can be broken down to generate energy for other cellular reactions. In a sense, cellular respiration can be thought of as a type of controlled burning. When something is burned, a great deal of energy is released. The process requires oxygen and releases carbon dioxide and water and produces ATP. Cellular respiration can be summarized as:

$C_6H_{12}O_6$	+	**6 O_2**	⟶	**6 CO_2**	+	**6 H_2O**	+	**32 ATP & heat**
carbohydrate		oxygen		carbon dioxide		water		energy

During cellular respiration, the energy stored in a glucose molecule is released slowly as the molecule is broken down (figure R3.1). Cellular respiration occurs in three phases. In the first steps, known as **glycolysis**, glucose is split into two 3-carbon molecules. This releases energy, some of which is transferred to ATP. Glycolysis takes place in the cell cytoplasm. The second stage is called the **Krebs cycle**. During the Krebs cycle, each of the 3-carbon molecules is disassembled in a series of reactions to form six carbon dioxide molecules. Hydrogen atoms are also released. Special molecules carry the hydrogen atoms to the third stage, the electron transport system. This system stores the relatively large amount of energy present in a glucose molecule in several smaller and more useful packets of ATP. Each hydrogen atom is separated into an electron and a proton. The electrons are eventually taken up by oxygen molecules to form water. The Krebs cycle and the **electron transport system** operate in the mitochondria (figure R3.2).

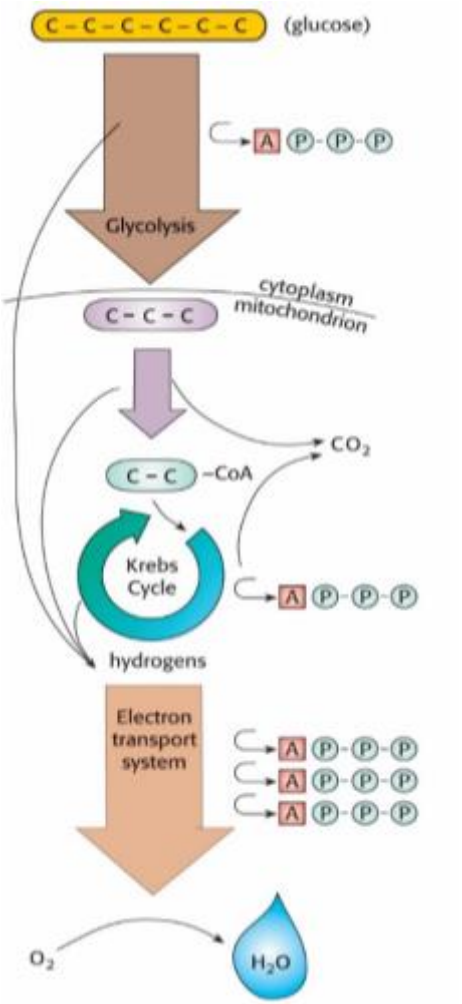

Figure R3.1: Cellular respiration occurs in three stages. Glycolysis occurs in the cytoplasm; the Krebs cycle and the electron transport systemtake place in mitochondria.

Figure R3.2: Mitochondria carry out two of the three phases of cellular respiration. The fingerlike projections, or cristae, are folds in the inner membrane which separates the intermembrane space and the large matrix.

Where Does the Mass of a Plant Come From?

When you started this unit you were asked to think about how a tiny seed can become one of the tallest trees on Earth—a giant sequoia. So where *does* all this mass come from—and what does photosynthesis have to do with it?

Remember that carbohydrates, including glucose, are outputs of photosynthesis. Glucose is a sugar made up of carbon, hydrogen, and oxygen. These carbon, hydrogen, and oxygen atoms then recombine to form glucose which is then used to make more new compounds that the plants need, including proteins, fats, and other carbohydrates that the plants use to survive and grow. This means that the mass in plants comes mostly from photosynthesis. It's amazing but true: Almost all of the mass in the giant sequoia comes from carbon dioxide in the atmosphere as the process of photosynthesis fixes one carbon dioxide molecule after another!

For example, glucose molecules, that were produced during photosynthesis from carbon dioxide and water, link together to form the polymer cellulose. Cellulose is a chain of several hundred to many thousands of linked glucose molecules. You might know that cellulose is the substance that forms the cell walls surrounding plant cells. Cellulose is the most abundant organic polymer on Earth. Approximately 50 percent of the matter in a tree is cellulose. Cellulose is also the substance that makes tree trunks and limbs strong.

Cellular Respiration and Mass

Virtually all cells, including plant cells, go through cellular respiration to break down food to provide the energy needed for normal functioning and growth. Similar to photosynthesis, the atoms in food molecules are rearranged during cellular respiration. Remember that one of the inputs to cellular respiration is carbohydrate, specifically glucose. Plants form glucose by photosynthesis and animals get glucose by breaking down the food they eat. During cellular respiration, glucose combines with oxygen to release energy and to form carbon dioxide and water. Most of the carbon dioxide in animals is released into the air when the animal breathes. This carbon dioxide can then be used by plants for photosynthesis. When plants respire, they also

release carbon dioxide that can be used for photosynthesis, or the excess may be removed from the plant through the leaves.

Plants and animals can also store energy in molecules such as fat or starch. In animals, including humans, if you do not have enough glucose in your bloodstream (from the food you eat) to supply your cells with glucose, your body will break down these fats into glucose for your body to use for cellular respiration. In this way, the carbon that is in the body fat is transformed to carbon dioxide which you breathe out.

Unlike animals, green plants go through both photosynthesis and cellular respiration. Determining which process is occurring at a greater rate depends on the state of the plant. If the plant is growing and gaining mass, which would be occurring at a greater rate, photosynthesis or cellular respiration?