**Photosynthesis**

**Photosynthesis** is the process of converting light energy to chemical energy and storing it in the bonds of sugar. This process occurs in plants and some algae (Kingdom Protista). Plants need only light energy, CO2, and H2O to make sugar. The process of photosynthesis takes place in the **chloroplasts**, specifically using **chlorophyll**, the green pigment involved in photosynthesis.

![[Leaf Cross-Section]]()Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the **upper and lower** **epidermis**, the **mesophyll**, the **vascular bundle(s)** (veins), and the **stomates**. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO2 in and O2 out. The vascular bundles or veins in a leaf are part of the plant's transportation system, moving water and nutrients around the plant as needed. The mesophyll cells have chloroplasts and this is where photosynthesis occurs.

![[Chloroplast]]()As you hopefully recall, the parts of a chloroplast include the outer and inner membranes, intermembrane space, **stroma**, and **thylakoids** stacked in **grana**. The chlorophyll is built into the membranes of the thylakoids.

Chlorophyll looks green because it absorbs red and blue light, making these colors unavailable to be seen by our eyes. It is the green light which is NOT absorbed that finally reaches our eyes, making chlorophyll appear green. However, it is the energy from the red and blue light that are absorbed that is, thereby, able to be used to do photosynthesis. The green light we can see is not/cannot be absorbed by the plant, and thus cannot be used to do photosynthesis.

The overall chemical reaction involved in photosynthesis is: 6CO2 + 6H2O (+ light energy) C6H12O6 + 6O2. This is the source of the O2 we breathe, and thus, a significant factor in the concerns about deforestation.

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| **Central Structure of Chlorophyll** |
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 |       | There are two parts to photosynthesis: The **light reaction** happens in the thylakoid membrane and converts light energy to chemical energy. This chemical reaction must, therefore, take place in the light. Chlorophyll and several other pigments such as **beta-carotene** are organized in clusters in the thylakoid membrane and are involved in the light reaction. Each of these differently-colored pigments can absorb a slightly different color of light and pass its energy to the central chlorphyll molecule to do photosynthesis. The central part of the chemical structure of a chlorophyll molecule is a **porphyrin ring**, which consists of several fused rings of carbon and nitrogen with a magnesium ion in the center.  |
| The energy harvested via the light reaction is stored by forming a chemical called **ATP (adenosine triphosphate)**, a compound used by cells for energy storage. This chemical is made of the nucleotide adenine bonded to a ribose sugar, and that is bonded to three phosphate groups. This molecule is very similar to the building blocks for our DNA.  | Structure of ATP |

The dark reaction takes place in the stroma within the chloroplast, and converts CO2 to sugar. This reaction doesn't directly need light in order to occur, but it does need the products of the light reaction (ATP and another chemical called NADPH). The dark reaction involves a cycle called the **Calvin cycle** in which CO2 and energy from ATP are used to form sugar. Actually, notice that the first product of photosynthesis is a three-carbon compound called **glyceraldehyde 3-phosphate**. Almost immediately, two of these join to form a glucose molecule.

Most plants put CO2 directly into the Calvin cycle. Thus the first stable organic compound formed is the glyceraldehyde 3-phosphate. Since that molecule contains three carbon atoms, these plants are called **C3 plants**. For all plants, hot summer weather increases the amount of water that evaporates from the plant. Plants lessen the amount of water that evaporates by keeping their stomates closed during hot, dry weather. Unfortunately, this means that once the CO2 in their leaves reaches a low level, they must stop doing photosynthesis. Even if there is a tiny bit of CO2 left, the enzymes used to grab it and put it into the Calvin cycle just don't have enough CO2 to use. Typically the grass in our yards just turns brown and goes dormant. Some plants like **crabgrass**, **corn**, and **sugar cane** have a special modification to conserve water. These plants capture CO2 in a different way: they do an extra step first, before doing the Calvin cycle. These plants have a special enzyme that can work better, even at very low CO2 levels, to grab CO2 and turn it first into **oxaloacetate**, which contains four carbons. Thus, these plants are called **C4 plants**. The CO2 is then released from the oxaloacetate and put into the Calvin cycle. This is why crabgrass can stay green and keep growing when all the rest of your grass is dried up and brown.

There is yet another strategy to cope with very hot, dry, desert weather and conserve water. Some plants (for example, cacti and pineapple) that live in extremely hot, dry areas like deserts, can only safely open their stomates at night when the weather is cool. Thus, there is no chance for them to get the CO2 needed for the dark reaction during the daytime. At night when they can open their stomates and take in CO2, these plants incorporate the CO2 into various organic compounds to store it. In the daytime, when the light reaction is occurring and ATP is available (but the stomates must remain closed), they take the CO2 from these organic compounds and put it into the Calvin cycle. These plants are called **CAM plants**, which stands for **crassulacean acid metabolism** after the plant family, Crassulaceae (which includes the garden plant *Sedum*) where this process was first discovered.

**Photosvnthesis Article Reading Guide**

1. What is Photosynthesis?
2. Where does photosynthesis occur?
3. What do plants need to complete photosynthesis?
4. Does photosynthesis happen in the stems of plants?
5. What are the 5 parts of a leaf?
6. What do the epidermal cells do for the leaf?
7. What are stomates?
8. What is the purpose of the veins in the leaf?
9. Do all cells in plants have chloroplasts? If not, which ones do?
10. What are the 5 parts of a chloroplast?
11. Where is chlorophyll found?
12. Why does chlorophyll look green?
13. What color of light does the plant use for energy?
14. What is the overall reaction for photosynthesis?
15. What are the two parts of photosynthesis?
16. What happens in the thylakoid membrane?
17. Other than chlorophyll, what is one pigment used in photosynthesis?
18. Why is there more than one type of pigment in the chloroplast?
19. Where is the energy from the light stored?
20. What other molecule uses similar building blocks?
21. What happens in the stroma?
22. Can the plant go through this reaction if it is never put into the light?
23. What is the final product of the dark cycle?
24. How can a plant keep more of its water in hot, dry conditions?
25. What type of a plant is crabgrass? What makes it less likely to turn brown?
26. What special way do plants in the desert use their stomates to conserve water?