Photosynthesis: How it functions through the plant, and what it means to the environment

Objectives:

- **Understand the importance of photosynthesis**
- **Interpret the chemical equation for photosynthesis**
- **Explain the Calvin Cycle**
- **Explain Light-Dependent Reactions**
- **Explain the Electron Transport Chain**

Vocabulary:

- **Stroma**
- **Chlorophyll**
- **Adenosine Tri-Phosphate**
- **Adenosine Di-Phosphate**
- **NADPH**
- **Thylakoid**
- **Chloroplast**
- **Photosystem I**
- **Photosystem II**
- **Electron Transport Chain**
- **Calvin Cycle**
- **Rubisco**
- **Reduction and Sugar Production**
- **3-Phosphoglycerate**
- **Triose Phosphate**
- **RuMP**
- **Biodiversity**
- **Evolution**
- **Food Chain**

Section 1.1: Location

The site where plants go through all the steps of photosynthesis is in the Chloroplast. The chloroplast is known for being the only area where photosynthesis takes place. These tiny green plastids absorb sunlight and use it in conjunction with water, and carbon dioxide gas, to produce food for the plant[1]. Chloroplasts are one of the main differences between plant and animal cells. They can be split into two separate parts. The inner most space is filled by thylakoids, and because of this it is called the thylakoid space. Thylakoids are disk shaped structures that stack together inside the chloroplast[2]. Later in the chapter, you will learn about what reaction occurs where; the thylakoids containing only light dependent reactions. The space that surrounds the green disks is filled with a fluid. This fluid is called stroma, and it allows carbon dioxide to produce glucose[3].

Section 1.2: Light Dependent Reactions

As mentioned before, light reactions take place in the thylakoids of the organelle. The main thing that light dependent reactions successfully do is capture the energy of light and uses it to make the energy-storage, and transport molecules ATP (Adenosine Tri-Phosphate) and NADPH. ATP and NADPH are both needed to be exchanged and moved around so that the plant can get the food it needs in the form of sugars. From this reaction, H_2O is converted to O_2 so that the broken off electrons from the hydrogen atom can help to synthesize ATP[4]. Overall, light energy is changed to chemical energy. There are two versions of this light dependent reaction. They are called Photosystem I and Photosystem II. These photosystems usually work together and are numbered in order of their discovery[5]. Electrons flow from photosystem II to I. The second photosystem captures photons and uses the energy to extract electrons from water molecules. This is where the broken off electrons from the hydrogen atoms come from. After this occurs, the first photosystem is ready to take part in the reaction. It optimally absorbs photons of wavelength 700 nm[6]. It is responsible for providing high energy electrons used to reduce NADP+ to NADPH so it can be used in the Calvin cycle. It takes the electrons and makes NADPH. Out of this reaction, ATP and NADPH are produced.

Molecules need to be able to move to the areas of the plant that they're destined for. This is where the Electron Transport Chain comes in. Across the membrane, a gradient is created that allows hydrogen ions to gather on one side and linger near[7]. These ions are pushed up from low concentration areas, and at some point, pushed back down into the low concentration area through ATP synthase. The broken off electrons can pass through the membrane as well. The electrons get passed along the membrane until it's eventually used in NADP reductase. The whole reason that the electrons can even undergo the movement that they do is because of the gradient the hydrogen ions gave off.

Section 1.3: Light Independent Reaction (The Calvin Cycle)

All the ATP and NADPH that was synthesizes can now be used. The Calvin Cycle is also known as the light independent reaction. Sunlight is not needed for this reaction to take place. Instead, the ATP and NADPH along with carbon dioxide come together to create chemical energy[8]. Glucose and other sugars are what make up this chemical energy. This is like food for the plant. This is how the plants gets the energy that it needs to grow and be prosperous after the process is done with. In the same way that the light dependent reaction could be split up in sections, so can the light independent reaction. The reaction is split up into three different parts: Carbon Fixation, Reduction and Sugar Production, and Regeneration. First, let's talk about Carbon Fixation. The Carbon atoms from the carbon dioxide are introduced to the system. It's this introduction that catalyzes the reaction of carbon dioxide, and a molecule called the Rubisco. Rubisco is the protein that helps synthesize this reaction, and the most abundant protein in the world[9]. After this encounter, the now bounded molecule is split into two.

The second phase is more about the specifics of the sugar making. This is where the ATP and NADPH come in heavy. In this sub-process that we call Reduction and Sugar Production, one compound is reduced to another with the aid of both ATP and NADPH. The compound used to begin with is called 3-Phosphorglycerate and is made up of three carbon molecule and one phosphorous molecule[10]. During the reaction, it is turned into Triose Phosphate, which also is made up of three carbon molecules and a phosphorous molecule. The adding and taking away of a phosphorous molecule in the reaction is how Triose Phosphate is made. From this process comes a glucose molecule that the plant uses as a source of energy. After Triose Phosphate is present, the next phase can begin. Now the five carbon two molecule compound, Rubisco, can be regenerated. Triose Phosphate is processed in a series of reactions that produce RuMP. ATP is required in this process to make a reaction that turns the RuMP into Rubisco. Now it can take in another carbon molecule and begin the Calvin Cycle again. In order to made one glucose molecule: 6 carbon atoms, 6 Rubisco molecules, 18 ATP, and 12 NADPH are all needed[11].

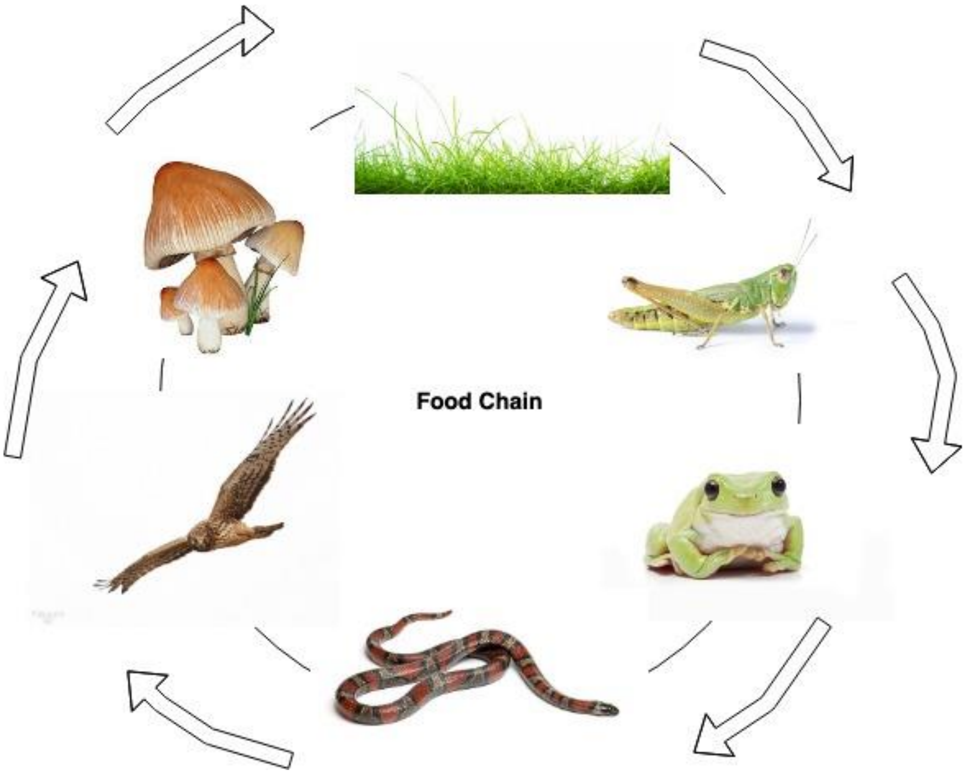
Section 1.4: Plants and the Environment

The environment that we live in is made up of millions of species of plants. Plants release oxygen into the atmosphere and absorb the carbon dioxide in the atmosphere. Carbon dioxide is not useful for most organisms and can be toxic if too much is in one area. Plants use it to help themselves go through photosynthesis, but in the process, it also helps other organisms. Habitats for wildlife, and ultimately humans, come from the aid of plants as well. Plants even go as far as contributing to the regulation of water. Just like carbon dioxide, water is needed for photosynthesis. In areas with excessive amounts of water at a given time period, this is very beneficial. Diversity is good in all aspects of live. Plant diversity, called Biodiversity, allows for the roles that plants might take in nature to do multiple tasks depending on the species. Biodiversity ensures natural sustainability for all life forms[12]. Although we try to account for all the different species of plants, they will never all be known to us. Plants take part in evolution, either from natural selection, or randomization. Because of this, new species are constantly coming about. Evolution is the change in genetic variation in a population[13].

Section 1.5: Plants and Us

Plants serve many benefits to the living organisms that live around them. Speaking specifically for humans, we can manipulate and manage plants to fulfill multiple tasks for our wellbeing. When listing the benefits of plants, the most common is that they give us the oxygen that we need as explained before. It is also common for us to know that they are the source for our food supply, regardless if plant based or carnivorous. The Food Chain describes visually how organisms in a given environment get the nutrition they need. At the top of the food chain are plants, meaning they give off the energy that allows for the chain to keep going past themselves[14]. Below is an example of what a food diagram might look like. The animals used are subject to change based on if it's a producer, consumer, or decomposer. The only producer would be the grass. The other organisms would be classified as consumers, and the fungi is considered a decomposer.

Food Chain Diagram 1.5



Ultimately, without plants we would be without a lot of organisms that survive on this earth. Other than nutrition, humans are always in need of supplements that helps to keep us health and fend off disease. Medicine was discovered and came from the extraction of plants. To this day, we still sample species of plants and make medicines and vitamins out of them.

Check your understanding:

- **What causes chlorophyll to appear green?**
- **How often does cellular respiration occur?**
- **What reactants are required for photosynthesis?**
- **Which comes first, Photosystem I or II?**
- **What are the properties needed for a plant to get one molecule of glucose?**
- **How many plant species are there in the world?**
- **How are plants beneficial to us as humans?**
- **What are some examples of human benefits from plants?**

References

1. CK-12. 2018. *4.2 Photosynthesis* retrieved from https://www.ck12.org/book/CK-12-Life-Science-For-Middle-School/r8/section/4.2/
2. OSU Plant Biology 1404. 2019. *Lec10 - Photosynthesis Details – Full*
3. Launchpad Plant Biology Textbook – Chapter

Footnotes

1. Reference (1)
2. Reference (1)
3. Reference (3)
4. Reference (2)
5. Reference (1)
6. Reference (2)
7. Reference (2)
8. Reference (1)
9. Reference (3)
10. Reference (3)
11. Reference (3)
12. Reference (2)
13. Reference (2)
14. Reference (3)