The photosynthesis and respiration cycle

The respiration and photosynthesis cycle is the process by which plants and animals interact in a codependent and symbiotic manner to produce the nutrients, gases, and energy that they require to survive. Plants obtain energy from sunlight and use it to combine carbon dioxide and water into glucose and oxygen. This process is called photosynthesis. Animals eat plants containing glucose, and combine glucose and oxygen, releasing energy, water, and carbon dioxide. This process is called respiration.

Plants take in carbon dioxide produced by animals, and release oxygen which animals require. Animals take in oxygen produced by plants, and release carbon dioxide which plants require. Plants obtain energy from the sun, store that energy in glucose, and animals obtain the energy stored in glucose by eating plants. Plant photosynthesis and animal respiration are symbiotic processes which occur in a continuous and cyclical manner, making life on Earth as we know it possible.

To many students, the most perplexing aspect of photosynthesis is how plants obtain energy from sunlight. To understand how plants obtain energy from sunlight, one must understand kinetic energy. Kinetic energy is energy resulting from motion (Brown & Schwartz, 2009). Light is literally a photon, a tiny moving particle. If a photon of light hits another object it can impart energy to that object.

This is similar to a game of pool in which a cue ball hits an object ball and causes it to move. If a photon of light hits a molecule in Just the right angle and Is moving Just the right speed, then it will cause the molecule it hits to eject an electron (Brown & Schwartz, 2009). Just as a person playing pool cannot hit a ball from any angle and make a shot, a photon of ight cannot hit a molecule from any angle or from any location and cause It to eject an electron. In fact, many molecules hit by light do not emit electrons.

The photon “ pool game” Is played In three dimensions, and In this three dimensional “ pool game” It Is exceedingly difficult to make a “ shot” and cause a molecule to eject an electron. If a pool player misses a shot, he won’t sink a ball, and If an electron does not hit a molecule at a precise angle, It will simple cause the molecule to oscillate and heat Its surroundings rather than ejecting an electron. Chlorophyll Is a molecule specifically dapted to the purpose of absorbing light and emitting an electron (Hopkins, 2006). The portion of the chlorophyll molecule that absorbs light Is dish shaped so that light can hit It from most any angle and still excite It enough to cause an electron to be ejected. Chlorophyll contains a long pole-Iike chain of hydrocarbons which It uses to mount Itself In the flesh of the plant so that Its antenna Is embedded In the plant facing outward.

This pole-Iike chain of molecules does not react with water, which Is Important because plants ” and most llvlng organisms ” are mostly water (Hopkins, 006). If the pole reacted with water It would essentially dissolve In water and could not function as a “ mount” for the “ dish” portion of the chlorophyll molecule. Photosynthesis takes place In chloroplasts. These are organelles containing chlorophyll. Chloroplasts situate themselves near the exterior membranes of plants, where they are exposed to light. Plants evolved leaves and grew upward around long central stems or stalks to maxlmlze the amount of surface area that they contain (Hopkins, 2006).

The more surface area a plant contains, the more chloroplasts that an be exposed to sunlight and generate energy. The drawback or opportunity cost of this large surface area is that large objects with massive surface area are intrinsically cumbersome, and therefore difficult to move or relocate. In developing a large surface area that maximized their capability for photosynthesis, plants chose an evolutionary road which made controlled movement impossible (Hopkins, 2006). Chlorophyll is a pigment. That is, a dye. Chlorophyll is a green dye, which is why most plants are green.

The peak wavelength of our sun is green. Sunlight should appear reen, not yellow (Hopkins, 2006). The Earth’s sky is blue because blue light is diffracted by our atmosphere; in English, the blue light is removed from sunlight, and is what makes our sky blue, but once this blue light is removed from green sunlight it appears yellow (Hopkins, 2006). Blue mixed with yellow produces green. Removing blue from green light results in a yellow color. The sun is emitting quadrillions of photons at any given moment.

This means that a steady stream of photons is bombarding the leaves of plants. This steady stream of photons continually hits hlorophyll molecules in the plant, causing them to continually eject electrons. A steady flow of electrons in the plant is thus created. A steady flow of electrons is called electricity. The plant basically creates a very narrow path directly under the edge of its leaves which contains chlorophyll which ejects electrons, creating a kind of organic electrical wire through which electrons flow (Hopkins, 2006).

A number of intermediary molecules are used to obtain and maintain this electron flow. This process is called the electron transport chain. It is essentially a series of cascading eactions of decreasing redox potential. One obvious problem is how a chlorophyll molecule can repeatedly emit electrons without running out of electrons.

Chlorophyll replenishes electrons via a process called photolysis. The magnesium in the center of a chlorophyll molecule can act as a collector of water (Hopkins, 2006). It essentially attracts water molecules and holds them in place so that they are hit by photons of sunlight which break the water molecules apart. The result is the release of free electrons, positive hydrogen ions, and oxygen gas. The oxygen is released into the tmosphere as a byproduct of photosynthesis.

The free electrons are used to replenish electrons lost by chlorophyll, and provide a stream of electrons. The positive hydrogen atoms are utilized in ATP synthesis, helping recharge the molecular “ batteries” of the plant. In some ways, a living plant is literally a power plant! Rather than burning fossil fuels, it “ burns” sunlight. Electricity has positive and negative charges which attract each other. This electrical attraction can be used to cause one charge to move another charge of opposite polarity. Photosynthesis ssentially breaks water down into electrons, positive hydrogen molecules, and oxygen gas, and then segregates the H+ and e- by placing them on opposite sides of a membrane (Hopkins, 2006).

As a hydrogen atom is merely a proton and an electron paired together, H+ is simply a hydrogen atom with the electron removed, or a proton.

Photosynthesis basically takes the simplest molecule that nature creates and breaks it up into its constituent particles, protons and electrons. Protons have 1836 times more mass than electrons, and are therefore much harder to move than lectrons (Hopkins, 2006). Plants create a movement of electrons on one side of a membrane, and the attractive electric force generated by these moving electrons causes a flow of the heavier protons.

Read aboutThis is a clever way to avoid having to expend massive effort which would otherwise be required to move protons. The electron transport chain is essentially a kind of biochemical lever which allows the plant to move heavy protons with much less effort than would normally be required, by using attractive electrical forces as a force-multiplying intermediary (Hopkins, 2006). The lowing protons are used by an enzyme called ATP synthase to convert ADP into ATP. Plants then utilize ATP, water, more protons, and carbon dioxide to create glucose, via a complex series of reactions called the Calvin Cycle (Hopkins, 2006). NADPH acts as a coenzyme in these reactions, functioning as a reducing agent, or source of electrons (Hopkins, 2006).

After being oxidized or acting as a reducing agent, NADPH becomes NADP+. When an electron is added to NADP+, it once again becomes NADPH, which once again acts as a reducing agent in “ dark” or light-independent reactions inside lants. ADP is continually converted into ATP inside a plant, and vice versa, in a cyclical manner. NADPH is continually converted into NADP+ inside a plant, and vice versa, in a cyclical manner. In summary, a plant uses sunlight to cause chlorophyll to release electrons and create a flowing electrical current of electrons on one side of a plant membrane.

A plant also uses sunlight to break water down into a proton, and electron, and oxygen gas. Electrons are used to convert NADP+ to NADPH, thereby renewing electrons which plants expend in Calvin Cycle reactions. Protons are made o flow on a gradient opposite the electrons, creating the biochemical energy impetus for “ dark” Calvin Cycle reactions. Calvin Cycle reactions use protons to create ATP from ADP, and then use ATP, carbon dioxide, NADPH, and protons to create glucose, leaving ADP, NADP+, inert phosphorous, and water as byproducts. Animals eat plants.

Their process of respiration, of obtaining energy from glucose that they ingest, is much simpler than photosynthesis. This is because plants have performed the trickiest task in the photosynthesis and respiration cycle, converting the kinetic nergy in photons into biochemical energy stored in glucose (Hopkins, 2006). Breaking down glucose and using the energy released to convert ADP to ATP is comparatively simple by comparison ” but still not easy. Glucose is simply a chain of carbons with hydroxyls (OH-molecules) attached.

If hydroxyls are ripped from glucose and oxygen is present, they will form water molecules, and this exothermic reaction will release heat. Significantly, the enthalpy or “ delta G” of this reaction is negative, meaning that it will occur spontaneously without significant acceleration by coenzymes being necessary. This is largely due to the significantly higher electronegativity of oxygen versus carbon. Oxygen has an electronegativity of 3. 5, carbon an electronegativity of 2.

5, a significant difference. Oxygen’s higher electronegativity means that it has more powerful attractive electrical capabilities than carbon, and can easily strip hydrogen molecules away from carbon. It can also easily strip carbon molecules away from carbon. Oxygen thus rips glucose apart, converting it completely into water and carbon dioxide, and releasing massive amounts of energy in the process. Again, this reaction is essentially spontaneous ssuming oxygen has free access to glucose, an access which the body carefully regulates. This need for oxygen to obtain energy from glucose is why living organisms breathe, obtaining oxygen from air or water.

It is also why this type of respiration is characterized as aerobic, which means requiring oxygen. The process of utilizing the heat released when glucose is oxidized and using it to convert ADP into ATP is trickier, much more complicated, and difficult to make completely efficient. As with any large heat release, capturing and utilizing all the heat is tricky. The body does his via glycolysis and the Citric Cycle. Glycolysis is the process of creating ATP from glucose without oxygen.

The Citric Cycle is the process of creating ATP from glucose with oxygen. In practice, glycolysis is a precursor of the Citric Cycle. A byproduct of the Citric Cycle is carbon dioxide. In summary, plants take in sunlight which provides energy, oxygen, and water, and produce glucose and oxygen.

Animals take in oxygen and glucose from plants or other animals, and produce energy and carbon dioxide. Both plants and animals store energy by converting ADP to ATP, which is a strong ndicator that they have the same evolutionary origins. Plants produce the oxygen and glucose which animals require via the process of photosynthesis, and animals produce the oxygen which plants require via the process of respiration, resulting in a continuous cycle of interdependent photosynthesis and respiration which is essential to life.