Plant Physiology – Photosynthesis and Respiration

Photosynthesis

Energy from the sun (see fig. 4.6)

Light has a duel nature consisting of particles (photons) that travel in waves

The sun produces electromagnetic radiation, of which visible light is a small portion

Wavelengths within the visible range are the ones absorbed by the chlorophylls and other photosynthetic pigments in green plants and algae

Light-absorbing pigments (see fig. 4.6 and 4.7)

When light strikes an object, it can pass through the object (be transmitted), be reflected from the surface, or be absorbed

Pigments are molecules that absorb light selectively, with different pigments absorbing different wavelengths and reflecting others

In higher plants, the major photosynthetic organ is the leaf, and the green chloroplasts in the mesophyll cells are the actual sites of photosynthesis; the major photosynthetic pigments are the green chlorophylls

There are two forms of chlorophyll in green plants, chlorophyll a and chlorophyll b, which absorb light mainly in the red and blue-violet regions; much of the yellow and green light is reflected

Chloroplasts also contain accessory pigments, the carotenoids – the orange carotenes and yellow xanthophylls absorb light in the violet, blue, and blue-green regions of the spectrum, and it is these pigments that become apparent in the autumn in temperate latitudes when chlorophyll degrades

Overview of photosynthesis (see fig. 4.8)

$CO_2 + H_2O$ + Light Energy → Glucose + O_2

Or, in words:

Carbon Dioxide + Water + Light Energy → Glucose + Oxygen

The process of photosynthesis provides an energy source that living things can use – carbohydrate

The necessities of photosynthesis

Carbon dioxide – The carbon to form glucose comes from carbon dioxide

Water (hydrogen) – During photosynthesis, carbon dioxide is fixed (taken from a gaseous to a solid state) and reduced (combined with hydrogen and stripped of oxygen) to form glucose (carbohydrate)

Energy – Photosynthesis is an energy-requiring process, because the major product, glucose, has a greater energy value than the carbon dioxide and water molecules that are used to make it

Getting the right stuff to the right place

Carbon dioxide enters the leaf (or stem) via stomata, dissolves in water, and enters the photosynthetic cells

Water is transported via the xylem from the root to the leaf (or stem) where it exits the vascular tissue and enters the photosynthetic cells

Energy comes from the photons of light striking the photosynthetic pigments

Cellular Respiration

Cellular respiration is the step-by-step breakdown of glucose and the release of energy contained in its bonds coupled with the capture of a portion of that released energy in the form of ATP

$C_6H_{12}O_6 + O_2 + \rightarrow CO_2 + H_2O + ATP$

Or, in words:

Glucose + Oxygen + → Carbon Dioxide + Water + ATP

The necessities of aerobic respiration

Hydrocarbons – Glucose (including higher carbohydrates), proteins, and fats

Oxygen – During respiration, carbon from hydrocarbons is combined with oxygen to form carbon dioxide, and hydrogen from hydrocarbons is combined with oxygen to form water

Energy – Respiration is an energy-releasing process, because the hydrocarbons being broken down have greater energy value than the carbon dioxide and water molecules that are being produced

Getting the right stuff to the right place

Oxygen enters the plant mainly via the root system

Hydrocarbons are transported from sources to sinks via the phloem

Other food sources

Proteins can be broken down to amino acids, which can be respired

Fats can be broken down to glycerol and fatty acids, which can be respired

Energy considerations – ATP is a transportable form of energy in a usable "size"

For every glucose molecule metabolized, approximately 36 ATPs are produced

Glucose has an energy value of 686 kcal/mole; ATP has an energy value of 7.5 kcal/mole

36 ATP x 7.5 kcal = 270 kcal; therefore, 270 kcal of the 686 kcal of energy in a mole of glucose is captured in a mole of ATP, making the efficiency of aerobic respiration about 39%

Energy can now be released from ATP to do the work of life (e.g., bonding amino acids together to make protein) in amounts that will do the job without releasing too much energy at one time

ATP can move to any part of the cell to provide energy for various endergonic (energy-requiring) reactions

Aerobic vs. anaerobic respiration

The complete metabolism and oxidation of glucose requires oxygen and is, therefore, known as aerobic respiration

Respiration in the absence of oxygen is known as anaerobic respiration or fermentation

In alcoholic fermentation, which is found in certain types of yeast, glucose is converted to ethanol and carbon dioxide

Fermentation of one glucose molecule will produce a net gain of only two ATPs, a very low yield of energy, but enough for certain organisms to survive

During fermentation to produce sparkling wine and beer, the carbon dioxide is contained within the system and the wine/beer becomes carbonated; in the production of non-sparkling wine, the carbon dioxide is vented from the system

If oxygen enters the system during fermentation, ethanol can be converted to acetic acid (vinegar)

This lecture outline was prepared mainly from *Plants and Society*, by Levetin and McMahon, 2003 (3rd edition), and may contain phrases or entire sentences taken verbatim from that source.