BIOL 101 - Fall 2007- Week 6 - Photosynthesis - Energy - Respiration
Gene Structure - Transcription

PHOTOSYNTHESIS

HISTORICAL

1577 - 1644	Jan-Baptista Van Helmont	Showed that soil contributed only a little to the increase in weight of a potted willow plant.
1733-1804	Joseph Priestley	Showed (1772) rejuvenation of air by (O_2) from mint sprig.
1742-1809	Jean Senebier	Showed (1782) that plants need CO_2.
1730-1799	Jan Ingen-Housz	Showed (1778) that light and green parts of plants are needed for O_2 generation and (1796) that C goes into the plant.
1767-1845	Nicholas de Saussure	Showed (1804) that equal volumes of CO_2 and O_2 are exchanged and also showed that H_2O was needed.
1843 - 1909	T.W. Engelmann	Action spectrum experiment (1883) showing red and blue light efficacy for photosynthesis.
1843 - 1909	Julius Sachs	Showed that photosynthesis occurs only in light
1934	C.B. van Niel	Theorized that O_2 is evolved from H_2O, *not* CO_2 in photosynthesis.

Sulphur bacteria: $\mathbf{CO_2 + 2H_2S + light \rightarrow CH_2O + H_2O + 2S}$
General equation: $\mathbf{CO_2 + 2H_2X + light \rightarrow CH_2O + H_2O + 2X}$

Green plants: $\mathbf{CO_2 + 2H_2O + light \rightarrow CH_2O + H_2O + 2O}$

1930s	Robin Hill	Showed that light drives the splitting of water. Hill showed that isolated chloroplasts can release O_2 in the absence of CO_2 if given a suitable electron acceptor for electrons removed from H_2O.
	Samuel Ruben; Martin Kamen	Proved (1941) above in experiment using $^{18}O_2$, a non-radioactive isotope of O_2.

The nature of light

1660	Sir Isaac Newton	Separated light into the spectrum.
1905	Albert Einstein	Proposed that light consists of **photons**, packets of energy. Light **intensity** depends on the number of photons absorbed per unit of time. The amount of energy carried by each photon is determined by its vibration. The distance moved during a complete vibration is

the **wavelength**. The energy of a photon is called a **quantum** and is inversely proportional to the wavelength: the longer the wavelength, the less energy per photon.

Ultraviolet radiation	Has too much energy for most organisms. Its *ionizing radiation* breaks weak bonds.
Infrared radiation	Has too little energy for living systems but does warm them up.
Visible light	Contains just the right amount of energy. But it must be absorbed by **pigments**.

PIGMENTS

Pigments absorb visible light and changes the configuration of electrons in the photons, resulting in transfer of energy to **heat**, **fluorescence** or **chemical** forms.

chlorophyll a	absorbs red, violet and blue; reflects green.

Accessory pigments broaden the *action spectrum* by passing energy to chlorophyll a. Are typically embedded in the **thylakoid membrane**.

chlorophyll b	25% of chlorophyll in leaves.
chlorophyll C	found in brown and other algae.
bacteriochlorophyll	purple photosynthetic bacteria.
chlorobium chlorophyll	green sulfur bacteria.

Carotenoids	
carotene	red, orange, yellow; fat-soluble. β-carotene is vitamin A.
xanthophylls	zeaxanthin
phycobilins	water soluble pigments found in red algae and cyanobacteria.

LIGHT (PHOTOCHEMICAL) REACTIONS

See Fig. 10.5, p. 177 of the Stern (9th edn.) text

Each photosystem (photosynthetic unit) includes an assembly of >200 pigment molecules. The pigment participate in two closely linked complexes:

(1) **The reaction center-protein complex**.
Although all pigments can absorb photons, only one pair of chlorophyll molecules per photosytem can use the energy in the photochemical reaction.

(2) **The antenna protein complex**.
This acts as an antenna for gathering light and transferring energy to the reaction center complex.

PHOTOSYSTEM II

This is described first because it is the dramatic step where light energy entering the system is used for *photolysis*, splitting the water molecule and releasing O_2. Photosystems I and II usually work together simultaneously and continuously.

Photosystem II contains a special chlorophyll, P_{680}. When *four photons* of light enter, their electrons are transferred to pheophytin (quinone) and water is split into protons and oxygen gas (Mn^{2+} is essential for this *photolysis*). This reaction occurs on the *inside* of the **thylakoid** membrane. The electrons then pass down a proton gradient, driving *photophosphorylation*.

PHOTOSYSTEM I

Four photons of light boost electrons from a P_{700} molecule to an electron acceptor (**ferredoxin**). The electrons then pass downhill to $NADP^+$, reducing it to NADPH.

In the light there is a continuous flow of electrons from water from photosystem II to photosystem I (the "*Z scheme*"). This is **noncyclic electron flow**. A total of eight photons are required to boost two electrons to form three molecules of ATP and two of NADPH.

Cyclic Photophosphorylation

Photosystem I can work independently of Photosystem II. In light, electrons are boosted from P_{700} to ferredoxin, but are *shunted* to plastoquinone **(cytochrome f)** in the photon gradient used to connect the two photosystems.

This *cyclic photophosphorylation* results in the synthesis of ATP, but: *no* water is split; *no* O_2 is evolved and *no* NADPH is formed. It is thought to occur when cells have sufficient NADPH but need more ATP.