Chapter 10 summary Bio

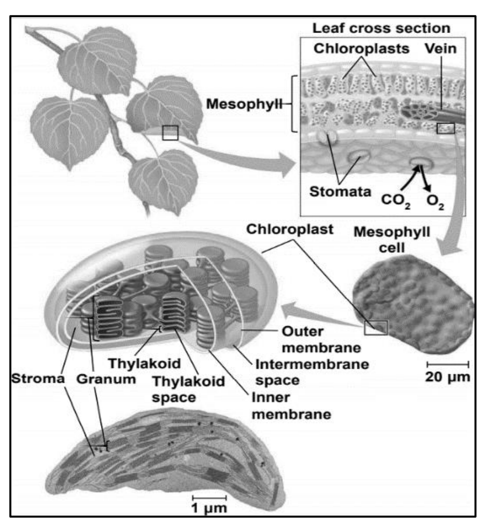
Photosynthesis

A. Photosynthesis:

- ✓ is the process that converts solar energy into chemical energy
- ✓ Directly or indirectly, photosynthesis <u>nourishes</u> almost the entire living world
- ✓ <u>Autotrophs</u>: sustain themselves without eating anything derived from other organisms
- ✓ Autotrophs are the **producers** of the biosphere, producing organic molecules from CO_2 and other inorganic molecules
- ✓ Almost all plants are **photo autotrophs**, using the energy of **sunlight** to make organic molecules from H_2O and CO_2
- ✓ Photosynthesis occurs in plants, algae, certain other protists, some prokaryotes
- ✓ Heterotrophs: obtain their organic material from other organisms **(consumers** of the biosphere**)** all heterotrophs including humans depend on <u>photoautotrophs</u> for food and O_2: $6CO_2 + 12H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

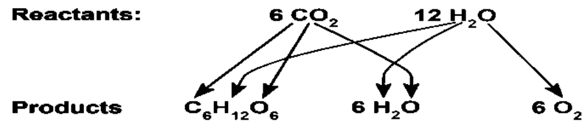
B. Chloroplasts: The Sites of Photosynthesis in Plants

- ✓ are structurally similar to and likely <u>evolved</u> from photosynthetic bacteria
- ✓ The structural organization of these cells allows for the chemical reactions of photosynthesis
- ✓ Leaves are the major locations of photosynthesis
- ✓ Their green color is from **chlorophyll**, the green pigment within chloroplasts, it absorbed Light energy drives the synthesis of organic molecules in chloroplast
- ✓ CO_2 enters and O_2 exits the leaf through microscopic pores called **stomata**
- ✓ Chloroplasts are found mainly in cells of the **mesophyll**(the interior tissue of the leaf) has 30–40 chloroplasts
- ✓ The chlorophyll is in the membranes of thylakoids (connected sacs in the chloroplast); thylakoids may be stacked in columns called **grana**
- ✓ Chloroplasts also contain **stroma**: a dense fluid



C. *Tracking Atoms Through Photosynthesis:*

- ✓ equation: $6CO_2 + 12H_2O$ + Light energy → $C_6H_{12}O_6 + 6O_2 + 6H_2O$

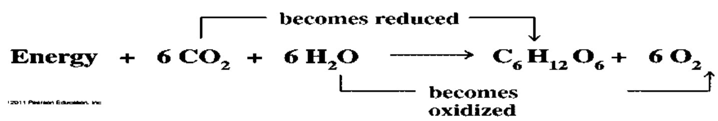


- ✓ Chloroplasts split H_2O into hydrogen and oxygen, incorporating the electrons of hydrogen into sugar molecules

– Plants: $CO_2 + 2H_2O \rightarrow [CH_2O] + H_2O + O_2$

– Sulfur bacteria: $CO_2 + H_2S \rightarrow [CH2O] + H_2O + S_2$

- ✓ CO_2 is **not** split into C and O_2!! This hypothesis was cancelled by van Neil
- ✓ Photosynthesis is a redox process in which H_2O is **oxidized** and CO_2 is **reduced**



- ✓ H_2O is split& electrons are transferred along with H ions from H_2O to CO_2 reducing it to sugars Endergonic reaction.

D. *The Two Stages of Photosynthesis:*

- ✓ Photosynthesis consists of the light reactions (the photo part) and Calvin cycle (the synthesis part)
- ✓ The light reactions (in the **thylakoids**):
  1. Split H_2O
  2. Release O_2
  3. Reduce NADP+ to NADPH
  4. Generate ATP from ADP by **photophosphorylation**
- ✓ The Calvin cycle (in the **stroma**) forms sugar from CO_2 , using ATP and NADPH
  - The Calvin cycle begins with carbon fixation, incorporating CO_2 into organic molecules

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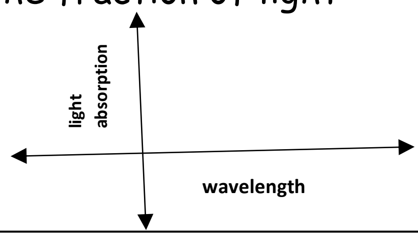
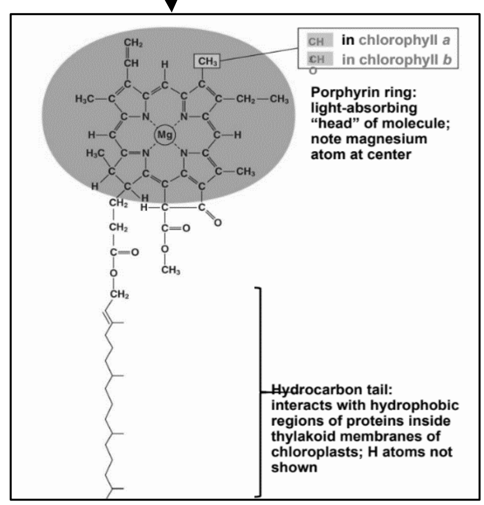
E. *light reactions:*

- ✓ Chloroplasts are solar-powered chemical factories
- ✓ thylakoids transform light energy into the chemical energy of ATP and NADPH
- ✓ Light is a form of: **electromagnetic energy = electromagnetic radiation**
- ✓ Light travels in rhythmic waves
- ✓ Wavelength is the distance between crests of waves, it **determines** the type of electromagnetic energy

- ✓ The electromagnetic spectrum: is the entire range of electromagnetic energy
- ✓ Visible light consists of wavelengths (including those that drive photosynthesis) that produce colors we can see (380-750nm)
- ✓ Light also behaves as though it consists of discrete particles called **photons**
- ✓ Longer wavelength→ Lower energy
  Shorter wavelength → Higher energy
- ✓ Photosynthetic Pigments: The Light Receptors
- o Substances that absorb visible light, Different pigments absorb different wavelengths
- o Wavelengths that are not absorbed are reflected or transmitted
- o Leaves appear green because chlorophyll reflects and transmits green light
- o Spectrophotometer: measures a pigment's ability to absorb various wavelengths
- o This machine sends light through pigments and measures the fraction of light transmitted at each wavelength
- o absorption spectrum: is a graph plotting a pigment's light
- o absorption versus wavelength



- o The absorption spectrum of chlorophyll a suggests that violet-blue and red light work best for photosynthesis
- o Chlorophyll a is the main photosynthetic pigment
- o Accessory pigments, such as chlorophyll b, broaden the spectrum used for photosynthesis
- o Accessory pigments called carotenoids absorb excessive light that would damage chlorophyll



- o When a pigment absorbs light, it goes from a ground state to an excited state, which is unstable
- o When excited electrons fall back to the ground state, photons are given off, an afterglow called fluorescence
- o If illuminated, an isolated solution of chlorophyll will fluoresce, giving off light and heat

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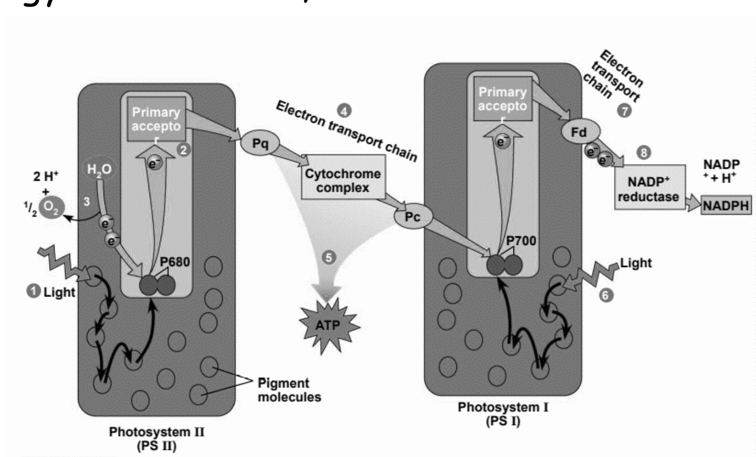
F. Photosystem:

- ✓ photosystem consists of a reaction-center complex (protein complex) surrounded by light-harvesting complexes
- ✓ The light-harvesting complexes (pigment molecules bound to proteins) funnel the energy of photons to the reaction center

- ✓ primary electron acceptor in the reaction center accepts an excited electron from chlorophyll a
- ✓ Solar-powered transfer of an electron from a chlorophyll a molecule to the primary electron acceptor is the first step of the light reactions
- ✓ Two types of photosystems in the thylakoid membrane:
- o Photosystem II (PS II) functions first (the numbers reflect order of discovery) and is best at absorbing a wavelength of 680 nm,The reaction-center chlorophyll a of PS II is called P680
- o Photosystem I (PS I) is best at absorbing a wavelength of 700 nm,The reaction-center chlorophyll a of PS I is called P700

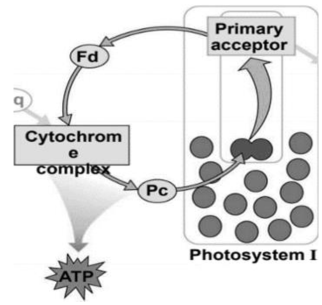
G. routes for electron flow:

- ✓ Linear electron flow: the primary pathway, involves both photosystems and produces ATP and NADPH using light energy
- o P680+ is a very strong oxidizing agent
- o H_2O is split by enzymes, and the electrons are transferred from the hydrogen atoms to P680+, thus reducing it to P680
- o O_2 is released as a by-product of this reaction
- o Each electron "falls" down an electron transport chain from the primary electron acceptor of PS II to PS I
- o Energy released by the fall drives the creation of a proton gradient across the thylakoid membrane
- o Diffusion of H + (protons) across the membrane drives ATP synthesis
- o In PS I (like PS II), transferred light energy excites P700, which loses an electron to an electron acceptor
- o P700+ (P700 that is missing an electron) accepts an electron passed down from PS II via the electron transport chain
- o Each electron "falls" down an electron transport chain from the primary electron acceptor of PS I to the protein ferredoxin (Fd)



- o The electrons are then transferred to NADP+ and reduce it to NADPH
- o The electrons of NADPH are available for the reactions of the Calvin cycle
- o This process also removes an H+ from the stroma

✓ Cyclic Electron Flow: Cyclic electron flow uses only photosystem I and produces ATP, but not NADPH



- Cyclic electron flow generates surplus ATP, satisfying the higher demand in the Calvin cycle

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*ATP and NADPH are produced on the side facing the stroma, where the Calvin cycle takes place

* In summary, light reactions generate ATP and increase the potential energy of electrons by moving them from H_2O to NADPH

H. ***Comparison of Chemiosmosis in Chloroplasts and Mitochondria***

✓ Chloroplasts and mitochondria generate ATP by chemiosmosis, but use different sources of energy ; Mitochondria transfer chemical energy from food to ATP; chloroplasts transform light energy into the chemical energy of ATP

I. ***The Calvin cycle:***

✓ The Calvin cycle, like the citric acid cycle, regenerates its starting material after molecules enter and leave the cycle

✓ The cycle builds sugar from smaller molecules by using ATP and the reducing power of electrons carried by NADPH

✓ Carbon enters the cycle as CO_2 and leaves as a sugar named glyceraldehyde-3-phospate (G3P)

✓ For net synthesis of 1 G3P, the cycle must take place three times, fixing 3 molecules of CO_2

✓ The Calvin cycle has three phases:

- Carbon fixation (catalysed by rubisco)
- Reduction
- Regeneration of the CO_2 acceptor (RuBP)