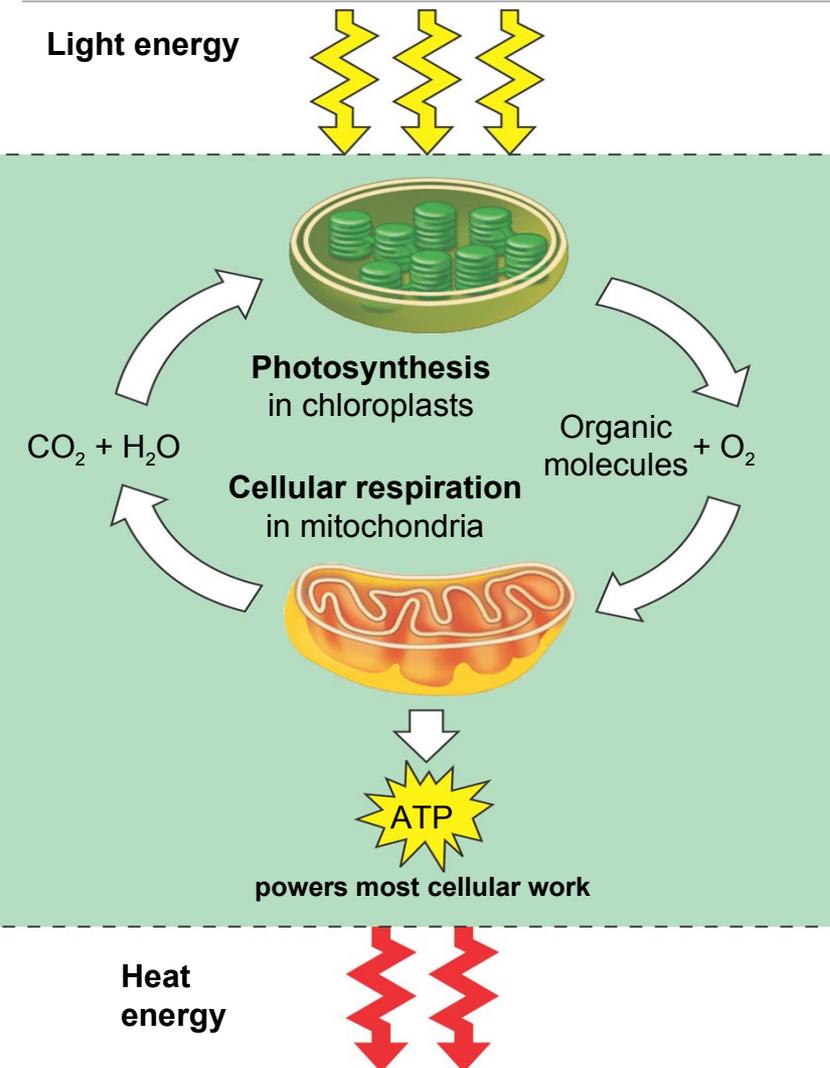


Photosynthesis Light Reaction

Photosynthesis

- Purpose: use energy from light to convert inorganic compounds into organic fuels that have stored potential energy in their carbon bonds
- Carbon dioxide + water \rightarrow glucose + oxygen
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$

Comparing Metabolic Processes



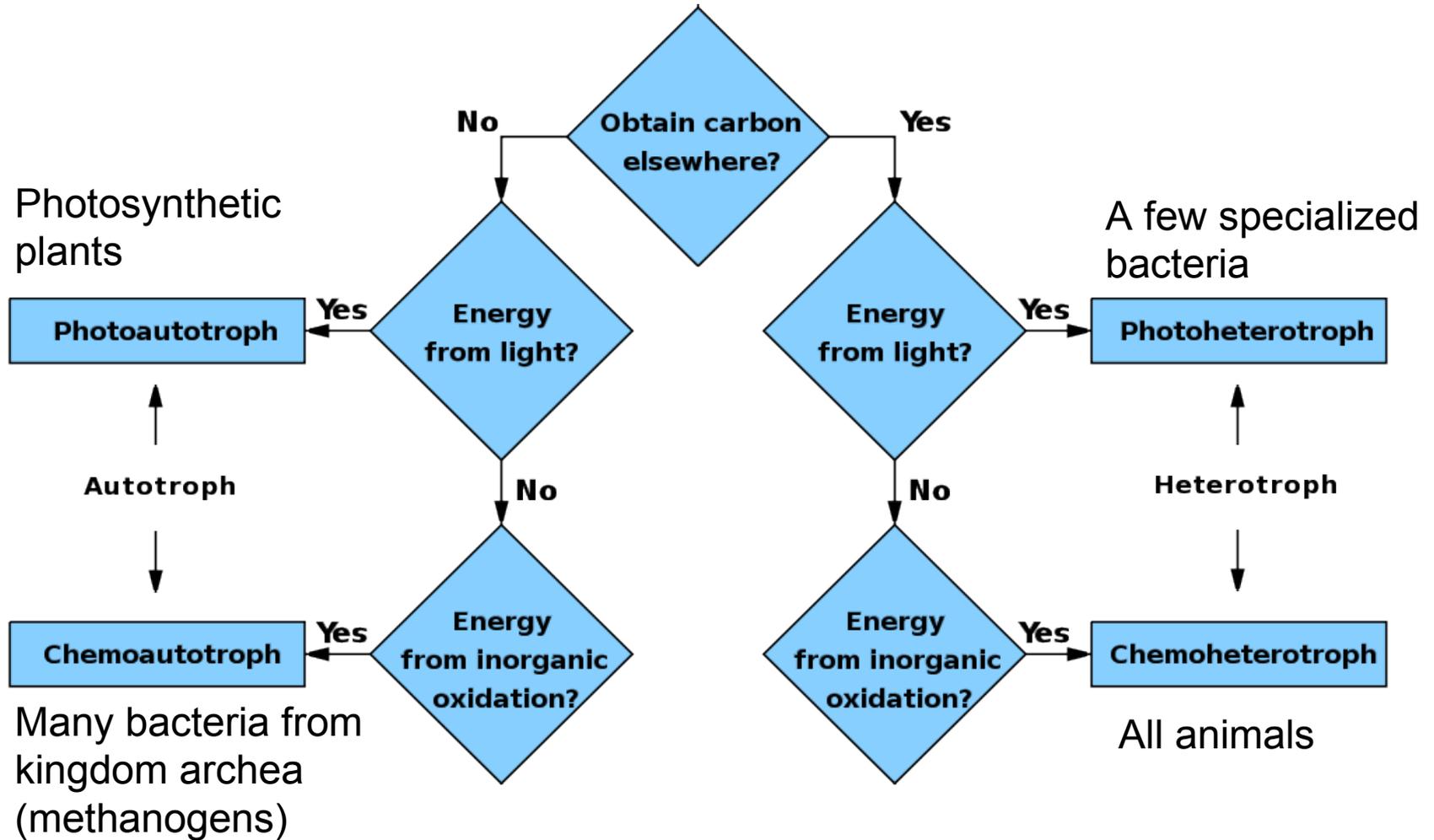
- Photosynthesis and cellular respiration are **complementary** processes
- They are not opposite reactions even though their overall equations are the reverse because the multiple steps that make up each process are different

Figure 9.2

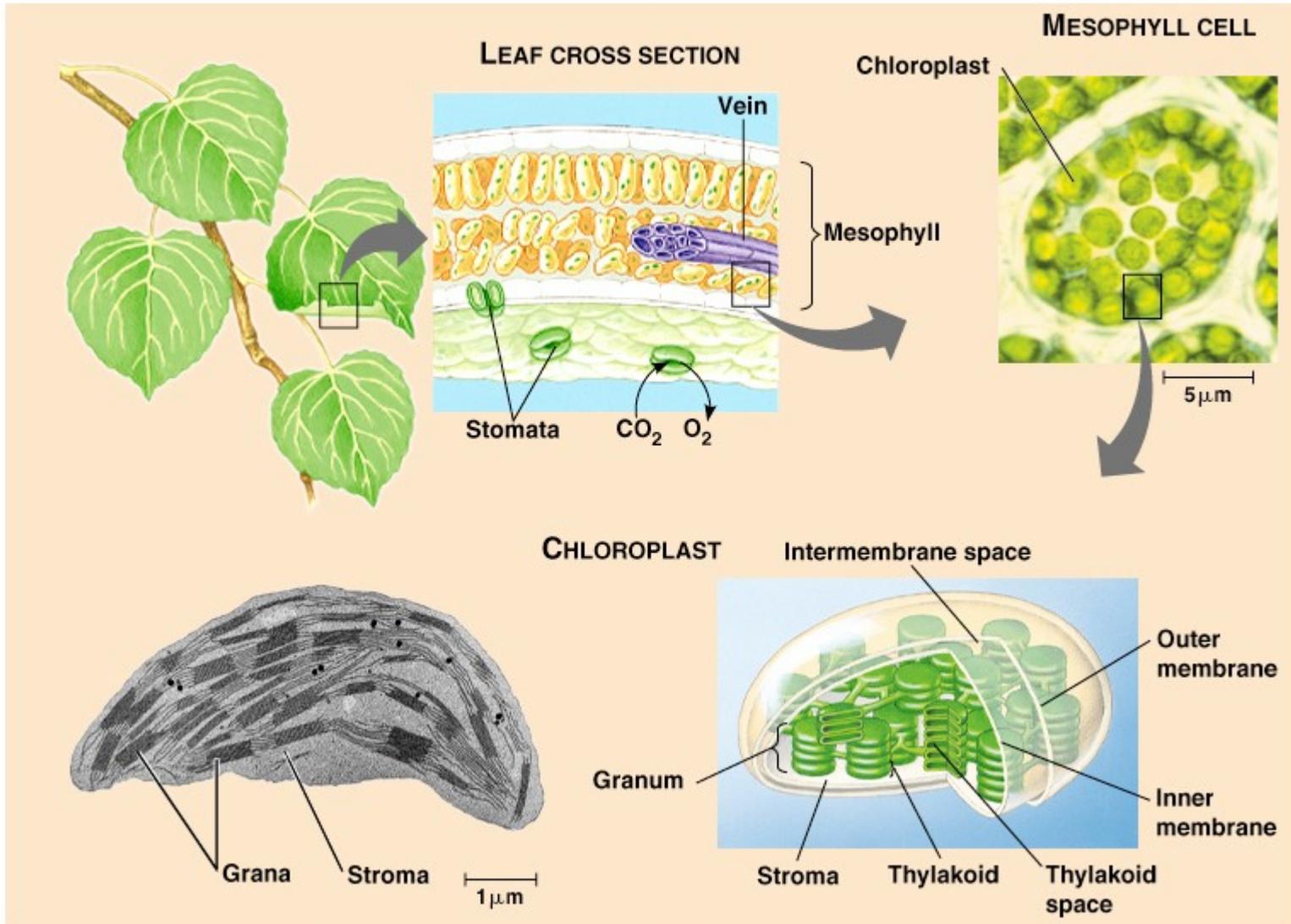
Autotrophs

- Organisms that obtain energy without needing to ingest other organisms
- Require the input of inorganic substances from the environment
- Photoautotrophs: also use light energy
 - Examples: green plants, algae, certain species of bacteria

Types of Variants



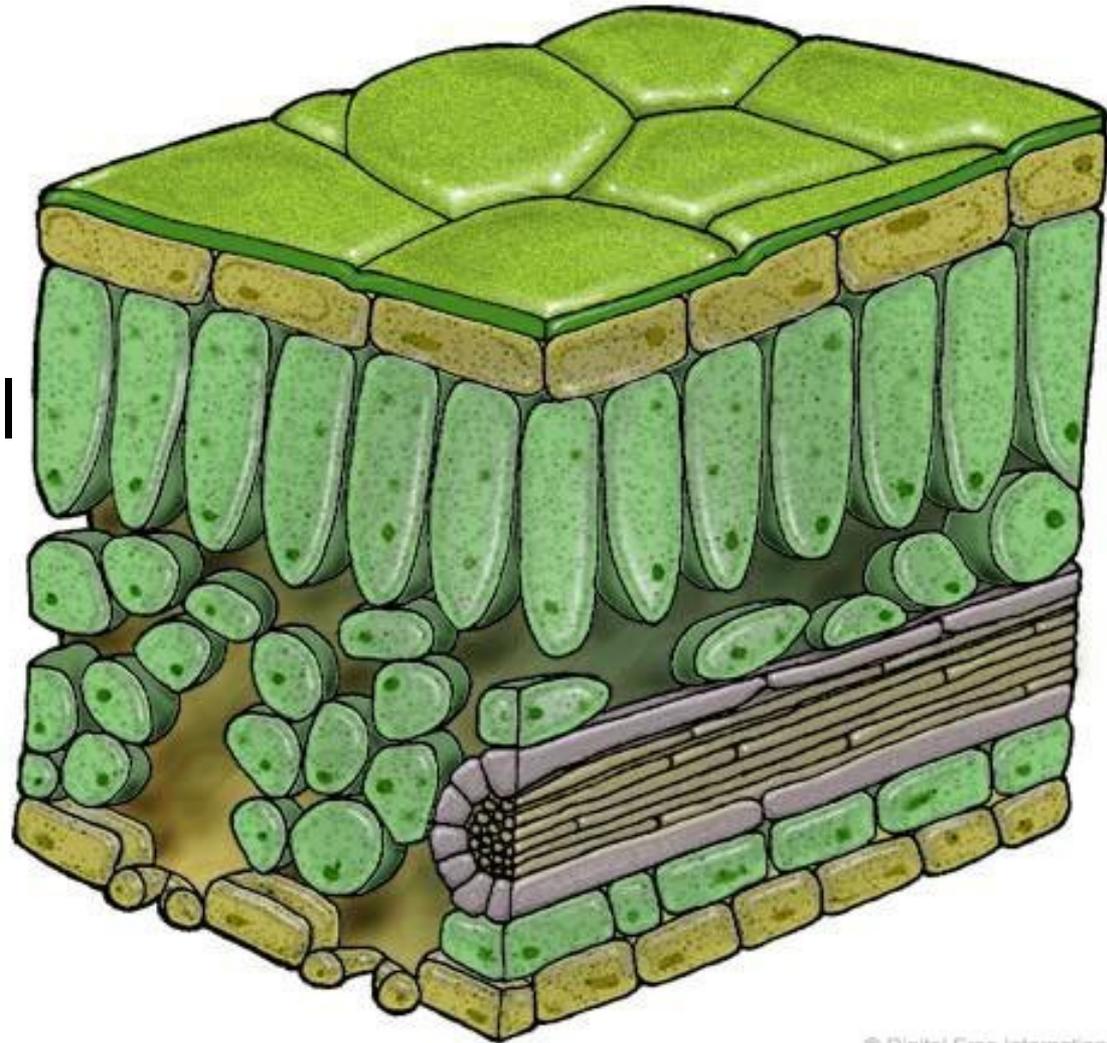
Review: Leaf Structure



Review: Leaf Structure

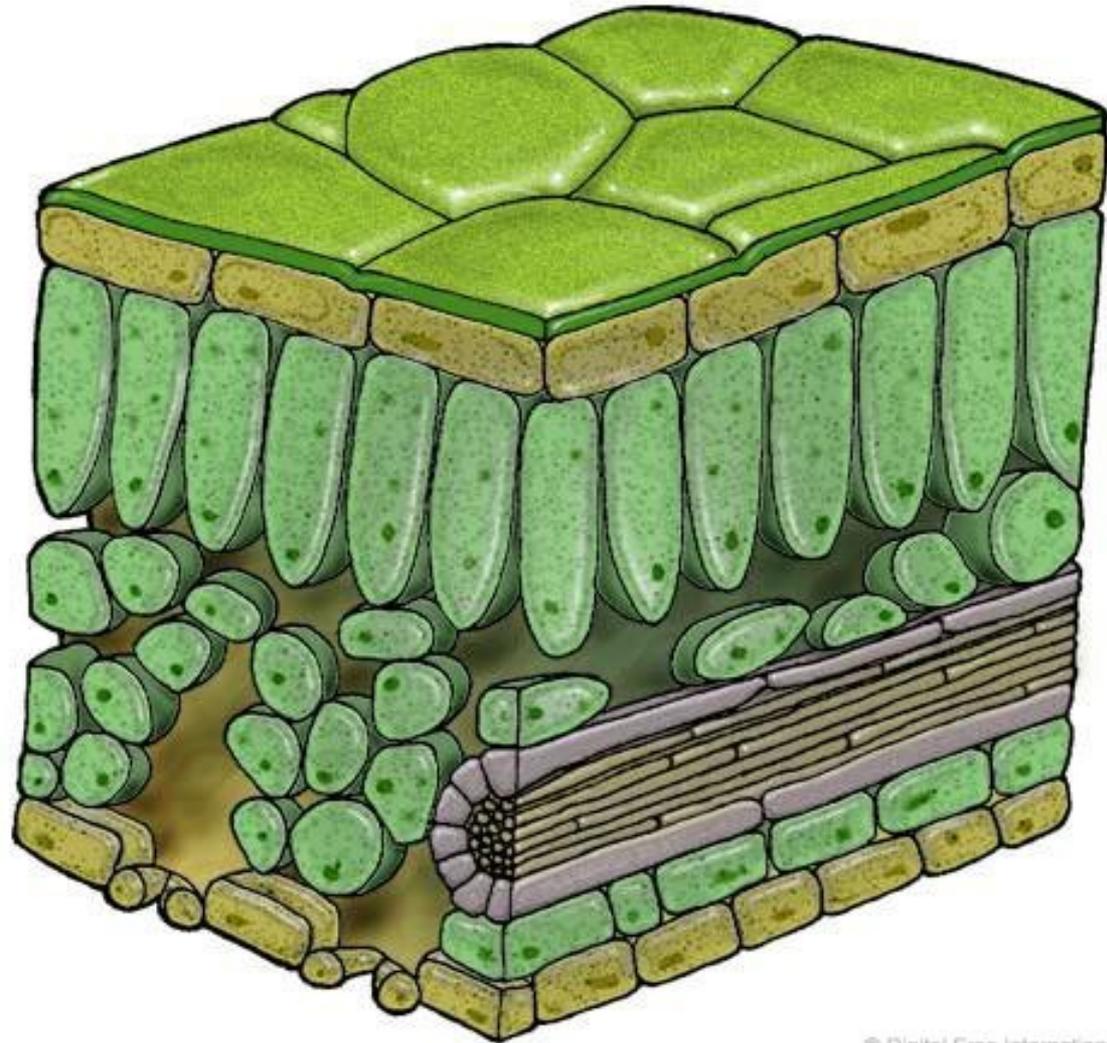
Identify:

- Cuticle
- Epidermis
- Palisade mesophyll
- Spongy mesophyll
- Guard cells
- Stoma / stomata
- Vascular bundle



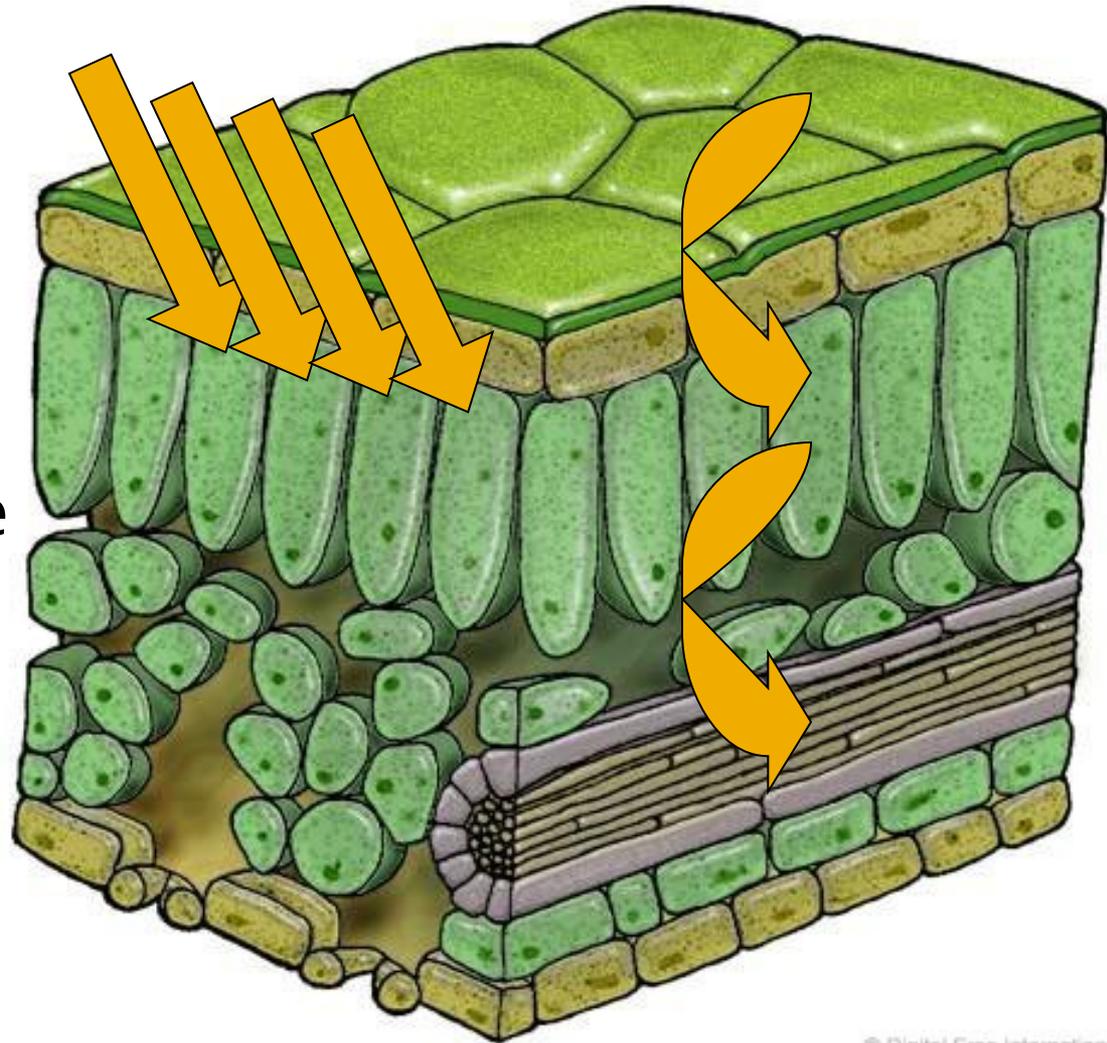
Review: Leaf Structure

- Which leaf structure perform each of these functions?
 - Prevent water loss and gas exchange
 - Regulates gas exchange
 - Transports water and nutrients
 - Mainly photosynthesis (contains the most chloroplast)

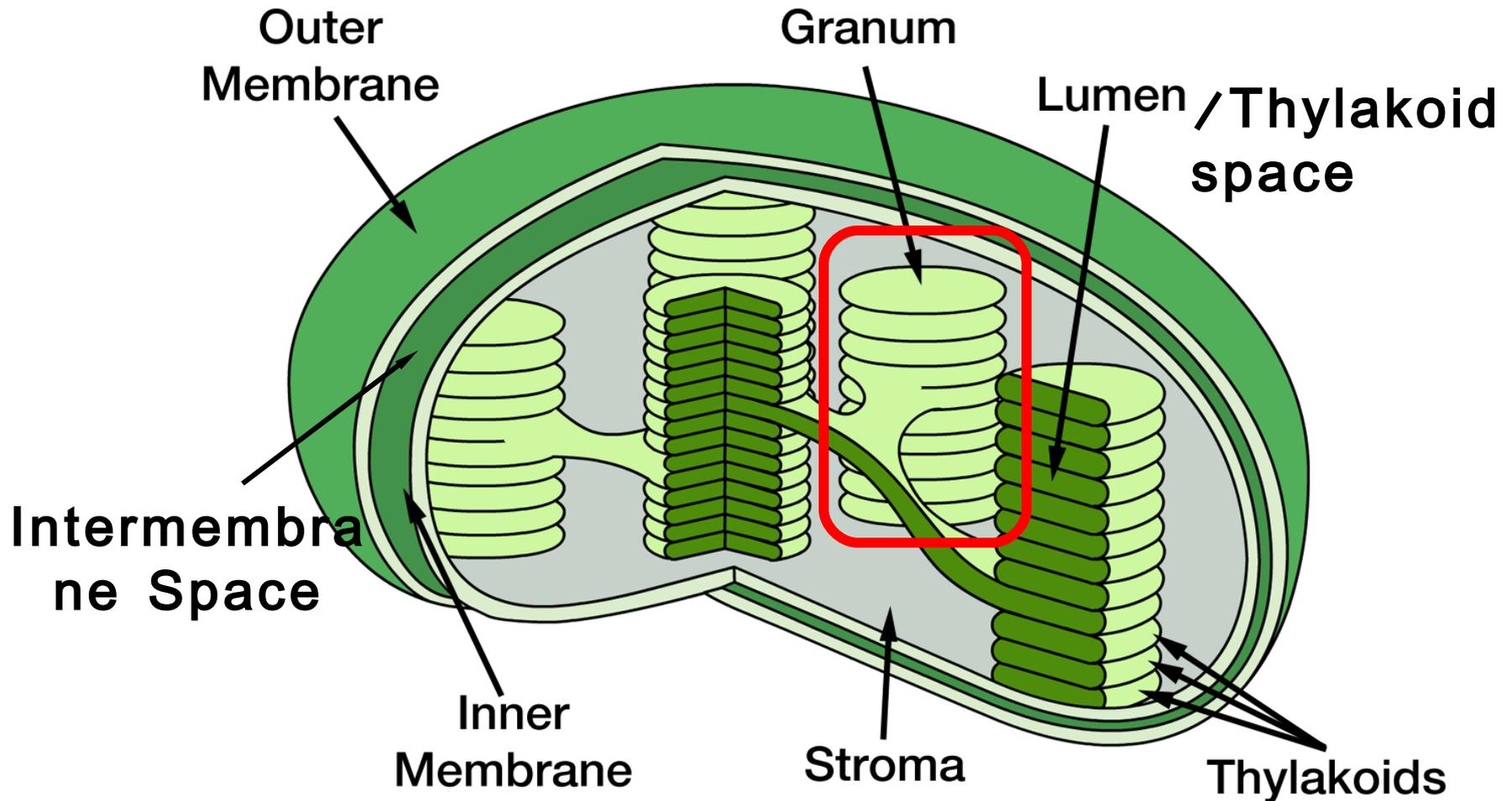


Review: Leaf Structure

- Why are palisade cells long and narrow?
 - Fit more cells in the same space for more photosynthesis
 - Interaction between photosynthetic side and nutrient / gas absorption side

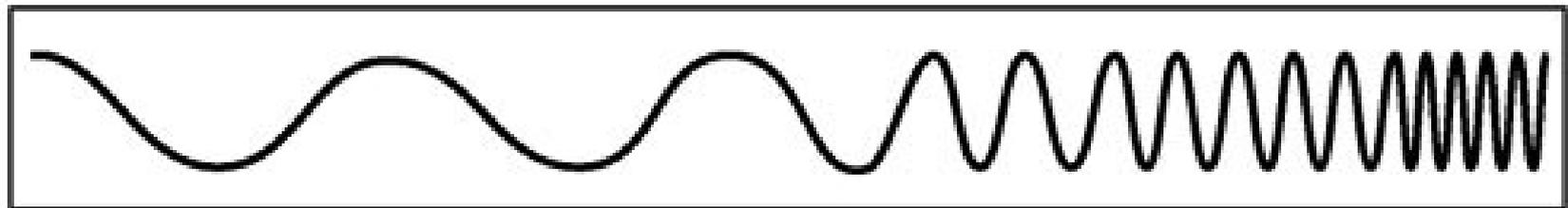
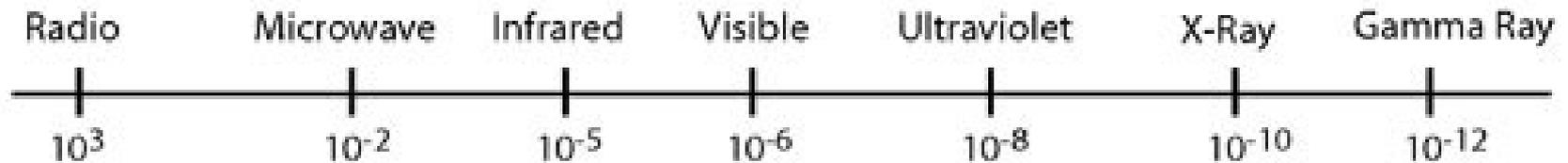


Review: Chloroplast Structure

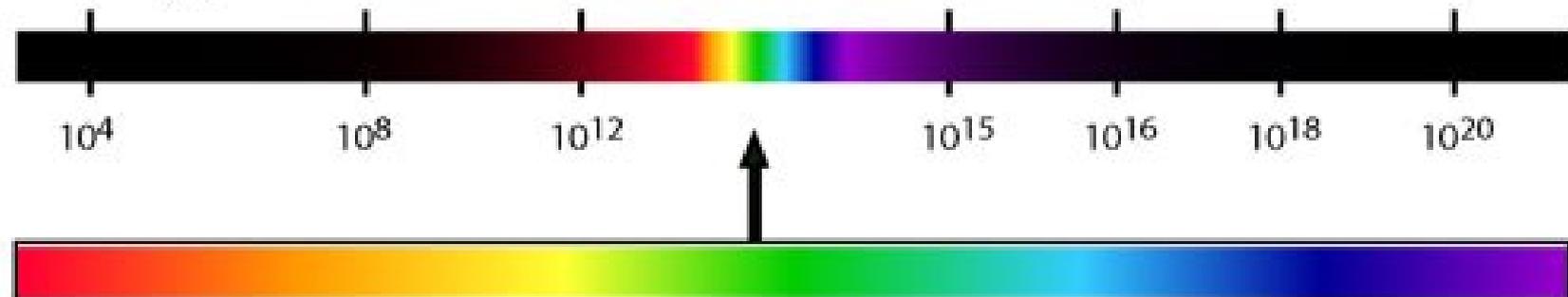


Nature of Light

Wavelength
(metres)



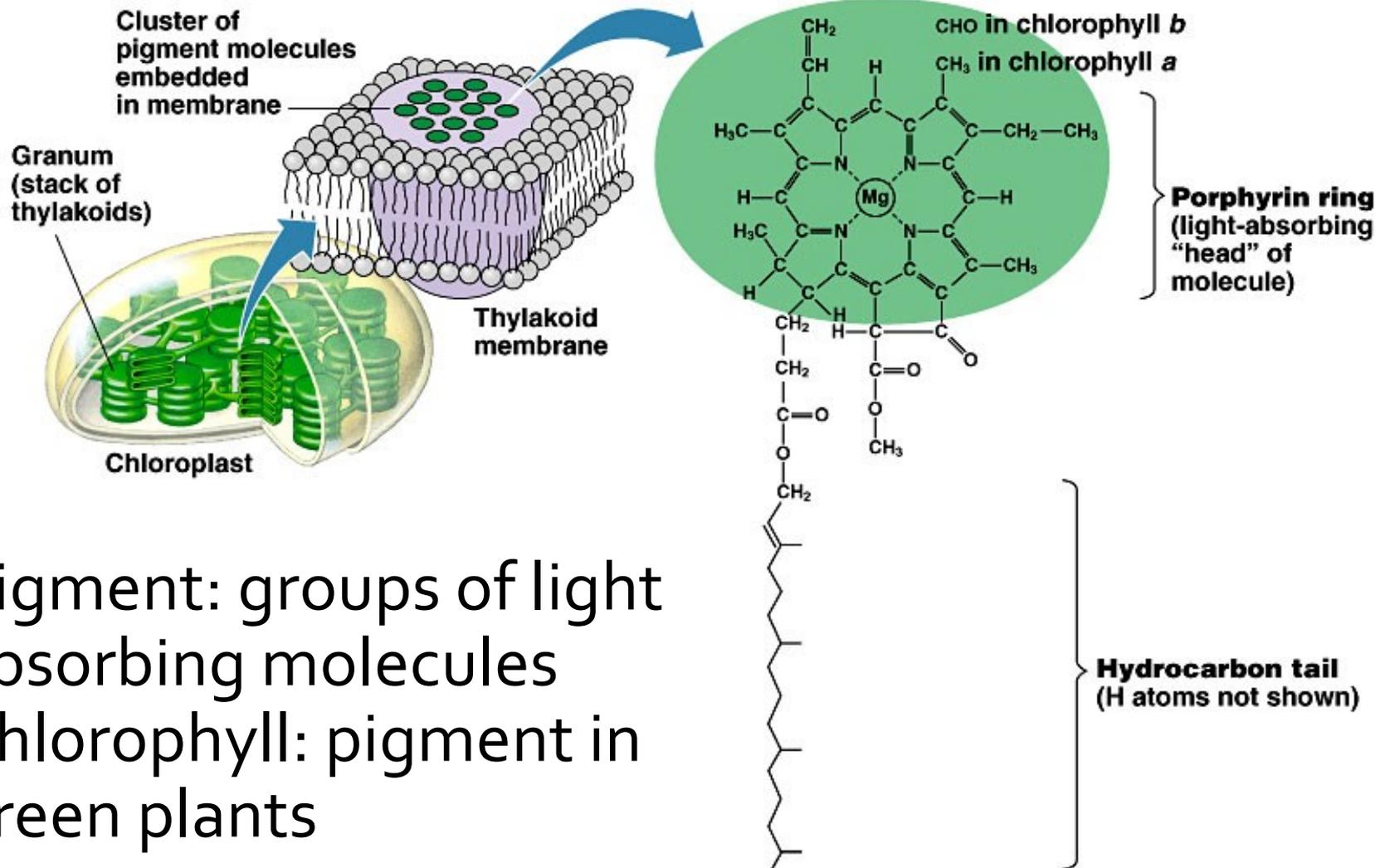
Frequency
(Hz)



Nature of Light

- Light is a form of energy with different wavelengths
- The shorter the wavelength, the greater the energy of each photon of light
- Certain wavelengths of light are detectable by human eyes and seen as colours
- Visible light drives photosynthesis

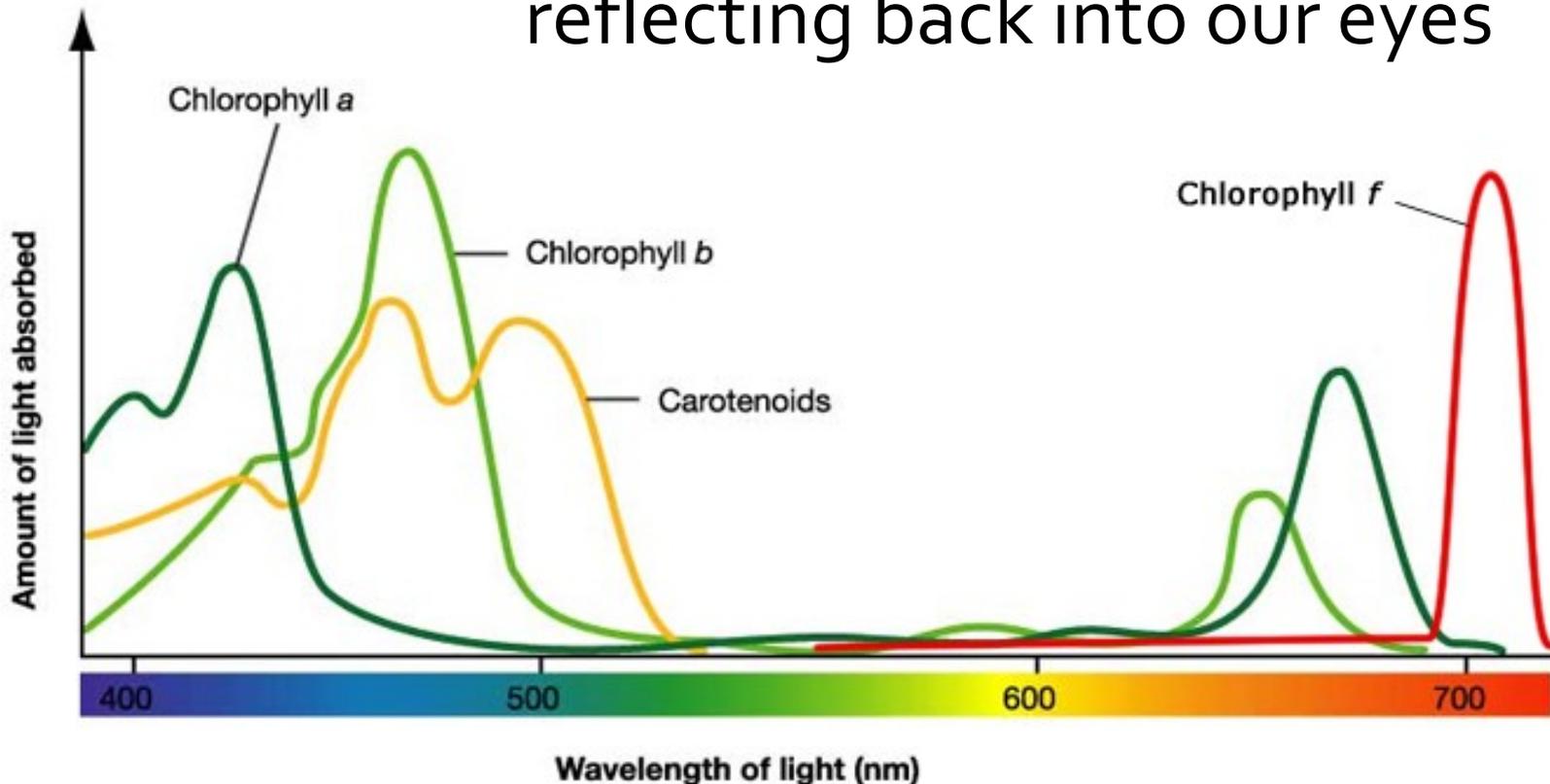
Light Absorbing Pigments



- Pigment: groups of light absorbing molecules
- Chlorophyll: pigment in green plants

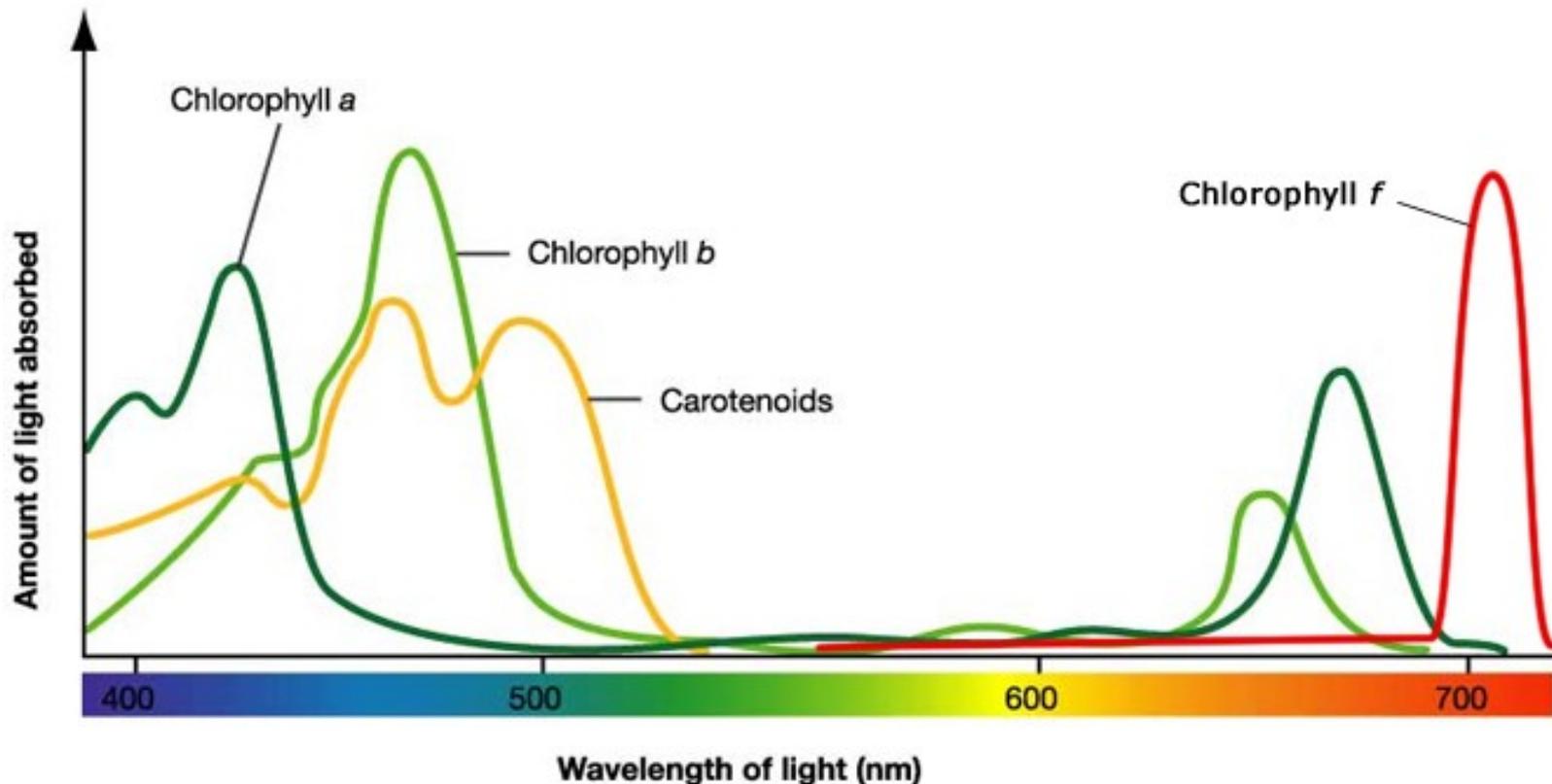
Absorption Spectrum

- The colour of the pigments is due to wavelengths of light reflecting back into our eyes



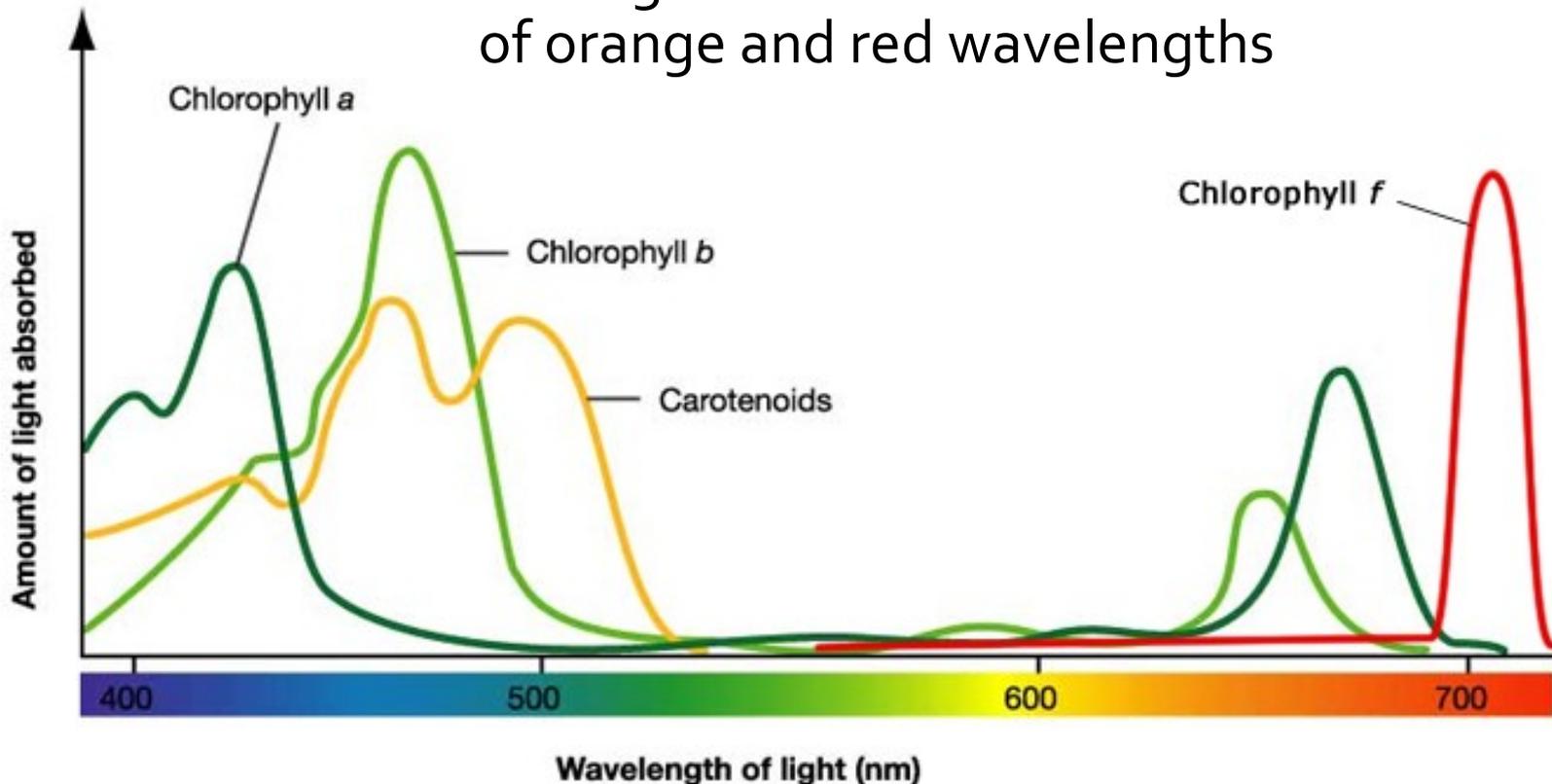
Absorption Spectrum

- Chlorophyll is a green pigment that absorbs mainly blue and red wavelengths of light reflecting back green



Absorption Spectrum

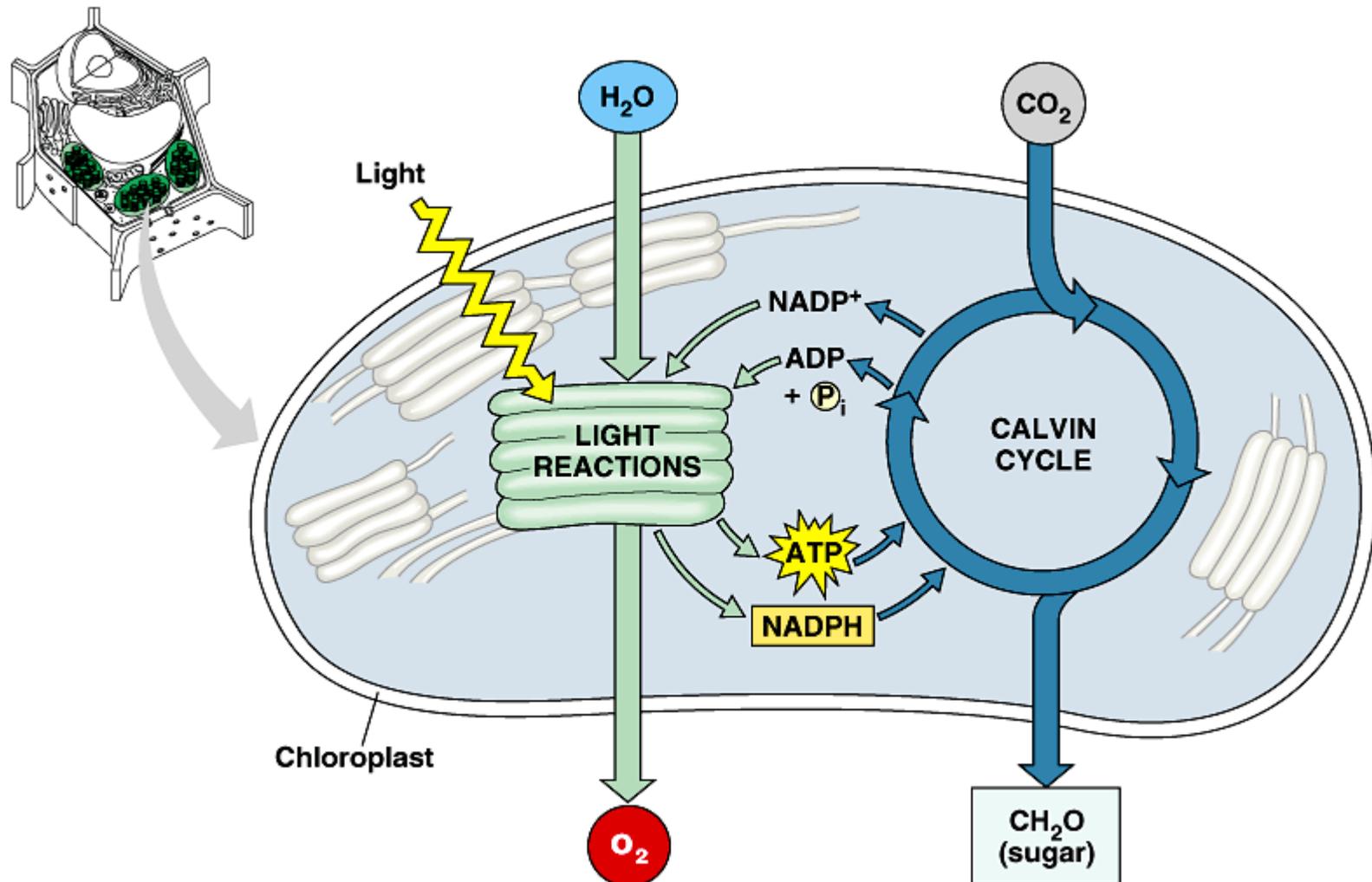
- Carotenoids are pigments that absorb mainly blue and green reflecting back orange and red
- In the fall chlorophyll pigments breakdown first leaving carotenoids which allow the reflection of orange and red wavelengths



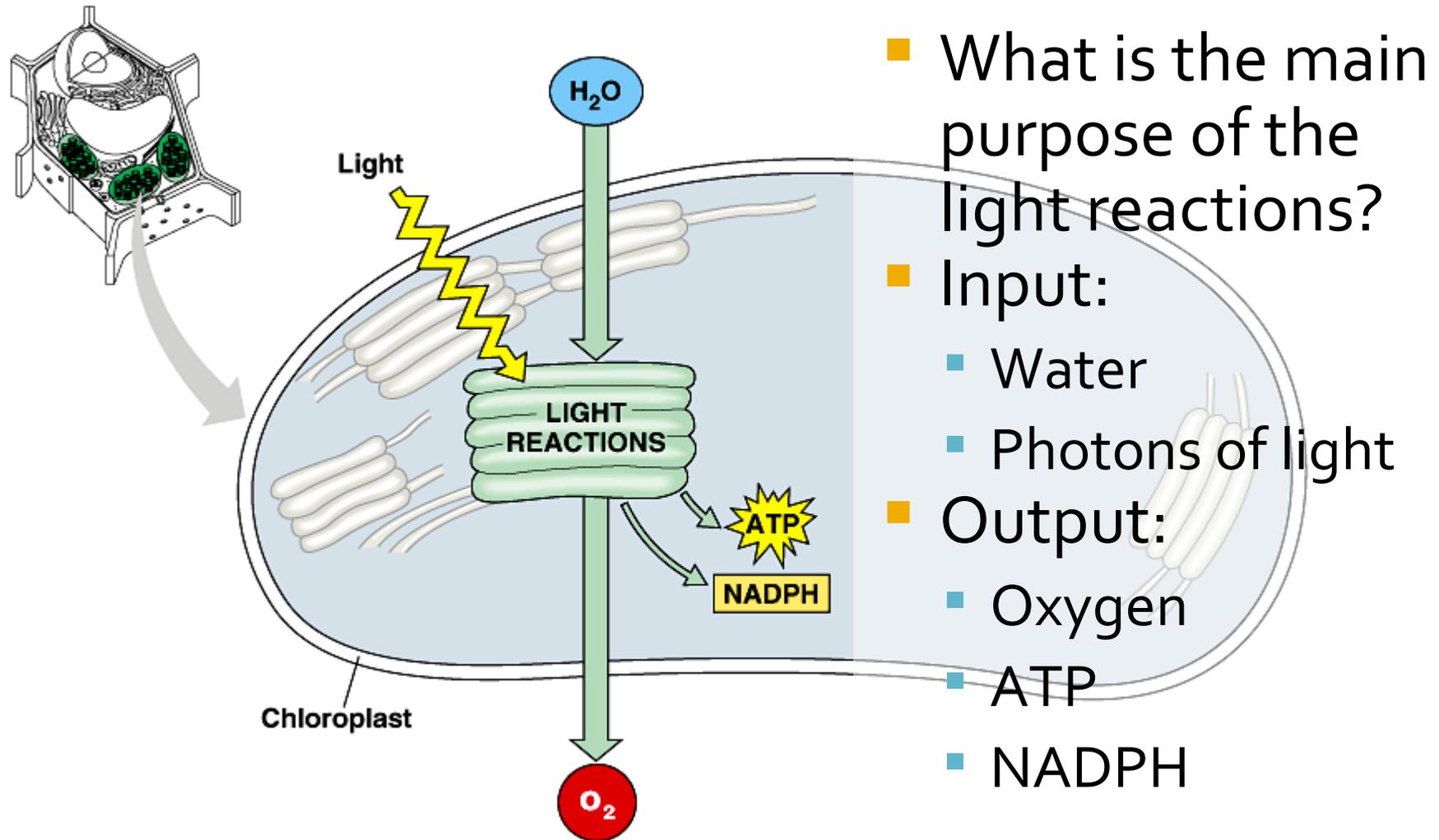
2 Stages of Photosynthesis

- “Photo” stage:
 - light dependent reactions
 - Energy fixing reactions
 - Convert light energy to make ATP & NADPH which will be used to drive the next stage
- “Synthesis” stage:
 - “dark” / light-independent reactions, Calvin cycle
 - Carbon fixing reactions
 - Uses ATP to convert inorganic molecules to organic fuel containing stored potential energy in the bonds

2 Stages of Photosynthesis



Light Reaction Purpose

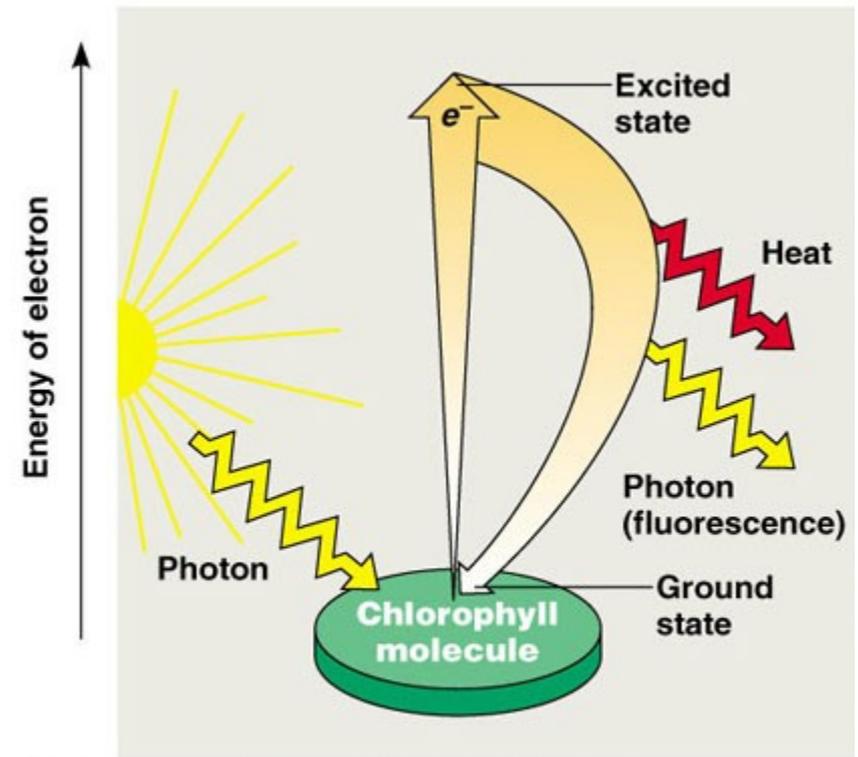


3 Parts to Light Reactions

- Photoexcitation
 - Absorption of light photons whose energy is used to split water releasing electrons
- Electron transport
 - Harnessing the energy in electrons to form an electrochemical gradient (pump hydrogen ions against its concentration gradient)
- Photophosphorylation (chemiosmosis)
 - ATP synthesis due to electrochemical gradient and the proton motive force

Photoexcitation

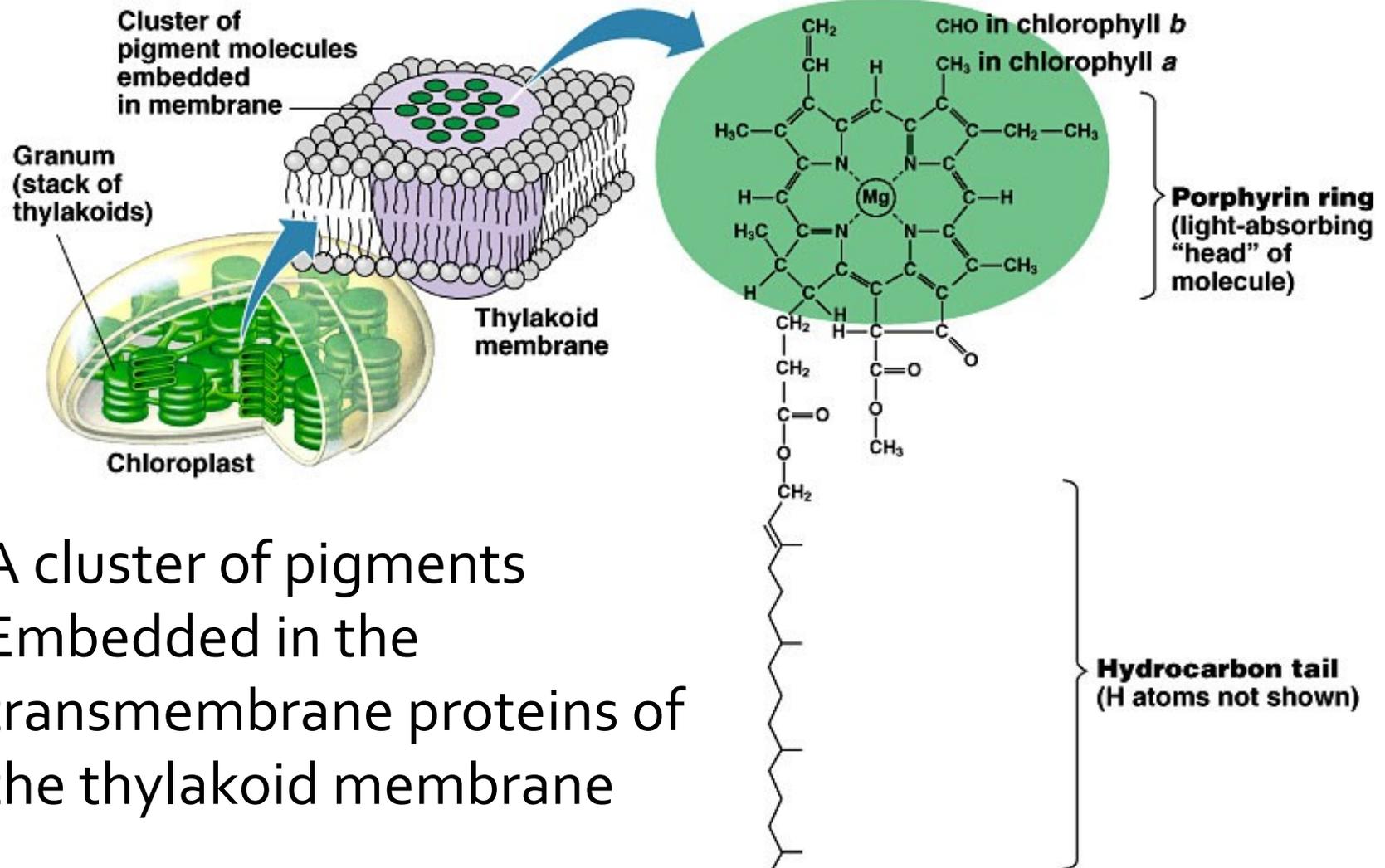
- When atoms absorb energy from the sun, electrons gain energy becoming excited
- Excited electrons will fall back to ground state if it isn't transferred to an electron acceptor



(a) Excitation of isolated chlorophyll molecule

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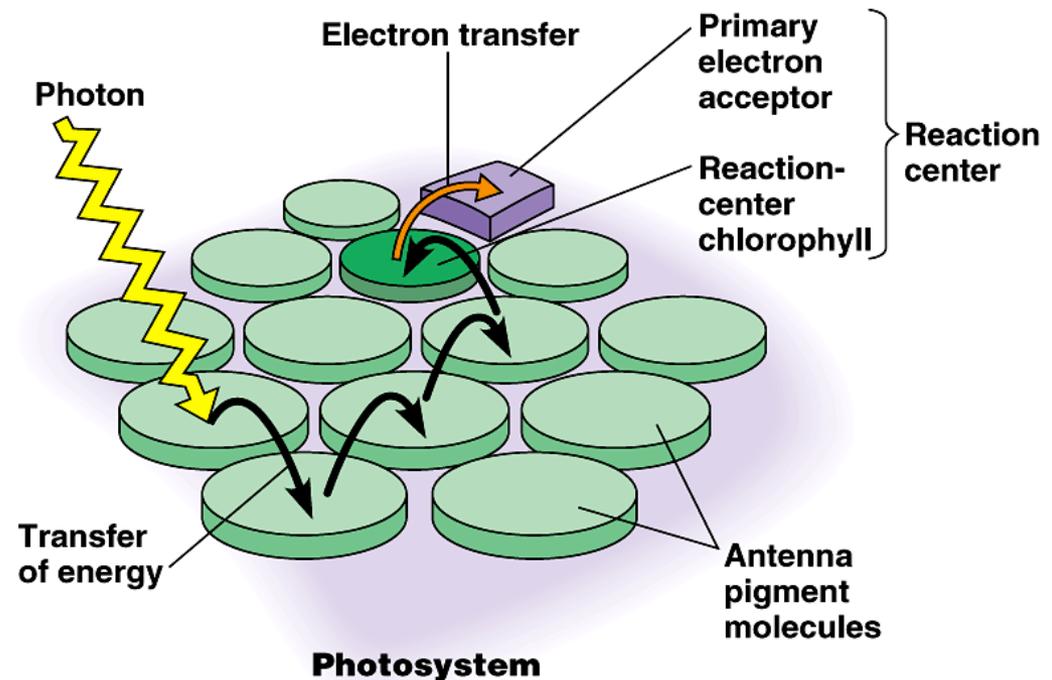
Photosystems



- A cluster of pigments
- Embedded in the transmembrane proteins of the thylakoid membrane

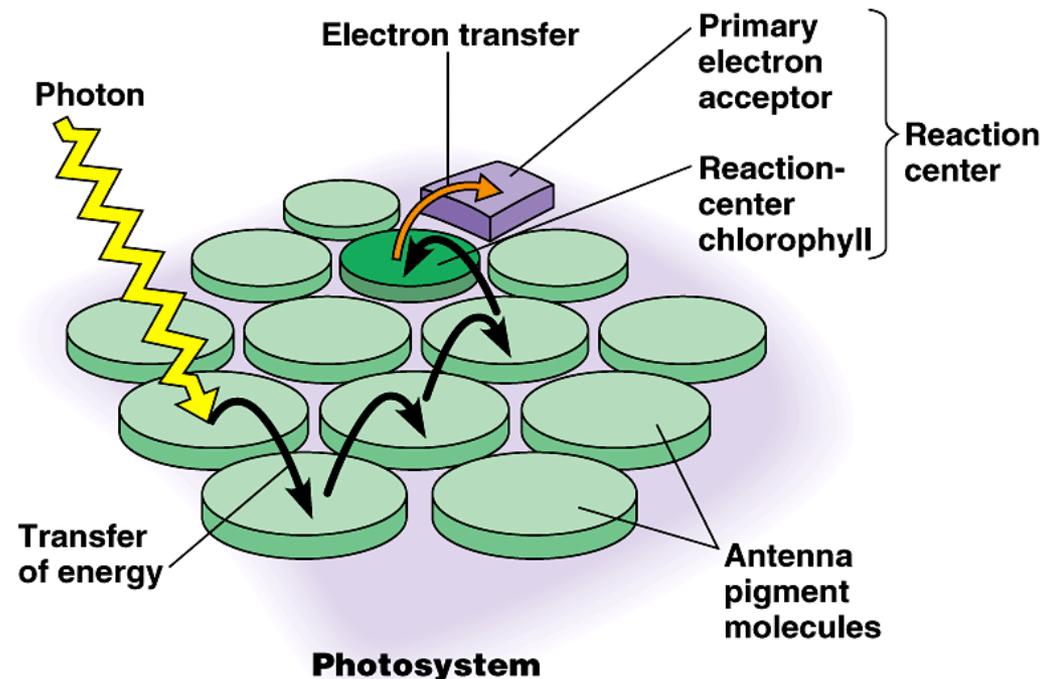
Photosystem Structure

- Consists of a few hundred pigment molecules
- Reaction centre contains a chlorophyll a that is located next to a primary electron acceptor



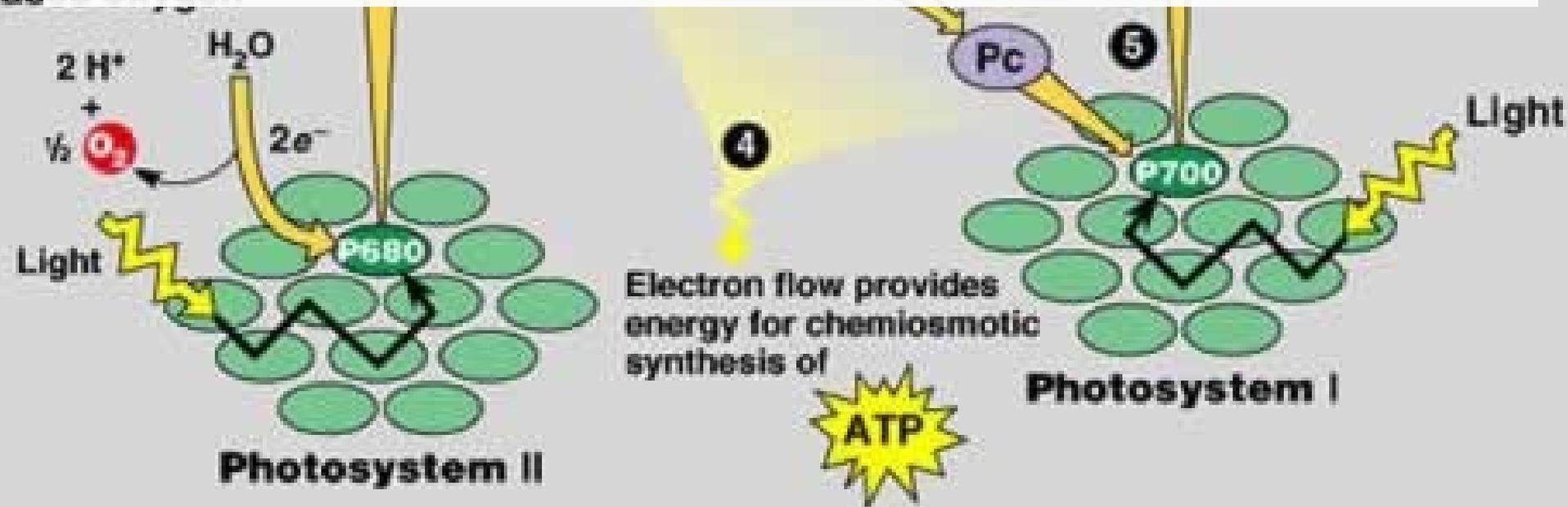
Photosystem Mechanism

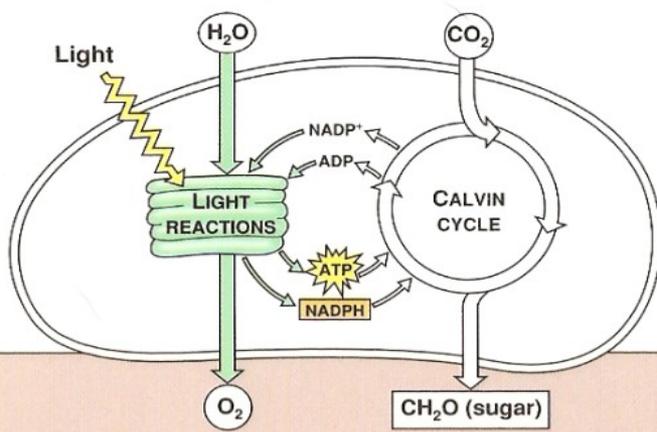
- Light excites an electron on the reaction-centre chlorophyll a
- Primary electron acceptor traps the high energy electron before it can return to ground state



Photosystem Mechanism

- **Photosystem I**: Reaction-centre chlorophyll is **P700**
- **Photosystem II**: Reaction-centre chlorophyll is **P680**
- Numbers indicate optimal wavelength for absorption
- different absorption preferences due to interaction with different proteins in photosystems





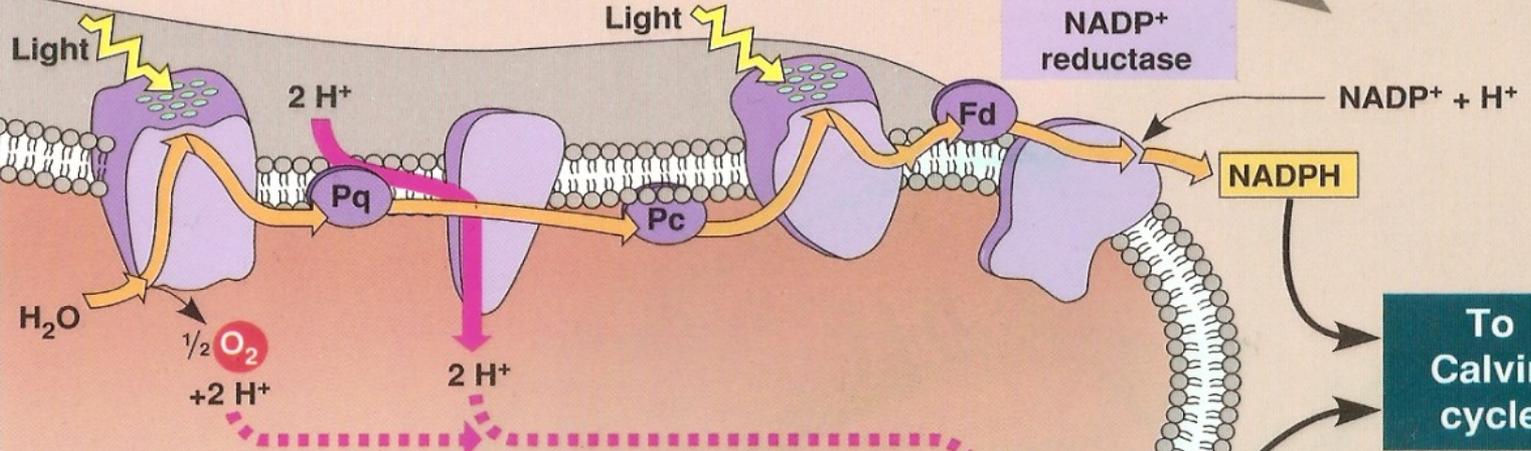
STROMA

Photosystem II

Cytochrome complex

Photosystem I

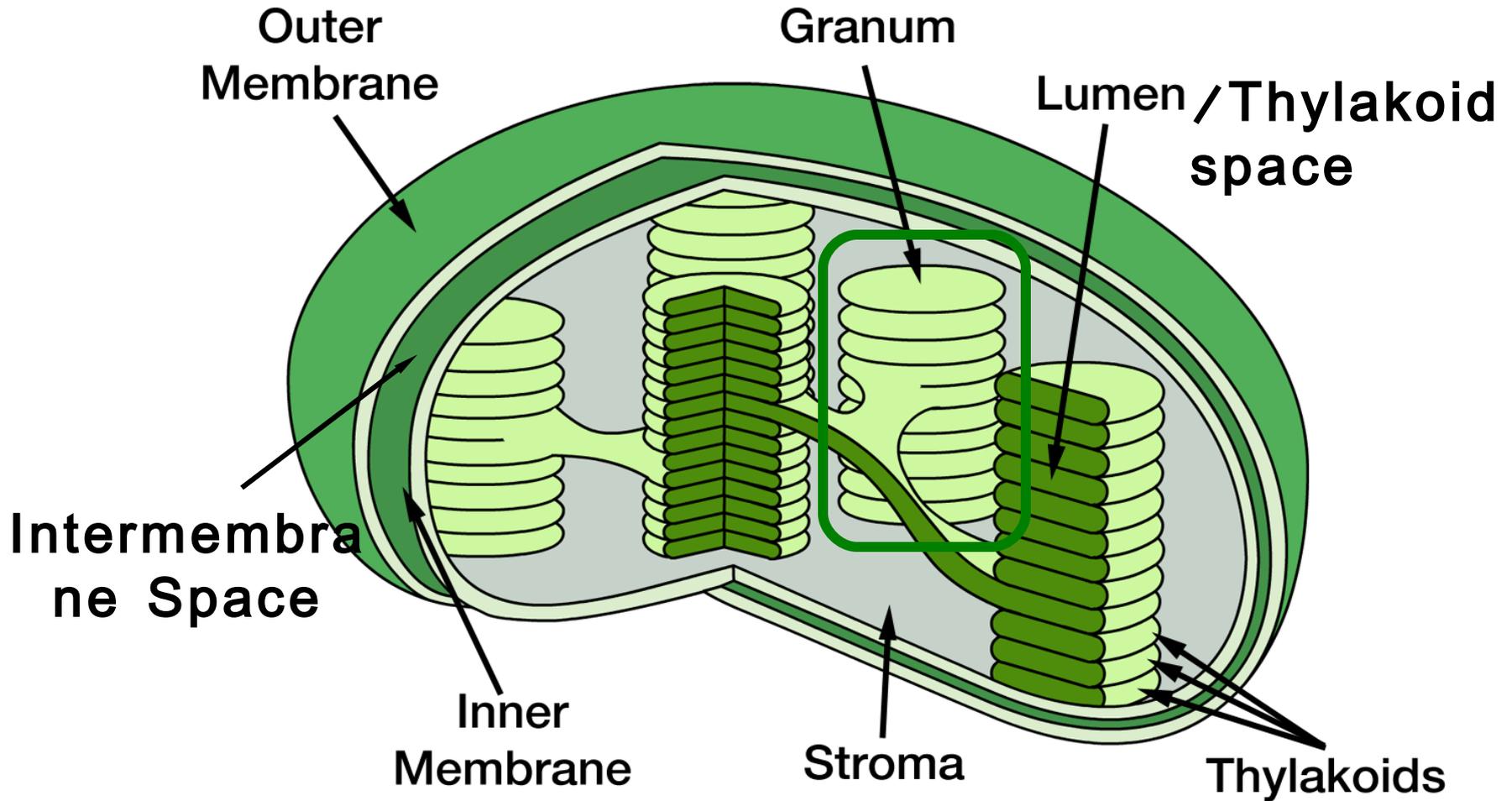
THYLAKOID MEMBRANE



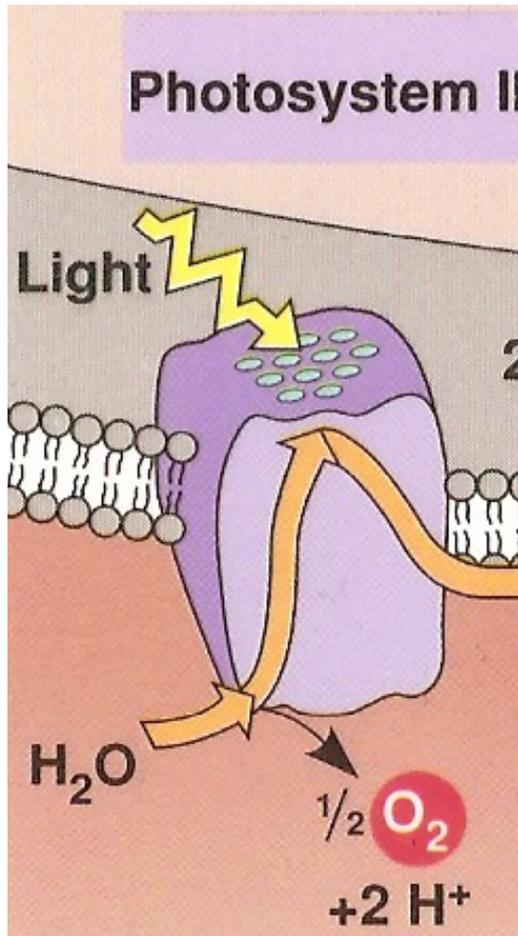
THYLAKOID SPACE

STROMA

Review: Chloroplast Structure

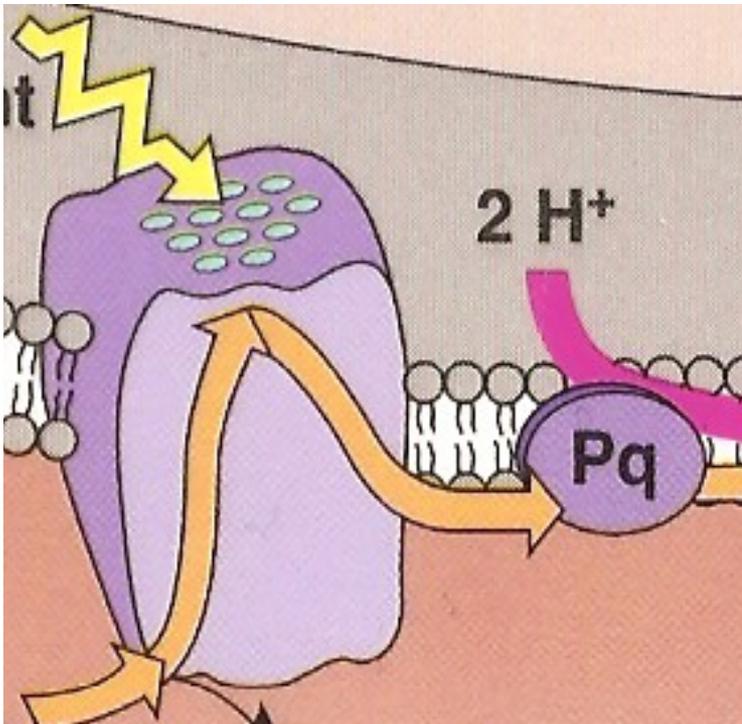


Thylakoid Proteins: PSII (P680)



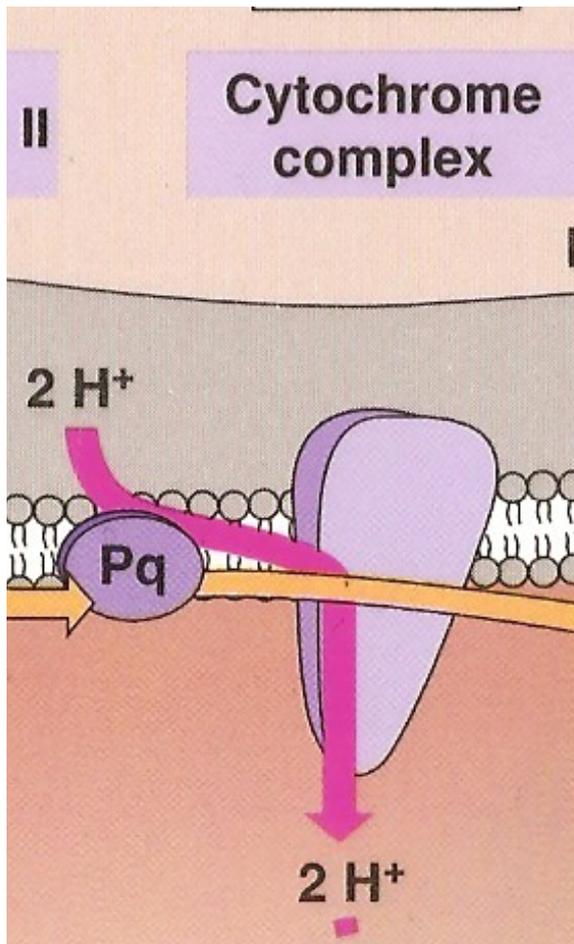
- PSII absorbs light
- Excited electron in the reaction-centre chlorophyll (P680) is captured by the primary electron acceptor
- P680 now “missing” an electron is a very strong oxidizing agent
- Electrons are extracted from water (in the lumen) to replace the missing electrons on P680
- As a result, water is split into oxygen and hydrogen ions

Thylakoid Proteins: Pq



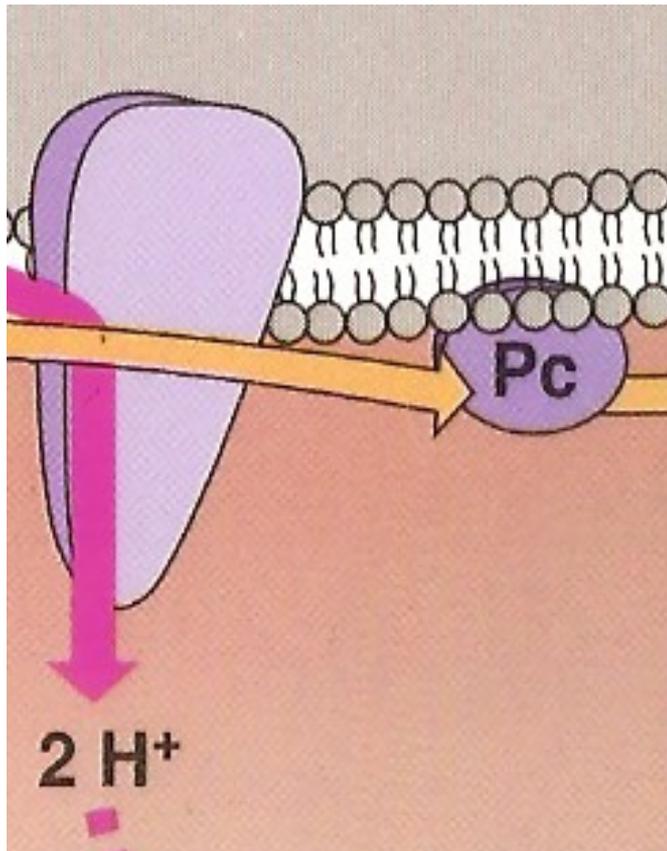
- Electron capture by primary electron acceptor of PSII will now be passed through an electron transport chain
- The electron is first transferred to plastoquinone (Pq)
- Pq is a mobile component within the thylakoid membrane

Thylakoid Proteins: Cytochrome Complex



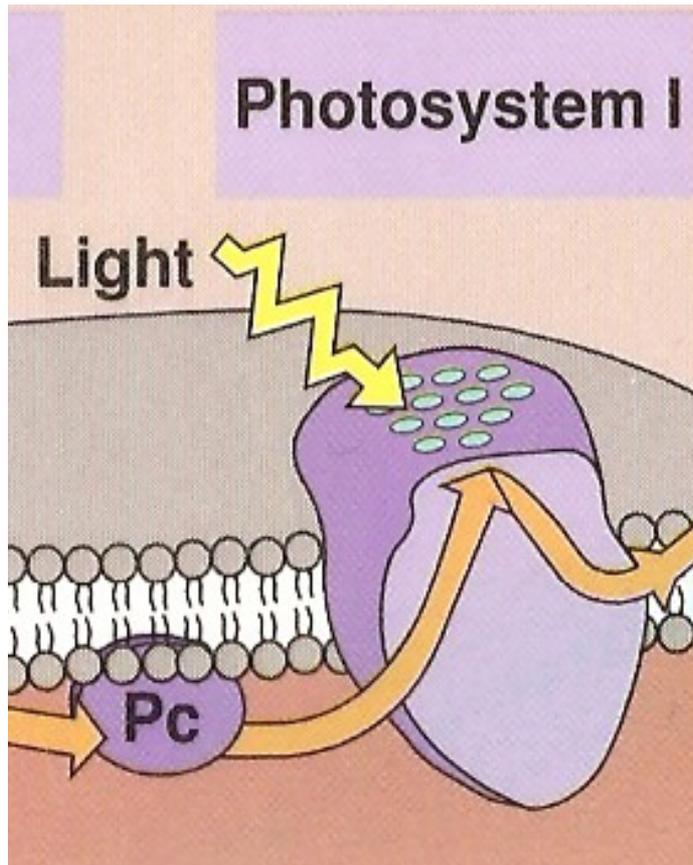
- Electrons are transferred from Pq to cytochrome complex
- protons are pumped against its concentration gradient from stroma across thylakoid membrane to the lumen

Thylakoid Proteins: Pc



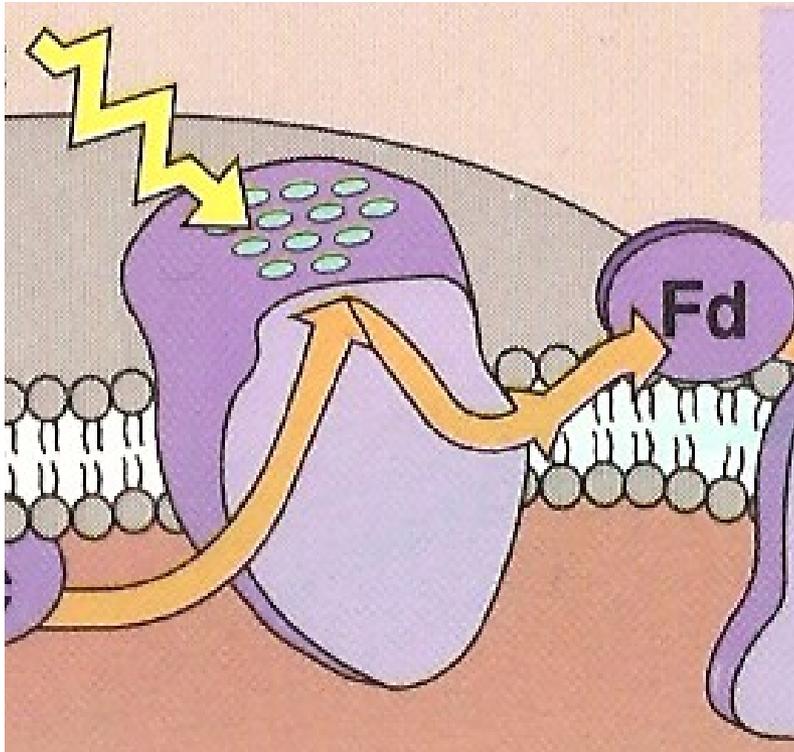
- Electrons are transferred to plastocyanin (Pc)
- Pc is a movable component on lumen side of the thylakoid membrane

Thylakoid Proteins: PSI (P700)



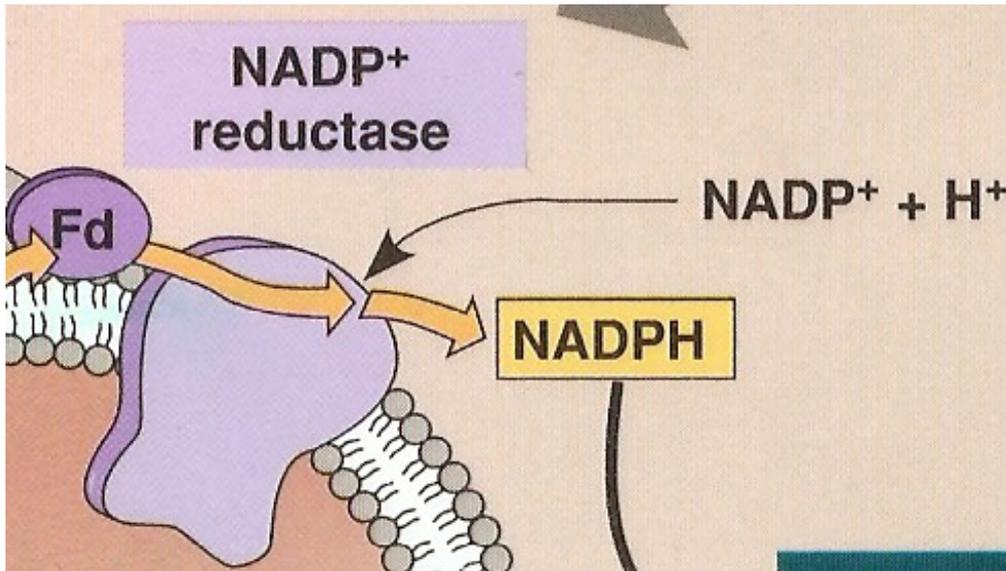
- Electrons on P700 is excited by light and captured by the primary electron acceptor leaving P700 oxidized
- Electrons transferred from Pc to P700 replaces the electrons that were lost

Thylakoid Proteins: Fd



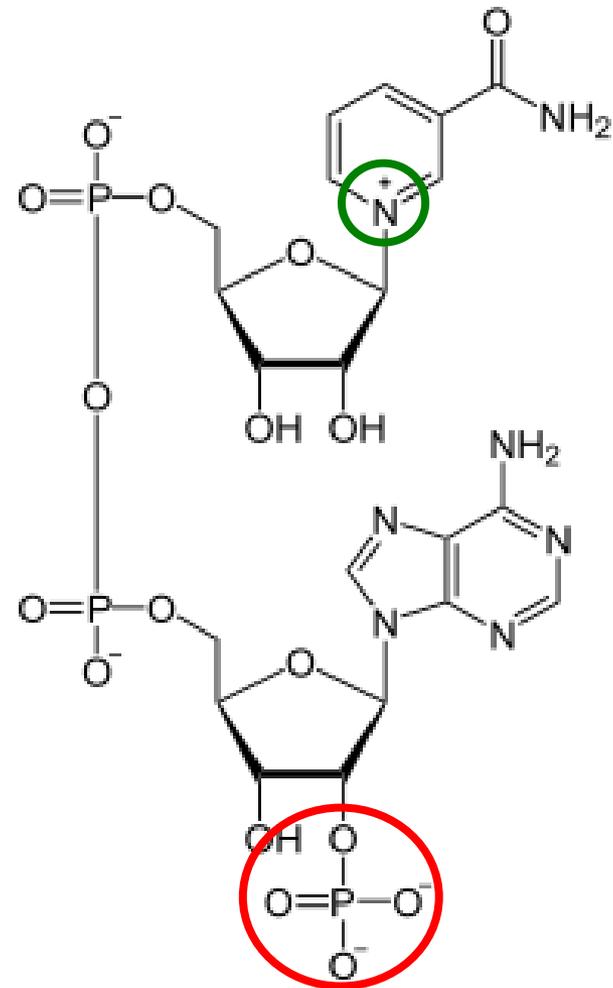
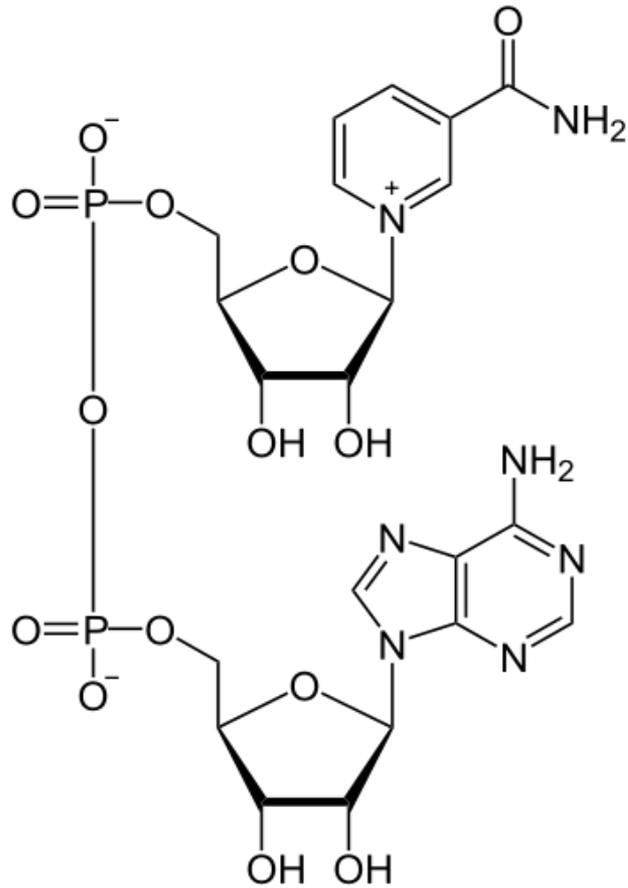
- Electrons undergo a second transport chain
- Electrons are transferred to ferredoxin (Fd)
- Fd is an iron containing mobile component on the stromal side of the thylakoid membrane

Thylakoid Protein: NADP⁺ Reductase



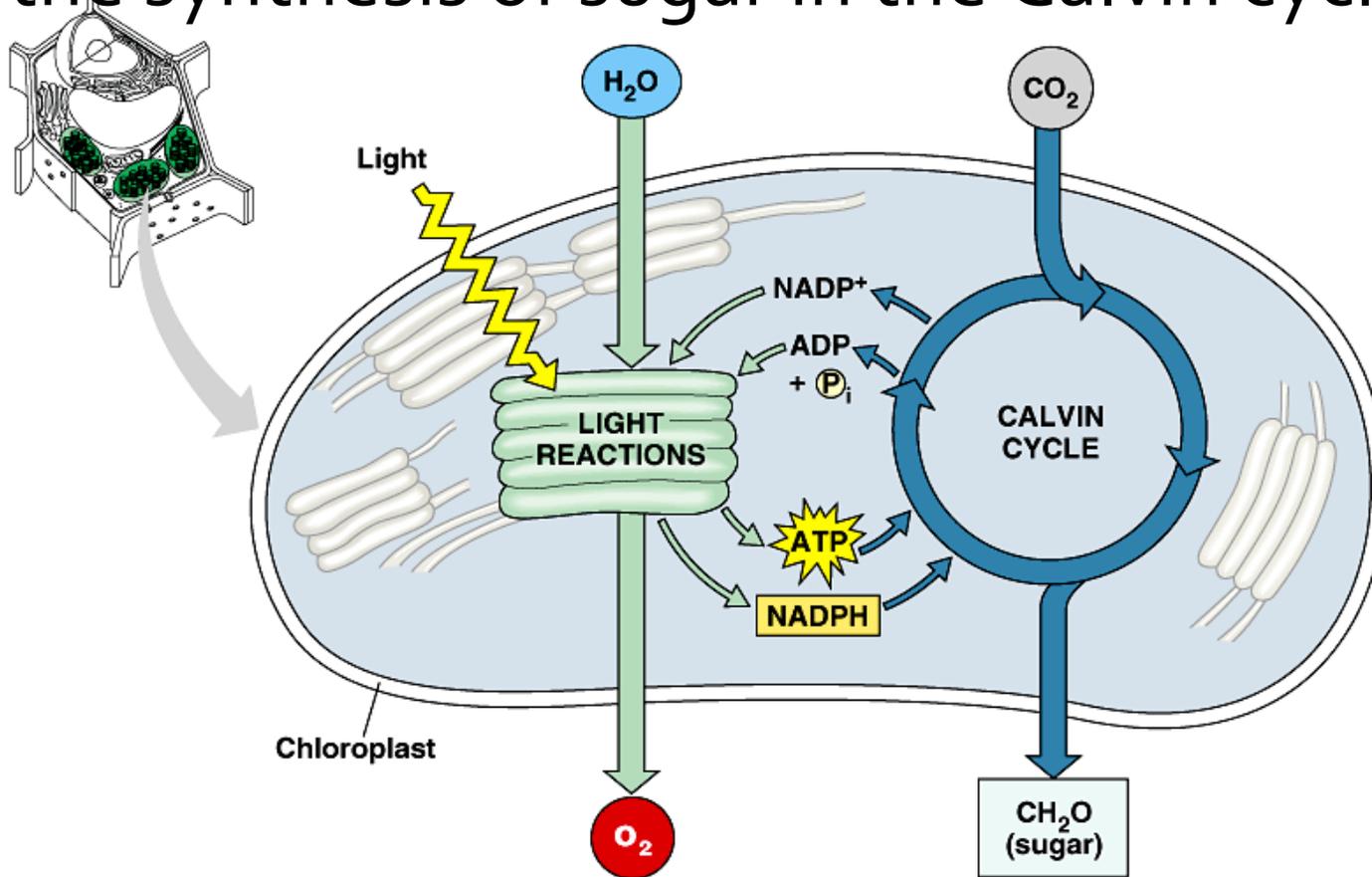
- electrons transferred by enzyme NADP⁺ reductase to the final electron acceptor NADP⁺
- NADP⁺ is reduced to NADPH

Compare NAD⁺ to NADP⁺

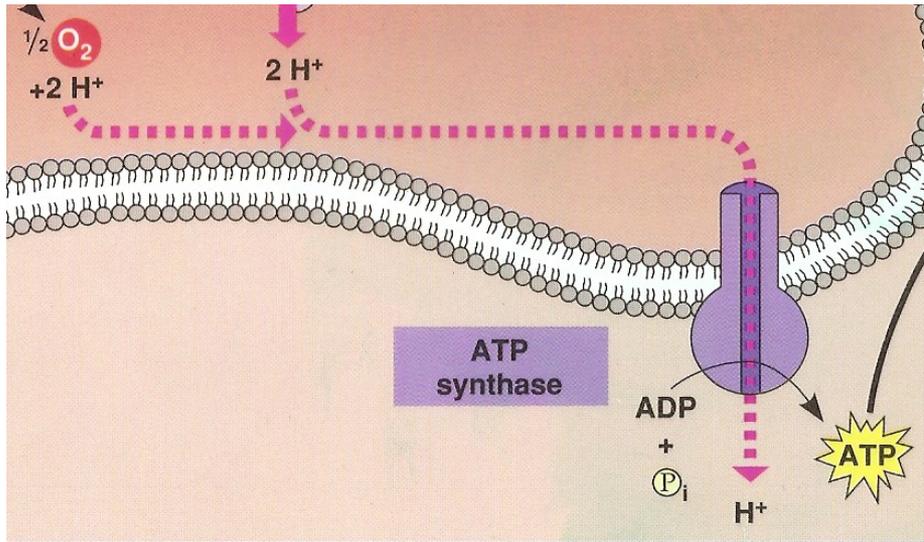


Purpose of NADPH

- NADPH will provide the reducing power for the synthesis of sugar in the Calvin cycle



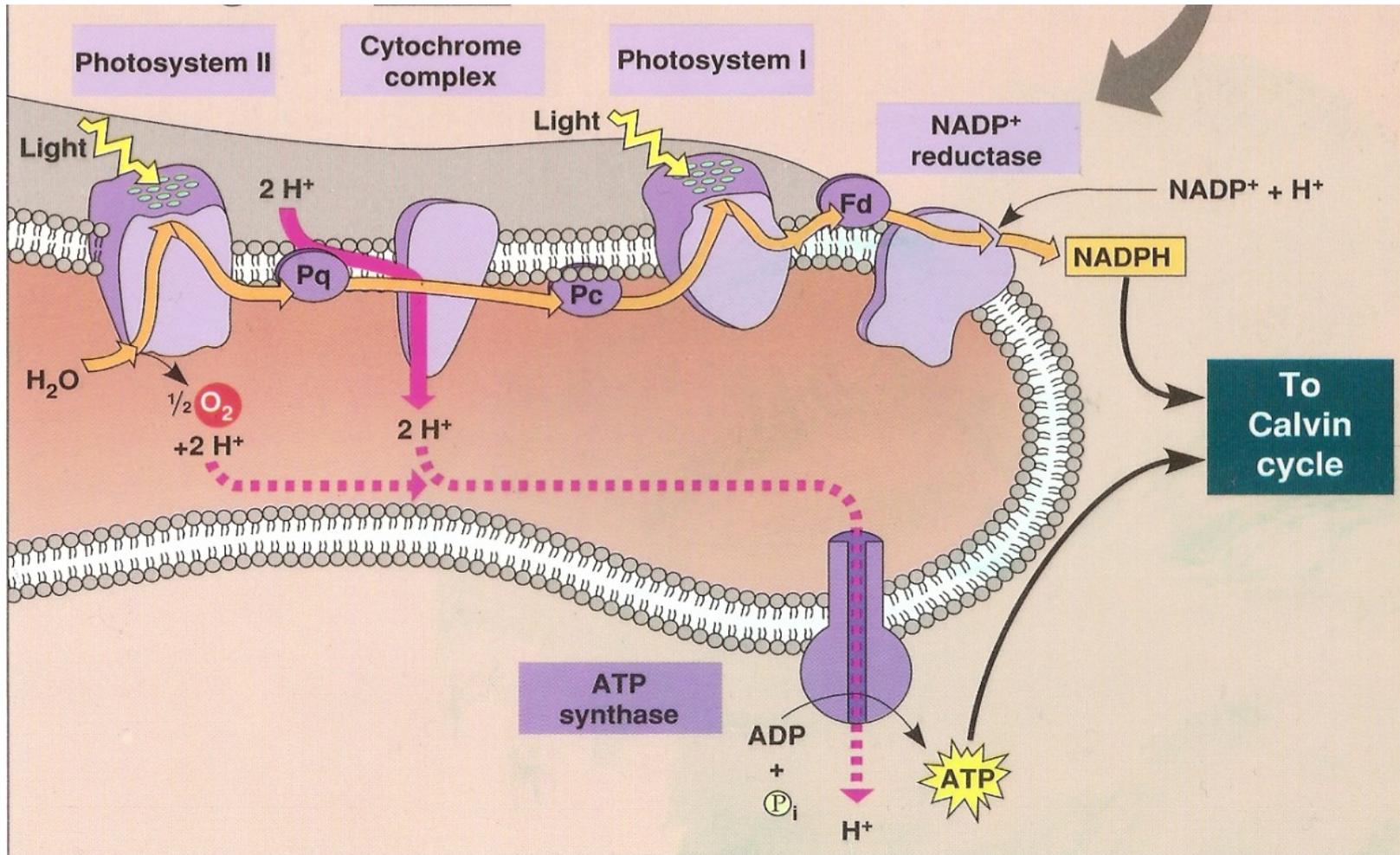
Thylakoid Proteins: ATP Synthase



- protons pumped into the lumen pass through ATP synthase using the same mechanism as seen in cellular respiration
- ATP is produced in the stroma

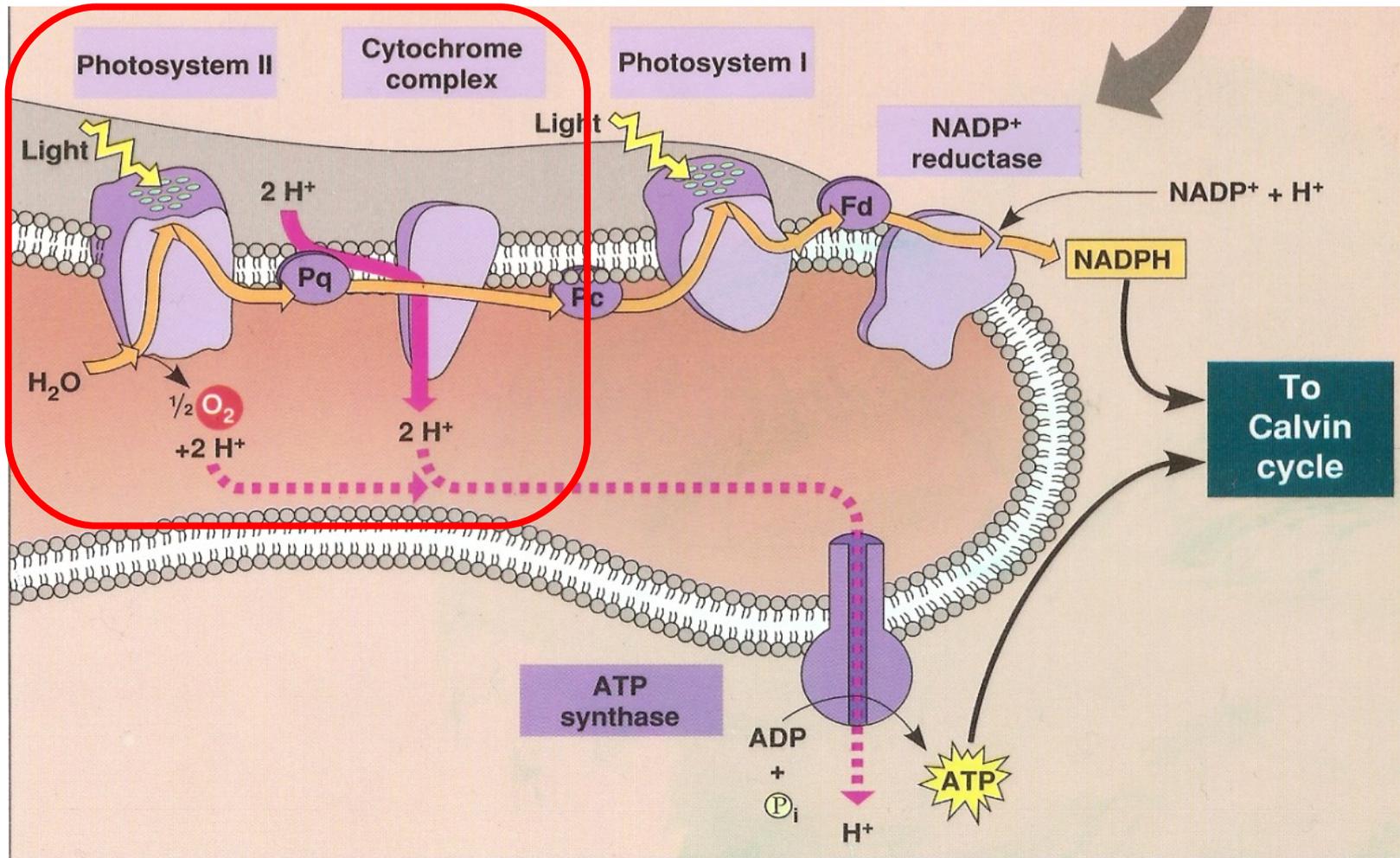
Photophosphorylation

- light-dependent formation of ATP by chemiosmosis



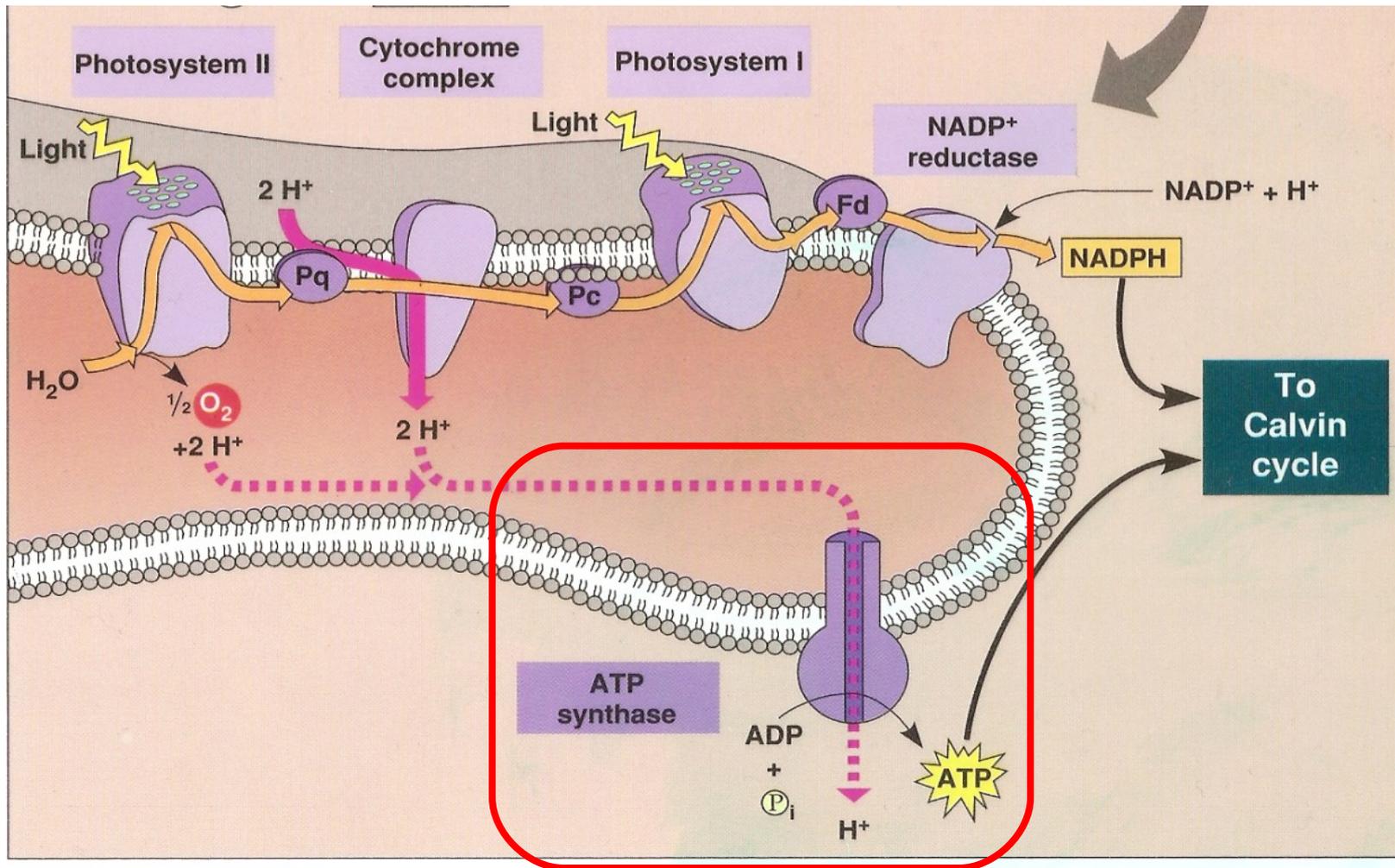
Photophosphorylation

- ETC provides energy for photosystems to pump H^+ from stroma to lumen



Photophosphorylation

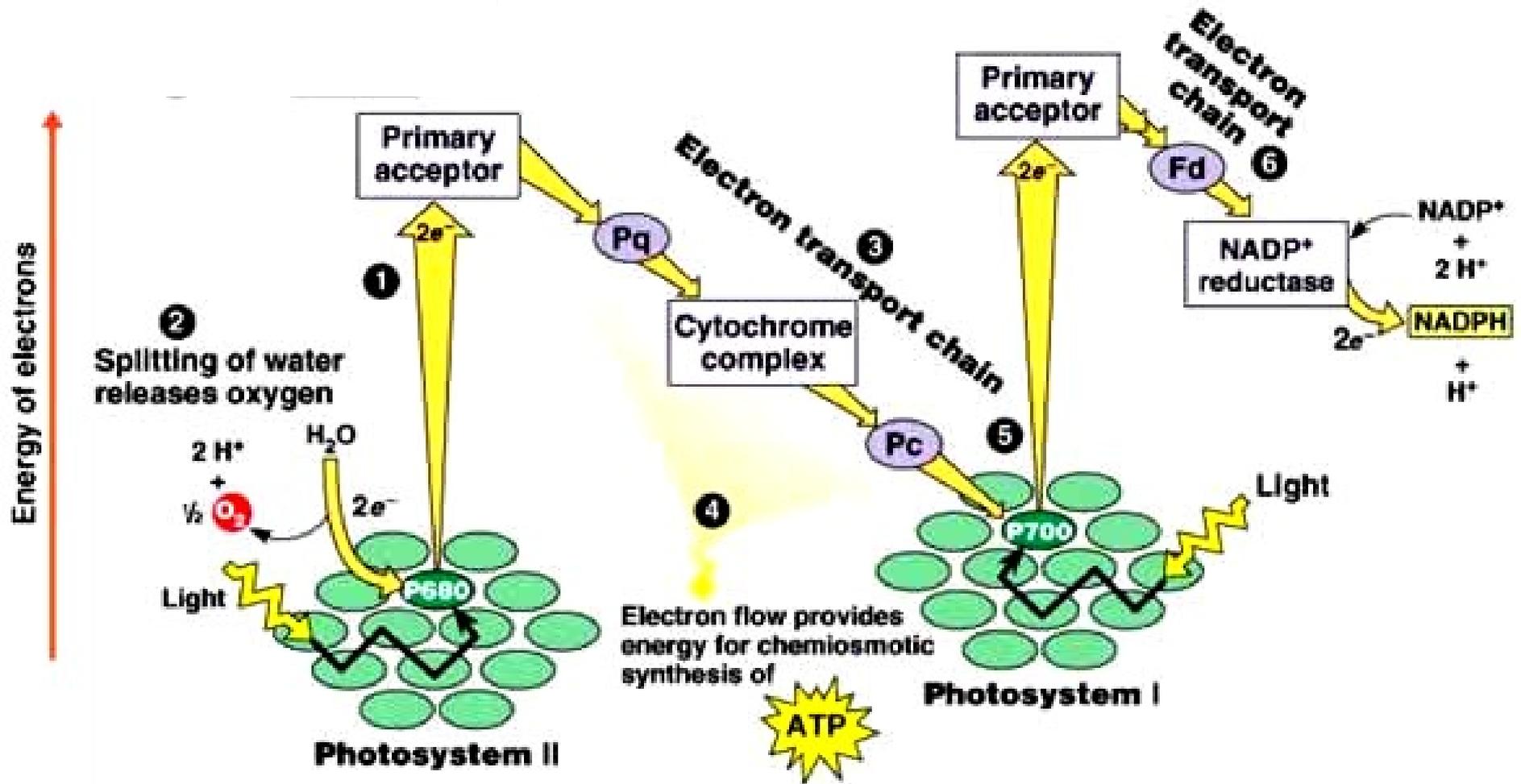
- Electrochemical proton gradient provides proton motive force needed to synthesize ATP



Types of Electron Transport Mechanisms

- Non-cyclic electron flow
- Cyclic electron flow

Non-cyclic Electron Flow: Z-Scheme



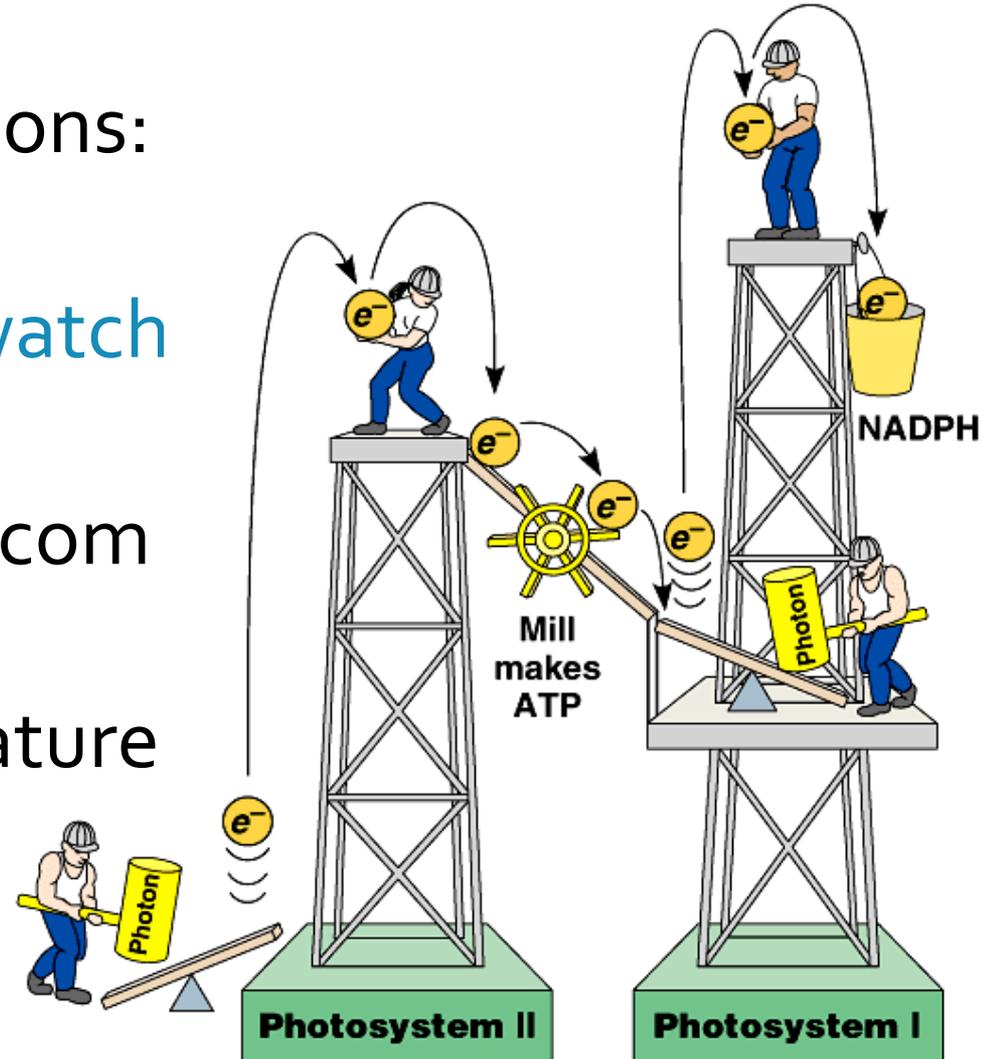
Non-cyclic Electron Transfer Summary

- H_2O is split to produce O_2 (released from cell) and H^+ ions (released into lumen)
- Electron transport chain helps establish electrochemical proton gradient
- **Photophosphorylation**: light-dependent formation of ATP by chemiosmosis
- NADP^+ is final electron acceptor and produces NADPH

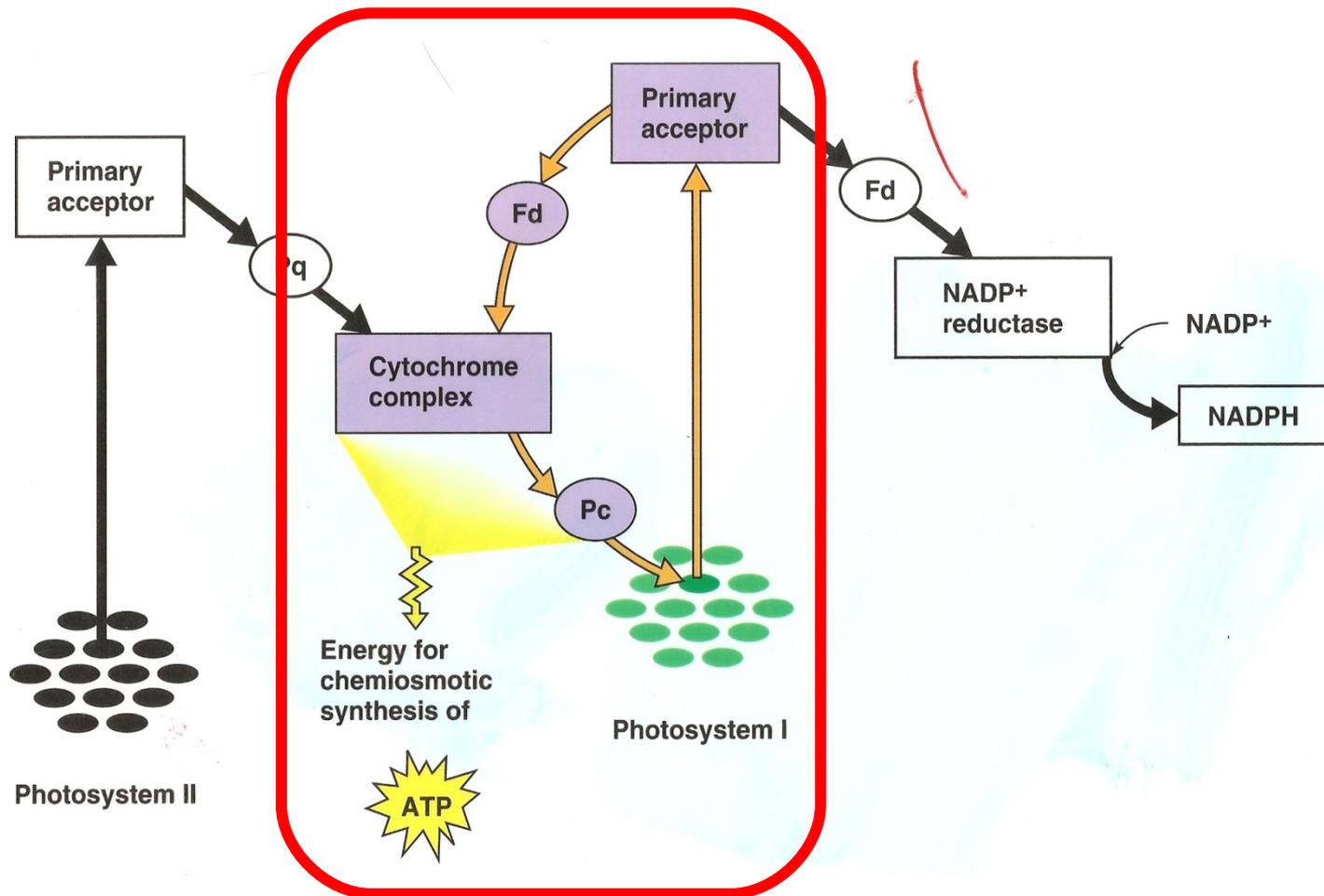
Noncyclic Electron Flow Analogy

Light Reaction Animations:

- <http://www.youtube.com/watch?v=v59oJJVg6lc>
- http://www.youtube.com/watch?v=hj_WKgnL6MI&feature=related



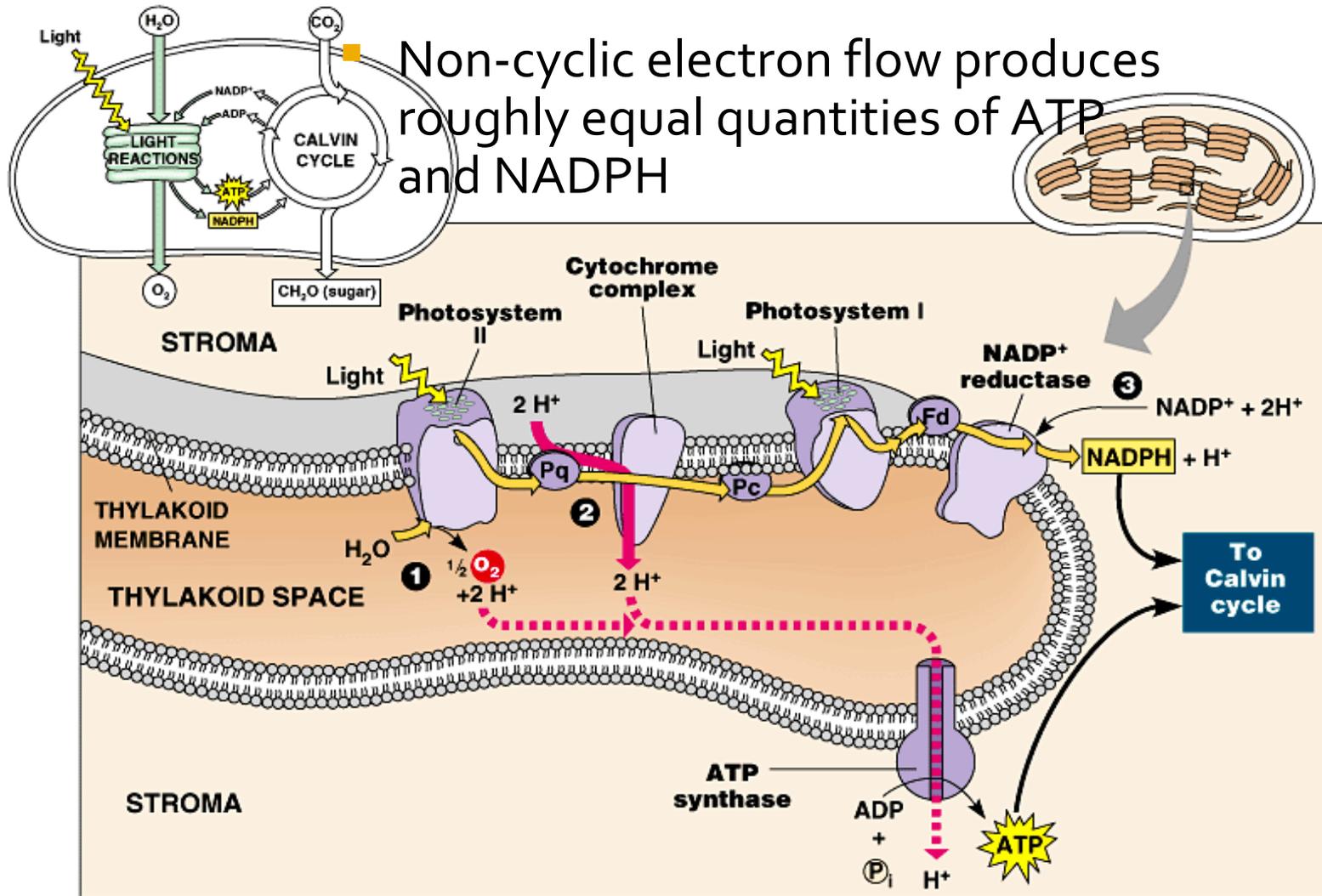
Cyclic Electron Flow



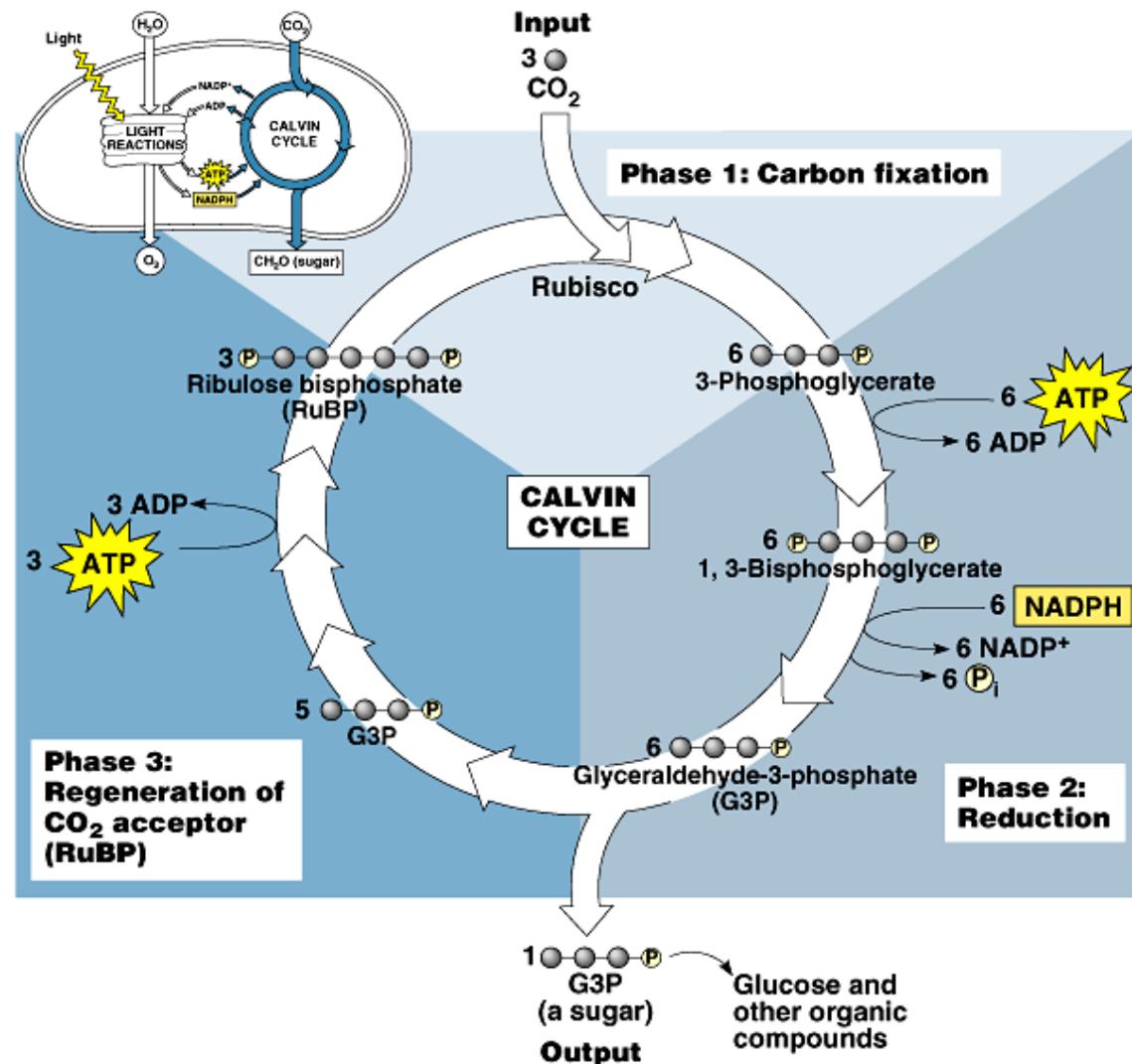
Cyclic Electron Transfer Summary

- only involves photosystem I (P700)
- ferredoxin returns electrons back to cytochrome complex
- protons pumped into lumen to produce more ATP through chemiosmosis
- no NADPH produced

Purpose of Cyclic Electron Flow

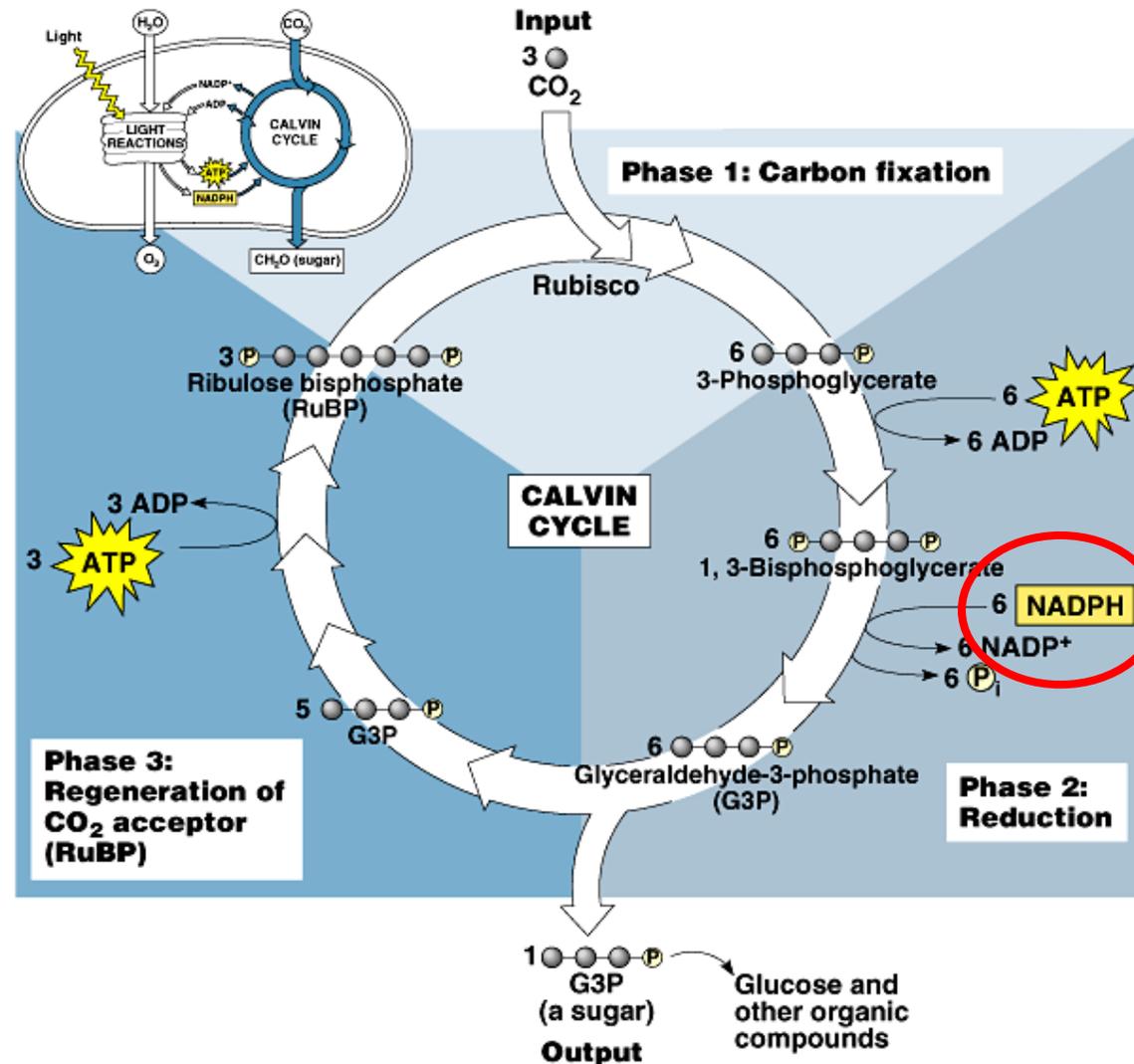


Purpose of Cyclic Electron Flow



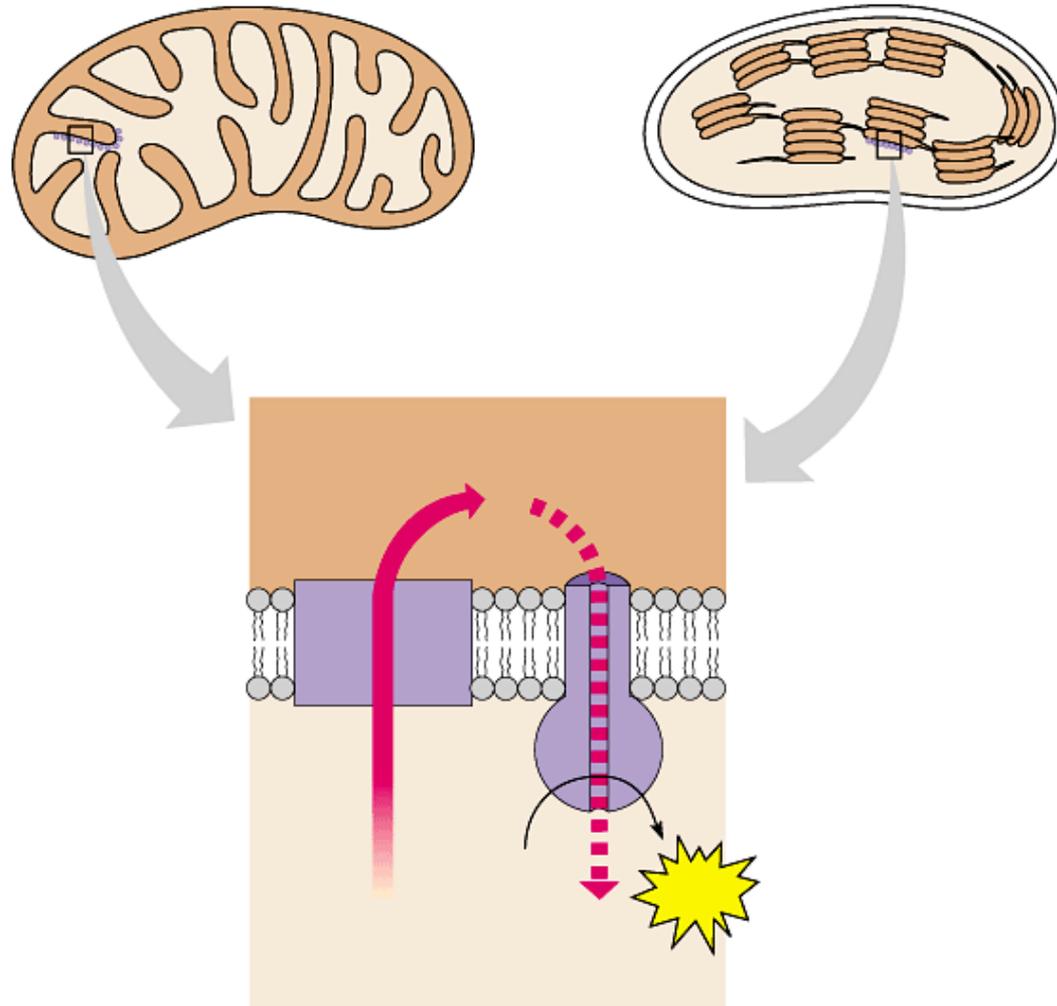
- In the Calvin cycle, more ATP is consumed than NADPH
- Need a method to increase ATP production without affecting NADPH

Purpose of Cyclic Electron Flow



- When ATP runs low, NADPH will accumulate because the Calvin cycle slows down
- Rise in NADPH levels stimulate a temporary shift to cyclic electron flow

Compare Cellular Respiration and Photosynthesis



Compare Cellular Respiration and Photosynthesis

