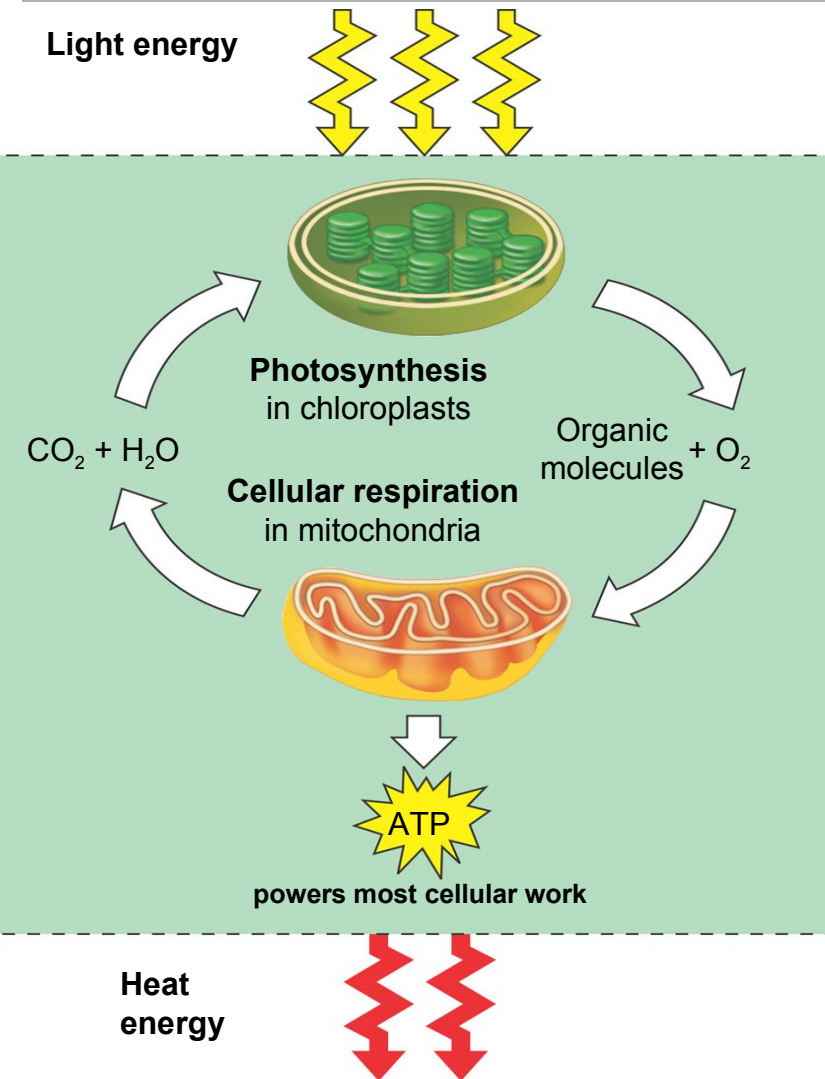


# Photosynthesis Light Reaction

# 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



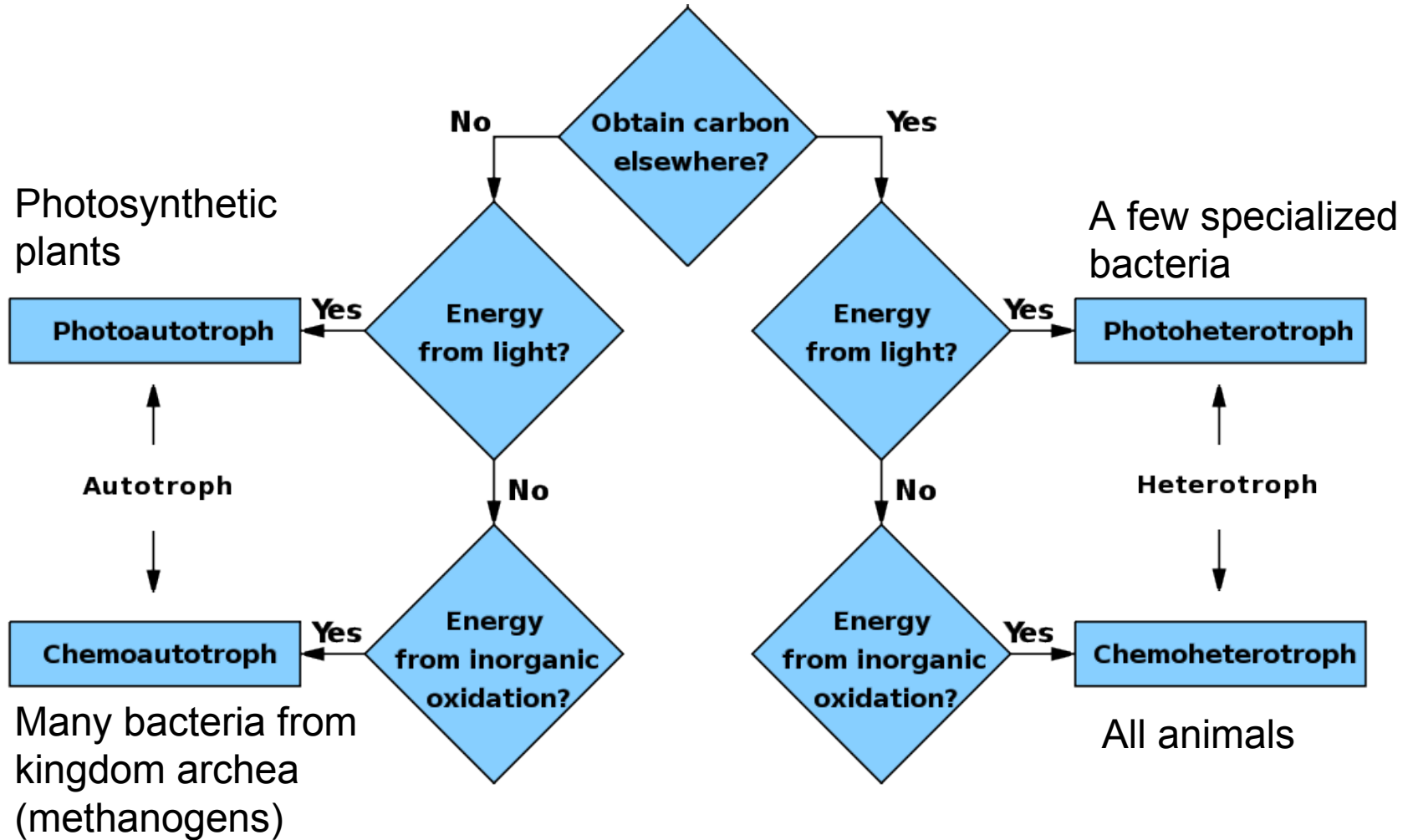
- Photosynthesis and cellular respiration are **complementary** processes
- They are not opposite reactions even though their overall equations are the reverse because the multiple steps that make up each process are different

Figure 9.2

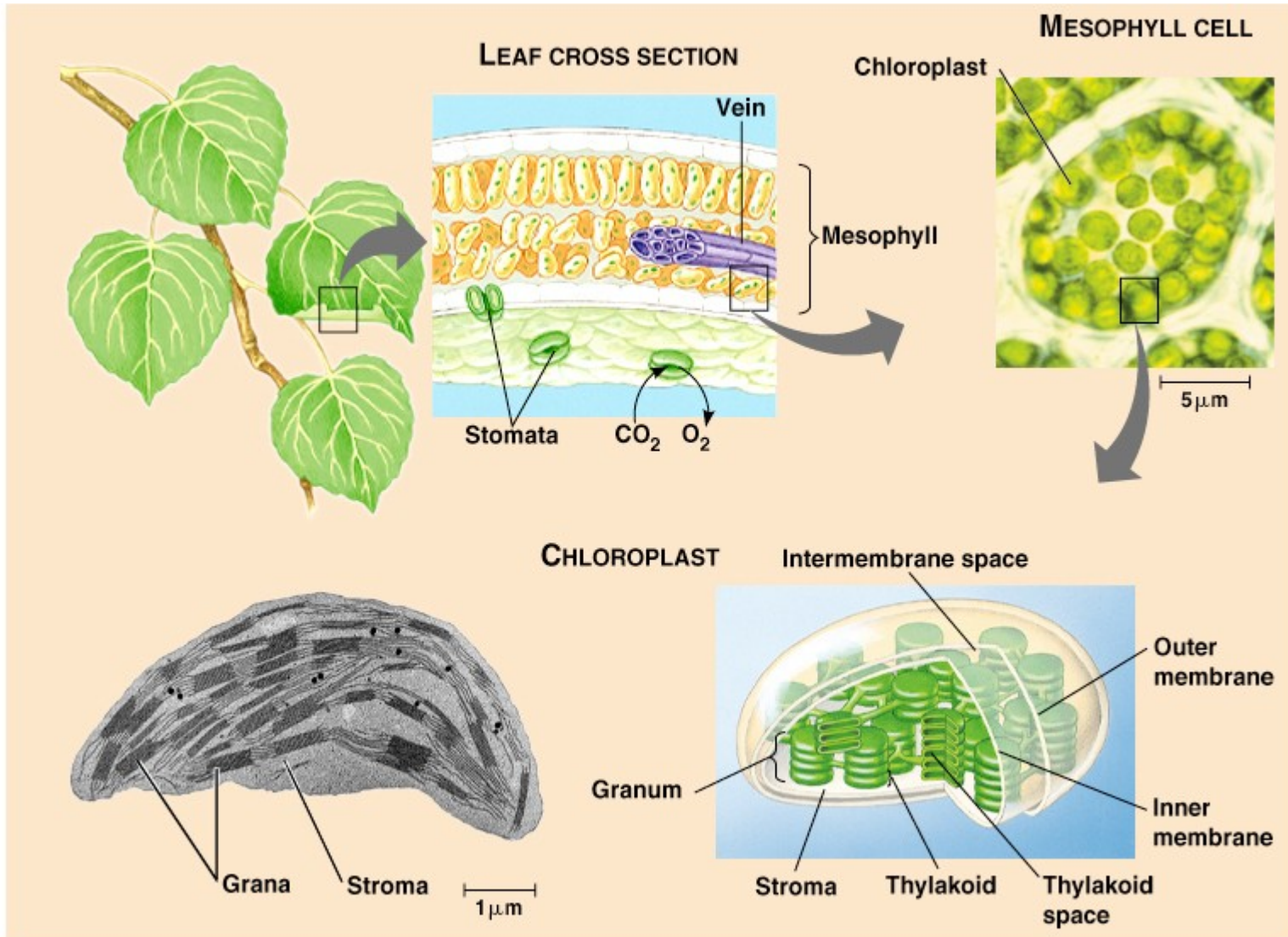
# Autotrophs

- 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

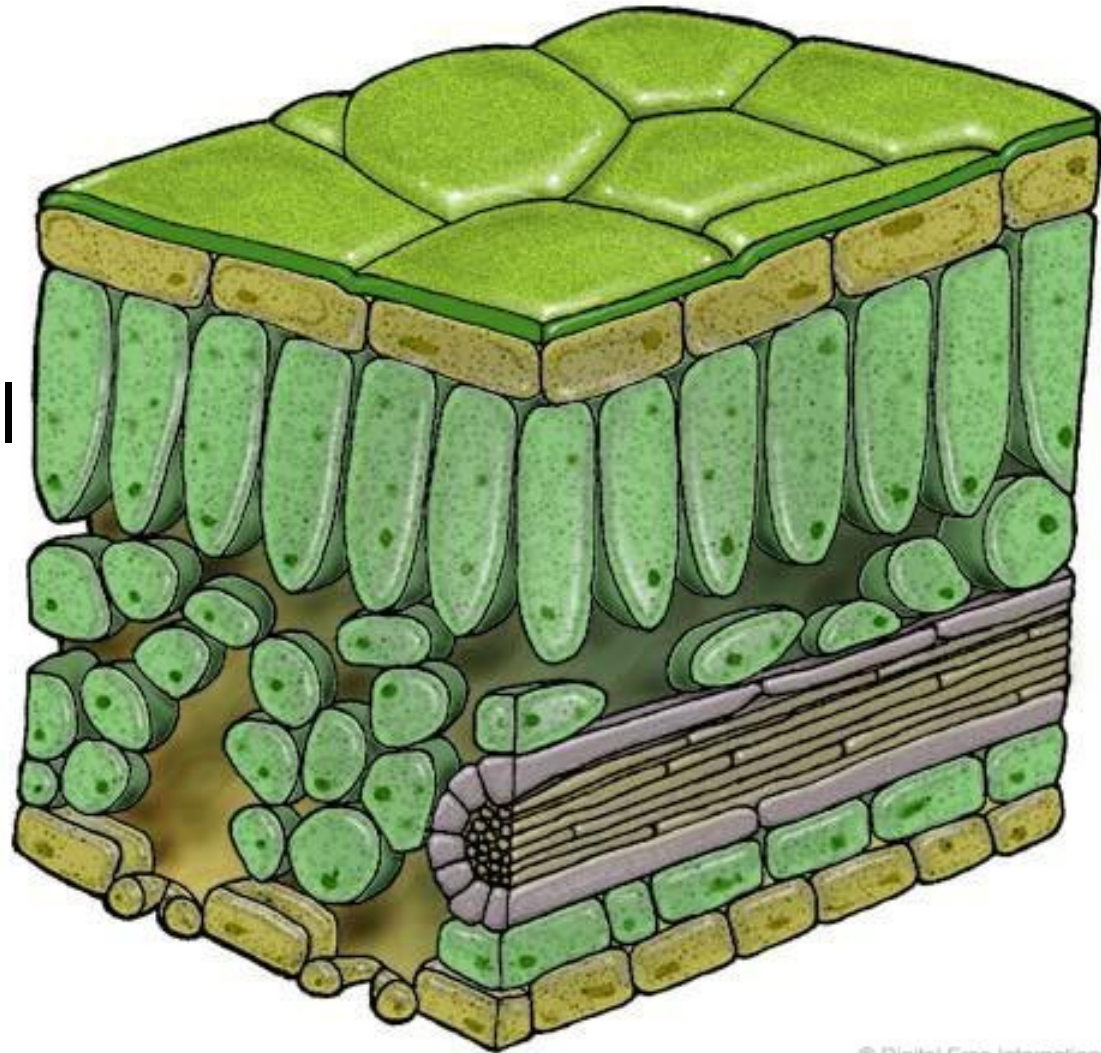




# Review: Leaf Structure

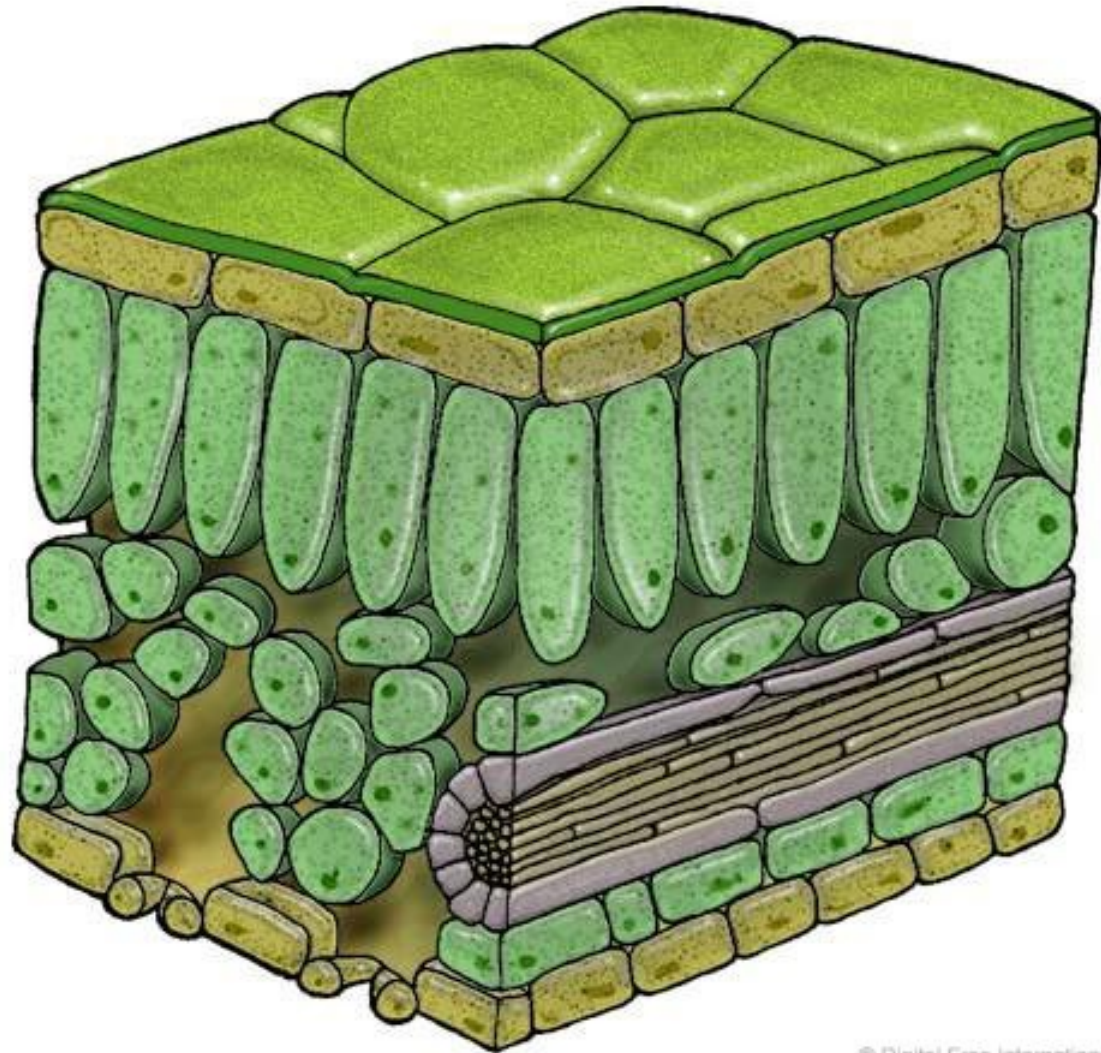
Identify:

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



# Review: Leaf Structure

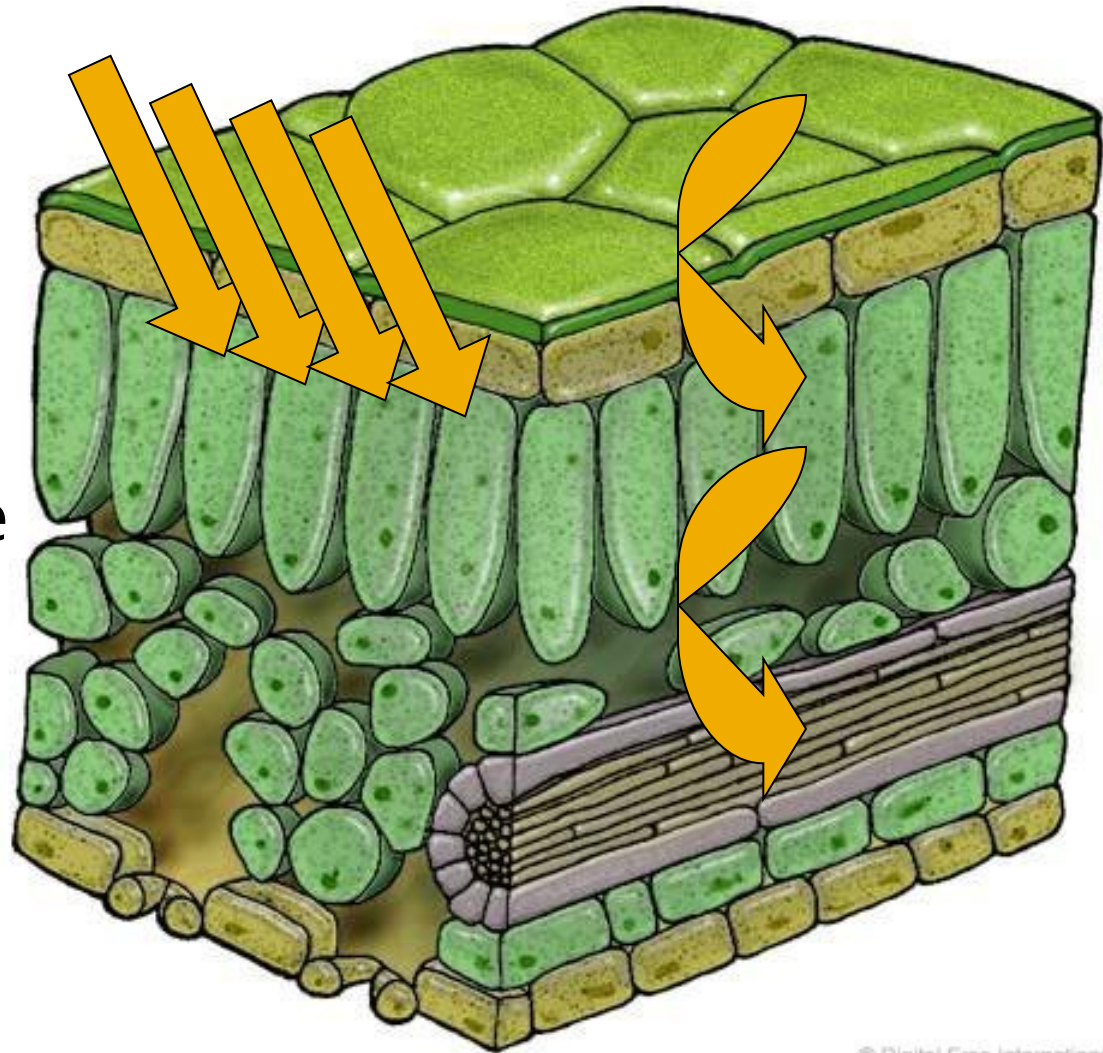
- Which leaf structure perform each of these functions?
  - Prevent water loss and gas exchange
  - Regulates gas exchange
  - Transports water and nutrients
  - Mainly photosynthesis (contains the most chloroplast)



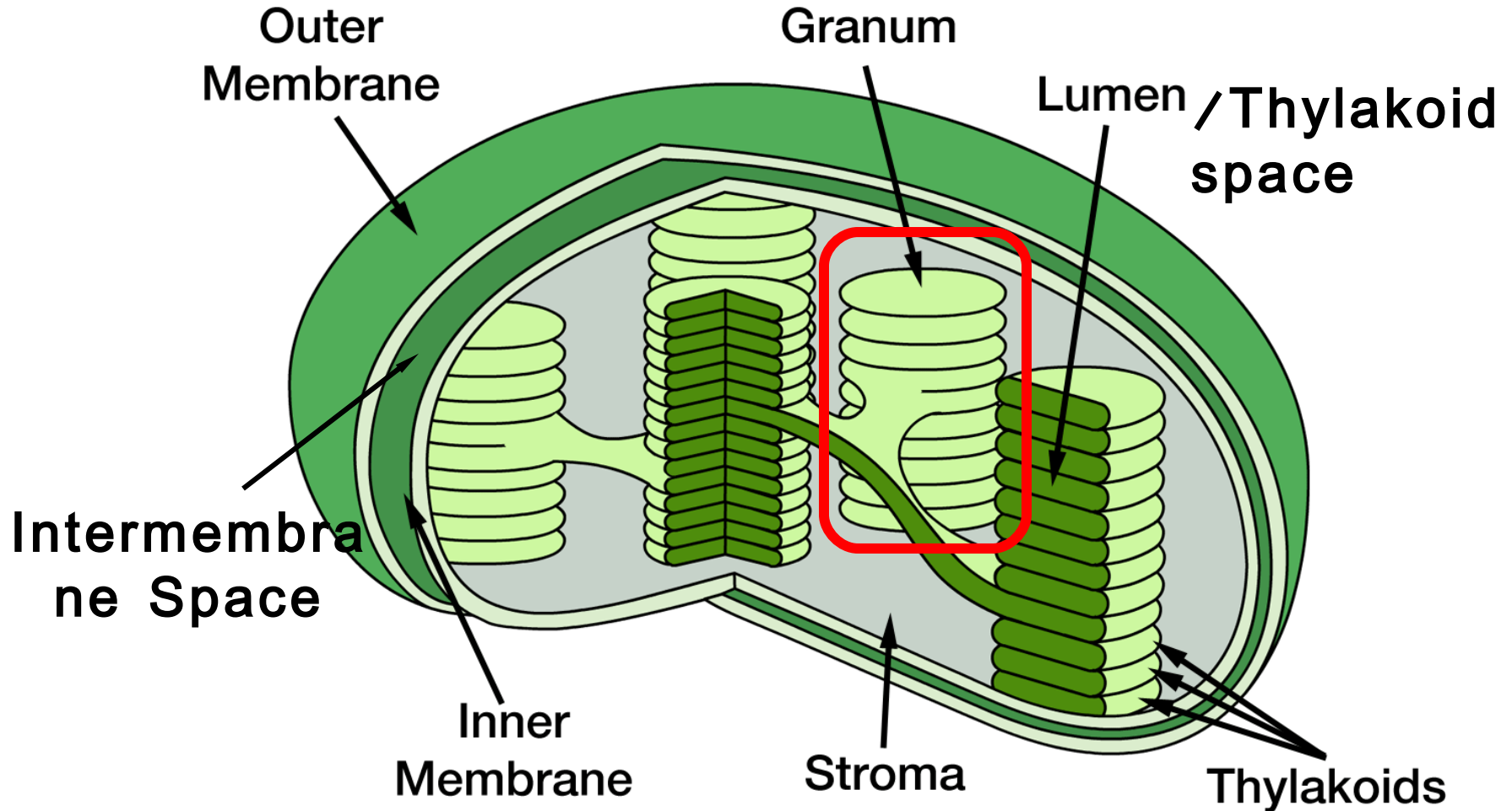


# Review: Leaf Structure

- 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

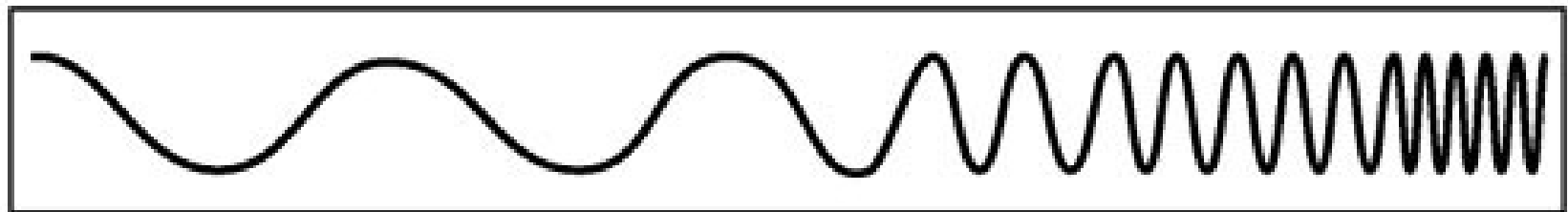
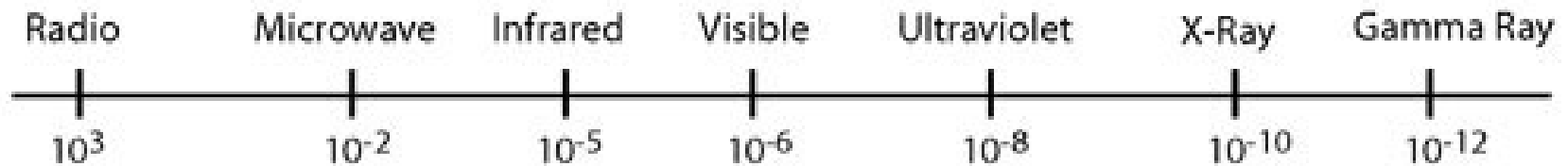


# Review: Chloroplast Structure

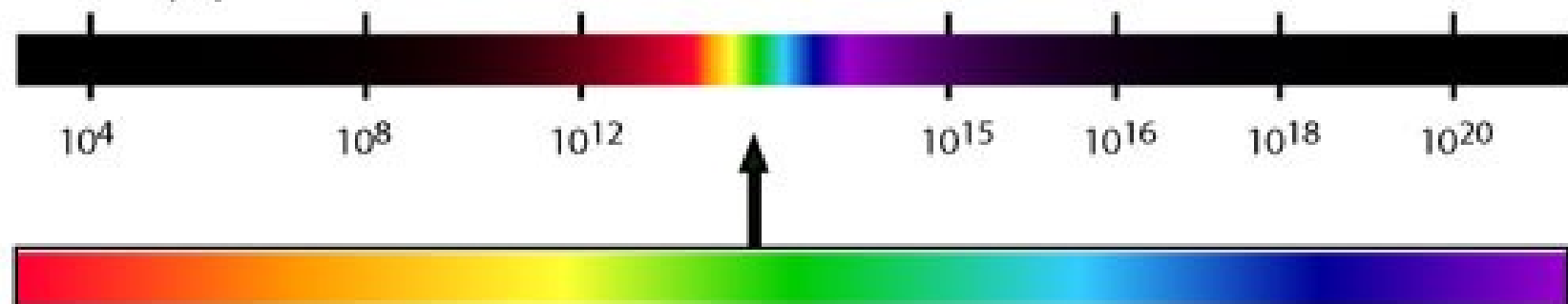


# Nature of Light

Wavelength  
(metres)



Frequency  
(Hz)

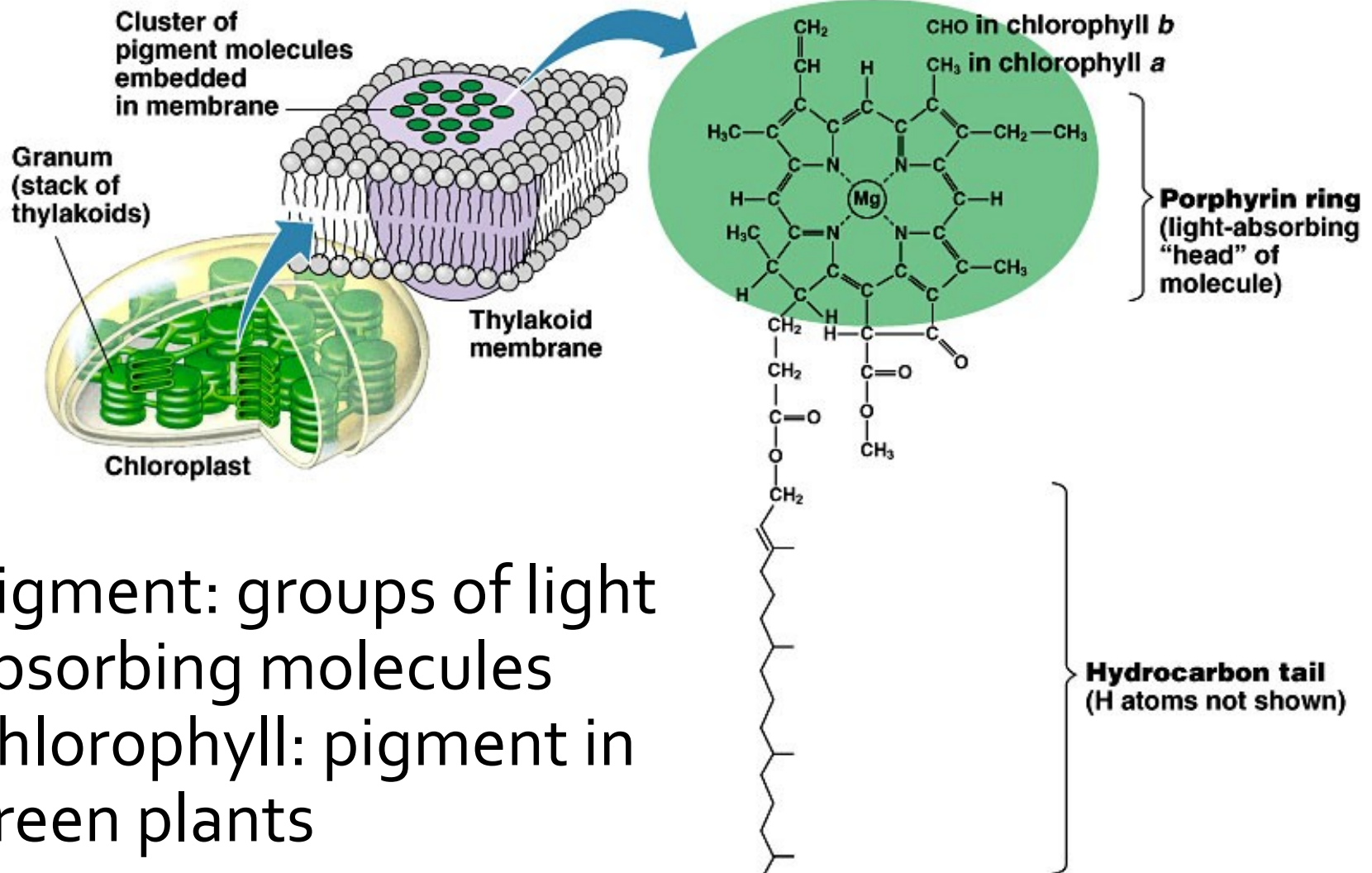


# Nature of Light

---

- 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

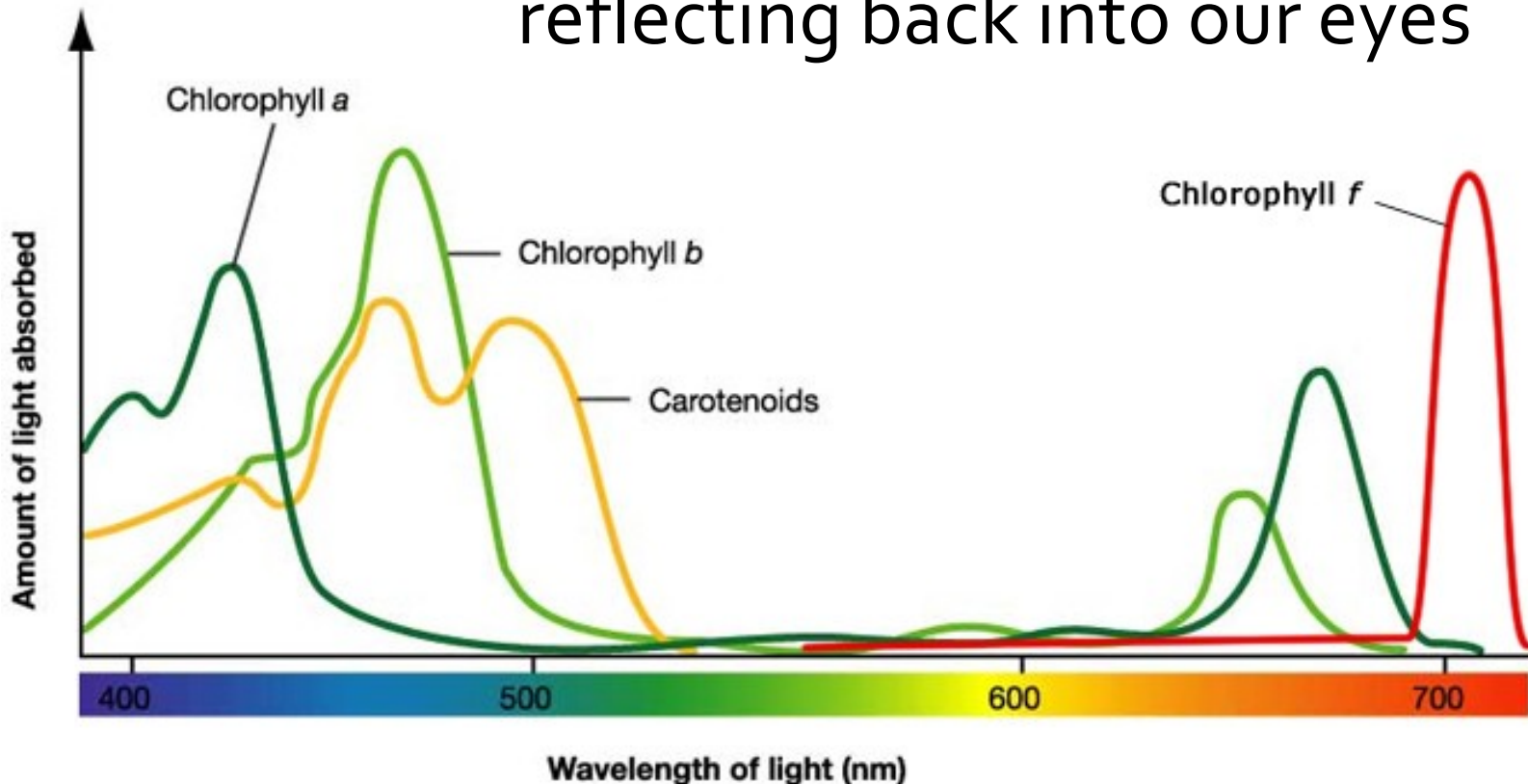


- Pigment: groups of light absorbing molecules
- Chlorophyll: pigment in green plants



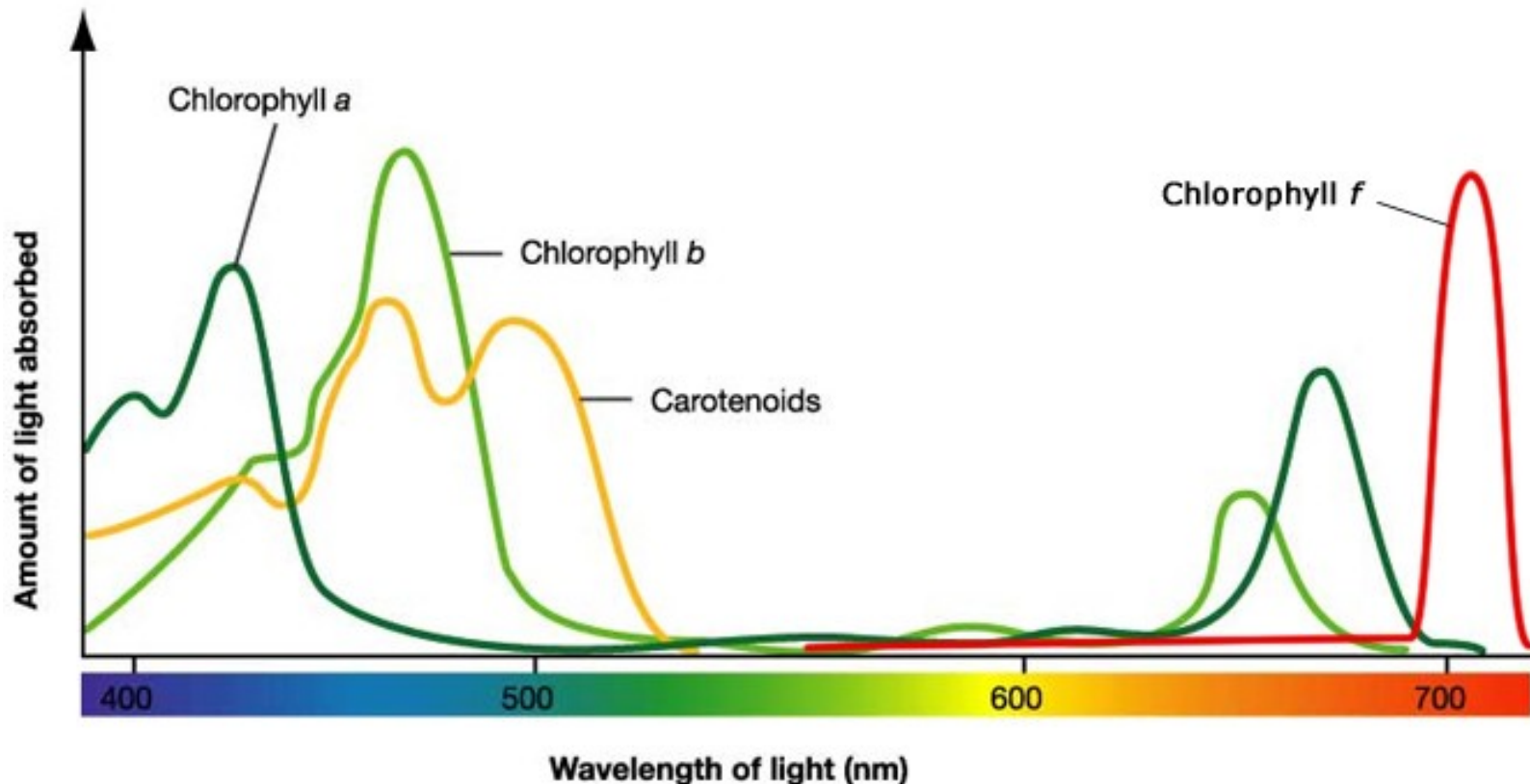
# Absorption Spectrum

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



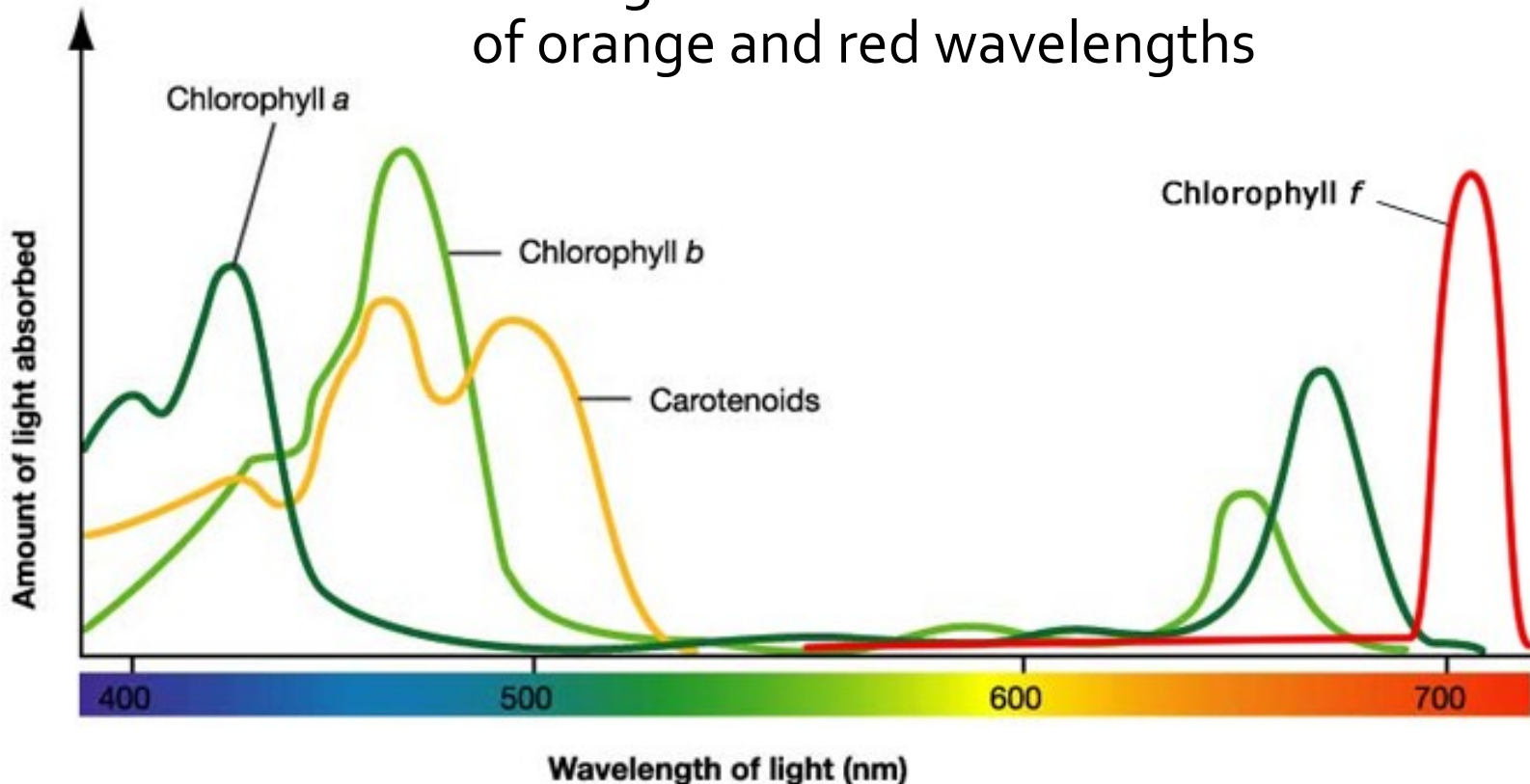
# Absorption Spectrum

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



# Absorption Spectrum

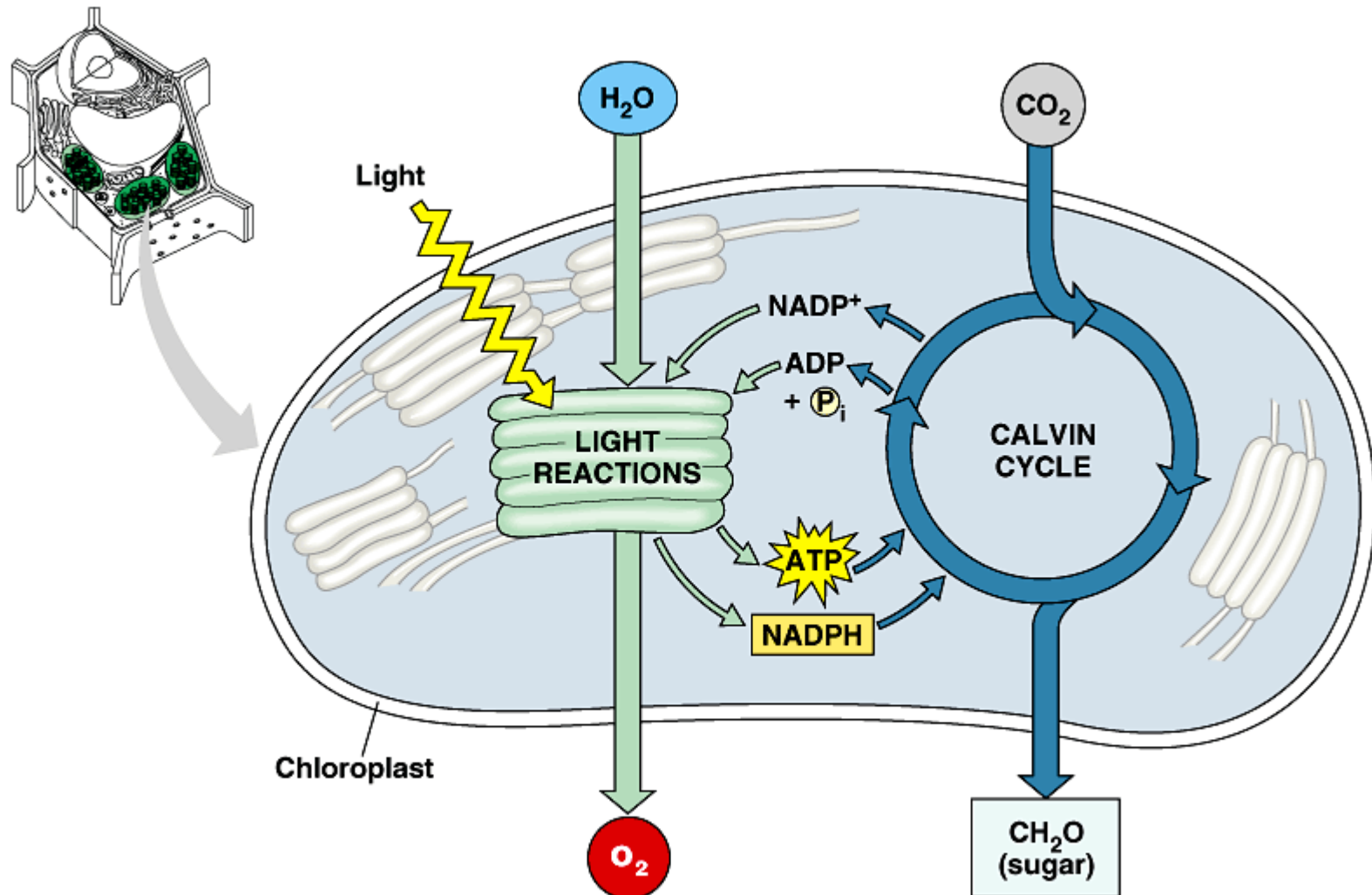
- Carotenoids are pigments that absorb mainly blue and green reflecting back orange and red
- In the fall chlorophyll pigments breakdown first leaving carotenoids which allow the reflection of orange and red wavelengths



# 2 Stages of Photosynthesis

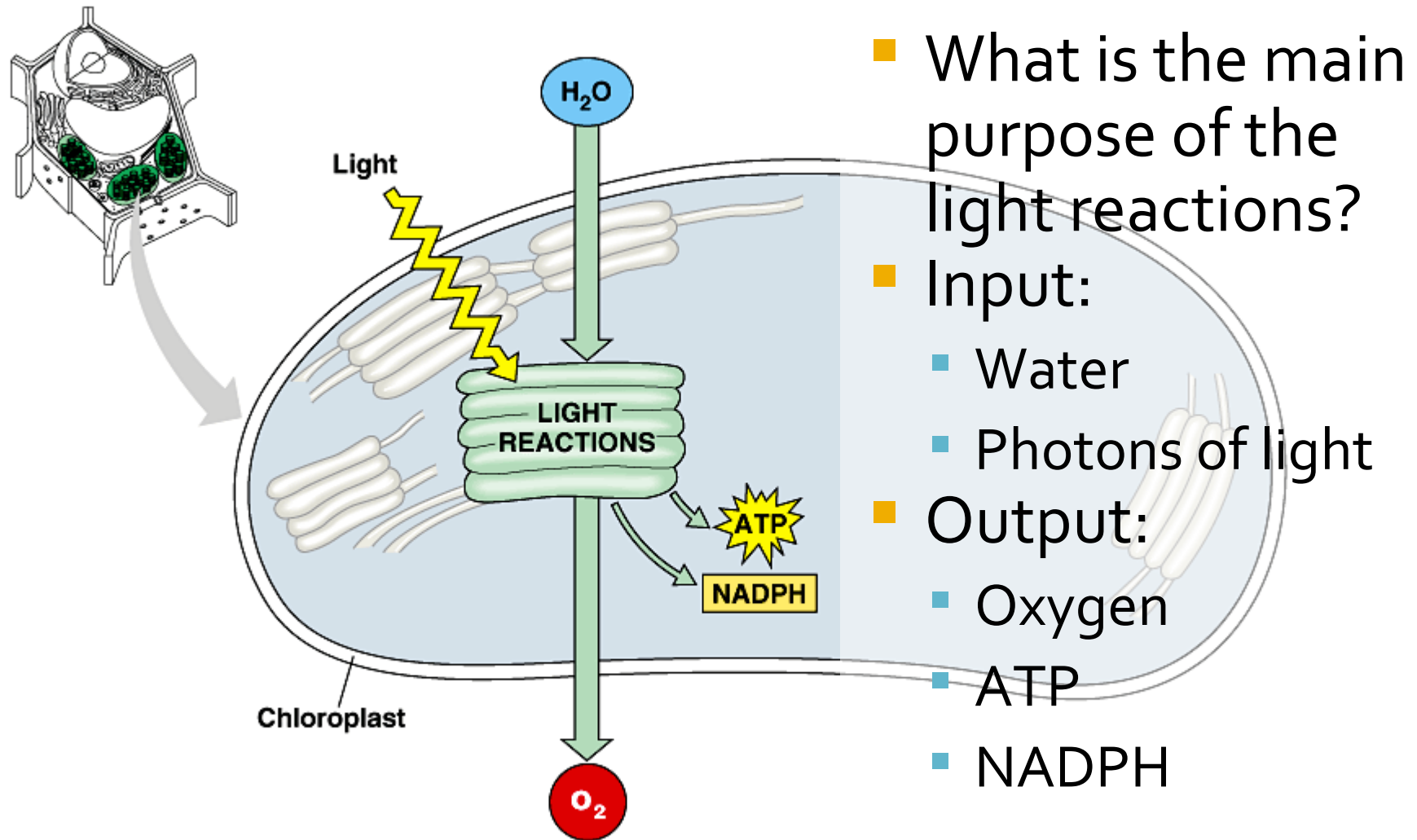
- “Photo” stage:
  - light dependent reactions
  - Energy fixing reactions
  - Convert light energy to make ATP & NADPH which will be used to drive the next stage
- “Synthesis” stage:
  - “dark” / light-independent reactions, Calvin cycle
  - Carbon fixing reactions
  - Uses ATP to convert inorganic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

# 2 Stages of Photosynthesis





# Light Reaction Purpose

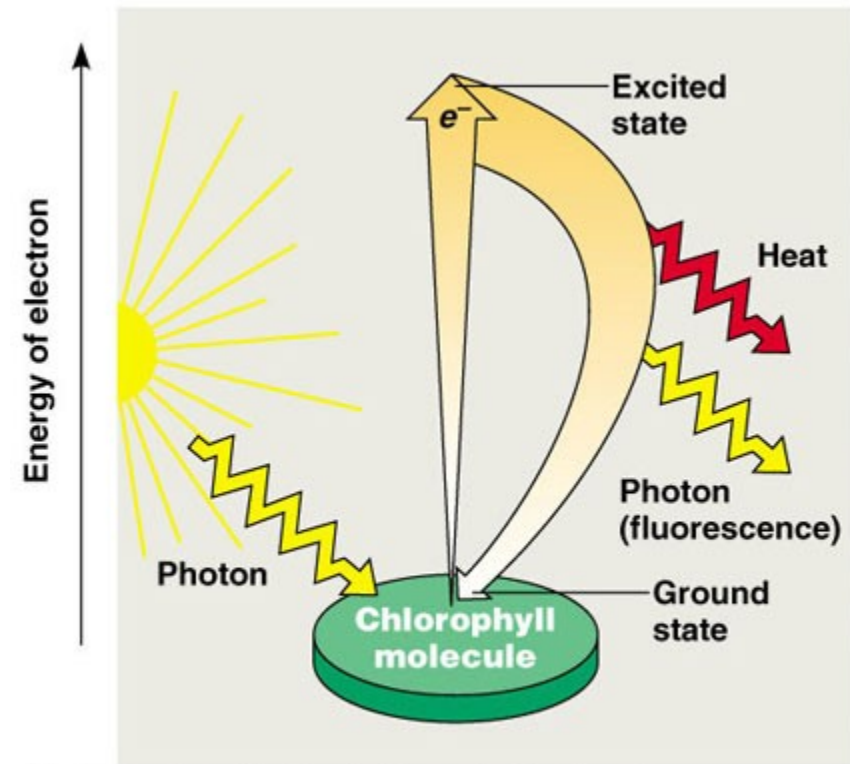


# 3 Parts to Light Reactions

- 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

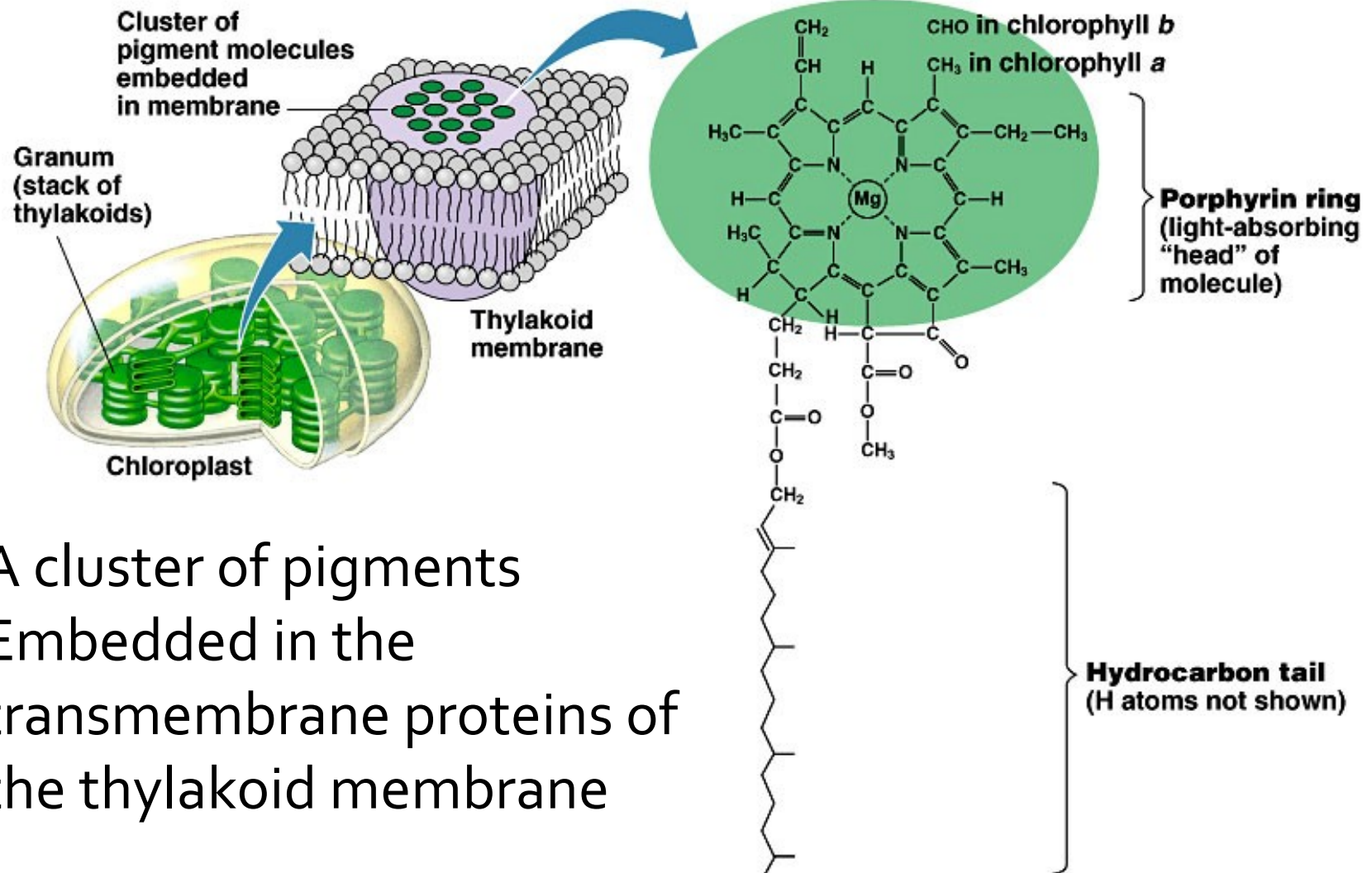
- When atoms absorb energy from the sun, electrons gain energy becoming excited
- Excited electrons will fall back to ground state if it isn't transferred to an electron acceptor



(a) Excitation of isolated chlorophyll molecule

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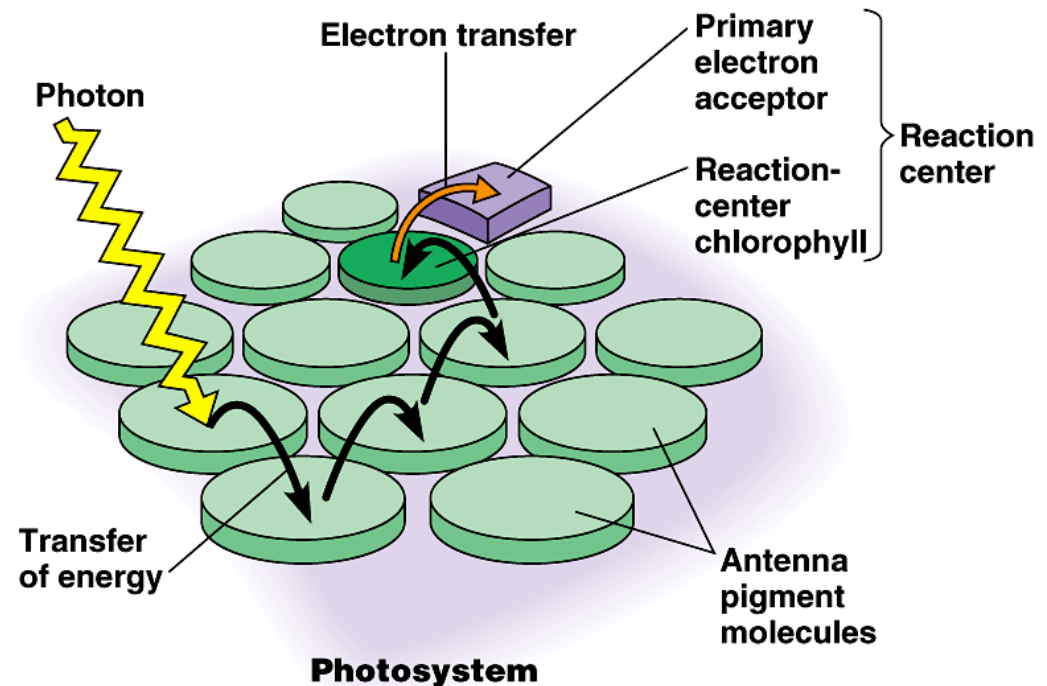
# Photosystems



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

# Photosystem Structure

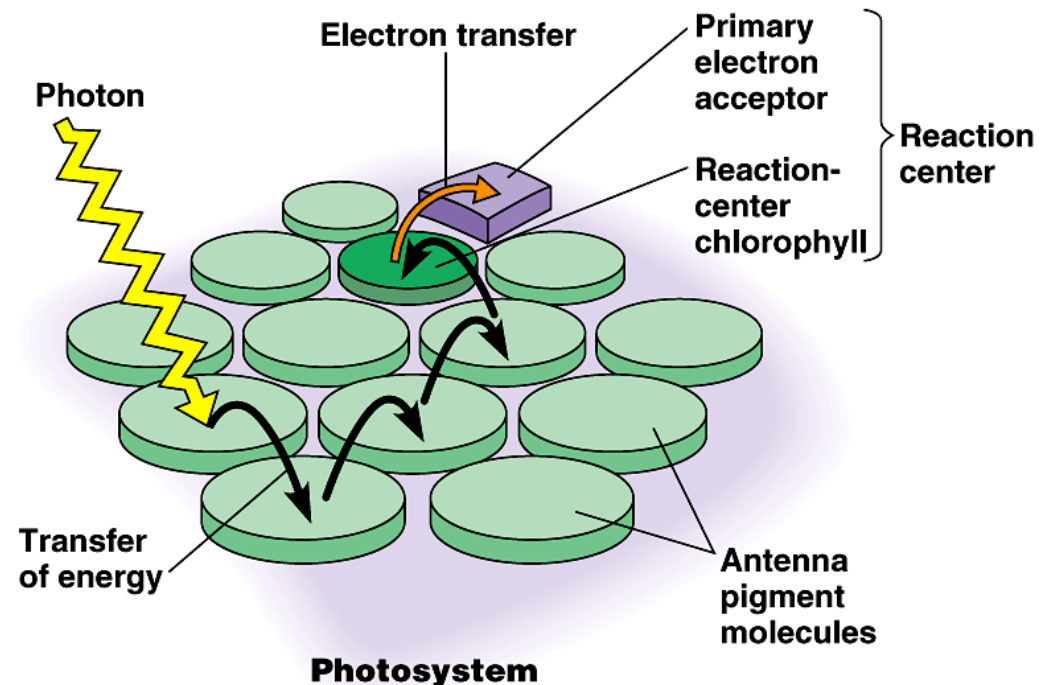
- Consists of a few hundred pigment molecules
- Reaction centre contains a chlorophyll a that is located next to a primary electron acceptor





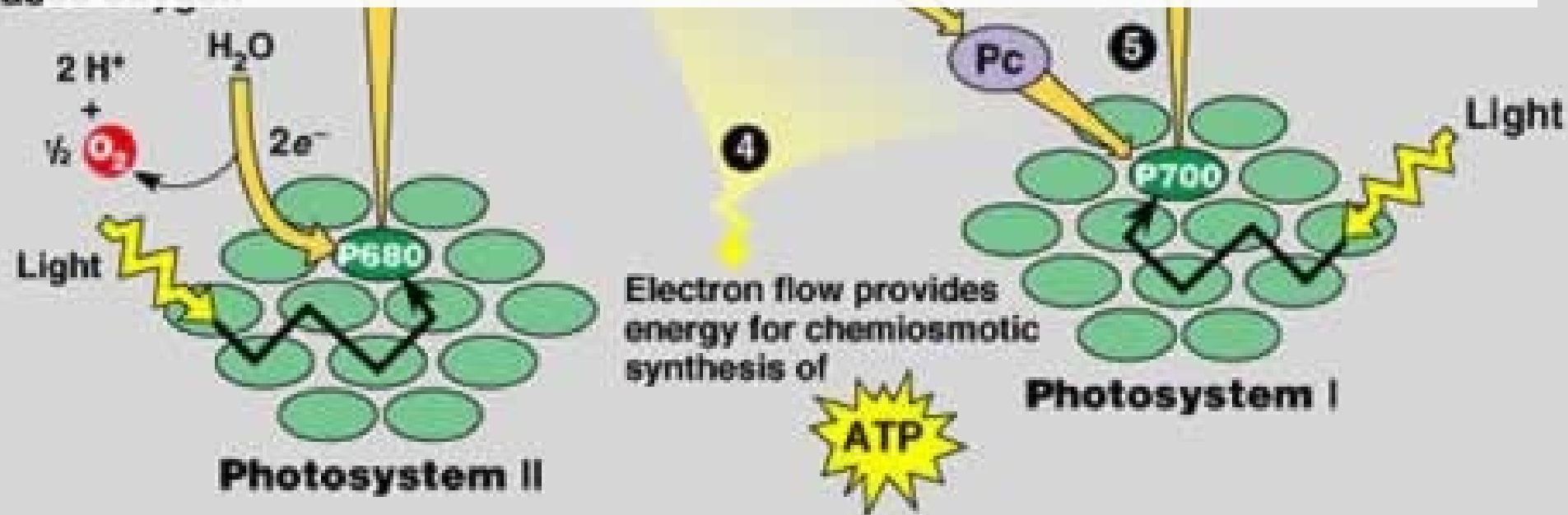
# Photosystem Mechanism

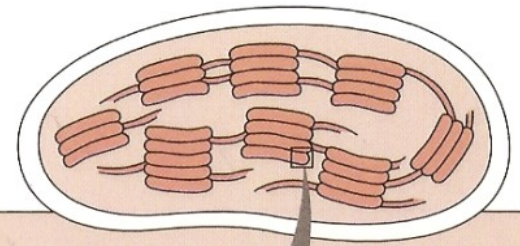
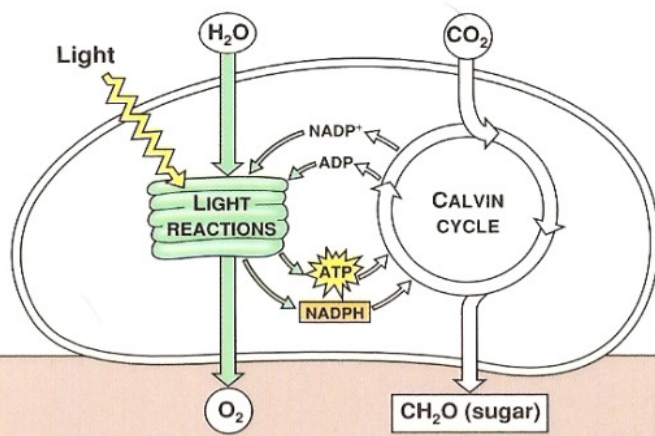
- Light excites an electron on the reaction-centre chlorophyll a
- Primary electron acceptor traps the high energy electron before it can return to ground state



# 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





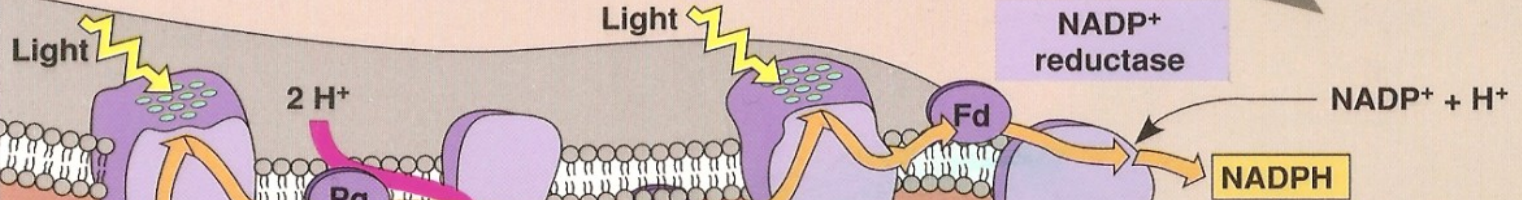
**STROMA**

**Photosystem II**

**Cytochrome complex**

**Photosystem I**

**THYLAKOID MEMBRANE**

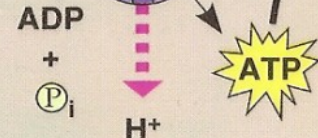


**THYLAKOID SPACE**

**To Calvin cycle**

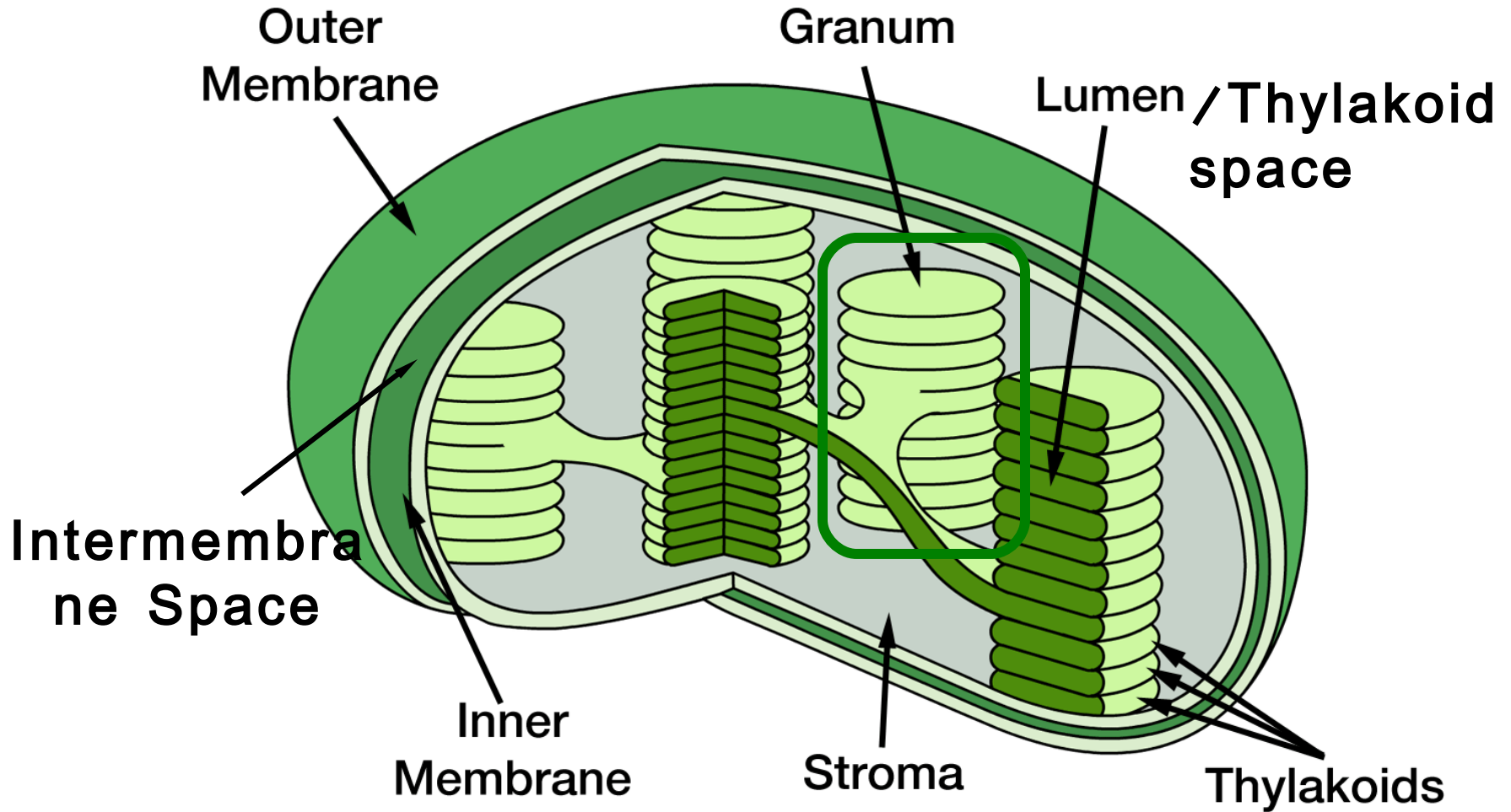
**STROMA**

**ATP synthase**

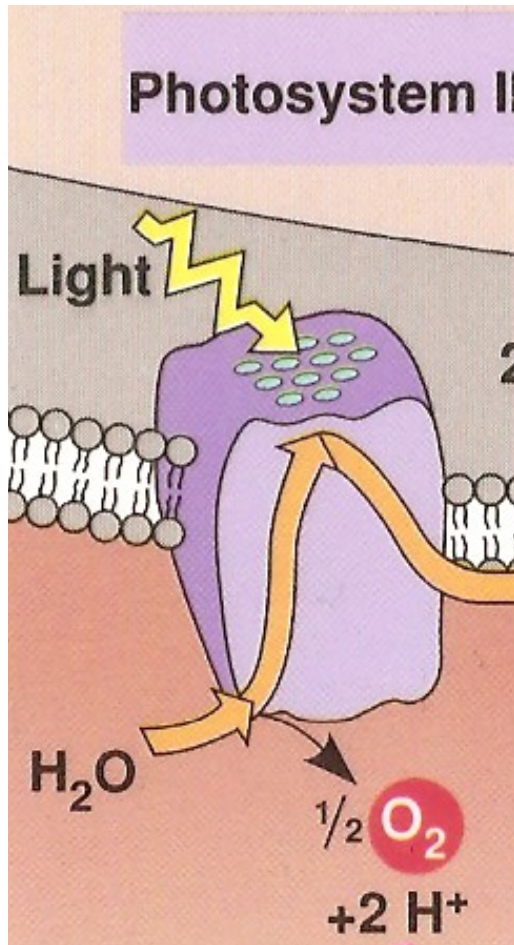




# Review: Chloroplast Structure

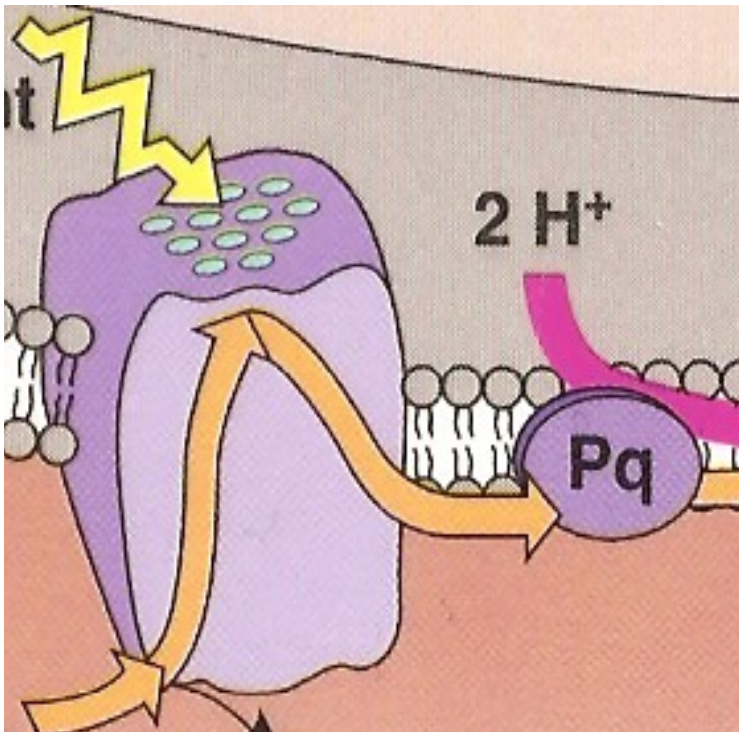


# Thylakoid Proteins: PSII (P680)



- 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

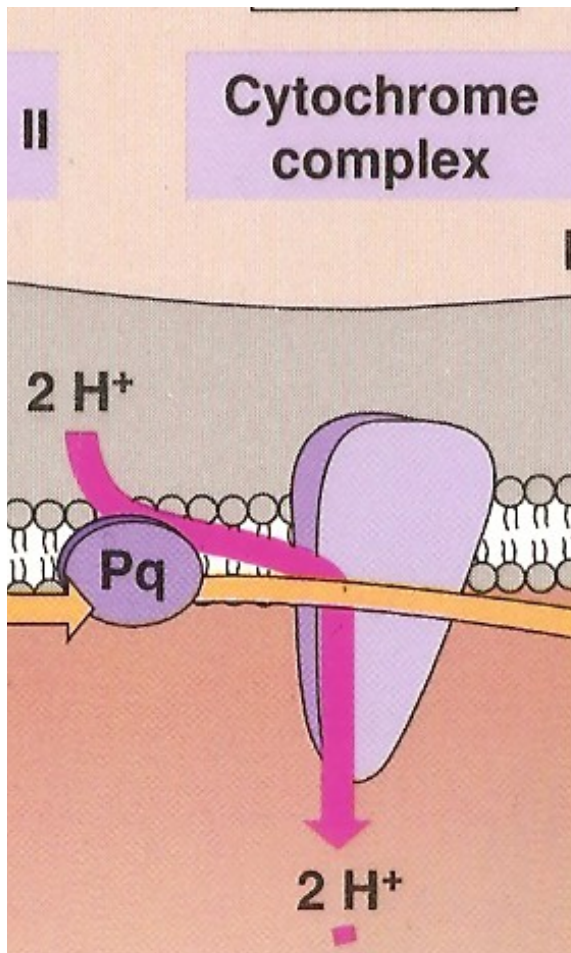
# Thylakoid Proteins: Pq



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

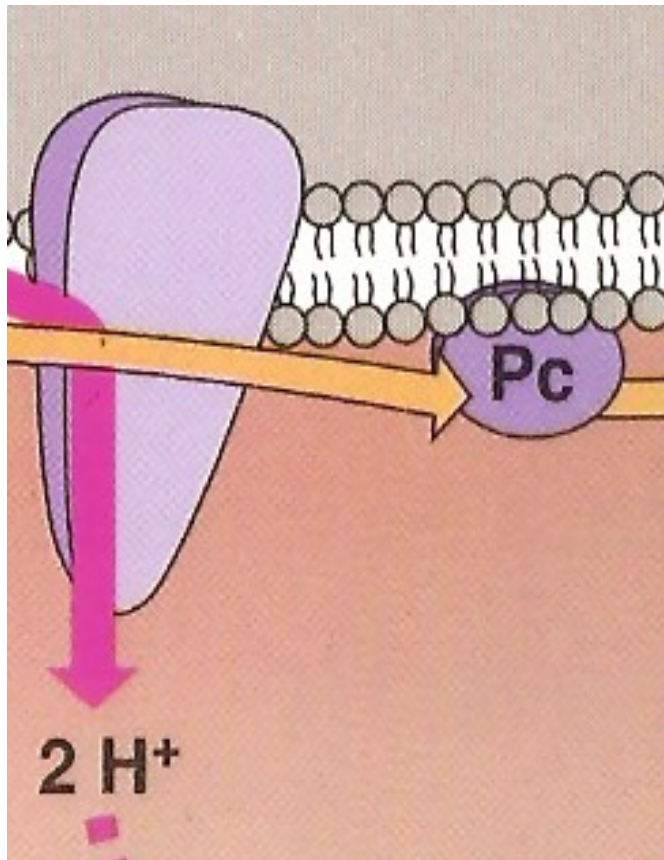


# Thylakoid Proteins: Cytochrome Complex



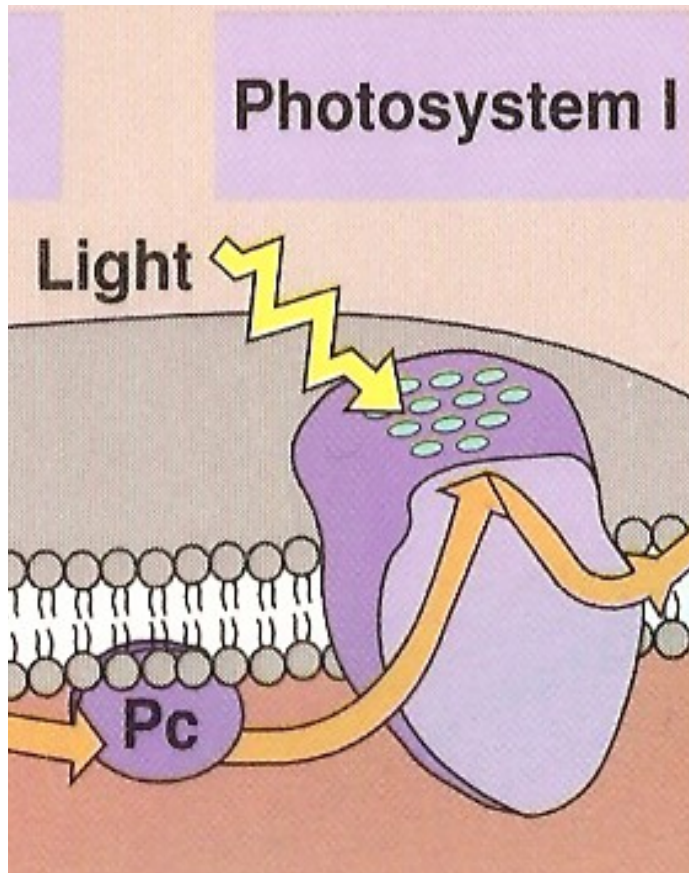
- Electrons are transferred from Pq to cytochrome complex
- protons are pumped against its concentration gradient from stroma across thylakoid membrane to the lumen

# Thylakoid Proteins: Pc



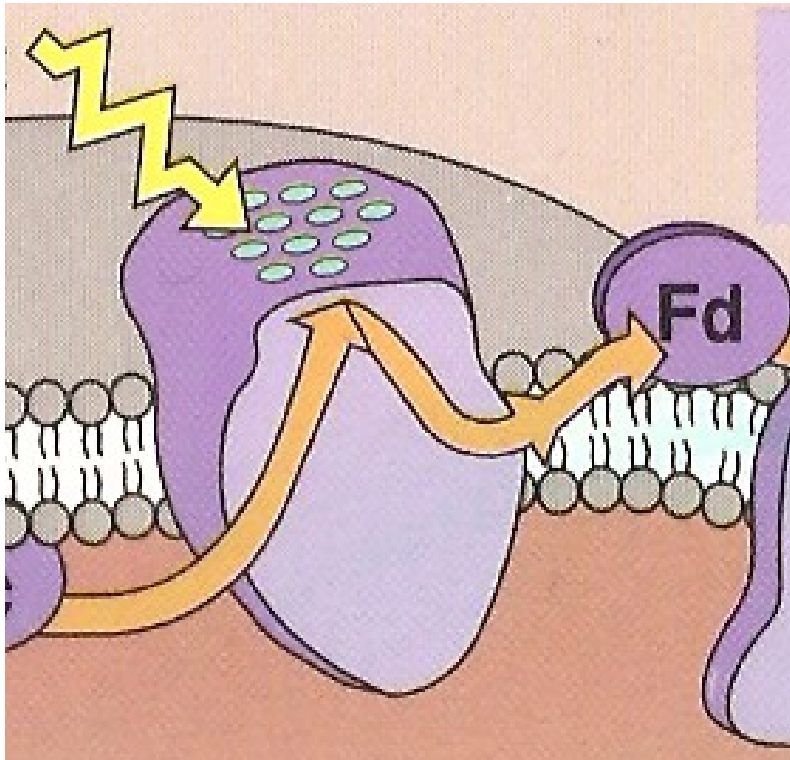
- Electrons are transferred to plastocyanin (Pc)
- Pc is a movable component on lumen side of the thylakoid membrane

# Thylakoid Proteins: PSI (P700)



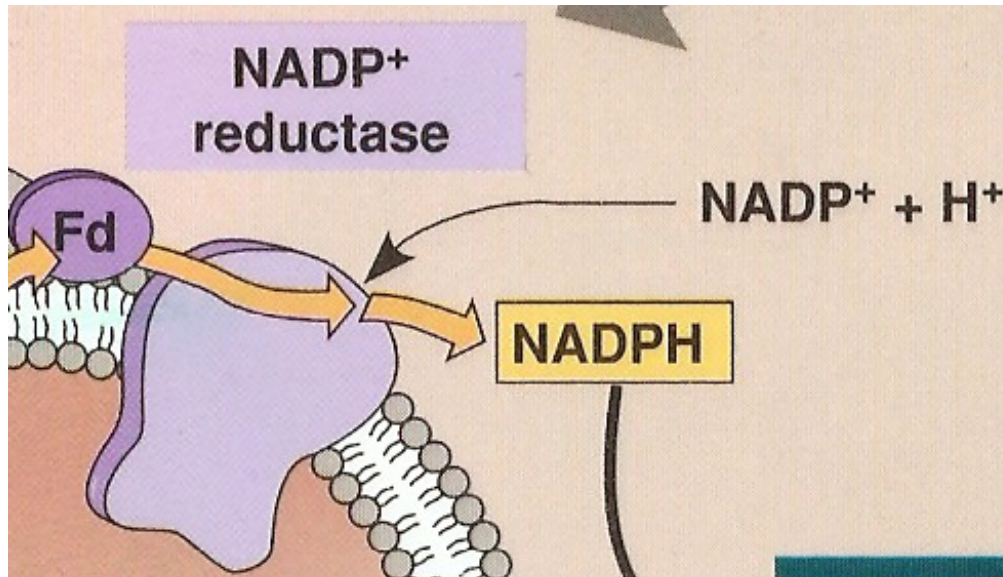
- Electrons on P700 is excited by light and captured by the primary electron acceptor leaving P700 oxidized
- Electrons transferred from Pc to P700 replaces the electrons that were lost

# Thylakoid Proteins: Fd



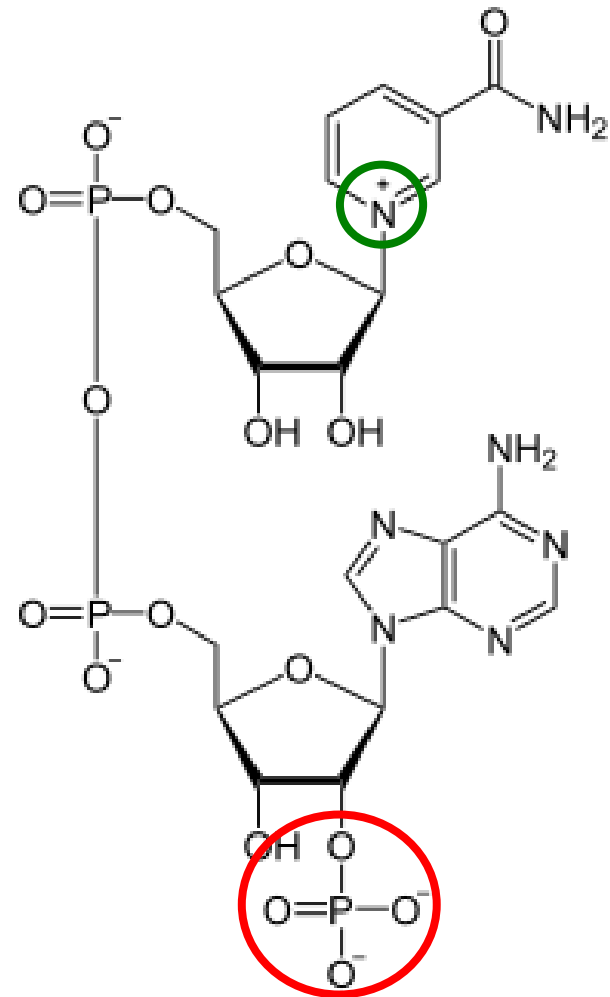
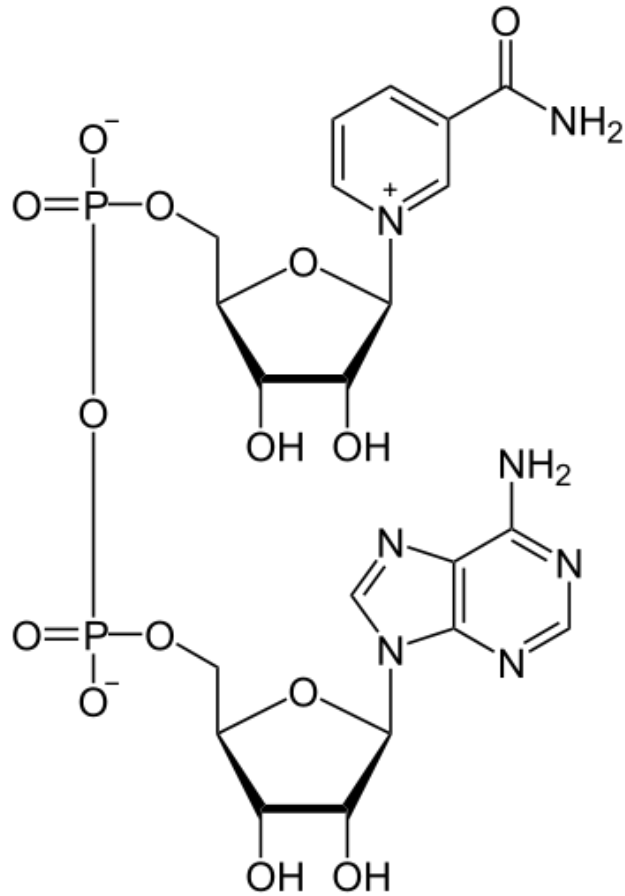
- Electrons undergo a second transport chain
- Electrons are transferred to ferredoxin (Fd)
- Fd is an iron containing mobile component on the stromal side of the thylakoid membrane

# Thylakoid Protein: NADP<sup>+</sup> Reductase



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

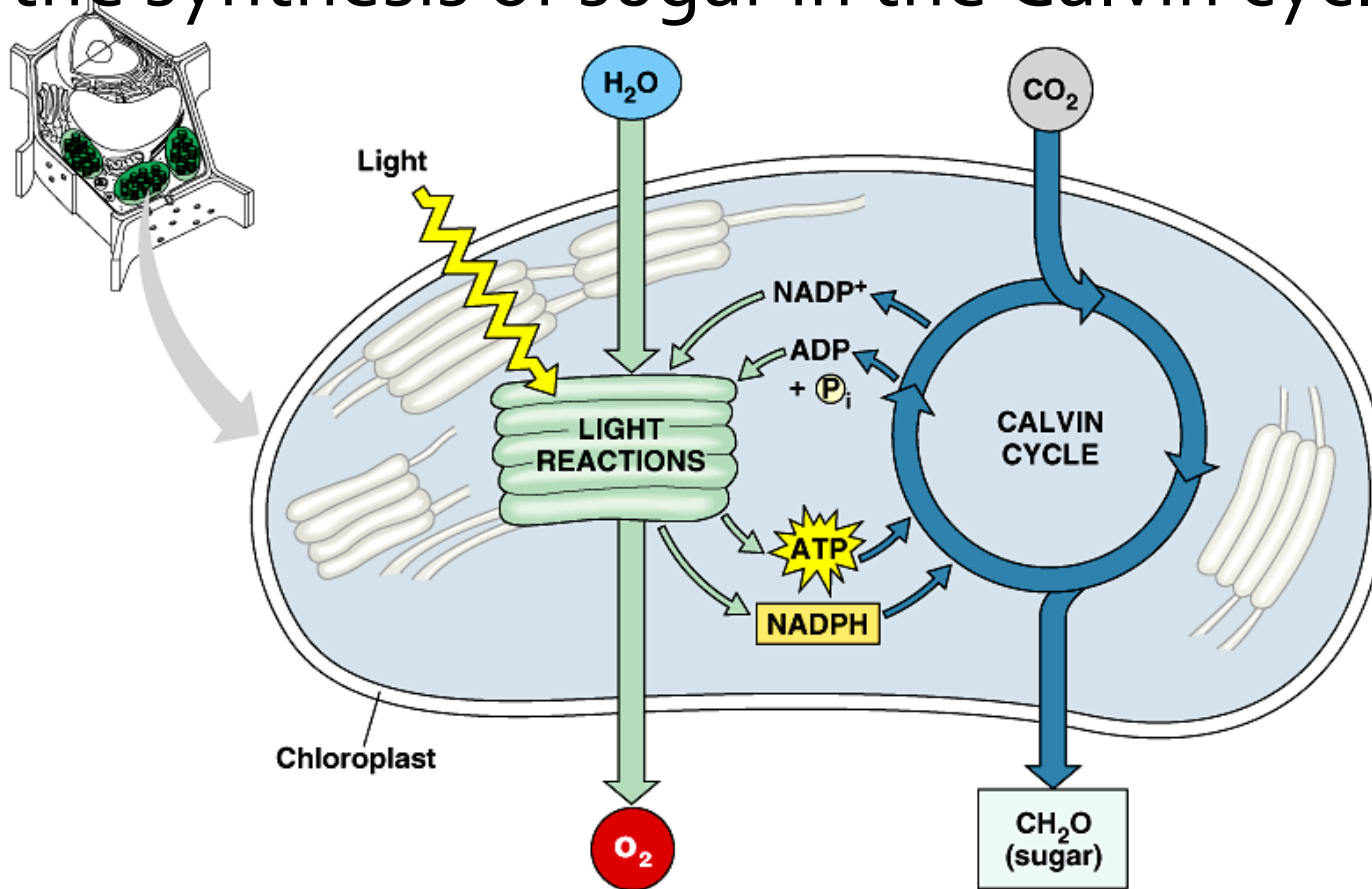
# Compare NAD<sup>+</sup> to NADP<sup>+</sup>



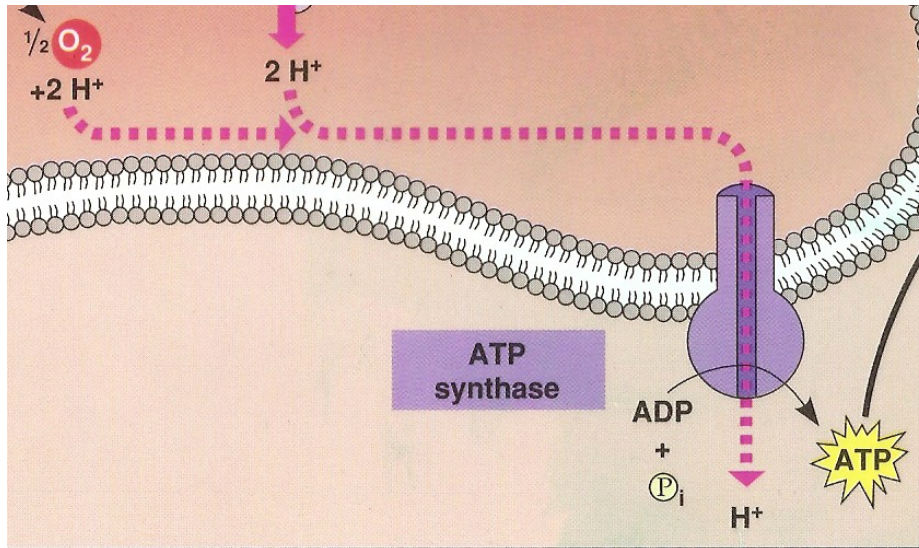


# Purpose of NADPH

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



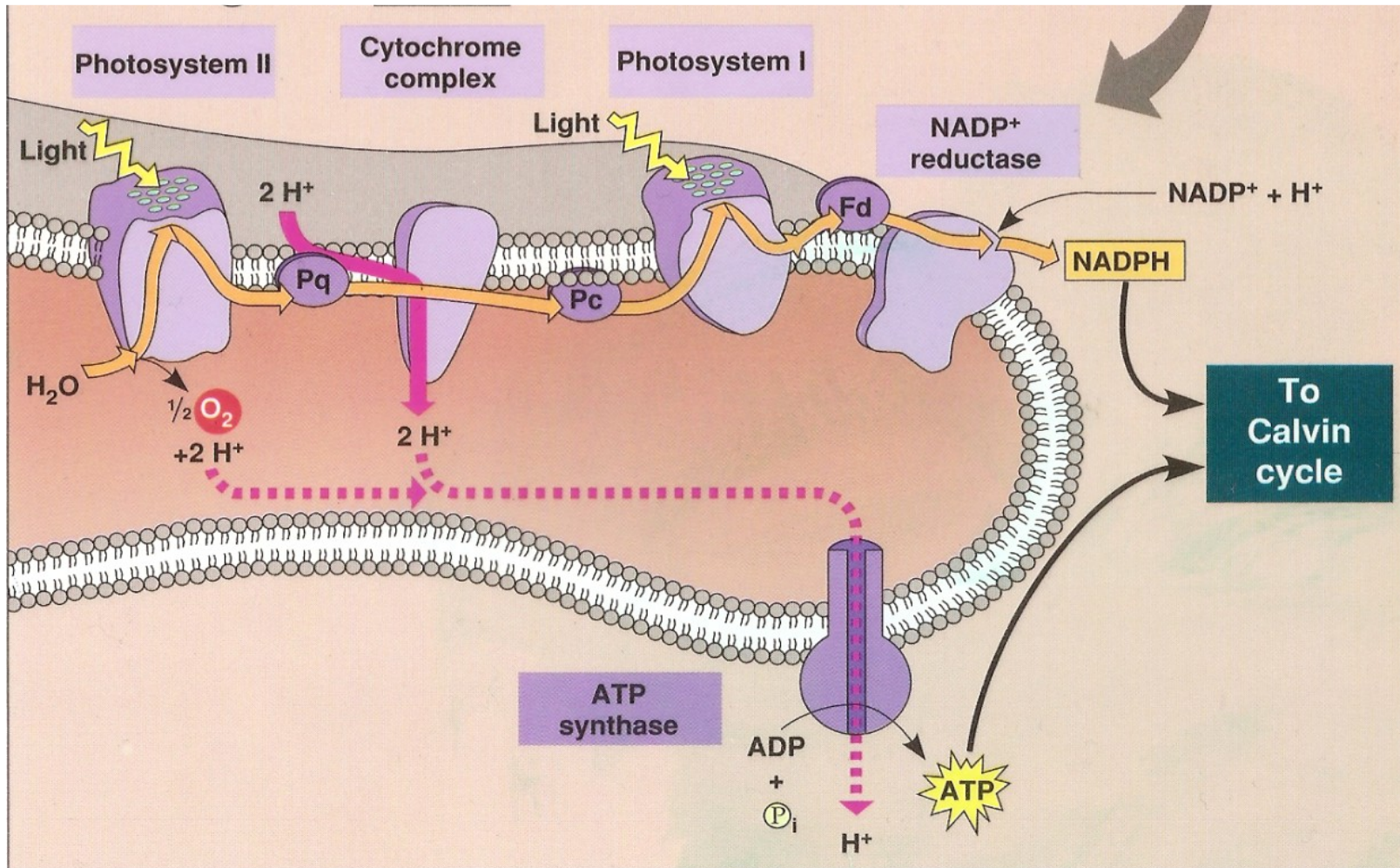
# Thylakoid Proteins: ATP Synthase



- 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

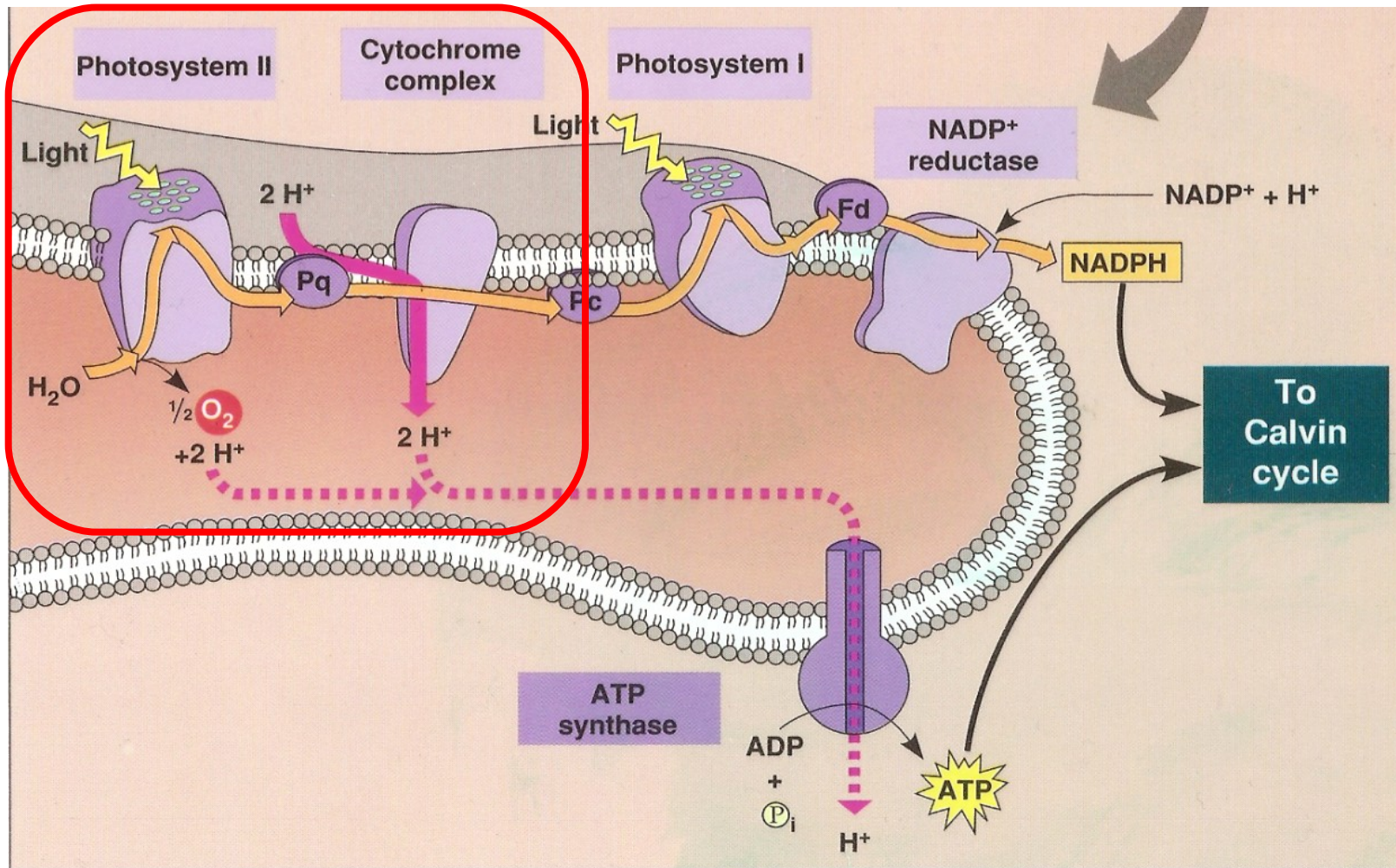
- light-dependent formation of ATP by chemiosmosis





# Photophosphorylation

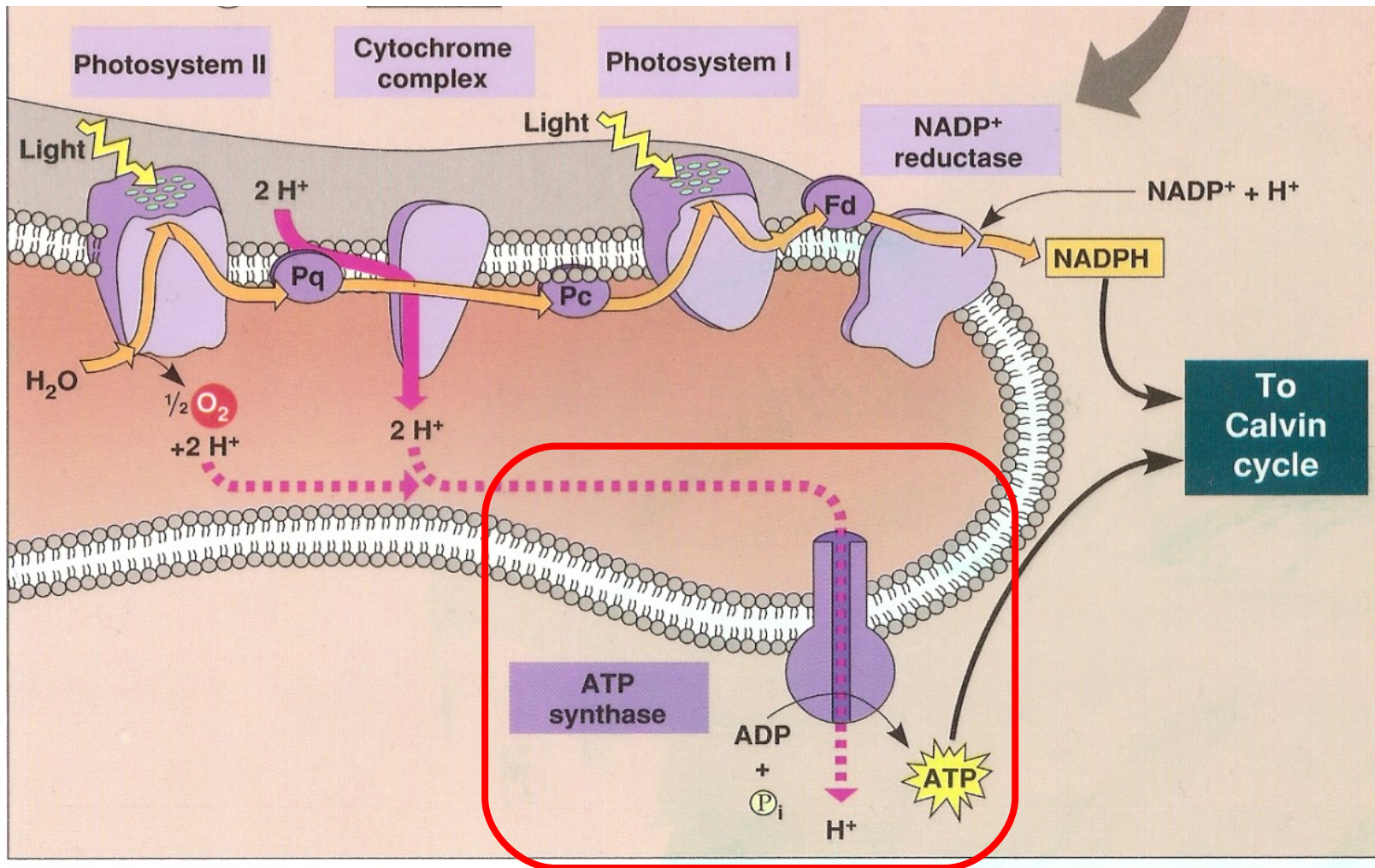
- ETC provides energy for photosystems to pump  $H^+$  from stroma to lumen





# Photophosphorylation

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



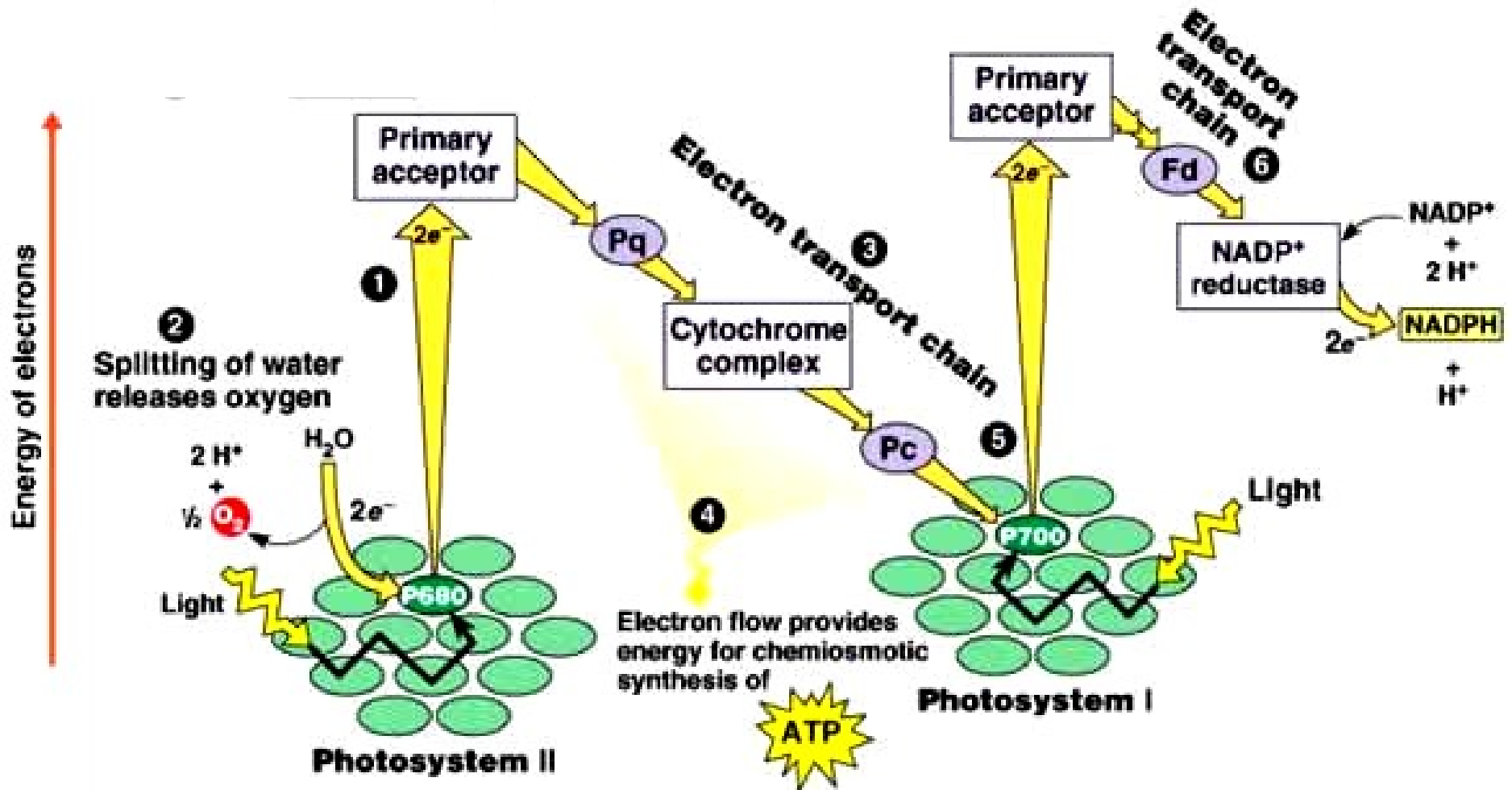
# Types of Electron Transport Mechanisms

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- Non-cyclic electron flow
- Cyclic electron flow



# Non-cyclic Electron Flow: Z-Scheme



# Non-cyclic Electron Transfer Summary

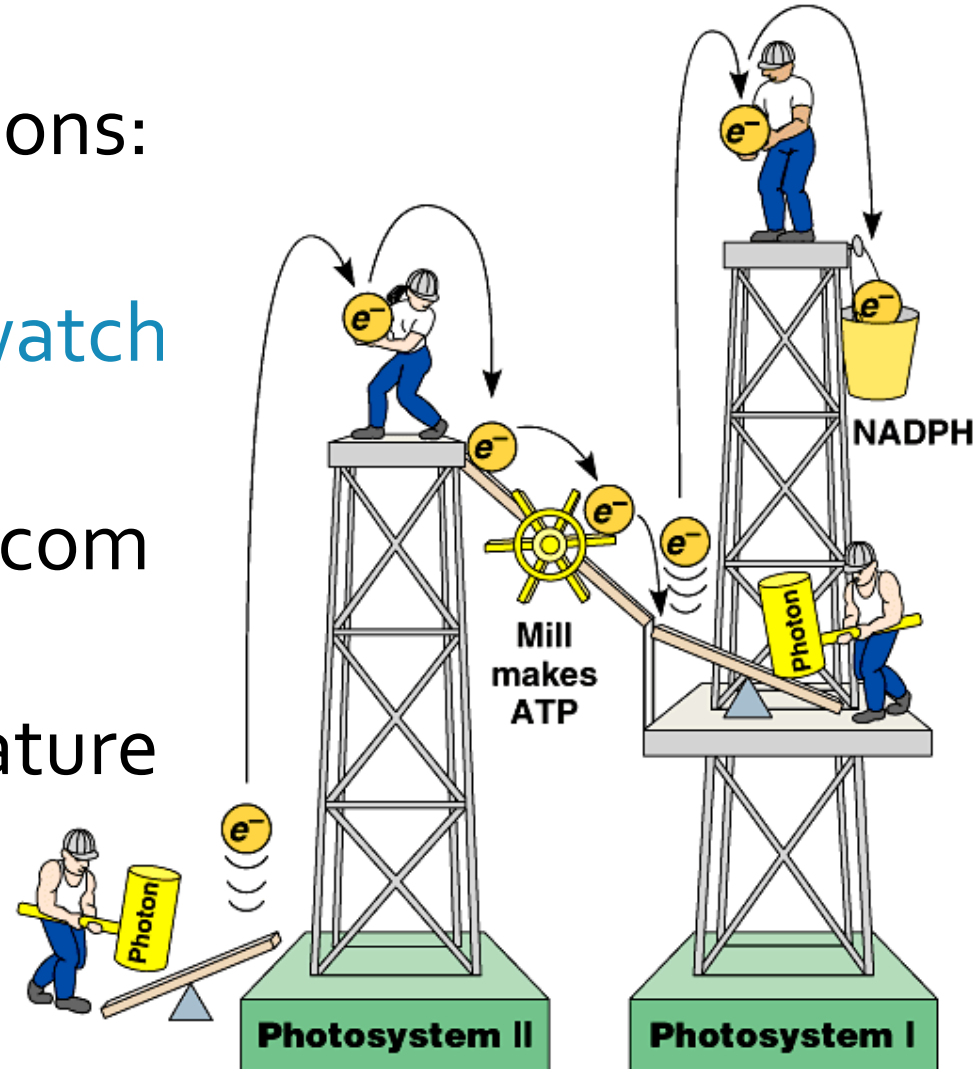
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- H<sub>2</sub>O is split to produce O<sub>2</sub> (released from cell) and H<sup>+</sup> ions (released into lumen)
- Electron transport chain helps establish electrochemical proton gradient
- **Photophosphorylation**: light-dependent formation of ATP by chemiosmosis
- NADP<sup>+</sup> is final electron acceptor and produces NADPH

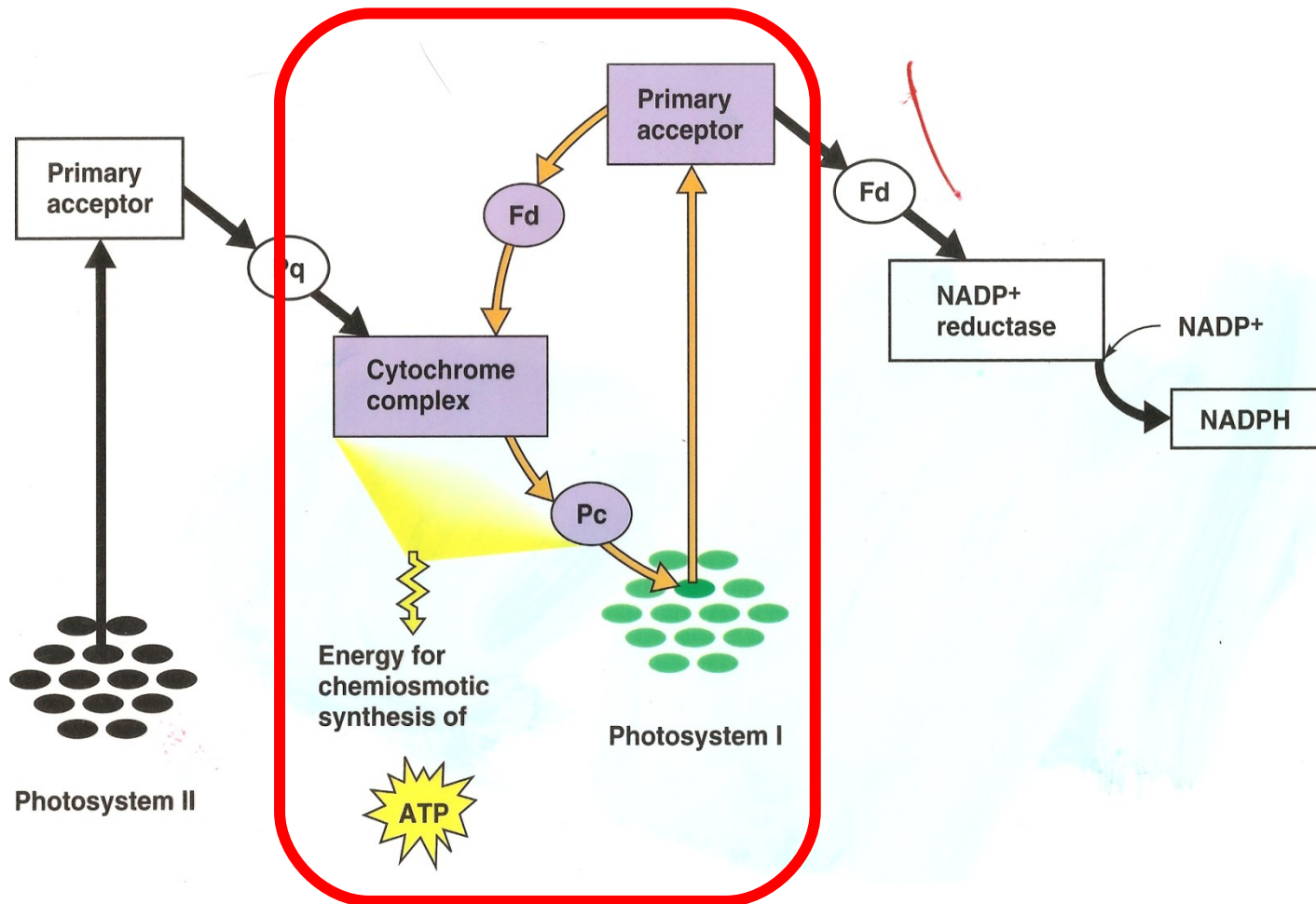
# Noncyclic Electron Flow Analogy

Light Reaction Animations:

- <http://www.youtube.com/watch?v=v59oJJVg6lc>
- [http://www.youtube.com/watch?v=hj\\_WKgnL6MI&feature=related](http://www.youtube.com/watch?v=hj_WKgnL6MI&feature=related)



# Cyclic Electron Flow

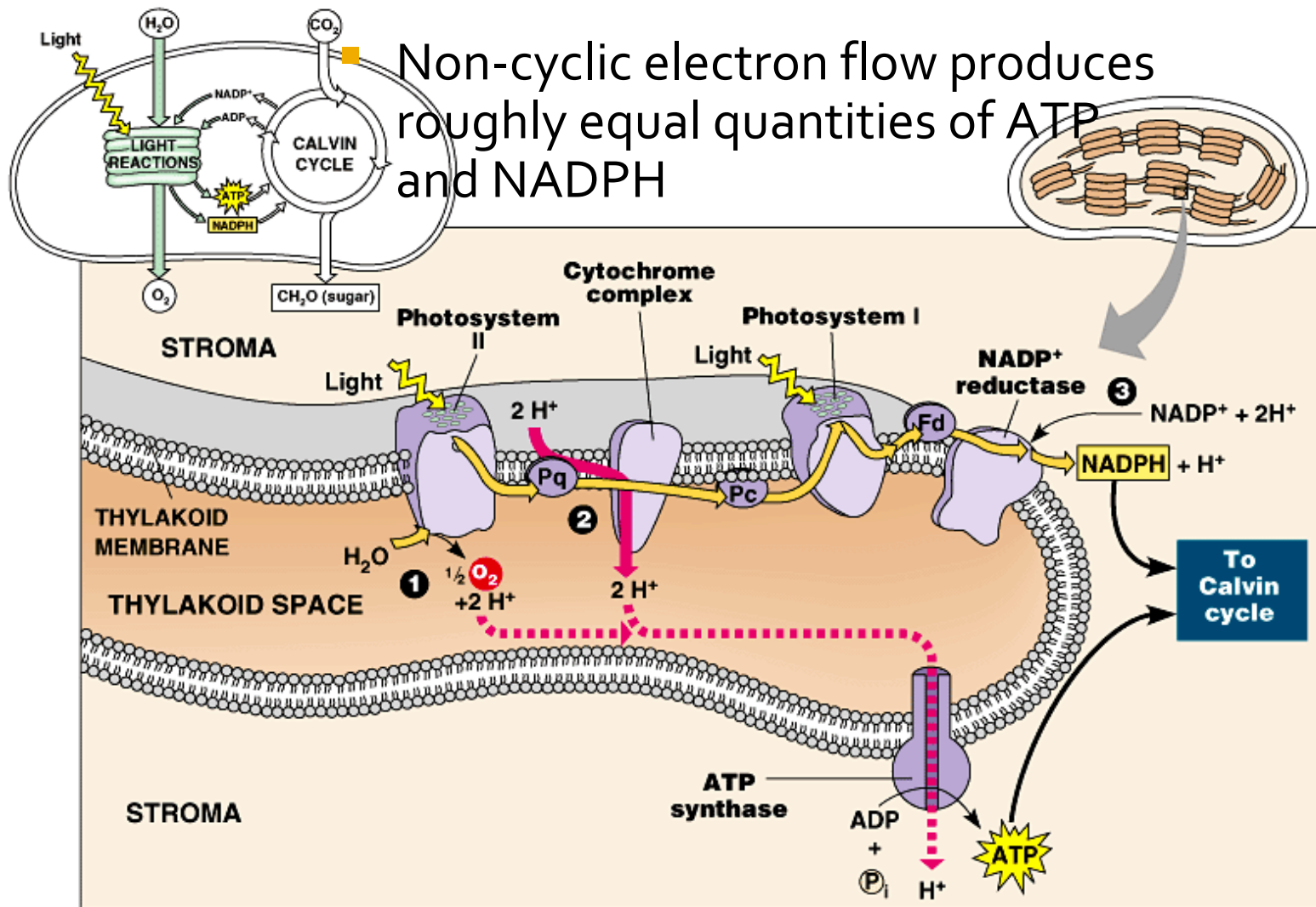


# Cyclic Electron Transfer Summary

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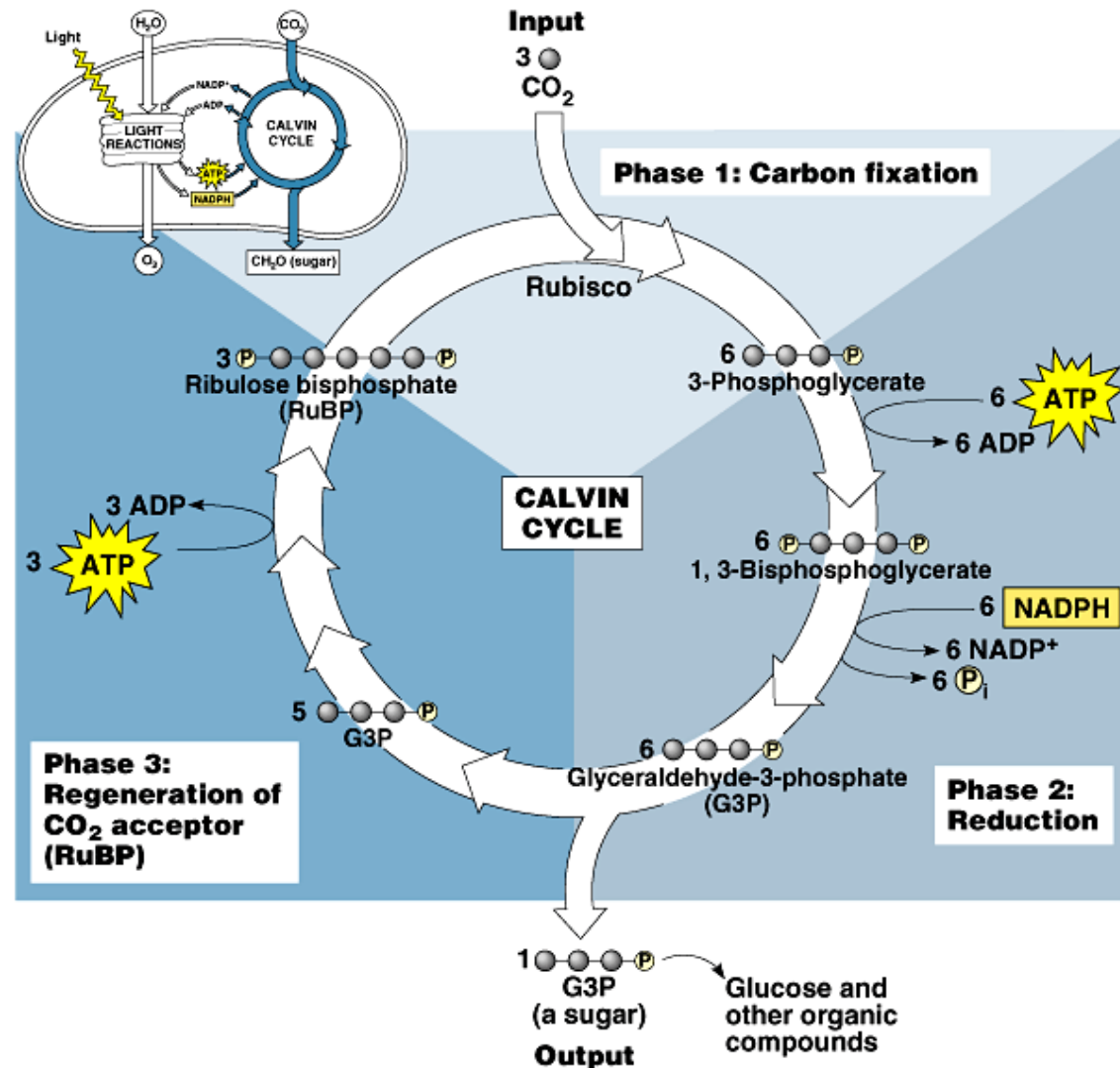
- only involves photosystem I (P700)
- ferredoxin returns electrons back to cytochrome complex
- protons pumped into lumen to produce more ATP through chemiosmosis
- no NADPH produced

# Purpose of Cyclic Electron Flow



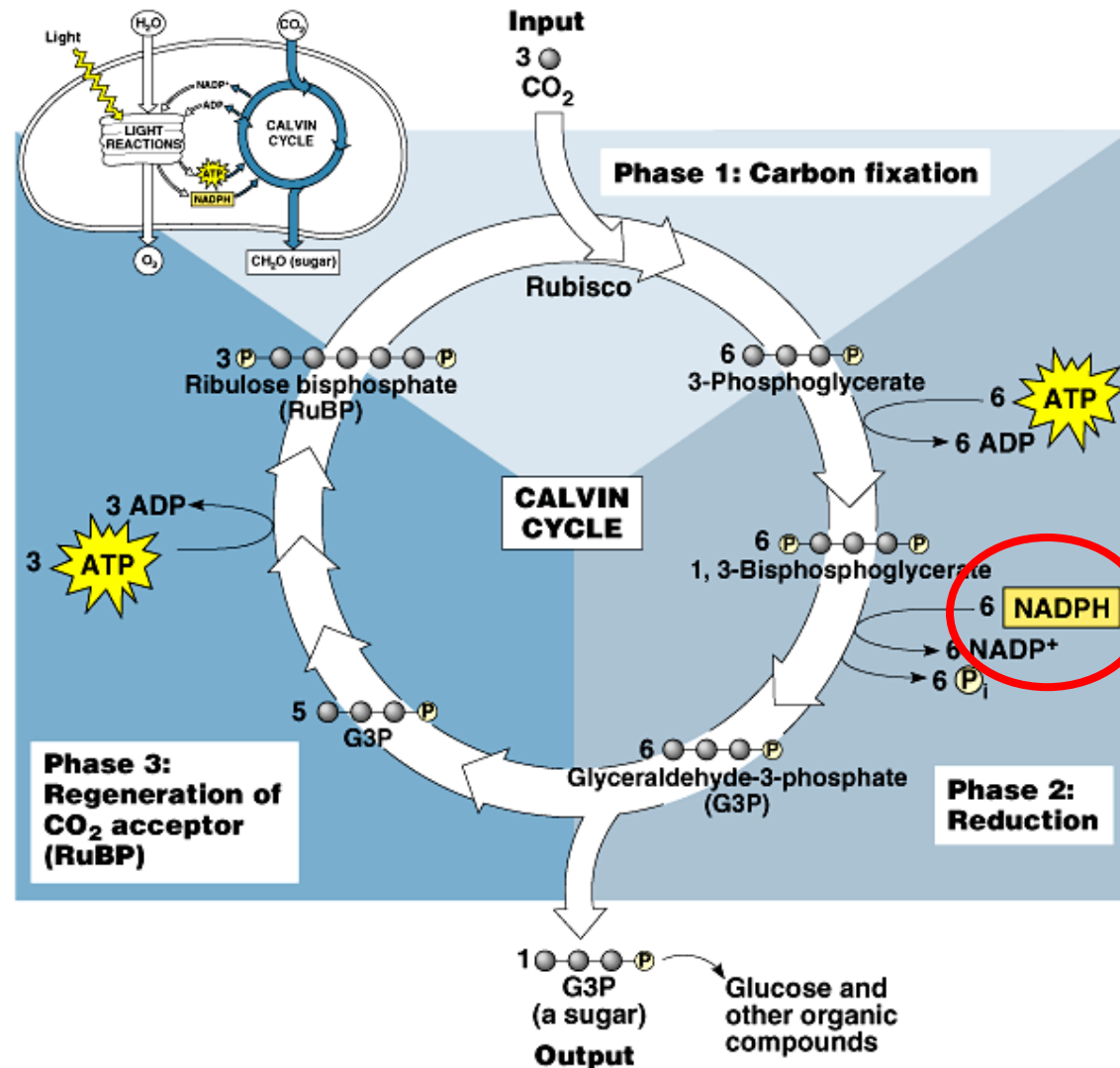


# Purpose of Cyclic Electron Flow



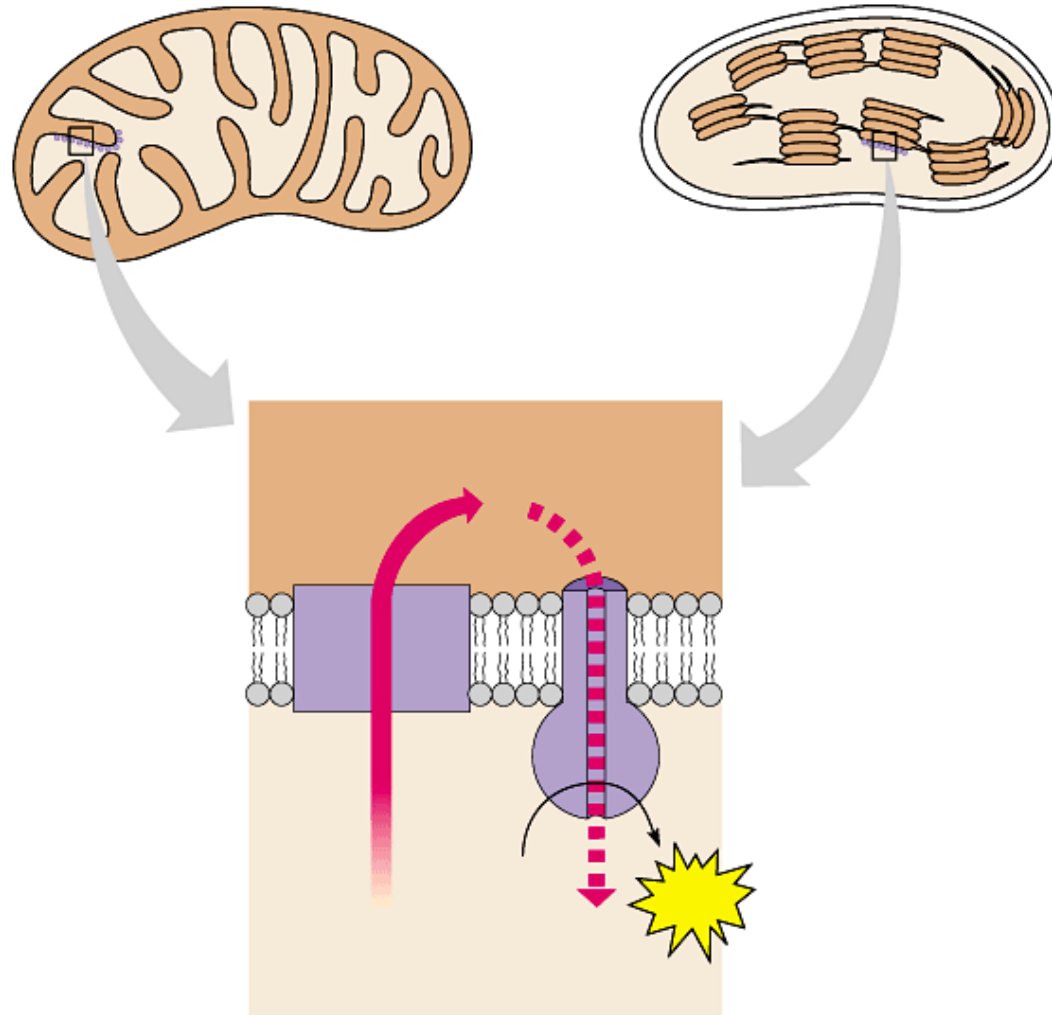
- In the Calvin cycle, more ATP is consumed than NADPH
- Need a method to increase ATP production without affecting NADPH

# 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

