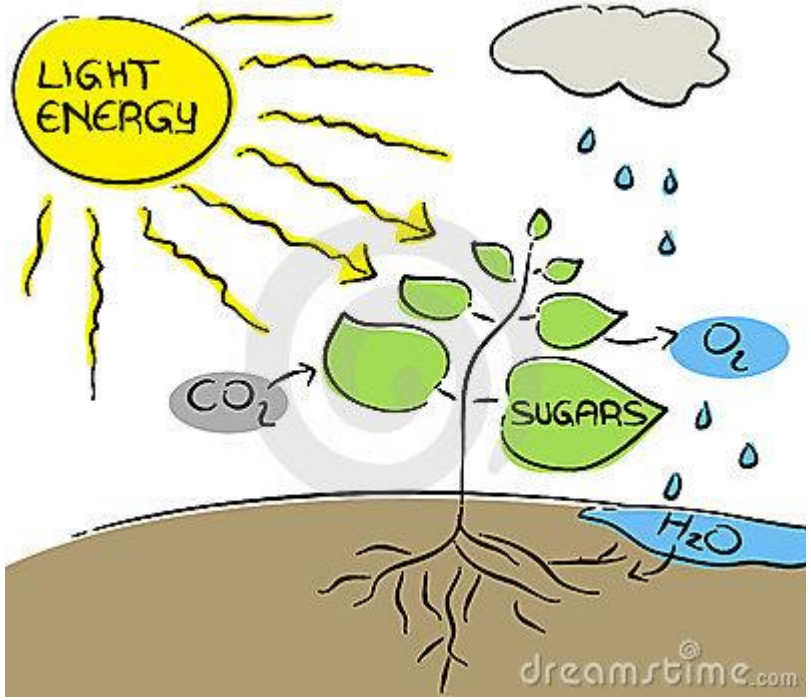
Section 4.1 – Light Dependent Reactions

SBI4UP

MRS. FRANKLIN

Photosynthesis Summarized

The process of photosynthesis can be summarized with the following equation:



$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{sun}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide from the atmosphere

Water

Organic matter

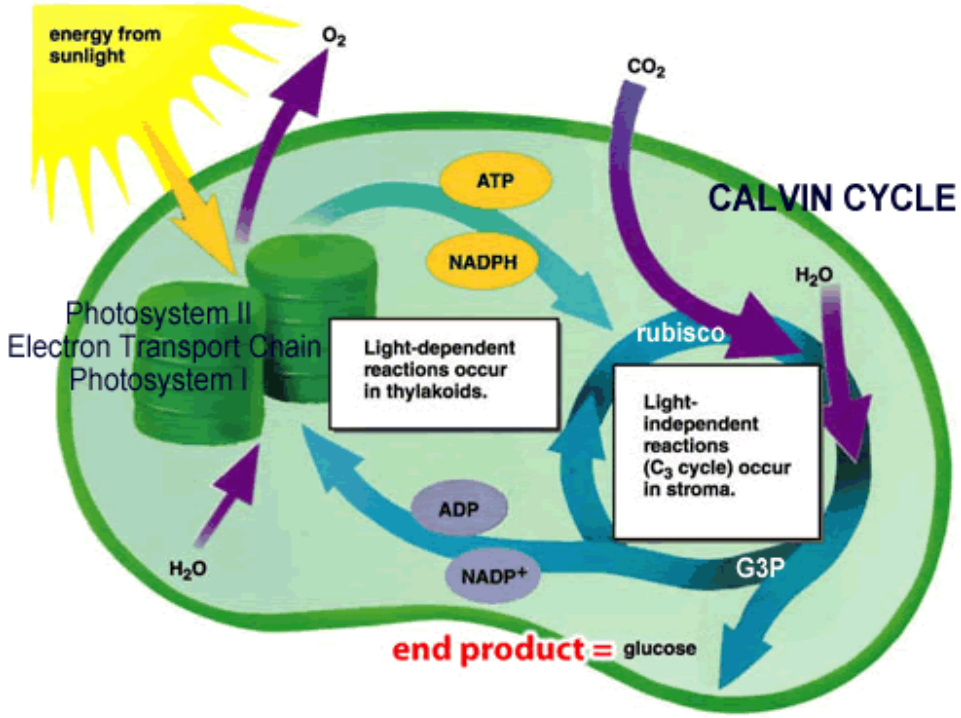
Oxygen

Process of Photosynthesis

The process of photosynthesis occurs in two main steps:

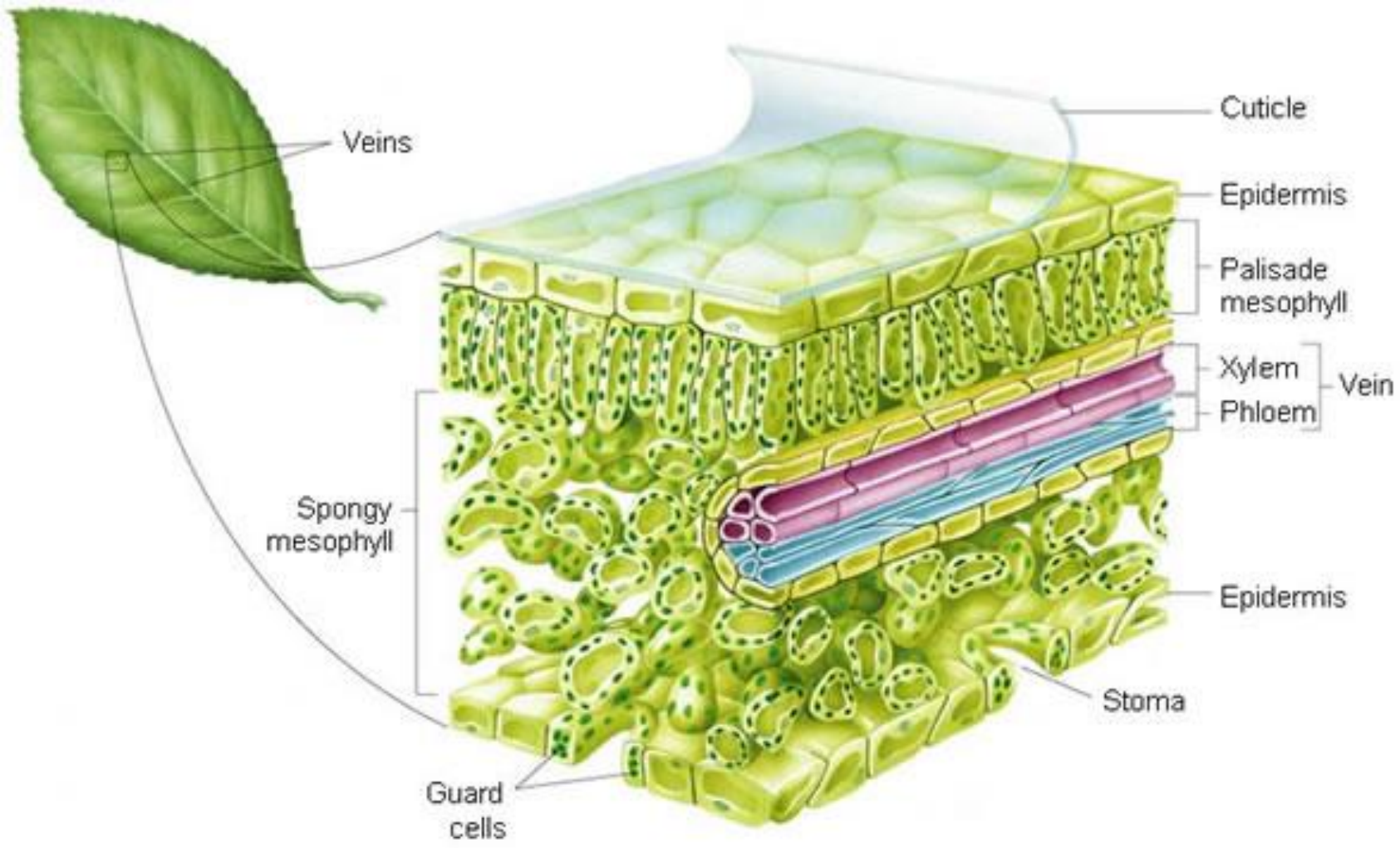
1) 'Photo' – ***Light-dependent reactions:*** uses energy to make ATP and NADPH

2) 'Synthesis' – ***Light-independent reactions:*** uses CO_2 and NADPH to make glucose



Photosynthesis occurs in the chloroplasts within the leaf

Leaf Structure



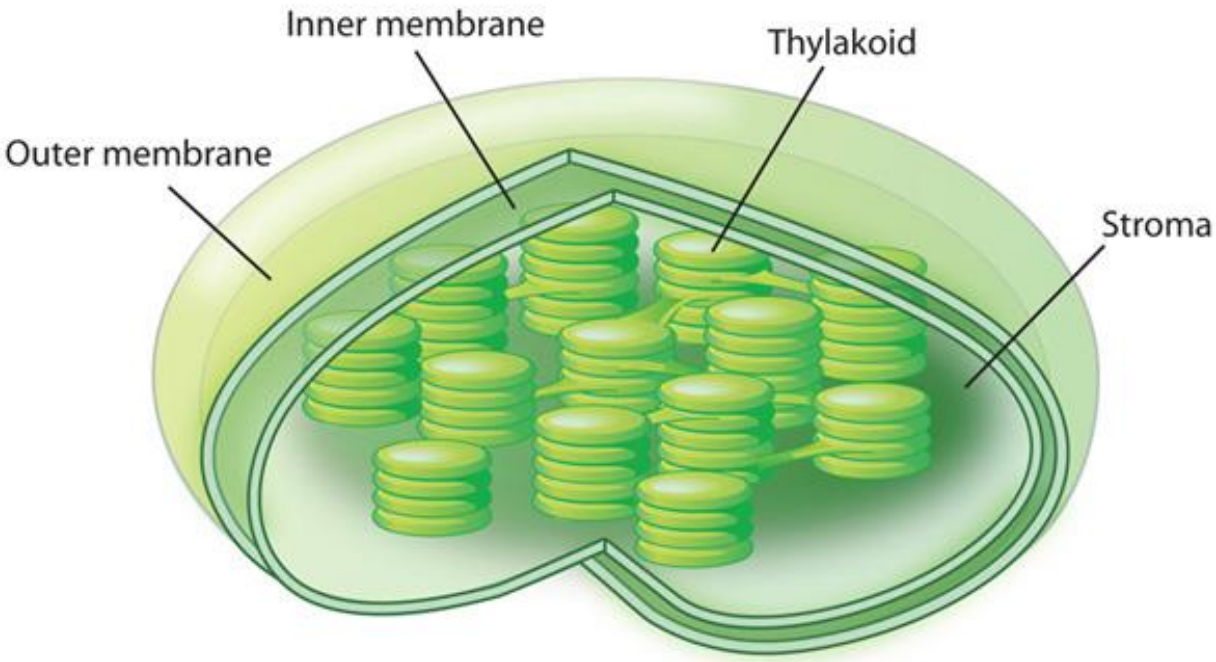
Chloroplast Structure

Stroma:

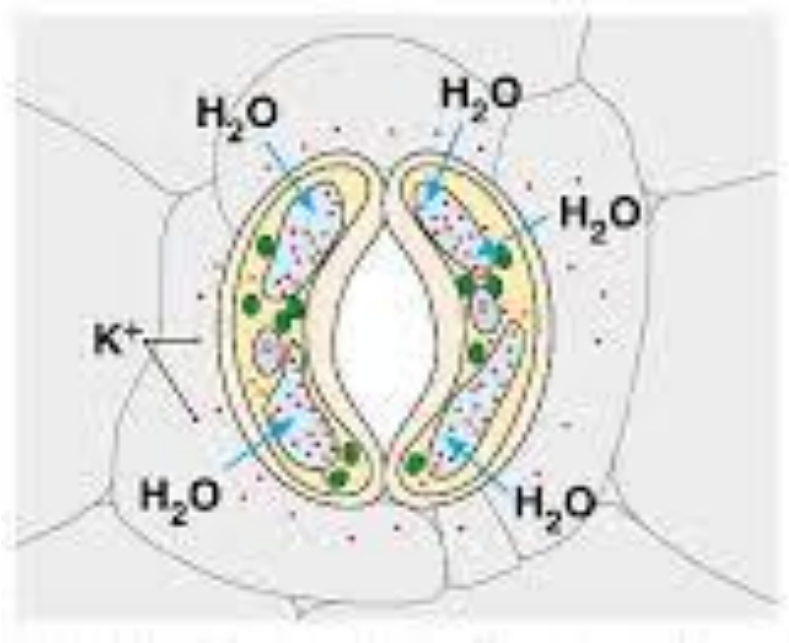
Thylakoid:

Light- Dependent Reactions:

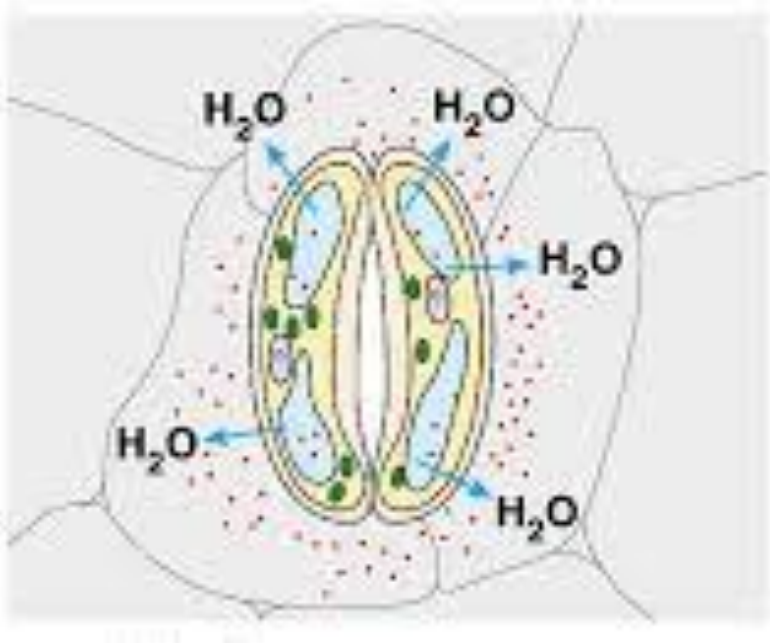
Light-Independent Reactions:



Opening/Closing of Stomata



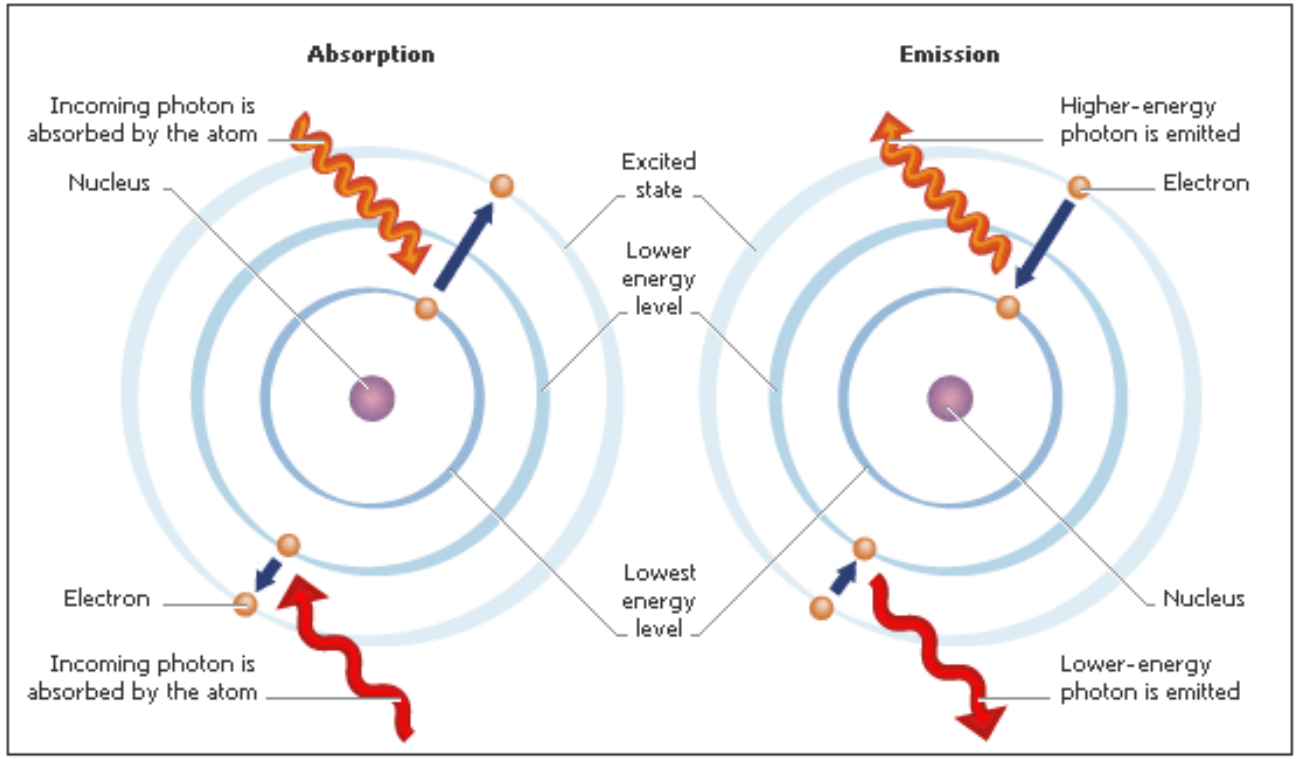
Opening of the guard cells



Closing of the guard cells

Absorption of Energy as Light

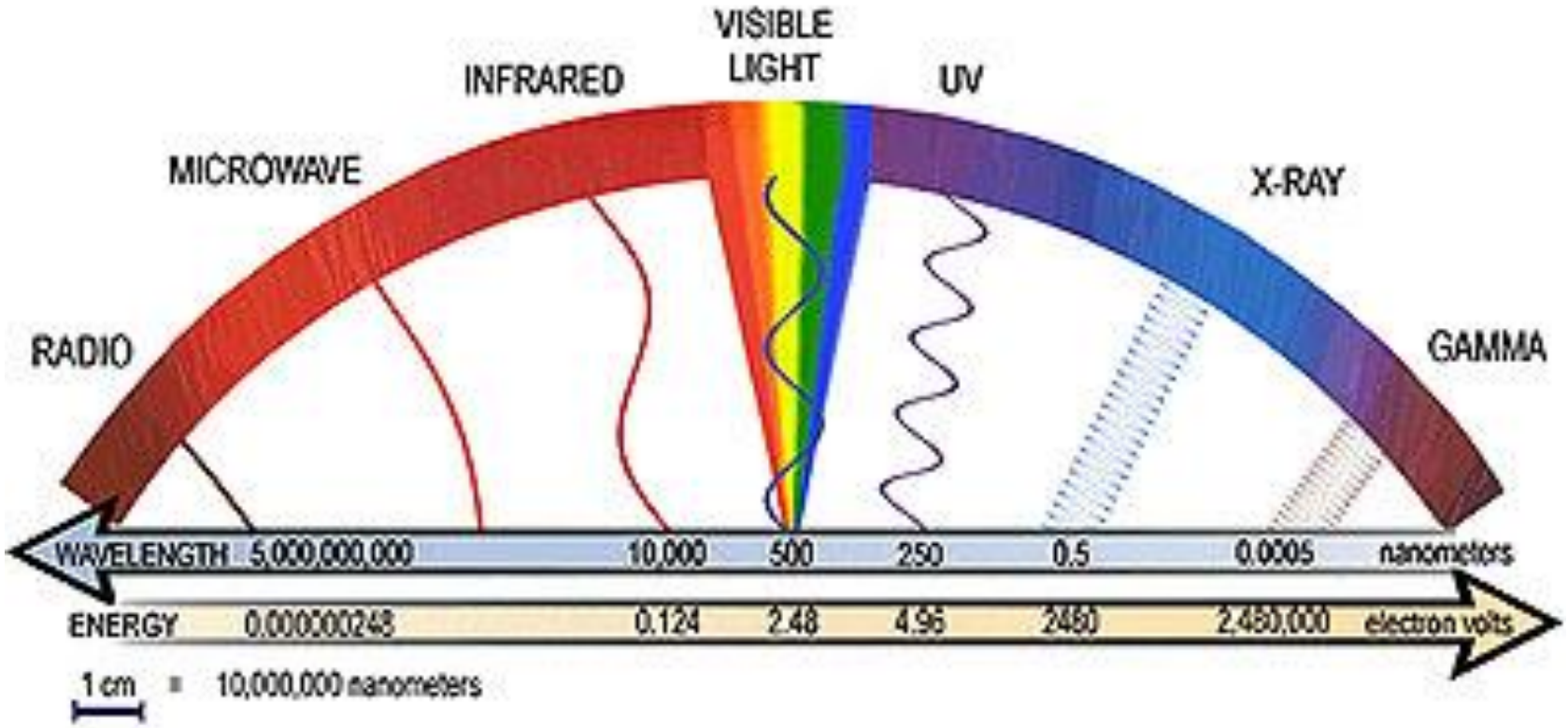
Light tends to be absorbed as photons and each photon can carry a specific amount of energy.



The photon must carry enough energy to enable the electrons to jump up into an upper level of energy.

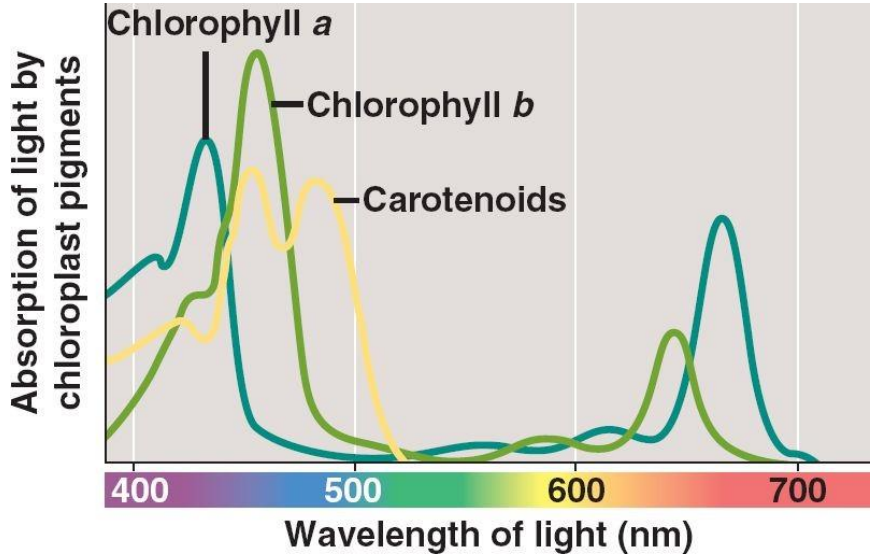
Absorption of Energy as Light

Each wavelength is associated with a certain amount of energy in its photons. The longer the wavelength the smaller the amount of energy.

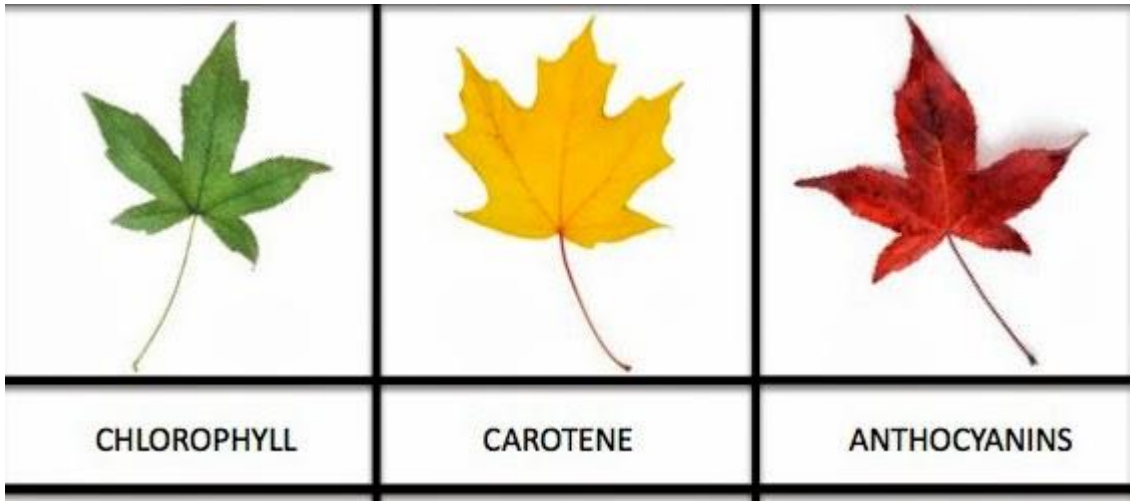


Pigments and Absorption of Energy

Pigments absorb different wavelengths of visible light. Depending on the pigment, it can absorb different combinations of colours.



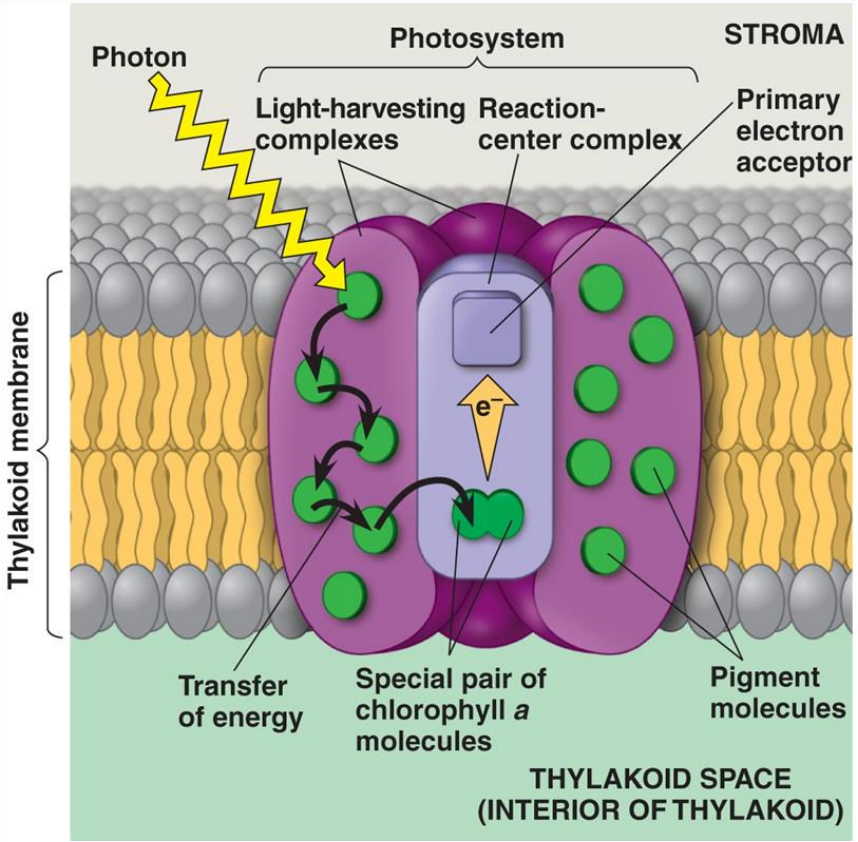
Absorbance spectrum: *a graph that shows the relative amounts of light of different wavelengths that a compound absorbs.*



Depending on the time of the year, different pigments will be exposed and absorb and emit different wavelengths of light.

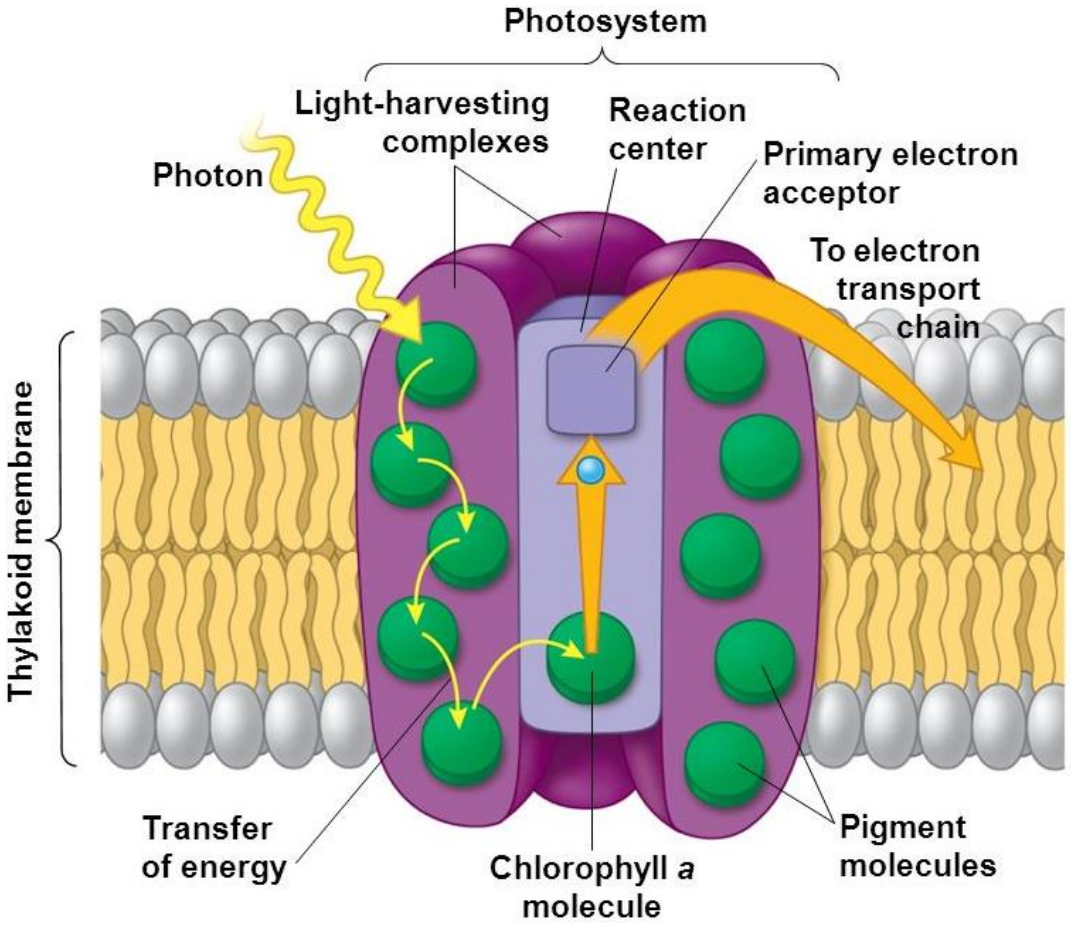
Photosystems and Energy

Photosystem: protein based complex composed of clusters of pigments that absorb light energy.



The clusters of pigments are located on the thylakoid membrane and can absorb a wide range of wavelengths when imbedded in a protein complex.

Photosystems and Energy



- ***Antenna complex:*** pigments molecules (chrlorophyll b, carotenoids etc) that capture the initial photons of light.
- ***Reactions center:*** composed of chlorophyll a molecules and proteins.
- Chlorophyll b molecules capture the photons of light emitted by the sun. This energy is transferred between chlorophylls until it reaches chlorophyll a (reaction center).
- Two electrons from the reaction center are ‘excited’ and jump up in energy level. These electrons are captured by an electron carrier.

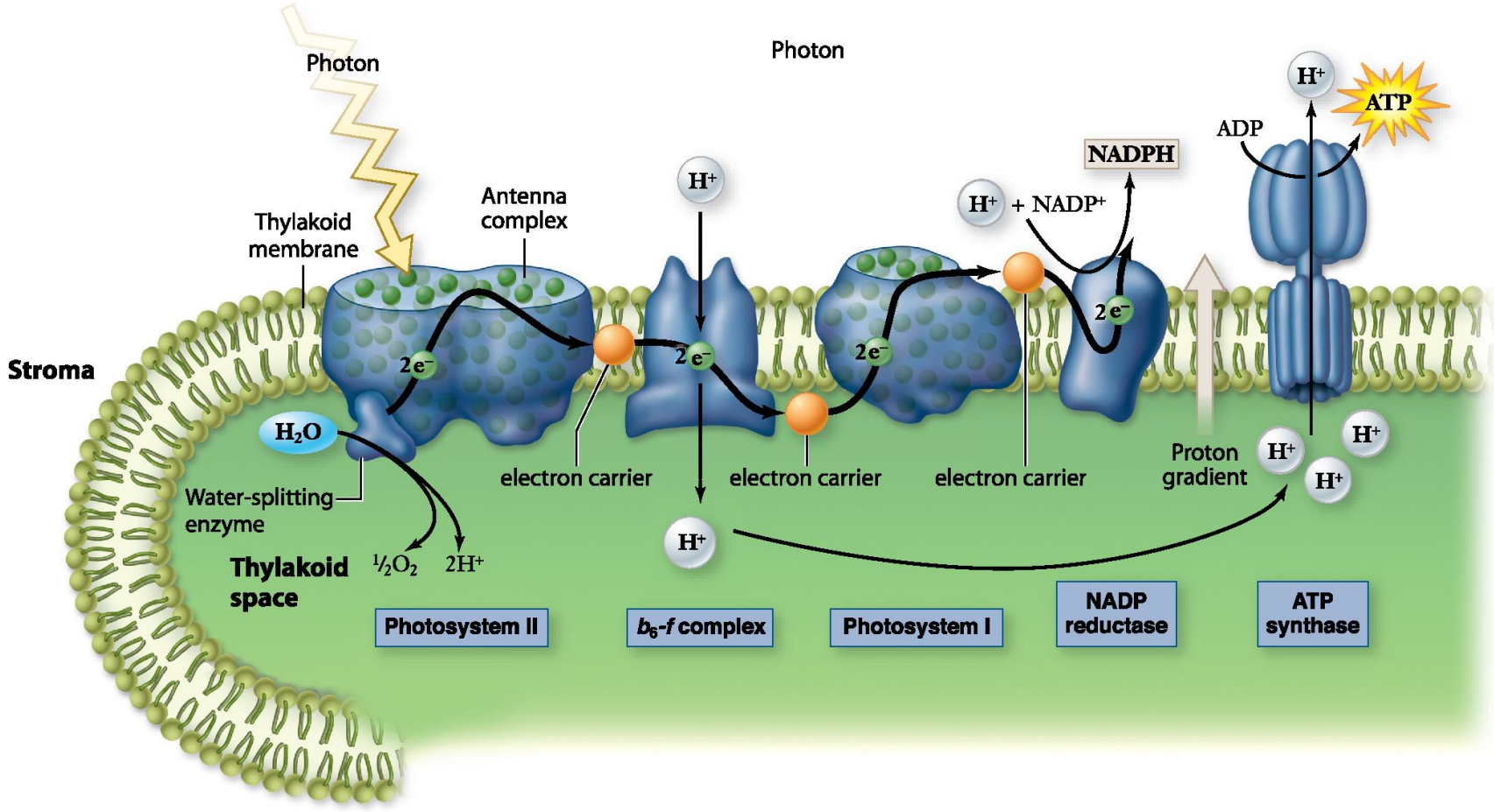
Photosystems I and II

Depending on the chlorophyll in the reaction center, they can absorb different wavelengths of light. There are two photosystems present in the thylakoid membrane.

- 1) ***Photosystem I (P700):*** the reaction center can absorb wavelengths of 700 nm.
- 2) ***Photosystem II (P680):*** the reaction center can absorb wavelengths of 680 nm.

Both work together during the Light-dependent reactions.

Light-Dependent Reactions



Light-Dependent Reactions

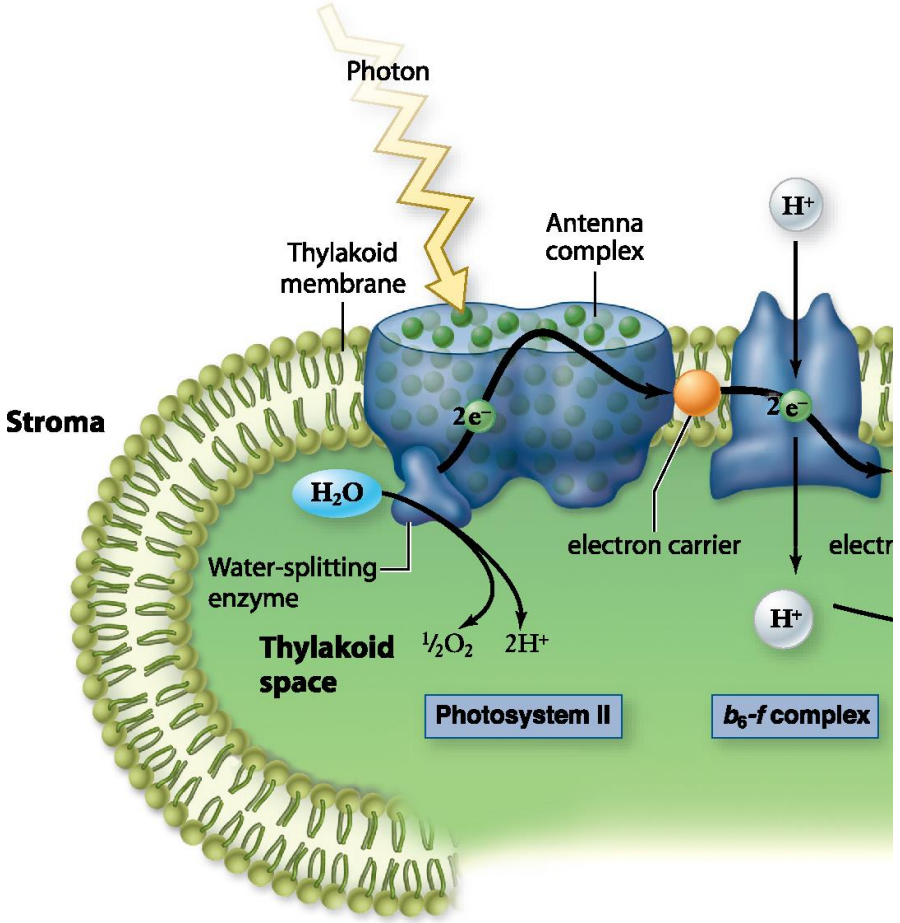
STEP 1:

- P680 (Photosystem II) absorbs a photon of light in its antenna complex and transfers the energy to the reaction center whereby an electron is ‘excited’.
- An electron acceptor takes the electrons and leaves the P680 with one less electrons (P680+).
- Two H_2O molecules are split and transfer their electrons to the reaction center of P680 to replenish it.
- The oxygen is released into the atmosphere and some is retained for further reactions.

Light-Dependent Reactions

STEP 2:

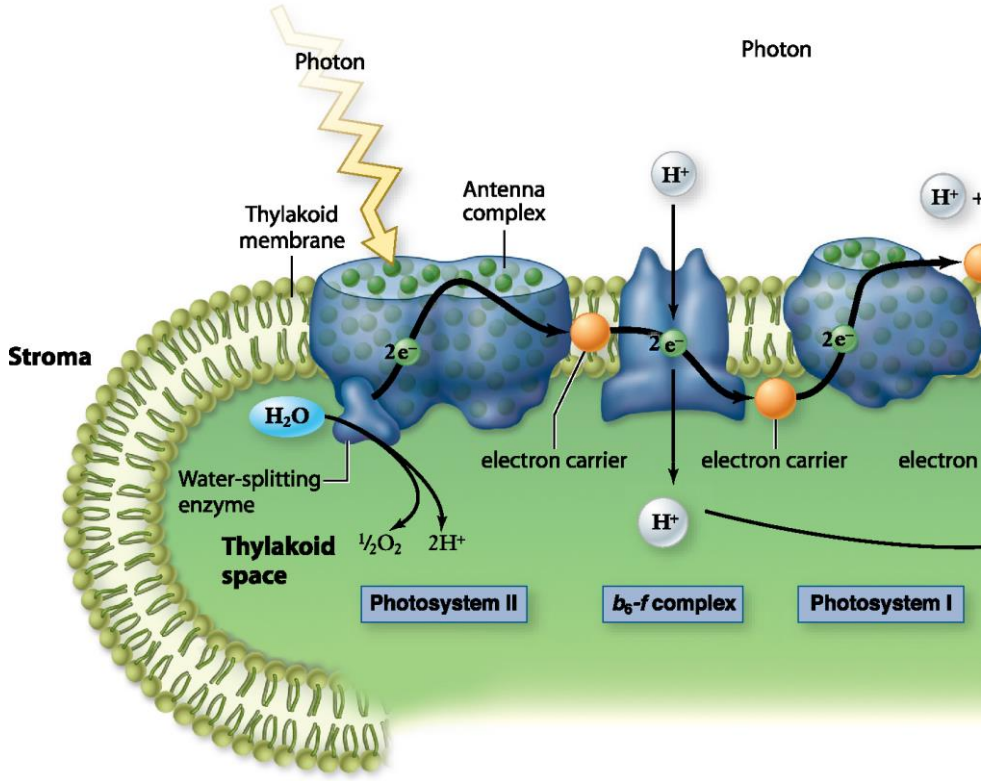
- The electron carrier transfers the electrons to a series of increasingly electronegative complexes (series of REDOX reactions).
- The energy released by the redox reactions is used by b_6-f complex to pump a H+ from the stroma into the thylakoid space to create an electrochemical gradient.



Light-Dependent Reactions

STEP 3:

- ***P700 (Photosystem I)*** absorbs photons of light in the antenna complex. The energy is transferred until it reaches the reaction center and excites another 2 electrons.
- The missing electrons are replaced by the 2 electrons being transferred in the ***electron transport system.***
- An electron carrier captures the 2 electrons and carries it to the next complex.

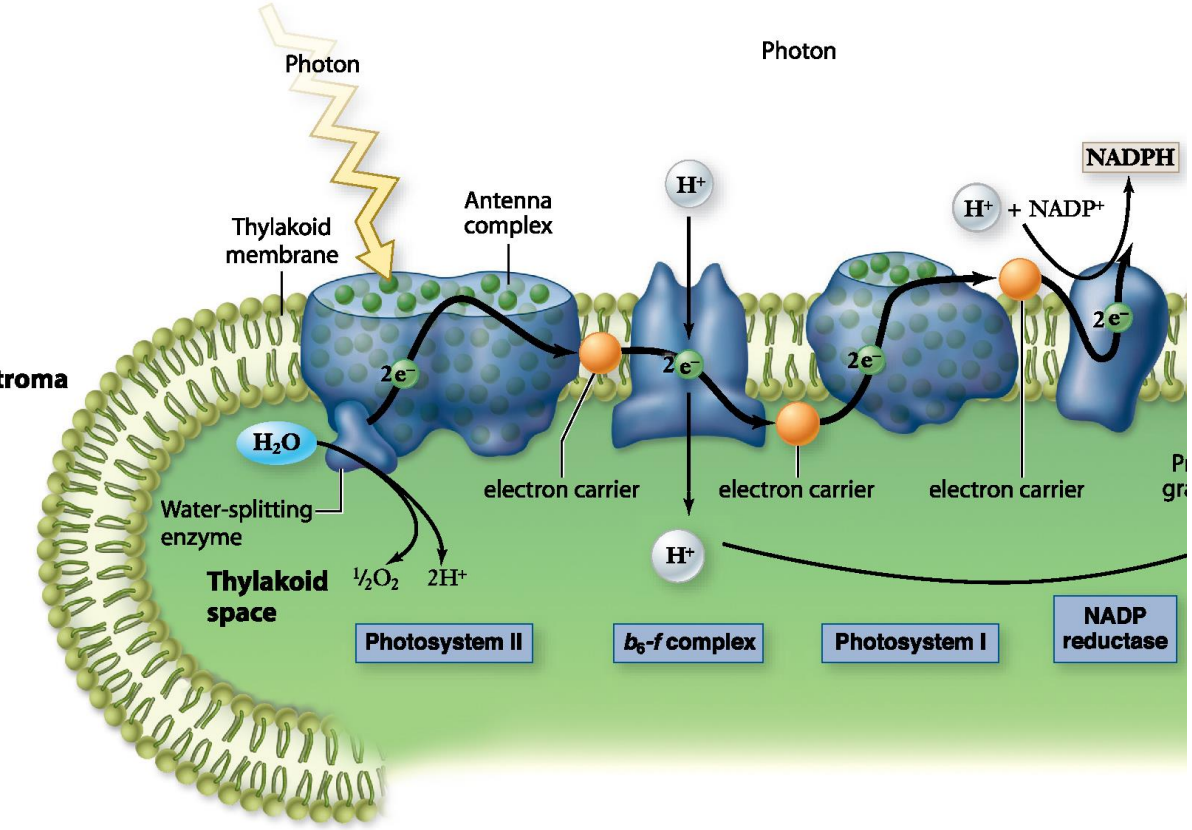


Light-Dependent Reactions

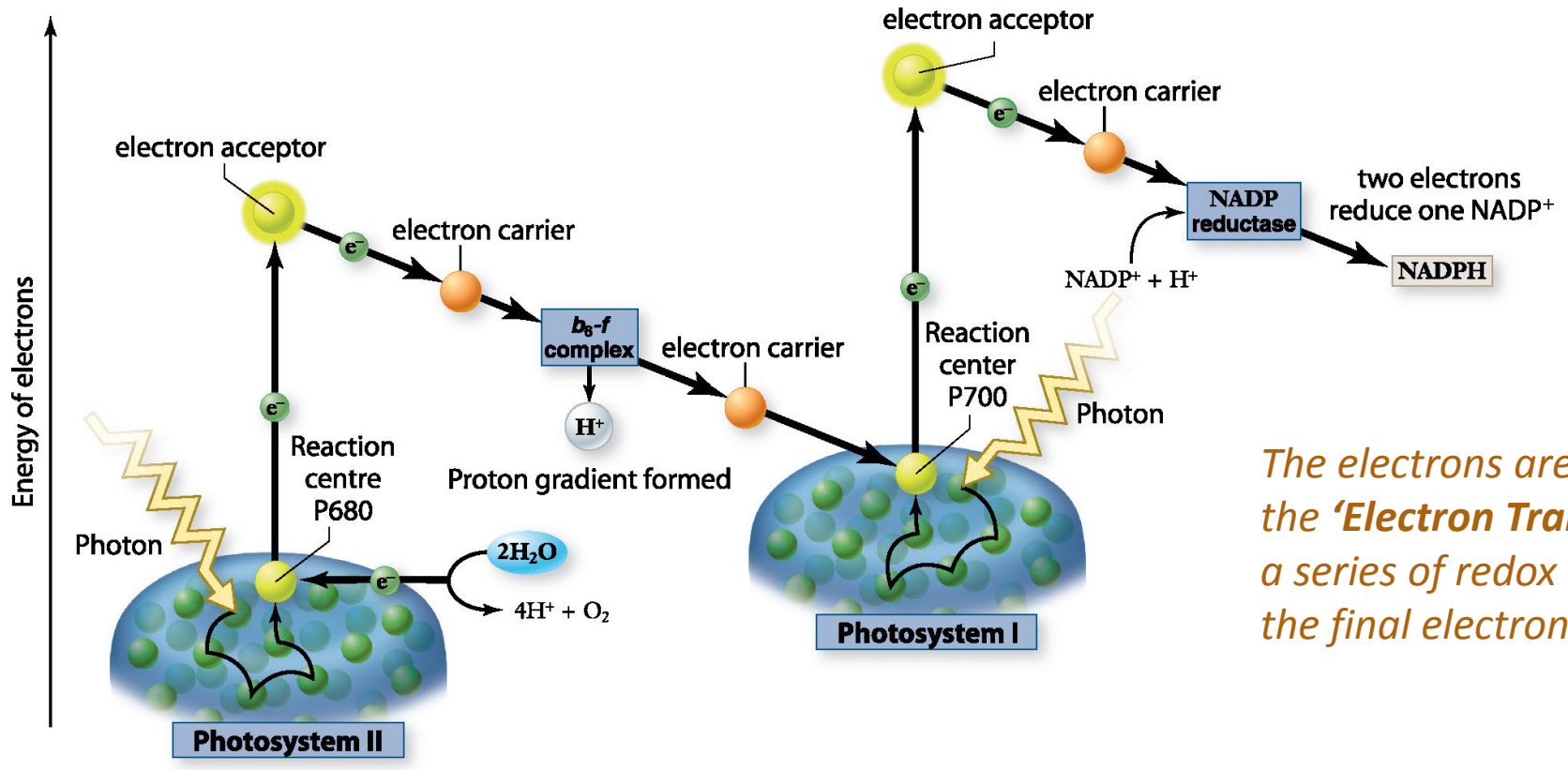
STEP 3:

- *The electron carrier brings the electrons to the enzyme NADP reductase.*

- *NADP+ undergoes a REDOX reaction with the NADP reductase and captures the remaining electrons to become NADPH.*



Light-Dependent Reactions

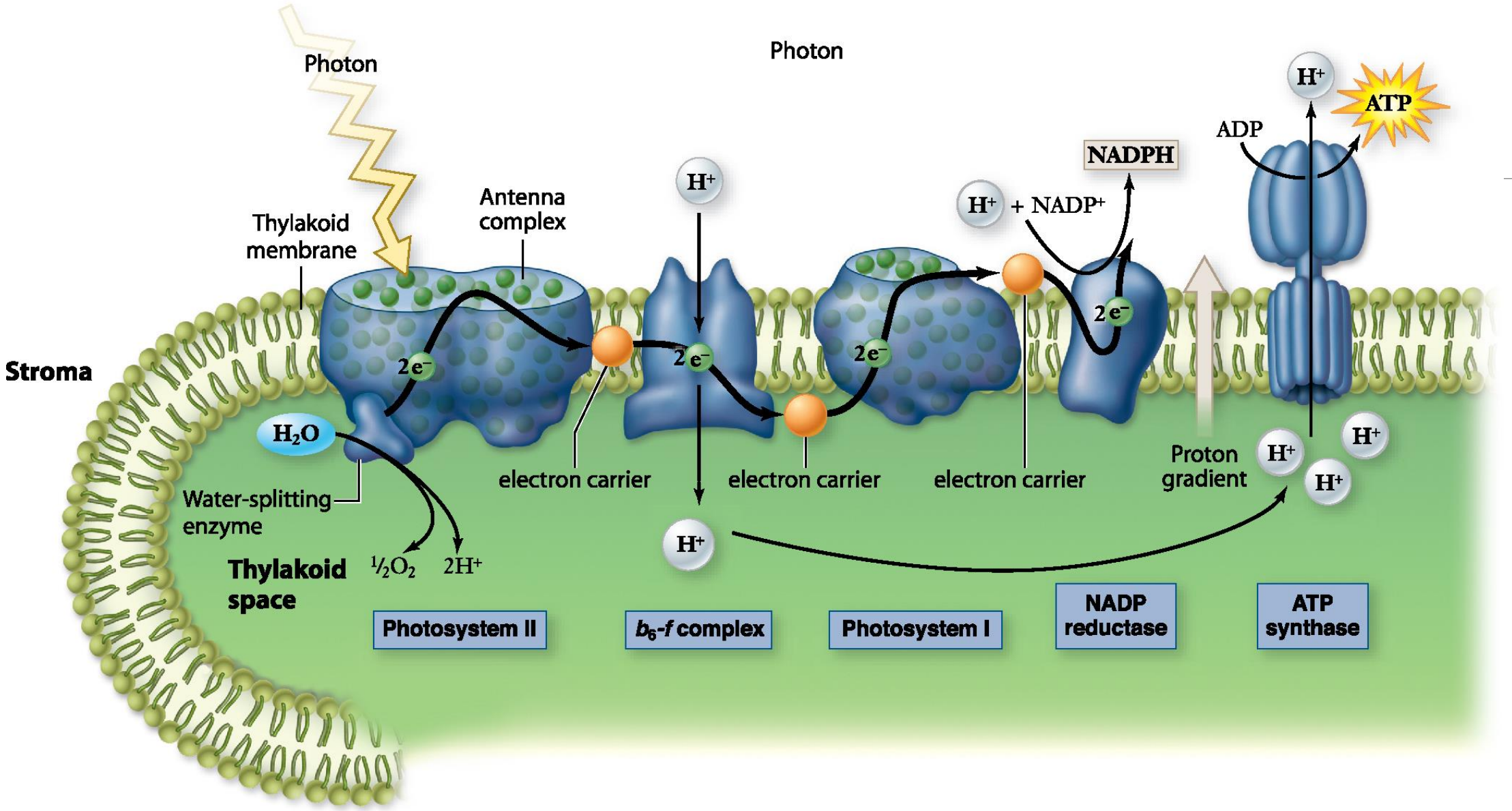


*The electrons are transported through the **'Electron Transport System'** through a series of redox reactions. The NADPH is the final electron acceptor.*

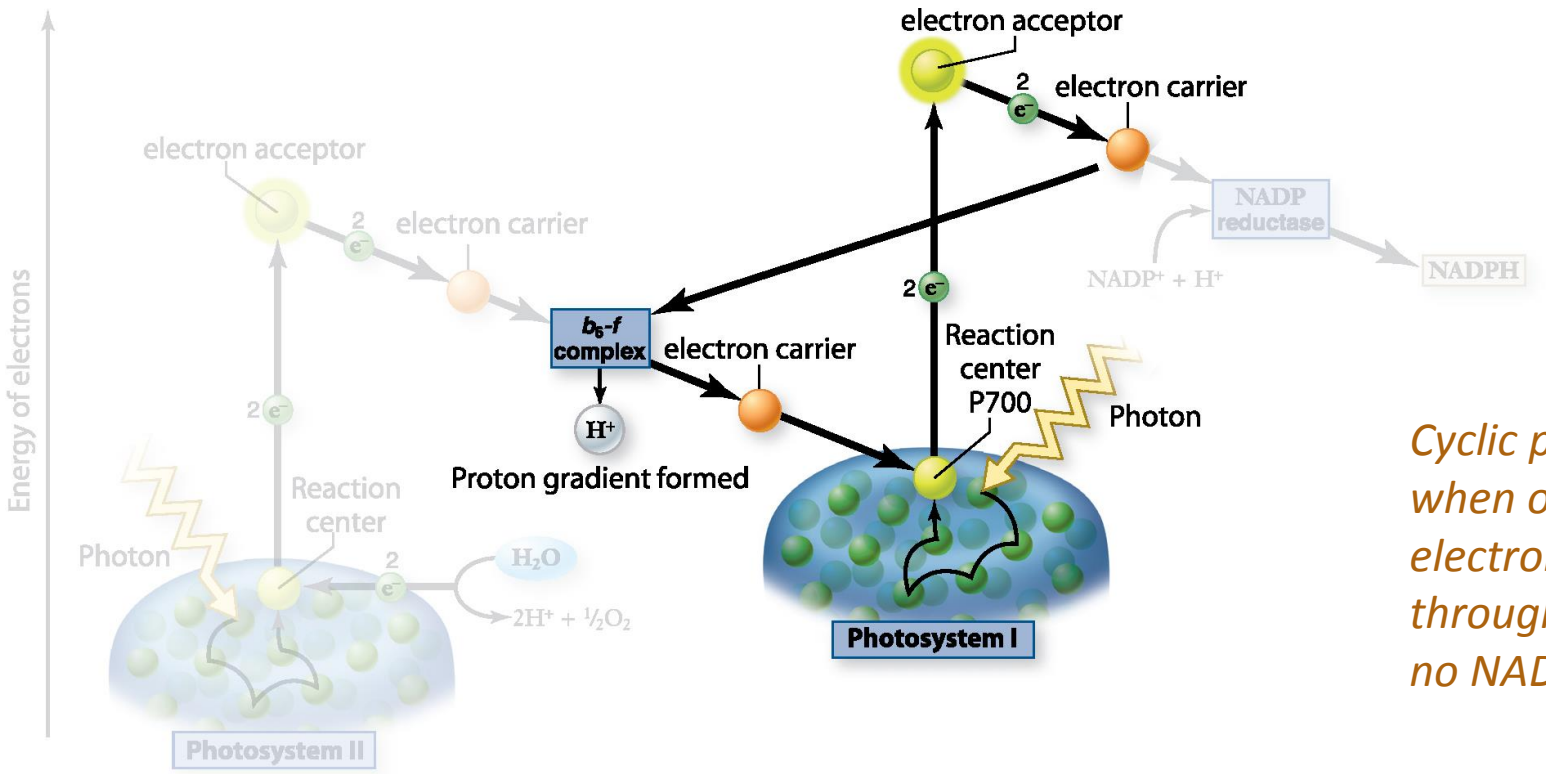
Production of ATP - Chemiosmosis

Photophosphorylation: the use of photons of light to drive the phosphorylation of ADP to produce ATP via chemiosmosis.

- Remember . . . The b_6-f complex releases a large quantity of H+ per second due to the numbers photons of light that are being captured by P680.
- The H+ released into the thylakoid space create an electrochemical gradient. The H+ naturally want to move with their concentration gradient (electrical and chemical force).
- The energy hat is released when the H+ are moving through ATP synthase is used for oxidative phosphorylation.


Photon
Photon
Thylakoid membrane
Antenna complex
Stroma
H+
NADPH
H+ + NADP+
ADP
ATP
2e−
2e−
2e−
2e−
H2O
electron carrier
electron carrier
electron carrier
Proton gradient
Water-splitting enzyme
Thylakoid space
½O2
2H+
H+
Photosystem II
b6-f complex
Photosystem I
NADP reductase
ATP synthase

Noncyclic vs. Cyclic Photophosphorylation



Cyclic photophosphorylation occurs when only PSI is involved. The electrons from PSI are recycled through the b_6-f complex. There is no NADHP or O_2 produced.

Checking for Understanding

1) Compare and contrast the thylakoid membrane in the plant cells to the cristae fond in mitochondria.

2) Compare and contrast the ETC (cellular respiration) and the ETS (photosynthesis)

Checking for Understanding

Light that is absorbed by a leaf is

A) not reflected

B) Captured by a photosystem

C) Used to increase the energy of an electron

D) Composed of most colours, other than green and yellow

E) All of the above

Checking for Understanding

Which of the following is false regarding light-dependent reactions?

A) produce ATP through chemiosmosis

B) produce NADPH

C) require carbon dioxide as an electron source

D) split water and releases oxygen

E) involve two photosystems

Checking for Understanding

The water necessary for photosynthesis

A) is split into H_2 and O_2

B) is directly involved in the synthesis of a carbohydrate

C) provides the electrons to replace lost electrons in photosystem I

D) provides H+ needed to synthesize G3P

E) none of the above

Checking for Understanding

The reaction center pigment differs from the other pigment molecules of the light-harvesting complex in the following way:

A) the reaction center pigment is a carotenoid.

B) the reaction center pigment absorbs light energy and transfers that energy to other molecules without the transfer of electrons

C) The reaction center pigment transfers excited electrons to other molecules

D) The reaction center pigment does not transfer excited electrons to the primary electron acceptor.

E) The reaction center acts as an ATP synthase to produce ATP.

Checking for Understanding

The electron flow that occurs I photosystem I during noncyclic photophosphorylation produces

A) NADPH

B) Oxygen

C) ATP

D) all of the above

E) a) and c) only.

Checking for Understanding

During the light-dependent reactions, the high-energy electron from an excited P680

A) eventually moves to NADP+

B) becomes incorporated in water molecules

C) is pumped into the thylakoid space to drive ATP production

D) provides the energy necessary to split water molecules

E) falls back to the low-energy state in photosystem II

Homework

Textbook: pg. 165 # 1, 4, 6, 8, 10 &14.