Photosynthesis

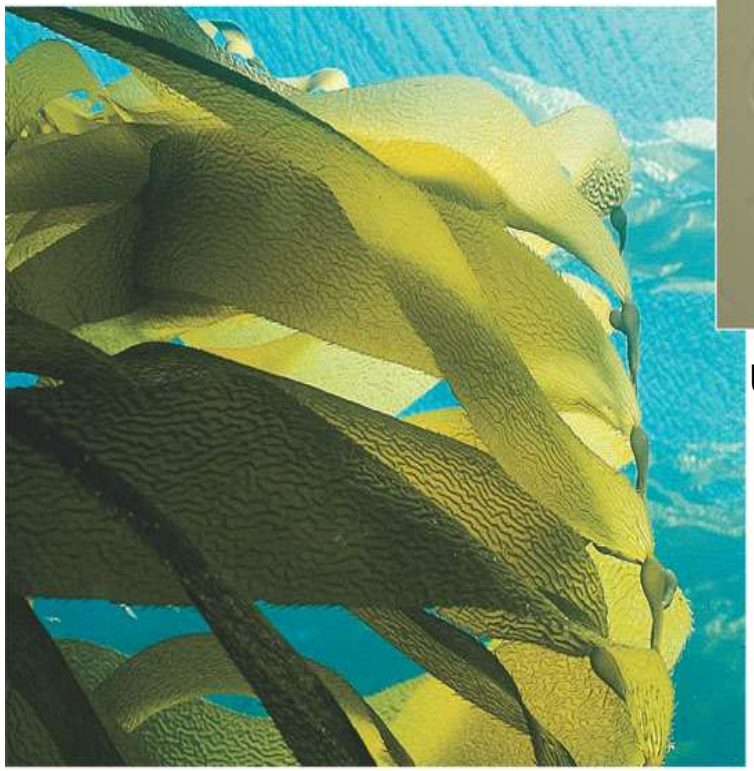
Introduction to Photosynthesis

- Life is solar powered
- **Photosynthesis**
- Photosynthesis nourishes *almost* all of the living world directly or indirectly.
- Photosynthesis has 3 stages.
- **1. Energy is captured from the sun light.**
- **2. Light energy is converted into chemical energy which is stored as ATP and NADPH.**
- **3. The energy stored in ATP and NADPH powers the formation of organic compounds using CO_2.**

Global View

- **Autotrophs = producers**
  - photoautotrophs and chemoautotrophs.
- **Heterotrophs = Consumers.**
  - Almost all heterotrophs rely on photoautotrophs for food and for oxygen
- **Circle of Life!!!...at Least on Earth!!!**

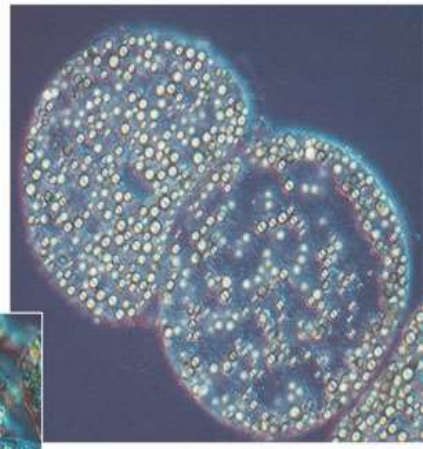
Plants



Multicellular algae

Unicellular protist

Cyanobacteria



Purple sulfur bacteria

Figure 10.2

Where Does Photosynthesis Occur

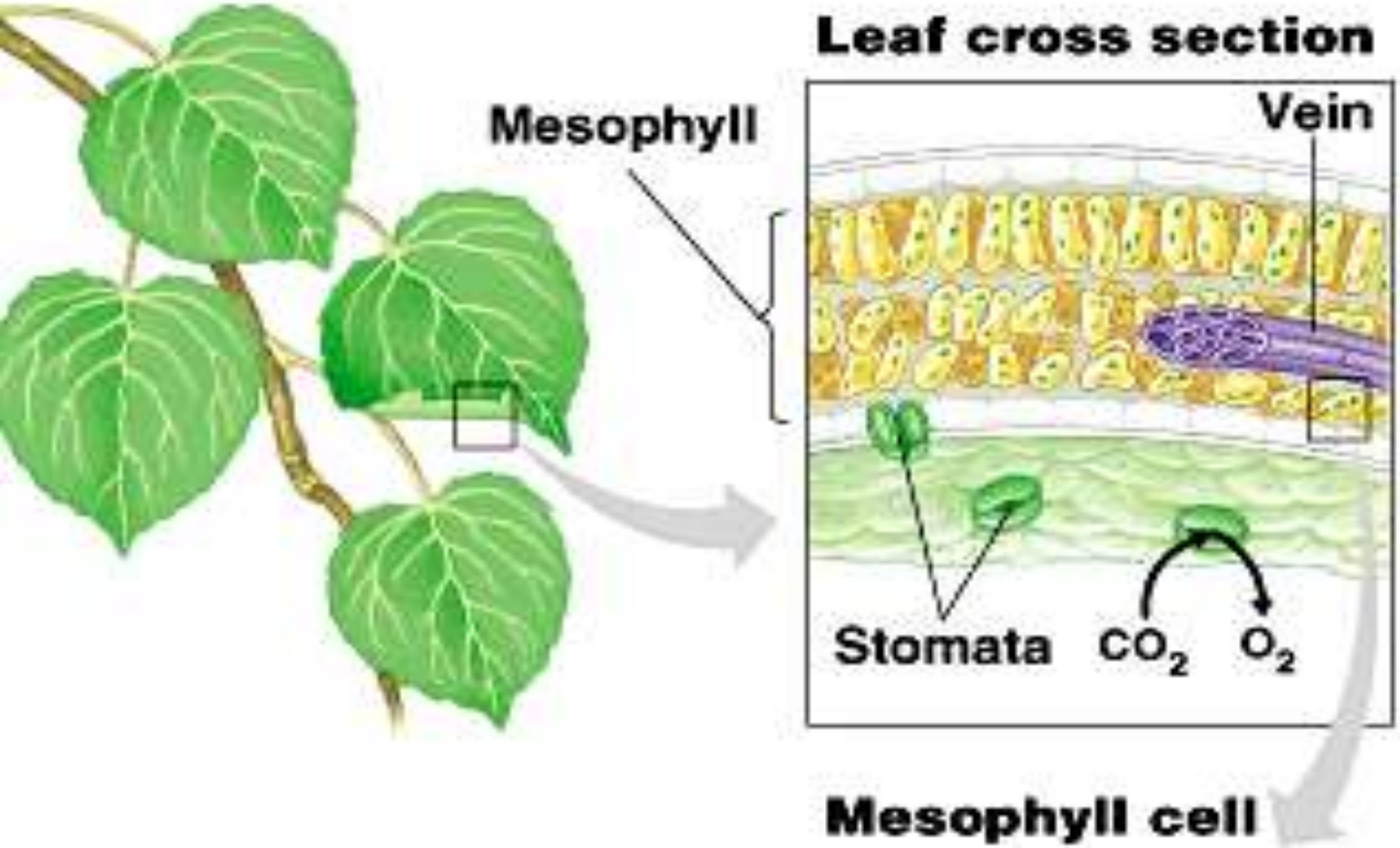
- **Chloroplasts**

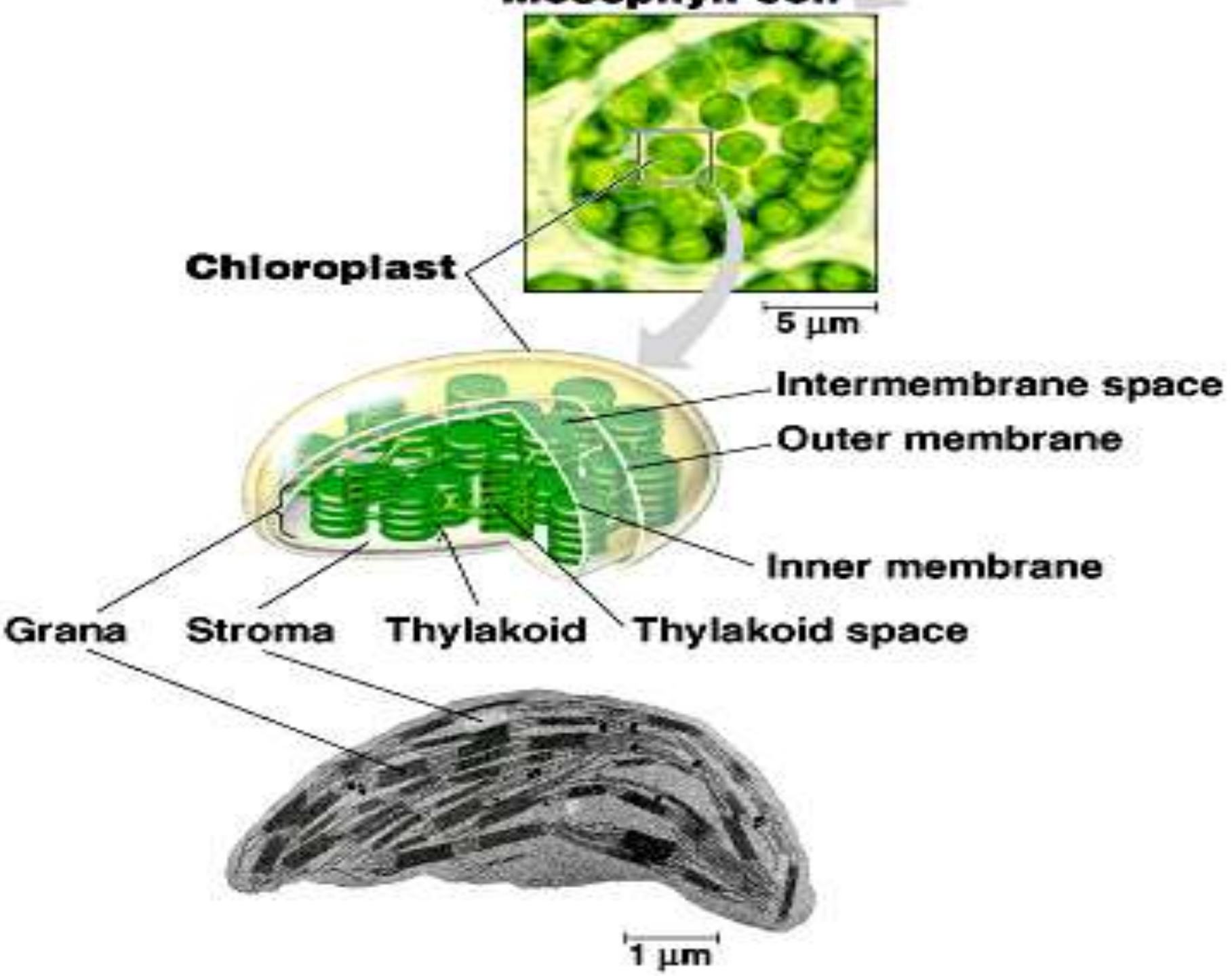
- **Any** green part of a plant contains chloroplasts
  - 500,000 chloroplasts per mm^2 of leaf surface.

- **Chlorophyll**.

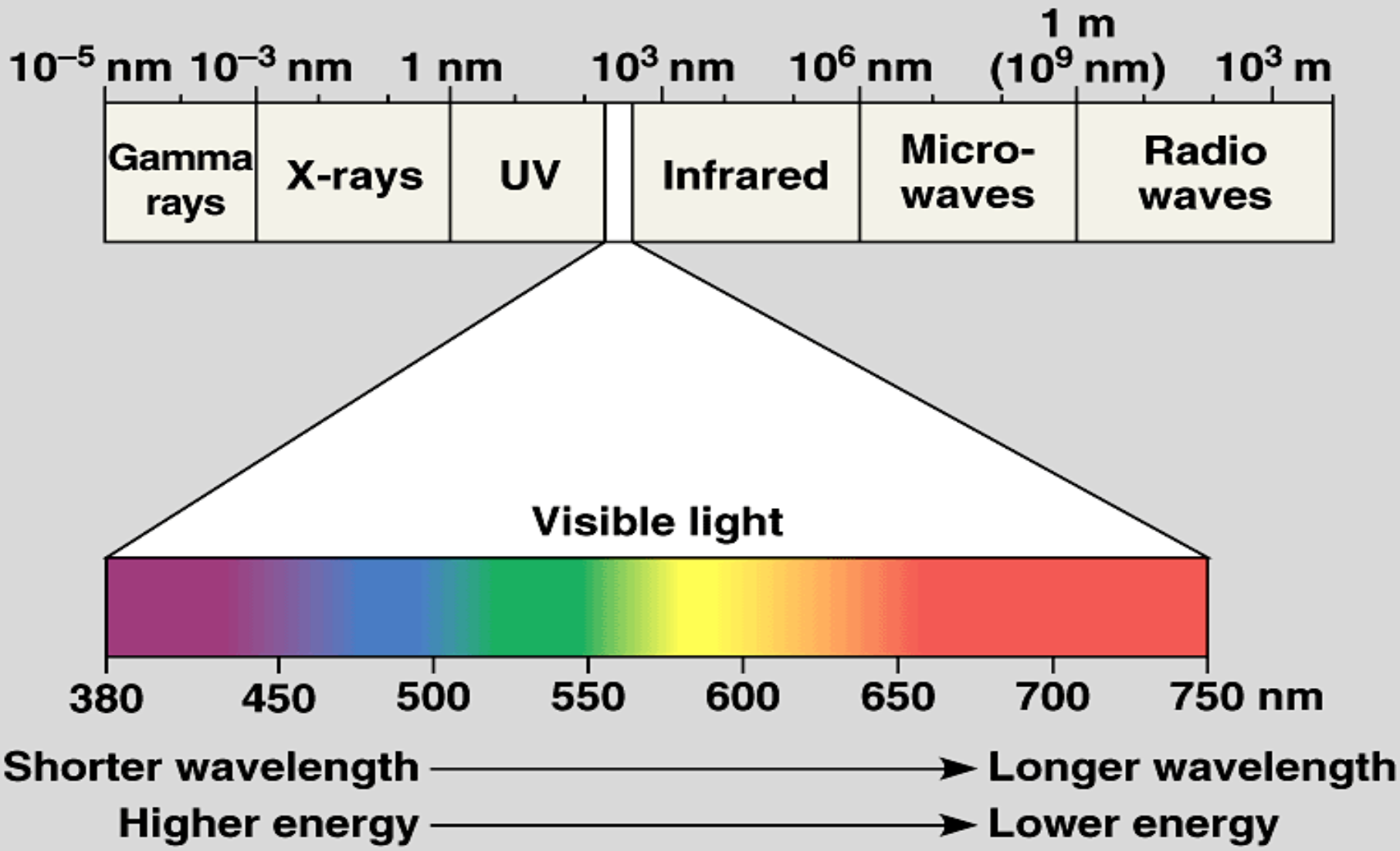
- Chloroplasts are found mainly in **mesophyll.**

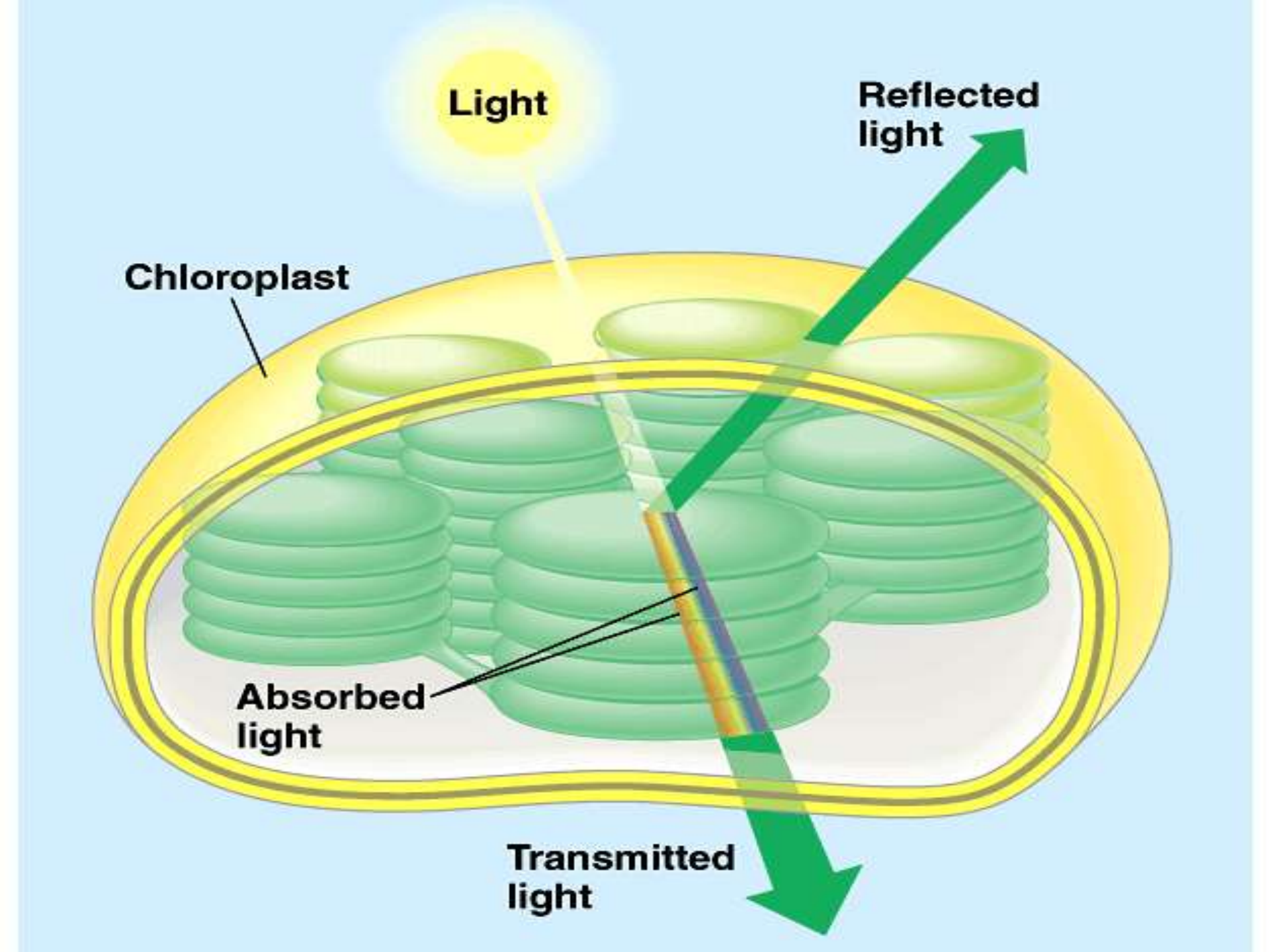
Stomata

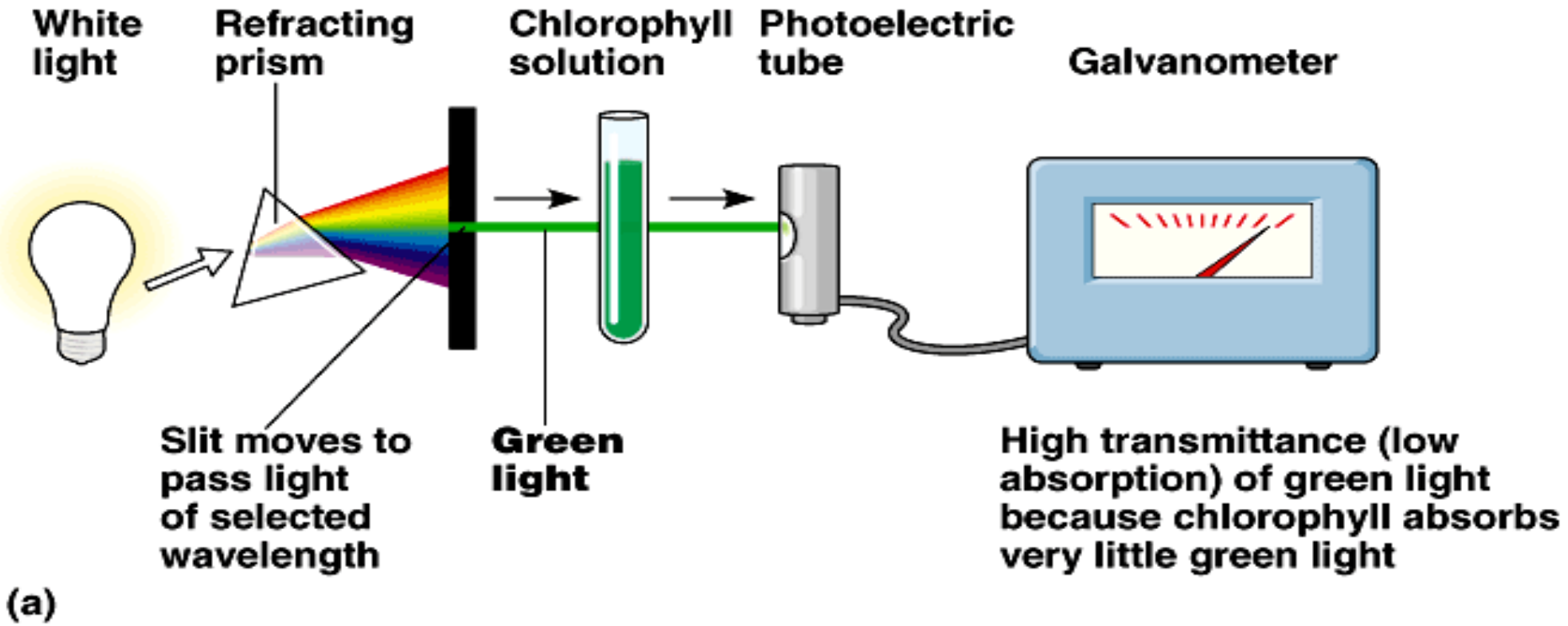

Leaf cross section
Mesophyll
Vein
Stomata
CO_2
O_2
Mesophyll cell

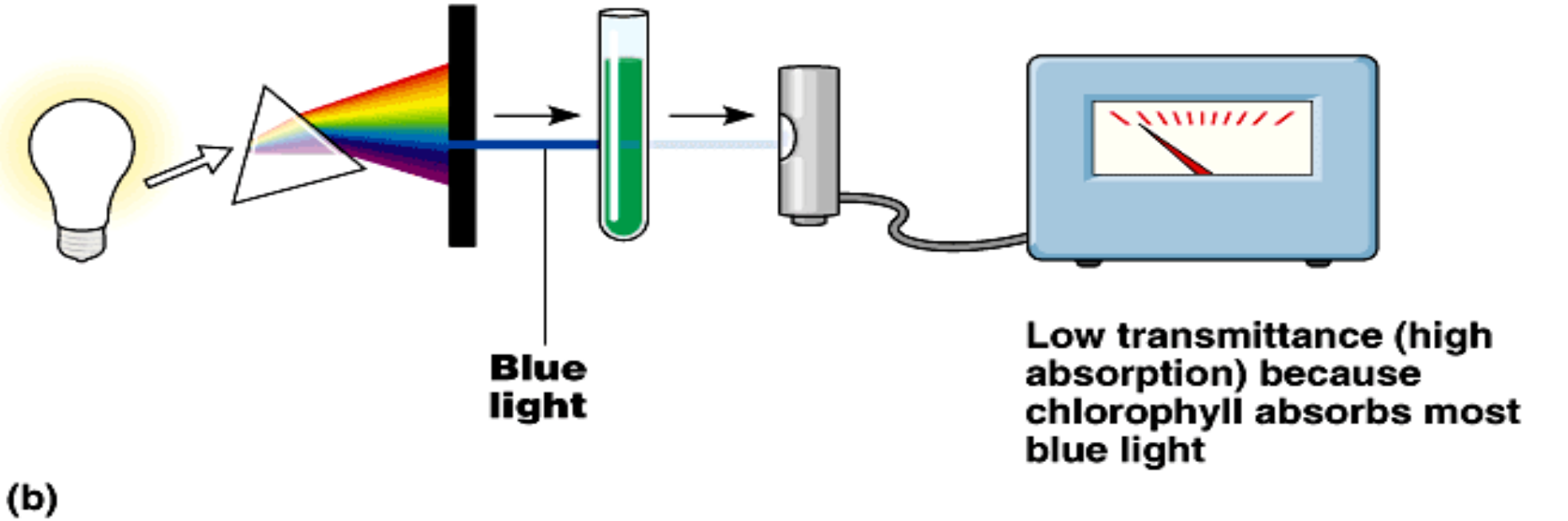

Chloroplast
5 µm
Intermembrane space
Outer membrane
Inner membrane
Grana
Stroma
Thylakoid
Thylakoid space
1 µm

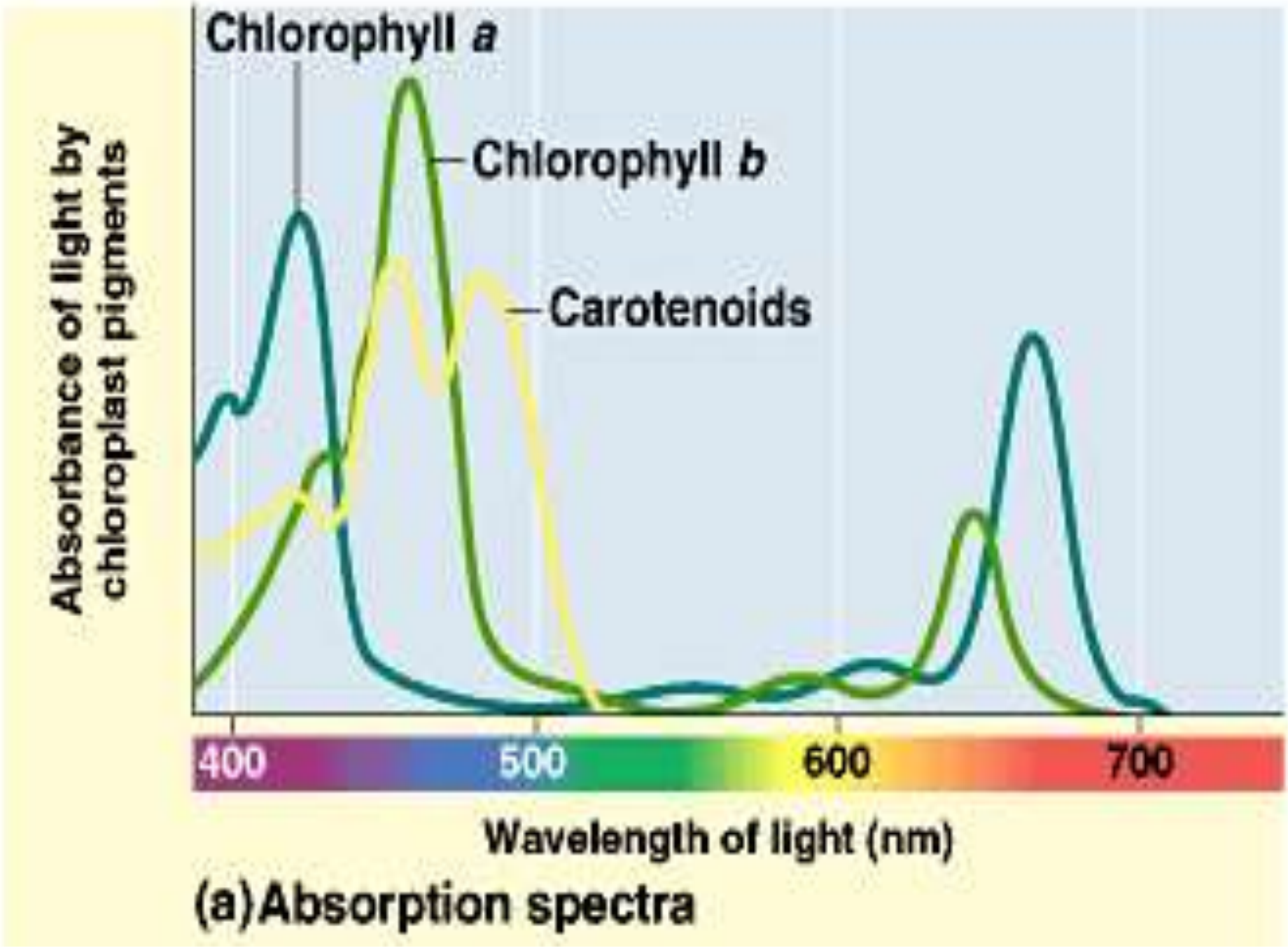
Electromagnetic Rays




Light
Reflected light
Chloroplast
Absorbed light
Transmitted light

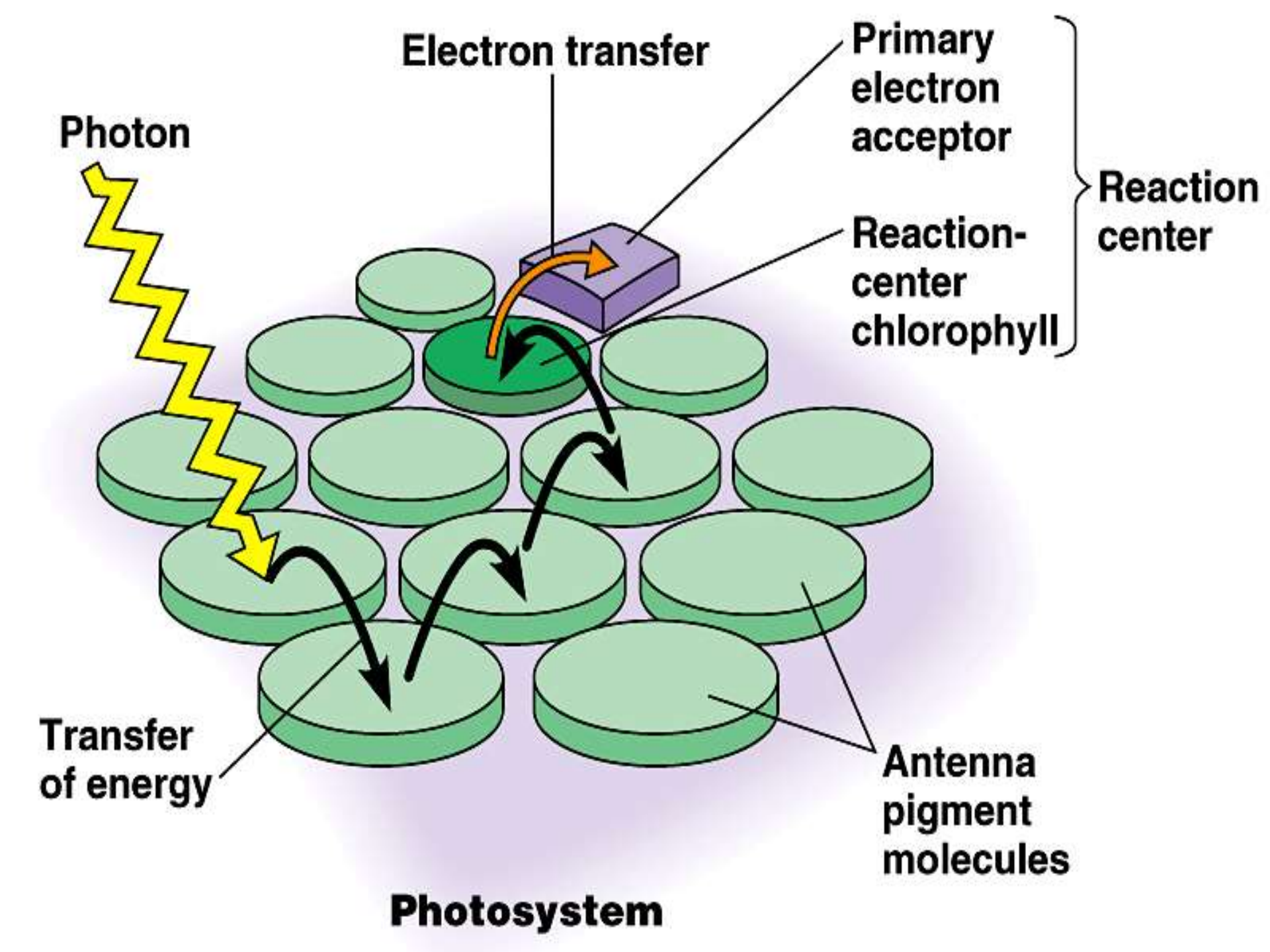

White light
Refracting prism
Chlorophyll solution
Photoelectric tube
Galvanometer
Slit moves to pass light of selected wavelength
Green light
High transmittance (low absorption) of green light because chlorophyll absorbs very little green light
(a)


Blue light
Low transmittance (high absorption) because chlorophyll absorbs most blue light
(b)


Chlorophyll *a*
Chlorophyll *b*
Carotenoids
Absorbance of light by chloroplast pigments
400
500
600
700
Wavelength of light (nm)
(a) Absorption spectra

The Light Reactions

- Occur on thylakoids
- light energy into the chemical energy of ATP and NADPH.
- **How:** When a molecule absorbs a photon of light, one of that molecule's electrons is elevated to an orbital with more potential energy so it is now **Excited.**
- Photons get absorbed by clusters of pigment molecules called **photosystems.**
- made of chlorophyll *a,* chlorophyll *b, a*nd carotenoid pigment molecules.


Electron transfer
Primary electron acceptor
Reaction center
Photon
Reaction-center chlorophyll
Transfer of energy
Antenna pigment molecules
Photosystem

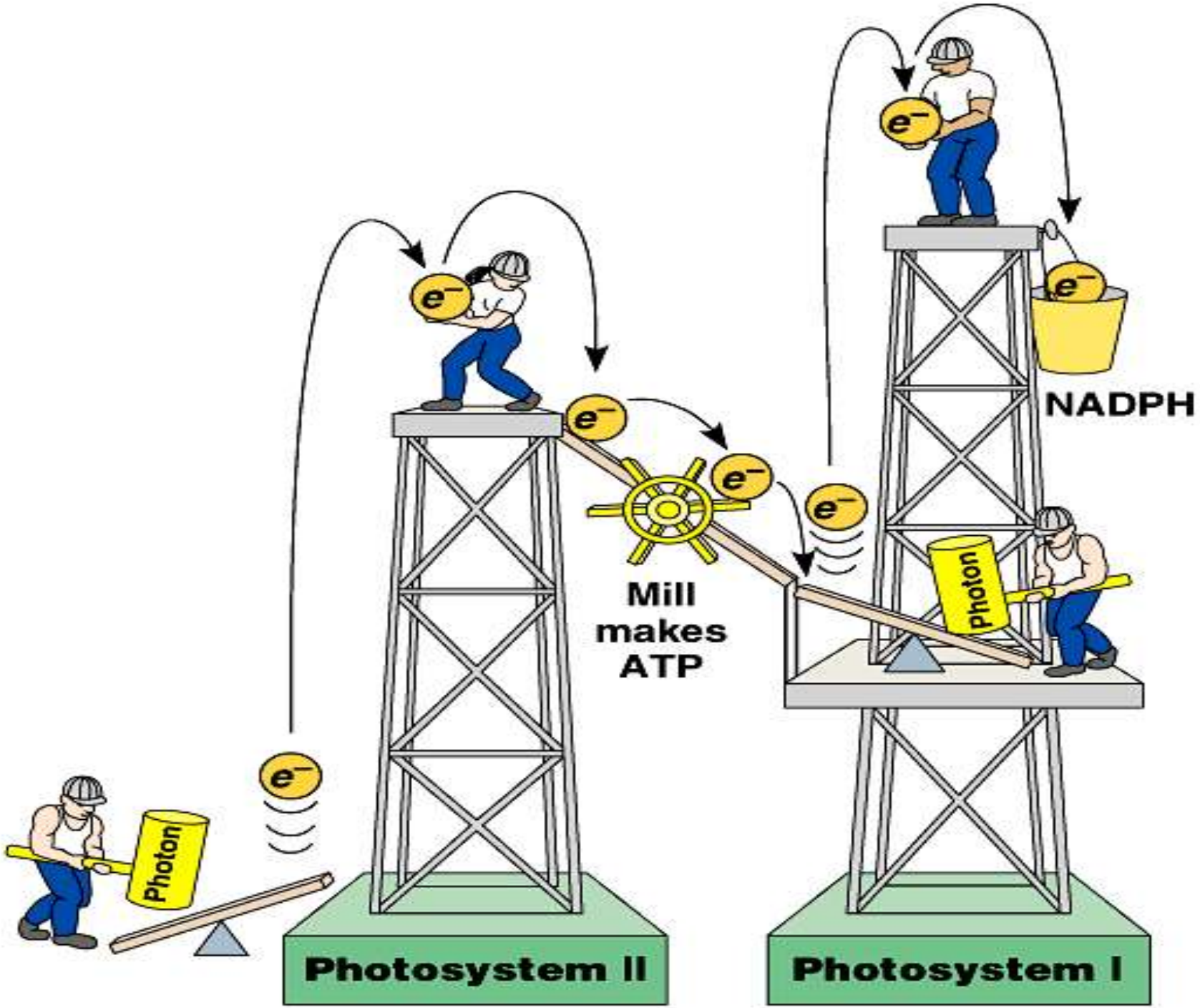
Light Reaction Cont…

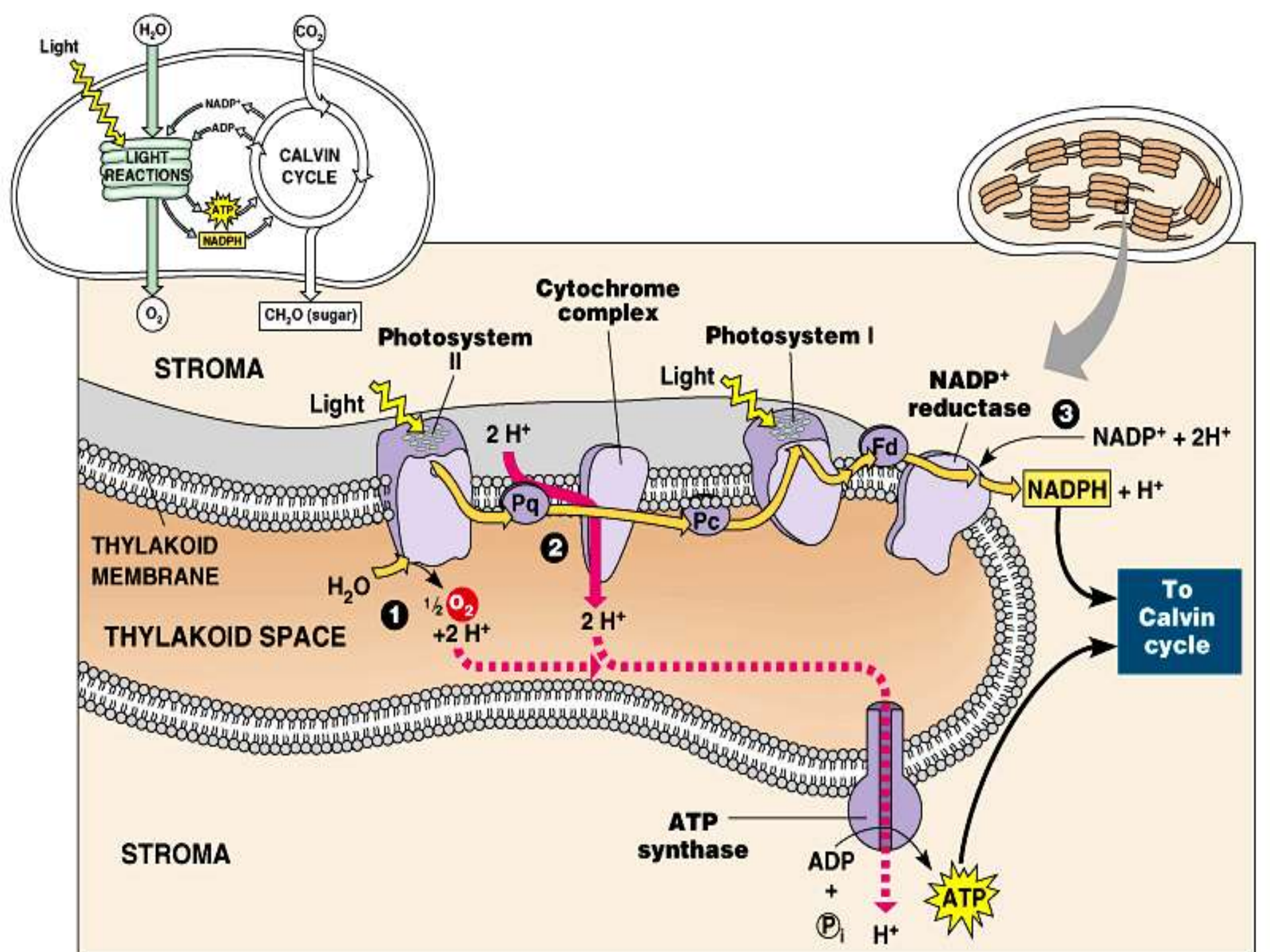
- **Chlorophyll *a* molecule**, the reaction center, absorbs photons from other molecules.

- **Primary electron acceptor** that removes the excited electron from the reaction center or chlorophyll a molecule. **<u>This starts the light reactions</u>**

Light Reaction Cont..

- 2 Kinds of Photosystems:
  - **Photosystem I** -absorption peak at 700nm.
  - **Photosystem II** - peak at 680nm.
- There are 2 routes the excited electron can take the Non-Cyclic path and the Cyclic path
- We focus on Non-Cyclic Path!

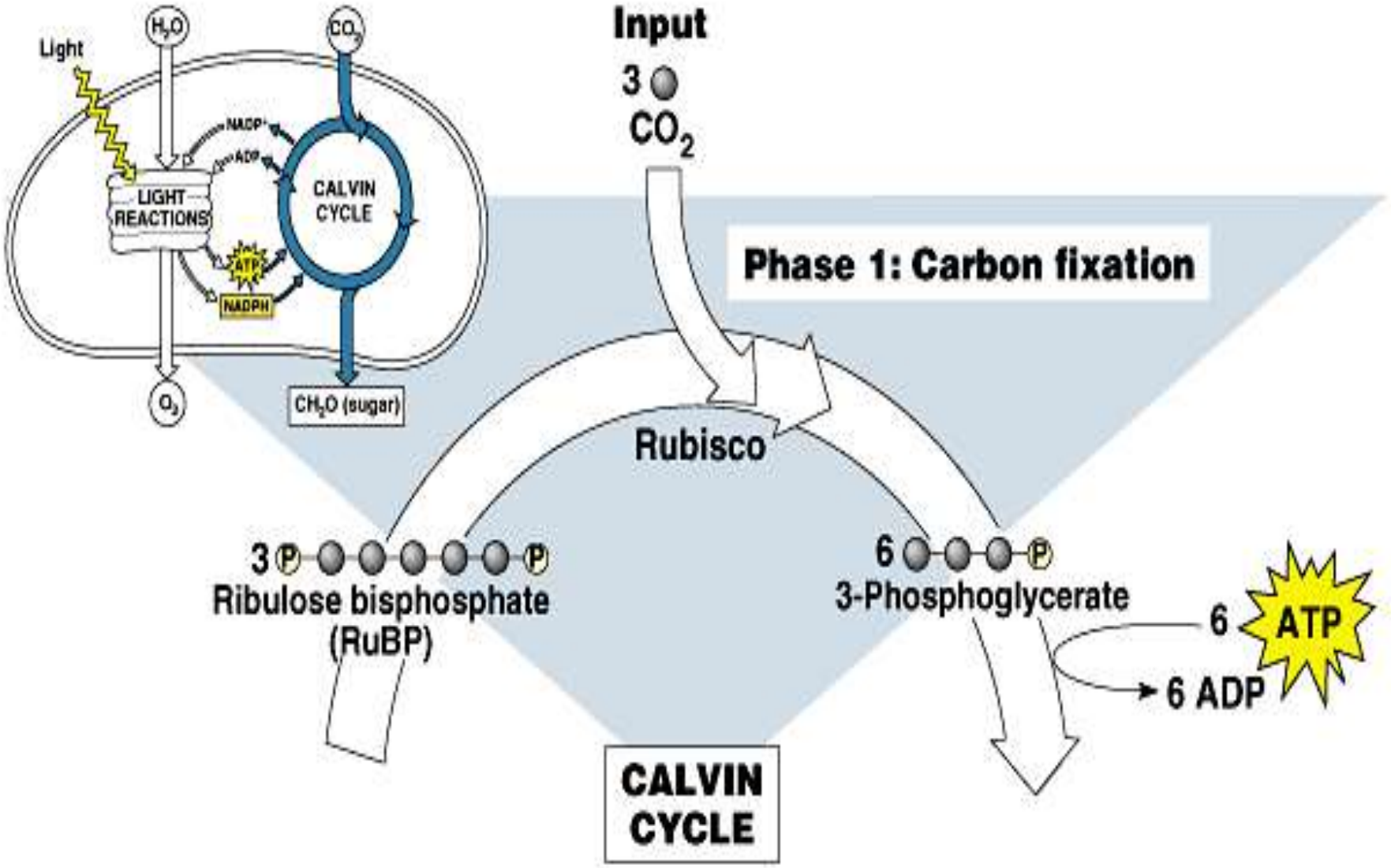

e⁻
e⁻
e⁻
e⁻
e⁻
NADPH
Mill
makes
ATP
Photon
Photon
Photosystem II
Photosystem I


Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
O_2
CH_2O (sugar)
STROMA
Photosystem II
Cytochrome complex
Photosystem I
Light
Light
NADP+ reductase
3
NADP+ + 2H+
Fd
NADPH + H+
2 H+
Pq
Pc
2
THYLAKOID MEMBRANE
H_2O
1
$\frac{1}{2}$ O_2 +2 H+
2 H+
THYLAKOID SPACE
To Calvin cycle
ATP synthase
STROMA
ADP + P_i
H+
ATP

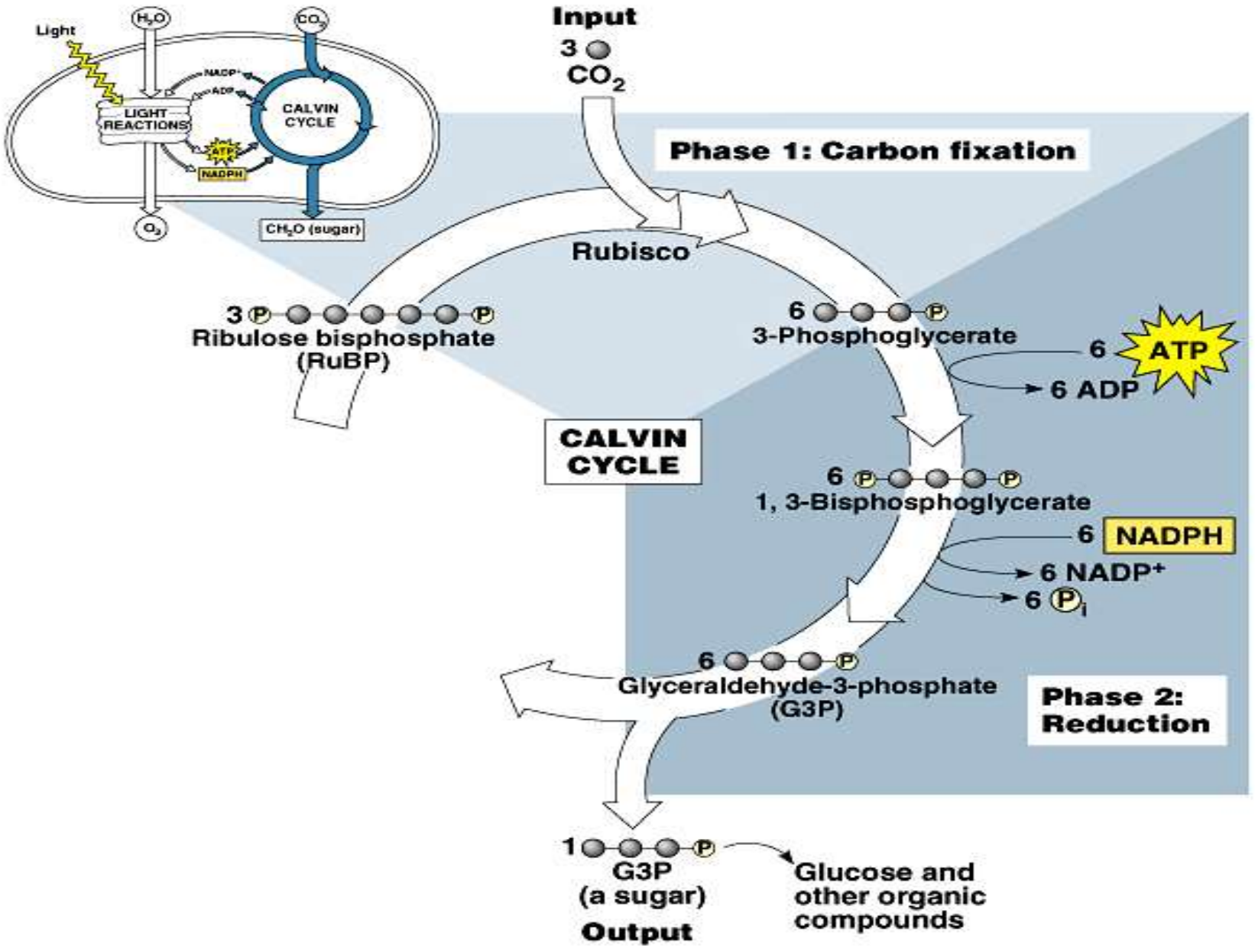
Dark Reactions (The Calvin Cycle)

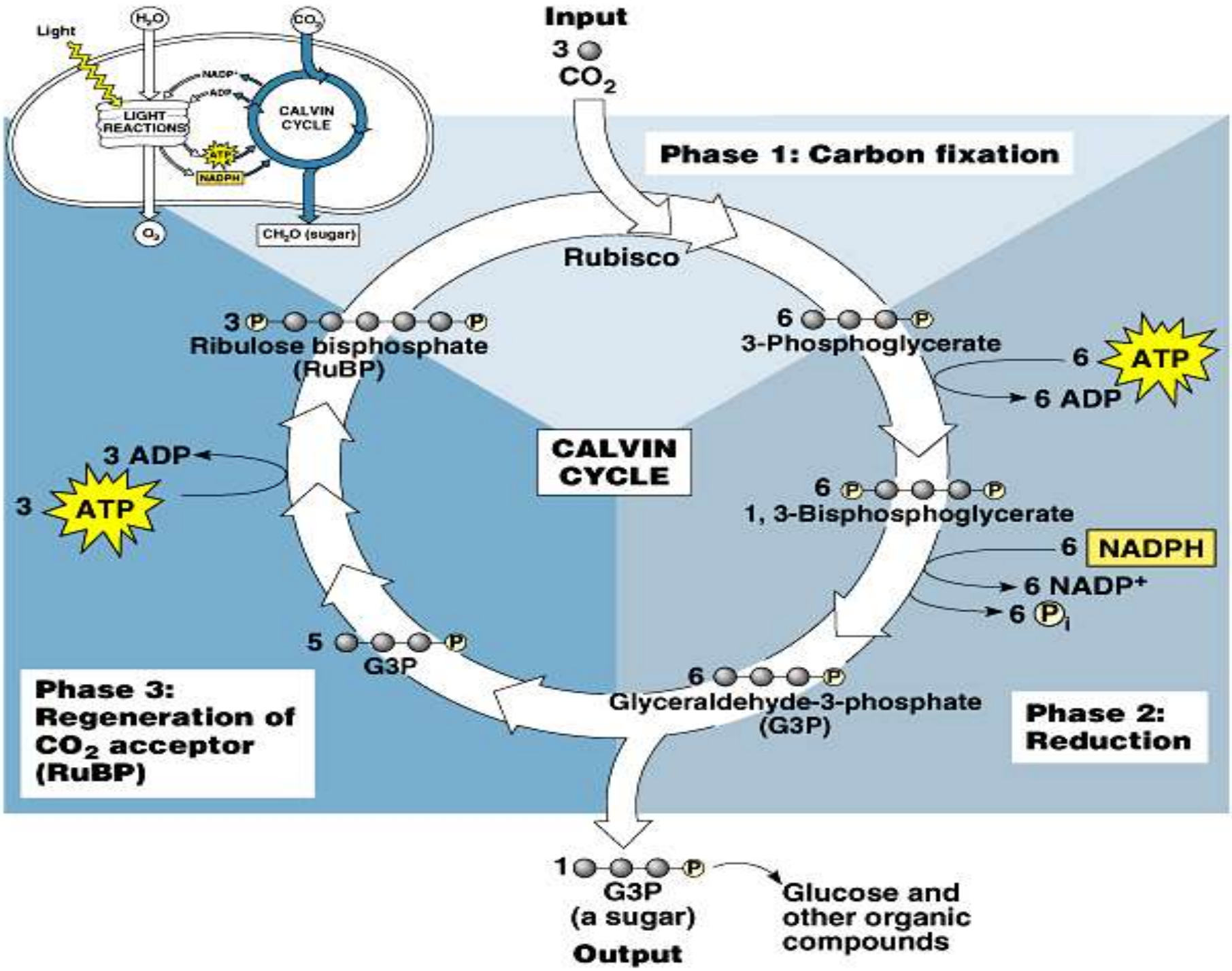
- CO_2 enters the cycle and leaves as sugar.
- Uses the energy in the ATP and NADPH
- Sugar product of the Calvin cycle is **not** glucose
  - **glyceraldehyde-3-phosphate** (**G3P**).

Phase 1


Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
O_2
CH_2O (sugar)
Input
3
CO_2
Phase 1: Carbon fixation
Rubisco
3
Ribulose bisphosphate (RuBP)
6
3-Phosphoglycerate
6
ATP
6 ADP
CALVIN CYCLE

Phase 2 Reduction Phase




Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
O_2
CH_2O (sugar)
Input
3 CO_2
Phase 1: Carbon fixation
Rubisco
3 Ribulose bisphosphate (RuBP)
6 3-Phosphoglycerate
6 ATP
6 ADP
CALVIN CYCLE
3 ADP
3 ATP
6 1, 3-Bisphosphoglycerate
6 NADPH
6 NADP+
6 P_i
5 G3P
6 Glyceraldehyde-3-phosphate (G3P)
Phase 3: Regeneration of CO_2 acceptor (RuBP)
Phase 2: Reduction
1 G3P (a sugar)
Output
Glucose and other organic compounds

There is more then one way to skin a cat C3,C4, and CAM Plants

- C3- What you just learned
- C4- 19 families use this mode
- Crassulacean Acid Metabolism- Desert plants
- **Read pg 200-203!!!**

References

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- Microsoft Encarta Encyclopedia 2004
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