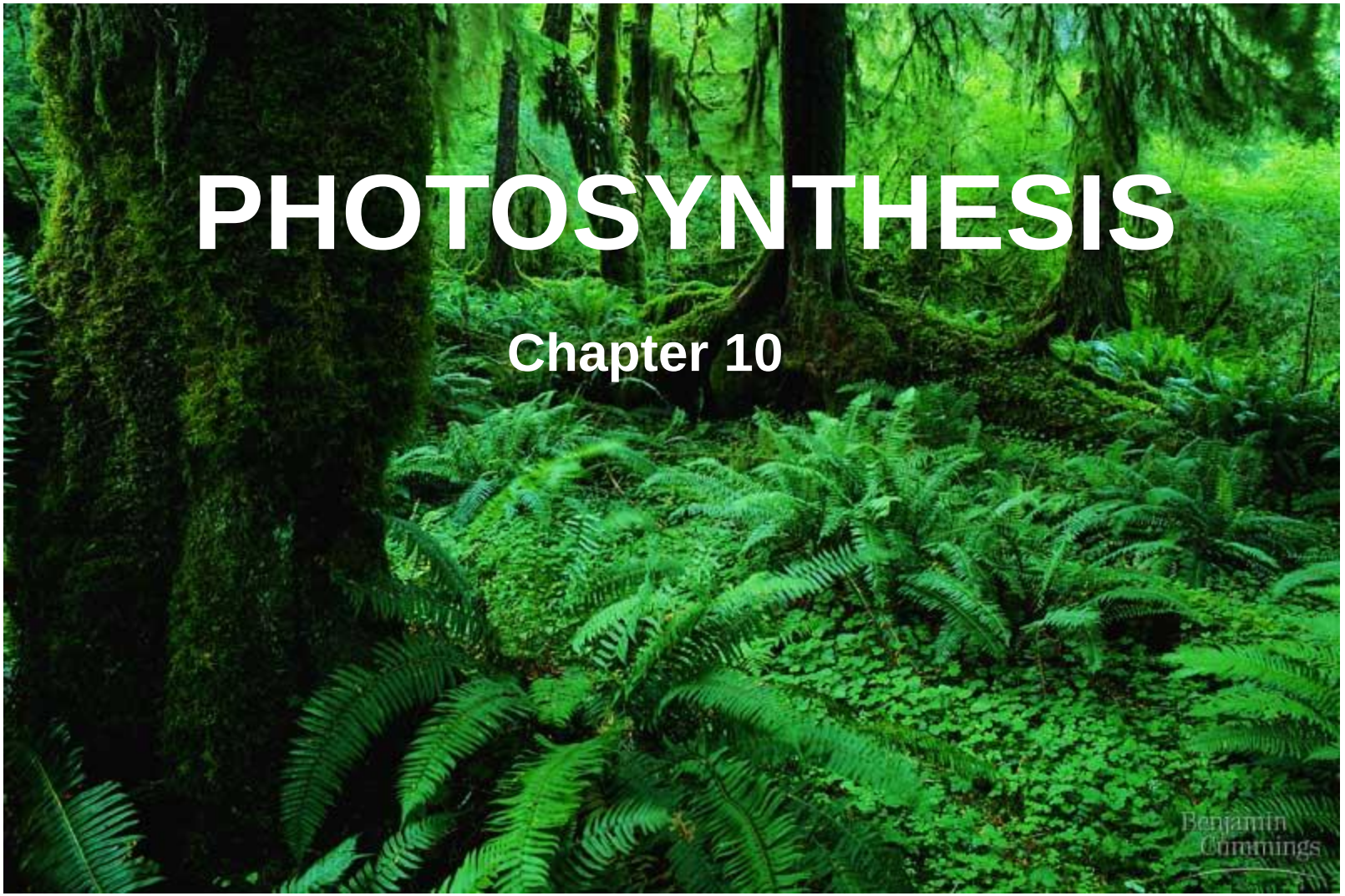

PHOTOSYNTHESIS
Chapter 10
Benjamin
Cummings

Modes of Nutrition

- **Autotrophs** – "_____"
  - Capture _____ from physical sources in the environment
    - Photosynthetic organisms = sunlight
    - Chemosynthetic organisms = small inorganic molecules (occurs in absence of oxygen)
  - Produce _____ from _____ and other inorganic raw materials from the environment
  - Are _____ of the biosphere

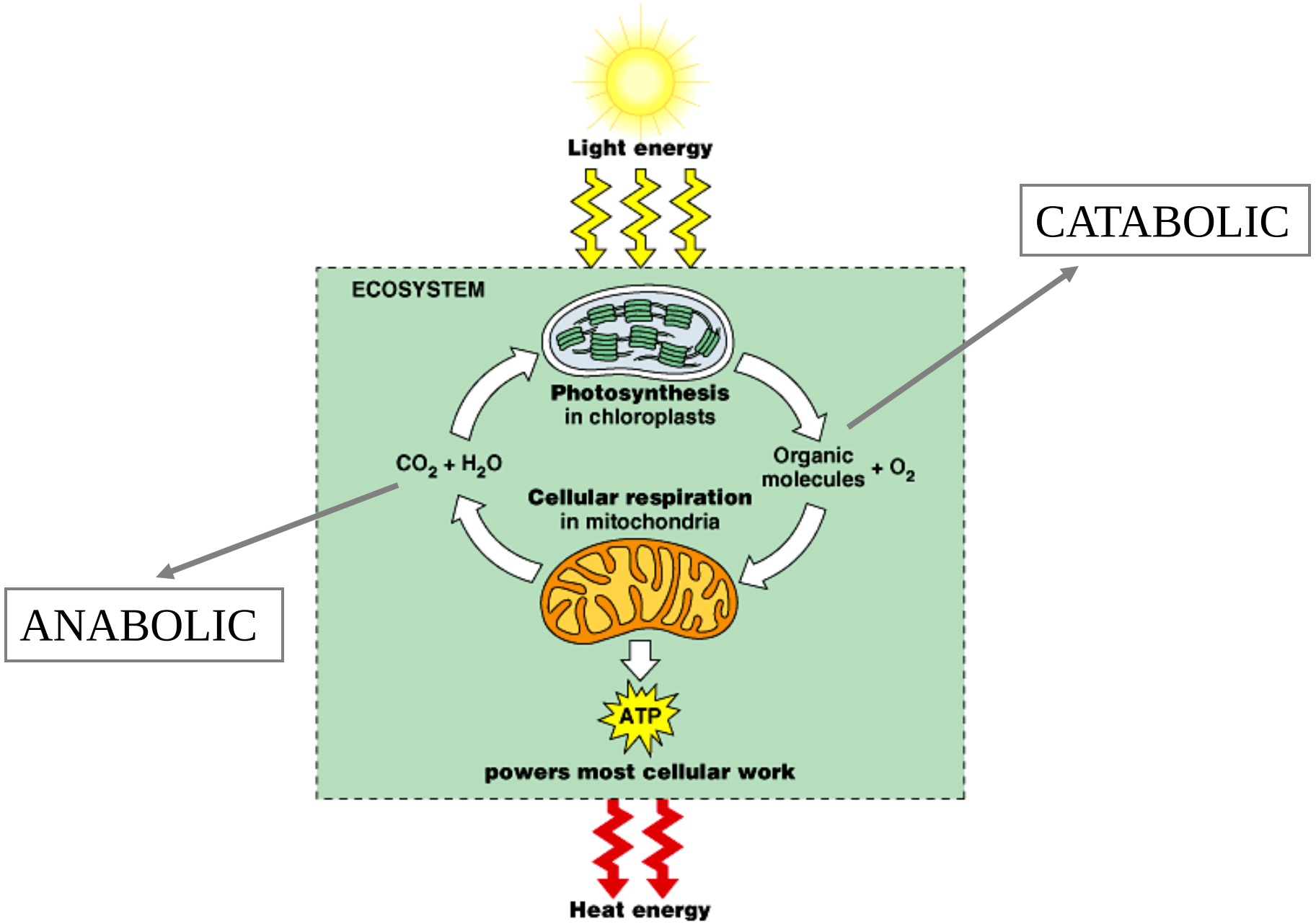
Modes of Nutrition

- **Heterotrophs** – "_____"
  - Captures free energy present in _____ produced by other organisms
  - Metabolize carbohydrates, lipids, and proteins by hydrolysis as sources of free energy
  - _____ of the biosphere

Photosynthesis & Cellular Respiration

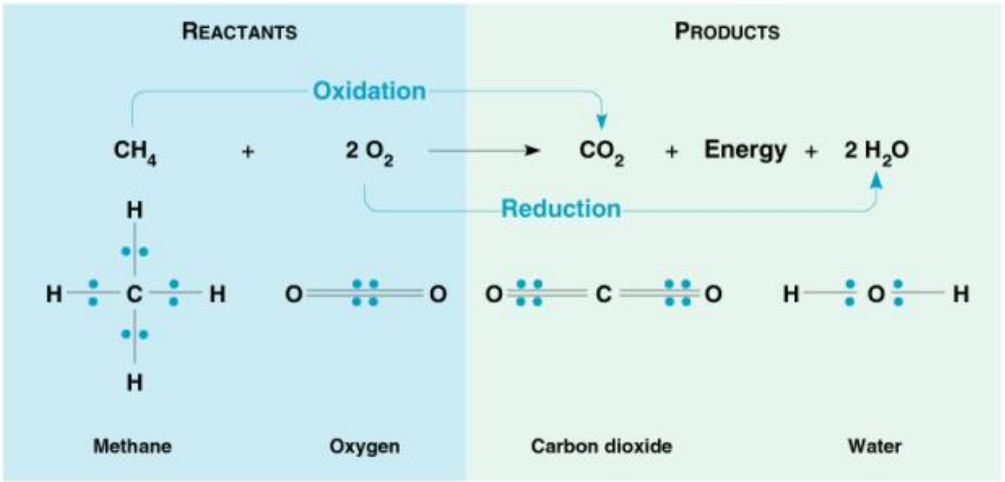
- Photosynthesis is the conversion of _____
_____

- Cellular respiration is the harvesting of **ENERGY** in the _____
_____



Oxidation-reduction (Redox) Reactions

-
  - OIL RIG (adding electron reduces + charge)
- Reducing agent is electron donor and Oxidizing agent is electron acceptor



Structure of a plant

- How they obtain the raw materials for photosynthesis:
  - **Sunlight**
    - Leaves = solar collectors
  - **CO2**
    - _____ = gas exchange
  - **H2O**
    - Uptake from roots
  - **Nutrients**
    - Uptake from roots

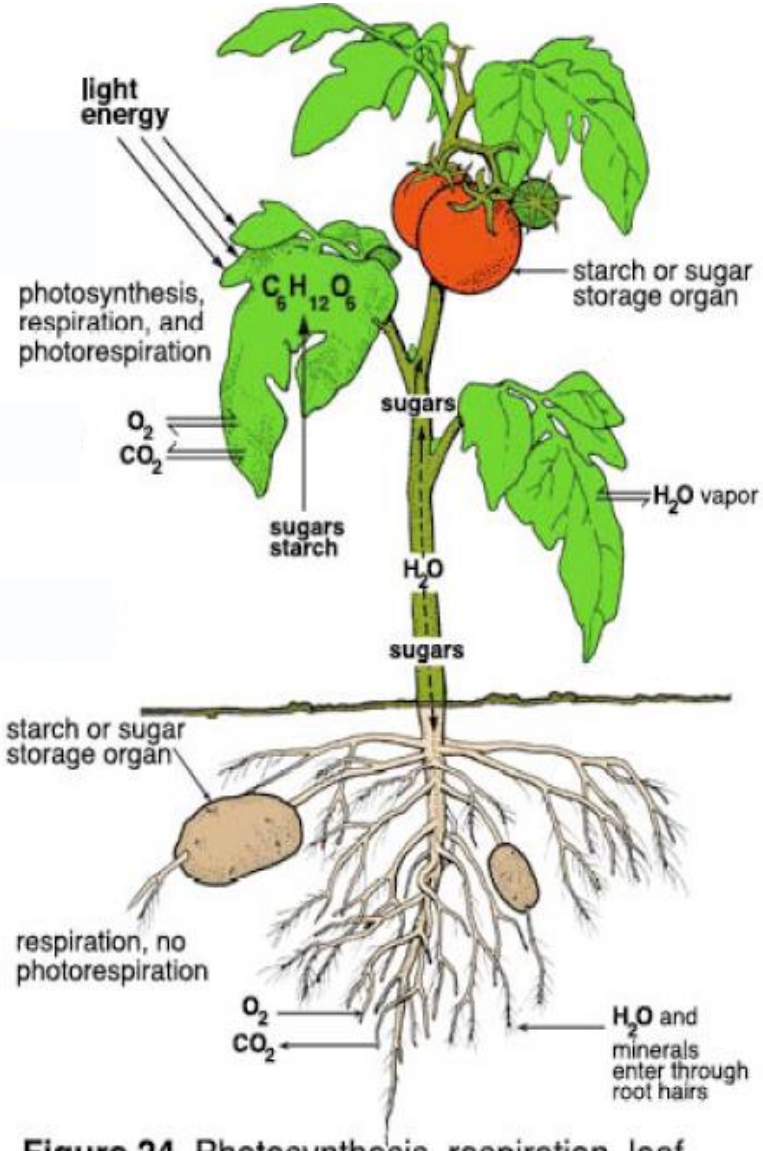
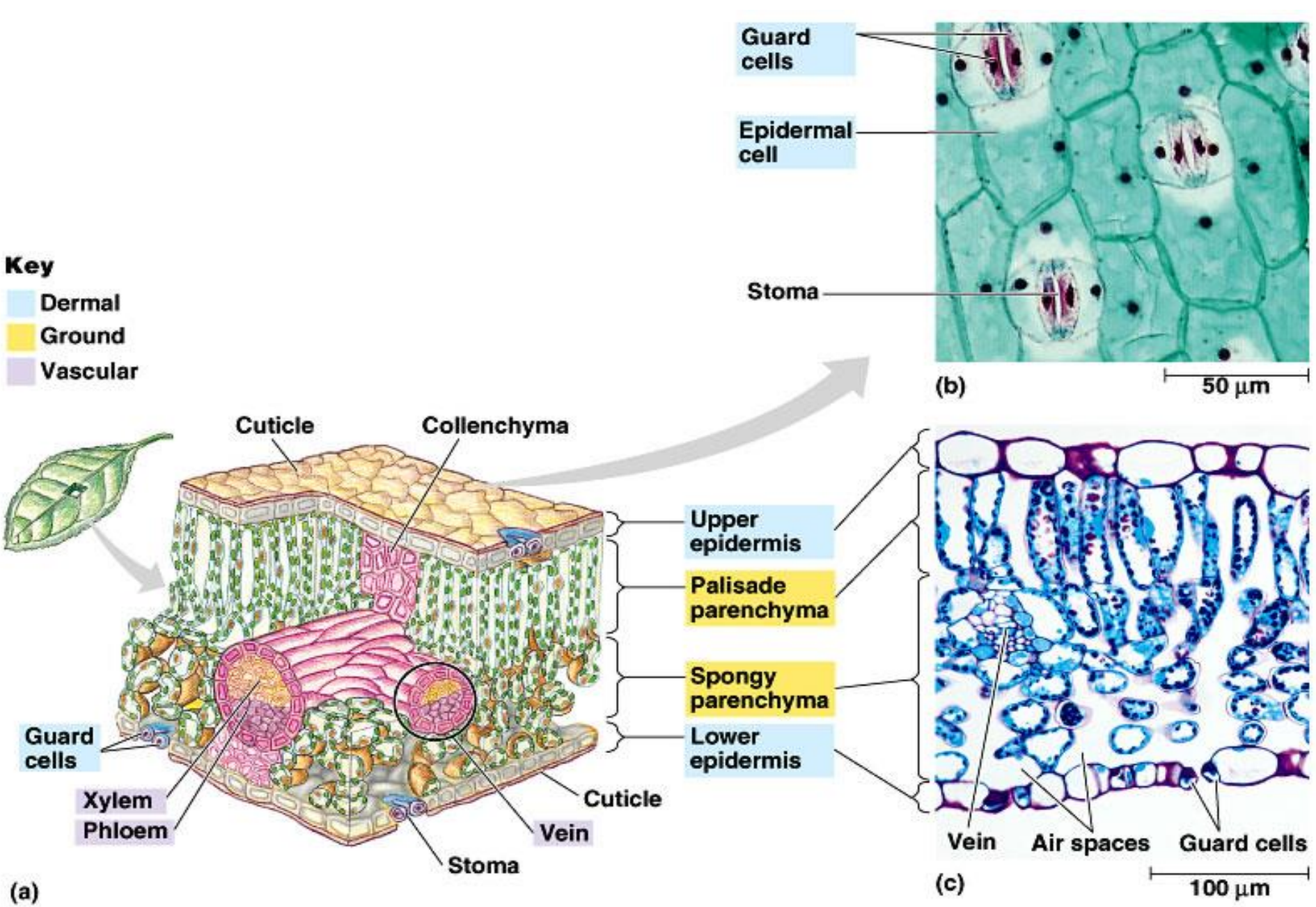


Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.



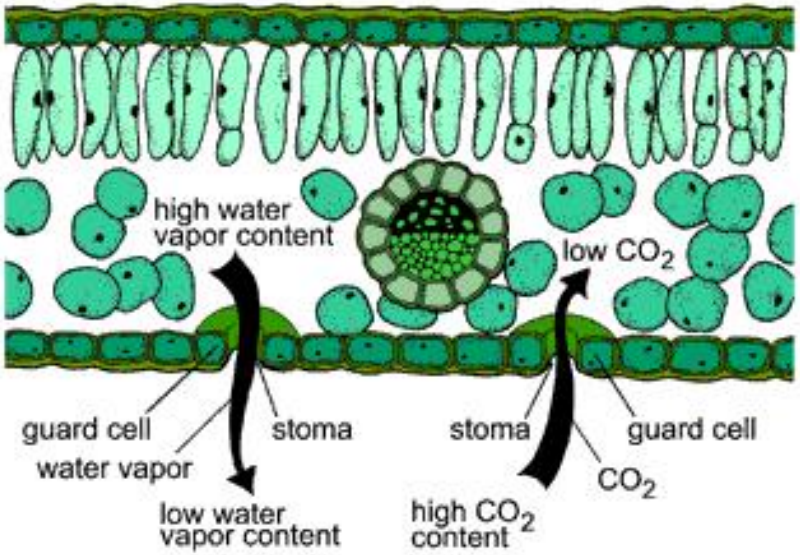
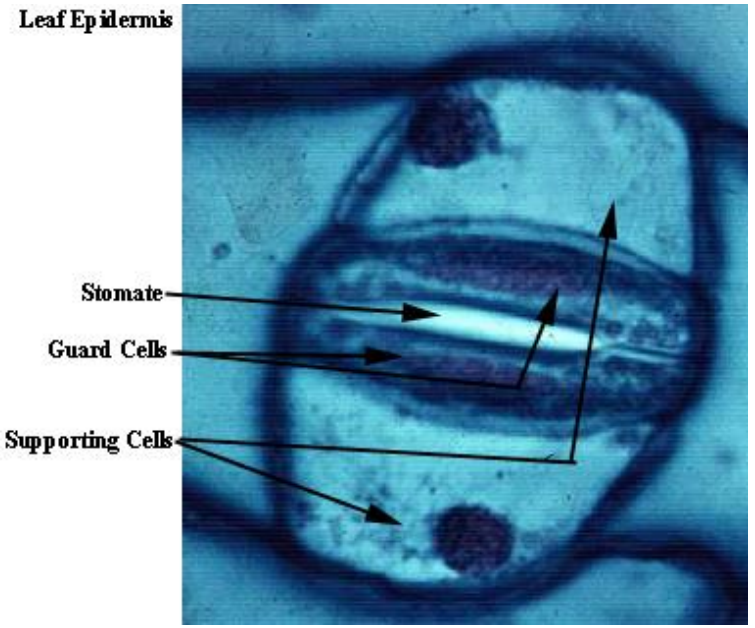
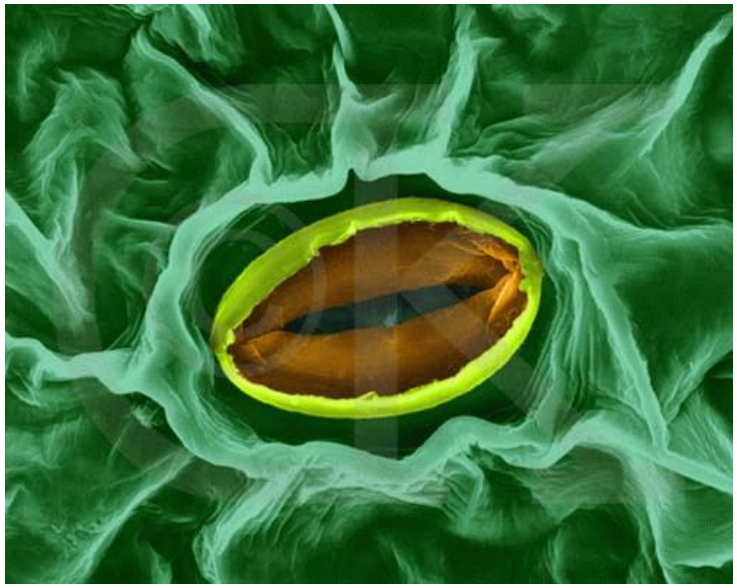
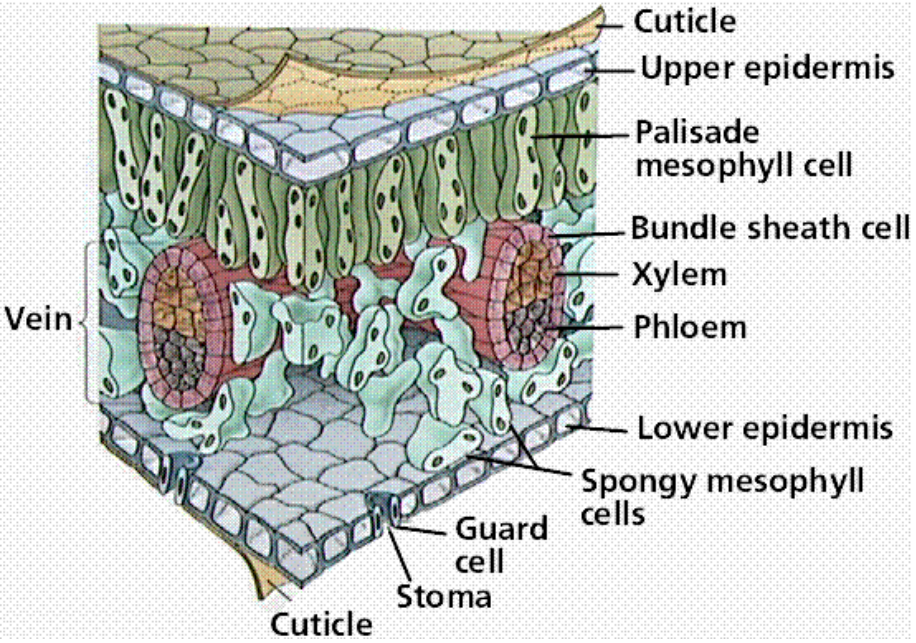


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

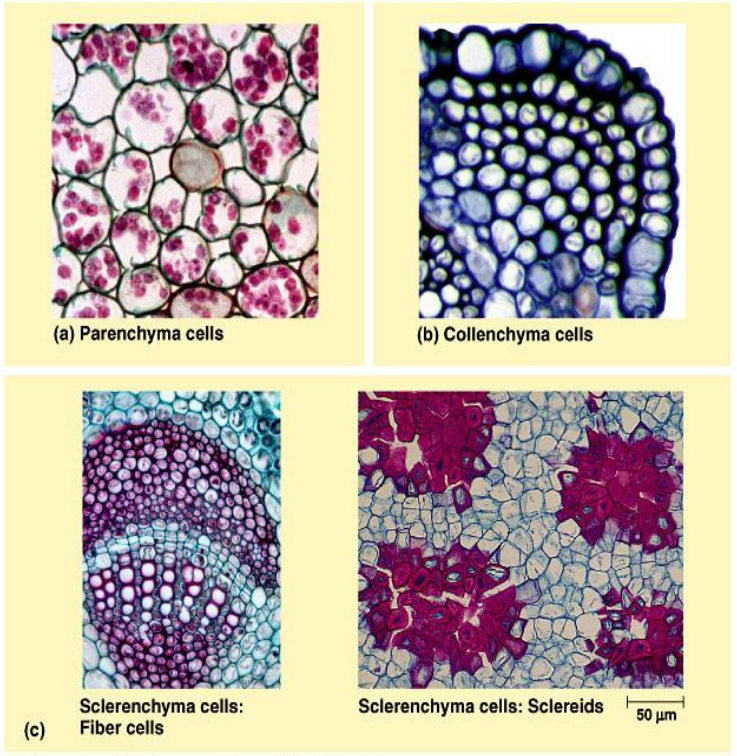






Plant Tissue Cell Types

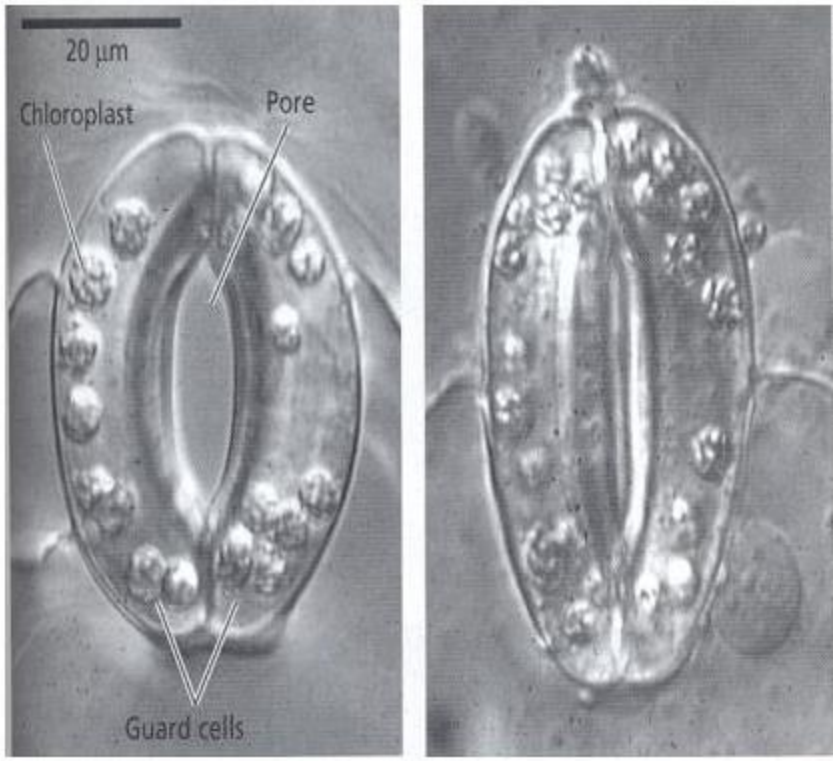
- Parenchyma
  - primary walls thin and flexible; no secondary walls; large central vacuole; most metabolic functions of plant (chloroplasts)
- Collenchyma
  - unevenly thick primary walls used for plant support (no secondary walls ; no lignin)
- Sclerenchyma
  - support element strengthened by secondary cell walls with lignin (may be dead; xylem cells); fibers and sclereids for support

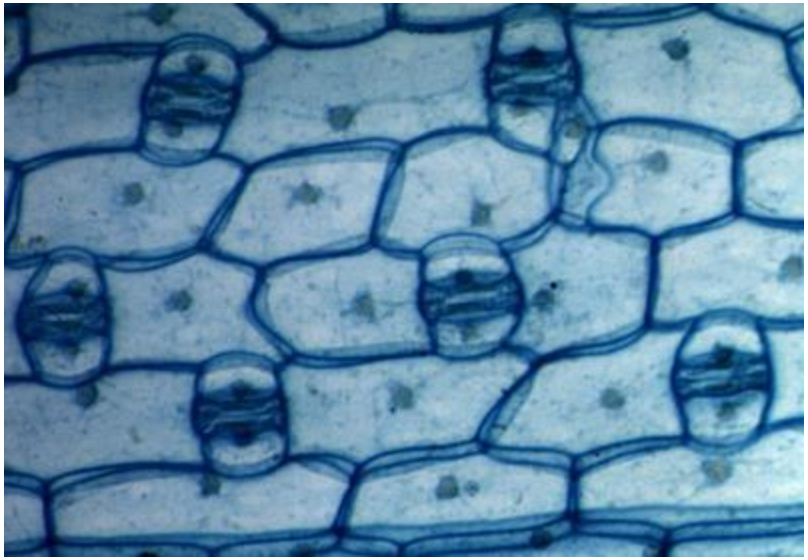


Primary Tissues of Leaves

- Epidermis/cuticle (protection; desiccation)
- *Stomata* (tiny pores for _____ and transpiration)/*guard cells*
- *Mesophyll*: ground tissue between upper and lower epidermis (parenchyma with chloroplasts);
  - palisade (most _____) and spongy (gas circulation)

STOMATA





Overview

- Photosynthesis is the conversion of light energy into chemical bond energy

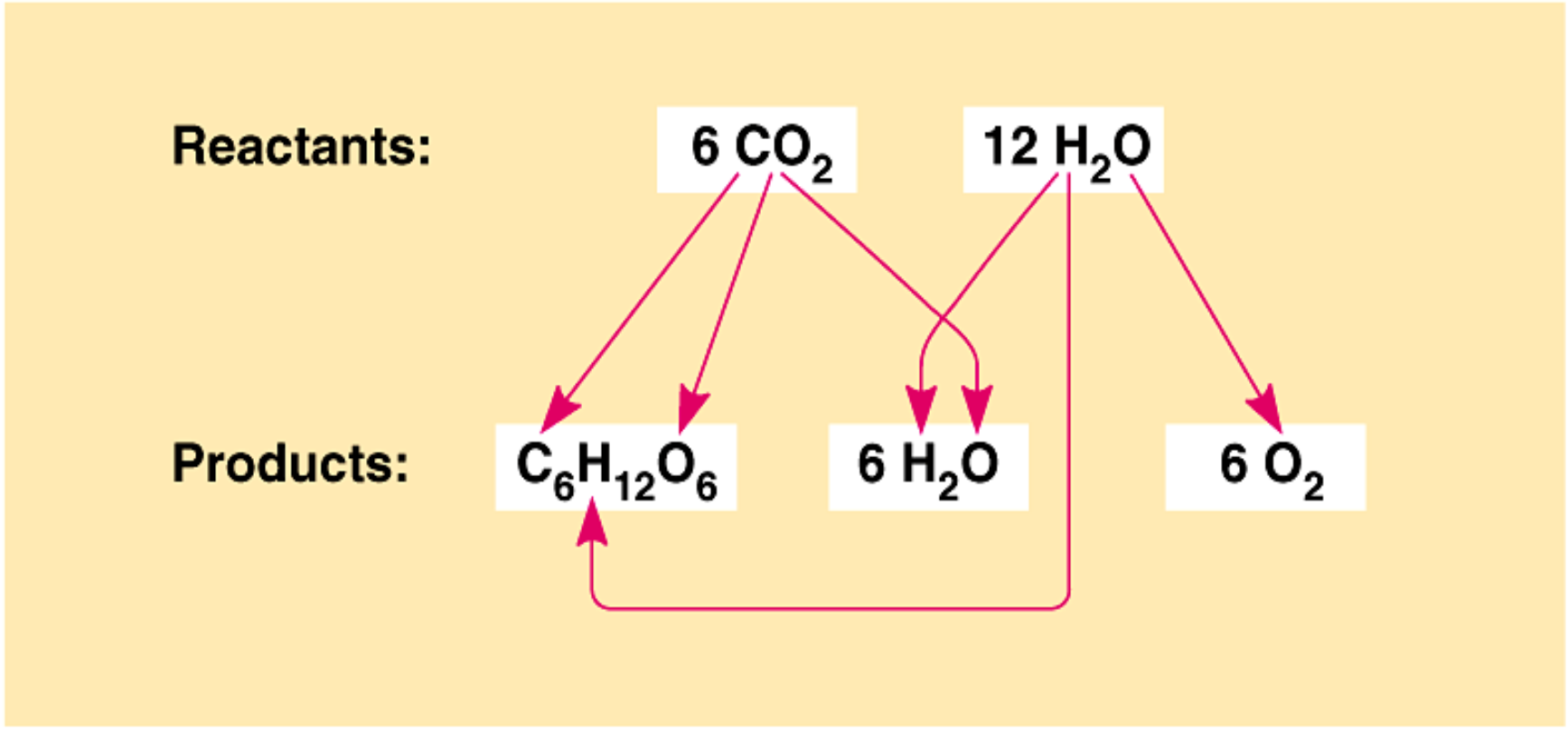
  $6\ CO_2 + 12\ H_20 \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_20$

  – This is the reverse of cellular respiration; thus, photosynthesis & cellular respiration are coupled reactions.

  – It occurs in two stages:

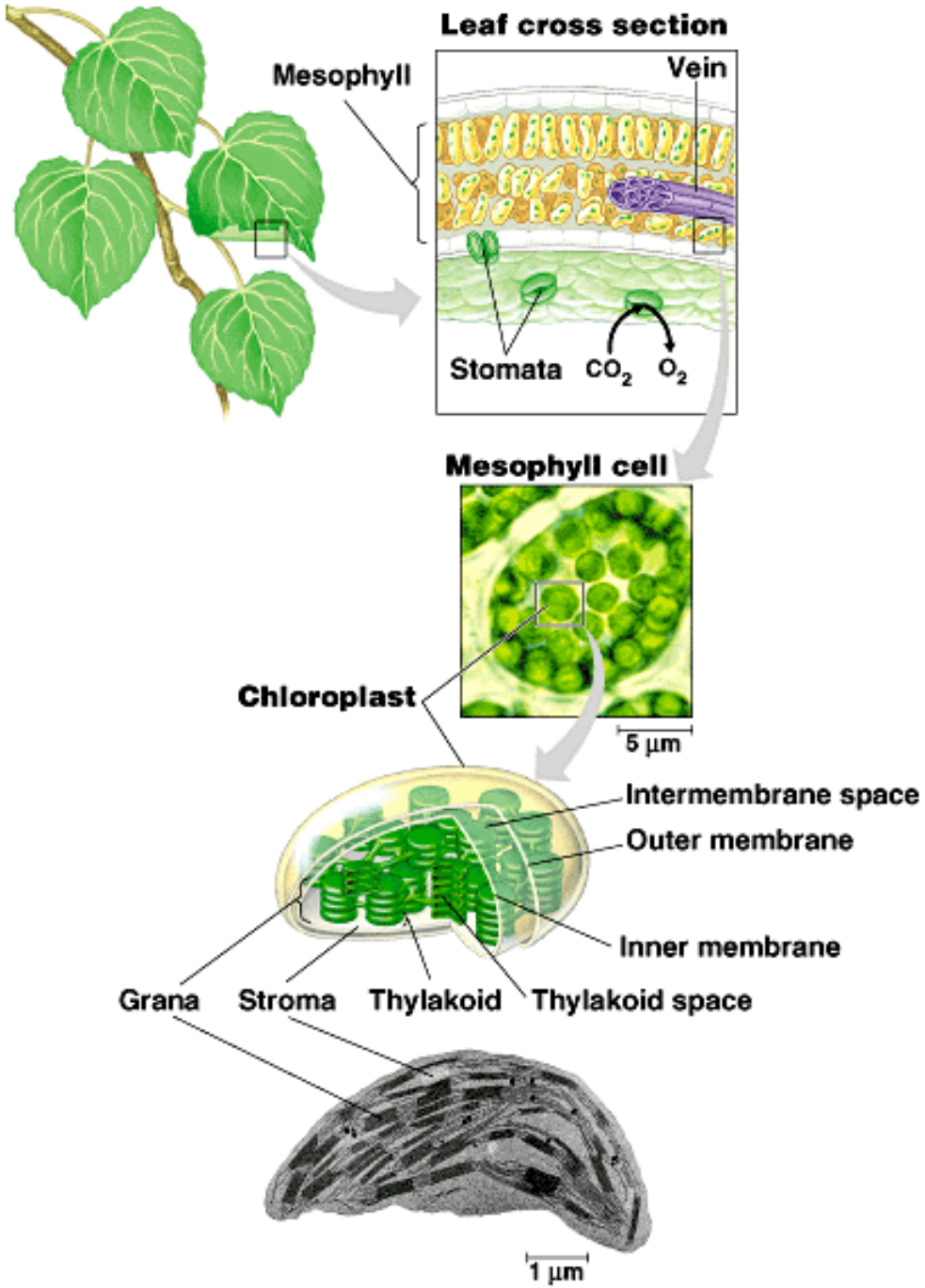
    - Light Reactions – in the thylakoid space
    - Calvin Cycle – in the stroma

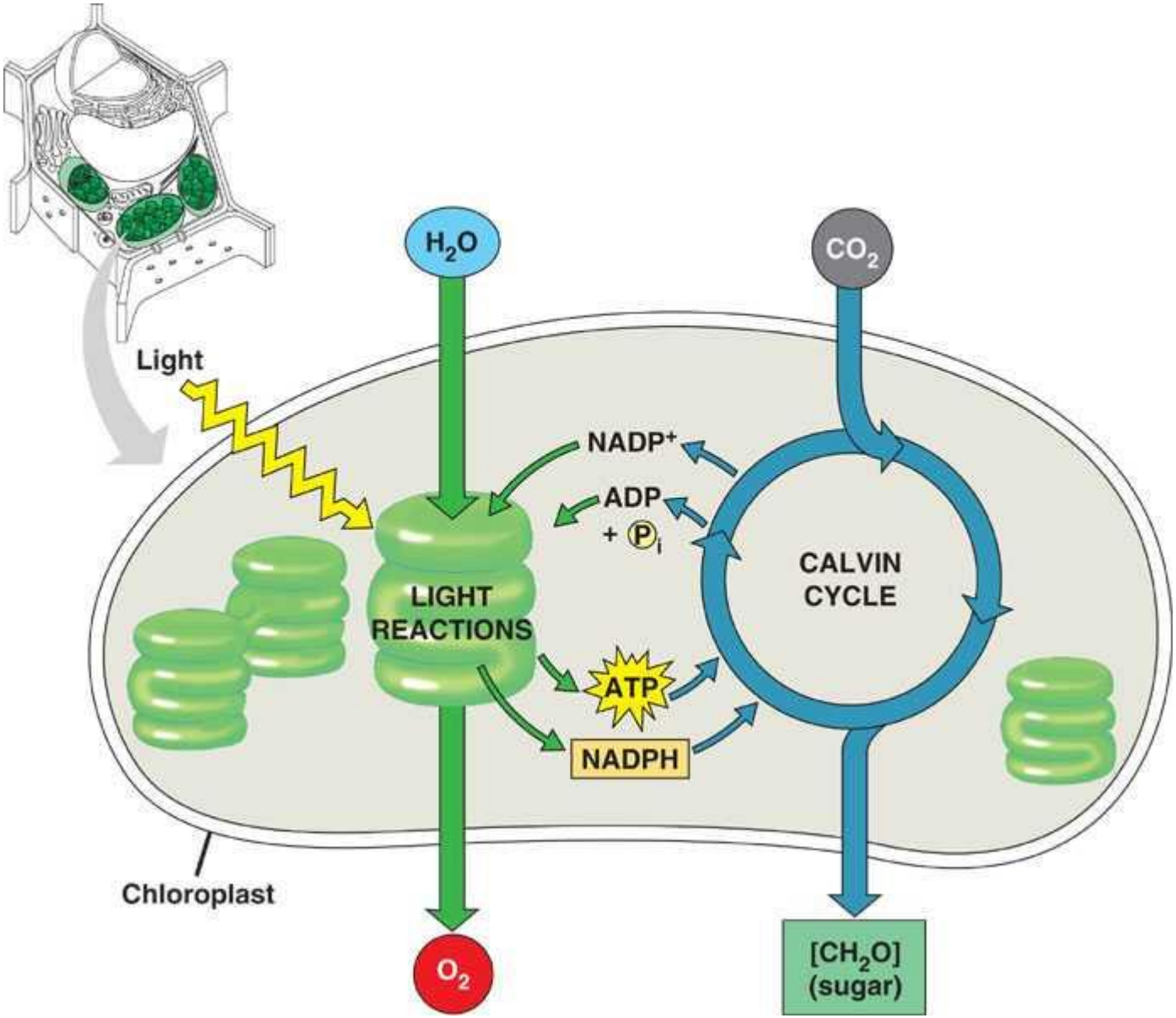
Tracking Atoms in Photosynthesis



Where does it occur?

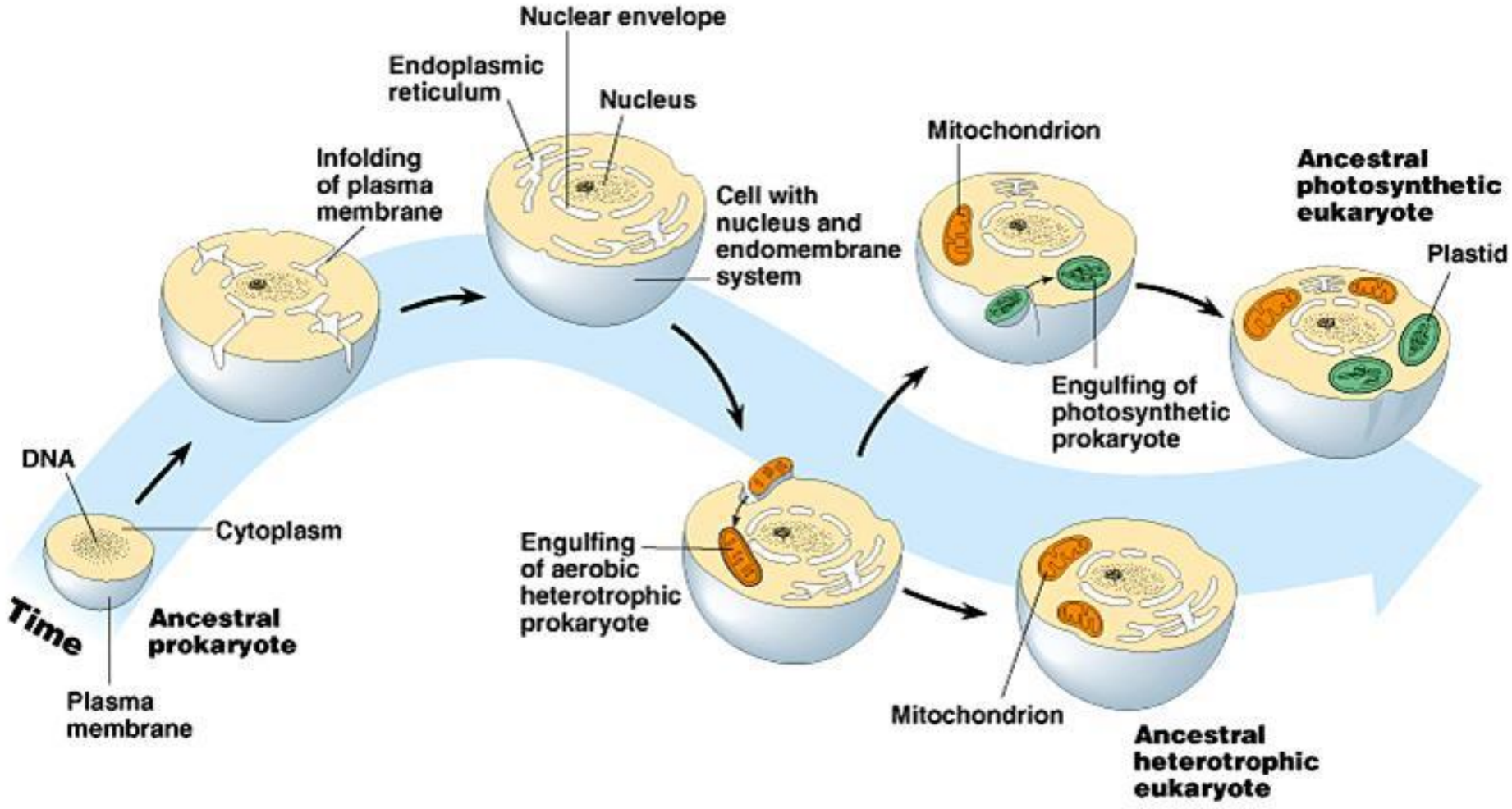
- Chloroplasts – photosynthetic organelles
  - All green parts of a plant contain chloroplasts
  - Divided into 3 distinct compartments:
    - **Intermembrane space**: separates the _____ _____chloroplast membrane
    - **Thylakoid space**: consists of stacks of thylakoids which are arranged in stacks called grana; _____
      - Light reactions occur here
    - **Stroma**: viscous (thick) _____ outside the thylakoids
      - Calvin cycle occurs here




H2O
CO2
Light
NADP+
ADP
+ Pi
LIGHT
REACTIONS
CALVIN
CYCLE
ATP
NADPH
Chloroplast
O2
[CH2O]
(sugar)

How did chloroplasts and mitochondria get into the plant cell?

- Endosymbiotic Theory
  - The arise of eukaryotic cells from _____ cells
  - First, _____ was formed from infolding of plasma membrane
  - Second, aerobic heterotrophic _____ was engulfed by another bacteria
  - Third, some of the cells engulfed photosynthetic bacteria
- Cells may have begun as prey or parasites, but a _____ relationship resulted



Nature of Light

- Visible light's wavelength stretches from 380nm to 750nm.

- The visible range of light is the radiation that drives photosynthesis.

- Light consists of particles called _____ which are fixed quantities of energy.

- What happens when chlorophyll & other pigments absorb photons?
  - When a molecule of a pigment (color) absorbs a photon, one of the molecules' _____ **is elevated** to an orbital or energy level where it has _____ **potential energy**
    - Increase wavelength; decrease energy
    - Decrease wavelength; increase energy

Ground State vs Excited State Electrons

- **Ground State** – electron is in its normal orbital

- **Excited State** – an electron in its higher energy orbital; occurs after the absorption of a photon; very unstable.

Light Reactions

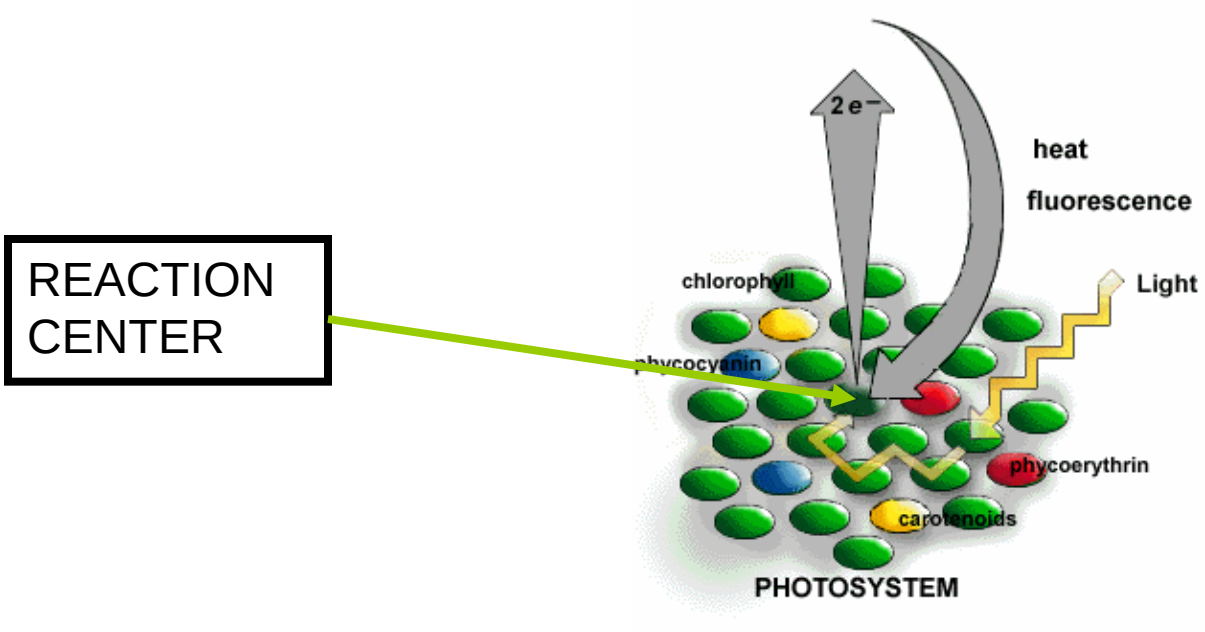
- Reactions that convert light energy to chemical bond energy in _____ and _____.
  - Occur in the _____ membranes of chloroplasts
  - _____ (gain electrons) $NADP^+$ to _____
  - Give off _____ as a by-product from the _____
  - Generate ATP through photophosphorylation

Photosystems

- Chlorophyll molecules are organized in the thylakoid membrane into photosystems
  - **Photosystem structure**:
    - **Reaction center** surrounded by light harvesting complexes
      - _____ = protein complex that includes 2 chlorophyll a molecules and a primary electron acceptor
      - In chlorophyll, the acceptor molecule functions as a dam, _____ the flow of electrons to plunge immediately back to their _____

– **<u>Photosystem structure</u>**:

- **<u>Light harvesting complex</u>** = chlorophyll a, chlorophyll b, & carotenoids bound to proteins
  - Acts as an _____ for the reaction center to absorb light



Photosystems I & II

- Thylakoid membrane has two photosystems (II and I) – named in order of discovery, but PHOTOSYSTEM II functions first followed by Photosystem I

- **<u>Photosystem II</u>**:
  - Reaction center = _____ chlorophyll a (functions best at wavelengths of 680nm of light)
- **<u>Photosystem I</u>**:
  - Reaction center = _____ chlorophyll a (functions best at wavelengths of 700nm of light)

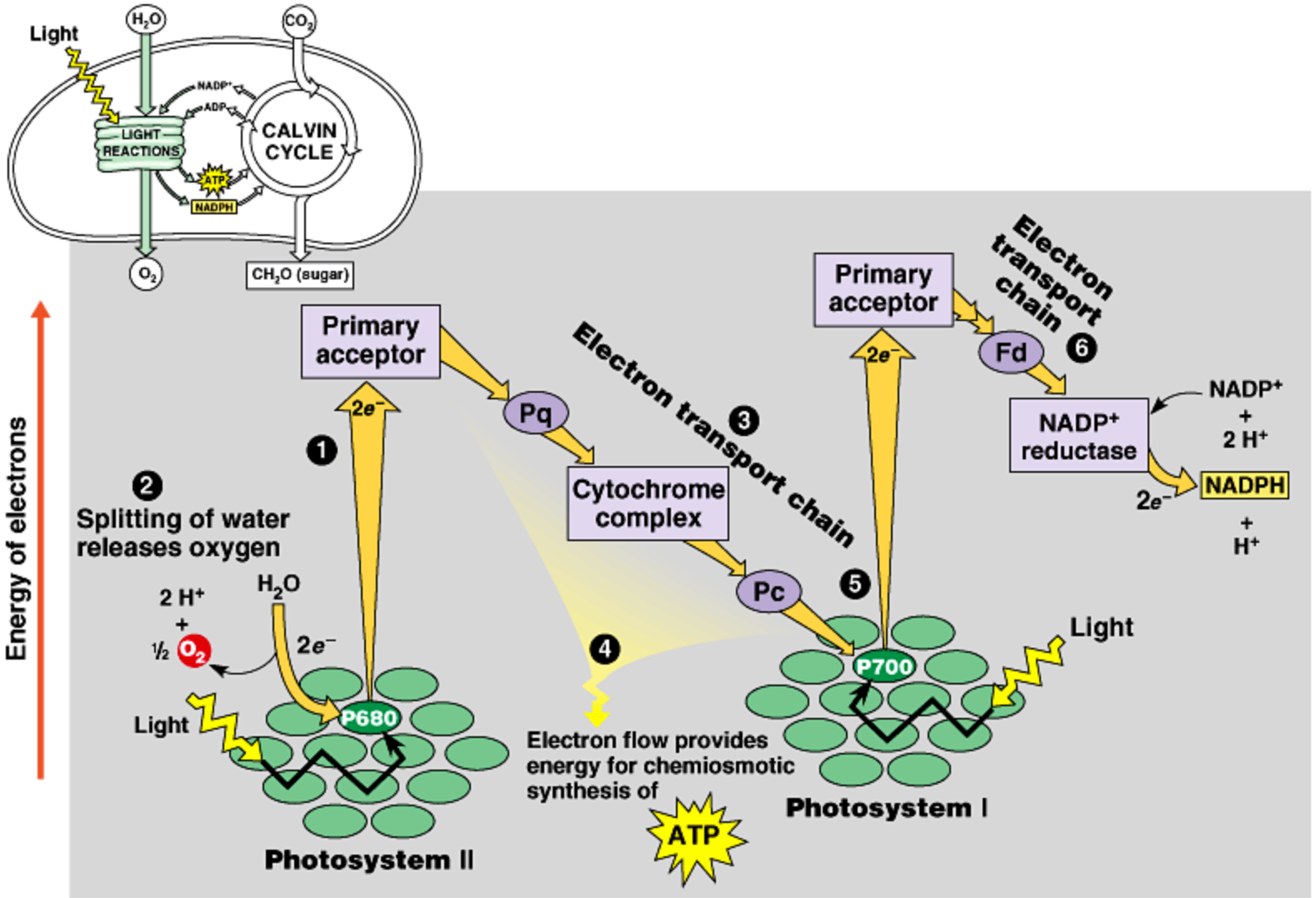
Photosystem II

- **<u>Non-cyclic electron flow</u>** – electrons pass _____ from _____ and _____to _____

- P680 absorbs light with a wavelength best of 680nm and _____ electrons in the chlorophyll
- Passes the electrons to _____

Photosystem II

- P680 gains back the _____ _____ by splitting H_20 – this also creates O_2.
- As the excited electrons slide down the chain connecting photosystem II with photosystem I, the chain _____ across the thylakoid membrane to the thylakoid space.
  - The build up of H+ can then drive ATP synthesis: _____



Photosystem I

- P700 – absorbs light with a wavelength of 700nm
- Light energy _____ in the chlorophyll, which is passed along the more of the protein chain
- Electrons from Photosystem II are used to replace the lost electron
- 2 electrons are used to make _____

Photosystem I

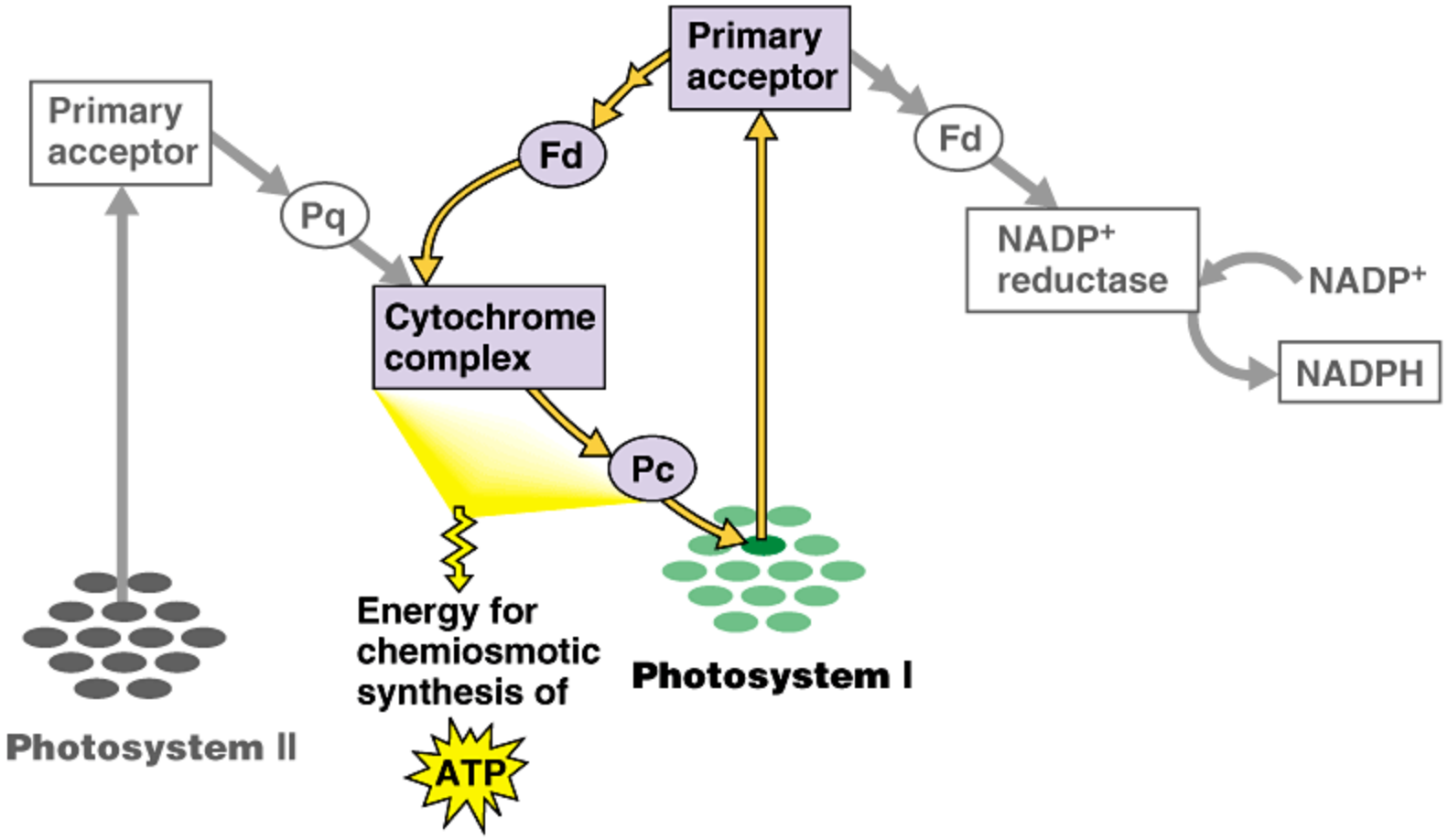
<u>Cyclic electron flow</u> – alternative pathway that just involves _____

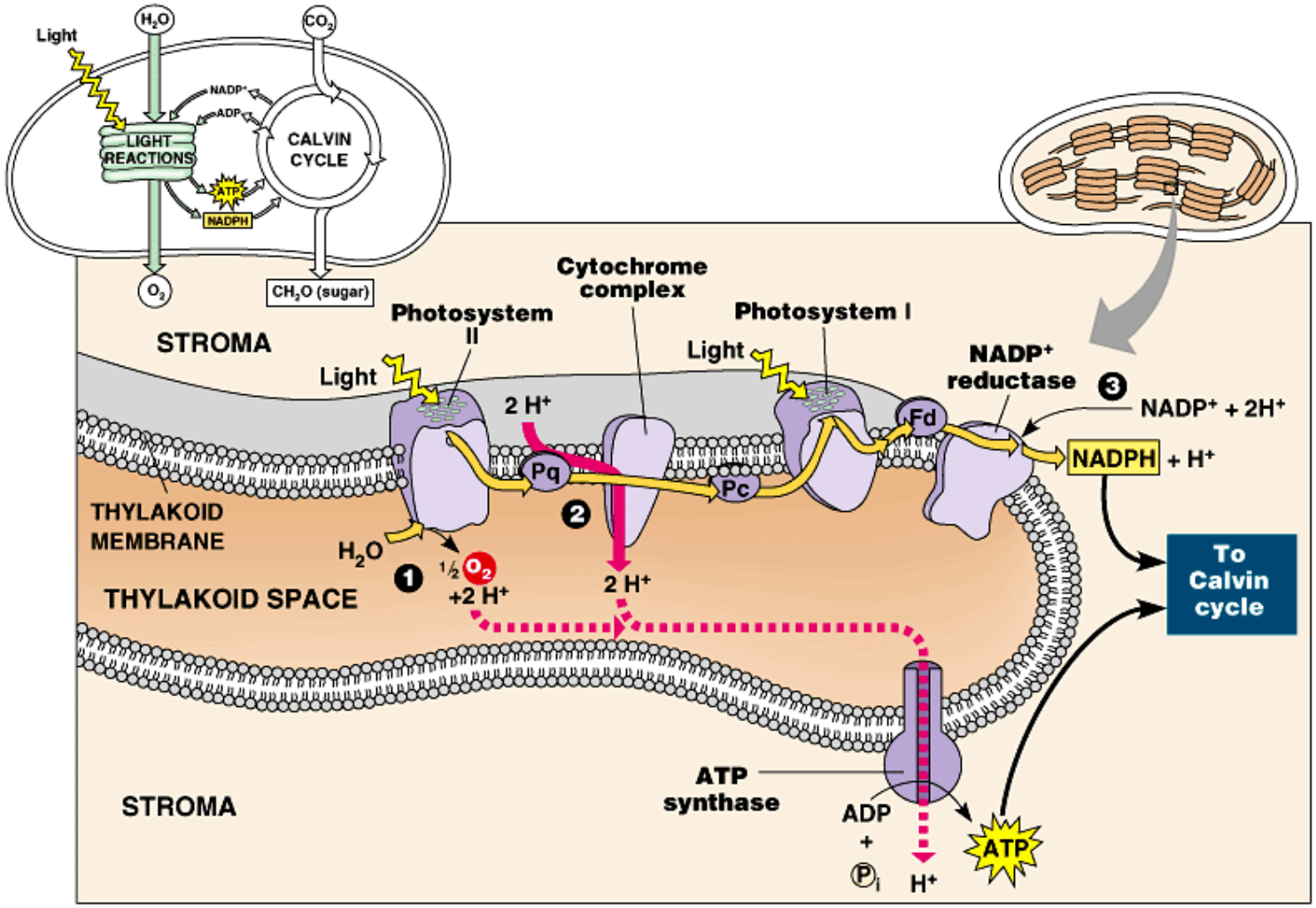
- Simpler pathway of electron flow than Photosystem II
- electrons cycle back to cytochrome complex (proteins in the chain) continues back into Photosystem I
- _____ – NO NADPH or O_2 is harvested
- Only used when there is a build up of NADPH or more ATP is required for Calvin Cycle

Summary Light Reactions

- Noncyclic electron flow = captures electrons from _____ and transfers to NADP+
  - low potential energy [water] to high potential energy [NADPH]
- Light reactions produce _____ from splitting H_2O
- Electron transport chain in the thylakoid membranes generate _____
  - ATP is released into the stroma for the DARK REACTION [Calvin cycle]
- ATP & NADPH are used in the Calvin cycle to produce carbohydrates and release O_2 as a byproduct.

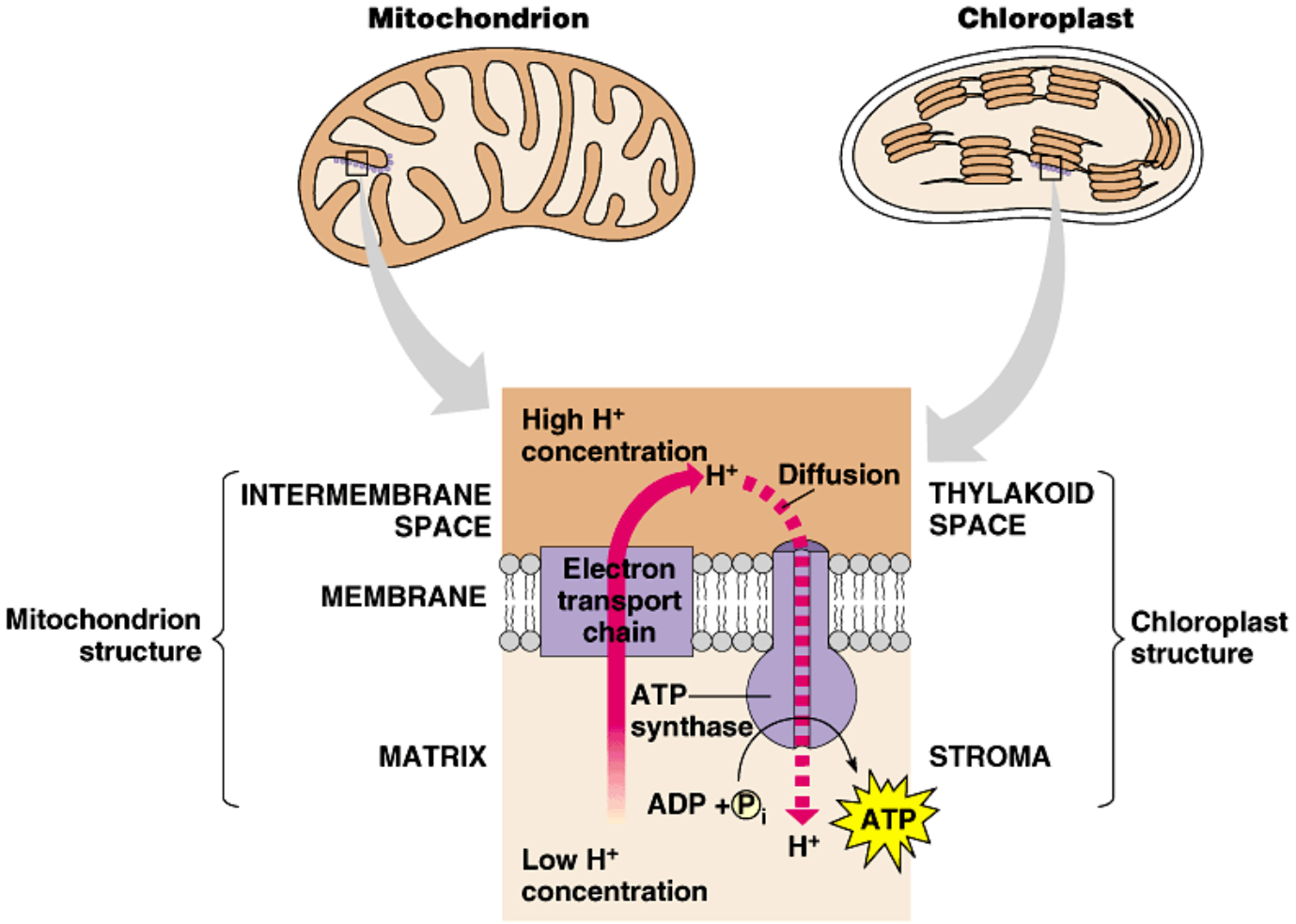
Cyclic electron flow





Chloroplasts and Mitochondria both generate ATP by chemiosmosis

Chemiosmosis – Mitochondria vs. Chloroplast



Calvin Cycle

- _____ to carbohydrates by a series of reactions in the Calvin cycle.
  - Reactions occur in the _____
  - Incorporate CO_2 into _____ _____ by a process called _____ and then is reduced to a carbohydrate.
  - Does NOT require light directly
  - NADPH provides the _____ power
  - ATP provides the _____

Calvin Cycle (Dark Reaction)

- Calvin cycle uses ATP and NADPH produced in the light reactions to convert CO_2 to sugar
- ATP is the energy source
- NADPH is the reducing agent that adds high-energy electrons to form the _____ (glyceraldehyde 3-phosphate)

- 3 CO_2 enter the Calvin Cycle to generate _____ G3P molecule

- G3P is the raw material, produced by the Calvin cycle, that is used to synthesize _____ and other carbs

Calvin Cycle

- _____ process that uses energy to build carbs from smaller molecules.
- Carbon enters the cycle in the form of CO_2 and leaves as sugar
- Carbohydrate actually produced is not glucose but a 3C sugar, glyceraldehyde-3-phosphate (G3P)

Phase 1 of Calvin Cycle: Carbon Fixation

- CO_2 is added to a 5C sugar, ribulose bisphosphate (_____).
  - Added by enzyme, _____
- Produces a _____ sugar that immediately splits in half (2 3C sugars) due to instability: 3-Phosphoglycerate (_____)

Phase 2 of Calvin Cycle : Reduction

- _____ added to make a different 3 carbon molecule
- NADPH donates _____ to produce G3P sugar molecule

Phase 3 of Calvin Cycle : Regeneration of the CO2 Acceptor (RuBP)

- 5 molecules of G3P are _____ by the last steps of the Calvin Cycle
  - Forms 3 molecules of RuBP
- For the NET synthesis of ONE G3P molecule, the Calvin cycle uses the products of the light reactions:
  - 9 ATP molecules
  - 6 NADPH molecules