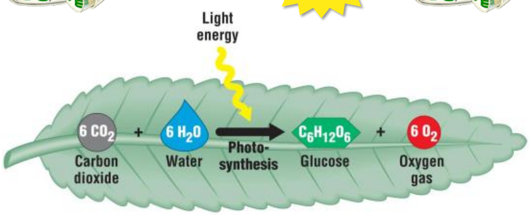
Chapter 10.1 – 10.2

Photosynthesis: Life from Light





Energy needs of life

- All life needs a constant input of energy
  - Heterotrophs
    - get their energy from eating others: "other feeders"
    - consumers of other organisms
    - consume organic molecules
  - Autotrophs
    - get their energy from "self"
    - get their energy from sunlight
    - use light energy to synthesize organic molecules

Energy needs of life

- Heterotrophs
  - consumers
  - animals
  - fungi
  - most bacteria
- Autotrophs
  - producers
  - plants
  - photosynthetic bacteria (blue-green algae)

How are they connected?

Heterotrophs

making energy & organic molecules from ingesting organic molecules

glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

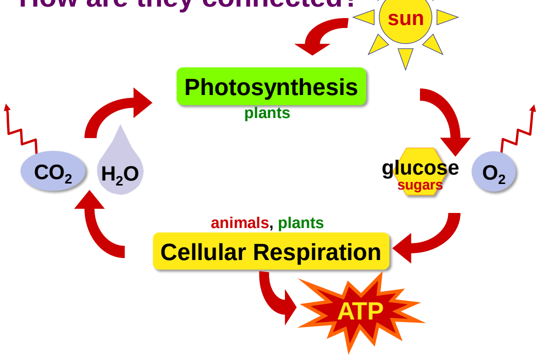
Autotrophs

making energy & organic molecules from light energy

carbon dioxide + water + energy → glucose + oxygen

$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$

How are they connected?



What does it mean to be a plant?

- Need to…
  - collect light energy
    - transform it into chemical energy
  - store light energy
    - in a stable form to be moved around the plant & also saved for a rainy day
  - need to get building block atoms from the environment
    - C, H, O, N, P, S
  - produce all organic molecules needed for growth
    - carbohydrates, proteins, lipids, nucleic acids

Plant Structure

- Obtaining raw materials
  - sunlight
    - leaves = solar collectors
  - CO_2
    - stomates = gas exchange
  - H_2O
    - uptake from roots
  - 'nutrients'
    - uptake from roots

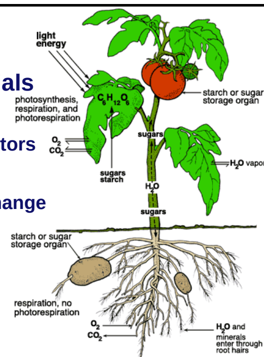


Figure 24. Photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant.

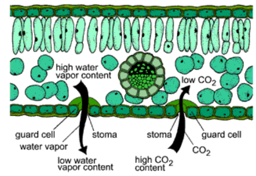
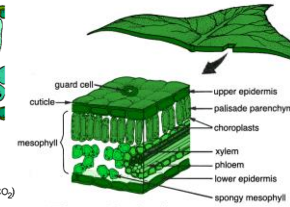
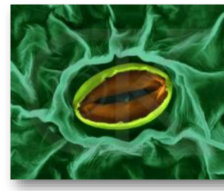
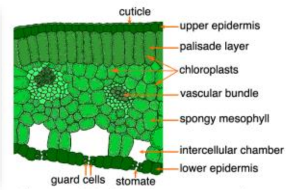


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

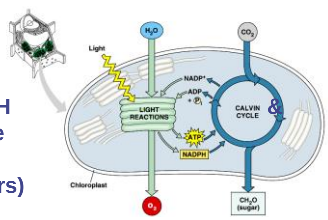






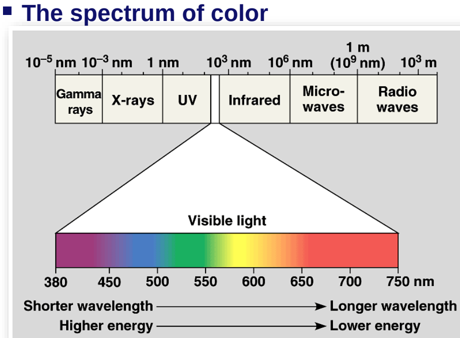
Photosynthesis Overview

- "Light" reactions (Light-Dependent Rxns)
  - convert solar energy to chemical energy
  - sun → ATP
- Calvin cycle
  - uses chemical energy (NADPH ATP) to reduce CO_2 to build $C_6H_{12}O_6$ (sugars)



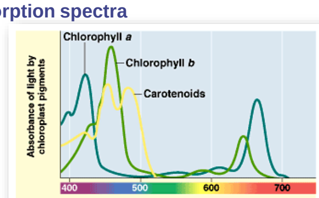
A Look at Light

- The spectrum of color



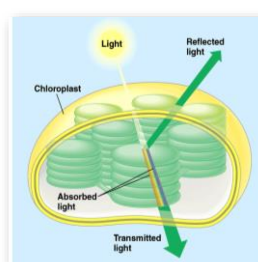
Light: Absorption Spectra

- Photosynthesis performs work only with <u>absorbed</u> wavelengths of light
  - chlorophyll *a* — the dominant pigment — absorbs best in red & blue wavelengths & least in green
  - other pigments with different structures have different absorption spectra



Chloroplasts

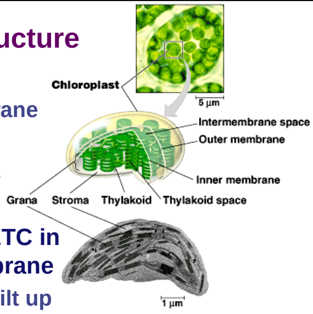
- Chloroplasts are green because they absorb light wavelengths in red & blue and reflect green back out

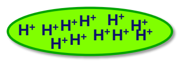


structure ⟷ function

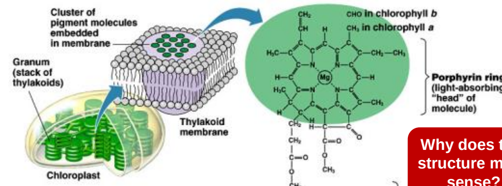
Chloroplast Structure

- Chloroplasts
  - double membrane
  - stroma
  - thylakoid sacs
  - grana stacks
- Chlorophyll & ETC in thylakoid membrane
  - H^+ gradient built up within thylakoid sac



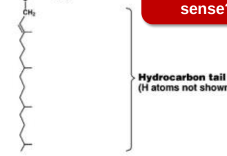


Pigments of Photosynthesis



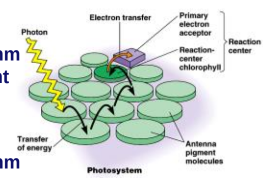
Why does this structure make sense?

- chlorophyll & accessory pigments
  - "photosystem"
  - embedded in thylakoid membrane
  - structure ←→ function



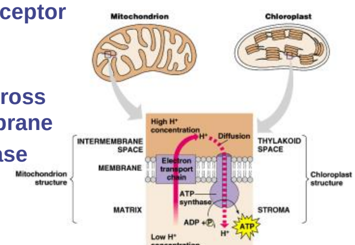
Photosystems

- Collections of chlorophyll molecules
- 2 photosystems in thylakoid membrane
  - act as light-gathering "antenna complex"
  - Photosystem II
    - chlorophyll *a*
    - P_{680} = absorbs 680nm wavelength red light
  - Photosystem I
    - chlorophyll *b*
    - P_{700} = absorbs 700nm wavelength red light



Light Reactions

- Similar to ETC in cellular respiration
  - membrane-bound proteins in organelle
  - electron acceptor
    - NADPH
  - proton (H^+) gradient across inner membrane
  - ATP synthase enzyme



The ATP that Jack built

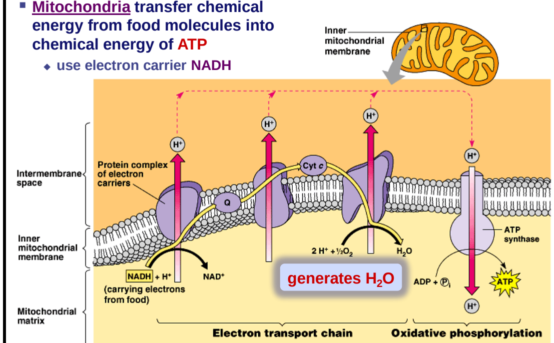
photosynthesis	respiration
sunlight	breakdown of $C_6H_{12}O_6$

- moves the electrons
- runs the pump
- pumps the protons
- forms the gradient
- releases the free energy
- allows the P_i to attach to ADP
- forms the ATP

… that evolution built

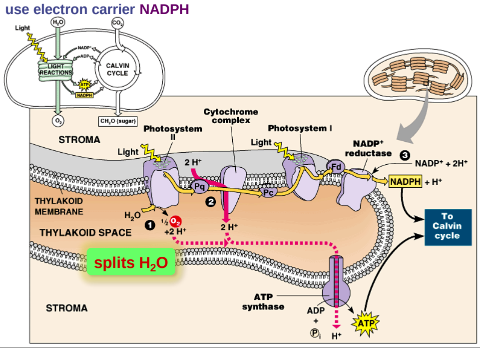
ETC of Respiration

- Mitochondria transfer chemical energy from food molecules into chemical energy of ATP
  - use electron carrier NADH

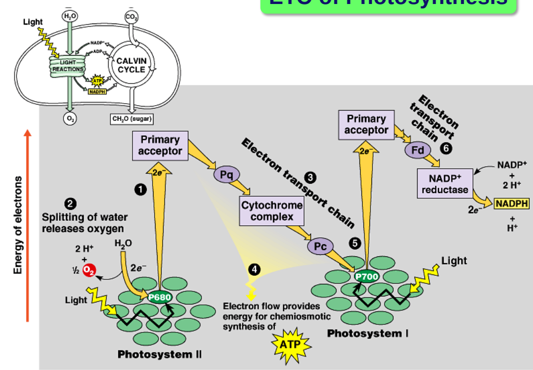


ETC of Photosynthesis

- Chloroplasts transform light energy into chemical energy of ATP
  - use electron carrier NADPH



ETC of Photosynthesis



ETC of Photosynthesis

- ETC produces from light energy:
  - ATP & NADPH
    - NADPH (stored energy) goes to Calvin cycle
- PS II absorbs light
  - excited electron passes from chlorophyll to "primary electron acceptor"
  - need to replace electron in chlorophyll
  - enzyme extracts electrons from H_2O & supplies them to chlorophyll
    - splits H_2O
    - O combines with another O to form O_2
    - O_2 released to atmosphere
    - and we breathe easier!

Experimental Evidence

- Where did the O_2 come from?
  - radioactive tracer = O_{18}

Experiment 1

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

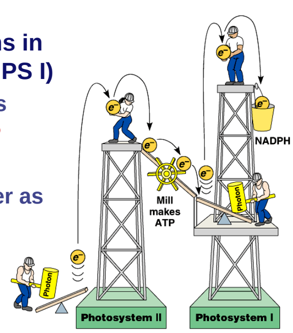
Experiment 2

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Proved O_2 came from H_2O not CO_2 = plants split H_2O

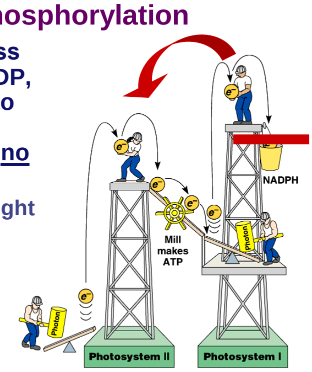
2 Photosystems

- Light reactions elevate electrons in 2 steps (PS II & PS I)
  - PS II generates energy as ATP
  - PS I generates reducing power as NADPH

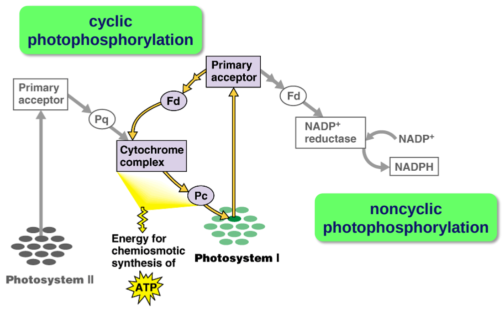


Cyclic Photophosphorylation

- If PS I can't pass electron to NADP, it cycles back to PS II & makes more ATP, but no NADPH
  - coordinates light reactions to Calvin cycle
  - Calvin cycle uses more ATP than NADPH



Photophosphorylation



Photosynthesis summary

- Where did the energy come from?
- Where did the H_2O come from?
- Where did the electrons come from?
- Where did the O_2 come from?
- Where did the H^+ come from?
- Where did the ATP come from?
- Where did the O_2 go?
- What will the ATP be used for?
- What will the NADPH be used for?

…stay tuned for the Calvin cycle