Page 8

C3 plants

C3 leaf XS with Calvin cycle in cell, open stoma • “Mesophyll”
• “Guard cells” • “Stoma” • “Moderate temperature”
• CO_2s enter, “High CO_2” • “High temperature”
• H_2O evaporates out • Stoma closes
• One CO_2 enters, “low CO_2” Temperate plants (P)
Earth from space (P) Tropical palms (P)

C4 plants

C4 leaf XS with Calvin cycle in cell, open stoma, one “Low CO_2”
• C4 cycle appears •CO_2 enters C4 cycle, fixed into C4, freeze
• C4 enters Calvin cycle, freeze • C4 disappears into Calvin cycle

C4 do better at hotter temperatures, C3 at moderate temperatures

• Loop of CO_2 entering leaf, C4, and Calvin cycle.
•C3 with high CO_2, moderate temperature
World map of C4 vs. C3 Crab grass

[Recap of major photosynthesis concepts]

Chloroplast with light dependent/independent reactions
Leaf XS Leaves in sun (P)

Autotrophs

Organisms that can make organic molecules (especially glucose) from CO_2 and H_2O.

• Photosynthesis is how almost all autotrophs make organic molecules

$$6CO_2 + 6H_2O \xrightarrow{\text{Sunlight}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2$$

√ All plants

√ Some protistans and bacteria

Fig 10.2

Heterotrophs

Organisms that cannot make organic molecules from CO_2 and H_2O.

• Heterotrophs must obtain their organic molecules from other organisms

• All animals, fungi, and archaea

• Some protistans and bacteria

Fig 10.2

Chloroplasts

A triple membrane organelle where photosynthesis occurs.

- Located in the mesophyll cells inside leaves
- Envelope = the outer two membranes
- Thylakoid = the inner membrane
  - √ Folded into discs called granum
- Stroma = the fluid that fills the chloroplast

Photosynthesis takes place in 2 stages:

- The light dependent reaction
- The light independent reaction

Light independent reaction (The Calvin cycle)(does **not** require light)

- Takes place in the stroma. CO_2 is fixed into glucose
- ATP and NADPH (from light dependent reaction) are consumed

Light dependent reaction (requires light energy)

- Takes place in the thylakoid membrane
- Sun shining on grana produces ATP and NADPH

Photon

A particle of light with wave-like properties

- The wavelength of the photon determines the color of the photon
- White light = a mixture of photons of many wavelengths (many colors)

Fig 10.6

Chlorophyll

The main photon-absorbing pigment in the thylakoid membrane

- Several fused rings with a magnesium ion in the center
- A non-polar tail anchors chlorophyll to the thylakoid membrane
- One of chlorophyll's electrons becomes energized when struck by a photon of light.

Fig 10.10

Photosystem (PS)

A cluster of chlorophyll molecules that channel energized electrons into the thylakoid's electron transport system

- Energized electrons are first channeled to the reaction center (a special pair of chlorophylls in the center of the PS)

- The reaction center passes electrons to an electron carrier in membrane

Fig 10.12

The light-dependent reaction produces ATP and NADPH using the energy in light. It consumes water and makes O_2 as a byproduct.

The light dependent reaction is two photosystems (PS II and PS I) and an electron transport system, all located in the thylakoid membrane.

- PS II energizes a pair of electrons and passes them into the electron transport system

  √ A molecule called plastoquinone (Pq) is the first electron carrier of the electron transport system

  √ Pq carries the electrons to an H^+ transport protein called the "the cytochrome complex"

- The cytochrome complex uses the electrons' energy to power active transport of H^+ ions into grana

- The H^+ ion gradient in the grana is used by a transport protein called ATP synthase to make ATP

- A molecule called plastocyanin (Pc) carries the electrons to PS I

- The electrons are re-energized by PS I

- The electrons then move to an enzyme called FNR

- FNR enzyme transfers the electrons to an NADP+ molecule in the stroma. An H+ is also transferred to NADP+, converting it to NADPH.

  √ $NADP^+$ is the final electron acceptor of the photosynthesis electron transport system

- PSII replaces its lost electrons by "splitting water" into H^+, oxygen, and electrons inside the grana

  $H_2O \longrightarrow 2H^+ + O + 2e^-$

(The equation for two water molecules: $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$)

The light-independent reaction (the Calvin cycle) is a circular metabolic pathway in the stroma that fixes CO_2 into carbohydrate

- Carbon dioxide is joined to a RuBP (a C5 (five carbon) molecule)
    - The enzyme Rubisco performs this reaction
- Two molecules of PGA (C3) are formed from the CO_2 and RuBP
- Each PGA is converted into a PGAL molecule (C3)
    - √ This step requires the ATP and NADPH made by the light dependent reaction
- 5 out of every 6 PGALs are used to regenerate RuBP
- The remaining PGALs are converted into new glucose molecules

Figs 10.5 and 10.18

C3 plants

Plants that initially fix CO_2 into the C3 molecule PGA in the Calvin cycle

- CO_2 fixing is very inefficient in hot weather
  - √ The plants close the stoma to slow evaporation out of the leaves, but this decreases the CO_2 entering the leaves
  - √ Rubisco (the CO_2-fixing enzyme of the Calvin cycle) cannot fix CO_2 efficiently at the low CO_2 concentration in a closed leaf

C4 plants

Plants that initially fix CO_2 into a C4 molecule

- This occurs in the C4 cycle (before the Calvin cycle)
  - √ The CO_2-fixing enzyme of the C4 cycle can fix CO_2 even at the low CO_2 concentration inside a closed leaf
  - √ The C4 cycle delivers fixed carbon atoms into the Calvin cycle, avoiding the inefficient fixing of that cycle
  - √ The C4 cycle requires one ATP per cycle
- In hot temperatures (when the stoma close) C4 plants are more efficient at photosynthesis than C3 plants