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C3 plants

C3 leaf XS with Calvin cycle in cell, open stoma • “Mesophyll”

- “Guard cells” • “Stoma” • “Moderate temperature”
- CO₂s enter, “High CO₂” • “High temperature”

• H₂O evaporates out • Stoma closes

• One CO₂ enters, “low CO₂” Temperate plants (P)

Earth from space (P) Tropical palms (P)

C4 plants

C4 leaf XS with Calvin cycle in cell, open stoma, one “Low CO₂”

- C4 cycle appears • CO₂ 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 CO₂ entering leaf, C4, and Calvin cycle.

• C3 with high CO₂, moderate temperature

World map of C4 vs. C3 Crab grass

[Recap of major photosynthesis concepts]

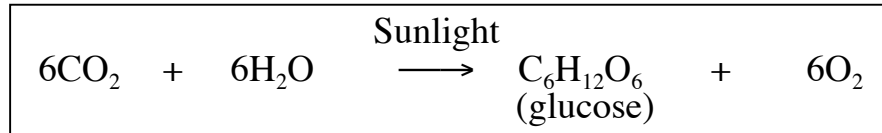
Chloroplast with light dependent/independent reactions

Leaf XS Leaves in sun (P)

Autotrophs

Organisms that can make organic molecules (especially glucose) from CO₂ and H₂O.

- Photosynthesis is how almost all autotrophs make organic molecules



✓ All plants

✓ Some protistans and bacteria

Fig 10.2

Heterotrophs

Organisms that cannot make organic molecules from CO₂ and H₂O.

- 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. CO₂ 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 O₂ 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



(The equation for two water molecules: $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{O}_2 + 4\text{e}^-$)

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