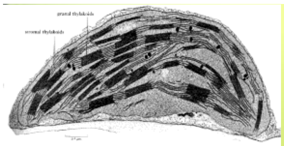
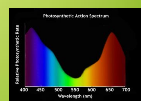


Molecular Biology 2.9- Photosynthesis

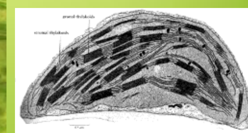


6CO2 Carbon dioxide + 6H2O Water —Light→ C6H12O6 Sugar + 6O2 Oxygen

$6CO_2 + 6H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6O_2$

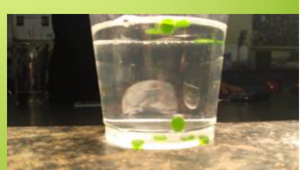
Essential idea:

- Photosynthesis uses the energy in sunlight to produce the chemical energy needed for life.



Nature of science:

- Experimental design
  - controlling relevant variables in photosynthesis experiments is essential. (3.1)



Equation

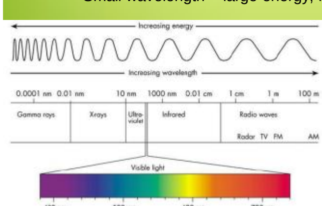
- Photosynthesis is the production of carbon compounds in cells using light energy.
  - Compare to cell respiration

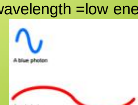
6CO2 Carbon dioxide + 6H2O Water —Light→ C6H12O6 Sugar + 6O2 Oxygen

$6CO_2 + 6H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6O_2$

Properties of Light

- Visible light has a range of wavelengths with violet the shortest wavelength and red the longest.
  - Remember ROY-G-BIV
  - Visible range is about 400nm-700nm
  - Small wavelength = large energy; large wavelength =low enery

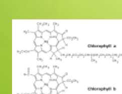




	Wavelength	Percentage of Sunlight
Ultraviolet	10 nm - 380 nm	46%
Violet	380 - 450 nm	7%
blue	450 - 495 nm	
green	495 - 570 nm	
yellow	570 - 590 nm	
orange	590 - 620 nm	
red	620 - 750 nm	
Infrared	750 - 1,000,000 nm	47%

Chlorophyll

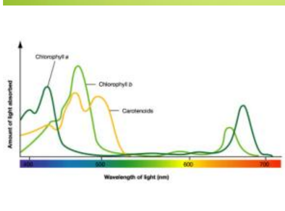
- Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colors.
  - Chlorophylls a and b are most prevalent
  - Accessory pigments contribute other colors

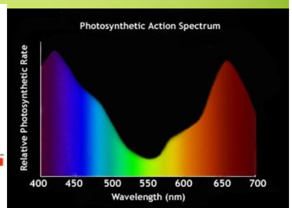


Name	Absorption maxima(s)			Emission color
Primary pigments:				
Chlorophyll a	410nm	428nm	662nm	blue-green
Chlorophyll c	448nm	584nm	634nm	light green
Carotenoids:				
Peridinin	475nm			brick red
Neo-peridinin	465nm			brick red
Diadinoxanthin	425nm	448nm	477nm	yellow
Dinoxanthin	418nm	442nm	470nm	yellow
Neo-dinoxanthin	425nm	440nm	466nm	pale yellow
β-carotene	430nm	450nm	475nm	orange

Absorbance and Action Spectrum

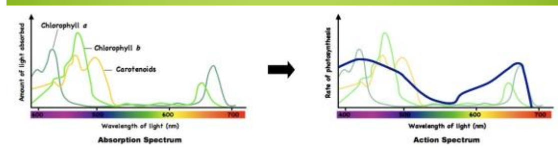
- An absorbance spectra show what wavelengths are absorbed by pigments
- An action spectra shows relative rate of photosynthesis for wavelength



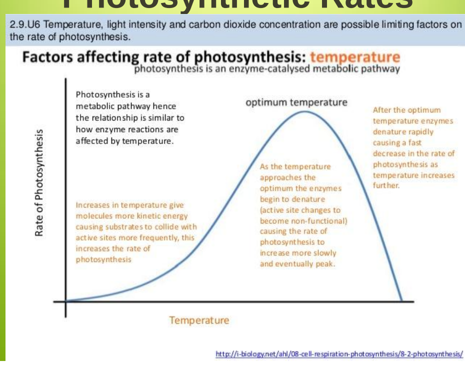


Absorbance and Action Spectrum

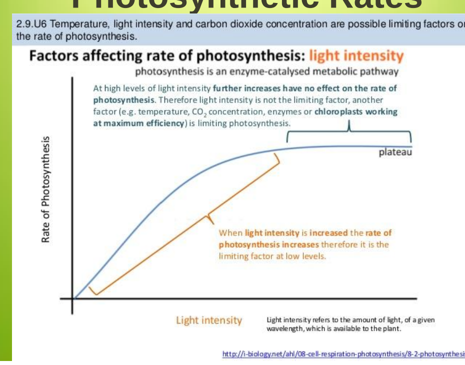
- Action spectrum of photosynthesis mimics chlorophyll absorbance
- Chlorophyll is most important pigment
- Lack of light in the fall brings causes chlorophyll breakdown
- Brings out accessory pigments (change colors)



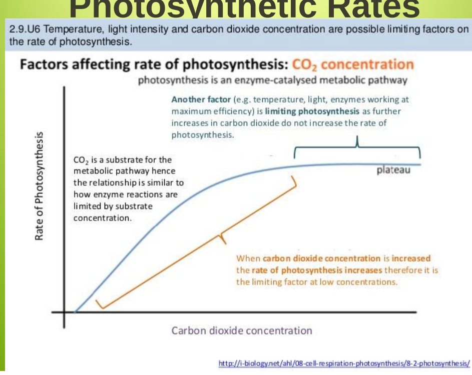
Limiting Factors on Photosynthetic Rates



Limiting Factors on Photosynthetic Rates

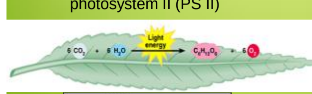


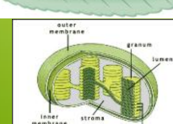
Limiting Factors on Photosynthetic Rates

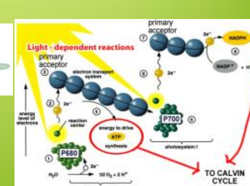


Light-dependent Reactions

- Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide.
  - Occur in the thylakoid membranes.
  - Oxygen is produced in photosynthesis from the photolysis of water.
  - ATP and NADPH are produced
  - Requires two light-gathering units; photosystem I (PS I) and photosystem II (PS II)

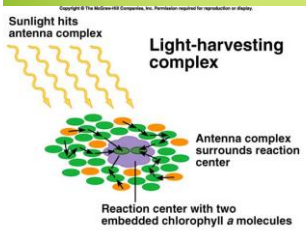


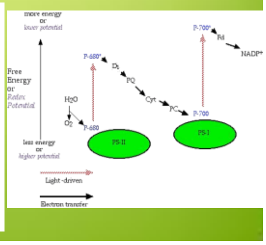




Light-dependent Reactions

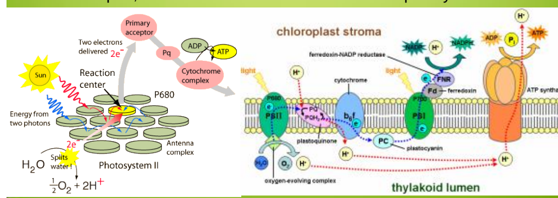
- Photosystems
  – A pigment complex and electron acceptor.
  – Pigments transfer energy to chlorophyll reaction center
  – Chlorophylls absorb free energy from light, boosting electrons to a higher energy level in Photosystems I and II.





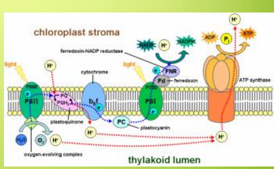
Light-dependent Reactions

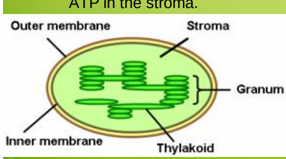
- Noncyclic Electron Pathway
  – Photosystem II absorbs solar energy
  – High-energy electrons (e-) leave the reaction-center chlorophyll molecule (P680)
  – PS II takes replacement electrons from H_2O, which splits, releasing O_2 and H^+
  – The H^+ ions temporarily stay within the thylakoid space.
  – High-energy electrons that leave PS II are captured by an electron acceptor, which sends them to an electron transport system.

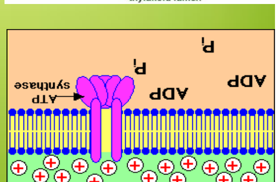


Light-dependent Reactions

- ATP Production
  – Electrons from PS II flow to ETC
  – As electrons flow, they give up energy to pump H^+ from stroma into thylakoid space.
  – The thylakoid space acts as a reservoir for H+ ions; each time H_2O is split, two H^+ remain.
  – Chemiosmosis occurs forming ATP in the stroma.

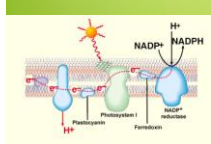


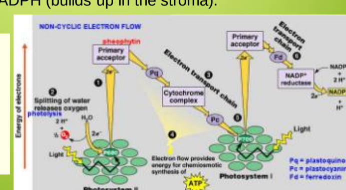




Light-dependent Reactions

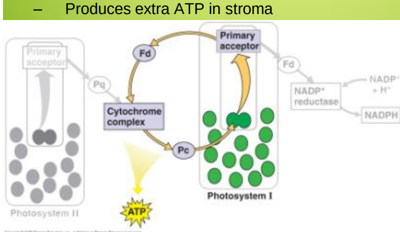
- NADPH Production
  – Low-energy electrons enter pigment of complex PS I from ETC and sunlight.
  – High-energy electrons leave reaction-center chlorophyll (P700) and are captured by an electron acceptor.
  – The electron acceptor passes them on to $NADP^+$
  – $NADP^+$ becomes NADPH (builds up in the stroma).

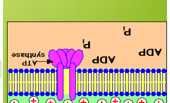




Light-dependent Reactions

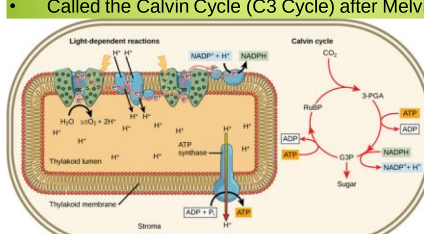
- Cyclic Electron Pathway
  – PS I (P700) pigment complex absorbs solar energy.
  – High-energy electrons leave PS I reaction-center
  – Build up of NADPH inhibits its production pathway
  – Electrons therefore travel down electron transport system.
  – Produces extra ATP in stroma





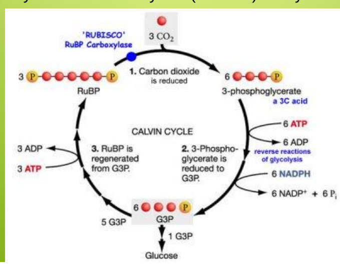
Light-independent Reactions

- Take place in the stroma
- Occur in either the light or the dark.
- Use NADPH and ATP to reduce CO_2.
- Called the Calvin Cycle (C3 Cycle) after Melvin Calvin



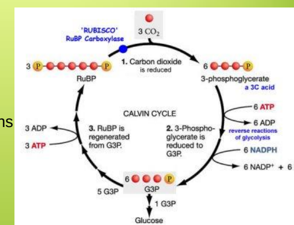
Light-independent Reactions

- Calvin Cycle Has Three Stages
  - Fixing Carbon Dioxide
    - The attachment of CO_2 to RuBP (ribulose bisphosphate)
    - Enzyme RuBP carboxylase (Rubisco) catalyzes reaction



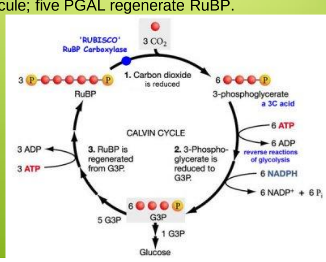
Light-independent Reactions

- Reducing PGA
  - Each PGA molecule undergoes reduction to PGAL (glyceraldehyde phosphate).
  - Light-dependent reactions provide NADPH (electrons) and ATP (energy) to reduce PGA to PGAL.



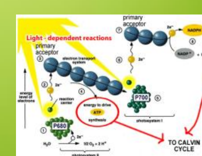
Light-independent Reactions

- Regenerating RuBP
  - Every three turns of Calvin cycle, five molecules of PGAL are used to re-form three molecules of RuBP.
  - Every three turns of Calvin cycle, there is net gain of one PGAL molecule; five PGAL regenerate RuBP.



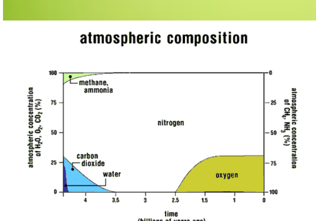
Evolution of Photosynthesis

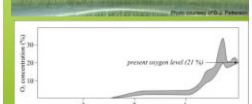
- Photosynthesis first evolved in prokaryotic organisms
- Scientific evidence supports that prokaryotic (bacterial) photosynthesis was responsible for the production of an oxygenated atmosphere
- Photosynthetic pathways were the foundation of eukaryotic photosynthesis. (Photorespiration, C_4 and CAM Plants)



Effects of Photosynthesis on Earth

- Primordial Earth had a reducing atmosphere that contained very low levels of oxygen gas (approx. 2%). Debatable?
- 2.5 bya Cyanobacteria (prokaryotes) containing chlorophyll first performed photosynthesis



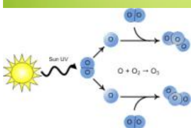
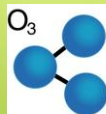


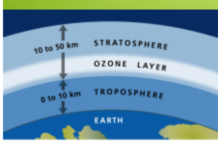
Effects of Photosynthesis on Earth

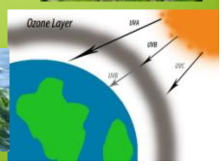
- Photosynthesis creates oxygen gas as a by-product (by the photolysis of water).
- Oxygen levels remained at 2% until about 700 mya.
- From 700 mya until the now there has been a significant rise to 21%.

Effects of Photosynthesis on Earth

- Oxygen generation also allowed the formation of an ozone layer (O_3).
  - Shielded the Earth from damaging levels of UV radiation.
  - Evolution of a wider range of organisms.

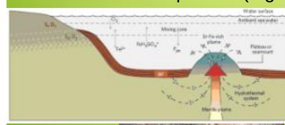



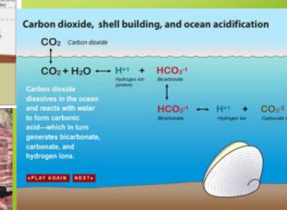



Effects of Photosynthesis on Earth

- Iron compounds in the oceans were oxidized:
  - The insoluble iron oxides precipitated onto the seabed.
  - Time and further sedimentation has produced rocks with layers rich in iron ore called the banded iron formations.
- Oxygen in the atmosphere lead to the production of oxidized compounds (e.g. CO_2) in the oceans.



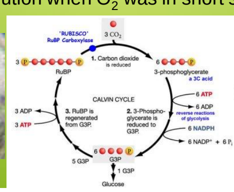


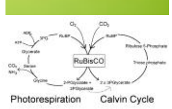
End

Photorespiration

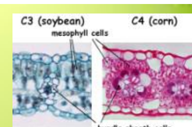
- In hot weather, stomates close to save water; CO_2 concentration decreases in leaves; O_2 increases.
- In C_3 plants, O_2 competes with CO_2 for the active site of rubisco.
- Called "photorespiration" since oxygen is taken up and CO_2 is produced.
- No sugar or ATP is produced.
- Relic of evolution when O_2 was in short supply.

Back

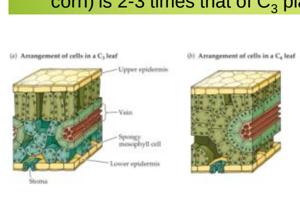
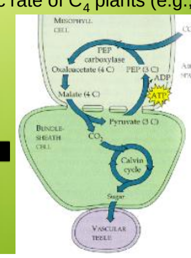





C_4 Plants



- Sugarcane, Corn, Grasses
- Fix CO_2 by first forming a C_4 molecule
- Shuttle C_4 into Bundle sheath cells
- CO_2 is released and used in Calvin Cycle.
- In hot, dry climates, net photosynthetic rate of C_4 plants (e.g., corn) is 2-3 times that of C_3 plants.

Back

CAM (Crassulacean-Acid Metabolism) Plants

- Succulent desert plants, cacti, pineapple
- CAM plants open stomates only at night
- Store CO_2 as aC_4 molecule
- Release CO_2 during the day in Calvin Cycle

Back