Photosynthesis

Photosynthesis in nature

Autotrophs:

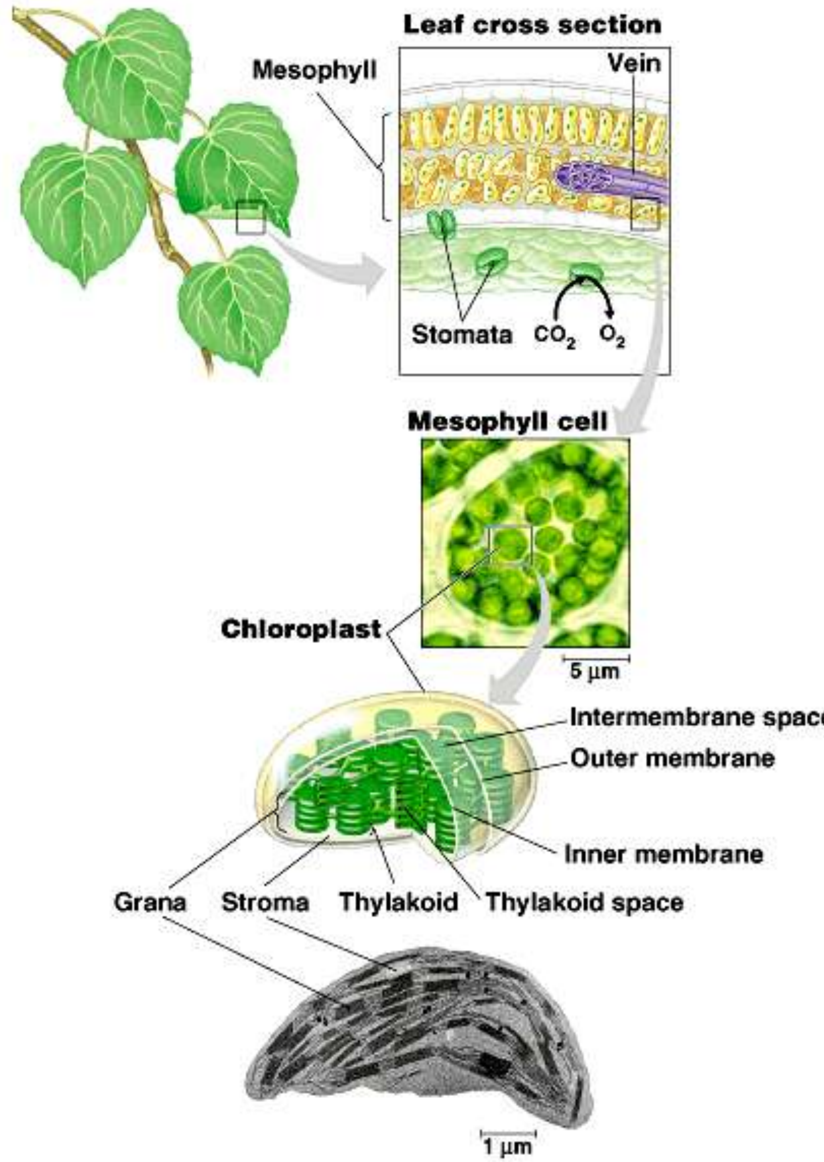
biotic producers; photoautotrophs; chemoautotrophs; obtains organic food without eating other organisms

Heterotrophs:

biotic consumers; obtains organic food by eating other organisms or their by-products (includes decomposers)

The chloroplast

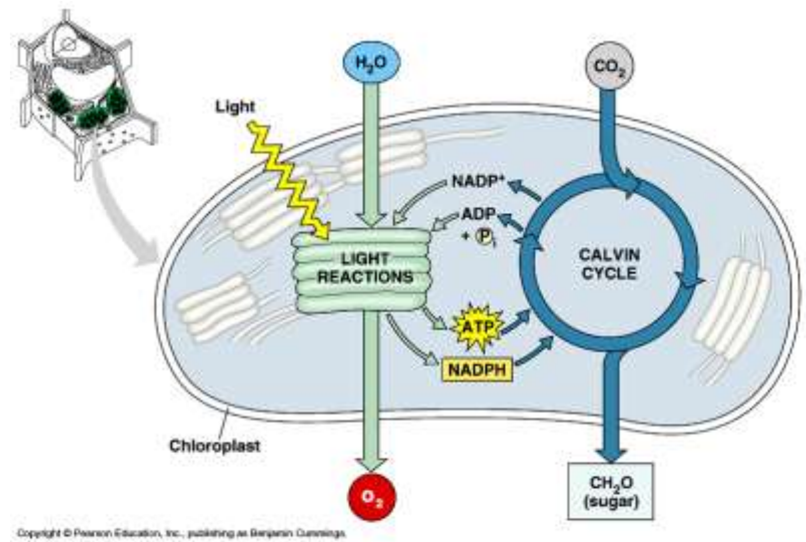
- Sites of photosynthesis
- Pigment: chlorophyll
- Plant cell: mesophyll
- Gas exchange: stomata
- Double membrane
- Thylakoids, grana, stroma



Photosynthesis: an overview

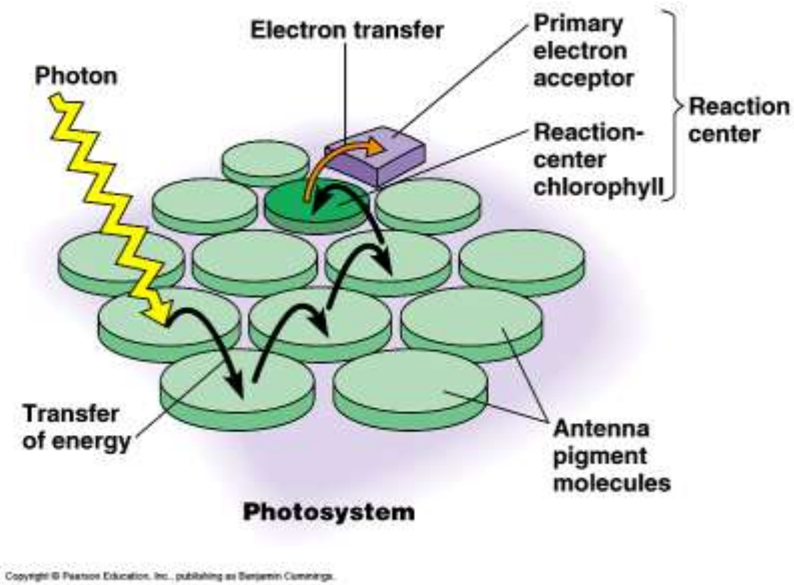
- Redox process
- H_2O is split, e- (along w/ H+) are transferred to CO_2, reducing it to sugar
- <u>2 major steps:</u>
  - light reactions (“*photo*”)
  - NADP+ (electron acceptor) to NADPH
- <u>Photophosphorylation:</u>
  - ADP ---> ATP
  - Calvin cycle (“*synthesis*”)

    <u>Carbon fixation:</u>
    carbon into organics



Photosystems

- Light harvesting units of the thylakoid membrane
- Composed mainly of protein and pigment antenna complexes
- Antenna pigment molecules are struck by photons
- Energy is passed to reaction centers (redox location)
- Excited e- from chlorophyll is trapped by a primary e- acceptor



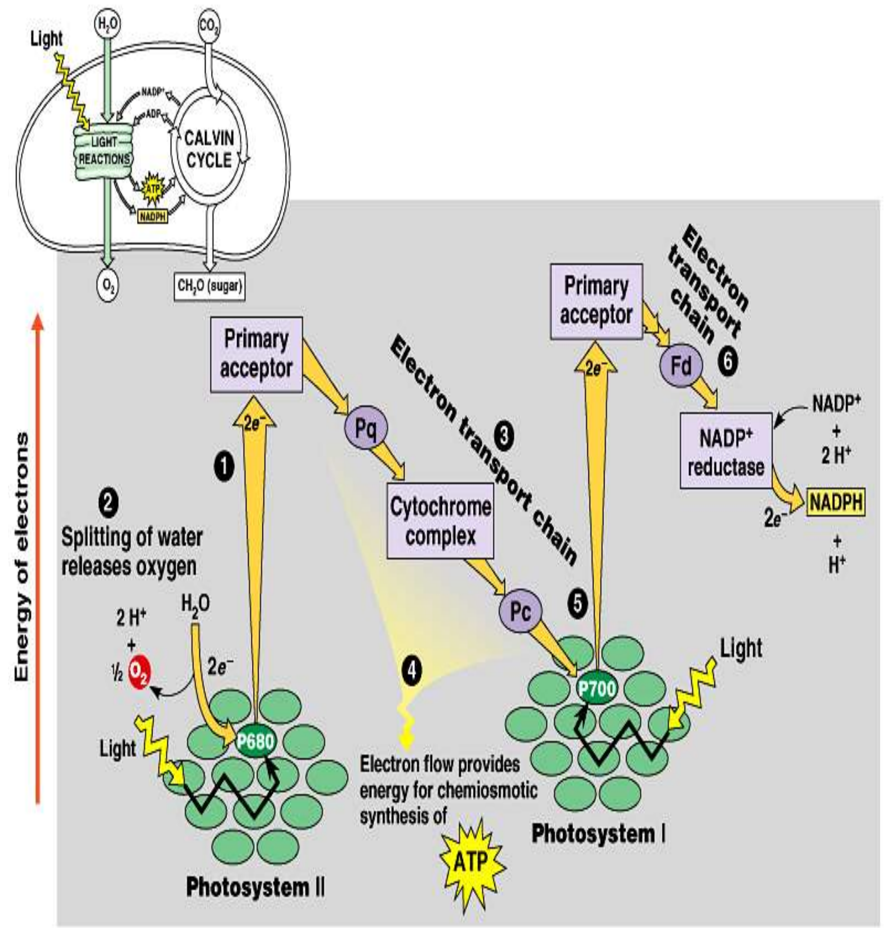
Noncyclic electron flow

<u>Photosystem II (P680):</u>

- photons excite chlorophyll e- to an acceptor
- e- are replaced by **splitting of H2O** (**release of O2**)
- e-'s travel to Photosystem I down an electron transport chain (Pq~cytochromes~Pc)
- as e- fall, ADP ---> ATP (noncyclic photophosphorylation)

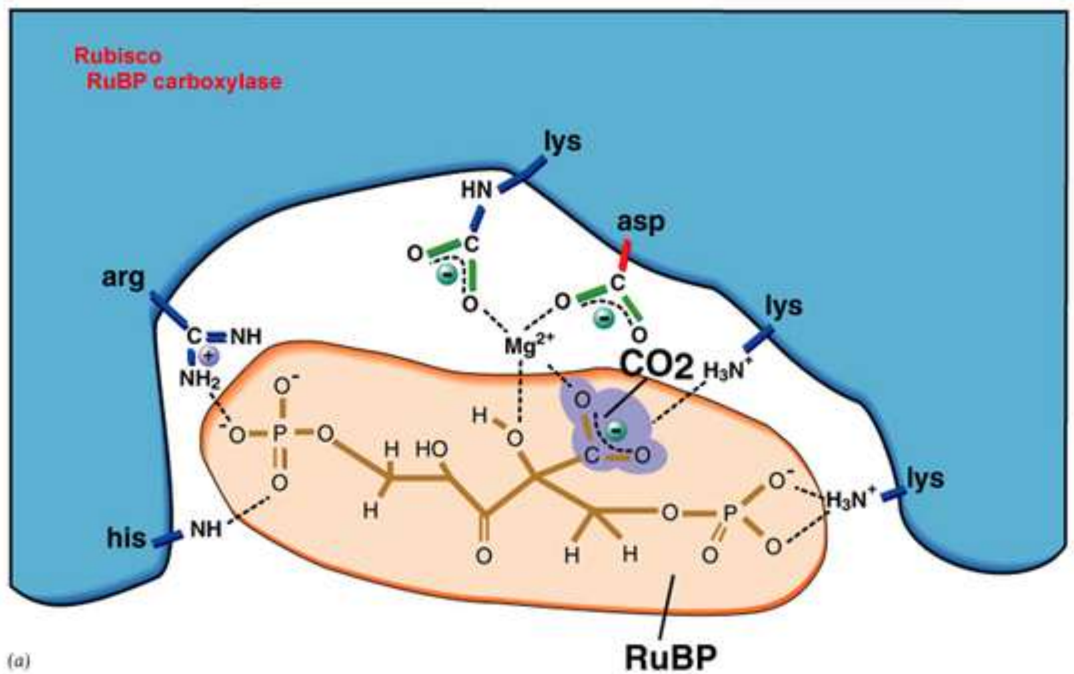
<u>Photosystem I (P700):</u>

- 'fallen' e- replace excited e- to primary e- acceptor
- 2nd ETC (Fd~NADP+ reductase) transfers e- to NADP+ ---> NADPH (...to Calvin cycle…)
- These photosystems produce equal amounts of **ATP and NADPH**



RUBISCO

- The most prevalent protein on the planet

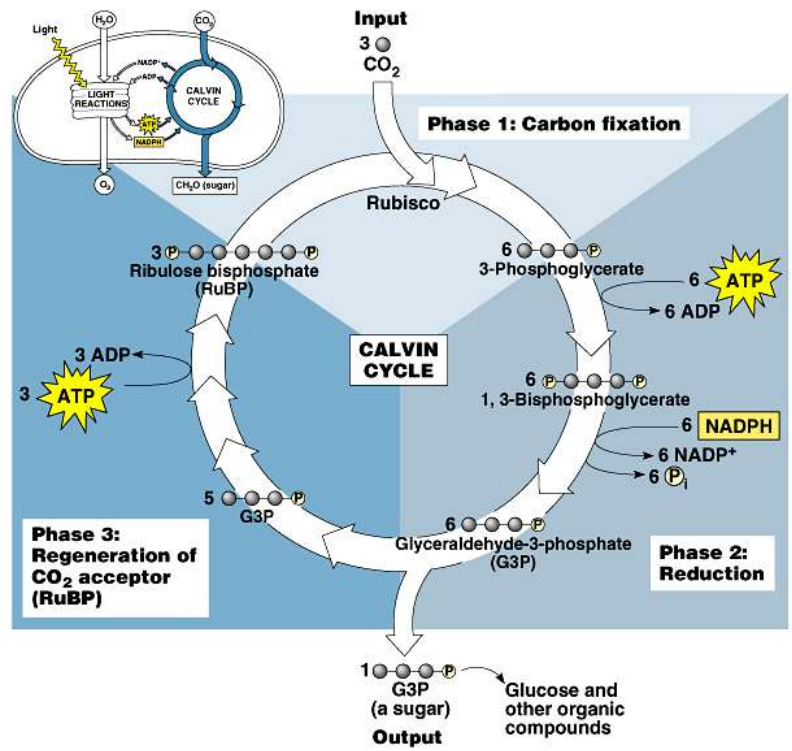


The Calvin cycle

3 molecules of CO_2 are 'fixed' into glyceraldehyde 3-phosphate (G3P)

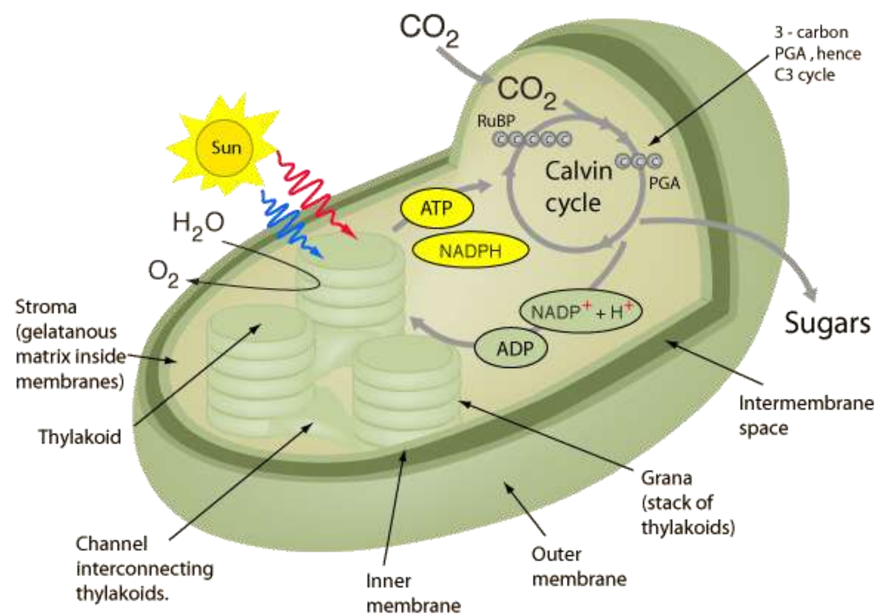
Phases:

- 1- Carbon fixation~ each CO_2 is attached to RuBP (rubisco enzyme)
- 2- Reduction~ electrons from NADPH reduces to G3P; ATP used up
- 3- Regeneration~ G3P rearranged to RuBP; ATP used; cycle continues



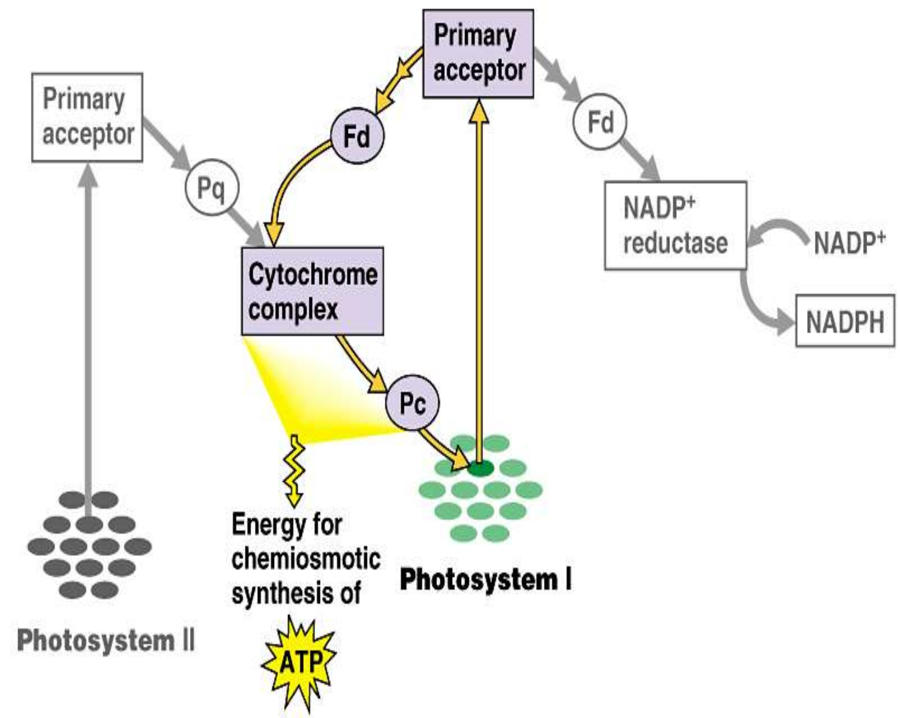
Calvin Cycle, net synthesis

- For each G**3**P (and for **3** CO2)……. Consumption of 9 ATP's & 6 NADPH(light reactions regenerate these molecules)
- G**3**P can then be used by the plant to make glucose and other organic compounds



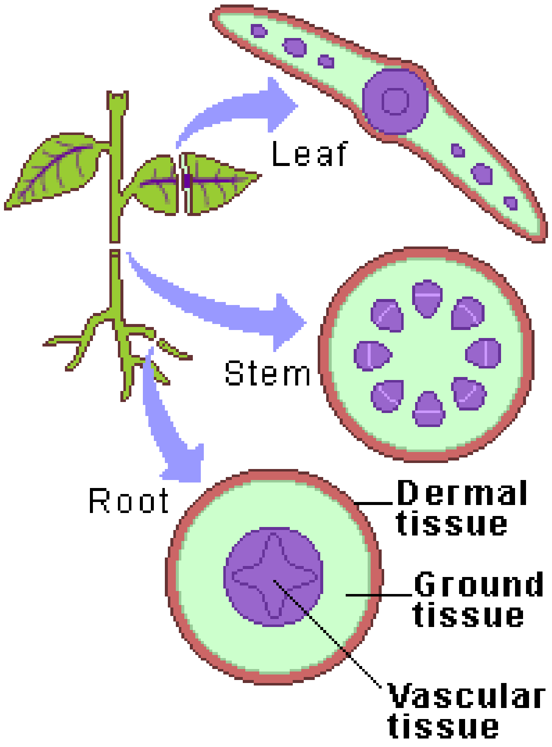
Cyclic electron flow

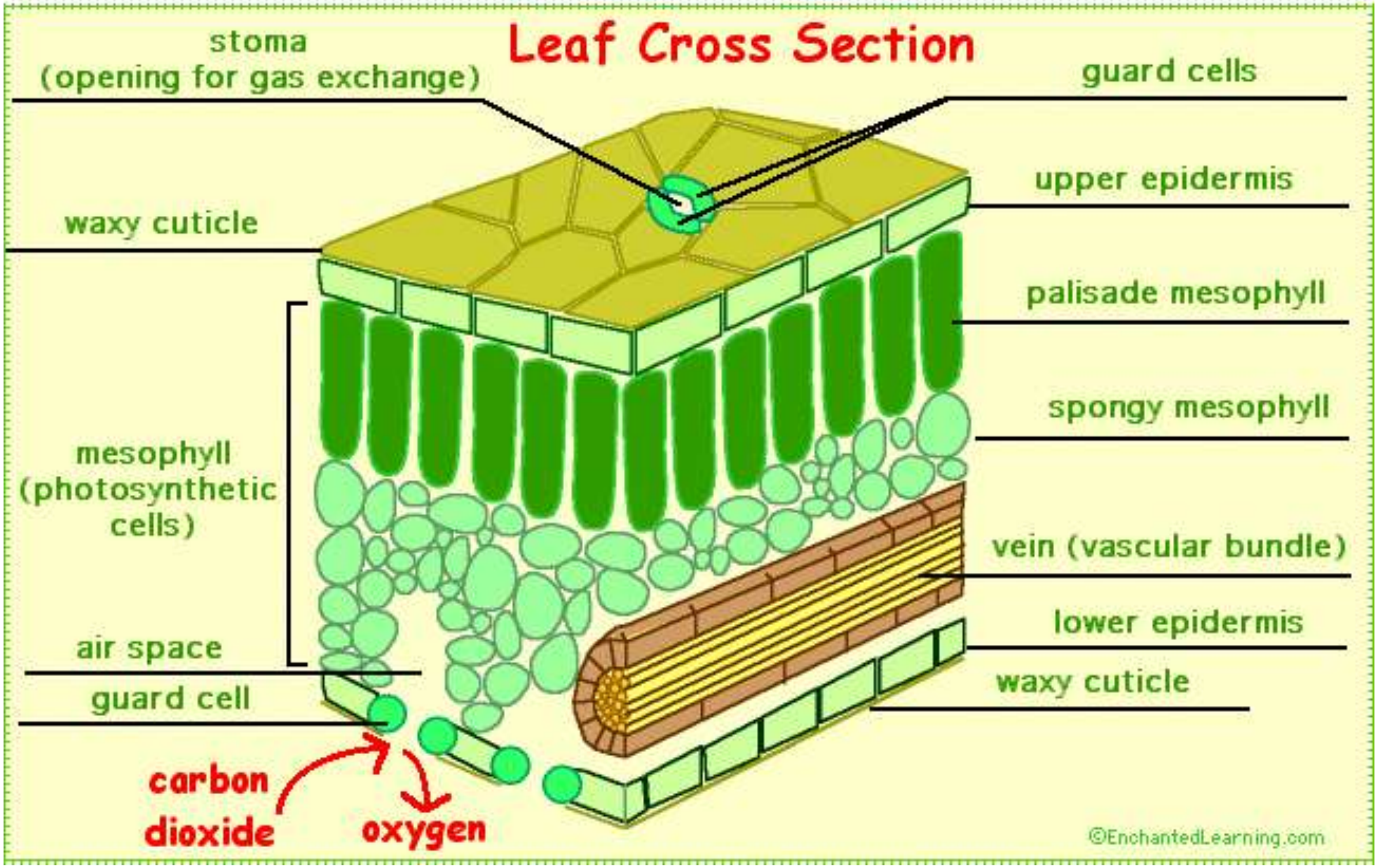
- Alternative cycle when ATP is deficient
- Photosystem I used but not II; produces ATP but no NADPH
- Why? The Calvin cycle consumes more ATP than NADPH…….
- Cyclic photophosphorylation



Plant Tissues

- Vascular
  - transport
- Dermal
  - protection
- Ground
  - Photosynthesis
  - Storage
  - support
  -





Leaf Cross Section
stoma
(opening for gas exchange)
guard cells
upper epidermis
waxy cuticle
palisade mesophyll
spongy mesophyll
mesophyll
(photosynthetic
cells)
vein (vascular bundle)
lower epidermis
air space
waxy cuticle
guard cell
carbon
dioxide
oxygen
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Photorespiration

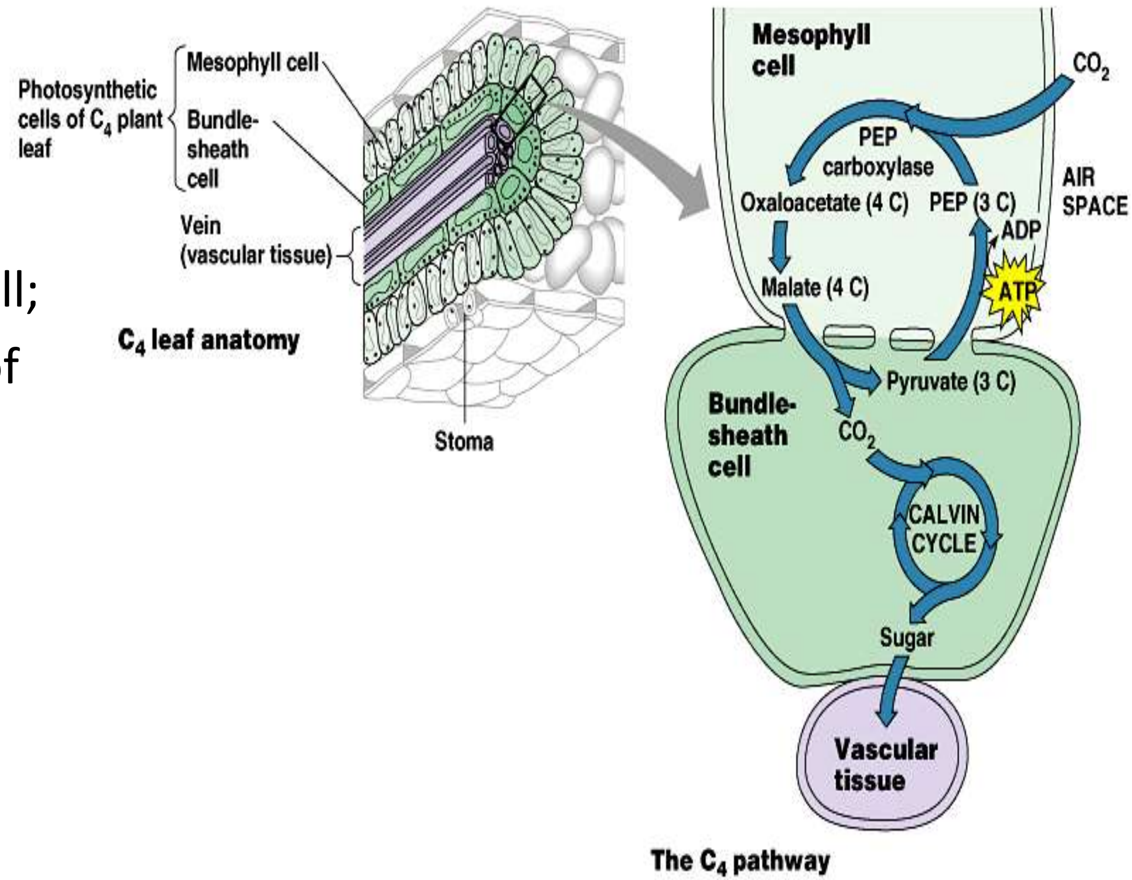
<u>Photorespiration</u>: on hot/dry days; stomata close;no ATP or food generated

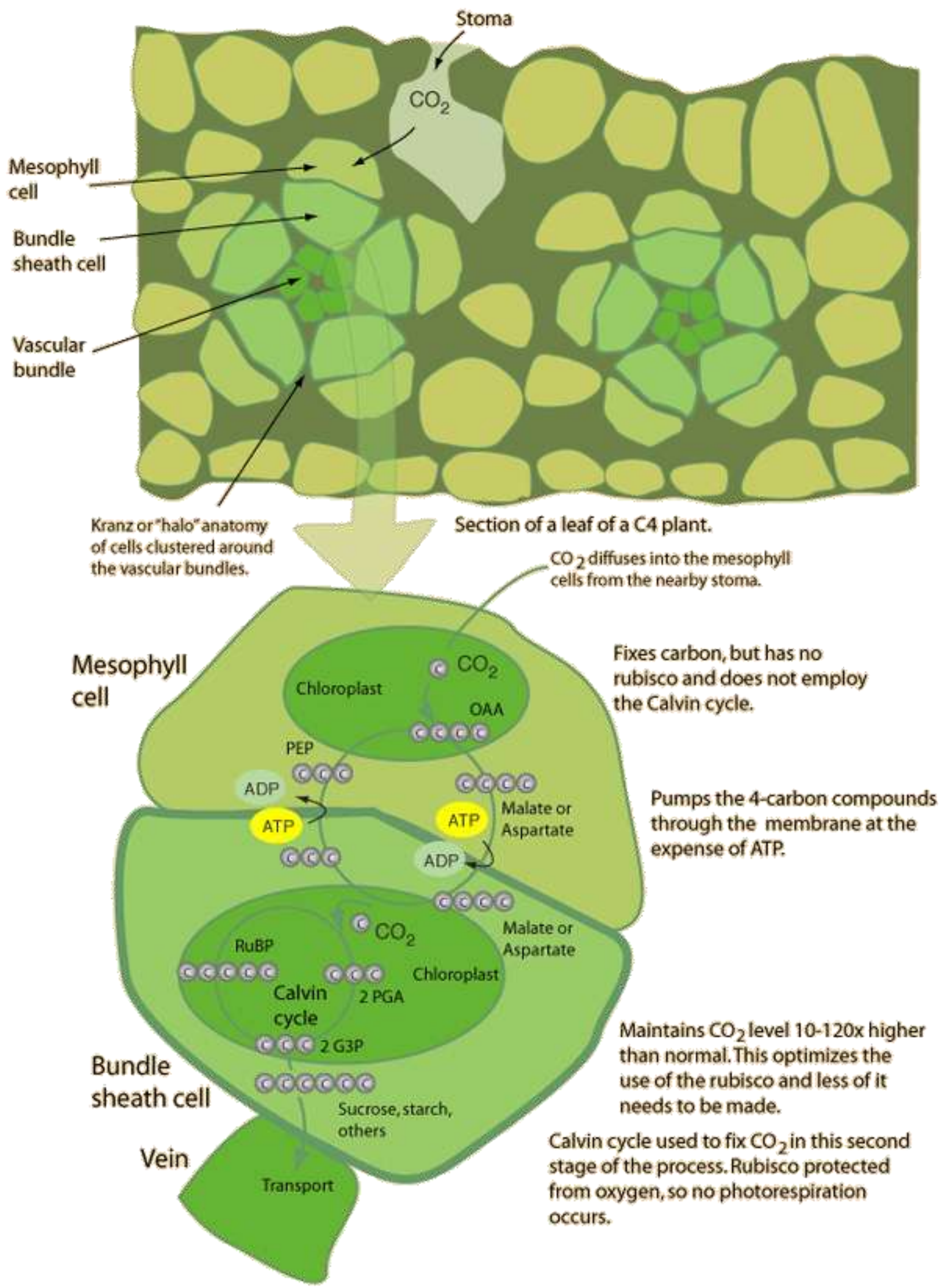
- *Two Solutions…..*

Alternative carbon fixation methods, I

C4 plants:

- 2 photosynthetic cells, bundle-sheath & mesophyll;
- PEP carboxylase (instead of rubisco)
- fixes CO2 in mesophyll;
- new 4C molecule releases CO2
- Happens in: grasses (monocots) like maize and sugarcane




Stoma
CO_2
Mesophyll cell
Bundle sheath cell
Vascular bundle
Kranz or "halo" anatomy of cells clustered around the vascular bundles.
Section of a leaf of a C4 plant.
CO_2 diffuses into the mesophyll cells from the nearby stoma.
Mesophyll cell
Chloroplast
CO_2
OAA
PEP
ADP
ATP
ATP
Malate or Aspartate
ADP
Fixes carbon, but has no rubisco and does not employ the Calvin cycle.
Pumps the 4-carbon compounds through the membrane at the expense of ATP.
Malate or Aspartate
CO_2
RuBP
Chloroplast
Calvin cycle
2 PGA
2 G3P
Sucrose, starch, others
Bundle sheath cell
Vein
Transport
Maintains CO_2 level 10-120x higher than normal. This optimizes the use of the rubisco and less of it needs to be made.
Calvin cycle used to fix CO_2 in this second stage of the process. Rubisco protected from oxygen, so no photorespiration occurs.

Location

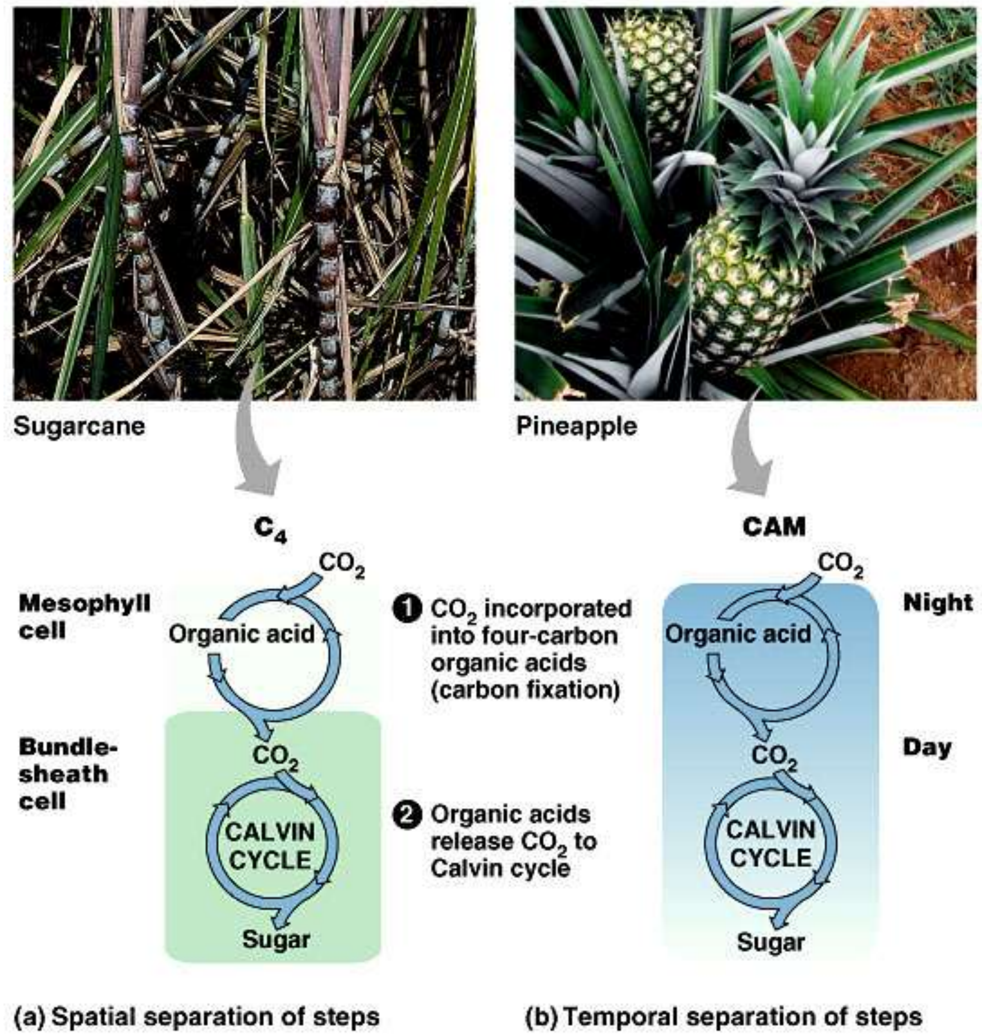
Alternative carbon fixation methods, II

<u>CAM plants</u>:

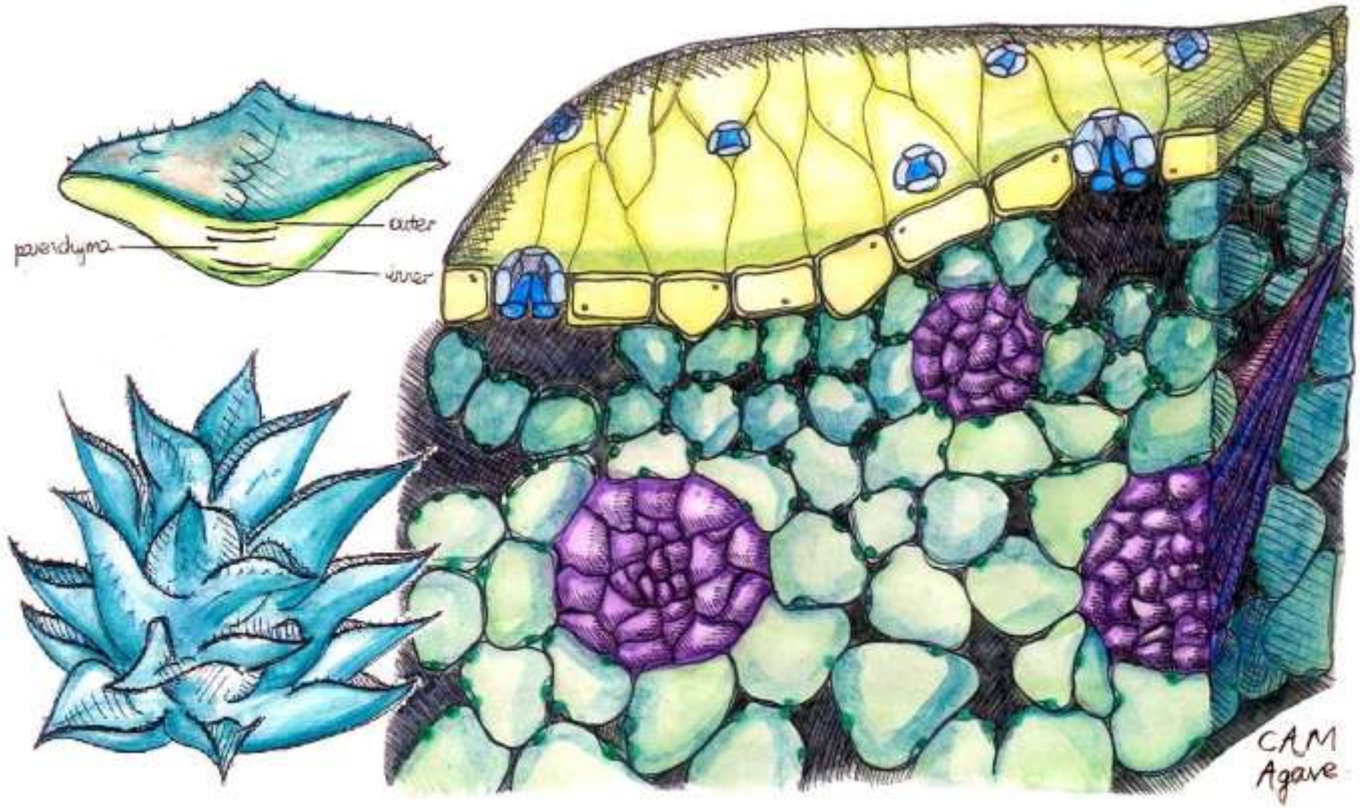
open stomata during night, close during day

(crassulacean acid metabolism);

cacti, pineapples, etc.



CAM Photosynthesis in Agave



A review of photosynthesis