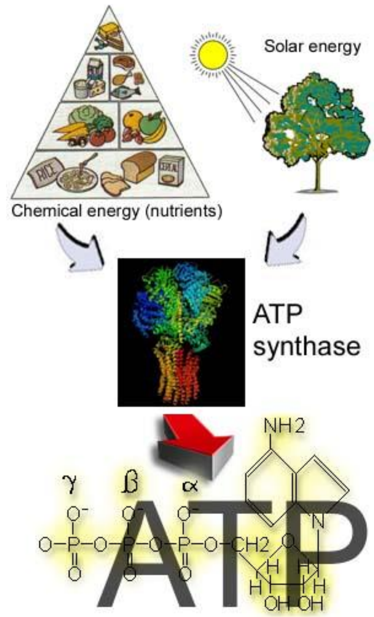
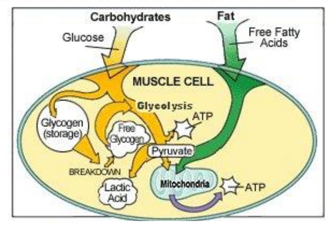
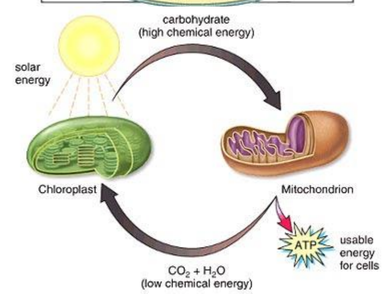


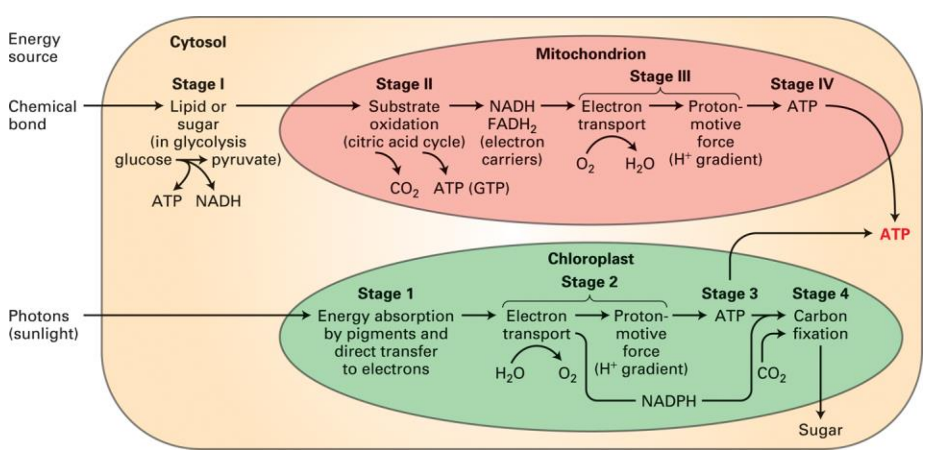
Cellular energetics





External sources of energy ➔ biologically energy : ATP

- prokaryotic cells: cell membrane
- eukaryotic cells : mitochondria, chloroplast

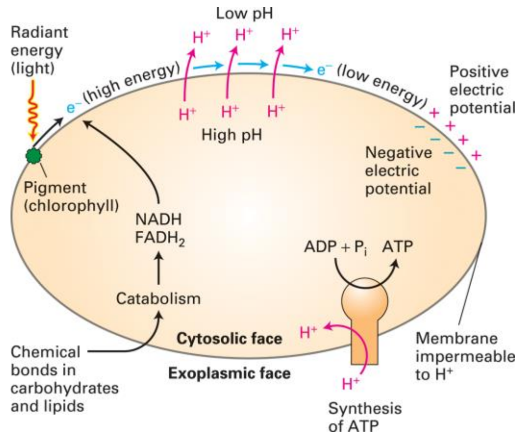


Aerobic oxidation & photosynthesis

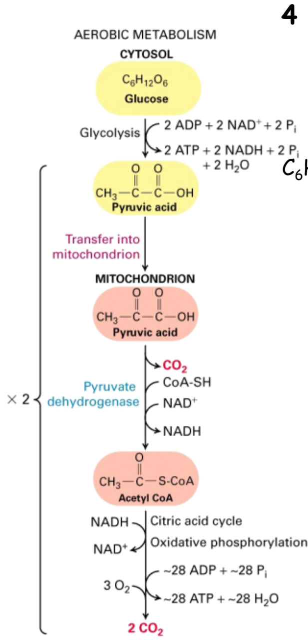
ADP + Pi ➔ ATP

➔chemiosmotic coupling → proton electrochemical gradient

- Electron transport chain
- Proton motive force



GLUCOSE OXIDATION IN EUCARYOTES



4 steps:

- Glycolysis
  - 6-C glucose → 2 3-C pyruvate + 2 ATP
  - Cytosol

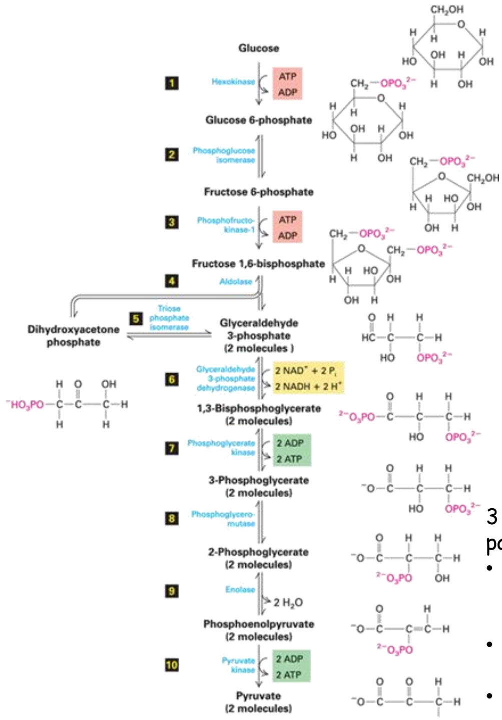
$C_6H_{12}O_6 + 2NAD^+ + 2ADP^{3-} + 2P_i^{2-} \rightarrow 2\ C_3H_4O_3 + 2NADH + 2\ ATP^{4-}$

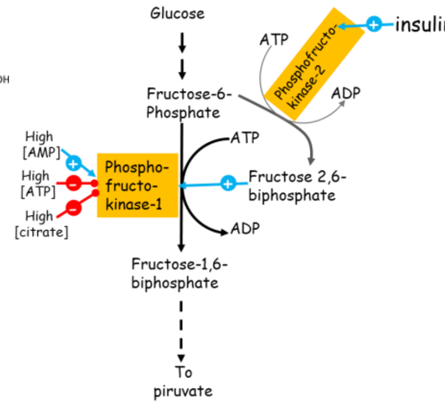
- Citric acid cycle
  - In mitochondrion
  - Pyruvate → CO_2 + NADH + $FADH_2$
- Electron transport chain
  - High energy electrons from NADH and $FADH_2$ →O_2
  - Convert energy released into a proton motive force (H^+ gradient)
- ATP synthesis
  - Proton motive force powers the synthesis of ATP as protons flow down their concentration and voltage gradients through the ATP synthesis enzyme

Overall reaction of aerobic metabolism:

Glucose + 6 O_2 + ~30 ADP + ~30 P_i ⟶ 6 CO_2 + 36 H_2O + ~30 ATP

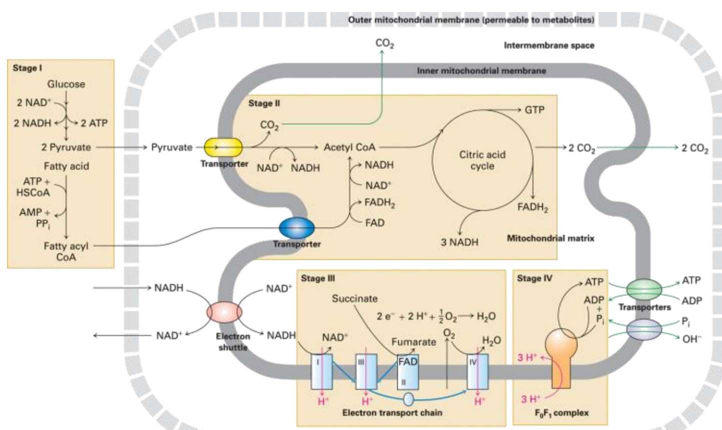
GLYCOLYTIC PATHWAY



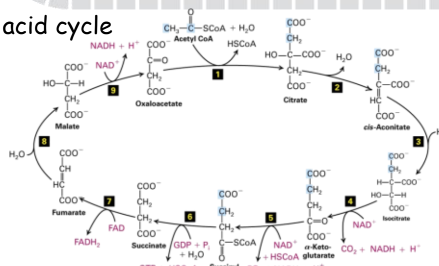


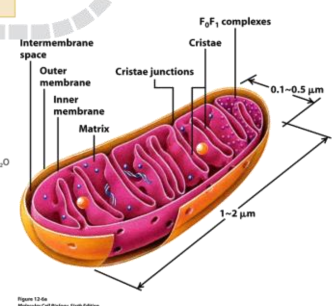
3 allosteric enzymes involved in glycolytic pathway

- Hexokinase
  - Inhibited by its reaction product : glucose 6-phosphate
- Pyruvate kinase
  - Inhibited by ATP
- Phosphofructokinase-1



Krebs/Citric acid cycle



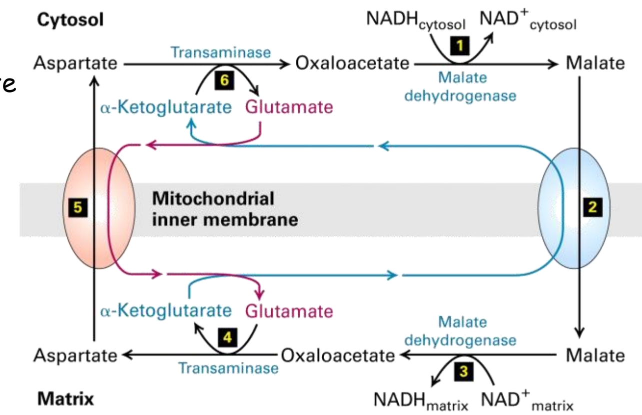


NAD+ & NADH CYTOSOL VS MITOCHONDRIAL MATRIX

Inner membrane of mitochondria: impermeable to NADH→ how to transfer energy (electrons) from cytosolic NADH into mitochondria?

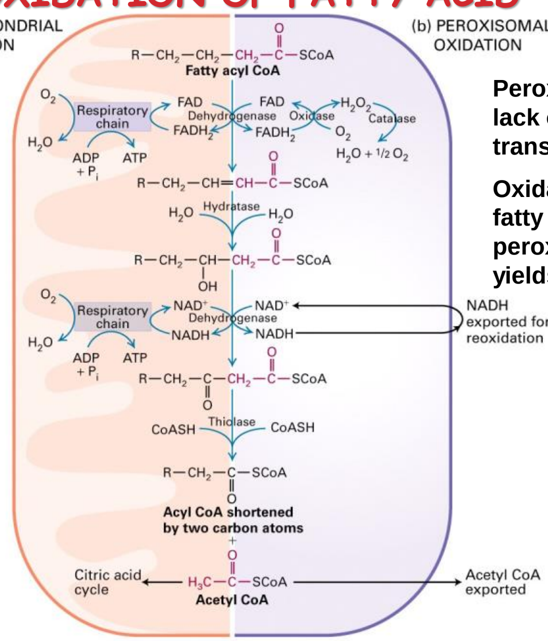
several *electron shuttles*: malate-aspartate shuttle

- 2 antiports: malate / a-ketoglutarate antiport and glutamate/ aspartate antiport



MITOCHONDRIAL & PEROXISOMAL OXIDATION OF FATTY ACID

- **Electrons from FADH2 & NADH are used to generate ATP**



Peroxisome → lack of electron transport

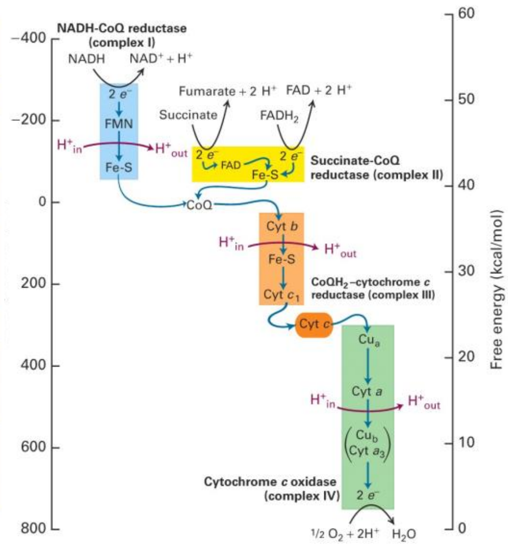
Oxidation of fatty acids in peroxisomes yields no ATP

ELECTRON TRANSPORT CHAIN AND GENERATION OF THE PROTON MOTIVE FORCE

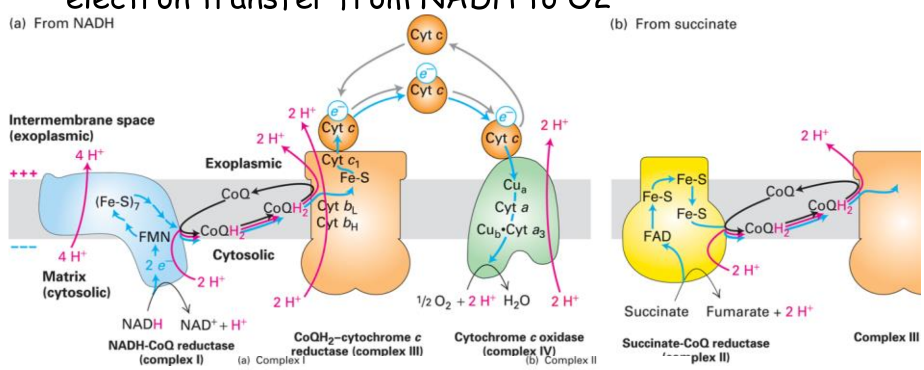
TABLE 8-2 Electron-Carrying Prosthetic Groups in the Respiratory Chain

Protein Component	Prosthetic Groups*
NADH-CoQ reductase (complex I)	FMN Fe-S
Succinate-CoQ reductase (complex II)	FAD Fe-S
$CoQH_2$–cytochrome *c* reductase (complex III)	Heme b_L Heme b_H Fe-S Heme c_1
Cytochrome *c*	Heme *c*
Cytochrome *c* oxidase (complex IV)	Cu_a^{2+} Heme *a* Cu_b^{2+} Heme a_3

*Not included is coenzyme Q, an electron carrier that is not permanently bound to a protein complex.
SOURCE: J. W. De Pierre and L. Ernster, 1977, *Ann. Rev. Biochem.* 46:201.



Translocation 10 protons from matrix through electron transfer from NADH to O2



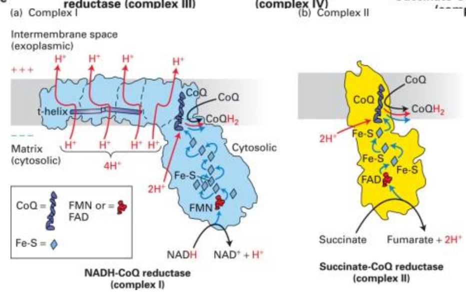
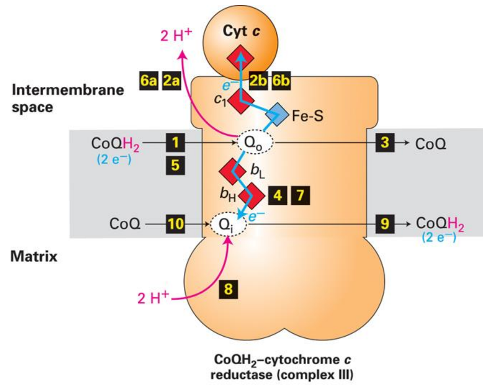


FIGURE 12.18 THE Q CYCLE.



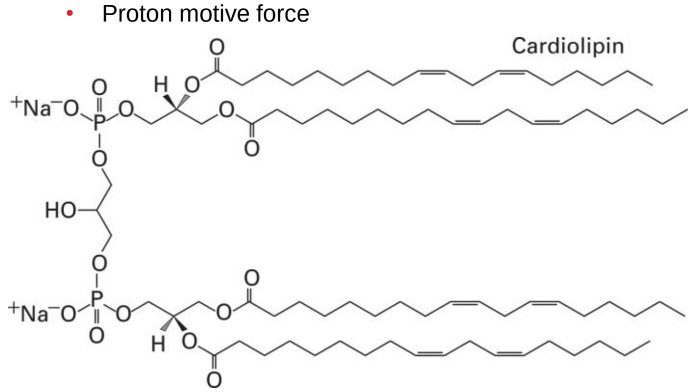
At Q_o site: $2\ CoQH_2 + 2\ Cyt\ c^{3+} \longrightarrow$ $(4\ H^+, 4\ e^-)$
$2\ CoQ + 2\ Cyt\ c^{2+} + 2\ e^- + 4\ H^+_{(outside)}$ $(2\ e^-)$

At Q_i site: $CoQ + 2\ e^- + 2\ H^+_{(matrix\ side)} \longrightarrow CoQH_2$ $(2\ H^+, 2\ e^-)$

Net Q cycle (sum of reactions at Q_o and Q_i):
$CoQH_2 + 2\ Cyt\ c^{3+} + 2\ H^+_{(matrix\ side)} \longrightarrow$ $(2\ H^+, 2\ e^-)$
$CoQ + 2\ Cyt\ c^{2+} + 4\ H^+_{(outside)}$ $(2\ e^-)$

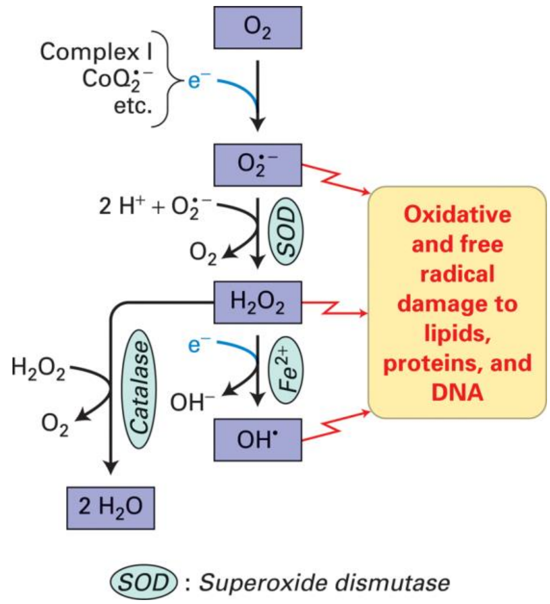
Per $2\ e^-$ transferred through complex III to cytochrome *c*, $4\ H^+$ released to the intermembrane space

- **Multiprotein complexes (Complex O, III, IV) assemble into supercomplexes**
  - Unique phospholipid : cardiolipin (diphosphatidyl glycerol) → play an important role :
    - in the assembly and function of these supercomplexes
    - Influence inner membrane's binding
    - Permeability to protons
    - Proton motive force



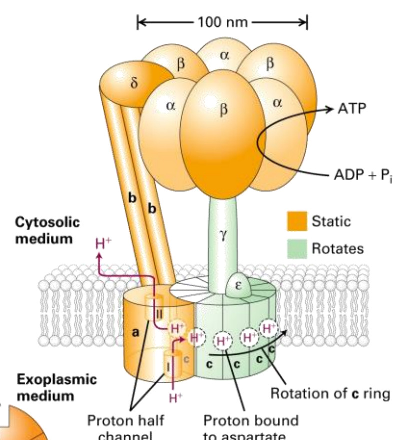
ROS : TOXIC BY-PRODUCT

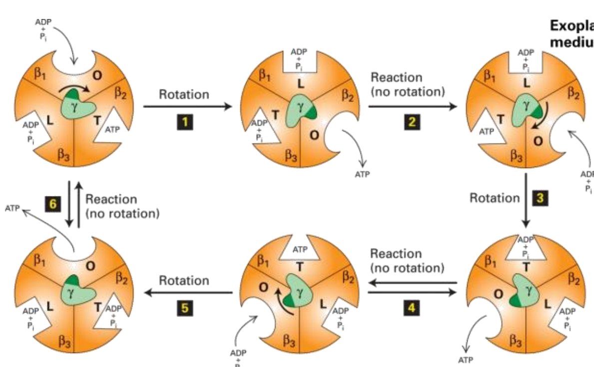
Generation and inactivation toxic ROS



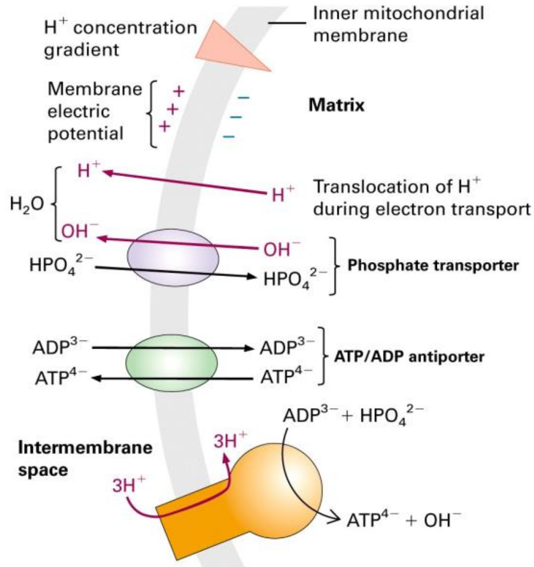
ATP SYNTHESIS

Mediated by ATP synthase

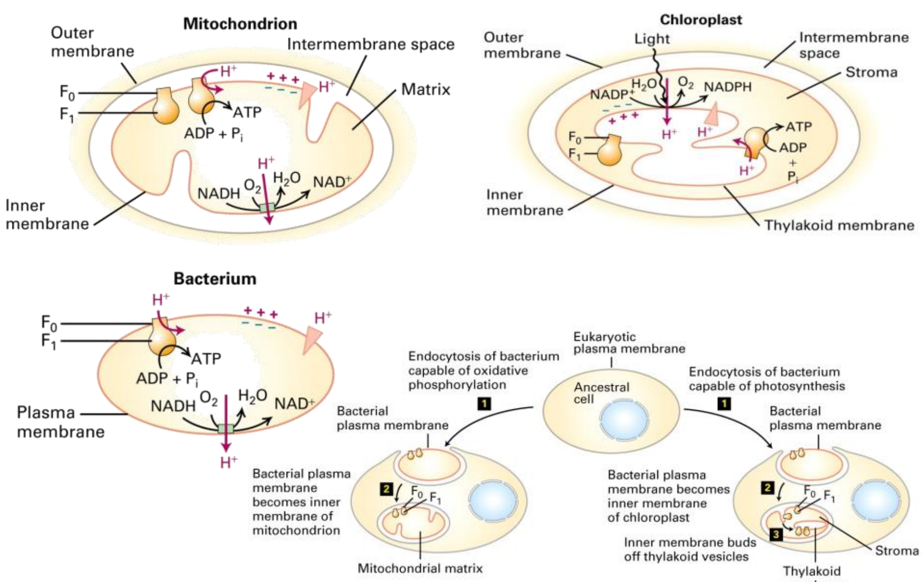




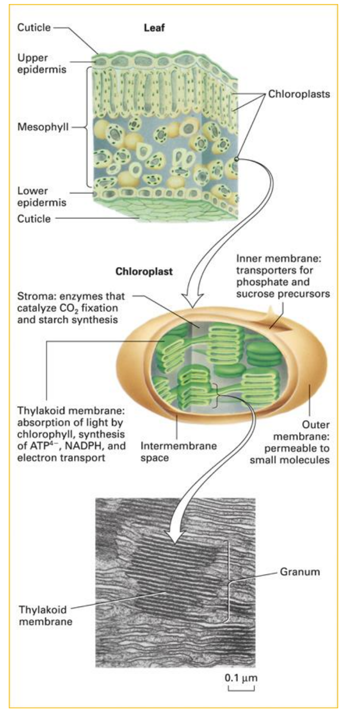
Phosphate and ATP/ADP transport system in the inner mitochondrial membrane



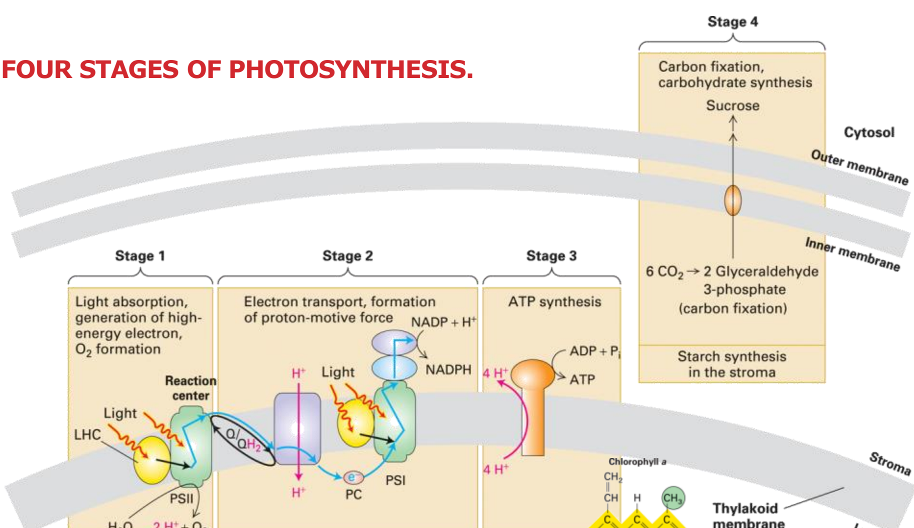
MEMBRANE ORIENTATION AND PROTON MOVEMENT



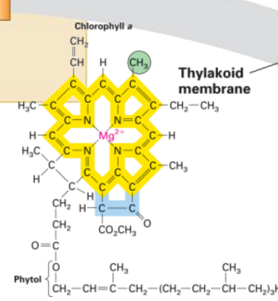
PHOTOSYNTHESIS AND LIGHT ABSORBING PIGMENTS



FOUR STAGES OF PHOTOSYNTHESIS.

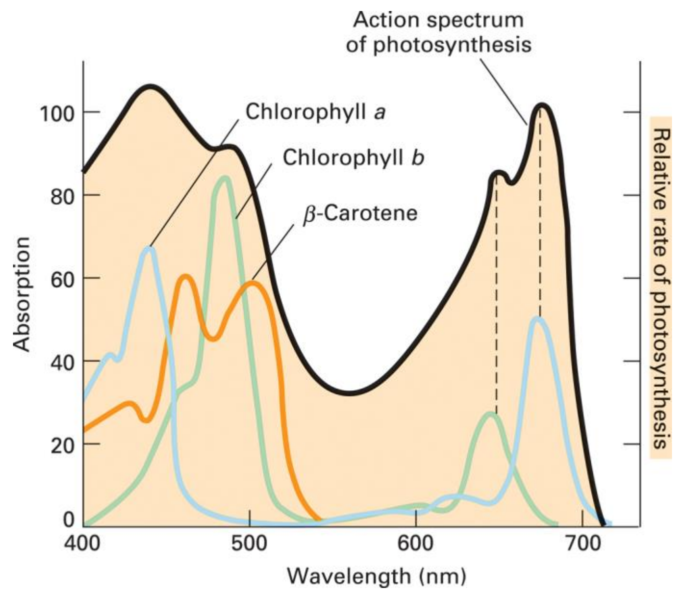


$2H_2O + 2\ NADP^+ \rightarrow O_2 + 2H^+ + 2NADPH$

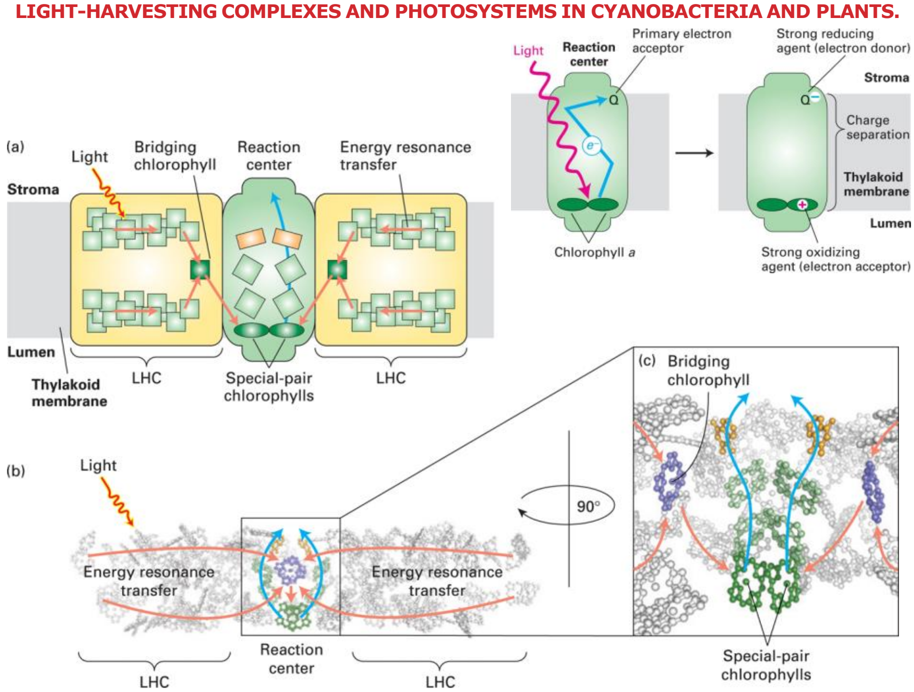


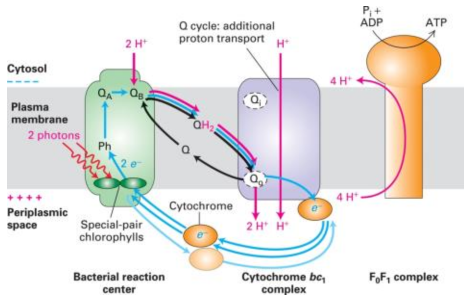
Structure of chlorophyll *a*

EXPERIMENTAL FIGURE 12.34 THE RATE OF PHOTOSYNTHESIS IS GREATEST AT WAVELENGTHS OF LIGHT ABSORBED BY THREE PIGMENTS.



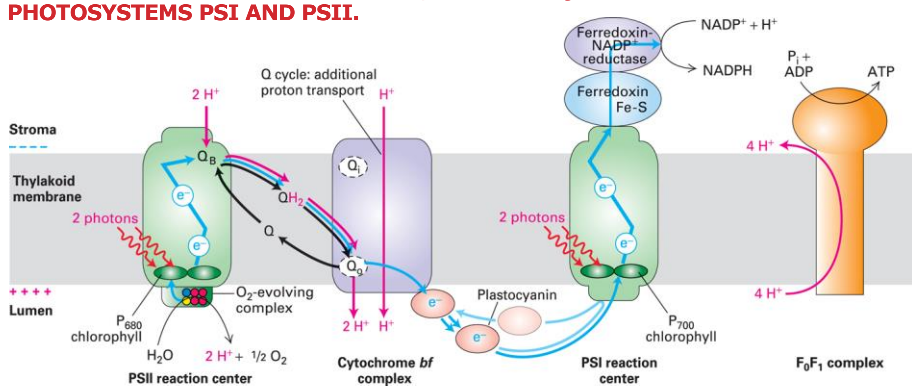
LIGHT-HARVESTING COMPLEXES AND PHOTOSYSTEMS IN CYANOBACTERIA AND PLANTS.



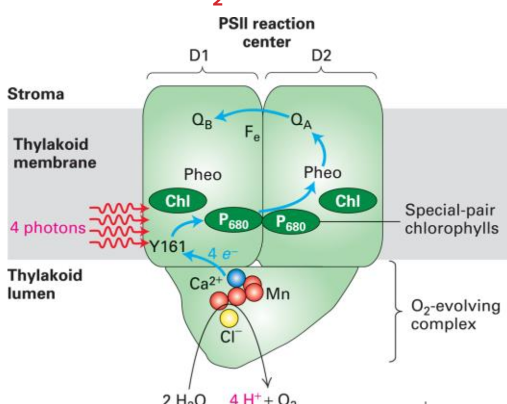


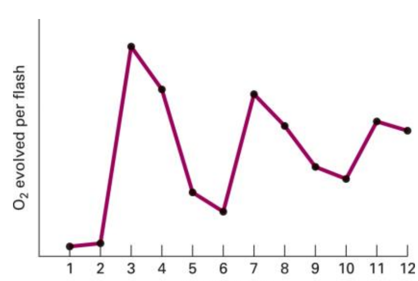
Cyclic electron flow in the single photosystem of purple bacteria

LINEAR ELECTRON FLOW IN PLANTS, WHICH REQUIRES BOTH CHLOROPLAST PHOTOSYSTEMS PSI AND PSII.



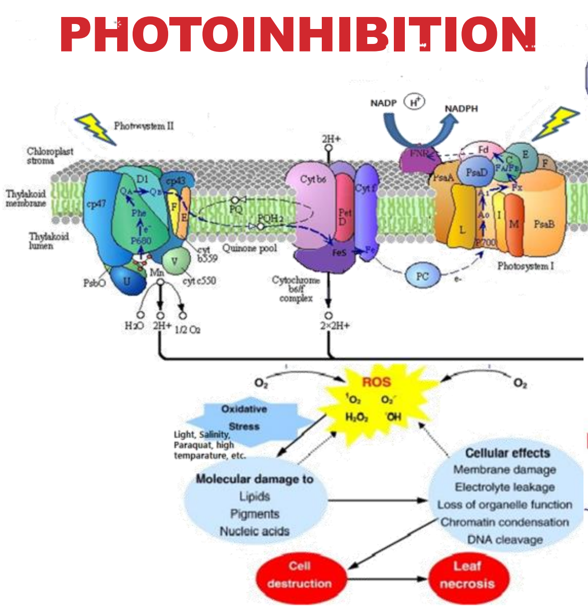
ELECTRON FLOW AND O_2 EVOLUTION IN CHLOROPLAST PSII.

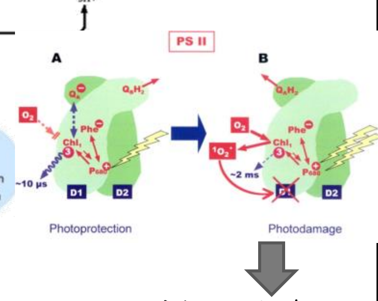




A single PSII absorbs a photon and transfers an electron four times to generate one O_2.

PHOTOINHIBITION



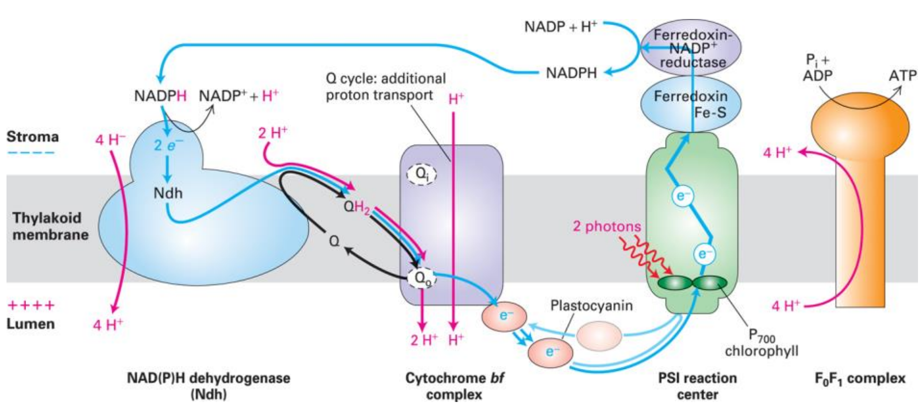


Carotene & α-tocopherol → $^1O_2$ quencher to protect plants

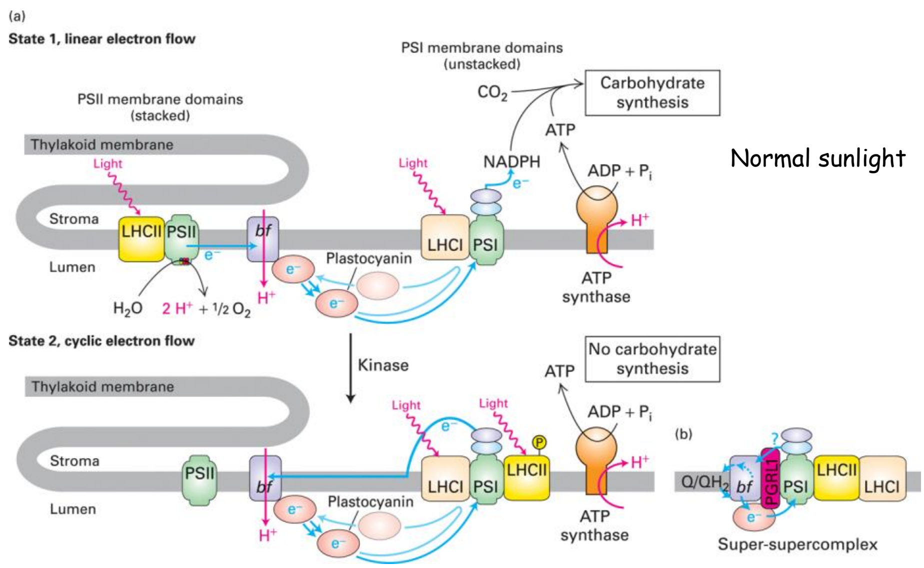
D1 protein damage repair cycle

❖**IN DROUGHT, HIGH LIGHT INTENSITY, OR LOW CARBON DIOXIDE LEVELS → NEED GREATER AMOUNTS OF ATP**

CYCLIC ELECTRON FLOW IN PLANTS, WHICH GENERATES A PROTON-MOTIVE FORCE AND ATP BUT NO OXYGEN OR NET NADPH.



PHOSPHORYLATION OF LHCII AND THE REGULATION OF LINEAR VERSUS CYCLIC ELECTRON FLOW.



PATHWAY OF CARBON DURING PHOTOSYNTHESIS.

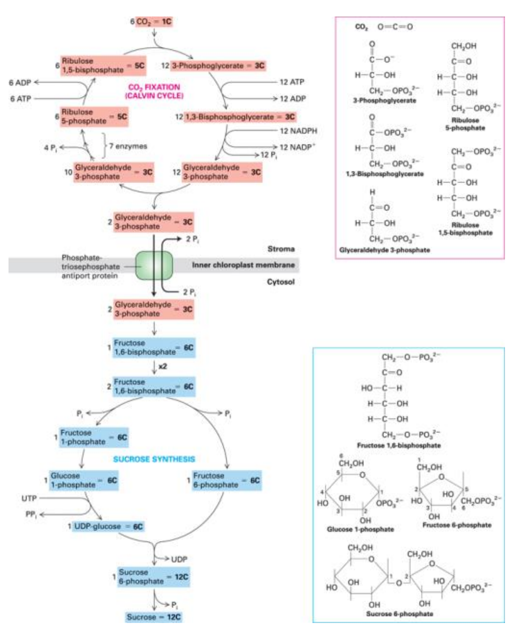


FIGURE 12.47 CO_2 FIXATION AND PHOTORESPIRATION.

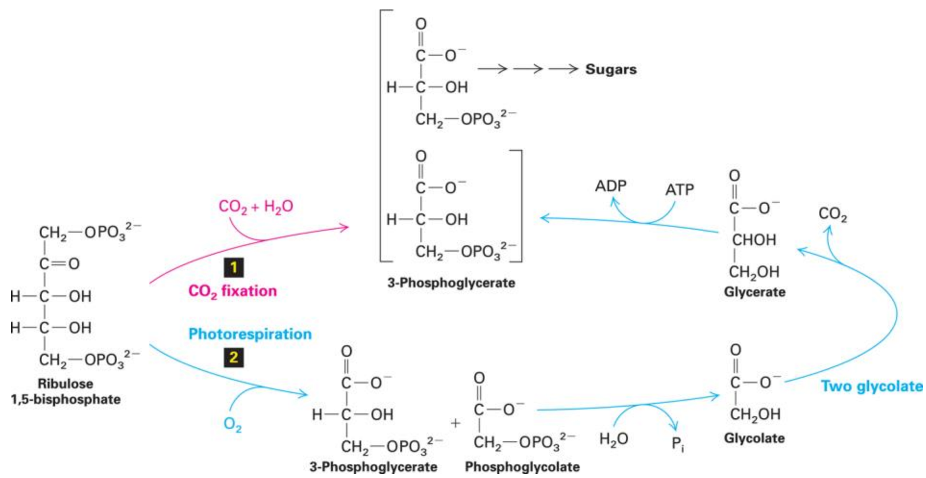


FIGURE 12.48 LEAF ANATOMY OF C_4 PLANTS AND THE C_4 PATHWAY.