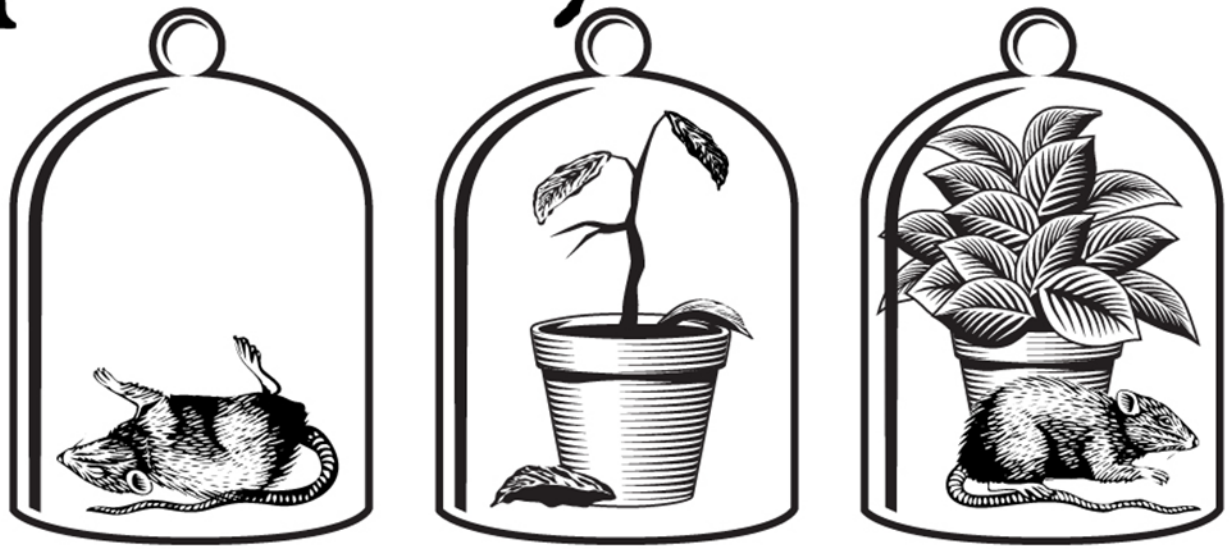
photosynthesis



Discovered by Joseph Priestly in 1774

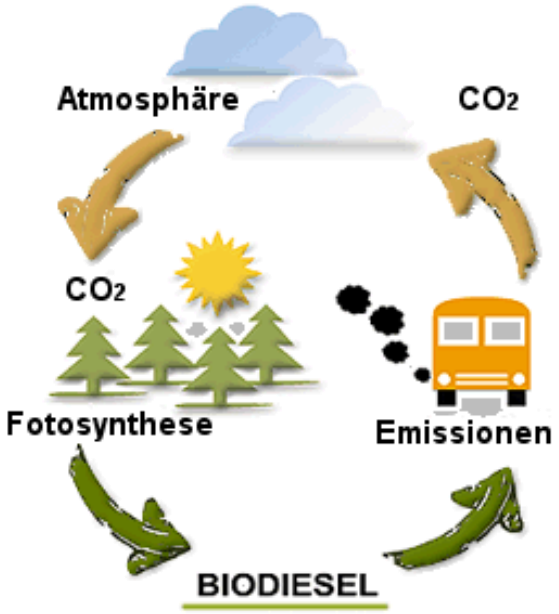
Luz

$$n\,CO_2 + n\,H_2O \longrightarrow C_n\,(H_2O)_n + n\,O_2$$

Keq = $[C\,(H_2O)]\,[O_2]$ / $[CO_2]\,[H_2O]$ = 10^{-496} !!

ΔG= 2879 kJ mol^{-1} reacción endergónica

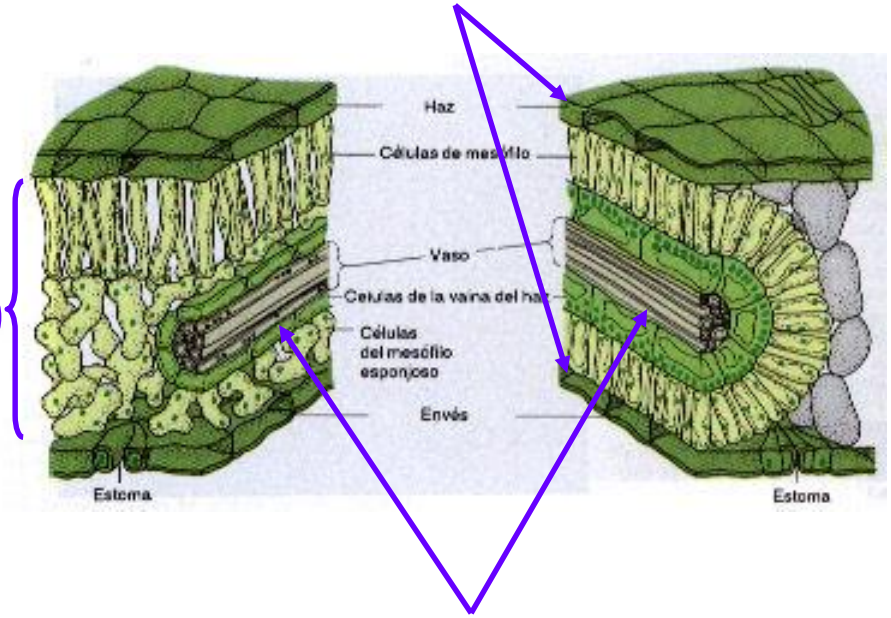

16
SOYBEAN POWERED
This Bus Runs On Soybean Bio-Diesel


Atmosphäre
CO2
CO2
Fotosynthese
Emissionen
BIODIESEL

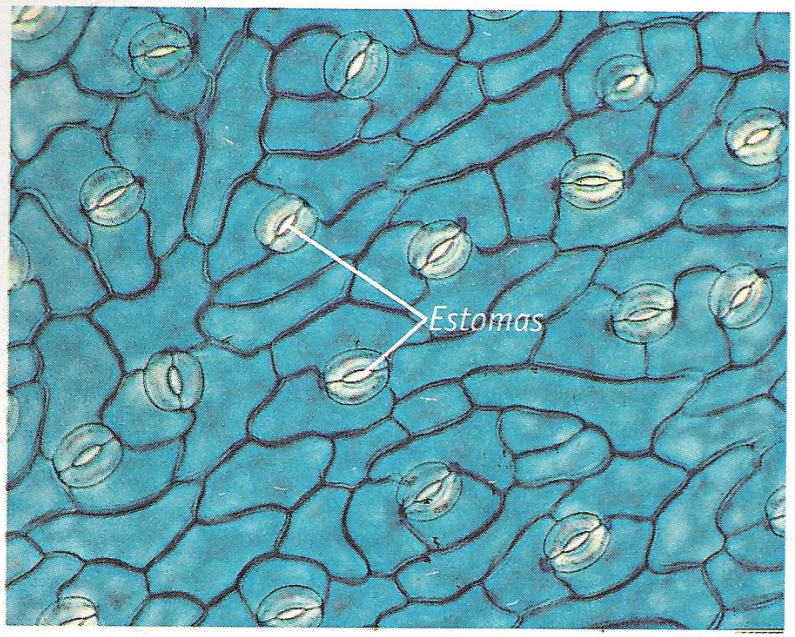
¿Dónde?

Epidemis (evita la desecación!)

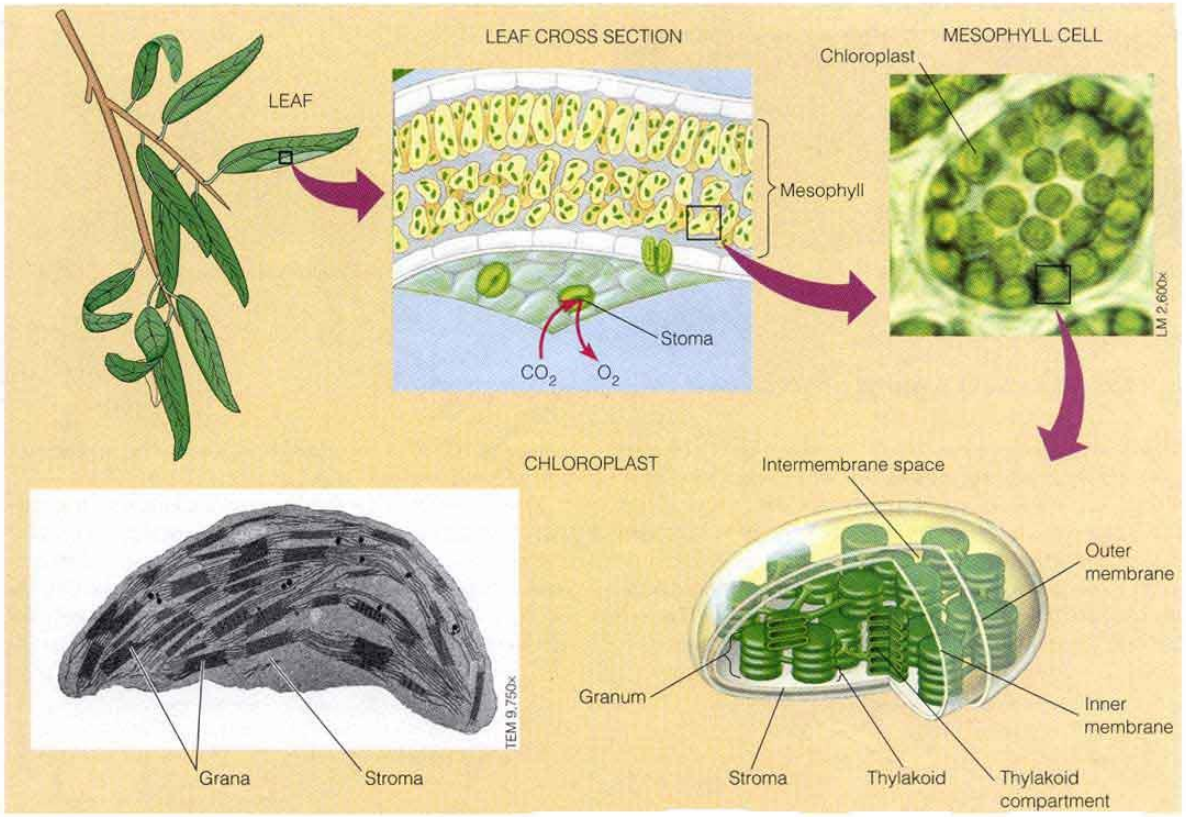
Mesófilo (fotosintético)



Haz vascular (transporte de agua, minerales y azúcares)

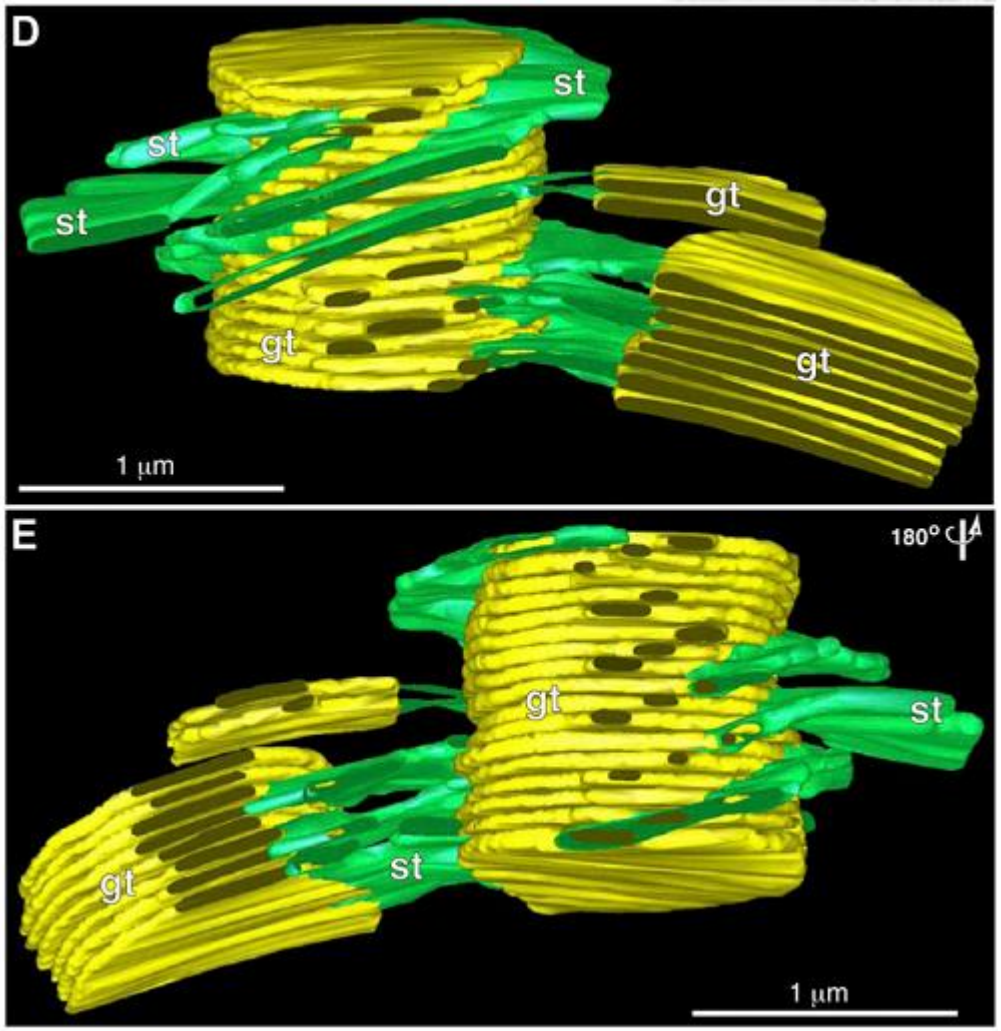


Epidermis con estomas, vista al microscopio óptico y coloreada artificialmente.

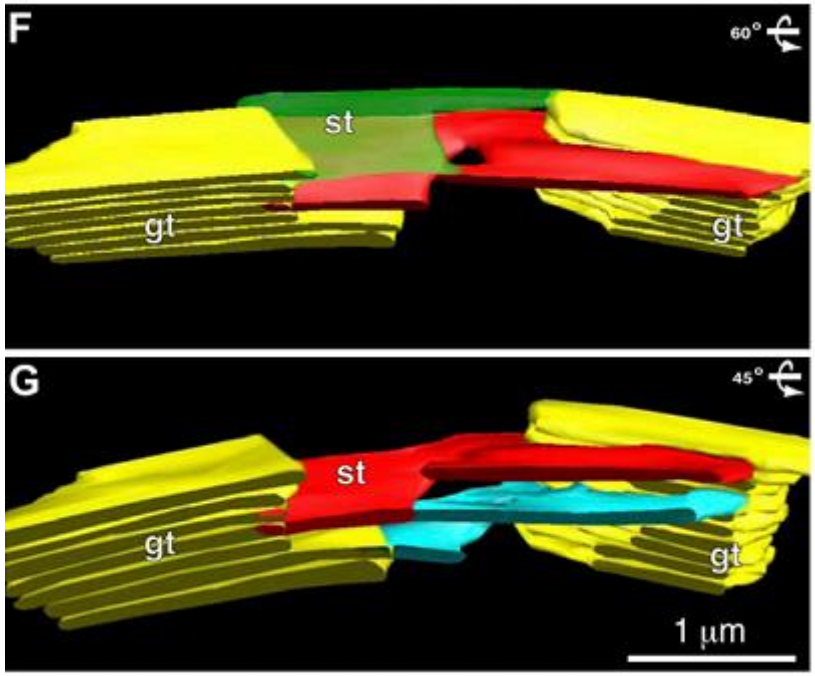


Gambar : Kloroplast : lokasi dan struktur. (Sumber : Campbell *et al.* 1999).

Estroma cloroplástico
Tilacoides
Lumen tilacoidal



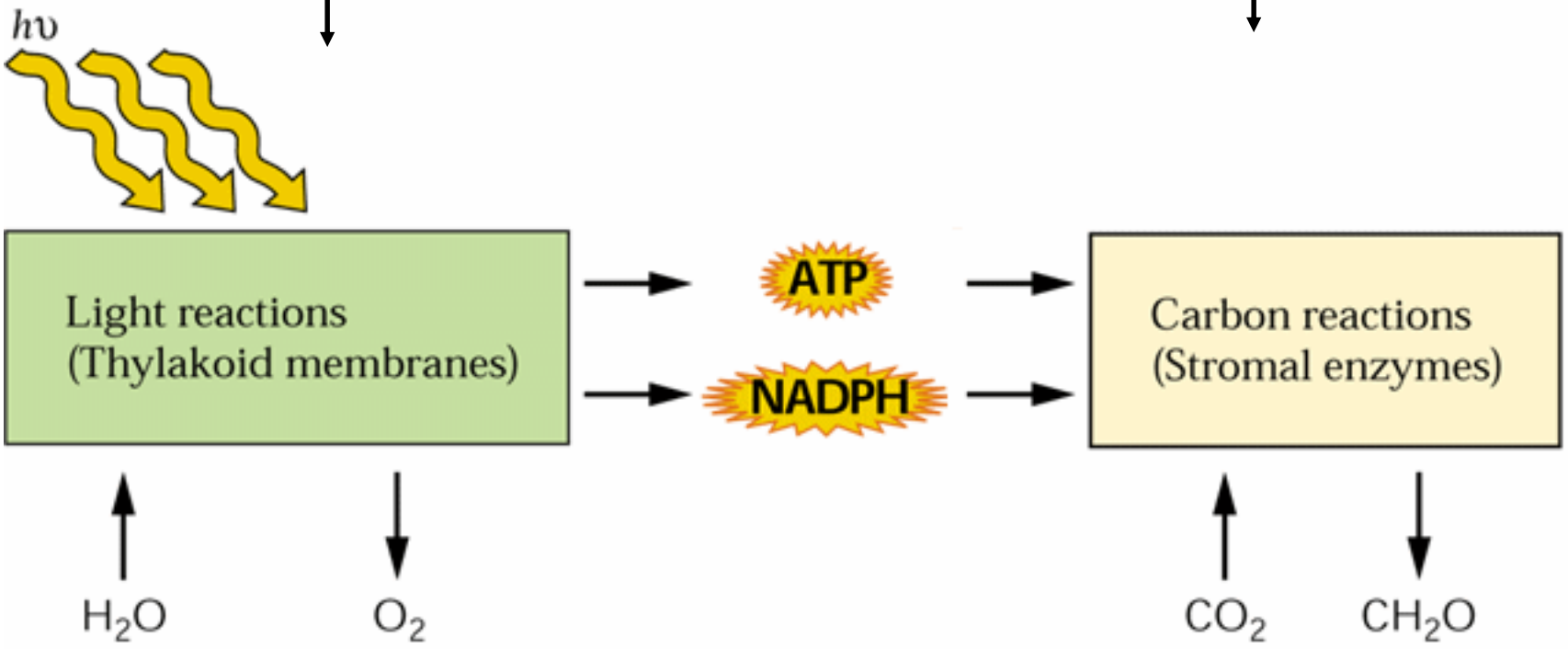
Three-Dimensional Architecture of Grana and Stroma Thylakoids of Higher Plants as Determined by Electron Tomography[1[W][OA]]

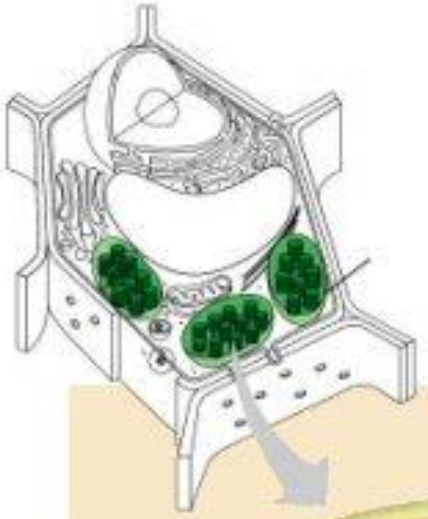

F
60°
st
gt
gt
G
45°
st
gt
gt
1 µm

Fotosíntesis

Reacciones lumínicas

Fase “oscura”

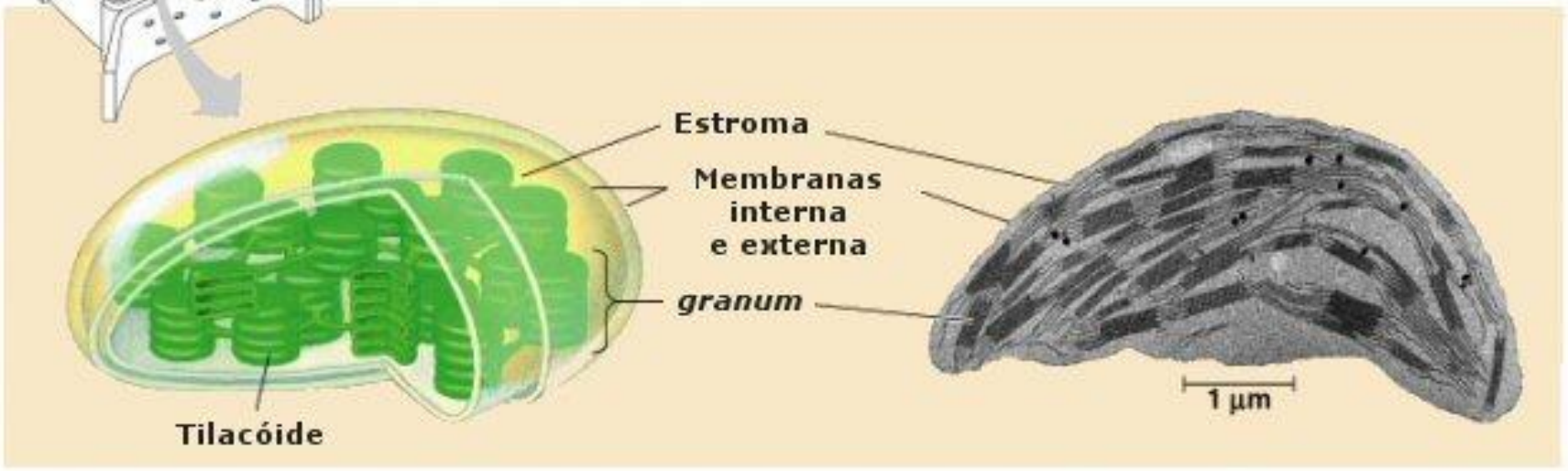




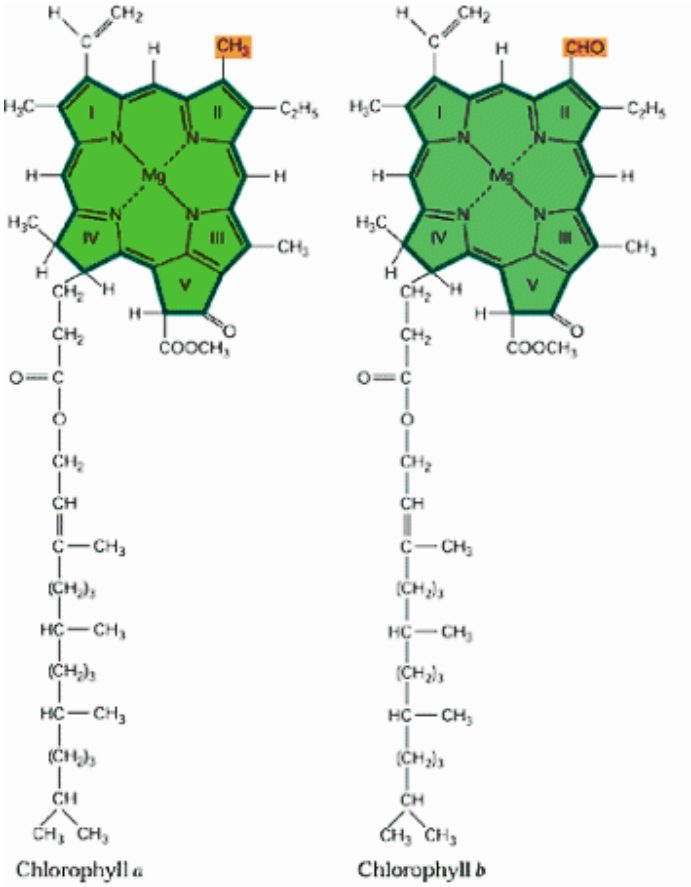
Tilacoides
Lumen tilacoidal

Fase lumínica

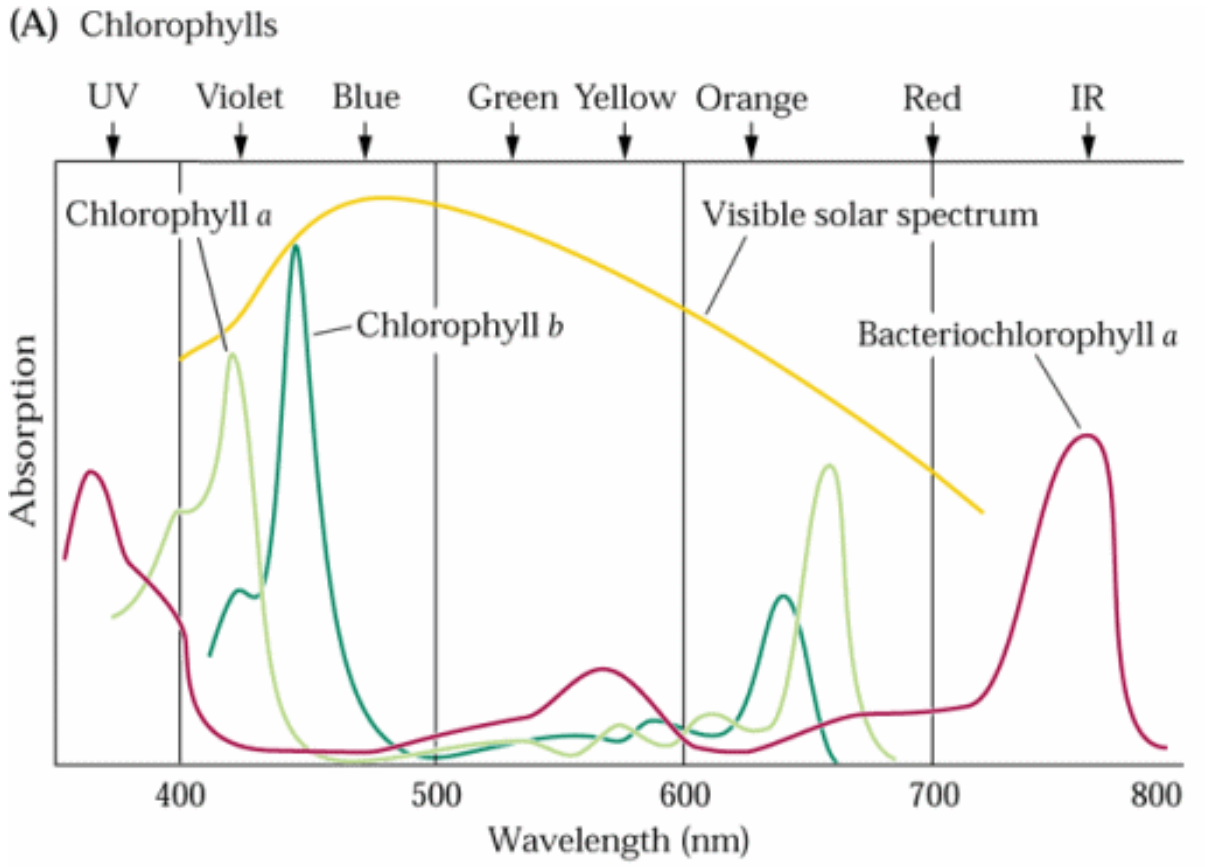
Estroma cloroplástico…….Fase “oscura”



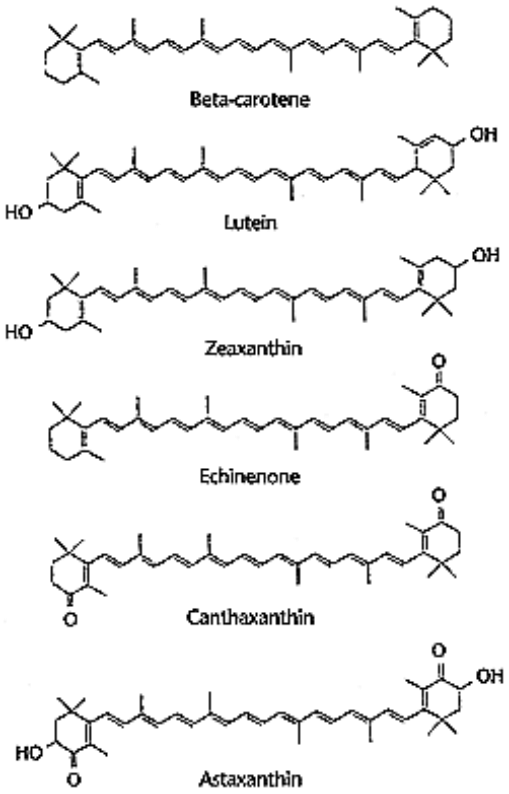
Clorofilas

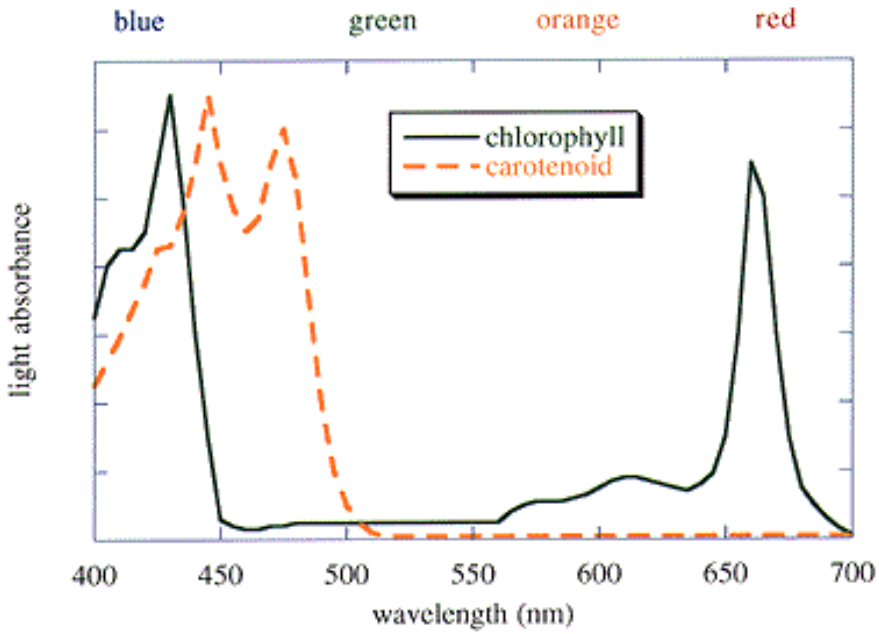


Espectros de absorción

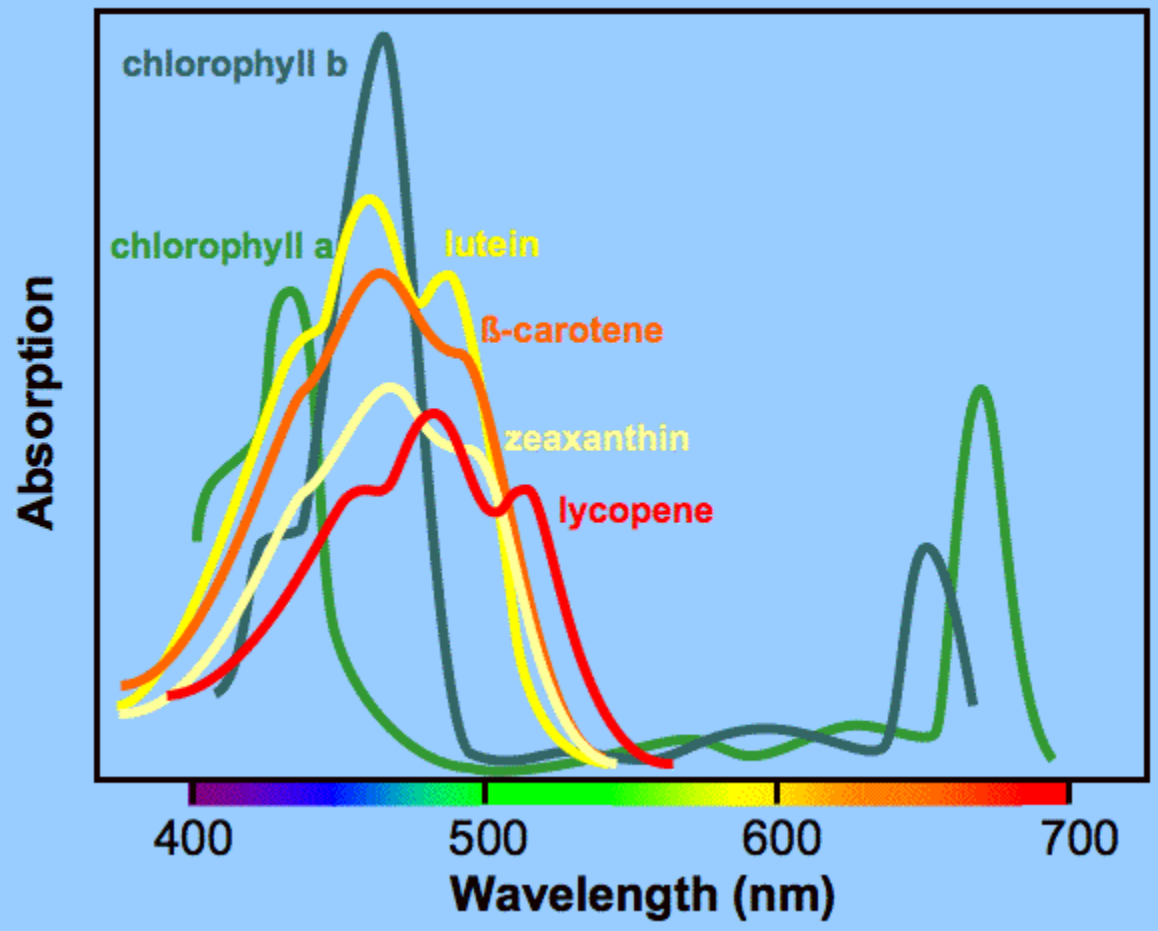


Carotenoides

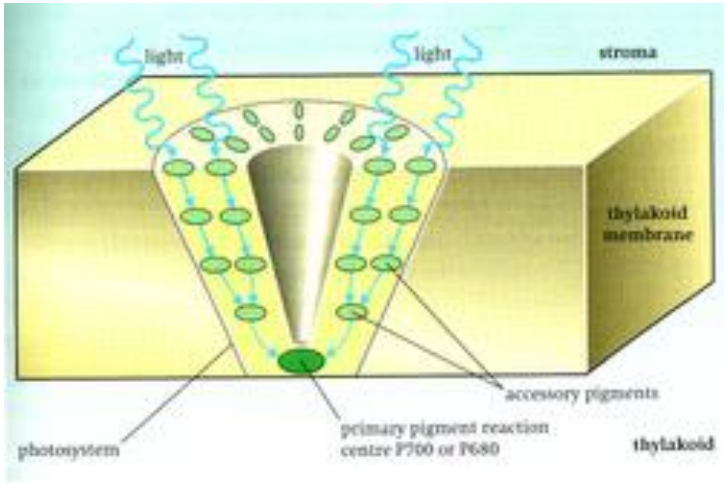


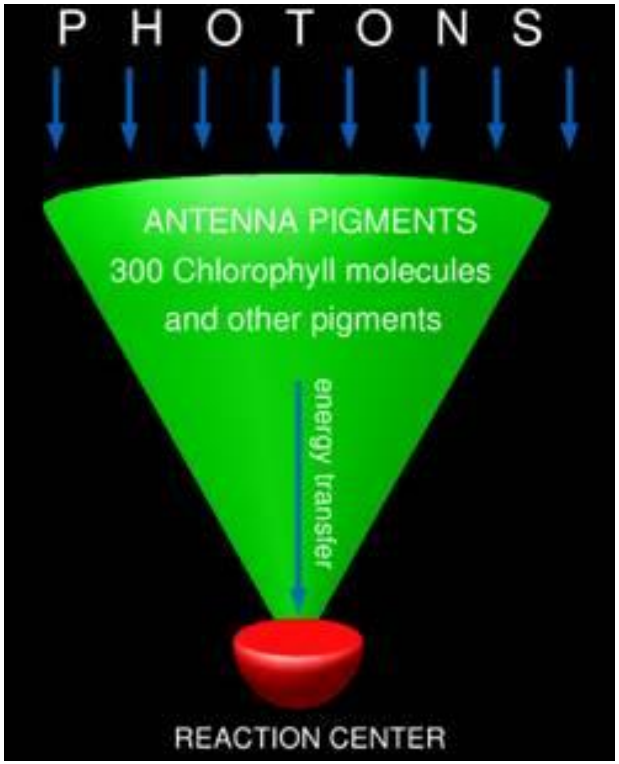


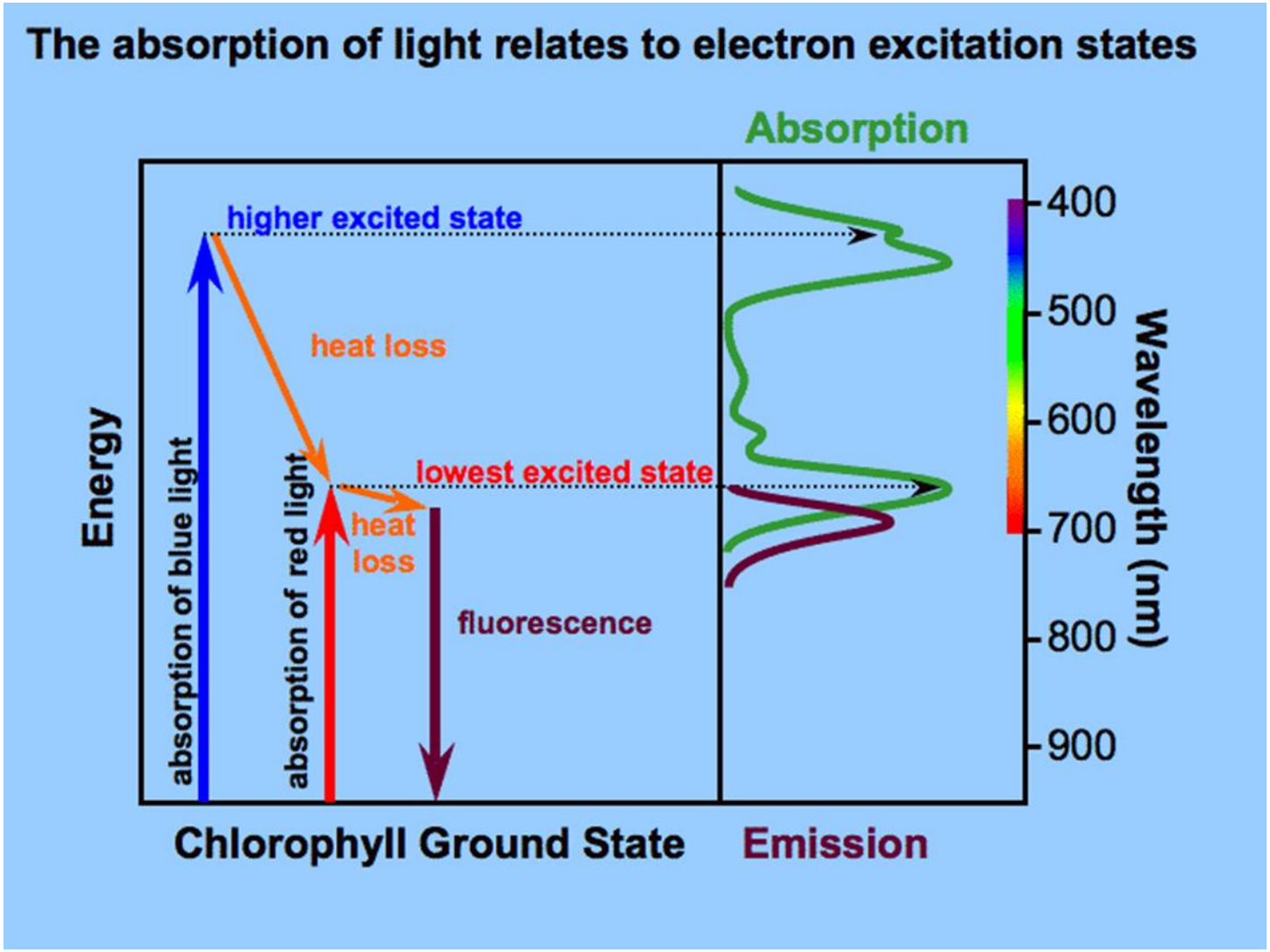
The photosynthetic pigments absorb much of the spectrum



Antena y centro de reacción

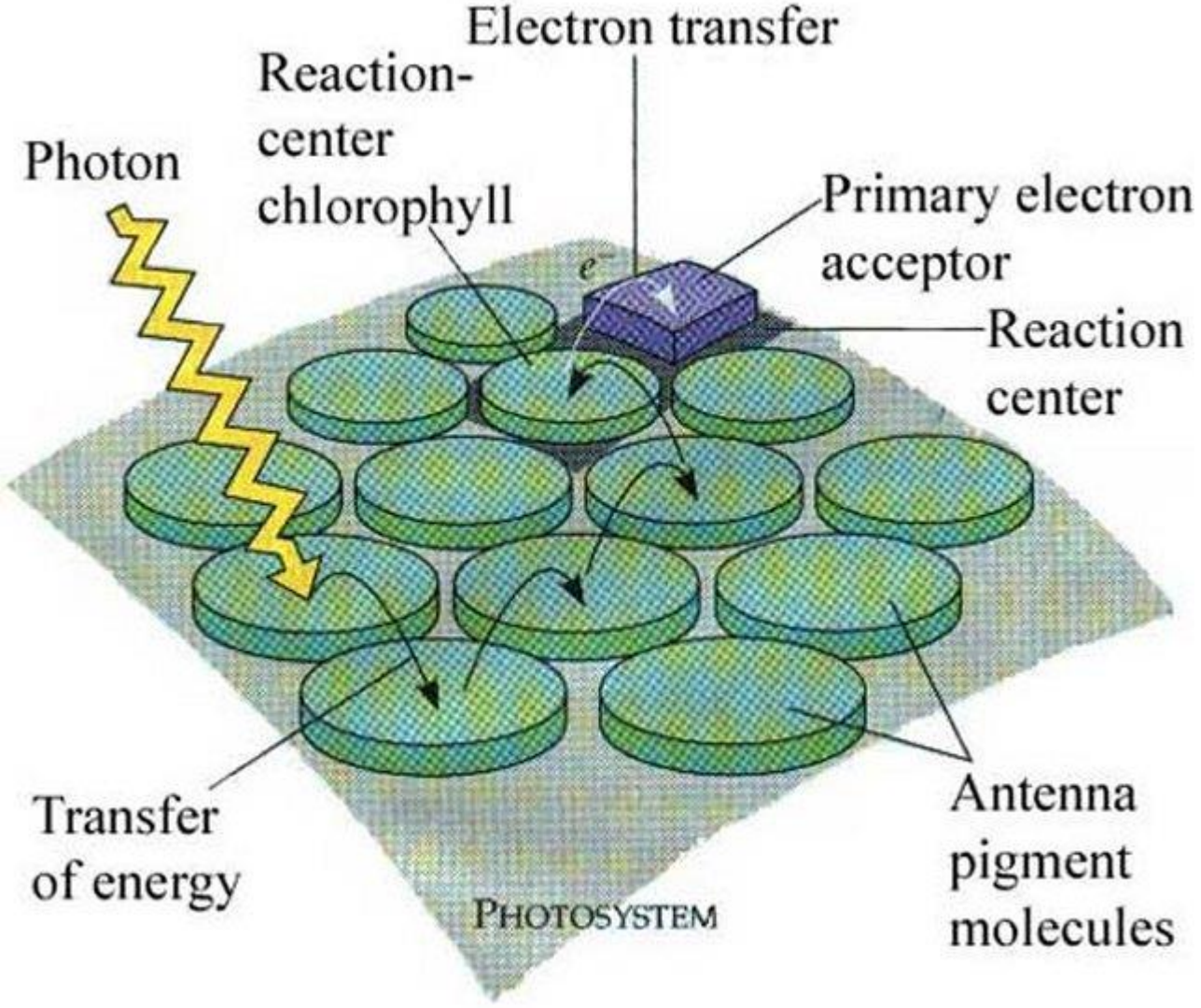


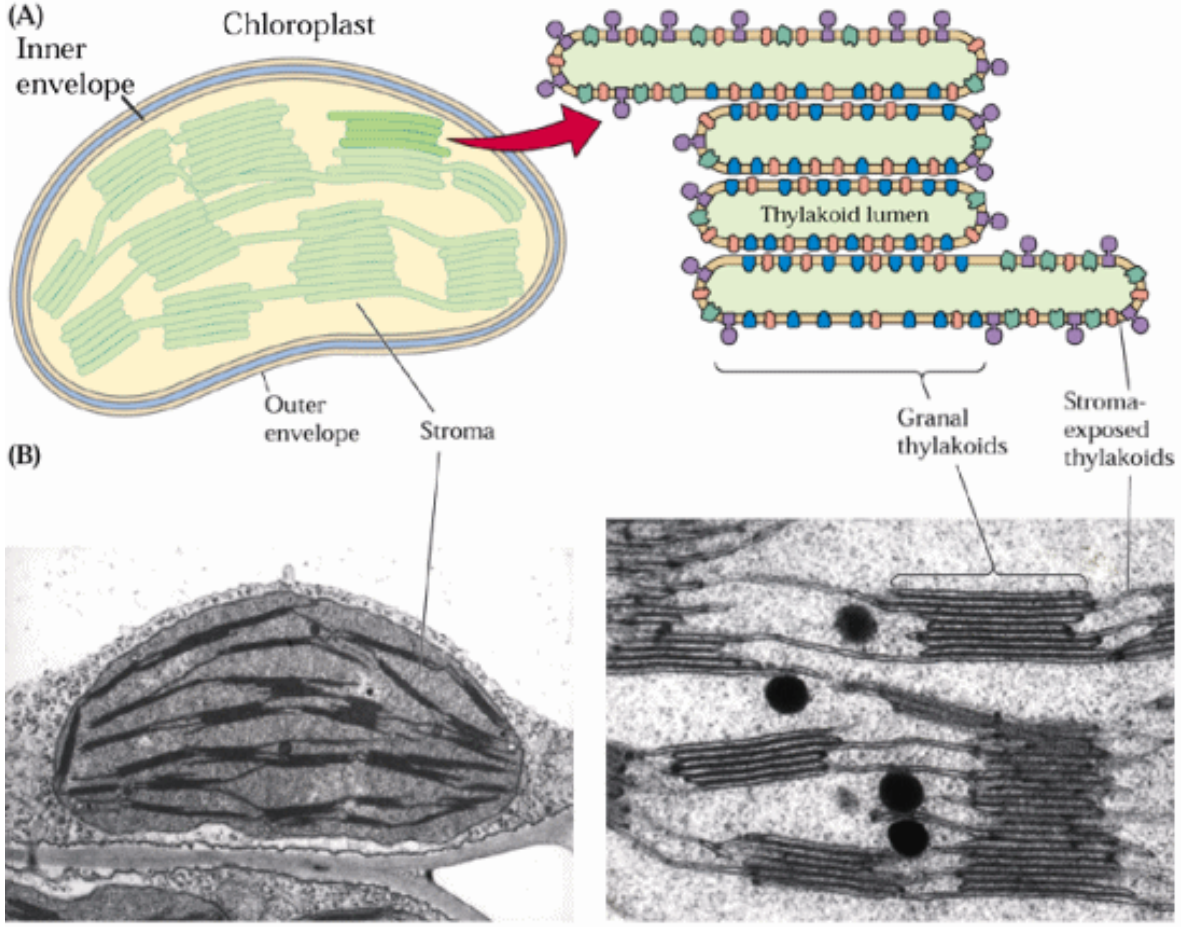



The absorption of light relates to electron excitation states
Absorption
higher excited state
heat loss
lowest excited state
heat loss
fluorescence
Energy
absorption of blue light
absorption of red light
400
500
600
700
800
900
Wavelength (nm)
Chlorophyll Ground State
Emission

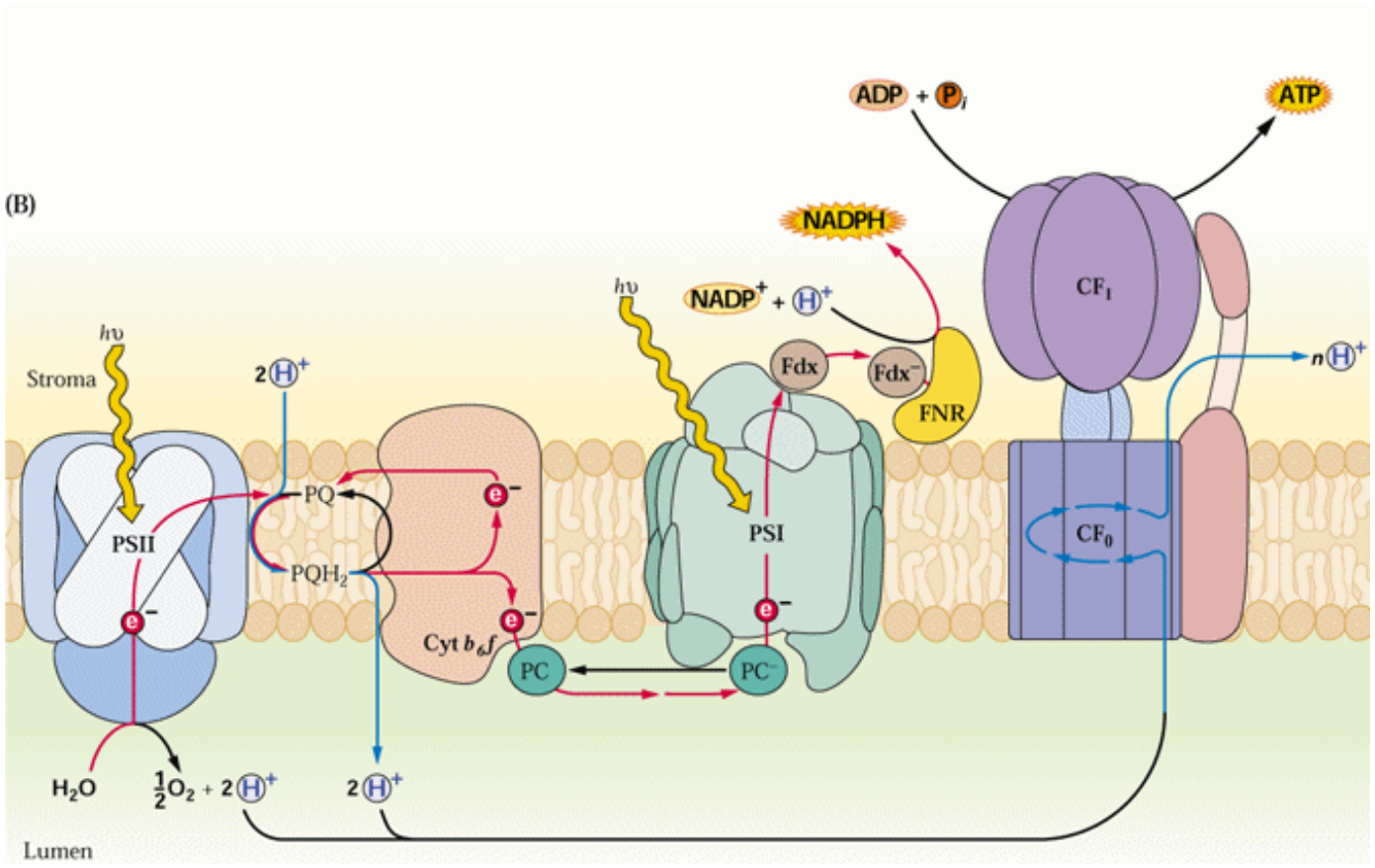
Desexcitación:

- ✓ **calor**
- ✓ **fluorescencia**
- ✓ **transferencia energética por resonancia**
- ✓ **transferencia de carga**


Electron transfer
Reaction-center chlorophyll
Photon
Primary electron acceptor
Reaction center
Transfer of energy
Antenna pigment molecules
PHOTOSYSTEM


(A)
Chloroplast
Inner envelope
Thylakoid lumen
Outer envelope
Stroma
Granal thylakoids
Stroma-exposed thylakoids
(B)

Transporte fotosintético de electrones



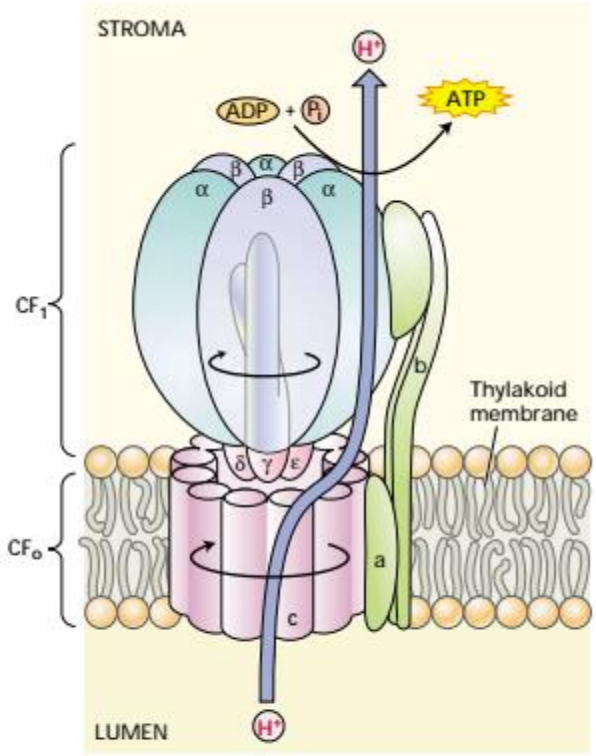


FIGURE 7.33 Structure of ATP synthase. This enzyme consists of a large multisubunit complex, CF_1, attached on the stromal side of the membrane to an integral membrane portion, known as CF_o. CF_1 consists of five different polypeptides, with a stoichiometry of α_3, β_3, γ, δ, ε. CF_o contains probably four different polypeptides, with a stoichiometry of a, b, b′, c_{14}.

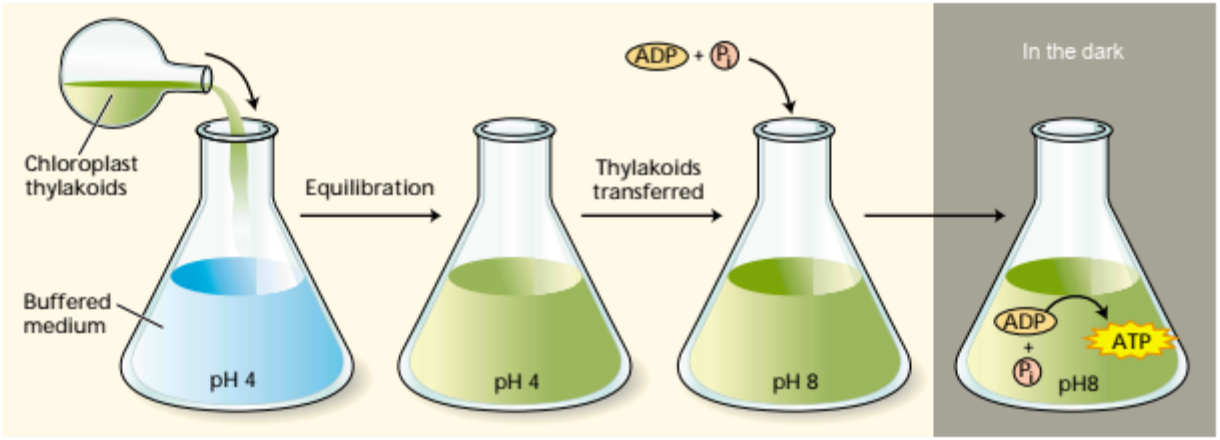
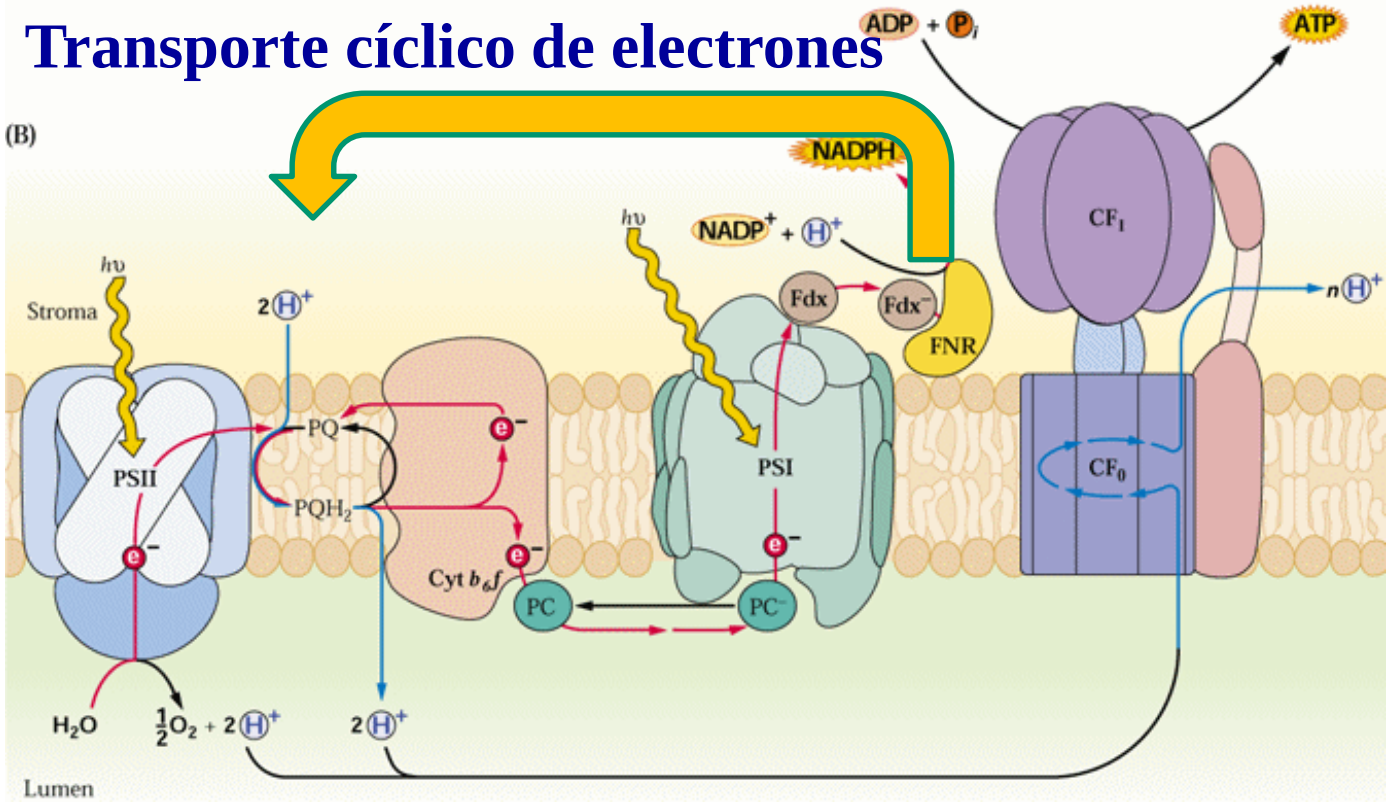
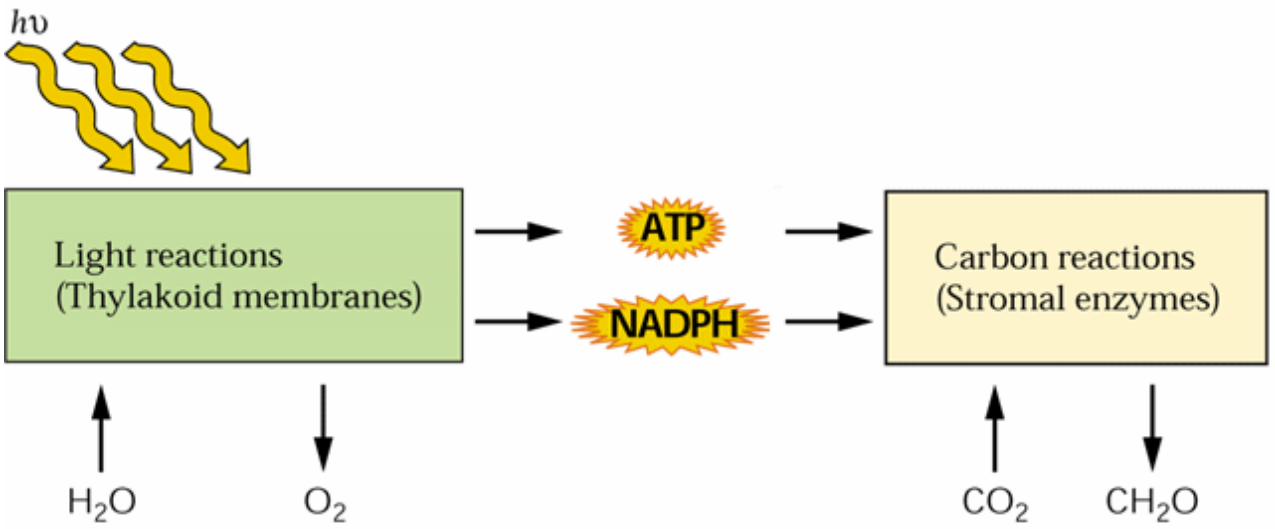


FIGURE 7.32 Summary of the experiment carried out by Jagendorf and coworkers. Isolated chloroplast thylakoids kept previously at pH 8 were equilibrated in an acid medium at pH 4. The thylakoids were then transferred to a buffer at pH 8 that contained ADP and P_i. The proton gradient generated by this manipulation provided a driving force for ATP synthesis in the absence of light. This experiment verified a prediction of the chemiosmotic theory stating that a chemical potential across a membrane can provide energy for ATP synthesis.

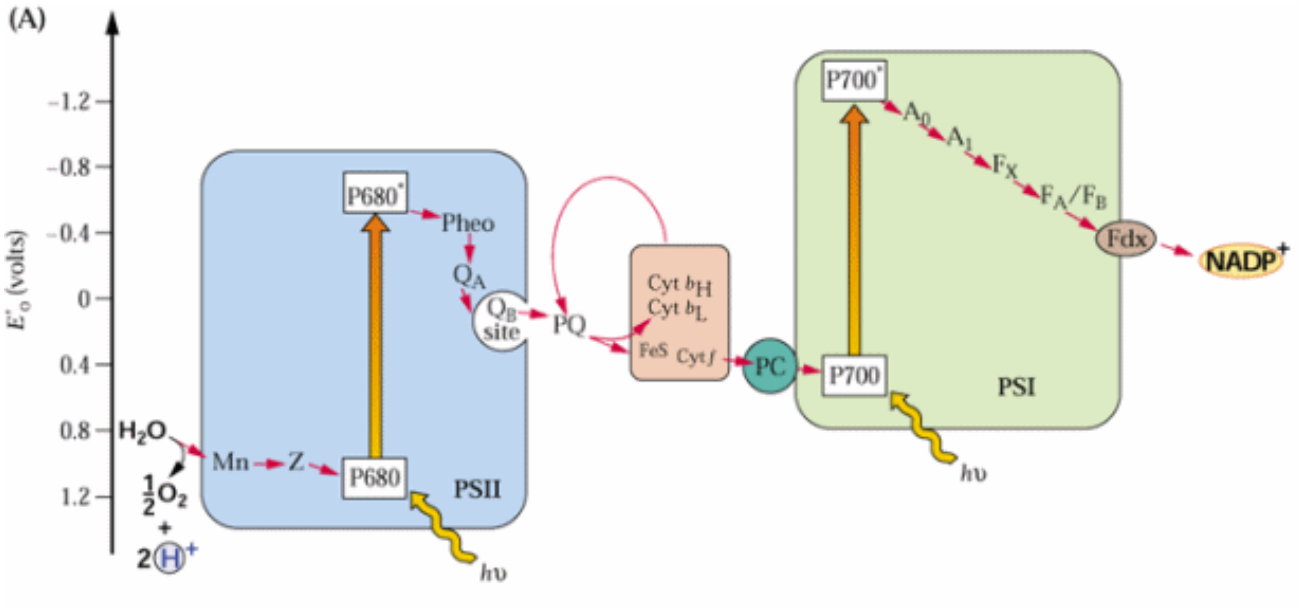
Transporte fotosintético de electrones

Transporte cíclico de electrones




hυ
Light reactions
(Thylakoid membranes)
ATP
NADPH
Carbon reactions
(Stromal enzymes)
H2O
O2
CO2
CH2O

Esquema Z


(A)
−1.2
−0.8
−0.4
0
0.4
0.8
1.2
E'o (volts)
H2O
½O2
+
2H+
Mn
Z
P680*
P680
Pheo
QA
QB site
PSII
hυ
PQ
Cyt bH
Cyt bL
FeS
Cyt f
PC
P700*
P700
A0
A1
FX
FA/FB
Fdx
NADP+
PSI
hυ

Esquema Z

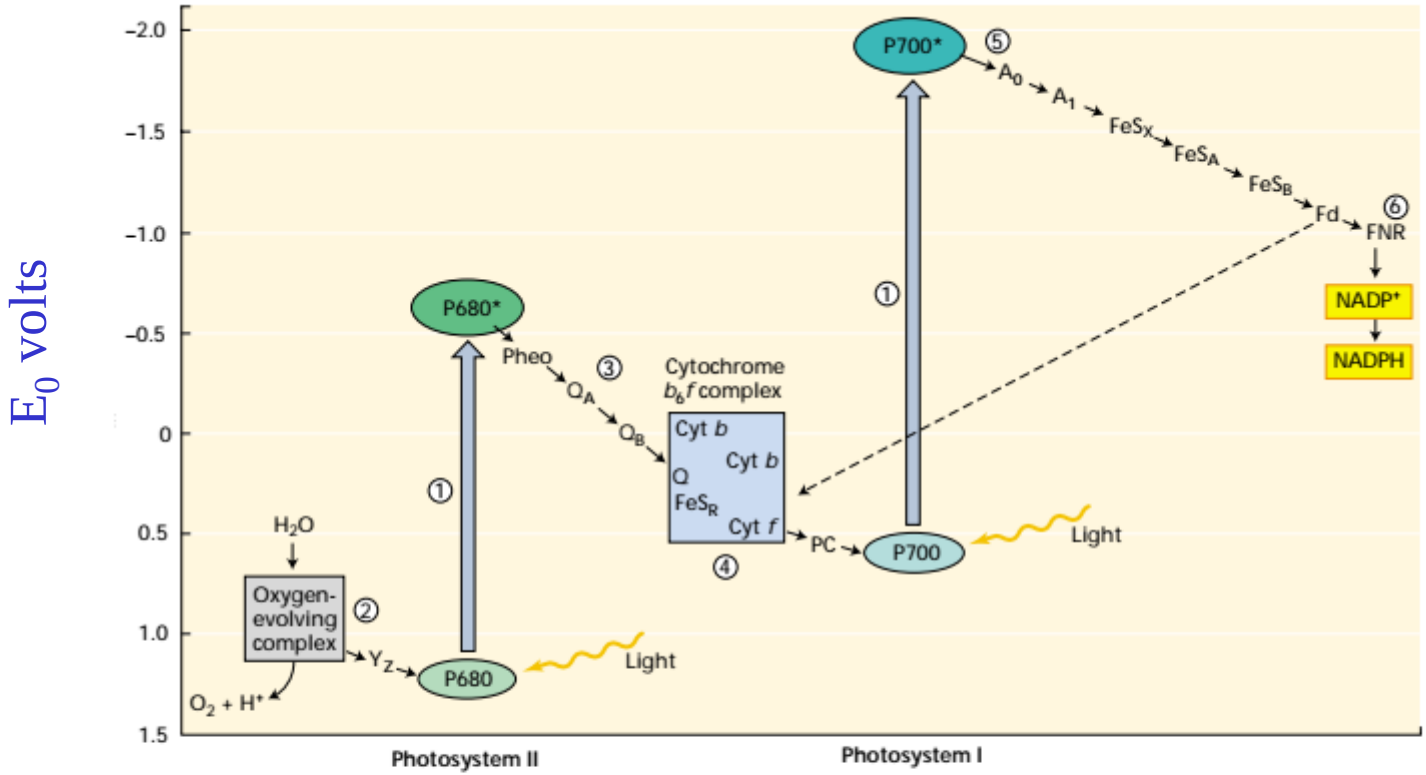


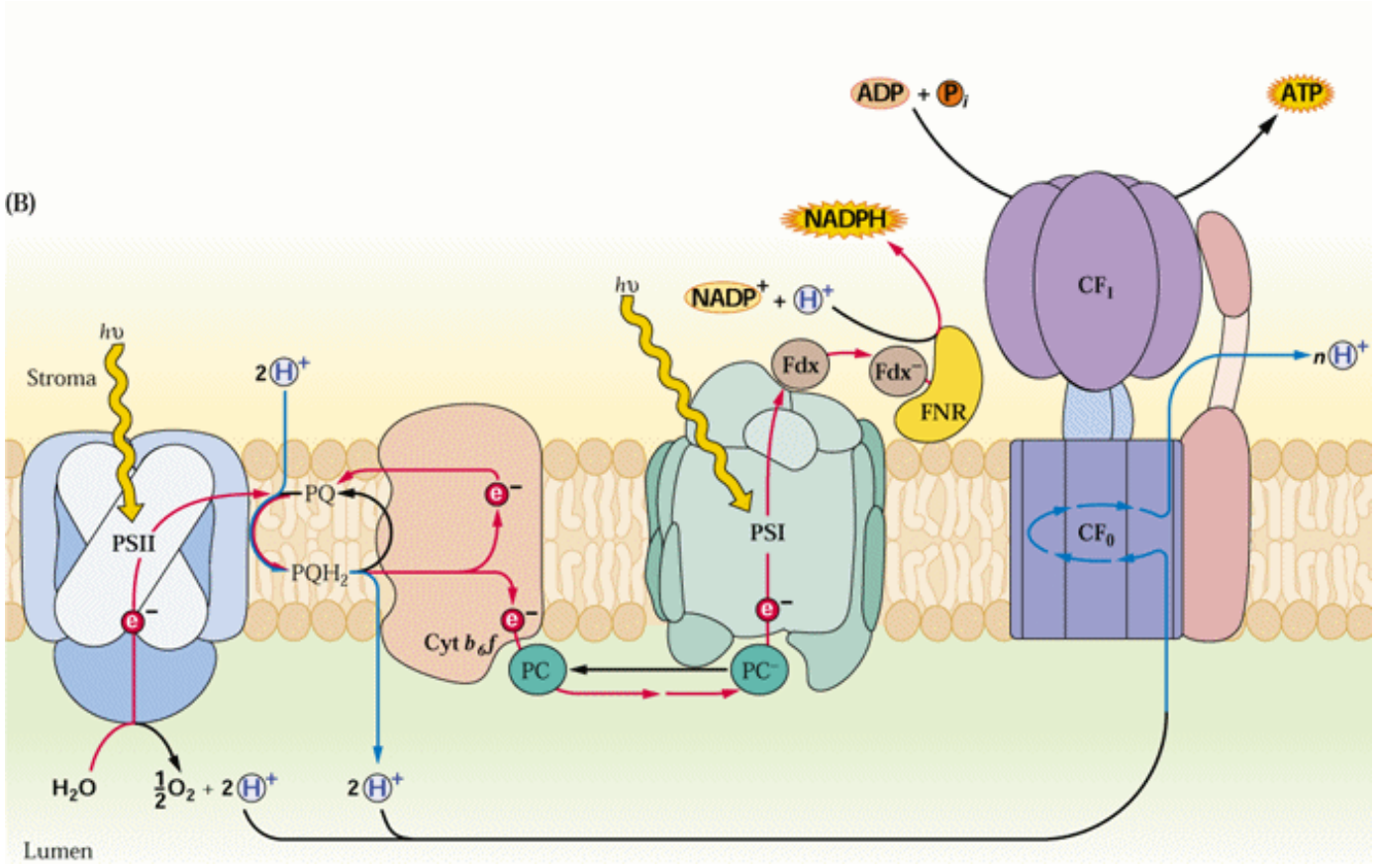
FIGURE 7.21 Detailed Z scheme for O_2-evolving photosynthetic organisms. The redox carriers are placed at their midpoint redox potentials (at pH 7). (1) The vertical arrows represent photon absorption by the reaction center chlorophylls: P680 for photosystem II (PSII) and P700 for photosystem I (PSI). The excited PSII reaction center chlorophyll, P680*, transfers an electron to pheophytin (Pheo). (2) On the oxidizing side of PSII (to the left of the arrow joining P680 with P680*), P680 oxidized by light is re-reduced by Y_z, that has received electrons from oxidation of water. (3) On the reducing side of PSII (to the right of the arrow joining P680 with P680*), pheophytin transfers electrons to the acceptors Q_A and Q_B, which are plastoquinones. (4) The cytochrome b_6f complex transfers electrons to plastocyanin (PC), a soluble protein, which in turn reduces P700+ (oxidized P700). (5) The acceptor of electrons from P700* (A_0) is thought to be a chlorophyll, and the next acceptor (A_1) is a quinone. A series of membrane-bound iron–sulfur proteins (FeS_X, FeS_A, and FeS_B) transfers electrons to soluble ferredoxin (Fd). (6) The soluble flavoprotein ferredoxin–NADP reductase (FNR) reduces $NADP^+$ to NADPH, which is used in the Calvin cycle to reduce CO_2 (see Chapter 8). The dashed line indicates cyclic electron flow around PSI. (After Blankenship and Prince 1985.)

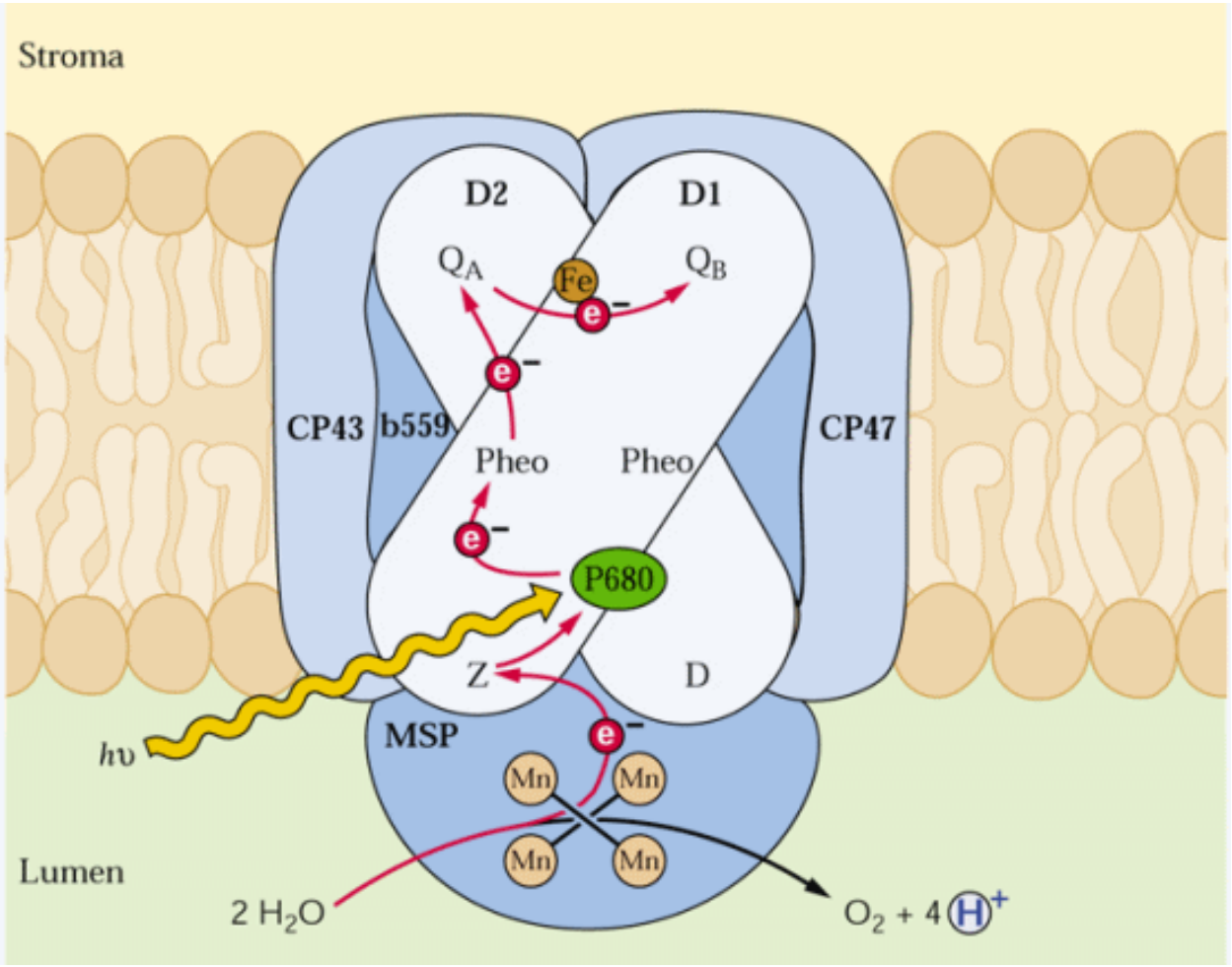
La fase lumínica como “blanco” de herbicidas:

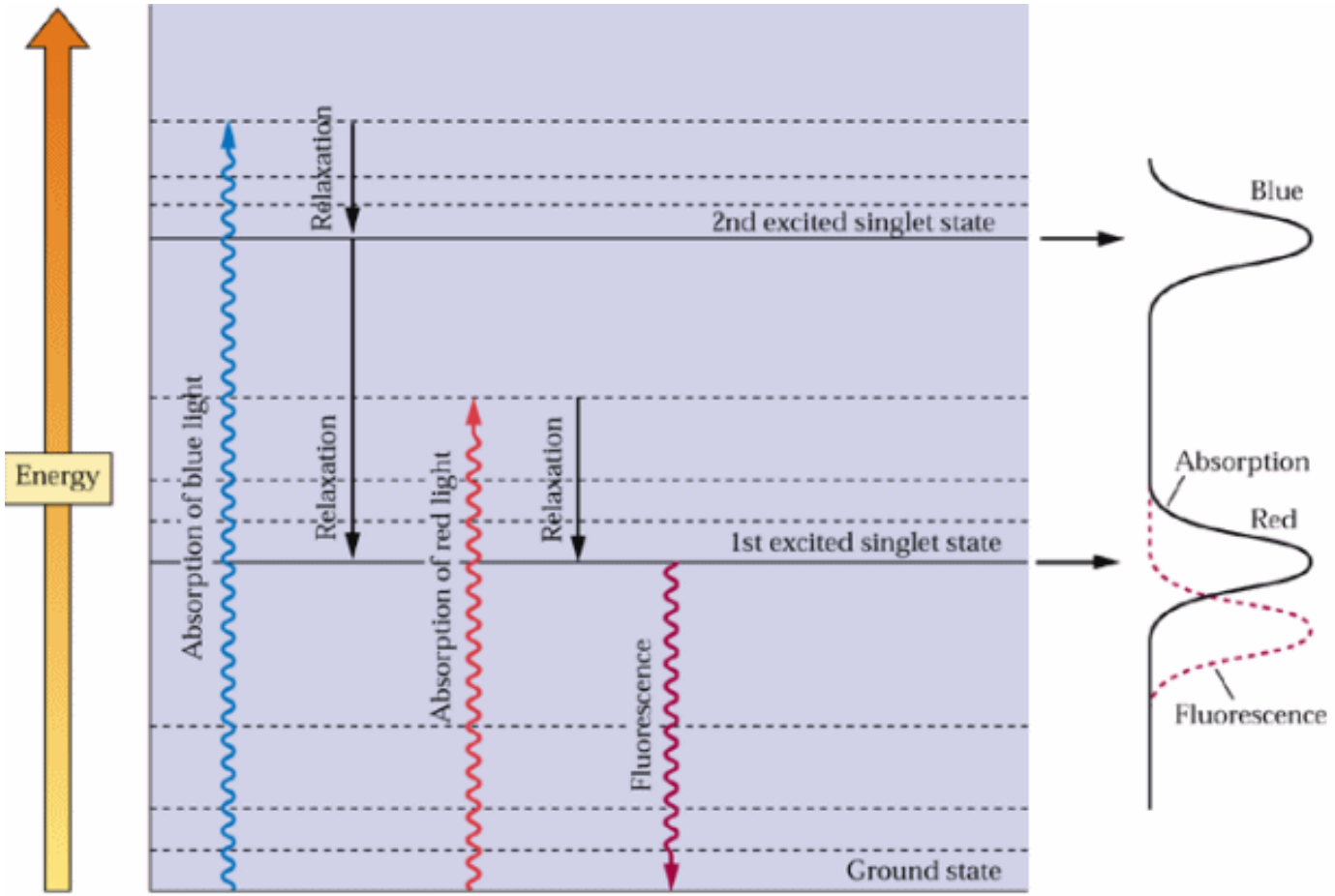
- ✓ **Inhibidores del fotosistema II**
- ✓ **Bipiridilos**
- ✓ **Inhibidores de la síntesis de carotenoides**
- ✓ **Inhibidores de la síntesis del grupo hemo (Chl)**

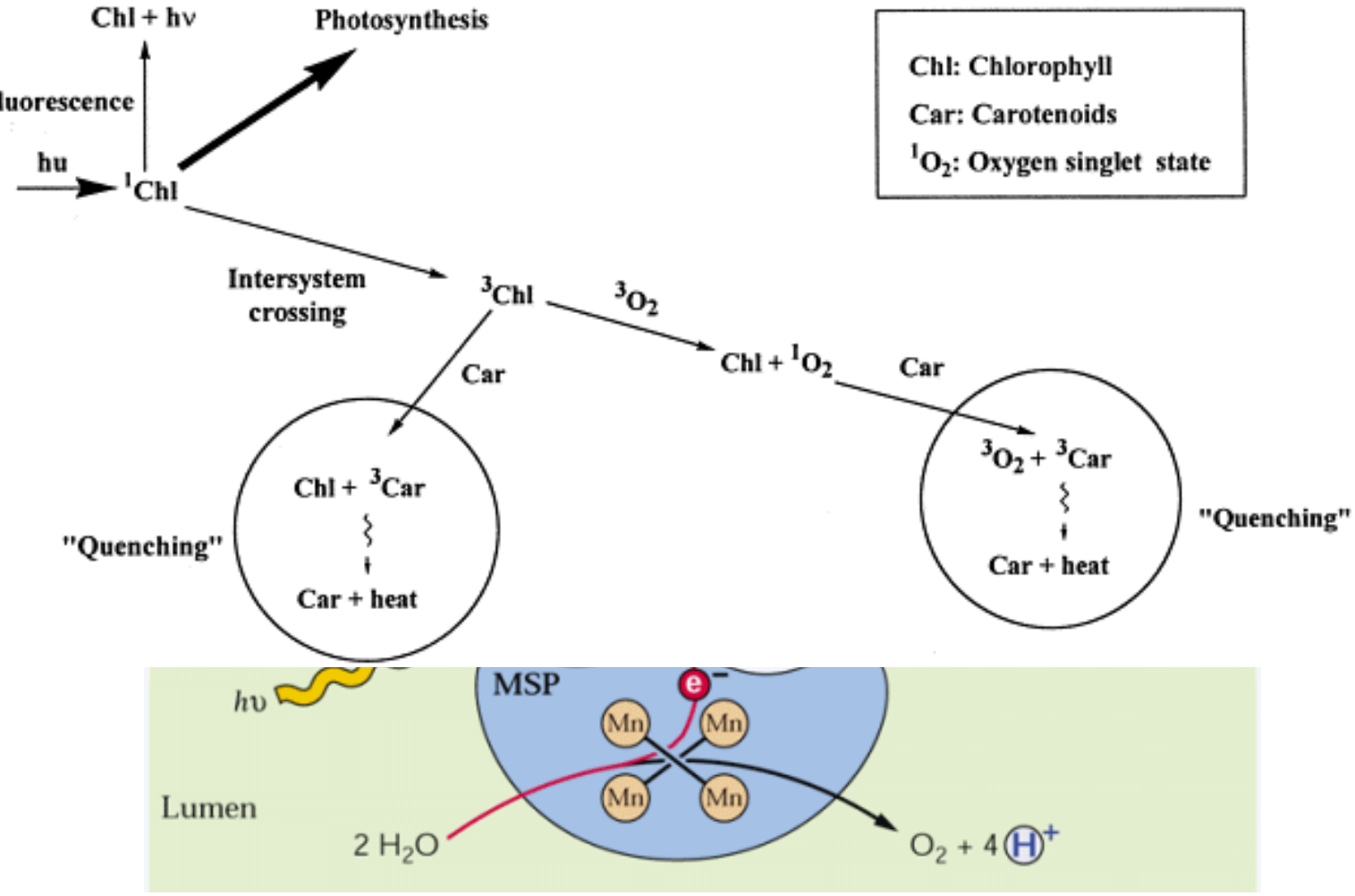
1. INHIBIDORES DEL FOTOSISTEMA 2:

- ✓**TRIAZINAS (ATRAZINA, SIMAZINA)**
- ✓**UREAS SUBSTITUÍDAS (DIURON, CLOROTOLURON)**


(B)
ADP + Pi
ATP
NADPH
NADP+ + H+
hν
hν
CF1
nH+
Fdx
Fdx−
FNR
Stroma
2H+
PQ
PQH2
PSII
PSI
CF0
e−
Cyt b6f
PC
PC−
H2O
½O2 + 2H+
2H+
Lumen


Stroma
D2
D1
Q_A
Fe
Q_B
e⁻
e⁻
CP43
b559
CP47
Pheo
Pheo
e⁻
P680
Z
D
MSP
e⁻
hυ
Mn
Mn
Mn
Mn
Lumen
2 H_2O
O_2 + 4 H^+

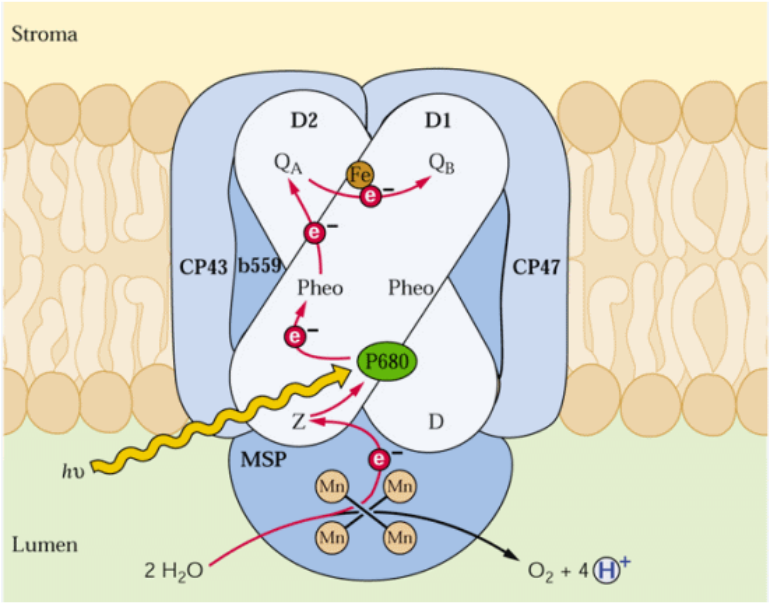

Energy
Absorption of blue light
Relaxation
2nd excited singlet state
Relaxation
Absorption of red light
Relaxation
1st excited singlet state
Fluorescence
Ground state
Blue
Absorption
Red
Fluorescence


Chl + hν
Photosynthesis
luorescence
hu
1Chl
Chl: Chlorophyll
Car: Carotenoids
1O2: Oxygen singlet state
Intersystem crossing
3Chl
3O2
Car
Chl + 1O2
Car
Chl + 3Car
Car + heat
"Quenching"
3O2 + 3Car
Car + heat
"Quenching"
hυ
MSP
e−
Mn
Mn
Mn
Mn
Lumen
2 H2O
O2 + 4 H+

Atrazina en caupí

Figura 6. Secuencia del daño causado por el herbicida atrazina en hojas de la maleza cola de alacrán (*Heliotropium indicum*). La hoja de la izquierda en la línea superior es de una planta que no fue aplicada y no muestran daño, las siguientes muestran una secuencia del daño, de izquierda a derecha. Al principio se observa una clorosis en la punta y el margen de las hojas, la clorosis avanza hacia la base y el interior de la hoja, la clorosis se torna una necrosis y finalmente toda la hoja está quemada.

MUTACIONES EN LA PROTEÍNA D1 CONFIEREN RESISTENCIA A TRIAZINAS Y UREAS SUSTITUÍDAS



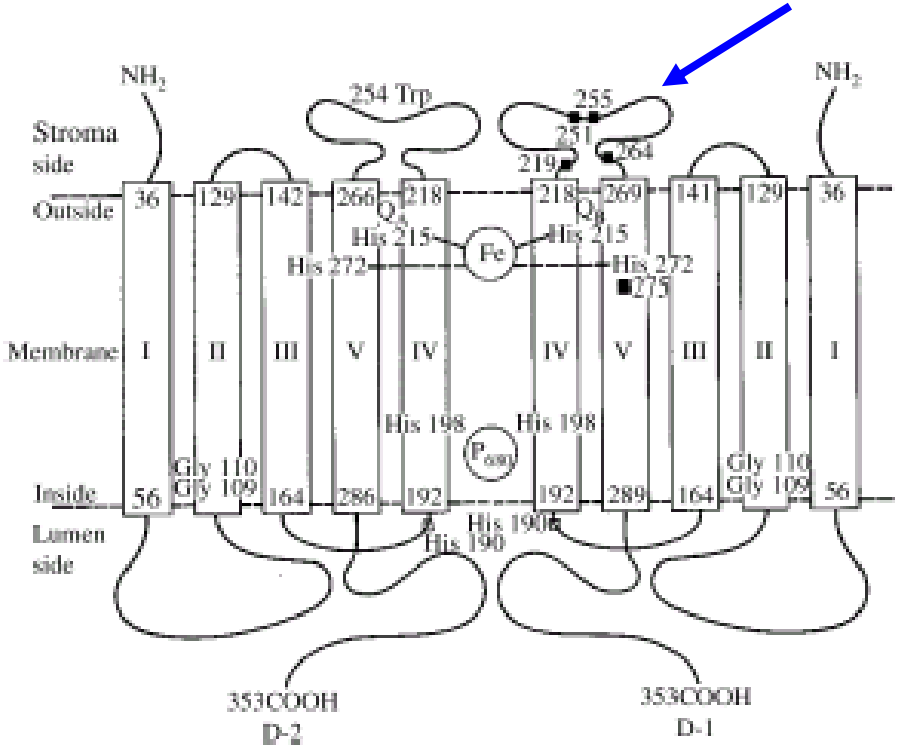
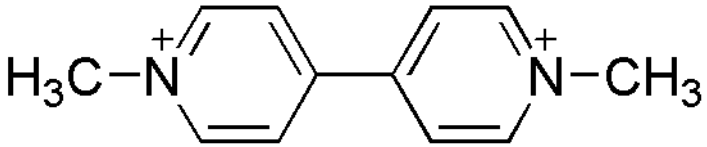


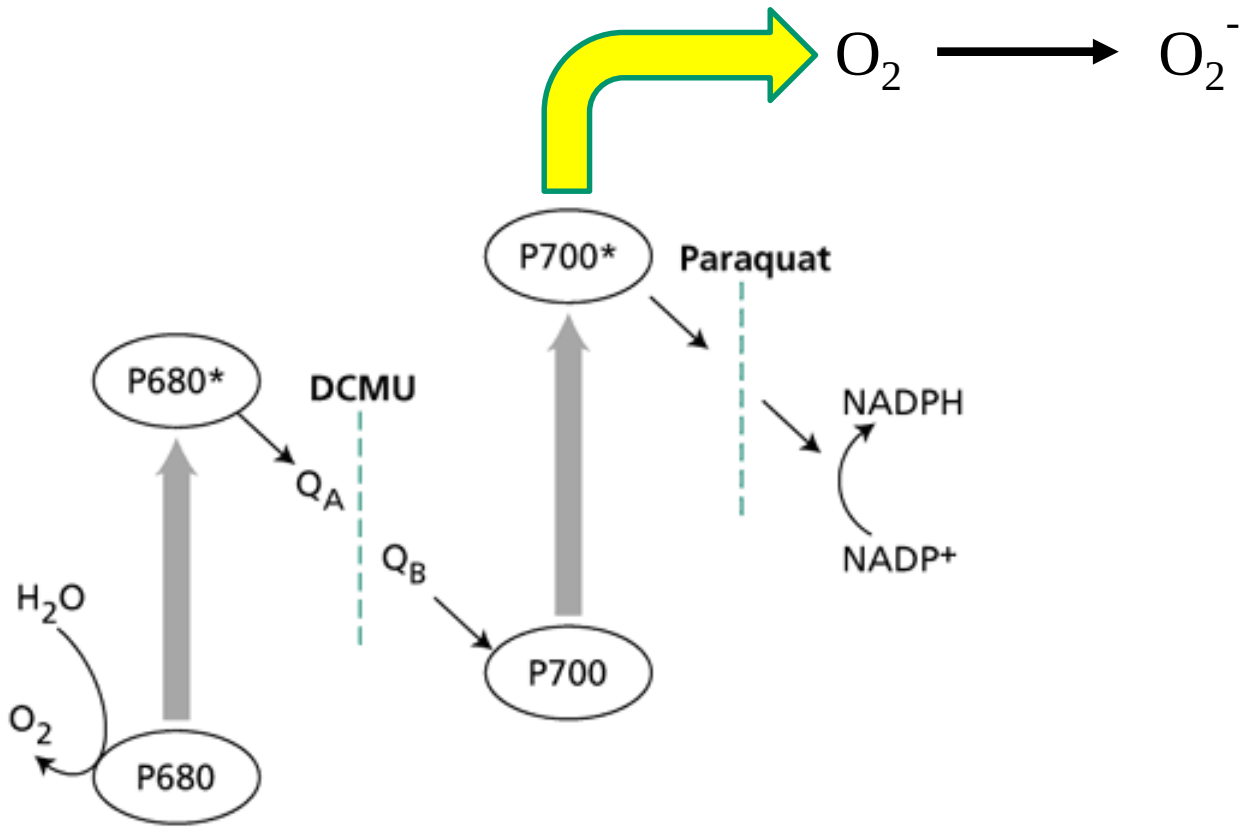
Fig. 1. Diagrammatic representation the D1/D2 protein complex in photosystem II. D1 mutation sites conferring resistance are represented by solid squares. Reproduced from Devine et al. (1993).

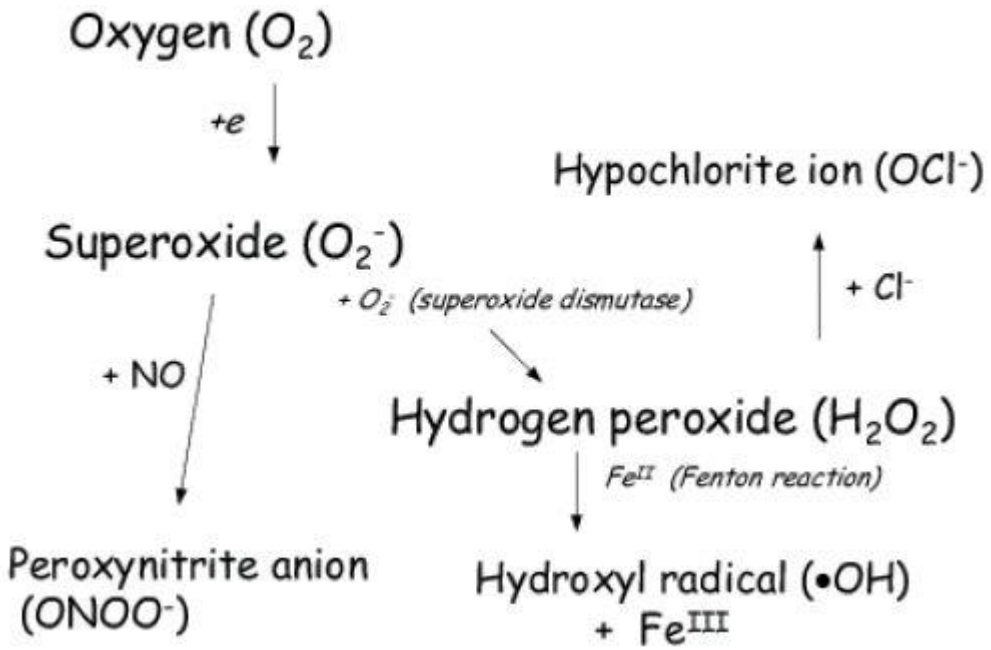
- **Mutaciones de herencia materna (!)**
- **Reducen la capacidad fotosintética**

BIPIRIDILOS



1,1′-dimethyl-4,4′-bipyridinium bis(methyl sulfate)

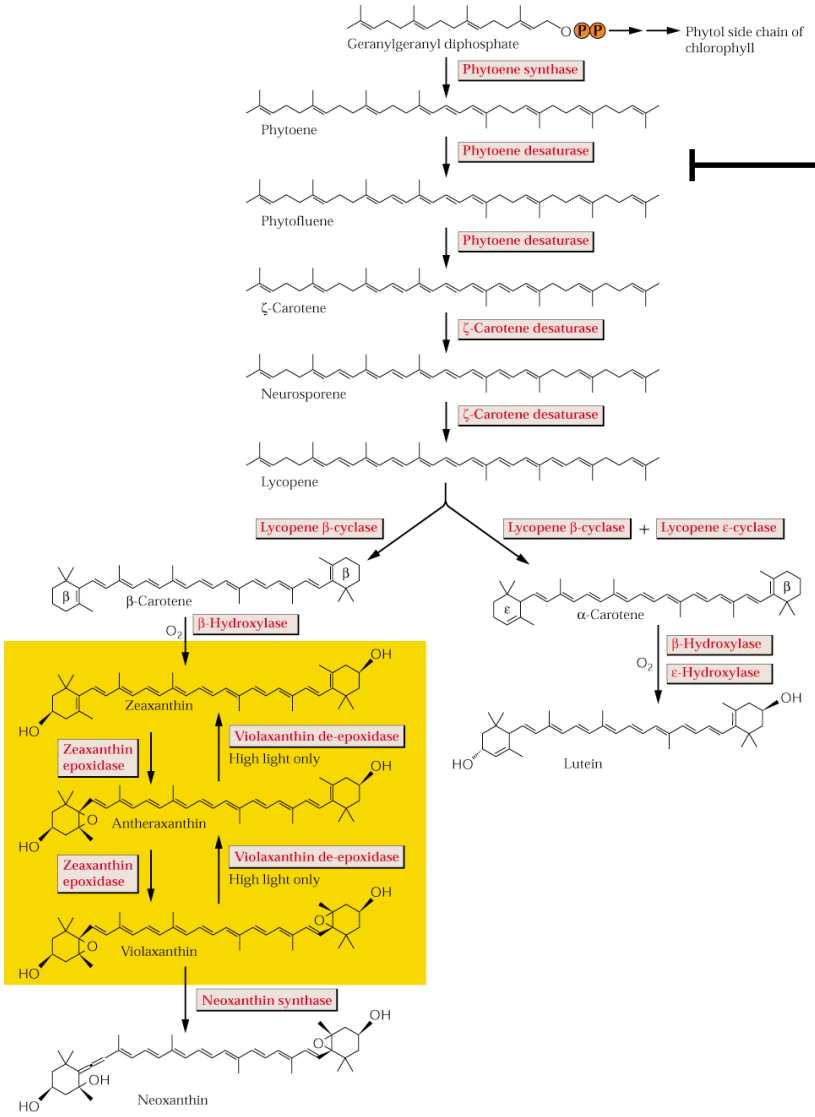

O_2
O_2^-
P700*
Paraquat
P680*
DCMU
NADPH
Q_A
Q_B
NADP+
H_2O
P700
O_2
P680


Oxygen (O_2)
+e
Superoxide (O_2^-)
+ NO
Peroxynitrite anion ($ONOO^-$)
+ O_2^- (superoxide dismutase)
Hydrogen peroxide (H_2O_2)
Fe^{II} (Fenton reaction)
Hydroxyl radical (•OH) + Fe^{III}
Hypochlorite ion (OCl^-)
+ Cl^-

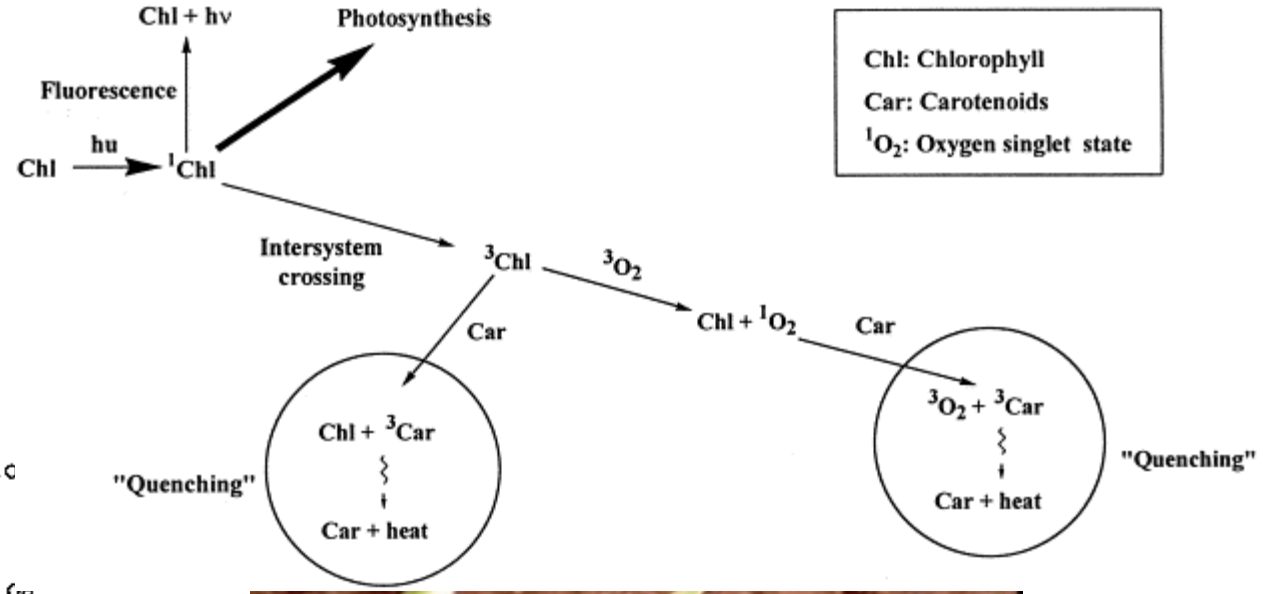
Poroto afectado por deriva de paraquat

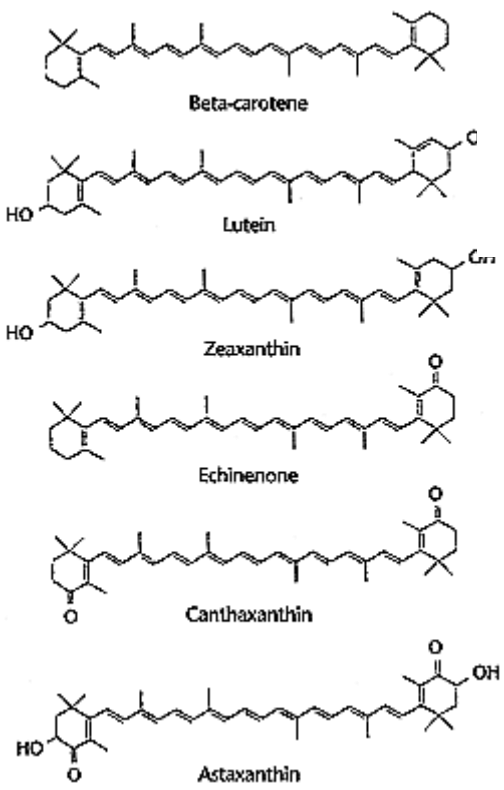
Inhibit carotenoid biosynthesis
(Pigment inhibitors)

Herbicide Family	Common Name	Trade Name
Isoxazolidinones	clomazone	Command
Pyridazinones	norflurazon	Zorial, Solicam
Isoxazoles	isoxaflutole	Balance



Norflurazon


Chl + hν
Photosynthesis
Fluorescence
hu
Chl
^{1}Chl
Intersystem crossing
^{3}Chl
$^3O_2$
Chl + $^1O_2$
Car
Car
"Quenching"
Chl + ^{3}Car
Car + heat
$^3O_2$ + ^{3}Car
Car + heat
"Quenching"
Chl: Chlorophyll
Car: Carotenoids
$^1O_2$: Oxygen singlet state


Beta-carotene
HO
Lutein
HO
Zeaxanthin
O
Echinenone
O
O
Canthaxanthin
O
OH
HO
O
Astaxanthin

Inhibidores de la síntesis del grupo hemo:

v.g., acifluorfen, lactofen,