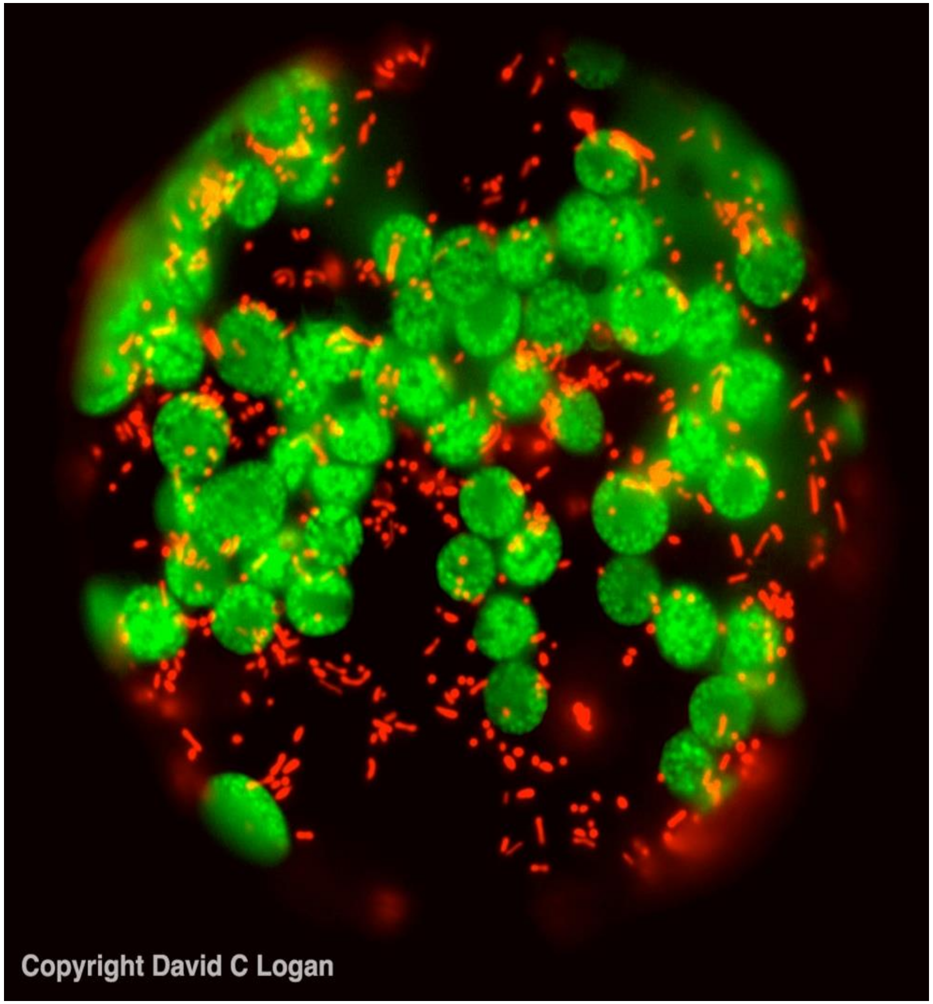
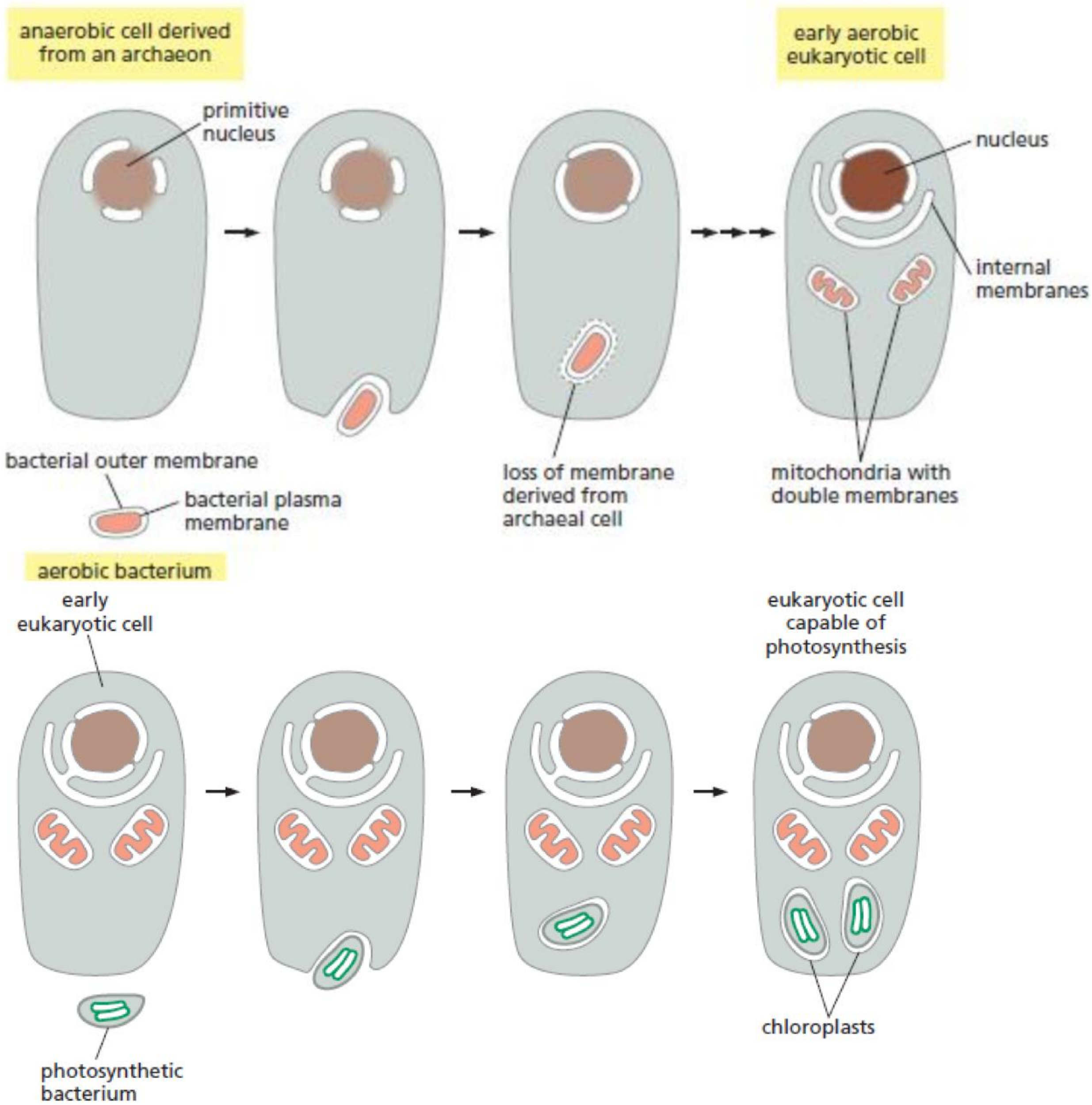
Mitocondrias y cloroplastos

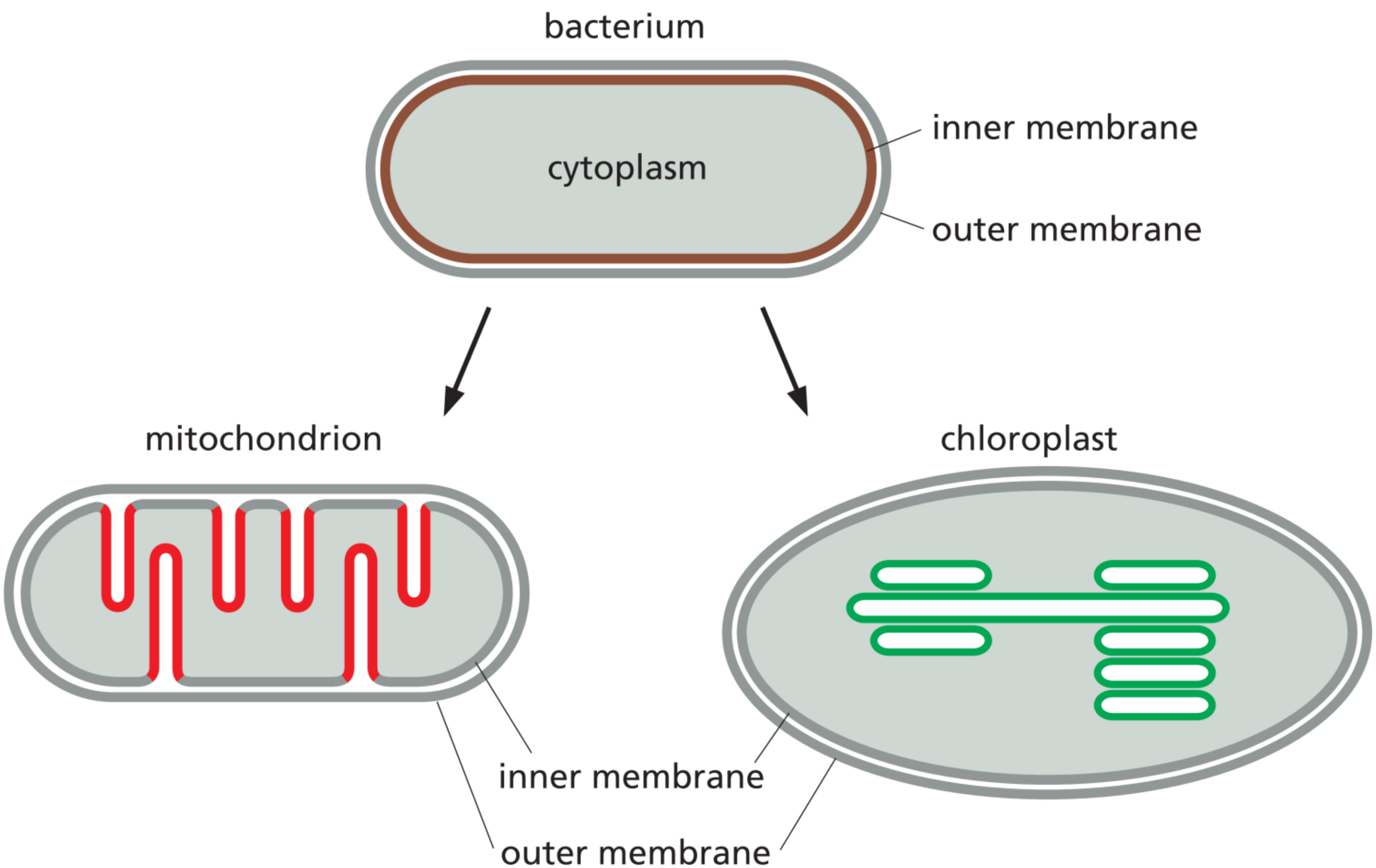


Cecilia Mathó cmatho@fcien.edu.uy

Endosimbiosis



Lynn Margulis
1938-2011


bacterium
cytoplasm
inner membrane
outer membrane
mitochondrion
chloroplast
inner membrane
outer membrane

Endosimbiosis - evidencia

- **Doble membrana mitocondrial y del cloroplasto**
  - ADN genómico propio (reducido)
  - Ribosomas y tRNAs propios
  - Similitud de ribosomas y proteínas a bacterias (alfa-proteobacterias / cianobacterias)

Mayoría de las proteínas mitocondriales y del cloroplasto se encuentran codificadas en el núcleo; transferidas a lo largo de la evolución de eucariotas tempranos

Proteínas mitocondriales codificadas en el núcleo deben ser importadas a la mitocondria

Proteínas del cloroplasto codificadas en el núcleo deben ser importadas al cloroplasto

Mitocondrias

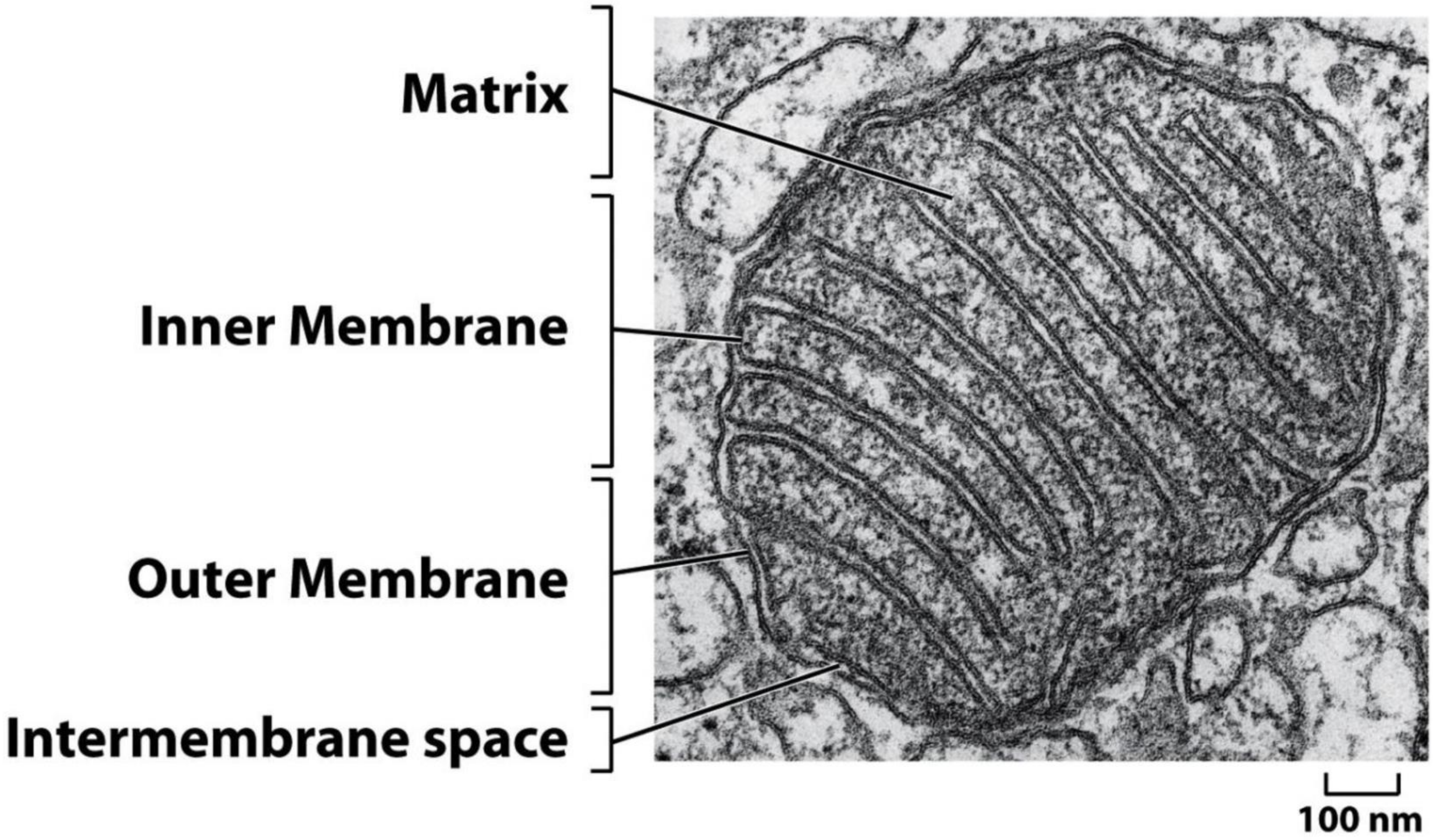
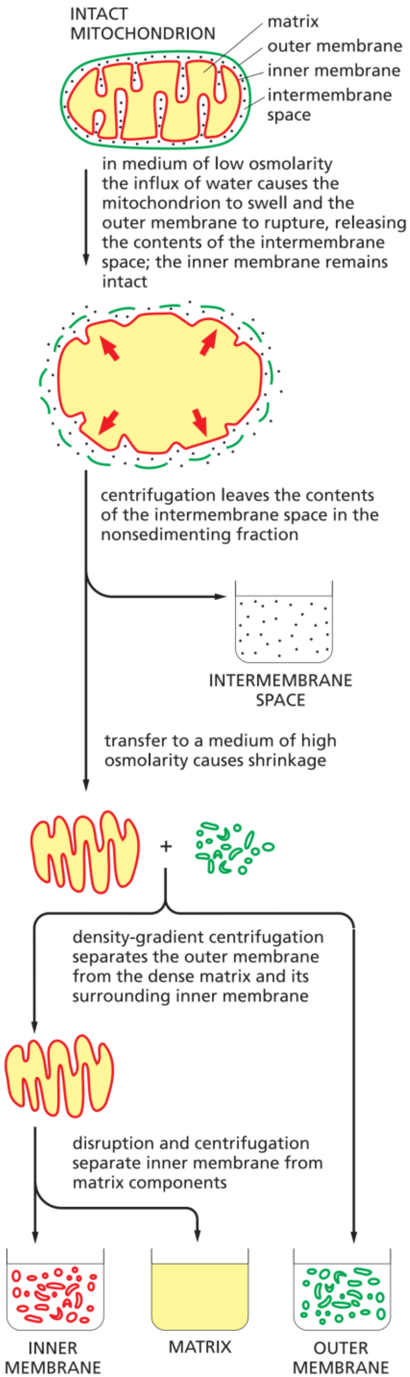


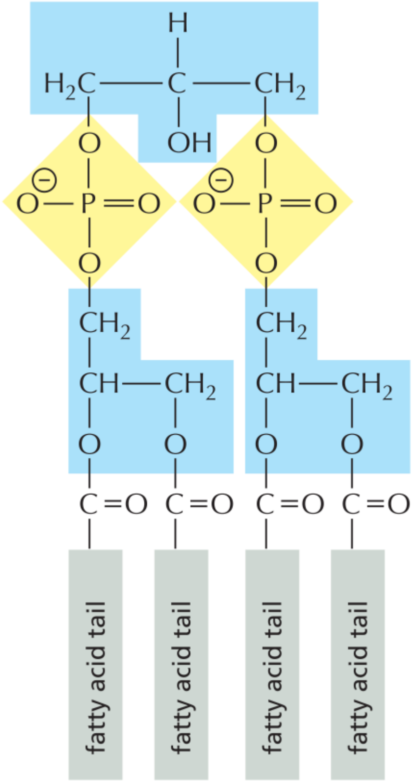
TABLE 12–1 Relative Volumes Occupied by the Major Intracellular Compartments in a Liver Cell (Hepatocyte)

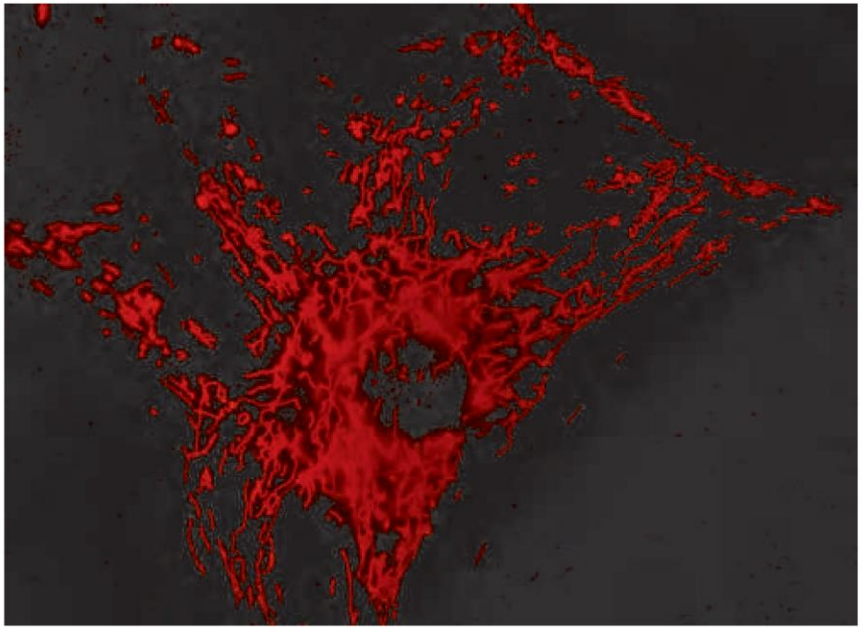
Intracellular compartment	Percentage of total cell volume
Cytosol	54
Mitochondria	22
Rough ER cisternae	9
Smooth ER cisternae plus Golgi cisternae	6
Nucleus	6
Peroxisomes	1
Lysosomes	1
Endosomes	1



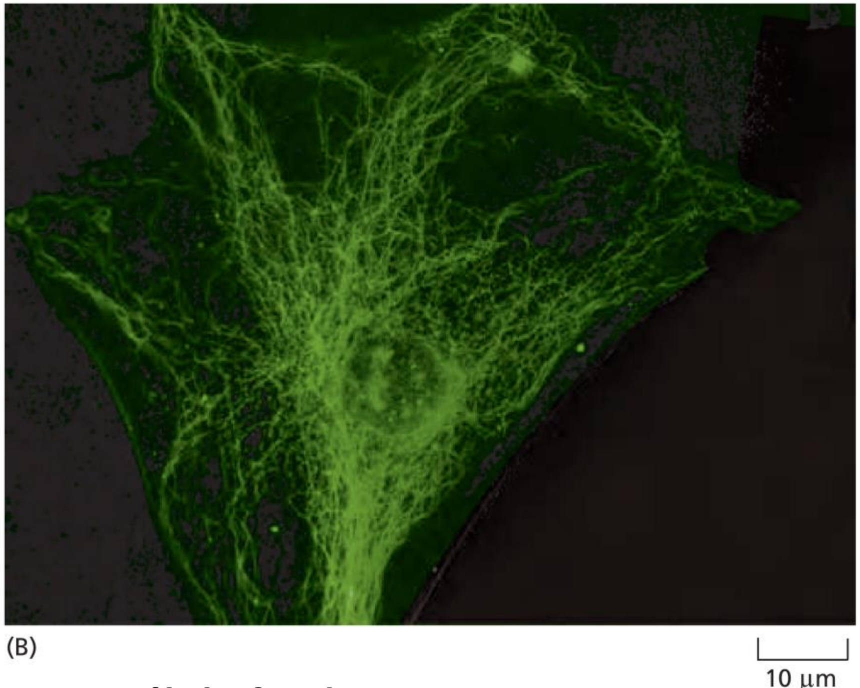
Porinas en membrana externa: perimiten pasaje de moléculas de menos de 5000 daltons

Membrana Interna: Cardiopilina





(A)



(B)

Célula viva
Rhodamine-123

Célula fijada
Anticuerpo anti-tubulina

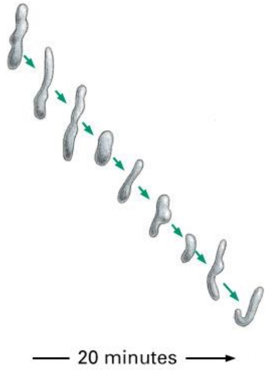
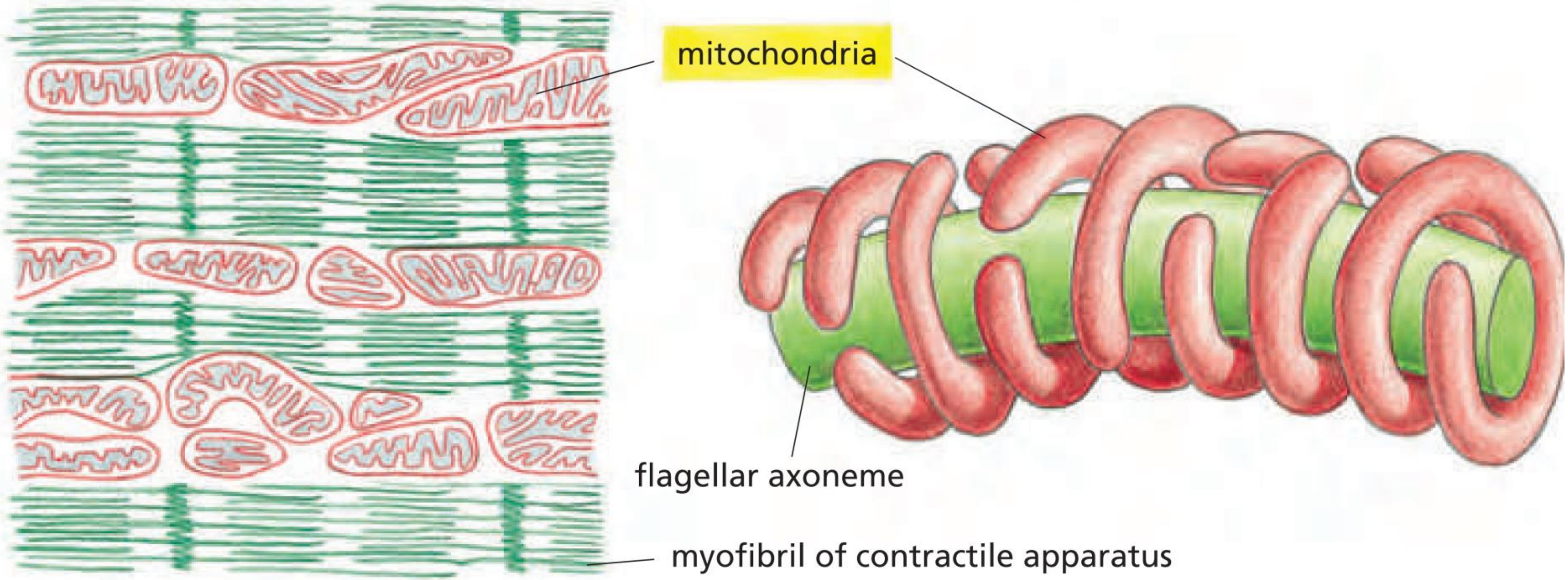


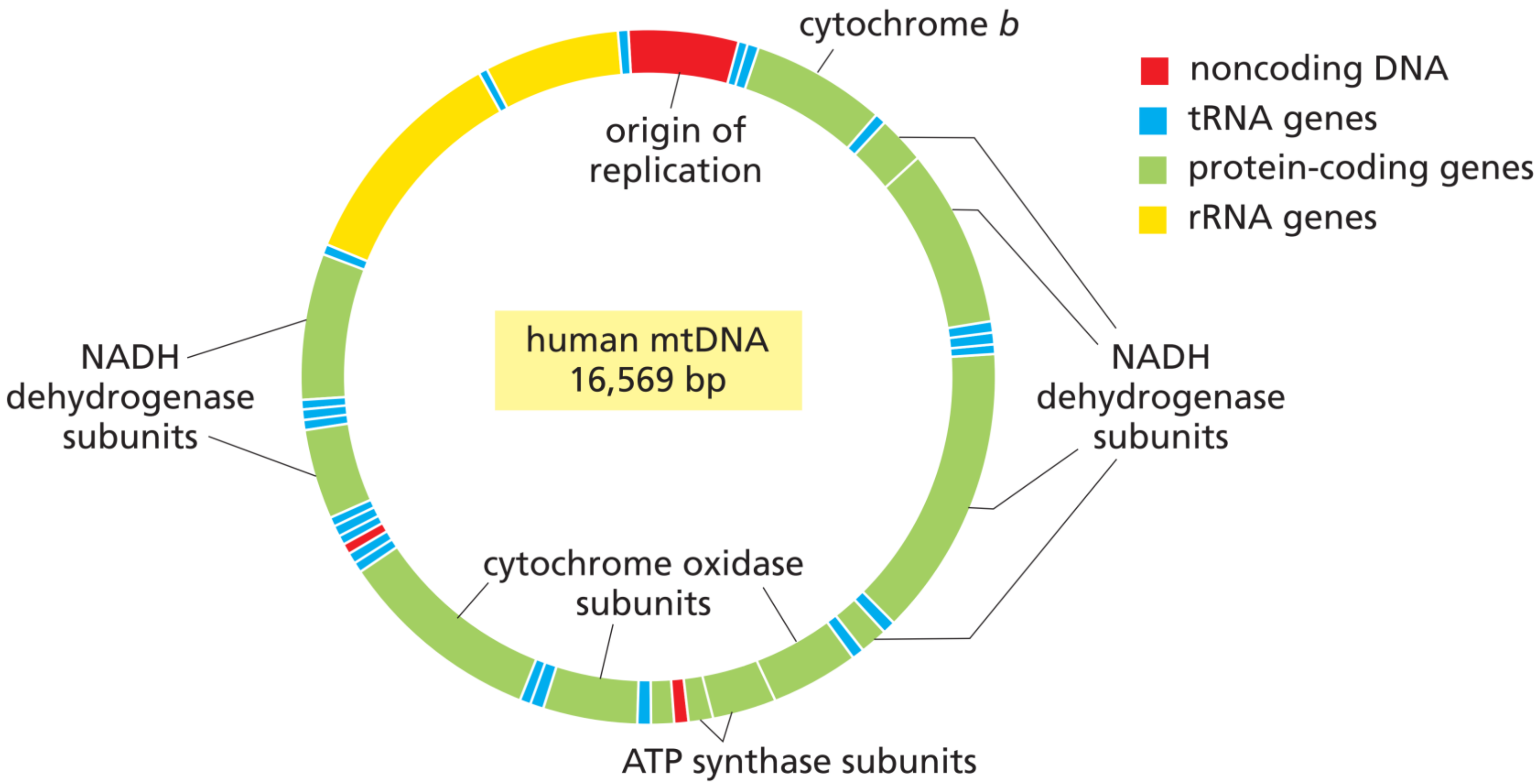
Figure 14–4. Molecular Biology of the Cell, 4th Edition.



(A) CARDIAC MUSCLE

(B) SPERM TAIL

ADN mitocondrial



Herencia materna en animales

TABLE 14–2 Relative Amounts of Organelle DNA in Some Cells and Tissues

Organism	Tissue or cell type	DNA molecules per organelle	Organelles per cell	Organelle DNA as percentage of total cellular DNA
Mitochondrial DNA				
Rat	Liver	5–10	1000	1
Yeast*	Vegetative	2–50	1–50	15
Frog	Egg	5–10	10^7	99

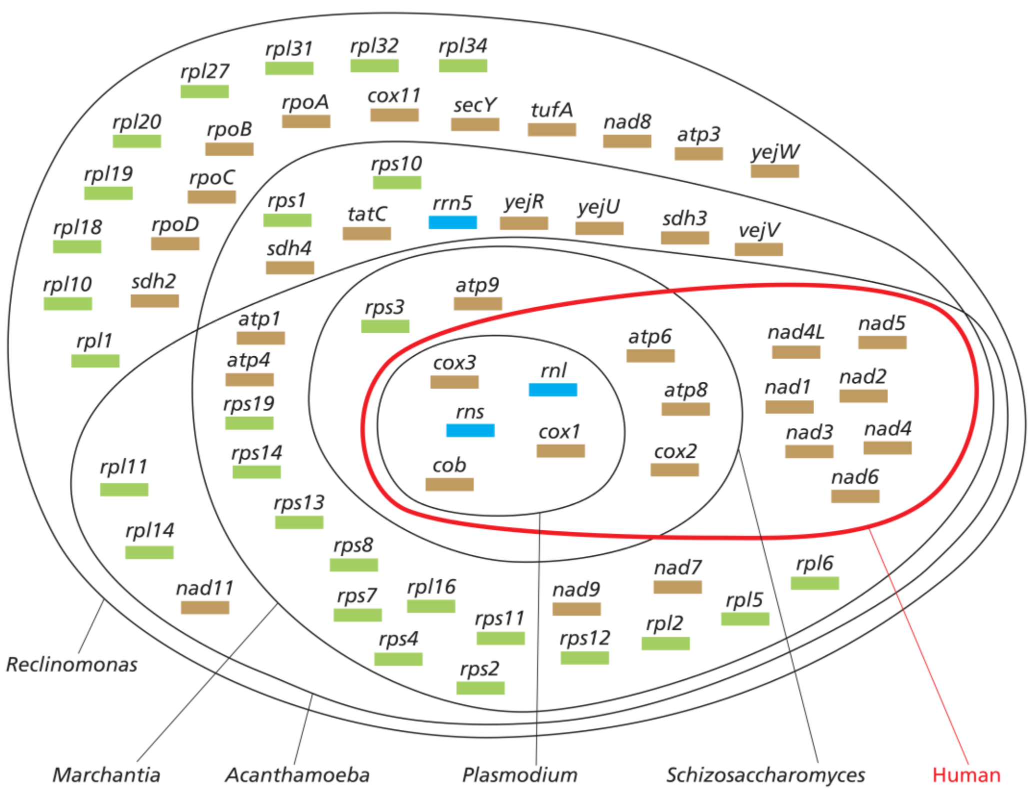


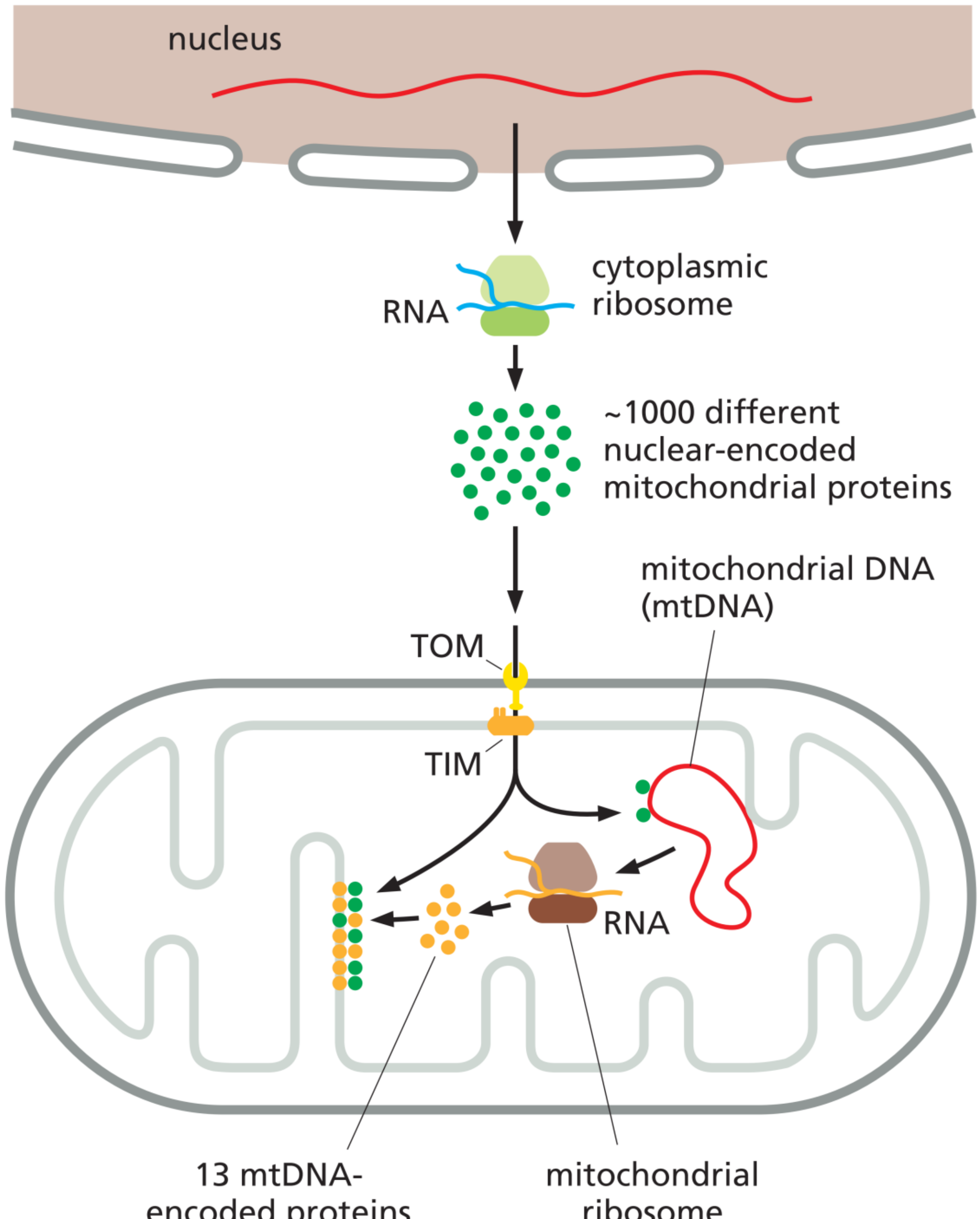
Figure 14–60 Comparison of mitochondrial genomes. Less complex mitochondrial genomes encode subsets of the proteins and ribosomal RNAs that are encoded by larger mitochondrial genomes. In this comparison, there are only five genes that are shared by the six mitochondrial genomes; these encode ribosomal RNAs (*rns* and *rnl*), cytochrome *b* (*cob*), and two cytochrome oxidase subunits (*cox1* and *cox3*). *Blue* indicates ribosomal RNAs; *green*, ribosomal proteins; and *brown*, components of the respiratory chain and other proteins. (Adapted from M.W. Gray, G. Burger and B.F. Lang, *Science* 283:1476–1481, 1999.)

TABLE 14–3 Some Differences Between the "Universal" Code and Mitochondrial Genetic Codes*

Codon	"Universal" code	Mitochondrial codes			
		Mammals	Invertebrates	Yeasts	Plants
UGA	STOP	*Trp*	*Trp*	*Trp*	STOP
AUA	Ile	*Met*	*Met*	*Met*	Ile
CUA	Leu	Leu	Leu	*Thr*	Leu
AGA AGG	Arg	*STOP*	*Ser*	Arg	Arg

**Red* italics indicate that the code differs from the "Universal" code.

-Pequeño número de genes y de codones permite "deriva" evolutiva del código genético
-Sistema simplificado de sólo 22 tRNAs (reglas "relajadas" de apareamiento codón – anticodón)


nucleus
cytoplasmic ribosome
RNA
~1000 different nuclear-encoded mitochondrial proteins
mitochondrial DNA (mtDNA)
TOM
TIM
RNA
13 mtDNA-encoded proteins
mitochondrial ribosome

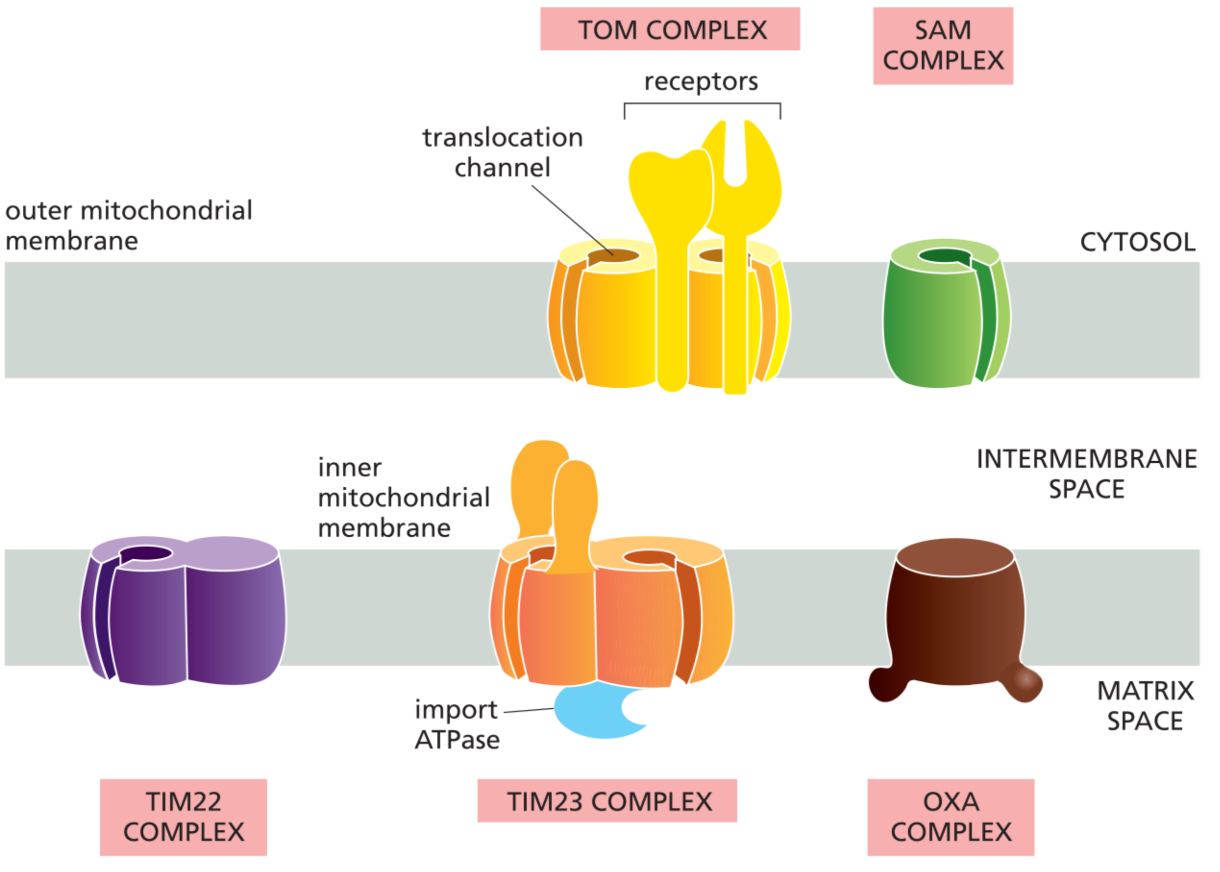
Secuencias Señal- Ejemplos

TABLE 12–3 Some Typical Signal Sequences

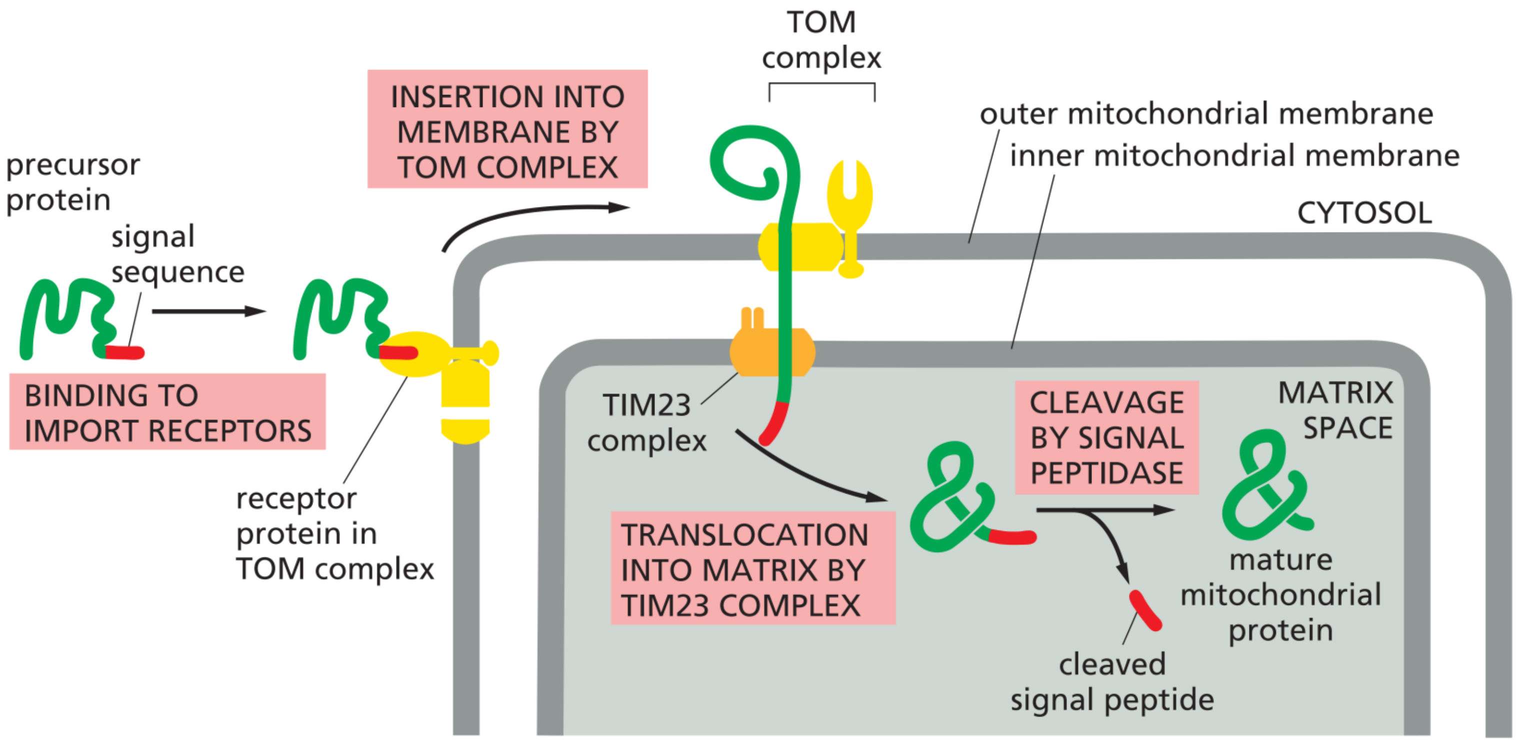
Function of signal sequence	Example of signal sequence
Import into nucleus	-Pro-Pro-Lys-Lys-Lys-Arg-Lys-Val-
Export from nucleus	-Met-Glu-Glu-Leu-Ser-Gln-Ala-Leu-Ala-Ser-Ser-Phe-
Import into mitochondria	$^{+}H_3N$-Met-Leu-Ser-Leu-Arg-Gln-Ser-Ile-Arg-Phe-Phe-Lys-Pro-Ala-Thr-Arg-Thr-Leu-Cys-Ser-Ser-Arg-Tyr-Leu-Leu-
Import into plastid	$^{+}H_3N$-Met-Val-Ala-Met-Ala-Met-Ala-Ser-Leu-Gln-Ser-Ser-Met-Ser-Ser-Leu-Ser-Leu-Ser-Ser-Asn-Ser-Phe-Leu-Gly-Gln-Pro-Leu-Ser-Pro-Ile-Thr-Leu-Ser-Pro-Phe-Leu-Gln-Gly-
Import into peroxisomes	-Ser-Lys-Leu-COO^-
Import into ER	$^{+}H_3N$-Met-Met-Ser-Phe-Val-Ser-Leu-Leu-Leu-Val-Gly-Ile-Leu-Phe-Trp-Ala-Thr-Glu-Ala-Glu-Gln-Leu-Thr-Lys-Cys-Glu-Val-Phe-Gln-
Return to ER	-Lys-Asp-Glu-Leu-COO^-

Some characteristic features of the different classes of signal sequences are highlighted in color. Where they are known to be important for the function of the signal sequence, positively charged amino acids are shown in *red* and negatively charged amino acids are shown in *green*. Similarly, important hydrophobic amino acids are shown in *orange* and important hydroxylated amino acids are shown in *blue*. $^{+}H_3N$ indicates the N-terminus of a protein; COO^- indicates the C-terminus.

Transporte de proteínas a la mitocondria



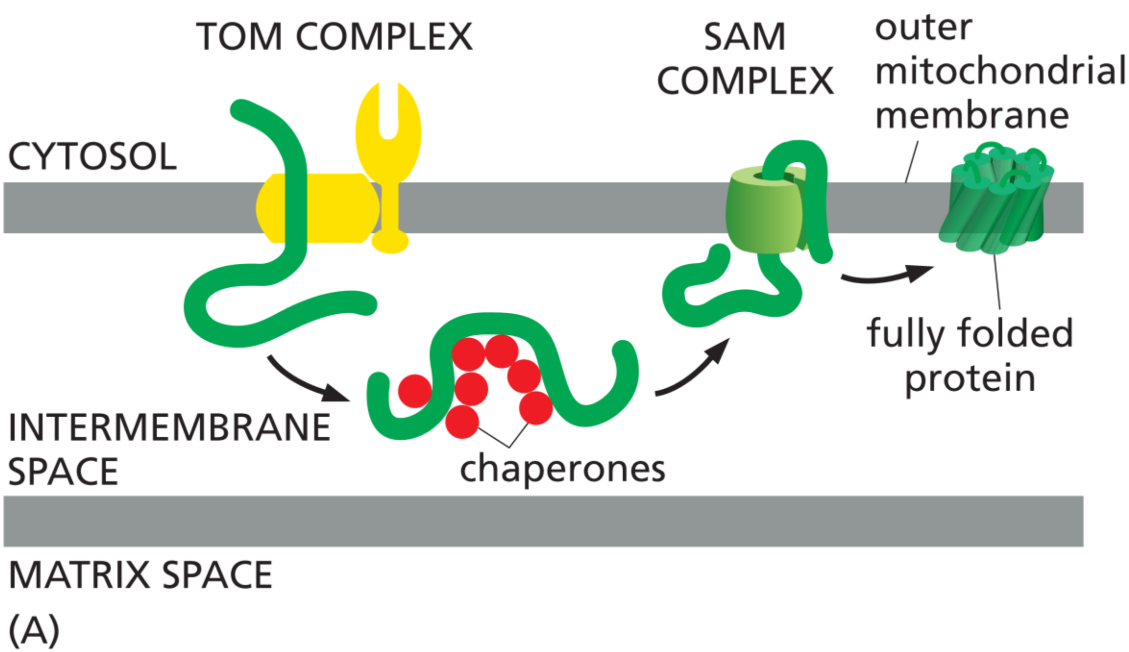
Translocación de proteínas a la matriz mitocondrial



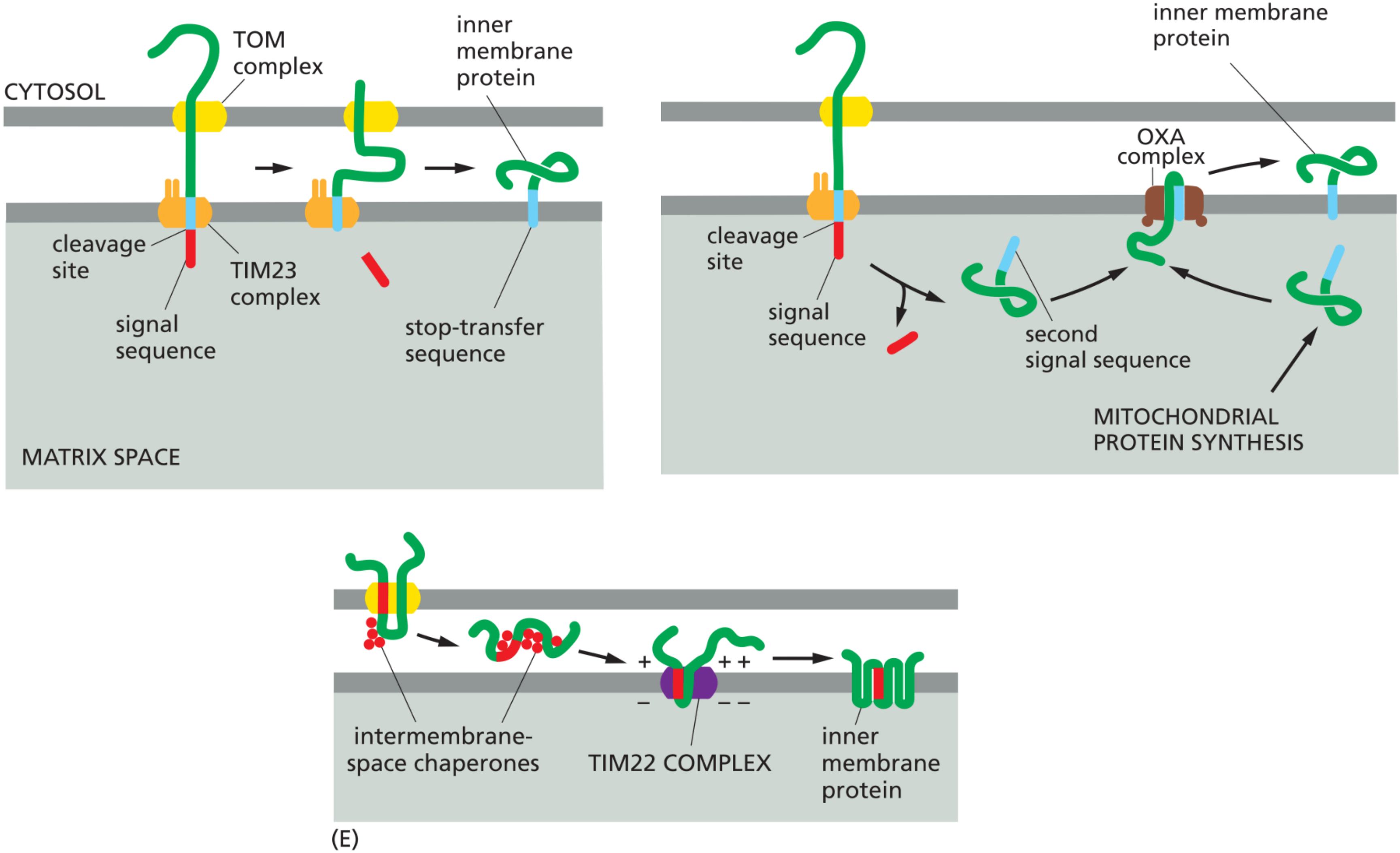
-Translocación Post-traduccional

-Proteína precursora es mantenida en forma desplegada por chaperonas

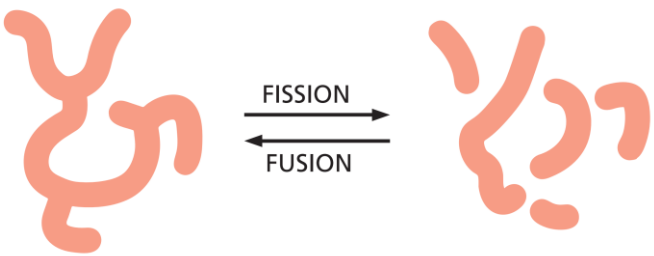
Inserción de proteínas en la membrana mitocondrial externa

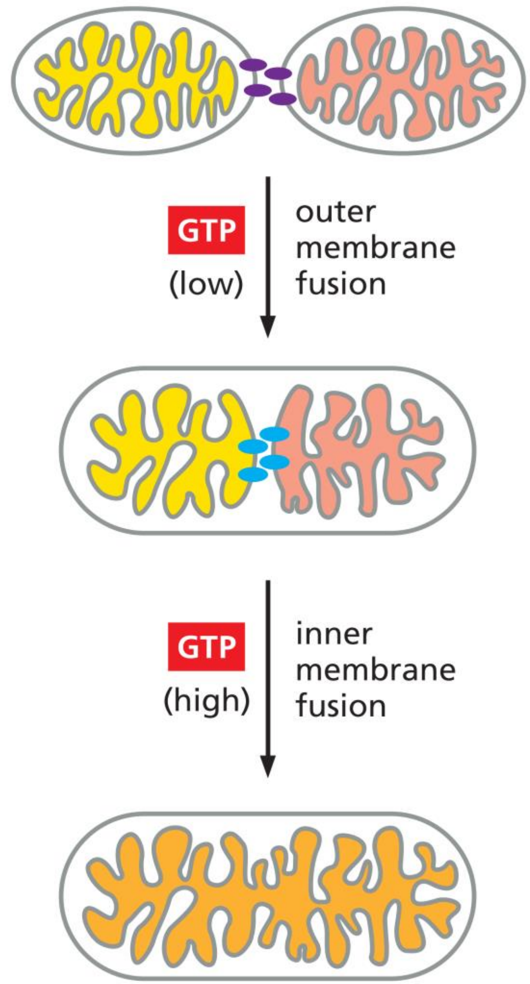


Inserción de proteínas en la membrana mitocondrial interna

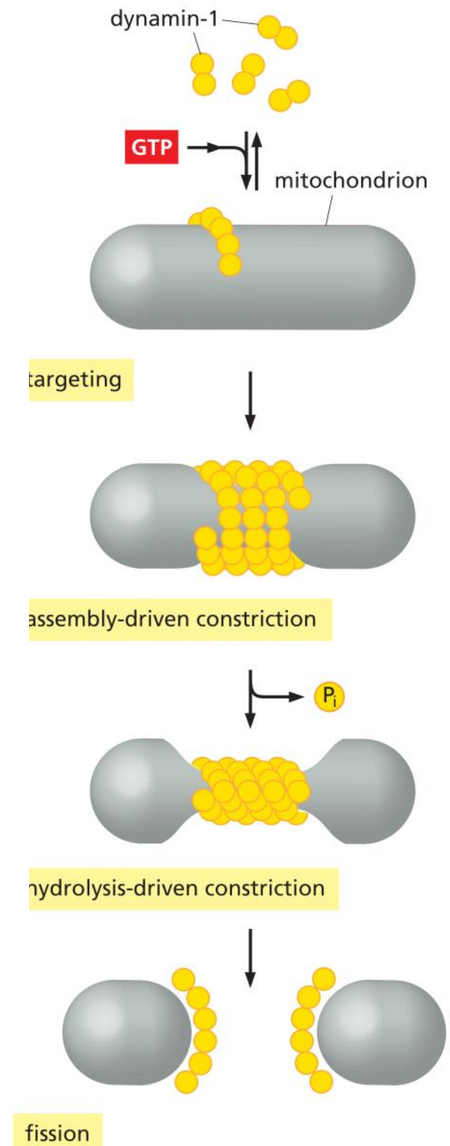


Fusión y Fisión



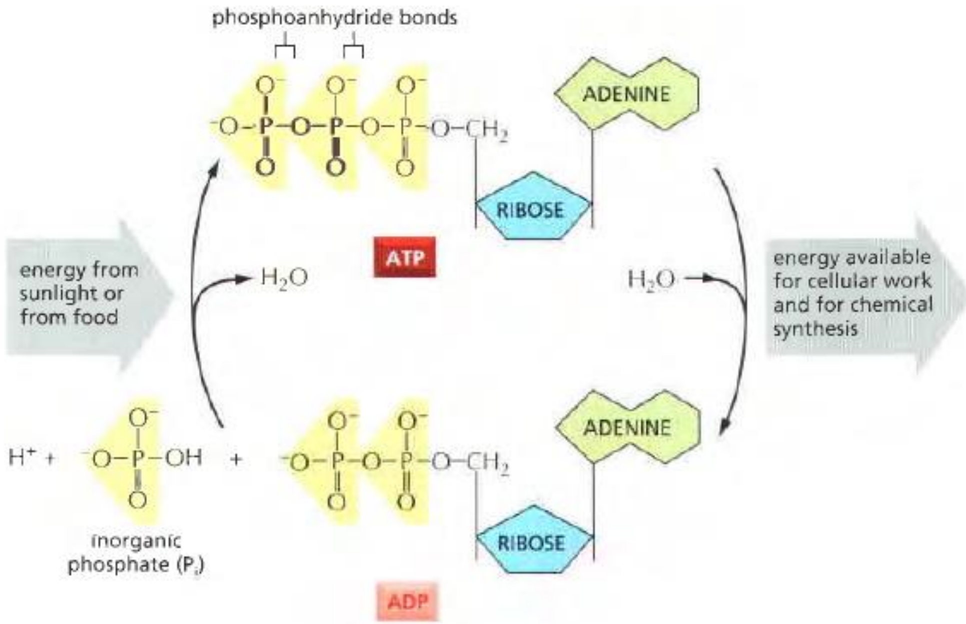


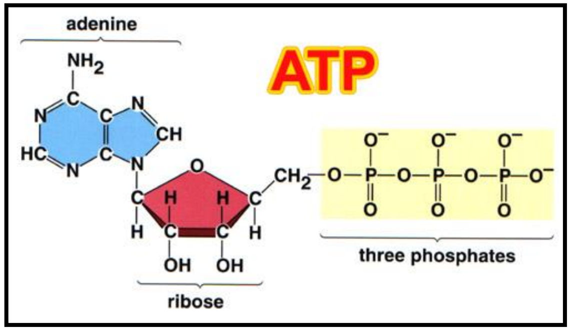
Mitofusinas
OPA-1

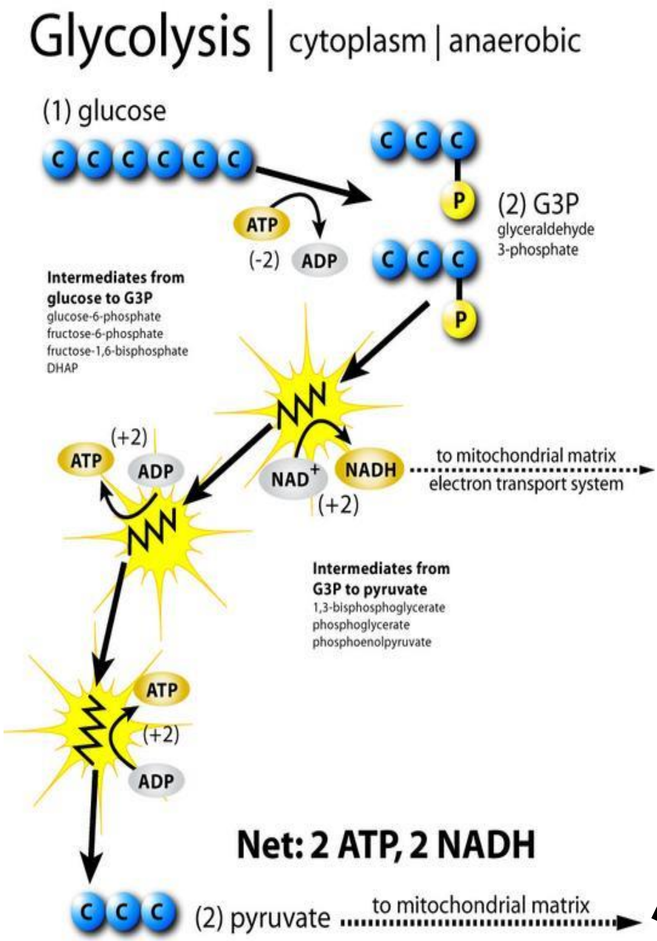


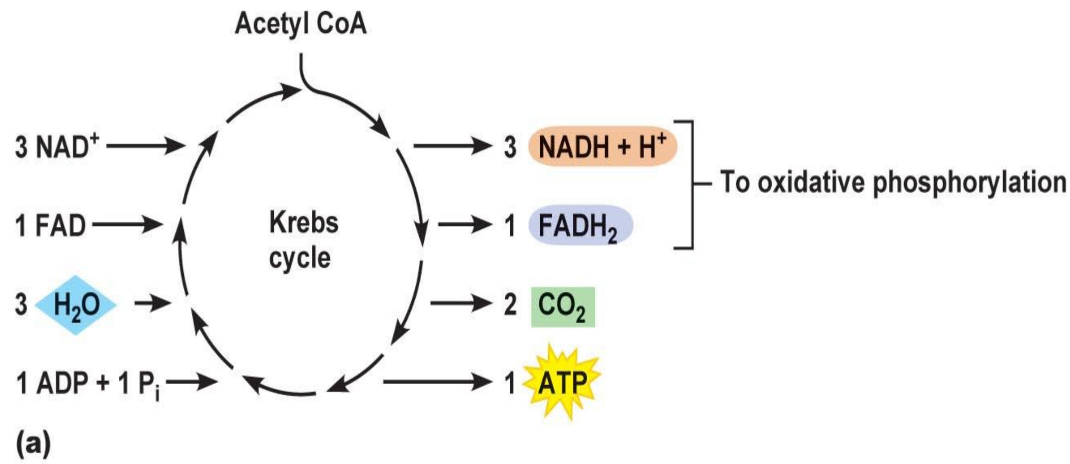
DRP-1

¿Qué reacción fundamental ocurre en las mitocondrias?



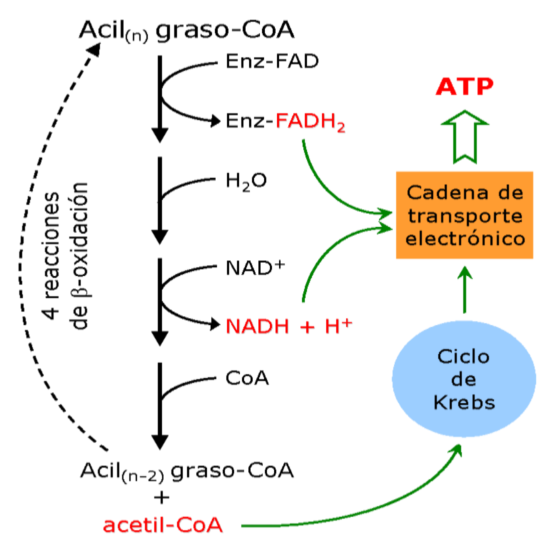






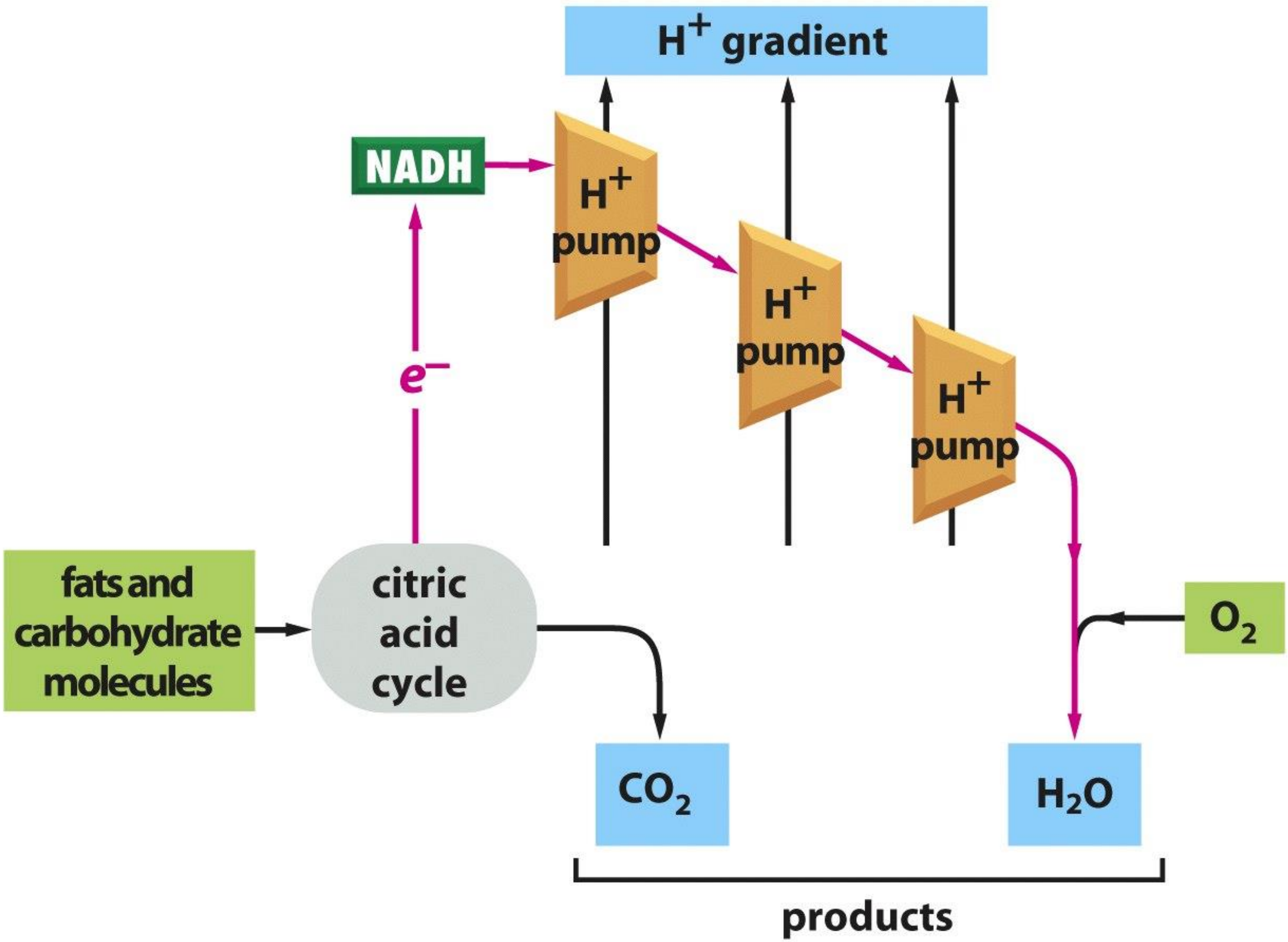
(b) Overall reaction: acetyl CoA + 3 NAD^+ + FAD + ADP + P_i + 3 H_2O $\longrightarrow$ 2 CO_2 + 3 NADH + 3 H^+ + $FADH_2$ + ATP + CoA

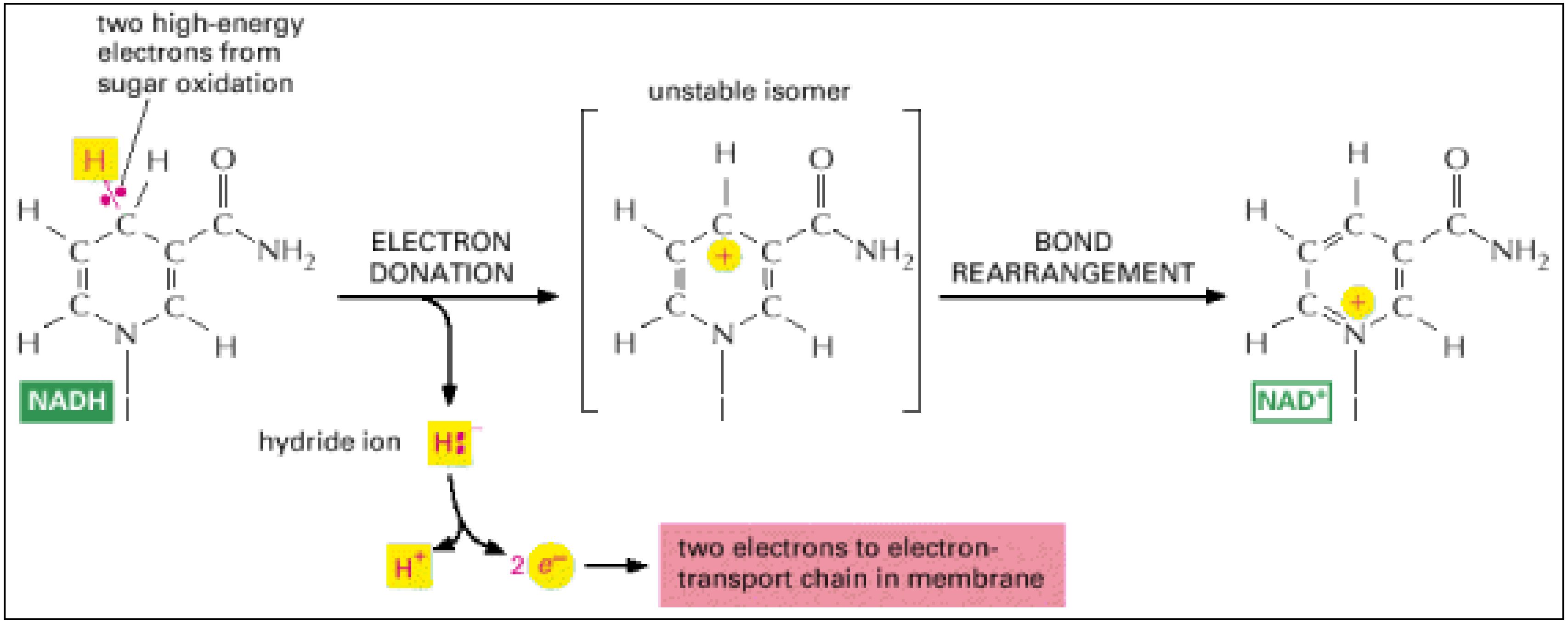
Matriz mitocondrial

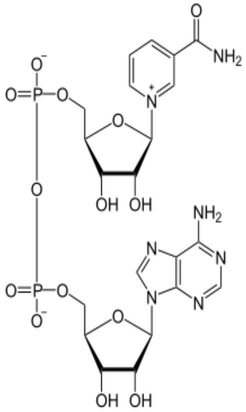


Citosol

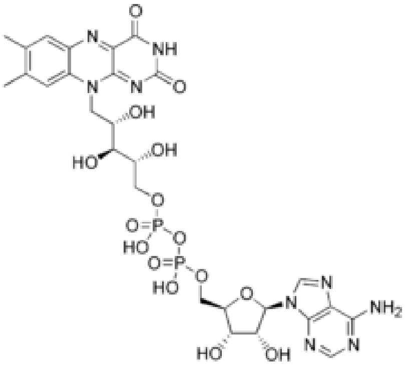
MITOCHONDRION




two high-energy electrons from sugar oxidation
unstable isomer
ELECTRON DONATION
BOND REARRANGEMENT
NADH
NAD+
hydride ion
two electrons to electron-transport chain in membrane



NADH



FADH2

¿Cómo se acoplan esas reacciones favorables energéticamente a la síntesis de ATP?

Teoría Quimiosmótica

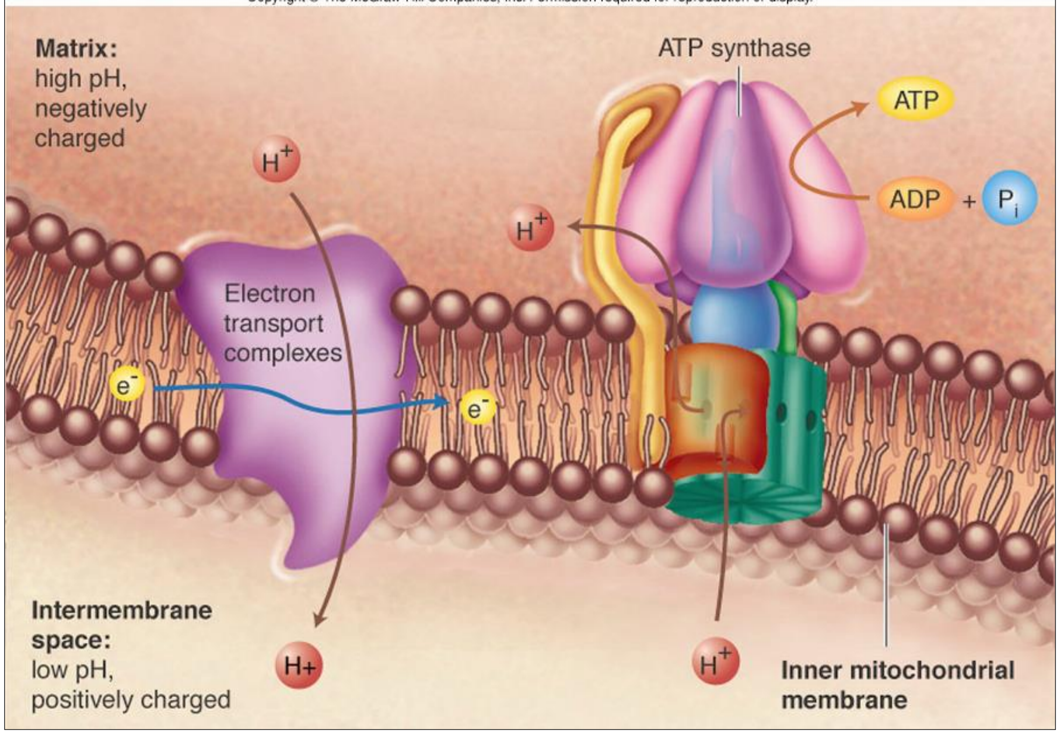
The Nobel Prize in Chemistry 1978

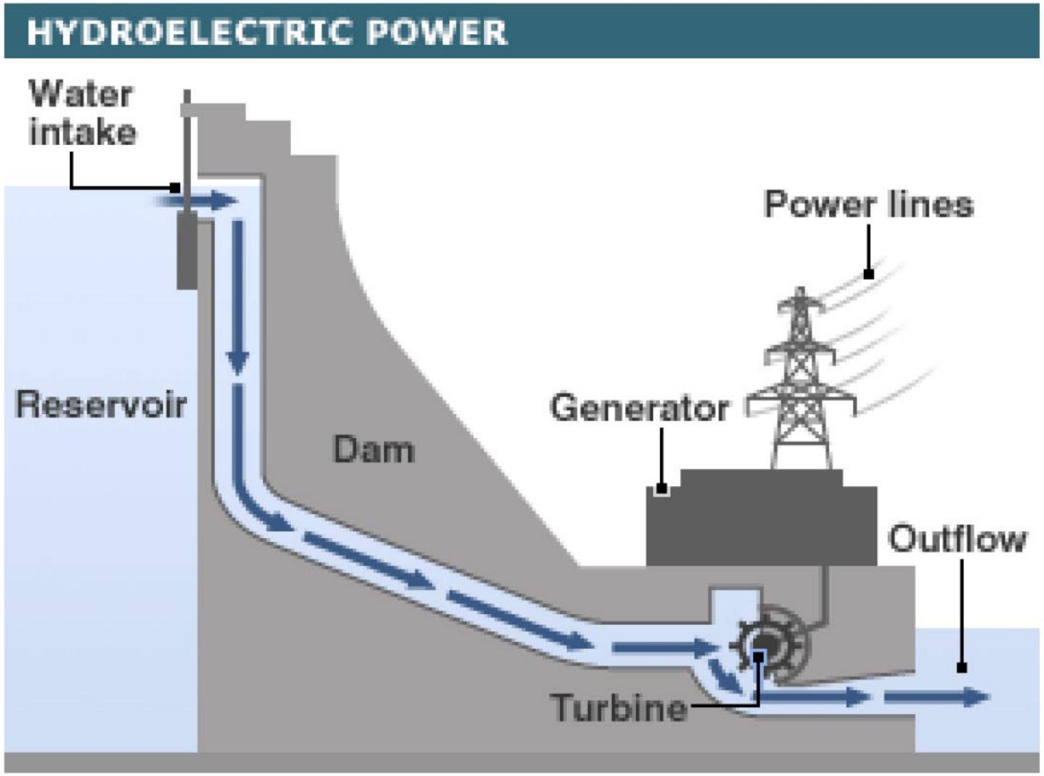
Photo from the Nobel Foundation archive.

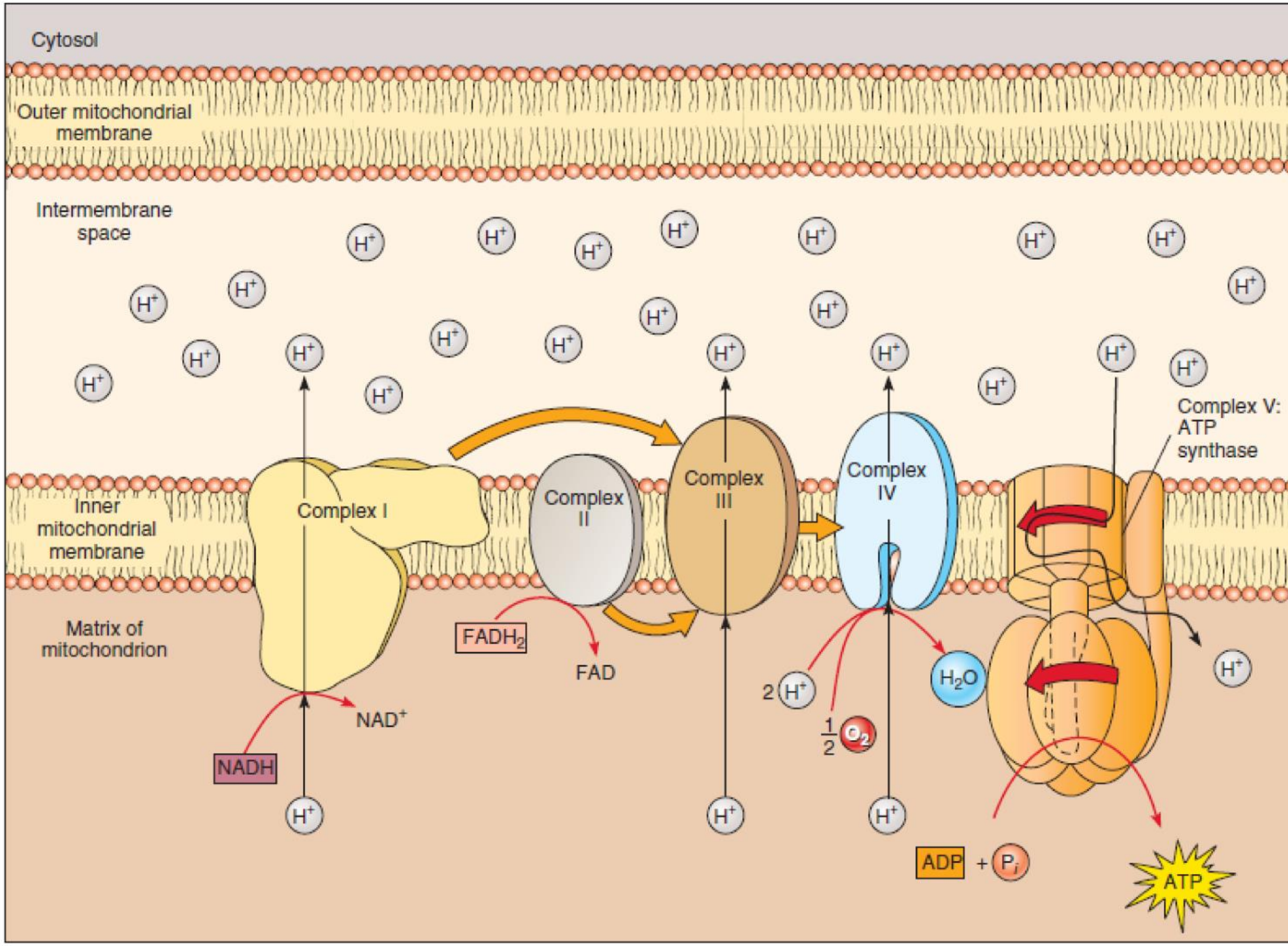
Peter D. Mitchell

Prize share: 1/1

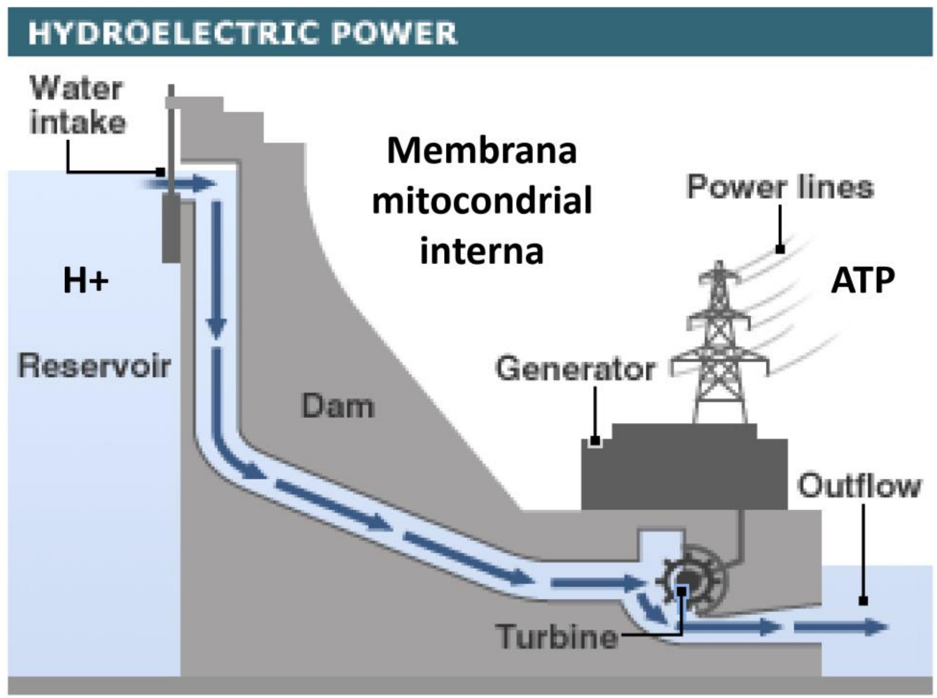
The Nobel Prize in Chemistry 1978 was awarded to Peter D. Mitchell "for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory."




HYDROELECTRIC POWER
Water intake
Reservoir
Dam
Power lines
Generator
Outflow
Turbine

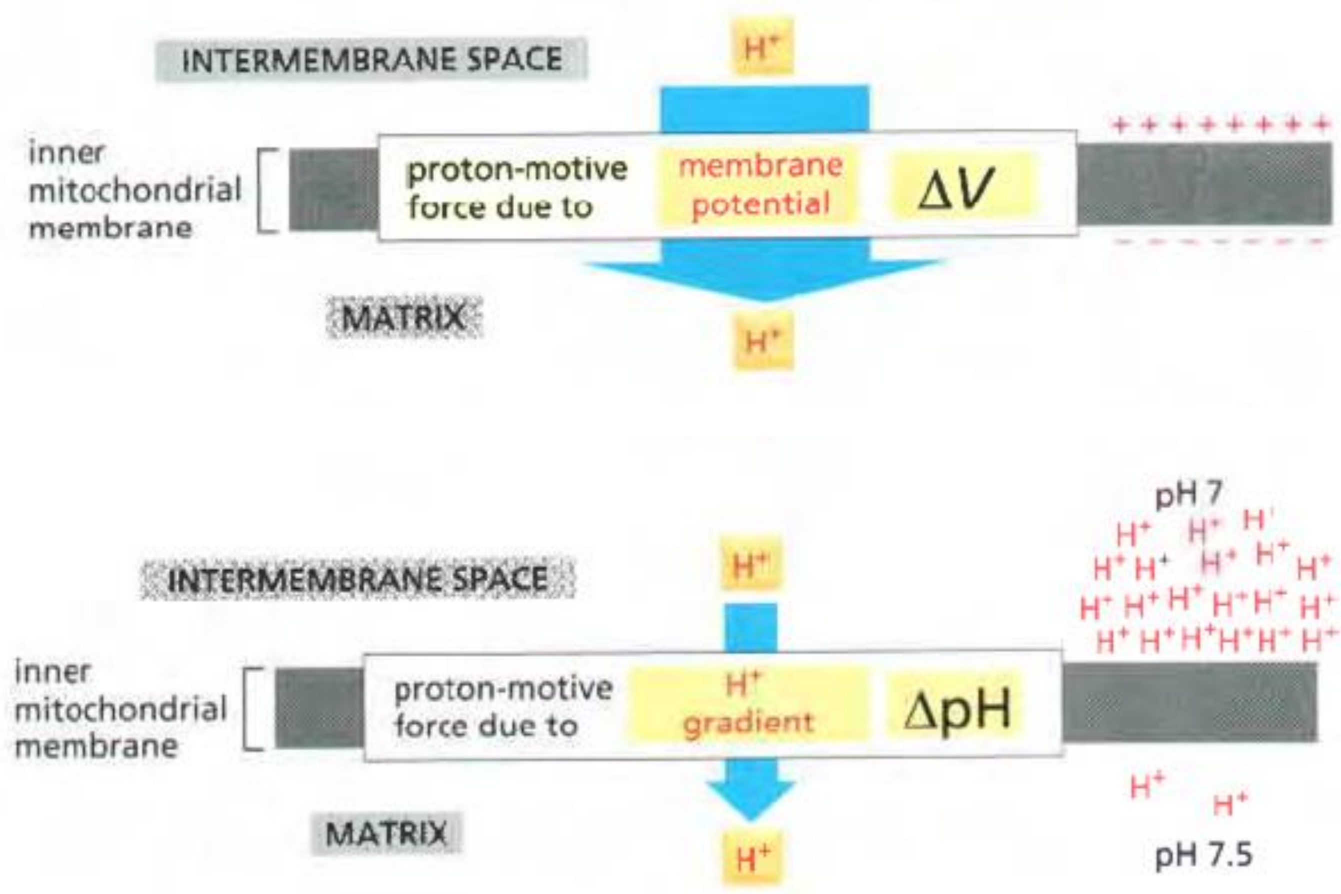


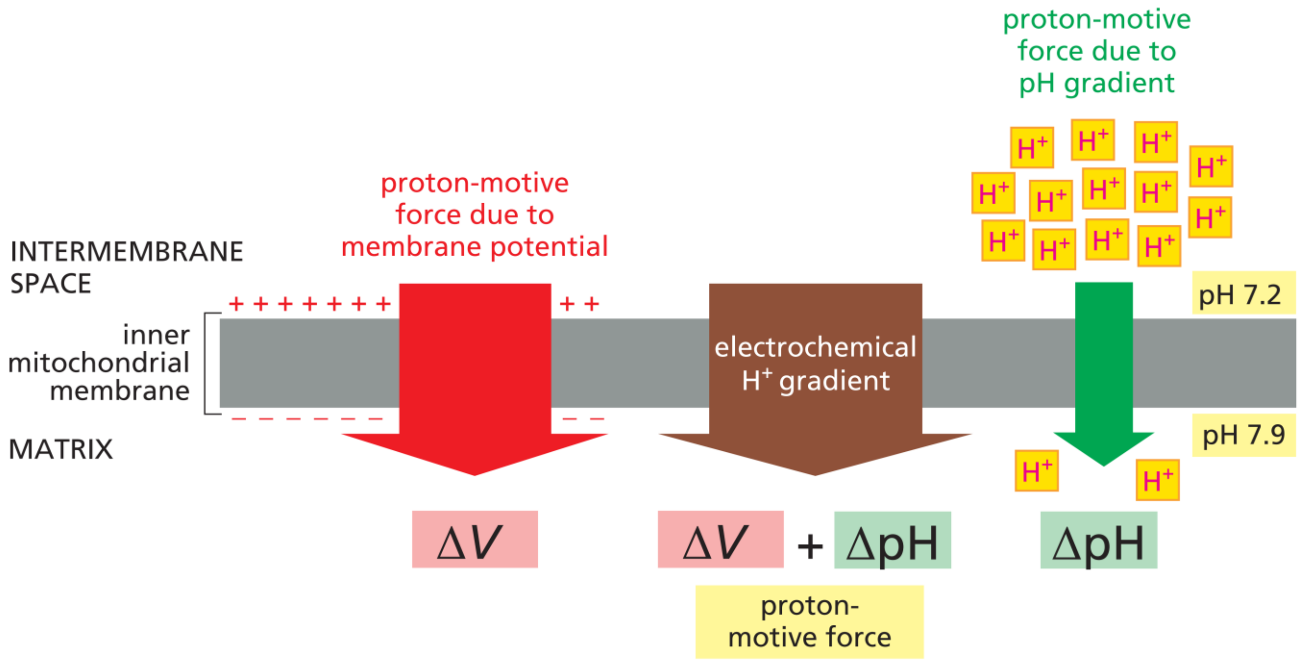
Cytosol
Outer mitochondrial membrane
Intermembrane space
Inner mitochondrial membrane
Matrix of mitochondrion
Complex I
Complex II
Complex III
Complex IV
Complex V: ATP synthase
NADH
NAD+
FADH2
FAD
2 H+
1/2 O2
H2O
ADP + Pi
ATP
H+


HYDROELECTRIC POWER
Water intake
Membrana mitocondrial interna
Power lines
H+
ATP
Reservoir
Generator
Dam
Outflow
Turbine

ATP sintasa

¿Qué ocurre al bombear protones de la matriz al espacio intermembrana?





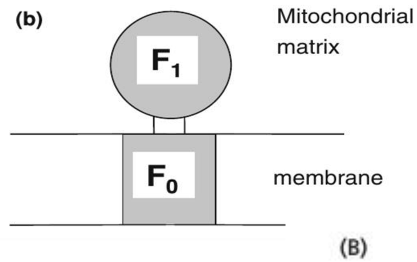
flujo de H+ que regresa a la matriz e impulsa la síntesis de ATP **Fuerza protón-motriz (Δp)** = **Gradiente químico ΔpH** (dentro alcalino) + **Gradiente de carga Δψ** (dentro negativo)

¿Cuánta energía libera un protón que regresa a la matriz a favor de su gradiente electroquímico?

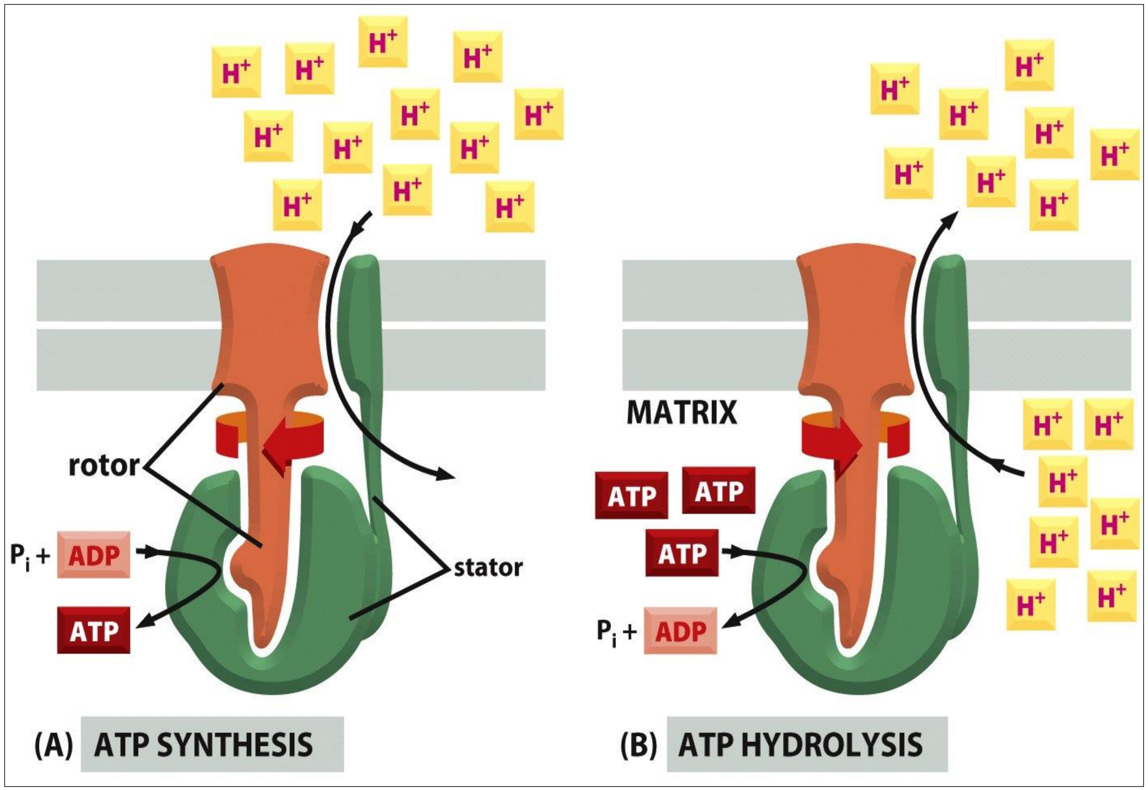
¿Cuánta energía cuesta sintetizar una molécula de ATP?

Para investigar ustedes…

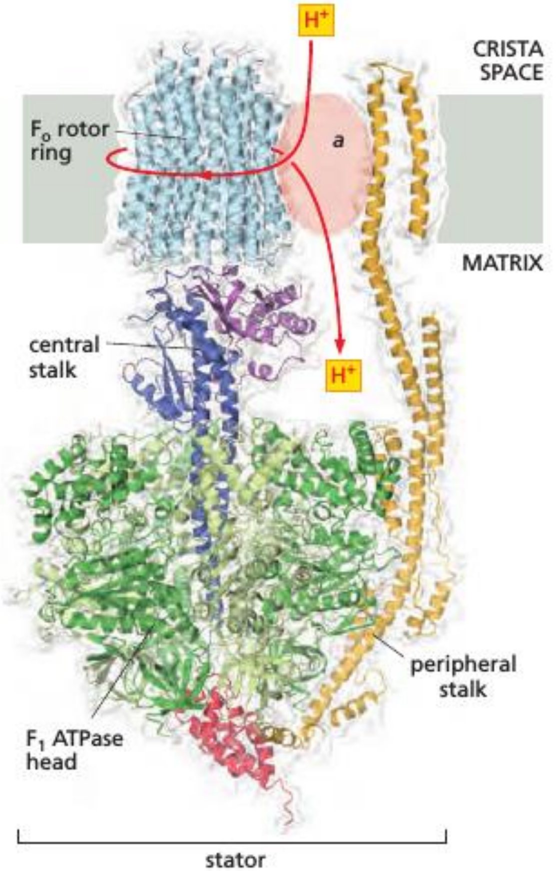
ATP sintasa



(b)
F1
Mitochondrial
matrix
F0
membrane
(B)



H+
rotor
stator
Pi + ADP
ATP
MATRIX
ATP
ATP
ATP
Pi + ADP
(A) ATP SYNTHESIS
(B) ATP HYDROLYSIS

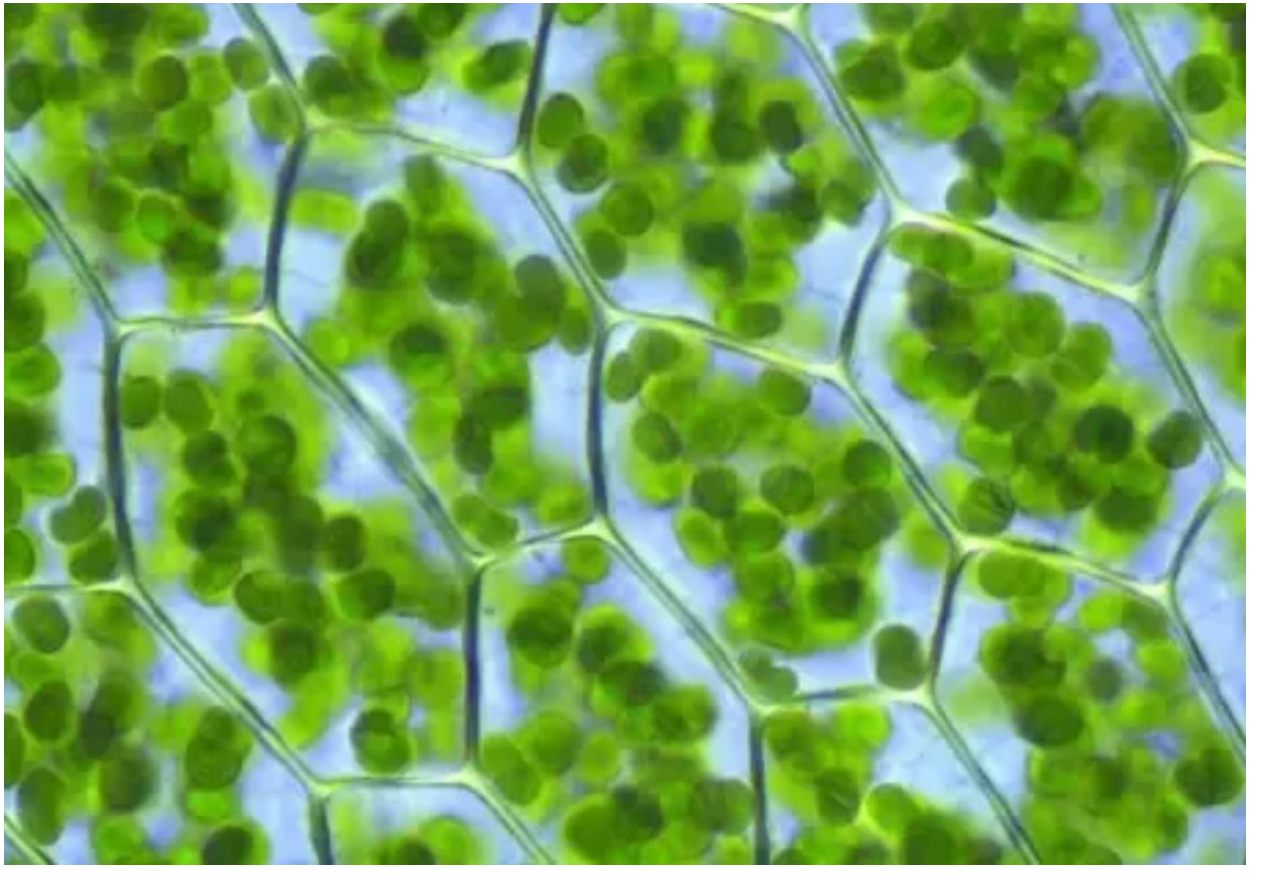


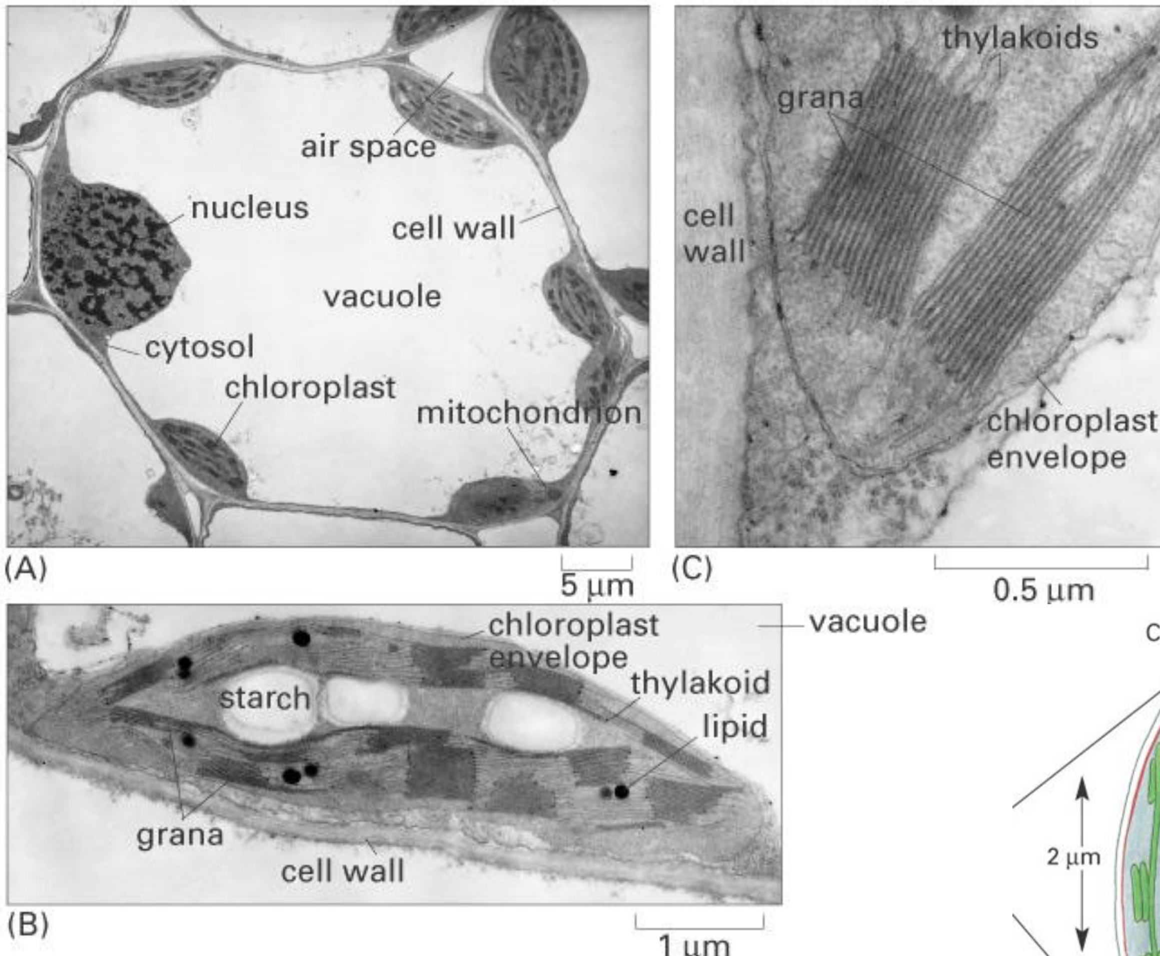
H+
CRISTA
SPACE
F0 rotor
ring
a
MATRIX
central
stalk
H+
peripheral
stalk
F1 ATPase
head
stator

Algunas otras funciones de las mitocondrias

- Ciclo de la urea (algunos pasos)
- Formación de centros Fe-S
- Síntesis de lípidos (junto a Retículo)
- Regulación de concentración de Calcio (junto a Retículo)
- Regulación de muerte celular programada (Apoptosis) – lo ven en téorico más adelante

Cloroplastos





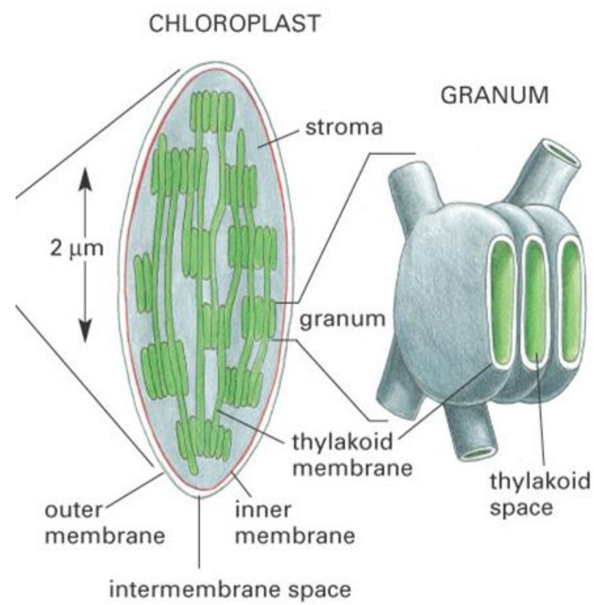


Figure 14-29 Essential Cell Biology, 2/e. (© 2004 Garland Science)

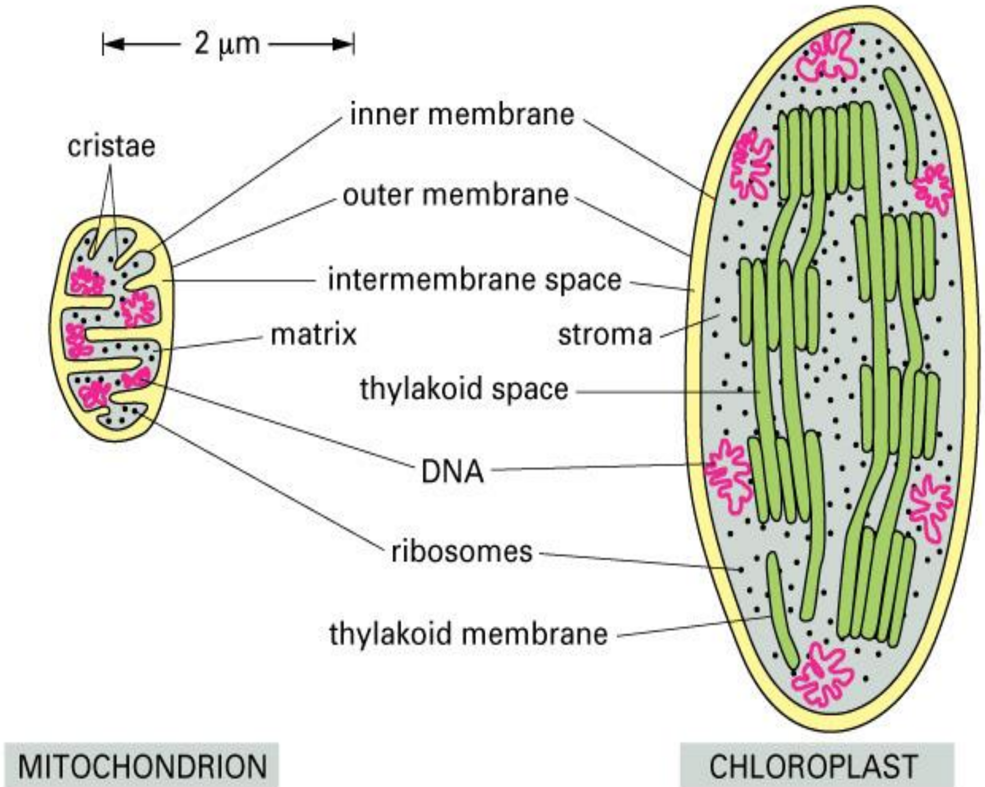
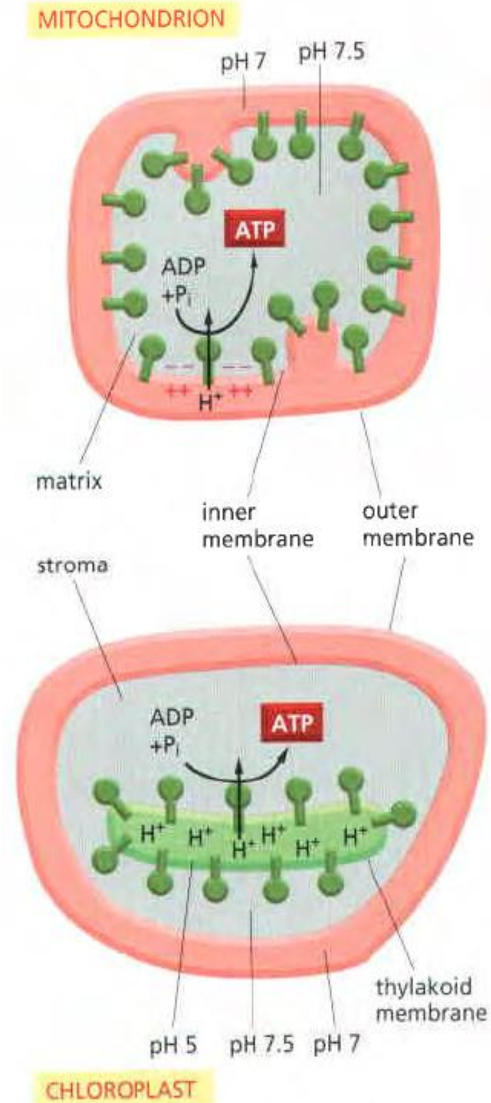
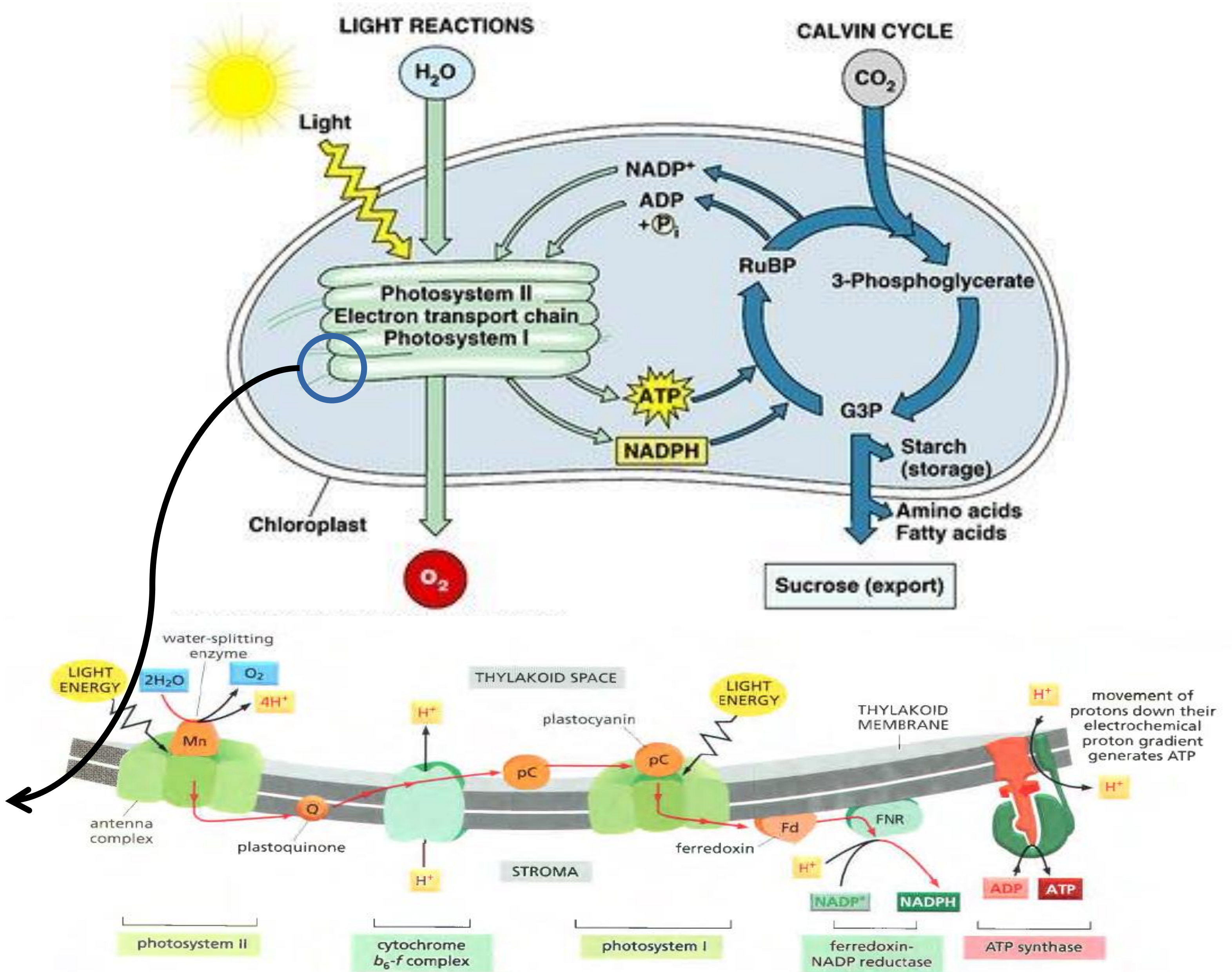


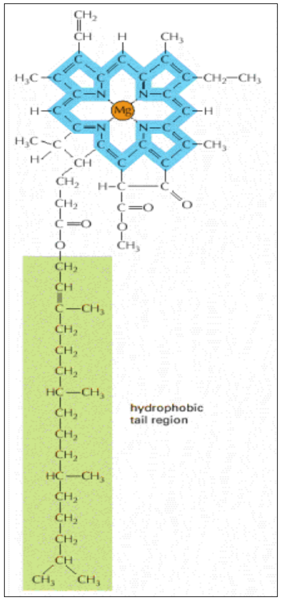
Figure 14-31 Essential Cell Biology, 2/e. (© 2004 Garland Science)

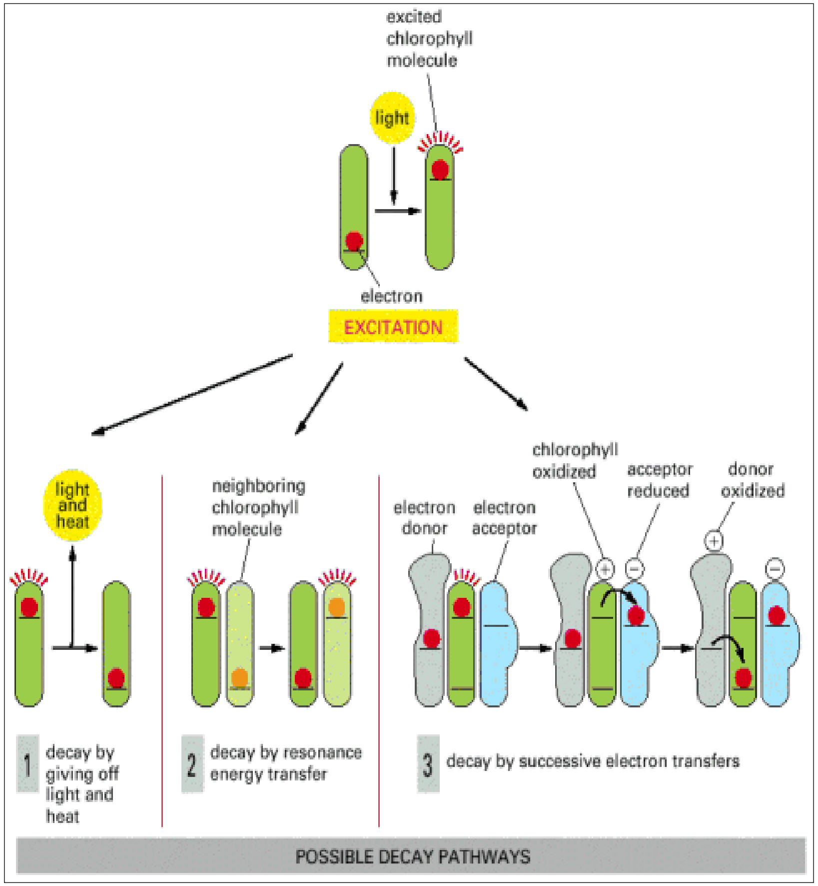


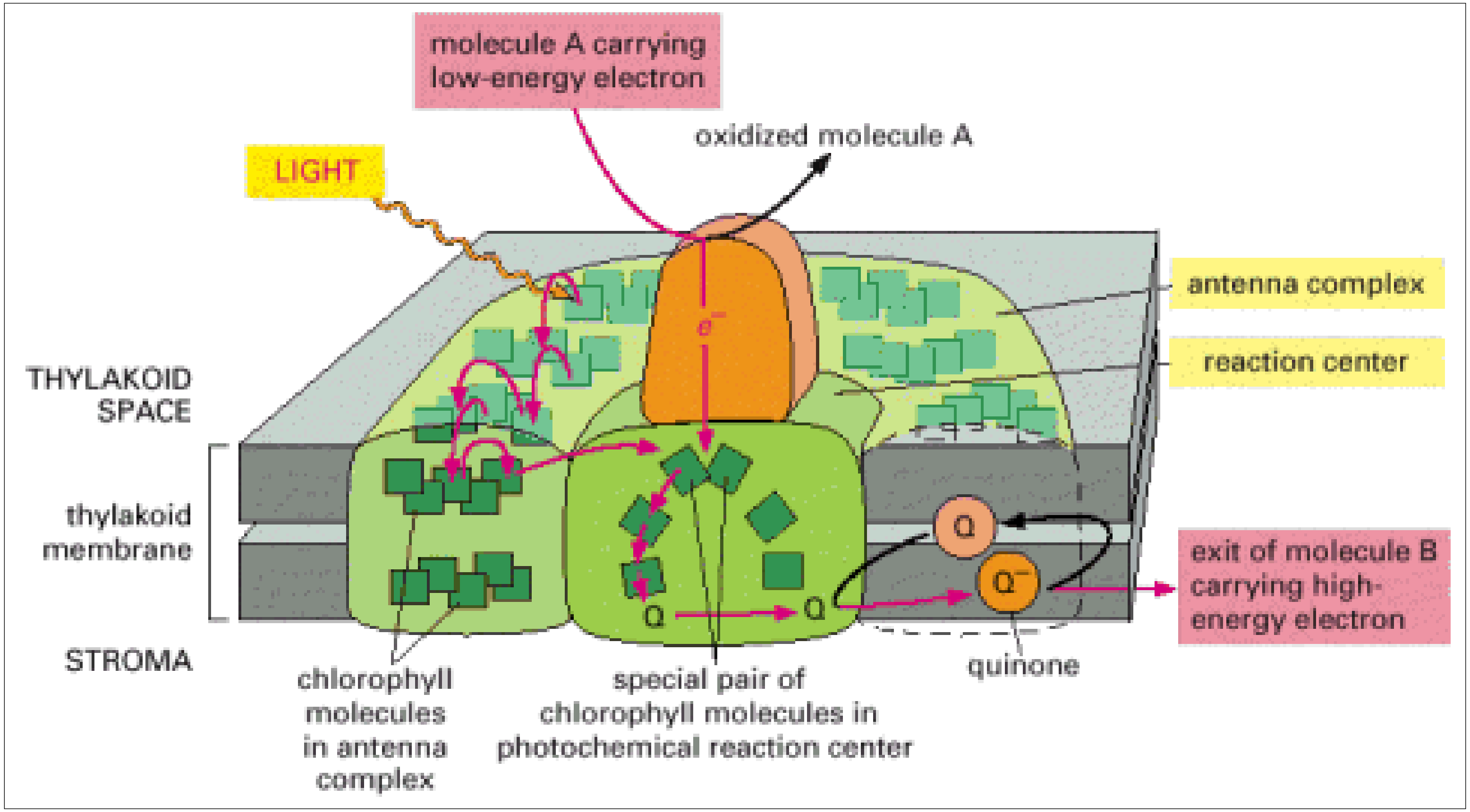


LIGHT REACTIONS
CALVIN CYCLE
H_2O
CO_2
Light
NADP+
ADP
+ Pi
RuBP
3-Phosphoglycerate
Photosystem II
Electron transport chain
Photosystem I
ATP
NADPH
G3P
Starch
(storage)
Amino acids
Fatty acids
Chloroplast
O_2
Sucrose (export)
water-splitting
enzyme
LIGHT
ENERGY
$2H_2O$
O_2
$4H^+$
THYLAKOID SPACE
H^+
plastocyanin
LIGHT
ENERGY
THYLAKOID
MEMBRANE
H^+
movement of
protons down their
electrochemical
proton gradient
generates ATP
Mn
pC
pC
H^+
Q
FNR
Fd
antenna
complex
plastoquinone
ferredoxin
H^+
STROMA
H^+
$NADP^+$
NADPH
ADP
ATP
photosystem II
cytochrome
b_6-f complex
photosystem I
ferredoxin-
NADP reductase
ATP synthase

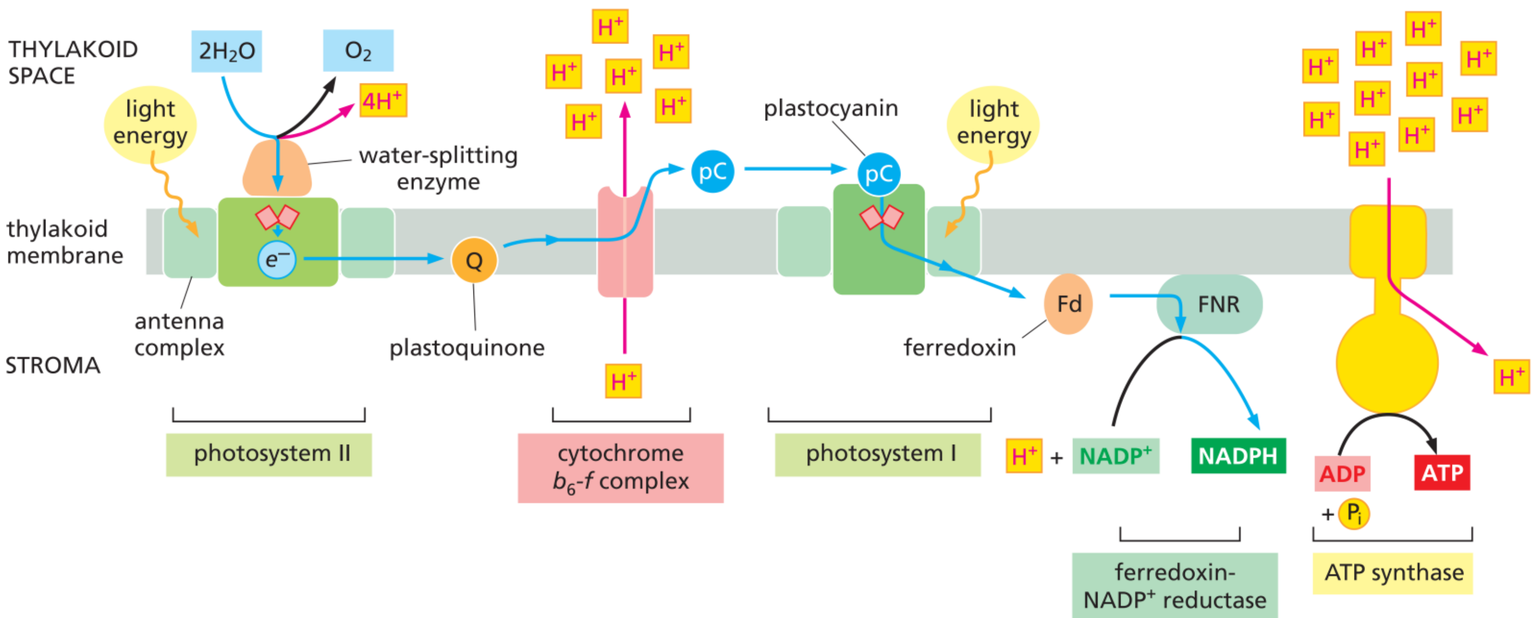
¿Cómo se generan el ATP y el NADPH necesarios para la fijación del CO_2?

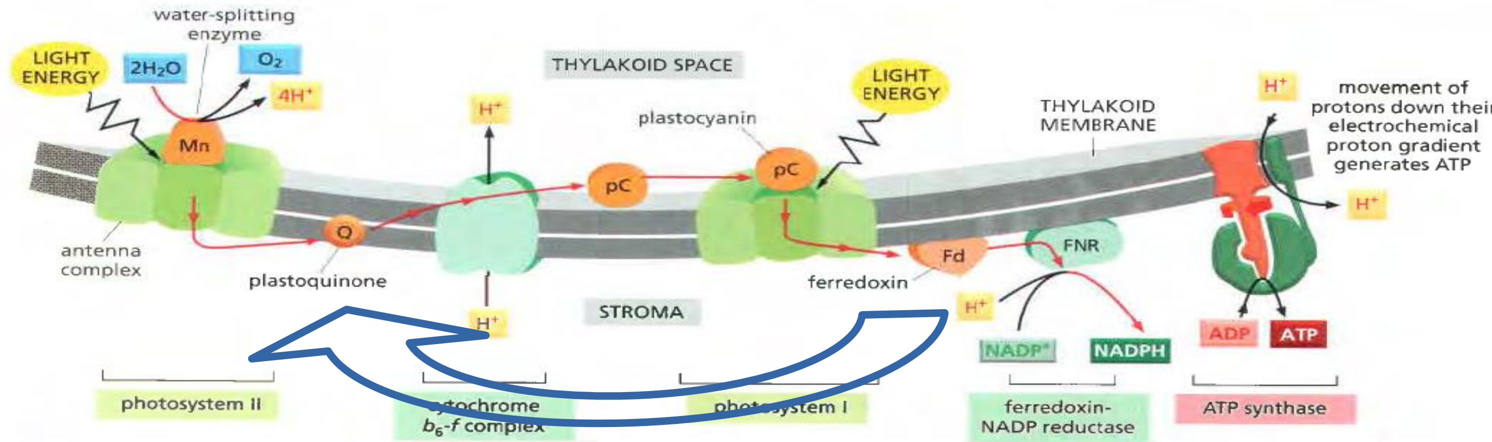




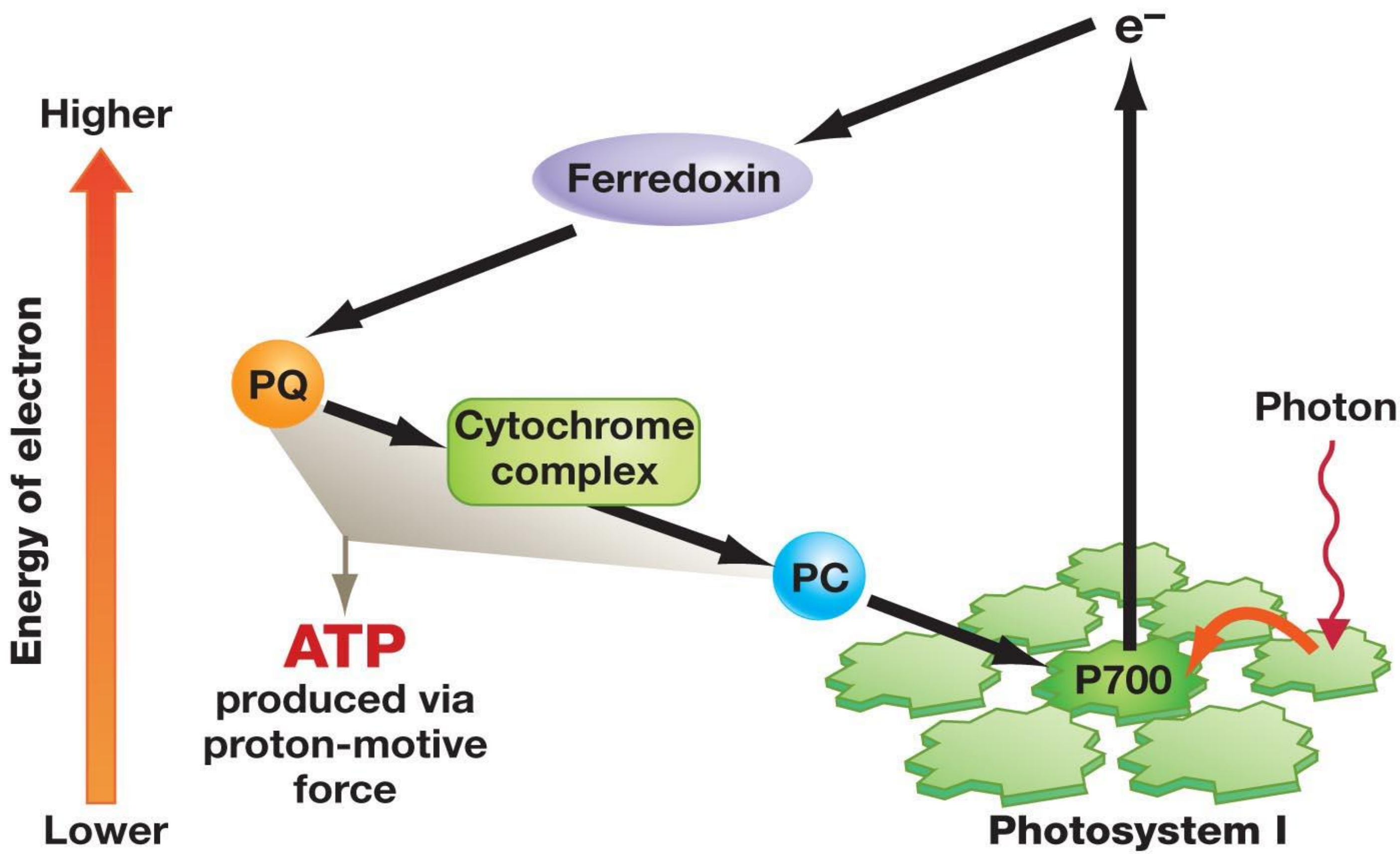

molecule A carrying low-energy electron
oxidized molecule A
LIGHT
antenna complex
reaction center
THYLAKOID SPACE
thylakoid membrane
STROMA
e⁻
Q
Q
Q
Q⁻
exit of molecule B carrying high-energy electron
chlorophyll molecules in antenna complex
special pair of chlorophyll molecules in photochemical reaction center
quinone

Fotofosforilación no cíclica



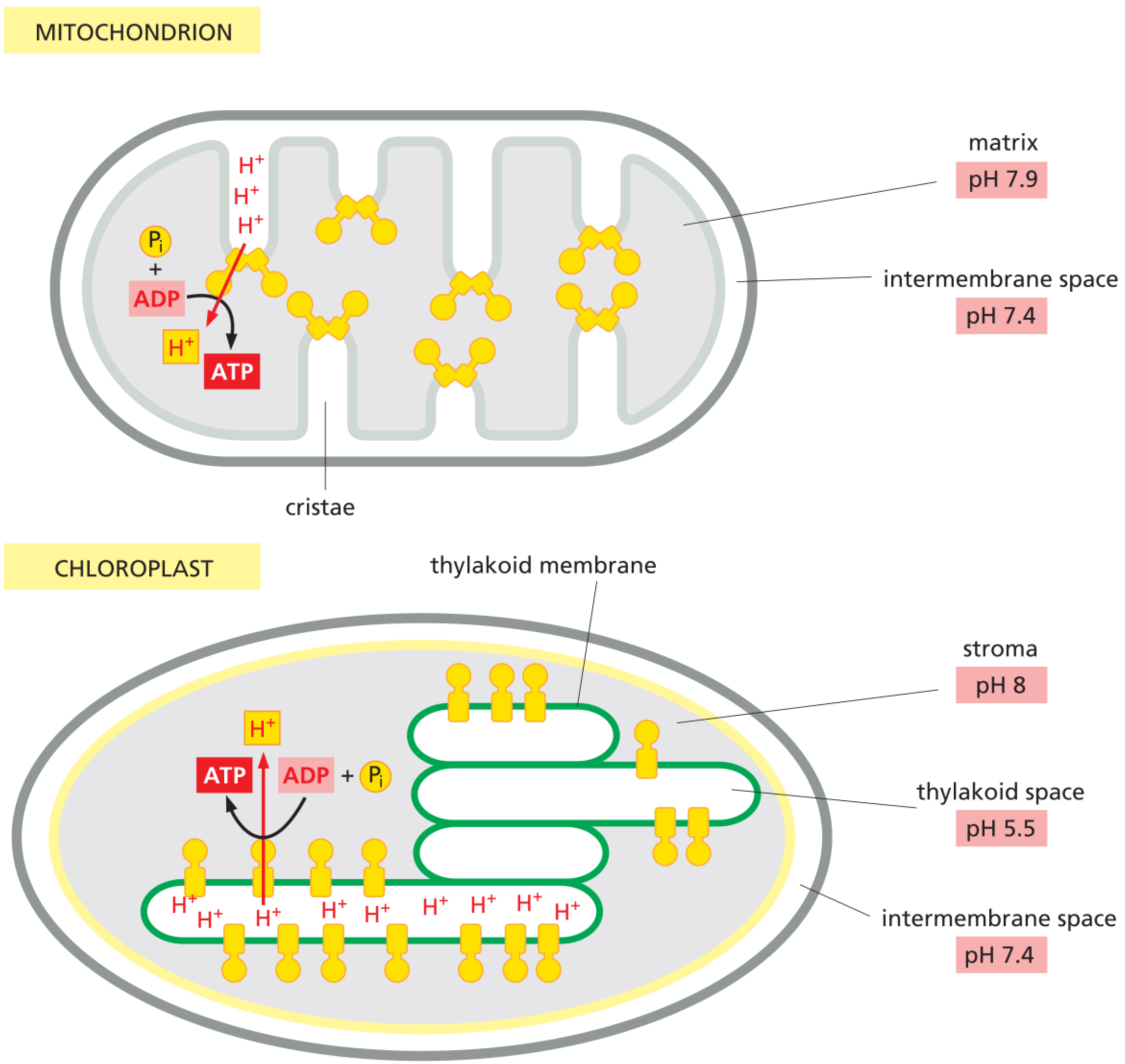


water-splitting enzyme
LIGHT ENERGY
2H2O
O2
4H+
Mn
H+
THYLAKOID SPACE
plastocyanin
LIGHT ENERGY
THYLAKOID MEMBRANE
H+
movement of protons down their electrochemical proton gradient generates ATP
pC
pC
Q
H+
antenna complex
plastoquinone
Fd
FNR
ferredoxin
STROMA
H+
H+
NADP+
NADPH
ADP
ATP
photosystem II
cytochrome b6-f complex
photosystem I
ferredoxin-NADP reductase
ATP synthase

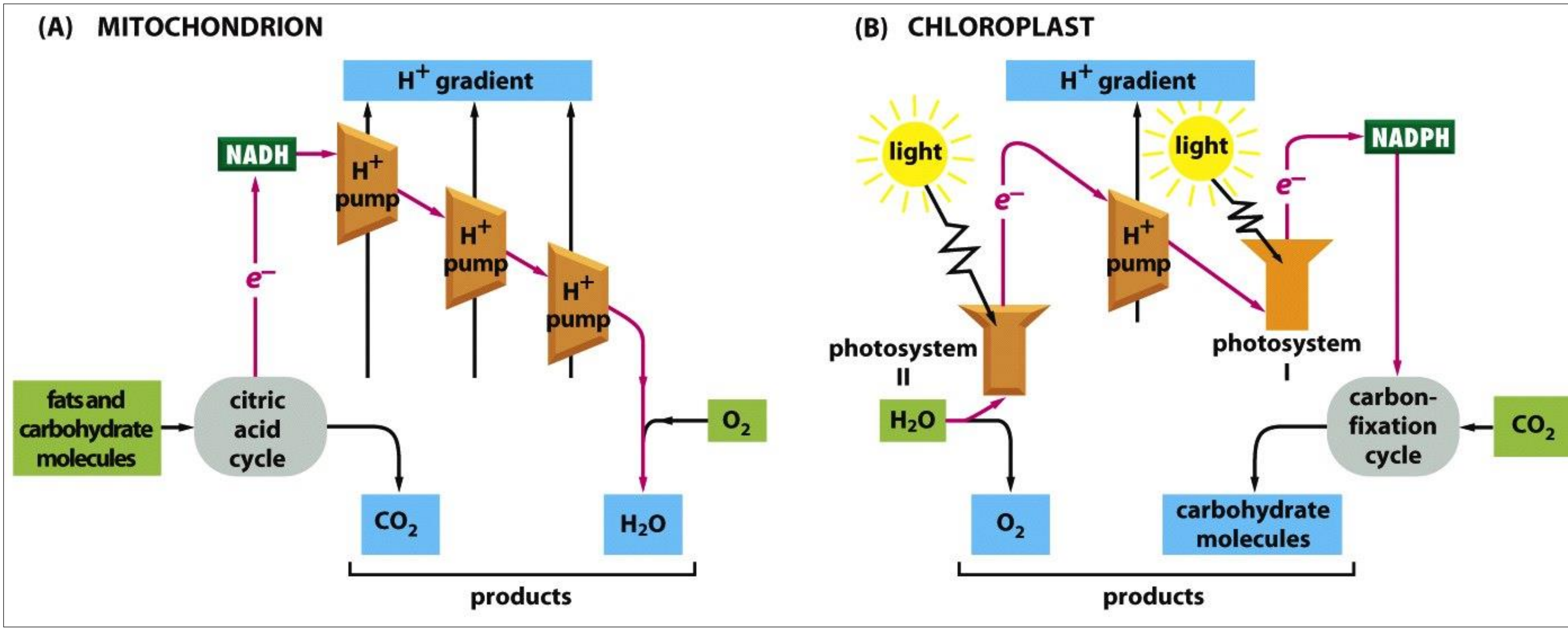


e−
Higher
Ferredoxin
Energy of electron
PQ
Cytochrome complex
Photon
PC
P700
ATP
produced via proton-motive force
Lower
Photosystem I

¿Cómo es la fuerza protón-motriz en cloroplastos?

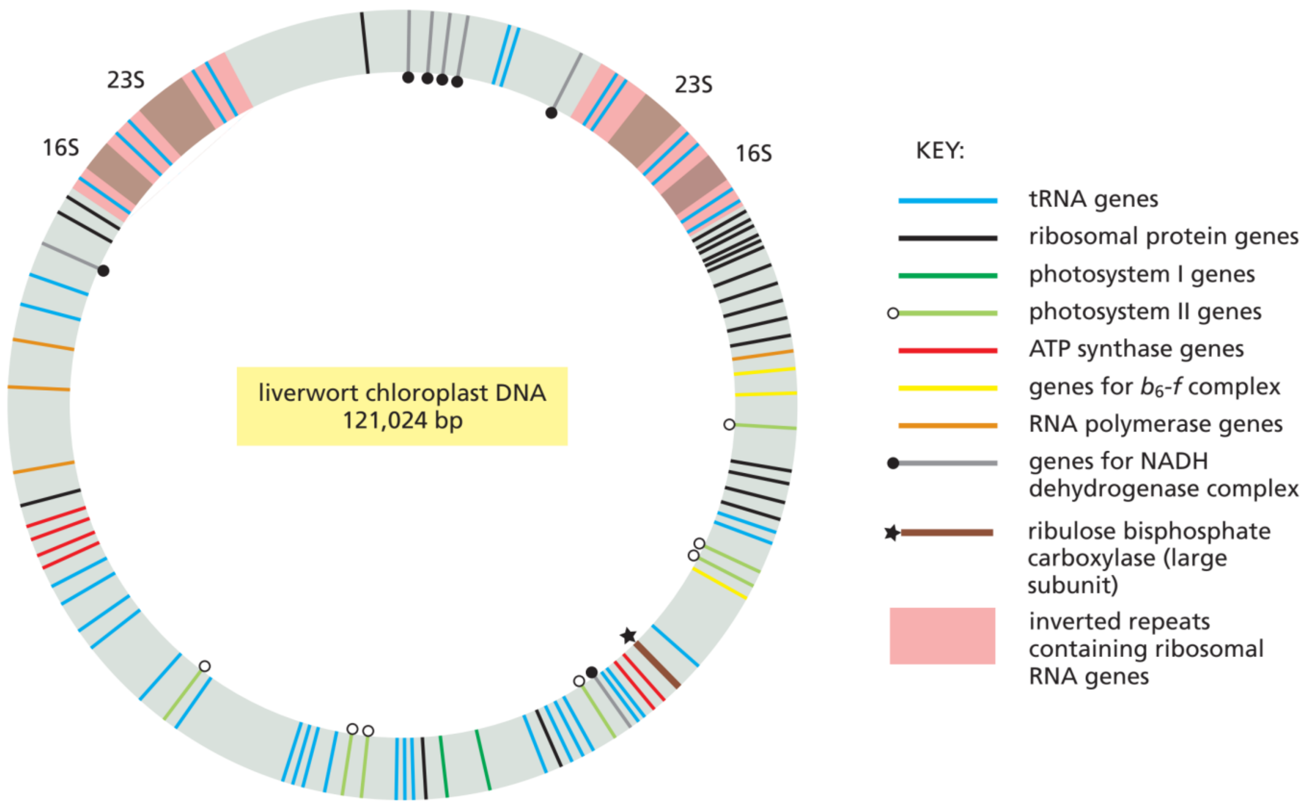


En resumen



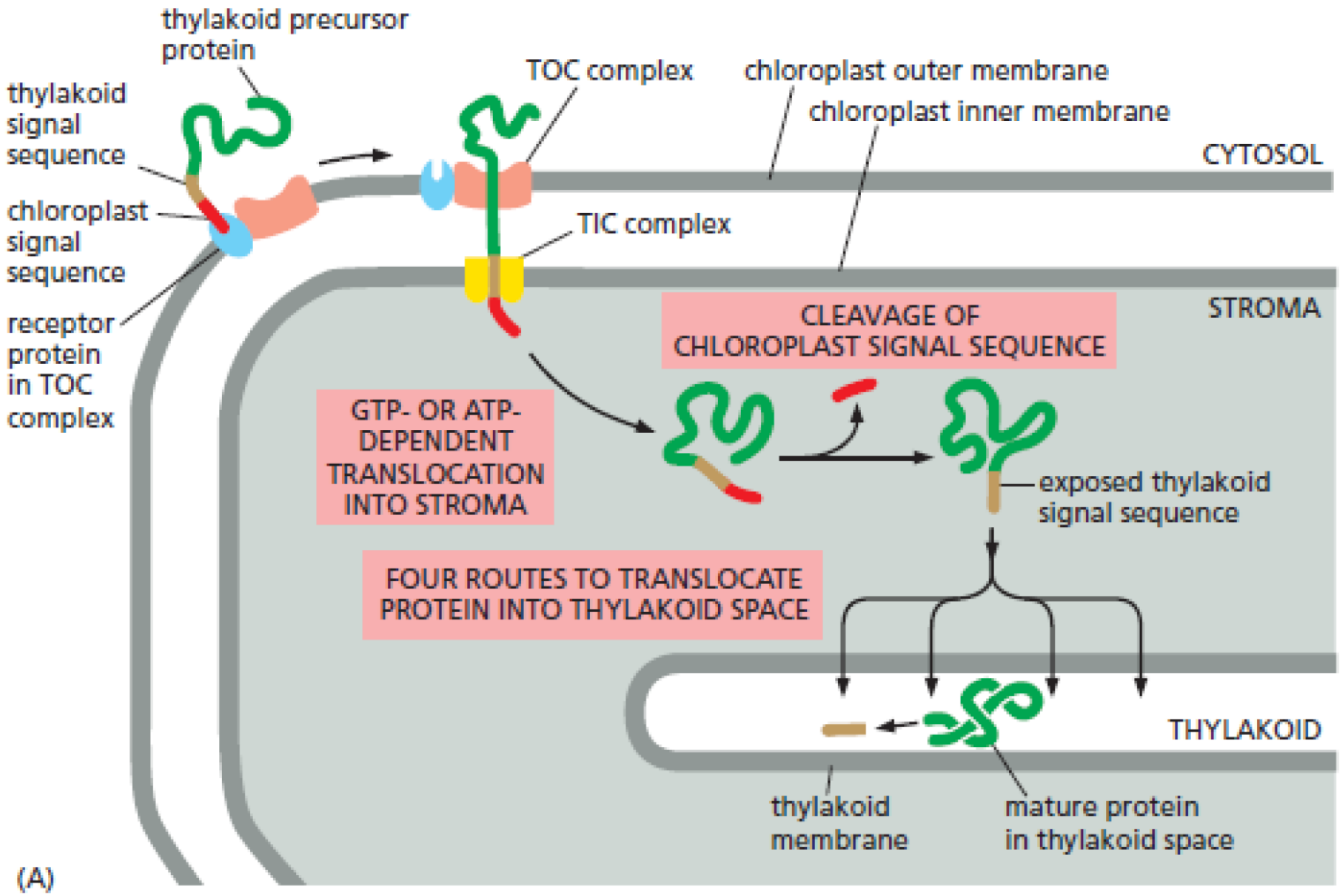
(A) MITOCHONDRION
H+ gradient
NADH
H+ pump
H+ pump
H+ pump
e−
fats and carbohydrate molecules
citric acid cycle
O2
CO2
H2O
products
(B) CHLOROPLAST
H+ gradient
light
light
e−
e−
NADPH
H+ pump
photosystem II
photosystem I
H2O
carbon-fixation cycle
CO2
O2
carbohydrate molecules
products

ADN del cloroplasto



2/3 plantas superiores heredan por vía materna (cloroplastos en los grano del polen no pueden ingresar al cigoto)
Otros pueden tener herencia biparental

Transporte de proteínas al cloroplasto



División de cloroplastos

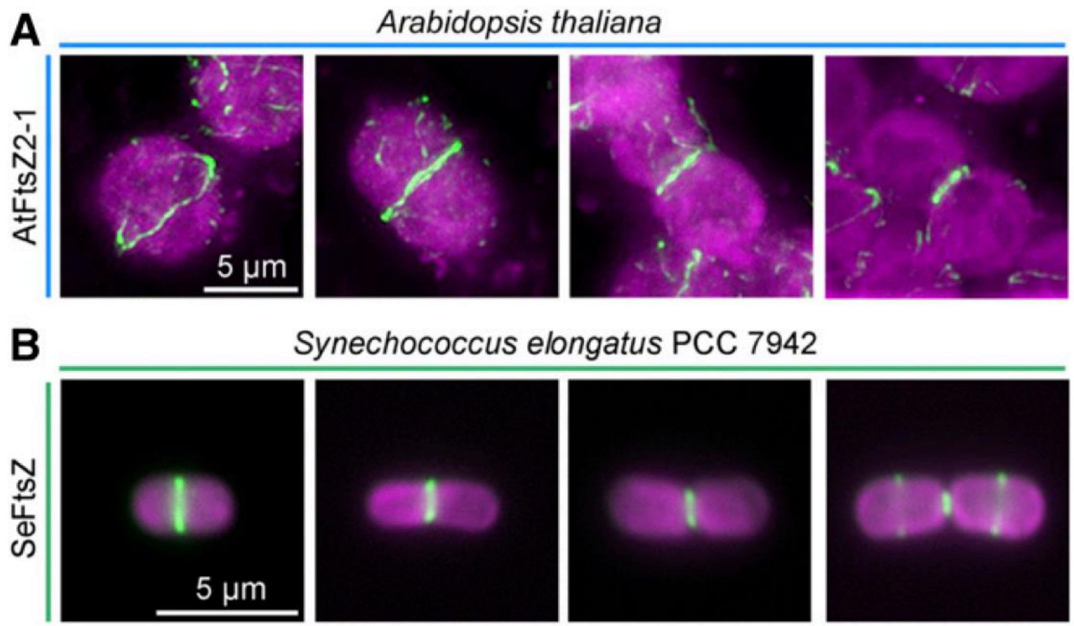


Figure 2. Immunofluorescence localization of the contractile Z ring in chloroplasts and cyanobacterial cells during division. A, Arabidopsis FtsZ2-1 (AtFtsZ2-1) detected with an anti-AtFtsZ2-1 antibody (McAndrew et al., 2001) in mesophyll cells of a fully expanded leaf obtained from a 3-week-old plant (Col-0). B, FtsZ in the cyanobacterium *Synechococcus elongatus* PCC 7942 (SeFtsZ) detected with an anti-*Anabaena* FtsZ antibody (Agrisera). Green, FtsZ; magenta, chlorophyll fluorescence. Bars, 5 μm.

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