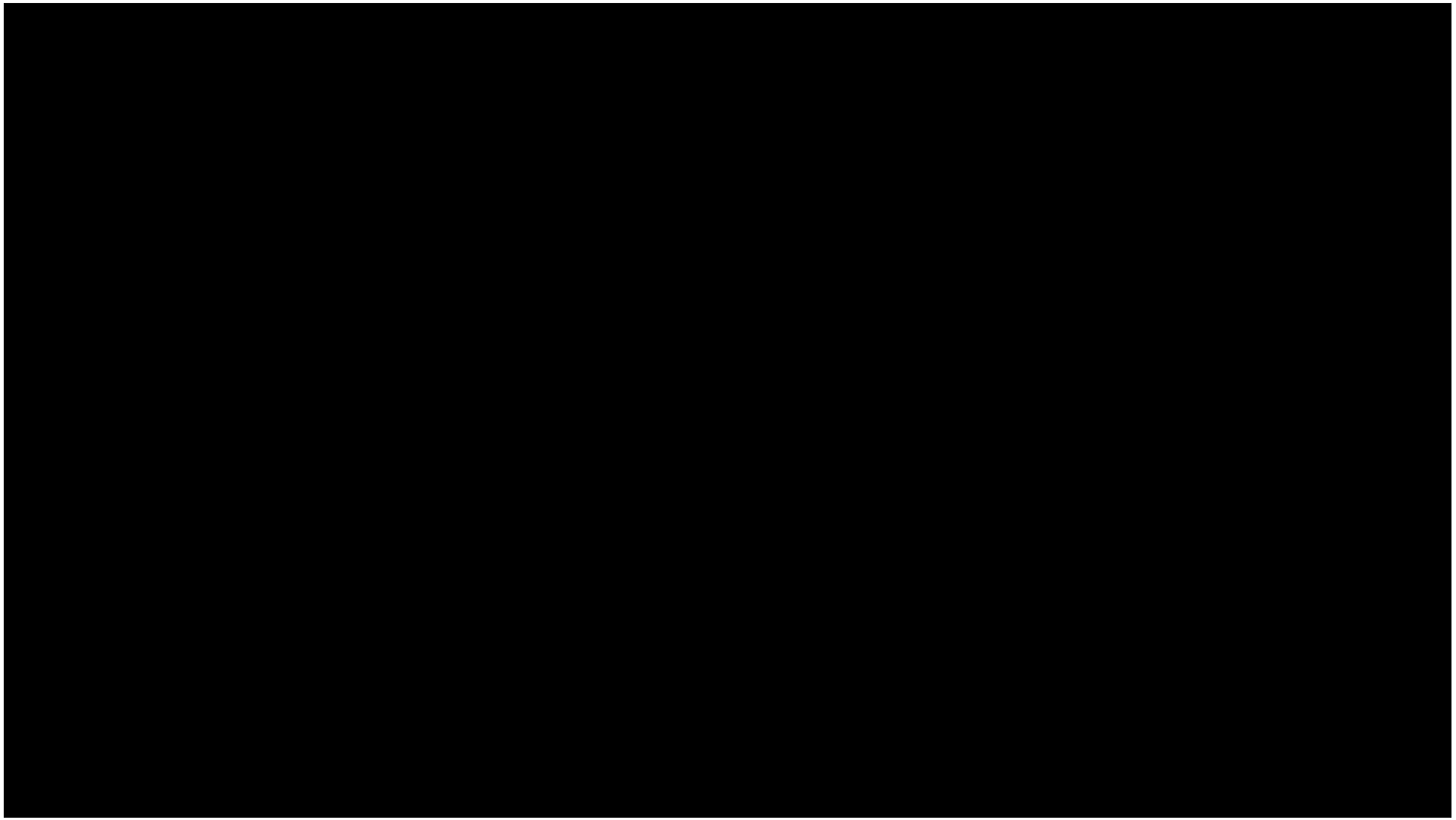
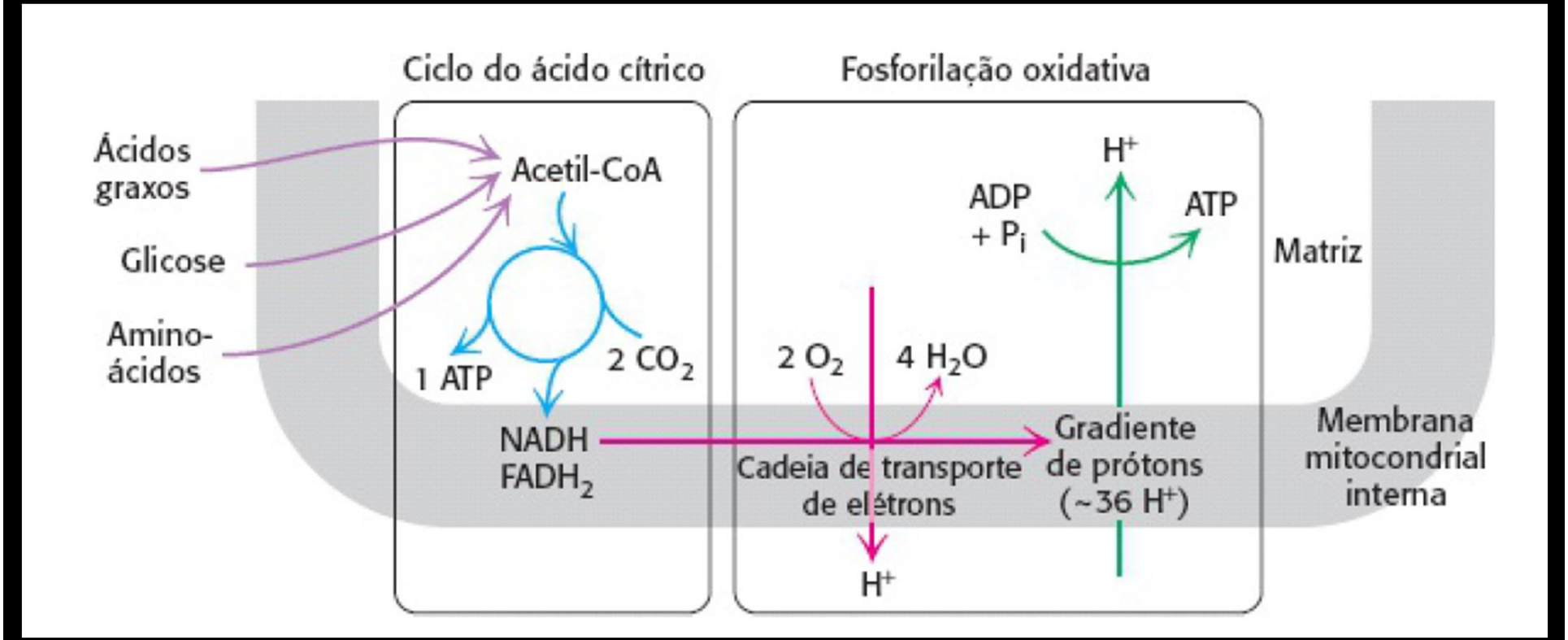
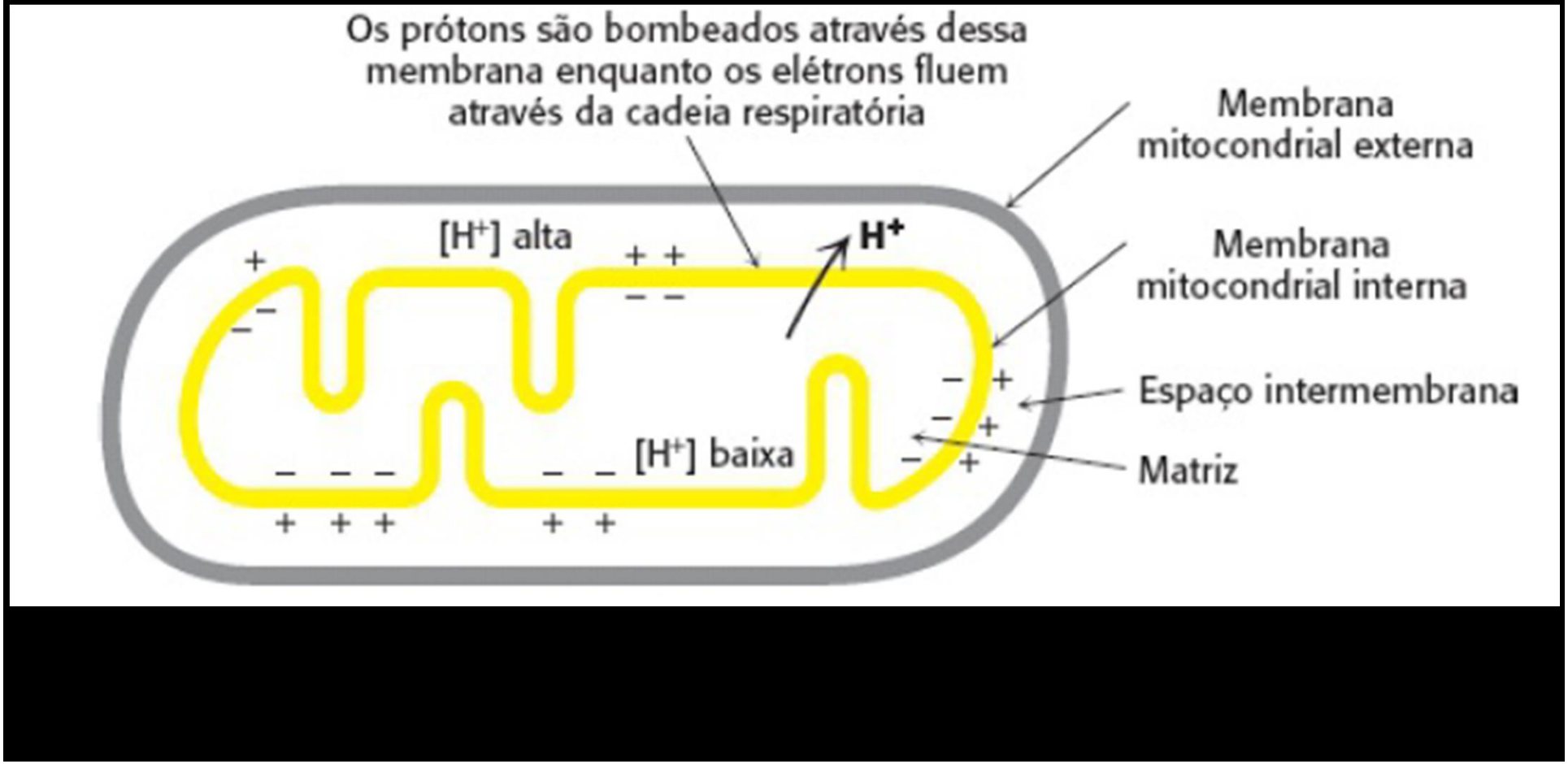


ATP Sintase

Ronaldo Bento Quaggio

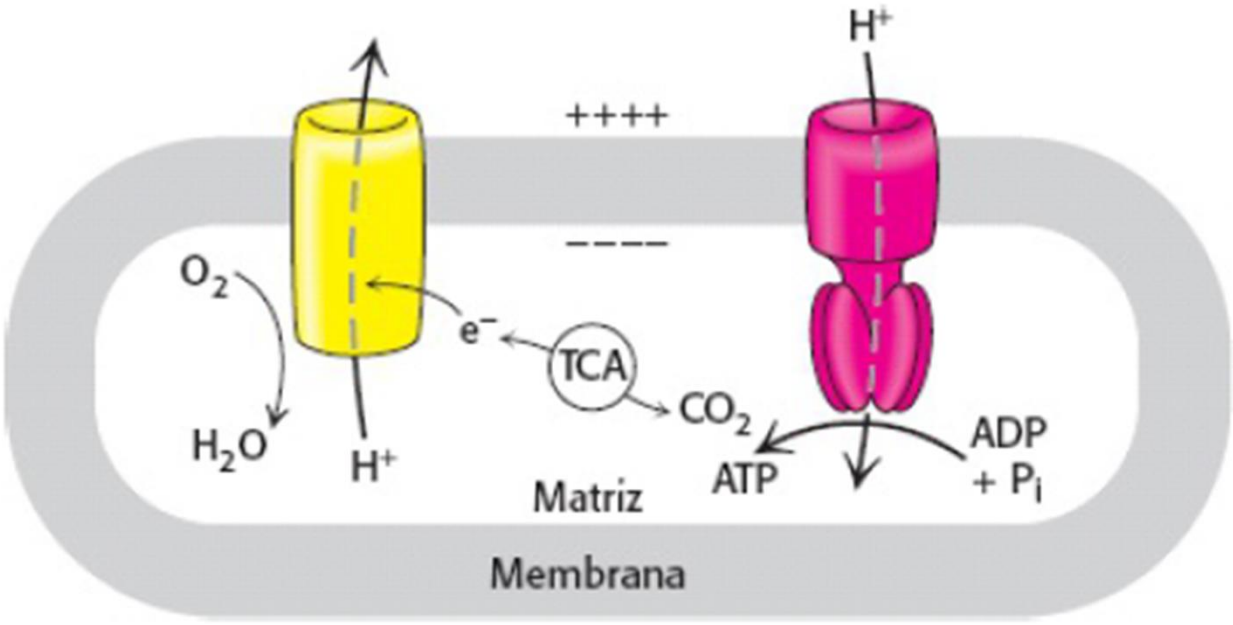
QBQ0204 - Bioquímica
Estrutura de Biomoléculas e Metabolismo

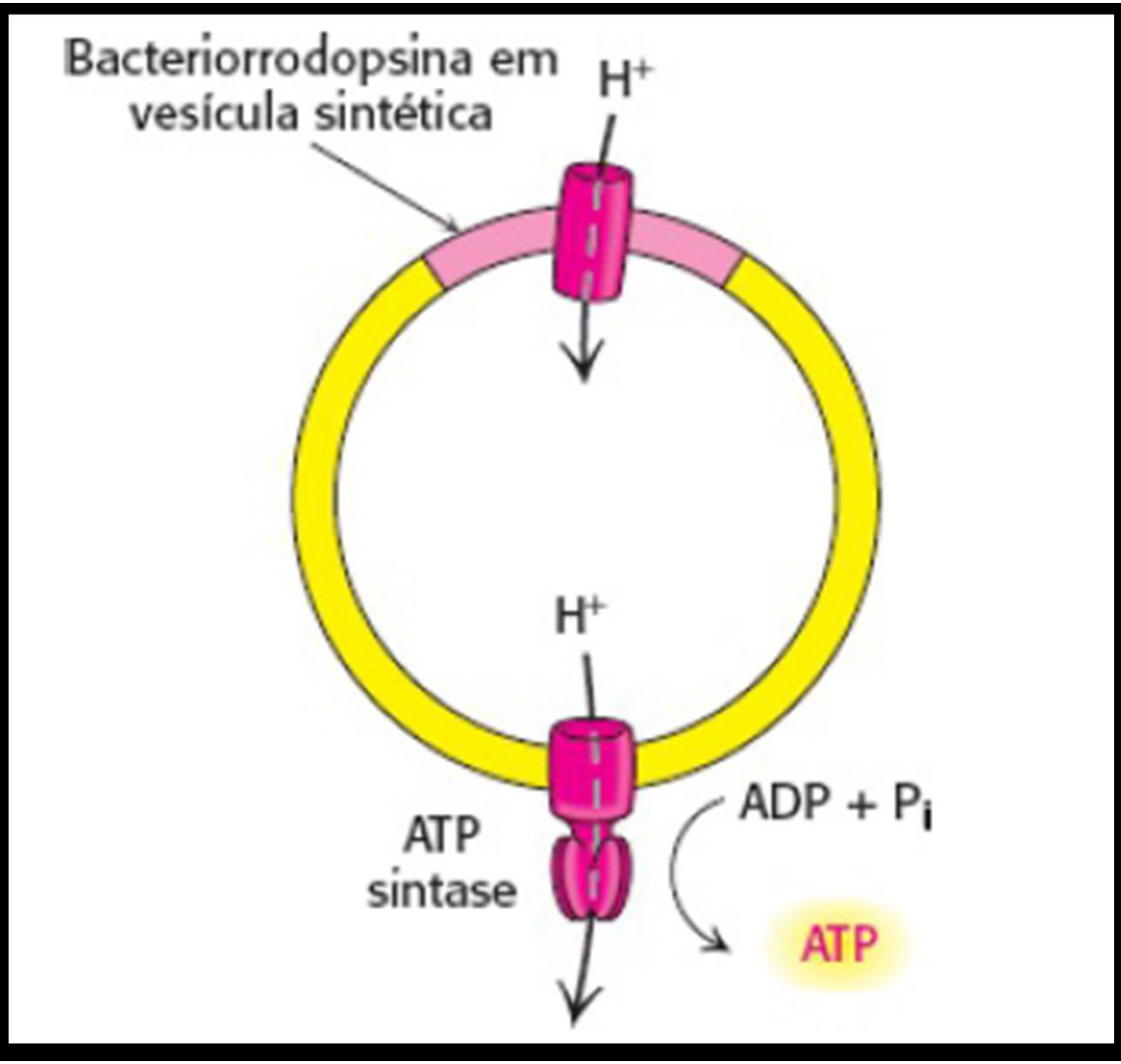

Ciclo do ácido cítrico
Fosforilação oxidativa
Ácidos graxos
Glicose
Amino-ácidos
Acetil-CoA
1 ATP
2 CO_2
NADH
$FADH_2$
2 O_2
4 H_2O
Cadeia de transporte de elétrons
H^+
ADP + P_i
ATP
H^+
Gradiente de prótons (~36 H^+)
Matriz
Membrana mitocondrial interna

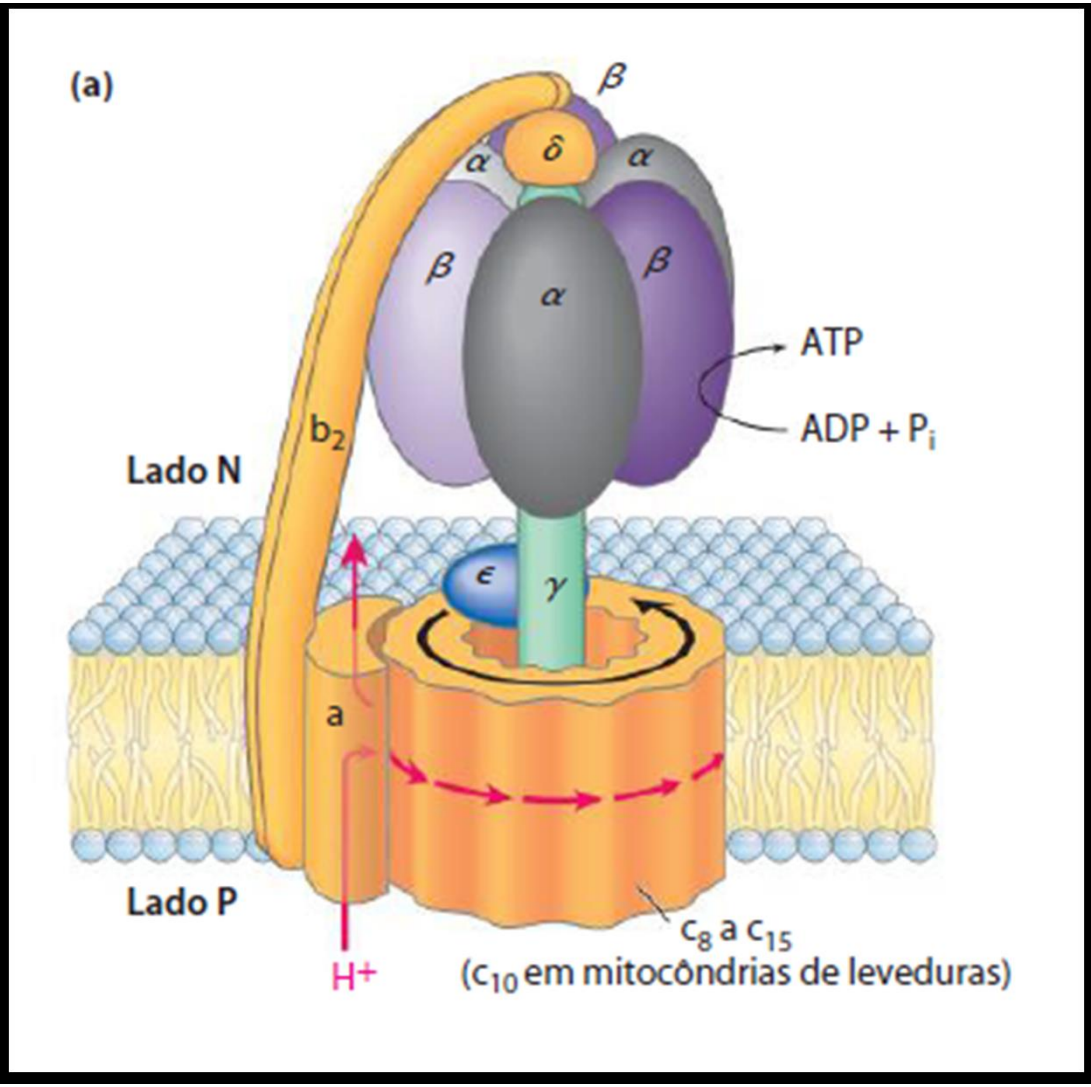

Os prótons são bombeados através dessa membrana enquanto os elétrons fluem através da cadeia respiratória
Membrana mitocondrial externa
Membrana mitocondrial interna
Espaço intermembrana
Matriz
[H+] alta
[H+] baixa
H+

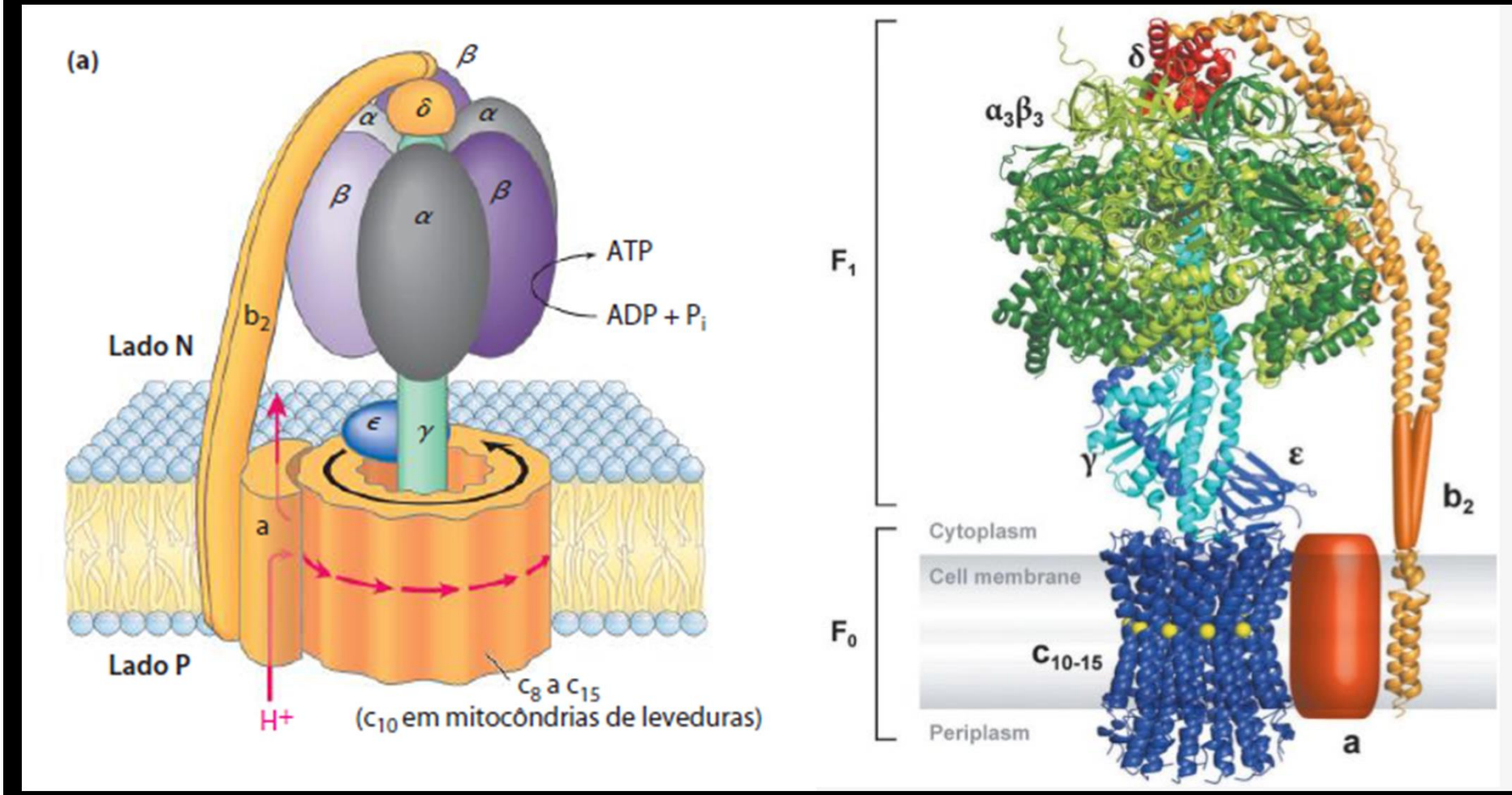
$$ADP + P_i + H^+ \rightarrow ATP + H^2O$$

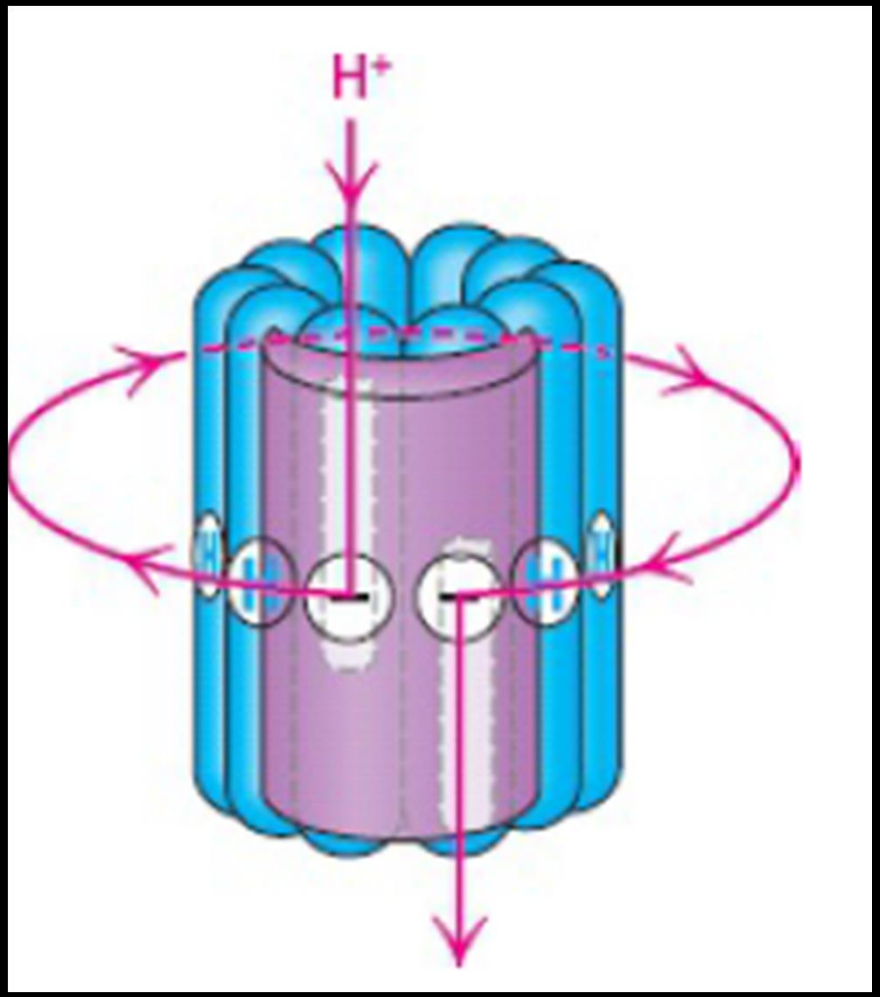
$$\Delta G^{o'} = +30{,}5 \text{ kJ mol}^{-1} (+7{,}3 \text{ kcal mol}^{-1})$$

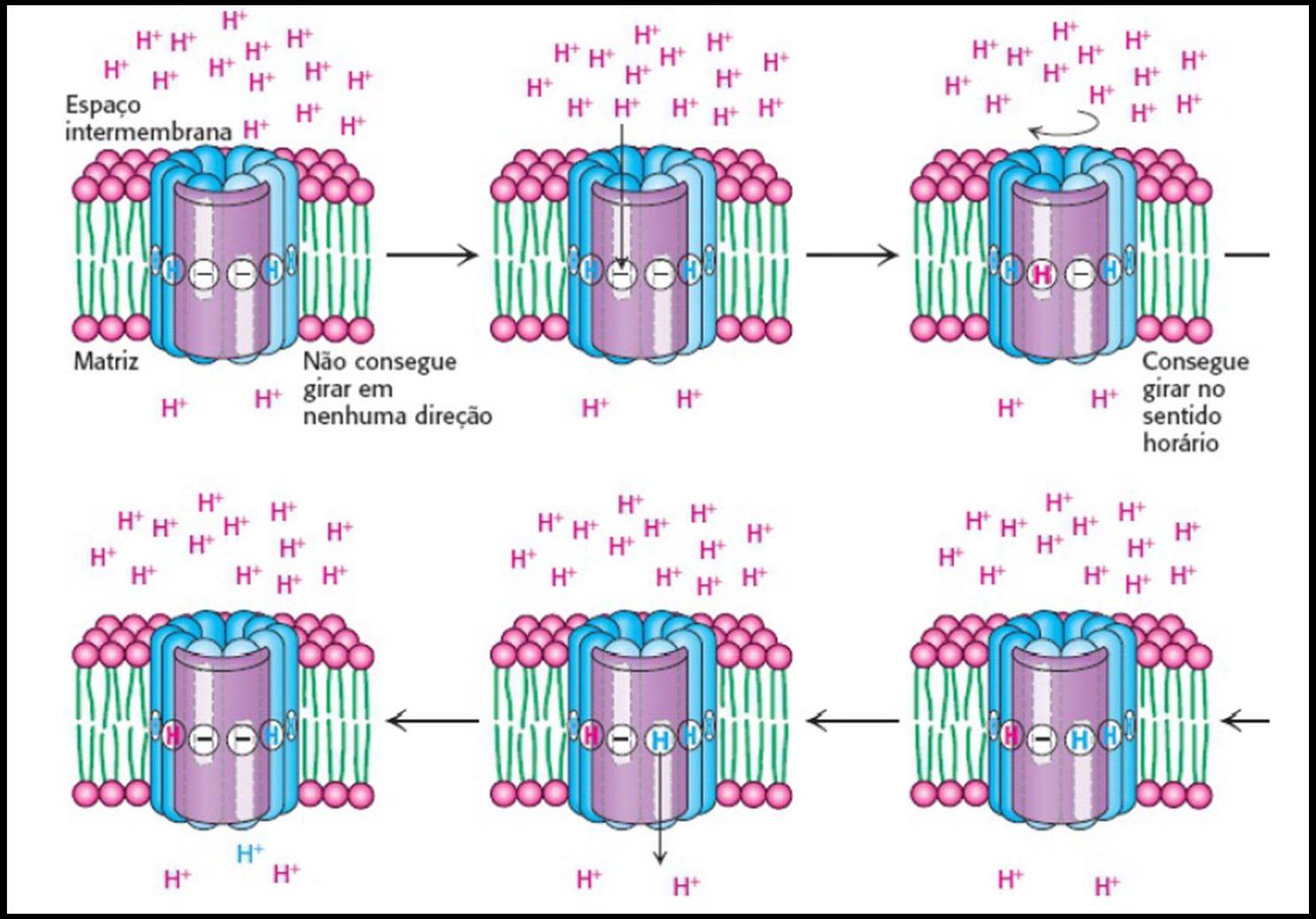


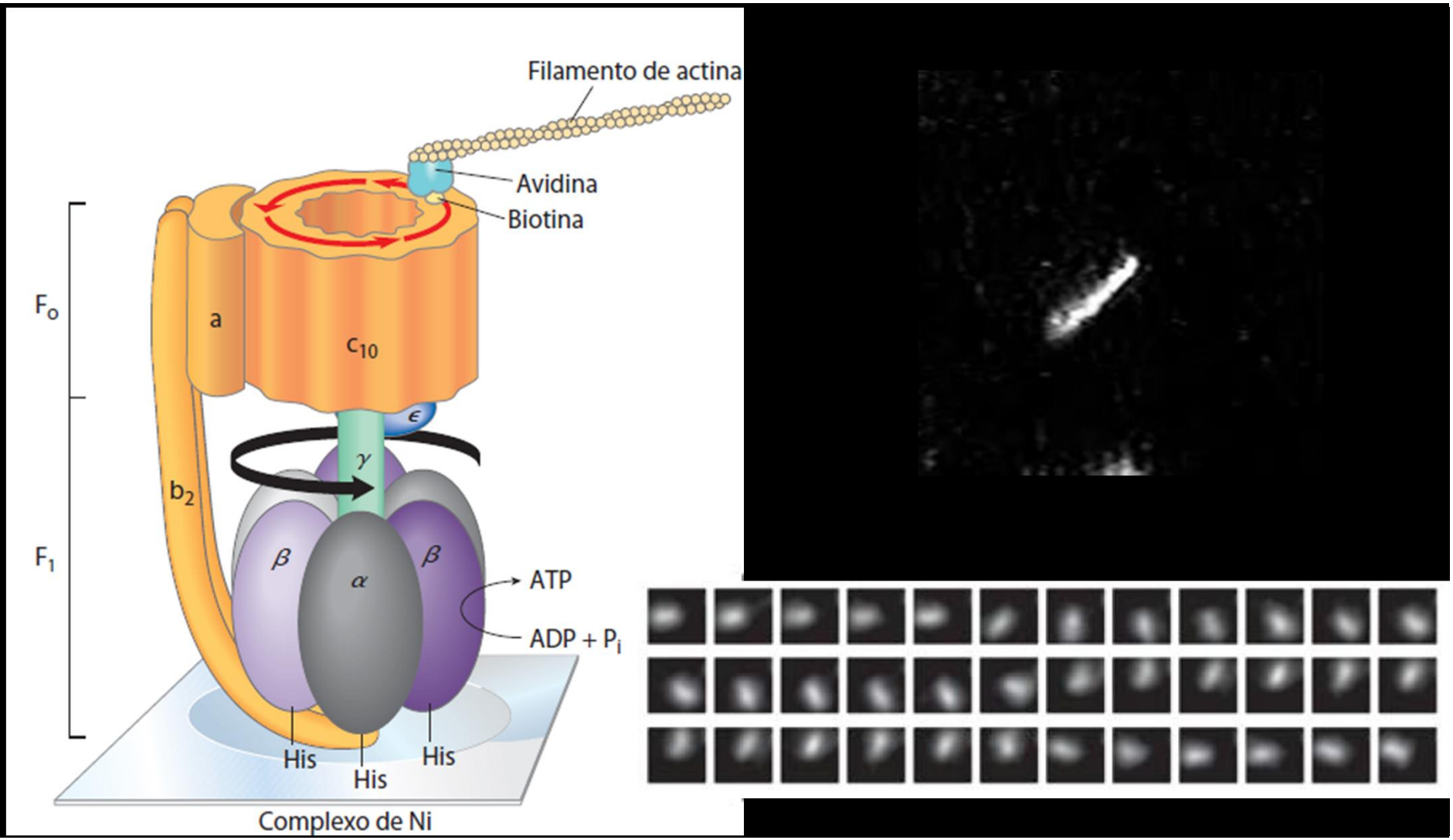

Bacteriorrodopsina em vesícula sintética
H+
H+
ATP sintase
ADP + Pi
ATP

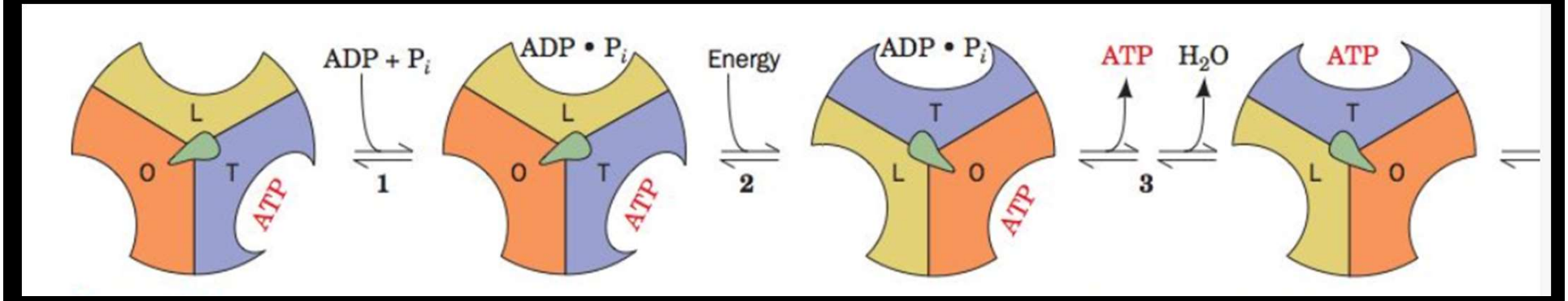

(a)
β
δ
α
α
β
α
β
ATP
ADP + Pi
b2
Lado N
ε
γ
a
Lado P
H+
c8 a c15
(c10 em mitocôndrias de leveduras)

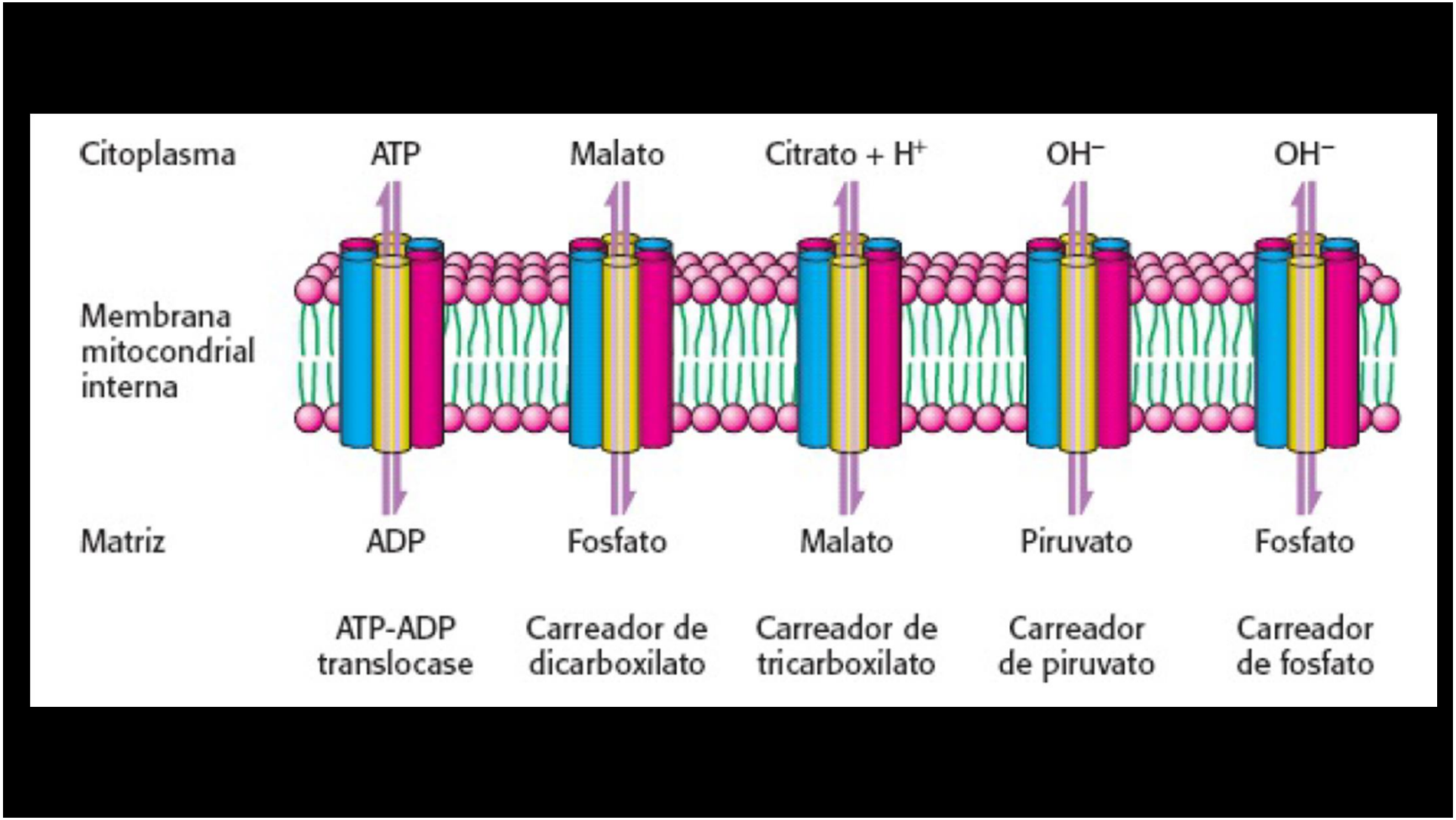

(a)
β
α
δ
α
β
α
β
ATP
ADP + Pi
b2
Lado N
ε
γ
a
Lado P
H+
c8 a c15
(c10 em mitocôndrias de leveduras)
F1
δ
α3β3
γ
ε
b2
Cytoplasm
Cell membrane
F0
c10-15
Periplasm
a

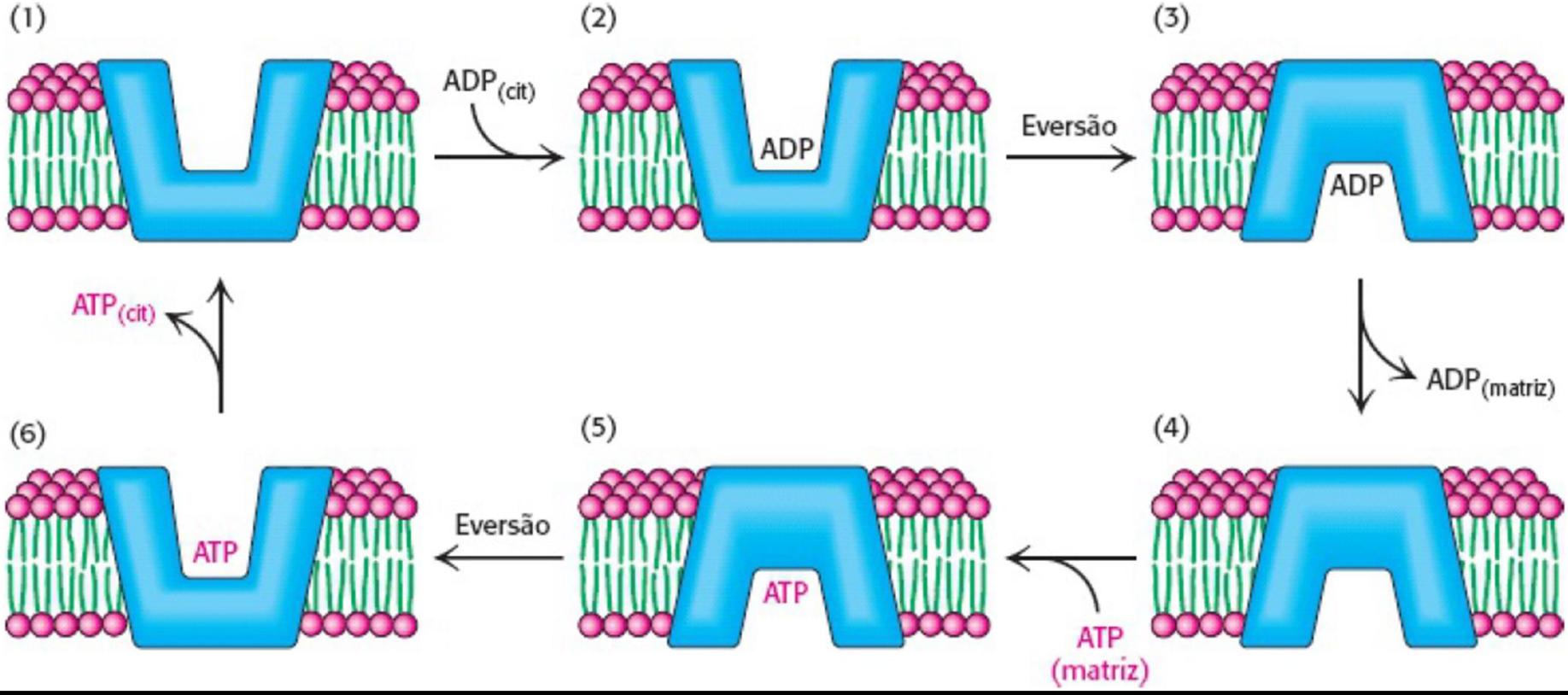

H+

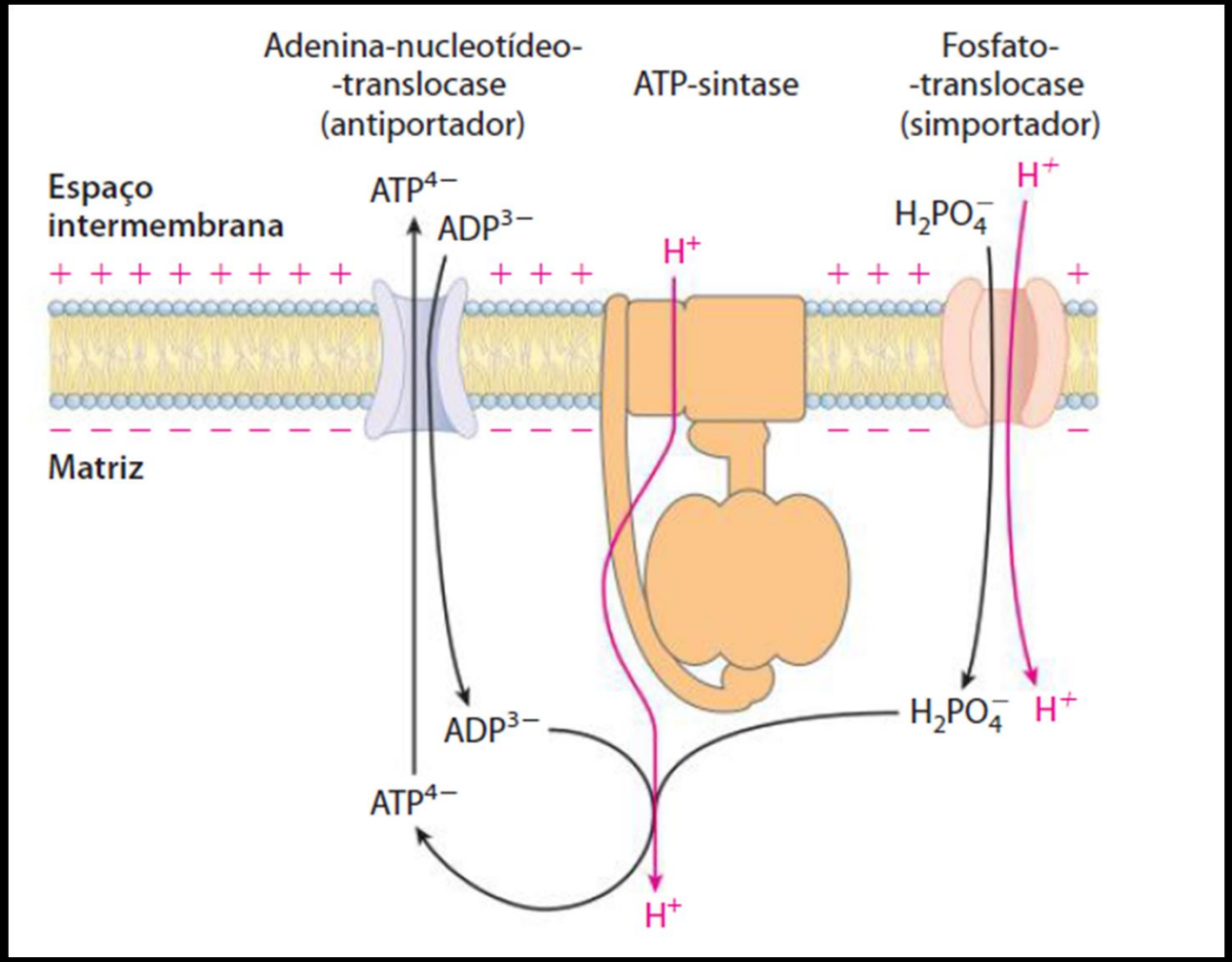

Espaço intermembrana
Matriz
Não consegue girar em nenhuma direção
Consegue girar no sentido horário

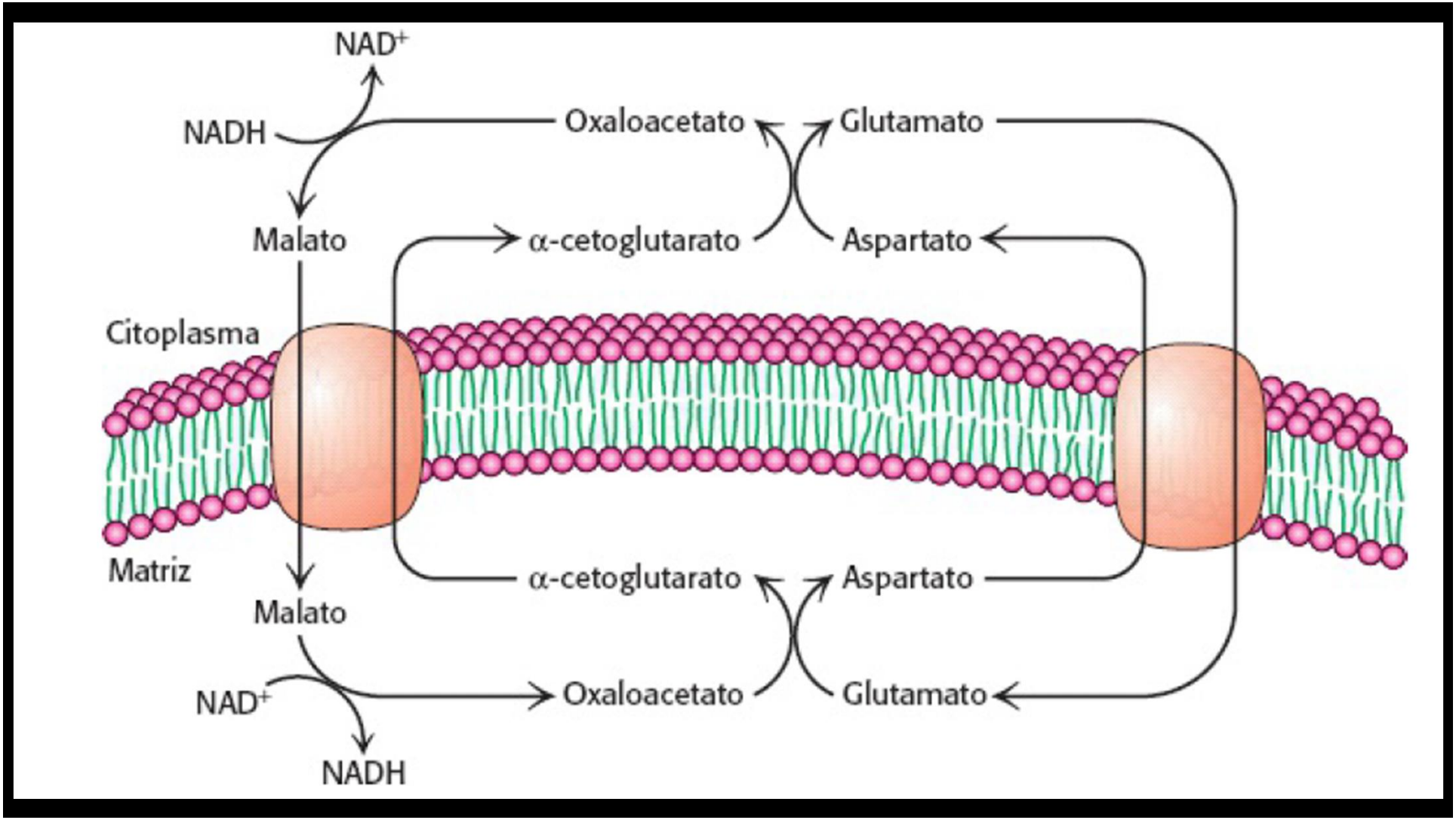

Filamento de actina
Avidina
Biotina
F_o
a
c_{10}
ϵ
γ
b_2
F_1
β
α
β
ATP
ADP + P_i
His
His
His
Complexo de Ni

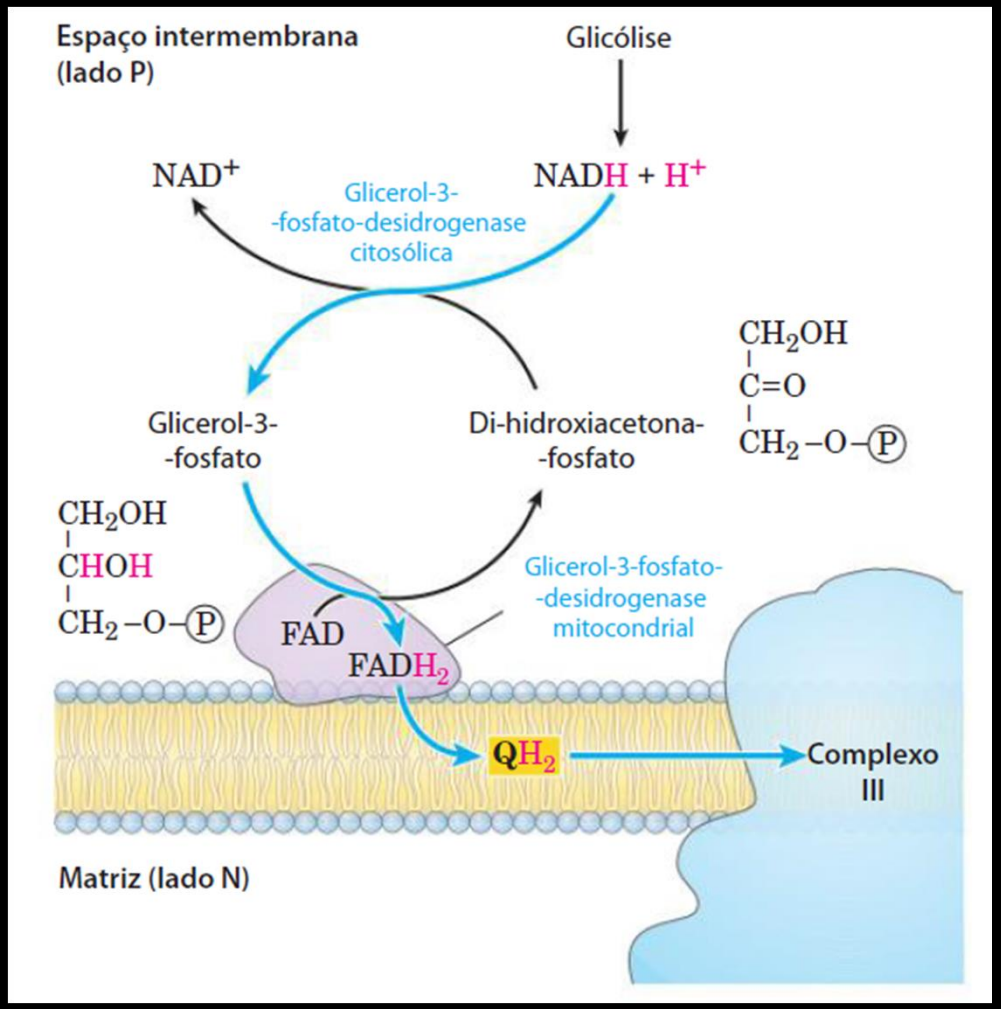

L
O
T
ATP
ADP + P_i
1
ADP • P_i
L
O
T
ATP
Energy
2
ADP • P_i
T
L
O
ATP
ATP
H_2O
3
ATP
T
L
O

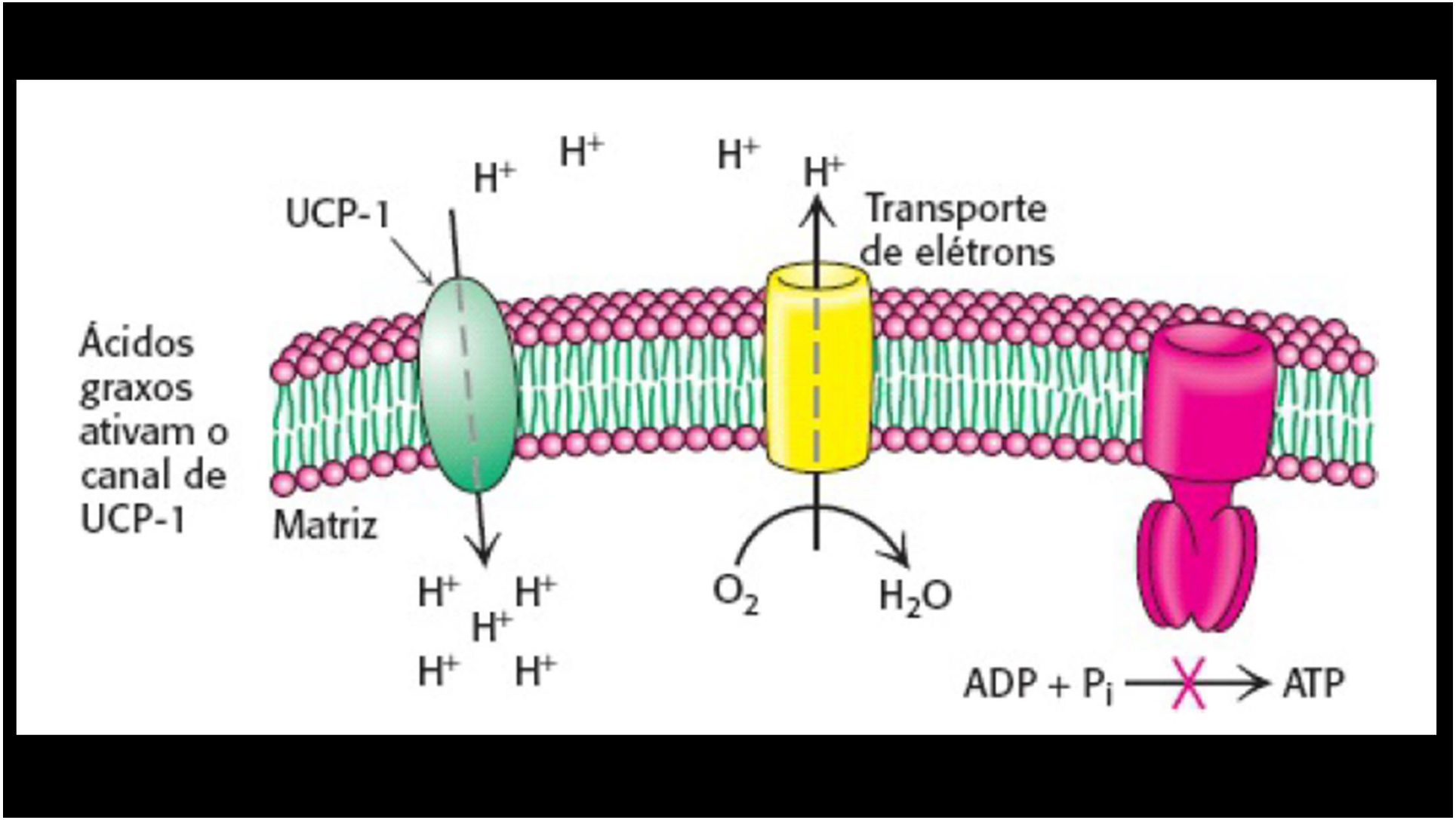

Citoplasma
ATP
Malato
Citrato + H+
OH−
OH−
Membrana mitocondrial interna
Matriz
ADP
Fosfato
Malato
Piruvato
Fosfato
ATP-ADP translocase
Carreador de dicarboxilato
Carreador de tricarboxilato
Carreador de piruvato
Carreador de fosfato

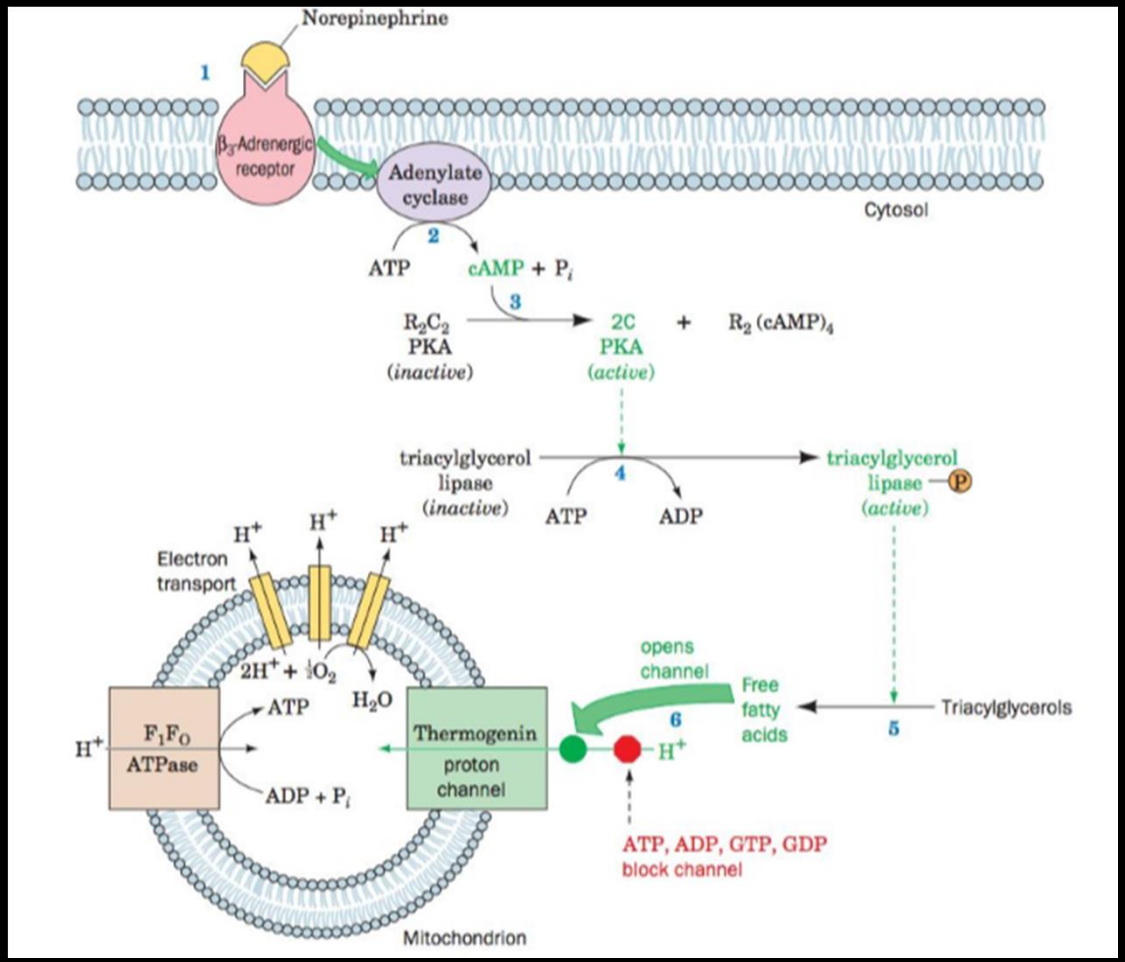

(1)
(2)
(3)
ADP(cit)
ADP
Eversão
ADP
ATP(cit)
ADP(matriz)
(6)
(5)
(4)
ATP
Eversão
ATP
ATP
(matriz)

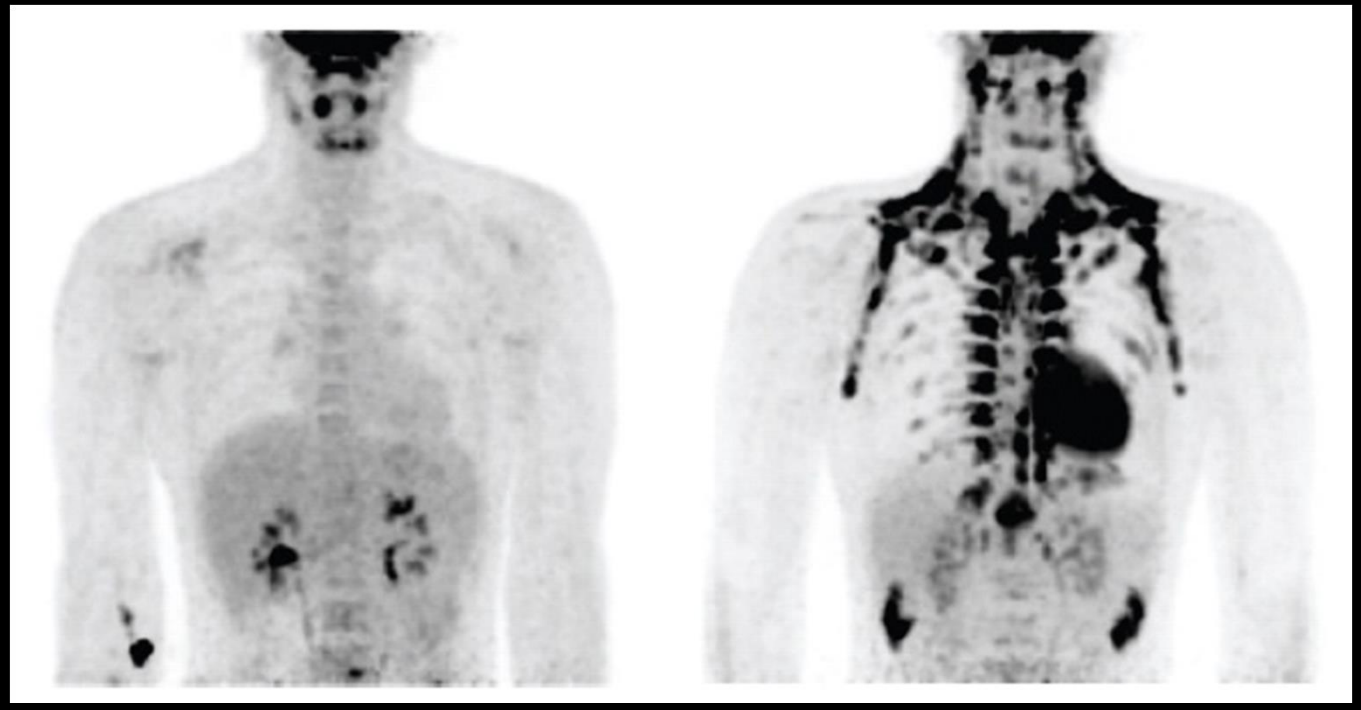

Adenina-nucleotídeo-
-translocase
(antiportador)
ATP-sintase
Fosfato-
-translocase
(simportador)
Espaço
intermembrana
Matriz
ATP^{4-}
ADP^{3-}
H^+
$H_2PO_4^-$
ADP^{3-}
ATP^{4-}
$H_2PO_4^-$
H^+
H^+
H^+

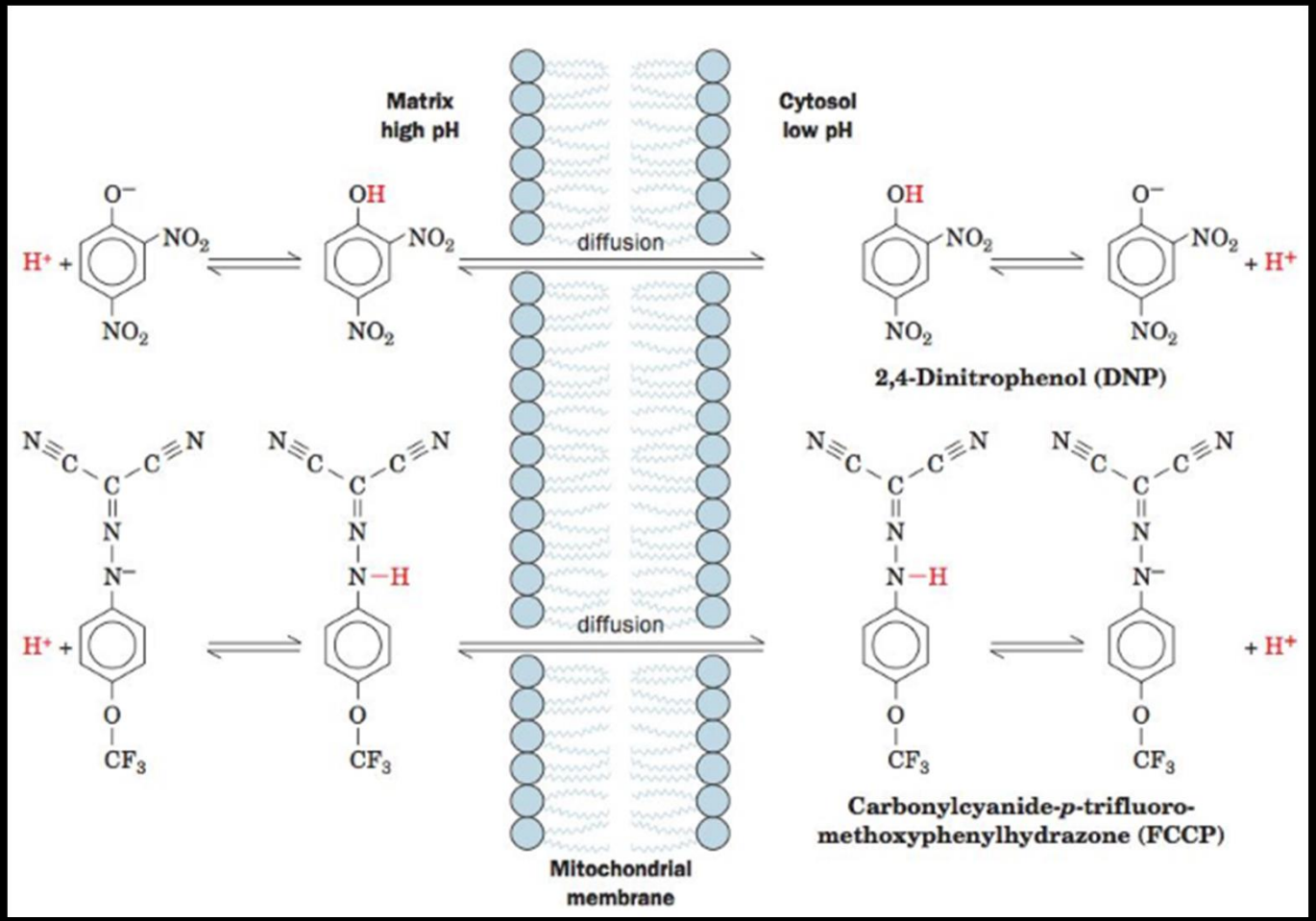

NAD+
NADH
Oxaloacetato
Glutamato
Malato
α-cetoglutarato
Aspartato
Citoplasma
Matriz
α-cetoglutarato
Aspartato
Malato
NAD+
Oxaloacetato
Glutamato
NADH

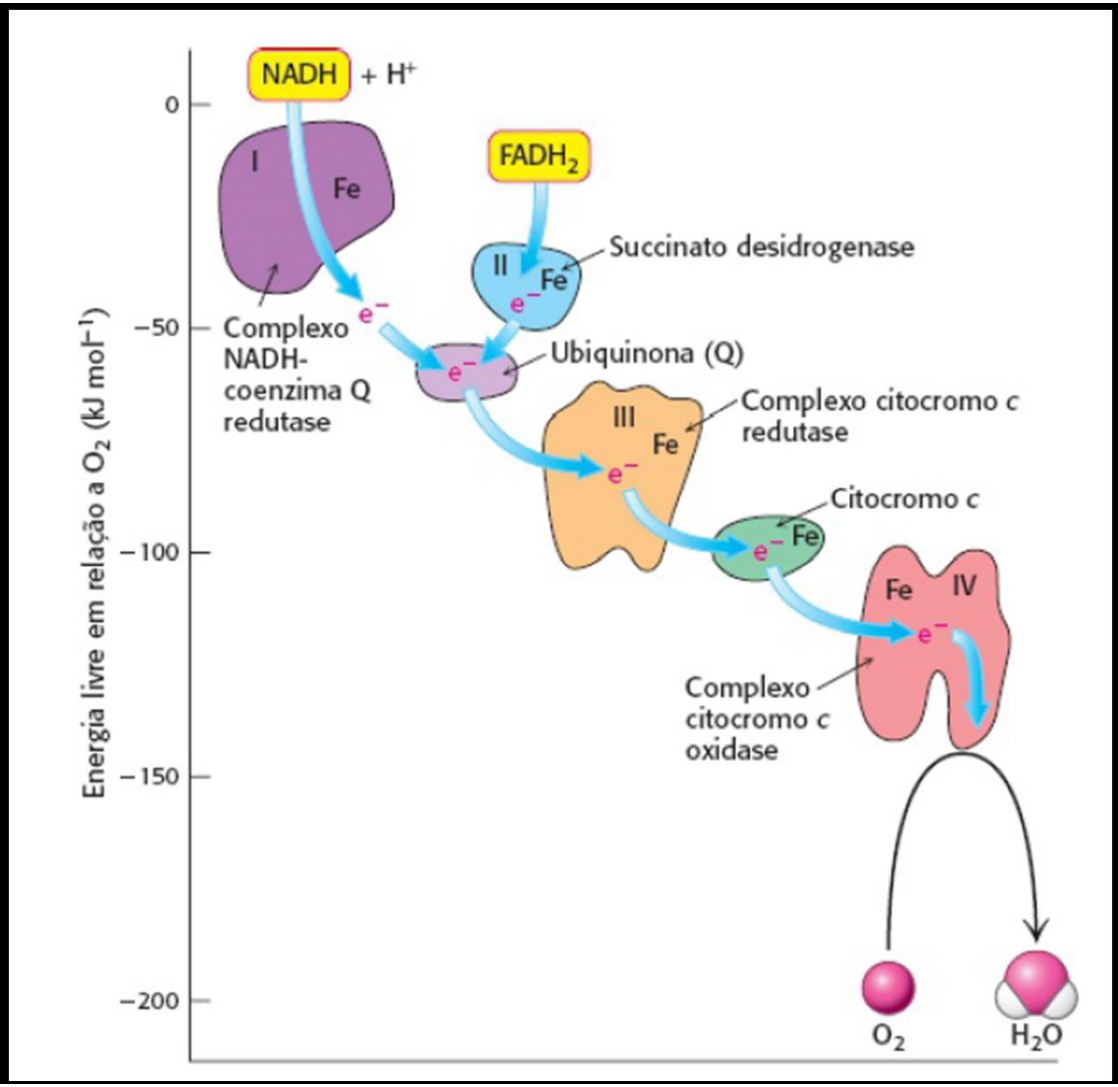

Espaço intermembrana
(lado P)
Glicólise
NAD+
NADH + H+
Glicerol-3-
-fosfato-desidrogenase
citosólica
Glicerol-3-
-fosfato
Di-hidroxiacetona-
-fosfato
CH2OH
C=O
CH2 –O–P
CH2OH
CHOH
CH2 –O–P
Glicerol-3-fosfato-
-desidrogenase
mitocondrial
FAD
FADH2
QH2
Complexo
III
Matriz (lado N)

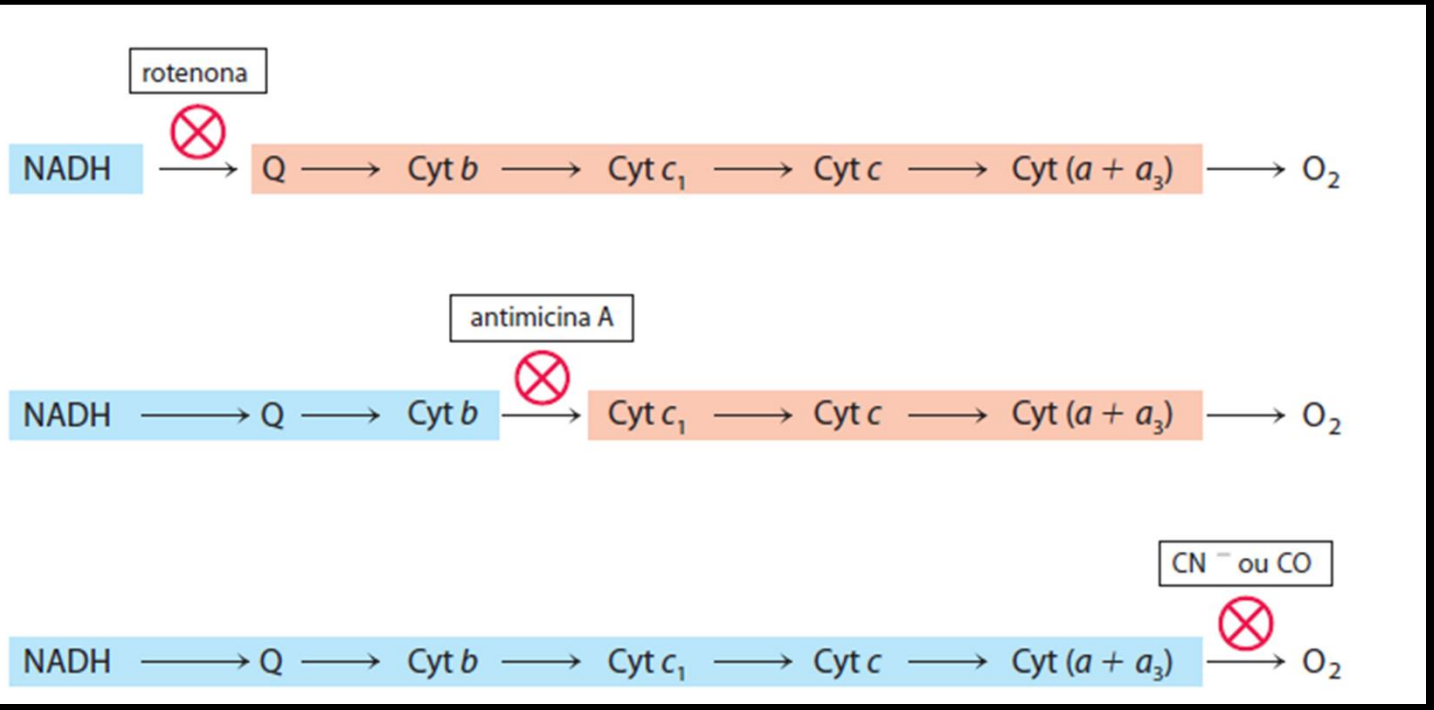

Ácidos graxos ativam o canal de UCP-1
UCP-1
H+
H+
H+
H+
Transporte de elétrons
Matriz
H+
H+
H+
H+
H+
O2
H2O
ADP + Pi
ATP

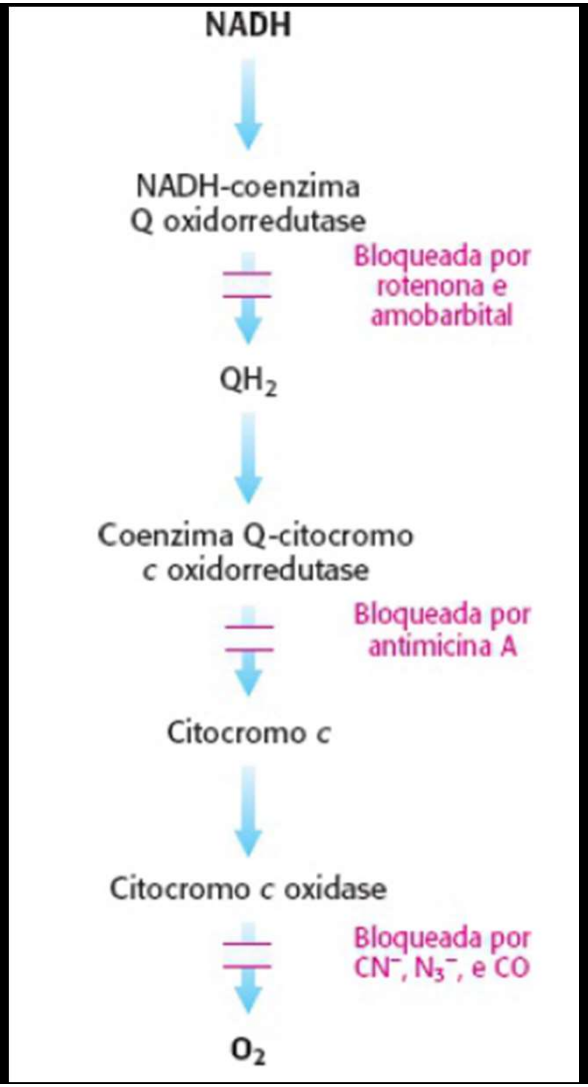

Norepinephrine
1
β3-Adrenergic receptor
Adenylate cyclase
Cytosol
2
ATP
cAMP + Pi
3
R2C2 PKA (inactive)
2C PKA (active)
+
R2 (cAMP)4
triacylglycerol lipase (inactive)
4
ATP
ADP
triacylglycerol lipase (active)
P
Electron transport
H+
H+
H+
2H+ + ½O2
H2O
ATP
ADP + Pi
F1FO ATPase
H+
Thermogenin proton channel
opens channel
6
Free fatty acids
H+
5
Triacylglycerols
ATP, ADP, GTP, GDP block channel
Mitochondrion

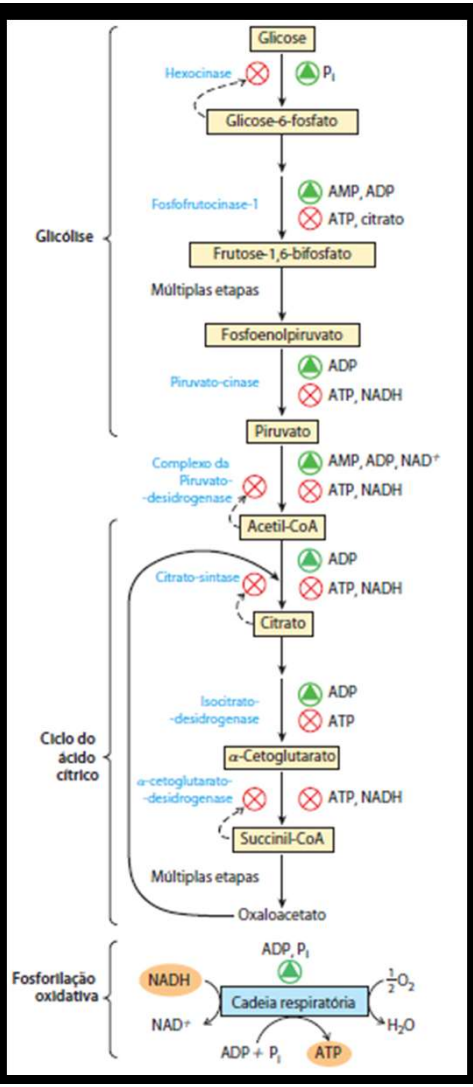


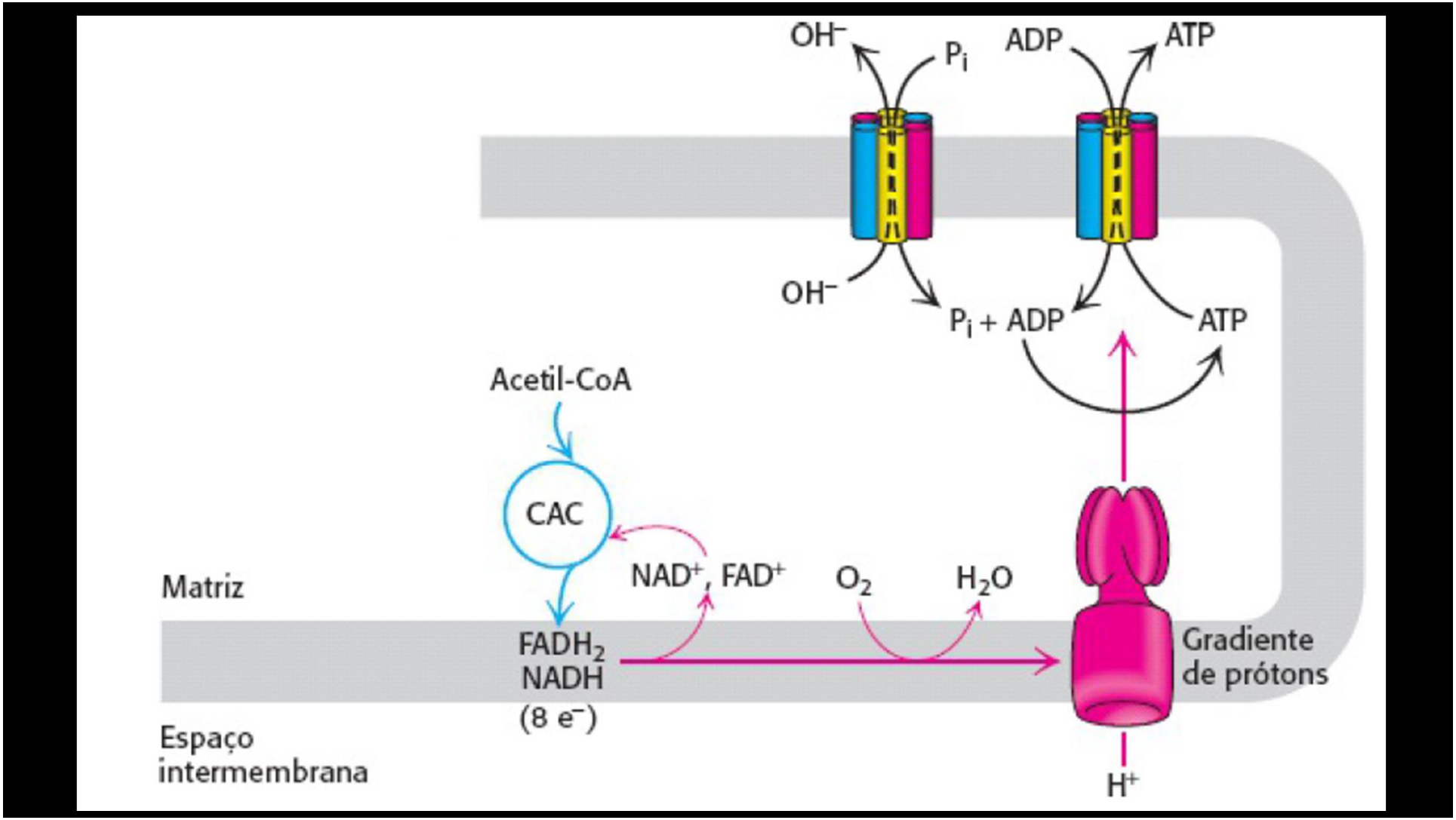

Matrix
high pH
Cytosol
low pH
diffusion
diffusion
2,4-Dinitrophenol (DNP)
Carbonylcyanide-p-trifluoro-
methoxyphenylhydrazone (FCCP)
Mitochondrial
membrane


NADH + H+
FADH2
I
Fe
II
Fe
Succinato desidrogenase
e−
Complexo NADH-coenzima Q redutase
Ubiquinona (Q)
III
Fe
Complexo citocromo c redutase
Citocromo c
Fe
Fe
IV
Complexo citocromo c oxidase
O2
H2O
Energia livre em relação a O2 (kJ mol−1)
0
−50
−100
−150
−200


rotenona
NADH
Q
Cyt b
Cyt c1
Cyt c
Cyt (a + a3)
O2
antimicina A
NADH
Q
Cyt b
Cyt c1
Cyt c
Cyt (a + a3)
O2
CN − ou CO
NADH
Q
Cyt b
Cyt c1
Cyt c
Cyt (a + a3)
O2


NADH
NADH-coenzima
Q oxidorredutase
Bloqueada por
rotenona e
amobarbital
QH_2
Coenzima Q-citocromo
c oxidorredutase
Bloqueada por
antimicina A
Citocromo c
Citocromo c oxidase
Bloqueada por
CN^-, N_3^-, e CO
O_2


Glicose
Hexocinase
P_i
Glicose-6-fosfato
Fosfofrutocinase-1
AMP, ADP
ATP, citrato
Frutose-1,6-bifosfato
Múltiplas etapas
Fosfoenolpiruvato
Piruvato-cinase
ADP
ATP, NADH
Piruvato
Complexo da Piruvato-desidrogenase
AMP, ADP, NAD^+
ATP, NADH
Acetil-CoA
Citrato-sintase
ADP
ATP, NADH
Citrato
Isocitrato-desidrogenase
ADP
ATP
α-Cetoglutarato
α-cetoglutarato-desidrogenase
ATP, NADH
Succinil-CoA
Múltiplas etapas
Oxaloacetato
Glicólise
Ciclo do ácido cítrico
Fosforilação oxidativa
ADP, P_i
NADH
Cadeia respiratória
$\frac{1}{2}O_2$
H_2O
NAD^+
ADP + P_i
ATP


OH⁻
Pi
ADP
ATP
OH⁻
Pi + ADP
ATP
Acetil-CoA
CAC
NAD+, FAD+
O2
H2O
Matriz
FADH2
NADH
(8 e⁻)
Gradiente
de prótons
Espaço
intermembrana
H+