Oxidative Phosphorylation

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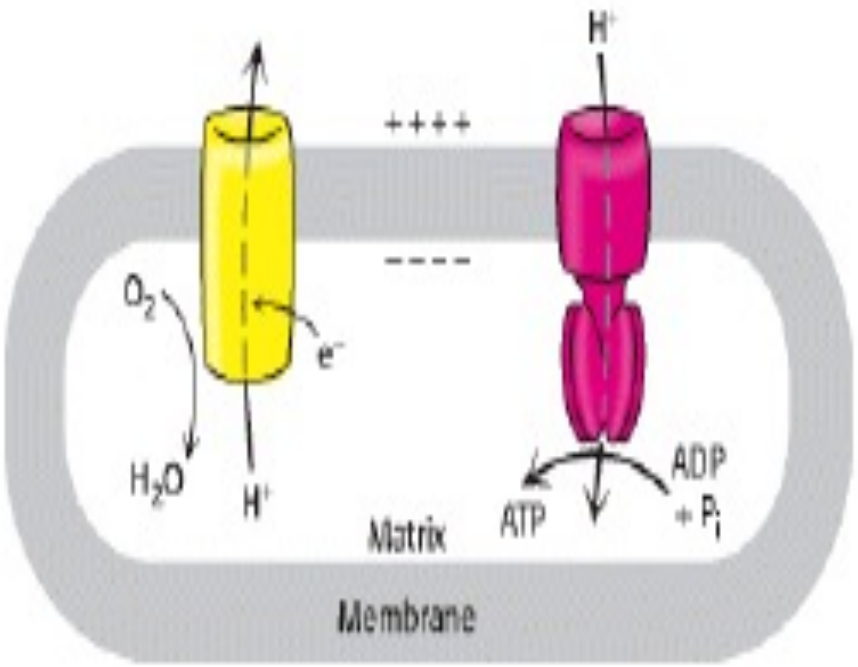
INTRODUCTION

- *Oxidative phosphorylation is the process in which ATP is formed as a result of the transfer of electrons from NADH or FADH2 to O2 by a series of electron carriers.*
- This process, which takes place in mitochondria, is the major source of ATP in aerobic organisms
- Oxidative phosphorylation is conceptually simple and mechanistically complex

- *Oxidative phosphorylation is the culmination of a series of energy transformations* that are called *cellular respiration*
- First, carbon fuels are oxidized in the citric acid cycle to yield electrons with high transfer potential → this electron-motive force is converted into a proton-motive force and → the proton-motive force is converted into phosphoryl transfer potential.
- The conversion of electron-motive force → proton-motive force is carried out by three electron-driven proton pumps NADH-Q oxidoreductase, Q-cytochrome *c* oxidoreductase, and cytochrome *c* oxidase
- The final phase of oxidative phosphorylation is carried out by *ATP synthase,* an ATP-synthesizing assembly that is driven by the flow of protons back into the mitochondrial matrix.

Essence of Oxidative Phosphorylation



- Oxidation and ATP synthesis are coupled by transmembrane proton fluxes.

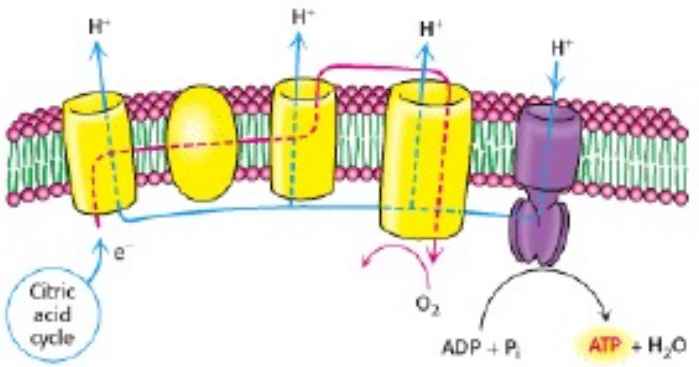
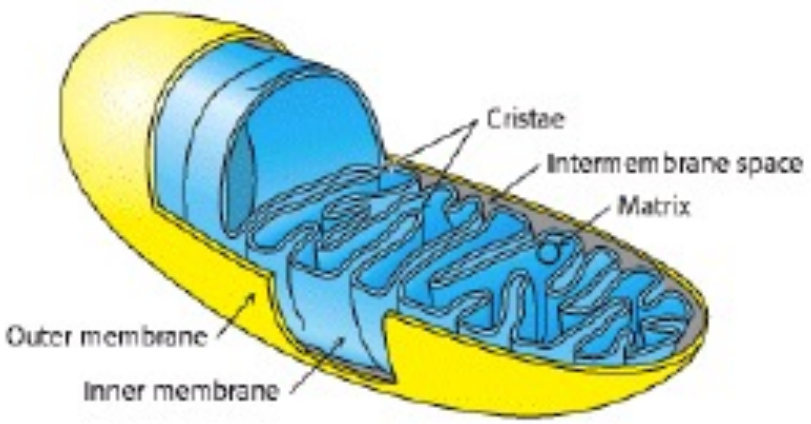
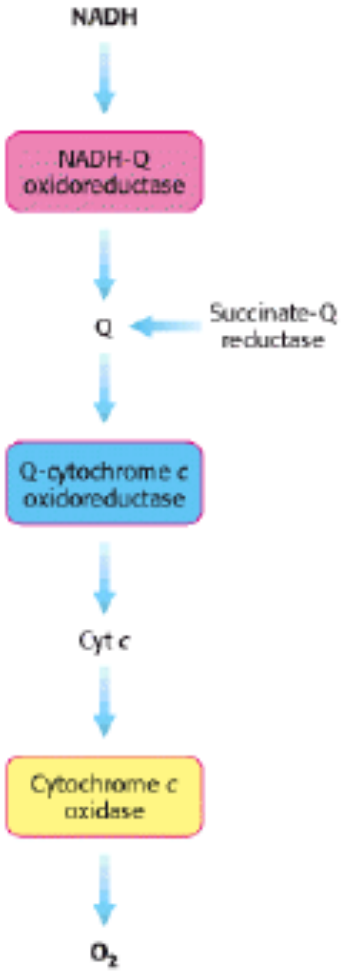


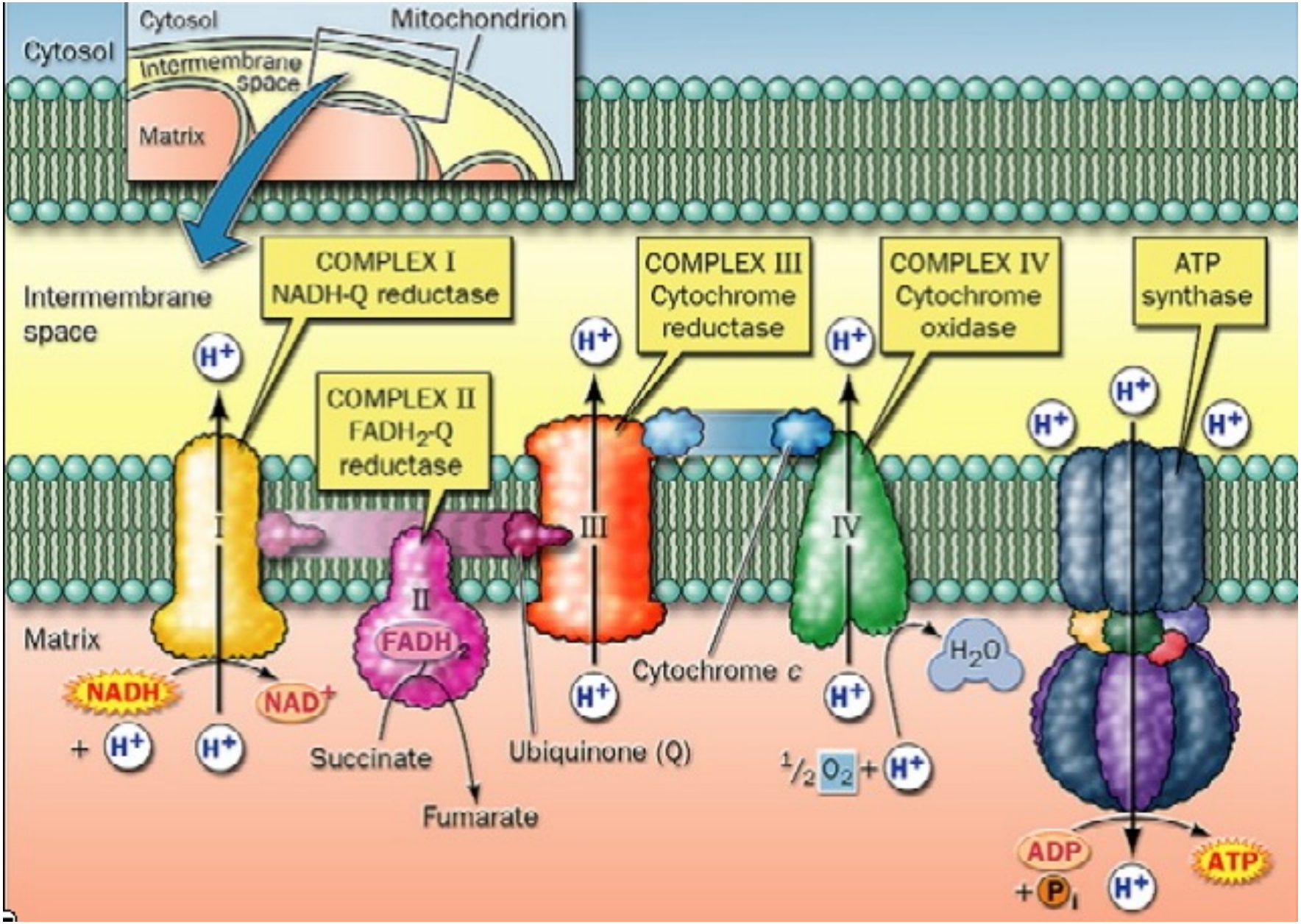
Diagram of a Mitochondrion



- Oxidative phosphorylation takes place in the inner mitochondrial membrane, in contrast with most of the reactions of the citric acid cycle and fatty acid oxidation, which take place in the matrix

The Respiratory Chain Consists of Four Complexes: Three Proton Pumps and a Physical Link to the Citric Acid Cycle




Cytosol
Mitochondrion
Intermembrane space
Matrix
Cytosol
Intermembrane space
COMPLEX I
NADH-Q reductase
COMPLEX II
FADH2-Q
reductase
COMPLEX III
Cytochrome
reductase
COMPLEX IV
Cytochrome
oxidase
ATP
synthase
H+
I
II
III
IV
FADH2
Matrix
NADH
NAD+
+ H+
H+
Succinate
Fumarate
Ubiquinone (Q)
Cytochrome c
H+
H+
H2O
½ O2 + H+
H+
H+
H+
H+
ADP
+ Pi
ATP
H+

The **respiratory chain** is one of the pathways involved in *oxidative phosphorylation*

It catalyzes the steps by which electrons are transported from NADH+H+ or reduced

ubiquinone (QH2) tomolecular oxygen

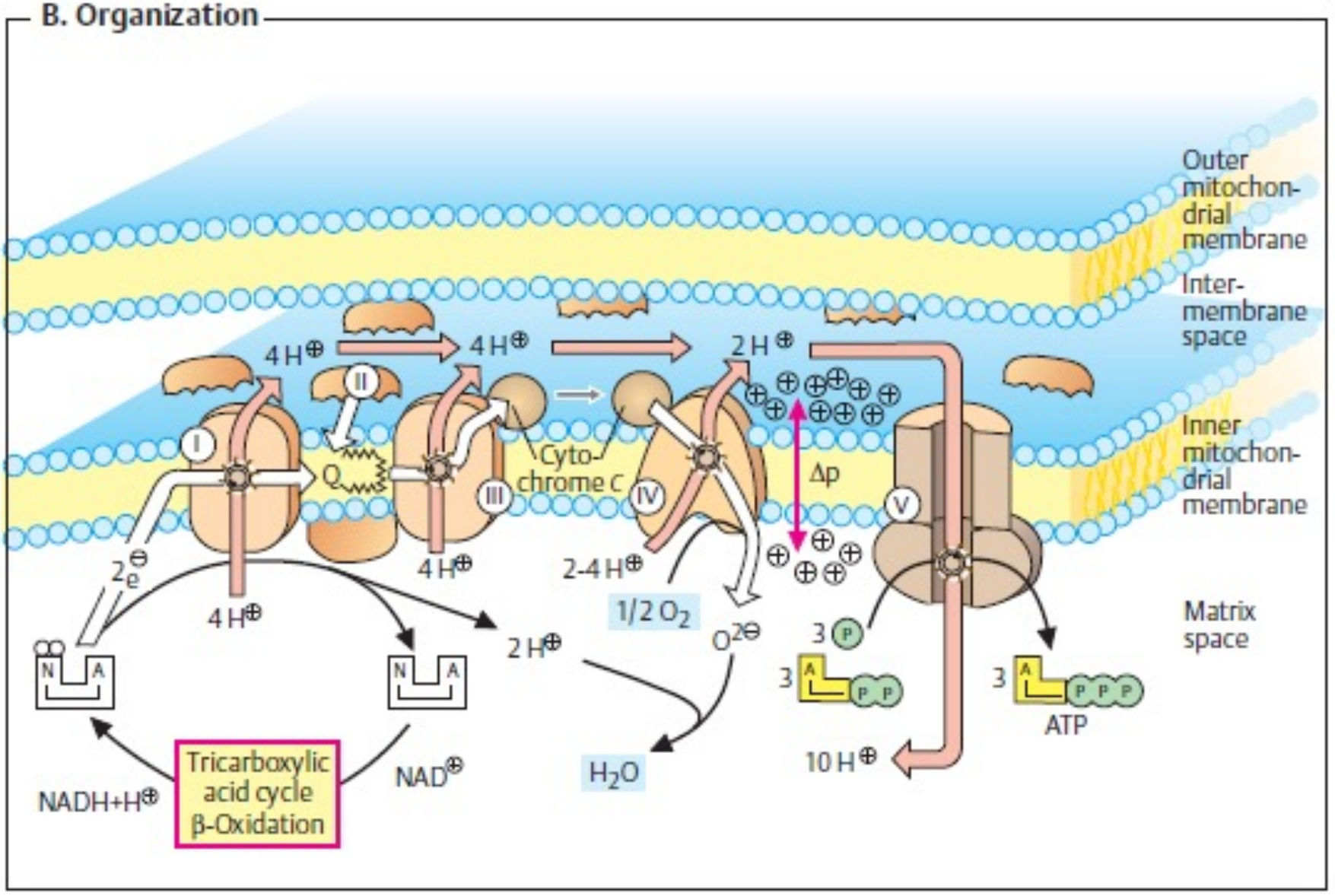
Most of the energy released is used to establish a proton gradient across the inner mitochondrial membrane, which is then ultimately used to synthesize ATP with the help of *ATP synthase.*

Components of the respiratory chain

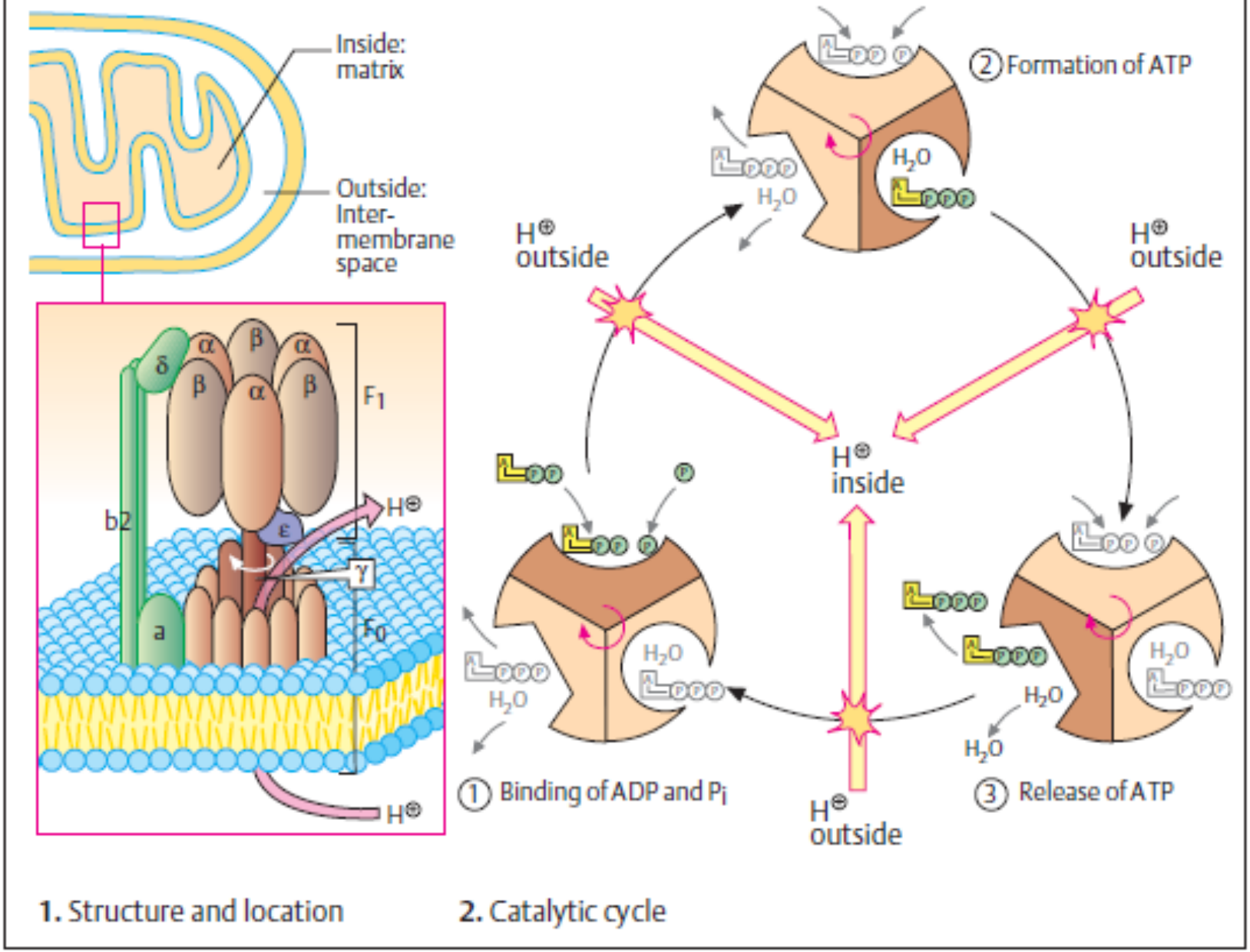
- The **electron transport chain** consists of:

✓ 3 protein complexes (**complexes I, III, and IV**), which are integrated into the innermitochondrial membrane, and

✓ 2 mobile carrier molecules— **ubiquinone** (coenzyme Q) and **cytochrome *c***


B. Organization
Outer mitochon-drial membrane
Inter-membrane space
Inner mitochon-drial membrane
Matrix space
4 H⊕
4 H⊕
2 H⊕
I
II
III
IV
V
Q
Cyto-chrome c
Δp
2e⊖
4 H⊕
4 H⊕
2-4 H⊕
1/2 O2
O2⊖
2 H⊕
3 P
3 A P P
3 A P P P
ATP
10 H⊕
H2O
NAD⊕
NADH+H⊕
Tricarboxylic acid cycle
β-Oxidation
N A
N A

B. ATP synthase



1. Structure and location

2. Catalytic cycle

Table 18.4. ATP yield from the complete oxidation of glucose

Reaction sequence	ATP yield per glucose molecule
Glycolysis: Conversion of glucose into pyruvate (in the cytosol)	
Phosphorylation of glucose	- 1
Phosphorylation of fructose 6-phosphate	- 1
Dephosphorylation of 2 molecules of 1,3-BPG	+ 2
Dephosphorylation of 2 molecules of phosphoenolpyruvate	+ 2
2 molecules of NADH are formed in the oxidation of 2 molecules of glyceraldehyde 3-phosphate	
Conversion of pyruvate into acetyl CoA (inside mitochondria)	
2 molecules of NADH are formed	
Citric acid cycle (inside mitochondria)	
2 molecules of guanosine triphosphate are formed from 2 molecules of succinyl CoA	+ 2
6 molecules of NADH are formed in the oxidation of 2 molecules each of isocitrate, α-ketoglutarate, and malate	
2 molecules of $FADH_2$ are formed in the oxidation of 2 molecules of succinate	
Oxidative phosphorylation (inside mitochondria)	
2 molecules of NADH formed in glycolysis; each yields 1.5 molecules of ATP (assuming transport of NADH by the glycerol 3-phosphate shuttle)	+ 3
2 molecules of NADH formed in the oxidative decarboxylation of pyruvate; each yields 2.5 molecules of ATP	+ 5
2 molecules of $FADH_2$ formed in the citric acid cycle; each yields 1.5 molecules of ATP	+ 3
6 molecules of NADH formed in the citric acid cycle; each yields 2.5 molecules of ATP	+ 15
NET YIELD PER MOLECULE OF GLUCOSE	+ 30

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