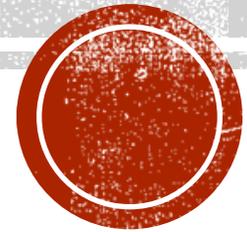


Introduction to Metabolism
Electron transport chain (ETC)
& Oxidative phosphorylation



Students Learning Outcomes

❖ *By the end of this lecture, the students should be able to:*

1. Illustrate ADP-ATP cycles and functions of ATP.
2. Define metabolism, its phases.
3. Define ETC, phosphorylation and oxidative phosphorylation.
4. Describe the components of ETC (complexes and mobile carriers).
5. Draw the flow of electrons in ETC if $\text{NADH} + \text{H}^+$ or FADH_2 join ETC.
6. Explain the relationship between electron flow and ATP production in mitochondria (Chemiosmotic theory ATP production).



Contents

I. Introduction to Metabolism

1. Energy & ATP
2. Metabolism (anabolism & catabolism)

II. Biological Oxidation (Oxidative Phosphorylation)

1) *Electron Transport Chain (oxidation)*

1. Def
2. Location
3. Components (Complexes & Mobile carriers)
4. Flow of electrons in ETC
5. NADH+H and FADH₂ entry to ETC

2) *Phosphorylation (Chemiosmotic theory of ATP production)*

1. Proton pumps
2. ATP synthase complex

3) *Coupling of Oxidative with phosphorylation*



Introduction to Metabolism



Body Energy and ATP

Energy:

- ✓ Energy is stored in organic and living matter
- ✓ After eating and digesting food → the free energy liberated during the degradation of food is collected in the form of high energy phosphate bonds (ATP)

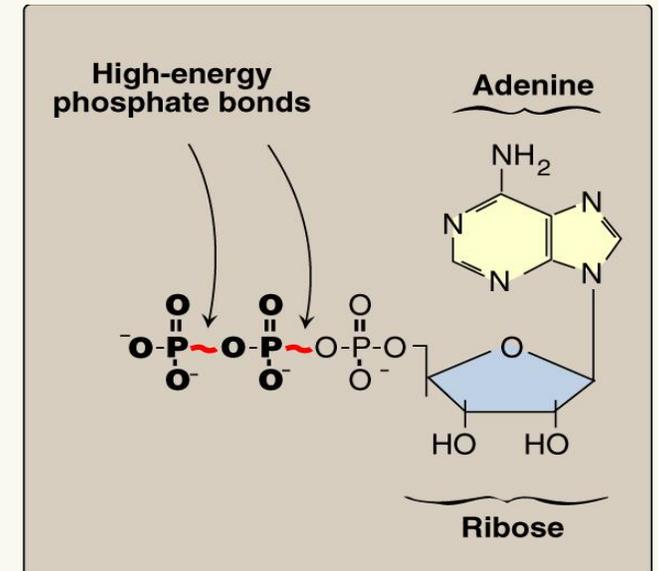
ATP (The energy currency of cell)

- ✓ **High-energy** phosphate compound.
 - ✓ Formed of **adenine + ribose + 3 inorganic phosphates**
 - ✓ Contain **2 high energy** phosphate **bond**.
 - ✓ Synthesized by Phosphorylation of ADP
- ADP + P → ATP**
- ✓ Phosphorylation occurs at two levels during the metabolism

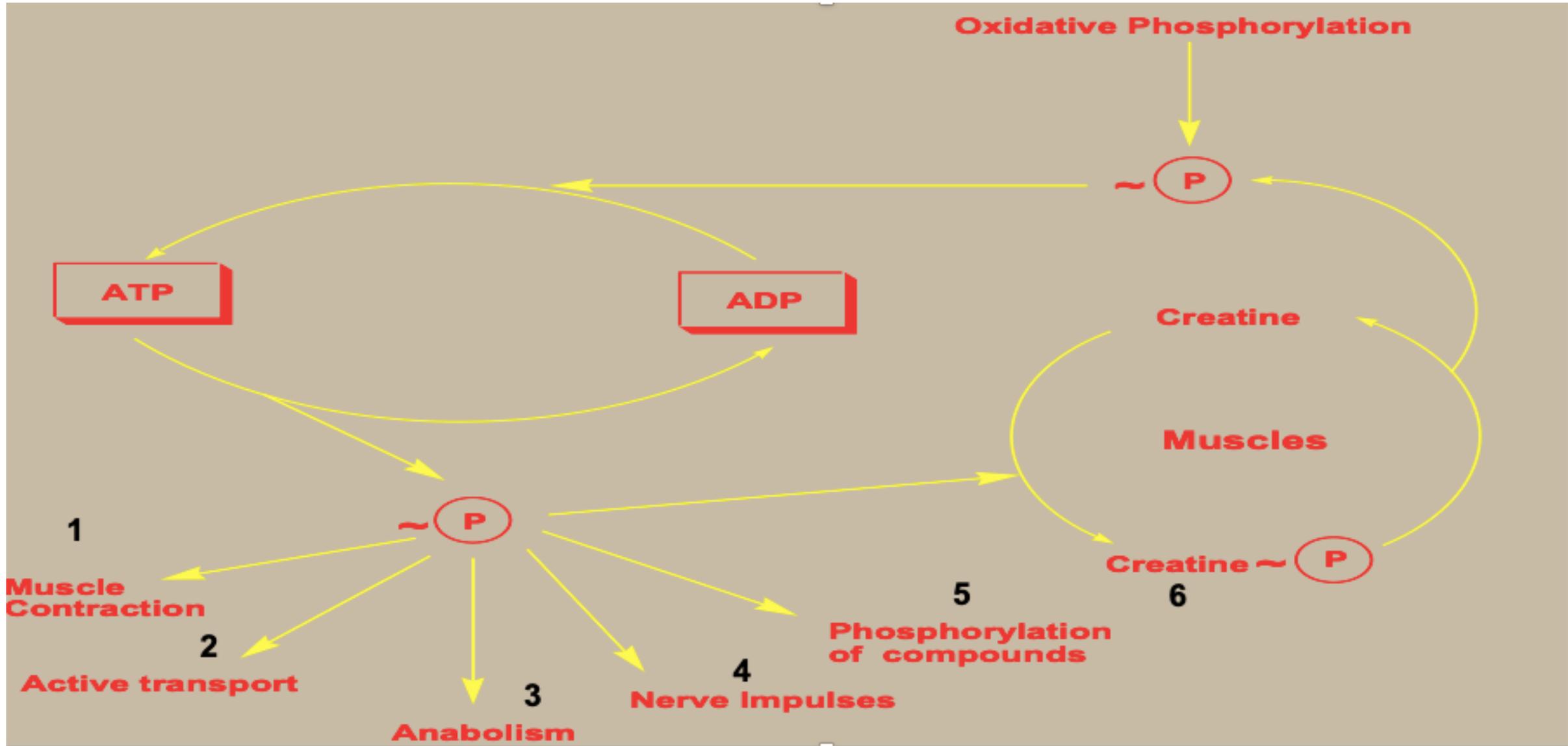
1. Substrate level phosphorylation. (minor)

By transferring the high energy phosphate group from substrates directly to ADP.

2. Respiratory chain level (Oxidative phosphorylation). (major)



✓ ATP-ADP cycle and function of ATP



Metabolism

■ Metabolism :

is the sum of all the reactions that take place in a living cell.

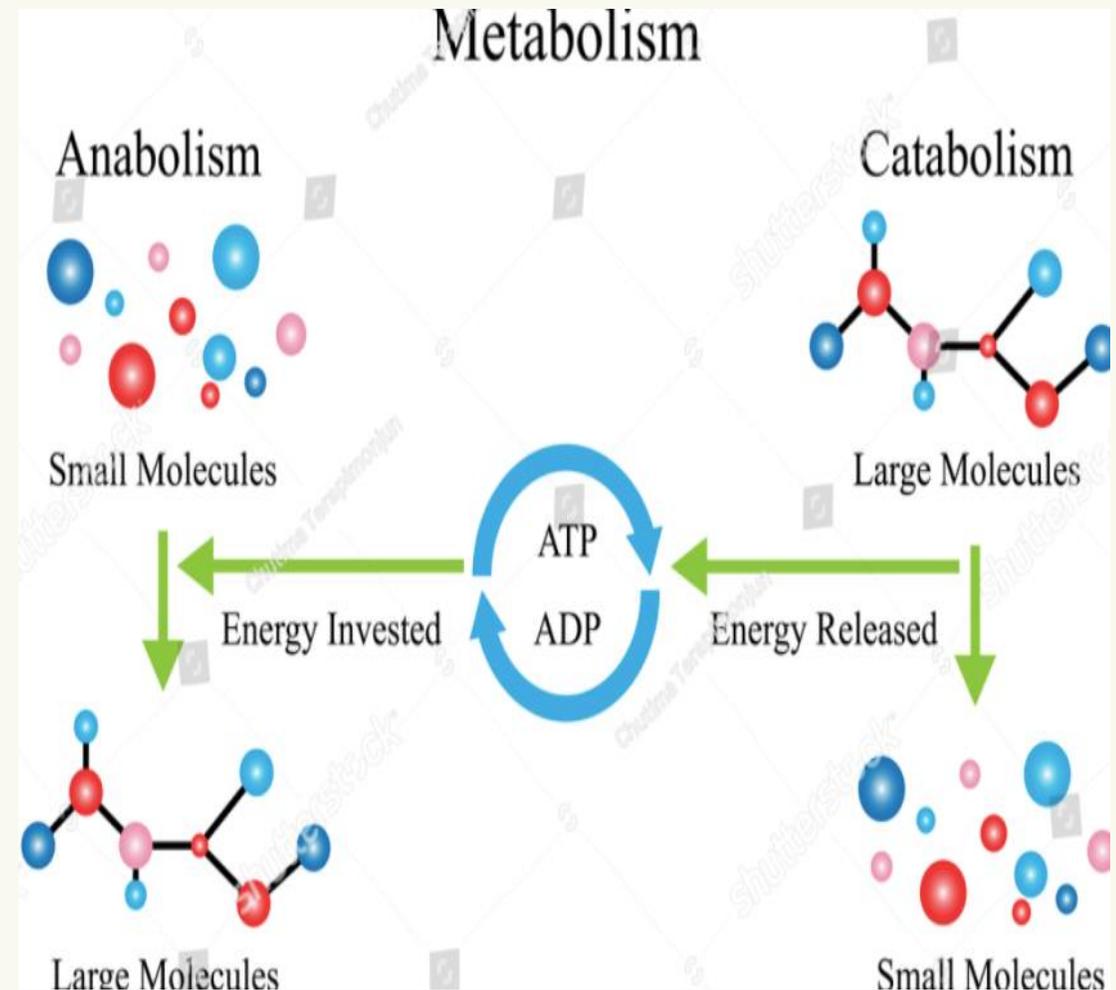
■ Metabolism = Anabolism + Catabolism

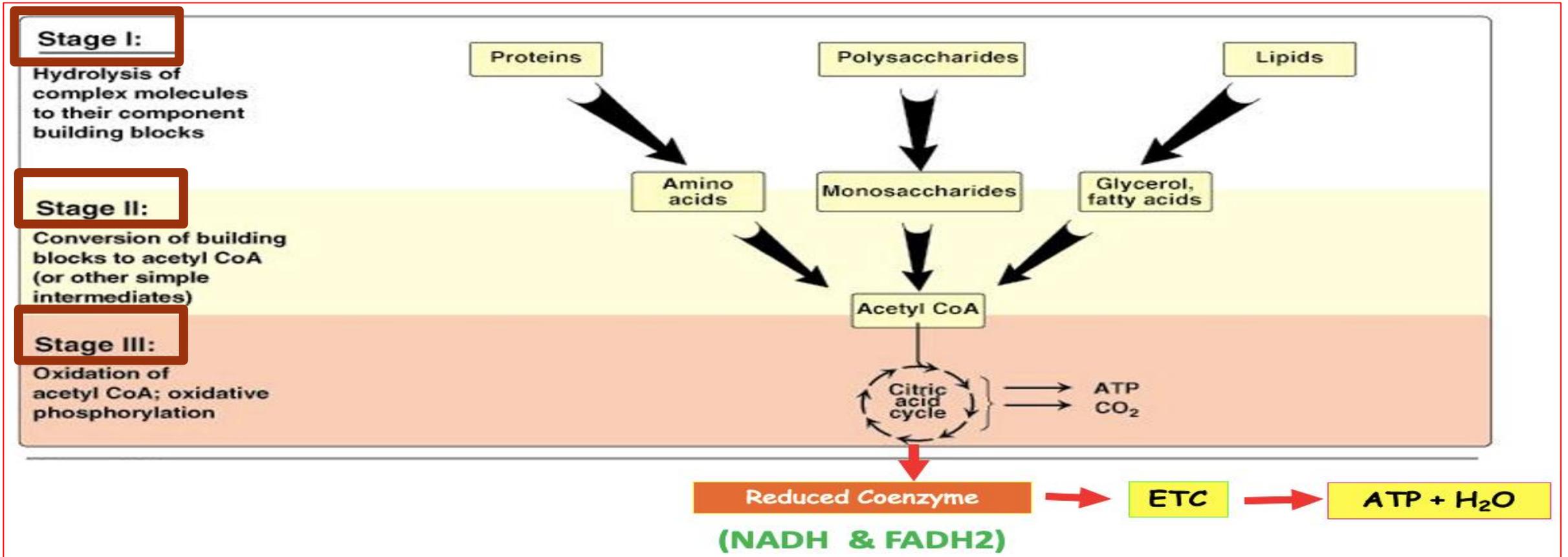
I. Anabolism-

- ✓ Synthesis of larger molecules from small ones.
- ✓ It usually requires energy.

II. Catabolism-

- ✓ Breakdown of larger molecules into smaller ones
- ✓ It usually releases energy.
- ✓ Energy released from the catabolism is used again, in the anabolism.
- ✓ Catabolism pass in three stages:





❖ When food is oxidized → electrons (e⁻) and hydrogen are removed by NAD and FAD forming reduced coenzymes: NADH+ H and FADH₂

❖ These reduced coenzymes (NADH+H & FADH₂) then transfer e⁻ to O₂ in the mitochondria by means of Electron Transport Chain (ETC) and generating ATP

Biological Oxidation

1-Electron Transport Chain (ETC)

2-Phosphorylation



Oxidative phosphorylation

Definition:

the synthesis of ATP by phosphorylation of ADP for which energy is obtained by electron transport that takes place in the mitochondria during aerobic respiration

Two steps

- A) Oxidation (electron transport Chain) (ETC)
- B) Phosphorylation (of ADP → ATP)



1) Electron Transport Chain (ETC)

Definition:

- ✓ a series of electron carriers, which catalyze a stepwise transfer of **electrons and hydrogen atoms** from **reduced coenzymes** (NADH & FADH₂) to **oxygen** to form H₂O & (energy).
- ✓ As electron pass in ETC → lose energy → the energy is used for
 - a) synthesis of **ATP**
 - b) the reminder free energy released as **heat**
- ✓ Oxygen is the final e' acceptor

Location

- ✓ Inner mitochondrial membrane.

Components of ETC

1. Reduced Coenzymes (H and electron carriers)
2. ETC Complexes
3. Mobile carriers
4. Oxygen (final e' acceptor)

Complexes of ETC

- ✓ Four membrane-bound **enzyme complexes**.
- ✓ All are embedded in **inner mitochondrial membrane (IMM)**.

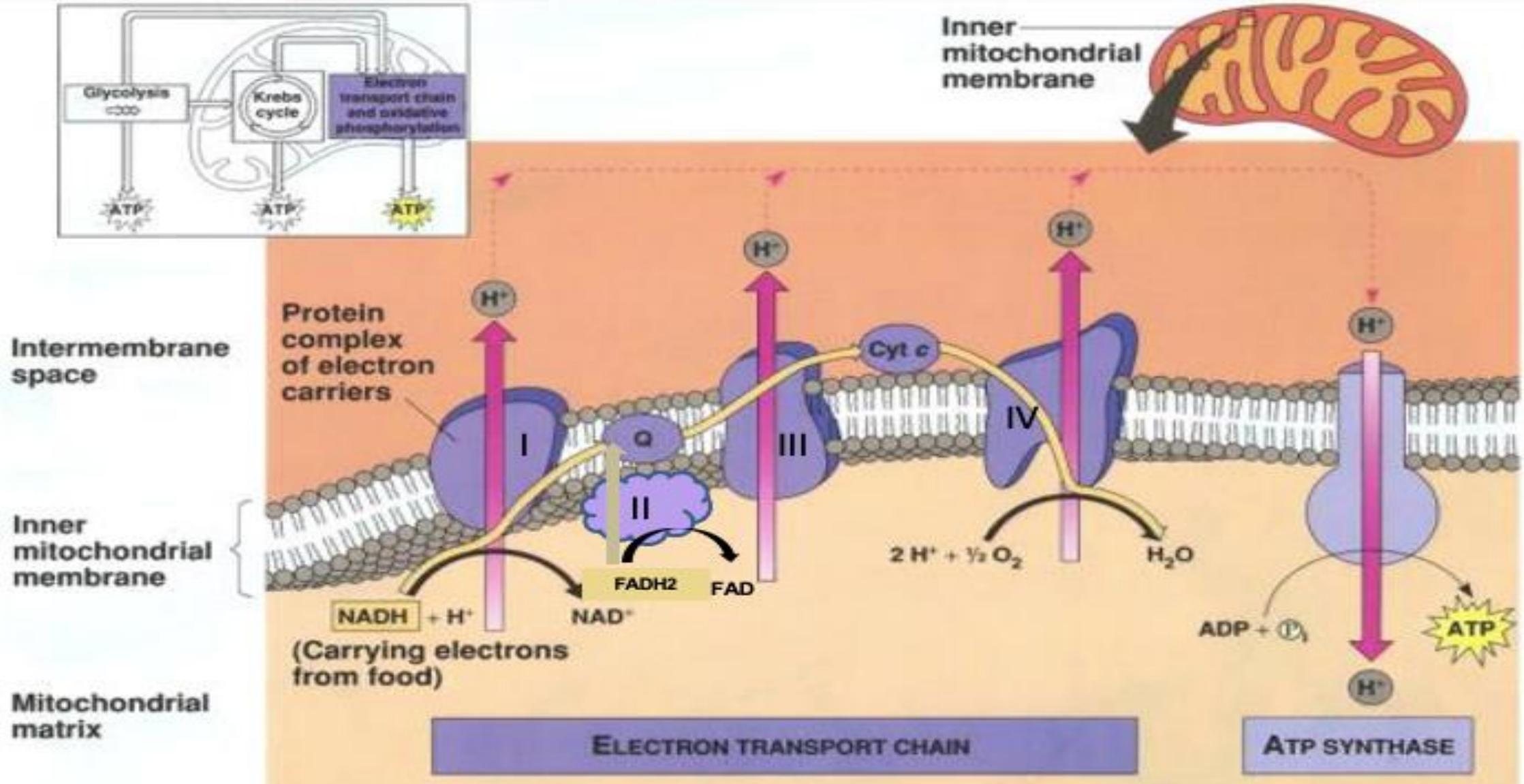
Type	Reaction	Chemistry	Every 2 e' transfer pumps
Complex I	NADH dehydrogenase.	Flavoproteins	4 H ⁺
Complex II	Succinate dehydrogenase.		Not pump H ⁺
Complex III	Ubiquinol (Coenzyme Q) dehydrogenase.	Cytochromes	4 H ⁺
Complex IV	Cytochrome oxidase.		2 H ⁺

Mobile Carriers of ETC

	1-Coenzyme Q (Co Q) Ubiquinone	2-Cytochrome C
location	Inner mitochondrial membrane (IMM)	Outer face of IMM
mobility	Mobile in lipid bilayer of IMM	loosely attached with the outer face of IMM
Accept e' from	- NADH (Complex 1) - FADH2 (Complex II)	Complex III
Transfer e' to	Complex III	Complex IV



Flow of electron in ETC



Entry of NADH & FADH₂ to ETC

1) Entry via NADH+H :

- ✓ NADH+H join the chain giving electron to **complex I** to **coenzyme Q** to **complex III** to **Cyt c** then **complex IV** to final acceptor (**O₂**) to form H₂O

2) Entry via FADH₂ :

- ✓ FADH₂ can join the chain directly to **complex II** giving electron to **coenzyme Q** to **complex III** to **Cyt c** then **complex IV** to final acceptor (**O₂**) to form H₂O
- ✓ FADH₂ **not pass** by complex I

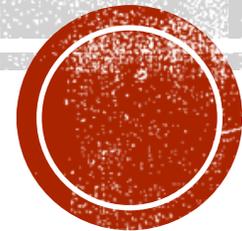
SO

The transport of a pair of electrons from

- **NADH** to O₂ via the ETC produces energy sufficient to produce **3 ATPs**.
- **FADH₂** to O₂ via the ETC produces energy sufficient to produce **2 ATPs** .



Phosphorylation (ATP Synthesis)



2) Phosphorylation =ATP production in (Chemiosmotic theory)

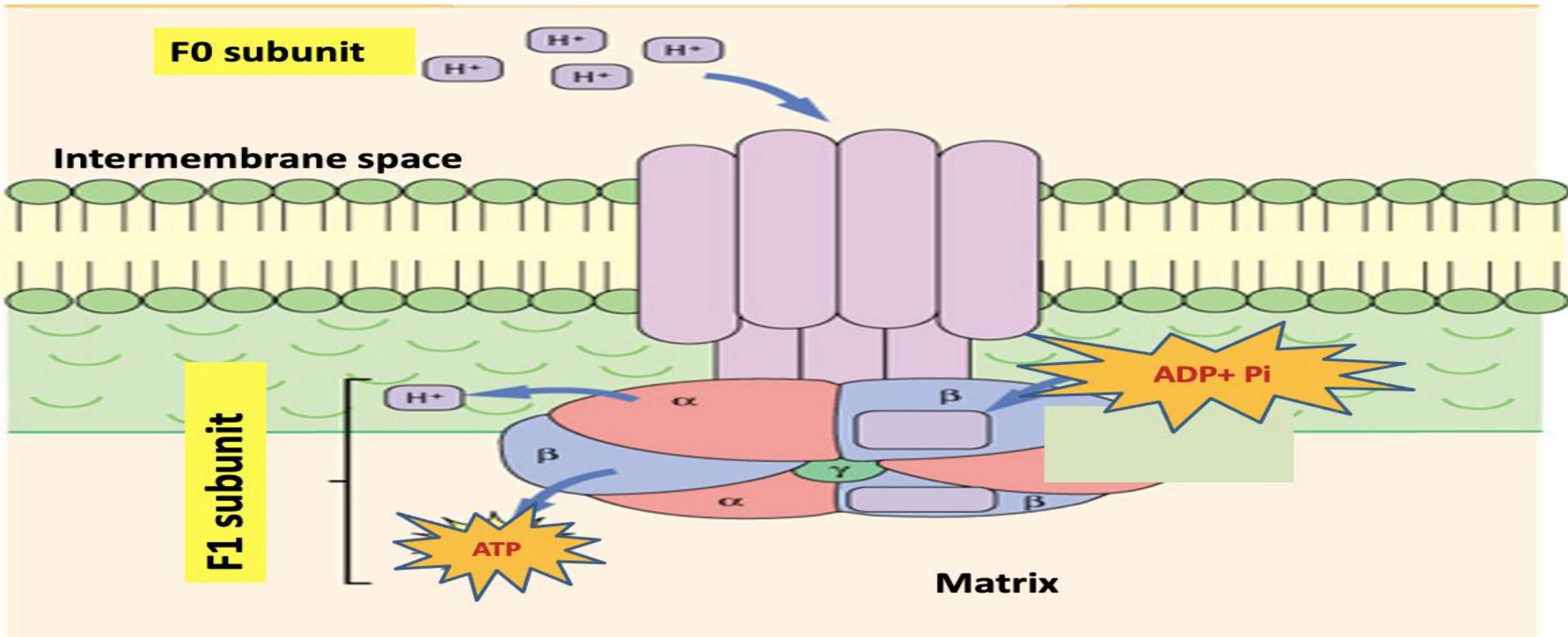
- ✓ Transfer of electrons down ETC does **not directly result in ATP** synthesis.
- ✓ Mechanism of ATP production is explained by **Chemiosmotic theory**.
- ✓ Chemiosmotic theory explains how free energy generated by transport of electrons by ETC is used to produce ATP from ADP + Pi.
 1. Proton pumps
 2. ATP synthase

1) Proton pump

- ✓ **Energy of electron** transport through the ETC is utilized by **complex I, III and IV** for transfer of protons (H^+) from the matrix to the inter-membrane space (**proton pumps**).
- ✓ This creates an **electrochemical potential difference** across the Inner membrane (IM) :
 - **electrical gradient:** more **+ve outside** than inside IM &
 - **chemical (PH gradient):** **lower pH outside** than inside IM.
- ✓ **Protons**, which are present in the inter-membrane space in great excess, can **pass back** into the matrix according to their concentration gradient through the **ATP synthase** → production of **ATP**.

2) ATP Synthase (Complex V)

- Present in the **inner** mitochondrial membrane.
- Responsible for synthesis of ATP from **ADP and Pi**.
- Formed of **2 main subunits (F_0 and F_1 subunits)**.
 - **F_0** : acts as **channel for H^+ re-entry to the matrix**
 - **F_1** : - **synthesis of ATP** from ADP and Pi
 - **formed of $3\alpha, 3\beta, 1\gamma$ subunits.**
 - **β subunits is the catalytic site at which ATP is synthesized**
- **H^+ reenter** through **F_0 subunit** → **rotation** of **$F_1\gamma$ -subunit** → providing **energy** to **β -subunits** that synthesize **ATP**.



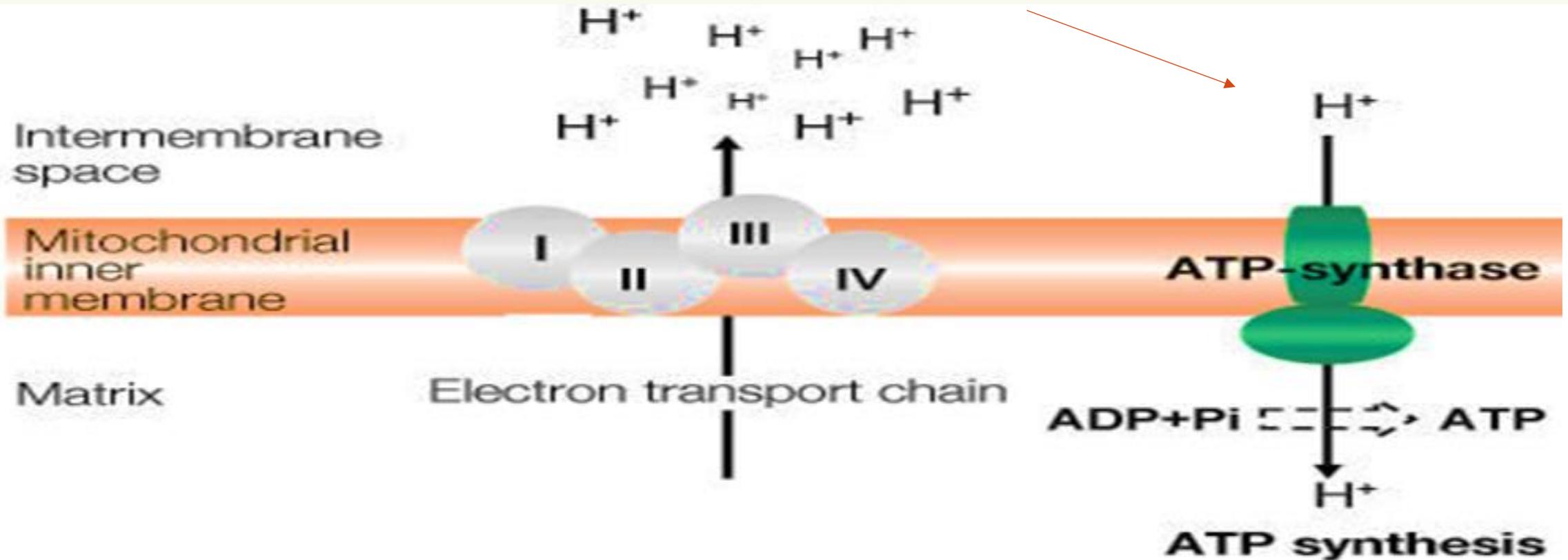
ATP synthase complex



3) Oxidative phosphorylation

Means **coupling of e⁻ transport in ETC with phosphorylation of ADP to form ATP** (by Complex V=ATP Synthase).

It is a process by which the energy of biological oxidation is ultimately converted to the chemical energy of ATP.



So Oxidation in (ETC) is coupled to phosphorylation of ADP to ATP

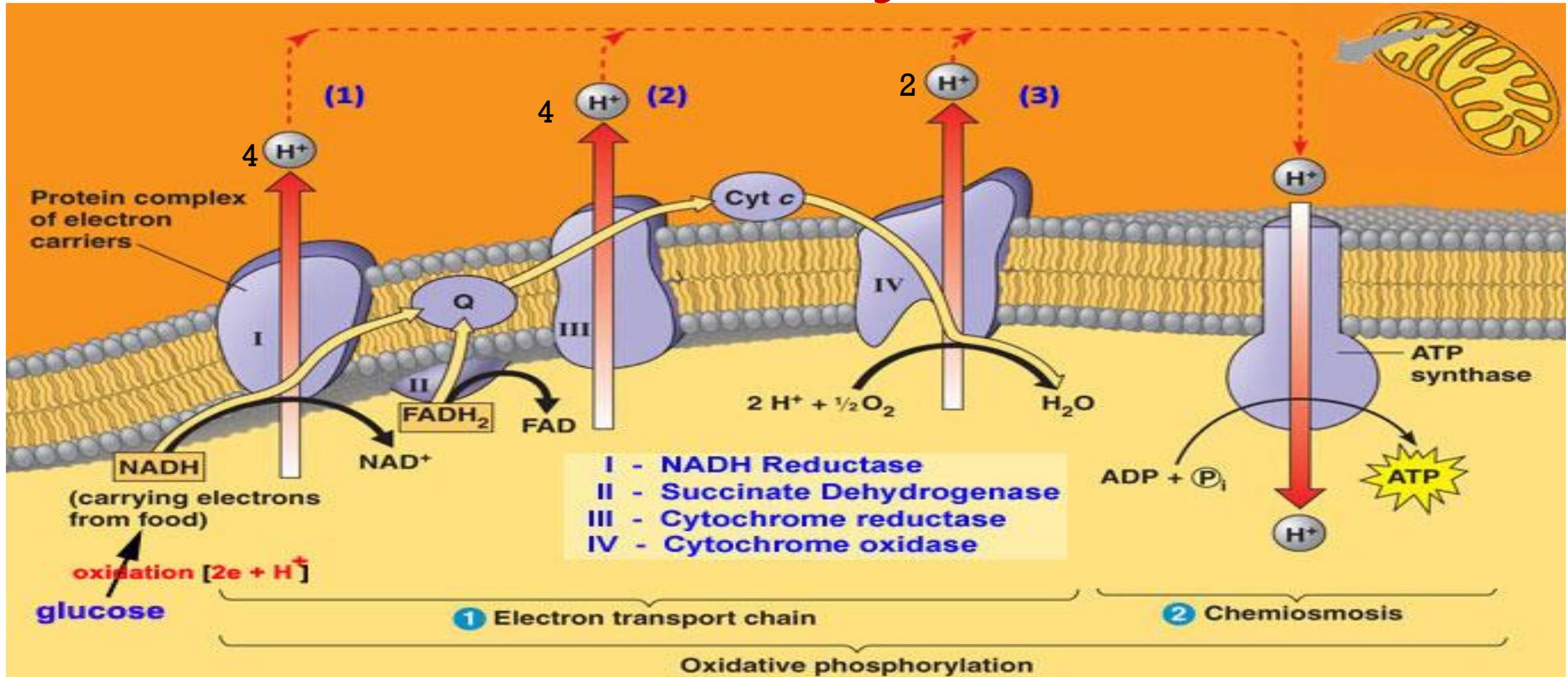
Definition

- **It is the ratio between:**
numbers of **ADP** changed into ATP by ATP synthase

the number of **Oxygen** atom utilized in ETC.
- **It is :**
3:1 if electron enter through **NADH+H**
2:1 if electron enter through **FADH₂**.



Summary



- H^+ is pumped **from** the matrix **to** intermembrane space by **ETC complexes I, III, IV**
- H^+ is **returned back** into the matrix by **ATP synthase (complex V)**

<https://youtu.be/39HTpUG1MwQ?si=4RRvEorWFBo49Os0>

Excerpt from a biomedical animation project.





A GOAL
WITHOUT
A PLAN
IS JUST A
WISH



REFERENCES

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- ❑ **<https://www.youtube.com/watch?v=c5j6ExHLFD8>**

