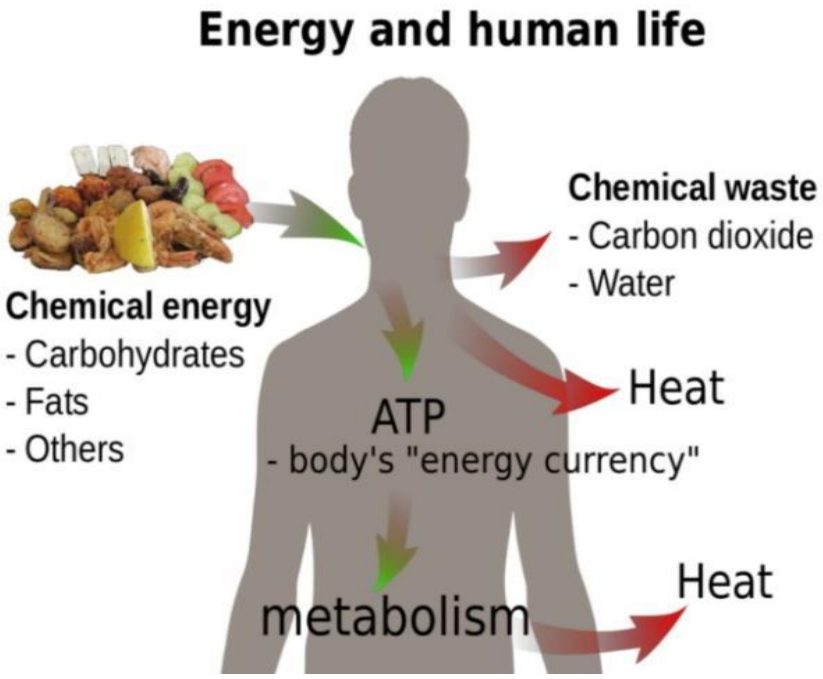
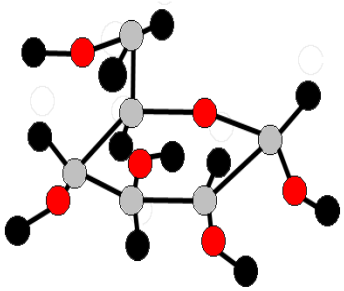
Bioenergetics *(bio: life or living , energetics : study of eneregy)*

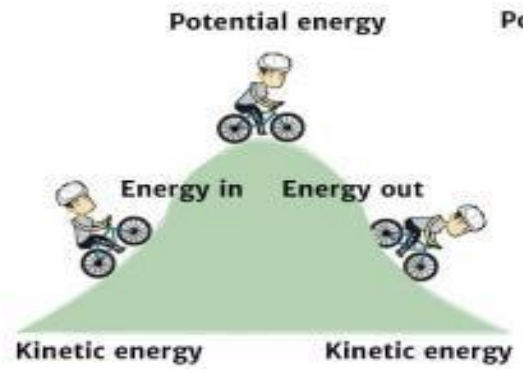
- ***Def:***
  - *A study of **thermodynamics (energy transformations)** inside body.*

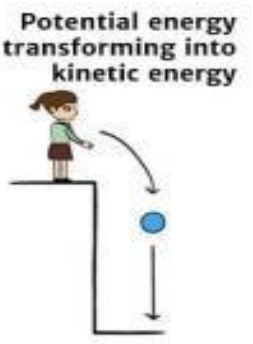


- ***Energy:***

Potential	*Kinetic*
(Has the potential to do work) *Energy of **position** (not been used yet)*	*Energy of **motion*** *(Energy in use)*
*Usually in the form of **covalent bonds** between carbon atoms or in the form of **ATP molecules.***	





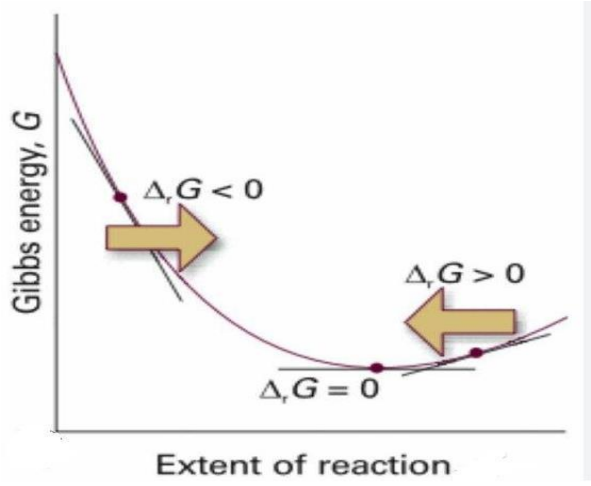


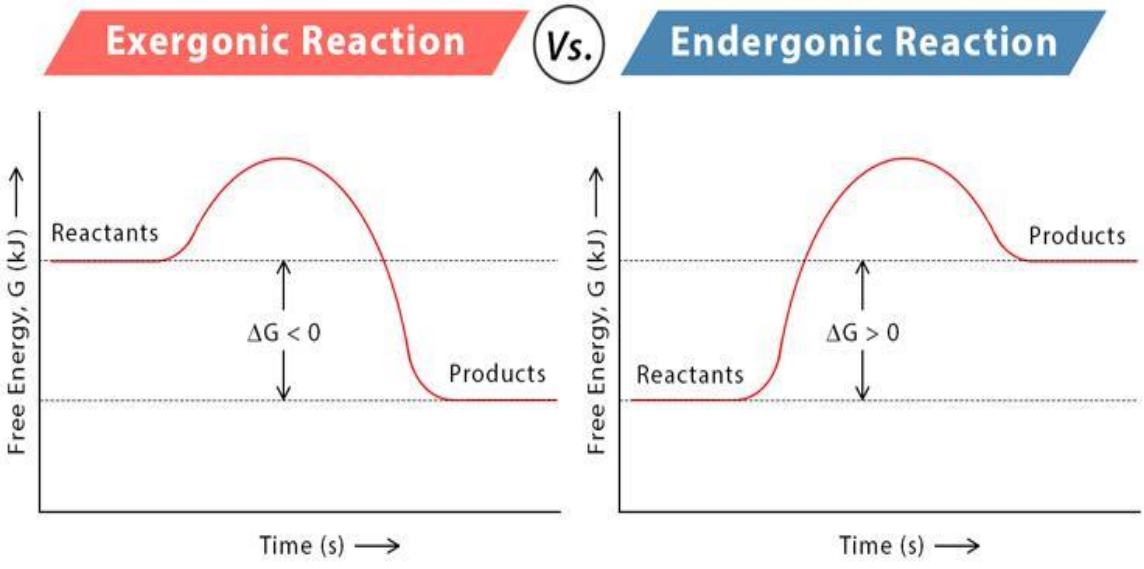
Free energy change (ΔG) (Useful energy)

- **Def :** *portion of energy that is **available** to do work (utilizable).*
- **Classification :**

ΔG is negative (ΔG <0)	ΔG is positive (ΔG > 0)
Energy is released	Energy is absorbed
Reaction is spontaneous	Reaction is non-spontaneous
Exergonic reaction	Endergonic reaction
E.g. catabolic (degradation) reactions	E.g. anabolic (building-synthetic) reactions

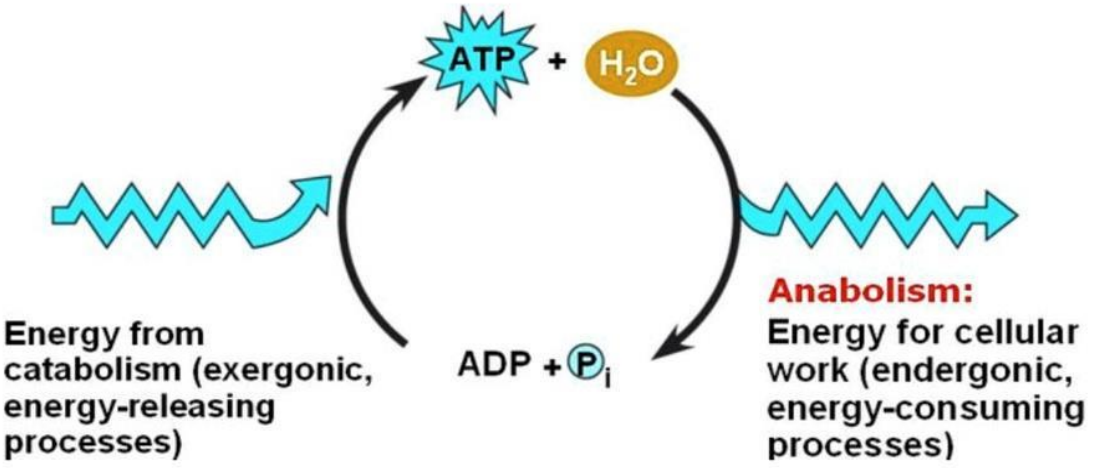
If ΔG is zero: *The system is at equilibrium and no net change takes place.*





Energy coupling

- **Def :**
  - *Coupling two biological reactions, so that energy generated from one reaction is **used** to drive the second reaction.*
  - *The living cells utilize the energy liberated from the **exergonic reactions** to synthesize high energy intermediate - **mainly ATP -** which in turn gives the energy to **endergonic reaction.***

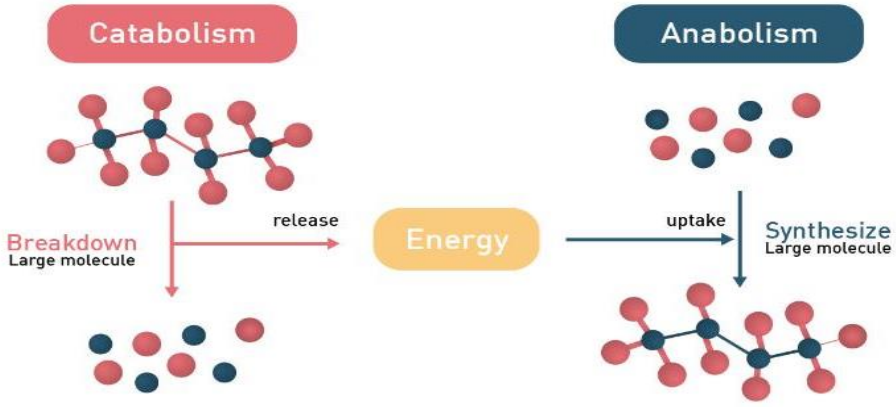


Metabolism

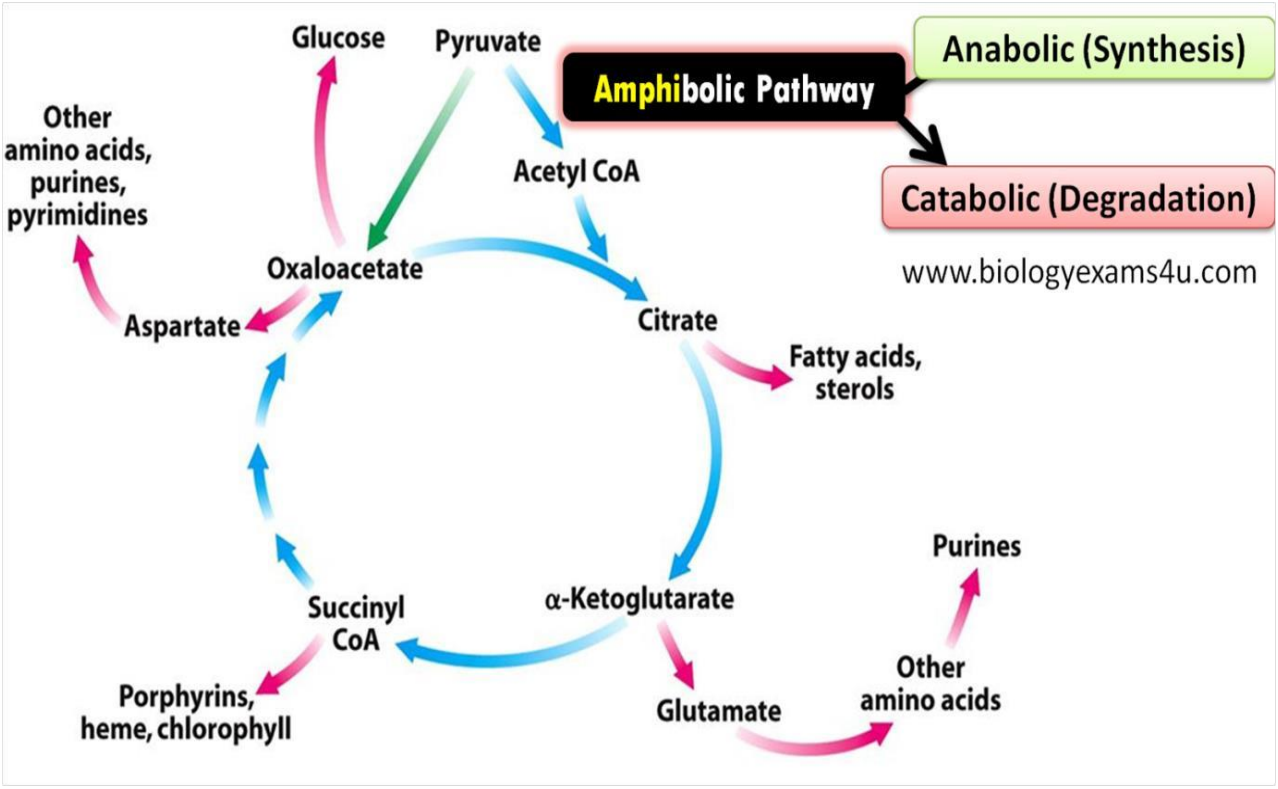
- **Def:**
  - *It is sum of **chemical reactions** that take place within each cell of a living organism and that provide **energy** for vital processes.*

- **It includes:**

Catabolism:	Anabolism:
• ***breaking down*** *complex molecules in simpler compounds.* • *This reaction release energy, usually as ATP* ***(exergonic)***	• ***build*** *complicated molecules from simpler compounds.* • *This reaction consume energy* ***(endergonic)***
• *ex:* ***glycolysis.***	• *ex:* ***gluconeogenesis.***



- ***Amphibolic pathways:***
  - *Biochemical pathway that includes both **anabolic and catabolic processes**.*
  - *Best understood through **Kreb's cycle**.*



Metabolic sources of energy

- ***Humans obtain energy from three classes of fuel molecules:***

  1) Carbohydrates.

  2) Lipids.

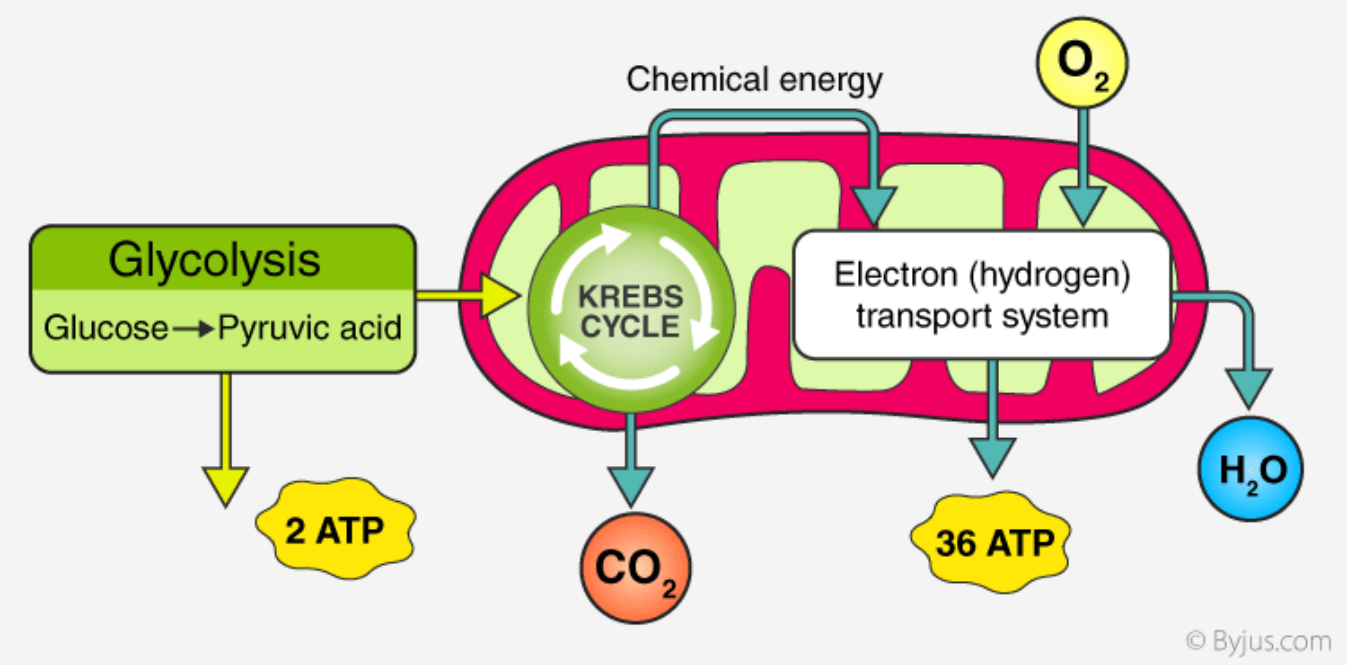
  3) Proteins.

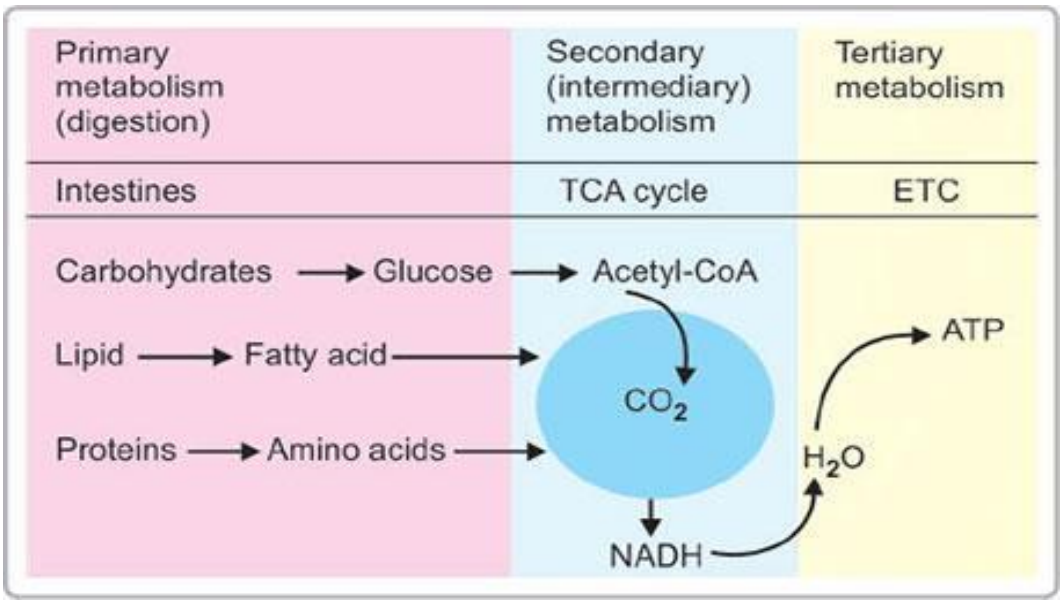
▪ Stages of food oxidation:

1st stage:	• **The primary metabolism:** ➢ *In GIT,* ***digestion*** *converts the metabolic fuels to the monomeric building blocks (glucose, fatty acids and amino acids) to be absorbed.*
2nd stage:	• **The secondary metabolism:** ➢ *The absorbed products are catabolized to smaller components, and oxidized to CO2, NADH and FADH2 in the mitochondria by the* ***Kreb's cycle.***
3rd stage:	• **The tertiary metabolism or cellular respiration:** ➢ *The NADH and FADH2 carrying 2H enter into* ***electron transfer chain (ETC)*** *where energy is released and used to produce* ***ATP.*** ➢ *This process requires* ***O2*** *which finally reacts with the* ***2H*** *to produce* ***H2O.***

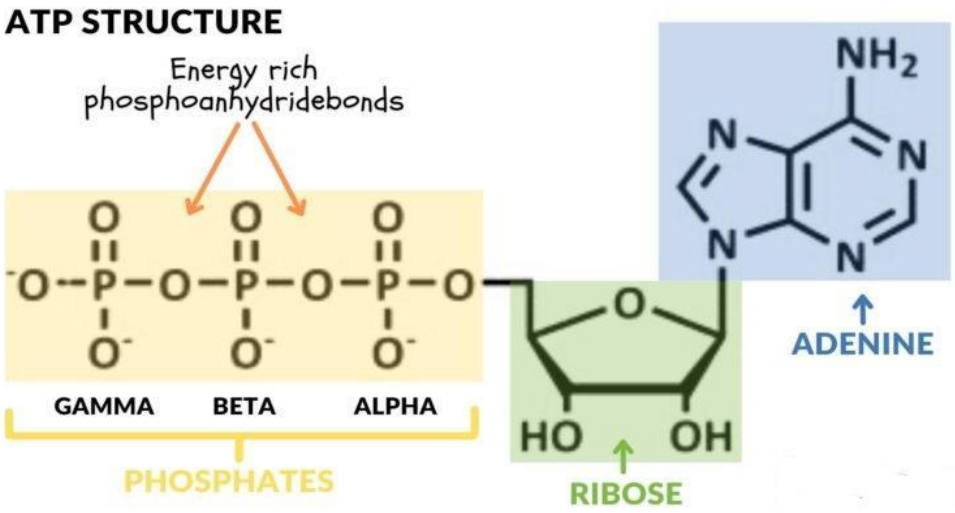
▪ NB :

In the presence of O2:	• ***Complete oxidation*** *of foodstuffs takes place in the mitochondria with the production of ATP, CO2 and H2O* ***(aerobic condition, stage 1, 2, 3).***
In the absence of O2:	• ***Incomplete oxidation*** *of foodstuffs* ***(anaerobic conditions, stage 1 and 2 only).***





ATP (Energy currency of the cell)



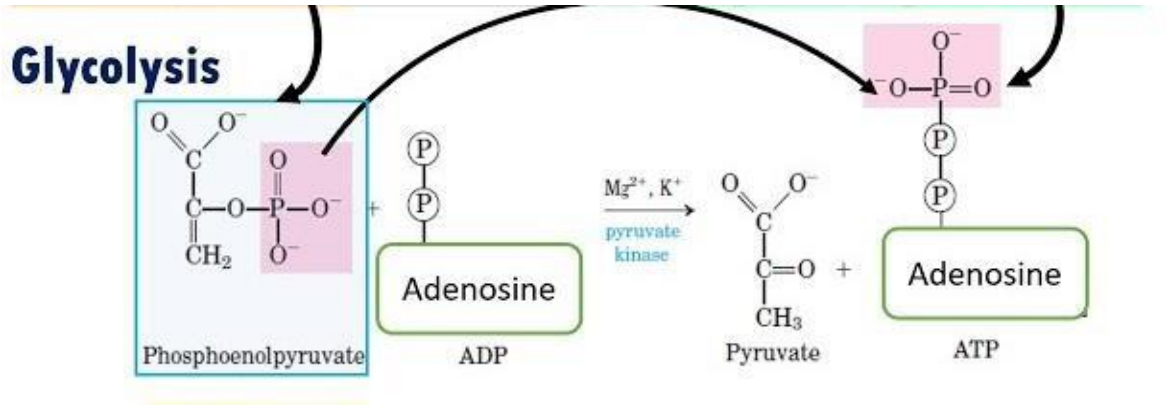
- **Def :**
  - ***A high energy compound,*** *considered the primary and universal carrier of chemical energy in the cell.*
  - *It plays a central role in the* ***transference of free energy*** *from the exergonic to the endergonic processes (high-energy Intermediate).*
  - *It is continually* ***hydrolyzed and regenerated.***

Mechanism of ATP formation

- **There are two basic mechanisms involved:**

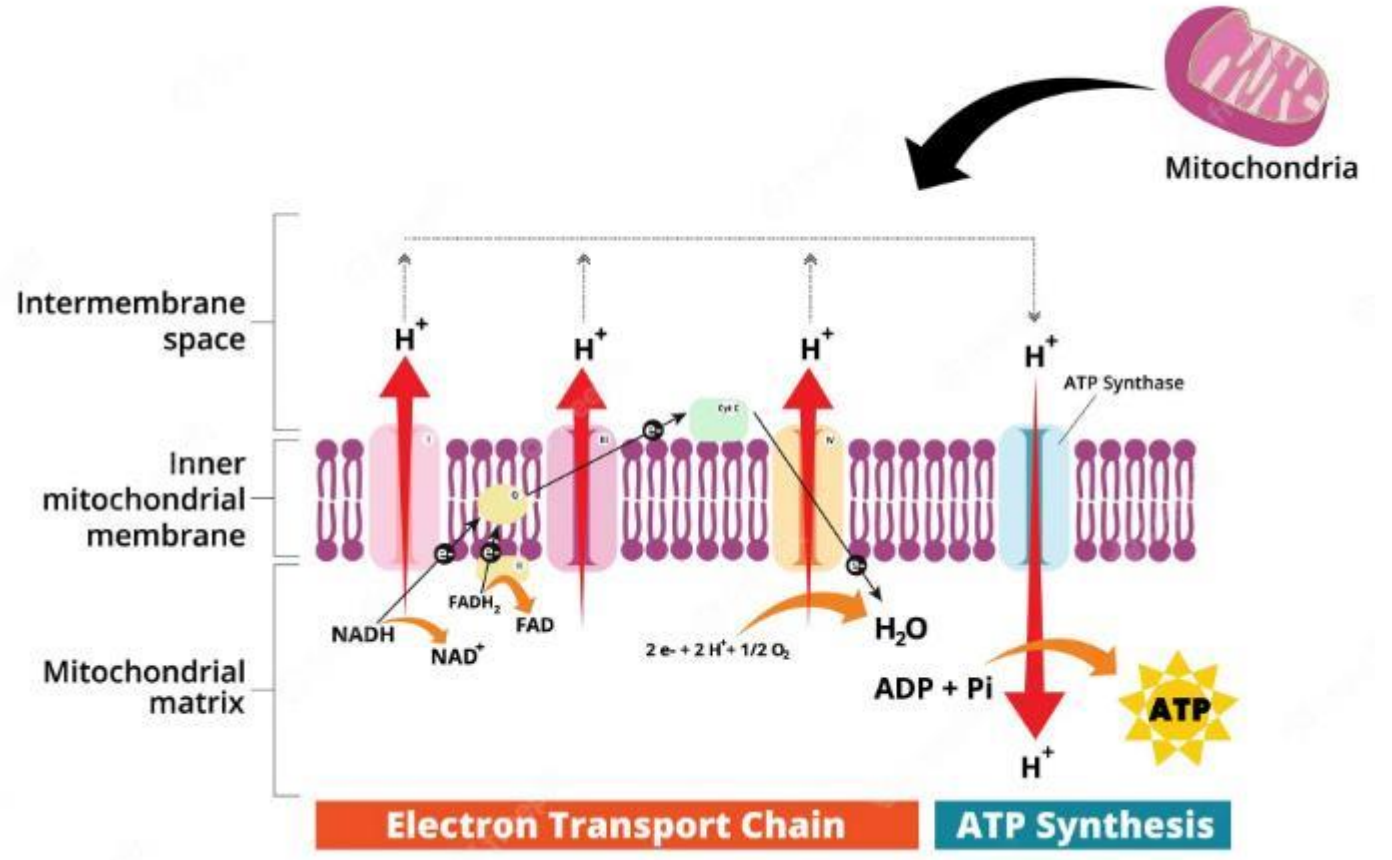
1) Substrate level phosphorylation:

- *It involves phosphorylation of ADP to form ATP* ***directly without*** *passing through the electron transport chain.*



2) Oxidative phosphorylation:

- *This process takes place in* ***mitochondria*** *and is energetically coupled to a* ***proton gradient*** *over a membrane.*
- *The H+ gradients established by electron transport chain are used by the* ***ATP synthase enzyme*** *as a source of energy for direct linking of an inorganic phosphate to ADP, producing* ***ATP.***

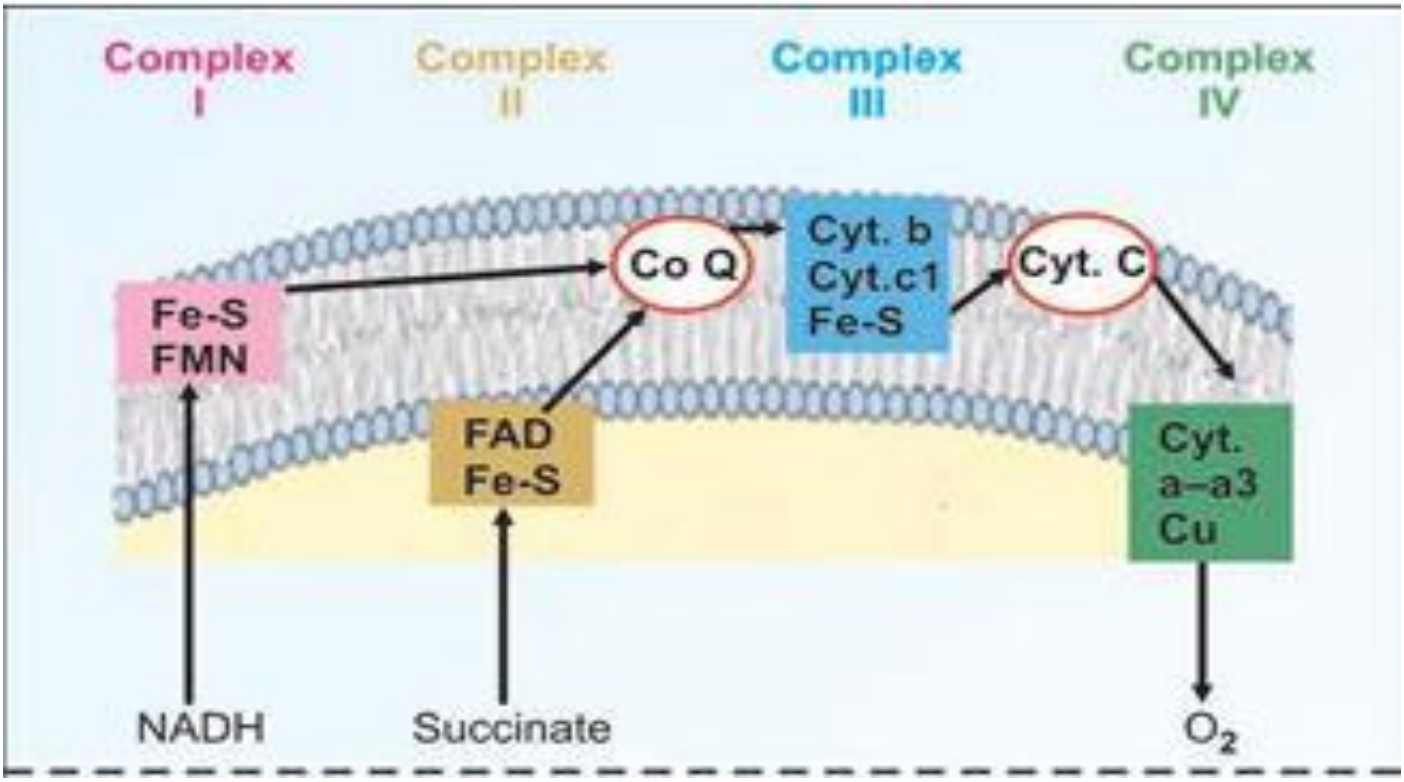


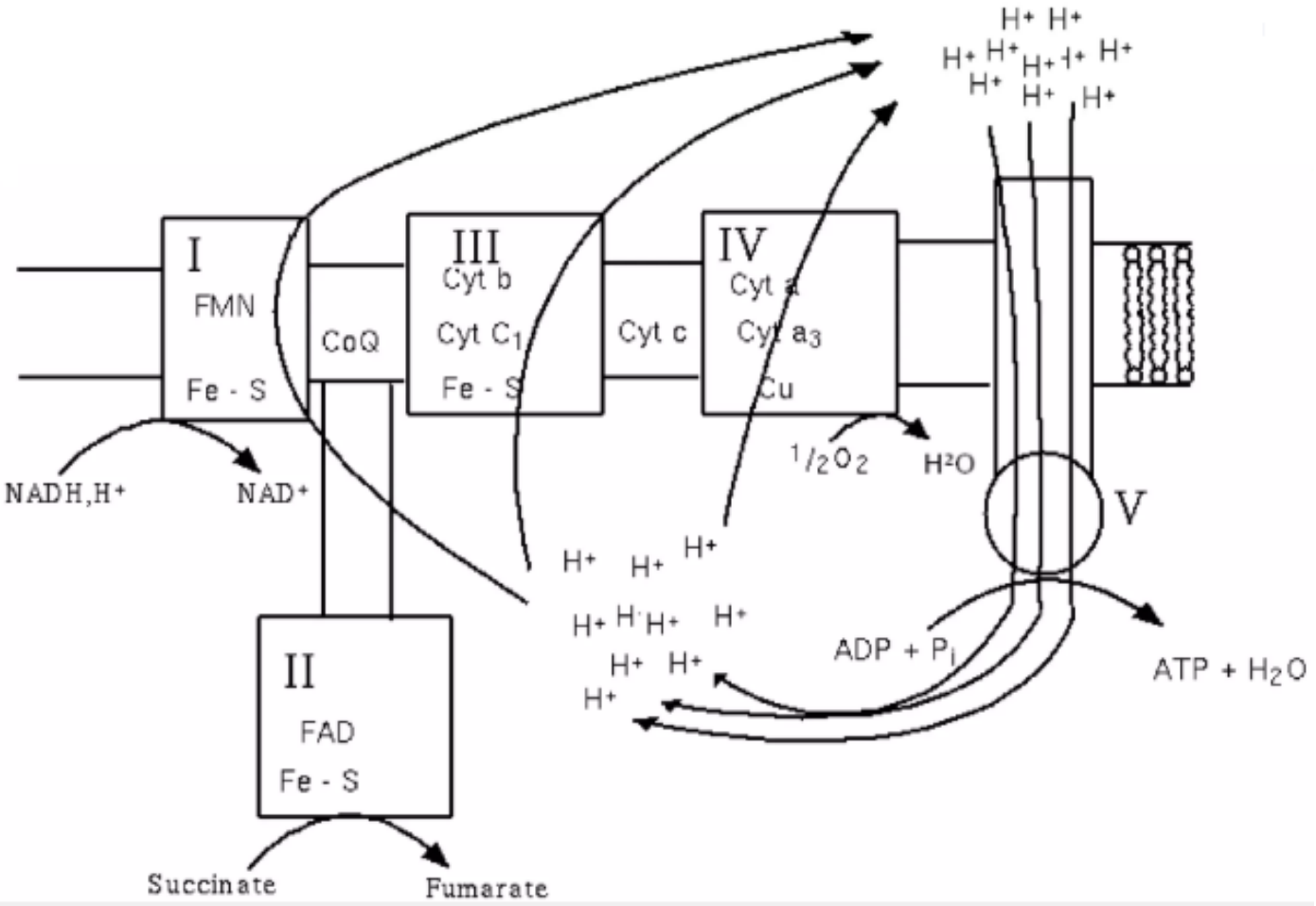
Electron Transport Chain (Respiratory Chain or oxidative phosphorylation)

Def:	• *Series of **four protein complexes** that couple redox reactions, creating an **electrochemical gradient** that leads to the creation of **ATP**.*
Site:	• *Inner mitochondrial membrane.*
Mechanism:	• *The electrons flow from the more **electronegative** components to the more **electropositive** components.* • ***<u>There are 4 distinct multi-protein complexes:</u>*** ➢ *These are named as **complex-I, II, III and IV**.* ➢ *These are connected by two mobile carriers, **co-enzyme Q and cytochrome C**.*

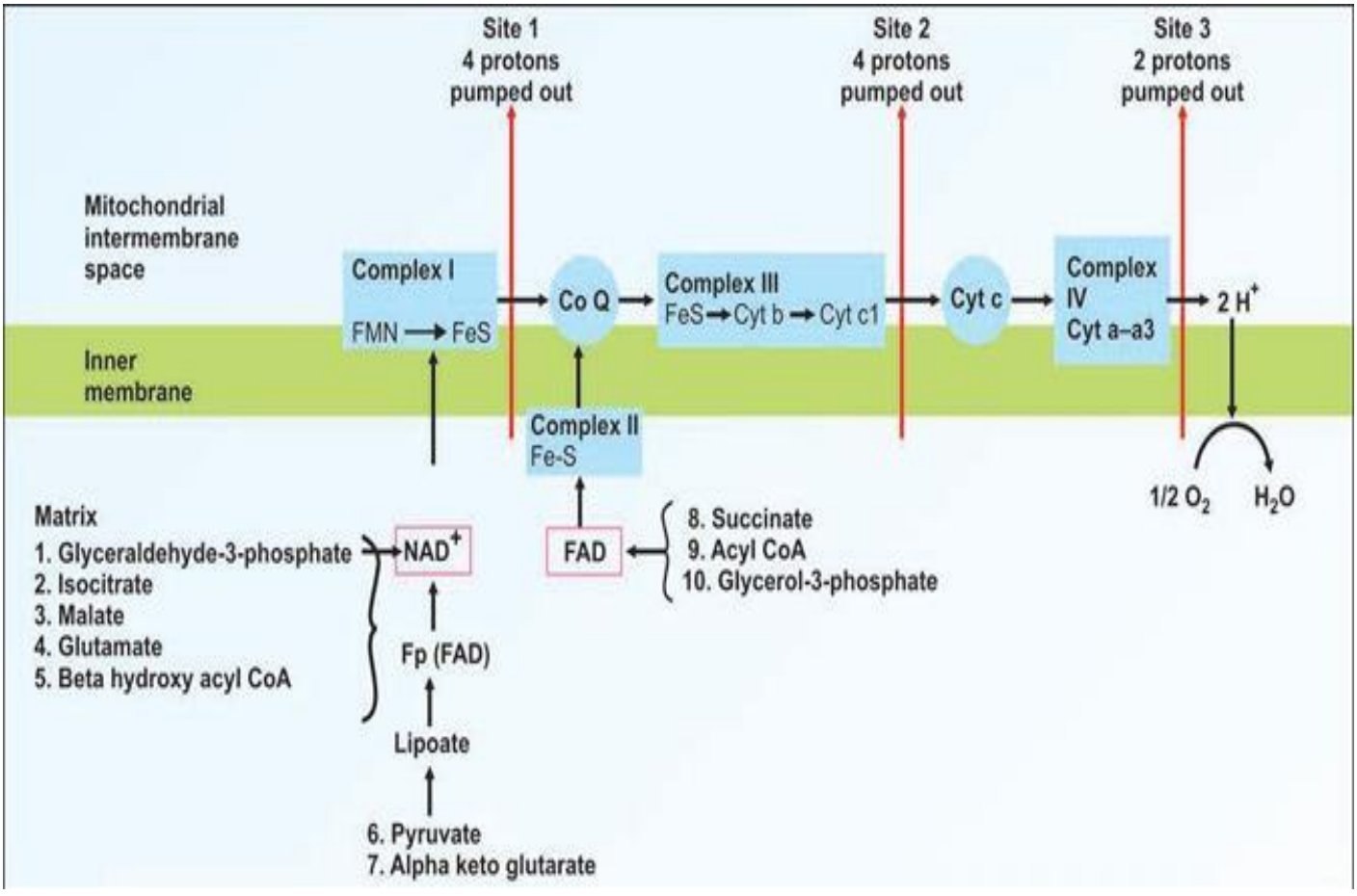
- **Complexes:**

Name	Other name	It contains
Complex I:	**NADH dehydrogenase.**	• *FMN and an iron-sulphur protein (Fe-S).*
Complex II:	**Succinate dehydrogenase.**	• *FAD and Fe-S as coenzymes.*
Complex III:	**Ubiquinol dehydrogenase.**	• *cyt b, cyt c1 and Fe-S as coenzymes.*
Complex IV:	**Cytochrome oxidase.**	• *Cu and cyt a and cyt a3 as coenzymes.*





CYCLE DE KREBS



- ***P:O (P/O) Ratio:***
  - ***Def:***
    - *The number of ATP molecules produced to the number of oxygen atoms consumed.*
    - *It measures the **efficiency** of oxidative phosphorylation.*
  - ***Example:***
    - *2.5 ATP from NADH.*
    - *1.5 ATP from FADH2.*

- ***Uncouplers:***

Def:	• *Substances that **dissociate** oxidation from phosphorylation (allow oxidation to proceed, but the energy, instead of being trapped by phosphorylation, is liberated as **heat**).*
P/O Ratio:	• *P/O Ratio is **zero.***
Mechanism:	• *This is achieved by ↑ **membrane permeability to protons** (H+), allow transport of H+ across the inner membrane but not through ATP synthase → removal of the **proton gradient.***
Significance:	• *In **hibernating animals** and in **newborn human infants**, the liberation of heat energy is required to maintain **body temperature.***
Example:	• *2.4 dinitrophenol – Thyroxine – Thermogenin.*

Inhibitors of electron transport chain (Inhibitors of ATP synthesis)

1) Specific site Inhibitors:	• **Complex I:** ➢ *Rotenone (insecticide)* ➢ *Barbiturates (amobarbital)* ➢ *Chlorpromazine, (tranquilizer)* • **Complex III:** ➢ *BAL (antidote of war gas)* ➢ *Antimycin (antibiotic)* • **Complex IV:** ➢ *CO* ➢ *Cyanide*
2) Non-Specific site Inhibitors	• **Inhibitors of Phosphorylation:** ➢ *Oligomycin (inhibits ATP synthase).*

Biological Importance of ATP

1- Activation of **monosaccharides, FAs and AAs.**

2- Active **absorption and secretion.**

3- **Active transport** across biological membranes.

4- Biosynthesis of **macromolecules.**

5- Biosynthesis of **cAMP.**

6- Biosynthesis of **creatine phosphate.**

7- **Nerve** conduction and **muscle** contraction.