# BIOENERGETICS
# Cellular Respiration

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# DEFINITION

- **Energetics** is the study of energy requirements and the flow of energy within systems.
- **Bioenergetics** is the quantitative study of the energy transductions that occur in living cells and of the nature and function of the chemical process underlying these transductions
- It is the study of the balance between energy intake in the form of food and energy utilization by animals for life-sustaining processes.
- It includes the study of thousands of different cellular processes such as cellular respiration and the many other metabolic processes that can lead to production and utilization of energy in forms such as ATP molecules.

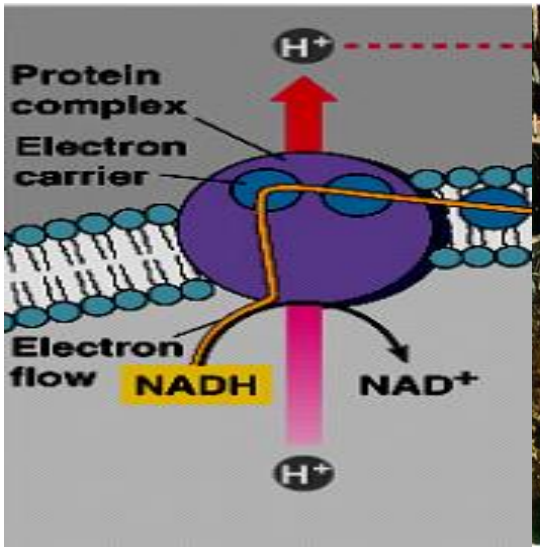
# Chemiosmotic theory

- **Chemiosmosis** is the movement of ions across a semipermeable membrane, down their electrochemical gradient.
- More specifically, it relates to the generation of ATP by the movement of hydrogen ions ($H^+$) across a membrane during cellular respiration or photosynthesis.
- An electrochemical concentration gradient of protons across a membrane can be harnessed to make ATP. Similar to osmosis, i.e diffusion of water across a membrane, hence is called "**chemiosmosis**".
- ATP synthase is the enzyme that makes ATP by chemiosmosis.
- It occurs in mitochondria, chloroplasts as well as in most bacteria and archaea.

# Electron transport chain pumps & $H^+$ gradient

## ATP synthase uses the $H^+$ gradient to generate ATP

**Higher $H^+$ concentration = lower pH**
Intermembrane space

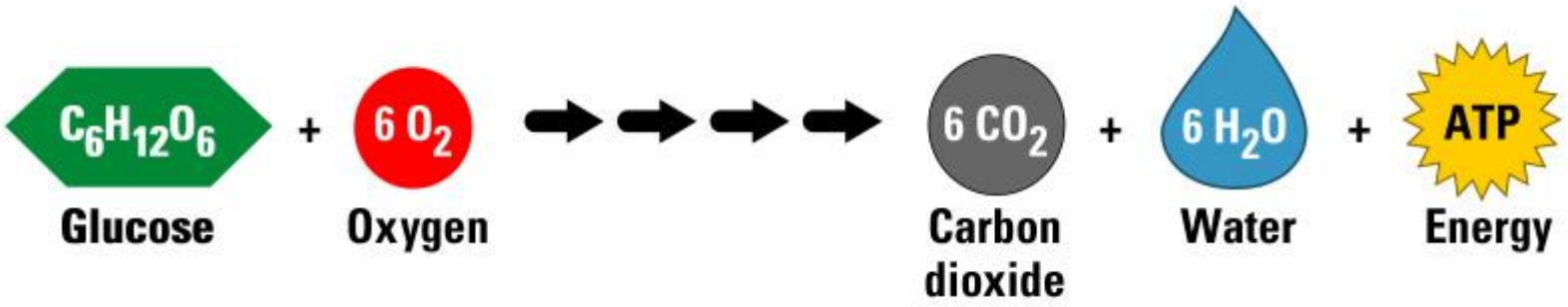



**Lower $H^+$ concentration = higher pH**
Mitochondrial matrix

# Cellular Respiration

How the cell makes ATP, which supplies the energy for a working cell?

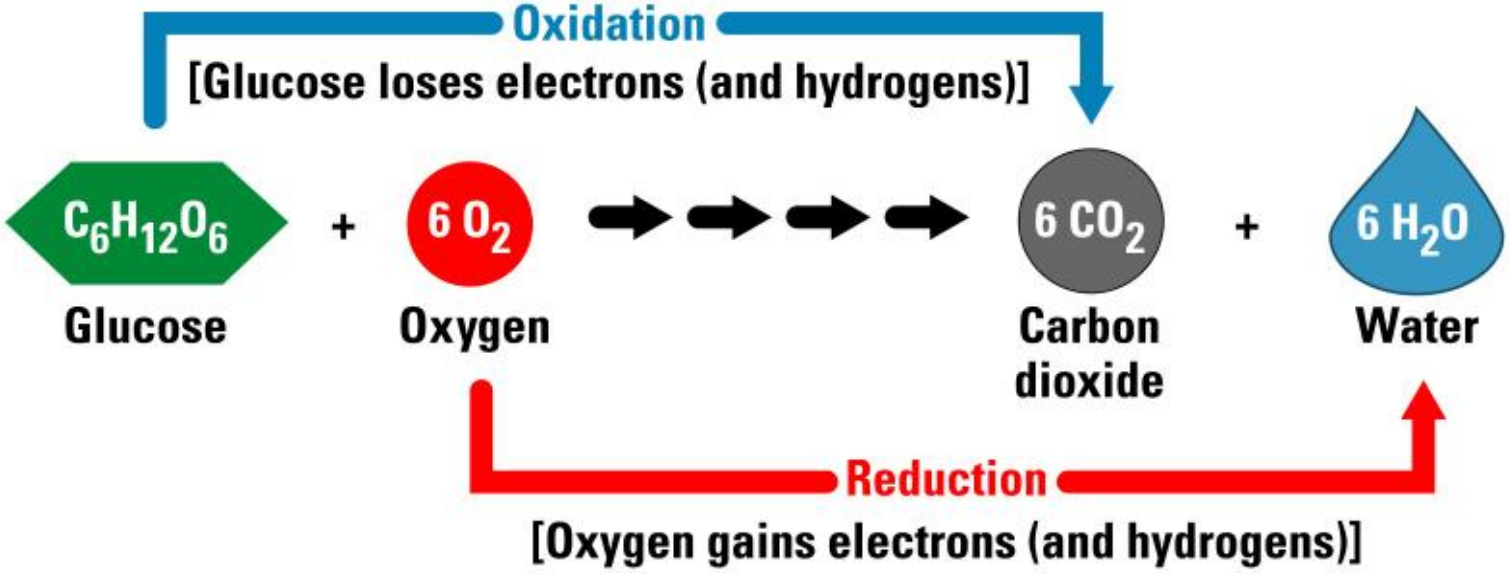
The process of aerobic (with oxygen) cellular respiration:




Cellular respiration is part of our metabolism (all the chemical reactions occurring in cells). The multiple arrows above show that cellular respiration is a metabolic pathway.

# Cellular Respiration is a Redox Reaction

The process of cellular respiration involves the transfer of electrons, so can be classed as a redox reaction.






- The glucose hydrogens and electrons are lost to oxygen meaning that glucose is OXIDISED.
- Oxygen accepts electrons and hydrogens to form water meaning it is REDUCED.

# The Metabolic Pathway of Cellular Respiration

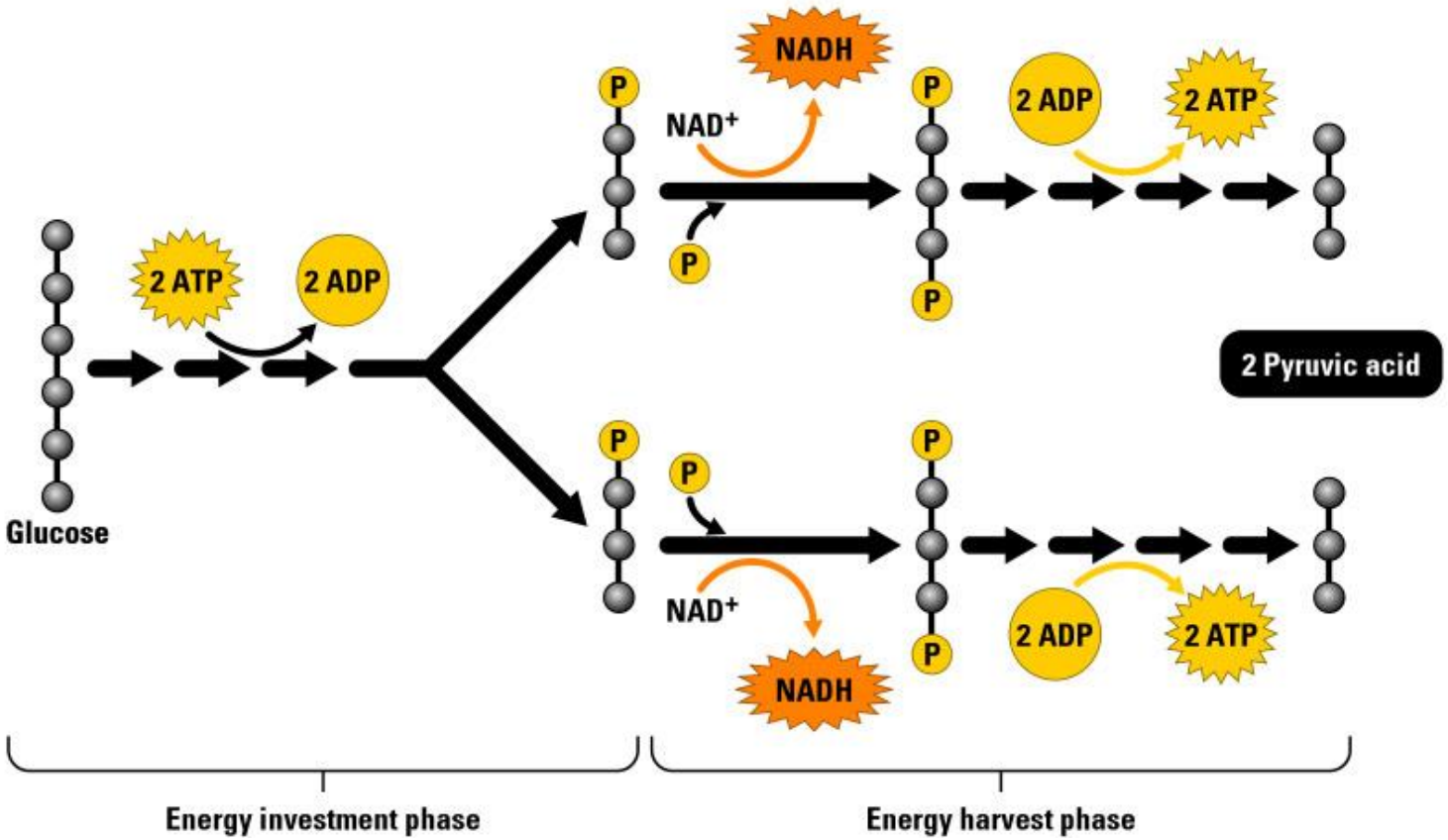
The reactions in cellular respiration are grouped into 3 main stages:

- GLYCOLYSIS – break down of glucose
- KREBS CYCLE – break down of glucose completed and carbon dioxide formed
- ELECTRON TRANSPORT – energy from break down of glucose is converted to ATP

# Glycolysis

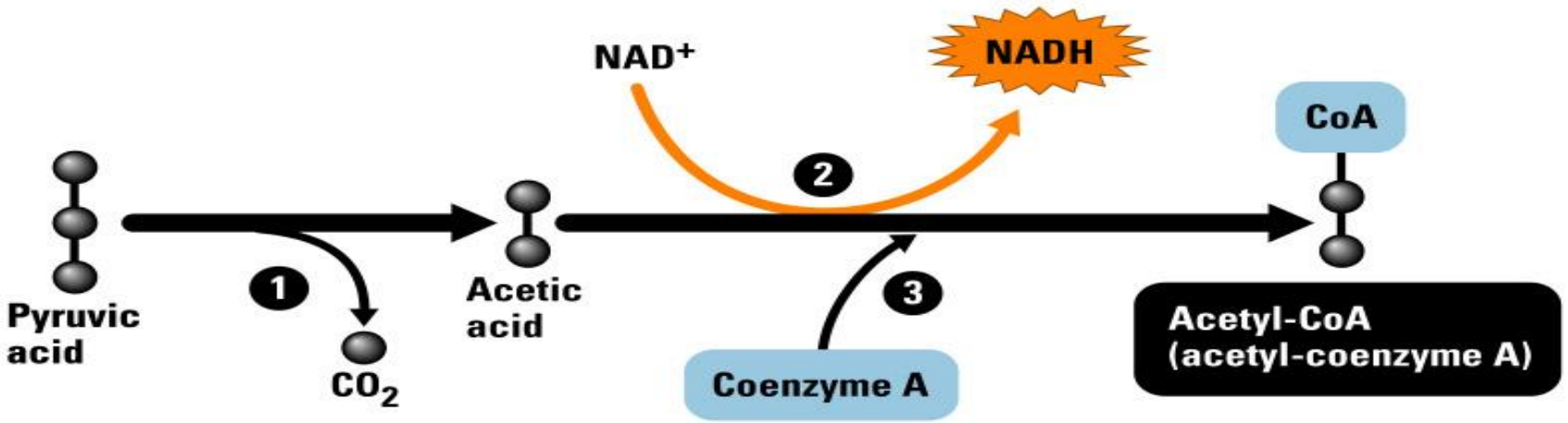
The first stage, called glycolysis (splitting of glucose), occurs in the cytosol as a series of nine reactions.

As the name suggests, the six-carbon structure of glucose is split into two three-carbon molecules called PYRUVIC ACID.



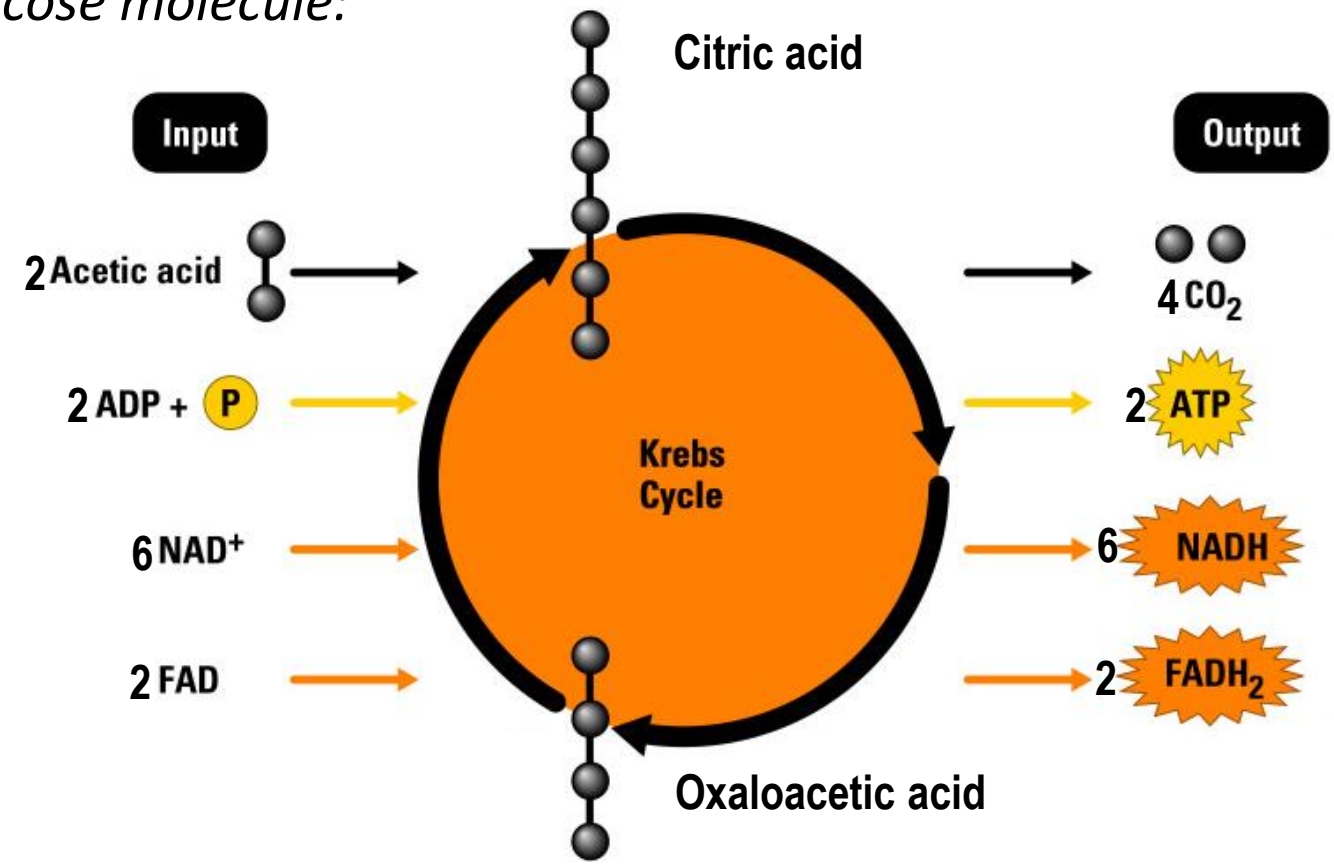
# The Citric Acid Cycle

- The citric acid cycle (Krebs cycle ) occurs in mitochondria.
- Energy extraction from glucose.
- Pyruvic acid passes from the cytoplasm to the mitochondria and is oxidised to the acetyl-CoA.
- The formation of acetyl-CoA is the link between glycolysis and the Krebs Cycle.



# The Citric Acid Cycle

*per glucose molecule:*

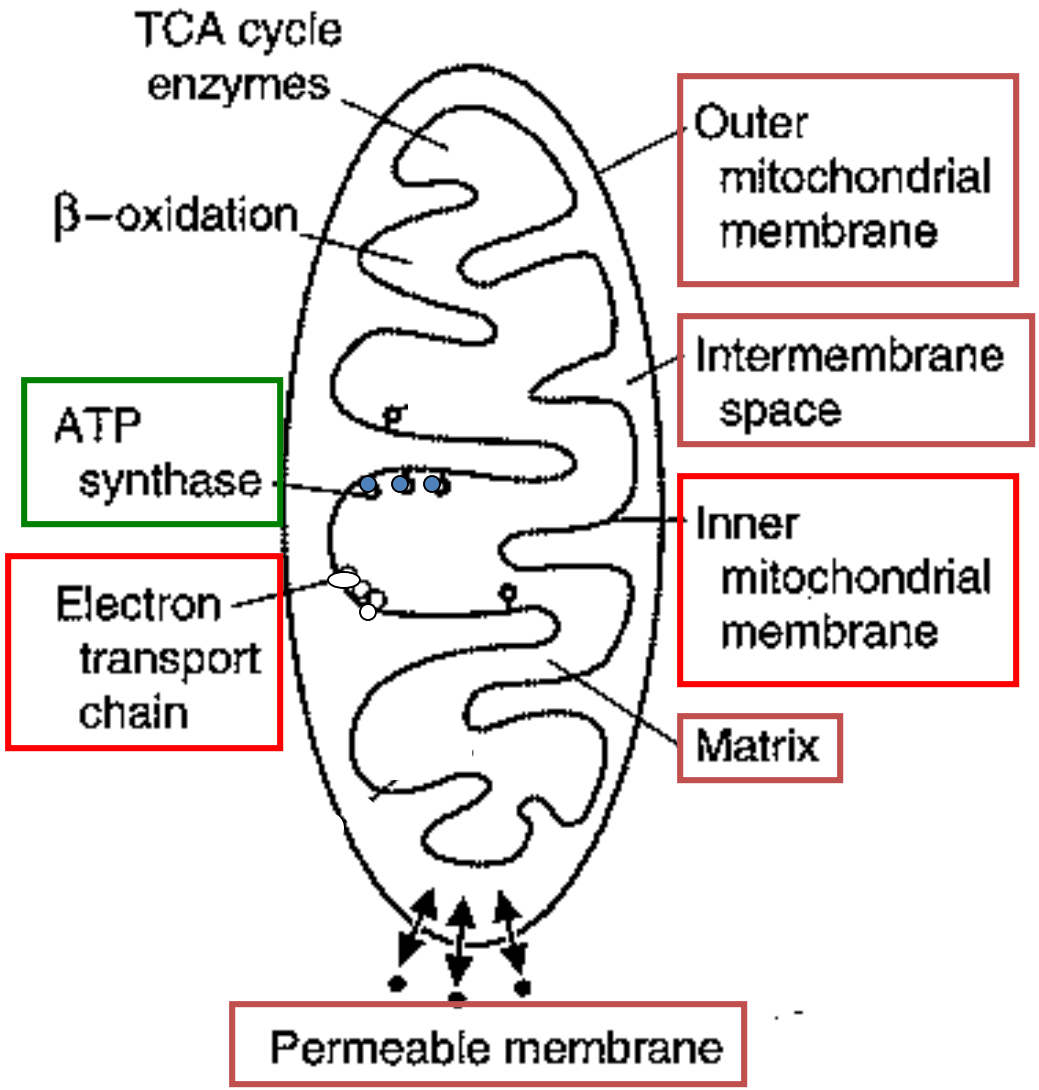



- During the cycle of reactions, most of the energy released is used to produce NADH and a second energy carrier $FADH_2$ (*flavin adenine dinucleotide*).

Free energy liberated (and stored in ATP, NADH and $FADH_2$) per acetic acid molecule:
$\Delta G = -2265$ kJ/mol

# Electron Transport and Oxidative Phosphorylation

# The mitochondrion contains the enzymes responsible for electron transport and oxidative phosphorylation




**In inner membrane knobs**

**Impermeable to ions and most other compounds**

# Electron Transport Chain (ETC) Complexes

- Complex I: NADH–Coenzyme Q Oxidoreductase
- Complex II: Succinate–Coenzyme Q Oxidoreductase
- Complex III: Coenzyme Q–Cytochrome *c* Oxidoreductase
- Complex IV: Cytochrome *c* Oxidase

# Functions of Mitochondrial Respiratory Chain

a) is to regenerate $NAD^+$ from NADH

b) is to regenerate FAD from $FADH_2$

c) is to finish oxidation of energy substrates and conserve their energy in a form of ATP

In reactions of the RCH

a) oxygen is reduced to $H_2O$

b) protons ($H^+$) are transfered into an intermembrane space

# Oxidation and Electron Transport

Electrons from NADH and $FADH_2$ are passed down *respiratory chain* to $O_2$

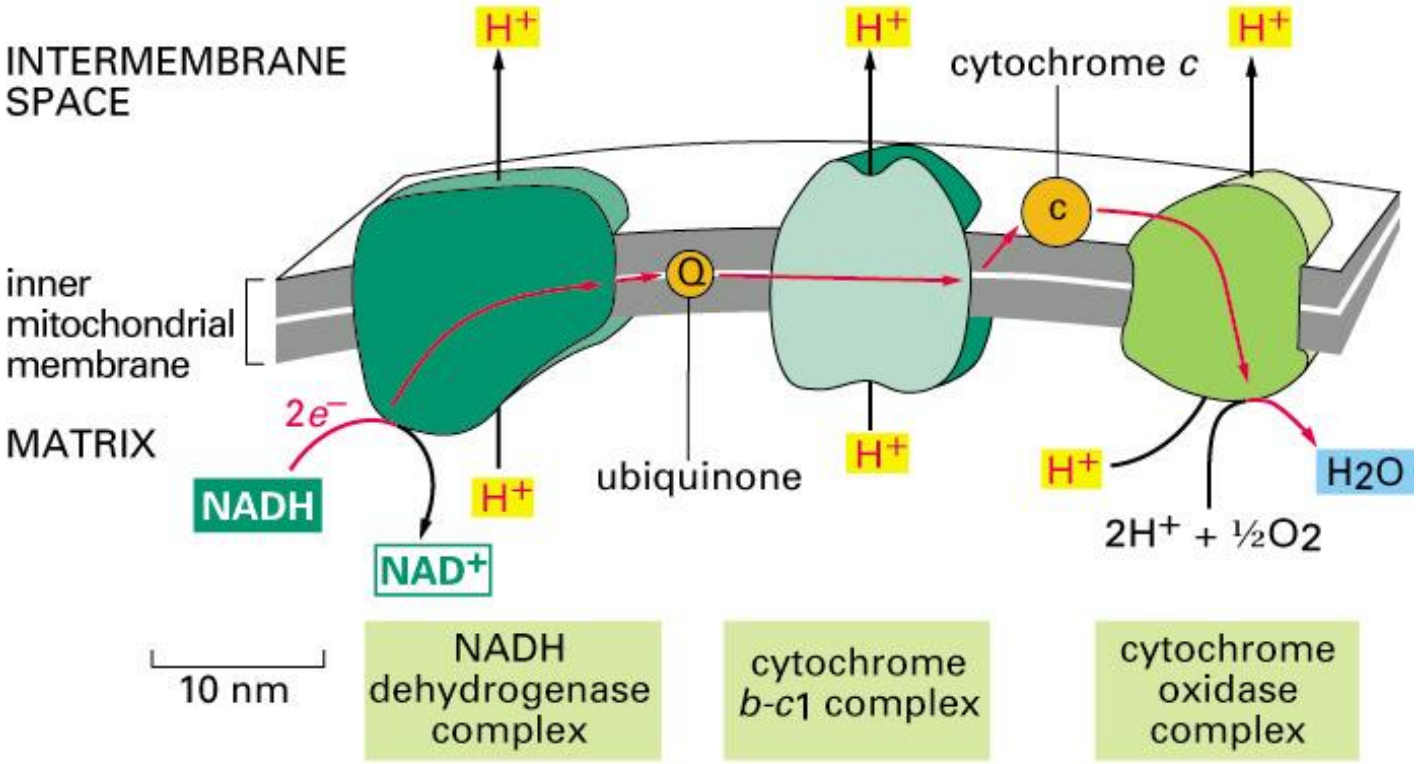



Figure 14–26. Molecular Biology of the Cell, 4th Edition.

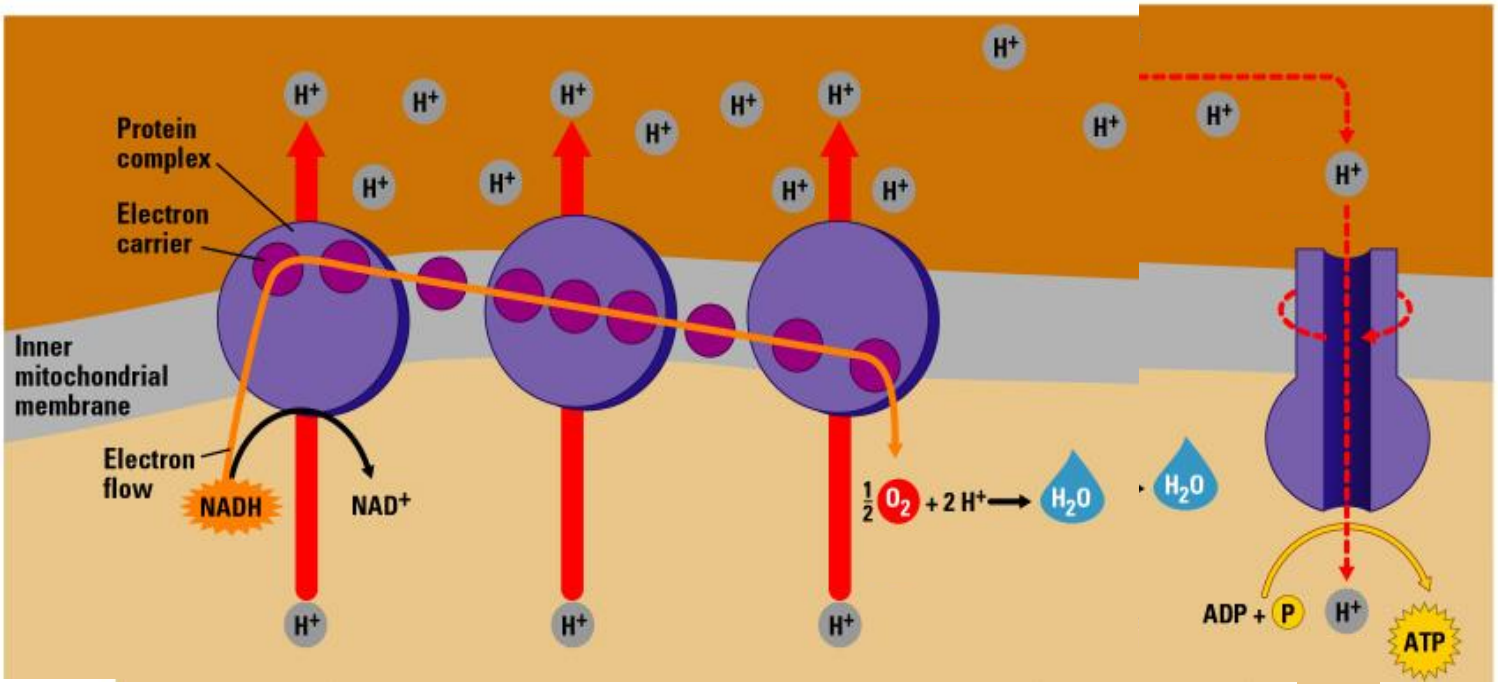
Electron transport expels protons, creating a proton gradient- the proton motive force (PMF)

# Electron Transport and ATP Production

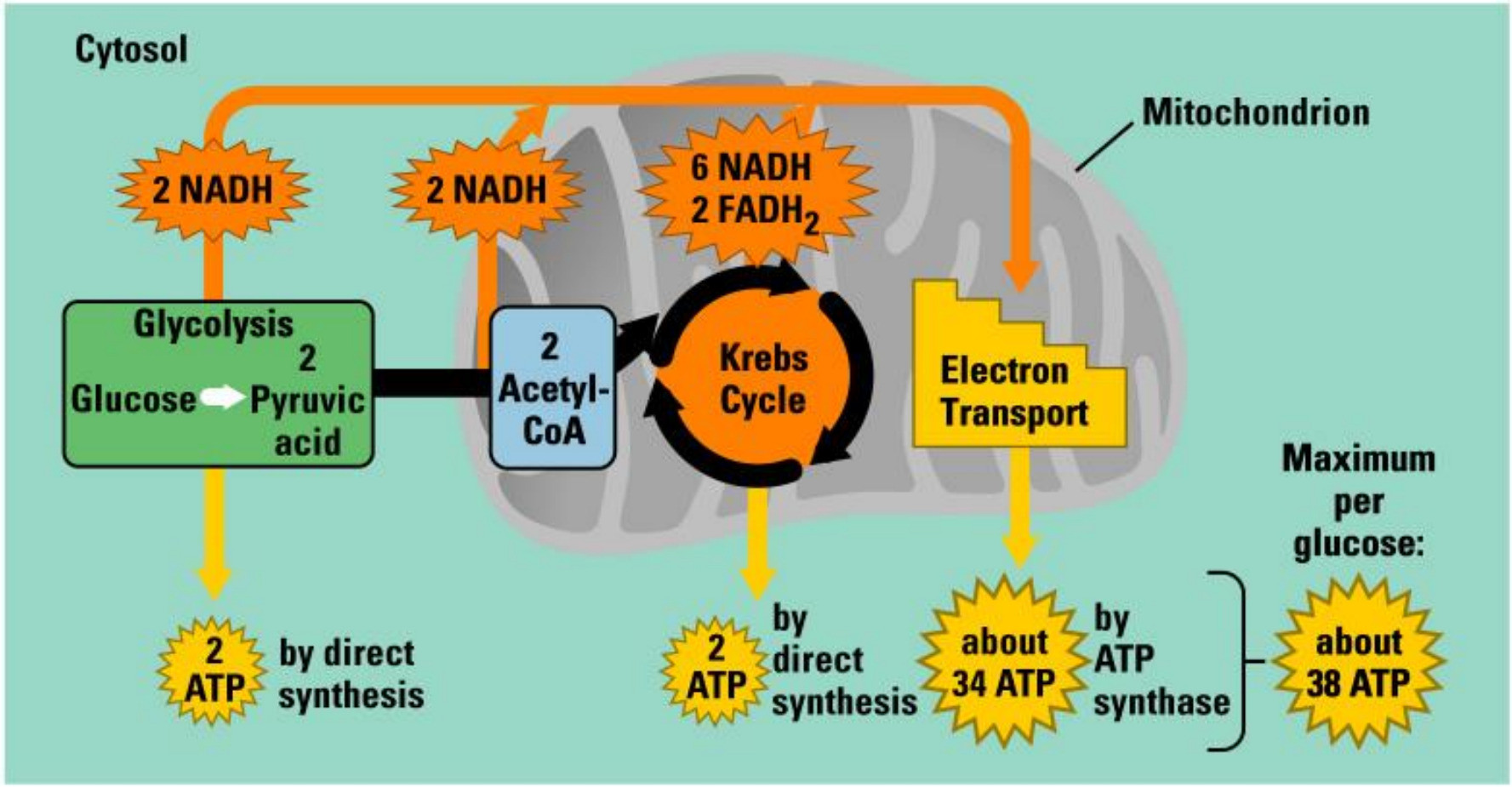
- Potential energy stored in the hydrogen ion gradient is released when the hydrogen ions re-enter the mitochondria through the enzyme complex called ATP SYNTHASE.
- ATP SYNTHASE uses the energy of the hydrogen ion gradient to generate ATP from ADP.

Input: 10 NADH, 2 $FADH_2$

Output: *approx.* 34 ATP



# Summary




One cell can have 1000 – 2000 mitochondria producing many energy-rich ATP molecules.