THE KREBS CYCLE

- The Krebs cycle, the citric acid cycle or Tri-Carboxylic Acid cycle (TCA).
- It is aerobic catabolic pathway seen in aerobic cellular respiration.
- Pyruvate is further metabolized in this process.
- Pyruvate is oxidized to reduce NAD+ and modified with coenzyme A to produce Acetyl-CoA complex.

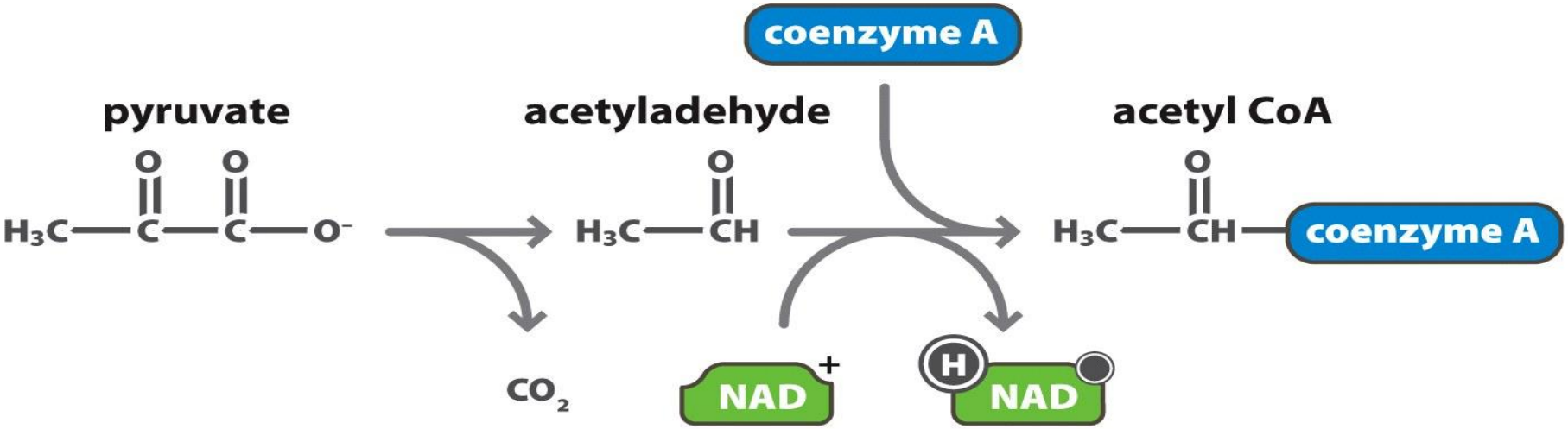


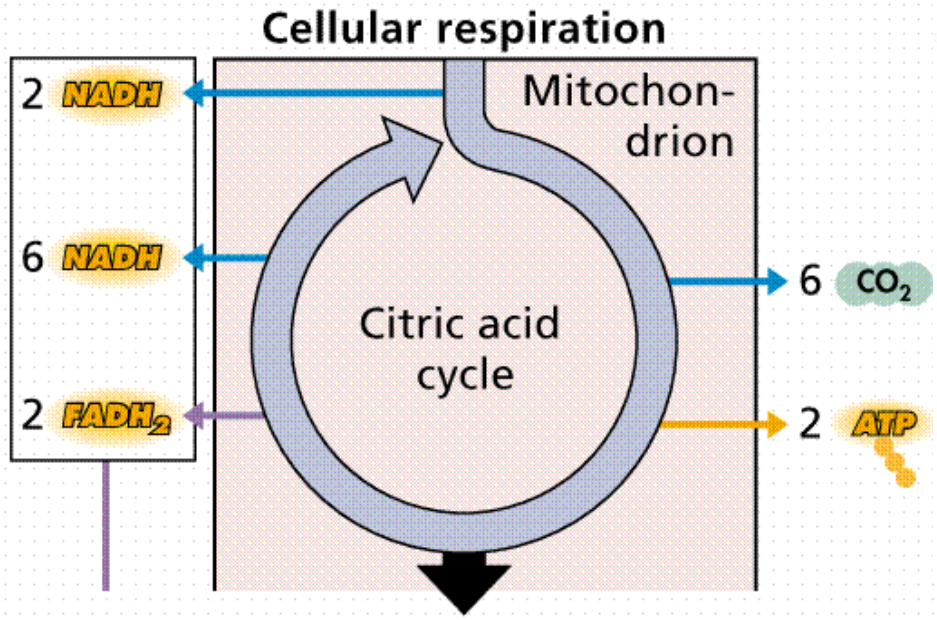
Figure 3.12 Microbiology: A Clinical Approach (© Garland Science)

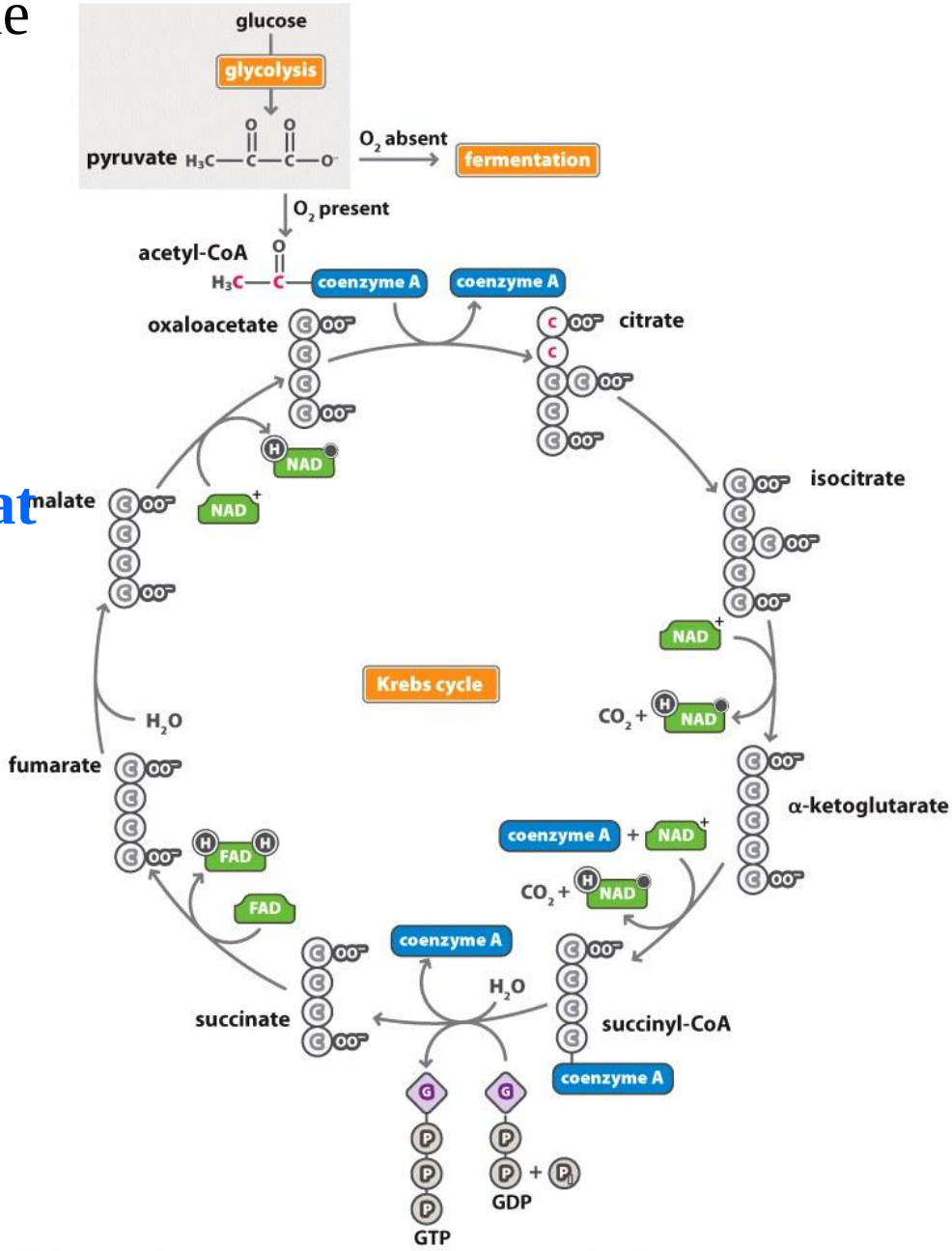
THE KREBS CYCLE

- The Krebs cycle is a series of reactions in which chemical changes occur.
  - Within these reactions, hydrogen atoms are removed and their electrons are transferred to coenzyme carrier molecules.
  - The hydrogen atoms are carried by NAD^+ and FAD to the electron transport system.

Three important things happen in the Krebs cycle:

- Carbon is oxidized as CO_2.
- Energy is stored when ADP is converted to ATP.
- **Electrons are transferred to coenzyme carrier molecules that take the electrons to the electron transport chain.**





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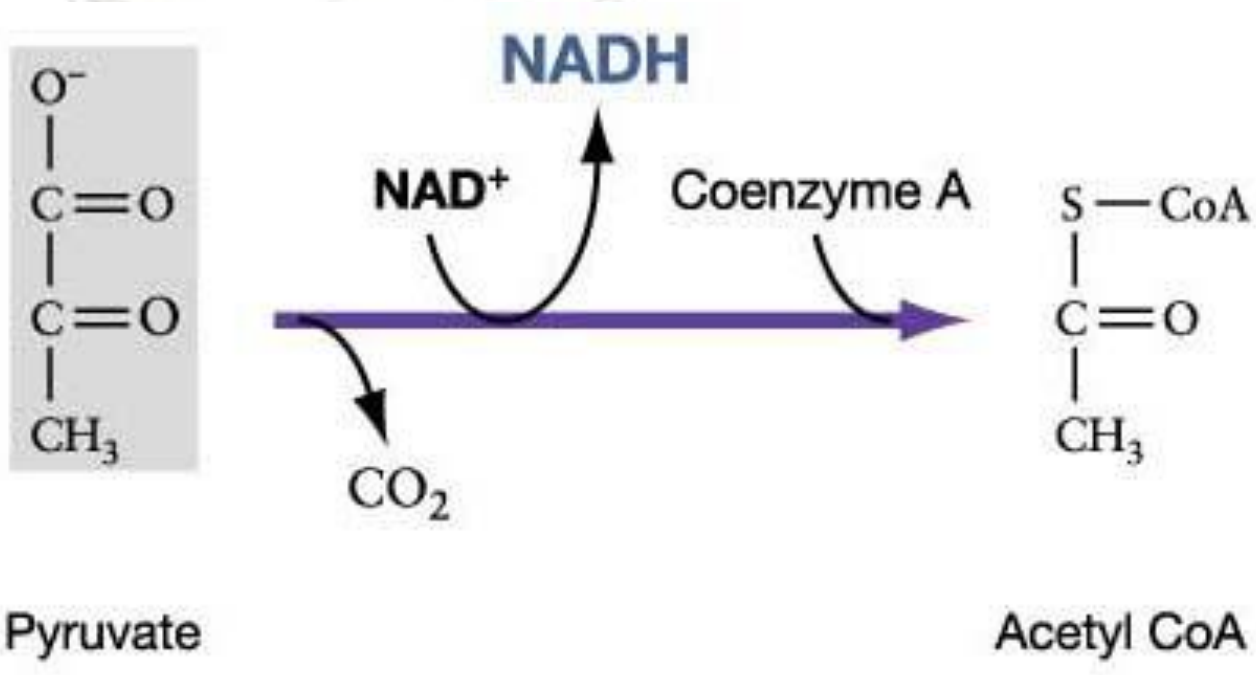
Oxidation of Pyruvate

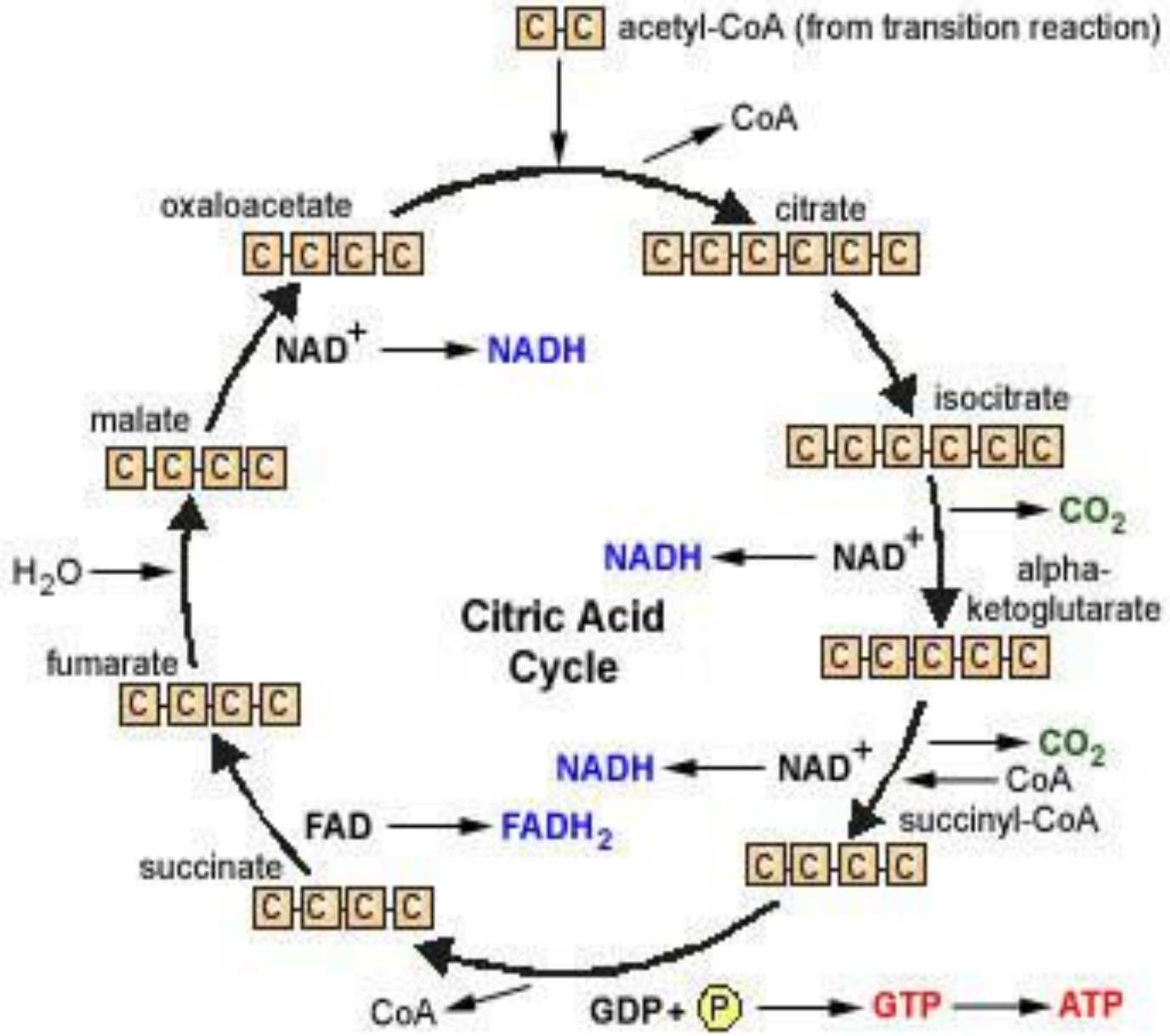
- The two molecules of pyruvate are oxidized and transformed into molecules of acetyl CoA.
- Takes place in mitochondria
- Also produces one molecule of NADH
- Releases CO_2

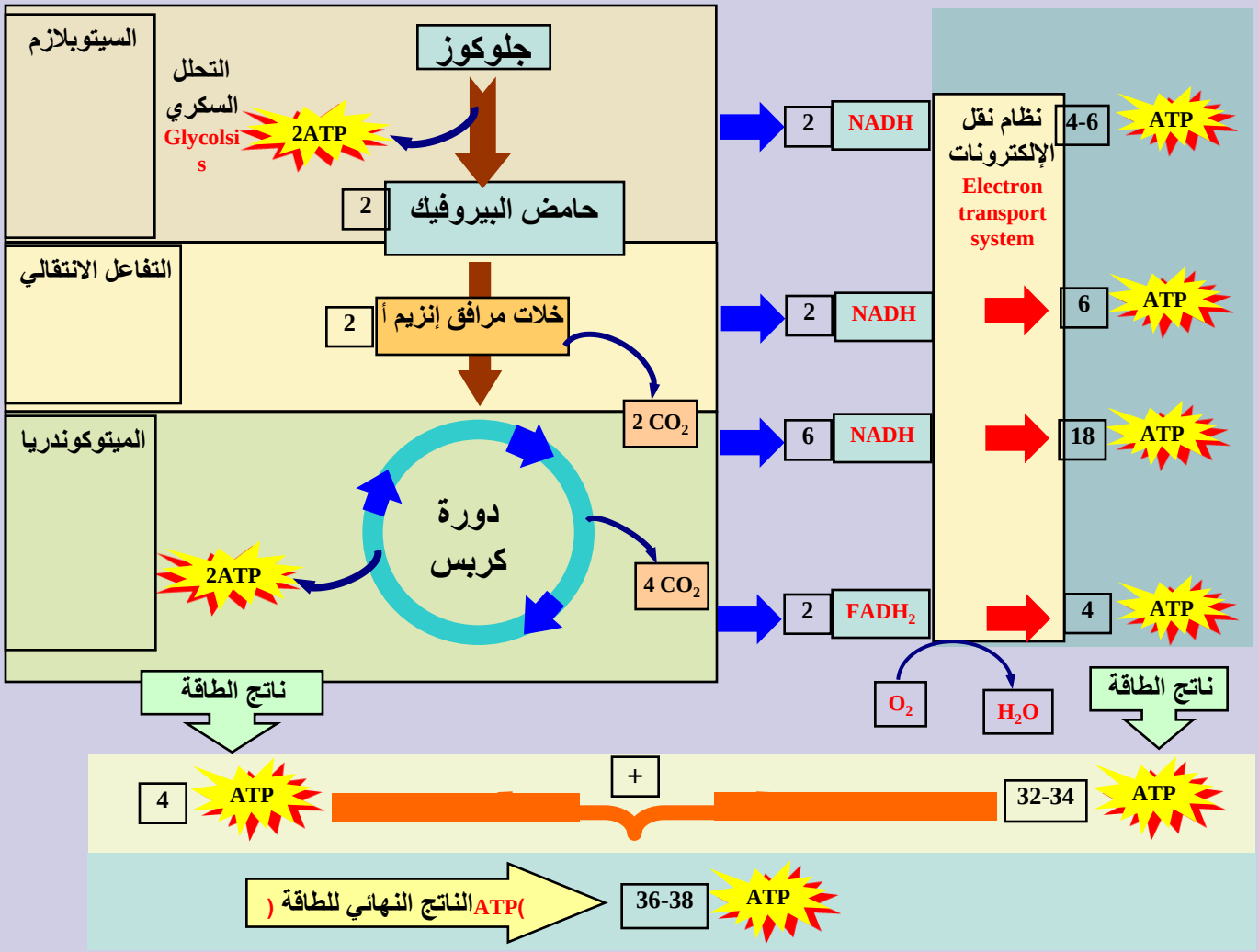


Kreb Cycle

- Takes place in matrix of the mitochondria
- Processes each acetyl CoA to produce 3 NADH, 1 $FADH_2$, and 1 ATP for a total of 6 NADH, 2 $FADH_2$, 2 ATP per glucose.
- Carbon dioxide is also released in this reaction.

Diagram of Kreb Cycle




السيتوبلازم
التحلل السكري Glycolsis
جلوكوز
2ATP
2
حامض البيروفيك
التفاعل الانتقالي
2
خلات مرافق إنزيم أ
2 CO_2
الميتوكوندريا
دورة كربس
2ATP
4 CO_2
2 NADH
2 NADH
6 NADH
2 $FADH_2$
نظام نقل الإلكترونات
Electron transport system
4-6 ATP
6 ATP
18 ATP
4 ATP
O_2
H_2O
ناتج الطاقة
ناتج الطاقة
4 ATP
+
32-34 ATP
الناتج النهائي للطاقة (ATP)
36-38 ATP

Oxidative Phosphorylation

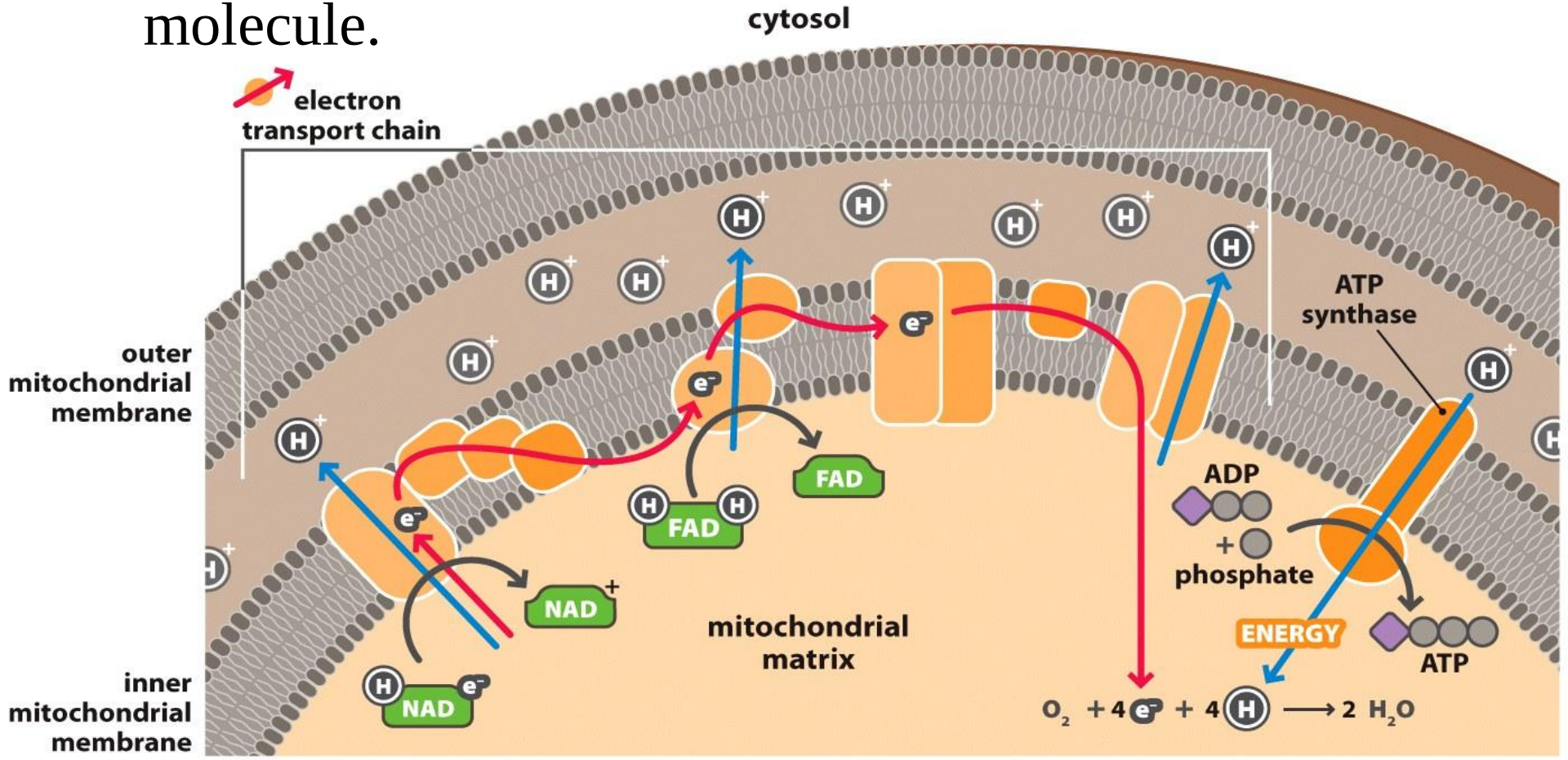
- After the Kreb Cycle, large amount of ATP produced from NADH (produces 3 ATP) and $FADH_2$ (produces 2 ATP)
- Requires the presence of oxygen in the mitochondria

ELECTRON TRANSPORT CHAIN

- The electron transport chain is a sequence of molecules.
  - In eukaryotes, they are found in the inner mitochondrial membrane.
  - In prokaryotes, they are organized in the plasma membrane.
- Is series of molecules embedded in the inner membrane of the mitochondria
- The 10 NADH and 2 $FADH_2$ (Produced from previous stages) power the production of the final 32 ATP

ELECTRON TRANSPORT CHAIN

- Electrons are transferred to a final electron acceptor.
  - In aerobic respiration, the final acceptor is oxygen.
  - In anaerobic respiration, the final acceptor is an inorganic molecule.



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CHEMIOSMOSIS

- As electrons move from one molecule to another in the chain, energy is released via a process called chemiosmosis.
- As electrons are transferred along the electron transport chain, protons are pumped out of the cell.
- This causes the proton concentration outside the cell to be higher than inside the cell, causing a concentration gradient to form.

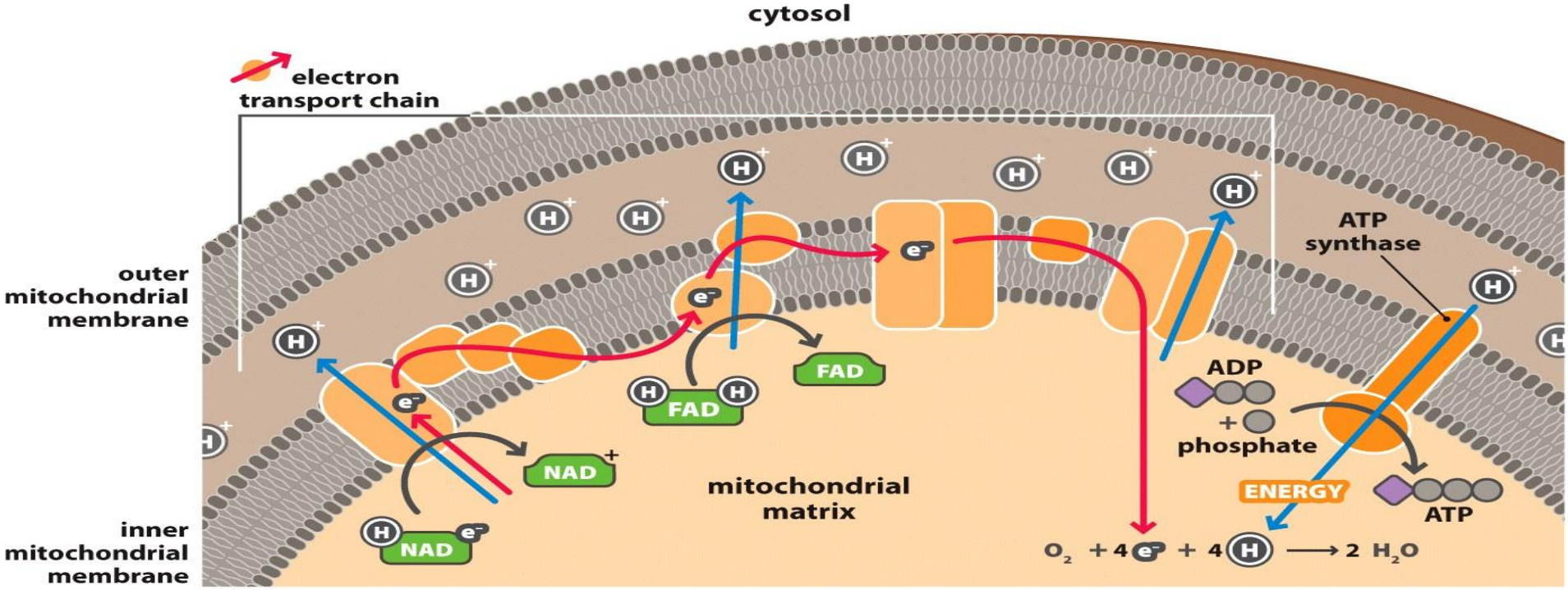


Figure 3.13 Microbiology: A Clinical Approach (© Garland Science)

CHEMIOSMOSIS

- Specialized membrane proteins allow protons to re-enter the cell.
  - Energy is released as protons re-enter the cell.
  - This energy is used to bind phosphate to ADP, making the high-energy molecule ATP.
  - The difference in proton concentration in this process is called the proton motive force.

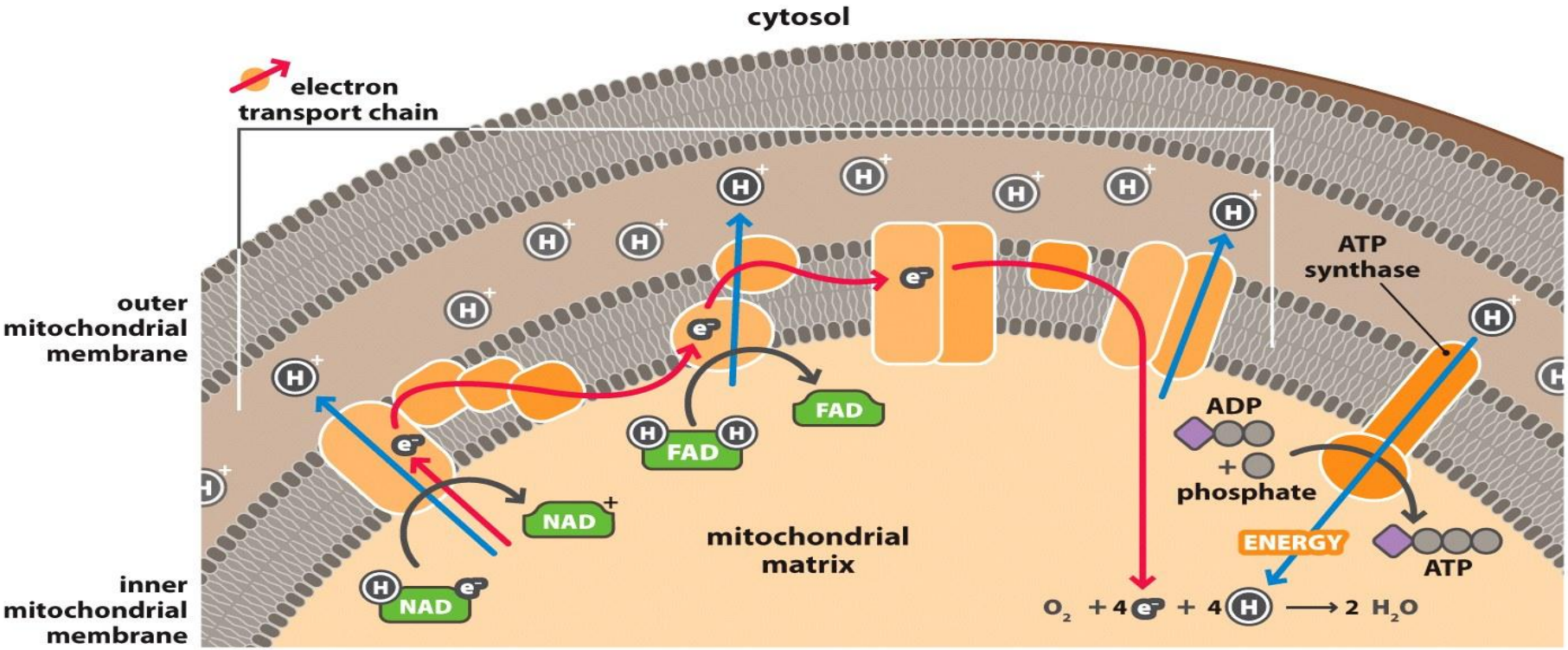
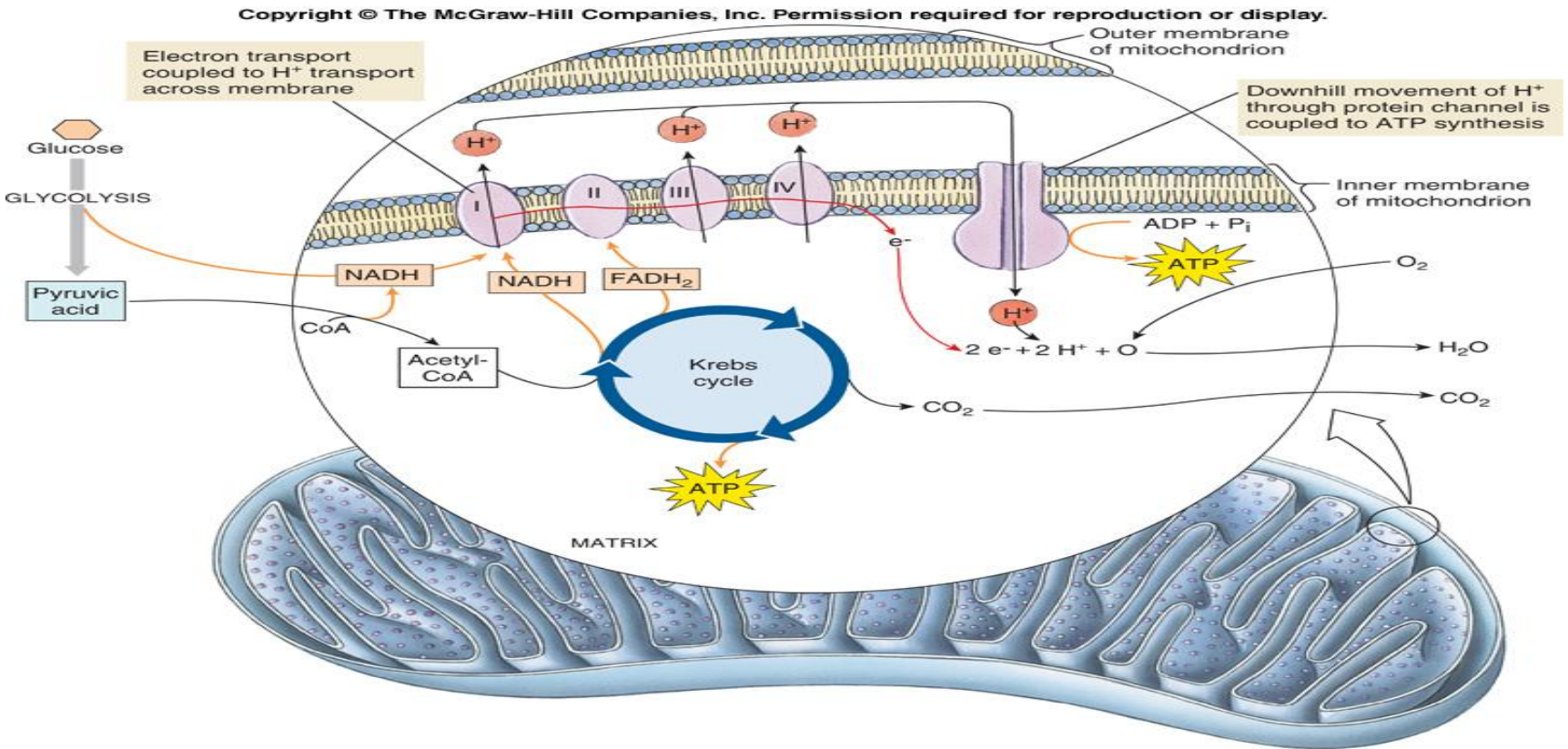


Figure 3.13 Microbiology: A Clinical Approach (© Garland Science)

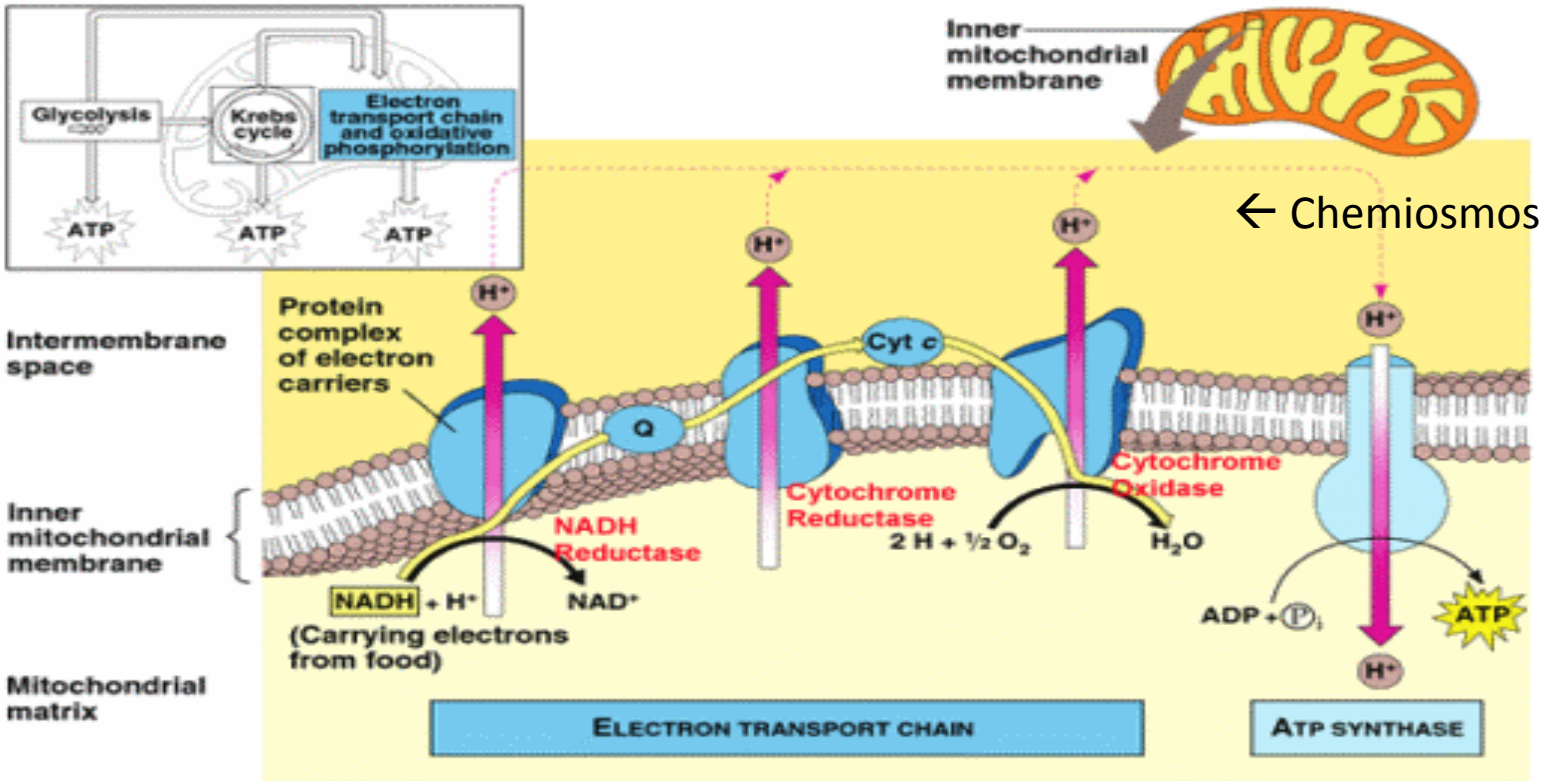
Using Electrons to Make ATP

- NADH & $FADH_2$ contain energized electrons.
- NADH molecules carry their electrons to the inner mitochondrial membrane where they transfer electrons to a series of membrane bound proteins – the **electron transport chain**.



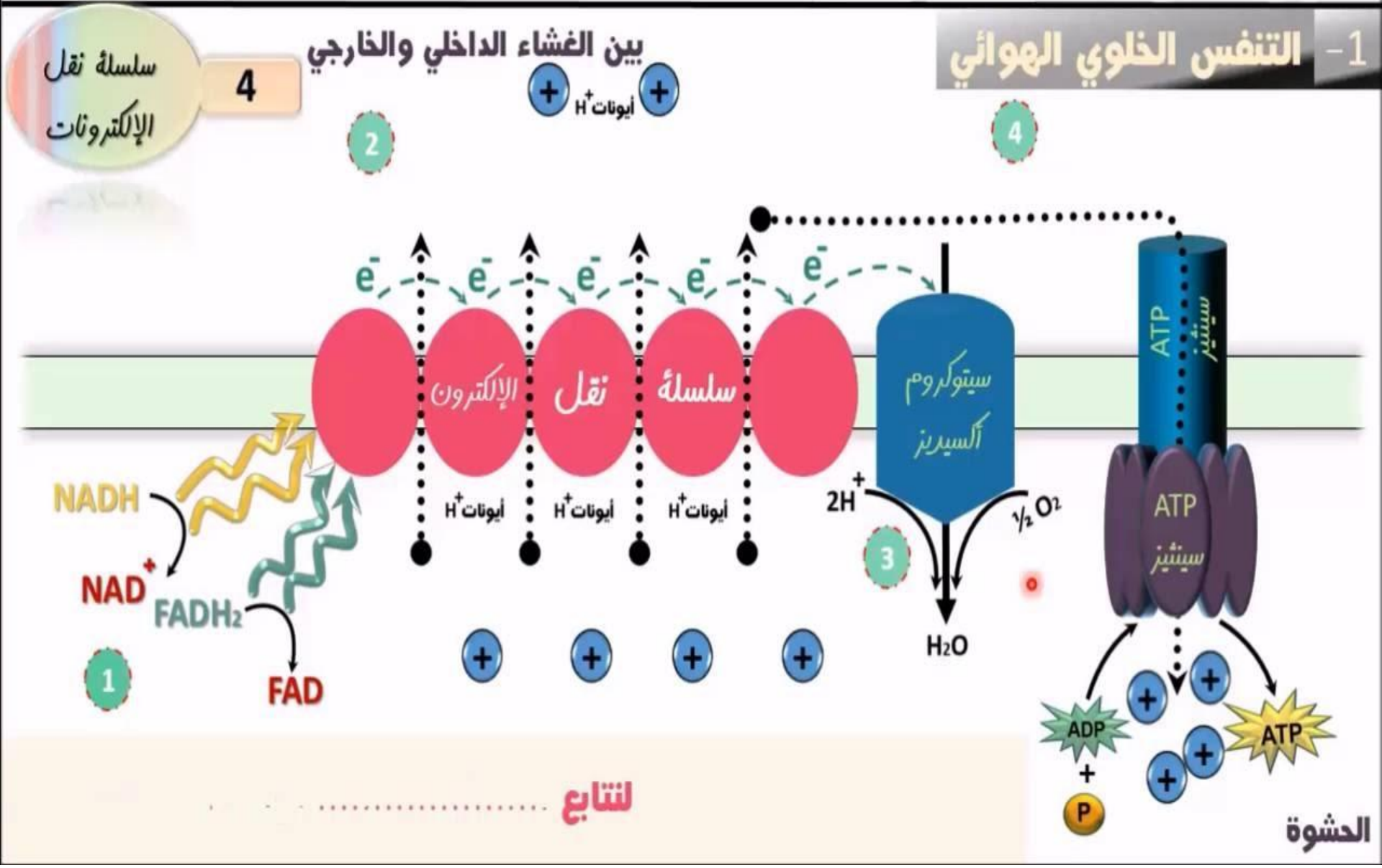
Continue…

- By pumping H+ into the intermembrane space, the electron transport chain sets up a high concentration gradient. H+ flows down gradient through the ATP synthase, a membrane protein that catalyzes the production of ATP from ADP.



←Oxidative phosphorylation

1- التنفس الخلوي الهوائي



CHEMIOSMOSIS

- Cells using anaerobic respiration generate two molecules of ATP from one glucose molecule.
- Cell using aerobic respiration generate thirty eight total molecules of ATP from one glucose molecule.

Aerobic respiration: 38 ATP / glucose molecule

Anaerobic respiration: 2 ATP / glucose molecule

Steps of the Electron Transport Chain

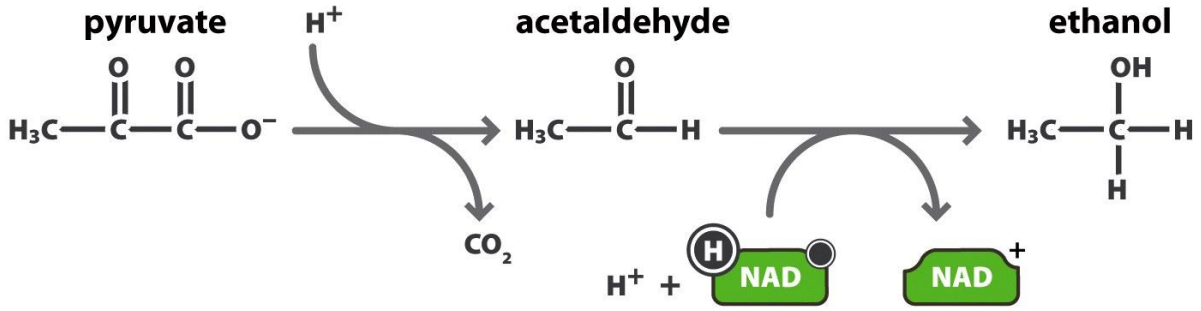
- 1- Electron carriers NADH and $FADH_2$ transferred electrons to the inner mitochondrial membrane.
- 2- NADH and $FADH_2$ donate their electrons in to series of membrane proteins. Each protein uses the energy in the electron to pump H+ into the intermembrane space of the mitochondrion before passing the electron the next carrier. The final electron receptor is O_2, which combines with two protons, H+ to form water

Summary of Cellular Respiration

Stage	Location	Reaction
Glycolysis	Cytosol	Converts 1 molecule of glucose to 2 molecules of pyruvate 2 ATP and 2 NADH molecules are produced and water is released
Oxidation of pyruvate	Mitochondria	Converts 2 molecules of pyruvate to 2 molecules of acetyl CoA 2 NADH molecules are produced and carbon dioxide is released
Kreb Cycle	Mitochondrial Matrix	Converts 2 molecules of acetyl CoA to 6 molecules of NADH, 2 molecules of $FADH_2$, and molecules of ATP. Carbon dioxide is released
Electron Transport Chain	Mitochnondria	10 NADH molecules and 2 $FADH_2$ are converted to 32 ATP molecules Oxygen is consumed and water is produced

FERMENTATION

- Fermentation is the enzymatic breakdown of carbohydrates in which the final electron acceptor is an organic molecule.



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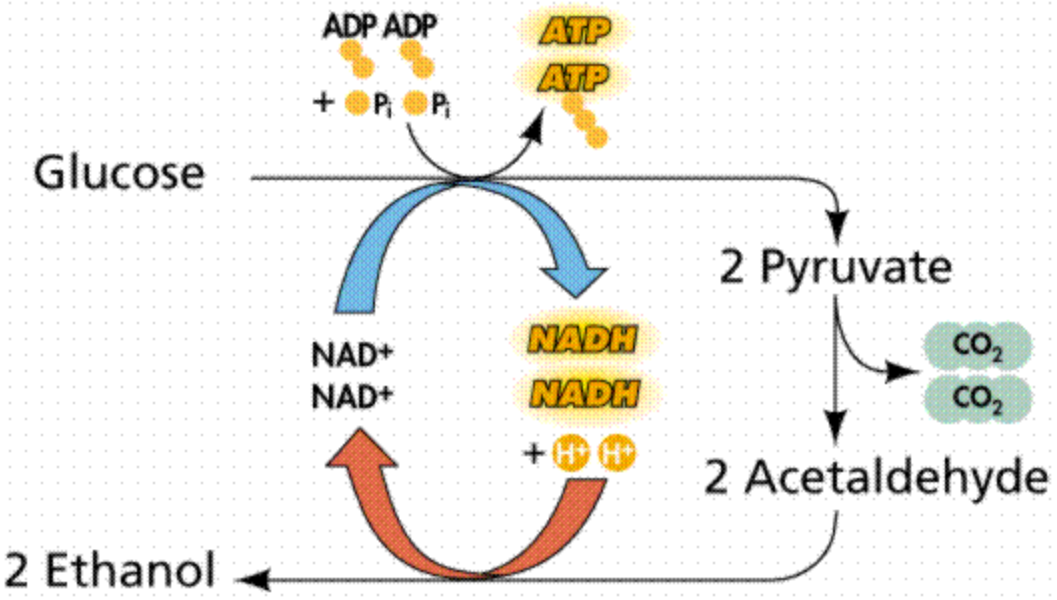

Fermentation

- Eukaryotic cells can produce ATP through fermentation.
- Fermentation is much less efficient than the four stages of cellular respiration, but allows ATP to produce when oxygen is not available
- Begins with glycolysis producing only 2 ATP.
- All other stages cannot be completed without oxygen.

Continue…

- Two types of fermentation:
  - 1- Alcoholic Fermentation: Pyruvic acid is converted to ethanol.
    - Used by fungi and some plants
    - Used to make beer, wine, and bread
  - 2- Lactic Acid Fermentation: Pyruvic acid is converted to lactate.
    - Lactic acid fermentation is used by animals and bacteria
    - Muscle Cramps (occurs when over exercise your muscles)
    - Sour Cream and buttermilk

Example: The sour taste of sourdough comes from the lactic acid produced by the fermentation of bacteria

Fermentation

- Can generate ATP in absence of O_2 – anaerobic
- Anaerobic organisms create ATP through glycolysis
  - Pyruvate converted to ethanol and CO_2 (yeast) or lactate (muscle)
- Process called fermentation