كلية الصيدلة - جامعة الزيتونة الأردنية
Faculty of Pharmacy
Al-Zaytoonah University of Jordan

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Biochemistry for Nursing

0201163

Dr. Bayan Al-Momany

2023-2024 / First semester

Subjects for part 4

- **Metabolism**

Introduction to metabolism

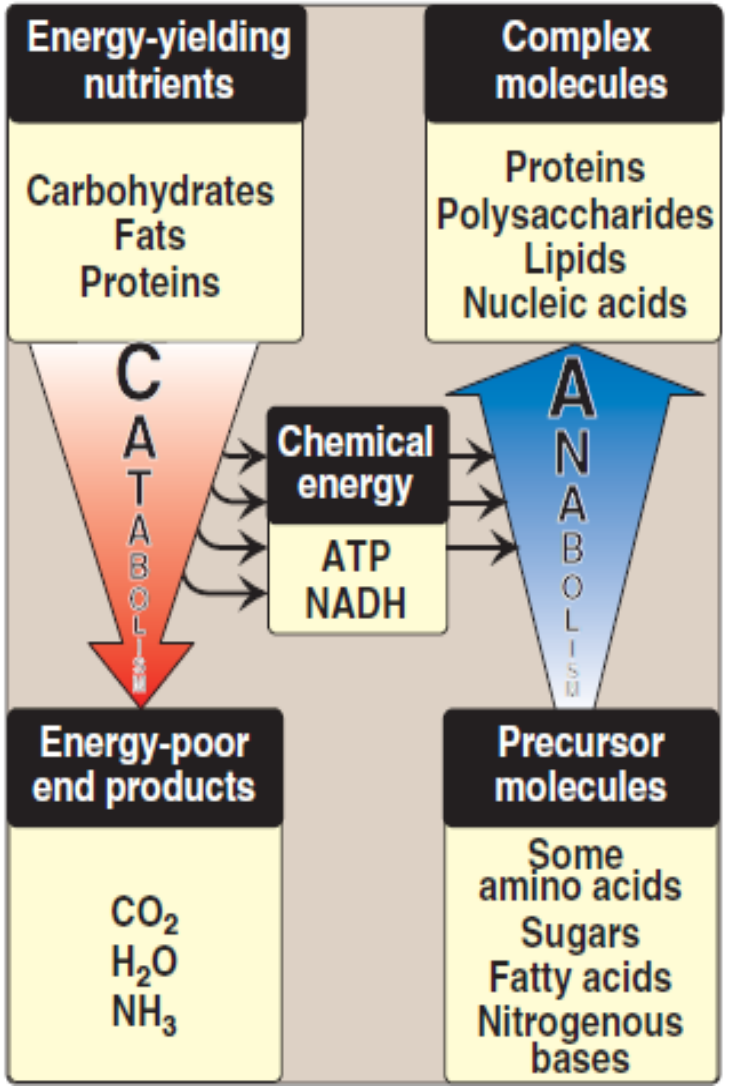
Metabolism: Metabolism refers to all chemical reactions involved in maintaining the living state of the cells and the organism.

Metabolism is divided into two types:

Catabolism: the breakdown of molecules to obtain energy (degradative pathways, E-producing).

Anabolism: the synthesis of compounds needed by the cells (Synthetic pathways, E-consuming).

Catabolic pathways produce energy, whereas anabolic pathways consume energy.

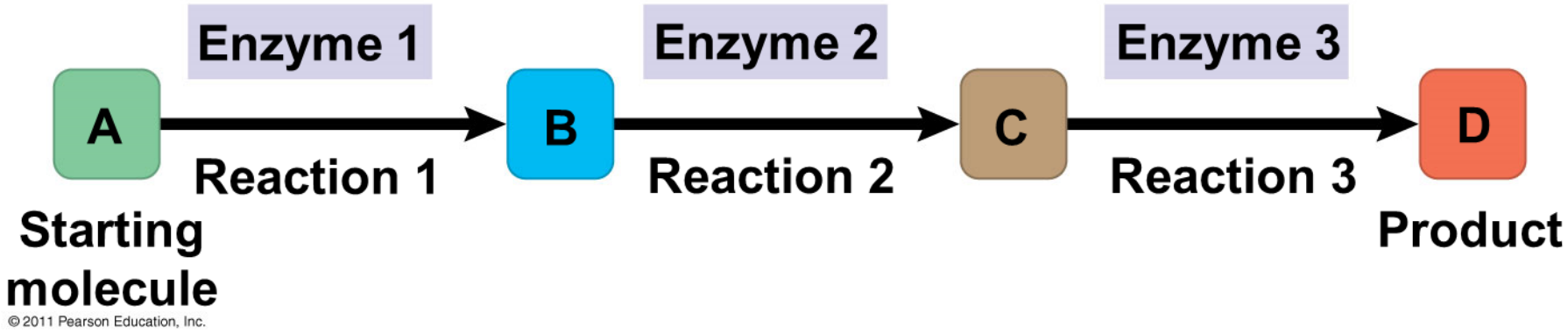


Bioenergetics is a term which describes the biochemical or metabolic pathways by which the cell ultimately obtains energy. Energy formation is one of the vital components of metabolism.

Metabolic pathway: a series of chemical reactions that take place in the cell to break down or synthesize molecules.

- ✓ Metabolic chemical reactions are catalyzed by enzymes.

Metabolic pathways are tightly regulated by different mechanisms including hormonal regulation.



Important metabolic compounds

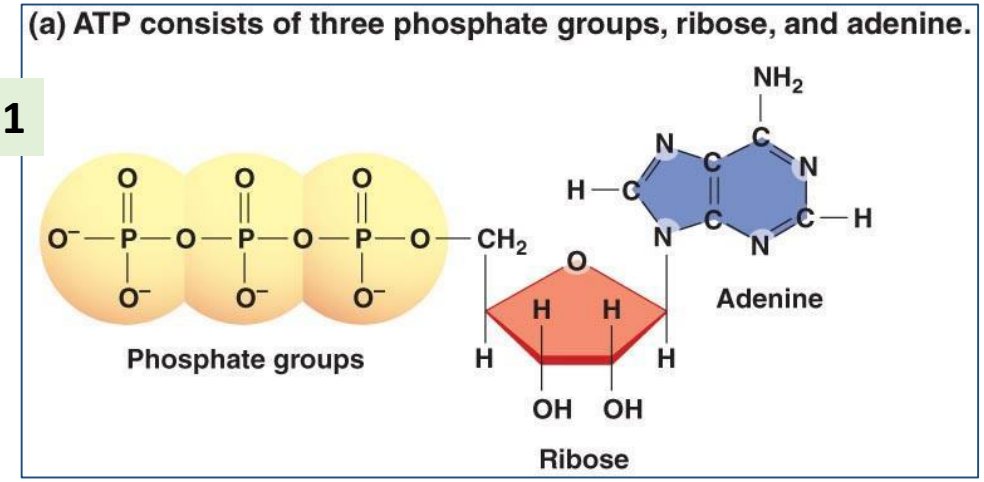
1. **ATP (Adenine triphosphate):** the energy currency of the cell.

2. The reducing equivalents: NADH, FADH2

- Reducing agents (rich in es) - e-donors
- coenzymes.
- A flavoprotein is a protein that contains a Flavin moiety (a derivative of riboflavin, vitamin B2).
- This may be in the form of FAD or Flavin mononucleotide (FMN):
- FADH2: Falvin Adenine Dinucleotide.
- NADH: Nicotinamide Adenine Dinucleotide (derived from the vitamin "niacin", vitamin B3).

3. Acetyl CoA = Acetyl group + β-mercaptoethylamine + Pantothenic acid (vit. B5) + 3', 5' ADP

1



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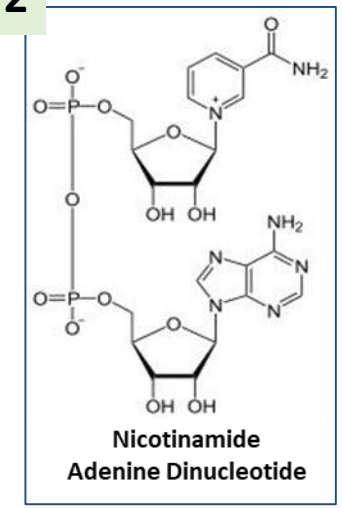

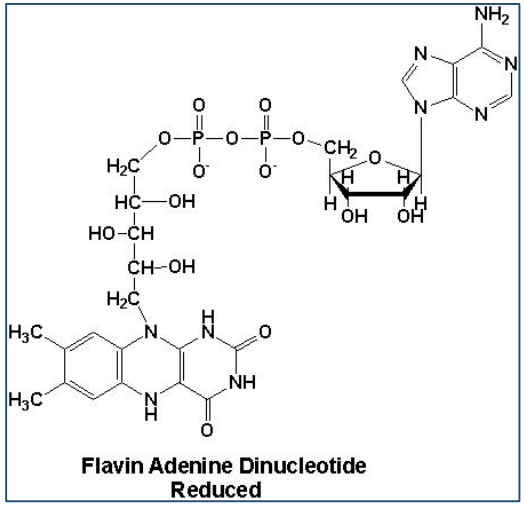

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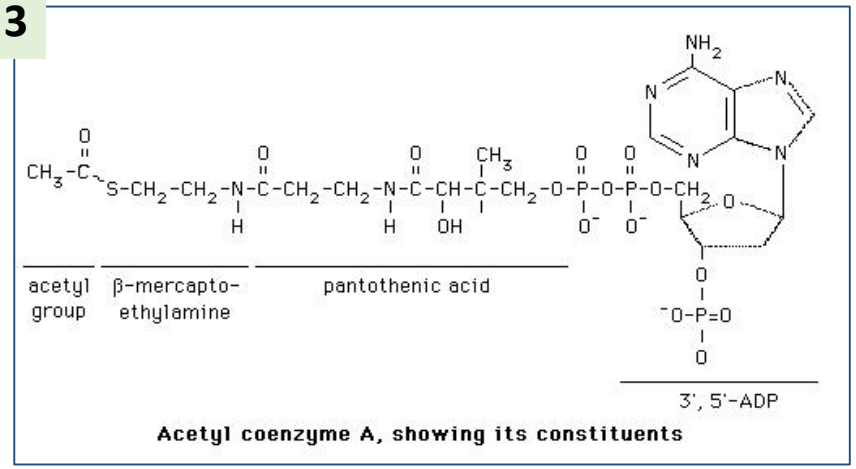
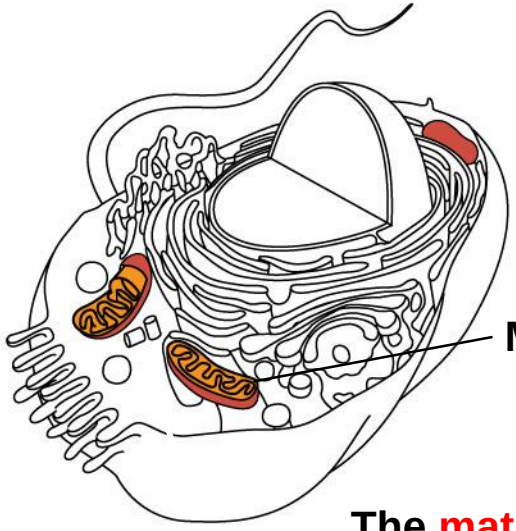
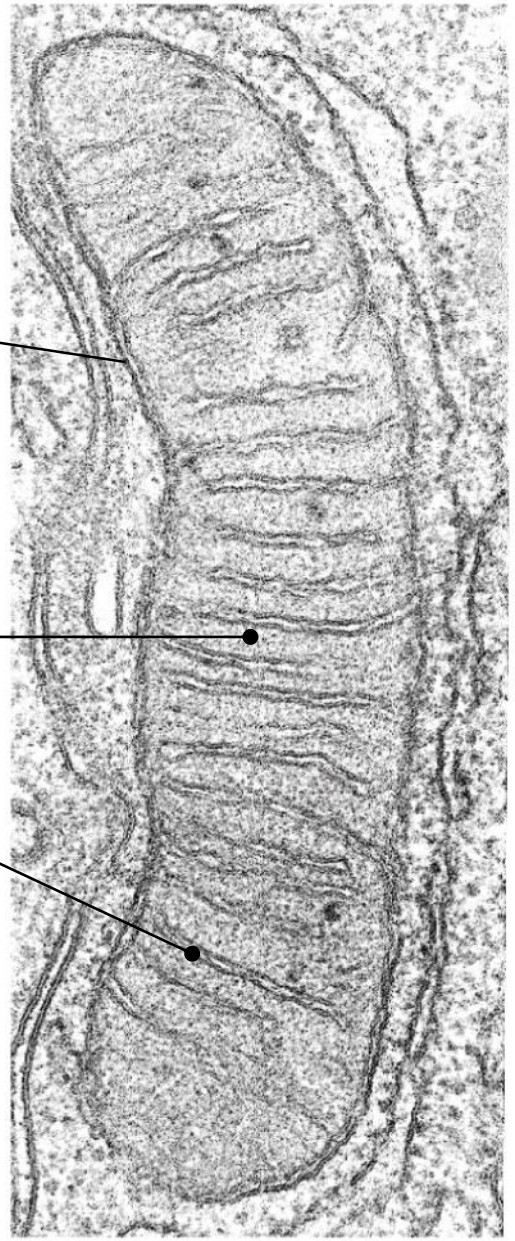


Mitochondria: the house of energy! An important organelle in cellular metabolism.





The matrix contains enzymes in solution that are involved in one stage of cellular respiration.

Enzymes for another stage of cellular respiration are embedded in the inner membrane.

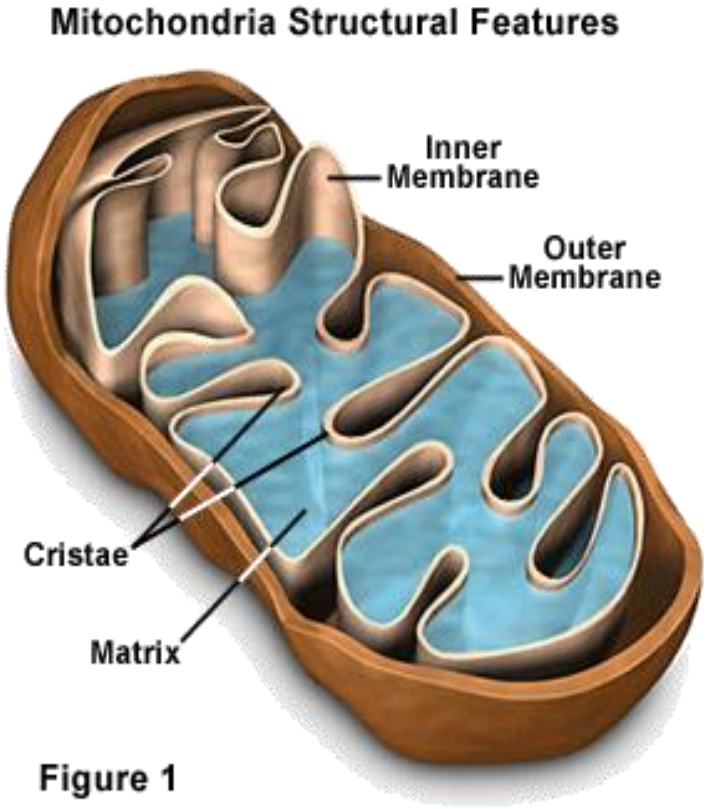


Figure 1

The inner mitochondrial membrane is **impermeable** to charged molecules, such as protons (H^+)

1 μm

Overview of cellular respiration

Cellular respiration includes both aerobic and anaerobic respiration but is often used to refer to aerobic respiration.

Although carbohydrates, fats, and proteins are all consumed as fuel, it is helpful to trace cellular respiration with the sugar glucose:

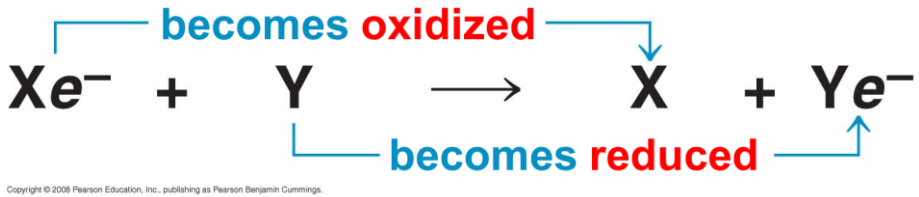
$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$$

(ATP + heat)

Redox Reactions: Oxidation and Reduction

Oxidation is a LOSS (of H or electrons).

Reduction is a GAIN (of H or electrons).

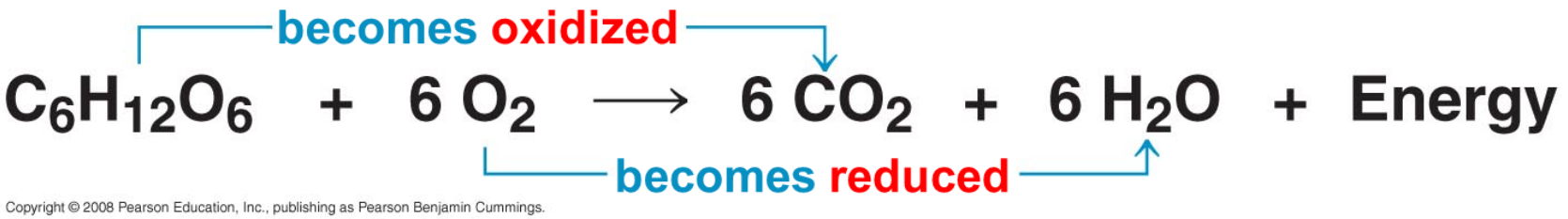


The transfer of electrons during chemical reactions releases energy stored in organic molecules.
This released energy is ultimately used to synthesize ATP.

Oxidation of Organic Fuel Molecules During Cellular Respiration

During cellular respiration:

The fuel C-H-O (such as glucose) is oxidized, looses H's and O_2 is reduced, gains H's



Stepwise Energy Harvest via NAD^+ and the Electron Transport Chain

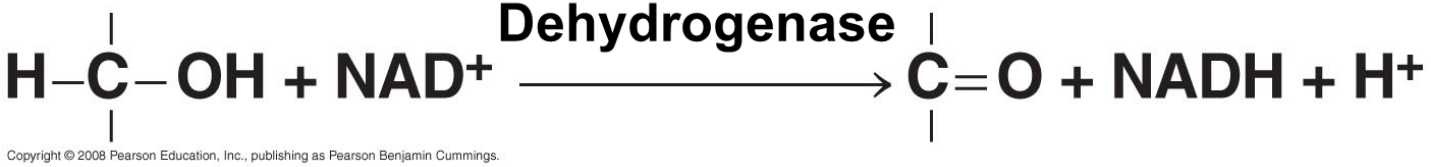
In cellular respiration, glucose and other organic molecules are broken down in a series of steps.

Electrons from organic compounds are usually first transferred to **NAD^+** = *a coenzyme*.

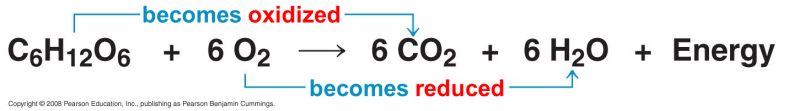
As an electron acceptor, NAD^+ functions as an oxidizing agent during cellular respiration.

NADH = the reduced form of NAD^+ . Each NADH represents stored energy that is tapped to synthesize ATP.

NAD+ is Reduced to NADH + H^+

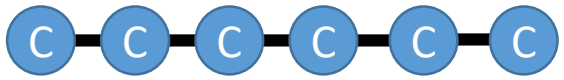


Cellular Respiration



Hydrocarbon molecule

energy within bonds



Breaking bond to release energy

Carbon dioxide (CO_2)

X 6

Get out by exhalation

Electrons from organic compounds are usually first transferred to **NAD^+**

NAD+ is Reduced to $NADH + H^+$

NADH →  → Oxidative phosphorylation <Electron transport chain>

Mitochondria

Low energy electrons are used to reduce O_2 (Take in by inhalation)

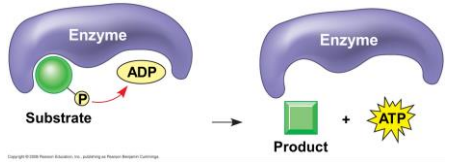
$6\ O_2 \rightarrow 6\ H_2O$

ATP ≈ 32 - 34

ATP = 4

Directly generated using special enzymes

Substrate-level phosphorylation



The Stages of Cellular Respiration: *A Preview*

Cellular respiration has four stages:

1. Glycolysis (breaks down glucose into two molecules of pyruvate)

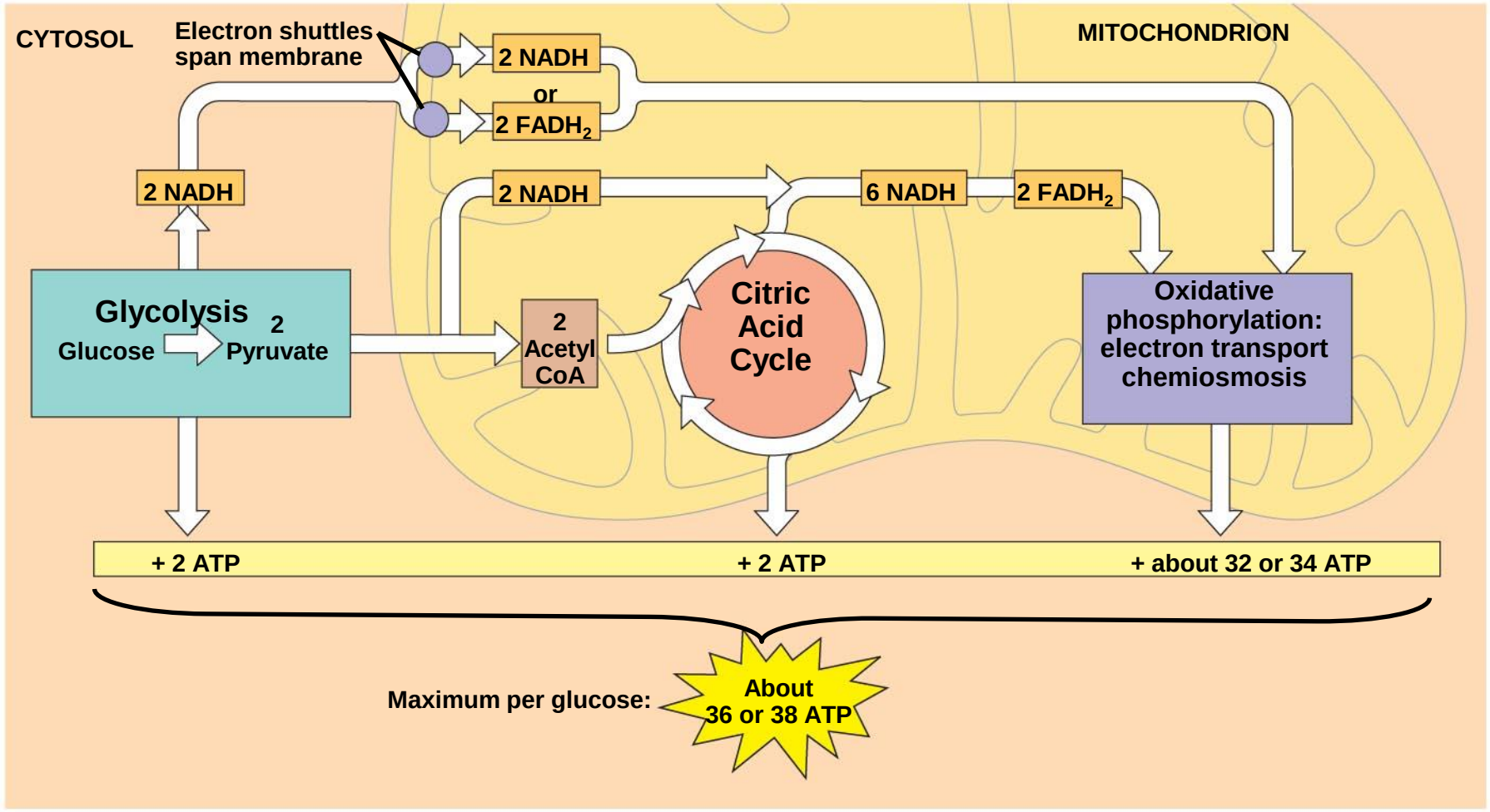
2. Pyruvate oxidation

3. The citric acid cycle: Tricarboxylic acid cycle (TCA) or Krebs Cycle (completes the breakdown of glucose)

4. Oxidative phosphorylation (accounts for most of the ATP synthesis) by ***chemiosmosis*.**

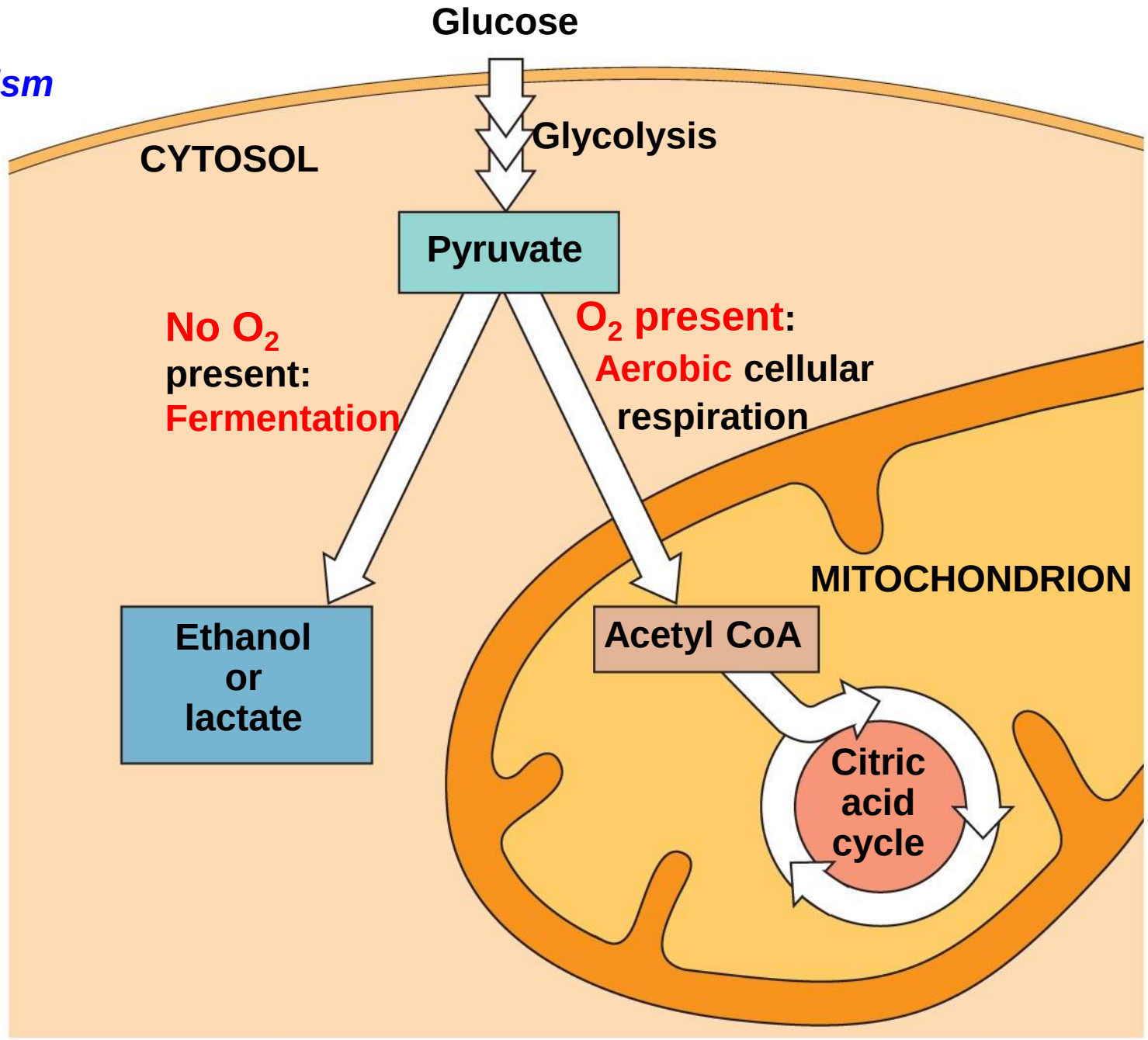
Aerobic Cellular Respiration

ATP yield per molecule of glucose at each stage of cellular respiration



The process in cell respiration that generates most of the ATP is oxidative phosphorylation (powered by redox reactions).
Oxidative phosphorylation accounts for almost 90% of the ATP generated by cellular respiration.
A smaller amount of ATP is formed in *glycolysis* and the *citric acid / Krebs Cycle* by *substrate-level phosphorylation.*

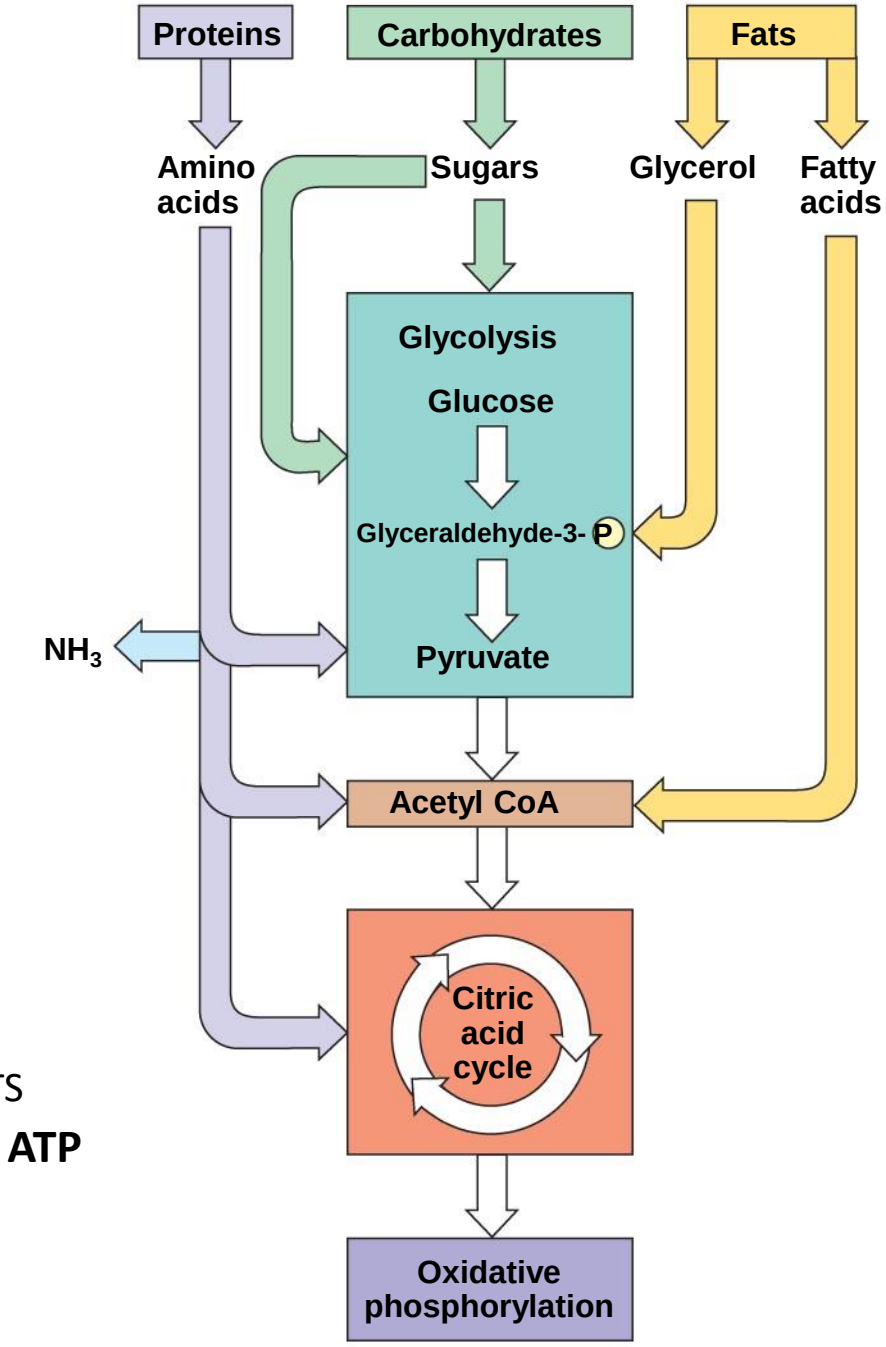
Pyruvate as a key juncture in catabolism



Overview of metabolism of dietary molecules

Note that the oxidation of ALL dietary macromolecules (CHO, protein, fat) finally results in the production of Acetyl CoA, which enters TCA cycle where it is oxidized to CO_2, producing NADH, $FADH_2$ which are then oxidized in the ETS and produce ATP.

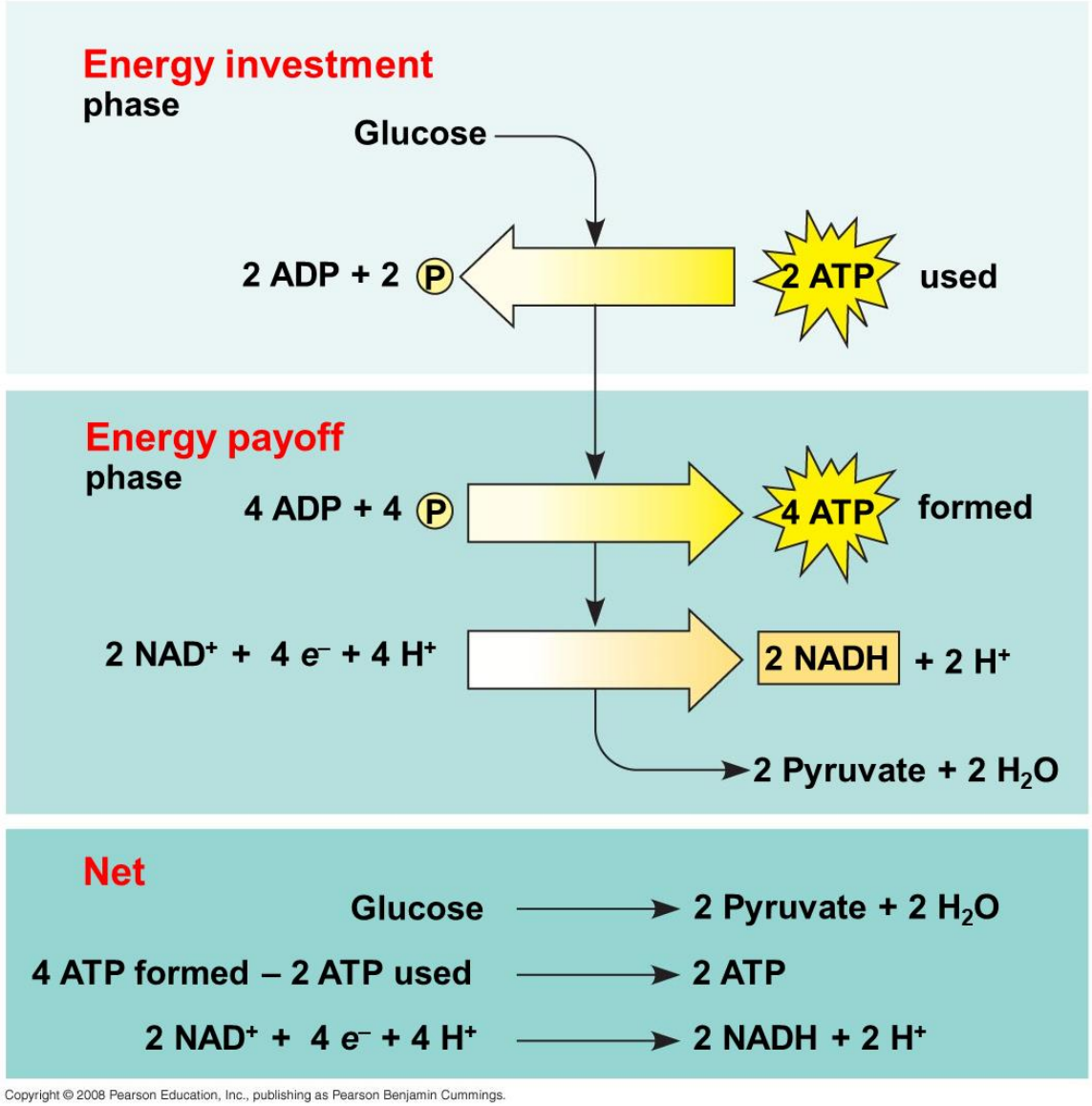
CHO / Fat / Protein —(oxidation)→ **Acetyl CoA** —(TCA)→ **NADH + $FADH_2$** —(ETS)→ **ATP**



- Good luck in your final exam ☺

Glycolysis harvests chemical energy by oxidizing glucose to pyruvate

- **Glycolysis** ("sugar splitting") breaks down glucose into two molecules of pyruvate.
- IN THE CYTOSOL
- 10 STEPS
- Glycolysis occurs in the cytoplasm and has two major phases:
  - Energy investment phase (FIRST 5 STEPS) = E_A
  - Energy payoff phase (LAST 5 STEPS) = ATP and NADH



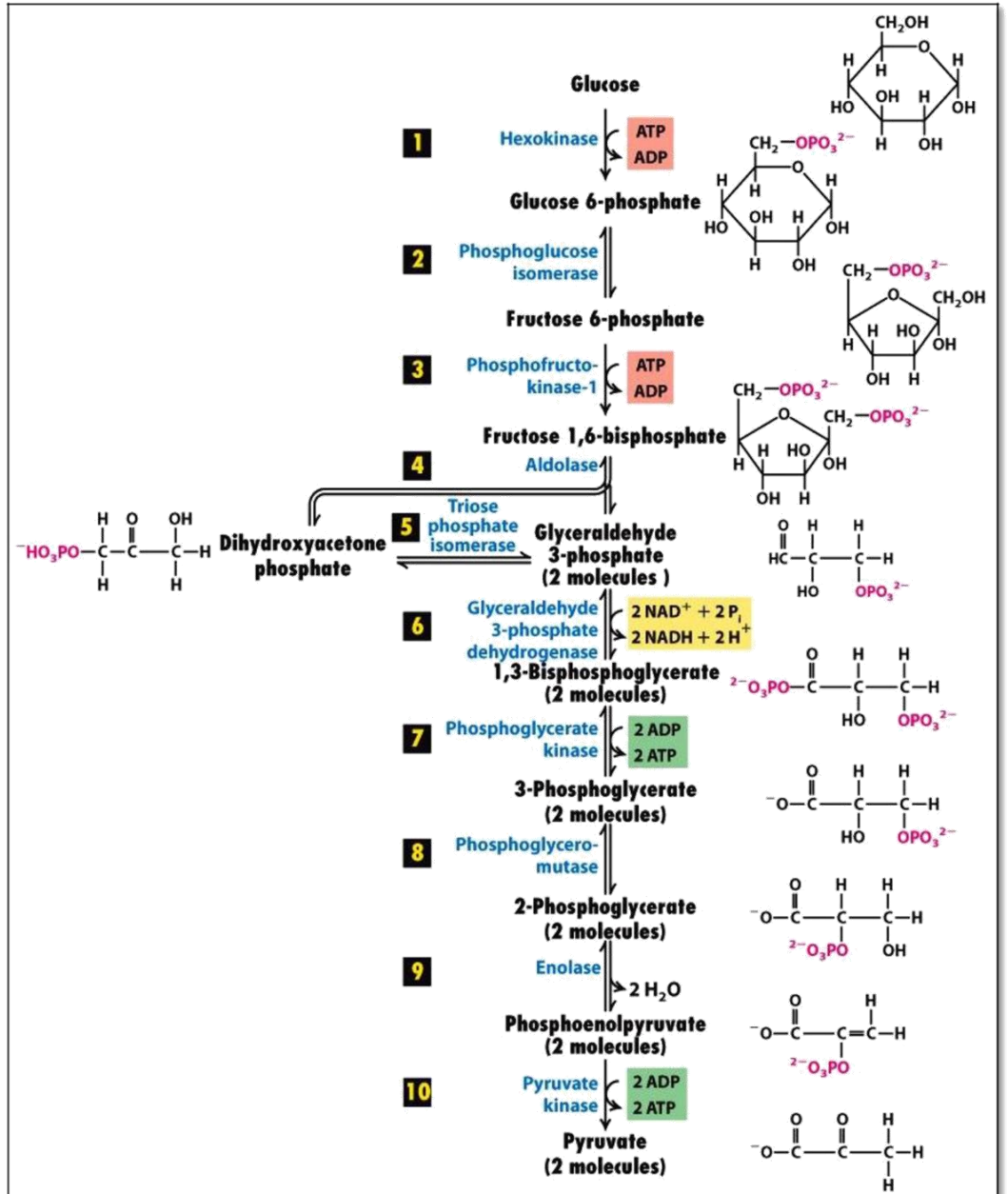


Figure 12-3
Molecular Cell Biology, Sixth Edition

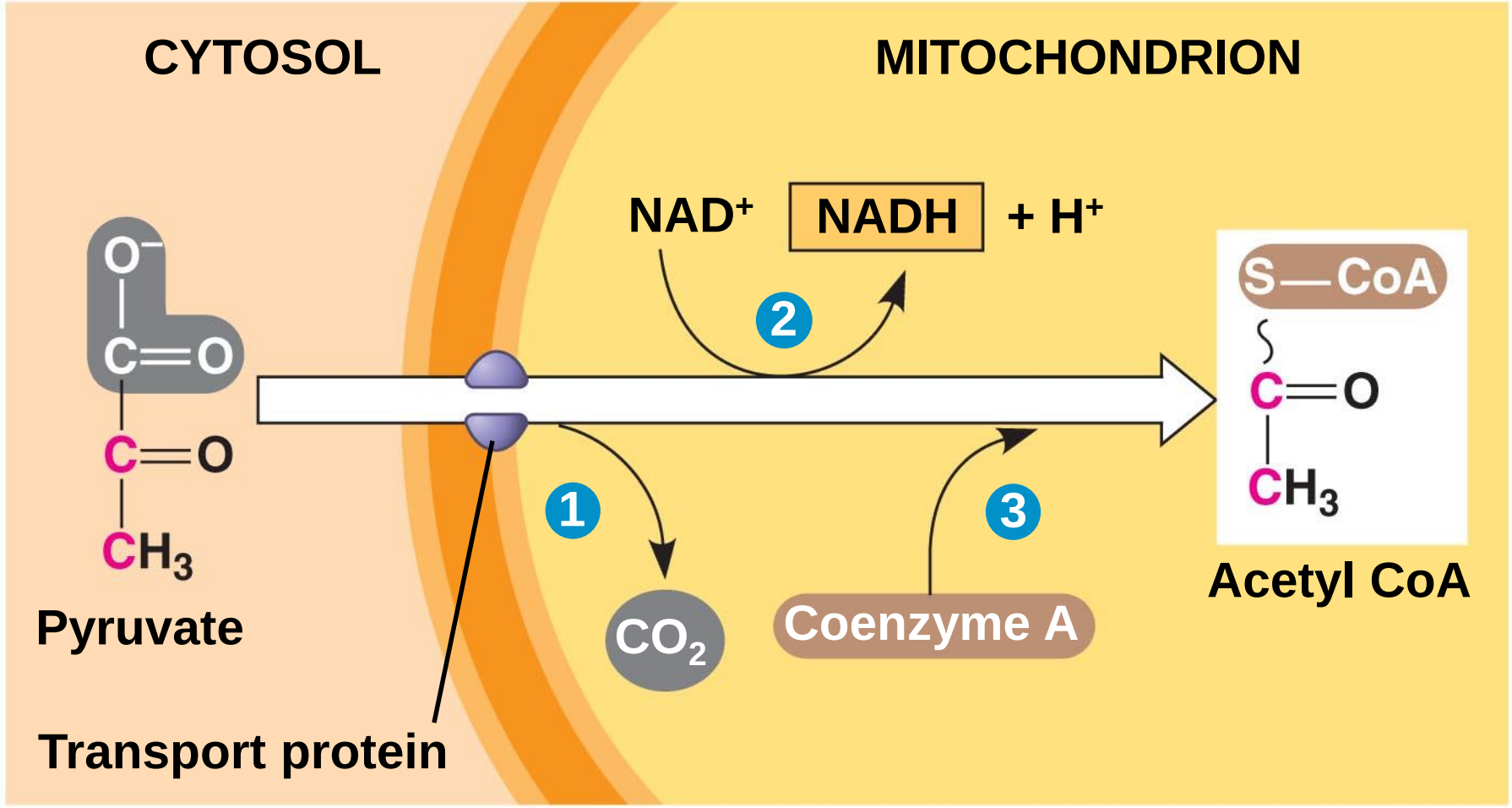
Conversion of pyruvate to acetyl CoA, the junction between glycolysis and the citric acid cycle

pyruvate must be converted to **acetyl CoA**

Acetyl CoA = Acetate + CoEnzyme A

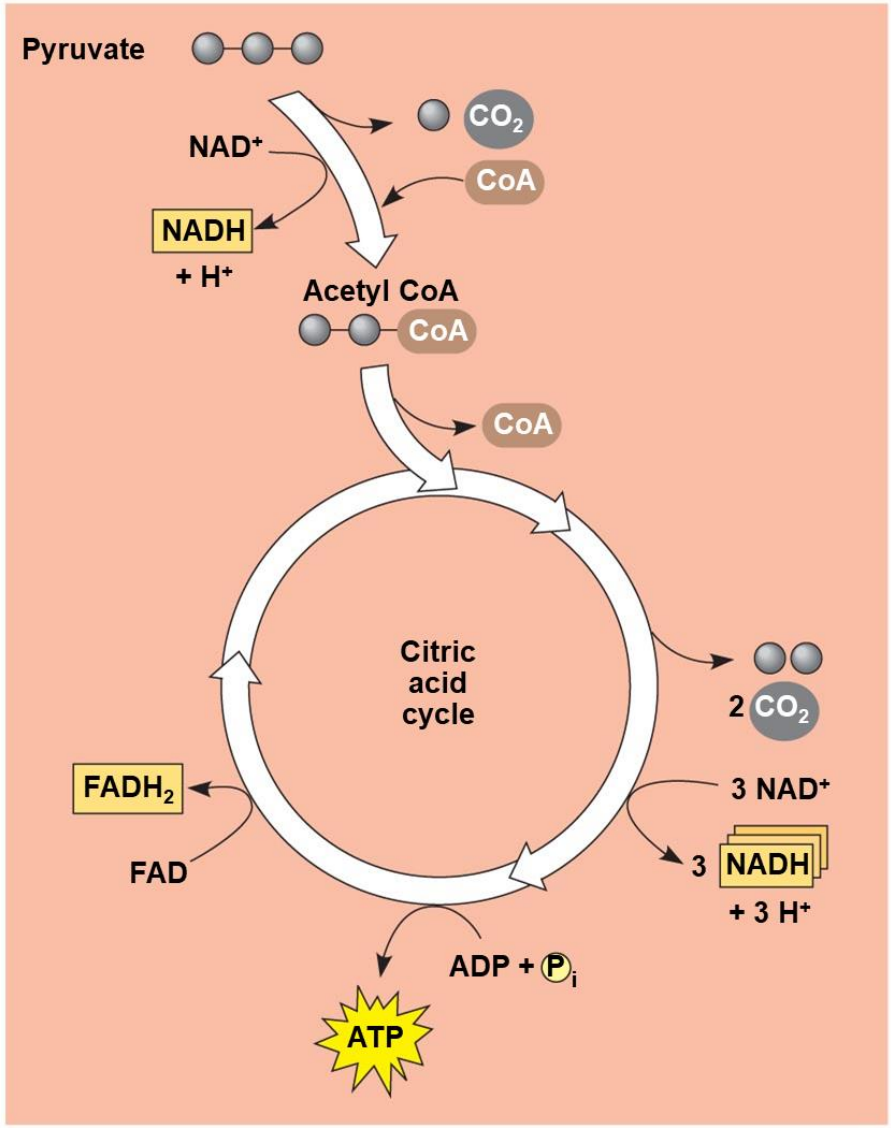
Acetate = a 2 carbon C-H-O

CoEnzyme A = a carrier molecule



The Citric Acid Cycle = Krebs Cycle: completes the energy-yielding oxidation of organic molecules

- The ***citric acid / Krebs cycle*** has eight steps, each catalyzed by a specific enzyme.
- The acetyl group of acetyl CoA joins the cycle by combining with oxaloacetate, OAA, forming citrate (citric acid).
- The next seven steps break down the citrate and regenerate oxaloacetate,OAA, making the process a cycle.
- The ***NADH*** and ***$FADH_2$*** produced by the Krebs Cycle carry electrons extracted from food (C-H-O) to the electron transport chain in the mitochondrial cristae membrane.



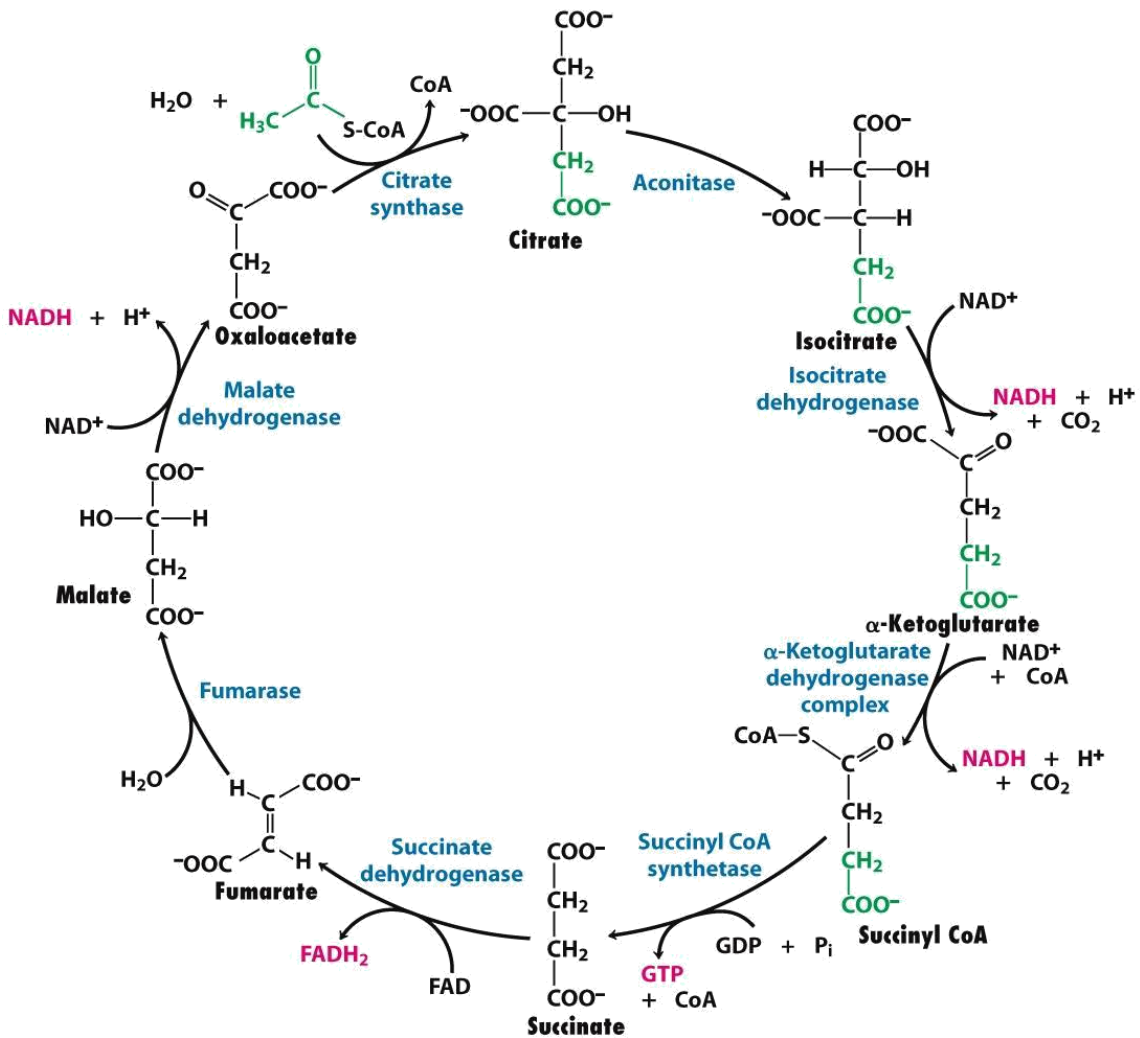


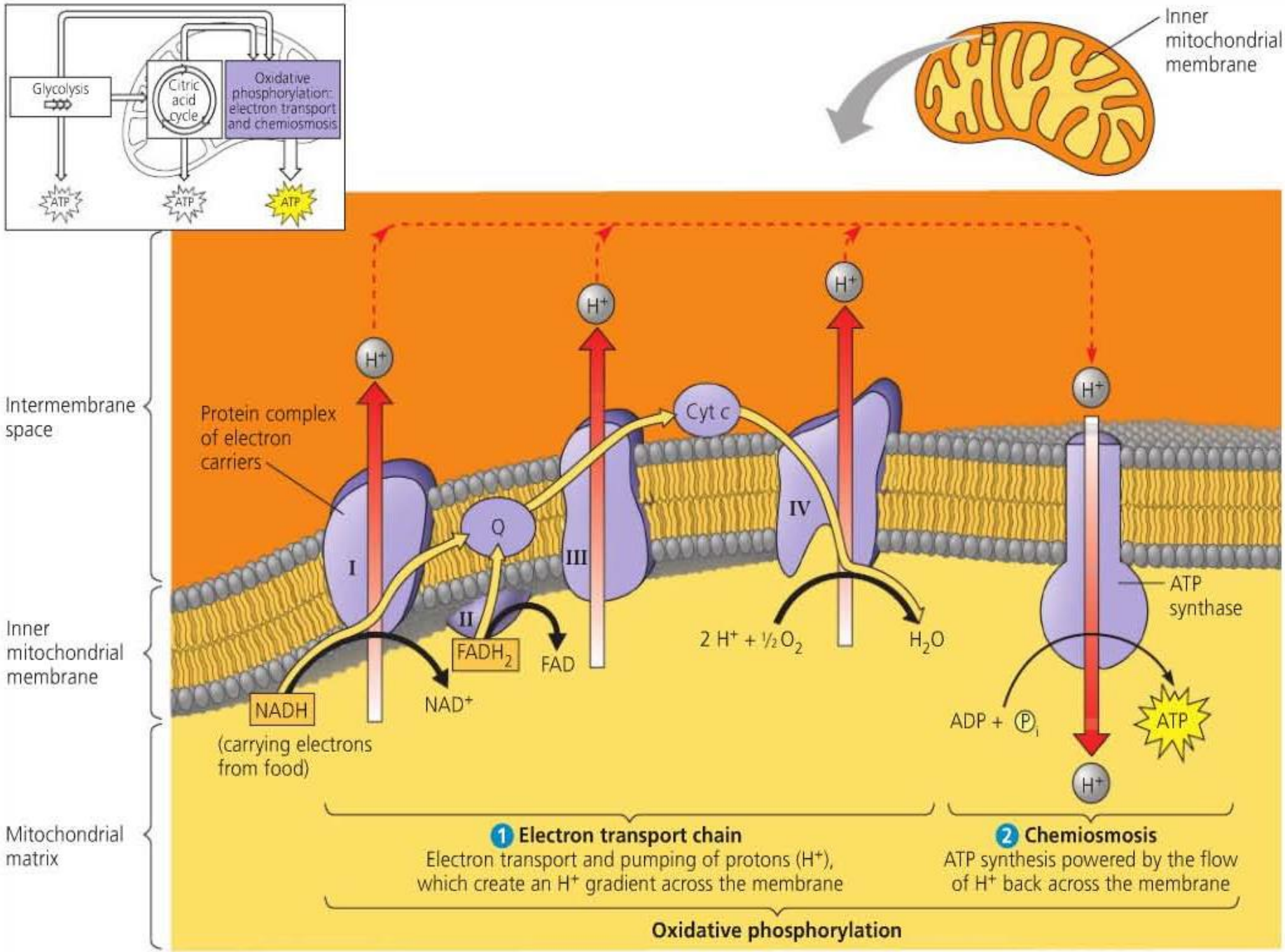
Figure 17.15
***Biochemistry,* Seventh Edition**

During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis

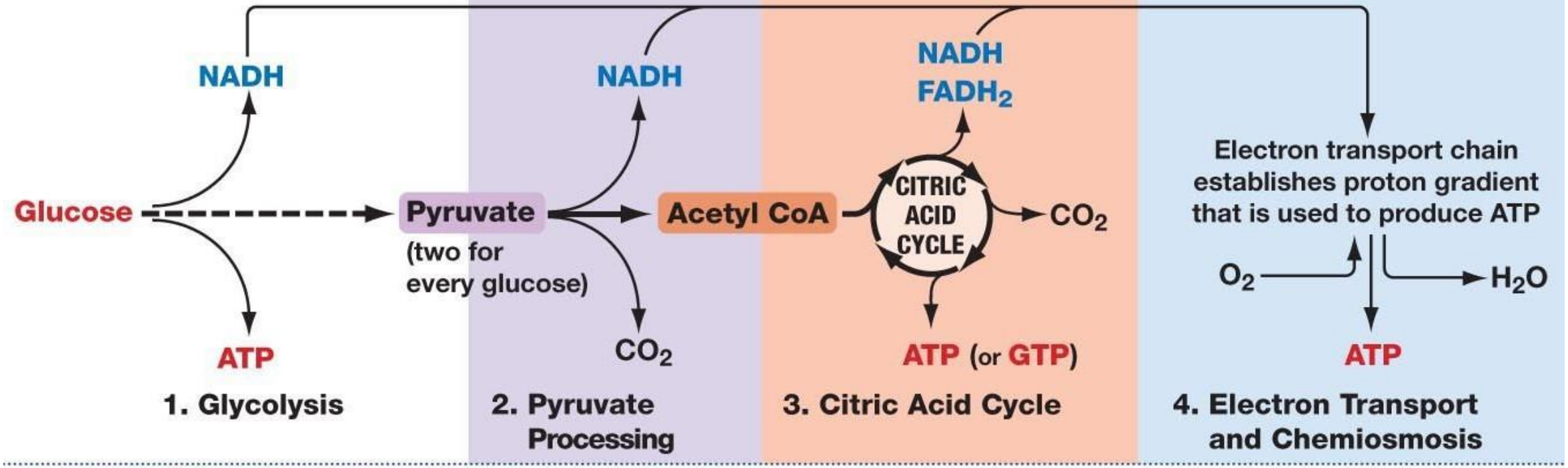
- Following glycolysis and the citric acid cycle, NADH and $FADH_2$ account for most of the energy extracted from food.
- These two electron carriers: NADH and $FADH_2$ donate electrons to the electron transport chain, which ***powers ATP synthesis via oxidative phosphorylation.***

The Pathway of Electron Transport

- The **electron transport chain** is in the cristae membrane of the mitochondrion.
- Most of the chain's components are proteins, which exist in multiprotein complexes.
- The carriers alternate reduced and oxidized states as they accept and donate electrons, ***redox***.
- *Electrons drop in free energy as they go down the chain and are finally passed to O_2, forming H_2O (waste)*.


Glycolysis
Citric acid cycle
Oxidative phosphorylation: electron transport and chemiosmosis
ATP
ATP
ATP
Inner mitochondrial membrane
Intermembrane space
Inner mitochondrial membrane
Mitochondrial matrix
Protein complex of electron carriers
H+
Cyt c
Q
I
II
III
IV
FADH2
FAD
NADH
(carrying electrons from food)
NAD+
2 H+ + ½ O2
H2O
ATP synthase
ADP + Pi
ATP
1 Electron transport chain
Electron transport and pumping of protons (H+), which create an H+ gradient across the membrane
2 Chemiosmosis
ATP synthesis powered by the flow of H+ back across the membrane
Oxidative phosphorylation

PROCESS: OVERVIEW OF CELLULAR RESPIRATION



Good Luck ☺