النادي الطبي

تَنوير

BIOLOGY

Lec no : 10 + 11

File Title : Chapter 10

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وَقُل رَّبِّ زِدْنِي عِلْمًا

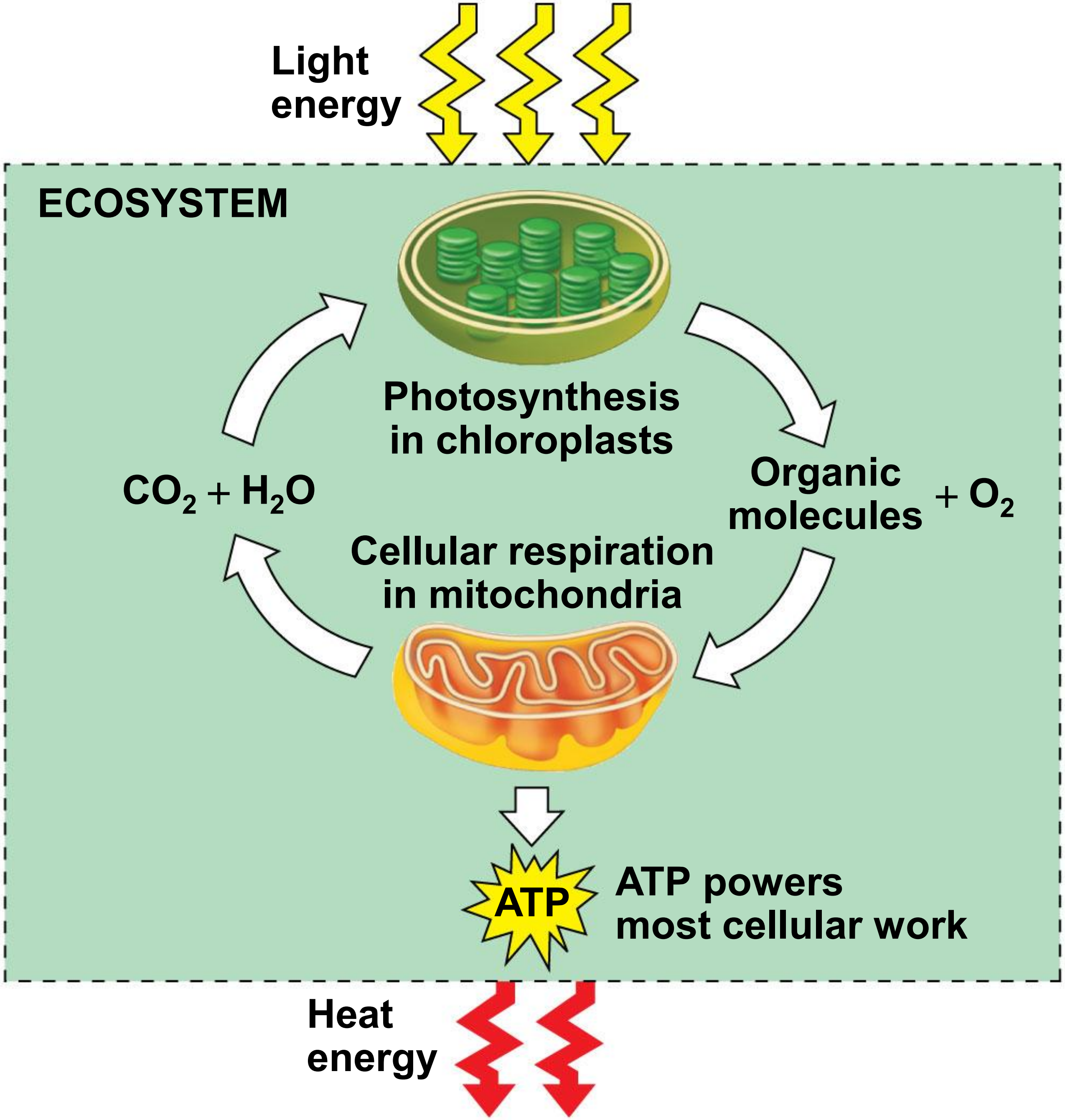
Overview: Life Is Work

- Living cells require energy from outside sources
- Some animals, such as the chimpanzee, obtain energy by eating plants, and some animals feed on other organisms that eat plants

Figure 9.1

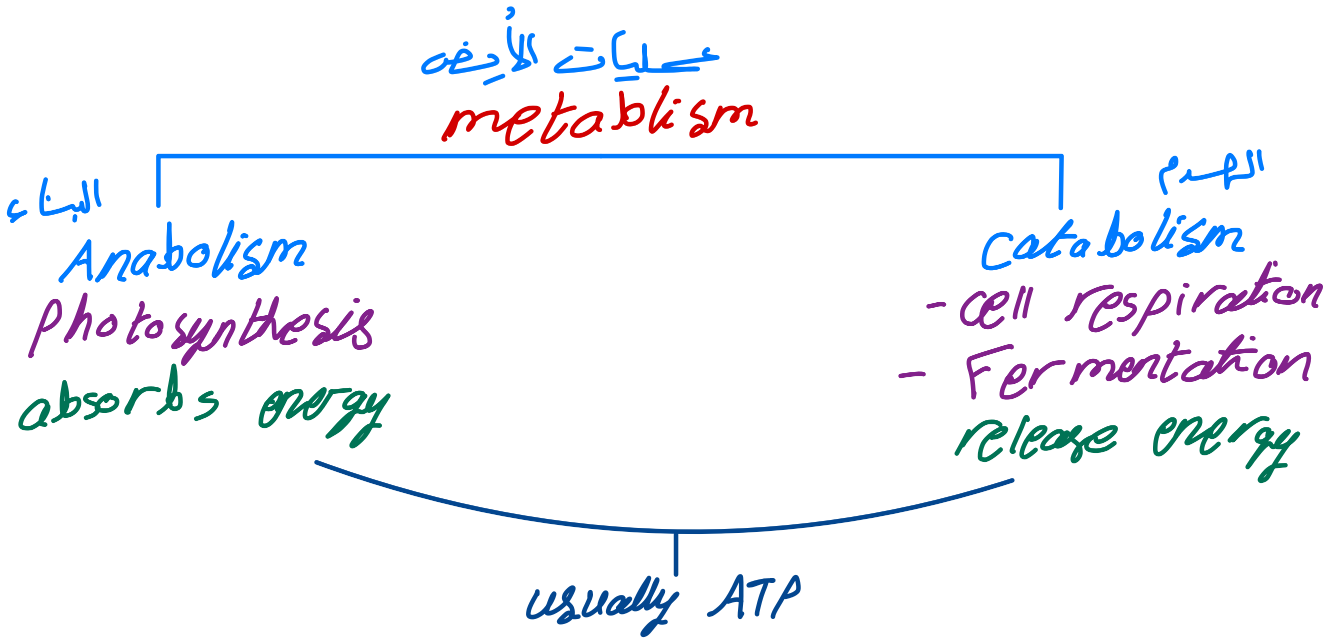
- Energy flows into an ecosystem as sunlight and leaves as heat
- Photosynthesis generates O_2 and organic molecules, which are used in cellular respiration
- Cells use chemical energy stored in organic molecules to regenerate ATP, which powers work

Figure 9.2


Light energy
ECOSYSTEM
Photosynthesis in chloroplasts
$CO_2 + H_2O$
Organic molecules
$+ O_2$
Cellular respiration in mitochondria
ATP
ATP powers most cellular work
Heat energy

Concept 9.1: Catabolic pathways yield energy by oxidizing organic fuels

- Several processes are central to cellular respiration and related pathways



Catabolic Pathways and Production of ATP

- The breakdown of organic molecules is exergonic
- **Fermentation** is a partial degradation of sugars that occurs without O_2
- **Aerobic respiration** consumes organic molecules and O_2 and yields ATP
- Anaerobic respiration is similar to aerobic respiration but consumes compounds other than O_2

- **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

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{Energy (ATP + heat)}$$

complete oxidation happens to the sugar

Redox Reactions: Oxidation and Reduction

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

The Principle of Redox

- Chemical reactions that transfer electrons between reactants are called oxidation-reduction reactions, or **redox reactions**
- In **oxidation**, a substance loses electrons, or is oxidized
  or protons (H^+)
- In **reduction**, a substance gains electrons, or is reduced (the amount of positive charge is reduced) or deoxidized
  or protons (H^+)

Figure 9.UN01

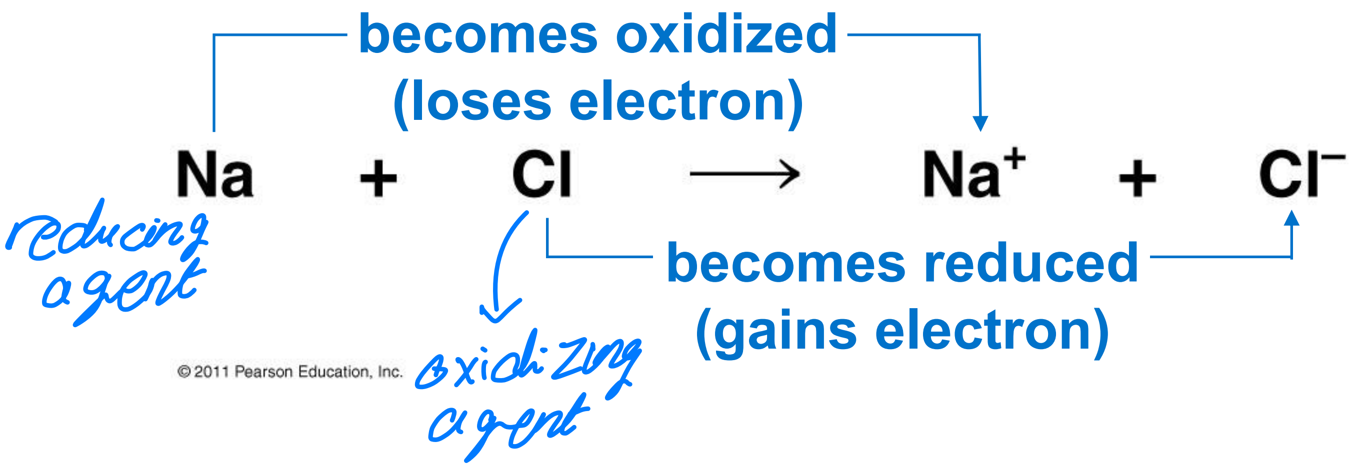
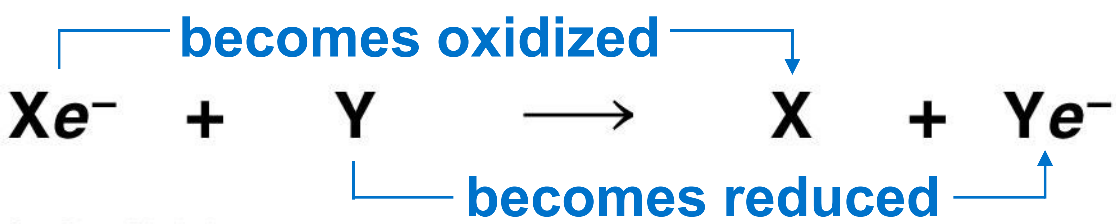
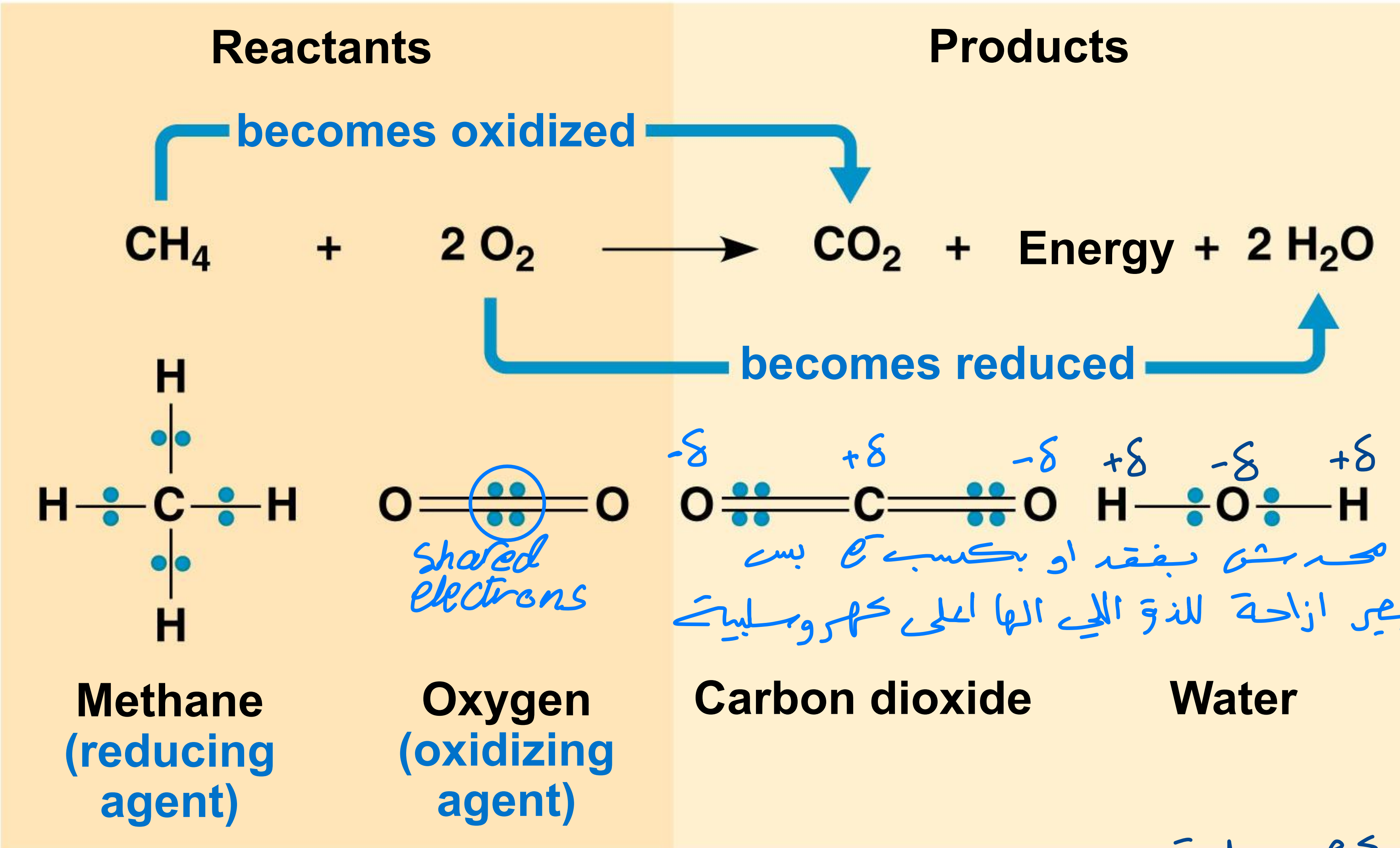


Figure 9.UN02



- The electron donor is called the **reducing agent**
- The electron receptor is called the **oxidizing agent**
- Some redox reactions do not transfer electrons but change the electron sharing in covalent bonds
- An example is the reaction between methane and O_2

Figure 9.3



كهروسلبية

Electrons are closer to the atom that has a higher electronegativity

Metabolism

- catabolism
  - Fermentation
    doesn't need O_2
  - cellular respiration
    - aerobic → most efficient
      uses O_2
    - anaerobic → some prokaryotes
      uses a substance other than O_2
- anabolism
  - photosynthesis

usually when we say cellular respiration we refer to aerobic respiration

Glucose degradation in cellular respiration:

$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy (ATP + Heat)}$$

Redox reactions

Reduction:

Loss of O_2, gain of e^- or H^+

oxidizing agent: e^- acceptor

also in covalent bonds change it electron degree

Oxidation:

gain of O_2, loss of H^+ or e^-

reducing agent: e^- donor

Oxidation of Organic Fuel Molecules During Cellular Respiration

- During cellular respiration, the fuel (such as glucose) is oxidized, and O_2 is reduced

the last electron

Figure 9.UN03

becomes oxidized

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

becomes reduced

All energy is stored in the bonds between atoms in the glucose , and to get the energy out of it wen need to break these bonds by giving them a little bit of energy to weaken them with the help of na enzyme (dehydrogenase) , and when they are broken the protons and electrons will be released holding all energy in electrons

(oxygen will receive the electrons and combine with the protons and form water)

The last electron receptor is the oxygen

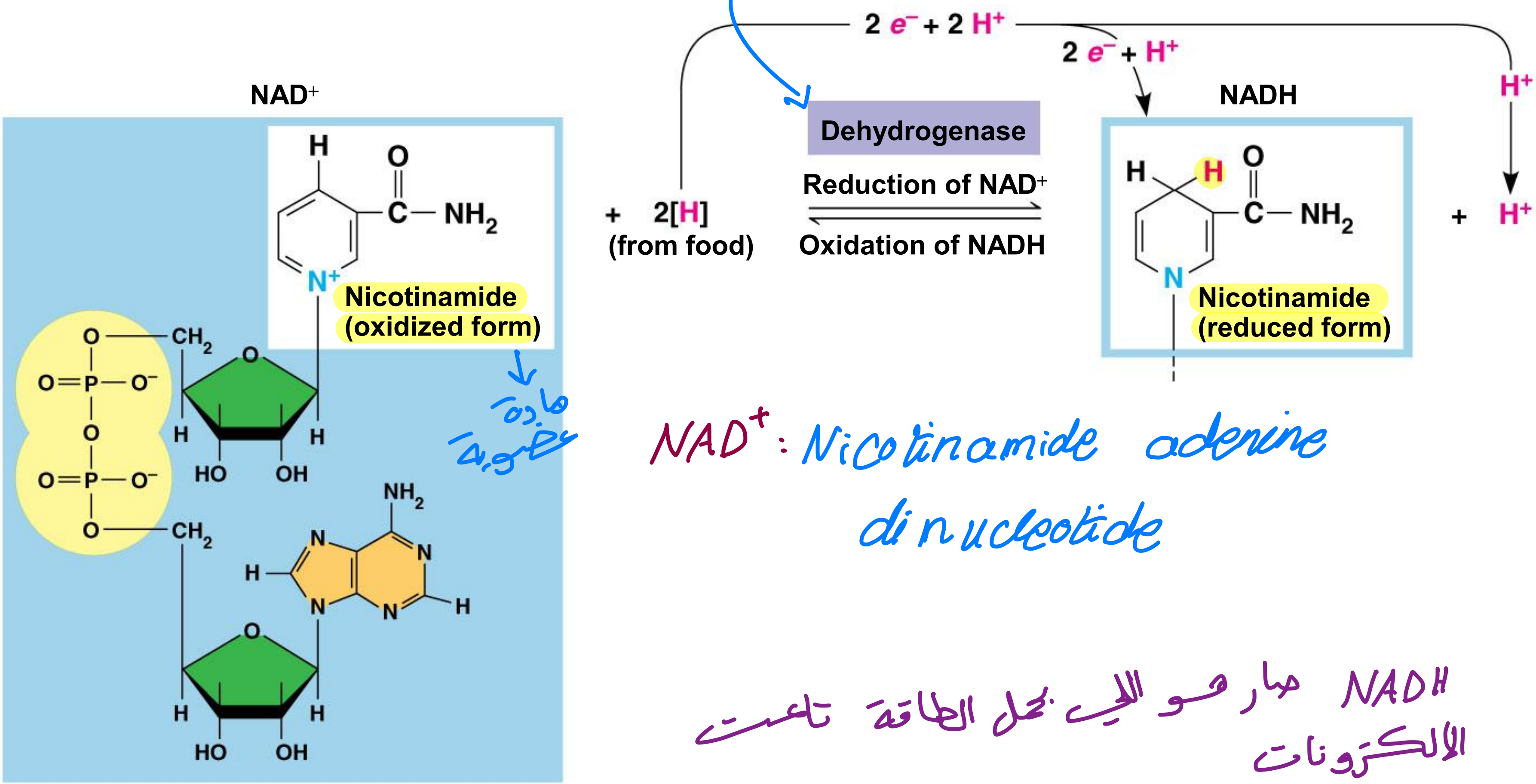
Primary electrons acceptor: NAD+

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
- Each NADH (the reduced form of NAD^+) represents stored energy that is tapped to synthesize ATP

Figure 9.4

removes 2H → $2e^-$ + $2H^+$

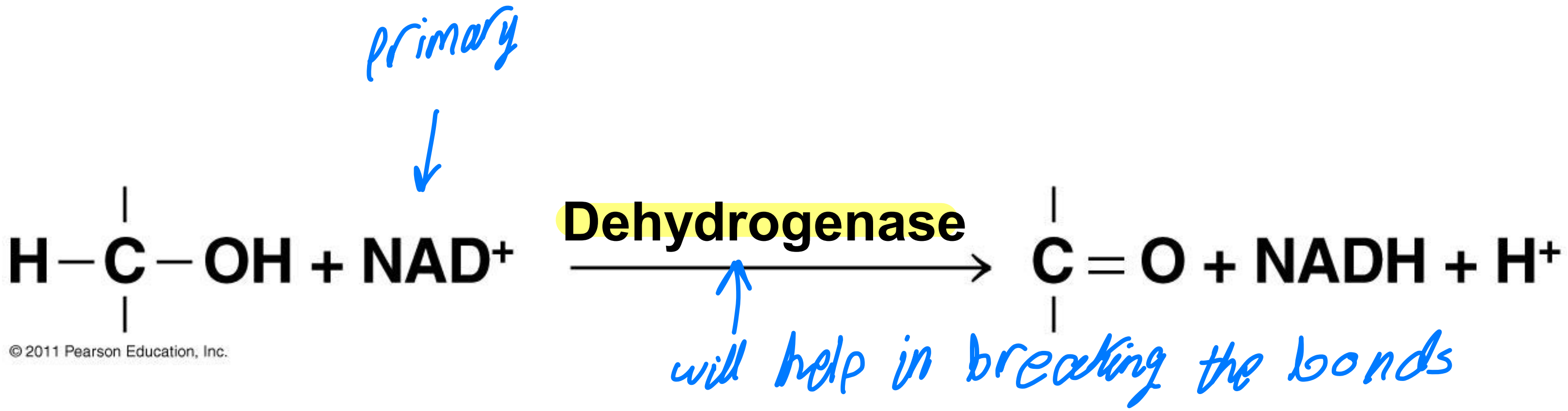


مادة عضوية

NAD^+: Nicotinamide adenine dinucleotide

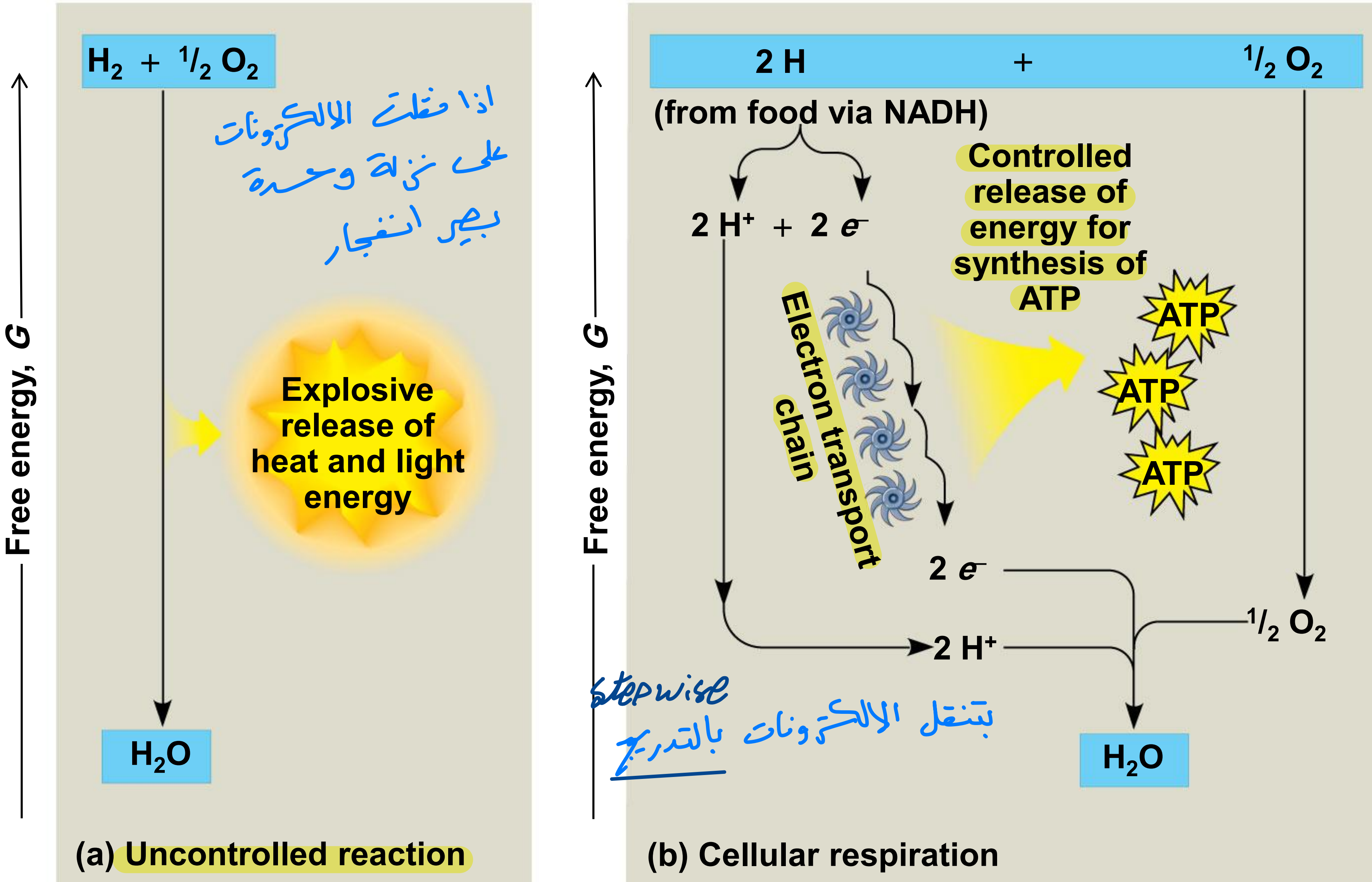
NADH صار هو الي بحمل الطاقة تاعت الالكترونات

Figure 9.UN04



- NADH passes the electrons to the **electron transport chain**
- Unlike an uncontrolled reaction, the electron transport chain passes electrons in a series of steps instead of one explosive reaction
- O_2 pulls electrons down the chain in an energy-yielding tumble
- The energy yielded is used to regenerate ATP

Figure 9.5


Free energy, G
H_2 + $^1/_2$ O_2
اذا نقلت الالكترونات
على نزلة وحدة
بيصير انفجار
Explosive release of heat and light energy
H_2O
(a) Uncontrolled reaction
2 H + $^1/_2$ O_2
(from food via NADH)
$2 H^+$ + $2 e^-$
Controlled release of energy for synthesis of ATP
Electron transport chain
ATP
ATP
ATP
$2 e^-$
$^1/_2$ O_2
$2 H^+$
stepwise
بتنقل الالكترونات بالتدريج
H_2O
(b) Cellular respiration

The Stages of Cellular Respiration: *A Preview*

- Harvesting of energy from glucose has three stages
  - **Glycolysis** (breaks down glucose into two molecules of pyruvate)
  - The **citric acid cycle** (completes the breakdown of glucose)
  - **Oxidative phosphorylation** (accounts for most of the ATP synthesis)

Stages of Cellular respiration

Glycolysis

- In cytoplasm
- No need for O_2

citric acid cycle

- In mitochandrial matix
- Needs O_2

Glycolysis and citric acid cycle: ATP synthesis by substrate-level phosphorylation

organic addition of phosphate to ADP

oxidative phosphorylation

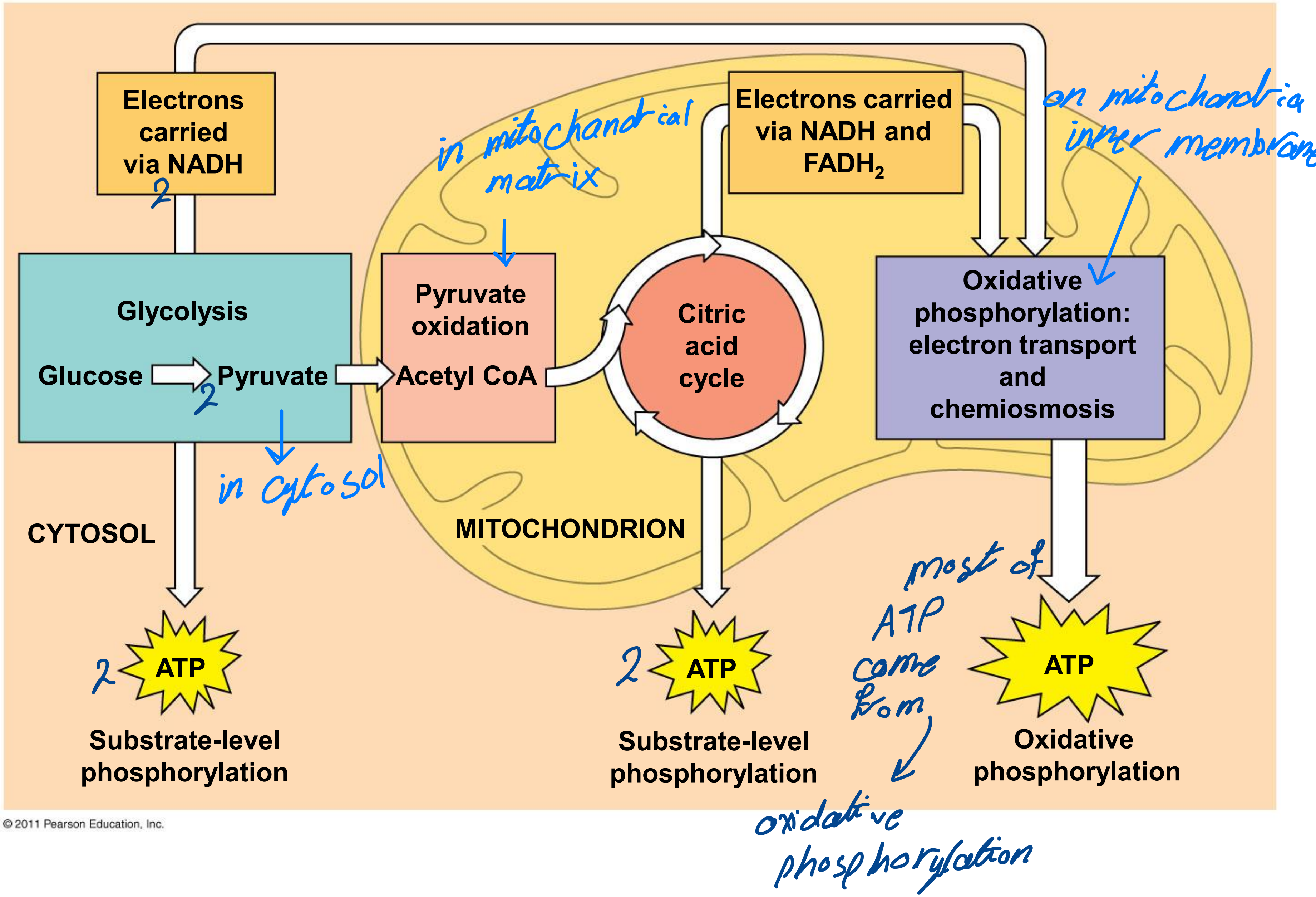
- on mitochandria inner membrane

→ ATP synthesis by oxidative phosphorylation

inorganic addition of phospate to ADP

In total about 32 ATP

Figure 9.6-3


Electrons carried via NADH
2
Electrons carried via NADH and $FADH_2$
in mitochondrial matrix
on mitochondria inner membrane
Glycolysis
Glucose
2
Pyruvate
in cytosol
Pyruvate oxidation
Acetyl CoA
Citric acid cycle
Oxidative phosphorylation: electron transport and chemiosmosis
CYTOSOL
MITOCHONDRION
most of ATP come from
oxidative phosphorylation
2
ATP
Substrate-level phosphorylation
2
ATP
Substrate-level phosphorylation
ATP
Oxidative phosphorylation

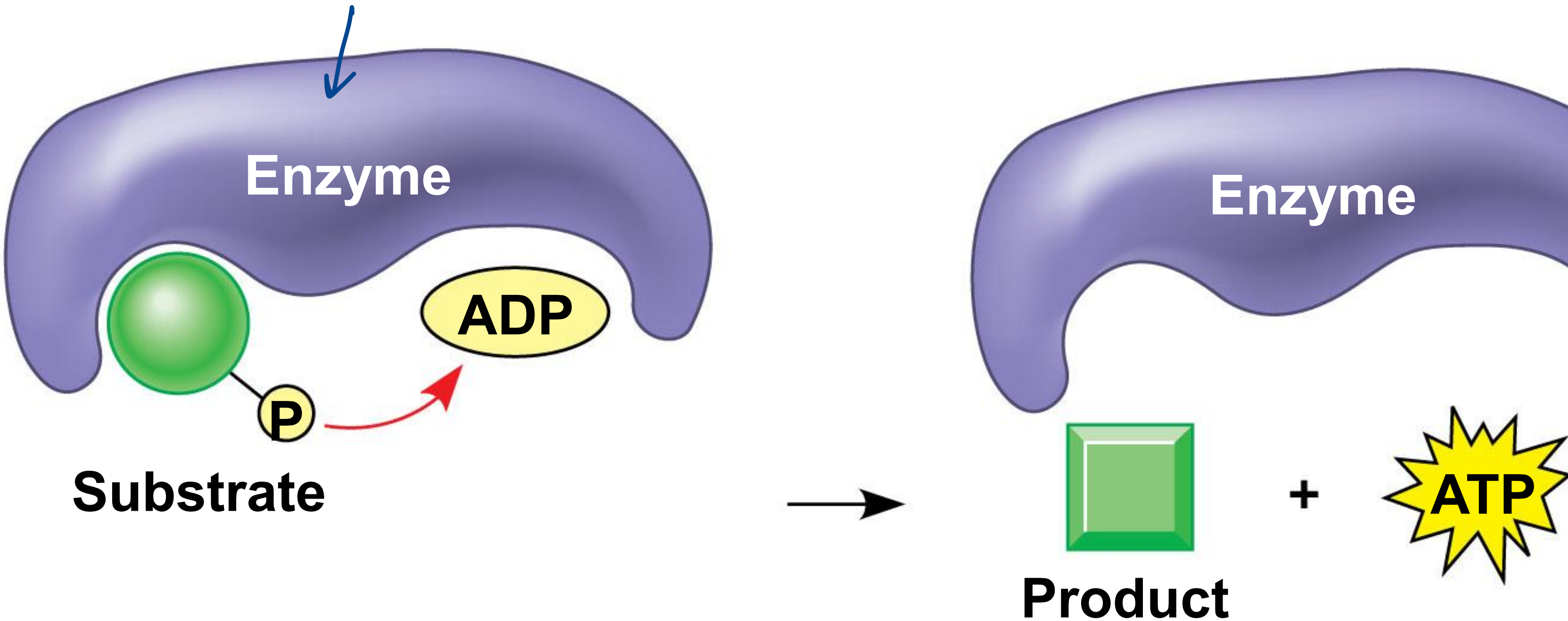
- The process that generates most of the ATP is called oxidative phosphorylation because it is powered by redox reactions

PLAY BioFlix: Cellular Respiration

- 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 cycle by **substrate-level phosphorylation**
- For each molecule of glucose degraded to CO_2 and water by respiration, the cell makes up to 32 molecules of ATP

Figure 9.7

ATP synthes



$ADP + P \longrightarrow ATP$

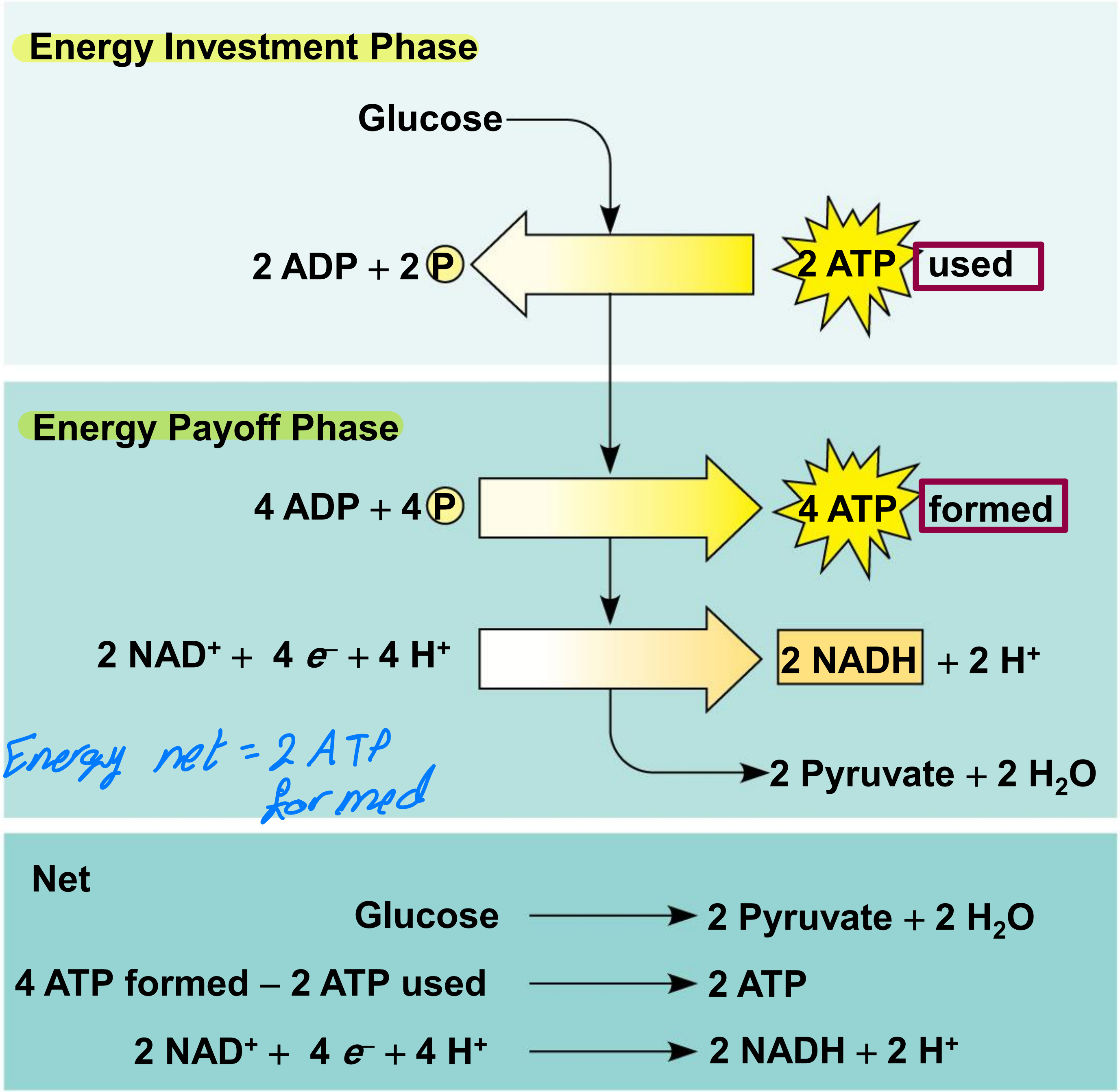
ببطل شكل المواد المتفاعلة ملائم
للموقع النشط في الانزيم فبتنفصل
المواد عنه

Concept 9.2: Glycolysis harvests chemical energy by oxidizing glucose to pyruvate

- Glycolysis ("splitting of sugar") breaks down glucose into two molecules of pyruvate
- Glycolysis occurs in the cytoplasm and has two major phases
  - Energy investment phase → 2 ATP بستهلك
  - Energy payoff phase → 4 ATP بنتج
- Glycolysis occurs whether or not O_2 is present

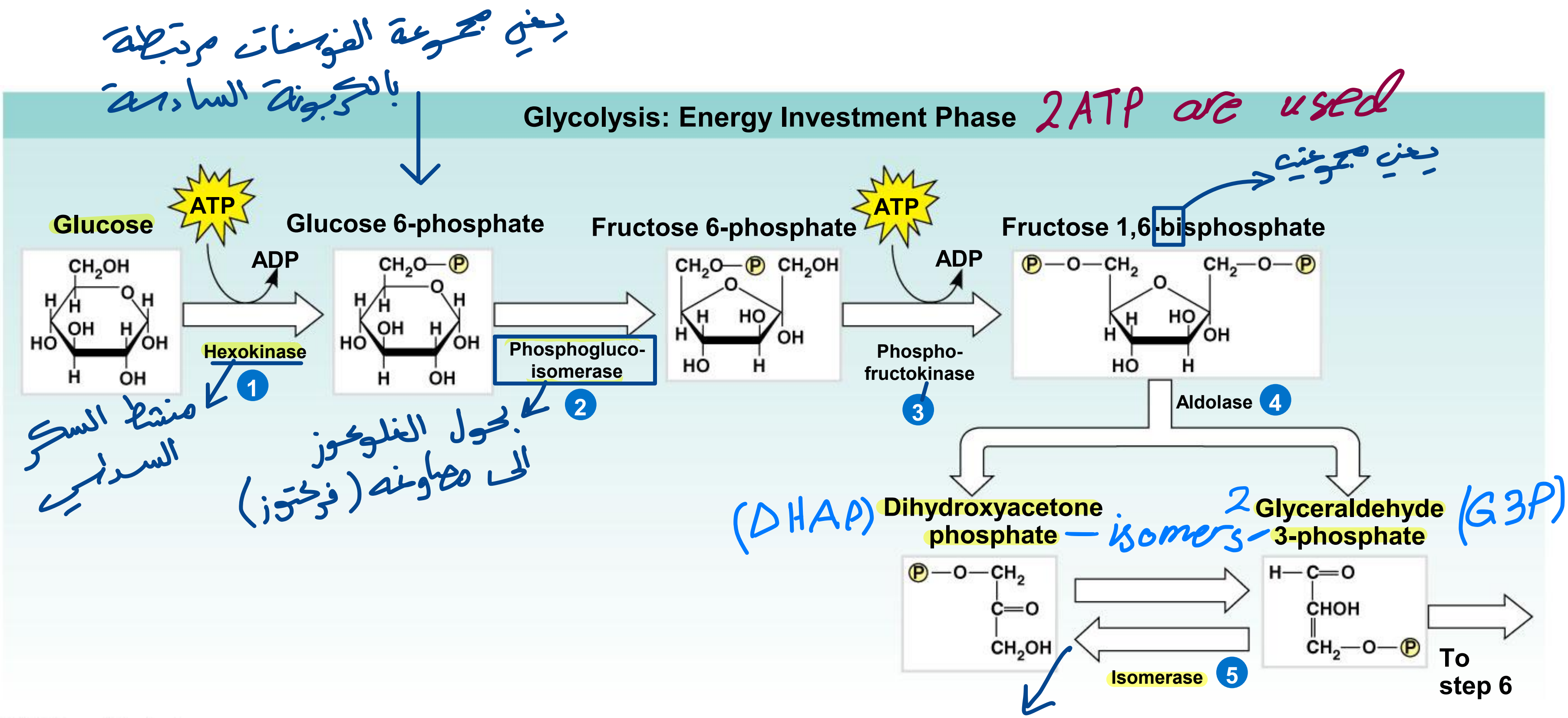
Happens in aerobic and anaerobic

Figure 9.8



Energy Investment Phase
Glucose
2 ADP + 2 P
2 ATP used
Energy Payoff Phase
4 ADP + 4 P
4 ATP formed
2 NAD+ + 4 e- + 4 H+
2 NADH + 2 H+
2 Pyruvate + 2 H2O
Energy net = 2 ATP formed
Net
Glucose → 2 Pyruvate + 2 H2O
4 ATP formed – 2 ATP used → 2 ATP
2 NAD+ + 4 e- + 4 H+ → 2 NADH + 2 H+

Figure 9.9-4

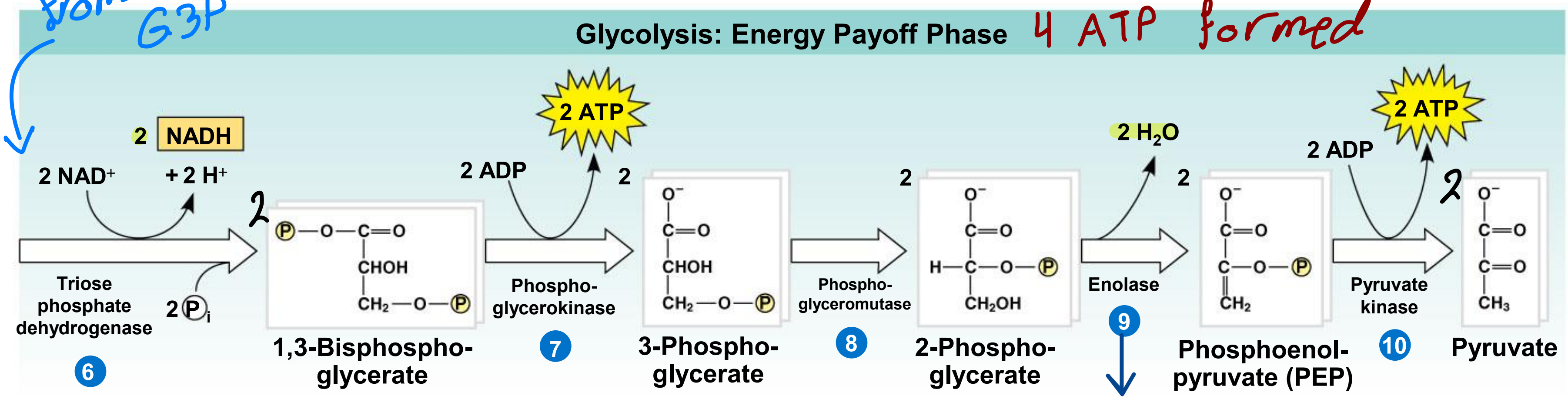


Conversion between DHAP and G3P: This reaction never reaches equilibrium; G3P is used in the next step as fast as it forms.

هسا المفترض انزيم isomerase يحول ال G3P ل DHAP او العكس لحد ما تصير
النسب متساوية بس اللي بصير هان ال G3P بستهلك عطول اول ما يتم انتاجه في الخطوة
اللي بعد بالتالي انزيم ال isomerase بضل يحول ال DHAP الى G3P

Figure 9.9-9

from 2 molecules of G3P



4 ATP formed

All ATP are formed by substrate-level phosphorylation

forms a double bond by extracting a water molecule

Concept 9.3: After pyruvate is oxidized, the citric acid cycle completes the energy-yielding oxidation of organic molecules

- In the presence of O_2, pyruvate enters the mitochondrion (in eukaryotic cells) where the oxidation of glucose is completed

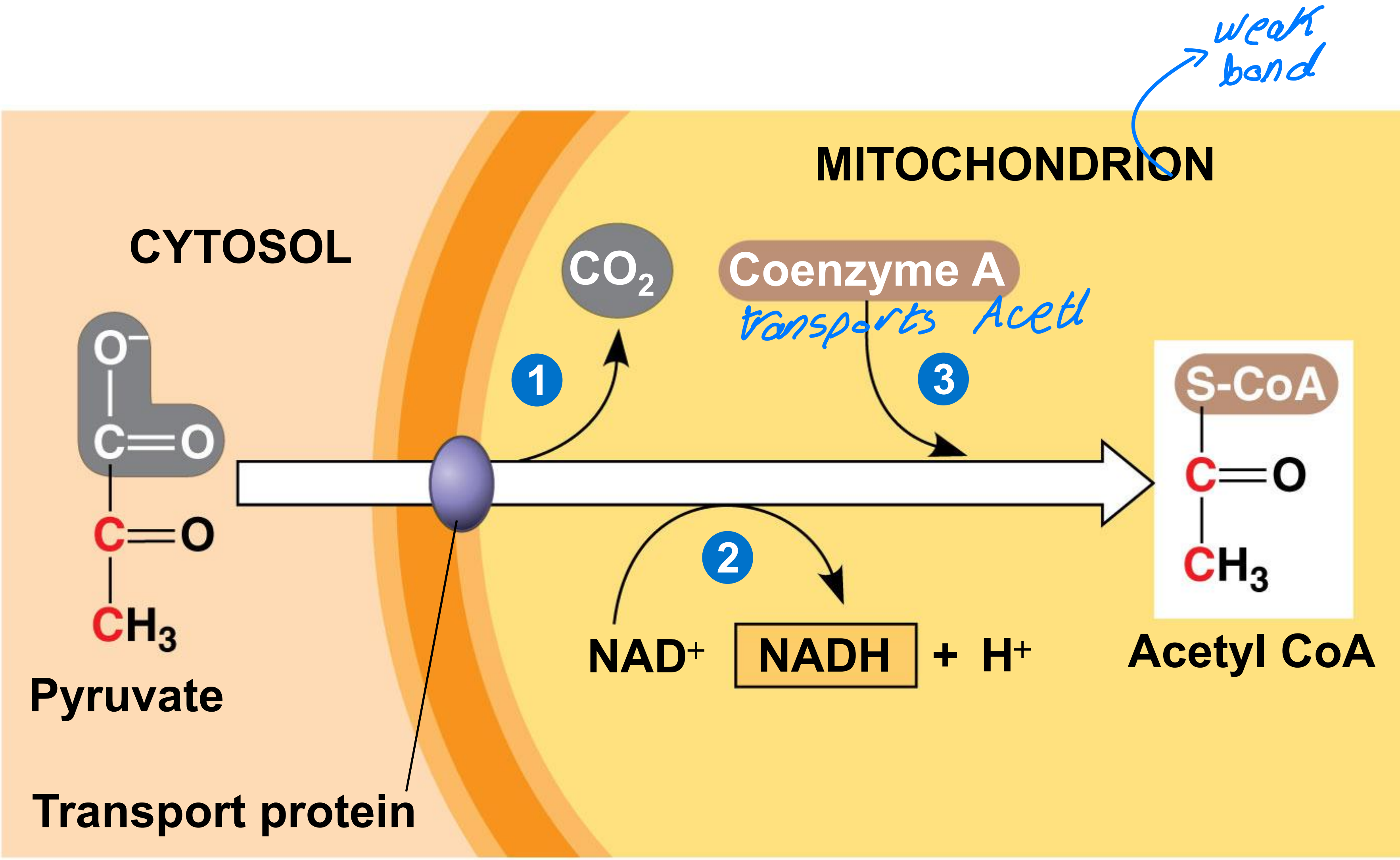
enters by active transport

Oxidation of Pyruvate to Acetyl CoA

there must be O_2

- Before the citric acid cycle can begin, pyruvate must be converted to acetyl Coenzyme A (**acetyl CoA**), which links glycolysis to the citric acid cycle
- This step is carried out by a multienzyme complex that catalyses three reactions

Figure 9.10


weak bond
MITOCHONDRION
CYTOSOL
CO_2
Coenzyme A
transports Acetl
1
3
2
S-CoA
C=O
CH_3
O⁻
C=O
C=O
CH_3
Pyruvate
NAD^+
NADH
+ H^+
Acetyl CoA
Transport protein

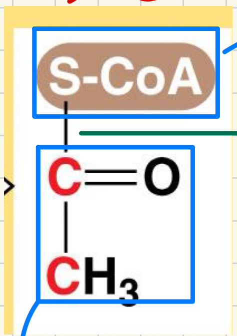
Coenzyme A (CoA): a compound that contain a (مجموعة) sulfur (S) atom

The carboxyl group in Pyruvate is fully oxidized and given off as CO_2

مجموعة الكربوكسيل في البيروفيت تتم اكسدتها بالكامل وتخرج من المركب على صورة CO_2

→ This is the first CO_2 to be released in the respiration

Acetyl CoA



→ Coenzyme A

→ CoA is attached to the 2 carbons by the sulfur atom

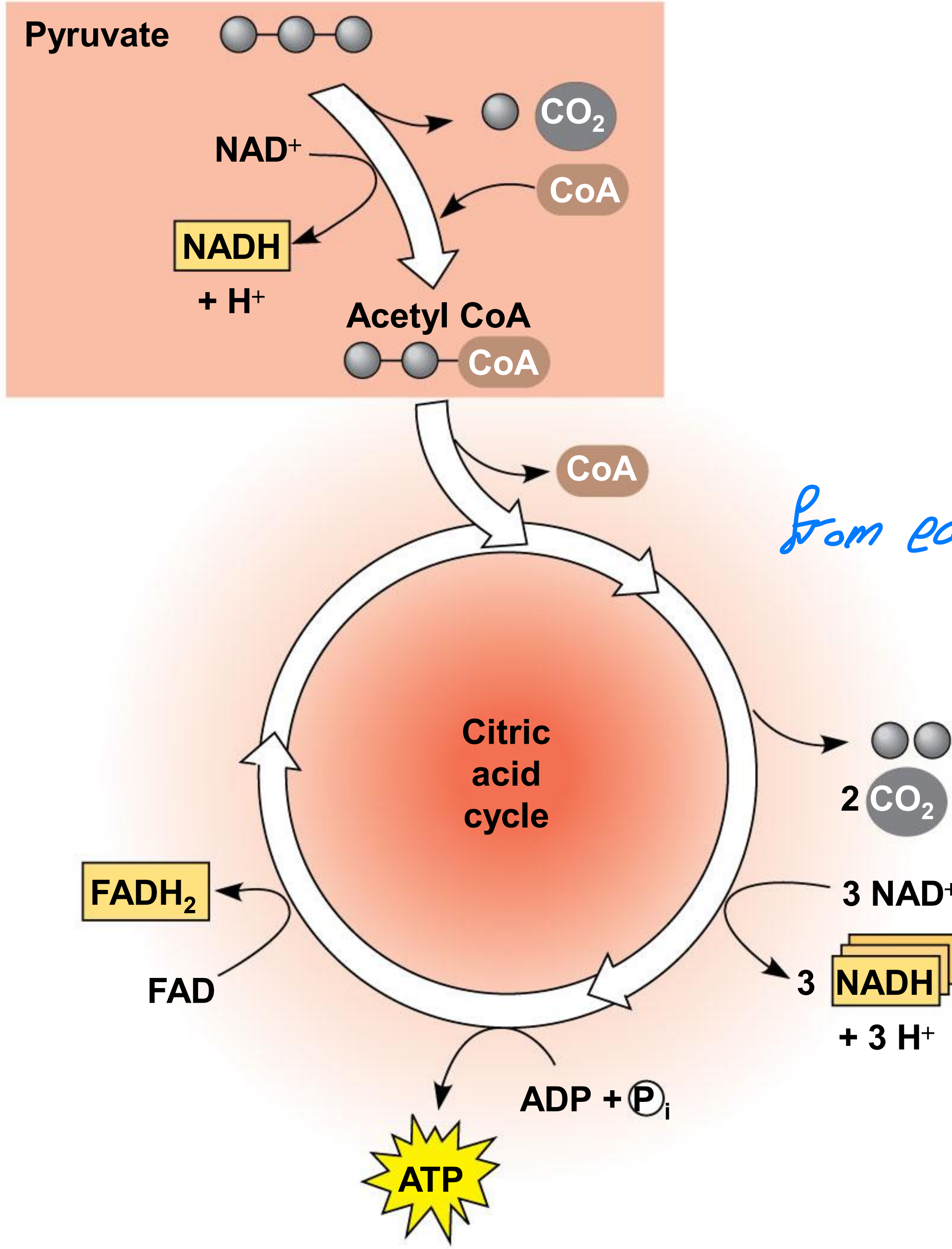
→ Pyruvate after losing it's carboxyl group

The Citric Acid Cycle

- The citric acid cycle, also called the Krebs cycle, completes the break down of pyruvate to CO_2
- The cycle oxidizes organic fuel derived from pyruvate, generating 1 ATP, 3 NADH, and 1 $FADH_2$ per turn → double every thing for a whole glucose molecule

citric Acid cycle = Krebs cycle = tricarboxylic acid cycle
(CAC) (TAC)

Figure 9.11



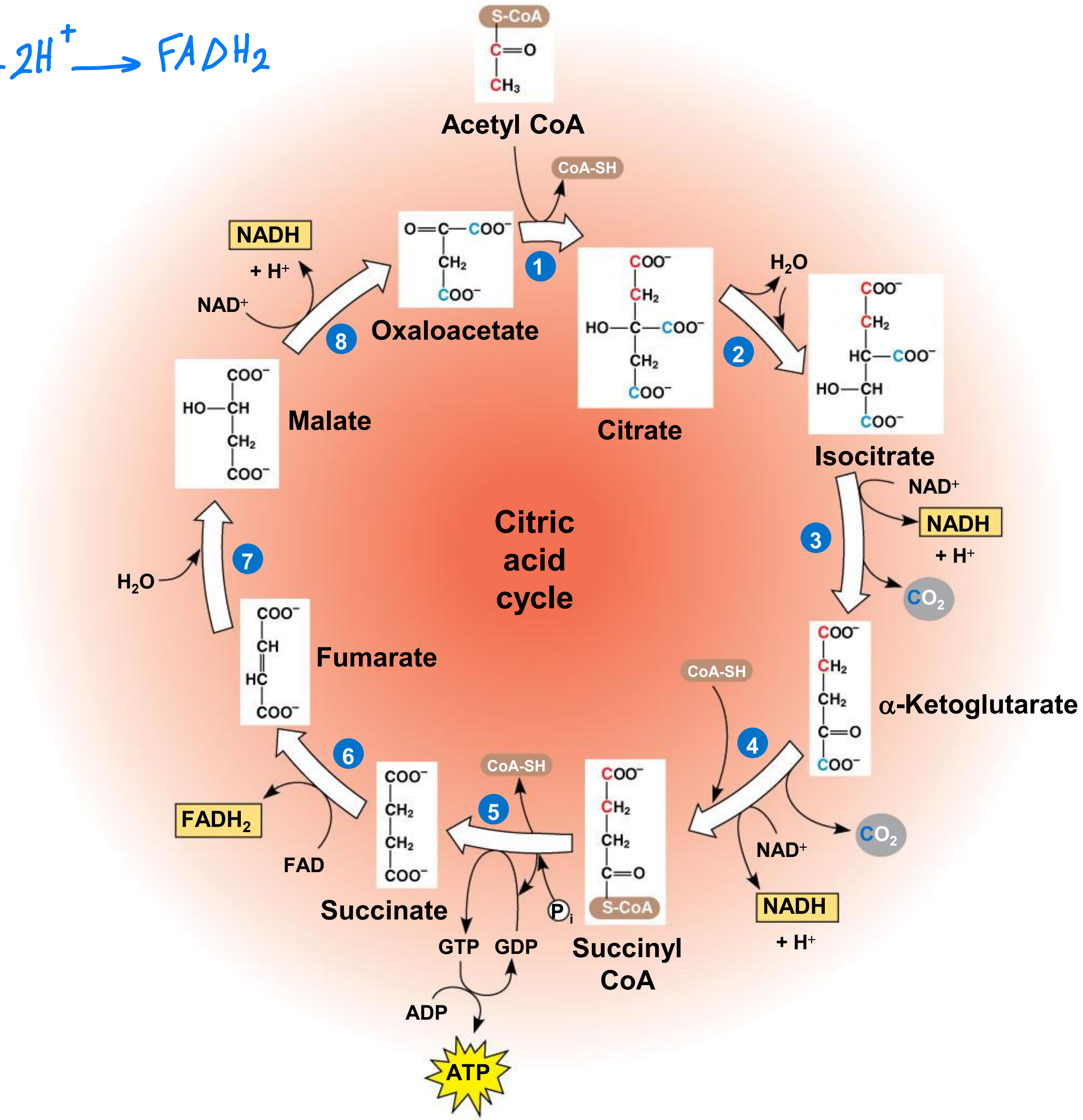
from each Acetyl COA

citrate is the ionized form of citric acid

- The citric acid cycle has eight steps, each catalyzed by a specific enzyme
- The acetyl group of acetyl CoA joins the cycle by combining with oxaloacetate, forming citrate
- The next seven steps decompose the citrate back to oxaloacetate, making the process a cycle
- The NADH and $FADH_2$ produced by the cycle relay electrons extracted from food to the electron transport chain

Figure 9.12-8

$FAD + 2e^- + 2H^+ \rightarrow FADH_2$



step 1: The 2-carbons in Acetyl CoA are attached to Oxaloacetate forming a 6-carbon compound called citrate

step2: Isocitrate (isomer for citrate) is formed by removal of one water molecule and addition of another

step3: The compound loses a CO_2 molecule

step4: another CO_2 molecule is lost and then the molecule is attached to Coenzyme A by an unstable bond

step5: CoA is displaced by a phosphate group which will be transferred to GDP (a molecule to ATP in function) forming GTP and it can be used to generate ATP

step6: 1 $FADH_2$ is formed and this step enzyme is found in the mitochondria's inner membrane (all of the other enzymes are found in the mitochondrial matrix)

step7: addition of a water molecule

step8: Oxaloacetate is regenerated

Citric acid cycle Outputs

From one glucose:

- 6 NADH ⟶ from steps 3, 4, 8
- 2 $FADH_2$ ⟶ from step 6
- 2 ATP ⟶ from step 5
- 4 CO_2 ⟶ from steps 3, 4

ملحوظة اضافية :
ذرتين الكربون اللي جايات من ال (Acetyl CoA) هم اللي بكملوا الحلقة (موجودات بلون احمر على الرسمة) و الذرتين اللي بطلعن على شكل CO2 هذول بكونوا من ال (oxaloacetate) (موجودات بلون ازرق على الرسمة)

- The ATP in citric acid cycle is generated by substrate-level phosphorylation

Figure 9.12a

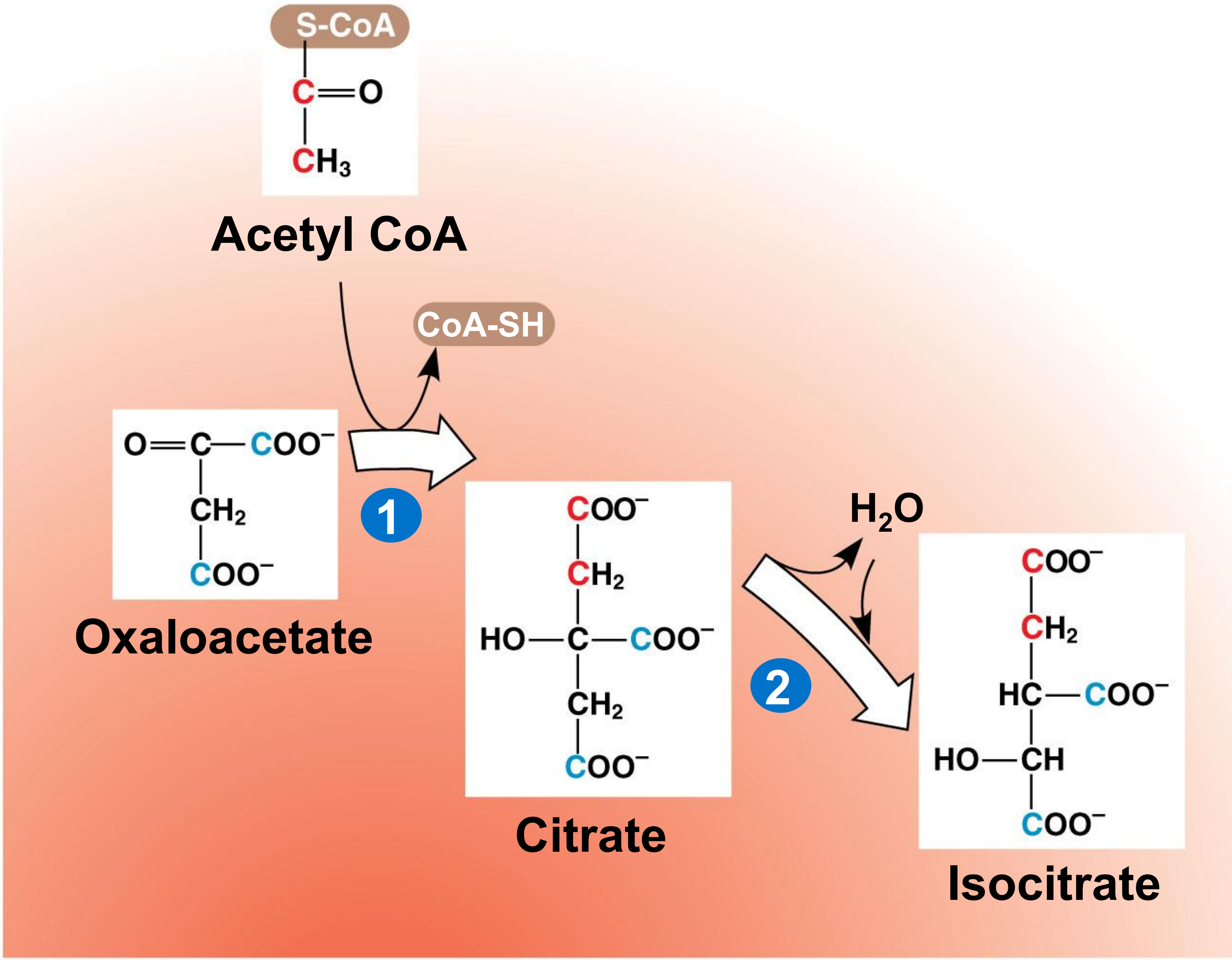
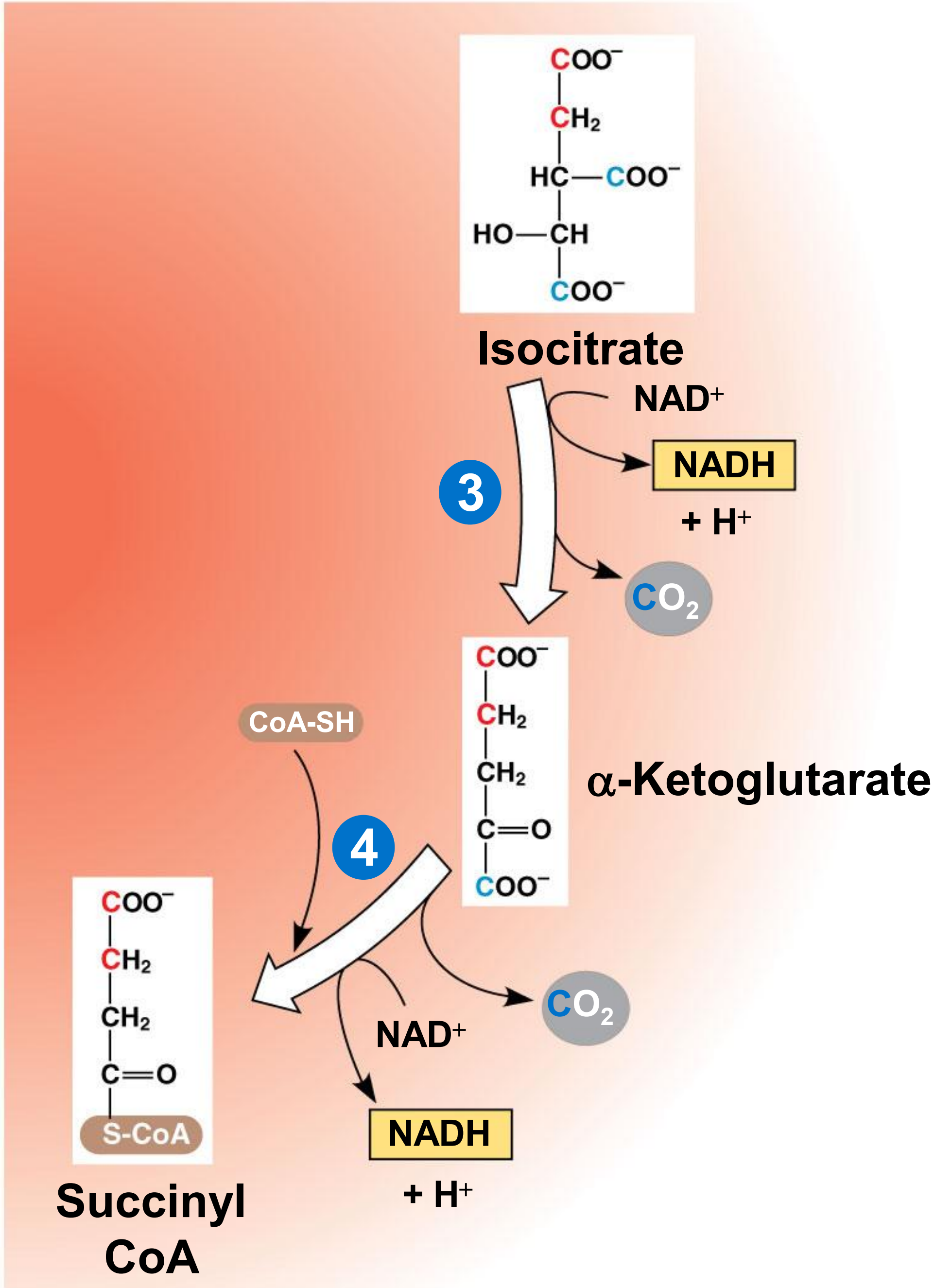

S-CoA
C=O
CH3
Acetyl CoA
CoA-SH
O=C—COO⁻
CH2
COO⁻
Oxaloacetate
1
COO⁻
CH2
HO—C—COO⁻
CH2
COO⁻
Citrate
H2O
2
COO⁻
CH2
HC—COO⁻
HO—CH
COO⁻
Isocitrate

Figure 9.12b



COO⁻
CH2
HC—COO⁻
HO—CH
COO⁻
Isocitrate
NAD+
NADH
+ H+
3
CO2
COO⁻
CH2
CH2
C=O
COO⁻
α-Ketoglutarate
CoA-SH
4
CO2
NAD+
NADH
+ H+
COO⁻
CH2
CH2
C=O
S-CoA
Succinyl CoA

Figure 9.12c

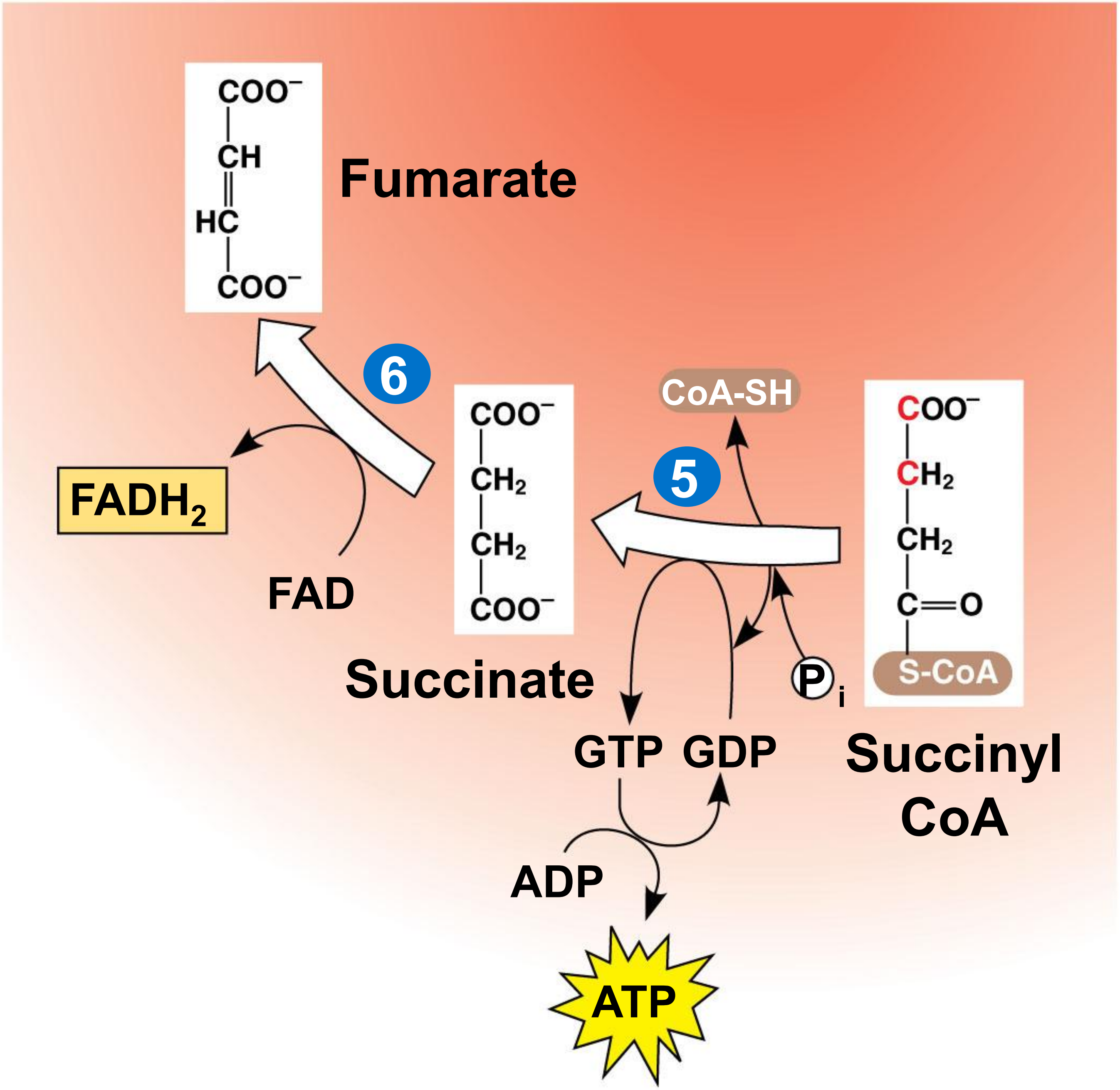
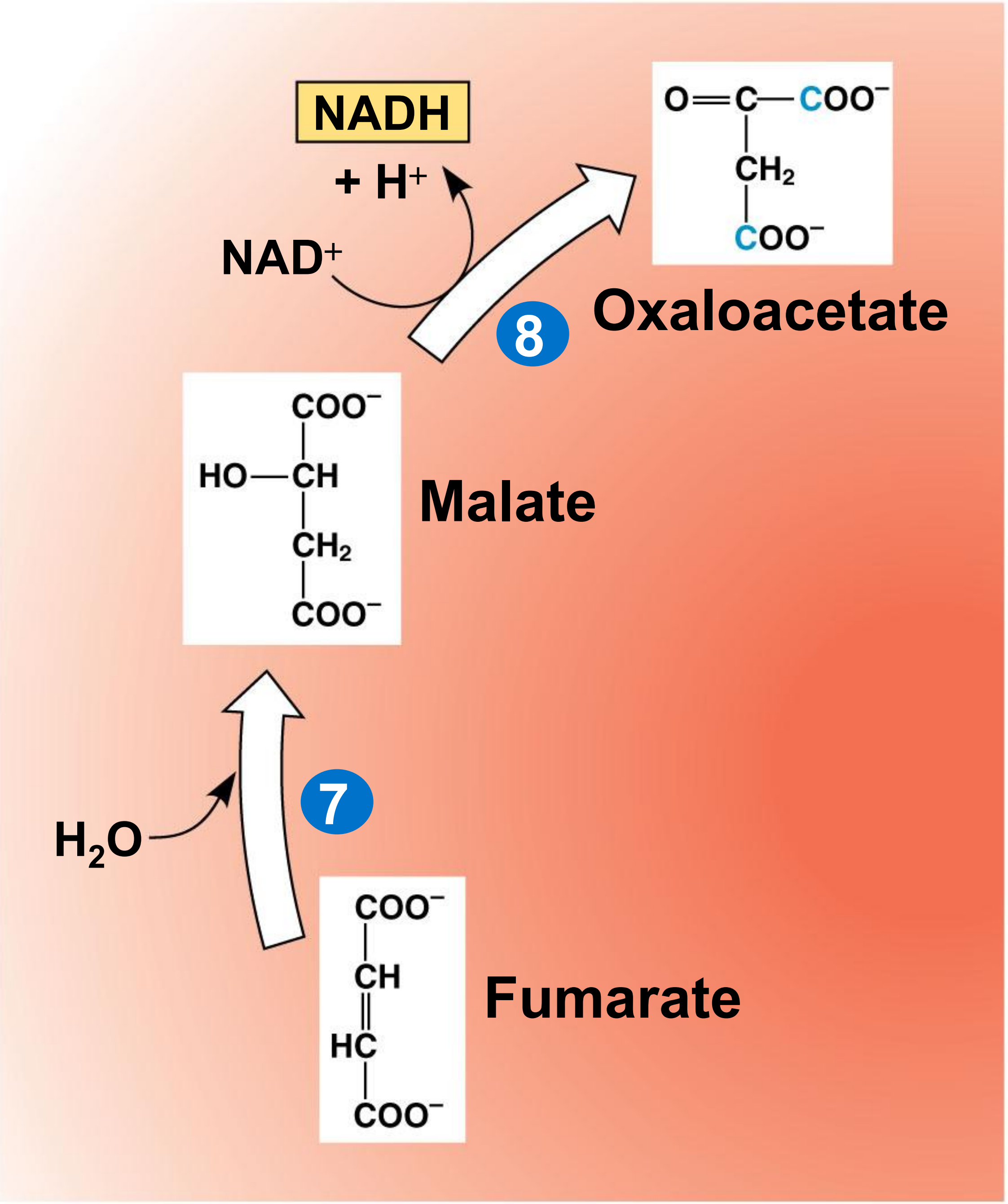

COO⁻
CH
HC
COO⁻
Fumarate
6
FADH2
FAD
COO⁻
CH2
CH2
COO⁻
Succinate
CoA-SH
5
GTP
GDP
ADP
ATP
P i
COO⁻
CH2
CH2
C═O
S-CoA
Succinyl CoA

Figure 9.12d


NADH
+ H+
NAD+
O═C─COO−
CH2
COO−
Oxaloacetate
8
COO−
HO─CH
CH2
COO−
Malate
7
H2O
COO−
CH
HC
COO−
Fumarate

Concept 9.4: 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 donate electrons to the electron transport chain, which powers ATP synthesis via oxidative phosphorylation

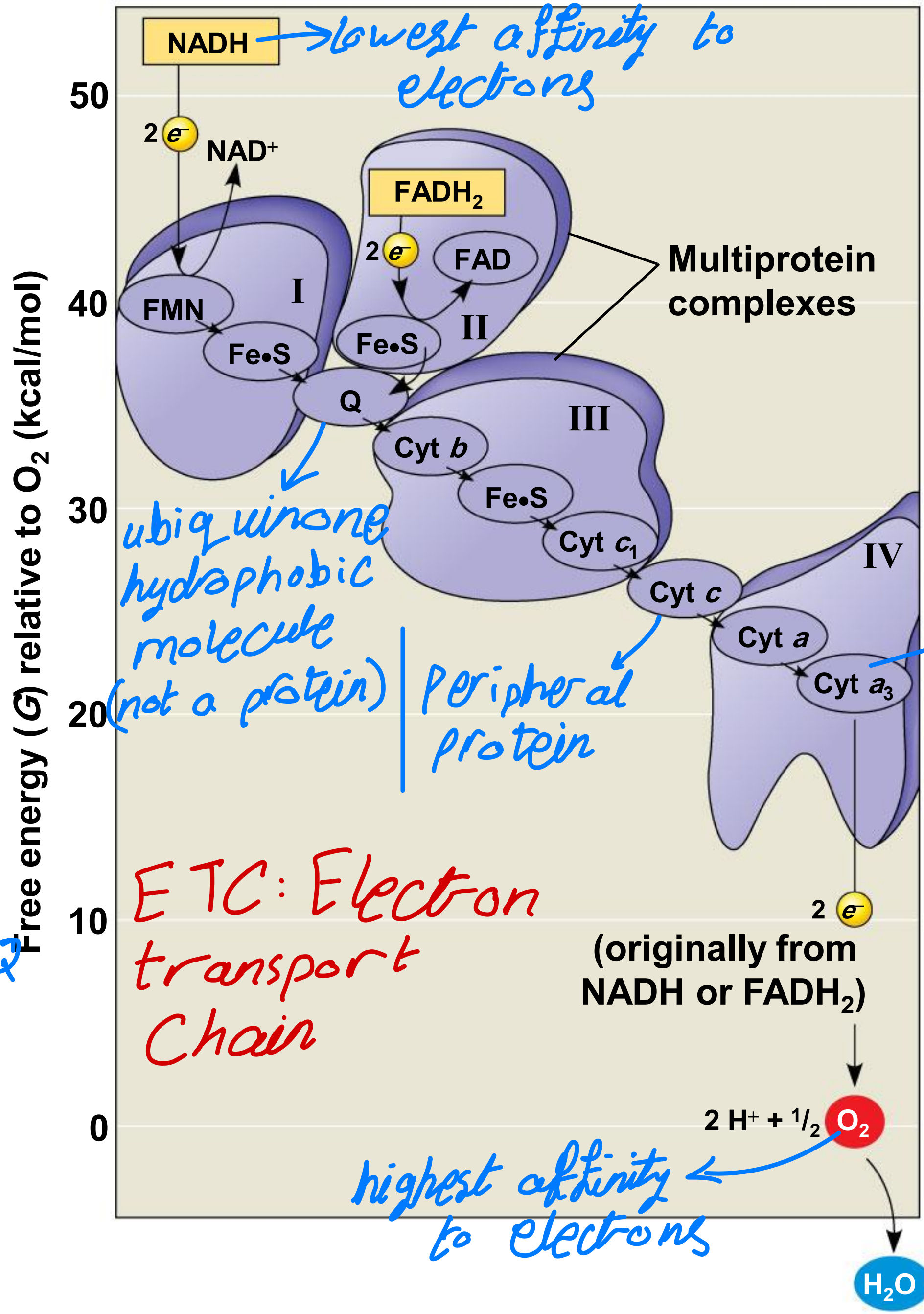
The Pathway of Electron Transport

- The electron transport chain is in the inner membrane (cristae) 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
- Electrons drop in free energy as they go down the chain and are finally passed to O_2, forming H_2O

Figure 9.13

Prosthetic groups :
A nonprotein components like cofactors and coenzymes that are bound tightly to the multiprotein complexes

ubiquinone is also called CoQ → coenzymeQ



1 NADH = 2.5 ATP

1 $FADH_2$ = 1.5 ATP

The last protein carrier

Electrons pathway

NADH

↓

multiprotein Complex I

↓

ubiquinone (Q)

↓

multiprotein complex III

$FADH_2$

↓

multi protein Complex II

↓

ubiquinone (Q)

↓

multi protein Complex III

- Electrons are transferred from NADH or $FADH_2$ to the electron transport chain
- Electrons are passed through a number of proteins including **cytochromes** (each with an iron atom) to O_2
- The electron transport chain generates no ATP directly
- It breaks the large free-energy drop from food to O_2 into smaller steps that release energy in manageable amounts