تَنوير

النادي الطبي

BIOLOGY

Lec no :

File Title : Chapter 10

Done By : Leen Al-Ashram

وَقُل رَّبِّ زِدْنِي عِلْمًا

Biology : chapter 10

celluler respiration & fermentation

Done by: leen Al-Ashram

BIOLOGY CHAPTER [redacted] 10

NO ATP

Cellular Respiration and Fermentation

(mitochondrion)

catabolic in present cell O_2

لجنة الطب البشري

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

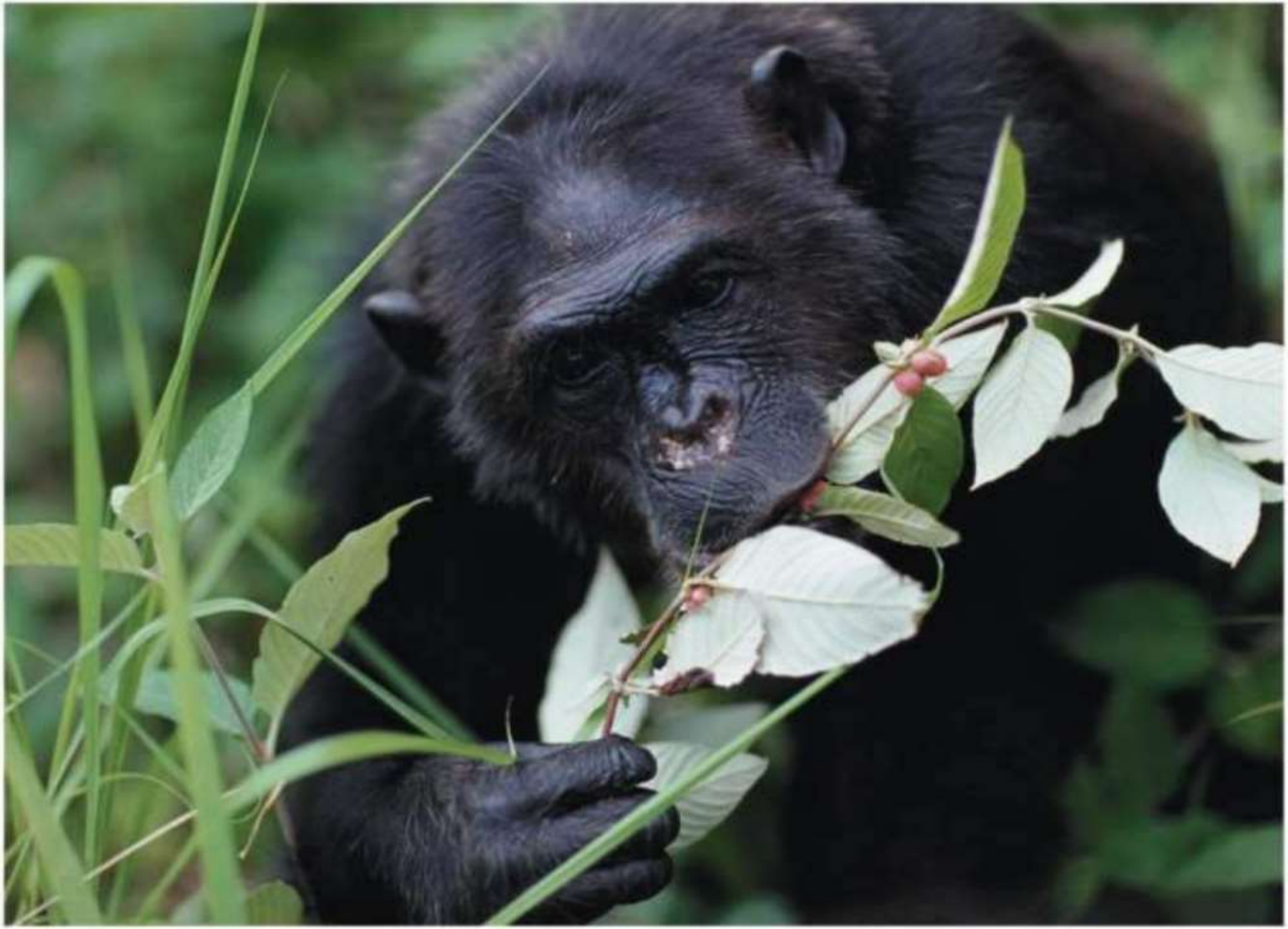
تتغذى

Metabolism → anabolism بناء photosynthesis → absorb energy (ATP) mostly
→ chloroplast (plants & algea)

→ catabolism هدم → cellular respiration → releases energy (ATP) mostly
& fermentation
→ mitochondria (plant & animal)

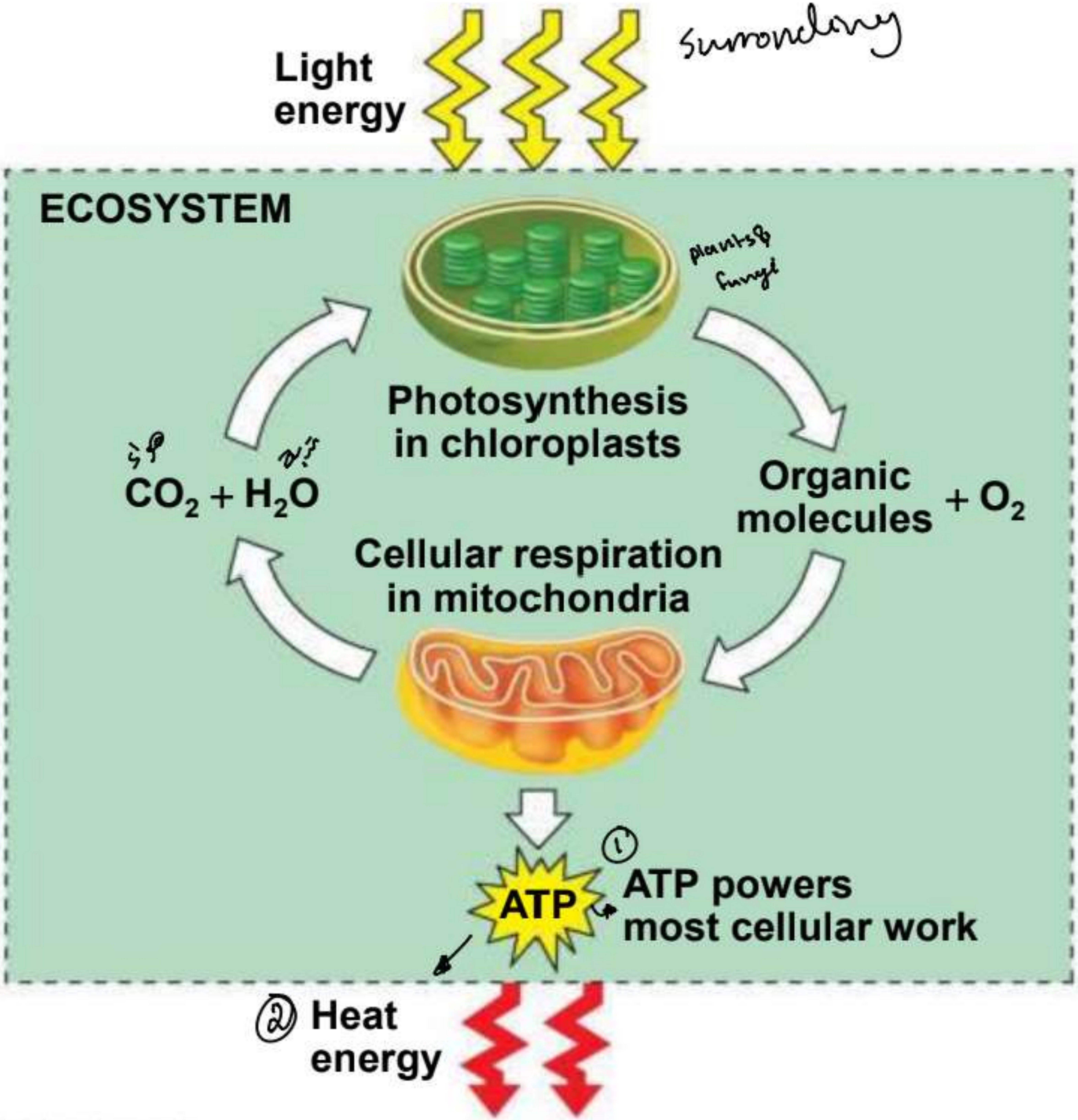
ecosystem نظام بيئي → كائنات حية + غير حية
living + non-living

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 generate → CO_2, water → Energy → inside the cell for the cellular work; → outside the cell as ATP
- 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

تنتج / release

- Several processes are central to cellular respiration and related pathways

catabolic pathways

- airobic respiration (بوجود O_2)
- complete oxidation for the glucose
  - e.i → cellular respiration
- Fermentation (without O_2 / تلجأ لمركبات أخرى)
- non-airobic respiration
- partial degradation of suger

Catabolic Pathways and Production of ATP

- The breakdown of organic molecules is exergonic → little ATP is needed
- **Fermentation** is a partial degradation of sugars that occurs without O_2
- **Aerobic respiration** consumes organic molecules and O_2 and yields ATP (e.g. cellular respiration; full oxidation)
- Anaerobic respiration is similar to aerobic respiration but consumes compounds other than O_2 (→ fermentation)

- **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

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

① oxidation : loss of e^-/H^+ // gain of O_2

② reduction : gain of e^-/H^+ // loss of O_2

بروتون وليس هيدروجين

$[e^-/H^+]$ ابدهم عل بعض دائماً

The Principle of Redox

- Chemical reactions that transfer electrons between reactants are called oxidation-reduction reactions, or **redox reactions**

* كل تفاعل oxidation بده تفاعل reduction جنبه.
* الالكترون اللي فقد في حد لازم يستقبله.

- In **oxidation**, a substance loses electrons, or is oxidized
- In **reduction**, a substance gains electrons, or is reduced (the amount of positive charge is reduced)

Figure 9.UN01

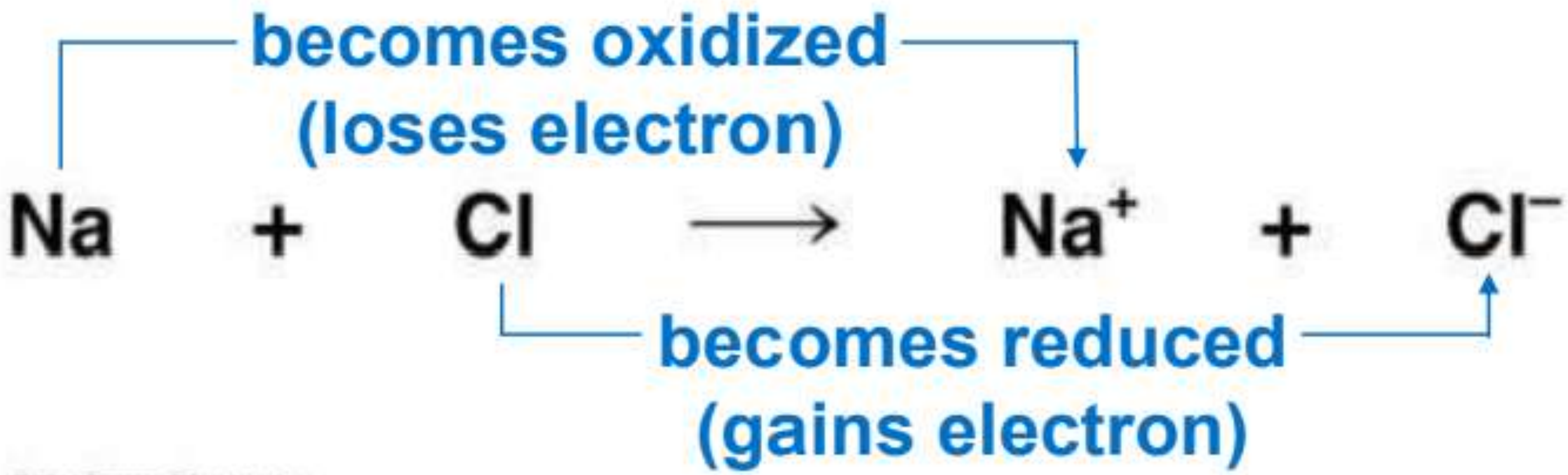
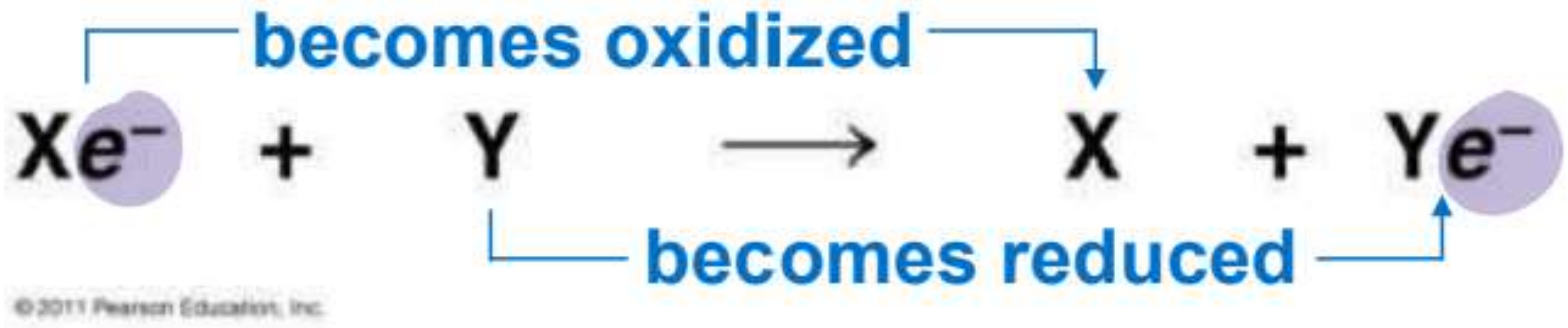


Figure 9.UN02

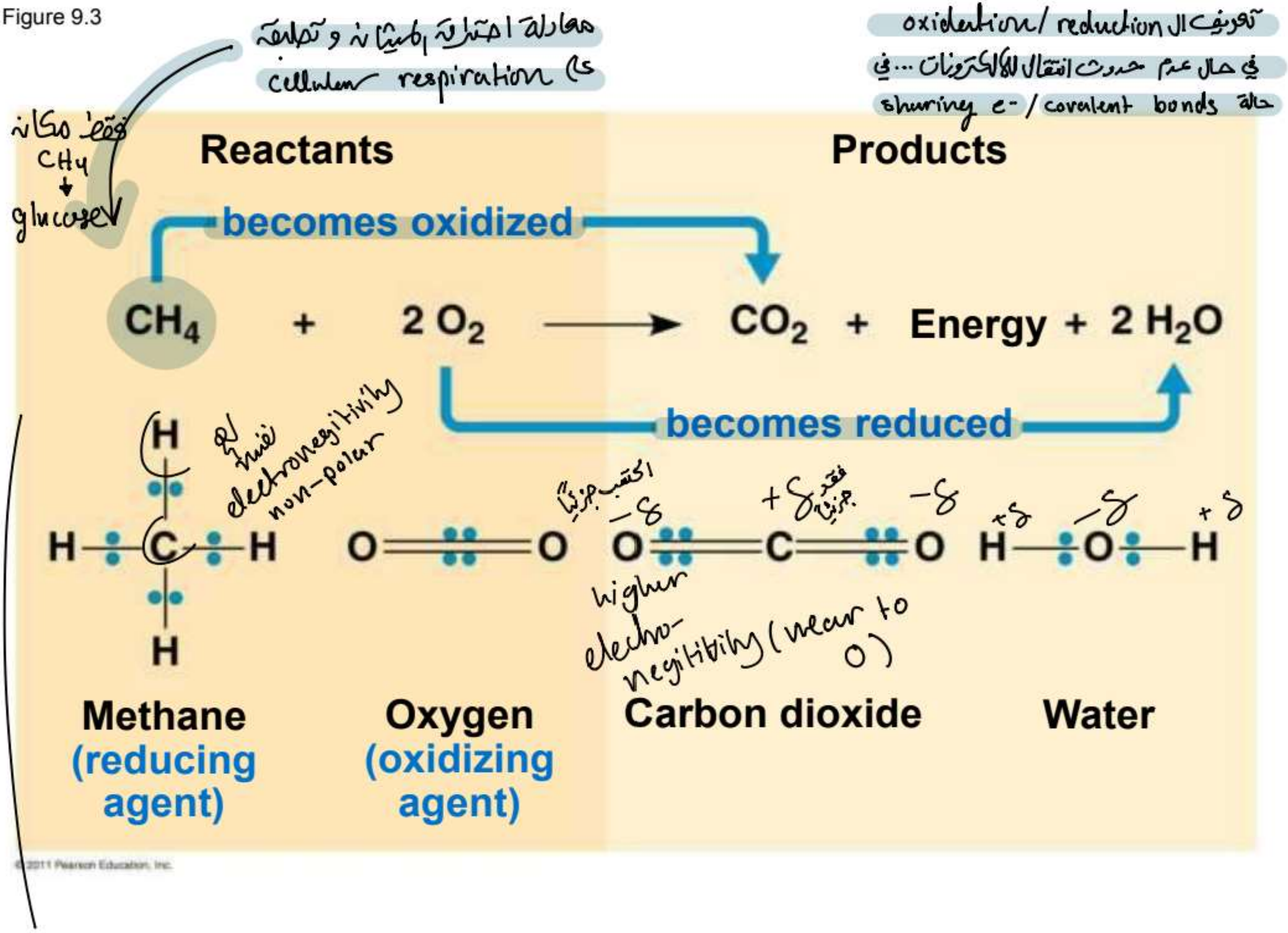


4. • The electron donor is called the **reducing agent**

5. • 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



Reactants
Products
becomes oxidized
CH_4 + $2\ O_2$ → CO_2 + Energy + $2\ H_2O$
becomes reduced
Methane (reducing agent)
Oxygen (oxidizing agent)
Carbon dioxide
Water
معادلة احتراق الميثان وتحليقه
cellular respiration ل
تعريف الـ oxidation/ reduction
في حال عدم حدوث انتقال للإلكترونات ... في
حالة sharing e- / covalent bonds
نضع مكانه
CH4 → glucose
نفس الـ electronegitivity
non-polar
-δ +δ -δ
+δ -δ +δ
higher electro-negitivity (near to O)

Oxidation of Organic Fuel Molecules During Cellular Respiration

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

Figure 9.UN03

تنفس inhalation

كل energy مختزلة بين الروابط في
glucose, ولتحرير الطاقة من الروابط المستقرة → * with help of dehydrogenase (an enzyme), takes H_2 of the glucose $(2e^- + 2H^+)$ → NAD^+ takes $2e^- + 1H^+$ we have extra H^+ → NADH تصبح
فنعطيه القليل من الطاقة لكي تضعف الروابط بين
[H/C/O] / عند تكسر الرابطة تتحرر e^- تحتوي الطاقة ؟،
تنتقل إلى O_2 [مستقبلها] لتتحول $O_2 \rightarrow H_2O$
* final electron (لأن انتقال e يصاحبه انتقال H^+ في) receptor in cellular respiration is O_2

* receptor who take electrons once they're out of glucose is NAD^+ [1st primary electron receptor] / it is a co-enzyme

becomes oxidized

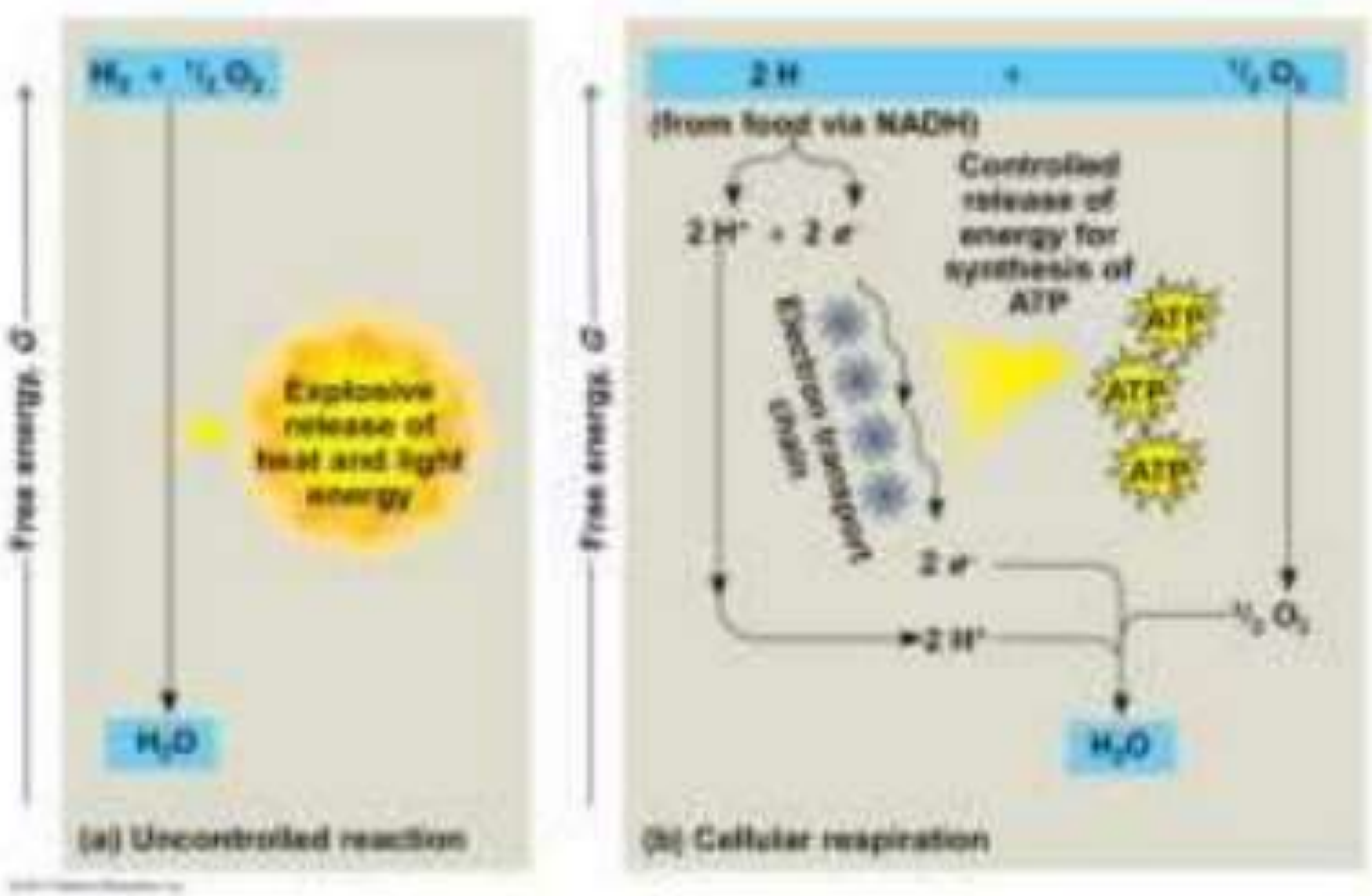
$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

becomes reduced

O_2: final electron receptor

Energy ↓ from the glucose

for this slide



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

Figure 9.4

Nicotinamide Adenine Dinucleotide

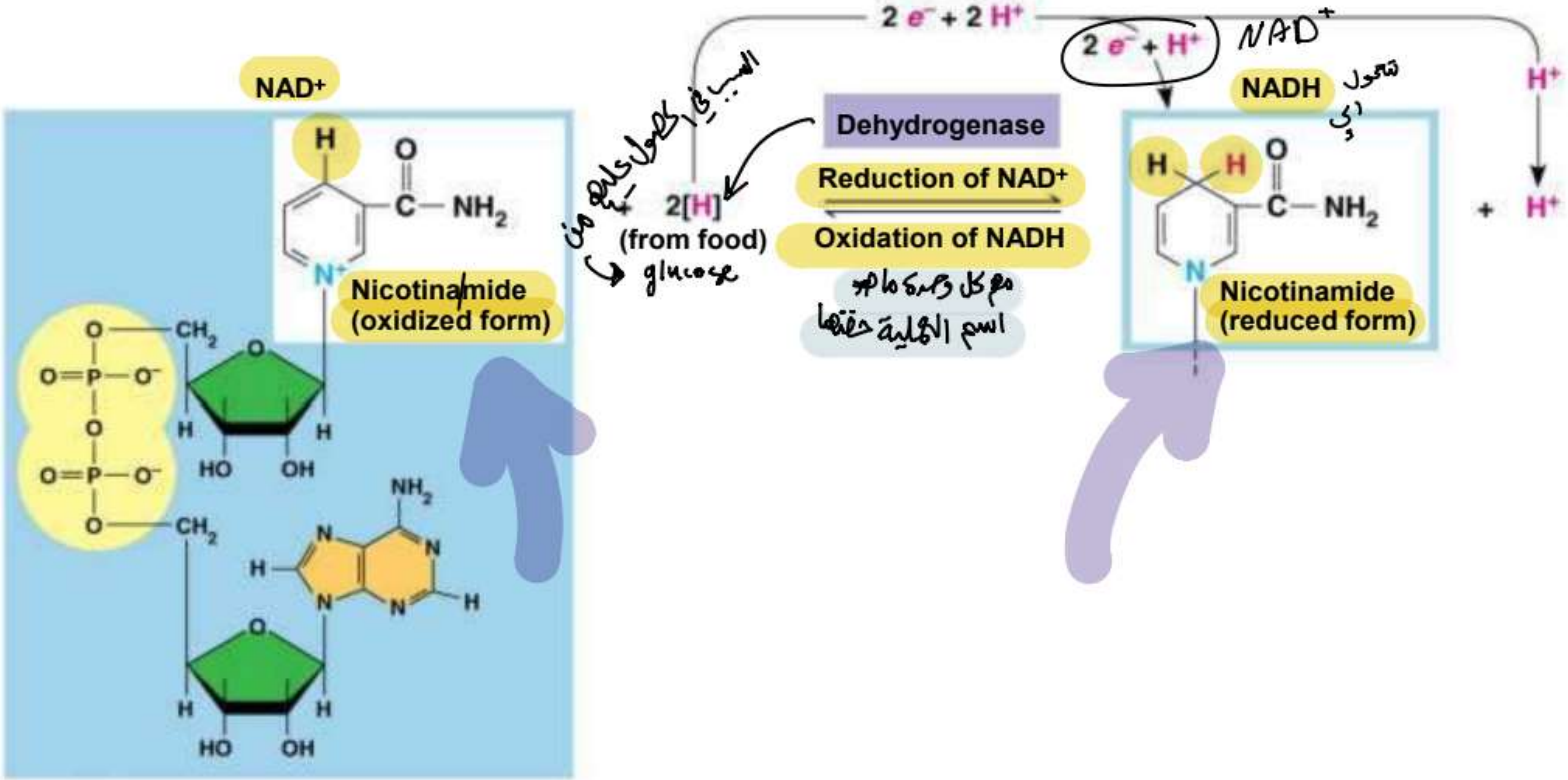
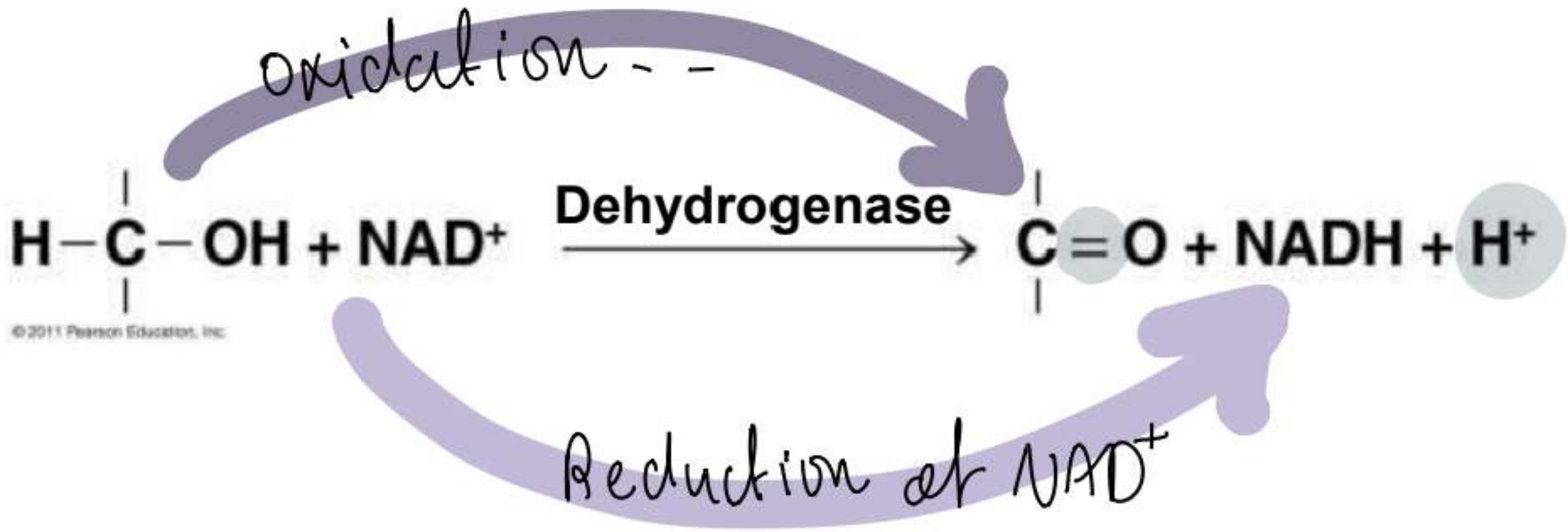


Figure 9.UN04



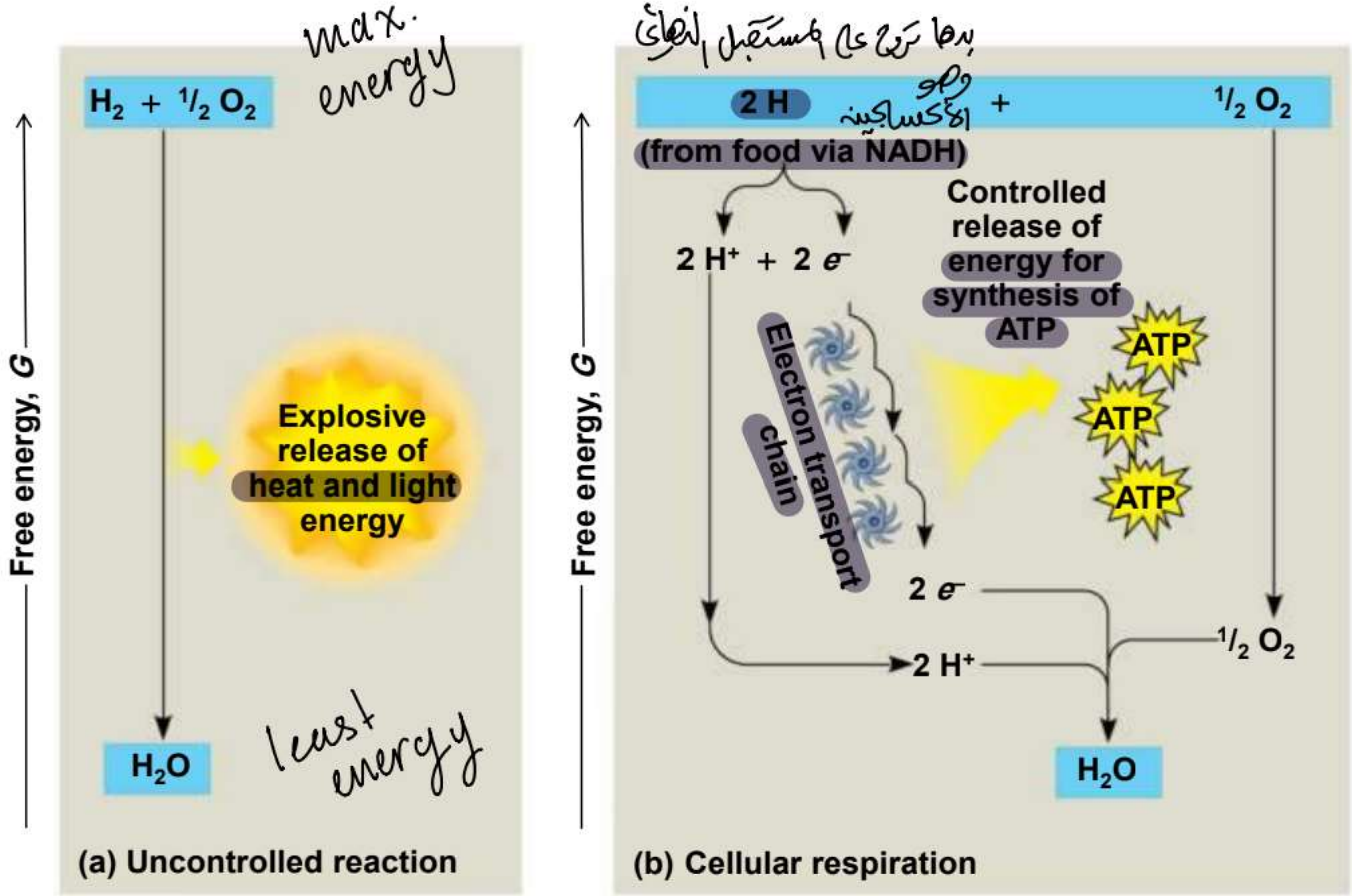
- NADH passes the electrons to the **electron transport chain**

[على عكس التفاعل غير المنضبط، تمرّر سلسلة نقل الإلكترونات بالإلكترونات في سلسلة من الخطوات بدلا من تفاعل متفجر واحد]

- 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

يتم استخدام الطاقة الناتجة لتجديد ATP

Figure 9.5



H_2 + $^1/_2$ O_2
Free energy, G
Explosive release of heat and light energy
H_2O
(a) Uncontrolled reaction
2 H
(from food via NADH)
+
$^1/_2$ O_2
Controlled release of energy for synthesis of ATP
2 H^+ + 2 e^-
Electron transport chain
ATP
ATP
ATP
2 e^-
$^1/_2$ O_2
2 H^+
H_2O
(b) Cellular respiration

The Stages of Cellular Respiration: *A Preview*

- Harvesting (taking) of energy from glucose has three stages
  1. – **Glycolysis** (breaks down glucose into two molecules of pyruvate) splitting sugar, in cytosol
     - between them: pyruvate oxidation
  2. – The **citric acid cycle** (completes the breakdown of glucose) in matrix
     - occurs in matrix
  3. – **Oxidative phosphorylation** (accounts for most of the ATP synthesis) in mitochondrial inner membrane/cristea: which is folded to increase efficiency of cellular respiration

Figure 9.UN05

1. Glycolysis (color-coded teal throughout the chapter)
2. Pyruvate oxidation and the citric acid cycle (color-coded salmon)
3. Oxidative phosphorylation: electron transport and chemiosmosis (color-coded violet)

Figure 9.6-1

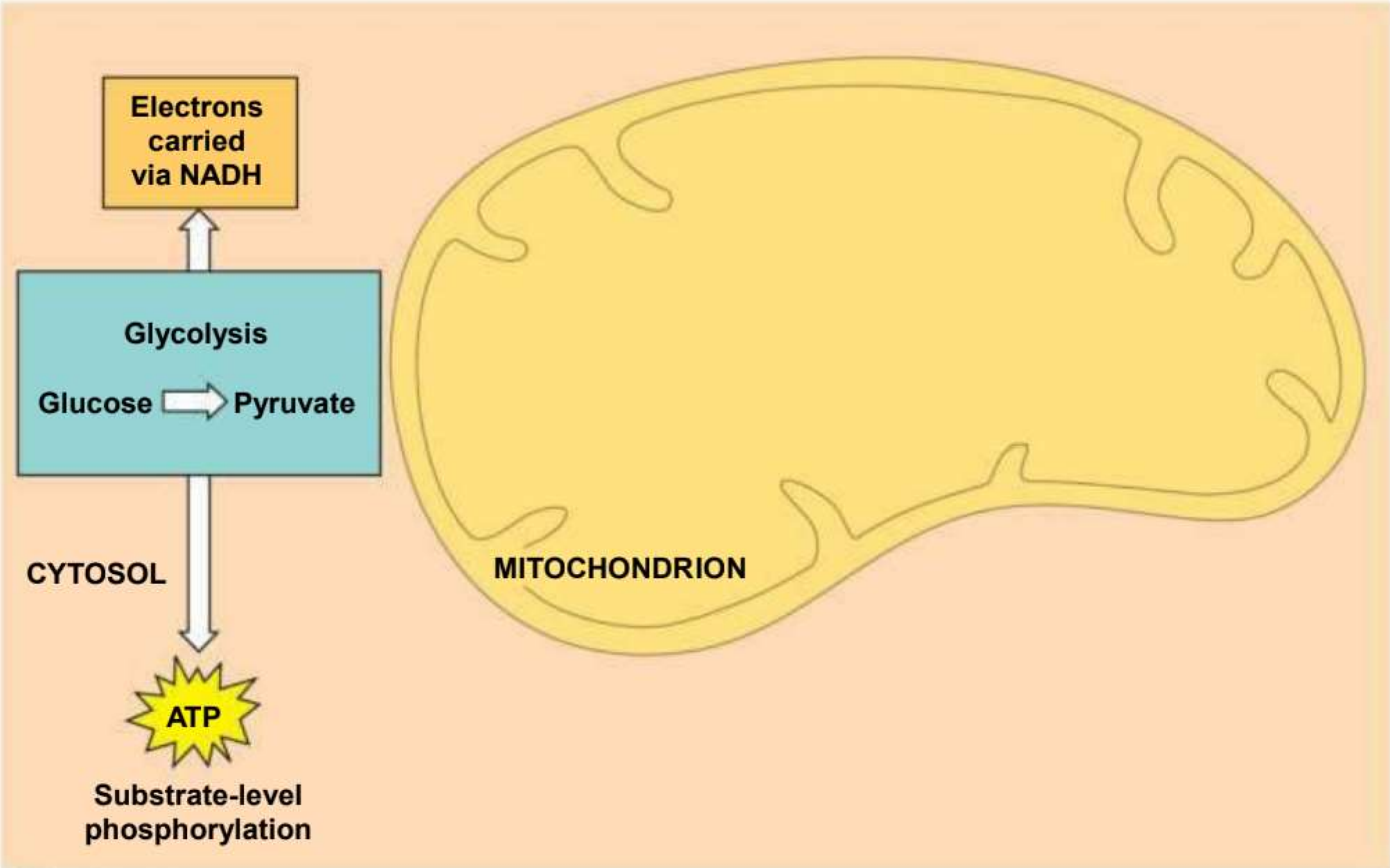
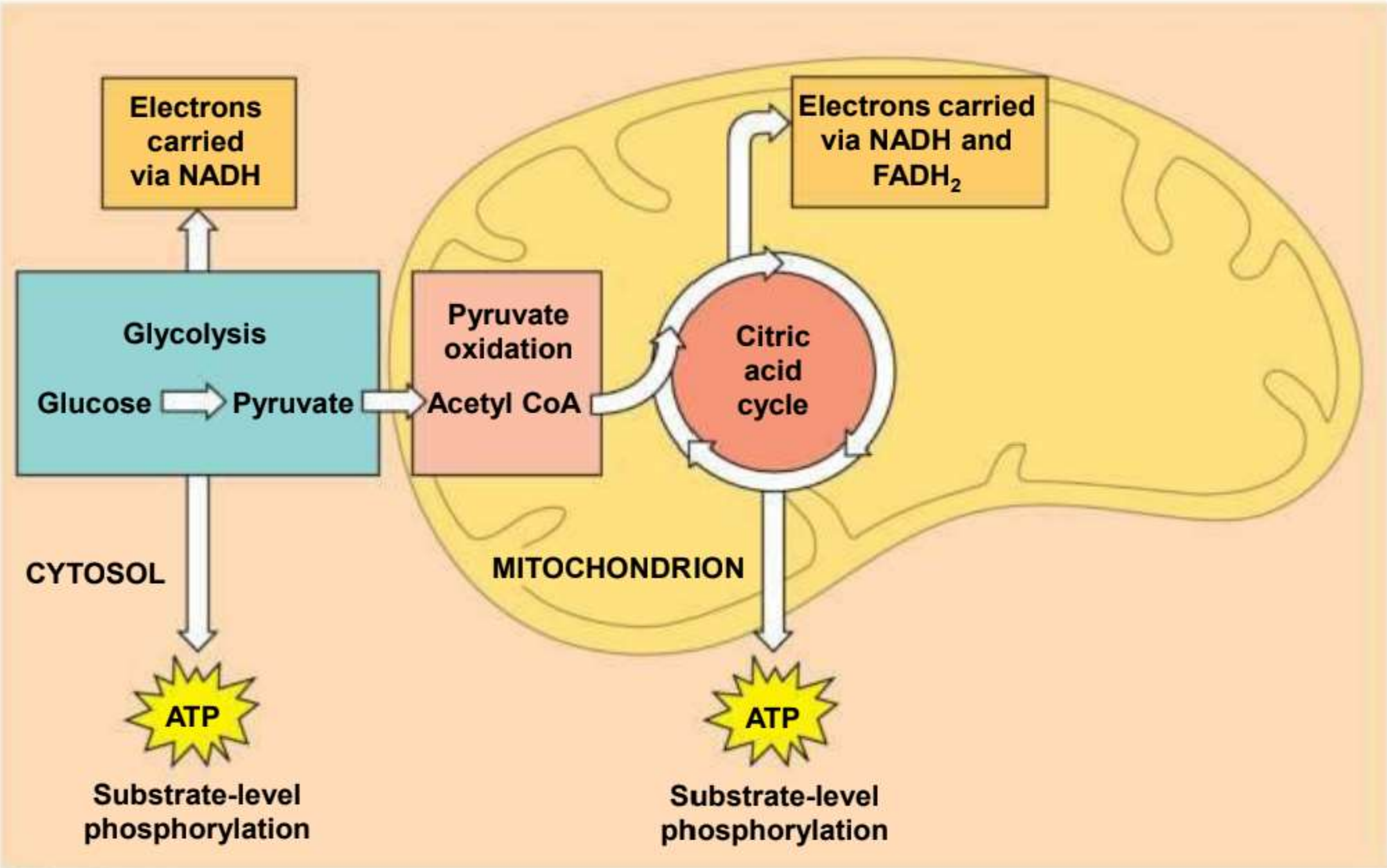
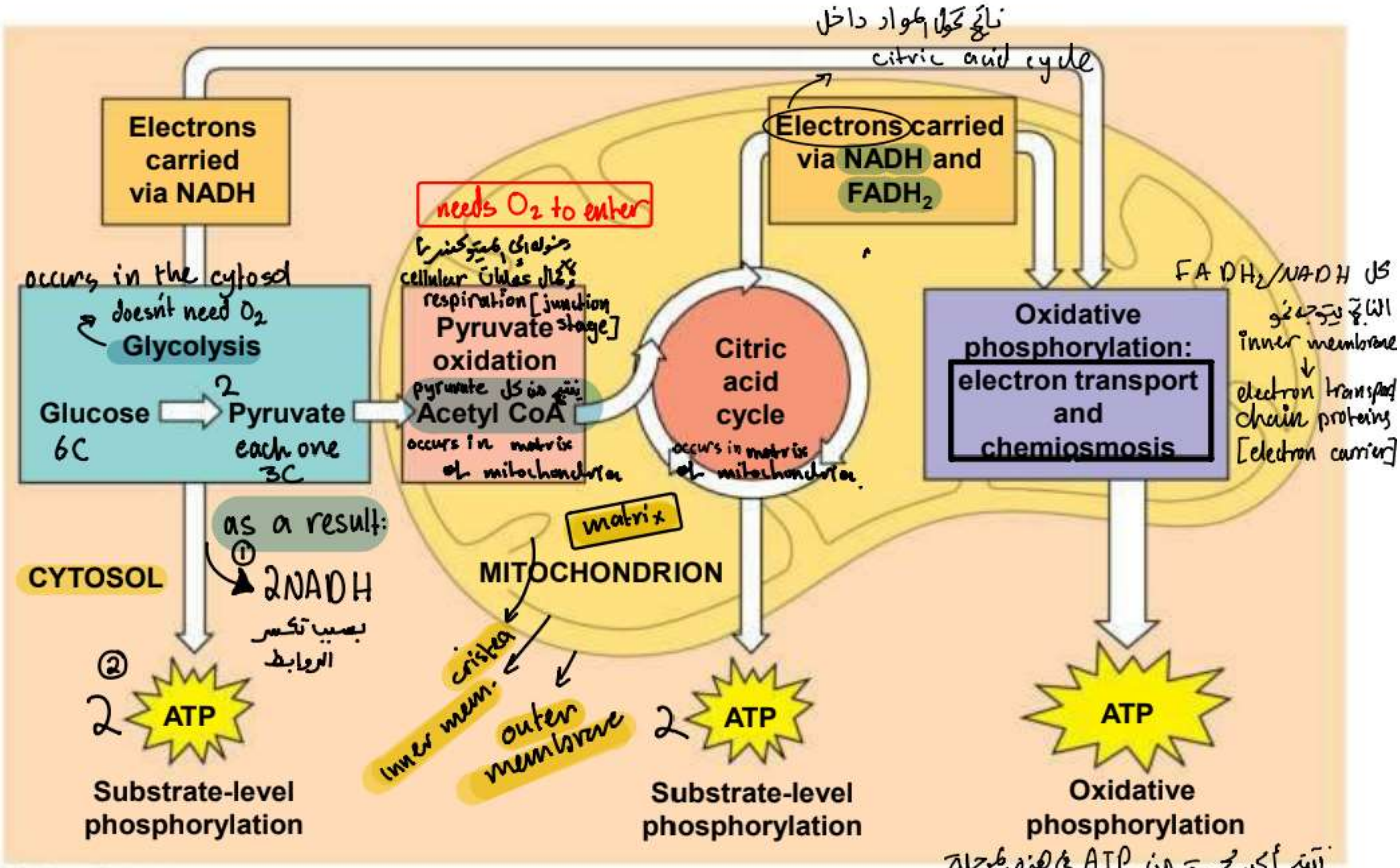

Electrons carried via NADH
Glycolysis
Glucose
Pyruvate
CYTOSOL
MITOCHONDRION
ATP
Substrate-level phosphorylation

Figure 9.6-2



Electrons carried via NADH
Electrons carried via NADH and $FADH_2$
Glycolysis
Glucose
Pyruvate
Pyruvate oxidation
Acetyl CoA
Citric acid cycle
CYTOSOL
MITOCHONDRION
ATP
ATP
Substrate-level phosphorylation
Substrate-level phosphorylation

Figure 9.6-3



تنتج أكبر كمية من ATP في هذه المرحلة
لانها تستفيد من الطاقة المحمولة في NADH و
$FADH_2$ من خلال الالكترونات في انتاج ATP

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

phosphorylation of ADP ← adding phosphate group

ADP + Ⓟ ⟶ ATP : لإنتاج ATP

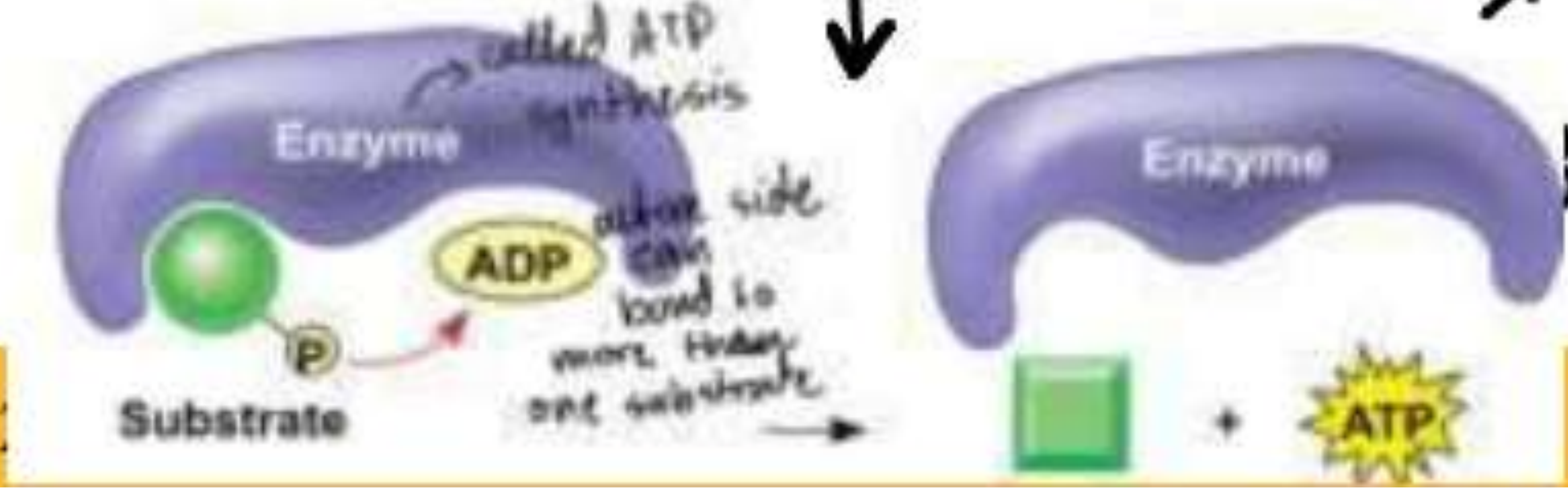
ويوجد طريقتان لإنتاجه / حسب مصدر مجموعة الفوسفات

1. **Substrate-level phosphorylation**

↓ phosphate group is from a substrate

2. **Oxidative phosphorylation**

بعد شوي ح تفرق هاي السلايد



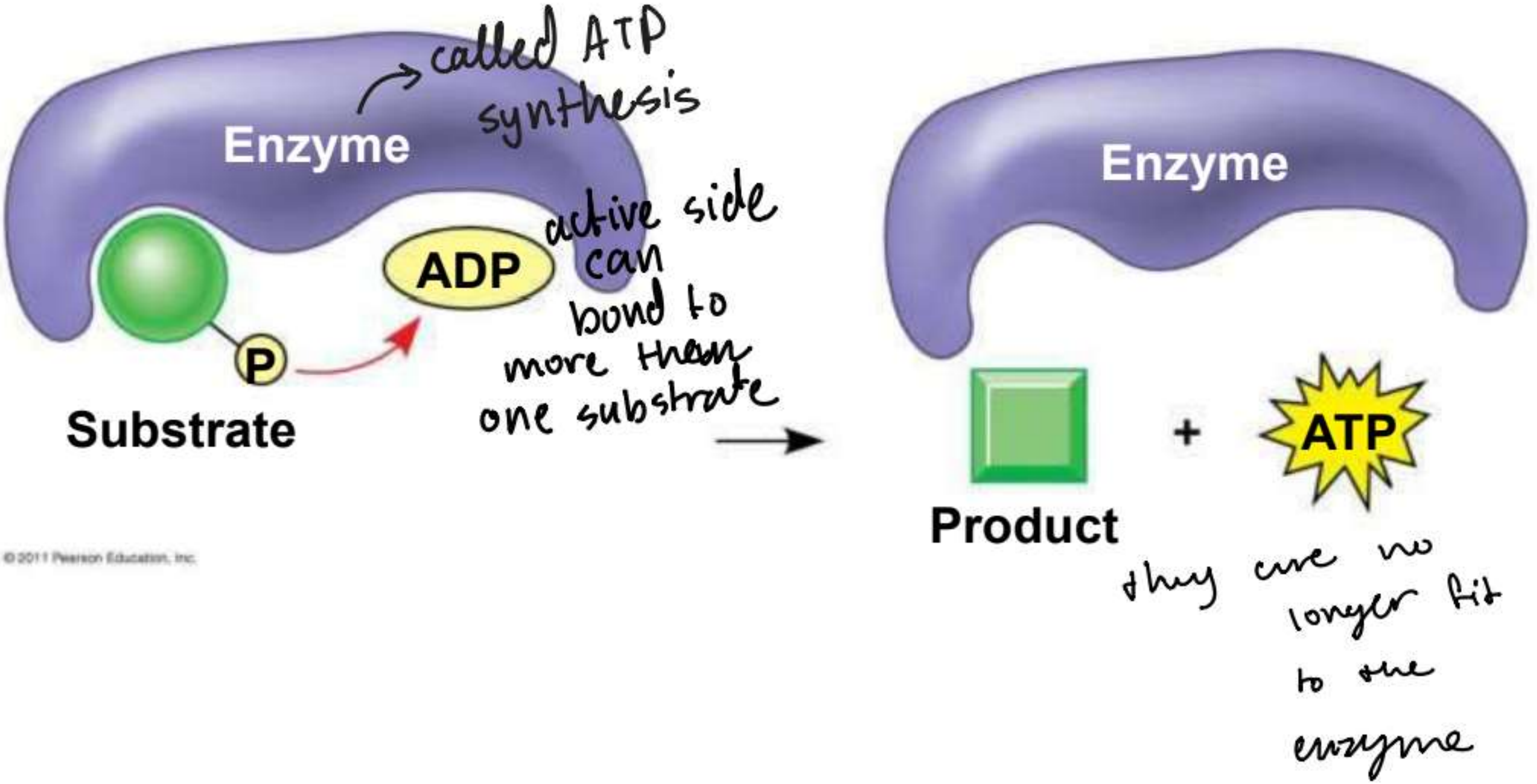
ioFlix: Cellular Respiration

- 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** → adding phosphate group to the compound
- 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

Substrate-level phosphorylation

→ less efficient than oxidative phosphorylation

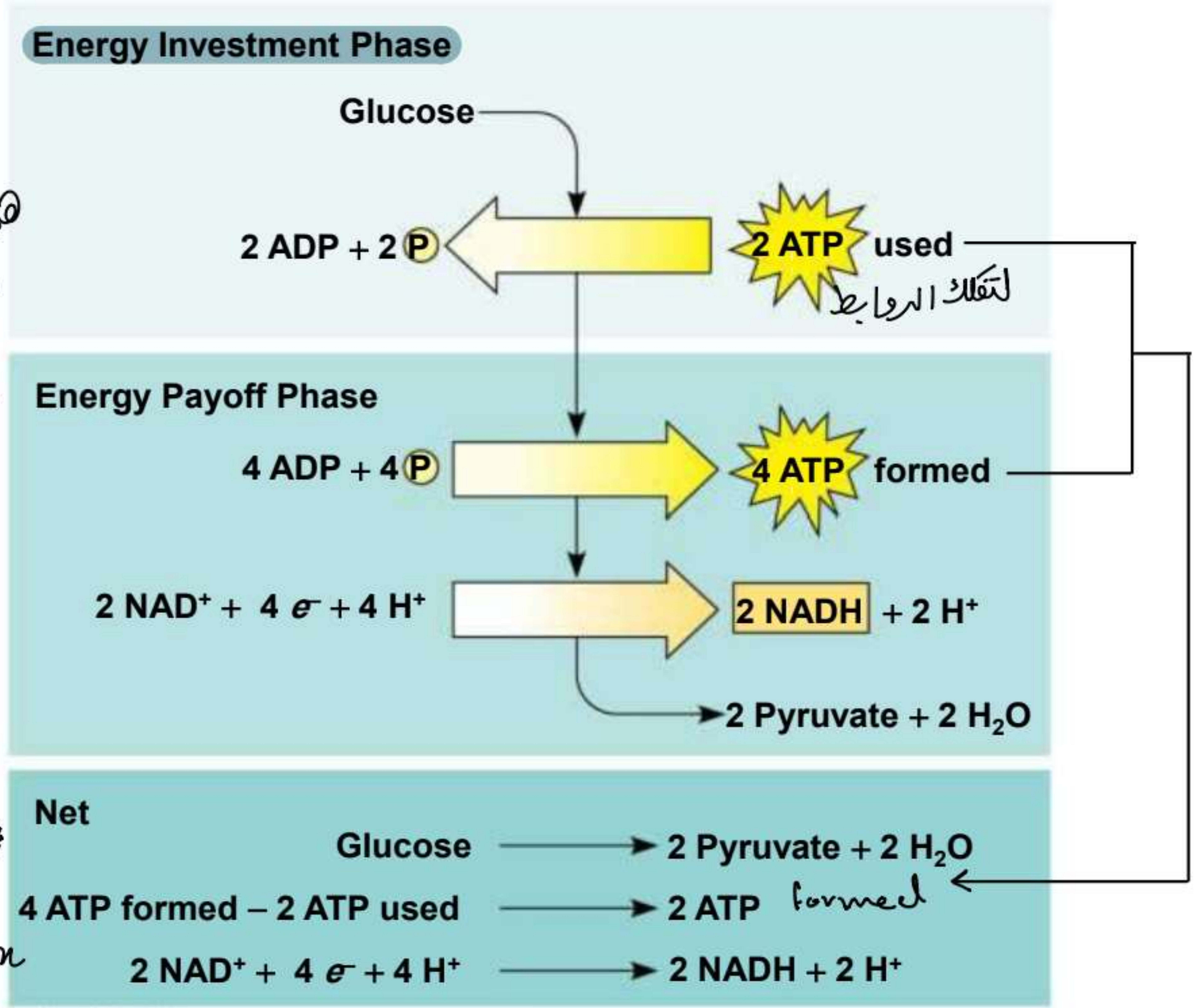


Concept 9.2: Glycolysis harvests chemical energy by oxidizing glucose to pyruvate

- 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
  - Energy payoff phase
- Glycolysis occurs whether or not O_2 is present

Figure 9.8

هون ح ناخذ كل عملية بالتفصيل

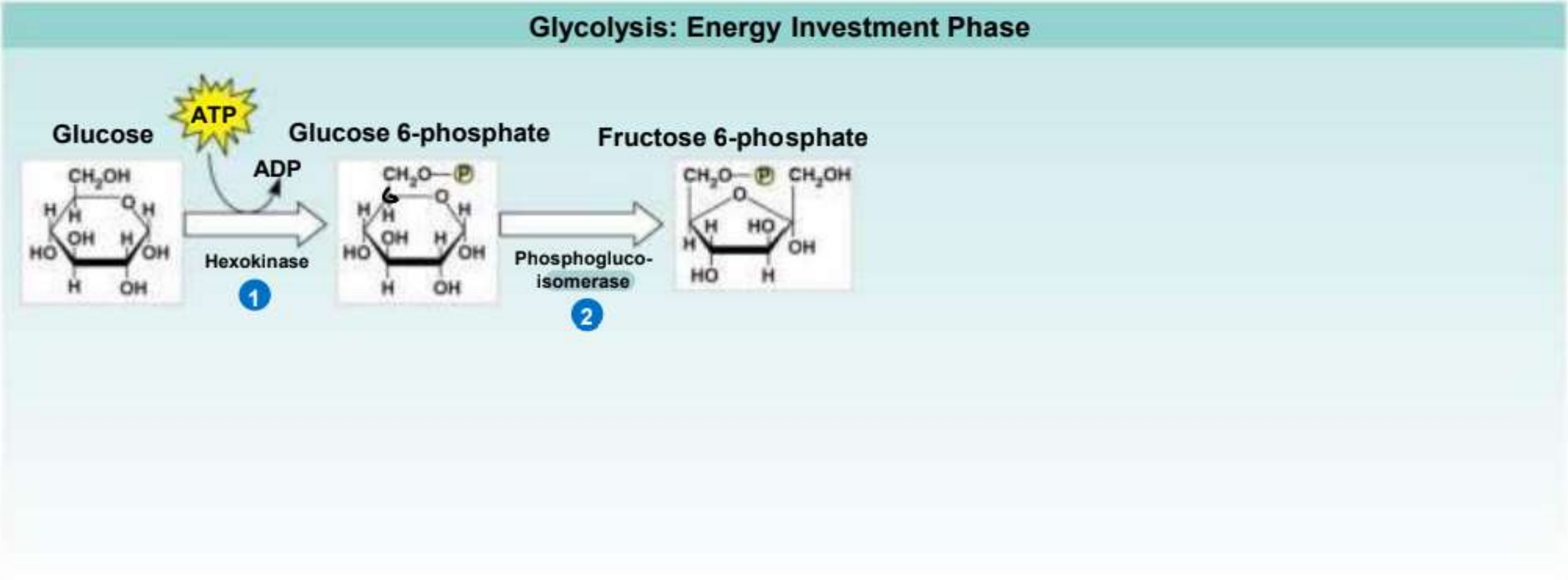


النواتج النهائية في عملية glycolosis by substrate-level phosphorylation

Figure 9.9-1

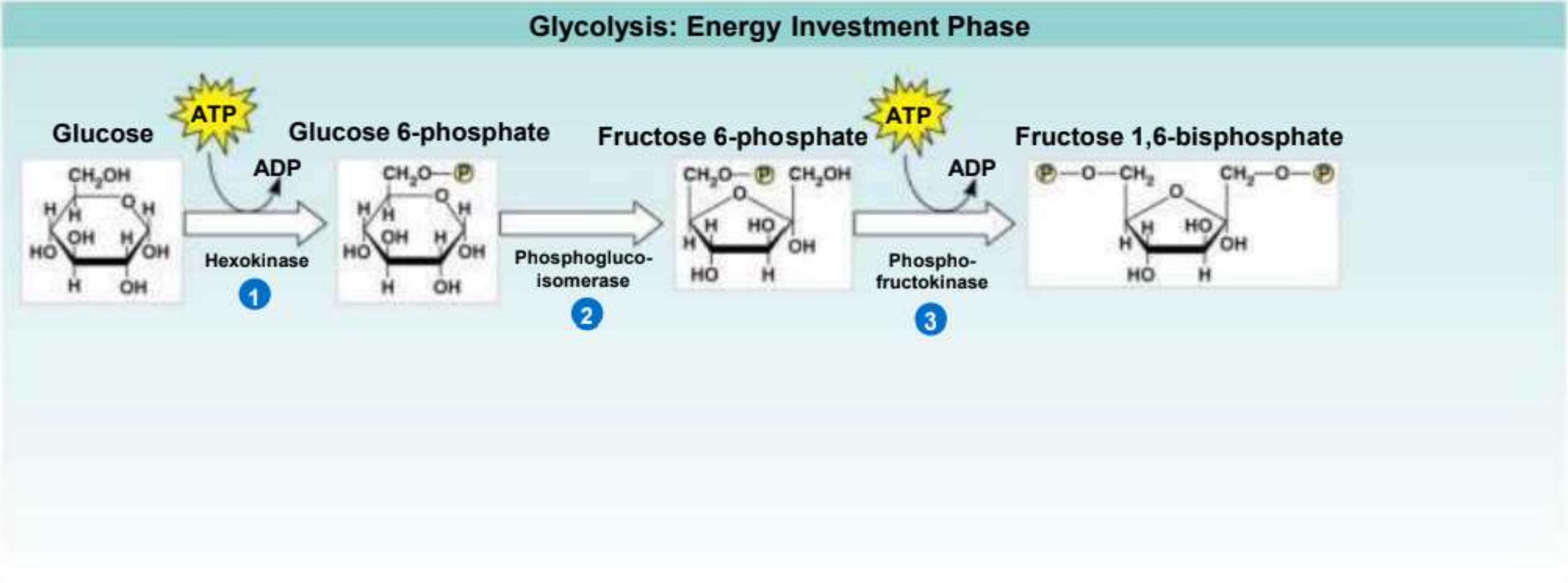

Glycolysis: Energy Investment Phase
Glucose
ATP
ADP
Glucose 6-phosphate
Hexokinase
1
CH2OH
CH2O—P
H
OH
HO

Figure 9.9-2



Glycolysis: Energy Investment Phase
ATP
Glucose
Glucose 6-phosphate
Fructose 6-phosphate
ADP
Hexokinase
1
Phosphogluco-
isomerase
2

Figure 9.9-3



Glycolysis: Energy Investment Phase
Glucose
ATP
ADP
Hexokinase
1
Glucose 6-phosphate
Phosphogluco-
isomerase
2
Fructose 6-phosphate
ATP
ADP
Phospho-
fructokinase
3
Fructose 1,6-bisphosphate

Figure 9.9-4

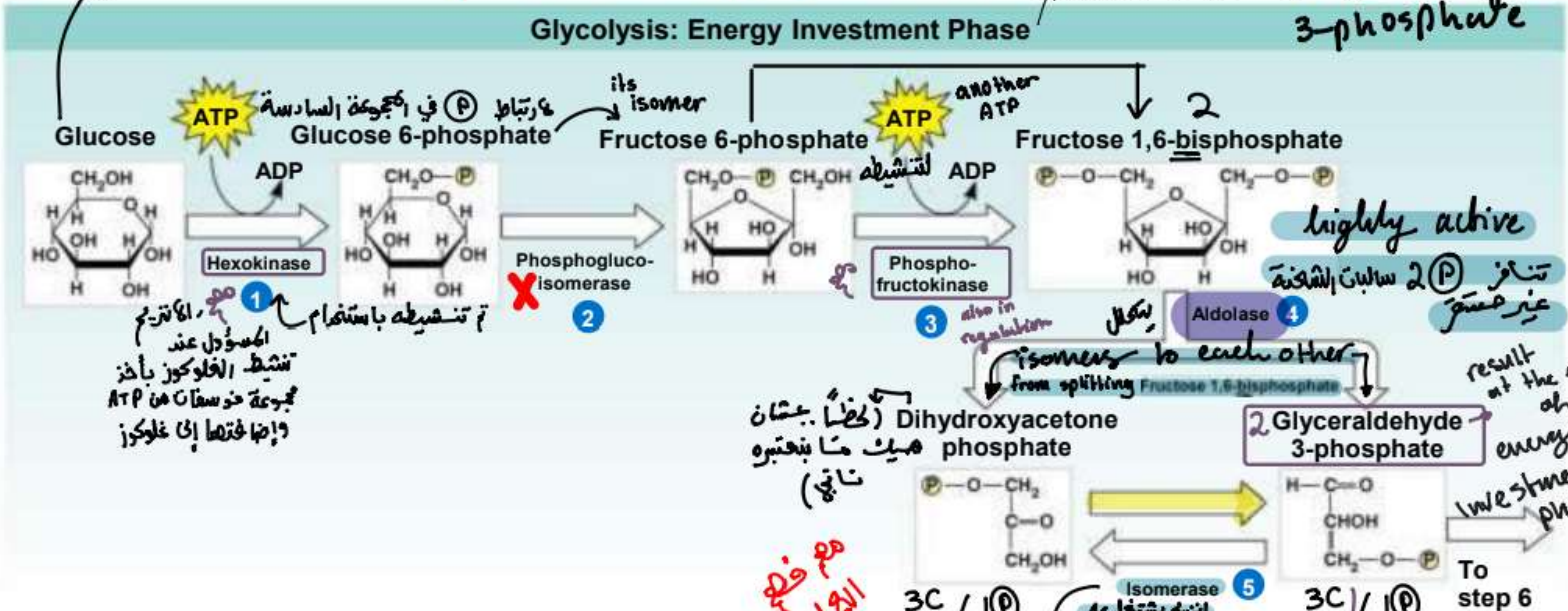
عشان نفكك روابطه بدنا ندخله 2ATP ولكن مش مرة وحدة - بالتدريج -

* معمم ATP دخل *

حفظ اوله انزيم نشط التفاعل Hexokinase

حفظ ثاني انزيم نشط الغلوكوز Phospho-fructokinase

. begin with one glucose &
. ends with 2 Glyceraldehyde 3-phosphate



© 2011 Pearson Education, Inc.

- وارتباط Ⓟ في المجموعة السادسة
- its isomer
- another ATP
- لتنشيطه
- تم تنشيطه باستخدام
- مهم، الانزيم المسؤول عند تنشيط الغلوكوز بأخذ مجموعة فوسفات من ATP وإضافتها إلى غلوكوز
- also in regulation
- highly active
- تنافر 2Ⓟ سالبات الشحنة غير مستقر
- يحلل
- isomers to each other
- from splitting Fructose 1,6-bisphosphate
- (خطأ. عشان هيك ما بنعتبره ناتج)
- result at the end of energy investment phase
- مهم فهم العملية
- 3C / 1Ⓟ
- works according to the concentration 2-sides
- انزيم يشتغل مع الجهتين / بشوف وين تركيزه اكثر بروح بحوله للاشي الثاني
- على حالونه مارح تتشفيد الخلية
- dehydrogenase نقلل من تركيزه ولذلك كل ما يتكون
- Dihydroxyacetone phosphate
- رح يتحول الى
- Glyceraldehyde 3-phosphate
- energy Payoff phases الي رح يدخلوا

Figure 9.9-5

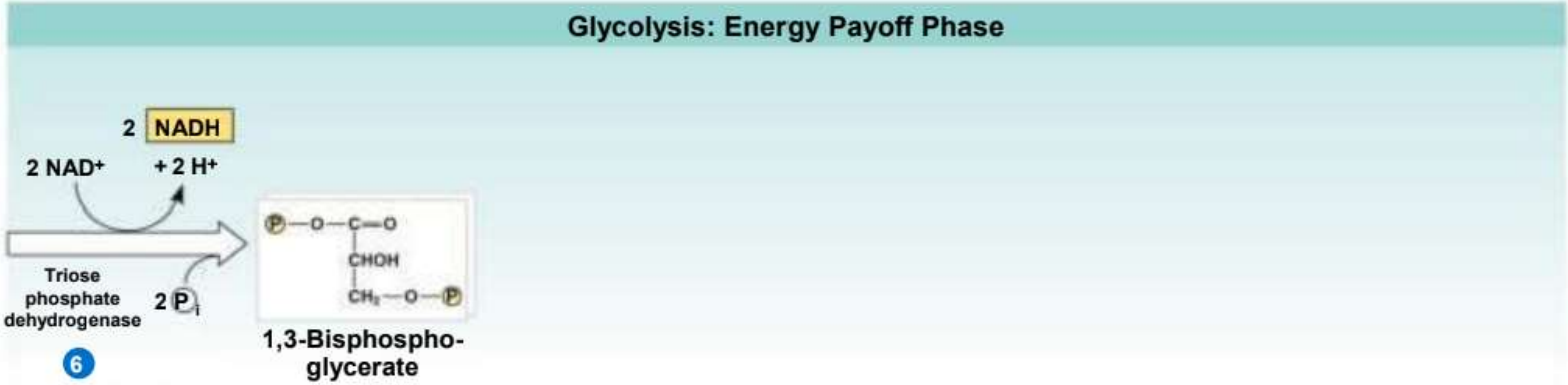

Glycolysis: Energy Payoff Phase
2 NADH
2 NAD+
+ 2 H+
Triose phosphate dehydrogenase
2 Pi
6
1,3-Bisphospho-glycerate

Figure 9.9-6

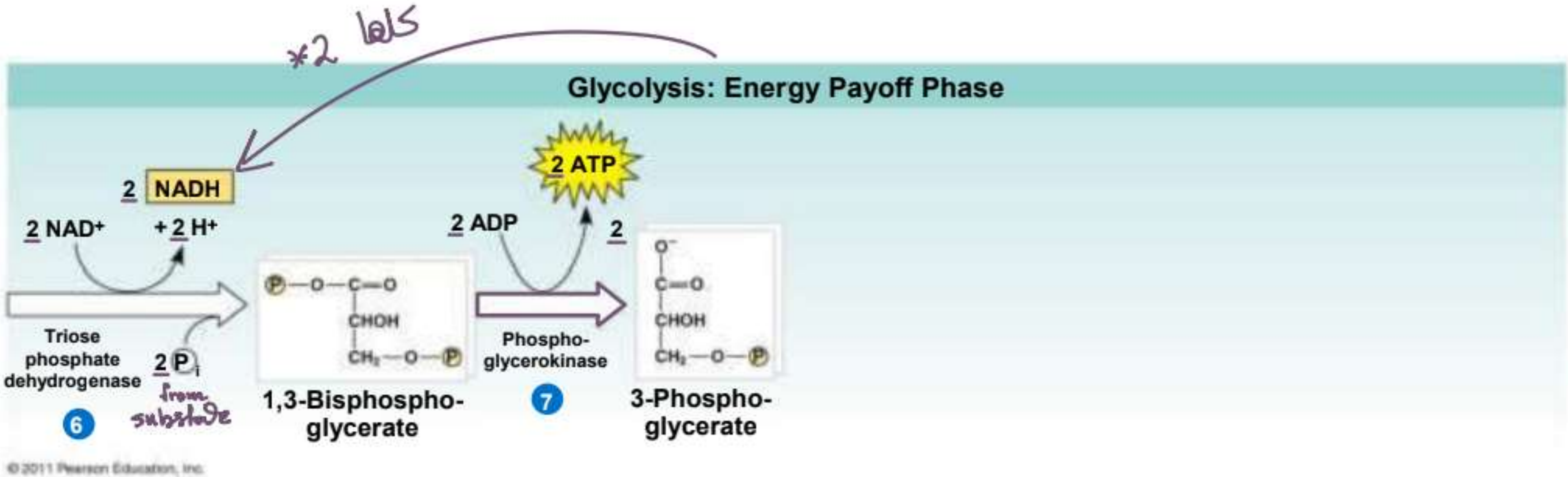
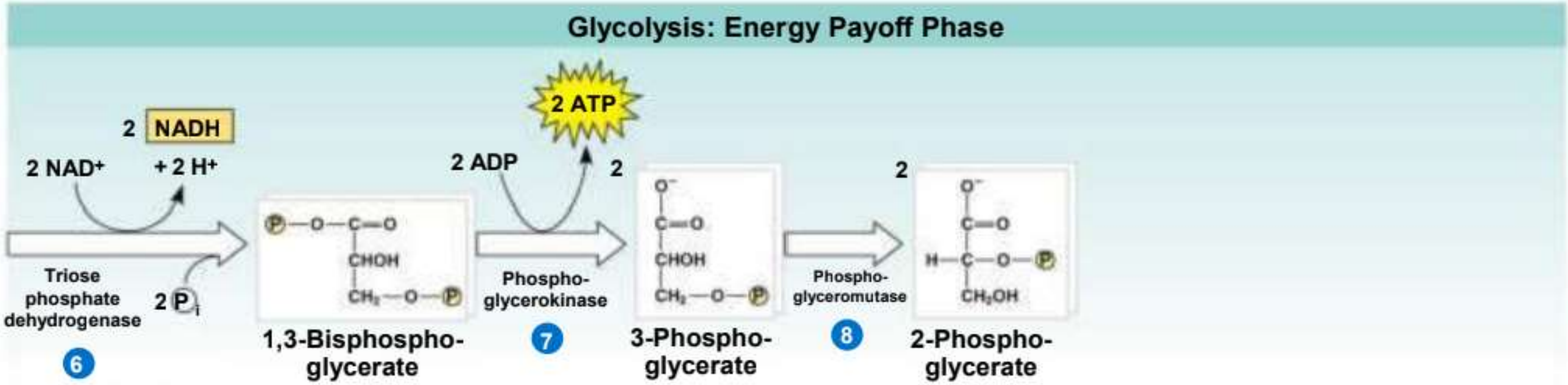

*2 lols
Glycolysis: Energy Payoff Phase
2 NADH
2 NAD+
+ 2 H+
Triose phosphate dehydrogenase
2 P i
from substrate
6
1,3-Bisphosphoglycerate
2 ATP
2 ADP
Phosphoglycerokinase
7
2
3-Phosphoglycerate
© 2011 Pearson Education, Inc.

Figure 9.9-7



Glycolysis: Energy Payoff Phase
2 NADH
2 NAD+
+ 2 H+
2 ATP
2 ADP
2
2
Triose
phosphate
dehydrogenase
2 P i
6
1,3-Bisphospho-
glycerate
Phospho-
glycerokinase
7
3-Phospho-
glycerate
Phospho-
glyceromutase
8
2-Phospho-
glycerate

Figure 9.9-8

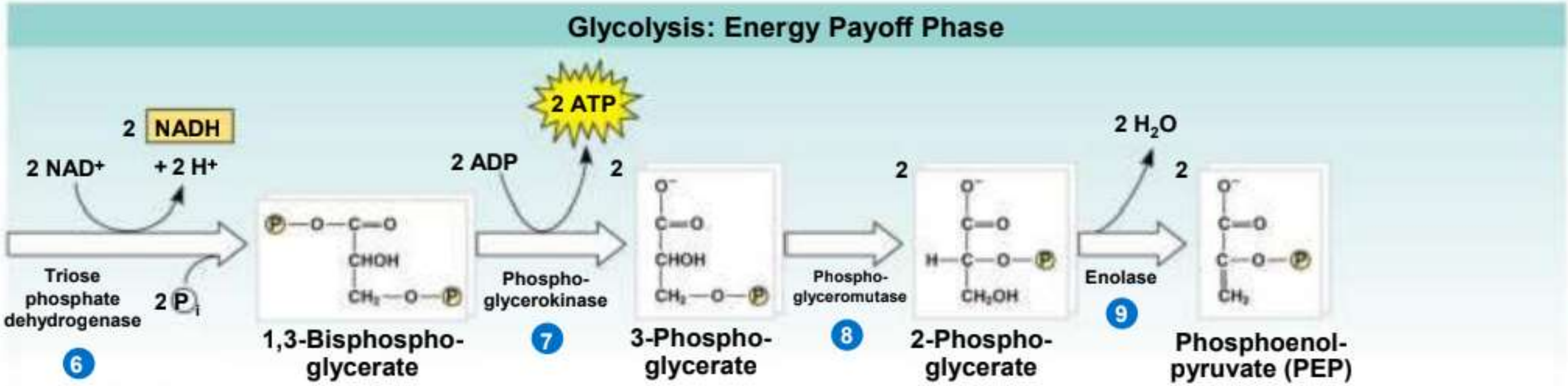
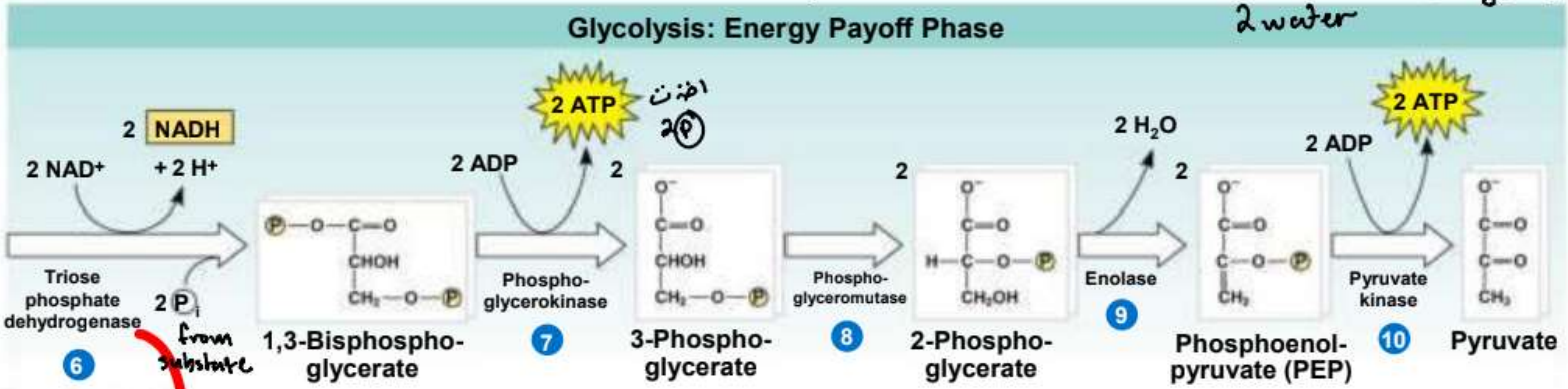

Glycolysis: Energy Payoff Phase
2 NADH
2 NAD+
+ 2 H+
2 Pi
Triose phosphate dehydrogenase
6
1,3-Bisphospho-glycerate
2 ADP
2 ATP
2
Phospho-glycerokinase
7
3-Phospho-glycerate
2
Phospho-glyceromutase
8
2-Phospho-glycerate
2 H2O
2
Enolase
9
Phosphoenol-pyruvate (PEP)

Figure 9.9-9

• Begins with enterence of 2 Glyceraldehyde 3-phosphate

*2 عشان هيك كل عملياتها

حفظ النتائج فقط : 2pyruvate/ 2H+/ 2NADH/ 4ATP/ 2water

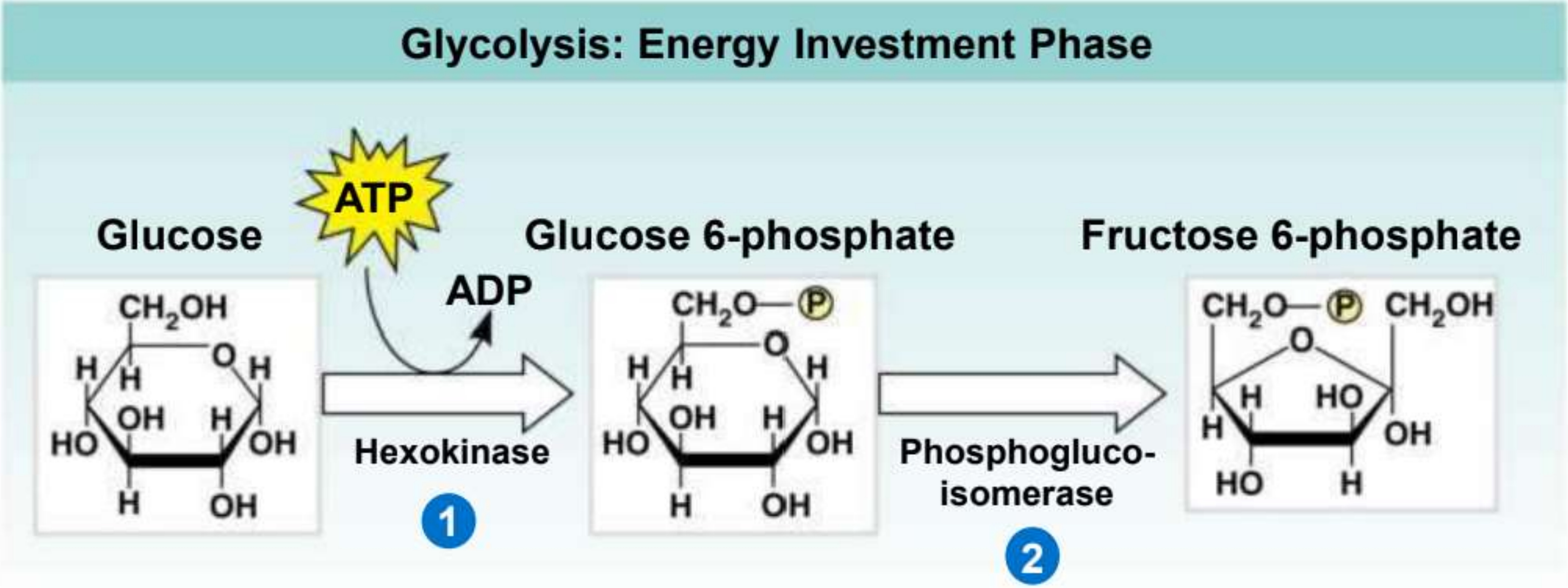


اخذت 2P

from substrate

انزيم ال dehydrogenase الذي سوف يشتغل ع Glyceraldehyde 3-phosphate سوف يأخذ H+/e- منه

Figure 9.9a



Glycolysis: Energy Investment Phase
ATP
Glucose
ADP
Glucose 6-phosphate
Fructose 6-phosphate
CH2OH
CH2O—P
CH2O—P
CH2OH
Hexokinase
1
Phosphogluco-
isomerase
2

Figure 9.9b

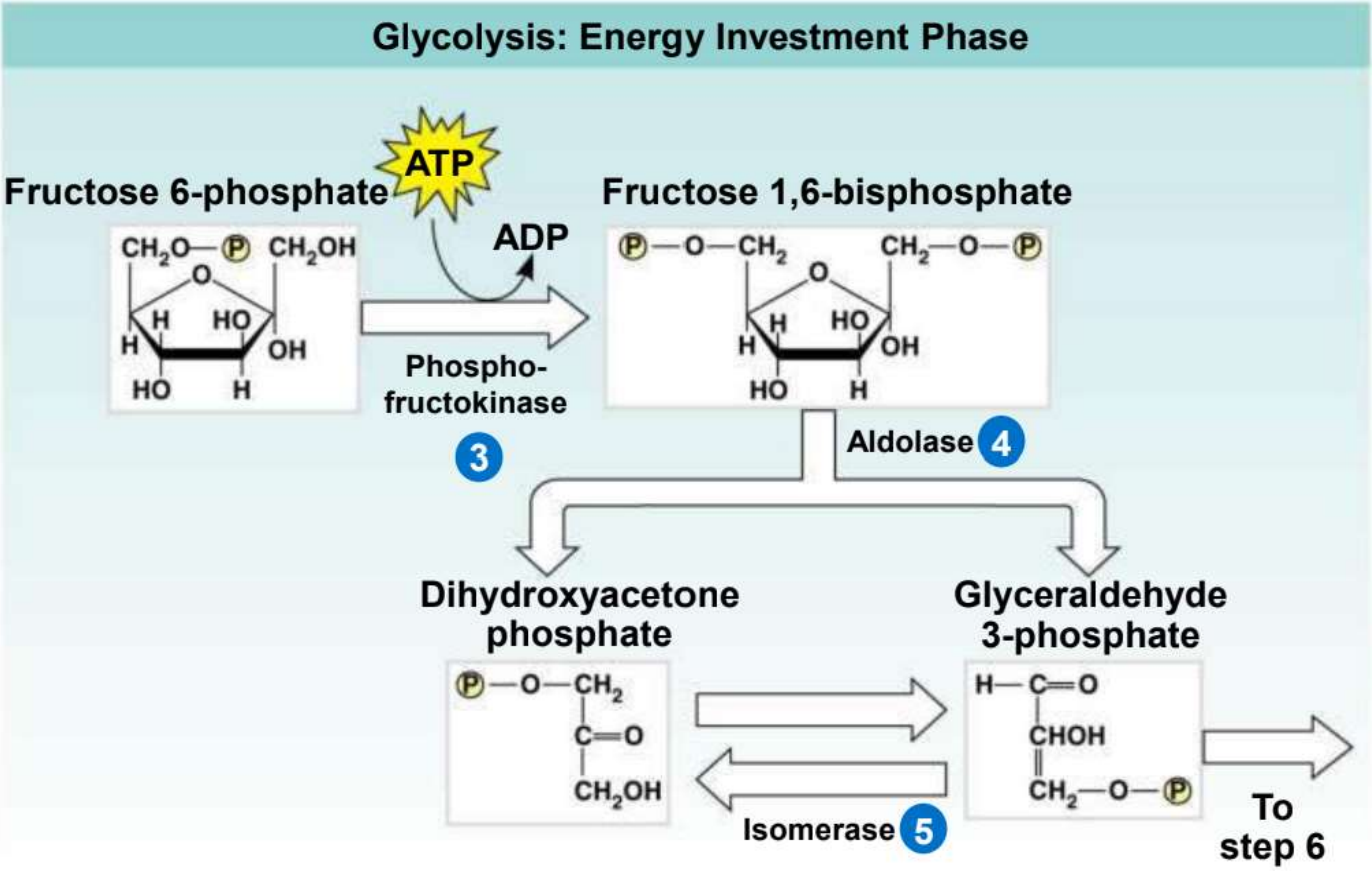
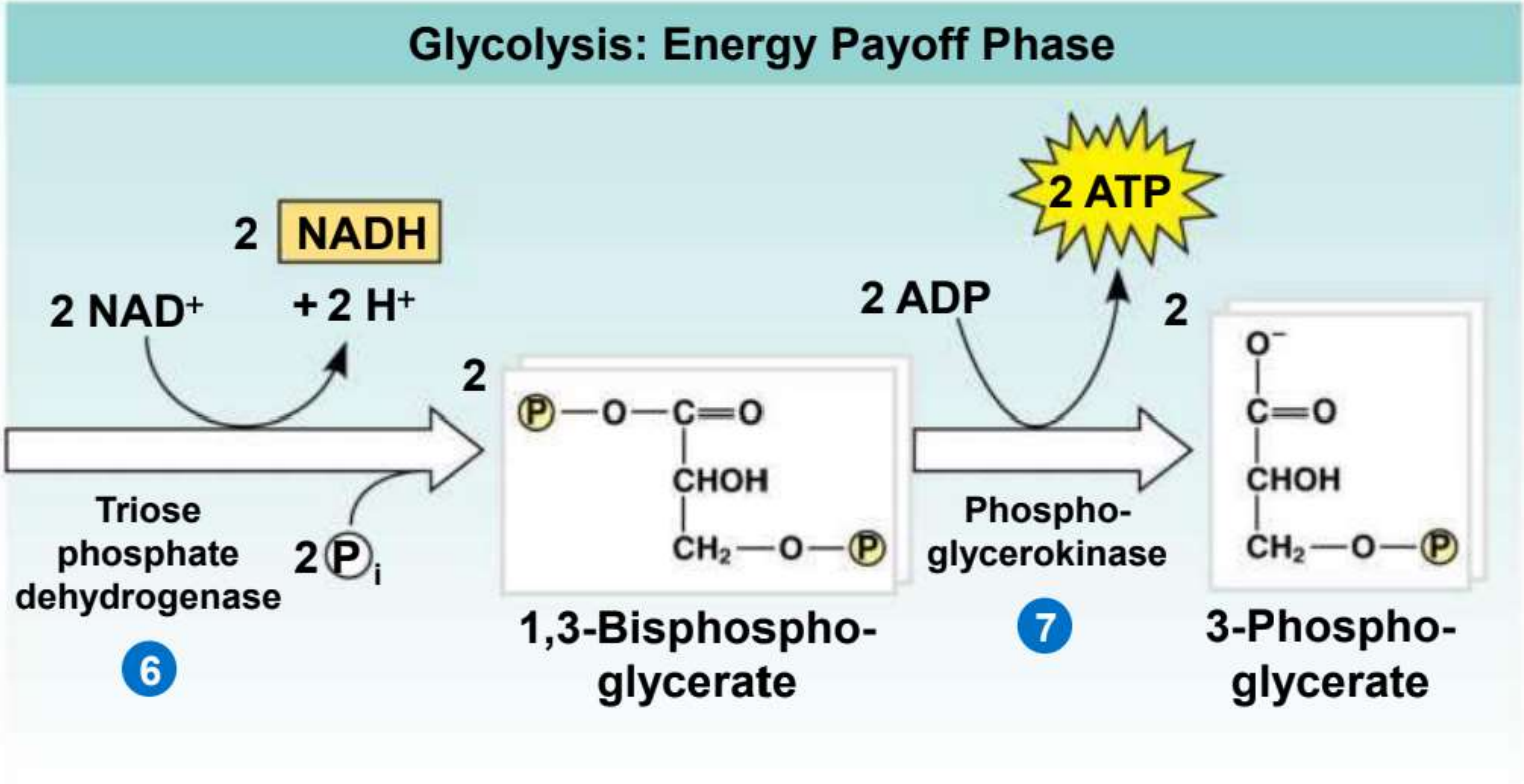
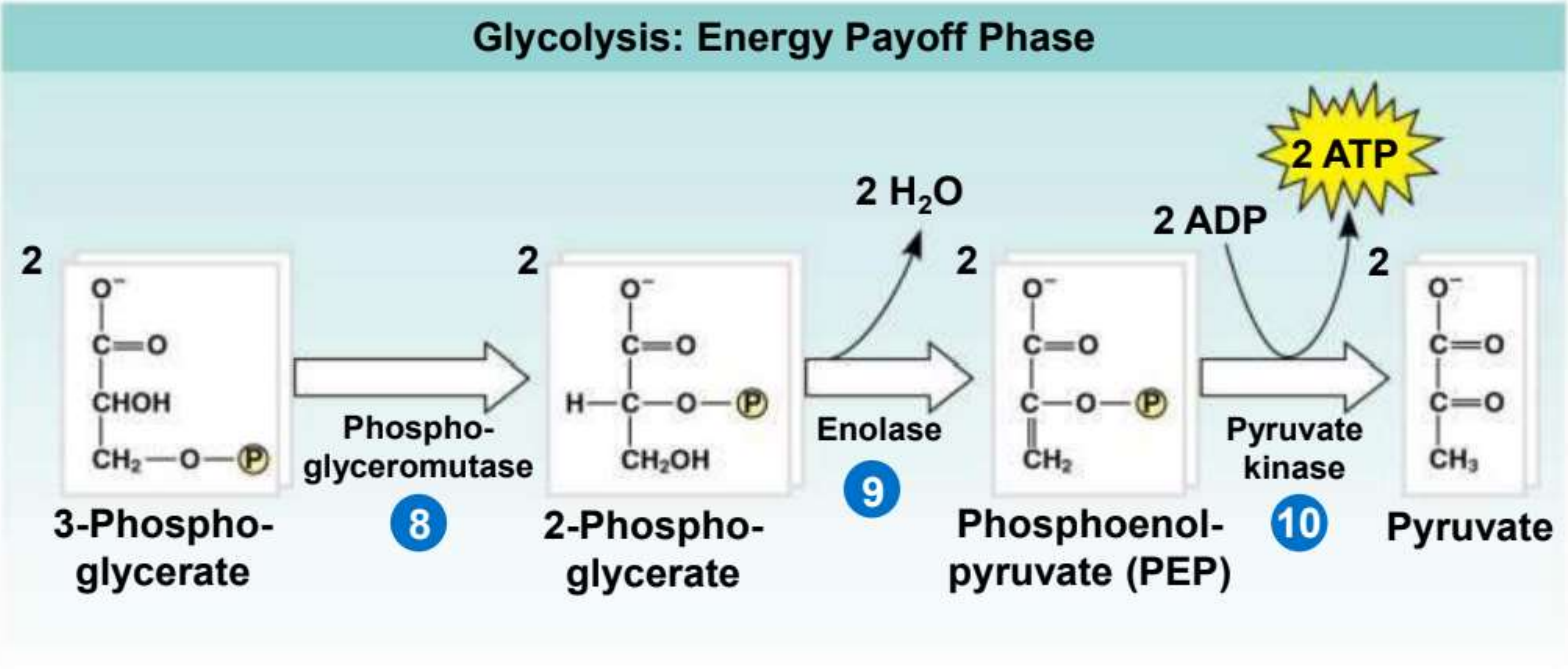

Glycolysis: Energy Investment Phase
ATP
Fructose 6-phosphate
ADP
Fructose 1,6-bisphosphate
Phospho-
fructokinase
3
Aldolase 4
Dihydroxyacetone
phosphate
Glyceraldehyde
3-phosphate
Isomerase 5
To
step 6

Figure 9.9c



Glycolysis: Energy Payoff Phase
2 NADH
2 NAD+
+ 2 H+
2
Triose
phosphate
dehydrogenase
2 P i
6
P—O—C=O
CHOH
CH2—O—P
1,3-Bisphospho-
glycerate
2 ATP
2 ADP
Phospho-
glycerokinase
7
2
O-
C=O
CHOH
CH2—O—P
3-Phospho-
glycerate

Figure 9.9d



Glycolysis: Energy Payoff Phase
2
O⁻
C=O
CHOH
CH₂—O—P
3-Phospho-
glycerate
Phospho-
glyceromutase
8
2
O⁻
C=O
H—C—O—P
CH₂OH
2-Phospho-
glycerate
2 H₂O
Enolase
9
2
O⁻
C=O
C—O—P
CH₂
Phosphoenol-
pyruvate (PEP)
2 ADP
2 ATP
Pyruvate
kinase
10
2
O⁻
C=O
C=O
CH₃
Pyruvate

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

شروط دخول pyruvate إلى داخل الmitochondria

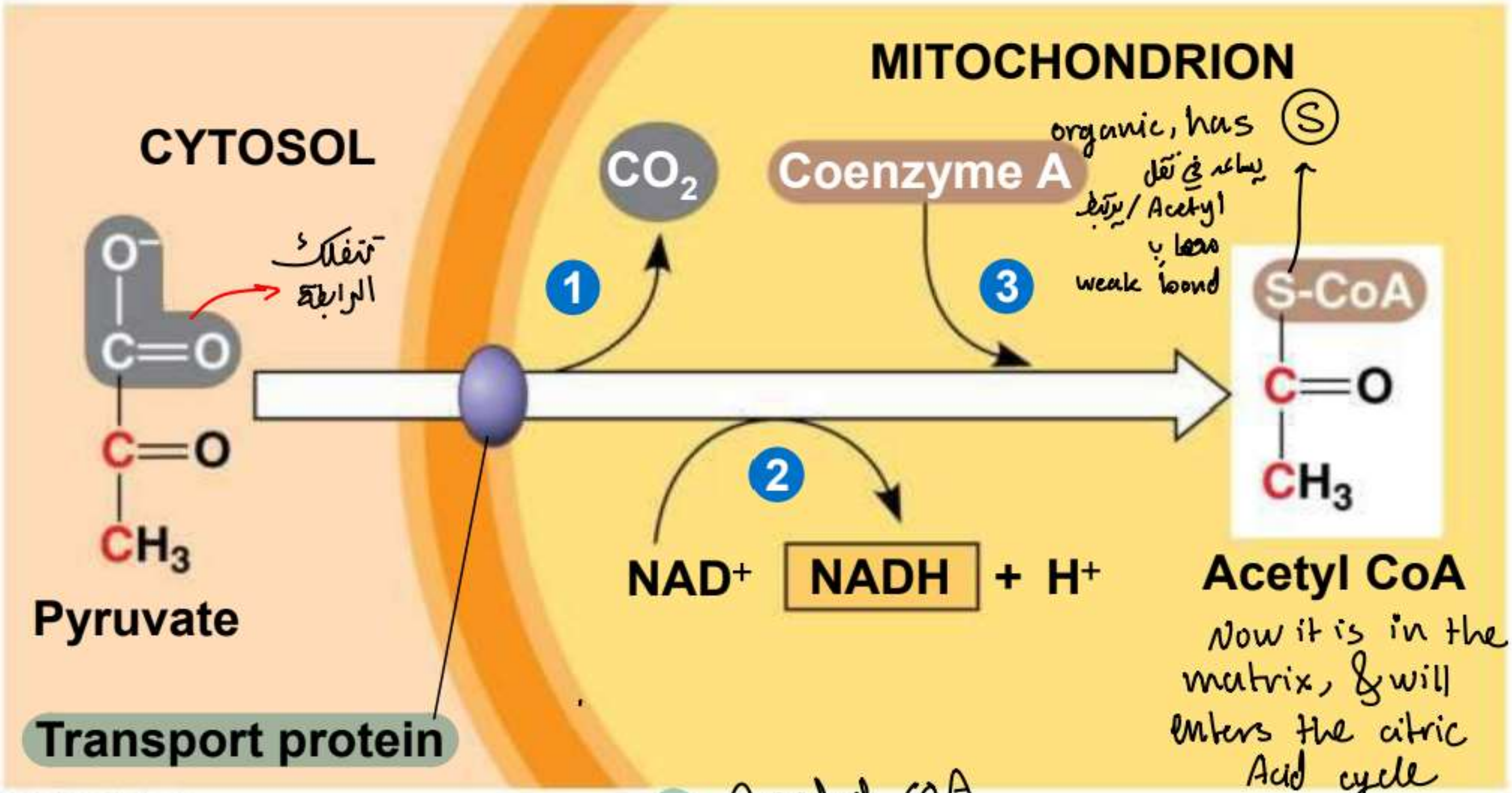
- ① In the presence of O_2, pyruvate enters the mitochondrion (in eukaryotic cells) where the oxidation of glucose is completed

② transport protein on the mitochondrial membrane, pyruvate enters by active transport

Oxidation of Pyruvate to Acetyl CoA

- 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

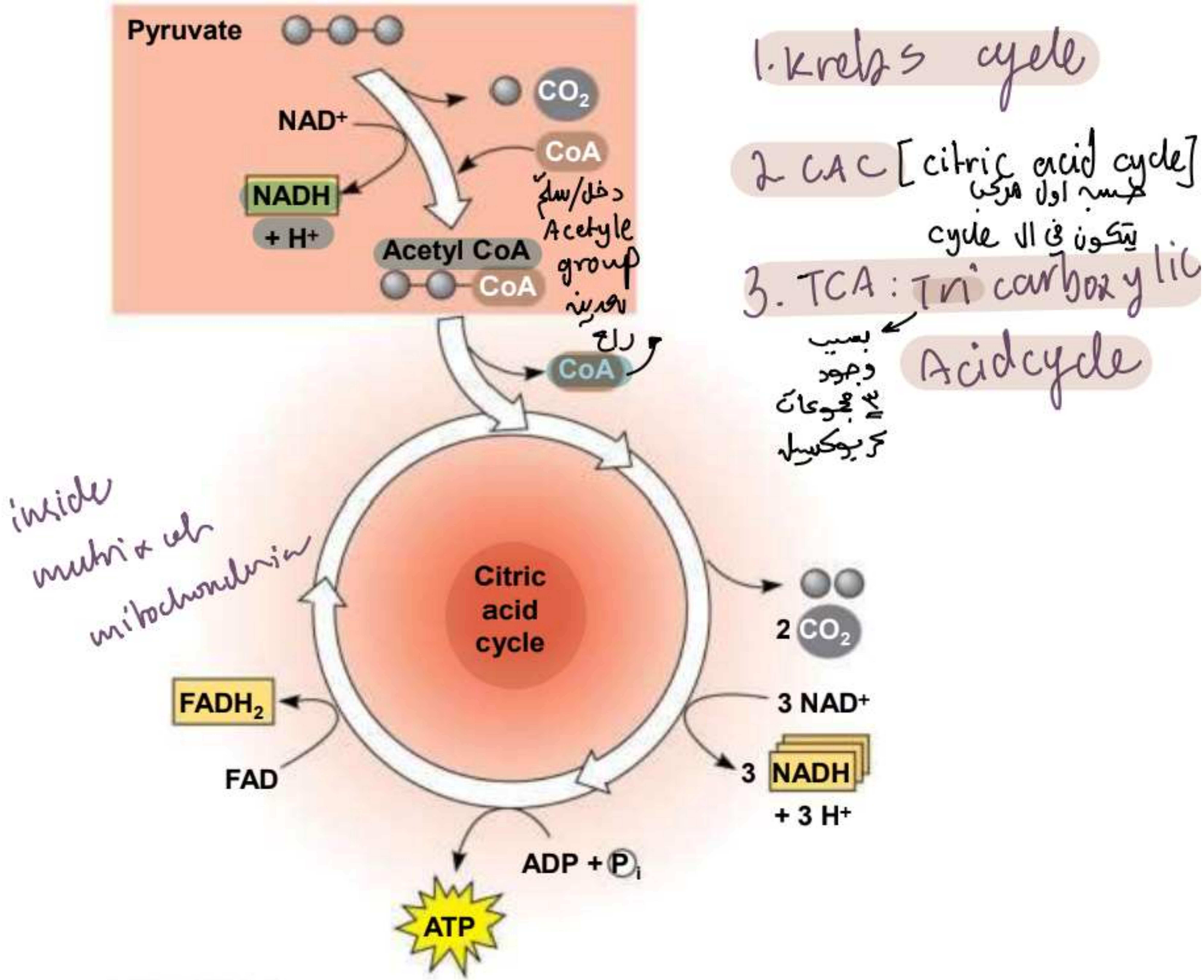


each pyruvate
- Acetyl CoA
- 1 CO_2
- 1 NADH
- 1 H^+

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

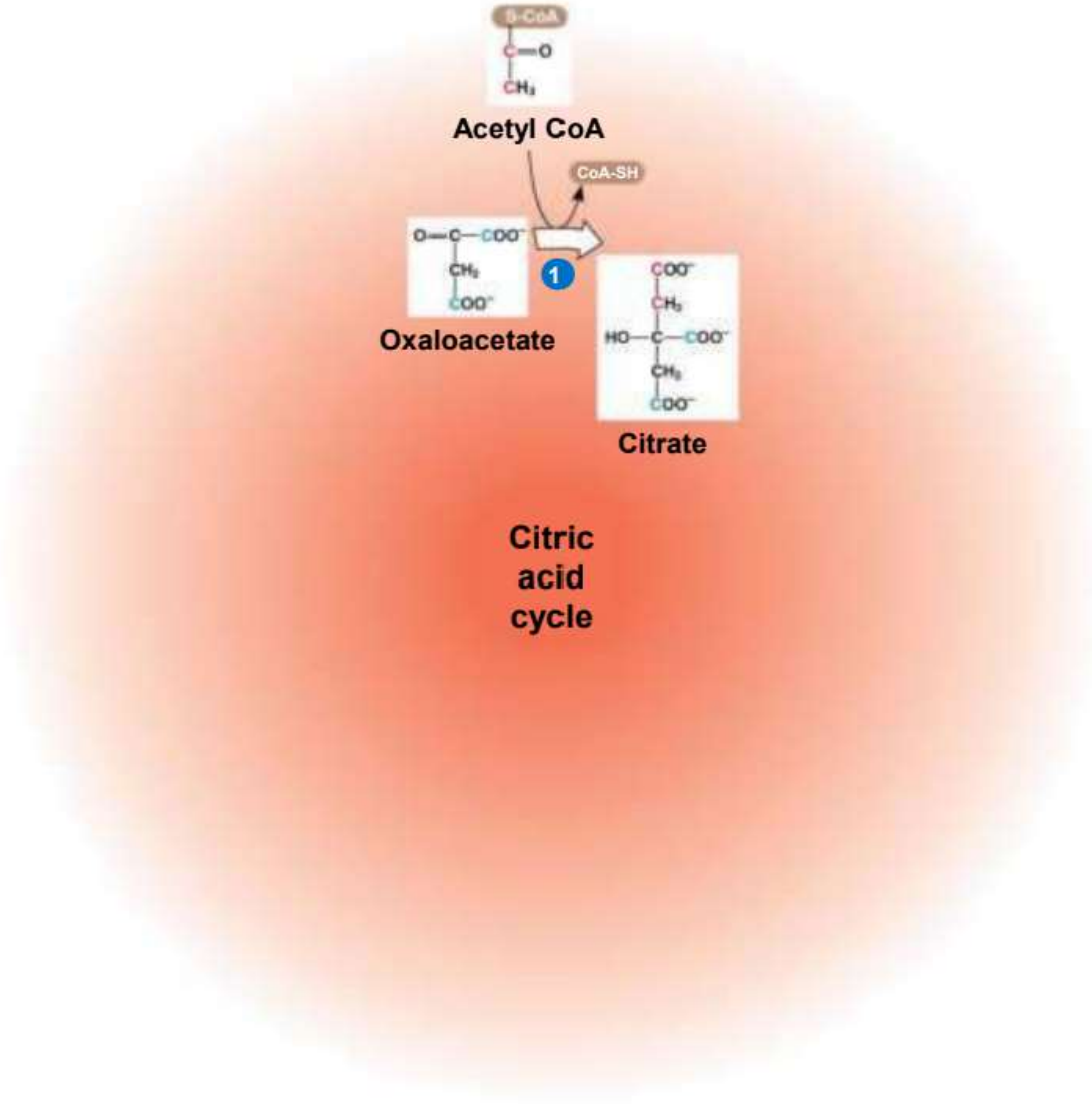
Figure 9.11



Pyruvate
CO2
NAD+
CoA
NADH
+ H+
Acetyl CoA
CoA
CoA
Citric acid cycle
2 CO2
3 NAD+
3 NADH
+ 3 H+
FADH2
FAD
ADP + Pi
ATP
1. krebs cycle
2. CAC [citric acid cycle]
3. TCA : Tri carboxylic Acidcycle
inside matrix of mitochondria
Acetyle group

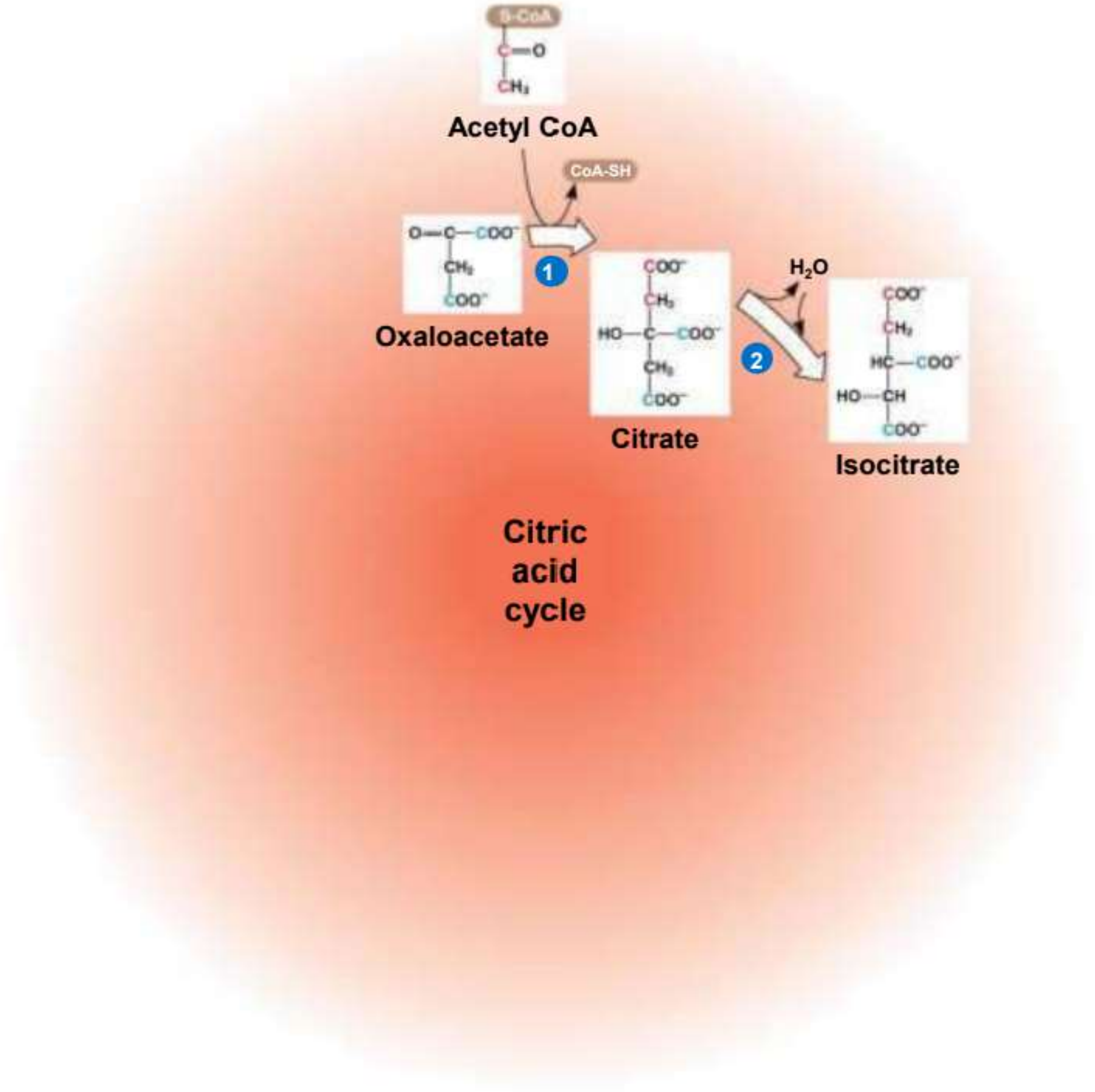
- The citric acid cycle has eight steps, each catalyzed by a specific enzyme
- The acetyl group of acetyl CoA joins the cycle by combining with oxaloacetate, forming citrate (leaves)
- The next seven steps decompose the citrate back to oxaloacetate, making the process a cycle
- The NADH and $FADH_2$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

Figure 9.12-1



S-CoA
C=O
CH3
Acetyl CoA
CoA-SH
O=C—COO⁻
CH2
COO⁻
1
Oxaloacetate
COO⁻
CH2
HO—C—COO⁻
CH2
COO⁻
Citrate
Citric
acid
cycle

Figure 9.12-2



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
Citric acid cycle

Figure 9.12-3

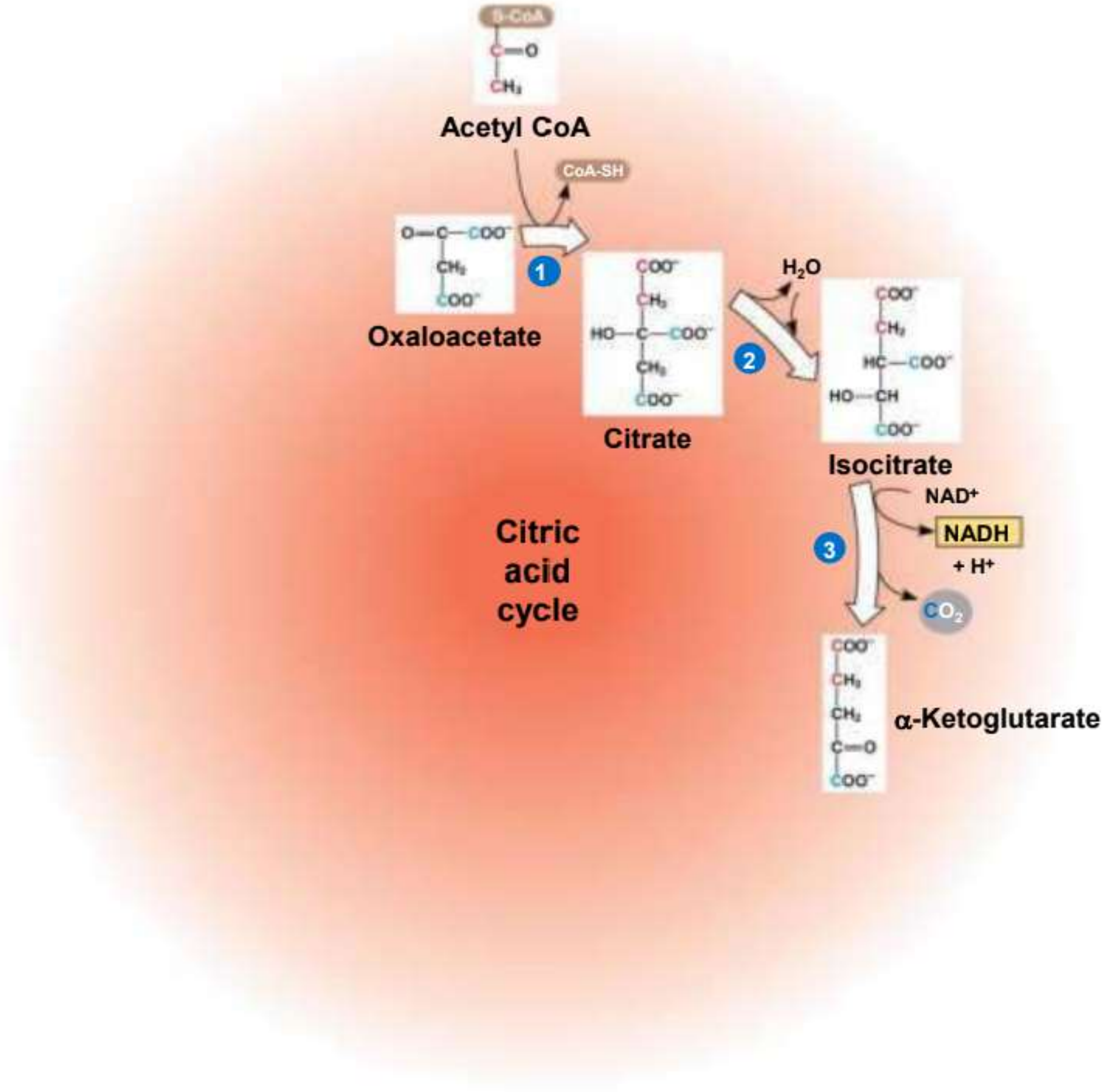
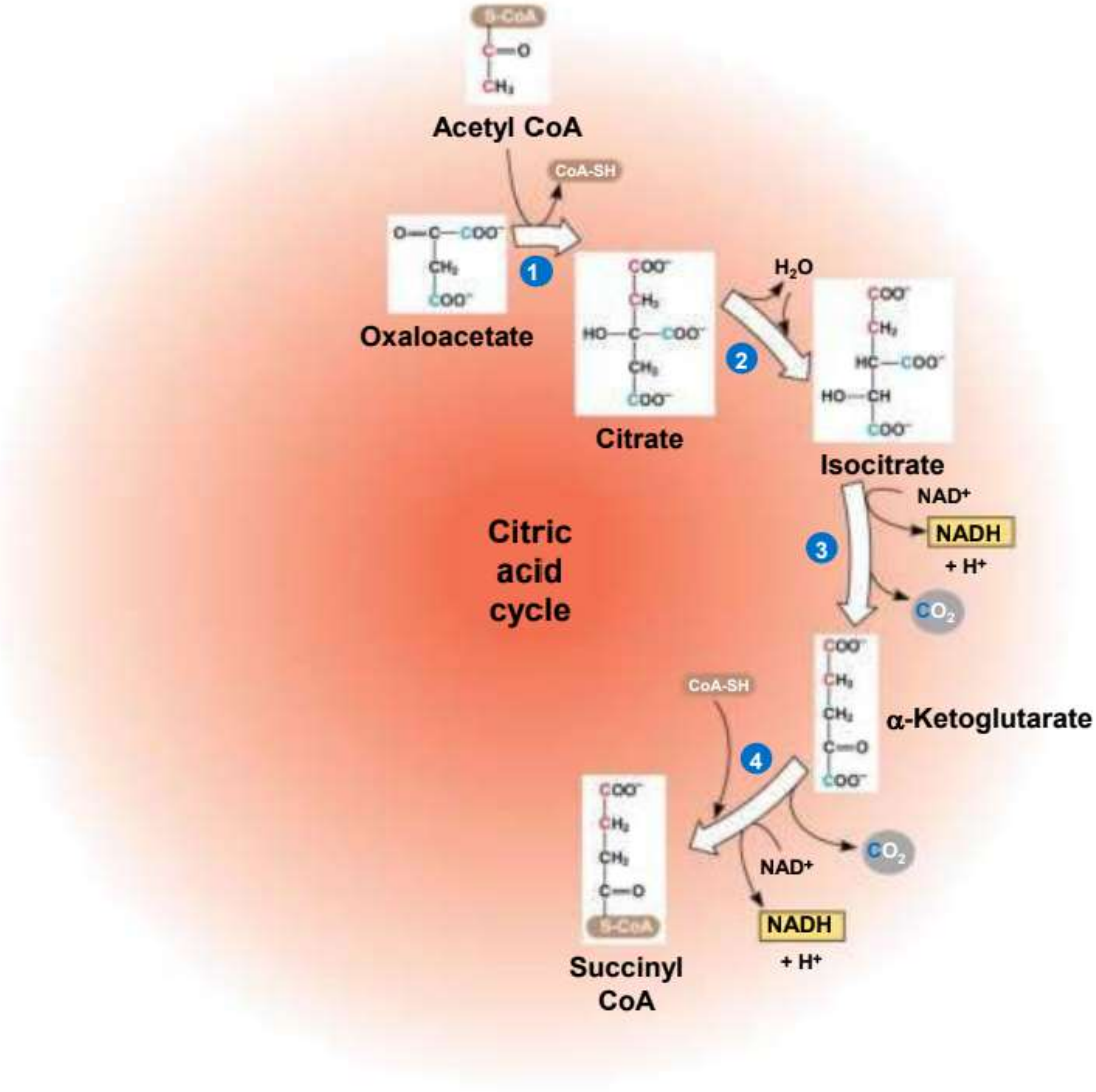
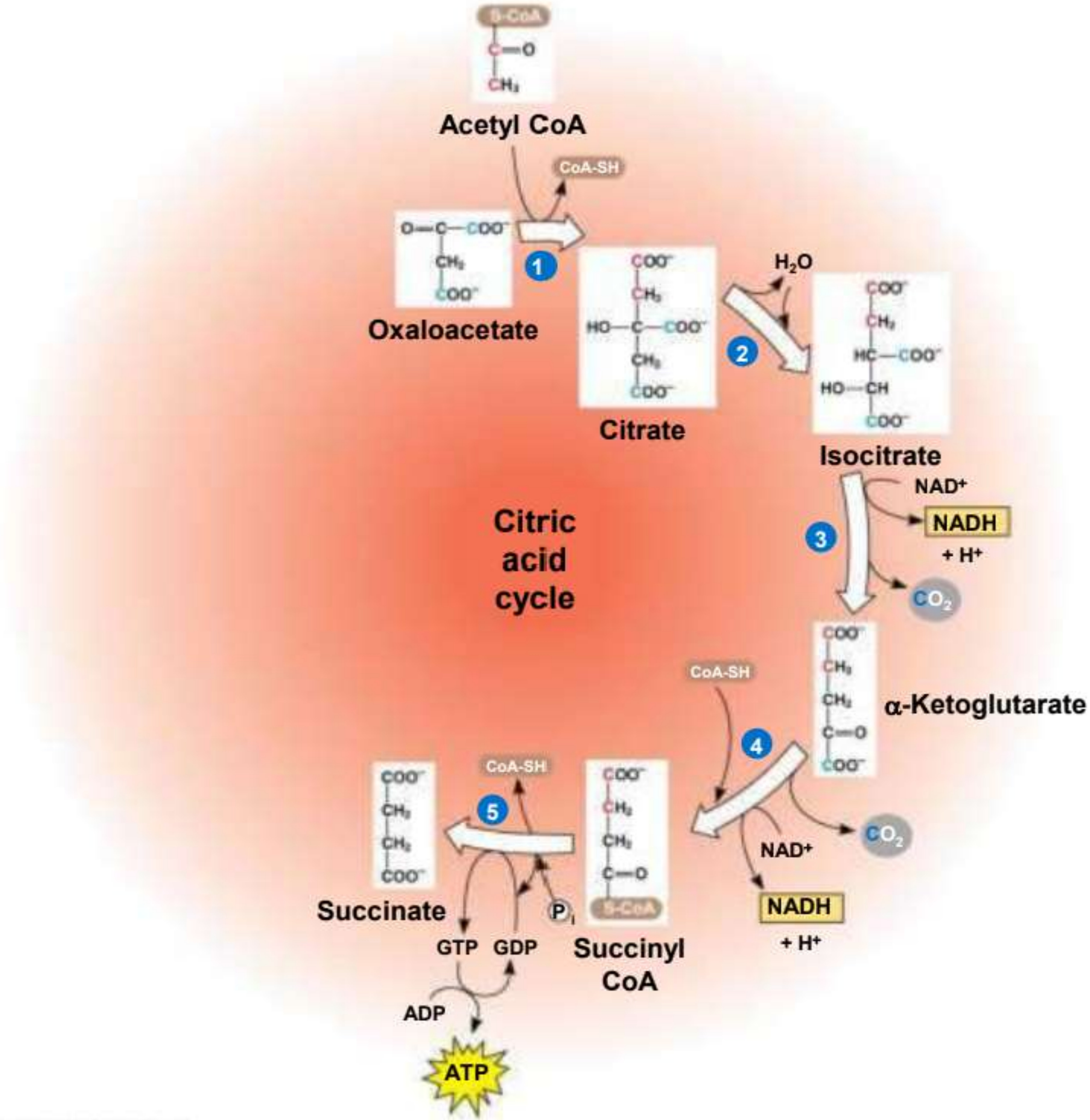

S-CoA
Acetyl CoA
CoA-SH
Oxaloacetate
1
Citrate
H_2O
2
Isocitrate
NAD^+
NADH
$+ H^+$
3
CO_2
α-Ketoglutarate
Citric acid cycle

Figure 9.12-4



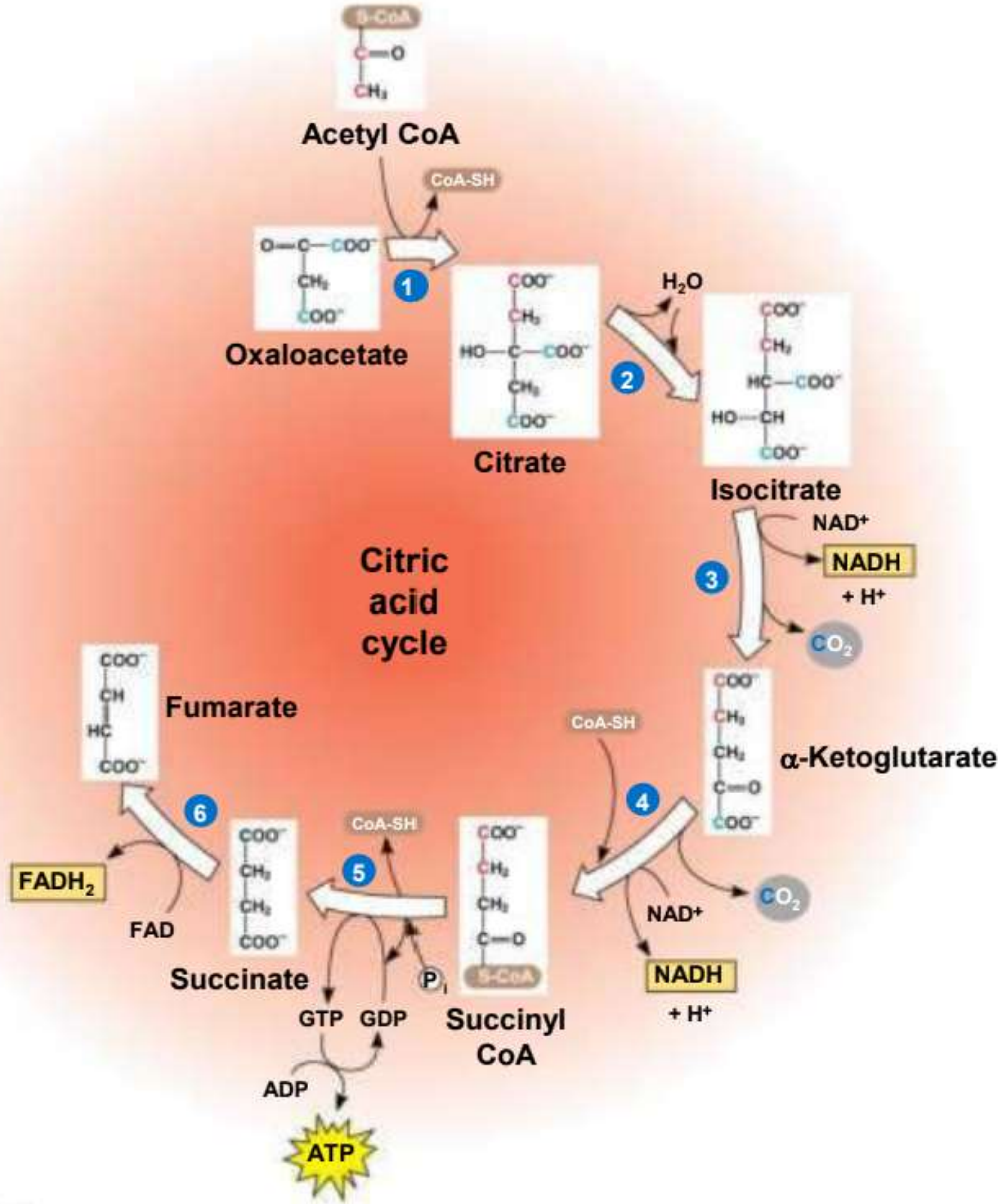
S-CoA
Acetyl CoA
CoA-SH
Oxaloacetate
1
Citrate
H_2O
2
Isocitrate
3
NAD^+
NADH
$+ H^+$
CO_2
α-Ketoglutarate
Citric acid cycle
CoA-SH
4
CO_2
NAD^+
NADH
$+ H^+$
Succinyl CoA

Figure 9.12-5



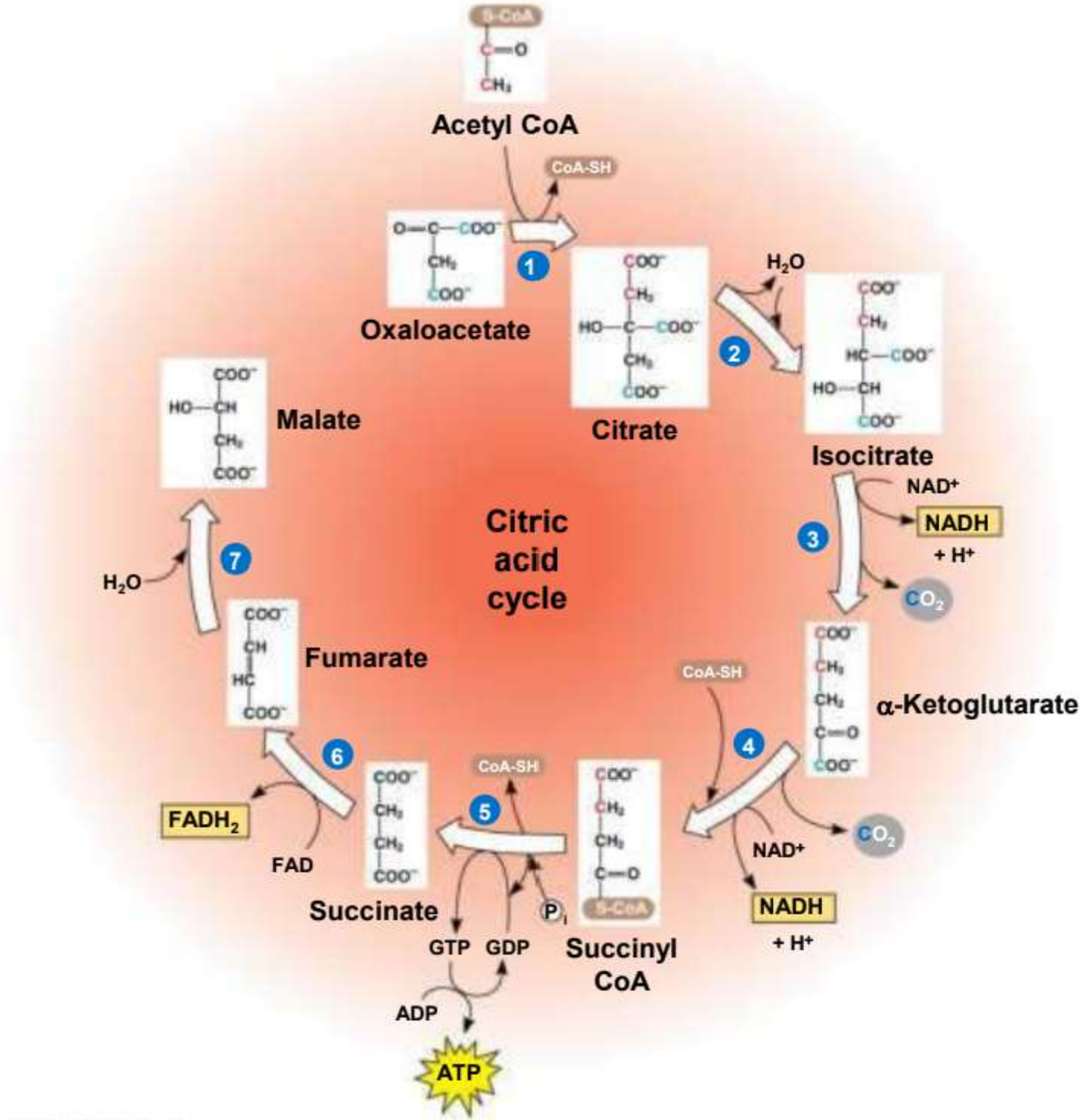
S-CoA
Acetyl CoA
CoA-SH
Oxaloacetate
1
Citrate
H2O
2
Isocitrate
NAD+
NADH
+ H+
3
CO2
α-Ketoglutarate
CoA-SH
4
CO2
NAD+
NADH
+ H+
Succinyl CoA
S-CoA
CoA-SH
5
Succinate
Pi
GTP
GDP
ADP
ATP
Citric acid cycle

Figure 9.12-6



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
NAD+
NADH
+ H+
3
CO2
COO⁻
CH2
CH2
C=O
COO⁻
α-Ketoglutarate
Citric
acid
cycle
CoA-SH
4
CO2
NAD+
NADH
+ H+
COO⁻
CH2
CH2
C=O
S-CoA
Succinyl
CoA
CoA-SH
5
Pi
GTP
GDP
ADP
ATP
COO⁻
CH2
CH2
COO⁻
Succinate
6
FADH2
FAD
COO⁻
CH
HC
COO⁻
Fumarate

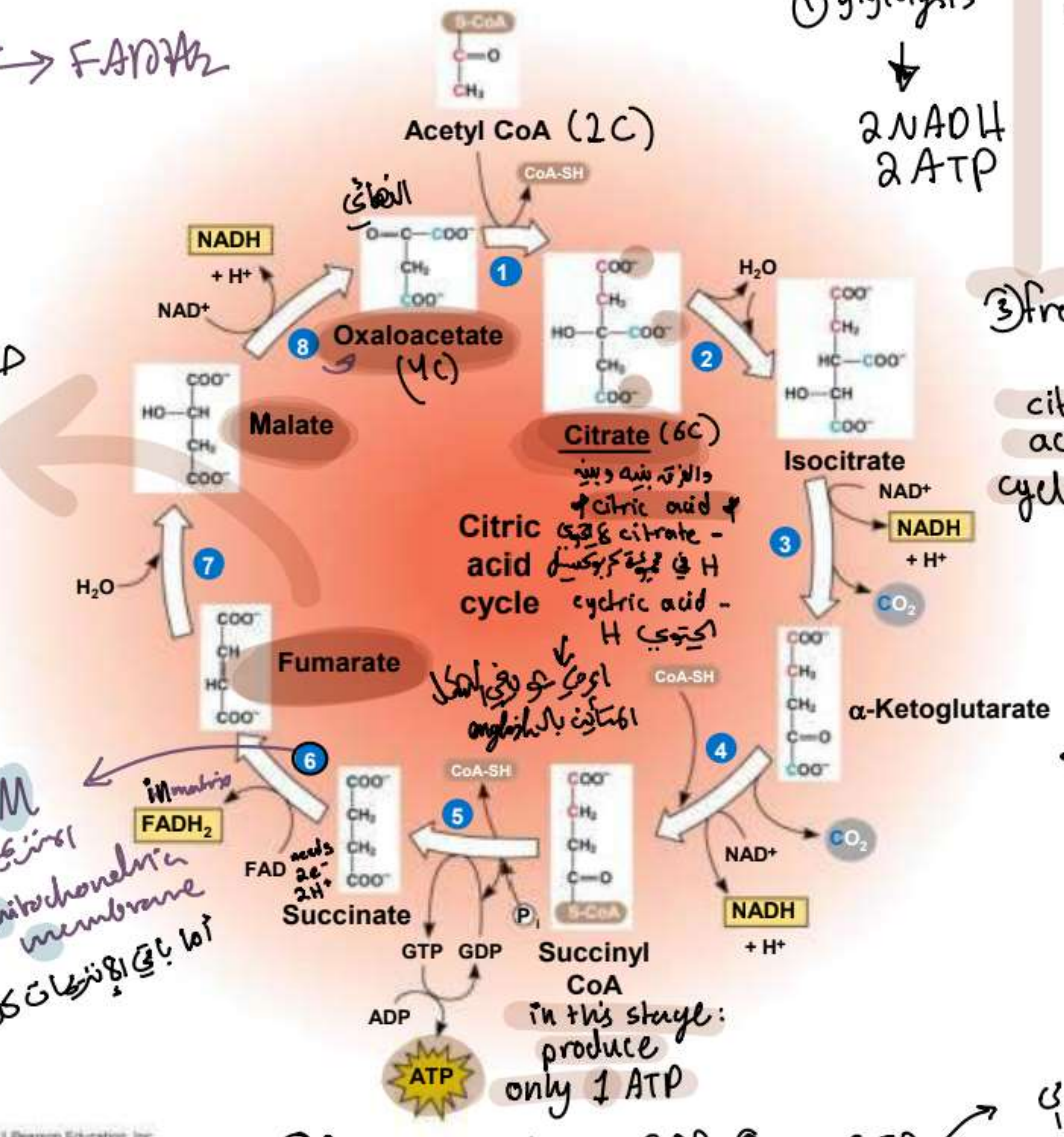
Figure 9.12-7



S-CoA
Acetyl CoA
CoA-SH
Oxaloacetate
1
H$_2$O
Citrate
2
Isocitrate
NAD+
NADH
+ H+
3
CO$_2$
α-Ketoglutarate
CoA-SH
4
CO$_2$
NAD+
NADH
+ H+
Succinyl CoA
S-CoA
P$_i$
GDP
GTP
ADP
ATP
CoA-SH
5
Succinate
FAD
FADH$_2$
6
Fumarate
H$_2$O
7
Malate
Citric acid cycle

Figure 9.12-8

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



© 2011 Pearson Education, Inc.

① glycolysis
↓
2NADH
2ATP

② from each pyruvate
↓
1 CO_2
1 NADH

③ from each one Acetyl CoA
citric acid cycle
↓
2CO_2
3NADH
1 $FADH_2$
1ATP

* from each glucose
6CO_2
4ATP
10 NADH
2$FADH_2$

Ⓟ from substrate → GDP + Ⓟ → GTP → ADP + Ⓟ → ATP

تنقل مجموعة الفوسفات إلى

matrix اما باقي الانزيمات كلها في

Figure 9.12a

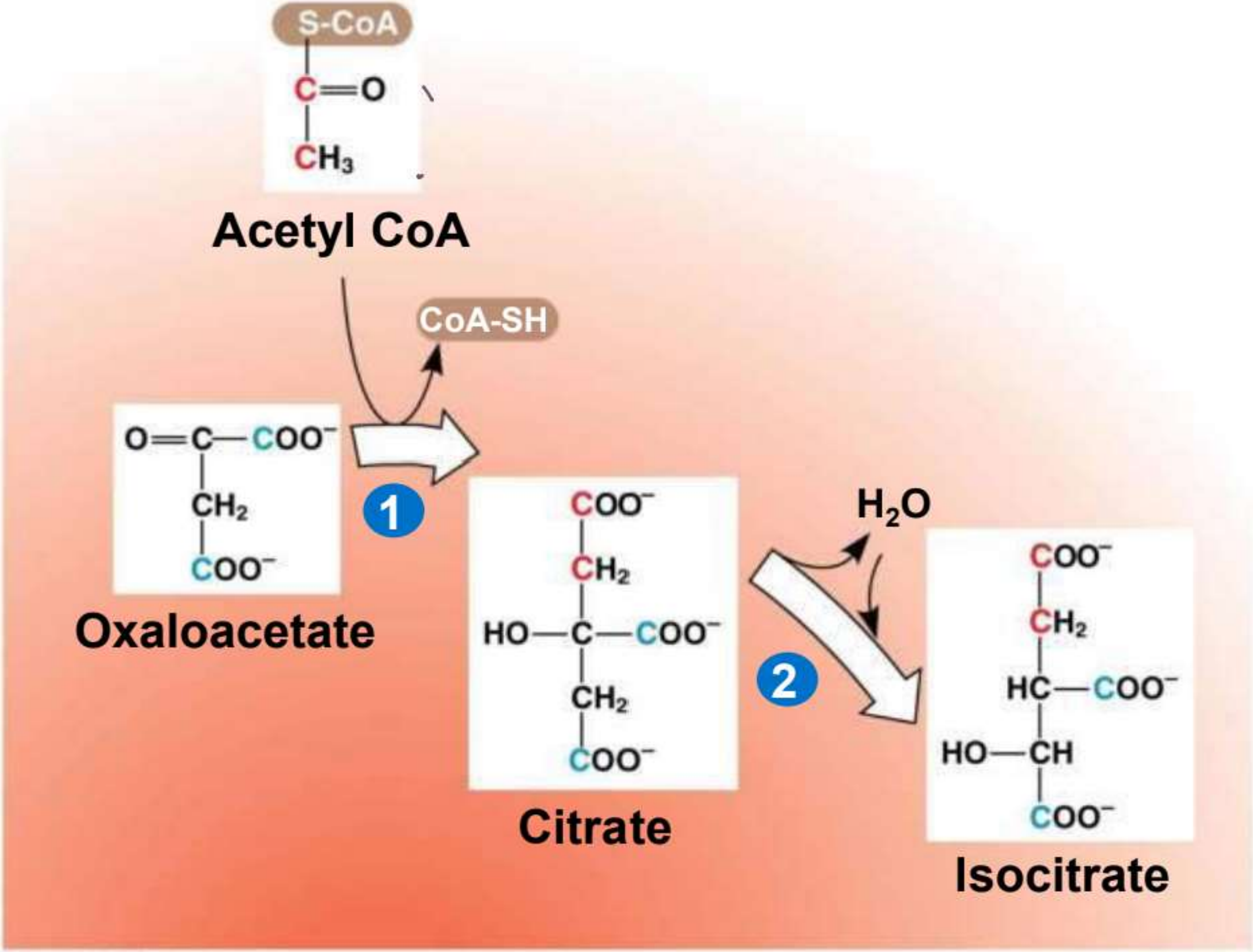
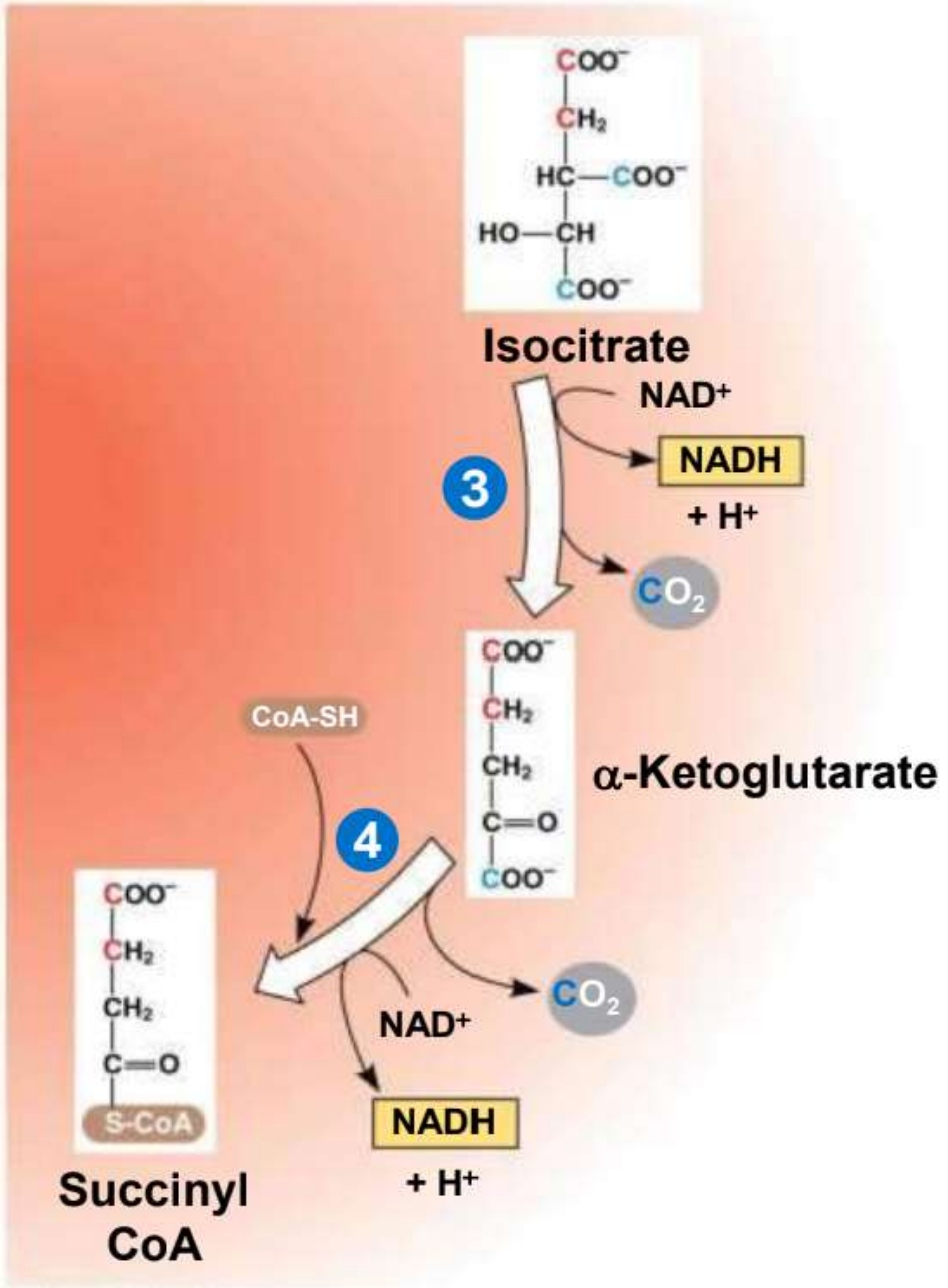
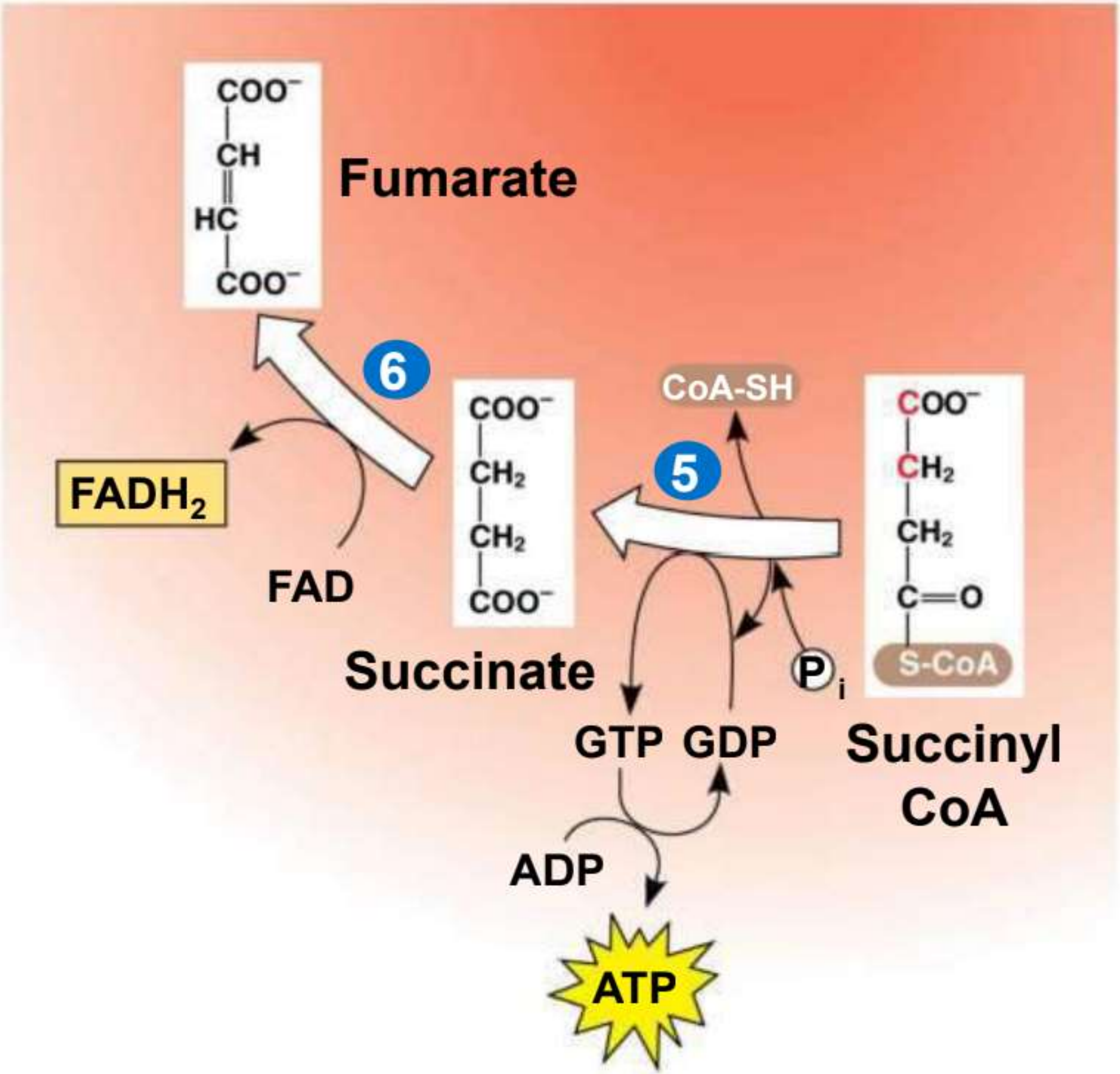

S-CoA
C=O
CH3
Acetyl CoA
CoA-SH
O=C—COO⁻
CH2
COO⁻
Oxaloacetate
1
COO⁻
CH2
HO—C—COO⁻
CH2
COO⁻
Citrate
H2O
2
COO⁻
CH2
HC—COO⁻
HO—CH
COO⁻
Isocitrate

Figure 9.12b



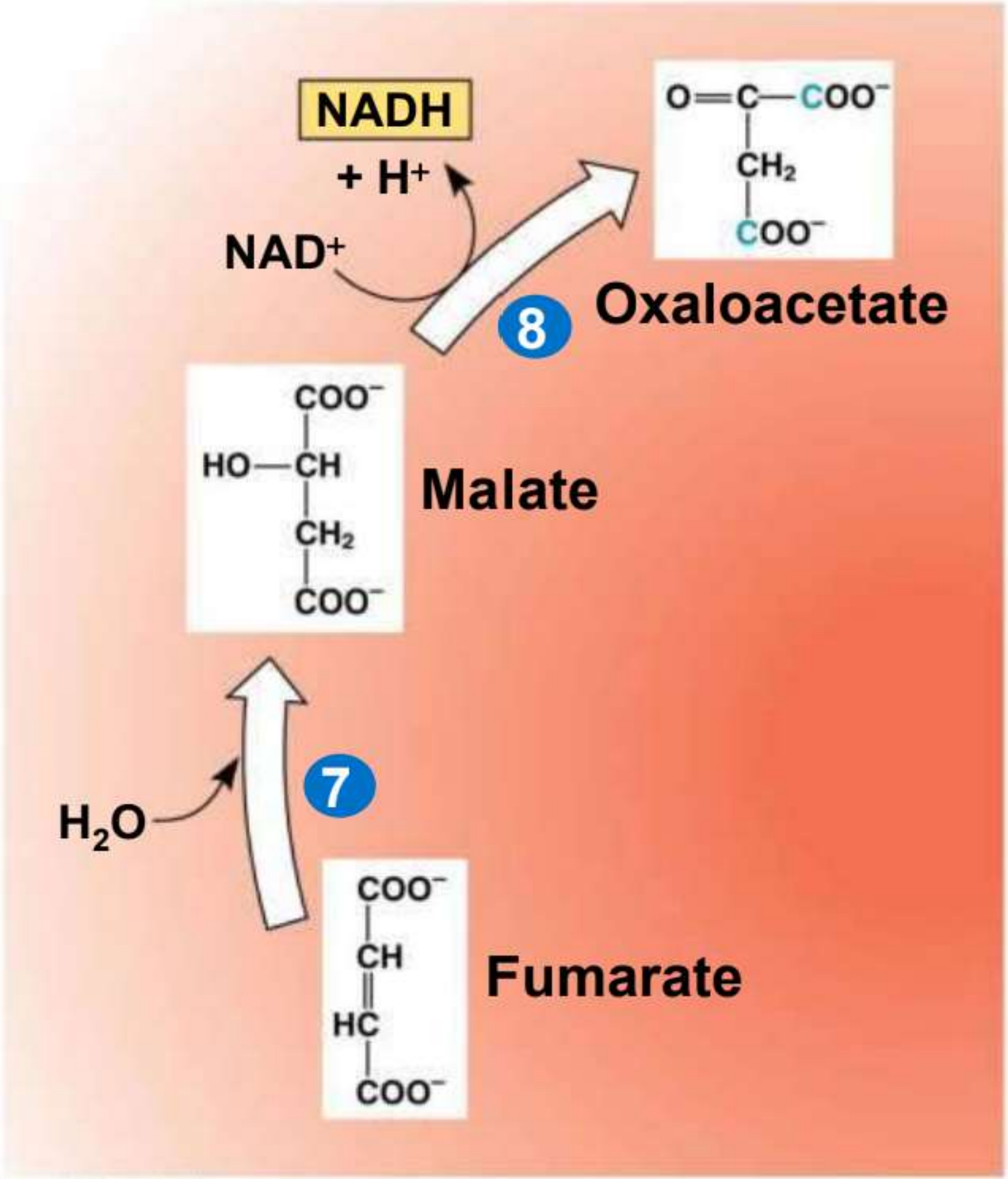
COO⁻
CH₂
HC—COO⁻
HO—CH
COO⁻
Isocitrate
NAD+
NADH
+ H+
3
CO2
COO⁻
CH2
CH2
C=O
COO⁻
α-Ketoglutarate
CoA-SH
4
CO2
NAD+
NADH
+ H+
COO⁻
CH2
CH2
C=O
S-CoA
Succinyl CoA

Figure 9.12c



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

Figure 9.12d


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

phosphate group from oxidation/reduction reaction

inner membrane

Concept 9.4: During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis

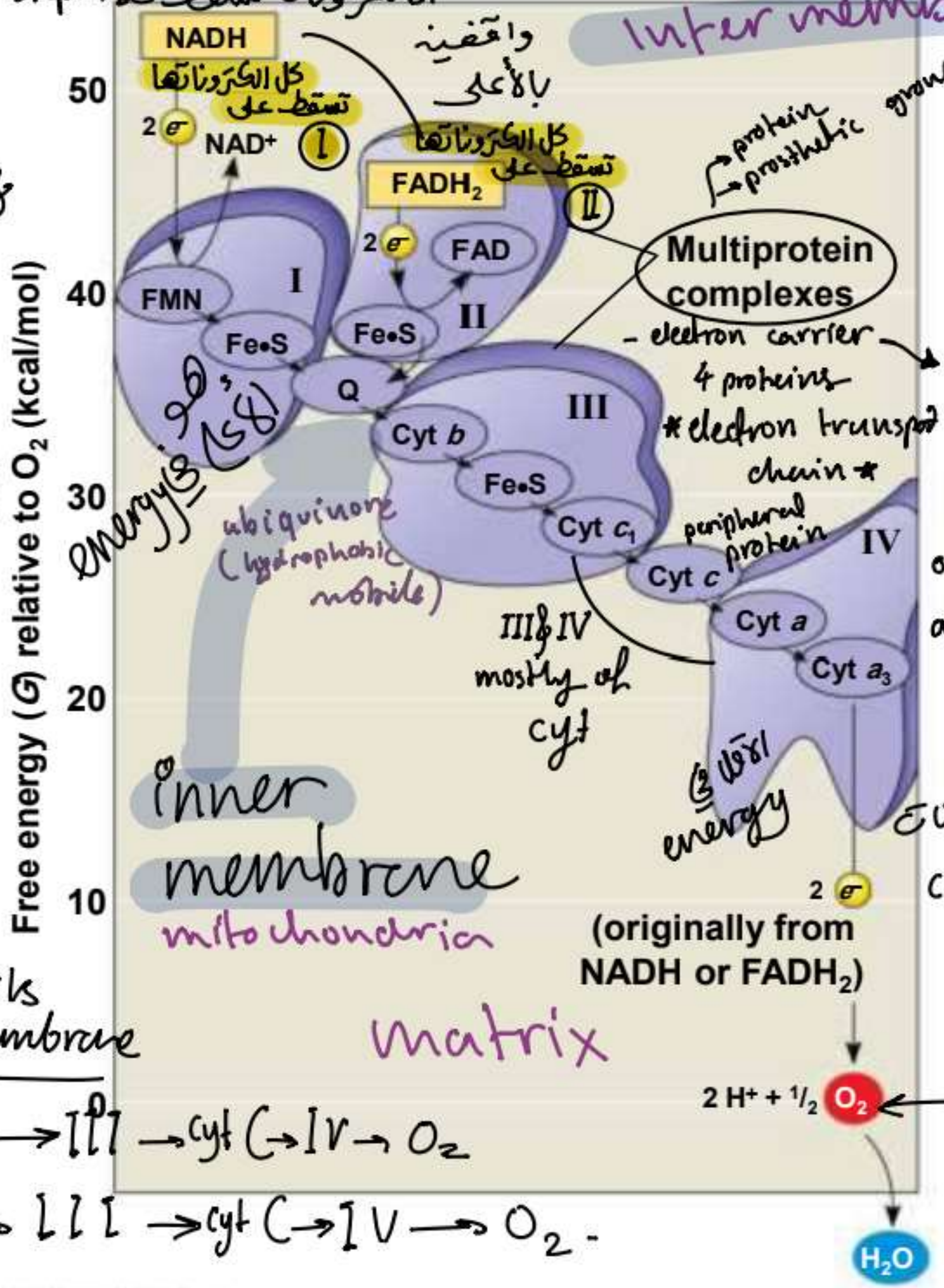
① electron transport chain / ② chemiosmosis

- 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 (redox reactions)
- Electrons drop in free energy (تنخفض طاقتها) as they go down the chain and are finally passed to O_2, forming H_2O

Figure 9.13



all of NADH & FADH2 from glycolysis & pyruvate oxidation & citric acid cycle will go to inner membrane to produce energy (ATP)

1 NADH → 2.5 ATP

1 FADH2 → 1.5 ATP

* protein is an organic compound, not active in oxidation & reduction of electrons

لذلك كل بروتين يرتبط بمجموعة فلزية مسؤولة عن نقل الالكترونات

called: prosthetic group

(Q) hydrophobic protein / e⁻ carrier (ubiquinone)

1 → 3

2 → 3 يوصل بين

between hydrophobic tails

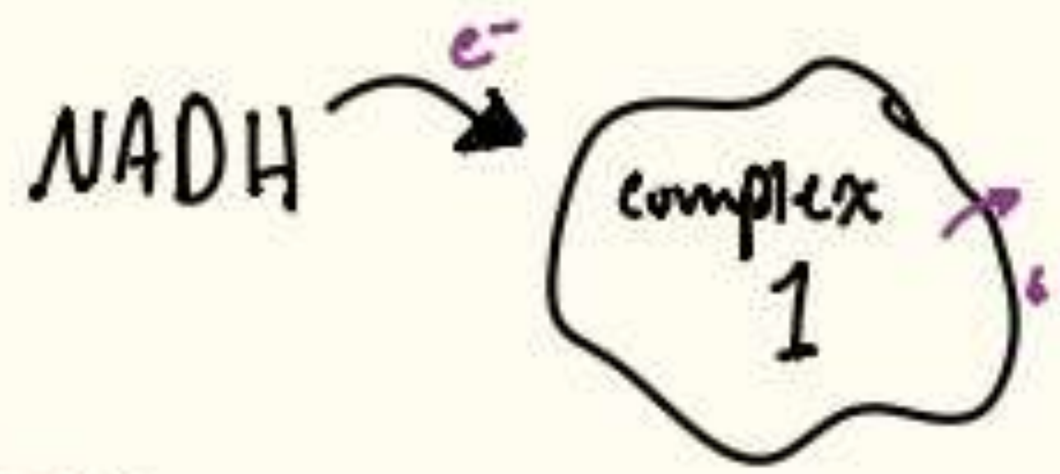
mobile / inside inner membrane

NADH → I → Q → III → cyt C → IV → O2

FADH2 → II → Q → III → cyt C → IV → O2 -

* oxidative phosphorylation → the phosphate group added to ATP is from <u>oxidation & reduction reaction</u>

↳ release of energy ، لأن الالكترونات تسقط من مرتفع إلى منخفض

* 

اكتسب الالكترون، حصله reduction

تسقط الكتروناتها / اي تفقدهم .. حصل لها oxidation

والآن، كيف نستخدم هذه الطاقة في تصنيع ATP ؟؟

complexes (1+3+4) will act like a proton pump

[pump H^+ from matrix to Intermembrane space

- 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

Chemiosmosis: The Energy-Coupling Mechanism

- Electron transfer in the electron transport chain causes proteins to pump H^+ from the mitochondrial matrix to the intermembrane space
- H^+ then moves back across the membrane, passing through the proton, **ATP synthase**
- ATP synthase uses the exergonic flow of H^+ to drive phosphorylation of ATP
- This is an example of **chemiosmosis**, the use of energy in a H^+ gradient to drive cellular work

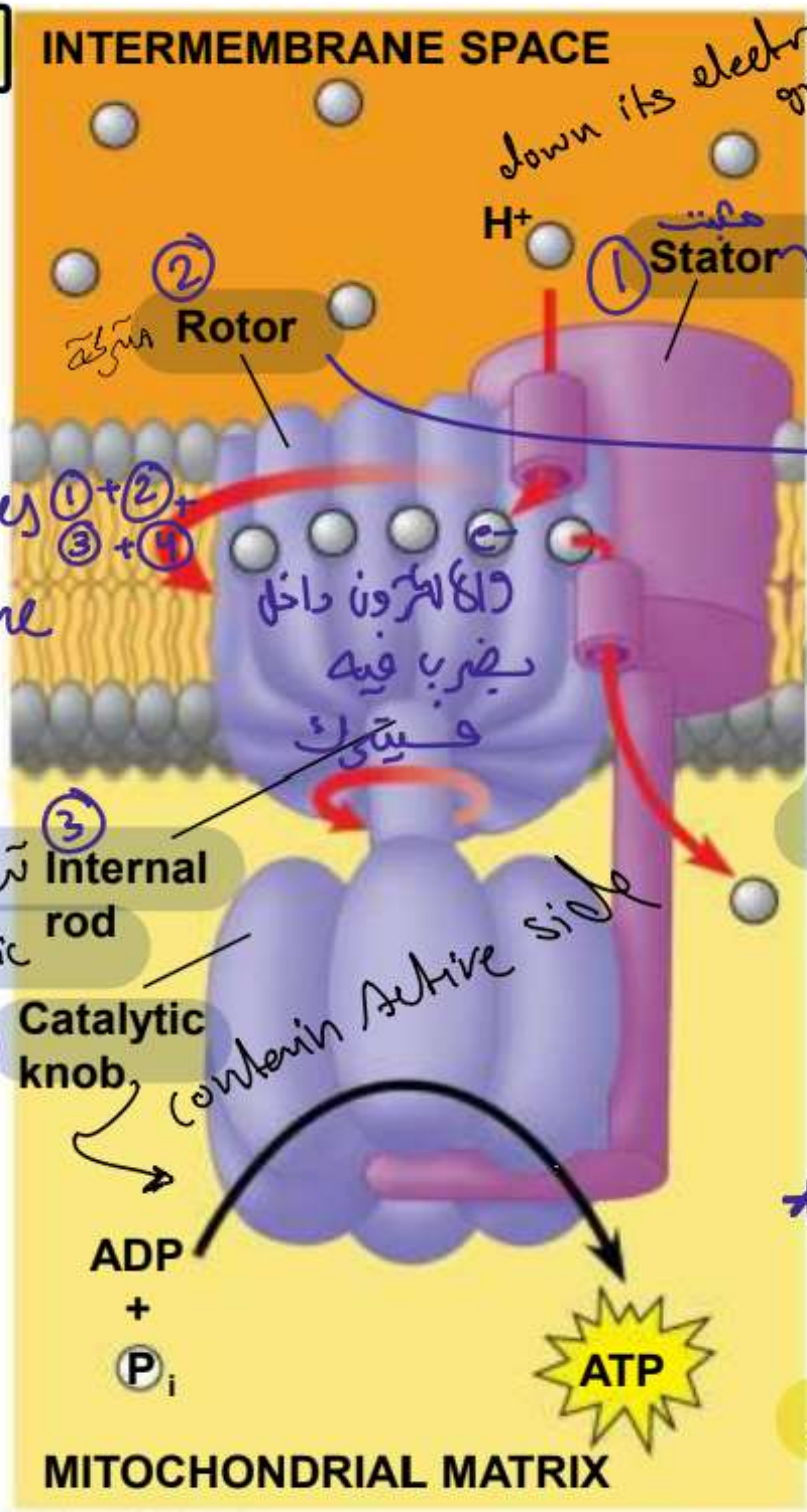
Figure 9.14

CHEMIOSMOSIS:

Structure of ATP synthase:

a protein consists of 4 subunits/4 polypeptides ①+②+③+④

* fixed into the membrane



down its electrochemical gradient (passive)

① Stator (مثبت) → anchors it to the membrane

② Rotor (متحركة)

والالكترون داخل بضرب فيه فيتحرك

والالكترون داخل بضرب فيها فبتتحرك وتحرك معها internal rod وتغير شكل catalytic knob ؟ فيها / يصبح active side

الانزيم active ← ADP+Ⓟ→ATP

③ Internal rod: تربط بين Rotor & catalytic knob

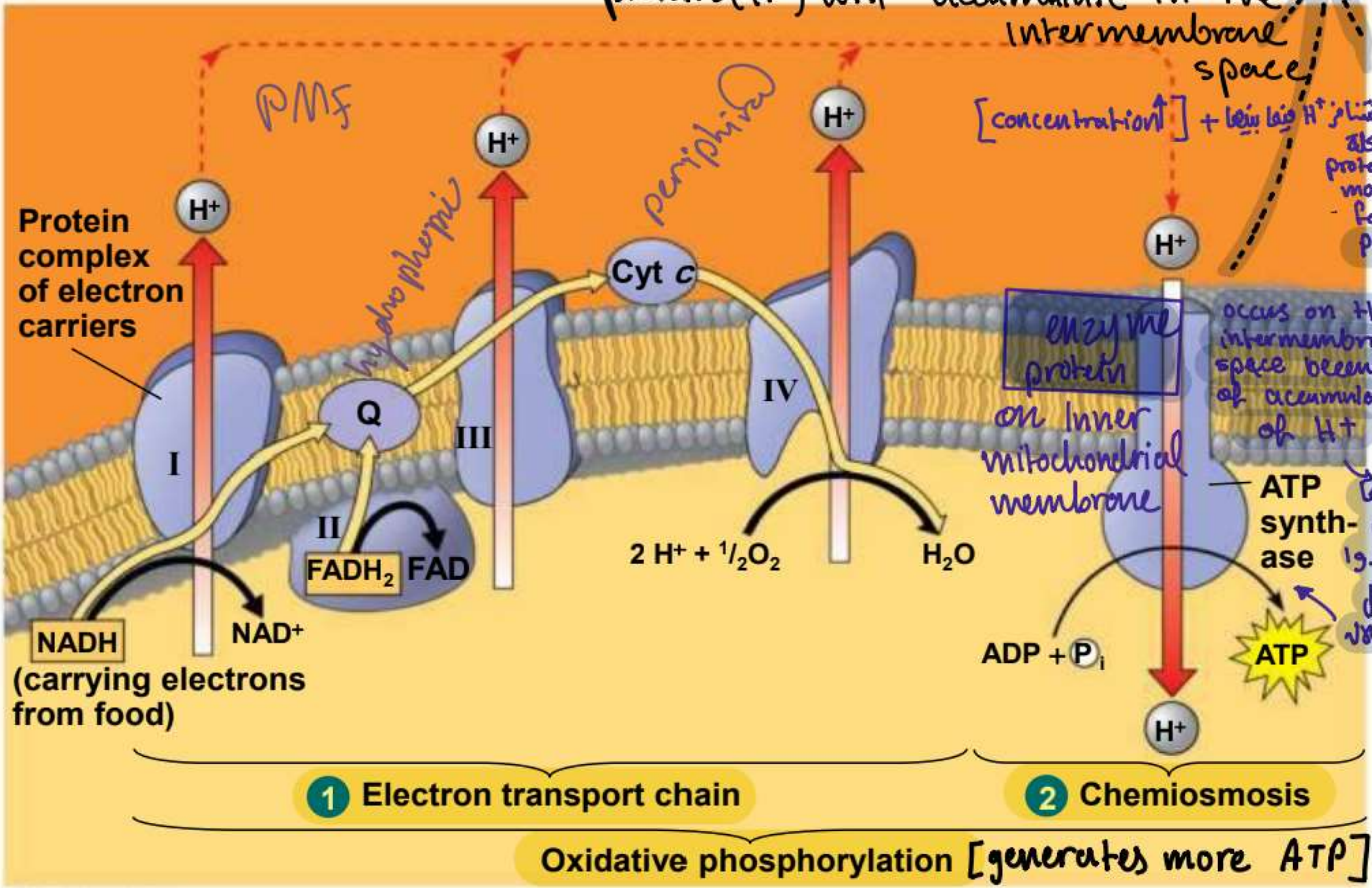
④ Catalytic knob: contain Active side

ما بكون شغال ع طول، لازم اشي يعطيه activation

* between stator & Rotor their is a gap that let H+ get in down its electrochemical gradient (passively)

Figure 9.15

تتراكم
protons (H+) will accumulate in the intermembrane space



①+③+④ → now act like a proton pumbs

from matrix → intermembrane

- The energy stored in a H^+ gradient across a membrane couples the redox reactions of the electron transport chain to ATP synthesis
- The H^+ gradient is referred to as a **proton-motive force**, emphasizing its capacity to do work

An Accounting of ATP Production by Cellular Respiration

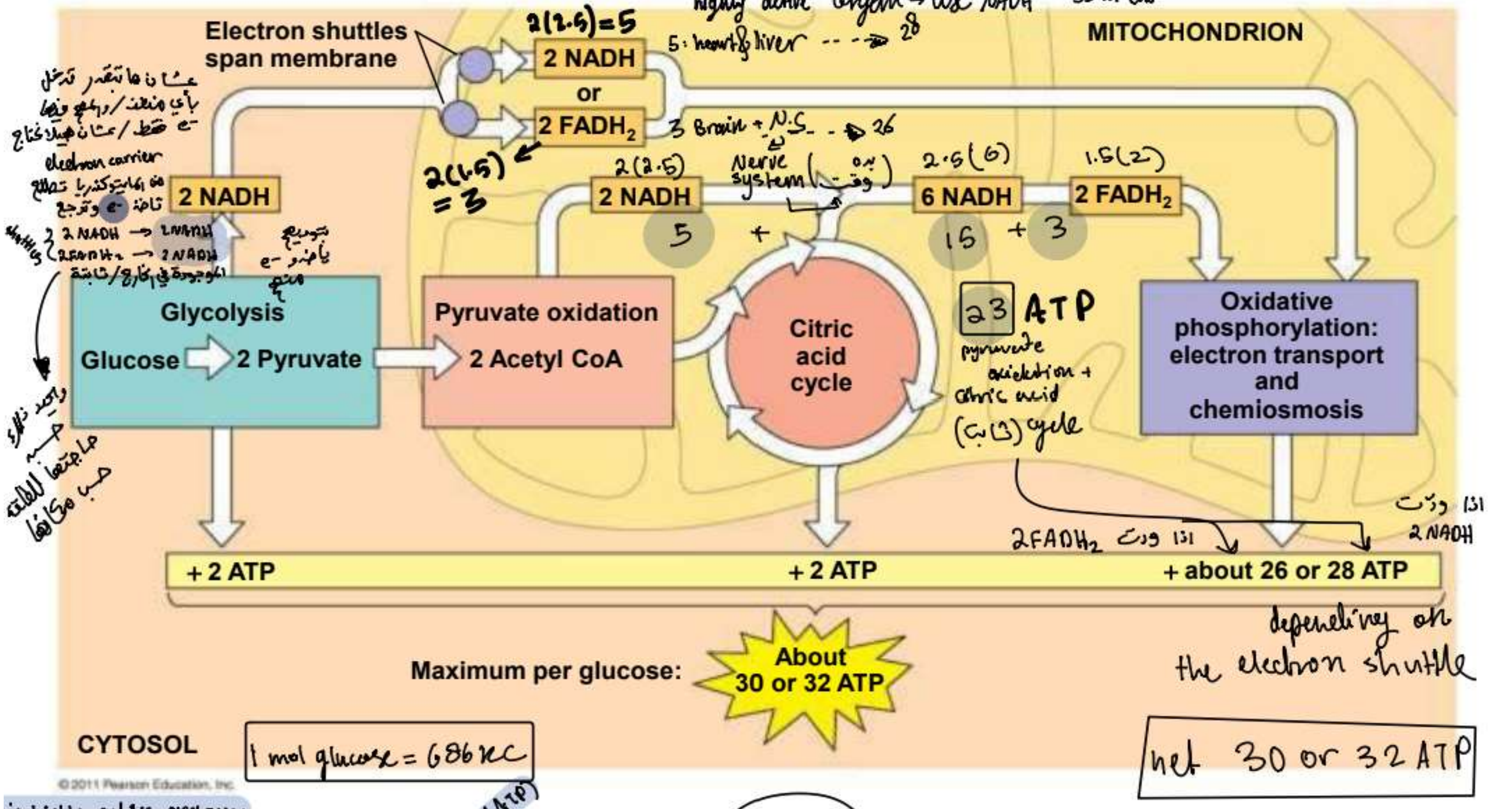
- During cellular respiration, most energy flows in this sequence:

  glucose → NADH → electron transport chain → proton-motive force → ATP
- About 34% of the energy in a glucose molecule is transferred to ATP during cellular respiration, making about 32 ATP
- There are several reasons why the number of ATP is not known exactly

Figure 9.16

* for each one glucose :

- NADH → 2.5ATP
- $FADH_2$ → 1.5ATP



© 2011 Pearson Education, Inc.

in highly active organs:

% Effeciency of cellular respiration = $\frac{32 \times 7.3}{686} \times 100\% \simeq 34\%$ ATP من طاقة الغلوكوز سوف تستخدم في

chemical energy in food → chemical energy in ATP

1ATP = 7.3 KC/mol

66% → heat to maintain (37°C) body temprature, because we are homoiotherm

4ATP

catabolic process to produce ATP without O_2/ unairobic respiration

Concept 9.5: Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen

- Most cellular respiration requires O_2 to produce ATP
- Without O_2, the electron transport chain will cease to operate
- In that case, glycolysis couples with fermentation or anaerobic respiration to produce ATP

- Anaerobic respiration uses an electron transport chain with a final electron acceptor other than O_2, for example sulfate
- Fermentation uses substrate-level phosphorylation instead of an electron transport chain to generate ATP

Types of Fermentation

→ in the cytosol
→ complete absence of O_2
→ first step is glycolysis

- Fermentation consists of glycolysis plus reactions that regenerate NAD^+, which can be reused by glycolysis
- Two common types are (1) **alcohol fermentation** and (2) **lactic acid fermentation**

(1)

- In alcohol fermentation, pyruvate is converted to ethanol in two steps, with the first releasing CO_2
- Alcohol fermentation by yeast is used in brewing, winemaking, and baking & alcohol

Alcohol fermentation أهمية

→ yeast [Industrially important]

→ (1) alcohol, beer, wine industry

→ (2) Baking industry → CO_2 تنفخ بسبب

PLAY Animation: Fermentation Overview

Figure 9.17

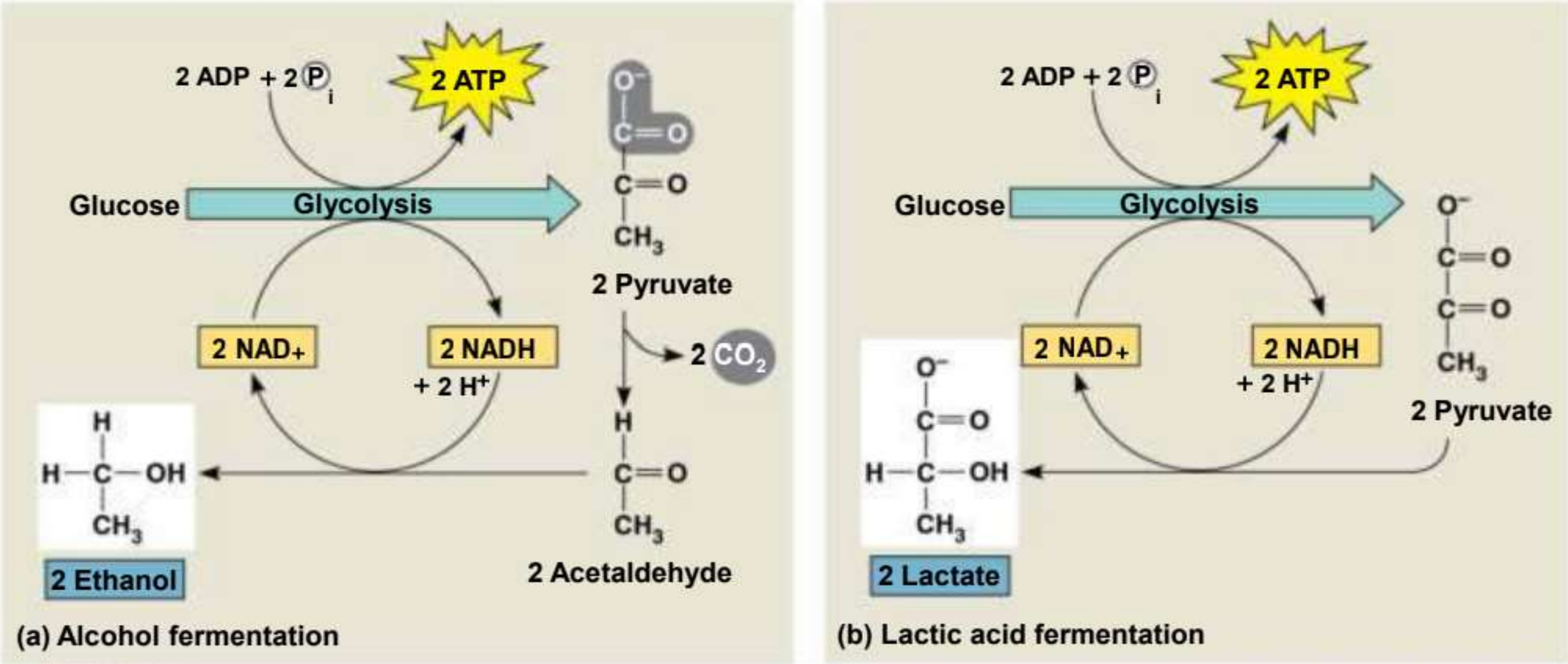
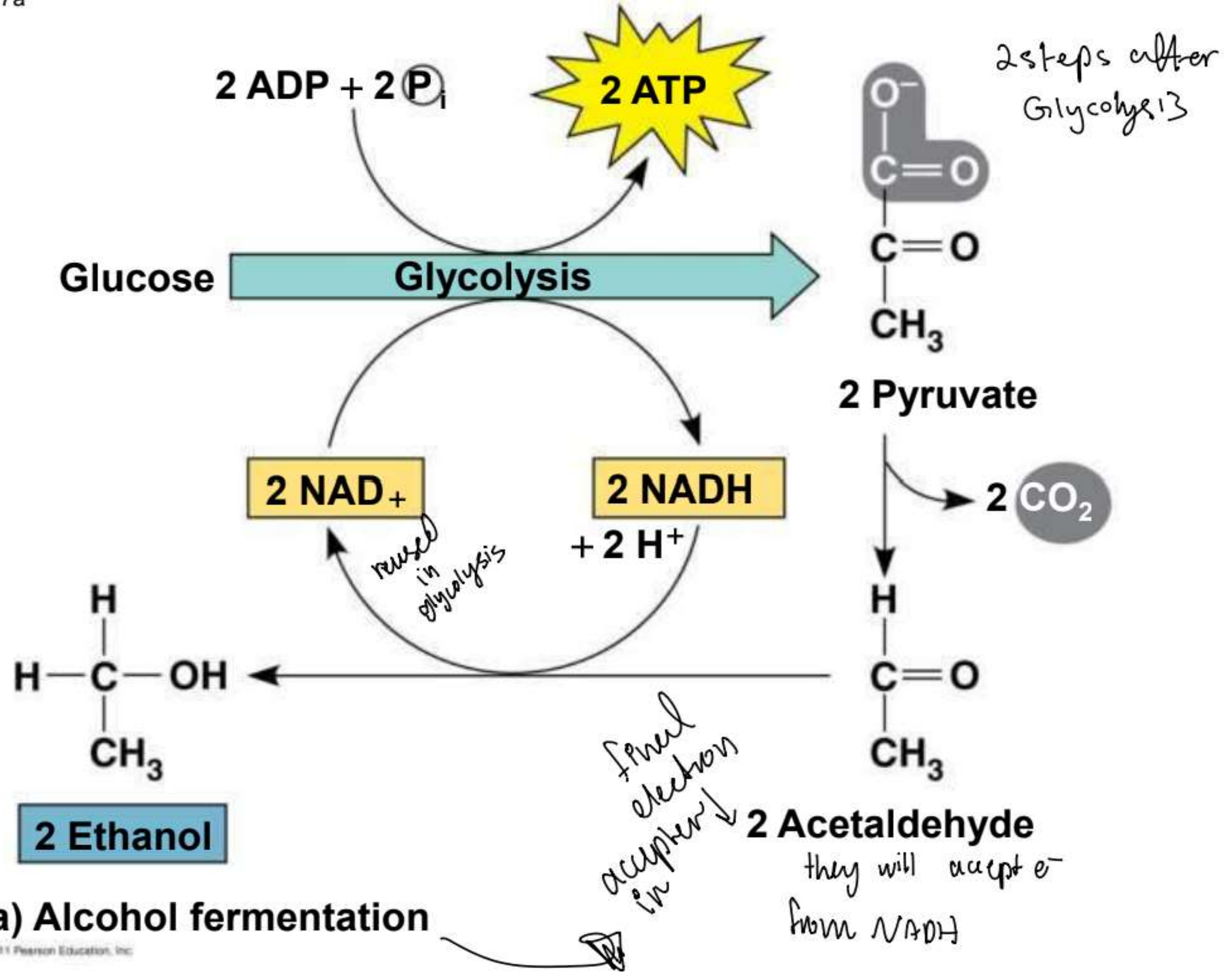

2 ADP + 2 P i
2 ATP
Glucose
Glycolysis
2 Pyruvate
2 NAD+
2 NADH
+ 2 H+
2 CO2
2 Ethanol
2 Acetaldehyde
(a) Alcohol fermentation
2 ADP + 2 P i
2 ATP
Glucose
Glycolysis
2 NAD+
2 NADH
+ 2 H+
2 Pyruvate
2 Lactate
(b) Lactic acid fermentation

Figure 9.17a



(a) Alcohol fermentation

(2)

- In lactic acid fermentation, pyruvate is reduced to NADH, forming lactate as an end product, with no release of CO_2
- Lactic acid fermentation by some fungi and bacteria is used to make cheese and yogurt
- Human muscle cells use lactic acid fermentation to generate ATP when O_2 is scarce

في هذه الحالة سوف يتراكم lactic acid على العضلات/سوف تجهد العضلة
لازم نرتاح عشان liver تتخلص من الزائد/ دلوقتي تفعل يحدث تخذفه

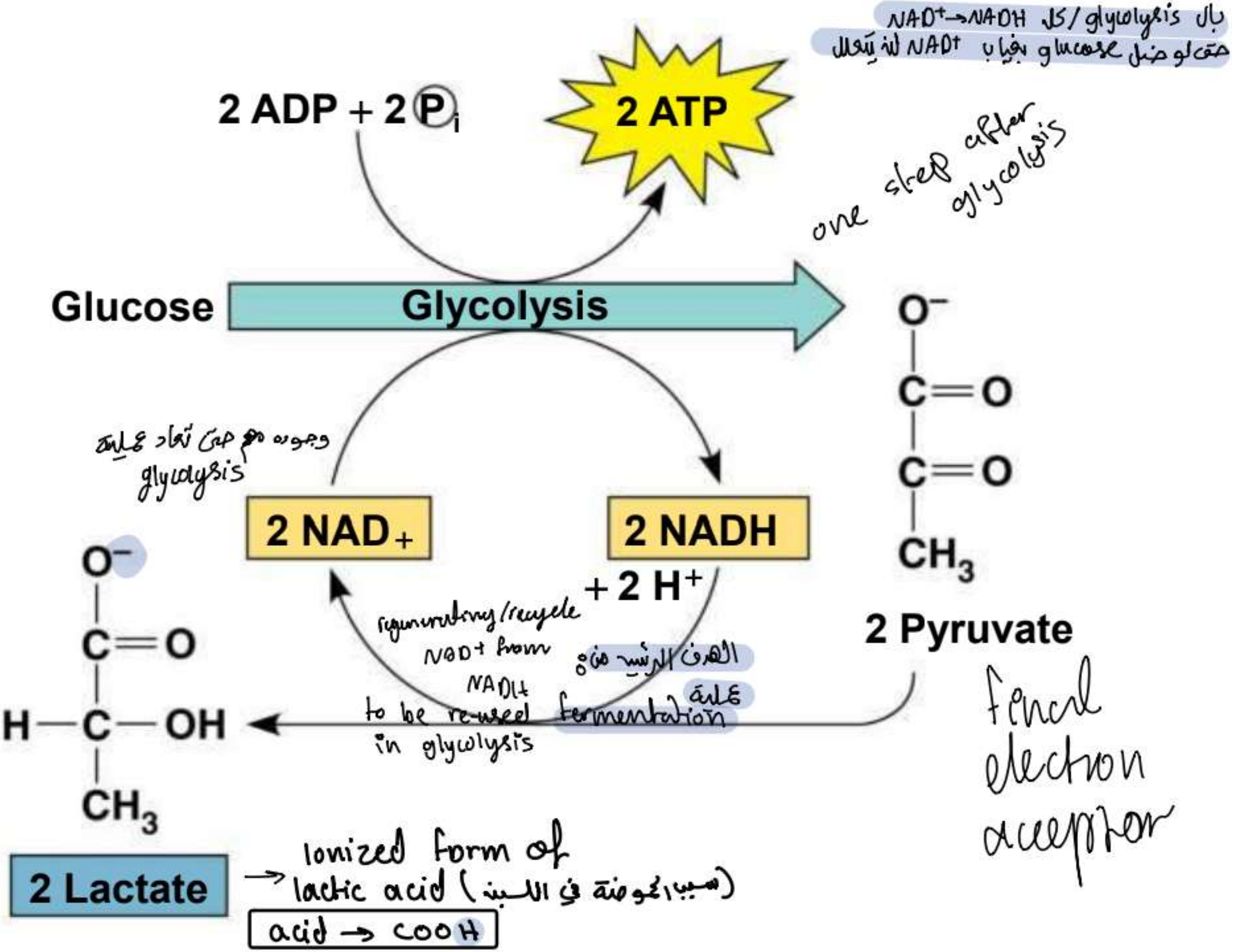
صناعات الألبانه
1. Dairy industry
2. body cell: inhibition

طريا كسم ممكن
1) cellular respiration → O_2 ✓
2) lactic acid fermentation → O_2 ✗

O_2
Breathing rate isn't enough for muscle

muscles that don't get O_2: they will make lactic acid fermentation

Figure 9.17b



(b) Lactic acid fermentation

Comparing Fermentation with Anaerobic and Aerobic Respiration

أوجه الشبه

- تشابه All use glycolysis (net ATP = 2) to oxidize glucose and harvest chemical energy of food, occurs in cytosol
- تشابه In all three, NAD^+ is the oxidizing agent that accepts electrons during glycolysis first electron acceptor
- اختلاف The processes have different final electron acceptors: an organic molecule (such as pyruvate [lactic acid] or acetaldehyde [alcohol]) in fermentation and O_2 in cellular respiration
- اختلاف Cellular respiration produces 32 ATP per glucose molecule; fermentation produces 2 ATP per glucose molecule fermentation عند ضعف 16/15 cellular respiration

تقسم الكائنات
الحية إلى :

لبعض البكتيريا قاتل (O2 is toxic for them)

1. • **Obligate anaerobes** carry out fermentation or anaerobic respiration and cannot survive in the presence of O_2

only make : - fermentation
- un-airobic

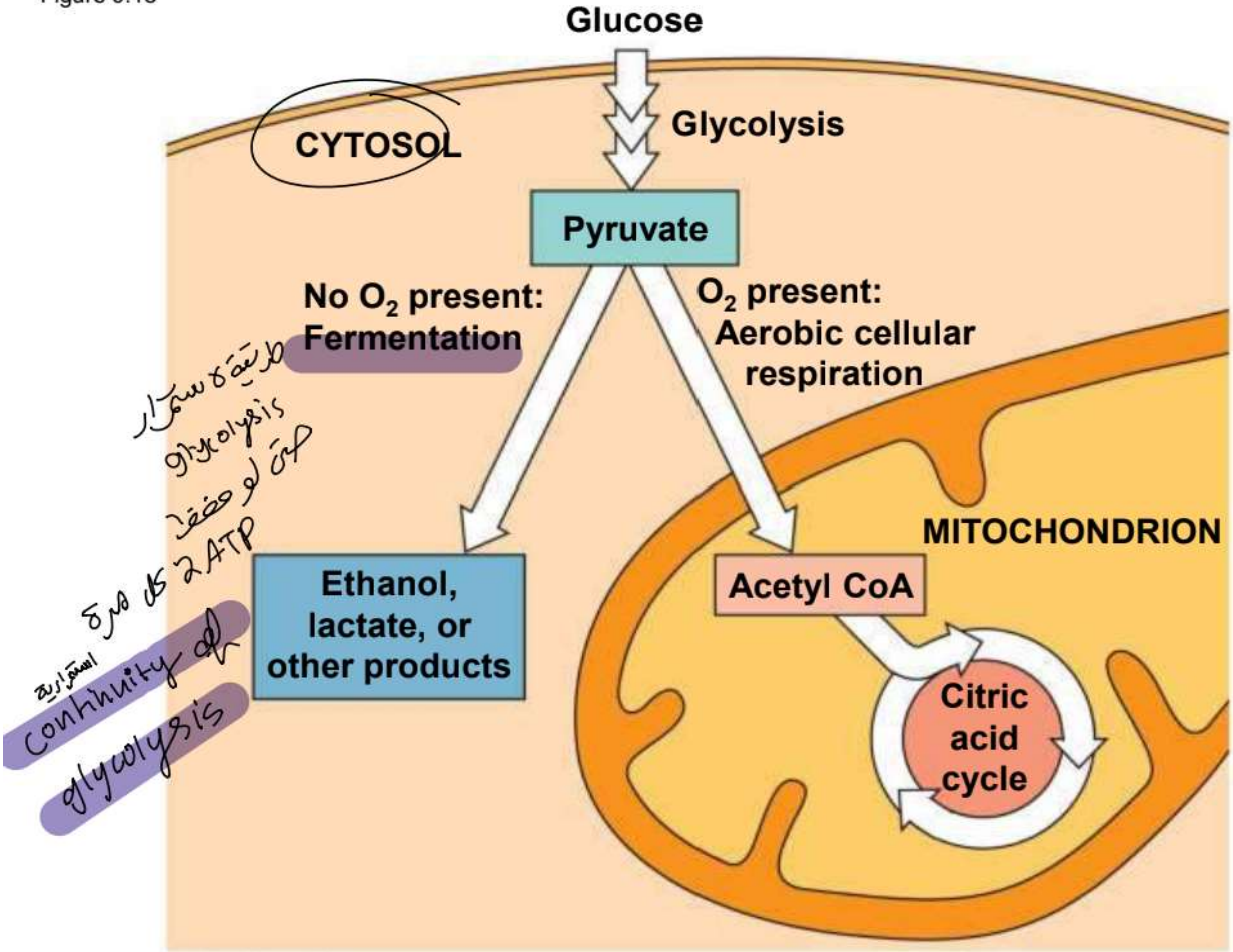
2. • Yeast and many bacteria are **facultative** اختياري **anaerobes**, meaning that they can survive using either fermentation or cellular respiration

e.g: our body cell

• In a facultative anaerobe, pyruvate is a fork in the metabolic road that leads to two alternative catabolic routes

cellular respiration / fermentation

Figure 9.18



Glucose
Glycolysis
CYTOSOL
Pyruvate
No O_2 present:
Fermentation
O_2 present:
Aerobic cellular
respiration
MITOCHONDRION
Ethanol,
lactate, or
other products
Acetyl CoA
Citric
acid
cycle
2ATP
continuity of
glycolysis

The Evolutionary Significance of Glycolysis

- Ancient prokaryotes are thought to have used glycolysis long before there was oxygen in the atmosphere
- Very little O_2 was available in the atmosphere until about 2.7 billion years ago, so early prokaryotes likely used only glycolysis to generate ATP
- Glycolysis is a very ancient process

Concept 9.6: Glycolysis and the citric acid cycle connect to many other metabolic pathways

- Gycolysis and the citric acid cycle are major intersections to various catabolic and anabolic pathways

حمية keto: no carbohydrates

* cellular respiration doesn't have to start with glucose

The Versatility of Catabolism

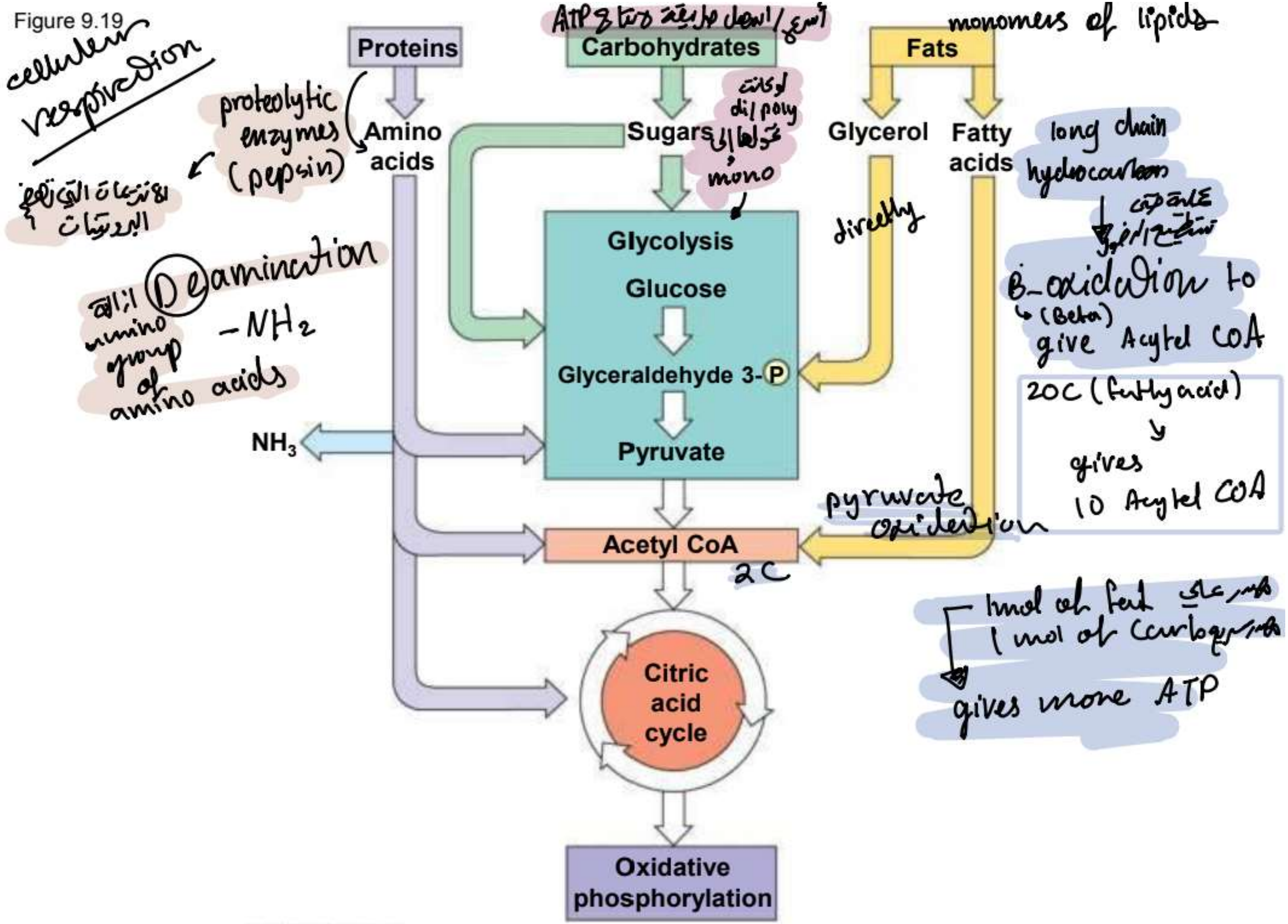
تنوع

their is also versatility in anabolism

- Catabolic pathways funnel electrons from many kinds of organic molecules into cellular respiration
- Glycolysis accepts a wide range of carbohydrates
- Proteins must be digested to amino acids; amino groups can feed glycolysis or the citric acid cycle

- Fats are digested to glycerol (used in glycolysis) and fatty acids (used in generating acetyl CoA)
- Fatty acids are broken down by **beta oxidation** and yield acetyl CoA
- An oxidized gram of fat produces more than twice as much ATP as an oxidized gram of carbohydrate

Figure 9.19


cellular respiration
Proteins
Carbohydrates
Fats
monomers of lipids
proteolytic enzymes (pepsin)
Amino acids
Sugars
Glycerol
Fatty acids
long chain hydrocarbons
directly
Deamination
amino group of amino acids
$-NH_2$
Glycolysis
Glucose
Glyceraldehyde 3-P
Pyruvate
NH_3
B-oxidation to (Beta) give Acytel COA
20C (fatty acid) gives 10 Acytel COA
pyruvate oxidation
Acetyl CoA
2C
1 mol of fat
1 mol of carbo
gives more ATP
Citric acid cycle
Oxidative phosphorylation

بناء

Biosynthesis (Anabolic Pathways)

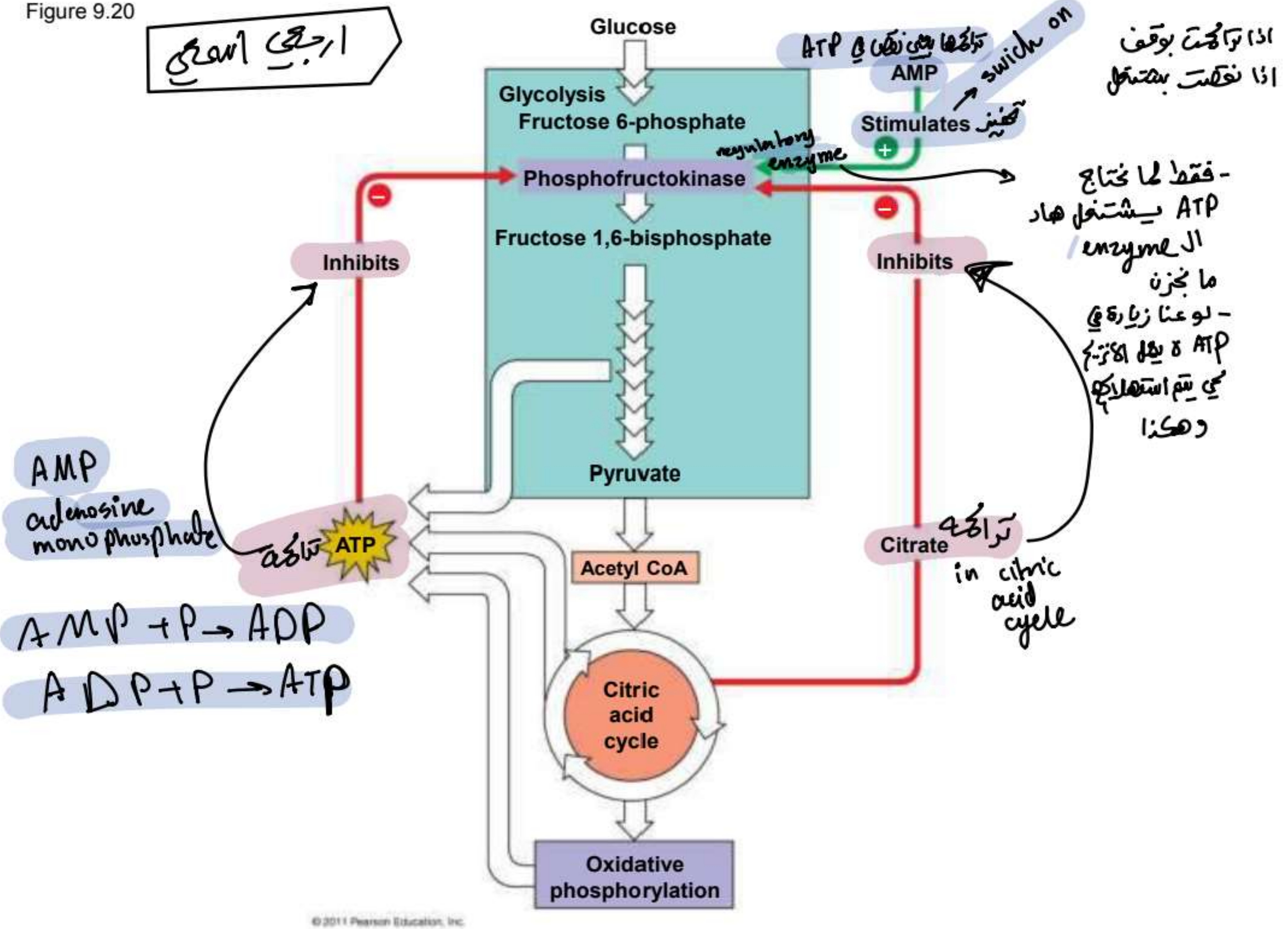
- The body uses small molecules to build other substances
- These small molecules may come directly from food, from glycolysis, or from the citric acid cycle

Regulation of Cellular Respiration via Feedback Mechanisms

الطريقة

- Feedback inhibition is the most common mechanism for control
- If ATP concentration begins to drop, respiration speeds up; when there is plenty of ATP, respiration slows down
- Control of catabolism is based mainly on regulating the activity of enzymes at strategic points in the catabolic pathway

Figure 9.20



ارجعي السهم
Glucose
Glycolysis
Fructose 6-phosphate
Phosphofructokinase
Fructose 1,6-bisphosphate
Pyruvate
Acetyl CoA
Citric acid cycle
Oxidative phosphorylation
AMP
Stimulates
Inhibits
Inhibits
ATP
Citrate
ATP تراكمها يعني نقص في
swich on
تحفيز
regulatory enzyme
اذا تراكمت بوقف
اذا نقصت بشتغل
- فقط لما نحتاج ATP يشتغل هاد ال enzyme
ما نخزن
- لو عنا زيادة في ATP ة يقل الأنزيم كي يتم استهلاكه وهكذا
تراكمه
in citric acid cycle
تراكمه
AMP
adenosine monophosphate
AMP + P → ADP
ADP + P → ATP

Figure 9.UN06

Figure 9.UN07

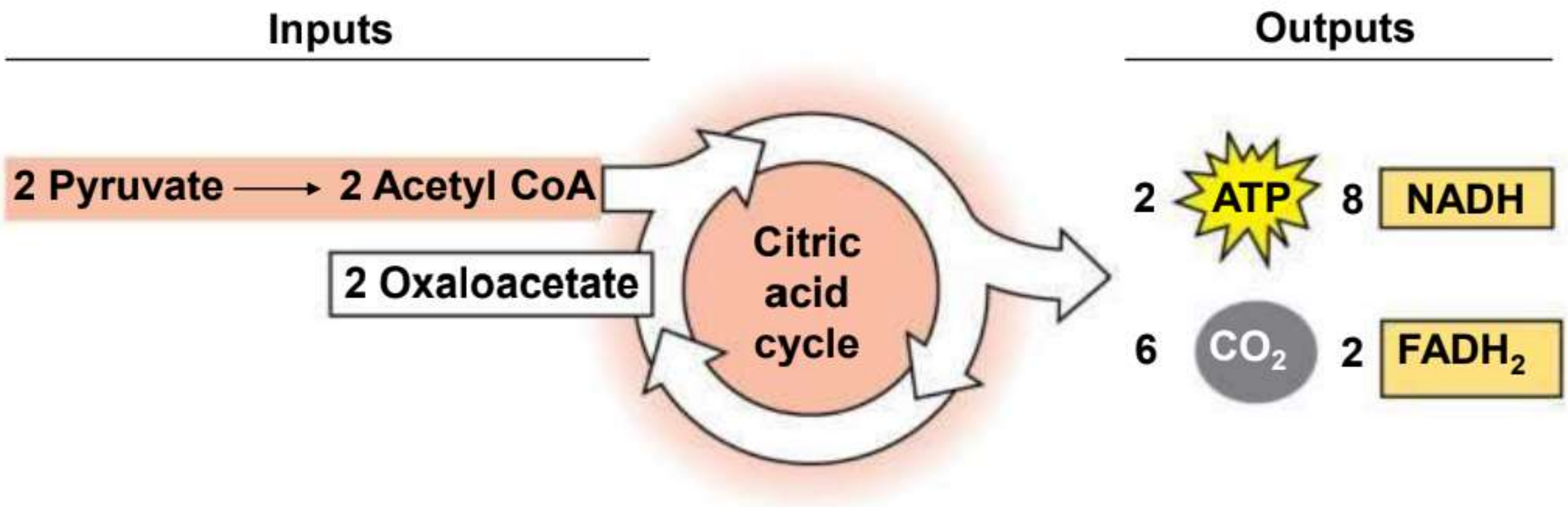


Figure 9.UN08

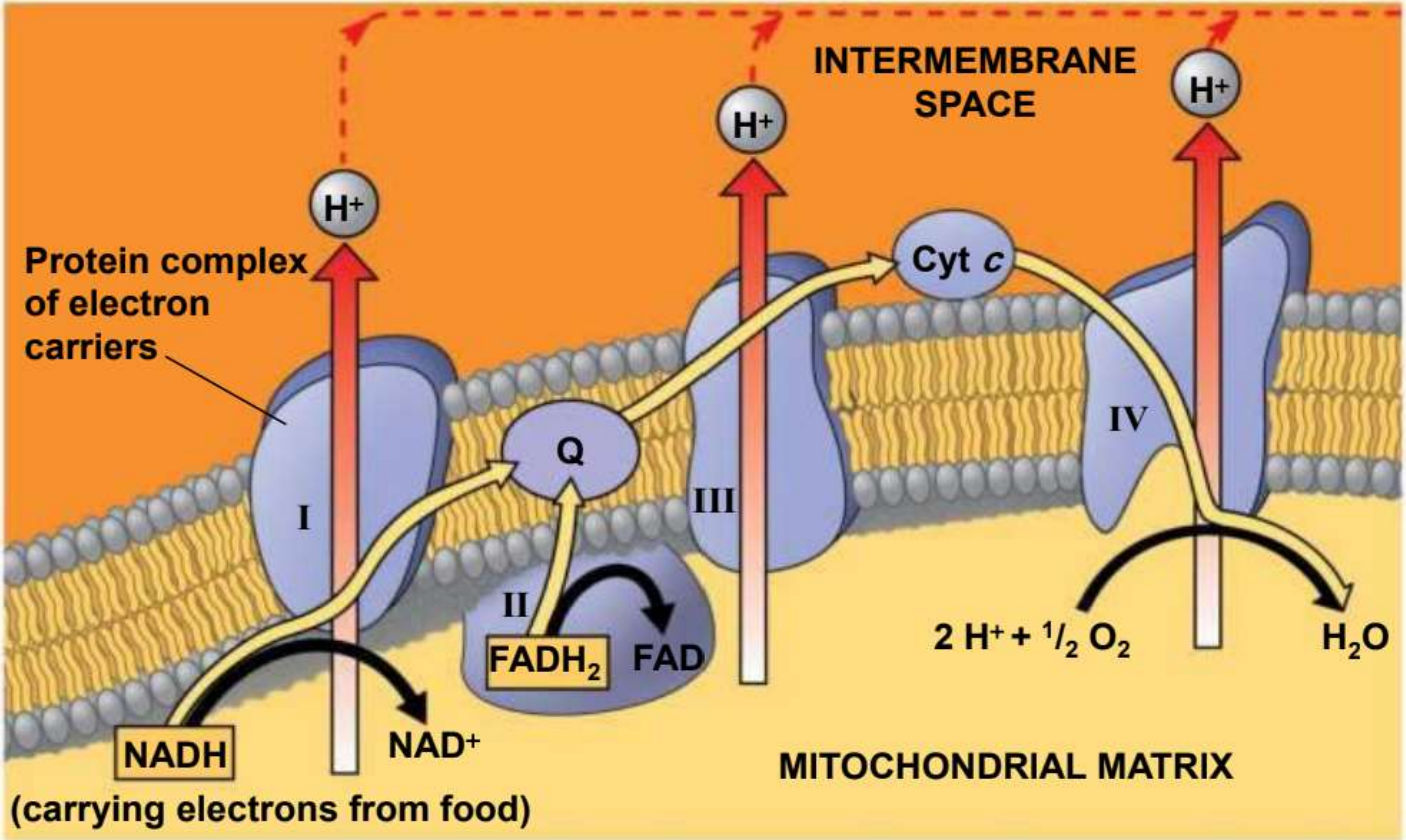


Figure 9.UN09

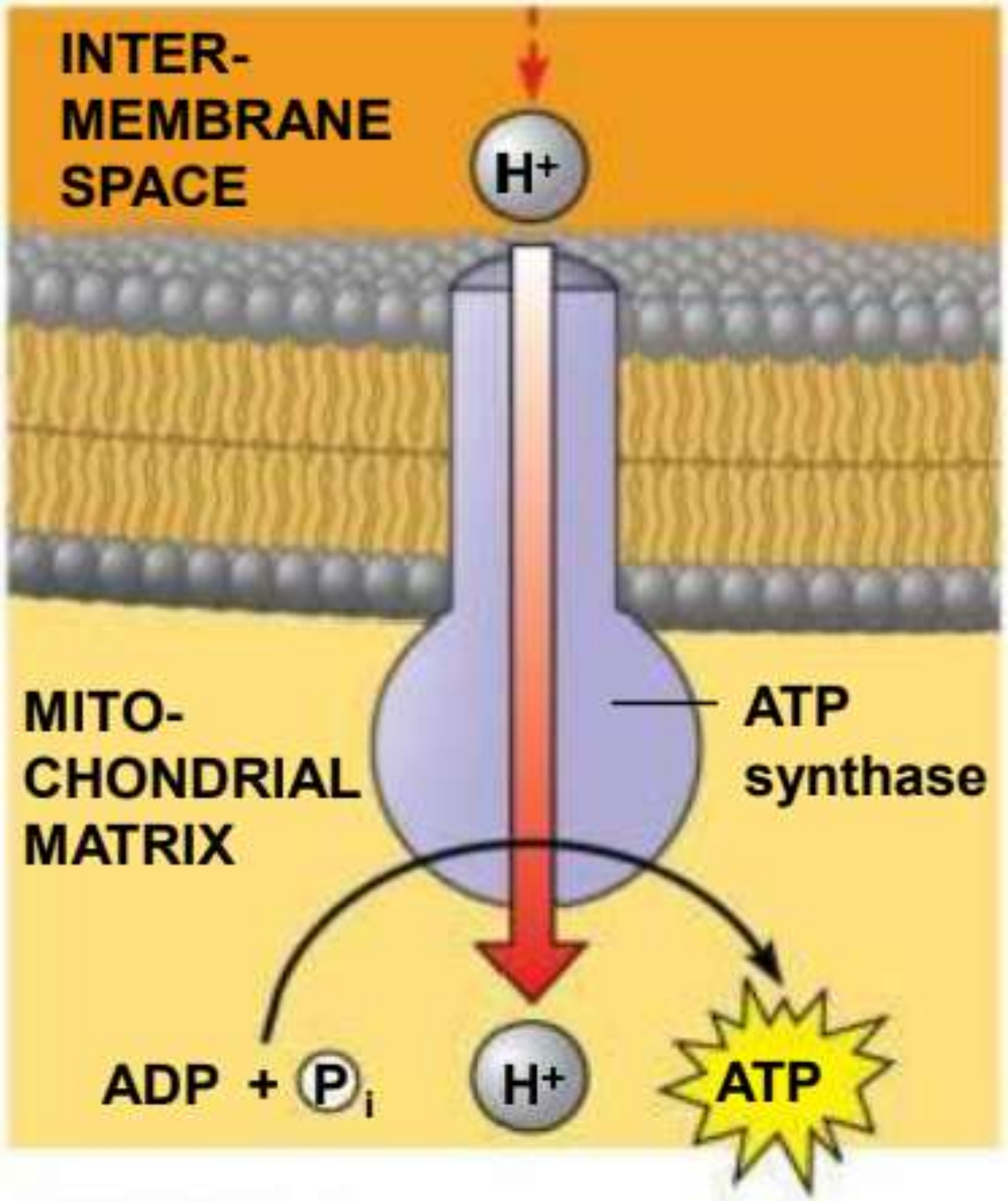


Figure 9.UN10

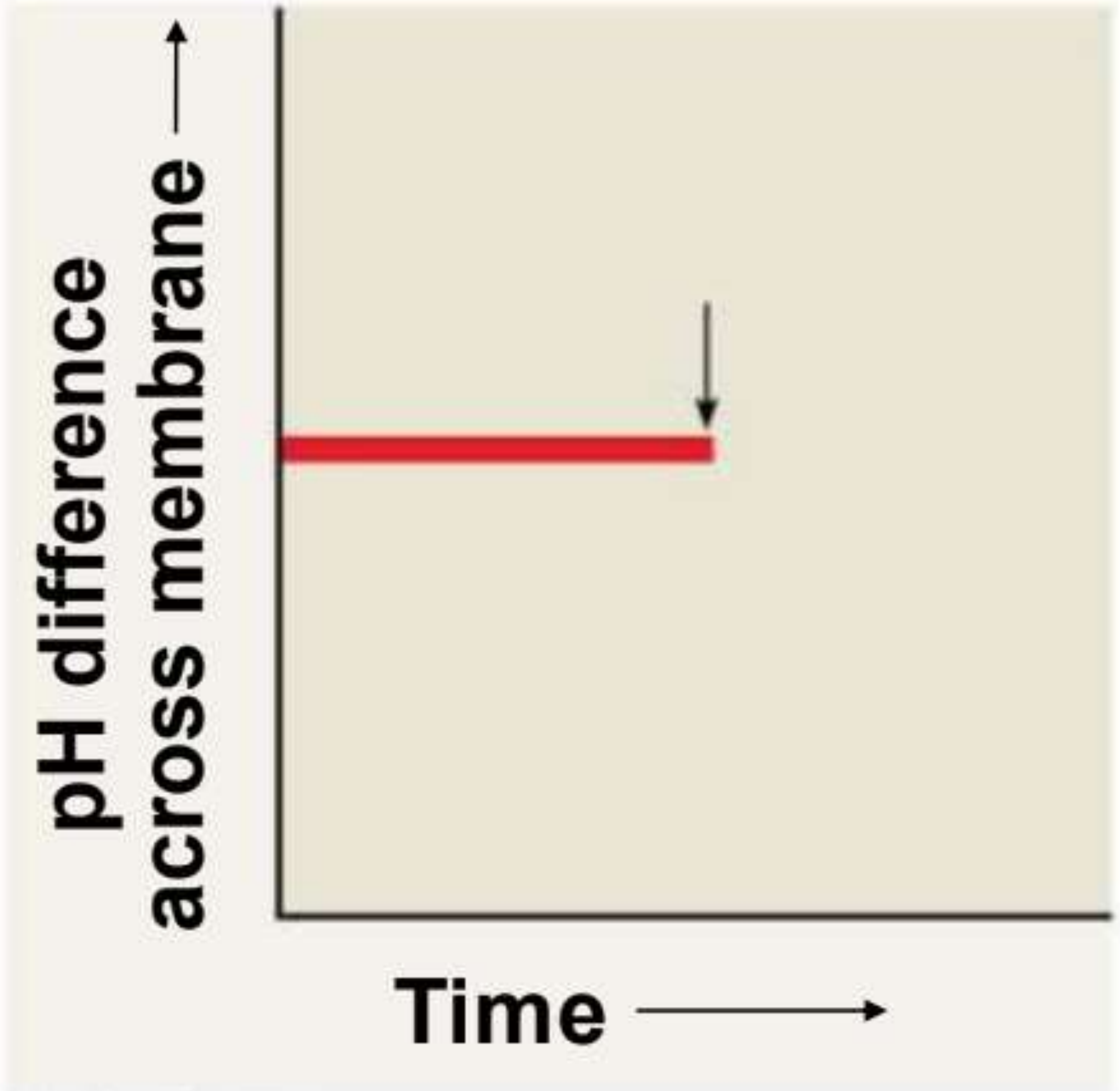


Figure 9.UN11

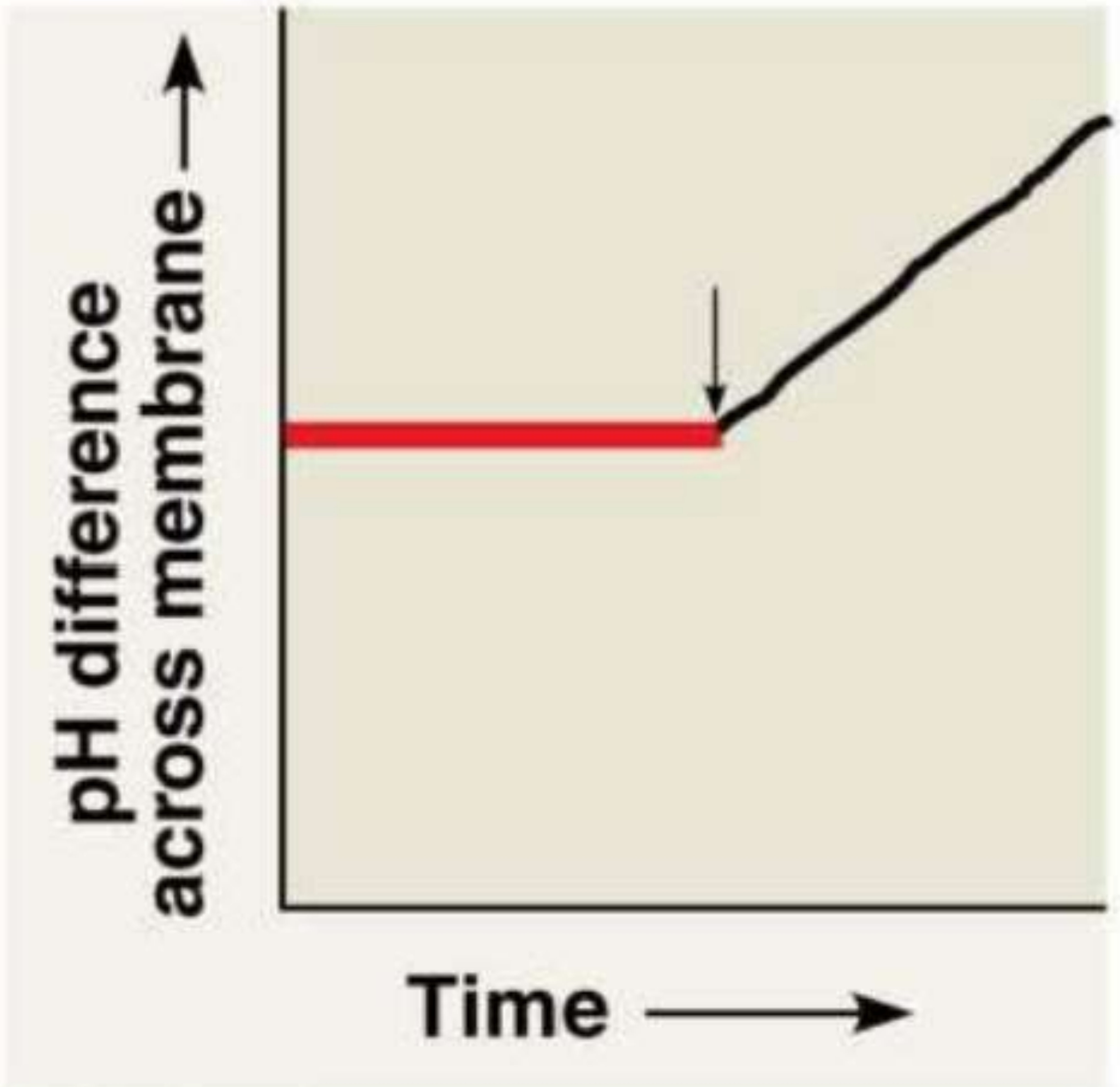


Figure 9.UN11