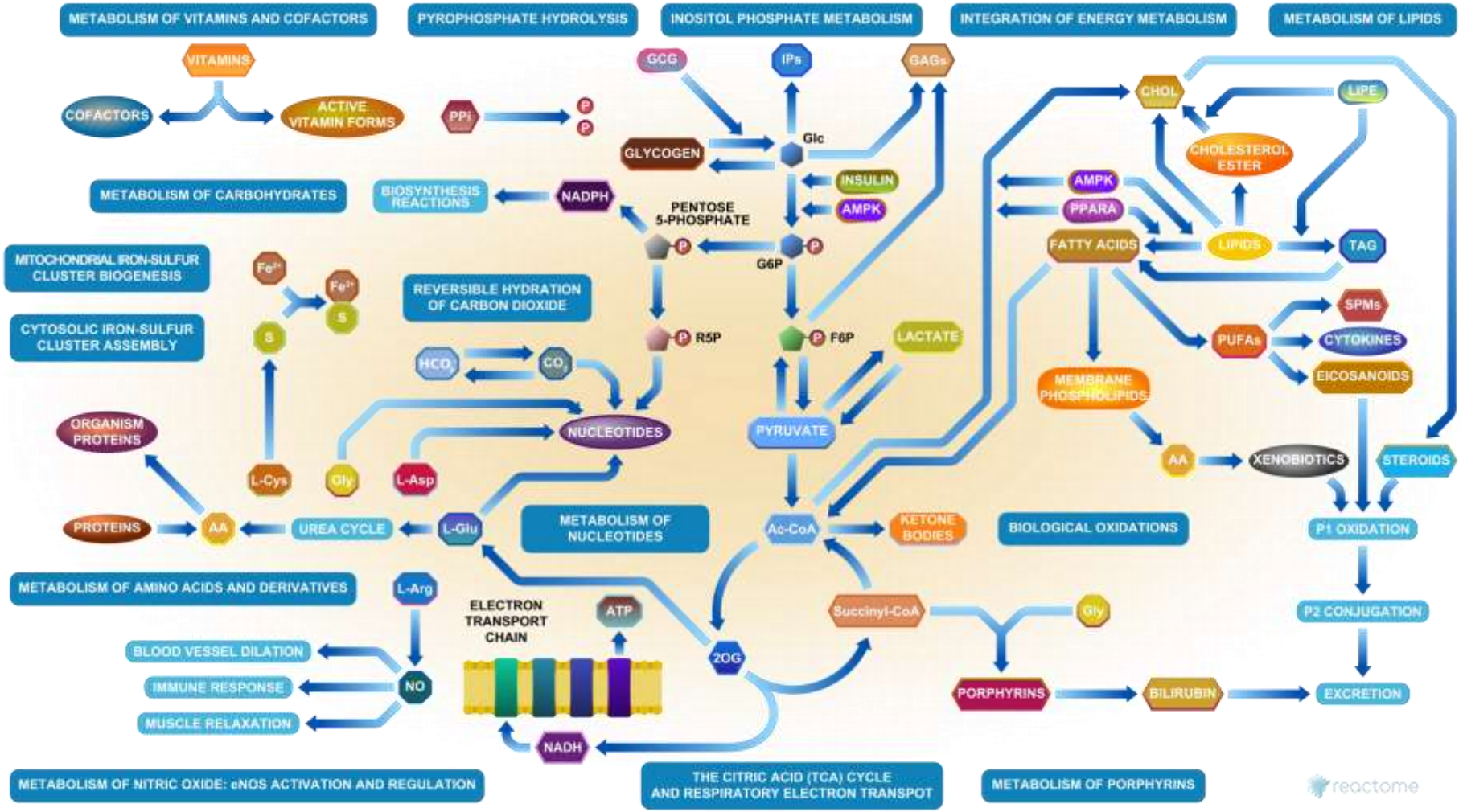
Cellular Respiration

Prof. Dr. Chiara Valsecchi

Class Goals

- Understand the different types of energy production pathways in animals
- Explore the ATP production in mitocondria

Cellular Metabolism



Metabolism

Two types of metabolic routes:

Catabolism: from food to energy

Anabolism: use energy to build larger molecules

In animal, the metabolism to produce energy is a type of **Aerobic Catabolism**, because it needs **Oxygen.**

3 steps:

Glycolysis
Krebs' Cycle
Oxidative Phosphorilation

} **Cellular Respiration**

Cellular Respiration

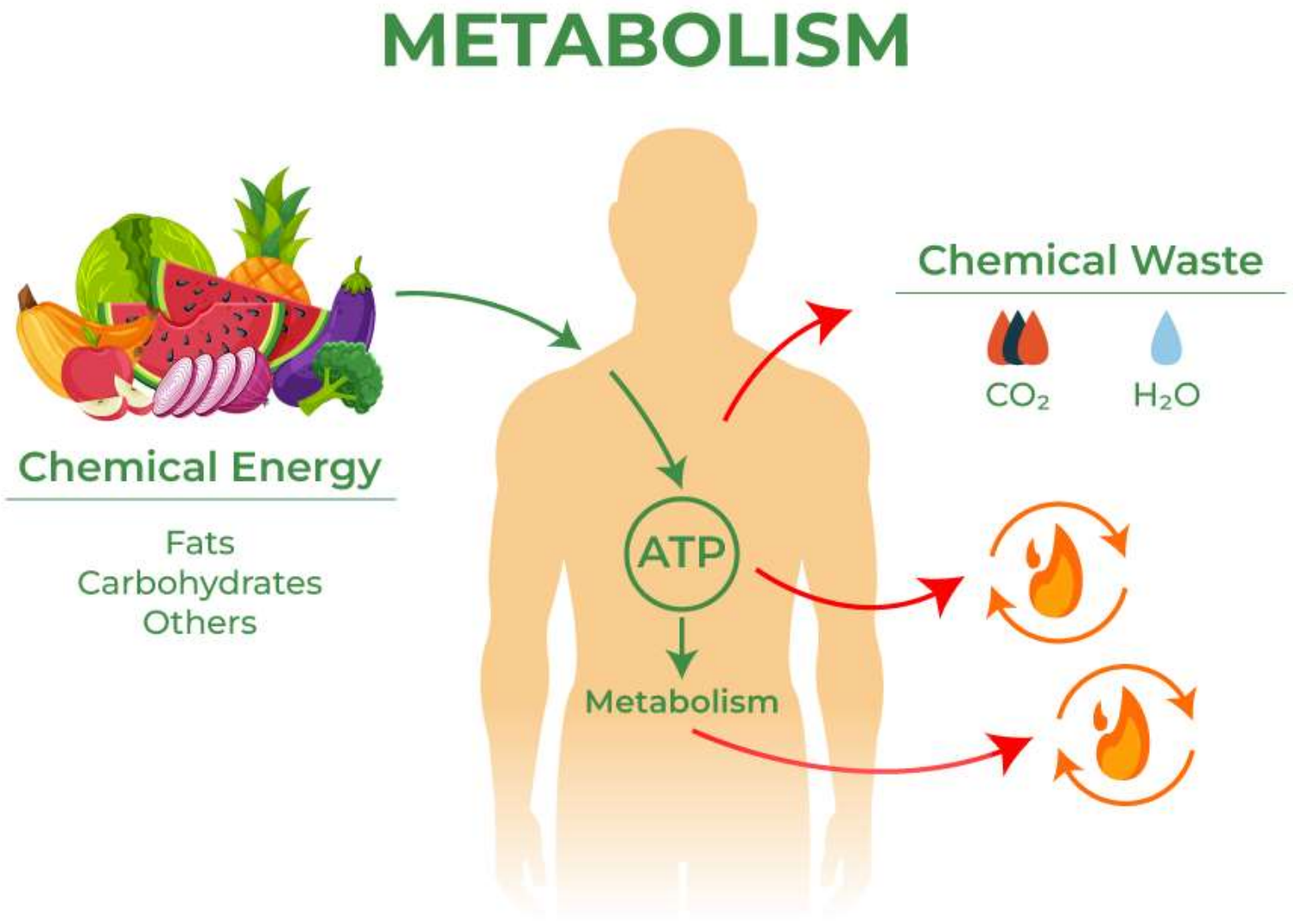
Cellular respiration is the process in which energy from chemical bonds is extracted and stored into ATP.

Mitochondria are responsible for this process.

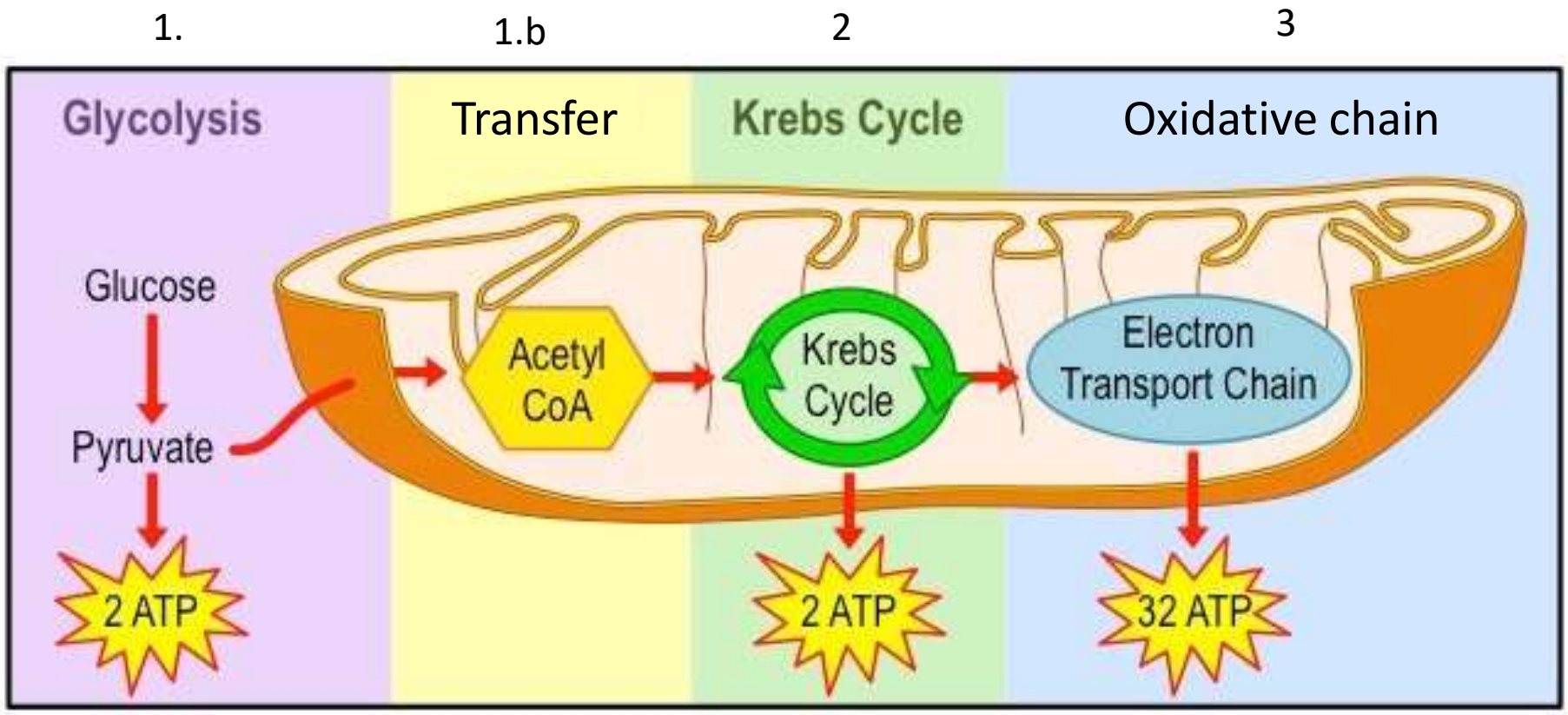
Together with ATP, other molecules are produced during the process:

- Carbon dioxide, CO_2
- Water
- Highly energetic molecules, like: **NADH, $FADH_2$**
  (precursor for more ATP molecules)

Cellular Respiration

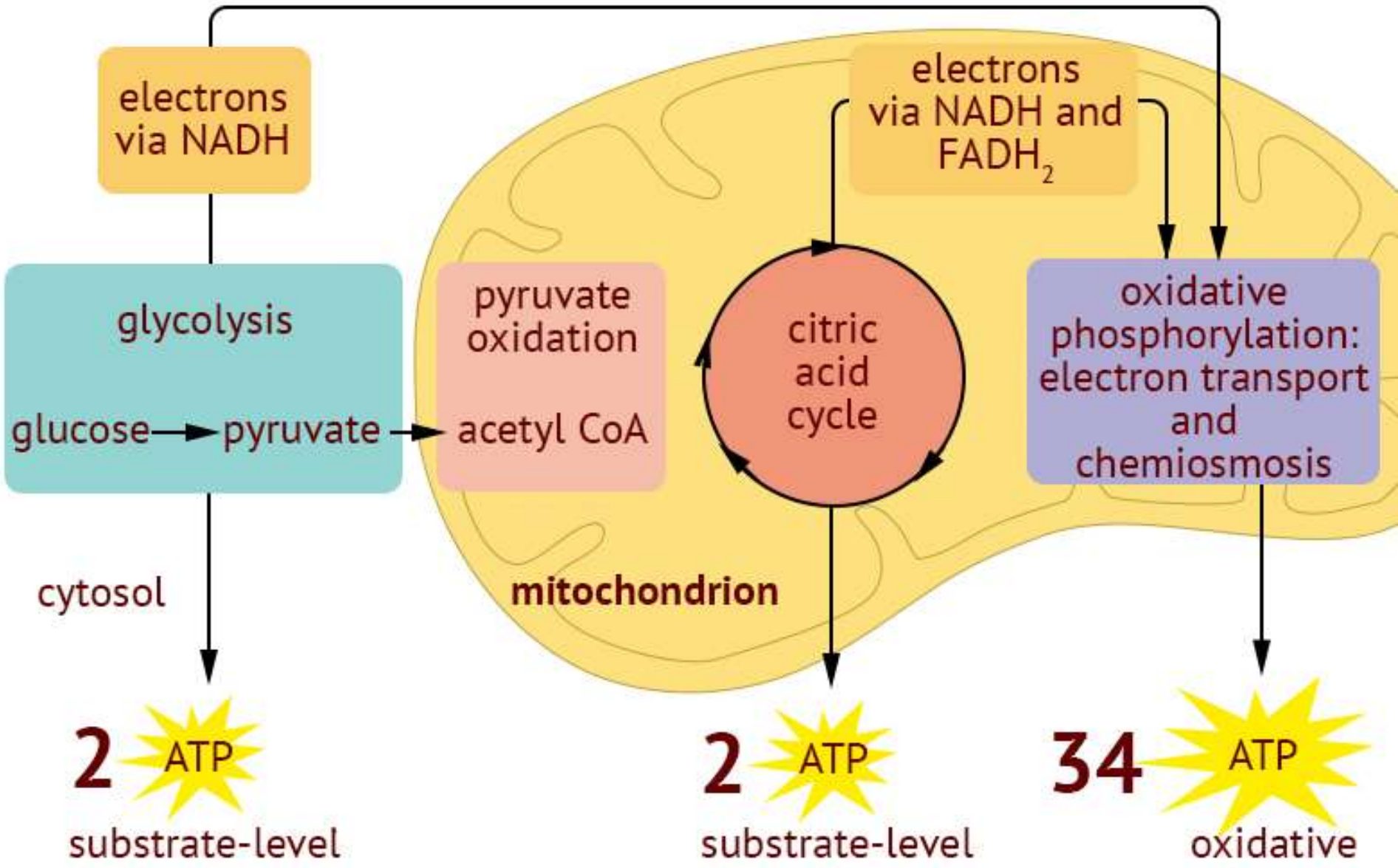


Cellular Respiration



ANAEROBIC
(no oxygen)

AEROBIC
(oxygen)

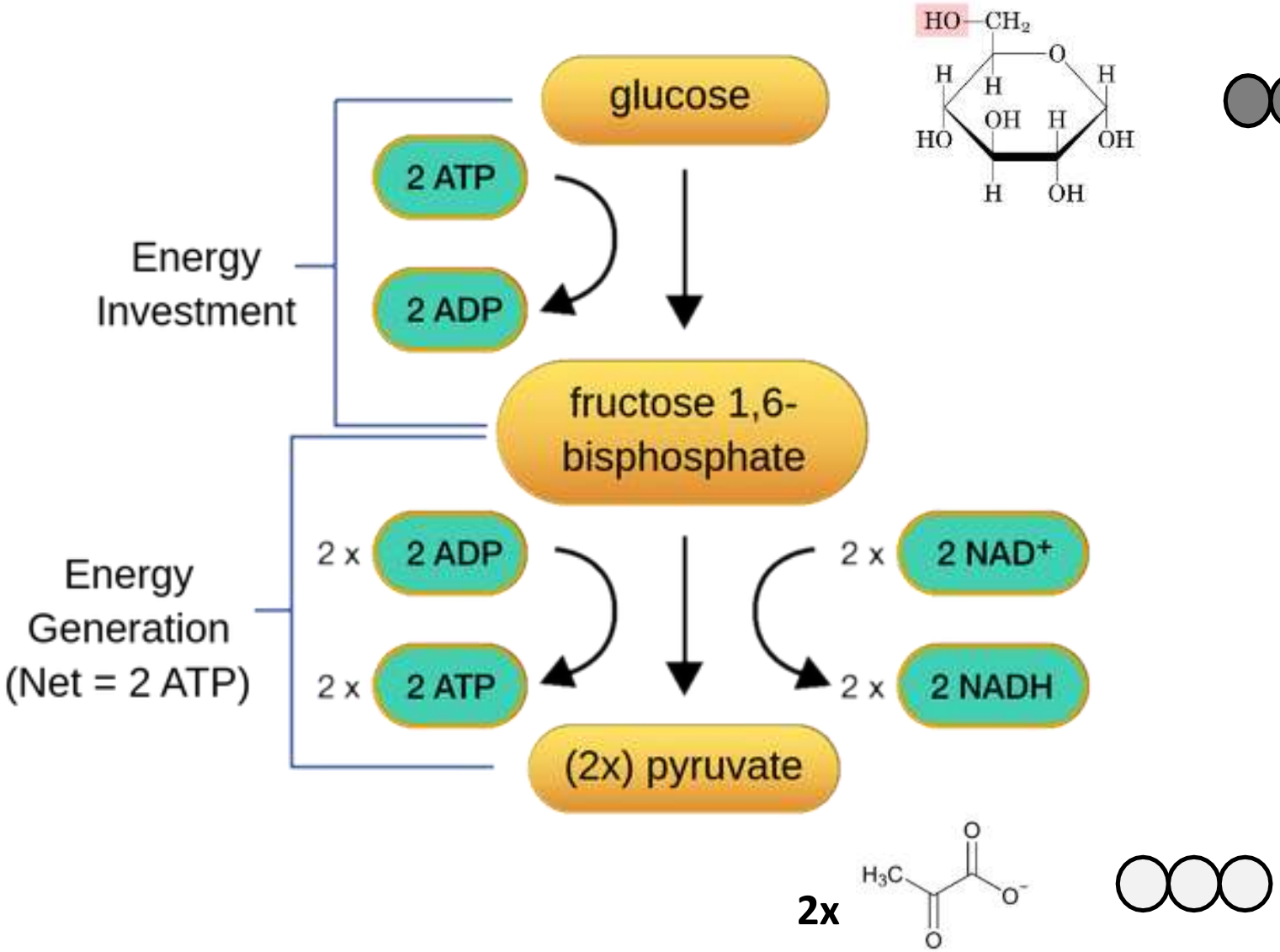

electrons via NADH
electrons via NADH and $FADH_2$
glycolysis
glucose → pyruvate
pyruvate oxidation
acetyl CoA
citric acid cycle
oxidative phosphorylation: electron transport and chemiosmosis
cytosol
mitochondrion
2 ATP
substrate-level
2 ATP
substrate-level
34 ATP
oxidative

1. Glycolysis

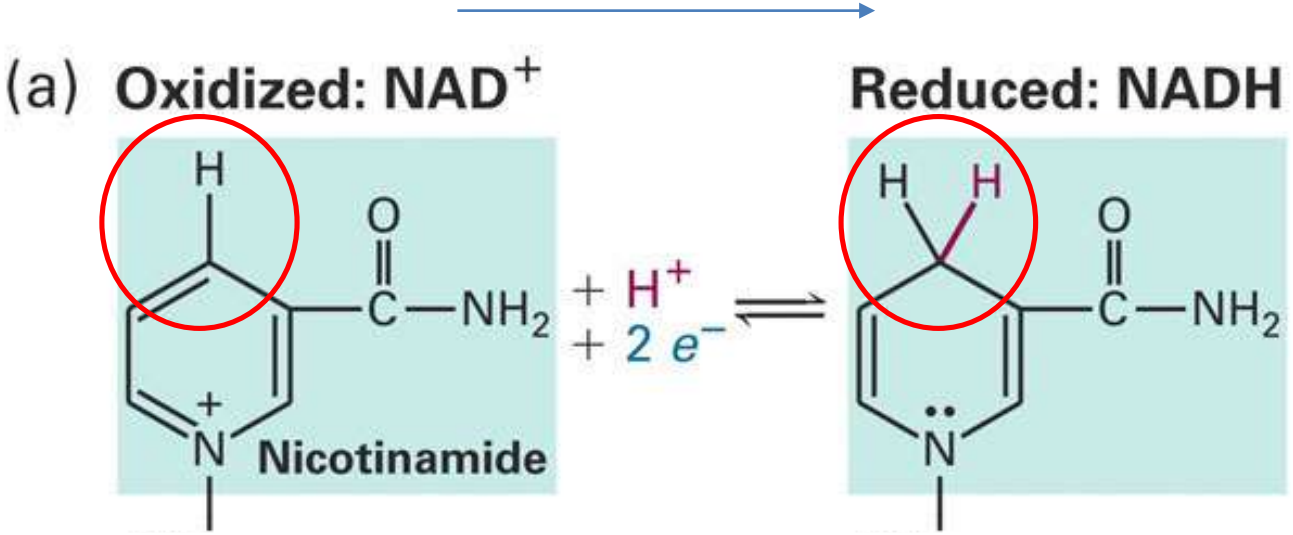
Glycolysis is a sequence of **10 reaction** that **rapidly** trasnform Glucose in 2 molecules of Piruvate.
It's a fast process and it does not need OXYGEN.

The energy gain is little, only 2 molecules of ATP.
Most of the **energy** is still **stored in the piruvate** molecules and in the **NADH** molecules

1. Glycolysis



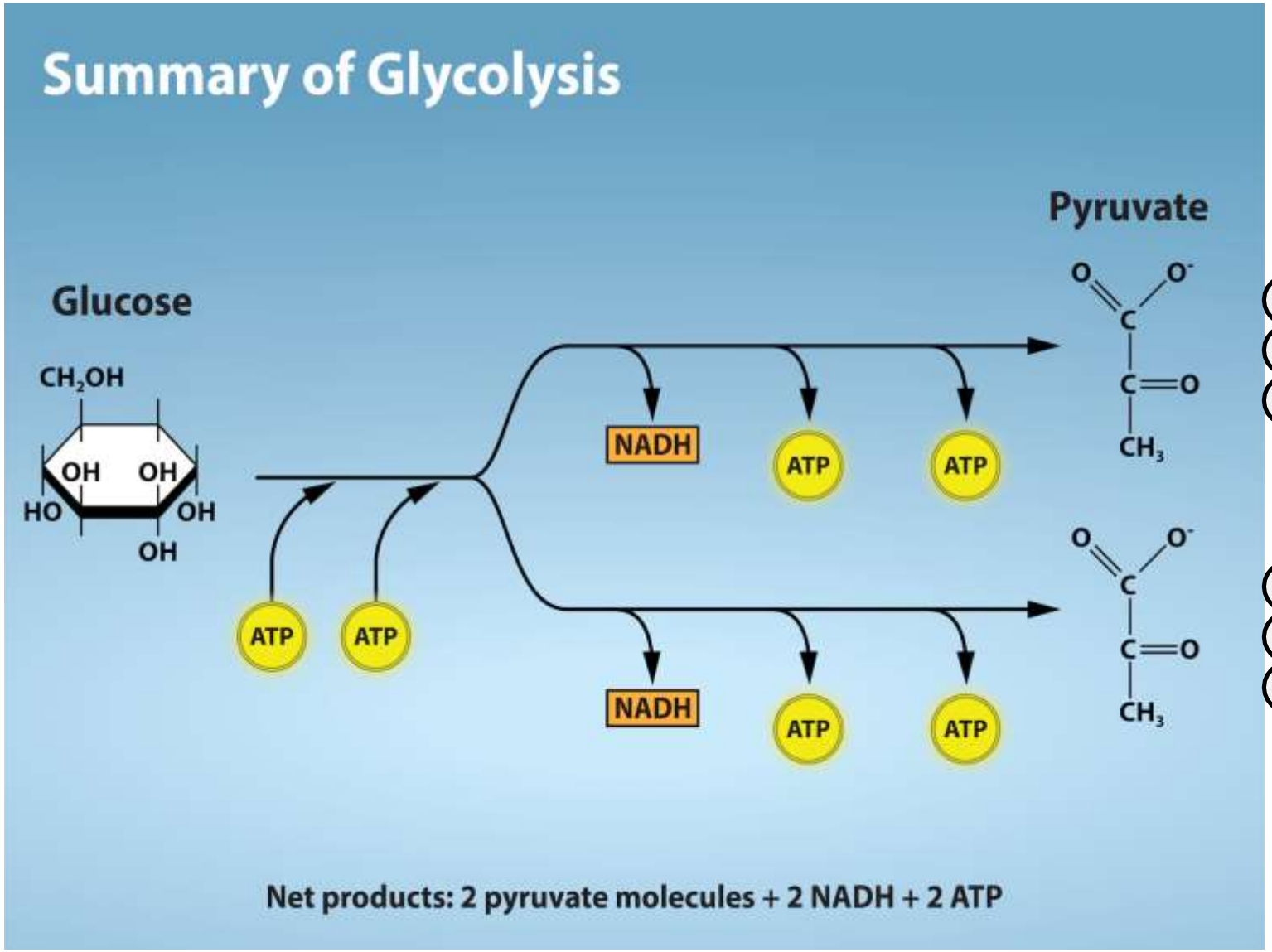
NAD^+



$$NAD^+ + H^+ + 2\,e^- \rightleftharpoons NADH$$

Each molecule transport 2 electrons

1. Glycolysis



Glucose

glycolysis (10 successive reactions)

2 Pyruvate

anaerobic conditions

2 Ethanol + $2CO_2$

Fermentation to alcohol in yeast

aerobic conditions

$2CO_2$

2 Acetyl-CoA

citric acid cycle

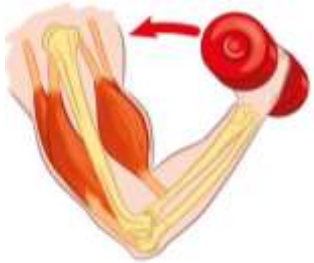
$4CO_2 + 4H_2O$

Animal, plant, and many microbial cells under aerobic conditions

anaerobic conditions

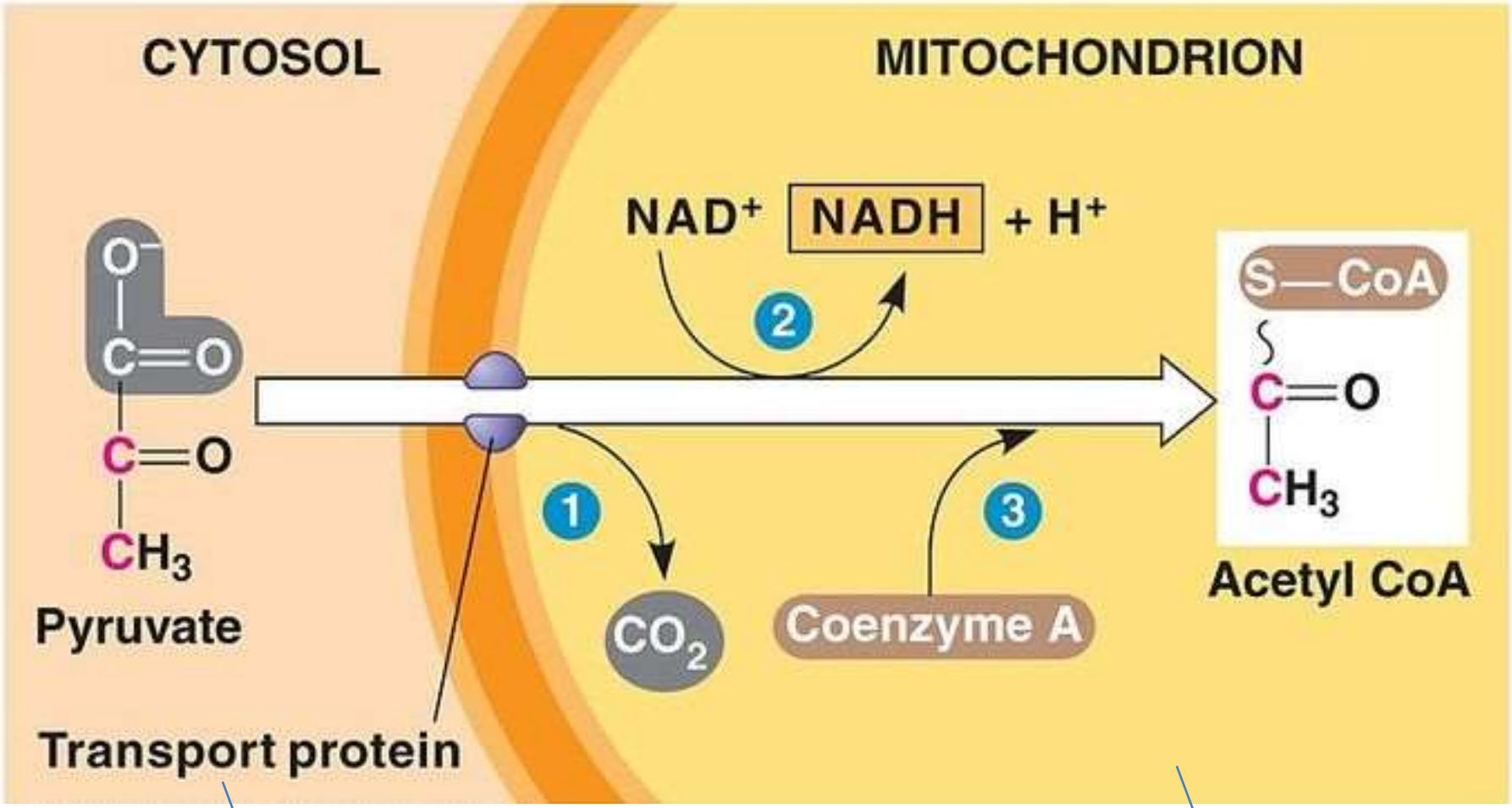
2 Lactate

Fermentation to lactate in vigorously contracting muscle,



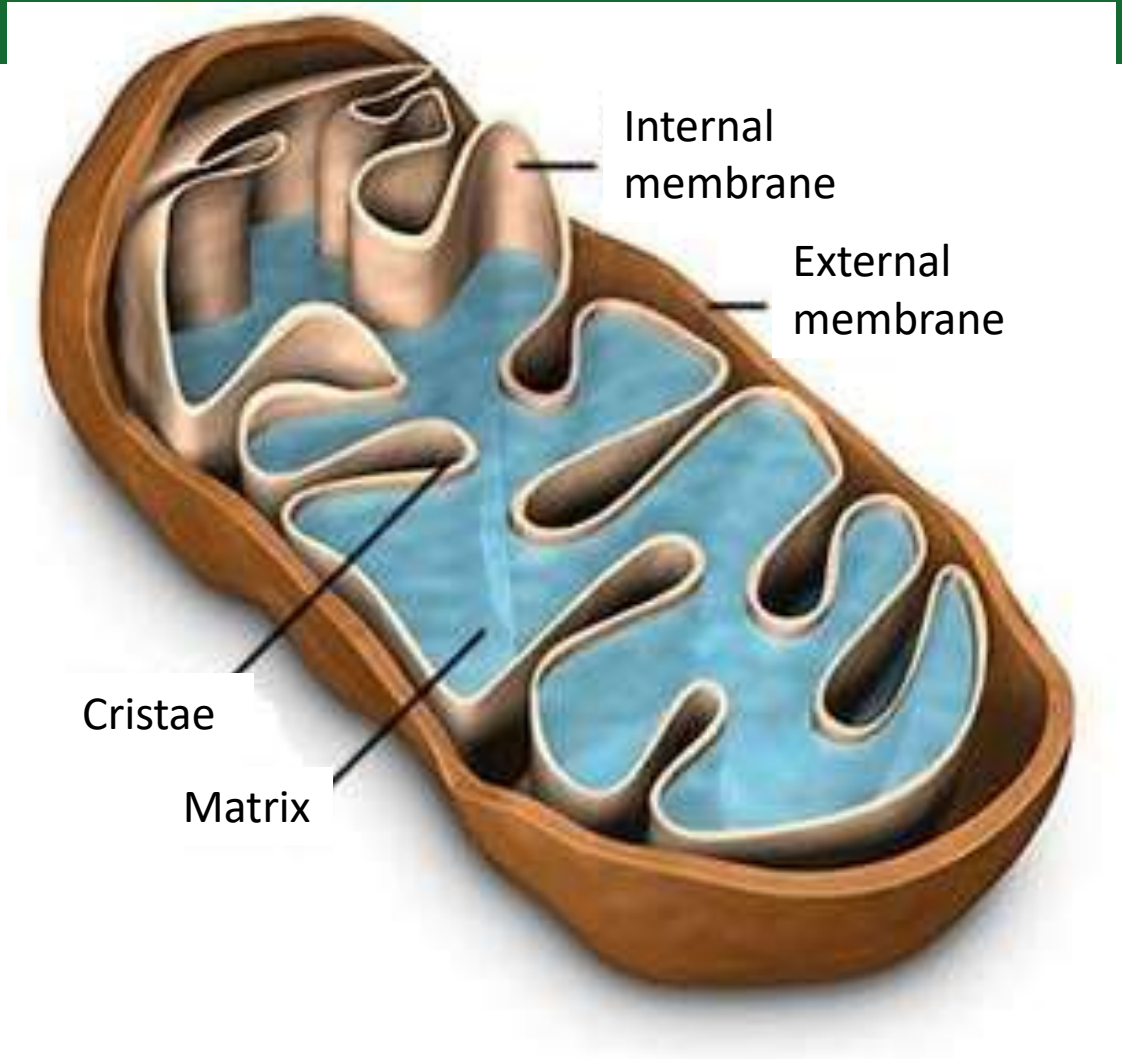
YEAST

1b. Transport inside Mitochondrion



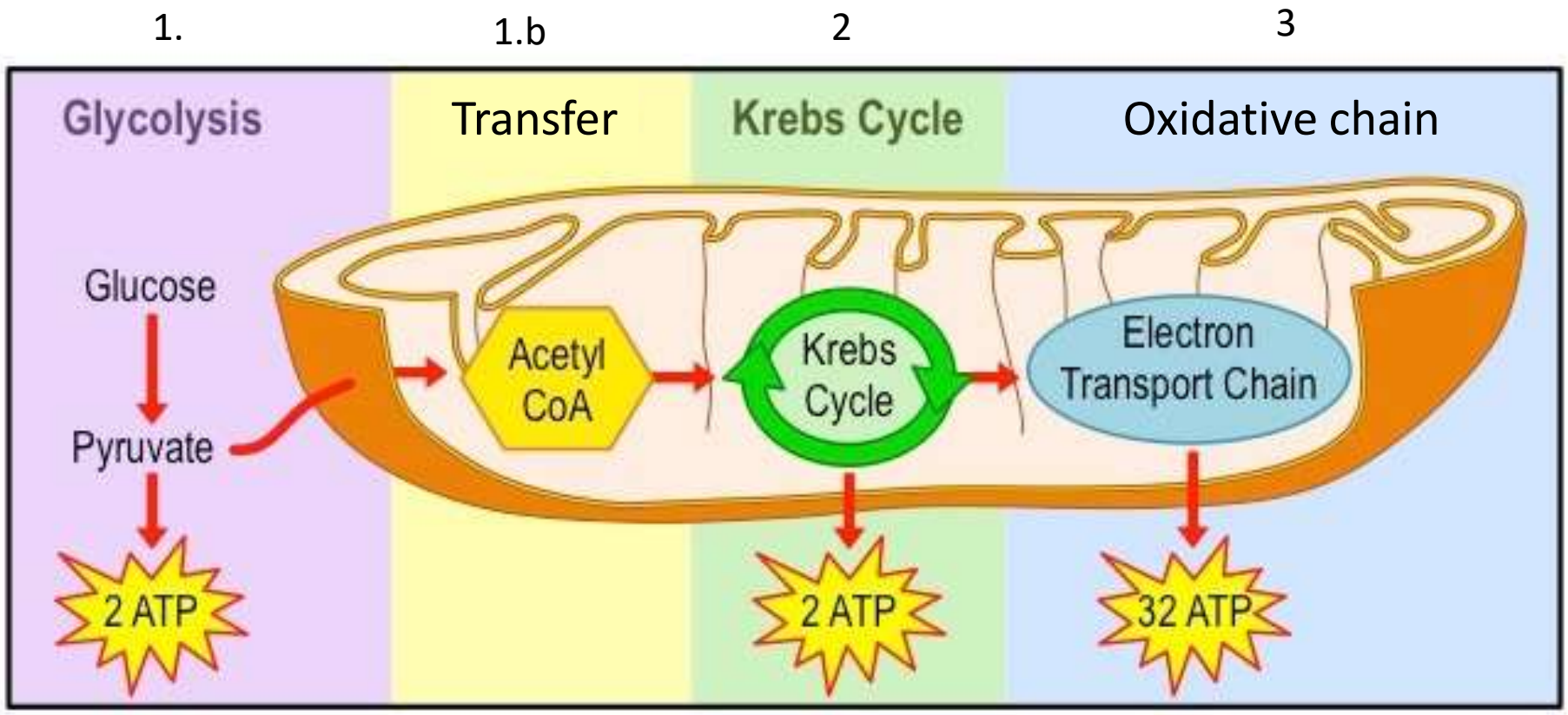
Consume 2 ATP molecules

In the INNER matrix



The Krebs' Cycle occurs inside the mitochondrial matriz → inside the inner membrane

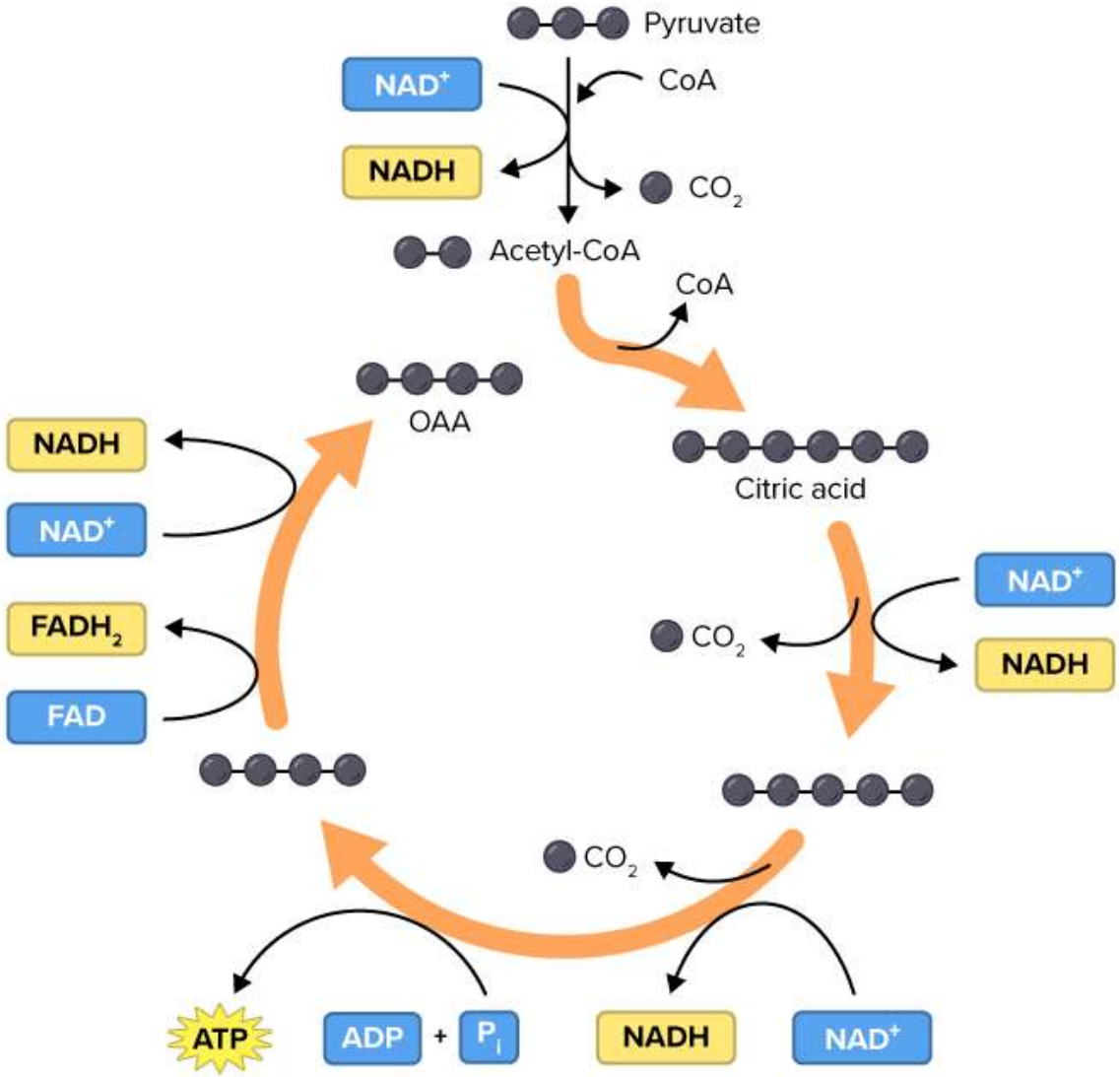
Cellular Respiration



ANAEROBIC
(no oxygen)

AEROBIC
(oxygen)

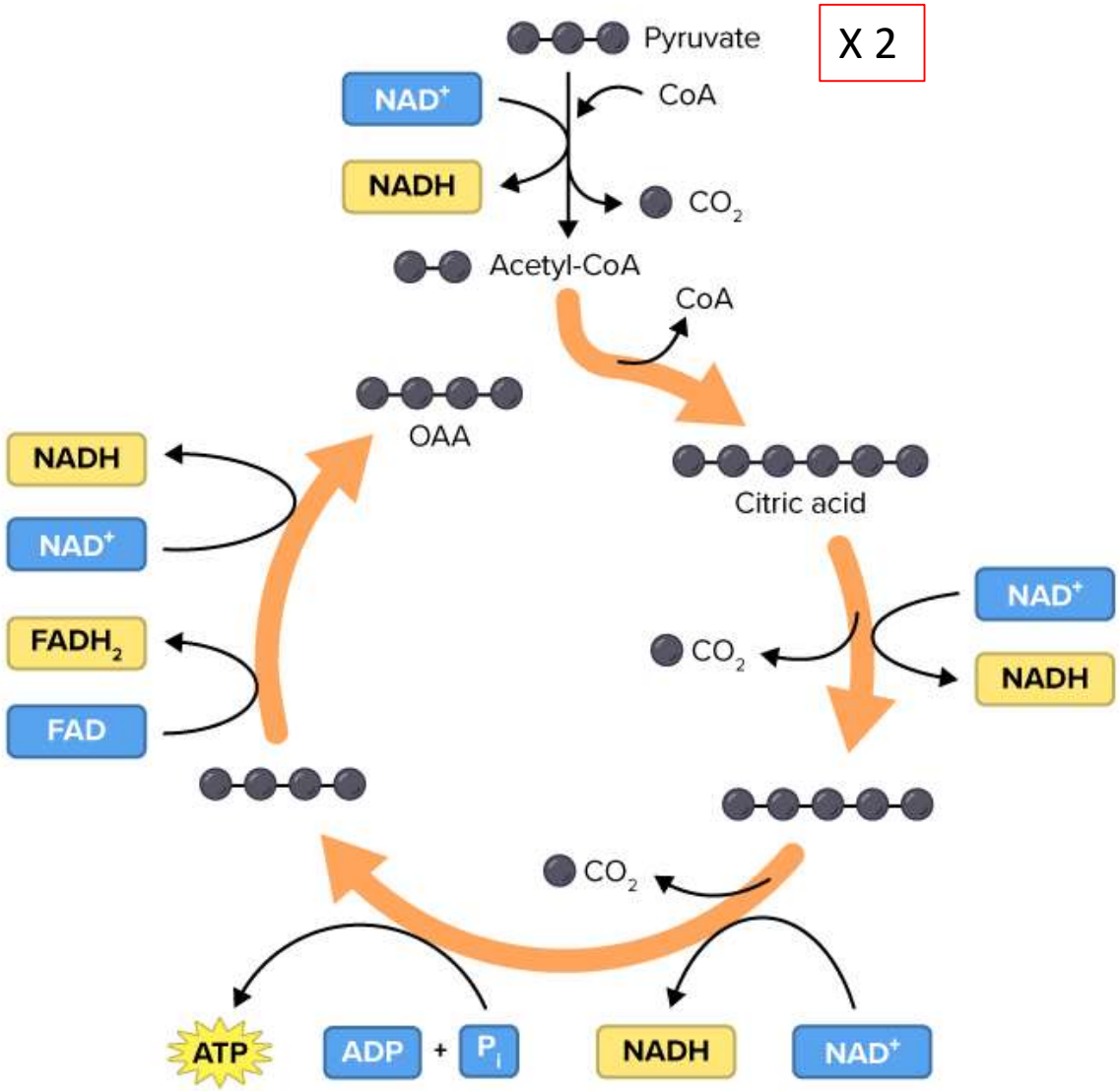
2. Krebs' Cycle



All the C-C bonds presente in the Glucose molecules are broken and eliminated as CO_2

All the energy is stored now into 2 new molecules of ATP and NADH and $FADH_2$.

2. Krebs' Cycle



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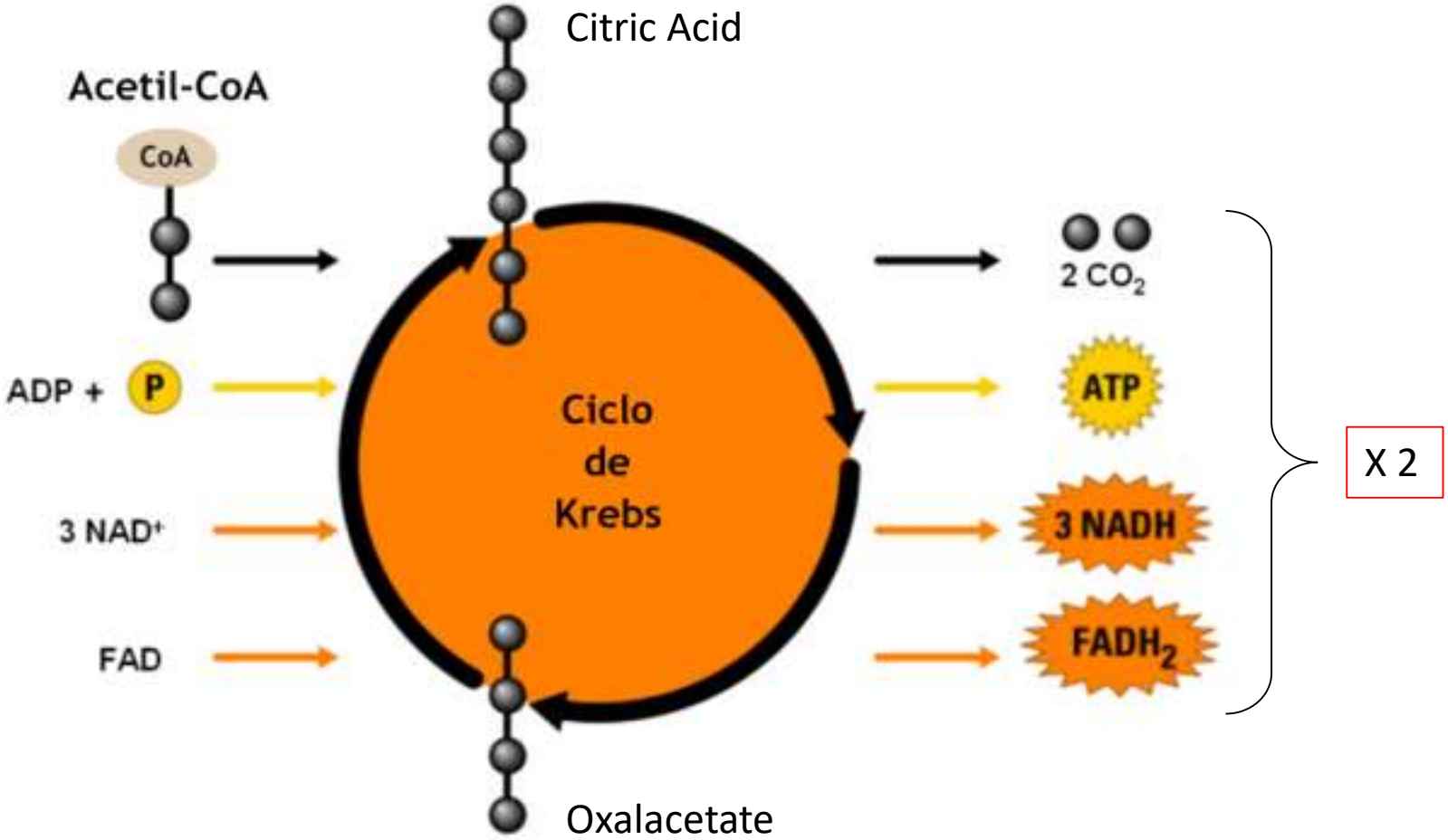
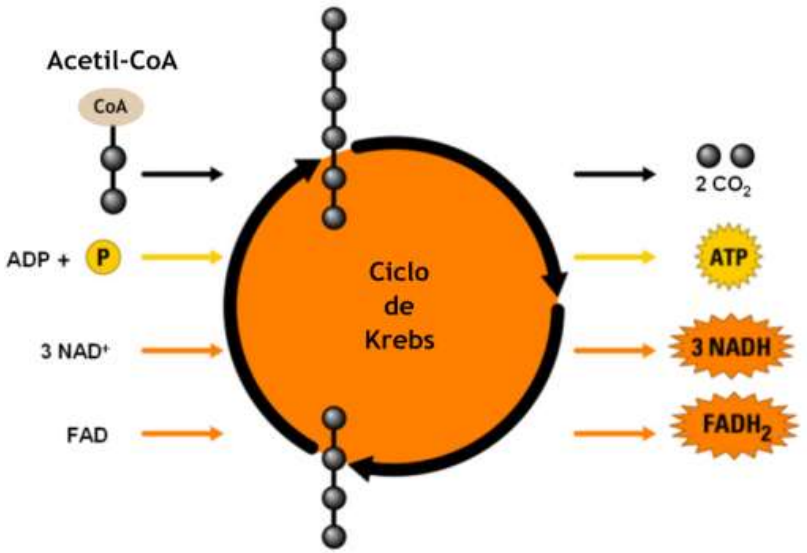


2. Krebs' Cycle Balance



The citric acid is gradually broken down to create high energy storage molecules inside the mitochondria, essential in the final step of the cellular respiration

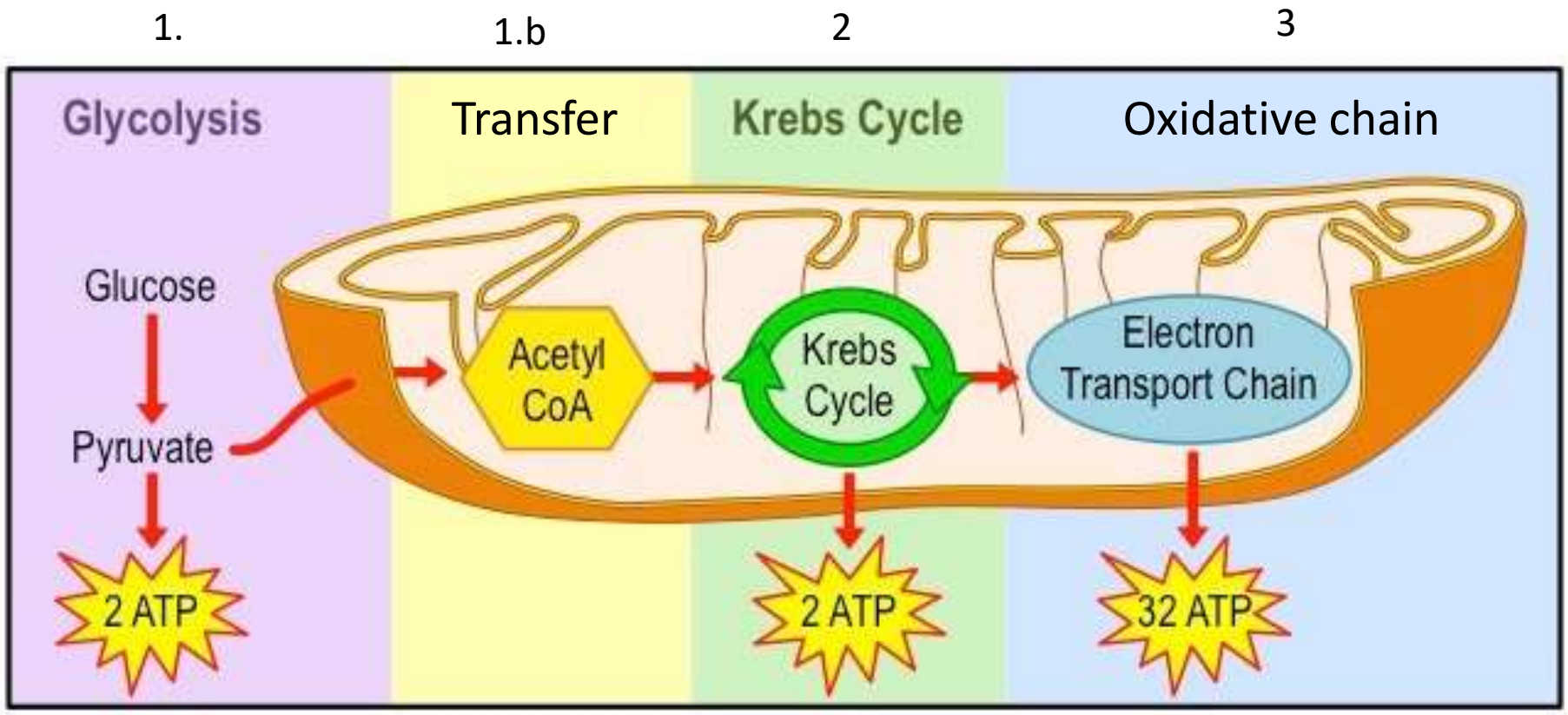
All carbons from glucose are used

2 PIRUVATOS + 2 Co-A → 8 NADH + 2 $FADH_2$ + 2 ATP + 6 CO_2

Energetic Yield so far...

Step	Result
Glycolysis	+ 2 ATP + 2 NADH
Transport inside mitochondria	-2 ATP
KREBS' Cycle	+2 ATP + 8NADH +2$FADH_2$
Phosphorillation Chain	
TOTAL	

Cellular Respiration



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(no oxygen)

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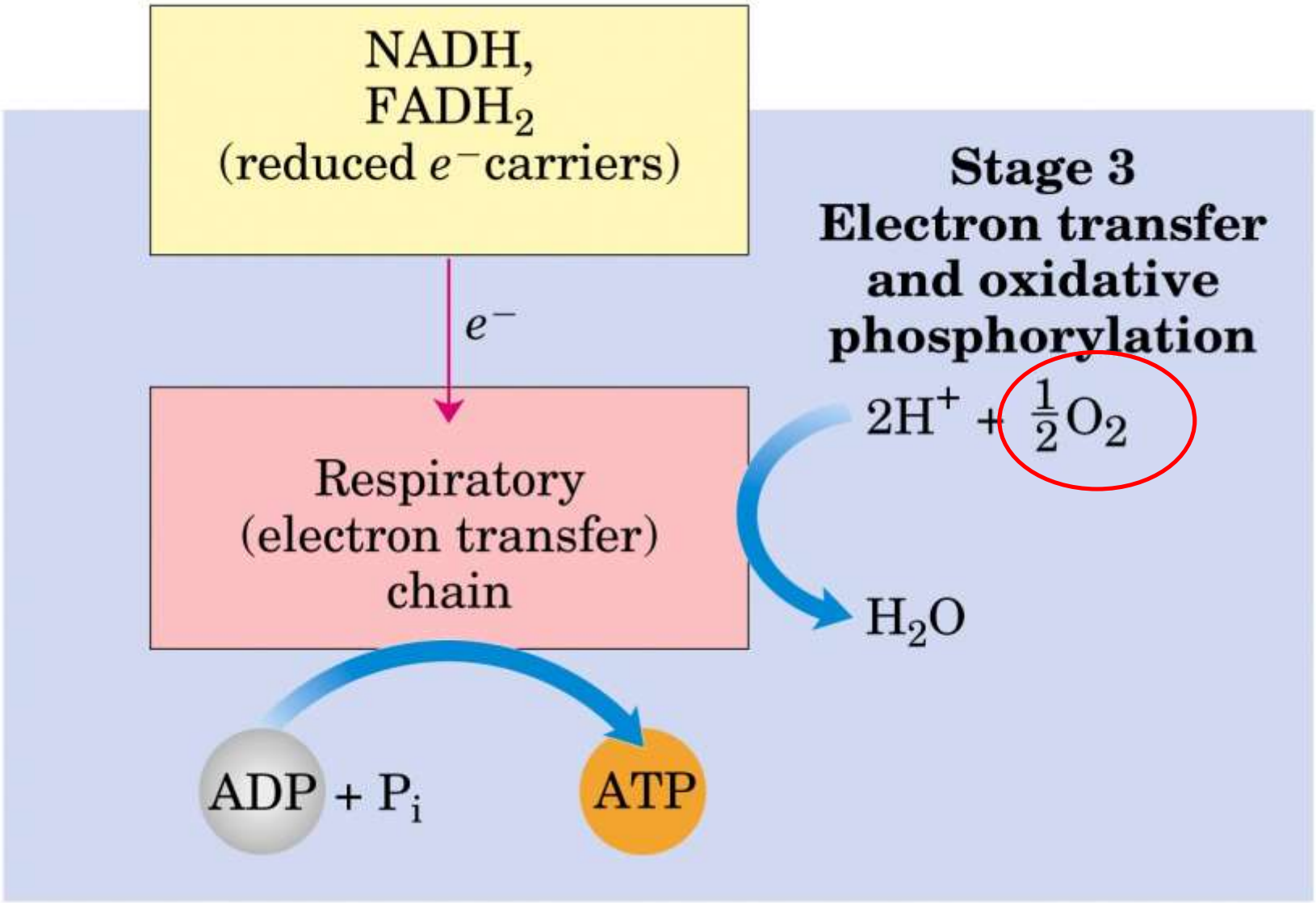
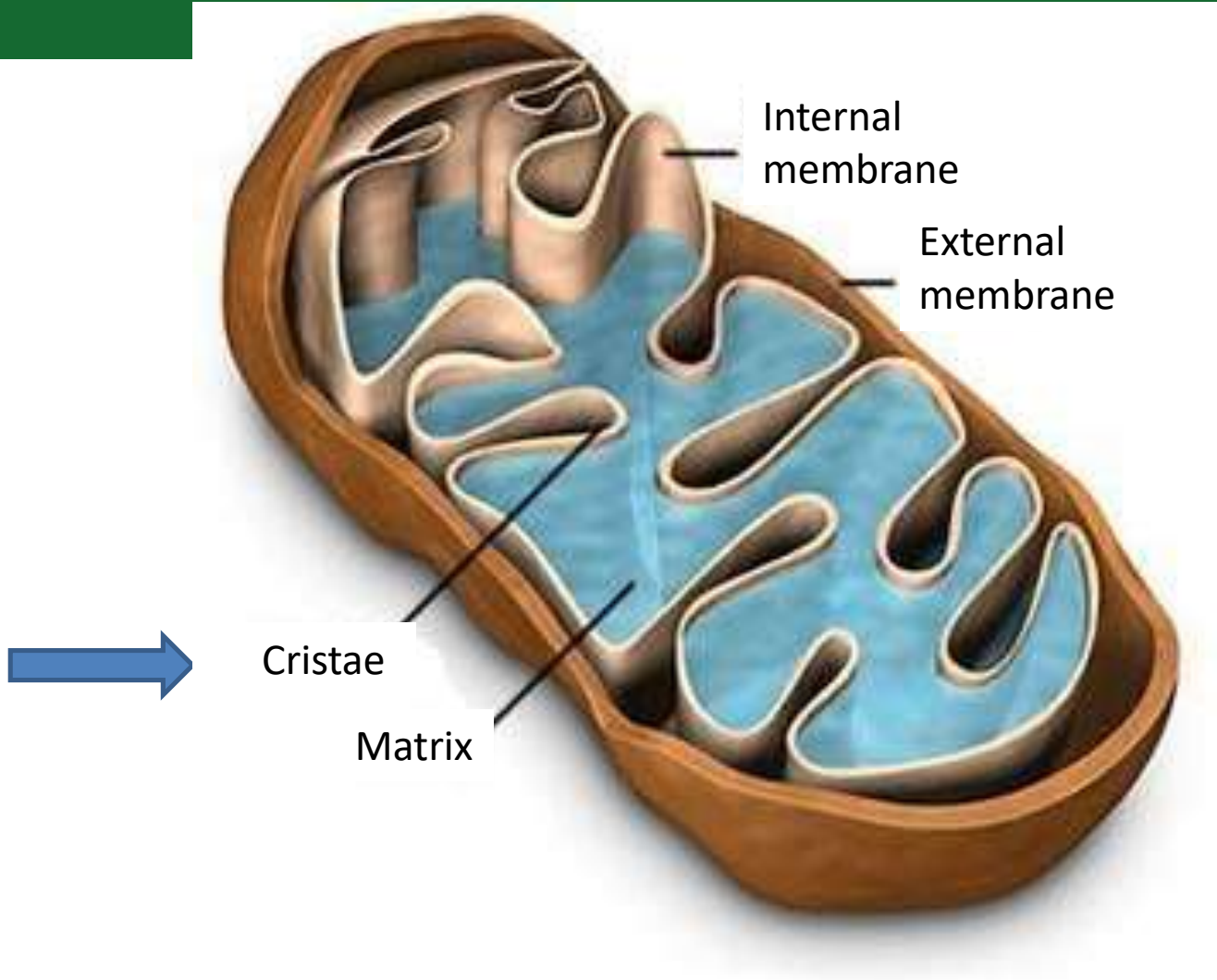
3. Oxidative chain





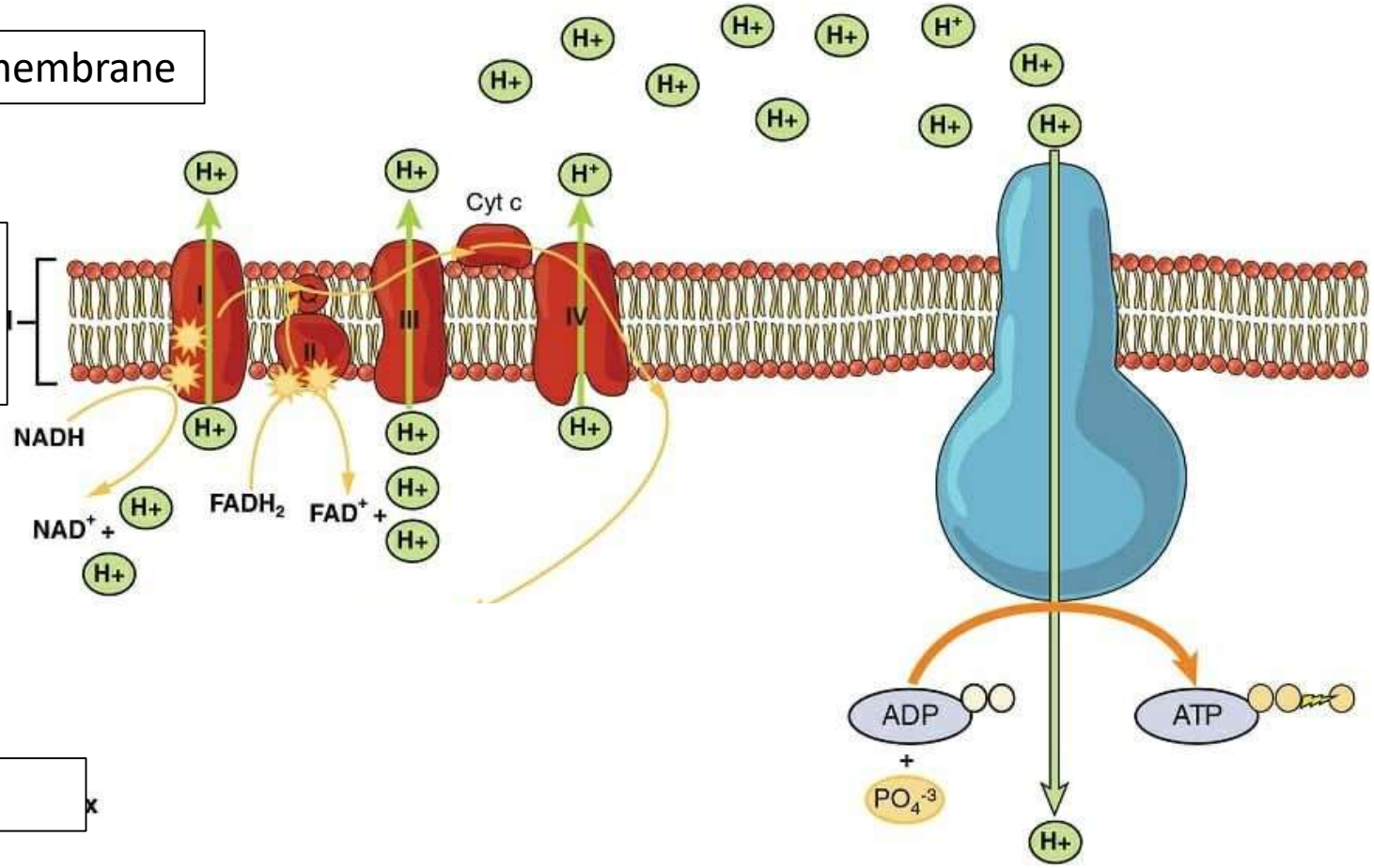
The phosphoryllation chain occurs at the CRESTAE of the mitochondria, on the inner membrane

3. Oxidative chain

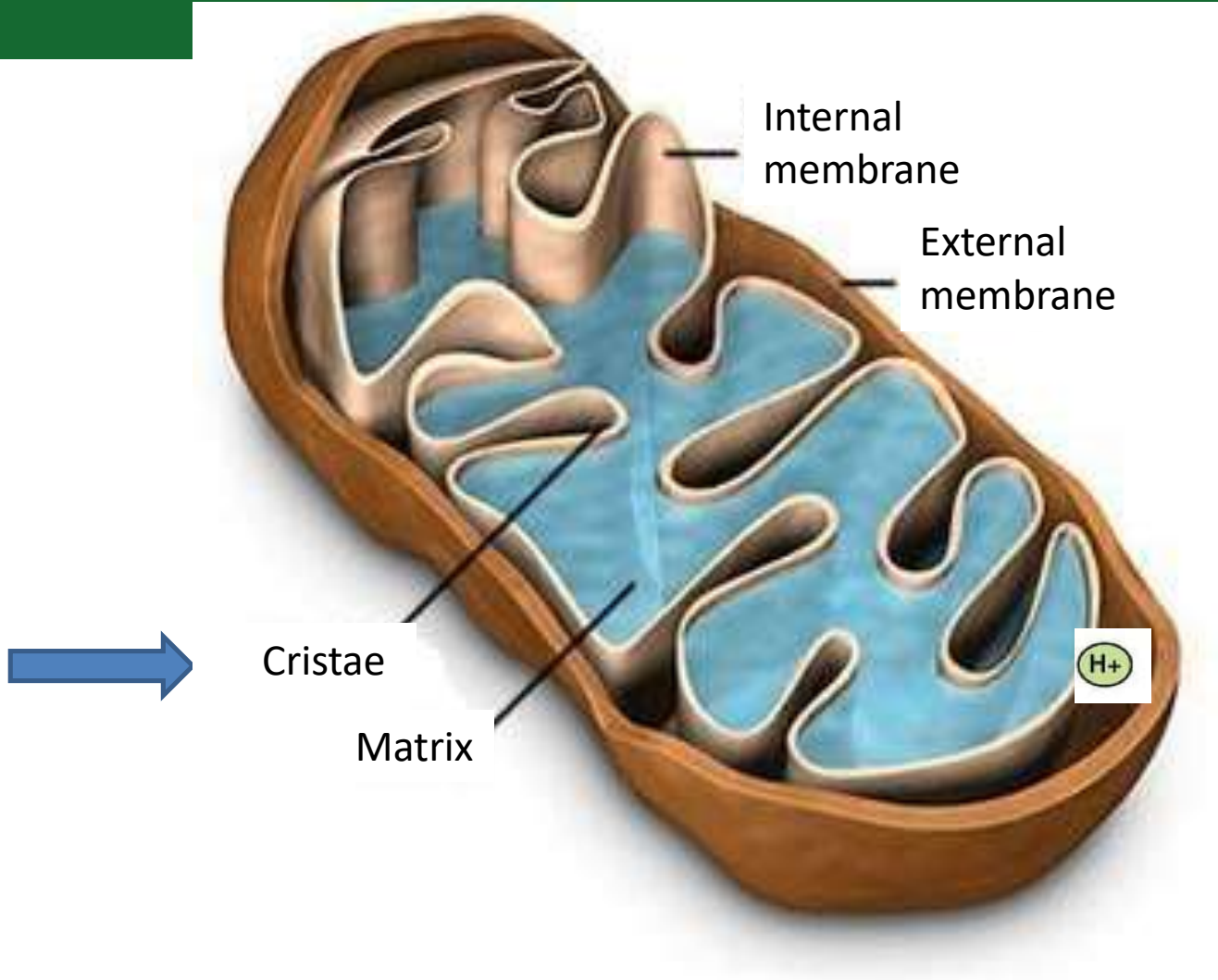
External membrane

Space Intermembrane

Inner membrane (Cresta)



Matrix



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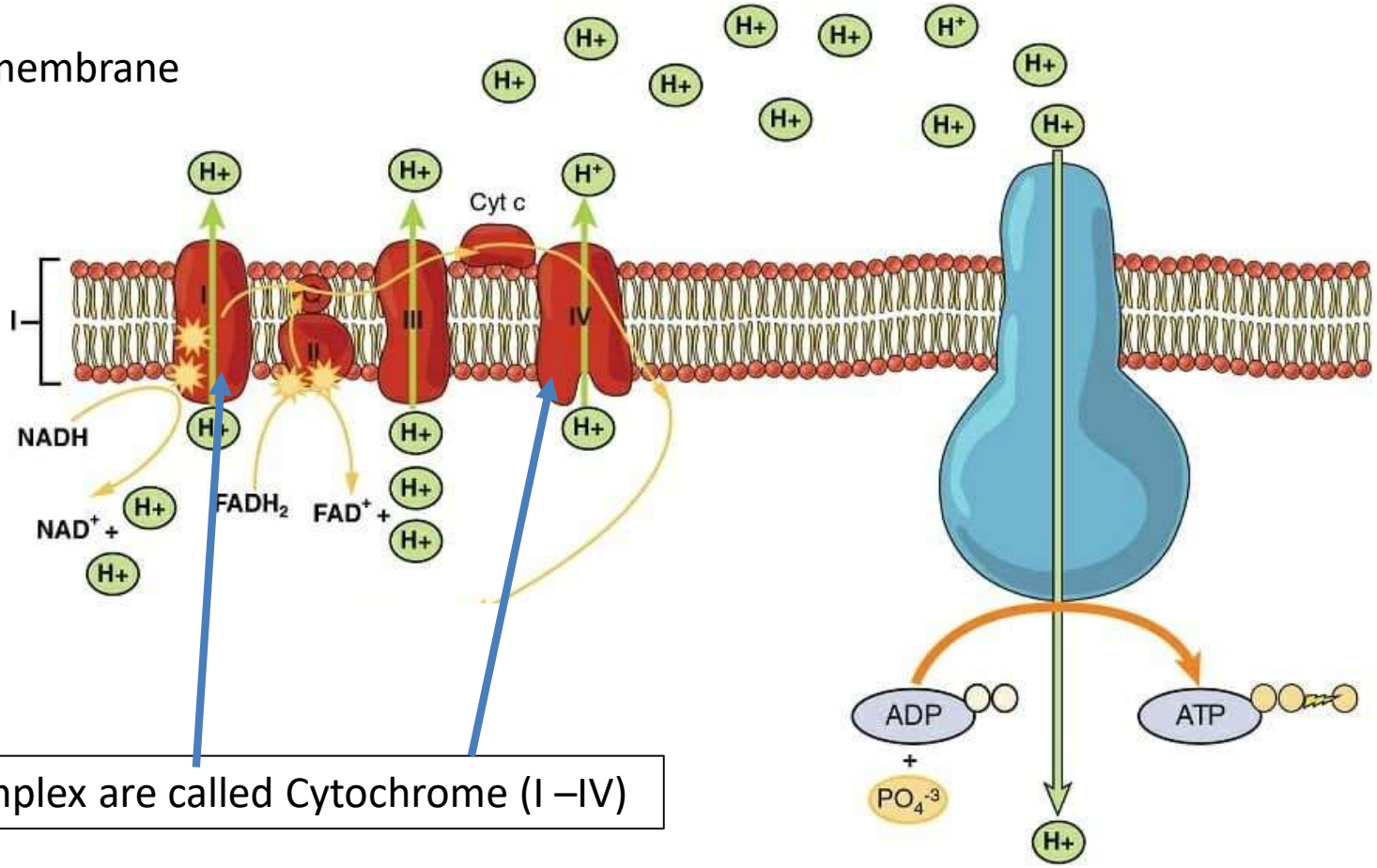


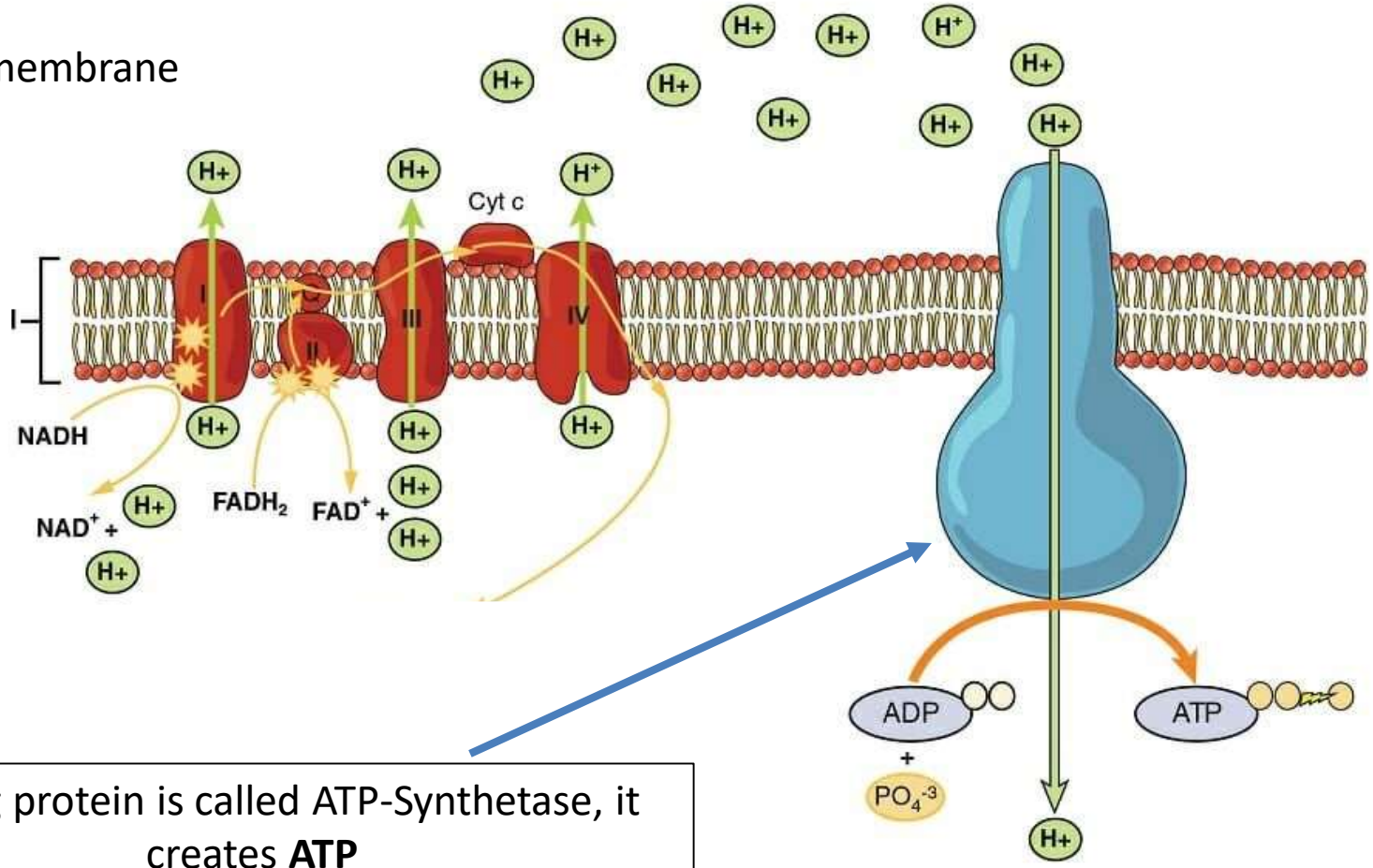
Those complex are called Cytochrome (I –IV)

3. Oxidative chain

External membrane

Space Intermembrane

Inner membrane (Cresta)



This big protein is called ATP-Synthetase, it creates **ATP**

3. Oxidative chain

Cytochrome :

1. Accept Hydrogens atoms from NADH or FADH, together with the electrons;

2. Transfer the Hydrogen atom to the other side of the membrane (interstitial space) and it transfer the eléctron to the next Cytochrome.

3. The last Cytochrome (IV) transfer the electrons to Oxygen to create Water

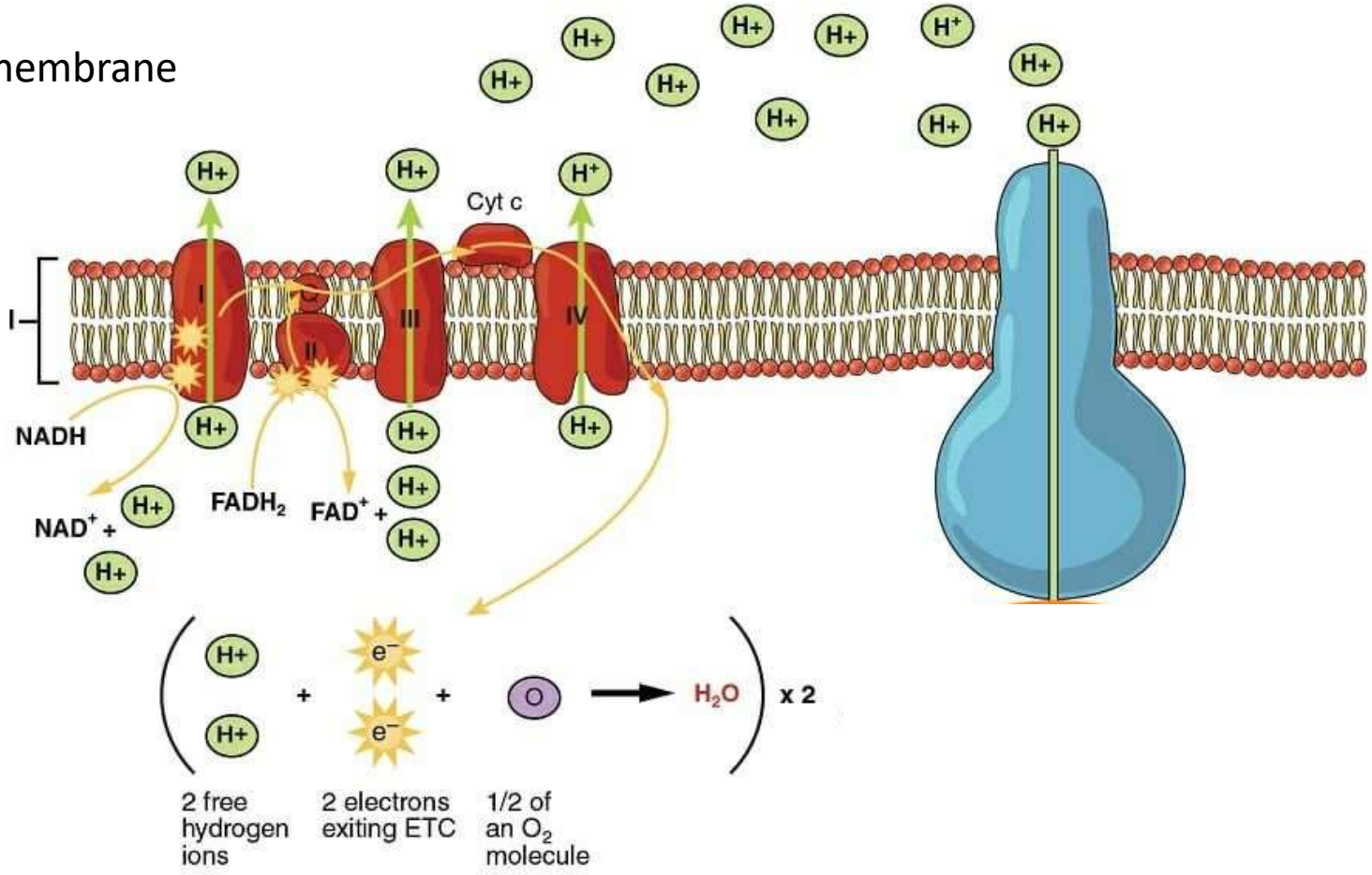
Nesta etapa ocorre a formação de **34 ATP**

3. Oxidative chain

External membrane

Space Intermembrane

Inner membrane (Cresta)



3. Oxidative chain

Why this happens ?

Because we have the formation of many H^+ ions on the interstitial space.

When all these H^+ ions pass through the protein **ATP-synthetase**, the energy of this flux can be converted into making ATP molecules.

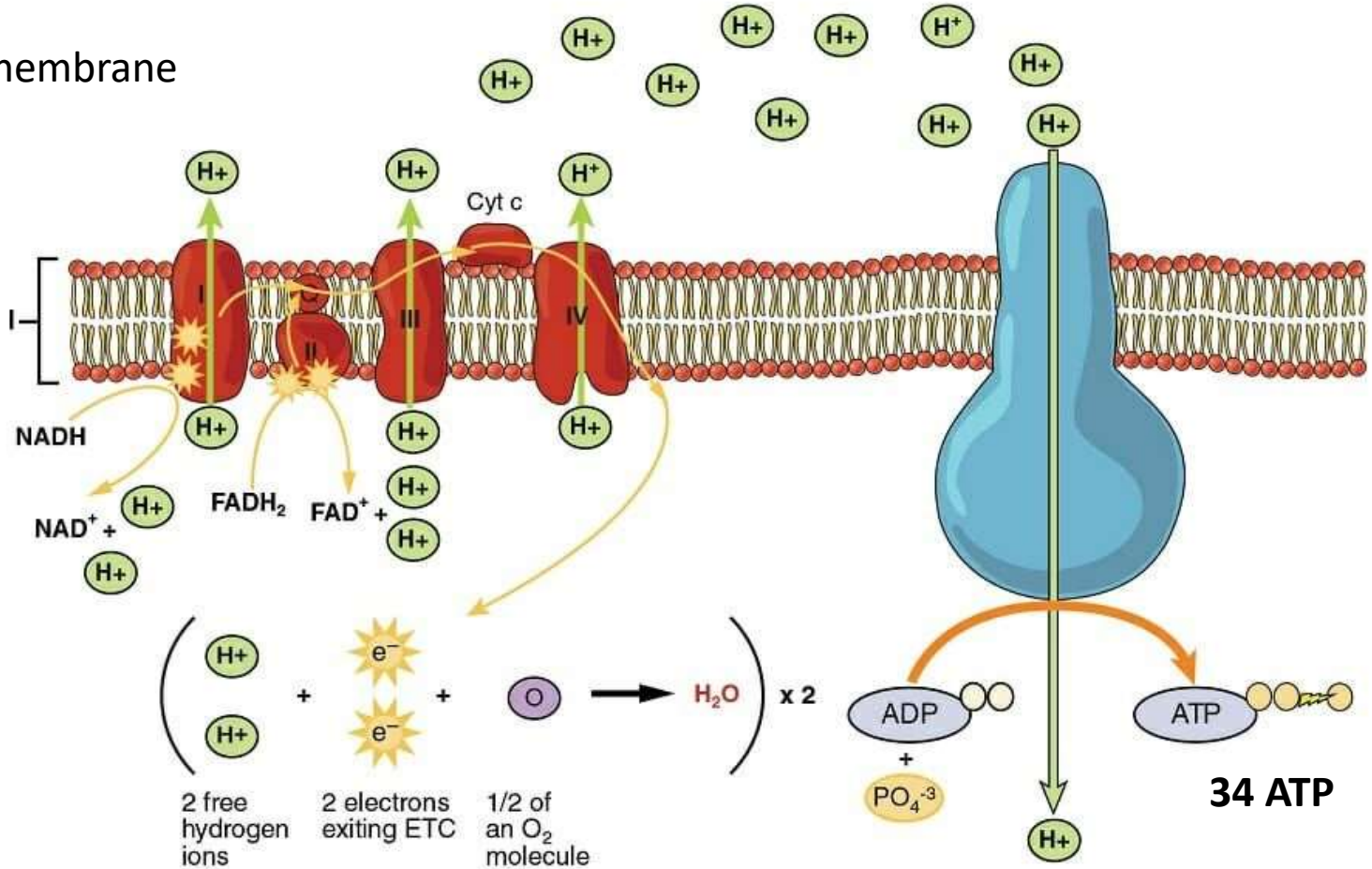
34 ATP are created in this step !

3. Oxidative chain

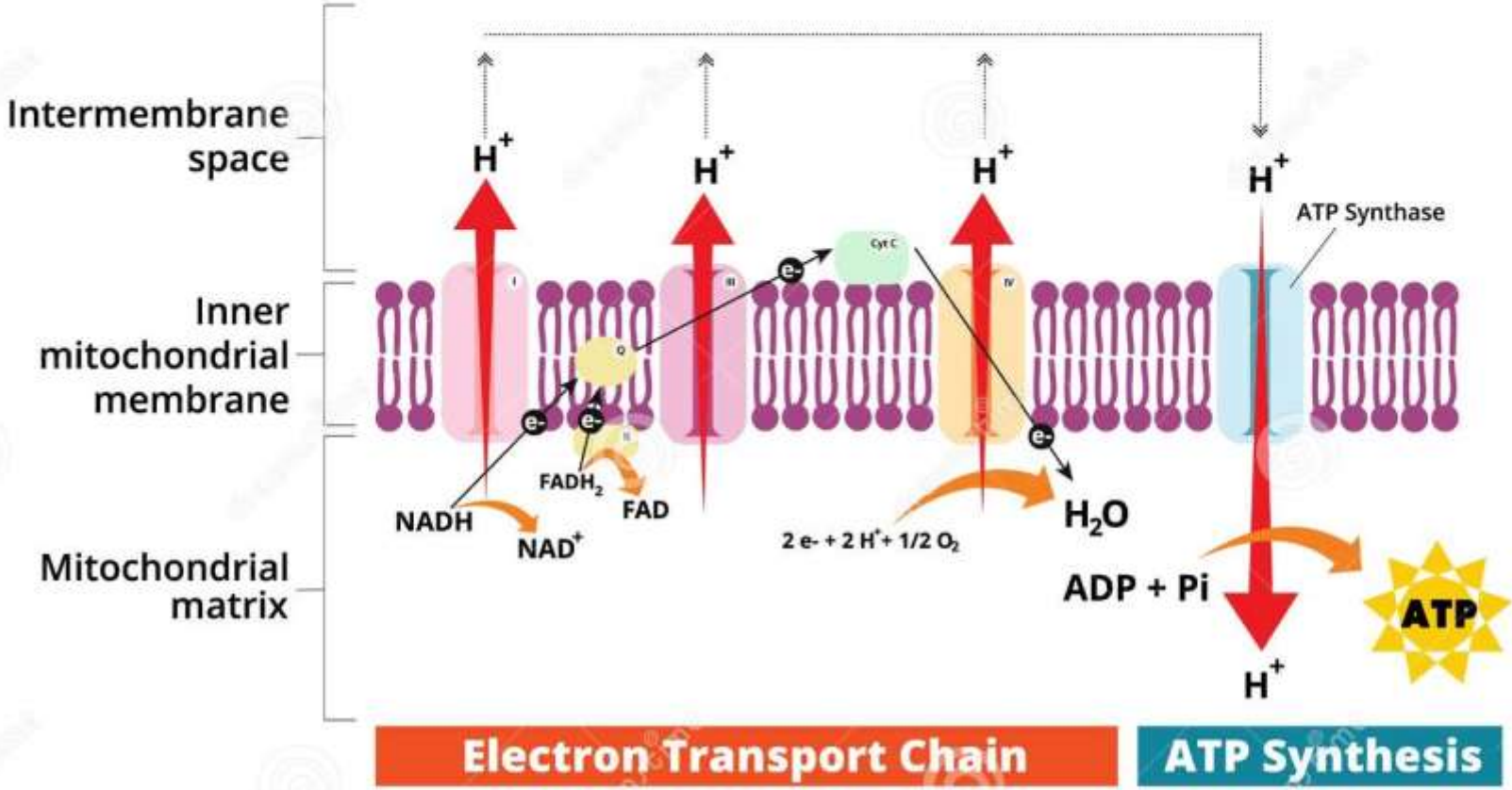
External membrane

Space Intermembrane

Inner membrane (Cresta)

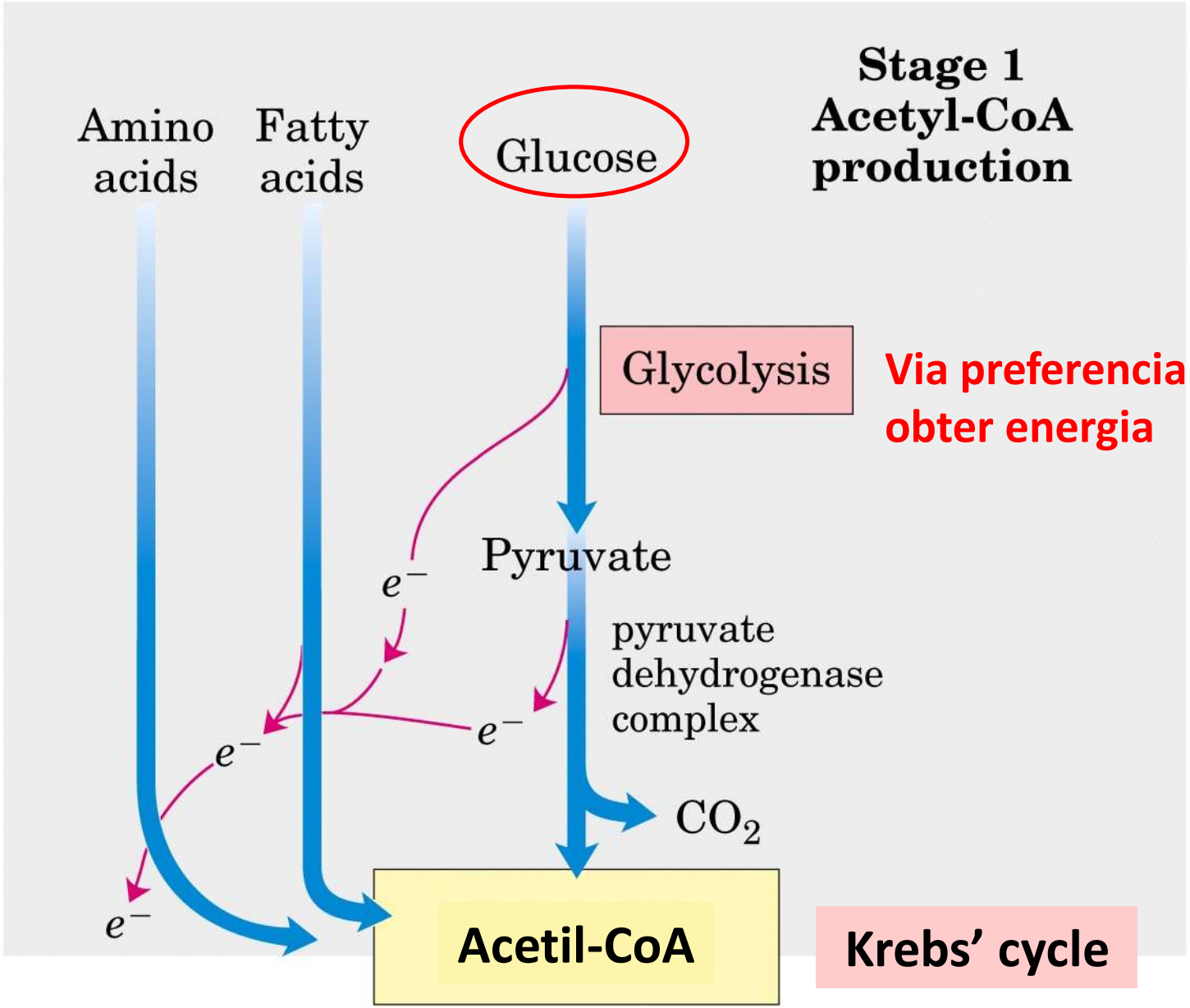


Oxidative Phosphorylation

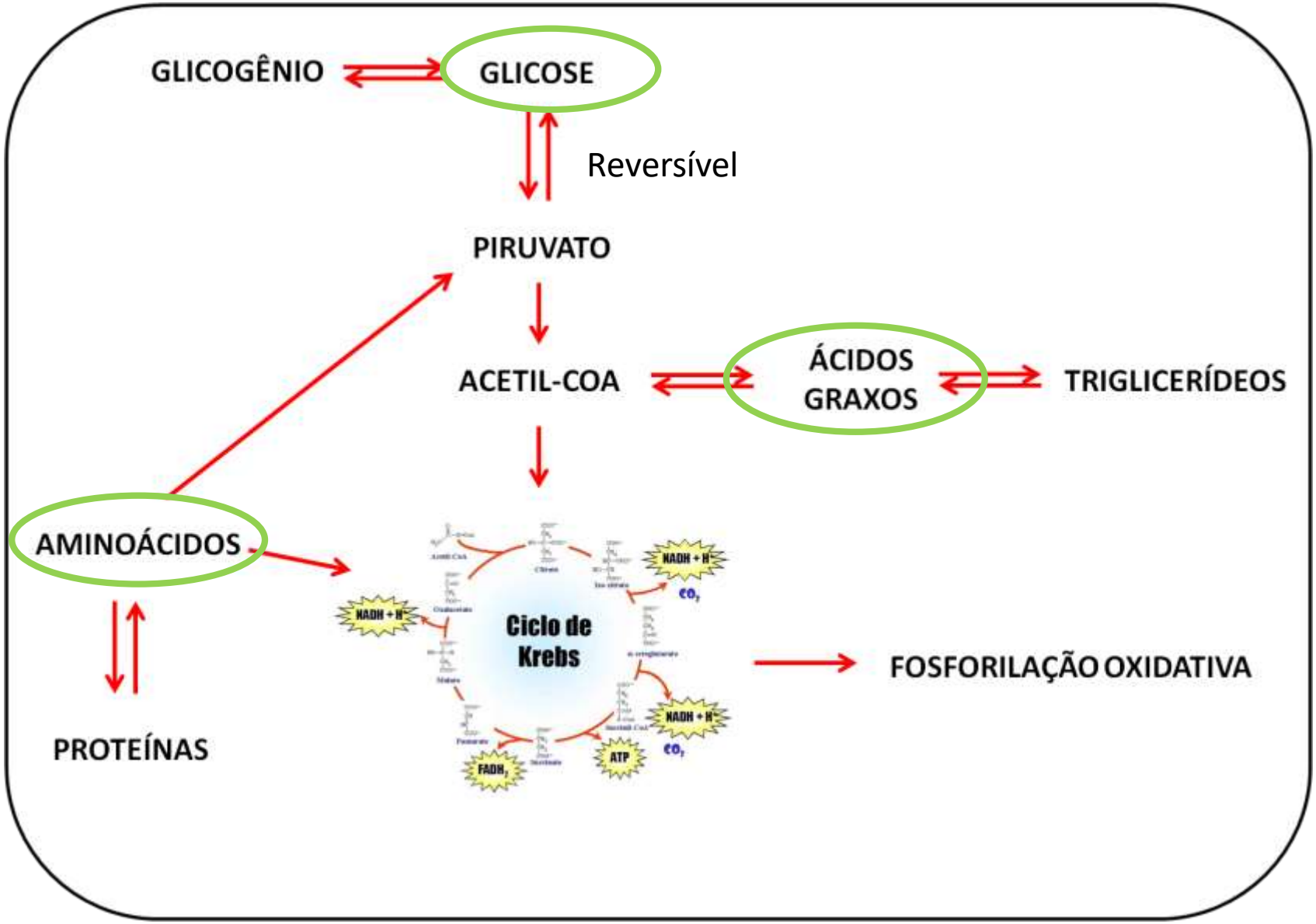


Energetic Yield at the end

Step	Result
Glycolysis	+ 2 ATP + 2 NADH
Transport inside mitochondria	-2 ATP
KREBS' Cycle	+2 ATP + 8NADH +2$FADH_2$
Phosphorillation Chain	+ 34 ATP
TOTAL	**36 ATP**


Stage 1
Acetyl-CoA
production
Amino acids
Fatty acids
Glucose
Glycolysis
Via preferencial para obter energia
Pyruvate
pyruvate dehydrogenase complex
e^-
e^-
e^-
e^-
CO_2
Acetil-CoA
Krebs' cycle

Metabolism – General Glance



Perguntas para estudar

GLICÓLISE:

Qual o produto inicial e final da glicólise? Forneça a equação geral. Quais as etapas que são reguladas?

Quantas moléculas de NAD/NADH são produzidas? Em qual parte da glicólise

Aonde há gasto de ATP? Aonde há produção ATP?

Qual o rendimento da glicólise?

Qual a importância da fermentação lática e de alcoólica? Quando a fermentação lática acontece nos animais?

Perguntas para estudar

Quais as vitaminas envolvidas em todo o processo da respiração celular?

Em qual nível da respiração celular entram as proteínas e os ácidos graxos?

É possível partir de proteínas e sintetizar glicose? E dos ácidos graxos?

Qual o rendimento do ciclo de Krebs?

Explica por que o ciclo de Krebs é aeróbico.

Explica como a ATP é produzida na cadeia respiratória.