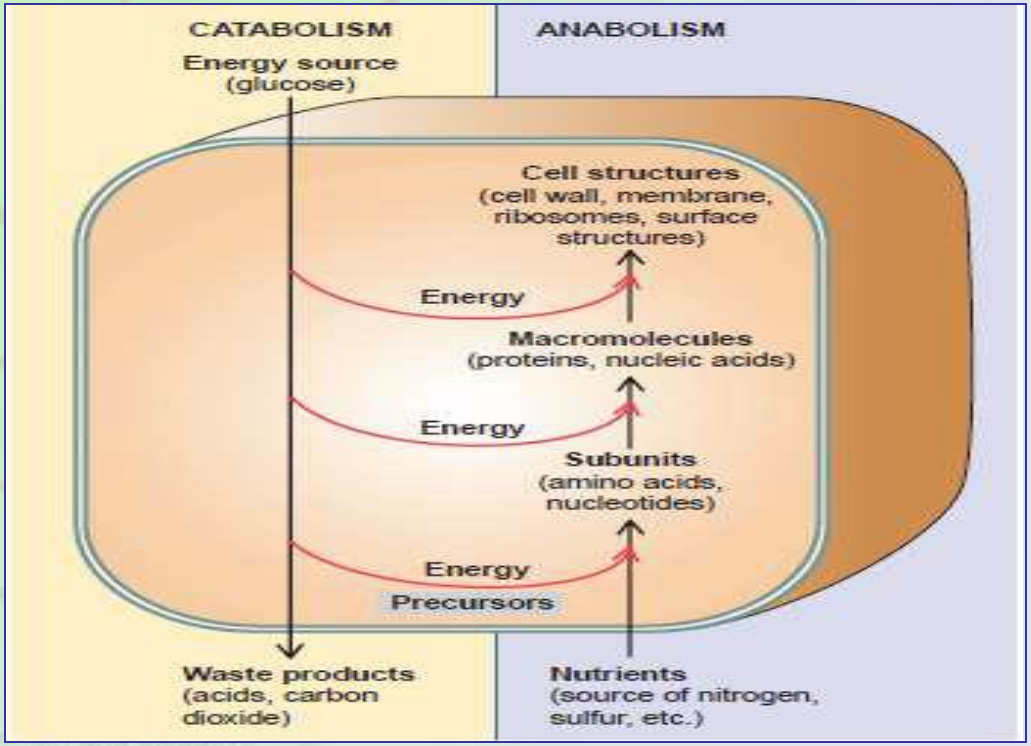
# Basrah University
# Al-Qurna Education college
# Biology department: 4th Stage

## 2nd Course -Lecture # 1: Bacterial Metabolism

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# Objectives

1. To understand the basic concept of Metabolism
2. To define the Enzyme & clarify its action
3. To explain the Glycolytic pathways
4. To explain  Respiration & Fermentation

# METABOLISM

- METABOLISM is a series of interconnected chemical reactions occurring within a cell and the chemical compounds involved in it are termed as METABOLITES.
- The enzymatic reactions are organized into discreet pathways which proceed in a stepwise manner, transforming substrates into end products through many specific chemical intermediates.

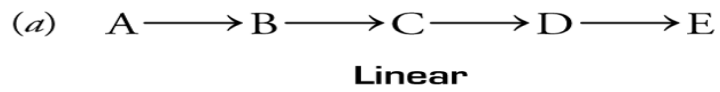
**Catabolism:** The processes by which a living organism obtains its energy and raw materials from nutrients

**Anabolism:** The processes by which energy and raw materials are used to build macromolecules and cellular structures (biosynthesis)

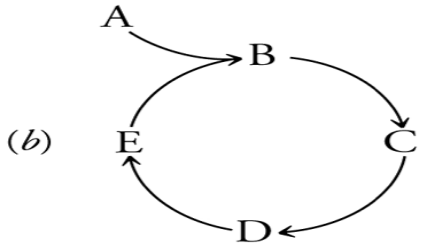
# Basic Concepts

- Metabolic pathways can be of following types:
  - LINEAR (Eg. Glycolysis)
  - CYCLIC (Eg. Citric acid cycle)
  - SPIRAL ( Eg. Biosynthesis of Fatty Acids)

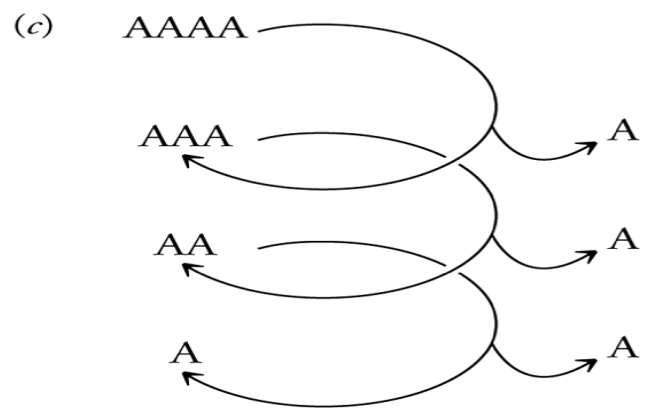
- Metabolic pathways serve 2 functions:
  - Generation of energy to drive vital functions.
  - Synthesis of biological molecules.



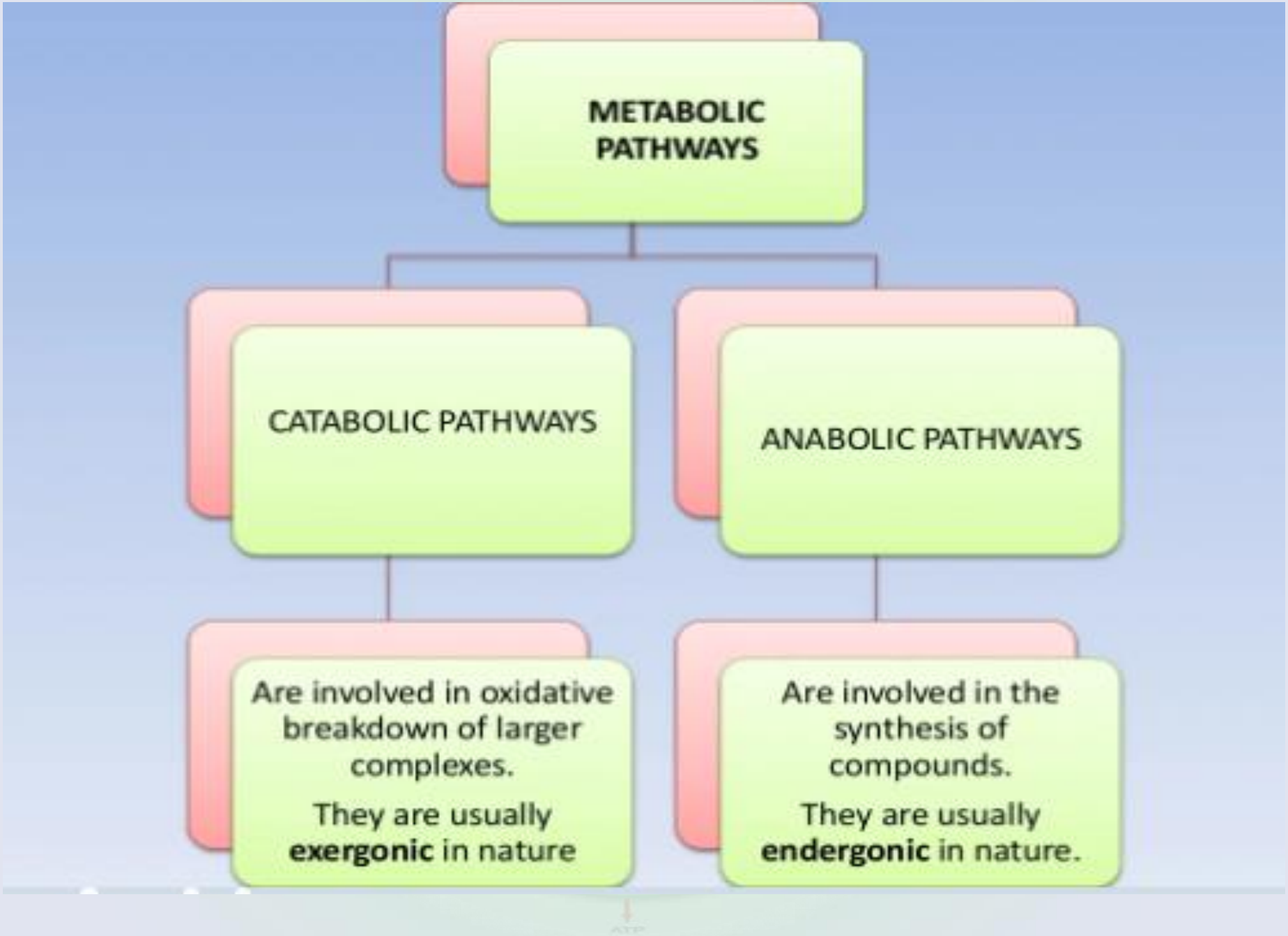
Linear



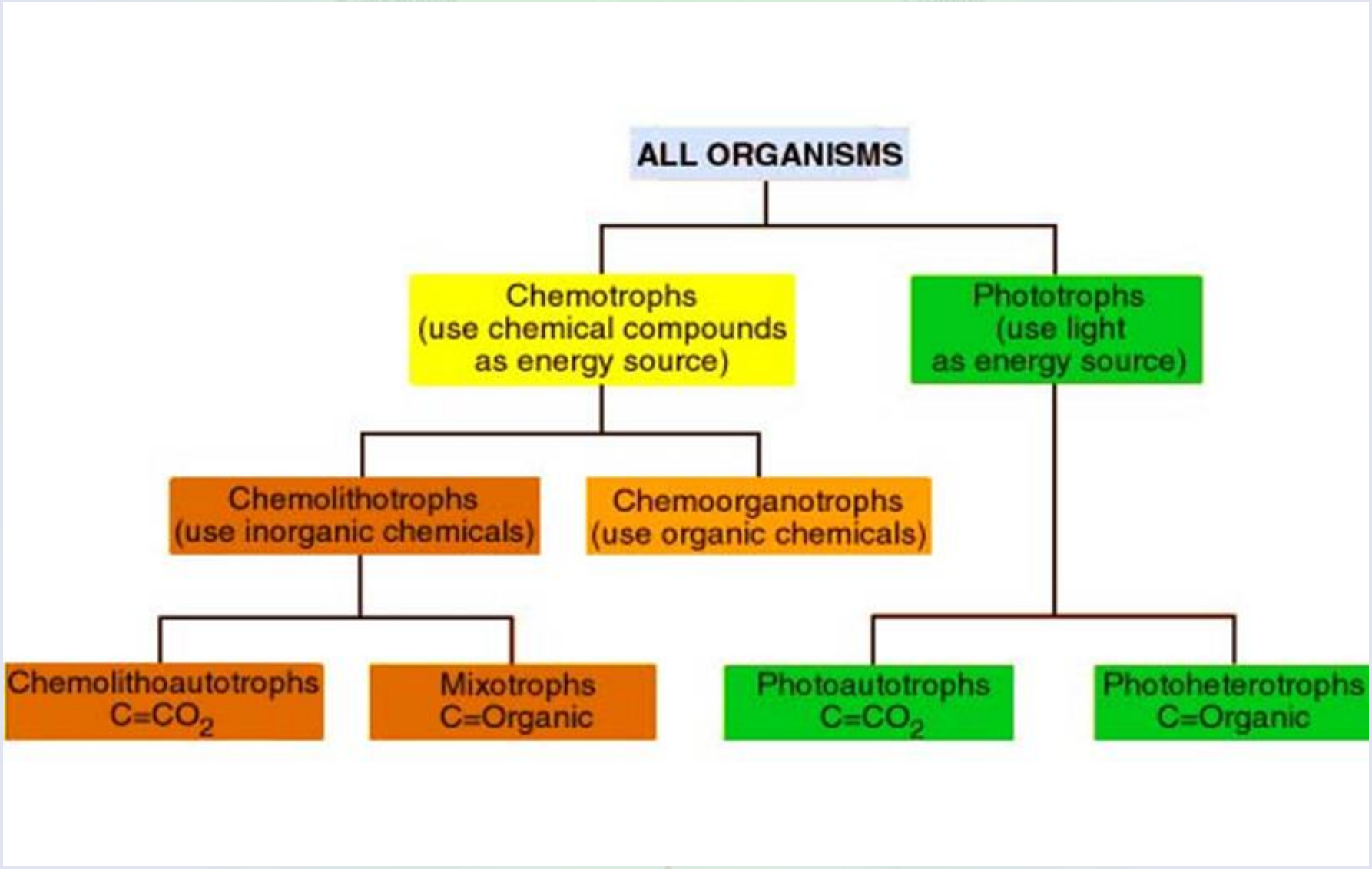
Circular



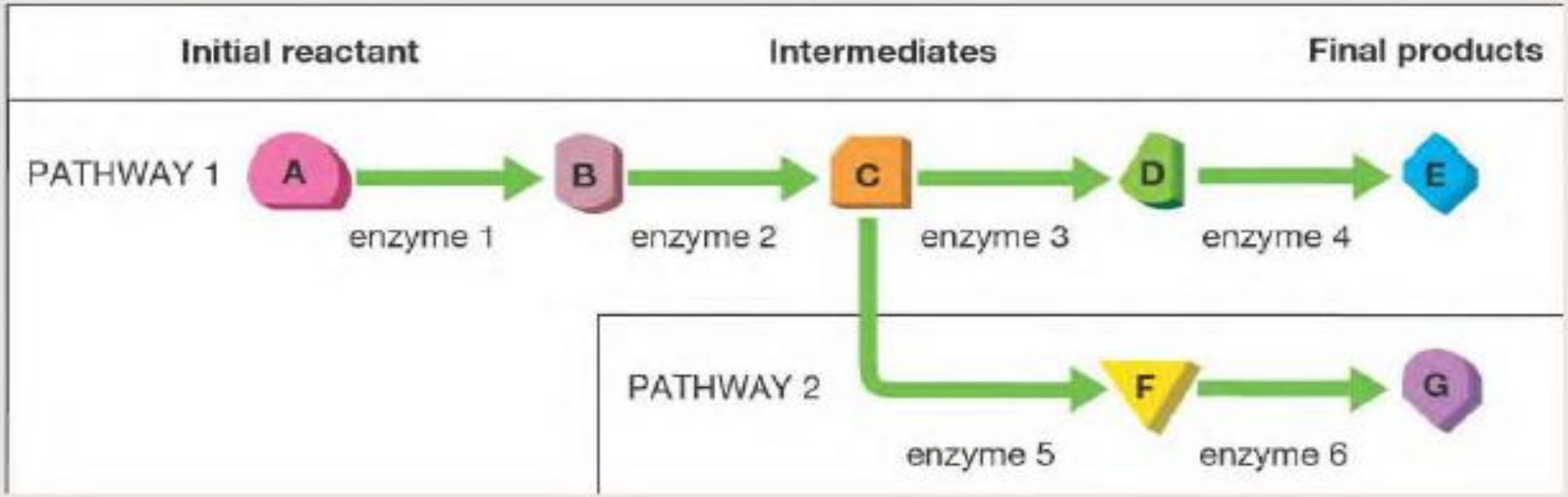
Spiral


METABOLIC PATHWAYS
CATABOLIC PATHWAYS
ANABOLIC PATHWAYS
Are involved in oxidative breakdown of larger complexes.
They are usually **exergonic** in nature
Are involved in the synthesis of compounds.
They are usually **endergonic** in nature.

# Energy/carbon classes of organisms



# Metabolic Pathways




- **Most biochemical reactions are part of a series of reactions referred to as a metabolicpathway:**
- **it usu. takes multiple reactions to make "end-product**
- **Pathways can be catabolic or anabolic**
- **each reaction is catalyzed by its own enzyme**

# 2. Reduction and Oxidation

Reduction and oxidation always occur together. In a reduction-oxidation reaction (redox reaction), one substance gets reduced , and another substance gets oxidized. The thing that gets oxidized is called the electron donor, and the thing that gets reduced is called the electron acceptor.

A: An atom becomes more reduced when it undergoes a chemical reaction in which it gains electrons and often this occurs when the atom becomes bonded to a hydrogen.

B: An atom becomes more oxidized when it undergoes a chemical reaction in which it loses electrons and often this occurs when the atom becomes bonded to an oxygen

- Enzyme: proteins that accelerate the rate of a reaction without being changed themselves)
- reactions won't occur unless the enzyme that catalyzes the reaction is present & active
- Cofactors for Redox Reactions
- Enzymes that catalyze redox reactions typically require a cofactor to "shuttle" electrons from one part of the metabolic pathway to another part.
- There are two main redox cofactors: NAD and FAD.
- NAD(oxidized) + H+ + Pair of electrons ® NADH(reduced)
- FAD(oxidized) + H+ + Pair of electrons ® FADH(reduced)

# Glycolytic Pathways

**4 major glycolytic pathways found in different bacteria:**

a) Embden - Meyerhoff- Parnas pathway

• "Classic" glycolysis - Found in almost all organisms

b) Hexose monophosphate pathway

• Also found in most organisms

• Responsible for synthesis of pentose sugars used in nucleotide synthesis

c) Entner- Doudoroff pathway - Found in *Pseudomonas*

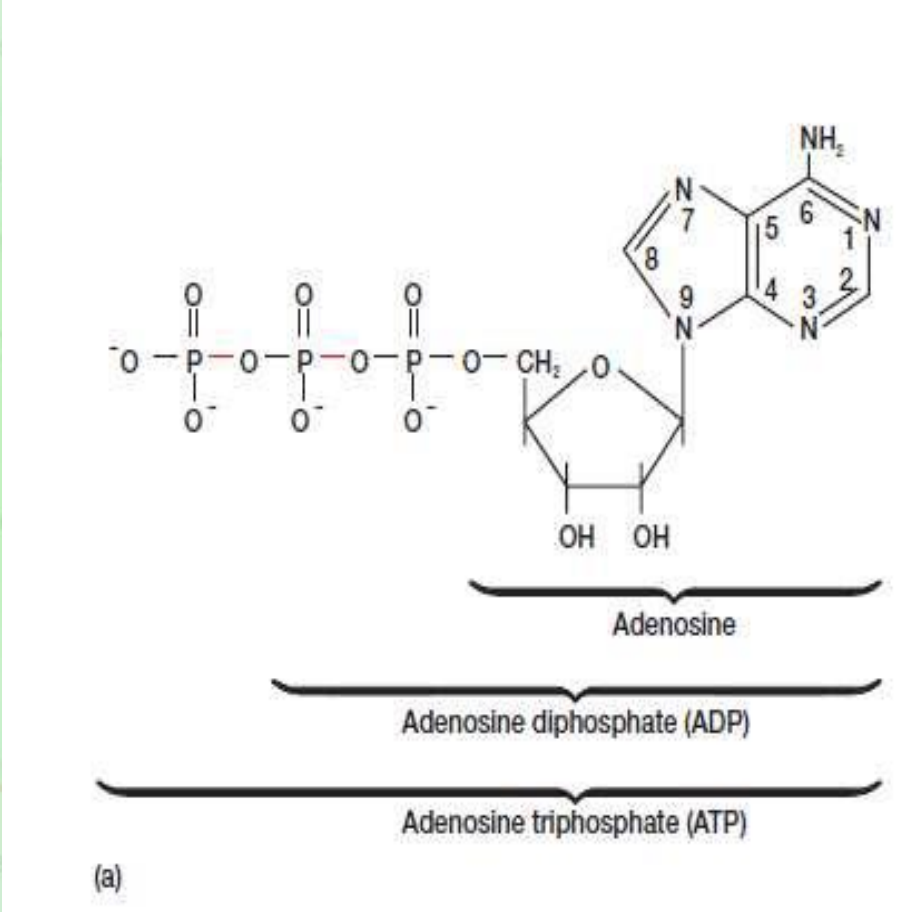
d) Phosphoketolase pathway - Found in *Bifidobacterium*

# Role of ATP

Is energy currency of cell, serving as ready and immediate donor of free energy.

Energy is releases when phosphate bond is broken,

Synthesis and breakdown of ATP continuously occurs in cell during degradative and synthetic process.



# Generation of ATP

Bacteria uses three mechanism of phosphorylation to generate ATP from ADP.

1)Substrate level phosphorylation:

In this mechanism , a high energy phosphate from a phosphorylated substrate is directly transferred to ADP


2) Oxidative phosphorylation:

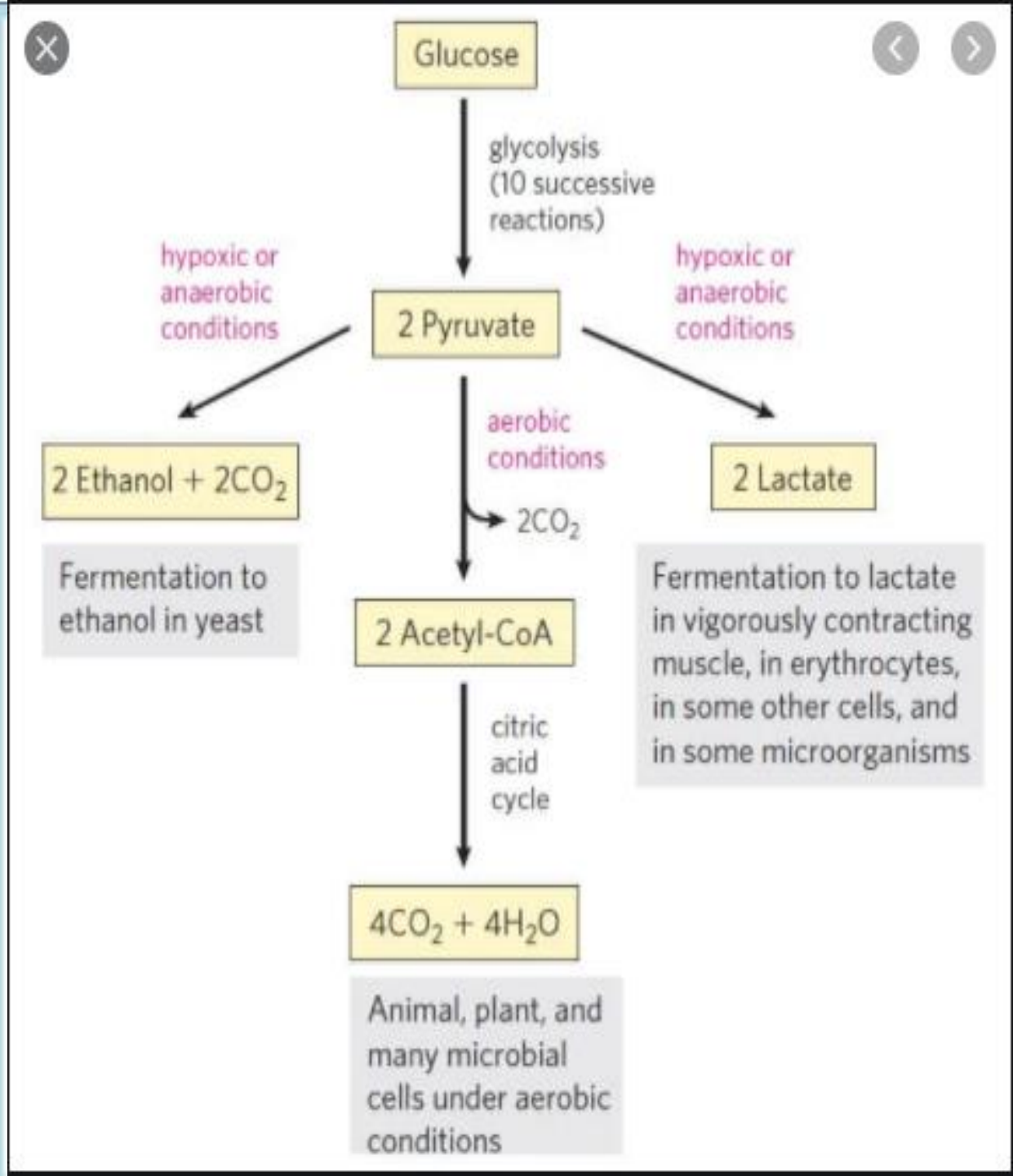
ATP generation during ETC

3)Photophosphorylation:

Occurs in prototroph, Derive ATP using radiant energy of the sun. These ATP are then utilized to synthesize mainly glucose .

# Carbohydrate Metabolism

- Glucose - major fuel of most tissues
- Metabolized to **pyruvate** aerobically and **lactate** anaerobically by the pathway of **glycolysis** which further gets reduced to **acetyl-CoA**
- Enter the **Citric acid cycle** - formation of ATP in the process of **oxidative phosphorylation**

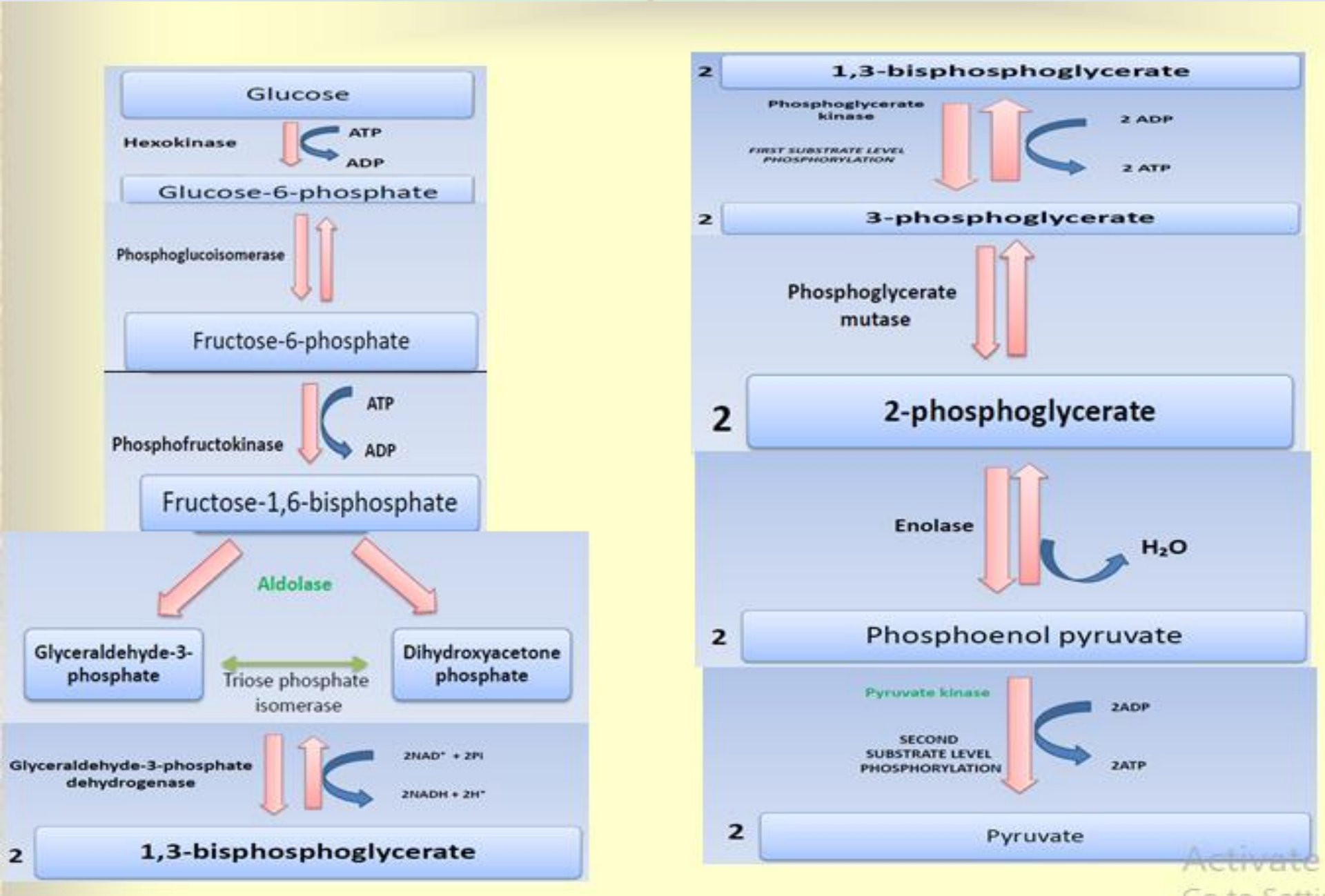


# Glycolysis

## Glycolysis is a series of 10 coupled reactions

- The pathway starts with glucose that comes into a cell from the blood and is immediately phosphorylated to glucose-6-phosphate.
  - The phosphorylation traps the glucose in the cell.
- The pathway then goes on to split (lyse) the the 6-carbon glucose molecule into two 3-carbon molecules and to oxidize these to α-keto acids (Pyruvic acid).
- The energy released in the pathway is used to produce two types of energy rich molecules:
  - Two molecules of ADP are phosphorylated to ATP.
  - Two molecules of $NAD^+$ are reduced to $NADH/H^+$.

# Stepwise explanation of glycolysis



- **ENERGY YIELD IN GLYCOLYSIS:**

| STEP NO. | REACTION | CONSUMPTION of ATP | GAIN of ATP |
|---|---|---|---|
| 1 | Glucose ⟶ glucose-6-phosphate | 1 | - |
| 3 | Fructose-6-phosphate ⟶ fructose-1,6-biphosphate | 1 | - |
| 7 | 1,3-diphosphoglycerate ⟶ 3-phosphoglycerate | - | 1x2=2 |
| 10 | Phosphoenolpyruvate ⟶ pyruvate | - | 1x2=2 |
| | | 2 | 4 |

# Cellular respiration and fermentation

Pyruvate obtained from glucose breakdown are channeled either to respiration or to fermentation.

**Respiration :** is ATP generating process in which NADH is oxidized to form NAD and the final electron acceptor is an inorganic molecules.

**Types of respiration :**

**Aerobic respiration**: final electron acceptor is $O_2$ and occurs in aerobes.

**Anaerobic respiration**: final electron acceptor is inorganic molecule other than $O_2$ (eg nitrate, nitrite, sulfate).

**Krebs cycle or TCA cycle:**

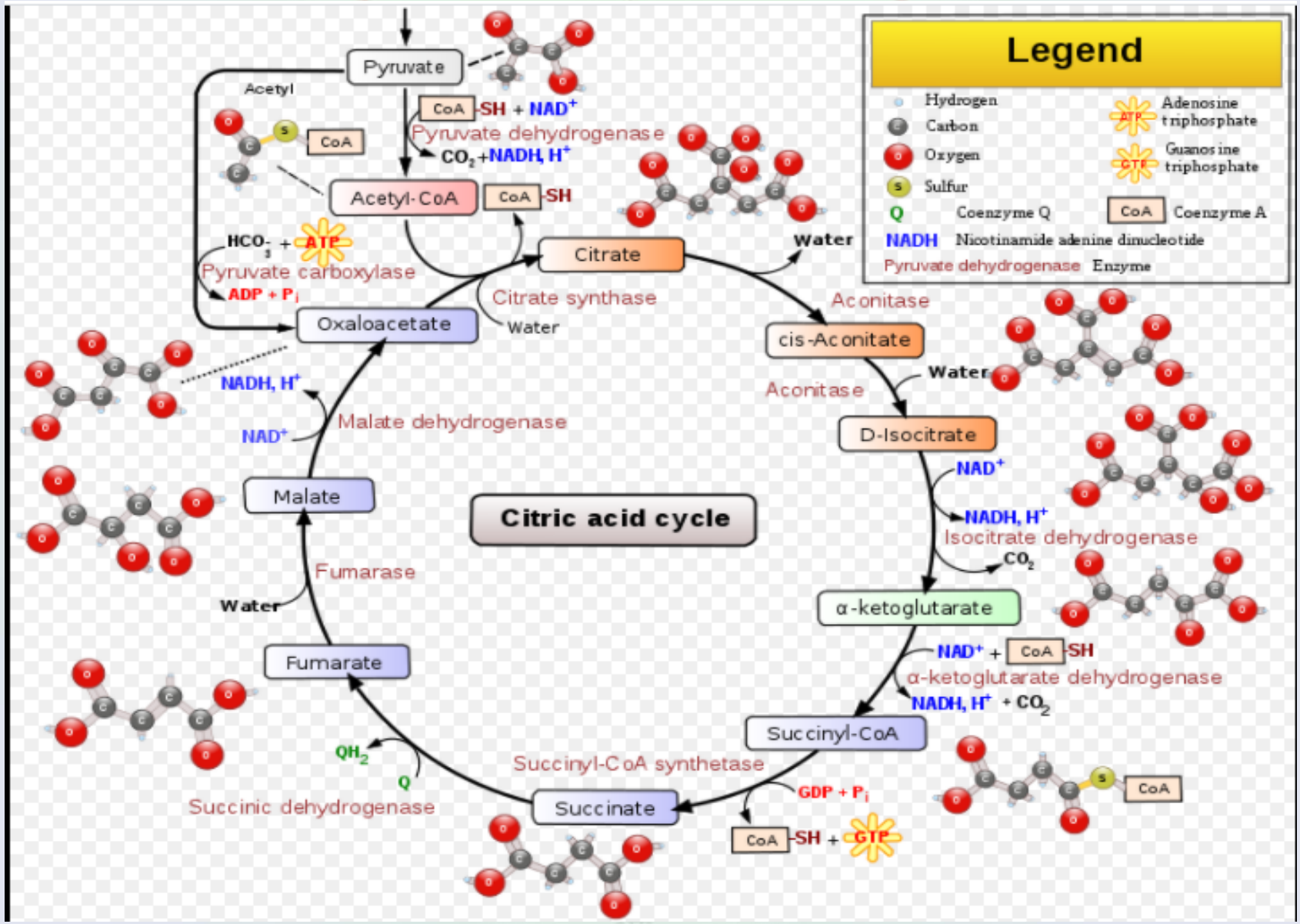
Is second phase of aerobic respiration.

Pyruvate formed enters TCA cycle only after converted into acetyl CoA by decarboxylation reaction ( transition phase).

Acetyl CoA is oxidized and released as CO2 and oxaloacetate is regenerated.

# Anaerobic respiration

- Final electron acceptor : never be O2: it is $NO3^-$ , $NO2^-$, $N_2O$,$SO_4^{--}$,$CO_3^{--}$, etc. and occurs in strict anaerobes and
- facultative anaerobes.
- Sometimes *Pseudomonas sps* and *Bacillus sps* can use nitrate as final $e^-$ acceptor.
- ATP generation varies from bacteria to bacteria
- and always less than aerobic respiration.
- Alternative electron carriers are used in the ETC.


Legend
Hydrogen
Carbon
Oxygen
Sulfur
Coenzyme Q
Nicotinamide adenine dinucleotide
Pyruvate dehydrogenase Enzyme
Adenosine triphosphate
Guanosine triphosphate
Coenzyme A
Citric acid cycle
Pyruvate
Acetyl
CoA-SH + NAD+
Pyruvate dehydrogenase
CO2 + NADH, H+
Acetyl-CoA
CoA-SH
HCO3- + ATP
Pyruvate carboxylase
ADP + Pi
Oxaloacetate
Citrate
Citrate synthase
Water
Water
Aconitase
cis-Aconitate
Water
Aconitase
D-Isocitrate
NAD+
NADH, H+
Isocitrate dehydrogenase
CO2
α-ketoglutarate
NAD+ + CoA-SH
α-ketoglutarate dehydrogenase
NADH, H+ + CO2
Succinyl-CoA
Succinyl-CoA synthetase
GDP + Pi
CoA-SH + GTP
Succinate
QH2
Q
Succinic dehydrogenase
Fumarate
Water
Fumarase
Malate
NADH, H+
NAD+
Malate dehydrogenase

# ATP Yield from the Aerobic Oxidation of Glucose by Eucaryotic Cells

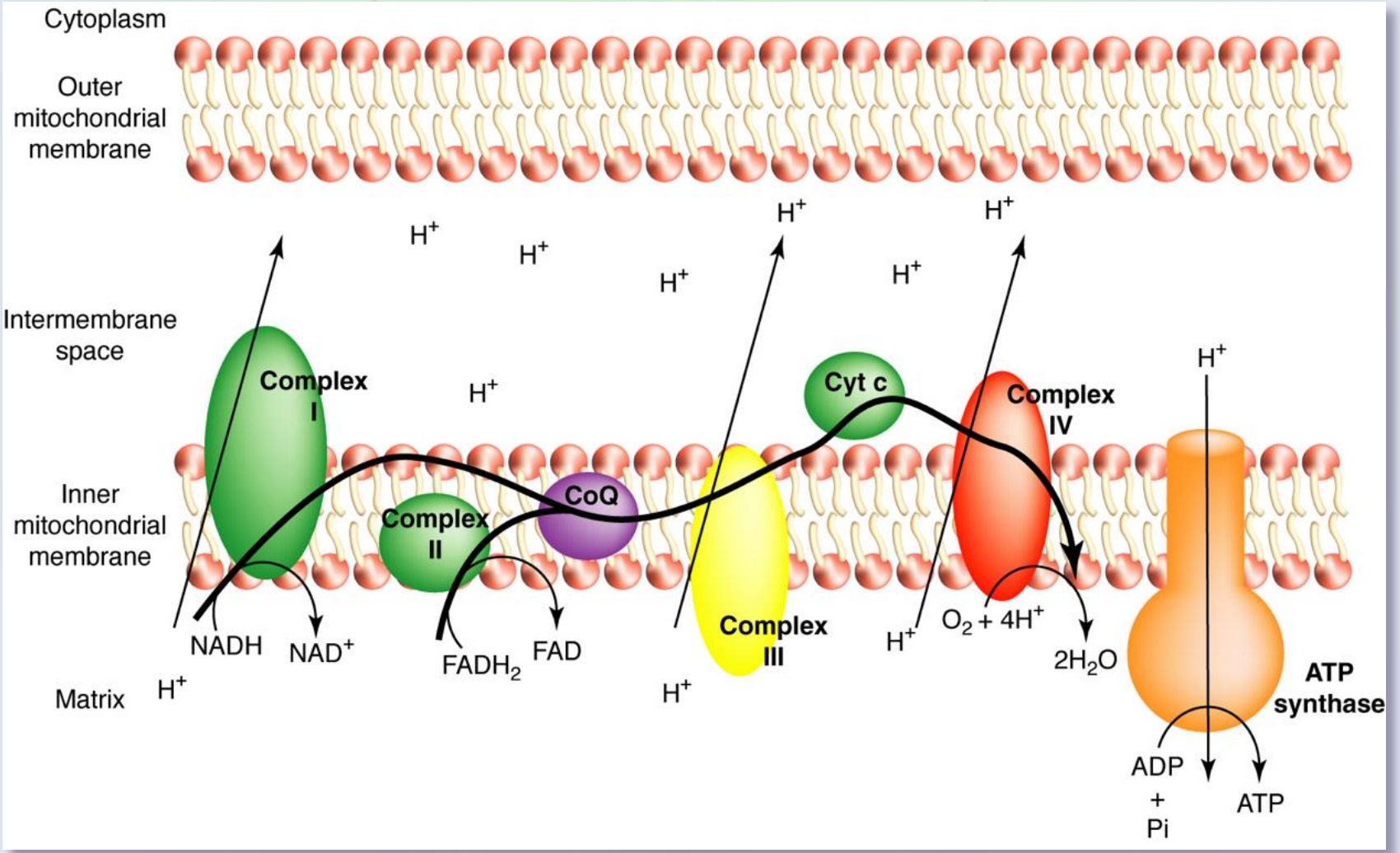
| | |
|---|---|
| **Glycolytic Pathway** | |
| Substrate-level phosphorylation (ATP) | 2 ATP[a] |
| Oxidative phosphorylation with 2 NADH | 6 ATP |
| **2 Pyruvate to 2 Acetyl-CoA** | |
| Oxidative phosphorylation with 2 NADH | 6 ATP |
| **Tricarboxylic Acid Cycle** | |
| Substrate-level phosphorylation (GTP) | 2 ATP |
| Oxidative phosphorylation with 6 NADH | 18 ATP |
| Oxidative phosphorylation with 2 $FADH_2$ | 4 ATP |
| **Total Aerobic Yield** | 38 ATP |

# Electron Transport Chain and Oxidative Phosphorylatioin

- The reoxidation of the $NADH/H^+$ to $NAD^+$ and $FADH_2$ to FAD using molecular oxygen ($O_2$) as the oxidizing agent, is carried out by the electron transport chain.

- The electron transport chain is located within the inner membrane of mitochondria.

# Electron Transport Chain and Oxidative Phosphorylatioin



# Electron transport chain

- Last phase of respiration which generates ATP from reduced substrates.
- Consists of a sequence of carrier molecules though which electrons passes.
- Occurs in plasma membrane ( eukaryotic cell- inner mitochondrial membrane).
- Electron transport chain is different in different bacteria ,even a single bacteria have more than one type of ETC but their target is to derive energy in the form of ATP.

# Fermentation

Used by organisms that cannot respire because of either lack of **inorganic electron acceptor** or **absence of ETS.**

- Terminal electron acceptor is always organic compound.
- End product depends on type of microorganisms.

## Fermentation pathways

a. Homolactic acid F. P.A -----> Lactic Acid,eg. Streptococci, Lactobacilli

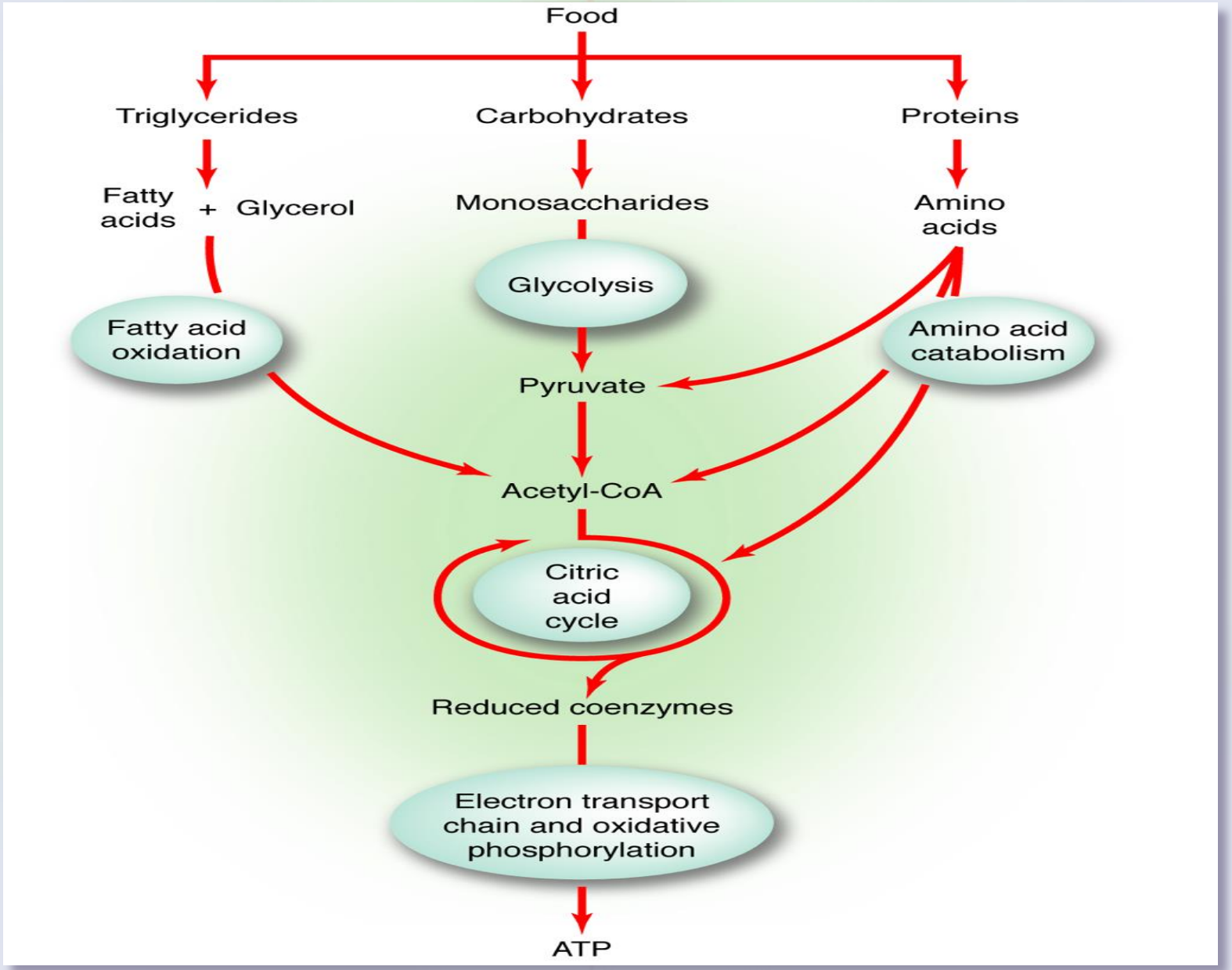
b. Alcoholic F. P.A -----> Ethyl alcohol, eg. Yeast

c. Mixed acid fermentation: eg. *E.coli* and some *enterbacter*

d. Butylene-glycol F. eg. *Pseudomonas*

e. Propionic acid F. eg. *Propionibacterium*

# Catabolism of the substrates



# Prokaryotic vs Eukaryotic

- Prokaryotic: Remember has no nucleus or no membranes around their organelles. So where does Aerobic Respiration occur here?

| Prokaryotic Cells | Eukaryotic Cells |
|---|---|
| Glycolysis: Cytoplasm | Glycolysis: Cytoplasm |
| Krebs Cycle: Cytoplasm | Krebs Cycle: Mitochondria |
| ETC: Cell Membrane | ETC: Mitochondrial Membrane |
| Fermentation: cytoplasm | Ferm: Cytoplasm |

Prokaryotic cells can yield a maximum of 38 ATP molecules while eukaryotic cells can yield a maximum of 36. In eukaryotic cells, the NADH molecules produced in glycolysis pass through the mitochondrial membrane, which "costs" two ATP molecules

**Note** :

In prokaryotes, all the steps of **cellular respiration** takes place within cytosol. In eukaryotes: glycolysis takes place within cytosol, Krebs cycle within mitochondrial matrix & ETC within inner mitochondrial membrane.


Thank You!