COURSE TITLE: Biomolecules and Microbial Metabolism

Course Code: 24MICCC2

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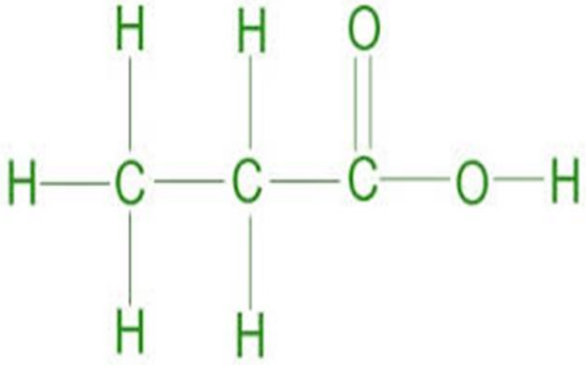
PROPIONIC ACID AND FORMIC ACID FERMENTATION

INTRODUCTION OF FERMENTATION:

- The word **"Ferment"** arises from Latin **" Fervere"** which means "to boil".
- Fermentation is the act in which organic molecules such as **glucose convert into acids, gases or alcohol** in an oxygen free environment.
- Fermentation is **named after products** like alcoholic fermentation, lactic acid fermentation, propionic acid fermentation and formic acid fermentation.
- Fermentation process requires assistance from **microorganisms** such as *Enterococcus, Streptococcus* and *Lactobacillus* to complete.

PROPIONIC ACID FERMENTATION

- Propionic acid is from the Greek words **"Protos – First"** and **"Pion – Fat".**
- It is a naturally occurring carboxylic acid with chemical formula **CH_3CH_2COOH**.
- It is **colourless, corrosive liquid** with a **pungent Odor** and in the pure state.
- It is **soluble liquid** in water, at any proportion .And widely found in animals , plants and microorganisms.
- **USES –** Wide range of industries in the manufacture of **pesticides , perfumes & pharmaceuticals and used as preservatives** in grain , feed and food processing. It inhibit Molds , Bacillus, Aerobacter and other microorganisms.



CHEMICAL AND PHYSICAL PROPERTIES OF PROPIONIC ACID :

- IUPAC Name - Propionic acid.
- Other Names - Ethane carboxylic acid.
- Molecular formula – $C_3H_6O_2$.
- Molar mass – 74.08g/mol.
- Appearance - Colourless.
- Melting point - -21°C.
- Boiling point - 141°C .

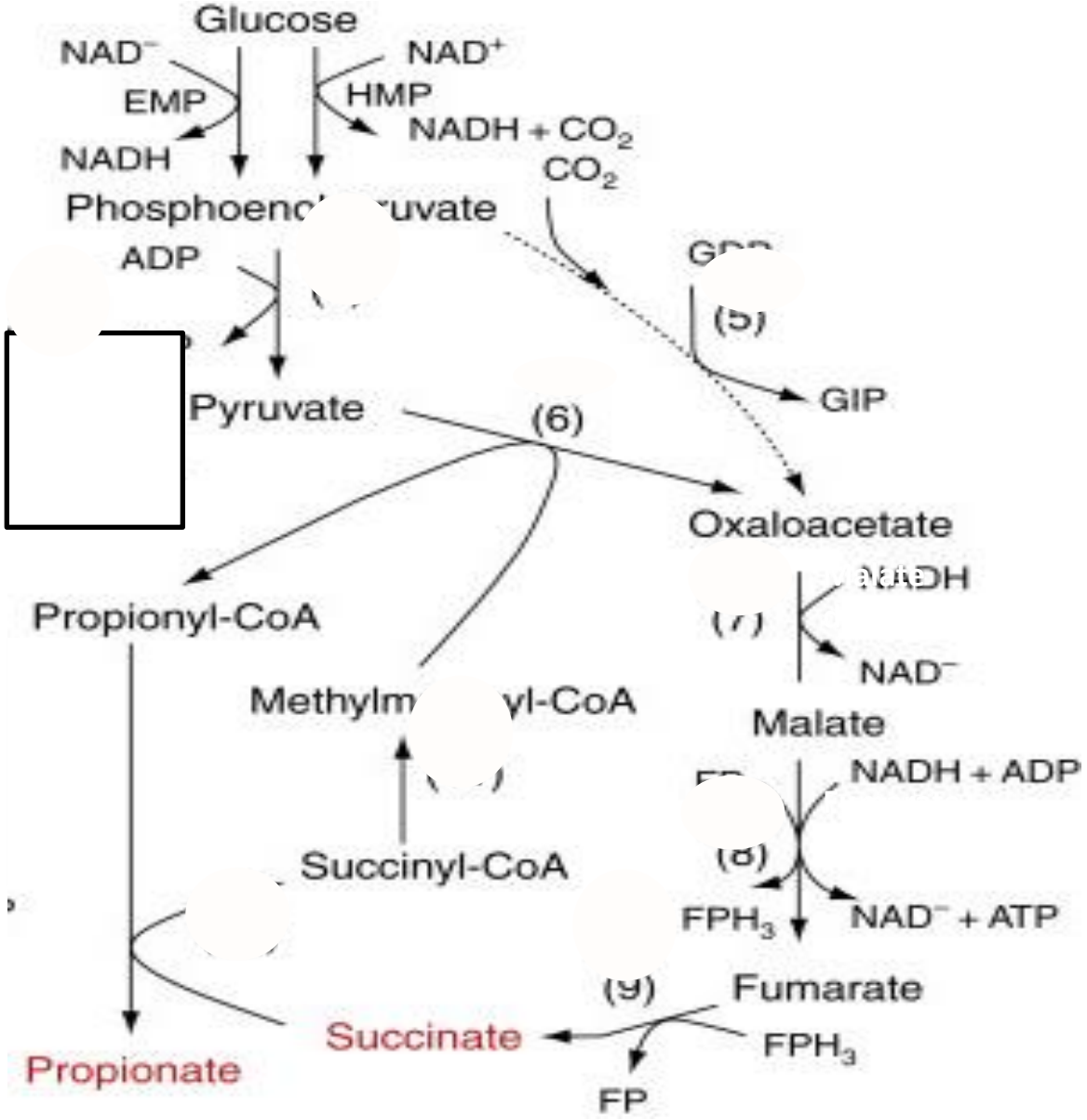
PROPIONIC ACID FERMENTATION BY *Propionibacterium*

- Propionic acid , CH_3CH_2COOH is produced by numerous bacteria such as ***Clostridium*** **and** ***Propionicbacterium***.

Choice of Microorganisms :

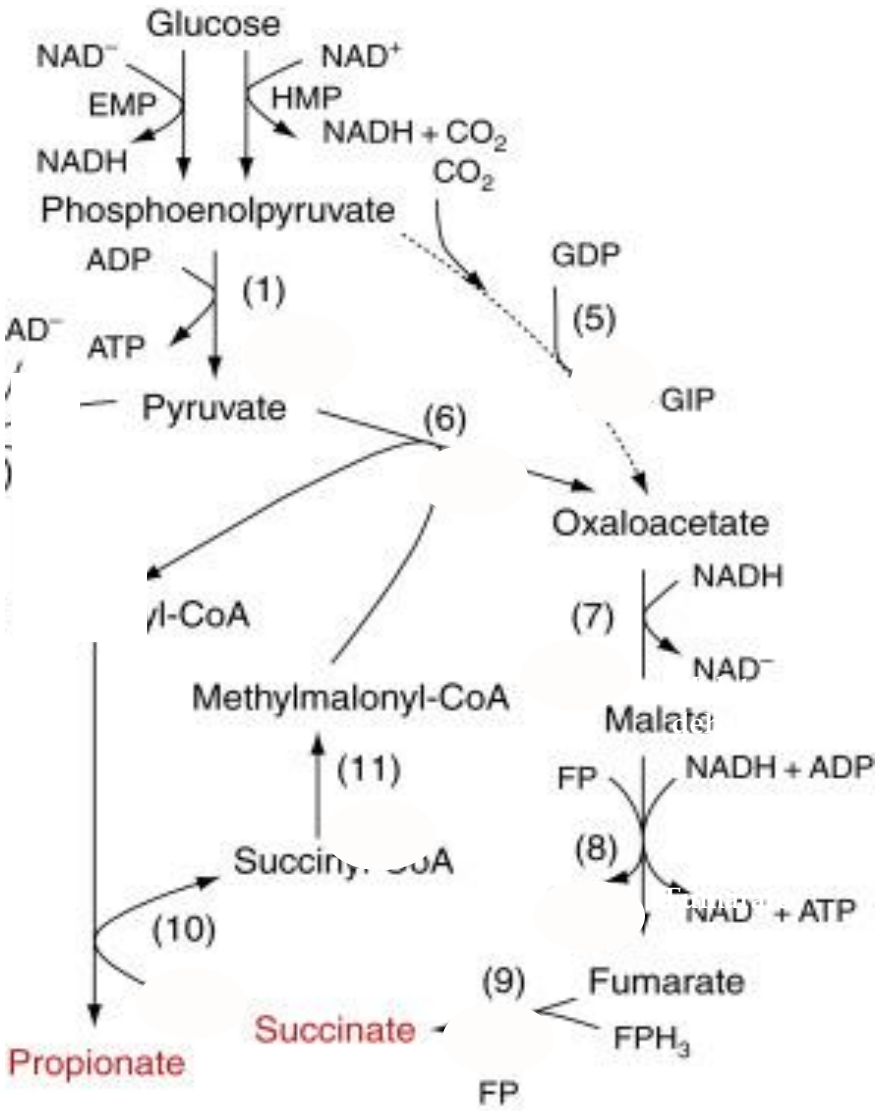
Propionibacteria are **gram-positive , facultative anaerobic** bacteria that have been granted "generally recognized as safe" that include ***Propionibacterium freudenreichii, Propionibacterium shermanii and Propionibacterium acidipropionici.***

METABOLIC PATHWAY OF PROPIONIC ACID FERMENTATION:



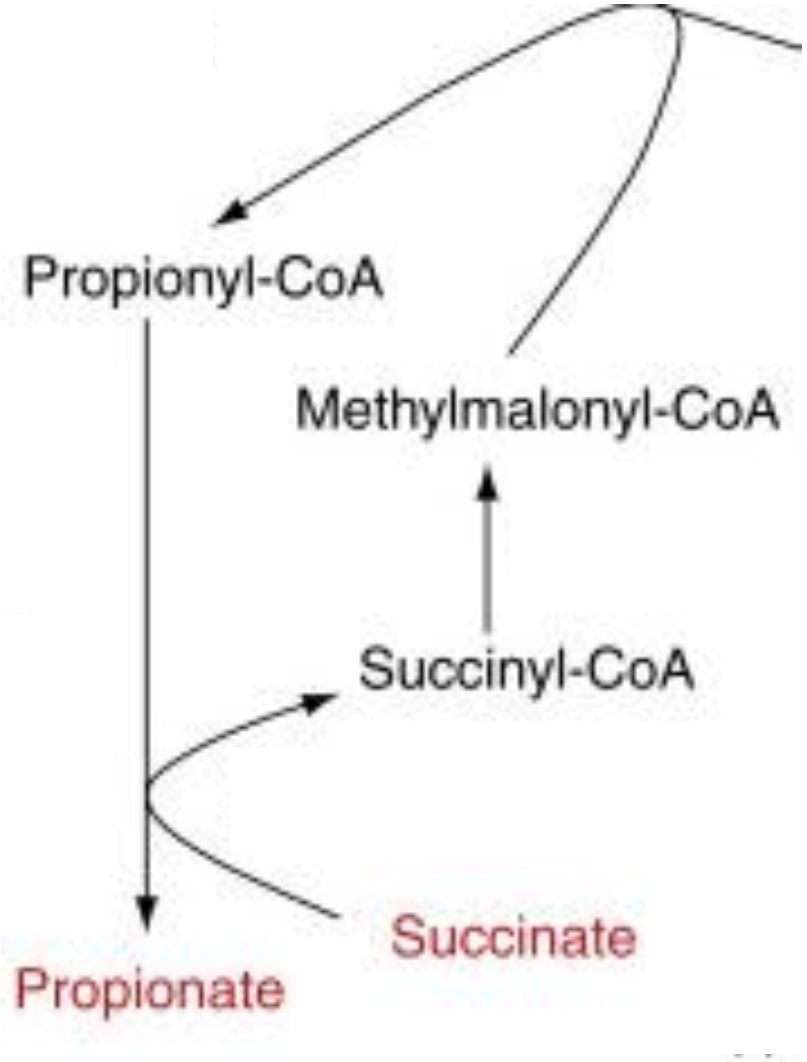
METABOLISM OF PROPIONIC ACID FERMENTATION:

- Pyruvic acid is obtained when the **Propionibacteria dissimilate glucose into pyruvate via EMP pathway.**
- Then, pyruvic acid is converted into **oxaloacetic acid** which is further reduced to succinic acid in two steps by reversal of the TCA cycle.
- The two steps include ,conversion of Malate by **Malate dehydrogenase** and conversion of Malate into Fumarate by **Fumarate hydratase**. And then succinate is formed.
- Due to the TCA cycle reversal process, the **succinyl-CoA** is obtained.



METABOLISM OF PROPIONIC ACID FERMENTATION:

- Succinic acid receives CoA by an enzyme, **CoA-transferase.** Then, Succinyl-CoA produces **methyl malonyl-CoA** by the action of Vitamin B12 – linked enzyme **methyl malonyl mutase**, which further catalyses an intramolecular rearrangement by the process of **decarboxylation.**
- Methyl malonyl-CoA is converted to **propionyl-CoA**.
- In the last step, **Propionic acid** is yielded from propionyl-CoA.

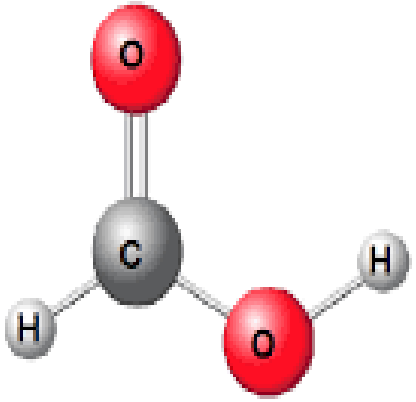


APPLICATION OF PROPIONIC ACID

- **Food preservative**: Propionic acid is a common **preservative** in food, especially bakery products. It's also used to **treat drinking water** for livestock.
- **Animal feed preservative:** Propionic acid is used to preserve compound **feed, grain, and corn in animal feed.**
- **Chemical intermediate**: Propionic acid is used as a chemical intermediate in the **production of many other products**, including polymers, flavorings, pesticides, and pharmaceuticals.
- **Thermoplastics**: Propionic acid is used in the **production** of thermoplastics.
- **Anti-arthritic drugs:** Propionic acid is used in the **production** of anti-arthritic drugs.
- **Perfumes:** Propionic acid is used in the **production** of perfumes.
- **Herbicides:** Propionic acid is used in the **production** of herbicides.

FORMIC ACID FERMENTATION

- Formic acid is the simplest carboxylic acid and systematically called **Methanoic acid**.
- It is **colourless**, **fuming liquid** with a pungent odour and irritates the mucous membranes and blisters the skin.
- The chemical formula of Formic acid is **HCOOH or HCO_2H**. It is **miscible** with water and most polar organic solvents, and is **soluble** in hydrocarbons.



CHEMICAL AND PHYSICAL PROPERTIES OF FORMIC ACID :

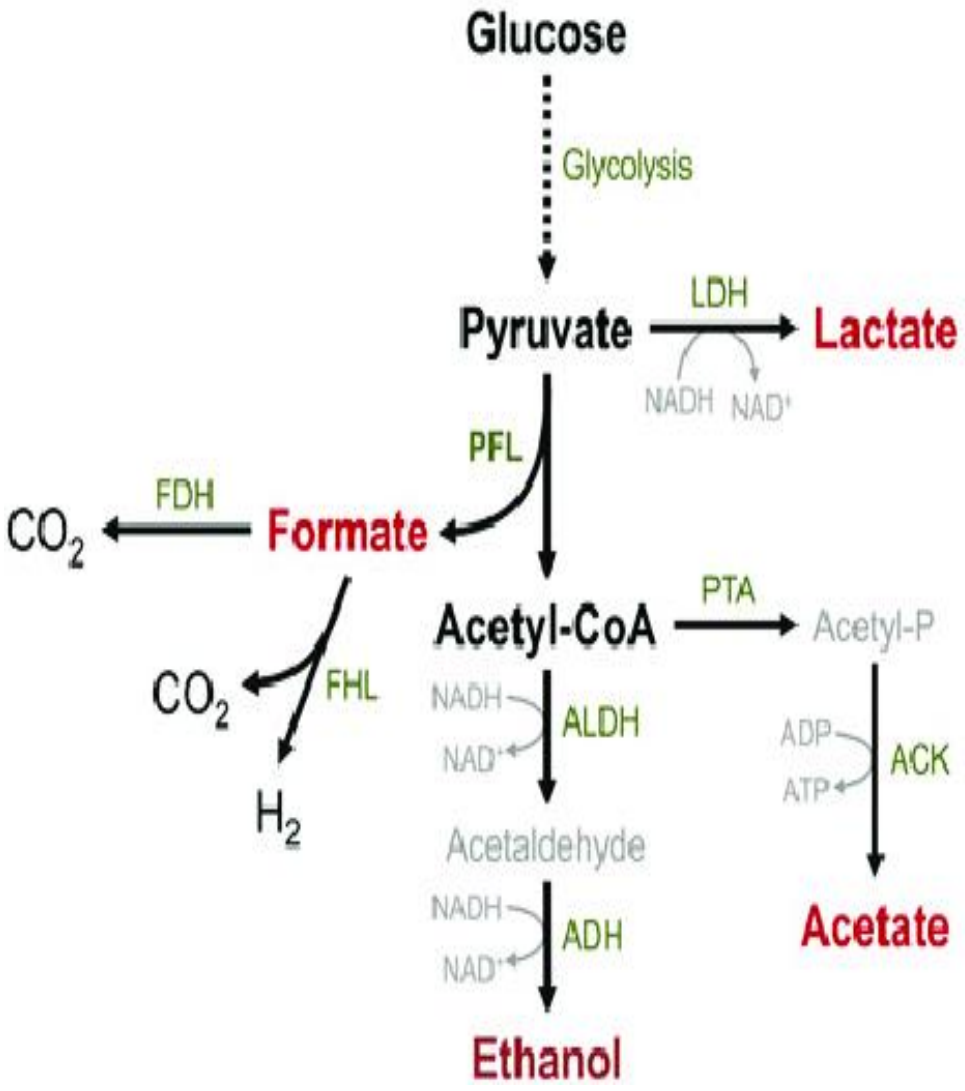
- ❖IUPAC Name - Formic acid.
- ❖ Other Names - Methanoic acid.
- ❖ Molecular formula – CH_2O_2 .
- ❖ Molar mass – 46.02g/mol.
- ❖ Appearance - Colourless liquid.
- ❖ Melting point - 8.4°C.
- ❖ Boiling point - 100.8°C .

FORMIC ACID FERMENTATION BY ENTEROBACTERIACEAE

- Formic acid fermentation is a process used by certain microorganisms to generate energy under anaerobic (oxygen-free) conditions that include the **Enterobacteriaceae**.
- These microorganisms can ferment monosaccharides, disaccharides, polyalcohol, and, less frequently, polysaccharides, via the **glycolytic pathway**, producing lactic, formic, succinic and acetic acids, and ethanol .This fermentation is called **Mixed acid fermentation** .
- **Choice of Microorganisms :**

Enterobacteriaceae are **rod-shaped, gram-negative**, facultatively anaerobic ,non-spore forming bacteria that ferment sugars by EMP pathway.

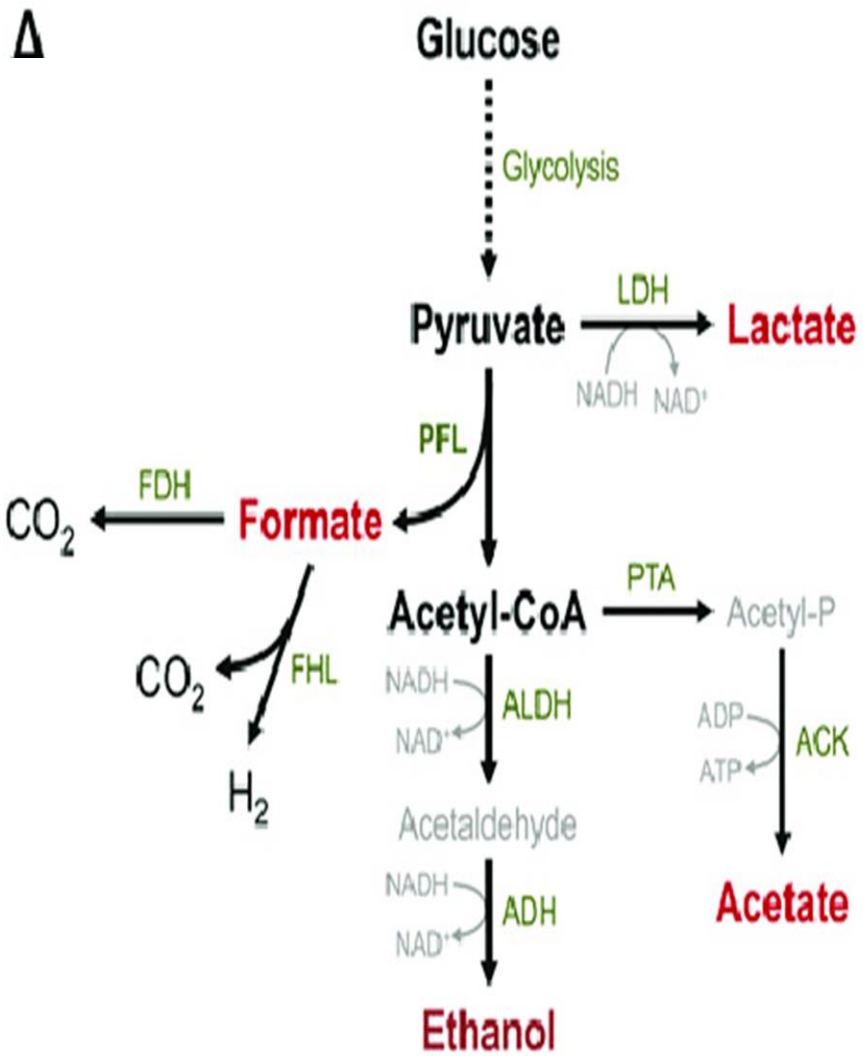
METABOLIC PATHWAY OF FORMIC ACID FERMENTATION:



PFL- Pyruvate Formate Lyase
FDH-Formate Dehydrogenase
FHL-Formate hydrogenlyase
LDH-Lactate Dehydrogenase
ALDH-Aldehyde Dehydrogenase
ADH-Alcohol Dehydrogenase
ACK-Acetate Kinase

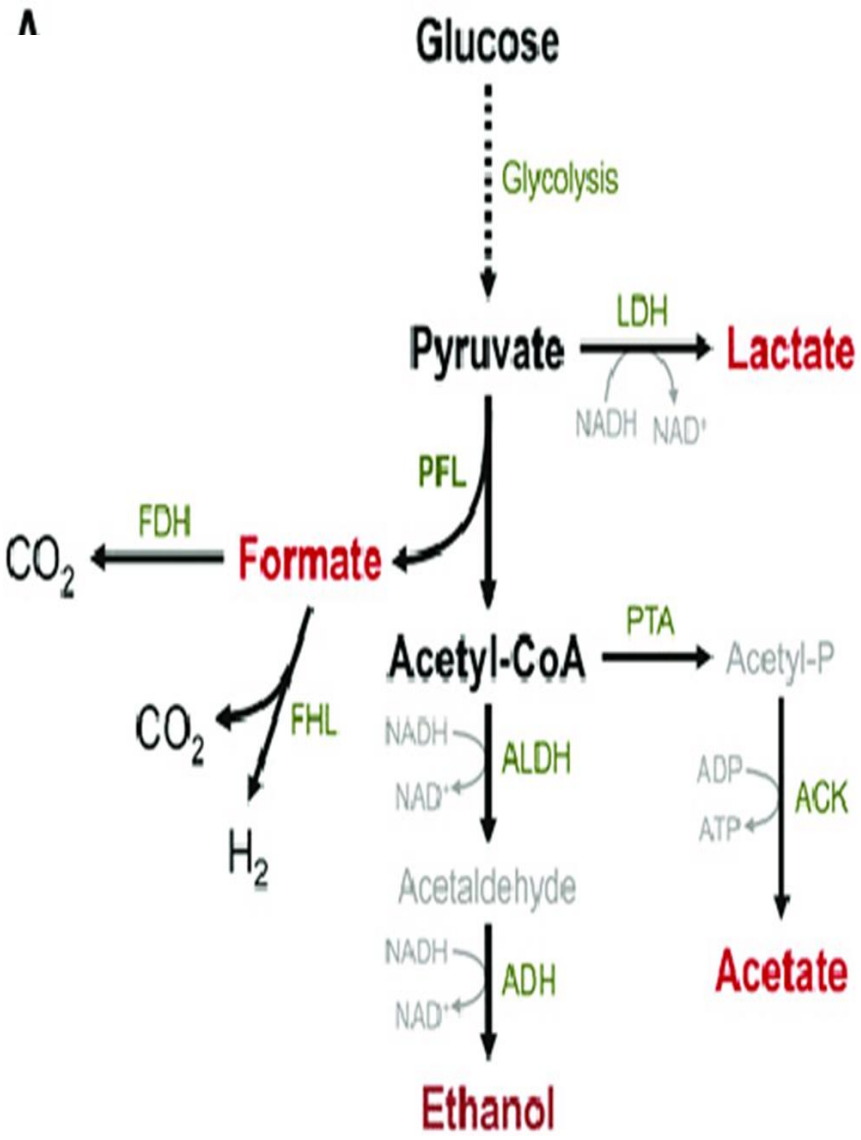
METABOLISM OF FORMIC ACID FERMENTATION

- Formic acid is a obtained from fermentation of **Enterobacteriaceae** and referred as formic acid fermentation.
- Formic acid fermentation pathway involves the **breakdown of carbohydrates,** primarily glucose into pyruvate and then formic acid, lactic acid, Acetate and other products by **Embden-Meyerhof-Parnas Pathway or Glycolysis**.
- Glycolysis takes place in the **cytoplasm** of the cell



METABOLISM OF FORMIC ACID FERMENTATION

- In Glycolysis/EMP Pathway, Glucose is split into two molecules of Pyruvate, also produces energy in the form of **2ATP** .
- Each pyruvate is split into Formate (Formic acid) by the enzyme **Pyruvate formate-lyase(PFL)** and then acetyl-CoA.
- Formate can be further converted into CO_2 and H_2 by **Formate dehydrogenase.**
- It is also referred as **mixed acid fermentation** because not only formic acid production but also lactic acid, acetic acid and alcohol production.



APPLICATION OF FORMIC ACID

- An ingredient of medicines for **rheumatism** or vasoconstricting medicines.
- An **additive** for animal feeds and fungicides
- An ingredient of **cosmetics** for body care and regeneration
- Formic acid shows **anti-bacterial properties** as a result formic acid is of very high use in the agriculture industry.
- It is very well known as a **pesticide** and is proven beneficial to prevent crops from being prone to attacks from different kinds of pests