

Aim: What is
fermentation?



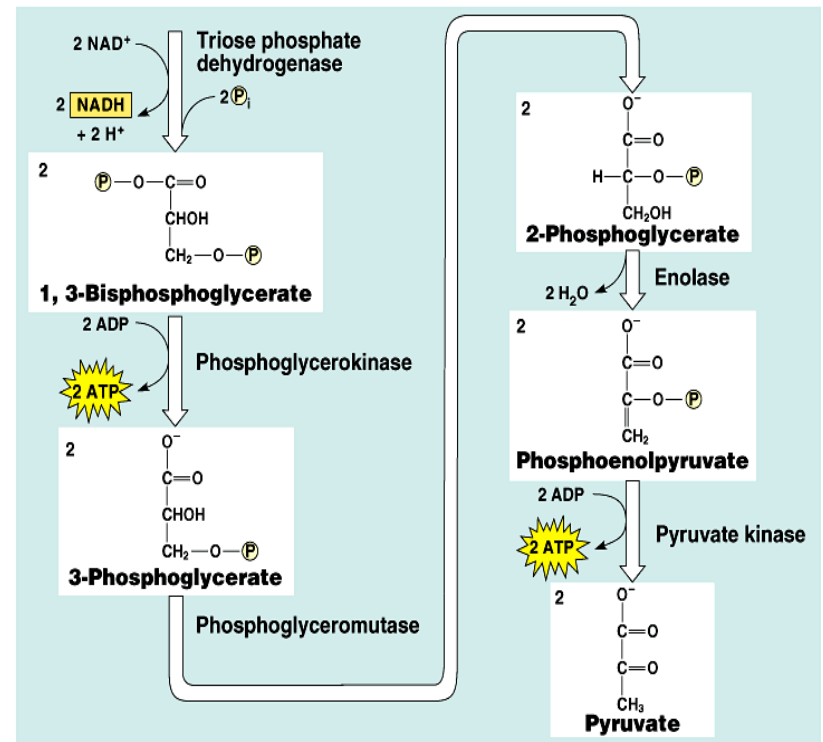


Anaerobic respiration enables some cells to produce ATP without the help of oxygen

- Oxidation refers to the loss of electrons to any electron acceptor, not just to oxygen.
 - In glycolysis, glucose is oxidized to two pyruvate molecules with NAD^+ as the receiver of electrons, not O_2 .
 - Some energy from this oxidation produces 2 ATP (net)
- Glycolysis generates 2 ATP whether oxygen is present (**aerobic**) or not (**anaerobic**).

Fermentation (2)

- Anaerobic catabolism of sugars can occur by fermentation.
- Glycolysis can generate ATP from glucose by substrate-level phosphorylation as long as there is a supply of NAD^+ to accept electrons.
 - If the NAD^+ pool is exhausted, glycolysis shuts down



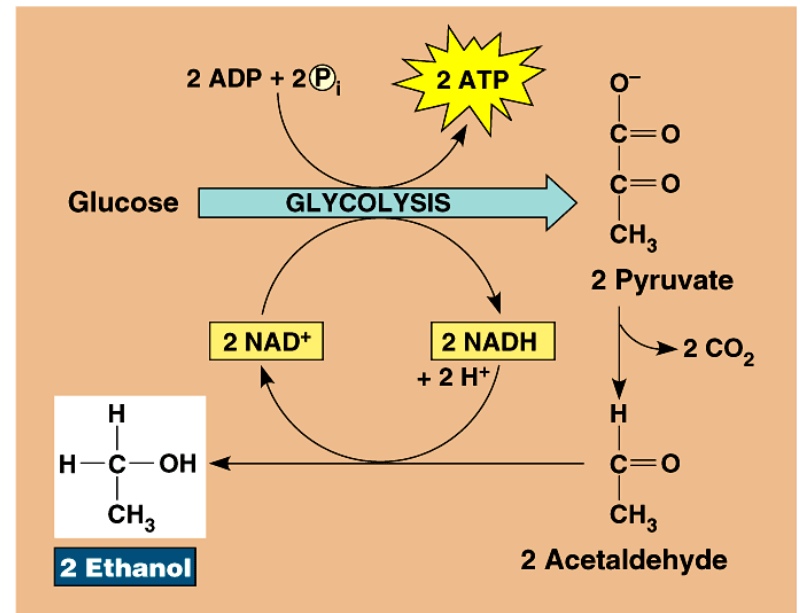


Fermentation (3)

- Under anaerobic conditions, various fermentation pathways generate ATP by glycolysis and recycle NAD^+ by transferring electrons from NADH to pyruvate or derivatives of pyruvate.

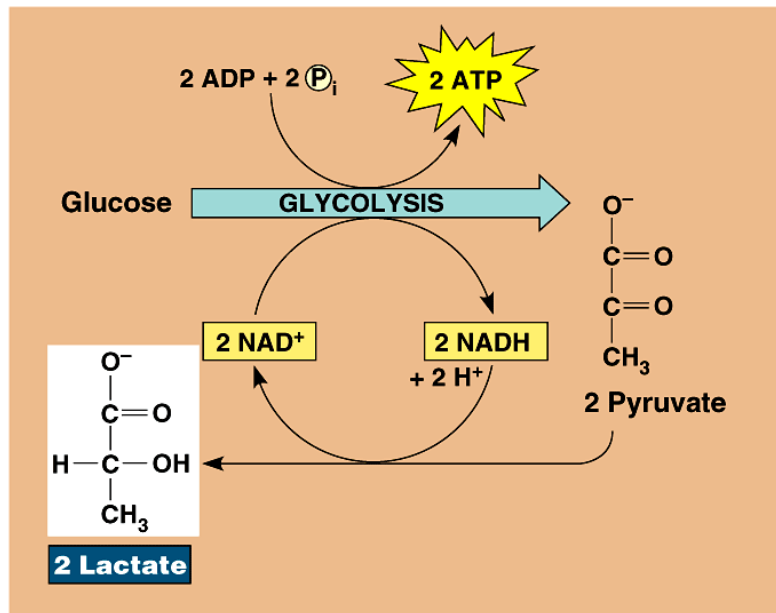
Alcoholic Fermentation

- In **alcohol fermentation**, pyruvate is converted to ethanol in two steps.
 - First, pyruvate is converted to a two-carbon compound, acetaldehyde, by the removal of CO_2 .
 - Second, acetaldehyde is reduced by NADH to ethanol. (NAD⁺ is regenerated.)
 - Alcohol fermentation by yeast is used in baking, brewing and winemaking.



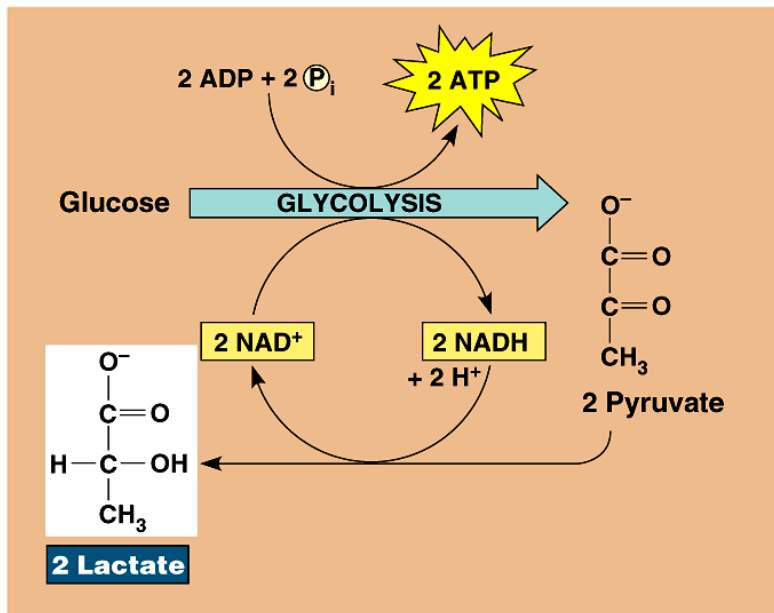
(a) Alcoholic fermentation

Lactic Acid Fermentation (5)



(b) Lactic acid fermentation

- During **lactic acid fermentation**, pyruvate is reduced directly by NADH to form lactate (ionized form of lactic acid).
 - Lactic acid fermentation by some fungi and bacteria is used to make cheese and yogurt.



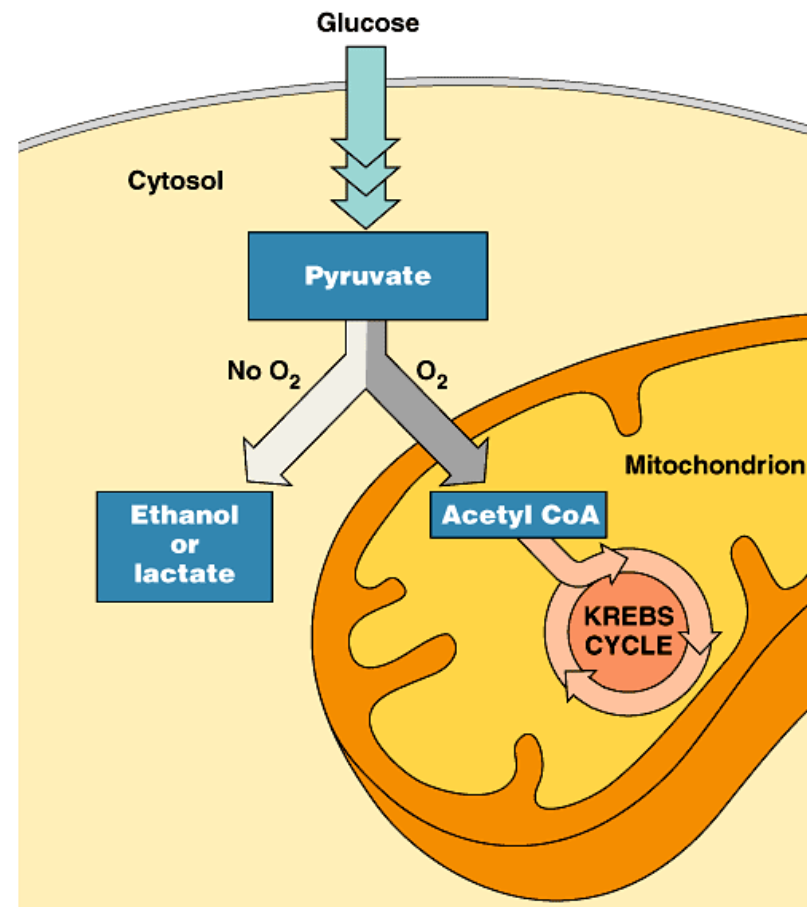
(b) Lactic acid fermentation

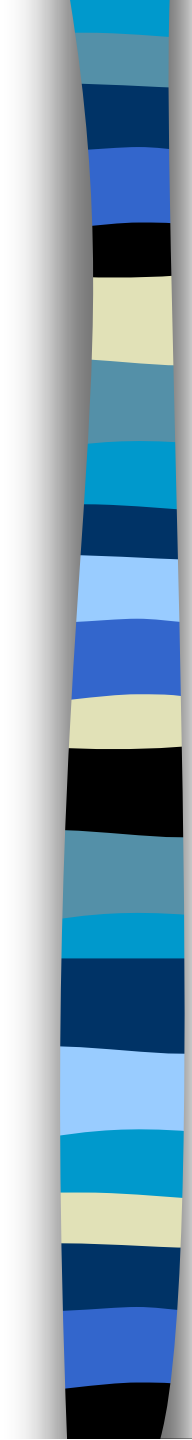
- Muscle cells switch from aerobic respiration to lactic acid fermentation to generate ATP when O_2 is scarce.
 - The waste product, lactate, may cause muscle fatigue, but ultimately it is converted back to pyruvate in the liver.

- Some organisms (**facultative anaerobes**), including yeast and many bacteria, can survive using either fermentation or respiration.

- At a cellular level, human muscle cells can behave as facultative anaerobes, but nerve cells cannot.

- For facultative anaerobes, pyruvate is a fork in the metabolic road that leads to two alternative routes.



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- The oldest bacterial fossils are over 3.5 billion years old, appearing long before appreciable quantities of O₂ accumulated in the atmosphere.
 - Therefore, the first prokaryotes may have generated ATP exclusively from glycolysis.
 - The fact that glycolysis is also the most widespread metabolic pathway and occurs in the cytosol without membrane-enclosed organelles, suggests that glycolysis evolved early in the history of life.