1.10: Yeast Metabolism

Yeasts are ubiquitous unicellular fungi widespread in natural environments. Yeast have a broad set of carbon sources (e.g., polyols, alcohols, organic acids and amino acids) that they can metabolize but they prefer sugars. Yeast are capable of metabolizing hexoses (glucose, fructose, galactose or mannose) and disaccharides (maltose or sucrose) as well as compounds with two carbons (ethanol or acetate). The metabolic pathways utilized by yeast are Embden-Meyerhof glycolysis, tricarboxylic acid cycle (TCA), the pentose phosphate pathway, and oxidative phosphorylation.

? Exercise 1.10.1

- The yeasts involved in food fermentation are identified are [**facultative / obligate**] fermenters and may display either respiratory or a fermentative metabolism or even both in a mixed respiratory-fermentative metabolism

Review Metabolism

Embden-Meyerhof Glycolysis is the pathway utilized by most eukaryotes.

? Exercise 1.10.2

- What is the final product of this glycolysis pathway in aerobic conditions?
- What is the fate of this molecule as it travels through the TCA Cycle?
- What happens in oxidative phosphorylation?

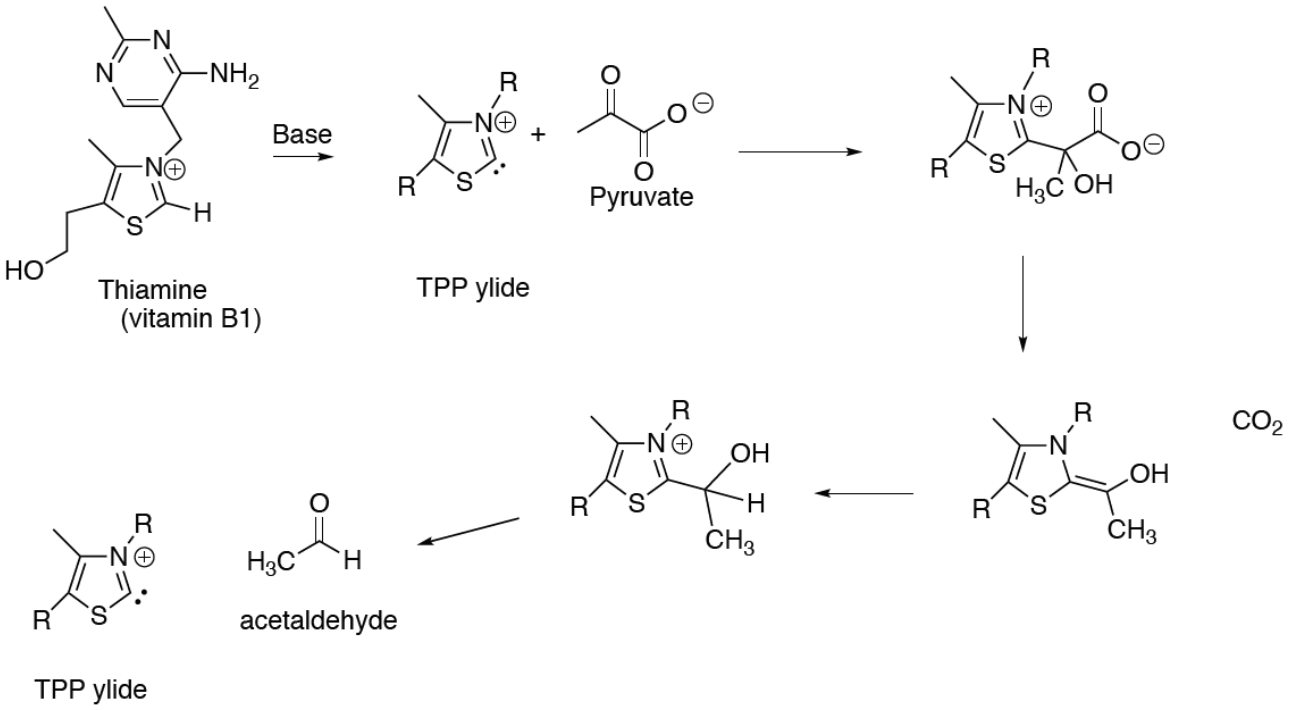
Ethanol Fermentation Key Steps

Ethanol fermentation reaction occurs in two steps, decarboxylation and then hydride reduction.

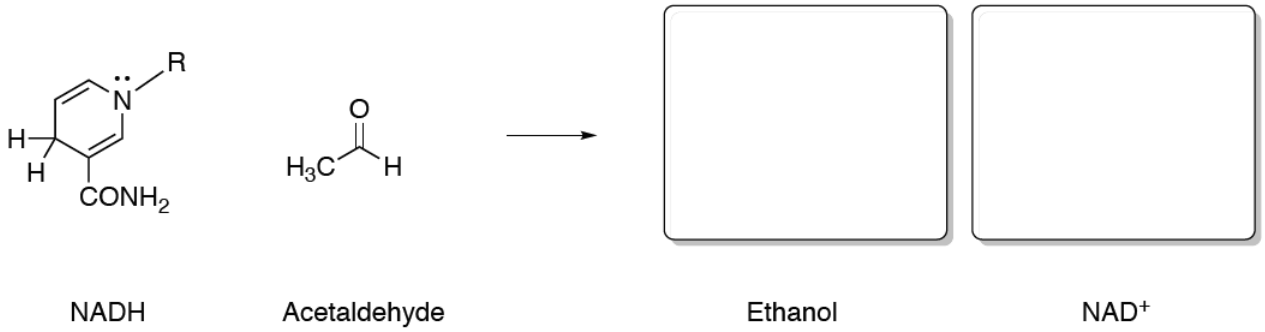
1. In the first reaction, the enzyme pyruvate decarboxylase removes a carboxyl group from pyruvate, releasing CO_2 gas and acetaldehyde.
2. Pyruvate decarboxylate utilizes the TPP ylide (seen previously in the conversion of pyruvate to acetyl CoA).

? Exercise 1.10.3

Show the curved arrows for this mechanism.



2. The second reaction, catalyzed by the enzyme alcohol dehydrogenase, regenerates NAD^+ by reducing the acetaldehyde to ethanol.



? Exercise 1.10.4

- How many NADH can be converted to NAD^+ using the ED Pathway? _____

Ethanol has the added benefit of being toxic to competing organisms. However, it will also start to kill the yeast that is producing the ethanol. at the accumulation of alcohol will become toxic when it reaches a concentration between 14-18%, thereby killing the yeast cells

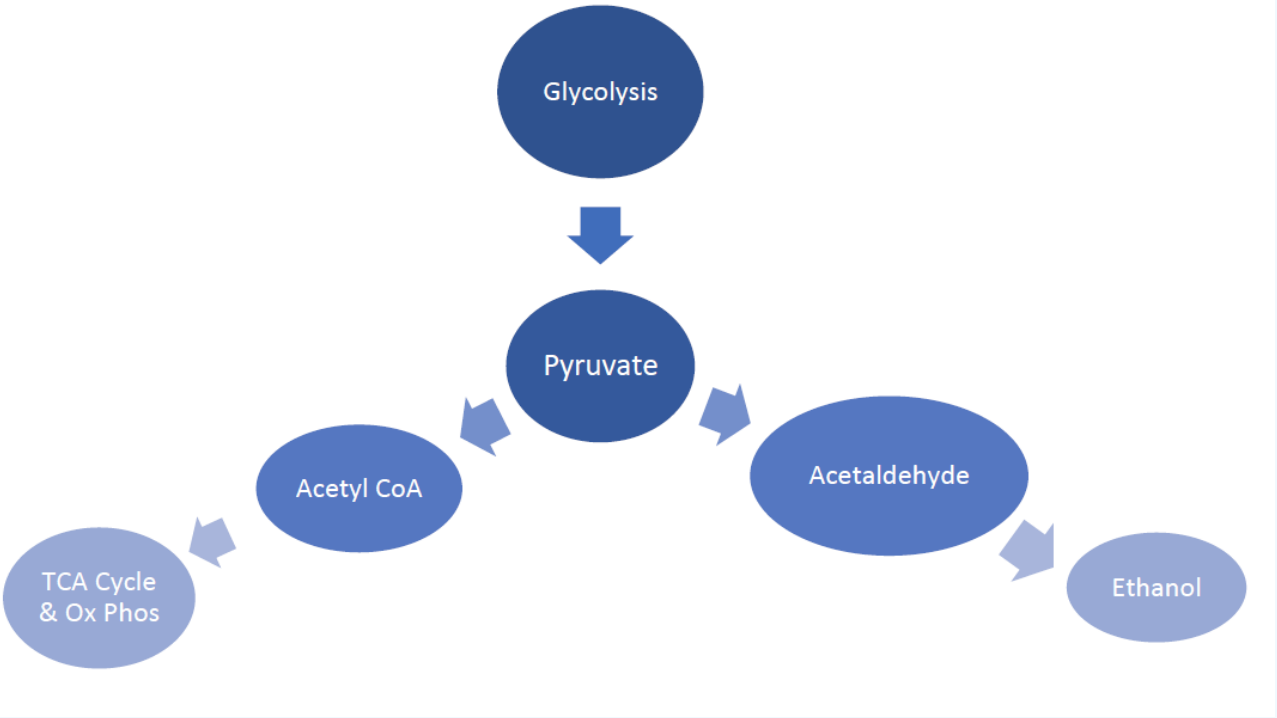
- Explain why the percentage of alcohol in wine and beer can only be approximately 16%.
- How would you produce beverages (liquor) with higher concentrations of alcohol?

Pyruvate Branch Point

Ethanol fermentation utilizes the pyruvate from glycolysis to regenerate NAD^+. This is an alternative pathway to metabolize glucose. The pathway is operated by *Saccharomyces* and other yeast fermenters that ultimately produces ethanol and CO_2.

Exercise 1.10.5

When would you expect that an organism would choose to operate each pathway?



- What molecule might be a regulator?

Aerobic or Anaerobic?

Pasteur Effect

Pasteur observed that yeast produce alcohol only as the product of a "starvation process" once they run out of oxygen. This observation has been shown to be incorrect!

Crabtree Effect

The Crabtree effect is the occurrence of alcoholic fermentation under **aerobic** conditions. The most common yeasts used in fermentation processes (*Saccharomyces* genus) will produce alcohol in both a beer wort and in bread dough immediately regardless of aeration. While you might expect the cell would perform aerobic respiration (full conversion of sugar and oxygen to carbon dioxide and water) as long as oxygen is present, while reverting to alcoholic fermentation, when there is no oxygen as it produces less energy.

However, if a *Saccharomyces* yeast finds itself in a **high** sugar environment, it will immediately start producing ethanol, shunting sugar into the anaerobic respiration pathway while still running the aerobic process in parallel. This phenomenon is known as the **Crabtree effect**. People have speculated that yeast use the ability to produce ethanol to kill competing organisms in the high-sugar environment.

Exercise 1.10.6

Summarize:

- [**Aerobic glycolysis / Alcoholic Fermentation**] is more efficient and yields higher ATP per glucose.
- *S. cerevisiae* will undergo [**aerobic glycolysis / fermentation**] when there is high sugar concentration and plenty of oxygen.

- *S. cerevisiae* will undergo [**aerobic glycolysis / fermentation**] when there is low sugar concentration and plenty of oxygen.
- *S. cerevisiae* will undergo [**aerobic glycolysis / fermentation**] when there is no oxygen.
- *S. cerevisiae* [**can / cannot**] tolerate alcohol while most competing organisms [**can / cannot**] survive in alcohol.
