

Introduction to Fermentation

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Key concepts, mechanisms, types, and practical applications

1. What Is Fermentation?

Aspect	Description
Definition	A metabolic process in which microorganisms (yeasts, bacteria, molds) convert organic substrates (usually sugars) into simpler compounds, releasing energy and producing characteristic by-products (e.g., ethanol, lactic acid, CO ₂).
Purpose in Nature	Allows organisms to generate ATP when oxygen is limited (anaerobic respiration) or to regenerate NAD ⁺ for glycolysis.
Human Relevance	Basis for many foods, beverages, pharmaceuticals, and industrial chemicals.

2. Core Biochemistry

2.1 Glycolysis – The Common Starting Point

- Glucose → 2 Pyruvate
- Net gain: 2 ATP and 2 NADH per glucose molecule.

2.2 Why Fermentation Is Needed

- NAD⁺ regeneration:** NADH must be oxidized back to NAD⁺ for glycolysis to continue.
- Energy extraction:** In the absence of a functional electron transport chain (e.g., low O₂), cells rely on substrate-level phosphorylation.

2.3 Main Fermentation Pathways

Pathway	Primary Organism(s)	Main Products	Key Enzyme(s)
Alcoholic Fermentation	<i>Saccharomyces cerevisiae</i> (yeast)	Ethanol + CO ₂	Pyruvate decarboxylase, Alcohol dehydrogenase

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Lactic Acid Fermentation	<i>Lactobacillus</i> , <i>Streptococcus</i> spp.	L?lactic acid (homo? fermentative) or mixture of lactate, ethanol, CO? (hetero?fermentative)	Lactate dehydrogenase
Propionic Fermentation	<i>Propionibacterium</i> spp.	Propionate + CO?	Propionyl?CoA carboxylase
Butyric Fermentation	<i>Clostridium</i> spp.	Butyrate + Acetate + CO? + H?	Butyrate kinase, Acetyl? CoA pathways
Acetone?Butanol? Ethanol (ABE) Fermentation	<i>Clostridium acetobutylicum</i>	Acetone, butanol, ethanol	Acetyl?CoA acetyltransferase, butyraldehyde dehydrogenase

3. Types of Fermentation (Industrial & Food Context)

Category	Examples	Typical Substrate	End?Products	Notable Uses
Alcoholic	Beer, wine, spirits	Sugars (glucose, fructose, maltose)	Ethanol, CO?	Beverage production, bio? fuel
Lactic	Yogurt, kimchi, sauerkraut, sourdough	Milk lactose, vegetable sugars	Lactic acid, sometimes CO?	Food preservation, flavor development
Acetic	Vinegar	Ethanol (from prior alcoholic fermentation)	Acetic acid	Food condiment, biocontrol
Mixed?Culture (e.g., Kombucha)	Kombucha tea	Sweetened tea (sucrose)	Acetate, ethanol, glucuronic acid	Functional drinks
Industrial Bulk	Bio?ethanol, biobutanol, lactic acid polymers	Corn starch, sugarcane, lignocellulose	Ethanol, butanol, PLA monomers	