General Microbiology Course
Lecture 4
(Microbial Growth and Metabolism)
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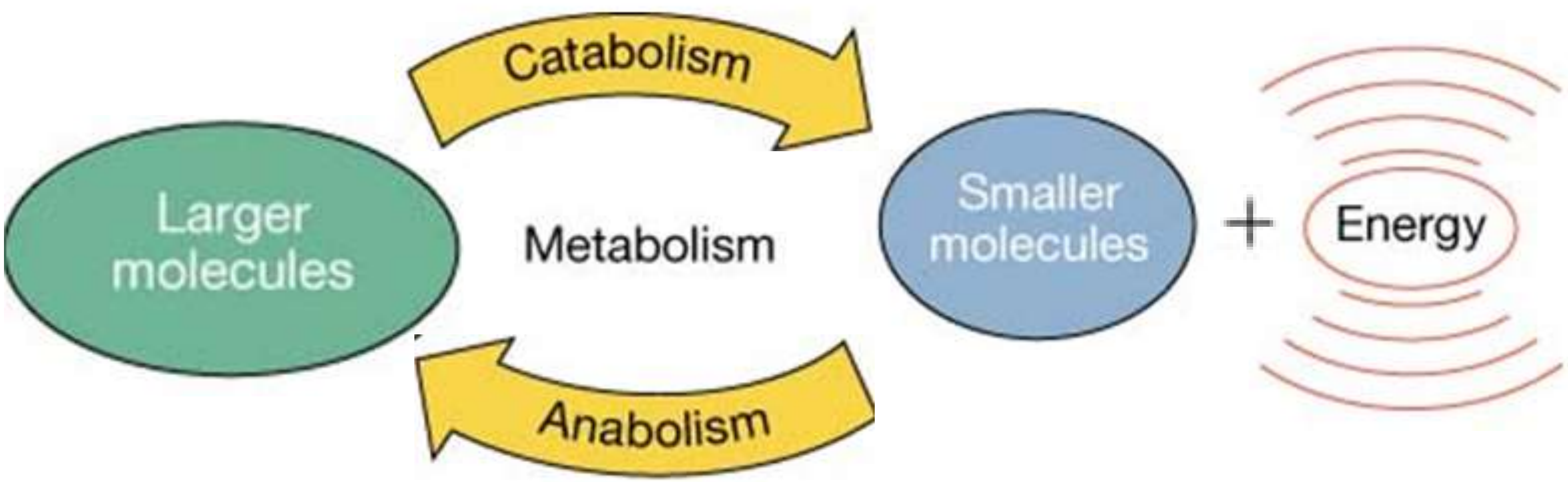
Lecture Outlines

- Some definitions.
- Microbial nutrition.
- Microbial growth and its requirements.
- Bacterial respiration.

Definitions

- **Bacterial growth:** refers to an increase in **cell number** , not in cell size.
- **Metabolism**: the sum of the chemical reactions in an organism.
- **Catabolism**: provides energy and building blocks for anabolism
- **Anabolism**: uses energy and building blocks to build large molecules



Microbial nutrition

Types of microbial nutrition

Bacteria are classified in two nutritional types on the basis of their carbon requirement into:

Autotrophic: that uses CO_2, an inorganic gas as its carbon source

- ✓ Photosynthetic bacteria.
- ✓ Chemosynthetic bacteria

Heterotrophic must obtain carbon in an organic form made by other living organisms

- ✓ Saprophytic
- ✓ Symbiotic
- ✓ Parasitic bacteria

Requirements for Growth

Physical Requirements

1. Temperature

Microbes classified into several groups based on their preferred temperature ranges.

A. Psychrophiles: "Cold-loving". Can grow at 0^o C. Two groups:

- **True Psychrophiles**
  Optimum growth at 15 C or below. Found in very cold environments (North pole, ocean depths). Seldom cause disease or food spoilage.
- **Psychrotrophs**: Optimum growth at 20 to 30 C. Responsible for most low temperature food spoilage.

Requirements for Growth

Physical Requirements

1. **Temperature**:

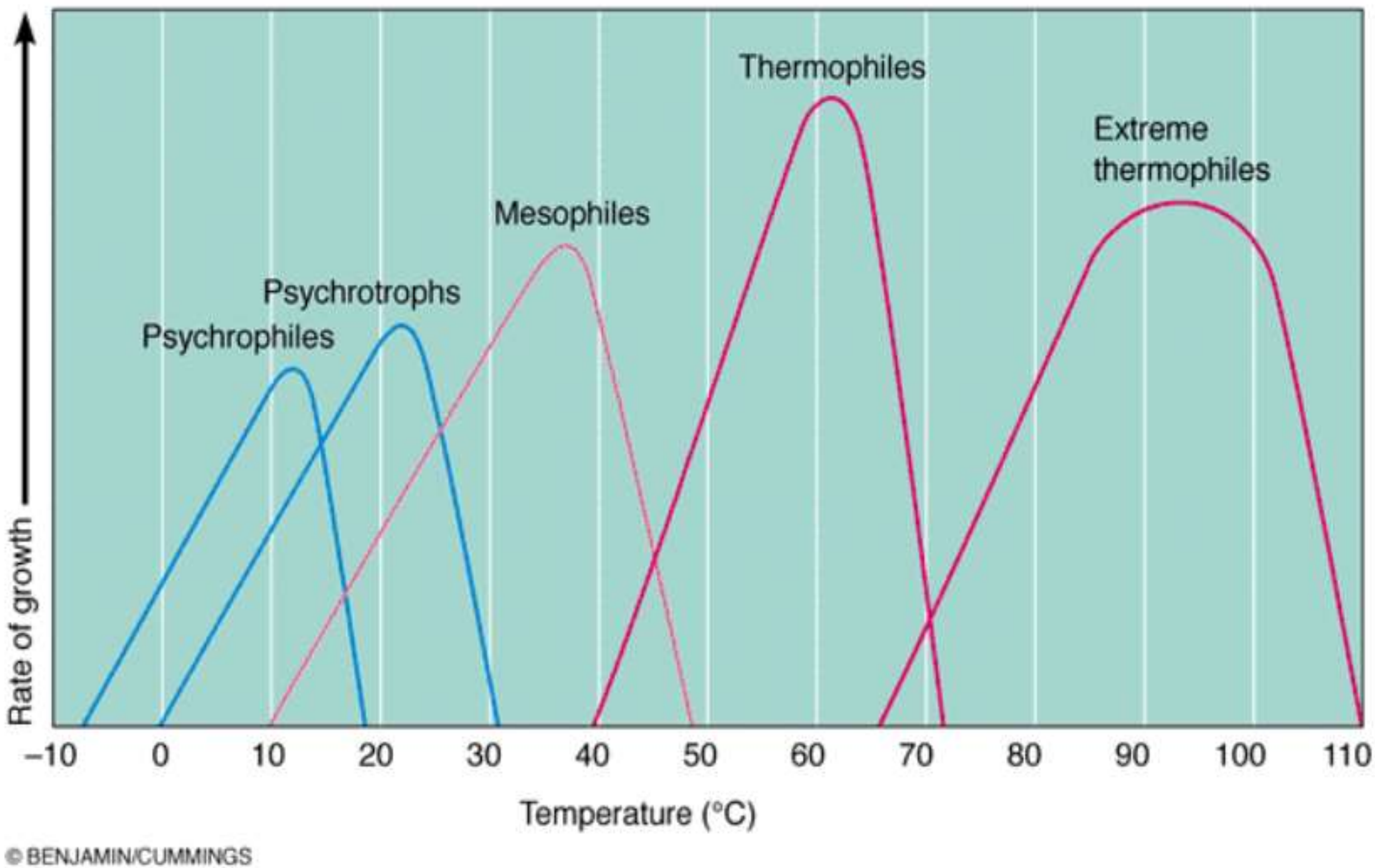
B. Mesophiles: “Middle loving”. Most bacteria.

- Best growth between 25 to 40^{o}C.
- Optimum temperature commonly 37^{o}C.
- Many have adapted to live in the bodies of animals.

C. Thermophiles: “Heat loving”.

- Optimum growth between 50^{o} to 60^{o} C.
- Adapted to live in sunlit soil, compost piles, and hot springs.
- **Extreme Thermophiles (Hyperthermophiles):** Optimum growth at 80^{o}C or higher. Archaebacteria. Most live in volcanic and ocean vents.

Growth Rates of Bacterial Groups at Different Temperatures



Requirements for Growth
Physical Requirements

2. <u>pH</u>: Organisms can be classified as:

A. <u>Acidophiles</u>: “Acid loving”.

- Grow at very low pH (0.1 to 5.4)
- *Lactobacillus* produces lactic acid, tolerates mild acidity.

B. <u>Neutrophiles</u>:

- Grow at pH 5.4 to 8.5.
- Includes most human pathogens.

C. <u>Alkaliphiles</u>: “Alkali loving”.

- Grow at alkaline or high pH (7 to 12 or higher)
- *Vibrio cholerae* optimal pH 9

Requirements for Growth
Physical Requirements

3. Osmotic Pressure: Cells are 80 to 90% water.

- **Halophiles** : Require moderate to large salt concentrations. Ocean water contains 3.5% salt.
  - Most bacteria in oceans.
- **Extreme or Obligate Halophiles** : Require very high salt concentrations (20 to 30%).
  - Bacteria in Dead Sea.
- **Facultative Halophiles** : Do not require high salt concentrations for growth, but tolerate 2% salt or more.

Requirements for Growth

Chemical Requirements

1. __Carbon__: Makes up 50% of dry weight of cell.

- Structural backbone of all organic compounds.
- **__Chemoheterotrophs__**: Obtain carbon from their energy source: lipids, proteins, and carbohydrates.
- **__Chemoautotrophs and Photoautotrophs__**: Obtain carbon from carbon dioxide.

Requirements for Growth
Chemical Requirements

2. Oxygen: bacteria are classified into

1- Aerobes: utilizes oxygen and can detoxify it

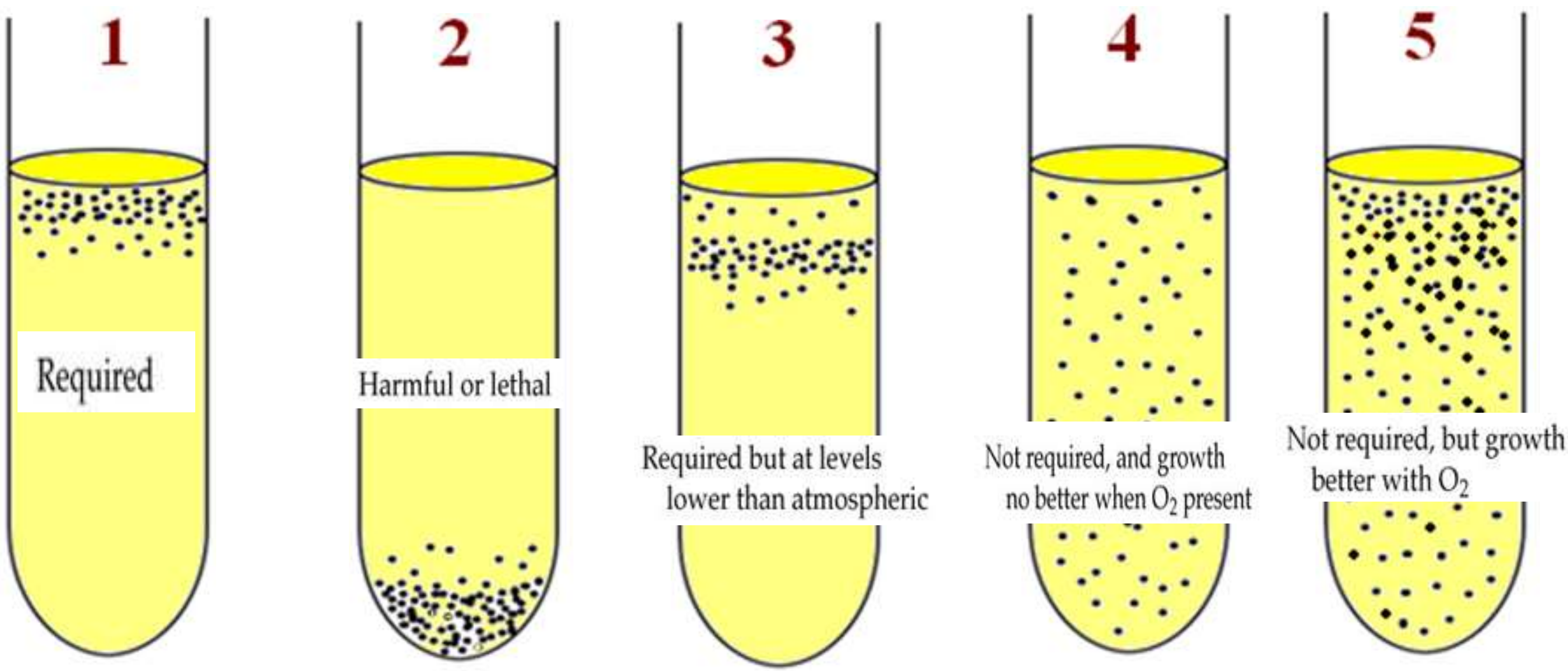
- **obligate aerobes**: cannot grow without oxygen
- **facultative anaerobes**: utilize oxygen but can also grow in its absence
- **microaerophilic** : requires only a small amount of oxygen

2- Anaerobes : do not utilize oxygen

- **obligate anaerobes**: lack the enzymes to detoxify oxygen so cannot survive in an oxygen environment
- **aerotolerance anaerobes**: do no utilize oxygen but can survive and grow in its presence

Requirements for Growth
Chemical Requirements

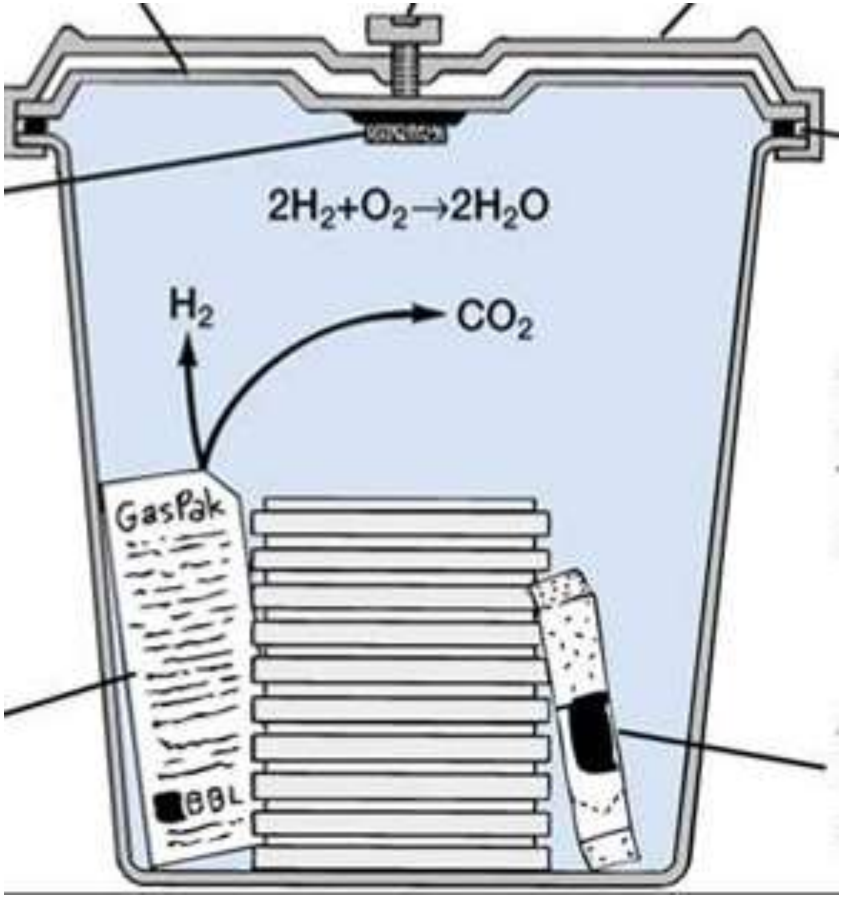
Categories of oxygen requirement



Obligate aerobe | **Obligate anaerobe** | **Microaerophile** | **Aerotolerant anaerobe** | **Facultative anaerobe**

Requirements for Growth
Chemical Requirements

Anaerobic conditions



Requirements for Growth
Chemical Requirements

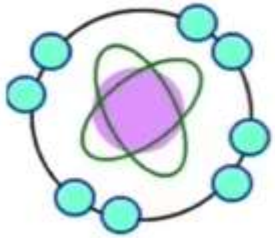
Q: Why do some bacteria are forced to live in oxygen free environment?

- To avoid the toxic forms of oxygen (Oxygen free radicals).
- If a microbe is not capable of dealing with toxic oxygen, it is forced to live in oxygen free habitats.
- The oxygen free radicals including:

A. Superoxide Free Radicals ($O_2^{-\cdot}$)

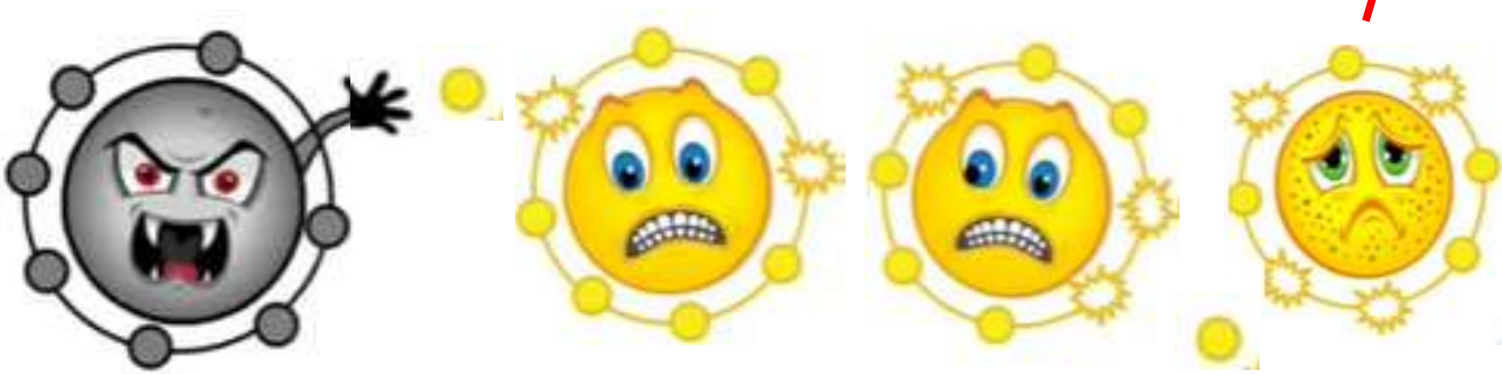
B. Hydrogen Peroxide (H_2O_2)

FREE RADICALS - What are they?



HEALTHY
STABLE
MOLECULE

Oxidative stress reaction
leading to cell damage



UNPAIRED
UNSTABLE
*M*OLECULE

Requirements for Growth
Chemical Requirements

The oxygen free radicals

1. <u>Hydrogen Peroxide</u> (H_2O_2):

There are two different enzymes that break down H2O2:

A. Catalase: Breaks hydrogen peroxide into water and O_2. Common. Produced by humans, as well as many bacteria.

Catalase

$$2\ H_2O_2 \text{-----------> } 2H_2O + O_2$$

Hydrogen peroxide — Gas Bubbles

B. Peroxidase: Converts hydrogen peroxide into water.

Peroxidase

$$H_2O_2 + 2H \text{ ---------> } H_2O$$

Hydrogen peroxide

Requirements for Growth
Chemical Requirements

The oxygen free radicals

2- **Superoxide Free Radicals** **($O_2^{-\cdot}$):** Extremely toxic and reactive form of oxygen. All organisms growing in atmospheric oxygen must produce an enzyme **superoxide dismutase (SOD)**, to get rid of them. SOD is made by aerobes, facultative anaerobes, and aerotolerant anaerobes, **but not** by anaerobes or microaerophiles.

Reaction:

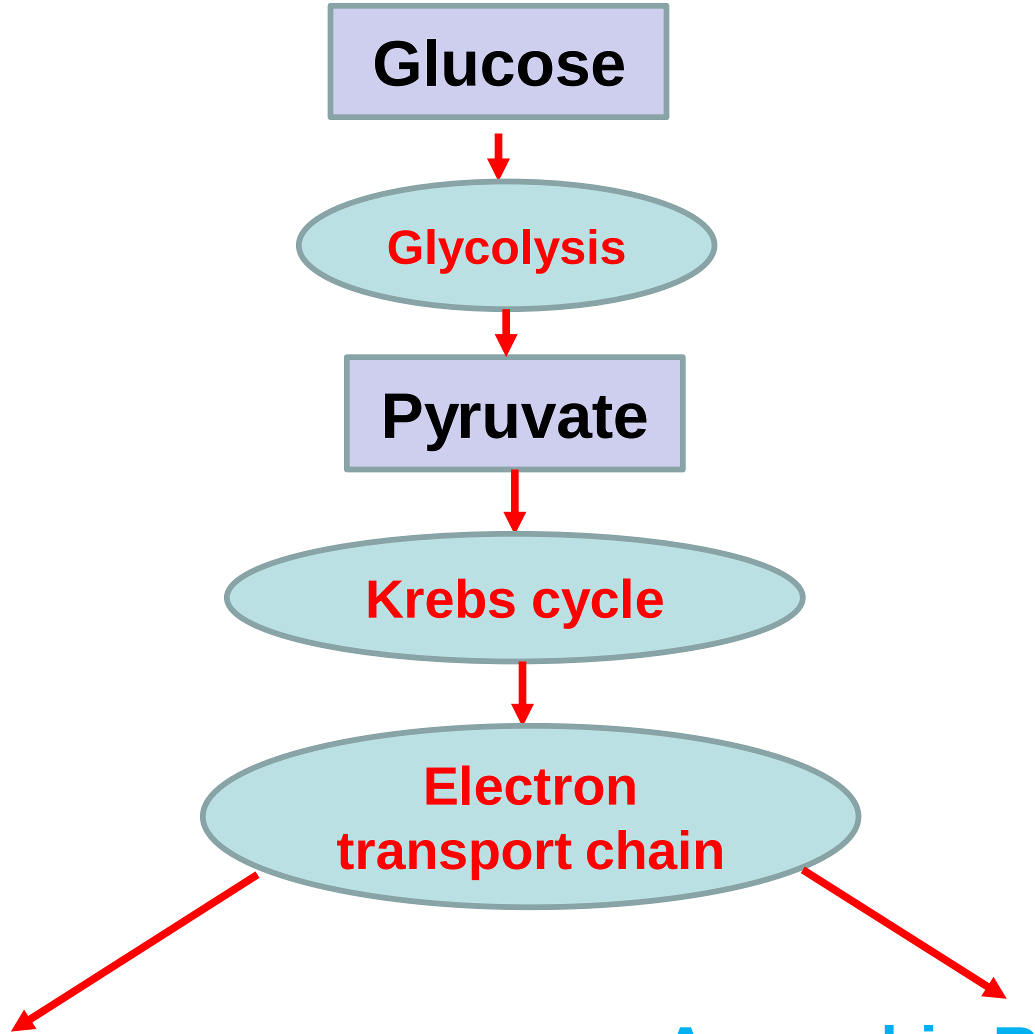
$$O_2^{-\cdot} + O_2^{-\cdot} + 2H^+ \xrightarrow{SOD} H_2O_2 + O_2 \xrightarrow{catalase} H_2O + O_2$$

Superoxide free radicals

Hydrogen peroxide

Bacterial Respiration

Aerobic vs Anaerobic Respiration



Aerobic Respiration

Oxygen as final electron acceptor

Anaerobic Respiration

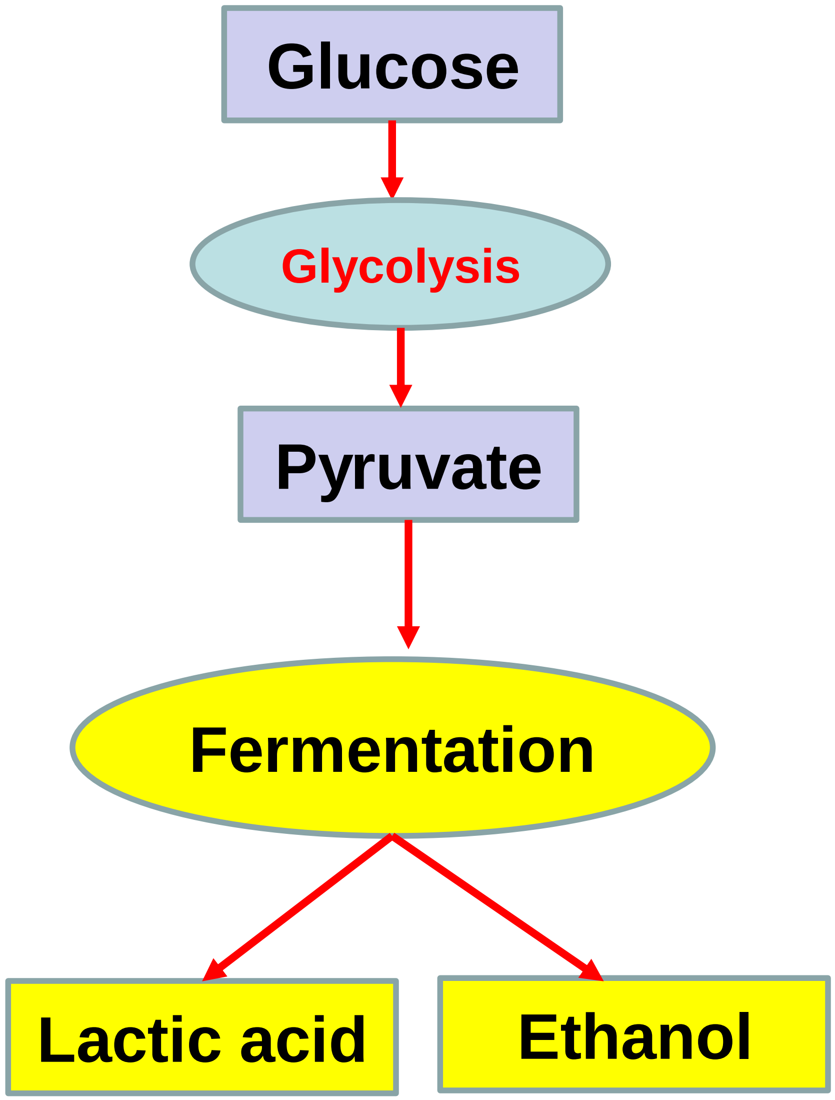
sulfate (SO_4^{2-}), nitrate (NO_3^-), or sulfur (S) are used as electron acceptors.

Fermentation

Occurs when

1. When the oxygen demands exceeds the glucose metabolism (during strenuous exercise).

2. Microbes are kept in an anaerobic environment (i.e., without oxygen), they switch to alcoholic fermentation to generate usable energy from food.



some methods of ATP production do not require oxygen

Anaerobic Respiration

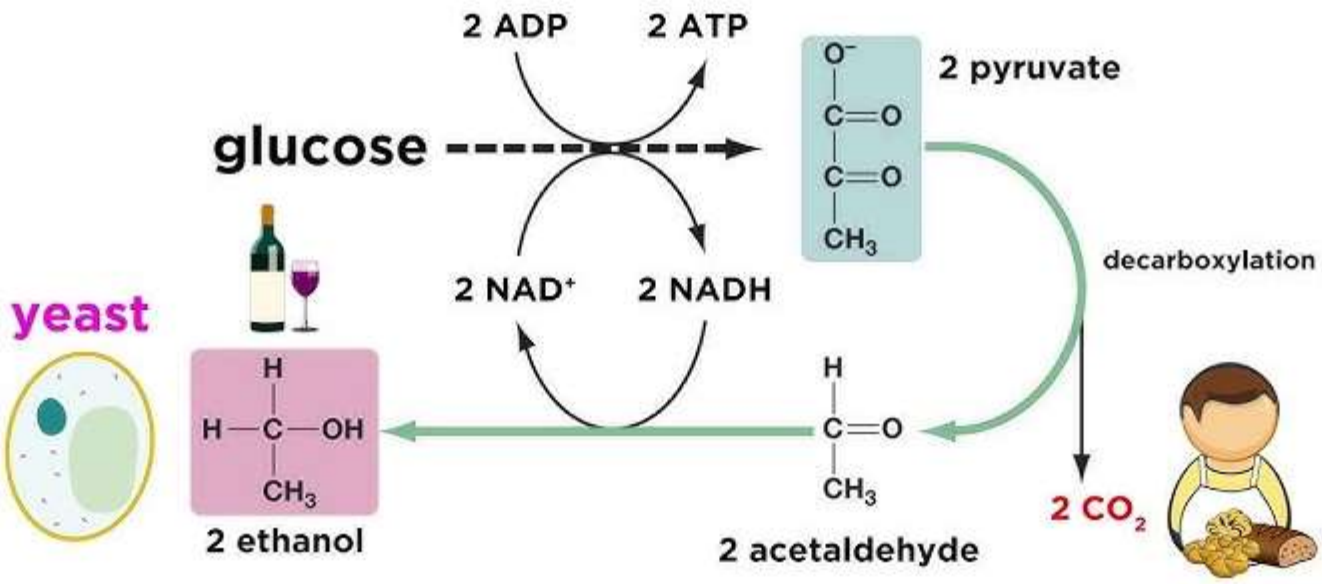
Fermentation

Alcohol Fermentation

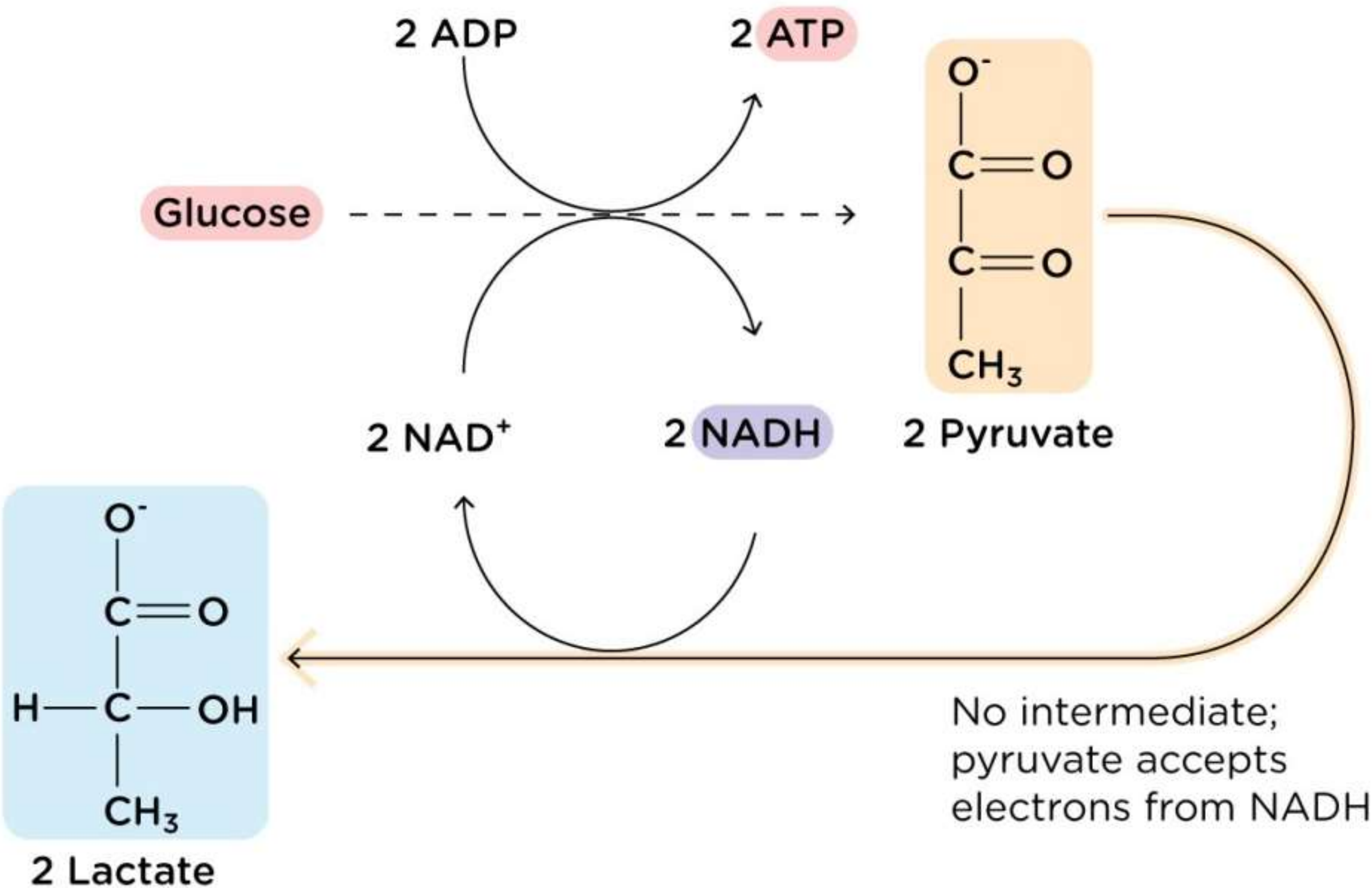
Lactic Acid Fermentation

Alcohol fermentation

Without any form of respiration, glycolysis products, pyruvate and NADH, will accumulate. To keep making any more ATP by glycolysis, fermenting cells must convert NADH back to NAD+ (ox.) by passing its electrons to pyruvate. Reaction pathways that do this convert pyruvate to many other compounds, depending on the organism.

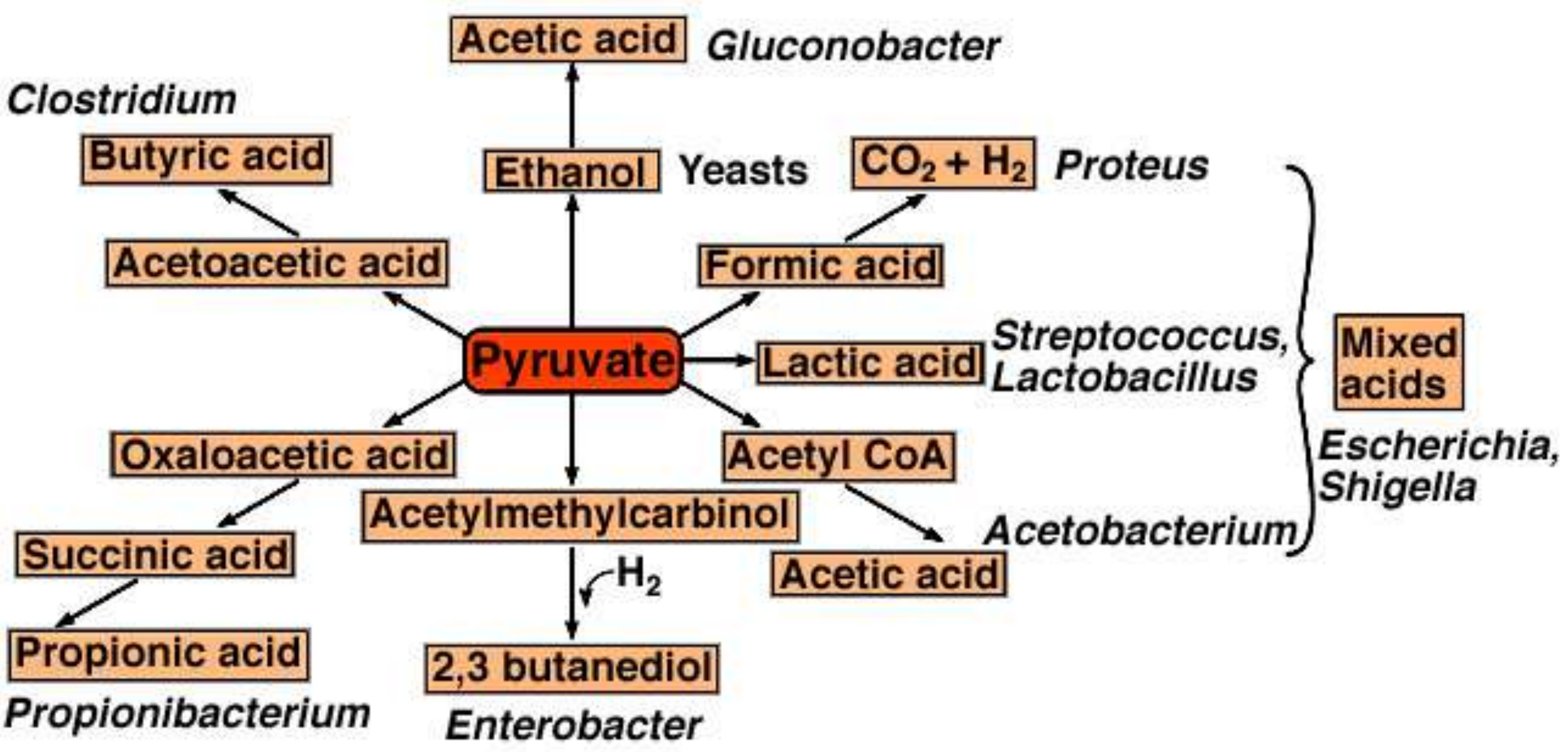


Lactic Acid Fermentation



Products of Fermentation

Without any form of respiration, glycolysis products, pyruvate and NADH, will accumulate. To keep making any more ATP by glycolysis, fermenting cells must convert NADH back to NAD+ (ox.) by passing its electrons to pyruvate. Reaction pathways that do this convert pyruvate to many other compounds, depending on the organism.



General Pathways