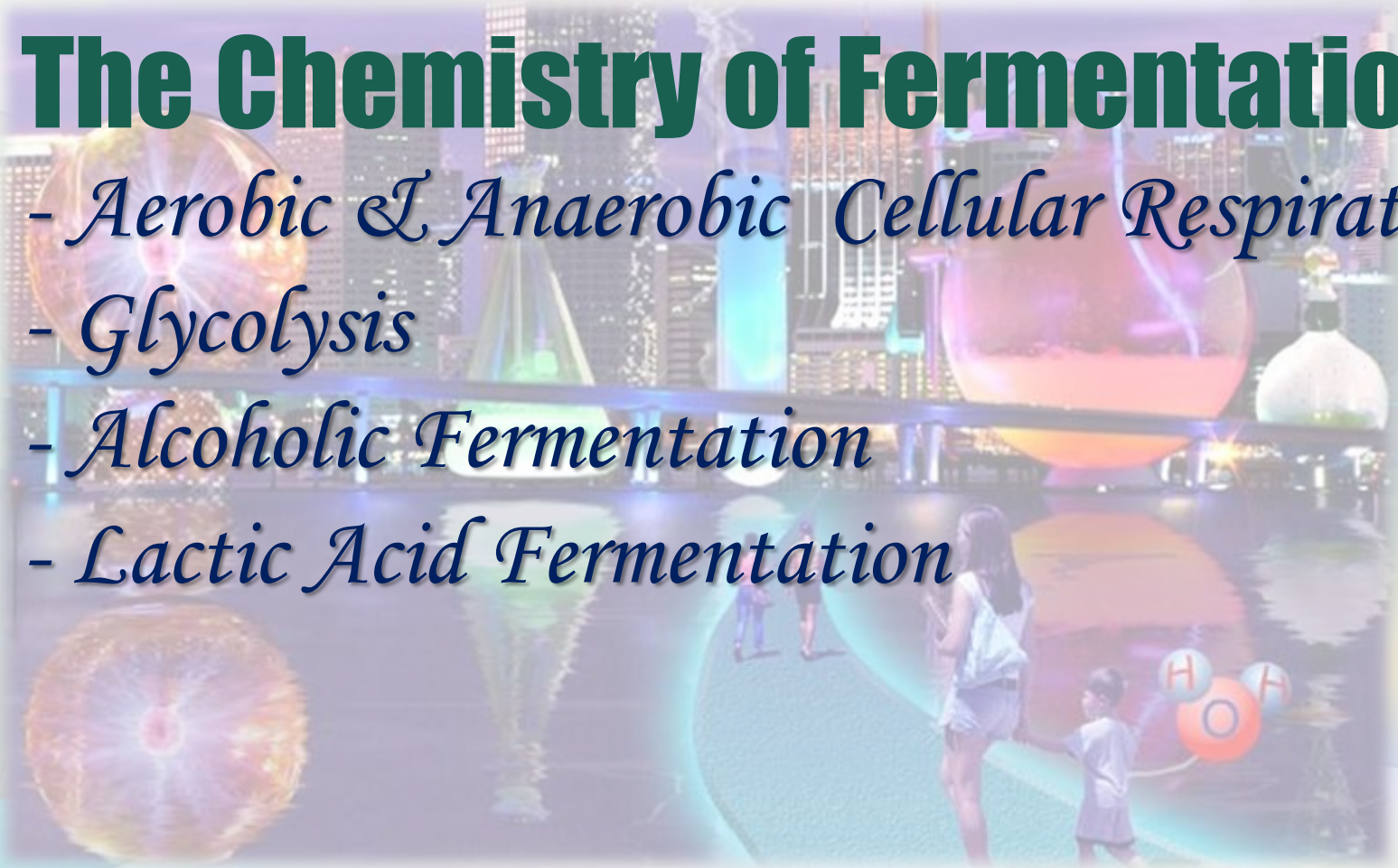
FERMENTATION PROCESSES AND THEIR APPLICATION

"fermentation, far from being a lifeless phenomenon, is a living process…"

- Louis Pasteur

The Chemistry of Fermentation

- *Aerobic & Anaerobic Cellular Respiration*
- *Glycolysis*
- *Alcoholic Fermentation*
- *Lactic Acid Fermentation*



Aerobic Cellular Respiration

- Aerobic means "with air". This type of respiration needs oxygen for it to occur so it is called aerobic respiration.

Glucose + Oxygen -> Carbon dioxide + Water + Energy

- The chemical equation is:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2900\ kj$

- 3 stages: -glycolysis
  -citric acid cycle
  -electron transport chain

Stages of Aerobic Cellular Respiration

- In glycolysis, a net of *2 molecules of ATP*, or chemical energy, are produced.
- The citric acid cycle produces another *2 molecules of ATP*
- The electron transport chain produces *28 molecules of ATP*.
- Oxygen is used in aerobic cellular respiration as the final electron acceptor in the electron transport chain, which is part of why it's able to create so much ATP.

But what happens when oxygen doesn't exist?

Anaerobic Cellular Respiration

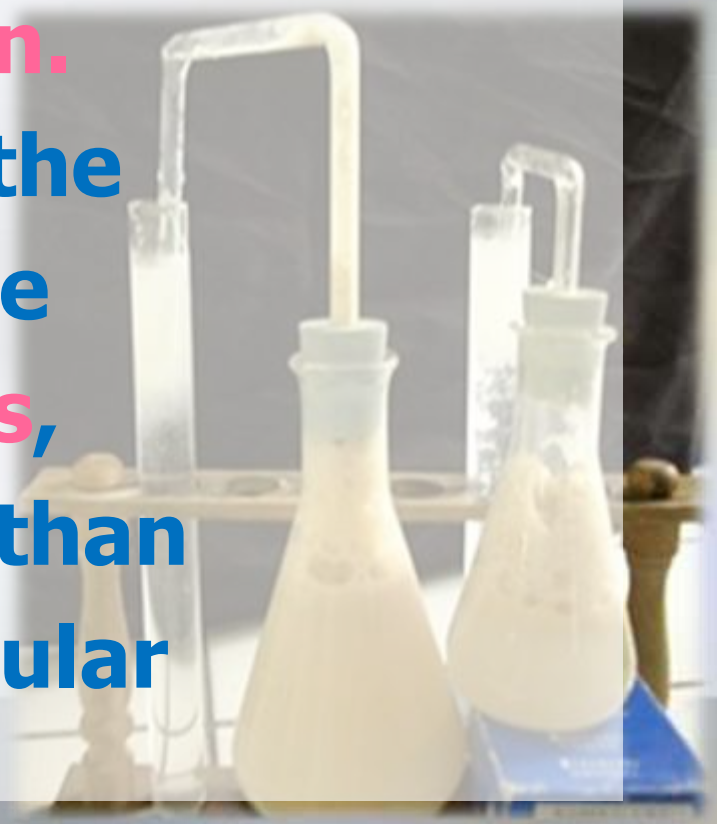
- **In anaerobic cellular respiration, the only step of this process that occurs is glycolysis.**

What is fermentation?

- Derived from the Latin verb '*fervere*' meaning 'to boil'

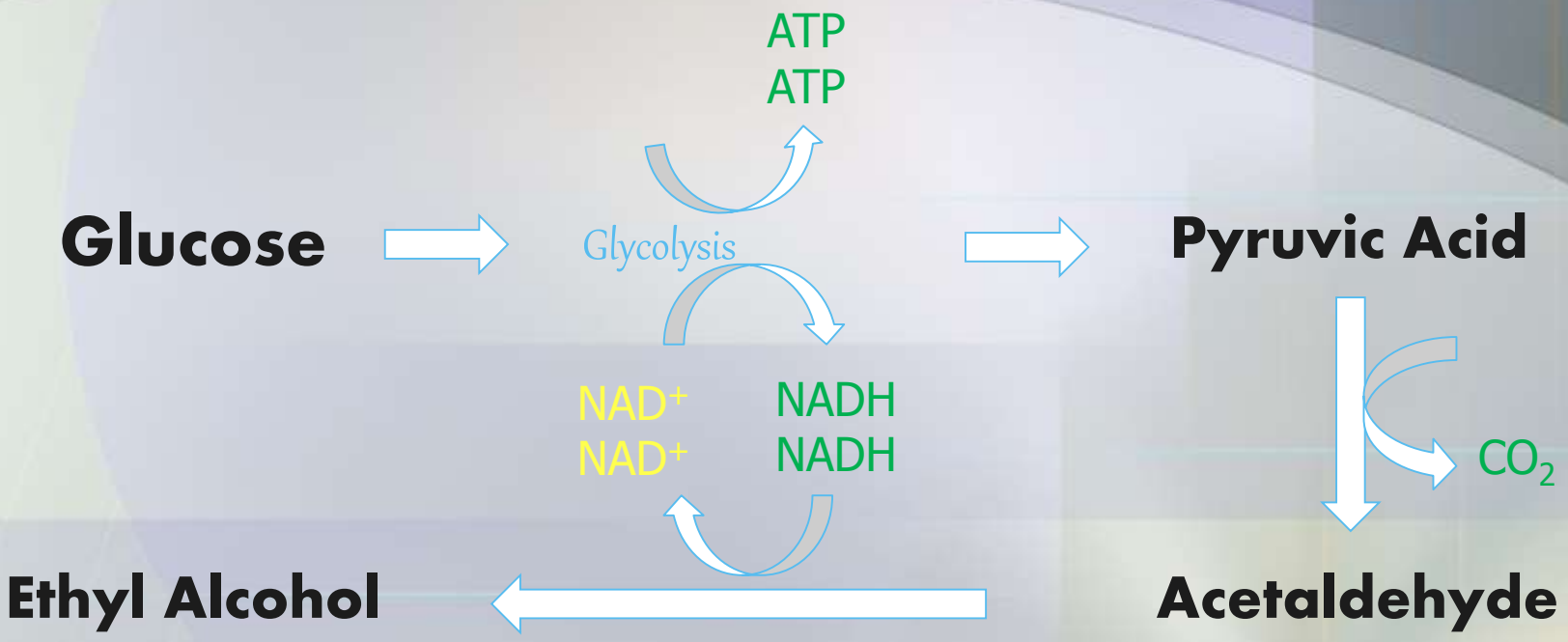
What is fermentation?

- It is a process by which the living cell is able to obtain energy through the breakdown of glucose and other simple sugar molecules without requiring oxygen.
- Fermentation results in the production of energy in the form of two ATP molecules, and produces less energy than the aerobic process of cellular respiration .



- **Louis Pasteur in the 19th century used the term fermentation in a narrow sense to describe the changes brought about by yeasts and other microorganisms growing in the absence of air (anaerobically);**
- **he also recognized that ethyl alcohol and carbon dioxide are not the only products of fermentation.**

Alcoholic Fermentation



Alcoholic fermentation of glucose

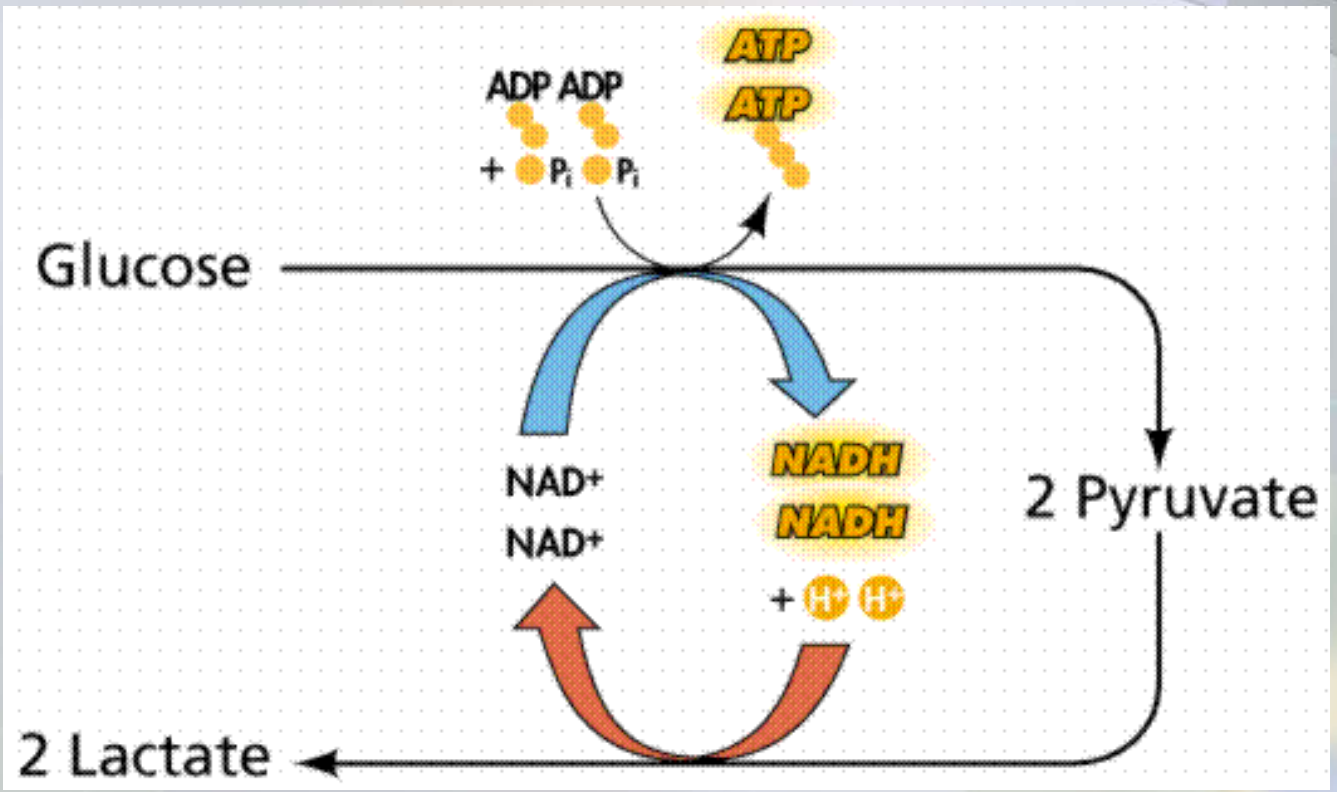
$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

glucose — ethanol — carbon dioxide

Lactic Acid Fermentation

- In lactic acid fermentation, the pyruvic acid from glycolysis is reduced to lactic acid by NADH, which is oxidized to NAD^+. This commonly occurs in muscle cells. Lactic acid fermentation allows glycolysis to continue by ensuring that NADH is returned to its oxidized state (NAD^+).

Lactic Acid Fermentation



The range of fermentation process

There are five major groups of commercially important fermentations:

(i) Those that produce microbial cells (or biomass) as the product.

(ii) Those that produce microbial enzymes.

(iii) Those that produce microbial metabolites.

(iv) Those that produce recombinant products.

(v) Those that modify a compound which is added to the fermentation the transformation process.

THE COMPONENT PARTS OF A FERMENTATION PROCESS

(i) The formulation of media to be used in culturing the process organism during the development of the inoculum and in the production fermenter.

(ii) The sterilization of the medium, fermenters and ancillary equipment.

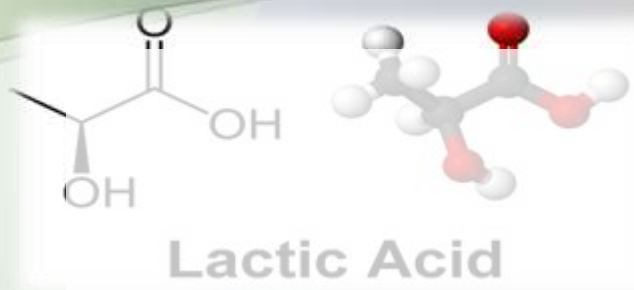
(iii) The production of an active, pure culture in sufficient quantity to inoculate the production vessel.

(iv) The growth of the organism in the production fermenter under optimum conditions for product formation.

(v) The extraction of the product and its purification.

(vi) The disposal of effluents produced by the process.

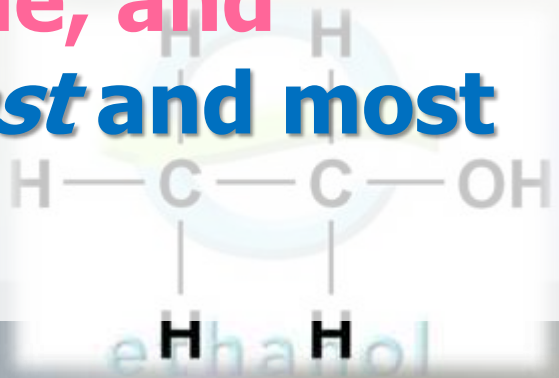
Products of Fermentation



Lactic Acid

The end products of fermentation differ depending on the organism.

- **lactic acid and lactate, carbon dioxide, and water – produced from many *bacteria, fungi, protists, and animals cells* (notably muscle cells in the body)**
- **ethyl alcohol, carbon dioxide, and water – produced from *yeast* and most *plant cells***

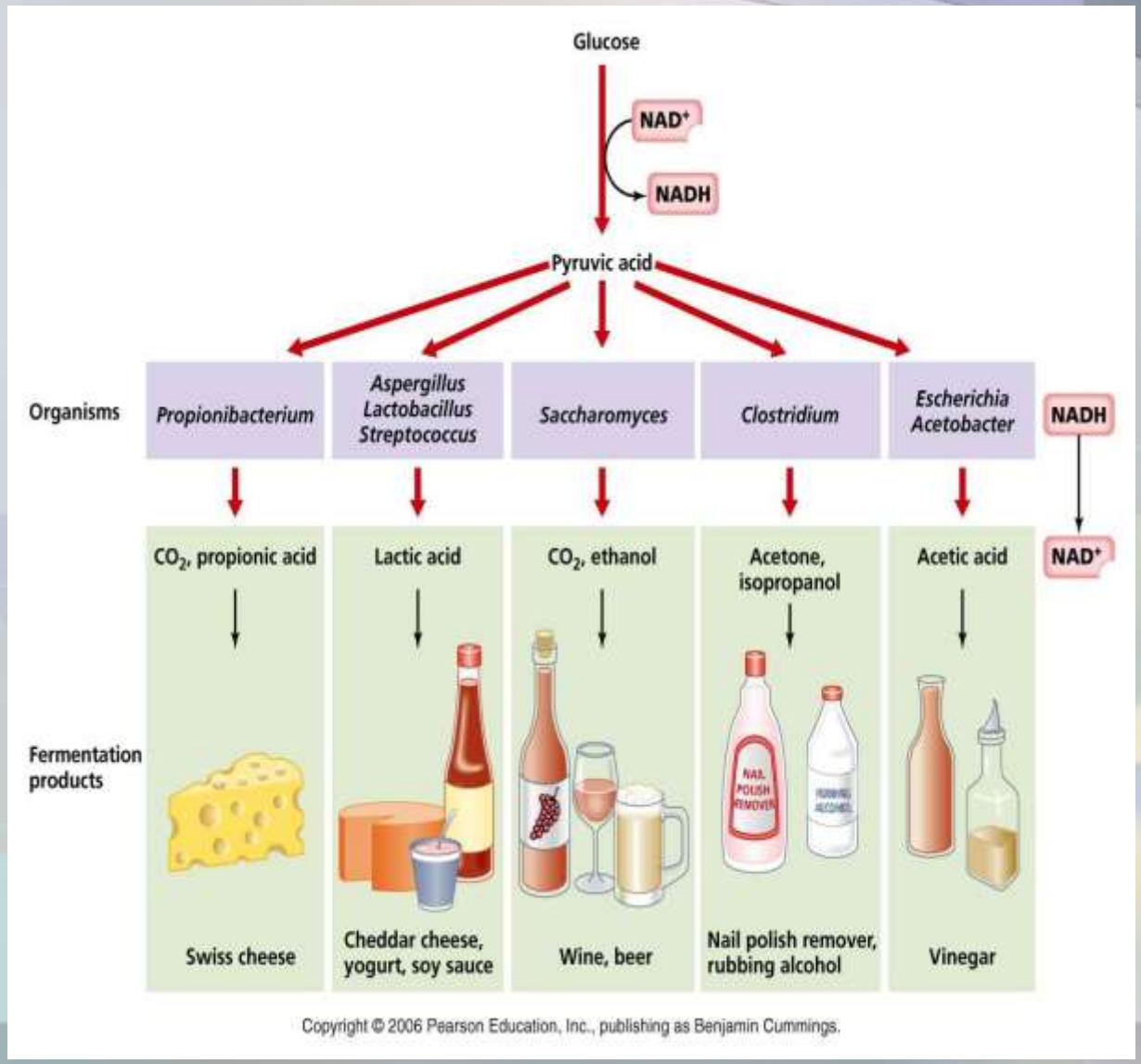


Products of Fermentation

Fermentation products include:

- **Food products: from milk (yogurt, kefir, fresh and ripened cheeses), fruits (wine, vinegar), vegetables (pickles, sauerkraut, soy sauce), meat (fermented sausages, salami)**
- **Industrial chemicals: (solvents: acetone, butanol, ethanol, enzymes, amino acids)**
- **Specialty chemicals (vitamins, pharmaceuticals)**

Products of Fermentation



FERMENTATION PROCESSES IN FOODS

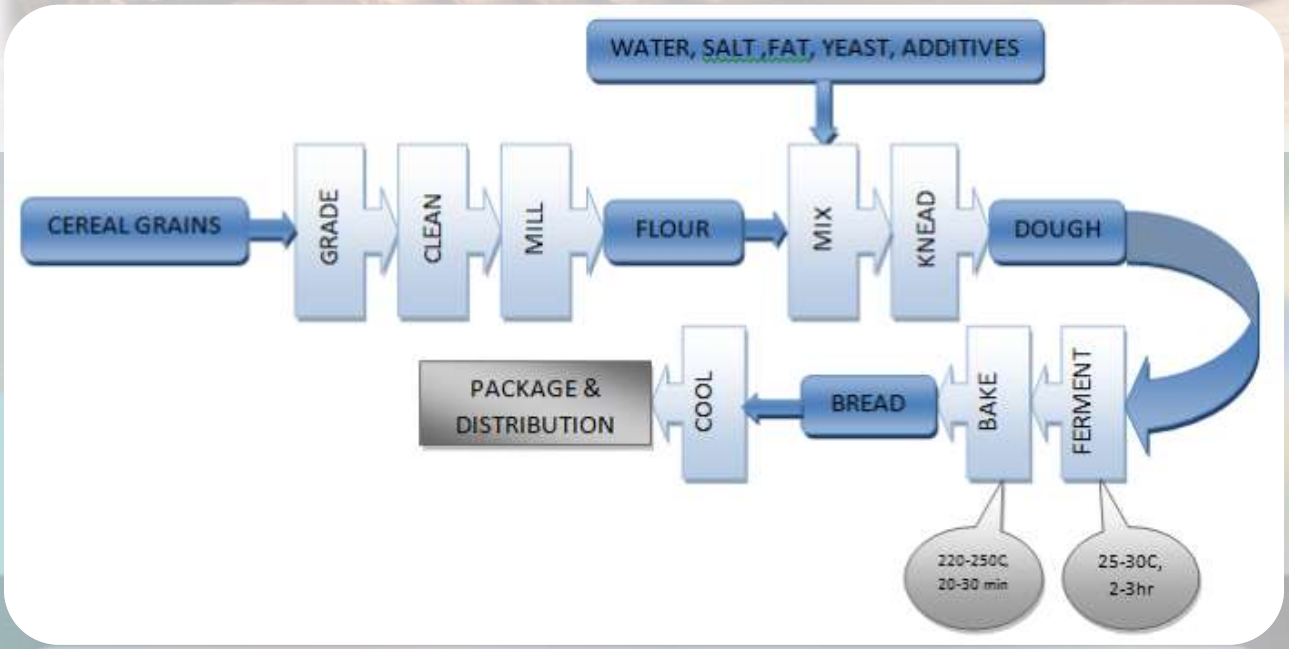
"fermentation, far from being a lifeless phenomenon, is a living process…"

- Louis Pasteur

Bread

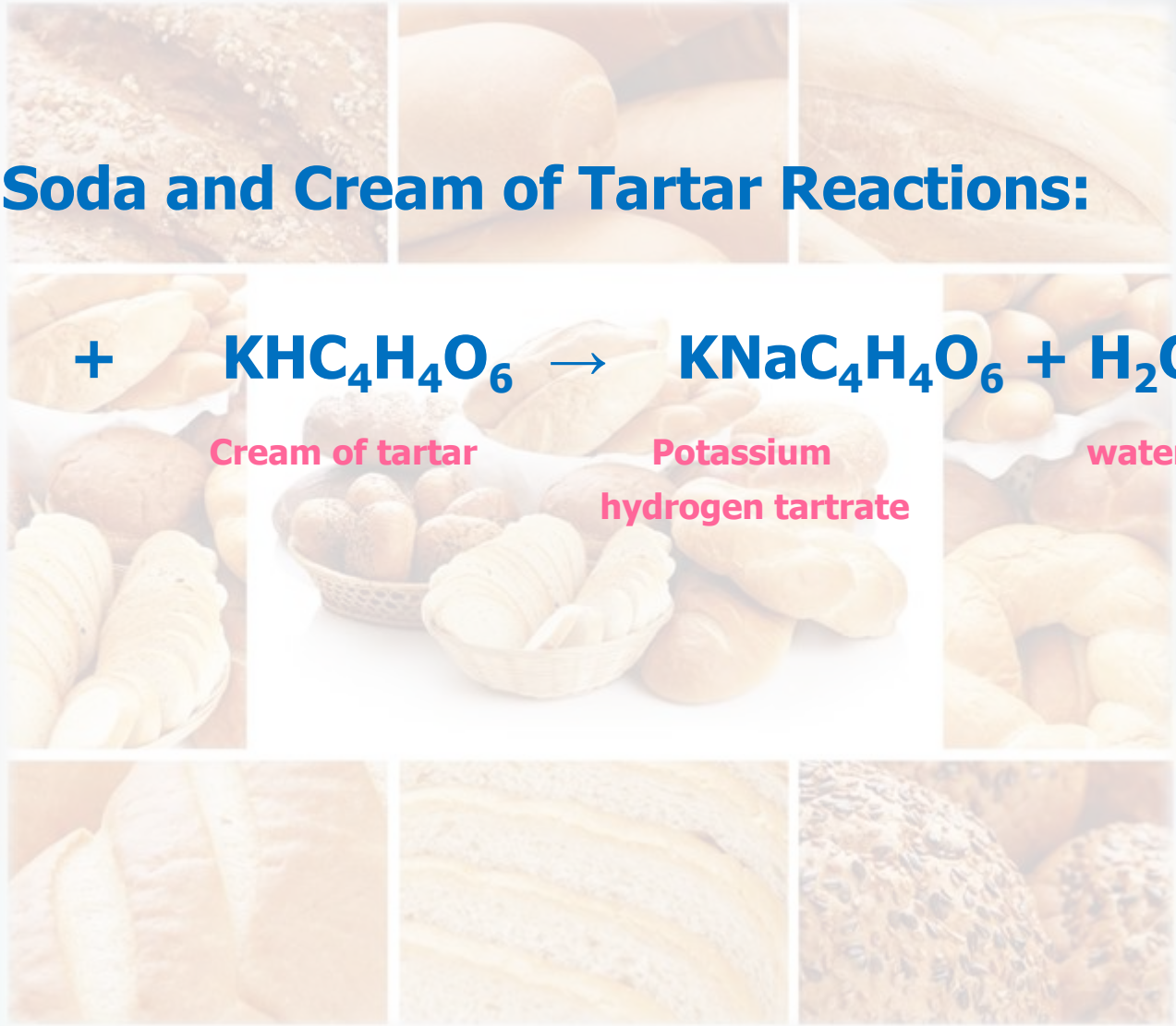
- It is a simple fermentation of sugar to CO_2 and alcohol.
- The steps in bread production are (1) preparation of raw materials; (2) dough fermentation and kneading; (3) processing of the dough (fermentation, leavening, dividing, moulding and shaping); (4) baking; (5) final treatments, such as slicing and packaging.

PROCESS FLOW



Bread

- **Baking Soda and Cream of Tartar Reactions:**



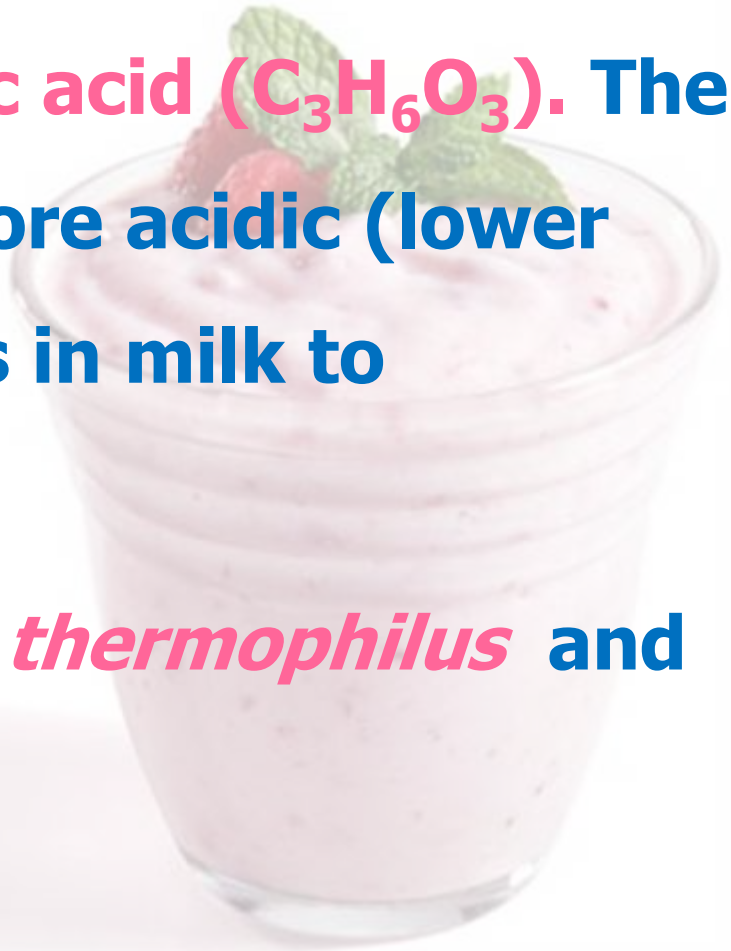
$$NaHCO_3 + KHC_4H_4O_6 \rightarrow KNaC_4H_4O_6 + H_2O + CO_2$$

Baking soda — Cream of tartar — Potassium hydrogen tartrate — water — carbon dioxide

Yogurt

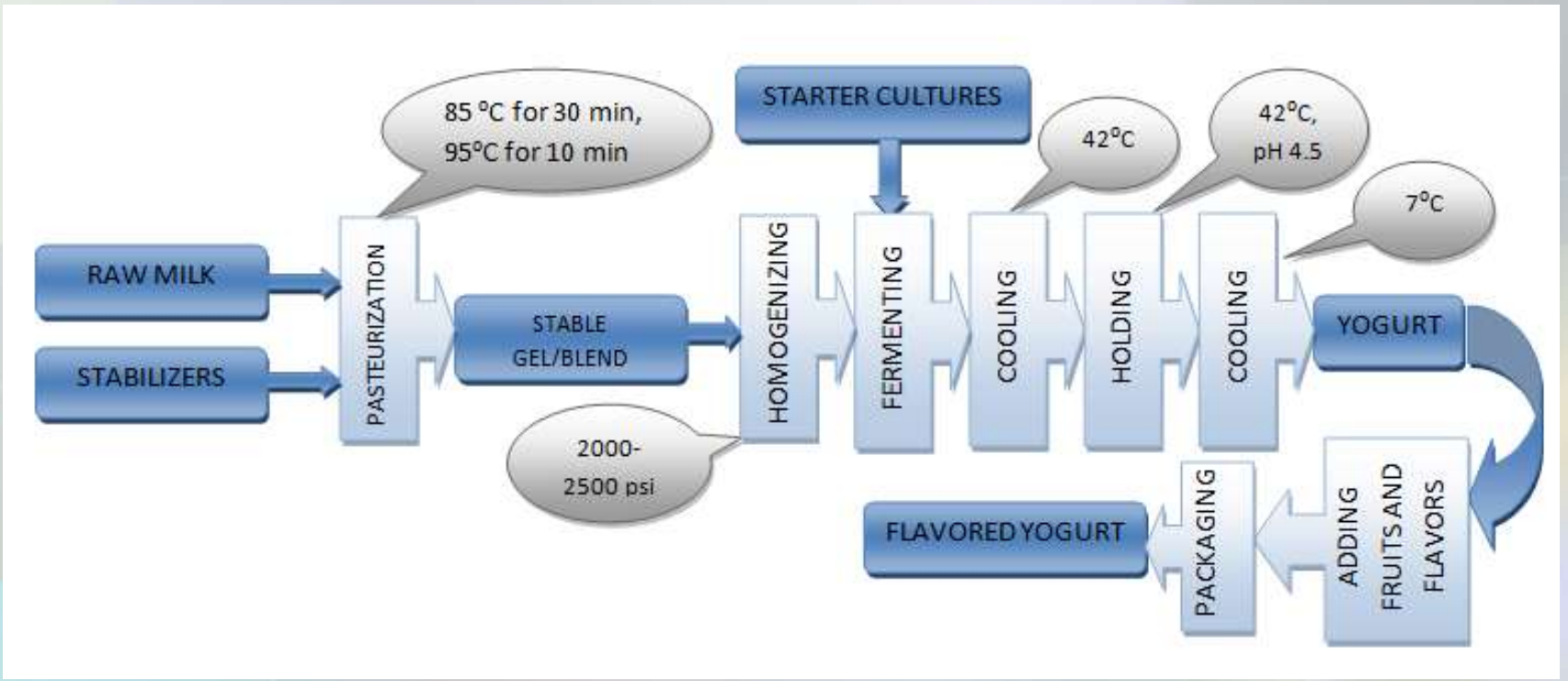
Yogurt forms when bacteria ferment the sugar lactose ($C_{12}H_{22}O_{11}$) into lactic acid ($C_3H_6O_3$). The lactic acid makes the milk more acidic (lower the pH), causing the proteins in milk to coagulate.

Two bacteria: *Streptococcus thermophilus* and *Lactobacillus bulgaricus*



Yogurt

Process Flow



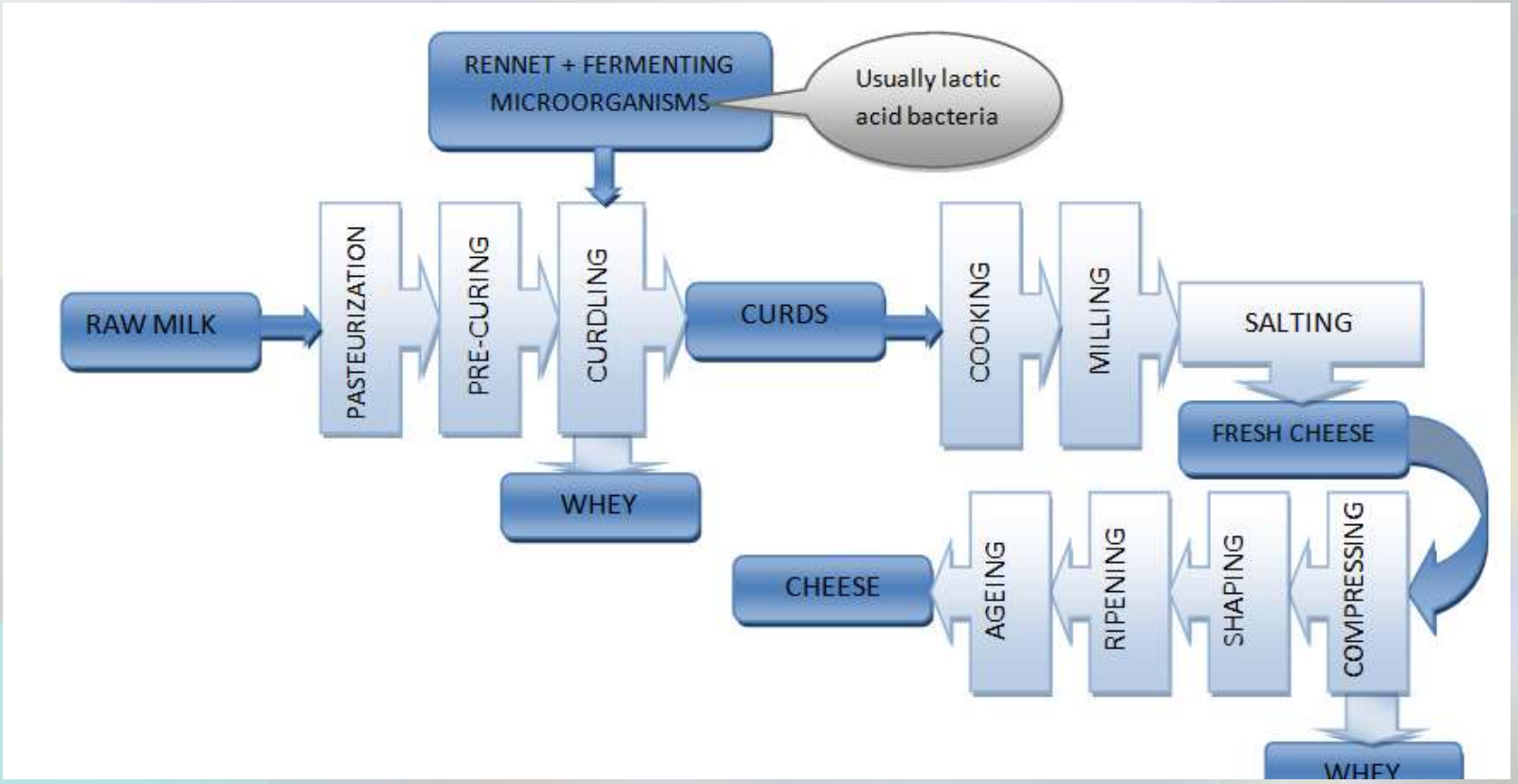
Cheese

Reaction :

$$\text{casein} \xrightarrow{\text{rennet}} \text{para-casein}_{(aq)} \xrightarrow{Ca^{++}} \text{para-casein}_{(ppt)}$$

Cheese

Process Flow



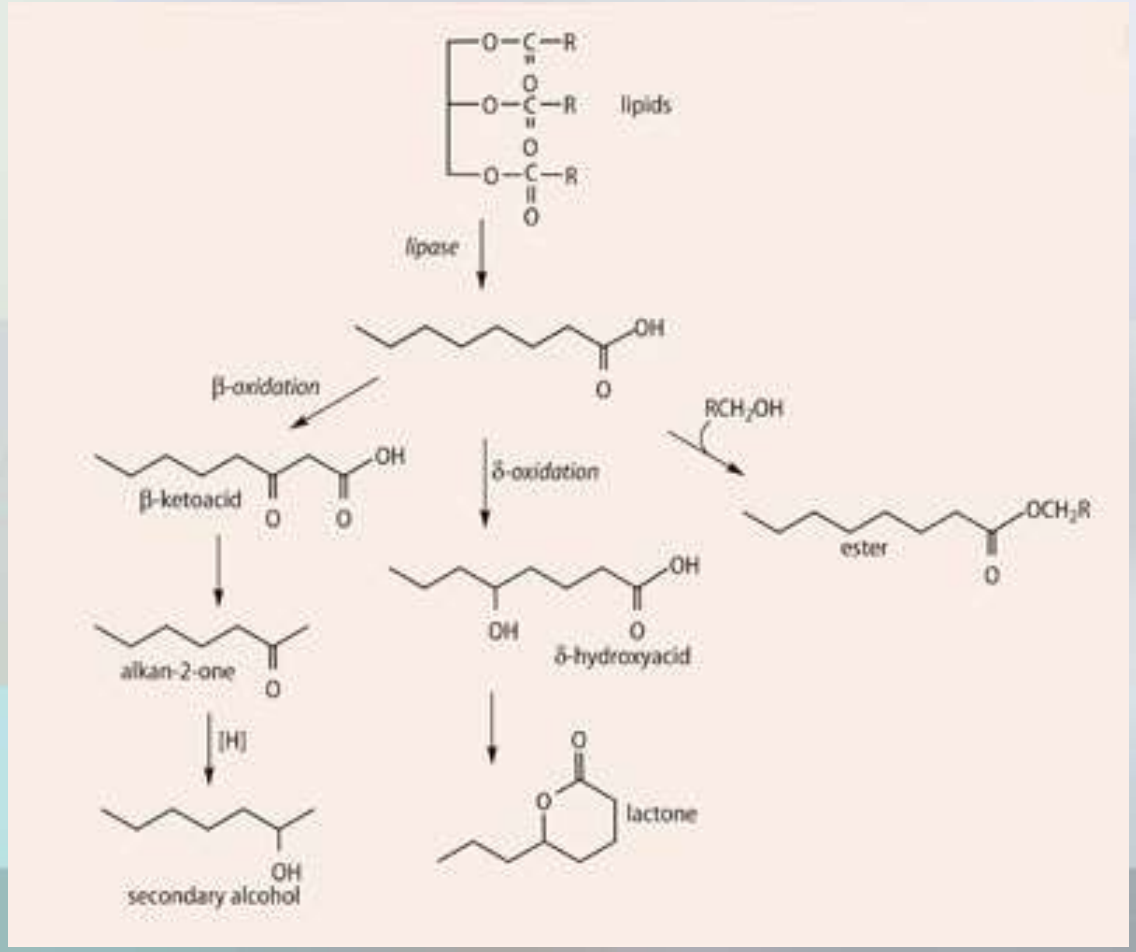
Cheese

Table 1 Breakdown products of major milk components.

Casein	Milk fat	Lactose
Ammonia	Carboxylic acids	Butane-2,3-dione
Ethanoic acid	β-hydroxy acids	Ethanal
Aldehydes	β-keto acids	Ethanoic acid
Alcohols	Methyl ketones	Ethanol
Carboxylic acids	Lactones	
Sulfur compounds		

Cheese

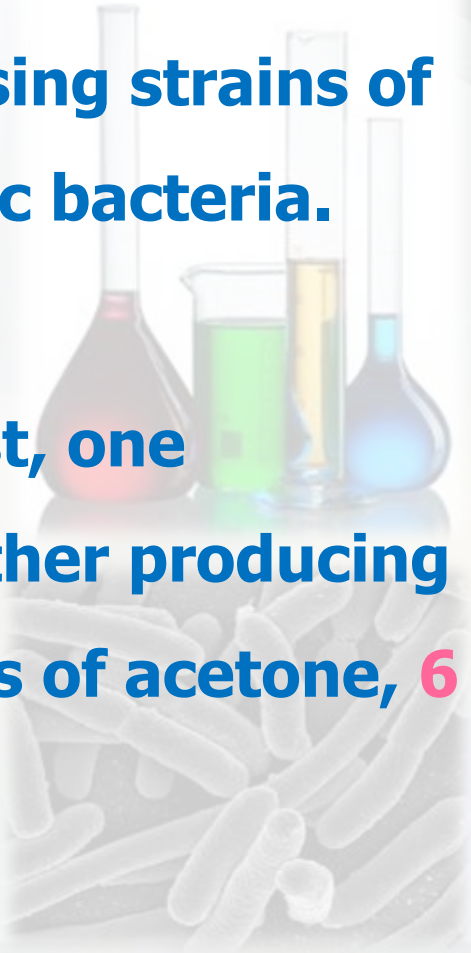
The breakdown of the lipids in milk yields carboxylic acids, the source of a range of smelly molecules.



FERMENTATION PROCESSES IN INDUSTRIAL CHEMICALS

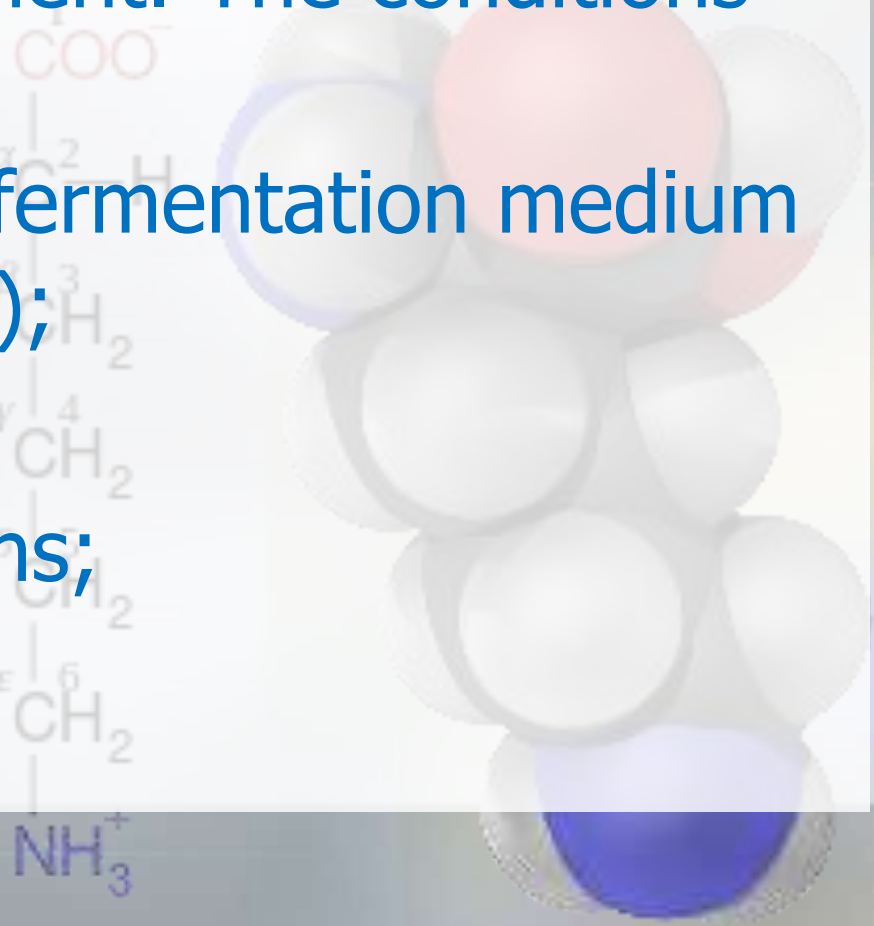
Acetone-Butanol- Ethanol (ABE) Fermentation

- In acetone-butanol fermentation, acetone and butanol are produced from glucose using strains of *Clostridia*, which are strictly anaerobic bacteria. Further, ethanol is also produced.
- Two distinct metabolic pathways exist, one producing butanol from starch, the other producing butanol from sucrose. It yields 3 parts of acetone, 6 of butanol and 1 of ethanol.

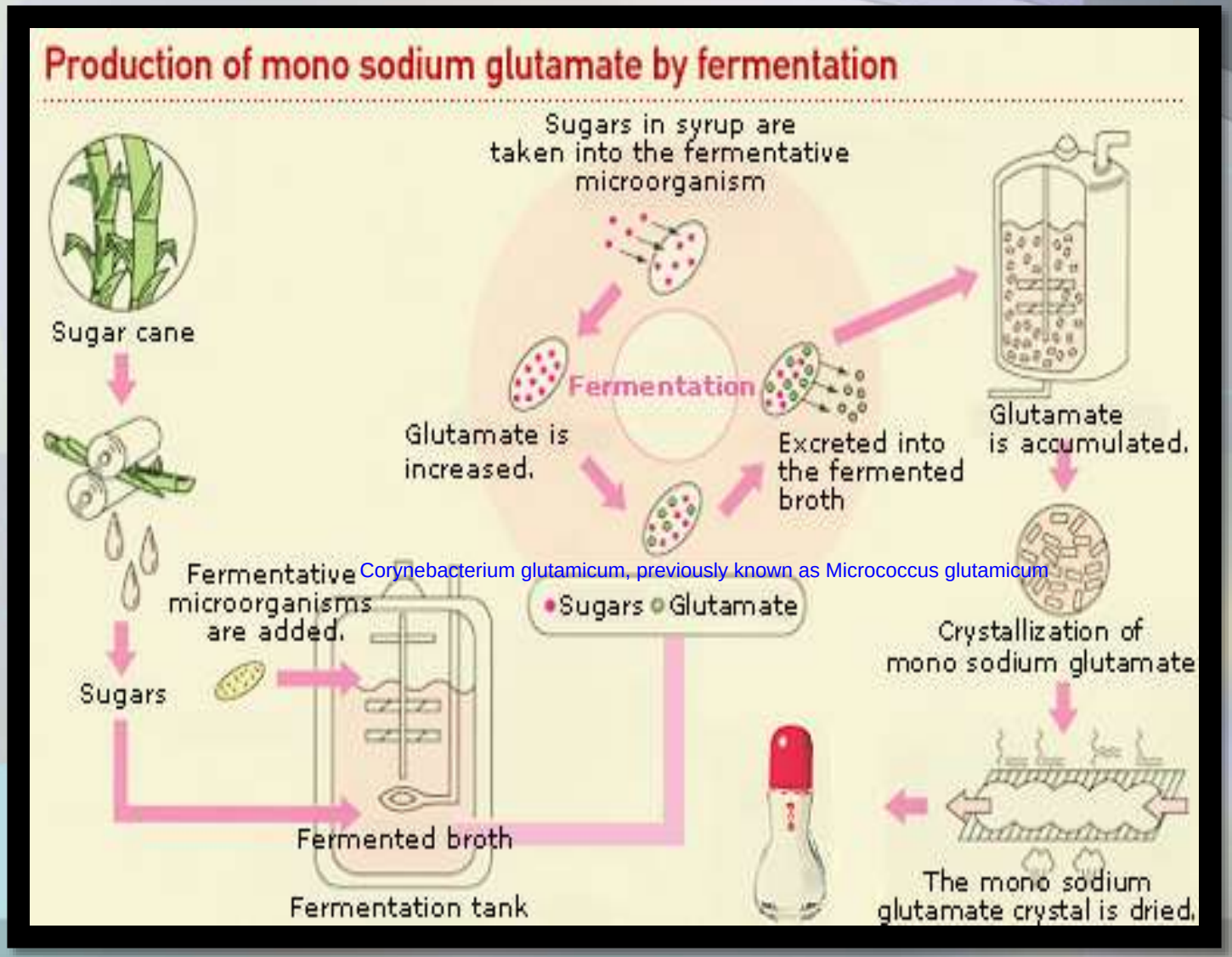


Amino acid fermentation

- The growth of **micro-organisms** used in the production ***of*** **amino** acids is done in a well balanced environment. The conditions *required* **are:**
- a controlled pH of the fermentation medium (approximately neutral);
- Rich growth media;
- highly aerobic conditions;
- sterile conditions



Monosodium Glutamate



Thank You!

By: Nina Vanessa A. Sabelita