Food Microbiology

Subject: Food & Dairy Microbiology
Subject Code: MMB-402

Anita Saini
Assistant Professor (Microbiology)
School of Basic & Applied Sciences
Maharaja Agrasen University, Baddi
Solan, HP , India

Contents

- Introduction to Food Microbiology
- Sources of Microorganisms in Foods
- Factors Influencing Microbial Growth in Food
- Beneficial Uses of Microorganisms in Food

Food Microbiology

Study of microbiological aspects of food science. It involves study of:

- Microbial sources in Raw and Cooked Foods
- Growth of Microorganisms in Different Food Materials
- Use of Microorganisms in Making Different Food Materials
- Harmful effects of microorganisms in food materials:-
  - Food Spoilage
  - Foodborne Diseases
- Prevention of food contamination and methods for control of microbial growth in foods

Progress in Food Microbiology

Before 1970s:

- Food microbiology was regarded as an ***applied science*** which was mainly involved in the microbiological ***quality control*** *(control and prevention of contamination)* of food.

- After that, the technology developments happened, e.g., ***advancements in food production, food processing, food packaging***, etc.

Modern-day food microbiology:

- Includes study of all above technological developments along with better ***quality control***.

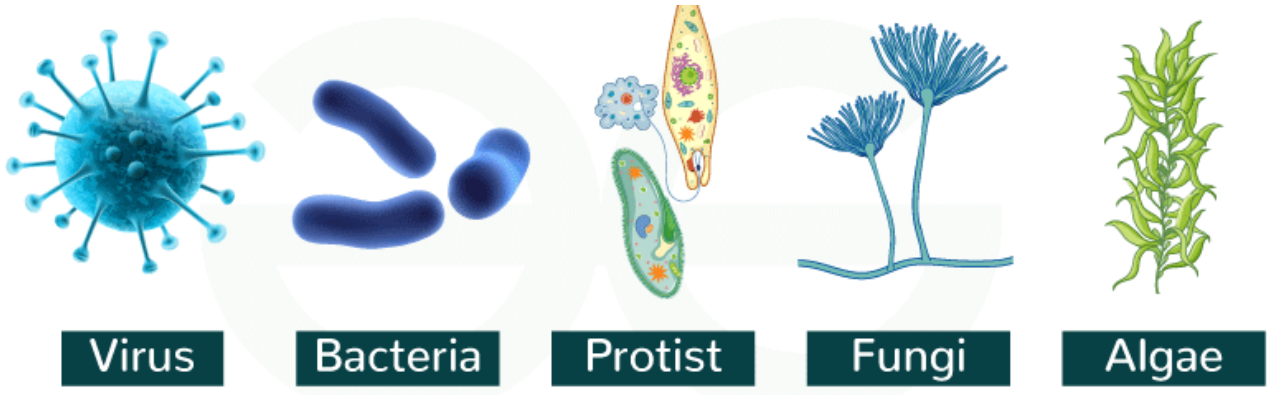
- Advancements are based on knowledge from interdisciplinary sciences (biotechnology, molecular biology, genetics, cell biology, fermentation technology, detection systems, etc).

- Availability of basic information on the physiological, biochemical, and biological characteristics of diverse types of food, microbial interactions in food environments and microbial physiology, biochemistry, genetics, and immunology has helped open new frontiers in food microbiology.

Microorganisms are living entities of microscopic size and include:

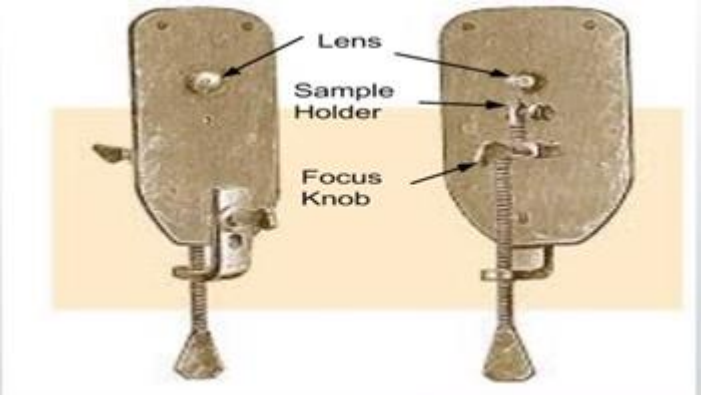
- bacteria,
- viruses,
- yeasts and molds (together designated as fungi),
- algae, and
- protozoa.

Among the microorganisms, some molds, yeasts, bacteria, and viruses have both **desirable** and **undesirable roles** in our food.

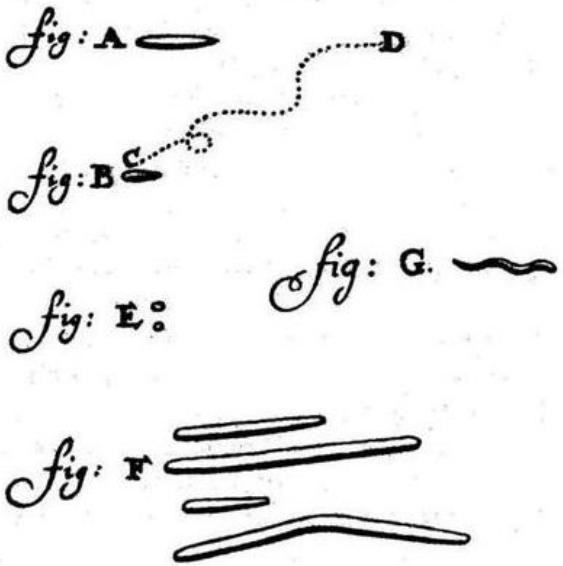


Discovery of Microorganisms

- Leeuwenhoek's discovery of Microscope
- Under a microscope that probably had a magnification power near 300x
- He observed bacteria in saliva, rainwater, vinegar, and other materials; sketched the three morphological groups (spheroids or cocci, cylindrical rods or bacilli, and spiral or spirilla); and also described some to be motile.
- He called them ***animalcules***, and between 1676 and 1683 he reported his observations to the newly formed leading scientific organization, ***The Royal Society of London***, where his observations got recognition.



Shapes and Motility Path of Animalcules



- Viruses were not identified until 1898 when a solution from which bacteria had been removed by filtration was still able to transmit disease.

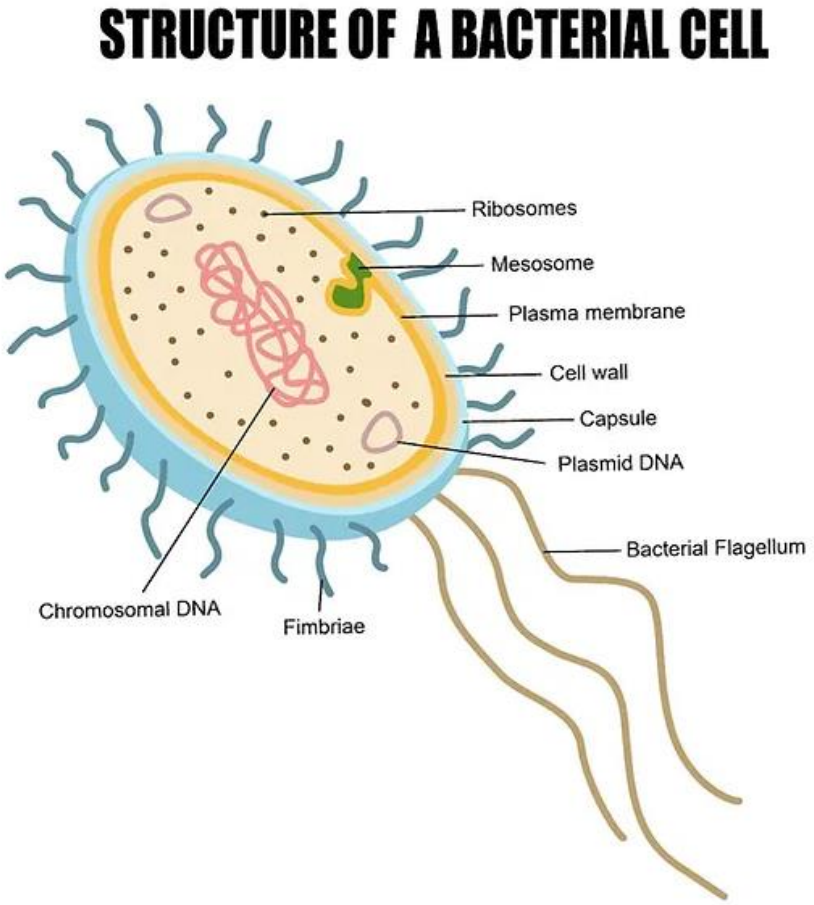
Major Microbes Found in Food

- ***Bacteria*** are unicellular, prokaryotic microorganisms that have size in micrometers range.

- Cytoplasmic materials are enclosed in a rigid **cell wall** on the surface and a **cell membrane** beneath the wall.

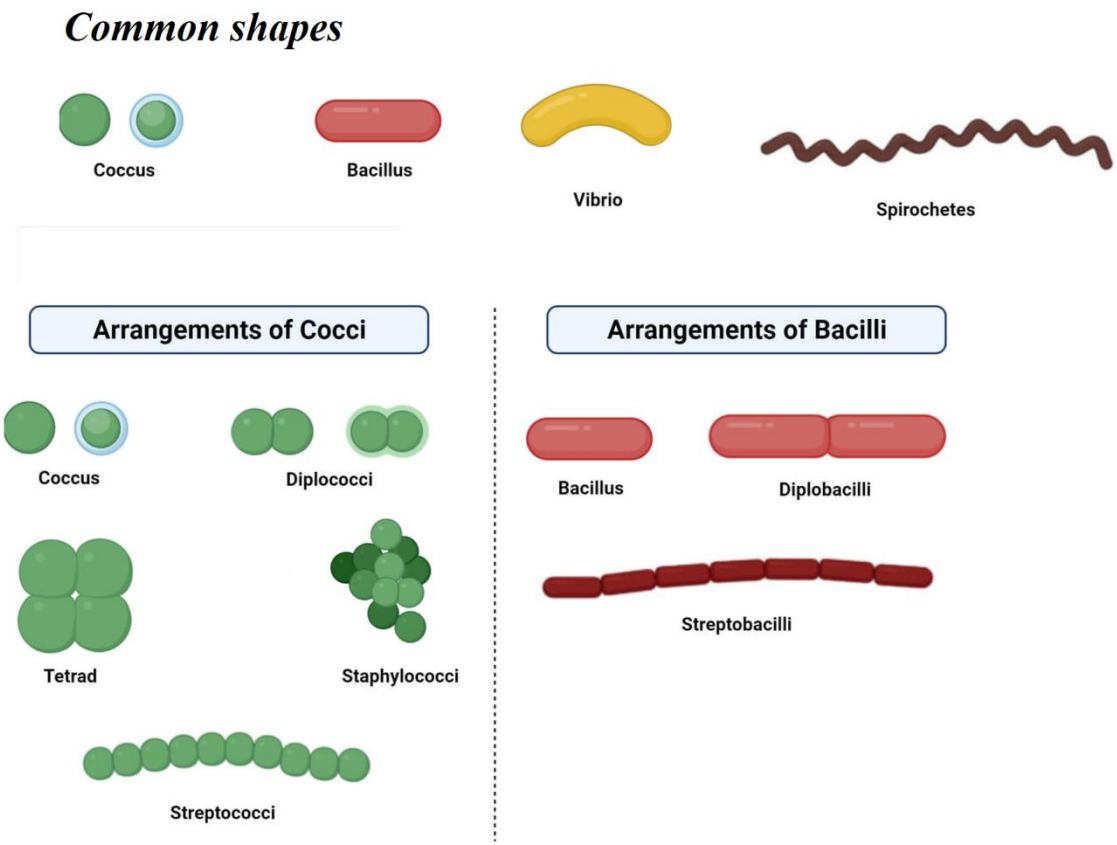
- The **ribosomes** are **70S** type and are dispersed in the cytoplasm.

- The genetic material (**DNA**) is circular, *not* enclosed in nuclear membrane, and do not contain basic proteins such as histones (No NUCLEUS).



DNA is coiled and present directly in cytoplasm in a region called as nuceloid.

- They may exist in different shapes such as most spherical (cocci), rod shaped (bacilli), curved (comma), and spiral, etc.
- They can form associations such as clusters, pairs, chains, or tetrads, etc.
- They can be motile (with flagella) or non-motile (without flagella) .



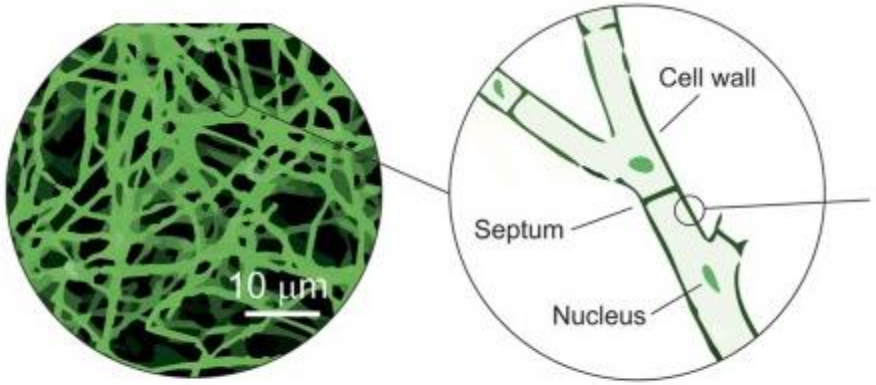
Yeasts and Molds

- Both yeasts and molds are eukaryotic, but yeasts are unicellular whereas molds are multicellular.

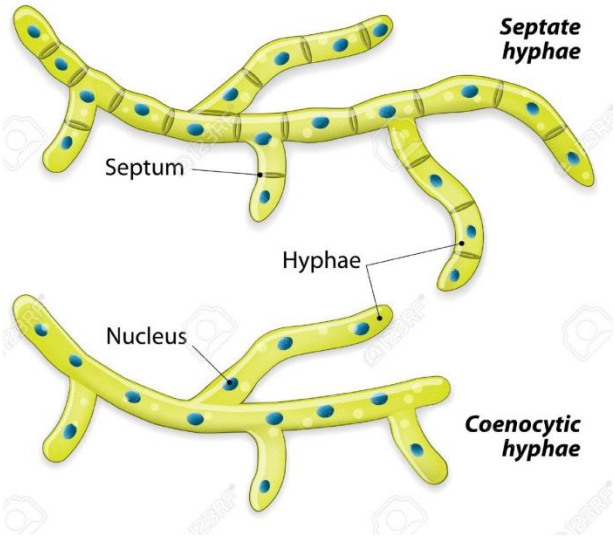
- Eukaryotic cells have:-
  - rigid cell walls
  - thin plasma membrane
  - Membrane bound organelles
  - Nucleus
  - Chromosomes with histones
  - 80S ribosomes, etc.

Molds are non-motile, ***filamentous***, and ***branched***.

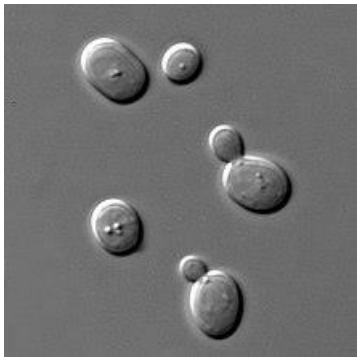
- The cell wall is mainly composed of ***chitin***.
- A mold (thallus) is composed of large numbers of filaments called ***hyphae***. An aggregate of hyphae is called ***mycelium***. A hypha can be ***non-septate, septate-uninucleate, or septate-multinucleate***.
- A hypha can be ***vegetative*** or ***reproductive***.
- The ***reproductive*** hypha usually extends in the air and
- form ***exospores***, either ***free*** (***conidia***) or in a ***sack*** (***sporangium***).
- Shape, size, and color of spores are used for taxonomic classification.



Mycelium **Hypha**

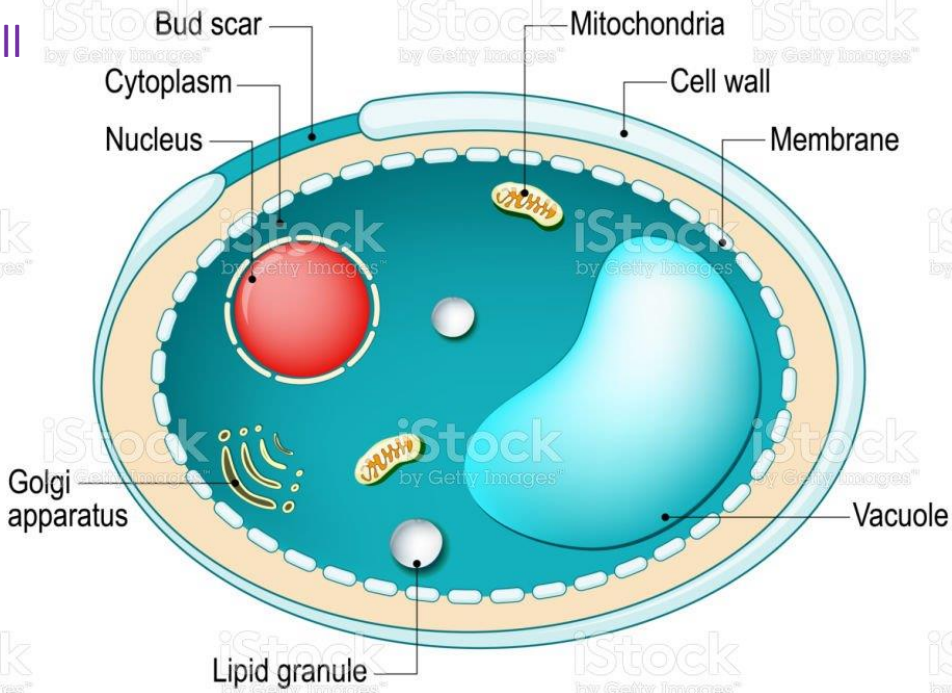


Yeasts are non-motile



- Cells are oval, spherical, or elongated, about 5–30 x 2^{-10} mm in size.
- The cell wall contains polysaccharides (glycans), proteins, and lipids.
- Show budding under favorable conditions and multiply rapidly.

Yeast Cell



Viruses

- May also be found in food materials.
- They are acellular entities.
- The viruses have a nucelocapsid structure, i.e., genetic material (DNA or RNA) surrounded by protein capsid.
- In enveloped viruses, an additional layer is also be present outside the nucelocapsid.
- They play role in different food-borne diseases.

Sources of Microorganisms in Foods

Microorganisms are present everywhere on Earth, including:-

- humans,
- animals,
- plants and
- other living creatures,
- soil,
- water, and
- atmosphere.

They can multiply everywhere except in the atmosphere.

Together, their numbers far exceed all other living cells on this planet.

They were the first living cells to inhabit the Earth more than 3 billion years ago and since then have played important roles, many of which are beneficial to other living systems.

Sources: Natural and External

Plants

- surfaces of fruits, vegetables, and grains,
- pores in some tubers (e.g., radish and onion)

Animals

- skin, hair, feathers, gastrointestinal tract, urinogenital tract, respiratory tract, and milk ducts (teat canal) in udders of milk animals

Air, soil, sewage, water, feeds, humans, food ingredients, equipment, packages, and insects

Natural microflora exist in ecological balance with their hosts, and their types and levels vary greatly with the type of plants and animals as well as their geographical locations and environmental conditions.

Microbial types and their levels from external sources vary widely and depend on the degree of sanitation used during the handling of foods.

Factors Influencing Microbial Growth in Food

A. Nutrients in Food

- Microbes associate with food materials derive nutrients for their growth from the food itself.
- These nutrients include carbohydrates, proteins, lipids, minerals, and vitamins.
- Water is not considered a nutrient, but it is essential as a medium for the biochemical reactions necessary for the synthesis of cell mass and energy.
- All foods contain these five major nutrient groups, either naturally or added, and the amount of each nutrient varies greatly with the type of food.
- In general, meat is rich in protein, lipids, minerals, and vitamins but poor in carbohydrates.
- Foods from plant sources are rich in carbohydrates but can be poor sources of proteins, minerals, and some vitamins.
- Some foods such as milk and many prepared foods have all five nutrient groups in sufficient amounts for microbial growth.

Carbohydrates

- Monosaccharides
  - Hexoses: glucose, fructose, mannose, galactose
  - Pentoses: xylose, arabinose, ribose, ribulose, xylulose
- Disaccharides
  - Lactose (galactose + glucose)
  - Sucrose (fructose + glucose)
  - Maltose (glucose + glucose)
- Oligosaccharides
  - Raffinose (glucose + fructose + galactose)
  - Stachyose (glucose + fructose + galactose + galactose)
- Polysaccharides
  - Starch (glucose units)
  - Glycogen (glucose units)
  - Cellulose (glucose units)
  - Inulin (fructose units)
  - Hemicellulose (xylose, galactose, mannose units)
  - Dextrans (α-1, 6 glucose polymer)
  - Pectins
  - Gums and mucilages

Lactose is found only in milk and thus can be present in foods made from or with milk and milk products. Glycogen is present in animal tissues, especially in liver. Pentoses, most oligosaccharides, and polysaccharides are naturally present in foods of plant origin.

- Simple food proteins are polymers of amino acids, such as ***albumins*** (in egg), ***globulins*** (in milk), ***glutelins*** (gluten in cereal), and ***albuminoids*** (collagen in muscle). These all are source of nutrients for microbial growth.
- ***Lipids*** in foods include free fatty acids, glycerides, phospholipids, waxes, and sterols.
- Lipids are relatively higher in foods of animal origin than in foods of plant origin, although nuts, oil seeds, coconuts, and olives have high amounts of lipids.
- Most foods have ***elements*** required for microbial growth in sufficient amounts. Examples include phosphorous, calcium, magnesium, iron, sulfur, manganese, and potassium.
- Many microorganisms can synthesize B ***vitamins***, and foods also contain most B vitamins.
- In general, most foods contain different carbohydrates, proteins, lipids, minerals, and vitamins in sufficient amounts to supply necessary nutrients for the growth of molds, yeasts, and bacteria, especially Gram-negative bacteria normally present in foods.

Water Activity (A_w) of Food

- Water activity (A_w) is a measure of the water available for biological functions of microbes.
- The free water in a food is necessary for microbial growth. It is necessary to transport nutrients and remove waste materials, carry out enzymatic reactions, synthesize cellular materials, and take part in other biochemical reactions, such as hydrolysis of a polymer to monomers (proteins to amino acids).
- Each microbial species (or group) has an optimum, maximum, and minimum A_w level for growth.
- In general, the minimum A_w values for growth of different microorganisms is:-
  - most molds: 0.8
  - most yeasts: 0.85
  - most Gram-positive bacteria: 0.90
  - Gram-negative bacteria: 0.93

pH:

- Most *fruits, fruit juices, fermented foods* (from fruits, vegetables, meat, and
- milk), and salad dressings are high-acid (*low-pH*) foods, whereas most vegetables, meat, fish, milk, and soups are low-acid (*high-pH*) foods. Tomato, however, is a high-acid vegetable (pH 4.1 to 4.4).
- The acid in the foods can either be present naturally (as in fruits), produced during fermentation (as in fermented foods), or added during processing (as in salad dressings).
- Each microbial species has an optimum and a range of pH for growth which decides which microbes will grow in which food.

Temperature

- Foods are exposed to different temperatures from the time of production until consumption.
- Depending on processing conditions, a food can be exposed to high heat, from 65^0C (roasting of meat) to more than 100^rC (in ultrahigh temperature processing).

- For long-term storage, a food can be kept at 5^0C (refrigeration) to -20^0C or below (freezing).
- Some relatively stable foods are also kept between 10 and 35^0C (cold to ambient temperature).
- Microorganisms important in foods are divided into three groups on the basis of their temperature of growth, each group having an optimum temperature and a temperature range of growth:

✓ (1) ***thermophiles*** (grow at relatively high temperature): optimum 55^0C and range 45-70^0C

✓ (2) ***mesophiles*** (grow at ambient temperature):optimum at 35^0C and range 10 -45^0C;

✓ (3) ***psychrophiles*** (grow at cold temperature): optimum at 15^0C and range –5 to 20^0C.

When the foods are exposed to temperatures beyond the maximum and minimum temperatures of growth, microbial cells die rapidly at higher temperatures and metabolize relatively slowly at lower temperatures.

Beneficial Uses of Microorganisms in Food

The major concern of microbial presence in food is due to its undesirable properties. Most are able to spoil foods, and several are associated with foodborne health hazards. However, there are other microorganisms that have beneficial properties in food production, maintaining normal health of the gastrointestinal tract of humans and controlling the undesirable spoilage and pathogenic bacteria in food. The beneficial attributes of the desirable microorganisms are briefly discussed in this section through the following topics:

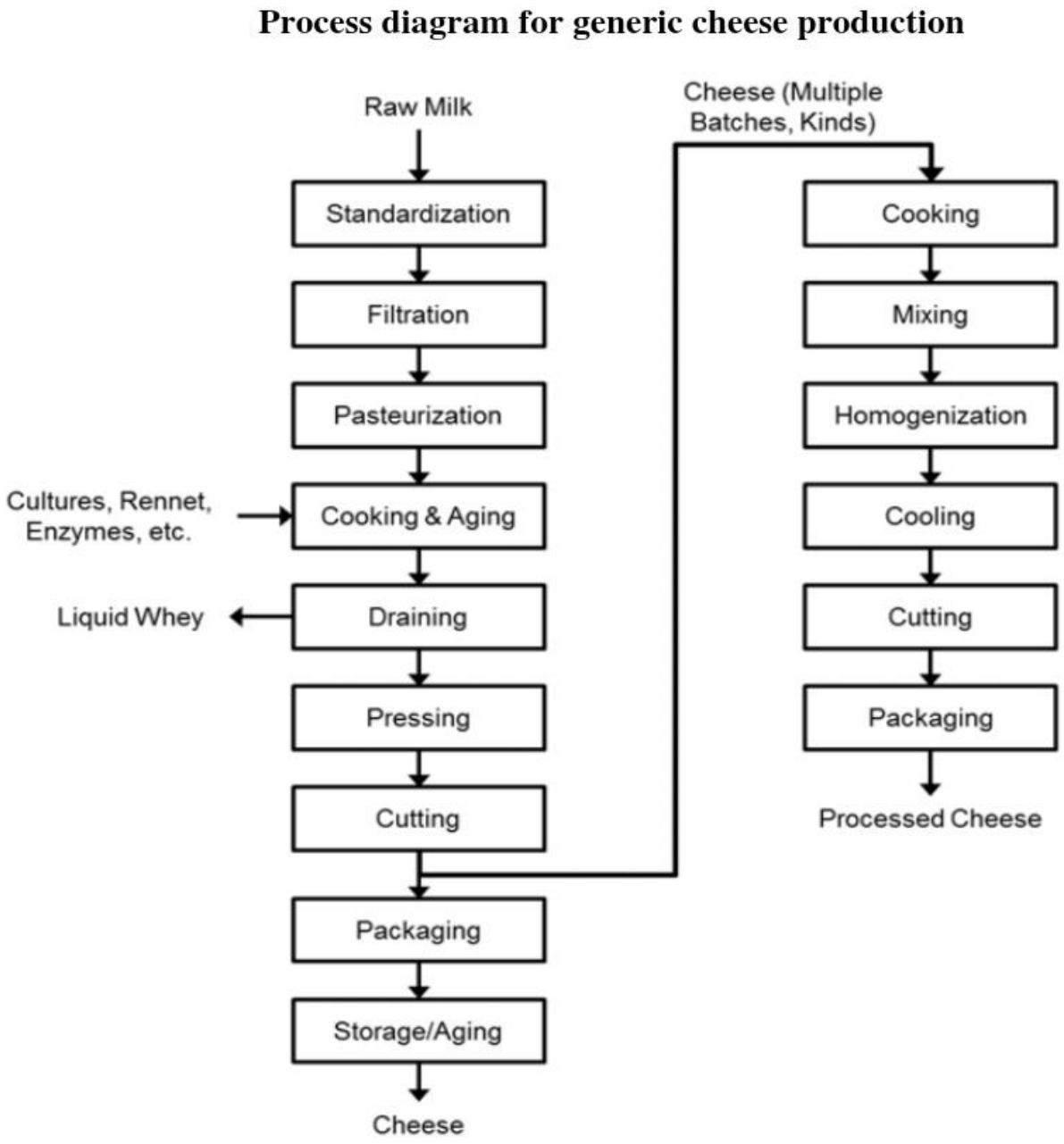
Microorganisms Used in Food Fermentation

Intestinal Beneficial Bacteria

Microorganisms used in production of other products such as food supplement (SCP, single cell protein), organic acids (lactic acid, acetic acid), alcohols (ethanol) that are used in food and beverage industries for different purposes.

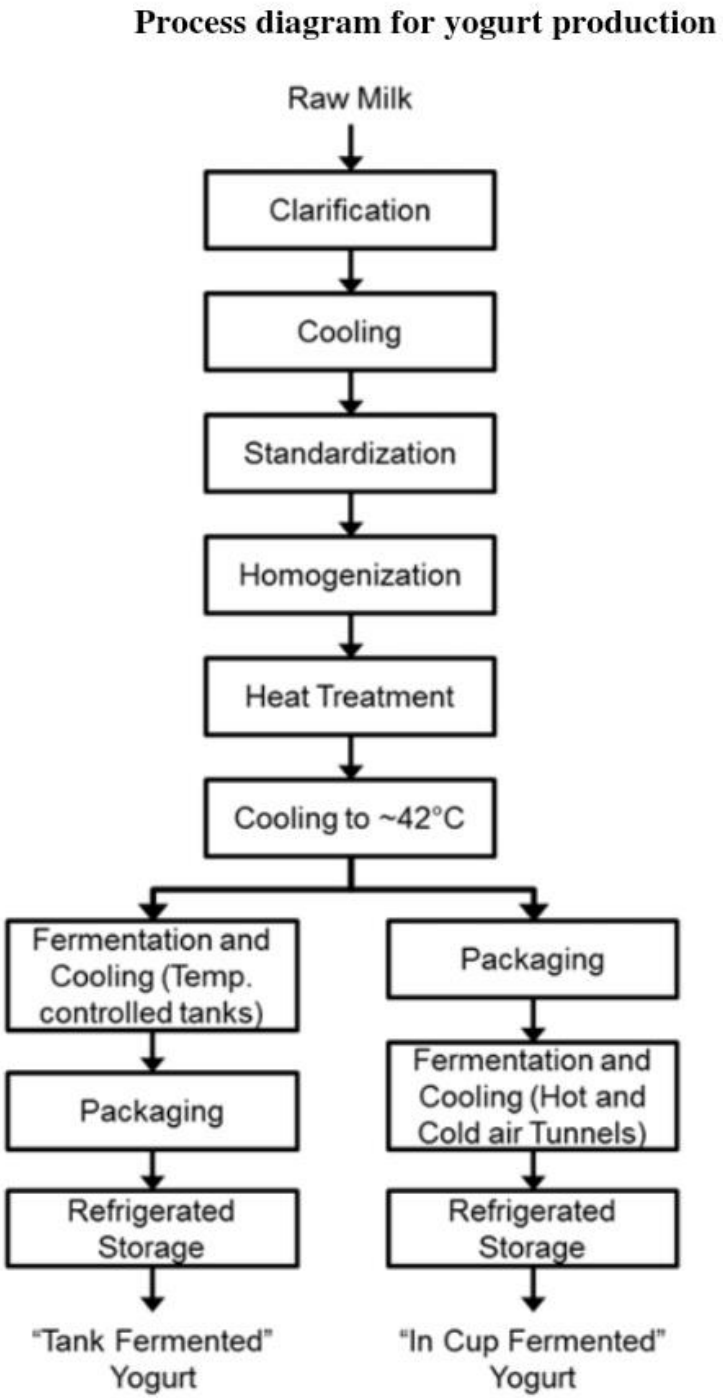
Lactococcus, Leuconostoc, Pediococcus, Streptococcus, Lactobacillus, Enterococcus, Aerococcus, etc } Dairy fermentation

- *Propionibacterium* spp is used for ***Swiss-type cheese*** fermentation
- Acetobacter aceti, is used to produce ***acetic acid*** from alcohol.
- *Saccharomyces cerevisiae:* used to leaven bread and produce ***beer, wine, distilled liquors, and industrial alcohol***; produce invertase (enzyme); and flavor some foods (soups)
- *Candida utilis* has been used to produce ***SCPs***.
- *Kluyveromyces marxianus* can hydrolyze lactose and have been associated with natural fermentation, along with other yeasts and lactic acid bacteria, of alcoholic dairy products such as ***kefir***.



Cheese-making microbes include many varieties of bacteria, yeast, and filamentous fungi (molds).

The most commonly added are lactic acid bacteria from the genera *Lactococcus* and *Lactobacillus*.



Yogurt formation is carried out mostly by lactic acid bacteria, including *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*.

During yogurt production, these bacteria produce lactic acid, decreasing pH and causing milk protein to coagulate.

Some microbial fermentations

Fermentation	Organisms	Products
Ethanol	Yeasts	Ethanol, CO_2
Lactate	*Streptococcus, Lactobacillus*	Lactate
Propionate	*Clostridium propionicum, Propionibacterium, Corynebacterium diphtheria*	Propionate, acetate, succinate, CO_2
Mixed acid	*Escherichia, Salmonella, Shigella, Proteus*	Lactate, acetate, succinate, H_2, CO_2, ethanol
Butanol-butyrate	*Butyribacterium, Clostridium, Neisseria*	Butanol, butyrate, acetone, ethanol, H_2, CO_2

Food	Raw Material	Fermentor
Pickles	Cucumber	*Leuconostoc mesenteroides* *Lactobacillus*
Chocolate	Cacao bean	*Saccharomyces cerevisiae* *Candida rugosa* *Kluyveromyces marxianus*
Bread	Flour	*Saccharomyces cerevisiae*
Coffee	Coffee bean	*Erwinia dissolvens*
Sauerkraut	Cabbage	*Leuconostoc plantarum*
Soy sauce	Soya bean	*Aspergillus oryzae*

Some fermented cereal foods

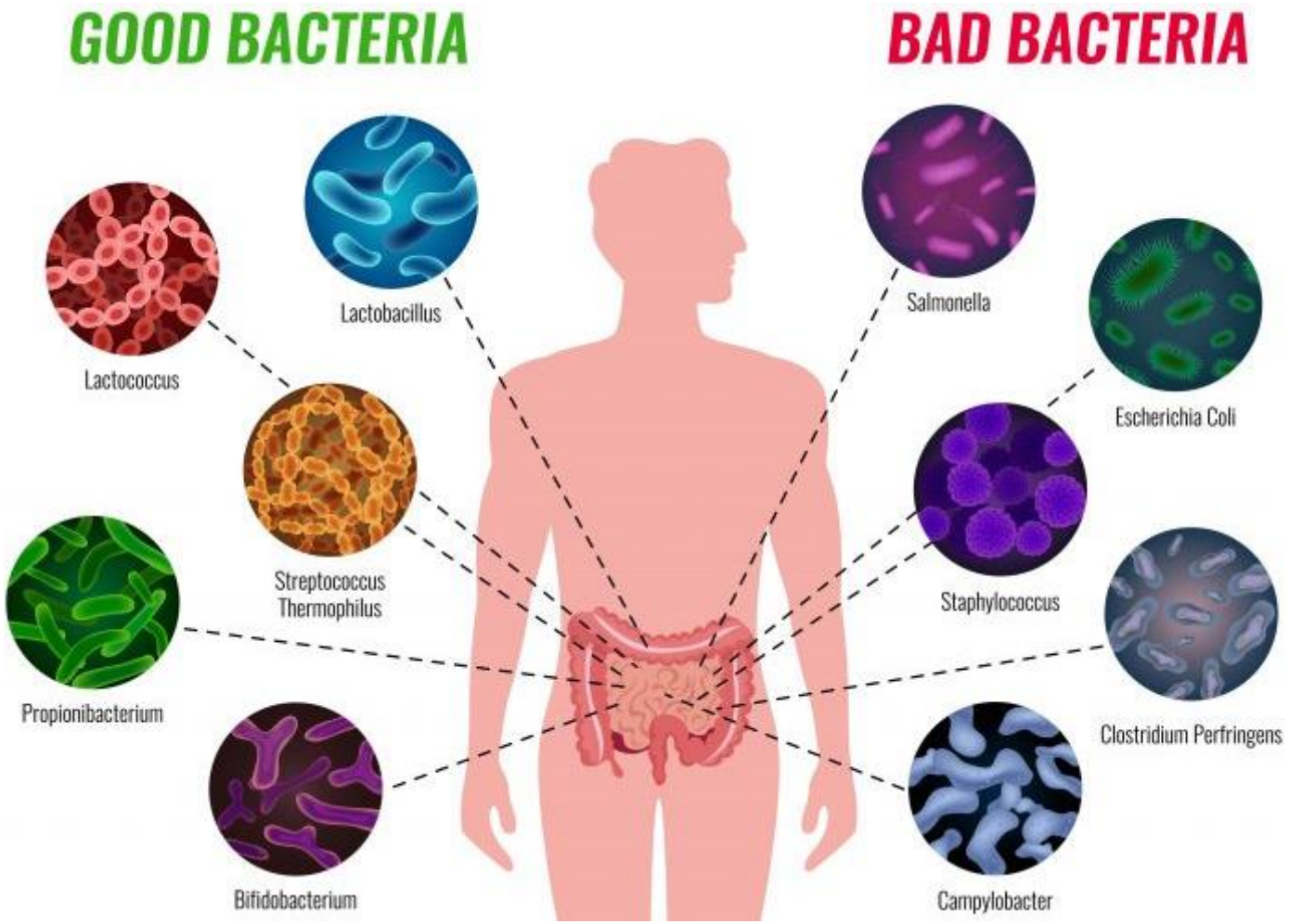
Cereal	Microorganism involved	Nature of use
Maize, sorghum, millet	*Lactobacillus, plantarum*	Liquid drink for infants and young children
Maize	*Aspergillus, Streptococcus, Lactobacillus*	Thick dough for adults and children
Sorghum, millet	*Streptococcus, Lactobacillus, Saccharomyces*	Liquid drink especially for sick children
Maize	Lactic acid bacteria	Liquid drink for adults and children
Maize, sorghum	Lactic bacteria yeasts and moulds	Paste for infants and young children

Some ethnic fermented food

Shoyu	Wheat and Soybean	*Aspergillus oryzae,* yeast and *Lactobacillus sp.*	Japan
Natto	Soybean	*Bacillus subtilis*	Japan
Tempeh	Soybean	*Rhizophus oligosporus*	Indonesia
Sufu	Soybean curd	*Actinomucor elegans*	China
Hamanatto	Soybean	*Aspergillus oryzae*	Japan
Tao-Si	Soybean	*Aspergillus oryzae*	Phillipines
Sake	Rice	*Lactobacillus sp. and Saccharomyces cerevisiae*	Japan
Indian idli	Soaked rice and mung beans are soaked separately, ground and incubated.	*Leuconostoc mesenterodies* and *Streptococcus faecalis*	Common in Southern India

Intestinal Beneficial Bacteria

The gut is inhabited by several good bacteria (beneficial for the health of human beings).



- In recent years, many studies have shown that some specific health benefits can be achieved by also consuming products containing dead cells or cell components of beneficial bacteria (e.g., immune modulation).

- These bacteria or their preparations are called as ***probiotics***.

- Some of the species *include:-*

    - *Lactobacillus acidophilus,*
    - *L. bulgaricus,*
    - *L. Casei*
    - *L. fermentum,*
    - *L. lactis,*
    - *Bifidobacterium bifidus,*
    - *B. longum,*
    - *B. brevis,*
    - *Streptococcus thermophilus*, and
    - some yeasts.

- The growth of desirable gut bacteria can be enhanced by supplying appropriate nutrients, called as ***Prebiotics***. The combination of probiotics and prebiotics is called as ***Synbiotics***.

THANK YOU