Introduction to Food Microbiology

Course Code: NFE-111
Course Title: Introduction to Food Science and Technology
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Introduction to Food Microbiology

1.0 OBJECTIVES

After reading the Unit, we shall be able to:

- explain the applied aspects of microbiology;
- comprehend the need and scope of food microbiology;
- enumerate the important genera of micro-organisms associated with food; and
- specify normal microflora of some common foods.

1.1 INTRODUCTION

Micro-organisms are living entities of microscopic size and include bacteria, viruses, yeasts and molds (together designated as fungi), algae, and protozoa. While bacteria are classified as prokaryotes (cells without definite nuclei), the fungi, algae, and protozoa are eukaryotes (cells with nuclei); viruses do not have regular cell structures and are classified separately. Micro-organisms are present everywhere on earth, which includes humans, animals, plants and other living creatures, soil, water, and atmosphere, and 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 over 3 billion years ago; and since then they have played important roles, many of which are beneficial to the other living systems.

Among the micro-organisms, some molds, yeasts, bacteria, and viruses have both desirable and undesirable roles in our food. In this unit, the scope of food microbiology, importance of microbes in food and predominant micro-organisms associated with food have been discussed.

1.2 THE SCIENCE OF MICROBIOLOGY

Microbiology is the branch of the biological sciences that deals with micro-organisms, i.e. bacteria, fungi, some algae, protozoa, viruses, viroids and prions. Most micro-organisms have the following characteristics:-

1) They are generally too small to be seen with the unaided human eye, and some form of microscopy is required for the study of their structure.
2) Cells or other structures are relatively simple and less specialized than those of higher plants and animals.
3) They are handled and cultured in the laboratory in ways that are generally quite similar.

Microbiology has developed into a science that can be studied from a number of perspectives. A specialist study can be made of each of the individual groups giving rise to the following disciplines:

- Bacteriology - the study of bacteria;
- Mycology - the study of fungi;
- Protozoology - the study of protozoa;
- Phycology (algology) - the study of algae;
- Virology - the study of viruses.

Micro-organisms can also be studied from the applied viewpoint, i.e. the relationship between micro-organisms, the environment and human activity. This again gives rise to a number of areas of specialist study:

- **Medical microbiology** includes some aspects of pathology (the study of diseases), immunology (how the immune system operates to prevent invasion by micro-organisms) and epidemiology (how diseases are distributed and spread).
- **Agricultural microbiology:** The study of micro-organisms for crop/ plant health and related areas.
- **Industrial microbiology / biotechnology:** The study of the use of Micro-organisms in large scale industrial processes.
- **Food microbiology:** The study of the role that micro-organisms play in food spoilage, food production, food preservation and food-borne disease.

None of these areas of specialist study can operate in isolation, e.g. food microbiology encompasses various aspects of industrial microbiology and biotechnology in the manufacture of fermented food and the production of single-cell protein. A study of food-borne disease involves aspects of medical microbiology and agricultural microbiology.

Specialist knowledge needs to be underpinned by an understanding of fundamental principles. The food microbiologist, for example, needs to have an understanding of microbial structure; the classification and identification of micro-organisms; how micro-organisms grow; the factors that influence growth and how growth can be controlled; death of micro-organisms; nutrition of Micro-organisms and how they are cultured in the laboratory.

1.3 FOOD MICROBIOLOGY - ITS ORIGIN AND SCOPE

Although processes of food spoilage and methods of food preservation and food fermentation have been recognized since ancient times, it was not until the 1800s that the relationship between foods and micro-organisms was established. In 1837 Schwann proposed that the yeast which appeared during alcoholic fermentation was a microscopic plant, and between 1857 and 1876 Pasteur showed that micro-organisms were responsible for the chemical changes that take place in foods and beverages.

Their observations laid the foundation for the development of food microbiology as we know it today. Soon after these early discoveries were made, knowledge about the role that micro-organisms play in food preservation, food spoilage and food preservation, food spoilage and food poisoning accelerated rapidly until food microbiology gradually emerged as a discipline in its own right. Food microbiology is now a highly developed area of knowledge with the main areas of interest highlighted in Fig. 1.1.

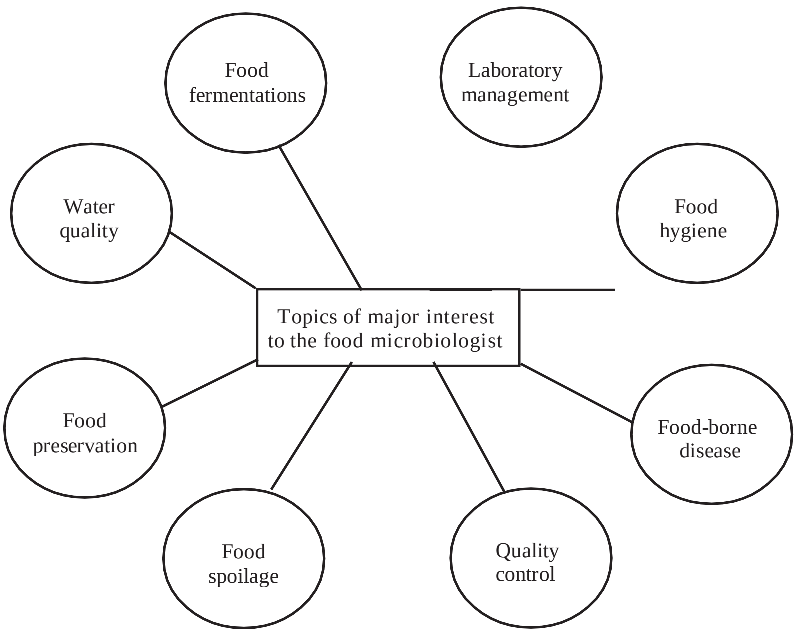

Fig. 1.1: Topics of major interest to the food microbiologist

Not all groups of micro-organisms are of equal interest to the food microbiologist. Bacteria come very much on top of the list with molds and yeasts also of considerable importance and viruses less so. The associations that these organisms have with the manufacture and consumption of foods are summarized in Fig. 1.2.

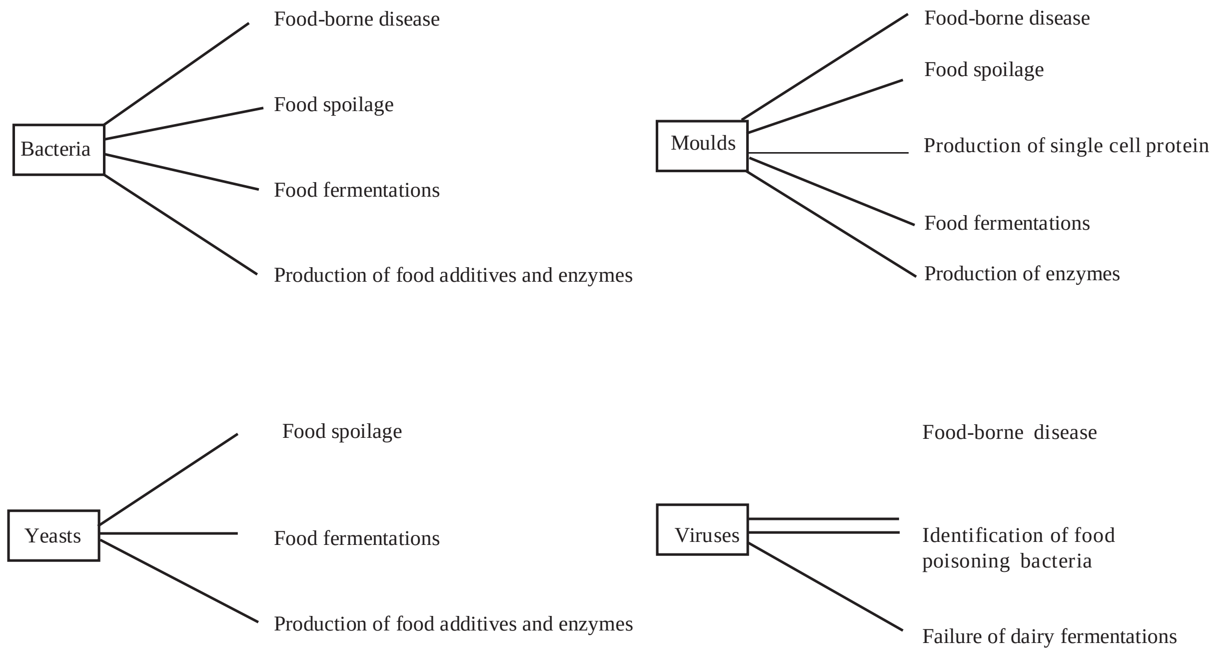

Fig. 1.2: Various groups of micro-organisms and their associations with food

Protozoa and algae have minimum direct impact on the production, processing and consumption of food. Food-borne disease can be caused by some protozoa and others belonging to this group are important in the treatment of wastes. Algae are used to produce alginates; some have the potential for use in the production of single-cell protein and some marine species produce toxins that might enter our food along with sea foods.

1.4 IMPORTANCE OF MICRO-ORGANISMS IN FOODS

Since 1900 A.D. our understanding of the importance of micro-organisms in food has increased greatly. Their role in food can be either desirable (food bioprocessing) or undesirable (food borne diseases and food spoilage), which is briefly discussed here.

1.4.1 Food-borne Diseases

Many pathogenic micro-organisms (bacteria, molds and viruses) can contaminate foods during various stages of their handling, between production and consumption. Consumption of these foods can cause food borne diseases. Food borne diseases can be fatal and may also cause large economic losses. Foods of animal origin are associated, more with food borne diseases than foods of plant origin. Mass production of food, introduction of new technologies in the processing and storage of food, changes in food consumption patterns, and increased import of food from other countries have increased the chances of large outbreaks as well as the introduction of new pathogens. Effective intervention technologies are being developed and implemented to ensure the safety of consumers against food borne diseases. New methods are also being developed to effectively and rapidly identify the pathogens in contaminated foods.

1.4.2 Food Spoilage

Except for sterile foods, all foods harbor micro-organisms. Food spoilage stems from the growth of these micro-organisms in food or is due to the action of microbial enzymes. New marketing trends, consumers' desire for foods that are not overly processed and preserved, extended shelf life, and chances of temperature abuse between production and consumption of foods have greatly increased the chances of food spoilage and, in some instances, with new types of micro-organisms. The major concerns are the economic loss and wastage of food. New concepts are being studied to reduce contamination as well as control the growth of spoilage microbes in foods.

1.4.3 Food Bioprocessing

Many food-grade micro-organisms are used to produce different types of fermented foods using raw materials from animal and plant sources. Consumption of these foods has increased greatly over the last 15 to 20 years and is expected to increase further in the future. There have been great changes in the production and availability of these micro-organisms (starter cultures) to meet the large demand. In addition, novel and better strains are being developed by using genetic engineering techniques.

1.4.4 Food Additives

Microbial enzymes are also being used to produce food and food additives. By employing genetic recombination techniques, and using diverse microbial sources enzymes of higher purity & activity are obtained. Many types of additives from microbial sources are being developed and used in food. Some of these include single-cell proteins, essential amino acids, colour compounds, flavour compounds, stabilizers and organic acids.

1.4.5 Food Biopreservation

Antimicrobial metabolites (e.g. bacteriocins and organic acids like acetic, propionic and lactic acids) of desirable Micro-organisms are being developed and used in foods in place of preservatives of non-food (chemical) origin to control pathogenic and spoilage micro-organisms in food. Economic production of these antimicrobial compounds and their effectiveness in food systems have generated wide interest.

1.4.6 Probiotics

Consumption of foods containing live cells of bacteria and that have apparent health benefits has generated interest among consumers. The role of these bacteria for health and bacterial efficacy benefits is being critically investigated.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What are Micro-organisms?

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2) What is Food Microbiology?

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3) What is a probiotic?

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1.5 CLASSIFICATION AND NOMENCLATURE OF MICRO-ORGANISMS

Living cellular organisms, on the basis of phylogenetic and evolutionary relationships, are grouped into five kingdoms in which bacteria belong to prokaryote (before nucleus), while the eukaryotic (with nucleus) molds and yeasts are grouped under fungi. Viruses are not considered as living cells and are not included in this classification system.

For the classification of yeasts, molds, and bacteria, several ranks are used after the kingdom. These are divisions, classes, orders, families, genera (singular, genus), and species. The basic taxonomic group is the species. Several species with similar characteristics form a genus.

A family is made up of several genera, and the same procedure is followed in the hierarchy. Ranks above species, genus, and family are seldom used in food microbiology. Among bacteria, a species is regarded as a collection of strains having many common features. A strain is the descendent of a single colony (single cell). Among the strains in a species, one is assigned as the type strain; it is used as a reference strain while comparing the characteristics of an unknown isolate.

The basic taxonomic group in bacteria, yeasts, and molds is the species, and each species is given a name. The name has two parts (binomial name); the first part is the genus name and the second part is the specific epithet (adjective). Both parts are Latinized; when written, they are italicised (or underlined) with the first letter of the genus written in a capital letter and species name in small letters. For e.g. ***Bacillus subtilis*** (genus is ***Bacillus*** and species is ***subtilis***)

1.6 MICRO-ORGANISMS IN FOOD

The Micro-organisms most common to food are bacteria and fungi. The fungi, which are less common than bacteria, consist of two major types of Micro-organisms, viz. molds and yeasts. Apart from these, food may contain viruses and other parasites such as protozoans, worms etc.

1.6.1 Bacteria

Bacteria are unicellular Micro-organisms that are approximately one micro meter (10^{-3}mm) in diameter with variations in morphology from short and

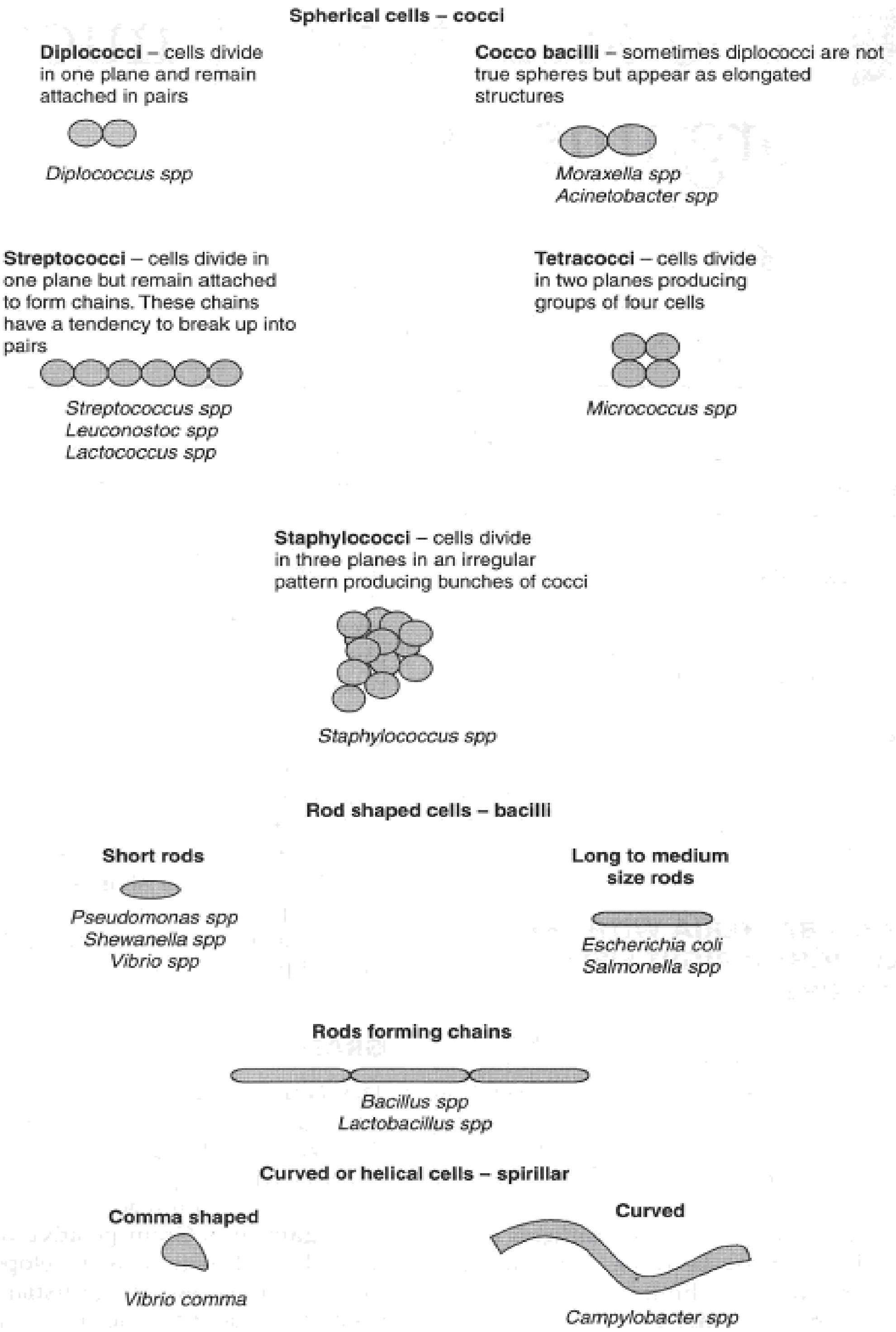

Fig. 1.3: Types of bacterial cells and their groupings

elongated rods (bacilli), spherical or ovoid forms(cocci), vibrio (comma shaped) and even spiral in shape (Refer Fig. 1.3). Cocci (meaning "berry") are sphere shaped bacteria. Individual bacteria closely combine in various forms according to genera. Some sphere-shaped bacteria occur in clusters similar to a bunch of grapes (i.e. staphylococci). Other bacteria (rod shaped or sphere shaped) are linked together to form chains (i.e. streptococci in case of cocci chain). Certain genera of sphere-shaped bacteria are found together in pairs (diplococci i.e. Pneumococci) or as a group of four (Square or cubical packets formation; i.e. Sarcinia), while other genera appear as an individual bacterium. Other bacteria (in majority) are rod shaped and possess flagella and are motile.

Bacteria produce various pigments which range from shades of yellow to dark pigments such as brown or black. Certain bacteria have pigmentation of intermediate colors such as red, pink, orange, blue, green, or purple. These bacteria cause food discoloration, especially, among foods with unstable color pigments such as meat. Some bacteria also cause discoloration by slime formation.

1.6.2 Molds

Molds are multicellular micro-organisms with mycelial (filamentous) morphology. These microbes are also characterized by their display of a variety of colors and are generally recognized by their mildewy or fuzzy, cotton like appearance. Molds can develop numerous tiny spores that are found in the air and can be spread by air currents. These spores can produce new mold growth if they are transferred to a location that has conditions conducive to germination. Molds generally withstand greater fluctuation in pH than bacteria and yeasts and can frequently tolerate more temperature fluctuation. Although molds thrive best at or near a pH of 7.0, a pH range of 2.0 to 8.0 can be tolerated, even though an acid to neutral pH is preferred. Molds thrive better at ambient temperature than in a colder environment, even though growth can occur below 0°C. Although mold growth is optimal at a water activity (A_w) of approximately 0.85, growth can and does occur below 0.80. At an A_w of 0.90 or higher, bacteria and yeasts grow more effectively and normally utilize available nutrients for growth at the expense of molds. When the A_w goes below 0.90, molds grow more effectively. That is why foodstuffs, such as pastries, cheeses, and nuts, that are low in moisture content are more likely to spoil from mold growth.

1.6.3 Yeasts

Yeasts are generally unicellular and differ from bacteria in their large cell size and morphology, and because they produce buds during the process of reproduction by division. Like molds, yeasts can be spread through the air, or other means, and alight on the surface of foodstuffs. Yeast colonies are generally moist or slimy in appearance and creamy white colored. Yeasts prefer an A_w of 0.90 - 0.94, but can grow below 0.90. These micro-organisms grow best in the intermediate acid range, pH from 4.0 to 4.5. Food that is highly contaminated with yeasts will frequently have a slightly fruity odour.

1.6.4 Viruses

Viruses are 10- 450 nm in size; cannot reproduce without a living host; attack only susceptible host cell lines; infect plants, animals, and bacteria; and have the capacity to produce specific diseases in specific hosts. Transmission occurs in foods, water and air. Viruses that infect bacteria are called bacteriophages. Viruses are included in the order **Virales.**

Viruses are too small to be visualized with an ordinary compound microscope. Only after the electron microscope was developed, the direct observation of viruses was possible. Viruses consist of a DNA or RNA core surrounded by a protein coat. Because they lack all the apparatus for normal cellular metabolism, they must utilize the cellular machinery of the host cell in order to grow and divide. Once they invade a host cell, however, viruses can multiply very rapidly.

1.6.5 Parasitic Organisms

A number of parasitic worms can also be transmitted by food to cause diseases in humans.

Cestodes are flatworms that inhabit the intestinal tract, heart, and lungs of animals. Beef, swine, dogs and other canine species, bears, and fish can all harbour tapeworms and flatworms, which can be transmitted to and can infect humans.

Trematodes are non segmented flatworms that possess a mouth and oral sucker and depend on a snail as an intermediate host before infecting humans by being ingested in drinking water or aquatic plants. Intestinal flukes, pyriform worms from fish, sheep and Chinese liver flukes, and oriental lung flukes are all examples of food-transmitted parasites.

Nematodes or true roundworms also can be transmitted from animals to humans. Eggs carried in excrement from roaches and dung beetles ingested by cattle, sheep and hogs contaminate humans. Trichinosis is an inflammation of the muscle tissue caused by ingesting the worm *Trichinella spiralis.* Pork is the most common vector. Capillary worms, whipworms, and pinworms are other examples of nematode parasites.

Protozoa are microscopic single-celled animals, which can be taken in with food or water to cause human illness. *Entamoeba histolytica, Toxoplasma gondii, Balantidium coli,* and *Giardia lamblia* are the most common food borne protozoan parasites.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What is Systematics?

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2) What are the two most common Micro-organisms found in food?

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3) Classify bacteria on the basis of their morphology.

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4) What is a bacteriophage?

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1.7 IMPORTANT MICRO-ORGANISMS IN FOOD

1.7.1 Important Mold Genera

Molds are important in food because they can grow in conditions in which many bacteria cannot, such as low pH, low water activity (a_w), and high osmotic pressure. They are important spoilage micro-organisms. Many strains also produce mycotoxins and have been implicated in food borne intoxication. Many are used in food bioprocessing. Finally, many are used to produce food additives and enzymes. Some of the most common genera of molds found in food are listed here.

1) ***Aspergillus* :** They are widely distributed and contain many species that are important in food. They have septate hyphae and produce a sexual spores (black color) or conidia. Many are xerophilic (able to grow in low A_w) and can grow in grains, causing spoilage. They are also involved in spoilage of foods such as jams, cured ham, nuts, and fruits and vegetables (rot). Some species/strains produce mycotoxin (e.g., *Aspergillus flavus* produces aflatoxin). Many species/strains are also used in food and food additive processing. *Aspergillus oryzae* is used to hydrolyze starch by alpha-amylase in the production of sake. *Aspergillus niger* is used to process citric acid from sucrose and to produce enzymes like-galactosidase.

2) ***Alternaria*:** They are also septate and form dark-brown colored many celled conidia on the conidiophere. They cause rot in tomatoes and rancid flavor in dairy products. Species: *Alternaria tenuis.*

3) ***Geotrichum*:** The hyphae are septate and form rectangular asexual arthrospores (oidia). They grow forming a yeast like, cottony, creamy colony. They establish easily in equipment and often grow on dairy products **(**also known as dairy mold**).** Species: *Geotrichum candidum.*

4) ***Mucor* :** They are widely distributed. They have nonseptate hyphae and produce sporangiophores. They produce cottony colonies. Some species are used in food fermentation and production of enzymes. They cause spoilage of vegetables. Species: *Mucor rouxii.*

5) ***Penicillium*:** They are widely distributed and contain many species. They have septate hyphae and form conidiophore on a blue-green, brush-like conidia head. Some species are used in food production, such as

Penicillium roquefortii and *Penicillium camembertii* in cheese. Many species cause fungal rot in fruits and vegetables.

6) **Rhizopus:** The hyphae are aseptate and form sporangiophores in sporangium. They are involved in the spoilage of many fruits and vegetables. *Rhizopus stolonifer* is the common black bread mold.

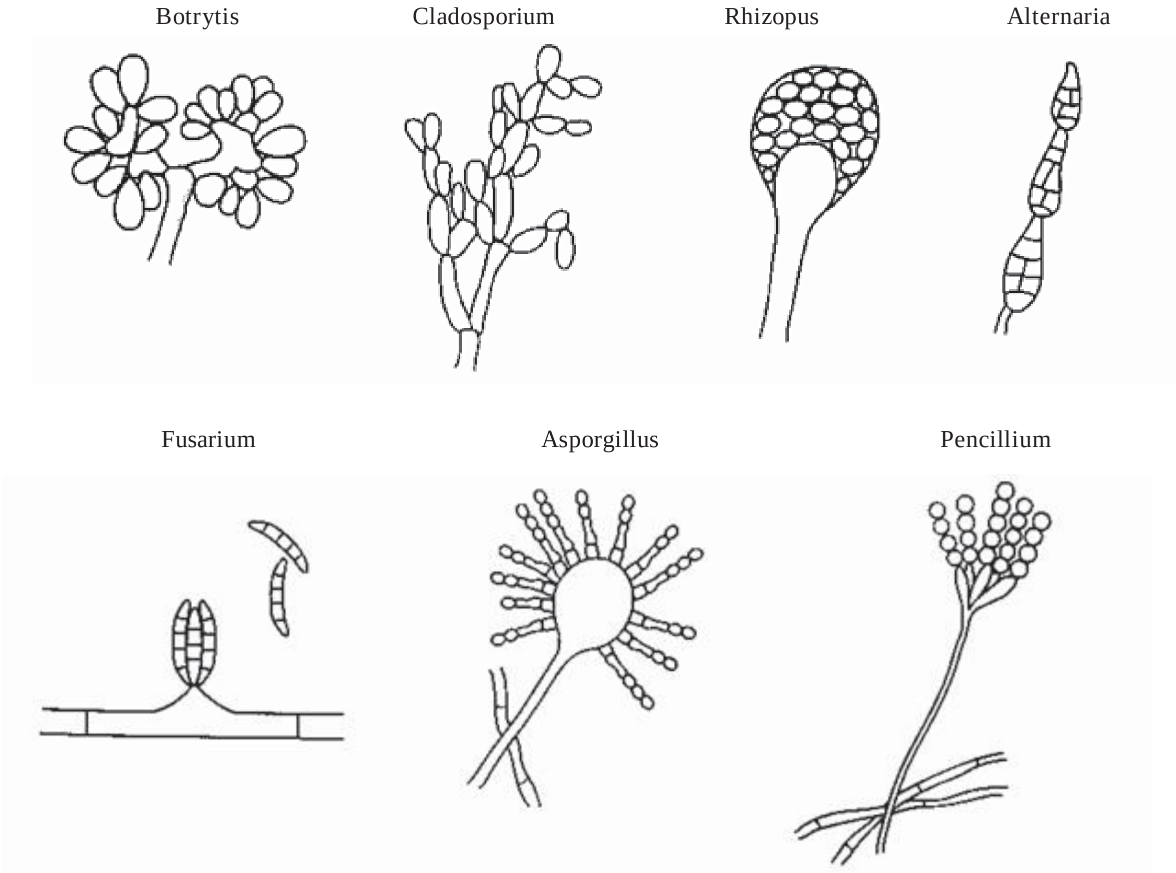

Fig. 1.4: Common mold species found in foods

1.7.2 Important Yeast Genera

Yeasts are important in food due to their ability to cause spoilage. Many are also used in food bioprocessing. Some are used to produce food additives. Several important genera are briefly described below.

1) ***Saccharomyces*:** Cells are round, oval, or elongated. It is the most important genus and contains heterogeneous groups. *Saccharomyces cerevisiae* variants are used in baking for leavening of bread and in alcoholic fermentation. They are also involved in spoilage of food with the production of alcohol and CO_2.

2)) ***Pichia*:** They are oval to cylindrical cells and form pellicle in beer, wine, and brine to cause spoilage. Some are also used in oriental food fermentation. Species: *Pichia membranaefaciens.*

3)) ***Rhodotorula*:** They are pigment (red, pink or yellow) forming yeasts and can cause discoloration of foods, such as in meat, fish, and sauerkraut. Species *Rhodotorula glutinis.*

4) ***Torulopsis*****:** They have spherical to oval structure. They cause spoilage of milk due to the ability to ferment lactose (*Torulopsis sphaerica*). They also spoil fruit juice concentrates and acid foods.

5) ***Candida*****:** Many spoil foods with high acid, salt, and sugar and form pellicle on the surface of liquids. Some can cause rancidity in butter and dairy products *(Candida lipolytica).*

6) ***Zygosaccharomyces*****:** Involved in spoilage of foods, containing high sugar/ salt levels ex. honey, sirups, molasses, soy sauce. (*Zygosaccharomyces nussbaumeri).* These yeasts are termed osmophilic, because they can grow in high concentrations of solutes.

1.7.3 Important Viruses

Viruses are important in food for three reasons. Some are able to cause enteric disease and thus, if present in a food, can cause food borne diseases. Hepatitis A and Norwalk viruses have been implicated in food borne outbreaks. Several other enteric viruses, such as Poliovirus, Echovirus, and Coxsackievirus, have the potential of causing food borne diseases. In some countries where the level of sanitation is not very high, they can contaminate foods and cause disease.

Some bacterial viruses (bacteriophages) are used in the identification of species/ strains by a process called tranduction (e.g., in *Escherichia, coli, Lactococcus lactis*).

Finally, some bacteriophages can be very important due to their ability to cause fermentation failure. Many lactic acid bacteria, used as starter cultures in food fermentation, are sensitive to different bacteriophages. These phages can infect and destroy starter culture bacteria, causing product failure. Among the lactic acid bacteria, bacteriophages have been isolated for many species in genera *Lactococcus*, *Streptococcus*, *Leuconostoc*, and *Lactobacills.* Methods are being studied to genetically engineer lactic acid start cultures so that they become resistant to multiple bacteriophages.

Table 1.1: Human Intestinal Viruses with High Potential as Food Contaminants

Types of Viruses	**Example**
Picornaviruses	Polioviruses Coxsackievirus A Coxsackievirus B Echovirus Enterovirus
Reoviruses	Reovirus Rotavirus
Parvoviruses	Human gastrointestional viruses
Papovaviruses	Human BK and JC viruses
Adenoviruses	Human adenoviruses

1.7.4 Important Bacterial Genera

Bacterial classification is rapidly changing. In the following Table 1.2, only those species and genera currently approved and listed in Bergey's Manual have been used.

Table 1.2 Genera of Bacteria Important in Food

Group	Family	Genera
Spiral and curved bacteria	Spirallaceae	*Campylobacter*
Gram-negative aerobic rods and cocci	Pseudomonadaceae	*Pseudomonas, Altermonas, Gluconobacter, Xanthomonas*
	Halobacteriaceae	*Halobacterium, Halococcus*
	Genera of uncertain affinity	*Alcaligenes, Acetobacter, Brucella*
Gram-negative facultative anaerobic rods	Enterobacteriaceae	*Escherichia, Citrobacter, Salmonella, Shigella, Klebsiella, Enterobacter, Serratia, Proteus, Yersinia, Erwinia*
	Vibrionaceae	*Vibrio, Aeromonas*
	Genera of uncertain affinity	*Flavobacterium, Chromobacterium*
Gram-negative diplococci and diplococcobacilli Gram-positive cocci	Neisseriaceae Micrococcaceae Streptococcaceae	*Moraxella, Acinetobacter* *Micrococcus, Staphylococcus* *Streptococcus, Leuconostoc, Pediococcus, Lactococcus, Enterococcus*
	Peptococcaceae	*Sarcina*
Endospore forming rods and cocci	Bacillaceae	*Clostridium, Bacillus*
Gram-positive asporogenous rod of regular shape	Lactobacillaceae	*Lactobacillus*
	Genera of uncertain affinity	*Listeria*
Non spore-forming rods of irregular shape	Coryneform bacteria	*Arthrobacter, Brevibacterium, Propionibacterium*
Rickettsia	Rickettsiaceae	*Coxiella*

1.7.4.1 Common Bacterial Groups in Foods

Among the Micro-organisms found in foods, bacteria constitute a major important group. This is not only because many different species can be present in foods, but is also due to their rapid growth rate, ability to utilize food nutrients, and their ability to grow under a wide range of temperatures, aerobiosis, pH, and water activity, as well as to survive under adverse situations, such as survival of spores at high temperature. For convenience, bacteria important in foods have been arbitrarily divided into several groups on the basis of similarities in certain characteristics. This grouping does not have any taxonomic significance. Some of these groups and their importance in foods are listed here.

1) **Lactic Acid Bacteria**

Those bacteria that produce relatively large quantities of lactic acid from carbohydrates. Include species mainly from genera *Lactococcus, Leuconostoc, Pediococcus, Lactobacillus* and *Streptococcus thermophilus.*

2) **Acetic Acid Bacteria**

Those bacteria that produce acetic acid, such as *Acetobacter aceti*.

3) **Propionic Acid Bacteria**

Those bacteria that produce propionic acid and are used in dairy fermentation. Include species such as *Propionibacterium freudenreichii*.

4) **Butyric Acid Bacteria**

Those bacteria that produce butyric acid in relatively large amounts. Some Clostridium spp., such as *Clostridium butyricum*.

5) **Proteolytic Bacteria**

Those bacteria that are capable of hydrolyzing proteins due to production of extracellular proteinases. Species in genera *Micrococcus, Staphylocccus, Bacillus, Clostridium, Pseudomonas, Alteromonas, Flavobacerium,* and *Alcaligenes;* some in *Enterobacteriaceae* and *Brevibacterium* are also included in this group.

6) **Lipolytic Bacteria**

Able to hydrolyze triglycerides due to production of extracellular lipases. Species in genera *Micrococcus, Staphylococcus, Serration, Pseudomonas, Alteromonas, Alcaligenes* and *Flavobacterium* are included in this group.

7) **Saccharolytic Bacteria**

Able to hydrolyze complex carbohydrates. Include some species in genera *Bacillus, Clostridium, Aeromonas, Pseudomonas,* and *Enterobacter*.

8) **Thermophillic Bacteria**

Able to grow at 50^0C and above. Include some species from genera *Bacillus, Clostridium, Pediococcus, Streptococcus,* and *Lactobacillus.*

9) **Psychrotrophic Bacteria**

Able to grow at refrigerated temperature ($<5^0$C). Include some species of *Pseudomonas, Alteromonas, Alcaligenes, Flavobacterium, Serratia, Bacillus, Clostridium, Lactobacillus, Leuconostoc, Listeria, Yersinia* and *Aeromonas.*

10) **Thermoduric Bacteria**

Able to survive pasteurization temperature. Include some species of *Micrococcus, Enterococcus, Lactobacillus, Pediococcus, Bacillus* (spores) and *Clostridium* (spores).

11) **Halotolerant Bacteria**

Able to survive high salt concentrations (>10%). Include some species of *Bacillus, Micrococcus, Staphylococcus, Pediococcus, Vibrio Streptococcus, Clostridium* and *Corynebacterium.*

12) **Aciduric Bacteria**

Able to survive at low pH (below 4.0). Include some species of *Lactobacillus, Pediococcus, Lactococcus, Enterococcus* and *Streptococcus.*

13) **Osmophilic Bacteria**

Can grow at a relatively higher osmotic pressure (environment) than other bacteria. Some species from genera *Staphylococcus, Leuconostoc,* and *Lactobacillus* are included in this group. They are much less osmophilic than yeasts and molds.

14) **Gas-producing Bacteria**

Produce gas (CO_2, H_2, H_2S) during metabolism of nutrients. Include spices from genera *Leuconostoc, Lactobacillus, Brevibacterium* and *Escherichia*.

15) **Slime Producers**

Produce slime due to synthesis of polysaccharides. Include some species or strains of *Xanthomonas, Leuconostoc, Alcaligenes, Enterobacter, Lactococcus,* and *Lactobacillus.*

16) **Spore formers**

Ability to produce spore. Include *Bacillus, Clostridium* and *Desulfotomaculum* spp. They are again divided into aerobic, anaerobic, flat sour thermophilic and sulfide-producing spore formers.

17) **Aerobes**

Require oxygen for growth and multiplication. Species o*f Pseudomonas, Bacillus,* and *Flavobacterium* are included in this group.

18) **Anaerobes**

Cannot grow in the presence of oxygen. Include species of *Clostridium.*

19) **Facultative Anaerobes**

Able to grow both in the presence and absence of oxygen. *Lactobacillus, Pediococcus, Leuconostoc,* enteric pathogens, some species of *Bacillus, Serratia***,** and coliforms are included in this group.

20) **Coliforms**

Include mainly species from *Escherichia, Enterobacter, Citrobacter,* and *Klebsiella,* and used as index of sanitation.

21) **Fecal Coliforms**

Include mainly *Escherichia coli.* Also used as index of sanitation.

22) Enteric Pathogens

Include pathogenic *Salmonella, Shigella, Campylobacter, Yersinia, Escherichia, Vibrio, Listeria, H*epatitis A, and others that can cause gastrointestinal infection.

1.8 NORMAL MICRO FLORA OF SOME COMMON FOODS

Under normal conditions a food generally harbours only a few types of Micro-organisms. They constitute those that are naturally present in raw foods (which provide the ecological niche) and those that get in from outside sources to which the foods are exposed from the time of production until consumption. The predominant type(s) will be the ones for which the optimum growth condition is present. The normal microflora of different food groups are listed below.

1.8.1 Meat

The carcass of a healthy animal slaughtered for meat and held in a refrigerated room is likely to have only nominal surface contamination while the inner tissues are sterile. Fresh meat cut from the chilled carcass has its surface contaminated with micro organisms characteristic of the environment and the implements (saws or knives) used to cut the meat. Each new surface of meat, resulting from a new cut, adds more micro organisms to the exposed tissue.

Among the most common species of bacteria occurring on fresh meats are Pseudomonads, Staphylococci, Micrococci, Enterococci and Coliforms. The low temperature at which fresh meats are held favors the growth of psychrophilic Micro-organisms.

1.8.2 Poultry

Freshly dressed eviscerated poultry have a bacterial flora on their surface (skin) that originates from the bacteria normally present on the live birds and from the manipulations during killing, defeathering, and evisceration. Under good sanitary conditions the bacterial count has been reported to be from 100 to 1000 bacteria per square centimeter of skin surface, whereas under less sanitary conditions the count may increase 100-fold or more. Pseudomonads constitute the major contaminants on the skin of freshly dressed poultry.

1.8.3 Eggs

The interior of a freshly laid egg is usually free of micro organisms; its subsequent microbial content is determined by the sanitary conditions under which it is held, as well as the conditions of storage, i.e. temperature and humidity. Micro-organisms particularly bacteria and molds, may enter the egg through cracks in the shells or penetrate the shells when the “bloom” (thin protein coat) covering the shell deteriorates. The type of micro organisms involved reflect those present in the environment.

1.8.4 Fruits and Vegetables

They are normally susceptible to infection by bacteria, fungi, and viruses. Microbial invasion of plant tissue can occur during various stages of fruit and vegetable development, and the likelihood of spoilage increases. A second factor contributing to the microbial contamination of fruits and vegetables pertains to their post-harvest handling. Mechanical handling is likely to produce breaks in the tissue which facilitates invasion by micro organisms. The pH of fruits is relatively acid i.e. ranging from 2.3 (for lemons) to 5.2 (for bananas). This restricts bacterial growth but does not retard fungal growth. The pH range for vegetables is slightly higher pH 5.0 to 7.0 and hence they are more susceptible than fruits to bacterial attack.

1.8.5 Shellfish and Finfish

The microbial flora of freshly caught oysters, clams, fish, and other aquatic specimens is very largely a reflection of the microbial quality of the water from where they are harvested. Of particular significance is whether the water is sewage-polluted, in which case the aquatic food is potentially capable of transmitting various pathogenic Micro-organisms. Shellfish that grow in contaminated water can concentrate viruses and may be the source of Hepatitis infection. For example, raw oysters and clams from polluted waters have caused numerous epidemics in various parts of the world.

1.8.6 Milk

Milk is an excellent growth medium for all of the common spoilage organisms, including molds and yeasts. Fresh, non pasteurized milk generally contains varying numbers of Micro-organisms, depending on the care employed in milking, cleaning, and handling of milk utensils. Raw milk held at refrigerator temperatures for several days invariably shows the presence of several or all bacteria of the following genera: *Enterococcus, Lactococcus, Streptococcus, Leuconostoc, Lactobacillus, Microbacterium, Propionibacterium, Micrococcus*, Coliforms, *Proteus, Pseudomonas, Bacillus*, and others. Those unable to grow at the usual low temperature of storage tend to be present in very low numbers. The pasteurization process eliminates all but thermoduric strains, primarily, Streptococci and Lactobacilli, and spore formers of the genus Bacillus (and clostridia if present in raw milk). The spoilage of pasteurized milk is caused by the growth of heat-resistant Streptococci utilizing lactose to produce lactic acid, which depresses the pH to a point (about pH 4.5) where curdling takes place.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Give the scientific names of the following :

i) Baker's Yeast ....

ii) Bread Mold ....

iii) Cocci in bunches ....

iv) Aerobic spore former ....

v) Anaerobic spore former ....

2) Define coliforms.

....

....

....

3) What is the main contaminant in the chilled and frozen meats?

....

....

....

1.9 LET US SUM UP

This unit outlines briefly the definition and applied aspects of science of microbiology. It highlights the scope of food microbiology. The contents of the unit emphasize on the types and importance of Micro-organisms in foods. The types of Micro-organisms (i.e. bacteria, fungi, molds and yeasts), viruses and parasitic organisms are discussed in terms of occurrence, morphology and their significance in food. Their role in food spoilage, food production, food preservation and food borne diseases has been discussed. Since micro-organisms are associated with most foods we eat, the normal micro flora of some common food groups is also mentioned. Thus, the entire unit deals with predominant Micro-organisms in food and highlights their harmful as well as beneficial role in foods.

1.10 KEY WORDS

Aerobe : An organism that grows in the presence of atmospheric oxygen.

Bacillus : A rod-shaped bacterium.

Bacteriocin : A protein produced by a bacterial strain that kills other closely related strains.

Binary Fission : Asexual mode of reproduction in which a cell or an organism separates into two identical cells.

Binomial system : The nomenclature system in which an organism is given two names; the first is the capitalized generic name, and the second is the uncapitalized specific epithet.

Endospore : An extremly heat- and chemical-resistant, dormant, thick-walled spore (resting structure) that develops within bacterial cell.

Halophile : A microorganism that requires high levels of sodium chloride for growth.

Hepatitis : Any infection that results in inflammation of the liver. Also refers to liver inflammation as such.

Microbiology : The study of organisms that are usually too small to be seen with the naked eye. Special techniques are required to isolate and grow them.

Prion : An infectious particle that is the cause of slow diseases like scrapie in sheep and goat; it has a protein component, but no nucleic acid has yet been detected.

Prokaryotic Cells : Cells that lack a true, membrane-enclosed nucleus; bacteria are prokaryotic and have their genetic material located in a nucleoid.

Taxon : A group into which related organisms are put together (classified).

Taxonomy : The science of biological classification; it consists of three parts: classification, nomenclature, and identification.

Vibrio : A rod-shaped bacterial cell that is curved to form a comma or an incomplete spiral.

Virion : A complete virus particle that represents the extracellular phase of the virus life cycle; at the simplest, it consists of a protein capsid surrounding a single nucleic acid molecule.

Viroid : An infectious agent of plants that is a single-stranded RNA not associated with any-protein; the RNA does not code for any protein and is not translated.

1.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points.

1) Micro-organisms are living entities of microscopic size which cannot be seen by naked eye and include bacteria, viruses, yeasts and molds (together designated as fungi), algae, and protozoa.

2) Food microbiology is the branch of microbiology that studies the role of Micro-organisms in food spoilage, food production and food borne diseases.

3) Probiotic is the oral administration of living Micro-organisms to promote the health and growth of an animal or human.

Check Your Progress Exercise 2

Your answer should include the following points.

1) The scientific study of organisms with the ultimate objective being to characterize and arrange them in an orderly manner is known as systematics.

2) The two most common Micro-organisms in foods are bacteria and fungi.

3) On basis of morphology bacteria can be classified as:

   a) Bacilli: rod-shaped

   b) Cocci: spherical

   c) Vibrio: comma-shaped

   d) Spirillum: spiral shaped

4) Bacteriophage is a virus capable of eating host bacteria.

Check Your Progress Exercise 3

Your answer should include the following points.

1) i) *Saccharomyces cerevisiae*

   ii) *Rhizopus stolonifer*

   iii) *Staphylococcous aureus*

   iv) *Bacillus* spp.

   v) *Clostridium* spp.

2) Coliforms are a group of gram-negative, nonsporing, facultative rods that ferment lactose into acid along with gas formation.

3) Pseudomonads