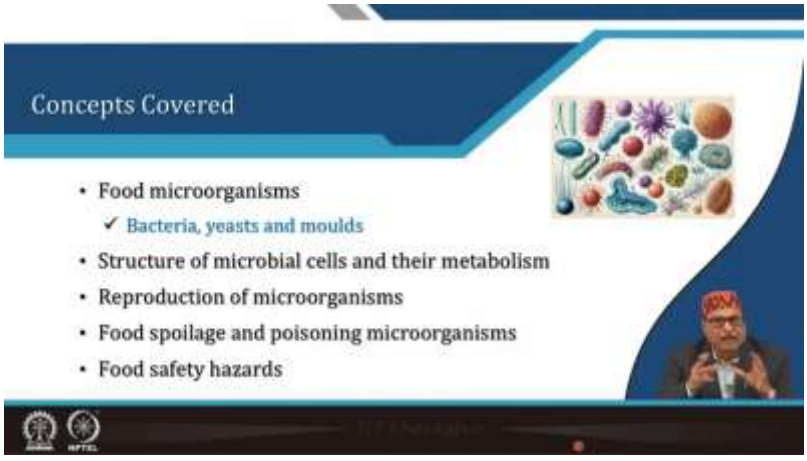
FOOD SCIENCE AND TECHNOLOGY

Lecture31

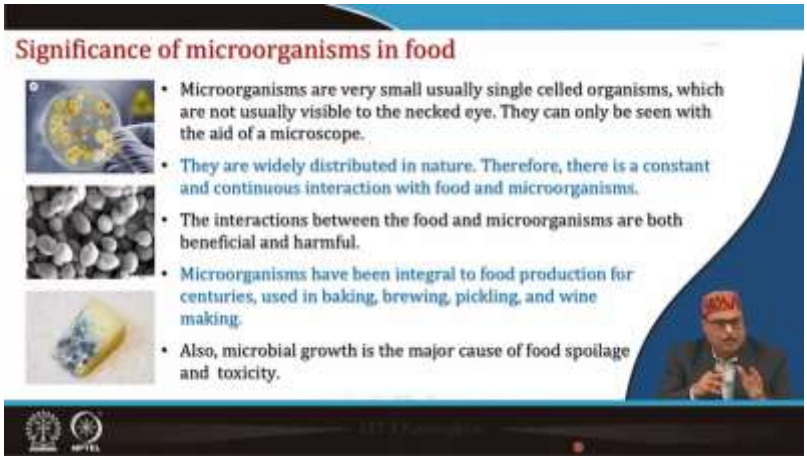
Lecture 31: Food Microorganisms

Hello everyone. Namaste. Now, we are in the seventh module.

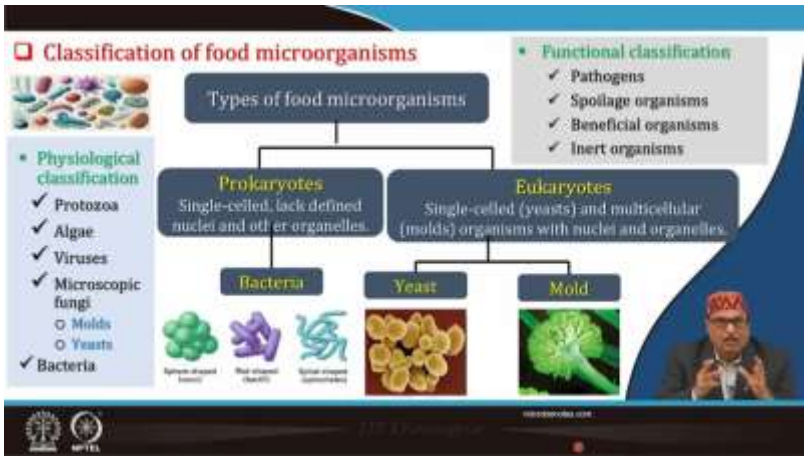
This module will be devoted to microorganisms associated with foods. So, in the first lecture of the seventh module and overall lecture 31, we will talk for about half an hour about food microorganisms.



The concepts covered in this lecture today include what food microorganisms are, the structure of microbial cells and their metabolism, and the reproduction of microorganisms; then we will also briefly talk about food spoilage, poisoning microorganisms and food safety hazards.

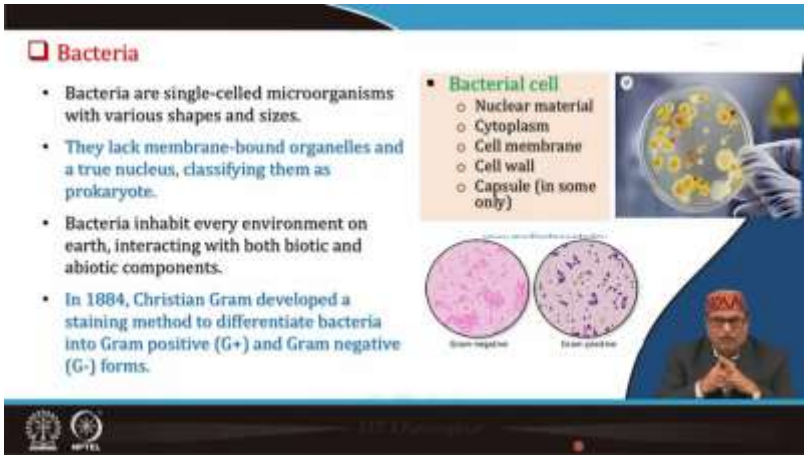


So, let us see the significance of microorganisms in food and I hope you know that microorganisms are very, very small. They are usually single-celled organisms which are not usually visible to the naked eye. They can only be seen with the aid of a microscope. They are widely distributed in nature; therefore, there is a constant and continuous interaction with food and microorganisms. The interaction between the food and microorganisms is both beneficial as well as harmful. Microorganisms have been integral to food production for centuries. They are used in the baking process, brewing, pickling, as well as in winemaking. Also, microbial growth is the major cause of food spoilage and toxicity. Therefore, microbes are both good and bad for food. So, we will take up these important aspects one by one in this lecture as well as in the coming lecture.

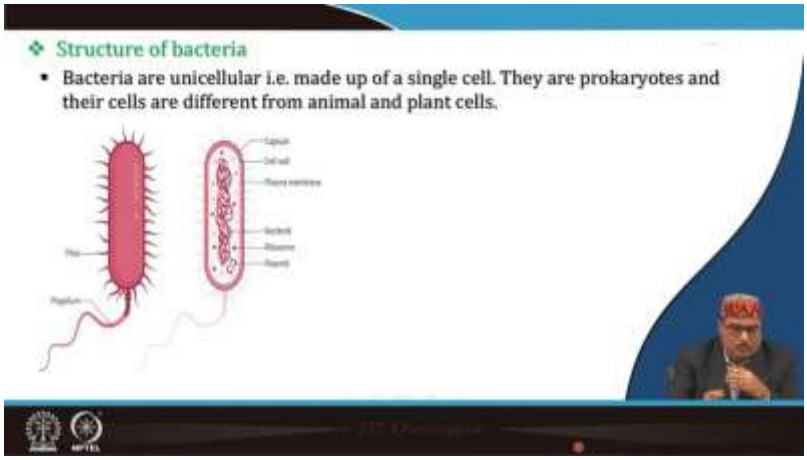


So, let us discuss the different types of microorganism classification. Under the physiological classification of microorganisms, we can say that they are prokaryotes, which are single-celled and lack defined nuclei and other organelles, and this includes bacteria. Then other types of microorganisms may be eukaryotes, which are also single-celled. These include yeast, and they are also multicellular, such as mould. So, single-celled and

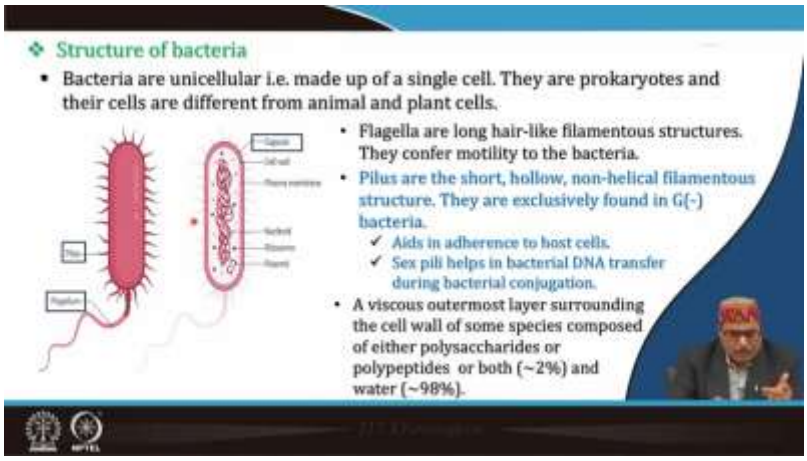
multicelled organisms have nuclei and other organelles, including yeast and mould. So, you can see that the three major types of microorganisms are associated with foods, and they are important in food technology; they include bacteria, yeast, and mould. Other physiological classifications include protozoa, algae, viruses, and even some other microorganisms, but these microorganisms can also be classified based on their functionalities under this classification. They can be pathogens, spoilage, beneficial, or inert organisms. Pathogens are organisms that make food toxic and cause diseases. Spoilage organisms are those that simply spoil food, but they do not cause any disease. Beneficial microorganisms, as we already discussed, are involved in food production. They bring about good changes in the food. Inert microorganisms may be single microorganisms, where one microorganism under certain situations may be a pathogen; under other situations, it may be spoilage, or in some cases, it may even be beneficial. There are specific examples of such organisms, like *E. coli*, a bacterium. It is sometimes a pathogen, sometimes spoils the food, and is occasionally beneficial.



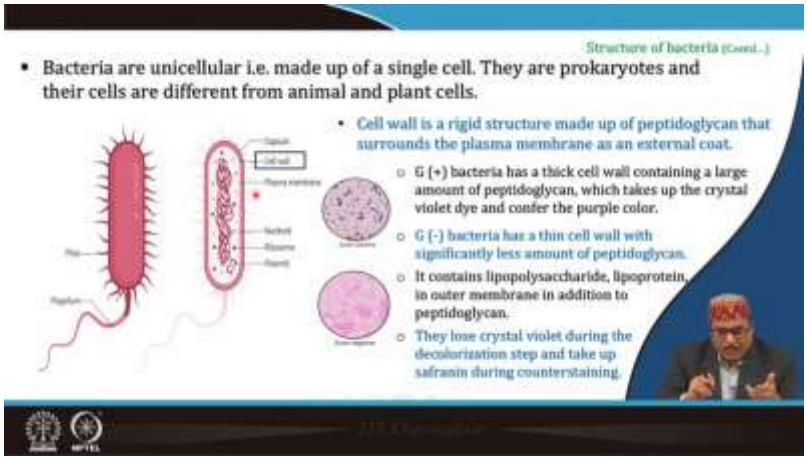
So, let us take this one by one, and first, we will start with bacteria. Bacteria are single-celled microorganisms with various shapes and sizes. They lack membrane-bound organelles and a true nucleus, classifying them accordingly. They do not have a nucleus or organelles, so they are prokaryotes. Bacteria inhabit every environment on Earth, interacting with both biotic and abiotic components. In 1884, Christian Gram developed a staining method to differentiate bacteria into gram-positive and gram-negative bacteria. So, if you take a bacterial cell, it contains different nuclear material from the original cell, and there is cytoplasm. Cell membrane, cell wall, and in some bacteria are provided with a capsule, which is a slimy material in some bacteria.



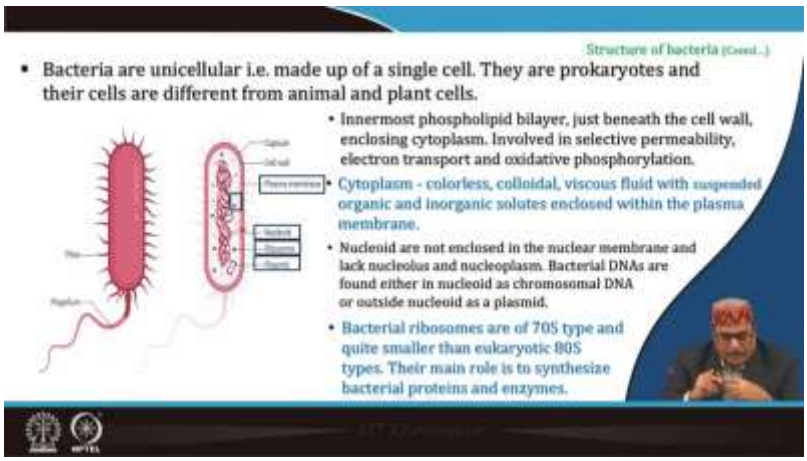
So, here is the structure of a bacterial cell. You can say they are unicellular, meaning they are made up of a single cell. They are prokaryotes, and their cells are different from animal as well as plant cells. So, you can see they have a flagella or flagellum. These are long, hair-like filamentous structures; they confer mobility. These flagella confer mobility to the bacterial cell or the bacteria. This is a pilus, as you can see here in the structure. These are short, hollow, non-helical filamentous structures, and they are exclusively found in gram-negative bacteria.



They aid in the adherence of the bacteria to host cells. Sex pili help in bacterial DNA transfer during bacterial conjugation. And then, the capsule. You can see the outer layer; it is a viscous outermost layer surrounding the cell wall of some species, composed of either polysaccharides or polypeptides or even both, and this constitutes around two percent, while the remaining ninety eight percent is water.

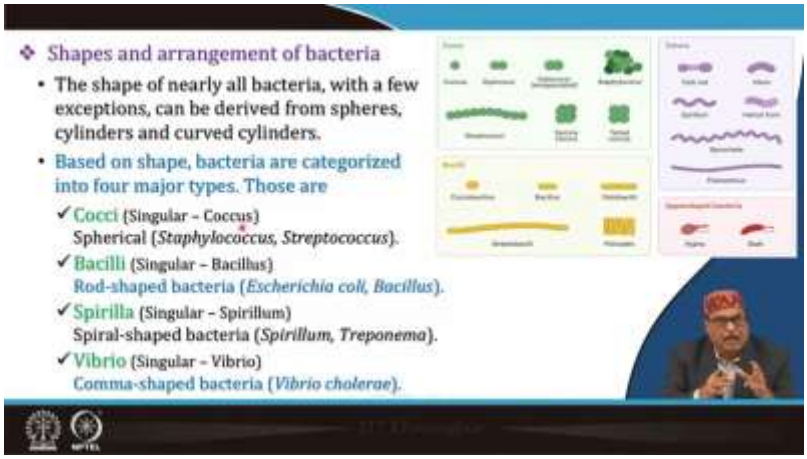


Then, beneath the capsule, there is a cell wall. It is a rigid structure made up of peptidoglycan that surrounds the plasma membrane as an external coat. Gram-positive bacteria have a thick cell wall containing a large amount of peptidoglycan, which may take up the crystal violet dye and confirm the purple colour on Gram staining. Gram-negative bacteria have a thin cell wall with significantly less peptidoglycan. The cell wall contains lipopolysaccharide and lipoprotein in the outer membrane in addition to the peptidoglycan, and they lose crystal violet during the decolourisation step and take saffron during the counterstaining. There is a gram-negative bacteria that lose crystal violet during the decolourization, and they take saffron during counterstaining.

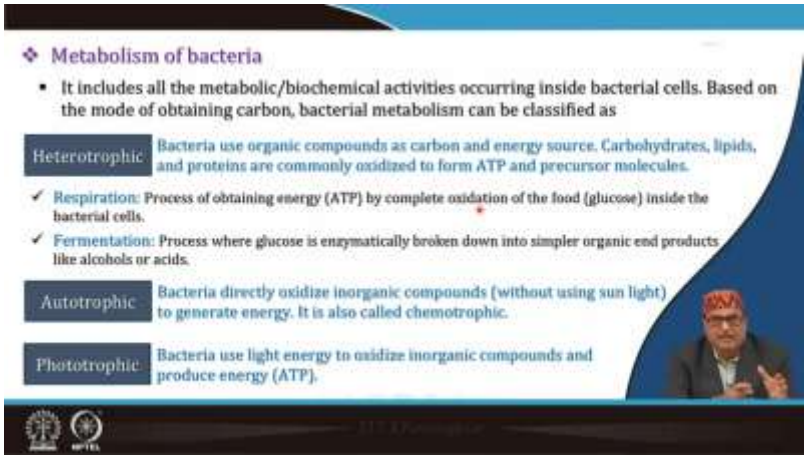


Innermost phospholipid bilayer just beneath the cell wall, which encloses the cytoplasm, is known as plasma membrane. That is the plasma membrane, which encloses cytoplasm. It is involved in selective permeability, electron transport and oxidative phosphorylation reactions. Cytoplasm is a colourless, colloidal, viscous fluid with suspended organic and inorganic solutes enclosed within the plasma membrane. That is inside the plasma membrane, enclosed in a fluid-like material, the cytoplasm. Then there are nucleoids that

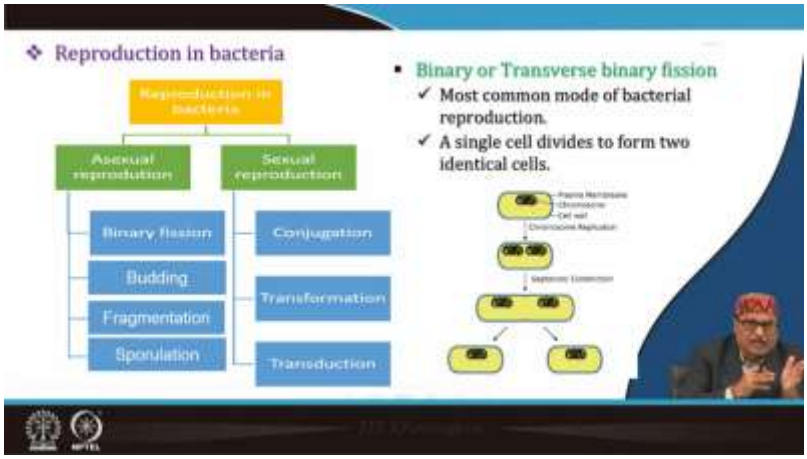
are enclosed in the nuclear membrane and lack a nucleus and nucleoplasm. Bacterial DNAs are found either in nucleotides as a chromosomal DNA or outside as a outside nucleoid as a plasmid. Bacterial ribosomes are the 70S type and quite smaller than the eukaryotic 80S types. Their main role is to synthesize bacterial proteins and enzymes. Now, let us talk about the shape and arrangement of bacteria.



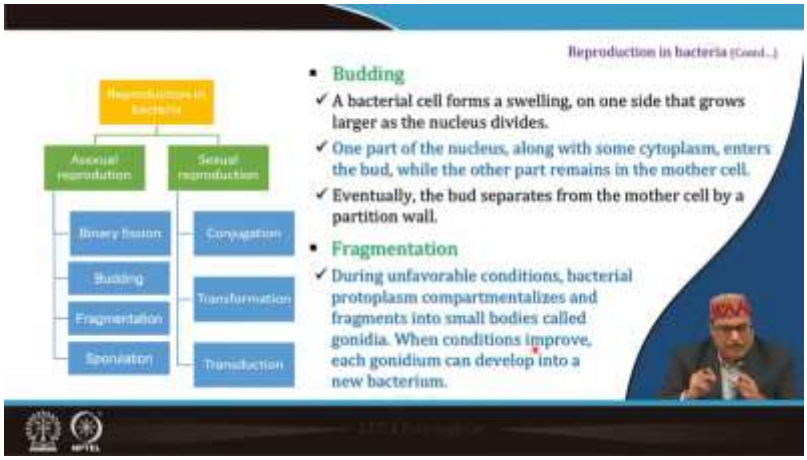
The shape of nearly all bacteria, with a few exceptions, can be derived from spheres, cylinders, and curved cylinders. So, based on shape, bacteria are categorized into four major groups: cocci (singular is coccus), which are spherical—they are mainly spherical, like this. Examples include *Staphylococcus, Streptococcus*, etc.; they are all spherical in nature. Another group is the bacilli (singular is bacillus), which are rod-shaped bacteria, such as *E. coli* or the Bacillus group of bacteria. Then there are spirilla (singular is spirillum), which are spiral-shaped bacteria. Examples *include Spirillum, Pterophomia*, *Treponema*, etc. Lastly, there are vibrios, which are short, curved rods—common comma-shaped organisms. A good example of this is Vibrio.



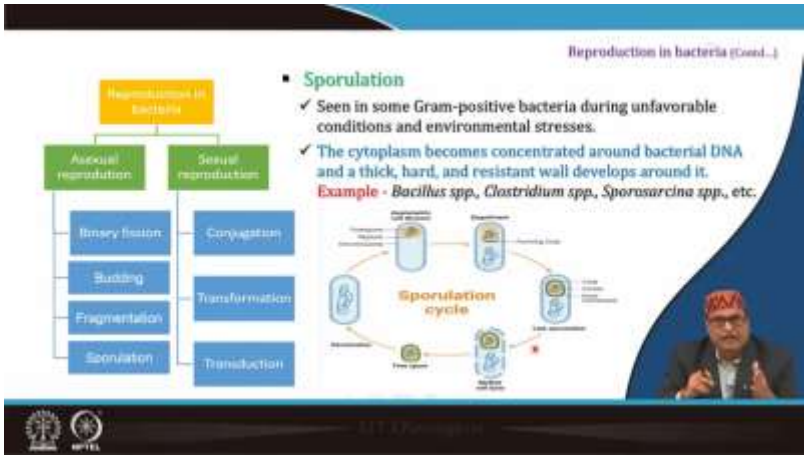
Regarding bacterial metabolism, it includes all the metabolic and biochemical activities occurring inside the bacterial cell. Based on the mode of obtaining carbon, bacterial metabolism can be classified as heterotrophic, autotrophic, or phototrophic. In the case of heterotrophic metabolism, bacteria use organic compounds as carbon and energy sources. Carbohydrates, lipids and proteins are commonly oxidised to form ATP and precursor molecules. Respiration and fermentation are the two major processes. The respiration process is the process of obtaining energy in the form of ATP by the complete oxidation of food, particularly glucose, inside the bacterial cell. Meanwhile, fermentation is the process where glucose is enzymatically broken down into simpler organic end products like alcohols or acids, directly oxidising inorganic compounds without using sunlight to generate energy. It is also called chemotrophic. As the name indicates, phototrophic bacteria use light energy to oxidise inorganic compounds and produce ATP energy molecules.



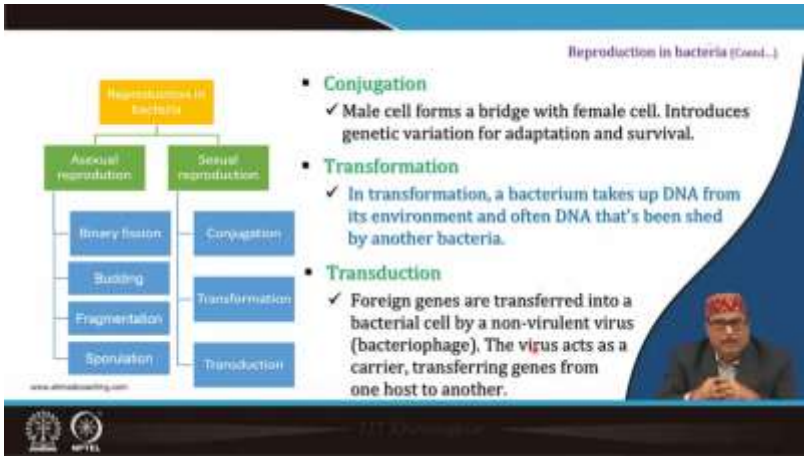
As far as the reproduction in bacteria is concerned, there may be both types. sexual reproduction like binary fission, budding, fragmentation and sporulation, where sexual reproduction may also take place, and this involves conjugation, transformation and transduction. So, in the case of binary or transverse binary fission, it is the most common mode of binary or bacterial reproduction. As you can see in this figure, a single cell divides to form two identical data cells.



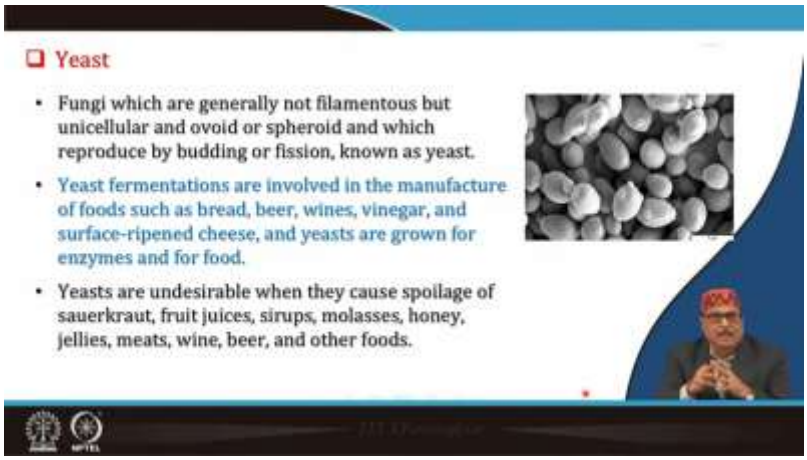
In the budding, a bacterial cell forms a swelling on one side that grows larger and larger as the nucleus divides, and one part of the nucleus, along with some cytoplasm, enters the bud. There is a buzzing in the cell at one point. So, this cytoplasm and nucleus enter the bud while the other part remains in the mother cell, and eventually, the bud finally separates from the mother cell by a partition wall. So, this is how the budding process of cell division occurs. Then, in fragmentation, what happens during unfavourable conditions is that the bacterial protoplasm compartmentalises and fragments into small bodies called gonidia. When conditions improve, each gonidium can develop into a new bacterium.



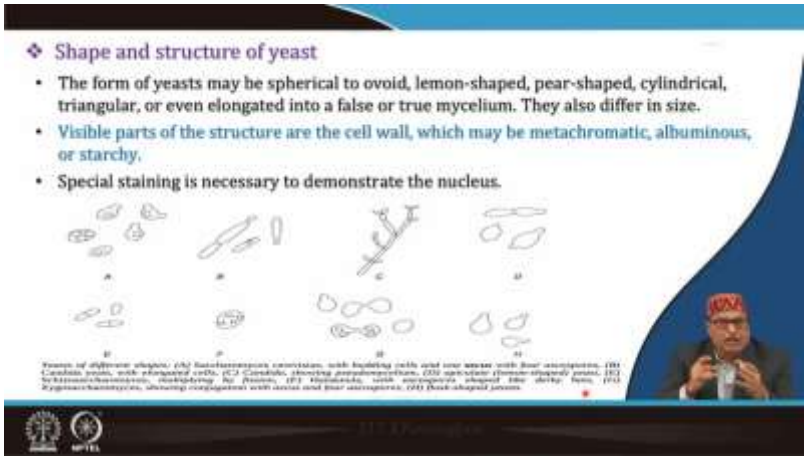
In sporulation, it is particularly seen in gram-positive bacteria during unfavourable conditions. when there is environmental stress. So, in this process, the cytoplasm becomes concentrated around bacterial DNA and a thick, hard, and resistant wall develops around it. For example, you can say that *Bacillus* spp., *Clostridium* spp. and even *Sporosarcina*, a species, all divide or reproduce using sporulation, and they form spores.



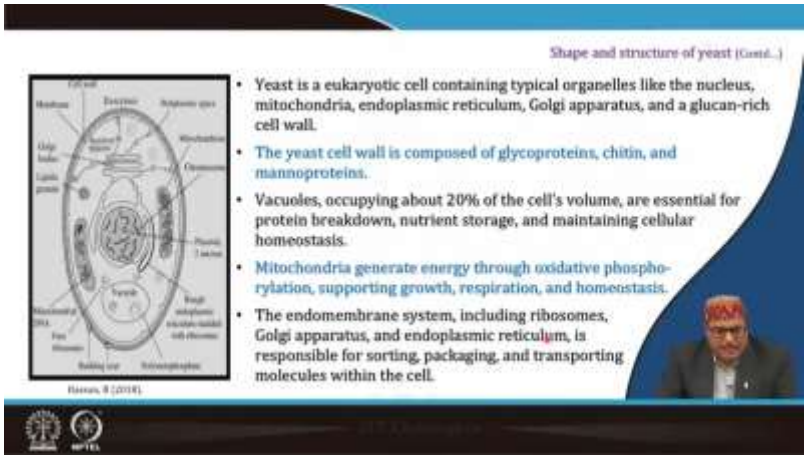
Then conjugation. Many male cells form a bridge with female cells and introduce genetic variation in adaptation and survival. Transformation is a process in which a bacterium takes up DNA from its environment, and often DNA that another bacterium has released. So, this is sexual reproduction. In transduction, foreign genes are transferred into a bacterial cell by a non-virulent virus, that is, a bacteriophage, and the virus acts as a carrier, transferring genes from one host to another. So, this is briefly how bacteria reproduce.



Then, let's talk about yeast. These fungi are generally non-filamentous but unicellular and ovoid; they are ovoid or spherical and reproduce by budding or fission. So, the fungi which have these characteristics are known as yeast. Yeast fermentations manufacture foods such as bread, beer, wine, vinegar, and surface-ripened cheeses and yeasts are grown for enzymes and food. Yeasts are undesirable when they cause spoilage of sauerkraut, fruit juices, syrups, molasses, honey, jelly, meats, wine, beer, and many other fruits.

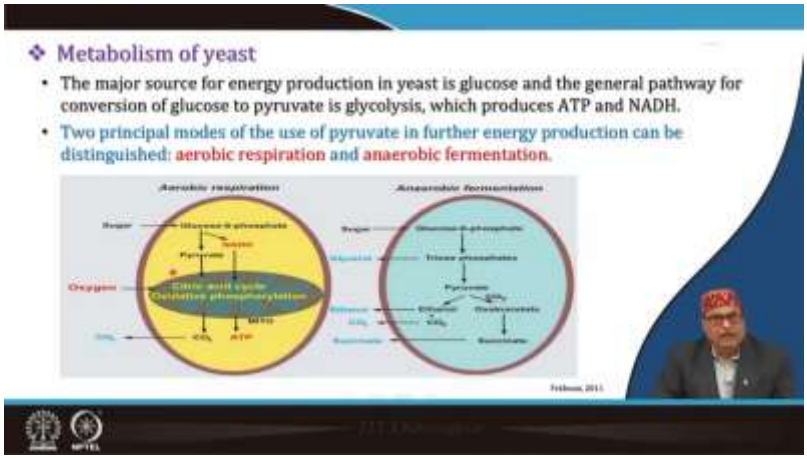


As far as the shape and structure of yeast is concerned, the form of yeast may be spherical to ovoid, lemon-shaped, pear-shaped, cylindrical, triangular, or even elongated into a false or true mycelium. So, they all differ in size, they also differ in size. Visible part of the structure or the cell wall, which may be metachromatic, albuminous or starchy. A special staining is necessary to demonstrate the nucleus in the yeast, and the various shapes are given here, as you can see. Like, for example, C, you can see here it is a *candida*. So, in the pseudo cycle, D is the apiculate lemon shape and various shapes of the yeast are shown in this figure.



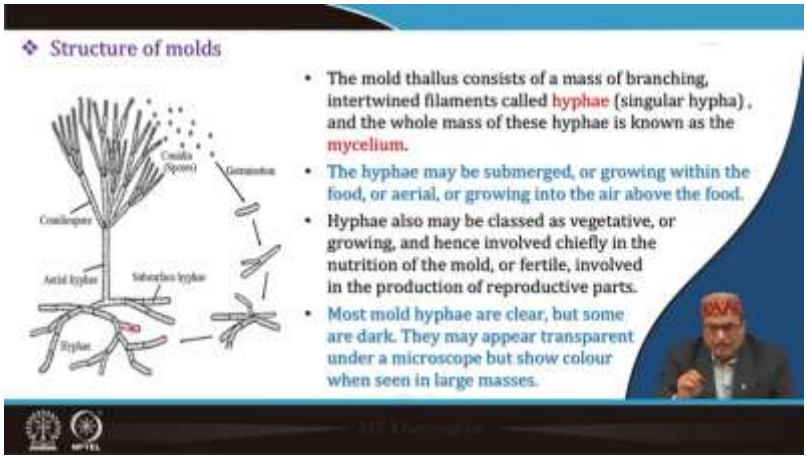
Yeast is a eukaryotic cell containing typical organelles like the nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus and a glucan-rich cell wall that you can see here in this figure, which is a description of one yeast cell. The yeast cell wall is composed of glycoproteins, chitin and manoproteins. Vacuoles occupying about 20 percent of the cell volume are essential for protein breakdown, nutrient storage and maintaining cellular homeostasis. Mitochondria generate energy through oxidative phosphorylation. supporting growth, respiration and homeostasis in the yeast cells. The endomembrane system

including ribosomes, Golgi apparatus and endoplasmic reticulum is responsible for sorting, packaging and transporting molecules within the cell.



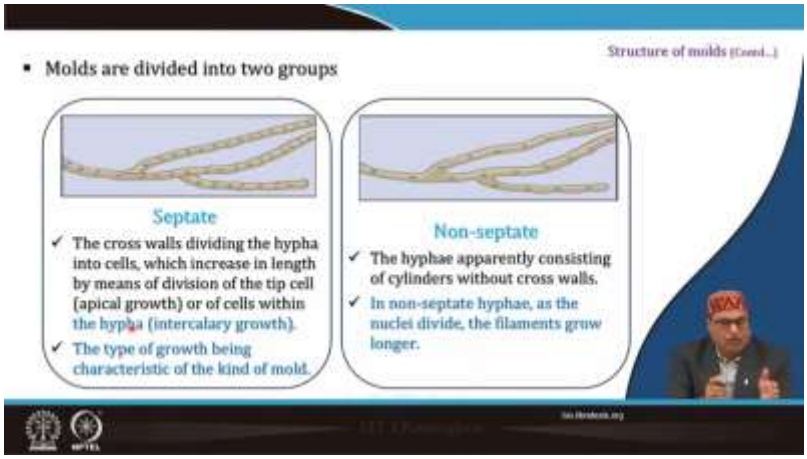
The metabolism of yeast: The major source of energy production in yeast is glucose, and the general pathway for the conversion of glucose to pyruvate is glycolysis, which produces ATP and NADPH. As you can see here in these two figures, it is shown in aerobic respiration and anaerobic fermentation, which are the two principal modes of the use of pyruvate in further energy production, okay. In aerobic respiration, consider the sugar glucose-6-phosphate, it goes to pyruvate, and then, with oxygen, it converts to the citric acid cycle and oxidative phosphorylation. Only carbon dioxide is released, and ATP is produced. Whereas, in anaerobic fermentation, glucose is converted into glucose-6-phosphate, then again to triose phosphate, pyruvate is converted, and pyruvate is completely converted into ethanol plus carbon dioxide or completely oxidised into carbon dioxide. It enters the TCA cycle: oxaloacetate, succinate. So, these are briefly the aerobic respiration and anaerobic fermentation pathways. Most yeasts reproduce asexually by budding, where a large form of the cell grows and eventually separates. You can see here that a bud is formed, it grows like a bud, and then finally, it separates. Some yeasts use a tube-like projection, which is budding. While a few reproduce by fission or a combination of fission and budding, both fission as well as budding. In true yeast like *Ascomycotina*, sexual reproduction leads to the formation of ascospores, with the yeast cell acting as the ascus. Ascospores are typically formed after the conjugation of two cells. Some species produce them without conjugation, followed by spore or daughter cell formation. False yeasts, which do not produce sexual spores, belong to the fungi imperfecti; some, like Candida, form thick-walled chlamydospores.

Now, let us talk about molds. The term mold is commonly applied to certain multicellular filamentous fungi whose growth on food usually has a fuzzy or cottony appearance. You must have seen that when bread or other material is stored in a humid environment, a cotton-like growth takes place; that is the mould. They are typically considered unfit for consumption due to spoilage and potential mycotoxin production. Certain molds are intentionally used in food production, such as mold-ripened cheeses like blue cheese, roquefort cheese, camembert, as well as Brie, which develop unique flavors and textures because of this mold growth. Molds are essential in oriental food production and products like soy miso, soy sauce, and sonti, contributing to the fermentation and flavor development. Some molds are cultivated for direct consumption or as animal feed. While others are used industrially to produce enzymes like amylase for bread making or organic acids like citric acid, which is used for soft drinks, etcetera.

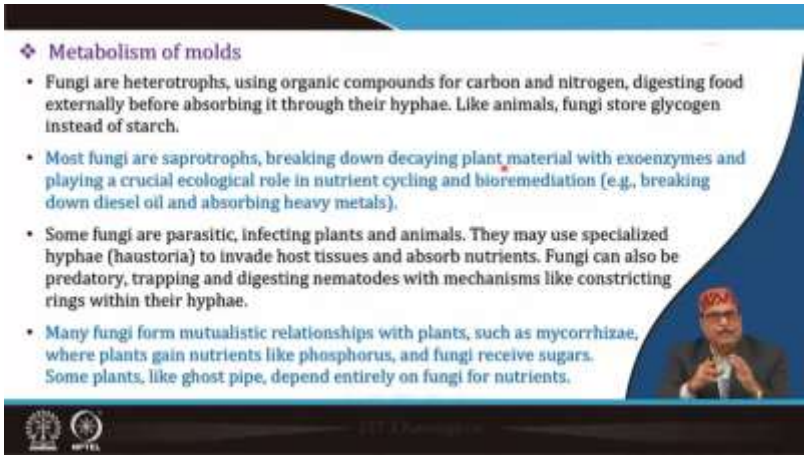


If you look at the structure of mold, as has been shown in this figure, the mold thallus consists of a mass of branching, intertwined filamentous cells called hyphae. The singular is hypha, and the whole mass of these hyphae is known as mycelium. The hyphae may be

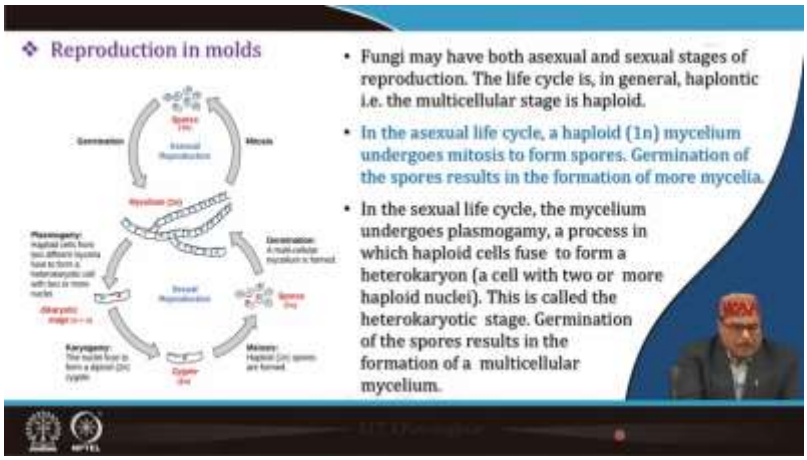
submerged or growing within the food or growing into the air above the food. Hyphae may also be classified as vegetative or growing and hence involved chiefly in the nutrition of the mold, or fertile, involved in the production of reproductive parts. Most mold hyphae are clear, but some are dark. They may appear transparent under a microscope but show color when seen in larger masses.



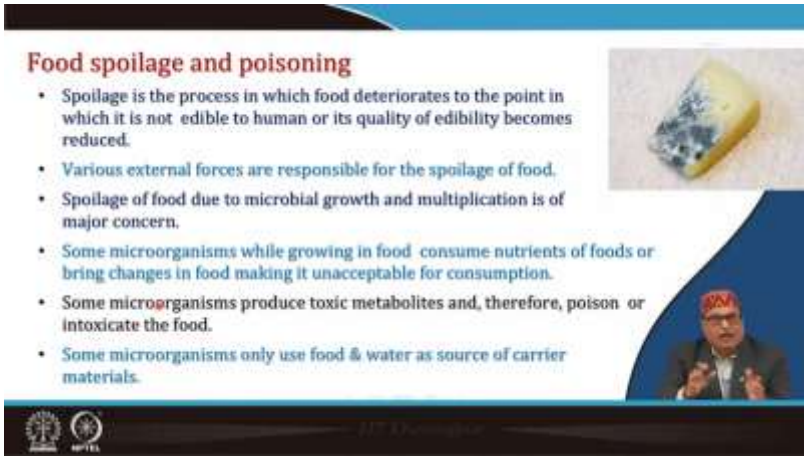
Moulds are divided into two groups, as you can see here in this figure: septate moulds and non-septate molds. In septate molds, as you can see, there are cross walls that divide the hypha into cells, which increase in length by means of division of the tip cell that is apical growth or of the cells within the hyphae, that is intercalary growth and this type of growth is characteristic of the kind of mould. In the non-septate mould, there is no clear-cut division; the hyphae apparently consist of a cylinder. Without any cross walls or tube-like material, there is no cross wall, no distinct nucleus, etcetera. No nucleus, but a nucleus can be seen, yet there is no separation of this. Non-septate hyphae, as the nuclei divide, the filamentous growth grows longer.



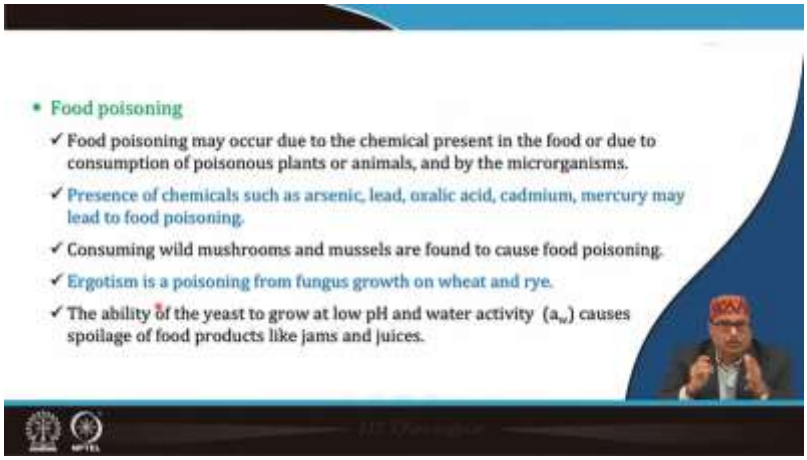
As far as the metabolism of moulds is concerned, you know, fungi are heterotrophs, using organic compounds for carbon and nitrogen, digesting food externally before absorbing it through their hyphae. Like animals, fungi store glycogen instead of starch. They function like animals, too. Most fungi are saprotrophs, breaking down decaying plant material with exoenzymes and playing a crucial ecological role in nutrient cycling and bioremediation, that is, breaking down diesel, oil, and absorbing heavy metals, etcetera. So, most fungi are involved in the bioremediation process. Some fungi are parasitic, infecting plants and animals. They may use specialised hyphae to invade host tissues and absorb nutrients. Fungi can also be predatory, trapping and digesting nematodes by constructing rings with their hyphae. Mutualistic relationships with plants, such as mycorrhizae, where plants gain nutrients like phosphorus and fungi receive sugars. Some plants, like ghost pipe, depend entirely on fungi for nutrients.



Reproduction in mould—you can say again—they are involved in both asexual reproduction and sexual reproduction. In their life cycle, it is generally haploid; that is, the multicellular stage is haploid. In the case of the asexual life cycle, a haploid mycelium undergoes mitosis to form spores. The germination of the spores results in the formation of more mycelium. In the case of the sexual life cycle, the mycelium, as you can see here in this figure, undergoes plasmogamy, a process in which haploid cells fuse to form a heterokaryon—that is, a cell with two or more haploid nuclei—and this is called the heterokaryotic stage. The germination of the spores results in the formation of multicellular mycelium.



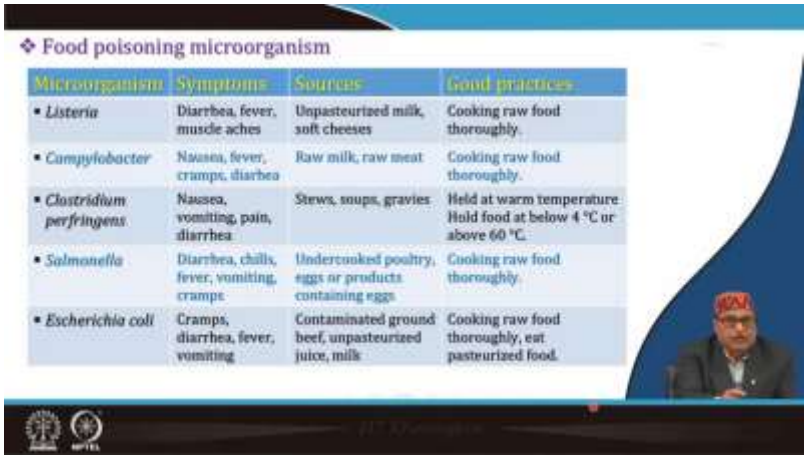
Now, let us briefly talk about food spoilage and poisoning. As I told you earlier, what happens is that microorganisms basically consume the same type of nutrients that we need. Humans need nutrients from food; the same type of nutrients microorganisms need for their survival. So, in what do they do when there is any biomaterial or food material? So, the microorganisms try to interact and consume the food nutrients for their own survival. And in the process, they sometimes change the characteristics of the nutrients or make them inedible, like the changes in the food components are such that a foul flavour is developed, a foul smell is present, its colour degrades, and its protein or carbohydrate content. So, all those things may occur, but it may not be toxic. So, that is what you can call food spoiling. The other is poisoning, which occurs when microorganisms grow or produce certain substances that cause disease, making the food poisonous. So, that is the basic difference between food spoilage and poisoning. Spoilage is the process in which food deteriorates to the point where it is not edible to humans or its edibility quality is reduced. Various external forces are responsible for food spoilage, like environmental forces, temperature, food-microorganism interactions, etc. Spoilage of food due to microbial growth and multiplication is a major concern. Some microorganisms, while growing in food, consume nutrients of the food or bring changes in the food, making it unacceptable for consumption. Some microorganisms, while growing, produce toxic metabolites. Therefore, the food becomes poisonous or intoxicated. Some microorganisms only use the food and water as a source of carrier material, which is called food infection. In food poisoning, there may be two categories: food poisoning and food intoxication.



Food poisoning may occur due to the chemicals in the food or due to the consumption of poisonous plants or animals by microorganisms. That is, food may be poisoned due to the presence of chemicals such as arsenic, lead, oxalic acid, cadmium, or mercury. They may also lead to natural food poisoning. Even consuming wild mushrooms and mussels has been found to cause food poisoning because these materials can naturally contain certain types of toxic or allergenic compounds. Ergotism is a poisoning from a fungus that grows on wheat and rye. The ability of yeast to grow at low pH and low water activity causes spoilage of food products like jam, juices, etcetera.

So, this is, but here in this lecture, we are more concerned about microbial food poisoning. So, microbial food poisoning may be of two types: food infection and food intoxication, as I told you earlier. So, in the case of food infection, intestinal organisms like *Salmonella*, *Shigella*, etc., cause food poisoning by the release of toxins after being consumed along with the food. These types of infectious microorganisms use food and water as a source of transport, and when the food gets contaminated with these bacteria or other microorganisms. And when we consume such food, they get established in our system and

grow and produce toxins, which may be endotoxins, exotoxins, etc., ok So, it takes some time, obviously, for the effect to be seen after the food is eaten. The infection may come from diseased animals, poultry, eggs, milk, or from food contaminated by rodents and insects. Trichinosis is a disease caused by a nematode, that is, Trichinella spiralis, which lodges in the muscle fibers of hogs or pork. The other type of poisoning is food intoxication, where certain bacteria, when they grow in the food, produce toxins prior to being eaten, meaning the food becomes toxic, and we consume toxic food. So, it causes poison called intoxication, which is an example of this type of food poisoning. It is caused by the ingestion of the toxin produced by Clostridium botulinum, particularly when it is found in canned food, etc. So, when this Clostridium botulinum grows in the food, it produces toxin, and the food becomes toxic. The spoilage of food by mould is primarily due to the mycotoxins, such as aflatoxin, ochratoxin, portulin, etc., which are secondary metabolites produced by moulds and the toxins are contained in the food.



So, here in this table, I have given you some major food poisoning microorganisms, which are the names of the microorganisms. And the symptoms when you consume such a toxic food or poison food because of these bacteria, what will be the symptoms, and are normal carbon sources which are get from the where you get this type of poisoning and what are the good practices that how one can avoid Like for example, *Lyseria*, if you consume a food with the Lyseria or contaminated food etcetera, then it will produce poisons, toxins etcetera and which will cause diarrhea, fever, muscle ache etcetera. It is basically the sources that are unpasteurized milk, soft cheeses, etc., that may contain these bacteria if you consume unpasteurized milk. So, what is the good practice to avoid this? Cooking raw food thoroughly, you cook it, sterilise the milk, pasteurise the milk, etc., all those things you can get. Then similarly, with *Campylobacter*, you get nausea, fever, cramps, diarrhoea. It is again in the case of raw milk or raw meat, it is common and cooking raw food

thoroughly is the best practice. *Clostridium perfringens* it may the symptoms because of the clostridium perfringens poisoning may be nausea, vomiting, pain, diarrhea etcetera and it may be due to the eating of the stews, soups, gravies and here the good practice to avoid this is the held Keep the food at warm temperature, hold the food at below four degree Celsius or above sixty degree Celsius. Then salmonella: *Salmonella* poisoning symptoms may include diarrhea, chills, fever, vomiting, cramps etcetera. And the sources of this poisoning may be undercooked poultry, eggs or products containing eggs. So, cooking the raw food thoroughly is the remedy for this type of poisoning. E. coli poisoning may lead to cramps, diarrhoea, fever, vomiting, etc., and contaminated ground beef, unpasteurized juices, milk, etc., may be the source of infection for this poisoning. raw food thoroughly, and eating pasteurised food or heat-treated food is a good way to avoid this type of poisoning. Then, finally, the food safety hazards.

You know, a food safety hazard can be defined as any factor present in the food that has the potential to cause harm to consumers, either by causing illness or injury. So, hazards are the factors that food safety practices seek to protect against and contain and eliminate from foods, and these hazards may be of different, difficult types due to various reasons, including physical hazards. That is the food safety hazards because of the physical hazards, such as handling processing material, glass, metal, hair, etc., which may be a source of physical food hazards for safety. There may be chemical reasons, chemical hazards like the presence of pesticides in the food, processing chemicals, which are used for processing, and they are also not good for food, not safe for health, drug residue, even allergens naturally present in food, bones, pits, bugs, etc., if they are found, they may be a chemical hazard. And the biological hazard is mainly the contamination of the food or the growth of the food. food poisoning bacteria, viruses, bacterial toxin, biogenic amines, mycotoxins etcetera. So, in this lecture, our main concern is the biological food safety or microbial

safety of the food, microbial food safety hazards, and we will take up this separately in a lecture in this module itself. A separate lecture will be devoted to this food safety hazard.

So, finally, I would like to summarise this lecture. Understanding the complex world of food microorganisms, encompassing bacteria, yeast, and mould, is crucial for ensuring food safety and quality. The structure and metabolism of microbial cells play fundamental roles in their survival, reproduction, and interaction within the food environment. Microorganisms can reproduce rapidly, leading to food spoilage and potential poisoning, posing significant hazards to public health. Some microorganisms are beneficial, such as those used for the production of vitamins, as well as many bioactive compounds; they are traditionally used in food fermentation and aging processes. Food spoilage microorganisms affect the quality of the food, while food pathogens make the food unsafe by causing food intoxication as well as food infection, and so on. So, from what you have learned so far, you can say that microorganisms are very important in food technology and they must be considered seriously for both their beneficial and harmful effects.

These are the references used in this lecture.

Thank you very much for your patience hearing.