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Module No. # 01
Lecture No. # 02
Glimpses of Microbial World-Bacteria

Good morning students.

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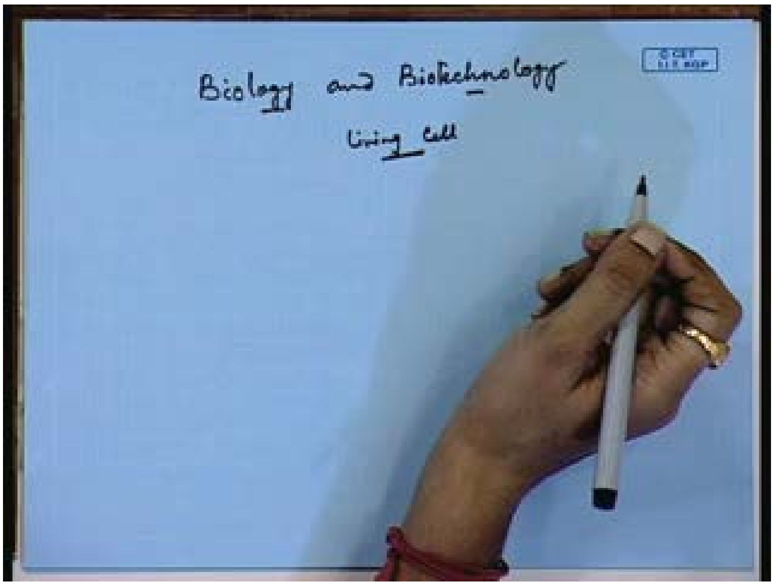

In my first lecture, I have already discussed about the difference between this Biology and Biotechnology, where I have already told you that, what are the differences between, this particular this living cell. And, I have also mentioned that, how this biology and biotechnology are inter-related with each other.

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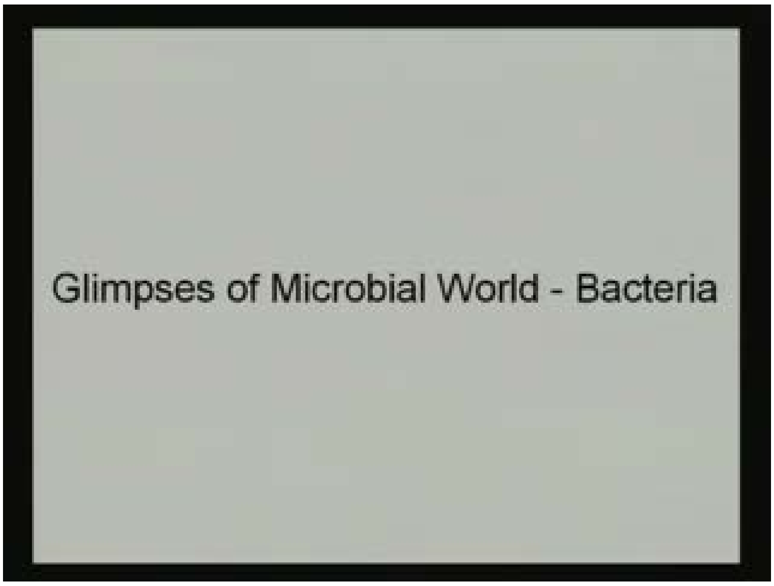

My today's lecture is on Glimpses of the microbial world. To live, if well informed, self existence modern world, it is becoming increasingly necessary to have the knowledge of the tiny particles which are present in this universe. And this tiny particles are so small, that we cannot see it in our naked eye. And, if we see that particular structure, we categorize them into different groups. Our today's lecture is on one of such micro-creature, which is present in this universe, is called bacteria. Today, in this lecture, we will be learning the architecture of a bacterial cell.

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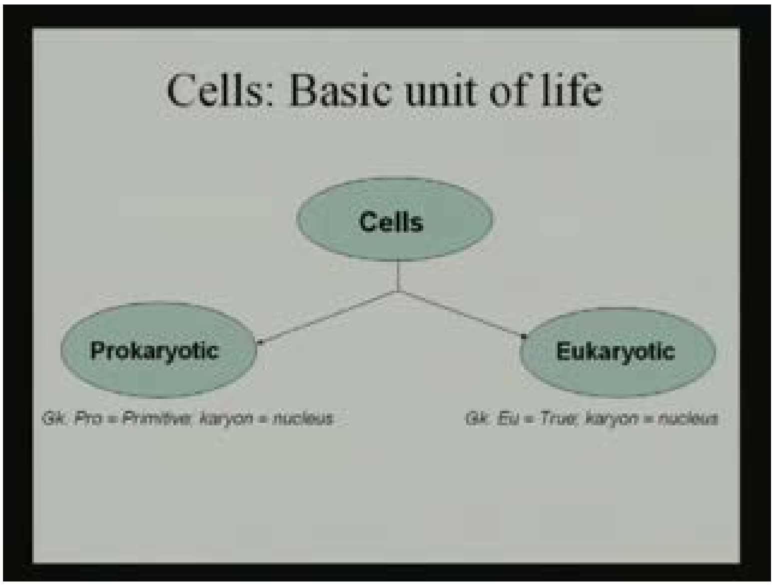

Now, in my earlier class, I have already mentioned you about the cell. And, I have also told you that, cell is the basic unit of life. Based on the cellular organization, the entire cells can be divided into two major categories. One is called the prokaryotic cell; another is called the eukaryotic cell. Prokaryotic cell, it, what does it mean? Pro means primitive; karyon means nucleus; that means, obviously, this group of microorganisms are very primitive in nature and obviously, bacteria is one of such example. Eukaryotes are the developed cell, where this nucleus has got its own nucleus membrane, which is not there in case of the prokaryotic organism.

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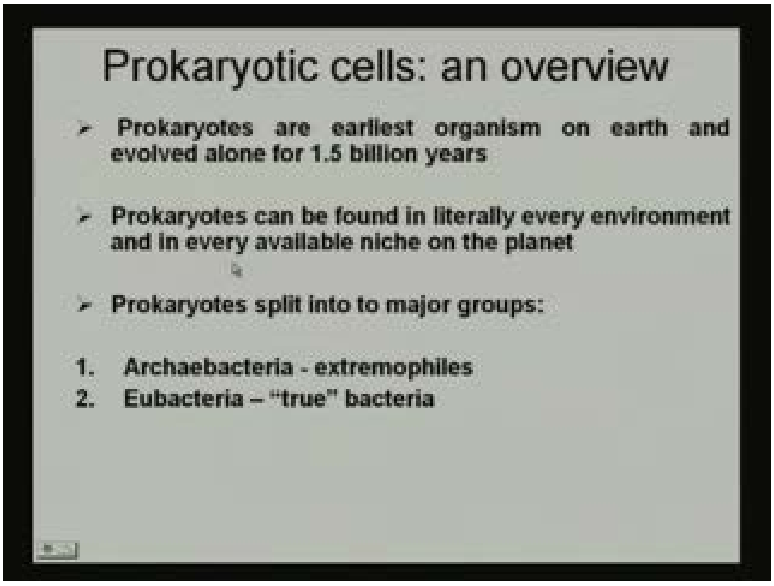

Now, if we see the overview of this prokaryotic cell, then, we can find that, this prokaryotic cells are the earliest organism in this universe, and evolved alone for 1.5 billion years. Prokaryotes can be found in, everywhere, in every niche available on this planet. Based on its structure, based on its, its, this different cellular organization, or structure, the prokaryotes can be divided into, can be divided into two major groups.

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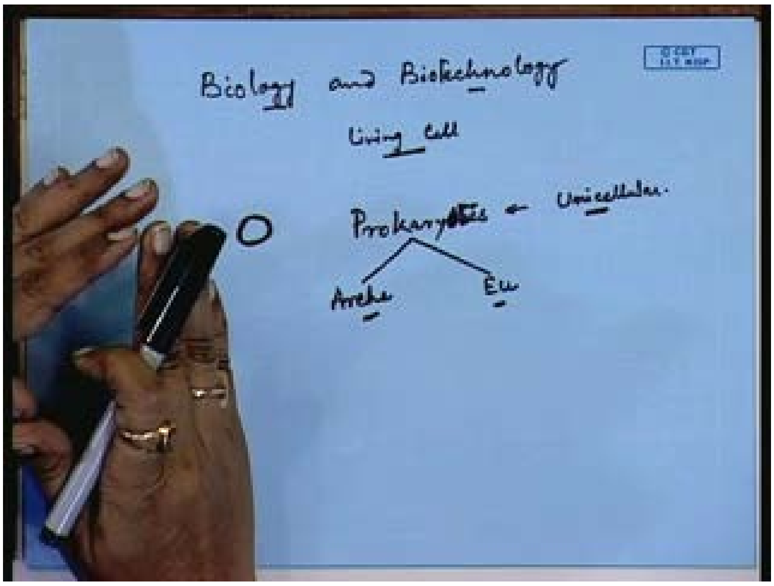

One is called, one is called the archebacteria; another is the eubacteria. Archebacteria is considered to be the most primitive type of bacteria, which is otherwise known as the extremophile. Eubacteria is the true bacteria. So, we will be learning that, what and obviously, it is worth mentioning that, this bacteria, this prokaryote are unicellular in nature; that means, it is having a single cell; that means, how this cell is, is, whatever maybe it is shape and size, it is only a single cell, which is doing all its metabolic activities. Now, let us learn systematically, the architecture of a particular prokaryotic cell.

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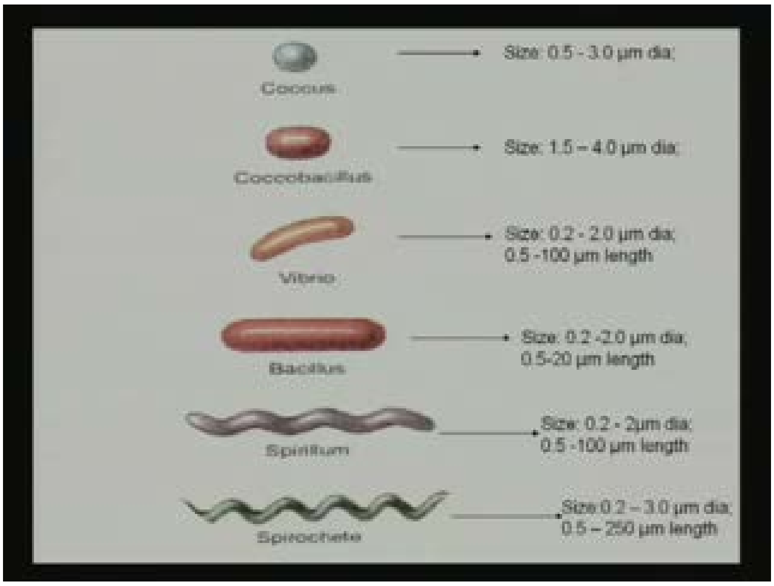

Now, if we see the entire bacterial world based on its shape, the bacteria can be categorized. And, if we see its shape, you will find that, some of this bacteria are round or spherical in nature, some are rod and some are spiral in nature. Now, this are the, this, this are some of this classification; some are comma shaped; some of this bacteria are neither round, nor rod, it is a oval shaped bacteria; and, based on this, we can categorize the entire bacterial world into different segments. Now, if it is a spherical shaped bacteria, we call it as coccus, and this group of bacteria, if we see its size, it varies from 0.5 to 3 micrometer in diameter.

In case of Coccobacillus, that is the oval shape, shaped bacteria, or oval shaped bacteria, its size varies from 1.5 to 4 micrometer in diameter. Vibrio is a comma shaped bacteria, and if we see its size, it ranges from 0.2 to 2 micrometer in diameter and 0.5 to 100 micrometer length. In case of bacillus, the size of this group of bacteria varies from, its size varies from 0.2 to 2 micrometer in diameter and 0.5 to 20 micrometer in length. In, in case of spiral shaped bacteria like spirillum, 0.2 to 2 micrometer diameter and 0.5 to 100 micrometer in length. In case of spirochete, this size varies from 0.2 to 3 micrometer in diameter and 0.5 to 250 micrometer in length. So, from this particular information, what we can conclude, we can conclude that, the minimum size of this bacteria irrespective of its shape, it can vary from 0.2 micrometer to 250 micrometer.

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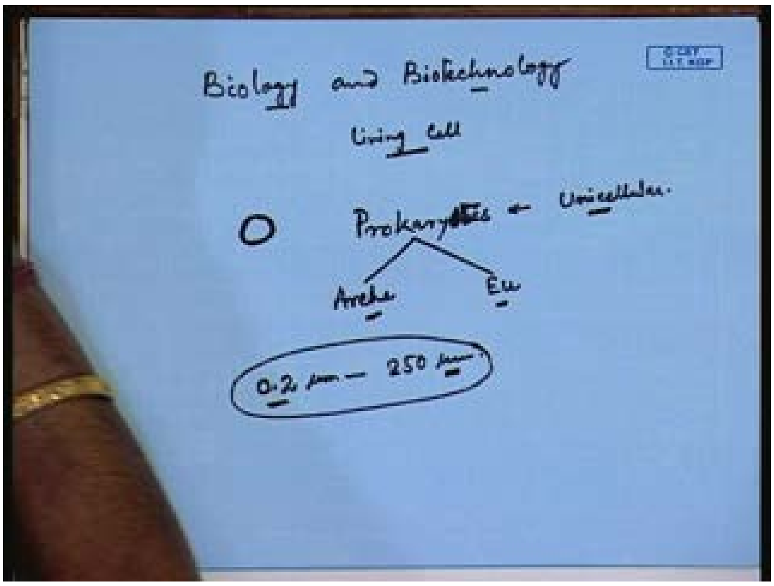

So, this is the size of this bacteria. Just, you can see that, it is in the tune of micrometer; so, how small you can understand.

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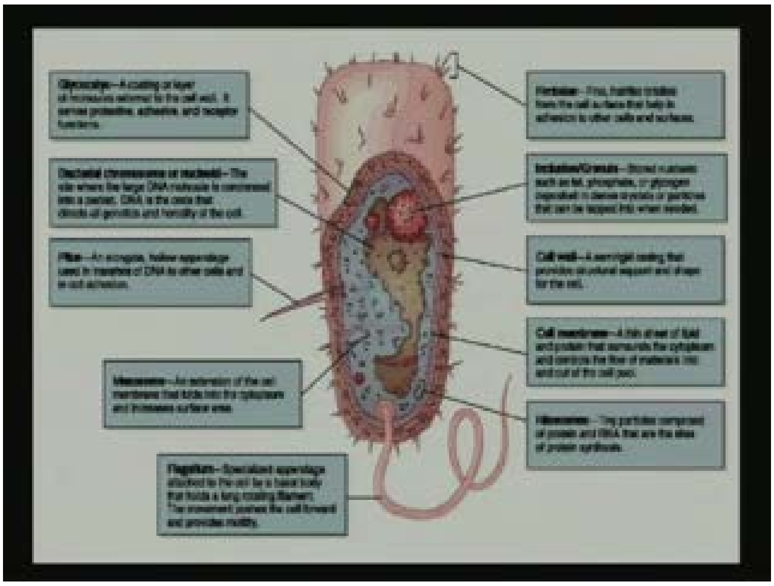

Now, if we see this particular bacteria under the microscope, then, with different magnification if we see, we can find that, there are different organelles which are present in this particular bacteria.

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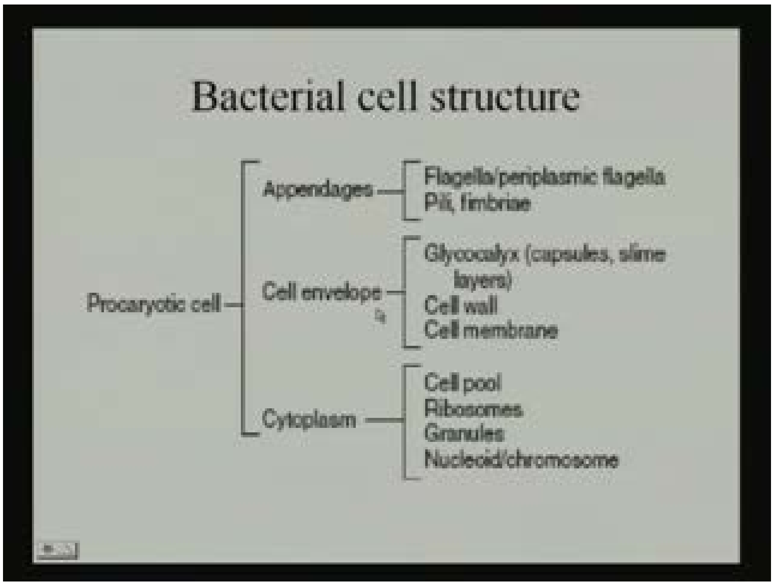

Now, based on this organelles, and their arrangement, the entire bacterial cell structure, or the prokaryotic cells, can be divided into three major groups. That is, the appendages, cell envelope and cytoplasm. This appendages means, the outer protecting layer, which is present external to this cell wall of this bacteria. Now, what are those? These are the flagella; this may be the pili; this may be the fimbriae. Immediately followed by this appendages, are the cell envelope, where we can see the glycocalyx, that is, the capsule or the slime layer, and here, this is the external protective layer which is present on the outer surface of this bacterial cell wall and we can see, followed by this glycocalyx, is the cell wall and then, cell membrane. When we are considering this cytoplasm, this cytoplasm is the cell pool; the internal liquid, or the internal material, which is getting protected by the cell membrane and the cell wall of this bacteria, followed by this appendages. So, if we see the cell, that three internal fluid, we can find that, it has got cell pool; it, it has ribosomes, granules and nucleoid or the chromosome, that is the genetic material, which is present inside the bacteria.

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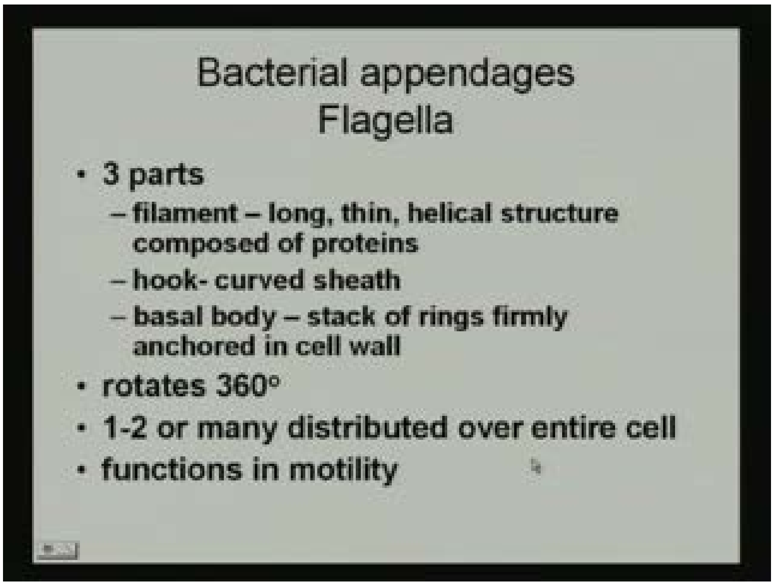

Now, let us come one by one, to each of this organelles which are present in the bacterial cell. Now, this bacterial appendages, this flagella, if we see, this flagella can be divided into three major parts. One is the filament; that is the long, thin, helical like structure, which is mainly composed of the protein. The protein is one of the biomolecule which are present in this particular living cell. It has got the hook like structure, that is curved and sheath and a basal body, that is the stack of rings, firmly anchored on the cell wall of this particular bacteria.

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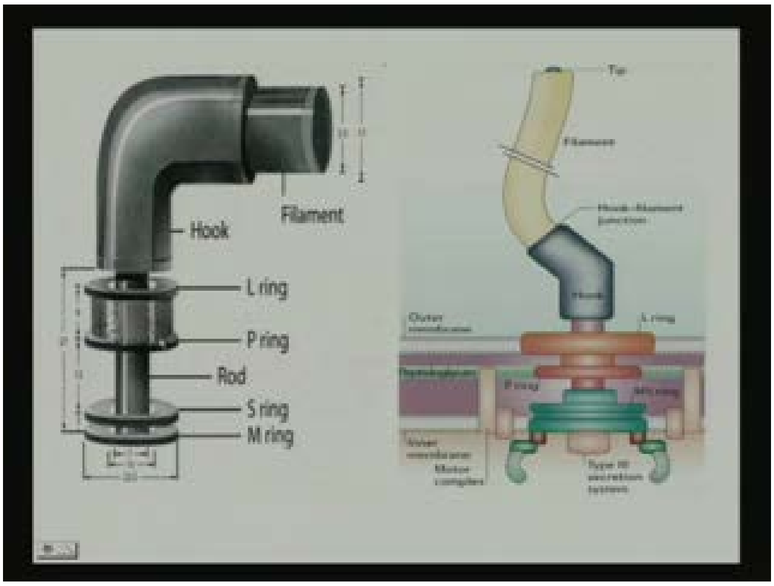

Now, if we see the particular structure of this flagella, then, we can find, see, this is the filament, this is the hook and this is the basal body, and this basal body, here, different type of rings are there; this is the m ring; that means, the part of this ring is attached to the cell internal, that inner membrane of the cell; followed by this s ring, and this p ring and l ring is present on the outer membrane of this cell wall of this bacteria; that means, on the cell wall of this bacteria, this flagella like structure is inserted and it is attached with this cell wall.

Now, here, this particular if we see that, the diameter of this particular filament, we can find that, it is 3.5 nanometer, this i d and o d is 17 nanometer. And here, the entire basal, basal bodies, which weld this entire the structure is attached, is 27 nanometer and if we see the filament which is inserted in this o ring, has got this, i d is 7 nanometer and o d is, o d of this, this this filament is 10 nanometer and this o ring, if we see, the o d of this o ring which is attached with this membrane, cell wall and cell membrane of this bacteria, is 22.5 nanometer in structure. Just, you imagine, how thin this particular filament, which is attached and which can rotate.

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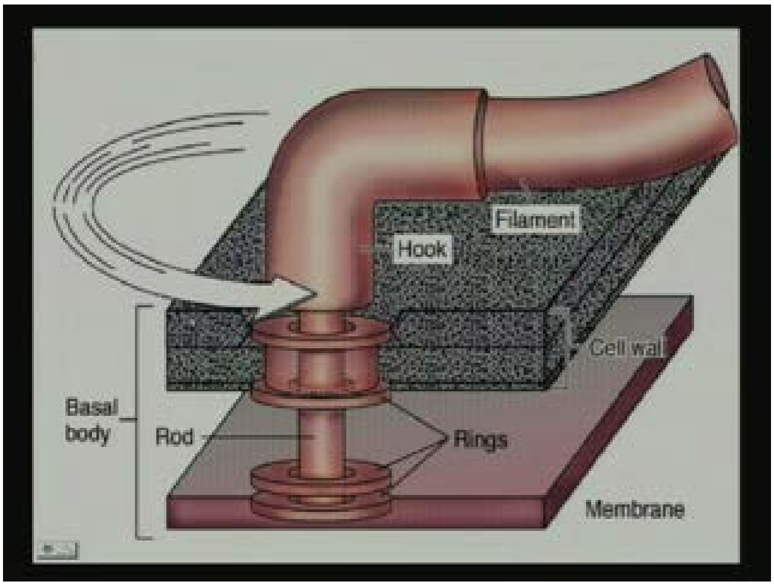

Now, what is this? If we see this, the arrangement and this is the cell wall and this is the cell membrane; in this way, this particular filament, this particular flagella is inserted inside the cell wall and here, this particular o ring to which this filament, this hook and filament is attached, it has got the capacity to move 360 degree. So, when it moves 360 degree, it needs the energy and that energy is in the form of a t p and this, and with that energy, it can rotate, this flagella can rotate.

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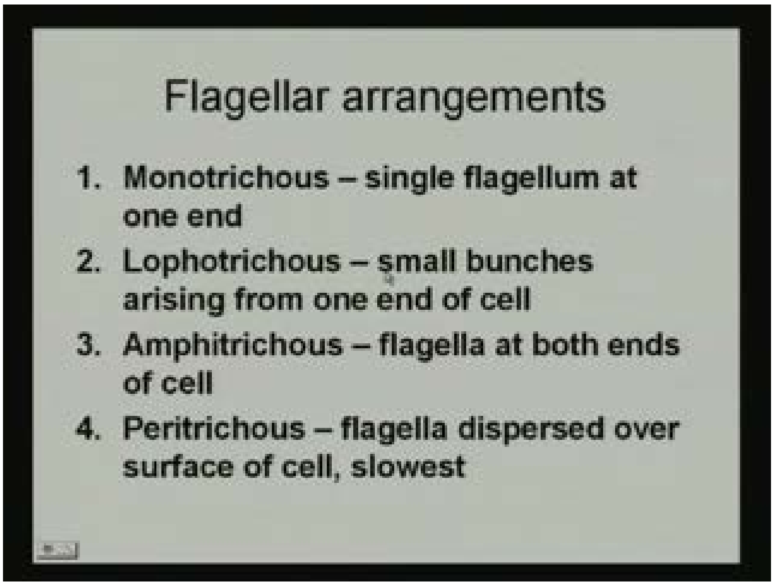

And, this is the actual structure of this flagella. Now, if we see the arrangement of this flagella in any bacterial cell, then, we can find that, this flagella may be a single flagella at one particular end of this bacteria; and that is, this particular arrangement is called monotrichous.

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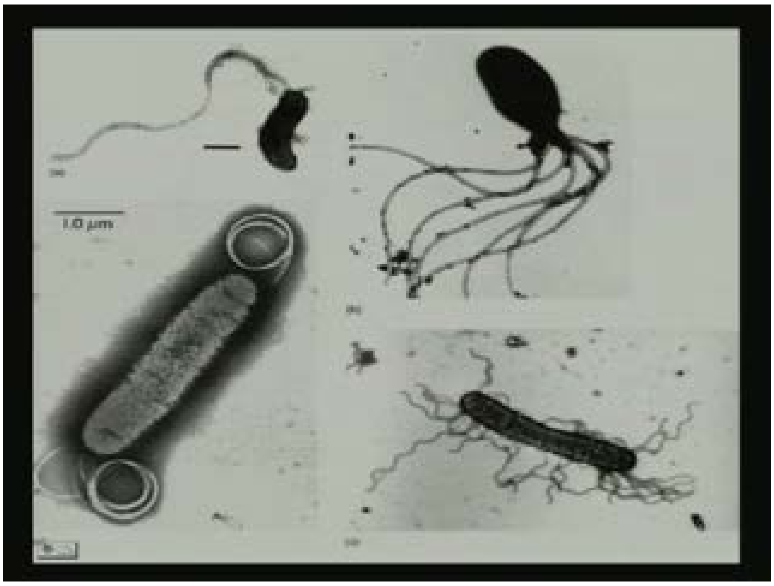

If a small bunches of flagella arising from one end of the cell is called lophotrichous. When the flagella at both the ends of the cells are present, are called amphitrichous and when this flagella is altogether, uniformly distributed throughout the bacterial cell, it is called peritrichous arrangement. So, this way, this flagellal arrangements are there.

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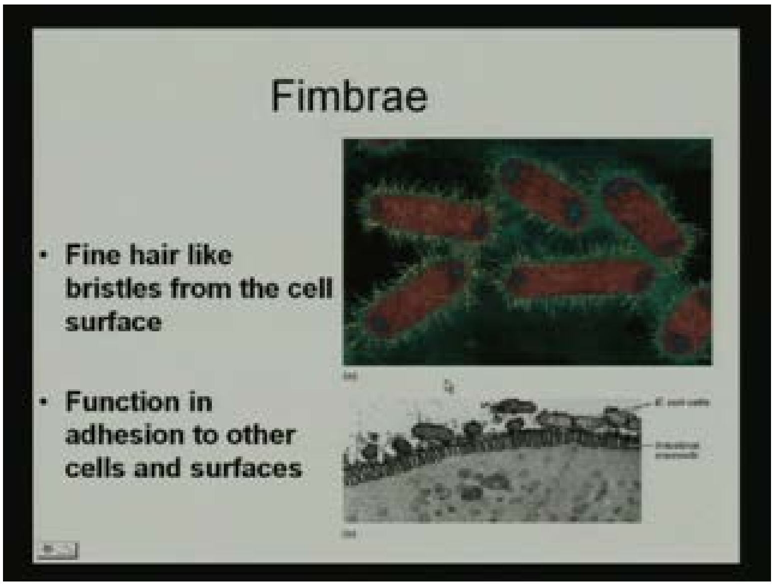

So, what is the main function of this flagella? It helps in, mainly, it helps in locomotion of the bacterial cell. Next to this flagella, is the fimbrae. Fimbrae is a hair-like structure which is present uniformly on the outer wall of this bacterial cell and its main function is to adhesion to the other cell; that means, with this hair-like structure, one cell is getting associated with another cell and in this way, they can form the colony like structure.

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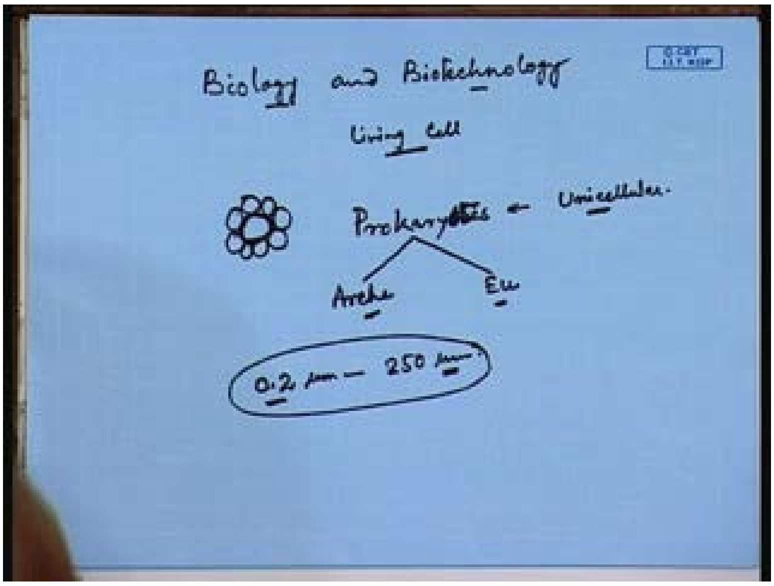

So, in this way, this bacterial structure, this colony is getting formed. So, when we are seeing any bacterial colony, n number of such micro-creatures are there. So, they are associated with each other, with the help of this fine hair-like structure.

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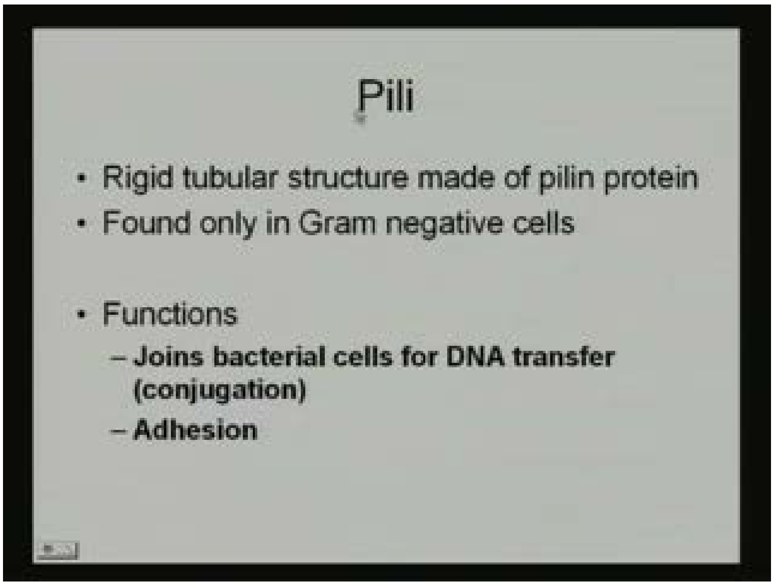

I have already mentioned you that, there is a, another external growth which is present on the bacterial cell wall is the pili. It is a rigid, tubular structure which is made up of, of a particular protein, which is called the pilin protein. It is found in the gram negative bacterial cell. Now, I had told you, based on the size, the, the bacteria can be differentiated; it can be grouped. Now, I will be coming to further classification; but now, you just understand, you just take it as granted that, gram negative is one of the another group of bacteria which is there, and to that group of bacteria, this pili are found. What is the function of this pili?

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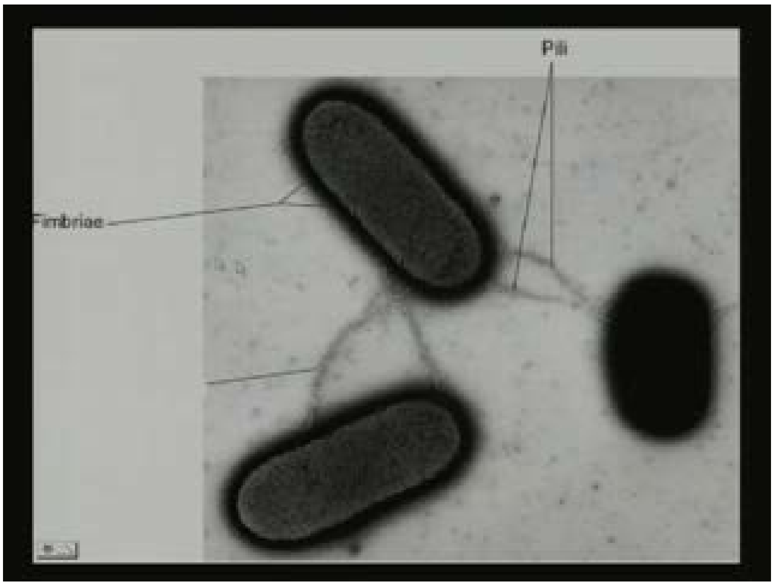

This pili, now, see the electron microscopic view. Then, we can find that, say, this is the pili of gram negative bacteria. Now, it helps in conjugation; when it is going for reproduction, now, one cell is coming in contact close to another cell…So, see, this is one cell and this is another cell.

So, this is the pili, which is donating partly, the genetic material from the donor cell to the recipient cell. And, in this way, the genetic material is getting transferred from the donor cell to the recipient cell. And, in this way, this pilin protein, this is the major function of pilin. And, if we see, the another, other function, it also helps in adhesion. So, this is the major function of the different appendages, which are present on the outer wall of the bacterial cell. Now, coming to the cell envelope. Now, we can divide the cell, cell envelope into three distinct groups.

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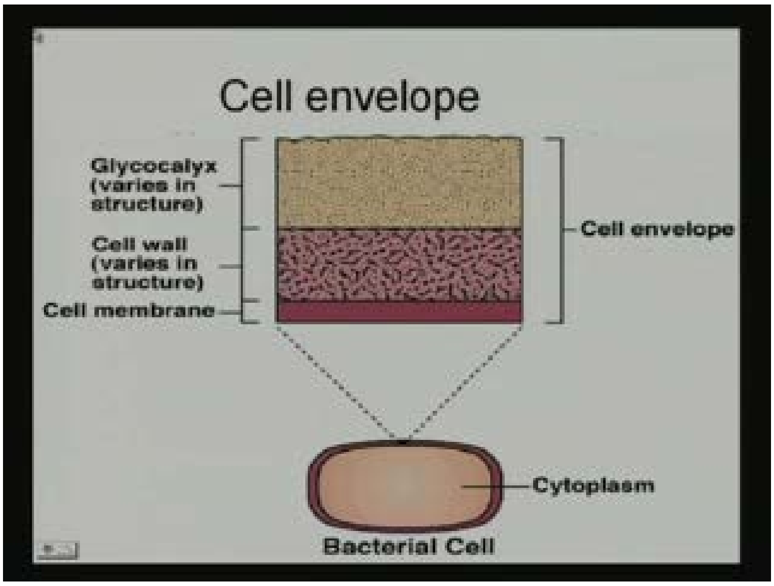

One is called, the outer most one is the glycocalyx, which is followed by the cell wall, and then, the cell membrane; that means, the glycocalyx is the outermost and then, cell wall and the cell membrane is the, that layer which, and after this, the cell pool are there; that means, it one side is exposed to the cytoplasmic fluid, which is present inside the cell.

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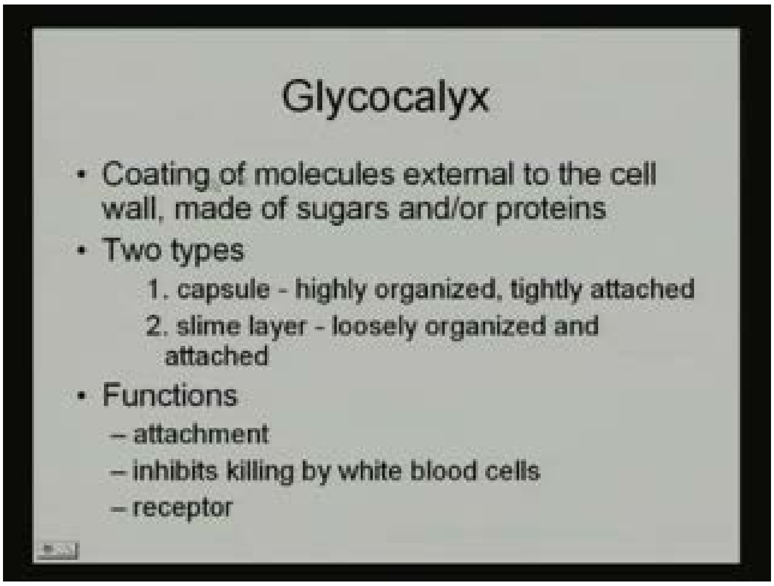

Now, if we magnify this cell wall of this particular bacteria, then, we can find that, this glycocalyx is the coating of molecule, external to the cell wall, made up of sugar and protein. We can get two types of glycocalyx; one is called capsule, which is tightly organized and tightly attached to the cell wall; another is the slime layer, which is loosely organized and attached.

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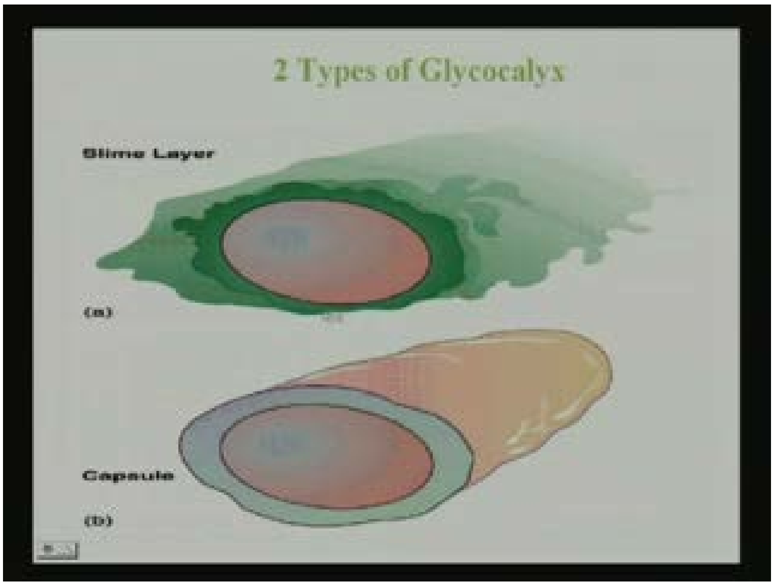

So, see, this is the slime layer, which is loosely organized and this capsule has got a definite structure.

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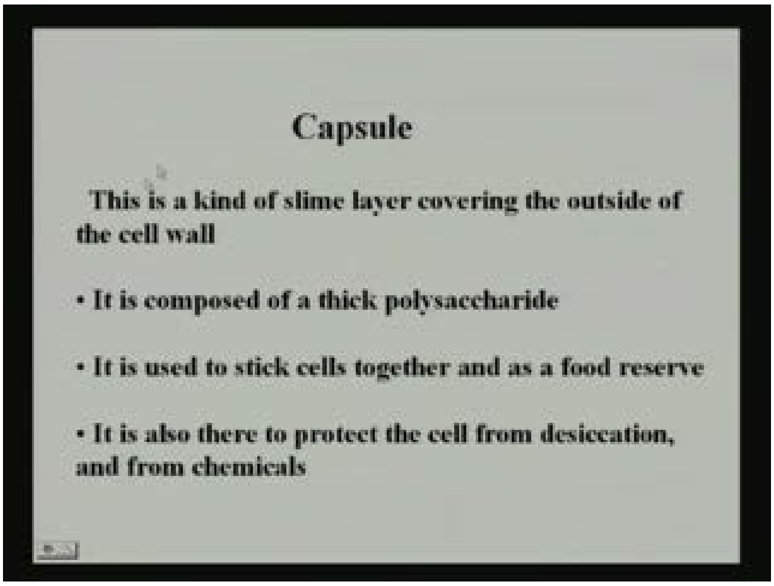

Now, if we see the structure of this capsule, this and its, the composition, we can find that, this is a kind of slime layer which is covering the outside of the cell wall. It is composed of thick polysaccharide. And, it is used to stick cells together, and it is also used as a food reservoir. It is also there to protect the cell from desiccation and from the other toxic chemicals. Now, if we see this capsule and the slime layer, then, we can find that, this is, it is the external attachment which are there and its main function of this particular capsule, or this glycocalyx, is that, it inhibits killing of this, by this white blood cell, and it is also acting as an, as a receptor of the cell. So, this is the major function of this glycocalyx.

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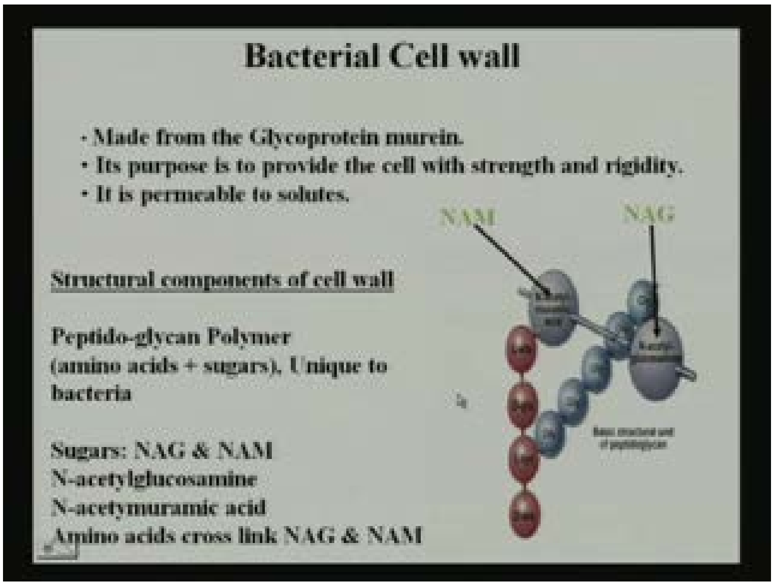

Immediately below this glycocalyx is the cell wall. Now, if we see the composition, biochemical composition of the cell wall, we can find that, this cell wall is made up of glycoprotein, which is…One of this example is a murein. Its purpose, purpose is to provide strength and rigidity to the cell; it is permeable to the solute. Now, if we see the biochemical components which are there in this glycoprotein structure, then, we can find that, it is mainly the, in the bacteria cell, one of the major component which is present is the peptidoglycan. Now, what is peptidoglycan? Peptidoglycan is a polymer, where we have the sugar and amino acids which are tightly binded with each other. It is a very very unique, as far as the bacterial cell wall is concerned. Now, if we classify further, this type of this peptidoglycan, the component, so, which are present, we can categorize this particular, this polymers into NAM and NAG. What is NAM and what is NAG? NAM is n-acetylmuramic acid and NAG is n-acetylglucosamine. Now, see, here, this, it is the composition of amino acid and sugar. Other way, we can tell that, it is an amino sugar.

So, here, this two polymers, this are present in the peptidoglycan chain. And, this particular component are also called as glycan chain and amino acids are attached to this particular glycan chain.

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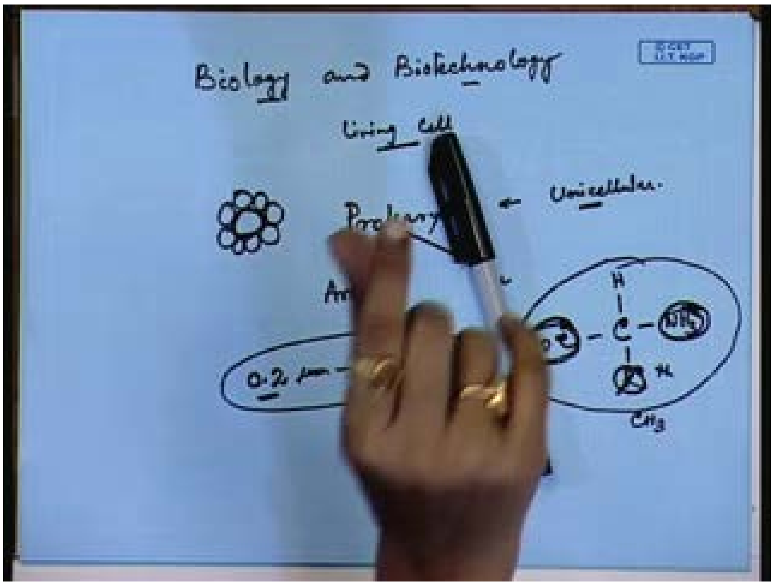

And, amino acid means, amino, in, in this particular biological molecule, it is asymmetric carbon atom in one; this, this R group is present and it has got the amino and and carboxyl group. So, this is the amino acid, where one amino end is there; another carboxyl end is there; and, here, this R group, one this R group is varying from one amino acid to another. Now, say for example, in case of glycan this R group is H; in case of alanine, this R group is C H 3. And, in this way, the structure and the composition of this particular amino acid and characteristics of this amino acids are getting varied. So, this says, this amino acids are linked together; that means, here, we have seen, it has got one amino group and here, one carboxyl group is there. So, when one amino group of one amino acid is getting linked with a carboxyl group of the second amino acid, it is called the peptide linkage. And, in this way, one amino acid and another amino acid, they form a chain like structure. So, I will be telling you, the structure of these amino acid, how they form, and what is this bonding called. This bonding is the peptide bonding; and, when this peptide linkages are there, one molecule of water is being released from this particular bonding. So, I will tell you the details about this amino acid, its structure and function. Now, for easy understanding, let us consider that, it has got this particular amino terminal and carboxyl terminal, and this particular amino acids are getting linked with this NAM and Nag; this is n-acetylglucosamine and n-acetylmuramic acid.

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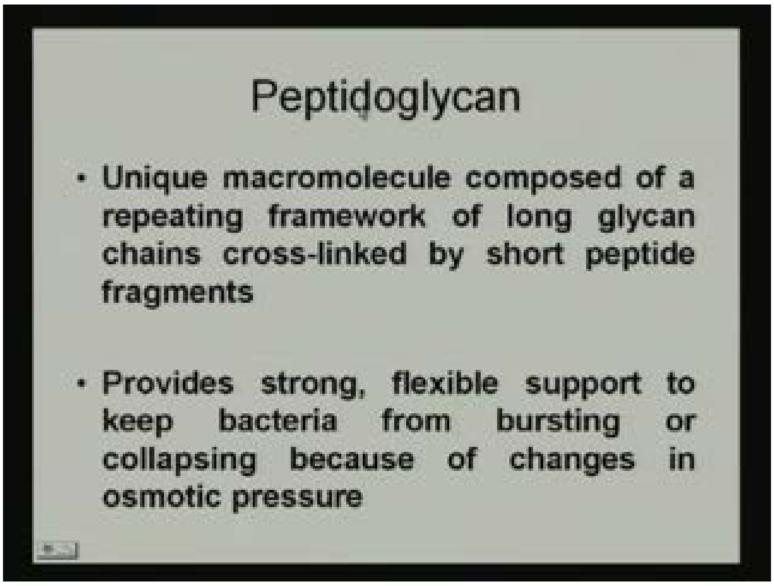

Now, if we see the structure of the peptidoglycan, then, we can find that, it is the unique macro molecule, composed of a repeating fragment of long glycan chains cross-linked by the short peptide fragment. So, as I have told, it provides strong, flexible support to keep bacteria from bursting, or collapsing, because of the change of the osmotic pressure.

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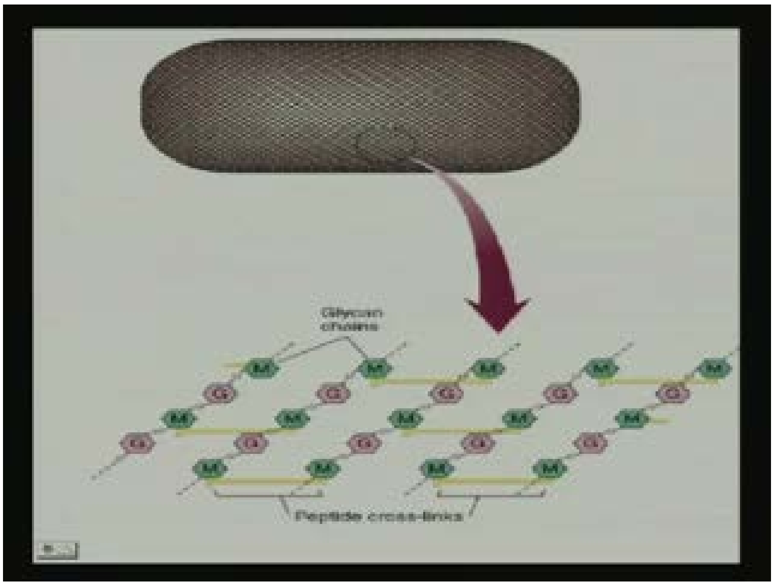

So, if we are seeing the structure and the composition, then, these are the, NAM, NAG are the glycan chain, and they are just a linear chain. And, in this way, this linear chains are there; and you see, this amino acids are getting linked with one chain to another, and this way, they form a matrix-like structure. And here, this network is nothing, but, it is the polymerization of NAM, NAG; that is, the glycan chain with the amino or peptide cross-linking.

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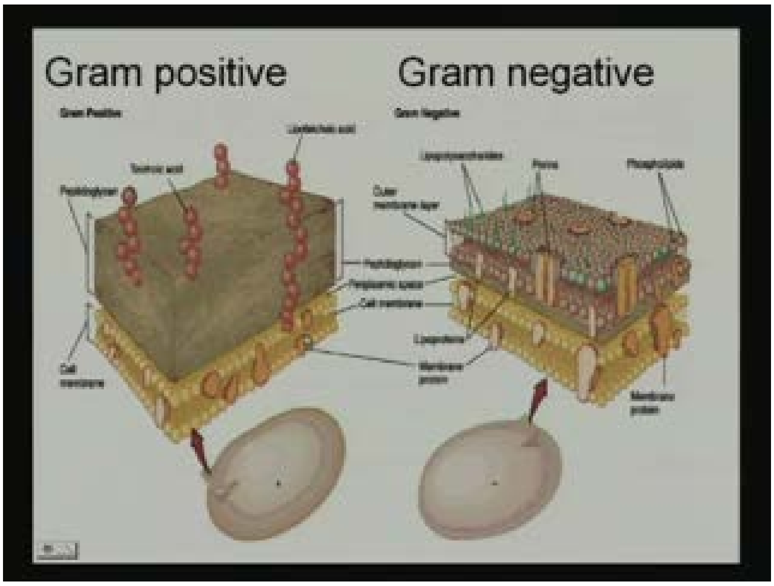

Now, if we see that gram positive and gram negative bacteria. Now, I have already told you that, gram negative bacteria has got pilin, pili. The pilin proteins are there; pili is present in gram negative bacteria. What is gram positive and what is gram negative bacteria? Now, this is a particular test, based on the cell wall composition of bacteria. Now, if we see and magnify, and if we draw the cell wall composition of two different groups of bacteria, then, we can find that, there are certain changes in one group and some differences are there, and it can be distinctly differentiated between one group to the other group. Now, in case of gram positive, now, how we, why it is called gram? Gram staining, gram positive, gram negative, because, this particular test was developed by the scientist called Hans Christian Gram. And, based on his name, it is called gram positive and gram negative.

In case of gram positive bacteria, it has been seen that, that see here, the cell membrane is there; here the periplasmic space is there, in both the cases. The peptidoglycan chains are there. Here also, peptidoglycan is there. See here, outer membrane is there, which is not there, in this group of bacteria. And here, the some other, this lipopolysaccharides, porins; here, some other complex membrane proteins and etcetera, are there; lipoproteins are there. But, in another case, we are getting the teichoic acid, lipoteichoic acid and so on; that means some differences are there. What is the difference? It has got a thick layer of peptidoglycan. Lipoteichoic acid and teichoic, teichoic acids are present here, which is not there. Here, this peptidoglycan chain is very thin. And, if we see that, it has got the outer membrane and some complex biological molecules which are there in case of gram negative bacteria. And, it differentiate that way, from this gram positive bacteria.

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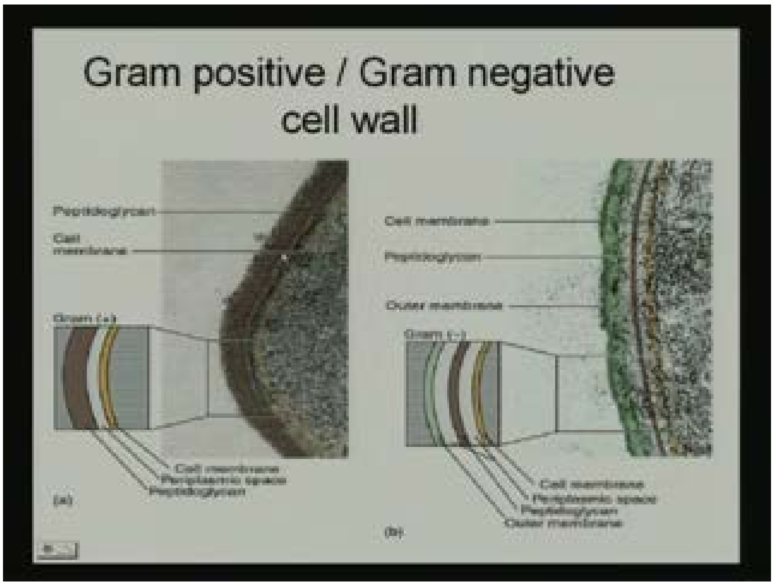

Now, if we see the further electronic, microscopic view, electron microscopic view tells that, that it has got a cell membrane, followed by this periplasmic space, then, peptidoglycan, thin layer of peptidoglycan, followed by the outer layer, say, which is not there in case of gram positive bacteria. In gram positive bacteria, you see, this is the cell membrane, followed by periplasmic space and peptidoglycan. And, this way, gram positive bacteria is different from gram negative bacteria. Then, how we can differentiate the one group to another? How, first of all, it is very micro in structure. And then, how will we differentiating that cell, based on the cell wall composition? There must be some test, which can differentiate this gram positive, from this gram negative.

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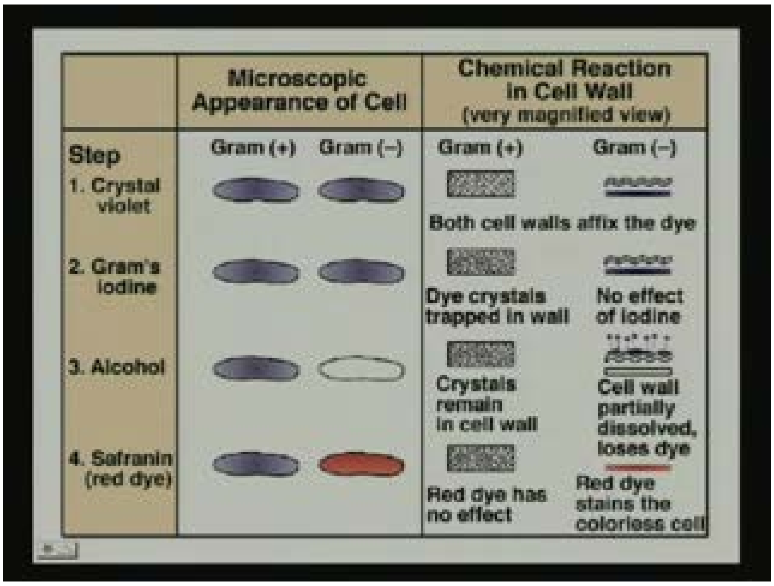

Now, if we see that, there are certain techniques, which can differentiate one group of bacteria to other group. Now, now, irrespective this bacteria, if we are taking some unknown bacteria, and if we form the smear of this bacteria, and to this, the two different dyes, if we add; that means, crystal violet is one dye and safranin is the another dye. These are the two dyes, which are used for this Grams staining purpose. Now here, this crystal violet, when it is added to this near of this bacteria, first it is going and with the gram iodine solution, it makes a very, this form complex and it is getting attached to this particular bacterial cell wall.

Now, after this, this addition of this crystal violet, we are just washing this particular bacterial smear with the organic solvent. Now, what is happening? When we are adding this organic solvent, this organic solvent may be alcohol, it may be alcohol and acetone mixture. So, what we are adding, we are adding this alcohol, or the organic solvent alcohol acetone mixture in excess, and we are just washing out the excess dye, which is present. In one case, we have seen that, this bacteria can retain the crystal violet gram iodine complex within its outer wall of the cell. In another cell, where this peptidoglycan chain is a very thin, and it cannot retain this gram iodine and crystal violet complex. And, it is coming out of the cell. And then, when we are just counter staining this cell with this safranin dye, as in one group, as they have already retained this crystal violet colour, they cannot once again bind with the new counter dye. And here, those group of bacteria, which do not have any, a such this dye within the cell wall, they can once again bind, bind with this red dye. And, when we are just washing it in running, mild, running tap water, then, one group of bacteria, which are retaining this crystal violet dye, they look violet, or blackish violet in colour. Another group of bacteria looks red in colour and this group of bacteria are called gram positive, which are giving this crystal violet colour and another group is called gram negative, which is red in colour. And, this way, this bacteria can be classified as gram positive and gram negative; that means, pili is present in this group of bacteria, where peptidoglycan chain is very, very thin and outer membrane is there.

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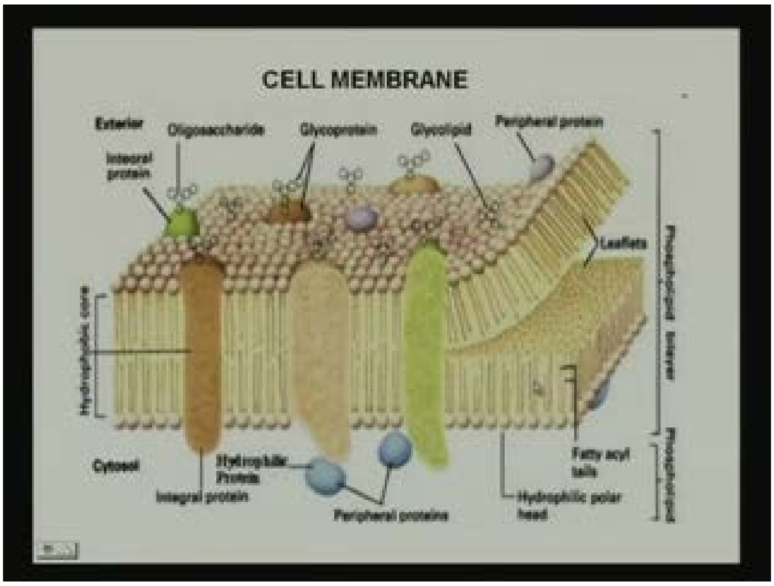

So, this is the structure of cell wall of bacteria.

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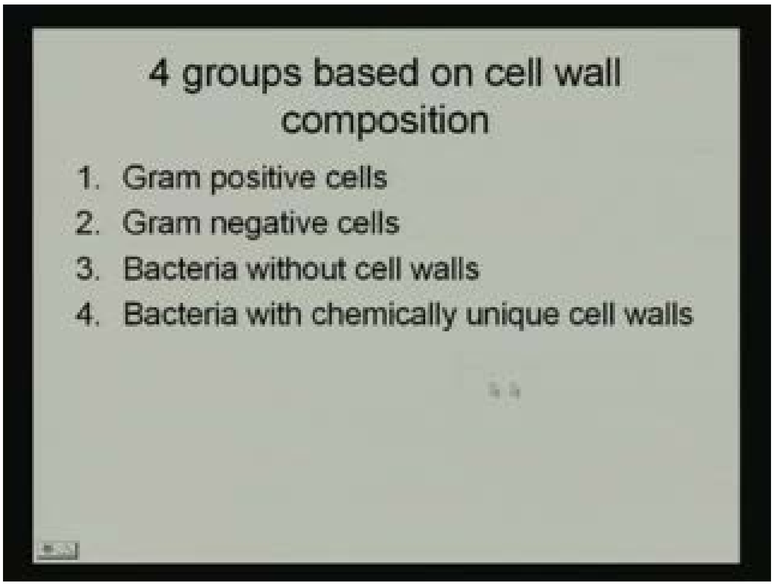

In some cases, we can find the bacteria having, without cell wall and some cases, bacteria with chemically unique cell wall; that means, this type of bacteria is coming under the category of this archebacteria.

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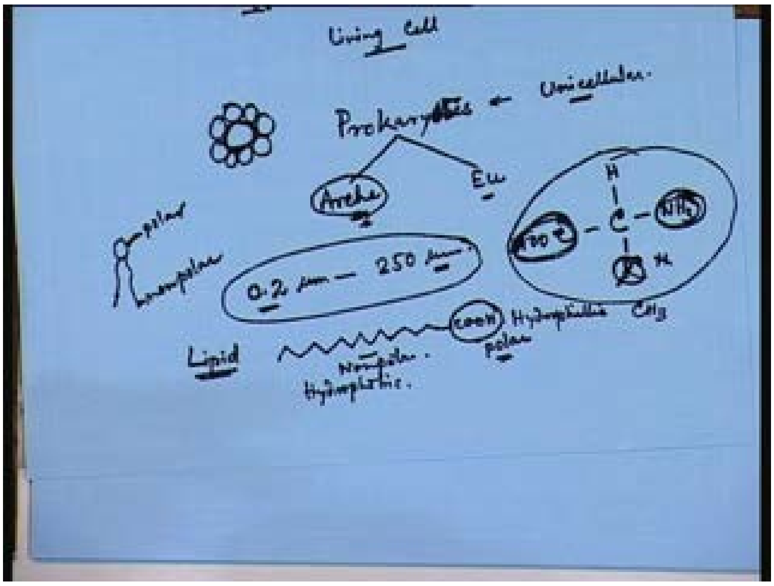

So, these are the very primitive group of bacteria, and here, they have certain change in this cell wall composition; and, that is the reason, why this, we are calling it, unique cell wall of this group of bacteria. And, some group of bacteria, they do not have any cell wall within it; and, that is, mycoplasma is one of that example of that group of bacteria.

Now, coming to this cell membrane, now, below this cell wall is the cell membrane. Now here, this, when we are talking about this cell membrane, we have to have the knowledge of another macro molecule which is present in this particular cell membrane, is the lipid. Now, lipid is a water insoluble molecule and if we see the structure of fatty acid, we can find that, fatty acid has got the chain-like structure and it has got the ending with the carboxyl group, which is polar in nature; that means, we can tell, this fatty acid that polar head and non-polar tail.

So, if this is the structure of the simple lipid molecule, this fatty acid molecules, then, we can tell that, this is the hydrophilic end of this lipid molecule, and it has got a hydrophobic tail. So, here, in this cell membrane, we can get a bi-layer of lipid and this lipid, this protein, carbohydrate, this macromolecules are not present in a pure form; but, they are conjugated; that lipoprotein, glycoprotein and such type of complex formations are, formation is there, in such type of structure, which is giving the extra protection to the cell. And, if we see, you see, this is the phospholipid layer and phospholipid bilayers are there. So, here you see, this the hydrophilic end of this lipid; that means, if we write the structure, we can find that, this, it is, it has got two end; one is the polar; another is the non-polar. So, this is the hydrophilic zone and this is the hydrophobic zone.

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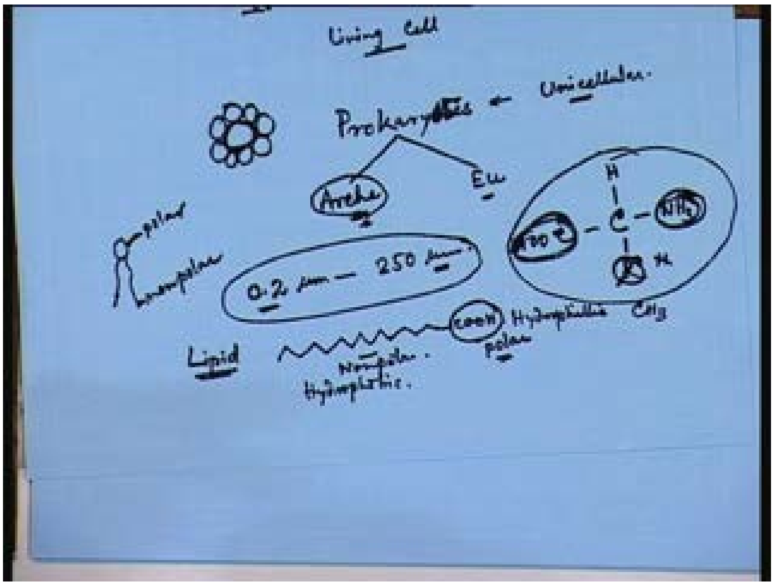

So, when we are talking about this polar end, this is the hydrophilic in nature, and non-polar end is the hydrophobic in nature. So, when this lipid molecules are, and below this is the cytoplasmic fluid; so, obviously, they are arranged in such a way that, hydrophilic moieties are exposed to this liquid portion, aqueous portion of the cell and hydrophobic portion are away from this particular environment. And, this way, there are different, this integral proteins, that is peripheral proteins, and integral proteins, which are the glycoprotein, glycolipid, oligosaccharides, etcetera, are present and they, they arrange themself in such a way that, they give extra protection to the cell wall of this bacteria.

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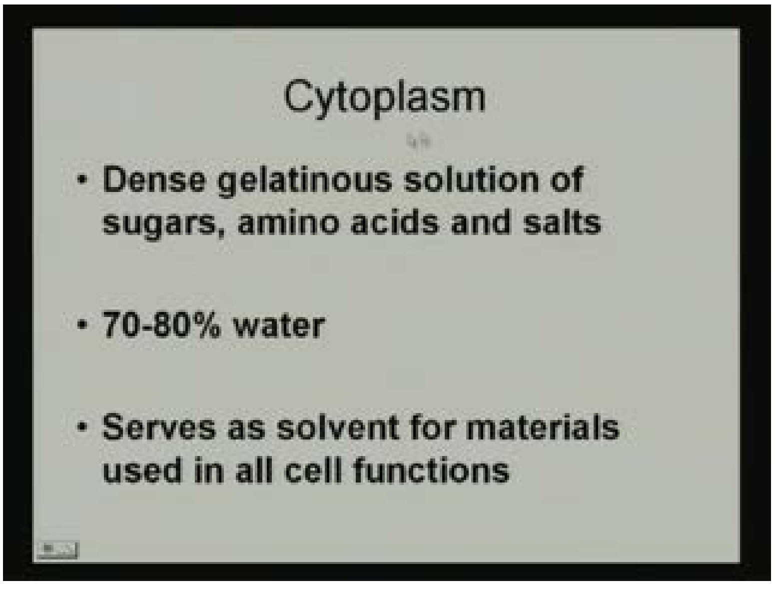

Now, below this is the cytoplasm. Now, we are now coming to the cell pool of this particular bacteria. Now, if we see the particular bacteria, then, it is the cytoplasmic fluid, where the cell pool is there; ribosome is there; granules are there, and the chromosomes, or the nuclear membrane, or the the nuclear genetic materials are there. Now, we have already learnt, the outer covering portion which are giving the protection to the internal cell pool. Now, when we are coming to this internal cell pool, we are taking about the liquid, or the fluid, and in most of the cell, two third is the liquid, or the fluid which is present; that means, here also, we can find that, 70 to 80 percent water is there, in this particular cell, bacterial cell. It is a dense gelatinous solution of sugar, amino acid and salt. It serves as the solvent for material used in a, in all cell, cell functions.

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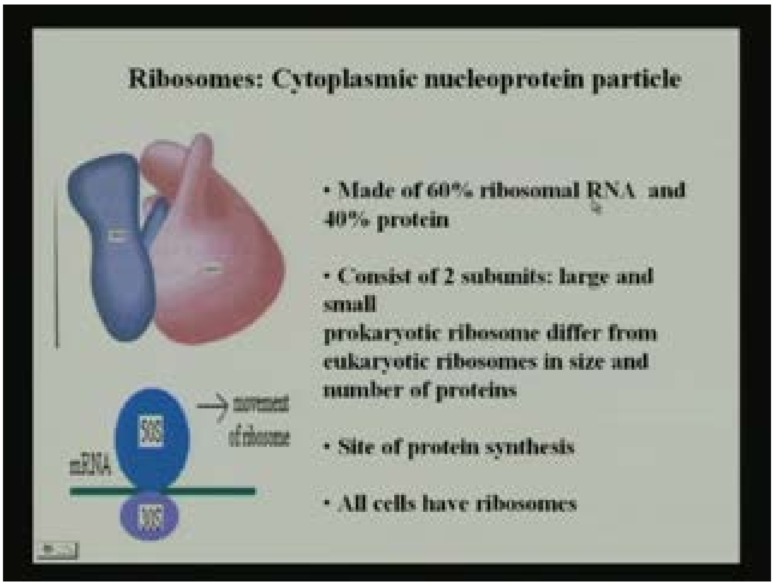

If we come to this ribosome, ribosome is made up of 60 percent ribosomal RNA and 40 percent protein. It consists of two subunits; one is the large subunit; another is the small subunit. In prokaryotic ribosome, we can see that, this large subunit, it is the crown like structure; a small subunit is the kidney shaped structure. And here, this bigger one is the 50 s and smaller one is the 30 s and when this 30 s and 50 s is coming and forming this complete shape of this ribosome, it is the, it is helping in protein synthesis. This is the mRNA and when this number of ribosomes are coming and attaching, we are calling it as polysome; and this is the site of protein synthesis. All bacterial cells have this ribosomes.

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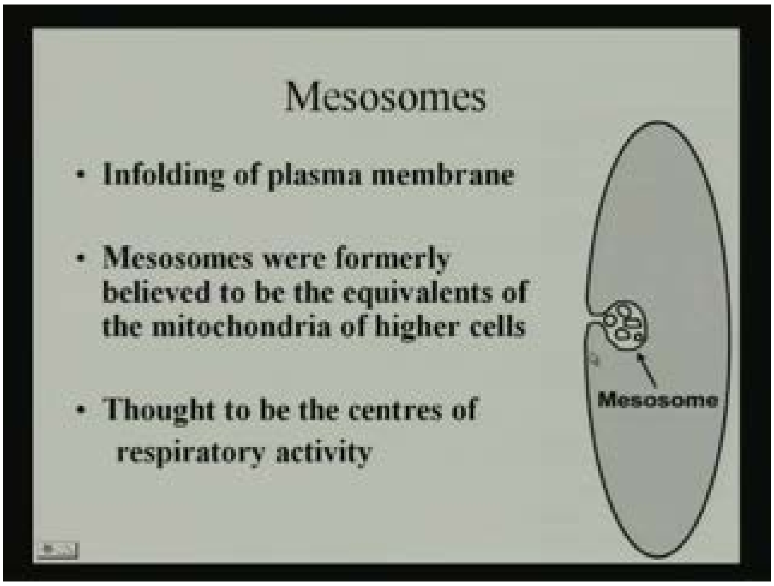

Now, coming to this mesosome. Mesosome is the infolding of plasma membrane of the cell. Mesosomes are formally believed to be the equivalents of mitochondria of higher cells. It is thought to be the centre of respiratory activities of the cell.

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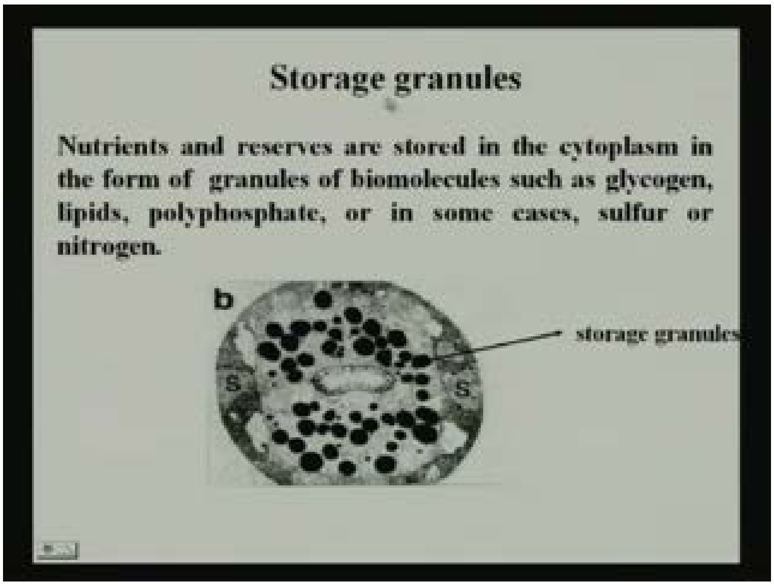

Besides this mesosome, we have the storage granule. The nutrients and reserves are stored in the cytoplasm in the form of granules in biomolecules, such as glycolgen, lipid, polyphosphate, or in some cases, sulfur and nitrogen which are there, is also getting accumulated in this, in in the form of a storage granule.

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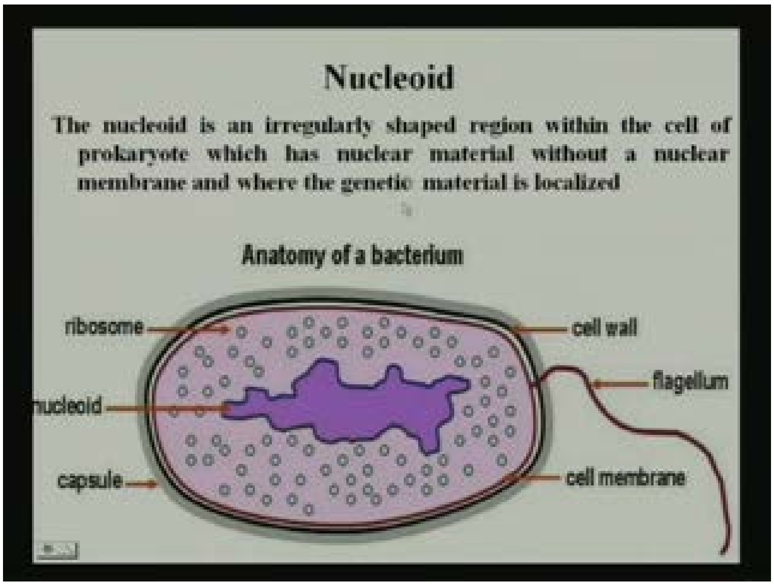

Now, coming to this nucleoid, as I have told that, primitive type of nuclear genetic material is there. This nuclear is irregularly shaped, as no nuclear membrane is there within the cell of all prokaryotes, which has nuclear material, without any nuclear membrane and it is here, it is the main controller of the, the genetic material and the, here, this genetic material are localized.

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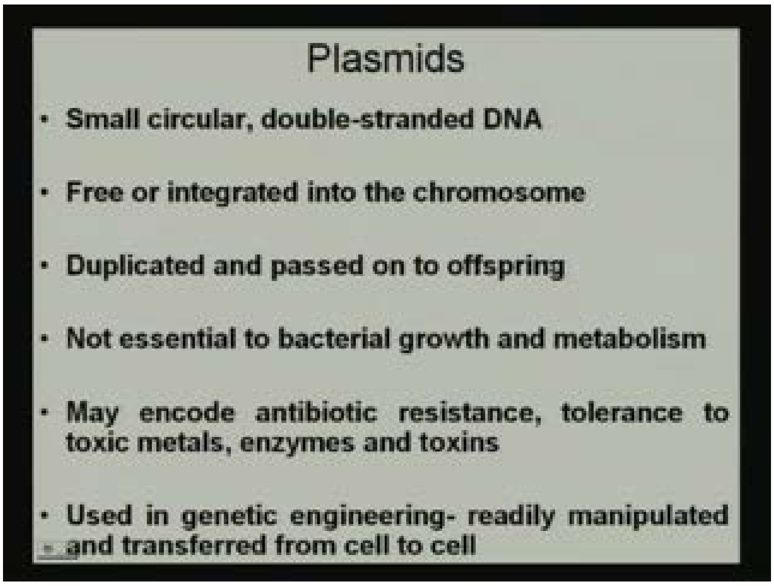

Now, coming to this plasmid, in this prokaryotes, it is very, very important to have this unique structure of this plasmid. This is the circular DNA. Besides this nuclear material, we have a small circular double stranded DNA which is present and it is free, or integrated into the chromosome. It can be duplicated and passed on to the offspring. It is not essential to bacterial growth and metabolism. It may encode the antibiotic resistance, tolerance and toxic material, enzymes and toxins. It is used in a genetic engineering.

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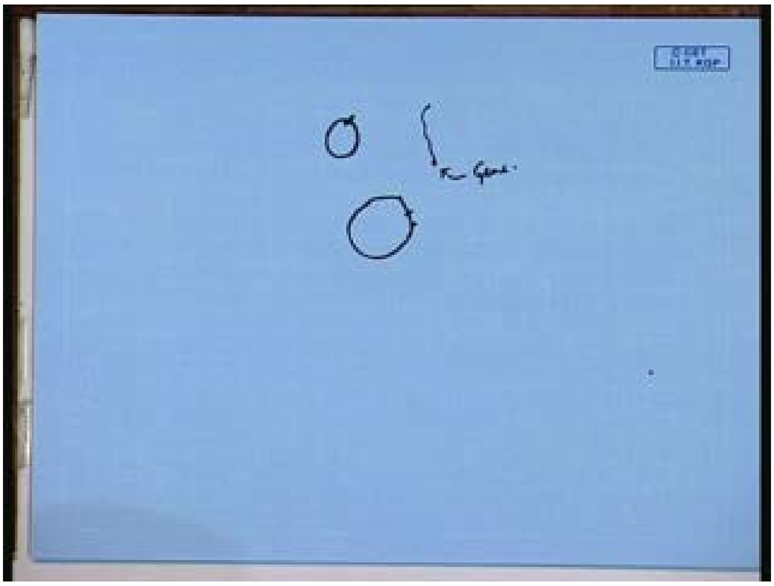

That means, this is a circular DNA. When it, we are just cutting it, this circular DNA, it becomes linear and then, we are inserting the gene of our interest. Now, when the gene is getting and getting inserted, once again, with the help of this ligase enzyme, we are just, once again, making a the, we are just joining this, and with the new incorporation of this gene, once again, it is getting ligated. And then, we are just going for this expression of this gene in a particular system. And this way, the new avenue of biotechnology has developed with this particular plasmid DNA.

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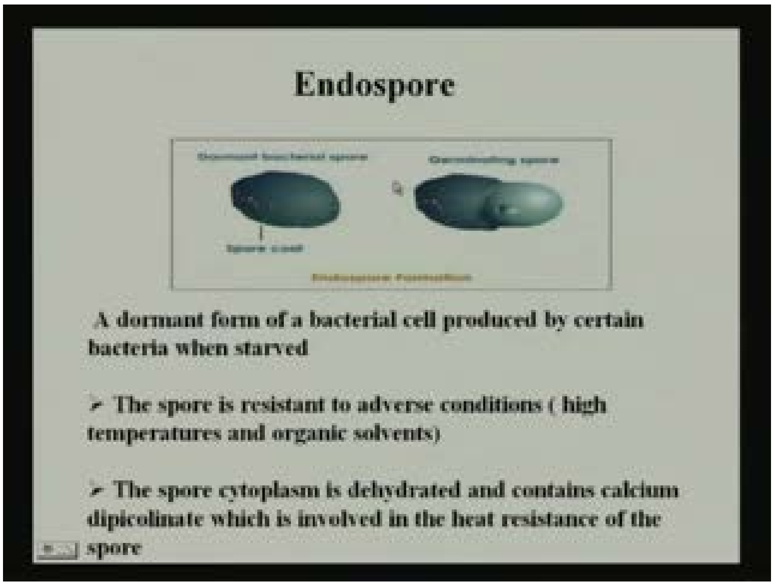

Now, endoplasm, endospore. Endospore is one of this very unique structure, where this bacteria can survive for years together. Now, it is a dormant form of bacteria, bacterial cell, produced by certain bacteria, when they are under starvation. The spore is resistant to adverse condition, that, that means, it can with stand high temperature and any adverse situation, that is, high organic solvent, or any such drastic environmental condition. The spore cytoplasm is dehydrated and contains calcium dipicolinate, and which is involved in the heat resistance of the spore.

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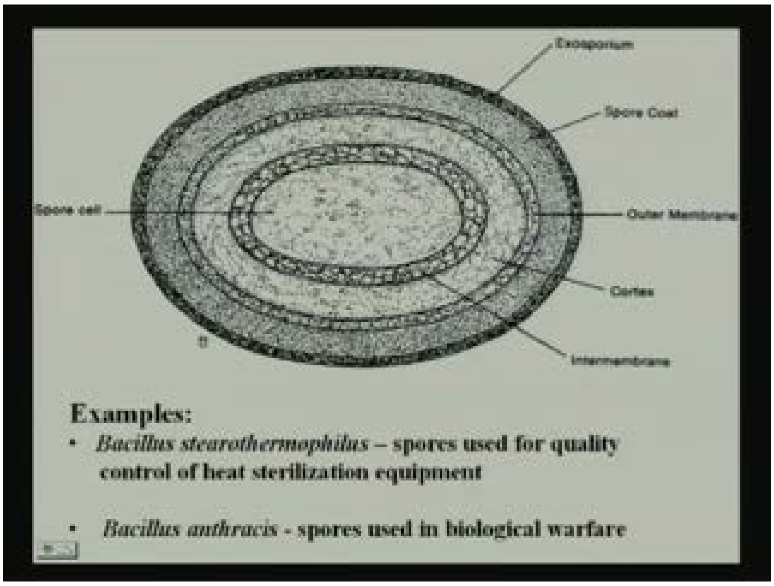

So, here, if we see the structure, that cytoplasm is getting dehydrated gradually and small coats are formed; that means, we can find the inter membrane, followed by the cortex, followed by the outer membrane, spore coat and the exosporium. And here, this spores, spore coats are so resistant, that any, under any drastic condition, this bacteria can withstand, and under normal environmental condition, this spore coats are getting open up and this bacteria can once again reproduce. So, this is the spore formation of bacteria. Now, some of the example of this spores are the bacillus stearothermophilus. It is the spore used for the quality control of heat sterilization equipment. Bacillus anthracis, that is the spore used for biological war warfare.

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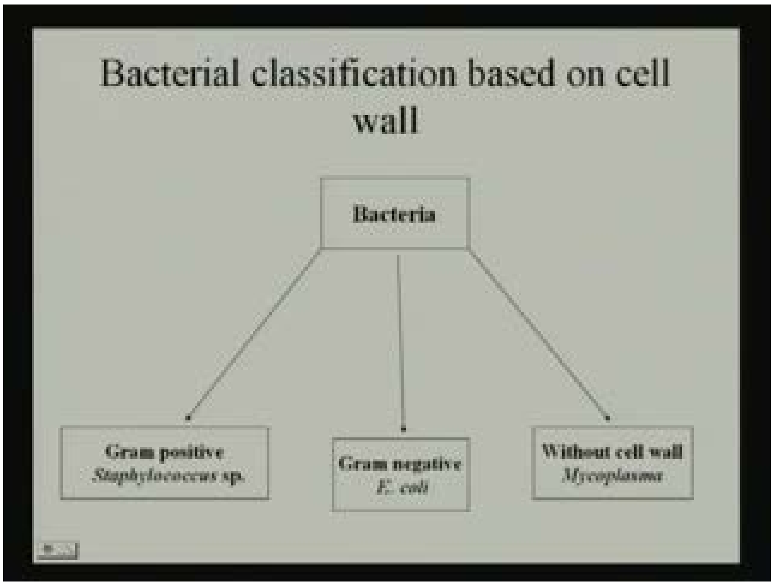

Now, in conclusion, what I would like to tell you that, if we classify the entire bacterial world, then, we can classify this bacteria into gram positive, gram negative, and the bacteria, which is not having any cell wall; and, we can divide this as, this is not having cell wall; as I have mentioned that, mycoplasma is one of that example.

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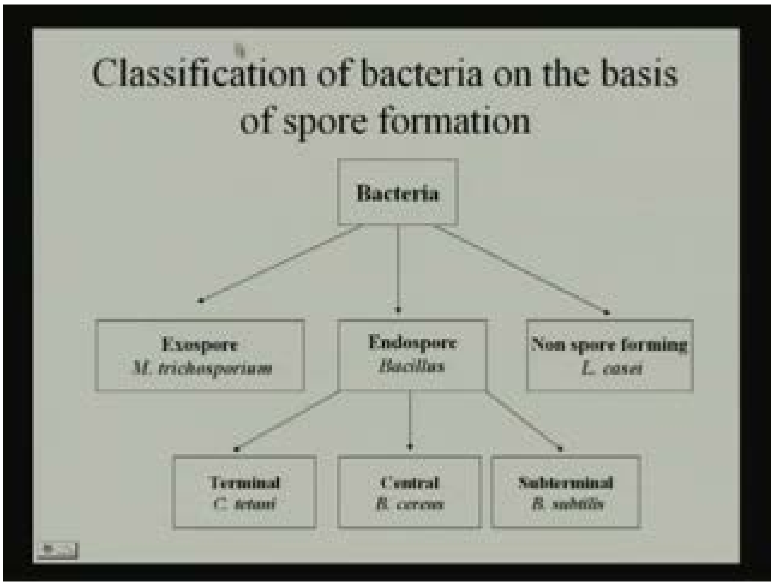

Now, when we are classifying this bacteria based on the spore formation, then, we can classify, we can further divide as the exospores, endospore and non-sporulating bacteria.

When we are talking about the endospore, based on its position, once again, we can divide it into terminal, central, or sub-terminal.

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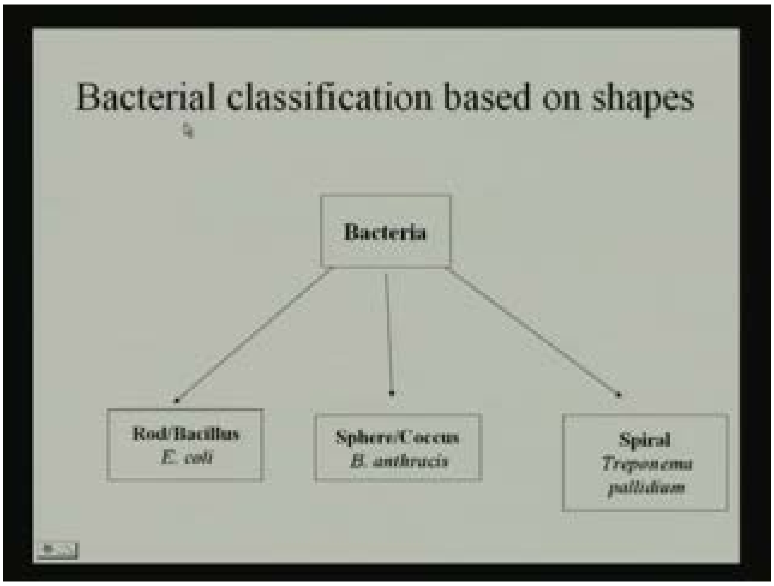

Bacteria, bacterial world can once again be divided into different group, based on its shape; that is the rod shaped, spherical or coccus, spiral, that is and the comma shaped bacteria.

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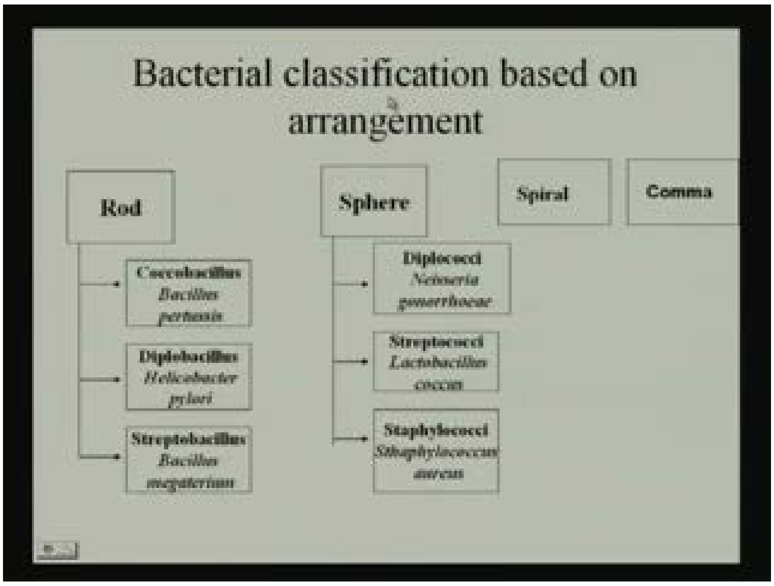

Based on that classification, the bacterial classification which are there, based on its arrangement, that is the rod shaped bacteria can further be divided into coccobacillus, that is diplobacillus, and streptobacillus; so, here, this, whether one rod, two rod, or group of rods are there. So, these are the classifications.

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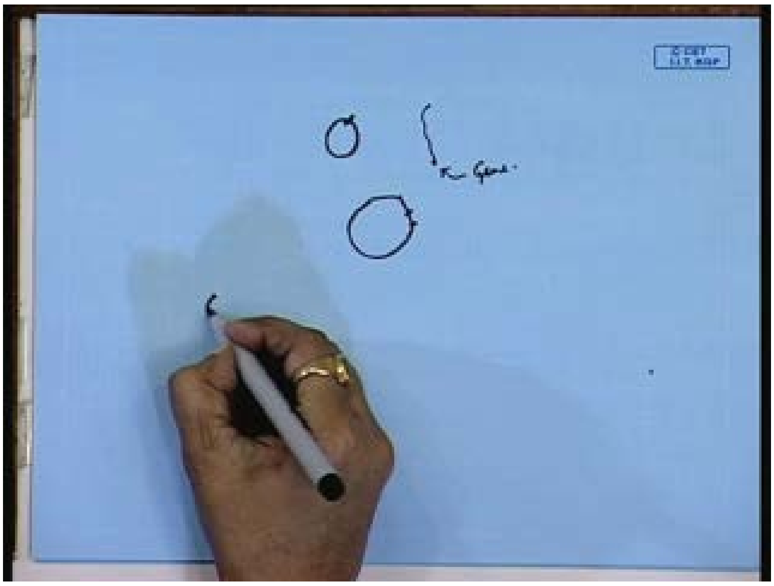

When we are talking about this spheres, then, it is diplococcus, that means, two cocci are arrange, arranged; here, streptococci, a chain of bacteria, it is forming a chain like structure; and, staphylococcus coccal, where a bunch of, just like grapes, the bunch of bacteria are attached together, and it can be also spiral, it can be the comma shaped bacteria.

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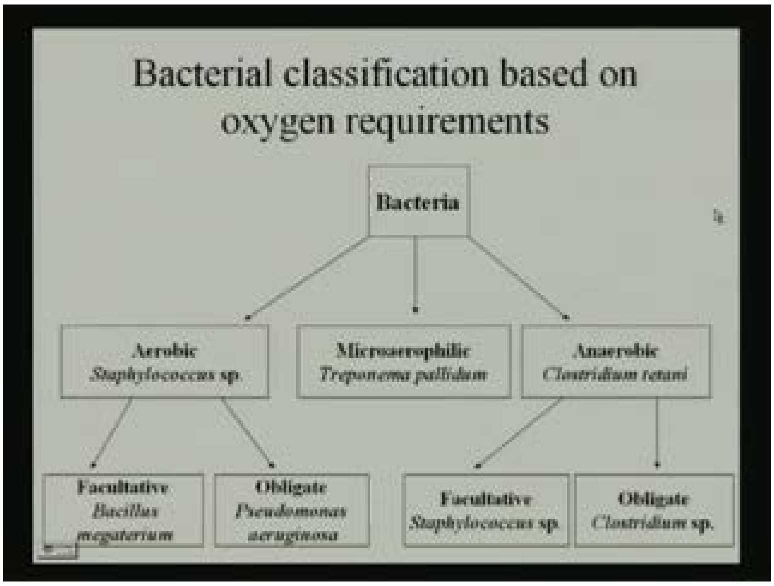

What we have learnt that, bacteria can be classified based on the oxygen requirement, and this bacteria may be aerobes, may be anaerobes, and microaerophilic. It may be facultative aerobes; it may be obligate aerobes; but, this type of bacteria, for their growth, oxygen is must. In case of obligate anaerobes, this oxygen is too much toxic; they do not need any trace of oxygen; and, some are microaerophilic; that means, it can grow, either in high oxygen demand or in trace oxygen demand.

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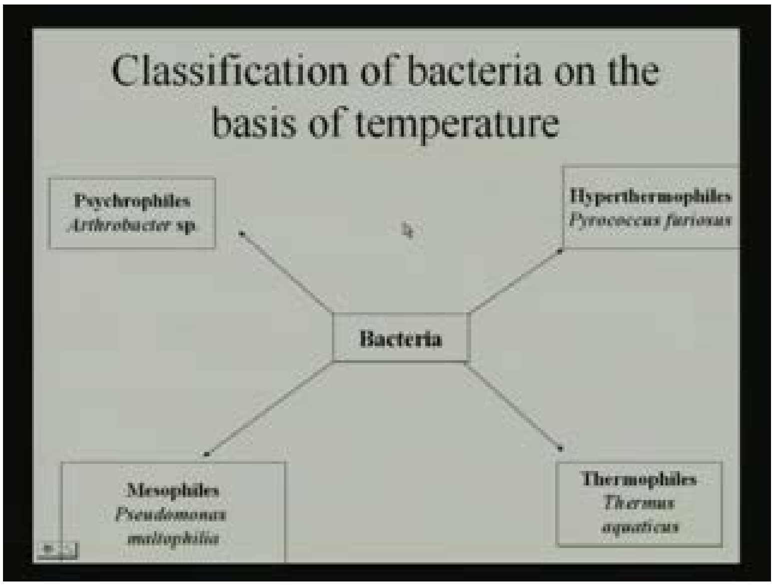

So, these are the classification based on oxygen requirement. When we are classifying this bacteria based on the temperature, we can once again divide it into psychrophilic, that means, cold loving; mesophilic, normal moderate temperature loving bacteria; thermophilic, that means, here, they need higher temperature; that means, temperature requirement is more than 50 degree to 70 degree centigrade; hyperthermophiles, that means, here, the temperature, it is this group of bacteria can withstand very high temperature, normally 70 to 90 degree or so. Some reports are there that, some bacteria can withstand up to 140 degree centigrade.

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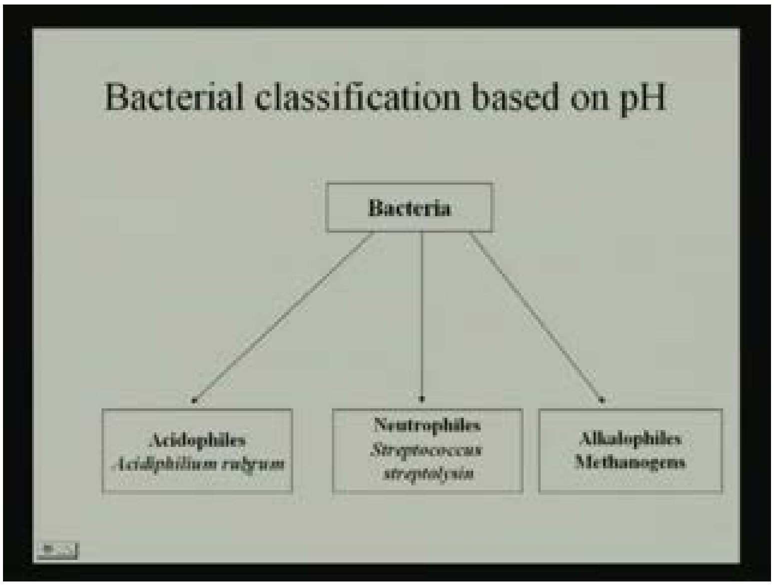

Based on the pH requirement, the bacterial world can be divided into acidophiles, that is, acid loving bacteria; neutrophiles, that means, in neutral pH condition, they are surviving; alkalophiles, that is the, in alkaline condition, this bacteria are very very comfortable to grow.

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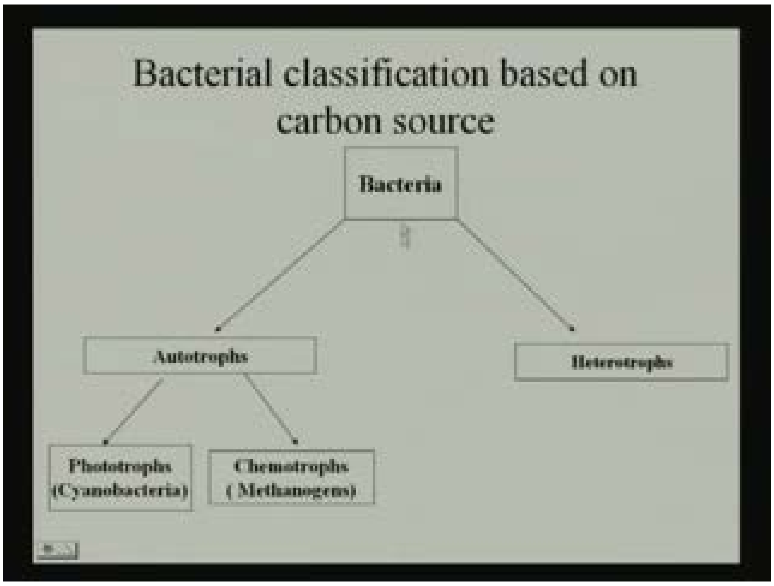

Based on the carbon sources, the bacteria can be once again divided into autotrophs and heterotrophs. Autotrophs are once again divided into photoautotrophs and chemoautotrophs; that means, cyanobacteria, their, this cyanobacteria has got this chlorophyll within it, and they can synthesize their own food. In case of chemoautotrophs, they need some inorganic sources for their normal behavior, in the form of nitrate, iron sulfur and so on. And, methanogens are one of such example of this chemoautotroph. Heterotrophic bacteria, they need external carbon and media content for their growth.

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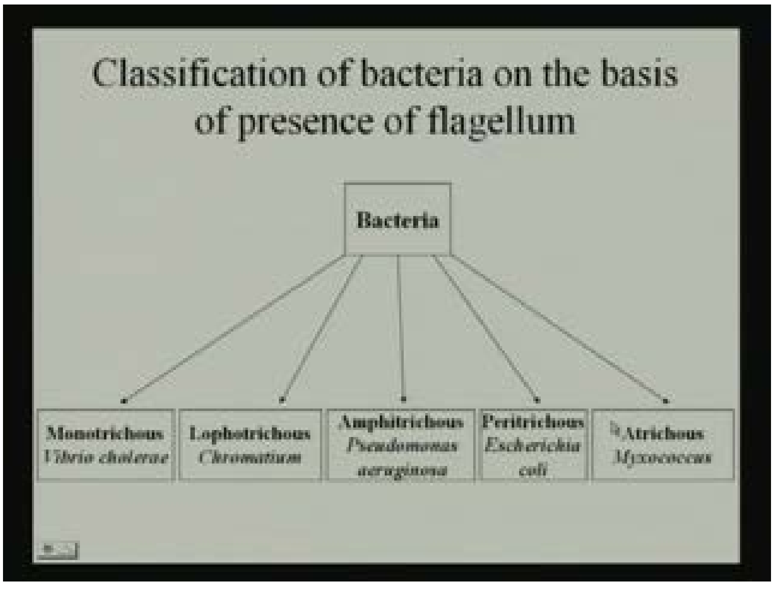

Now, if we see this classification of bacteria based on the flagellum arrangement, then, we can find that, it can be the monotrichous, that is one flagella in one end; lophotrichous, a bunch of flagella in one end; amphitrichous, the flagella in both polar end and peritrichous, throughout the body, the flagella is attached. And, sometimes, no arrangement, that is the atrichous. And, these are the classification of bacteria, and what we have learnt about the entire bacterial world. These informations are very very essential for all of you, when we will be, you will be working with the bacterial system, and when you will be going for any metabolite production, using bacteria as one of the living cell. And there, if we have these information, it will be very easy for us to select the group of bacteria, the group and the, if we know their nature, it will be very easy for us to select the system, the type of bacteria, what we need for our metabolite production. Thank you very much.