

Applied Environmental Microbiology
Dr. Gargi Singh
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Lecture – 04
Cell Structure II

Hello students, today in the 4th lecture of Applied Environmental Microbiology course. We will be continuing where we left off last time on cell structure and then proceed ahead to talk about the informational molecules in inside the cell.

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Cytoplasmic Membrane and Transport

- Membranes are fluid with membrane proteins
 - Integral and peripheral membrane proteins
 - They interact with each other at times for certain functions and in these cases are often clustered together
 - G+ve cells and periplasmic proteins of G-ve cells

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Lipid bilayer	Lipid monolayer
Bacteria and eukaryotes	Some archaea

- Phospholipid bilayer generally
- Common fatty acids in the phospholipid bilayer have 14-20 carbon atoms

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So, last time we talked about cytoplasmic membrane and I told you about; the bilayer in bacteria and monolayer in Archaea and how the external and the internal portions are Hydrophobe a hydrophilic till of the water and the inside portion is hydrophobic these are fatty acids long chain of fatty acids.

Now, today we will study about cytoplasmic membranes how they differ in bacteria and Archaea little bit more in detail. So, let us take a look at this beautiful picture here where this picture is a; occur to in showing a cellular membrane of a eukaryotic cell and many of the elements in this cellular membrane are shared by bacterial cells also. So, many of the features in this are also are similar to what we will see in what we see in bacteria.

So, let us start with this blue protein here now notice that these protein transverses the inner face of the cellular membrane with the outer face and this such kind of membrane proteins are called as integral protein or intrinsic protein. These another integral protein here in purple color many a times these integral proteins are used for transporting compounds in an out of the cell. So, many efflux pump for example, or integral protein and this one particularly is designed shape to look like an efflux pump.

Now, you can also notice that there are sugar side chains on the outer face and these sugar side chains they have very specific conformation very specific features both chemically physically and in stereo. So, Stereocally; now these sugar chains they act as sensors. So, now, the cell using these sugar chains can sense different kinds of particles and any compounds in it is environment it can find out where the glucose concentration is increasing, what kind of virus and bacteriophage are present in the environment what kind of compounds microbes can also talk to each other and they can sense PH and change an another chemical. So, these are very very important the sugar side chain one of the recent applications also the sugar side chain is that we are targeting them as because they are very specific to each cell let us say bacterial cell staphylococcus aureus cell will have a very specific sugar side chain on it can be used as a marker as a target to design biosensors.

And then you see here purple balls these bubble balls are the hydrophilic part of the cellular membranes cell membrane and that is their facing the aqueous a environment and then here we have blue lines, which are hydrophobic portion and they the blue lines they attach to each other they stick to each other and they make by lipid membrane you can also note here that look here there is another peripheral membrane protein.

So, not all proteins have to be integral proteins some of them only face either the exterior or the interior part of the cell. So, exterior could be as a sensor or as to respond to different kinds of bacteria for the attacks and the internal are used for different purposes like a receiving certain compounds or just sending the message or other things.

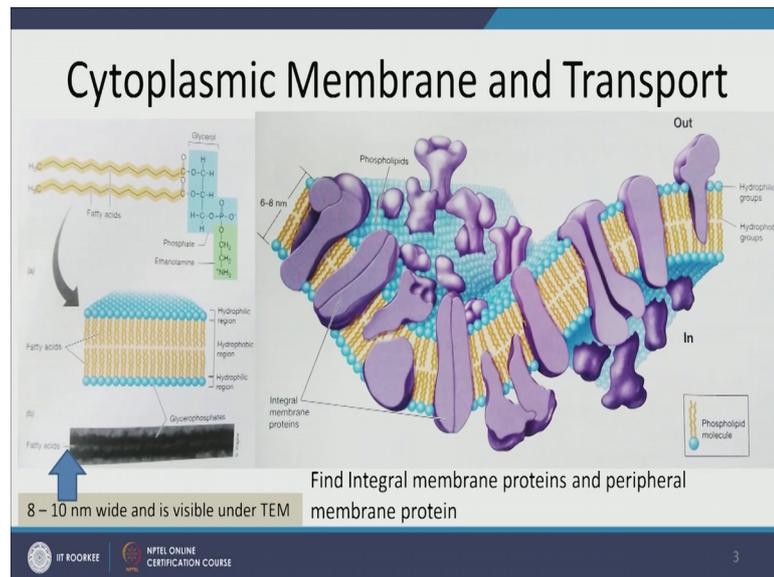
Now notice here in this yellow dots this is you, but specific to eukaryotic cells these are called as strong and we bacteria have equivalents of cholesterol, but not cholesterol itself and this helps in giving certain amount of fluidity to cellular membrane, because cells need to move locomotion is important for different reasons very few cells very very few

rare eukaryotic cells have complete rigidity and do not have much of cholesterol or cholesterol like substances to give them flexibility.

Now, here we have a lipid bilayer example and this is shared both by bacteria and eukaryotes and whereas, in archaea we have lipid monolayer I also talked in the previous class about gram positive and gram negative cell briefly gram positive and gram negative cell are classified on basis of how they respond to gram staining. So, doctor gram he discovered that certain bacteria were able he was able to stain them using gram; gram stain, he called them gram positive cell and gram negative cells he could not stain; the reason is that the stain actually interacts with cytoplasmic membrane and is visible then under light microscope or bright field microscope.

So, in gram negative cell they have an additional layer of Periplasmic proteins which do not allow staining and there is called gramming, it yourself. Even though gram positive and gram negative cell classification is a classification based on cellular membrane and structure and in not genetic structure that people often talk about nowadays in microbiology, it is a very important and informative classification. I also shared information about lipid bilayer in lipid monolayer and how lipid monolayer of are some archaea give them particular strength and resistance to heat and extreme environment. This will remind you one of the previous lectures where we shared information on how archaea can live in extreme environments such as extreme high PH or low PH high and high temperature and high pressure.

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Here is another photograph of cytoplasmic membrane that I showed last time what is very important for you to notice this time is the size of the cytoplasmic membrane it is at the range of 6 to 8 nanometer which is very very small and thankfully we have techniques such as tem and electron microscopies that can give us beautiful images of cellular membrane. Enough beautiful that now we have such beautiful detailed information and we can create such nice graphics.

And notice here on the top left of the slide that the hydrophilic end of the cytoplasmic membrane in bacteria is often glycerol with a nice phosphate end.

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Archaeal membranes

- In Bacteria and Eukarya, fatty acids are linked with ester links to glycerol, whereas in Archaea, hydrophobic side chains are linked with ether bonds
- Archaeal membranes are monolayered
- Both rings and sugars maybe present in archaeal membrane
- Despite differences the three domains' membranes are structurally similar; fittest for survival and selective permeability

The diagram illustrates the structural differences between Archaeal, Bacterial, and Eukaryotic membranes. It shows two types of phospholipids: one from Archaea with a phytanyl side chain (labeled 1) and one from Bacteria and Eukarya with a fatty acid side chain (labeled 2). The Archaeal phospholipid has an ether linkage between the side chain and the glycerol backbone, while the Bacterial/Eukaryotic phospholipid has an ester linkage. Below these, the bilayers are shown: a monolayer for Archaea and a bilayer for Bacteria and Eukarya. Labels include: Phospholipid from Archaea, Phytanyl sidechain, Ether linkage, Phospholipid from Bacteria and Eukarya, Ester linkage, Glycerol, and Phosphate group.

In archaeal membrane there is the difference the archaeal membrane and bacteria membrane bacteria and eukaryotic membrane differ from each other in a very essential manner in bacteria and eukaryotic cell cytoplasmic membrane the fatty acids. So, long chain fatty acids are linked using ester bonds.

So, ester bond is when we have seen a ketonic bond here double o 1 o oxygen here. So, this is an ester bond fatty acid attached with ester bond to the glycerol phosphate group in Archaea they are often at they are almost always attached by ether bond. So, they are missing this double bond o here the other important differences that I mentioned earlier Archaeal membranes are monolayered and bacteria and eukaryotic membranes are bilayer um.

Let me just spend a minute here to explain to remind you of what Eukarya is. So, earlier we talked about 3 domains of life. So, let us take a look at what Eukarya eukaryotic cells are we believe that life started from a particular kind of cellular structure and we can refer to it as last Common ancestor.

hydrophilic and using ester bonds whereas, Archaea uses ether bonds. Another common thing between eukaryotes and bacteria is again coming back to their cellular structure is that in a eukaryotes it is very unlikely to find anything else except fatty chains simple fatty chains in Archaea; however, we can have fatty chains that have other appendages attached to them. In fact, sometimes they have cyclic compounds that are attached to their fatty chains or an important difference now between eukaryotic cell and bacteria and Archaea is as I mentioned earlier they have nucleus and other organelles bacteria Archaea do not.

Now, to throw some more relevance in light about it most pathogens that afflict humankind or at least the one thing we know about and are concerned about are bacteria Archaea are nowadays found very often in extreme environments such as deep under the earth, in hot sulphurous springs, in deep ocean volcanoes, eukaryotes is every almost every kind of life we see. So, this would range from algae, fungus, chimpanzee, trees, tiger, ourselves, insects, butterflies all of them will come under eukaryotes.

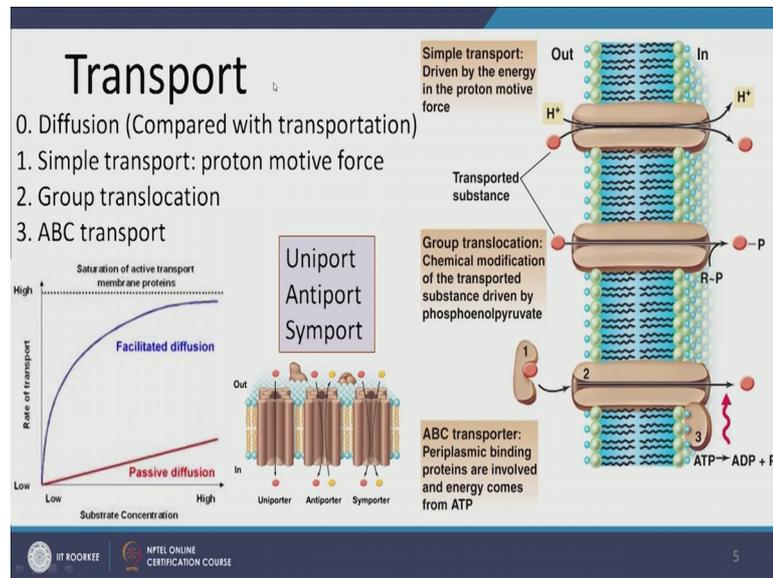
So, just imagine this way that the diversity in eukaryotes is considered to be miniscule very small compared to the diversity that we know in bacteria and we also have reasons to believe that we have only scratched the surface of bacterial communities. So, there is unprecedented bacteria bacterial diversity that we would have not seen here we know this by genetic sequencing and fingerprinting of bacterial communities.

So, imagine if the eukaryotic diversity that we see we talk about diversity of ecological life forms may and we have these many species of trees and plants and insects and animals and even within humans, we have such diversity in terms of how we look like and how our bodies are structured we cannot even begin to imagine that if we had eyes to actually see bacteria how much diversity there would be and; obviously, still much is not known about Archaea.

Now, coming back here we notice that despite differences in there in the membranes of Archaea eukaryotes and bacteria they still have very similar structure. In sense that the inner side of their cytoplasmic membrane is hydrophobic and the outer ends are hydrophilic they will now so here hydrophobic outside hydrophilic. Similarly here hydrophobic and outside hydrophilic and this is important to survive in environment to keep the insides of the cells intact and together and also give it selective permeability.

So, not everything that is inside can go outside the cell not everything it outside it can come inside they have to get the permission from the cytoplasmic membrane, which brings us to transport.

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So, if we have a cellular membrane or any kind of membrane that we need to transport stuff across in microbiological molecular scale we have the first phenomenon diffusion which is probable transportation, but we can notice that when we have passive diffusion or just the Brownian diffusion we do not get very high rate of transport and when the cells actively transport or facilitated diffusion they are actively transporting their spending energy and chemicals and other things to get things in out or throw things out then the rate of transportation increases. So, this is inertia this is action.

So, when it comes to diffusion which I have bulleted as 0 this is just general diffusion that is already is happening except for water other molecules find it really hard to diffuse inside and outside the cell in events then cells need more water, then what they will receive by diffusion or at a higher rate than, what they will received by diffusion they use aquaporins and will talk about them.

Now, a facilitated diffusion or active transport is in generally classified into 3 groups; 1 is simple transport transportation the other is group translocation and then is ABC transportation. Now same in simple transportation let us take a look here simple transportation uses proton motive force. Now remember I told you that the outer layer of

cell membrane will have positively charged proton inner layer will have negatively charged O H minus.

So, if the cell makes use of this electron gradient remember like a battery. So, it makes use of this electron potential to transport the substance here in red inside. So, when it transports the substance in the proton travels from here to the inside or in other words the electron travels from inside to outside. So, the cellular potential is reduced by one charge and the substance has been transported inside is a simple transport.

Now, in group translocation this is really neat in group translocation we have our substance waiting outside to come inside using this integral protein by the way this brown thing is integral protein and here we have phosphoenolpyruvate waiting to phosphorylate with the substance. So, basically this substance is pulled in it is phosphorylated and it is chemically modified when it comes in, but it still comes in. So, here the energy is chemical energy of phosphorylation in ABC transportation this is usually it is common in gram negative cells we have periplasmic proteins which bind with the substance that we want to bring in.

So, these they bind with this protein a protein bind with the substance they bring it to the integral membrane that that wants to transport it and one ATP is utilize now remember ATP is the currency of energy. So, how in are human societies money is the currency with which we do our transactions in biochemistry ATP at least in biochemistry ATP is the currency of energy. So, ATP loses it is one phosphate and what we have is the substance coming in. So, cell expends 1 of it is ATP it converts into ADP and the substance comes in.

Now, it is very important for you to note and think about these 3 different kinds of 4 different kinds of transportation across the cellular membrane and wonder in all these for diffusion simple transportation group translocation in ABC transportation, what is the source of energy of transportation. We know it by law of mechanics any action requires some energy if we are breaking through the inertia thing is lying outside we want to bring it and we want to do work any work requires energy.

So, what is the source of energy or diffusion what is the source of energy of simple transportation what is the energy for group translocation and for ABC transportation the other thing, I want you to understand and ask yourself is form for all these 4 kinds of

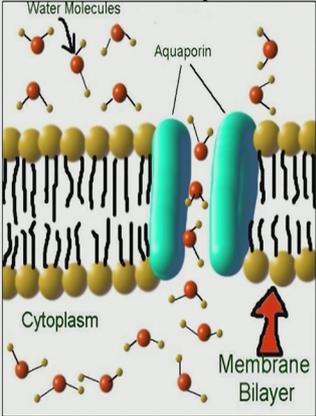
transportation in, which of the cases is the substance that is transported inside not modified and in which of the cases the substance and when it comes inside has been modified.

Now, here is another beautiful picture with the text box here saying Uniport, Antiport, Symport this informs you basically about the direction of transportation not only do we bring things from outside to inside, but we can also take things that are inside outside. So, Uniport would be unidirectional outside inside motion Antiport is one substance comes in and other substance is thrown out Symporter is 2 different substances are brought in together in synergy with each other.

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Cytoplasmic Membrane and Transport

- Cytoplasm is mixture of salts, sugars, amino acids, nucleotides, and many other biomolecules
- Small hydrophobic molecules can diffuse through it but polar and charged molecules need to be transported across, even H^+
- Water passes freely; and is accelerated by aquaporins



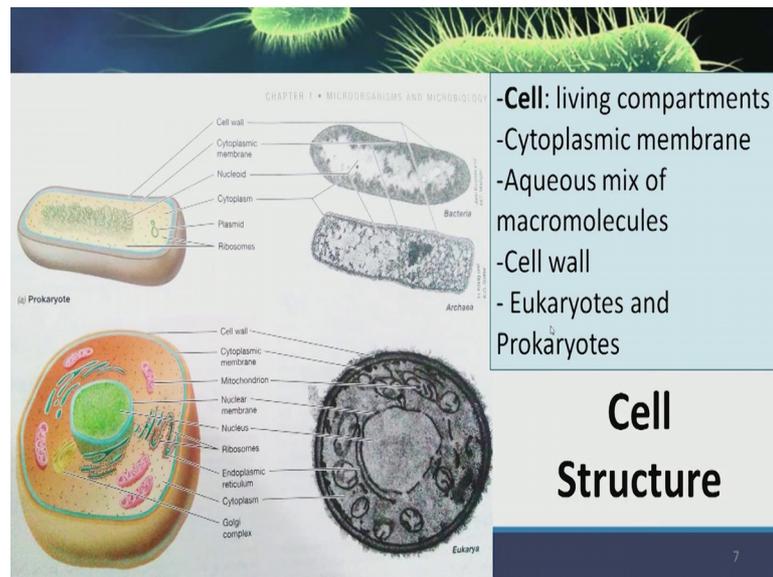
The diagram illustrates a cross-section of a cell membrane, showing a phospholipid bilayer with hydrophilic heads (yellow spheres) and hydrophobic tails (black lines). Two blue, cylindrical aquaporin proteins are embedded in the bilayer, providing a pathway for water molecules (represented as red and white spheres) to pass through. Labels include 'Water Molecules' at the top, 'Aquaporin' pointing to the proteins, 'Cytoplasm' at the bottom, and 'Membrane Bilayer' at the bottom right. A red arrow points upwards from the cytoplasm towards the membrane.

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And as I said before water for water transportation we can have passive diffusion we always have passive diffusion, but we also have specialized integral proteins called aquaporin these are special doors for water to come in and go out, and through the cytoplasmic membrane if there is a chemical that is small and it is hydrophobic it can diffuse, but if it is polar if it is charged it needs some active transportation already.

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Now, this is this is where we will complete our inquiry on cell structure this is a slide from your first lecture and I hope you reminded of it. So, we have 2 pictures on the left panel we have a prokaryotic cell and we have a eukaryotic cell. Now in a prokaryotic cell you can see there are no cellular compartments apart from cytoplasmic membrane in eukaryotic we have all these different structures and I want to briefly go through them and tell you what they are.

So, here we have nucleus in prokaryote this yellow liquid is cytoplasm which is an aqueous mixture of bio chemicals that are necessary for survival it has carbohydrate it has proteins it has some polar compounds as well this green 8 here is the plasmid. And we will talk about it in the next lecture in more detail, but for now it is important to know that most of the genetic material most of genetic material what is genetic material genetic material is the material that stores information about the cell it tells the cell how are you going to live what are you going to do.

So, most of this genetic informational material is stored together in prokaryotes in one long circular chain; however, it can have some extra material that is stored separately and it is one of them is plasmid in eukaryotic cells we have a more complex and a multi layered structure.

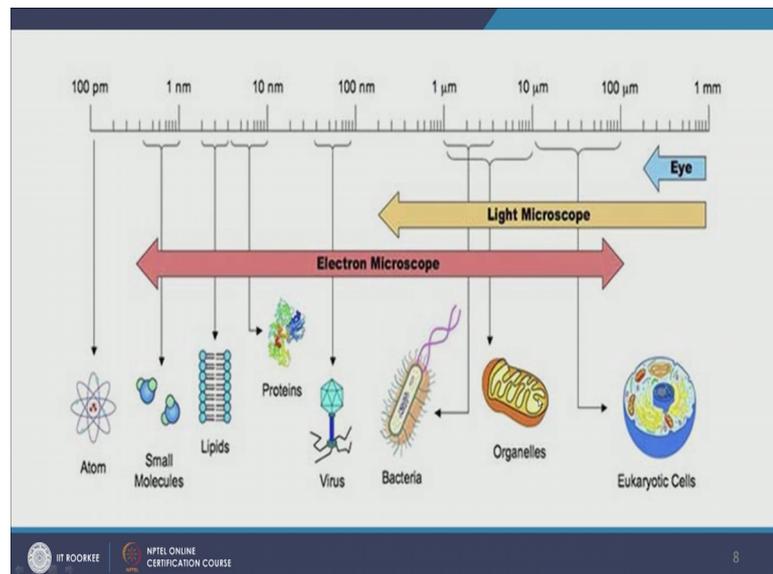
So, I have mentioned this before the yellow bodies here are called Golgi complexes and it is good for you to know that they are used for processing, even preparing,

transportation and separation of different kinds of proteins, they have many many purposes, but protein transportation sorting and processing it is are the main functions the green things here endoplasmic reticulum, sometimes they join the outer end to the nucleus and they are used for many many reasons again such as protein formation and sharing.

The pink structure here is a mitochondria and this is something I want to highlight in this particular cell we have 1 2 3 4 5 mitochondria. Now mitochondria is interesting because it has its own genetic material it seems to have a mind of its own its genes are different from the genes inside nucleus its genetic material looks and behaves differently than the genetic material here and what would be very interesting for you to find out is that mitochondria by the mitochondria is the powerhouse of the cell it gives it its currency. So, it is like a bank that that the prints notes for the cell.

So, mitochondria is slightly bigger than prokaryote mitochondrial genome or genetic material or the informational material resembles prokaryotic material, which gives an idea to many microbiologists that mitochondria was once an independent bacteria, which was engulfed by an eukaryote and now it is an essential part of all eukaryotic cells.

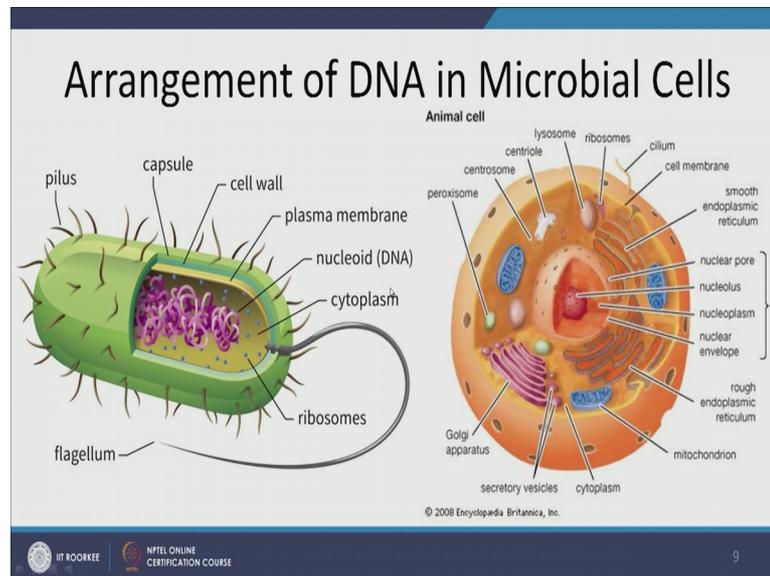
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And this is me giving you an idea of difference between mitochondrial size, few micrometers, eukaryotic cell size really big and bacteria up to few micrometers.

So, many of the organelles inside eukaryotic cell are actually size of prokaryotes.

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And then today we are just going to talk little bit about arrangement of DNA in microbial cell. And in next lecture I will give you a more detailed information of what DNA is how it works for now it is very important for you to understand that there are 2 kinds of material in cell, when we talk about cellular structure and the components by chemical components of the cell one of them one kind are informational and the other kind are non-informational.

So, all carbohydrates the cytoplasmic membrane and cytoplasmic many things in the cytoplasm are non-informational, because they do not inform the cell how to go about life. They act like sensors that respond to information they do not have information in themselves, but the cells have a highly sophisticated DNA or genetic material in them that inform the cell what to do when to do how to do how to respond. So, it is basically like the code the code of life it is akin to library of the cell and it is own, but here is important thing it is a library of cell it tells us cell the information that it needs.

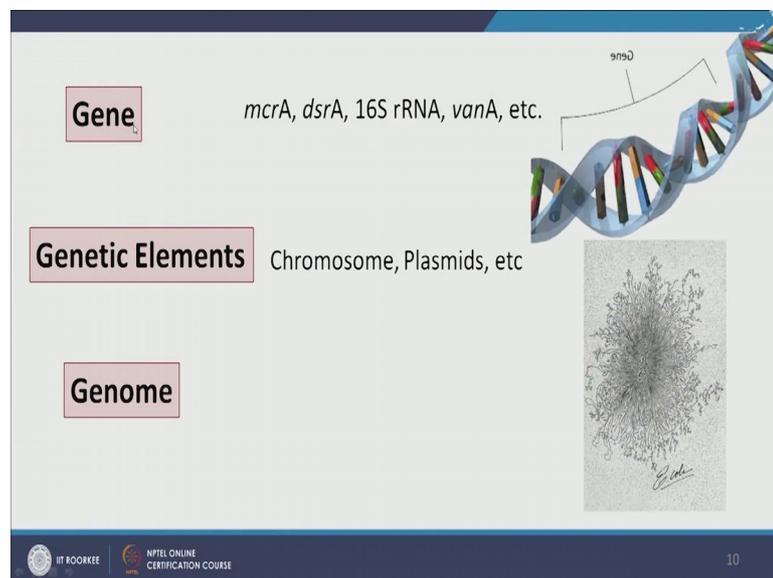
But only the information that it needs and the information that it does not need just sits quietly within the genetic material. So, not all the information inside the genetic material is provided to the cell at any given time, but when it is appropriate only then it gives the information now how it does that how it interacts with the cell how it responds to the

environment. Let us say environment is glucose rich it has lot of glucose around it. So, the bacteria and bacteria can process glucose.

So, bacteria would like to have the information of genetic material would like to tell in bacteria hey there is a lot of glucose use it. Now how would genetic material know that there is lot of glucose the sensors outside the cell would send chemical signals informing or triggering; triggering the genetic material to convert into proteins, which will allow it to process the glucose same thing happens in eukaryotic cell only that their arrangement of genetic material is very different like earth has a core which holds inner core and outer core which holds liquid lava.

Similarly, eukaryote has an inner core nucleus that holds it is genetic material and they have a very sophisticated system for transporting information into the cell and interacting and making sure that the cell survives. So, today we will only talk about basically what genes are what genetic elements are and what genome is and in the next lecture we will go more in detail.

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So, for now what you need to understand that gene is the smallest size of information that a cell can decode. So, this is like a sentence when it comes like for language what the sentence is it is the minimum complete set of information. So, I have given names of some genes here and we will talk more about in them in detail later, but mcrA dsrA 16S rRNA vanA these are names of genes that serve a particular information to the cell. So,

mcrA this particular gene would tell the cell to make a particular enzyme that will allow the cell to produce methane and create energy.

Similarly, dsrA would tell the cell some information that we allow it to reduce sulfate and get energy now many of these genes often are not often almost always are clustered together and join together to form one big one big genetic element and the most popular among them are relevant among them are chromosome plasmid. And here is one of the early pictures of chromosome of e coli and together all the genetic elements that are present in a cell are referred to as genome.

And in the next lecture I will go in depth about gene and genetic elements and genome and how they inform the cell and how this beautiful molecular biology of cell works and what are the promises of this molecular biology until then.

Thank you very much.