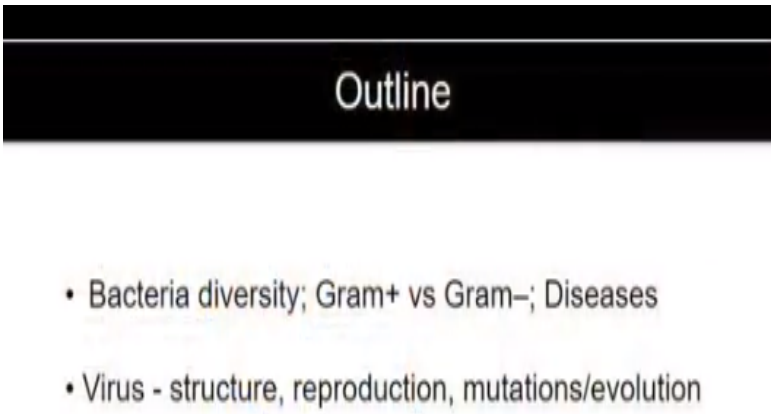
Bioengineering: An Interface with Biology and Medicine
Prof. Sanjeeva Srivastava
Department of Biosciences and Bioengineering
Indian Institute of Technology - Bombay

Lecture – 24
Bacteria and Viruses

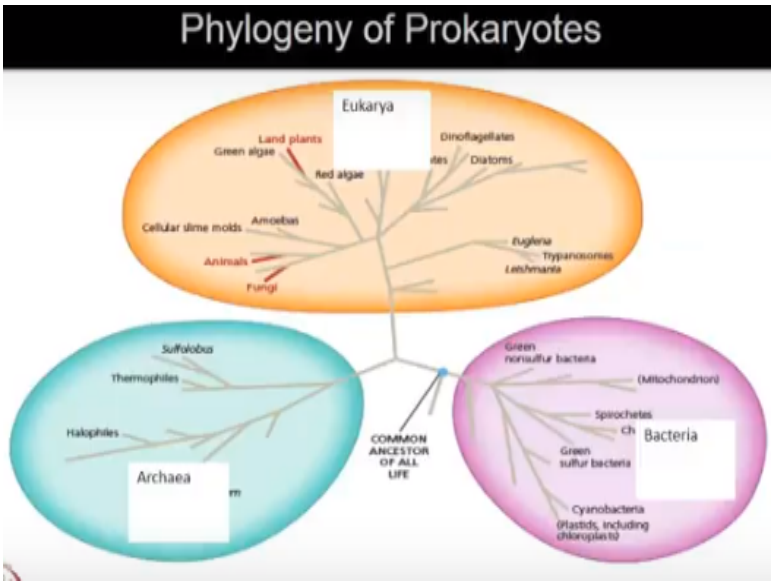
Welcome to MOOC-NPTEL course on bioengineering an interface with biology and medicine today were going to talk about bacteria and viruses. There is a brief outline of the lecture.

(Refer Slide Time: 00:32)



We will talk about the diversity in bacteria gram positive and gram negative type of bacteria and different type of harmful as well as useful applications from bacteria. We will also talk about viruses their structure reproduction how they mutate and how that is relevant for the evolutionary context. Previously we have discussed about the tree of life.

(Refer Slide Time: 01:04)

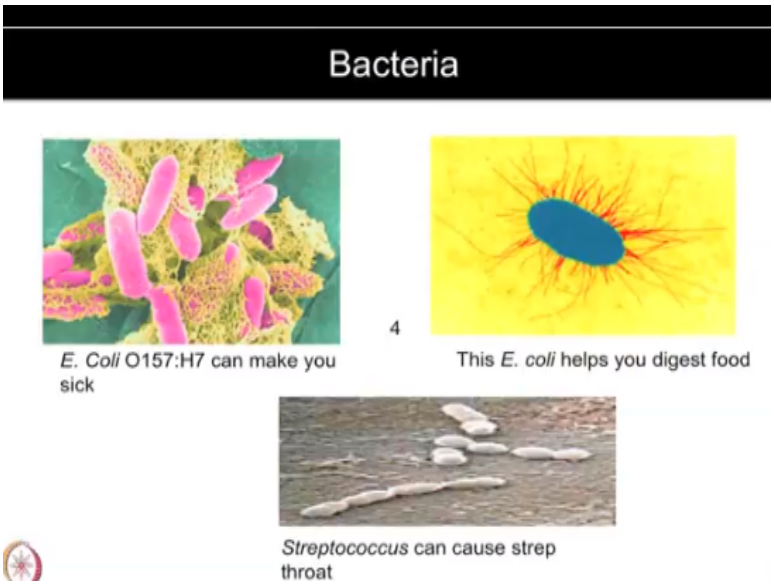


Let us look at phylogeny of prokaryotes and try to compare archaea Eukarya and bacteria. So, if you think about nuclear envelope bacteria and archaea, they do not have nuclear envelope whereas Eukarya they have the nuclear envelope intact. If you look at membrane enclosed organelles again in bacteria and archaea it is absent. Whereas in new carrier it is present if you look at what are the specific component of cell wall.

Which is peptidoglycan it just present in bacteria, but it is absent in archaea and Eukarya if you look at membrane lipids it is very uniquely present in archaea where there is some sort of branched hydrocarbons are present. Whereas in bacteria and Eukarya it is mainly unbranched hydrocarbons. So, this kind of you know gives you a little bit comparison and a uniqueness of each group on one hand and a lot of commonalities between bacteria and archaea.

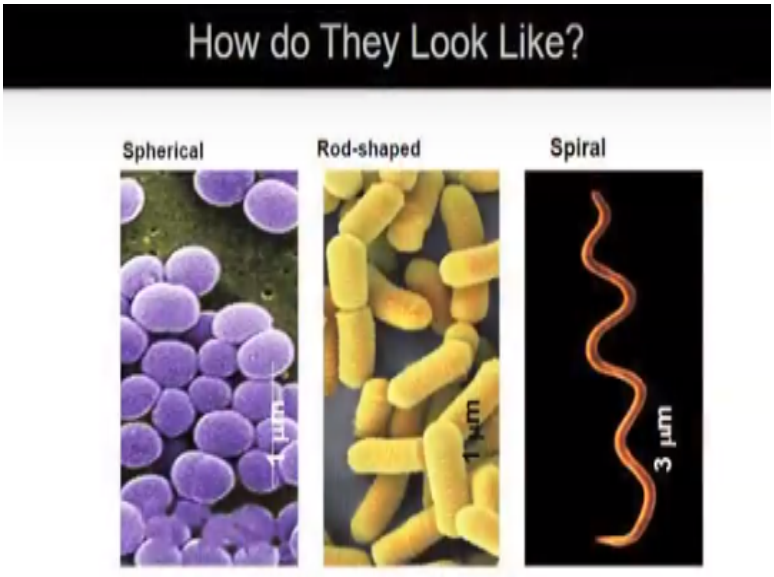
And sometime the common features shared between archaea and the Eukarya. Let us first talk about bacteria what are bacteria that single cell organism very small you in fact need a microscope to visualize bacteria they can be found on any material or surfaces. And even now billions of bacteria are on are in your body. Even right now there are different types of bacteria shown on the screen.

(Refer Slide Time: 02:42)



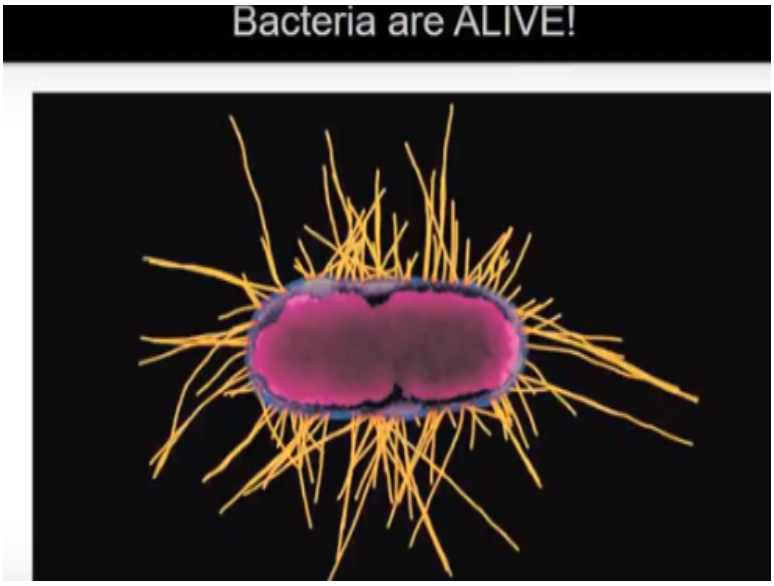
E coli, Streptococcus there are many bacteria which are harmful there are many bacteria which are also useful how do they look like? So bacteria can be present in three basic shapes.

(Refer Slide Time: 02:59)



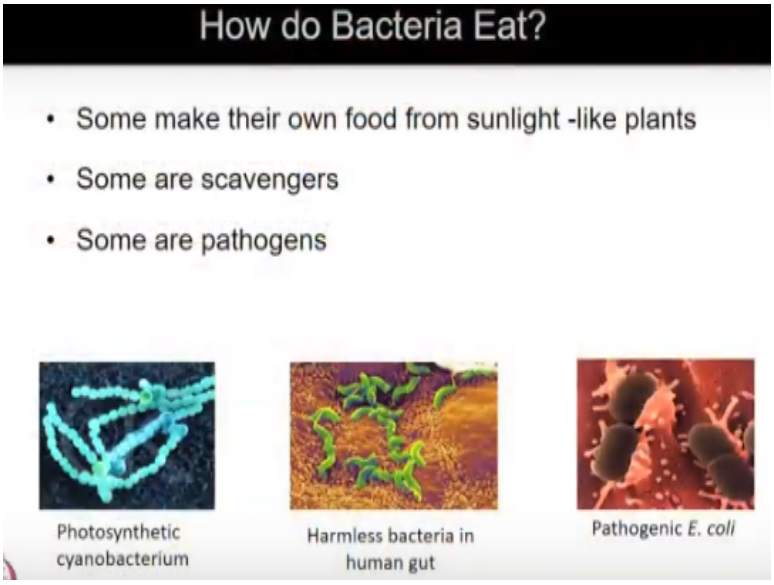
Its sphere or Coci rods or Boselli and spiral shape. Most prokaryotic cells are which is 0.5 to 5 micron they are much smaller than the 10 to 100 microns of many eukaryotic cells. Are bacteria alive?

(Refer Slide Time: 03:19)



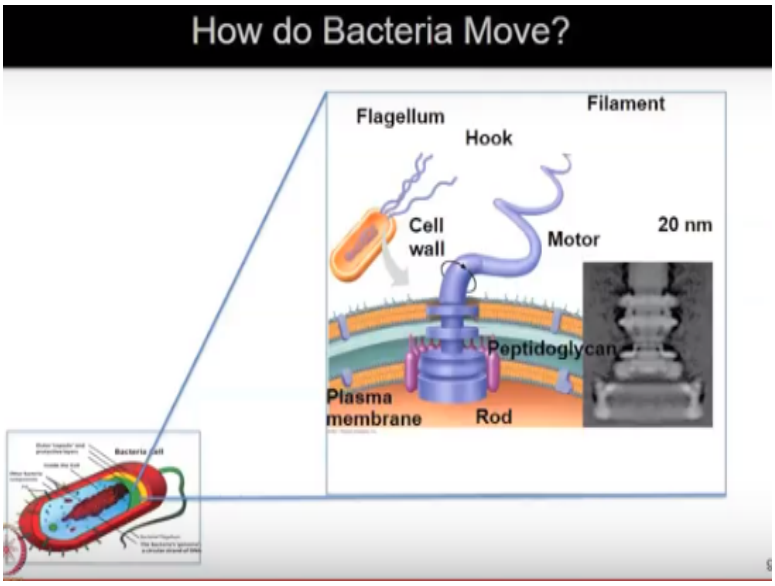
So, what does it mean to be alive? it means they can reproduce they can make their own copies themselves do they need to eat? yes, they also eat but then the question comes how do bacteria eat.

(Refer Slide Time: 03:37)



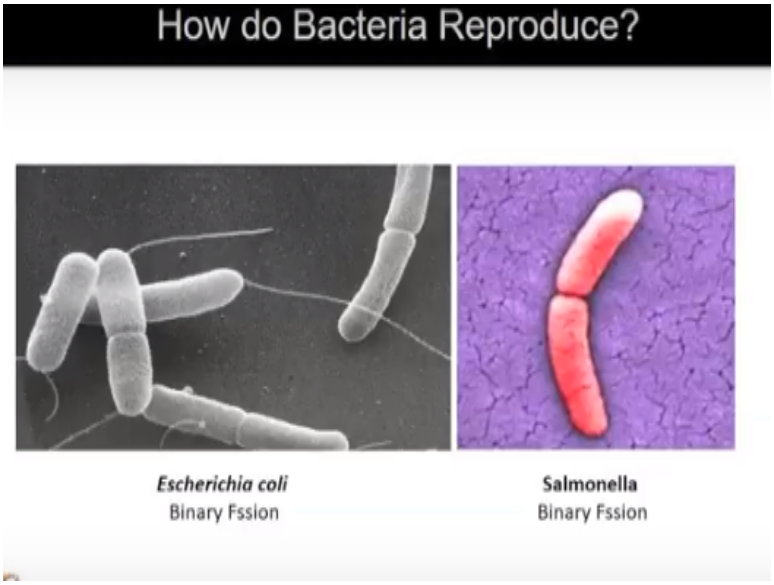
Many bacteria they make their own food from the sunlight like a plant some bacteria are scavengers they share the environment around them for example bacteria in your stomach are now eating what you eat today in the breakfast or the lunch. Some bacteria are pathogens the attack another living organism or other living things for example even this bacteria on your face which can attack the skin. And some of them causes infection and even acne.

(Refer Slide Time: 04:11)



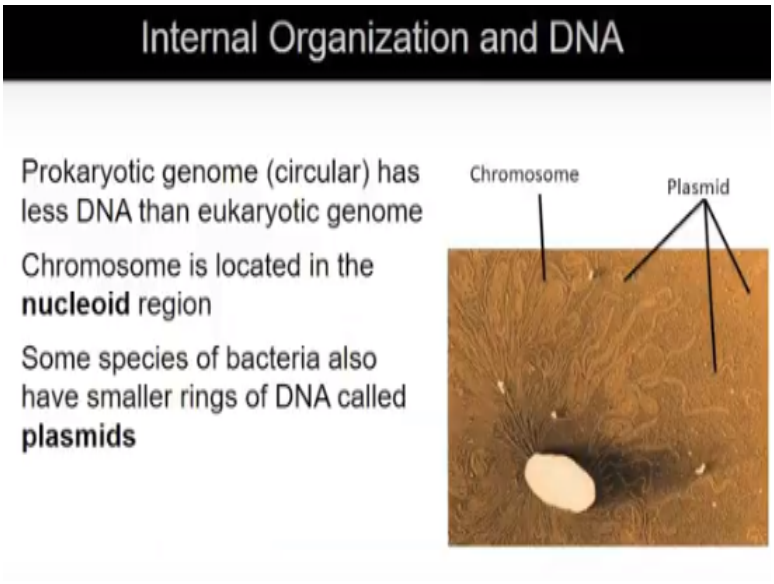
How do bacteria move? so most of the mortal bacteria they propel themselves by the flagella which is a scattered on the surface at one or both ends. So, many bacteria the exhibit taxis or that is the ability for bacteria to move towards or away from the stimulus for example chemotaxis. If we talk about chemotaxis that is a moment to worse or away from the chemical stimulus.

(Refer Slide Time: 04:40)



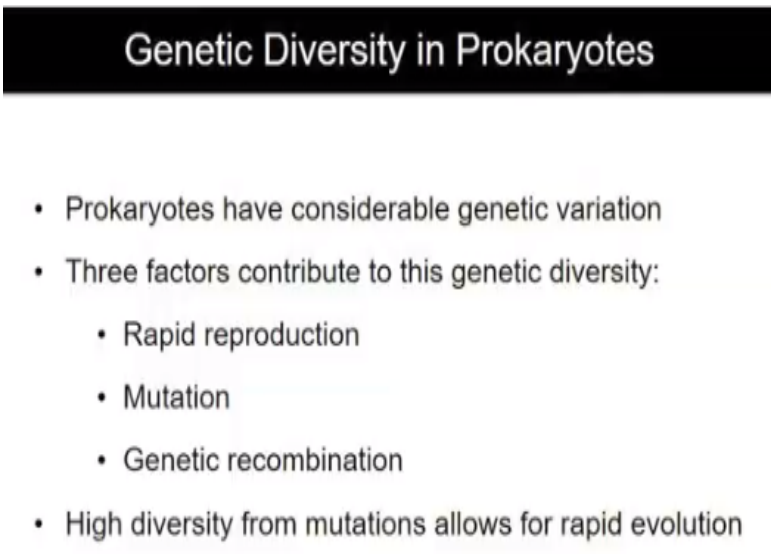
How do bacteria reproduce? so bacteria mainly rely on binary fission for their propagation. And in this process the cell grows in number it also needs to grow to twice its starting size and then it splits into the two bacteria. In binary fission bacteria makes copies by dividing is actually some of the process shown on the screen here for Escherichia coli as well as salmonella showing binary fission.

(Refer Slide Time: 05:12)



What is the internal organization and DNA component inside bacteria? bacteria cells usually lack very complex architecture which is present in the eukaryotes the prokaryotic genome it is circular it has this DNA as compared to the eukaryotic genome. The chromosome is located in the nuclear region and some species of bacteria they also have a small ring shape DNA which is extra chromosomal DNA called plasmids. So, what are the genetic diversity in the prokaryotes?

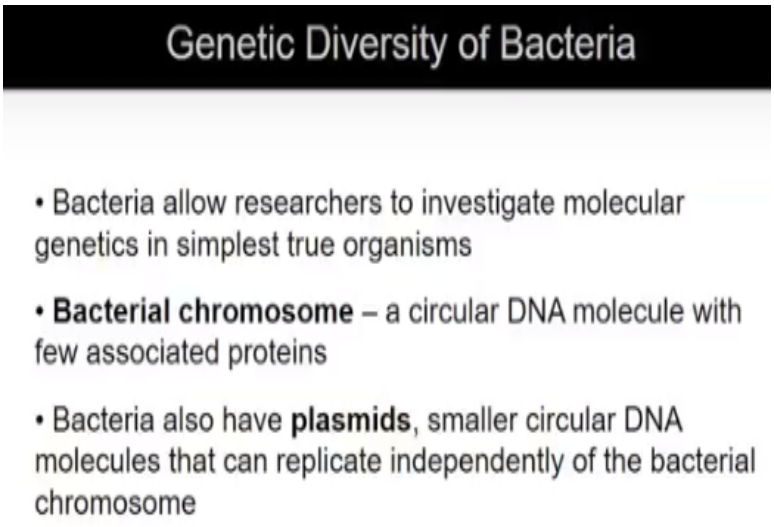
(Refer Slide Time: 05:47)



Prokaryotes have considerable genetic variation and they are mainly three factors which are actually contributing to the genetic diversity of prokaryotes. It is rapid reproduction, Mutation

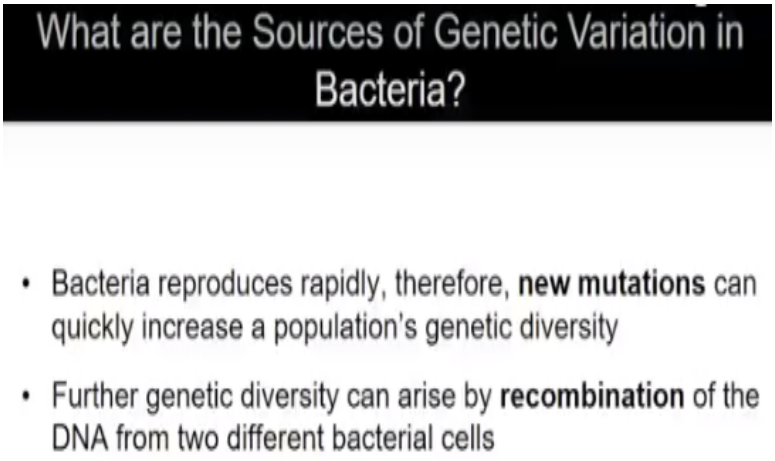
and genetic recombination. The high diversity arises from the mutation allows for their rapid evolution. Now let us discuss specifically the genetic diversity of bacteria.

(Refer Slide Time: 06:14)



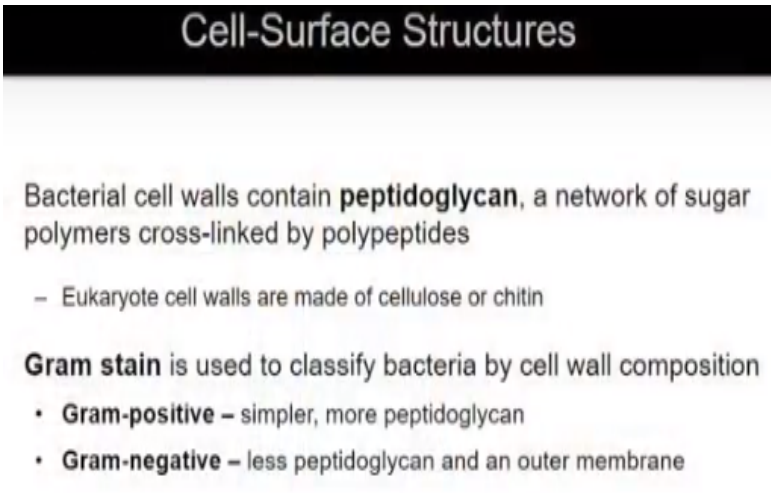
So, bacteria allow researchers to investigate the molecular genetics in simplest true organisms. Bacterial chromosomes it is a circular DNA molecule with very few associated proteins. Bacteria also have the plasmids which are the small circular DNA molecules which can replicate independently of their bacterial chromosomes. What are the sources of genetic variability in bacteria?

(Refer Slide Time: 06:45)



Bacteria reproduce rapidly therefore the new mutation can very quickly increase a populations genetic diversity. Further the genetic diversity can also arise by the recombination of the DNA from two different bacterial cells. Let us now look at the cell surface structures of bacteria.

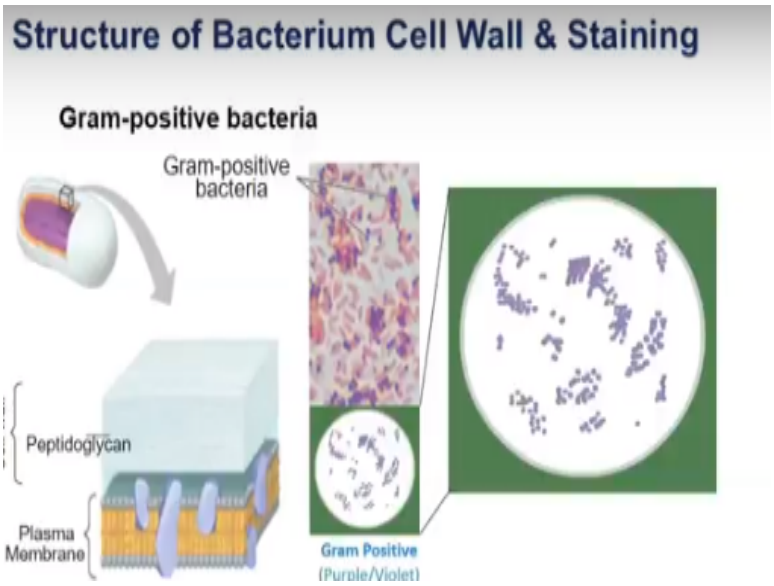
(Refer Slide Time: 07:10)



Bacterial cell wall contain peptidoglycan a network of sugar polymers cross linked by the polypeptides. The eukaryotic cell walls they are made of cellulose or chitin. Gram stain can be used to classify based on their cell wall compositions. There two type of a broader group we can make based on the gram staining. One is gram positive which is much more simple it is a surface structure having more popular peptidoglycan.

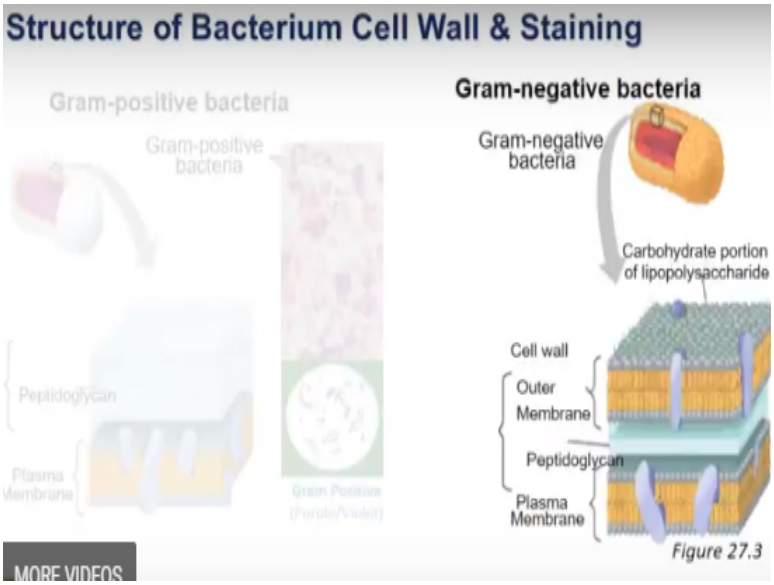
Whereas gram negative is having less peptidoglycan and also contained an outer membrane. Let us look at the structure of bacterium cell wall and how the gram staining works in a little bit more detail.

(Refer Slide Time: 08:02)



First shown on the left side of the screen the gram positive bacteria they have this thick cell wall which is made of peptidoglycan it traps a crystal violet testing and then after rinsing with alcohol it does not remove the crystal violet testing. So, therefore these bacteria if you look at it under microscope they look like purple or violet colored bacteria which is known as gram positive bacteria.

(Refer Slide Time: 08:32)



Now on the right side you can see the structure of gram negative bacteria where there is a very thin layer of peptidoglycan present. So, crystal violet stain can be very easy rinsed off from the cytoplasm and after further re staining the cell appears pink or red in color. So, now if you look

at under the microscope these gram negative bacteria looks like pink color notice. Let us have a lab session specifically for gram staining.

Because you can easily do this kind of experiment where several washing and rinsing steps are involved and just by doing this straining you can broadly classify the bacteria into gram positive or gram negative. So, let us have a lab demonstration session on gram staining.

(Refer Slide Time: 08:59)

Let us get started with gram staining this is the bacterial culture that were going to use for making the smear. This is clean glass slide this is a nichrome loop which is going to be used to make the smear on the slide. This is a spirit lamp which we are going to use for heat fixation step. First, we will sterilize this loop so that there is no contamination in the bacterial culture. We will let it cool so that the cells do not die.

In case if we dip the hot loop, we really take a loop full of culture and make this smear on the slide. We will first let it air dry once the smear air dries, we will use to heat fix the smear the heat fixation step is done so that the cells get stuck onto this slide and do not get washed up and we wash the slide.

(Refer Slide Time: 10:46)

After the heat fixation step, we will add crystal violet for one minute. After one minute we will wash off the stain.

(Refer Slide Time: 11:17)

And then add grams iodine the grams iodine forms a complex with crystal violet and get stuck to the bacterial cell walls. So, when we wash the smear with de colorizer the gram positive bacteria cells stay violet and the gram negative cells lose the primary stain that is the crystal violet and then get stained with the second counter stain which is the safranin. We will now add de colorizer which is acetone alcohol.

After a few seconds we will wash off the de colorizer.

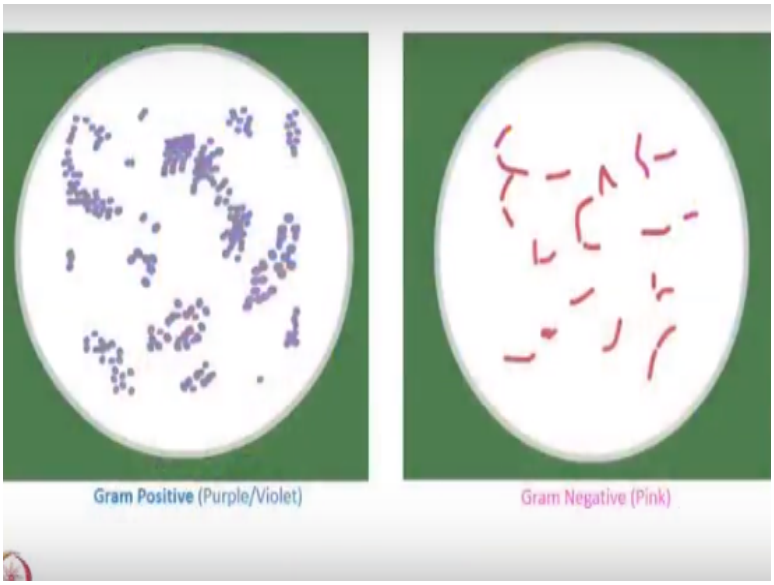
(Refer Slide Time: 12:23)

We will now add safranin after two minutes we will wash up the safranin we will let the smear get air dried. Once the smear has dried, we will add emotion oil and observe the smear.

(Refer Slide Time: 12:23)

Under the oil emotional lens of the microscope.

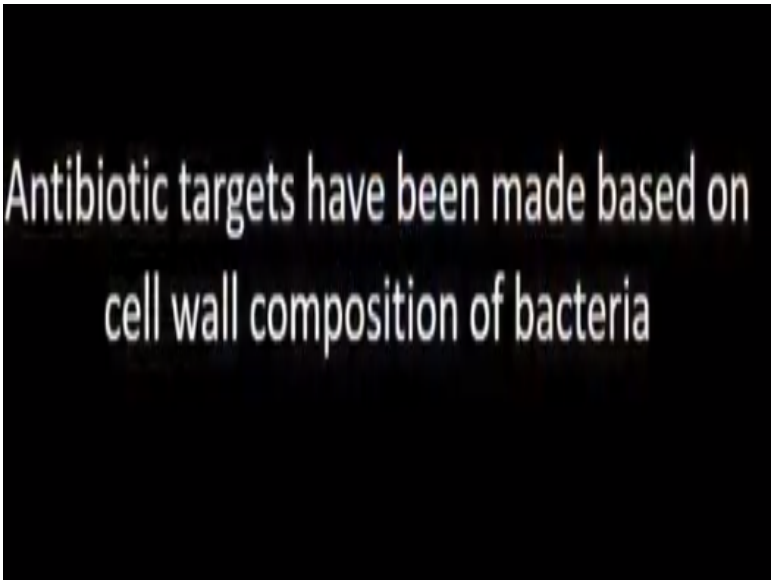
(Refer Slide Time: 13:11)



For gram positive bacteria we will see coci in clusters in purple and if we have gram negative bacteria cells then we will absorb red cells that was all for gram staining. Thank you. Alright so let us say the patient comes to a clinician and doctor have no clue about you know what type of bacterial diseases affecting this that individual. So, in that case the gram staining can immediately give the first level of information.

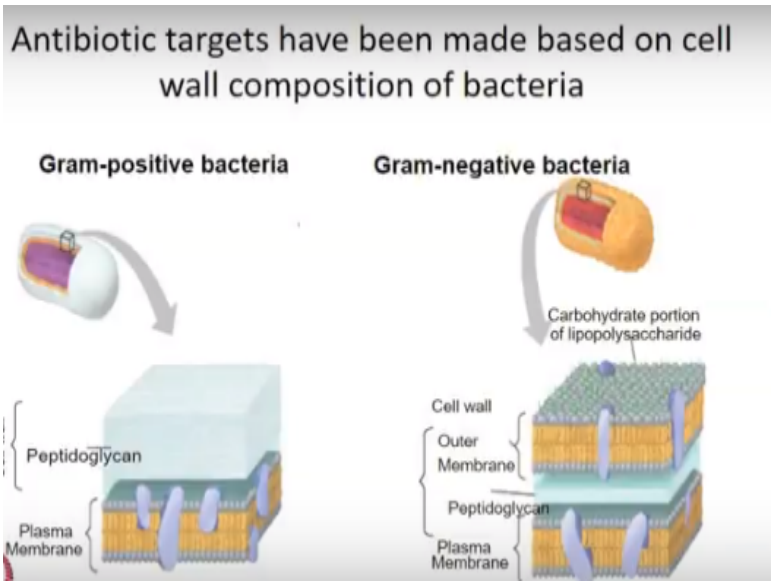
Whether these bacteria belong to gram positive or gram negative. Now looking at the cell surface composition of bacteria.

(Refer Slide Time: 13:57)



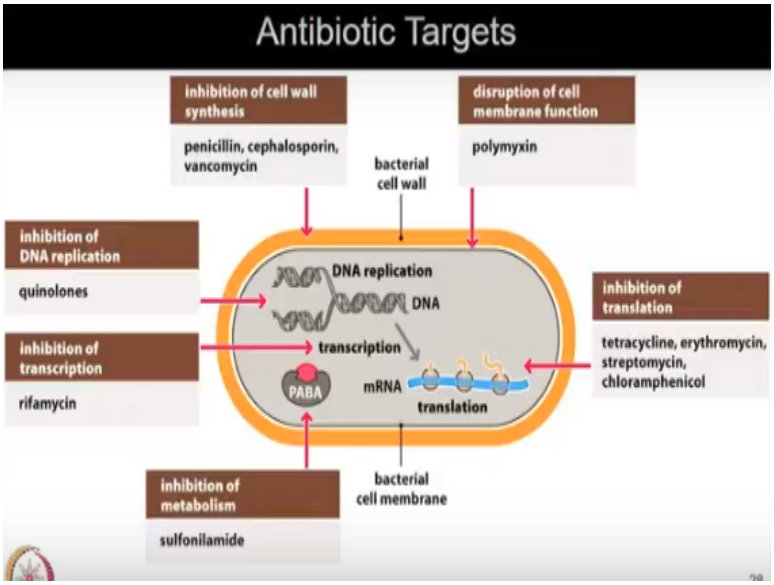
There are many antibiotic targets have been made.

(Refer Slide Time: 14:04)



So, many antibiotics they target peptidoglycan and they damage bacterial cell wall. The gram negative bacteria they are more likely to be antibiotic resistant a polysaccharide or the protein layer which is called capsule that covers many prokaryotes.

(Refer Slide Time: 14:23)

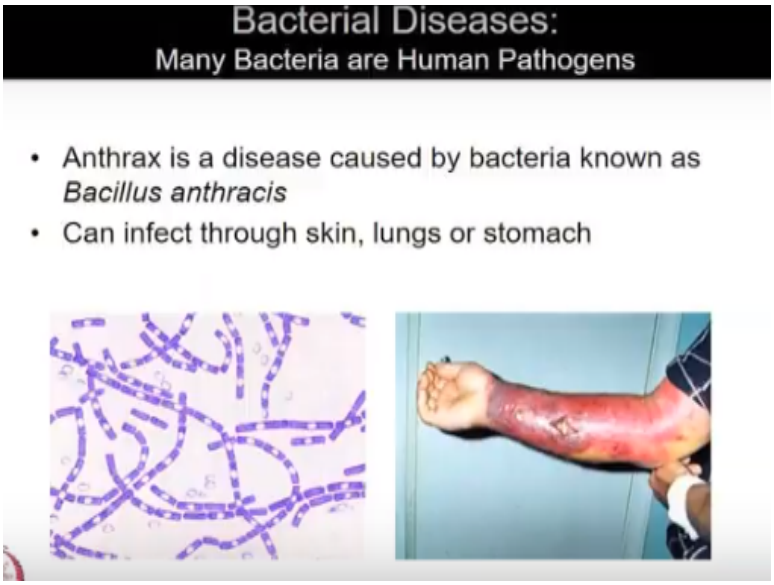


For the slide here I have shown many targets for the antibiotics for example the inhibition of cell wall synthesis that can be governed and that can be controlled by antibiotics like penicillin cephalosporin and vancomycin. If we look at a deception of cell membrane function of that is what is being directed by antibiotic polymyxin. Inhibition of translation process is controlled by antibiotics like tetracycline, erythromycin, streptomycin and chloramphenicol.

Inhibition of metabolism can be targeted by sulfanilamide inhibition of transcription can be controlled by antibiotics rifamycin and inhibition of DNA replication had been targeted by quinolones. So, again you can see looking at the composition and of the cell wall and different membranes a different type of antibiotic targets they try to damage the bacterial cell wall and try to control bacteria for many infections.

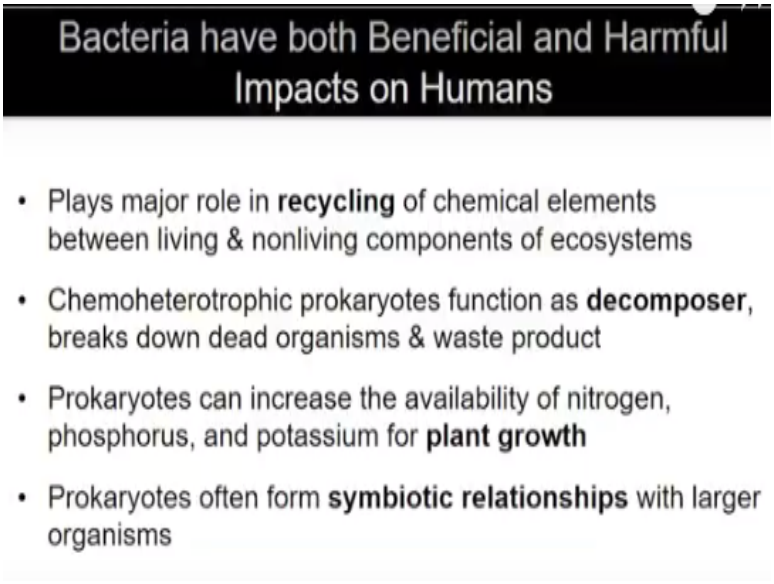
So, bacterial diseases I am sure we have all encountered one of the other bacterial infection many bacteria they are human pathogens.

(Refer Slide Time: 15:46)



Just shown here is one of the example for anthrax disease which is caused by bacteria known as Bacillus anthracis. Which can infect through the skin lung or the stomach. So, bacteria has both beneficial as less harmful impact on humans if you think about the broader environmental issues.

(Refer Slide Time: 16:08)



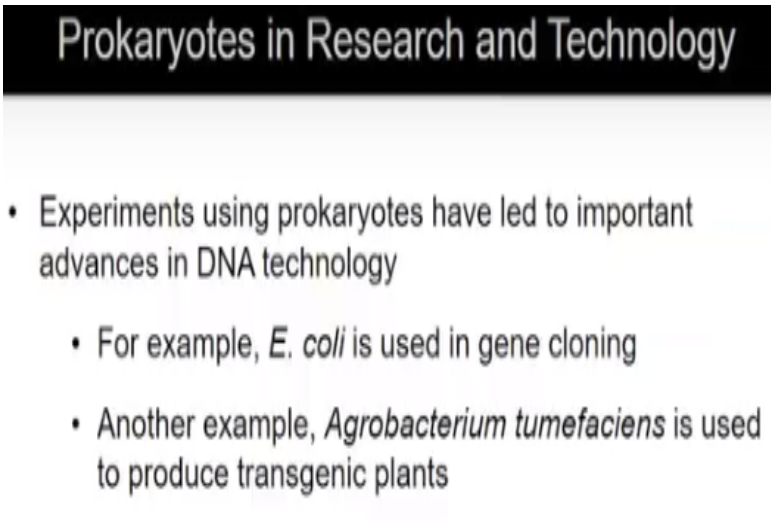
So, bacteria plays a major positive role in the recycling of chemical elements between the living and the nonliving components of ecosystems. The Chemoheterotrophic prokaryotes they function as decomposers which could break down dead organisms as well less waste products.
Prokaryotes they can also increase the availability of nitrogen phosphorus and potassium for the plant growth.

Prokaryotes also a form a biotic relationship with larger organisms and that can be very useful. So, we have seen that bacteria on one hand are very harmful they can cause many diseases and on other hand they can be very helpful especially for many environmental related issues.

(Refer Slide Time: 16:57)

So, scientists have been trying to harness the benefits out of these Prokaryotes and this is one of the hot topic in research and technology development.

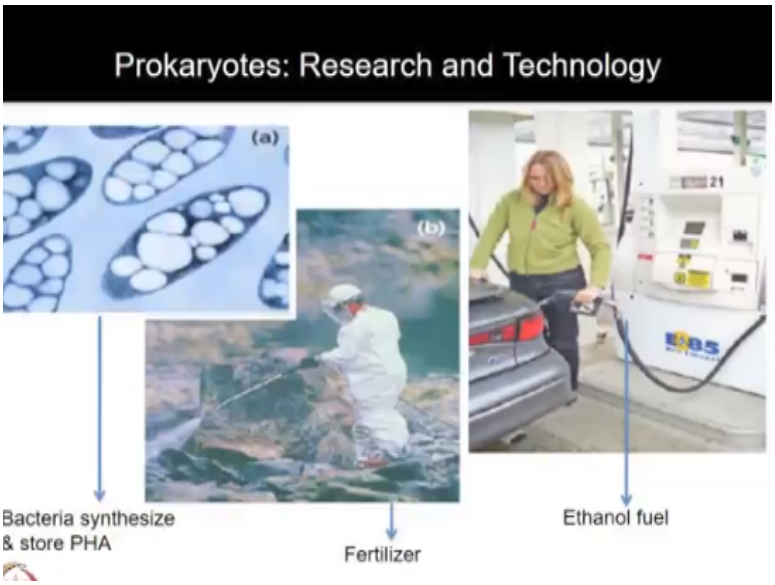
(Refer Slide Time: 17:11)



Experiments have been performed using prokaryotes which have led to some important advancements in the DNA technology for example Escherichia coli has been used for the gene cloning. We have discussed that how agrobacterium tumefaciens can be used to produce transgenic plants. They are various niches or plastics, antibiotics, vitamins, ethanol production all of these are governed by prokaryotes.

So, as the bioremediation which is really important from the environmental point of view.

(Refer Slide Time: 17:48)



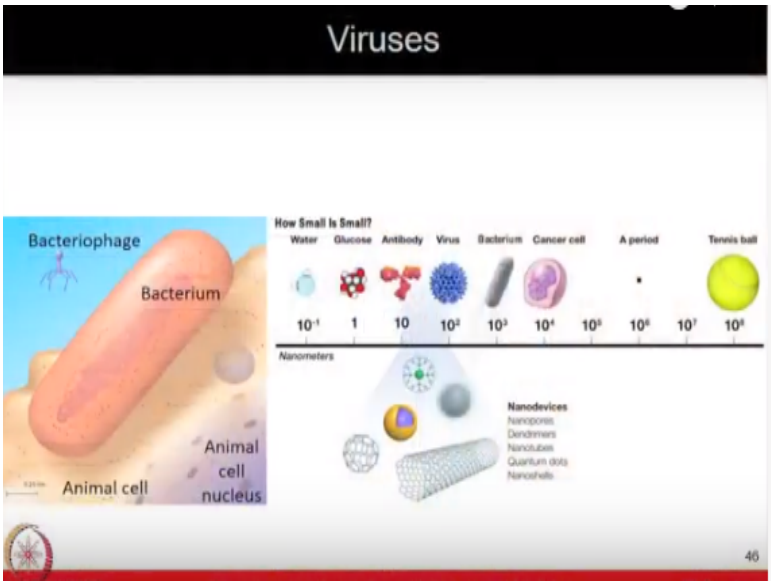
Here there are some examples shown that how bacteria can synthesize and store poly hydroxy alkenoate which can be used for making biodegradable plastics. One of the key areas for research the fertilizer spray they can stimulate bacteria growth which can metabolize even oils. Or one could develop bacteria to produce ethanol fuel from the renewable plant products. Some of these are you know some remarkable examples.

How research on prokaryotes can be so beneficial for many type of products and processes.

(Refer Slide Time: 18:26)

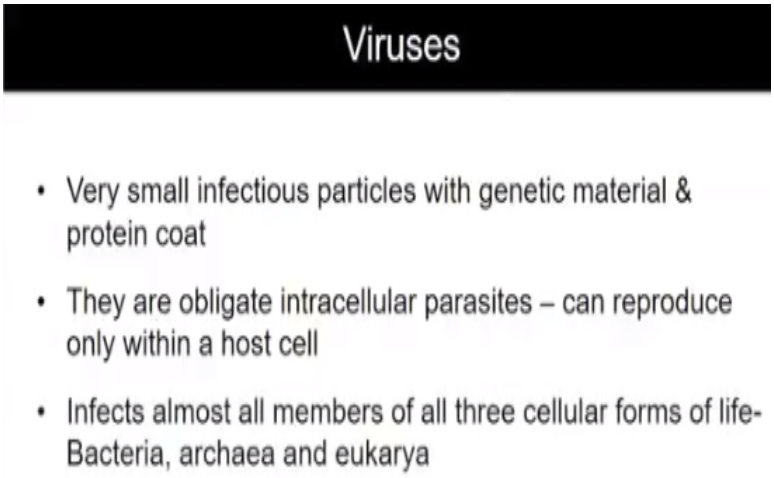
Let us now move on and talk about viruses. So, what are viruses these are much smaller.

(Refer Slide Time: 18:35)



And much simpler as compared to a eukaryotes and of course they are even if you compare to the bacteria, right?

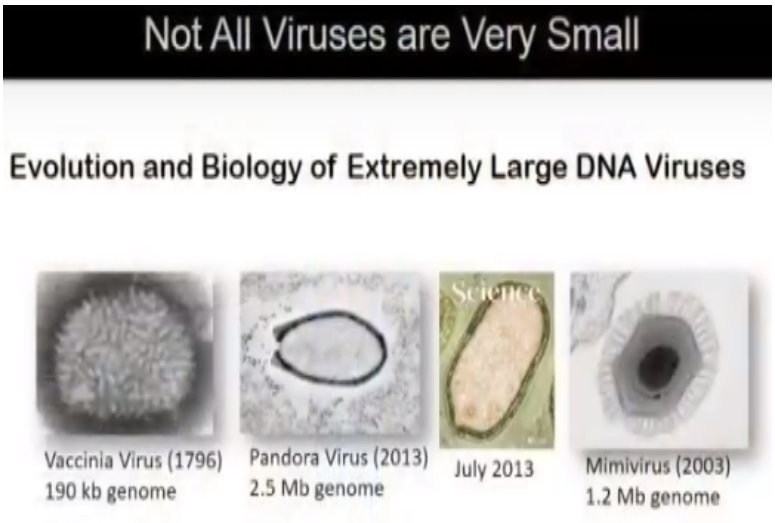
(Refer Slide Time: 18:43)



So, they are very small infectious particles which has their own genetic material and the protein coat. They are obligate intracellular parasite which can reproduce only when they are present inside a host cell. They infect almost all the members of the three cellular forms of life with a bacteria, archaea, or Eukaryote the question comes are viruses alive or they have the kind of a borrowed life.

Viruses lack their energy metabolism are all viruses very small no not all viruses are very small.

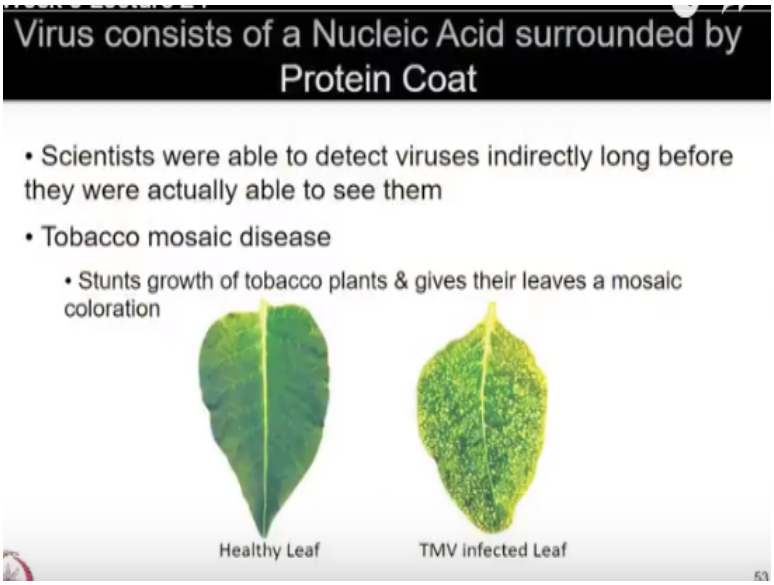
(Refer Slide Time: 19:28)



In fact, people are studying different types of viruses and they are reported that there are some large DNA viruses which are extremely useful to study evolution and biology. They are example like vaccinia virus 190 kb genome, pandora virus which is 2.5 mb genome and Mimi virus which is 1.2 mb genome. So, such you know large DNA viruses are they alive? why are they so big? you know how do they invade the host?

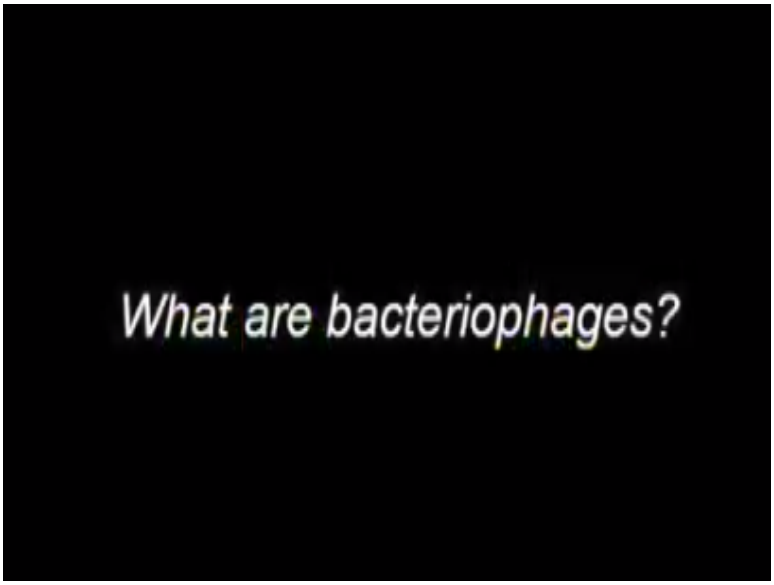
How do they manage to package their genome inside the capsid. There are many interesting aspects of your studying viruses and which are still pretty much unknown and one of the hot areas of research also looking at the evolutionary context.

(Refer Slide Time: 20:16)



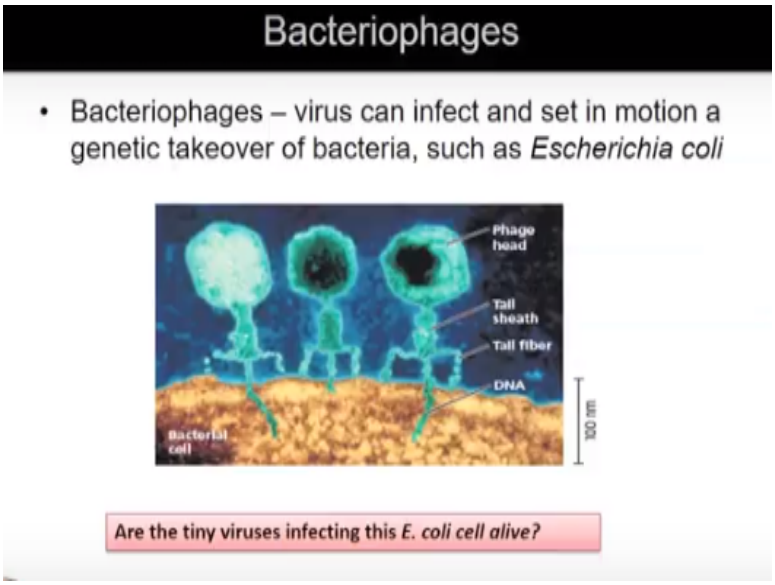
Broadly virus consist of a nucleic acid surrounded by the protein coat. Historically scientists were able to detect viruses indirectly before they were even actually able to see them under the microscope. For example, tobacco was a virus which causes tobacco mosaic disease. It stunts growth of tobacco plants and give their leaves a mosaic kind of coloration. So, shown here is the healthy leaf and then compare with the tobacco mosaic virus infected leaf.

(Refer Slide Time: 20:49)



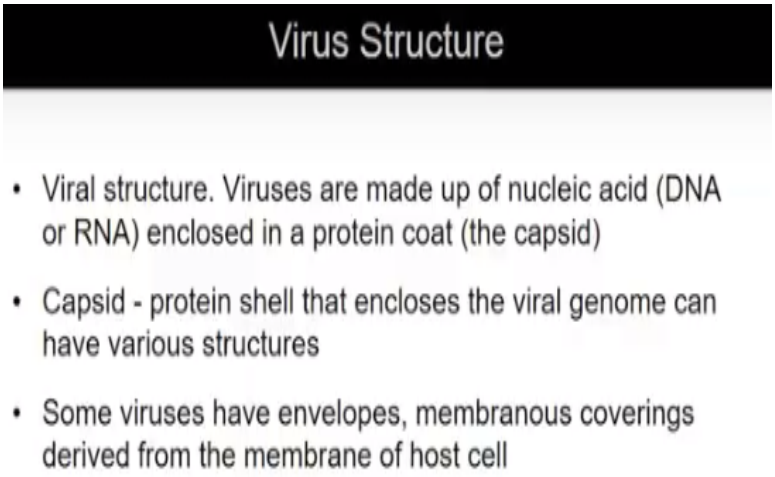
What are the bacteriophages?

(Refer Slide Time: 20:55)



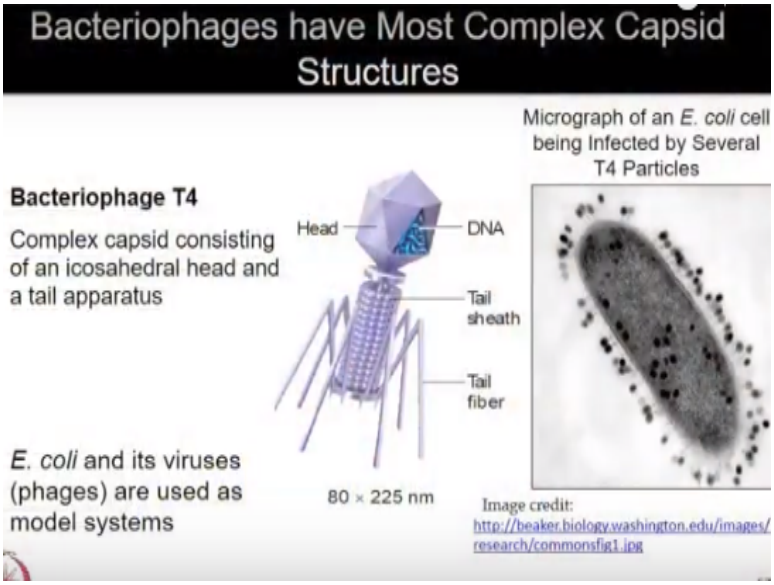
Bacteriophages virus can infect and set in motion a genetic takeover of bacteria such as E Coli Are the tiny virus infecting this E coli cells alive that I think an interesting topic for you to go back and study and then think about how these viruses infect bacteria cell. Let us now think about viruses structure. the viruses are made of nucleic acid DNA or RNA and then enclosed in a protein coat which is capsid.

(Refer Slide Time: 21:23)



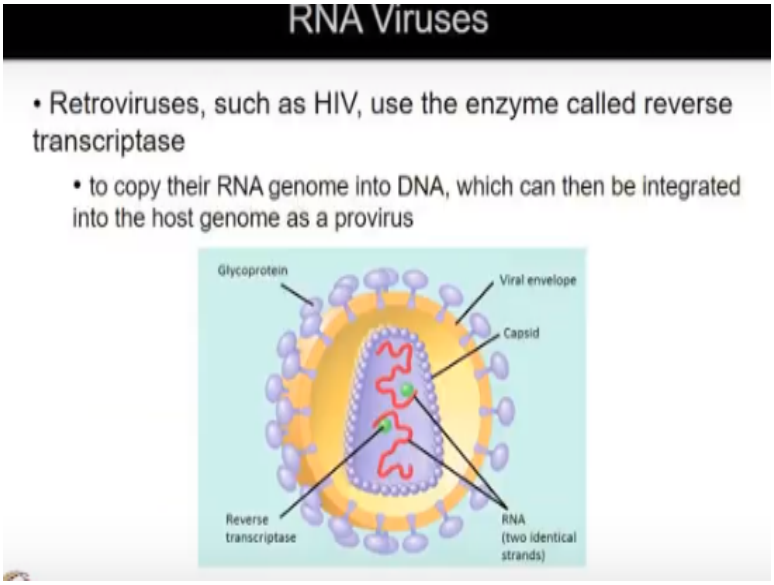
Capsid is a protein shell that encloses the viral genome which can have various structures. Some viruses have envelopes, membranous covering which are derived from the membrane of host cells.

(Refer Slide Time: 21:42)



So, bacteriophages have most complex capsid structure as you can see on the screen the bacteriophage T4 is shown but the complex capsid which consists of an icosahedral head and a tail apparatus. E coli and its viruses are used as a model system for many type of research? Let us now talk about RNA viruses

(Refer Slide Time: 22:04)

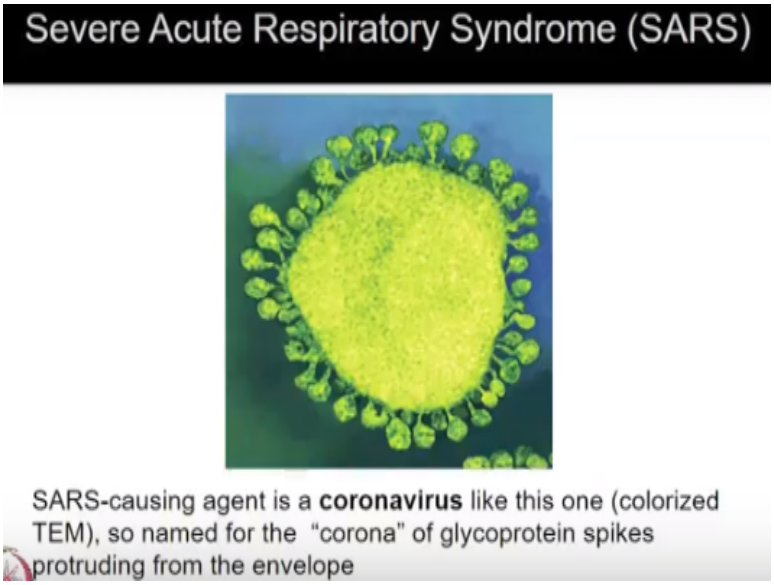


Retroviruses such as human immune deficiency virus they use enzyme called reverse transcriptase. This can help to copy their RNA genome into DNA which can then be integrated into the host genome as a pro virus.

(Refer Slide Time: 22:22)

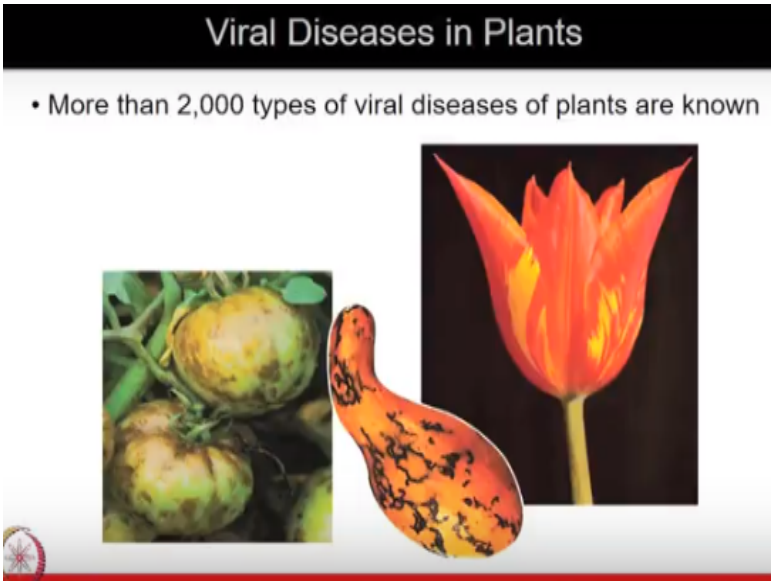
Here on the screen you can see one of the major disease caused by viruses which is polio myelitis or the infantile paralysis which is caused by polio virus. The polio virus invades the nervous system which causes paralysis in one out of every 200 children. Polio still remains endemic in several parts of the world including Afghanistan, Nigeria and Pakistan.

(Refer Slide Time: 22:53)



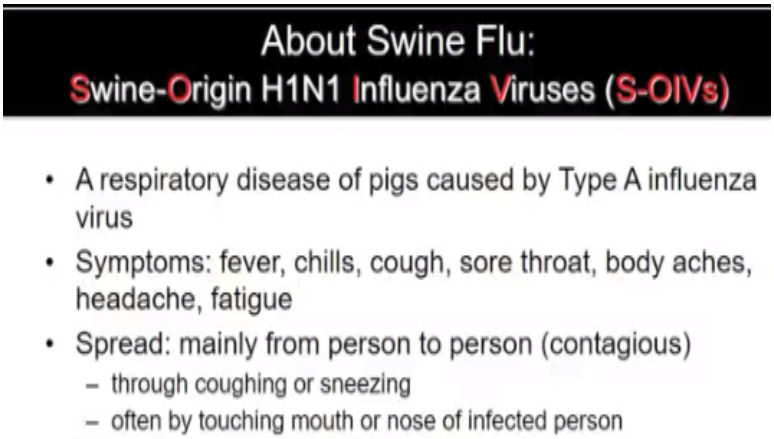
Let us now look at another type of virus which is SARS virus or severe acute respiratory syndrome. The SARS causing agent is a coronavirus lake what is shown on the screen here the name comes from the corona of glycoproteins spikes protruding from the envelope. There are many viral diseases which one could observe in the plants.

(Refer Slide Time: 23:20)



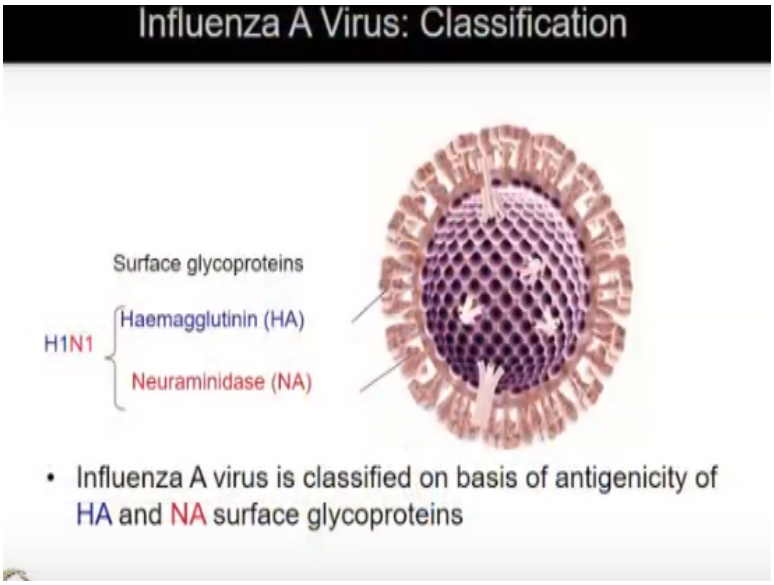
There are more than 2000 types of viral disease of plants which are already known the common symptoms of these vital diseases and these viral infections include the spots on the leaf and fruit stunted growth and damaged flowers or roots.

(Refer Slide Time: 23:37)



Let us now talk about find flu swine origin H1N1 influenza viruses a respiratory disease of pigs caused by type A influenza virus. Its symptoms include fever, chills, cough, sore throat, body ache, headache, fatigue etc. It is very contagious it spreads mainly from person to person through the cough or sneezing and often by touching mouth or nose of the infected individuals. How influenza A viruses can be classified.

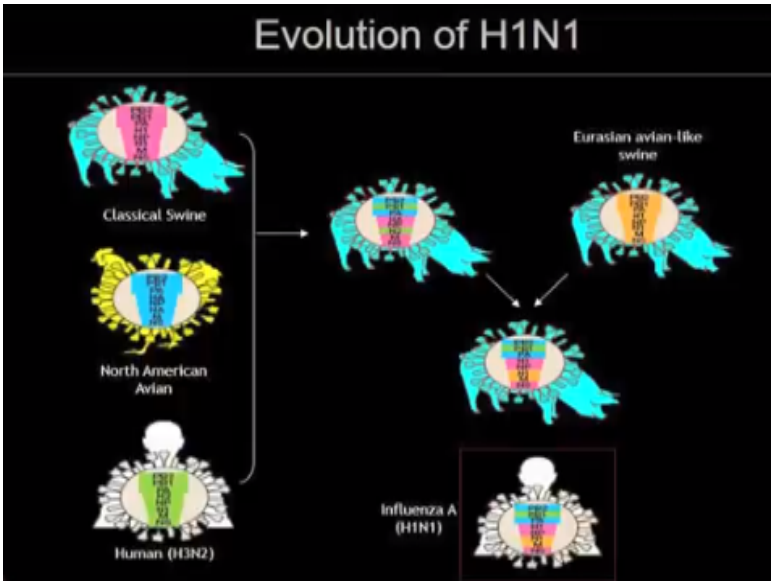
(Refer Slide Time: 24:12)



Let us look at their structure so there are surface glycoproteins which is having two major components a hemagglutinin or HA and Neuraminidase which is NA and this what gives, give the term H1N1. So, influenza viruses classified on the basis of antigenicity of HA and any surface glycoproteins and there in fact 16 HA subtypes H1 to H16 as well as 9 NA N1 to N9 of these proteins.

The HA proteins are very important for the cellular receptor binding fusion of vital and Endosomal membranes whereas any proteins the help to virus to release from the infected cells with lot of these heterogeneity of H and N proteins. Now let us briefly look at evolution of H1N1.

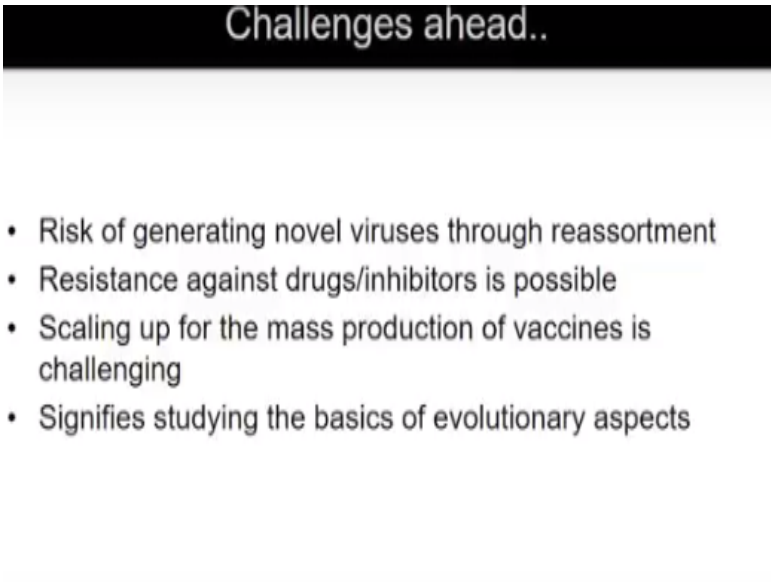
(Refer Slide Time: 25:09)



The swine origin influenza A or H1N1 virus es they resulted from the reassortment of avian or human or swine. The triple reassortment viruses with Eurasian Avian swine viruses cross sort of important to note here that because of lot of phonetic reassortment which is happening in the viruses. They can give rise to new type of viruses and actual N1 got evolution from similar kind of reassortment.

So, studying viruses actually it can be very helpful and there are many challenges ahead which can be posed by viruses.

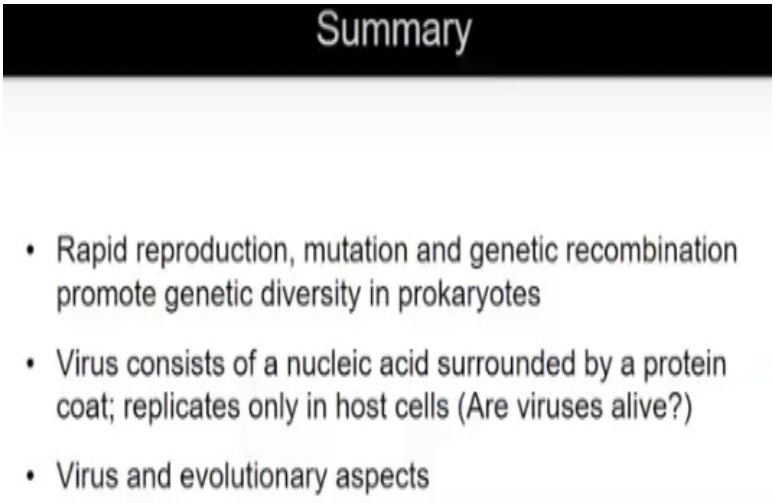
(Refer Slide Time: 25:58)



For example, risk of generating novel viruses through reassortment. Resistance against drug or inhibitors is very much possible and for us to scale up or the mass production of vaccines is very challenging. It also signifies that is studying viruses can be very helpful from the evolutionary aspects if we know their genetic makeup if you know the possibilities of genetic reassortments then you know in case of new species arises.

I think one could still make some sort of guess that help control that kind of viral infection.

(Refer Slide Time: 26:31)



So, in summary today we briefly discussed about a different bacteria and viruses we discussed about the rapid reproduction and bacteria mutation and genetic recombination which promotes genetic diversity in prokaryotes. Viruses they consist of nucleic acid surrounded by a capsid proteins. They replicate only in host cell which poses a question are they alive? we also looked at how genetic reassortment can give rise to different strains of viruses.

And therefore studying viruses are very important in terms of the evolutionary aspects. We will stop here and continue on the next topic in next lecture. Thank you.

(Refer Slide Time: 27:31)

References

• Campbell Biology - Reece, Urry, Cain, Wasserman, Minorsky, Jackson 10th Edition, Pearson