Environmental Biotechnology
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Lecture – 05
Microbial Ecology

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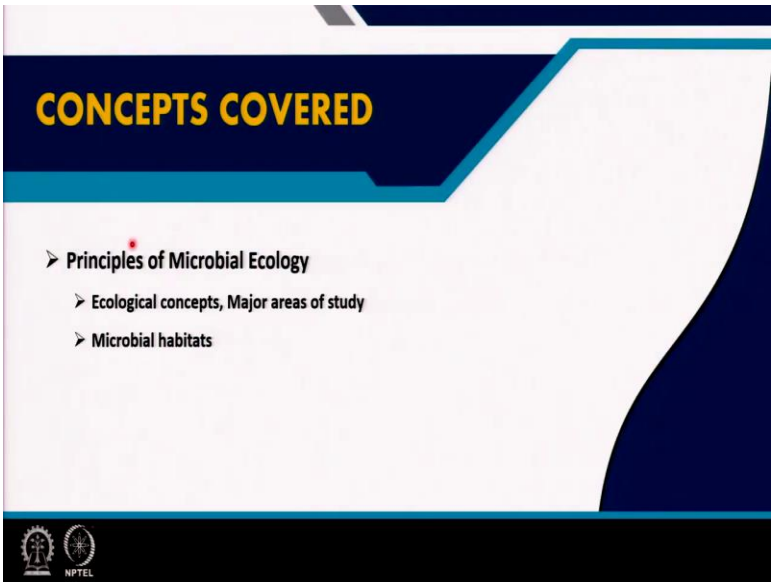

In today's lecture we are going to discuss about the concept of microbial ecology. The major topics that are going to be covered in this part will be the principles of microbial ecology including the ecological concepts. Major areas of study within microbial ecology and the concept of microbial habitats and how microbial ecosystems or microbial communities are able to function within different microbial habitats are also going to be discussed.

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Now we begin with this note that microorganisms do not live alone in nature. In any environment microorganisms are naturally present and the representative bacteria archaea or other organisms like the protozoans or the fungi they interact with higher organisms. They interact with other members of the community or the other species and also they interact with the environment.

They carry out all the necessary activities within their environment that support life on earth to all together.

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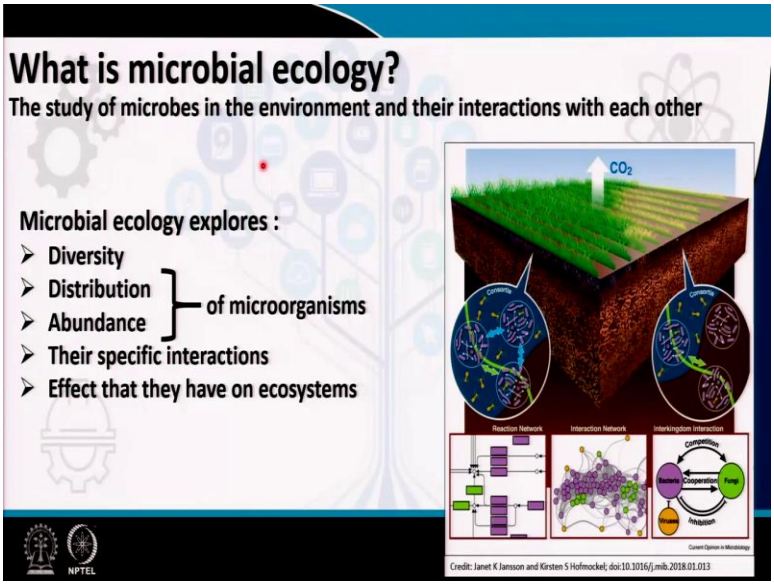

Now the principles of microbial ecology we define microbial ecology as the study of microbes in

the environment and their interactions with each other. So, all the microorganisms present in a particular environment are considered when we study the microbial ecology of that particular environment. So, it has to be remember that microbial ecology is basically focused on the environment and it the ecological details may vary from one environment to the other environment.

As you can understand the kind of microorganisms present in any environment the kind of interactions they have within themselves and with their other members and higher organisms and the interaction with their surrounding environments may vary from one environment to the other environment. As for example this picture is shown to highlight that within a particular soil environment you can see there could be numerous layers.

And in each of the layers you will have different type of microbial assemblages which are referred as microbial consortium. So, numerous microorganisms the bacteria, archaea mainly the prokaryotic organisms along with fungi they form different consortium different assemblages and they function within the ecosystem through those consortia or the assemblages. Now microbial ecology tries to explore the kind of microbial diversity present within each of this environment.

For example if we consider this particular soil environment if we take a sub sample of this let us assume that we take a sub sample just beneath the the top soil then the microbial ecology of this top soil would fastly target the diversity of the organisms present within it. We are going to discuss about what is diversity and how we measure it in the due course. But the first and foremost is the enumeration or the exploration of the diversity of the microorganism present in any environment or the samples collected from any environment.

The second is the distribution of the microorganism. So, if we consider samples taken from different depths across this environment from the top soil to the samples collected from undergrounds. So, the distribution of species across the different depths or across the different sampling points would be necessary to understand the distribution of microorganisms of microbial species or microbial members within this microbial environment.

The third point would be the abundance of the members abundance is basically a reflection of the relative proportion of each of the members there would be numerous species numerous microbial taxa present in any environment any sample taken from the environment. So, the relative abundance of each of these members would be enumerated and included in the microbial ecology study. So, along with this diversity distribution and abundance of microorganism from any environmental sample the fourth point would be the specific interaction among these organisms.

So, as you can understand that there will be numerous species. So, this species interaction can be studied either using a reaction network or using the interaction network. So, eventually we would like to highlight or we would like to decipher the interaction among these pieces that could be as we discussed earlier intra species and interspecies interaction and interaction of these species members with their environment like the different physical and chemical parameters as we also highlighted in some of our earlier discussion.

So, these interactions mean the interactions all kind of interactions which are possible in the particular environment. And the final and the fifth point is what could be the effect that these organisms have on the ecosystem this particular ecosystem. If we consider this is a sub surface soil sample in a paddy soil paddy field or an agricultural field then after delineating the diversity distribution abundance of the microorganisms present in this particular environment. They are specific interactions we need to emphasize or we need to explore the effect they have on ecosystem.

So, this effect is actually the manifestations of all the metabolic activities which are performed by the microbial species microbial members who are present in that particular environment. So, their cumulative effect on the environment or the ecosystem is reflected by the term effect that they have on the ecosystem.

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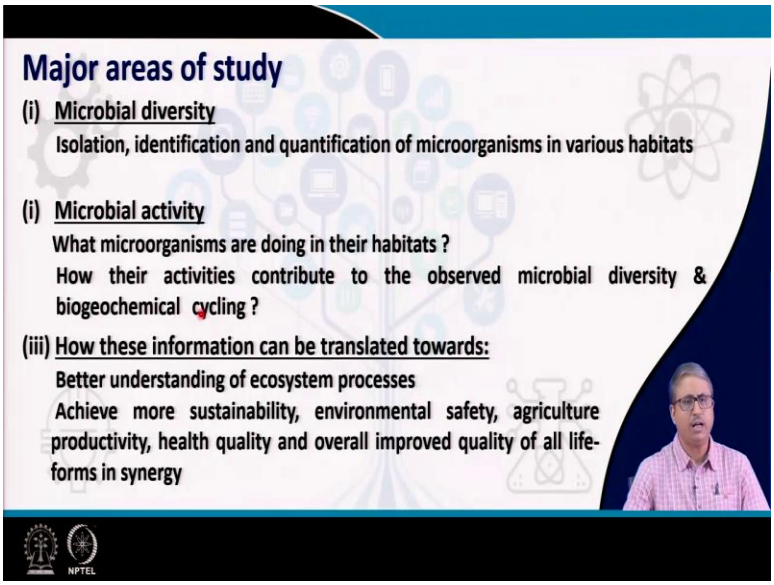

Now the major area of study within the microbial ecology includes microbial diversity. Diversity includes isolation of the microorganisms that is if we indicate the prokaryotic microorganisms then it may be the bacteria, archaea and if we want to include other organisms including the eukaryotic organisms that we can surely do that. But it is to be it is it is to be targeted only towards the microorganisms.

So, let us for example we consider bacteria and archaea as the prokaryotic most abundant species present there. So, microbial diversity would in that case would include all the bacteria and the archaea present there. But if anyone wants to expand the term of microbial diversity considering all the microbes present there then he or she can include all the fungus and others other micro organisms include eukaryotic microorganisms also.

So, isolation of these organisms, identification of all these microbial species or microorganisms and quantification of microorganisms in various habitats. So, isolation means isolation as possibly as pure culture that means only one species or one strain is there in the culture in the growth medium or it may be a mixture of several culture or several strains what we referred as the consortium or a mixed culture identification of these members.

The identification means basically we refer to the taxonomic identification in which we delineate the taxonomy of these members whatever we have isolate to isolated from this environment and

quantification. The term quantification refers to their relative abundance that how abundant is one particular species is. So, if we have let us say 4 species A, B, C, D then the relative abundance let us say A is 25% and B is another 20% and c and d could be maybe 20% or 30% altogether.

So, the relative abundance of these species are delineated during this quantification support quantification can be done by various methods. So, we will learn about these various methods during our subsequent lectures on the methods adopted in environmental biotechnology and microbial ecology. The second major activity is the microbial activity. Now what microorganisms are doing in their habitat?

This is a very important question in order to establish the link between the microorganisms which are present there and the functions they are going to perform in any of the environment. Assessment of the microbial activity is considered to be one of the major area of areas of work in the microbial ecology after the enumeration of microbial diversity. So, what microorganisms are doing in their habitat?

For that also we can adopt a number of strategies including the assay of different enzymes present and produced by these microorganisms which are there in that particular sample collected from an environment or the expression of different genes encoding different enzymes or other proteins which are possibly having some function in the community. So, together the microbial activity must be assessed when we are trying to understand or explore any community.

The other important aspect of microbial activity assessment is how their activities contribute to the observed microbial diversity and biogeochemical cycling. Now these are the two things that seems to be different one is the diversity where the members present are delineated by different methods that what are the species present in an environment and the other one is what are the activities of these organisms.

Now the importance of linking this diversity with activity is very much required because each of these species members are often genetically endowed with some kind of activities. So if we get

or if we find that such type of organisms are there in our samples through the diversity study then we can have some kind of clues that possibly this, this community is going to have similar type of activities which are generally described in the literature that these organisms perform this type of activities.

So, connecting this activity to the diversity that if we; have this diversity then what could be their functions. If you are observing some functions we need to connect that observed function to the diversity whatever we are obtaining if we are unable to observe certain activities. But we see the organisms are there who might be doing some other activities then we need to replan our methodology.

So, that we can actually establish the activities properly and then establish the connection between the observed diversity and the activity. Again we will be discussing about the methods to enumerate or delineate these activities during our methodology related lecture. The other component within the activity is that how the diversity is supporting the activity and this activity could be a general activity and activity could be the activity towards the biogeochemical cycling.

Because one of the; major goal of environmental biotechnology and microbial ecology is to establish the role of microorganisms inhabiting different ecosystem towards biogeochemical cycling. So, how existing microorganisms or prevailing microorganisms are involved in biogeochemical cycling through their activities need to be established. So, again we will discuss the methods and all these things in detail later in our lectures.

And the third area of study is how this information can be translated towards a better understanding of the ecosystem process. So, these information mean meaning the diversity information that is the kind of microbial species present in an environment. The kind of microbial activities carried out by the members present in an environment. Now how we can put all these information together including their linkage that this diversity is connected to their activities.

Then how can we actually improve our understanding of an ecosystem function. For example if

you are working on a paddy soil or a lake system or a ground water ecosystem if we are able to explore or trying to explore the microbial ecology of that. So, at the end of the research we should have one of the research goals that how this approach or this exploration study helps us to improve our understanding of the ecosystem process wherever we are sampling.

And since the one of the major goals of this microbial ecology is to provide the important resources for environmental biotechnology in context to environmental biotechnology achieving sustainability environmental safety agricultural productivity health quality and overall improved quality of all life forms in synergy is found to be one of the basic and fundamental criteria of microbial ecology study as well.

So, now that is how all the information regarding the microbial diversity related to microbial activities must be collated must be analyzed in order to develop a better understanding on how can we achieve better sustainability, better functionality, safety and health quality etcetera form any kind of environment.

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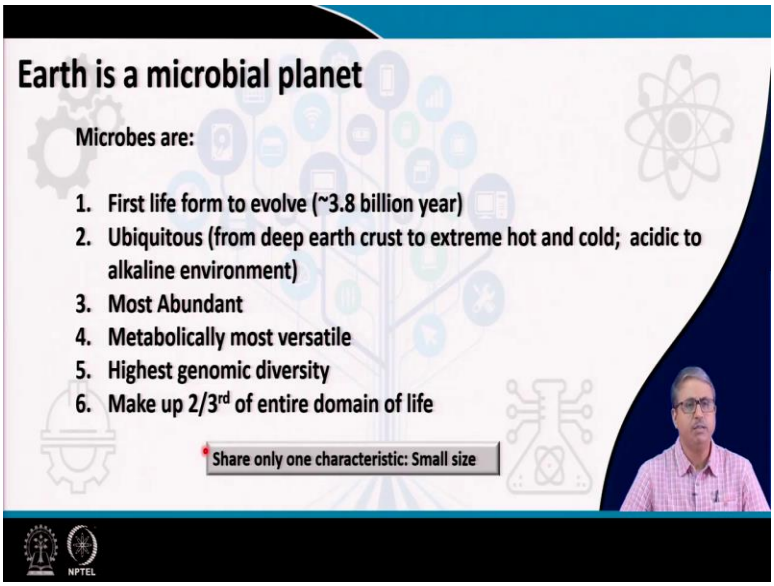

Now I will discuss little bit about why we are again interested in microbial ecology and particularly the microorganism's bacteria and archaea etcetera. Why they are in the point of central focus. Just to have a recapitulation on the fact that the microbes are the first life form to evolve on this planet nearly three point billion of billion years. Sometimes the question comes to

mind that what is the relevance of this evolutionary history of these organisms?

It is to be remembered that because of their evolutionary history the microorganisms have encountered different type of changes on our planet. All these changes have enabled the microorganism to evolve themselves. So, along with the microbial evolution we see that the planet has also evolved from a very hot anoxic environment to with a minimal or no photosynthesis or no or very, very less biologically produced oxygen to a kind of atmosphere or toxic atmosphere that we see today.

So, this is kind of an evolution of the entire planet planetary the chemical and physical property of the planet has planet earth I am talking about it has evolved in the past 4 billion or 4.5 billion or so, far the life has evolved on this planet. So, during their journey microorganisms have also evolved they have learned how to how to resist, how to adapt to different environments and or different stress conditions.

So, this is going to be one of the major advantages for the microorganisms the second important point is the ubiquity of these microorganisms. It would be difficult to find out a habit within this planet earth where microorganisms are not there. So, from deep earth crust to extreme hot and cold ecosystems or environments acidic to alkaline environment everywhere we see microorganisms particularly the bacteria and archaea are there and they are the dominant members and most of the cases in the extreme conditions they are the only members present .

They are also most abundant. So, if we count the number of species present number of eukaryotic and prokaryotic species present in any environment. We can confirm that micro prokaryotic microorganisms particularly that is the bacteria and archaea they are the most abundant living form in any environment. They are also metabolically most versatile and this is connected to or well connected to the genomic diversity that they possess.

Any kind of microbial species will have intraspecies genomic diversity which actually is supporting enormous metabolic flexibility to the organisms and also they make up two third of the entire domain of life. All these microorganisms which are truly diverse in all forms of their

genomic content their metabolism their function their choice of ecosystems etcetera. They share only one characteristic that is they are all small in size.

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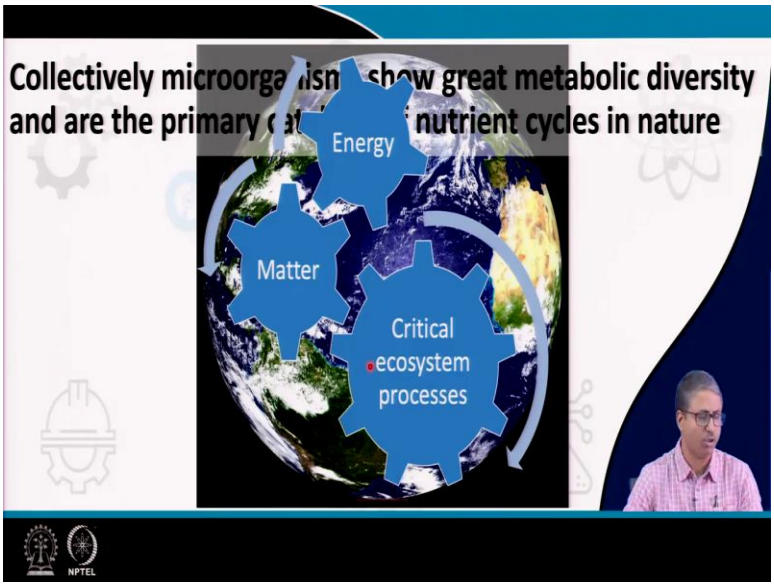

Now collectively all these microorganisms that present on our planet they show great metabolic diversity and the primary source or primary catalyst for nutrient cycling in the nature. So, all these microorganisms together maybe in individual ecosystem we can study them. But they are again all connected or interconnected rather. So, they perform the critical processes responsible for ecosystem function.

So, it is it is said that for ecosystem services this microorganism or microbial communities all the microbes together they play the most critical role in correct system functions. And this ecosystem function or ecosystem processes catalyzed by the microorganisms actually drive the cycling of matter and also the transformation of energy within all the ecosystems or all the habitats where microorganisms are present.

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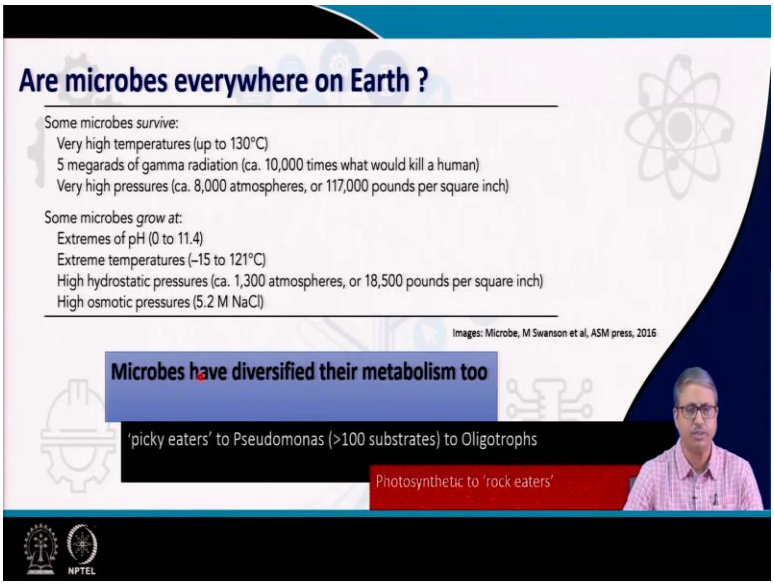

Now there could be some more information about are microbes everywhere on earth. You can see that some microbes can survive up to a temperature of 130 degree centigrade 5 megahertz of gamma radiation that is 10000 times a more than what could kill a human, very high pressure and some microbes can even grow at extreme pH like 0 to 11.4, extreme temperature minus 15 degree to 121 degree centigrade.

High hydrostatic pressure and high osmotic pressure as well and the microorganisms has also they have diversified in their metabolism as I mentioned earlier. From peak heaters like pseudomonas to oligotrophic organisms who are who can live in extremely nutrient limiting condition and we have also the photosynthetic organisms to rock eaters. Rock eaters means the chemolithotrophic bacteria particularly who can obtain the electrons from the inorganic electron donors and also can fix atmospheric carbon dioxide therefore they they do not need any kind of organic resources for their survival. So, they are called rock eaters.

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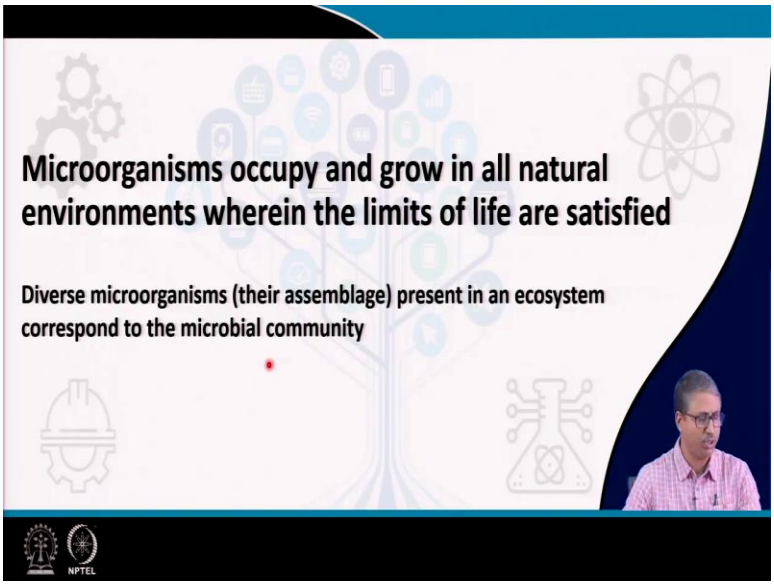

Now micro organisms with that kind of background occupy and grow in all natural environments as I mentioned wherein the limits of life are satisfied like till. Now we see that 130 degree centigrade possibly is the limit of life. So, far we have whatever environments we have explored. And diverse microorganisms diverse microorganism means the diverse type of species that occupy a microbial species that occupy any particular environment and their assemblage.

Assemblage means their interaction their aggregation how they communicate with each other the the totality of these microbial community that present in an ecosystem correspond to the microbial community. So, microbial community refers to all kind of microbial population present in an environment. So, we are going to define that term as well in due course.

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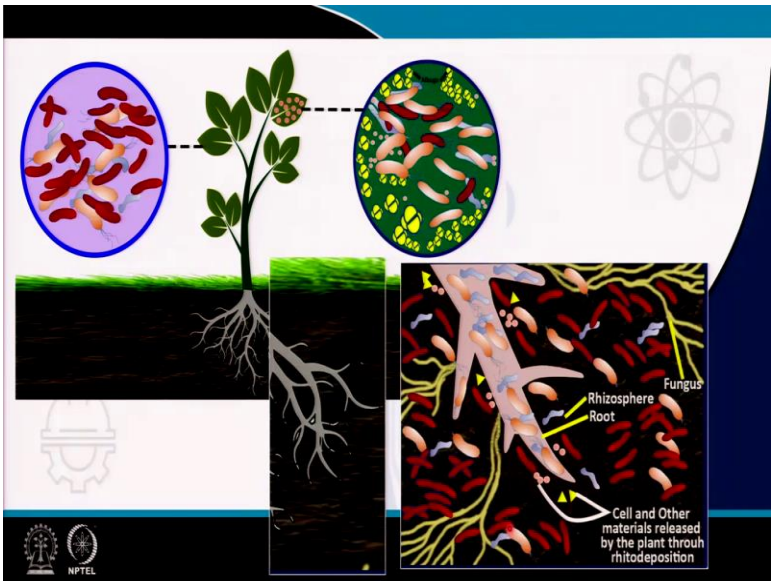

Now if we look into the different type of microbial habitats in a simple the plant growing on a soil system you can you can see that if we just magnify the root. We can see that within the soil there in the bulk soil rather there are numerous microorganisms maybe around 10 to the power um 6 to 10 to the power 9 cells per gram of soil corresponding to around 10 to the power 4 to 10 to the power 5 different species of bacteria and archaea together per gram of soil.

So, 10 to the power 4 to 10 to the power 5 different species per gram of soil. So, it is it is it is astonishingly very high number of species diversity that has been found through different type of molecular microbial ecology techniques. So within the bulk soil as I was mentioning within the bulk soil this is that is a different habitat we will see what is habitat is? So, we see in the bulk soil there are certain group of microorganisms within the root associated region or the rhizosphere.

What we call there are certain other group of specialist microorganism who may be dependent on the the materials which are released by the roots like the organic compounds mostly released by the plant roots and those organisms they prefer to occupy close to the the root rhizosphere or that is called rhizospheric microbial community. So, we have a bulk soil microbial community, we have a root associated microbial community.

We can have a leaf or phylosphere microbial community, we can have a microbial community

associated to the leave stocks and other parts of the stem etcetera. So, within the within the plant itself or plant body itself there could be numerous microbial communities occupying different habitats and they must be specialized.

So, the bulk soil community and the community occupying the rhizosphere, the community occupying the phylosphere, community occupying the stems and other parts of the plants are different. They are all different because the kind of species assemblages the interaction the nutrients and the environments that get around them are different and this is true not only for the plant system. But also for the animal system and any kind of other environments where we see that different type of physical or chemical conditions prevail.

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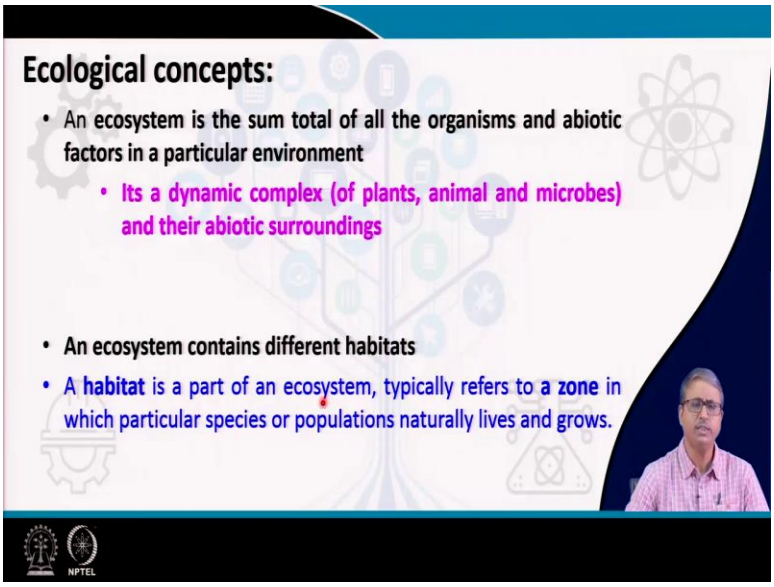

Now we continue with some of the ecological concept and then connect the microbial ecology to that. Now in ecological concept we have learnt that an ecosystem is the sum total of all organisms and there are biotic factors in a particular environment. So, when you say all organisms it could be all the prokaryotic and eukaryotic organisms. And it is a dynamic complex of plant animal in the microbes and their abiotic surroundings it is dynamic why because with respect to change in time and change in the um space that is the location there will be some kind of change in the conditions.

That the physical chemical conditions the other conditions and the kind of microbes kind of

plants kind of animals you expect in an environment. For example if you consider a paddy soil. So, within the subsurface or the top soil even in a few meter distances we can expect some kind of changes because with the change in some physical or chemical parameters of the soil you can expect some kind of change in the microbial community or the microbial ecology of that soil.

Now an ecosystem contains different habitats. So, ecosystem is kind of a broad terminology. So, it can be a paddy soil ecosystem it can be a ground water ecosystem, it can be a kind of Lake Ecosystem, it can be a forest ecosystem, it can be a subsurface ecosystem. So, there could be numerous type of ecosystem that prevail on this on this earth. Now within each of the ecosystem we can find there are different habitats.

Now what are these habitats a habitat is a part of an ecosystem typically refers to a zone. So, it is a zone which is a smaller section of that particular environment in which particular species or populations naturally leaves and they grow. So, within a paddy soil, if we have a paddy soil field of a particular geographical location, so, we if we are studying that ecosystem, so, it has to be very specific to us to a location.

So, within that particular paddy soil or paddy agricultural field we can expect that there are different habitats these habitats are specially different. On the top soil you can expect that if there are important variations or major variations there will be different habitats. On the below the soil top soil there will be different zones or different habitats. And in each of the habitats which are basically physically sometimes very clear and it is very evident that these are different from the other parts.

So, different type of species microbial species they naturally occupy those habitats and they function in a different way in each of these habitats. And these functions allow them to grow and catalyze the required reactions within that habitat.

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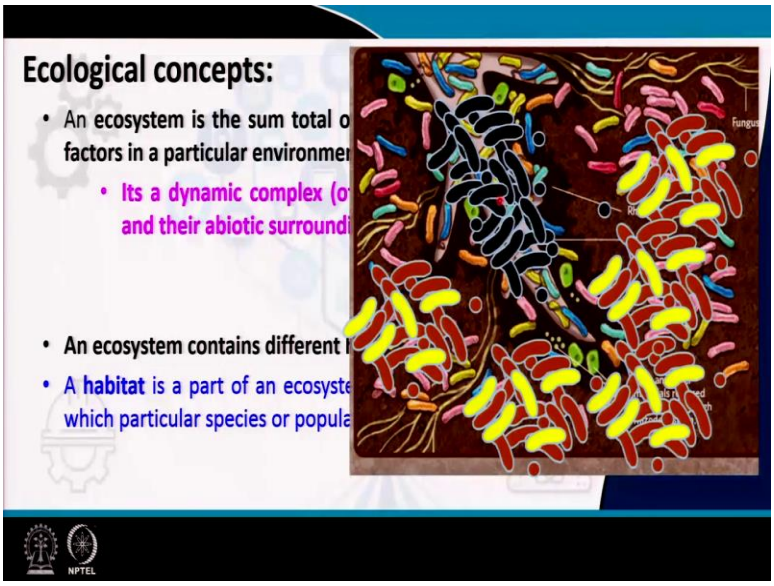

So, for example if again if we come back to this particular image of where the plant root or a part of plant root system is visible within the soil system we can see there are plenty of microorganisms colonizing the bulk soil. So, that could be one of the habitats present here. So, the part of the zone there is a bulk soil which is away from the root is one type of habitat whereas on the top of the route that is another zone or habitat where some other specific group of microorganisms lives.

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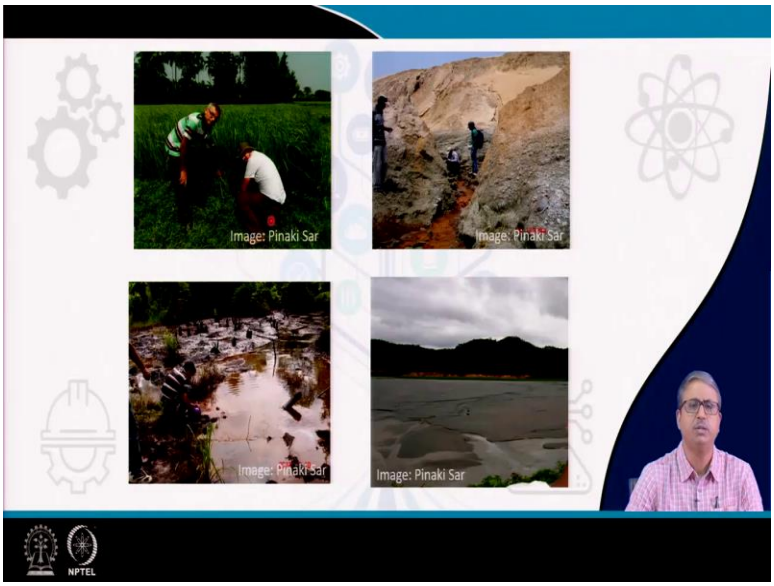

Now this type of habitats could be easily seen or demarcated some representative pictures or some pictures are given here in order to have a better clarity. For example a paddy field where we were sampling again an acid mine drainage which is a highly acidic waste water coming out

from the mine site or a petroleum naturally petroleum oil shipping a forest area part of the forest area and it is rich in petroleum oil or a mine tailings dump site where the very contaminated tailings are dumped into a for in forest area.

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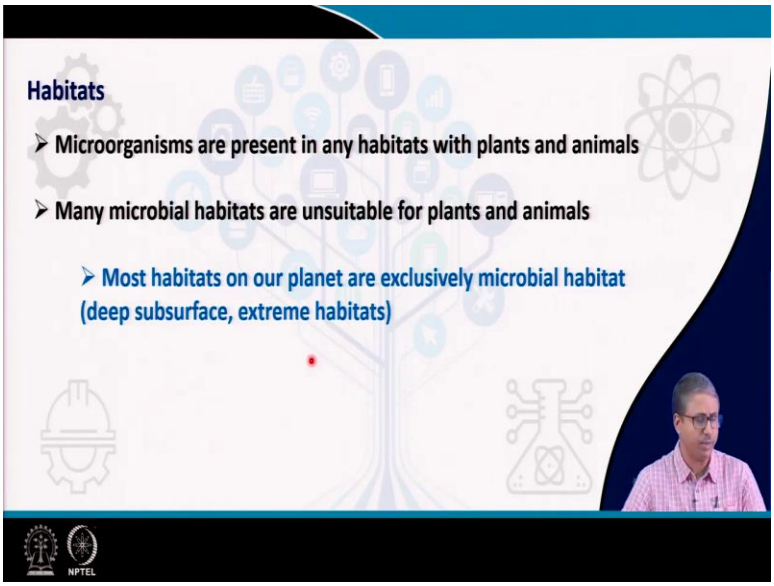

So, we can have different type of habitats even within these different environments. So, within these habitats microorganisms are present in any habitats. So, not only the four pictures that I have shown. So, you should be able to understand that any kind of environment will have different multiple habitats. And microorganisms are present in any habitats they may be present along with the plants and animals, who are present there.

Many microbial habitats are unsuitable for plants and animals where you can see that only microorganisms can survive. And it has been found that most habitats on our planet are exclusively microbial habitats like the deep subsurface extreme habitats like the hot spring and other habitats. So, except the top soil or the surface of the planet where we see the green plants and other things are growing there.

So, except that almost all the other environments which are beyond the reach of the sunlight or solar energy it is basically dominated by microbes. So, it is very, very interesting to know that the deep subsurface particularly or the terrestrial subsurface oceanic subsurface we see it is exclusively it is dominated by the microorganisms the prokaryotic microorganisms.

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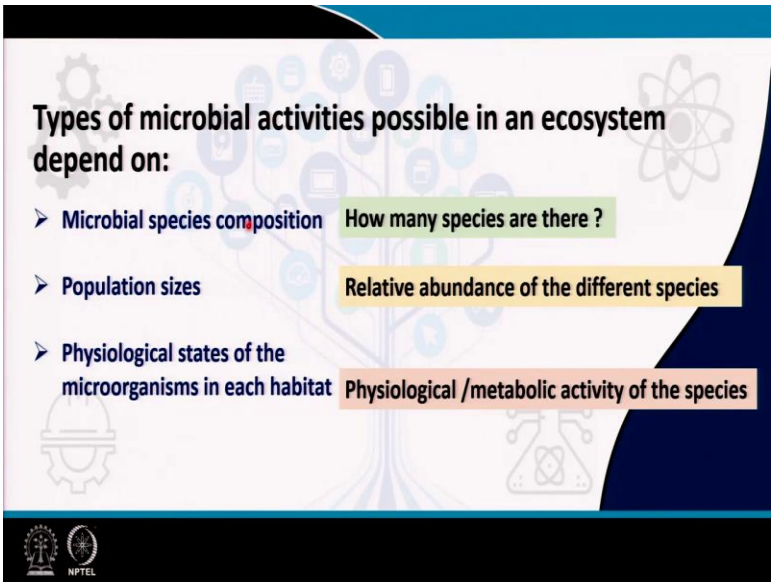

Now the types of microbial activities possible in an ecosystem depend on microbial species composition that is how many species are there. In any environment be it a soil be it water be it acid mine drainage be it a petroleum refinery waste or any kind of other contaminated or non contaminated pristine environment. So, we can delineate how many species are there. So, when we delineate how many species are there by adopting appropriate methodology we try to answer the question that what is the species composition that are microbial species composition with respect to a particular environment.

The second one is the population sizes. So, relative abundance again of each of these groups of species. So, a population is represented by members of the same species. So, population sizes so, relative abundance of different species and finally the physiological state of the microorganisms in each of these habitats. Now physiological state is defined by the physiological or metabolic activity of the species.

So, there may be many species but they are not physiologically active or that that means they are not metabolically active that means they are not playing apparently any important role any functional role in that particular environment or the community.

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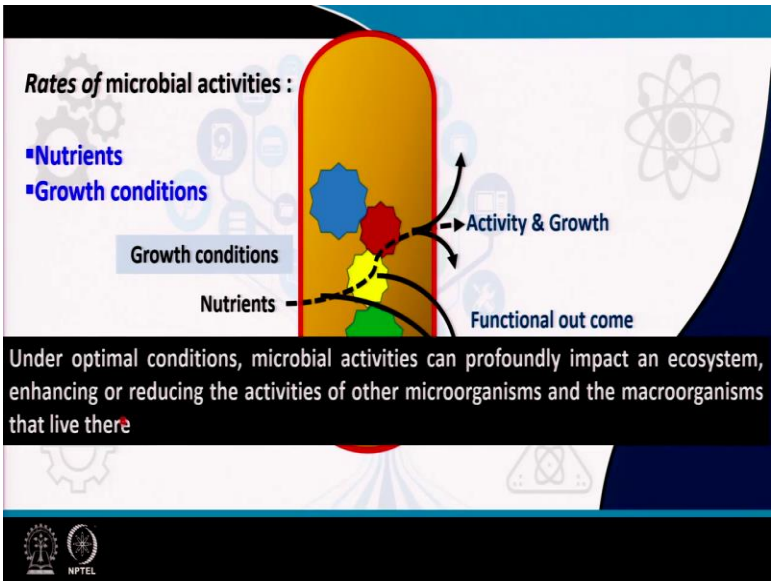

So for example if we; take two important things the nutrients and the growth conditions. Now why we are considering the; nutrient and growth conditions because within any kind of ecosystem where microbial within a microbial habitat that is a subset of the any kind of microbial environment or an environment in general. The microbial activities which are basically controlled by the; microbial species present there and the relative abundance of the organisms and their physiological state of the organisms as we mentioned before.

So, impact of microbial activities within an ecosystem depends on several factors. It is of course controlled by this species present their relative abundance and physiological state. But the species who are metabolically active or species who are abundant or species who are present over there is subjected to the nutrients and the growth conditions whatever are allowed are present there.

So, nutrients are the nutrients are the chemical compounds which are required for the microbial metabolism. So, that supports different kind of microbial activities and eventually allow the microbial cells to grow and far from different type of activities. So, these activities could include interaction between other species. Interactions could be a positive interactions in interactions could be negative interactions.

Interactions could be neutral interactions. So, all kind of interactions between the species

between the species member of the back cell to its environment. So, all kind of functional outcome is possible and it is not only the nutrients which are controlling these microbial activities or microbial species activities but also the growth conditions. Even if the nutrients are there if the growth conditions like the temperature like the pH the dissolved oxygen concentration and other things.

If they are not favourable then possibly even if the nutrients are there many of the microbial species would not grow and they are able to perform their activities. Now under optimal conditions the microbial activities can profoundly impact an ecosystem enhancing or reducing the activities of other microorganism and the macro organism that live there.

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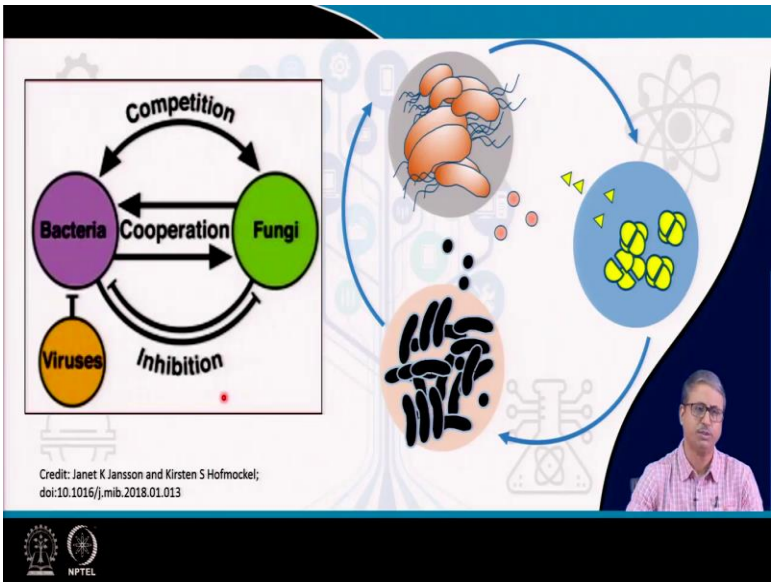

So, as I was mentioning that when they are supplied with the required nutrients required growth conditions they grow they perform their activity and that that activity leads to mutual interaction. As you can see they are able to interact with each other by releasing different type of chemical molecules mostly the chemical signaling molecules or chemical substances which are consumed by other species or which are which are actually antagonistic to other species.

And thereby some kind of either cooperation is established or competition is established or sometimes inhibition is also executed.

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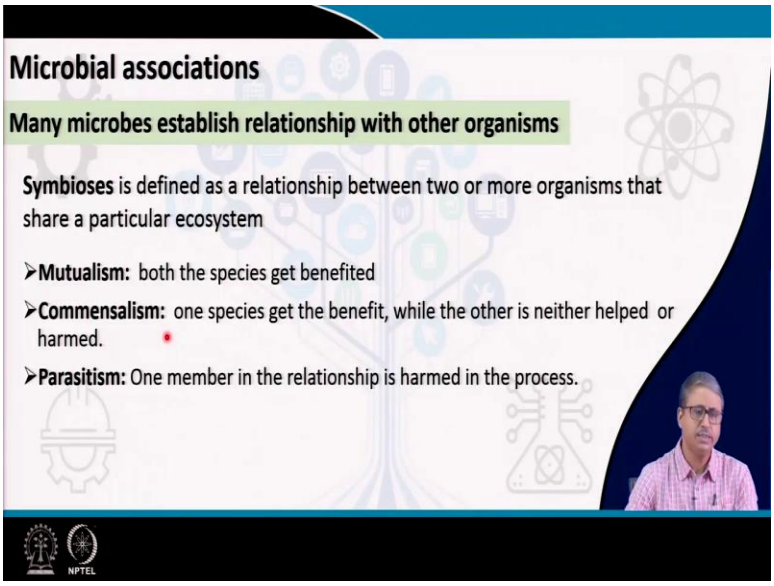

These interactions lead to finally microbial associations. So, many microbes establish relationship with other organisms. These relationship include the symbiosis which are broadly categorized as the relationship between two or more organisms that share a particular ecosystem. So, within an ecosystem or within a particular habitat of an ecosystem we will find that that there are relationships among the organisms.

So, these relationships could be categorized into 3 types where the first type is the mutualism where both the species are benefited. So, the species A and species B if they are they are engaged with some kind of relationship between them through interaction of the different substrates different chemical signals or some other products released by them. So, that is called mutualism that both are getting the benefit they are together they are able to utilize the resources or the nutrients present there.

Commensalism where one species get the benefit while the other is neither helped or harmed and parasitism where one member of the relationship is harmed in the process because one of the members among the two members involved in the relationship. One of the members might be producing some chemical or some other other product which is actually toxic or inhibitory to the other member. So that is that is how the parasitism is actually developed.

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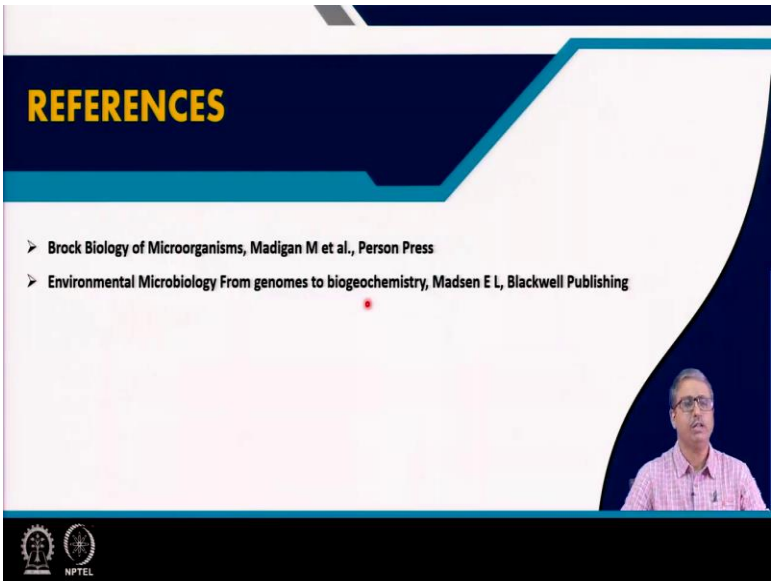

Now this part of my lecture is basically for this part of the lecture we can use block biology of microorganism. Along with that environmental microbiology book that is environmental microbiology from genomes to biogeochemistry by Madsen may be followed.

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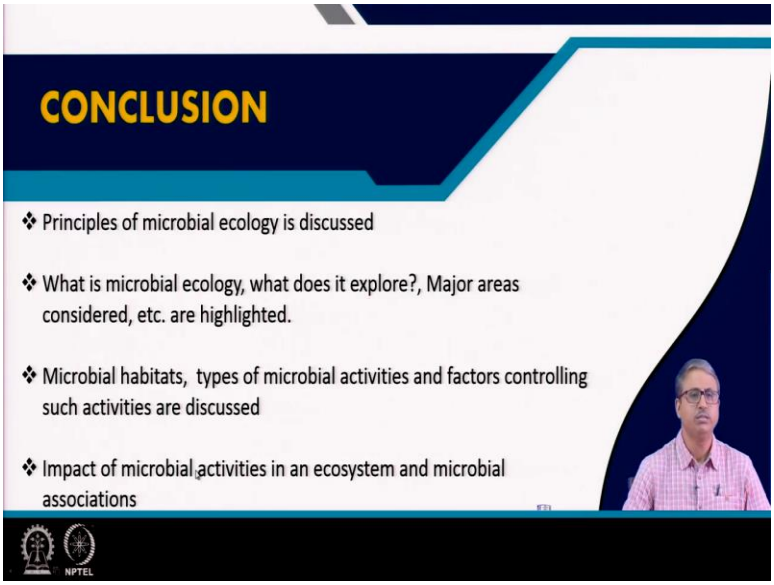

In conclusion principles of microbial ecology are discussed in this lecture. We have also explained what is microbial ecology and what does it explore major areas are what are considered within this microbial ecology etcetera are highlighted. Microbial habitat is discussed; types of microbial activities and factors controlling such activities are also discussed. Impact of microbial activities in an ecosystem and microbial association are also highlighted, thank you.