Environmental Biotechnology
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Lecture – 07
Microbial Ecosystems and Biogeochemical Cycling

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Welcome to the next lecture on Microbial Ecosystem and Biogeochemical Cycling. In this lecture we are going to discuss about the concept of guilds formed within a microbial community or within an ecosystem and how the formation of guilds by different members of the community actually facilitate the workings of the ecosystem. And during this deliberation we are also going to highlight the interrelations between the different microbial populations that actually form the basis of the guild.

And guilds barging into comillimeterunities and the comillimeterunities actually facilitated the workings of the ecosystem. We are also going to discuss the microorganisms and micro environment. So in particular how microorganisms play role within different micro environment that present in any habitat will be emphasized. And finally will proceed towards the biogeochemical cycling.

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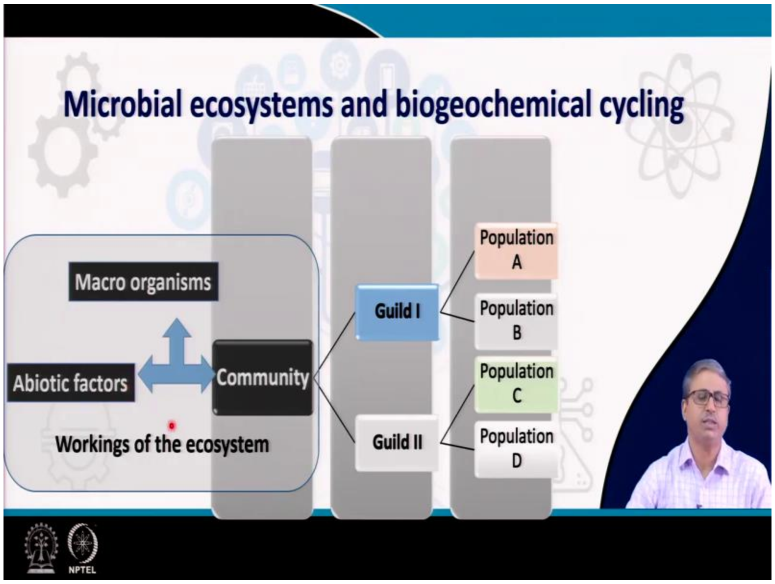

So we begin with the basic concept of how the different microbial populations interact to form the guild and community and the community functions towards the ecosystem are the broader working or brought broader ecosystem goals or functions that are created by the comillimeterunities. So as you can understand that any in any ecosystem and with any ecosystem we have multiple habitats are within the habitat we have numerous microbial populations.

As for example, we have actually taken 4 populations. So, these populations like A, B, C, D are marked and thus each of these populations are actually represented by a group of microbial organisms which belong to same species of population A is actually a member of all members of a particular species. Population B another species, population C another species and population D is another species. So, 4 species are taken as an example.

Now metabolically linked metabolically related populations deform guild. So, guild is kind of a representation where microbial functional assemblage is indicated or discussed. So, a group of populations that may be more than 2 or more than 3 or more than 4 for simplicity we have considered too, but it can be all any number of populations, but they are definitely distinct populations and each of these populations are having some kind of metabolic relatedness or interconnectedness.

So they basically share metabolic functions and they depart from certain metabolic functions together. Metabolic linkage forms basis of guilt in this case the population A and population B forms the guild 1 and population C and population D form the guild 2. Now there could be large number of guilds as we can understand within a particular environment or within the particular habitat and all these guilds are they represents the community function.

Basically the metabolic linkage among the populations and all together this gives the represent the community. Now, this is the microbial community, now this microbial community present in any habitat or any ecosystem are continuously interacts with the abiotic factors that we have learnt earlier and it is not only the abiotic factor and microbial community interaction but it is also the interaction between the microorganisms, the Eukaryotic organisms are mostly.

And these interaction continuous it is kind of a 3 way interaction between this community microbial community microorganisms and abiotic factor and that ultimately leads to the workings of the forms the basis of the workings of the ecosystem. So, whenever we are working on any kind of environment ecosystem maybe for energy recovery maybe for Carbon sequestration maybe for any kind of issues environmental biotechnology issues related to climate change or removal of a particular pollutant.

And or remediation of any specific pollutants so we must need to understand the workings of the ecosystem, which is fundamentally catalysed by these interactions and interactions are again facilitated by multilayer structure of these populations and their activities.

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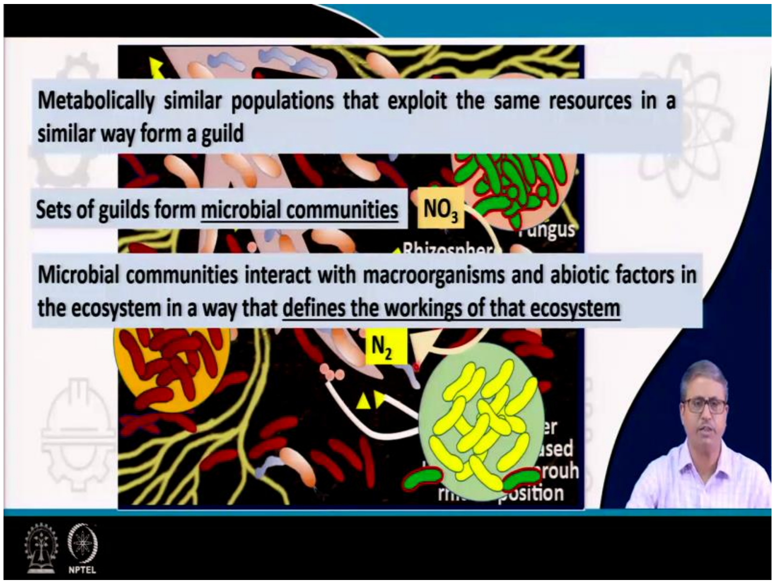

Now this linkage that is the linkage between the multiple populations present forming the guilds, guilds to comillimeterunities. So, in a habitable ecosystem whose resources and growth conditions are suitable. That means the conditions are favourable the nutrients are available to the organism. Individual microbial cells present there to grow for the population that is a kind of inevitable. If you have sufficient nutrient resources sufficient are favourable growth conditions obviously the microorganism species who are present there will grow and proliferate.

And that proliferation will lead to the formation of different cluster of population. So, we can see there are 3 populations which actually have grown into the soil where fraction of the plant root is also there. Now these metabolic any similar population for example as indicated earlier population A and population B for example that exploit the same resources. Like for example in this case I have considered nitrate as the electron acceptor.

Maybe for these two populations the green population and yellow population these 2 are 2 populations. These populations are capable of both of them are capable of denitrification. So they are capable of reducing nitrate to nitrogen. They form a guild so we can consider that the metabolic linkage between or metabolic cloness and metabolic association between these two populations are forming the guild.

And there could be several deals present within the community and all these guilds represent the community and the comillimeterunities interact with the as I mentioned with the other organisms and abiotic factors and that is actually going to define the working of the ecosystem.

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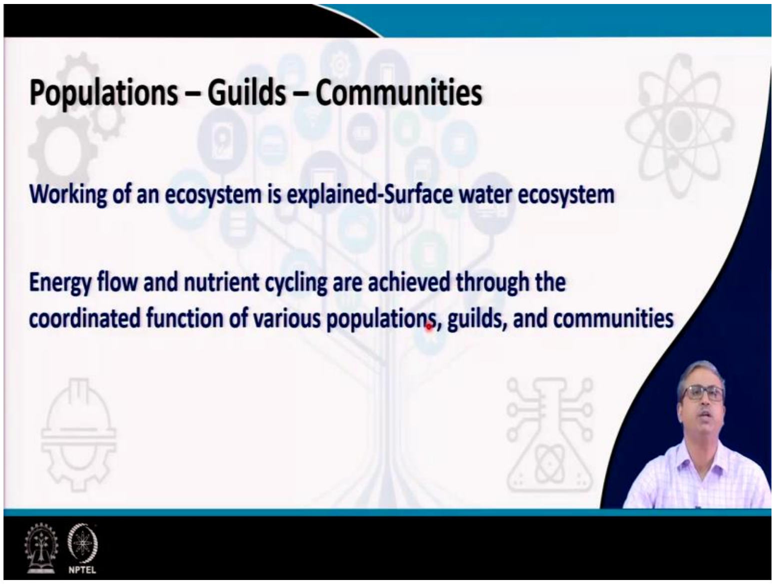

Now this can be very well explained using a surface water ecosystem where we will see also not only the association of different metabolically linked or metabolically associated or metabolically connected microbial population. Each of them are represented by a particular species but also will see how the flow of energy, flow of nutrients are allowed. And we also will see how that facilitate the cycling of nutrients, which forms the basis of the biogeochemical cycle within any environment.

Now energy flow and nutrient cycling: In any ecosystem are achieved through a coordinated function of various population. So remember these populations we are referring to access the microbial populations which are represented by numerous species. So each population is basically a specific or pull specific species. And these populations group together to form the guilds and the energy flow and nutrient cycling are achieved as populations interact or interlinked through Metabolic relatedness and they form the guilds and guilds form the community.

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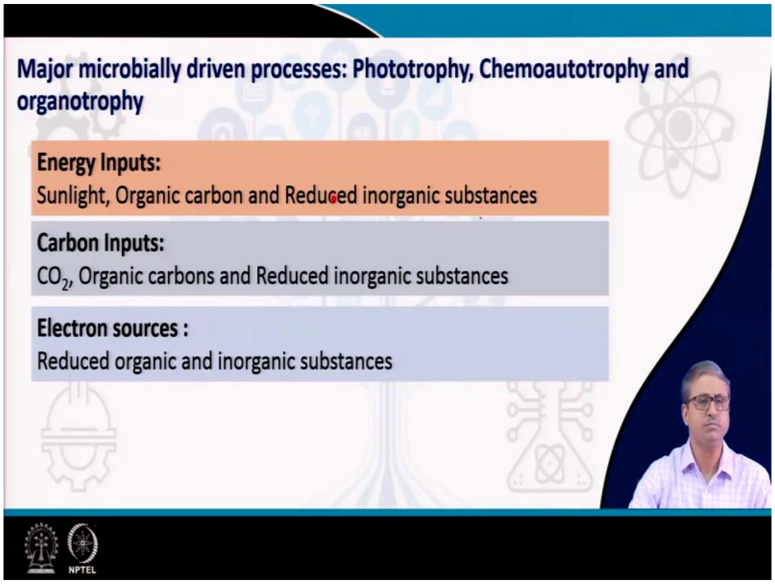

Now before we go into this one water surface water system and try to understand how actually these functions are we need to understand that in any kind of ecosystem the major microbiology really driven processes are can be categorised into three ways. There are many ways that we can actually categorise the microbial activities within any ecosystem. But for our simplicity at this moment of time, we are considering three main microbially driven process, which are the phototrophy that is using the Solar Energy as the source of energy.

The microorganisms are capable of their growth and nutrition. They fixed the atmospheric carbon dioxide into organic matter. Chemoautrophy that means the chemical energy is used and the atmospheric carbon dioxide is used to convert the carbon into organic matter. And these organisms chemoautotrophy could be chemolithoautotrophs because the electron source could be inorganic materials and organotrophy that means organic carbon is used as the source of electron, source of energy. So, simply categorising microbial processes into these 3 phototrophy, chemotrophic and organotrophy.

Now within each of the echo system or most of the echo system or most of the environment so that is a pristine environment whether it is a contaminated environment. We see there are three important other inputs or sources for driving the entire flow of nutrients and energy through microbially catalyzed reaction. So, first and foremost is the energy input. The energy may come from the sunlight energy may come from the oxidation of organic matter and oxidation of other reduced inorganic substances.

The second one is the carbon inputs. That is the carbon sources and the extraction of the carbon and its assimilation into the cellular molecules and this source of carbon could be dioxide could be organic carbon and other reduced inorganic carbon could also be used. Electron sources included the reduced organic and inorganic substances. So we are going to discuss in detail in our subsequently that how these are actually facilitated and how they are connected to the environmental biotechnology related processes.

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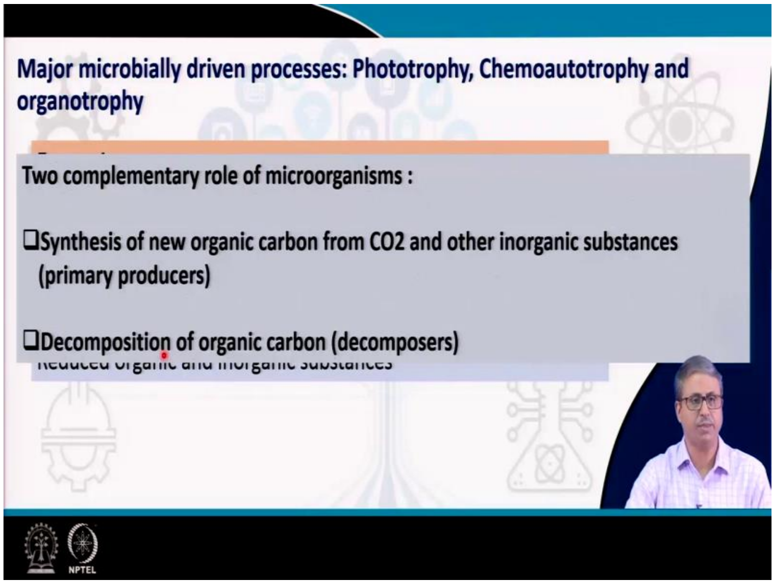

Now apart from these three input or sources to complementary roles of microorganisms can be clearly identified any of these ecosystems or any ecosystem habitats. So, one is the synthesis of new organic carbon from the carbon dioxide and using other inorganic substances. This the primary producers so mostly in case of microbial ecosystem as we understand that higher plants are green algae might be there or might not be there.

So, some of the ecosystem could we are could be solely populated by bacteria and archaea but still there could be many bacteria who are chemoautotrophic bacteria or would be photoautotrophic bacteria. There could be surely a many algae photosynthetic algae or photosynthetic other bacteria, but there could be many places where we do not see any kind of photosynthetic or photoautotrophic organisms particularly in the subsurface environment where there is no solar energy or sunlight cannot penetrate those habitats.

So anyway so two complementary roles that is data played by microorganisms number 1 is a synthesis of organic carbon that is the assimilation of inorganic carbon into organic carbon and along with organic carbon lot of nutrients are also assimilated. As the; cell grows by utilizing the carbon dioxide and energy and inorganic nutrients available in its vicinity or in its environment. It grows in number. It creates lot of biomass and within this biomass this carbon is assimilated as organic carbon.

And along with the organic carbon the other nutrients inorganic nutrients are also assimilated. They represent this type of organisms which are basically the autotrophic organisms, mostly a for surface environment these are the photoautotrophic microorganisms or for different other subsurface or other environments where solar light of Sunlight cannot penetrate or sunlight is not available many of the cave environment or something like that.

We see that chemoautotrophs that they are predominant. They are the primary producers the second type of organisms and their role is basically the oxidation and decomposition of the organic carbon which is available there. This may be because of the dead microbial cells or the organic matter released by different microbial cells during the course of their metabolism. So these decomposition is facilitated by the oxidation of the organic carbon and release of energy carbon and other nutrients which are subsequently utilised by other species or other members who are present in this particular Habitat.

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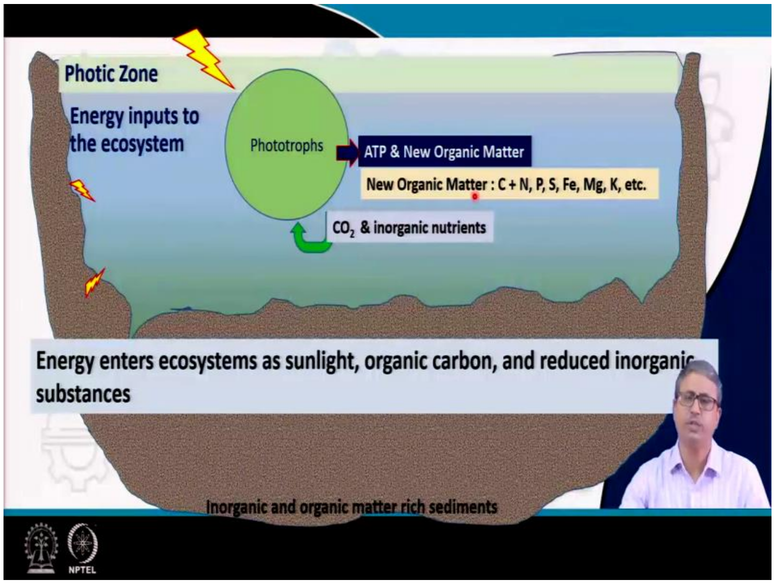

Now let us look into this surface water community. This is kind of a pictorial image which depicts a surface water scenario. And you can see that there is a water column on the above and we have also the sediment which is rich in inorganic and organic materials naturally. So this would be a lake or this could be a river or this could be a pond. This is one of the simplest way of explaining how these populations interactive form guilds.

Guilds are forming the entire part of the community and this association between the population to community drive different type of microbially catalysed reactions facilitating the nutrient cycling of biogeochemical cycling. So, to begin with, in this system for example the energy could be obtained from sunlight as the surface is exposed to the outer atmosphere energy could also be obtained from the organic carbon.

And it could also be obtained from the reduced organic or inorganic substances or these inorganic substances reduced inorganic substances are often present as a part of the sediment or as part of the deposition. The organic carbon is naturally it would be available in the sediment or it could be also present as kind of an external source or it could be generated in situ. That is the microorganisms and other organism’s phototrophic organisms when they grow within this ecosystem.

They produce the organic the biomass as I mentioned earlier and that biomass could actually form the organic carbon or provide the organic carbon. The cells after their death the cell mass is utilised and decompose and also the different metabolites which are released by a functionally active cell are often also contribute to this organic carbon pool. Now as I mentioned the energy could be the energy inputs in this ecosystem could be from the solar system.

It could also be the inorganic material or the oxidation of organic carbon. So with the exposure to sunlight the fast zone that we can identify in this kind of ecosystem is the top layer where the sunlight is available that is called the Photic zone. Now within photic zone it is obvious that the sunlight will be utilised by the microorganisms present over there and naturally the phototrophic organisms who are the photoautotroph.

Who are capable of utilising the carbon dioxide present in the atmosphere or the dissolved in the water column will be utilised in the form of bicarbonate will be assimilated inside the cell and then will be utilized through carbon fixation pathway and along with the inorganic carbon the nutrient will be required. So inorganic nutrients will be also assimilated like nitrogen, phosphorus, Sulphur, Iron etcetera which are often present as soluble form within the water column.

So the phototrophic organisms will be capable of converting this carbon into the essential energy form that is the ATP and also new organic matter will be synthesized. Now this new organic matter as we discussed and will contribute to the organic matter pool of this ecosystem, which would can be cell mass itself or released metabolites or the metabolic products from this phototrophic organisms.

Now this organic matter which synthesizers call me call new organic matter in situ synthesized new organic matter by the phototrophs actually represent the bulk carbon and along with carbon as I mentioned it will also have lots of nitrogen, Phosphorus and sulphur, iron, magnesium potassium etcetera which are assimilated within the biomass. So, as the biomass is available or metabolic products are available into the broader pool of nutrients this will also be available to the systems. Any microorganism like to use them would possibly like to use them.

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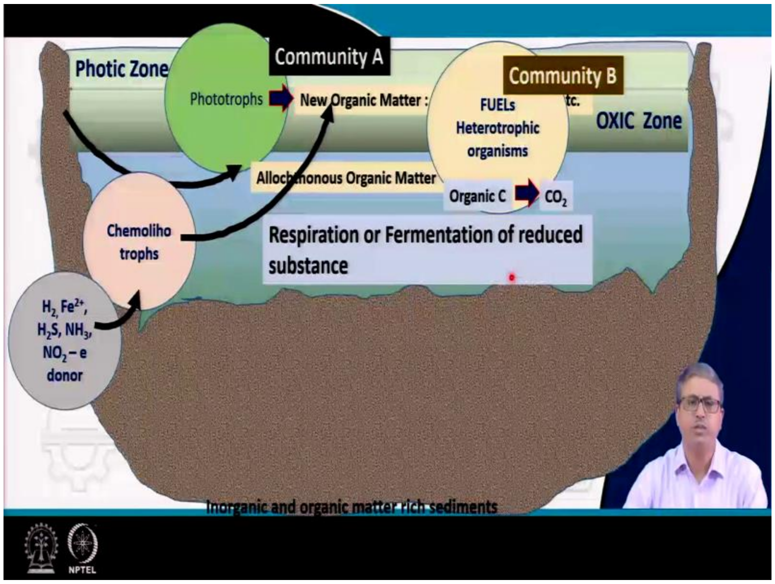

So, in addition to this new organic matter, so there would be some other organic matter sources also there. So, let us now proceed so along with the Photic zone the imillimeterediate vicinity will be the Oxic zone. The Photic zone in fact is also the Oxic zone because the concentration of the oxygen the atmospheric oxygen will be higher and of course there will be a gradient within this Oxic zone because. As we go deeper into the water column level of oxygen will be declined.

It is also a fact that the utilisation of oxygen by aerobic microorganisms will further reduce the level to the oxygen or the Oxic might have a gradient within itself but for our simplicity we are not considering the gradient at this moment of time. We are just considering that along with the Photic zone there is the Oxic zone. Now within the Oxic zone there are certain important activities from the microbial point of view.

So as we have learnt earlier that the organic matter will be synthesized by the phototrophic organism that corresponds to the new organic matter. Along with new organic matter externally derived or leased organic matter can also contribute into the organic matter or organic matter pool of this ecosystem. So that is actually called Allochthonos organic matter. Allochthones means these are externally derived organic matter which could be the runoff Agricultural runoff or any kind of other sources.

May be from the sediment deposits these are will be leeching into the mobilized or solubilized and then they are coming into this water system. So together these will represent the total organic carbon or organic matter present in the system. Now within the Oxic it is expected that this organic carbon which is present their will fuel the growth of heterotrophic microorganisms. Heterotrophic bacteria heterotrophic or other archaea would metabolized the organic carbon no matter whether it is Autochthones or Allochthones.

Autochthones means in situ to produce or the Allochthones that is externally derived this organic carbon will be metabolized to microbial respiration because oxygen is there. So, using oxygen as an electron acceptor aerobic organism will respire or in presence of different other terminal electron acceptor, some of the organisms may also grow if oxygen is not sufficiently available at some point of time.

So basically the respiration and under some situation we see that along with respiration or in some bacteria fermentation can also proceed because there if there is lack of oxygen or lack of suitable electron acceptor or some microorganisms prefer to do fermentation. So basically the fermentation of the other reduced substances like glucose is fermented to lactic acid or acetic acid or something like that or that can also be produced.

Otherwise the organic carbon will be metabolized to carbon dioxide. Now here we should also include that the organic carbon which is actually utilised by this heterotrophic organisms are obtained from the phototrophic bacteria are the phototrophs including algae. It could be or most likely external organic matter will also be there. But in addition to this phototrophic bacteria, they are or they are likely to be chemolithotrophic bacteria this chemolithotrophic bacteria, utilizes different reduced inorganic material.

And then try to oxidize them like hydrogen Fe 2+, H 2 S, Amillimeteronia, nitrate etcetera as electron donor. These are also naturally available. Hydrogen might be available because of many of the fermentative reaction produced hydrogen. Fe, sulphides, Amillimeteronia, nitrite these are naturally available because of the products of the microbial activity or often they are also present in the sediments. Essentially or they may enter into the system from external sources.

Essentially chemolithotrophic microorganisms, they are also contributing to the new organic matter. So essentially the organic matter which is present in the system is going to be oxidized and by these heterotrophic organisms leading to the formation of the carbon dioxide or some of the fermentative products. Now, we can actually did these groups of population. One could represent the community A where many of the phototrophic organisms could be there or autotrophic organisms are there with different sets of populations.

Like chemolothotrophic population and photoautotrophic populations and within photoautotrophic and have again different type of the population. Together they might represent the community A. The heterotropic organisms could be of different represented by different populations together they form the community B.

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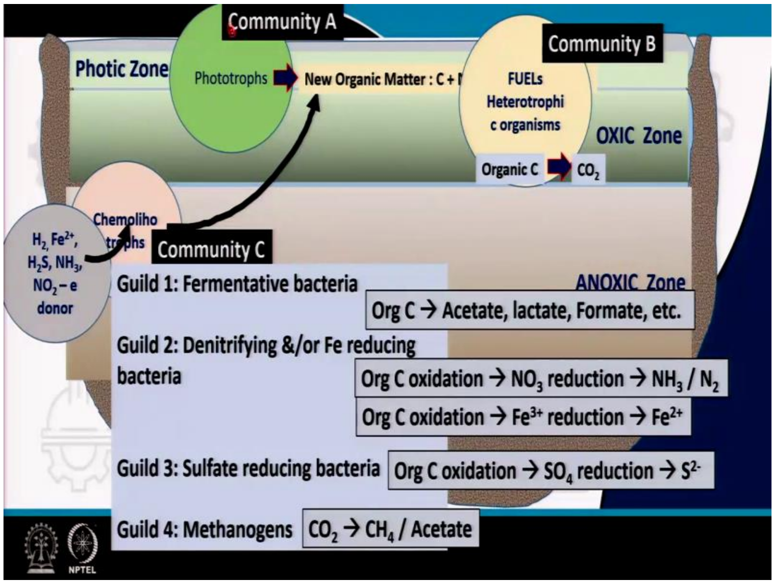

Now we move forward that below the Oxic zone it is expected that the anoxic is going to prevail. So anoxic zone means it is oxygen free zone because of the diffusional barrier and also the use and utilisation of the dissolved oxygen by the microbial activity the oxygen level will decline and essentially this is going to be anoxic zone and oxygen free zone. Now within these oxygen free zone we can clearly identify a number of guilds.

And all these guilds which are indicated here are actually represented or are facilitated by a group of populations as we know that each of the guild must be represented by a number of population and together they represent the community C. So, together all together, we can identify that in this aquatic ecosystem we have the community B and community C for examples there would be actually numerous other comillimeterunities also present but generally we can boardly and easily categorised these 3 comillimeterunities.

Now for example, the community C in this case is represented or constituted by 3 guilds. Guilds A or Guild 1 is the fermentative bacteria which are responsible for utilising the organic carbon and fermenting it to acetate, lactate, formate etcetera under the anoxic conditions because oxygen is not there. Guild 2 could be represented by the denitrifying or the Iron reducing bacteria who will use nitrate as an terminal electron acceptor forming Amillimeteronia or nitrogen from nitrate or will reduce the Fe 3+ as their terminal electron acceptor and will produce Fe 2+.

Guild 3 will be represented by the organisms or the populations responsible for sulphate deductions. Sulphate deduction sulphate will be reduced to sulphite under anaerobic conditions meaning of many of these anaerobic bacteria. They are capable of utilising sulphate as the terminal electron acceptor. And lastly the guild 4 would be the Methanogens these are basically the archaea present over there.

These archaea would be to acetatoclastic or they could be hydrogenotrophic or hydrogen utilising it archaea or could be Acetate utilising archaea and some of them could also help in acetogenesis to these 4 wheels could be easily expected. Now and in addition to these 4 guilds there could be some other guilds represented by organisms who are capable of oxidizing methane. Methane which is going to be produced under this anoxic environment will be available as a carbon source.

So there would be some organisms both archaea and bacteria it would be capable of utilising or oxidizing rather methane. So, these are methane oxidizing bacteria or Methane oxidizing archaea so essentially Methane can be oxidized to see you want different type of C 1 compounds and then C 1 compounds will be again used as a organic carbon going to the organic pool. So essentially we can see that the carbon which actually are derived from the atmospheric carbon or the dissolved inorganic carbon from the organic matter.

Organic matter finally trickle down to the formation of Methane or so and then Methane can essentially be converted again or the acetate can essential be converted again towards the carbon dioxide and that carbon dioxide can again be recycled within the system. So we are going to see a kind of the brief idea of the carbon cycling within this. We are going to discuss about the carbon cycling and biogeochemical processes of other nutrients maybe in some other class.

So these are the 4 major guilds and as I said there could be many other guilds which would be prevailed there based on the conditions which after prevailing there. This is one kind of example. So real situations are might be more complicated, more zones can be defined because of the availability of the nutrients or the fluctuations within the physicochemical environment within this environment.

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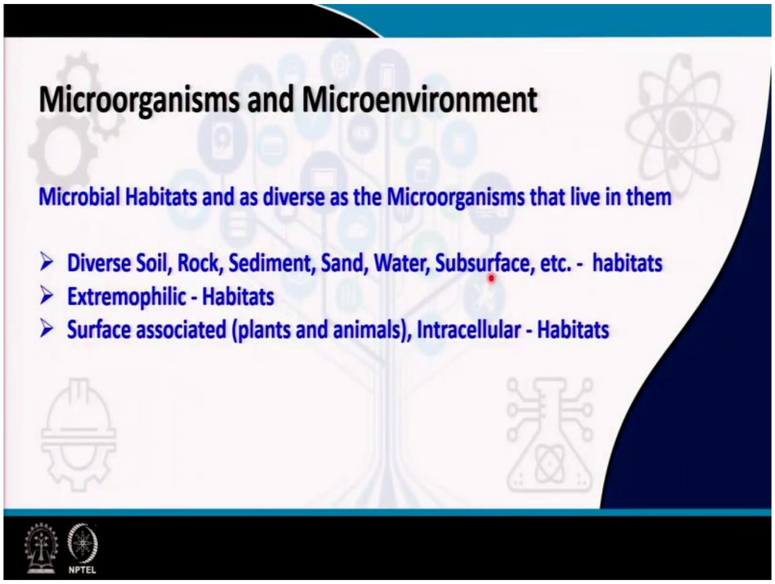

The next point that I would like to discuss after this is the concept of micro environment. The microbial habitats are as diverse as the microorganisms that live in them. So, you know the microorganisms are diverse and just now we have seen they could be photoautotroph, chemoautotroph they could be heterotrophy and they could be Methane utilising they could be Methane producing.

There are many different types of microorganisms from their metabolism point of view there taxonomy their physiology. There are many ways that we can we can find out the diversity of microorganisms. But along with the diversity of the microorganisms habitats where they live are also diverse. For example, the normal habitats that we see the soil, rock, sediments, sand and water. Different type of subsurface habitats, they are all replacing the different type of habitats.

There are extremophilic habitats also. Many involvement many habitats are extreme with respect to their temperature, with respect to their pH, with respect to the salinity. So again within that environment, we see a gradient of conditions prevailing. So, there are multiple habitats within each of these extremophilic Habitat itself. And also there are some more interesting habitats like this surface associated. Surface means the plant and animal surface associated microorganisms those are habitats actually where like the philoshpere where the leaf surface.

This is very special Habitat on the plant leaves were the microbial comillimeterunities are present and their function only on the microbial plant leaves. The rigoespheric community or the root associated microbial community. These are externally associated comillimeterunities there are also intracellular habitats like endophytes, for example, so they also represent habitats. So, what we see essentially that there are numerous habitats within our planet earth or in the biosphere.

So along with microorganism habitats are also significantly diverse. Now within these habitats there are microenvironments.

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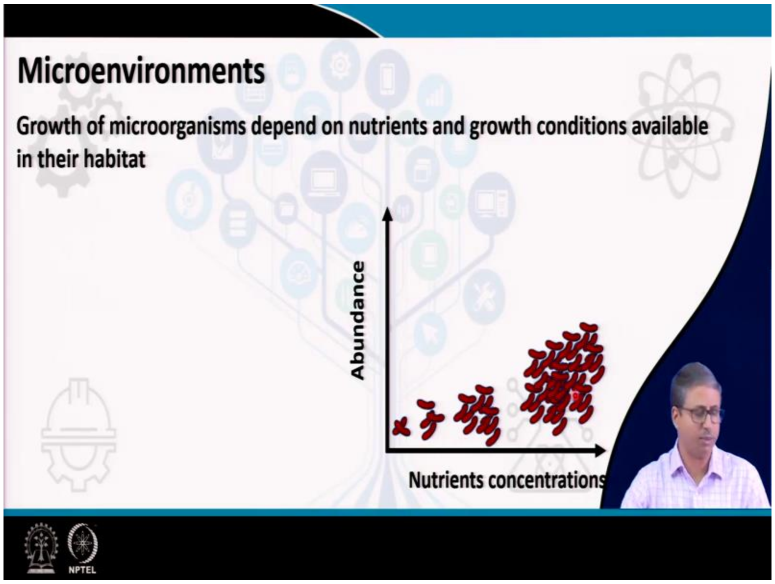

So the growth of microorganisms as we have learned already depends on nutrients and growth conditions available in their habitat. So as we can see that with increasing nutrient availability the microbial growth happens and unless and until there are certain kind of other reasons the growth will continue and then its saturation obviously at some point of time there will be a limitation of some nutrients or competition among the species and eventually the cell decay or cell death will begin.

But before that the supply of nutrients the favourable growth condition with all favour the growth of cells present in any environment and obviously their activities.

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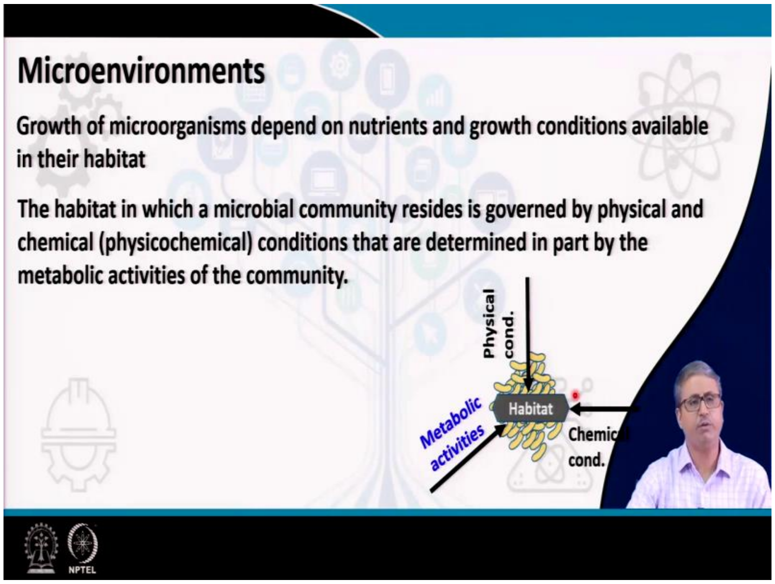

The habitat in which a microbial community resides, a community is represented by numerous populations within a habitat will see numerous populations are there forming community. The community which is present within a particular habitat is governed by the physical condition and also the chemical conditions which are defined as the physico-chemical conditions.

And together as we have also learnt that together these physical and chemical conditions they determine the metabolic activities of the organisms which are present there. So these physical conditions and the chemical condition together form the basis of the physico-chemical condition and physico-chemical conditions basically drive the community composition and community function. It is not difficult to understand that the physico-chemical condition actually creates the strong pressure on the community structure.

That what type of microorganisms will present there because some of them might be very stressful or some of them might create a favourable condition for some organisms and unfavourable conditions from some other organisms. So, naturally guide the community structure. And it is not only the guide the community structure alone they also guide the community metabolic activity. So, the physic-chemical and conditions actually control the metabolic activities of the community members.

Now, you can easily take for an example the organic carbon reach environment like paddy soil or pond water or some similar environment where lot of organic carbon is available compared oligotrophic environment where nutrients are very limiting particular the carbon is limiting maybe Phosphorus and nitrogen is limiting. So, if you look at the metabolic activities which are contributed by the microorganisms present over there.

We see that the supply and physico-chemical condition together the control the microbial activity significantly.

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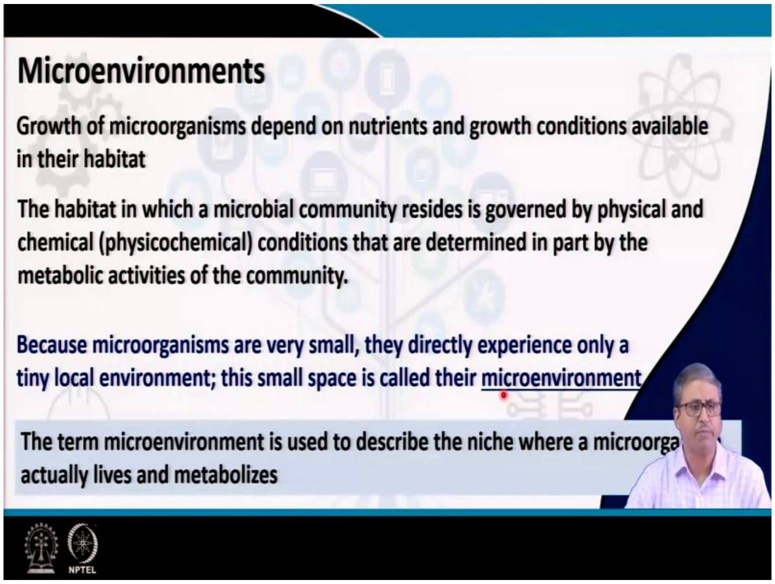

Now to understand this further because the microorganisms they are very small in the order of few microns generally on the size scale. They directly experience only local tiny environment. This small space is called the micro environment that is a few micrometre or few millimeter within their territory may be very significant for them because they are themselves micron size so we will take one example after that.

Now the term micro environment is used to describe the niche where a microorganism actually leaves and metabolism. So, as we define earlier the niche, niche is the all the interactions the species member or a particular species member they carry out among themselves and among their environment or among their abiotic counterpart to function in that environment to live in that environment is the niche.

So, micro environment is basically used to describe the niche within which a particular species function, but we should not get confused with the micro environment that it is a kind of synonymous to niche it cannot be a synonymous because in a micro environment there could be many such species present many niche. So will see that within the micro environment a dozens of a species of population are there and each of them are having their own niche into that.

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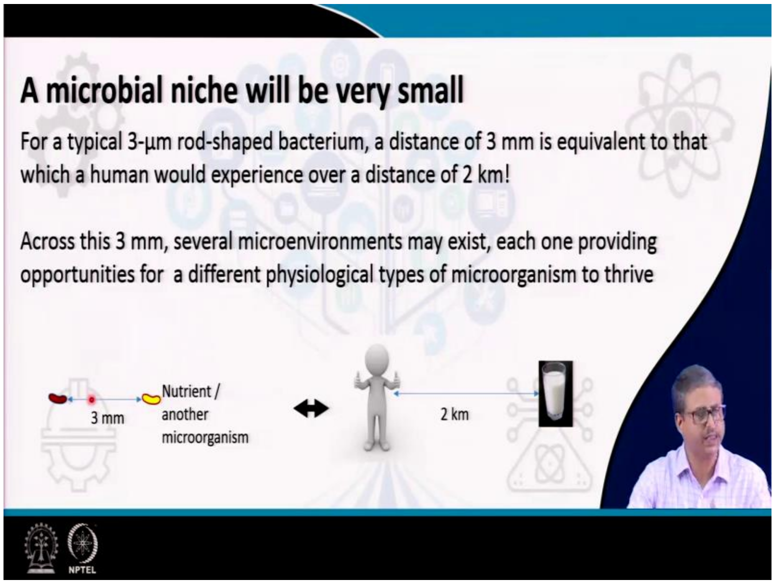

Now the microbial niche is actually a truly very small. As an analogy we can take this example that for a typical 3 micrometer rod shaped bacterium like this. A distance of 3 millimeter, distance between this particular bacterium to another bacterium or some nutrient molecule which is which is available 3 millimeter away it may be oxygen it may be nitrate, it may be ammonia it may be glucose or whatever nutrient or maybe it cell who is producing something or who is consuming something.

So ultimately this bacterium is going to be affected by this bacterium or the nutrients which are present over there. So the points is the difficult 3 micro cell will experience a huge distance related factor because this 3 millimeter gap between the nutrient molecule or another species who might be producing something or consuming something on which this species has some interest. Then this is equivalent to a distance that human would experience over the length of 2 kilometer.

Like this 3 millimeter distance could be equivalent 2 kilometer distance for a human. So, just assume that you have a glass of milk 2 kilometer away. So is it readily accessible? I do not think it is readily accessible. So there maybe water tanker away from person 2 kilometer away from the person. So the person has to think that how I am going to access that a glass of milk or it is just a representative that the source of nutrition. So, that maybe glass of milk or it may be at water tanker or it may be pond or it may be some other nutrients sources or maybe some other activities which are directly influences on going to influence human activity.

So it is so important that distance going to a very important parameter in microbial physiology microbial metabolism and within ecosystem function. Now within this 3 millimeter which is 3 millimeter for human it maybe 2 kilometer several micro environments may exist and it is easy to understand. So 2 kilometer for a human to a glass of milk distance might include many hurdles many burdens in between.

So, similarly for microbial cell 3 millimeter distance might have variations within its environment physical or chemical parameters might vary and each one of these micro environments. There could be numerous microenvironments which are basically the alteration in their physical or chemical properties. So, each one of these micro environment will going to provide opportunities for different physiological types of microorganism to thrive.

Now these micro environment will eventually will have different conditions in which other organisms will prevail. So for example if there is a bunch of organic carbon or a kind of a huge deposit of organic carbon over here these bacterium is thinking that it is 3 millimeter away so I need to plan about accessing this nutrient either I can move if I have a flagella possibly I will move or I will release some products or I will how I can access this nutrient or carbon source.

But these bacteria will face numerous challenges on numerous favours because in the intermediate space there will be many micro environments and within each of the micro environment there will be numerous other bacteria are present. All these bacteria would interact some of them will surely interact with this carbon itself and eventually the availability of the carbon or the overall physiological activity of these particular bacterium will be not only control by this carbon available over here but also the micro environment and also the microorganisms who are living over there.

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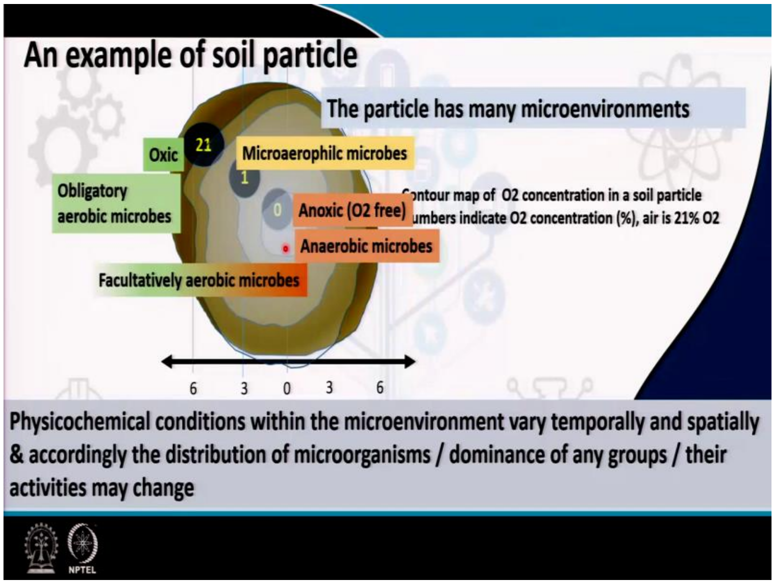

Now we can consider a soil particle if you take a soil particle, which is around 6 millimeter in its radius we can see. So here we are representing a contour map. The contour map of oxygen concentration is actually a plotted. This is an arbitrary plot and there are actually method by which micro sensors are available through which one can measure the amount of oxygen present within a soil particle.

Now if we are able to measure the oxygen concentration within the soil particle we will be able to see that the exterior of the particle will have almost the equal concentration of a percentage level concentration that is 21% which is equivalent to the concentration of oxygen in the air. So, the external periphery of the soil particle will have almost like in equilibrium it will have 21 or 20% oxygen. But as a enter inside the cell or enter inside the soil particle the oxygen level will be declining.

And you can see that at the centre of the soil particle the oxygen is almost zero and it is going to represent different zone of oxygen present within the soil particle. Now in terms of oxygen relationship for microorganisms each zones there are zones which are typically lack of oxygen or just 1% oxygen or just 5% oxygen or just 10% oxygen or there may be 21% oxygen. So there are numerous oxygen enriched zones are there and each of these zones are going to prefer or allow growth of certain microorganism within it.

So, each zone can be considered as a micro environment. So here in the picture, we can clearly see that could be at least 1, 2, 3 micro environment or more micro environment because we have not plotted all the oxygen concentrations zones over here. Now, this is actually going to going to affect microorganisms present over the soil particle. This is a story of a single soil particle. So this particle has many microenvironments.

Now the external or exterior most environment is the oxic environment where we have almost the concentration of oxygen which is equivalent to the atmospheric oxygen. Whereas the interior part of the core of the soil particle is absolutely oxygen free that is the anoxic environment. Now with respect to microorganisms, which and going to naturally occupy a soil particle and it is different zone. So, we will expect that within the core of the soil particle, which is basically oxygen free will have an aerobic micro.

Whereas the oxic zone which is the outer territory or the close vicinity to the outerr territory will have obligatory aerobic microbes, and the intermediate zone will have the microaerophilic microbes. Because they are microaerophilic means that prefer to grow on low concentration of oxygen present over there. And facultatively anaerobic microbes who can switch to anaerobic streak, anaerobic metabolism or anaerobic metabolism very well and as well as they can perform the aerobic metabolism also, they will be spread across the soil particle. So, within the soil particle we can expect that there will be numerous or several micro environment.

And each of these micro environments are occupied or populated by distinct set of population within them or distinct set of populations or community they are actually they will be forming community. So the core of the soil particle will have a community and the exterior part of the soil particle will have another community. Now, physic-chemical conditions within this micro environment. So there are several micro environments as we can identify. Now these physico-chemical conditions within these micro environments will vary temporally and spatially.

So, it is not a static phenomenon of that all the time the oxygen gradient to like this because the soil particle may experience some kind of water logging at its top. And as soon as there is water logging there maybe decline in the dissolved oxygen concentration. So these oxic zones might be suitable for microaerophilic organisms. So this is not a static event.

So in any kind of particle or small section of microbial habitat we can see that the distribution of microorganisms within each of these micro environment or the dominance of any particular group and over and above the activity of any type of microbial group present in these micro environment are subject to change because this change is basically constraint by different kind alteration in the physico-chemical conditions.

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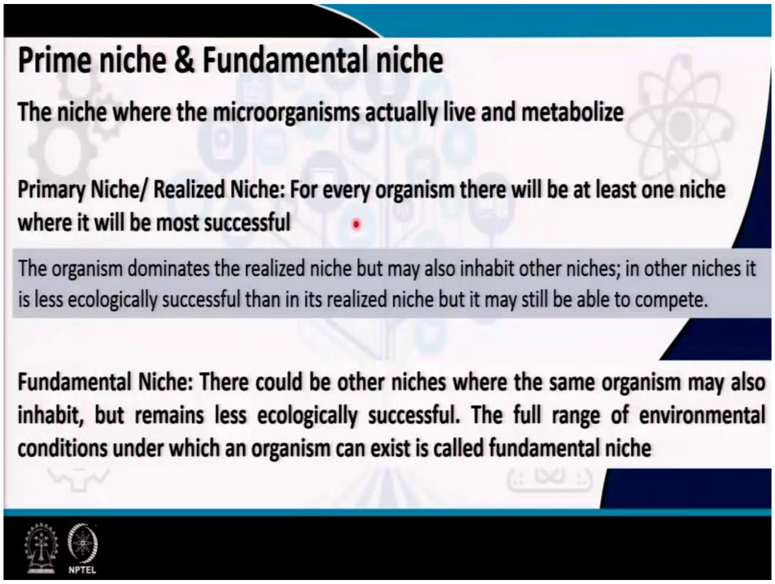

And also it is not only this micro environment is working like this. So within this micro environment, we see that there are a prime niche and fundamental niche. So basically niche as we defined the earlier where the micro organism will leave a metabolite and primary niche is also referred as realise niche that for every organism there will be at least one niche where it will be most successful.

So metabolically it will be on in its peak and it will be very successful in its performing in its activities. The organisms dominates the realised niche but may also in inhibit other nature. So, the dominant is most preferable one but any particular species can occupy other habitats also. And in other niches it is less ecological successful then in its realised niche. So microorganism or a particular species can occupy multiple niches obviously.

But it will have primary niche and there will be many other niche which are the fundamental niche together. There could be other niches where the same organism the same species may inhibit may occupy may grow but remains placed ecologically successful. For example in several cases we have seen a bacterium like a species **(()) (44:35)** or a species of pseudomonas aeruginosa or some kind of other species.

So, these organisms often have been found to occupy several ecosystems and several habitats, but obviously all the habitats will have micro habitats and in all the habitats they may not be very successful. In some niches they are going to be very successful, but there will be other niches while they are there but they are not very successful. They may not be playing very critical role or very important role within environment.

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So, this part of my lecture is basically basically developed based on this material which can be followed are the Brock Biology of Microorganisms and along with that did the Prescott Hartley and Kline Microbiology and Environmental Microbiology from Genomes to Biogeochemistry.

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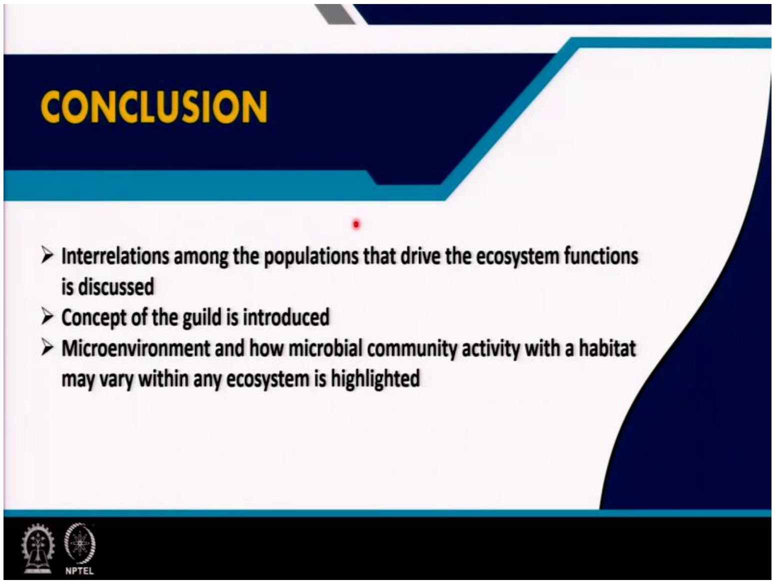

So at the end we conclude this part of the lecture that interrelations among the populations that drive the ecosystem functions are discussed. Concept of the guild is introduced and micro environment and how microbial community activity within a habitat and habitat may vary and ecosystem within the type of ecosystem that is also highlighted. Thank you.