Environmental Biotechnology
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Lecture – 03
Ecosystem: Basic Concepts of Structure and Function

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Welcome to the third lecture of this NPTEL course on environmental biotechnology. In today's lecture we are going to discuss about the basic concept of ecosystem including the definitions of different terminologies, the components of ecosystems and interrelations among the different components of the ecosystem.

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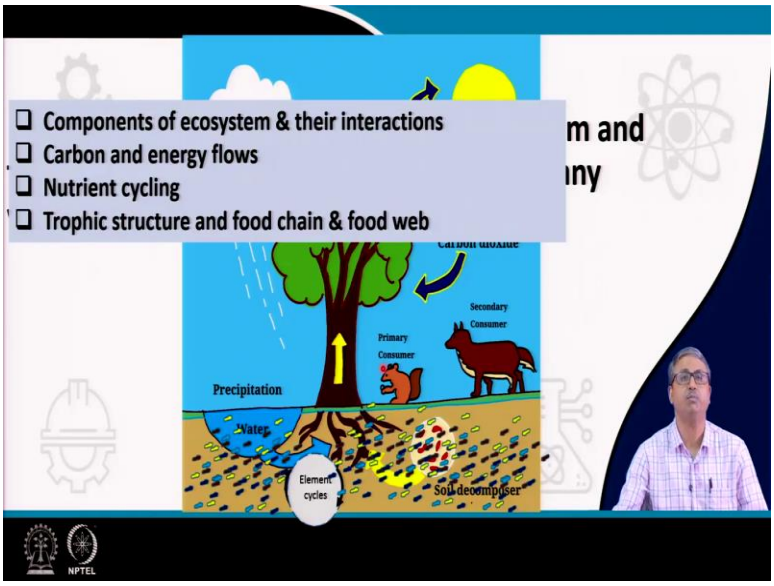

Now understanding the basic concept of ecosystem and function of its various components is considered to be a very important aspect for any work related to environment. And considering its fundamental importance the requirement for the understanding of the basic components and how they function within any kind of ecosystem this lecture will be required for this environmental biotechnology course.

Now as we can understand from this the very the basic concept of the ecosystem function that within ecosystem or almost in every ecosystem we have the plants that is the green photosynthetic plants or photosynthetic organisms who are considered to be the producers because they are able to capture the sunlight and convert the energy gained from the sunlight or the solar energy is converted to to complex organic carbon utilizing the the other nutrients, moisture etcetera from the atmosphere and the soil.

And the organic material produced by these green plants are eventually supplied to different levels of other heterotrophic organisms which are identified as primary consumers or secondary consumers and as this organic material produced by the green plants are consumed by the different types of consumers the carbon flow and energy flow starts. And it is not only the carbon and energy flow but it is also the flow of different nutrients which the green plants acquire from the from the root systems and from the soil through the root system.

Now within this the soil system where these green plants actually live. We find that there are numerous microorganisms who are who are there naturally in the in the soil and these microorganisms play very important role in all components of the ecosystem function including the element cycling and other processes which are responsible for controlling the flow of nutrient and and also the flow of energy within the ecosystem. So, during this course.

We are also going to talk about some of these important aspects that will include the components of ecosystem and their interaction as you can possibly identify some of the components in this picture itself. Carbon and energy flows a nutrient cycling and the tropic structure and food chain and food wave.

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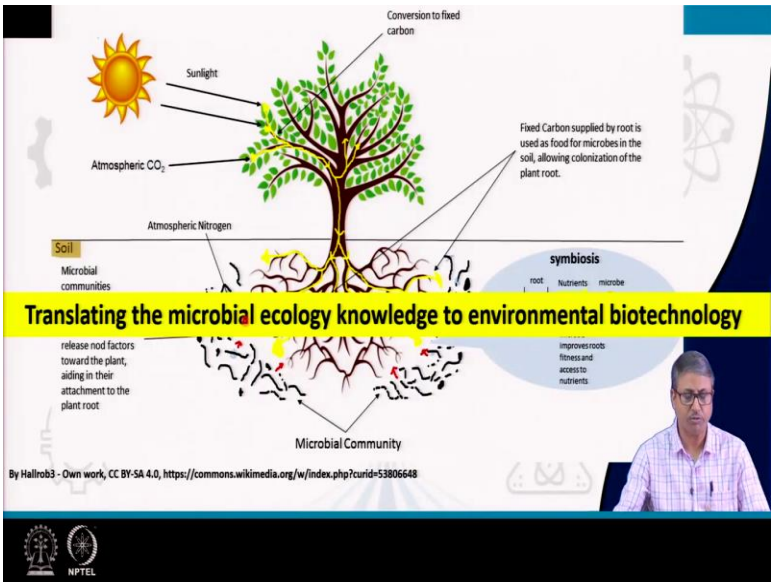

Now in order to understand the entire of the process of ecosystem function before we go into the details of some of the aspects I would like to introduce to you some of the the important points about the role of the soil microorganisms in particular in any kind of ecosystem function. So, considering this particular the cartoon where you can see that again a plant is acquiring different type of nutrients from the extensive root system which is present within the soil.

And it is very clear that the the solar light is converted to organic material and this conversion of the carbon dioxide to the fixed or the organic carbon is one of the fundamental properties of the green plant. And the fixed carbon supplied through the root. Now is playing an important role

because the fixed carbon which is essentially present also in the root is often excreted as organic acids and other organic compounds released by the plant roots.

And these plant roots released organic materials are often used by numerous microorganisms who are living close to this root what we refer as the rhizospheric microorganisms that is the roots root region microorganisms. Now these root region microorganisms they are specialized in terms of their metabolic abilities to utilize the organic materials released by the plants and often they are also able to provide different type of other materials to the plants and thereby establishing the symbiotic relationship with the plants.

For example many of you are already aware about the nitrogen fixing microorganisms where the the the atmospheric nitrogen which is otherwise remains unavailable to the green plants are assimilated in the form of ammonical nitrogen and that ammonical nitrogen is converted into various other forms and given to the plants ultimately for their utilization. So, now we would like to appreciate that translating this the specific segment of my ecological knowledge which is in this case the microbial knowledge is very critical for any kind of environmental biotechnology application.

So, in the due course we will learn more details about the the processes the concept and why microbial ecology is considered to be so, important in environmental biotechnology.

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Now; right now we are going to come back to our core concept of the the ecology and ecosystem. Ecology is basically a well defined term which is the study of the life at home that is the the totality or the pattern of relations between the organisms and their environment. Now it is very important to understand the emphasis ecology gives on organisms and their environment and it is the relationship between these organisms these organisms means all the organisms present in any kind of environment or a sample collected from any kind of environment.

Now it is actually as you can see that it is the study of oikos means the household. So, it is it is coined long term ago 1869, Earnest Heckle coined this term ecology.

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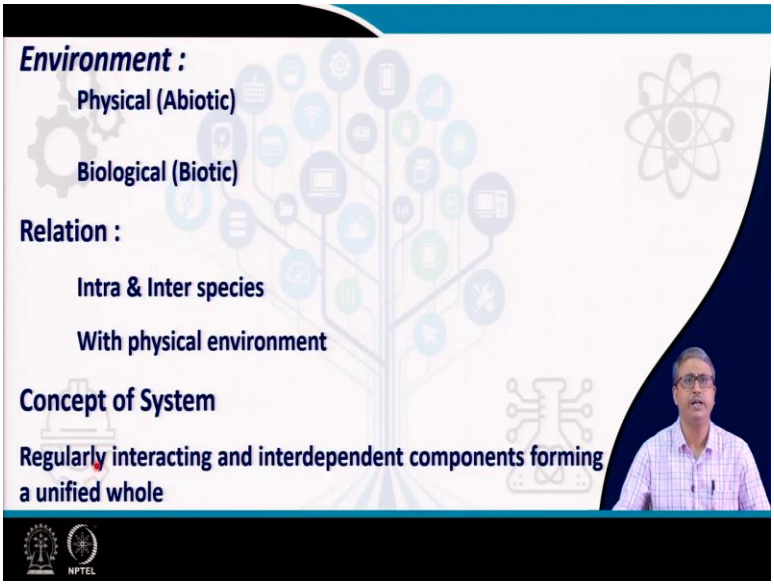

Now it has actually not only ecology per se. But environment in general is having two components one is the physical or abiotic component another is the biological or biotic component. Now in this case I would like to emphasize that the physical world is actually used to to include all the abiotic components. So, it is the kind of a contrast to the biotic compound component of the ecosystem or the environment the physical component is included.

So, ideally it is going to include all kind of a biological or abiotic parameters including the chemical um compounds present in an ecosystem as well as the different type of physical parameters which are often found to be very important in controlling the the ecosystem function or environmental function environmental species composition and many other thing. So, the physical refers to the abiotic component and the biological refers to the biotic component.

Now first is this point that within any ecosystem we are going to have two distinct components or the environment one is the abiotic component another is the biotic component. It is also very important to note that these two components are inseparable. You cannot; you can identify or one can identify the biotic component like one can easily identify the the kind of organisms present kind of species present.

And also one can easily identify or characterize the physical or the chemical that means the abiotic environment of any kind of ecosystem like the temperature like the pH like the moisture content and many other abiotic parameters. But what is very important and interesting is these two components of the of ecosystem or any kind of environments are intrinsically interrelated it is not possible to separate one from the other.

The second very important aspect of this ecosystem or ecological concept is the relationship between the species that is the intra and interspecies relationship. That means the relationship between the members of the same species as well as the relationship among the members of the different species. Now beyond this relationship between these species and between different types of species that is the intra and interspecies relationship.

The relationship is also existing and it is very important that this relationship is is to be discussed

is to be highlighted is the relationship with the physical that is again the abiotic environment. That means the species themselves they interact the species interact with other species and eventually the species also interact with their physical environment. Some time ago I said that it is it is almost impossible to separate the biotic component from the abiotic component. We can characterize them. We can identify them.

But physically it is it is almost impossible to to segregate them because the moment you segregate them they are going to die. The living organisms are going to die if you if you separate them from their from their physical environment like the the the they will die they will die possibly because of the the lack of oxygen or the lack of required electron donor or electron acceptor or some other physical or chemical parameters.

Now this interaction or the relation is very important for any kind of ecosystem function. And eventually this interaction of the relation between the species, across the species and species to the physical or about environment leads to the development of the concept of a system. Now system refers to regularly interacting and interdependent components forming a unified hole that means these species these species with their abiotic components are interacting continuously and they are interdependent.

Interdependent means without one the other one will not survive or possibly not survive. So, they are there they are obligatory dependent on on the interaction and that is going to form the unified hall or that forms the unified whole which is referred as a system that is why it is called ecosystem.

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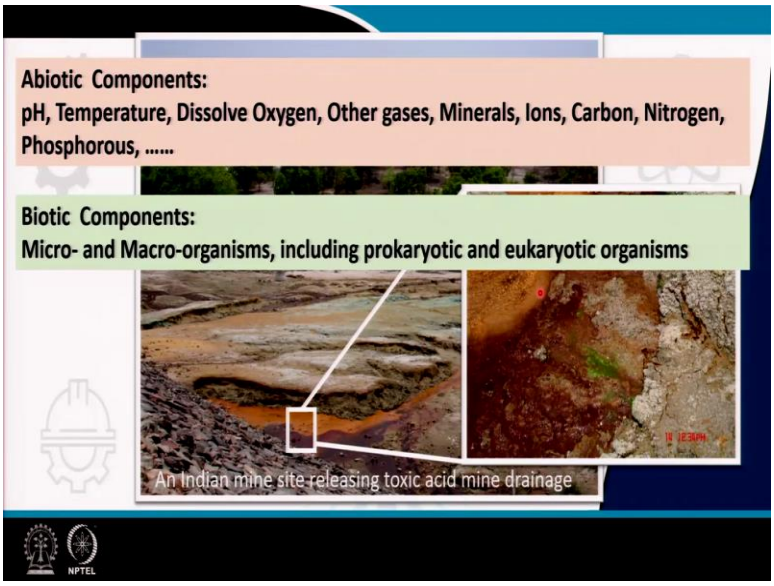

Now I will take you to one of the field sites which is very very interesting as you can see this is an Indian mine site where some very important metals are recovered metal ores are recovered and this mine site is releasing toxic acid mine drainage. So, as you can see that there is some kind of rock embarkment and underneath this rock embarkment this reddish coloured the flow of water which is having a very strong acidic pH and also rich in iron and different other heavy metals organic carbon concentration is very low.

So, this is it is naturally flowing because of some oxidation events going on over there. Now if we zoom some part of this environment. We can see that this kind of things and little bit of green patch. Now this green patch is basically some kind of algae or some kind of photosynthetic organisms are growing there. So, if you just try to remember that sometimes ago I was showing you some basic picture of the ecosystem where organic carbon is synthesized out of inorganic carbon or carbon dioxide by the the producers or the photosynthetic organism.

So, here are these photosynthetic organism in this very unusual and we we call it is a kind of extreme environment. So, it is it is extreme pH extremely sulfate iron and different heavy metal rich environment. But nevertheless some extremo tolerant autotrophic organisms are growing over here they are photosynthetic they are able to produce the organic carbon and possibly supplying this organic carbon to the other organisms playing over here or present over here.

Now if we would like to discuss little bit on the environments that the abiotic and biotic components of the environment. So, what about the biotic antibiotic components environmental components in this particular environment. So, the abiotic components in this case would possibly include the pH, temperature, dissolve oxygen, other gases different type of minerals and eventually from the minerals different ions are going to be produced.

Carbon in particular nitrogen and phosphorus and numerous other ingredients which are which which include maybe the physical as well as the chemical but surely they are abiotic components. Now along with these abiotic components if anyone is interested or we are generally interested to know what are the biotic components. So, biotic components should necessarily include the micro and macro organisms.

So, microorganisms as all of you understand these are organisms which cannot be seen with unaided eyes. So, you need a microscope because they are. So, small in size. So, that microorganism category would include different type of prokaryotic organisms as well as eukaryotic organisms like the microalgae and some kind of lower protist whereas there could be the different type of macro organisms who are again in this case since it is I said that it is an extreme environment.

So, extreme tolerant extreme condition tolerating organ some organisms might be there. So, if if anyone is interested you can characterize these organisms from this habitat.

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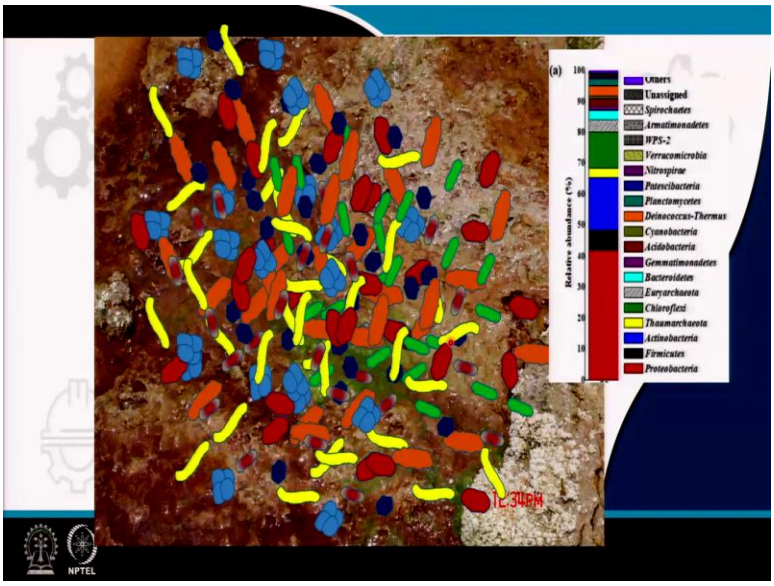

Now if we look a little bit in detail within this particular environment. We would be able to identify that there are numerous organisms I want to mention that we can characterize them. We can identify them they can be as I said eukaryotic or prokaryotic. So, this is just just a cartoon to represent that there would be millions of organisms millions of cells millions of different type maybe thousands of different species could be there.

Now there are methods that we are going to talk in in our due time that there are methods by which we can actually identify each of these members. So, if we can identify this species or the identity of this organism then possibly we are one step forward in our characterization of this ecosystem in terms of the the biotic organisms.

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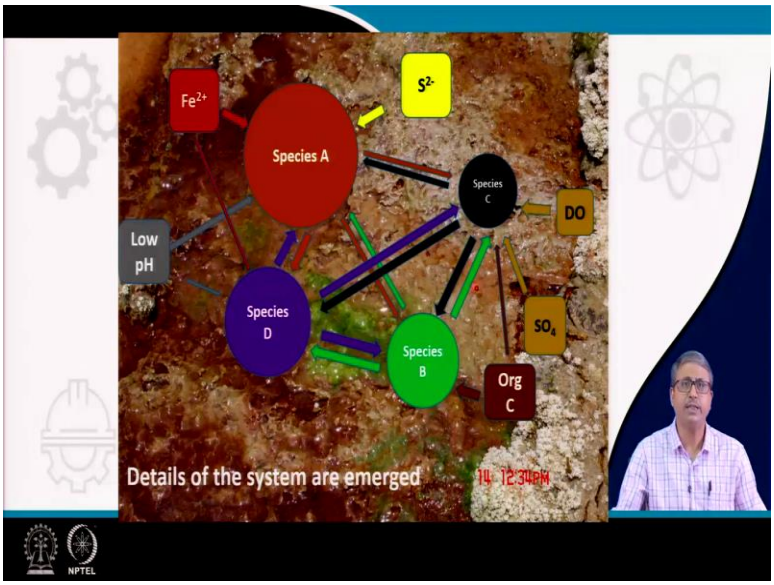

Now once we identify the the biotic components like all the members all these species all the organisms present over there. We can also establish the interrelation as I mentioned earlier that how the species A is related or interdependent to species B or species C or species D and it is not only the relationship between these species itself it can be extrapolated it can be extended up to the interaction where you can see that interaction of species A particularly with iron Fe 2 plus or sulfide or even low pH is very prominent.

Whereas species C as you can see could be more dependent or interrelated with dissolved oxygen sulfate level organic carbon and species B has some kind of interaction with organic C as well. So, eventually as. We characterize any environment. So, this is just an example as. We characterize any environment with respect to its abiotic components as well as with respect to its biotic components. We are eventually in a position to characterize the details of this ecosystem.

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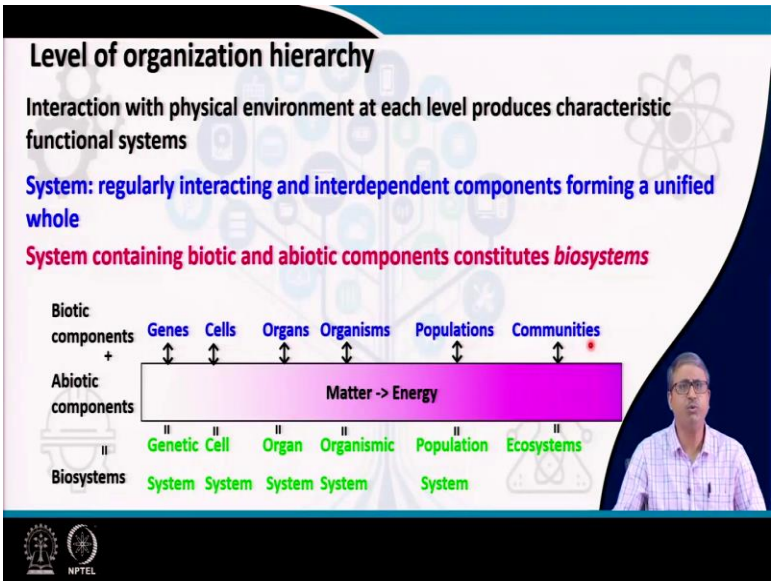

Now these organisms which are present in this ecosystem or any kind of ecosystem they will follow some kind of organizational hierarchy. Now there are different levels of organization hierarchy which is observed in any kind of environment in any kind of ecosystem. Now this level of organization hierarchy includes interaction with physical environment at each level that produces characteristic functional systems.

So, let us discuss this in detail. Now before I go into the details the systems refer to regularly interacting and interdependent components forming and unified holes as I mentioned earlier. And systems containing the biotic and abiotic components constitute the bio system. So, in this case it is actually a bio system because. We have the biot component within it. Now as you can identify the biotic components starts with different genes which are present within the organisms.

Now these organisms are actually represented by cells in case of eukaryotic organism. We find that the cells of specialized functions are grouped together to form the organs and organs are representing different type of organisms. And organisms which belong to the same species are referred to as the population and the all the populations occupying a particular habit at any particular point of time are representing the communities.

Now if we want to identify the interaction of all these different levels of biotic component with their abiotic counterpart that is the the physical and chemical materials present or the physical

and chemical conditions or parameters or characteristics present in an environment. We would be surely achieving into defining the systems like the genes are able to interact with whatever environment is available and thereby generating the genetic system.

The cells they interact with the abiotic components generating the cell system and eventually these interactions follow and finally at community level when all the population members are able to interact with the the ability components which are present over there the concept of ecosystem emerge. Now during this interaction what is the purpose of this interaction why this interaction is going on.

This interaction is actually providing the the survival means to the organisms and and allowing the ecosystem to function. And basically it allows the flow of matter and the flow of energy. So, essentially we see that the flow of nutrients the flow of energy is is going on is achieved only because of this interaction is going on. Just for an example the cells might be interacting with some of the substrates organic compounds or some of the other compounds which are potential electron acceptors in respiratory process.

So, thereby they are metabolically used as as their resources. So, enabling them to survive utilizing those inorganic materials using or the chemical species as their important metabolic resources.

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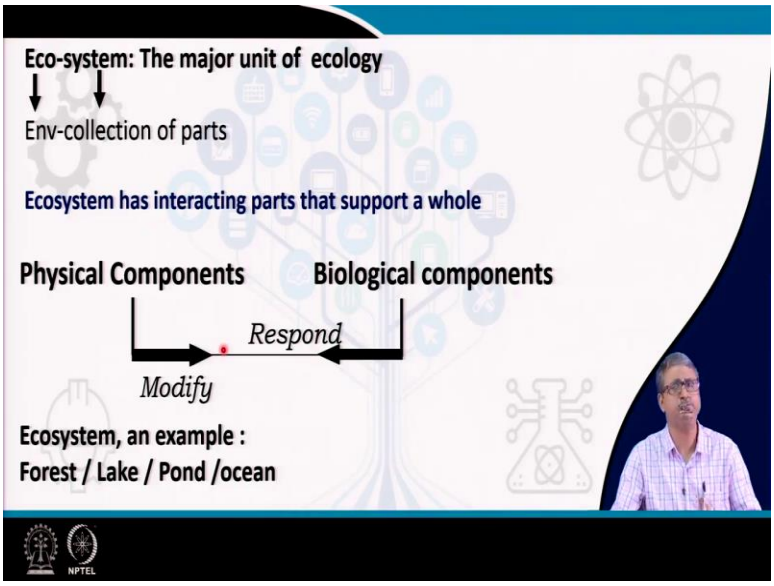

Now as can possibly, now understand that ecosystem is considered to be the major unit of ecology and it has two important aspect one is the environment that is the eco refers to the environment and system refers to the collection. Collection in the sense as I mentioned earlier it is the the interrelated and interdependent assemblage of all the components present within a particular environment.

Now ecosystem has the interacting parts that supports a whole that is the interdependent nature of the ecosystem. So, it has the the physical component and the biological component. Now the physical component again is the abiotic component. We we actually refer as physical component. But that is the that is the the abiotic component. Now it is very interesting that these abiotic components are trying to modify the biological components like the species.

The organisms who are living in any environment are subject to different kind of stress subject to the resources which are which are provided by this the physical or the abiotic component like the level of oxygen, the level of organic carbon, the level of carbon dioxide, level of different electron donors, level of different electron acceptor. The kind of pH, the kind of toxic compounds and many other things which are all included within these abiotic components.

So, the abiotic components are trying to create some kind of pressure allowing them to possibly respond to this. So, it is as represented in this graphic that it is a kind of a two way response. So,

one way the physical components about components are always trying to modify the the biological components on the other hand the biological components that is the the organisms present within an ecosystem are trying to or eventually they do it they respond to this.

They respond to this and respond to what respond to the the the the abiotic components and that is how the the entire process actually reaches to a kind of a homeostasis or a kind of an equilibrium where the ecosystem flow of nutrient flow of energy continues.

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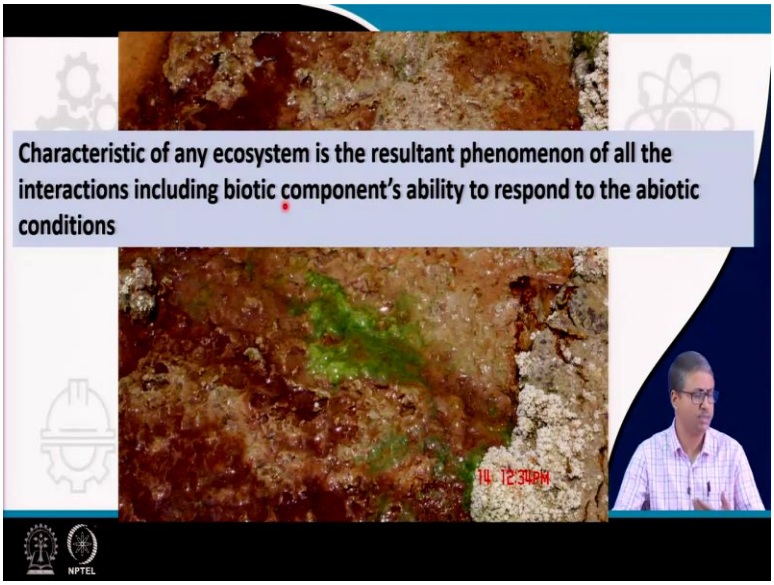

Now again if we come back to this kind of ecosystem. We can easily understand that this kind of flow of energy flow of materials. And we are going to talk about this this detail of this flow of energy and all these things in our new lectures. Now within this particular case that we have presented here that is a kind of a contaminated or toxic waste generated by a mine site. We can easily identify that the characteristic of any ecosystem.

In this case may be this mine contaminated mine site or or similar environment. So, characteristic of any ecosystem is basically the resultant phenomenon of all the interactions including the biotic components biotic components ability to respond to the abiotic conditions. So, it is not essentially just identifying few species or identifying few compounds some of them may be toxic some of them may be may not be toxic but essentially required as important important component of their their nutrients or may be present as a characteristic of property of

that particular environment.

But taking into consideration everything how the biotic components are interacting with these abiotic components and what is the resultant equilibrium the homeostasis how that is maintained that actually defines the the the characteristic property of any of the ecosystem.

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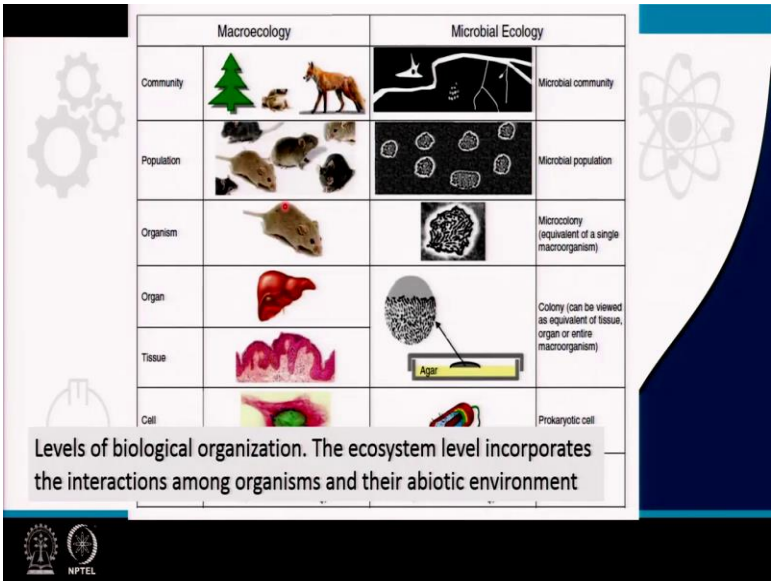

So, as we can also see that within this macro ecological concept and microbial ecological concept we can identify that at each level whether it is a cell in case of eukaryotic organism and or tissue or organ or in case of a prokaryotic cell as you can see the prokaryotic cells to colony. And then colony means the numerators are the million cells together and then cells are together and then they form population when they belong to same species and the populations are actually all the populations together from the microbial community.

So, in case of both macro ecology and micro ecology we see that this this this type of hierarchy where we can see that there is a tre trend from the cellular or maybe the molecular level to the community level. Now this represents the levels of biological organization. So, ecosystem level incorporates the interaction among the organism and their abiotic environment. So, it is already as I have already discussed that each level the the members are interacting with the with the their surrounding environment.

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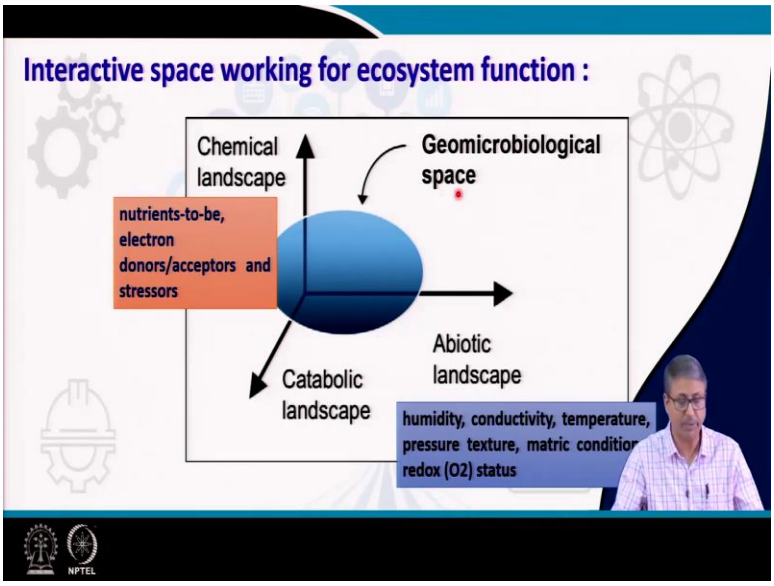

Now this environment is referred as the interactive space. Interactive space where the species members they themselves interact of course as well as they interact with the abiotic components. Now here I am able to identify these biotic components as the the chemical landscape as well as the other other factors which are considered as the the abiotic landscape typically the physical landscape I would I would say.

So, the chemical landscapes are basically the materials or the new compounds including the nutrients to be that means which are utilized or potentially utilized by microorganisms including the electron donors, electron acceptors, different stressors, carbon sources, nitrogen sources and many other things which are potentially the nutrients or the or the metabolic resources for the organisms who are living in that environment.

The typical a biotic landscape that is the physical typically physical landscape includes the the humidity conductivity temperature pressure texture the metric condition redox status etc. Now as you can see that is it is having three vectors this I would like to introduce you to you in this context with the term geo microbiological space because in in any kind of environment we have several geological components hidden within it.

So, characterizing those geological components that include basically the chemical landscape and the physical landscape and the microbiological properties that is the catabolic landscape that

is all the organisms who are having their enzymes basically capable of performing the catabolic reactions and that is allowing the flow of material and energy within this ecosystem are defined as the the the geo microbiological space within any ecosystem. So, in any ecosystem we would be able to define these three landscapes surely.

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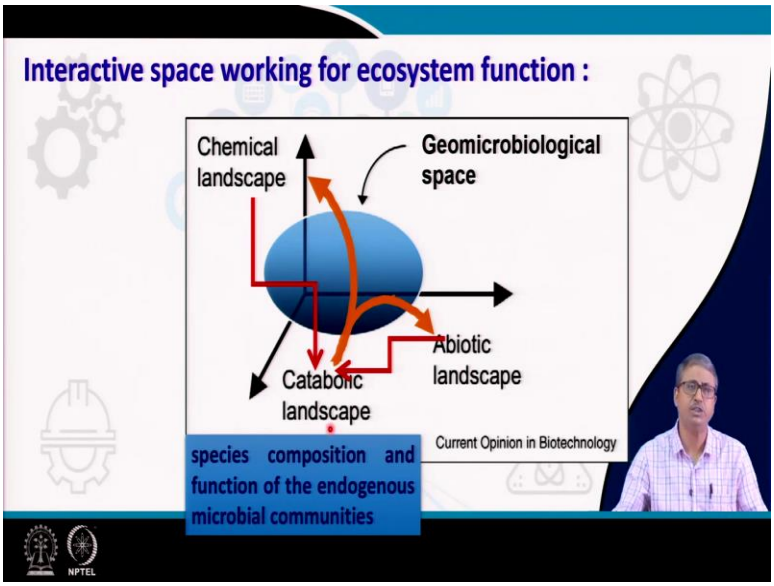

And in our our lectures we are going to discuss maybe maybe in the later classes. I will talk in detail about how to characterize this. Now if we look into into some more detail that these chemical landscapes like the nutrients what type of nutrients? Is it organic carbon or it is inorganic carbon whether organic carbon acts as the electron donor in this case or it is the inorganic species which are or inorganic materials which are used as electron donors?

What are the types of electron acceptors available. All these chemical parameters actually define the the species who are living in in that particular environment that is the the kind of species living in a particular environment. It is just if I take you to the same mine site where we were investigating something you can identify that the the low pH the presence of high iron high sulphate lack of organic carbon could have a direct implication on the the kind of biotic members present in that organism in that ecosystem surely.

The other component is the the abiotic factors that that also the abiotic factor also has a very significant control on the catabolic landscape. So, basically catabolic landscape would be would

be discussed in detail later. But at this moment as I said earlier that it is representing all the enzymes encoded by all the species member present in that particular environment. Now this is one side of the story why it is one-sided side of the story?

Because so, far we have talked about how the different chemical factors and different other factors which are not biological. But they are like the pH and redox and other factors they control the catabolic activity including the the kind of species present in that environment and the functions they are capable of carrying out in that particular environment. But it is not only that it has another another because some time ago I I talked about that modify and respond.

So, the chemical and abiotic landscape possibly try to modify or control the species composition and their function that is the catabolic landscape. But eventually the organisms present over there they also they also execute their ability to control or to change to some extent at least the chemical conditions and the the the abiotic landscape of this environment. So, again it is it is modify and respond.

So, the chemical antibiotic or the physical or biotic components are able to exert some kind of effect on the ecosystem surely. But it is not one-sided the organisms are also able to respond and try to change the environment environmental conditions then eventually as I mentioned the equilibrium is reached. So, and that continues.

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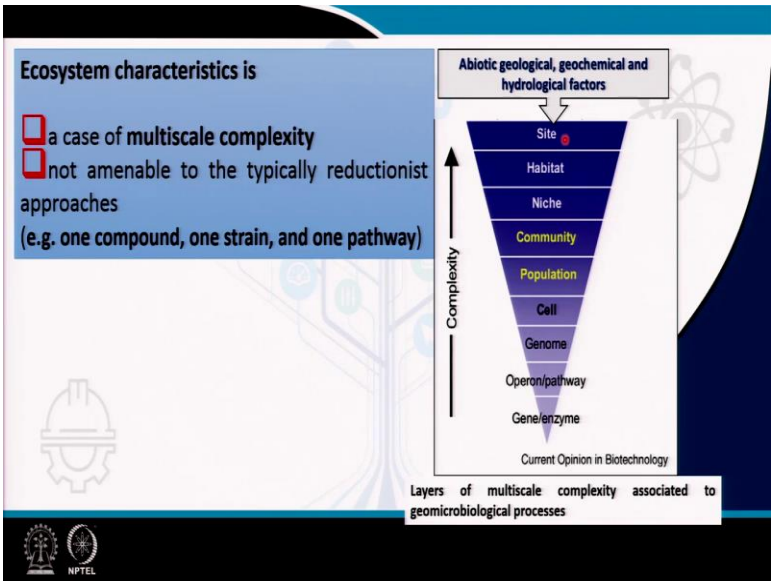

Now ecosystem the characteristic is a basically a case of multi scale complexity and it is it is ideally suggested that it is not amenable to the typically reductionist approach like there there is only one compound to be used as a nutrient resource or there are only one strain or one species which is predominant. And perhaps there is only one major pathway which is going to be regulating the major ecosystem function within a particular ecosystem.

So ideally that is not advisable. So, it is it is considered to be a multiscale complexity, why? It is considered to be a multiscale complexity because sometime ago I was talking to you that the interaction starts from the gene or even from the enzyme level and it goes through the pathway and genome to the cell to the to the community and further up from the community the niche habitat and the site.

So, all kind of a biotic, geological, geochemical, hydrological factors which are present in any kind of site that is any kind of environment or ecosystem is going to control by the organisms present there and the organisms themselves they also try to control the entire environment. So, when we talk about environmental biotechnology whether it is a pollution abutment technology, whether it is a carbon sequestration technology or whether it is some kind of other technology which is which is useful for developing a sustainable way of handling a particular environment.

We need to remember that environmental systems are highly complex where multiple species

interact at different levels.

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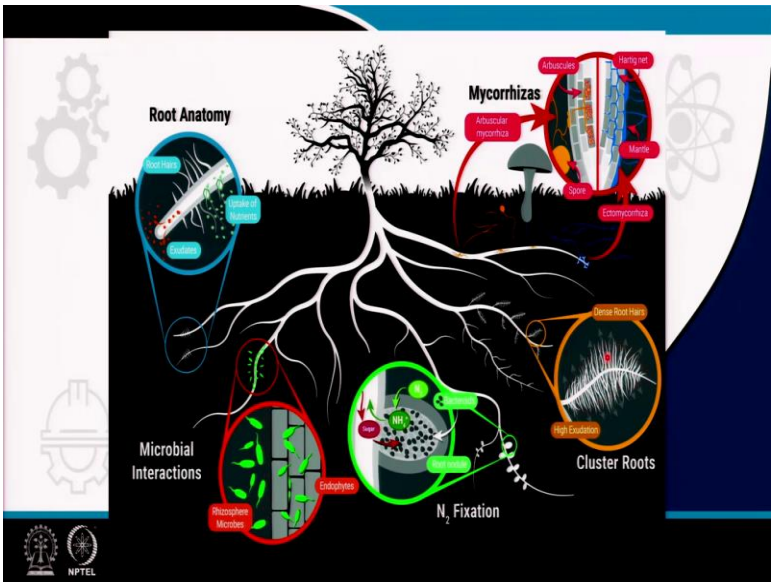

And this multiple species interacting at different levels can be visualized through this type of cartoons where you can see that under in underground system how the plant roots are allowing different type of microbial interactions within the the rhizosphere where the some kind of endophytes are there. Where root nodules are involved in nitrogen fixation and also the roots are able to produce some organic chemicals or depending on which many organisms are surviving.

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And we can actually take a part of this this picture and again come back to our the catabolic landscape where you can see that there are numerous microbes who are able to perform in in root

nodules. And the chemicals different chemicals like the nitrogen or the ammonia or the sugars which are released by the root nodules are essentially controlling the kind of species present over there.

And the the abiotic landscape is the different other factors including the humidity, conductivity temperature pressure etcetera.

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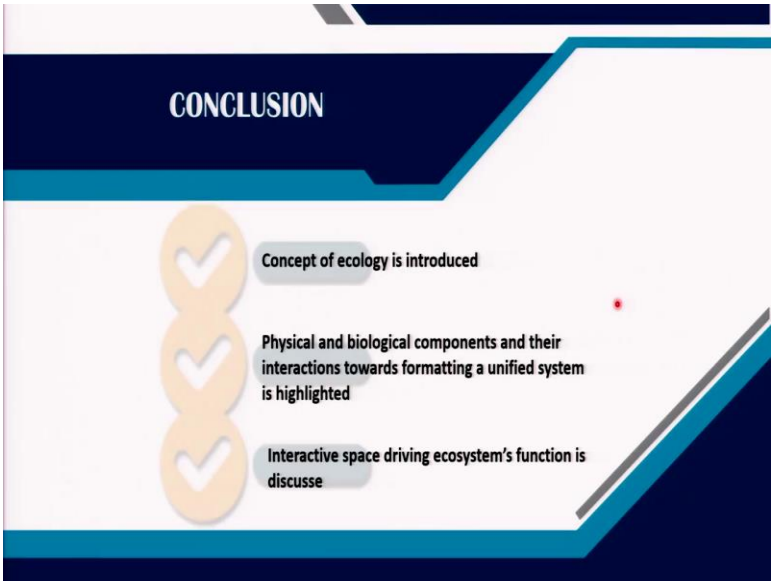

So, in conclusion in this session we have introduced the the basic concept of ecology. And the physical and the biological components are identified and their interactions towards forming a unified system is also discussed in brief. The interactive space driving the ecosystem function is also discussed, thank you.