Environmental Biotechnology
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Lecture – 08
Biogeochemical Cycles

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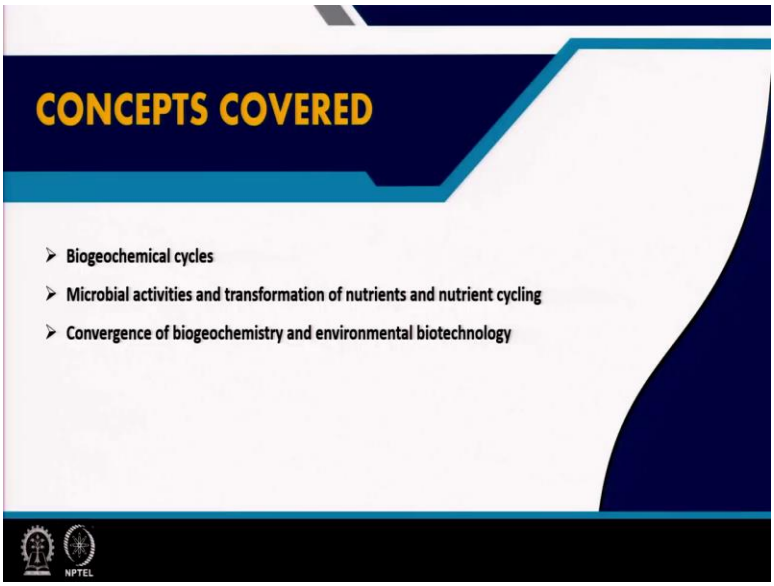

Our next lecture will be on biogeochemical cycles in this particular session we are going to discuss the concepts related to the biogeochemical cycling, microbial activities which control these transformation or bio transformation of nutrients and facilitate the nutrient cycling. And also we will see how the biogeochemistry and environmental biotechnology these two fields actually they converge together.

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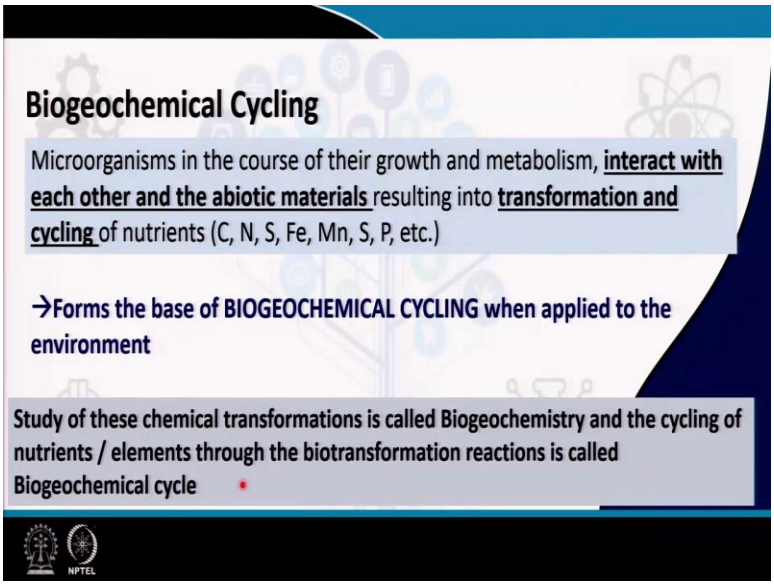

So, biogeochemical cycling microorganisms in the course of their growth and metabolism interact with each other and with the abiotic materials or abiotic environment resulting into the transformation of elements and nutrients and resulting into also the cycling of the nutrients. Now, there are actually a couple of points to be to be discussed it is actually multiple species as we know that present in any environment.

So, multiple species they interact. So, as we have just learned that how microbial populations interact to form the gills and microbial community interacts with their abiotic environment. So, basically multiple populations together they form the community and the communities are also of different types. So, these species members or the populations or the communities they interact with each other.

So, the interactions occur at each level. So, it may be the inter species intra species inter species between the communities and it is also interaction between the abiotic material. So, there are lot of exchange of chemicals and mostly the chemical interactions between all these things. So, these interactions the lead to the transformation of the materials like the carbon as we see the carbon dioxide is converted to organic carbon organic carbon is again oxidized to carbon dioxide and then carbon dioxide again reduced to methane.

Methane is again really oxidized to some kind of other carbon form including the carbon dioxide

and the carbon cycle goes on. So, that leads to cycling of the nutrients. So, within biogeochemical cycling we are going to see how microbial activities play the critical role in these transformations and nutrient cyclings. Now, these processes that is the; bio geochemical cycling or the transformation or the interaction between the multiple species and multiple communities along with their abiotic materials a biotic environment that forms the basis of biogeochemical cycling.

So, what forms the basis of the micro bio geochemical cycling? It is the interaction between the different members of an ecosystem or the community and also with their abiotic counterpart that is the all the aquatic physiochemical environment when applied to an environment. So, in any kind of environment or any part of the environment any habitat we see the biogeochemical cycling is going on.

Now, this biogeochemical cycling involves both biological and chemical processes. So, many of the reactions are chemical reactions which are actually catalyzed by the microorganisms or the enzymes. So, they have a strong the biological control into that chemical transformation it is also true that in many of the cases the microorganisms they sequester or they accumulate different type of nutrients within them.

So, the nutrients or the different type of elements including some of the heavy metals they remain unavailable to the rest of the chemical reactions which are happening in the external in the bulk environment. So, together it is basically the interaction between again the biological and chemical processes which control the or regulate the bio geochemical cycling. Now, study of these chemical transformations.

So, chemical transformation means as I try to briefly mention that the microorganisms during their growth during their metabolism they continuously transform different chemical species. For example the carbon dioxide is transformed to glucose or organic carbon organic carbon is again oxidized to carbon dioxide carbon dioxide is reduced to methane. So, these are all chemical transformation. So, study of these chemical transformations is called biogeochemistry.

So, there could be a carbon biogeochemistry there could be a kind of a biochemistry of all the nutrients which are there because often the biogeochemical cycles or biogeochemical transformations are interconnected. And the cycling of nutrient elements through the biotransformation reactions are called biogeochemical cycles. So, there are two things those two things are interconnected.

So, one is the biogeochemistry which is the study of these chemical transformations and the second is the biogeochemical cycle which refers to the cycling of the nutrients or elements through different type of biotransformation reactions.

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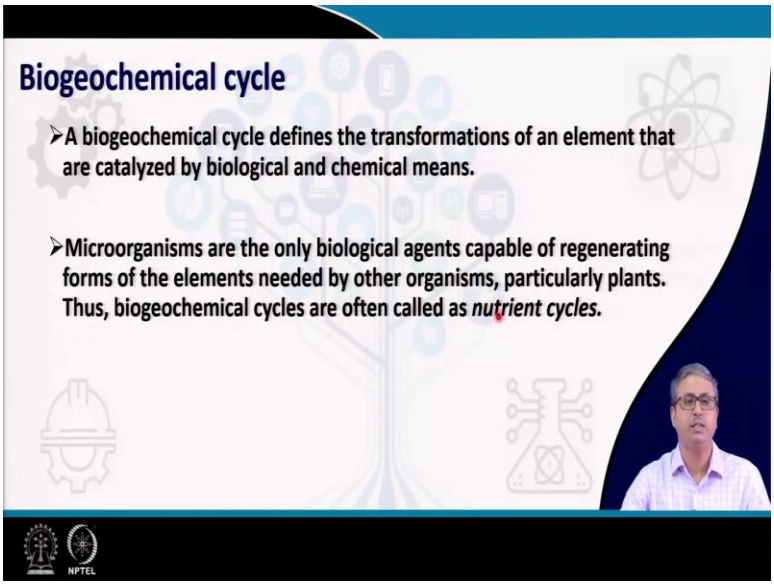

So, biogeochemical cycle is defined as the transformation of an element that are catalyzed by biological and chemical means. And microorganisms are the only biological agents who are capable of regenerating forms of the elements needed by other organisms. So, they continuously transform the elements around them and they regenerate the materials regenerate in the sense they regenerate the material in a form.

So, that that is accessible to other organisms particularly plants for example nitrogen the atmospheric nitrogen is inert and cannot be assimilated by any other plant materials or plant cells. So, it is the nitrogen fixing microorganisms, who convert the nitrogen to ammonia and the ammonia is released or ammonia is again converted to nitrate and the nitrate is also or nitrite

which are available to the other organisms including plants.

Plants assimilate ammonia nitrate or nitrite and then use it for its own synthesis of amino acids and other nitrogen containing compound and that nitrogen eventually goes to all kind of eukaryotic other organisms like who are who are dependent on the plants. Thus the biogeochemical cycles are often called as the nutrient cycle because many of the element cycle elements which are cycled within the biogeochemical processes are basically different type of nutrients.

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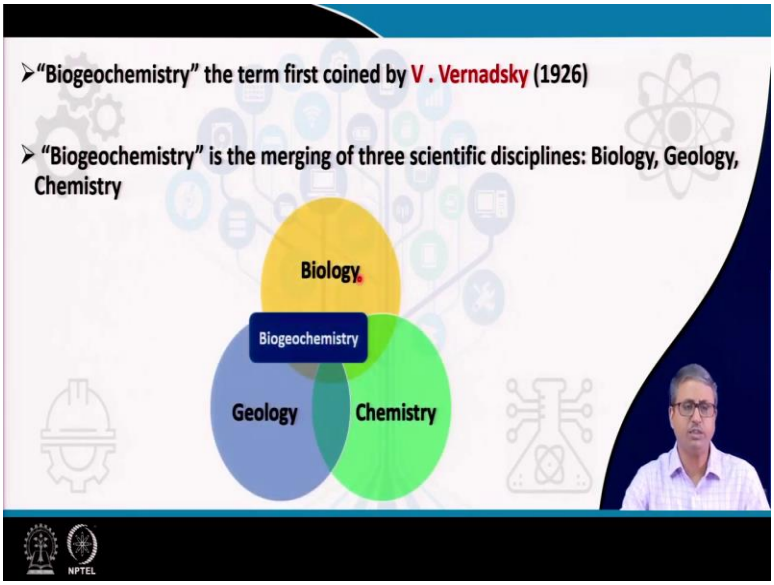

It is the term the biogeochemistry is the term first coined by ah Warnersky in 1926 and it is actually merging three scientific disciplines and these are biology geology and chemistry as you can see. So, biology is a biological reaction catalyzed through the chemical transformations and it is a great deal of geological context because these reactions are happening in different geological settings. So, overall it represents the bio geochemistry because it has it is the merging of three scientific disciplines.

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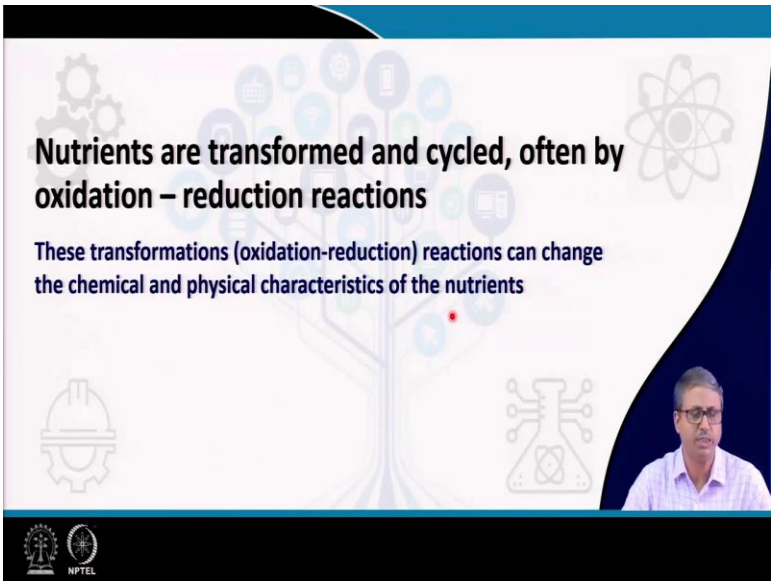

Now, within this biogeochemical transformation or the biogeochemistry the study of these reactions we see that the nutrients are transformed and cycled. Often by the involvement of a very specific set of reactions which are called oxidation reduction reactions that is something is oxidized or some other thing is reduced. These transformations reactions that is the oxidation reduction reactions can change the chemical and physical characteristics of the nutrients as well.

So, these oxidation some of the oxidation reactions can alter the chemical and physical properties in some way whether and as well as some other reduction reactions can again bring back those nutrients or other chemicals to their original form or can alter them subsequently. So, these alterations are we call them physical or chemical alterations the alterations of their physical and chemical properties.

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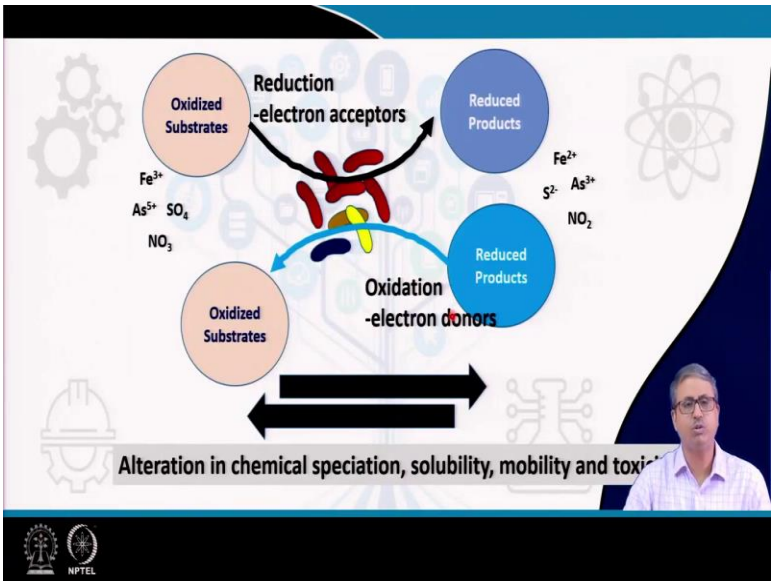

So, I think that will be very clear if we look at this simple graphic. So, as you can see over here. So, we have actually couple of microbial cells and some of the cells are capable of actually utilizing some substrate which are the reduced product. For example the sulfides nitride Fe 2+ or arsenic 3+ etcetera and some of them are used as the source of electrons also in lithotropic reaction.

Like as you know that chemolithotrops they use the reduced inorganic materials like ammonia nitrite sulfides iron as their source of electrons. So, they oxidize some other reactions are also there. So, eventually its oxidation reaction, so, these reduced materials are all oxidized and the electrons are taken out the electrons are used in the metabolism of these microbial cells and they produce oxidized substances.

So, for example the sulphide will be oxidized to sulphate the nitrite nitrite could be oxidized to nitrate the Fe 2+ could be oxidized to Fe 3+ arsenic 3 could be oxidized to arsenic 5+ and so, on. So, numerous inorganic materials inorganic molecules will be or can be utilized by microbial cells or microbial populations as their electron source as we learned earlier electron as energy electron input of electrons or electron sources.

So, they oxidize them. Now, these oxidized substrates like for example sulfide is oxidized to sulphate. Now, this sulfate could be utilized by some other organisms as a source as a electron

acceptor as a potential electron acceptor. So, under anaerobic condition we know that alternate electron acceptors are required to drive the metabolic processes or metabolic reactions. So, this sulphate or the Fe 3+ or arsenic 5 or the nitrate all these oxidized products which products which are produced by the oxidation reactions or they may be available naturally in these forms.

So, these oxidized substrates are eventually the substrate for the further reduction reactions many a time they are reduced because they drive the metabolism when they are used as a terminal electron acceptor or electron acceptor during their anaerobic respiration. Sometimes the reduction is also facilitated to combat the toxicity of the compound like for example for different type of other elements.

We see that maybe for chromium and other things we see the reduction is facilitated because of or even for arsenic also. So, to change the toxicity of these molecules. So, essentially these oxidized substrates are reduced and reduced products like Fe 3ee is converted to Fe 2+, sulphate is reduced to sulfide nitrate is reduced to nitrite and so, on will be produced. Now, this is one part of the entire transformation reactions where two types of transformation reactions are clearly seen one is the oxidative type of reactions another is reductive trans type of reactions.

And what we also see that these type of reactions they change the chemical parameters. So, the change in chemical parameters will be our second part of discussion. The major first part of discussion is these oxidation reduction reactions are facilitating most of the time the microbial metabolism. So, microbes are interested in these oxidative reactions or reductive reactions because they are either gaining energy out of it or they are able to drive their electron transport process which facilitate the growth and survival in any kind of environment.

But the other part of the this interaction is that these oxidation reduction reaction facilitate alteration in the chemical speciation or chemical properties of these inorganic molecules inorganic compounds they alter the solubility of these compounds they alter the mobility of the compound in the environment and sometimes they alter the toxicity of these compound which are present in an habitat. So, these redox transformation or oxidation reduction transformations these are facilitated catalyzed by specific group of microorganisms owing to the presence of

specific enzymes.

So, these oxidation or reduction reactions produce or convert some molecules to other molecules with altered physic-chemical properties which actually often are connected to their solubility or may be solubility in the sense their water solubility their mobility within the environment and also their toxicity.

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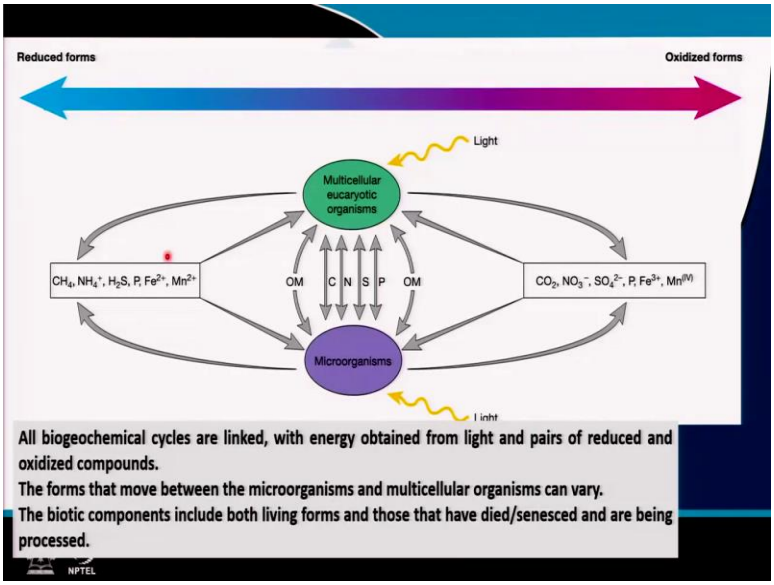

And these interactions are not limited within the microorganisms or a set of microorganisms within itself. In fact all the different type of transformation including the organic carbon, carbon, nitrogen, sulphur, phosphorous these are all interlinked as the reduced forms are getting oxidized and the oxidized forms are getting reduced by the microorganisms themselves but also they produce the product or they consume the substrates which are eventually going to be affecting the multicellular eukaryotic organisms their activity as well.

So, as I mentioned earlier that in any kind of community there will be a close interaction between the macro organisms. So, the microorganisms which are catalyzing this redox transformations. These redox transformations catalyzed by the microorganisms are also interconnected with the activities of the multicellular or macro organisms. So, the essentially that means the all the biogeochemical cycles or all the cycling of the nutrients different nutrients and elements are essentially linked and they are linked.

As these processes could be coupled and with the energy obtained from either light or pairs of reduced and oxidized compound. As we can see that oxidation will provide the electrons and if an energy also for chemolithotropic organism for example. The forms that move between microorganisms and multicellular or macro organisms can vary. The biotic components include both living forms and those that have died or sensed and are being continuously processed within the system.

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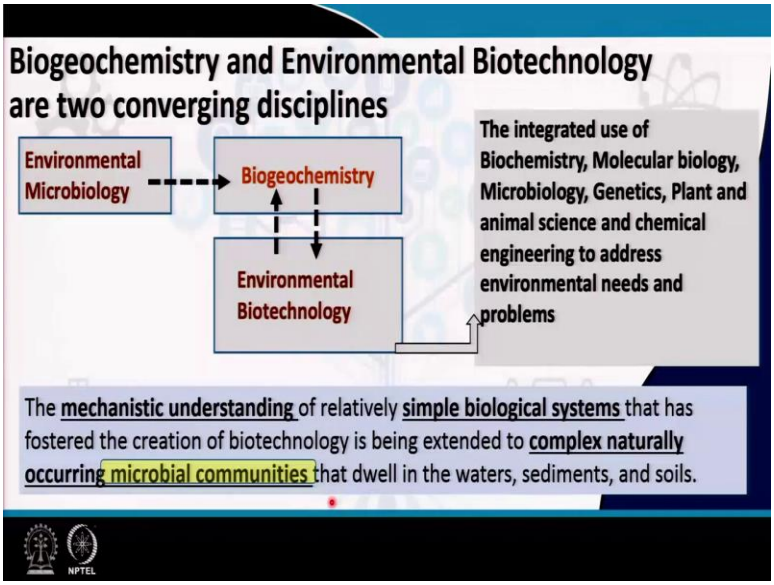

Now, the biogeochemistry this particular subject or this particular field and the environmental biotechnology are actually two converging disciplines. Why it is said that these are these two are converging disciplines because the environmental microbiology or in is connected to the biogeochemistry and biogeochemical processes biogeochemical details are actually intricate part of the environmental biotechnology.

Because as we know within environmental biotechnology we use the integrated system where the biogeochemistry or biochemistry of the organisms biochemistry of the processes, the molecular biology, the microbiology genetics plant and animal sciences everything is included including the chemical engineering principles to address the environmental needs and the problem. Now, within this area of integrated use the biogeochemistry plays a very significant role.

The mechanistic understanding of relatively simple biological system it may be a very simple electron transfer system. Electron transform from the one particular compound to the another compound this mechanistic understanding, understanding this entire process that how this is facilitated. Simple oxidation of sulfide or a reduction of sulfate in a given environment or oxidation of a particular species of arsenic or reduction of iron within a particular type of environment that has fostered the creation of biotechnology.

And is being extended to complex naturally occurring microbial communities in order to like microbial fuel cell, in order to have advanced wastewater treatment system, in order to generate lipids and other biologically useful molecules from carbon dioxide everywhere we see that the extension of these mechanistic understanding is achieved. So, environmental biotechnology has a core within itself that is actually the community function.

And the community function is basically represented by the biogeochemistry where the organisms they function they carry out the chemical transformation within a particular geological or physic-chemical environment. Now, the core issue is the microbial communities their activities within a particular environment that facilitate the chemical transformation which leads to the basis of the biogeochemistry.

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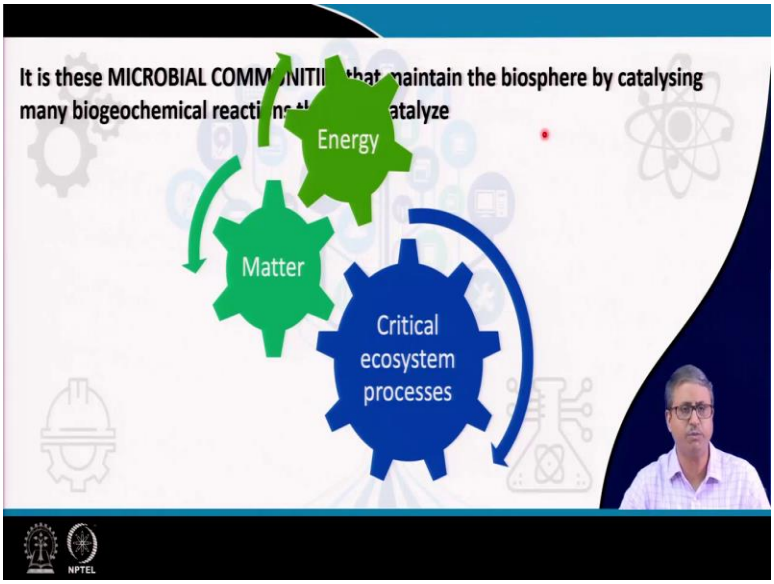

Now, it is these microbial communities which are prevalent in any kind of applied system or any kind of natural system which we wish to understand and then improve or use that understanding to develop a technology. So, it is these microbial communities that maintain the biosphere by catalyzing many biogeochemical reactions that they catalyze. So, we have seen this kind of events earlier that the entire planet the biosphere is driven by the microbial transformation reactions where the matter and energy are continuously being transformed into or recycled within the entire planet planetary system or the biosphere.

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But what we can gain from the knowledge of these biogeochemical reactions. So, modern biogeochemistry demands fundamental knowledge on enzymatic, genomics, genetics, biochemical and physiological basis of a plethora of microbially mediated processes because as we can understand in any kind of habitat or any kind of environment or ecosystem we have multiple habitats or within habitats we have multiple micro environments.

So, within each of these environments we have multiple actually layers of microbial communities. So, each of these communities are actually having very unique set of reactions going on within themselves. So, understanding those reactions at the enzymatic level at their genomics level at their genetics level and the biochemical and physiological levels will be essential in order to translate the basic understanding to any kind of applied processes.

And such knowledge that that basic knowledge about the enzymatic processes for example of the genomics or the genetic or the physiological basis of these kind of transformation reactions which are conducted or catalyzed by the community members who are present in an environment will provide the deep level understanding which is the gateway of two important goals. And these goals are intrinsically connected our goals these goals are focused towards environmental biotechnology.

Number one is the wise and efficient management of ecosystem if we want to manage any ecosystem. If we want to restore a degraded ecosystem if we want to restore or remediate a contaminated lake or want to devise a strategy in which the ground water can be the contaminated groundwater can be treated or we want to develop a wastewater treatment system which will be more efficient than its earlier versions.

So, we need to have the understanding about how the microorganisms are microbially catalyzed bio geochemical processes are going on within that particular system. And the second one is the potential exploitation of the process which will help us to develop new or improved services or technologies. So, one aspect is to have the better understanding of the process and another is the development of improved or new processes based on like microbial fuel cells for example or carbon sequestration technologies or development of a technology where gaseous carbon dioxide or atmospheric carbon dioxide can be converted to lipid molecules.

So, in any of those new technologies we will be able to we will be requiring that the exploitation of this knowledge which is knowledge at all levels enzymatic to genomics to the physiological levels will be essential.

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So, for this part of my lecture Brock Biology of Microorganisms, Prescott, Harley and Klien microbiology books these books will be useful along with that Environmental Microbiology From Genomes to Biogeochemistry will be will be good microorganisms and their roles in Fundamental Biogeochemical Cycles by Madsen will be very useful for this particular part of my lecture.

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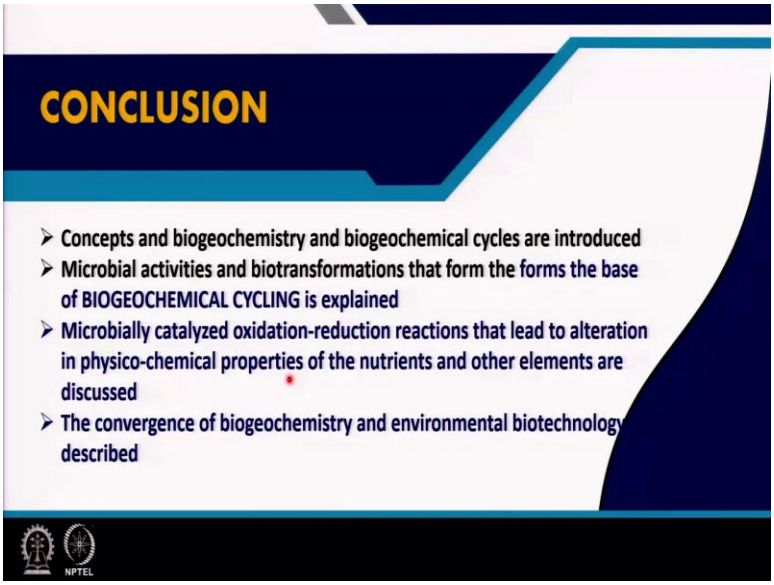

So, in conclusion concepts of biogeochemistry and biogeochemical cycles are introduced microbial activities and bio transformations that form the base of biogeochemical cycling is explained. Microbially catalyzed oxidation reduction reaction that leads to alteration in physiochemical properties of the nutrients and other elements are discussed. And finally the

convergence of biogeochemistry and environmental biotechnology is also described, thank you.