Environmental Biotechnology
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Lecture – 21
Physiological Ecology and Resource Exploitation by Microorganisms

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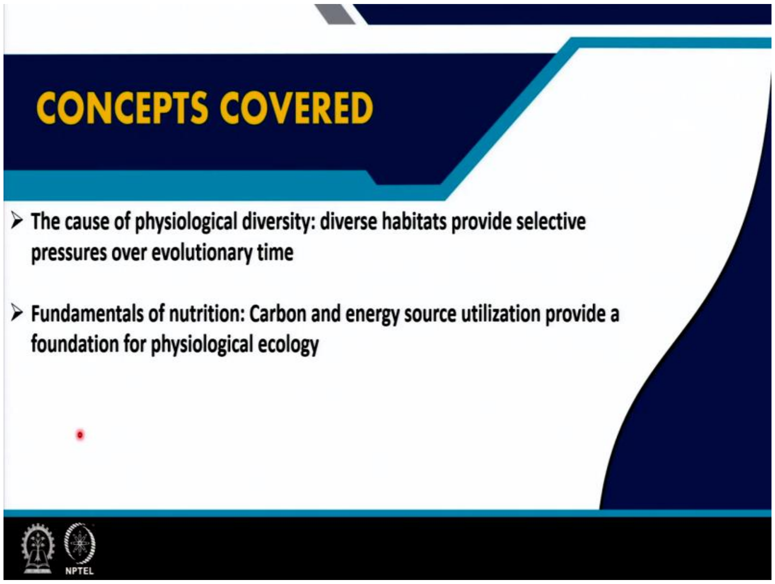

Welcome to the next lecture on Physiological Ecology and Resource Exploitation by Microorganisms. In this lecture the following concepts are going to be covered the cause of physiological diversity, diverse habitats that provide the selective pressures over the evolutionary time. And the fundamentals of nutrition carbon and energy source utilization that provide a foundation for physiological ecology will be discussed.

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So, to begin with diverse habitats on our planet provide a large number of selective pressures and these selective pressures have been in action over the evolutionary time. And as a resultant of these selective pressures over a very prolonged time the physiological diversity of microorganisms have been manifested.. Now in this regard we must appreciate that metabolism replication and heredity are the 3 critical traits of life.

And the 3 processes like the metabolism replication and heredity are inseparable for from the environmental context which provides the resources for metabolism and selective pressure for both replication and heredity. In our earlier lectures we have noticed that how DNA replication and subsequent division of cells are controlled or influenced by the availability of the nutrients and the concept of exotrophy and endotrophy where the G1 and G2 phase or the synthesis and mitotic phases are found to be strongly connected particularly in eukaryotic cells.

With respect to prokaryotic organisms like the bacteria and archaea although we do not have such discrete types of events in the cell cycles but we have learned that there are systematic events which facilitate the division of the cells. And this division of the cells that is the cell multiplication and cell growth and proliferation are intricately connected to the cell metabolism and the cell metabolism and the cell proliferation and cell growth these phenomenon are again closely related to the environment.

So, when we design any environmental system or we start working on any environmental system for environmental biotechnology purposes we need to understand and appreciate the importance of these environmental factors environmental context which provides the resource for the metabolism or other functions like the replication and hereditary control or transmission of the of the genotypic traits into the subsequent population substitute subsequent progeny.

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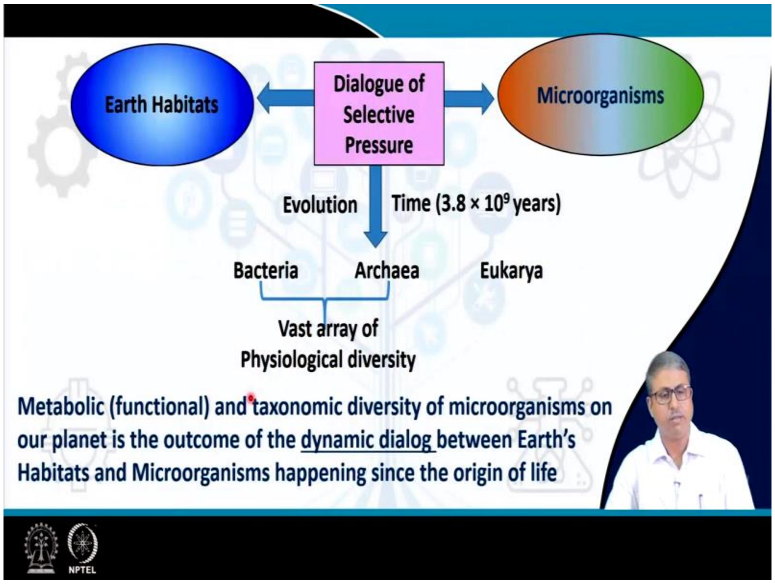

So, in this slide we are going to discuss the metabolic that is the functional and taxonomic diversity of microorganisms that is present today on the earth that is called the extant diversity is the outcome of the dynamic dialogue between Earth's habitats and microorganisms happening since the origin of life. Since we know that the origin of life on our planet took place sometimes around close to 4 into 10 to the power 9 years ago.

And since then the earth habitats both the above ground and below ground on the surface of the soil and surface of the sea or the other water aquatic habitats to the deep oceanic sub surface etcetera. The earth habitats are continuously in interaction with the microorganisms in order to shape the microbial metabolic properties their genetic mechanisms and other properties and at the same time as we have learned earlier the microbial properties are also continuously affecting the earth habitats where wherein these microorganisms are living.

So, this is called the dialogue between this between these two particular parts one is the earth habitats the different type of habitats those are present in the earth planet earth and the numerous type of microorganisms which occupy those habitats.. Now these dialogues so, it is a kind of a multiple levels of interactions which are considered as the dialogue and this is referred as dialogue of selective pressure because these kind of interactions as we will see will result into different kind of forces.

And these forces are going to shape the microbial function microbial activity their ability to reproduce proliferate and act within the environmental context. So, wherever it is by remediation of the polluted soil or bioremediation of a contaminated river or a lake or sequestration of carbon or any other environmental biotechnology process we must understand how the organisms working there for our benefit are subjected to the selective pressure.

And the local and the regional selective pressures for our purposes may be and how they are going to work on the functions of these organisms.. Now going back to the original point of discussion that these interactions or this dialogue between the microbes and the earth habitats are in place for a very very long period of time like 3.8 billion years or so. And because of these continuous interaction both planetary system the planetary habitats which are which we observe where microbial cells or other life forms are living.

And the microorganisms themselves they are evolving both of them are evolving and resulting into different types of organisms particularly if we try to keep our focus on the prokaryotes and the eukaryotes then the bacteria, archaea and the eukarya. So, diverse kind of these bacteria, archaea and eukarya are eventually evolved. And it is not only the diver taxonomic types of these organisms like more than more than 120 or so, or even more than that different bacterial phyla or numerous type of eukaryote eukaryotic phyla etcetera have been evolved.

But also what is important is the vast array of physiological diversity. Within each bacterial group within each bacterial taxa or genus we may we may find that there are huge amount of physiological diversity within a particular taxa or a taxon like pseudomonas or rhizobium or clostridium like genera. We can find out within a within a particular genus each of the members each of the strains they might have extensive diversity of different physiological properties.

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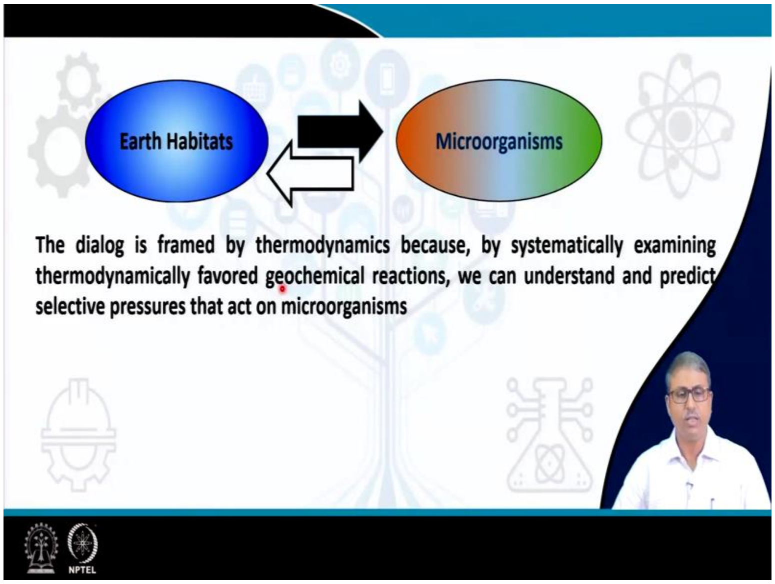

Now there is another very interesting point about this interaction or interaction or the dialogue. The dialogue between the earth habitats and the microorganisms which continuously is posing this electric pressure is framed by thermodynamics. Because this systematically by systematically examining the thermodynamically favoured geochemical reactions we can understand and predict this elective pressure that act on microorganisms.

So, such some of the thermodynamic some of the processes chemical or biogeochemical processes may be thermodynamically more favourable than others. And they might have a different impact on the cellular processes or the metabolism.

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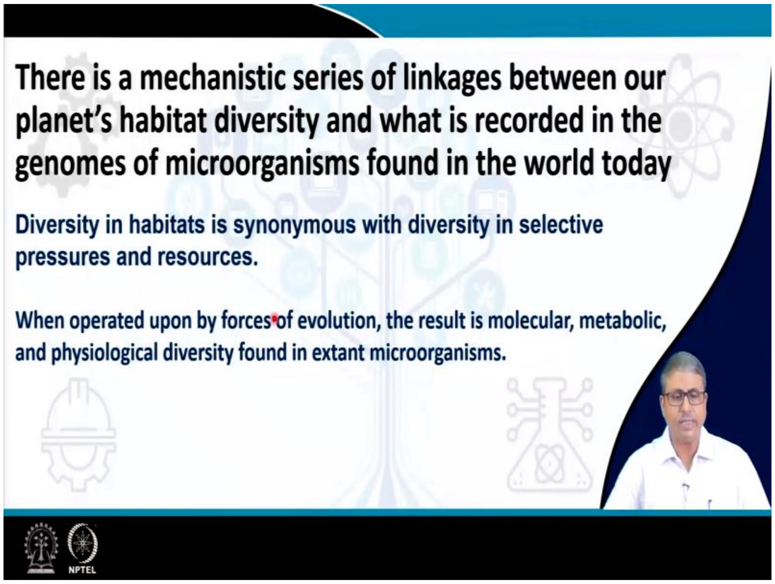

So, there is a mechanistic series of linkage between our planets habitat diversity and what is recorded in the genome of microorganisms found in the world today.. Now since the discovery of the whole genome sequencing technique and approach we have been sequencing the entire bacterial genomes huge number of bacterial and other archaeal genomes are sequenced. So, as we try to look into the genome sequences of the numerous organisms.

We find that there is a linkage between the habited diversity and what is recorded or what is imprinted on the genome that is basically the allocations of genes to different functional categories.. Now here the diversity inhabitants synonymous with diversity in selective pressure and resources it is easy to understand that each of the different type of habitats like the aquatic habitats to terrestrial habitat the river system to a pond system.

The oligotrophic or low nutrient ground water to a nutrient rich river or lake system. Each of these systems are different in terms of the kind of selective pressure they put or they enforce on the organisms who are living there and also the resources they provide to the living organisms present in that system. When operated upon by forces of evolution the result is molecular metabolic and physiological diversity found in the extant microorganisms.

Now this availability of resources and the selective pressures which are prevalent in each of the different types of habitats that we encounter in our planet and where living cells are there or microorganisms particularly are surviving. So, these re-selective pressure and resource availability type of the resources and the net quantity of the resources. So, they act like a force of evolution and with a prolonged period of time that result into the different kind of physiological which are basically encoded by the appropriate genetic and metabolic properties within these extant microorganisms.

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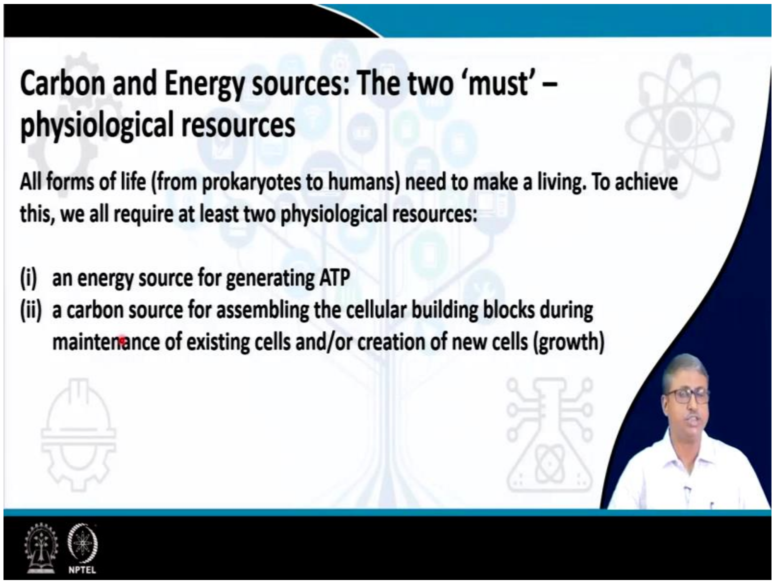

Now fundamentals of nutrition carbon and energy sources utilization will provide a foundation for physiological ecology. Now carbon and energy sources are considered to be two must physiological resources, why? Because all forms of life particularly from prokaryotes and even the humans also and in between all other heterotrophic organisms need to make a living they need to live. How each of the cells of a particular organism live?

Because in order to live they need certain resources and the two must resources are the carbon and the energy source. Now to achieve this all these cells including the human cells and the microbial like bacterial cells they require at least two physiological resources. The first one is an energy source for generating the ATP and the second one is the carbon source for assembling the cellular building blocks during the maintenance of existing cells and or creation of new cells.

Sometimes a same or the single substrate like a glucose molecule can be utilized by a cell to provide both the carbon source as well as the energy source because as we have learned that the oxidation of carbon or reduced carbon compound or the complex organic compounds can produce energy. They can also produce the reducing power and the reducing power can be subsequently utilized for the biosynthetic reactions.

So, when we have carbon source the carbon source sometimes can be performing two functions. So, carbon source as well as the energy source but it is not essential in some other organisms or some particular type of organisms they make they require two different type of sources one carbon source another energy source.

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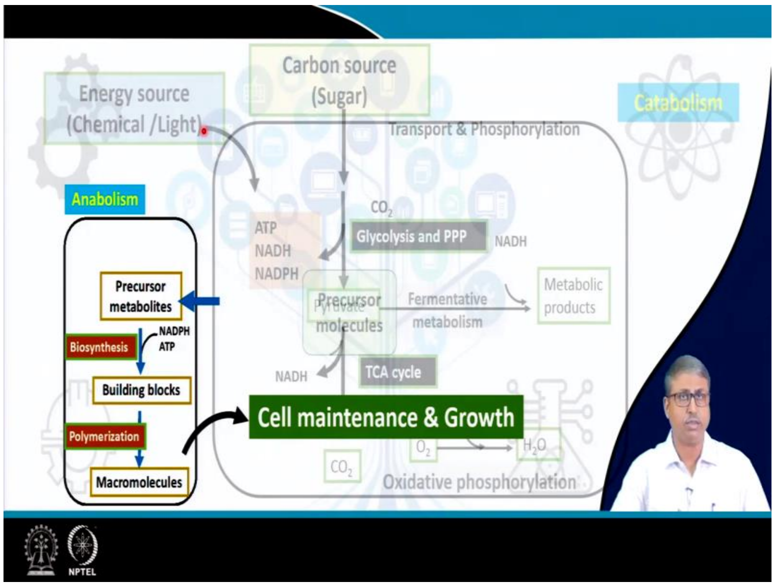

So, let us look at this diagram. So, any kind of microorganisms or cells will require the two sources that is the carbon source and the energy source. So, if I look at the carbon source for example the reduced carbon like sugar molecule following its transport and phosphorylation and all kind of standard biochemical reactions like the glycolysis, pentose phosphate pathway and the TCA cycle etcetera. This will lead to the production of the precursor metabolites of precursor molecules.

These are the small molecules like acetyl coa or pyruvic acid or phosphoglyceraldehyde or phosphoenol pyruvate type of molecules which then will form the resource for the biosynthetic reaction. Now it is not true that this oxidation of the carbon source will lead to the formation of only precursor molecules it is not true it is partly true. So, what else it will produce it will produce the energy and the reducing equivalent.

Because at many steps of this oxidation of the carbon we find that there are release of energy and that released energy can be trapped through phosphorylation reaction or by transferring the electrons to suitable electron carriers like nicotinamide adenine dinucleotide NAD to NADH like in glycolysis or embryonine male or furnace pathway or NADPH in case of pentose phosphate pathway. Some molecules of ATP can be generated directly out of these reactions or some more number of ATP's can be generated when the reduced NAD or electron carrier is reoxidized with the help of the terminal electron acceptor like oxygen and produce water molecule and leads to the formation of more ATP.

So, essentially the oxidations of the carbon sources produce the precursor molecules as well as the energy and reducing power. These ATP NADH or NADPH are the products of utilization of energy source as well. So, in case of some organisms like heterotrophic bacteria like E coli who can utilize carbon source and like a glucose molecule can be utilized as both carbon and energy source both ATP NADH and NADPH and precursor molecules can be simultaneously produced by the oxidation of the same carbon sugar molecule or carbon source.

However for certain other molecules like thio bacillus species or are acid thyroid bacillus species or certain other organisms like ammonia oxidizers iron hydrogen oxidizing bacteria they rely on or a phototrophic organism they rely on a different energy source which can be chemical energy or can be a light energy. So, they rely on the chemical energy or light energy either the organic or inorganic form and derive the energy from that and that energy can be translated to produce the necessary ATP and the reducing equivalent.

So, organisms particularly the microorganisms are equipped to utilize either different types of sources energy source and carbon source might be different in some type of organism it may be same in some other type of organisms or depending on the substrate also. Like reduced organic carbon often can serve the purposes as an electron source or energy source as well as a carbon source.

Now the products like the precursor molecules and the energy that is gained out of the reaction can be utilized for the anabolic reactions and the anabolism leads to the production of the macromolecules and eventually these macromolecules which are produced help the cell to engage themselves into the cell maintenance or facilitate the cell growth or even the both. So, ultimately it is the carbon source and the energy source these are the two fundamental sources.

Of course we need the other nutrients as well but these are the two major sources that that drive the entire process of cell metabolism within the within the living system.

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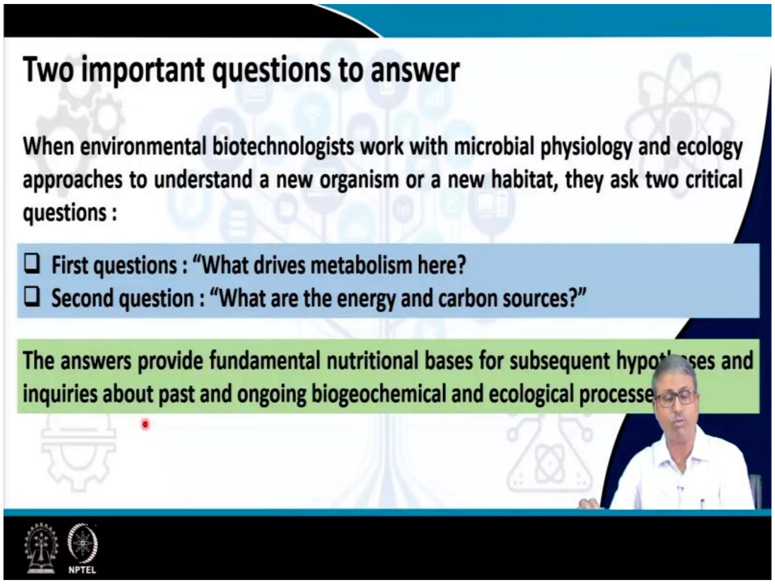

Now here we have two important questions to answer. Now when environmental biotechnologist work with the microbial physiology and ecology approaches to understand a new organism or a new habit be it a activated sludge system or a microbially enhanced nutrient removal, enhanced petroleum oil recovery or sequestration of carbon or other gases conversion of methane to useful molecule or a bioremediation project.

So, in any kind of environment where for a system where environmental biotechnologists are intend to work on some microorganisms or microbial processes or within a particular habitat they must ask two critical questions. First question is what drives the metabolism here. If it is let us assume a carbon sequestration or geosequestration of carbon dioxide there have been a global interest in geological sequestration of carbon dioxide to mitigate the climate change challenges.

Now when we look into the earth habitats or earth geological settings. So, there have been reports that are observation that some of the geological strata are more suitable for the sequestration of gaseous carbon dioxide. Now when we think of that we must understand that how this habitat. So, underground several 1000 kilometers or several 100 kilometers or 100 meters down the earth surface if we want to inject carbon dioxide and store it.

Or if we want to store nuclear waste in many countries nuclear waste are dumped or deposited or stored in safe depositories under the ground. So, those are habitats where microbes are also there you cannot throw out the microorganism. So, microorganisms are there. So, you can you are planning to store your waste or store your carbon dioxide in a stable form. So, microbes are going to be very important player in long term sustainability of such processes.

And sometimes they are critical for facilitating the processes particularly producing the minerals carbonate minerals out of carbon dioxide. So, the first question would be what drives the metabolism here and this is so, true for any other waste treatment or any other biotechnology environmental biotechnology process as well. So, first is what drives metabolism here. Now metabolism essentially means how the carbonyl energy sources are basically utilized.

So, then the second question is obvious question what are the energy and carbon sources available there and are being utilized by these microorganisms. Now the answers of these two questions provide the fundamental nutritional base for the subsequent hypothesis. And also in queries about past and ongoing biogeochemical and ecological processes relevant within such ecosystem or such habitats or such systems or with a particular organism.

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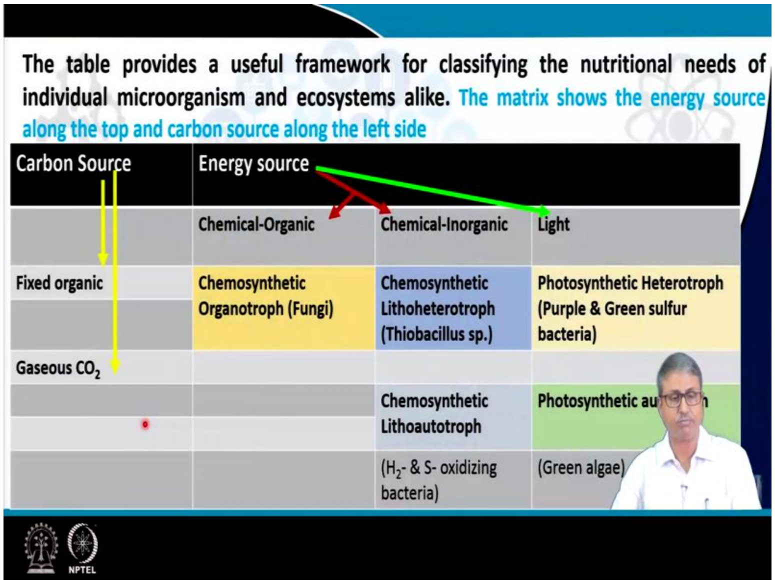

Now this table that I am showing here provides a useful framework for classifying the nutritional needs of individual microorganisms and ecosystems alike. Now the matrix here shows the energy sources on the top. So, we have the energy sources over here. So, basically we have put 3 different types of energy sources and the carbon sources over here the left side. So, we have two different type of carbon sources.

Now if I look carefully within the energy sources as I have mentioned earlier chemical energy and the light energy these two are main energy resources. So, far we know that the microorganisms or the cellular life forms they are capable of utilizing. Now the chemical energy can also be derived from two different way one is from the organic compounds breaking the C-C carbon bonds carbon-carbon bonds or its the inorganic like hydrogen sulfur nitrogen compounds which can be oxidized to produce the energy out of it.

And we have the light energy which basically drives the photosynthetic reactions. On the other hand the carbon sources could be fixed carbon or the reduced organic carbon for example the glucose but it could be other molecules like other polymers starch etcetera the cellulose etcetera or it could be the overall dead biomass for example or it could be the petroleum derived compound like alkanes and aromatic compounds which are abundant in natural system.

May be in the low concentration but for microbial activities they are enough. Gaseous forms of carbon dioxide and of course carbon monoxide as well also drive the or are found to be responsible for driving microbial metabolism. Now based on this utilization pattern we can surely identify simply two groups which are very, very prominent. One is the photosynthetic auto crops. So, everybody possibly understand that with utilizing this light and utilizing the gaseous carbon dioxide present in the atmosphere.

So, these are the organisms the green algae for example or the higher plants they are capable of photosynthesizing and producing the complex organic matter for themselves and also for all the other organisms heterotrophs who depend on them. On the other hand the chemosynthetic organograph for example the human or the fungi or many other in between organisms who are all heterotrophic even many bacteria are also there.

So, they all depend on the the food which is produced by the autotroph not only photosynthetic or but other type of autotroph as well. So, the chemosynthetic organotroph and the photosynthetic autotroph are considered to be two the primary or major groups or nutritional groups rather. Now along with that we can have or we will have the chemosynthetic litho heterotroph which are represented by mainly the prokaryotes a relatively rare.

Similarly photosynthetic heterotrophs different type of purple and green sulphur bacteria for example they are also exclusively prokaryotes. And compared to the chemosynthetic organotroph they are generally there except few specific habitats or environments where the predominance of these photosynthetic heterotrophs are observed. There could be another very interesting group which is called chemosynthetic litho autotroph.

So, these are litho autotrophs. So, they derive the energy chemical energy from the oxidation of inorganic substances like hydrogen, sulphur, ammonia, nitrite etcetera and they fix atmospheric carbon. So, they are very interesting group. So, they are not photosynthetically fixing carbon they are fixing carbon but the energy is derived from oxidation of inorganic molecules like hydrogen etcetera.

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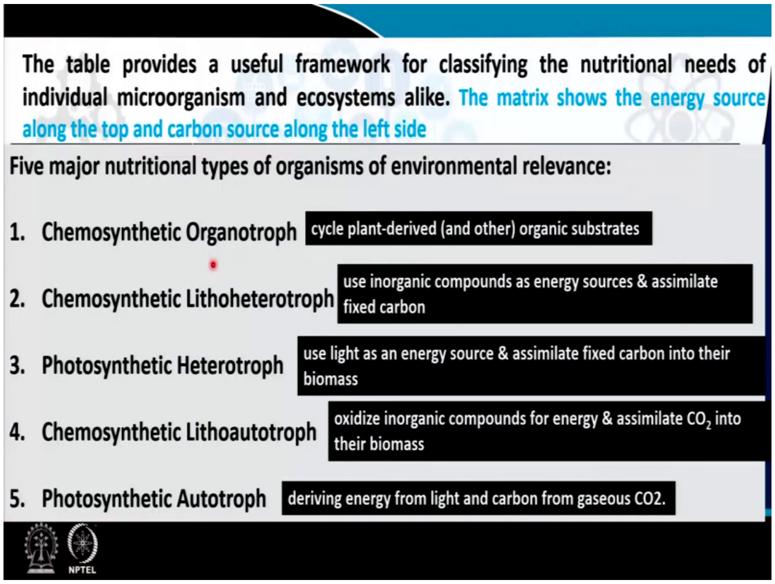

So, essentially we have the 5 major nutritional types of organisms of environmental relevance these are the chemosynthetic organotroph. These are chemosynthetic litho heterotroph photosynthetic heterotroph chemosynthetic lithotroph and photosynthetic autotroph. Now with respect to the first one the chemosynthetic organotroph it cycles the plant derived and other autotrophic or other heterotrophic organisms derived biomass or organic matter within the system.

So, in any ecosystem or habitats wherever these organisms are there and generally they are quite abundant they play a very important role because they can metabolize the reduced carbon or fixed carbon. So, either the it is fixed by plants, it may be fixed by algae, it may be produced by certain other microorganisms or it may be the carbons or small reduced carbon released by different other cells as a part of the metabolism or maybe the part of the degradation of their dead cells etcetera.

Next is the chemosynthetic litho litho heterotroph they utilize the inorganic compounds as energy resources but they assimilate the fixed carbon. So, they are heterotroph but they derive the energy from the oxidation of hydrogen or sulphur kind of things. Photosynthetic heterotrophs as i mentioned the purple and green sulphur bacteria they use light as the energy source but they assimilate fixed carbon into their biomass they are heterotrophy.

Chemosynthetic litho autotroph they derive the energy from the oxidation of hydrogen sulphur etcetera. So, inorganic compounds are oxidized for the energy but they assimilate carbon dioxide into their biomass. And finally the very well known photosynthetic phototroph which derive the energy from the light and carbon from the gaseous carbon sources.

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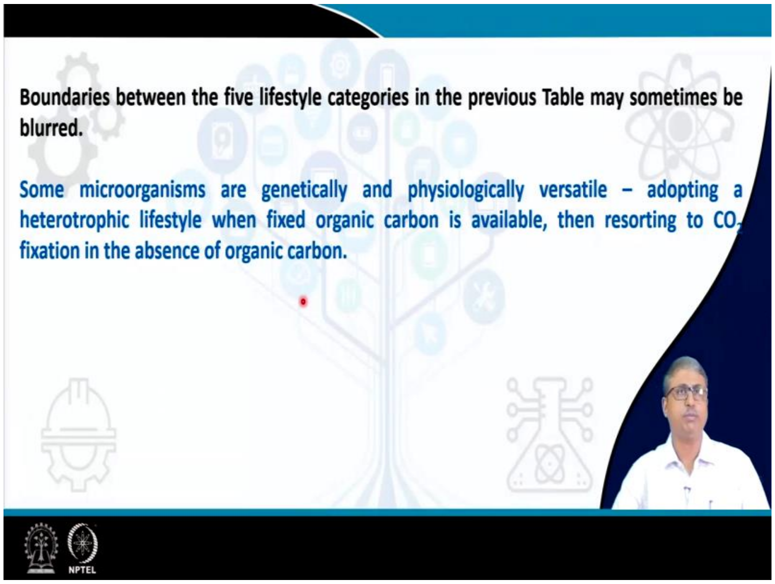

Now we may have these 5 well-defined nutritional types but the boundaries between the 5 lifestyles categories in the in the stable that we just discussed maybe sometimes be blurred. Because some microorganisms are genetically and physiologically more versatile they are they are truly very versatile. Versatile in the sense they can perform autotrophy as well as heterotrophic they may oxidize hydrogen but at the same time if required they can oxidize glucose or alkyne molecule also.

So, that means adopting a heterotrophic lifestyle when fixed organic carbon is available then resorting to carbon dioxide fixation in absence of organic carbon. So, whatever suits them they switch to that. So, they are more versatile in a physiological or metabolic sense. It is interesting to note that these type of organisms which are physiologically are genetically also they are versatile and this versatility is said to be genetical genetic as well because it is not a physiological manifestation only it is very well encoded by the by the respective genes.

So, if we look at their genomes we find that yes the genes are there for the relevant function. So, a single bacterium can fix carbon dioxide atmospheric carbon dioxide that is working as an autotroph but at the same time it can utilize the fixed organic carbon and perform the the heterotrophic mode of nutrition.

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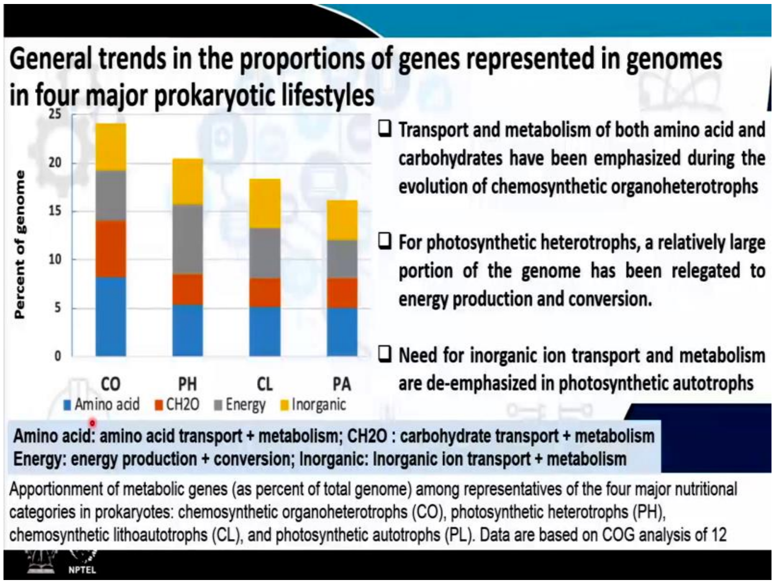

Now the general trends in the proportions of genes represented in genomes in the 4 major prokaryotic lifestyles are presented over here. So, this is basically a aport mainspring of the metabolic genes. So, we try to allocate the different type of relative proportion of the metabolic genes as percentage of the total genome among representative of 4 major nutritional categories in prokaryotes. So, we have considered CO that stands for the chemosynthetic organo heterotrophs, photosynthetic heterotrophs, chemosynthetic litho autotrophs and the photosynthetic autotron.

So, for each of these type of categories we have taken 3 very well known bacterial species and their genome sequences are studied and within their genomes we have tried to understand how many genes or how many cogs we basically refers to this a cluster of orthologous groups responsible for amino acid metabolism, responsible for carbohydrate metabolism carbohydrate transport, energy related phenomena, energy metabolism and inorganic ion transport and its metabolism are categorized.

So, for these purposes we have retrieved the information and then we try to look into this. So, as we try to look into this we find some very interesting things. So, we have 4 different types of organisms. So, say co is the chemosynthetic organo heterotrophs. So, as we compare this data we find that the transport and metabolism of both amino acid and carbohydrates have been emphasized more during the evolution of chemosynthetic organo heterodrops.

So, for example if you look into this chemosynthetic organoheterotroph you can find out for amino acids and for this carbohydrate transport and carbohydrate metabolism more number of genes are allocated to say simply. So, more number of genes are allocated that means they are genetically more equipped to transport to metabolize to utilize different type of amino acids as well as different type of carbon substrates.

Whereas for photosynthetic heterotrophs you can very well see the relatively large portion of the genome has been delegated to energy production and conversion. So, relatively higher on the contrary if we look into the photosynthetic autotroph genomes need for inorganic iron transport and metabolism are de-emphasized in photosynthetic autocross. So, relatively less number of less proportionately less number of genes are allocated to inorganic ion transport and metabolism because they are photosynthetic they can manage their produce their food by themselves maybe because of that.

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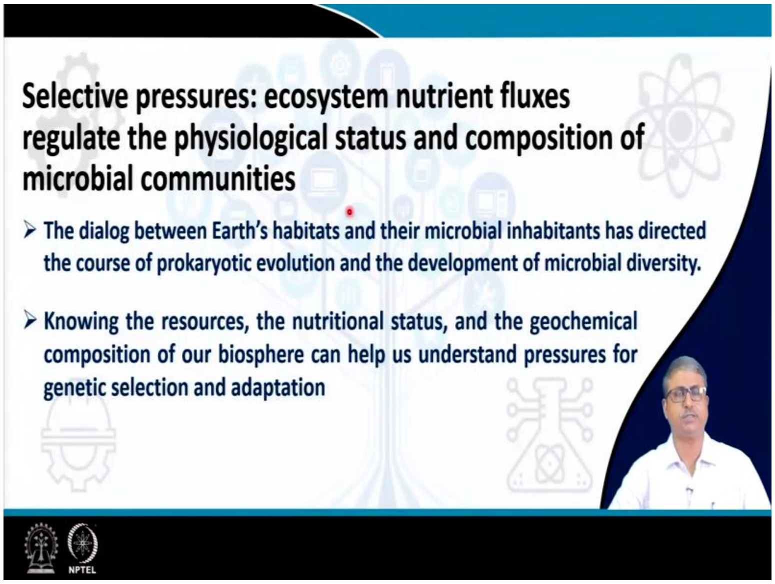

So, now we are going to talk about the selective pressures because we started with this node that the selective pressures are forming the basic dogma of this dialogue between the habitats and the microbes the microbial functions and the nature of the habitats. So, within any ecosystem nutrient fluxes that regulates the physiological status and composition of the microbial community. So, we will try to study this briefly.

Now the dialogue between earth's habitats and their microbial inhabitants has directed the course of prokaryotic evolution and development of the microbial diversity. And knowing the resources the kind of resource the amount of resource the nutritional status and the geochemical composition of our biosphere can help us to understand the pressures for genetic selection and adaptation.

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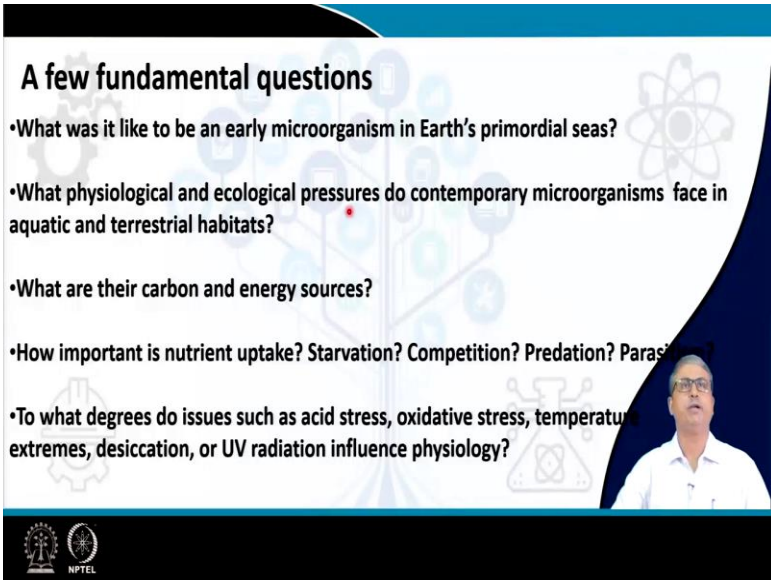

Now in this regard a few fundamental questions have been posed that include what was it like to be an early microorganism in earth primordial seas where the life has originated possibly. What physiological and ecological pressure do contemporary microorganisms face in aquatic and terrestrial habitats. What are their carbon energy sources how important is nutrient uptake starvation competition predation parasitism etcetera.

And to what degrees to do issues such as the stress different kind of stresses they influence the physiology of the organism.

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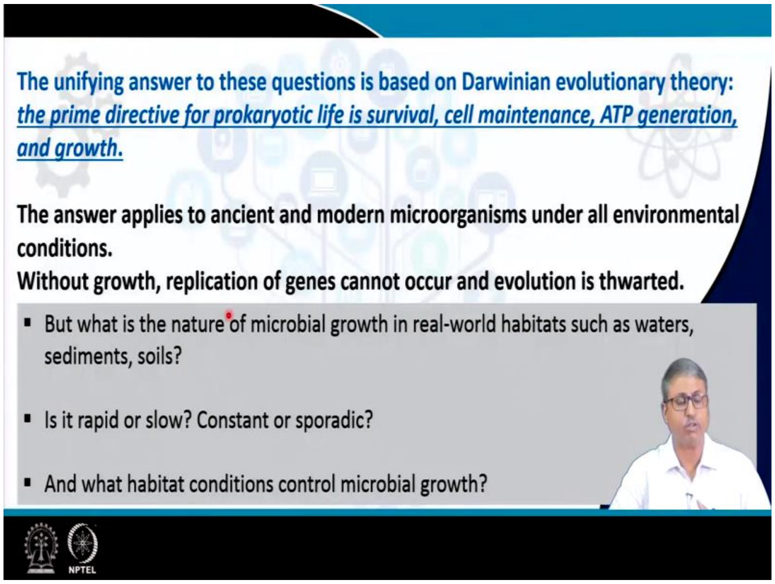

Now one unifying answer to this question could be based on the Darwinian evolutionary theory that the prime directive for prokaryotic life is survival cell maintenance ATP generation and growth. So, they would try their best to survive to perform the metabolic functions towards cell maintenance and energy generation and then eventually they will grow. Now the answer applies to ancient and modern microorganisms under all environmental conditions and without growth replication of genes cannot occur and evolution is thought.

So, it is important that the microorganism will try to try to grow continuously but what is the nature of microbial growth in real world habitat such as water sediment soils in contaminated or other non contaminated or in pristine environment under the ground where we plan or propose to put our carbon dioxide or put our waste is it rapid or slow constant or sporadic because these microbial growths and microbial activities are going to play a pivotal role.

And in environmental biotechnology we often rely on those activities and what habitat conditions control microbial growth.

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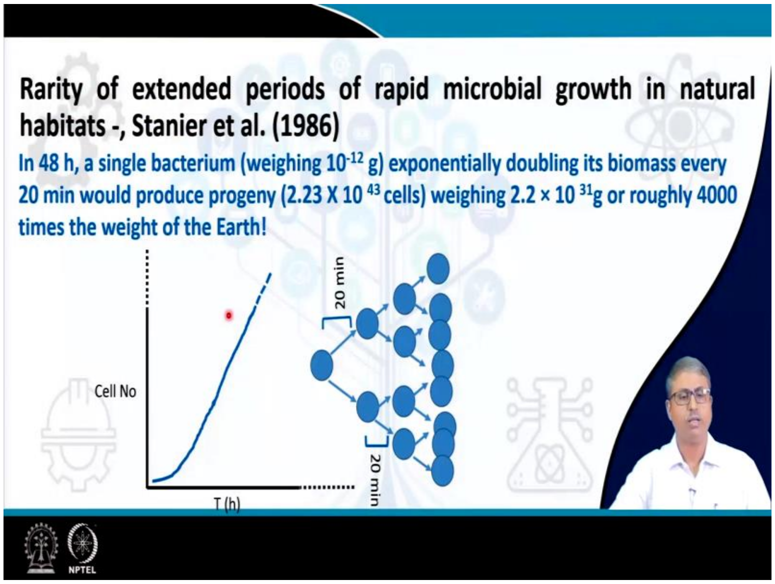

Now it is very important to also appreciate the fact that reality of extended period of rapid microbial growth in natural habitats is a known fact and Stanier proposed that in 1986. It is rare that extended period of growth will continue why it is so? Let us look at this example. So, if we take a tiny bacterium weighing maybe close to 10 to the power minus 12 gram. So, within 40 who has a doubling time of 20 minutes.

So, in a 20 minutes time the one bacterium bacterial cell will double into two and then in another 20 minutes the two will double into 4 and in another 20 minute double into another 4 or so. So, if this continues. So, within 48 hours how many cells will be there and what will be the total weight of that cell. So, from a single cell within 48 hours time they will continue. So, many generations so, that we have an astonishing number of cells.

And if we put the biomass into account that each of the cells are around one Femtogram or so. Then possibly we will have a and kind of another astonishing number which is roughly 4000 times of the weight of the earth which is simply impossible. So, that means the cells are actually not growing continuously at least not even in 20 minutes doubling time.

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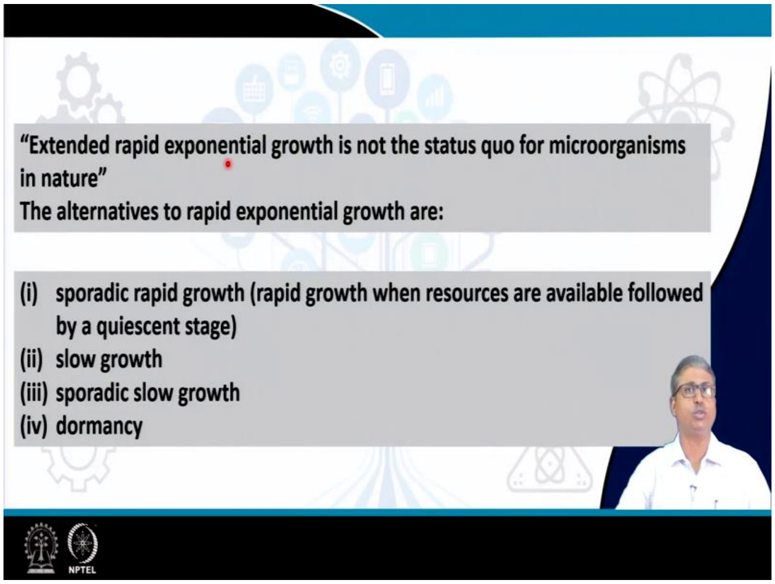

So, the extended rapid exponential growth is not the status quo for microorganisms in nature that is true that microorganisms in any environment are not growing continuously into through their exponential phases. So, the alternatives to rapid exponential growth could be number one the sporadic rapid growth that means sometimes they are growing rapidly particularly when the resources are available followed by equation stage that means when the nutrients and other conditions are not favourable they are not growing very actively.

Slow growth they are growing very slowly sporadic slow growth sometimes they are growing slowly but other times they are not growing and dormancy they are in a dormant stage that means they are maintaining their viability but they are not growing at all.

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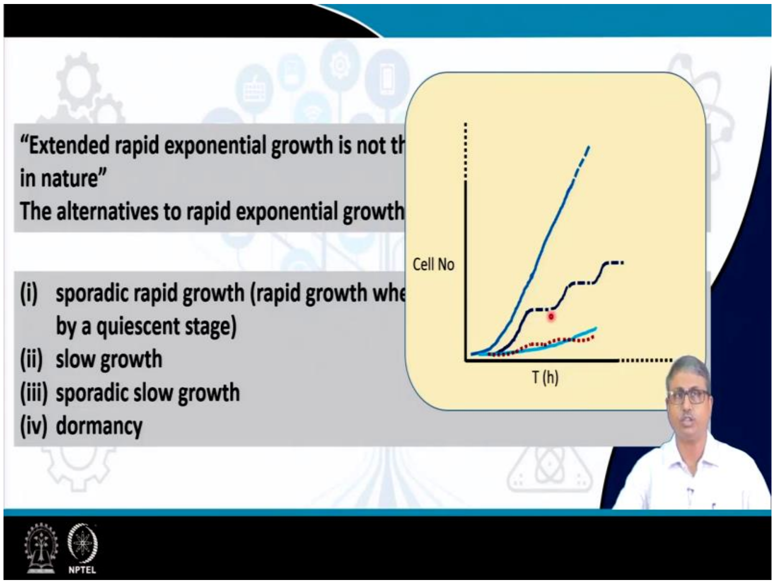

So, in that case our growth curves or growth pattern would be something like this that instead of a kind of exponential growth crop continuing to have impossible number of cells they might be actually growing like intermittent or sporadic rapid growth followed by some kind of rest or very slow growth or sporadic slow growth or a dormancy where the cells are not growing or very rarely growing within a particular environment.

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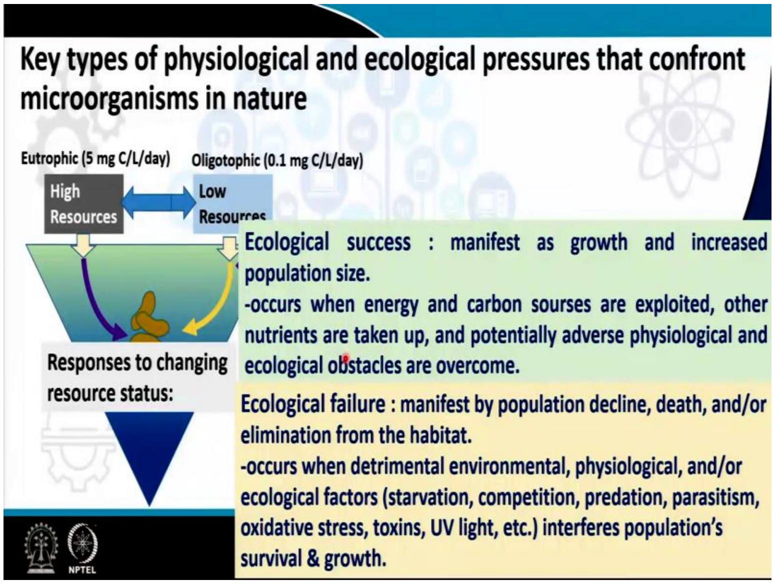

Now our next and the last point for this lecture would be the key types of physiological and ecological pressures that confront microorganisms within the nature. So, if we for example if we take the planktonic cells the cells which are not attached within the environment like a kind of a water system, like contaminated lake or a pristine lake or a river or water body or even a ground water any kind of ecosystem we can take where the cells are in a planktonic stage.

And the resources like the metabolic resources nutrient resources are available to the cells and the cells are cells are capable to function and grow within this environment. Now the forces of nature confronted by any cell and its fellow members of its populations are complex. Because it is simply few cells or a huge number of cells whatever it may be cells are there cells are functioning because the nutrients are there like carbon and energy sources are there the cells are happy.

So, if we predict some function by the cells be it carbon fiber sequestration carbon fixation methane oxidation production of methane from carbon dioxide. We must assume that this is not going to be static this is going to be dynamic it is not true that these cells will experience same kind of nutrient flow over a long period of time no it is not going to happen. So, there could be forces which will be confronted by these cells what are the force forces?

The forces could be the physical biological or chemical changes in their habitats which will be varying in space and in time. This is very important to understand because any kind of environmental biotechnology process whenever it is designed to be adopted in a real environment be it by remediation or be it resource recovery or any other kind of aspects we must appreciate that they will function in a kind of a dynamic environment.

Actually it is dynamic apparently it may be the same geographical location where we are going to adopt it but actually the system is going to be very, very dynamic with respect to the time and micro scale in space as well. So, what are the main fluctuations going on there. So, one part could be the physiological fluctuations physical fluctuations biological and chemical. So, if we keep our discussion mainly on the physical or the chemical properties which are the nutrient resources for example.

So, they may have high resources sometimes which are exemplified by the eutrophic condition like five milligram organic carbon per liter per day but they could be oligotrophic also like low resources. So, same lake same river or a same soil system might be experiencing high resources at some point of time whereas they might be experiencing low resources at some point of time. So, organism surviving and that environment are to be needs to be acting on this dynamic state of resource availability and also the resource nature of the resources.

So, with respect to this change in resource conditions resource availability and resource quality the responses will be very clear because the responses to the changing resource status will lead to number one the ecological success some organism will happily switch to the new ecological or new nutritional status. Let us assume that one river was experiencing more of like inorganic resources, in organic electron donors.

Suddenly the releases of some organic pollutants or organic materials have been achieved or have been occurring there. So, some organisms will be very happy to utilize the organic substances they are they may be heterotrophs and they are capable of switching to heterotrophic mode. So, they will be ecologically more successful. So, one of the status is your ecological success.

The other ecological status will be the ecological failure some organisms will succumb to the altered condition and they will finally possibly die. But there could be another state which is second state mentioned here is the survival and maintenance of sporadic slow growth. So, these are the some organisms which are very clever organisms. So, they are rather having some ability that they will wait for the time that they will just which is said that they will wait.

And see they will wait within these dynamic or altered conditions and they will expect that sometimes the condition will be reverse or condition will be changed to another one and possibly then they will start growing. So, within this ecological success we will see that the success is going to be manifest as the growth and increased population size. So, those particular type of cells will grow more and they will represent the population in a large quantity.

And this will occur when energy and carbon sources are exploited adequately other nutrients which are available nitrogen, phosphorous, sulphur etcetera are taken up and potentially adverse physiological and ecological obstacles like the adverse conditions are minimum or they could be overcome very easily. On the other hand the ecological failures could be manifested by population decline.

So, we will see a particular population which might be playing a very important role otherwise in our environmental biotechnology process is now declined because the cells are dying and they are getting eliminated from the habitat because with respect to this changed resource condition they are unable to adopt. And these occur when there are detrimental environmental effect physiological and or ecological factors, change in the composition of the water.

For example somebody was growing algae for carbon sequestration and synthesis of some repeats or certain biomass for other biotechnology or bioenergy processes. The composition of the water may not be very static. So, as soon as there is a change in the composition of the waste water somebody might be using an industrial effluent for this. Now due to flood or due to other reasons the water the composition of the water might be altered maybe some industrial effluents are mixed with that.

So, when the water composition is changed they may find that it is a detrimental environment and that will interfere the populations survival and growth.

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And eventually as these things happen like the selective pressures are changing and with respect to selective pressures the organisms are responding some organisms are responding immediately they are considered as successful. Some organisms are not able to respond adequately considered as failed and some organisms are maintaining a status quo and they are just waiting for time that they will they will possibly act as soon as the conditions will restore or will be in their favour.

So, in this slide we are going to talk briefly about the two types of strategies what is called all selected another case selected growth strategy. The r-selected species are adapted to high rates of reproduction exploit the nutrient inputs rapidly exhibiting high rates of growth in an uncrowded habitat. So, they are the organisms who are able to grow very quickly utilizing the resources available over there whereas the case elected species adapted to conserve resources exhibit slow constant growth rates appropriate for the habitats featuring crowded high density populations.

So, in an environment you may find out some species are growing very rapidly and then they are decreasing whereas some species are maintaining almost a uniform slow but uniform growth or their abundance of those species are relatively maintained an uniformity. So, they could be represented k-selected species whereas the former one could be represented as the r-selected species.

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Now we end our lecture here this part of the lecture and for this part of the lecture the following reference may be consulted.

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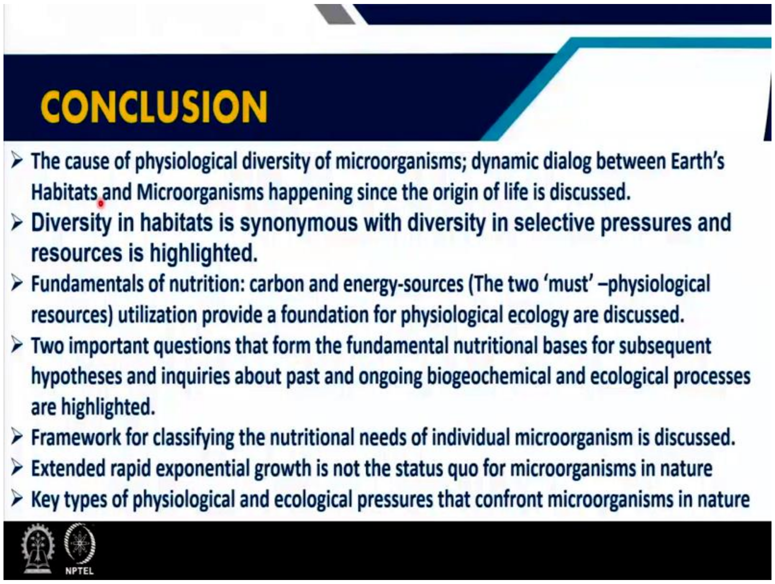

And in conclusion the cause of physiological diversity of microorganisms, the dynamic dialogue between earth's habitat and microorganisms happening since the origin of life is discussed. Diversity of habitats is synonymous with diversity in selective pressure and resources which is highlighted fundamentals of nutrition. Two important questions that we ask with respect to this fundamental nutrition basis are discussed.

Framework for classifying the nutritional needs and identification of the 5 major nutritional classes are discussed. Extended rapid exponential growth is not the status quo for microorganisms. Key types of physiological and ecological pressures that confront microorganisms in nature is also discussed, thank you.