Environmental Chemistry and Microbiology

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Module - 7
Lecture - 34
Overview of Microbial Life - II

Welcome everyone to the fourth lecture in our series. We are going to go through an overview of microbial life. This is the second part of this particular topic.

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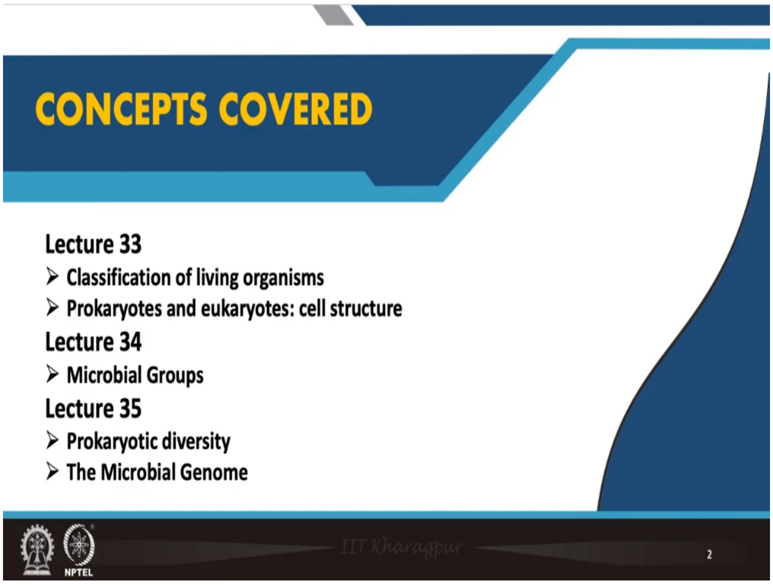

I think I mentioned in lecture 3 (lecture 33) that we covered the classification of living organisms, the differences between prokaryotes and eukaryotes. We looked at cell structure, some basic organelles that are part of all cells, the unit of life. So, we have covered that in lecture 3 (33). What we are going to cover in lecture 4 (lecture 34) is the different microbial groups that are present on the planet literally. And in lecture 5 (lecture 35), we will be covering prokaryotic diversity and a little bit about the microbial genome.

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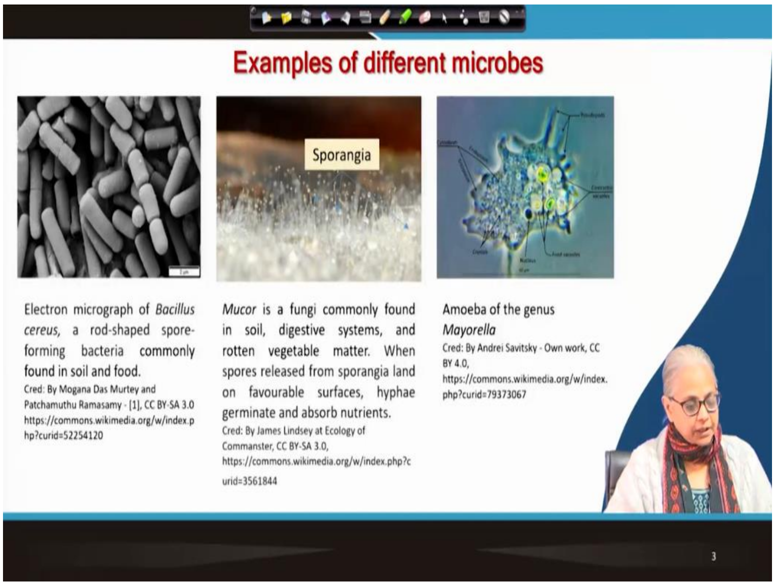

So, let us take a quick look at some different types of microbes. Here, I have some examples, mostly graphics, where we have - in the first case, we have an electron micrograph of a *Bacillus cereus*. So, these are rod shaped spore forming bacteria. They are very common in soil and food. And we will go into some details about these kinds of bacteria in subsequent topics.

In the second graphic, what you can see is a fungi. This is mucor. Mucor is very common. It is a mold that grows on food. So, in this case, it is mentioned that mucor is a fungi that is found in soil, digestive systems, rotten vegetable matter. I can tell you from experience, if you leave anything out on the table, when the weather is warm and humid, what you will find within 24 hours there is growth of a fuzzy layer at the surface of the food. Leave it outside, not in the fridge. Leave it outside at ambient temperatures. It should be warm. It should be humid. You will get this fuzzy whitish layer on the surface of food and that is basically what mucor is. If you take a very close look at it; even a magnifying glass might help you with that.

[[repeated video from (()) (02:46) to (()) (03:48)]]

Amoeba is something that you are all most likely familiar with. You can see, it is a eukaryotic cell. It has an irregular shape. It has a clear cell wall as well as a nucleus, endoplasm. The cytoplasm has two parts, the ectoplasm and the endoplasm. The nucleus is also shown over here, including food vacuoles. And these are the pseudopods that allow the amoeba to move towards its food and ingest it.

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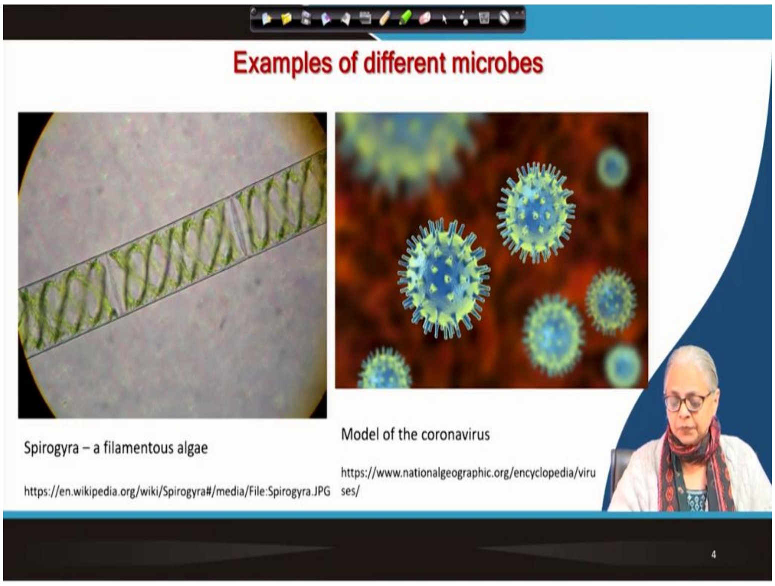

Here is an example of an algal cell. So, here you have a filamentous algae, *Spirogyra*. And the next graphic shows you an example of Coronavirus. This is not a real photo. It is a model. And you can see the spikes (of spike proteins) on the top of the coat or the capsid of the virus.

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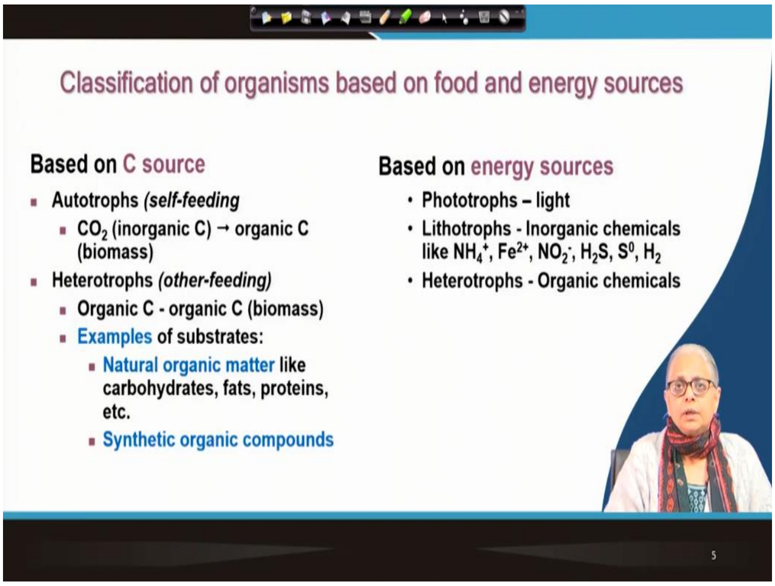

Let us go into another direction. And that is, you can also classify organisms, not the way we saw; that is the official classification; but you can also look at it in another way. You can think in terms of food and energy sources. So, we use certain terms; and I thought of adding it to these slides so that, even though you may be knowing them from your high school, but it is worth remembering them, because we are going to be using these terms over and over again, in the remaining part of the course.

So, if I am classifying organisms based on food or rather carbon source, we use 2 words; autotrophs, which means self-feeding. They do not use organic carbon from other sources or other organisms. They use carbon, inorganic carbon, mainly from the atmosphere. It can be from water as well. They can use inorganic carbon and convert it to biomass, which is organic carbon.

Heterotrophs, which are feeding on other organisms are therefore in contrast to autotrophs. They utilize organic carbon that has been generated either by autotrophs or by other heterotrophs. For example, we are heterotrophs, but we feed on organic matter that has been created either by autotrophs or by heterotrophs. So, organic carbon is then converted; we ingest food, we convert it to new biomass. So, all heterotrophs including human beings are capable of taking organic carbon from other organisms and converting it to new biomass. Microbial organisms or microorganisms are going to be able to utilize either natural organic matter which comes in the form of carbohydrates, fats, proteins, any type of natural organic compounds constitute natural organic matter. These organisms, especially bacteria, which we will go into some detail about later, these bacteria can basically also be acclimated to use synthetic organic compounds. They are not very used to synthetic organic compounds. And this is a major area of research and development. We will go into it, like I said, in some detail in subsequent lectures. But this is another type of substrate that some types of bacteria are capable of acclimating themselves to and utilizing them as food or substrate.

If we look at the energy sources that microorganisms can utilize, then there are 3 different types of energy sources.

The first is phototrophs. Phototrophs means they will utilize light and convert it to chemical energy in the form of compounds.

Lithotrophs are not dependent on light. They will use the redox reactions that are happening due to the coupling of inorganic compounds. So, depending on the oxidation state of various inorganic compounds, they will be able to form redox reactions, which are energy releasing reactions. And this energy that is released will then be tapped and stored in the form of ATP and so many other things. We will go into all these details in subsequent lectures. So, we will spend a long time on many of these issues.

And finally, heterotrophs. So, heterotrophs, as I said, are deriving both mass in terms of organic carbon, as well as energy from organic compounds. So, just think of yourself. You are a heterotroph. What do you do? You eat food. What does food give you? It gives you both mass as well as energy. So, that energy and mass, both are coming from the food. So, that is what heterotrophs are all about.

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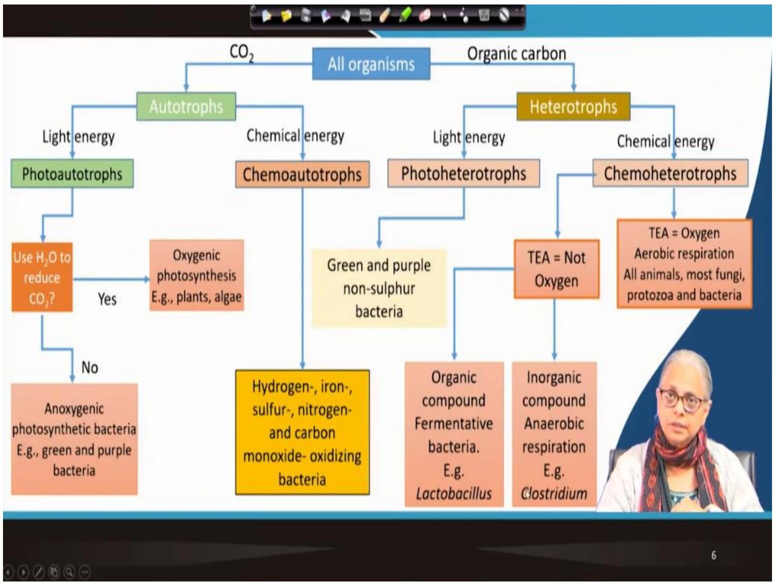

So, this is a rather complicated diagram that goes into all possible microorganisms that exist; in fact, not just microorganisms, I have the higher organisms here as well. But the graphic is literally dominated by microorganisms, because they frankly dominate the biodiversity of the planet. So, this is all organisms. And like I said, there are 2 sources of carbon, either CO_2 or organic carbon.

If they are utilizing CO_2, they are autotrophs; if they are utilizing organic carbon, they are heterotrophs. Let us focus on the autotrophs. The autotrophs have two choices in terms of energy source. They can use light or they can use chemical energy. So, if they are using light, they are called photoautotrophs. If they are using chemical compounds, that is chemoautotrophs.

The photoautotrophs; we ask a question here; can water be used to reduce CO_2 to organic compounds? Because, remember the final end product is biomass. So, if water can be used to reduce carbon dioxide to organic carbon, then if the answer is yes, that means, those organisms are what we call photosynthesizers that are capable of generating oxygen. So, the plants around you as well as the algal cells, these are all organisms that are capable of oxygenic photosynthesis.

Now, if the answer to this question is no, then we have another group of bacteria that are capable of reducing, not H_2O but H_2S. They will utilize; let me put it another way; they will utilize H_2S, that means, hydrogen sulphide and convert it to elemental sulphur and so on. And in the process, CO_2 will be converted to biomass. So, instead of water going to oxygen and CO_2 going to organic carbon, we now have hydrogen sulphide going to elemental sulphur and sulphate.

And in the process, CO_2 goes to organic carbon. So, that is, that process is called anoxygenic photosynthesis. And the bacteria that are involved are called green and purple bacteria. Then we come to chemoautotrophs. Chemoautotrophs, like I just mentioned in the previous slide, they are capable of utilizing several inorganic compounds. You can use the term lithotrophs or chemoautotrophs. Both are equally acceptable.

Hydrogen, iron, sulphur, nitrogen, carbon monoxide, oxidizing bacteria; these are all examples of chemoautotrophs. A simple example for those of you from an environmental engineering or civil engineering background. In wastewater treatment, we talk about nitrifying bacteria. So, nitrifying bacteria are the best-known examples that we use quite frequently. So, they are the ones that convert ammonia to nitrite and nitrate. So, these are autotrophic bacteria that utilize oxygen and convert ammonia to nitrite and nitrate. Here we come to organic carbon. So, here we have the heterotrophs. Again, the heterotrophs have two choices, light energy or chemical energy. If they are using light, then they are photoheterotrophs; if they are using chemical energy, they are chemoheterotrophs.

Photoheterotrophs, the best-known groups of bacteria that are capable of being photoheterotrophs are green and purple non-sulphur bacteria. So, we will go into some detail in subsequent topics.

So, chemoheterotrophs have two choices. One is where the terminal electron acceptor; TEA stands for Terminal Electron Acceptor. So, in the normal course of events, if oxygen is available and the microorganism has the ability to utilize organic compounds, then the organic compound along with oxygen will result in CO_2 and water plus new biomass. So, that is what we call aerobic respiration. All animals, fungi, protozoa, bacteria; most of these species, the bulk of the species that you see around you and humans as well, they are all dependent on aerobic respiration. So, how do we get our food? We use organic carbon and we need oxygen;

and that is converted to CO_2, water and biomass. So, we are the best examples of aerobic respiration and so are most other animals around us.

And many fungi, protozoa and bacteria are also in the same class or category. Now, supposing there is no oxygen in the environment, does that mean life ceases to exist? Not at all. It means that there are other species that are capable of thriving under anoxic condition. So, even if oxygen is not available, there are species of bacteria that have adapted themselves or rather, they come from more primitive conditions perhaps; whatever the reasons, they are capable of surviving without oxygen.

So, where you have no oxygen, there are two possibilities again. So, we have anaerobic respiration, where inorganic compounds serve as the terminal electron acceptor. So, we will again go into all these details like I said, in subsequent topics. And one example is *Clostridium*. *Clostridium* is something that you see in your food and so on. It causes food poisoning.

The first part is inorganic compounds. And then the second part is organic compounds. Now, if these organic compounds are utilized either by bacteria or by yeast, you can have fermentation reactions. Alcohol production is based on yeast; and they convert organic material to alcohol. So, it is organic compounds being partly reduced and partly oxidized. We have wastewater treatment where biogas is formed. Again, that is a fermentation process, where part of the organic compound goes to methane and part of it goes to CO_2. And then we have organic compounds where, for example, your daily process of making yogurt. What do we do? We add a bio-inocula that is literally an inoculum of lactobacilli, which are added to warm milk and within about 6 to 10 hours, it gets converted to yoghurt or curd. So, that is also a fermentation reaction. So, these are very common reactions that do not need oxygen. No oxygen is required by these bacterial or yeast species.

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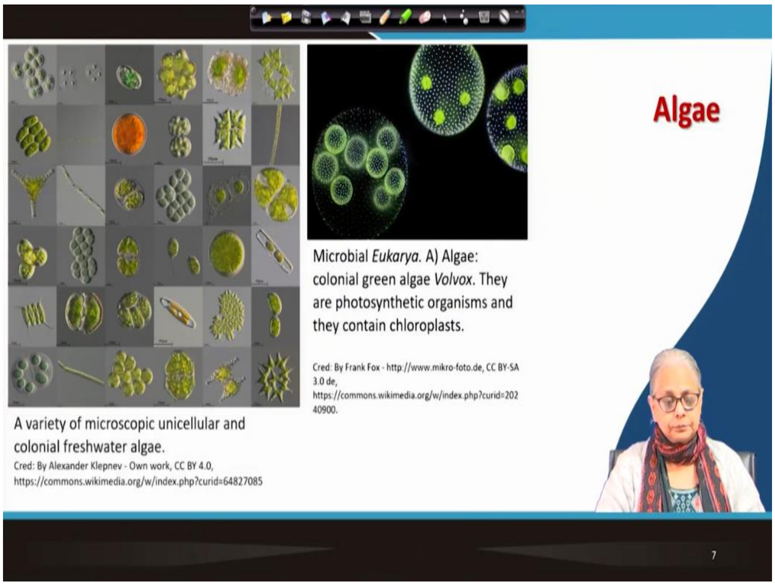

Here are some more examples. We will be going into some details of all of them in, like I said, subsequent topics. But for now, I am just giving you an overview for this particular topic. Algae are everywhere around you as well. In any aquatic medium, you will find especially in surface water bodies, whether they are small ponds or large reservoirs, you are likely to find algal cells. And they come in two categories. You can have unicellular forms, which are called microalgae; and you have colonial algae as well. So, you can see several examples. This is all from Wikipedia. So, you can see several examples here, of both unicellular algae, as well as multicellular algal cells. Here are more examples. So, these are eukaryotes. This is colonial green algae called *Volvox*. They are all photosynthetic organisms and they all contain chloroplasts. So, you can see the green colour. However, there is one example of a red coloured alga here. And there are several other pigmented forms of algae, which I will go into later. I am not going to go into it here right now. We will go into that later.

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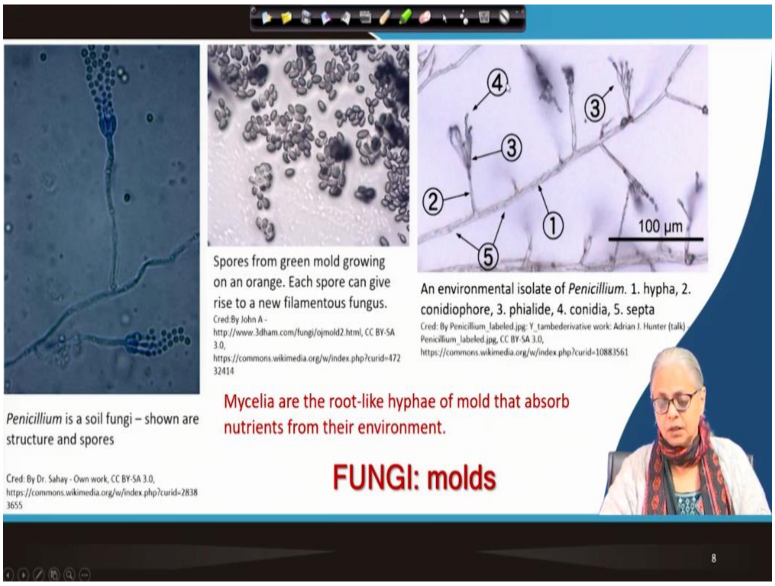

Here are examples of fungi. So, here we have *Penicillium*. This is a soil fungi. And you can see the structure of the fungal cells and the spores. It is the spores that spread far and wide. Whenever they find a favourable environment, they will start breeding and reproducing over there. This is another example of a filamentous fungi. You cannot see the filaments in this, but you can see the spores. This is a good micrograph of spores from green mold that is growing on a fruit. Green mold is very common, especially in our country where you have damp conditions, when it is warm; and like I said, all it needs is warmth and humidity. And in general, fungi can grow anywhere and everywhere. It is very difficult to control their growth. They are everywhere. And here are more details of the *Penicillium* fungi.

You can see the hyphae. So, this filamentous part is called the hypha or the hyphae. The second part is the conidiophore, which will have the spores at the top. So, you have the sporangia or the spores. So, that is the conidia. And the final one is a septae. That is the filament part of it.

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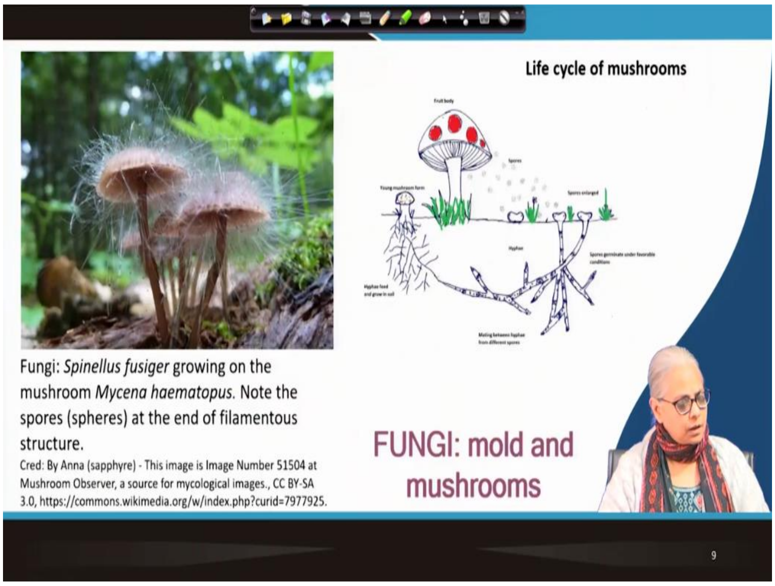

Here we have an example of an interesting combination of mold and mushrooms. Mushrooms are multicellular fungi. Mushroom also has spores, where each spore can result in a new mushroom. So, that is also true. But the mushroom by itself is a multicellular organism. So, here you have *Spinellus* growing on the mushroom, *Mycena haematopus*. So, you have two different organisms growing together.

And you can see the conidia and the spores at the end of each one of these conidiophores. Now, how do these mushrooms propagate? So, you have let us say a spore form. It forms and it drops off from the original fruiting body. It falls in a place where there are favourable conditions. So, what are the favourable conditions? Mushrooms will generally be found where there is ample moisture and ample nutrients.

So, generally, in the monsoon season, you can find them in tropical areas. You can find them in the monsoon season mushrooming, literally mushrooming everywhere. And dead wood and rocks and those kinds of places are great places because, they find these little niches where nutrients have accumulated; and they are able to thrive over there. So, these spores, when they fall on favourable surfaces; they are generally attached to solid surfaces, which we call substrata or substratum.

So, these spores will first enlarge. They will absorb nutrients from the environment that they are in. They will start growing bigger and bigger. And one of the key characteristics of fungi is that they secrete acids into the environment where they are. And these acids eat into (dissolve) the substratum. So, as they form these root-like structures. These hyphae are the root like structures that the fungi form and attach themselves to whatever substratum they are on. So, this substratum is basically like that. And you can always examine it, you know; just pull up a mushroom or even the fungi that grows on surfaces. If you happen to have anything in the house, for example, leather bags and so on, are a great surface for you to take a look at that. So, wood surfaces, leather surfaces, which have been untouched for a while; you can just scrape off the growth on the surface and you can find these kinds of things. So, these are the hyphae that are formed slightly below the surface. And that is how the organism attaches itself to the material where it is absorbing nutrients from. It absorbs moisture from the air and it will continue to spread and grow. So, in the wild, where you see mushrooms growing; they grow on dead wood, they grow on living wood as well; and you find them growing in soil and so on. So, first they will form this young fruiting body which will over a period of time, it will get bigger and bigger until the spores which are at the bottom will at some point be released. These spores that are airborne will fall on different places and the whole cycle will start all over again.

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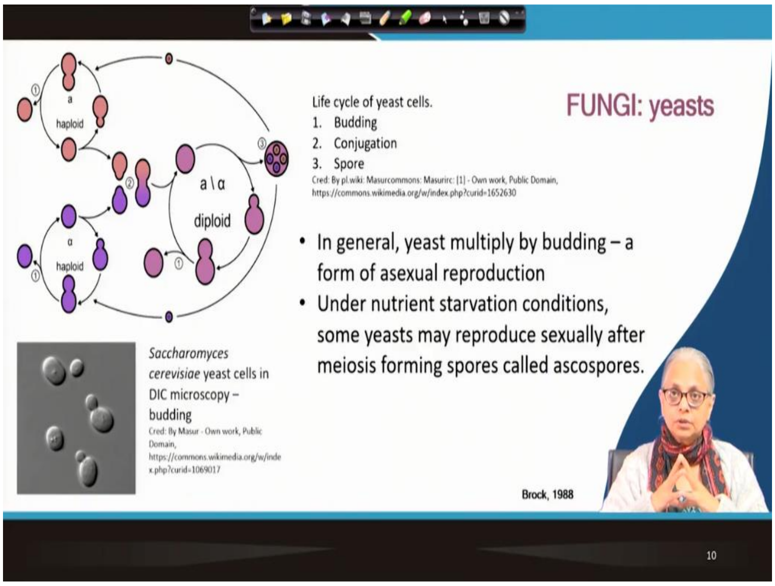

What about yeast? Yeast, like I said, are used for making alcohol. They are used in baking breads and cakes and all of that. So, there are two methods that yeasts are capable of using for their reproduction. The most common one is budding. Budding is asexual reproduction. It is not like binary fission, where the parent cell ceases to exist and two daughter cells are formed. Unlike that, the yeast will form, it will replicate the DNA. It will create a small bud into which the new DNA is injected. And you can see the small bud will eventually over a period of time, it will remain attached to the parent cell, but it will grow bigger and bigger. At some point, when it is big enough, then it will detach itself or it may never detach itself. So, these are yeast organisms that are growing by budding. And under nutrient starvation conditions, some yeasts are capable of reproducing by what is called sexual reproduction.

So, they create haploid cells. The normal budding does not require haploid cells, the cell remains a diploid cell. But under nutrient starvation conditions, they will create 2 haploid cells. These 2 haploid cells will create buds which remain haploid and eventually form what are called spores. So, these ascospores will be in dormant form until conditions become favourable, conjugation happens and a new diploid cell will be generated from those yeasts. So, that is another form of reproduction for yeast cells under specific conditions.

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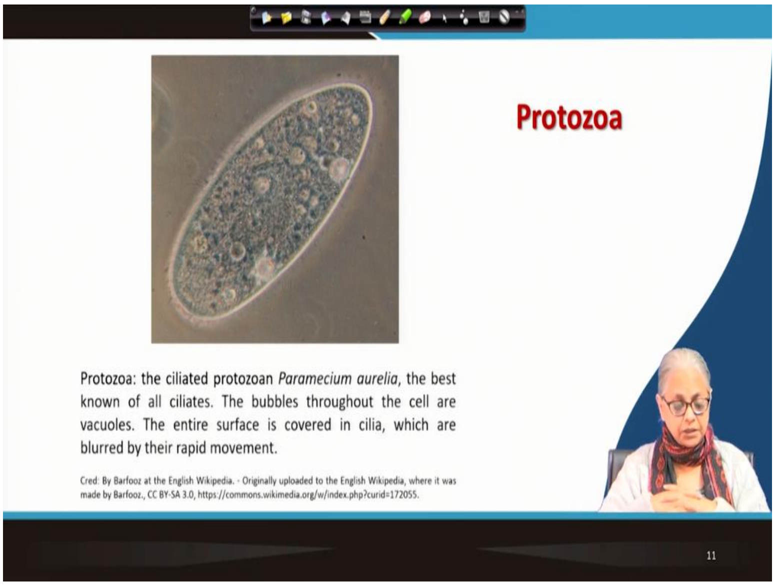

Here we have protozoa. Protozoa, like I said initially, they are protists. And this is a very common one. It is called *Paramecium aurelia*. You can find it in water; you can find it in wastewater. This is a ciliated protozoa. Cilia means, you can see these hairy appendages all around the cell wall. They are not very clear because they are moving. So, if you remember, I think in my introductory slide, I had a video showing you paramecium moving right across the screen and ingesting bacteria that came in their way.

So, these are very well-known ciliates or protozoa. And you can see in that particular video, you could have seen the rapid movement of these protozoa or paramecium. And, like I said, they ingest bacteria, that is the food for these protozoa. And the entire surface is covered by the cilia which is their means of movement.

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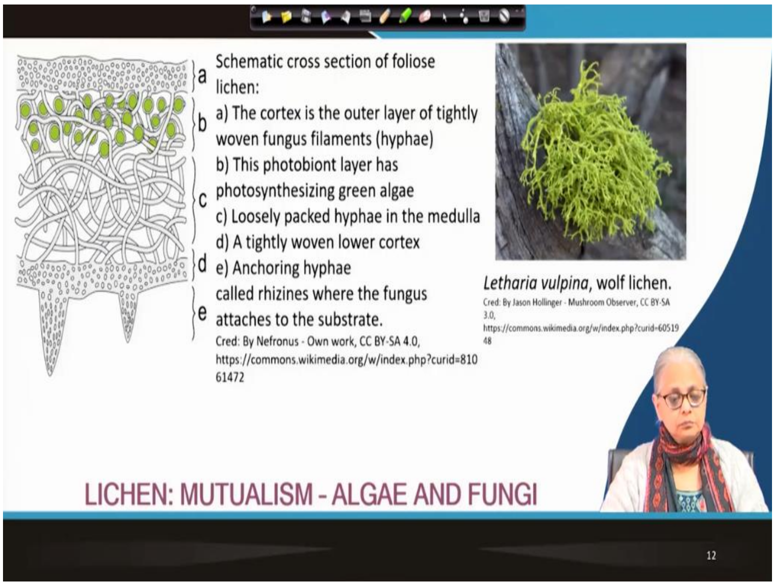

Then we come to another interesting phenomenon in nature. And that is mutualism between different groups of microorganisms. So, lichen, which are fairly common in many parts of the environment. You can find them in dry environments, where nothing else thrives, lichen can be found. So, I have seen them growing in absolutely barren environments where no other living organism seems to be able to survive; it is the lichen that are still able to survive.

That is because it is a symbiosis between two types of microorganisms, the algae and fungi. So, let us take a look at how this mutualism or symbiosis happens. So, this is a cross section of foliose lichen. You can find lichen growing on the bark of trees; you can find them growing on rocks, where it is completely dry. In general, you find them where the environment is very dry; because there is very little moisture; and that is why you have this mutualism or symbiosis between algae and fungi.

So, here you have the top layer. The top layer is the cortex. And it has fungal cells which have hyphae. And these hyphae are going deep down. In the second layer or sometimes even at the top, you will find algal cells. That is the photosynthesizing green algae. Now, what is the advantage of having algal cells at the top? They will absorb sunlight and moisture. And they are going to be supplied nutrients by the fungi that are below them.

So, you have these hyphae, which are root like structures; very long and complicated root like network that is both above and below (the substratum). And the algae are protected from desiccation, because it is a dry environment, they are protected from desiccation; and they have sunlight. They have access to sunlight, so they are able to grow. And you have these hyphae that are absorbing nutrients from the substratum that they are attaching themselves to. So, you have this cortex. You have this loose network of hyphae. They are also the anchoring hyphae, which have dug deep into the substratum and they cause pitting; remember that there is some amount of acid secretion from the fungus that allows them to create these root-like attachments to whatever surface they are growing on. So, this is the cross section of the lichen. And this is what they look like.

This is just one example. It has got more hair on it. Some of them have very little hair on them. They have just a felt like appearance. So, you get all kinds of different microorganisms in the environment depending on the nature of the environmental conditions.

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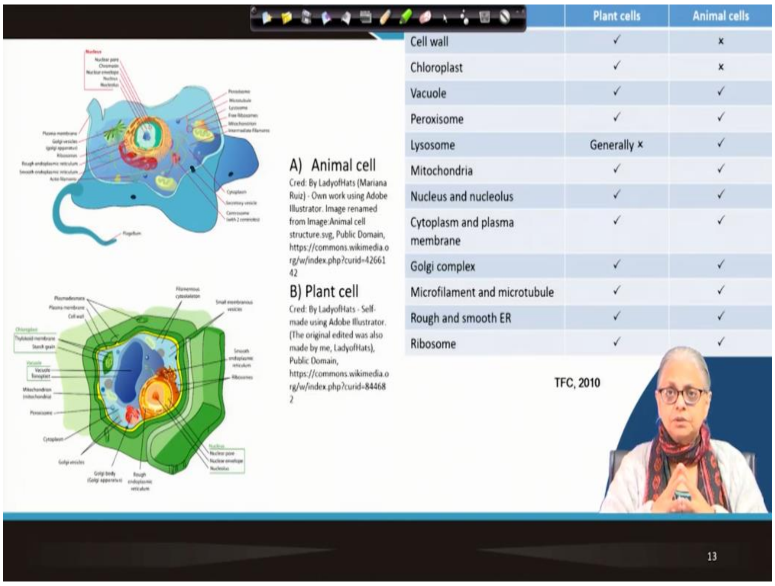

What I have here is a differentiation and schematic of animal cells and plant cells. You may have studied this, but just to remind you. What do they have in common? And what do they have that is different? So, animal cells, like I said, animal cells do not have cell walls. They do not have chloroplasts. They do not have photosynthetic ability. That belongs to the plant cells. So, plant cells have cell walls; they have chloroplasts; and they have photosynthesizing ability. And all the other organelles are common to both types of cells. So, both plant cells and animal cells have vacuoles; they have peroxisomes, lysosomes, in some cases of plant cells. Mitochondria are common to both; nucleus and nucleolus are common to both; cytoplasm and the plasma membrane are common to both. Golgi complex, microfilament, microtubules, rough and smooth endoplasmic reticulum, ribosomes; all of these organelles are common to both animal as well as plant cells. I will stop at this point. Thank you.