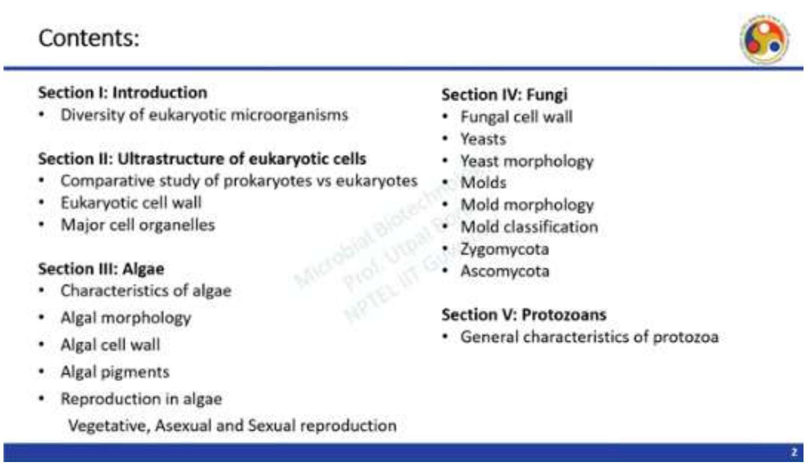
MICROBIAL BIOTECHNOLOGY

Prof. Utpal Bora
Department of Biosciences and Bioengineering
Indian Institute of Technology Guwahati

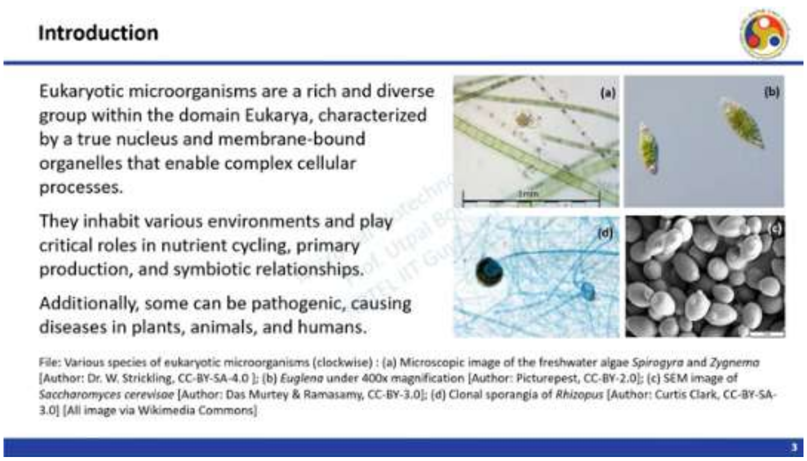
Lecture08
Lec 8: Diversity and Structure of selected eukaryotic microorganisms

Welcome to my course on microbial biotechnology. We are at module 2 where we are discussing about structure and life cycle of representative groups of viruses, prokaryotic and eukaryotic microorganisms. In the last lecture, we discussed in detail about the ultra structure of bacteria and how the endospore formation takes place. In this lecture, number 4, we will be discussing about the diversity and structure of a few selected eukaryotic microorganisms. These are the contents of this lecture.

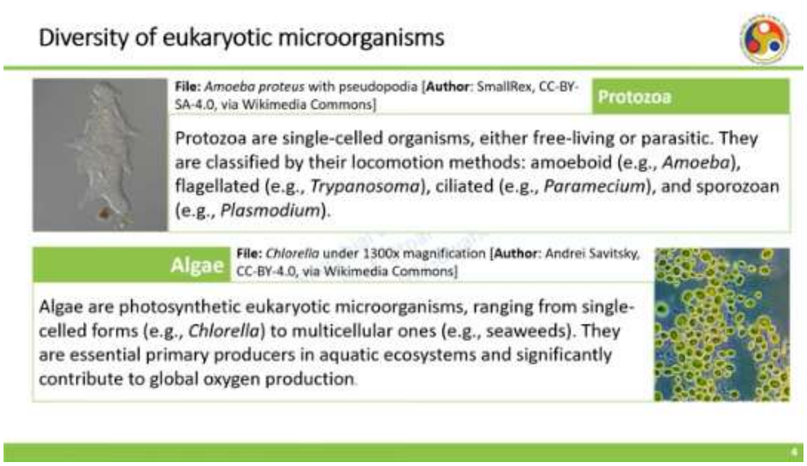
We start with an introduction about the diversity of eukaryotic microorganisms. Then we will study about the ultrastructure of eukaryotic cells in the way we study about the ultrastructure of bacteria. Then we will discuss about algae, what are the characteristics, morphology, cell wall pigments, then reproduction in algae and then we move on to discuss about fungi structure, morphology, then mould classification and also finally about the protozoans just dealing with the general characteristics of protozoa. So, eukaryotic microorganisms are a rich and diverse group within the domain Eukarya characterized by a true nucleus and membrane-bound organelles that enable complex cellular processes. We have discussed about nucleoid which is a false nucleus in bacteria and we discussed about various organelles in the bacteria.



So, in these eukaryotic microorganisms we will be also discussing about them which are different from the bacterial organelles. These eukaryotic microorganisms inhibit various environments and play important roles in nutrient cycling. primary production and also in symbiotic relationships. Additionally, some of them are pathogenic, which causes disease in plants, animals, including humans. So here we can see various types of eukaryotic microorganisms.



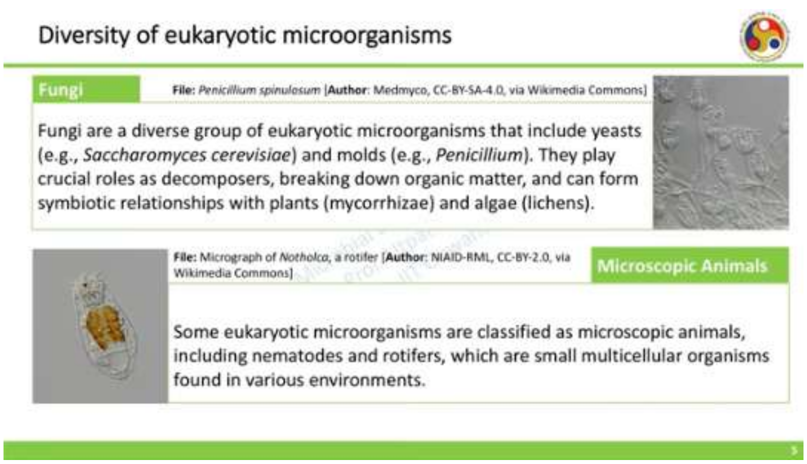
For example, in A, we can see the freshwater algae Spirogyra and Gignema. Then in B, we can see Euglena, and then we can see the image of Saccharomyces cerevisiae in C, and we can see the image of the clonal sporangia of Rhizopus in figure D. So, eukaryotic microorganisms are quite diverse, as we have already mentioned. In this figure, you can see an amoeba with pseudopodia. And let us begin with one of those types of eukaryotic microorganisms.



For example, protozoa. These are single-celled organisms. They are either free-living or parasitic. They are classified by their locomotion methods: amoeboid (for example, amoeba), flagellated (trypanosoma), ciliated (paramecium), and sporozoan (which includes plasmodium). Another type of eukaryotic microorganisms are the algae, and here you can see Chlorella under 1300X magnification.

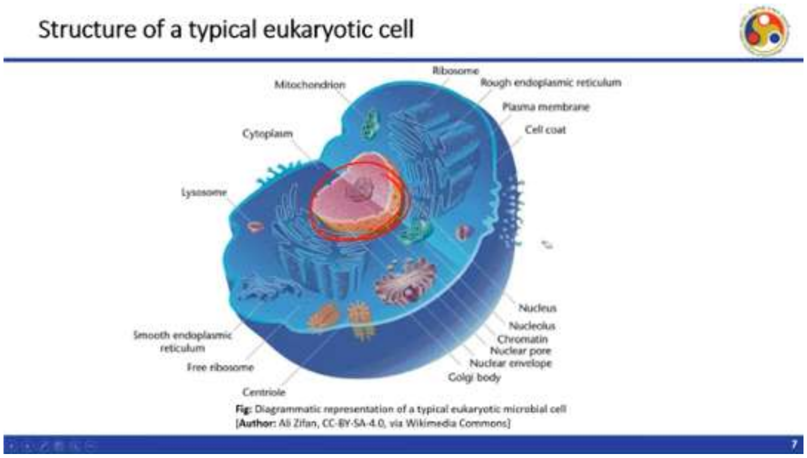
Here, you can see some green coloration, which is because algae are photosynthetic eukaryotic microorganisms. They range from single-celled forms to multicellular ones, for example, the seaweeds. They are essential primary producers in aquatic ecosystems and significantly contribute to global oxygen production. So, apart from trees, algae are very important in the production of oxygen, which helps in the survival of animals like us. Another example is that of fungi; in this picture, you can see Penicillium spinulosum.

Fungi are basically a diverse group of eukaryotic microorganisms not one or two type and it includes yeasts and moles. They play crucial roles as decomposers, breaking down organic matter and can form symbiotic relationship with plants and algae. For example, mycorrhizae form symbiotic relationship with plants and lichens form symbiotic relationship with algae. Then there are other interesting types like the microscopic animals. You can see here Nautilus which is a rotifer.

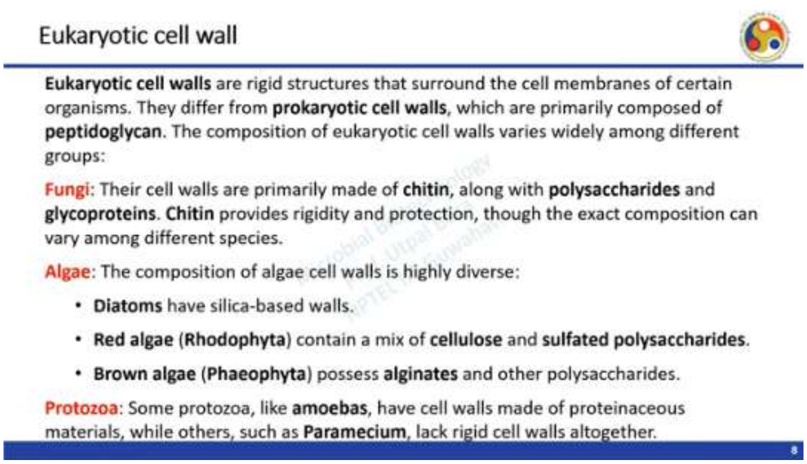


These eukaryotic microorganisms are classified as microscopic animals like nematodes, rotifiers and they are small multicellular organisms found in various environments. Now let us look into the ultra-structure of a eukaryotic cell. So, this is the structure of a typical eukaryotic cell with so many different well-defined organelles like the mitochondrial which is a powerhouse, then this is the cytoplasm which is basically the fluidic material which includes all the different organelles as well as soluble proteins and other biochemical molecules. Then we have structures like lysosomes and a well-defined nucleus and then we have the plasma membrane and the ribosome which is the protein translation machinery.

We'll discuss about these in detail in the next few slides. Let us now discuss about the various components of a eukaryotic cell. Let us start with the eukaryotic cell wall. Eukaryotic cell walls are rigid structures that surround the cell membranes of certain organisms. They differ from prokaryotic cell walls,

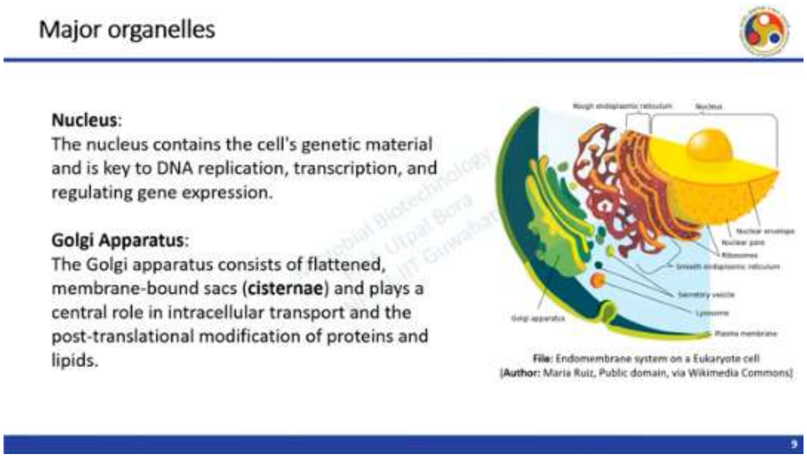


which are primarily composed of peptidoglycan. The composition of eukaryotic cell walls varies widely among different groups, for example, fungi. Their cell walls are primarily made of chitin, along with polysaccharides and glycoproteins. Chitin provides rigidity and protection, though the exact composition can vary among different species. Algae, where the composition of the cell wall is again highly diverse.

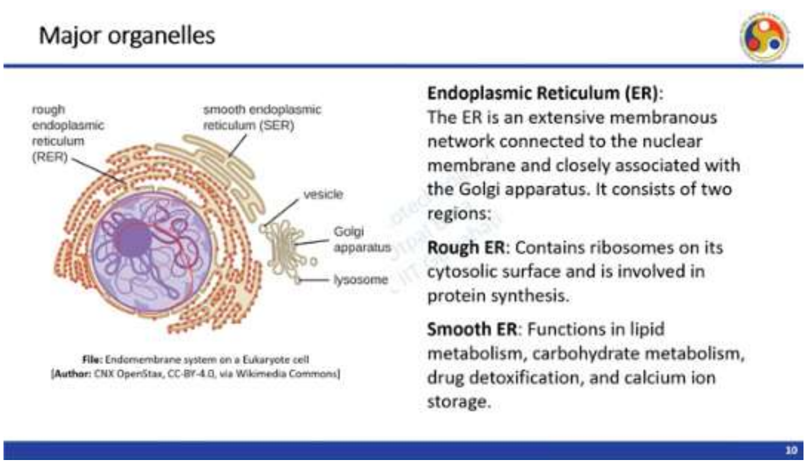


For example, diatoms have silica-based walls. Red algae, Rhodophyta, contain a mix of cellulose and sulfated polysaccharides. Brown algae, Phaeophyta, possess alginates and other polysaccharides. Protozoa: some protozoa, like amoebas, have cell walls made of proteinaceous materials, while others, such as paramecium, lack rigid cell walls altogether. Mesoorganelles: the nucleus.

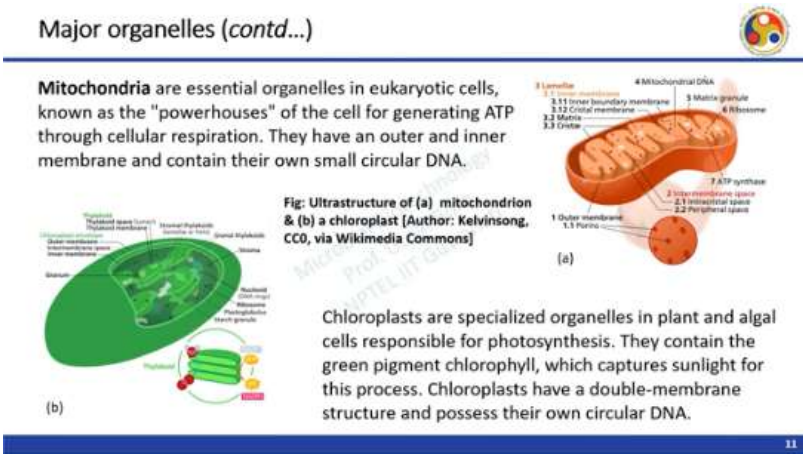
The nucleus contains the cell's genetic material and is key to DNA replication, transcription, and regulating gene expression. The Golgi apparatus consists of flattened membrane-bound sacs called cisternae and plays a central role in intracellular transport and the post-translational modification of proteins and lipids. Here, you can see a Golgi apparatus and the nucleus of a eukaryotic cell. The endoplasmic reticulum is an extensive membranous network connected to the nuclear membrane and closely associated with the Golgi apparatus. Here, you can see the nuclear membrane on one side and the connection with the Golgi apparatus on the other side.



Now, there are two types. One is the rough endoplasmic reticulum. This contains ribosomes on its cytosolic surface and is involved in protein synthesis, and there is the smooth endoplasmic reticulum. It functions in lipid metabolism. Carbohydrate metabolism, drug detoxification, and calcium ion storage.

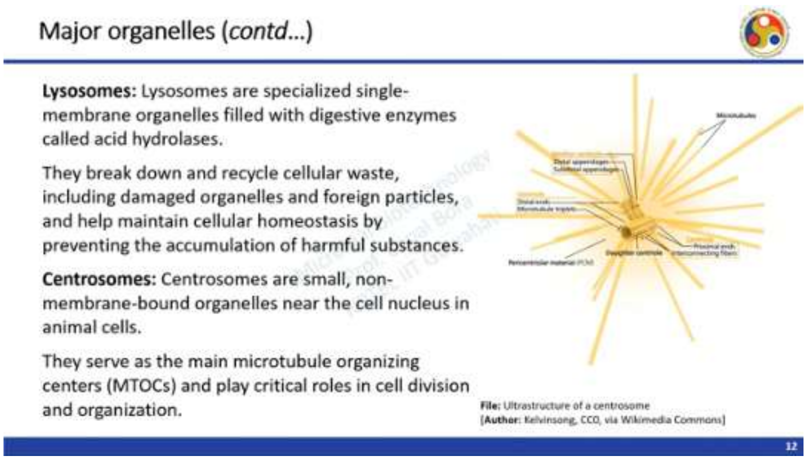


The next important organelle is the mitochondria. These are essential organelles in eukaryotic cells, known as the powerhouses of the cell for generating ATP through cellular respiration. They have an outer and inner membrane and contain their own small circular DNA. So, you can see the mitochondrial DNA over here, and then you can see the inner membrane, and then you can see the outer membrane and the intermembrane space between these two membranes.



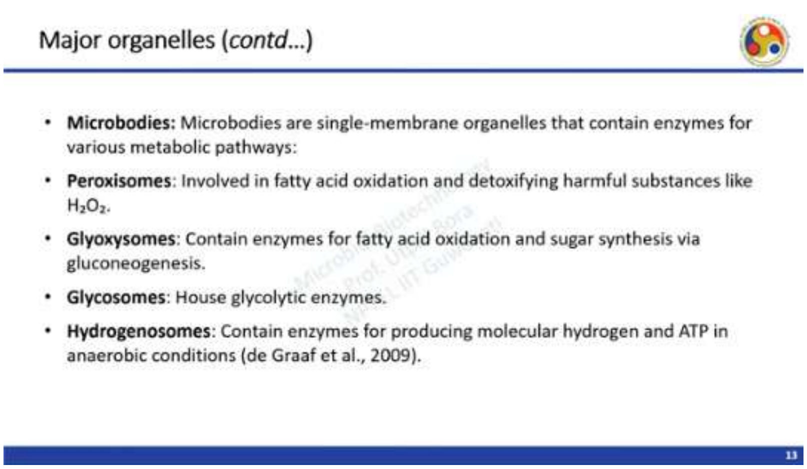
Another important structure is the chloroplast, not available in all kinds of eukaryotic microorganisms. These chloroplasts are specialized organelles in plants, as we know, and are also present in algal cells, responsible for photosynthesis. They contain the green pigment chlorophyll, which captures sunlight for this process. Chloroplasts have a double-membrane structure and possess their own circular DNA, as in the case of mitochondria. So, you can see here certain structures called thylakoids, and there is a chloroplast envelope; again, it has an outer membrane, inner membrane, and an intermembrane space, and then you have this nucleoid, which are the DNA rings, and then we have ribosomes over here.

And also, it has the starch granules, which are basically produced as a result of the metabolic processes inside. One more important organelle is the lysosome. These are specialized single-membrane organelles filled with digestive enzymes called hydrolases, which break down and recycle cellular waste, including damaged organelles and foreign particles, and help maintain cellular homeostasis by preventing the accumulation of harmful substances. Centrosomes are small, non-membrane-bound organelles near the cell nucleus in animal cells. They serve as the main microtubule-organizing centers (MTOCs) and play a critical role in cell division and organization.

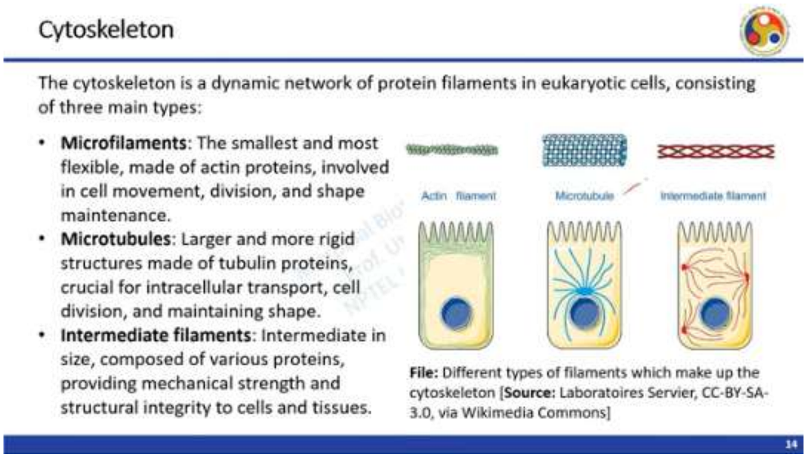


And then you can see here the central, the mother centriole, and these microtubules. And then here are the daughter centrioles. Other important organelles are the micro bodies. These are single-membrane organelles that contain enzymes for various metabolic pathways. The peroxisomes are involved in fatty acid oxidation and detoxification

of harmful substances like hydrogen peroxide. Then there are the glyoxysomes, which contain enzymes for fatty acid oxidation and sugar synthesis via gluconeogenesis. Then there are glycosomes, which contain glycolytic enzymes. And there are the hydrogenosomes, which contain enzymes for producing molecular hydrogen and ATP in anaerobic conditions. One of the important components of a eukaryotic cell or eukaryotic microbial cell is the cytoskeleton.

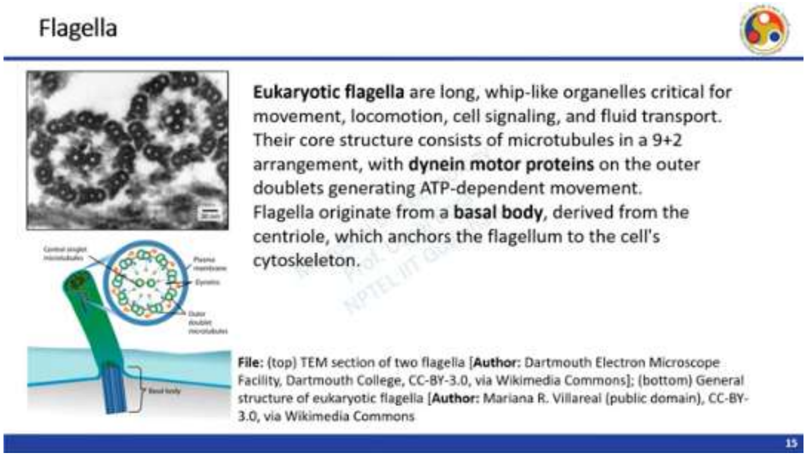


This is a dynamic network of protein filaments, and it consists of three main types: the microfilaments, microtubules, and intermediate filaments. The smallest and most flexible microfilaments are made up of actin proteins. These are involved in cell movement, division, and the maintenance of cell shape. The microtubules are larger and more rigid structures made of tubulin proteins, crucial for intracellular transport, cell division, and also in maintaining the shape of the cells. The intermediate filaments are intermediate in size and are composed of various proteins, providing mechanical strength and structural integrity to cells and tissues.

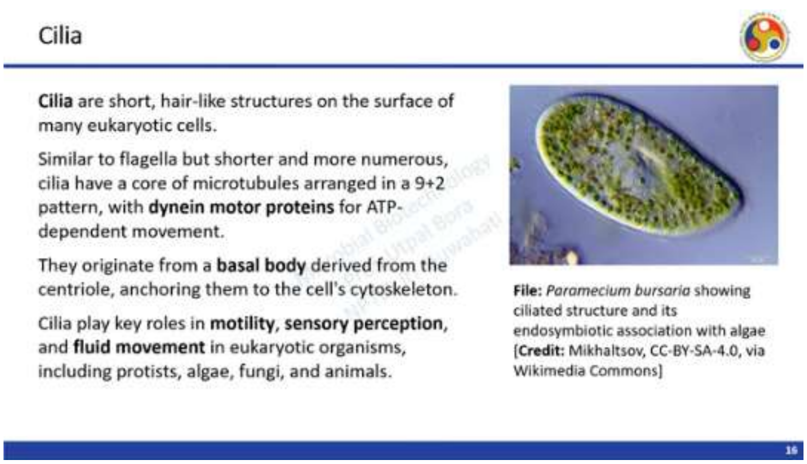


So here you can see how an actin filament, a microtubule, and an intermediate filament help in maintaining the structure of the cell overall. Like prokaryotic bacteria, eukaryotic microorganisms may also have flagella. These eukaryotic flagella are long, whip-like organelles, critical for movement, locomotion, cell signaling, and fluid transport. The core structure consists of microtubules in a 9 plus 2 arrangement, with dynein motor proteins on the outer doublets generating ATP-dependent movement.

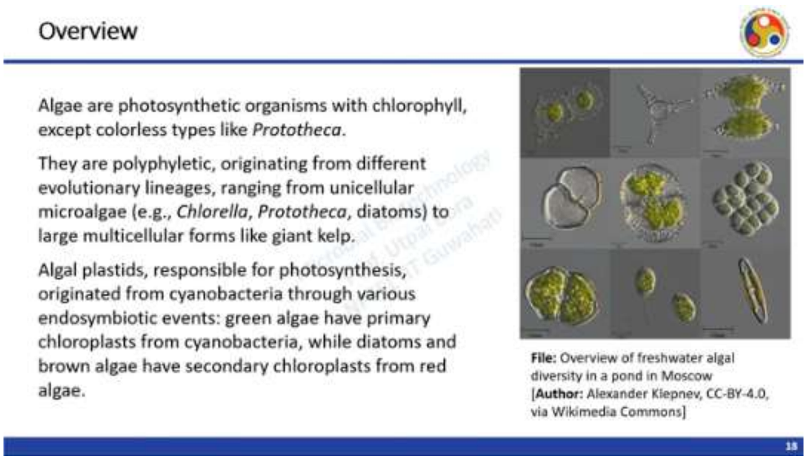
Flagella originate from a basal body derived from the centriole, which anchors the flagellum to the cell's cytoskeleton. So here is the basal body, as we can see, and then these are the cross-sections where you can see the plasma membrane and the dyneins, as we have mentioned in this lecture. Another important component is the cilia. These are short, hair-like structures on the surface of many eukaryotic cells, similar to flagella but shorter and more numerous. Cilia have a core of microtubules, again arranged in a 9 plus 2 patterns, with dynein motor proteins for ATP-dependent movement.



They originate from a basal body derived from the centriole, anchoring them to the cell's cytoskeleton. Cilia play key roles in motility, sensory perception, and fluid movement in eukaryotic organisms like protists, algae, fungi, and other eukaryotic microbial animals. Let us now discuss algae. In this picture, you can see the image of marine algae. The long, hairy strands of that rope are about 1 meter.

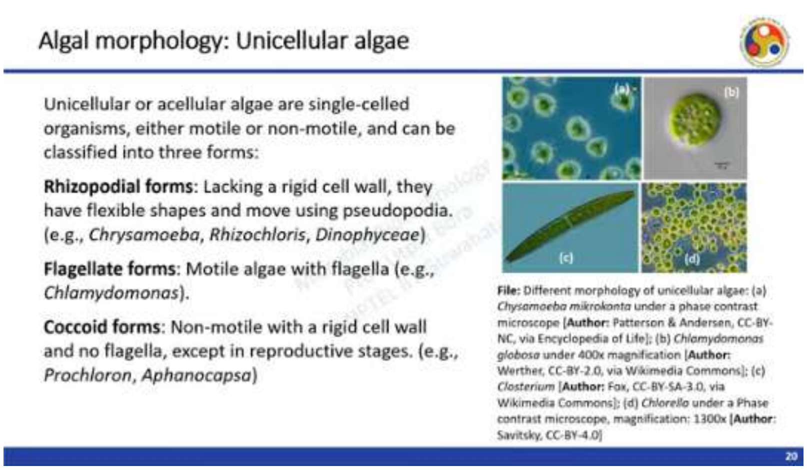


High, and the bottom is covered with soft, blank weed. Overall, algae are photosynthetic organisms with chlorophyll, except for colorless types like Prototheca. Here, you can see some of the freshwater algae diversity in a pond in Moscow, recorded by Alexander Klapnev. Algae are polyphyletic, originating from different evolutionary lineages, ranging from unicellular microalgae—examples include Chlorella, Prototheca, and diatoms—to large multicellular forms like giant kelp. Algal plastids are responsible for photosynthesis.



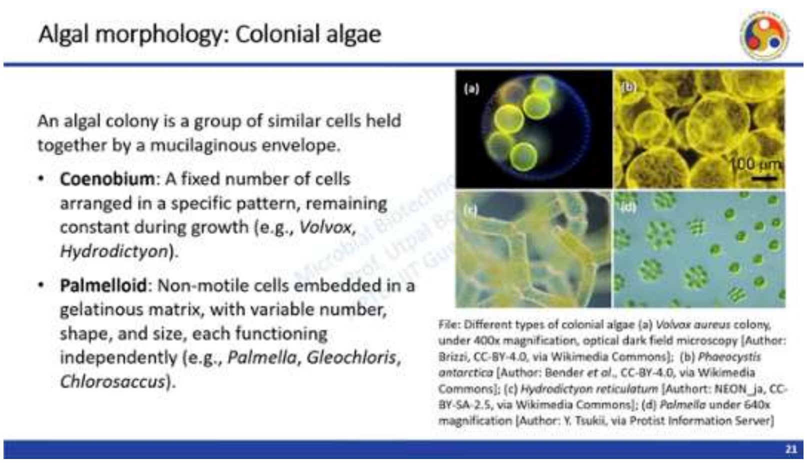
They originated from cyanobacteria through various endosymbiotic events. Green algae have primary chloroplasts from cyanobacteria, while diatoms and brown algae have secondary chloroplasts from red algae. Unlike terrestrial plants, algae are characterized by a lack of specialized cells and tissues, such as stomata, xylem, and phloem, as well as structures like leaves, roots, and rhizoids. Most algae are phototrophic, using photosynthesis, while some are mixotrophic, obtaining energy from both photosynthesis and organic matter. Certain unicellular algae, like green algae, euglenoids, and dinoflagellates, are heterotrophic and depend on external energy sources.

All the called blue-green algae, cyanobacteria are excluded from algae as they are prokaryotes. Algal morphology, let us look into unicellular algae. Unicellular or acellular algae are single-celled organisms which may be either motile or non-motile and be classified into three forms. Rhizopodial forms lacking a rigid cell wall. They have flexible shapes and move using pseudopodia.



Some examples are Chrysemioba, then Rhizochloris, Denophyse. The flagellated forms are the motile algae with flagella, example Chlamydomonas. Then there are coccoid forms, these are non-motile with a rigid cell wall and absence of flagella except in reproductive stages. Example, Plochloron and Afanocapsa. So here in this picture we can see various morphologies of unicellular algae.

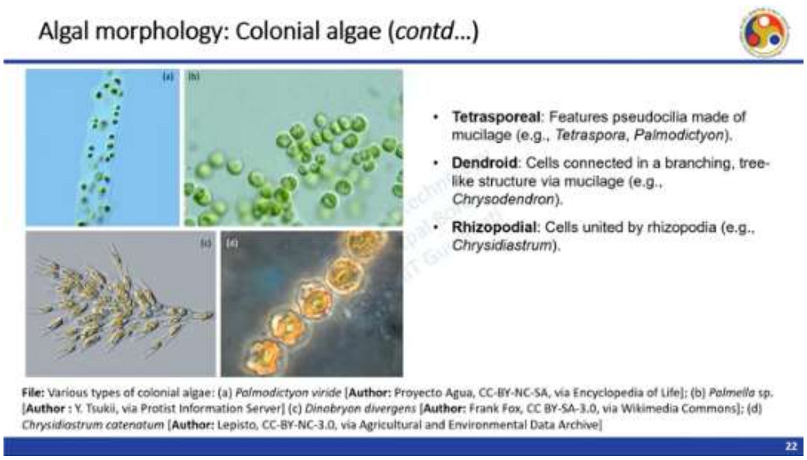
Here we can see Chrysemioba and then in B we can see Chlamydomonas and then in C we can see Clostridium and then in D we can see the Chlorella. An algal colony is a group of similar cells held together by a mucilaginous envelope. So, some of the algae are unicellular as we have discussed and they may exist independently. But in an algal colony they all exist together which are held together by a mucilaginous envelope.



One important concept here is that of conubium. A fixed number of cells arranged in a specific pattern is called a conubium, and these remain constant during growth—for example, Volvox and Hydrodictyon. Next is the palmelloid. The non-motile cells are embedded in a gelatinous matrix with a variable number, shape, and size, each functioning independently. For example, Palmella and Gloeochloris.

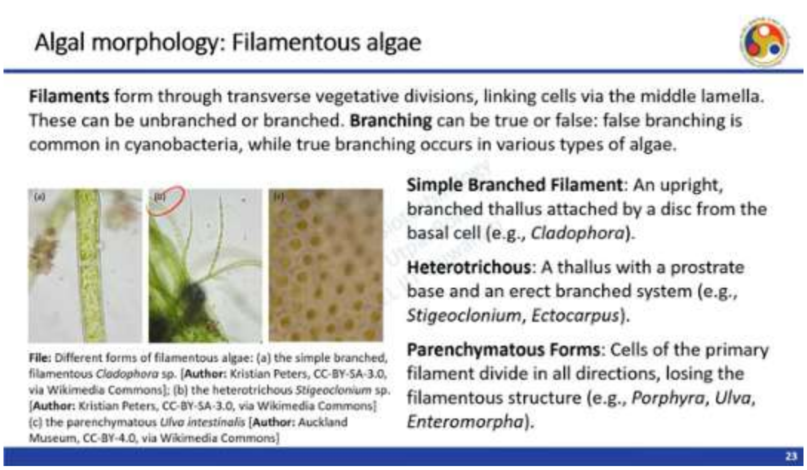
Here we have Volvox aureus in Figure A, then Phaeocystis antarctica in Figure B, and in Figure C we have Hydrodictyon reticulatum. In D, we have Palmyra. These are different kinds of morphologies of algal colonies. In addition to these, we may have tetrasporal. Here, these feature pseudocilia made of mucilage.

Next comes the dendroid. These are cells connected in a branching, tree-like structure via the mucilage. Then we have the rhizopodial morphology, where the cells are united by the rhizopodia. In A, we can see Palmodictyon viride, which is a tetrasporal morphology. Then in B, we see Palmella.

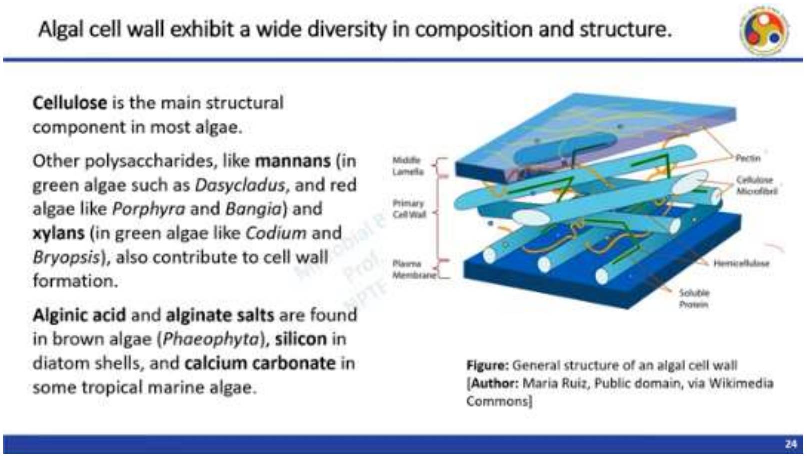


And then in C, we see the Dinobrion divergence, and in D, we see Chise diastrum catenatum, which is basically rhizopodial. Let us now study another morphological form of algae: the filamentous algae. These filaments form through transverse vegetative divisions, linking cells via the middle lamella. This can be unbranched or branched. Branching can be again true or false.

False branching is common in cyanobacteria, while true branching occurs in various types of algae. So this branching can be simple, which is an upright branched talus attached by a disc from the basal cell, as in the case of Cladophora, which you can see in Figure A. Or it can be heterotrichous, which is basically a talus with a prostrate base and an erect branch system. An example is Stegoclonium, as seen in Figure B. Or it can be parenchymatous, where cells of the primary filament divide in all directions, losing the filamentous structure, as seen in Figure C. Some examples of parenchymatous forms are Porphyra, Alva, and Enteromorphic.

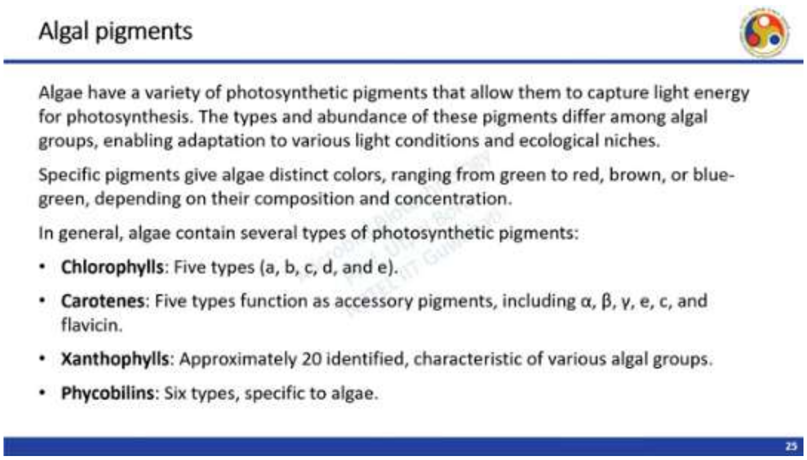


Algal cells exhibit a wide diversity in composition and structure. In very simple terms, you can see that it has a primary cell wall, then a middle lamella, and here on the other side, you can see the plasma membrane and various components over here, like pectin, cellulose microfibrils, as well as hemicellulose, and here we can see the presence of certain soluble proteins. Cellulose is the main structural component in most algae. Other polysaccharides, like mannans in green algae and red algae such as Porphyra, and xylans also contribute to cell wall formation.

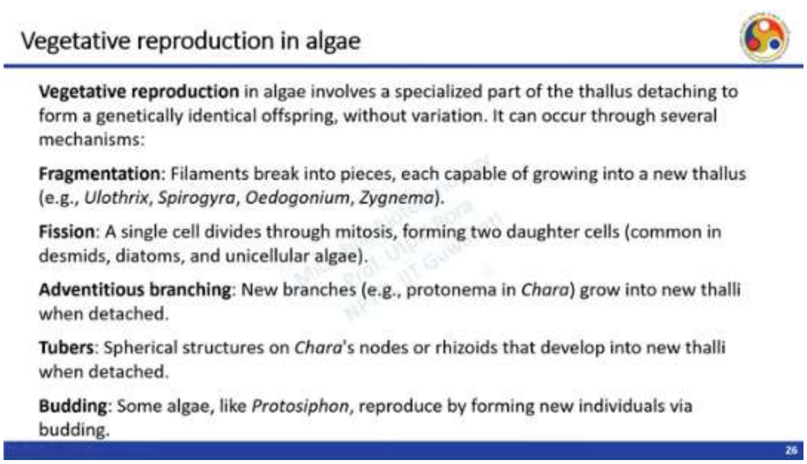


Alginic acid and alginate salts are found in brown algae, silicon in diatom cells, and calcium carbonate in some tropical marine algae. Algae also have certain pigments, and as we know, the main pigment visible to us is the green pigment or the photosynthetic pigment. These allow them to capture light energy for photosynthesis. The types and abundance of these pigments differ among algal groups, enabling adaptations to various light conditions and ecological niches. Specific pigments give algae distinct colors, ranging from green to red, brown, or blue-green, depending on the composition and concentration.

In general, algae contain several types of photosynthetic pigments. For example, they may have chlorophylls, which are of five types—A, B, C, D, and E—or carotenes, again of five types, which function as accessory pigments, including alpha, beta, gamma, and so on also flavicin. Then we have gentrophils. There are approximately 20 different gentrophils identified, and these are also characteristic of various algal groups, often aiding in their identification.

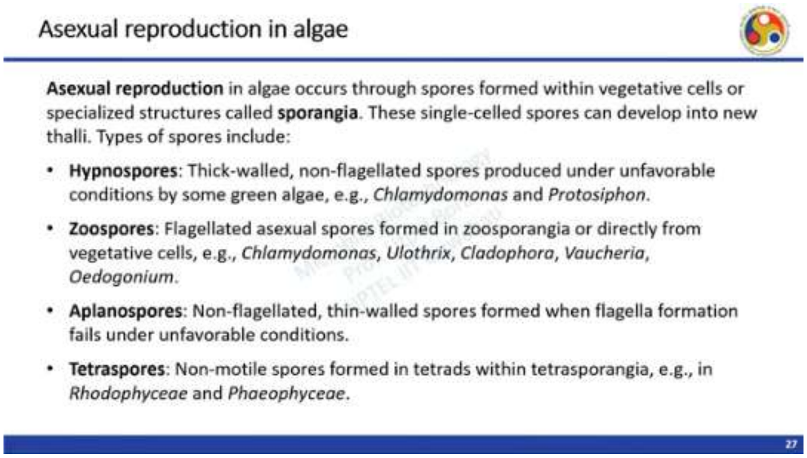


Then we have phycobilins, around six types, and these are also specific to some algae. Let us now discuss the reproductive systems or reproduction processes in algae. So, basically, one of the important reproduction methods in algae is through vegetative means. This involves a specialized part of the thallus, which detaches to form a genetically identical offspring without variation. So, this is true to type. It can occur through several mechanisms, for example, fragmentation.



Filaments break into pieces, capable of growing into a new talus, as in the case of Eulotrix spirogyra. Another method is diffusion. A single cell divides through mitosis, forming two daughter cells, common in Desmedes, diatoms, and unicellular algae. Then, we have advantageous branching. Here, new branches, for example, Protonema in Chara, grow into new talus when detached.

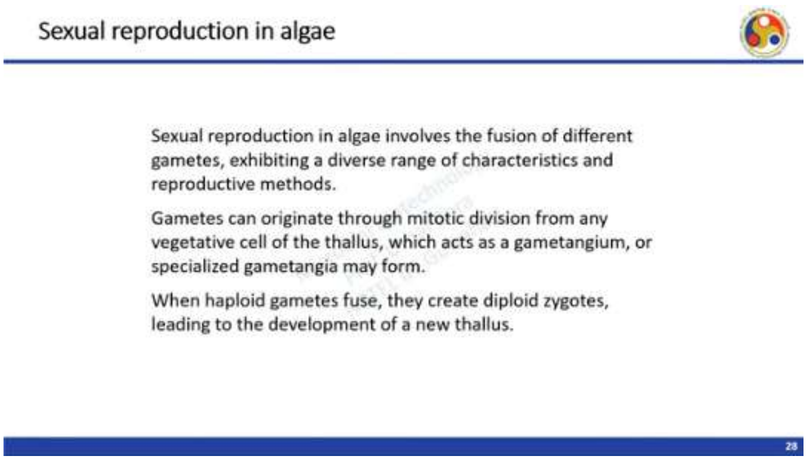
Then, another method is tubers, which are spherical structures on Chara's nodes or rhizoids that develop into new talus when detached. In some cases, algae also undergo budding, as in the case of Protosiphon, where new individuals are formed through a process called budding. Another method of reproduction is asexual reproduction. This asexual reproduction in algae occurs through spores formed within vegetative cells or specialized structures called sporangia. These single-cell spores can develop into new talus.



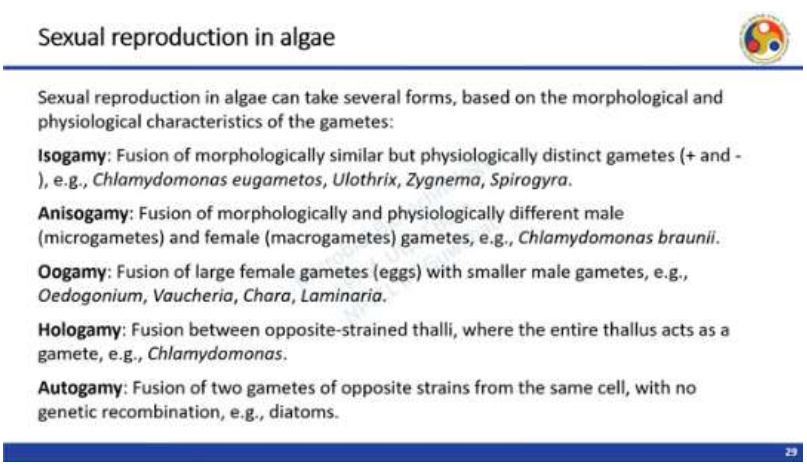
The types of spores include hypnospores. These are thick-walled, non-flagellated spores produced under favorable conditions by some green algae like Cladophora and Protosiphon. Then we have zoospores, as the name suggests. These are flagellated asexual spores formed in zoosporangia. Or directly from vegetative cells, for example, in Chlamydomonas and Eulotrix.

And then we have aplanospores. These are non-flagellated tenual spores formed when flagella formation fails under unfavorable conditions. Then we have tetraspores. These are non-motile spores formed in tetrads within tetrasporangia. For example, in the case of rhodophyceae and pheophyceae.

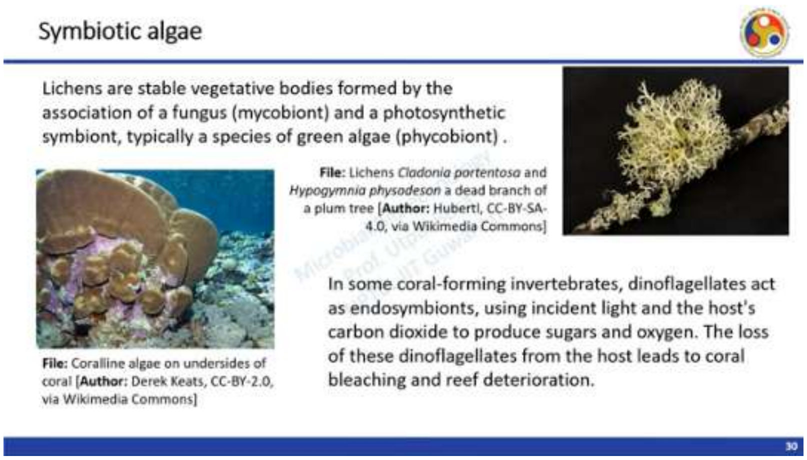
Algae also undergo sexual reproduction, which involves the fusion of different gametes. They exhibit a diverse range of characteristics and reproductive methods. Gametes can originate through mitotic divisions from any vegetative cell of the thallus, which acts as a gametangium or specialized gametangium in a form. When haploid gametes fuse, they create diploid zygotes, leading to the development of a new thallus. Sexual reproduction in algae can take several forms based on the morphological and physiological characteristics of the gametes.



For example, it may be isogamy, anisogamy, oogamy, hologamy, or otogamy. Isogamy is the fusion of morphologically similar but physiologically distinct gametes, positive and negative. For example, in the case of Chlamydomonas, Eulotrix, Gignema, and Spirogyra. Anisogamy is the fusion of morphologically and physiologically different male microgametes and female macrogametes, for example, in the case of Chlamydomonas braunii. Oogamy is the fusion of large female gametes with smaller male gametes, for example,

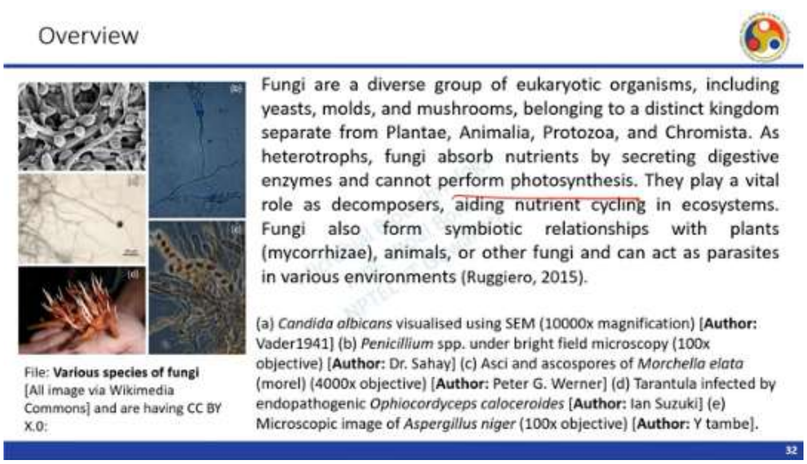


Udogonium, Bhocheria, Cara, and Laminaria. Then we have hologamy, which is the fusion between opposite-strain thallae, where the entire thallus acts as a gamete, as seen in Chlamydomonas. Autogamy is the fusion of two gametes of opposite strains from the same cell with no genetic recombination, as in the case of diatoms. Now, let us discuss algae, which form symbiotic relationships. Lichens are stable vegetative bodies formed by the association of a fungus and a photosynthetic symbiont, typically a species of green algae called a phycobiont.



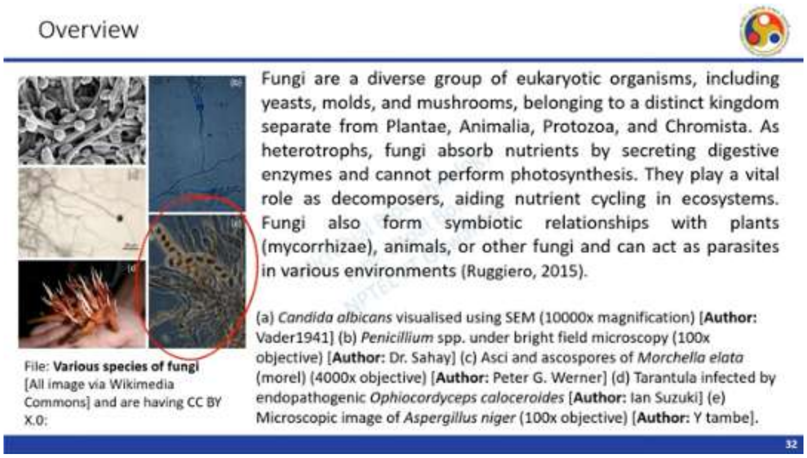
So, in this figure, we can see the lichen Cladonia portentosa, Hypogimnea physodacin, and a dead branch of a plum tree. In some coral-forming invertebrates, dinoflagellates act as endosymbionts, using incident light and the host's carbon dioxide to produce sugars and oxygen. The loss of these dinoflagellates from the host leads to coral bleaching and reef deterioration. Thus, they are of huge ecological importance.

Here, you can see the picture of coralline algae on the other side of a coral. Now, let us discuss fungi. Fungi are a diverse group of eukaryotic organisms, including yeasts, molds, and mushrooms, and they belong to different kingdoms separate from Plantae, Animalia, Protozoa, and Chromista. As heterotrophs, fungi absorb nutrients by secreting digestive enzymes and cannot perform photosynthesis. They play a vital role as decomposers.

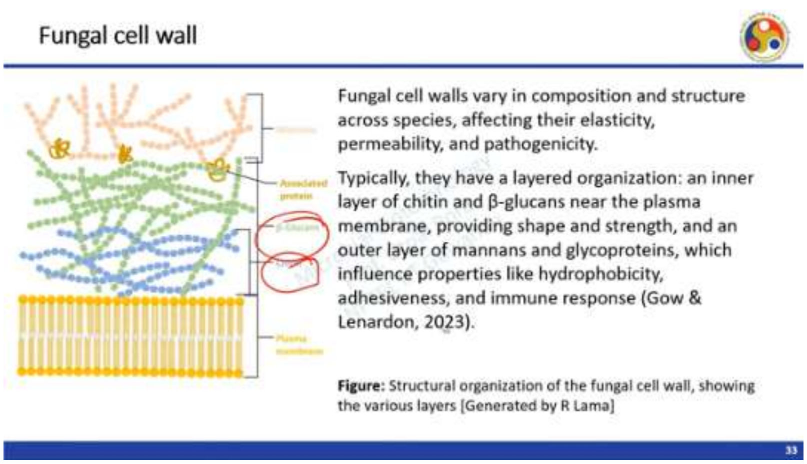


Aiding nutrient cycling in ecosystems. Fungi also form symbiotic relationships with plants like mycorrhizae, animals, or other fungi and can act as parasites in various environments. So, in this panel, we can see in Figure A the Candida albicans. And then in B, we can see the Penicillium species. And in C, we can see SK or ascospores of Morchella elata.

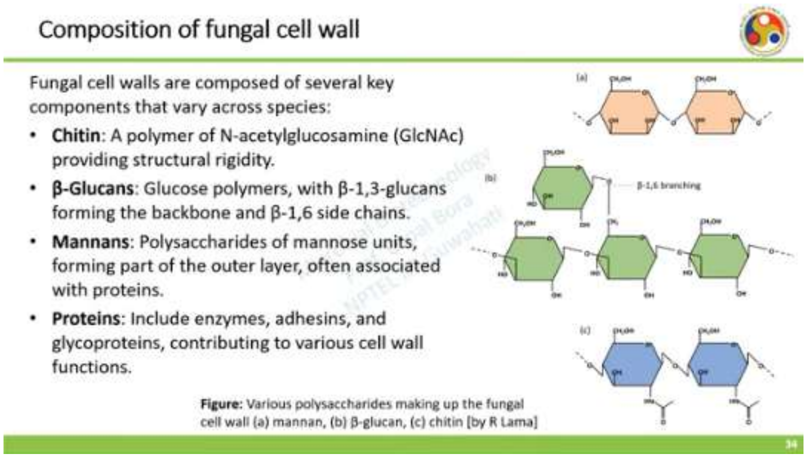
And in D, we can see a tarantula, which is infected by entomopathogenic fungi of the Cordyceps. And this is actually also economically very important. And then in E, we can see the microscopic image of Aspergillus niger. So, these are the diverse types of fungi in brief, but there are many more which cannot be shown in one single slide. The structure of the fungal cell wall varies in composition and structure across species, affecting their elasticity, permeability, and pathogenicity.



Typically, they have a layered organization: an inner layer of chitin and beta-glucans, these provide shape and strength, and an outer layer of mannans and glycoproteins, which influence properties like hydrophobicity, adhesiveness, and immune response. And there are also certain associated proteins in this cell wall. The composition of the fungal cell wall has several key components that vary across phases. We already discussed chitin; it is a polymer of N-acetylglucosamine, which provides structural rigidity.

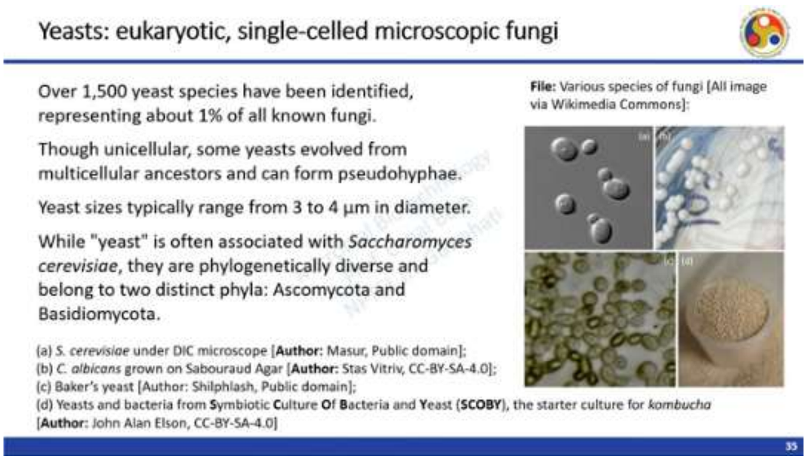


Then we have the beta-glucans; these are glucose polymers with beta-1,3-glucans forming the backbone and beta-1,6 side chains. Then we have the mannans. These are polysaccharides of mannose units forming part of the outer layer, often associated with proteins, which include enzymes, adhesins, and glycoproteins contributing to various cell wall functions. Let us now discuss yeast, which are eukaryotic single-celled microscopic fungi. So, in this picture, you can see Saccharomyces cerevisiae in figure A.

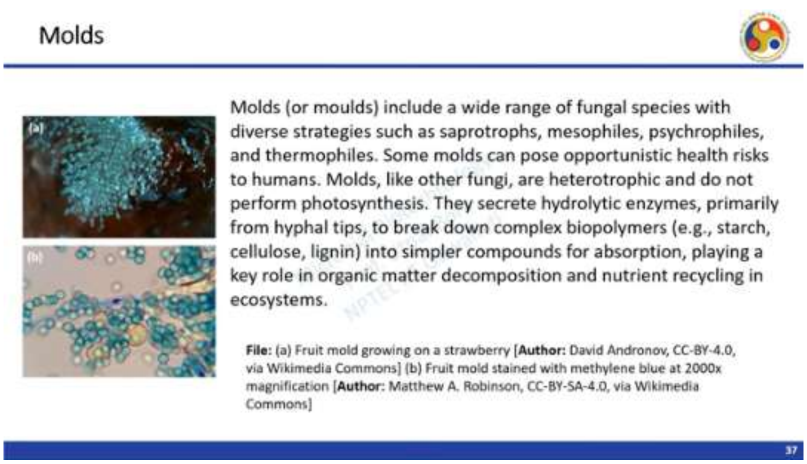


Then you can see Candida albicans, which is grown on Sabouraud agar. Then in C, we can see the baker's yeast, and in D, we can see yeast and bacteria from a symbiotic culture of bacteria and yeast, or SCOBY. There are over 1,500 species identified, and this represents only about 1% of all known fungi. Though in the cellular level, some yeast evolved from multicellular ancestors and can form pseudohyphae. Yeast sizes typically range from 3 to 4 micrometers in diameter.

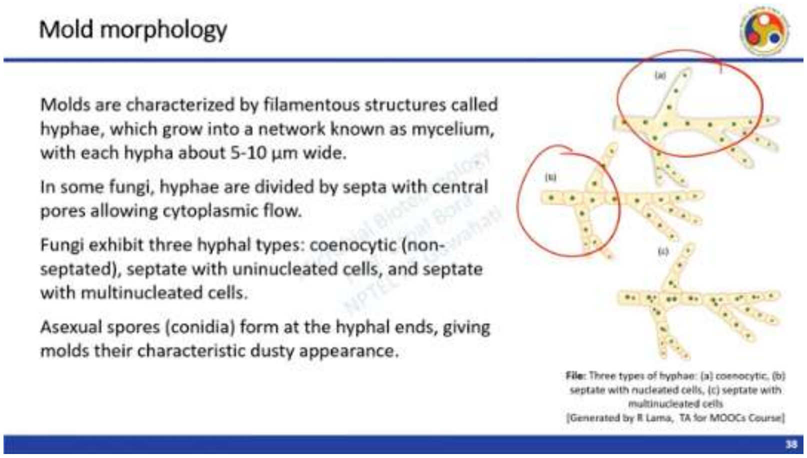
While yeasts are often associated with Saccharomyces cerevisiae, they are phylogenetically diverse and belong to two distinct phyla: Ascomycota and Basidiomycota. In most yeast, the common morphotype involves one nucleus per cell. However, SBR Gossypii displays a syncytium where multiple nuclei share a single cytoplasm, each following its own replication cycle. In Toxoplasma gondii, daughter cells form inside the mother cell after nuclear division, leading to distinct plasma membranes for each nucleus, and this is linked to spore formation.



These include a wide range of fungal species with diverse strategies such as saprotrophs, mesophiles, psychrophiles, and thermophiles. Some molds can pose opportunistic health risks to humans. Molds, like other fungi, are heterotrophic and do not perform photosynthesis. They secrete hydrolytic enzymes. Primarily from hyphal tips, to break down complex biopolymers like starch, cellulose, and lignin into simpler compounds for absorption, playing a key role in organic matter decomposition and nutrient recycling in ecosystems.

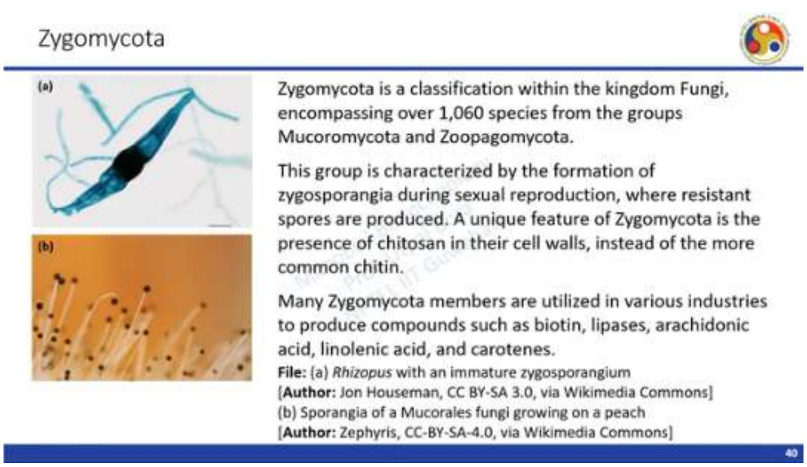


In this picture, we can see a fruit mold growing on a strawberry, and then in B, we can see fruit mold stained with methylene blue under 2000X magnification. The morphology of molds. Molds are characterized by filamentous structures called hyphae, which grow into a network known as mycelium, with each hypha about 5 to 10 micrometers wide. In some fungi, hyphae are divided by septa with central pores, allowing cytoplasmic flow. Fungi exhibit three hyphae types: pseudocytic, which are non-septated, then septate with uninucleated cells, and septate with multinucleated cells. Asexual spores form at the hyphae tips, giving molds their characteristic dusty appearance. So, these are the three types of hyphae: coenocytic, septate, and then septate with multinucleated cells. So here you can see several nuclei in one cell.



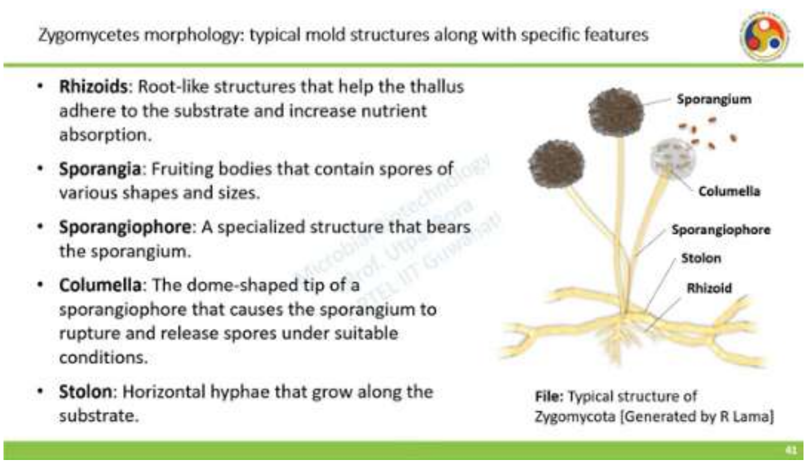
And here there is no any septa. How moles are classified? Moles are classified as microbes but do not belong to a specific taxonomic group primarily founded the divisions Zygomycota and Ascomycota. Many moles were formerly classified as Deuteromycota.

Zygomycota or conjugated fungi feature non-segmented hyphae with multiple nuclei which fuse during sexual reproduction to form zygospores. In contrast, Ascomycota have septate hyphae with a single nucleus per cell and produce spores in sac-like structures called ASCII during sexual reproduction. Gygomycota. Gygomycota is a classification within the kingdom of fungi which encompasses over 1060 species from the groups of Mucuromycota and Zupagomycota.



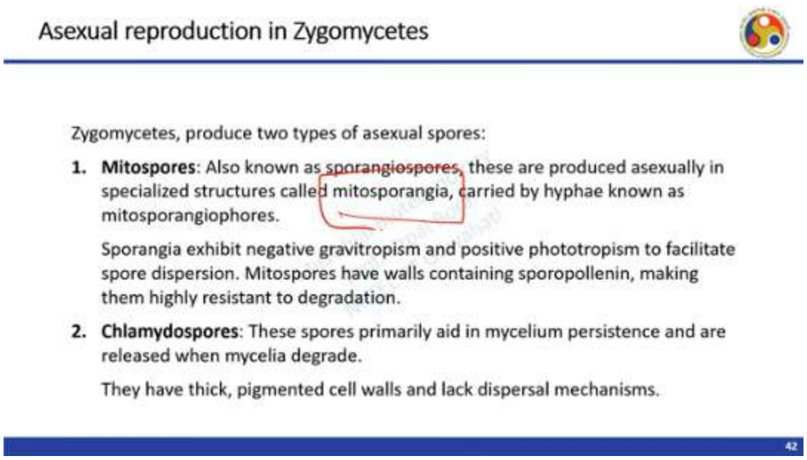
This group is characterized by the formation of zygosporangia during sexual reproduction where resistant spores are produced. A unique feature of zygomycota is the presence of chitosan in the cell walls instead of the more common chitin. Many zygomycota are utilized in various industries to produce compounds such as biotin, lipases, arachidonic acid, linonic acid, and keratins, and are therefore very important from the point of view of microbial biotechnology. In figure A here, we can see rhizopus with an immature zygosporangium, and then in figure B, we can see sporangia of a mucaral fungi growing on a pitch. The morphology of zygomycetes.

These are typical moose structures, along with specific features. And you can see this typical structure of the zygomyceta, where you have this sporangium, then columella, and then the rhizoid, stolon, and sporangiophore. The rhizoids are root-like structures that help the thallus adhere to the substrate and increase nutrient absorption. Yeah. Sporangia are fruiting bodies that contain spores of various shapes and sizes.



Sporangiophore is a specialized structure that bears the sporangium. Columella, the dome-shaped tip of a sporangiophore, causes the sporangium to rupture and release spores under suitable conditions. Then we have the stolon, which is horizontal hyphae that grow along the substrate. Let us look into the reproduction in zygomycetes—the asexual reproduction. Zygomycetes produce two types of asexual spores: the mitospores and chlamydospores.

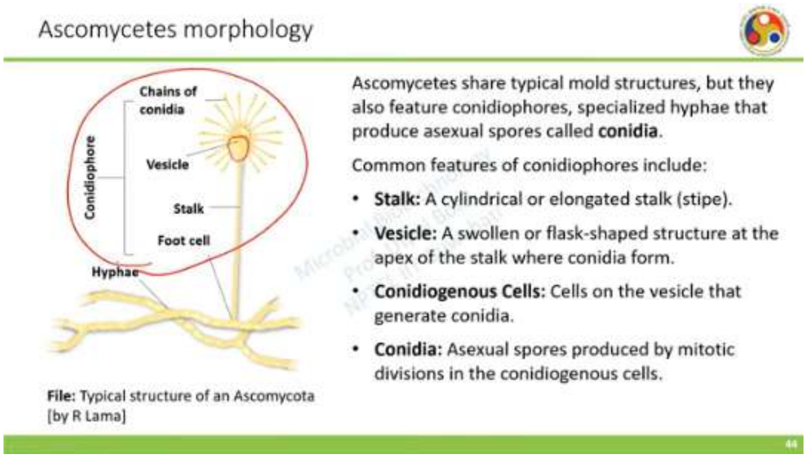
Mitospores, also known as sporangiospores, are produced asexually in specialized structures called mitosporangia. These are carried by hyphae known as mitosporangiophores. Sporangia exhibit negative gravitropism and positive phototropism to facilitate spore dispersion. Mitospores have walls containing sporopollenin, making them highly resistant to degradation. Chlamydospores are spores primarily aiding in mycelium persistence and are released when mycelia degrade.



They have thick pigmented cell walls and lack dispersal mechanisms. Let us now discuss about Ascomycota. Ascomycota or sex fungi is the largest phylum of fungi comprising over 64,000 species. The defining feature of this group is the ascus, a microscopic sexual structure that produces non-motile spores called ascospores. Family examples include morels, truffles and yeast used in baking and brewing.

Ascomycetes are crucial for humans, providing antibiotics, aiding in fermentation of bread and beverages, and serving as model organisms in rhesus, for example, Neurospora crassa and various yeasts. In this figure, we can see some of the species of mold which belong to Ascomycota. The morphology of Ascomycetes. So here we can see the presence of hyphae which is again running parallel to the substrate. Then we have a food cell from which the stock emerges and then we have a vesicle and then we have the chains of conidia.

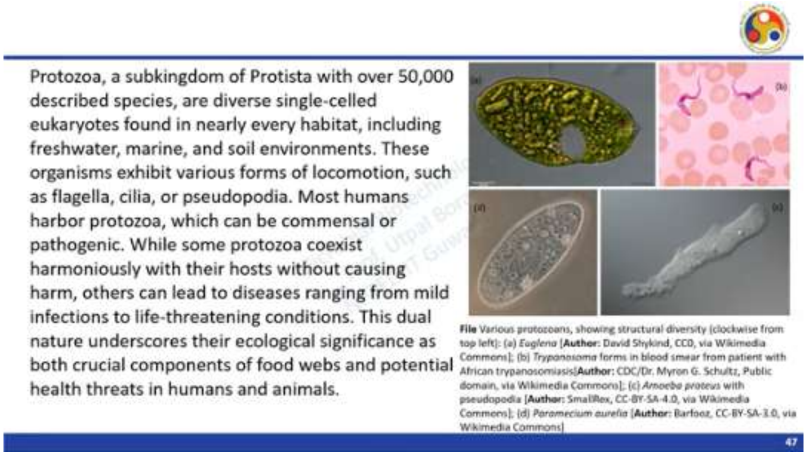
So together these at their structure forms the conidiophore. Ascomycetes, they are typical mole structures but they also feature conidiophores which are specialized hyphae that produce asexual spores called conidia. Common features of conidiophores include as already discussed in this figure, stalk which is a cylindrical or elongated stalk, then vesicle Swollen or flaccid structure at the apex of the stock where conidia form. Then conidiogenous cells.



These are cells in the vesicle that generate conidia. And then finally, conidia, which are asexual spores produced by mitotic divisions in the conidiogenous cells. Asexual reproduction is the primary method of propagation in Ascomycota, primarily through the production of vegetative spores called conidia. Conidia are single-nucleus spores resulting from mitotic divisions, making them genetically identical to the mycelium from which they originated. So, they are also true to type.

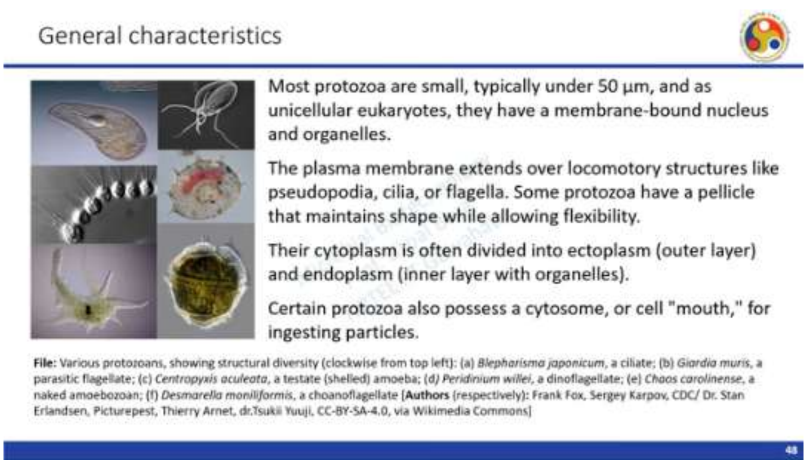
Depending on the species, conidia can disperse via wind, water, or animals. Various types of conidia can be distinguished by color, shape, and release methods, serving as taxonomic characteristics for classifying Ascomycota. Let us now discuss protozoans briefly. Protozoa is a sub-kingdom of Protista with over 50,000 described species. They are diverse single-celled eukaryotes found in nearly every habitat, including freshwater, marine, and soil environments.

These organisms exhibit various forms of locomotion, such as flagella, cilia, or pseudopodia. Most humans harbor protozoa, which can be commensal or pathogenic. While some protozoa coexist harmoniously with their host, without causing harm.



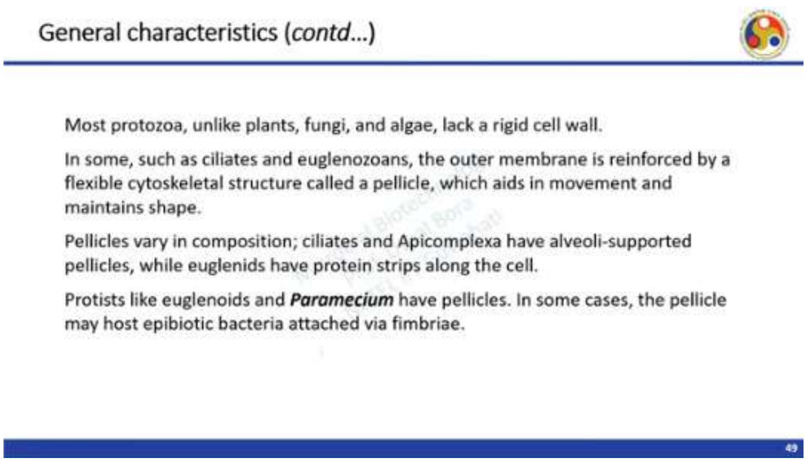
Others can lead to diseases ranging from mild infections to life-threatening conditions. This dual nature underscores the ecological significance as both crucial components of food webs and potential health threats in humans and animals. In this panel, we can see various protozoans showcasing the structural diversity. You can see Euglena in Figure A. Then we see Trypanosoma in Figure B, which is taken from the blood smear of patients with African trypanosomiasis, a disease. And we have mentioned that some of these cause diseases in humans.

Then you have the Amoeba proteus with pseudopodia in Figure C and Paramecium aurelia in Figure D. So, protozoans are quite diverse, as we have discussed and as we can see from this panel. So, let us discuss some of the general characteristics of protozoa. Most protozoa are small, typically under 15 micrometers, and as unicellular eukaryotes, they have a membrane-bound nucleus and organelles. The plasma membrane extends over locomotor structures like pseudopodia, cilia, or flagella. Some protozoa have a pellicle that maintains shape while allowing flexibility.



Their cytoplasm is often divided into ectoplasm, the outer layer, and endoplasm, the inner layer, which contains the organelles. Certain protozoa also possess a cytostome or cell mouth for ingesting particles. So, here in this figure, we can see various protozoans once again, focusing on the structural diversity as we have discussed in the earlier slide. So, with this, we can see that protozoa are actually quite diverse and also very unique, particularly being eukaryotic microorganisms. Most protozoans, like plants, fungi, and algae, lack a rigid cell wall.

That is one of the unique features. In some, such as ciliates and euglenozoans, the outer membrane is reinforced by a flexible cytoskeletal structure called a pellicle, which aids in movement and maintains shape. Pellicles vary in composition. Ciliates and apicomplexa have alveoli-supported pellicles, while euglenids have protein strips along the cell. Protists like euglenoids and paramecium have pellicles in some cases.



The pellicle may host epibiotic bacteria attached via fibrils. So with this, we come to the end of this lecture. We will be discussing various eukaryotic microorganisms in the next lecture. Thank you. Amen.