MICROBIAL BIOTECHNOLOGY

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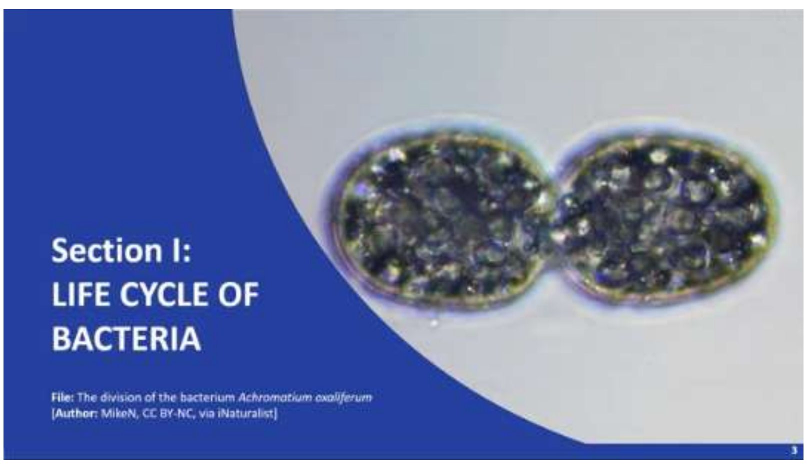
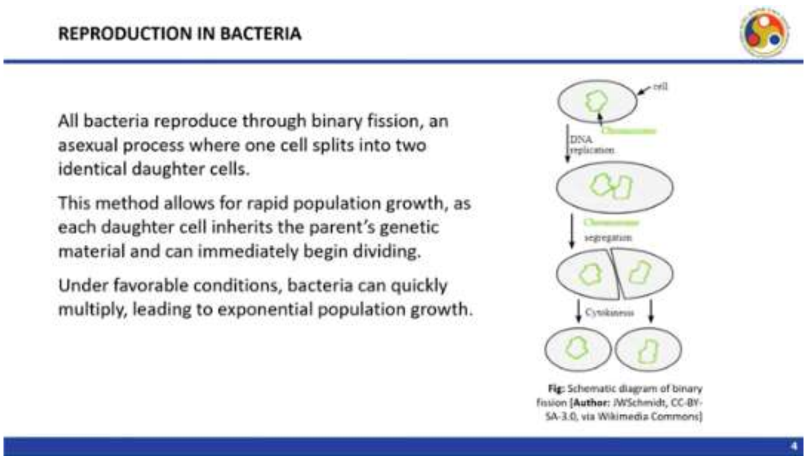
Lecture09
Lec 9: Life cycle of representative groups of microbes

Hello friends, welcome to my course on microbial biotechnology. We are in module 2. Today, we will be discussing the life cycle of representative groups of microbes. Particularly, we will discuss the life cycle of bacteria, algae, and also fungi. So, let us start with the life cycle of bacteria.

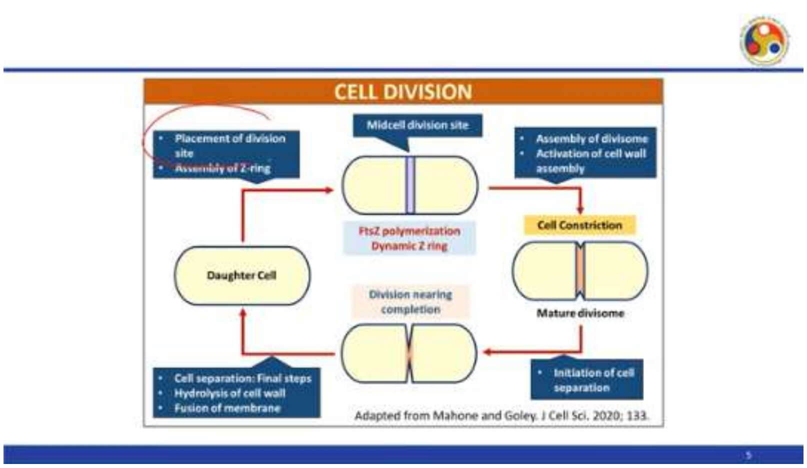
Here, you can see the division of the bacterium Achromatium, where it is dividing into two cells. How does this happen? We will discuss this in this section of the lecture. So, what is reproduction in bacteria, and how does it happen? All bacteria reproduce through binary fission, an asexual process where one cell splits into two identical daughter cells, as shown in the earlier introductory slide.



If you see here, one single cell results in two daughter cells, and what happens in between will be discussed now. This essential method allows for rapid population growth, doubling every cycle of cell division. Each daughter cell inherits the parent's genetic material and can immediately begin dividing. Under favorable conditions, bacteria can multiply quickly, leading to exponential population growth. Cell division involves first partitioning the nucleic acid or genetic material equally between the two daughter cells, followed by the formation of a septum, after which the two daughter cells separate.

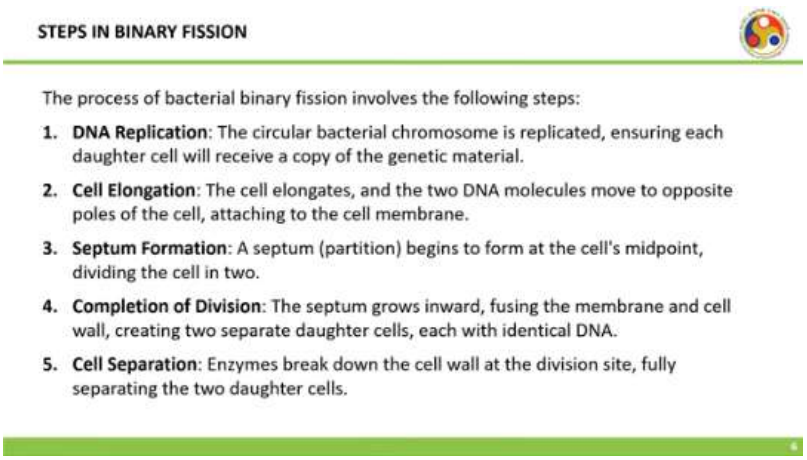


So if you look into it in more detail, say this is the starting point or this is the mother cell as well as the daughter cell which has become matured, there is a placement division site where there will be assembly of a jet ring so this is the mid cell division site so you see the FTS jet polymerization which gives to a dynamic jet ring Then there is assembly of divisome, activation of cell wall assembly and we can see that there is a cell constriction over here taking place and then after this there will be initiation of separation. This constriction will keep on growing as you can see over here. So it is growing inside to the cell.



And then finally there will be cell separation in the final steps and hydrolysis of the cell 1 and fusion of the membrane giving rise to not one, two daughter cells. We draw here only one for sake of simplicity. So, this cycle goes on and on. So, for every cycle, one cell will produce two cells. What are the steps in binary fission?

The process of bacterial binary fission involves the following steps. Number one, as I have already told, DNA replication. The circular bacterial chromosome is replicated, ensuring each daughter cell will receive a copy of the genetic material. Then there will be cell elongation. The cell elongates and the two DNA molecules move to opposite poles of the cell attaching to the cell membrane.



STEPS IN BINARY FISSION

The process of bacterial binary fission involves the following steps:

1. **DNA Replication**: The circular bacterial chromosome is replicated, ensuring each daughter cell will receive a copy of the genetic material.
2. **Cell Elongation**: The cell elongates, and the two DNA molecules move to opposite poles of the cell, attaching to the cell membrane.
3. **Septum Formation**: A septum (partition) begins to form at the cell's midpoint, dividing the cell in two.
4. **Completion of Division**: The septum grows inward, fusing the membrane and cell wall, creating two separate daughter cells, each with identical DNA.
5. **Cell Separation**: Enzymes break down the cell wall at the division site, fully separating the two daughter cells.

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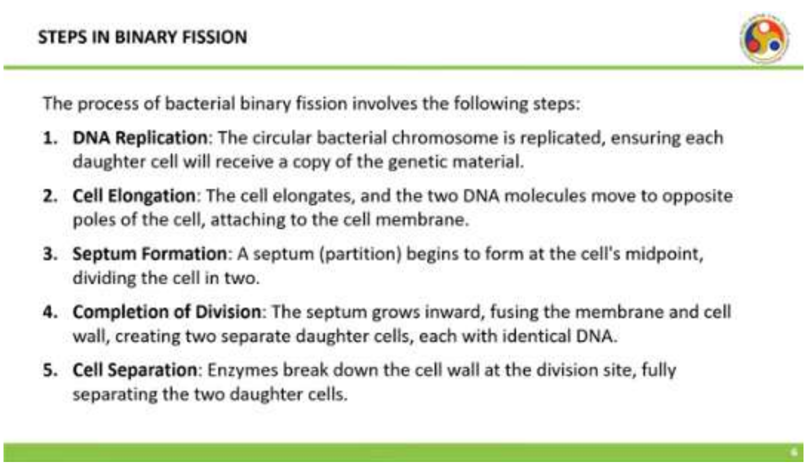

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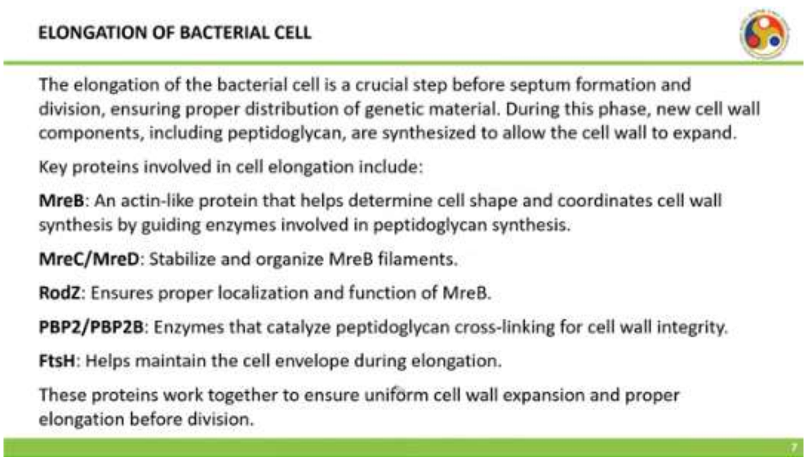
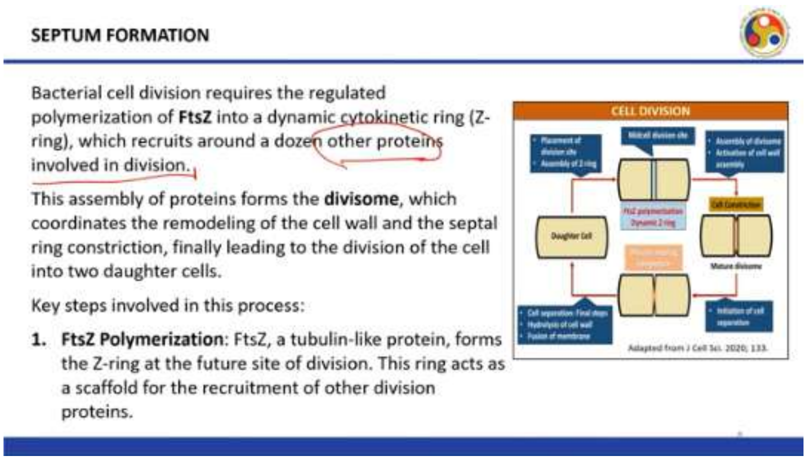
Elongation of the bacterial cell. The elongation of the bacterial cell is a crucial step before septum formation and division. Ensuring proper distribution of genetic material during this phase, New cell wall components, including peptidoglycan, are synthesized to allow the cell wall to expand. Some of the key proteins involved in cell elongation include MreB, an actin-like protein that helps determine cell shape and coordinates cell wall synthesis by guiding enzymes involved in peptidoglycan synthesis. Then we have MreC and MreD, which stabilize and organize the MreB filaments. Then there is the RodZ protein, which ensures proper localization and function of MreB. And then there are PBP2 and PBP2B, which are enzymes that cause peptidoglycan cross-linking for cell wall integrity. Then there is FtsH, which helps maintain the cell envelope during elongation.



These proteins will work together to ensure uniform cell wall expansion and proper elongation before division. The septum formation. So, this is the septum formation pre-stage where there is FTSZ polymerization, as I have already mentioned. Let us look into how this happens.

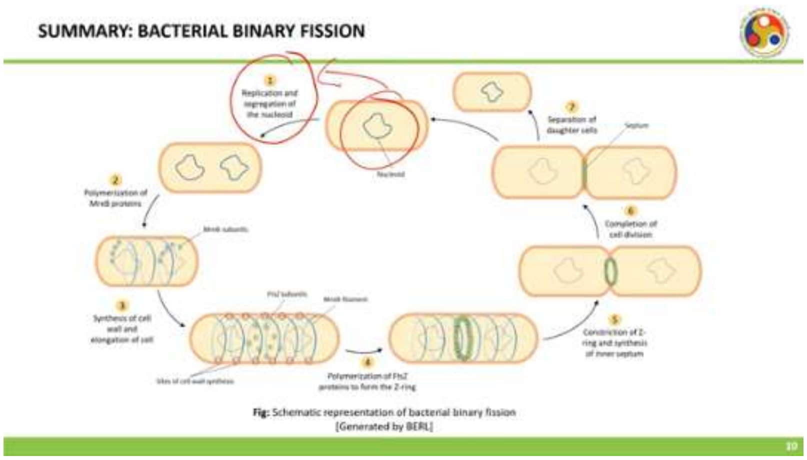
So, the bacterial cell division requires the regulated polymerization of FTSZ into a dynamic cytokinetic ring called the Z-ring, which recruits a dozen other proteins involved in division. This assembly of proteins forms the divisome. As we have shown here in this picture, which helps coordinate the remodeling of the cell wall and the septal ring constriction, finally leading to the division of the cell into two daughter cells. The key steps involved in this process: number one, FTSZ polymerization. FTSZ is a tubulin-like protein



that forms the Z-ring at the future site of division. This ring acts as a scaffold for the recruitment of other division proteins. Divisome assembly. Once the Z-ring forms, a series of proteins—FTSA, GIPA, FTSW, FTSI or PVP3, and others—are recruited to form the divisome. These proteins play a crucial role in cell wall synthesis, regulation, and coordination of constriction. Activation of the cell wall synthesis.

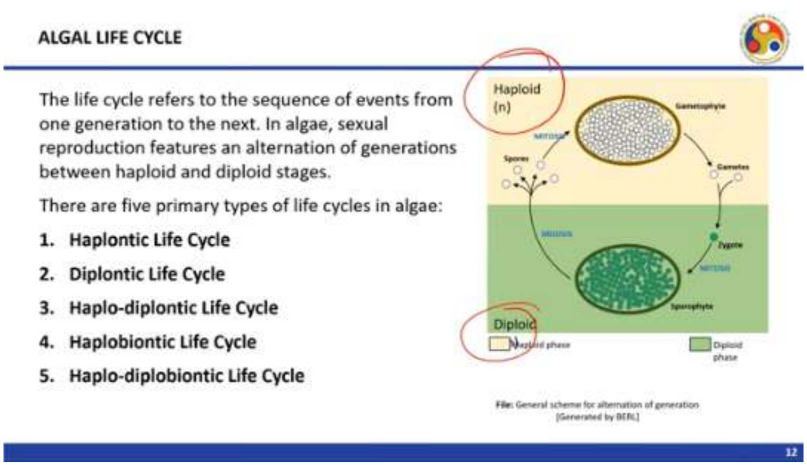
The division activates penicillin-binding proteins and other enzymes that synthesize, remodel, and reshape the peptidoglycan, enabling cell wall construction during division. Then, the cell wall construction and separation will occur. The combined action of the Z-ring cell wall synthesis machinery and other regulatory proteins leads to the inward constriction of the cell membrane, eventually pinching the cell into two separate daughter cells. So, if you look into the binary fission of bacteria overall, we can see that replication and segregation of the nucleoid occur.

And then, there is a polymerization of the MreB proteins. And then, these are the MreB subunits, as you can see over here. Synthesis of the cell wall and elongation of the cell are happening. So, you can see here—this is the size of the cell, and here it is getting elongated. And these are the sites of cell wall synthesis.



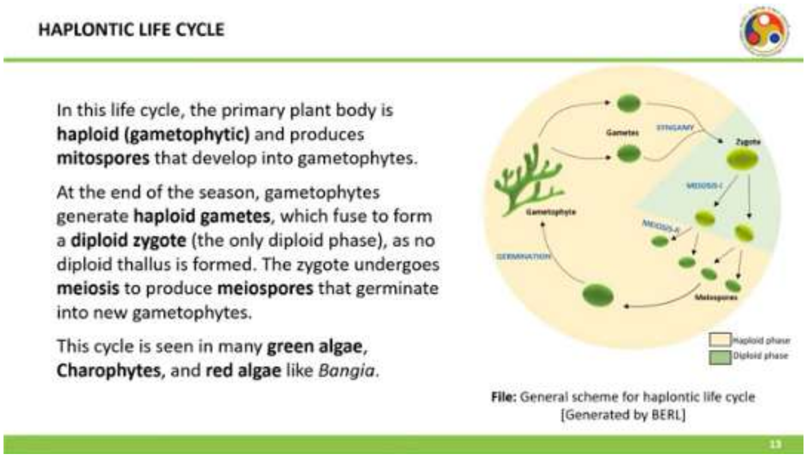
This is the FtsZ subunit, and this is the MreB filament, as you can see. Then, the polymerization of the FtsZ proteins forms the Z-ring in the center, which we have discussed in the earlier slides. And then, this constriction is happening in the Z-ring. And then, the completion of the cell division and finally the separation of the daughter cells, which are complete in every aspect. Let us now discuss the life cycle of algae.

So here you can see the colonial algae, Palmodictyon viral, in this picture. So the life cycle of algae refers to the sequence of events from one generation to the next. Sexual reproduction features an alternation of generations between haploid and diploid stages. So you have the haploid phase here and the diploid phase here. So from the haploid, it becomes diploid, and from the diploid, it becomes haploid.



So this is a general scheme for alternation of generations. There are five primary types of life cycles in algae. Number one is the haplontic life cycle, then diplontic. Then there is a haplodiplontic life cycle, a haplobiontic life cycle, and a haplodiplobiontic life cycle. We will be discussing these various life cycles one by one.

Let us start with the haplontic life cycle. So, before we start, just notice this haploid phase here, which is maybe around 75 to 80%. This life cycle includes the diploid phase, and as we have discussed, there is an alternation of generations between the haploid and diploid in algal life cycles. So, this diagram shows the fraction of time the particular algal species is in a particular phase. A particular phase.

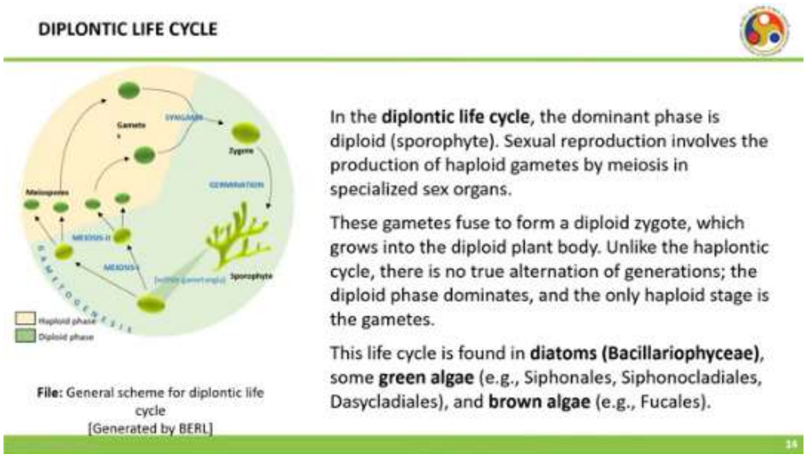


How much more time it is spending in haploid phase and how much time it is spending in diploid phase can be seen from this colored circle. So, this is the gametophyte. At the end of the season, gametophytes will generate haploid gametes. These are haploid. So, their number will be n.

which fuse to form a diploid zygote. So, there is a fusion over here. So, the zygote is getting formed. So, this is the diploid phase as you can see over here. So, the zygote undergoes meiosis to produce meospores that will germinate into finally gametophytes.

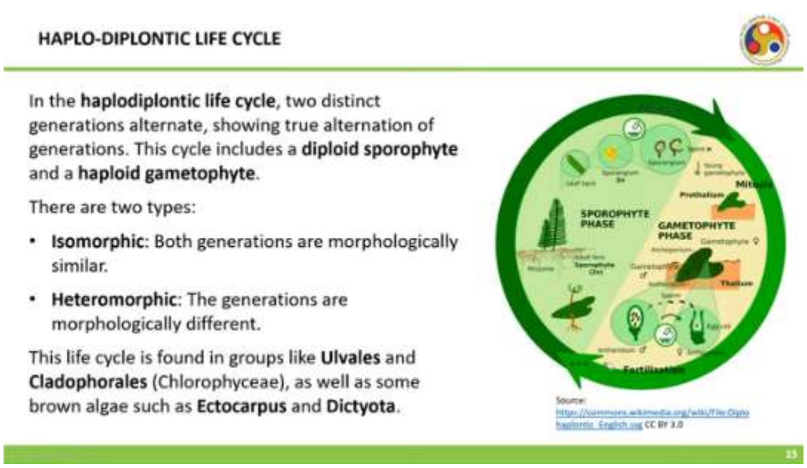
This cycle is seen in many green algae, carophytes and red algae like Bangia. So, this is the haplontic life cycle. Then we have the diplontic life cycle. Here you can see that compared to the haplontic life cycle, the hemp comes from the dominating haploid phase. And here the diplonic comes from the dominating diploid phase.

Nevertheless, both phases are present. So, in the diplontic life cycle, the dominant phase is diploid or the sporophyte, not the gametophyte as in the earlier case. So sexual reproduction here involves the production of haploid gametes by meiosis. In specialized sex organs, these gametes fuse to form a diploid zygote, as in the earlier case, of course, which grows into the diploid plant body.



Unlike the haploid cycle, there is no true alternation of generations. The diploid phase dominates, and the only haploid phase is the gametes. This life cycle is found in diatoms, certain green algae, and some brown algae. The next stage is the haplodiplontic life cycle. So, you have both the hap and dip here.

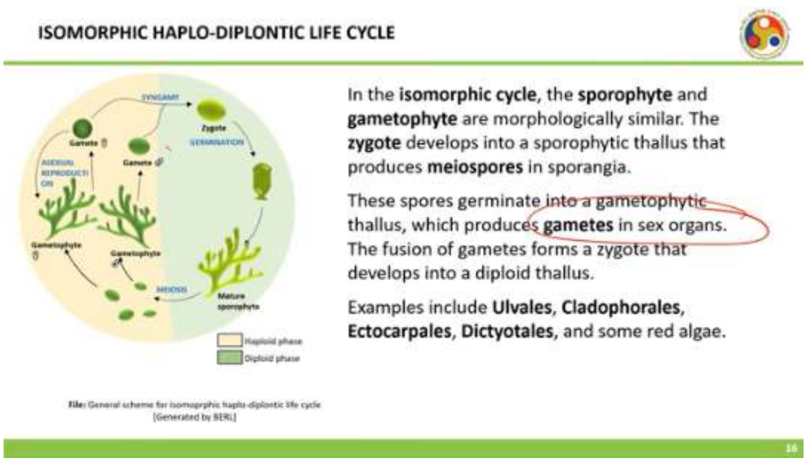
So, in these haplodiplontic life cycles, two distinct generations alternate, showing the true alternation of generations. This cycle includes a diploid sporophyte and a haploid gametophyte. So, this is the sporophyte phase, and this is the gametophyte phase. So, there are two types: isomorphic, where both generations are morphologically similar (we cannot separate the sporophytes from the gametophytes), and heteromorphic, where the generations are morphologically distinct or different.



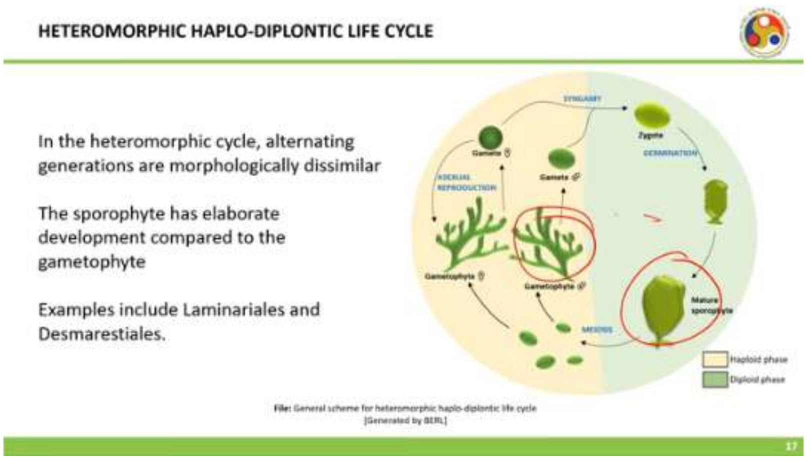
This life cycle is found in groups like wool whales, cladophorales, as well as ectocarpus and dictoata. So, this sporophyte is diploid, and this gametophyte is haploid. Then we have the first subclass of this type of haplodiplontic life cycle, the isomorphic haplodiplontic life cycle. So, you can see here the mature sporophyte and gametophyte; they all look similar.

So, the sporophyte and the gametophyte are morphologically similar. And now, one more thing to notice here is the gender of these gametophytes. One is male, and another is female. The zygote develops into a sporophytic thallus that produces meiospores in sporangia. These spores germinate into a gametophytic thallus, which produces gametes in the sex organs.

So, this is the male gamete, and this is the female gamete; then they fuse, or there is syngamy. The fusion of these gametes forms a zygote that develops into a diploid thallus, and this thallus will give rise to the mature sporophyte. So, we have this type of life cycle in wool whales, cladophorales, ectocarpus, and dictyota, as well as some red algae. Next comes the heteromorphic haplodiplontic life cycle. So here we see there is again the mature sporophyte, and then you have the female and the male gametophytes.

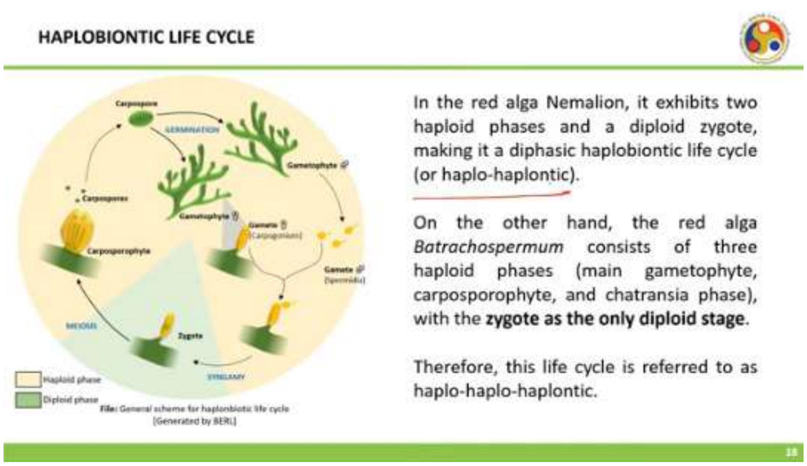


But they are morphologically different. They are not the same. So that's why they have a heteromorphic haplodiplontic life cycle. But in a similar way, there will be meiosis from the mature sporocyte, which will produce the gametophytes—male and female—which in turn will give rise to the gametes. And then the fusion of the gametes gives rise to the zygote and finally the thallus.

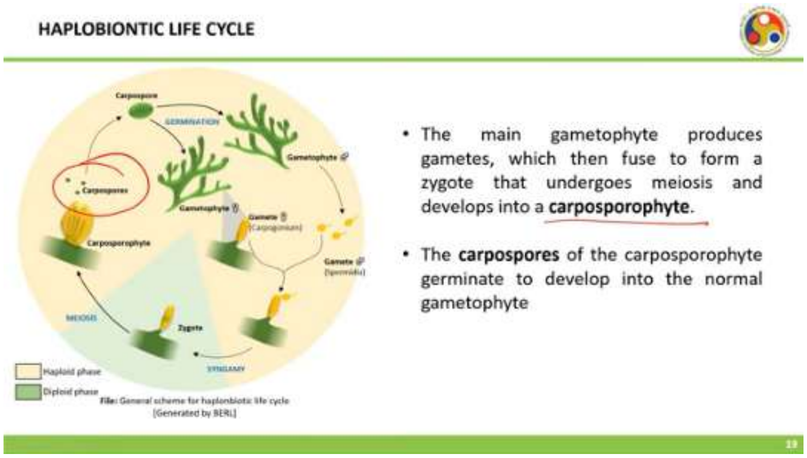


So, the sporophyte has elaborate development compared to the gametophyte. Examples include laminarials and desmarestials. Then there is a haplobiontic life cycle. Here, you can see the haploid phase is dominant, and the diploid phase is comparatively smaller. In the case of red algae, Nemalion.

It exhibits two haploid phases and a diploid zygote, making it a diphasic haplobiontic life cycle or haplontic. On the other hand, the red algae consist of three haploid phases: the main gametophyte, carposporophyte, and tetrasporangial phase with the zygote as the only diploid stage. Therefore, this life cycle is referred to as the haplohaplontic. The main gametophyte produces gametes.

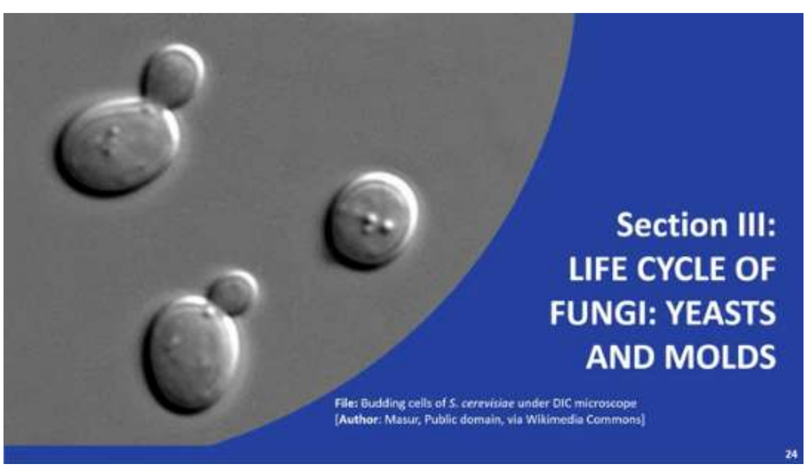


This is the gametophyte, which is producing the gametes that then fuse to form a zygote, which undergoes meiosis and develops into a carposporophyte. So after this fusion, this zygote will form the carposporophyte. The carposporophyte will produce carpospores, which germinate to develop into the normal gametophyte, as you can see here. The next cycle is the haplodiplobiontic life cycle, also known as the diplohaplontic life cycle. It is seen in certain members of red algae, like Polysiphonia, and involves three phases, with two being diploid and

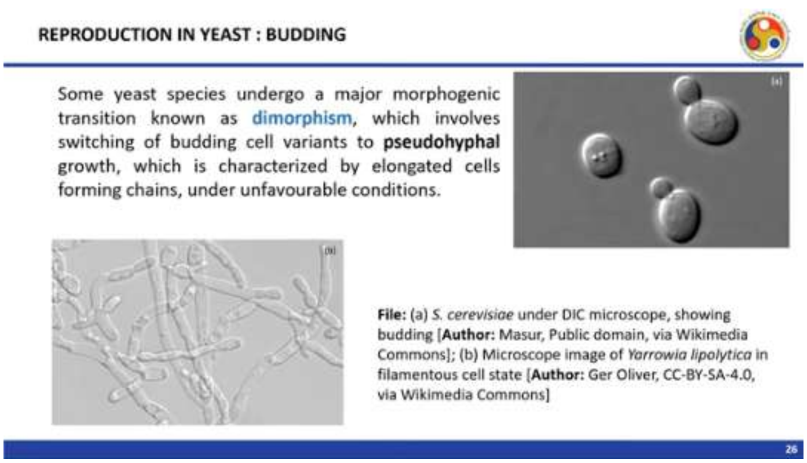


one haploid. The main plant body, the gametophyte, produces gametes, and the zygote is, as usual, formed through syngamy. So, you can see here the haploid phase and the diploid phase. And you have here certain specialized spores called tetrasporophyte or tetrasporangium, which produce the tetraspores. These then undergo formation into gametophytes, which give rise to gametes, the female gamete. Carpogonium and the spermatia, the male gamete, fuse to form the zygote, which gives rise to the carposporophyte. This produces carpospores and finally gives rise to the tetrasporophyte.

So, this is the haplodiplobiontic life cycle. Let us now discuss the life cycle of fungi. We will discuss yeast and molds one by one. So, let us learn about budding, which is a key feature of yeast reproductive strategy, particularly in Saccharomyces. The ctc family reproduces by budding, a form of asymmetric cell division. You can see here the mother cell is bigger, and the daughter cell is smaller.

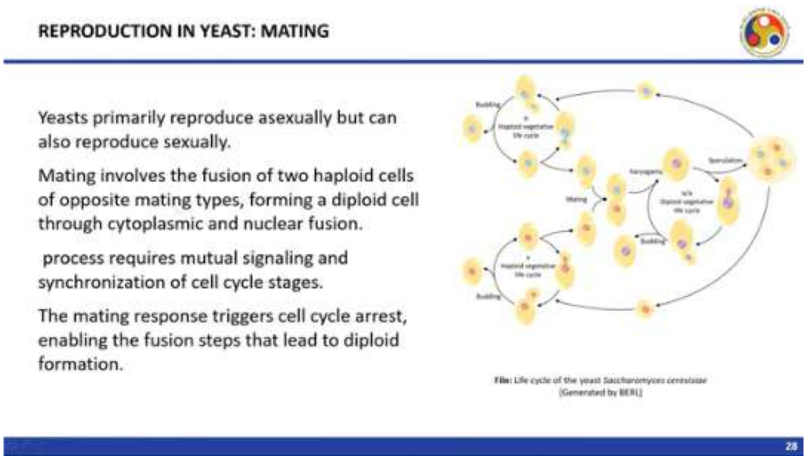


This contrasts with classical cell division, where both resulting cells are typically equal in size, as seen in the case of bacteria. In this process, mature mother cells form smaller daughter cells, which grow to about two-thirds of the mother's size. In Saccharomyces cerevisiae, Once the bud reaches this size, cytokinesis occurs, separating the cell's cytoplasm. Some yeast species undergo a major morphogenic transition known as dimorphism, which involves switching from budding cell variants to pseudo-hyphal growth, characterized by elongated cells forming chains under unfavorable conditions, as seen here.



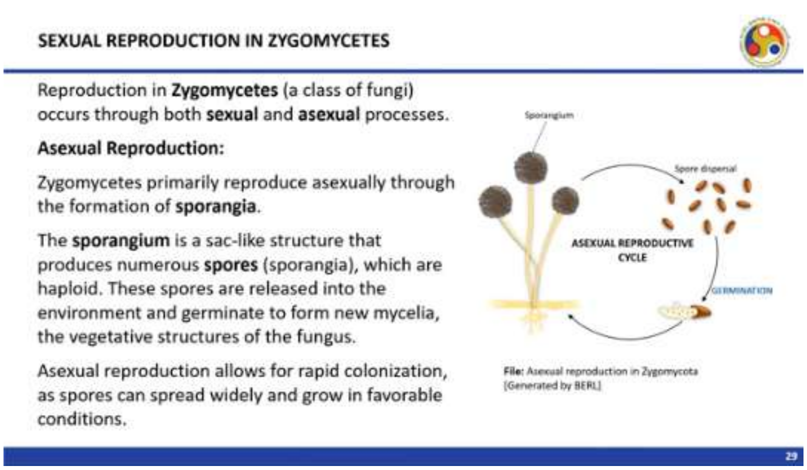
This can transition to a sporogenic form from budding cells, pseudohyphae, or hyphae. Spore formation generally follows meiosis, producing a meiospore through endobudding, where multiple nuclei within a shared cytoplasm become separated, similar to the transition from a multinucleated syncytium to individual cells. In Saccharomycetaceae, meiotic division leads to the formation of tetrads—four spores. While in species like Glubemirobiasis, additional mitotic divisions increase the number of nuclei, resulting in asci containing dozens of spores. Each species shows great variability in the number, shape, and size of their spores, depending on the genus and environmental conditions.

Another mode of reproduction in yeast is through mating. Yeast primarily reproduce asexually but can also reproduce sexually. Mating involves the fusion of two haploid cells of opposite mating types, forming a diploid cell through cytoplasmic and nuclear fusion. This process requires mutual signaling and synchronization of cell cycle stages. The mating response triggers cell cycle arrest, enabling the fusion steps that lead to diploid formation.



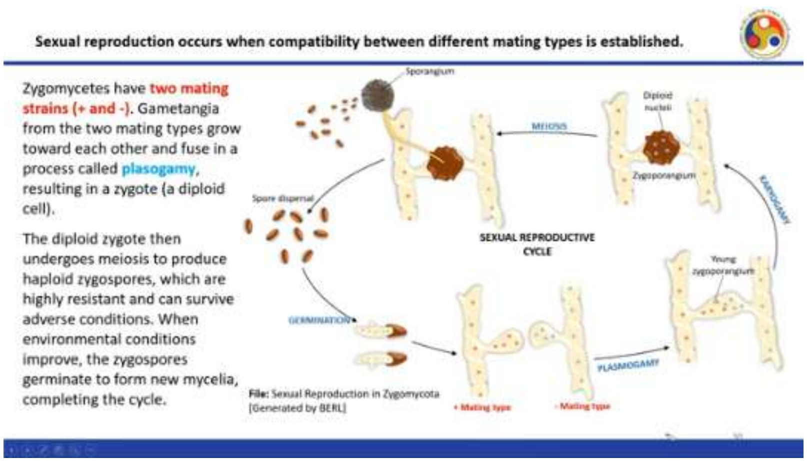
So here, the mating has occurred, and then this enters the diploid vegetative life cycle. And then again, due to sporulation, these are released, and it enters the haploid vegetative life cycle. Now, let us discuss the sexual reproduction in Zygomycetes, which is a fungus. It occurs through both sexual and asexual processes. So, this is the asexual reproductive cycle of Zygomycetes.

These Zygomycetes primarily reproduce asexually through the formation of sporangia from the sporangium, which is a sac-like structure that produces numerous haploid spores. These spores are released into the environment and germinate to form new mycelia, the vegetative structure of the fungus. Asexual reproduction allows for rapid colonization, as spores can spread widely and grow in favorable conditions. Now, let us look into the sexual reproduction of Zygomycetes, which occurs when compatibility between different mating types is established.

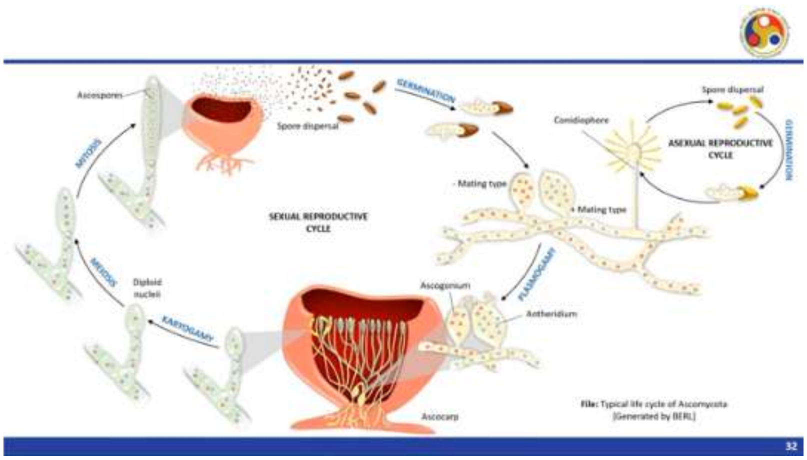


Zygomycetes have two mating types, strains, or types: the positive mating type and the negative mating type. Now, what happens when a positive mating type and a negative mating type are nearby? Gametangia from the two mating types grow toward each other and fuse in a process called plasmogamy. So, this one is getting fused over here, as you can see. The diploid zygote results in the formation of a zygote, which is actually diploid.

These diploid zygotes then undergo meiosis to produce haploid zygospores, which are highly resistant and can survive adverse conditions. When environmental conditions improve, the zygospores will be germinating to form new mycelia, thereby completing the life cycle. So, these two mating types approach each other, fuse, forming the zygote, which later becomes a diploid cell and undergoes meiosis, releasing haploid spores that will germinate under favorable conditions, thereby completing the life cycle of sexual reproduction in zygomycetes. Overall, we can see that there is a sexual reproduction cycle here in zygomycetes and an asexual reproduction cycle here.



It can also transition from the sexual reproductive cycle to the asexual reproductive cycle through this common linkage: the formation of spores. So, this is the overall typical life cycle of Zygomycetes or Zygomycota. Now, this is the typical life cycle of Ascomycota, which also reproduces through both sexual and asexual reproductive methods. Certain aspects here are also similar. Now let us examine in detail how reproduction in Ascomycota occurs, as in the case of Zygomycota.



So sexual reproduction in Ascomycetes begins with plasmogamy, as you can see here, where haploid hyphae of opposite mating types—positive and negative, as in the earlier case—will fuse and form dikaryotic hyphae. This is the dikaryotic hyphae produced as a result of plasmogamy. No, here. Karyogamy will follow, where the nuclei fuse to create a diploid zygote nucleus.

Here, this karyogamy is happening. Then, meiosis will occur, reducing the diploid nucleus to four genetically unique haploid cells. So, here these are the meiosis products—these are the four unique haploid nuclei happening over here. Often, an additional mitotic division occurs, resulting in eight haploid nuclei. So, from these four, it will become eight, and that is the ascospore or the ascus.

These nuclei are enclosed in a sac-like structure called an ascus, which develops from specialized ascogenous hyphae. The ascus eventually releases haploid ascospores for dispersal. So, these are all getting released for dispersal, and then they germinate and give rise to the two mating types, which fuse by plasmogamy and complete the life cycle. Within the ascus, each haploid nucleus typically undergoes one mitotic division, resulting in eight ascospores.

SEXUAL REPRODUCTION IN ASCOMYCETES

Sexual reproduction in Ascomycetes begins with plasmogamy, where haploid hyphae of opposite mating types (+) and (-) fuse, forming dikaryotic hyphae, each cell containing two genetically distinct nuclei.

Karyogamy follows, where the nuclei fuse to create a diploid (2n) nucleus. Meiosis then occurs, reducing the diploid nucleus to four genetically unique haploid (n) nuclei.

Often, an additional mitotic division occurs, resulting in eight haploid nuclei.

These nuclei are enclosed in sac-like structures called asci, which develop from specialized ascogenous hyphae.

The asci eventually release haploid ascospores for dispersal.

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Though the number of ascospores can vary between species, upon maturity, the ascospores are discharged through mechanisms such as rupture of the ascus wall or expulsion through an opening at the ascus tip. Once released, the ascospores disperse to new environments where they can germinate and develop into new hyphae. So, with this, we come to the end of this lecture. Thank you for your attention. We will continue this with some other organisms in the next lecture.

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