BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA AND FUNGI (PAPER CODE: BOT 501)

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OBJECTIVES

The main objective of the present lecture is to cover the topic and make it easy to understand and interesting for our students/learners.

BLOCK – III : FUNGI – I

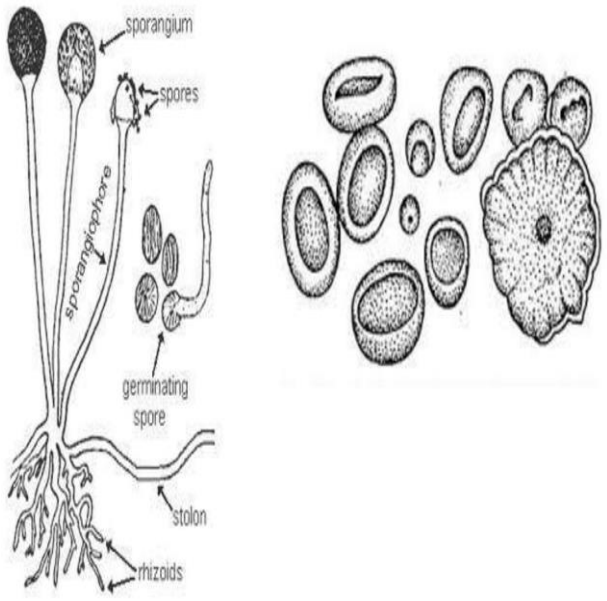
Unit –14 : Heterothallism, Heterokaryosis and Parasexuality

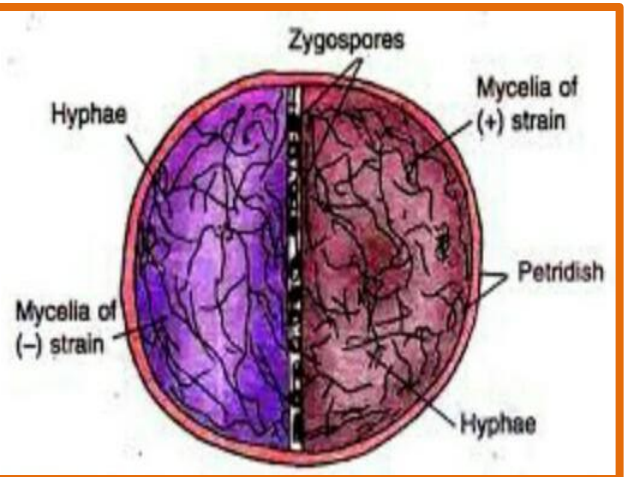
CONTENT

- Heterothallism in fungi
  - Pattern of distribution of sex in fungi
    - Hermaphrodite fungi
    - Dioecious fungi
    - Sexually undiffentiated fungi
    - Bipolar heterothallism
    - Tetrapolar heterothallism
    - Secondary homothallism
- Heterokaryosis in fungi
- Parasexuality in fungi
- Significance of parasexuality in fungi
- Key points of the lecture
- Terminology
- Some Assessment Questions

HETEROTHALLISM IN FUNGI

- A. F. Blakeslee, an American Geneticist, in 1904 made an important observation with Mucor, which resulted in the discovery of Heterothallism.
- Blakeslee observed, that while some isolates of Mucor formed sporangia as well as zygospores (e.g., M. tenuis), some others failed to form the zygospores and reproduced only by sporangiospores.
- When he grew these non-sexually reproducing isolate with other similar isolates, zygospores appeared in the region where the hyphae of the different isolates came in contact with each other.
- Blakeslee coined the terms homothallism and heterothallism to explain this phenomenon. The homothallic species were those that produced zygospores independently, while heterothallic species required the presence of the opposite mating type.
- *M. hiemalis, M. mucedo, Rhizopus nigricans* are examples of heterothallic species. Since the two mating types were morphologically indistinguishable, Blakeslee designated them as the (+) and (-) mating types or strains (not male or female).





Zygospore formation indicating the heterothlllism

PATTERN OF DISTRIBUTION OF SEX IN FUNGI

- On the basis of the distribution of sex organs, fungi can be put in the following categories:

  - **Hermaphrodite -** in which both male and female sex organs occur on the same thallus: A hermaphroditic fungus having both the sex organs may be homothallic or heterothallic. When the two sex organs, present on the same mycelium, are unable to mate, this is because of self-sterility and is called physiological heterothallism. Such fungi need genetically-different nuclei, which does not occur when the same thallus forms both the sex organs.

  - **Dioecious** (sexually dimorphic)- The two sex organs are present on different thalli: The dioecious fungi, in which the male and the female sex organs are borne on different thalli are, by necessity, heterothallic. This is called morphological heterothallism. In this case, heterothallism is made obligatory because the opposite and morphologically distinct sex organs are formed only on different thalli.

  - **Sexually undifferentiated-** The male and female sex organs are morphologically similar and, therefore, indistinguishable: The sexually-undifferentiated fungi e.g., *Mucor*, *Rhizopus*, and several members of Asco-and Basidiomycota, do not have morphologically distinguishable sex organs. These can also be homo or heterothallic. The heterothallic forms provide another example of physiological heterothallism. The requirement for the other thallus does not lie in morphologically distinct sex organs, but in genetically-different nuclei which are not available in the same mycelium.

- So, heterothallism, according to Whitehouse (1949) can be caused by the absence of the morphological sex organs of the opposite type (morphological heterothallism) or by the absence of genetically-different nuclei (physiological heterothallism).

- Whatever be the reason for heterothallism, the fact remains that different thalli are needed for sexual reproduction.

- A heterothallic species may not be of only two mating types. There can be four types of thalli and one thallus can mate with only one of the rest three. This is called tetrapolar heterothallism.

✓ Bipolar Heterothallism:

- Fungi in this category have two mating types, each containing genetically different nuclei. The sexual compatibility is controlled by a pair of genetic factors A and a located at the same locus on different chromosomes. This is, therefore, also called as 'two allele heterothallism'.

- During meiosis, the two chromosomes, containing the alleles A and a are separated in the haploid spores (germ spores, ascospores, or basidiospores).

- The spores give rise to two types of thalli, which must come together to bring together the two nuclei carrying the compatibility factors A and a. The two mating types are designated (+) and (-) strains.

- The two allele or bipolar heterothallism is found in Mucorales (Mucor, Rhizopus, Phycomyces), Ascomycota (Neurospora, Ascobolous), Basidiomycota (Puccinia graminis and Ustilago levis).

✓ Tetrapolar Heterothallism:

- Fungi in this group form thalli of four mating types. This type of heterothallism is governed by two pairs of compatibility factors Aa and Bb, located at different chromosomes, which segregate independently during meiosis. If crossing over occurs between the mating type loci, four types of segregations (AB, Ab, aB, ab) are possible depending on the chromosomal arrangement.

- Thus four types of spores (AB, Ab, aB and ab) are formed which give rise to four types of thalli.
- Only those thalli that have nuclei carrying opposite genes for both the factors can mate. The resulting zygote must have the genotype Aa, Bb.
- Majority (63 per cent) of the heterothallic Basidiomycota are tetrapolar, forming four types of basidiospores.
- However, if crossing over does not take place, only two types of spores (AB and ab or Ab and aB) are formed and only two types of thalli are produced. Since it is governed by two factors it is called tetrapolar.

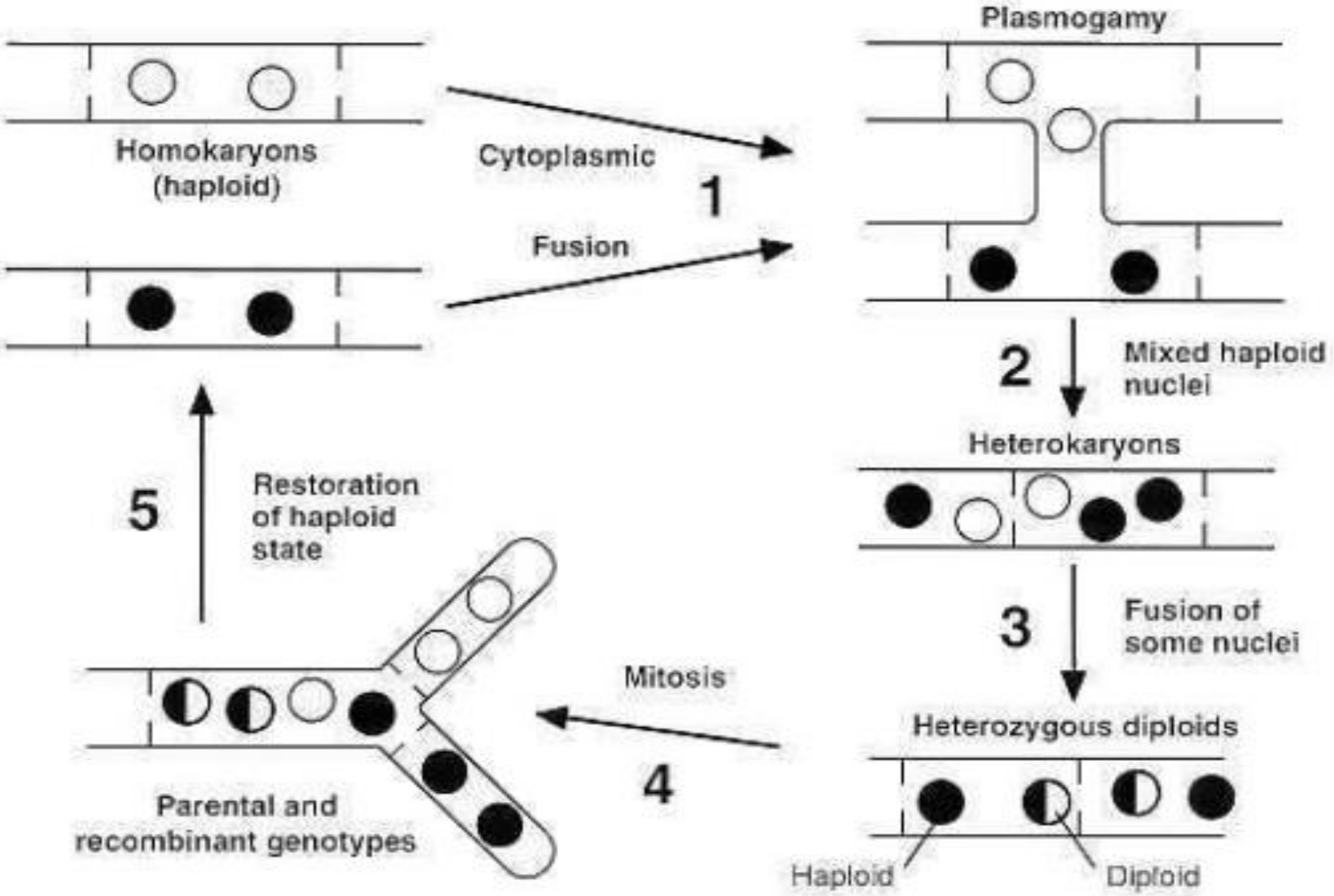
Secondary Homothallism:

- In some bipolar species the two nuclei, which should give rise to hyphae of two mating types, are contained in the same spore.
- Thus, the hyphae produced behave as homothallic, though it involves genetically-different nuclei. This situation is termed secondary homothallism.
- Korf (1952) and Hartman (1956) recommended that the terms homothallism and heterothallism should be abandoned.
- Esser (1959) suggested the use of the terms monoecious and dioecious, as done in higher plants. Call by whatever 'term' you please, the function of heterothallism remains unaltered.
- Heterothallism is a device for achieving outbreeding, which is a genetic desirability. Homothallism brings in inbreeding and provides no chance for genetic change.

HETEROKARYOSIS IN FUNGI

- Heterokaryosis is the main source of variation in the anamorphic (imperfect) fungi, which lack sexual reproduction. The term Heterokaryosis was proposed by Hansen and Smith in 1932, who reported it for the first time in *Botrytis cinerea*.
- The presence of genetically-different nuclei in an individual is called heterokaryosis, and the organism heterokaryon.
- Essentially, a heterokaryon possesses two sets of chromosomes, just like a diploid organism, but instead of being contained in a single nucleus, the two sets of chromosomes lie in separate nuclei, sharing the same cytoplasm.
- Heterokaryons show dominance and, thus, resemble diploids in many respects. Heterokaryosis is a major factor in natural variability and sexuality.
- The heterokaryotic condition can arise in a fungus by three methods, viz., (1) Mutation, (2) Anastomosis i.e., fusion between genetically-different hyphae, and (3) Diplodization-fusion between haploid nuclei to form diploid nuclei.
- Mutations occur frequently in fungi, and a homokaryotic mycelium is frequently converted into a heterokaryotic one. Anastomosis between spores and hyphae is a universal feature of higher fungi and certainly must be a potential source of heterokaryosis and, thus, of variability.
- Whether nuclei migrate from one thallus to another is a debated point but the hyphae having nuclei of both parents arise at the point of fusion.
- Heterokaryosis is often accompanied by parasexual cycle.

HETEROKARYOSIS AND PARASEXUALITY IN FUNGI



PARASEXUALITY IN FUNGI

- Until 1944, the sexual cycle was the only means of exchange of genetic material.
- It is to the credit of microbial geneticists that a series of novel methods of genetic recombination are now known in bacteria, which do not involve karyogamy and meiosis.
- These are transformation, conjugation, transduction, lysogeny, and sexduction which differ from the standard sexual cycle.
- A similar alternative to sexual reproduction was discovered in the imperfect fungus, *Aspergillus nidulans*, in 1952 by Pontecorvo and Roper Glasgow. They called this parasexual cycle.
- In this, genetic recombination occurs in somatic cells by the mechanism of mitotic crossing over, which brings the same result as is achieved by the meiotic crossing over.
- The parasexual cycle involves the following steps:
  - Formation of heterokaryotic mycelium.
  - Nuclear fusions and multiplication of the diploid nuclei.
  - Mitotic crossing over during division of the diploid cells.
  - Sorting out of the diploid strains.
  - Haplodization.

➢ Formation of Heterokaryotic Mycelium

❖ The methods of formation of heterokaryotic mycelium are described earlier under 'heterokaryosis.

➢ Nuclear Fusions and Multiplication of the Diploid

❖ Nuclear fusion in somatic heterokaryotic hyphae was first noted by Roper (1952) in *Aspergillus nidulans*.

❖ Nuclear fusion may occur between genetically similar and dissimilar nuclei, resulting in the formation of homozygous and heterozygous diploid nuclei, respectively.

❖ Diploid heterozygous nuclei are formed very rarely (at a frequency of one in a million).

❖ In such hyphae, five types of nuclei are present- 2 types of haploid nuclei, their two types of homozygous diploids, and the one type of heterozygous diploids.

➢ Mitotic Crossing Over

❖ Crossing over is a phenomenon which occurs during meiosis and gives rise to new linkage of genes, gene recombination. A similar mitotic crossing over occurs during the multiplication of the diploid heterozygous nuclei, though at a low frequency of 10^{-2} per nuclear division.

❖ However, in some other fungi e.g., *Penicillium chrysogenum* and *Aspergillus niger*, the frequency of mitotic crossing over is as high as during meiosis in sexual reproduction. (Both species lack sexual reproduction.) Mitotic crossing over is the most important, or 'key' event in the parasexual cycle, as it is during this step that genetic recombination occurs.

➢ Sorting Out of Diploid Strains

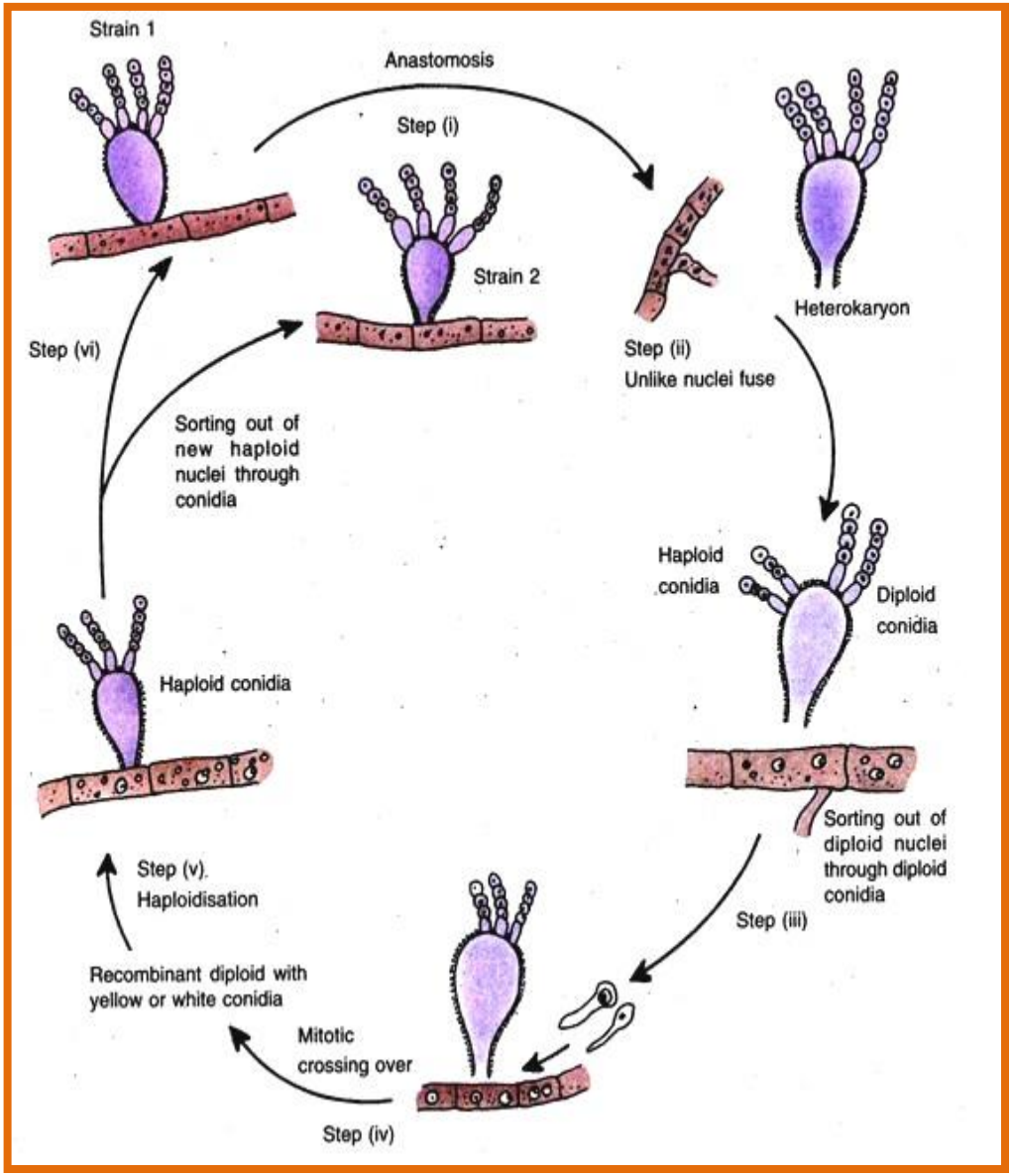
❖ The segregation of the diploid strains occurs when uninucleate diploid conidia are formed. The colonies that are formed by diploid conidia are recognized by various methods, e.g., higher DNA content and bigger size of the conidia and certain phenotypic characters of the colony

➢Haplodization:

- The diploid colonies show appearance of sectors on the Petri plate, which produce haploid conidia. This indicates that some diploid nuclei must have undergone haplodization, forming haploid nuclei, which later get sorted out in haploid conidia.
- Some of these haploids are genetically different from the original haploid parental nuclei. This is because of the recombination that occurred during the mitotic crossing over.
- Haplodization occurs at a constant frequency of 10^{-3} per nuclear division. The haplodization occurs not by a reduction division (meiosis), but by aneuploidy, a phenomenon in which chromosomes are lost during mitotic divisions.
- It happens in the following manner. During mitosis of the diploid nucleus, the chromatids fail to separate (non-disjunction) in the anaphase stage.
- One daughter nucleus gets one chromosome more (2n + 1), while the other gets one chromosome less (2n – 1) than the normal 2 sets of chromosomes (2n). Both the daughter nuclei are called aneuploidy. The deficient aneuploid nucleus (2n – 1) may lose more chromosomes in the successive mitotic division and finally reduce to haploid state (n).
- Mitotic crossing over and haplodization also occur with the diploid homozygous nuclei, but since the two nuclei are similar, crossing-over products or the haploid nuclei formed by haplodization, are genetically no different from the haploid parent nuclei.
- The parasexual cycle, thus, like the sexual cycle, involves plasmogamy, karyogamy and haplodization, but not at a specified time or place. Every step differs drastically.

SIGNIFICANCE OF PARASEXUALITY

- Parasexual cycle is of importance in industrial processes.
- Several fungi which are used in various industrial processes belong to fungi imperfecti or Deuteromycetes and in these fungi only parasexual cycle operates.
- New and better strains of these fungi are obtained by mutation through parasexual cycle.
- The strains of desirable characters can be developed through mitotic recombination.
- Parasexuality can also be applied in the analysis of genetic and physiological processes of perfect and imperfect fungi.
- Parasexual cycle has also been successfully employed in genetic control of pathogenicity and host-range in several species of Fusarium.



Pontecarvo's (1958) idea of parasexual cycle

KEY POINTS OF THE LECTURE

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- In 1904 made an important observation with Mucor, which resulted in the discovery of Heterothallism.
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- *M. hiemalis, M. mucedo, Rhizopus nigricans* are examples of heterothallic species.
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- The parasexual cycle involves the following steps:Formation of heterokaryotic mycelium, Nuclear fusions and multiplication of the diploid nuclei, Mitotic crossing over during division of the diploid cells, Sorting out of the diploid strains, Haplodization.
- Parasexual cycle is of importance in industrial processes. Several fungi which are used in various industrial processes belong to fungi imperfecti or Deuteromycetes and in these fungi only parasexual cycle operates.
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TERMINOLOGY

- **Ascocarp:** Fruitbody of an ascomycete fungus
- **Ascomycetes:** A - Class of fungi that produce their spores in sac-like cells called asci
- **Ascospores:** Sexual spores produced in the asci of ascomycetes fungi
- **Ascus:** (Pl., asci) the spore-producing cell of an ascomycetes fruitbody
- **Basidiocarp:** Fruitbody of a basidiomycete fungus
- **Basidiomycetes:** A - Class of fungi that produce their spores on basidia
- **Basidiocarp:** Fruitbody of a basidiomycete fungus
- **Basidiospores:** Sexual spores produced on the basidia of basidiomycetes fungi
- **Basidium:** (Pl., basidia) spore-producing cell of a basidiomycete fungus
- **Chlamydospores:** Asexual spores formed by the breaking up of fungal hyphae
- **Deuteromycetes:** Obsolete term for a group fungi not known to reproduce sexually
- **Endophyte :** fungus living within a plant without causing visible symptoms of harm
- **Hyphae:** (Pl., hyphae) filamentous thread of fungal mycelium
- **Mycelium:** Body of a fungus, most of which is underground or hidden within wood
- **Myxomycetes:** A large and commonly encountered group within the slime moulds
- **Rhizomorph:** A root-like mycelial strand comprising bunched parallel hyphae
- **Saprophyte:** An organism that obtains its nutrients from dead organic material
- **Septate:** (Describing hyphae) partitioned by cross walls known as septa
- **Septum:** (Pl., septa) a cross wall separating cells of a hyphal thread
- **Spore:** Reproductive structure of a fungus, usually a single cell
- **Sporophore:** Fungal fruitbody
- **Thallus:** (Pl., thalli) the body of a fungus or a lichen
- **Uredinales:** Rust fungi (an order within the Basidiomycota)
- **Zygomycota:** A - Class of simple fungi whose hyphae generally lack cross walls

SOME QUESTIONS RELATED TO THE LECTURE

- **Question 1:** What do you understand by heterothallism in fungi?
- **Question 2:** Highlight the pattern of distribution of sex in fungi.
- **Question 3:** Write a note on hermaphrodite fungi?
- **Question 4:** Describe the dioecious fungi.
- **Question 5:** Describe the sexually undifferentiated fungi.
- **Question 6:** What do you understand by bipolar and tetrapolar heterothallism?
- **Question 7:** Write the note on secoundry homothallism.
- **Question 8**: What do understand by heterokaryosis in fungi?
- **Question 9:** Discuss the parasexuality in fungi.
- **Question 10:** Describe the parasexual cycle in the fungi .
- **Question 11:** Give significance of parasexuality in fungi.

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