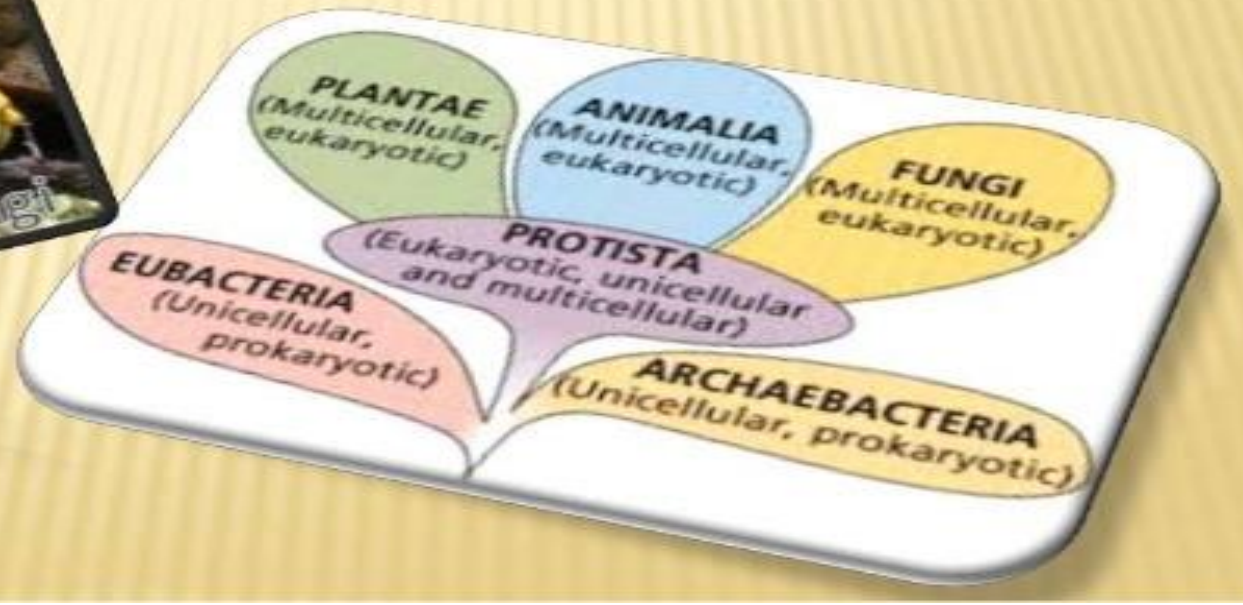

FUNGI

THE SIX KINGDOMS

- Fungi are placed in a separate kingdom called the kingdom fungi



FUNGI

- **Fungi** are eukaryotic microorganisms

  Two major groups of organisms make up the fungi.
- The multicellular filamentous fungi - **molds**
- The unicellular fungi - **yeasts.**
- Study of fungi – **mycology**
- Study of fungal diseases - **mycoses**

All molds are fungi but all fungi are not molds--

yeasts are fungi but they are unicellular and produce no aerial mycelium

molds filamentous fungi that produce aerial mycelium

THE CHARACTERISTICS OF FUNGI

- Fungi are **NOT** plants
- Nonphotosynthetic
- Eukaryotes
- Nonmotile
- Most are **saprobes** (live on dead organisms)

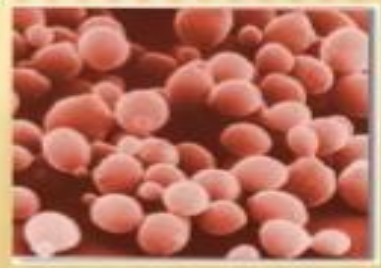
THE CHARACTERISTICS OF FUNGI

- **Absorptive heterotrophs** (digest food first & then absorb it into their bodies
- Release **digestive enzymes** to break down organic material or their host
- Store food energy as **glycogen**

BREAD MOLD

THE CHARACTERISTICS OF FUNGI

- Important **decomposers** & **recyclers of nutrients** in the environment
- Most are **multicellular**, except **unicellular yeast**
- Lack **true roots, stems or leaves**

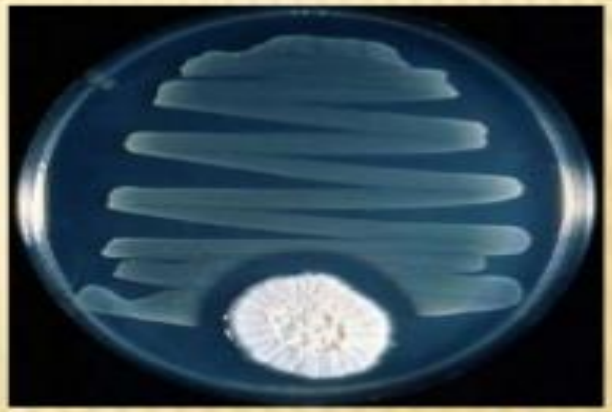


UNICELLULAR YEAST

MULTICELLULAR MUSHROOM

THE CHARACTERISTICS OF FUNGI

- Fungi include puffballs, yeasts, mushrooms, toadstools, rusts, smuts, ringworm, and molds
- The antibiotic penicillin is made by the *Penicillium* mold



Penicillium mold

Puffball

THE CHARACTERISTICS OF FUNGI

- Grow best in **warm, moist** environments
- **Mycology** is the study of fungi
- **Mycologists** study fungi
- A **fungicide** is a chemical used to kill fungi

Fungicide kills leaf fungus →

HUMAN-FUNGUS INTERACTIONS

- **Beneficial Effects of Fungi**
  - Decomposition - nutrient and carbon recycling.
  - Biosynthetic factories. Can be used to produce drugs, antibiotics, alcohol, acids, food (e.g., fermented products, mushrooms).
  - Model organisms for biochemical and genetic studies.
  - Production of vitamin
  - Hormone production
  - Edible fungi
  - Production of insecticides

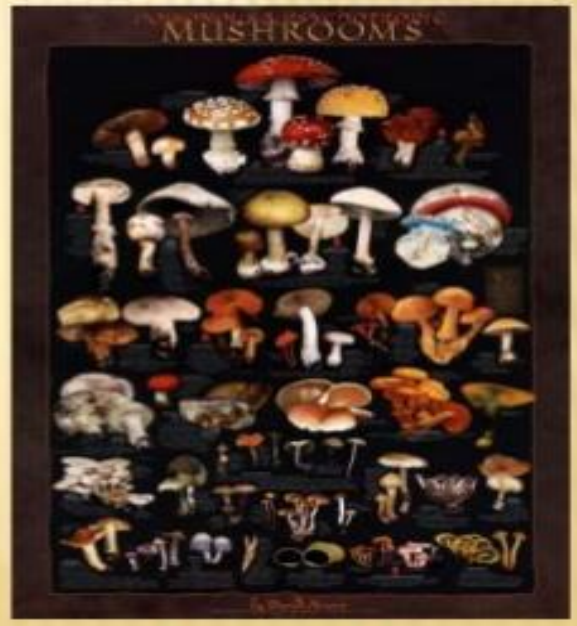
FUNGI FORM BENEFICIAL PARTNERSHIPS (SYMBIOSIS) WITH OTHER ORGANISMS SUCH AS TREES AND FLOWERING PLANTS:

Lichen – symbiotic relationship between algae and fungi

THE CHARACTERISTICS OF FUNGI

- Some are **edible**, while others are **poisonous**

EDIBLE



POISONOUS

HUMAN-FUNGUS INTERACTIONS

- **Harmful Effects of Fungi**
  - Destruction of food, lumber, paper, and cloth.
  - Plant diseases.
  - Animal diseases
  - human diseases, including allergies.
  - Toxins produced by poisonous mushrooms and within food (e.g., grain, cheese, etc.).

Yeast

Yeasts are very important economically:

- Yeasts are responsible for fermentation of beer and bread. (*Saccharomyces cerevisiae*)

- Ethanol production

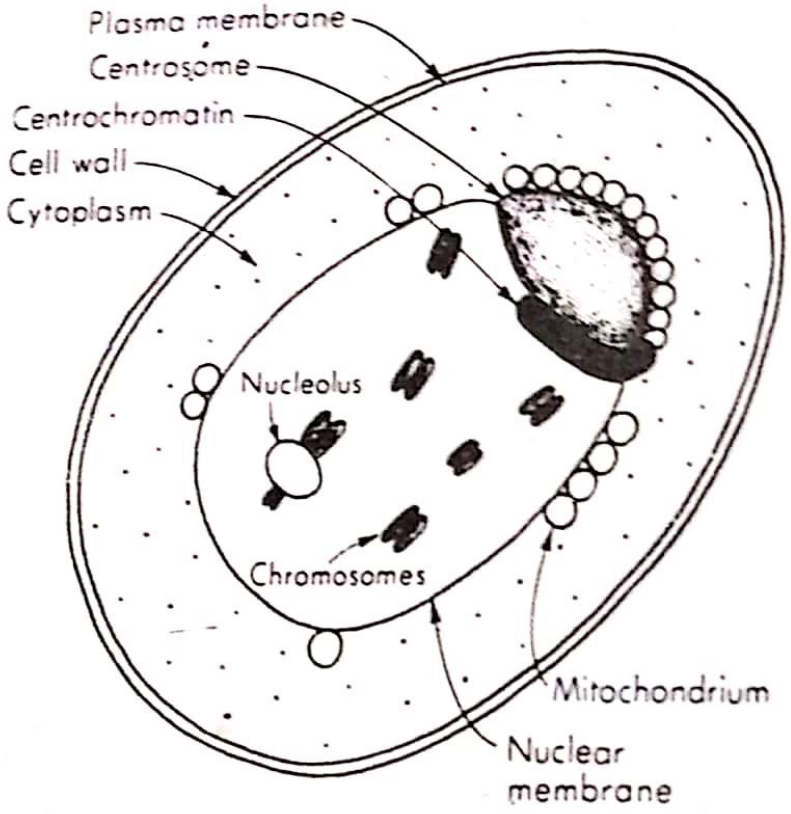
- Wastewater treatment:

a mixed culture of yeasts *Candida lipolytic Candida tropicalis*, and *Yarrowia lipolytica* grown on hydrocarbons or gas oil.

Yeasts

- **Yeasts** are single-celled eukaryotic microorganisms.
- **Size**: yeasts are 1 to 5 µm in diameter.
- They are larger than bacteria.
- Yeasts are non filamentous unicellular fungi.
- Typically spherical or oval in shape
- **Yeasts** consists single nucleus and eukaryotic organelles.
- classified in the kingdom Fungi, with 1,500 species currently described.
- estimated to be 1% of all fungal species.

Structure of a Yeast Cell



- Shape & Size
- Cell Wall
- Cytoplasmic Membrane
- Capsule- *Torulopsis rotundata*, T. *neoformans*
- Protoplast & Spheroplast- Snail- *Helix pomata*
- Cytoplasm
- Mitochondria
- Centrosome
- Centrochromatin
- Nucleus
- Vacuoles- S-adenosylmethionine
- Granules- metachromatic granules (volutin)
- glycogen granules
- Fat globules

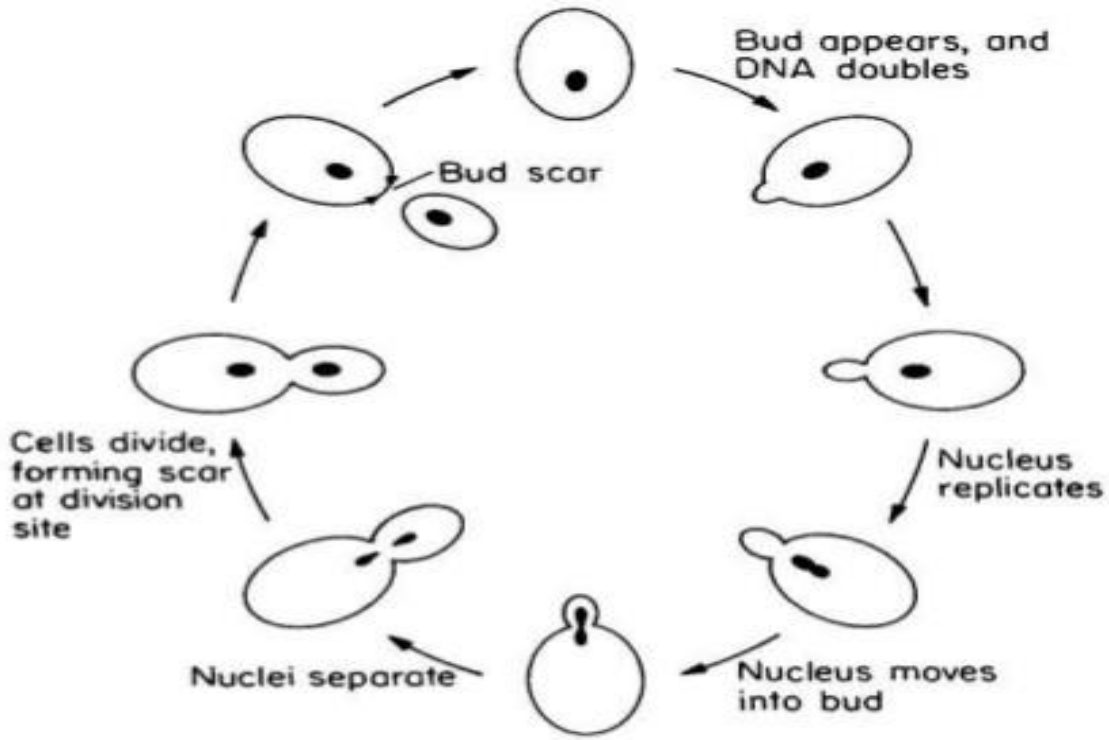
Reproduction

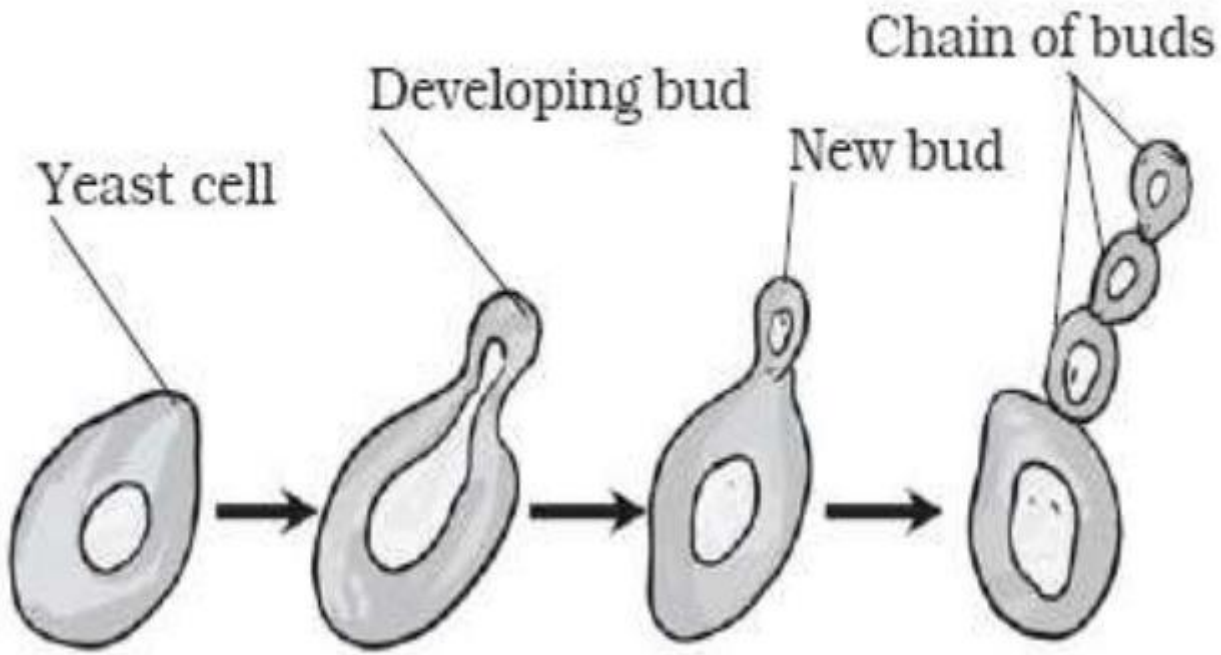
- Most yeasts reproduce asexually.
- Yeasts grow as single cells producing daughter cells either by

  an asymmetric division process called **Budding** - the **budding**

  yeasts or by
- **Binary fission** (splitting in two) - the **fission yeasts**.
- Budding: a small bud cell forms on the cell, which gradually enlarge and separate from the mother cells.
- Most of the yeasts reproduce by budding.

Budding


Bud appears, and DNA doubles
Bud scar
Nucleus replicates
Nucleus moves into bud
Nuclei separate
Cells divide, forming scar at division site



- Some yeasts produce buds that fail to detach themselves; these buds form a short chain of cell called a **pseudohypha.**

Budding

- In budding the parent cell forms a protuberance (bud) on its outer surface. As the bud elongates, the parent cell's nucleus divides, and one nucleus migrates into the bud. Cell wall material is then laid down between the bud and parent cell, and the bud eventually breaks away.
- Yeasts reproduce rapidly. One yeast cell can in time produce up to 24 daughter cells by budding.
- **Budding yeasts** divide unevenly (Saccharomyces)

Structure of Yeast Cell

- In contrast to mammalian cells, peculiarities of yeast cells are that they are surrounded by a rigid cell wall and develop birth scars during cell division, the vacuole corresponds to lysosomes is higher cells.
- Bud scars are specialized, ring –shaped convex protrusions at the cell surface which remain on the mother cells (of budding yeasts) after cell division and birth of daughter cells. The concave indentations remaining on the surface of the daughter cell after budding are called birth scars.
-

Fission: similar to budding

During this parent cells elongates, grow to certain size its nucleus divides, and two equal daughter cells are produced.

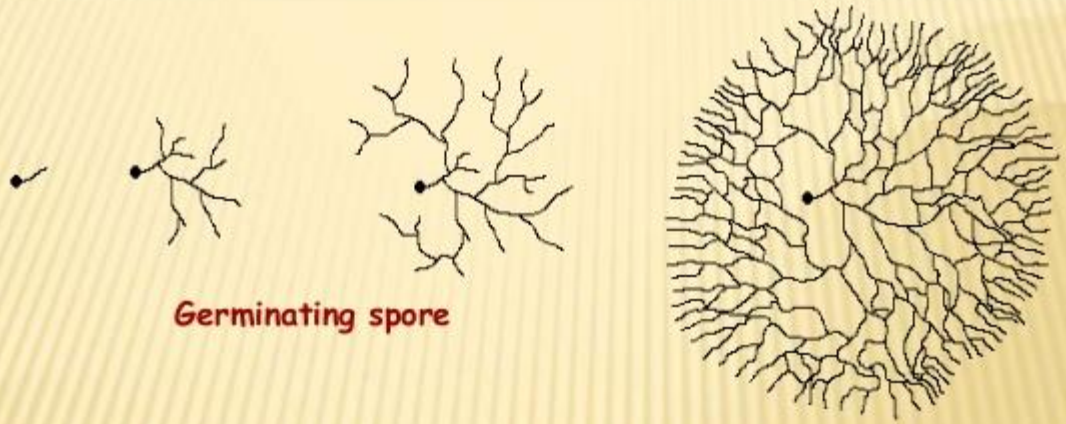
Only a few yeast species reproduce by fission. e.g. *Schizosaccharomyces*

- divide evenly to produce two new cells.

THE CHARACTERISTICS OF FUNGI

- **Cell walls** are made of **chitin** (complex polysaccharide)
- Body is called the **Thallus**
- Grow as **microscopic** tubes or filaments called **hyphae**

HYPHAL GROWTH FROM SPORE

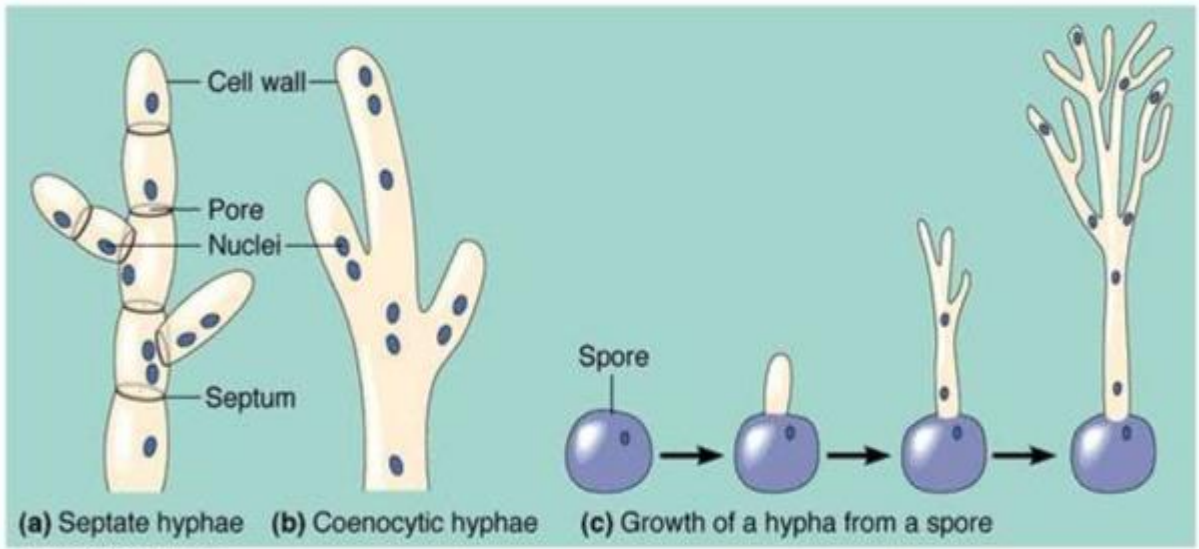


Germinating spore

mycelium

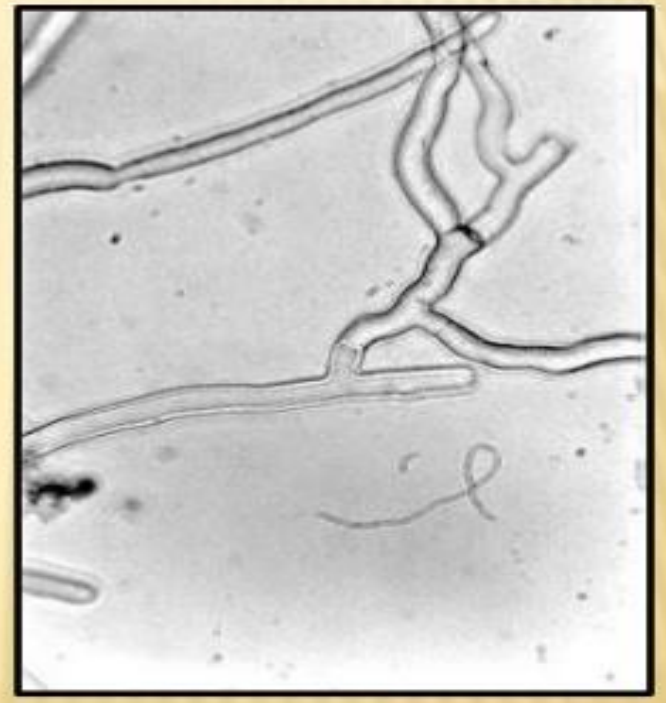
- Mycelia have a huge surface area
- More surface area aids digestion & absorption of food

Characteristics of Fungal Hyphae: Septate versus Coenocytic



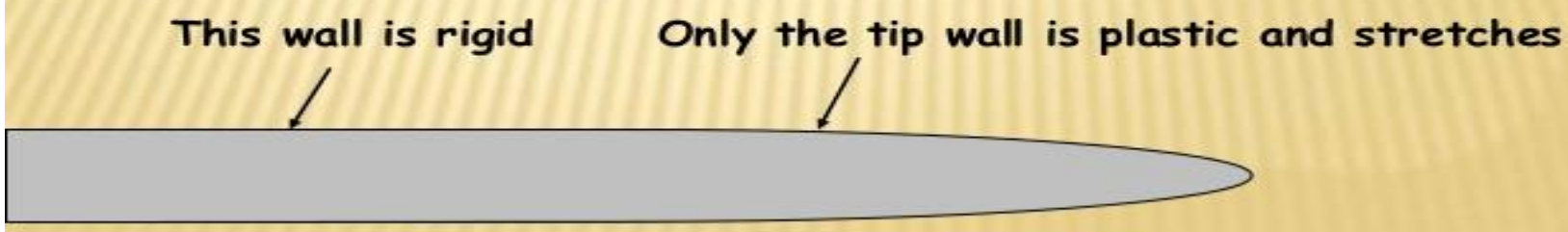
HYPHAE

- **Tubular** shape
- **ONE** continuous cell
- Filled with **cytoplasm & nuclei**
- **Multinucleate**
- Hard cell wall of **chitin** also in insect exoskeletons

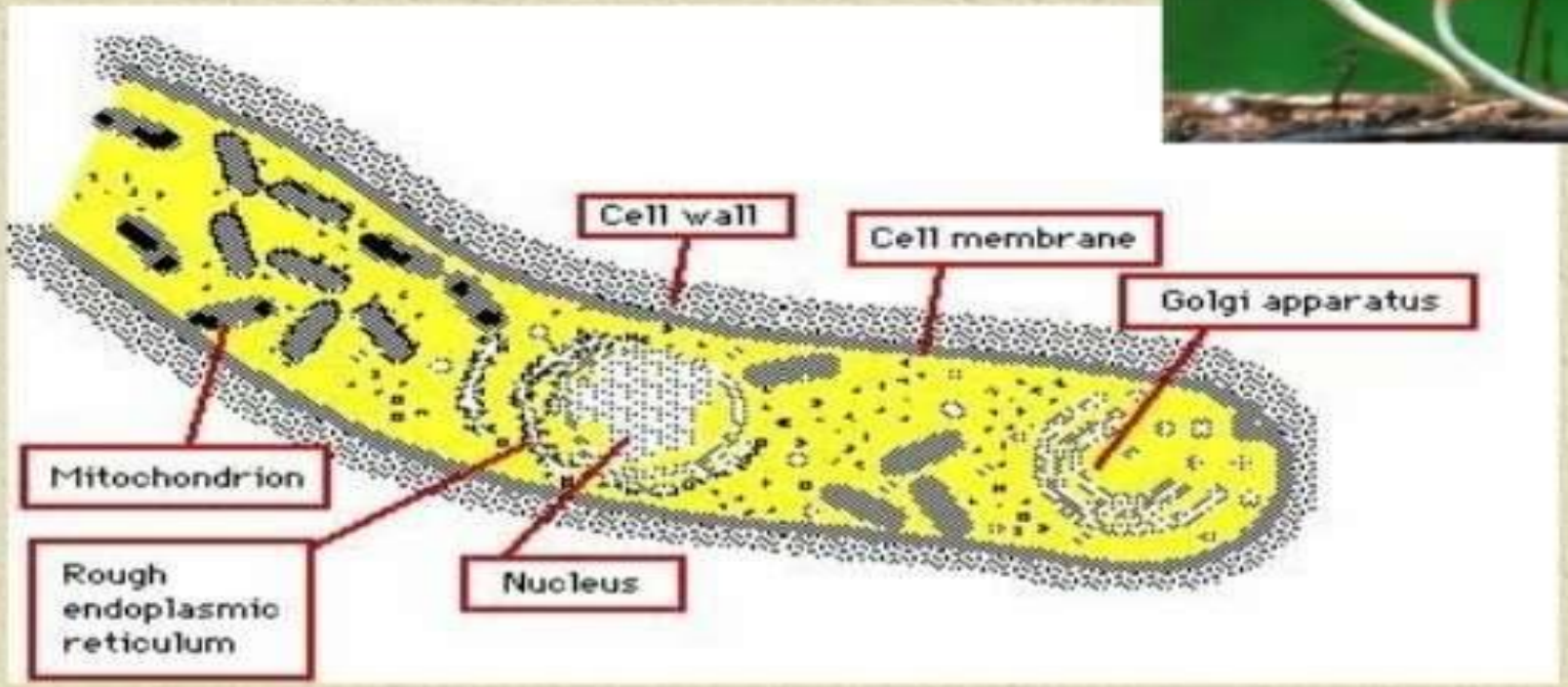


HYPHAL GROWTH

- Hyphae grow from their tips
- **Mycelium** is an extensive, feeding **web of hyphae**
- Mycelia are the **ecologically active** bodies of fungi

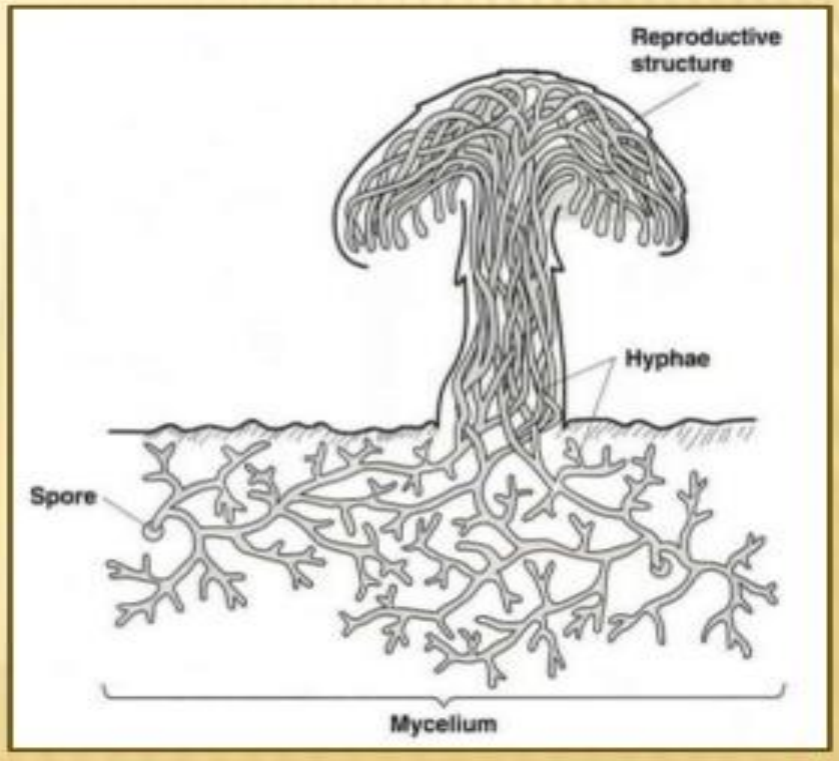


Structure of fungi



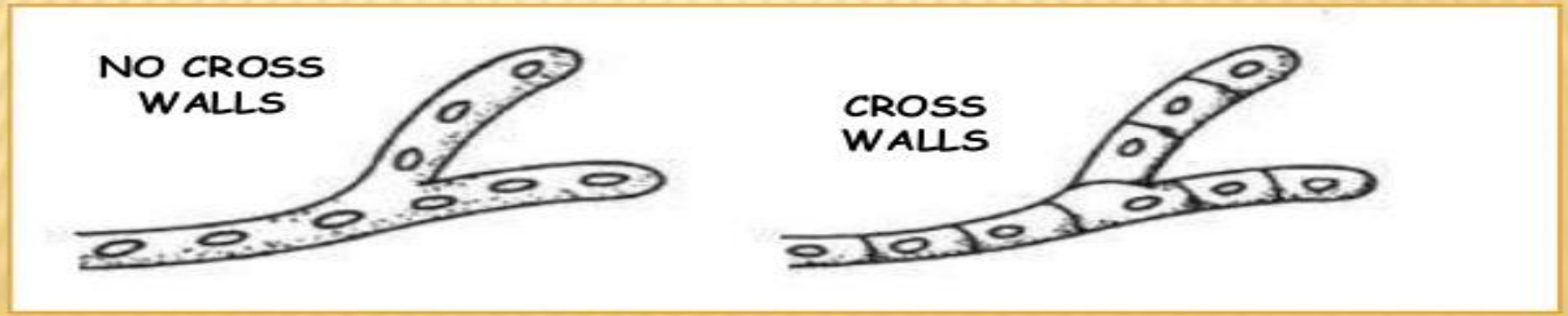
HYPHAE

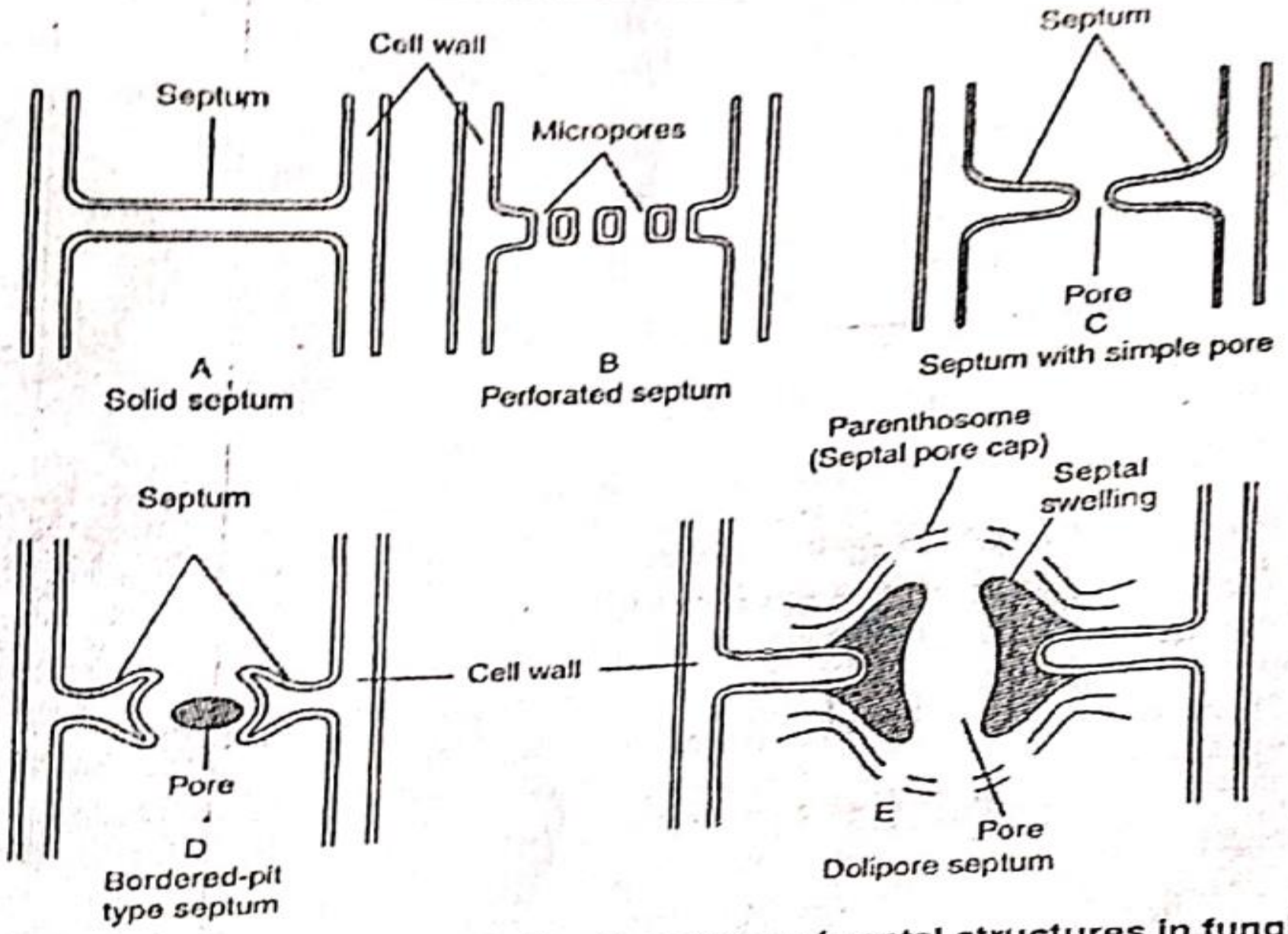
- Cross-walls called **SEPTA** may form compartments
- Septa have **pores** for movement of cytoplasm
- Form network called **mycelia** that run through the **thallus** (body)



MODIFICATIONS OF HYPHAE

- Fungi may be classified based on cell division (with or without cytokinesis)
  - Aseptate or coenocytic (without septa)
  - Septate (with septa)

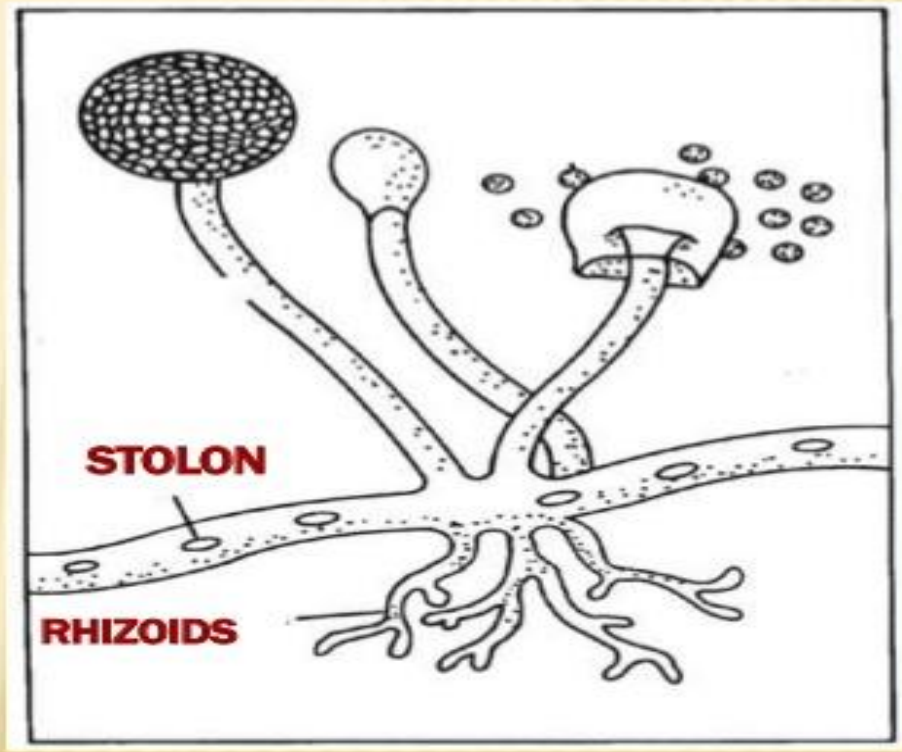




.2. **Diagrammatic representation of various types of septal structures in fungi.** (A) Lower fungi. (B) *Geotrichum*. (C) *Ascomycota* and mitosporic ascomycetes. (D) *Trichomycetes*. (E) Most of the *Basidiomycota* and asexual basidiomycetes excepting *Teliomycetes*.

HYPHAE

- **Stolons** – horizontal hyphae that connect groups of hyphae to each other
- **Rhizoids** – rootlike parts of hyphae that anchor the fungus



Structure - Hyphae

- Hyphae grow by elongating at the tips.
- Each part of hyphae is capable of growth, and when a fragment breaks off, it can elongate to form a new hyphae.
- In the laboratory, fungi are usually grown from fragments obtained from a fungal thallus.
- Portion of a hyphae that obtains nutrients is called the **vegetative hyphae**
- Portion concerned with reproduction is the **reproductive** or **aerial** hypha, so named because it projects above the surface of the medium on which the fungus is growing.
- Aerial hypae often bear **reproductive spores**

REPRODUCTION

- Most fungi reproduce **Asexually** and **Sexually** by spores
- ASEXUAL reproduction is **most common** method & produces **genetically identical** organisms
- Fungi reproduce SEXUALLY when **conditions are poor & nutrients scarce**

FOUR TYPES OF ASEXUAL REPRODUCTION

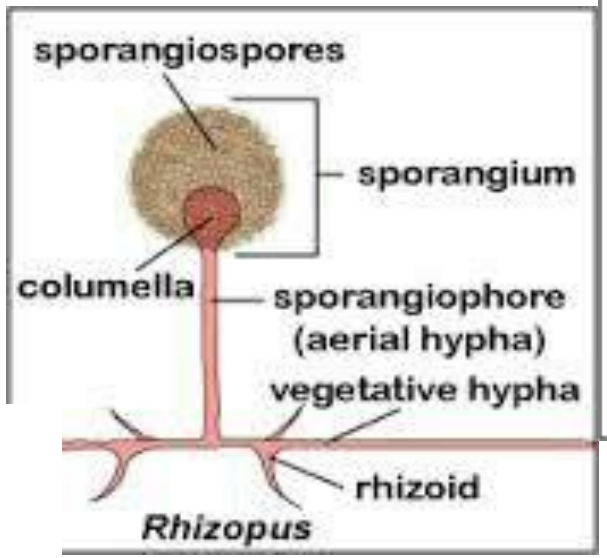
- **Fragmentation** – part of the mycelium becomes separated & begins a life of its own
- **Budding** – a small cell forms & gets pinched off as it grows to full size
  - + Used by yeasts
- x **Fission**
- **Asexual spores** – production of spores by a single mycelium

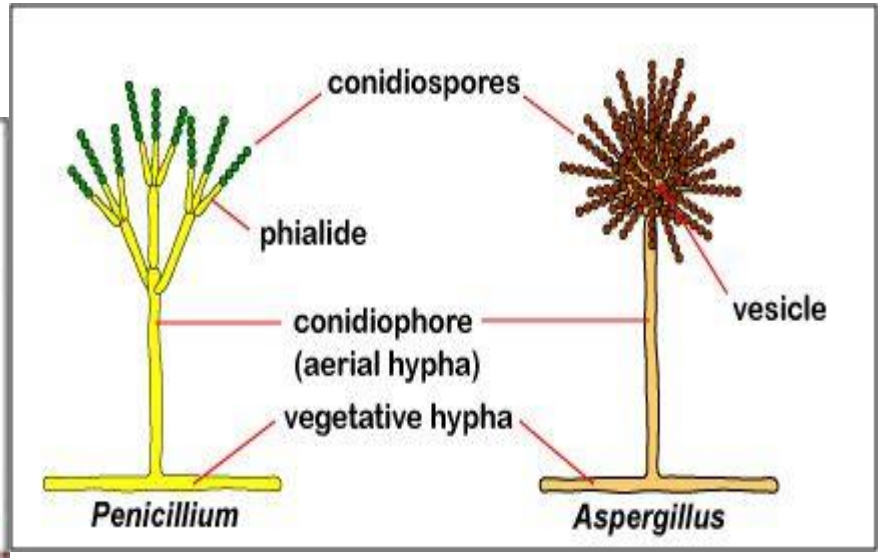
SPORES

- Spores are an **adaptation** to life on land
- Ensure that the **species will disperse to new locations**
- Each spore contains a **reproductive cell** that forms a new organism
- **Nonmotile** / motile
- Dispersed by **wind**

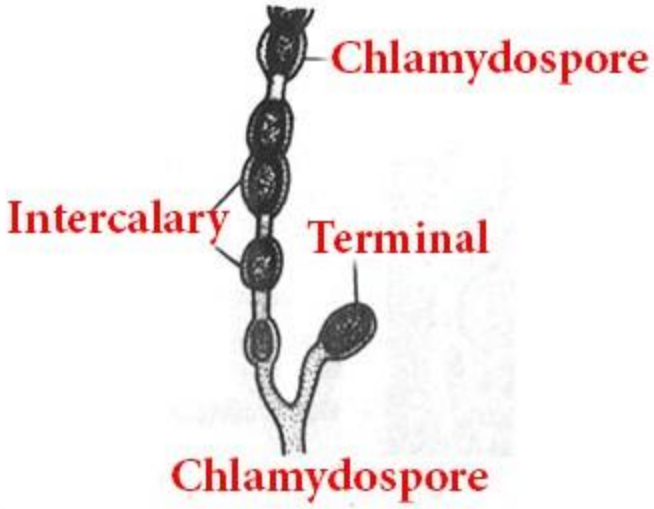
Different Types of Asexual Spores

1. Sporangiospores
2. Conidiospores
3. Oidia or arthrospores
4. Chlamydospores
5. Blastospores





Coprinus sp

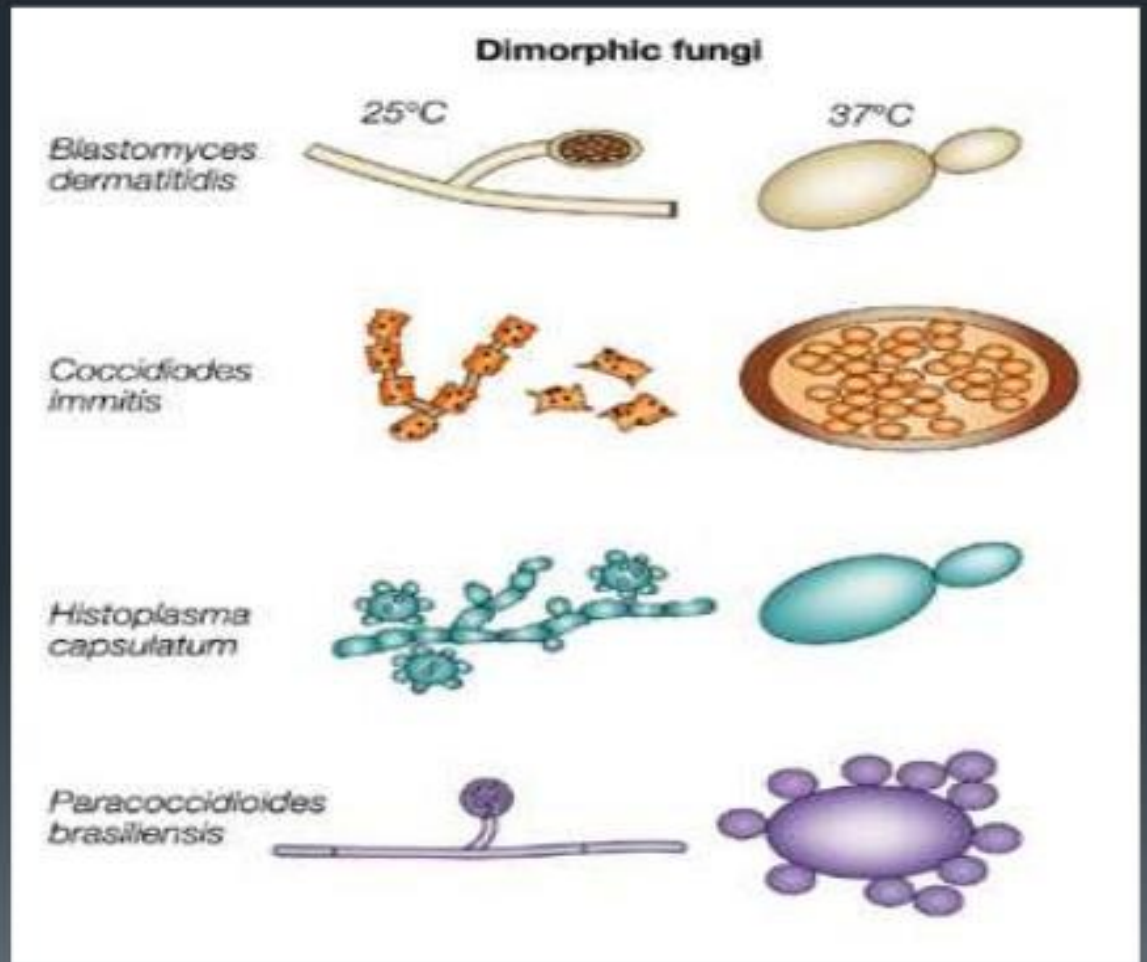


Candida sp

SEXUAL REPRODUCTION

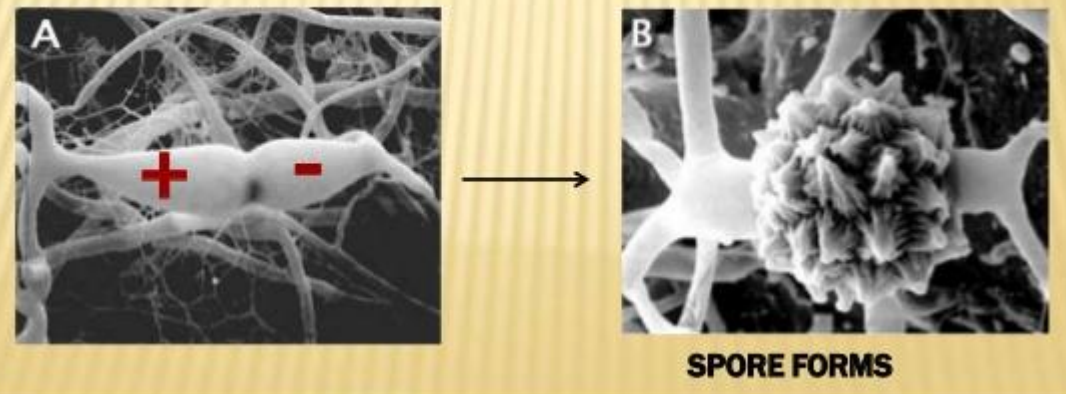
- Used when environmental conditions are poor (lack of nutrients, space, moisture…)
- No male or female fungi
- Some fungi show dimorphism
  - May grow as MYCELIA or a YEAST –LIKE state (Filament at 25°C & Round at 37°C)

4. Dimorphic fungi



SEXUAL REPRODUCTION

- Haploid 1n hyphae from 2 mating types (+ and -) FUSE (Fertilization)
- Forms a hyphae with 2 nuclei that becomes a ZYGOTE
- The zygote divides to make a SPORE



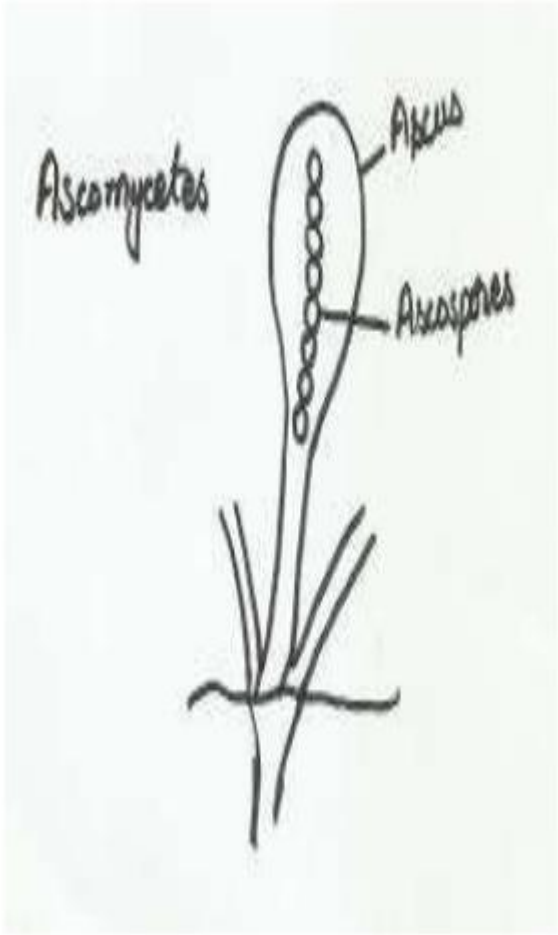
Sexual Spores

- Fungal sexual spores results from sexual reproduction which consists of **three** phases:
- **Plasmogamy (Cell fusion):** A haploid nucleus of a donor cell (+) penetrates the cytoplasm of a recipient cell (-).
- **Karyogamy(Nuclear fusion):** The (+) and (-) nuclei fuse to form a diploid zygote nucleus.
- **Meiosis.** The diploid nucleus gives rise to haploid nuclei (sexual spores), some of which may be genetic recombinants.

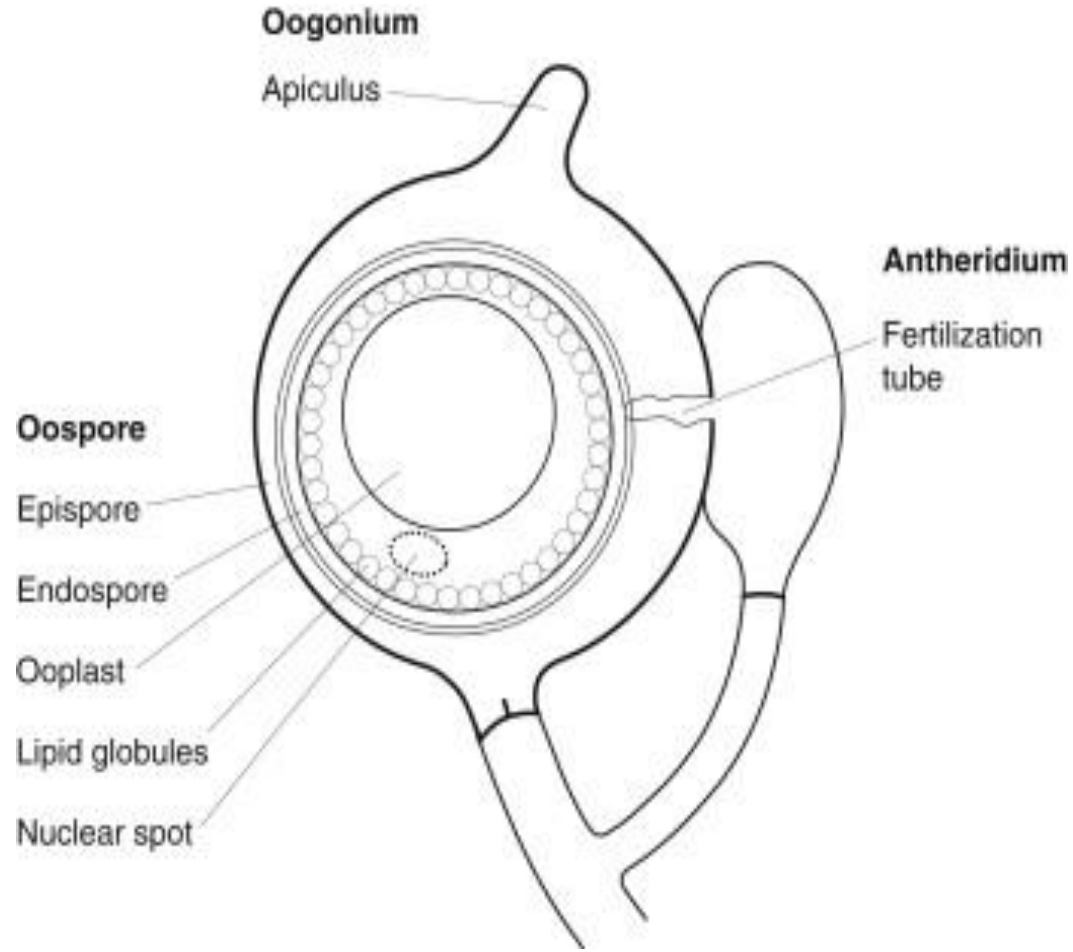
The various methods of sexual reproduction by which compatible nuclei are brought together in plasmogamy-

- **Gametic copulation**
- **Gamete-gametangial copulation**
- **Gametangial copulation**
- **Somatic copulation**
- **Spermatization**

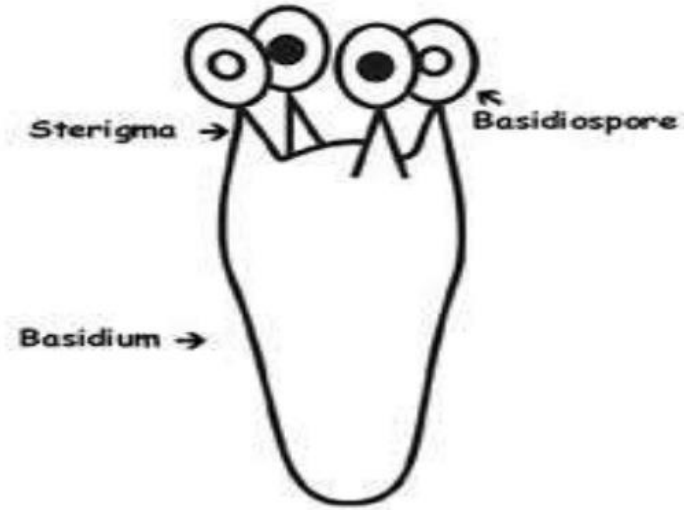
- ***Oospores*** are produced when male gametes (reproductive nuclei)enter a large spherical cell (*oogonium*) and fertilize the eggs within.
- ***Ascospores*** are produced within spherical cells called ***asci***
- most often in groups of 4 or 8
- Usually the asci are produced within some kind of enclosing structure and thus are not found exposed on the hyphae.


Ascomycetes
Ascus
Ascospores

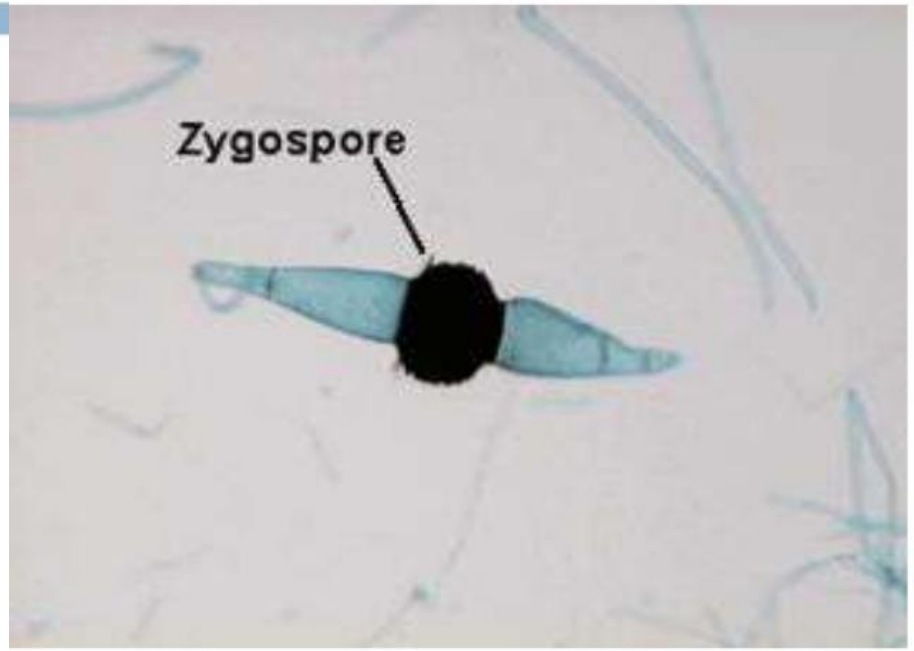

oospore
oogonium


Oogonium
Apiculus
Antheridium
Fertilization tube
Oospore
Epispore
Endospore
Ooplast
Lipid globules
Nuclear spot

- ***Basidiospores*** **:** produced externally on a structure called a ***basidium***. Basidia come in a variety of forms, but those commonly encountered on moulds will be **club-shaped** and bear four or eight spores on sharp projections at the apex.



- ***Zygospores*** **:**
- Do not occur inside any kind of enclosing structure
- produced by the direct fusion of two hyphal protrusions from neighbouring filaments.
- Usually zygospores are recognized as large, nearly spherical, often dark brown or black, rough-walled spores with two connecting hyphae, representing the two mating gametangia



Both asexual and sexual spores are covered by highly organized protective structures called **fruiting bodies.**

Asexual fruiting bodies- Acervulus, Pycnidium

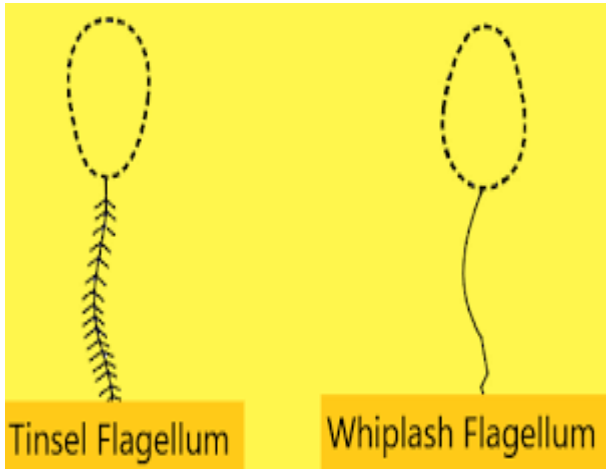
Sexual fruiting bodies- Perithecium, Apothecium

Major Organisms of the Kingdom Fungi

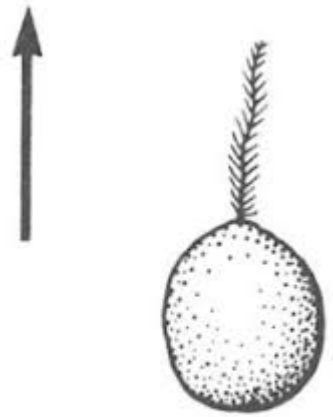
Division/Class	Major Distinguishing Characteristics	Representative Organism
1.Division Gymnomycota (slime molds)	Lack cell wall, move with the help of pseudopodia. Ingest particulate nutrients	
(i) Class Acrasiomycetes (cellular slime molds)	Asexual reproduction by binary fission and sporangiospores formation. Sexual phase absent.	*Dictyostelium discoideum*
(ii) Class Myxomycetes (acellular slime molds)	Asexual reproduction by sporangiospores formation. Sexual reproduction is isogamous type.	*Physarum polycephalum*

Major Organisms of the Kingdom Fungi

Division/Class	Major Distinguishing Characteristics	Representative Organism
2. Division Mastigomycota (flagellated lower fungi)	Aquatic fungi producing motile flagellated cells	
(i) Chytridiomycetes	Motile cells bearing one posteriorly directed whiplash type flagella. Asexual reproduction by sporangiospores formation. Sexual reproduction by gametic union.	*Allomyces macrogynus*
(ii) Hyphochrytridiomycetes	Motile cells bearing one anteriorly directed tinsel type flagella. Asexual reproduction by sporangiospores formation. Sexual reproduction by gametic union.	*Hyphochrytrium catenoides*
(iii) Plasmodiophoromycetes	Motile cells with 2 unequal anteriorly directed whiplash type flagella. Asexual reproduction by sporangiospores formation. Sexual reproduction by gametic union.	*Plasmodiophora brassica*
(iv) Oomycetes	Motile cells with 2 laterally inserted flagella- one tinsel type anteriorly directed and one whiplash type posteriorly directed. Asexual reproduction by sporangiospores formation. Sexual reproduction by oospores formation.	*Saprolegnia ferax.*

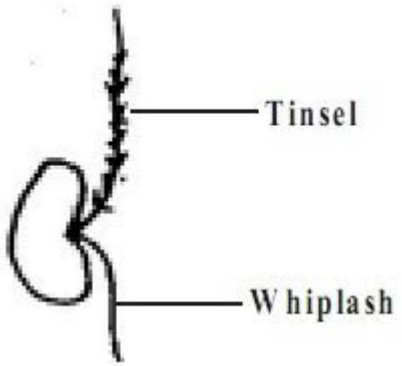


Chytridiomycetes



Hyphochrytridiomycetes

Plasmodiophoromycetes



Oomycetes

Major Organisms of the Kingdom Fungi

Division/Class	Major Distinguishing Characteristics	Representative Organism
3. Amastigomycota (terrestrial fungi)	Flagella absent	
(i) Zygomycetes	Asexual reproduction by sporangiospores formation. Sexual reproduction by zygospores formation.	*Rhizopus stolonifer* *Mucor rouxii*
(ii) Ascomycetes	Asexual reproduction by conidiospores formation. Sexual reproduction by ascospores formation.	Yeasts *Neurospora crassa*
(iii) Basidiomycetes	Sexual reproduction by basidiospores formation.	Mushrooms, puffballs, rusts, smuts, jelly, bracket fungi *Agaricus campestris*
(iv) Deuteromycetes	Asexual reproduction by conidiospores formation. Sexual phase absent.	*Aspergillus niger* *Penicillium notatum*

Mushrooms

Puffballs

Rust fungi

Smut fungi

Jelly fungi

Bracket fungi

1. Phycomycetes

- Fungi having non-septate hyphae, forms endogenous asexual spores (sporangiospores) contained within a sac like structures called sporangia.
- Also produce sexual spores known as oospores and zygospores.
- Example: *Mucor, Rhizopus.*

2. Ascomycetes

- Form sexual spores within a sac and are called ascospores.
- The sac is called as ascus.
- They form septate hyphae.
- Include both yeasts and filamentous fungi e.g. *Histoplasm, Candida* etc.

3. Basidiomycetes

- Reproduce sexually and form septate hyphae.
- These basidiospores are borne at the tip of the basidium
- Example: *Cryptococcus neoformans*

4. Fungi imperfecti

- Also called as Deuteromycetes or Hyphomycetes.
- Consist of group of fungi whose sexual phases have not been identified and they form septate hyphae and asexual conidia.
- Majority of the pathogenic moulds, yeasts, yeasts like fungi and dimorphic fungi.
- Example: *Trichophyton, Epidermophyton*

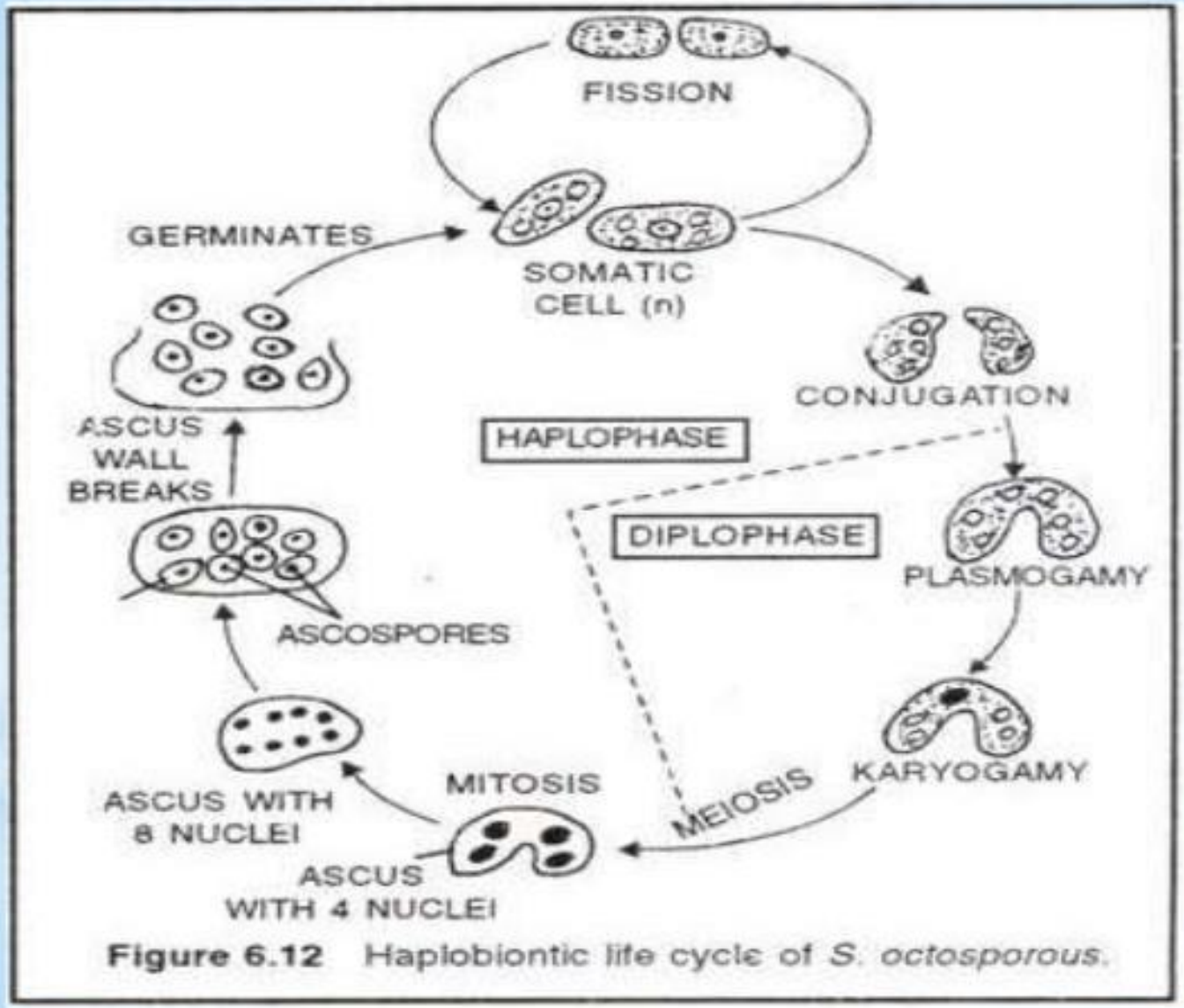
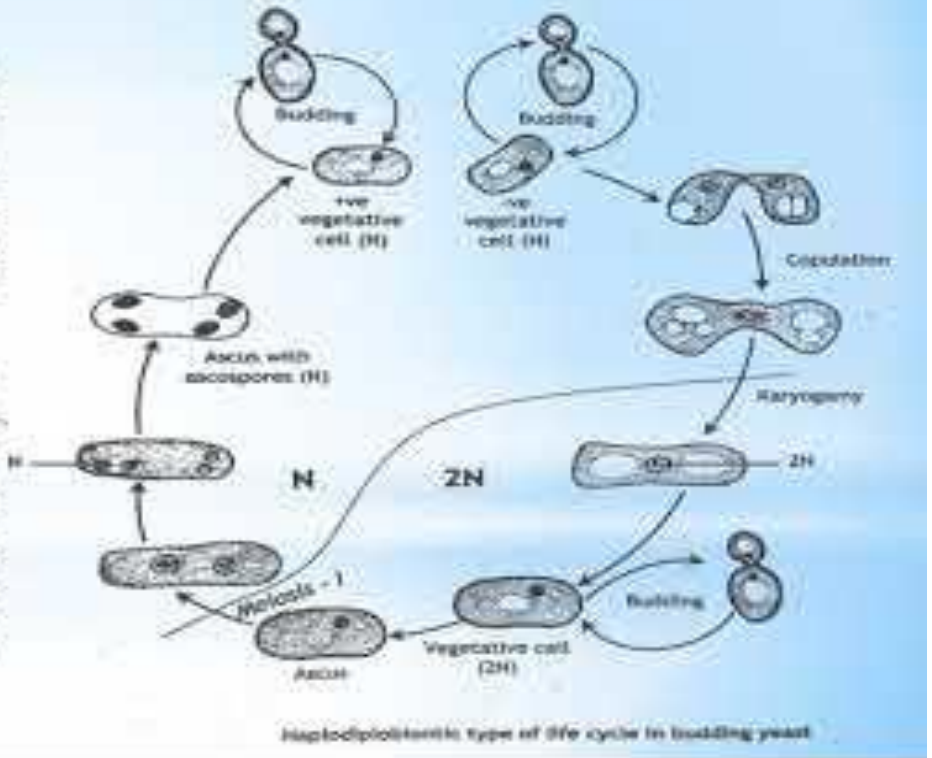


Figure 6.12 Haplobiontic life cycle of *S. octosporous*.

HAPLODIPLOBIONTIC LIFE CYCLE

In this type of life cycle, both haploid phase and diploid phase delay for longer period and equally participate in multiplication by budding. It is found in haploid species of yeast like Saccharomyces cerevisiae.

When condition becomes favourable, it multiplies by budding and forms a number of haploid yeast. When scarcity of food materials exists in the medium, two yeast cell of opposite strains come close to each other and produce a small lateral outgrowth towards one another.

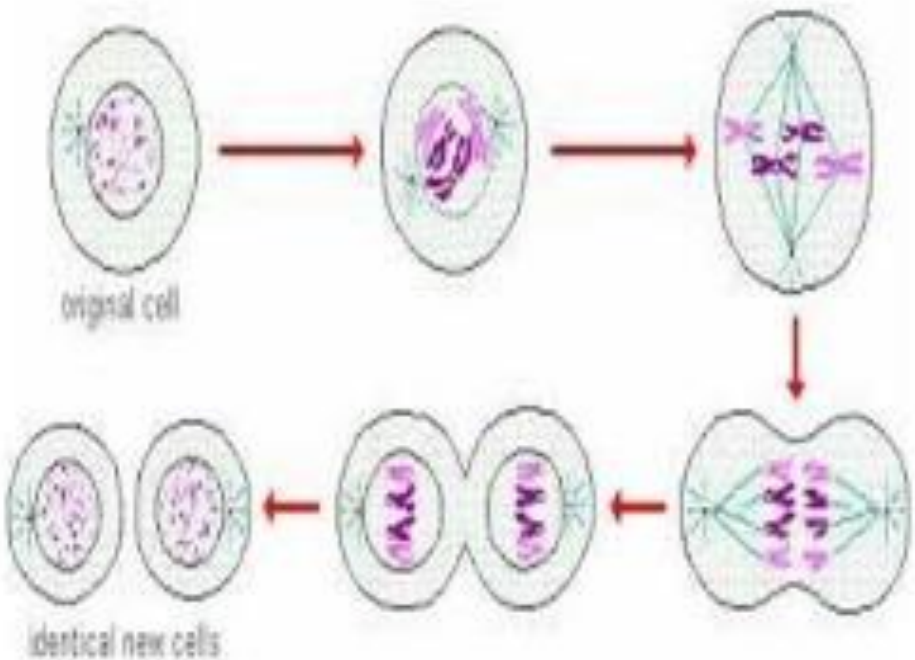


Difference between Fungi and Bacteria

Characteristics	Fungi	Bacteria
Cell type	Eucaryotic	Procaryotic
Optimum pH	4-6	6.5-7.5
Optimum temperature	25-30°C (saprophytes) 32-37°C (parasites)	32-37°C
Cell membrane	Sterols present	Sterols absent except mycoplasm
O_2 requirement	Strictly aerobic (moulds) Facultative anaerobic(Some yeasts)	Aerobic to anaerobic
Light requirement	None	Some photosynthetic gr.
Carbon source	Organic	Organic/ Inorganic
Conc. of sugar in media	4-5%	0.5-1%
Cell wall components	Chitin, cellulose or hemicellulose	Peptidoglycan
Susceptibility to antibiotics	Sensitive to griseofulvin, Resistant to penicillinis, chloramphenicol etc.	Sensitive to penicillinis, Resistant to griseofulvin, tetracyclines etc.

FUNGI

Nuclear Status



Karyochorisis

Sexual Reproduction

Plasmogamy
Karyogamy
Dikaryon

LIFE CYCLES IN FUNGI

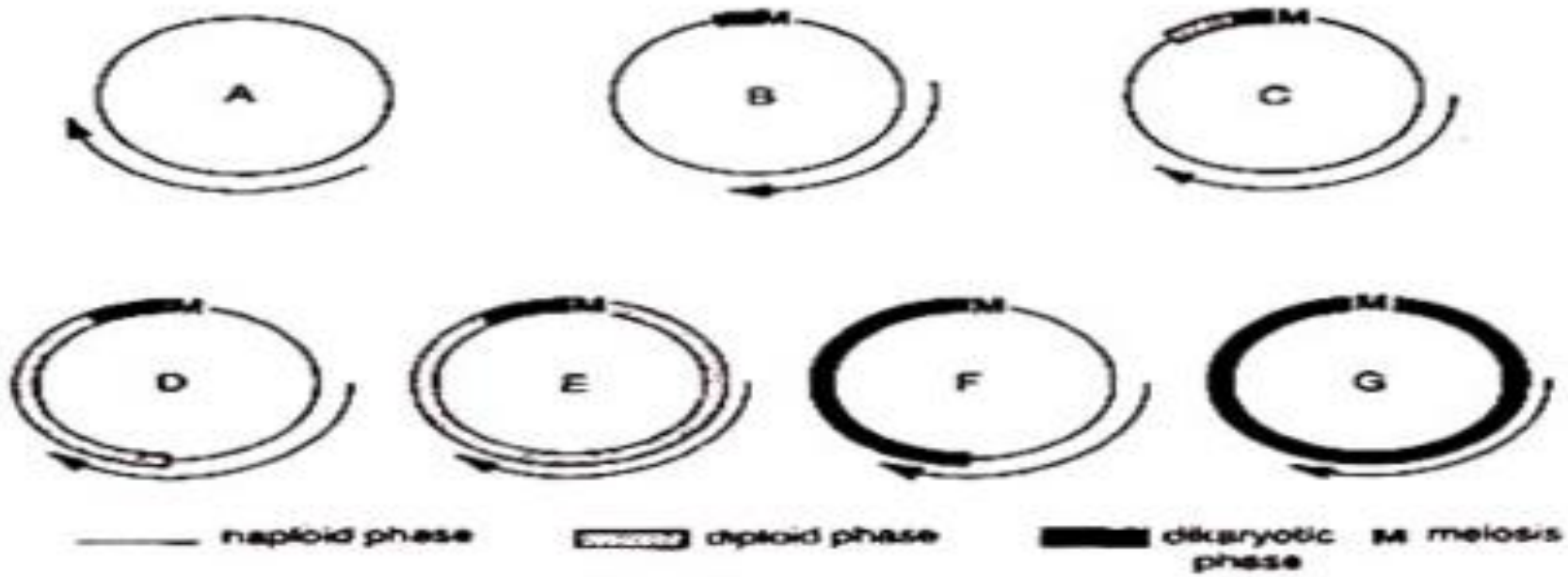


Fig. 38 (A–G). Fungi : Life cycle patterns. (A) Asexual, (B) Haploid, (C)Haploid cycle with restricted dikaryon, (D) Haploid dikaryotic cycle, (E) Dikaryotic cycle, (F) Haploid-diploid cycle, (G) Diploid cycle

HETEROKARYOSIS

Heterokaryosis may originate in a fungal thallus in four ways

On the basis of sex most fungi can be classified into three categories

1. Monoecious
2. Dioecious
3. Sexually undifferentiated

Fungi in the above sex categories belong to one of the groups-

- ✓ Homothallic Fungi
- ✓ Heterothallic Fungi

HETEROTHALLISM

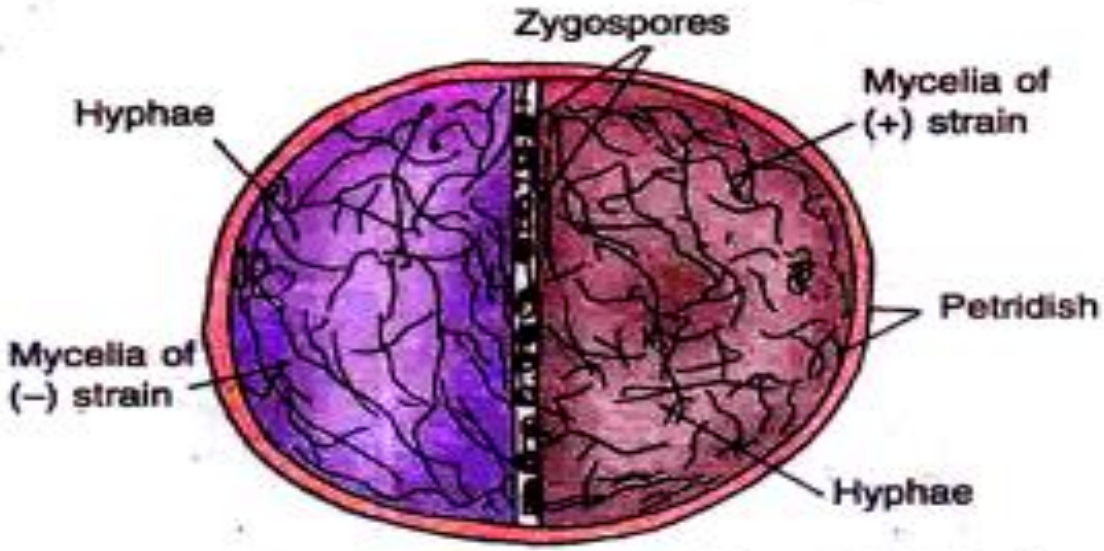


Fig. 17.2 *Mucor hiemalis*. Zygospore formation indicating Heterothallism.

Heterothallism may be of 2 types-

1. Morphological heterothallism
2. Physiological heterothallism

Physiological heterothallism may be of 2 types-

- Two- Allele Heterothallism
- Multiple Allele Heterothallism

Multiple Allele Heterothallism can be of two types-

I. Bipolar Multiple Allele Heterothallism
II. Tetrapolar Multiple Allele Heterothallism

SECONDARY HOMOTHALLISM

	A_1	A_2	A_3	A_4
A_1	-	+	+	+
A_2	+	-	+	+
A_3	+	+	-	+
A_4	+	+	+	-

Bipolar Multiple Allele Heterothallism

	A_1B_1	A_1B_2	A_2B_1	A_2B_2
A_1B_1	-	FL	B	+
A_1B_2	FL	-	+	B
A_2B_1	B	+	-	FL
A_2B_2	+	B	FL	-

Tetrapolar Multiple Allele Heterothallism

Flat Reaction- Such heterokaryons show poor growth, hyphae are curly and irregularly branched.

Barrage Reaction-The hyphae at the point of contact show cessation of growth, resulting in a barrage or zone of no growth between the colonies of the two thalli.

THE PARASEXUAL CYCLE

The sequence of events in a complete parasexual cycle is somewhat as follows-

1. Formation of heterokaryotic mycelium
2. Fusion between two nuclei
a. Fusion between like nuclei
b. Fusion between unlike nuclei
3. Multiplication of diploid nuclei side by side with the haploid nuclei
4. Occasional mitotic crossing-over during the multiplication of the diploid nuclei
5. Sorting out of diploid nuclei
6. Occasional haploidization of the diploid nuclei
7. Sorting out of new haploid strains

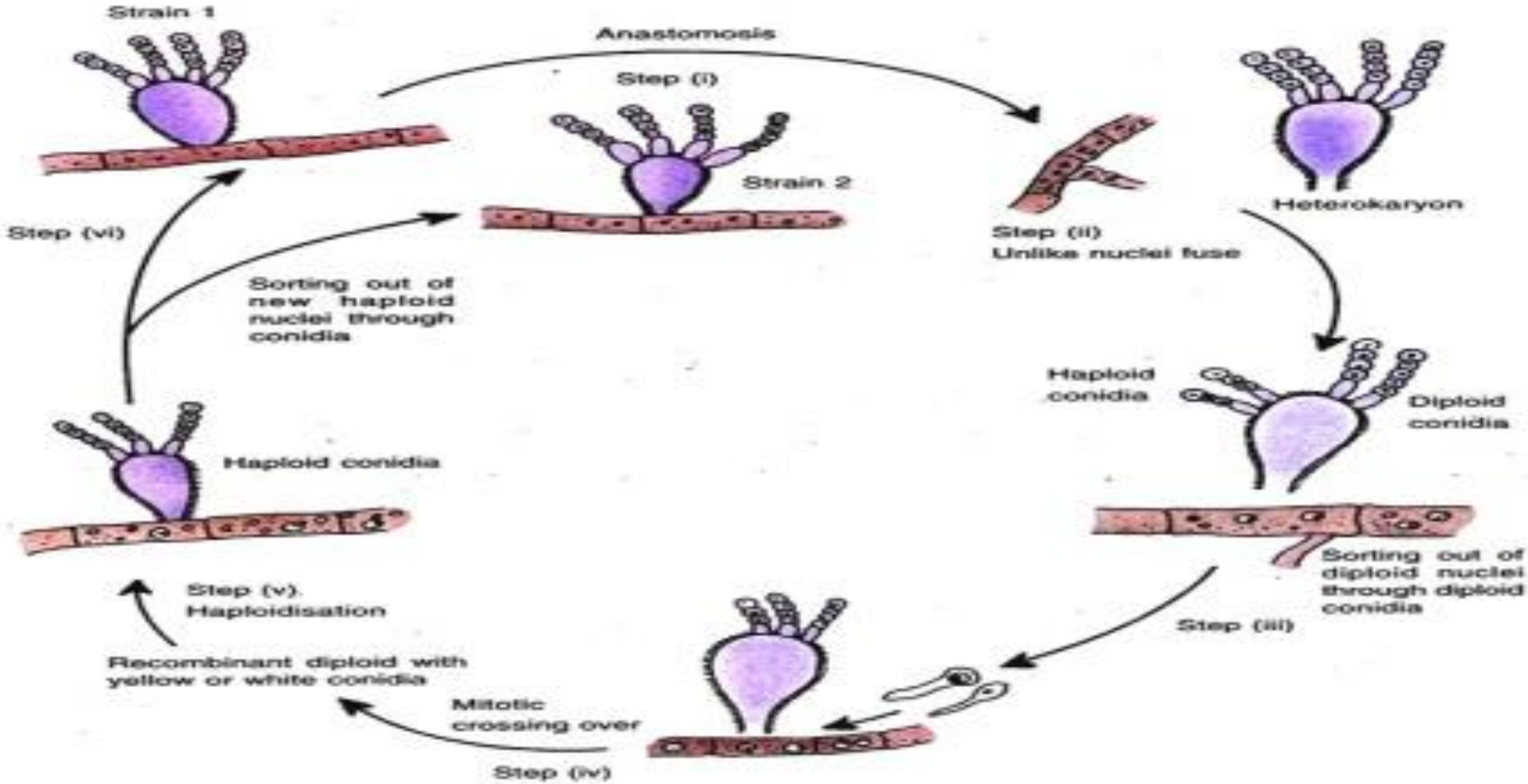


Fig. 17.10. Pontecarvo's (1958) idea of Parasexual cycle

Comparison between Sexual and Parasexual Cycle

Sexual Cycle

- Nuclear fusion takes place in specialized structures.
- Zygotes usually persist one nuclear generation.
- Recombination occurs by crossing over during meiosis. The crossing over occurs in all chromosome pairs and is accompanied by a reduction in the chromosome number.
- Products of meiosis are readily recognizable which can be isolated easily.

Parasexual Cycle

- Rare Nuclear fusion takes place in somatic cells
- Zygote persists through many mitosis.
- Recombination by mitotic crossing over, which is a rare event and occurs in a single chromosome arm. Haplodization, unlike meiosis, is independent of crossing over.
- Recombinant nuclei lie in the somatic cells and can be recognized only by suitable genetic markers.