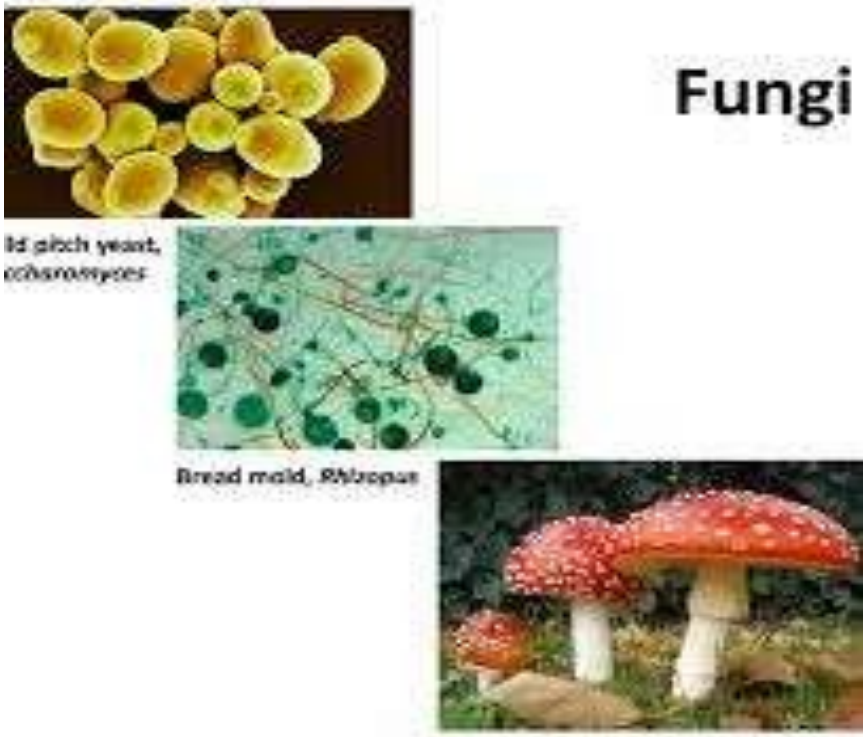
Microbiology in Bioengineering

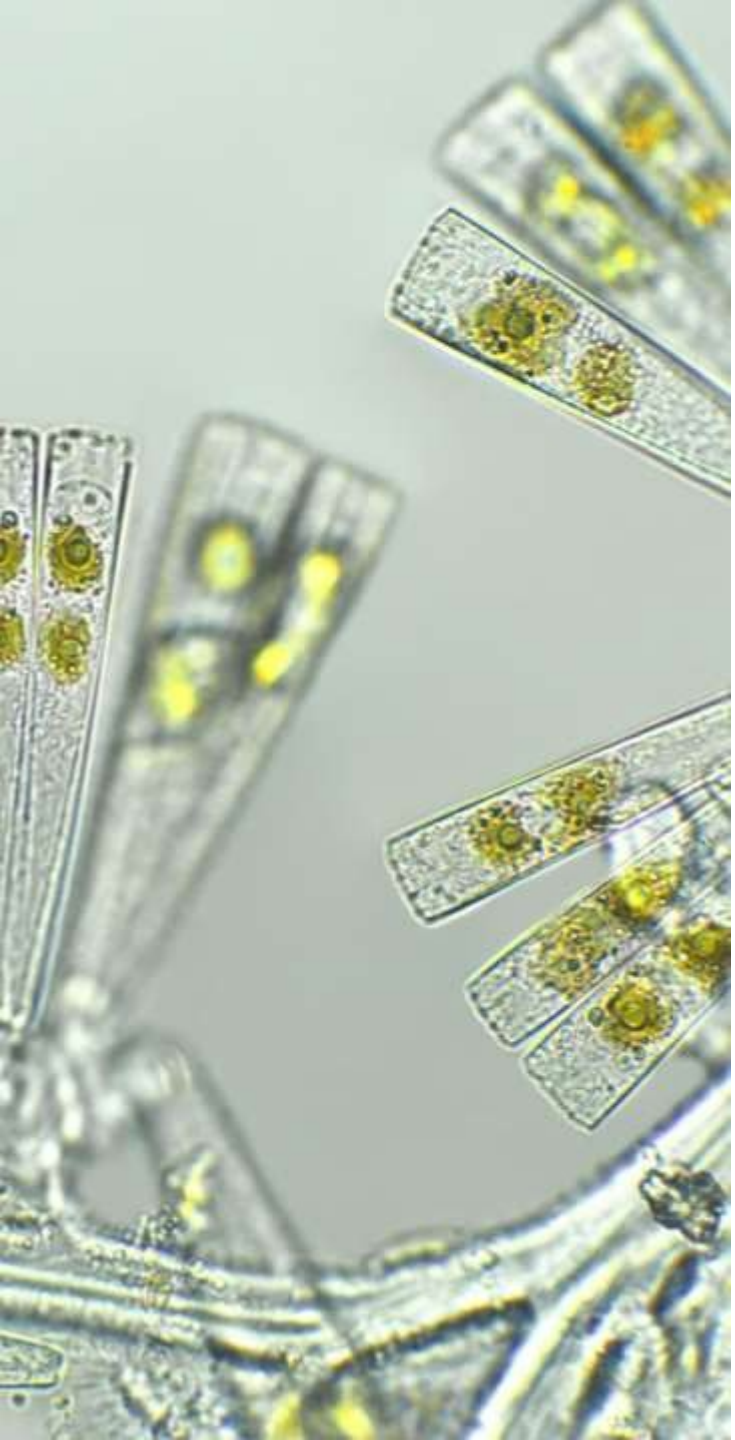
Basic Mycology

Assoc. Prof. Dr. Emrah Şefik Abamor

What is Fungi?

- Fungi is a eukaryotic organism that includes microorganisms such as **yeasts, moulds, and mushrooms**. These organisms are classified under kingdom fungi.





Features of Fungi

Following are the important characteristics of fungi:

1) Fungi are eukaryotic, non-vascular, non-motile and heterotrophic organisms.
2) They may be unicellular or filamentous.
3) They reproduce by means of spores.
4) Fungi exhibit the phenomenon of alternation of generation.
5) Fungi lack chlorophyll and hence cannot perform photosynthesis.
6) Fungi store their food in the form of starch.
7) Biosynthesis of chitin occurs in fungi.

Features of Fungi

- The nuclei of the fungi are very small.
- During mitosis, the nuclear envelope is not dissolved.
- The fungi have no embryonic stage. They develop from the spores.
- The mode of reproduction is sexual or asexual.
- Some fungi are parasitic and can infect the host.
- Fungi produce a chemical called pheromone which leads to sexual reproduction in fungi.
- For eg., mushrooms, moulds, yeast.

Comparative physiology of fungi and bacteria.

Characteristic	Fungi	Bacteria
Optimum pH	3.8 - 5.6	6.5 - 7.5
Optimum temperatures	22 – 30°C (saprohytes) 30 – 37°C (parasites)	20 - 37 °C (mesophiles)
Oxygen requirement	Strictly aerobic (moulds) Facultative (some yeasts)	Aerobic to anaerobic
Light requirement	None	Some photosynthetic bacteria occur
Sugar concentration in laboratory media	4 - 5%	0.5- 1%
Carbon requirement/ Metabolism	Require organic Carbon	Require Inorganic and/ or organic carbon
Antibiotic susceptibility	Resistant to penicillin, tetracycline, chloromphenicol; sensitive to griseofulvin	Resistant to griseofulvin; sensitive to penicillin, tetracycline, chloramphenicol.

What are Fungi?

- **Fungi** are eukaryotic heterotrophs that have cell walls made of **chitin** (a carbohydrate).

- Fungi **DO NOT** ingest their food, but rather they digest food **OUTSIDE** their bodies and the **ABSORB** it! (Fungi are decomposers)

Reasons Fungi Not Plants!

- No chlorophyll
- Cell wall not Cellulose
- NO vascular tissue
- Do not photosynthesize (Not an autotroph)

Basic Morphological Elements of Fungi

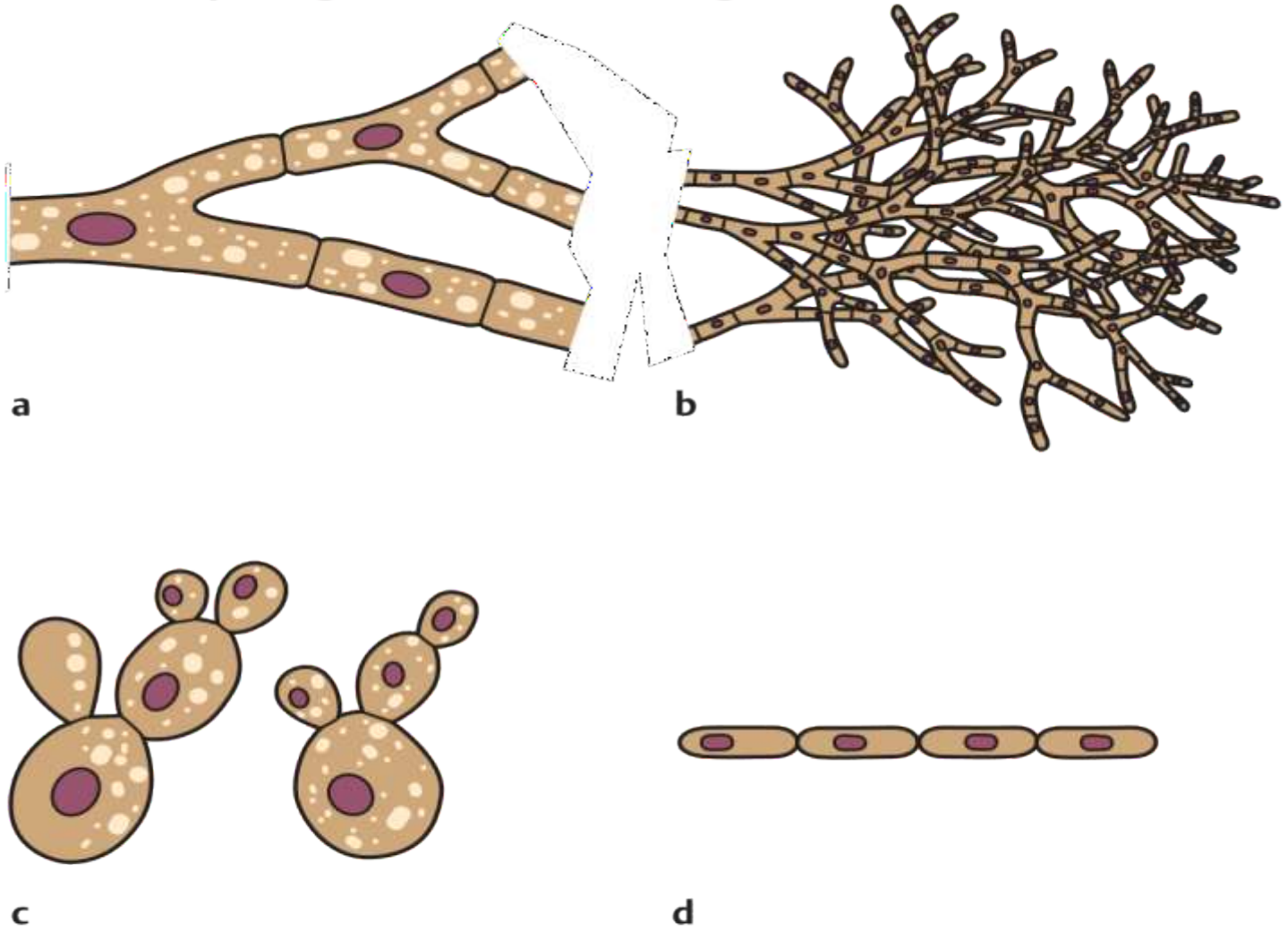
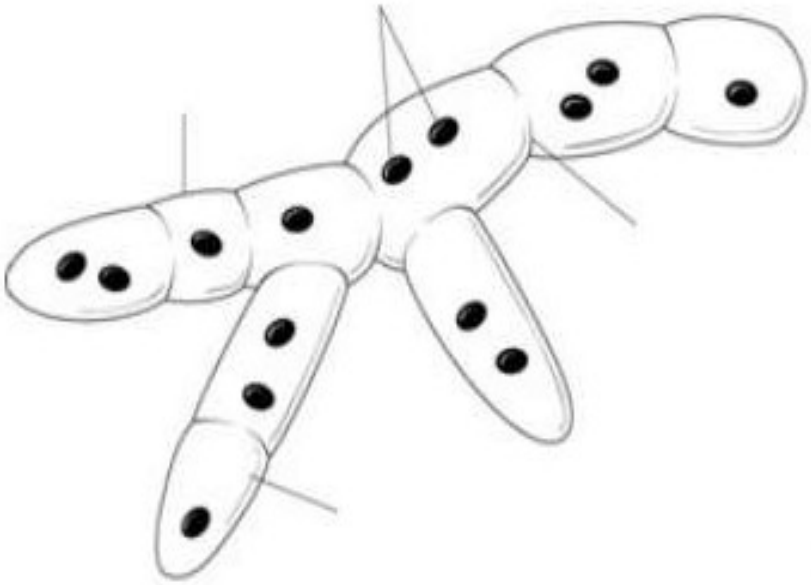


Fig. 5.1 There are two basic morphological forms: hypha and yeast.
a Hypha, septate, or nonseptate.
b Mycelium: web of branched hyphae.
c Yeast form, budding (diameter of individual cell 3–5 µm).
d Pseudomycelium.

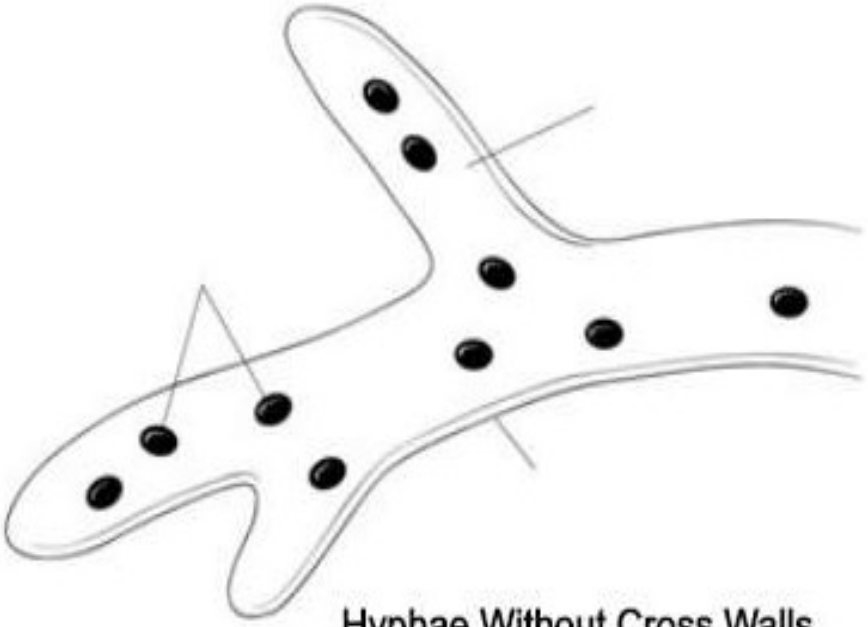
Structure of Fungi

- Vegetative structures involved in catabolism and growth
- **Thallus-** in molds and fleshy fungi
  - Tubular filaments of cells-**hyphae**
  - **Septate hyphae** - cross walls that divide them into unicellular units
    - Pores to allow cytoplasm & nuclei to pass
  - **Coenocytic hyphae**- no septa, continuous cells with many nuclei

Hyphae Structure Close-Up



Hyphae With Cross Walls

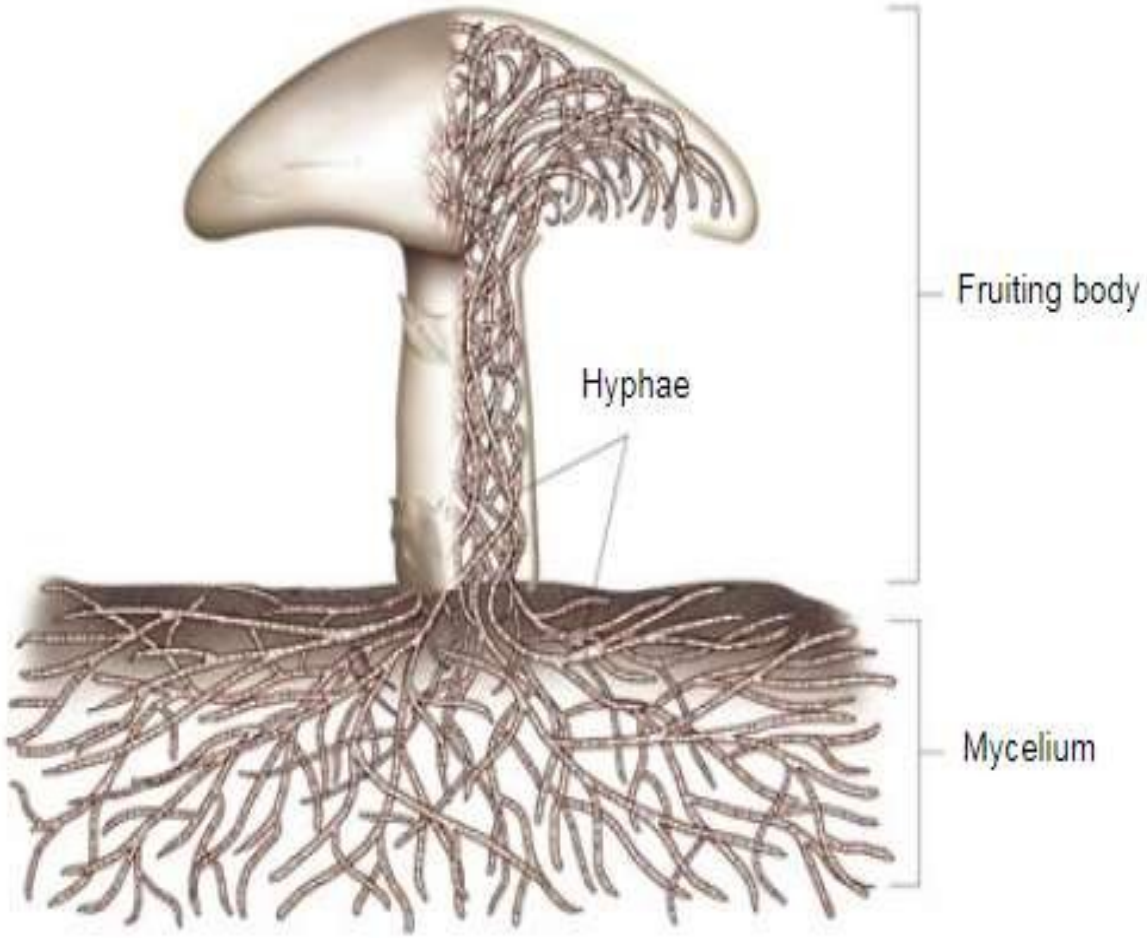


Hyphae Without Cross Walls

Structure & Function of Fungi

- Except for yeasts, ALL fungi are multi-cellular and composed of tiny filaments called hyphae.
  - The bodies of multicellular fungi are composed of many **hyphae** tangled together into a thick mass called a **mycelium.**
  - The mycelium is well suited to absorb food.
  - The **fruiting body** is a reproductive structure that develops from a mycelium that grows below the surface of the ground.

Fungi Structure



How Fungi Spread

- How Fungi Spread
  - Fungal spores
    - Scatter easily in the wind
    - Must land in favorable environment
      - Temperature
      - Moisture
      - Food
    - Some are specialized to lure animals, flies
      - Disperse spores over long distances

Basic structure of Fungus

- Cell wall is rigid
- Contains

Chitin,Mannan, Polysaccharides,

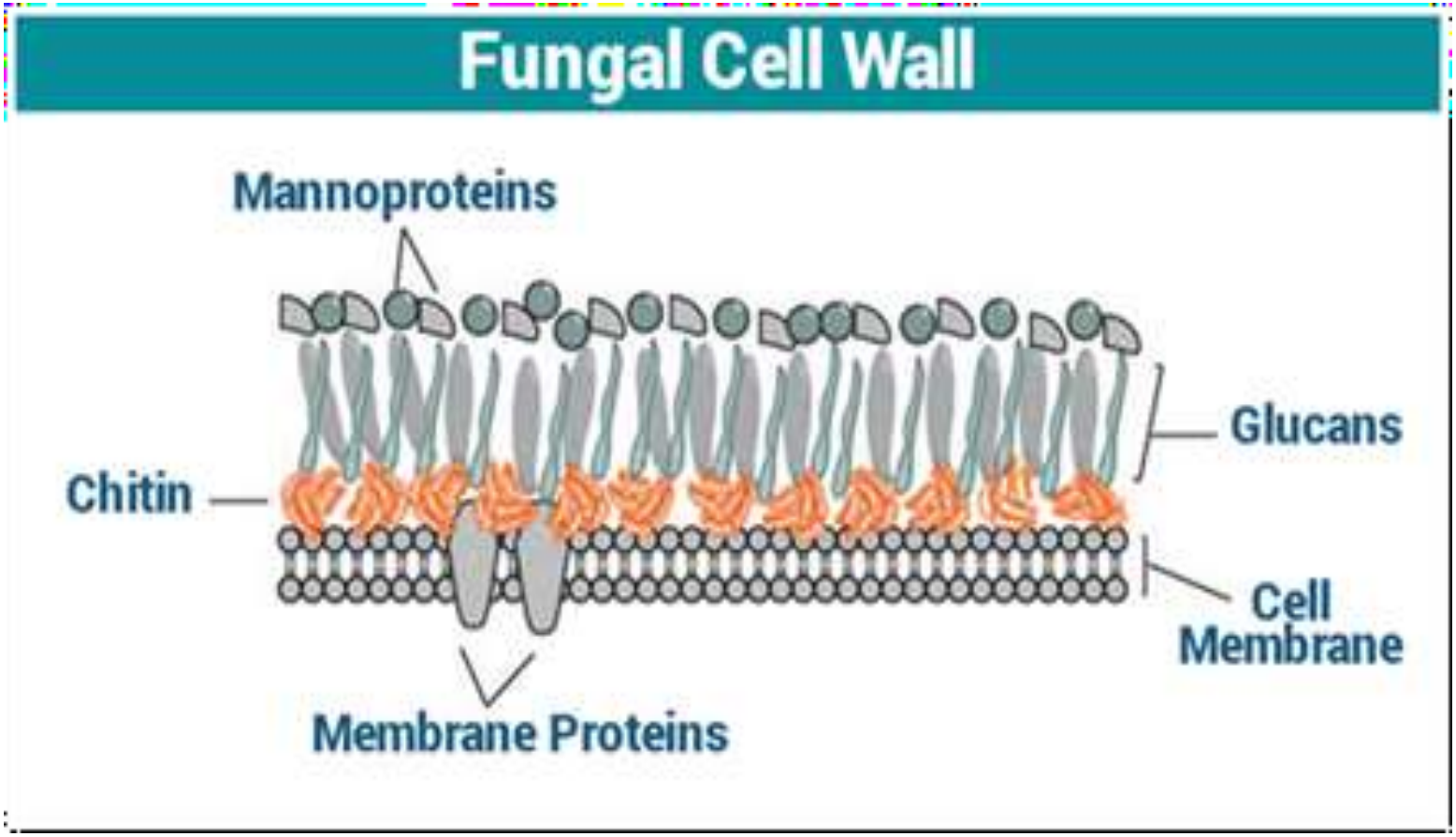
Cytoplasm contains Sterols.

Contains True Nuclei, Paired chromosome.

Divide

Sexually, Asexually or by Both

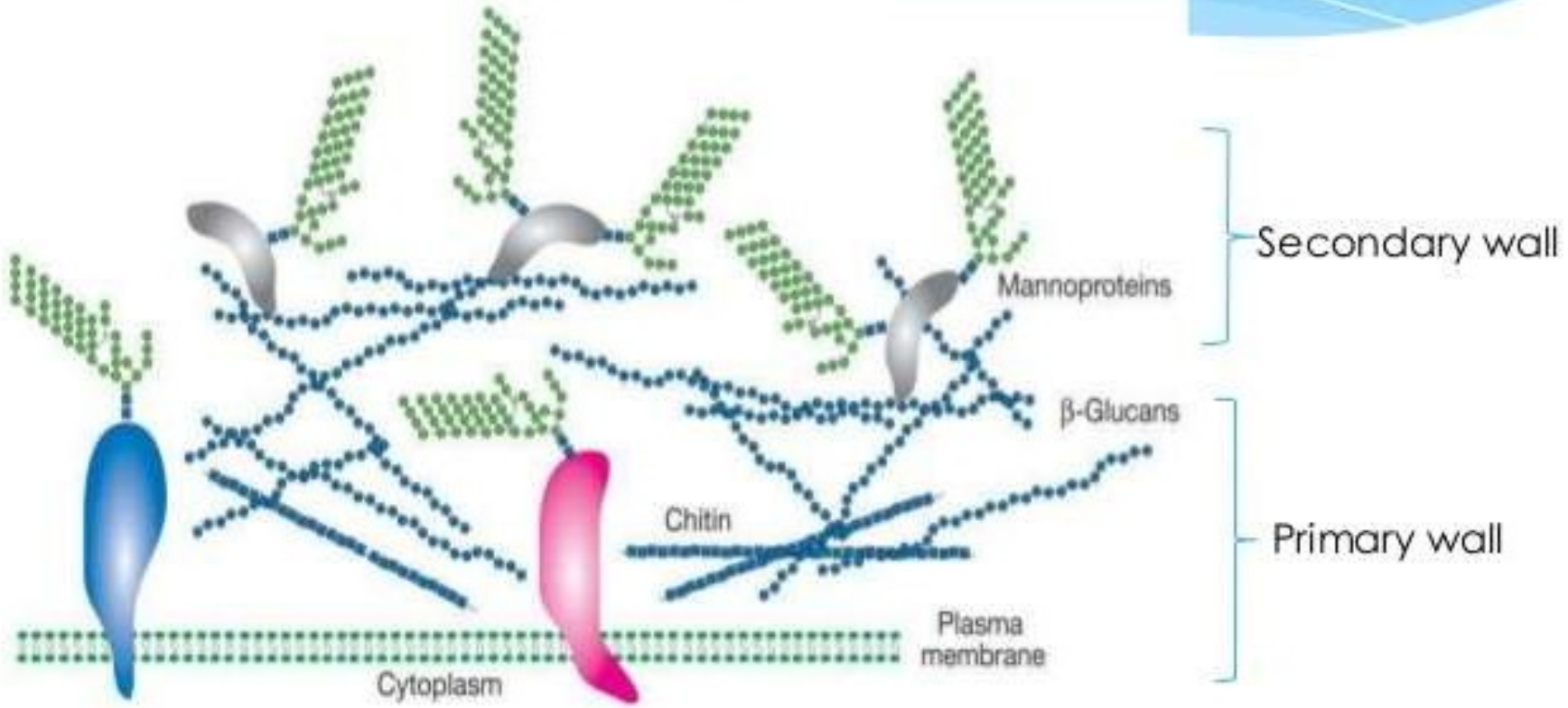
Can have specialized cells


Fungal Cell Wall
Mannoproteins
Glucans
Chitin
Cell Membrane
Membrane Proteins

Fungal cell wall

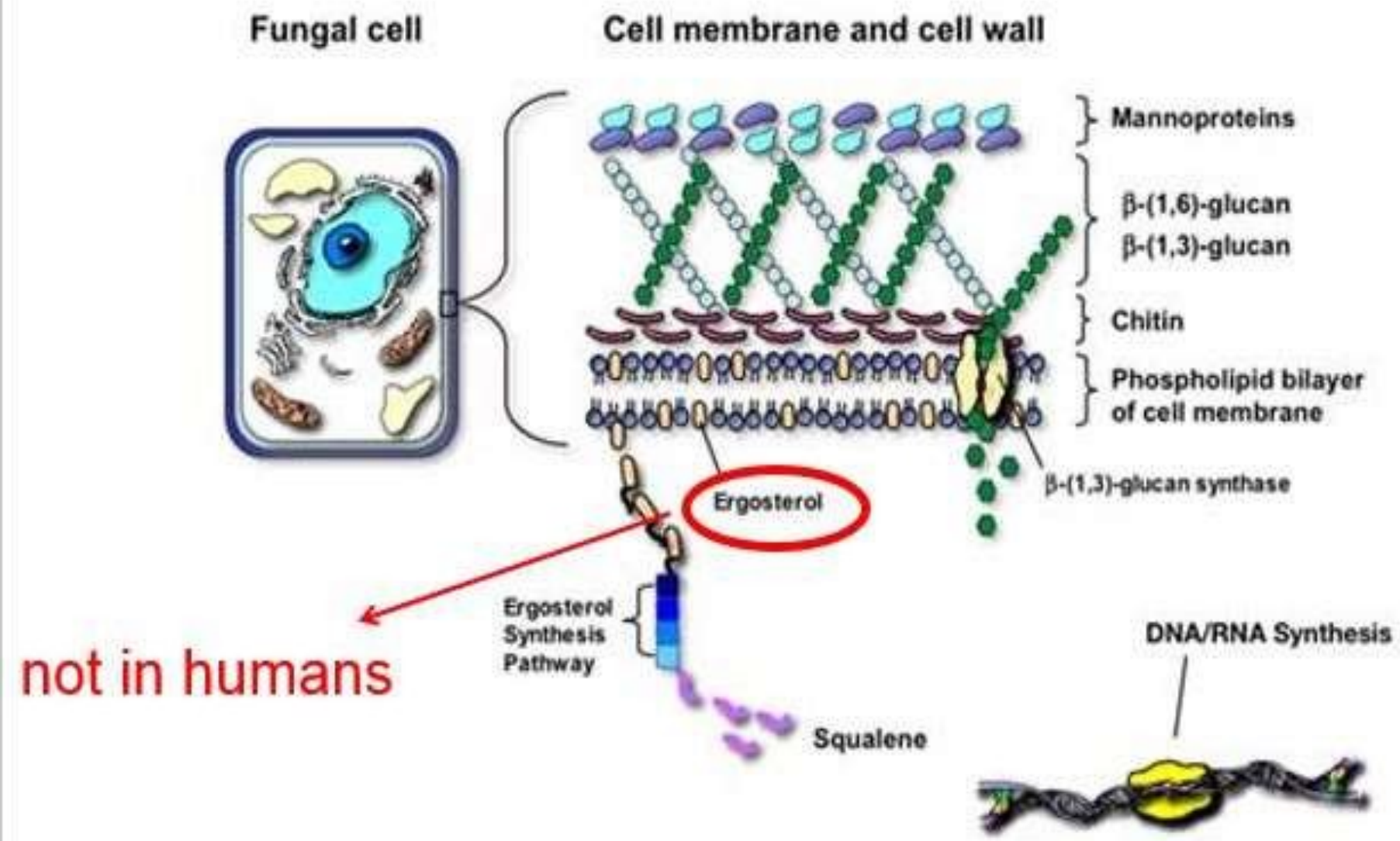
- The cell wall is made up of:
  1) chitin (polymers of acetylated amino sugar *N*-acetyl-glucosamine)
  2) glucan
  3) Proteins
- Glucan and chitin are components of the primary wall.
- Proteins are components of the secondary wall.
- Other components include chitosan, melanins and lipids.
- Enzymes include cellulase which acts on cellulose of plants.

Basic component of fungal cell wall



Cell Wall and Membrane

- Composed mainly of ***chitin*** rather than peptidoglycan (bacteria)-so unaffected by antibiotics
- Chitin: consists of a polymer of N-acetylglucosamine
- Fungal Membrane contains ***ergosterol*** rather than cholesterol found in mammalian cells, use in antifungal agents such as amphotericin which binds to ergosterol⇒pores that disrupts membrane function ⇒cell death


Fungal cell
Cell membrane and cell wall
Mannoproteins
β-(1,6)-glucan
β-(1,3)-glucan
Chitin
Phospholipid bilayer of cell membrane
β-(1,3)-glucan synthase
Ergosterol
Ergosterol Synthesis Pathway
Squalene
DNA/RNA Synthesis
not in humans

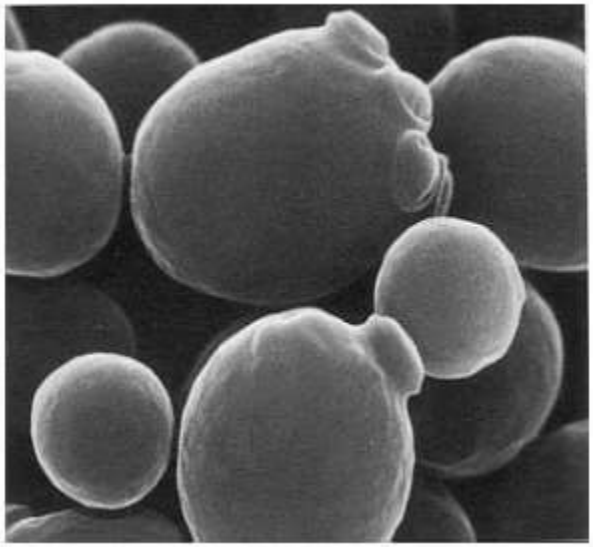
Asexual vs. Sexual Reproduction

- Remember –
  - asexual reproduction = one parent
  - sexual reproduction = two parents

- When conditions are favorable (lots of food/moisture), fungi will produce asexually
- When conditions are unfavorable, fungi can produce sexually to produce spores that may be more suited to survive

The Exception….Yeast

- Yeast are unicellular fungi.
- They reproduce by budding.
- **Budding** – small yeast cell grows from the body of a large yeast cell



Classification of fungi

1. Morphological classification

2. Systematic classification

Morphological classification

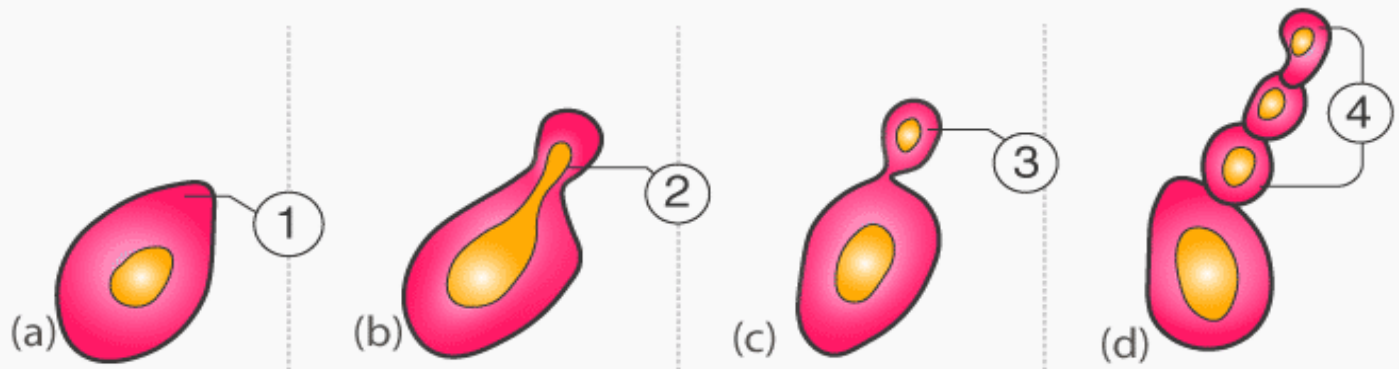
1. Yeasts
2. Yeast-like fungi
3. Filamentous fungi (molds)
4. Dimorphic fungi

Yeasts

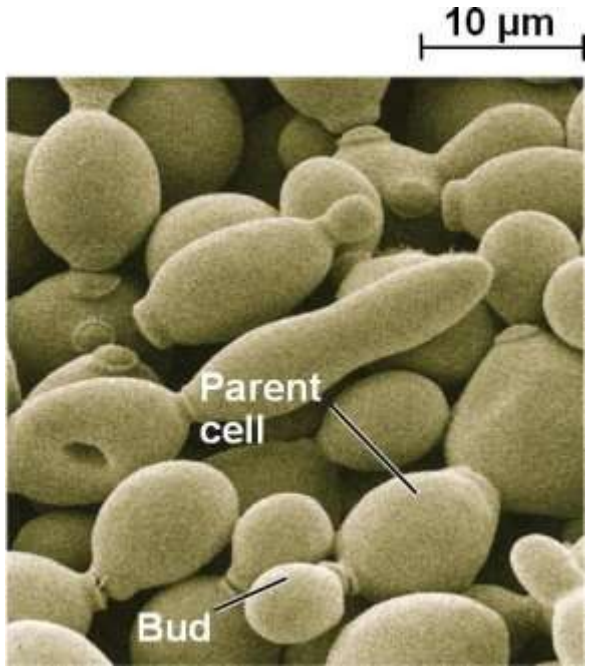
- These occur in the form of round or oval bodies which reproduce by an asexual process called budding in which the cell develops a protuberance which enlarges and eventually separates from the parent cell.
- Yeasts colonies resemble bacterial colonies in appearance and in consistency
- Examples are- *Saccharomyces cerevisiae, Cryptococcus neoformans*

REPRODUCTION IN FUNGI : YEAST

BYJU'S The Learning App



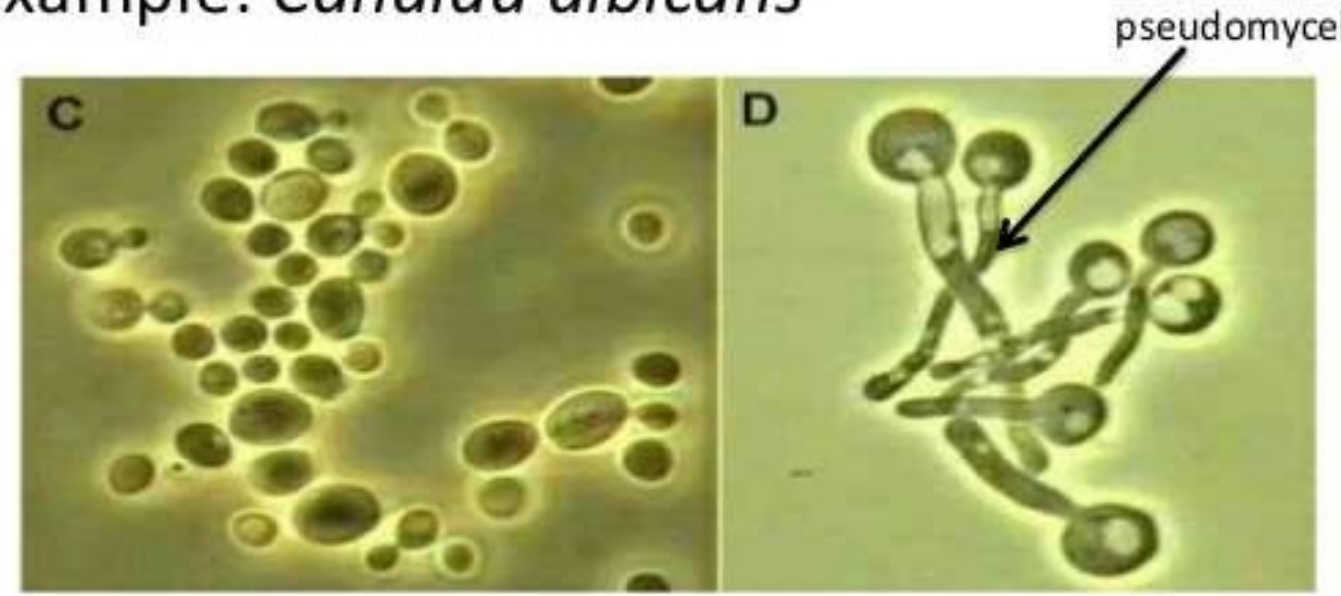
1 Yeast Cell | 2 Developing Bud | 3 New Bud | 4 Chain of buds



Yeast-Like

Yeast like fungi grow partly as yeast and partly as elongated cells resembling hyphae. The latter form a pseudomycelium.

Example: *Candida albicans*



Molds or Filamentous Fungi

- The basic morphological elements of filamentous fungi are long branching filaments or hyphae, which intertwine to produce a mass of filaments or mycelium
- Colonies are strongly adherent to the medium and unlike most bacterial colonies cannot be emulsified in water
- The surface of these colonies may be velvety, powdery, or may show a cottony aerial mycelium.
- Reproduce by the formation of different types of spores
- Example: *Dermatophytes, Aspergillus, Penicillium, Mucor, Rhizopus*

Dimorphic Fungi

- These are fungi which exhibit a yeast form in the host tissue and in vitro at 37^0C on enriched media and mycelial form in vitro at 25^0C

Examples:

Histoplasma capsulatum

Blastomyces dermatitidis

Coccidioides immitis

Paracoccidoides brasiliesis

Penicillium marneffei

Sporothrix schenckii

Dimorphism

- Some fungi are **dimorphic** depending on environmental conditions
- These organisms produce both yeast-like and mold-like thalli
- Many are pathogenic

- *Candida albicans*

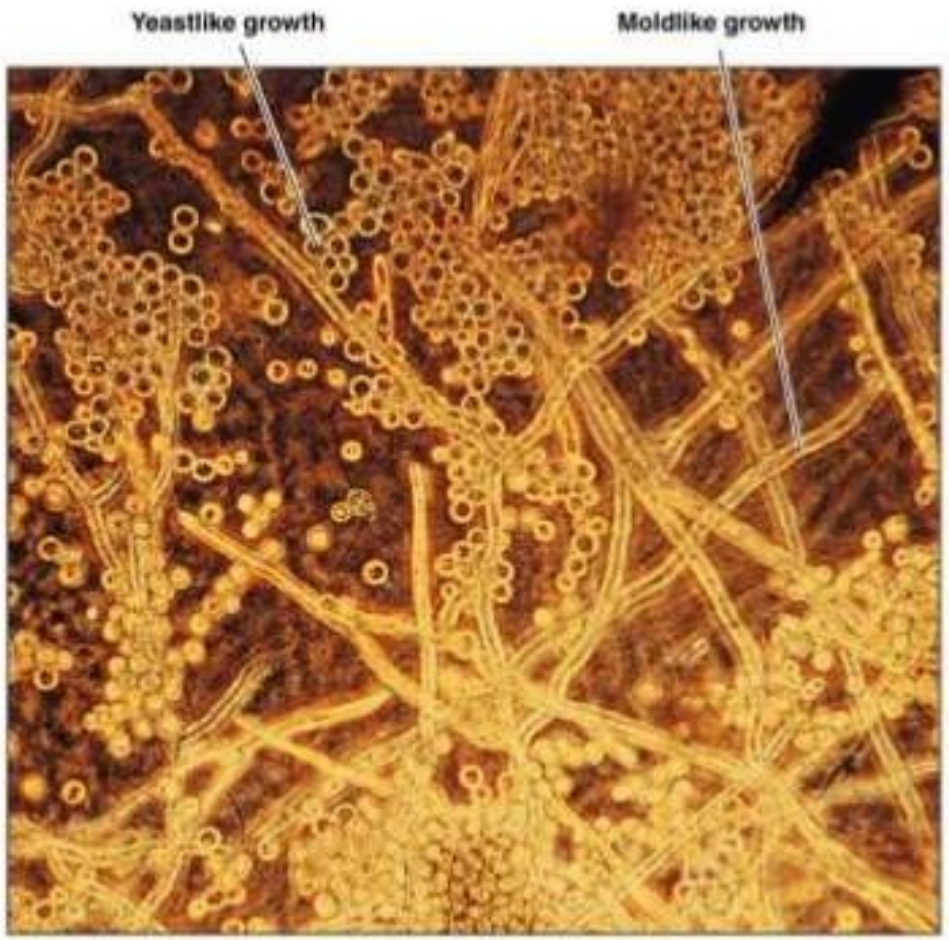
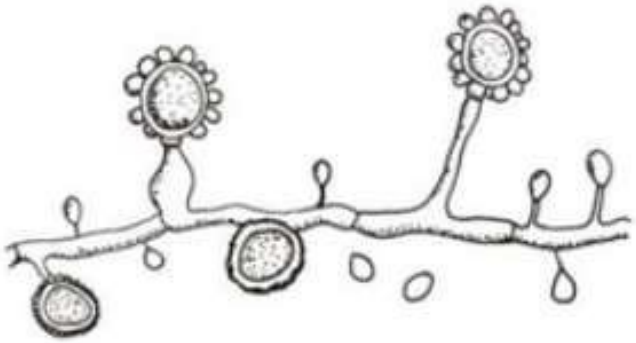


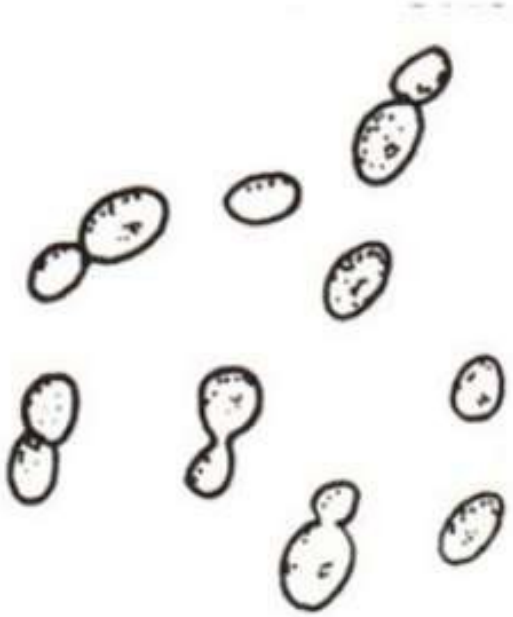
Figure 12.4

e.g. *Histoplasma*

At room temperature (25C)



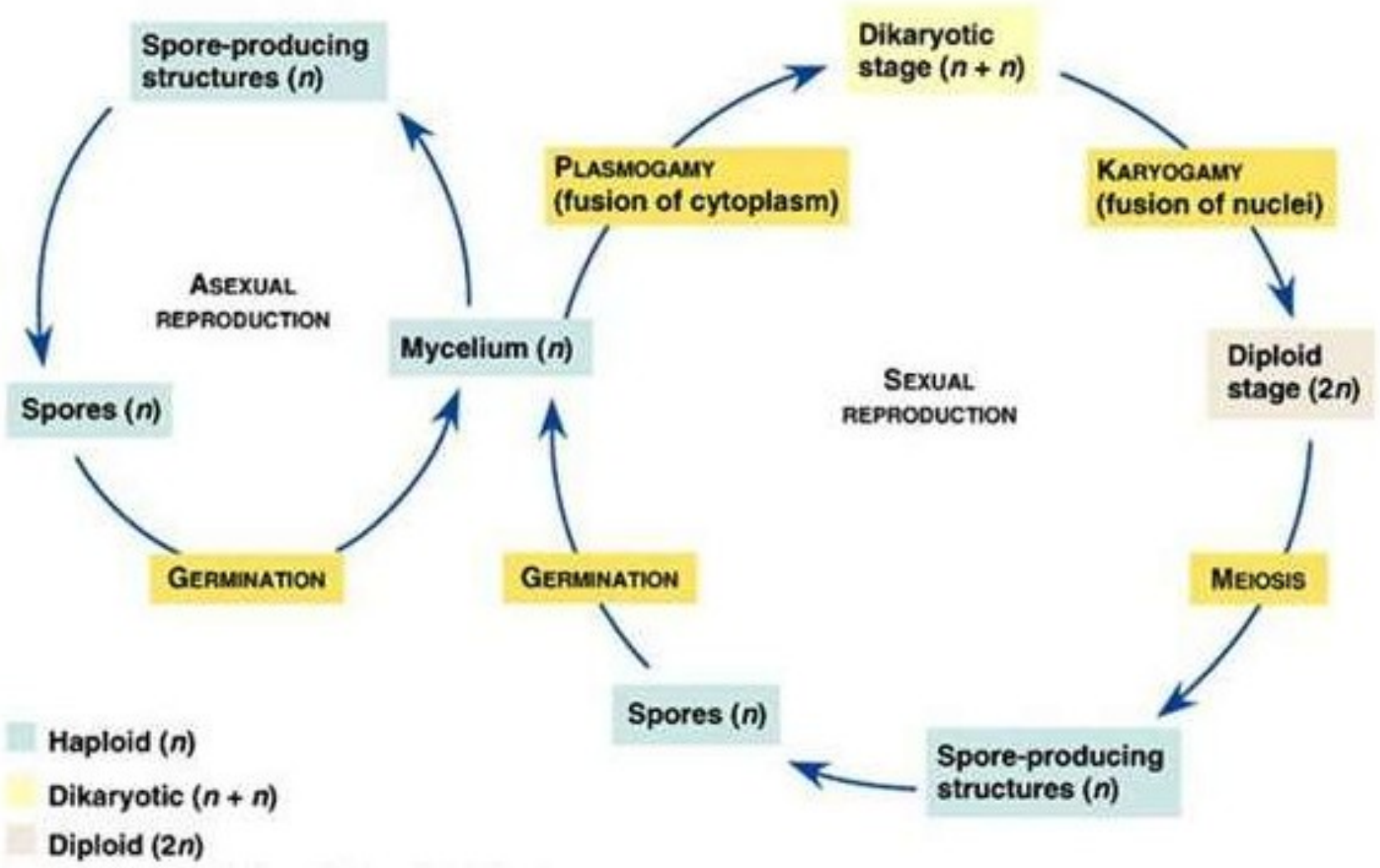
At 37C

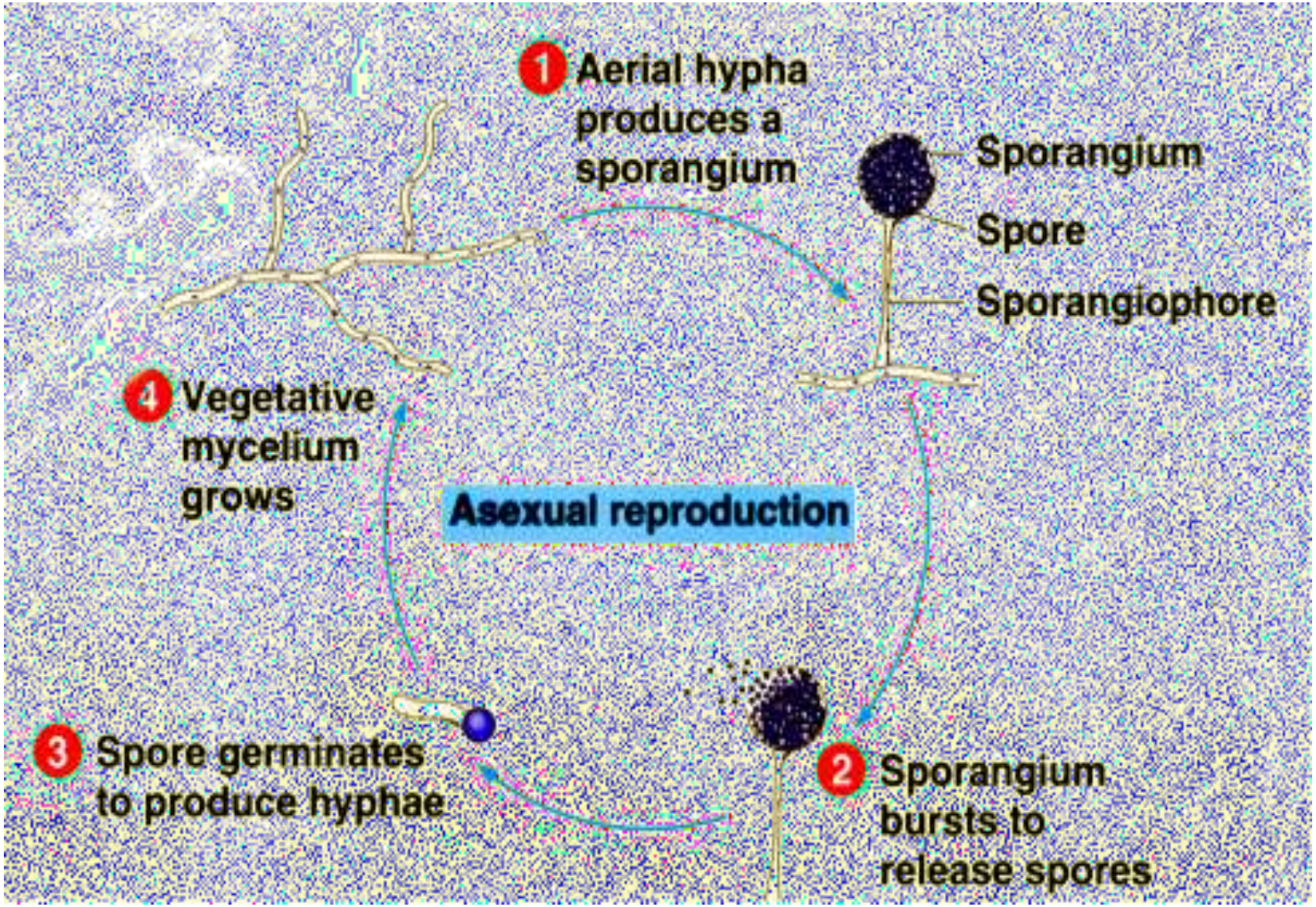


Reproduction of Fungi

- Reproduction in fungi is both by sexual and asexual means. The sexual mode of reproduction is referred to as teleomorph and the asexual mode of reproduction is referred to as anamorph.
- **Vegetative reproduction** – By budding, fission, and fragmentation
- **Asexual reproduction** – This takes place with the help of spores called conidia or zoospores or sporangiospores
- **Sexual reproduction** – ascospores, basidiospores, and oospores

Generalized Life Cycle of a Fungus




1 Aerial hypha produces a sporangium
Sporangium
Spore
Sporangiophore
4 Vegetative mycelium grows
Asexual reproduction
3 Spore germinates to produce hyphae
2 Sporangium bursts to release spores

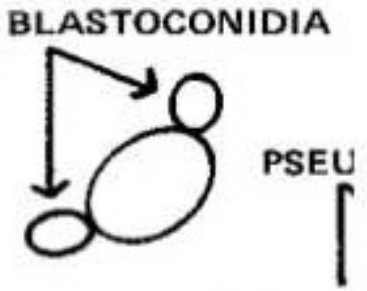
Asexual spores

- These spores are produced by mitosis

1. Vegetative spores
2. Aerial spores

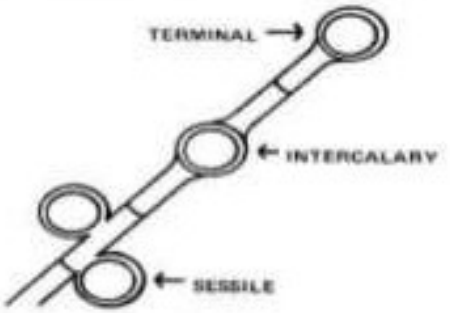
Vegetative spores

- **Blastospores:** These are formed by budding from parent cell, as in yeasts



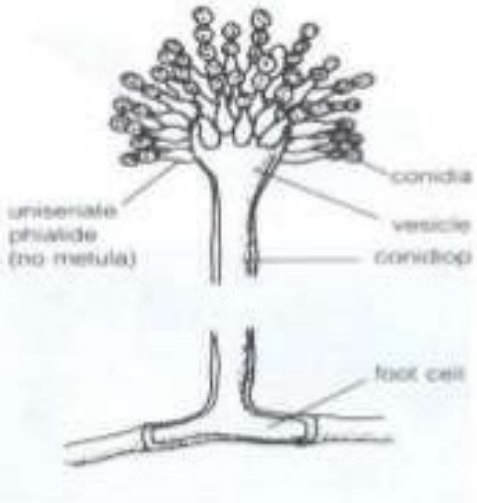
- **Arthrospores –** formed by segmentation & condensation of hyphae

- **Chlamydospores –** thick walled resting spores e.g. *C.albicans*



Aerial spores

1. Conidiospores

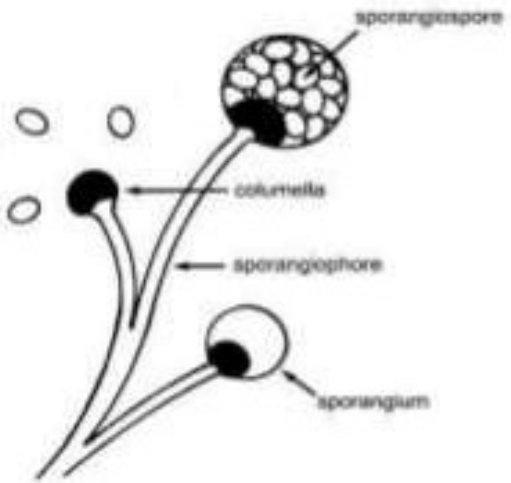


- Spores borne externally on sides or tips of hyphae are called conidiospores or simply conidia

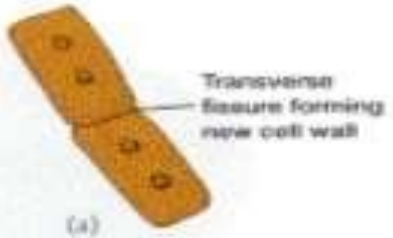
2. Microconidia

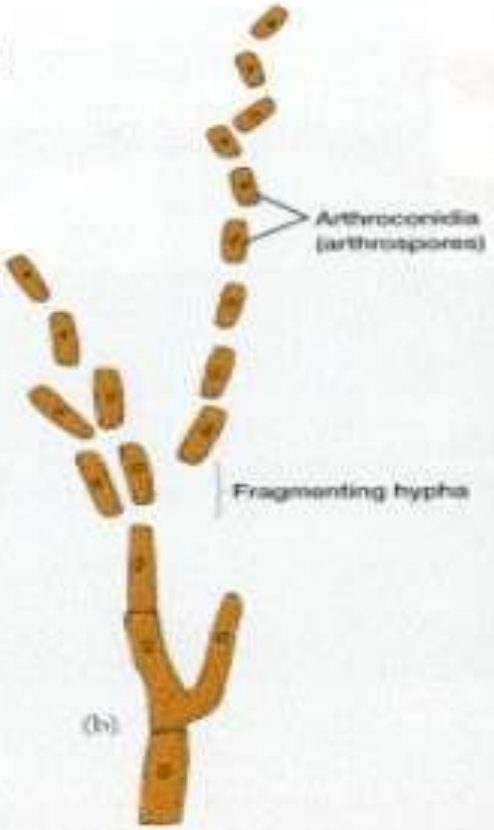
3. Macroconidia

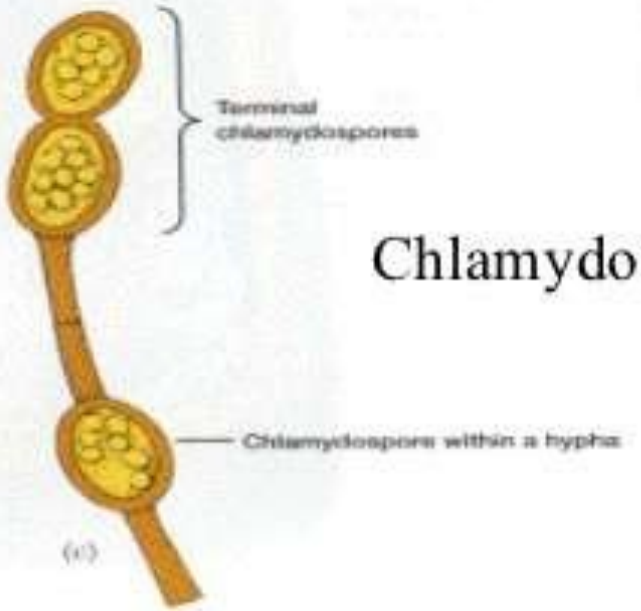
4. Sporangiospores



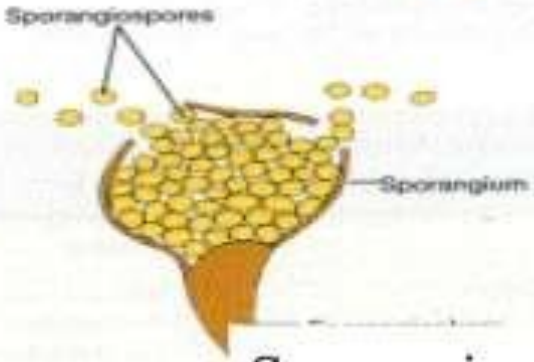
Arthrospores





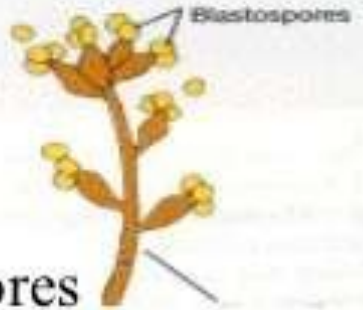


Chlamydospores



Sporangiospores

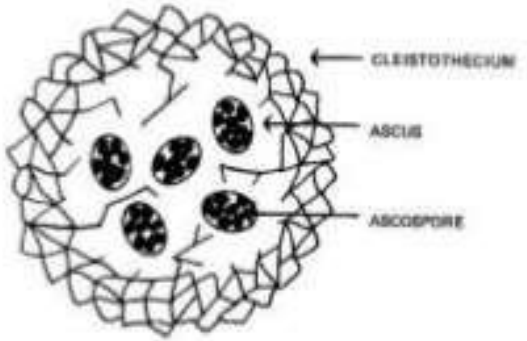
Conidiospores



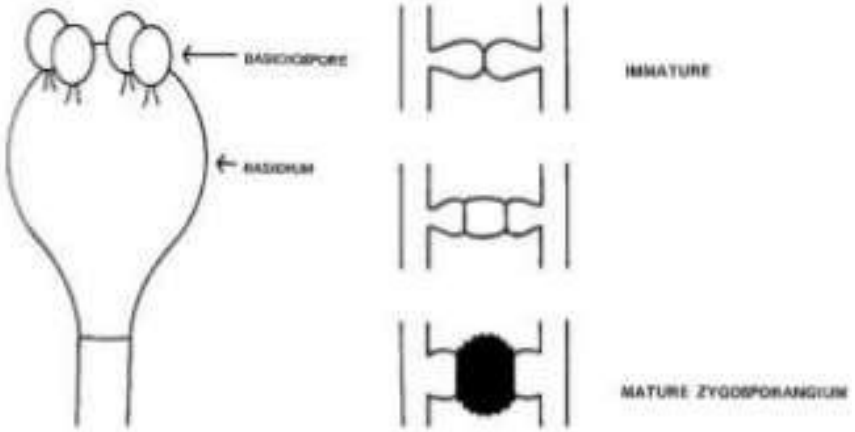
Blastospores

Sexual spores

- Sexual spore is formed by fusion of cells and meiosis as in all forms of higher life
- Ascospores
  - Ascus
  - Ascocarp



- Basidiospores
- Zygospores



Sexual Spores

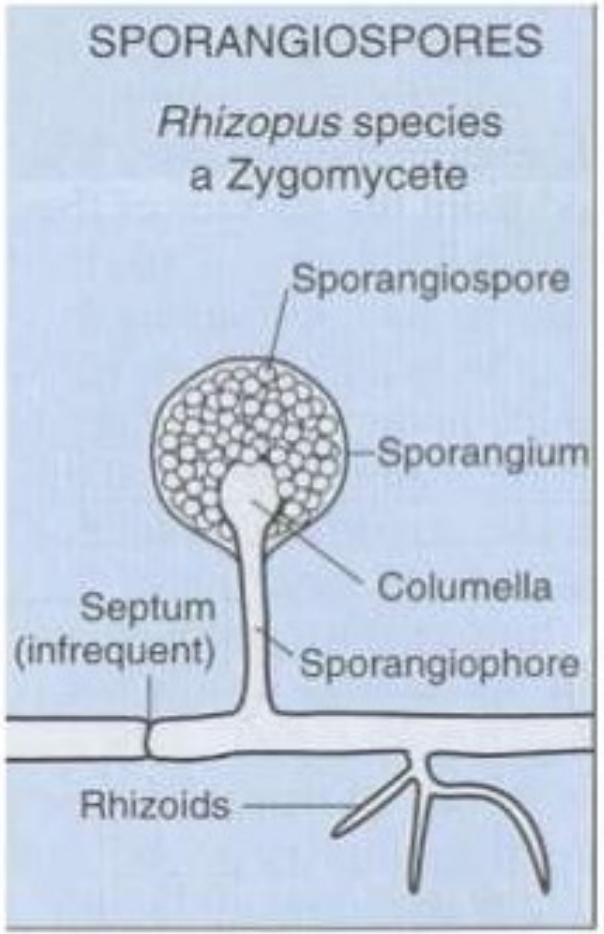
- Three phases of development
  - **Plasmogamy**-haploid nucleus of a **donor cell** (+) penetrates the cytoplasm of a **recipient cell** (-)
  - **Karyogamy-** the 2 nuclei fuse to form a diploid nucleus
  - **Meiosis**-diploid nucleus gives rise to haploid nuclei
  - Sexual spores, some + , some -,some recombinants
  - Sexual spores used to classify fungi into divisions

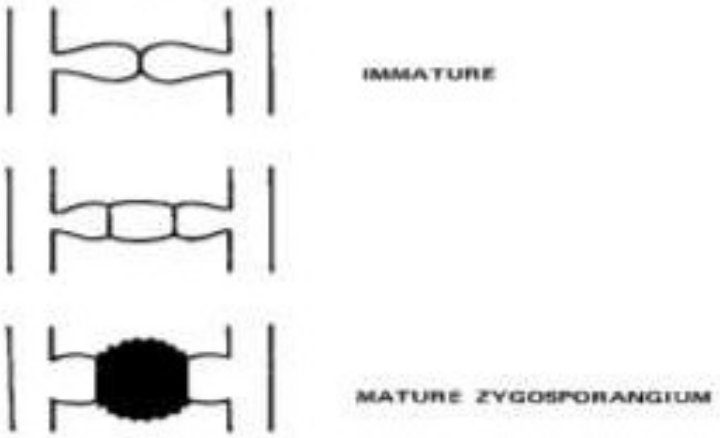
21-2 Classification of Fungi

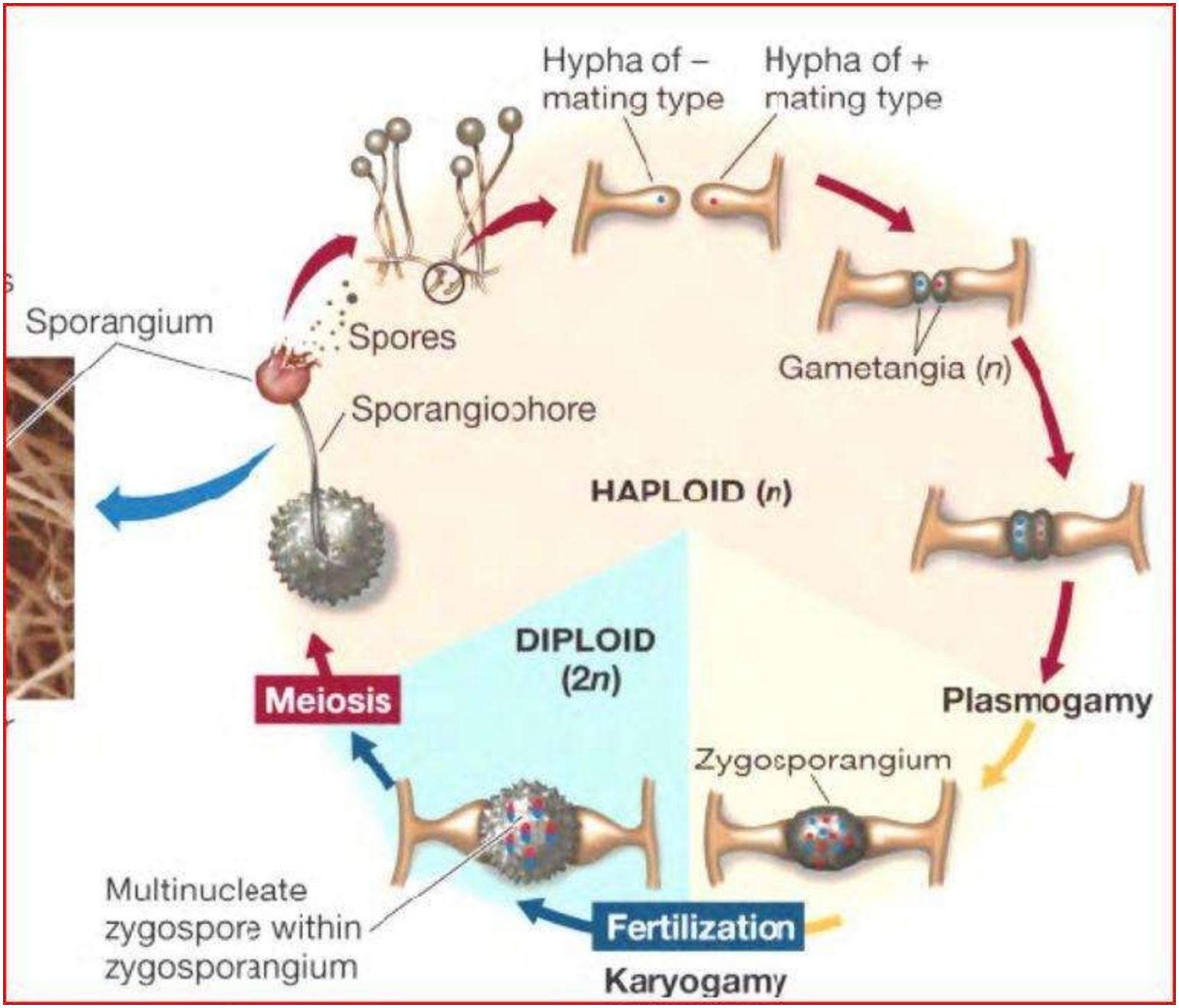
- Fungi are classified according to their structure and method of reproduction
- The 4 main groups of fungi are:
  1. **Zygomycota** (common molds)
  2. **Ascomycota** (sac fungi)
  3. **Basidiomycota** (club fungi)
  4. **Deuteromycota** (imperfect fungi)

Zygomycetes

- Lower fungi
- Broad, nonseptate hyphae
- Asexual spores - **Sporangiospores:** present within a swollen sac- like structure called **Sporangium**
- **Examples:** Rhizopus, Absidia, Mucor






Hypha of – mating type
Hypha of + mating type
Sporangium
Spores
Sporangiophore
Gametangia (n)
HAPLOID (n)
DIPLOID (2n)
Meiosis
Plasmogamy
Zygosporangium
Multinucleate zygospore within zygosporangium
Fertilization
Karyogamy

Ascomycetes

- Sexual spores called ascospores are present within a sac like structure called Ascus.
- Several asci may be seen within a fruiting body as seen in Penicillium, Aspergillus
- Each ascus has 4 to 8 ascospores.

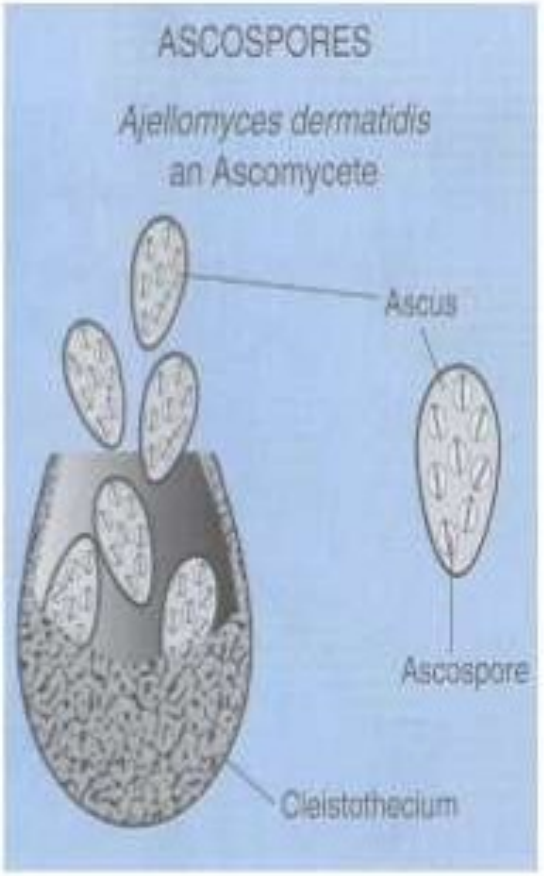


Figure 21-7 The Life Cycle of an Ascomycete

Section 21-2

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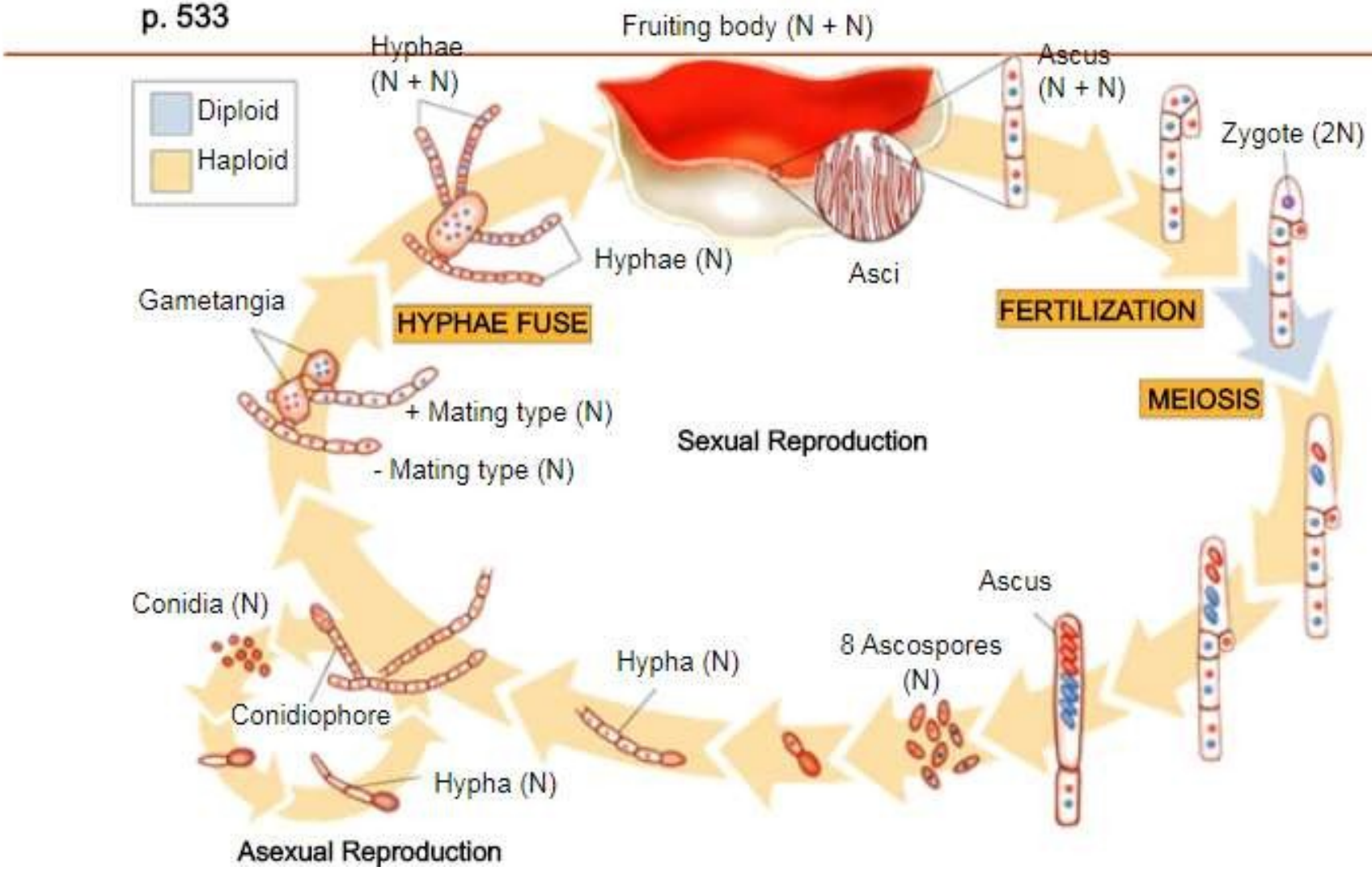
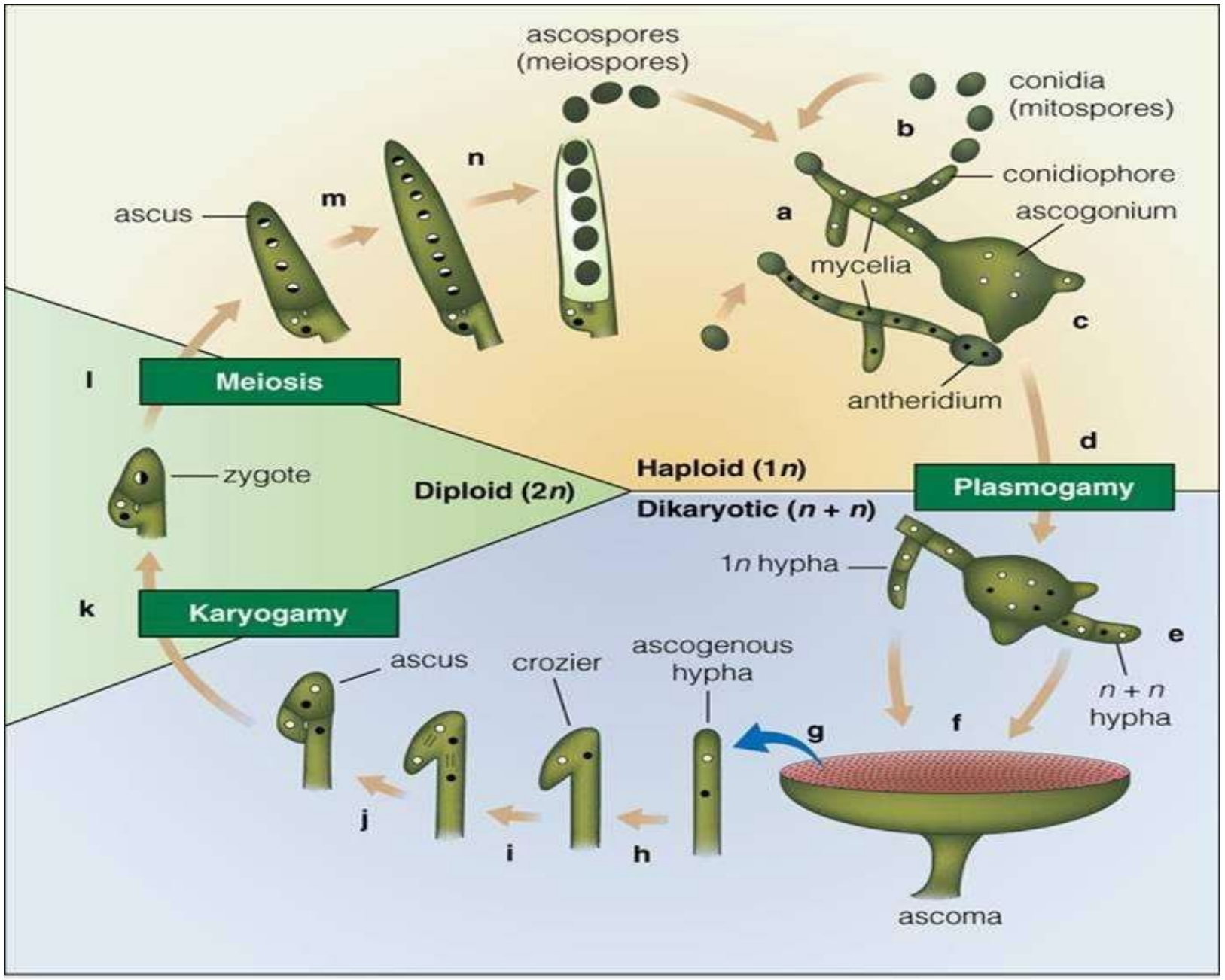


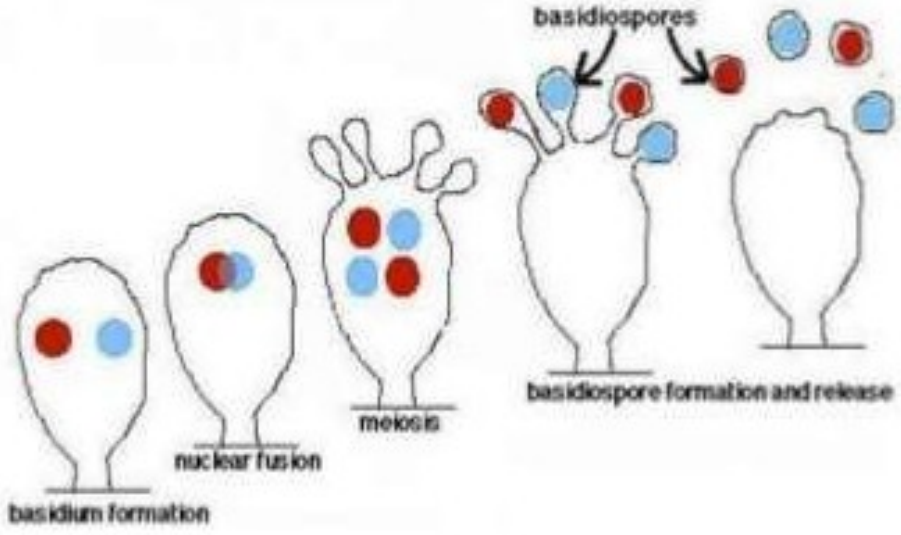


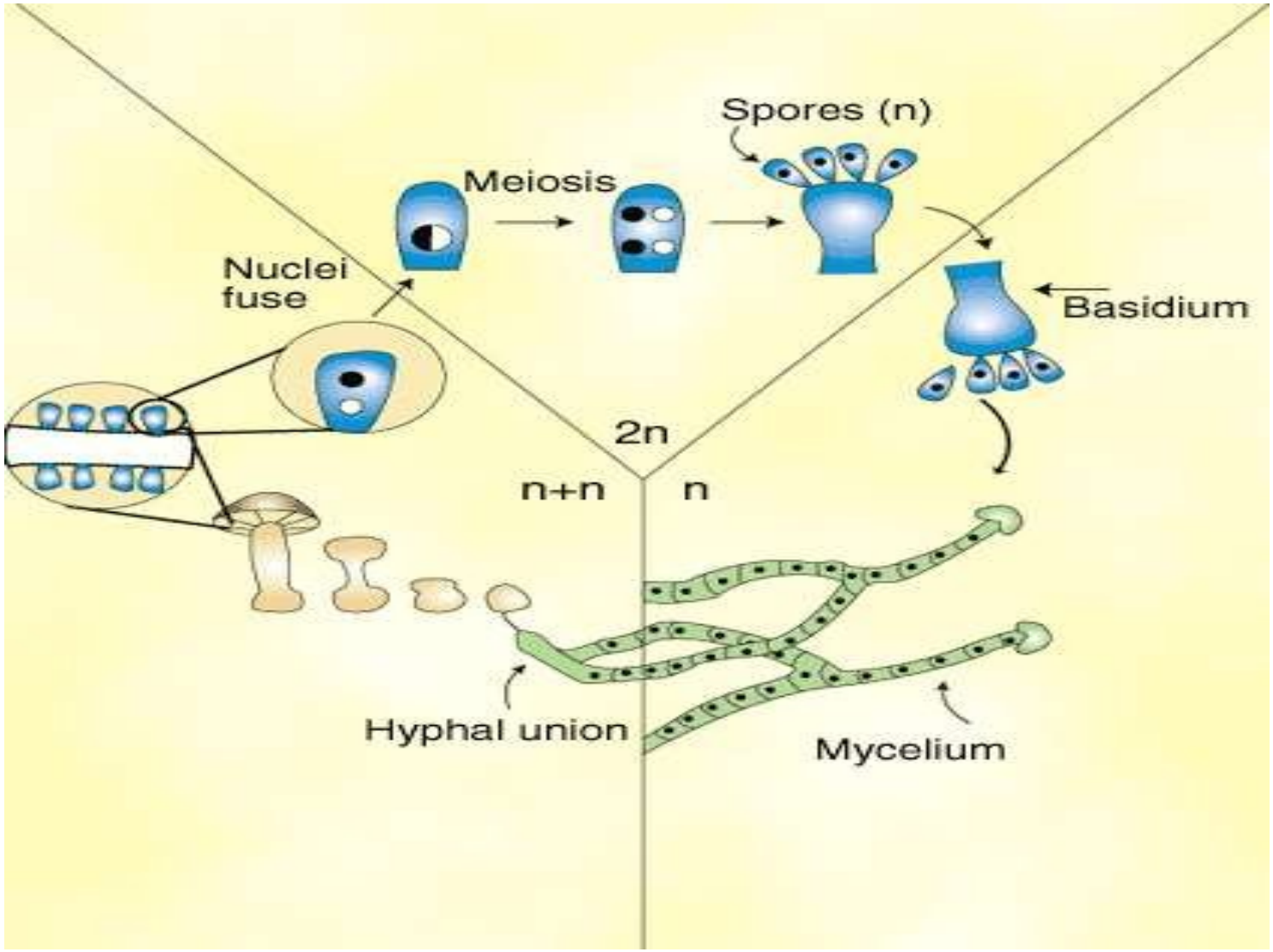
Basidiomycota – The Club Fungi

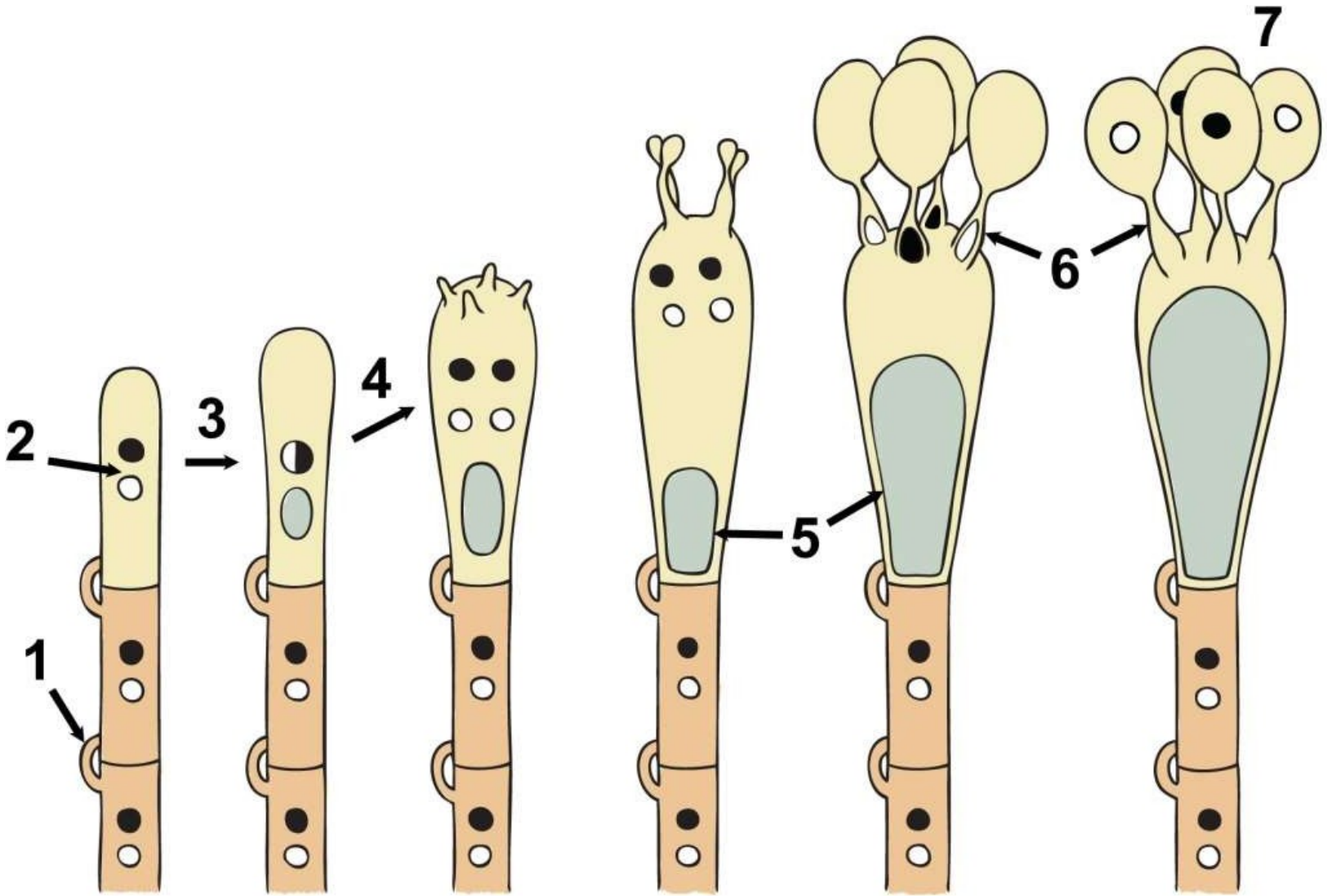
- The phylum Basidiomycota gets its name from a specialized reproductive structure (called a **basidium**) that resembles a club.
- Includes:
  - Mushrooms
  - Shelf fungi
  - Puffballs
  - Earthstars
  - Jelly fungi
  - Plant rusts
  - Bird's nest fungi

Basidiomycetes

- Sexual fusion results in the formation of a club shaped organ called base or basidium which bear spores called basidiospores



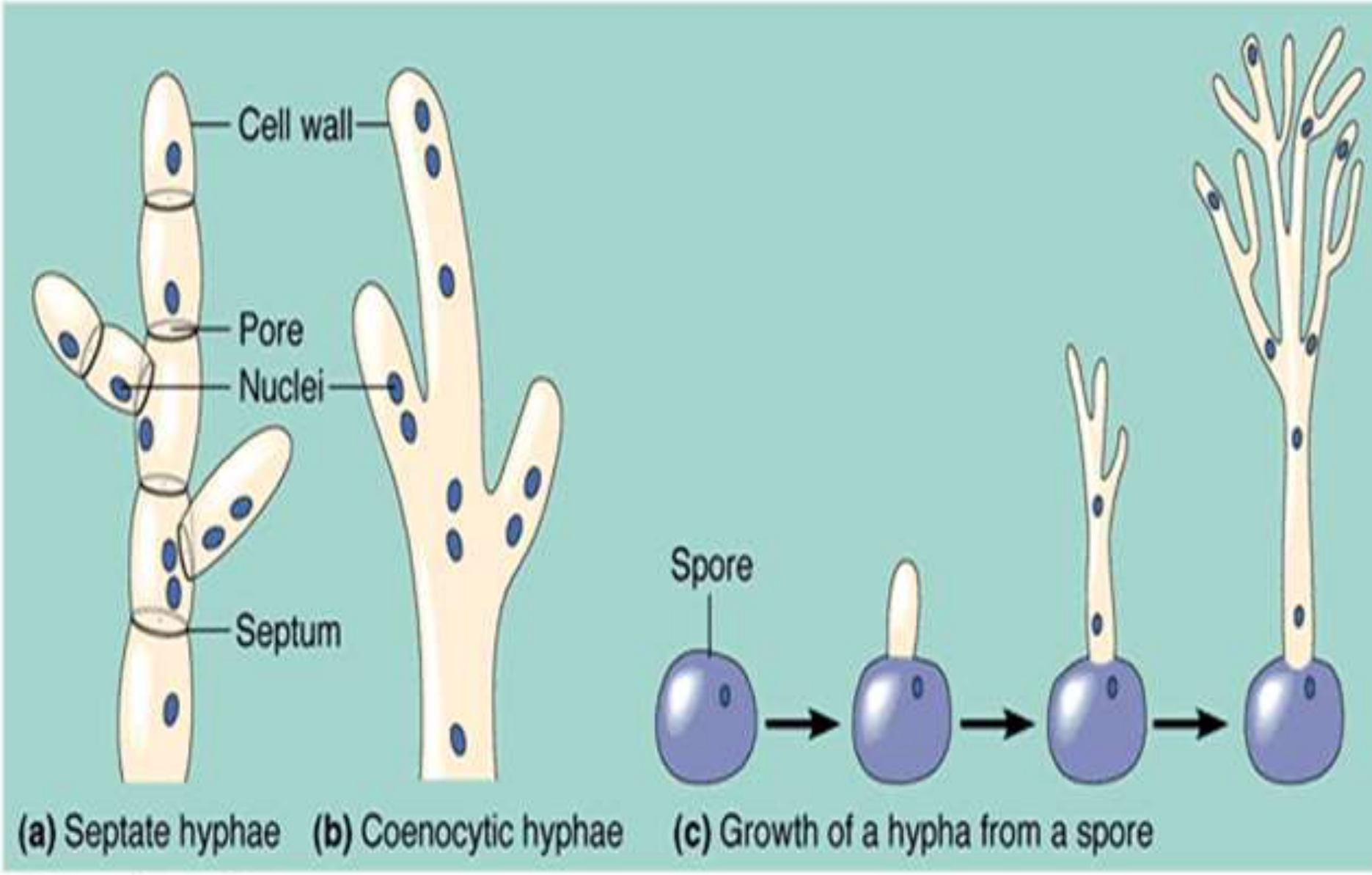

Spores (n)
Meiosis
Nuclei fuse
Basidium
2n
n+n
n
Hyphal union
Mycelium

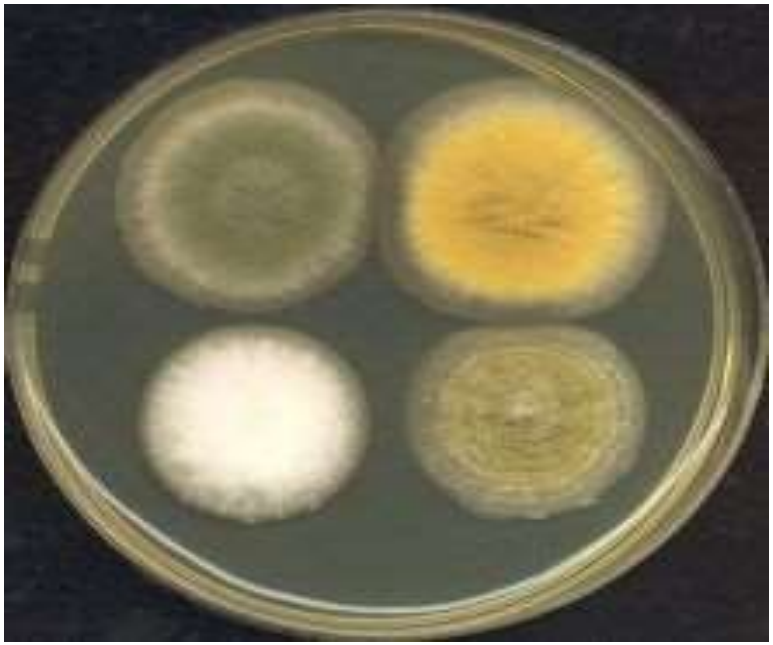


Development of a holobasidium and basidiospores. 1: clamp; 2: nuclei; 3 karyogamy; 4: meiosis; 5: vacuole; 6: sterigma; 7: basidiospore.

Deuteromycota – The Imperfect Fungi

- Deuteromycota is an extremely varied phylum composed of those fungi that are not placed in other phyla.
  - The term imperfect implies that these fungi do not *appear* to have sexual reproduction.
  - Ex: *Penicillium notatum* – the source of antibiotic penicillin.



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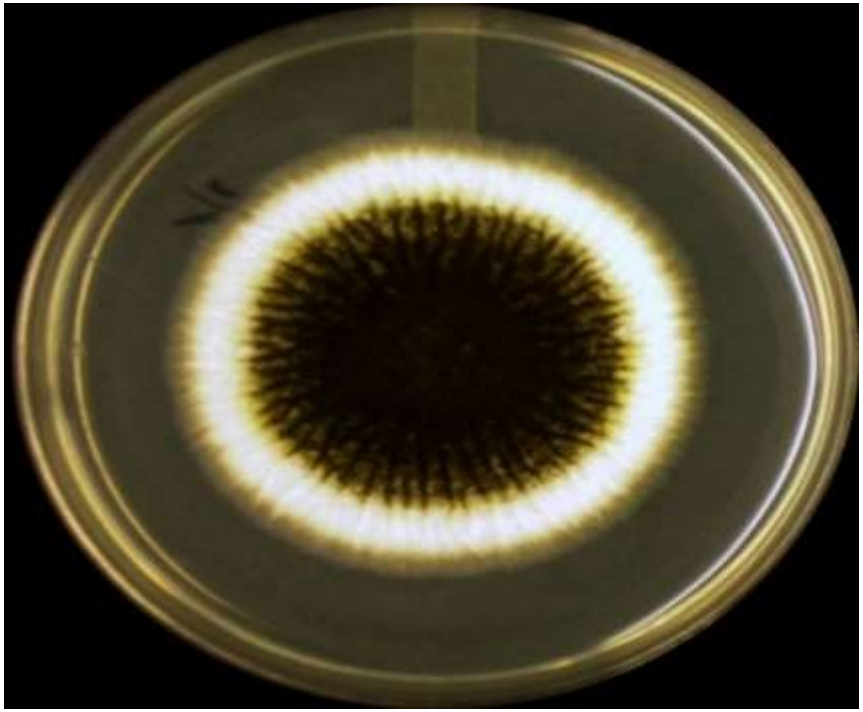


Pathogenesis of the Fungi

- Portal of entry
  - Cutaneous and superficial – contamination of skin surface
  - Subcutaneous - inoculated skin; trauma
  - Systemic mycoses – respiratory portal; inhaled spores
- Virulence factors – thermal dimorphism, toxin production, capsules and adhesion factors, hydrolytic enzymes, inflammatory stimulants

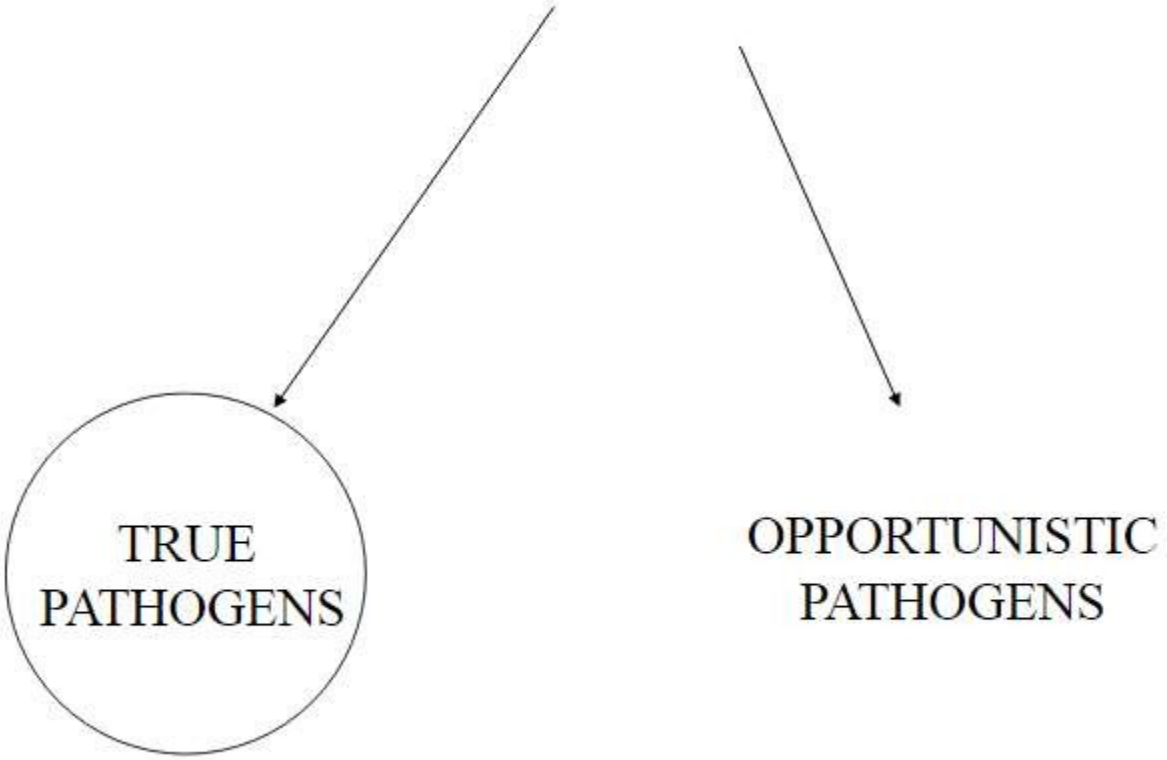
Pathogenesis

- Yeasts, (eg. *C. albicans*) are able to colonise mucosal surface of the GI and female genital tracts.
- Adhesion → Invasion → Tissue injury
- Invasion through mechanical breaks eg. *Sporothrix* following a thorn prick. *C. albicans* undergoes morphologic change, formation of hyphae to penetrate and spread. Extracellular enzymes (proteases and elastases).
- Tissue injury mainly due to the inflammatory and immune responses stimulated by prolonged presence of the fungus eg. Dimorphic fungi resist phagocytosis. None by extracellular products or endogenous toxins in a manner analogous to bacterial toxins.

Mycotoxins

- Mycotoxins= Exotoxins produced in environment, not *in vivo*. Produced by a number of mushrooms and molds.
- Mycotoxin acts on CNS, liver, GIT, bone marrow or kidney.
- *Amanita phalloides* is the deadliest, whose cap contains enough toxin to kill an adult.
- *Aflatoxin* from *Aspergillus flavus*, is found in contaminants of grains, corn and peanuts.

PATHOGENIC FUNGI



TRUE PATHOGENS

Cutaneous infective agents

Epidermophyton species
Microsporum species
Trichophyton species

Subcutaneous infective agents

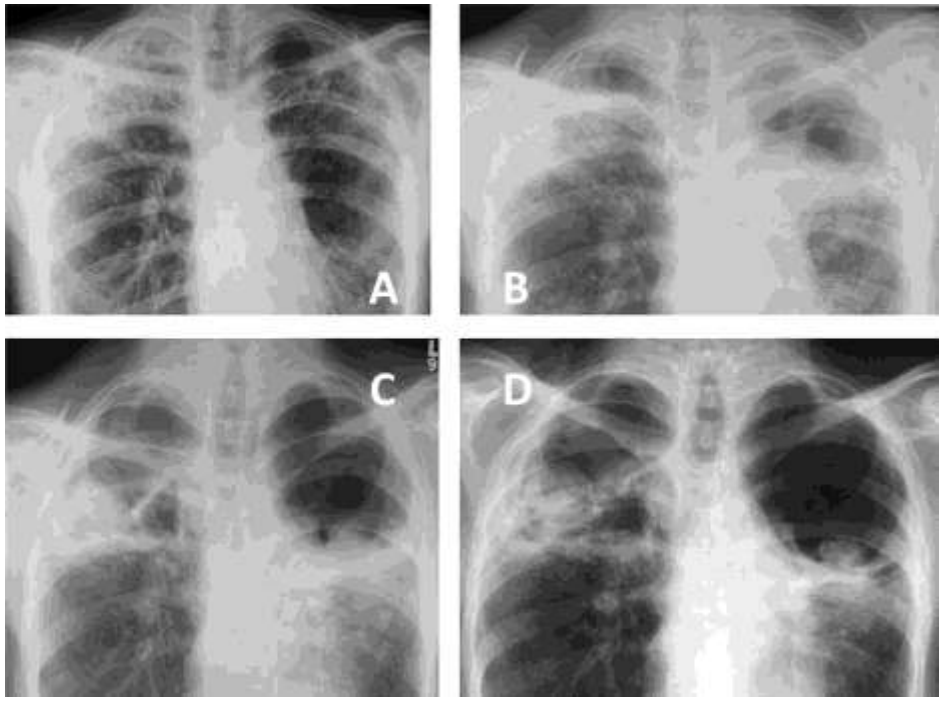
Actinomadura madurae
Cladosporium
Madurella grisea
Phialophora
Sporothrix schenckii

Systemic infective agents

Blastomyces dermatitidis
Coccidioides immitis
Histoplasma capsulatum
Paracoccidioides brasiliensis

OPPORTUNISTIC PATHOGENS

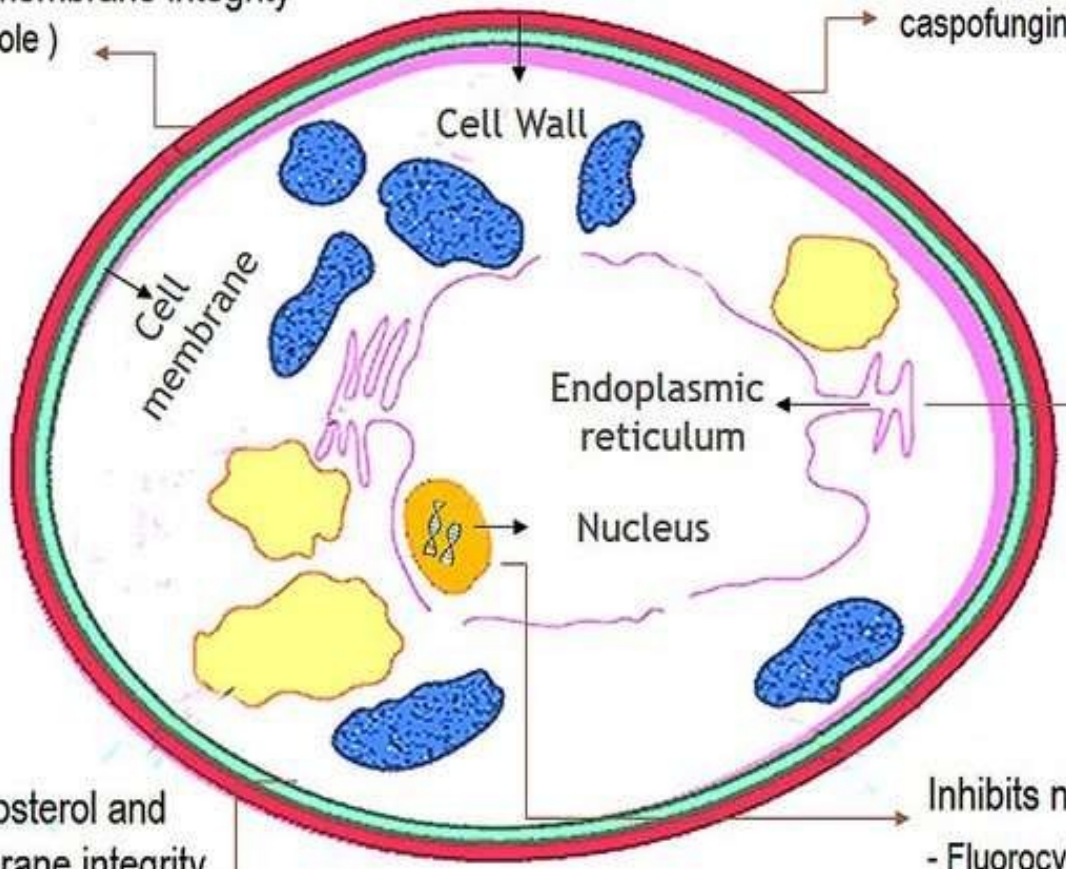
Absidia corymbifera
Aspergillus fumigatus
Candida albicans
Crytococcus neoformans
Pneumocystis carinii
Rhizomucor pusillus
Rhizopus oryzae (R.arrhizus)


A
B
C
D

Classification based on mechanism of action

1. Fungal cell wall synthesis inhibition: Caspofungin.
2. Bind to fungal cell membrane ergosterol: Amphotercin–B, Nystatin.
3. Inhibition of ergosterol + lanosterol synthesis: Terbinafine, Naftifine, Butenafine.
4. Inhibition of ergosterol synthesis: Azoles
5. Inhibition of nucleic acid synthesis: 5–Flucytosine.
6. Disruption of mitotic spindle and inhibition of fungal mitosis: Griseofulvin.
7. Miscellaneous:
   - Ciclopirox, Tolnaftate, Haloprogin, Undecylenic acid, Topical azoles.

Antifungal Drugs



Binds the nonsterol lipids and alters cell membrane integrity (Sertaconazole)

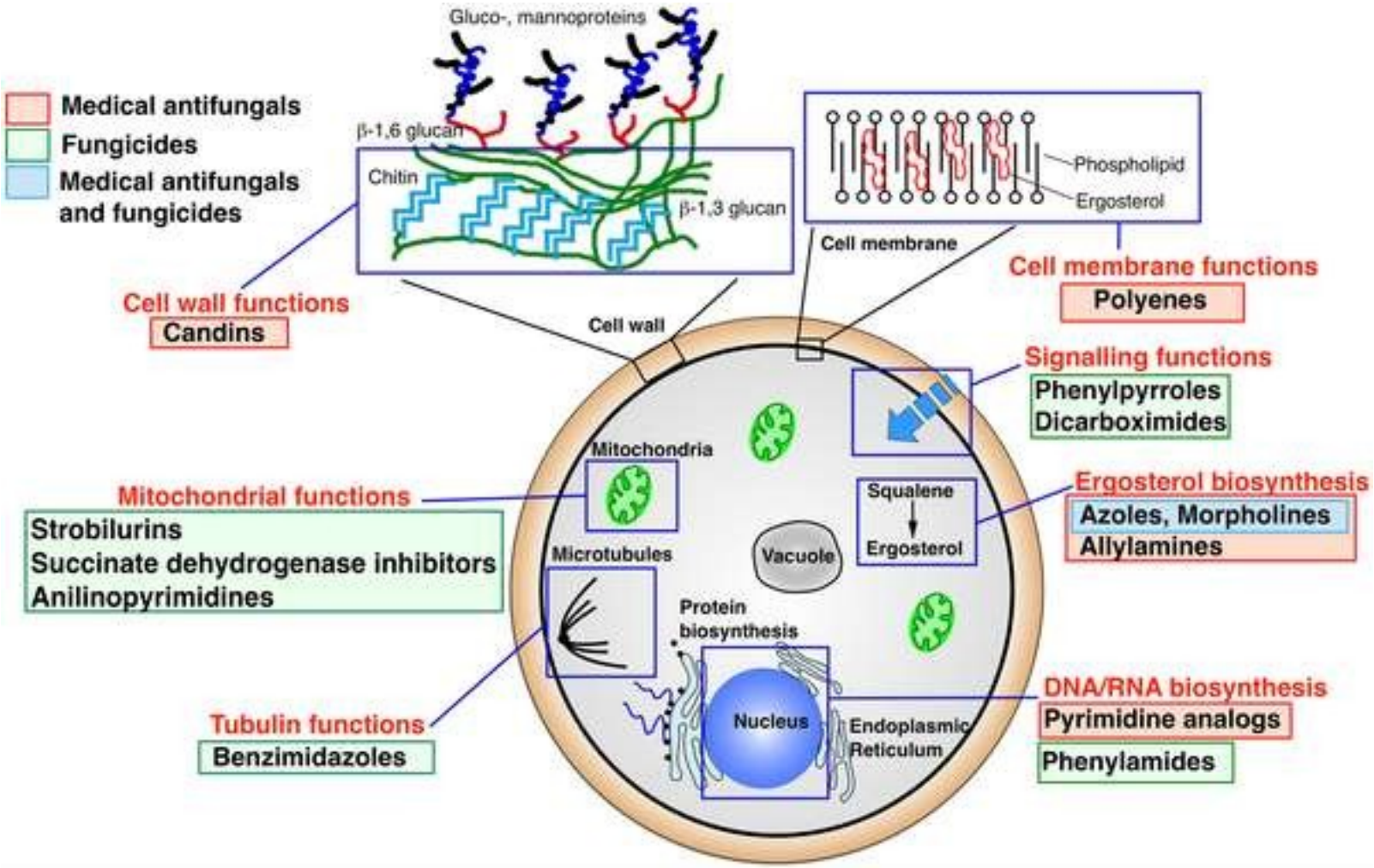
Inhibit the -glucan biosynthesis Pathway- Echinocandins (anidulafungin, caspofungin and micafungin)

Inhibit the ergosterol biosynthesis pathway
- Azoles (flucanozole, miconazole and sertaconazole)

Inhibits nucleic acid synthesis
- Fluorocytosine

Binds with ergosterol and disrupts membrane integrity
- Polyenes (amphotericin B and nystatin)

Antifungal Drugs



Immunity to fungal diseases

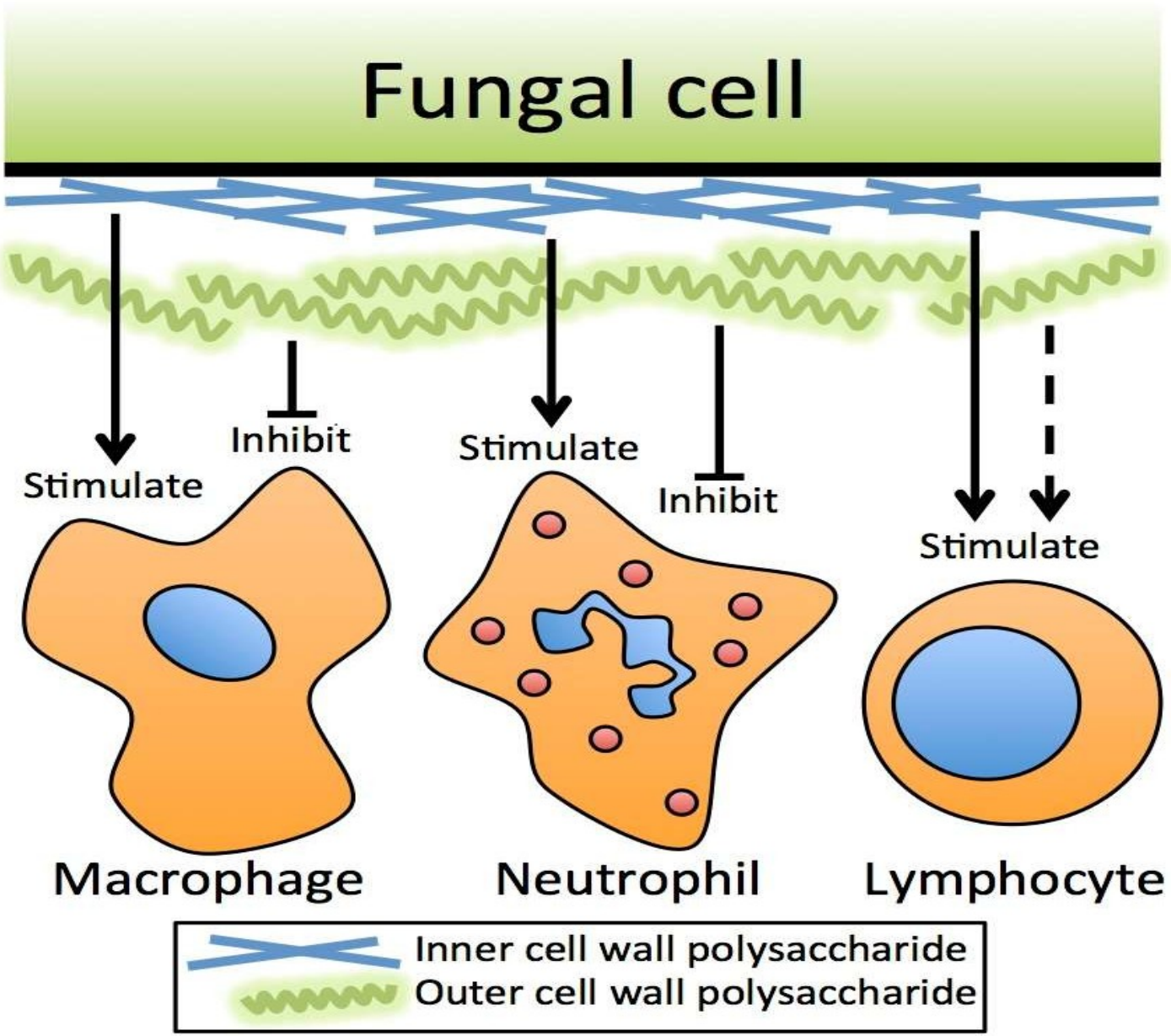
- The defense to fungal infection involves both innate and aquired immunity
- The passive protection is provided by intact skin and mucosal surfaces
- The fatty acids like sebum also provide protection because of their antifungal activity
- The alveolar macrophages are important in engulfing cells in lungs which are removed by ciliary action and coughing
- A variety of innate defense factors in saliva such as lysozymes and lactoferrin contribute to mucosal protection

Cellular immunity

- For the most of fungi, cellular immunity is mainstay of host defenses
- Monocyte-macrophage activity, especially in respiratory tract, appears to be major defence mechanism against most fungi
- Renal transplant recipients have peculiar predilection for cryptococcal infection

Humoral immunity

- The precise role of humoral immunity in host defense against fungal infections is difficult to determine


Fungal cell
Stimulate
Inhibit
Stimulate
Inhibit
Stimulate
Macrophage
Neutrophil
Lymphocyte
Inner cell wall polysaccharide
Outer cell wall polysaccharide

Uses of Fungi

- Fungi are one of the most important groups of organisms on the planet as it plays a vital role in the biosphere and has great economic importance on account of their both benefits and harmful effects.
- Following are some of the important uses of fungi:
- **Recycling** – They play a major role in recycling the dead and decayed matter.
- **Food** – Mushrooms species are edible which are cultured and are used as food by humans.

Uses of Fungi

- **Medicines** – There are many fungi which are used to produce antibiotics, which are used to control diseases in humans and animals.
  Penicillin antibiotic is derived from a common fungi Penicillium.
- **Biocontrol Agents** – Fungi are involved in exploiting insects, other small worms and help in controlling pests. Spores of fungi are used as spray-on crops.
- **Food spoilage** – Fungi play a major role in recycling organic material and are also responsible for major spoilage and economic losses of stored food.

Fungi

- On the basis of nutrition, kingdom fungi can be classified into 3 groups.
- **Saprophytic** – The fungi obtain their nutrition by feeding on dead organic substances. Examples: Rhizopus, Penicillium, and Aspergillus.
- **Parasitic** – The fungi obtain their nutrition by living on other living organisms (plants or animals) and absorb nutrients from their host. Examples: Taphrina, and Puccinia.
- **Symbiotic** – These fungi live by having an interdependent relationship association with other species in which both are mutually benefited.Examples: Lichens and mycorrhiza.

21-3 Ecology of Fungi

- All Fungi Are Heterotrophs
  - Saprobes - Organisms that obtain food from decaying organic matter
  - Parasites - which harm other orgnisms
  - Symbionts - live in close and mutually beneficial association with other species
  - Capture live animals
    - *Pleurotus ostreatus*
    - Lives on the sides of trees and trap worms to digest them

21-3 Ecology of Fungi

- Fungi as Decomposers
  - Maintain equilibrium in nearly every ecosystem by recycling nutrients
  - Release digestive enzymes that break down organic material into simple molecules which diffuse into the fungus

21-3 Ecology of Fungi

- Fungi as Parasites
  - Cause serious plant and animal diseases and a few cause diseases in humans
  - Plant Diseases
    - Smuts, mildews, rusts

Corn smut

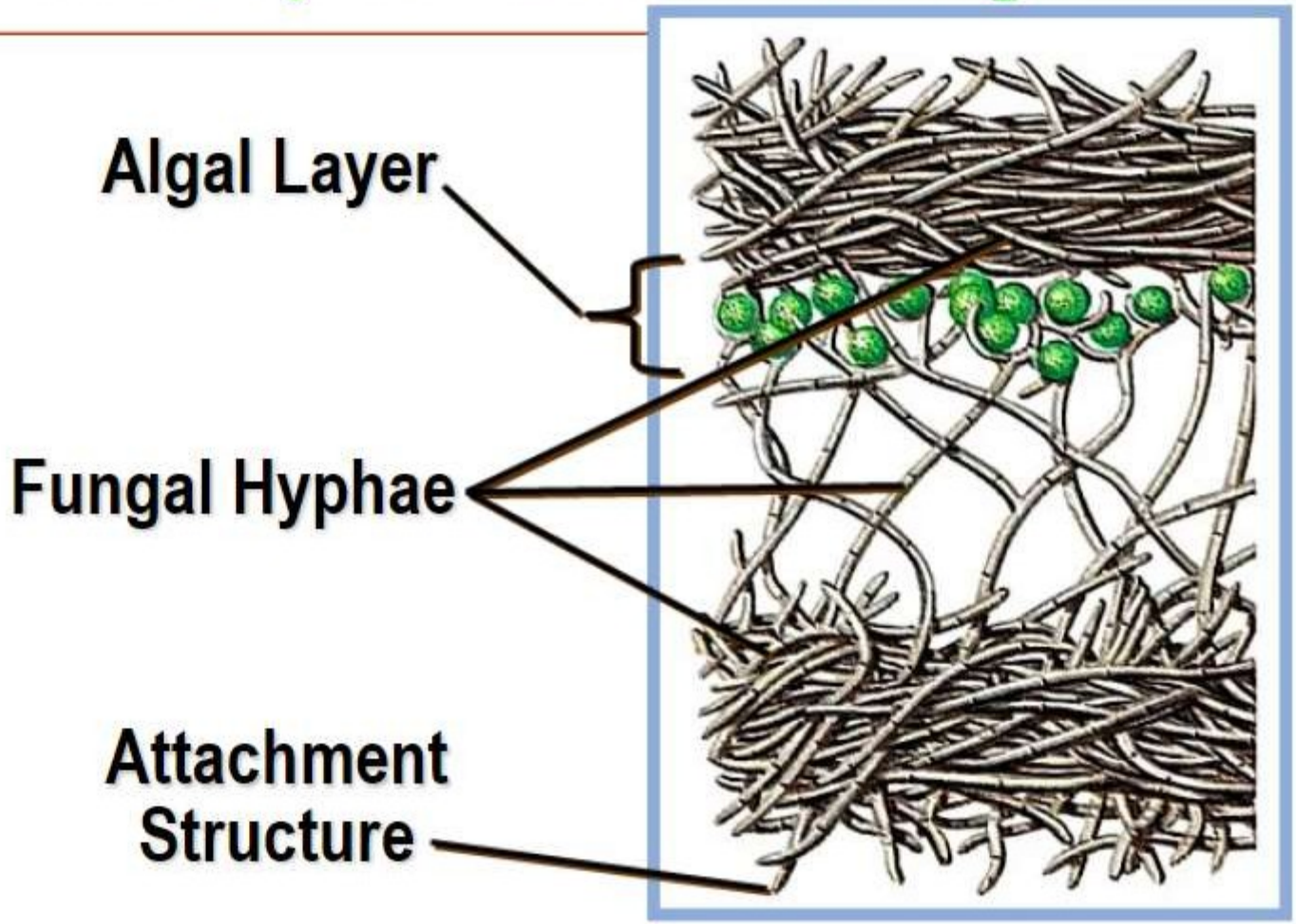
Plant mildew

Spruce rust

21-3 Ecology of Fungi

- Symbiotic Relationships
  - Mutualistic (both benefit)
  - Lichens
    - Fungus and an alga or a cyanobacterium or both
    - Live mostly on bare rock and in places that most other organisms cannot live
    - Break down rock into soil
    - Autotroph makes food, fungus absorbs water and nutrients and serves as an anchor

Lichens: Symbiotic Partnerships



Symbiotic Relationships

- **Mycorrhizae**
  - A symbiotic associations of plant roots and fungi.
  - Fungi increases the surface area of the plants roots.
  - Its presence is often necessary for the growth of many plants.

mycorrhizae

21-3 Ecology of Fungi

- **Mycorrhizae**
  - Plant roots and fungi
  - Plant roots provide energy and fungus provides a large surface area for more absorption of water and minerals