INTRODUCTION TO FUNGI
(YEAST & MOLDS)

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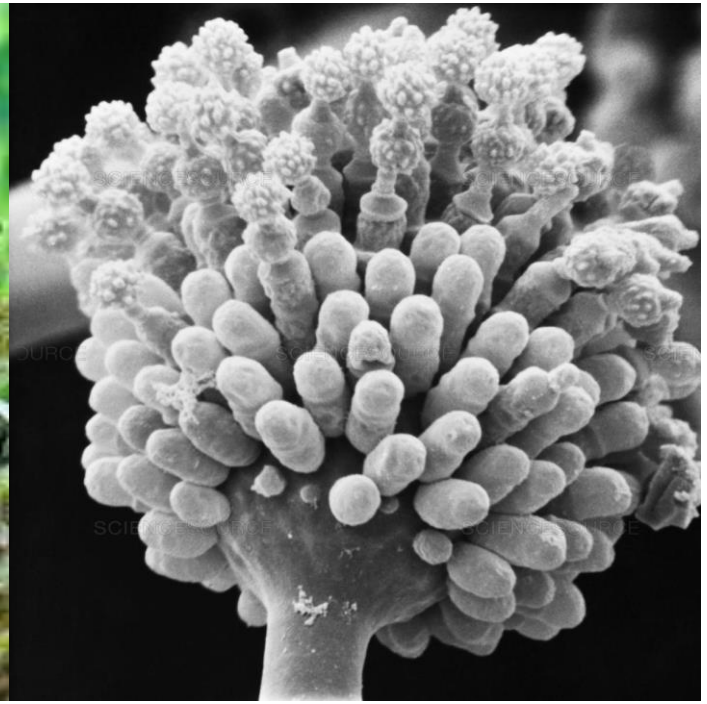
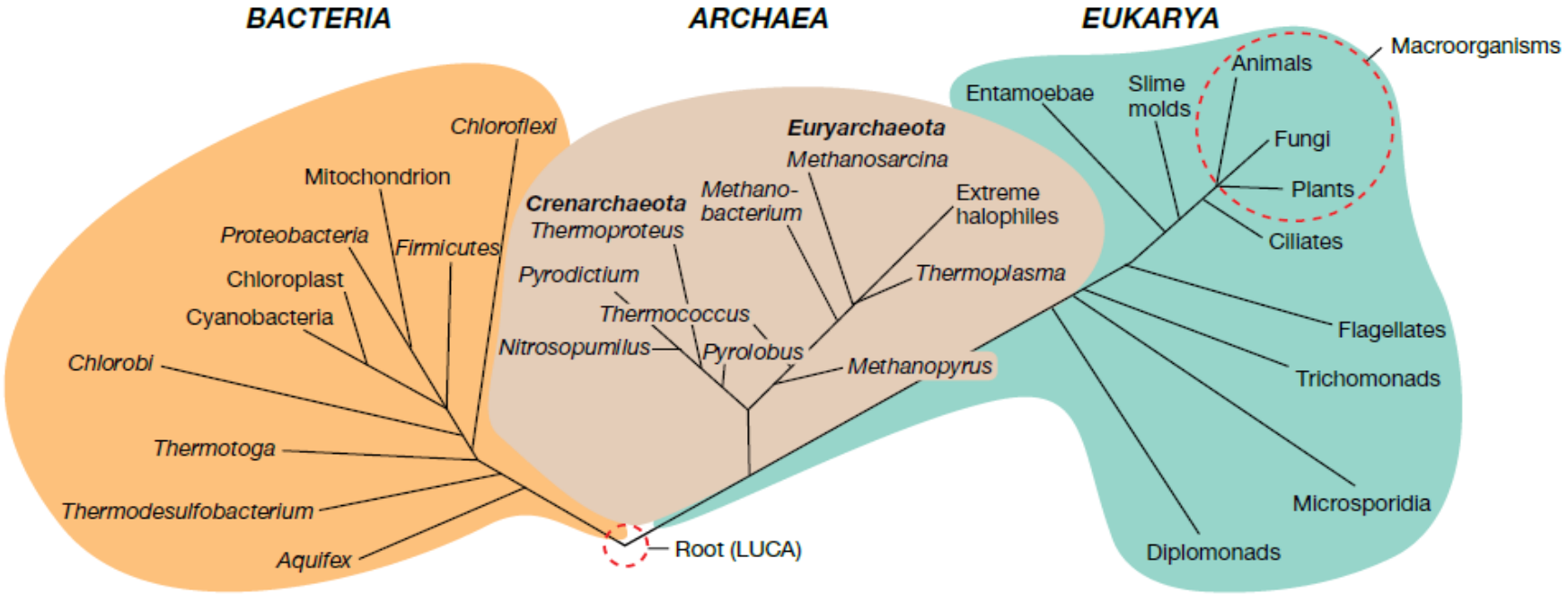


CONTENT

- Introduction
- Structure of fungi
- Fungal reproduction
- Life cycle
- Fungal division
  - *Chytridiomycota*
  - *Zygomycota*
  - *Glomeromycota*
  - *Ascomycota*
  - *Basidiomycota*

MAJOR DIVISION OF LIFE



(b)

Figure 1.36 Evolutionary relationships and the phylogenetic tree of life. *(a)* The technology behind ribosomal RNA gene phylogenies. 1. DNA is extracted from cells. 2. Copies of the gene encoding rRNA are made by the polymerase chain reaction (PCR; Section 12.1). 3, 4. The gene is sequenced and the sequence aligned with sequences from other organisms. A computer algorithm makes pairwise comparisons at each base and generates a phylogenetic tree, 5, that depicts evolutionary relationships. In the example shown, the sequence differences are highlighted in yellow and are as follows: organism 1 versus organism 2, three differences; 1 versus 3, two differences; 2 versus 3, four differences. Thus organisms 1 and 3 are closer relatives than are 2 and 3 or 1 and 2. *(b)* The phylogenetic tree of life. The tree shows the three domains of organisms and a few representative groups in each domain.

DOMAIN EUKARYA

- The domain Eukarya is divided into four kingdoms by most biologists:
  - Kingdom **Animalia,** multicellular animals
  - Kingdom **Plantae**, multicellular plants
  - Kingdom **Protista,** unicellular and multicellular including the protozoa and algae
  - **Kingdom Fungi,** unicellular and multicellular fungi (**molds, yeast, and fleshy fungi**)
    - Consist of 6 major groups
      - ✓ *Chytridiomycota*
      - ✓ *Zygomycota*
      - ✓ *Glomeromycota*
      - ✓ *Ascomycota*
      - ✓ *Basidiomycota*
      - ✓ *Microspiridia*

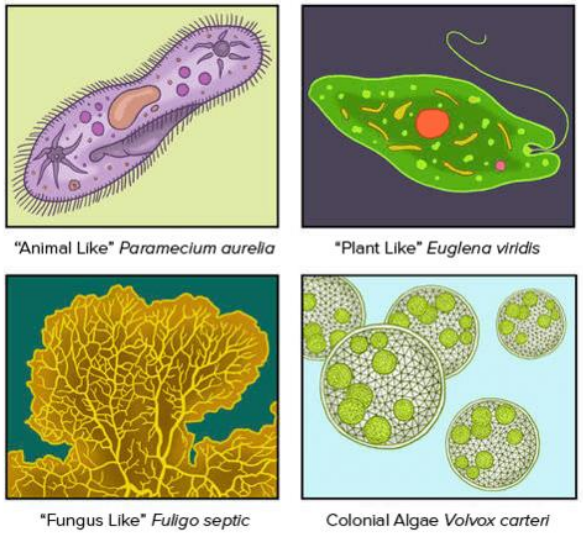
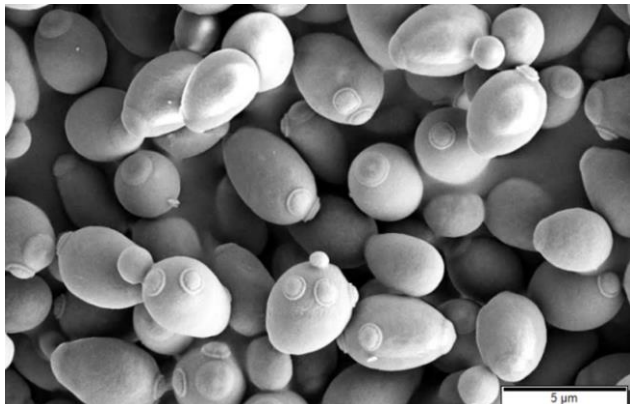


Table 26.1 Abbreviated Classification of *Fungi*

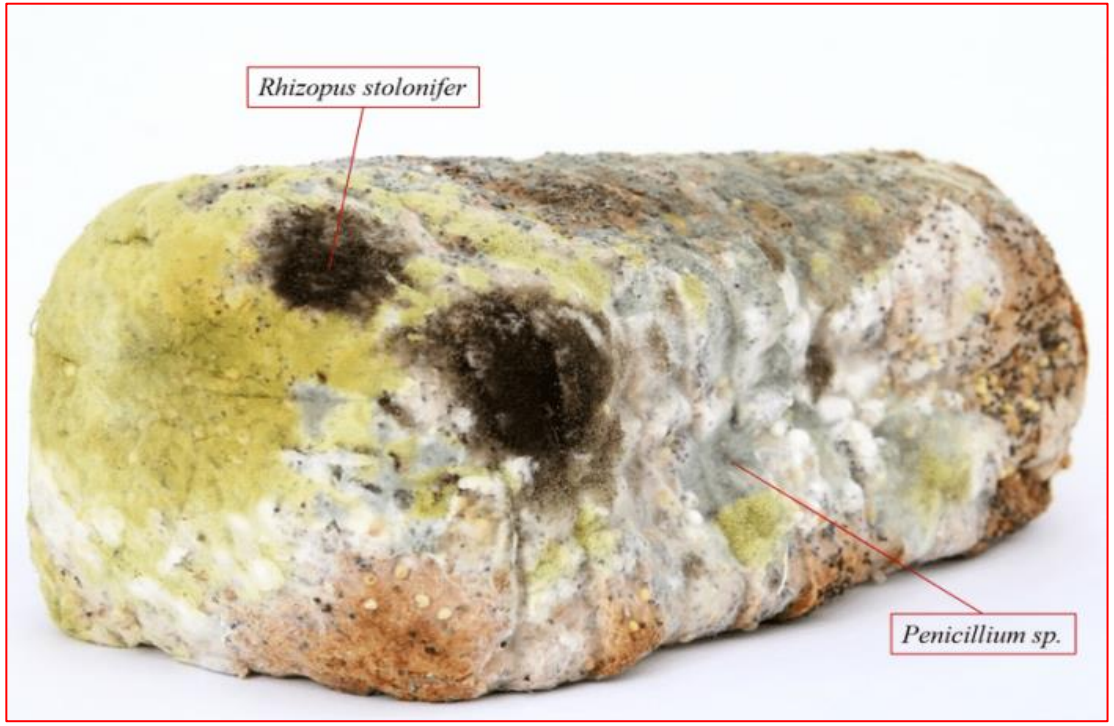
Subclass	Characteristics	Examples
Chytridiomycota	Flagellated cells in at least one stage of life cycle; may have one or more flagella. Cell walls with chitin and β-1,3 / 1,6-glucan; glycogen is used as a storage carbohydrate. Sexual reproduction often results in a zygote that becomes a resting spore or sporangium; saprophytic or parasitic. Chytrid subdivisions include *Blastocladiales, Monoblepharidales, Neocallimastigaceae, Spizellomycetales,* and *Chytridiales.*	*Allomyces* *Blastocladiella* *Coelomomyces* *Physoderma* *Synchytrium*
Zygomycota	Thalli usually filamentous and nonseptate, without cilia; sexual reproduction gives rise to thick-walled zygospores that are often ornamented. Includes seven subdivisions: *Basidiobolus, Dimargaritales, Endogonales, Entomophthorales, Harpellales, Kickxellales, Mucorales,* and *Zoopagales.* Human pathogens found in *Mucorales* and *Entomophthorales.*	*Amoebophilus* *Mucor* *Phycomyces* *Rhizopus* *Thamnidium*
Ascomycota	Sexual reproduction involves meiosis of a diploid nucleus in an ascus, giving rise to haploid ascospores; most also undergo asexual reproduction with the formation of conidiospores with specialized aerial hyphae called conidiophores. Many produce asci within complex fruiting bodies called ascocarps. Includes saprophytic, parasitic forms; many form mutualisms with phototrophic microbes to form lichens. Four monophyletic subdivisions: *Saccharomycetes, Pezizomycotina, Taphrinomycotina,* and *Neolecta.*	*Ascobolus* *Aspergillis* *Candida* *Crinula* *Neurospora* *Penicillium* *Pneumocystis* *Saccharomyces*
Basidiomycota	Includes many common mushrooms and shelf fungi. Sexual reproduction involves formation of a basidium (small, club-shaped structure that typically forms spores at the ends of tiny projections) within which haploid basidiospores are formed. Usually four spores per basidium but can range from one to eight. Sexual reproduction involves fusion with opposite mating type resulting in a dikaryotic mycelium with parental nuclei paired but not initially fused. No subdivisions recognized. Also includes plant pathogens (rusts and smuts) belonging to *Urediniomycota* and *Ustilaginomycota.*	*Agaricus* *Boletes* *Dacrymyces* *Lycoperdon* *Polyporus* *Uromyces* *Ustilago*
Glomeromycota	Filamentous, most are endomycorrhizal, arbuscular; lack cilium; form asexual spores outside of host plant; lack centrioles, conidia, and aerial spores. No subdivisions recognized.	*Acaulospora* *Entrophospora* *Glomus*
Microsporidia	Obligate intracellular parasites usually of animals. Lack mitochondria, peroxisomes, kinetosomes, cilia, and centrioles; spores have an inner chitin wall and outer wall of protein; produce a tube for host penetration. Subdivisions currently uncertain.	*Amblyospora* *Encephalitozoon* *Enterocytozoon* *Nosema*

WHAT IS A FUNGUS?

- A large, diverse, and widespread group of organisms (approximately 100, 000 species), which includes
  - Molds (multicellular)
  - Mushrooms (multicellular)
  - Yeast (unicellular)
- Includes both microscopic and macroscopic organisms
- Decomposer: Important saprophytes (consume dead and decaying matter)
- Some species are pathogenic to plant / human – cause disease
- Mycotoxigenic fungi produce mycotoxins – *Aspergillus* spp. *Penicillium* spp. , *Fusarium* spp.
- Beneficial to plant – form important association with plant root
- Beneficial to human – edible mushroom, fermented products, antibiotic



YEAST & MOLDS IN FOOD

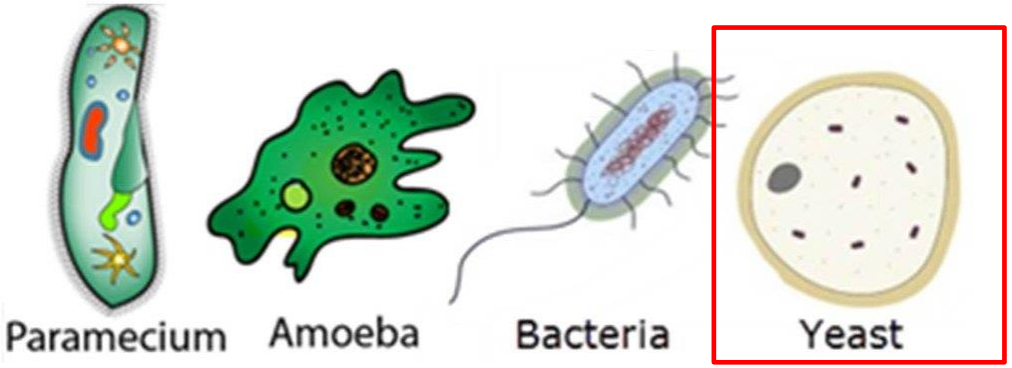


Rhizopus oligosporus

Penicillium roqueforti

WHAT IS A FUNGUS?

- Characteristics
  - Eukaryotic cell
  - Most are multicellular, but yeasts are unicellular.
  - Most are aerobes or facultative anaerobes.
  - Cell walls are made up of chitin (polysaccharide).
  - Lack of chlorophyll
  - Reproduce both sexually and asexually - spores

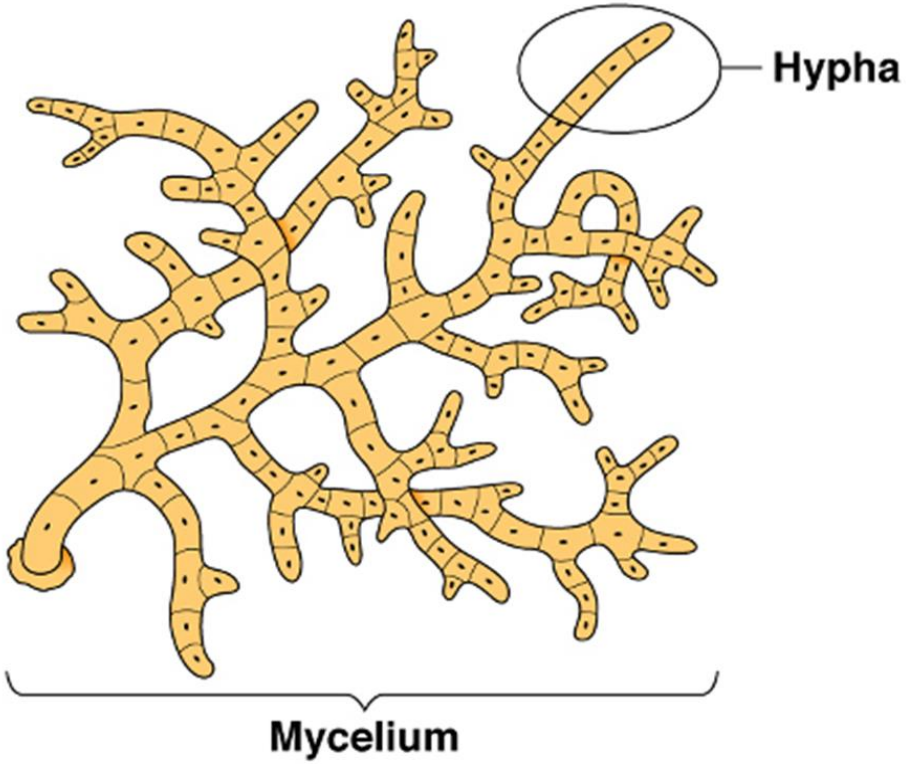


Unicellular organism

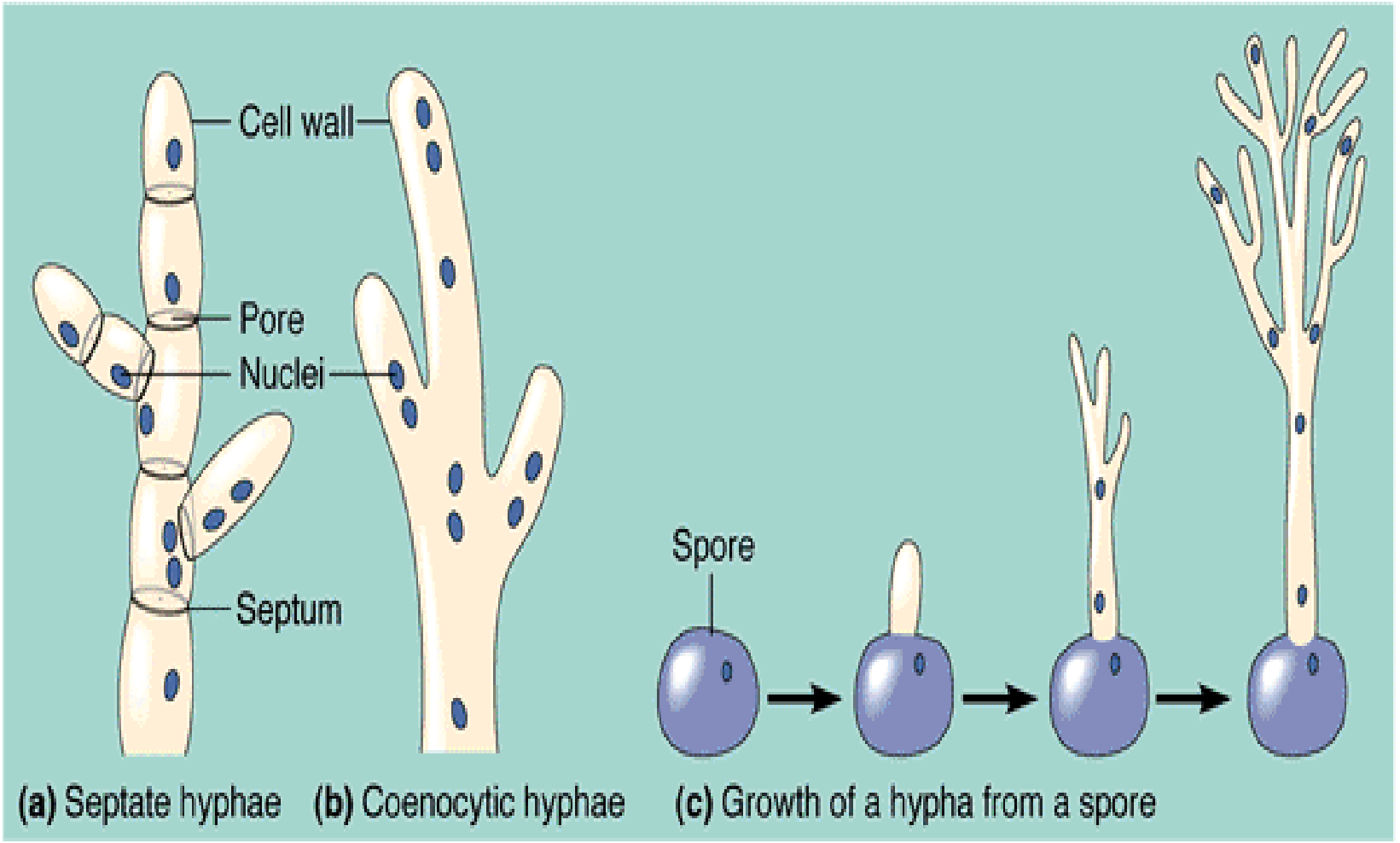
Multicellular organism

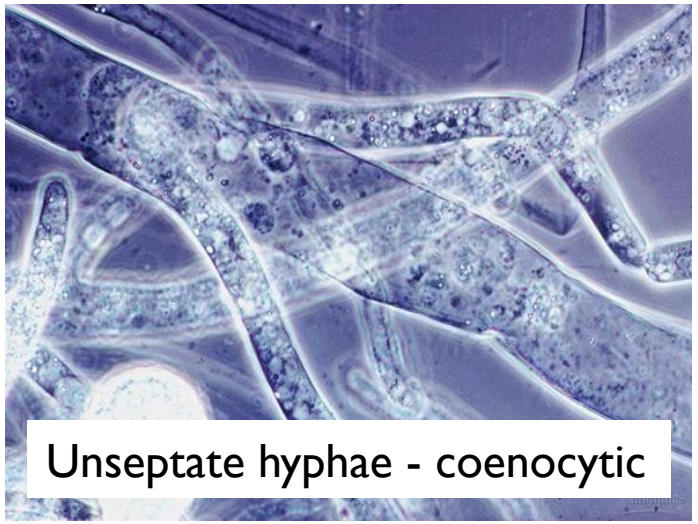
STRUCTURE OF FUNGI

- Filaments of fungi are called hyphae
- The cell walls contain chitin.
- The mycelium is a mat of hyphae visible to the unaided eye (e.g. tempeh)
- Some hyphae may divided by cross sections called septa
- The size, shapes, colour, spores morphology are important for fungal identification and classification
- Produce spores (asexual /sexual spores)
  - Enable fungi to survive in stress environment (e.g. desiccation, nutrient limitation, extreme temperature)
  - Aid in fungal dissemination (e.g. spores adhere to animal bodies)



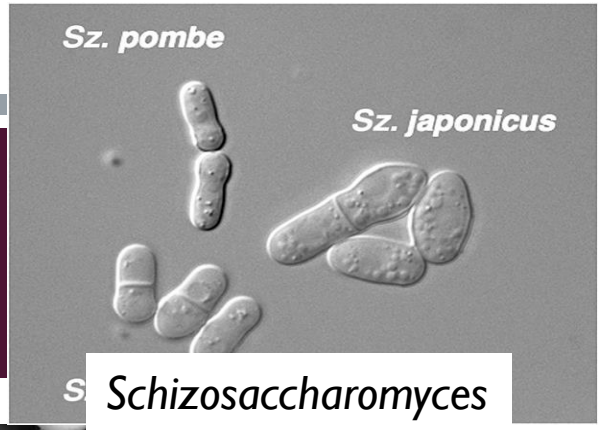
FUNGAL HYPHAE: SEPTATE & COENOCYTIC



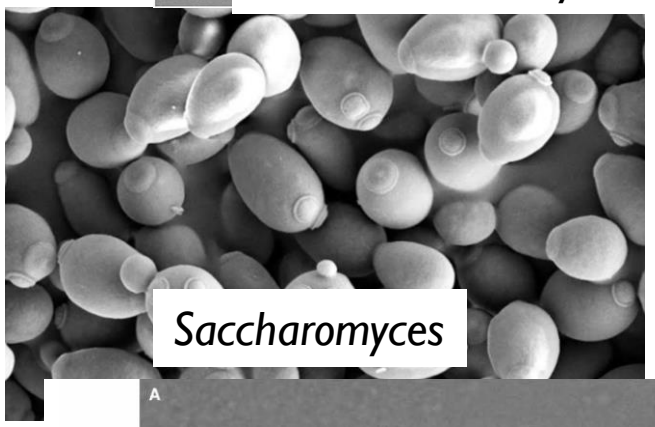


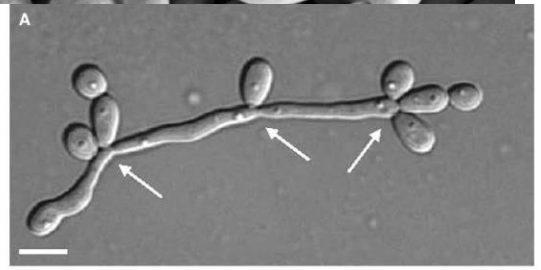
YEAST (UNICELLULAR)

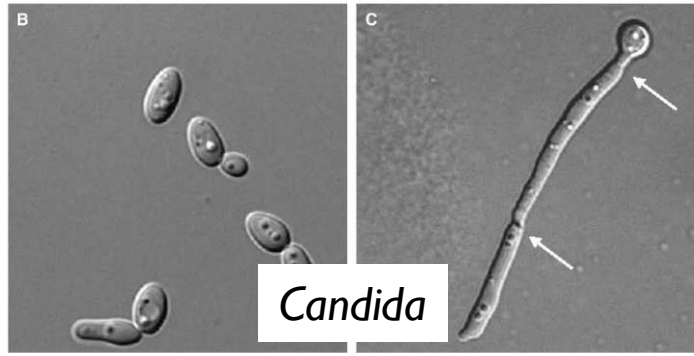
- **Unicellular fungi**, **nonfilamentous**, typically **oval or spherical cells**.
- Reproduce by **mitosis**:
  - Fission yeasts: Divide evenly to produce two new cells *(Schizosaccharomyces)*.
  - Budding yeasts: Divide unevenly by budding (*Saccharomyces*).
  - Budding yeasts can form pseudohypha, a short chain of undetached cells.
  - Candida albicans invade tissues through pseudohyphae.
- Yeasts are facultative anaerobes, which allows them to grow in a variety of environments.
  - When oxygen is available, they carry out aerobic respiration.
  - When oxygen is not available, they ferment carbohydrates to produce ethanol and carbon dioxide.



Schizosaccharomyces

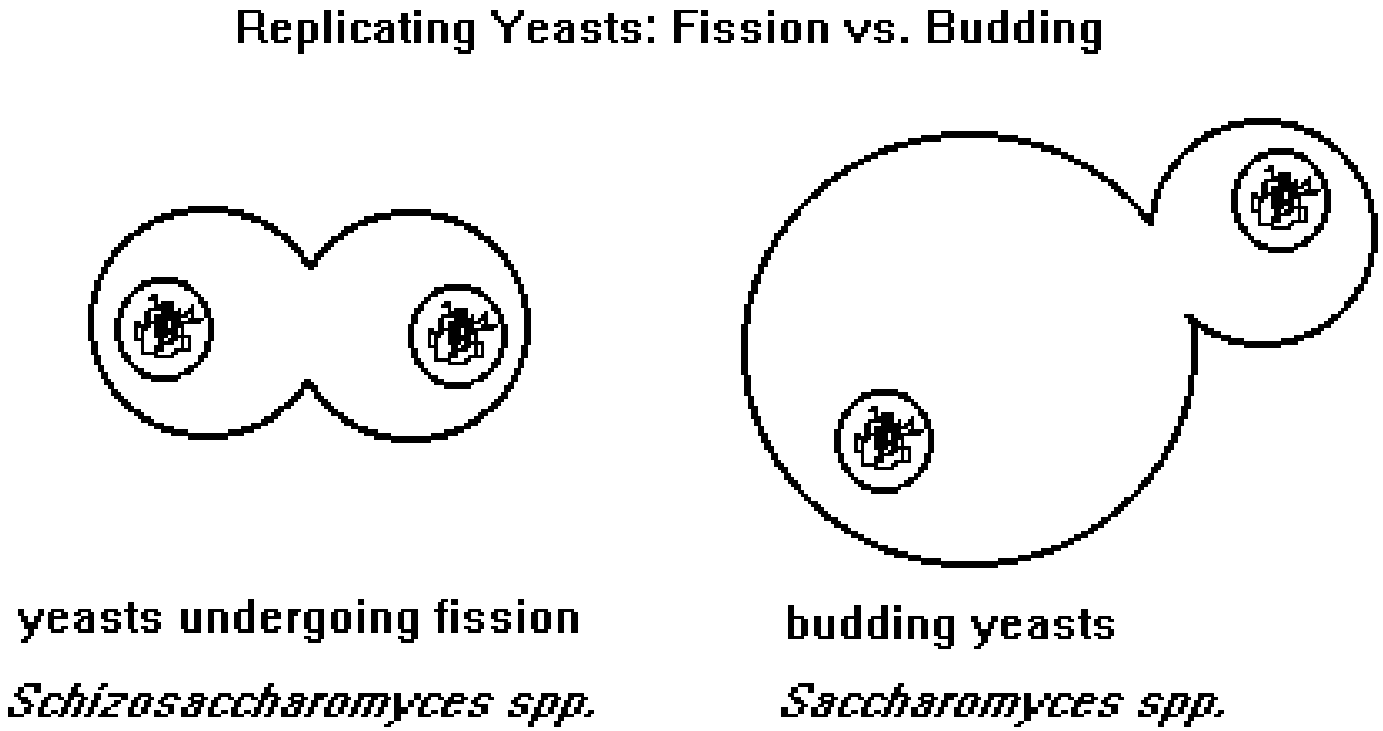

Saccharomyces





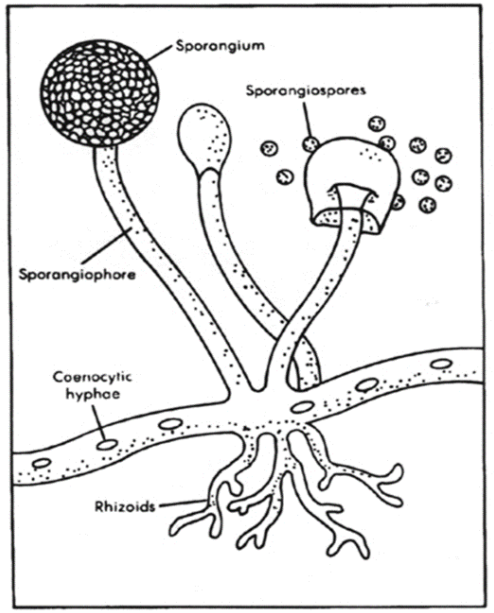
Candida

FISSION VS BUDDING



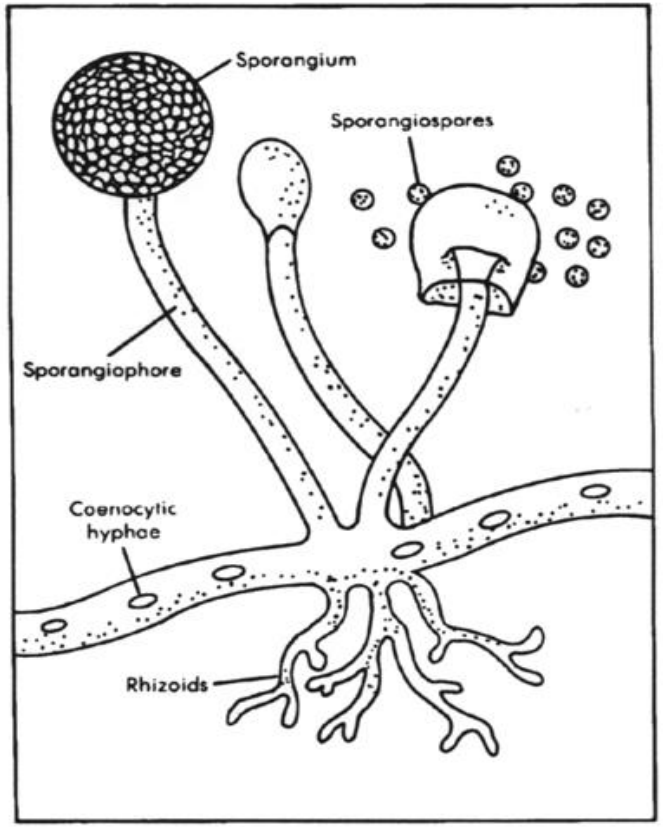
MOLDS AND FLESHY FUNGI (MULTICELLULAR)

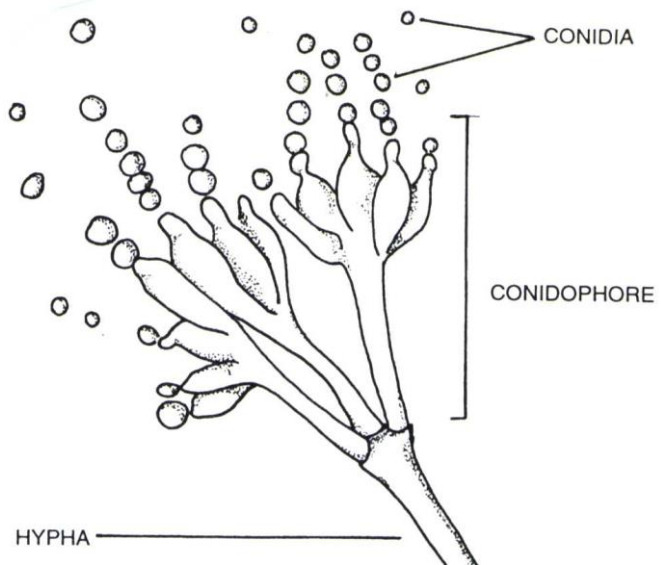
- Multicellular, filamentous fungi.
- Identified by physical appearance, colony characteristics, and reproductive spores.
  - **Thallus:** Body of a mold or fleshy fungus. Consists of many hyphae.
  - **Hyphae** (Hypha): Long filaments of cells joined together.
    - ✓ Septate hyphae: Cells are divided by cross-walls (septa).
    - ✓ Coenocytic hyphae: Continuous cells that are not divided by septa (Aseptate)
  - Hyphae grow by elongating at the tips.
  - Each part of a hypha is capable of growth.
    - ✓ Vegetative Hypha: Portion that obtains nutrients.
    - ✓ Reproductive or aerial hypha: Portion connected with reproduction.
  - **Mycelium:** Large, visible, filamentous mass made up of many hyphae.



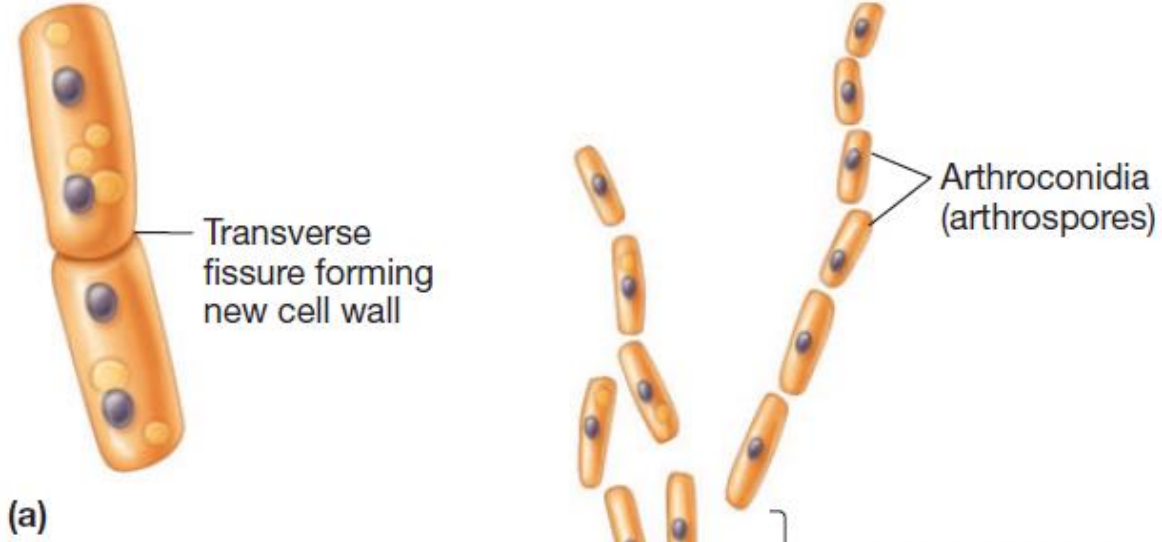
ASEXUAL REPRODUCTION

- Asexual reproduction – production of various types of asexual spores
  - Sporangiophores – asexual spore formed within a sac (sporangium) e.g. bread mold
  - Conidiospores/conidia – upright stalk with no enclosed sac
  - Arthrospores – Fragment of hyphae split and release individual cells that act like spores (e.g. athlete's foot fungus)
  - Blastospores – small offspring produce from vegetative mother cell budding
  - Chlamydospore: Thick-walled spore formed within a hyphal segment.





Asexual spores



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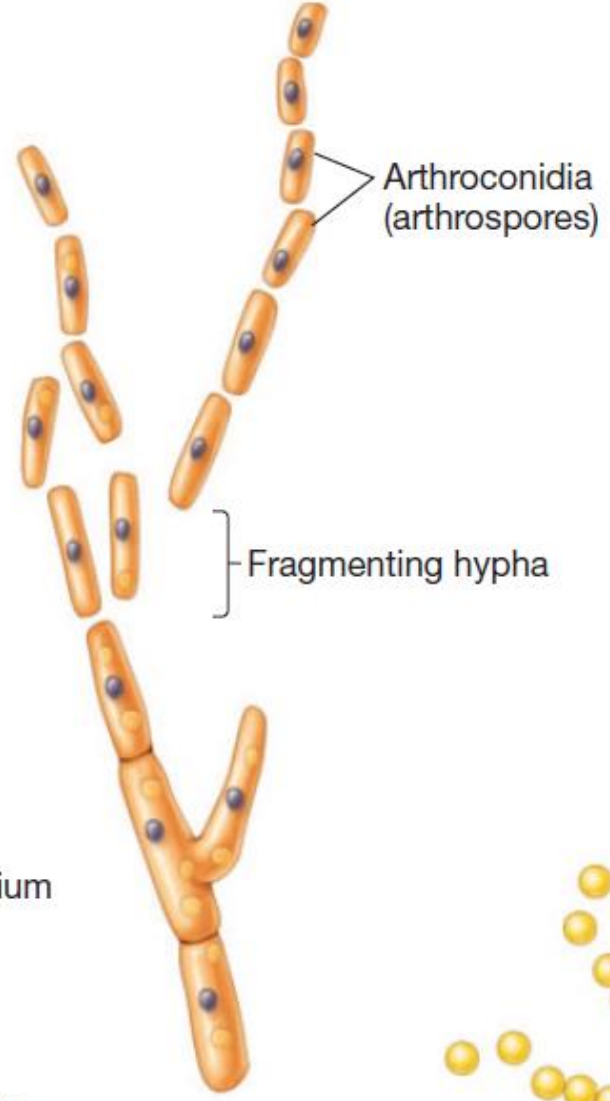

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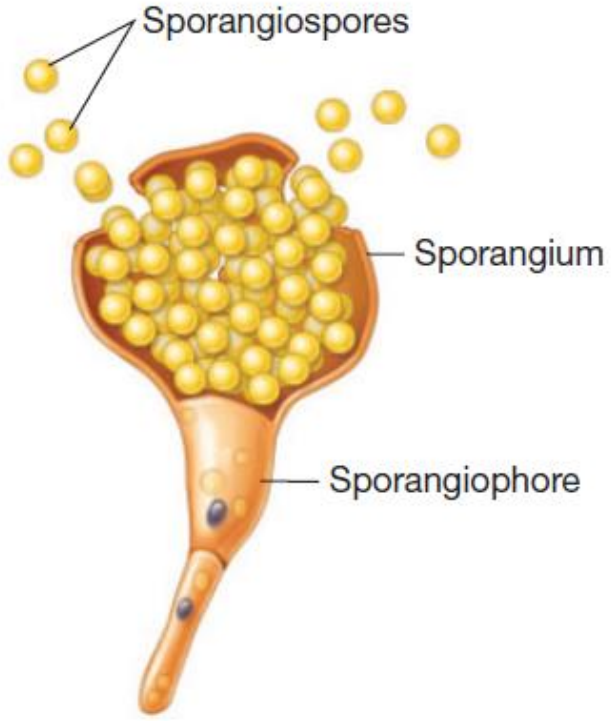

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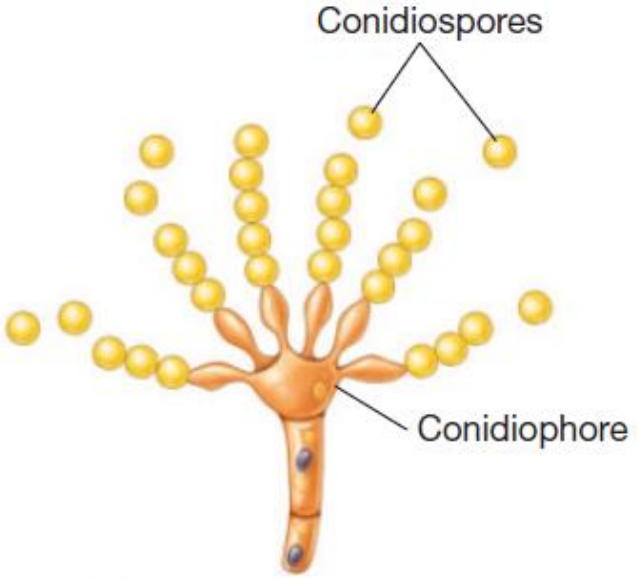

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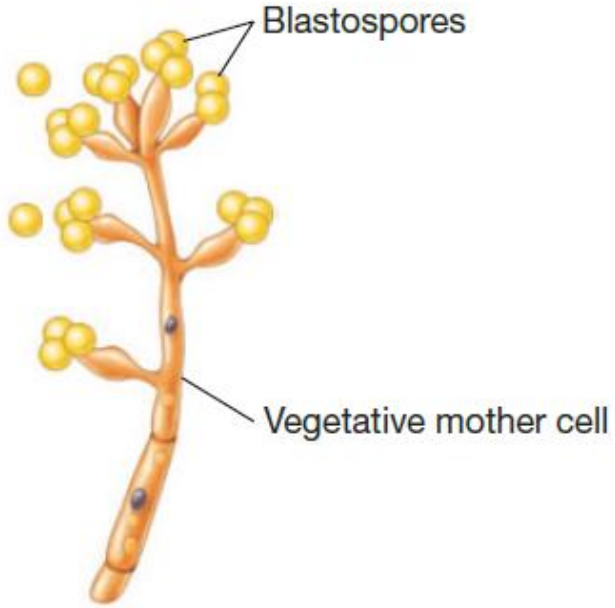

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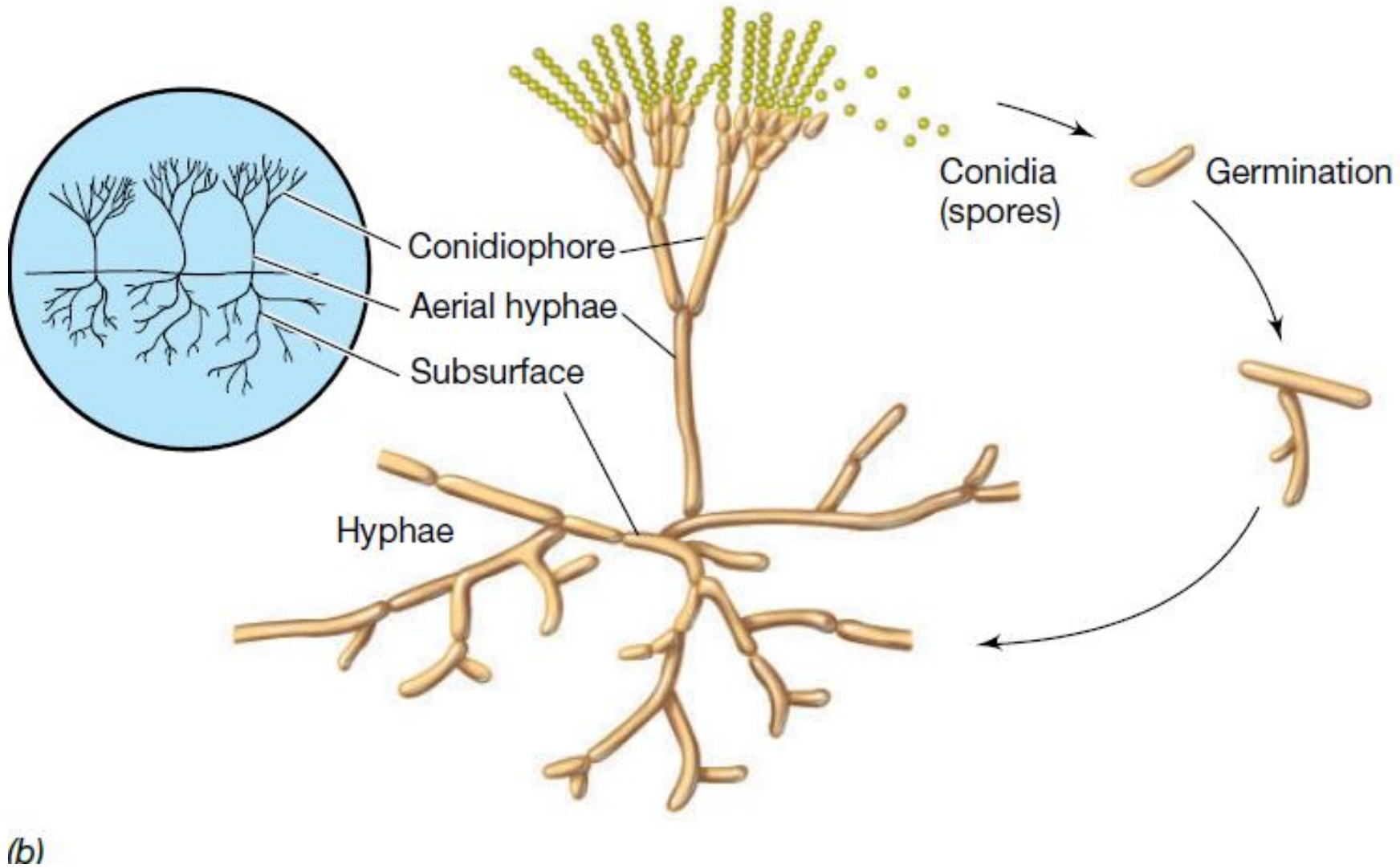


Life cycle of fungi at the asexual stage

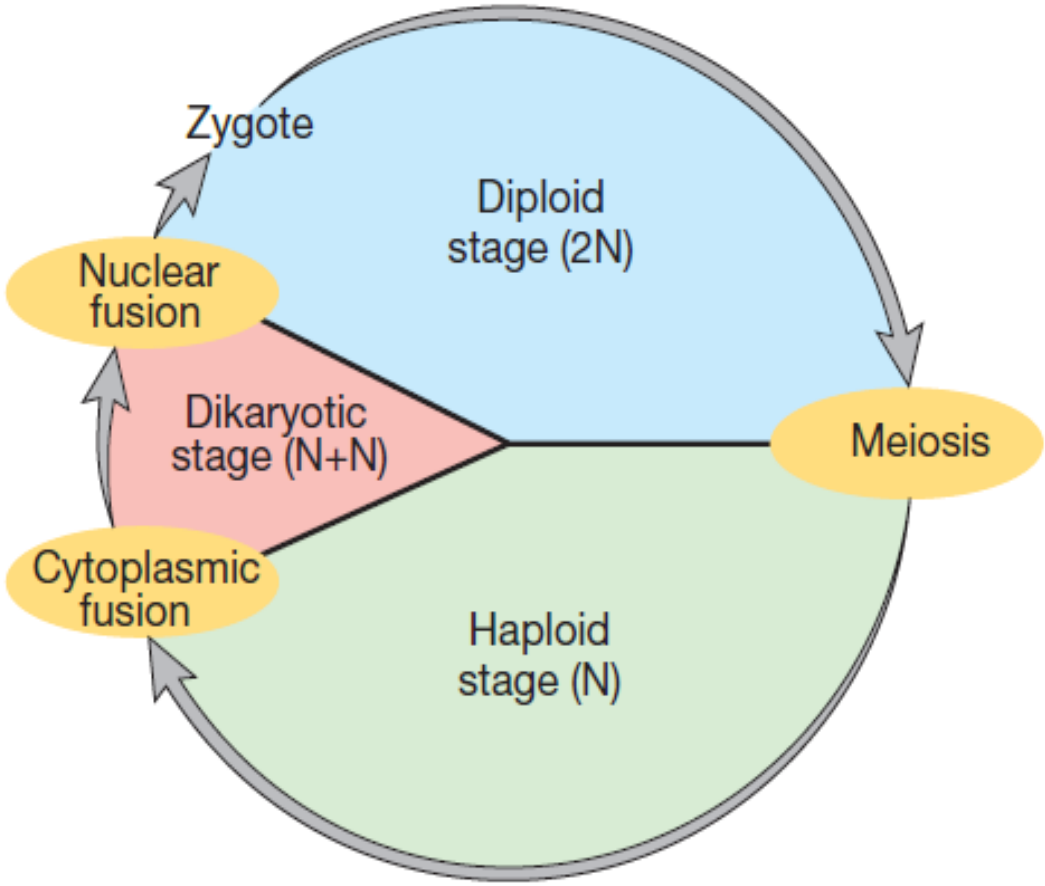
SEXUAL REPRODUCTION

- Sexual reproduction involve fusion of compatible nuclei from different mating type
  - Requires compatible strain of opposite mating types :"plus and minus" (+) (-) (haploid stage)
  - Hyphae of different mating types fuse and give rise to a specialized structure that produces spores (gametangia – diploid stage)
  - Most fungi are haploid throughout most of their life cycle
- When environmental conditions are favorable, asexual reproduction occurs rapidly.
- When unfavorable conditions stress the organism, sexual reproduction occurs and the offspring have an increased likelihood that they will be better suited for the environment.

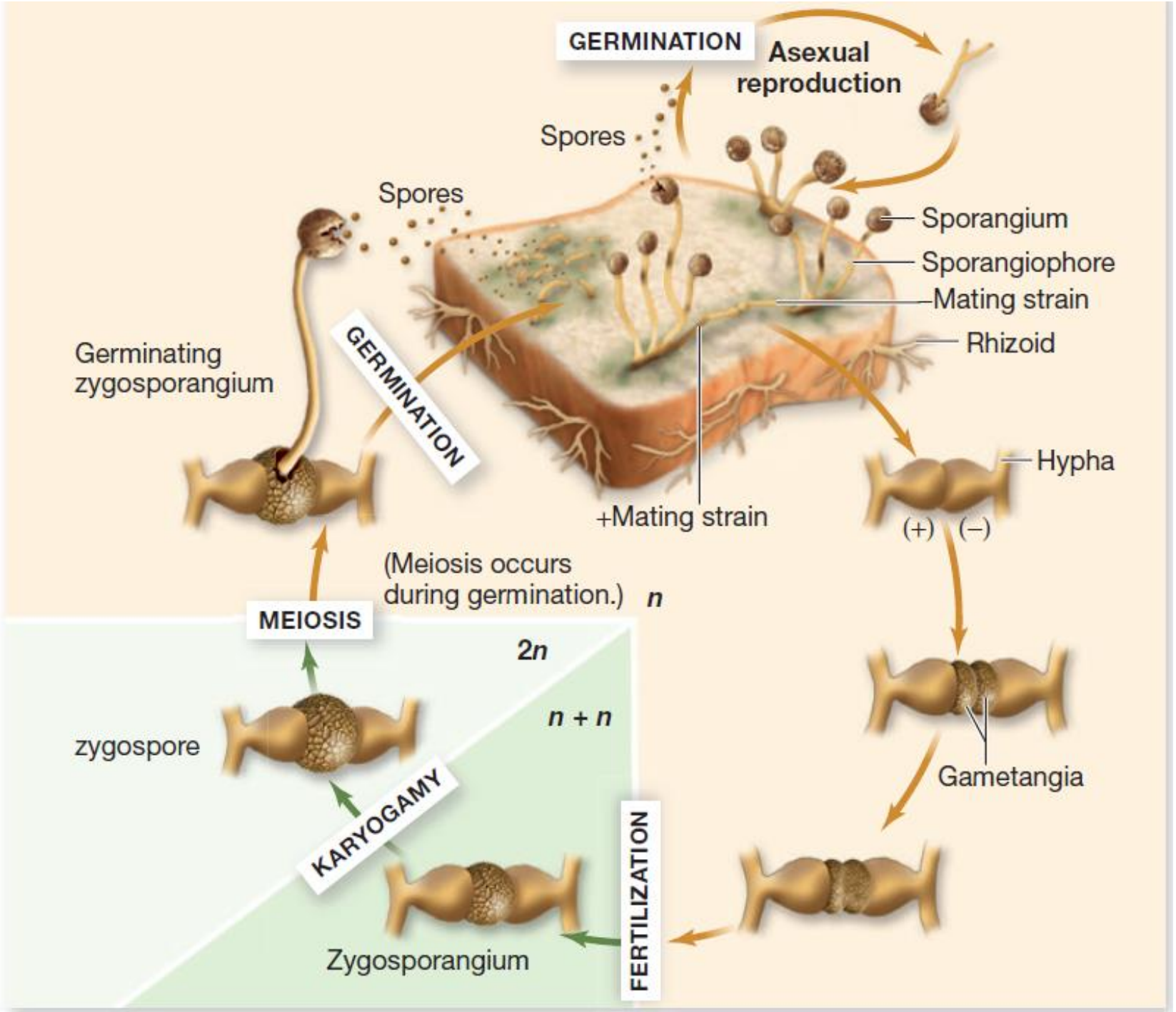
- Sexual spores is formed by the fusion of nuclei from two opposite mating strains of the same species.
  - Ascospores – spores formed within an enclosed sac (ascus)
  - Basidiospores – spores produced by the basidium (club-shape structure)
  - Zygospores – produced by zygomycetes (e.g. bread mold *Rhizopus* spp.)
  - Zoospores – motile spores produces by chytrid fungi
- Sexual spores are resistant to drying, heating, freezing, and some chemical agents

LIFE CYCLE OF FUNGI

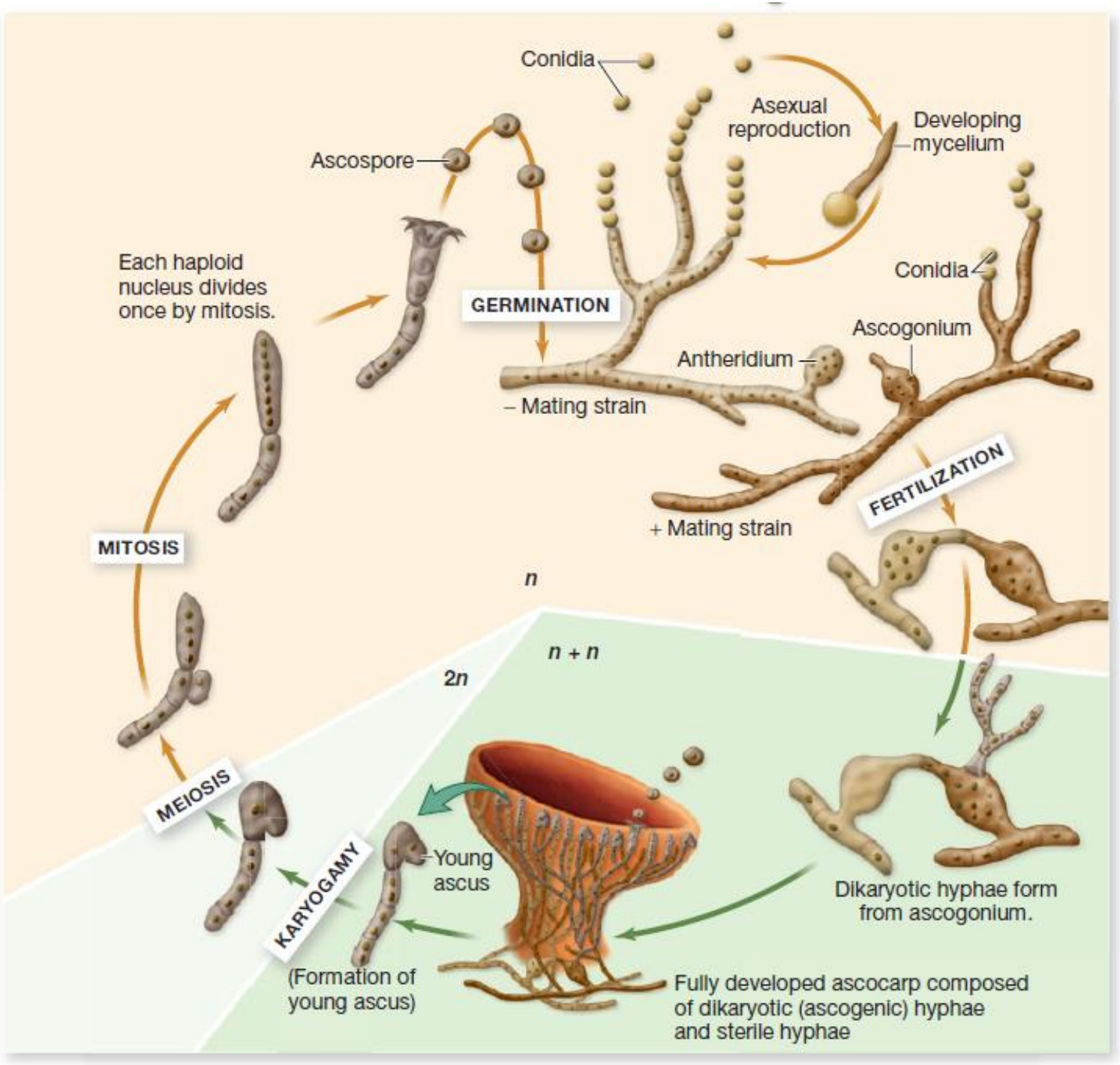
- The life cycle of most fungi include both haploid and diploid stage.
- The asexual stage (haploid) produce spores that aid in the dissemination of species
- The sexual stage (diploid) produce spores that survive extreme environmental conditions
- Dikaryotic stage – occur in ascomycetes and basidiomycetes
  - a delay between cytoplasmic and nuclear fusion.
  - Cells contain two separate haploid nuclei (N + N) from each parent



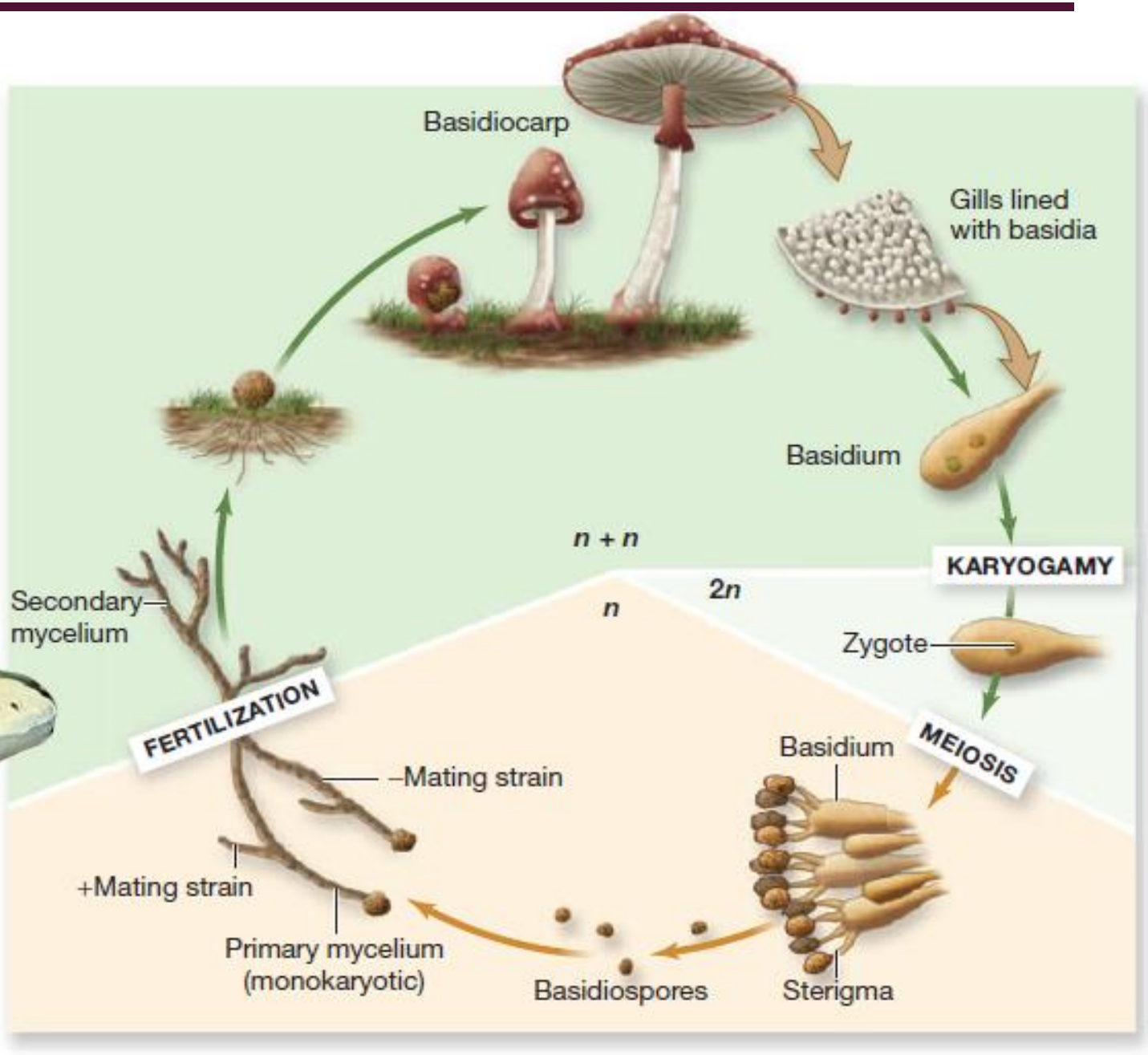
Life cycle of *Rhizopus stolonifer* that involves sexual and asexual phase



Life cycle of filamentous ascomycetes that involves sexual and asexual phase

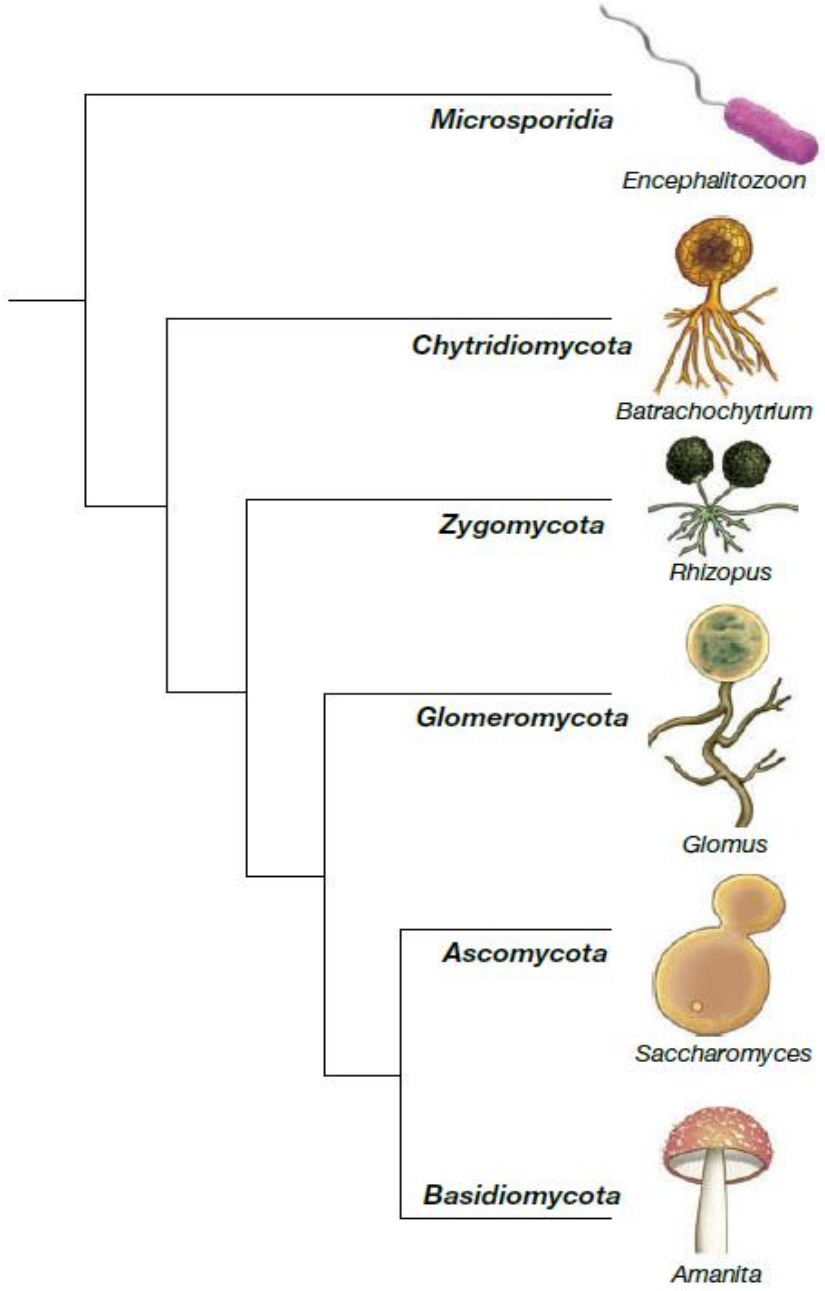


Life cycle of soil basidiomycetes



DIVISION OF FUNGI

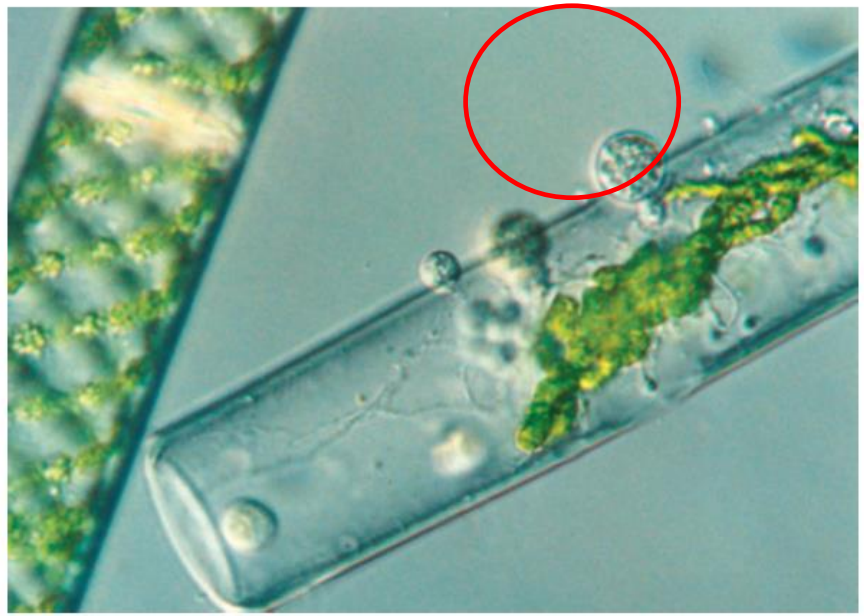
- Kingdom Fungi consist of 6 major groups
  1. *Chytridiomycota*
  2. *Zygomycota*
  3. *Glomeromycota*
  4. *Ascomycota*
  5. *Basidiomycota*
  6. *Microspiridia*



Phylogeny of fungi showing the relationships among major groups of fungi

CHYTRIDIOMYCOTA

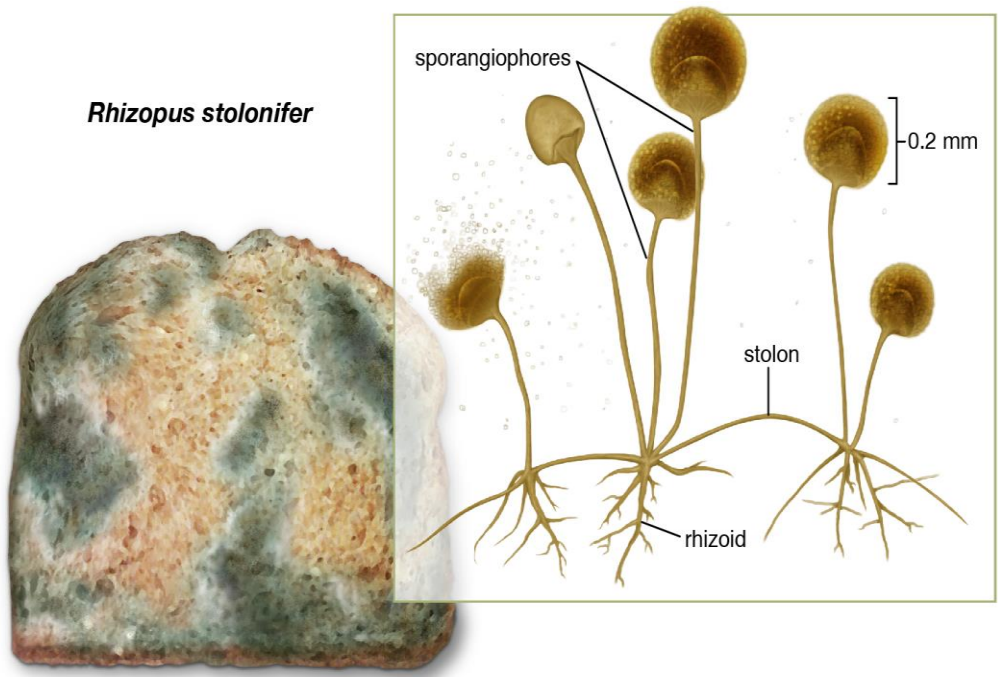
- The simplest form of fungi, microscopic, commonly called chytrids
- Sapropyhytic – living on plant and animal mater in freshwater, mud, and soil.
- Parasites to aquatic plan and animals
- Unique – produce a zoospores (flagellated & motile spores)



Parasitic chytrids attached to the green algae

ZYGOMYCOTA

- Zygomycetes are saprophytes – live on dead plant and animal, also known as bread mold
- The hyphae are coenocytic with haploid nuclei
- Asexual spores – developed in sporangium
- Sexual spores – zygospores (thick-walled spores)
- *Rhizopus stolonifer* grow on carbohydrate rich-rich food (e.g. bread)
- *Rhizopus oligosporus* used in tempeh production

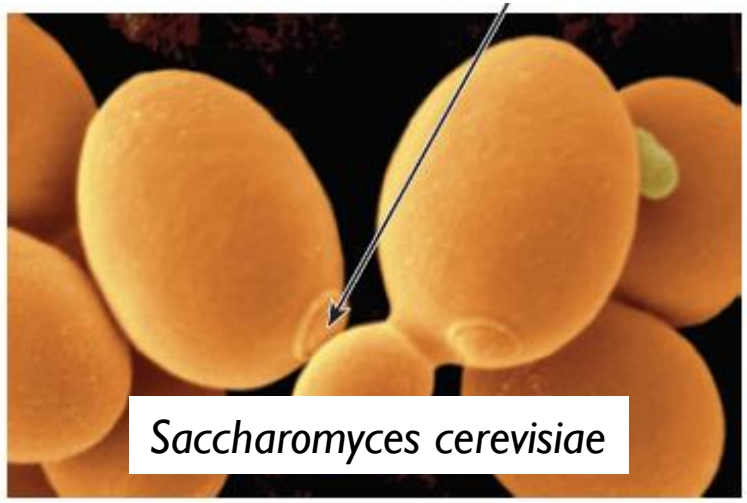


GLOMEROMYCOTA

- Glomeromycetes have a symbiotic relationships with vascular plant (mycorrhiza)
- The fungi helps to deliver nutrients from the soil to the plat, and the plant provide carbohydrates to the fungus (mutualism)
- Coenocytic hyphae and produce multinucleate spores
- Reproduce asexually by fragmentation of hyphae in the soil

ASCOMYCOTA

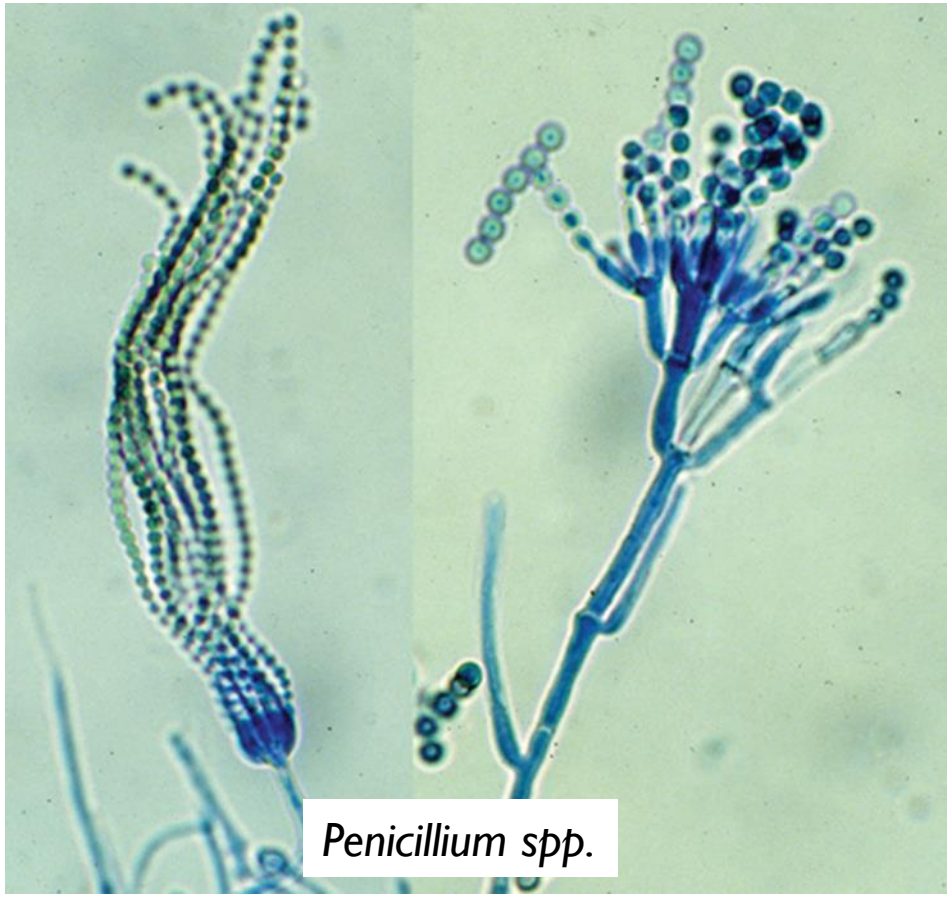
- Ascomycetes includes yeast (single-celled fungi) and molds (filamentous fungi, e.g. *Aspergillus, Penicillium*)
- Also known as sac fungi (saclike reproductive structure – ascus)
- Important decomposer – degrade chemically stable organic compound such as lignin, cellulose, and collagen (saprophyte)
- Pathogens – *Candida albicans*
- Reproduce sexually (produce ascospores) and asexually (produce conidiospores)



Saccharomyces cerevisiae

Aspergillus flavus

- Include common antibiotic producing fungi and yeasts, and several human pathogens.
  - *Penicillium notatum* (Produces penicillin)
  - *Saccharomyces* (Brewer's yeast)
  - *Trychophyton* (Athlete's foot)
  - *Aspergillus* (Carcinogenic aflatoxin in peanuts),
  - *Blastomyces* (Respiratory infections)
  - *Histoplasma capsulatum* (Respiratory and systemic infections)



Penicillium spp.

BASIDIOMYCOTA

- Basidiomycetes are commonly known as club fungi which include mushroom, rusts, puffballs, etc.
- Basidium is the sexual reproduction structure produced at the tip of byphae (club shaped) – produce basidiosphores
- Basidiospores held within the fruiting bodies called basidiocarps.
- Most are saprophytic fungi that decompose plant debris
- Edible mushroom: *Agaricus campestris*
- Poisonous mushroom: *Amanita phalloides & A. muscaria* – produces alkaloids that acts as poisons or hallucinogens
  - Phalloiden – attack liver cells, rupture plasma membrane
  - Alpha-amanitin – attack the cells lining the small intestines, causing severe gastrointestinal disease

NUTRITIONAL ADAPTATION OF FUNGI

Fungi absorb their food, rather than ingesting it.

- Fungi grow better at a pH of 5, which is too acidic for most bacteria.
- Almost all molds are aerobic. Most yeasts are facultative anaerobes.
- Fungi are more resistant to high osmotic pressure than bacteria.
- Fungi can grow on substances with very low moisture.
- Fungi require less nitrogen than bacteria to grow.
- Fungi can break down complex carbohydrates (wood, paper), that most bacteria cannot.

FUNGI IN INDUSTRY

- Fungi produce many products used in the medical field such as penicillin, cephalosporin antibiotics, cortisone

- Yeasts are used in the fermentation of fruits to produce wines, cereals to make beer, in bread manufacture and flavouring in the form of yeast extract

CERTAIN FUNGI PRODUCE TOXINS!!

(MYCOTOXINS)

Poisonous mushrooms found in southern China. A. *Amanita fuliginea* ; B. *A. exitialis* ; C. *A. subjunquillea var. alba* ; D. *A. cf. pseudoporphyria* ; E. *A. kotohiraensis* ; F. *A. gymnopus* ; G. *Galerina sulciceps* ; H. *Russula subnigricans* ; I. *Russula japonica* ; J. *Chlorophyllum molybdites* ; K. *Pulveroboletus ravenelii* ; L. *Psilocybe samuiensis*

Mushroom poisoning symptoms: gastroenteritis, acute liver failure, acute renal failure, psychoneurological disorder, hemolysis

Amanita was responsible for 70.49 % of fatalities

Psilocybe samuiensis caused psychoneurological disorders -visual hallucinations

Chen, Z. Zhang, P. & Zhang, Z. (2014) Investigation and analysis of 102 mushroom poisoning cases in Southern China from 1994 to 2012. Fungal Diversity, 64:123–131

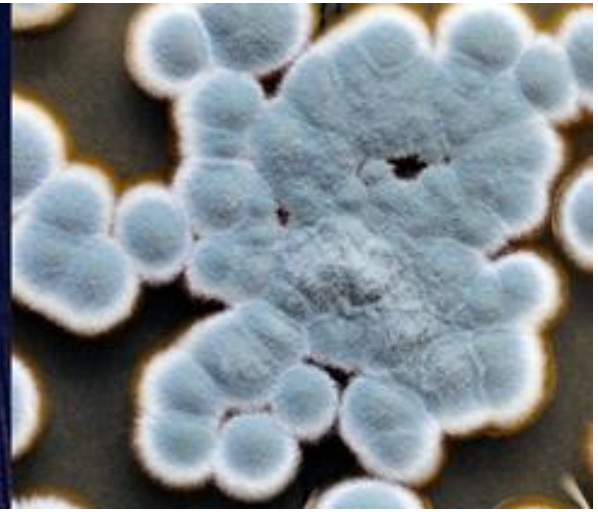
Aflatoxins

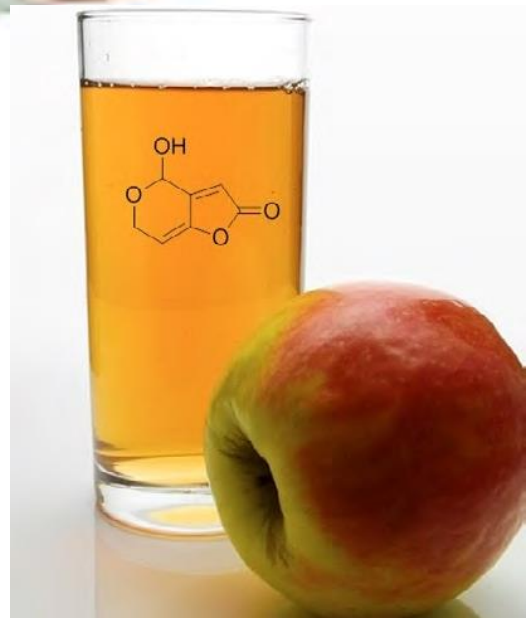
Aflatoxins are carcinogenic compound which mainly produced by *Aspergillus flavus* and *A. parasiticus*.

AFB_1 is classified as a Group 1 carcinogen by IARC which is linked to the development of liver cancer (International Agency for Research on Cancer [IARC], 1993).

Aflatoxins & fumonisins in maize

Patulin





CLASS ACTIVITY

During a breakout session in Webex, you will be randomly selected into 10 different groups. Based on the given topic, you need to find information from textbooks / online resources and prepare a slide presentation (5 – 10 slides) using Ms Power Point or any online platform such as Google Slides, Canva, Genially, etc. You are given 30 minutes to finish the task, upload / share your slide in Padlet (see eLearn), and present it in class. Give a "LIKE" to the best slide in Padlet. The best group with the highest number of "LIKE" will receive a **Mystery Gift** from me!! =P.

TITLES:

- Group 1 & 2: Chytridiomycota
- Group 3 & 4: Zygomycota
- Group 5 & 6: Glomeromycota
- Group 7 & 8: Ascomycota
- Group 9 & 10: Basidiomycota
- Group 11 & 12: Microsporidia

THANK YOU