

CHAPTER

5

Fungi



Overview

- **Fungi are diverse and widespread**
- **They are essential for the well-being of most terrestrial ecosystems because they break down organic material and recycle vital nutrients**
- **Despite their diversity, fungi share key traits, most importantly the way in which they derive nutrition**

Nutrition and Ecology

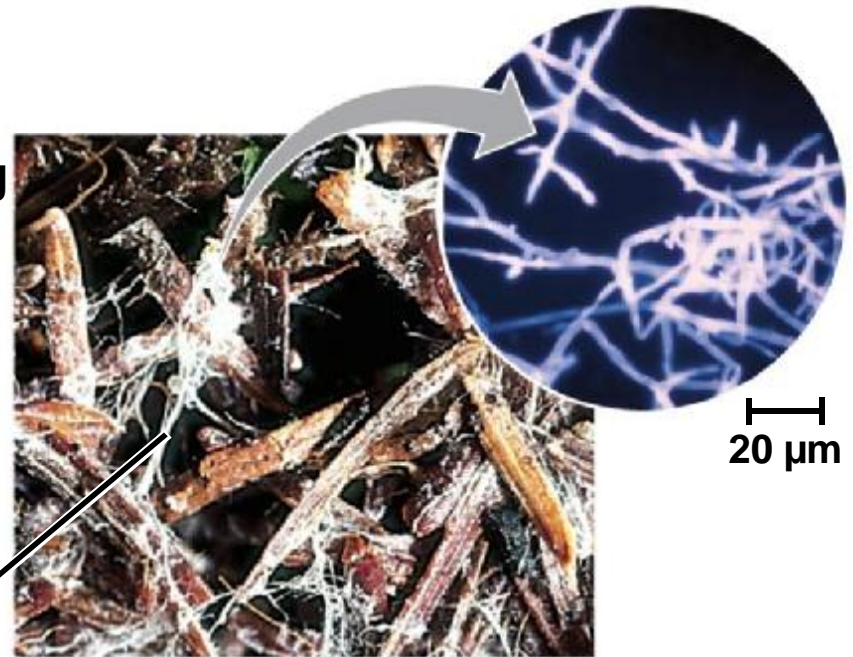
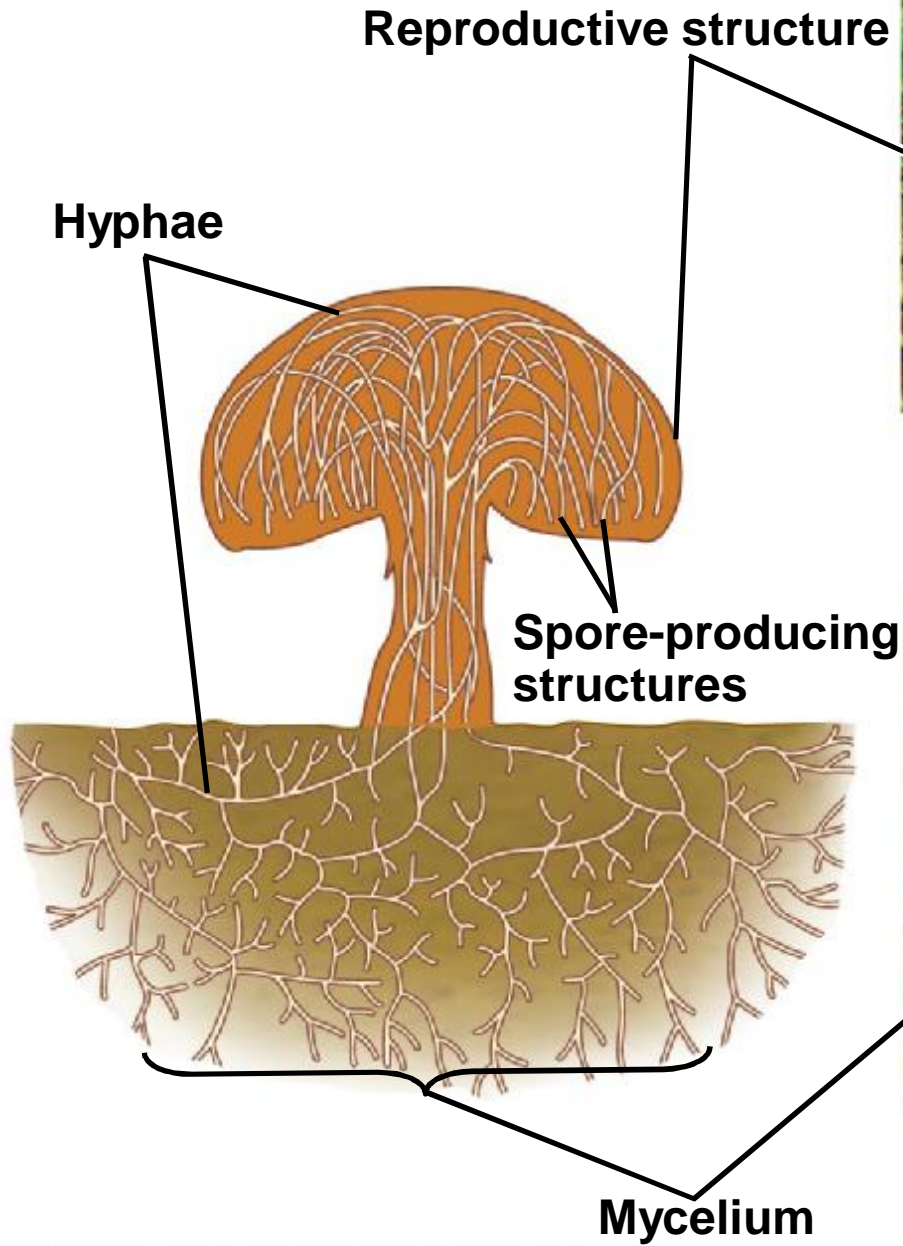
- **Fungi are heterotrophs and absorb nutrients from outside of their body**
- **Fungi use enzymes to break down a large variety of complex molecules into smaller organic compounds**
- **Fungi exhibit diverse lifestyles:**
 - **Decomposers (Saprotrophs)**
 - **Parasites**
 - **Symbionts**

Body Structure

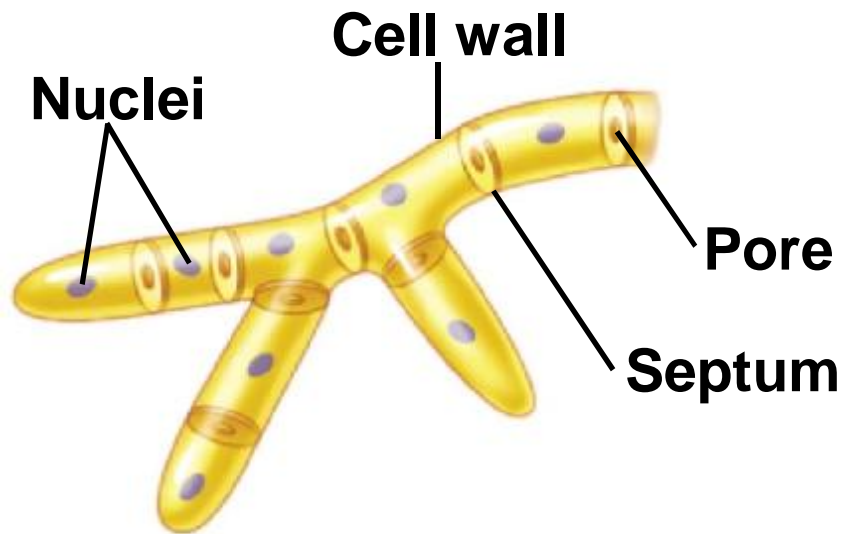
- **The most common body structures are multicellular filaments and single cells (yeasts)**
- **Some species grow as either filaments or yeasts; others grow as both**

Morphology

- **The morphology of multicellular fungi enhances their ability to absorb nutrients**
- **Fungi consist of mycelia , networks of branched hyphae adapted for absorption**
- **Most fungi have cell walls made of chitin**

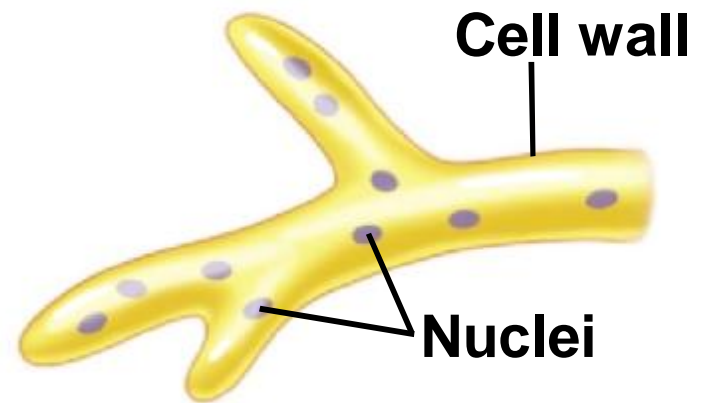


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- **Some fungi have hyphae divided into cells by septa, with pores allowing cell-to-cell movement of organelles**
 - **Coenocytic fungi lack septa**



(a) Septate hypha

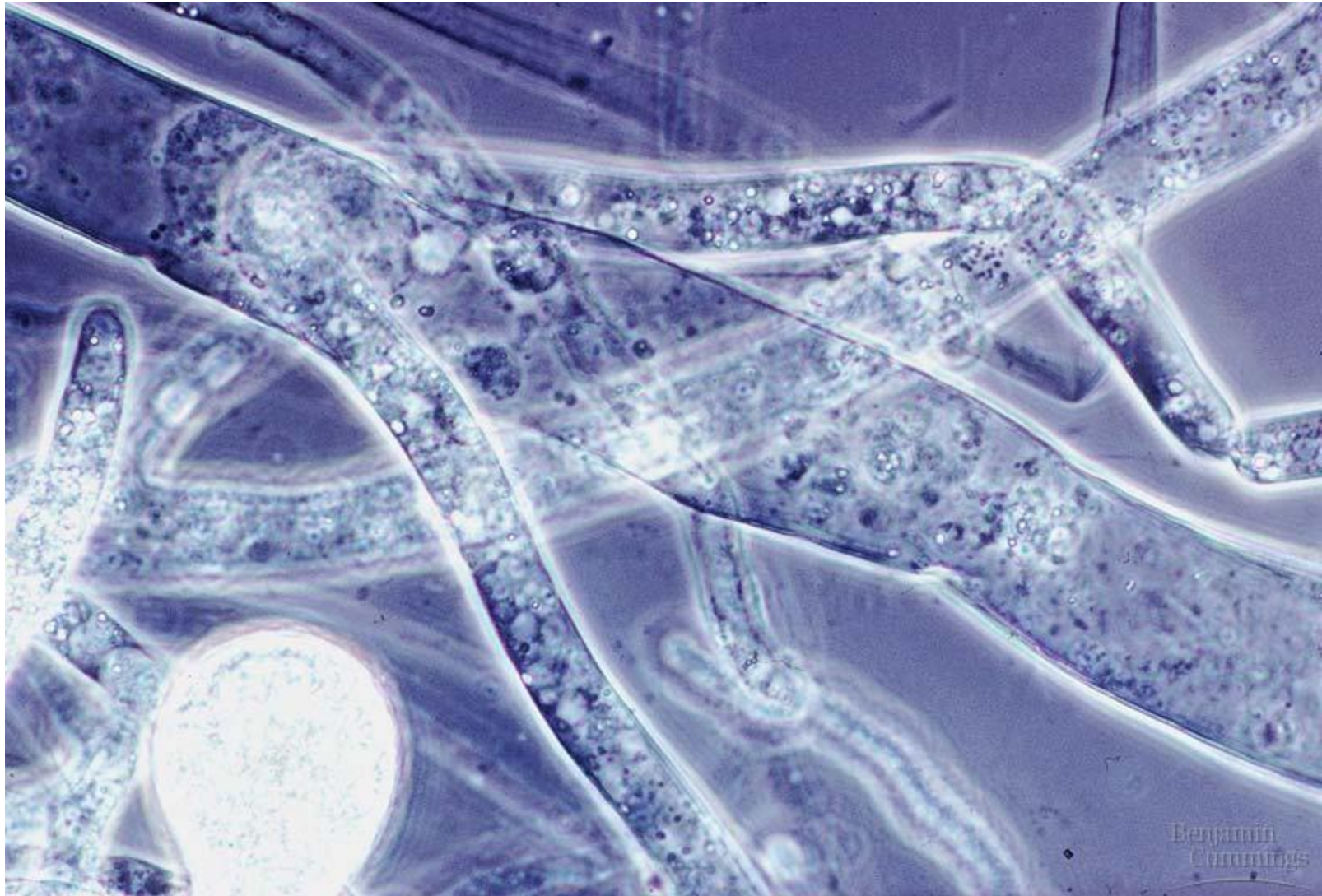
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(b) Coenocytic hypha



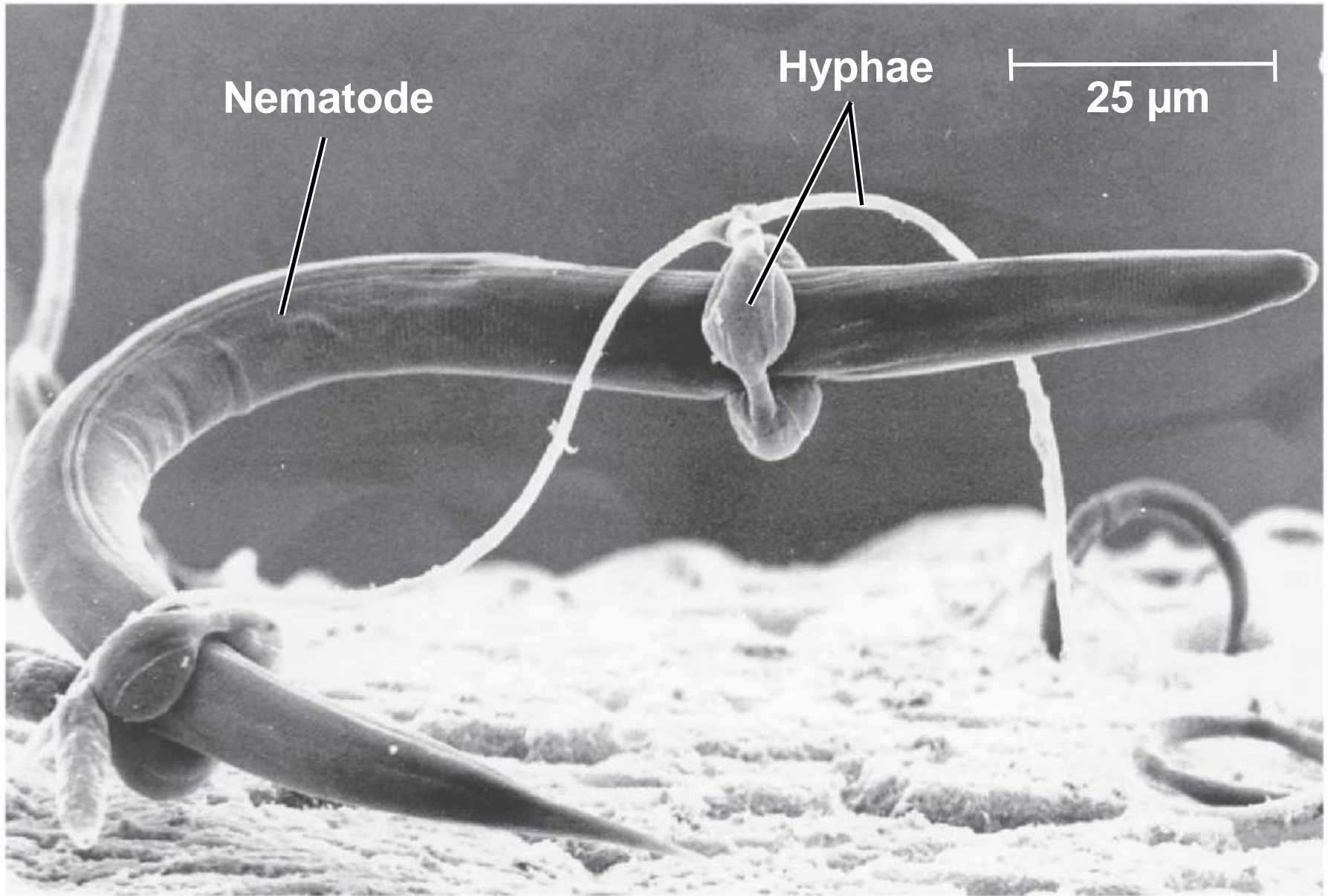
(a) Septate hypha



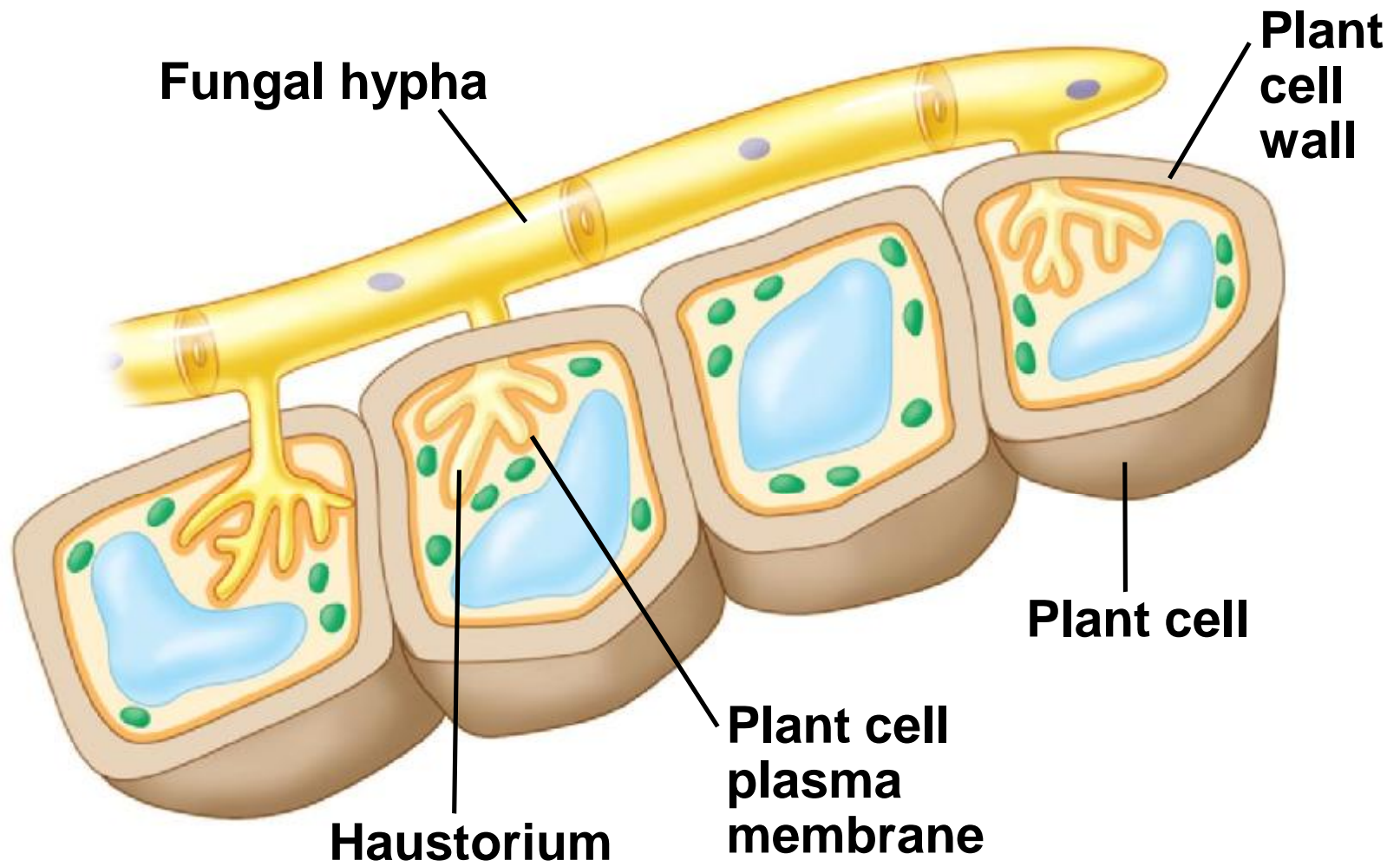
(b) Coenocytic hypha

Specialized Hyphae in Mycorrhizal Fungi

- **Some unique fungi have specialized hyphae called haustoria (giác mút) that allow them to penetrate the tissues of their host**



(a) Hyphae adapted for trapping and killing prey



(b) Haustoria

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- **Mycorrhizae are mutually beneficial relationships between fungi and plant roots**
 - **Ectomycorrhizal fungi form sheaths of hyphae over a root and also grow into the extracellular spaces of the root cortex**
 - **Arbuscular mycorrhizal fungi extend hyphae through the cell walls of root cells and into tubes formed by invagination of the root cell membrane**

Reproduction

- **Fungi propagate themselves by producing vast numbers of spores, either sexually or asexually**
- **Fungi can produce spores from different types of life cycles**




Sexual Reproduction

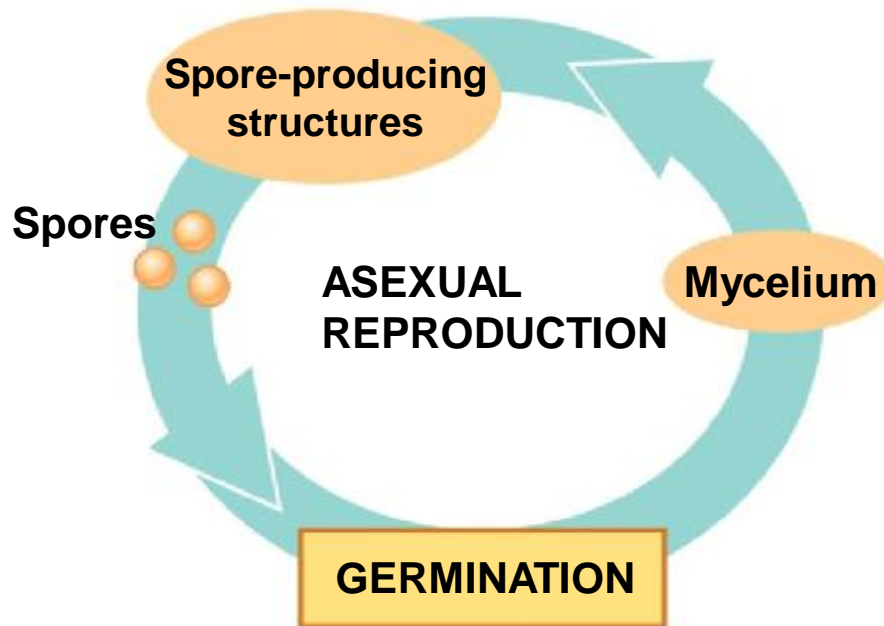
- **Fungal nuclei are normally haploid, with the exception of transient diploid stages formed during the sexual life cycles**
- **Sexual reproduction requires the fusion of hyphae from different mating types**
- **Fungi use sexual signaling molecules called pheromones to communicate their mating type**

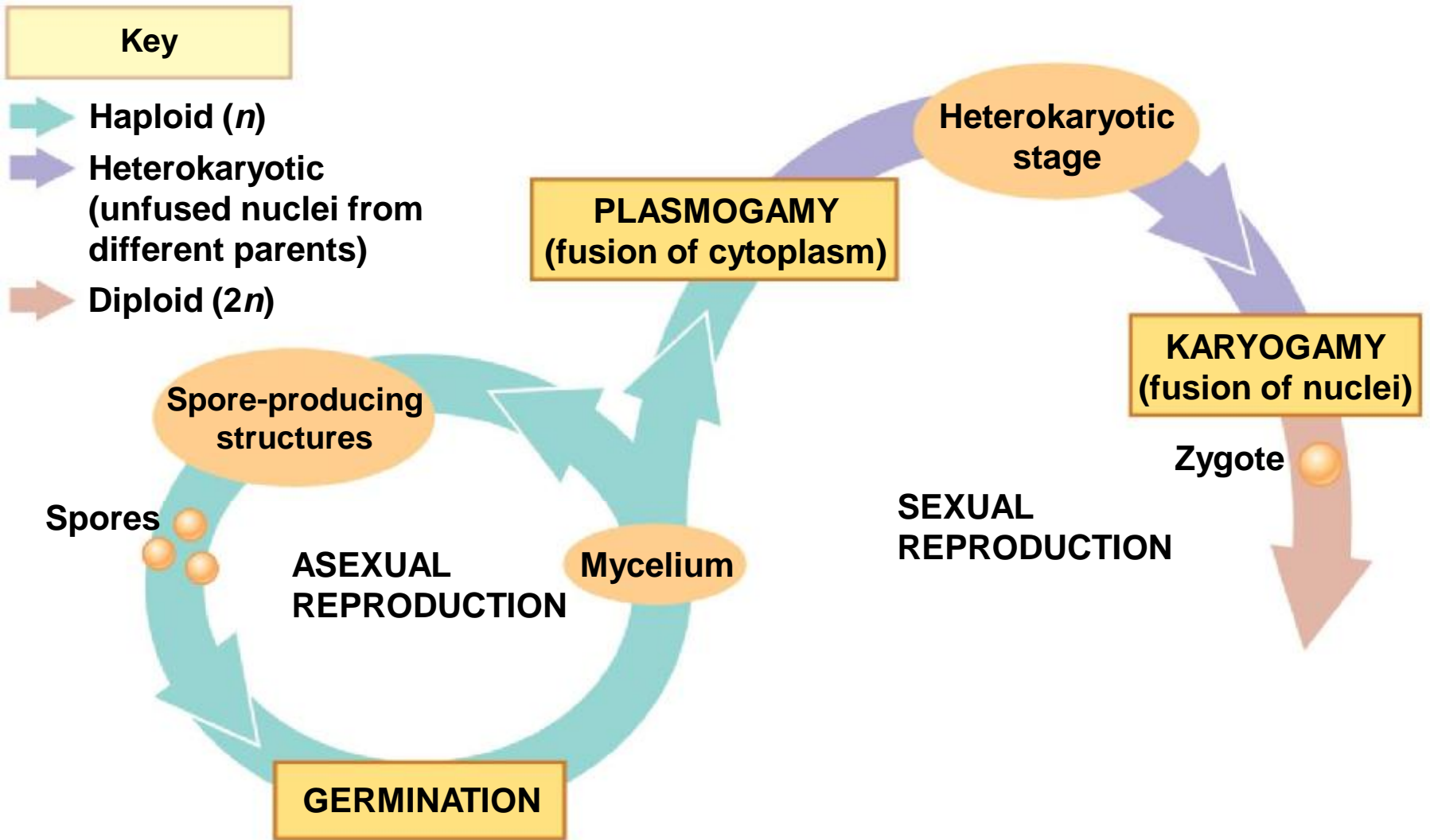
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- **Plasmogamy is the union of two parent mycelia**
 - **In most fungi, the haploid nuclei from each parent do not fuse right away; they coexist in the mycelium, called a heterokaryon**
 - **In some fungi, the haploid nuclei pair off two to a cell; such a mycelium is said to be dikaryotic**

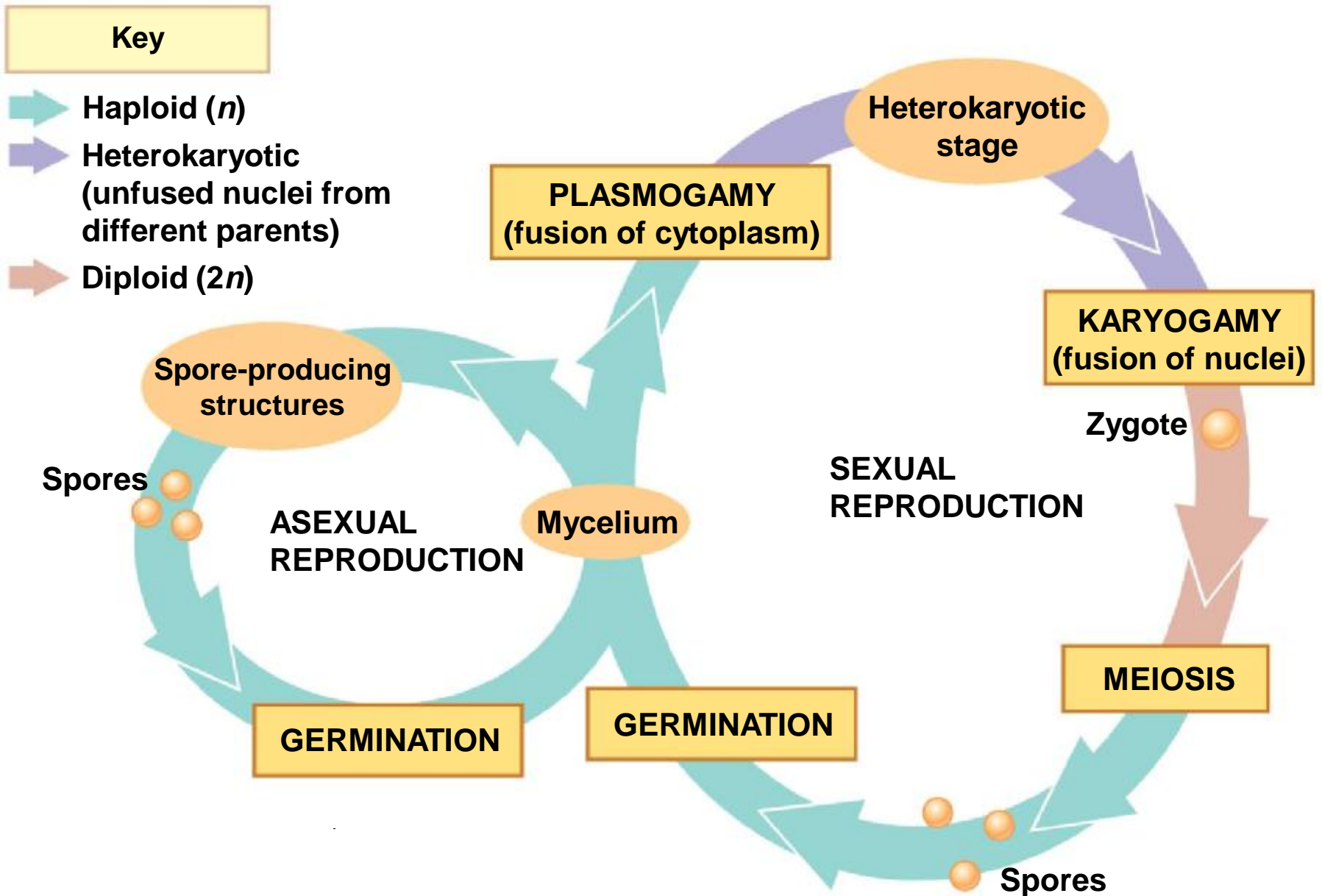
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- **Hours, days, or even centuries may pass before the occurrence of karyogamy, nuclear fusion**
 - **During karyogamy, the haploid nuclei fuse, producing diploid cells**
 - **The diploid phase is short-lived and undergoes meiosis, producing haploid spores**

Key

-  Haploid (n)
-  Heterokaryotic
(unfused nuclei from
different parents)
-  Diploid ($2n$)

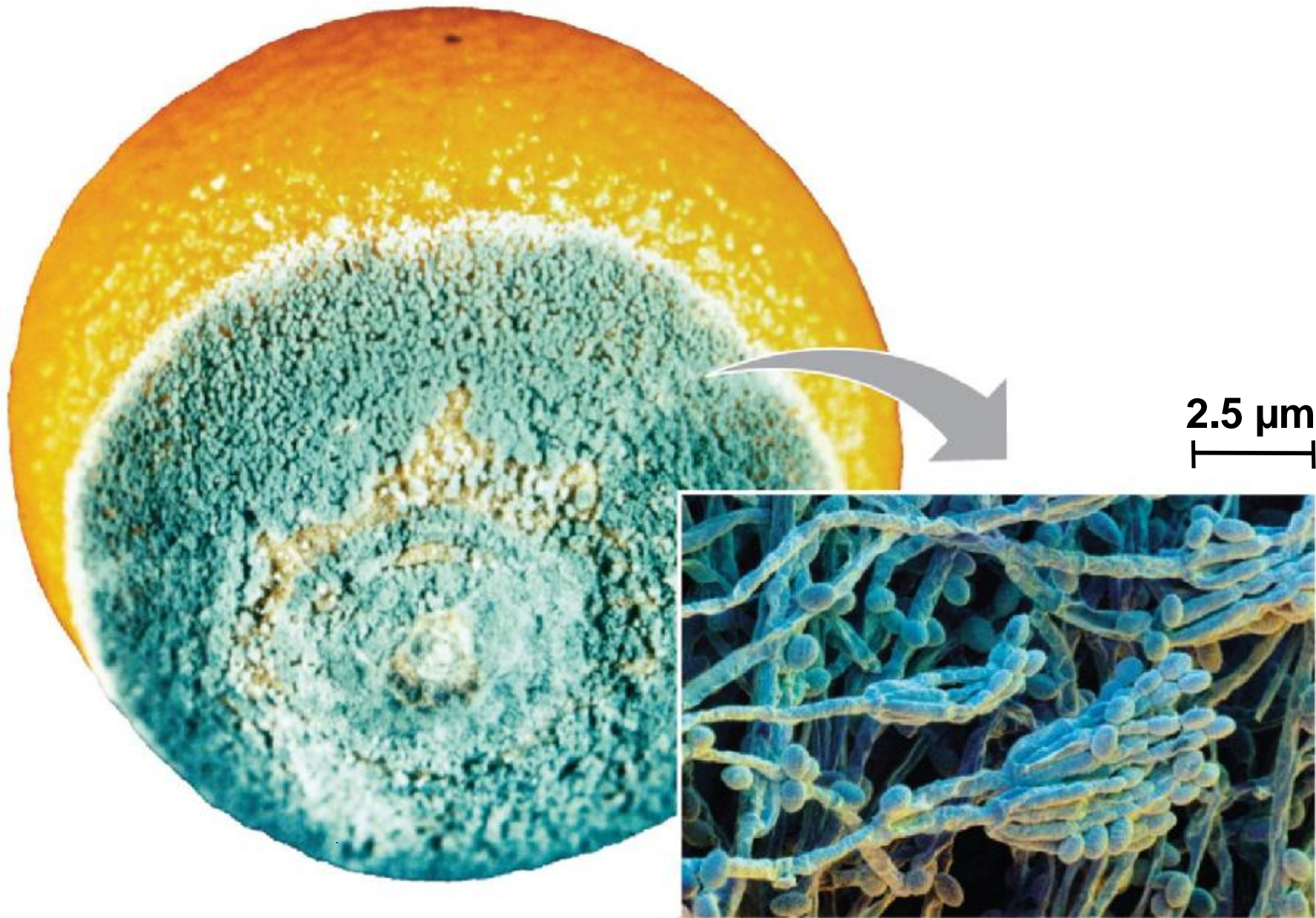




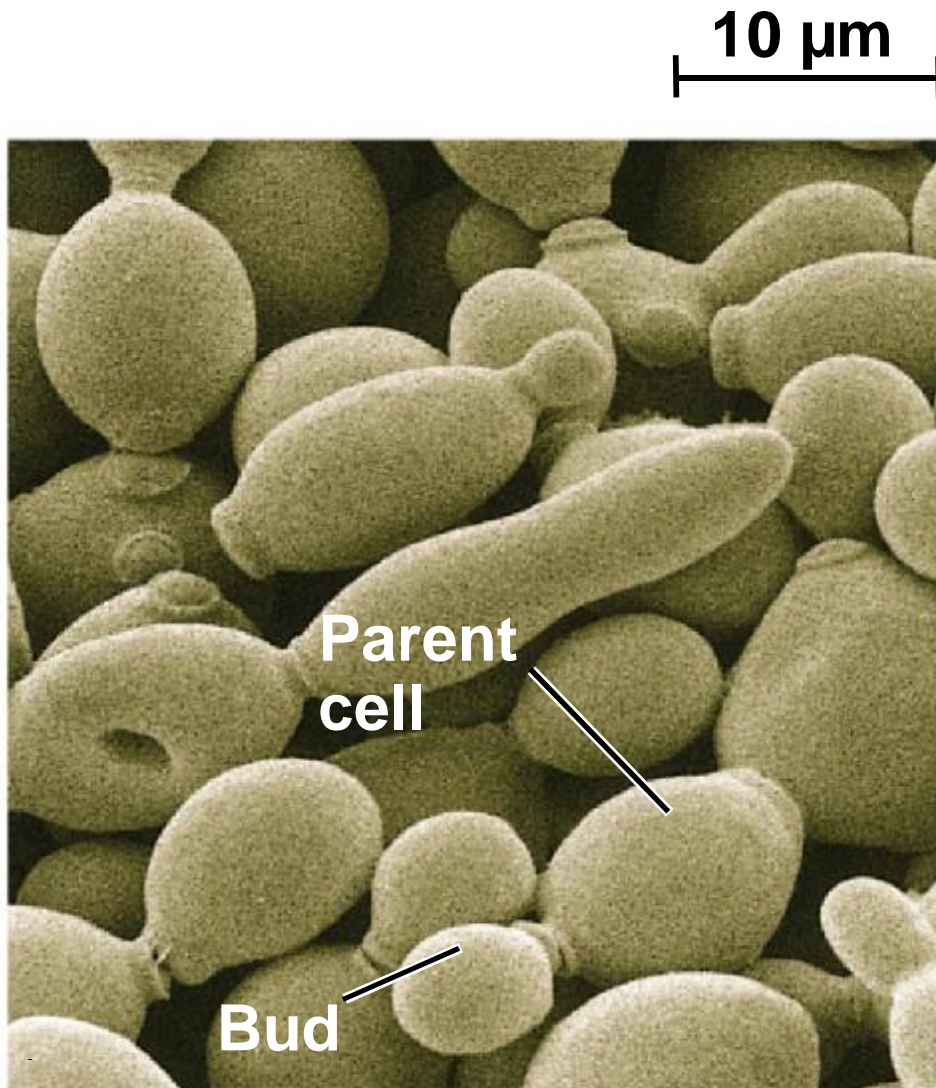


Asexual Reproduction

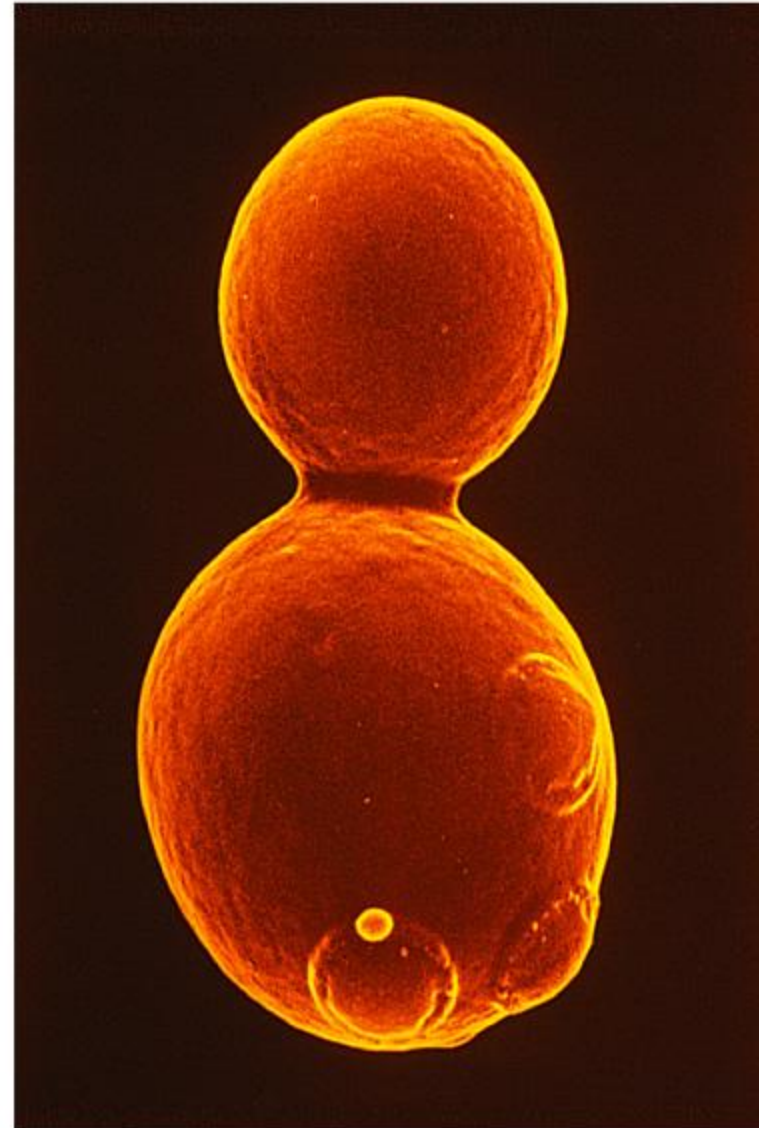
- **In addition to sexual reproduction, many fungi can reproduce asexually**
- **Molds produce haploid spores by mitosis and form visible mycelia**



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- **Other fungi that can reproduce asexually are yeasts, which inhabit moist environments**
 - **Instead of producing spores, yeasts reproduce asexually by simple cell division and the pinching of “bud cells” from a parent cell**



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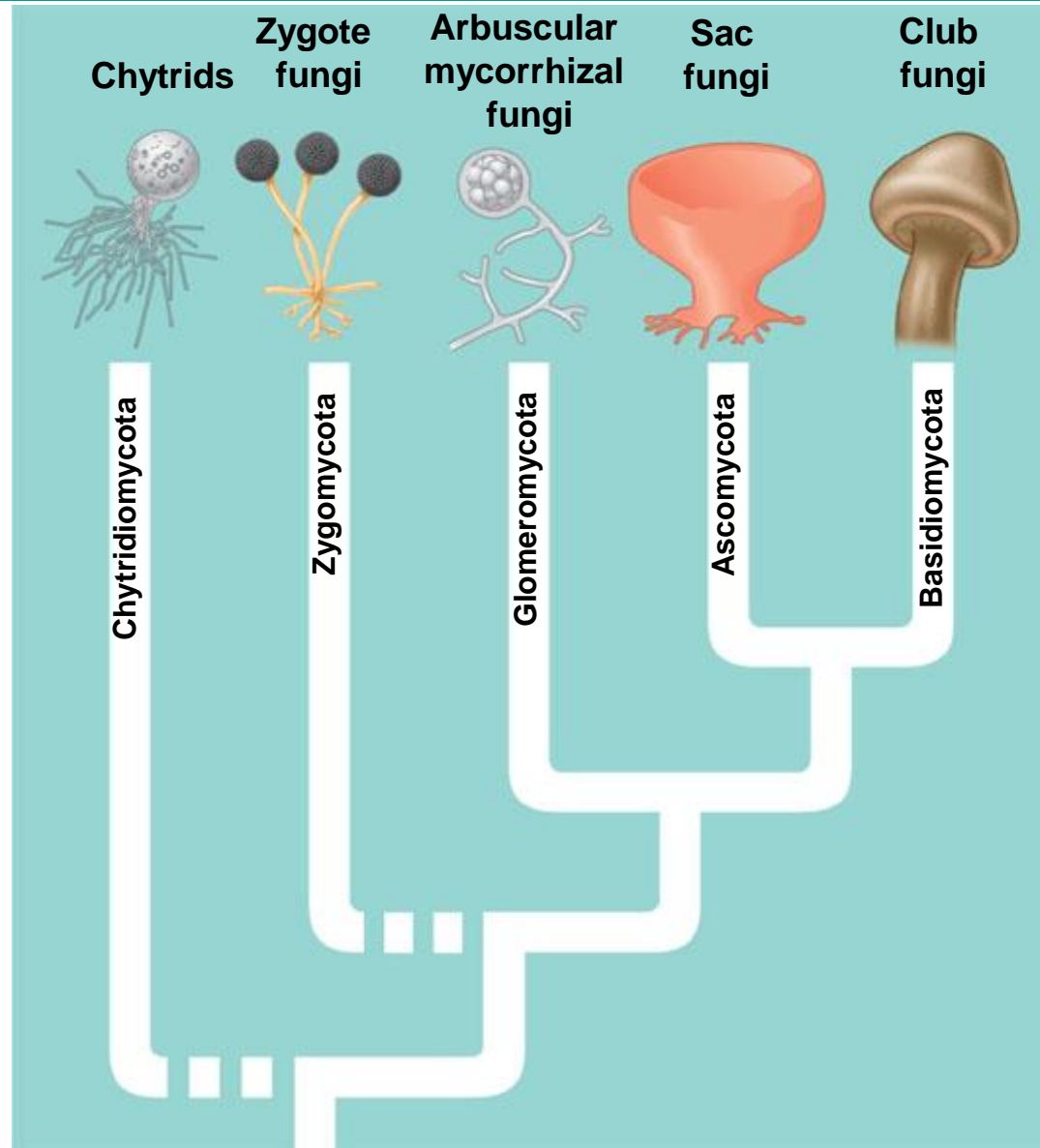
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- **Many molds and yeasts have no known sexual stage**
 - **Mycologists have traditionally called these deuteromycetes, or imperfect fungi**

Fungal diversity

- **Molecular analyses have helped clarify evolutionary relationships among fungal groups, although areas of uncertainty remain**

The phylogeny of fungi



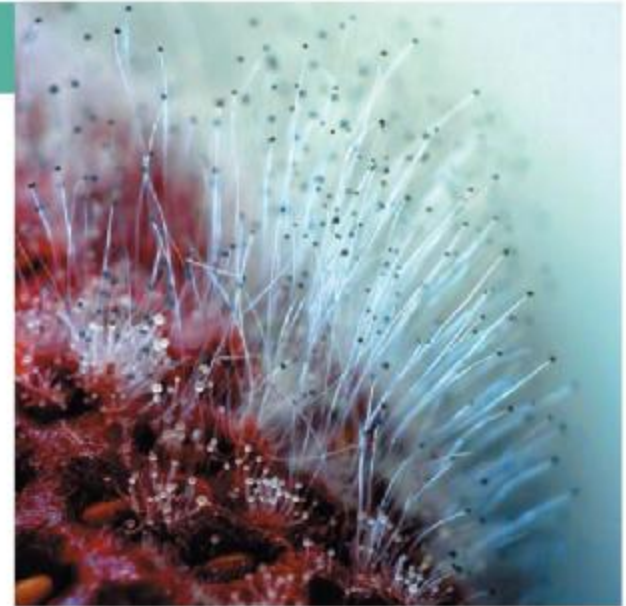
Chytrids (1,000 species)

Hyphae

25 μm

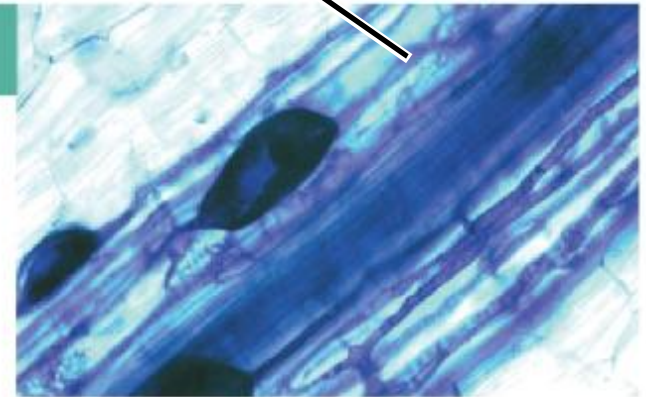


Zygomycetes (1,000 species)



Glomeromycetes (160 species)

Fungal hypha



Ascomycetes (65,000 species)

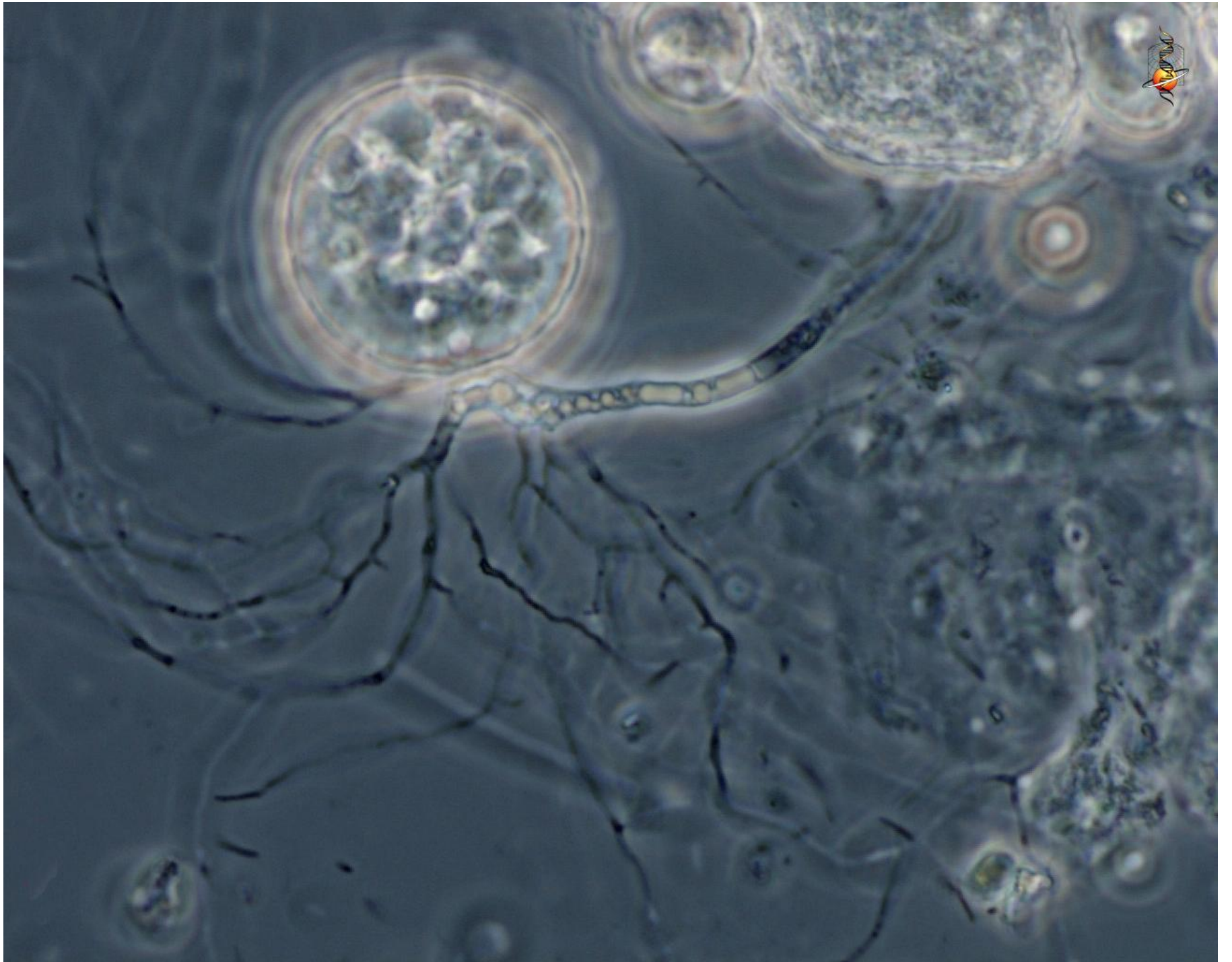


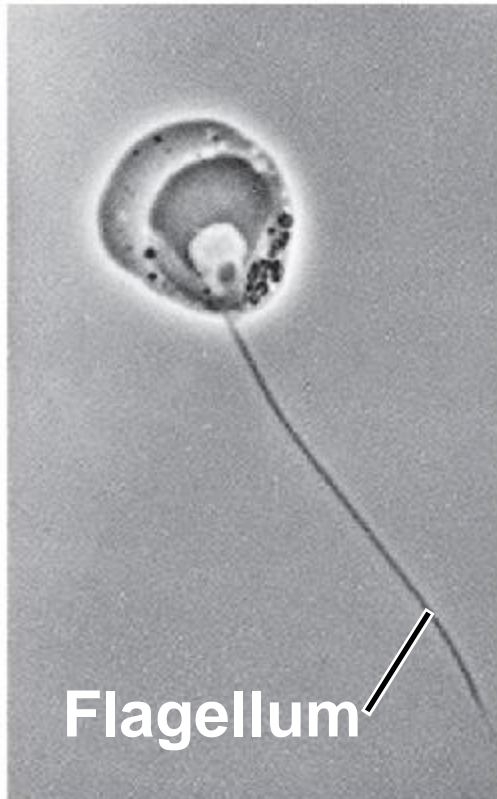
Basidiomycetes (30,000 species)



Chytrids

- **Chytrids (phylum Chytridiomycota) are found in freshwater and terrestrial habitats**
- **They can be decomposers, parasites, or mutualists**
- **Molecular evidence supports the hypothesis that chytrids diverged early in fungal evolution**
- **Chytrids are unique among fungi in having flagellated spores, called zoospores**





Flagellum

4 μm

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- **Until recently, systematists thought that fungi lost flagella only once in their evolutionary history**
 - **Molecular data indicate that some “chytrids” are actually more closely related to another fungal group, the zygomycetes; chytrids are a paraphyletic group**

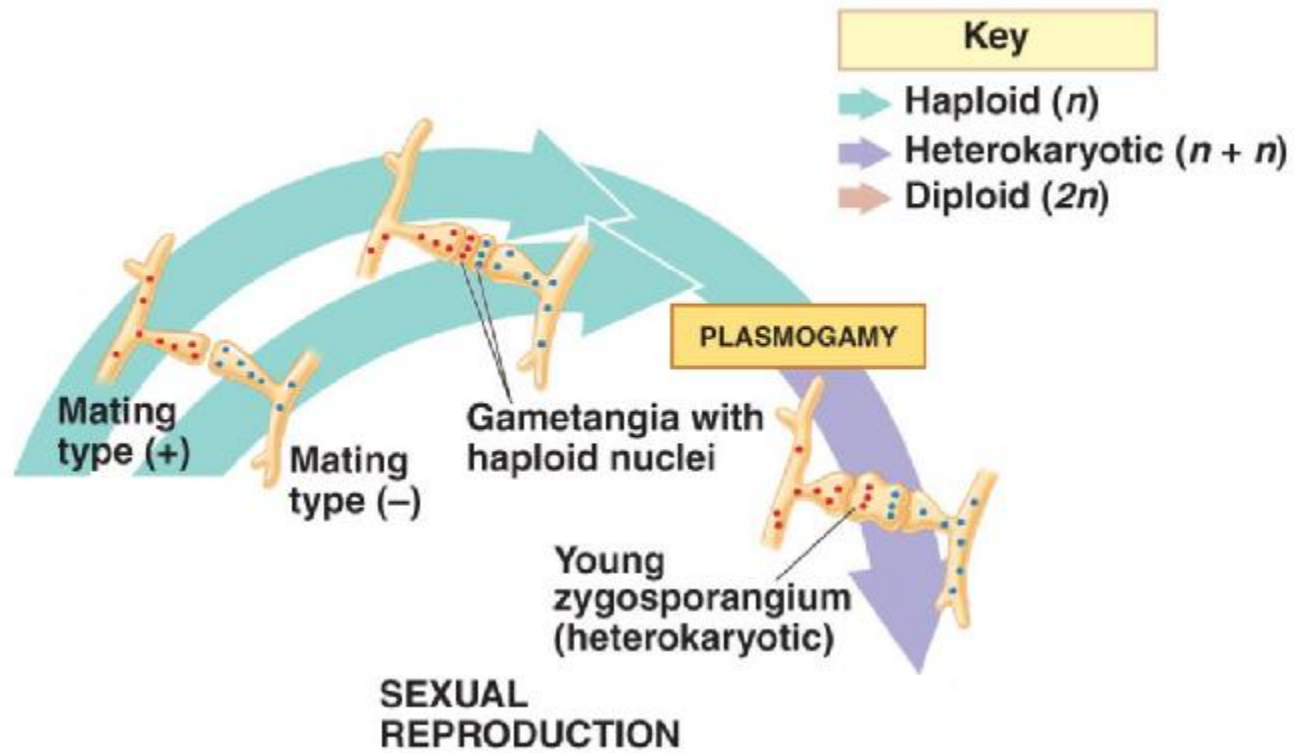
Zygomycetes

- **The zygomycetes (phylum Zygomycota) exhibit great diversity of life histories**
- **They include fast-growing molds, parasites, and commensal symbionts**
- **The zygomycetes are named for their sexually produced zygosporangia**
- **Zygosporangia, which are resistant to freezing and drying, can survive unfavorable conditions**

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- The life cycle of black bread mold (*Rhizopus stolonifer*) is fairly typical of the phylum

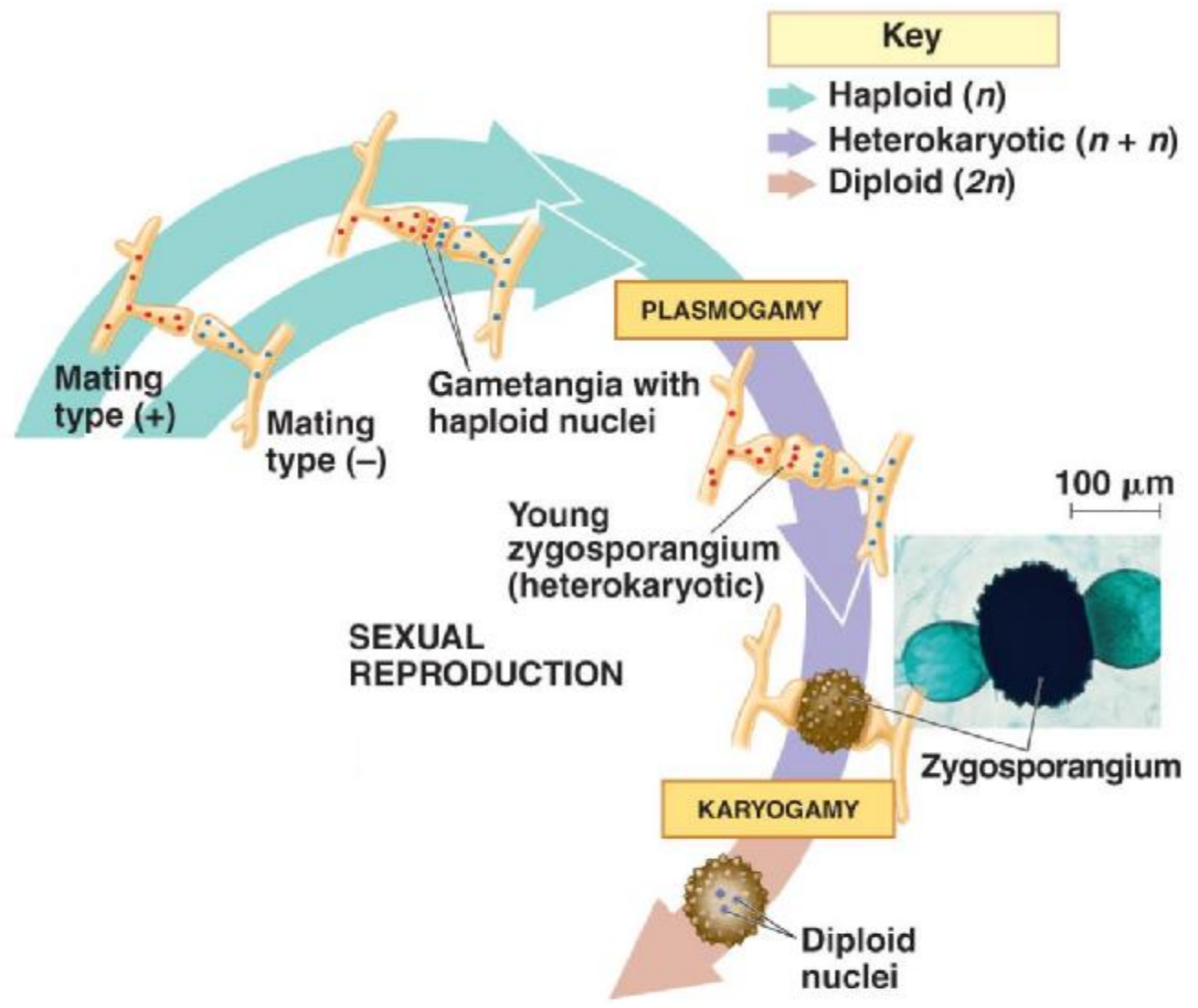


Rhizopus
growing
on bread



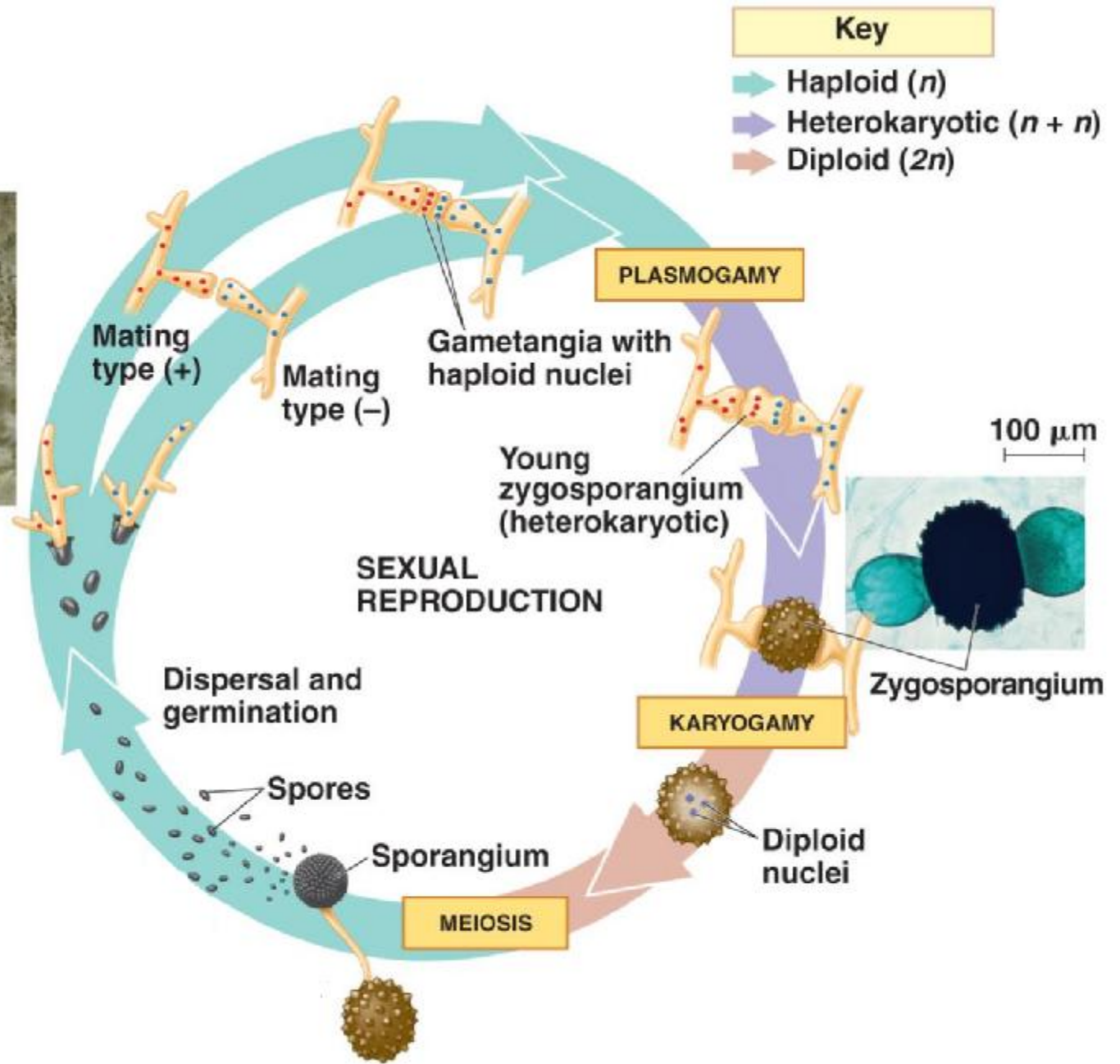


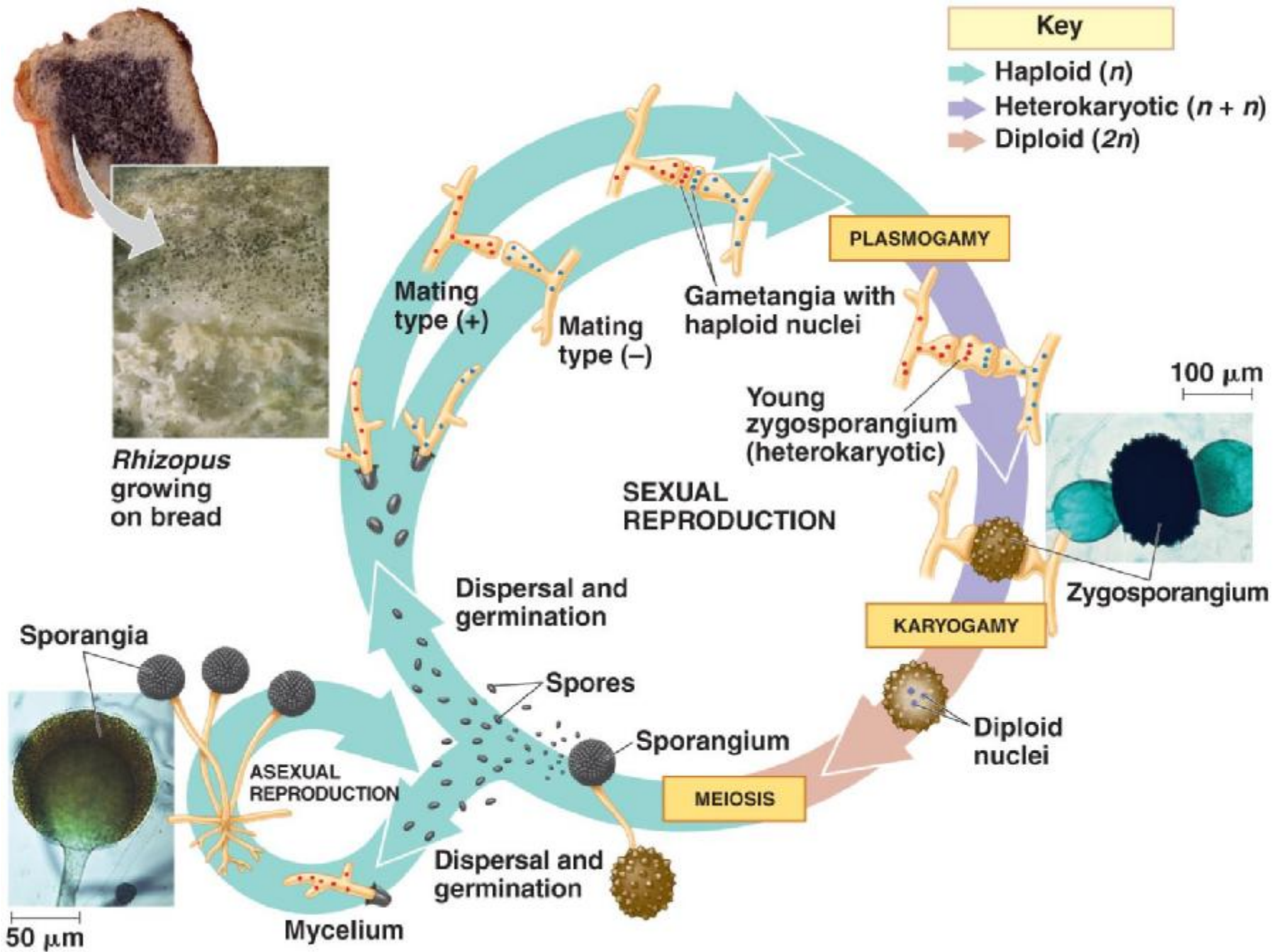
Rhizopus
growing
on bread



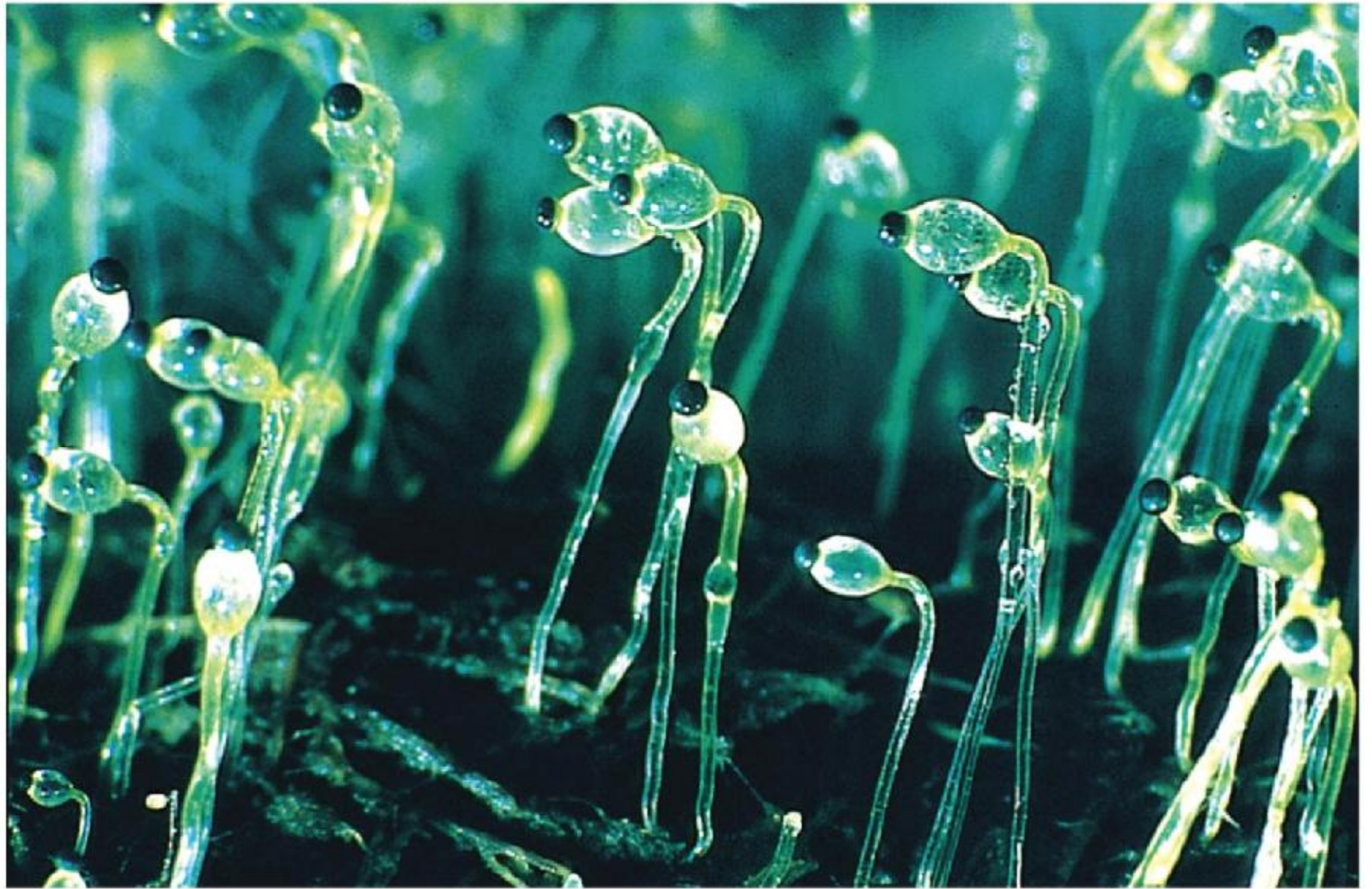


Rhizopus
growing
on bread



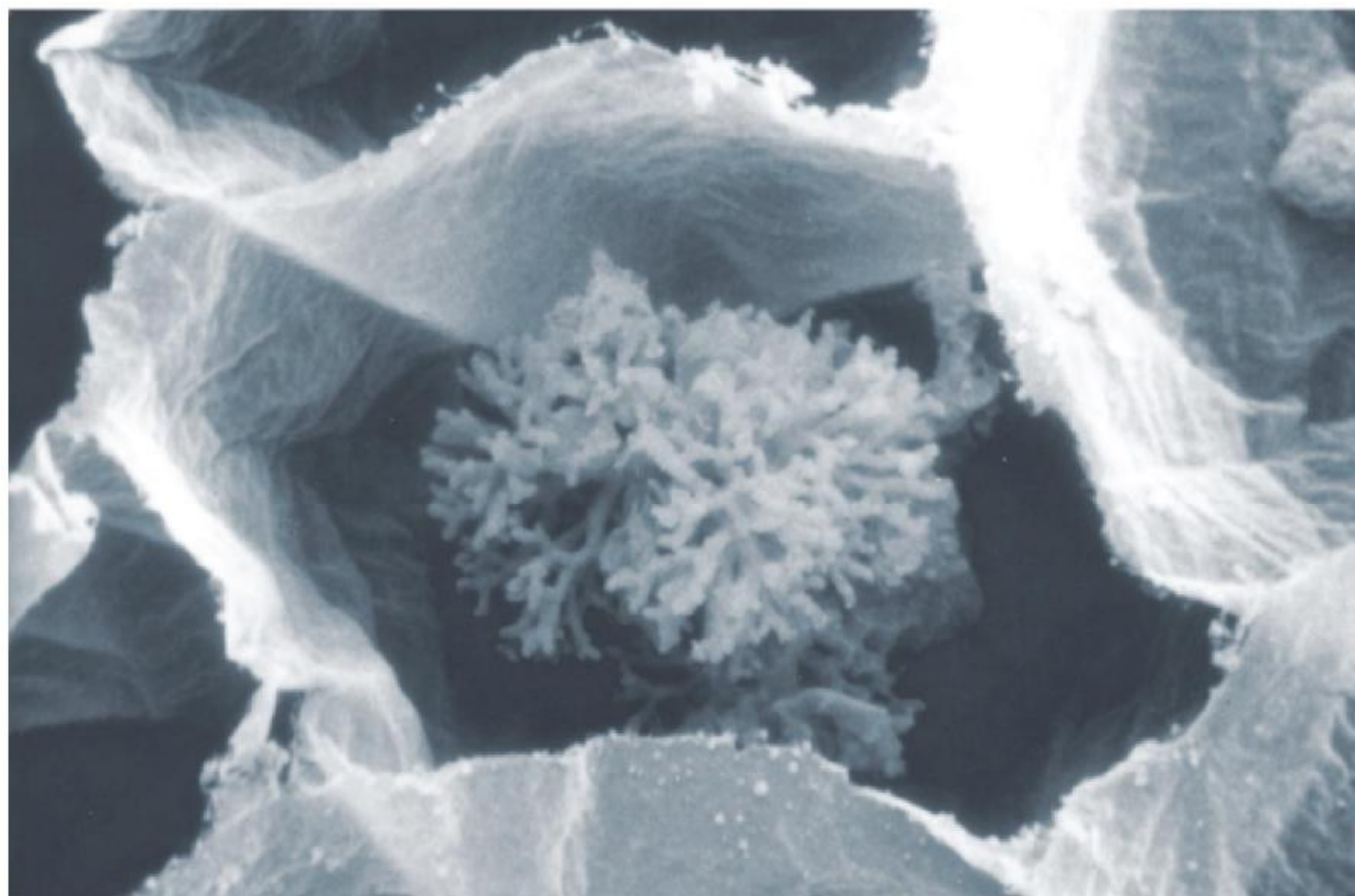


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- Some zygomycetes, such as *Pilobolus*, can actually “aim” their sporangia toward conditions associated with good food sources



Glomeromycetes

- **The glomeromycetes (phylum Glomeromycota) were once considered zygomycetes**
- **They are now classified in a separate clade**
- **Glomeromycetes form arbuscular mycorrhizae**



2.5 μm

Ascomycetes

- **Ascomycetes (phylum Ascomycota) live in marine, freshwater, and terrestrial habitats**
- **The phylum is defined by production of sexual spores in saclike asci, usually contained in fruiting bodies called ascocarps**
- **Ascomycetes are commonly called sac fungi**
- **Ascomycetes vary in size and complexity from unicellular yeasts to elaborate cup fungi and morels**

***Morchella esculenta*,**
the tasty morel



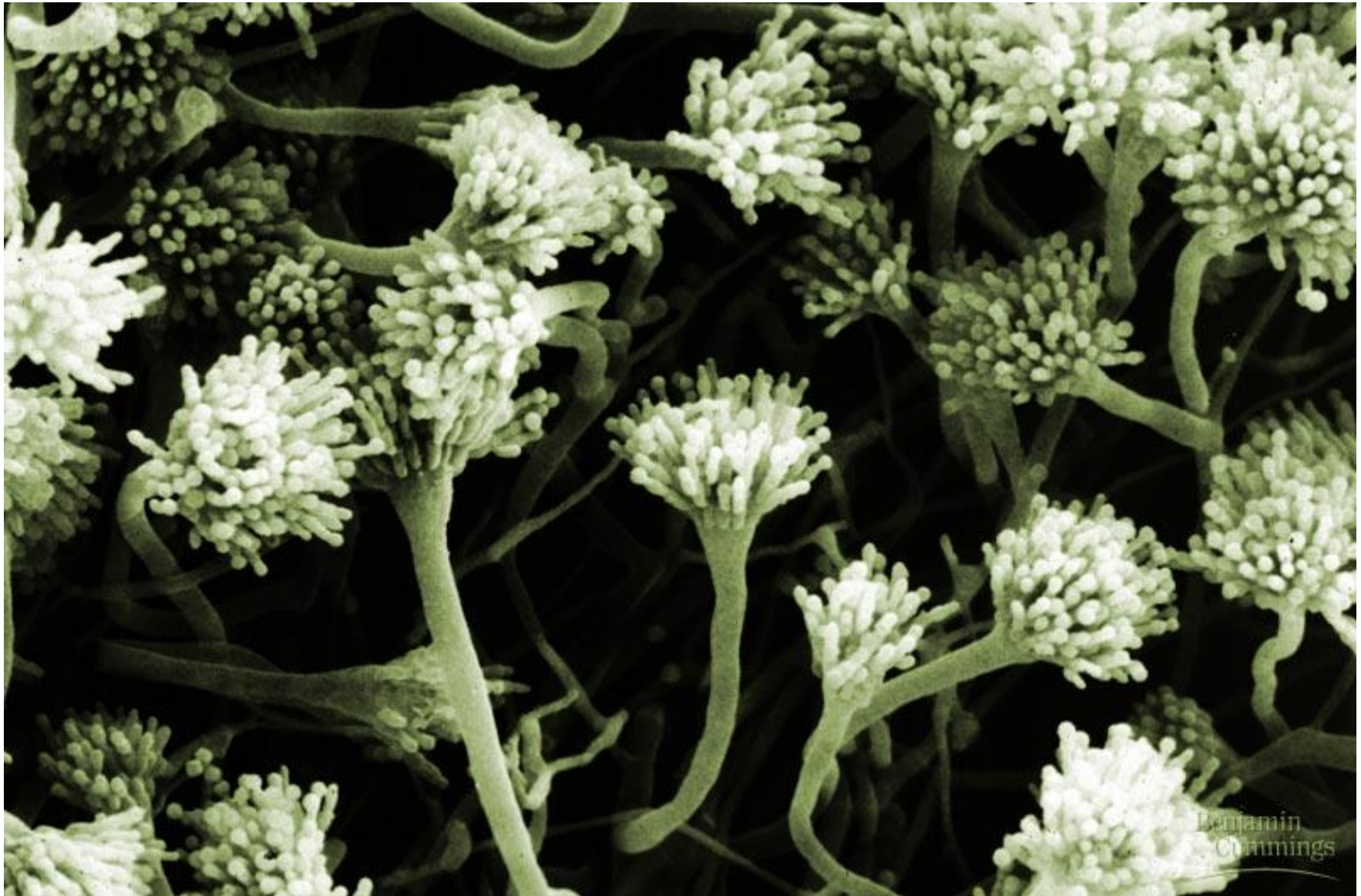
***Tuber melanosporum*, a truffle**



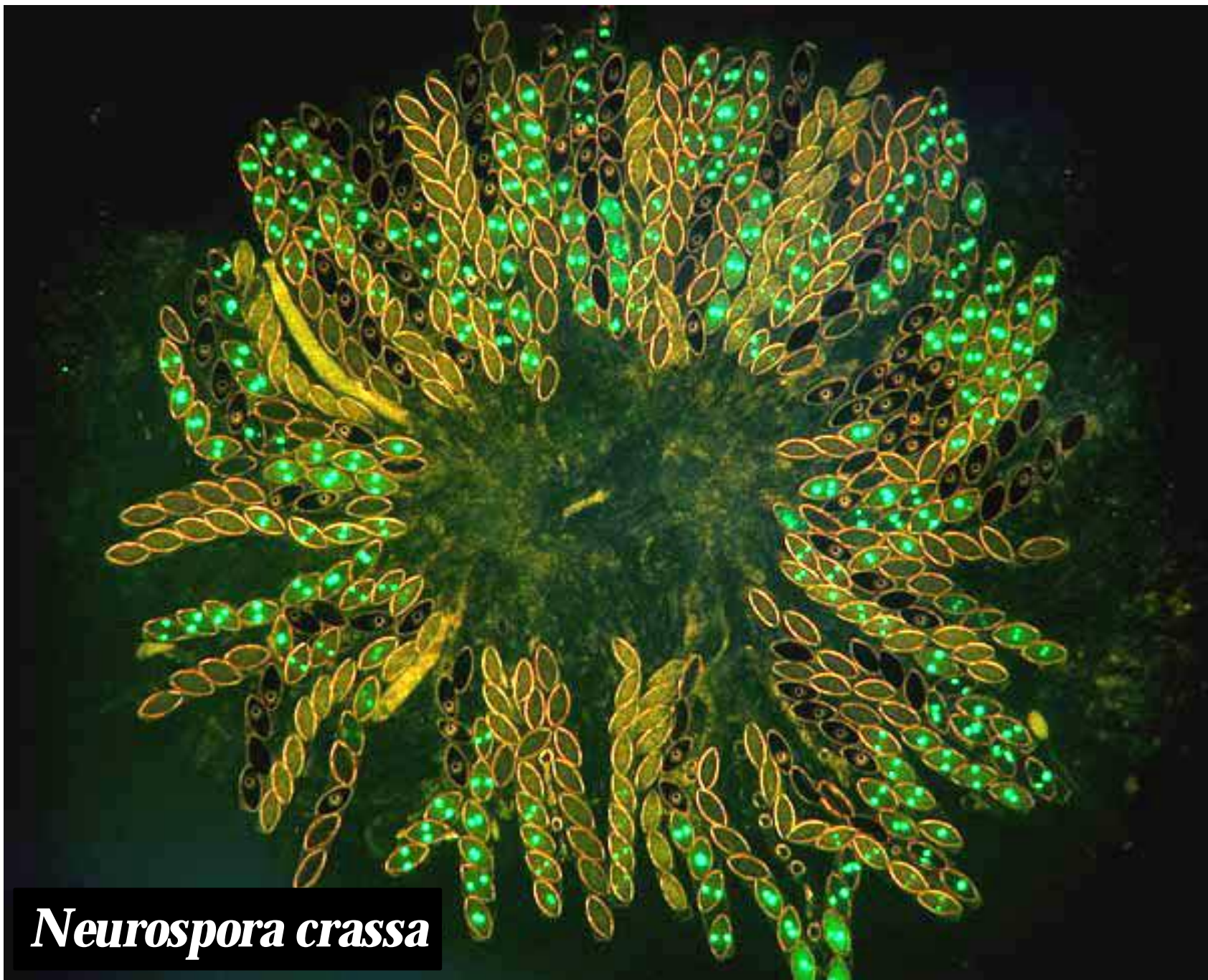
Peziza badia



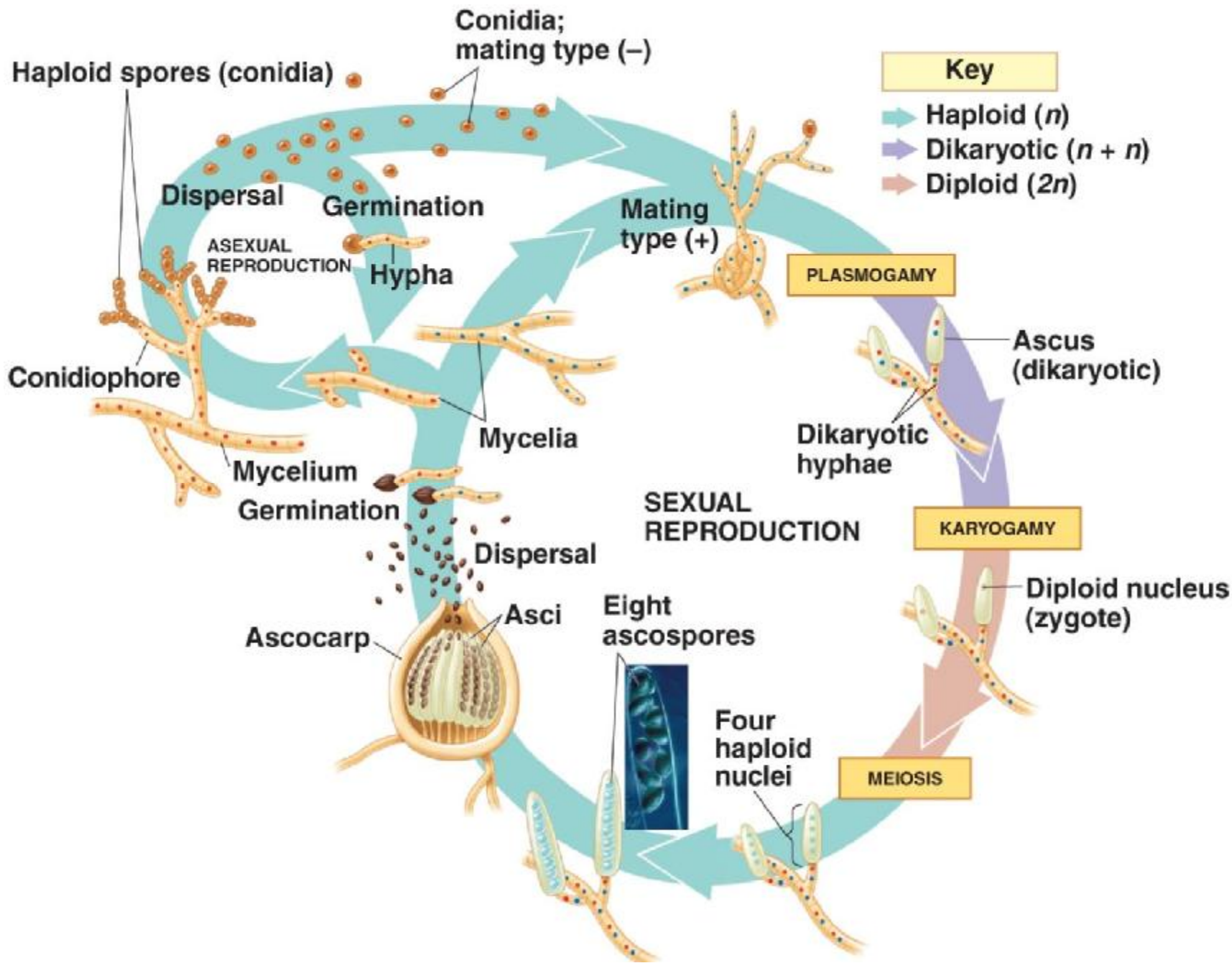
Aspergillus



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- **Ascomycetes include plant pathogens, decomposers, and symbionts**
 - **Ascomycetes reproduce asexually by enormous numbers of asexual spores called conidia**
 - **Conidia are not formed inside sporangia; they are produced asexually at the tips of specialized hyphae called conidiophores**
 - ***Neurospora* is a model organism with a well-studied genome**



Neurospora crassa



Basidiomycetes

- **Basidiomycetes (phylum Basidiomycota) include mushrooms, puffballs, and shelf fungi, mutualists, and plant parasites**
- **The phylum is defined by a clublike structure called a basidium, a transient diploid stage in the life cycle**
- **The basidiomycetes are also called club fungi**

Maiden veil fungus (*Dictyophora*)





Puffballs



◀ Puffballs emitting spores

Sheft fungi



Amanita





Coprinus

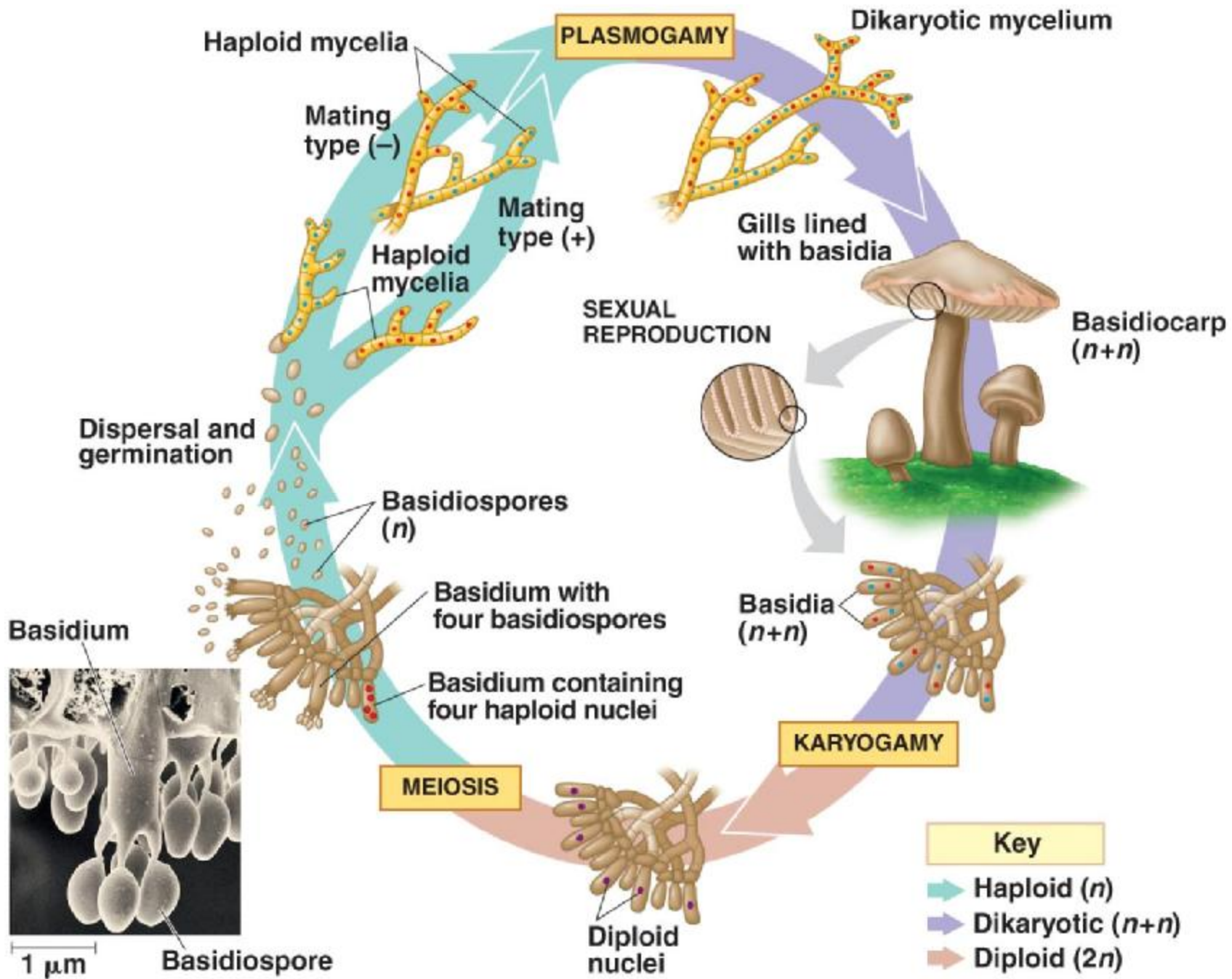


Trametes



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Roles of Fungi

- **Fungi play key roles in nutrient cycling, ecological interactions, and human welfare**
- **Fungi interact with other organisms in many ways**

Fungi as Decomposers

- **Fungi are efficient decomposers**
- **They perform essential recycling of chemical elements between the living and nonliving world**

Fungi as Mutualists

- **Fungi form mutualistic relationships with plants, algae, cyanobacteria, and animals**
- **All of these relationships have profound ecological effects**

Fungus-Plant Mutualisms

- **Mycorrhizae are enormously important in natural ecosystems and agriculture**
- **Plants harbor harmless symbiotic endophytes that live inside leaves or other plant parts**
- **Endophytes make toxins that deter herbivores and defend against pathogens**

Fungus-Animal Symbioses

- **Some fungi share their digestive services with animals**
- **These fungi help break down plant material in the guts of cows and other grazing mammals**
- **Many species of ants and termites use the digestive power of fungi by raising them in “farms”**



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Lichens

- **A lichen is a symbiotic association between a photosynthetic microorganism and a fungus in which millions of photosynthetic cells are held in a mass of fungal hyphae**

A fruticose (shrublike) lichen





Crustose (encrusting) lichens



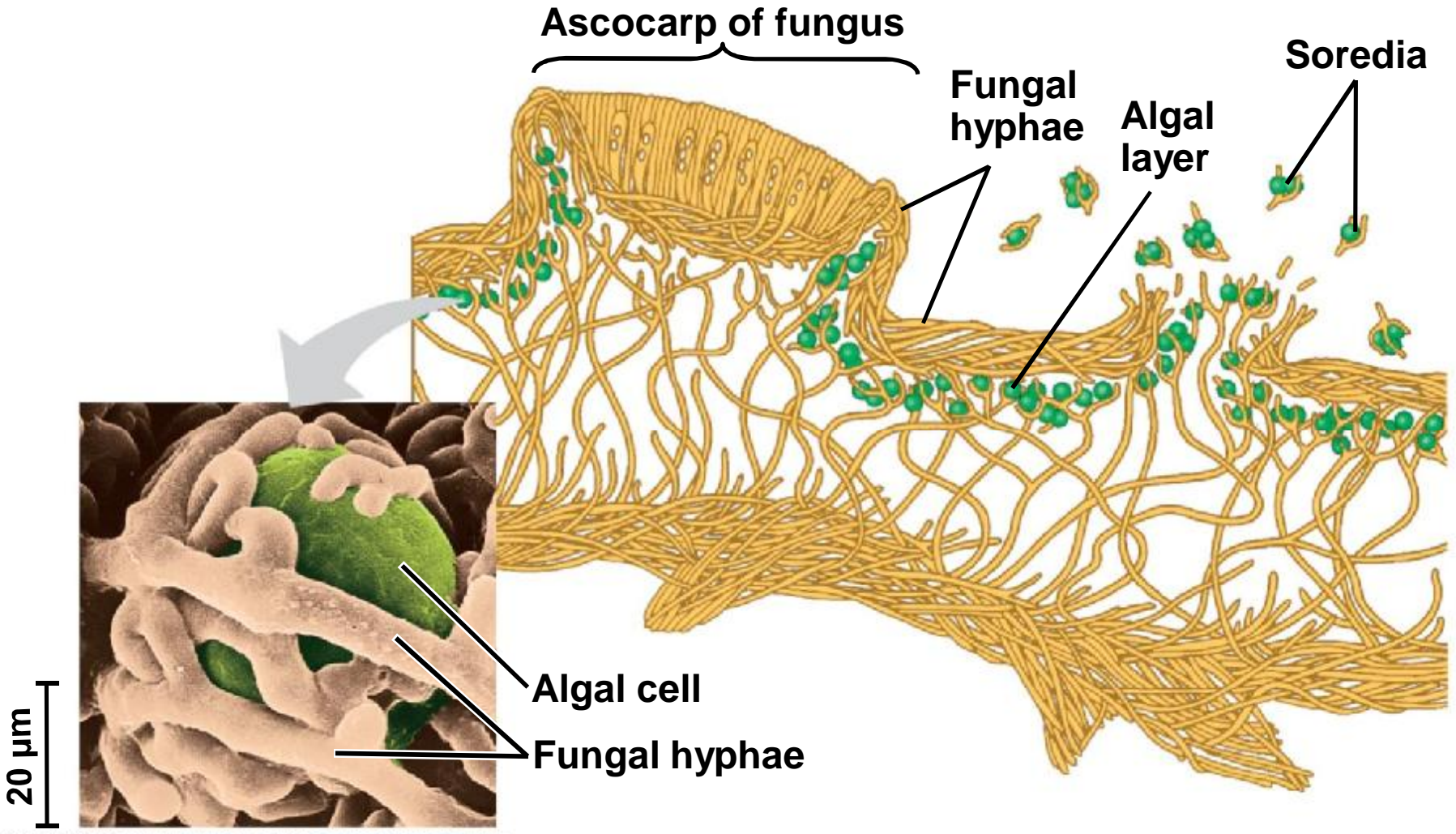


A foliose (leaflike) lichen





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- **The fungal component of a lichen is most often an ascomycete**
 - **Algae or cyanobacteria occupy an inner layer below the lichen surface**



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- **The algae provide carbon compounds, cyanobacteria provide organic nitrogen, and fungi provide the environment for growth**
 - **The fungi of lichens can reproduce sexually and asexually**
 - **Asexual reproduction is by fragmentation or the formation of soredia, small clusters of hyphae with embedded algae**

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- **Lichens are important pioneers on new rock and soil surfaces**
 - **Lichens are sensitive to pollution, and their death can be a warning that air quality is deteriorating**

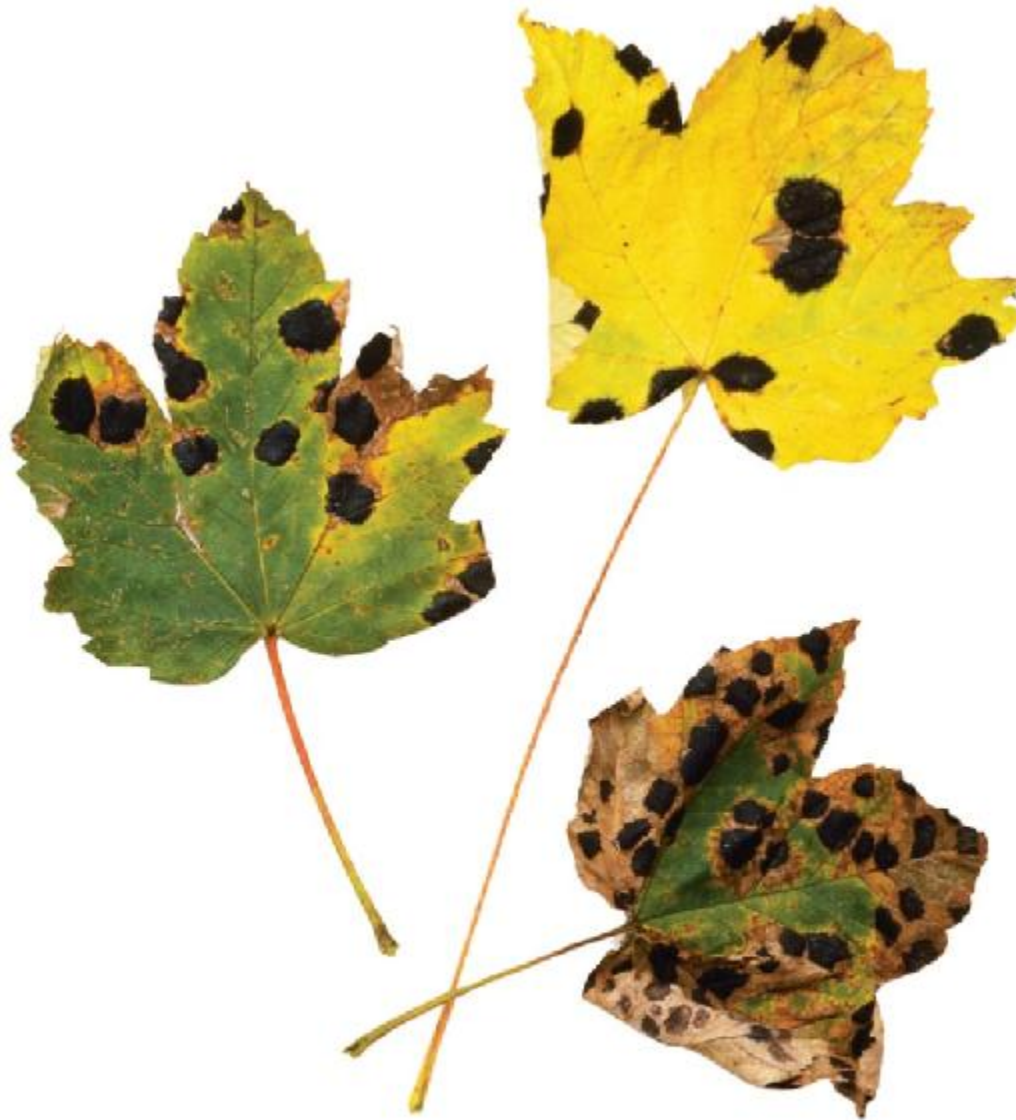
Fungi as Pathogens

- **About 30% of known fungal species are parasites or pathogens, mostly on or in plants**
- **Some fungi that attack food crops are toxic to humans**
- **Animals are much less susceptible to parasitic fungi than are plants**
- **The general term for a fungal infection in animals is mycosis**



(a) Corn smut on corn

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**(b) Tar spot fungus on
maple leaves**



(c) Ergots on rye

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Practical Uses of Fungi

- Humans eat many fungi and use others to make cheeses, alcoholic beverages, and bread
- Some fungi are used to produce antibiotics for the treatment of bacterial infections, for example the ascomycete *Penicillium*
- Genetic research on fungi is leading to applications in biotechnology
 - For example, insulin-like growth factor can be produced in the fungus *Saccharomyces cerevisiae*

Penicillium



Staphylococcus

Penicillium

Zone of inhibited growth

