Chapter 31

Fungi

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Mighty Mushrooms

- 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

Fig. 31-1

Concept 31.1: Fungi are heterotrophs that feed by absorption

- 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
- The versatility of these enzymes contributes to fungi's ecological success

- Fungi exhibit diverse lifestyles:
  - Decomposers
  - Parasites
  - Mutualists

Body Structure

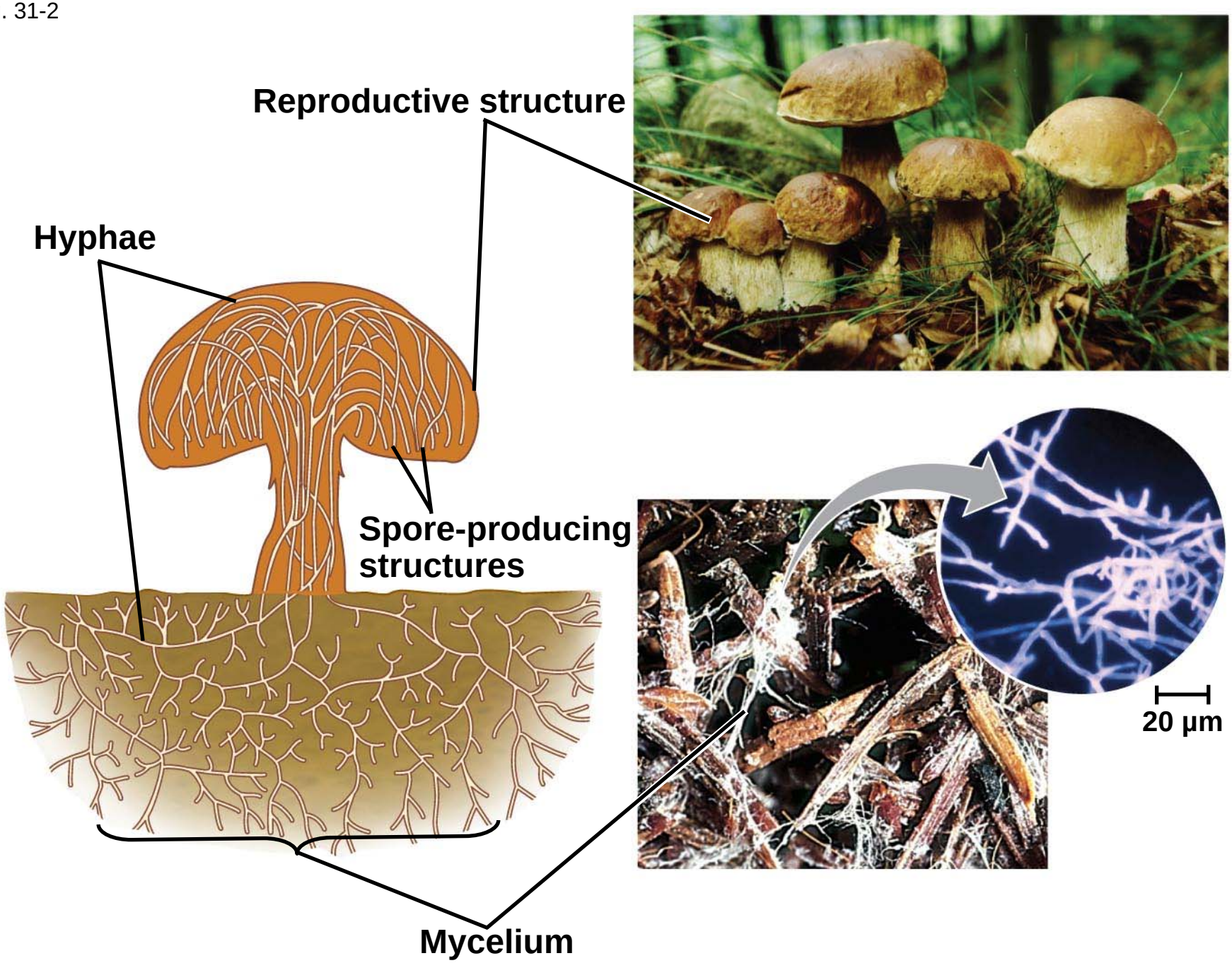
- The most common body structures are multicellular filaments and single cells (**yeasts**)
- Some species grow as either filaments or yeasts; others grow as both

PLAY Animation: Fungal Reproduction and Nutrition

Fungal Morphology

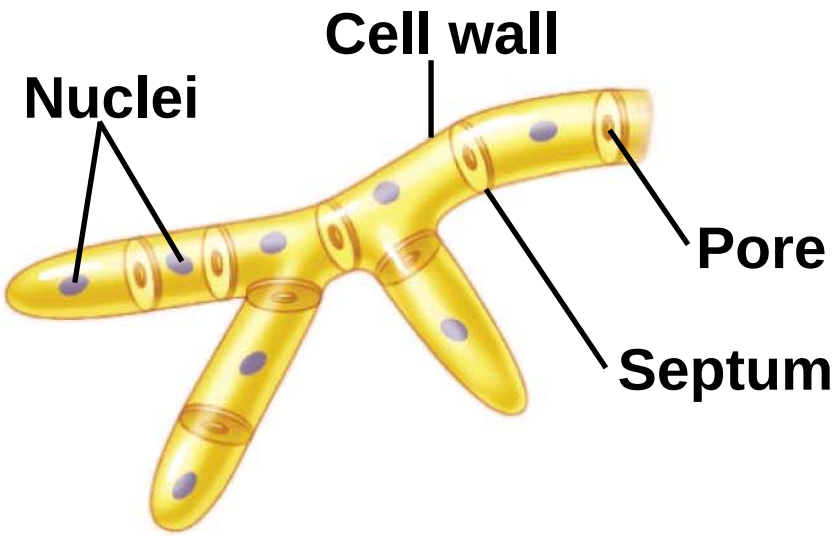
- The morphology of multicellular fungi enhances their ability to absorb nutrients
- Fungi consist of **mycelia**, networks of branched **hyphae** adapted for absorption
- Most fungi have cell walls made of **chitin**

Fig. 31-2

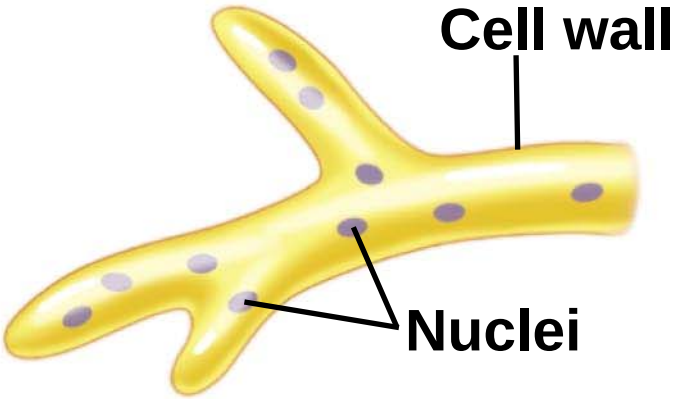


- Some fungi have hyphae divided into cells by **septa**, with pores allowing cell-to-cell movement of organelles
- **Coenocytic fungi** lack septa

Fig. 31-3



(a) Septate hypha

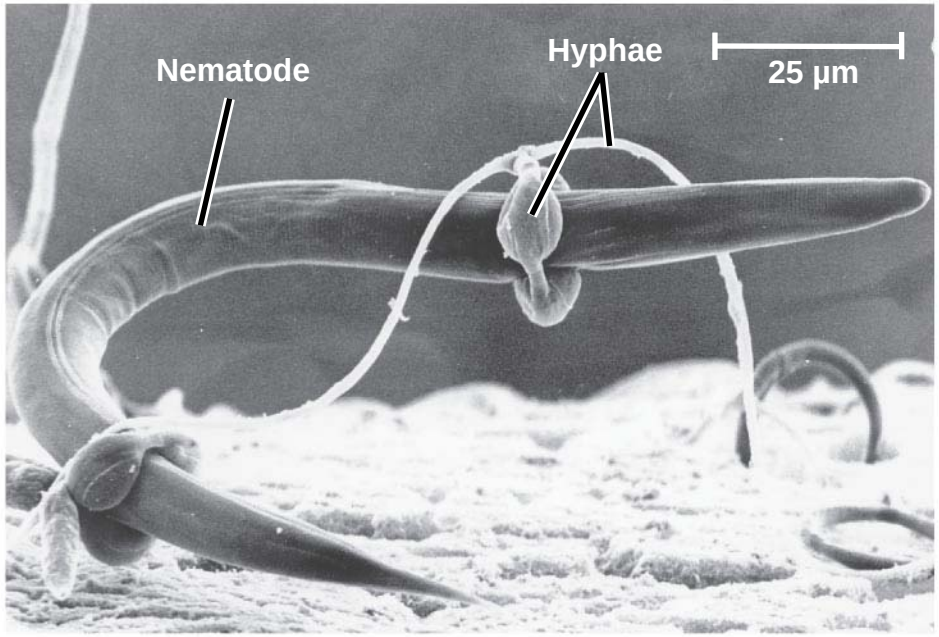


(b) Coenocytic hypha

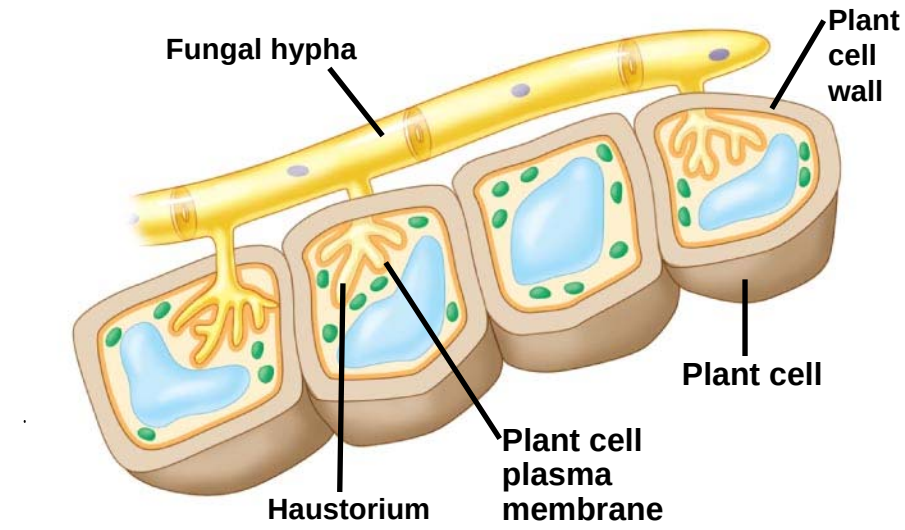
Specialized Hyphae in Mycorrhizal Fungi

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

Fig. 31-4

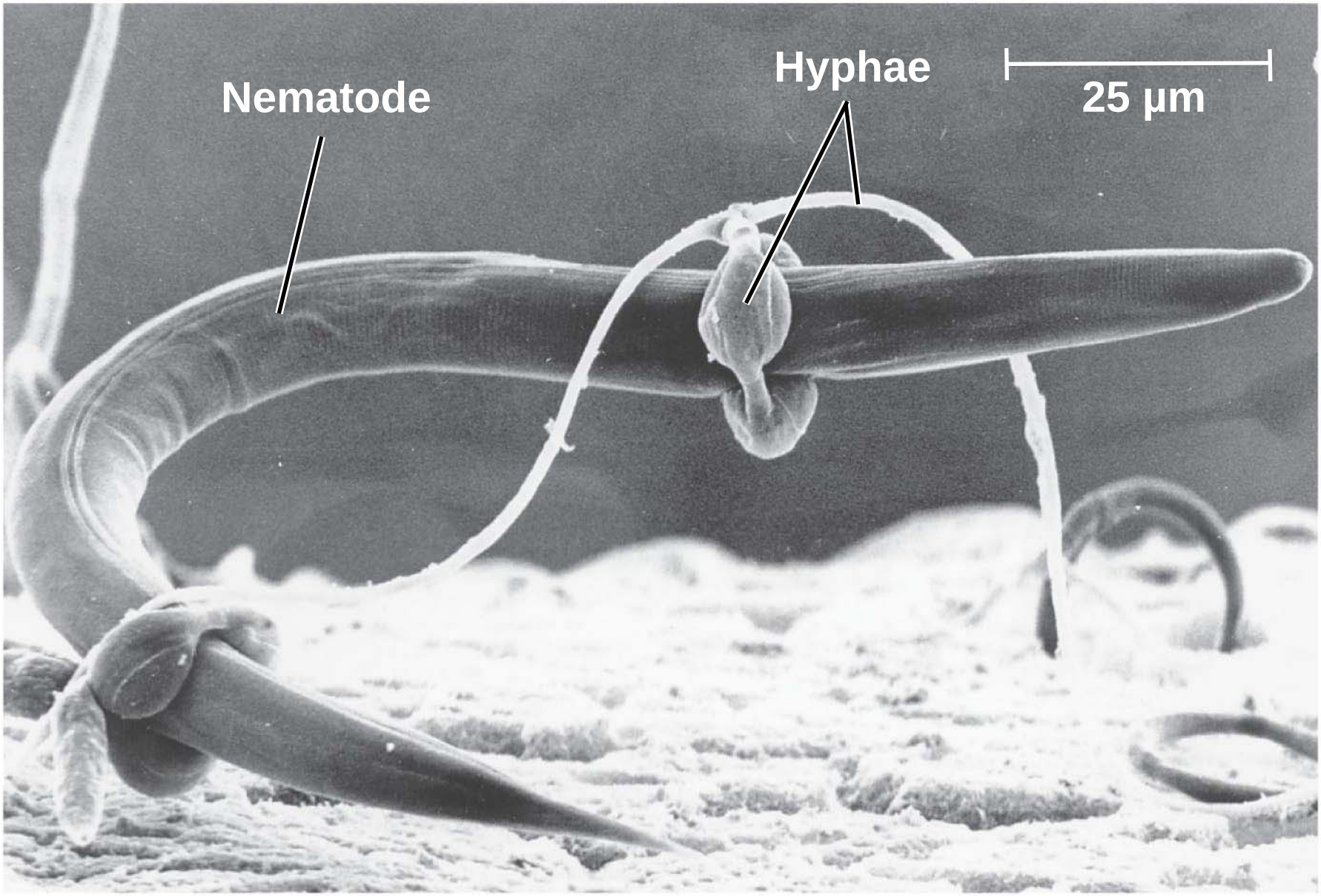


(a) Hyphae adapted for trapping and killing prey



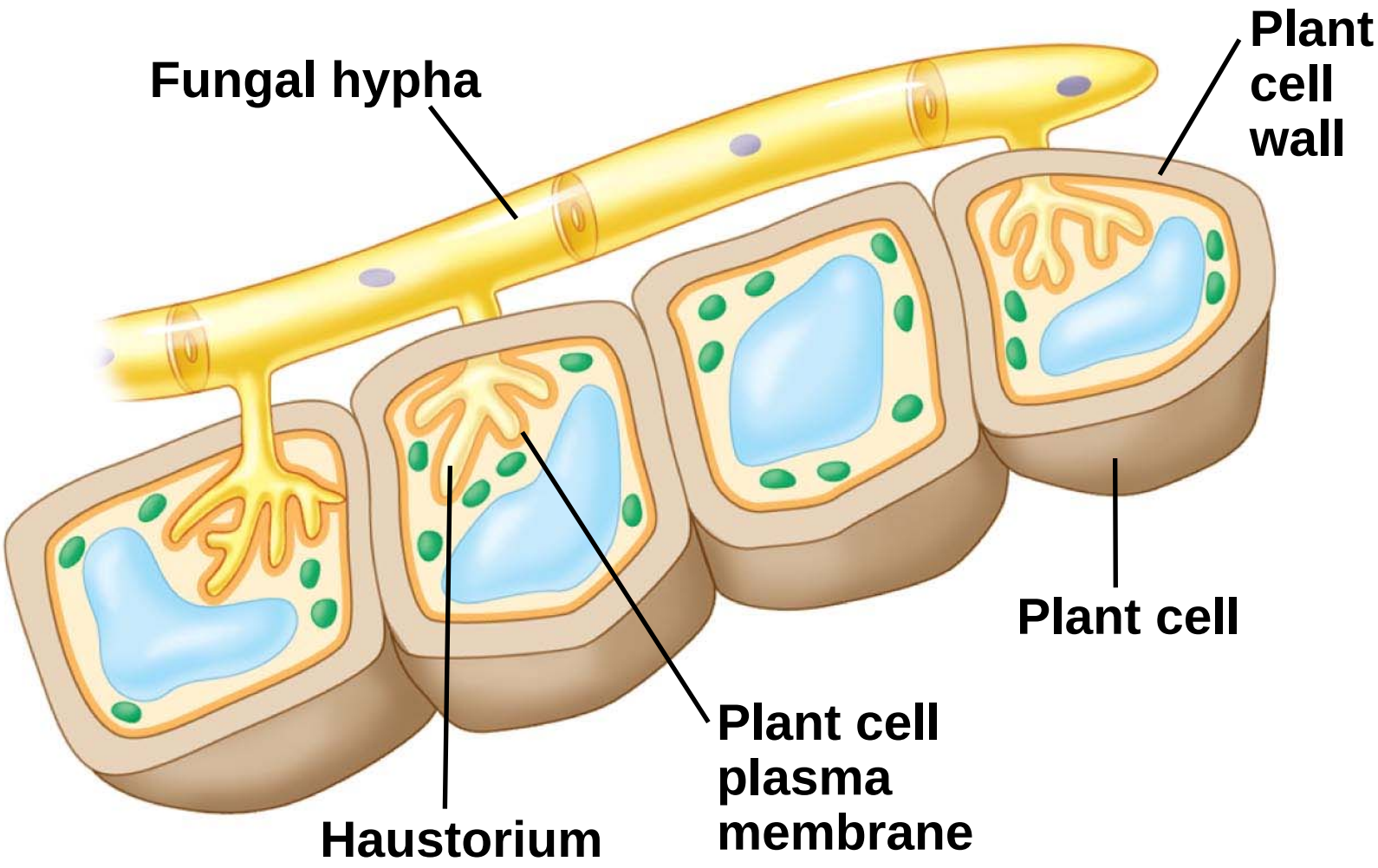
(b) Haustoria

Fig. 31-4a



(a) Hyphae adapted for trapping and killing prey

Fig. 31-4b



(b) Haustoria

- **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

Concept 31.2: Fungi produce spores through sexual or asexual life cycles

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

Fig. 31-5-1

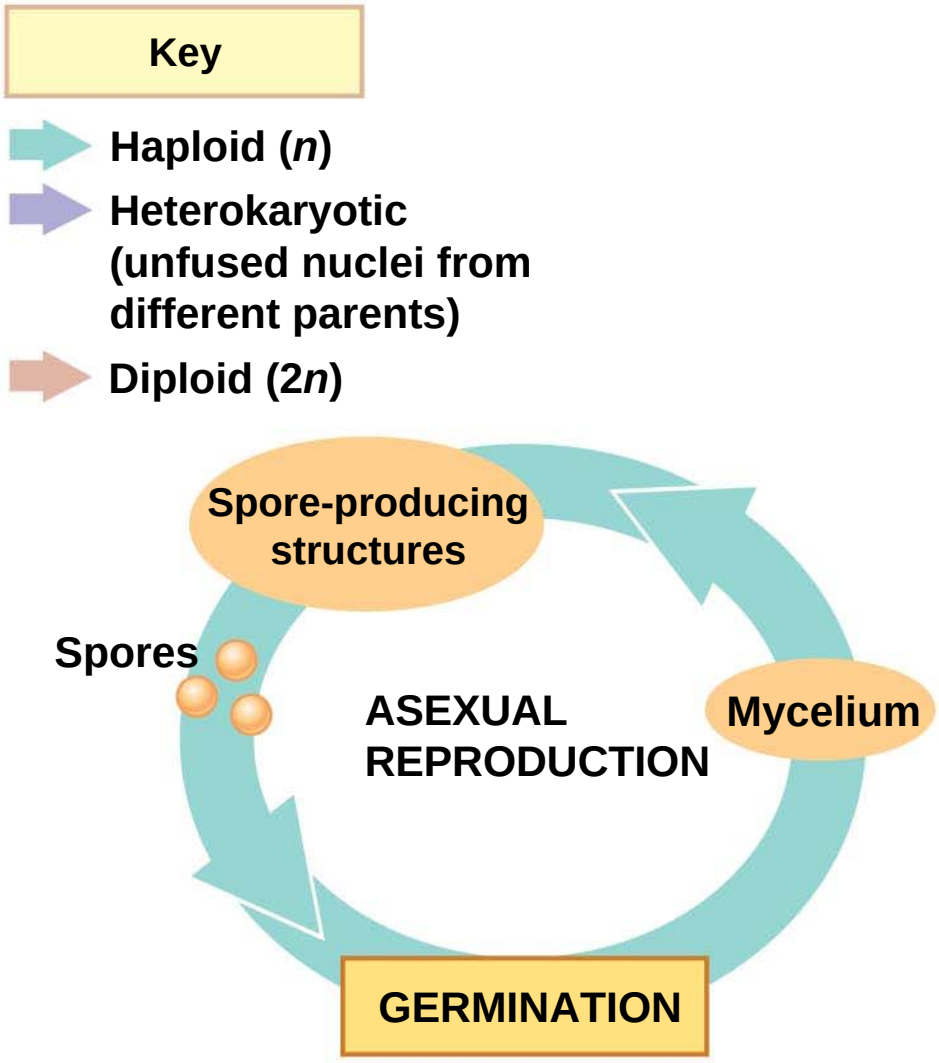


Fig. 31-5-2

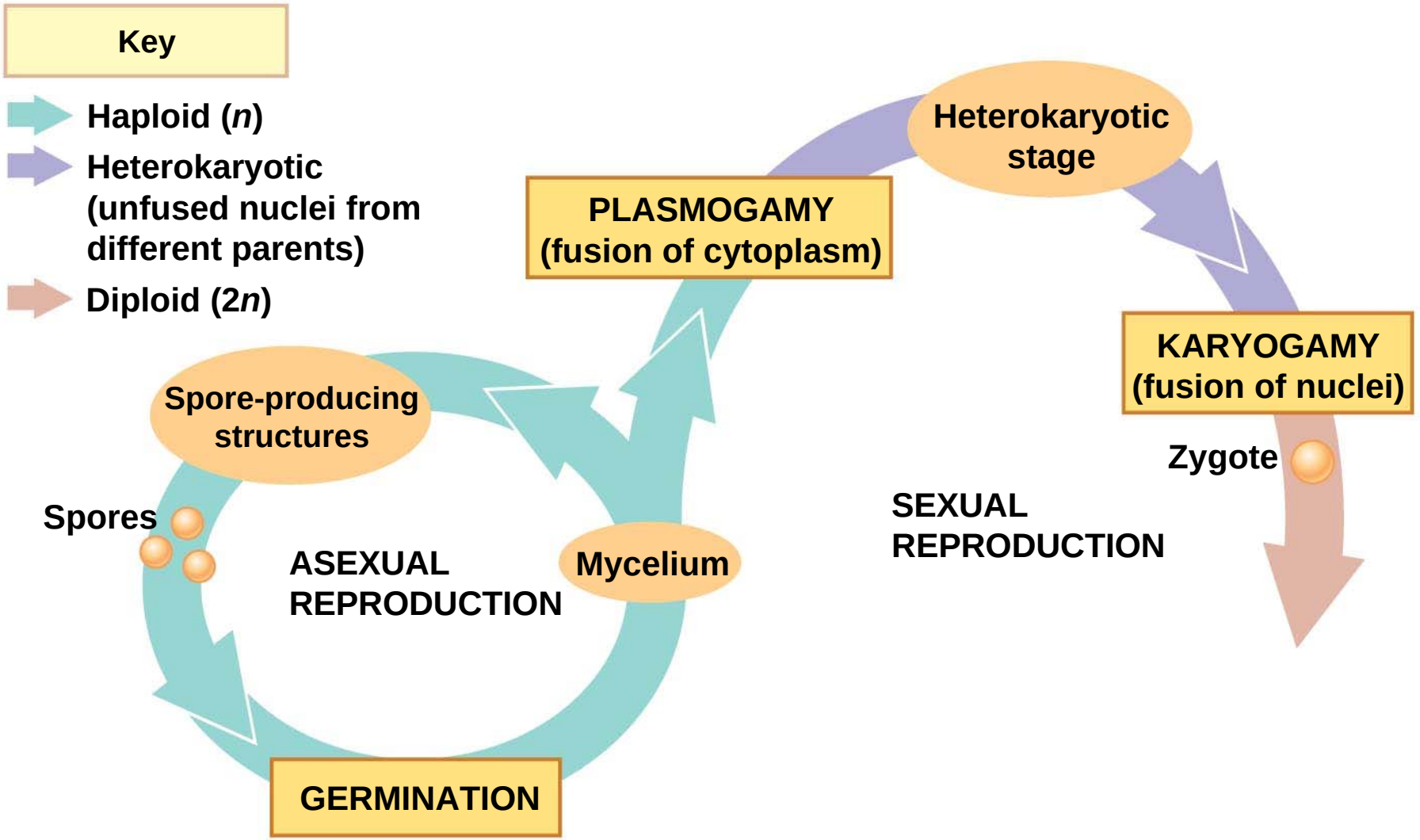
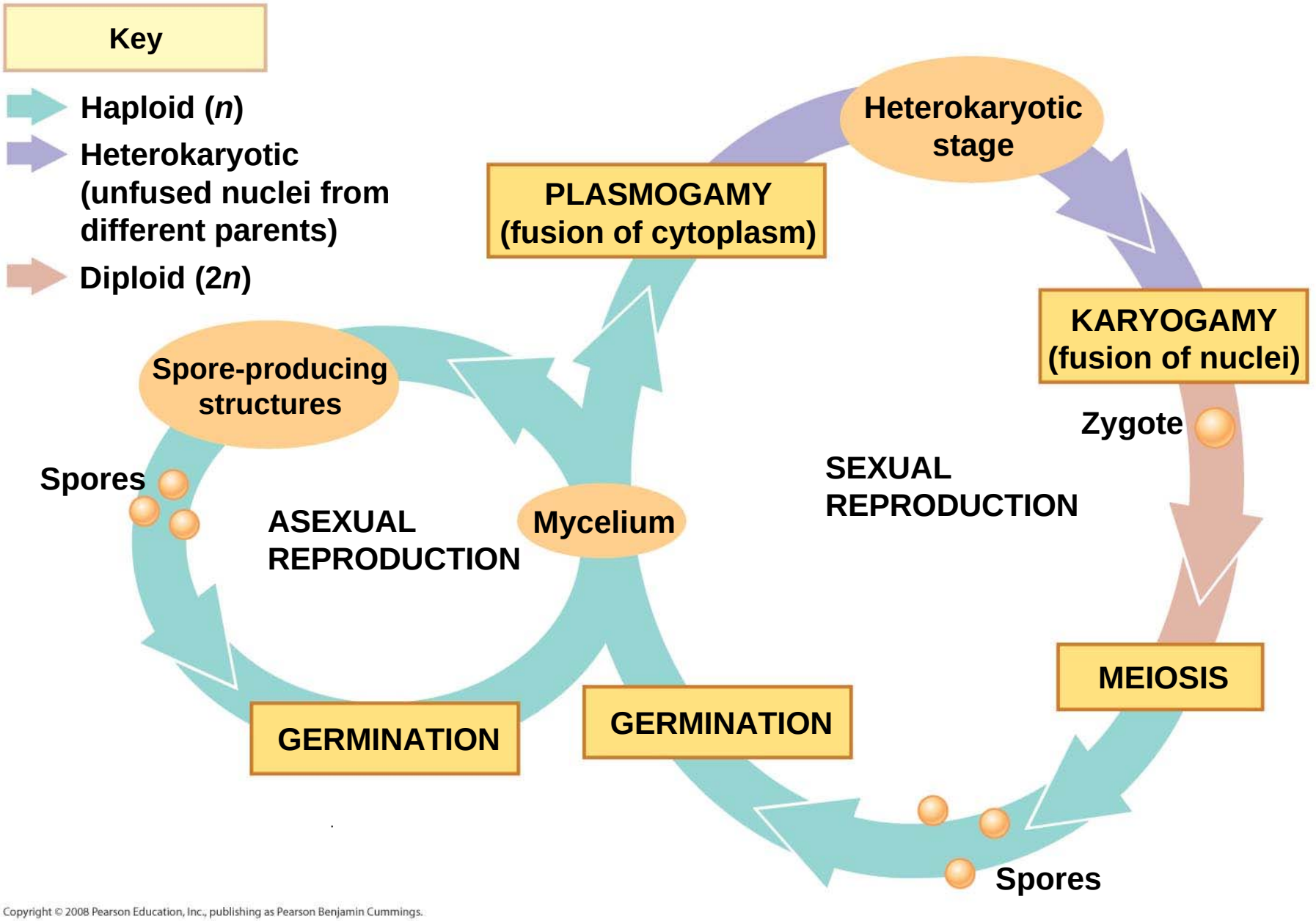


Fig. 31-5-3



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

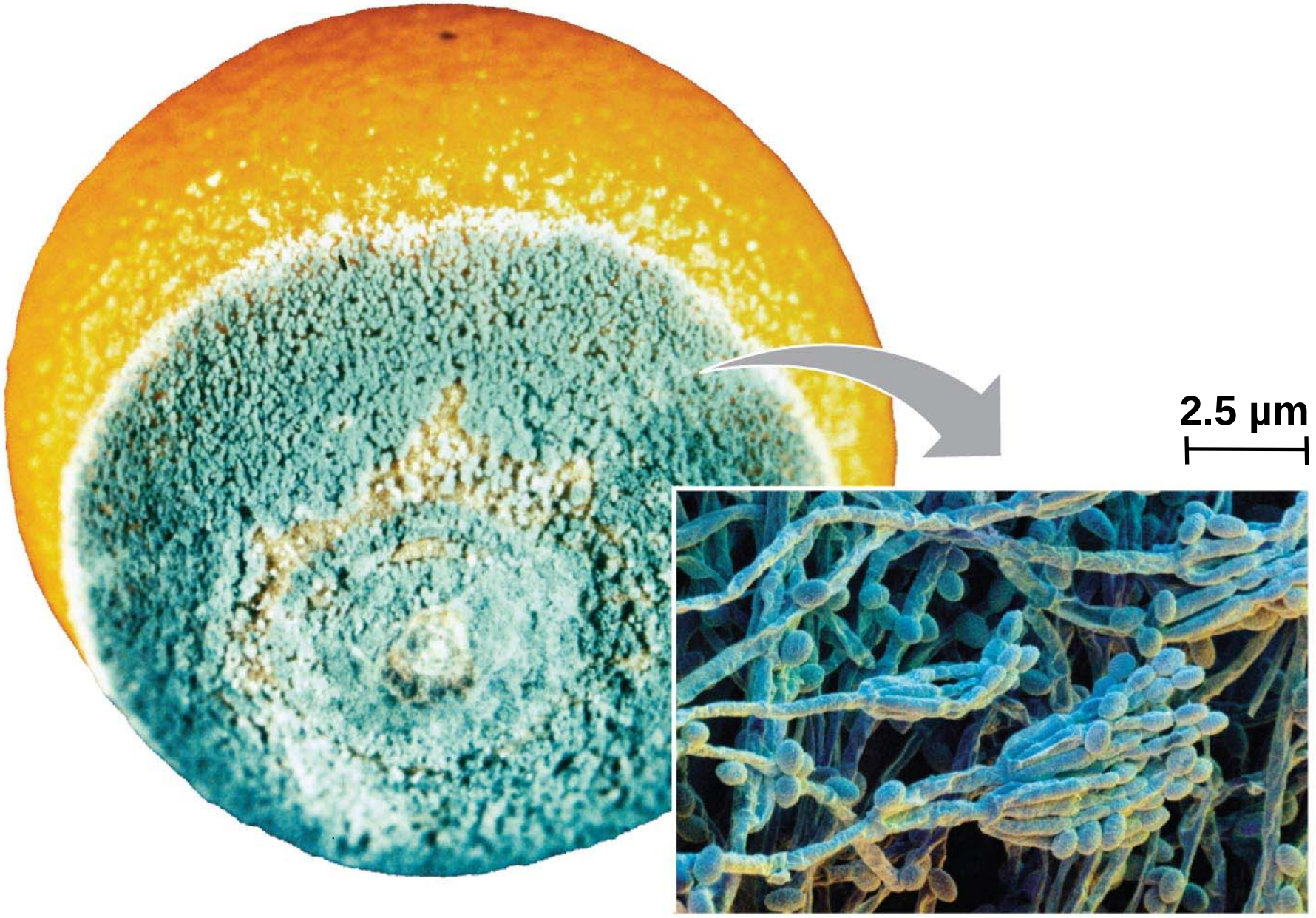
- **Plasmogamy** is the union of two parent mycelia
- In most fungi, the haploid nuclei from each parent do not fuse right away; they coexist in the mycelium, called a **heterokaryon**
- In some fungi, the haploid nuclei pair off two to a cell; such a mycelium is said to be **dikaryotic**

- 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

Asexual Reproduction

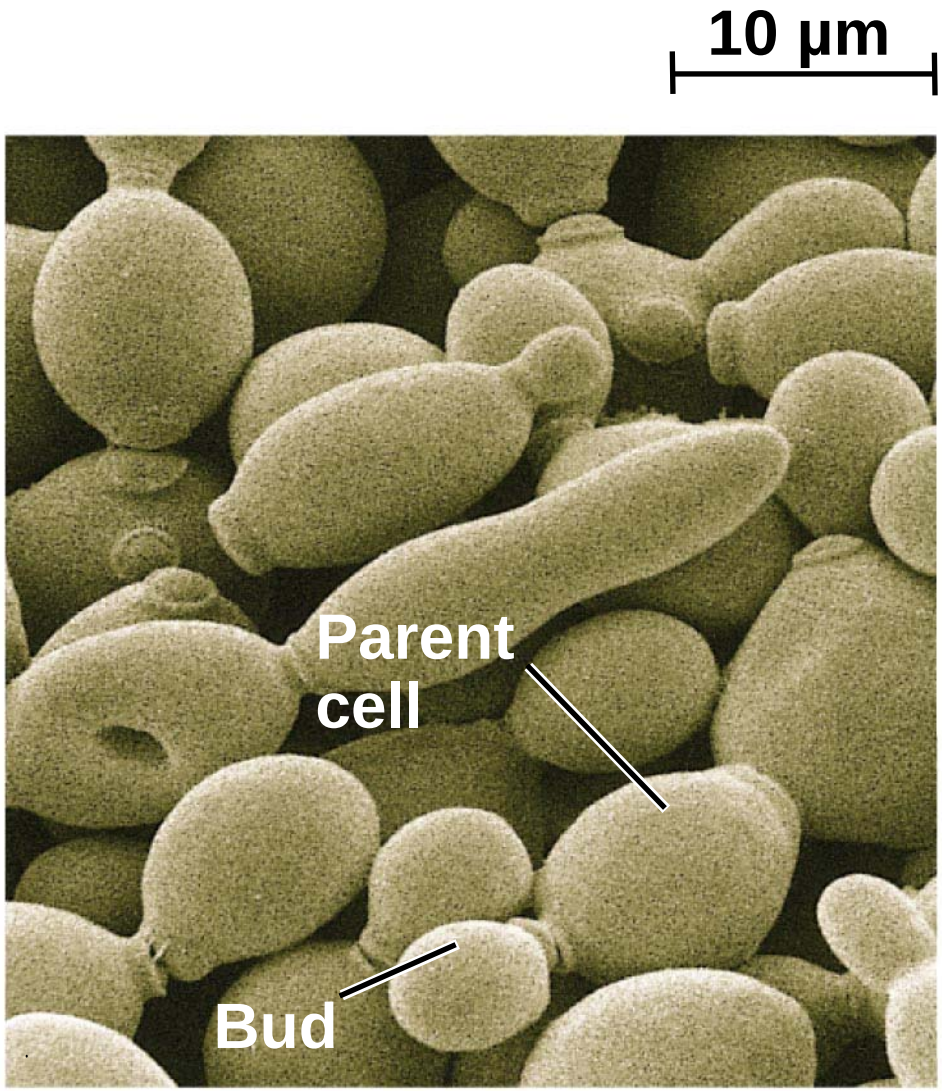
- In addition to sexual reproduction, many fungi can reproduce asexually
- **Molds** produce haploid spores by mitosis and form visible mycelia

Fig. 31-6



- 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

Fig. 31-7



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

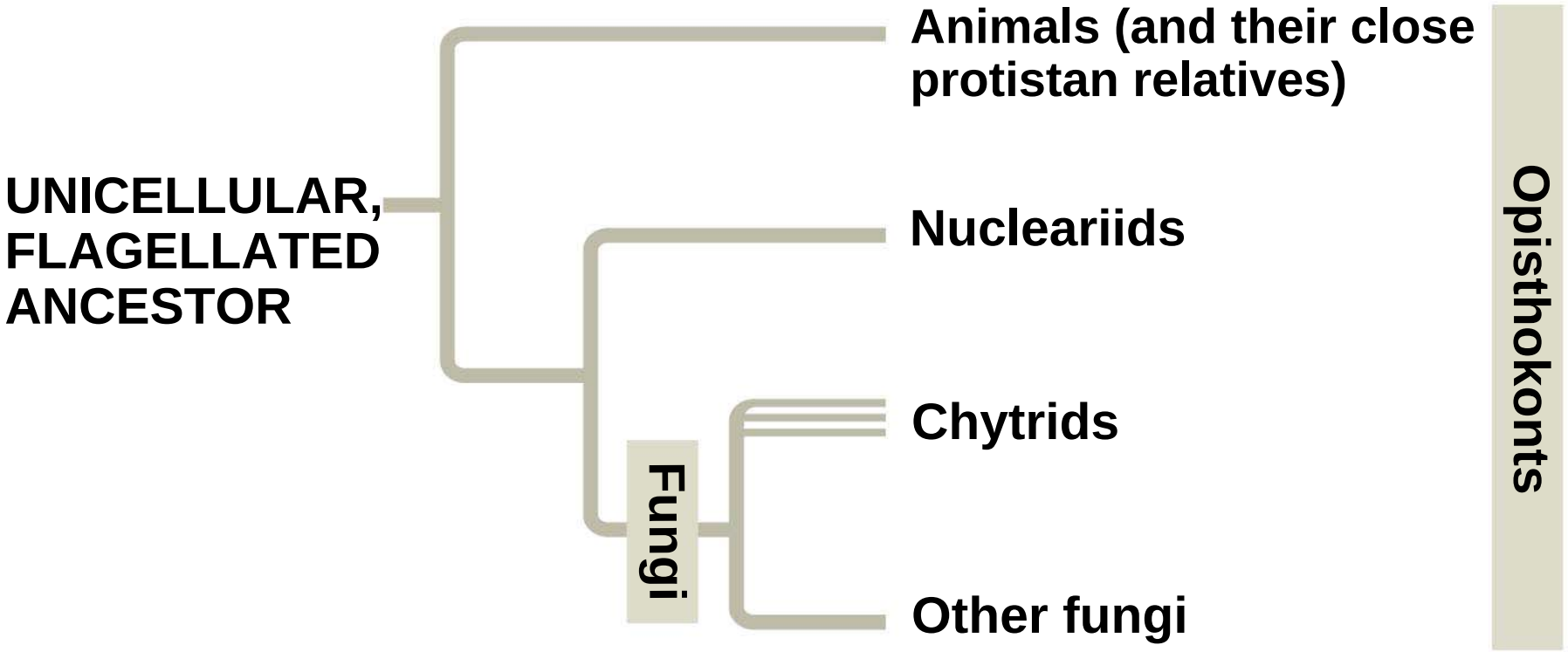
Concept 31.3: The ancestor of fungi was an aquatic, single-celled, flagellated protist

- Fungi and animals are more closely related to each other than they are to plants or other eukaryotes

The Origin of Fungi

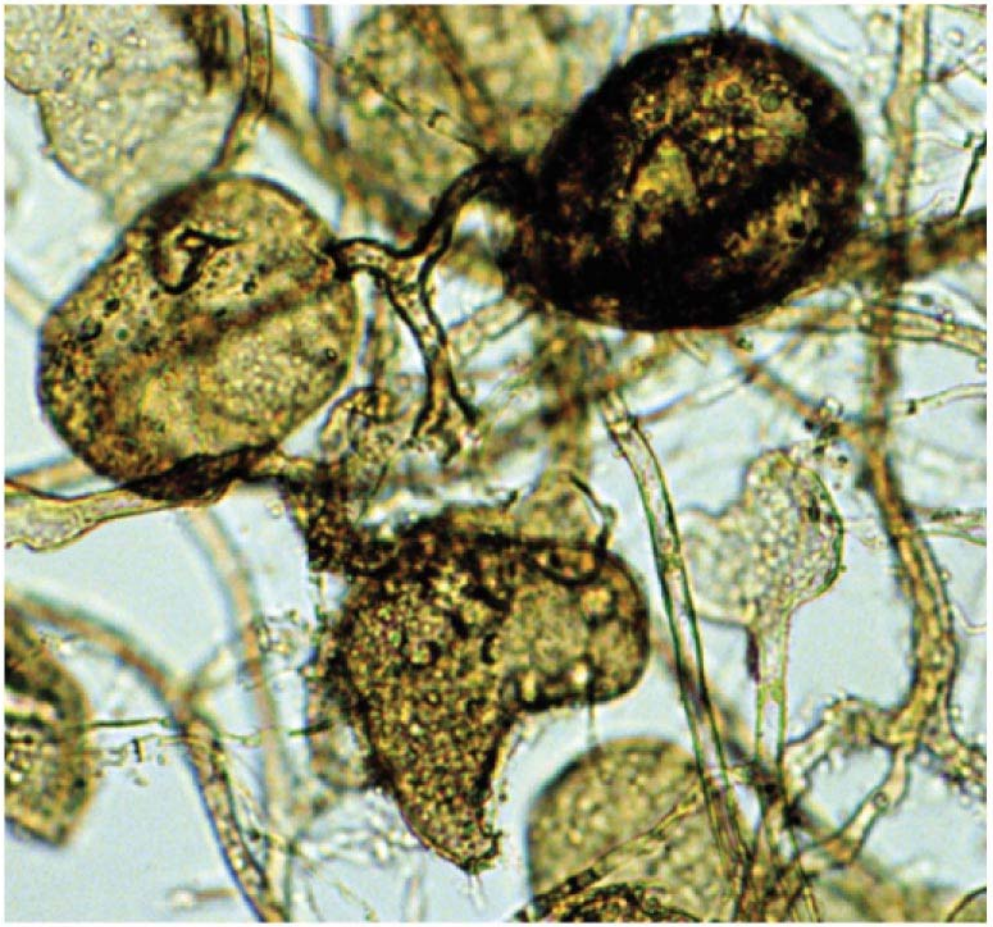
- Fungi, animals, and their protistan relatives form the **opisthokonts** clade

Fig. 31-8



- DNA evidence suggests that fungi are most closely related to unicellular **nucleariids** while animals are most closely related to unicellular choanoflagellates
- This suggests that fungi and animals evolved from a common flagellated unicellular ancestor and multicellularity arose separately in the two groups
- The oldest undisputed fossils of fungi are only about 460 million years old

Fig. 31-9

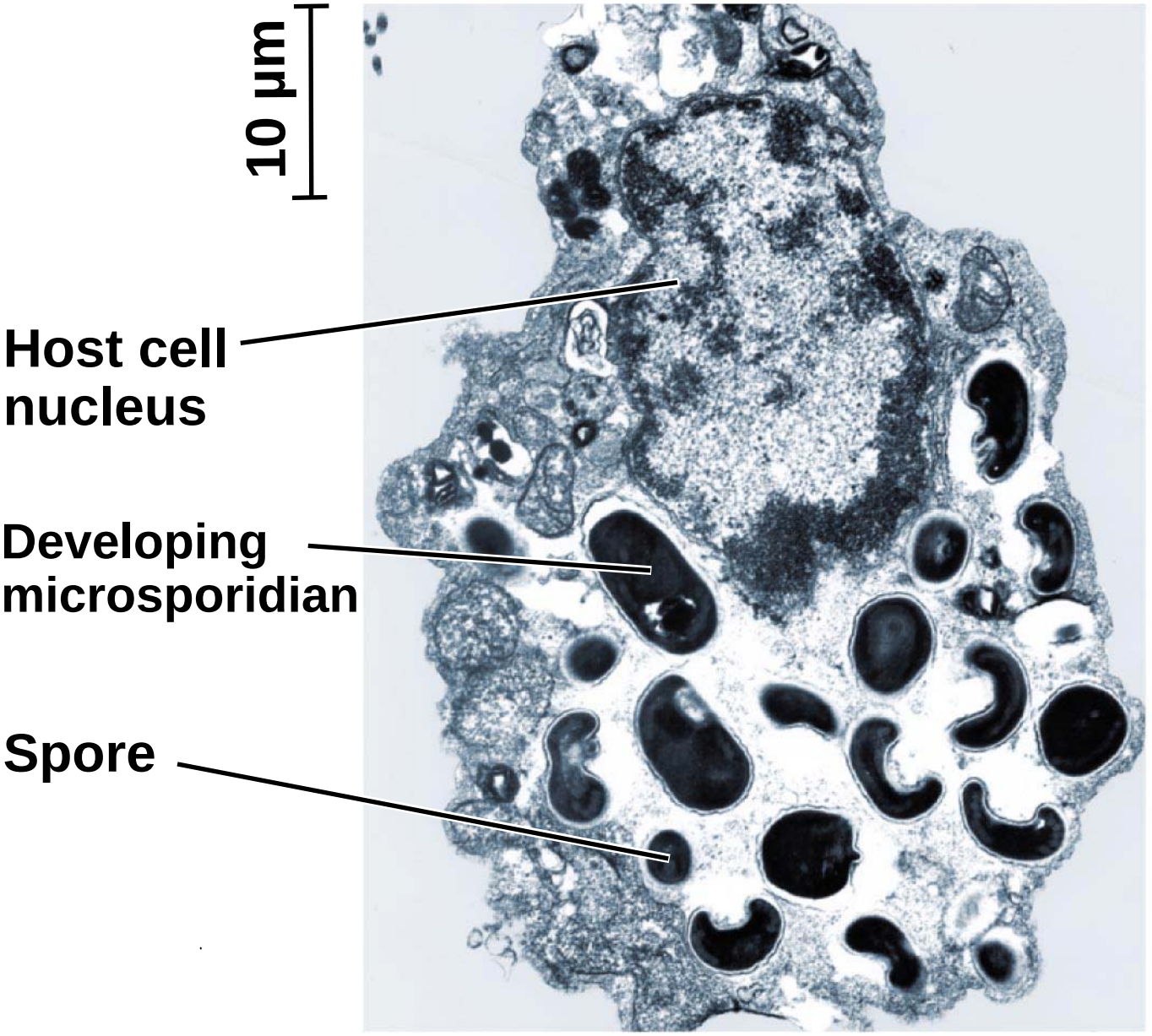


50 µm

Are Microsporidia Closely Related to Fungi?

- Microsporidia are unicellular parasites of animals and protists
- They have tiny organelles derived from mitochondria but not conventional mitochondria
- Molecular comparisons indicate they may be closely related to fungi

Fig. 31-10



The Move to Land

- Fungi were among the earliest colonizers of land and probably formed mutualistic relationships with early land plants

Concept 31.4: Fungi have radiated into a diverse set of lineages

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

Fig. 31-11

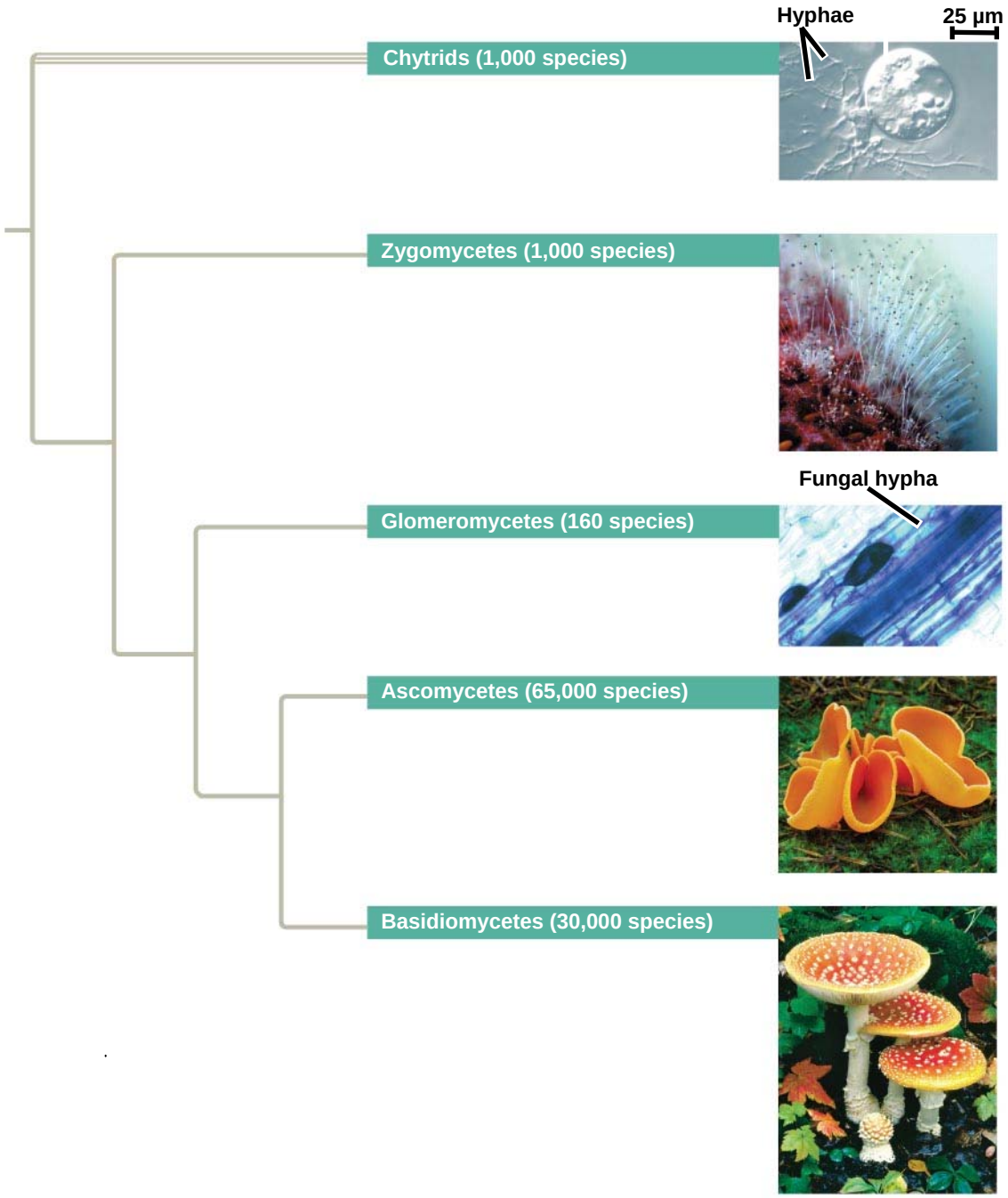


Fig. 31-11a

Chytrids (1,000 species)

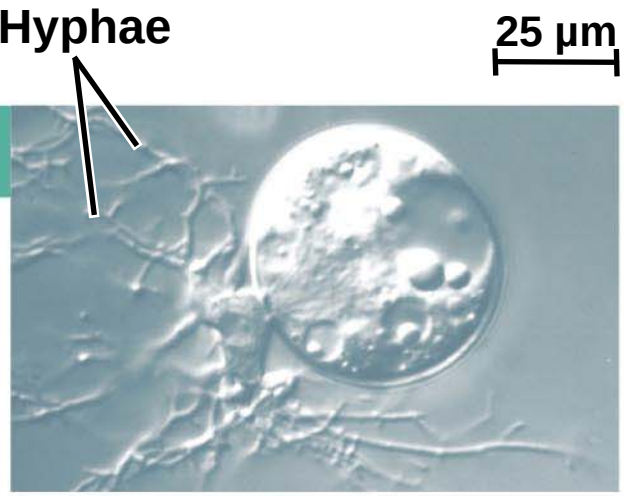


Fig. 31-11b

Zygomycetes (1,000 species)

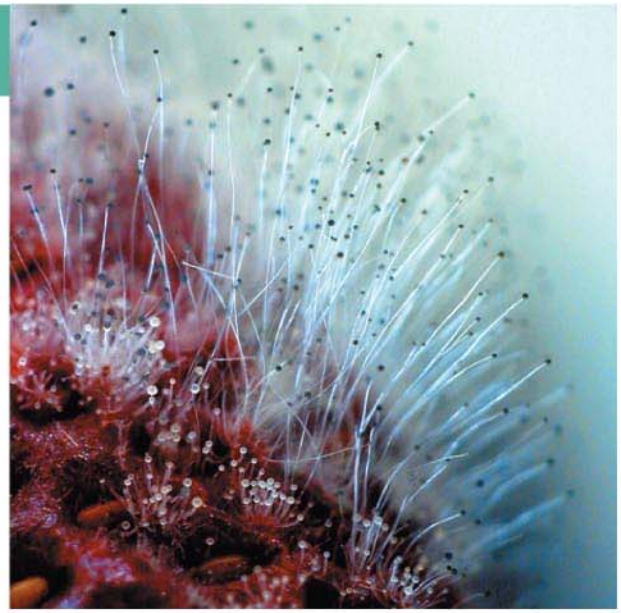


Fig. 31-11c

Glomeromycetes (160 species)

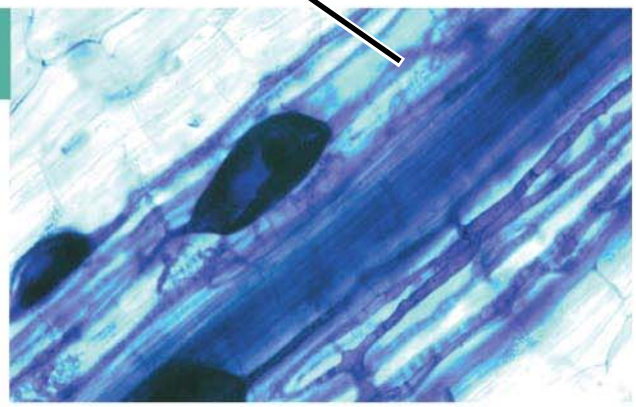


Fig. 31-11d

Ascomycetes (65,000 species)

Fig. 31-11e

Basidiomycetes (30,000 species)

Chytrids

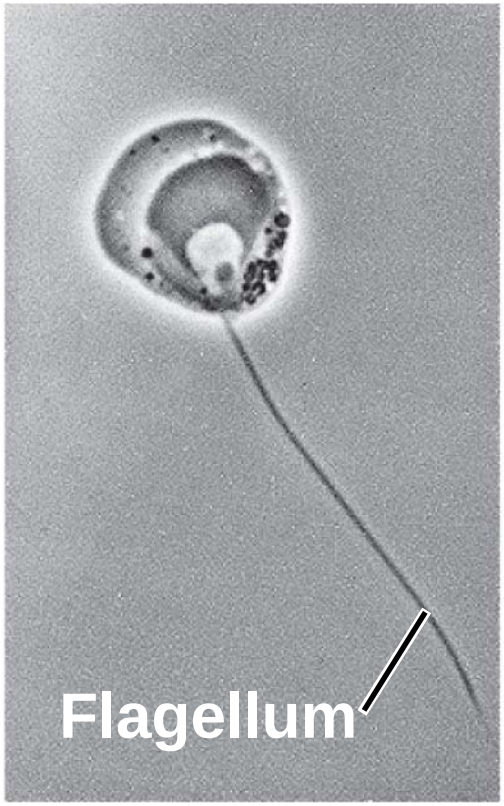
- **Chytrids** (phylum Chytridiomycota) are found in freshwater and terrestrial habitats
- They can be decomposers, parasites, or mutualists
- Molecular evidence supports the hypothesis that chytrids diverged early in fungal evolution
- Chytrids are unique among fungi in having flagellated spores, called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

PLAY Video: *Allomyces* Zoospore Release

PLAY Video: *Phlyctochytrium* Zoospore Release

Fig. 31-UN1

Fig. 31-12

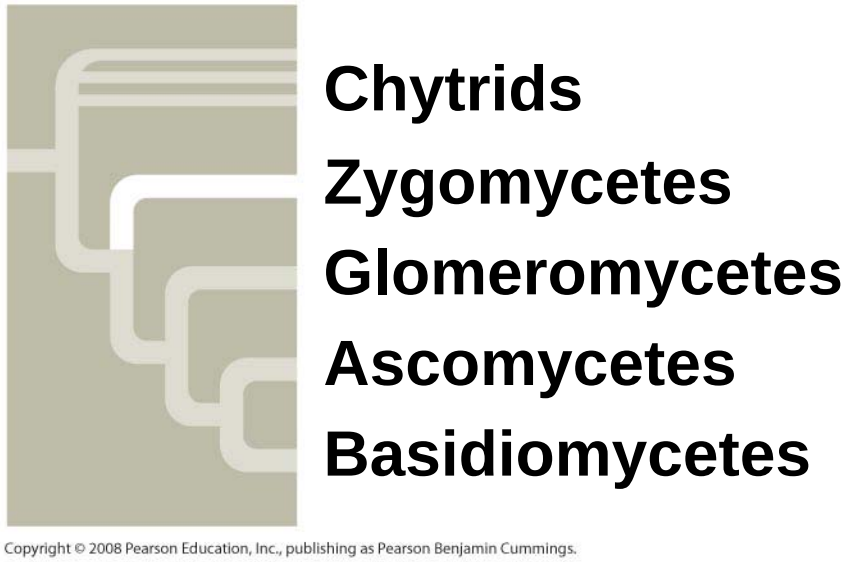


- Until recently, systematists thought that fungi lost flagella only once in their evolutionary history
- Molecular data indicate that some “chytrids” are actually more closely related to another fungal group, the zygomycetes; chytrids are a paraphyletic group

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

Fig. 31-UN2



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

Fig. 31-13-1

Rhizopus growing on bread

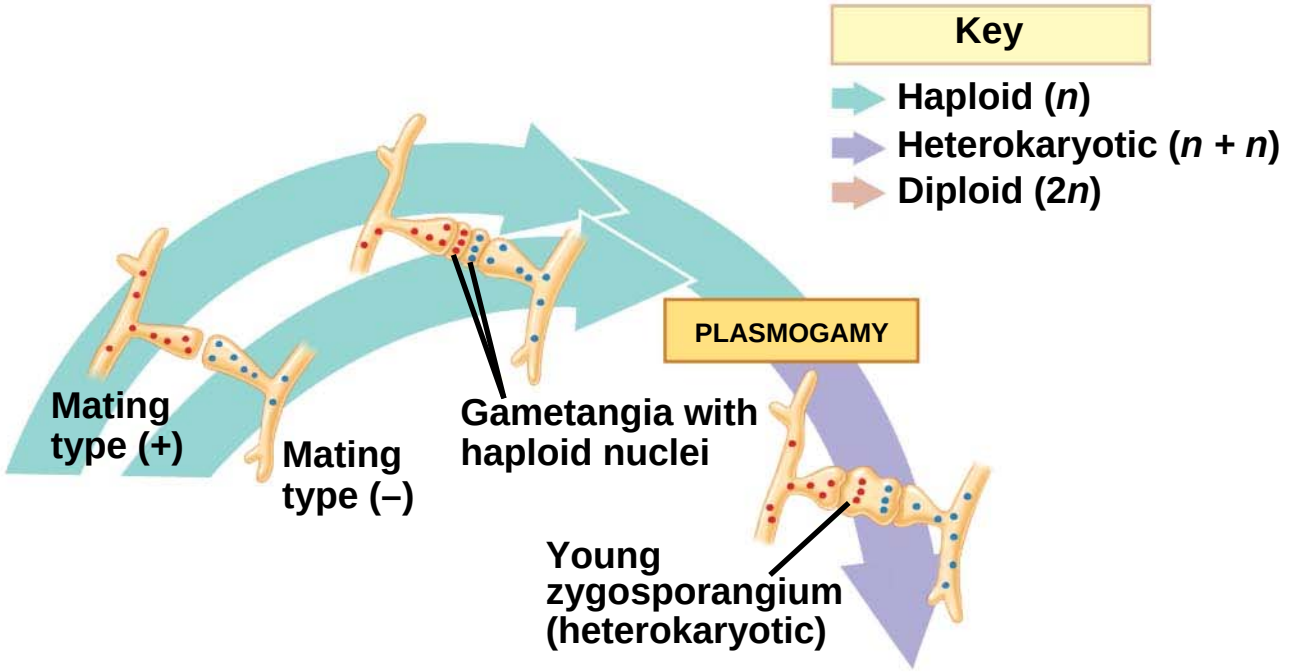


Fig. 31-13-2

Rhizopus growing on bread

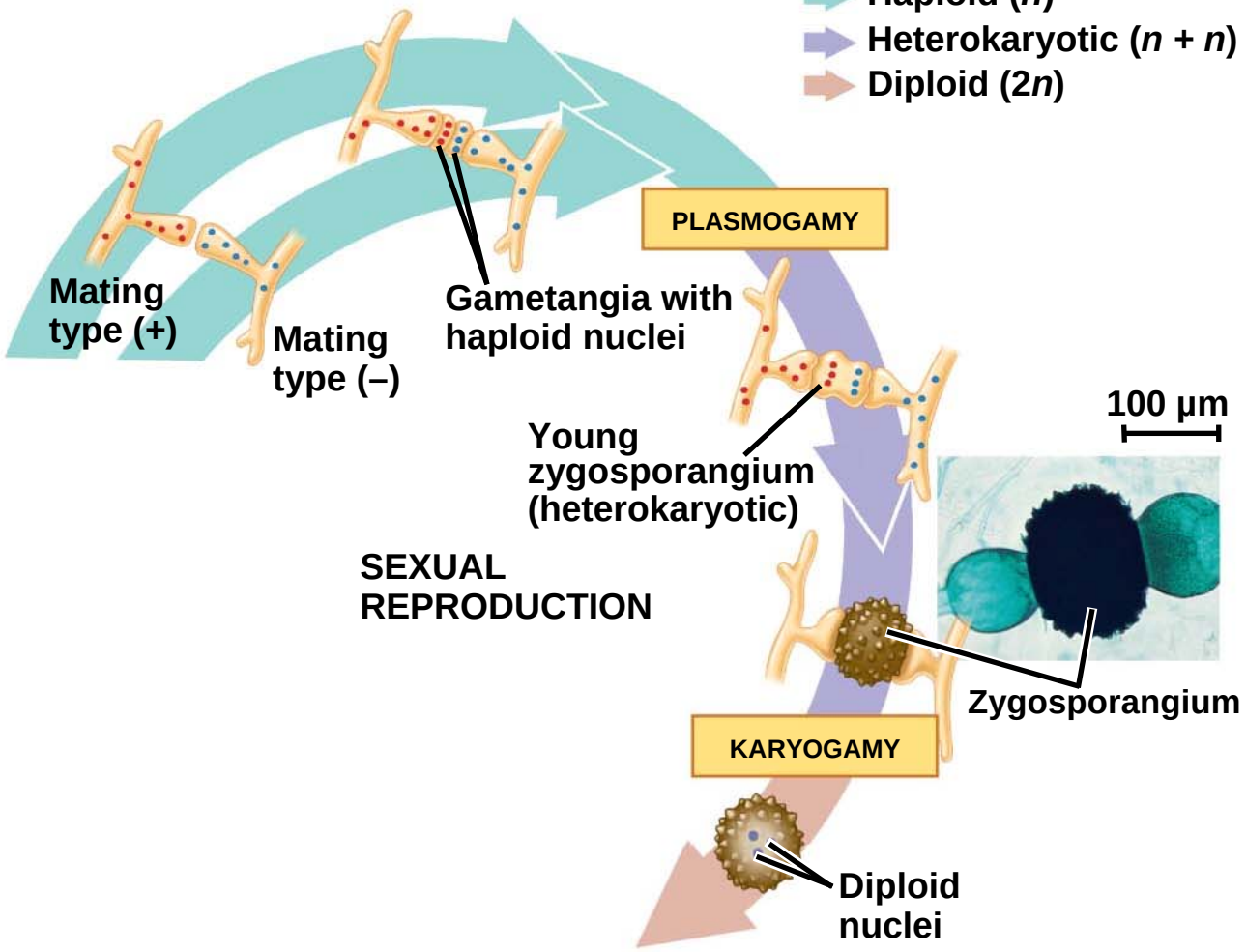


Fig. 31-13-3

Rhizopus growing on bread

Key

- Haploid (*n*)
- Heterokaryotic (*n* + *n*)
- Diploid (2*n*)

SEXUAL REPRODUCTION

Mating type (+)

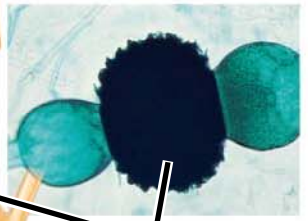
Mating type (–)

Gametangia with haploid nuclei

PLASMOGAMY

Young zygosporangium (heterokaryotic)

100 µm



Zygosporangium

KARYOGAMY

Diploid nuclei

MEIOSIS

Sporangium

Spores

Dispersal and germination

Fig. 31-13-4

Rhizopus growing on bread

Key

- Haploid (*n*)
- Heterokaryotic (*n* + *n*)
- Diploid (2*n*)

SEXUAL REPRODUCTION

Mating type (+)

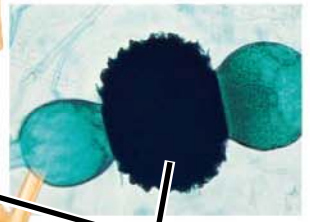
Mating type (–)

Gametangia with haploid nuclei

PLASMOGAMY

Young zygosporangium (heterokaryotic)

100 µm



Zygosporangium

KARYOGAMY

Diploid nuclei

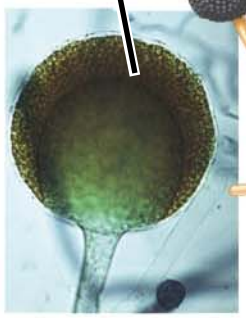
MEIOSIS

Sporangium

Spores

Dispersal and germination

Sporangia



50 µm

ASEXUAL REPRODUCTION

Mycelium

Dispersal and germination

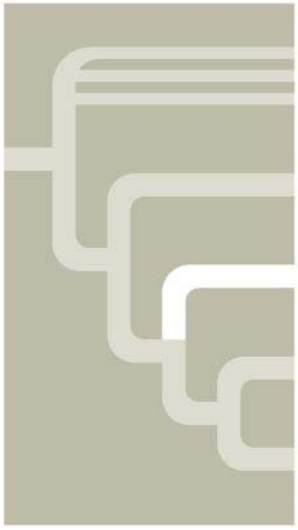
- Some zygomycetes, such as *Pilobolus,* can actually “aim” their sporangia toward conditions associated with good food sources

Fig. 31-14

Glomeromycetes

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

Fig. 31-UN3



Chytrids

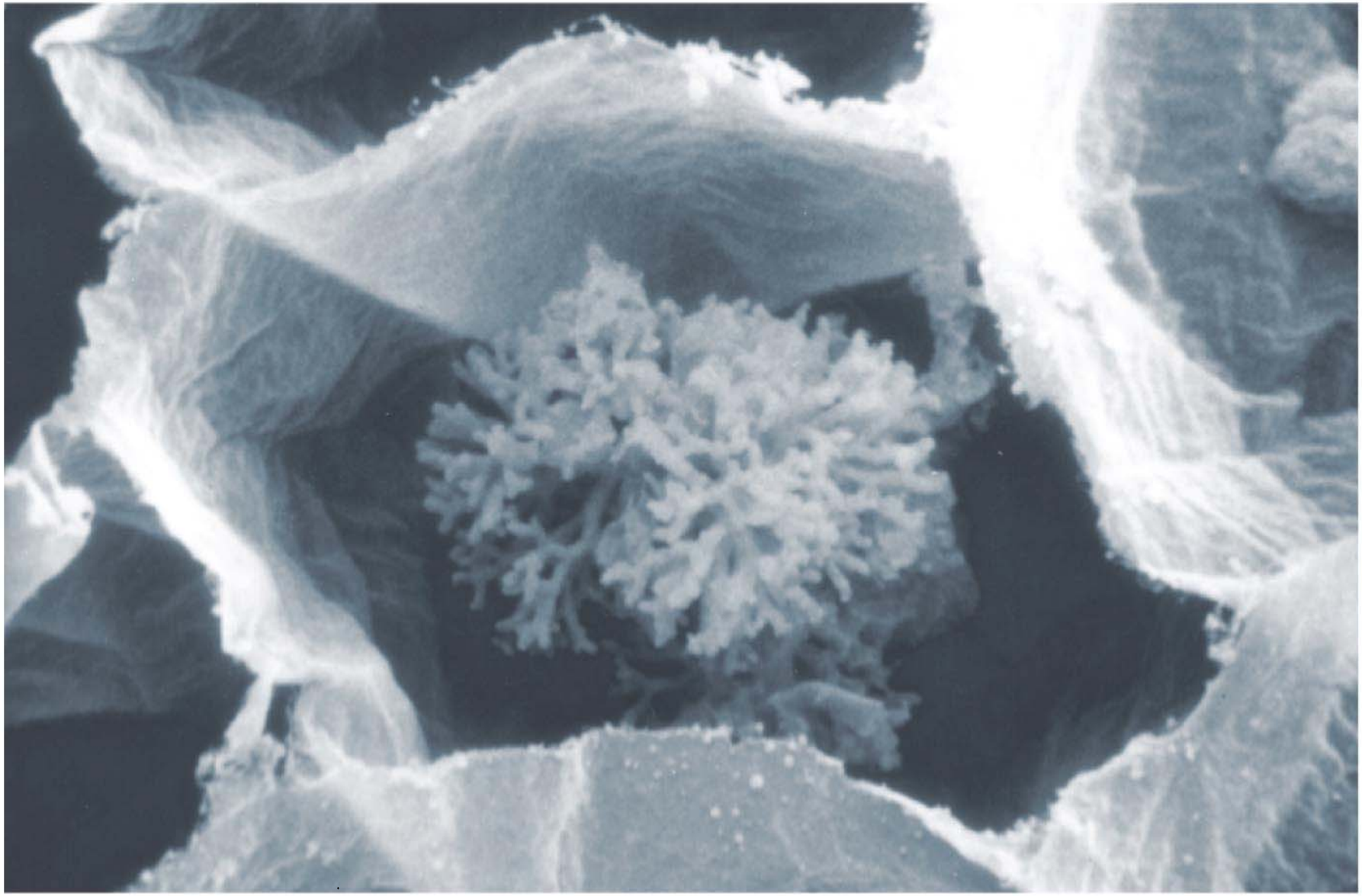
Zygomycetes

Glomeromycetes

Ascomycetes

Basidiomycetes

Fig. 31-15



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

Fig. 31-UN4

Fig. 31-16

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

***Tuber melanosporum*, a truffle**

Fig. 31-16a

Morchella esculenta, the tasty morel

Fig. 31-16b

Tuber melanosporum, a truffle

- 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

Fig. 31-17-1

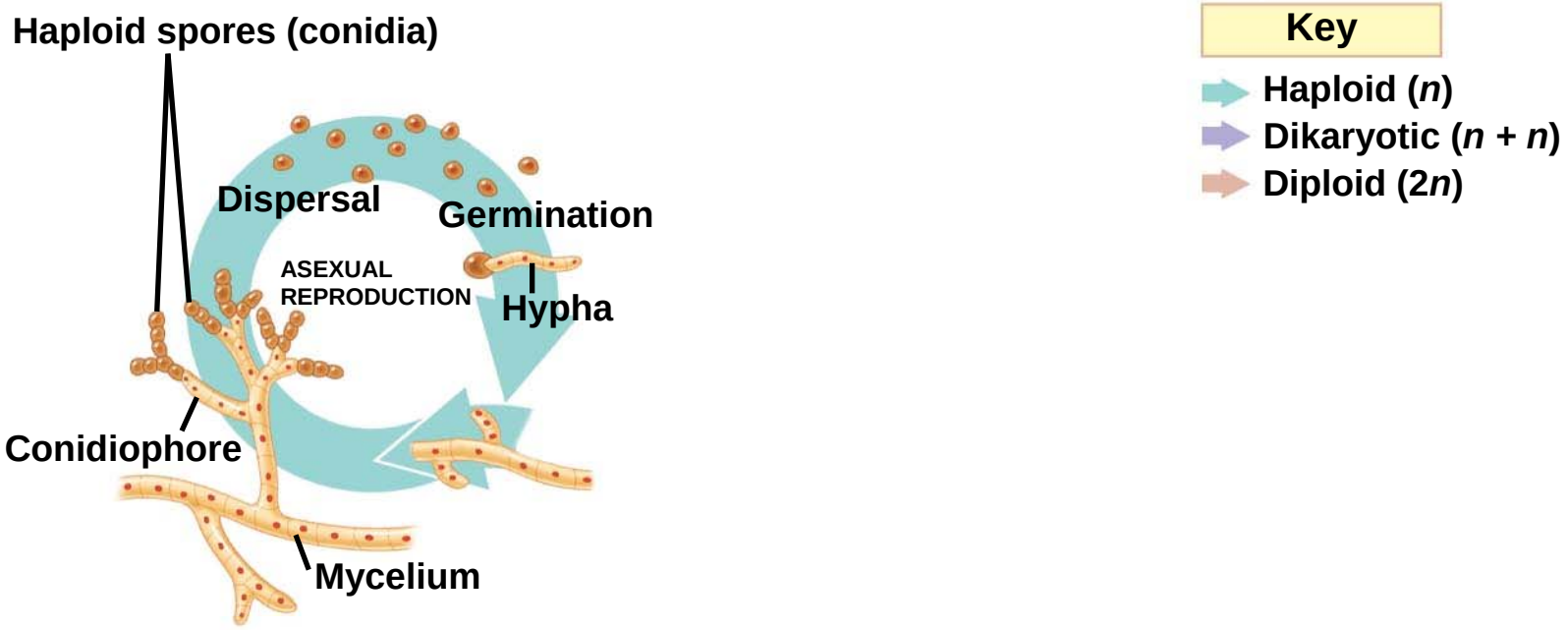


Fig. 31-17-2

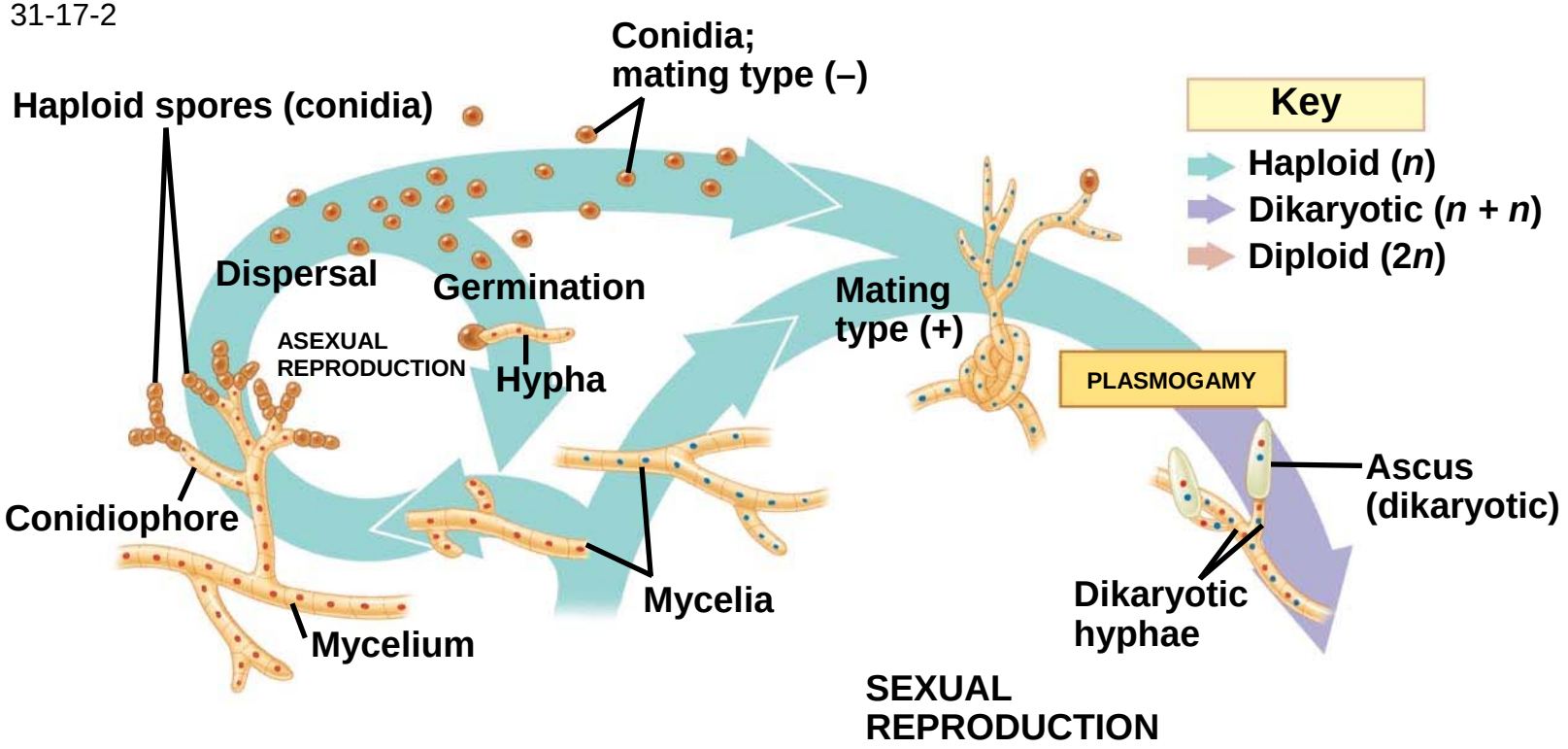


Fig. 31-17-3

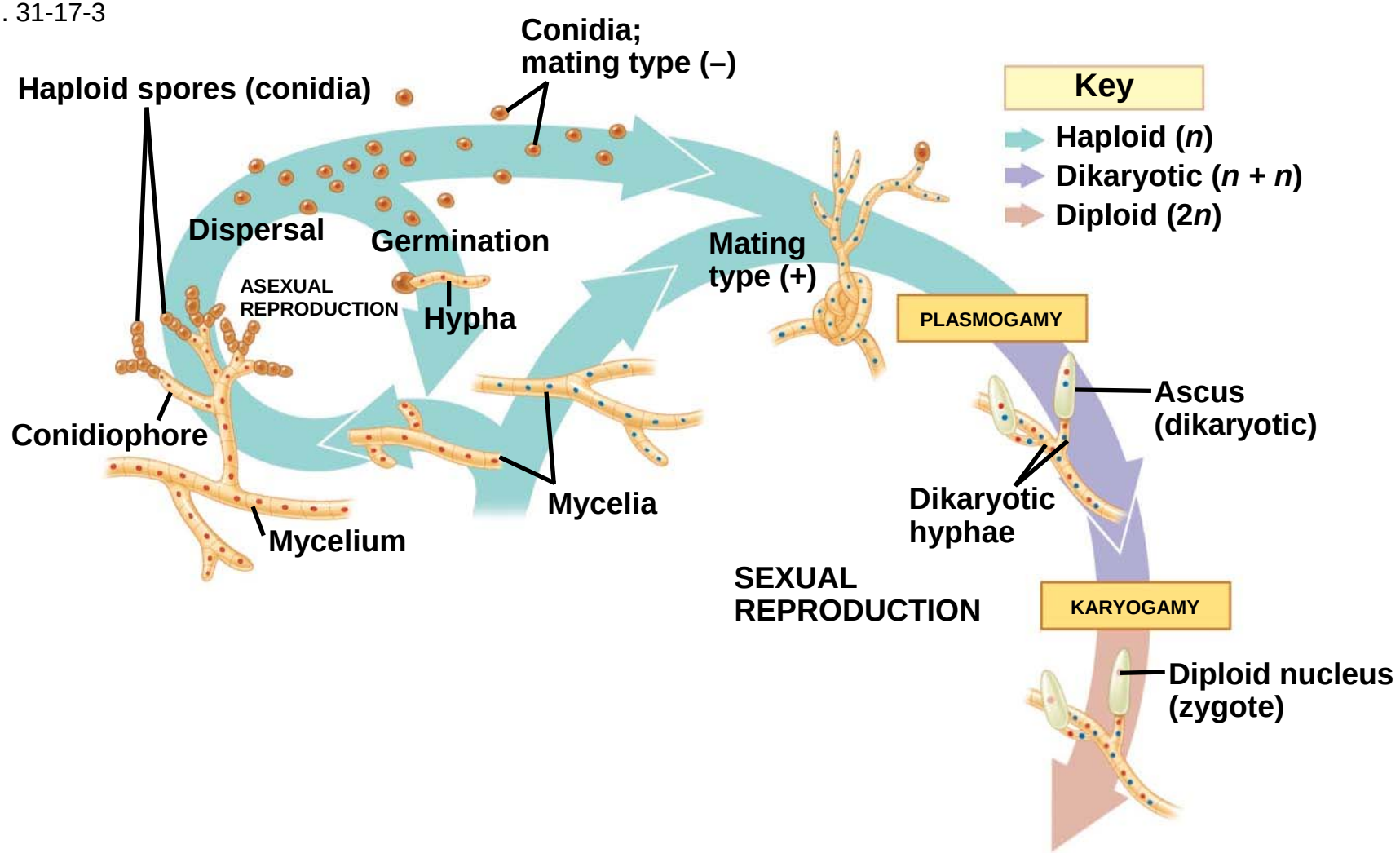
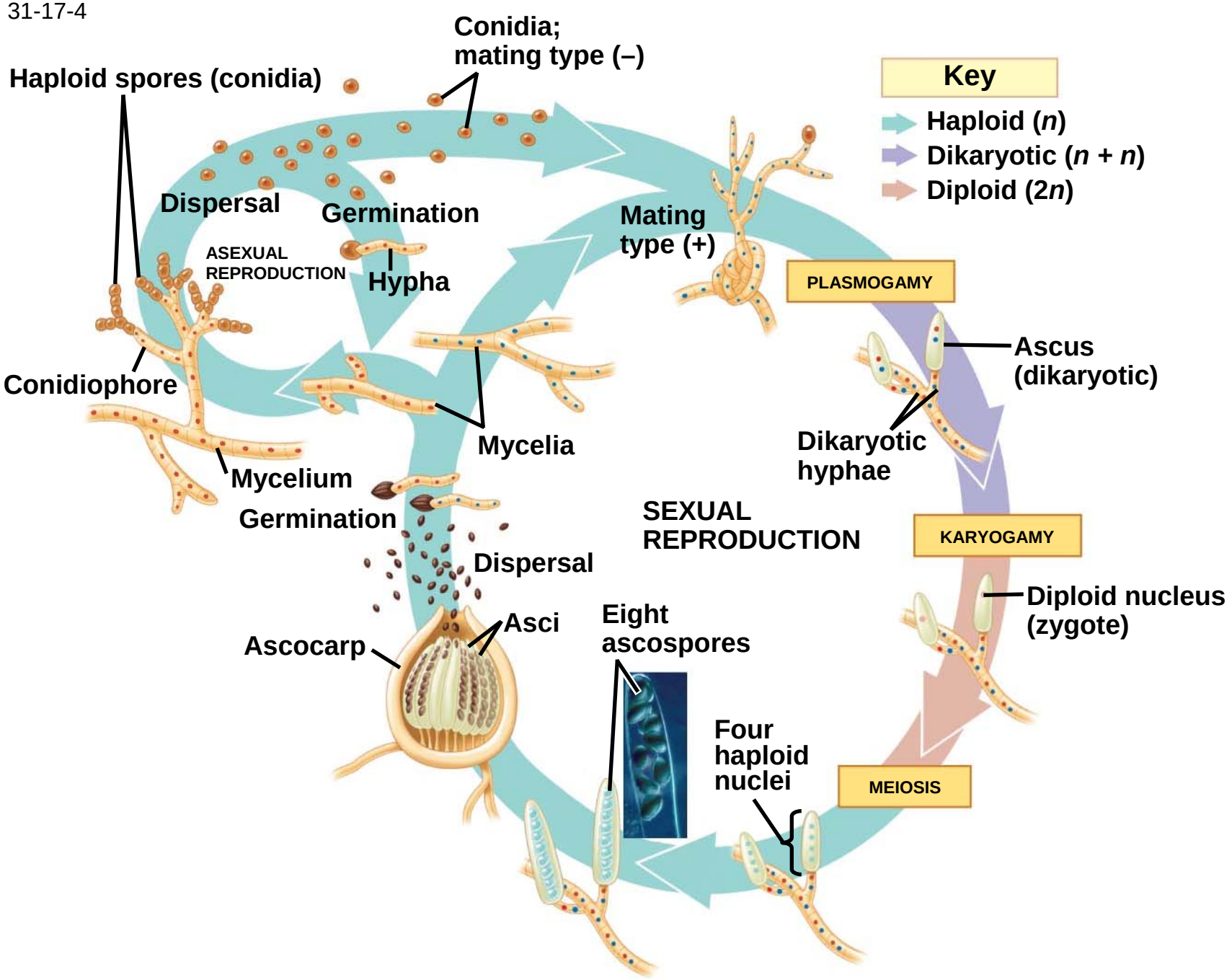


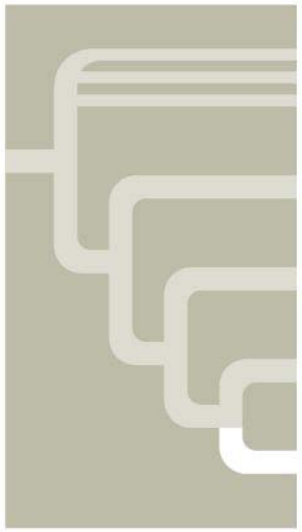
Fig. 31-17-4



Basidiomycetes

- **Basidomycetes** (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**

Fig. 31-UN5



Chytrids

Zygomycetes

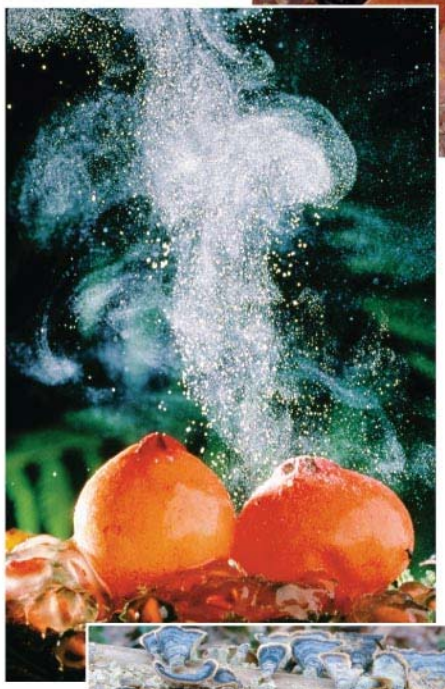
Glomeromycetes

Ascomycetes

Basidiomycetes

Fig. 31-18

▶ **Maiden veil fungus (*Dictyphora*), a fungus with an odor like rotting meat**



◀ **Puffballs emitting spores**

▼ **Shelf fungi, important decomposers of wood**

Fig. 31-18a

- **Maiden veil fungus (*Dictyphora*), a fungus with an odor like rotting meat**

Fig. 31-18b

◀ **Puffballs emitting spores**

Fig. 31-18c

Shelf fungi, important decomposers of wood

- The life cycle of a basidiomycete usually includes a long-lived dikaryotic mycelium
- In response to environmental stimuli, the mycelium reproduces sexually by producing elaborate fruiting bodies call **basidiocarps**
- Mushrooms are examples of basidiocarps
- The numerous basidia in a basidiocarp are sources of sexual spores called basidiospores

Fig. 31-19-1

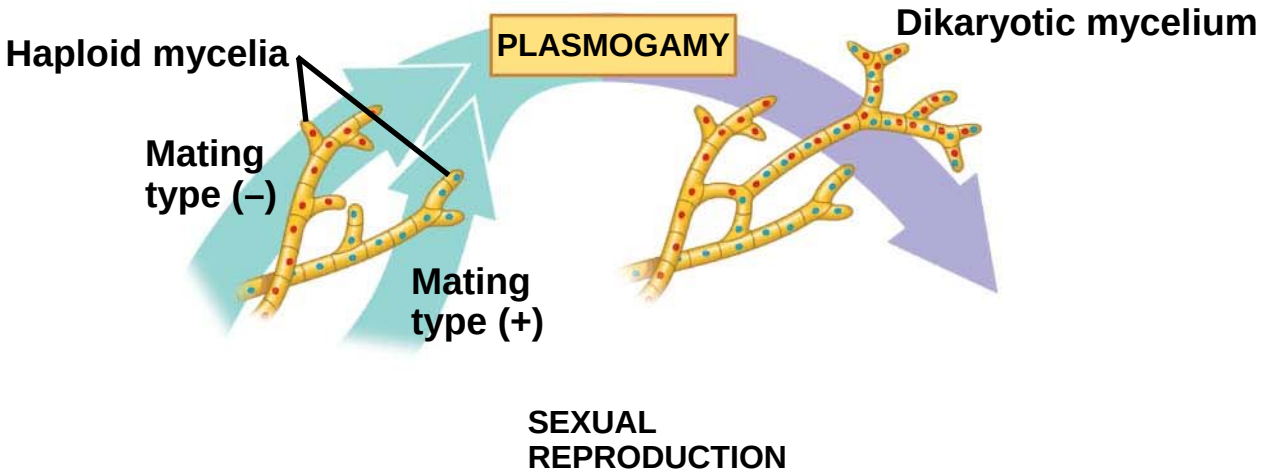


Fig. 31-19-2

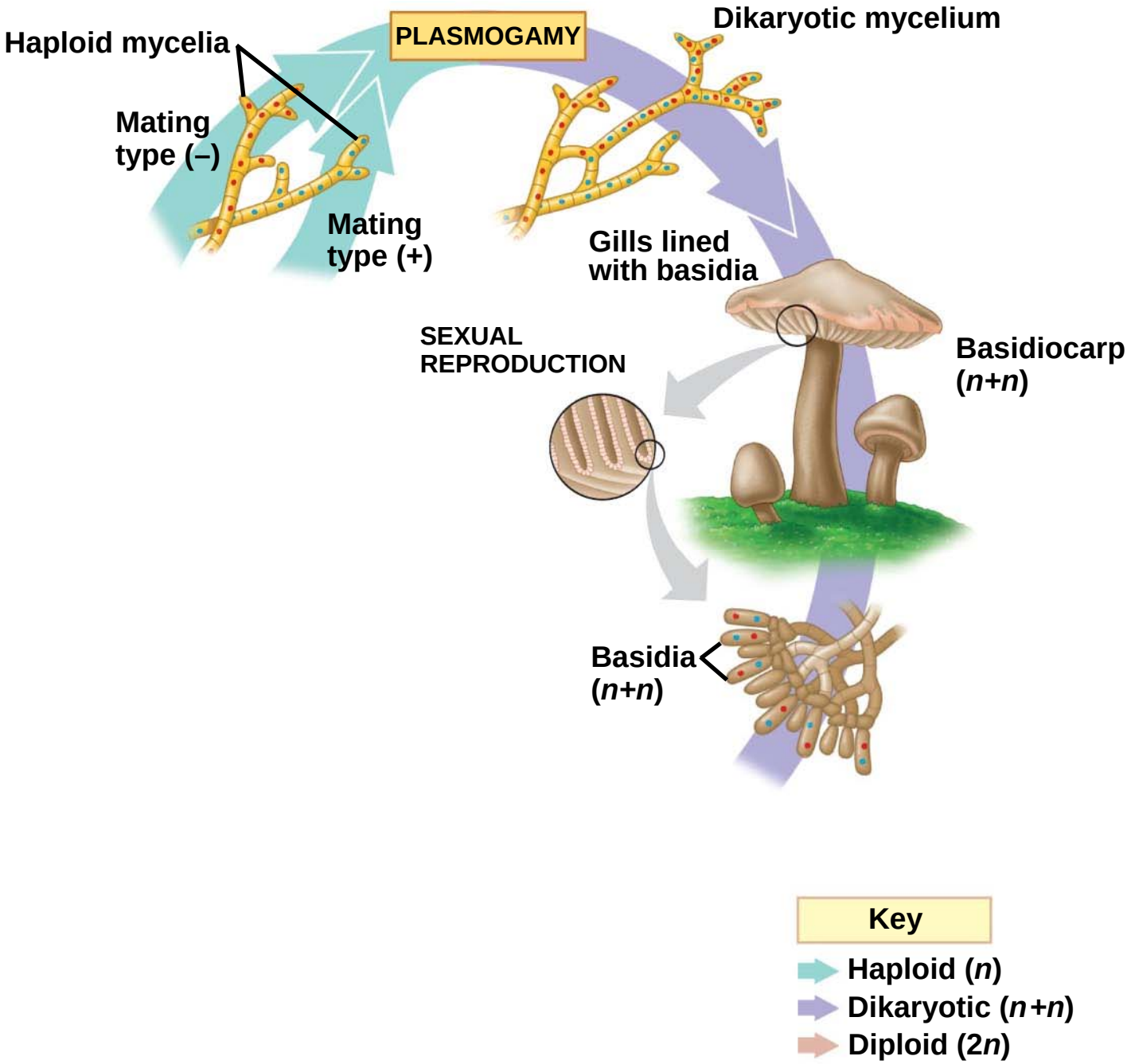


Fig. 31-19-3

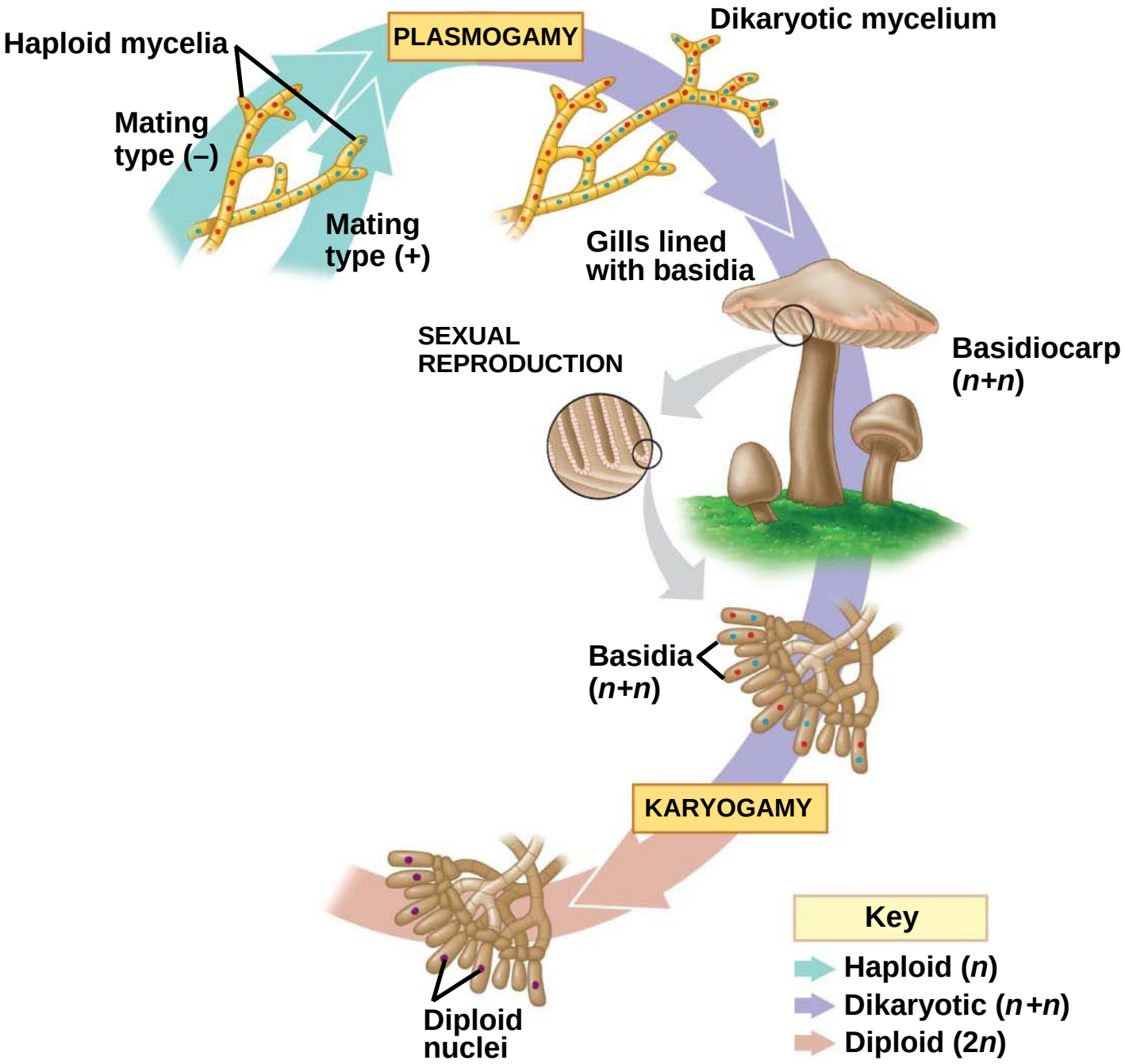


Fig. 31-19-4

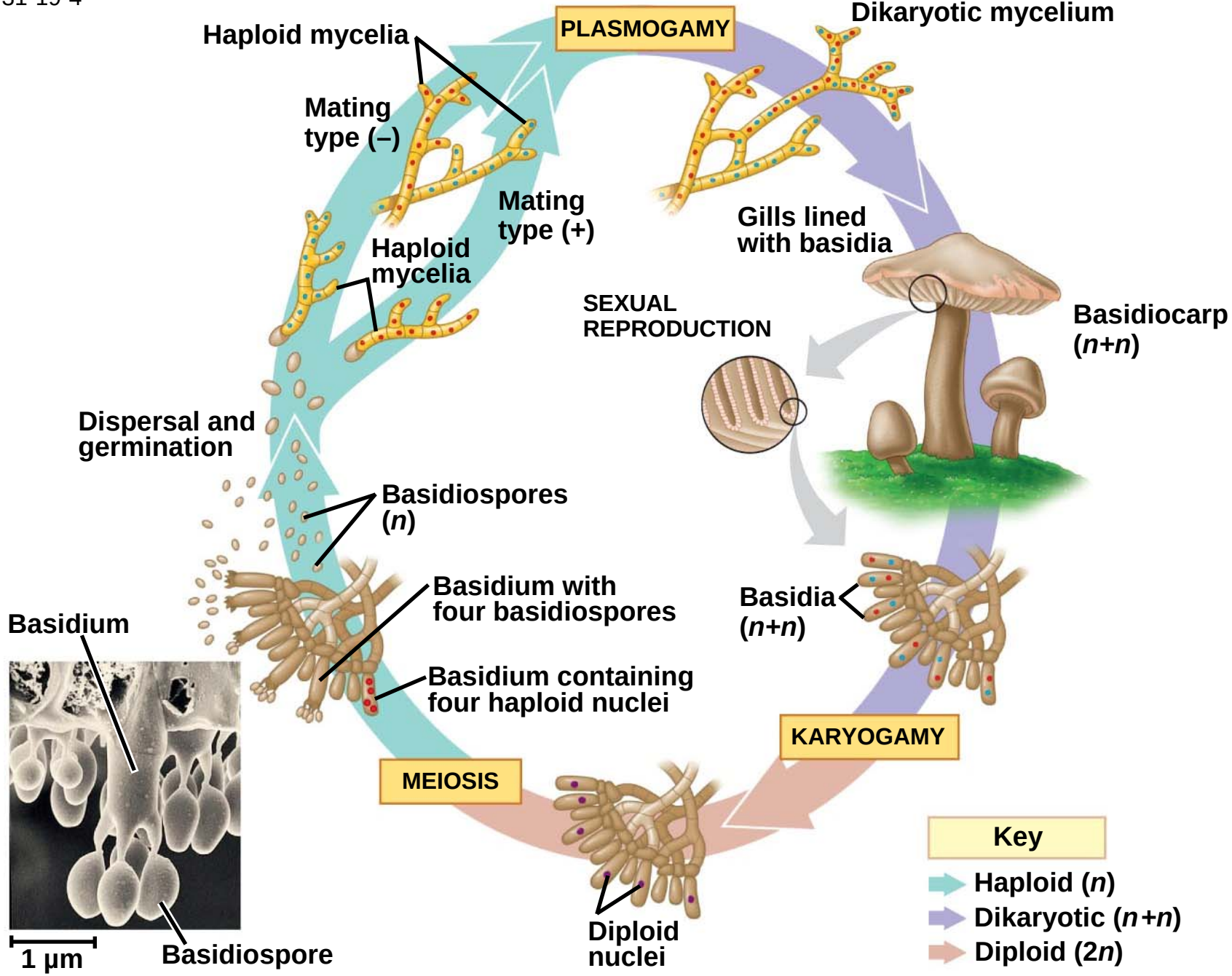


Fig. 31-20

Concept 31.5: 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

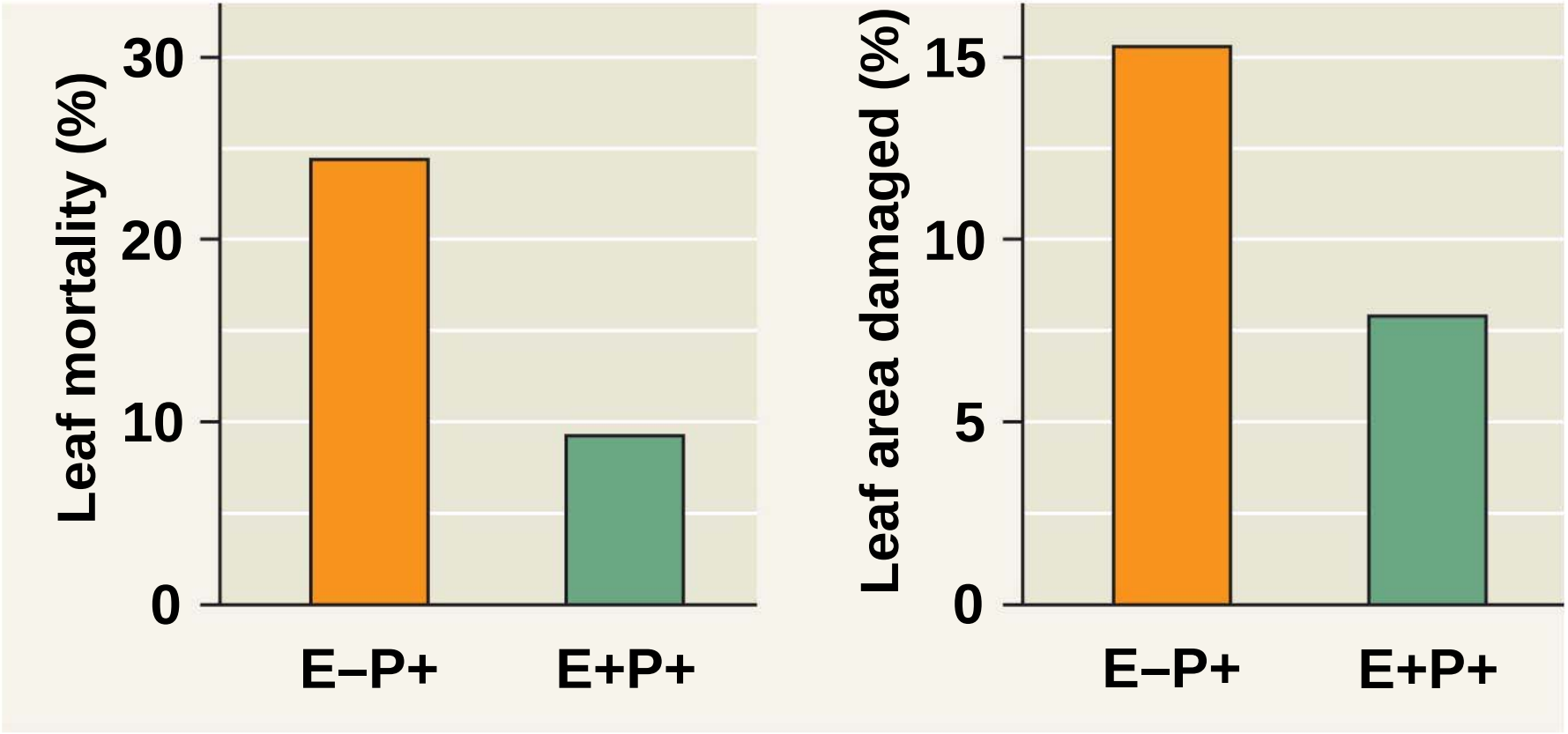
- Mycorrhizae are enormously important in natural ecosystems and agriculture
- Plants harbor harmless symbiotic **endophytes** that live inside leaves or other plant parts
- Endophytes make toxins that deter herbivores and defend against pathogens

Fig. 31-21

RESULTS

Endophyte not present; pathogen present (E–P+)

Both endophyte and pathogen present (E+P+)



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”

Fig. 31-22

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

Fig. 31-23

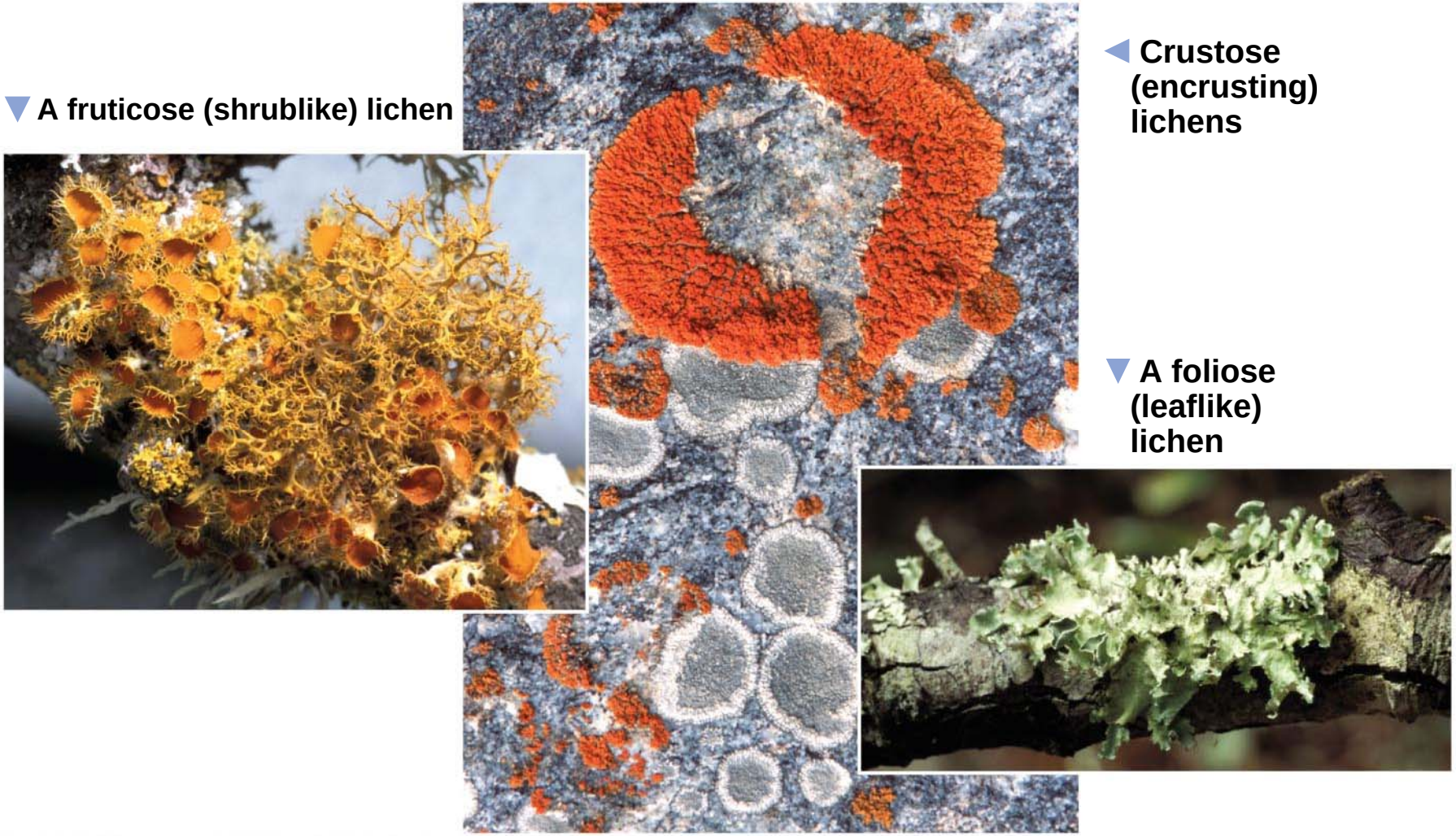


Fig. 31-23a

A fruticose (shrublike) lichen

Fig. 31-23b

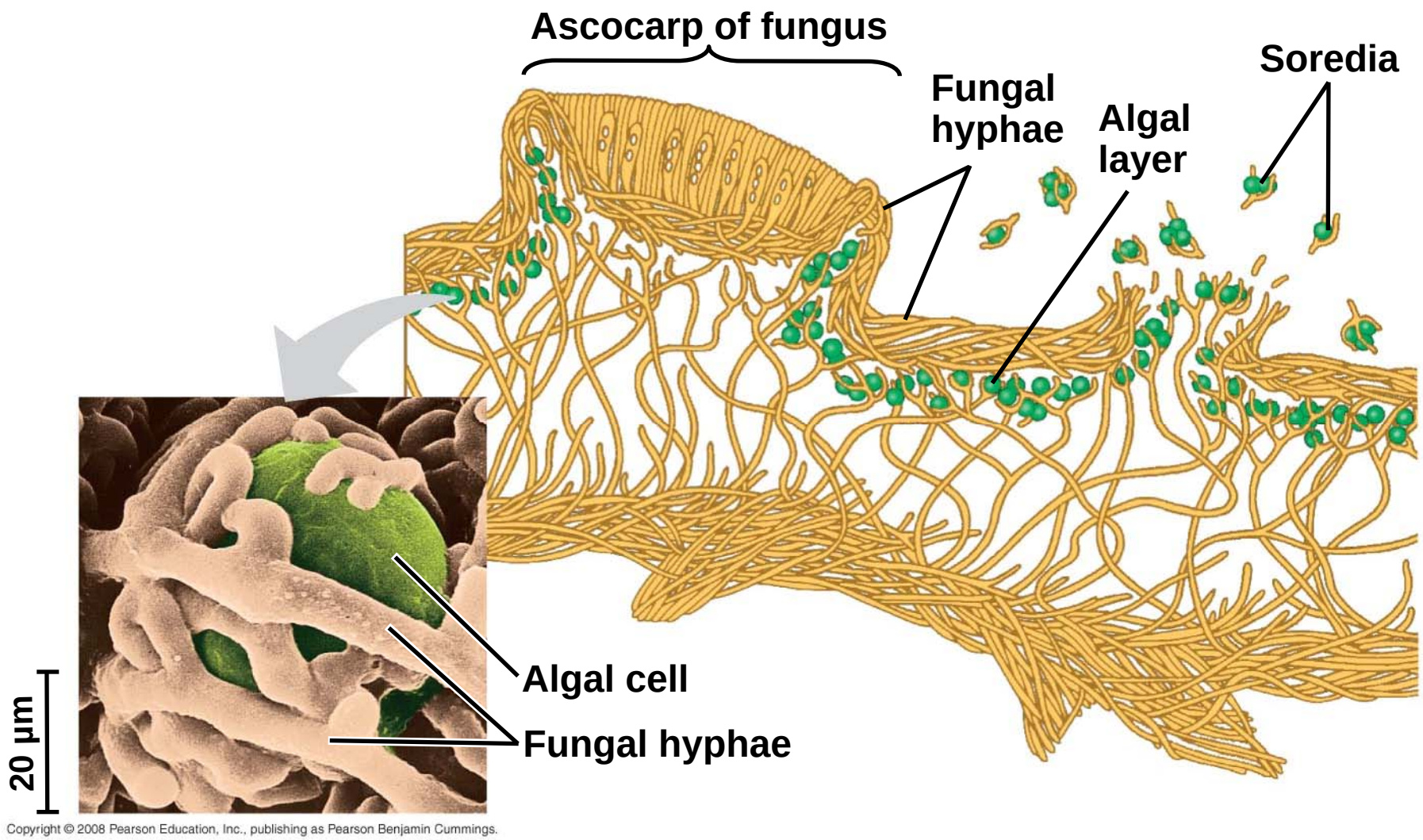
- **Crustose (encrusting) lichens**

Fig. 31-23c

- **A foliose (leaflike) lichen**

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

Fig. 31-24



- 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

- 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**

Fig. 31-25

(a) Corn smut on corn

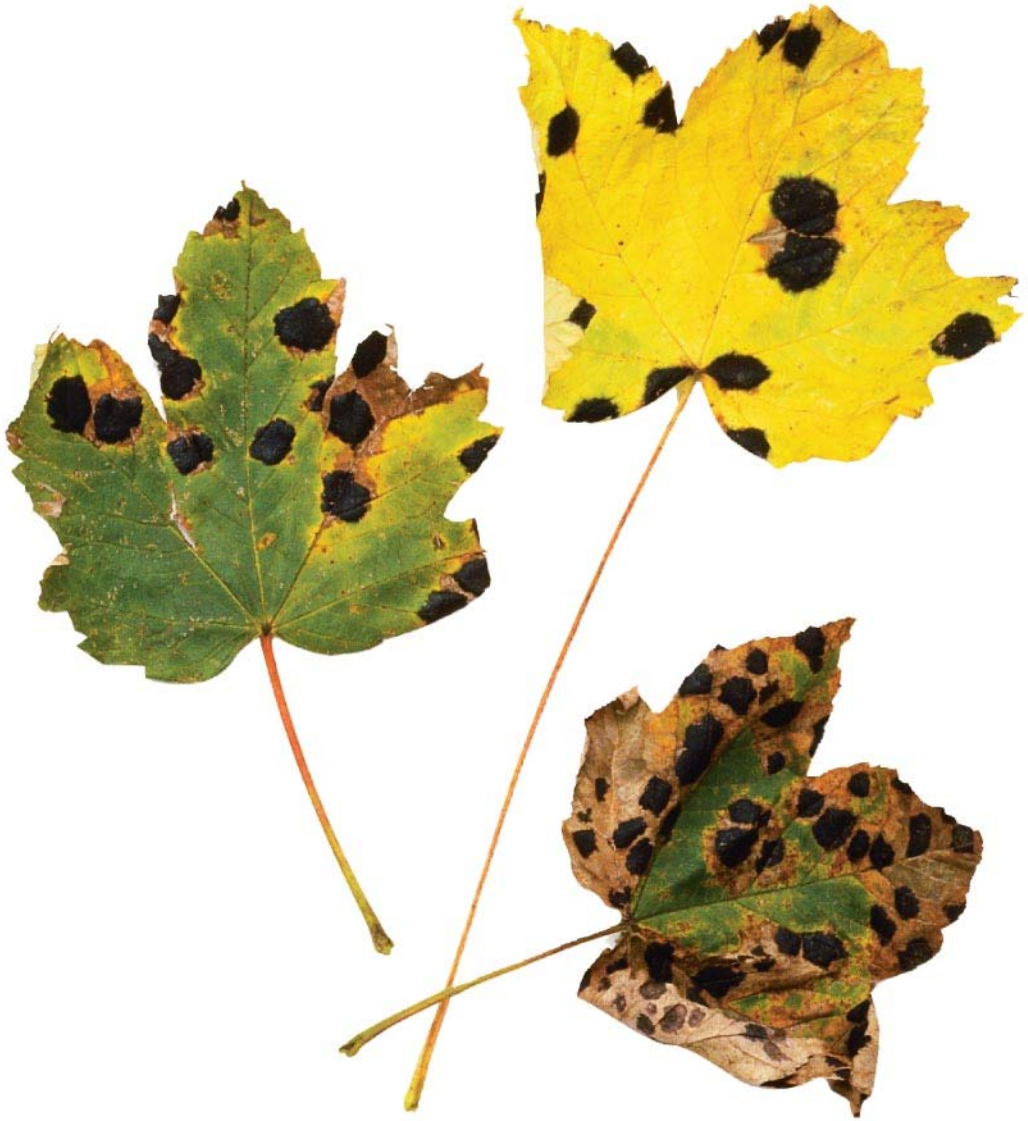
(b) Tar spot fungus on maple leaves

(c) Ergots on rye

Fig. 31-25a

(a) Corn smut on corn

Fig. 31-25b



(b) Tar spot fungus on maple leaves

Fig. 31-25c

(c) Ergots on rye

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*

Fig. 31-26

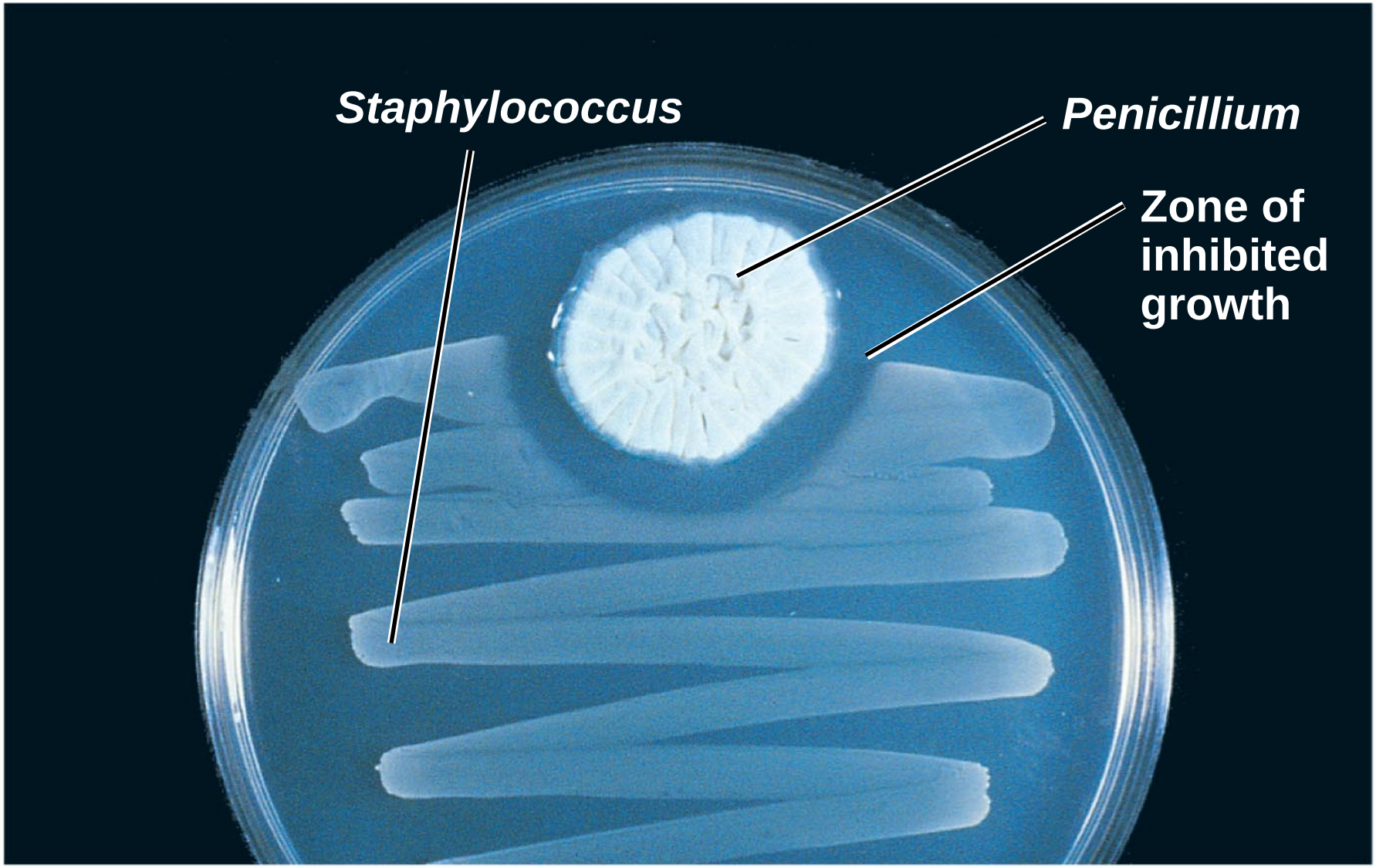


Fig. 31-UN6

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles	
Chytridiomycota (chytrids)	Flagellated spores	
Zygomycota (zygote fungi)	Resistant zygosporangium as sexual stage	
Glomeromycota (arbuscular mycorrhizal fungi)	Form arbuscular mycorrhizae with plants	
Ascomycota (sac fungi)	Sexual spores (ascospores) borne internally in sacs called asci; ascomycetes also produce vast numbers of asexual spores (conidia)	
Basidiomycota (club fungi)	Elaborate fruiting body (basidiocarp) containing many basidia that produce sexual spores (basidiospores)	

Fig. 31-UN6a

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles
Chytridiomycota (chytrids)	Flagellated spores

Fig. 31-UN6b

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles
Zygomycota (zygote fungi)	Resistant zygosporangium as sexual stage

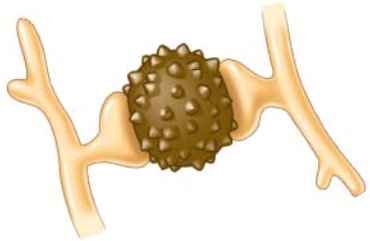


Fig. 31-UN6c

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles
Glomeromycota (arbuscular mycorrhizal fungi)	Form arbuscular mycorrhizae with plants

Fig. 31-UN6d

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles
Ascomycota (sac fungi)	Sexual spores (ascospores) borne internally in sacs called asci; ascomycetes also produce vast numbers of asexual spores (conidia)

Fig. 31-UN6e

Fungal Phylum	Distinguishing Features of Morphology and Life Cycles
Basidiomycota (club fungi)	Elaborate fruiting body (basidiocarp) containing many basidia that produce sexual spores (basidiospores)

Fig. 31-T1

Soil Temp.	*Curvularia* Presence	Plant Mass (g)	Number of New Shoots
30°C	E−	16.2	32
	E+	22.8	60
35°C	E−	21.7	43
	E+	28.4	60
40°C	E−	8.8	10
	E+	22.2	37
45°C	E−	0	0
	E+	15.1	24

Source: R. S. Redman et al., Thermotolerance generated by plant/fungal symbiosis, *Science* 298:1581 (2002).

You should now be able to:

1. List the characteristics that distinguish fungi from other multicellular kingdoms
2. Distinguish between ectomycorrhizal and arbuscular mycorrhizal fungi
3. Describe the processes of plasmogamy and karyogamy
4. Describe the evidence that multicellularity evolved independently in fungi and animals

5. Describe the life cycles of *Rhizopus stolonifer* and *Neurospora crassa*

6. Distinguish among zygomycetes, ascomycetes, and basidiomycetes

7. Describe some of the roles of fungi in ecosystems, lichens, animal-fungi mutualistic symbioses, food production, and medicine and as pathogens