PowerPoint® Lecture Presentations

CHAPTER 23

Microbial Symbioses with Microbes, Plants, and Animals

I. Symbioses between Microorganisms

- 23.1 Lichens
- 23.2 “*Chlorochromatium aggregatum*”
- Microbes live with macroorganisms and other microorganisms in long-term relationships called *symbioses*.
  - Mutualisms are interactions where both organisms interact to the benefit of both.
  - Most mutualistic organisms evolved together (coevolution) over millions of years.

23.1 Lichens

- Lichens
  - leafy or encrusting microbial symbioses
  - often found growing on bare rocks, tree trunks, house roofs, and the surfaces of bare soils (Figure 23.1)
  - Lichens are a mutualistic relationship between a fungus and an alga (or cyanobacterium).
    - Alga is photosynthetic and produces organic matter; many are nitrogen-fixing as well.
    - The fungus provides a structure within which the phototrophic partner can grow protected from erosion and with dissolved inorganic nutrients. (Figure 23.2)
    - Lichens are more complex than previously considered as they contain bacterial and archaeal microbiota.

T. D. Brock

(a)

M. T. Madigan

(b)

Figure 23.1

23.2 "*Chlorochromatium aggregatum*"

- In freshwater there are microbial mutualisms called *consortia*.
- Green sulfur bacteria (called *epibionts*) and a flagellated rod-shaped bacterium (Figure 23.3 and 23.4)
  - consortium given a "genus species" name
  - These consortia are found in stratified sulfidic lakes.
  - Green sulfur bacteria are obligate anaerobic phototrophs that make up nearly 70 percent of the bacterial biomass in these lakes.
  - discovered over 100 years ago but details unknown until modern culture methods and molecular techniques allowed for more detailed studies (Figure 23.5)
- The epibiont of "*Chlorochromatium aggregatum*" has been isolated and grown in pure culture.

II. Plants as Microbial Habitats

- 23.3 The Legume–Root Nodule Symbiosis
- 23.4 Mycorrhizae

23.3 The Legume–Root Nodule Symbiosis

- The mutualistic relationship between legumes, which are plants with seeds in pods, and nitrogen-fixing bacteria is one of the most important symbioses known.
- Examples of legumes include soybeans, clover, alfalfa, beans, and peas.
- *Rhizobia* are the best-known nitrogen-fixing bacteria engaging in these symbioses.
- Rhizobia are a group of species of *Alphaproteobacteria* or *Betaproteobacteria* that can grow freely in soil or infect leguminous plants. (Figure 23.6)

23.3 The Legume–Root Nodule Symbiosis

- Infection of legume roots by nitrogen-fixing bacteria leads to the formation of root nodules that fix nitrogen. (Figure 23.7)
  - leads to significant increases in combined nitrogen in soil
- Nodulated legumes grow well in areas where other plants would not. (Figure 23.8)

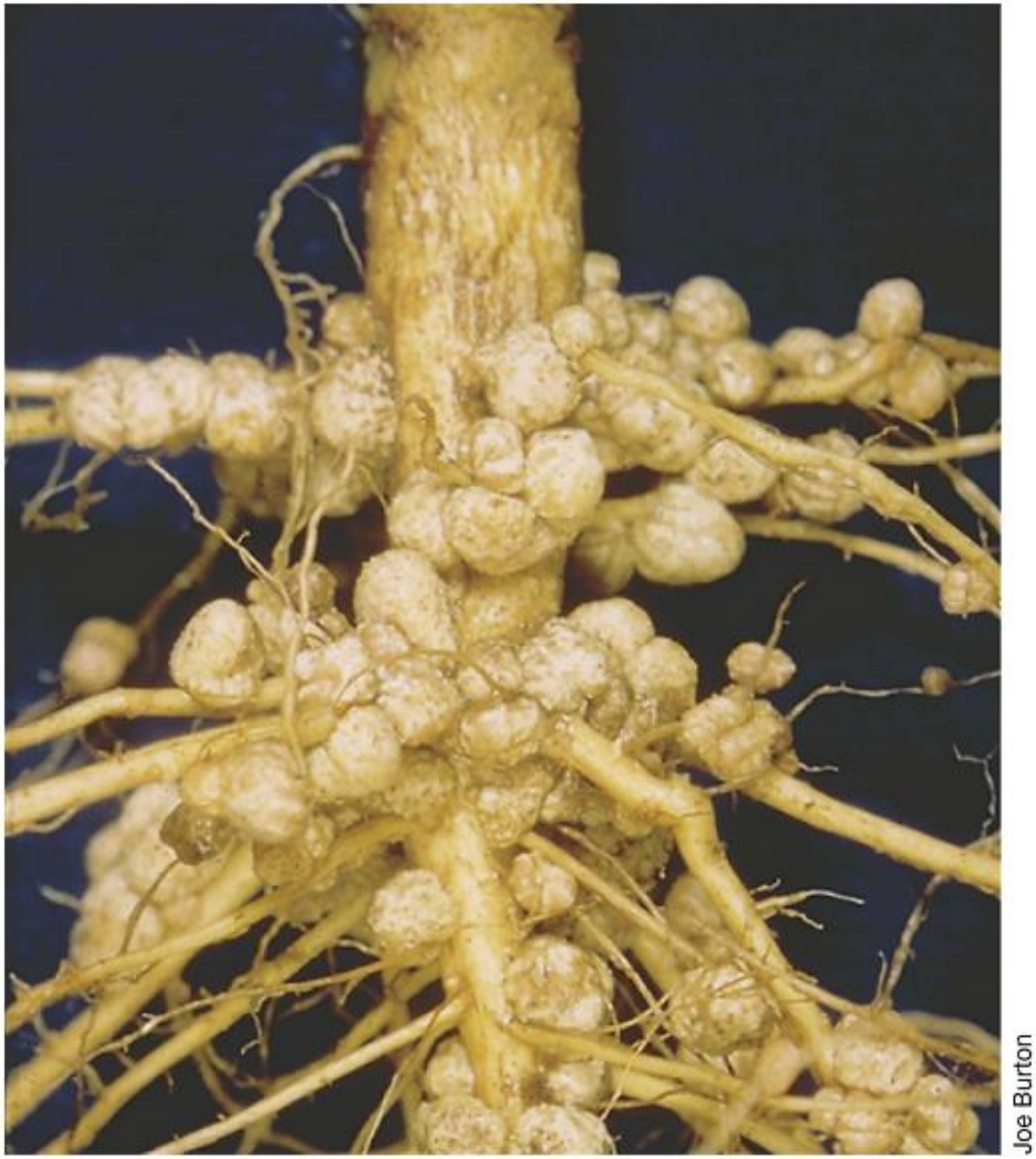


Figure 23.7

23.3 The Legume–Root Nodule Symbiosis

- Nitrogen-fixing bacteria need O_2 to generate energy for N_2 fixation, but the enzymes that fix nitrogen, the *nitrogenases*, are inactivated by O_2.
- In the nodule, free oxygen is bound up by O_2-binding protein leghemoglobin that serves as an "oxygen buffer" to protect nitrogenases from free oxygen. (Figure 23.9)

23.3 The Legume–Root Nodule Symbiosis

- In general, different rhizobia infect different species of legumes, so the bacteria that infect peas are different than those that infect clover.
- *Cross-inoculation group*
  - group of related legumes that can be infected by a particular species of rhizobia

23.3 The Legume–Root Nodule Symbiosis

- After infection, rhizobia rapidly divide in the root nodule.
- These bacteria change shape and are called bacteroids that form a *symbiosome* within the nodule. (Figure 23.11)

23.3 The Legume–Root Nodule Symbiosis

- *NodD* is a positive regulator that is induced by plant flavonoids. (Figure 23.14)

23.3 The Legume–Root Nodule Symbiosis

- Bacteroids are dependent on the plant to provide fuel in the form of pyruvate for nitrogen fixation.
- The legume–bacteria symbiosis is characterized by oxygen sequestration, several metabolic reactions, and nutrient exchange. (Figure 23.15)

23.3 The Legume–Root Nodule Symbiosis

- A few legume species form nodules on their stems. (Figure 23.16)
- Stem-nodule formation is more common in tropical regions, where soil is nutrient depleted and nitrogen poor due to leaching and intense biological activity.

23.3 The Legume–Root Nodule Symbiosis

- Nonlegume nitrogen-fixing symbiosis also occurs, but with bacteria other than rhizobia.
- The water fern *Azolla* contains a species of heterocystous nitrogen-fixing cyanobacteria known as *Anabaena.* (Figure 23.17)

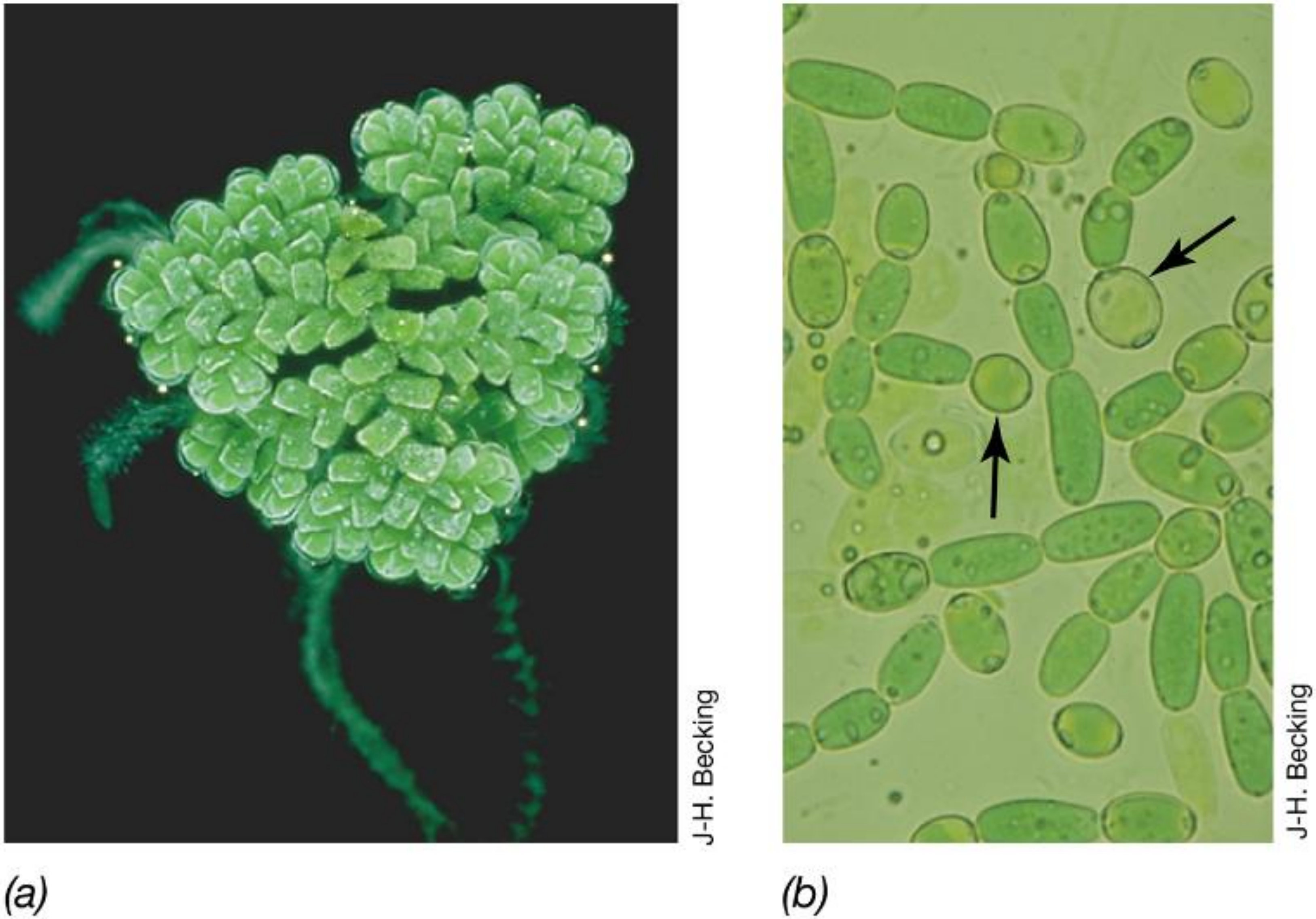


Figure 23.17

23.4 Mycorrhizae

- Mycorrhizae
  - mutualistic associations of plant roots and fungi
  - The fungus transfers inorganic nutrients from the soil to the plant, while the plant donates carbohydrates to the fungus.

23.4 Mycorrhizae

- *Ectomycorrhizae* remain outside the plant roots.
  - Fungal cells form an extensive sheath around the outside of the root with only a little penetration into the root tissue. (Figure 23.19)
  - found primarily in forest trees, particularly boreal and temperate forests

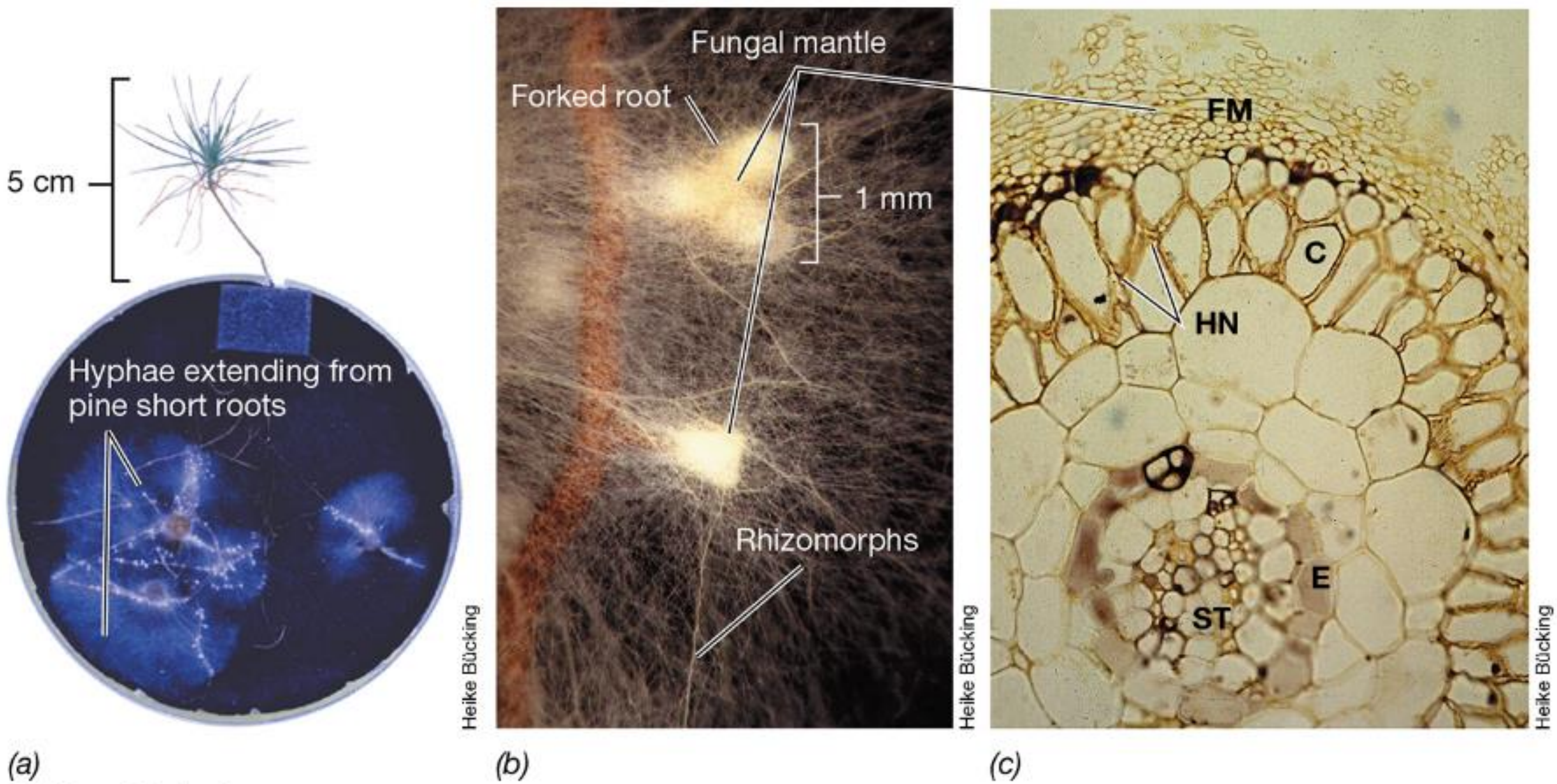

5 cm
Hyphae extending from pine short roots
Heike Bücking
Fungal mantle
Forked root
1 mm
Rhizomorphs
Heike Bücking
FM
C
HN
E
ST
Heike Bücking
(a)
(b)
(c)

Figure 23.19

23.4 Mycorrhizae

- *Endomycorrhizae*
  - Fungal mycelium becomes deeply embedded within the root tissue (Figure 23.20) and is called *arbuscular mycorrhizae*.
  - more common than ectomycorrhizae
  - Found in >80 percent of terrestrial plant species, but cannot be cultured in pure culture.

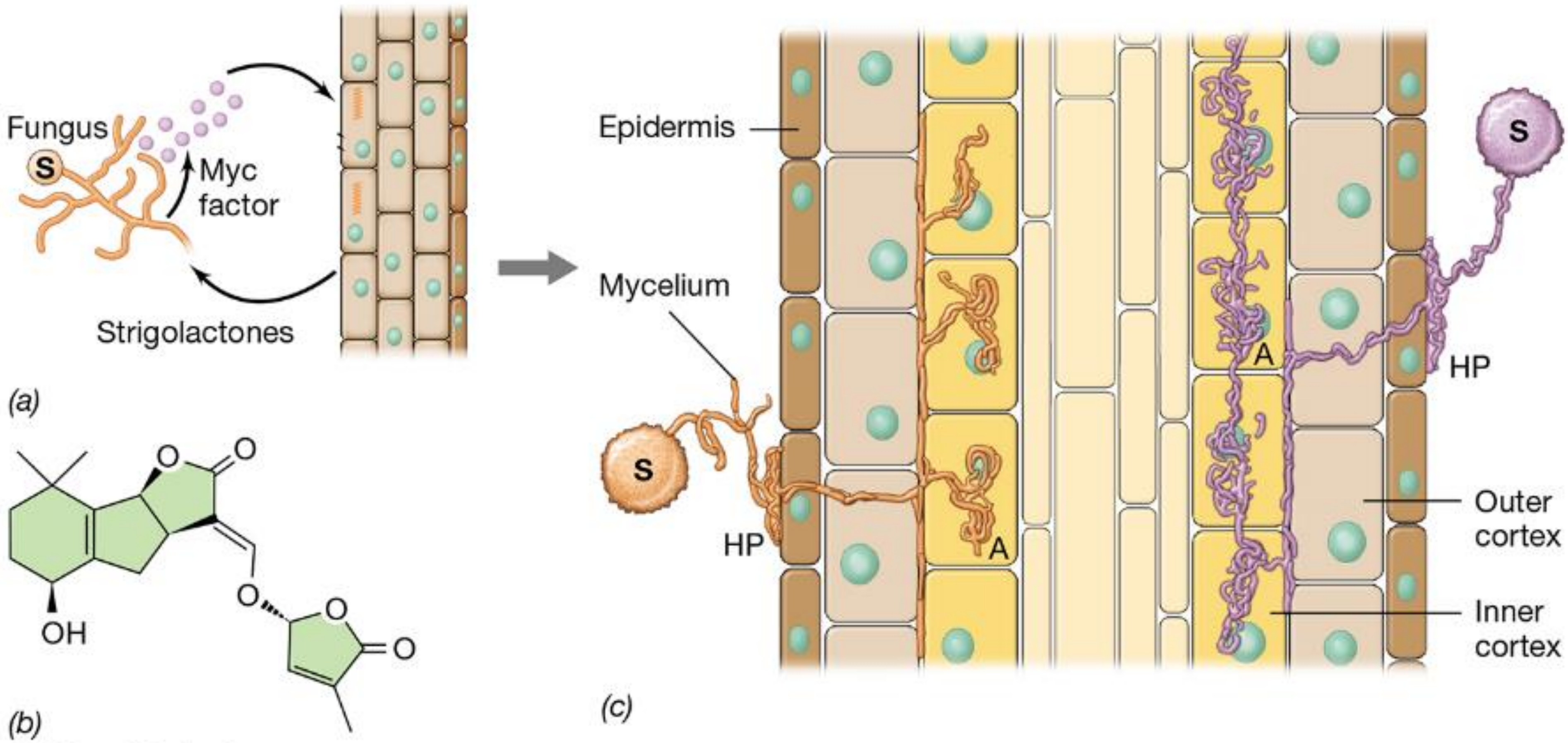

Fungus
S
Myc
factor
Strigolactones
(a)
O
O
O
O
O
OH
(b)
Epidermis
Mycelium
S
HP
A
A
S
HP
Outer
cortex
Inner
cortex
(c)

Figure 23.20

23.4 Mycorrhizae

- Mycorrhizal fungi assist plants.
  - improve nutrient absorption (Figure 23.21)
    - This is due to the greater surface area provided by the fungal mycelium.
  - help to promote plant growth (Figure 23.22)

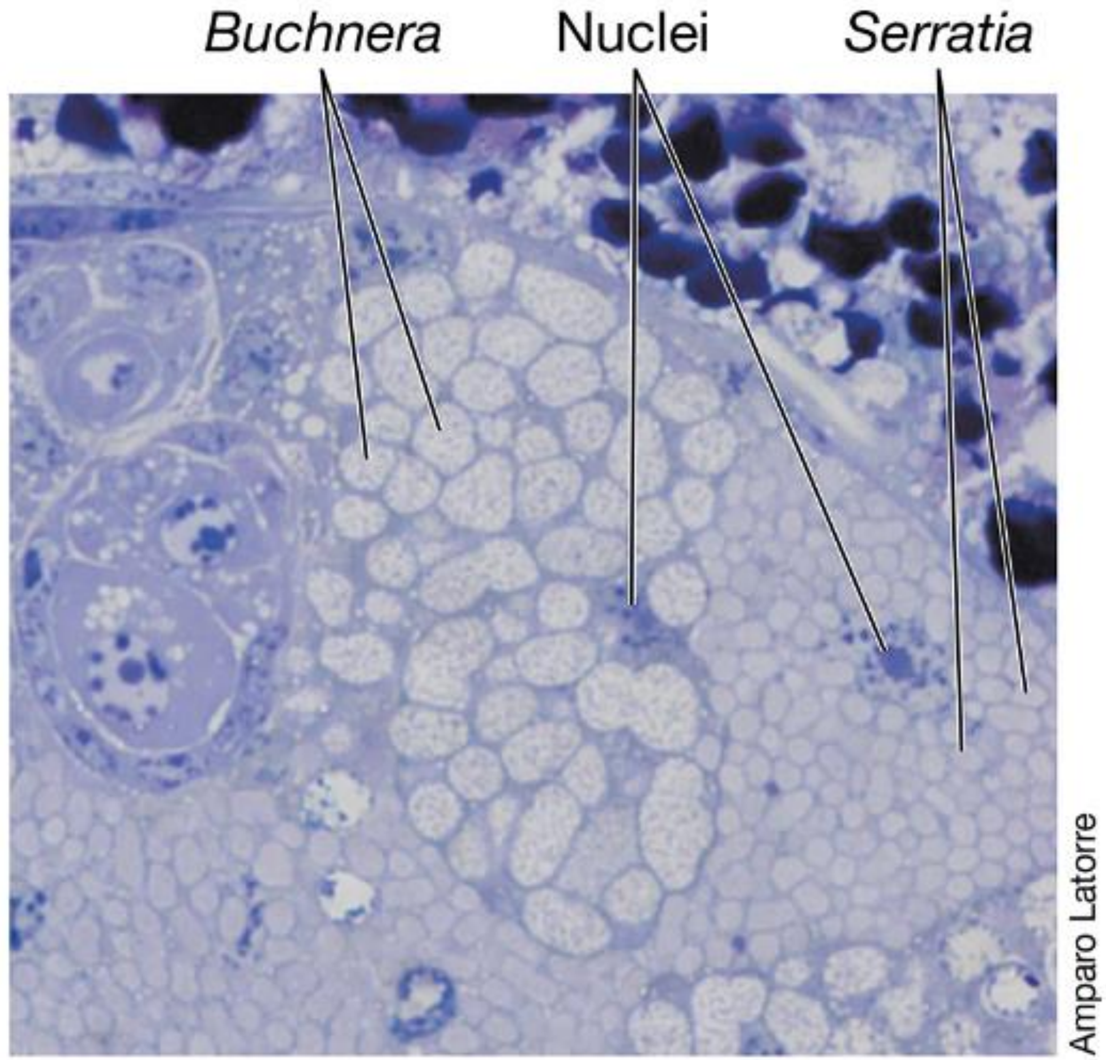
III. Insects as Microbial Habitats

- 23.6 Heritable Symbionts of Insects
- 23.7 Termites

23.6 Heritable Symbionts of Insects

- Microbial symbionts can be acquired from:
  - environmental reservoir (*horizontal transmission*)
  - parent (*vertical* or *heritable transmission*)
- Heritable symbionts of insects are *obligate* (lack a free-living replicative stage).
- *Primary symbionts* are required for the host to reproduce.
  - restricted to bacteriome
    - Bacterial cells are found in bacteriocytes. (Figure 23.26)

(a)



(b)

Figure 23.26

23.6 Heritable Symbionts of Insects

- *Secondary symbionts*
  - not required for reproduction
  - not always present in every individual
  - can invade different cells and live extracellularly
  - must provide a benefit
    - nutritional
    - protection from environment
    - protection from pathogens
- Some parasitic symbionts manipulate host's reproductive tissue
  - *Rickettsia*-infected white flies produce twice the number of offspring compared to uninfected flies.
  - The sperm of *Wolbachia*-infected males can sterilize uninfected females.

23.6 Heritable Symbionts of Insects

- Some insects exploit the metabolic potential of the symbiont.
- Primary symbionts exhibit extreme gene reduction.
  - genome of insect symbiont ~160 to 800 kbp
  - genome of related free-living bacteria ~2 to 8 Mbp
  - retain only genes needed for host fitness
    - lose catabolic genes
    - Pathogens normally lose anabolic genes.

23.7 Termites

- Termites decompose cellulose and hemicellulose.
- Termites classified as higher or lower based on phylogeny
- Termite gut consists of foregut, midgut, and hindgut. (Figure 23.27)
  - posterior alimentary tract of higher termites (*Termitidae*)
    - diverse community of anaerobes, including cellulolytic anaerobes (Figure 23.28), capable of digesting cellulose
  - Termites contain both acetate producing
  - lower termites
    - anaerobic bacteria and cellulolytic protists