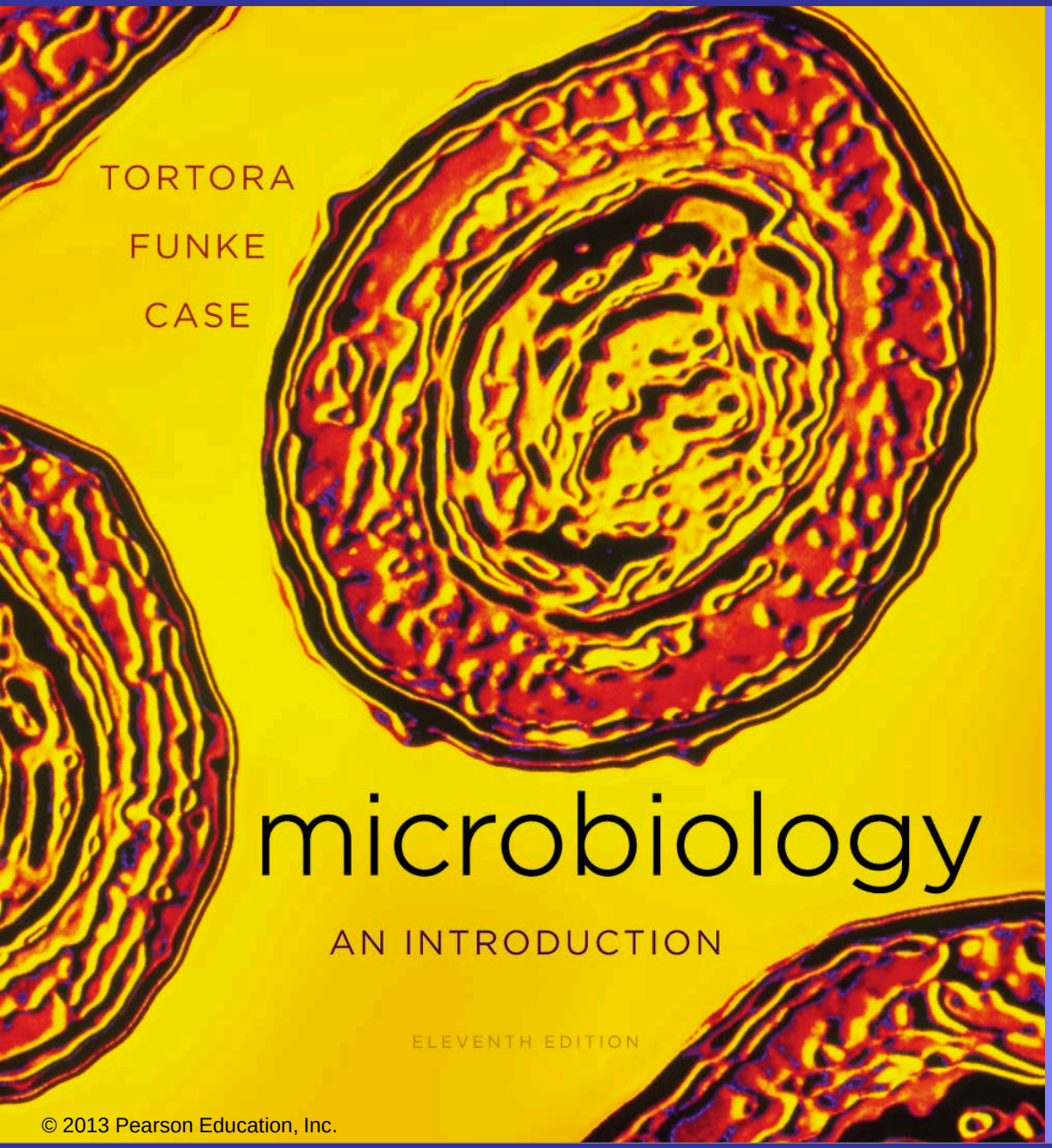
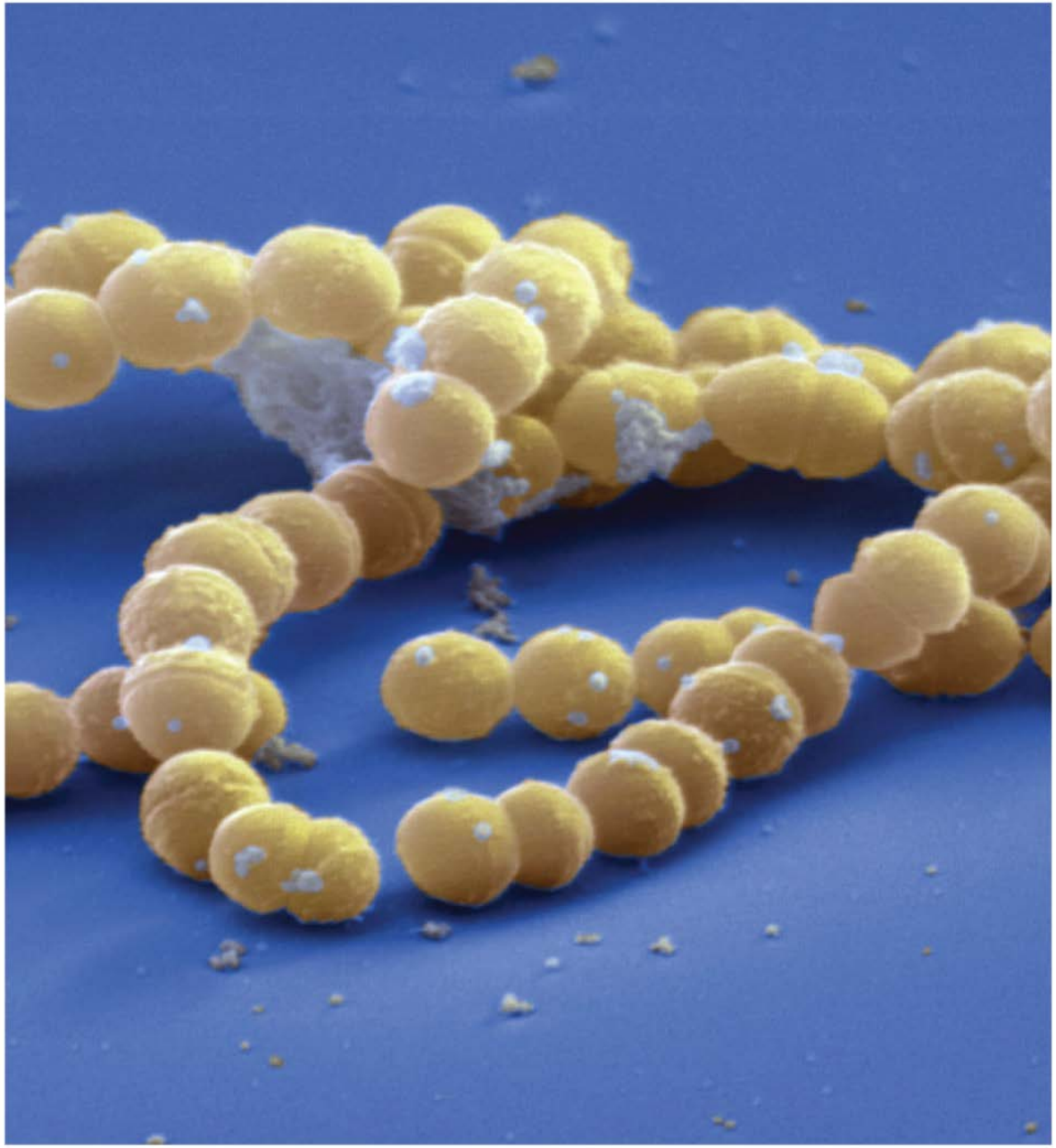


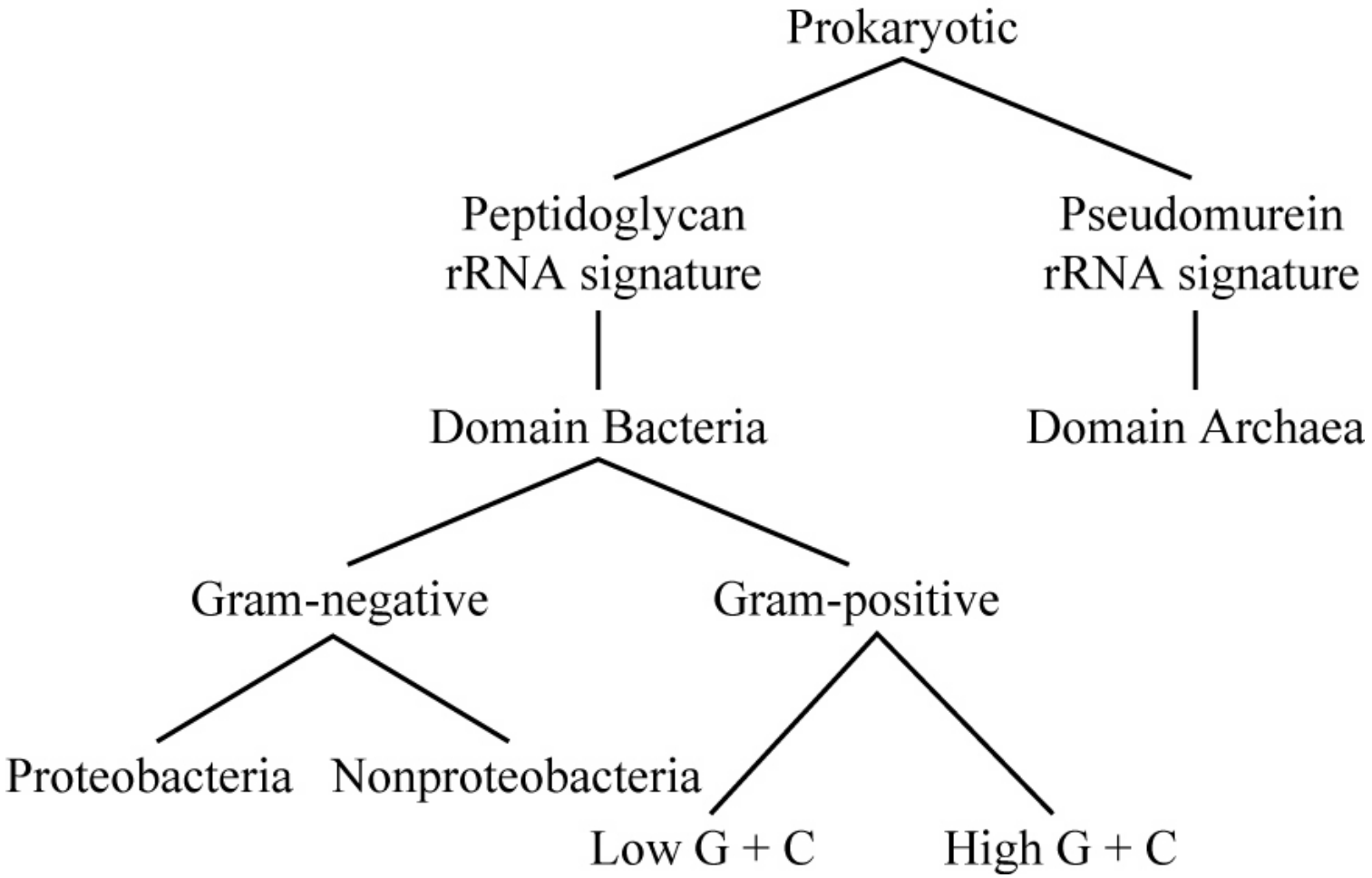
Chapter 11

The Prokaryotes: Domains of Bacteria and Archaea

Lectures prepared by Christine L. Case



The Prokaryotes



Domain Bacteria

- **Proteobacteria**
  - From the mythical Greek god Proteus, who could assume many shapes
  - Gram-negative
  - Chemoheterotrophic

The Alphaproteobacteria

Learning Objective

11-1 Differentiate the alphaproteobacteria described in this chapter by drawing a dichotomous key.

The Alphaproteobacteria

- ***Pelagibacter ubique***
  - Discovered by FISH technique
  - 20% of prokaryotes in oceans
  - 0.5% of all prokaryotes
  - 1354 genes

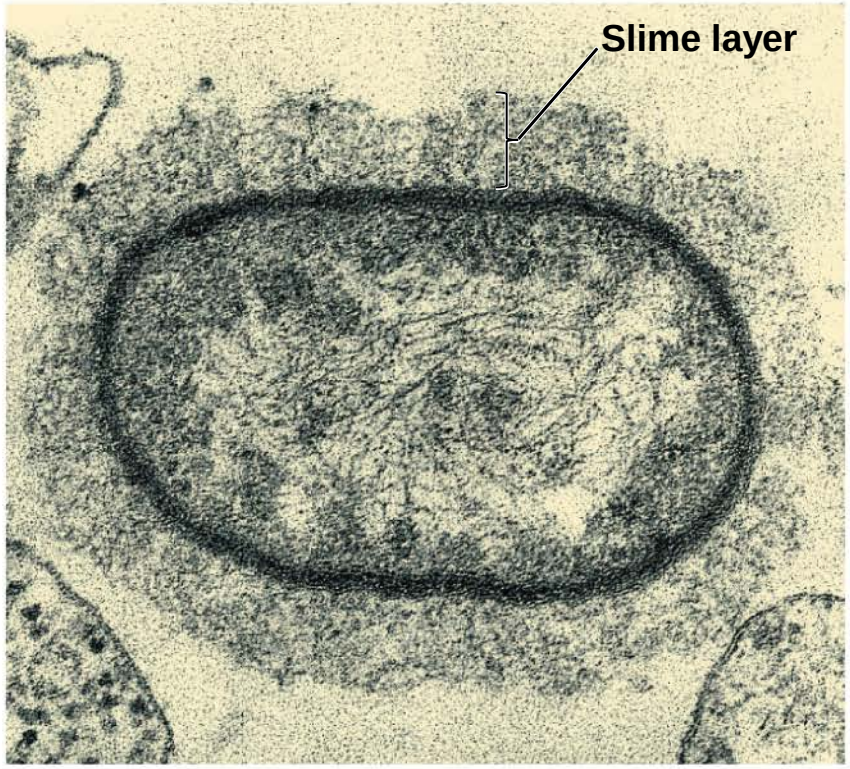
The Alphaproteobacteria

- Human pathogens
  - ***Bartonella***
    - *B. henselae*: cat-scratch disease
  - ***Brucella***: brucellosis
  - ***Ehrlichia***: tickborne

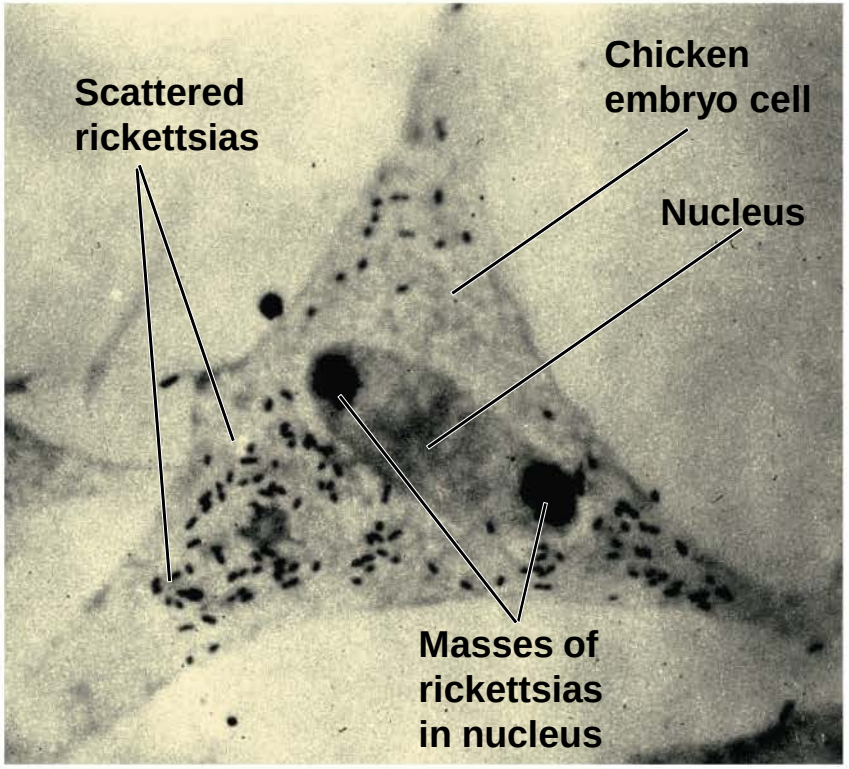
The Alphaproteobacteria

- Obligate intracellular parasites
  - ***Ehrlichia***: tickborne, ehrlichiosis
  - ***Rickettsia***: arthropod-borne, spotted fevers
    - *R. prowazekii*: epidemic typhus
    - *R. typhi*: endemic murine typhus
    - *R. rickettsii*: Rocky Mountain spotted fever

Figure 11.1 Rickettsias.



(a) A rickettsial cell that has just been released from a host cell

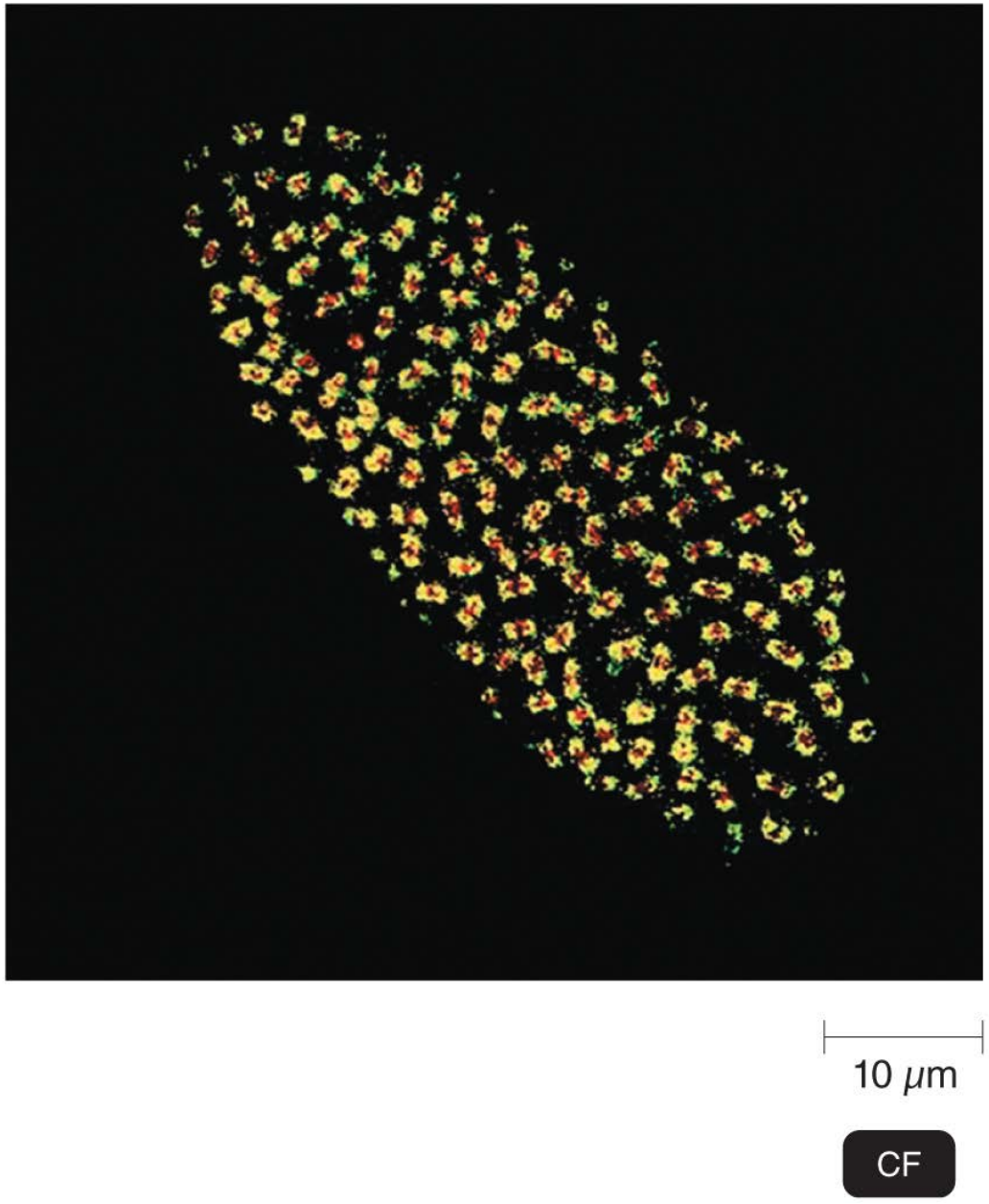


(b) Rickettsias grow only within a host cell, such as the chicken embryo cell shown here. Note the scattered rickettsias within the cell and the compact masses of rickettsias in the cell nucleus.

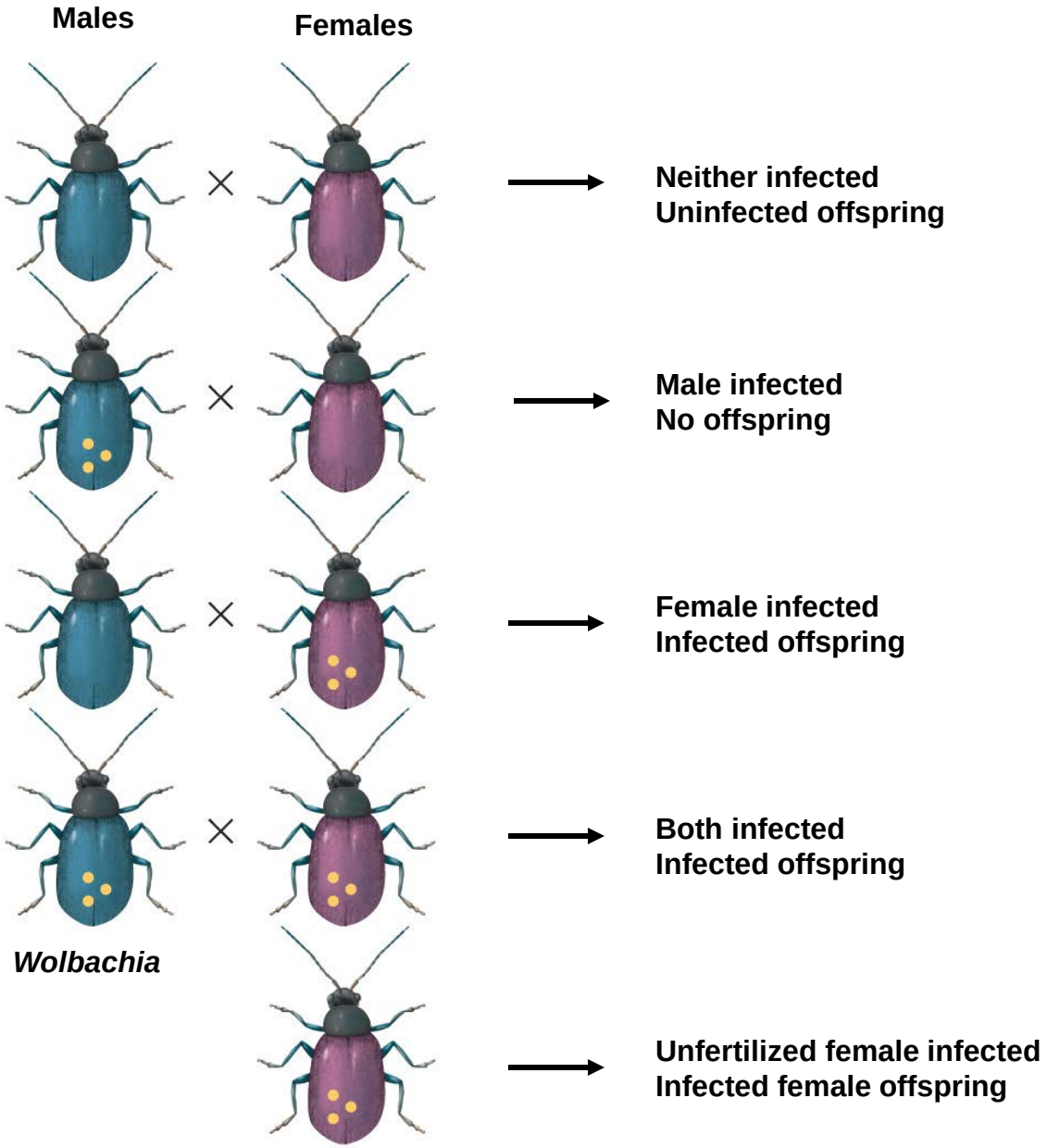
The Alphaproteobacteria

- ***Wolbachia***: live in insects and other animals

Applications of Microbiology 11.1a *Wolbachia* are red inside the cells of this fruit fly embryo.



Applications of Microbiology 11.1b In an infected pair, only female hosts can reproduce.

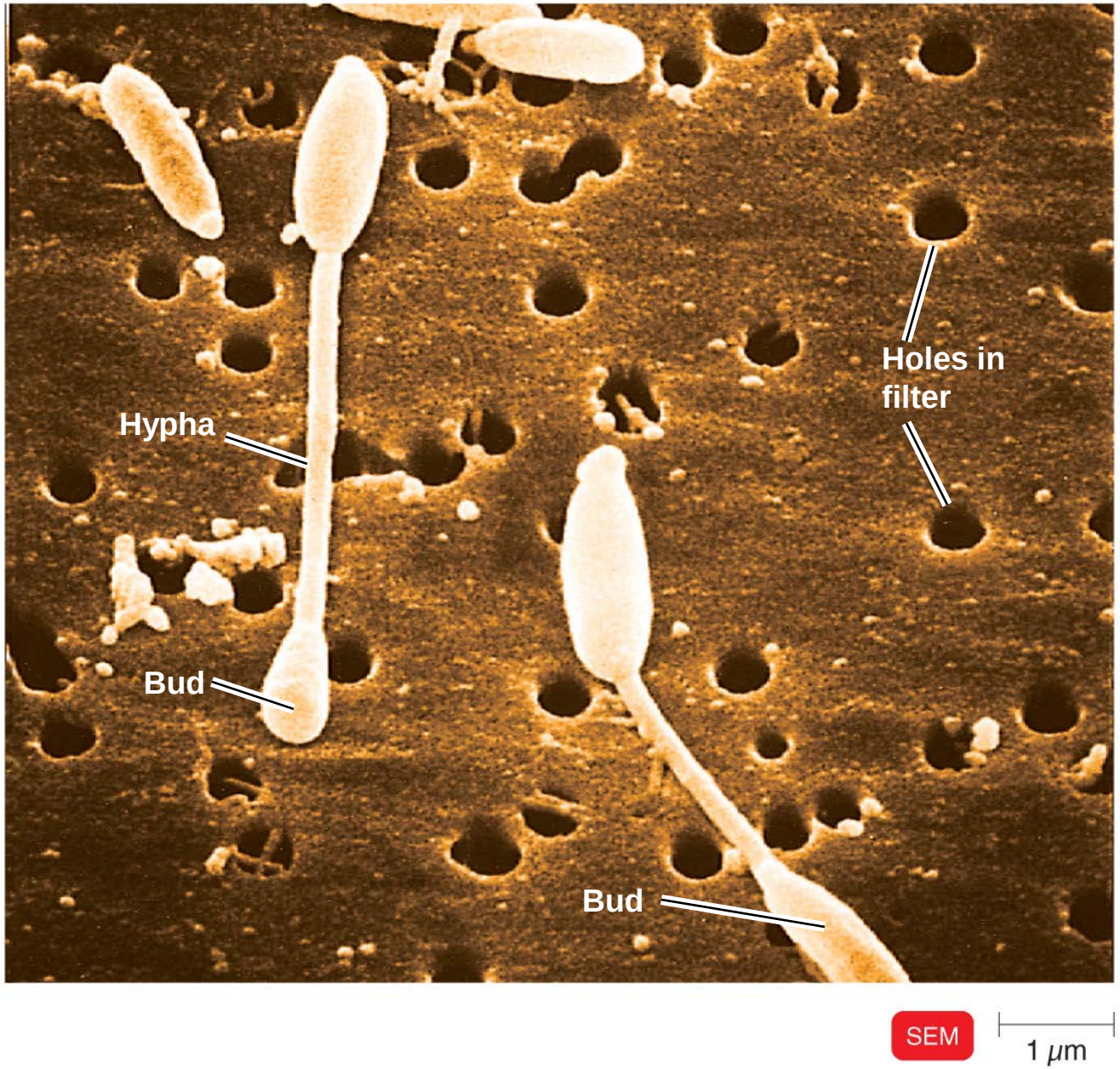


The Alphaproteobacteria

- Have prosthecae
  - ***Caulobacter***: stalked bacteria found in lakes
  - ***Hyphomicrobium***: budding bacteria found in lakes

Figure 11.2b *Caulobacter*.

Figure 11.3 *Hyphomicrobium,* a type of budding bacterium.



The Alphaproteobacteria

- Plant pathogen
  - ***Agrobacterium***: insert a plasmid into plant cells, inducing a tumor

Figure 9.19 Crown gall disease on a rose plant.

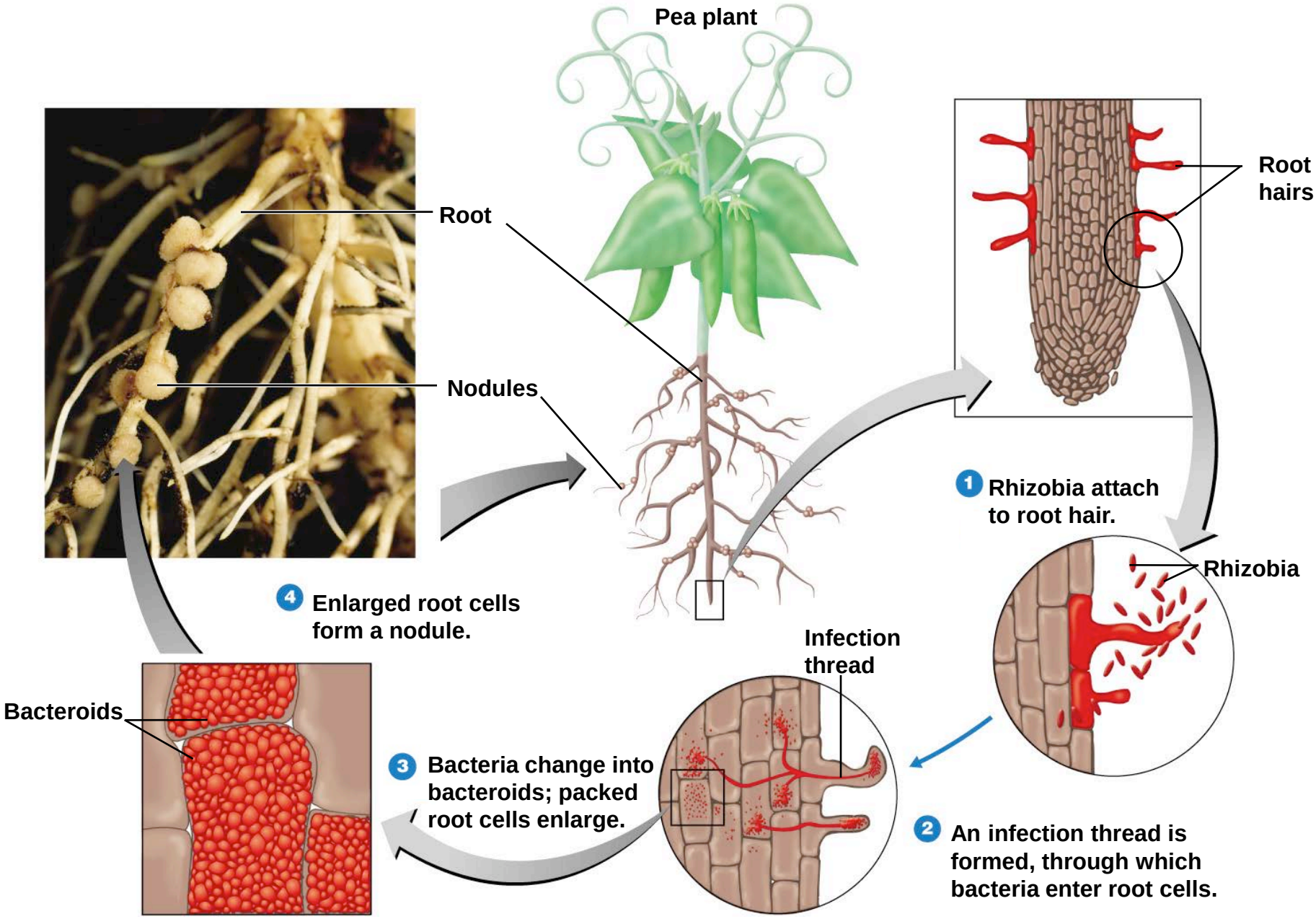
The Alphaproteobacteria

- Chemoautotrophic
  - Oxidize nitrogen for energy
  - Fix CO_2
    - *Nitrobacter*: $NH_3 \rightarrow NO_2^-$
    - *Nitrosomonas*: $NO_2^- \rightarrow NO_3^-$

The Alphaproteobacteria

- Nitrogen-fixing bacteria
  - ***Azospirillum***
    - Grow in soil, using nutrients excreted by plants
    - Fix nitrogen
  - ***Rhizobium***
    - Fix nitrogen in the roots of plants

Figure 27.5 The formation of a root nodule.



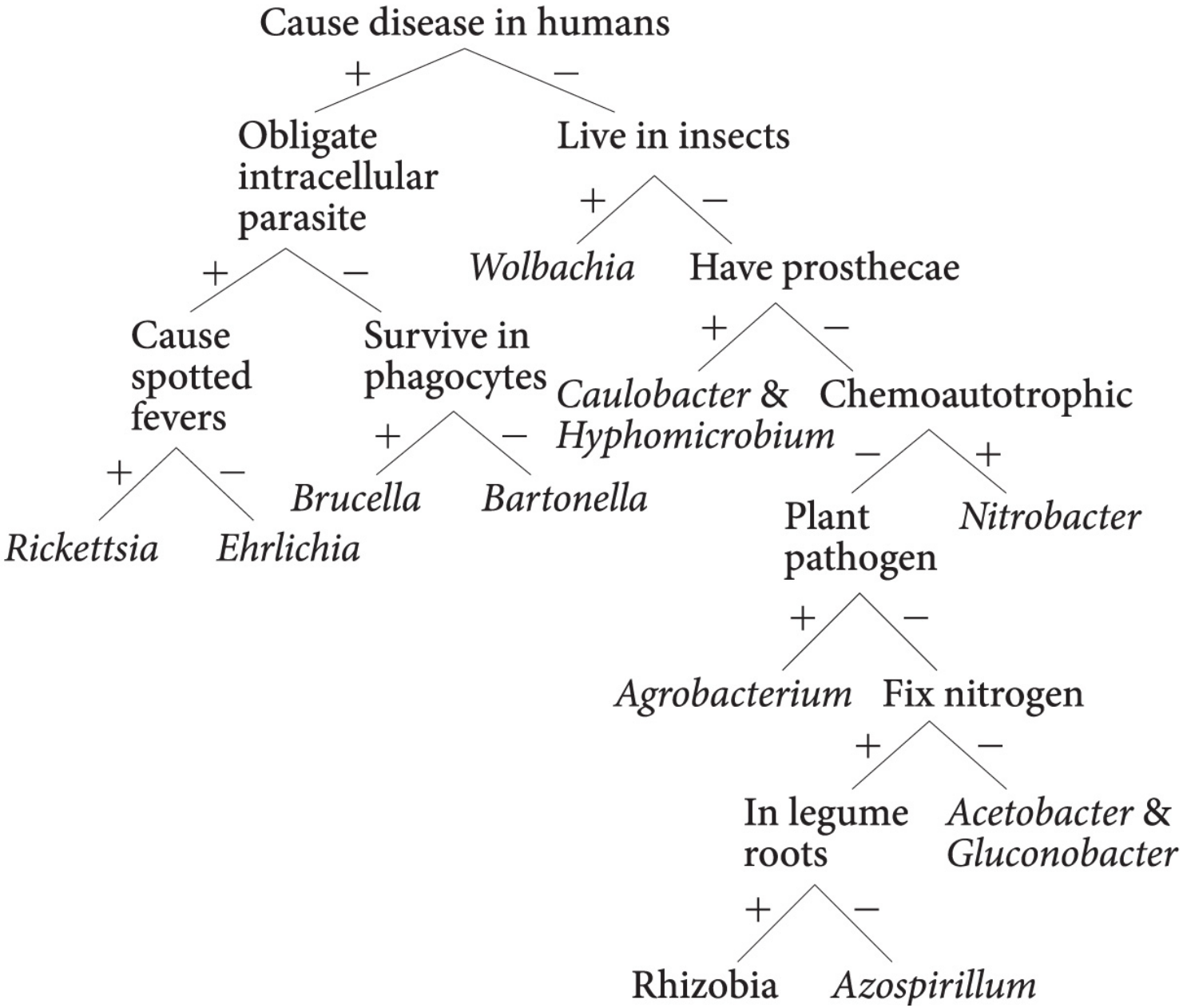
The Alphaproteobacteria

- Produce acetic acid from ethanol
  - *Acetobacter*
  - *Gluconobacter*

Check Your Understanding

- ✓ Make a dichotomous key to distinguish the orders of alphaproteobacteria described in this chapter. 11-1

Chapter 11, unnamed figure, page 303.



The Betaproteobacteria

Learning Objective

11-2 Differentiate the betaproteobacteria described in this chapter by drawing a dichotomous key.

The Betaproteobacteria

- ***Thiobacillus***
  - Chemoautotrophic; oxidize sulfur: $H_2S \rightarrow SO_4^{2-}$
- ***Sphaerotilus***
  - Chemoheterotophic; form sheaths

Figure 11.5 ***Sphaerotilus natans.***

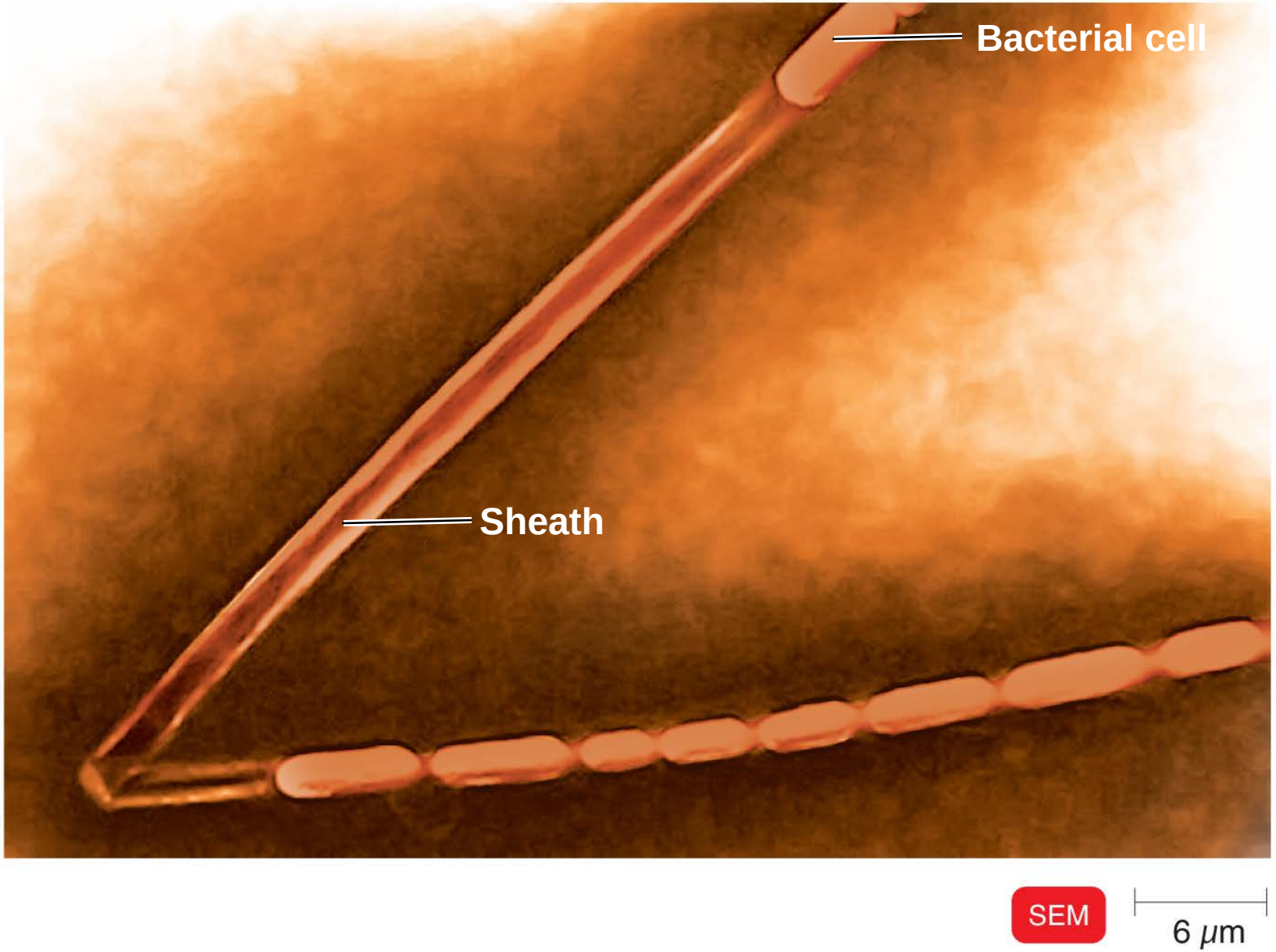


Figure 11.6 The gram-negative coccus *Neisseria gonorrhoeae.*

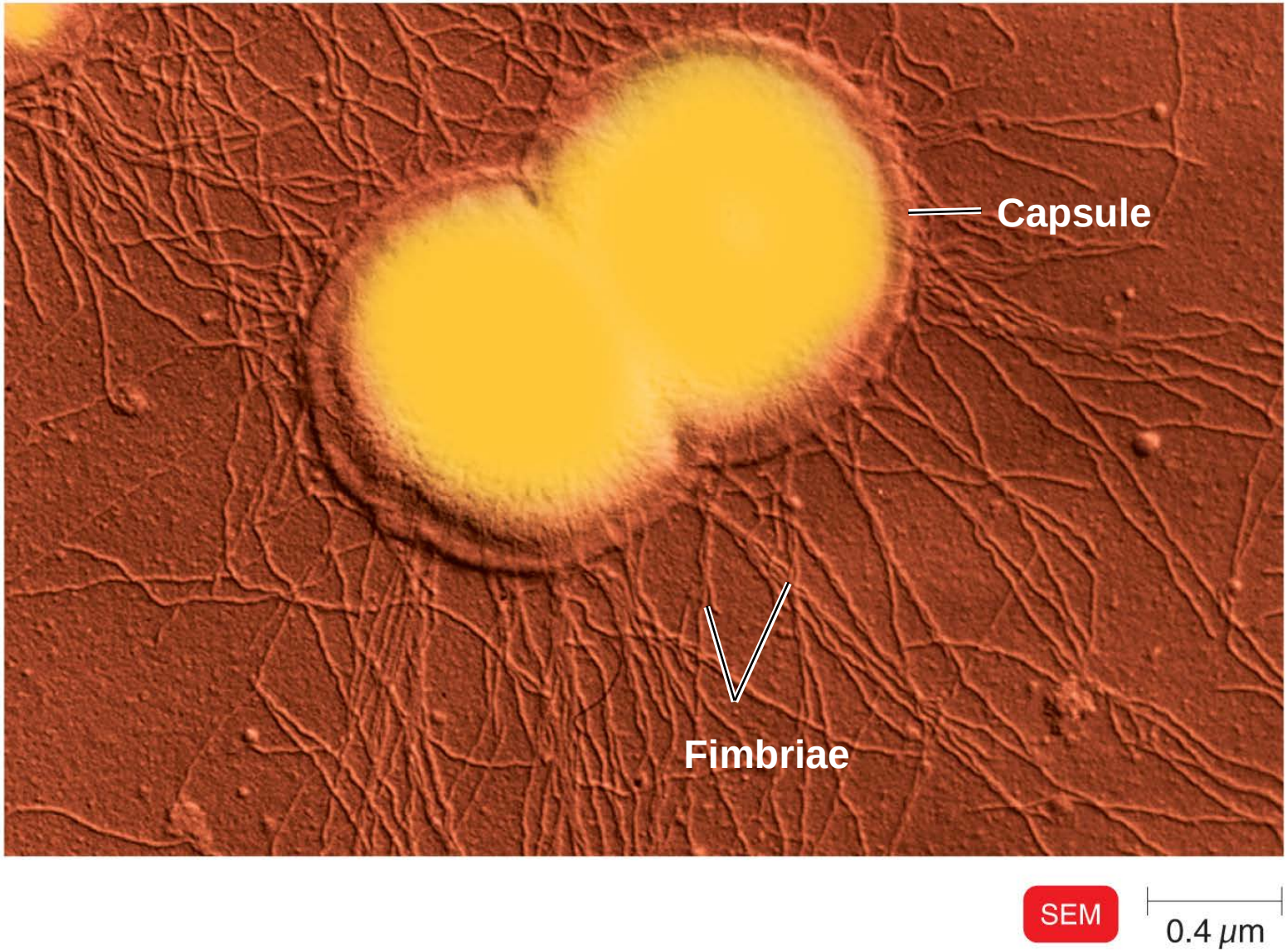


Figure 11.4 ***Spirillum volutans.***

The Betaproteobacteria

- ***Bordetella***
  - Chemoheterotrophic; rods
  - *B. pertussis*
- ***Burkholderia***
  - Nosocomial infections

Figure 24.7 Ciliated cells of the respiratory system infected with *Bordetella pertussis*.

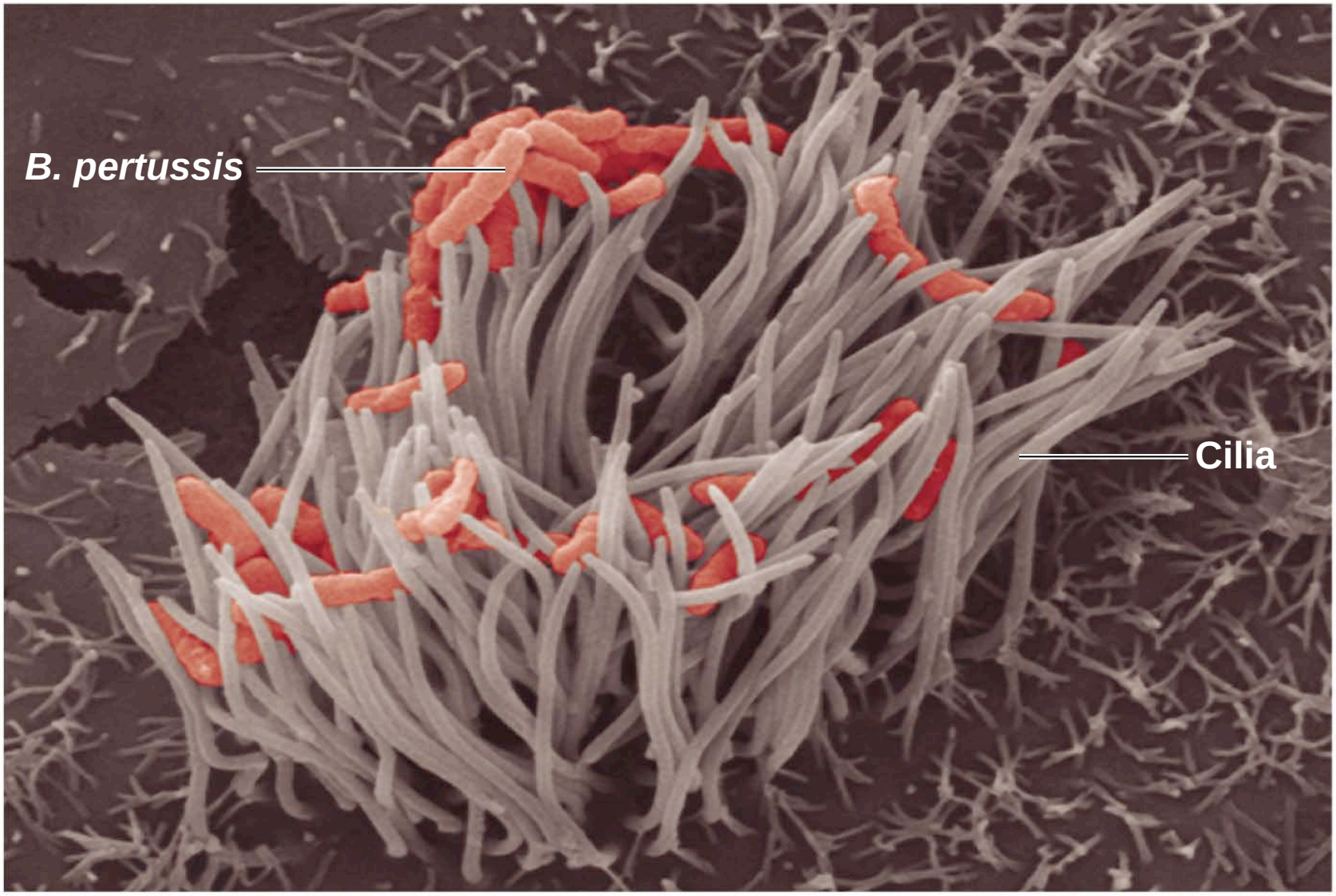
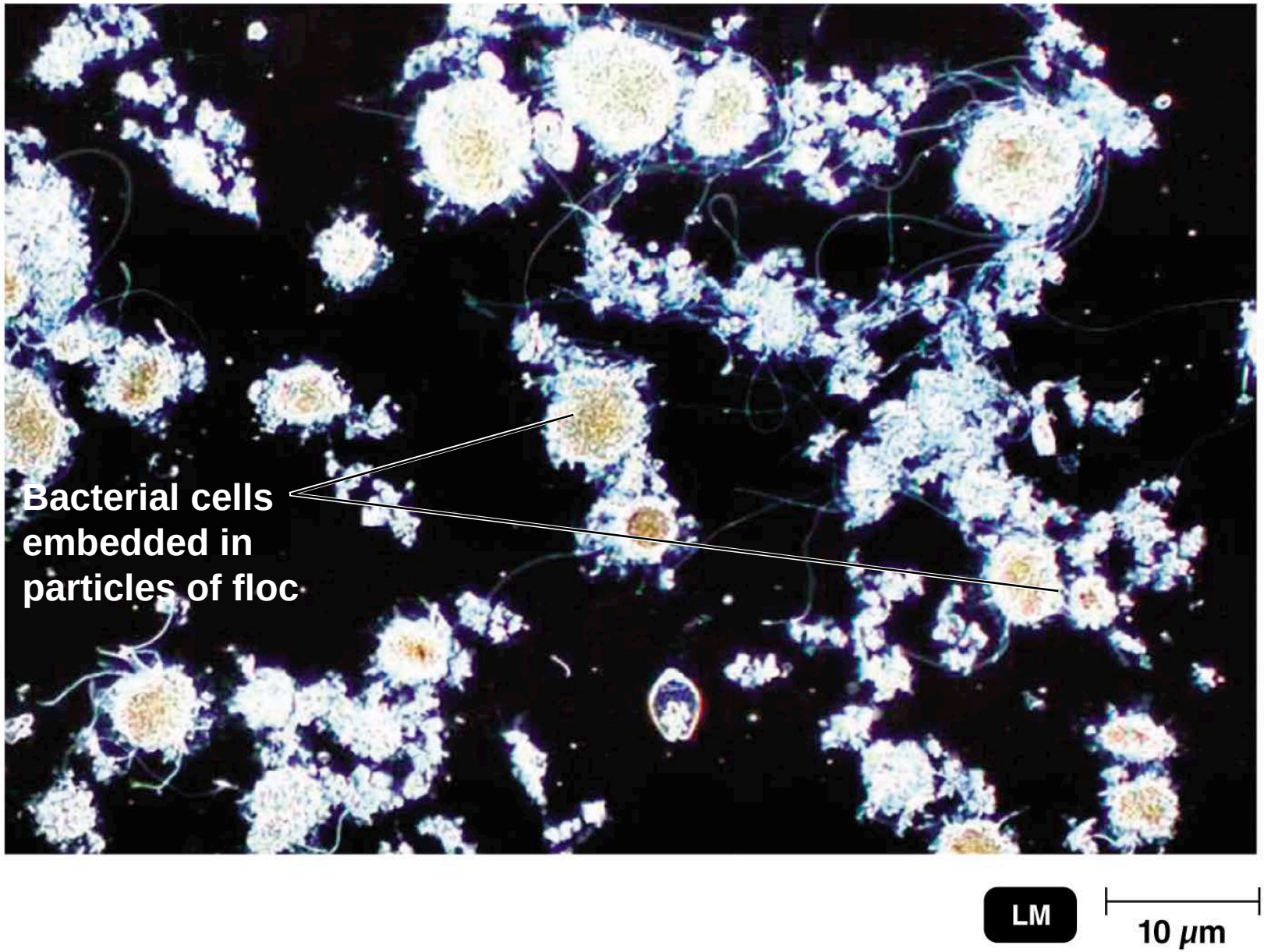


Figure 27.19 Floc formed by an activated sludge system.



Check Your Understanding

- ✓ Make a dichotomous key to distinguish the orders of betaproteobacteria described in this chapter. 11-2

The Gammaproteobacteria

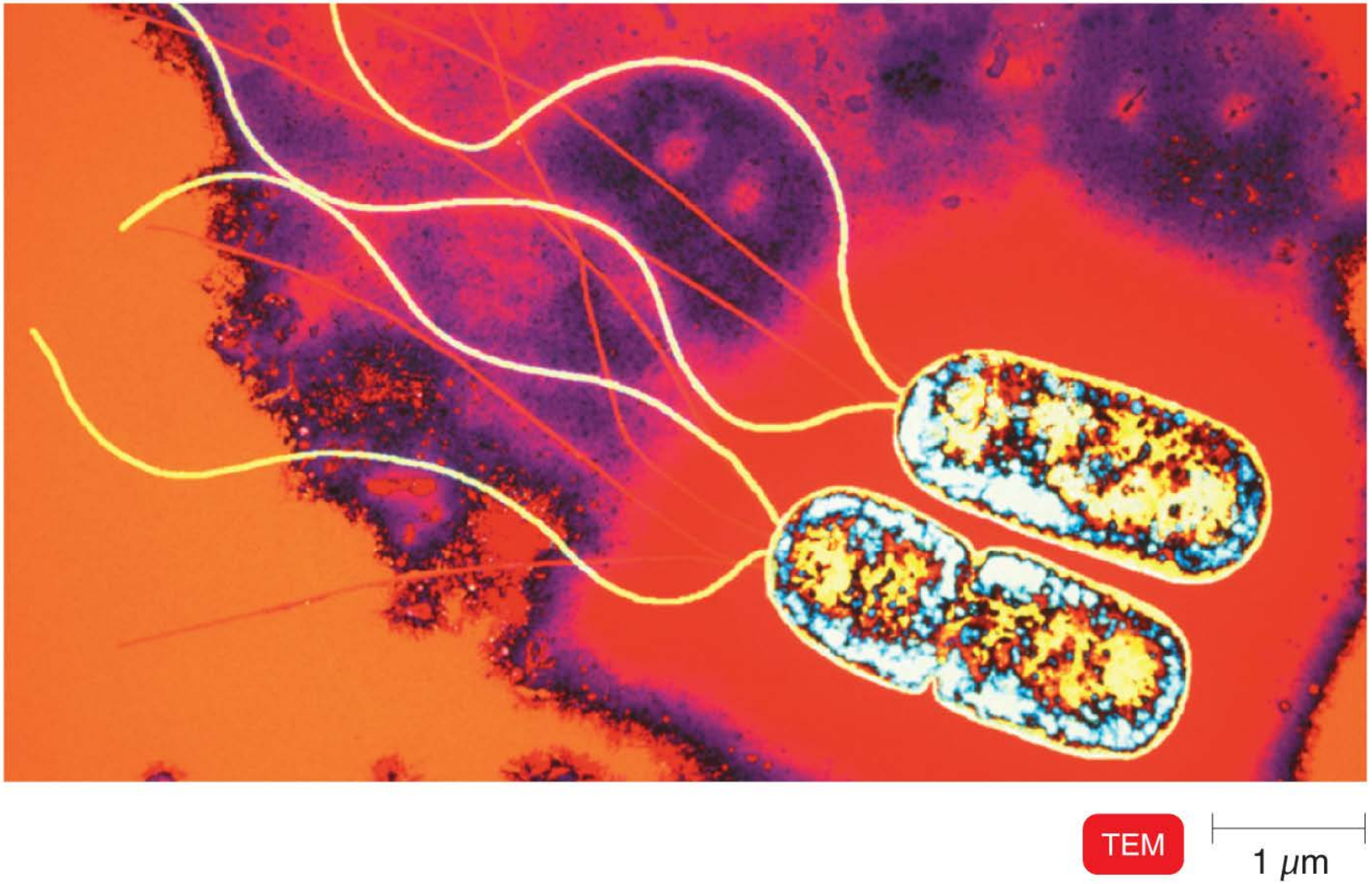
Learning Objective

11-3 Differentiate the gammaproteobacteria described in this chapter by drawing a dichotomous key.

The Gammaproteobacteria

- **Pseudomonadales**
  - ***Pseudomonas***
    - Opportunistic pathogens
    - Metabolically diverse
    - Polar flagella

Figure 11.7 *Pseudomonas.*



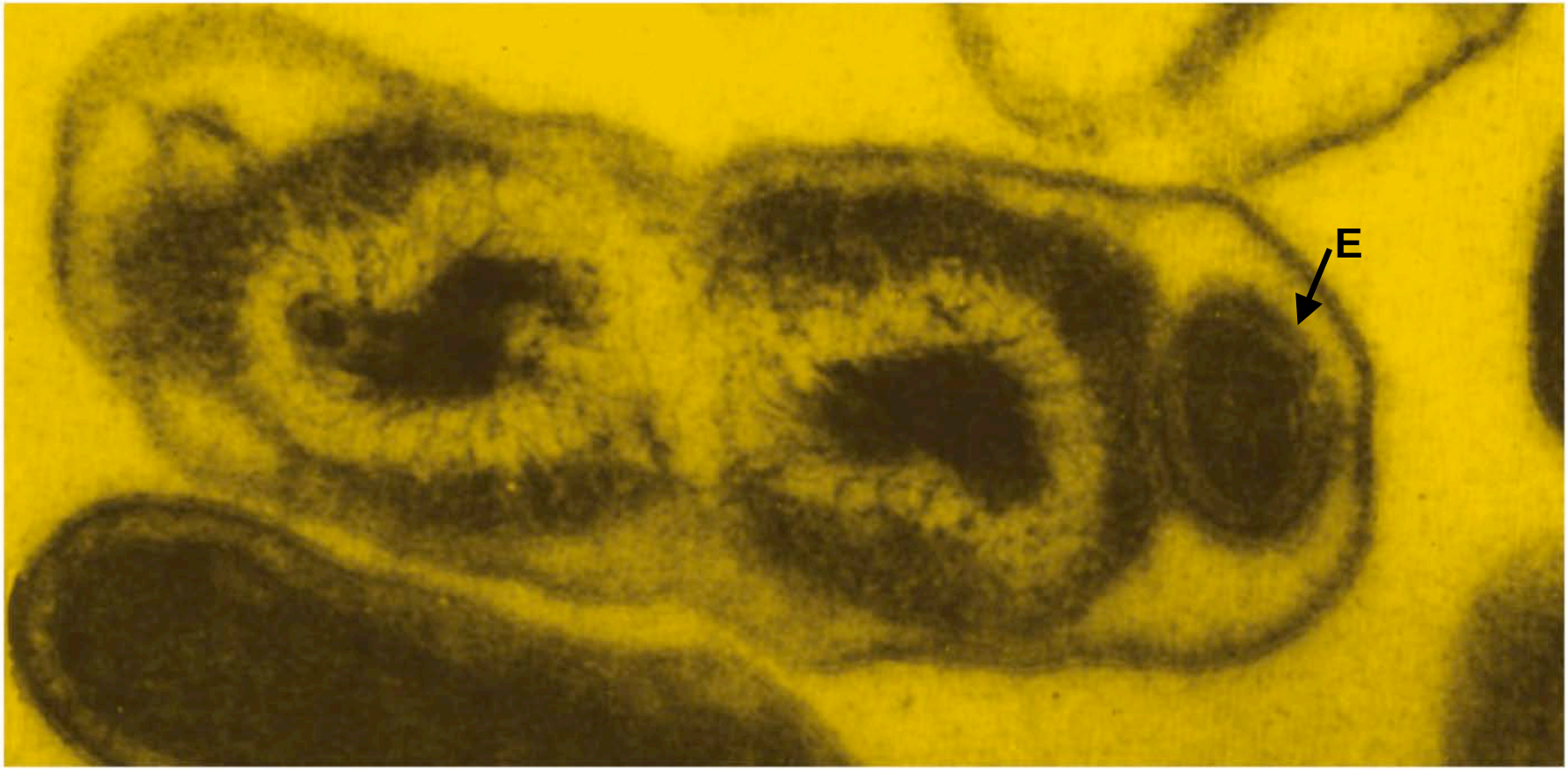
The Gammaproteobacteria

- Pseudomonadales
  - ***Moraxella***
    - Conjunctivitis
  - ***Azotobacter* and *Azomonas***
    - Nitrogen-fixing

The Gammaproteobacteria

- **Legionellales**
  - ***Legionella***
    - Found in streams, warm-water pipes, cooling towers
    - *L. pneumophilia*
  - ***Coxiella***
    - Q fever transmitted via aerosols or milk

Figure 24.14b *Coxiella burnetii*, the cause of Q fever.



(b) This cell has just divided; notice the endospore-like body (E), which is probably responsible for the relative resistance of the organism.

The Gammaproteobacteria

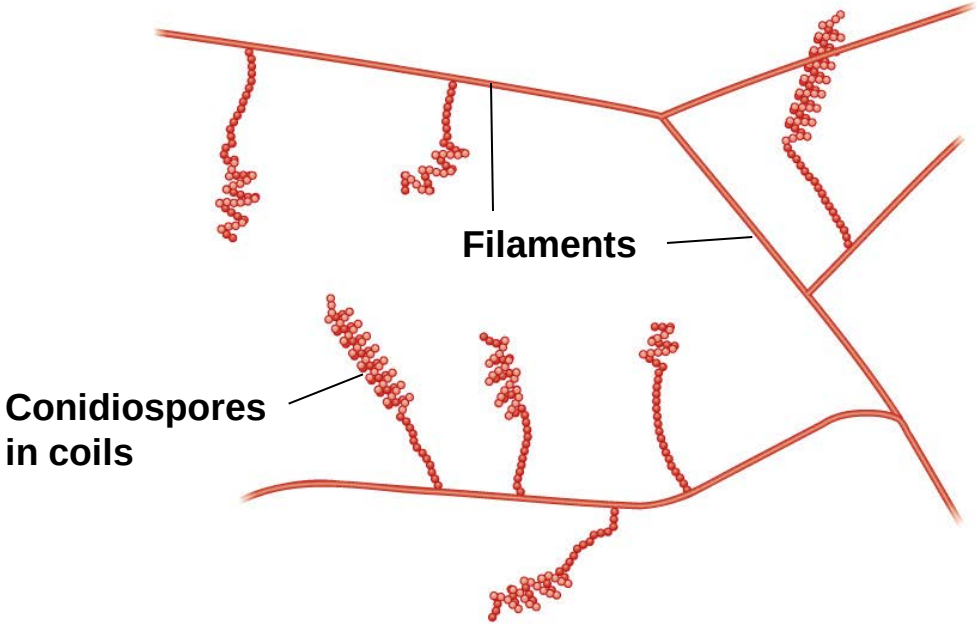
- **Vibrionales**
  - Found in coastal water
    - *Vibrio cholerae* causes cholera
    - *V. parahaemolyticus* causes gastroenteritis

Figure 11.8 ***Vibrio cholerae.***

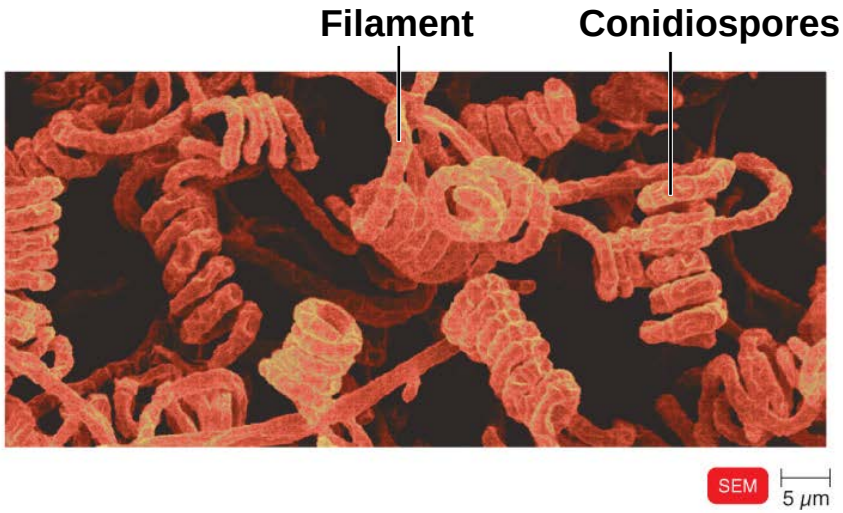
The Gammaproteobacteria

- **Enterobacteriales** (enterics)
  - Peritrichous flagella; facultatively anaerobic
  - *Enterobacter*
  - *Erwinia*
  - *Escherichia*
  - *Klebsiella*
  - *Proteus*
  - *Salmonella*
  - *Serratia*
  - *Shigella*
  - *Yersinia*

Figure 11.19 ***Streptomyces.***



(a) Drawing of a typical streptomycete showing filamentous, branching growth with asexual reproductive conidiospores at the filament tips.



(b) Coils of conidiospores supported by filaments of the streptomycete.

The Gammaproteobacteria

- **Pasteurellales**
  - ***Pasteurella***
    - Cause pneumonia and septicemia
  - ***Haemophilus***
    - Require X (heme) and V (NAD^+, $NADP^+$) factors

The Gammaproteobacteria

- ***Beggiatoa***
  - Chemoautotrophic; oxidize H_2S to S^0 for energy
- ***Francisella***
  - Chemoheterotrophic; tularemia

Check Your Understanding

- ✓ Make a dichotomous key to distinguish the orders of gammaproteobacteria described in this chapter. 11-3

The Deltaproteobacteria

Learning Objective

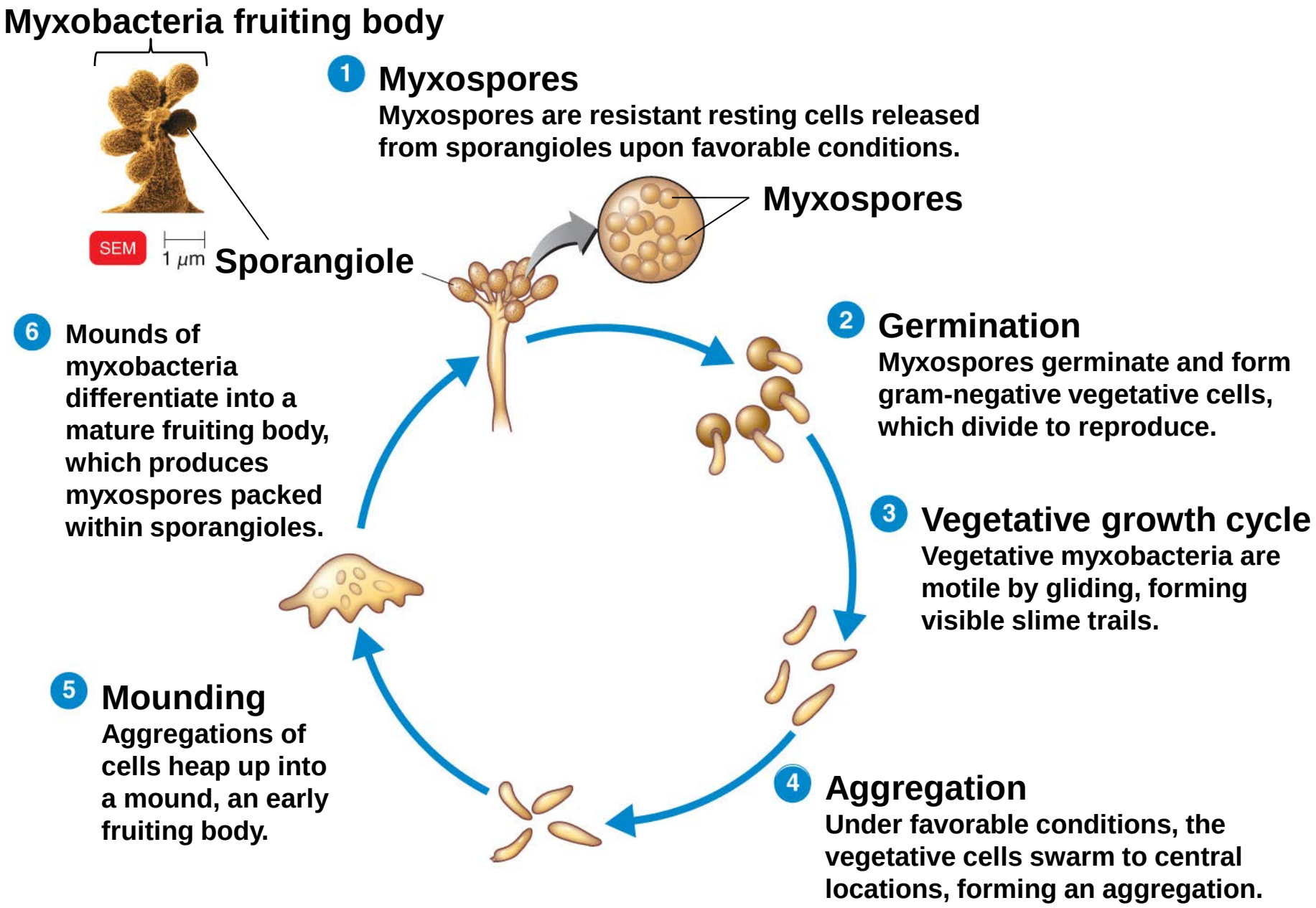
11-4 Differentiate the deltaproteobacteria described in this chapter by drawing a dichotomous key.

Figure 11.10 ***Bdellovibrio bacteriovorus.***

The Deltaproteobacteria

- ***Desulfovibrionales***
  - Use S instead of O_2 as final electron acceptor

Figure 11.11 Myxococcales.



Check Your Understanding

- ✓ Make a dichotomous key to distinguish the deltaproteobacteria described in this chapter. 11-4

The Epsilonproteobacteria

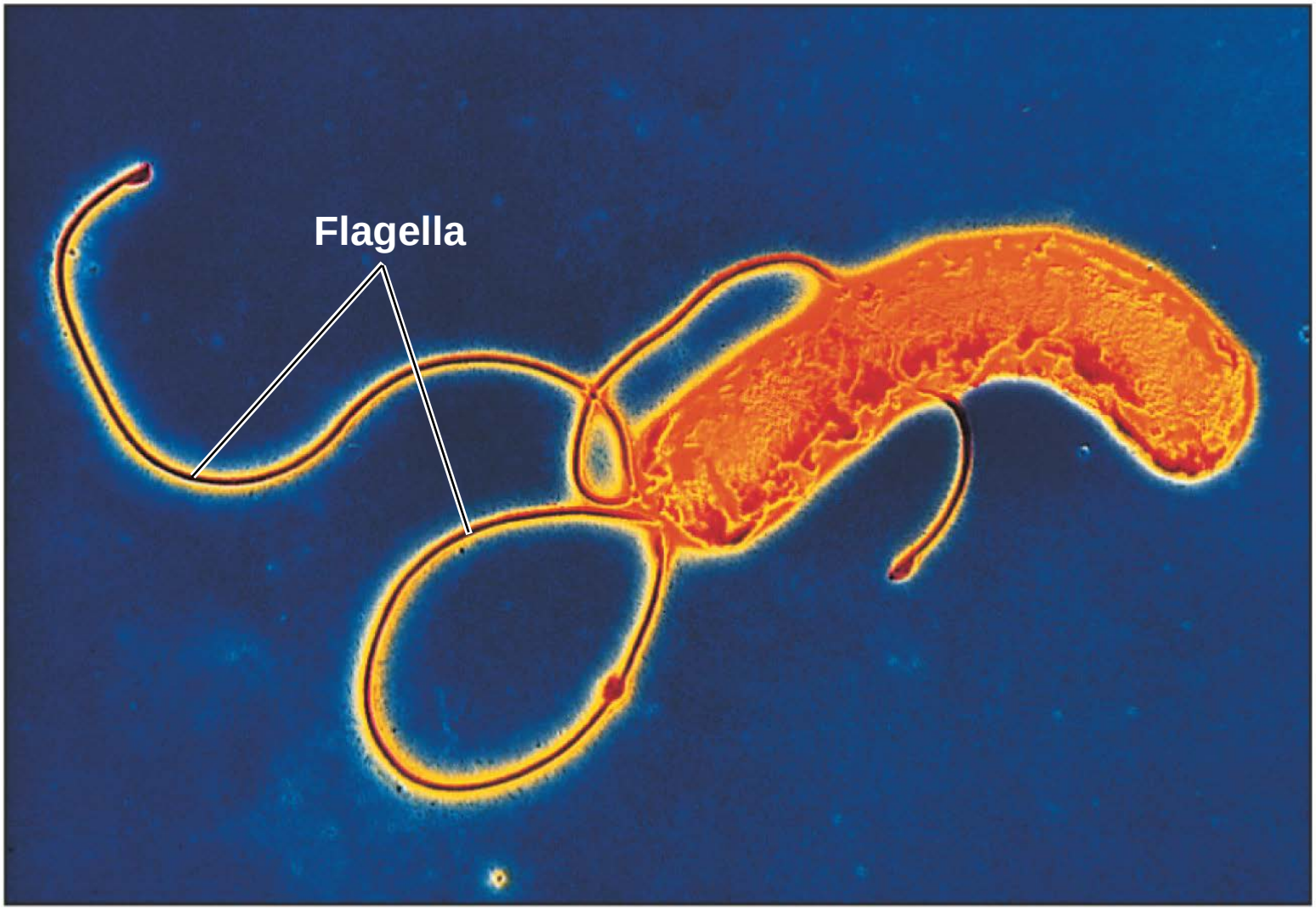
Learning Objective

11-5 Differentiate the epsilonproteobacteria described in this chapter by drawing a dichotomous key.

The Epsilonproteobacteria

- ***Campylobacter***
  - One polar flagellum
  - Gastroenteritis
- ***Helicobacter***
  - Multiple flagella
  - Peptic ulcers
  - Stomach cancer

Figure 11.12 *Heliobacter pylori*.



Check Your Understanding

- ✓ Make a dichotomous key to distinguish the epsilonproteobacteria described in this chapter. 11-5

The Gram-Positive Bacteria

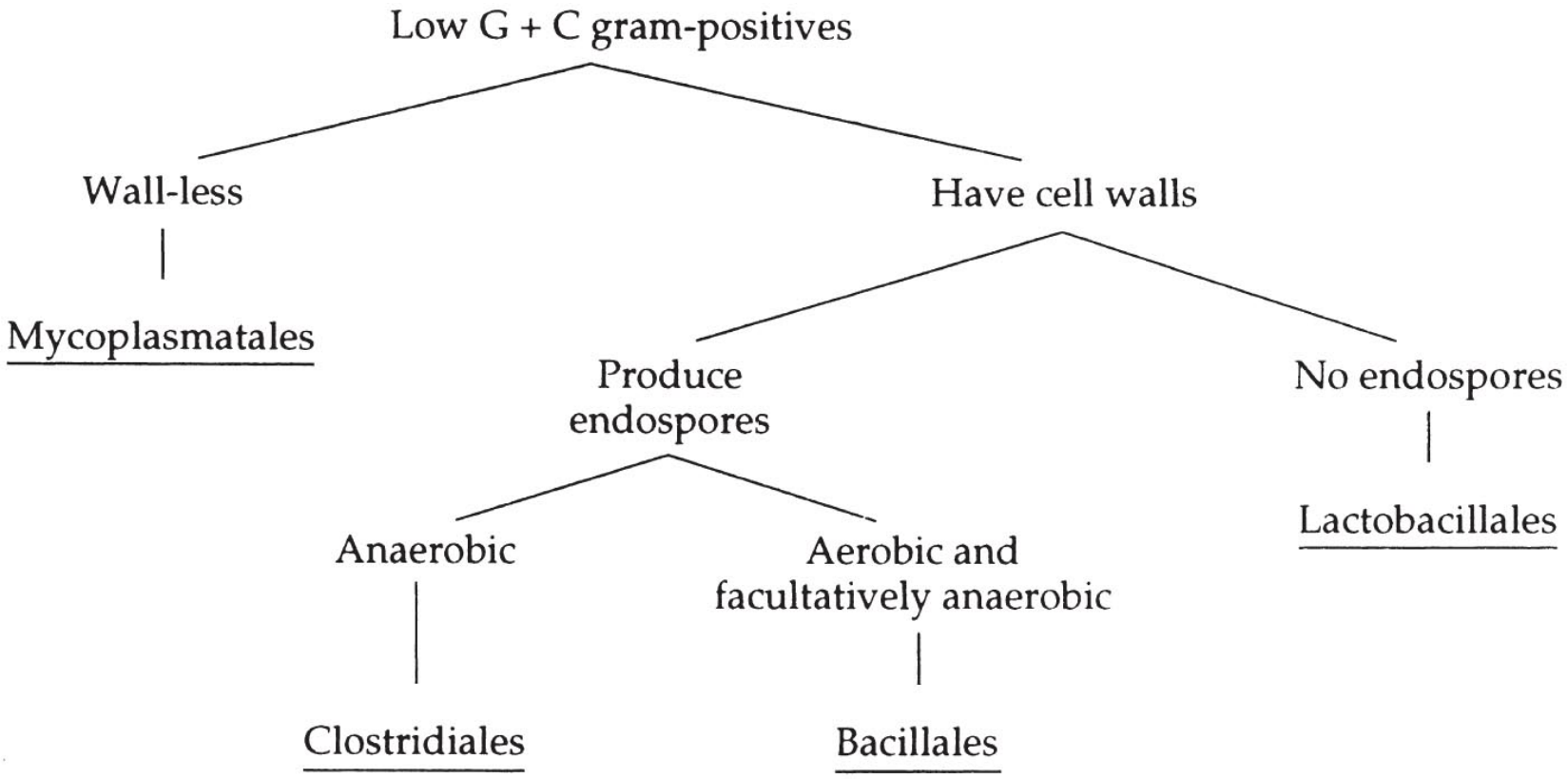
Learning Objectives

11-6 Differentiate the genera of firmicutes described in this chapter by drawing a dichotomous key.

11-7 Differentiate the actinobacteria described in this chapter by drawing a dichotomous key.

Firmicutes

- Low G + C
- Gram-positive



Clostridiales

- ***Clostridium***
  - Endospore-producing
  - Obligate anaerobes
- ***Epulopiscium***

Figure 11.13 ***Clostridium difficile.***

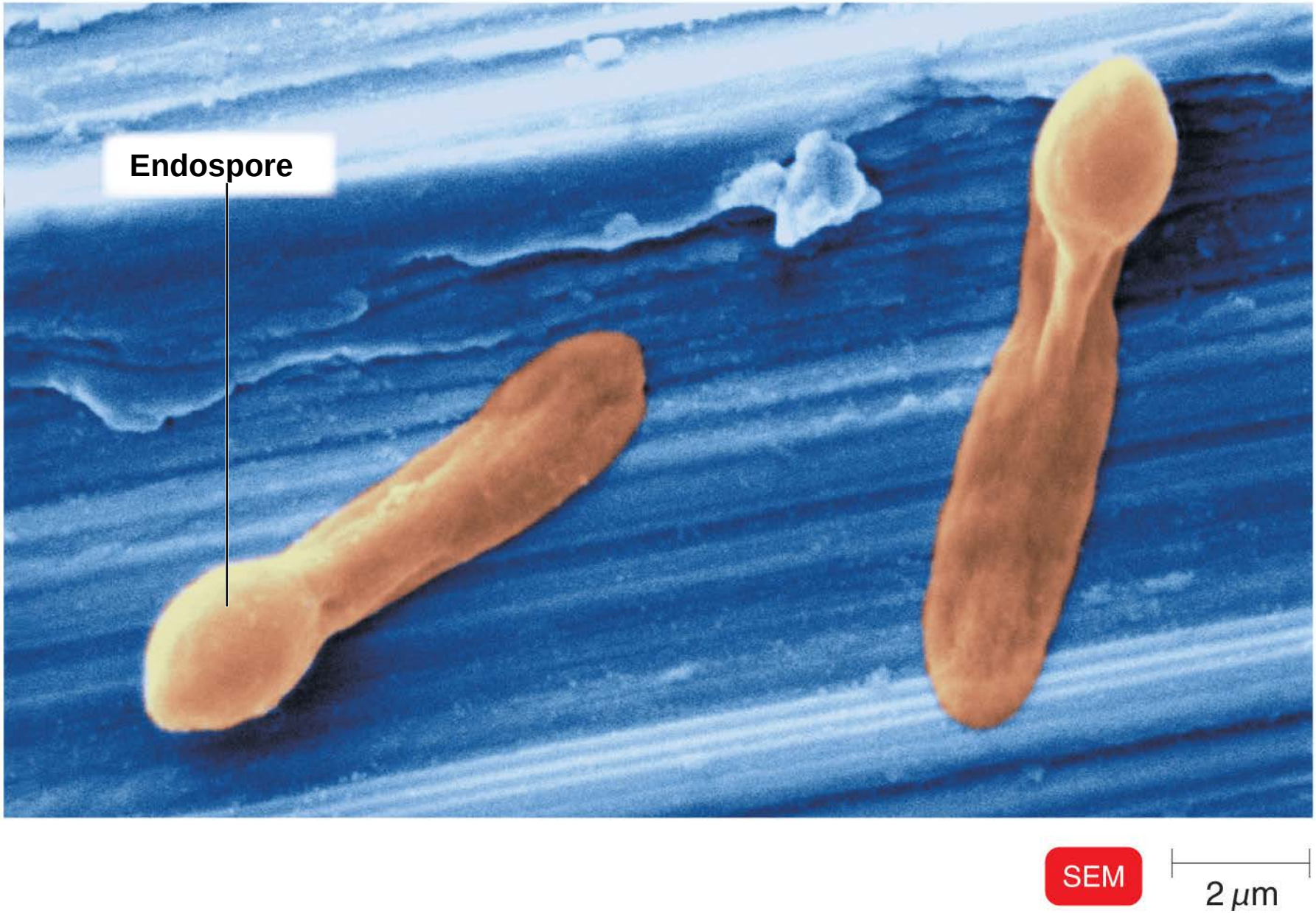
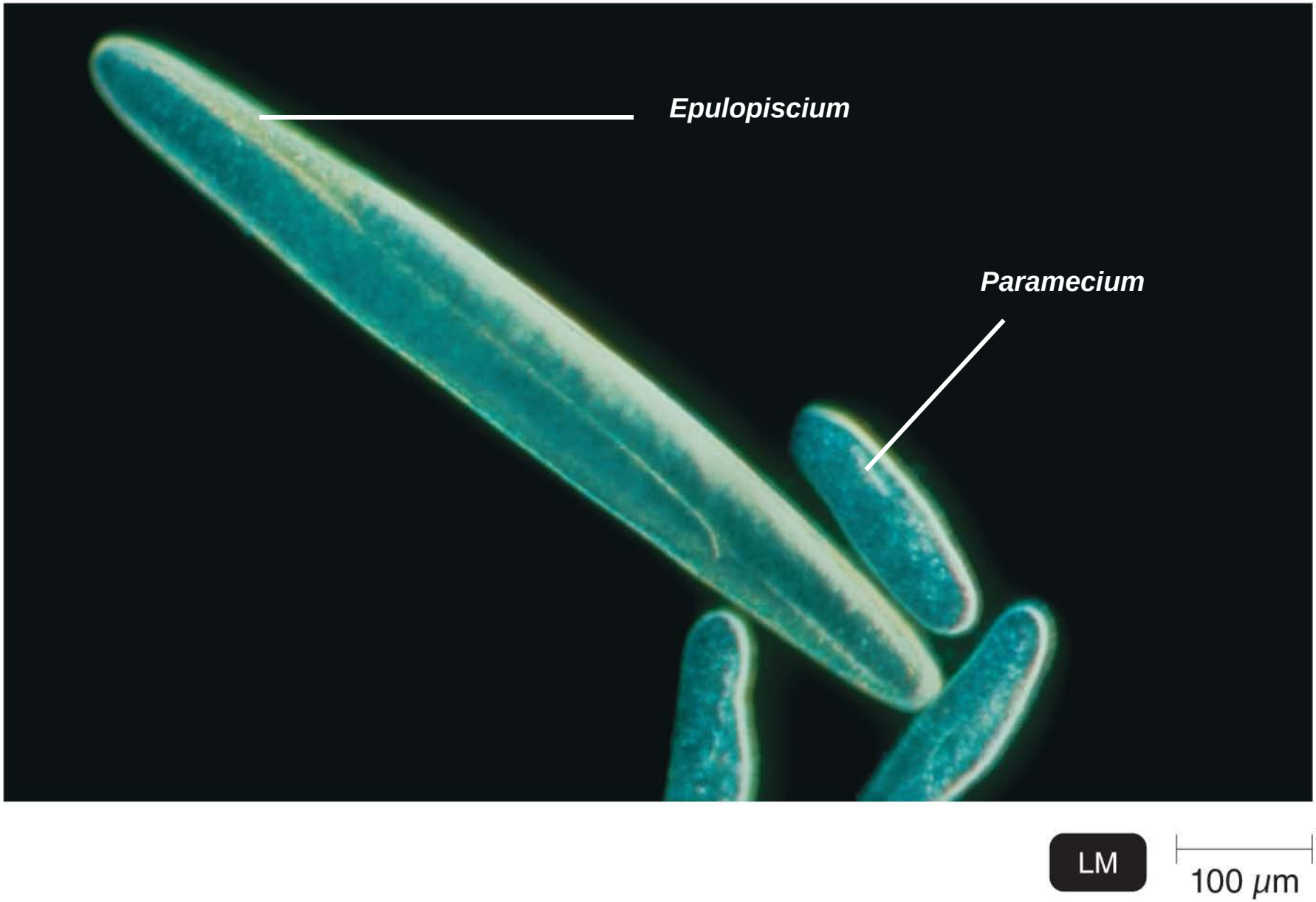


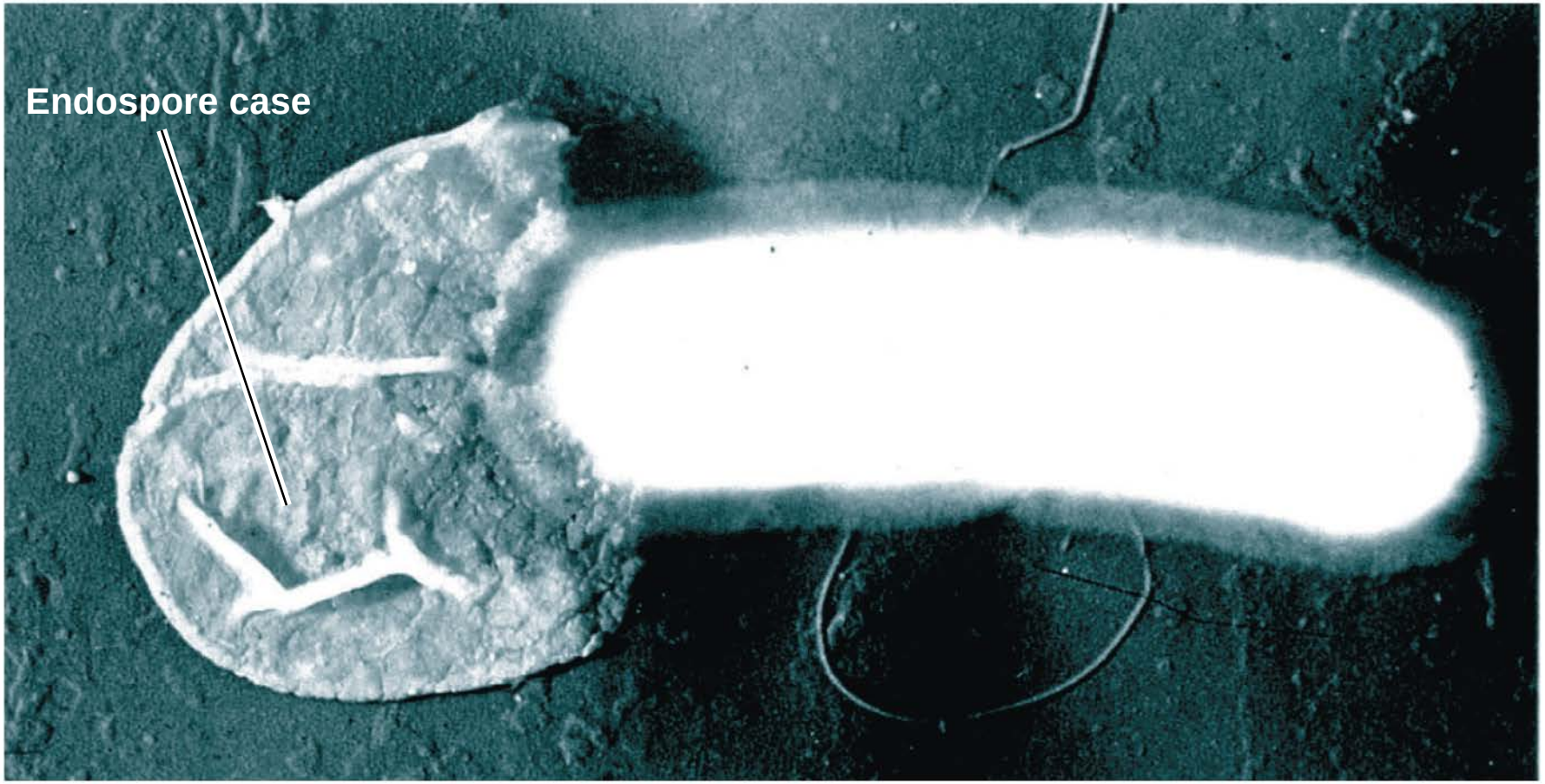
Figure 11.14 A giant prokaryote, *Epulopiscium fishelsoni.*



Bacillales

- ***Bacillus***
  - Endospore-producing rods
- ***Staphylococcus***
  - Cocci

Figure 11.15 *Bacillus*.



(b) This *Bacillus cereus* cell is shown emerging from the endospore.

Figure 11.16 ***Staphylococcus aureus.***

Lactobacillales

- Generally aerotolerant anaerobes; lack an electron transport chain
  - *Lactobacillus*
  - *Streptococcus*
  - *Enterococcus*
  - *Listeria*

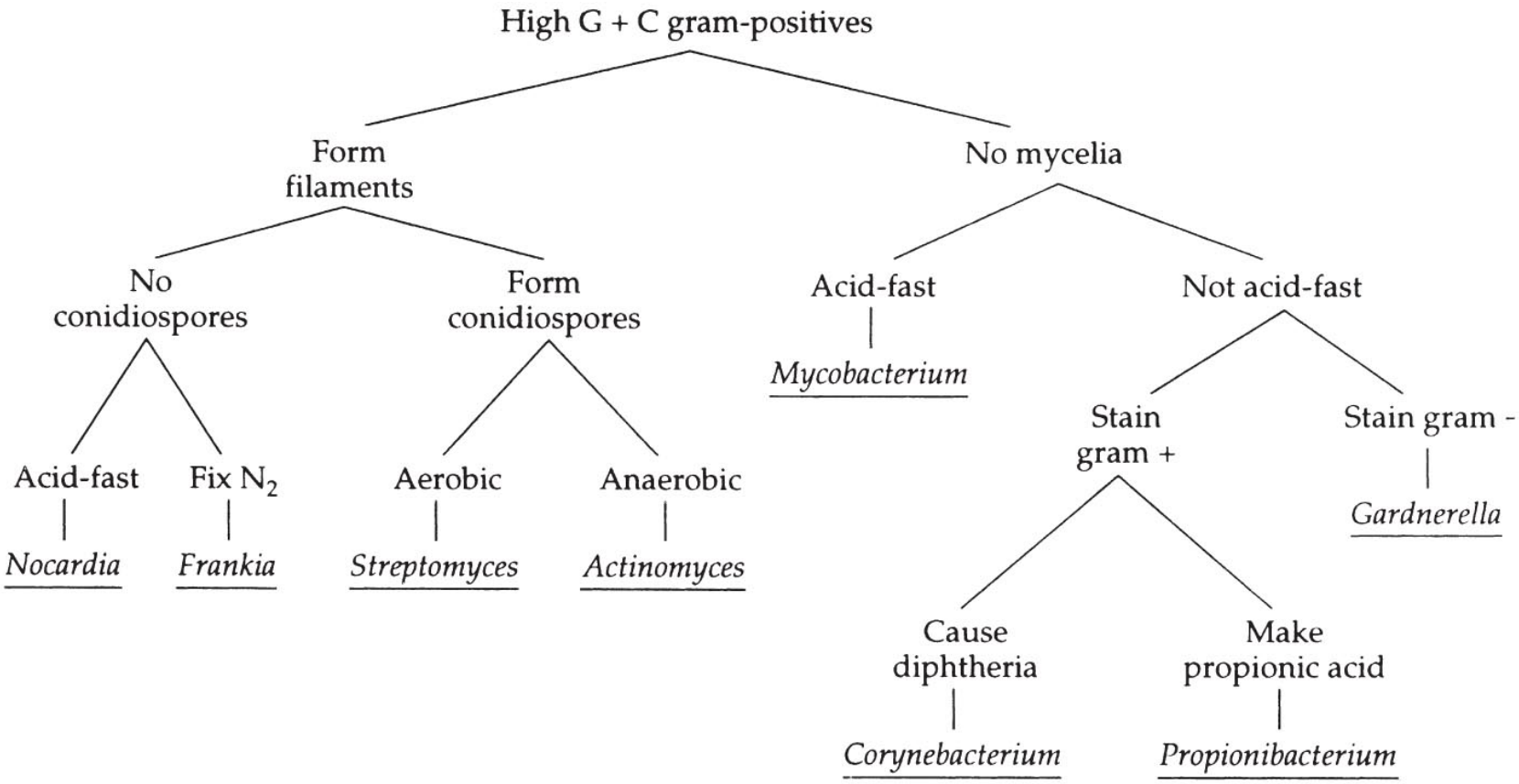
Figure 11.17 ***Streptococcus.***

Mycoplasmatales

- Wall-less; pleomorphic
- 0.1–0.24 µm
- *M. pneumoniae*

Actinobacteria

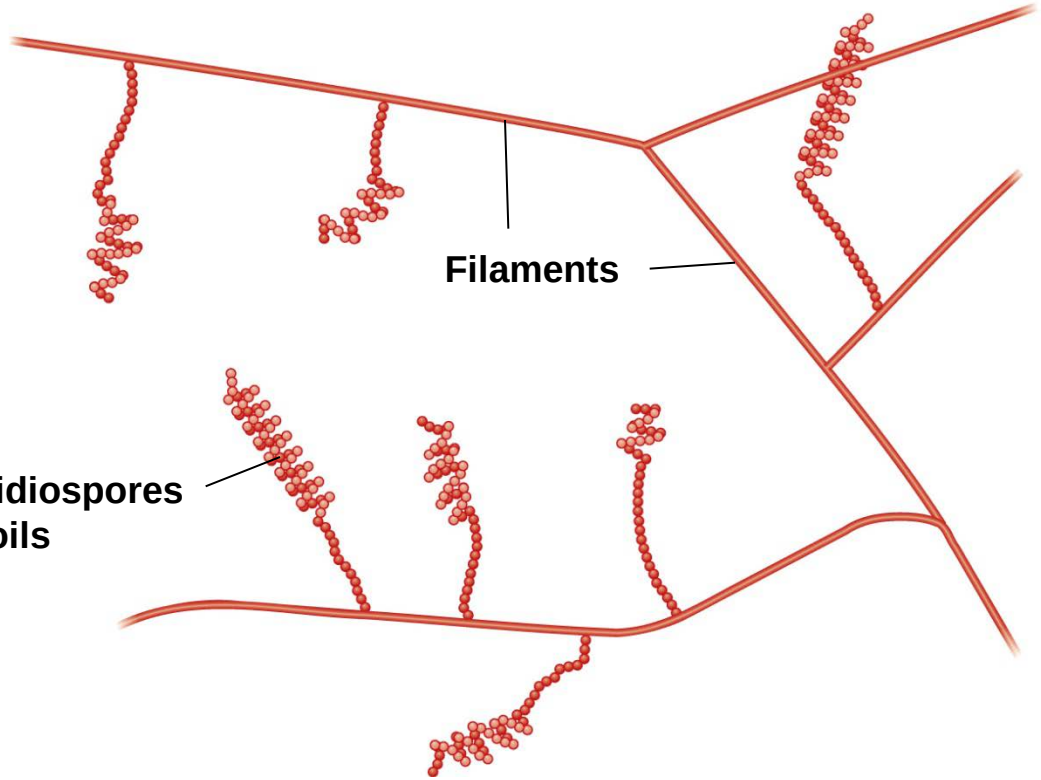
- High G + C
- Gram-positive



Actinobacteria

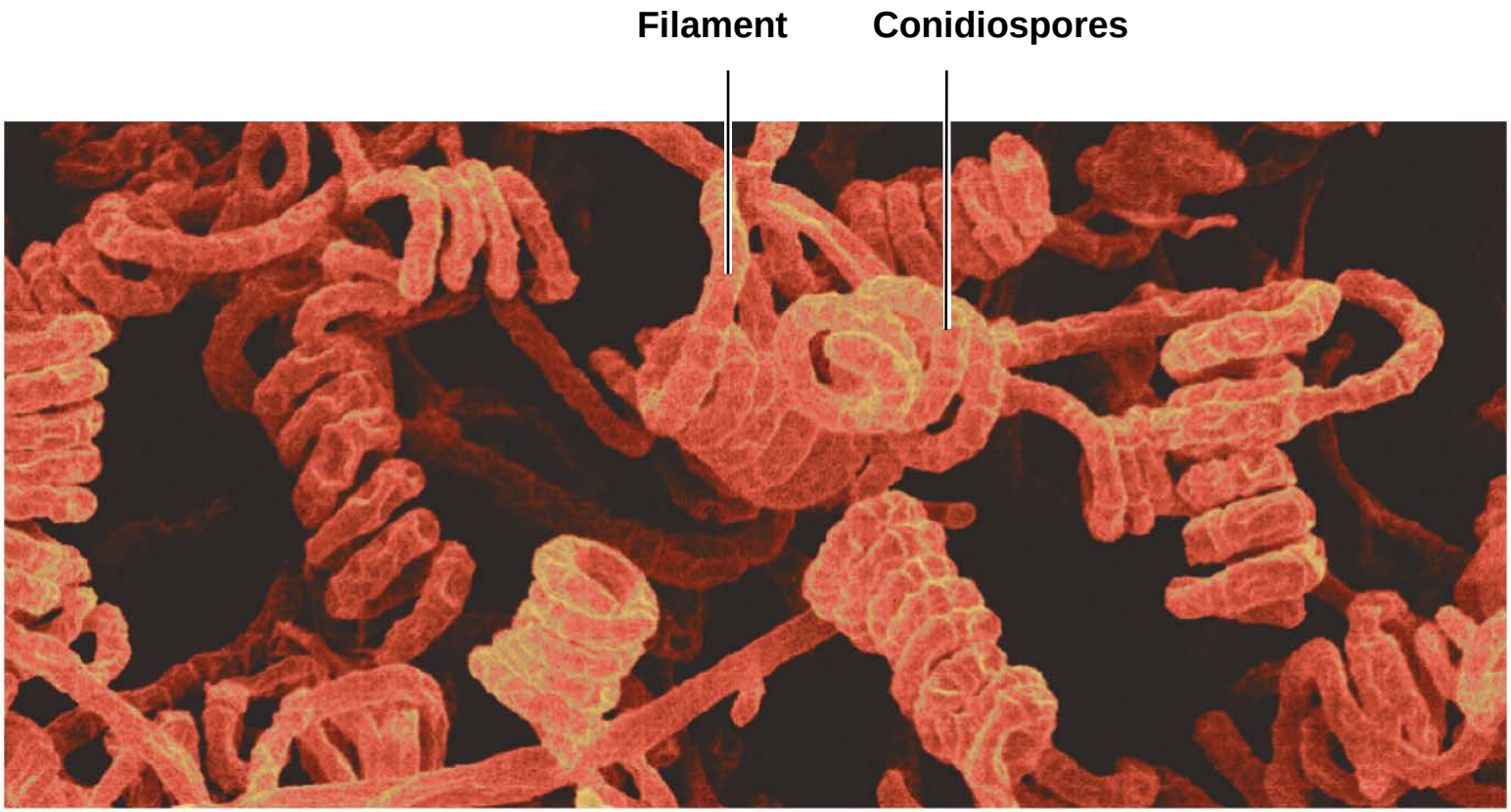
- *Actinomyces*
- *Corynebacterium*
- *Frankia*
- *Gardnerella*
- *Mycobacterium*
- *Nocardia*
- *Propionibacterium*
- *Streptomyces*

Figure 11.19a *Streptomyces.*



(a) Drawing of a typical streptomycete showing filamentous, branching growth with asexual reproductive conidiospores at the filament tips.

Figure 11.19b *Streptomyces.*



(b) Coils of conidiospores supported by filaments of the streptomycete.

Figure 11.20 ***Actinomyces.***

Check Your Understanding

- ✓ To which genus is *Enterococcus* more closely related: *Staphylococcus* or *Lactobacillus*? 11-6
- ✓ What group of bacteria makes most of the commercially important antibiotics? 11-7

Nonproteobacteria Gram-Negative Bacteria

Learning Objectives

11-8 Differentiate among planctomycetes, chlamydias, Bacteroidetes, *Cytophaga*, and Fusobacteria by drawing a dichotomous key.

11-9 Compare and contrast purple and green photosynthetic bacteria with the cyanobacteria.

11-10 Describe the features of spirochetes and *Deinococcus*.

Phototrophic

- Oxygenic photosynthesis
- Anoxygenic photosynthesis

$$2H_2O + CO_2 \xrightarrow{light} (CH_2O) + H_2O + O_2$$

$$2H_2S + CO_2 \xrightarrow{light} (CH_2O) + H_2O + 2S^0$$

Oxygenic Photosynthetic Bacteria

- Cyanobacteria
  - Gliding motility
  - Fix nitrogen

Figure 11.21 Cyanobacteria.

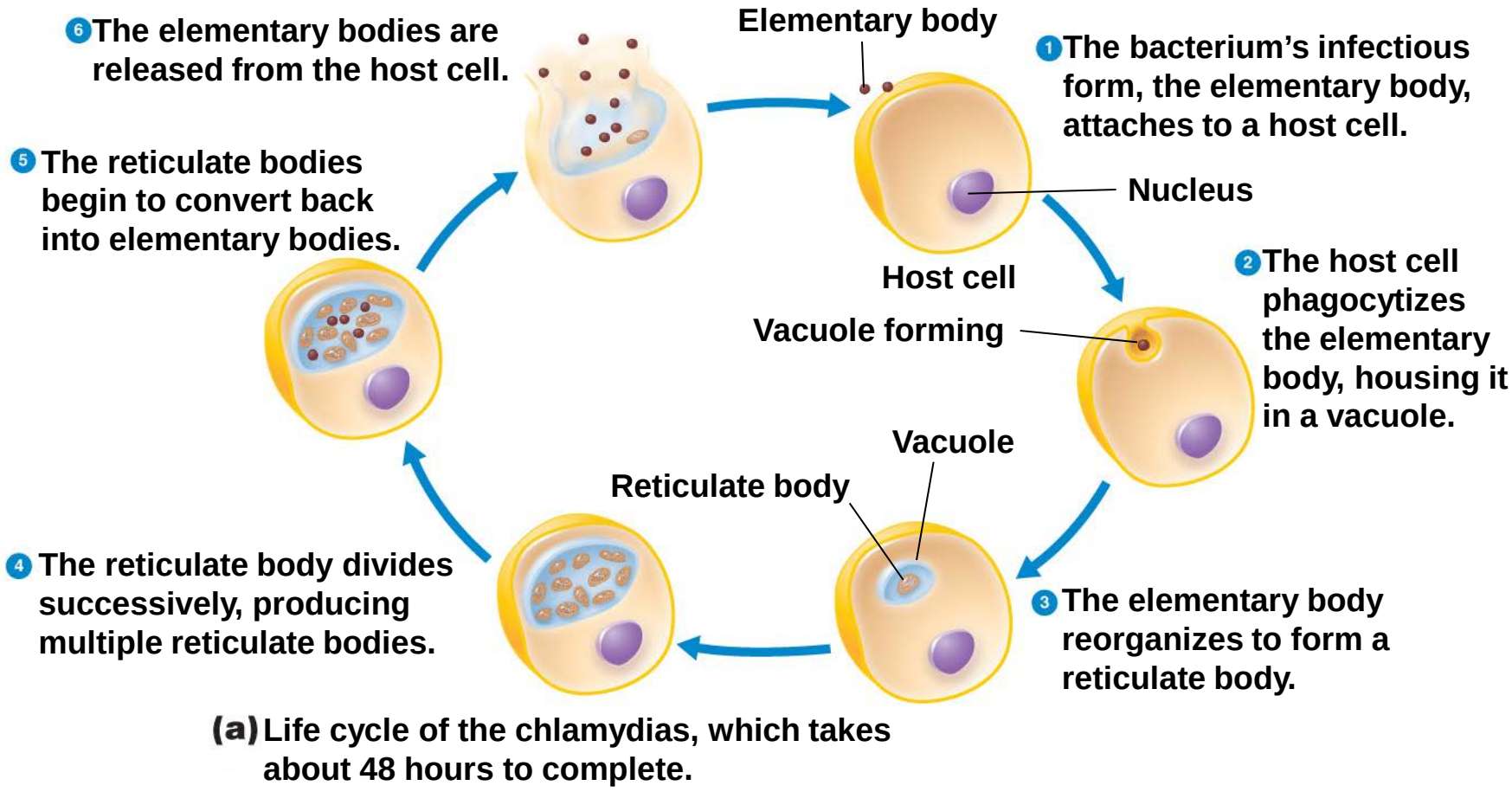
(a) Filamentous cyanobacterium showing heterocysts, in which nitrogen-fixing activity is located.

(b) A unicellular, nonfilamentous cyanobacterium, *Gloeocapsa*. Groups of these cells, which divide by binary fission, are held together by the surrounding glycocalyx.

Chlamydias

- *Chlamydia trachomatis*
  - Trachoma
  - STI, urethritis
- *Chlamydophila pneumoniae*
- *Chlamydophila psittaci*
  - Psittacosis

Figure 11.22a Chlamydias.

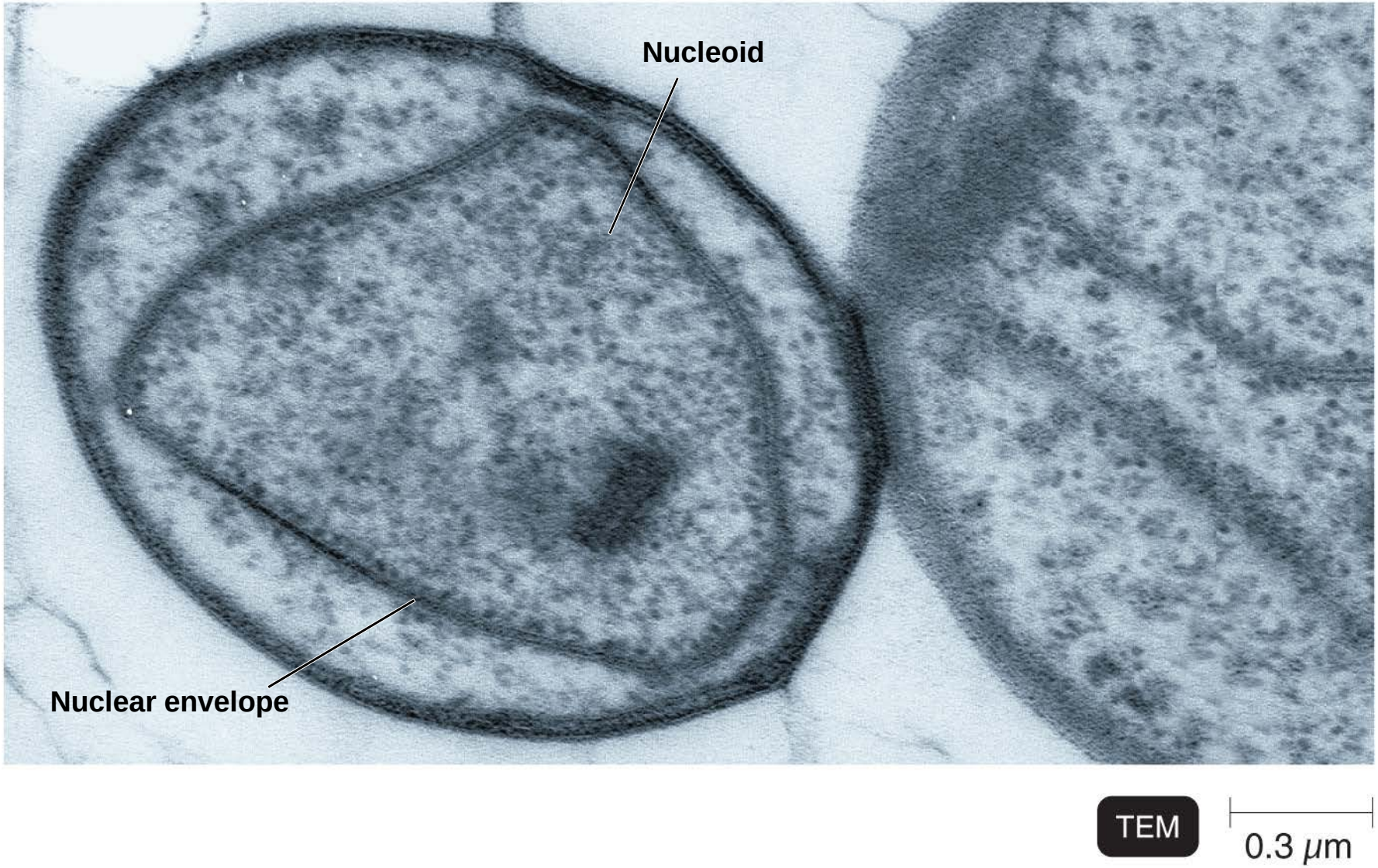


(a) Life cycle of the chlamydias, which takes about 48 hours to complete.

Planctomycetes

- *Gemmata obscuriglobus*
  - Double internal membrane around DNA

Figure 11.23 ***Gemmata obscuriglobus.***



Nonproteobacteria Gram-Negatives

- **Bacteroidetes**
  - Anaerobic
    - ***Bacteroides*** are found in the mouth and large intestine
    - ***Cytophaga***: degrade cellulose in soil
- ***Fusobacterium***
  - Are found in the mouth
  - May be involved in dental diseases

Anoxygenic Photosynthetic Bacteria

- Purple sulfur
- Purple nonsulfur
- Green sulfur
- Green nonsulfur

Figure 11.25 Purple sulfur bacteria.

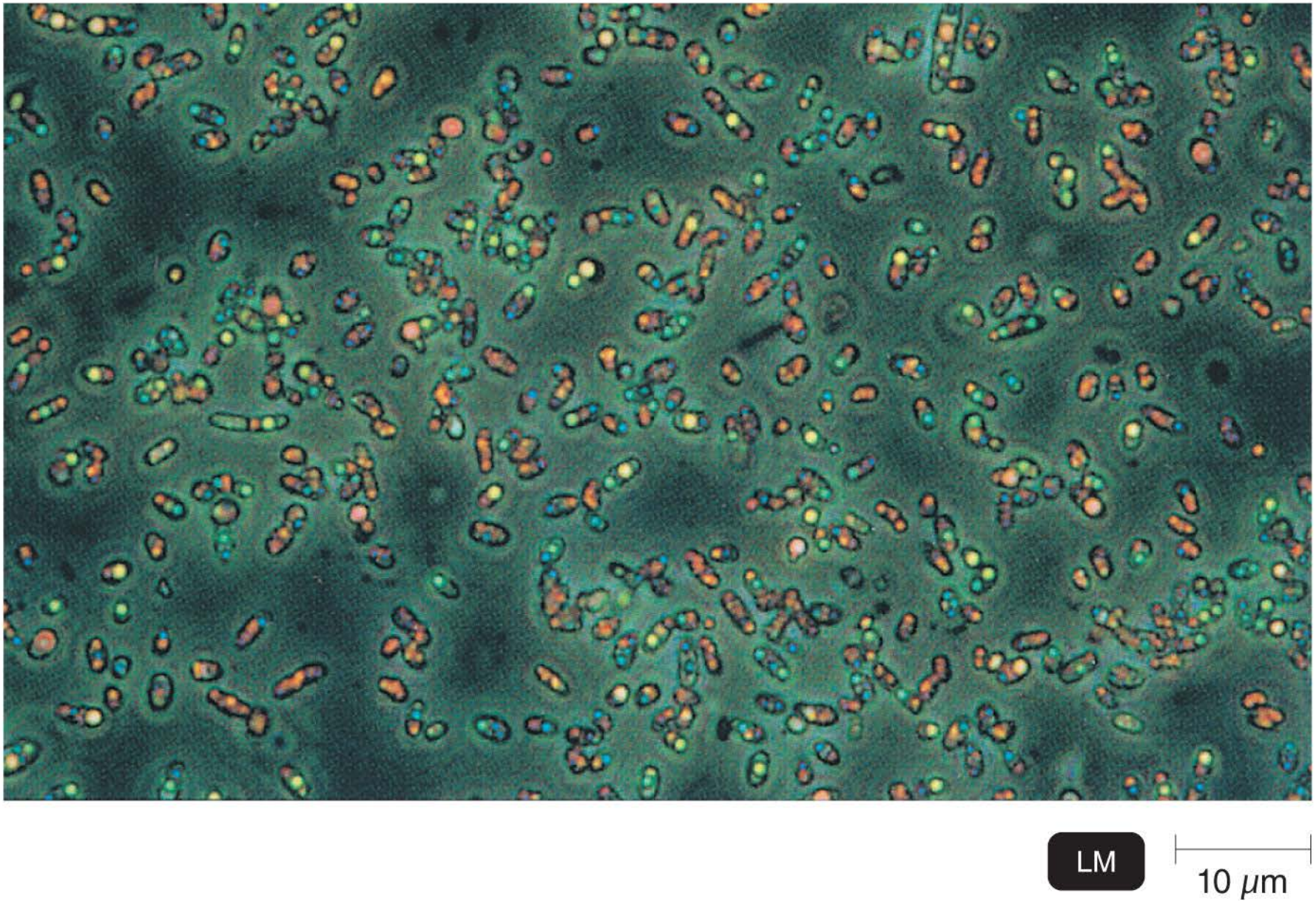
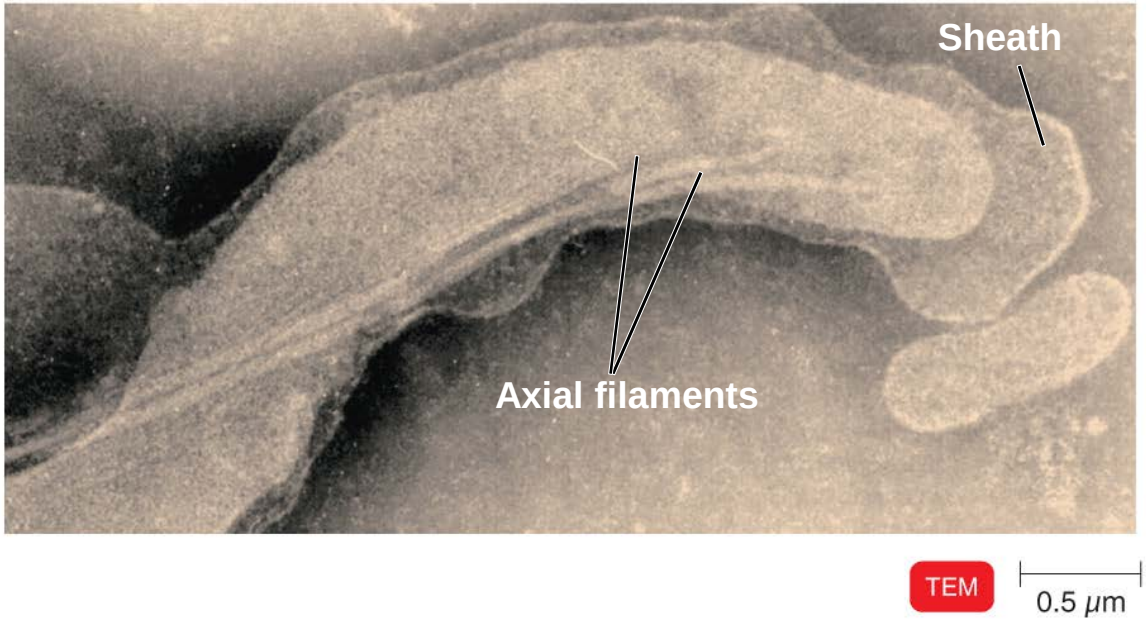


Figure 11.26 Spirochetes.

(a) This cross section of a spirochete shows numerous axial filaments between the dark cell and the outer sheath.



(b) This micrograph of a portion of *Treponema pallidum* shows the sheath, which has shrunk away from the cell, and two axial filaments attached near one of the cell under the sheath.

Deinococci-*Thermus*

- *Deinococcus radiodurans*
  - More resistant to radiation than are endospores
- *Thermus aquaticus*
  - Hot spring in Yellowstone National Park
  - Source of Taq polymerase

Check Your Understanding

- ✓ Which gram-negative group has a life cycle that includes different stages? 11-8
- ✓ Both the purple and green photosynthetic bacteria and the photosynthetic cyanobacteria use plantlike photosynthesis to make carbohydrates. In what way does the photosynthesis carried out by these two groups differ from plant photosynthesis? 11-9
- ✓ The axial filament distinguishes what genera of bacteria? 11-10

Domain Archaea

Learning Objective

11-11 Name a habitat for each group of archaea.

Domain Archaea

Extremophiles

- Hyperthermophiles
  - *Pyrodictium*
  - *Sulfolobus*
- Methanogens
  - *Methanobacterium*
- Extreme halophiles
  - *Halobacterium*

Figure 11.27 Archaea.

Check Your Understanding

- ✓ What kind of archaea would populate solar evaporating ponds? 11-11

Microbial Diversity

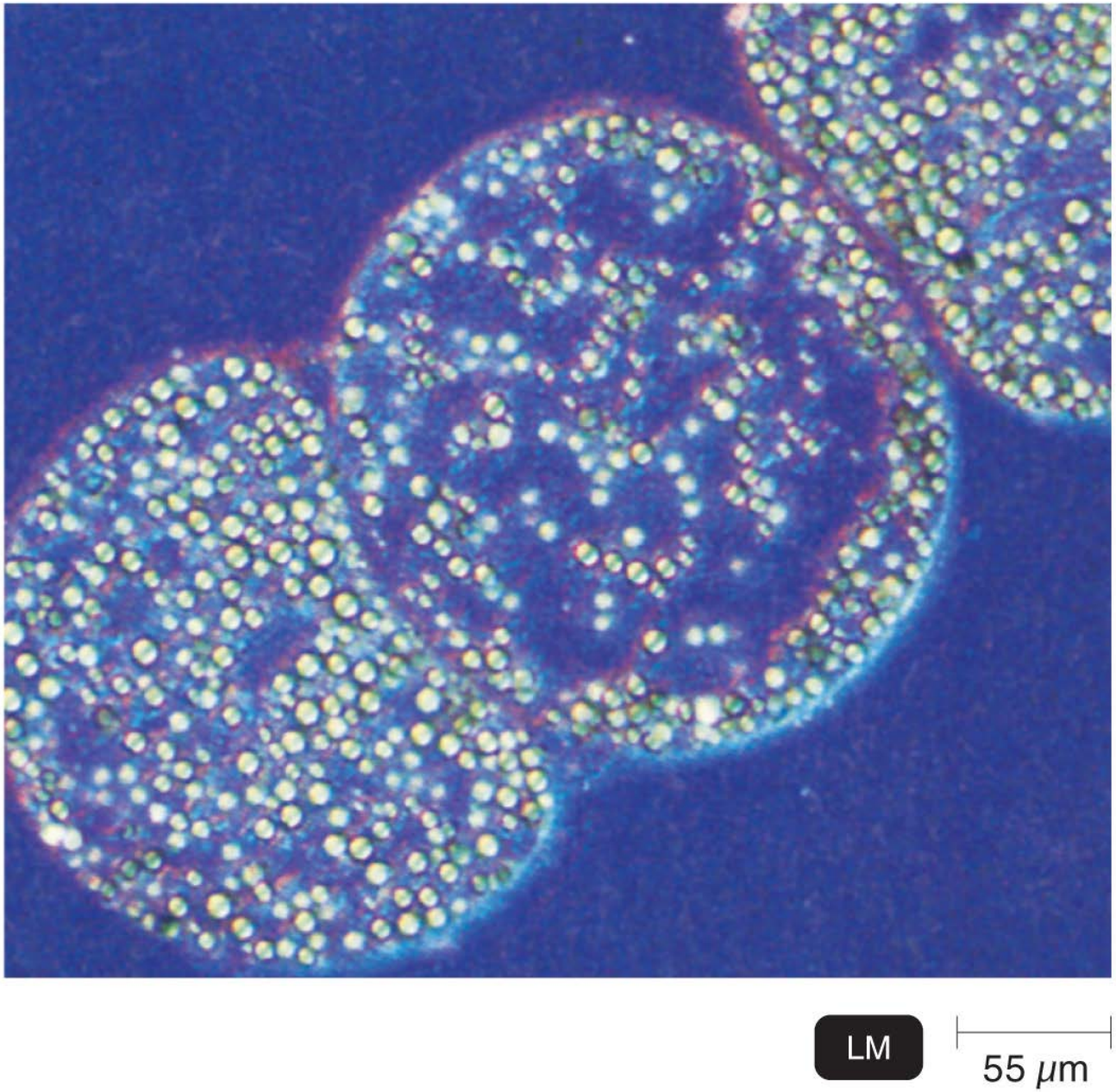
Learning Objective

11-12 List two factors that contribute to the limits of our knowledge of microbial diversity.

Microbial Diversity

- Bacteria size range
  - *Thiomargarita* (diameter of 750 µm)
  - *Carsonella ruddii* (182 genes)
- Metagenomics
  - PCR
  - GeoChip

Figure 11.28 *Thiomargarita namibiensis*.



Microbial Diversity

- PCR indicates up to 10,000 bacteria per gram of soil
- Many bacteria have not been identified because they
  - Have not been cultured
  - Need special nutrients
  - Are a part of complex food chains requiring the products of other bacteria
  - Need to be cultured to understand their metabolism and ecological role

Check Your Understanding

- ✓ How can you detect the presence of a bacterium that cannot be cultured? 11-12