The Most Important Bacteria

By: Dr. M. Mobini-Dehkordi

Bacteria

Bacteria are the smallest, most abundant, and hardiest life-forms on Earth. They are so microscopic that 0.06 cubic inch (1 ml) of saliva may contain up to 40 million bacterial cells. They exist and live everywhere, from our skin to the smallest cracks in rocks. Most are benign and even vital to the survival of other living beings, but some are pathogenic and can cause diseases, some of them deadly. Almost all nourish themselves by absorbing substances from their surroundings, but some make use of the energy of the sun, and others use the chemical energy in volcanic emissions. All are made up of one cell and usually reproduce by dividing in two. ●

What Are Bacteria?

Bacteria have the capacity to survive in extremely hostile environments, even at temperatures of 480° F (250° C). For this reason, they are the most ancient living organisms on the planet. In a common habitat, such as the human mouth, there can be as many as 25 different species of bacilli among the 40 million bacterial cells in just 0.06 cubic inch (1 ml) of saliva. And, if there are so many in just a small amount of saliva, imagine how many there might be in the entire world —millions and millions of species. However, only 1 percent of bacteria produce diseases. Likewise, 70 percent of antibiotics are produced through bacterial fermentation.

CLASSIFICATION OF BACTERIA

Some 10,000 bacteria species have been identified, and it is estimated that there are still many left to be discovered. They are classified both by their shape and through chemical tests to help identify specific species.

A COCCUS
Spherical cocci can live isolated, and others can group into pairs, chains, or branches.

B BACILLUS
Many bacteria have this rod-shaped form.

C VIBRIO
These bacteria have the shape of a comma or boomerang.

D SPIRILLA
This class of bacteria has a corkscrew shape.

Benign

Almost all bacteria are benign and even healthy for living beings. *Lactobacillus acidophilus*, for example, is a bacterium that transforms lactose into lactic acid to produce yogurt, and it is also present in the human body in the vagina and in the intestinal tract. The bacterium *Rhizobium*, on the other hand, allows roots of legume plants to absorb nitrogen from the soil.

Harmful

Harmful bacteria are pathogenic and are present in all living beings and in agricultural products. They can transfer from food to people, from people to food, or among people or foodstuffs. In the 14th century, the *Yersinia pestis* bacterium, present in rats and fleas, caused many deaths in what was known as the plague.

70% **OF ANTIBIOTICS** are produced from bacterial fermentation.

Parts of a Bacterium

Bacteria are usually considered the most primitive type of cell there is, because their structure is simpler than most others. Many are immobile, but others have flagella (thin hairs that move like whips to propel the bacteria in liquid media). The cell wall is generally made up of carbohydrates, including murein, a peptidoglycan complex, lipids, and amino acids. No organelles or protoplasmic formations are found in their cytoplasm.

FIMBRIAE
are used to attach to other bacteria or the cells of other living beings.

PLASMA MEMBRANE
The laminar structure that surrounds the cytoplasm of all cells like bacteria

FLAGELLA
can be fingerlike projections.

RIBOSOMES
Organelles without membranes that produce proteins. They exist in all cells. Their function is to assemble proteins based on the genetic information from the DNA that arrives in the form of messenger RNA.

PLASMID

CIRCULAR CHROMOSOME
DNA molecule closed at its ends

CELL MEMBRANE
is involved in the transport of substances and contains elements that can be toxic when they come in contact with other beings.

CELL WALL
keeps the cell from exploding if it absorbs too much water. The flagella are attached to it.

PLASMA MEMBRANE
lets certain substances into the cell while impeding the entrance of others.

FLAGELLA
Bacteria use the flagella to move. Along the length of the flagellum, there is a single row of tiny hairs. The hairs provide greater support for the flagellum in water.

ANTIBIOTIC ACTION

Certain microorganisms—fungi or bacteria—produce chemical substances that are toxic for some specific bacteria; they cause their death or stop their growth or reproduction. Penicillin and streptomycin are examples. These substances are called antibiotics.

1 When a bacterium breaks through the body's barriers, the immune system recognizes it as an antigen and generates antibodies against it.

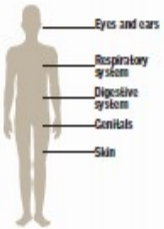
2 The leukocytes release cytokines, substances that attract more leukocytes, and by means of antibodies, they attach to the bacterium to destroy it.

3 Once the leukocytes are attached to the bacterium, they eat it.

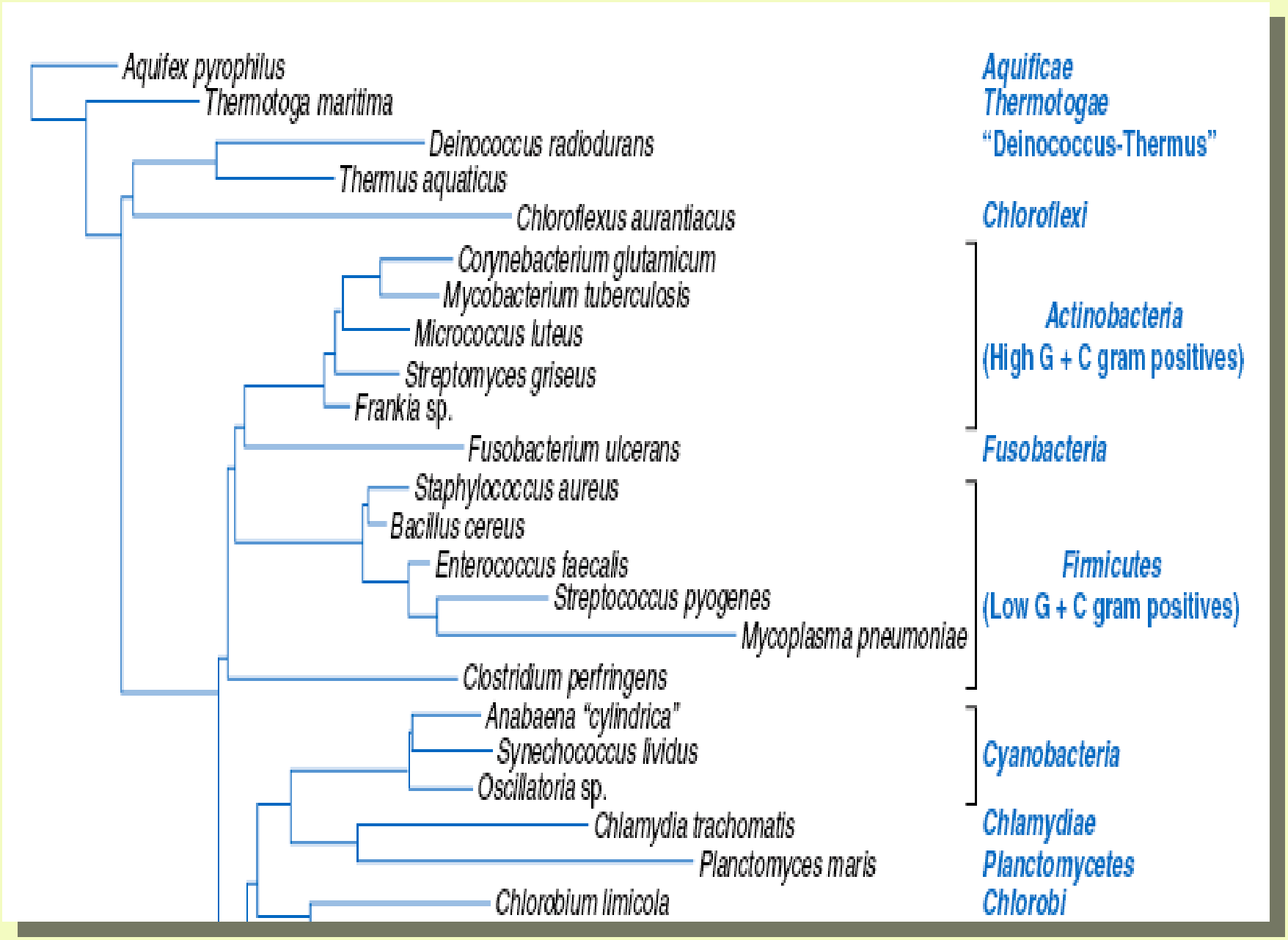
40 MILLION BACTERIAL CELLS exist in only 0.06 cubic inch (1 ml) of saliva.

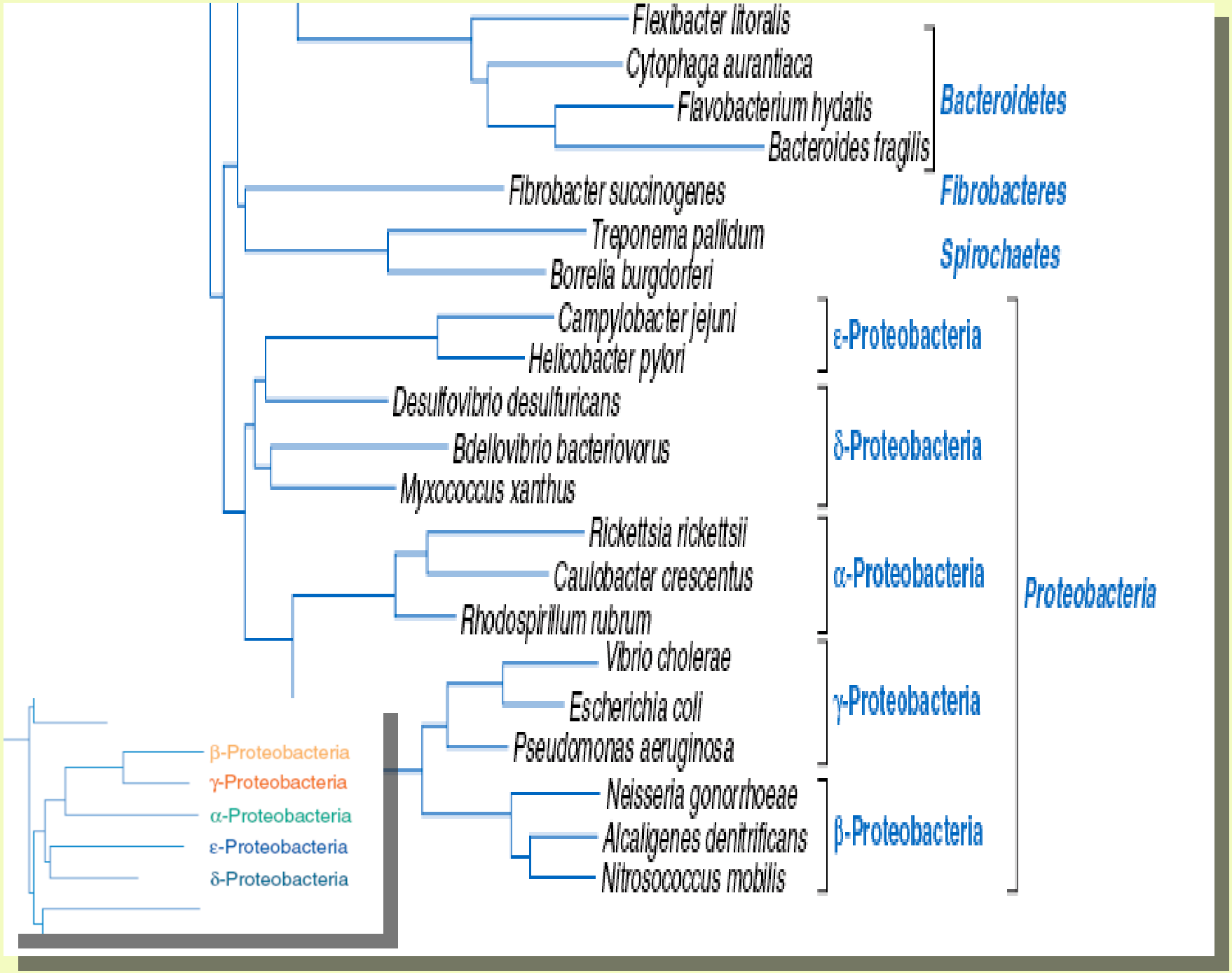
WHERE THEY ENTER

Bacteria have various established pathways to the interior of the human body: the eyes and ears; the respiratory system, through the nose and mouth; the digestive system, in food and water; the genitals and anus; and the skin, the most exposed pathway, although the bacteria can enter only through wounds.



Procaryotic Dendrogram

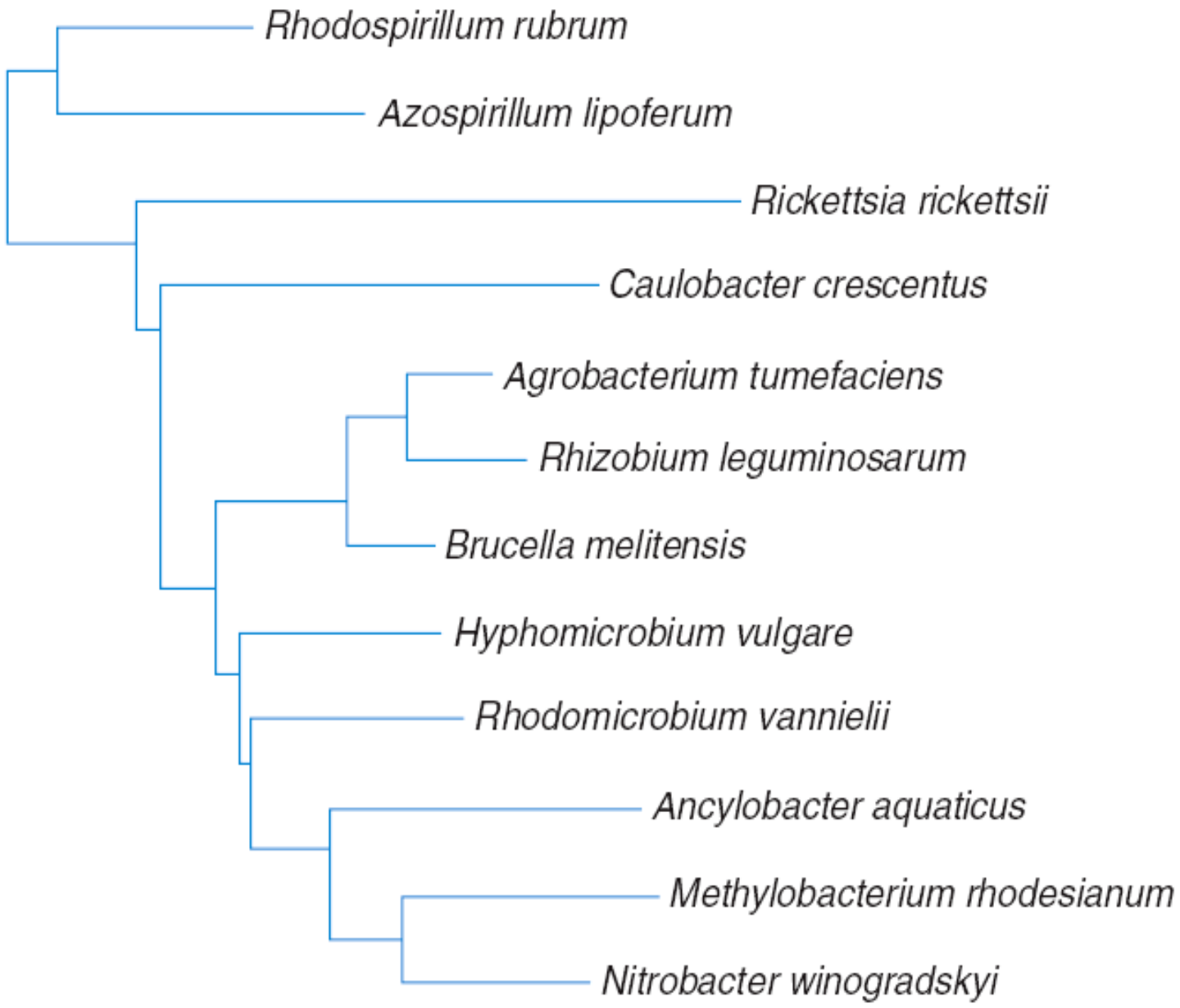



Flexibacter litoralis
Cytophaga aurantiaca
Flavobacterium hydatis
Bacteroides fragilis
Bacteroidetes
Fibrobacter succinogenes
Fibrobacteres
Treponema pallidum
Borrelia burgdorferi
Spirochaetes
Campylobacter jejuni
Helicobacter pylori
ε-Proteobacteria
Desulfovibrio desulfuricans
Bdellovibrio bacteriovorus
Myxococcus xanthus
δ-Proteobacteria
Rickettsia rickettsii
Caulobacter crescentus
Rhodospirillum rubrum
α-Proteobacteria
Proteobacteria
Vibrio cholerae
Escherichia coli
Pseudomonas aeruginosa
γ-Proteobacteria
Neisseria gonorrhoeae
Alcaligenes denitrificans
Nitrosococcus mobilis
β-Proteobacteria
β-Proteobacteria
γ-Proteobacteria
α-Proteobacteria
ε-Proteobacteria
δ-Proteobacteria

Class Alpha-proteobacteria

Table 22.1 Characteristics of Selected α-Proteobacteria

Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Oxygen Requirement	Other Distinctive Characteristics
Agrobacterium	0.6–1.0 × 1.5–3.0; motile, nonsporing rods with peritrichous flagella	57–63	Aerobic	Chemoorganotroph that can invade plants and cause tumors
Caulobacter	0.4–0.6 × 1–2; rod- or vibrioid-shaped with a flagellum and prostheca and holdfast	62–67	Aerobic	Heterotrophic and oligotrophic; asymmetric cell division
Hyphomicrobium	0.3–1.2 × 1–3; rod-shaped or oval with polar prosthecae	59–65	Aerobic	Reproduces by budding; methylotrophic
Nitrobacter	0.5–0.8 × 1.0–2.0; rod- or pear-shaped, sometimes motile by flagella	60–62	Aerobic	Chemolithotroph, oxidizes nitrite to nitrate
Rhizobium	0.5–0.9 × 1.2–3.0; motile rods with flagella	59–64	Aerobic	Invades leguminous plants to produce nitrogen-fixing root nodules
Rhodospirillum	0.7–1.5 wide; spiral cells with polar flagella	62–64	Anaerobic, microaerobic, aerobic	Photoheterotroph under anaerobic conditions
Rickettsia	0.3–0.5 × 0.8–2.0; short nonmotile rods	29–33	Aerobic	Obligately intracellular parasite


Rhodospirillum rubrum
Azospirillum lipoferum
Rickettsia rickettsii
Caulobacter crescentus
Agrobacterium tumefaciens
Rhizobium leguminosarum
Brucella melitensis
Hyphomicrobium vulgare
Rhodomicrobium vannielii
Ancylobacter aquaticus
Methylobacterium rhodesianum
Nitrobacter winogradskyi

Rickettsia and Coxiella

- These bacteria are rod-shaped, coccoid, or pleomorphic with typical gram-negative walls and no flagella. Although their size varies, they tend to be **very small**. For example, ***Rickettsia*** *is 0.3 to* 0.5 m in diameter and 0.8 to 2.0 m long; . All species are parasitic or mutualistic.
- The **parasitic forms** grow in vertebrate erythrocytes, macrophages , and vascular endothelial cells. Often they also live in **blood-sucking arthropods** such as fleas, ticks, mites, or lice, which serve as vectors or primary hosts.
- This order contains many important pathogens.
- ***Rickettsia prowazekii*** and ***R. typhi*** are associated with **typhus fever**, and ***R. rickettsii,*** with Rocky Mountain spotted fever.
- ***Coxiella burnetii*** causes Q fever in humans.

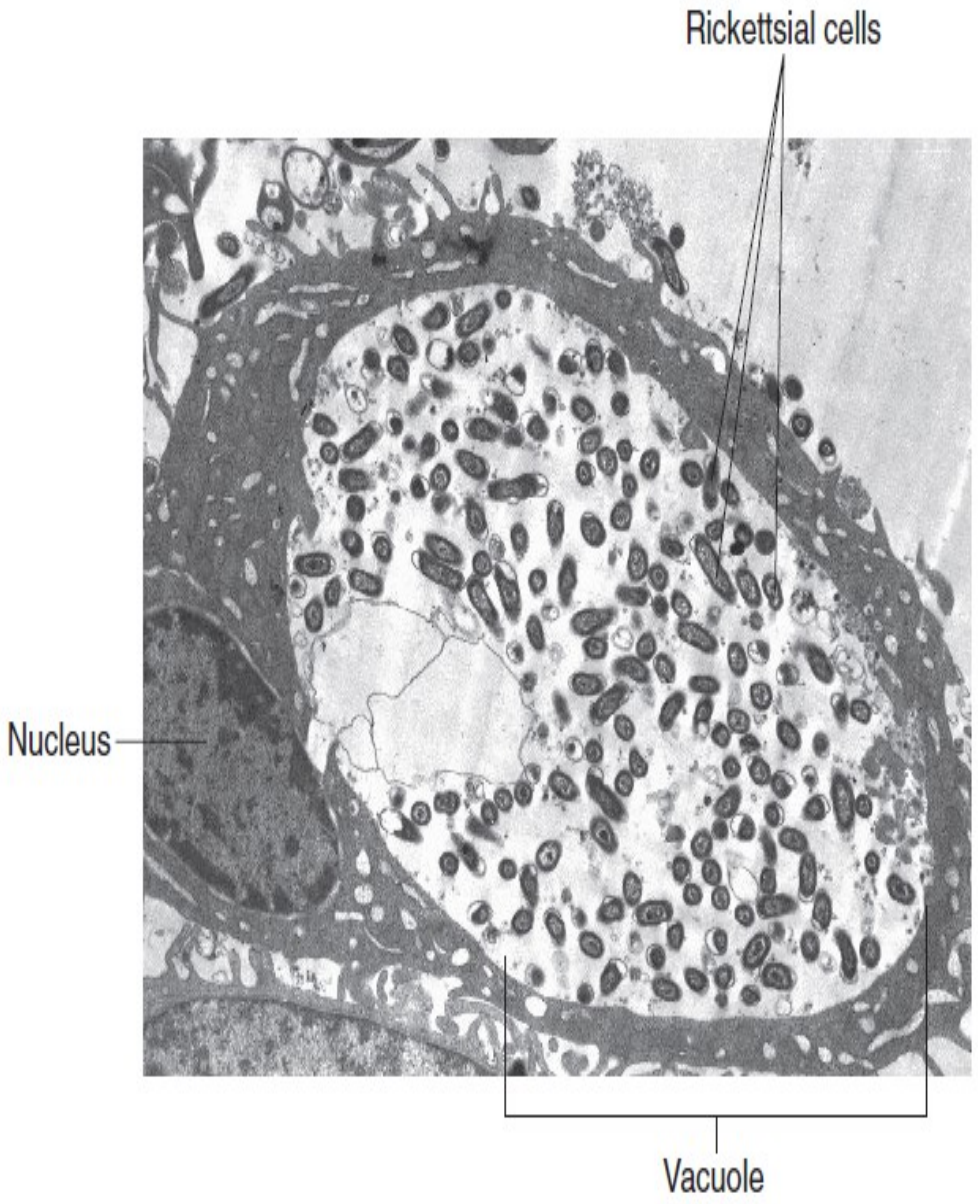
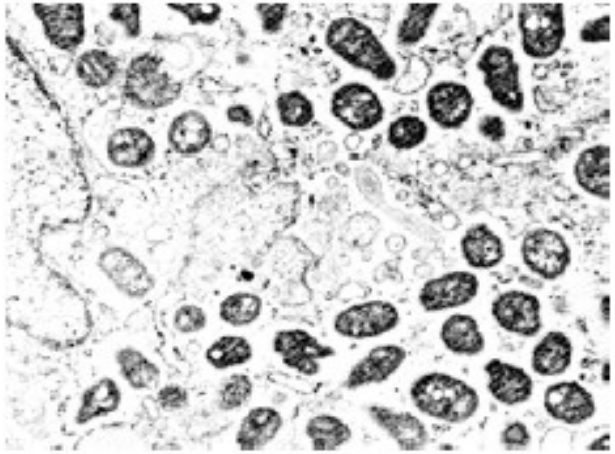


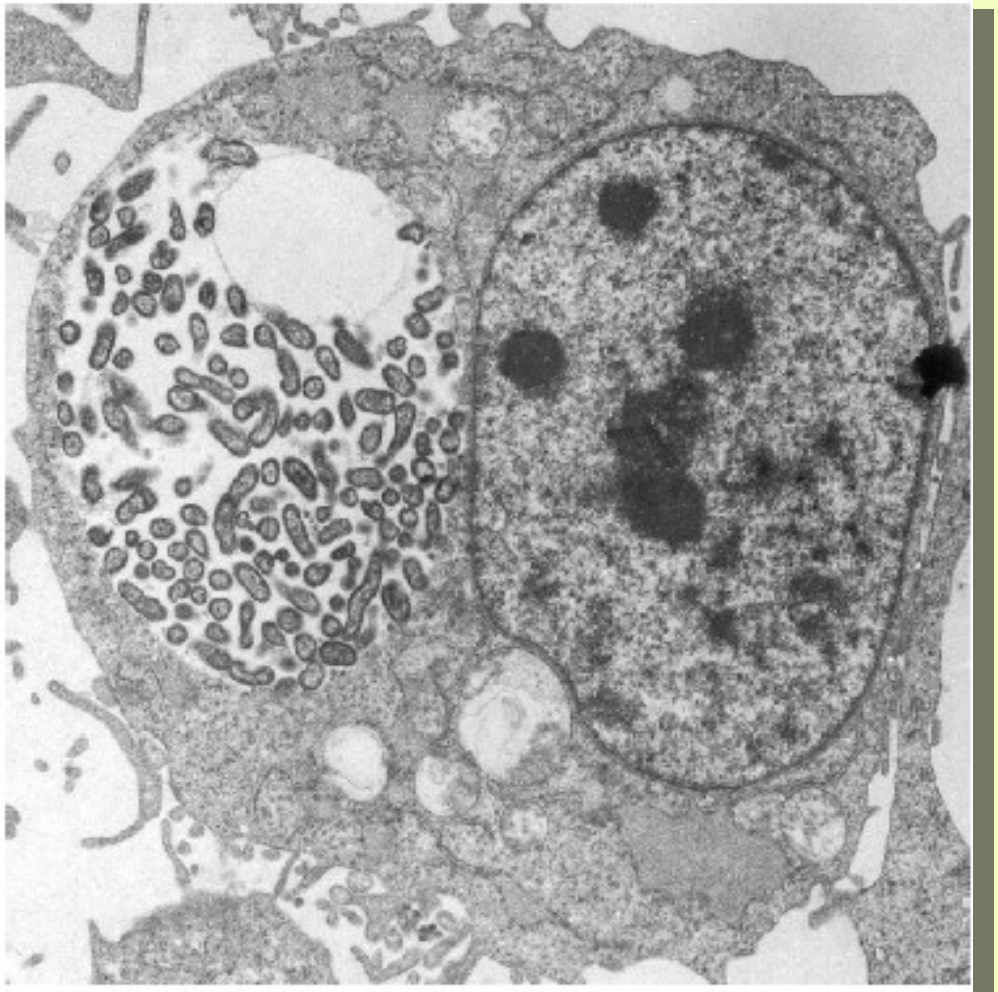
FIGURE 4.32

Transmission electron micrograph of the rickettsia *Coxiella burnetii*, the cause of Q fever. Its mass growth inside a host cell has filled a vacuole and displaced the nucleus to one side.

(a)



(b)



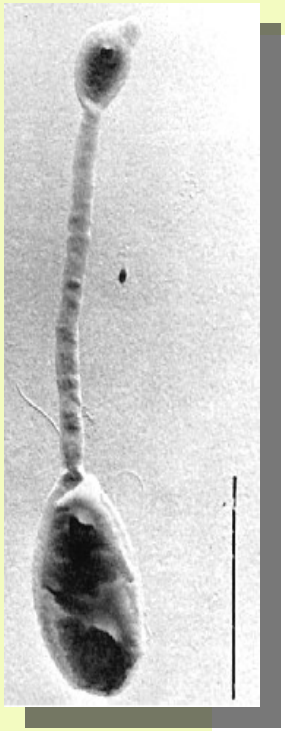
(c)

Figure 22.3 ***Rickettsia* and *Coxiella*.** Rickettsial morphology and reproduction. (**a**) A human fibroblast filled

Caulobacteraceae and *Hyphomicrobiaceae*

- These bacteria can have at least **one of** three different features: a **prostheca**, a **stalk**, or reproduction by **budding**.
- A **prostheca (pl., prosthecae)** is an extension of the cell, including the plasma membrane and cell wall, that is narrower than the mature cell. A **stalk** is a nonliving appendage produced by the cell and extending from it. **Budding** is distinctly different from the binary fission normally used by bacteria.

Hyphomicrobiaceae



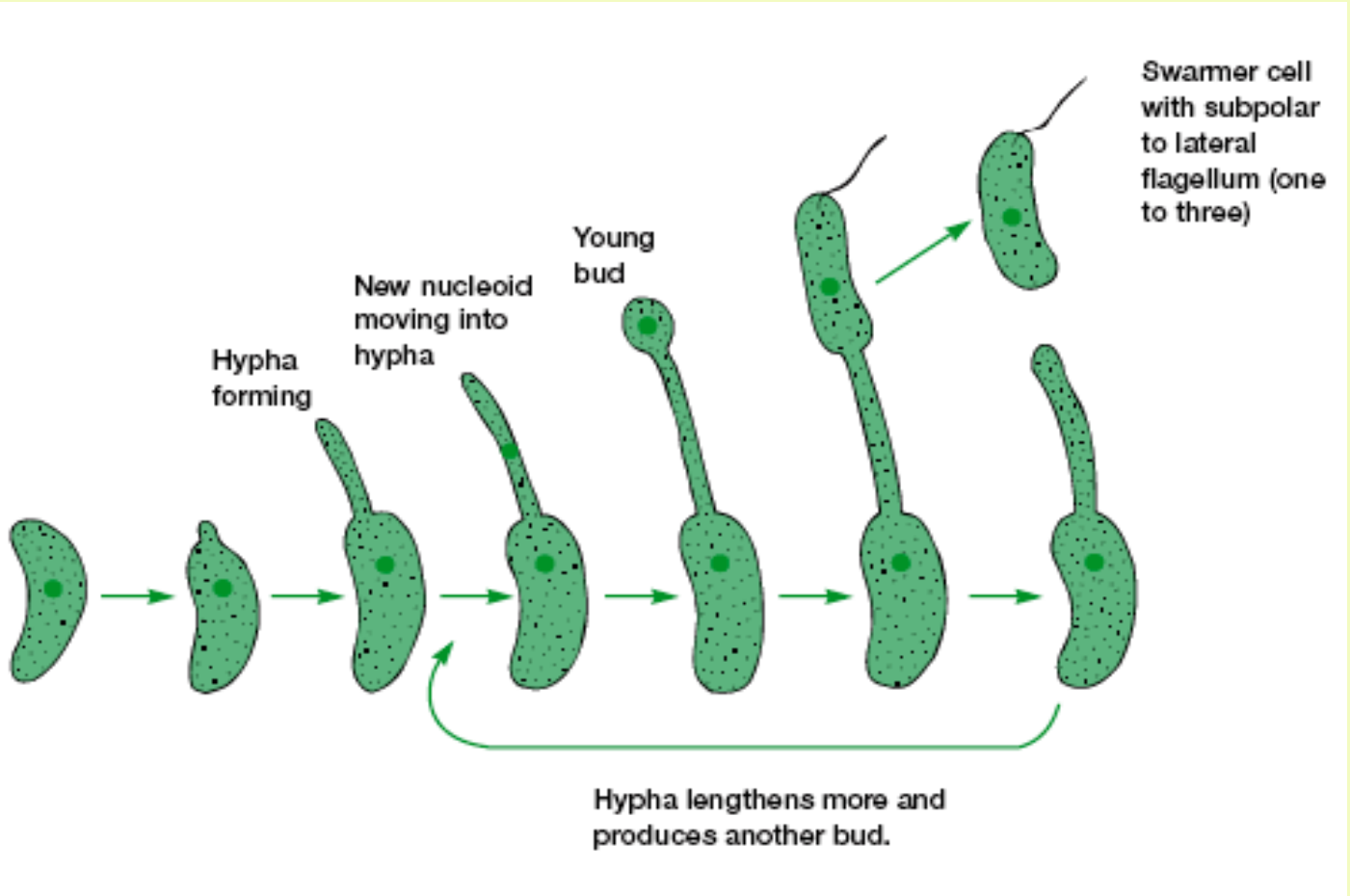
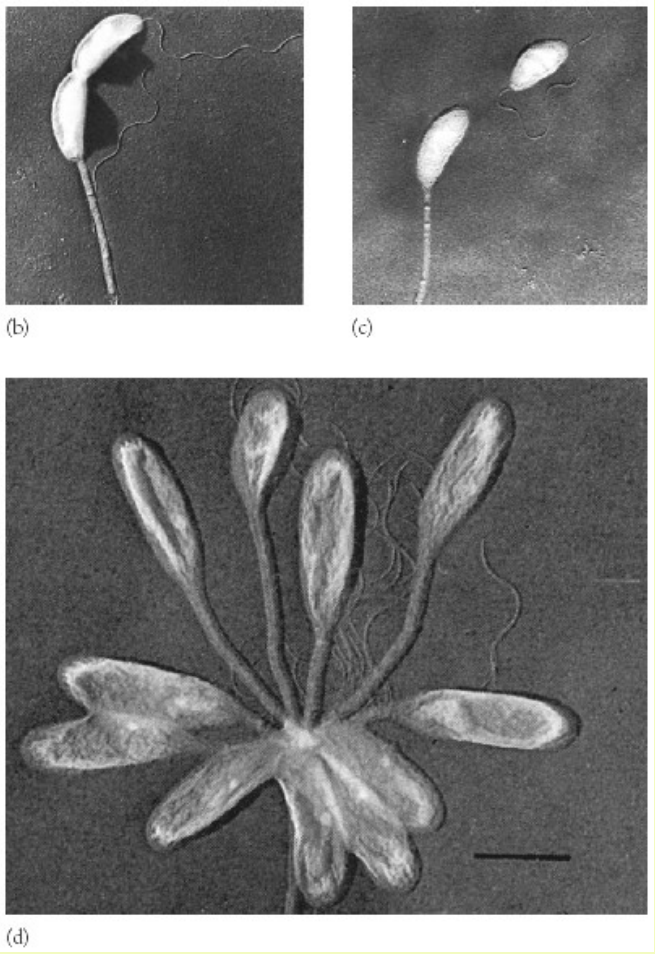


Figure 22.5 The Life Cycle of *Hyphomicrobium*.

Caulobacteraceae



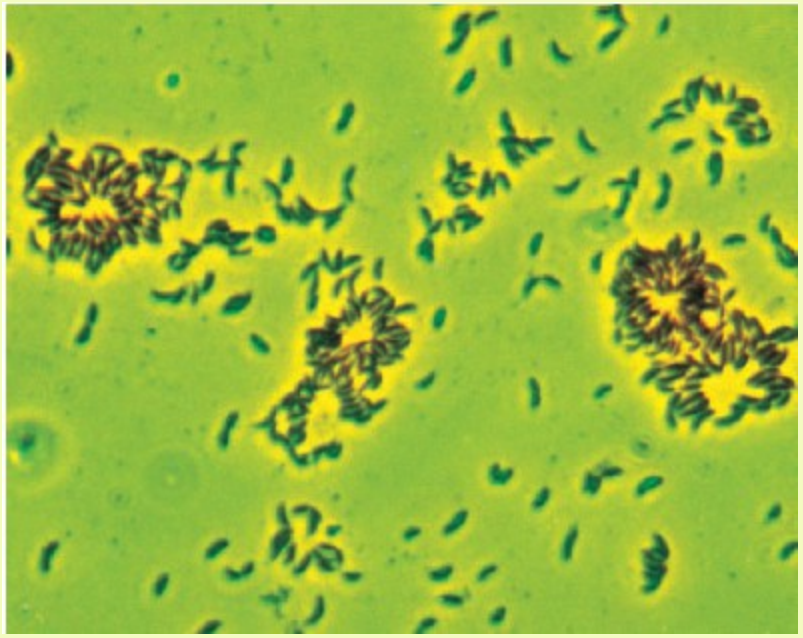
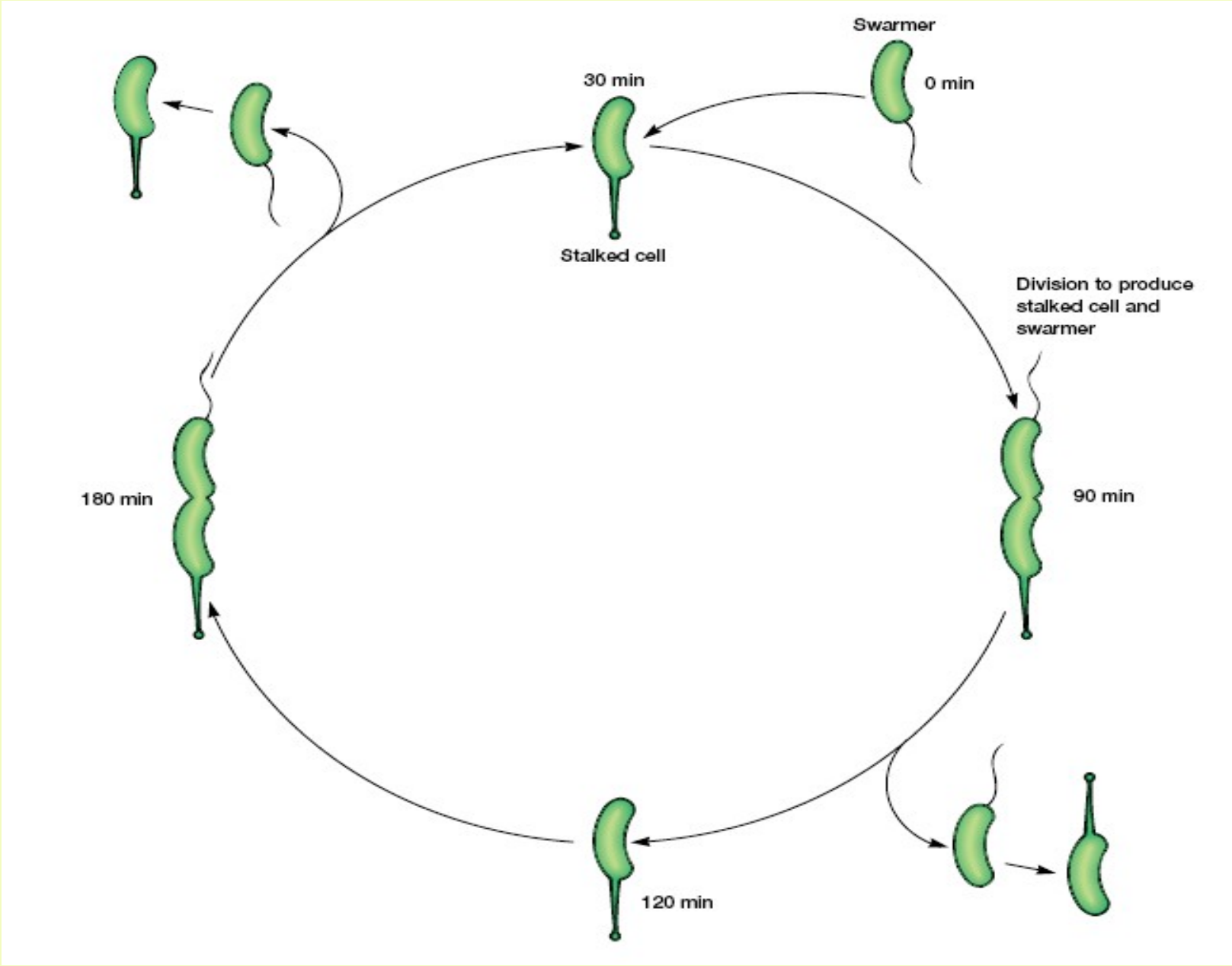


Figure 22.6 *Caulobacter* Morphology and Reproduction.

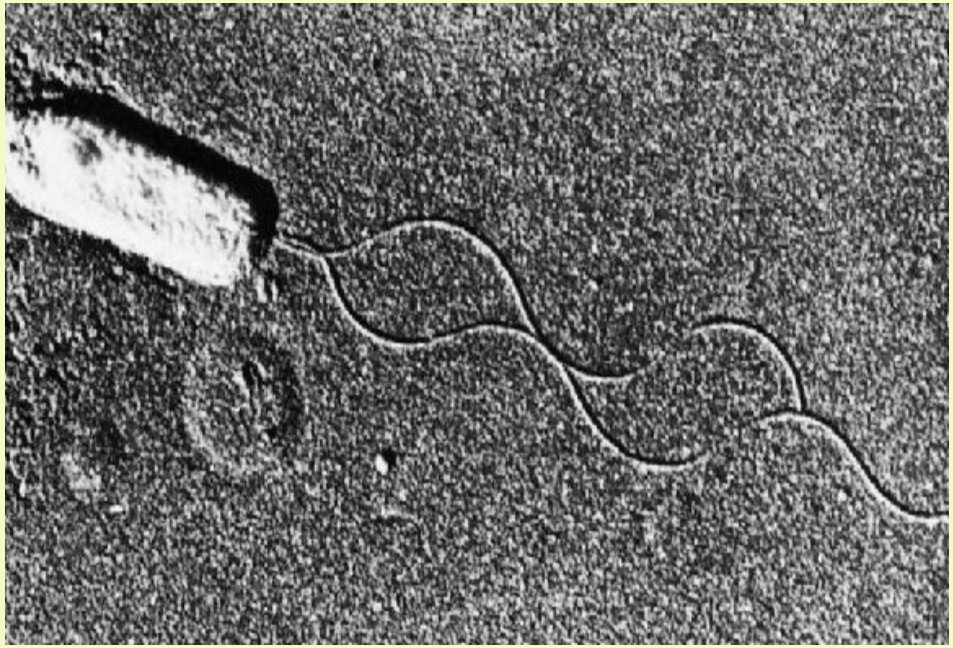

Swarmer
0 min
30 min
Stalked cell
Division to produce stalked cell and swarmer
90 min
120 min
180 min

Family *Rhizobiaceae*

- Gram-negative, aerobic genera ***Rhizobium*** and ***Agrobacterium***.
- Members of the genus ***Rhizobium*** *are 0.5 to 0.9 by 1.2 to 3.0* m motile rods, often containing **poly--hydroxybutyrate (PHB)** granules, that become pleomorphic under adverse conditions. They grow **symbiotically** within root nodule cells of legumes as nitrogen-fixing bacteroids .
- In contrast*,* ***Azotobacter*** *is* a free-living soil genus and fixes atmospheric nitrogen nonsymbiotically.

Family *Rhizobiaceae*

- The genus ***Agrobacterium*** is placed in the family Rhizobiaceae but differs from Rhizobium in not **stimulating root nodule formation** or **fixing nitrogen**. Instead, agrobacteria invade the crown, roots, and stems of many plants and transform plant cells into autonomously proliferating **tumor cells**. The best-studied species is ***A. tumefaciens,*** which enters many broad-leaved plants through wounds and causes **crown gall disease.**
- The ability to produce tumors is dependent on the presence of a large **Ti** (tumor-inducing) plasmid.



Rhizobium leguminosarum **with two polar flagella**

Crown gall tumor of a tomato plant caused by ***Agrobacterium tumefaciens.***

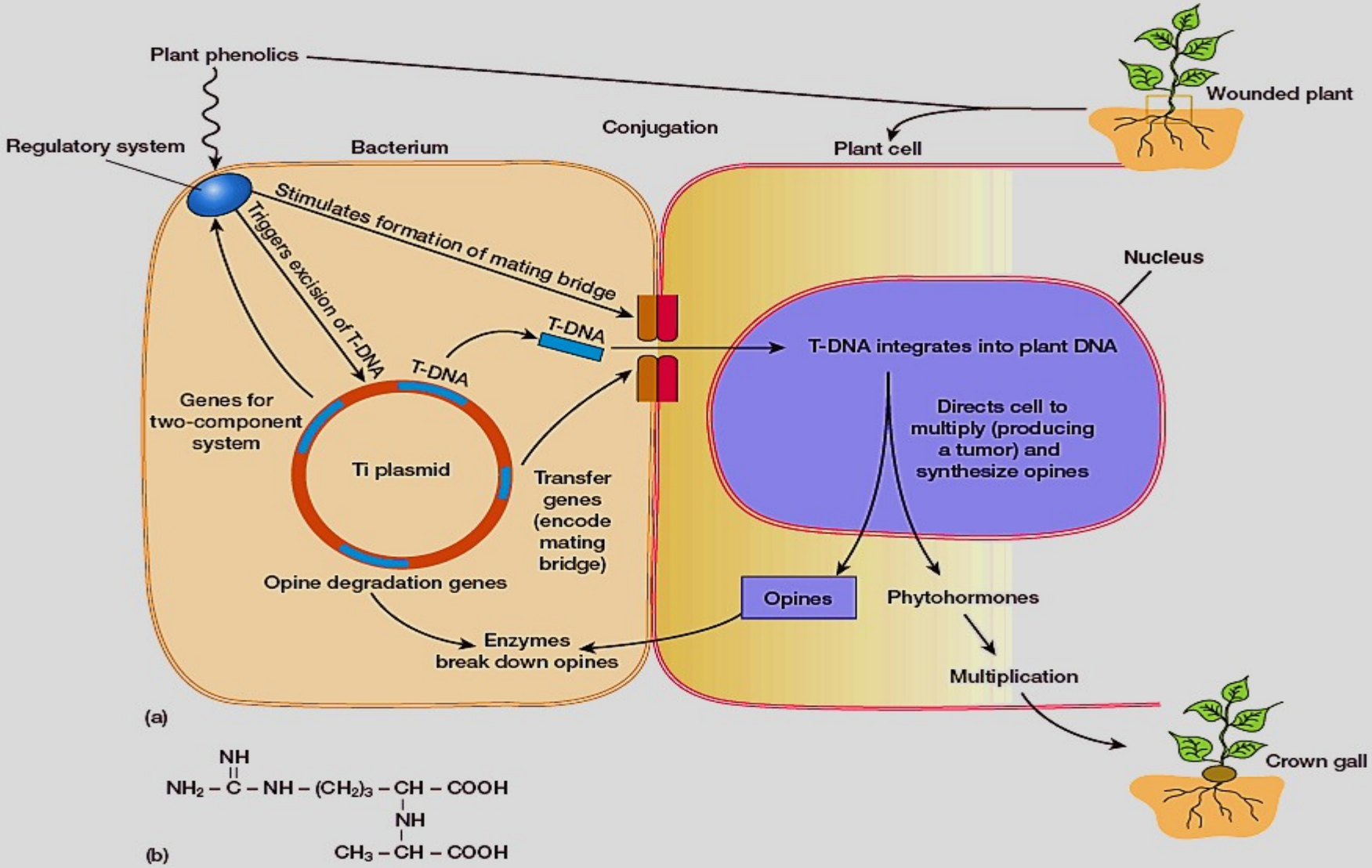


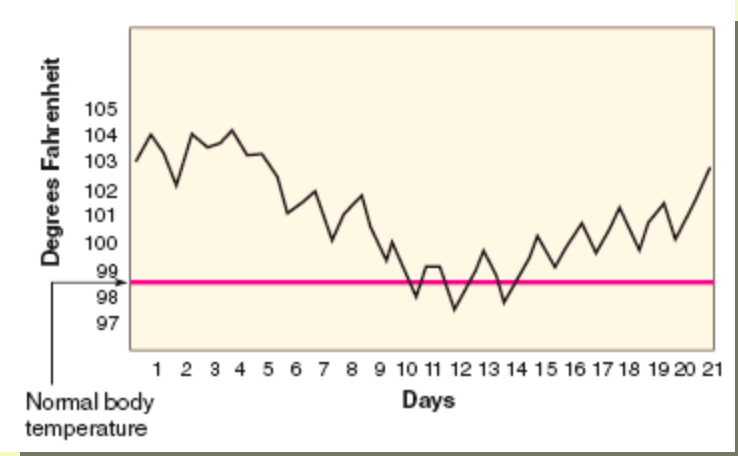
Figure 30.20 **Functions of Genes Carried on the *Agrobacterium* Ti Plasmid.** (a) Genes carried on the Ti plasmid of *Agrobacterium* control tumor formation by a two-component regulatory system that stimulates formation of the mating bridge and excision of the T-DNA. The T-DNA is moved by transfer genes, which lead to integration of the T-DNA into the plant nucleus. T-DNA encodes plant hormones that cause the plant cells to divide, producing the tumor. The tumor cells produce opines (shown in b) that can serve as a carbon source for the infecting *Agrobacterium*. This results in the formation of a crown gall on the stem of the wounded plant above the soil surface.

Brucella

- Tiny, gram-negative coccobacilli, aerobic, non-motile,
- **Malta fever**, **undulant fever**, and **Bang disease** are synonyms for brucellosis, a zoonosis transmitted to humans from infected animals or contaminated animal products harboring ***Brucella***.
- *B. abortus* (from cattle) and *B. suis (from pigs)*
  B. Cannis (from dog).

Brucellosis

- *Brucella* enters through damaged **skin or mucous** membranes of the **digestive** tract, **conjunctiva**, and **respiratory** tract. Infected phagocytes carry bacteria into the bloodstream, creating **focal** lesions in the liver, spleen, bone marrow, and kidney.
- Fluctuating pattern of fever.
- Treatment: Pen. + Strep.



Class Beta-proteobacteria

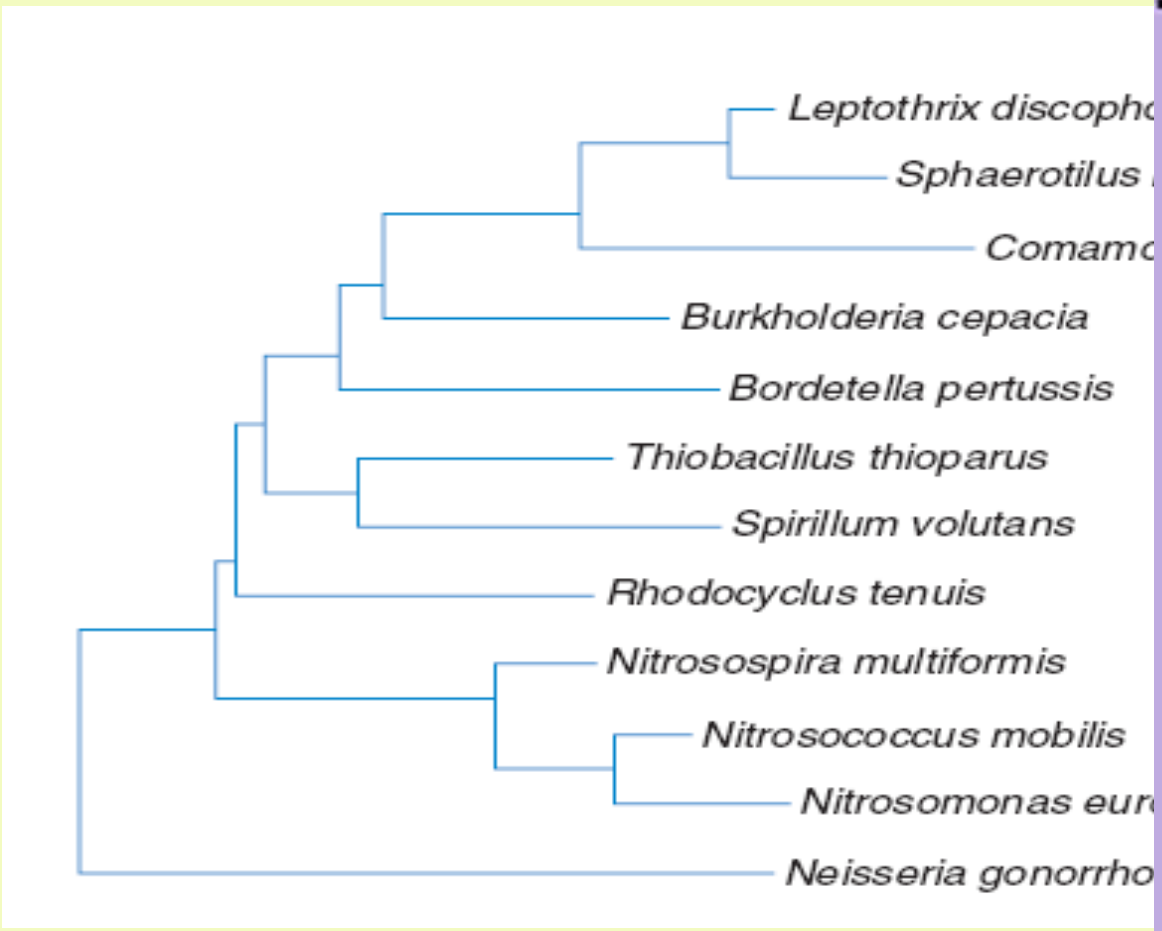


Table 22.3

Genus
Bordetella
Burkholderia
Leptothrix
Neisseria
Nitrosomonas
Sphaerotilus
Thiobacillus

Class Beta-proteobacteria

Table 22.3 Characteristics of Selected β-Proteobacteria

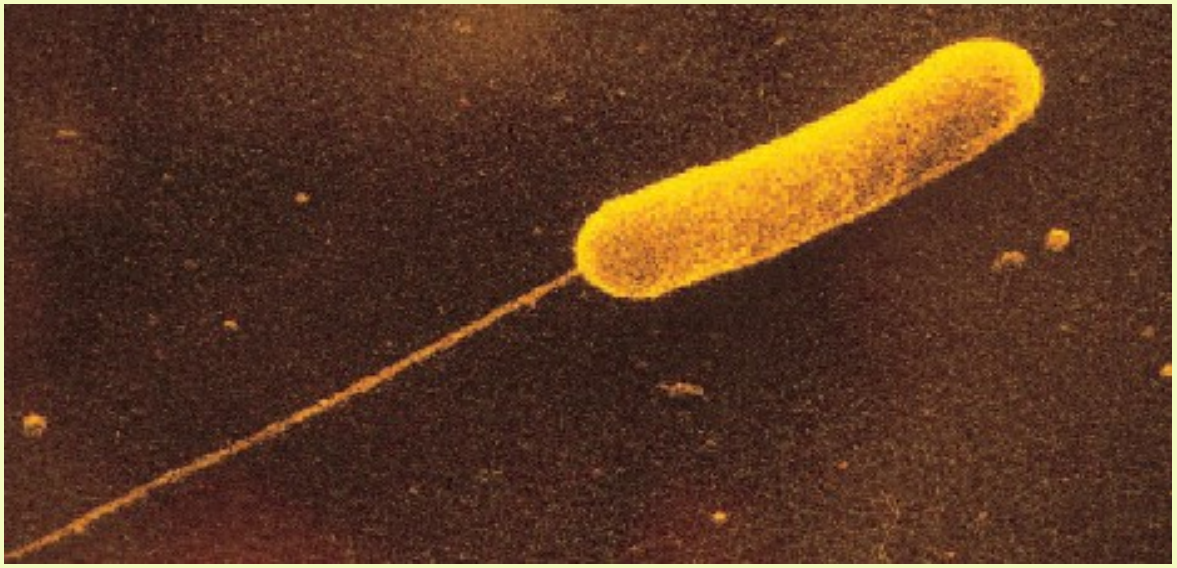
Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Oxygen Requirement
Bordetella	0.2–0.5 × 0.5–2.0; nonmotile coccobacillus	66–70	Aerobic
Burkholderia	0.3–1.0 × 1–5; straight rods with single flagella or a tuft at the pole	59–69.5	Aerobic
Leptothrix	0.6–1.4 × 1–12; straight rods in chains with sheath, free cells flagellated	69.5–71	Aerobic
Neisseria	0.6–1.0; cocci in pairs with flattened adjacent sides	46–54	Aerobic
Nitrosomonas	Size varies with strain; rod-shaped or ellipsoidal cells with intracytoplasmic membranes	45–54	Aerobic
Sphaerotilus	1.2–2.5 × 2–10; single chains of cells with sheaths, may have holdfasts	70	Aerobic
Thiobacillus	0.5 × 1–4; rods, often with polar flagella	52–68	Aerobic

Burkholderia

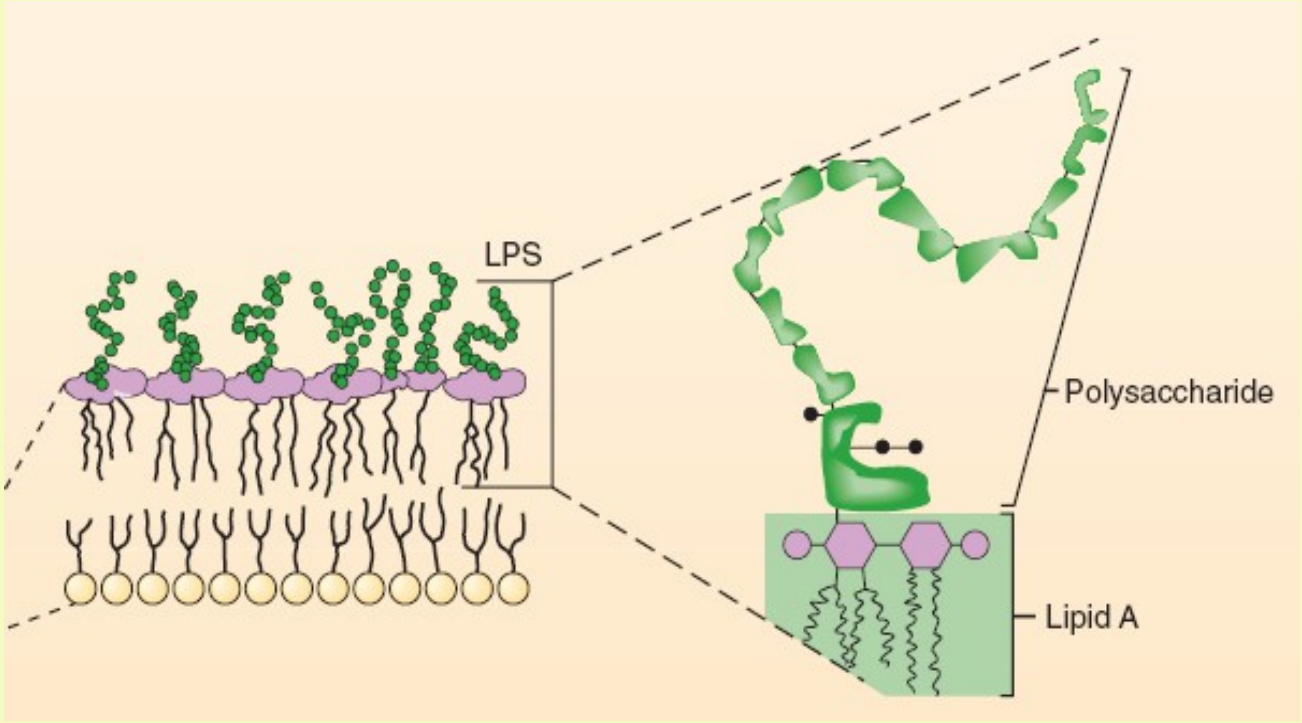
- The ***Pseudomonas*** was divided into at least seven new genera based on rRNA data: *Acidovorax, Aminobacter, Burkholderia, Comamonas, Deleya, Hydrogenophaga,* and *Methylobacterium.*
- Members of the genus ***Burkholderia*** are gram-negative, aerobic, nonfermentative, non–spore-forming, mesophilic straight rods. With the exception of one species, all are **motile** with a single polar flagellum or a tuft of polar flagella.

Burkholderia

- Catalase is produced and they often are oxidase positive. Most species use **poly--hydroxybutyrate** as their carbon reserve.
- One of the most important species is ***B. cepacia,*** which will degrade over **100** different organic molecules and is very active in recycling organic materials in nature. This species also is a plant pathogen and causes disease in hospital patients due to contaminated equipment and medications.



Single, polar flagellum



Endotoxic Shock

Neisseria

- The family *Neisseriaceae,* has 14 genera to it. The best-known and most intensely studied genus is ***Neisseria***.
- *Members of this genus are* nonmotile, aerobic, gram-negative cocci that most often occur in **pairs** with adjacent sides flattened.
- They may have **capsules** and **fimbriae**. The genus is chemoorganotrophic, oxidase positive, and almost always catalase positive.

Neisseria

- Species are inhabitants of the mucous membranes of mammals, and some are human pathogens. ***Neisseria gonorrhoeae*** is the causative agent of gonorrhea; ***Neisseria meningitidis*** is responsible for some cases of bacterial meningitis.

- *Neisseria gonorrhoeae inside a PMN.*

Bordetella

- **Pertussis** sometimes called “whooping cough,” is caused by the gram-negative bacterium ***Bordetella pertussis***.
- Pertussis is a highly **contagious** disease that primarily affects children. It has been estimated that over 95% of the world’s population has experienced either mild or severe symptoms of the disease. Around 500,000 die from the disease each year.

Bordetella

- Transmission occurs by inhalation of the bacterium in **droplets** released from an infectious person. Once inside the upper respiratory tract, the bacteria attach to the ciliated epithelial cells by producing **adhesins** such as the factor called **filamentous hemagglutinin**, which recognizes a complementary molecule on the cells. After attachment, the bacteria synthesize **several toxins** that are responsible for the symptoms. The most important toxin is **pertussis toxin**, which causes increased tissue susceptibility to histamine and serotonin, and an increased lymphocyte response.
- *B. pertussis also produces* **tracheal cytotoxin** and **dermonecrotic toxin**, which destroy epithelial tissue.

Thiobacillus

- *Thiobacillus*, one of the best-studied chemolithotrophs and most prominent of the **colorless sulfur bacteria**.
- *Thiobacillus* is a gram-negative rod. It grows aerobically by oxidizing a variety of **inorganic** sulfur compounds (elemental sulfur, hydrogen sulfide, thiosulfate) to sulfate. ATP is produced with a combination of oxidative **phosphorylation** and substrate-level phosphorylation by means of adenosine 5'-phosphosulfate.

Thiobacillus

- Some species are very flexible metabolically. For example, ***Thiobacillus ferrooxidans*** also uses ferrous iron as an electron donor and produces ferric iron as well as sulfuric acid. ***T. denitrificans*** even grows anaerobically by reducing nitrate to nitrogen gas.

Sphaerotilus and Leptothrix

- *Sphaerotilus and Leptothrix* have a **sheath,** a hollow tubelike structure surrounding a chain of cells. Sheaths often are close fitting, but they are never in intimate contact with the cells they enclose and may contain **ferric or manganic oxides**.
- They have at least **two functions**. Sheaths help bacteria **attach** to solid surfaces and acquire nutrients from slowly running water as it flows past, even if it is nutrient-poor. Sheaths also protect against **predators** such as protozoa and ***Bdellovibrio***.
- ***Sphaerotilus*** forms long sheathed chains of rods, 0.7 to 2.4 by 3 to 10 m, attached to submerged plants, rocks, and other solid objects, often by a holdfast. The sheaths are not usually encrusted by metal oxides.

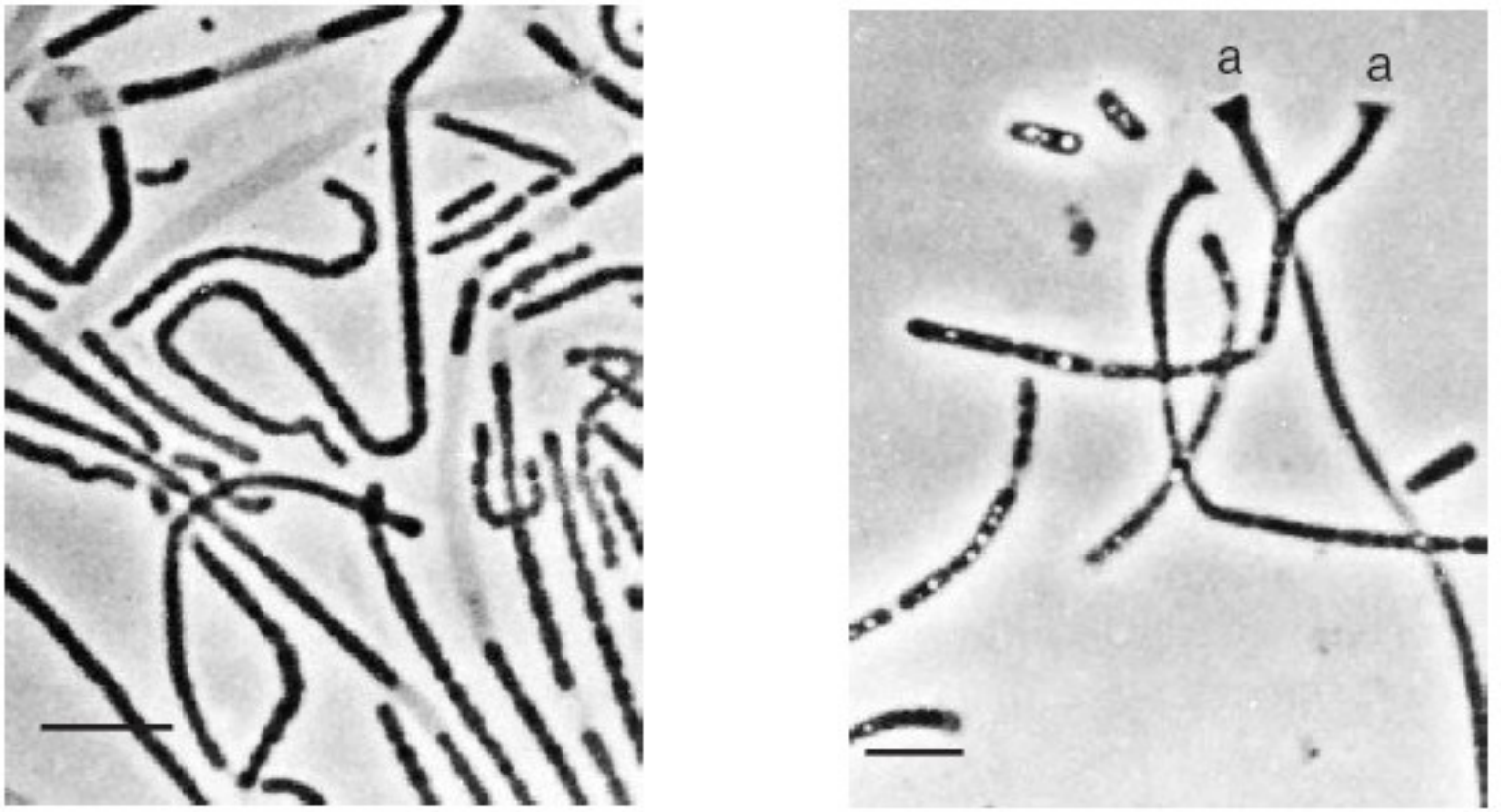
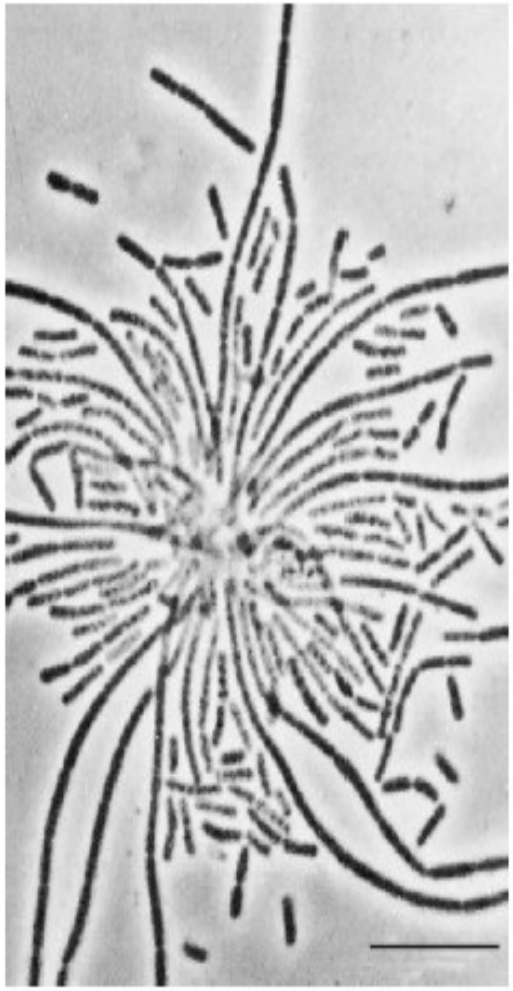


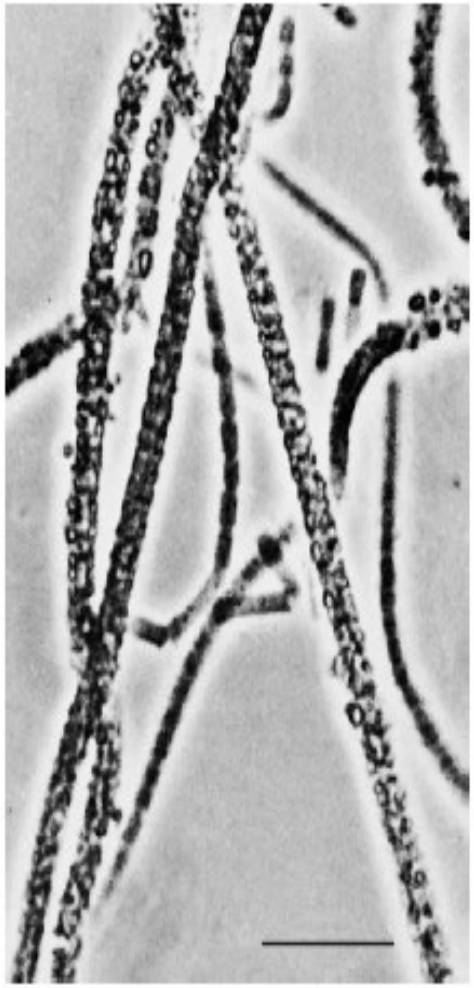
Figure 22.12 **Sheathed Bacteria, *Sphaerotilus natans*.**
(**a**) Sheathed chains of cells and empty sheaths. (**b**) Chains with holdfasts (indicated by the letter a) and individual cells containing poly-β-hydroxybutyrate granules. Bars = 10 μm.

Leptothrix

- ***Leptothrix*** characteristically deposits large amounts of **iron** and **manganese** oxides in its sheath. This seems to protect it and allow *Leptothrix* to grow in the presence of high concentrations of soluble iron compounds.



(a)



(b)

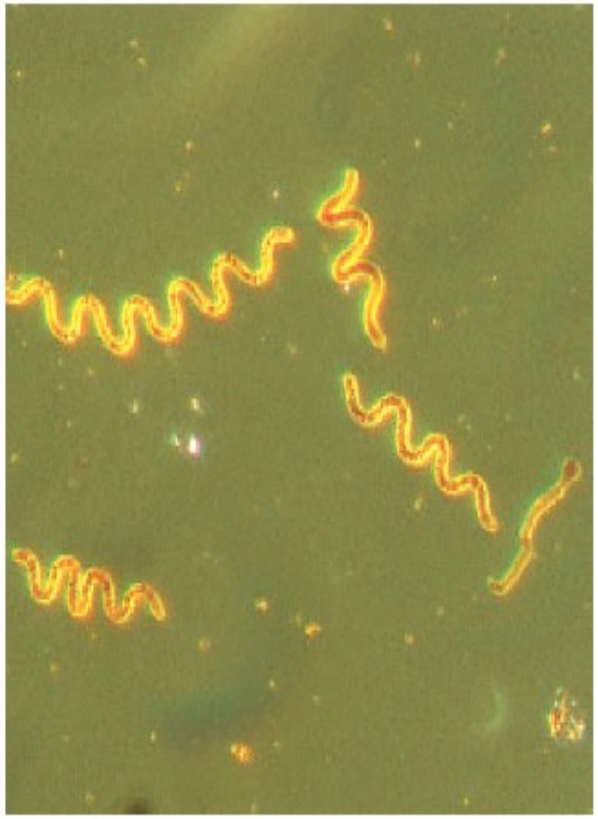
Figure 22.13 Sheathed Bacteria, *Leptothrix* Morphology. (a) *L. lopholea* trichomes radiating from a collection of holdfasts. (b) *L. cholodnii* sheaths encrusted with MnO_2. Bars = 10 μm.

Family *Spirillaceae*

- The family *Spirillaceae* has one genus, ***Spirillum***. A genus of Gram-negative, asporogenous bacteria. Cells: rigid, helical, ca. 1*.4–1.7 × 14–60 µm.*
- Microaerophilic. Metabolism is respiratory;
- ***S. minus****' (= 'S. minor'), causal agent* of one form of RAT-BITE FEVER.
- Bacteria were passed from **rodent to human** via the rodent's urine or mucous secretions.

- ***Spirillum volutans*** *with bipolar* flagella.

(a)



(b)

Figure 22.14 **The Genus *Spirillum*.** (**a**) *Spirillum volutans* with bipolar flagella visible (×450). (**b**) *Spirillum volutans;* phase contrast (×550).

1- Chills
2- Fever
3- Open sore at the site of the bite
4- Rash -- may be red/purple plaques
5- Swollen lymph nodes near the bite