II. THE PROKARYOTIC CELL: BACTERIA

A. SIZES, SHAPES, AND ARRANGEMENTS OF BACTERIA

Fundamental Statements for this Learning Object:

1. There are three basic shapes of bacteria: coccus, bacillus, and spiral.
2. Based on planes of division, the coccus shape can appear in several distinct arrangements: diplococcus, streptococcus, tetrad, sarcina, and staphylococcus.
3. The bacillus shape can appear as a single bacillus, a streptobacillus, or a coccobacillus.
4. The spiral shape can appear in several forms: vibrio, spirillum, and spirochete.
5. The metric unit micrometer (1/1,000,000 or 10^{-6} of a meter) is used to measure bacterial size.

LEARNING OBJECTIVES FOR THIS SECTION

1*. List the three basic shapes of bacteria.

2*. List and describe 5 different arrangements of cocci.

3. Define and give the abbreviation for the metric unit of length termed micrometer and state the average size of a coccus-shaped bacterium and a rod-shaped bacterium.

4. List and describe 2 different arrangements of bacilli.

5*. List and describe 3 different spiral forms of bacteria.

Bacteria are:

a. prokaryotic.

b. single-celled, microscopic organisms (Exceptions have been discovered that can reach sizes just visible to the naked eye. They include *Epulopiscium fishelsoni*, a bacillus-shaped bacterium that is typically 80 micrometers (μm) in diameter and 200-600 μm long, and *Thiomargarita namibiensis*, a spherical bacterium between 100 and 750 μm in diameter.)

c. generally much smaller than eukaryotic cells.

d. very complex despite their small size. Even though bacteria are single-celled organisms, they are able to communicate with one another through a process called quorum sensing. In this way they can function as a multicellular population rather than as individual bacteria.

Bacterial cell shape is determined primarily by a protein called MreB. MreB **forms a spiral band** – a simple cytoskeleton – **around the interior of the cell just under the cytoplasmic membrane**. It is thought to define shape by recruiting additional proteins that then direct the specific pattern of bacterial cell growth. For example, bacillus-shaped bacteria that have an inactivated MreB gene become coccoid shaped, and coccus-shaped bacteria naturally lack the MreB gene.

Most bacteria come in one of **three basic shapes**: **coccus, rod or bacillus, and spira**l.

1. Coccus
The cocci are spherical or oval bacteria having one of several distinct arrangements (see Fig. 1) based on their planes of division.

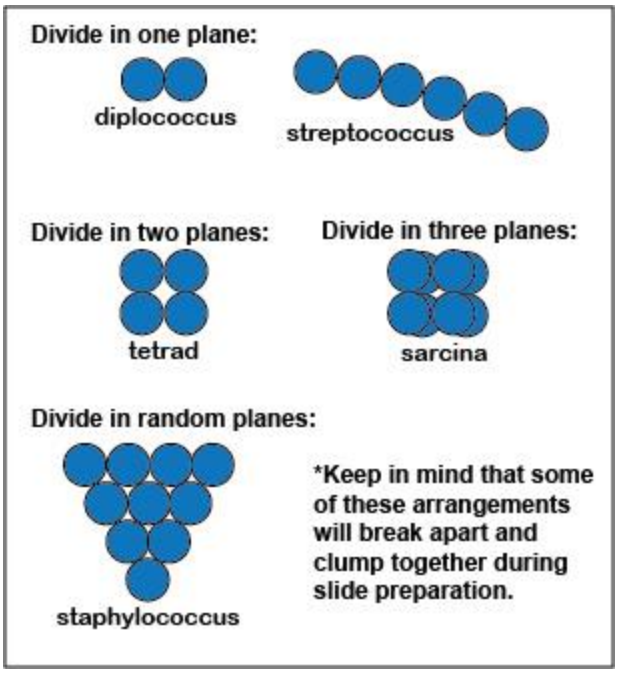

Figure 1

a. Division in **one plane** produces either a diplococcus or streptococcus arrangement.

diplococcus: cocci arranged in pairs (see Fig. 2)

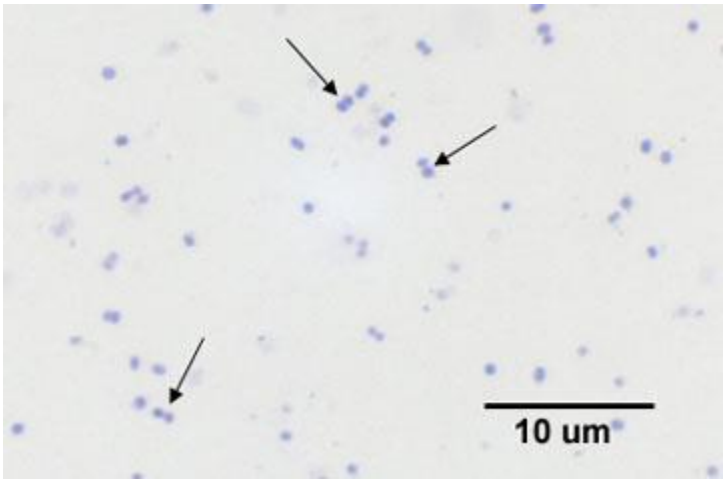

Figure 2

- scanning electron micrograph of a *Streptococcus pneumoniae*, a diplococcus; courtesy of CDC
- scanning electron micrograph of a *Neisseria*, a diplococcus; courtesy of Dennis Kunkel's Microscopy

streptococcus: cocci arranged in chains (see Fig. 3)

Figure 3

- scanning electron micrograph of a *Streptococcus pyogenes*, a streptococcus; courtesy of Dennis Kunkel's Microscopy
- transmission electron micrograph of *Streptococcus* from the Rockefeller University web page.
- scanning Electron Micrograph of Enterococcus

b. Division in **two planes** produces a tetrad arrangement.

tetrad: cocci arranged in squares of 4 (see Fig. 4)

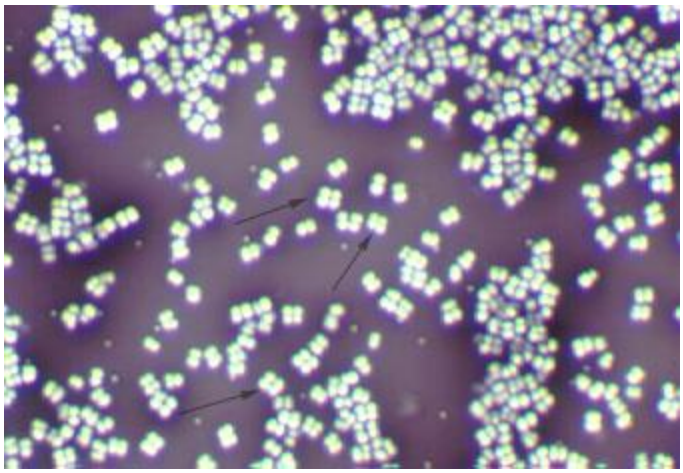

Figure 4

- scanning electron micrograph of *Micrococcus luteus* showing several tetrads

c. Division in **three planes** produces a sarcina arrangement.

sarcina: cocci in arranged cubes of 8 (see Fig. 5)

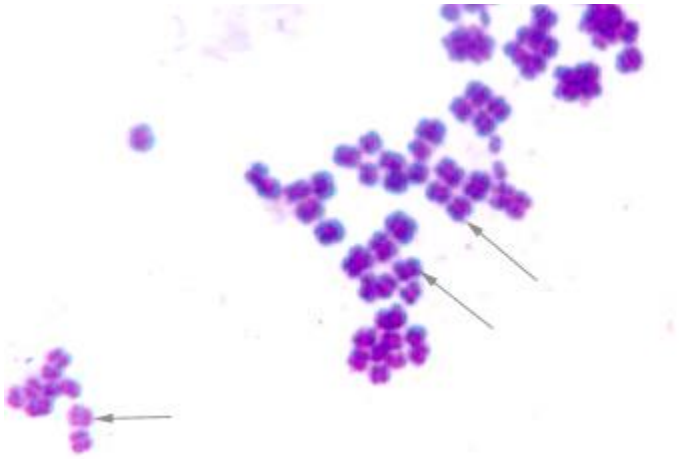

Figure 5

d. Division in **random planes** produces a staphylococcus arrangement.

staphylococcus: cocci arranged in irregular, often grape-like clusters (see Fig. 6)

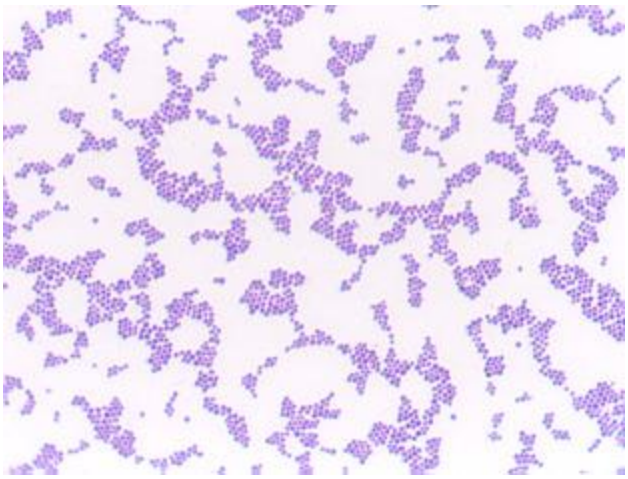

Figure 6

- negative image of *Staphylococcus aureus*
- scanning electron micrograph of *Staphylococcus aureus,* a staphylococcus; courtesy of Dennis Kunkel's Microscopy
- Scanning electron micrograph of methicillin-resistant *Staphylococcus aureus* (MRSA); courtesy of CDC

An average coccus is about 0.5-1.0 micrometer (µm) in diameter. (A micrometer equals 1/1,000,000 of a meter.)

2. The rod or bacillus

Bacilli are rod-shaped bacteria. Bacilli all divide in one plane producing a bacillus, streptobacillus, or coccobacillus arrangement (see Fig. 7).

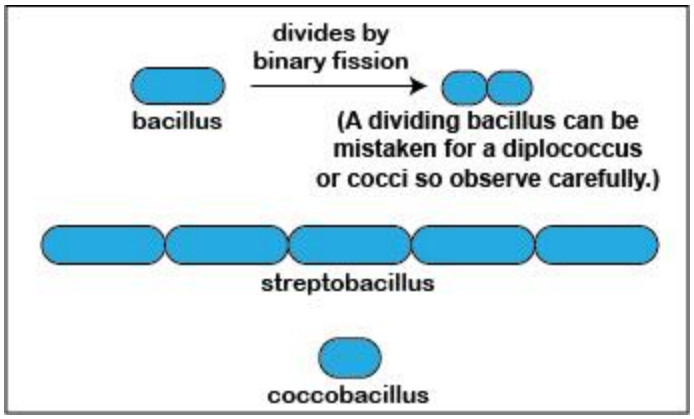

Figure 7

a. **bacillus**: single bacilli (see Fig. 8)

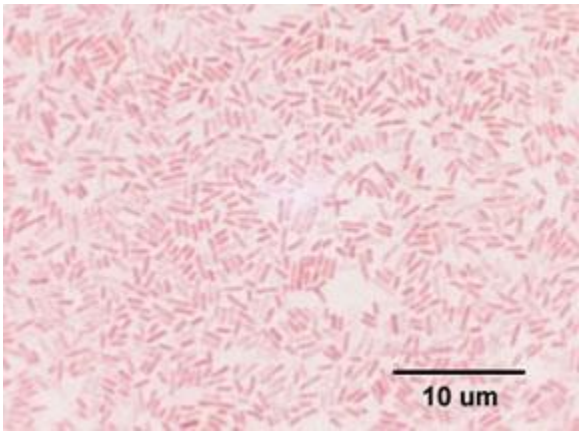

Figure 8

- scanning electron micrograph of a bacillus; courtesy of CDC
- scanning electron micrograph of *Escherichia coli* O157H7, a bacillus; courtesy of CDC

b. **streptobacillus**: bacilli arranged in chains (see Fig. 9)

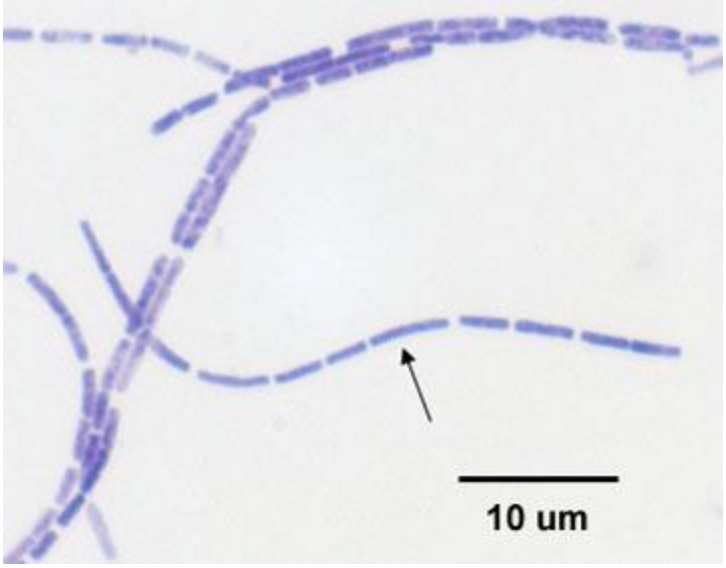

Figure 9

c. **coccobacillus**: oval and similar to a coccus (see Fig. 9A and Fig. 9B)

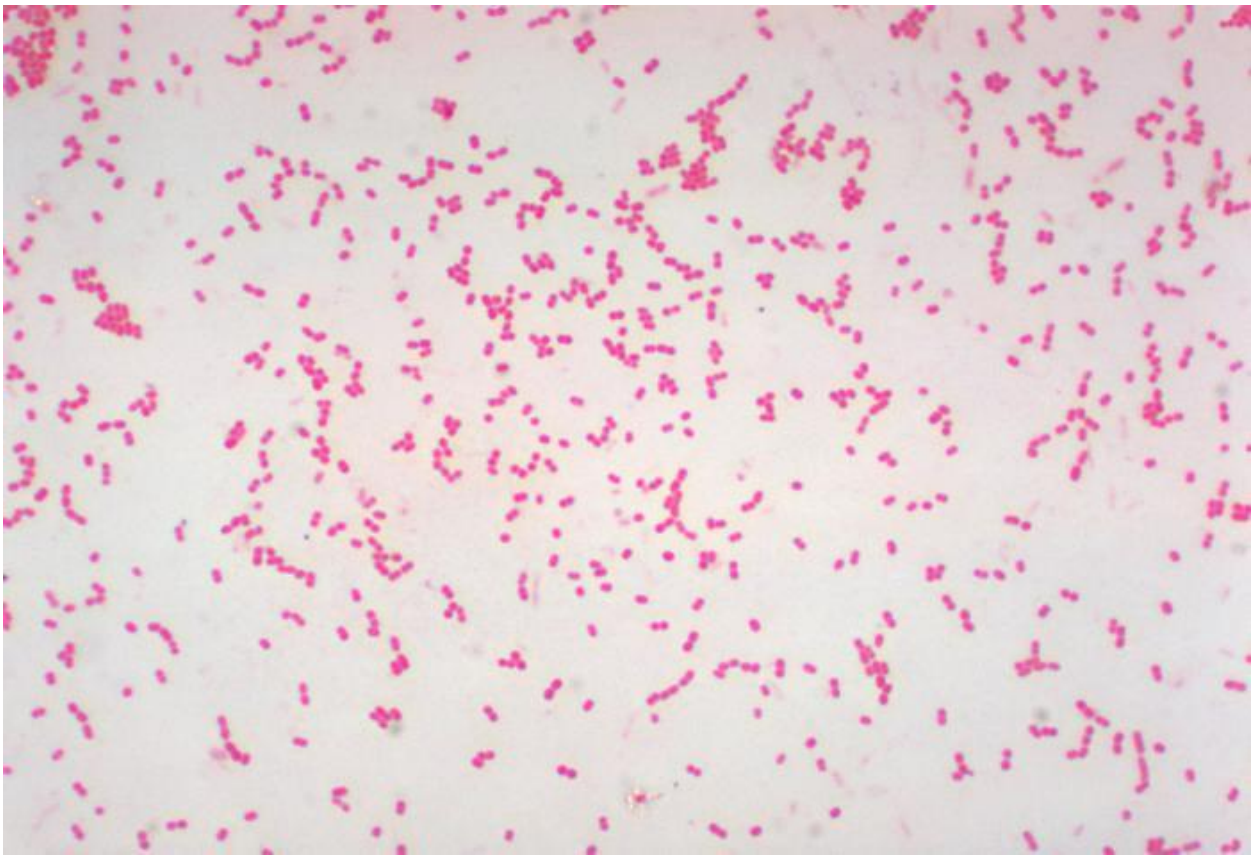

Figure 9A

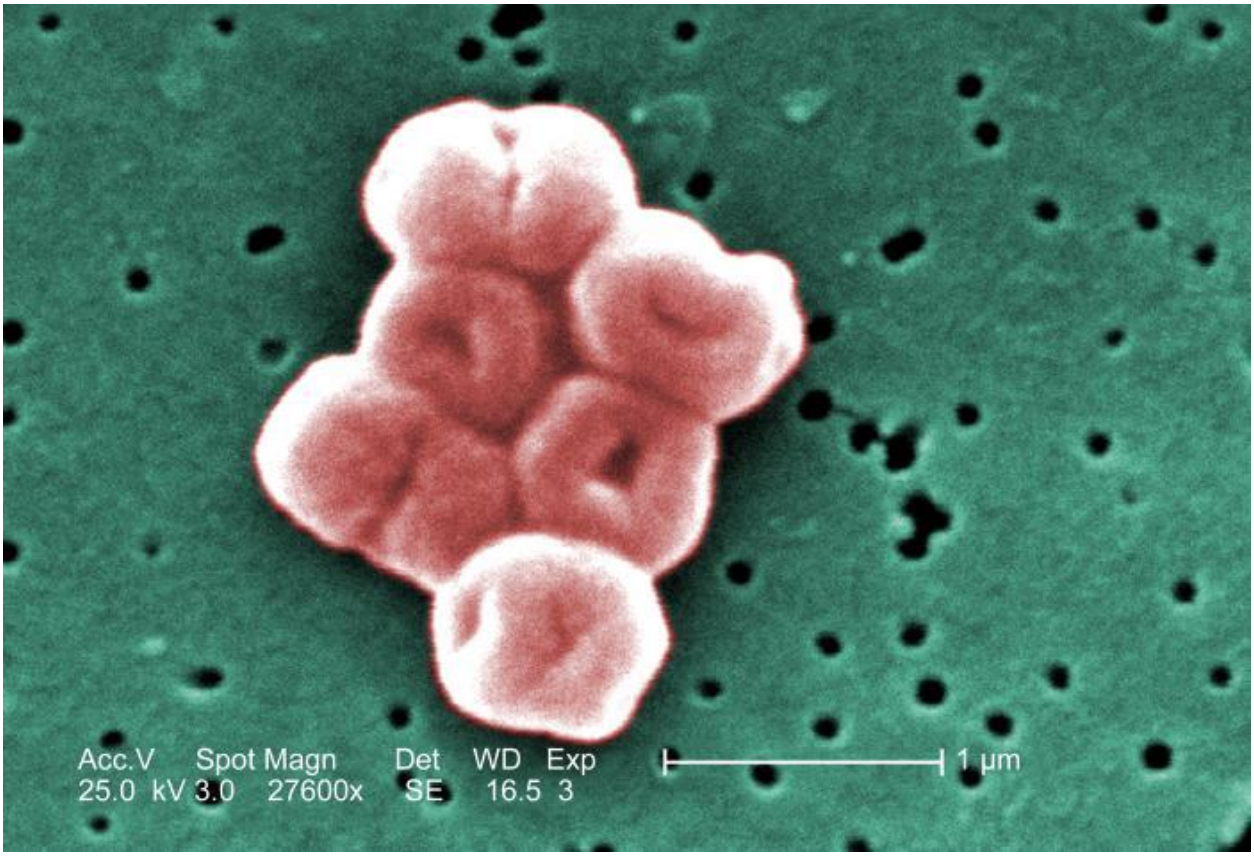

Figure 9B

An average bacillus is 0.5-1.0 µm wide by 1.0-4.0 µm long.

3. The spiral

Spirals come in one of three **forms**, a vibrio, a spirillum, or a spirochete. (see Fig. 10)

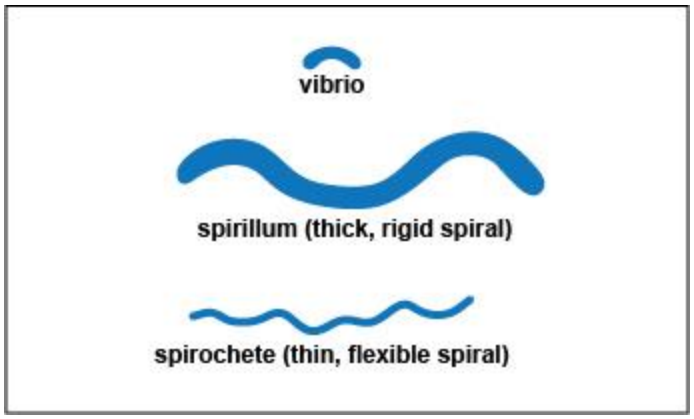

Figure 10

a. **vibrio**: a curved or comma-shaped rod (see Fig. 11)

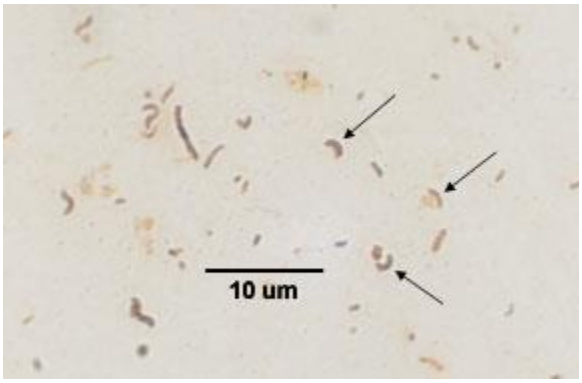

Figure 11

- scanning electron micrograph of a *Vibrio cholerae*, a vibrio; courtesy of Dennis Kunkel's Microscopy

b. **spirillum**: a thick, rigid spiral (see Fig. 12)

Figure 12

c. **spirochete**: a thin, flexible spiral (see Fig. 13)

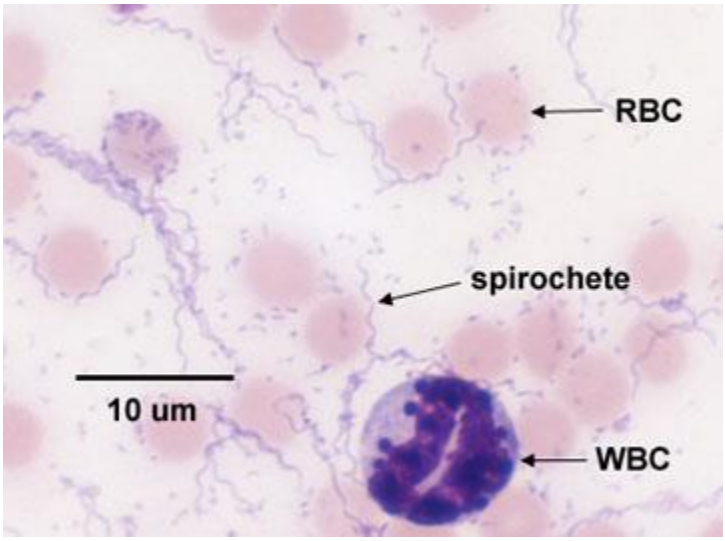

Figure 13

- scanning electron micrograph of the spirochete *Leptospira*; courtesy of CDC
- scanning electron micrograph of the spirochete *Treponema pallidum*; courtesy of CDC

Spirals range in size from 1 µm to over 100 µm in length.

4. Exceptions to the above shapes

There are exceptions to the three basic shapes of coccus, bacillus, and spiral. They include sheathed, stalked, filamentous, square, star-shaped, spindle-shaped, lobed, trichome-forming, and pleomorphic bacteria.

5. Ultrasmall Bacteria: 150 could fit in a single *Escherichia coli*

Ultrasmall bacteria have been discovered in groundwater that was passed through a filter with a pore size of 0.2 micrometers µm). They showed an **average length of only 323 nanometers (nm) and an average width of 242 nm**. They contain DNA, an average of 42 ribosomes per bacterium, and possessed pili. It is thought that they use these pili to attach to other bacteria from which they scavenge nutrients. Because the surface to volume ratio is even greater than in more traditional sized bacteria, they might be better designed to take up scarce nutrients from more nutrient-poor environments.