**ADVANCED BIOLOGY**

**Cell Unit: *Overview of Prokaryotic Cells:* Text, Pp. 98; Figure 26.21 on page 552; Table 27.2 on page 566; text from Chapter 27 – 27.1, p. 556-560 & 27.3, p. 564-565**

* See **The Secret, Social Lives of Bacteria** (A 20 minute TED Talk)

Prokaryotes were the Earth's earliest organisms, inhabiting our planet more than 3.5 billion years ago!

Short NG video: "Are these the oldest fossils ever found?"

These unicellular organisms were the Earth's only inhabitants for 2 billion years. As Chapter 27 begins, "They're (almost) everywhere! Their collective biological mass (biomass) is at least ten times that of all eukaryotes. The number of prokaryotes in a single handful of fertile soil is greater than the number of people who have ever lived!" An appreciation for these organisms begins by reading the introduction to this Chapter 27, beginning on page 534.

Approximately 5,000 species of prokaryotes are known today - a mere fraction of the estimated 4 million species. DNA sequencing studies support the idea that all organisms have been evolving along 3 independent lines for over 1.5 billion years, with 2 of these "domains" being comprised of prokaryotic cells. "In reconstructing the evolutionary history underlying the varied lifestyles of prokaryotes, biologists are discovering that **these organisms have an astonishing genetic diversity**. For example, comparing ribosomal RNA reveals that two strains of the bacterial species *Escherichia coli* are genetically more different than a human and a platypus."

You think you know all the places bacteria can live?

See Table 27.2 on page 566 for an overview of the 3 domains of organisms.

Figure 27.17 on page 568-569 further describes the known diversity among bacteria.

## Biologists classify prokaryotes using a number of criteria. These include:

- **shape** (see Fig. 27.2, p. 557)

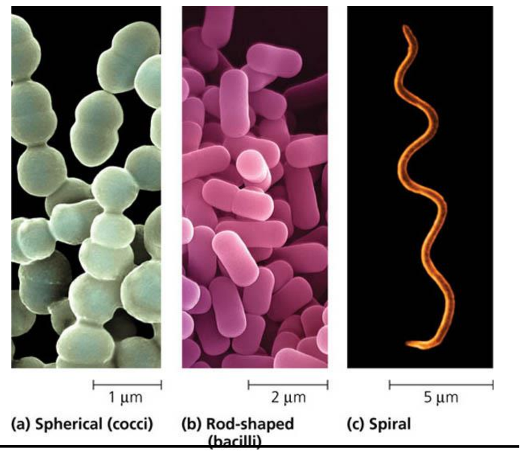
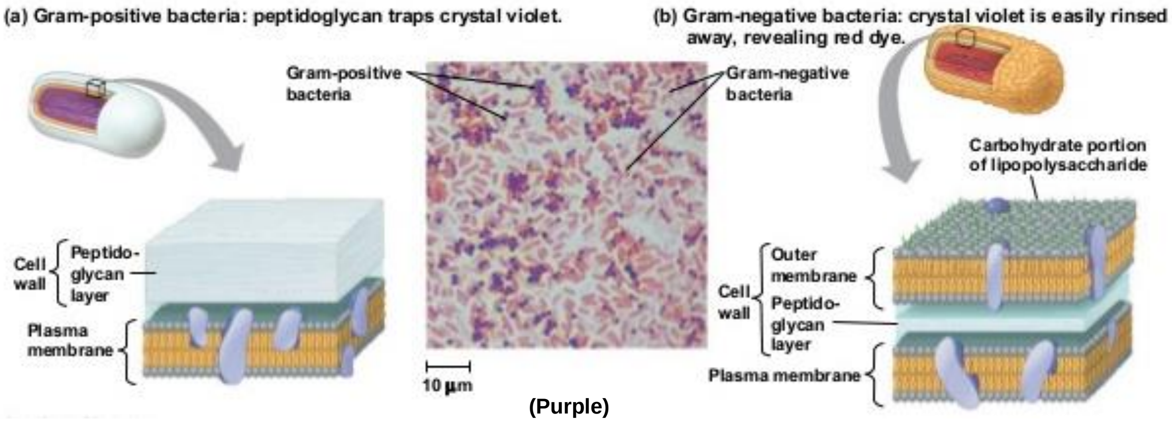



**Figure 27.2 The most common shapes of prokaryotes.**
(a) Cocci are spherical prokaryotes.
(b) Bacilli are rod–shaped prokaryotes.
(c) Spiral prokaryotes include spirochetes (shown here), which are corkscrew–shaped.

- **absorption of Gram stain** (see Fig. 27.3, p. 557)




**(Purple)**

"Danish scientist Hans Christian Gram devised a method to differentiate two types of bacteria based on the structural differences in their cell walls. In his test, bacteria that retain the crystal violet dye do so because of a thick layer of peptidoglycan and are called **Gram-positive bacteria**. In contrast, **Gram-negative bacteria** do not retain the violet dye and are colored red or pink." ***http://www.diffen.com/difference/Gram-negative_Bacteria_vs_Gram-positive_Bacteria***

- **energy acquisition** (see p. 564-565; Table 27.1)

**Table 27.1** Major Nutritional Modes

| Mode | Energy Source | Carbon Source | Types of Organisms |
|---|---|---|---|
| AUTOTROPH | | | |
| **Photoautotroph** | Light | $CO_2$, $HCO_3^-$, or related compound | Photosynthetic prokaryotes (for example, cyanobacteria); plants; certain protists (for example, algae) |
| **Chemoautotroph** | Inorganic chemicals (such as $H_2S$, $NH_3$, or $Fe^{2+}$) | $CO_2$, $HCO_3^-$, or related compound | Unique to certain prokaryotes (for example, *Sulfolobus*) |
| HETEROTROPH | | | |
| **Photoheterotroph** | Light | Organic compounds | Unique to certain aquatic and salt-loving prokaryotes (for example, *Rhodobacter*, *Chloroflexus*) |
| **Chemoheterotroph** | Organic compounds | Organic compounds | Many prokaryotes (for example, *Clostridium*) and protists; fungi; animals; some plants |

[Examine this video of a hydrothermal vent!]

- **nitrogen use and oxygen metabolism**

Nitrogen is an exceedingly important element in the cells of organisms. Nitrogen contributes to the bases found in the nucleotides of DNA and RNA. In addition, the amino group of every amino acid contains nitrogen. Since most organisms are unable to access the atmospheric nitrogen available in the air (**$N_2$**), virtually all life relies on the species of bacteria that can convert $N_2$ into usable forms of nitrogen – inorganic nitrogen-containing ions nitrate (**$NO_3^-$**), nitrite (**$NO_2^-$**) and ammonium (**$NH_4^+$**).

These processes begin when *Rhizobium* or *Azotobacter* bacteria "fix" atmospheric nitrogen, producing ammonia, **$NH_3$.** The equation for this reaction is:

$$N_2 + 3H_2 \text{ ----> } 2NH_3$$

*Rhizobium* bacteria form "nodules" on the roots of plants. Their conversion of nitrogen into ammonia ("**nitrogen fixation**") allows the plant to absorb nitrogen in a form that can be used by the plant. These nitrogen compounds can then move through organisms in food webs, providing building blocks for DNA, RNA, & protein.

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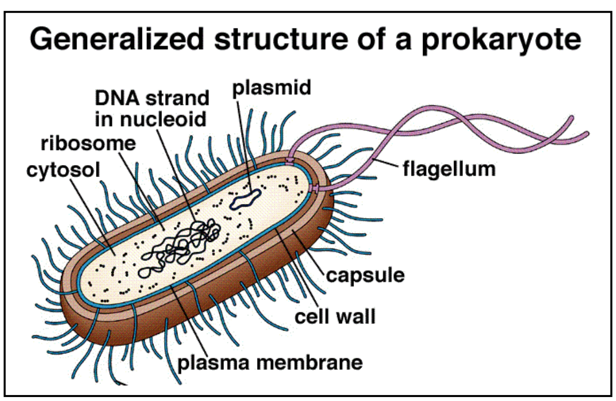
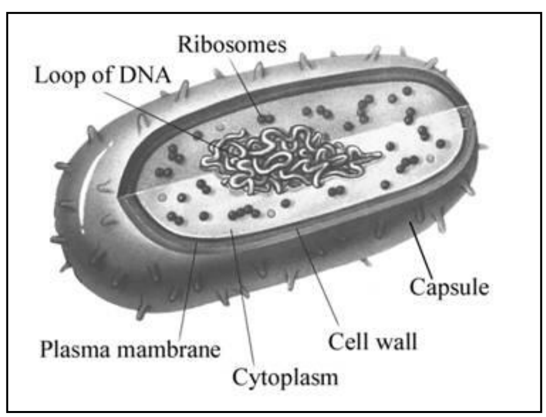
"Prokaryotic metabolism also varies with respect to oxygen (see Chapter 9). **Obligate aerobes** use $O_2$ for cellular respiration and cannot grow without it. **Facultative anaerobes** use $O_2$ if it is present but can also grow by fermentation in an anaerobic environment. **Obligate anaerobes** are poisoned by $O_2$."

**Structure of Prokaryotic Cells**: (See Fig. 6.5, page 98)
- 1 -5 *u*m in size
- lack membrane-bound organelles
- encased within a lipid bilayer membrane
- encased within a rigid cell wall (see the next note page), which provides protection, shape, and prevents bursting when the cell is in a hypotonic environment.




**Cell Wall Structure**: The prokaryotic cell wall is composed of a complex molecule known as **peptidoglycan.** This molecule is briefly mentioned on page 557, and in the Gram stain discussion on the prior page. Peptidoglycan consists of polymers of **disaccharides that are cross-linked with short polypeptides**. These short chains of amino acids are species-specific. This cell wall is essentially one large molecule! Below is a descriptive illustration.

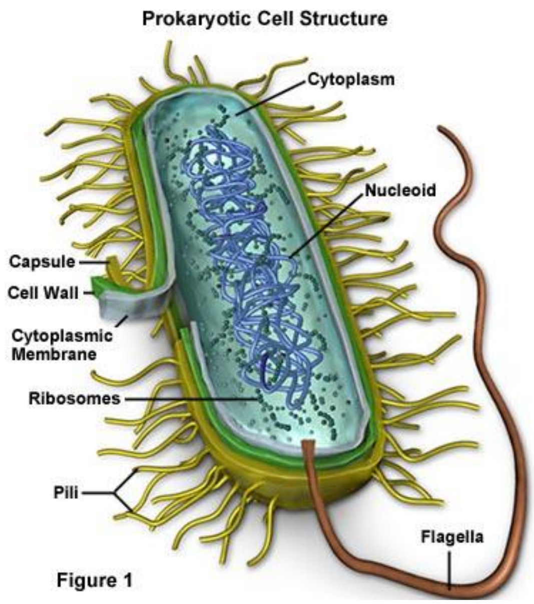
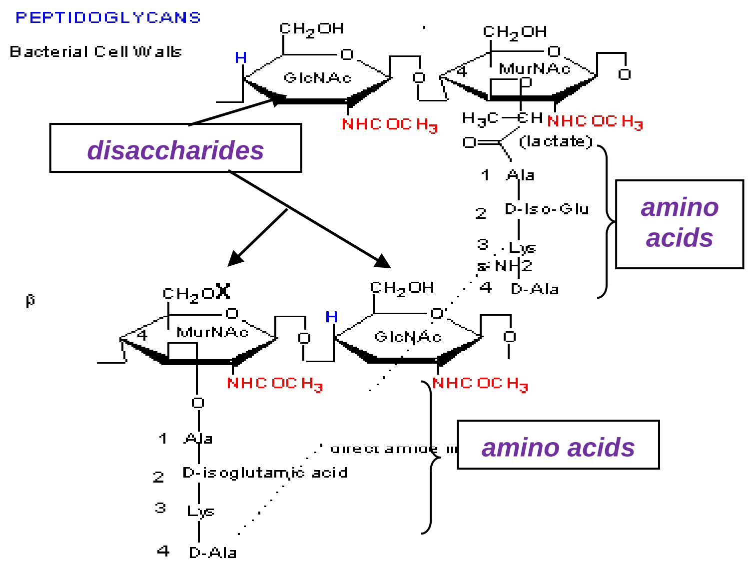
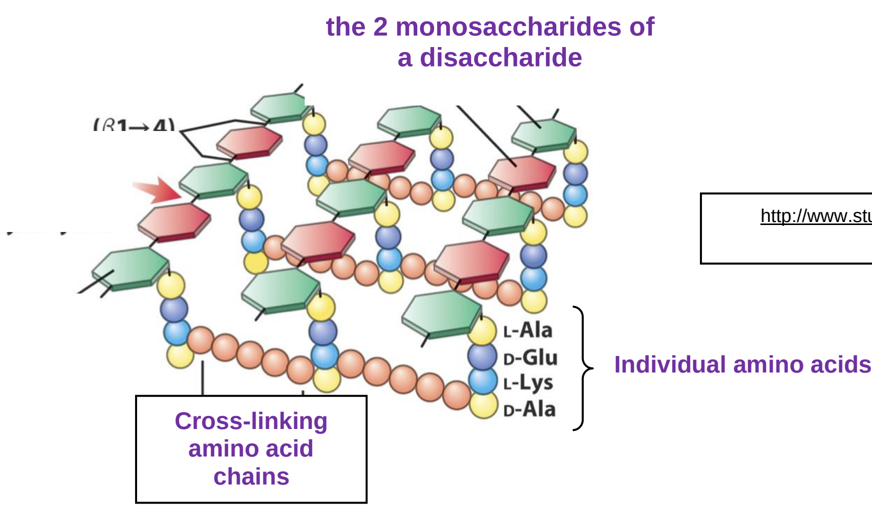



Figure 1

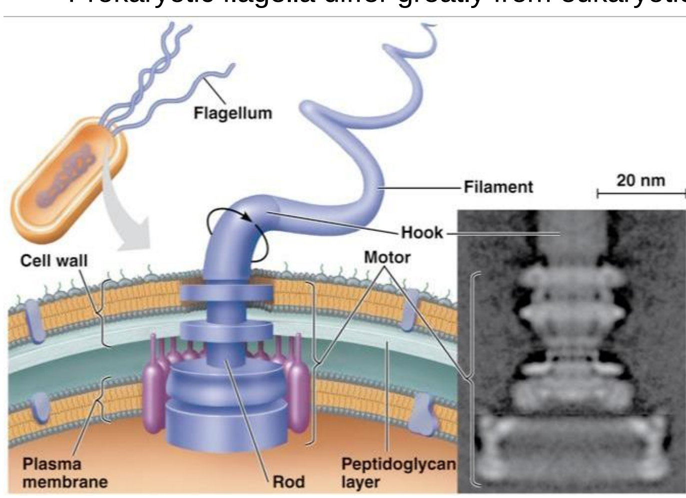



http://employees.csbsju.edu/HJAKUBOWSKI/classes/ch331/cho/peptidoglycan.gif




http://www.studyblue.com/notes/note/n/bacterial-cell-structure-/deck/4713270

**<u>Bacterial Movement:</u>** The most common structure for movement in bacteria is the ***flagellum***. Prokaryotic flagella differ greatly from eukaryotic flagella. See p. 558-9 of our text, as well as Figure 27.6.




*Scientists explored how such a complex structure could evolve. Much evidence indicates that bacterial flagella originated as simpler structures that were modified in a stepwise fashion over time. Like the human eye, biologists asked whether a less complex version of the flagellum could still benefit its owner.*

*Genetic analyses revealed that 19 of the 21 proteins in this structure are modified versions of proteins that perform other tasks. Ten of the proteins in the motor portion of the flagellum are homologous to secretory proteins in bacteria, and two other proteins are homologous to ion transport proteins!*

*These and additional findings suggest that the bacterial flagellum evolved as other proteins were added to an ancestral secretory system. This is an example of **exaptation**, **the process in which existing structures take on new functions through descent with modification**.*

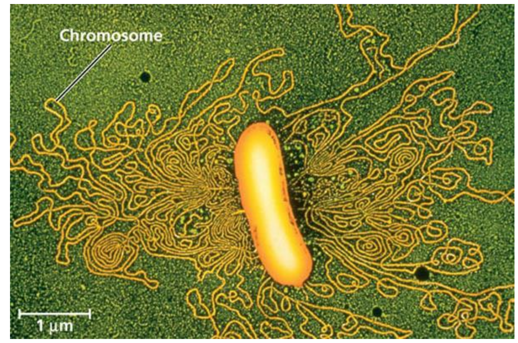
**<u>Lack of Interior Cellular Organization</u>:**

The cytoplasm of prokaryotes is one continuous compartment with no internal support network.

All of the cell's strength comes from its rigid cell wall.

From our 7th edition

**Figure 27.8 A prokaryotic chromosome.** The thin, tangled loops surrounding ruptured *E. coli* cell are parts of a single ring of DNA (colorized TEM).

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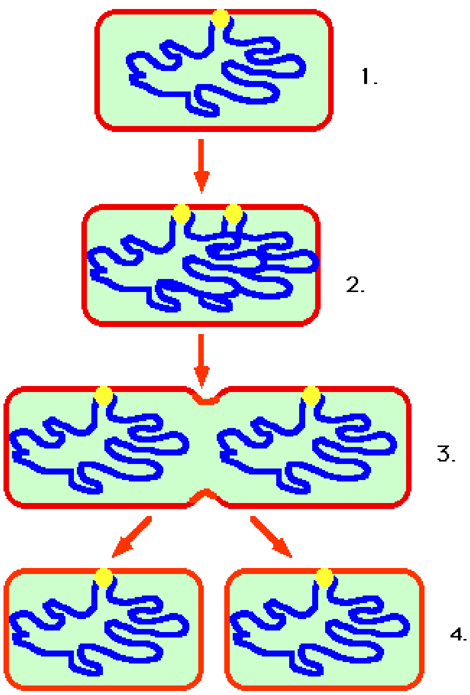
The internal side of the cell membrane often intrudes into the interior of the cell. These intrusions of membrane into the cytoplasm of bacteria are known as **mesosomes**.

Mesosomes occur at sites where replicated DNA has attached to the cell membrane in preparation for cell division. **These mesosomes are thought to aid in the equal separation of DNA between dividing cells.**

**Also, mesosomes increase the membrane area available for membrane functions, such as the transport of nutrients and the storage of pigments.** For example, in some photosynthetic bacteria, the membrane extensively intrudes into the cytoplasm by convoluting into a spiral pattern, thus greatly increasing the surface area devoted to absorbing light energy for food production.

***Never does this intruding cell membrane completely "wall off" any portion of the cell. All cell areas are accessible, an essential characteristic of prokaryotic cells.***




http://preuniversity.grkraj.org/html/2_CELL_DIVISION.htm

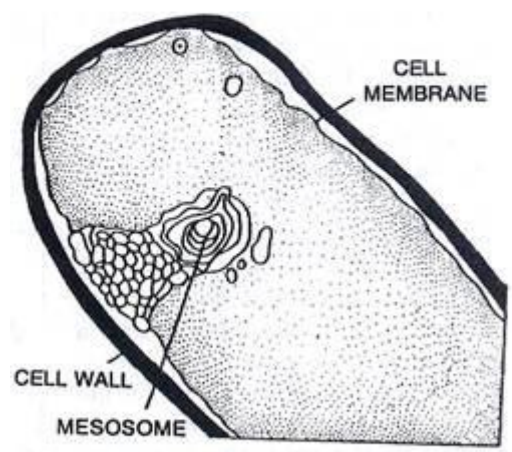



**Fig. 2.8.** Bacteria. Structure and position of mesosome in bacterial cell.

http://www.yourarticlelibrary.com/wp-content/uploads/2013/08/clip_image002112.jpg

**Notice how an intruding cell membrane increases the efficiency of this system, which is limited from the standpoint of eukaryotic cells. Without any "organelle compartmentalization," any complex metabolism is impossible, because there cannot be many independently ongoing processes, which are of course occurring in eukaryotes. It is thought that this limitation has maintained prokaryotes as unicellular organisms for the ~3.5 billion years of their evolution.**