

Chapter 27: Bacteria and Archaea

1. What are the “masters of adaptation”?

Prokaryotes can tolerate extreme conditions. *Deinococcus radiodurans* can survive 3 million rads of radiation, and *Picrophilus oshimae* can grow at a pH of 0.03 (acidic enough to dissolve metal). Some prokaryotes have even been found living in rocks 3.2 km (2 miles) below Earth’s surface. Prokaryotic species are also very well adapted to more “normal” habitats.

2. Which two domains include prokaryotes?

Prokaryotes are found in the domains Archaea and Bacteria.

3. What are prokaryotes?

Most prokaryotes are unicellular. Prokaryotic cells typically have diameters of 0.5–5 μm , much smaller than the 10–100 μm diameter of many eukaryotic cells. The three most common shapes are spherical (cocci), rod-shaped (bacilli), and spiral (spirilla and spirochetes). In contrast, most bacterial cell walls contain peptidoglycan, a polymer composed of modified sugars cross-linked by short polypeptides. This molecular fabric encloses the entire bacterium and anchors other molecules that extend from its surface.

4. What three functions does the cell wall provide for prokaryotic cells?

A prokaryote’s cell wall maintains cell shape, protects the cell, and prevents it from bursting in hypotonic environments.

5. What material comprises the cell wall of plants and fungi?

In eukaryotes that have cell walls, such as plants and fungi, the cell walls are usually made of cellulose or chitin.

6. How are the cell walls of Archaeans different?

Archaeal cell walls contain a variety of polysaccharides but lack peptidoglycan.

7. What is the difference between gram-positive and gram-negative bacteria?

Gram-positive bacteria have simpler walls with a relatively large amount of peptidoglycan. Gram-negative bacteria have less peptidoglycan and are structurally more complex, with an outer membrane that contains lipopolysaccharides.

8. What is a bacterial capsule? What functions may it serve?

The cell wall of many prokaryotes is surrounded by a sticky layer of polysaccharide or protein. This layer is called a capsule if it is dense and well defined or a slime layer if it is less organized. Both kinds of sticky outer layers enable prokaryotes to adhere to their substrate or to other individuals in a colony. Some capsules and slime layers protect against dehydration, and some shield pathogenic prokaryotes from attacks by their host’s immune system.

9. What is directional movement in prokaryotes called?

About half of all prokaryotes are capable of taxis, a directed movement toward or away from a stimulus.

10. What bacterial feature makes directional movement in many prokaryotes possible?

Of the various structures that enable prokaryotes to move, the most common are flagella, which may be scattered over the entire surface of the cell or concentrated at one or both ends. Prokaryotic flagella differ greatly from eukaryotic flagella: they are one-tenth the width and are not covered by an extension of the plasma membrane. Overall, structural and molecular comparisons suggest that the flagella of bacteria, archaea, and eukaryotes arose independently.

11. How quickly can *E. coli* divide under ideal conditions? What conditions check prokaryotic reproduction?

Under optimal conditions, many prokaryotes can divide every 1–3 hours; *E. coli* can divide every 20 minutes. If reproduction continued unchecked at this rate, a single prokaryotic cell could give rise to a colony outweighing Earth in only two days! However, prokaryotic reproduction is limited because the cells eventually exhaust their nutrient supply, poison themselves with metabolic wastes, face competition from other microorganisms, or are consumed by other organisms.

12. What three key features allow prokaryotic populations to consist of trillions of individuals?

Reproduction in prokaryotes draws attention to three key features of their biology: they are small, they reproduce by binary fission, and they have short generation times.

13. Compare prokaryotes to eukaryotes.

| | <i>Prokaryotes</i> | <i>Eukaryotes</i> |
|---------------------------|---|--|
| <i>Size</i> | smaller | larger |
| <i>Genome</i> | smaller; not much attached protein | larger; attached histone proteins common |
| <i>Membranes</i> | plasma membrane; no membrane-bound organelles | plasma membrane; nuclear membrane; membrane-bound organelles |
| <i>Location of genome</i> | nucleoid region | linear chromosomes in the nucleus |
| <i>Plasmids</i> | yes | no |
| <i>Ribosomes</i> | yes | yes |

14. What are the small, circular, self-replicating pieces of DNA found in bacteria called?

Plasmids are independently replicating DNA molecules, most carrying only a few genes.

16. What are endospores?

Certain bacteria develop resistant cells called endospores when they lack an essential nutrient. The original cell produces a copy of its chromosome and surrounds it with a tough multilayered structure, forming the endospore. Water is removed from the endospore, and its metabolism halts. The original cell then lyses, releasing the endospore. Killing endospores requires heating lab equipment to 121°C under high pressure. In less hostile environments, endospores can remain dominant but viable for centuries, able to rehydrate and resume metabolism when their environment improves.

17. Explain three major ways in which genetic variation is introduced in prokaryotes.

| <i>Source of Variation</i> | <i>Explanation</i> |
|----------------------------|--|
| Transformation | genotype of a prokaryotic cell is altered by the uptake of foreign DNA from its surroundings |
| Transduction | phages carry prokaryotic genes from one host cell to another; may result in recombination |
| Recombination | incorporation of prokaryotic DNA acquired from the donor cell into the recipient cell's chromosome |

18. What is transformation?

In transformation, the genotype and possibly phenotype of a prokaryotic cell are altered by the uptake of foreign DNA from its surroundings. Transformation occurs when a nonpathogenic cell takes up a piece of DNA carrying the allele for pathogenicity and replaces its own allele with the foreign allele, an exchange of homologous DNA segments. The cell is now a recombinant.

19. What is transduction?

In transduction, phages carry prokaryotic genes from one host cell to another. In most cases, transduction results from accidents that occur during the phage reproductive cycle. A virus that carries prokaryotic DNA may be unable to replicate because it lacks some or all of its own genetic material. However, the virus can attach to another prokaryotic cell (a recipient) and inject prokaryotic DNA acquired from the first cell (the donor). If some of this DNA is then incorporated into the recipient cell's chromosome by DNA recombination, a recombinant cell is formed.

20. Compare and contrast transduction and transformation.

Both transduction and transformation result in a recombinant cell. However, in transduction, the recipient cell takes up a piece of DNA carrying an allele for pathogenicity, while in transformation, the recipient cell takes up some of a phage's prokaryotic DNA, which does not necessarily carry an allele for pathogenicity. Also, in transformation, the recipient cell replaces its own allele with the foreign allele, while in transduction, the foreign DNA is simply incorporated into the recipient cell's chromosome.

21. *What is a sex pilus? What is the F factor? How are the two related?*

The sex pilus, a flexible tube of protein subunits (TEM), extends from the donor and attaches to the recipient cell, a key first step in the transfer of DNA. The ability to form pili and donate DNA during conjugation results from the presence of a particular piece of DNA called the F factor (F for fertility). The F factor can exist either as a plasmid or as a segment of DNA within the bacterial chromosome.

22. *What is an episome? What is an F plasmid?*

An episome is a piece of DNA that can be integrated within the main chromosome of the bacterium or exist as an independent plasmid. The F factor in its plasmid form is called the F plasmid. Cells containing the F plasmid, designated F⁺ cells, function as DNA donors during conjugation. Cells lacking the F factor, designated F⁻ cells, function as DNA recipients during conjugation. Chromosomal genes can be transferred during conjugation when the donor cell's F factor is integrated into the chromosome, forming a recombinant cell.

23. *What occurs in bacterial conjugation?*

In a process called conjugation, DNA is transferred between two prokaryotic cells (usually of the same species) that are temporarily joined. In bacteria, the DNA transfer is always one-way: one cell donates the DNA, and the other receives it.

24. *When a mating bridge forms between an F⁺ cell and an F⁻ cell and the F plasmid is replicated and transferred, what is the status of the F⁻ cell afterward?*

The F⁺ condition is transferable in the sense that an F⁺ cell converts an F⁻ cell to F⁺ if a copy of the entire F⁺ plasmid is transferred.

25. *What is an Hfr cell?*

A cell with the F factor built into its chromosome is called an Hfr cell (for high frequency of recombination).

26. *How are Hfr cells related?*

Like an F⁺ cell, an Hfr cell functions as a donor during conjugation with an F⁻ cell.

27. *Summarize the transfer of genetic information from an Hfr cell to an F⁻ cell.*

When chromosomal DNA from an Hfr cell enters an F⁻ cell, homologous regions of the Hfr and F⁻ chromosomes may align, allowing segments of their DNA can be exchanged. This results in the production of a recombinant bacterium.

28. *What are R plasmids?*

Sometimes, mutation in a chromosomal gene of pathogenic bacteria can confer resistance. In other cases, bacteria have "resistance genes," which code for enzymes that specifically destroy or otherwise hinder the effectiveness of certain antibiotics. Such resistance genes are carried by plasmids known as R plasmids (R for resistance).