

Session 15 - Bacteria (formerly Monera) and simple protista**Objectives**

At the completion of this session, each student should be able to:

1. recognize typical bacteria and Protistans.
2. describe the structure and body organization of typical bacteria and Protistans.
3. describe and understand reproductive strategies typical of bacteria and Protistans.

Session 15 - Background information

Use this information plus the information in Chapters 21 and 22 in Starr and Taggart to answer the questions on the worksheets.

I. Kingdom Eubacteria**A. Cell Structure** (Figures 21.2, 21.4-8 in Starr and Taggart)

1. The structure of bacterial cells is prokaryotic, meaning that the DNA containing the cell's genetic information is in a nuclear area in the cytoplasm of the cell rather than in an organized nucleus separated from the cytoplasm by a nuclear membrane.
2. Ribosomes are scattered throughout the cytoplasm, but no other prominent granular or fibrous organelles are found in the cytoplasm.
3. The cytoplasm usually contains no membranous structures which are not extensions from the plasma membrane of the cell.

Heterotrophic bacteria frequently contain infoldings from the plasma membrane which are used in aerobic respiration. Cyanobacteria usually contain complex infoldings from the plasma membrane which contain chlorophyll and which trap light during photosynthesis.

4. Because of their small cell size and lack of large cytoplasmic structures, the contents of most bacterial cells appear smooth when viewed with a light microscope.
5. Cells of some parasitic bacteria lack cell walls, but most bacterial cells are surrounded by a peptidoglycan (protein + carbohydrate) cell wall located just outside of the plasma membrane (cell membrane) of the cell.

Since eukaryotic cells do not use peptidoglycans in their cell structures, many fungi (which are eukaryotes) reduce the number of bacteria competing with the fungi for dead organic matter by secreting molecules which interfere with bacterial cell wall formation or function. These molecules include some of the first successful antibiotics (such as penicillin) which were isolated and used in treating human diseases caused by bacteria.

6. Bacterial cells may also be surrounded by a gelatinous capsule located outside of the cell wall.

In bacteria in which the cells remain attached in colonies, the capsule commonly surrounds the entire colony as well as the individual cells.

The capsule is important in some bacterial diseases. In some cases, the capsule may protect parasitic bacteria from the immune system of the host. In other cases, the host immune system may over-react to capsule components and damage surrounding tissues.

B. Body Organization

Some bacteria are capable of forming multiple cell types.

1. Bacteria normally exist as vegetative cells, but many types of bacteria form spores in response to unfavorable conditions.

Spores typically have a more resistant cell wall than typical cells of the same species, and the metabolism in a spore is usually very slow so that its existing food resources are conserved until conditions improve. Some bacterial spores will survive boiling and freezing, so sterilization of hospital equipment requires harsh chemical treatment or exposure to steam under high pressure to ensure that all bacteria are killed.

2. Most vegetative cyanobacterial cells are photosynthetic, but many types of cyanobacteria form non-photosynthetic cells called heterocysts in response to starvation for usable nitrogen.

Heterocysts convert atmospheric nitrogen to a form the photosynthetic cells can use. The ability to form heterocysts allows cyanobacteria to grow rapidly in ecosystems which are polluted with some mineral nutrients (especially phosphate) but which are not enriched with nitrogen compounds.

C. Cell-environment Interactions

1. With the exception of bacteria which live in large colonies, most bacteria have relatively little control over their immediate environment and are heavily influenced by their environment due to their small size.
2. Many bacteria can move by flagella or by gliding movement, but due to their small size, their ability to migrate to a more favorable environment is quite limited.
3. The survival strategy of these organisms appears to primarily be one of altering their vegetative (active, growing cell) phenotype to match their environment, then switching to a spore (inactive, protected cell) phenotype if the environment becomes too extreme.

Genetic control systems of the operon type allow turning entire metabolic pathways on and off in response to surrounding conditions. Very small cells in which the DNA is in the cytoplasm allow mRNA to be used for protein synthesis very quickly after it is formed, further increasing the speed with which bacterial cells respond to changes.

D. Ecology

1. Ecological strategies of bacteria are quite variable, since they include all possible feeding modes except ingestion (the cell wall would get in the way).

In addition to autotrophic forms which use photosynthesis and heterotrophic forms which feed by absorption, bacteria also include autotrophic forms which use chemosynthesis (use chemical sources of energy to allow production of their organic materials).

2. Photosynthetic autotrophic bacteria (most of which are cyanobacteria) function as important producing organisms in aquatic and moist terrestrial ecosystems.

Since cyanobacteria have relatively high r_{\max} values, they frequently proliferate quickly to obnoxious population levels following addition of excess mineral nutrients (nutrient pollution) to fresh water ecosystems. In addition, some cyanobacteria are toxic to some consumers and are therefore not preyed upon as heavily as non-toxic producers.

3. Heterotrophic bacteria primarily function as decomposers of dead organic materials.

Heterotrophic bacteria are probably the most important decomposers of non-woody organic matter, especially when it occurs in small deposits. Fungi are usually more important than bacteria in decomposing woody organic matter.

4. Some bacteria don't wait until the "previous owner" of the organic material is dead. These forms are parasitic and may cause diseases, especially in host organisms to which they are not well adapted or whose immune systems cannot keep the growth of the bacteria in check.

Many long-term parasitic interactions between bacteria and host organisms appear to evolve toward mutualism, with our own intestinal bacteria probably being an example. These evolving interactions involve changes in both the bacteria and in the host. Initial use of a new host by bacteria favors bacterial phenotypes which rapidly spread from host to host and which reproduce as rapidly as possible. As the bacteria kill off the host population, bacterial phenotypes which kill their host will eventually become extinct due to lack of new hosts, while bacterial phenotypes which allow host survival or which benefit the host will allow the bacteria to use the existing hosts longer and will therefore be much more reproductively successful.

E. Reproduction

1. Bacteria and cyanobacteria usually reproduce asexually, and usually use binary fission (the prokaryotic version of mitosis).

During binary fission the cell replicates its genetic material, separates the replicates to opposite ends of the cell, and then pinches in half. Since the cellular structures which must be replicated are small and since many bacteria replicate their DNA continuously, the rate of binary fission can be very rapid (divisions every 20 minutes in some bacteria).

2. Under some conditions, some bacteria may use sexual-like processes such as conjugation, but most variation in bacteria appears to occur by mutation followed by natural selection. Conjugation, transfer of DNA between bacteria by viruses, or uptake of DNA from their environment by bacteria provide additional variations in phenotype and may be important in spreading genes for antibiotic resistance through bacterial populations.

II. Unicellular and Simple Colonial Protista (Kingdom Protista)

The following sections of this session will include unicellular and simple colonial green algae in the discussion of protistans even though green algae are classified with plants in some taxonomic schemes. My reason for doing this is that the structure and reproductive processes in simple green algae resemble those in protistans more than those in complex plants. In contrast, complex green algae, most brown algae, and most red algae resemble simple plants in many of their features.

A. Cell Structure (Figures 22.3 – 9, 22.11 – 12, 22.19 - 21 in Starr and Taggart)

1. Protistan cells are eukaryotic, meaning that the majority of the DNA (other than that in mitochondria and chloroplasts) is in an organized nucleus separated from the cytoplasm by a nuclear membrane.
2. The cytoplasm contains numerous membranous organelles.
 - a. All protistan cells contain mitochondria which do critical steps in aerobic (oxygen requiring) respiration.
 - b. Autotrophic protistan cells contain chloroplasts in which photosynthesis occurs.
 - c. Heterotrophic protistan cells which feed by ingesting food typically contain phagocytic vacuoles within which digestion of ingested food occurs.
3. Because of their relatively large size and membranous cytoplasmic organelles, the cytoplasm of protistan cells usually does not appear smooth when viewed with a light microscope.
4. Protistan cells may or may not have cell walls surrounding the plasma membrane.
 - a. Most heterotrophic protistans lack cell walls.
 - b. Most photosynthetic protistans (except euglenoids) have cell walls of some type.
5. Protistan cells may be immotile (nonmoving) or motile (capable of movement).
 - a. Diatoms, filamentous green algae, and some unicellular green algae are immotile.
 - b. Dinoflagellates, euglenoids, and some unicellular green algae move by flagella (Figures 22.3 - 5, 22.20 in Starr and Taggart).
 - c. Heterotrophic protistans are usually motile.

- (1) Amoeboid protistans move by extending and retracting cell processes called pseudopods (Figure 22.6 and 22.21 in Starr and Taggart).

These movements tend to be slow, and the pseudopods give the cell an irregular outline.

- (2) Flagellated protistans move using one or more flagella.

Most flagellated protistans are small single cells which move in a wiggling pattern. Attached colonies of flagellated protistans use their flagella to move water over the colony but the colony only swims if it becomes detached..

- (3) Ciliated protists move using hundreds of cilia (Figure 22.7 in Starr and Taggart).

Ciliated protists range from small to very large single cells. Unattached ciliated protists move relatively smoothly and can reverse direction and turn quickly. Attached individuals and colonies of ciliated protists use their cilia to trap food organisms.

- d. Some protists can change their motility mechanisms as they progress through different stages of their "life cycle". Pfiesteria has one of the most complex Protistan life "cycles" so far described. Flagellated stages closely resemble typical photosynthetic dinoflagellates, but encysted stages and amoeboid stages also occur (Figure 22.9 in Starr and Taggart).

B. Body Organization

Unicellular and filamentous protists usually have only one cell type in their body (1 cell = 1 body in unicellular forms), but some species can form additional cell types under some conditions.

1. Many simple protists can form environmentally resistant spores when exposed to unfavorable conditions.
2. Many non-motile colonial green algae form flagellated gametes (which closely resemble flagellated unicellular green algae) during sexual reproduction.

C. Cell-environment Interactions

Simple protistan cells are similar to bacterial cells in that they are too small to control their environment. Cell-environment interactions in protists are not as well understood as in monerans, but the strategies are probably similar and involve altering genetic control mechanisms to adopt the cellular phenotype to the environment. The environmental conditions which trigger transformation of Pfiesteria from non-toxic to toxic phenotypes and which control population levels of the organisms are poorly understood. A more complete understanding will be critical in controlling these organisms.

D. Ecology

1. Many protists (green algae, euglenoids, diatoms, dinoflagellates) function as photosynthetic autotrophs.

Protists are important producers in aquatic and marine ecosystems. Green algae are major microscopic producers in many fresh water ecosystems, and diatoms and/or dinoflagellates are major microscopic producers in many marine ecosystems. Some dinoflagellates like Pfiesteria have lost the ability to do photosynthesis and function as heterotrophic organisms.

2. Many protistans (amoebae, flagellates, ciliates) are ingestive heterotrophs.

These protistans serve as important microconsumers (especially of bacteria) in aquatic and marine ecosystems. Some heterotrophic protistans apparently had photosynthetic ancestors but now are heterotrophic. The active flagellated non-parasitic forms in the Pfiesteria life cycle closely resemble photosynthetic dinoflagellates but feed on bacteria and small algae. The non-parasitic amoeboid forms in the Pfiesteria life cycle resemble other amoeboid protistans and feed on bacteria and algae.

3. A few protistans are parasitic or mutualistic.

- a. A number of human and domestic animal diseases are caused by parasitic heterotrophic protistans. The relatively recently (1988) discovered Pfiesteria functions under some conditions as an ectoparasite which produces a toxin to immobilize fish, then digests parts of the body surface, producing characteristic deep lesions in the fish. Apparently if large populations of Pfiesteria are triggered to release toxins simultaneously, large-scale fish kills result and humans in excessive contact with water in those locations may develop skin lesions and memory loss.

- b. Both autotrophic and heterotrophic protistans are among the species that have become mutualistic.

- (1) Green algae are mutualistic in lichens and in some animals.

- (2) Protistans which can digest cellulose are mutualistic in the guts of termites and ruminant mammals.

E. Reproduction

1. Unicellular protistans usually reproduce asexually, in most cases by some type of mitotic division of the cell.

The mitotic process is frequently more complex than in cells of multicellular plants or animals as a result of the macronucleus needed to maintain the large cell volume in larger protistans.

2. Many protistans also practice sexual reproduction involving fertilization or conjugation.

In many protistans which have been studied under laboratory conditions, sexual processes are triggered by unfavorable conditions such as starvation or temperature stress (Figure 22.8 in Starr and Taggart).

3. Parasitic unicellular protistans typically have complex reproductive cycles involving asexual reproduction with or without sexual reproduction (Figure 22.11 in Starr and Taggart).

Session 15 - Worksheets

Group _____

1. Make the next observation on your algal growth experiment.
2. Observe the bacteria and protistans available in lab.
3. Identify each of the unknown specimens.

a. Kingdom = _____
Group = _____
Type of structure = _____

b. Kingdom = _____
Group = _____
Type of structure = _____

c. Kingdom = _____
Group = _____
Type of structure = _____

d. Kingdom = _____
Group = _____
Type of structure = _____

e. Kingdom = _____
Group = _____
Type of structure = _____

4. Describe the cell structure (as you can see it with your light microscope) that is typical of all the bacteria in lab.

8. How can bacteria (as seen with a light microscope) and protists (as seen with a light microscope) be distinguished?

9. How do heterotrophic protists (as seen with a light microscope) differ from photosynthetic protists (as seen with a light microscope)?

10. What would be the advantage to a protist in using asexual reproduction by mitotic division when conditions are favorable and switching to sexual reproduction (probably by conjugation) when conditions become less favorable?

11. Observe the displays on *Pfiesteria*. How does *Pfiesteria* resemble a "typical" photosynthetic dinoflagellate? How does *Pfiesteria* (at least in Burkholder's life cycle) resemble a "typical" heterotrophic protist? What characteristics of *Pfiesteria* are seen in other parasitic protists?

