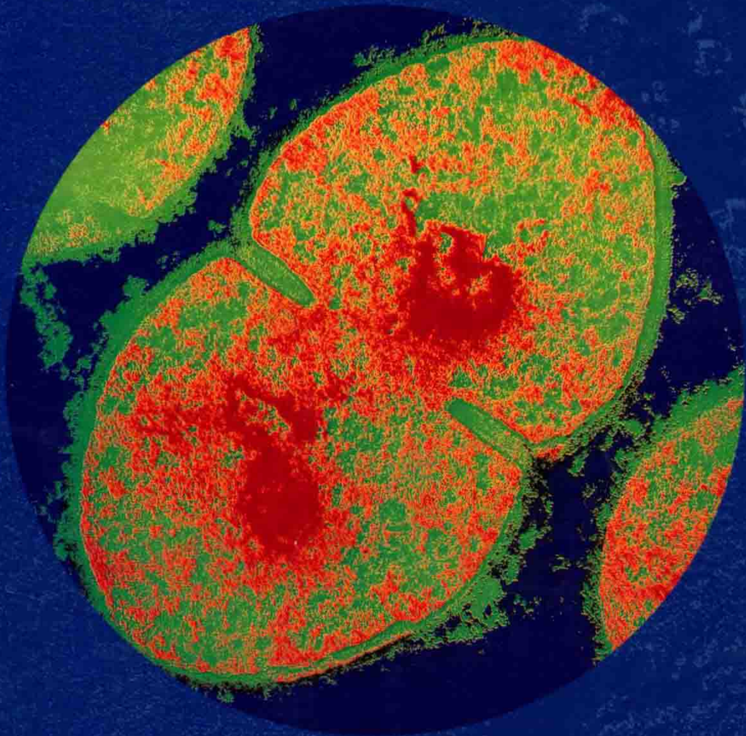
STUDY GUIDE FOR



MICROBIOLOGY

AN INTRODUCTION

SIXTH EDITION

TORTORA ▪ FUNKE ▪ CASE

BERDELL R. FUNKE

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AN INTRODUCTION

SIXTH EDITION

Tortora ■ Funke ■ Case

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North Dakota State University

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Preface

To the Student

Welcome to microbiology. As with any subject, you'll find some parts more interesting than others. But you will encounter few subjects in college that touch on daily living in so many ways. You'll find out things that are quite certain to interest you: how you become immune to diseases, how penicillin works, why oranges get moldy, and other "facts of life." On the other hand, now and then you may feel like the little girl thanking her aunt for a book on penguins. "Thank you very much," she wrote, "for the book on penguins. It told me a lot about penguins, even more than I wanted to know."

The Importance of Tutoring Yourself

I teach microbiology regularly to students required to take it for nursing, pharmacy, home economics, agriculture, civil engineering, and a number of other fields, including mortuary science. Not long ago, a mortuary science student attempted the course and failed miserably. In none of three exams did he reach a score of 50%. At the end of the following term he told me, woefully, that he had just repeated the course and had missed a grade of C by two points. To transfer the credit to the school of mortuary science he needed at least a C.

It happens that our school has a policy of providing tutors for those who need them. I turned his case over to a bacteriology graduate student who tutored in his spare time. On the first exam this formerly hapless undergraduate scored a 92 . . . and never looked back. Had three terms of exposure to my lectures finally enlightened him? Probably not; the tutor reported that in preparing for the first exam, the student denied having ever heard of the procaryotic cell.

What, then, made the difference? The tutor did, of course. But a tutor can't really put anything into your head that you can't put there all by yourself. What a tutor does is force you to think about the material instead of just staring at it. The tutor exposes your areas of ignorance, but instead of letting it go at that, forces you to pave over these areas with information.

You can do the same thing the tutor does—tutor yourself. The suggestions that follow and the use of this study guide will help you.

Lectures and Note Taking

Instructors vary in their approaches to microbiology courses. Some give lectures that largely paraphrase the text, and exams are based mainly on the text. Others scarcely use the book at all in their lectures and base the exams solely on the lectures; successful students must be careful note takers. (I have even heard of some cases in which there seems to be no apparent relationship between the information available to the student and the exams. These cases, of course, can only be left to the chaplain.)

It is important to take notes in an organized fashion such as this:

Staining of Bacteria
  Gram Stain
    Insert all material about Gram staining.
    Take down all terms likely to be associated with Gram staining.

  Acid-Fast Stain
    Insert all material about the acid-fast stain.
    Take down all terms likely to be associated with acid-fast staining.

If you look back at notes like this, you can see that you were hearing about the staining of bacteria and that there were basically two types of bacterial stains discussed. Note that you also clearly kept the information about the Gram stain separate from information about the acid-fast stain. Never let your notes run together so that one topic merges with another. On objective tests this failure to separate discussions can be fatal. Make sure you have definitions straight. Never leave your notes or your mind a blank on something as obvious as the definition of a term.

Studying

I always invite students with grade problems in the course to come see me. I ask them to bring their notes and a copy of the offending exam, corrected from a key. Very often certain patterns show up. One is that the notes have no "study marks"; that is, no underlining or circling. Another is that the student often misses a cluster of questions pertaining to one group of topics—for example, the characteristics of different antibiotics. In other words, the student has encountered a list of antibiotics and failed to differentiate one from another. This is why it is important to organize information by general headings and a system of indentation as I have described. I also notice occasionally that a term, such as the word *autotroph,* stands alone in the notes without definition or explanation. Surely the student could have filled in such an omission by consulting the book or the instructor. In my presentation of the material I am not trying to keep things secret, nor, presumably, is your instructor.

My recommendations are these: First, *organize your notes* so that it is obvious where a discussion of a topic, such as the disease diphtheria, starts, and where it ends. The most obvious way of doing this is to underline the main topic and inset all the information about that topic. (If you have trouble writing rapidly enough, or you have trouble with English as a language, ask the instructor if you can record the lectures.)

Second, *never confuse staring at a page with studying a page.* As you read, do your eyes ever travel down half a page while your mind fails to take in a single word written on it? A person has a limited capability for concentration, and by staying up all night before an exam, he or she is likely to exceed it. Do your studying in short bursts within the limits of your full attention span; start early. In order to ensure concentration, go through the notes or the text with a pencil or highlighting marker. Look deliberately at the material, and try to think like the person who goes through it to create an exam. You will find that your mind and the instructor's mind will often travel the same path. If the topic is penicillin, for example, mark the important facts: that it is produced by a mold, that its mode of action affects cell wall synthesis, that it has a β-lactam ring in its structure, that it affects mainly gram-positive bacteria, and so on. When you have done this, you have actually *thought* about the material instead of just staring at it. This method will also teach you how to take notes. You'll begin to recognize material that is likely to be on an exam and get it down, leaving to casual memory the instructor's anecdote about his memories of childhood chickenpox.

Study Guide Contents

This study guide provides a chapter-by-chapter summary that contains the important terms and concepts likely to be on examinations. This chapter summary is usually organized by the headings used in the text. Important terms are printed in boldface and defined, and important figures and tables from the text are included. Following each chapter synopsis is a sample exam, which is an extensive self-testing section containing matching questions, fill-in-the-blanks, critical thinking and label the art questions. An answer key is provided. (You may wish to supplement these questions with the Study Questions at the end of each chapter in the textbook.) Obviously, not all questions can be anticipated, and a good instructor will usually introduce material other than that found in the text. But going through these sample exams will work as a self-tutoring device to direct attention to any areas of ignorance.

If you are going to improve your time in running the mile or the amount of weights you can lift, you must do more than read a book on techniques. You must apply them to build up your endurance or your muscles. The same applies to study habits. A guide cannot do your work for you; it can only serve as a tutor. You must do the work yourself.

Credits

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Contents

CHAPTER 1

The Microbial World and You

Learning Objectives

After completing this chapter, you should be able to:

- Describe several ways in which microbes affect our lives.
- Explain the importance of observations made by Hooke and van Leeuwenhoek.
- Compare the theories of spontaneous generation and biogenesis.
- Identify the contributions to microbiology made by Needham, Spallanzani, Virchow, and Pasteur.
- Describe the importance of Koch's postulates.
- Describe how Pasteur's work influenced Lister and Koch.
- Identify the contributions to microbiology made by Ehrlich, Fleming, and Dubos.
- Define immunology, virology, and microbial genetics.
- Recognize the system of scientific nomenclature that uses genus and specific epithet names.
- List the five kingdoms of living organisms and the major members of each kingdom.
- Differentiate among the major groups of organisms studied in microbiology.
- List at least four beneficial activities of microorganisms.
- List two examples of biotechnology that use genetic engineering and two examples that do not.
- Define normal microbiota.

Microbes in Our Lives

Microbes include bacteria, fungi (yeasts and molds), protozoa, viruses, and the microscopic forms of algae. Most of these microorganisms are not harmful and indeed play a vital role in maintaining our global environment. Only a minority are **pathogenic** (disease producing). They are part of the food chain in oceans, lakes, and rivers; they break down wastes, incorporate nitrogen gas from the air into organic compounds, and participate in photosynthesis, which generates food and oxygen.

A Brief History of Microbiology

The First Observations

Anton van Leeuwenhoek was the first to report on the observation of microorganisms seen with magnifying lenses, beginning in 1674. He made detailed drawings of "animalcules" that have since been identified as representing bacteria and protozoa. About this time, **Robert Hooke** observed with a microscope the pores in slices of plants. He called them "cells." His discovery, reported in 1665, marked the beginning of the **cell theory**—that all living things are composed of cells.

The Debate over Spontaneous Generation

Until the second half of the nineteenth century, it was generally believed that life could arise spontaneously from nonliving matter, a process known as **spontaneous generation.** An early opponent of spontaneous generation. An early opponent of spontaneous generation, **Francesco Redi,** demonstrated in 1668 that maggots, the larvae of flies, do not arise spontaneously from decaying meat. He filled three jars with decaying meat and sealed them; three similar jars were left open. Maggots appeared only in the open vessels, which flies had entered. In subsequent experiments, in which he covered the first three jars with gauze rather than sealing their tops, the results were the same. These experiments demonstrated that access to air was not a factor.

Many, however, still believed that the simpler organisms observed by Leeuwenhoek might undergo spontaneous generation. In 1745, **John Needham** found that heated nutrient fluids poured into covered flasks were soon teeming with microorganisms. He took this as evidence of spontaneous generation. Twenty years later, **Lazzaro Spallanzani** showed that Needham's microorganisms had entered the fluid after boiling. Heating such fluids in a sealed flask, he showed, prevented the growth Needham had observed. Objections still remained; Needham felt that the heating had destroyed some vital force necessary for spontaneous generation. The concept of **biogenesis,** that living cells can arise only from other living cells, was introduced in 1858 by **Rudolf Virchow.**

In 1861, **Louis Pasteur** designed the experiments that finally ended the debate about spontaneous generation. He showed that flasks left open to the air after boiling would soon be contaminated, but if they were sealed, they remained free of microorganisms. He also used flasks whose long necks he bent into S-shaped curves. Air, with its presumed vital force, could enter these flasks, but airborne microorganisms were trapped in the tubes. The flask contents remained sterile. Pasteur showed that microorganisms are present throughout the environment and that they can be destroyed. He also devised methods of blocking the access of airborne microorganisms to nutrient environments; these methods were the basis of **aseptic** (germ-free) **techniques,** which are among the first things that a beginning microbiologist learns.

Fermentation and Pasteurization

At this time Pasteur was asked to investigate the problem of spoilage of beer and wine. Pasteur showed that, contrary to the belief that air acted on the sugars to convert them to alcohol, microorganisms called yeasts were responsible—and in the absence of air. This process is called **fermentation** and is used in making wine or beer. Spoilage occurs later when bacteria, in the presence of air, change the alcoholic beverage into acetic acid (vinegar). Pasteur prevented spoilage by heating the wine or beer just enough to kill such bacteria, a process that came to be known as **pasteurization.**

The Germ Theory of Disease

This association of yeasts with fermentation was the first concept to link a microorganism's activity to physical and chemical changes in organic materials. It suggested the possibility that microorganisms might be able to cause diseases as well—the **germ theory of disease.** In 1835, **Agostino Bassi** made the first association between a microorganism and a disease by proving that a silkworm disease was caused by a fungus. In 1865, Pasteur found that another silkworm disease was caused by a protozoan. Also in the 1860s, **Joseph Lister** applied the germ theory to medicine. He used carbolic acid (phenol) on surgical dressings and wounds, and greatly reduced the numbers of infections and deaths. In the 1840s, **Ignaz Semmelweiz** demonstrated that chemically disinfecting the hands of physicians minimized infections of obstetrical patients. In 1876, **Robert Koch** demonstrated that rod-shaped bacteria in the blood of cattle that had died of anthrax were the cause of death. He showed that these bacteria could be isolated and grown in pure culture, be injected into healthy animals, and cause their death by anthrax. The same bacteria could then be isolated from the dead animals. This demonstration, which proved that a specific microbe is the cause of a specific disease, followed a set of criteria known today as **Koch's postulates.**

Vaccination

In 1798, **Edward Jenner** showed that the mild disease cowpox gave immunity to smallpox. He inoculated people with cowpox material by scratching their arm with a cowpox-infected needle. This process became known as **vaccination** (*vacca* is the Latin word for cow). The protection from disease provided by vaccination is called **immunity.** Years later, around 1880, Pasteur showed why vaccinations work. He found that the bacterium for fowl cholera lost its **virulence** (ability to cause disease) after it was grown for long periods in the laboratory. However, he showed that the weakened bacteria still retained their ability to induce immunity. Apparently the cowpox virus is related closely enough to smallpox to induce effective immunity.

The Birth of Modern Chemotherapy: Dreams of a "Magic Bullet"

The treatment of disease by chemical substances is called **chemotherapy.** When prepared from chemicals in the laboratory, these substances are called **synthetic drugs,** and when produced naturally by bacteria and fungi they are called **antibiotics. Paul Ehrlich** speculated about a "magic bullet" that would destroy a pathogen without harming the infected host. In 1910, he found *salvarsan,* an arsenic derivative, that was effective against syphilis. *Quinine,* an extract of South American tree bark, had until then been the only other such chemical available. Spanish conquistadors used it to treat malaria. In the late 1930s, a survey of dye derivatives uncovered the important group of antibacterial *sulfa drugs.* The first antibiotic was discovered by **Alexander Fleming,** who observed the inhibition of bacterial growth by the mold *Penicillium notatum* and the inhibitor penicillin. Penicillin was mass-produced and clinically tested in the 1940s. Since then, many antibiotics have been discovered.

Modern Developments in Microbiology

Bacteriology is the study of bacteria. **Mycology** is the study of fungi. **Parasitology** is the study of protozoa and parasitic worms.

Immunology, the study of immunity, has expanded rapidly in the twentieth century. Smallpox has been eliminated, and many new vaccines have become available. A major challenge will be to defeat the AIDS virus, which attacks the immune system. In 1933, **Rebecca Lancefield** proposed an immunologically based classification system for streptococci bacteria, classifying them as serotypes (variants within a species).

Virology, the study of viruses, really began in 1892 when **Dmitri Iwanowski** demonstrated that tobacco plant pathogens would pass through filters too fine for known bacteria. Much later, **Wendell Stanley** showed that the organism, called the tobacco mosaic virus, was so simple and homogeneous it could be crystallized.

Recombinant DNA Technology

Recombinant DNA technology had its origin in **microbial genetics** (how microbes inherit traits) and **molecular biology** (how genetic information is carried in DNA, which is then used to direct synthesis of proteins). Because of their simplicity and rapid reproduction rate, bacteria are the preferred organisms in this field. Beginning in the early 1940s, **George W. Beadle** and **Edward L. Tatum** demonstrated the relationship between genes and enzymes. DNA was established as the hereditary material by **Oswald Avery, Colin MacLeod,** and **Maclyn McCarty. Joshua Lederberg** and **Edward L. Tatum** discovered bacterial genetic transfer by conjugation. In 1958, **James Watson**

and **Francis Crick** proposed the structure of DNA. In the 1960s, **François Jacob** and **Jacques Monod** discovered messenger RNA, important in protein synthesis, and later made major discoveries about the regulation of gene function in bacteria. **Paul Berg** showed that fragments of animal DNA—genes—could be attached to bacterial DNA, the first examples of **recombinant DNA.** These genetically altered bacteria can be used to make large quantities of a desired protein.

Naming and Classifying Microorganisms

The system of naming **(nomenclature)** we now use was established by **Carolus Linnaeus.** Scientific nomenclature assigns each organism two names. The **genus,** the first name, is always capitalized, and the **specific epithet (species),** which follows, is not capitalized. The scientific names of organisms are always either underlined or italicized. At first, organisms were grouped into either the animal kingdom or the plant kingdom. In 1978, **Carl Woese** devised a system of classification based on the cellular organization of organisms, grouping them as follows: *Eubacteria* (bacteria with peptidoglycan in cell walls), *Archaea* (bacteria without peptidoglycan), and *Eucarya* (which include protozoa, yeasts, molds, algae, plants, insects and animals). A detailed discussion of classification will be presented in Chapters 10 through 13.

The Diversity of Microorganisms

Bacteria

Bacteria are simple, one-celled organisms whose genetic material is not enclosed in a special nuclear membrane. For this reason, bacteria are called **procaryotes** (prenucleus). Bacterial cells generally have one of three shapes: **bacillus** (rodlike), **coccus** (spherical or ovoid), and **spiral** (curved or corkscrew). Individual bacteria may form pairs, chains, or other groupings, which are usually the same within a species. Bacteria are enclosed in cell walls largely made of peptidoglycan (cellulose is the main substance of plant cell walls). Bacteria generally reproduce by **binary fission** into two equal daughter cells. Many move by appendages called flagella, and although most use organic material for nutrition, some use inorganic substances or carry out photosynthesis.

Fungi

Fungi are **eucaryotes;** they contain DNA within a distinct nucleus surrounded by a nuclear membrane. They may be unicellular or multicellular. Their cell walls are composed primarily of *chitin.* **Yeasts** are unicellular nonfilamentous fungi larger than bacteria. **Molds** form *mycelia* of long filaments (*hyphae*).

Protozoa

Protozoa are unicellular, eucaryotic microbes, members of the kingdom Protista. They are classified by their means of locomotion, such as *pseudopods, cilia,* or *flagella.*

Algae

Algae are photosynthetic eucaryotes, mostly of the kingdom Protista, and are usually unicellular. They need light and air for growth.

Viruses

Viruses are very small and are not cellular. They have a core of either DNA or RNA, surrounded by a protein coat. They may have a lipid envelope layer as well. They reproduce only inside the cells of a host organism.

Multicellular Animal Parasites

Flatworms and **roundworms,** collectively called **helminths,** are not strictly microorganisms. A part of their life cycles involves microscopic forms, however, and identifying them requires many of the techniques used in identifying traditional microorganisms.

Microbes and Human Welfare

Recycling Vital Elements

Microbes recycle vital elements such as nitrogen, carbon, oxygen, sulfur, and phosphorus. *Cyanobacteria* (called blue-green algae) and certain soil bacteria may use atmospheric nitrogen directly (*nitrogen fixation*). The nitrogen fixed from the air is incorporated into living organisms and eventually returned as gaseous nitrogen, making up the **nitrogen cycle. Martinus Beijerinck** and **Sergei Winogradsky** first showed how bacteria helped recycle vital elements. In the **carbon cycle,** carbon dioxide is removed from the air by plants and algae, which convert it to food. In the **oxygen cycle,** oxygen is recycled to the air during photosynthesis. Microbes are used in treatment of sewage. Microbes are useful in treating oil spills, toxic waste sites, and so on, a process called **bioremediation.** Bacteria such as *Bacillus thuringiensis* are used in control of insect pests.

Modern Biotechnology and Genetic Engineering

Practical applications of microbiology are called **biotechnology.** The use of recombinant DNA technology has led to the advent of **genetic engineering,** which now produces insulin, interferon, clotting substances, vaccines, and other substances. Eventually it may become common to replace missing or defective genes in human cells, a process called **gene therapy.** Agricultural applications, including drought resistance and resistance to insects and microbial diseases, may also result from genetic engineering.

Microbes and Human Disease

The relationship between microbes and disease will remain of great interest to us all. Indeed, we are seeing many emerging infectious diseases such as bovine spongiform encephalopathy (mad cow disease), outbreaks of *E. coli* 0157.H7 infections, Ebola hemorrahgic fever, Hantavirus, and, of course, AIDS. The study of the body's resistance to microbial infection and disease is a continuing part of microbiological research.

Self-Tests

In the matching section, there is only one answer to each question; however, the lettered options (a, b, c, etc.) may be used more than once or not at all.

I. Matching

1. In 1668, demonstrated that maggots appeared only in decaying meat that had been exposed to flies.
2. Introduced the concept that living cells arise from other living cells.
3. Introduced the technique of vaccination for smallpox.
4. First to use the microscope to observe "cells."
5. Made an association between silkworm disease and a fungus.
6. A surgeon who used carbolic acid to control wound infections.
7. First to speculate about the possibility of a "magic bullet" that would destroy a pathogen without harming the host.
8. Discovered penicillin.
9. Using anthrax as a model, demonstrated that a specific microorganism is the cause of a specific disease.
10. Originated our system of scientific nomenclature.

a. Anton van Leeuwenhoek
b. John Needham
c. Lazzaro Spallanzani
d. Louis Pasteur
e. Francesco Redi
f. Agostino Bassi
g. Joseph Lister
h. Robert Koch
i. Paul Ehrlich
j. Alexander Fleming
k. Edward Jenner
l. Carolus Linnaeus
m. Robert Hooke
n. Rudolph Virchow

II. Matching

1. Assigned a microbial cause to fermentation.
2. First to crystallize a virus.
3. Showed that mild heating of spirits kills spoilage bacteria without damage to the beverage.
4. Developed a classification system that groups organisms by their cellular organization.
5. Devised a classification system for the streptococci based on an immunological system of serotypes.
6. Demonstrated that infections in obstetrical wards could be minimized by disinfecting the hands of physicians.
7. Participated in determining the structure of DNA.
8. First demonstrated that genetic information could be exchanged between bacteria by conjugation.

a. Louis Pasteur
b. Wendell Stanley
c. Carl Woese
d. Francis Crick
e. Paul Berg
f. Ignaz Semmelweiz
g. Rebecca Lancefield
h. George Beadle
i. Joshua Lederberg

III. Matching

1. Grouped as Procaryotae, or Monera.
2. Noncellular; reproduce only inside cells of host organism.
3. Helminths.
4. Yeasts.
5. Procaryotes.
6. Unicellular, eucaryotic microorganisms; members of kingdom Protista.

a. Protozoa
b. Elephants
c. Fungi
d. Bacteria
e. Viruses
f. Multicellular animal parasites

IV. Matching

1. Protection from a disease that is provided by vaccination.
2. The treatment of a disease with chemical substances.
3. The use of microbes to clean up, for example, an oil spill.
4. The process by which yeasts change sugars into alcohol.
5. Techniques that keep areas free of unwanted microorganisms.

a. Bioremediation
b. Chemotherapy
c. Fermentation
d. Aseptic
e. Immunity

V. Matching

1. Also called blue-green algae; may fix nitrogen from air.
2. Photosynthetic eucaryotes.
3. Eucaryotes classified primarily by their means of locomotion.
4. General name for a rod-shaped bacteria.
5. General name for a sperical bacterium.

a. Cyanobacteria
b. Coccus
c. Bacillus
d. Protozoa
e. Algae

VI. Fill-in-the-Blanks

1. Bacteria generally reproduce by a process called ________________ into two equal daughter cells.
2. The set of criteria that prove that a specific microorganism is the cause of a specific disease is known today as ________________.
3. The concept that living cells can arise only from other living cells is called ________________.
4. One objection that proponents of spontaneous generation made to experiments in which nutrient fluids were heated in sealed containers was that heating destroyed some ________________ in the air.
5. According to the rules applied to the scientific naming of a biological organism, the ________________ name is always capitalized.
6. Paul Ehrlich discovered an arsenic derivative, ________________, that was effective against syphilis.
7. Antimicrobial chemicals produced naturally by bacteria and fungi are called ________________.

VII. Critical Thinking

1. Discuss some contributions microorganisms make that help maintain a balanced environment.

2. What are the advantages of using microorganisms to control insect pests?

3. Discuss three ways that microorganisms have been harnessed to improve the environment.

4. Although penicillin was first discovered in 1928, it wasn't clinically tested until the 1940s. What kinds of issues and problems must have been addressed before making penicillin available for treatment of infectious diseases?

5. Discuss the similarities and differences between the syphilis epidemic of the 1940s and the current AIDS epidemic.

6. List three characteristics unique to procaryotes.