**Chapter 1**

**Introduction to Microbes and Their Building Blocks**

Microorganisms are defined as “living organisms too small to be seen with the naked eye.” Members of this huge group of organisms are bacteria and archaea (prokaryotes), algae, protozoa, fungi, parasitic worms (helminths) (eukaryotes), and viruses. Microorganisms live nearly everywhere and influence many biological and physical activities on earth. There are many kinds of relationships between microorganisms and humans; most are beneficial, but some are harmful. Microbes are crucial to the cycling of nutrients and energy necessary for all life on earth.

Humans have learned how to manipulate microbes to do important work for them in industry, medicine, and in caring for the environment. In the past 120 years, microbiologists have identified the causative agents for many infectious diseases. They have discovered distinct connections between microorganisms and diseases whose causes were previously unknown. The microscope made it possible to view microorganisms and, thus, to identify their widespread presence, particularly as agents of disease. Medical microbiologists developed the germ theory of disease and introduced the critically important concept of aseptic technique to control the spread of disease agents. Our current understanding of microbiology is the cumulative work of thousands of microbiologists, many of whom literally gave their lives to advance knowledge in this field.

Excluding the viruses, there are two types of microorganisms: prokaryotes, which are small and lack a nucleus and organelles; and eukaryotes, which are larger and have both a nucleus and organelles. Viruses are not cellular and are, therefore, sometimes called particles rather than organisms. They are included in microbiology because of their small size and close relationship with cells.

Macromolecules are very large organic molecules (polymers) usually built up by polymerization of smaller molecular subunits (monomers). Carbohydrates are biological molecules whose polymers are monomers linked together by glycosidic bonds. Their main functions are protection and support (in organisms with cell walls), and also nutrient and energy stores. Lipids are biological molecules, such as fats, that are insoluble in water. Their main functions are as cell components, and nutrient and energy stores.

Proteins are biological molecules whose polymers are chains of amino acid monomers linked together by peptide bonds. Proteins are called the “shapers of life” because of the many biological roles they play in cell structure and cell metabolism. Protein structure determines protein function. Structure and shape are dictated by amino acid composition and by the pH and temperature of the protein’s immediate environment. Nucleic acids are biological molecules whose polymers are chains of nucleotide monomers linked together by phosphate–pentose sugar covalent bonds. Double-stranded nucleic acids are linked together by hydrogen bonds. Nucleic acids are information molecules that direct cell metabolism and reproduction. Nucleotides such as ATP also serve as energy-transfer molecules in cells. As the atom is the fundamental unit of matter, so is the cell the fundamental unit of life.

The taxonomic system has three primary functions: naming, classifying, and identifying species. The major groups in the most advanced taxonomic system are (in descending order): domain, kingdom, phylum or division, class, order, family, genus, and species.

**Digital Tool Suggestions for Chapter 1**

1. Prior to starting class, assigning LearnSmart® Prep Microbiology is an excellent way to help students get started in the course. This can be assigned to be as time intensive as desired. There are two ways to assign Prep:
   1. Adaptive Study Plan:
      1. This version of Prep creates and individualized study plan for students that they can use to help with time management during the term.
      2. The adaptive study plan can be used to integrate metacognitive and growth mindset activities into the course by having students review their results and reflect on where they are starting from at the beginning of the term.
   2. Customized Study Plan:
      1. This plan allows the instructor to provide a guided study plan for students.
2. Assigning the SmartBook®/LearnSmart® activity prior to class will help ensure that students are familiar with the content prior to beginning the chapter. In general, setting the amount of the time for these assignments should be dictated by the amount of out of class work expected for the course. Approximately 20–30 minutes seems to work well for students when balanced with other assignments.
   1. If used before class, it is suggested to assign a due date with enough time for instructor review of the reports prior to class so the lecture can target the material students are struggling with the most.
   2. In addition, to reinforce moving material from short-to-long-term memory, have students complete the recharge activity regularly prior to the exam to help them solidify learning.
3. The question bank can be used for a variety of activities as it has a number of different types of questions that vary across Bloom’s levels.
   1. Case Studies:
      1. These are excellent questions and are an easy way to engage students at upper Bloom’s levels.
      2. Each chapter has at least one case study set with about 3–4 questions in each set. Each question typically has multiple sub-questions and typically there is at least one manual grading question in the set.
         1. The entire set can be assigned or a subset of the questions can be assigned.
      3. These case studies can be included in other assessments or used as a stand-alone activity.
      4. If you will be using these in a lock-down timed assessment, do not use the research question as these questions can require students to access outside research materials.
   2. Quizzes:
      1. Depending on the focus of the quiz, this question bank can be a useful way to reinforce concepts such as image labeling etc. However, if quizzes are intended to prepare students for the format and question style of an exam using solely the test bank, the test bank may be a better source for quiz questions.
   3. Technology-Enhanced Active Learning:
      1. This is an excellent use of the question bank and can replace worksheets within the course. By creating a question series, groups can work through the question set in class.
   4. NCLEX® practice questions:
      1. If your course is primarily used to prepare nursing students, the NCLEX® questions in the question bank can be used to prepare students for the test bank NCLEX® questions as well as nursing school and NCLEX® exams.
      2. Many times, nursing students enjoy having these questions as it helps them connect the course material to their professional goals.
4. The test bank questions can be utilized for a variety of assessments. The bank consists of multiple choice or true/false questions allowing for an automatic grading of the assessment. Custom questions (of any type) can be added to the assessment.

**Pre-Class Ideas for Chapter 1**

*Below are suggested activities to assign before covering the material of Chapter 1 in class. The activities are designed to provide opportunities for students to engage with the topics prior to class. Some activities also have students preparing materials that will enable students to teach one another in class.*

1. Students complete a written reflection on what they know about microbiology and how their lives and academic careers have intersected with microbiology.
2. Students review the definition of “microbiology” prior to class and create a worksheet that introduces the different forms of microorganisms. Students exchange and complete worksheets in class.
3. Students create a list of diseases they believe are caused by microorganisms and the type of microorganism that causes the disease (bacteria, virus, etc.). Student then compare this list with the information described in Section 1.1, “Microbes Harming Humans,” and list any new observations.
4. Students, in groups or as individuals, are assigned a section/subsection of the text and create a short presentation for their peers in class. If utilizing groups, a jigsaw could be performed where the original groups disperse to form new groups with a representative from each of the old groups. These members are now the topic expert and present to the class.
5. Students define theory, hypothesis, observation and law and identify examples of each. In class students compare examples and discuss. Using this homework, a class discussion about the theory of evolution can be discussed.
6. Using Section 1.2, “Microbes in History,” as a guide, each student selects a scientific contribution in the field of medical microbiology and reports to the class a current example of how this contribution continues to affect patient care.
7. Students are required to research protocols in medicine during the 1800s and a list is created based on each student’s findings.
8. Students can recreate the swan-neck flask experiment at home and record observations. They can then present their experiment to their classmates.
9. Prior to class, students create a list of characteristics that define a “cell.” Then in class, have students identify characteristics of prokaryotic and eukaryotic cells to determine if the definition fits.
10. Assign each student one of the major biochemical groups to research with a focus on the monomer, basic structure, and role of the macromolecule in life. Students create a picture or model to present to the class.
11. Provide students a list of some microorganism names: *Escherichia coli*, *Staphylococcus aureus*, and so on. Ask student to find meanings behind the names.
12. Have students write their name as a scientific name.

**Activities Associated with Learning Objectives for Chapter 1**

***Section 1.1 Student Learning Objectives—Microbes: Tiny but Mighty***

1. *List the various types of microorganisms that can colonize humans.*
2. *Describe the role and impact of microbes on the earth.*
3. *Explain the theory of evolution and why it is called a theory.*
4. *Explain the ways that human manipulate organisms for their own personal uses.*
5. *Summarize the relative burden of human diseases caused by microbes.*
6. *Differentiate among bacteria, archaea, and eukaryotic microorganisms.*
7. *Identify an acellular infectious agent that is studied in microbiology.*
8. *Compare and contrast the relative sizes of the different microbes.*

**Lecture Suggestions and Guidelines for Section 1.1**

1. Introduce students to the study of microbiology and how this particular course will focus on a specific area of microbiology—primarily infectious diseases.
2. Identify how microbes have shaped the planet we know.
3. Emphasize that microbes have both beneficial and harmful effects in relation to humans.
4. Introduce the idea that some diseases, such as stomach ulcers, may have a microbial component. (Optional, expand into latest research of how microbiome may cause diseases previously thought to not involve microorganisms.)
5. Emphasize the different forms of microorganisms, and perhaps begin to introduce the idea of how this is related to treatment of different infectious diseases.
6. Help students understand the relationship between bacteria, archaea, and eukaryotes.

**In-Class Activities for Section 1.1**

1. Recreate figure 1.1 adding notes about the distinction in the branches from research.
2. Create a drawing comparing the size of various microorganisms.
3. Define theory and explain what the theory of evolution states.
4. Create a “Pro/Con” chart elucidating the positive and negative effects of microbes on human life.
5. Create a discussion board listing the products that would no longer be available to humans if microorganisms became extinct.
6. Compare and contrast similarities and differences between microorganisms. Which microorganisms are most closely related to human cells?
7. Have students discuss why viruses are referred to as “particles” rather than as “organisms.”
8. Create a chart listing tissues of the body and some ideas relating to the microbiota of the tissues.
9. Summarize the focus of the course and identify the key classes of organisms that will be discussed.
10. Make a quick list of microbes that can colonize humans.

**Additional Research Issues for Section 1.1**

1. Research how genetic recombination is currently affecting human lives.
2. Research emerging infectious diseases.
3. Research diseases that emerging data indicates may be causes or influenced by microbiomes.
4. Research other scientific theories and compare these theories to the theory of evolution.

**Critical Thinking Issues for Section 1.1**

1. How do microbes use humans and how do humans use microbes? Who has the advantage?
2. Many people have a fear of microorganisms or “germs.” Why do you think this is a realistic fear? Why do you think such a fear may be unrealistic?

***Section 1.2 Student Learning Objectives—Microbes in History***

1. *Make a time line of the development of microbiology from the 1600s to today.*
2. *List some recent microbiology discoveries of great impact.*
3. *Identify the important features of the scientific method.*

**Lecture Suggestions and Guidelines for Section 1.2**

1. Relate to students how prior findings in microbiology are still being applied today.
2. Demonstrate how new findings in microbiology are changing our current understanding of microbes and disease.
3. Provide examples of the scientific method and discuss how the process of science works in today’s scientific community.

**In-Class Activities for Section 1.2**

1. Create a time line showing the major scientists and discoveries in microbiology. Mark those discoveries that are still being applied today.
2. Given a scenario of a patient walking into an Emergency Department with a suspected infectious disease, list some procedures and protocols used in relation to the patient that are based on discoveries made during the Golden Age of Microbiology.
3. Select a discovery and present an argument for why this discovery is more important than the others outlined in the chapter.
4. Practice developing a hypothesis and design an experiment to test the hypothesis.

**Additional Research Issues for Section 1.2**

1. Research biofilms and present a case underlining how their formation may be impacting the treatment of diseases.
2. Provide information on the basic format of the Human Microbiome Project.

**Critical Thinking Issues for Section 1.2**

1. How may our understanding of diseases that are “caused” by infectious agents be changing?
2. How may our understanding of biofilms affect protocols and procedures in a health care setting?

***Section 1.3 Student Learning Objectives—Macromolecules: Superstructures of Life***

1. *Name the four main families of biochemicals.*
2. *Provide examples of cell components made from each of the families of biochemicals.*
3. *Differentiate among primary, secondary, tertiary, and quaternary levels of protein structure.*
4. *List the three components of nucleotide.*
5. *Name the nitrogen bases of DNA and RNA.*
6. *List the three components of ATP.*
7. *Recall three characteristics common to all cells.*

**Lecture Suggestions and Guidelines for Section 1.3**

1. Students will need a strong understanding of the basic biochemical groups. Student understanding of these concepts will likely be helped if connections to the microbial world can be made—i.e., how is denaturing proteins relevant to microbial control? Or how is the genetic code used in biotechnology?
2. Review the four main families of biochemicals and connect these to everyday life and microbial life.
3. Introduce the concept of the structure and function relationship and explain how this relationship is a key to biology.
4. Discuss carbohydrate structure and function.
5. Discuss lipid structure and function.
6. Discuss protein structure, levels of folding and function.
7. Discuss nucleic acid structure and function.

**In-Class Activities for Section 1.3**

1. Create a chart comparing the four main biochemicals in the body. List the monomers for each, their roles in the body, and one molecular example.
2. Using various materials, such as toothpicks and Styrofoam balls, create a macromolecular structure.
3. Using a large diagram of a cell, have students indicate where they may find examples of each of the four main biochemicals within a cell.
4. Have students develop a way to demonstrate protein denaturing in the laboratory setting.
5. Create a scenario in which one of four main biochemicals is unavailable to a cell. Ask students to explain how the cell would or would not be able to function.

**Additional Research Issues for Section 1.3**

1. The four main biochemicals are critical for life function. If these structures are damaged, a cell may be unable to survive. How may we apply this understanding in the development of antimicrobial agents?
2. The genetic code is consistent across organisms, including microorganisms. How has this consistency aided humans in their work with microbes (i.e., technologies using microbes) and how has this consistency between organisms been detrimental to humans (i.e., certain medications that affect the processing of this code)?
3. Sickle cell anemia is a classic example of protein error, researching how this disease arises and comparing to other diseases that involve protein misfolding can help students understand the importance of the structure and function relationship.

**Critical Thinking Issues for Section 1.3**

1. It is often said, “form follows function.” Explain how this phrase relates to cellular proteins.
2. Now that the four basic biochemical groups have been defined, which of these may a viral particle contain? Which may it be lacking?
3. What characteristic is a virus lacking so that it is considered “acellular”?

***Section 1.4 Student Learning Objectives—Naming, Classifying, and Identifying Microorganisms***

1. *Differentiate among the terms* nomenclature,taxonomy, *and* classification.
2. *Create a mnemonic device for remembering the taxonomic categories.*
3. *Correctly write the binomial name for a microorganism.*
4. *Draw a diagram of the three major domains.*
5. *Explain the difference between traditional and molecular approaches to taxonomy.*

**Lecture Suggestions and Guidelines for Section 1.4**

1. The binomial nomenclature system should be introduced to students, along with an understanding of the proper way to display an organism’s name.
2. A review of the reasons behind the names of some microorganisms will help students gain confidence in understanding the naming process.
3. Review of the major taxonomic categories is needed, along with an understanding of how these categories have evolved over time and how they may continue to change as more information is learned.

**In-Class Activities for Section 1.4**

1. Create a list of common microorganisms and practice the pronunciation as a class to give students confidence in saying the names.
2. Choose a favorite organism (does not have to be microbial) and place the organism in the correct taxonomic categories.
3. Discuss the relationship between figure 1.1 and figure 1.17.
4. Compare and contrast traditional and molecular approaches to taxonomy.
5. Explain the relationship between the theory of evolution and figure 1.17.

**Additional Research Issues for Section 1.4**

1. How are genetics and molecular sciences altering our view of how organisms are classified?
2. Are there any organisms that have been reclassified using molecular techniques? How has molecular classification changed the tree of life in the modern era?

**Critical Thinking Issues for Section 1.4**

1. It has been suggested that a web may be a more suitable model than a tree to show the interrelatedness of life. Can you explain why this may be?

**SmartGrid Bloom’s Level 5 & 6 Activities for Chapter 1**

1. **Activity for Question #3:** Using internet searches, find one image of a tree of life and one of the web of life. Working in groups, create a list of key similarities and differences between the two layouts. Then have students identify why the web of life is the more accurate of the two.
2. **Activity for Question #6:** Create a Venn Diagram comparing cellular structures found in bacteria, archaea, eukaryotic microbes and human cells. After a discussion of how drugs work (including “side effects”), using the Venn Diagram, identify cellular targets for drug development.
3. **Activity for Question #9 and #15:** Focusing on the microbiome, research key functions of the microbiome of each site within the body (gut, skin, etc.). Discuss the relationship between these organisms and the human host and propose a process of a coevolution between microbes and humans. Then, propose that a key group of organisms is missing from a host and identify possible outcomes. Finally, review the impact of diet on various cultures and their microbiomes. With the differences in colonization, why are the same functions performed by each microbiome?
4. **Activity for Question #12:** Using internet searches, identify all the roles the membrane of the nucleus of eukaryotes plays. Then identify which activities are still performed by prokaryotic cells and where. Using the list of activities that only occur in eukaryotic cells using the membrane of nucleus suggest where the nucleus came from and what evolutionary factors drove this development.
5. **Activity for Question #18:** In teams, work to create an all-inclusive list of activities that microbes do to allow for human life to exist and flourish. In a “boggle” style review, groups cross off activities identified by other groups leaving only unique answers that can be scored to identify the winner.
6. **Activity for Question #21:** Design an experiment to demonstrate the existence of a microbiome on the skin of a subject and trade with a partner to identify assumptions or “holes” in the approach. Finally report out on the keys to a well-designed experiment and the importance of each step.

**Cowan Microbiology Fundamentals, 3/e, Critical Thinking Answers**

**Chapter 1**

1. a. Humans belong to the domain Eukarya.

b. Based on analysis of ssu rRNAs, it is believed that the three domains - Archaea, Bacteria, and Eukarya- all arose from a common, now extinct, ancestor cell type. Thus, it is not surprising that eukaryotic organisms are related to the other cell types.

That eukaryotic organisms may be more closely related to archaea than bacteria may be surprising, given that for a long time it was believed that eukaryotic cells derived and evolved from bacterial cells. Now, the three cell types are known to be distinct. However, the cell types share some similarities due to horizontal gene transfer between cells. Eukaryotic cells show similarities with archaeal cells in the form of ribosome structure, ribosomal RNAs, and protein synthesis.

1. Bioremediation is the use of microorganisms to restore stability to the environment or to clean up toxic pollutants. Many examples of the effectiveness of bioremediation can be found in the news. Bacteria are being used to “eat garbage” and neutralize harmful contamination of landfill soil. Bacteria have also been used to metabolize harmful hydrocarbons, like those elicited by oil spills, such as the [Deepwater Horizon oil spill](http://www.scientificamerican.com/article/gulf-oil-eating-microbes-slide-show/), which occurred in the Gulf of Mexico in 2010. Other, more recent research, shows the development of [bacteria that can degrade PCBs](http://www.newswise.com/articles/view/623252/?sc=rssn) (polychlorinated biphenyls). PCBs are virtually indestructible and remain in the environment indefinitely. In the past, PCB toxins were managed by capping or dredging and landfilling.
2. In some ways, we are entering an age in which the role of microorganisms in disease processes is being reexamined. Many diseases, such as diabetes and certain cancers, have been shown to be associated with microbial infections. Obesity is an example of a disease that was once thought to be an issue of genetics, diet, and exercise; it is being looked at to have a microbial component. Current research seems to be pointing to a possible connection between the microbiota of the gut tissue, metabolic processes, and body weight. Almost 90% of the cells in the body are living bacteria within the gut. The metabolic processes of these bacteria may have a profound impact of caloric absorption and the maintenance of body weight. Thus, in the future, a disease such as obesity may be most effectively addressed through medications or other processes that modify the gut bacteria in a way that favors a healthy body weight.
3. Significant changes in surgical protocols and surgical environments have certainly been instituted since the early 1800s. The early 1800s were a time before the formulation of the germ theory and the subsequent development of aseptic techniques. Thus, in the early 1800s, it was common for surgeons to enter operating suites wearing their street clothes, attend to one patient after another without washing their hands in between, and to use unsterilized equipment when performing procedures. Of course, in modern medicine, such practices have been abandoned. The formulation of the germ theory and the understanding of the role of endospores in diseases revolutionized medicine and patient safety. Basic aseptic and hygienic practices are now standard in surgical suites in order to limit the spread of infectious organisms.
4. In situations in which a town posts an advisory for water to be boiled before using it for drinking or cooking, the purpose is to limit contamination by any microorganisms that may be present when the integrity of the water supply is compromised. Boiling water is an example of microbial control, which affects the proteins in microorganisms. The temperature elevation due to boiling causes the proteins within any microorganism to denature and lose their function. As many cellular processes are dependent on functioning proteins, the loss in protein integrity results in cellular destruction. Although boiling water eliminates some microorganisms, it is not strong enough to destroy endospores, and thus boiling water is not considered a sterilization procedure.

**Cowan Microbiology Fundamentals, 3/e, Critical Thinking Questions**

**Chapter 1**

1. Review figure 1.17 from this chapter and discuss the following:

1. To which domain of life do humans belong?
2. Most scientists believe that eukaryotic organisms are more closely related to archaea than to bacteria. Is this surprising? Why or why not?

2. Conduct additional research and discuss one current example in which microorganisms are used in the bioremediation of contaminated environments.

3. Discuss why it has been suggested that in the future obesity may be treated with antimicrobial drugs.

4. Compare and contrast how the maintenance of surgical suites and the use of basic surgical protocols have changed since the early 1800s.

5. Often when there is a local water main break, the town will post an advisory for everyone to boil their water before using for drinking or cooking. Discuss how this action would target the biological molecules discussed in this chapter, minimizing the microbial contaminants.

Cowan Microbiology Fundamentals, 3/e, Answers to Visual Connections

Chapter 1

Figure 1.2. Look at the red bar (the time that bacteria have been on earth) and at the time that humans appeared. Speculate on the probability that we will be able to completely eliminate all bacteria from our planet, and discuss whether or not this would even be a beneficial action.

ANSWER:

The probability that our planet can be completely eliminated of all bacteria would be very, very, small. Bacteria have been in Earth’s environment for a long time, much longer than humans, with bacterial cells preceding the first animal cells by more than 2 billion years.

This speaks to the adaptability and survivability of bacteria. Bacteria are ubiquitous organisms, capable of living in diverse environments. They exist on and inside most other life forms and can live and reproduce in very inhospitable conditions. In addition, bacteria are constantly adapting and changing to any means introduced to control them. For example, many bacteria now carry antibiotic-resistance genes that counter the medications designed to destroy them.

Given the adaptation of bacteria, our ability to completely eliminate them is not likely, nor would we want to eliminate bacteria entirely. Bacteria are essential players in maintaining life on Earth, through the development of such processes as photosynthesis and through their relationship with plants and animals. Humans have also utilized bacteria for beneficial purposes, as exemplified by genetic engineering and bioremediation. And as we are continuing to learn, bacteria play an essential role in both human disease and human health.