CHAPTER 1: Microbial Life: Origin and Discovery

MULTIPLE CHOICE

1. Viruses are:
   a. infectious agents that infect multi-cellular organisms
   b. noncellular particles that take over the metabolism of a cell to generate more virus particles
   c. pathogens that replicate in complex growth media
   d. cellular particles that belong to the archaea domain
   e. microbes that consist of lipid membrane enclosed genomes

   ANS: B DIF: Easy REF: 1.1 TOP: I.A | I.B
   MSC: Remembering

2. Analysis of DNA sequences reveals:
   a. the ancient convergence of two cell types, i.e., prokaryotes and eukaryotes
   b. prokaryotes and eukaryotes evolved from a common ancestral cell
   c. that bacteria share common ancestor with archaea, but not with eukarya
   d. prokaryotes are cells with a nucleus
   e. the genome of *Haemophilus influenzae* has about 2 billion base pairs

   ANS: B DIF: Easy REF: 1.1 TOP: I.A | I.B
   MSC: Remembering

3. Which of these groups are considered to be microbes but NOT considered to be cells?
   a. viruses
   b. bacteria
   c. archaea
   d. protists
   e. filamentous fungi

   ANS: A DIF: Easy REF: 1.1 TOP: I.A.i
   MSC: Remembering

4. A microbe is commonly defined as:
   a. a virus that requires a microscope to be seen
   b. a bacterium that requires a microscope to be seen
   c. a single-cellular prokaryote that requires a microscope to be seen
   d. a multicellular eukaryote that requires a microscope to be seen
   e. a living organism that requires a microscope to be seen

   ANS: E DIF: Easy REF: 1.1 TOP: I.A.i | I.A.ii
   MSC: Remembering

5. Which one of the following statements regarding microbial cells is NOT true?
   a. Microbial cells acquire food, gain energy to build themselves, and respond to environmental change.
   b. Most single-celled organisms require a microscope to render them visible, but some bacterial cells are large enough to be seen with naked eyes.
   c. Microbes function as individual entities.
   d. Many microbes form complex multicellular assemblages.
   e. Viruses are not considered as microbial cells.

   ANS: C DIF: Easy REF: 1.1 TOP: I.A.i | I.A.ii
   MSC: Remembering

6. Which of the following statements is FALSE?
   a. A genome is the total genetic information contained in an organism's chromosomal DNA.
   b. If a microbe's genome includes genes for nitrogenase, that microbe probably can fix nitrogen.
   c. By comparing DNA sequences of different organisms, we can figure out how closely related they are.
   d. Fred Sanger developed the first applicable DNA sequencing method.
   e. Fred Sanger completed the sequences of *Haemophilus influenzae*.

   ANS: E DIF: Easy REF: 1.1 TOP: I.B
   MSC: Remembering

7. The first cellular genomes to be sequenced were those of:
   a. humans
   b. bacteria
   c. viruses
   d. prions
   e. fungi

   ANS: B DIF: Easy REF: 1.1 TOP: I.B.i
   MSC: Remembering

8. The environment of early Earth may have contained all of the following EXCEPT:
   a. ferrous iron
   b. methane
   c. ammonia
   d. oxygen
   e. hydrogen gas

   ANS: D DIF: Easy REF: Special Topic 1.1
   TOP: II.D MSC: Remembering

9. The development of the theory of the "RNA world" resulted from the discovery of:
   a. archaea
   b. prions
   c. bacteria
   d. ribozymes
   e. endosymbionts

   ANS: D DIF: Medium REF: Special Topic 1.1
   TOP: II.D MSC: Remembering

10. Which microbes may resemble those of the earliest life forms?
    a. archaea
    b. photosynthetic algae
    c. viruses
    d. cyanobacteria
    e. protists

    ANS: A DIF: Medium REF: Special Topic 1.1
    TOP: II.D MSC: Remembering

11. Early metabolism may have been catalyzed by:
    a. DNA
    b. RNA
    c. protein
    d. amino acids
    e. carbohydrates

    ANS: B DIF: Medium REF: Special Topic 1.1
    TOP: II.D MSC: Remembering

12. Which of the following diseases accounts for more than half of all human mortality?
    a. cardiovascular disease
    b. cancer
    d. microbial disease
    e. strokes

c. accidents

ANS: D DIF: Easy REF: 1.2 TOP: II.A
MSC: Remembering

13. Which century is known as the golden age of microbiology?
    a. the seventeenth
    b. the eighteenth
    c. the nineteenth
    d. the twentieth
    e. the twenty-first

ANS: C DIF: Easy REF: 1.2 TOP: II.A
MSC: Remembering

14. All of the following have been found in mummies and tomb art EXCEPT:
    a. tuberculosis
    b. polio
    c. leprosy
    d. smallpox
    e. AIDS

ANS: E DIF: Medium REF: 1.2 TOP: II.A.i
MSC: Remembering

15. How did European invaders to North America kill much of the native population?
    a. tuberculosis
    b. leprosy
    c. smallpox
    d. HIV
    e. bubonic plague

ANS: C DIF: Medium REF: 1.2 TOP: II.A.i
MSC: Remembering

16. Nightingale:
    a. is better known as the founder of professional nursing
    b. was the first to use disinfectant to demonstrate the significance of aseptic technique
    c. developed the pie chart of mortality data during the Crimean War
    d. performed the first controlled experiment on the chemical conversion of matter, known today as chemotherapy
    e. all of the above

ANS: A DIF: Easy REF: 1.2 TOP: II.A.ii
MSC: Remembering

17. Who developed the concept of medical statistics?
    a. Francis Crick
    b. Florence Nightingale
    c. Edward Jenner
    d. Louis Pasteur
    e. Alexander Fleming

ANS: B DIF: Easy REF: 1.2 TOP: II.A.ii
MSC: Remembering

18. The first person to visualize individual microbes was:
    a. Antonie van Leeuwenhoek
    b. Robert Hooke
    c. Louis Pasteur
    d. Lady Montagu
    e. Edward Jenner

ANS: A DIF: Easy REF: 1.2 TOP: II.B.ii
MSC: Remembering

19. Which technique was developed to distinguish bacteria from human cells?
    a. Gram stain
    b. electron microscopy
    c. X-ray diffraction
    d. DNA sequencing
    e. polymerase chain reaction (PCR)

    ANS: A DIF: Medium REF: 1.2 TOP: II.B.ii
    MSC: Remembering

20. How is most sterilization performed for the controlled study of microbes?
    a. boiling
    b. pasteurization
    c. filter sterilization
    d. autoclaving
    e. irradiation

    ANS: D DIF: Medium REF: 1.2 TOP: II.C.iii.a
    MSC: Remembering

21. Microbes can shape human history via:
    a. lithotrophic activities
    b. production of alcoholic beverages
    c. diseases that they cause
    d. production of cheese
    e. all of the above

    ANS: E DIF: Medium REF: 1.2 TOP: II.A
    MSC: Understanding

22. Suppose Pasteur's swan-necked flasks containing boiled broth became cloudy 24 hours after boiling. Which choice could best explain the turbidity or cloudiness in the broth without supporting spontaneous generation?
    a. Endospores in the broth survived boiling and grew after the broth cooled.
    b. Contaminating organisms in the broth killed by boiling became alive again after the broth cooled.
    c. Chemicals in the broth came together to form living organisms.
    d. The broth allowed light to pass through it with less interference after boiling.
    e. Solid material in the broth dissolved during boiling.

    ANS: A DIF: Difficult REF: 1.2 TOP: II.C.ii.b
    MSC: Applying

23. Robert Koch's greatest accomplishment in the field of medical bacteriology was with:
    a. *Escherichia coli*
    b. *Bacillus subtilis*
    c. *Mycobacterium tuberculosis*
    d. rabies
    e. smallpox

    ANS: C DIF: Medium REF: 1.3 TOP: III.B.i
    MSC: Remembering

24. The use of agar as the gelling agent in solid media was suggested by:
    a. Robert Koch
    b. Ignaz Semmelweis
    c. Angelina Hesse
    d. Louis Pasteur
    e. Richard Petri

    ANS: C DIF: Easy REF: 1.3 TOP: III.B.i.a
    MSC: Remembering

25. It took the advent of the PCR to detect the presence of the causative agent for which disease?
    a. anthrax
    b. tuberculosis
    d. rabies
    e. smallpox

c. AIDS

ANS: C DIF: Difficult REF: 1.3 TOP: III.B.ii
MSC: Remembering

26. The word "vaccination" is derived from the Latin word *vacca*, which means:
a. inject
b. smallpox
c. immunize
d. cow
e. pustule

ANS: D DIF: Easy REF: 1.3 TOP: III.C.i
MSC: Remembering

27. What is the basis for the modern smallpox vaccine?
a. chickenpox virus
b. cowpox virus
c. rabies virus
d. smallpox virus
e. anthrax

ANS: B DIF: Easy REF: 1.3 TOP: III.C.i
MSC: Remembering

28. Penicillin was first used to save the lives of many people during which war?
a. Civil War
b. Korean War
c. Vietnam War
d. World War I
e. World War II

ANS: E DIF: Easy REF: 1.3 TOP: III.C.iv
MSC: Remembering

29. Which of the following can safely be ingested to fight bacterial infections?
a. antiseptics
b. disinfectants
c. phenol
d. chlorine
e. antibiotics

ANS: E DIF: Easy REF: 1.3 TOP: III.C.iv
MSC: Remembering

30. All of the following are true about penicillin EXCEPT:
a. It was discovered by Alexander Fleming.
b. It was an accidental discovery.
c. It is produced by a bacterium.
d. It was the first antibiotic used by humans.
e. It was purified by Florey and Chain.

ANS: C DIF: Difficult REF: 1.3 TOP: III.C.iv
MSC: Remembering

31. Which one of the following statements regarding viruses is FALSE?
a. They are too small to be seen by a light microscope.
b. They are "filterable agents" that can pass through porcelain filters having a pore size that blocks microbes.
c. Their genomes could be composed of DNA or RNA.
d. They are smaller than viroids and prions.
e. Viral particles, when pure enough, can be crystallized.

ANS: D DIF: Medium REF: 1.3 TOP: III.D

MSC: Remembering

32. You have isolated a bacterium that you believe to be the causative agent of a new disease in frogs. How would you test the third of Koch's postulates?
    a. Determine the shape of the bacterial cells.
    b. Inject the bacteria into a healthy frog.
    c. Isolate the bacterium from a sick frog.
    d. Show that the bacterium is not present in healthy frogs.
    e. Grow a pure culture of the bacterium outside the frog.

    ANS: B DIF: Difficult REF: 1.3 TOP: III.B.ii
    MSC: Applying

33. How did Sergei Winogradsky grow lithotrophs?
    a. enrichment culture
    b. organic media
    c. pure culture
    d. endosymbiosis
    e. chain of infection

    ANS: A DIF: Easy REF: 1.4 TOP: IV.A.iii
    MSC: Remembering

34. Organisms that live symbiotically inside a larger organism are known as:
    a. organelles
    b. cyanobacteria
    c. mitochondria
    d. endosymbionts
    e. chloroplasts

    ANS: D DIF: Easy REF: 1.4 TOP: IV.B
    MSC: Remembering

35. Which group of microorganisms includes many that grow in extreme environments?
    a. algae
    b. bacteria
    c. protists
    d. archaea
    e. fungi

    ANS: D DIF: Easy REF: 1.4 TOP: IV.B
    MSC: Remembering

36. Carl Woese's discovery replaced the classification scheme of five kingdoms with a scheme of three:
    a. phyla
    b. domains
    c. classes
    d. orders
    e. genera

    ANS: B DIF: Easy REF: 1.5 TOP: V.D
    MSC: Remembering

37. The genetic expression machinery of archaea is most similar to:
    a. monera
    b. prokaryotes
    c. bacteria
    d. eukaryotes
    e. mitochondria

    ANS: D DIF: Medium REF: 1.5 TOP: V.D
    MSC: Remembering

38. In the three-domain model, the bacterial ancestor of mitochondria derives from ancient:
    a. fungi
    b. cyanobacteria
    d. archaea
    e. protists

c. proteobacteria

ANS: C DIF: Medium REF: 1.5 TOP: V.D
MSC: Remembering

39. Which of the following organelles are thought to be of prokaryotic origin?
a. chloroplast
b. mitochondria
c. nucleus
d. chloroplast and mitochondria
e. chloroplast and nucleus

ANS: D DIF: Medium REF: 1.5 TOP: V.D
MSC: Remembering

40. In the three-domain model, the bacterial ancestor of chloroplasts derives from ancient:
a. fungi
b. cyanobacteria
c. proteobacteria
d. archaea
e. protists

ANS: B DIF: Medium REF: 1.5 TOP: V.D
MSC: Remembering

41. How are microbes classified today?
a. comparative genomics
b. microscopy
c. X-ray diffraction
d. protein sequencing
e. 16S rRNA sequencing

ANS: E DIF: Medium REF: 1.5 TOP: V.D
MSC: Applying

42. What is used to focus the beam of electrons in an electron microscope?
a. electromagnets
b. condenser lens
c. light rays
d. X-ray diffraction
e. glass

ANS: A DIF: Easy REF: 1.6 TOP: VI.A.i
MSC: Remembering

43. Peter Mitchell and Jennifer Moyle discovered the _____ theory in the 1960s.
a. germplasm
b. evolution
c. chemiosmotic
d. DNA synthesis
e. polymerase chain reaction

ANS: C DIF: Easy REF: 1.6 TOP: VI.B.ii
MSC: Remembering

44. The X-ray diffraction studies by which of the following scientists concluded that DNA was a double helix?
a. James Watson
b. Rosalind Franklin
c. Francis Crick
d. Maurice Wilkins
e. Kary Mullis

ANS: B DIF: Easy REF: 1.6 TOP: VI.C
MSC: Remembering

45. What type of analysis was used to discover the overall structure of the DNA double helix?
a. microscopy
d. DNA sequencing

b. X-ray diffraction
c. polymerase chain reaction
e. recombinant DNA

ANS: B DIF: Medium REF: 1.6 TOP: VI.C
MSC: Remembering

46. Which scientist first discovered the process of transformation?
a. Francis Crick
b. Robert Koch
c. Edward Jenner
d. Louis Pasteur
e. Frederick Griffith

ANS: E DIF: Difficult REF: 1.6 TOP: VI.C
MSC: Remembering

47. Taq polymerase formed the basis of a multibillion-dollar industry of:
a. comparative genomics
b. recombinant DNA
c. X-ray diffraction
d. DNA amplification
e. DNA sequencing

ANS: D DIF: Easy REF: 1.6 TOP: VI.C.ii
MSC: Remembering

48. The Asilomar Conference was held to regulate and restrict the field of:
a. recombinant DNA
b. comparative genomics
c. DNA sequencing
d. DNA amplification
e. forensic microbiology

ANS: A DIF: Easy REF: 1.6 TOP: VI.C.iii
MSC: Remembering

49. The study of and cause of disease in humans, animals, and plants is called:
a. microbiology
b. phylogeny
c. genomics
d. epidemiology
e. forensics

ANS: D DIF: Easy REF: 1.6 TOP: VI.D
MSC: Remembering

50. The analysis of microbial strains as evidence in criminal investigations is known as:
a. forensic microbiology
b. recombinant DNA
c. comparative genomics
d. classification
e. gene regulation

ANS: A DIF: Easy REF: 1.6 TOP: VI.D
MSC: Remembering

SHORT ANSWER

1. What is the most recent evidence suggesting that all life on Earth shares a common ancestry?

ANS:
Many genomes have now been sequenced and those sequences are available in databases for comparison. This field is referred to as comparative genomics. Comparisons have revealed that there is a set of core genes shared by all organisms.

DIF: Difficult REF: 1.1 TOP: I.B.i MSC: Understanding

2. How are prokaryotes and eukaryotes different?

   ANS:
   A prokaryote lacks a nucleus and membrane-bounded organelles, whereas a eukaryote has a nucleus and membrane-bounded organelles.

   DIF: Easy REF: 1.1 | 1.5 TOP: I.A.i | I.A.ii | V.C
   MSC: Remembering

3. How do microbes help in the extraction of minerals?

   ANS:
   Several lithotrophic bacteria help in the rapid oxidation of minerals, which generates strong acids that expedite the breakdown of mineral ore. Currently, approximately 20% of the world's copper, as well as some uranium and zinc, are produced by bacterial leaching.

   DIF: Medium REF: 1.2 TOP: II.A MSC: Understanding

4. Antonie van Leeuwenhoek worked as a cloth draper, inspecting the quality of cloth. How did this lead to his interest in microscopy?

   ANS:
   Briefly, his work introduced him to magnifying lenses. He began the hobby of grinding lenses, ultimately making a microscope that enabled him to observe single-celled microbes.

   DIF: Medium REF: 1.2 TOP: II.B.ii MSC: Understanding

5. What was the major complaint about Lazzaro Spallanzani's experiment to disprove spontaneous generation, and how did Louis Pasteur's swan-neck flasks overcome this?

   ANS:
   Spallanzani's flasks were plugged so as not to let organisms accidentally enter the boiled medium. Opponents argued that no growth was observed simply due to the lack of oxygen. Pasteur's swan-neck flasks did not allow organisms to enter the flask, but did allow oxygen to enter. Growth was still not observed.

   DIF: Medium REF: 1.2 TOP: II.C.i MSC: Understanding

6. Describe the discoveries of Louis Pasteur while working with the French beer and wine manufacturers.

   ANS:
   Previously, it was believed that the conversion of grapes and grain to wine and beer was a spontaneous chemical process. He discovered that this fermentation was caused by living yeast, which did not require oxygen for growth. He also discovered that when the grapes or grain are contaminated with bacteria instead of yeast, acetic acid is produced instead of alcohol.

   DIF: Medium REF: 1.2 TOP: II.C.ii MSC: Understanding

7. Describe the effects of three microbial diseases that have significantly affected human populations throughout history.

   ANS:

Answers may vary. Some examples include bubonic plague, which killed one-third of Europe's population in the fourteenth century; tuberculosis, which was common in the nineteenth century; AIDS, which affects many people today; and smallpox, which killed a large number of native North Americans.

DIF: Medium REF: 1.2 TOP: II.A.i | II.A.ii
MSC: Applying

8. Why did it take so long for humans to determine that microbes cause infectious diseases?

ANS:
Microbes are too small to be seen with the naked eye, so until microscopes were invented, humans did not know that microbes existed. Even after humans were aware of the presence of microbes, they did not suspect them of causing disease until people such as Joseph Lister and Ignaz Semmelweis performed experiments that showed antiseptics decrease the incidence of infection.

DIF: Difficult REF: 1.2 | 1.3 TOP: II.B.i | III.C.iii
MSC: Understanding

9. Robert Koch's postulates have not been used to prove HIV as the causative agent of AIDS. Why not?

ANS:
Answers may vary, but a major reason is that humans cannot be injected with HIV to see if they develop AIDS!

DIF: Difficult REF: 1.3 TOP: III.B.ii MSC: Understanding

10. Define attenuation and describe some mechanisms used to attenuate pathogens.

ANS:
Attenuation results in a weakened organism that will not produce full-blown disease, but will generate immunity. Answers for mechanisms may vary. See discussion in textbook, Section 1.3, entitled "Immunization Prevents Disease."

DIF: Medium REF: 1.3 TOP: III.C.i | III.C.ii
MSC: Understanding

11. What is the significance of the work of Ignaz Semmelweis and Joseph Lister?

ANS:
They showed that use of antiseptics on doctors' hands and medical instruments drastically reduced the mortality rate of hospital patients. They made these observations before Robert Koch's germ theory of disease.

DIF: Medium REF: 1.3 TOP: III.C.iii MSC: Understanding

12. How would you use Robert Koch's postulates to prove that a specific organism causes a new disease in mice?

ANS:
See Figure 1.18 in the textbook.
(1) The suspected organism is found in all diseased mice, but is absent from healthy mice.
(2) The suspected organism is isolated from the diseased mice and grown in pure culture.
(3) When the suspected organism is introduced into a healthy mouse, the same disease occurs.

(4) The same strain of microbe is obtained from the newly diseased mouse.

DIF: Medium REF: 1.3 TOP: III.B.ii MSC: Applying

13. Explain why the organisms that were studied by Sergei Winogradsky could not be grown on Robert Koch's plate media containing agar or gelatin.

ANS:
The organisms studied by Winogradsky were lithotrophs, which feed solely on inorganic substances. Koch's plate media contained organic nutrient sources.

DIF: Difficult REF: 1.4 TOP: IV.A.ii MSC: Understanding

14. Is it true that only culturable bacteria contribute to ecology? Explain your answer.

ANS:
No, this is not a true statement. It is estimated that barely 0.1% of microbial species can be cultured. The work of Winogradsky and later microbial ecologists showed that bacteria are necessary for geochemical cycling. Many of these organisms can't be grown in pure culture on laboratory media, but can be grown in enrichment culture such as a Winogradsky column.

DIF: Difficult REF: 1.4 TOP: IV.B MSC: Understanding

15. Define the term "endosymbiont" and give an example of an endosymbiotic relationship found in nature.

ANS:
An endosymbiont is an organism living symbiotically inside a larger organism. Examples may vary, but include the following: *Rhizobium* in a leguminous plant; bioluminescent bacteria in the light organs of fish and squid; photosynthetic algae and coral.

DIF: Medium REF: 1.4 TOP: IV.B MSC: Applying

16. Give two reasons why microbes have been difficult to classify.

ANS:
First, even with the use of light microscopes, only the basic shape of microbes can be determined, and many microbes have similar shapes even though they are very different in other ways. Second, microbes do not fit the classic definition of a species, which is a group of organisms that interbreed. Microbes typically reproduce asexually. When they do exchange genes, they may do so with distantly related species.

DIF: Medium REF: 1.5 TOP: V.A.i | V.A.ii
MSC: Understanding

17. Briefly explain the endosymbiosis theory and the evidence that supports it.

ANS:
The endosymbiosis theory proposes that mitochondria and chloroplasts evolved from bacteria that were engulfed by pre-eukaryotic cells, and that over time these endosymbiotic prokaryotic cells lost the ability to survive outside of the host cell but were maintained as organelles. Evidence supporting the endosymbiosis theory includes the fact that mitochondria and chloroplasts possess circular DNA with similarity to modern bacteria.

DIF: Difficult REF: 1.5 TOP: V.C MSC: Understanding

18. What were the contributions of Rosalind Franklin toward discovering the structure of DNA and why wasn't she one of the recipients of the Nobel Prize for this discovery?

ANS:
She was an X-ray crystallographer who studied the structure of DNA. Her X-ray micrographs showed for the first time that DNA was a double helix. A colleague showed her micrographs to James Watson, who was also studying the structure of DNA. Watson and Francis Crick published their model of the structure of DNA in the journal *Nature* and denied that they had used Franklin's micrographs.

DIF: Medium REF: 1.6 TOP: VI.C.i MSC: Remembering

19. Briefly describe how the ultracentrifuge is used to determine the sizes of cellular macromolecules.

ANS:
The ultracentrifuge uses centrifugal forces to separate cell components. Theodor Svedberg calculated that the particle sizes could be determined based on the rate of sedimentation of the particles in an ultracentrifuge.

DIF: Medium REF: 1.6 TOP: VI.B.ii MSC: Understanding

20. If you want to produce DNA polymerases like those used in polymerase chain reaction (PCR) for amplification of DNA, from which natural environment would you try to isolate the producers?

ANS:
Taq DNA polymerase used in PCR amplification of DNA was extracted from *Thermus aquaticus*, a bacterium found in a hot spring in Yellowstone National Park. Since DNA polymerase has to survive many rounds of cycling to near-boiling temperatures, the most conducive environment for finding DNA polymerase, such as the enzymes used in PCR reactions, would be searching for microbes in an environment where the temperature is extremely high.

DIF: Difficult REF: 1.6 TOP: VI.C.ii MSC: Applying