

## Chapter 4- Diversity of Microorganisms

### Part 1: Acellular and Procaryotic Microbes

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#### Terms Introduced in This Chapter

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After reading Chapter 4, you should be familiar with the following terms. These terms are defined in Chapter 4 and in the Glossary.

Acid-fast stain	Nitrogen fixation
Aerotolerant anaerobe	Obligate aerobe
Anaerobe	Obligate anaerobe
Anoxygenic photosynthesis	Octad
Bacteriophage	Oncogenic viruses
Capnophile	Oxygenic photosynthesis
Capsid	Pleomorphism
Capsomeres	Prions
Coccobacillus	Simple stain
Differential staining procedures	Staphylococci
Diplobacilli	Streptobacilli
Diplococci	Streptococci
Facultative anaerobe	Structural staining procedures
Gram stain	Temperate bacteriophage
Inclusion bodies	Tetrad
L-forms	Vectors
Lytic cycle	Virions
Microaerophiles	Viroid
Nanobacteria	Virulent bacteriophage

#### Insight

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#### Microbes in the News—"Mad Cow Disease"

The disease known to most people as "mad cow disease" has received a great deal of publicity during recent years and has led to the slaughter of millions of cows, primarily in the United Kingdom. The scientific name for what the press calls "mad cow disease" is bovine spongiform encephalopathy (BSE). It is a progressive neurologic disorder of cattle that results from infection by an unconventional transmissible agent. The most accepted theory is that the agent is a modified form of an abnormal cell surface component known as a prion protein. As of November, 2005, only two BSE cases in cows have been diagnosed in the United States.

There is strong epidemiologic and laboratory evidence for a causal association between BSE and variant Creutzfeldt-Jakob disease (vCJD) of humans. In contrast to the classic form of CJD, the new variant form in the United Kingdom predominantly affects younger persons. It has atypical clinical features, with prominent psychiatric or sensory symptoms at the time of clinical presentation and delayed onset of neurologic abnormalities. These include ataxia (an inability to coordinate the muscles in the execution of voluntary movement) within weeks or months, dementia and myoclonus (clonic spasm or twitching of a muscle or group of muscles) late in the illness, a duration of illness of

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at least 6 months, and a diffusely abnormal nondiagnostic electroencephalogram. The characteristic neuropathologic profile of vCJD includes, in both the cerebellum and cerebrum, numerous kuru-type amyloid plaques surrounded by vacuoles and prion protein accumulation at high concentration indicated by immunohistochemical analysis. (Kuru is described in Chapter 4 in the text.)

Variant CJD was first reported in 1996, in the United Kingdom. As of November 2005, a total of 185 cases of vCJD have been reported. The majority of the cases (85%) were reported from the United Kingdom. Although 2 cases have been reported from the United States, the CDC suspects that both patients were exposed to the BSE agent while they resided in the United Kingdom.

### Life in the Absence of Oxygen

Someday, you may overhear someone erroneously state that “Life is impossible there (perhaps referring to one of the planets) because there isn’t any oxygen.” But, you’ll know differently! You’ll be able to point out that life is indeed possible in the absence of oxygen. Furthermore, you’ll be able to explain that organisms capable of life in the absence of oxygen are called anaerobes.

But, who discovered anaerobes? The credit for discovering anaerobes can be given to three scientists: a 17th-century scientist, an 18th-century scientist, and a 19th-century scientist. Each of them made scientific observations that contributed to our present knowledge and understanding of anaerobes.

In 1680, **Anton van Leeuwenhoek** performed an experiment using pepper and sealed glass tubes. In a letter to the Royal Society of London, he wrote that “animalcules developed although the contained air must have been in minimal quantity.” [Leeuwenhoek used the term “animalcules” to refer to the tiny organisms that he observed, using the simple, single lens microscopes, which he made.]

**Lazzaro Spallanzani**, an Italian scientist, performed similar experiments in the latter half of the 18th century. He drew the air from microbe-containing glass tubes, fully expecting the microbes to die—but some did not. He wrote in a letter to a friend, “The nature of some of these animalcules is astonishing! They are able to exercise in a vacuum the functions they use in free air....How wonderful this is! For we have always believed there is no living being that can live without the advantages air offers it.”

It was **Louis Pasteur** who actually introduced the terms “aerobe” and “anaerobe.” In an 1861 paper, he wrote “these infusorial animals are able to live and multiply indefinitely in the complete absence of air or free oxygen....These infusoria can not only live in the absence of air, but air actually kills them....I believe this is...the first example of an animal living in the absence of free oxygen.” [The term “infusoria” was used by early microbiologists to refer to microorganisms. Infusoria was later used to specifically refer to ciliated protozoa, but the term is now obsolete.]

We know now that anaerobes are quite common and that they live in specific ecologic niches. They can be found in soil, in freshwater and saltwater sediments (mud), and in the bodies of animals and humans. The indigenous microflora of humans contains many species of anaerobes, some of which are opportunistic pathogens. Anaerobes cause a wide variety of human diseases, including botulism, tetanus, gas gangrene, pulmonary infections, brain abscesses, and oral diseases. It was Louis Pasteur who, in 1877, discovered the first pathogenic anaerobe—the bacterium that today is known as *Clostridium septicum*.

### The Oxygen Holocaust

In the beginning, all the world was anaerobic—there was no oxygen. Scientists tell us that the first organisms were anaerobic microorganisms that evolved some 3 to 4 billion years ago. Life on earth then remained anaerobic for hundreds of millions of years.

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Then, about 2 billion years ago, the first worldwide pollution crisis occurred. “The oxygen holocaust” (as described by Margulis and Sagan) came about as the result of the evolution of the purple and green photosynthetic microbes. These organisms were able to make use of the hydrogen in water, by photosynthesis, leaving a waste product called oxygen. Yes, the oxygen that we humans consider so precious was originally a gaseous poison dumped into the atmosphere.

As oxygen gains electrons (becomes reduced), highly reactive, short-lived chemicals (called free radicals) are produced. These free radicals wreak havoc with the organic compounds that are the very basis of life. They destroy membranes and enzymes and are lethal to cells.

As stated by Lovelock, “the first appearance of oxygen in the air heralded an almost fatal catastrophe for early life.” Many anaerobic microbes were immediately destroyed. The microbes able to survive were those that responded to the crisis by developing ways to detoxify and eventually exploit the dangerous pollutant. These were the organisms that developed the ability to produce enzymes—like catalase, peroxidase, and superoxide dismutase—that break down and neutralize the various toxic reduction products of oxygen.

Those organisms lacking such enzymes either died or were forced to retreat to ecologic niches devoid of oxygen, such as soil and mud and deep within the bodies of animals. Those anaerobes that constitute part of our own indigenous microflora, for example, lead a rather pampered existence. We provide them with warmth and nutrients and a safe haven from their worst enemy—oxygen.

(To learn more about this subject, refer to *Microcosmos: Four Billion Years of Microbial Evolution*, by Lynn Margulis and Dorion Sagan [Summit Books, 1986] and *Gaia: a New Look at Life on Earth*, by J.E. Lovelock [Oxford University Press, 1979]).



### Increase Your Knowledge

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Information about *Bergey's Manual of Systematic Bacteriology* and the Bergey's Manual Trust (the organization responsible for publishing the manual) can be found at

[www.cme.msu.edu/bergeys](http://www.cme.msu.edu/bergeys)



### Microbiology—Hollywood Style

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The German chemist, **Paul Ehrlich** (1854–1915), made significant contributions to microbiology. In 1882, he developed a method of staining the causative agent of tuberculosis (*Mycobacterium tuberculosis*). His method was subsequently modified, and is today referred to as the acid-fast staining procedure. Ehrlich was also the first person to use chemicals to treat infectious diseases (discussed in Chapter 9). Students wishing to gain a better understanding of Paul Ehrlich and his contributions to microbiology should rent the thoroughly enjoyable video entitled *Dr. Ehrlich's Magic Bullet*. This 1940 black-and-white movie starred Edward G. Robinson as Dr. Ehrlich.



### Critical Thinking

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1. Be prepared to discuss key differences between viruses and bacteria.
2. Be prepared to explain why rickettsias, chlamydias, and mycoplasmas are described as unique bacteria.
3. Be prepared to discuss key differences between bacteria and archaeans.

**Additional Chapter 4 Self-Assessment Exercises**

(Note: Don't peek at the answers before you attempt to solve these self-assessment exercises.)

**Matching Questions**

- |                   |           |  |
|-------------------|-----------|--|
| A. diplococci     | _____ 1.  | Spherical bacteria arranged in pairs are called _____.   |
| B. diplobacilli   | _____ 2.  | Rod-shaped bacteria arranged in chains are called _____.   |
| C. staphylococci  | _____ 3.  | Spherical bacteria arranged in clusters are called _____.  |
| D. streptobacilli | _____ 4.  | Rod-shaped bacteria arranged in pairs are called _____.  |
| E. streptococci   | _____ 5.  | Spherical bacteria arranged in chains are called _____.  |
|                   |           |  |
| A. chlamydias     | _____ 6.  | The bacteria that cause syphilis and Lyme disease are _____.   |
| B. cyanobacteria  | _____ 7.  | _____ are obligate intracellular pathogens that cause diseases such as trachoma, inclusion conjunctivitis, and urethritis. |
| C. mycoplasmas    | _____ 8.  | _____ are photosynthetic.  |
| D. rickettsias    | _____ 9.  | _____ have no cell walls.  |
| E. spirochetes    | _____ 10. | _____ are obligate intracellular pathogens that cause diseases such as typhus and Rocky Mountain spotted fever.            |

**True/False Questions**

- \_\_\_\_\_ 1. All diseases caused by *Rickettsia* spp. are arthropodborne.
- \_\_\_\_\_ 2. Viruses contain both DNA and RNA.
- \_\_\_\_\_ 3. The cell walls of archaeans contain a thicker layer of peptidoglycan than bacterial cell walls.
- \_\_\_\_\_ 4. On entering a bacterial cell, all bacteriophages immediately initiate the lytic cycle.
- \_\_\_\_\_ 5. Mycoplasmas cannot grow on artificial media.
- \_\_\_\_\_ 6. Viruses are the smallest infectious agents.
- \_\_\_\_\_ 7. *Rickettsia* spp. and *Chlamydia* spp. cannot be grown on artificial media.
- \_\_\_\_\_ 8. Prions are infectious RNA molecules.
- \_\_\_\_\_ 9. HIV is an enveloped, double-stranded RNA virus.
- \_\_\_\_\_ 10. Organisms in the genus *Vibrio* are curved bacilli.

**Answers to the Chapter 4 Self-Assessment Exercises in the Text**

- |    |   |     |   |
|----|---|-----|---|
| 1. | D | 6.  | B |
| 2. | A | 7.  | C |
| 3. | A | 8.  | A |
| 4. | C | 9.  | D |
| 5. | A | 10. | A |

**Answers to the Additional Chapter 4 Self-Assessment Exercises****Matching Questions**

- |    |   |     |   |
|----|---|-----|---|
| 1. | A | 6.  | E |
| 2. | D | 7.  | A |
| 3. | C | 8.  | B |
| 4. | B | 9.  | C |
| 5. | E | 10. | D |

**True/False Questions**

1. True
2. False (they contain either DNA or RNA)
3. False (archaeal cell walls do not contain peptidoglycan)
4. False (temperate bacteriophages cause lysogeny)
5. False (yes they can)
6. False (viroids and prions are infectious agents that are smaller than viruses)
7. True
8. False (prions are infectious proteins; viroids are infectious RNA molecules)
9. True
10. True