

Chapter 1 - The Microbial World and You

Microbes in Our Lives

- Microorganisms are organisms that are too small to be seen with the unaided eye
- Germ refers to a microbe
 - Bacteria
 - Fungi
 - Protozoa
 - Viruses

Microbes in Our Lives

- A few are pathogenic (disease-causing)
- Decompose organic waste
- Are producers in the ecosystem by photosynthesis
- Produce industrial chemicals such as ethanol and acetone
- Produce fermented foods such as vinegar, cheese, and bread
- Produce products used in manufacturing (e.g., cellulase) and treatment (e.g., insulin)

Designer Jeans: Made by Microbes?

- Stone-washing: *Trichoderma* (fungus)
- Cotton: *Gluconacetobacter* (bacterium)
- Bleaching: Mushroom peroxidase
- Indigo: *E. coli* (bacteria)
- Plastic: Bacterial polyhydroxyalkanoate

Microbes in Our Lives

- Knowledge of microorganisms
 - Allows humans to
 - Prevent food spoilage
 - Prevent disease occurrence
 - Led to aseptic techniques to prevent contamination in medicine and in microbiology laboratories

Naming and Classifying Microorganisms

- Linnaeus established the system of scientific nomenclature
- Each organism has two names:
 - **Genus** (capitalized)
 - **specific epithet** (not capitalized)
 - Example: *Homo sapiens* (human)

Scientific Names

- Are italicized or underlined. The genus is capitalized, and the specific epithet is lowercase.
- Are “Latinized” and used worldwide.
- May be descriptive or honor a scientist.
- May see an abbreviation of the individual who classified and/or named the organism after the scientific name
 - *Thiomargarita namibiensis* Schultz
 - Gr. *Theion/Thio* (sulfur) + L. *margarita* (pearl) because it looks like a string of pearls
 - Namibia honored as location of origin

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Escherichia coli

- *Escherichia coli*
 - Honors the discoverer, Theodor Escherich
 - Describes the bacterium’s habitat—the large intestine, or colon

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Staphylococcus aureus

- *Staphylococcus aureus*
 - Describes the clustered (*staphylo-*) spherical (*cocci*) cells
 - Describes the gold-colored (*aureus*) colonies

Scientific Names

- After the first use, scientific names may be abbreviated with the first letter of the genus and the specific epithet:
 - *Escherichia coli* and *Staphylococcus aureus* are found in the human body. *E. coli* is found in the large intestine, and *S. aureus* is on skin.
 - *T. namibiensis* is found in the sulfur-rich coastal sediments of Namibia (Africa).

Types of Microorganisms

Bacteria

- Prokaryotes
- Peptidoglycan cell walls
- Binary fission
- For energy, use organic chemicals, inorganic chemicals, or photosynthesis

Archaea

- Prokaryotic
- Lack peptidoglycan
- Live in extreme environments
- Include
 - Methanogens
 - Extreme halophiles
 - Extreme thermophiles

Fungi

- Eukaryotes
- Chitin cell walls
- Use organic chemicals for energy
- Molds and mushrooms are

multicellular, consisting of masses of mycelia, which are composed of filaments called hyphae

- Yeasts are unicellular

Protozoa

- Eukaryotes
- Absorb or ingest organic chemicals
- May be motile via pseudopods, cilia, or flagella

Algae

- Eukaryotes
- Cellulose cell walls
- Use photosynthesis for energy
- Produce molecular oxygen and organic compounds

Viruses

- Acellular/nonliving
- Consist of DNA or RNA core
- Core is surrounded by a protein coat
- Coat may be enclosed in a lipid envelope
- Viruses are replicated only when they are in a living host cell

Multicellular Animal Parasites

- Eukaryotes
- Multicellular animals
- Parasitic flatworms and roundworms are called helminths.
- Microscopic stages in life cycles.

Classification of Microorganisms

- Three domains
 - Bacteria
 - Archaea
 - Eukarya
 - Protists
 - Fungi
 - Plants
 - Animals

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A Brief History of Microbiology

- Ancestors of bacteria were the first life on Earth, some 3.6 billion years ago
- Humans first evolved about 200,000 years ago
- The first microbes were observed about 230 years ago, in 1673

The First Observations

- 1665: Robert Hooke reported that living things were composed of little boxes, or cells
- 1858: Rudolf Virchow said cells arise from preexisting cells (biogenesis)
- Cell theory: All living things are composed of cells and come from preexisting cells
- 1673-1723: Anton van Leeuwenhoek described live microorganisms

The Debate over Spontaneous Generation

- Spontaneous generation: The hypothesis that living organisms arise from nonliving matter; a “vital force” forms life
- Biogenesis: The hypothesis that the living organisms arise from preexisting life

Evidence Pro and Con

- 1668: Francesco Redi filled 6 jars with decaying meat
- 1745: John Needham put boiled nutrient broth into covered flasks
- 1765: Lazzaro Spallanzani boiled nutrient solutions in flasks
- 1861: Louis Pasteur demonstrated that microorganisms are present in the air

The Theory of Biogenesis

- Pasteur’s S-shaped flask kept microbes out but let air in

The Golden Age of Microbiology

- 1857–1914
- Beginning with Pasteur’s work, discoveries included the relationship between microbes and disease, immunity, and antimicrobial drugs

Fermentation and Pasteurization

- Pasteur showed that microbes are responsible for fermentation
 - **Fermentation** is the conversion of sugar to alcohol to make beer and wine
- Microbial growth is also responsible for spoilage of food
 - Bacteria that use alcohol and produce acetic acid spoil wine by turning it to vinegar (acetic acid)
- Pasteur demonstrated that these spoilage bacteria could be killed by heat that was not hot enough to evaporate the alcohol in wine
- Pasteurization is the application of a high heat for a short time

The Germ Theory of Disease

- 1835: Agostino Bassi showed that a silkworm disease was caused by a fungus
- 1865: Pasteur believed that another silkworm disease was caused by a protozoan
- 1840s: Ignaz Semmelweis advocated hand washing to prevent transmission of puerperal fever from one OB patient to another
- 1860s: Applying Pasteur’s work showing that microbes are in the air, can spoil food, and cause animal diseases, Joseph Lister used a chemical disinfectant to prevent surgical wound infections
- 1876: Robert Koch proved that a bacterium causes anthrax and provided the experimental steps,

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Koch's postulates, to prove that a specific microbe causes a specific disease

Vaccination

- 1796: Edward Jenner inoculated a person with cowpox virus, who was then protected from smallpox
 - Vaccination is derived from *vacca*, for cow
 - The protection is called **immunity**

The Birth of Modern Chemotherapy

- Treatment with chemicals is chemotherapy
- Chemotherapeutic agents used to treat infectious disease can be synthetic drugs or antibiotics
- Antibiotics are chemicals produced by bacteria and fungi that inhibit or kill other microbes

The First Synthetic Drugs

- Quinine from tree bark was long used to treat malaria
- Paul Ehrlich speculated about a “magic bullet” that could destroy a pathogen without harming the host
- 1910: Ehrlich developed a synthetic arsenic drug, salvarsan, to treat syphilis
- 1930s: Sulfonamides (sulfa drugs) were synthesized

A Fortunate Accident—Antibiotics

- 1928: Alexander Fleming discovered the first antibiotic
- Fleming observed that *Penicillium* fungus made an antibiotic, penicillin, that killed *S. aureus*
- 1940s: Penicillin was tested clinically and mass produced

Modern Developments in Microbiology

- Bacteriology is the study of bacteria

- Mycology is the study of fungi
- Virology is the study of viruses
- Parasitology is the study of protozoa and parasitic worms
- Immunology is the study of immunity. Vaccines and interferons are being investigated to prevent and cure viral diseases.
- The use of immunology to identify some bacteria according to serotypes was proposed by Rebecca Lancefield in 1933.

Recombinant DNA Technology

- Microbial genetics: The study of how microbes inherit traits
- Molecular biology: The study of how DNA directs protein synthesis
- Genomics: The study of an organism's genes; has provided new tools for classifying microorganisms
- Recombinant DNA: DNA made from two different sources.
 - In the 1960s, Paul Berg inserted animal DNA into bacterial DNA, and the bacteria produced an animal protein
- 1941: George Beadle and Edward Tatum showed that genes encode a cell's enzymes
- 1944: Oswald Avery, Colin MacLeod, and Maclyn McCarty showed that DNA was the hereditary material
- 1961: Francois Jacob and Jacques Monod discovered the role of mRNA in protein synthesis

Nobel Prizes for Microbiology Research

- * The first Nobel Prize in Physiology or Medicine.
- 1901* von Behring = Diphtheria antitoxin
1902 Ross = Malaria transmission
1905 Koch = TB bacterium
1908 Metchnikoff = Phagocytes
1945 Fleming, Chain, Florey = Penicillin

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- 1952 Waksman = Streptomycin
- 1969 Delbrück, Hershey, Luria = Viral replication
- 1987 Tonegawa = Antibody genetics
- 1997 Prusiner = Prions
- 2005 Marshall & Warren = *H. pylori* & ulcers

Microbial Ecology

- Bacteria recycle carbon, nutrients, sulfur, and phosphorus that can be used by plants and animals

Bioremediation

- Bacteria degrade organic matter in sewage
- Bacteria degrade or detoxify pollutants such as oil and mercury

Biological Insecticides

- Microbes that are pathogenic to insects are alternatives to chemical pesticides in preventing insect damage to agricultural crops and disease transmission
- *Bacillus thuringiensis* infections are fatal in many insects but harmless to other animals, including humans, and to plants

Biotechnology

- Biotechnology, the use of microbes to produce foods and chemicals, is centuries old
- Recombinant DNA technology, a new technique for biotechnology, enables bacteria and fungi to produce a variety of proteins including vaccines and enzymes
 - Missing or defective genes in human cells can be replaced in **gene therapy**
 - Genetically modified bacteria are used to protect crops from insects and from freezing

Normal Microbiota

- Bacteria were once classified as plants, giving rise to use of the term flora for microbes
- This term has been replaced by microbiota
- Microbes normally present in and on the human body are called normal **microbiota**

Normal Microbiota

- Normal microbiota prevent growth of pathogens
- Normal microbiota produce growth factors such as folic acid and vitamin K
- Resistance is the ability of the body to ward off disease
- Resistance factors include skin, stomach acid, and antimicrobial chemicals

Biofilms

- Microbes attach to solid surfaces and grow into masses
- They will grow on rocks, pipes, teeth, and medical implants

Infectious Diseases

- When a pathogen overcomes the host's resistance, disease results
- Emerging infectious diseases (EIDs): New diseases and diseases increasing in incidence

Avian influenza A

- Influenza A virus (H5N2)
- Primarily in waterfowl and poultry
- Sustained human-to-human transmission has not occurred yet

MRSA

- Methicillin-resistant *Staphylococcus aureus*
- 1950s: Penicillin resistance developed

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- 1980s: Methicillin resistance
- 1990s: MRSA resistance to vancomycin reported
 - VISA: Vancomycin-intermediate-resistant *S. aureus*
 - VRSA: Vancomycin-resistant *S. aureus*

West Nile Encephalitis

- Caused by West Nile virus
- First diagnosed in the West Nile region of Uganda in 1937
- Appeared in New York City in 1999

Bovine Spongiform Encephalopathy

- Caused by a prion
 - Also causes Creutzfeldt-Jakob disease (CJD)
- New variant CJD in humans is related to cattle fed sheep offal for protein

Escherichia coli O157:H7

- Toxin-producing strain of *E. coli*
- First seen in 1982
- Leading cause of diarrhea worldwide

Ebola Hemorrhagic Fever

- Ebola virus
- Causes fever, hemorrhaging, and blood clotting
- First identified near Ebola River, Congo
- Outbreaks every few years

Cryptosporidiosis

- Cryptosporidium protozoa
- First reported in 1976
- Causes 30% of diarrheal illness in developing countries
- In the United States, transmitted via water

Acquired immunodeficiency syndrome (AIDS)

- Caused by human immunodeficiency virus (HIV)
- First identified in 1981
- Worldwide epidemic infecting 30 million people; 14,000 new infections every day
- Sexually transmitted infection affecting males and females
- HIV/AIDS in the U.S.: 30% are female, and 75% are African American