Main Themes of Microbiology

Chapter 1

Adapted from McGraw Hill
by Dr. G Cornwall

1.1 The Scope of Microbiology

- **Microbiology**: The study of living things too small to be seen without magnification
  - *micron* = small and *biologia* = study of living things
- **Microorganisms** or **microbes**- these microscopic organisms
  - Commonly called "germs, viruses, agents…" but not all cause disease and many more are useful or essential for human life

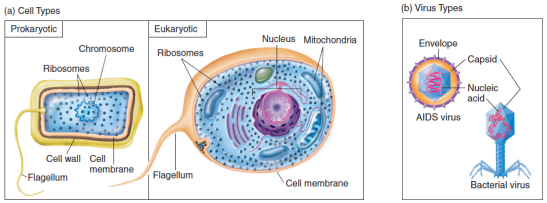
Relative Microbial Sizes

- If poliovirus (27 nm) was the size of a quarter… 

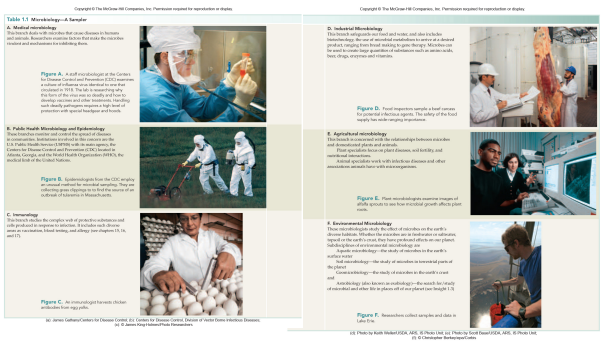
• *Staphylococcus aureus* (0.8 μm)	Beach ball
• *Escherichia coli* (0.7 x 2.5 μm)	Adult human
• *Saccharomyces cerevisiae* (5 μm)	Elephant
• *Paramecium caudatum* (50 x 250 μm)	Large yard (2.5 acres)
• *Amoeba proteus* (800 μm)	10 city blocks (100 acres)

Major Groups of Microorganisms

- **Bacteria**, **algae**, **protozoa**, **helminthes**, and **fungi** (cellular microbes)
- **Viruses**- noncellular, parasitic, protein-coated genetic elements that can infect all living things, including other microorganisms



Branches of Microbiology



Sub-Disciplines of Microbiology

- Microbiologists are sometimes referred to by the type of microbial system that they study
- **Bacteriology**: Study of prokaryotes
- **Mycology**: Study of fungi
- **Phycology**: Study of algae
- **Protozoology**: The study of protozoa
- **Virology**: The study of viruses
- **Immunology**: The study of the immune system

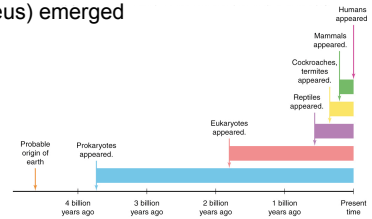
Concept Check

Which of these are acellular microbes?

A. Bacteria
B. Viruses
C. Protozoa
D. Yeasts

1.2 The Impact of Microbes on Earth: Small Organisms with a Giant Effect

- Microorganisms have a profound influence on all aspects of the earth and its residents
- Bacterial-like organisms in the fossil record as far back as 3.5 billion years ago (**prokaryotes**- organisms without a true nucleus)
- 2 billion years later, **eukaryotes** (organisms with a true nucleus) emerged



Importance of Microbes

- The study of microbiology is relevant to our everyday life in many different ways.
  1. Microbes are the earliest organisms found in the fossil record
  2. They perform essential reactions in the environment
  3. Microbes can be harnessed to work for us
  4. They sometimes cause infectious diseases

Ubiquity of Microorganisms

- Found nearly everywhere (ubiquitous)
- Occur in large numbers
- Live in places many other organisms cannot

(a) (b)

Microbes in the Environment

- Study of **Environmental Microbiology**
- Microbial **photosynthesis** account for most of the atmospheric oxygen on Earth
- Microbes are essential for **decomposition** of dead organisms
- Many biologically important elements (S, N, P) are cycled by microbes

(a)

(b)

1.3 Human Use of Microorganisms

- Humans have been using microorganisms for thousands of years
  - Baker's and brewer's yeast
  - Cheeses
  - Moldy bread on wounds

(a)

(b)

(c)

Harnessing the Power of Microbes

- Studies of **Industrial Microbiology** and **Food Microbiology**
- Microbes can be used to make or preserve food products (e.g. yogurt, salami, cheeses)
- Microbes can produce important compounds (e.g. antibiotics, MSG, ethanol)

(b)

Biotechnology and Bioremediation

- **Biotechnology**- when humans manipulate microorganisms to make products in an industrial setting
  - **Genetic engineering**- create new products and genetically modified organisms (GMOs)
  - **Recombinant DNA technology**- allows microbes to be engineered to synthesize desirable proteins (i.e. drugs, hormones, and enzymes)
- **Bioremediation**- introducing microbes in to the environment to restore stability or clean up toxic pollutants
  - Oil spills
  - Chemical spills
  - Water and sewage treatment

(c)

1.4 Infectious Diseases and the Human Condition

- Increasing number of emerging diseases (SARS, AIDS, hepatitis C, viral encephalitis)
- Other diseases previously not linked to microorganisms now are (gastric ulcers, certain cancers, schizophrenia, multiple sclerosis, obsessive compulsive disorder, coronary artery disease)
- Increasing number of drug resistant strains

Microbial Diseases

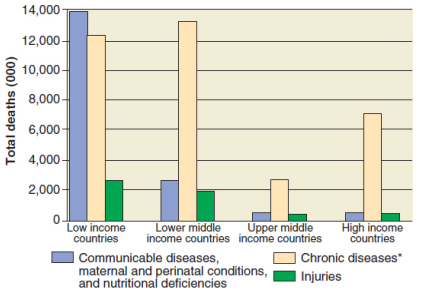
- Some microbes cause infectious diseases
- Only a few percent of all microbes are associated with disease

Table 1.2 Top Causes of Death—All Diseases

United States	No. of Deaths	Worldwide	No. of Deaths
1. Heart disease	652,000	1. Heart disease	12.2 million
2. Cancer	559,000	2. Stroke	5.7 million
3. Stroke	144,000	3. Cancer	5.7 million
4. Chronic lower-respiratory disease	131,000	4. Respiratory infections*	3.9 million
5. Unintentional injury (accidents)	118,000	5. Chronic lower-respiratory disease	3.6 million
6. Diabetes	75,000	6. Accidents	3.5 million
7. Alzheimer's disease	72,000	7. HIV/AIDS	2.9 million
8. Influenza and pneumonia	63,000	8. Perinatal conditions	2.5 million
9. Kidney problems	44,000	9. Diarrheal diseases	2.0 million
10. Septicemia (bloodstream infection)	34,000	10. Tuberculosis	1.6 million

*Diseases in red are those most clearly caused by microorganisms.
Source: Data from the World Health Organization, 2008..

The role of infectious disease vs other causes of death in countries of varying income



*Chronic diseases include cardiovascular diseases, cancers, chronic respiratory disorders, diabetes, neuropsychiatric and sense organ disorders, musculoskeletal and oral disorders, digestive diseases, genito-urinary diseases, congenital abnormalities and skin diseases.

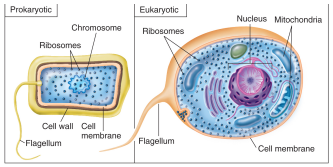
Concept Check

If you study HIV, what sort of microbiologist would you be considered?

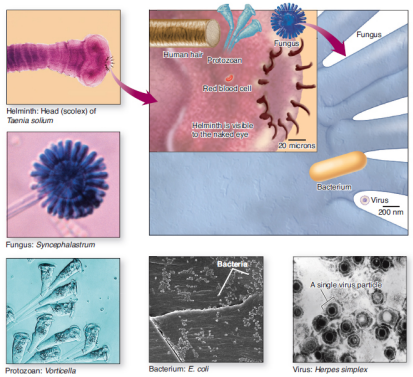
A. Bacteriologist
B. Protozoologist
C. Mycologist
D. Virologist

1.5 The General Characteristics of Microorganisms

- Cellular Organization
  - Prokaryotic vs. eukaryotic cells
    - Prokaryotic cells are about 10 times smaller than eukaryotic cells
    - Prokaryotic cells lack many cell structures such as **organelles**
    - All prokaryotes are microorganisms, but only some eukaryotes are

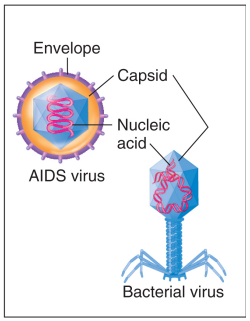


Microorganism Examples



Viruses

- Not independently living cellular organisms
- Much simpler than cells- basically a small amount of DNA or RNA wrapped in protein and sometimes by a lipid membrane
- Individuals are called a **virus particle** or **virion**
- Depend on the infected cell's machinery to multiply and disperse



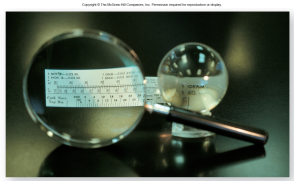
1.6 The Historical Foundations of Microbiology

Now a summary of the prominent discoveries made in the past 300 years:

- microscopy
- the rise of the scientific method
- development of medical microbiology

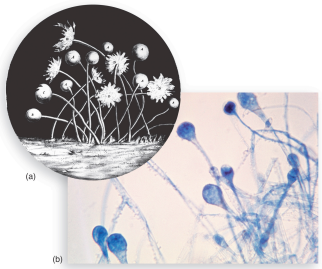
The Discovery of Microbes

- People have long been aware of the effects of microbial growth
- Spoilage, disease, decomposition
- Microbes are too small to be seen even with hand lenses
- Microscopes changed that



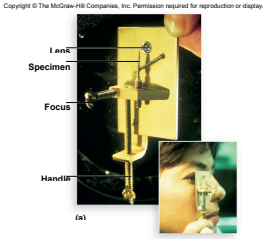
Robert Hooke

- 1664
- English naturalist and architect
- May have been the first to see microorganisms
- Coined the word **"cell"** to describe what he saw while viewing tree bark from a cork oak.



Antonie van Leeuwenhoek

- 1684
- Dutch fabric merchant
- **First person to accurately describe living microbes**
- Used a simple microscope
- Made and reported many detailed observations



- Key to the study of microorganisms was the development of the **microscope**
- Earliest record of microbes was from the work of **Robert Hooke** in the 1660s
- The most careful observations of microbes was possible after **Antonie van Leeuwenhoek** created the single-lens **microscope**
  - Known as the father of bacteriology and protozoology
  - Revealed microbes as discrete entities
  - Allowed awareness of the widespread distribution of microorganisms

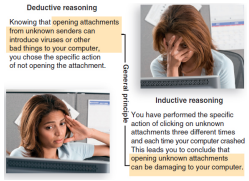
More recently

- some very recent discoveries that have had huge impacts on our understanding of microbiology
  - **Discovery of restriction enzymes—1970s.**
    - little molecular “scissors” inside prokaryotes that chop up DNA in specific ways
  - **The invention of the PCR technique—1980s.**
    - The polymerase chain reaction (PCR) was a breakthrough in our ability to detect tiny amounts of DNA and then amplify them into quantities sufficient for studying

- **The importance of biofilms in infectious diseases—1980s, 1990s, and 2000s.**
    - Biofilms are accumulations of bacteria and other microbes on surfaces
    - may be responsible for infections that are tough to conquer, such as some ear infections and recalcitrant infections of the prostate
- **The importance of small RNAs—2000s**
    - critical roles in regulating what happens in the cell. This is important not just to correct scientific assumptions but there are important practical uses as well. It has led to new approaches to how diseases are treated

Establishment of the Scientific Method

- Early scientists tended to explain natural phenomena by a mixture of belief, superstition, and argument
- During the 1600s, true scientific thinking developed
- From that, the development of the scientific method
    - Formulate a **hypothesis**
    - Most use the **deductive approach** to apply the scientific method
    - Experimentation, analysis, and testing leads to conclusions
    - Either support or refute the hypothesis



The Development of Medical Microbiology

- The Discovery of Spores and Sterilization
    - **Louis Pasteur**- worked with infusions in the mid-1800s
        - showed air dust as a source of microbes
    - **John Tyndall**- showed evidence that some microbes have very high heat resistance and are difficult to destroy
    - **Ferdinand Cohn**- discovered heat resistant endospores and sterilization
        - clarified why heat would not completely eliminate all microorganisms
- The Development of Aseptic Techniques
    - Physicians and scientist began to suspect that microorganisms could cause disease
    - **Joseph Lister**- introduced **aseptic technique**

The Discovery of Pathogens and the Germ Theory of Disease

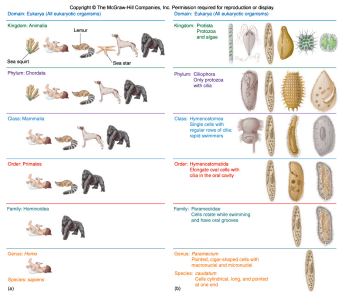
- **Louis Pasteur**
  - Pasteurization
  - The Germ Theory of Disease - microorganisms can be the cause of disease
- **Robert Koch**
  - Koch's postulates - a series of proofs that verified the germ theory and could establish whether an organism was pathogenic and which disease it caused

1.7 Taxonomy: Naming, Classifying, and Identifying Microorganisms

- **Microbial nomenclature**- naming microorganisms
- **Taxonomy**- classifying living things
  - Originated over 250 years ago with the work of Carl von Linné (Linneaus)
- **Identification**- discovering and recording the traits of organisms so they can be named and classified

Levels of Classification

- Domain
- Kingdom
- Phylum or division
- Class
- Order
- Family
- Genus
- Species



Microbial Classification

- **Taxonomy** is the science of living things
- **Carl von Linné** began systematically classifying living things
- Every organism has a two-name (**binomial**) designation – *Genus species*
- Note italics and the capitalization!
- Microorganisms push at the limits of our ability to create schemes to organize and classify them

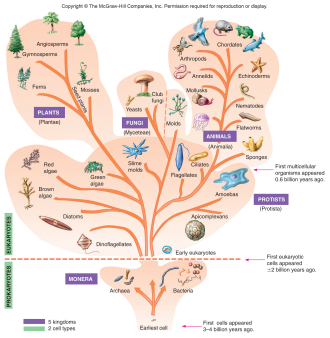
Naming Examples

- *Staphylococcus aureus*
  - staphule-bunch of grapes
  - kokkus- berry
  - aureus - golden
- *Campylobacter jejuni*
  - kampylos-curved
  - bakterion- little rod
  - jejunum- part of intestine
- *Giardia lamblia*
  - Alfred Giard- Fr. Microbiologist
  - Victor Lambl – Bohemian physician

The Five Kingdom Model

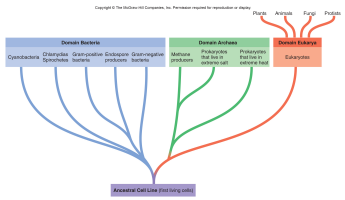
Robert Whittaker
(1959)

1. Animals
2. Plants
3. **Fungi** (microbes)
4. **Protists** (microbes)
5. **Monera** (microbes)



New Views of Phylogeny

- **Carl Woese** (1975)
- Used 16S rRNA
- Three "Domains"
  1. **Archaea**
     (all microbes)
  2. **Bacteria**
     (all microbes)
  3. **Eukarya**
     (some microbes)



Concept Check

Which of these is the correct scientific name for a common laboratory bacterium?

A. Escherichia Coli
B. *Escherichia coli*
C. *Escherichia Coli*
D. Escherichia coli