Microbiology: A Systems Approach,

Chapter 1: The Main Themes of Microbiology

1.1 The Scope of Microbiology

- **Microbiology**: The study of living things too small to be seen without magnification
  - **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

Major Groups of Microorganisms

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

Branches of Microbiology

- Agricultural microbiology
- Biotechnology
- Food, dairy, and aquatic microbiology
- Genetic engineering and recombinant DNA technology
- Public health microbiology and epidemiology
- Immunology
- Many, many more

Emerging Areas of Microbiology

- Geomicrobiology
- Marine microbiology
- Astromicrobiology

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

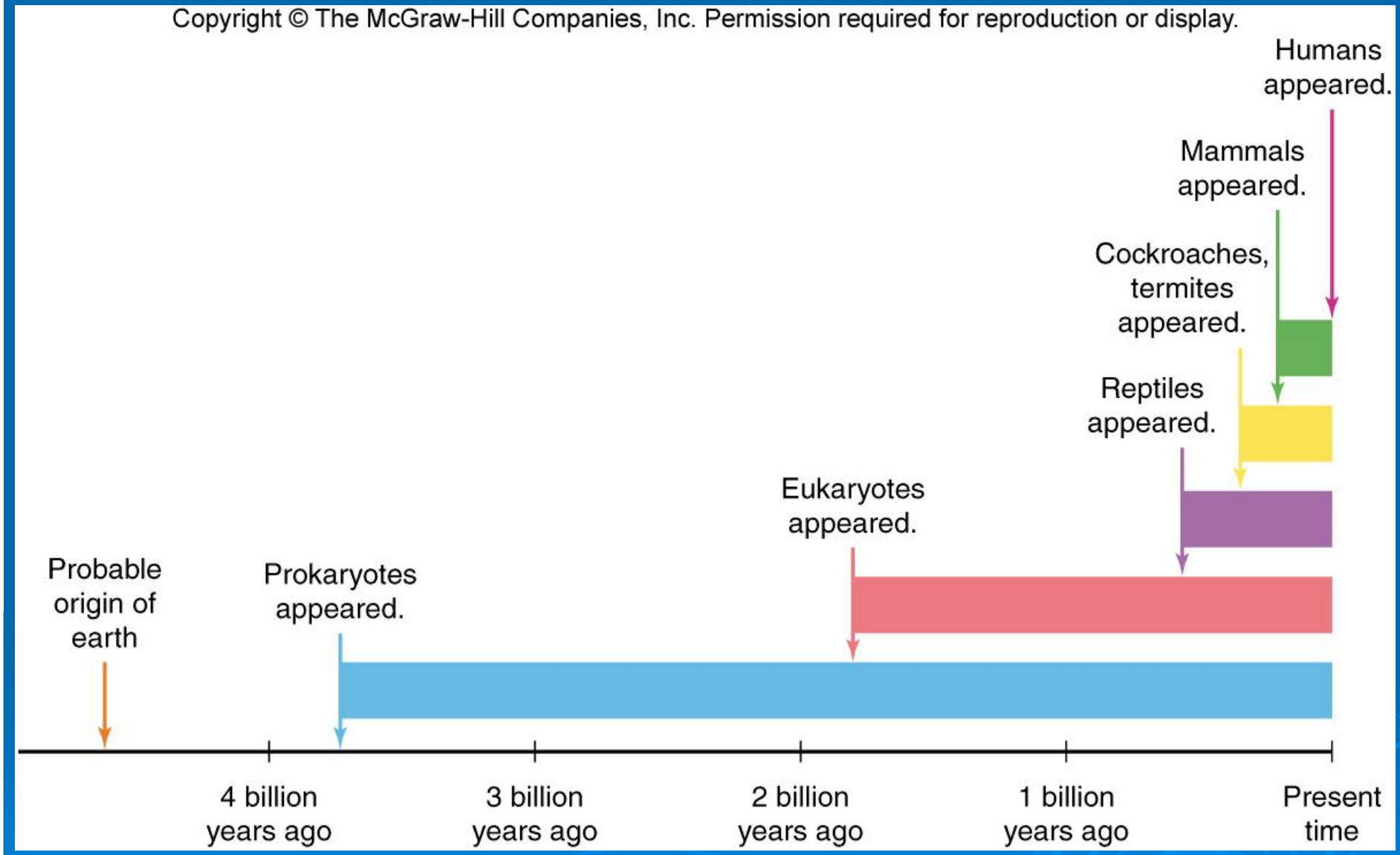


Figure 1.1

Ubiquity of Microorganisms

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

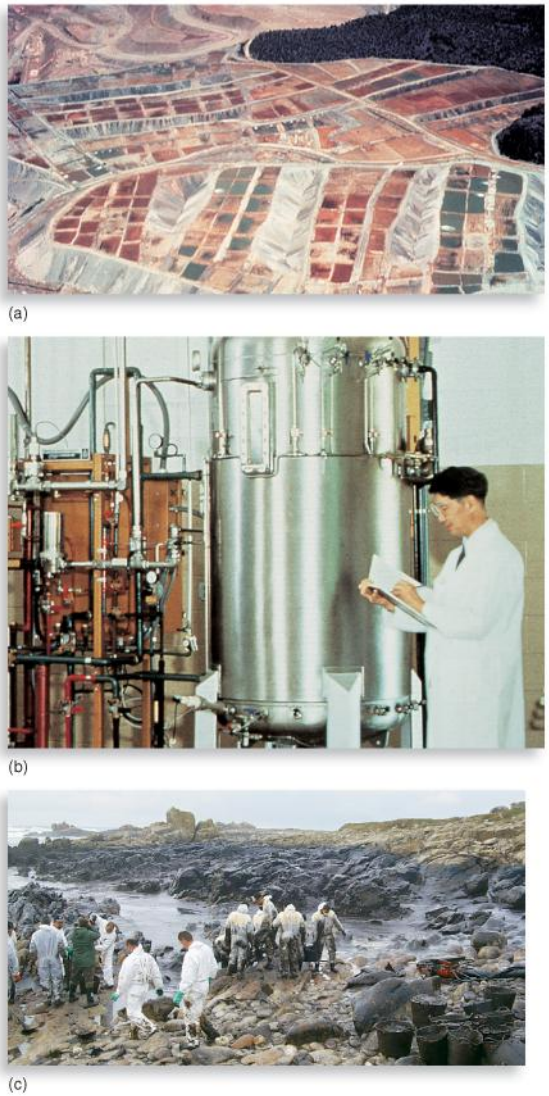
Figure 1.2

Microbial Involvement in Energy and Nutrient Flow

- Bacteria conducted **photosynthesis** before plants appeared
  - Anoxygenic photosynthesis
  - Oxygenic photosynthesis
- Biological **decomposition** and nutrient recycling

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)

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(c)

Figure 1.3

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

1.4 Infectious Diseases and the Human Condition

- **Pathogens**- disease-causing organisms

TABLE 1.1 Top Causes of Death—All Diseases

United States	No. of Deaths	Worldwide	No. of Deaths
1. Heart disease	725,000	1. Heart disease	11.1 million
2. Cancer	550,000	2. Cancer	7.1 million
3. Stroke	167,000	3. Stroke	5.5 million
4. Chronic lower-respiratory disease	124,000	4. Respiratory infections*	3.9 million
5. Unintentional injury (accidents)	97,000	5. Chronic lower-respiratory disease	3.6 million
6. Diabetes	68,000	6. Accidents	3.5 million
7. Influenza and pneumonia	63,000	7. HIV/AIDS	2.9 million
8. Alzheimer's disease	45,000	8. Perinatal conditions	2.5 million
9. Kidney problems	35,000	9. Diarrheal diseases	2.0 million
10. Septicemia (bloodstream infection)	30,000	10. Tuberculosis	1.6 million

*Diseases in red are those most clearly caused by microorganisms.

Source: Data adapted from The World Health Report 2002 (World Health Organization).

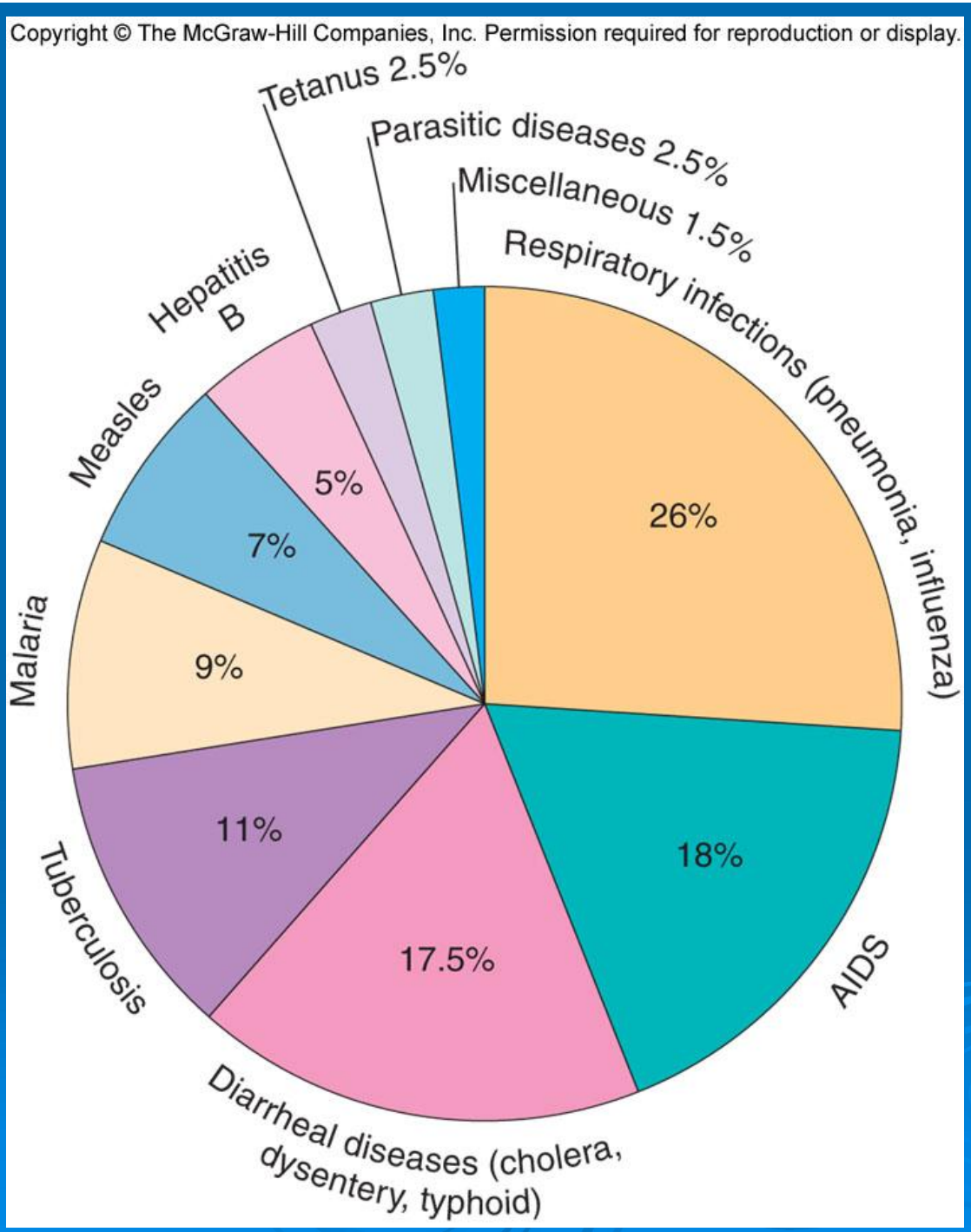

Figure 1.4

Worldwide Infectious Diseases

- 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

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

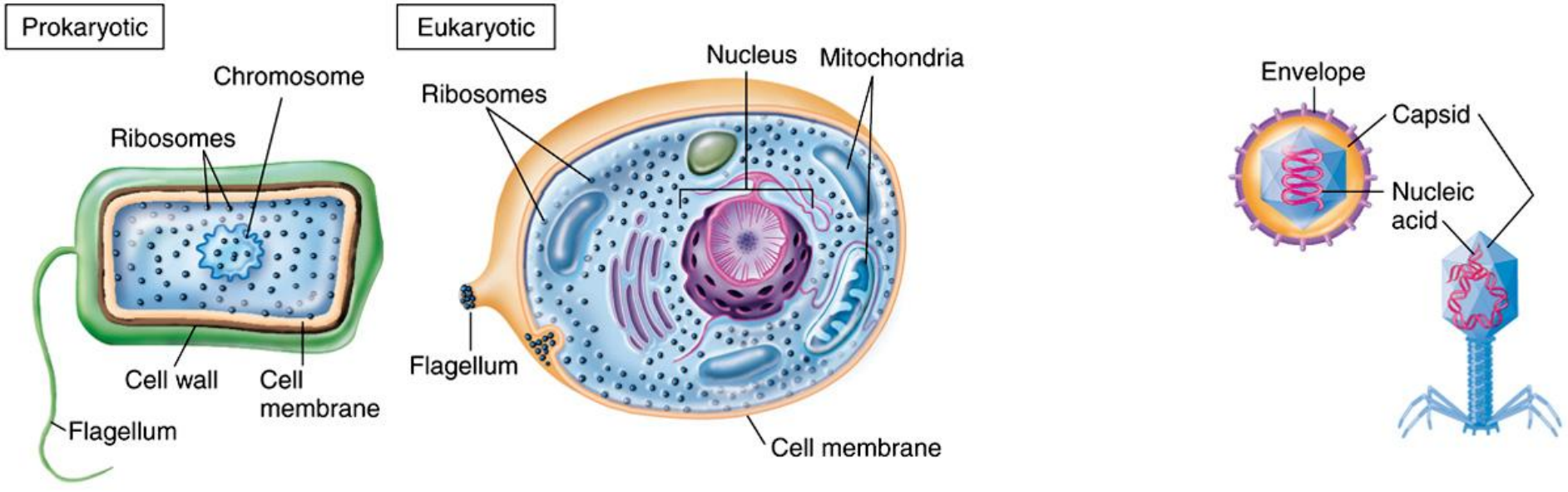

Figure 1.5

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

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Jennifer; 21.01.2008

Microbial Dimensions

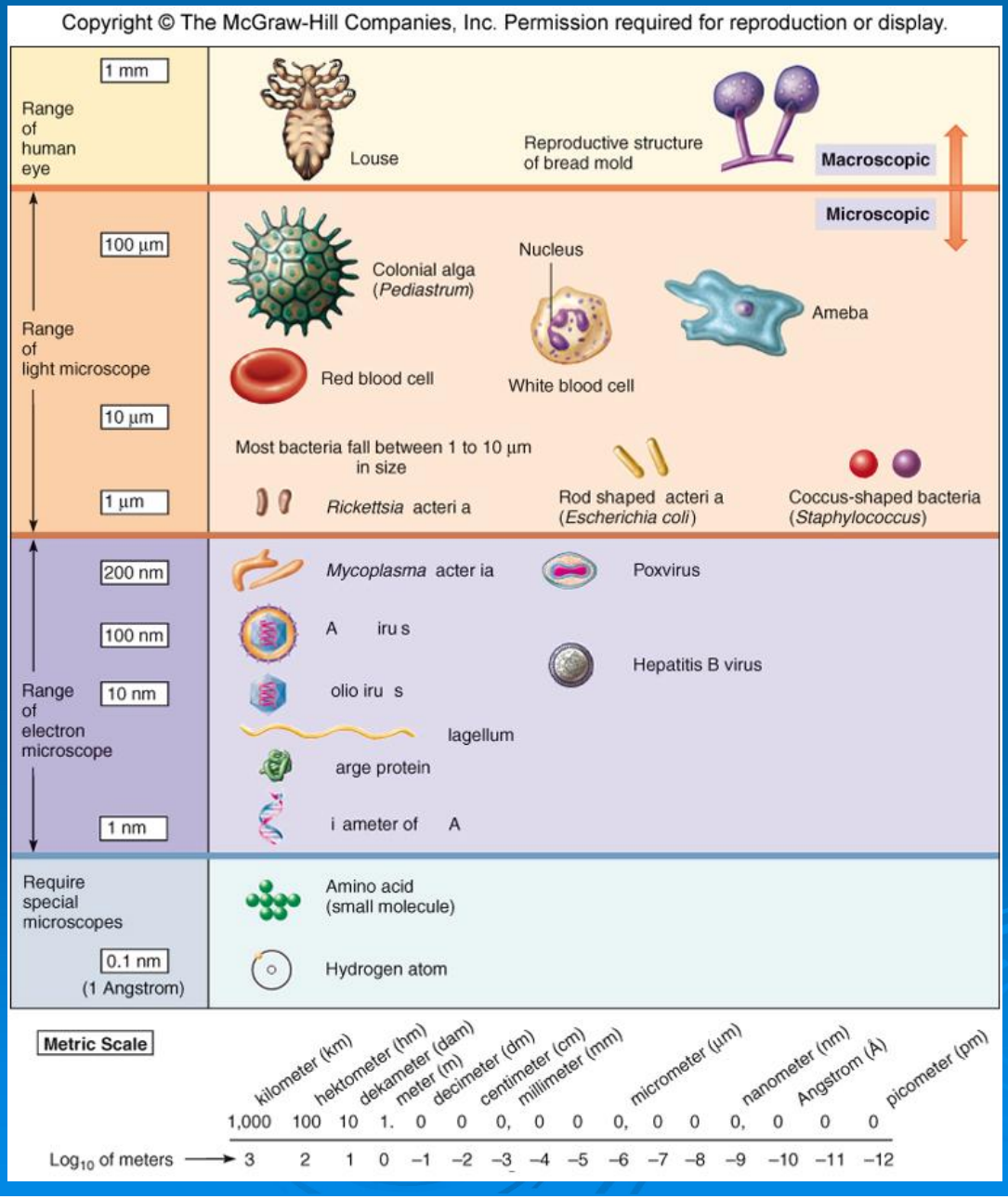
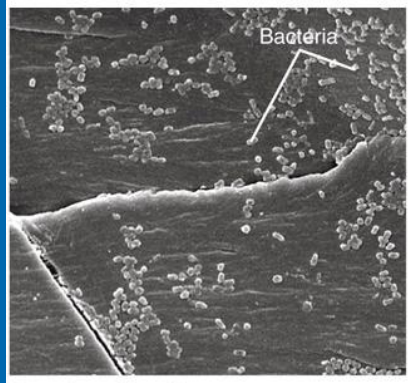


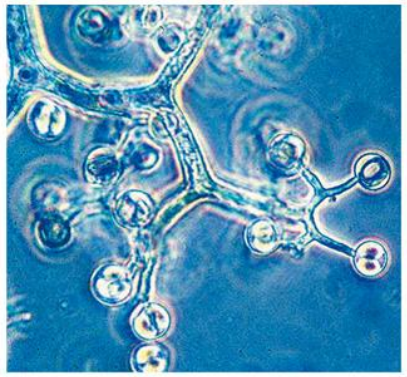
Figure 1.7

Lifestyles of Microorganisms

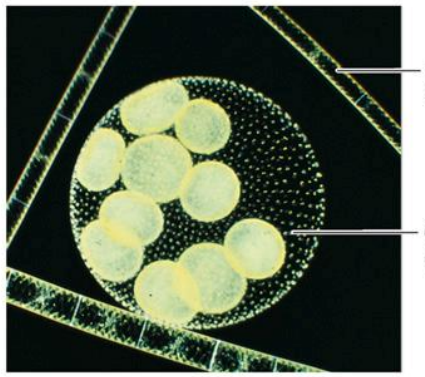
- Most live a free existence (in soil or water, for example)
- Some are **parasites**



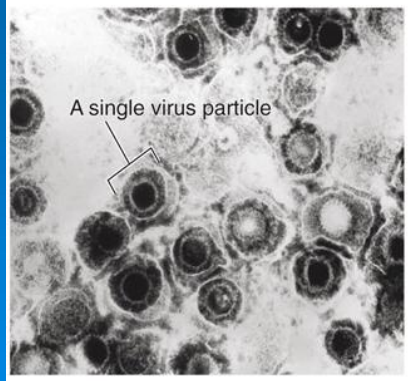
Bacterium: *E. coli*



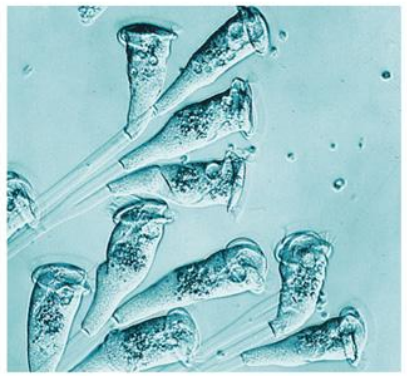
Fungus: *Thamnidium*



Algae: *Volvox* and *Spirogyra*



Virus: *Herpes simplex*



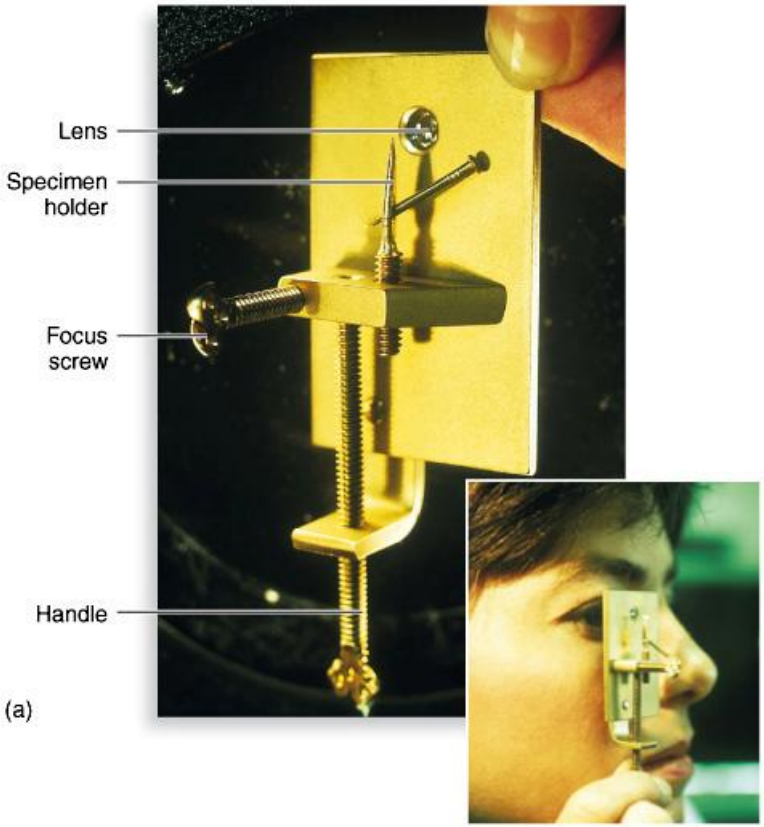
Protozoan: *Vorticella*

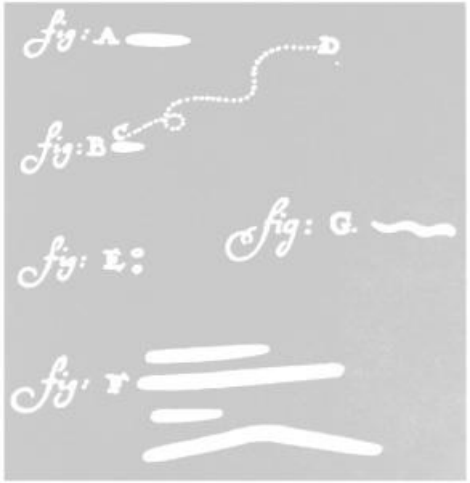
Helminth: Head (scolex) of *Taenia solium*

Figure 1.6

1.6 The Historical Foundations of Microbiology

- 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





(b)

Figure 1.9

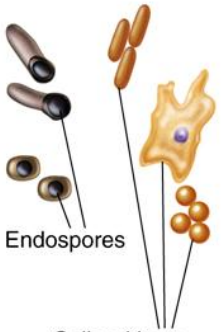
Establishment of the **Scientific Method**

- 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
- Hypotheses can eventually become theories
- Theories can eventually become laws or principles

Hypothesis → **Predictions** → **Testing** → **Theory/Principle**

Hypothesis

Bacterial endospores are the most resistant structures of life on earth.



(a)

Predictions

If hypothesis is true, endospores can survive extreme conditions such as:

Testing

Compare endospore formers to non-endospore-forming microbes.

	Survival of endospore former	Survival of non-endospore former
• temperature (boiling)	+	−/+*
• radiation (ultraviolet)	+	−
• lack of water (drying)	+	−/+
• chemicals (disinfectants)	+	−/+

*Only 1 out of 4 cell types survives.

Additional tests show that endospores have thick coverings and protective features and that endospores are known to survive over millions of years.

Theory/Principle

Endospores are the only structures of life consistently capable of surviving a wide range of destructive environmental conditions. In order to sterilize, endospores must be eliminated.

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Tests give contradictory results. Continued testing of other rocks and samples from Mars' surface are ongoing.

? **Modify** → **Hypothesis**

? **Discard**

Hypothesis → **Predictions** → **Tests/Results** → **Theory**

Hypothesis

Tiny, rod-shaped objects from a billion-year-old Martian meteor are microorganisms.

Predictions

- Objects will be within expected size range of bacteria.
- Objects will contain carbon and other elements in an expected ratio.
- They will occur in samples from Mars but not in rocks from other planets.

Tests/Results

- Supportive findings are that the objects appear to be dividing and occur in colonies, not randomly.
- They contain more carbon than surrounding minerals.
- Microbiologists say that objects are too small to be cells.
- Tests show similar crystals are common in geologic samples that are not possibly microbial.
- Chemical tests indicate objects are the result of heat.

Theory

- Results are too contradictory to rise to this level.
- Mars projects will continue to examine the Martian landscape for signs of life. See Insight 1.3.

(b)

Figure 1.10

The Development of Medical Microbiology

- The Discovery of Spores and Sterilization
  - **Louis Pasteur**- worked with infusions in the mid-1800s
  - **John Tyndall**- showed evidence that some microbes have very high heat resistance and are difficult to destroy
  - **Ferdinand Cohn**- spores and sterilization
- 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**
  - **Robert Koch**
    - **Koch's postulates**- verified the germ theory

Figure 1.11

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
- **Identification**- discovering and recording the traits of organisms so they can be named and classified
- Levels of Classification

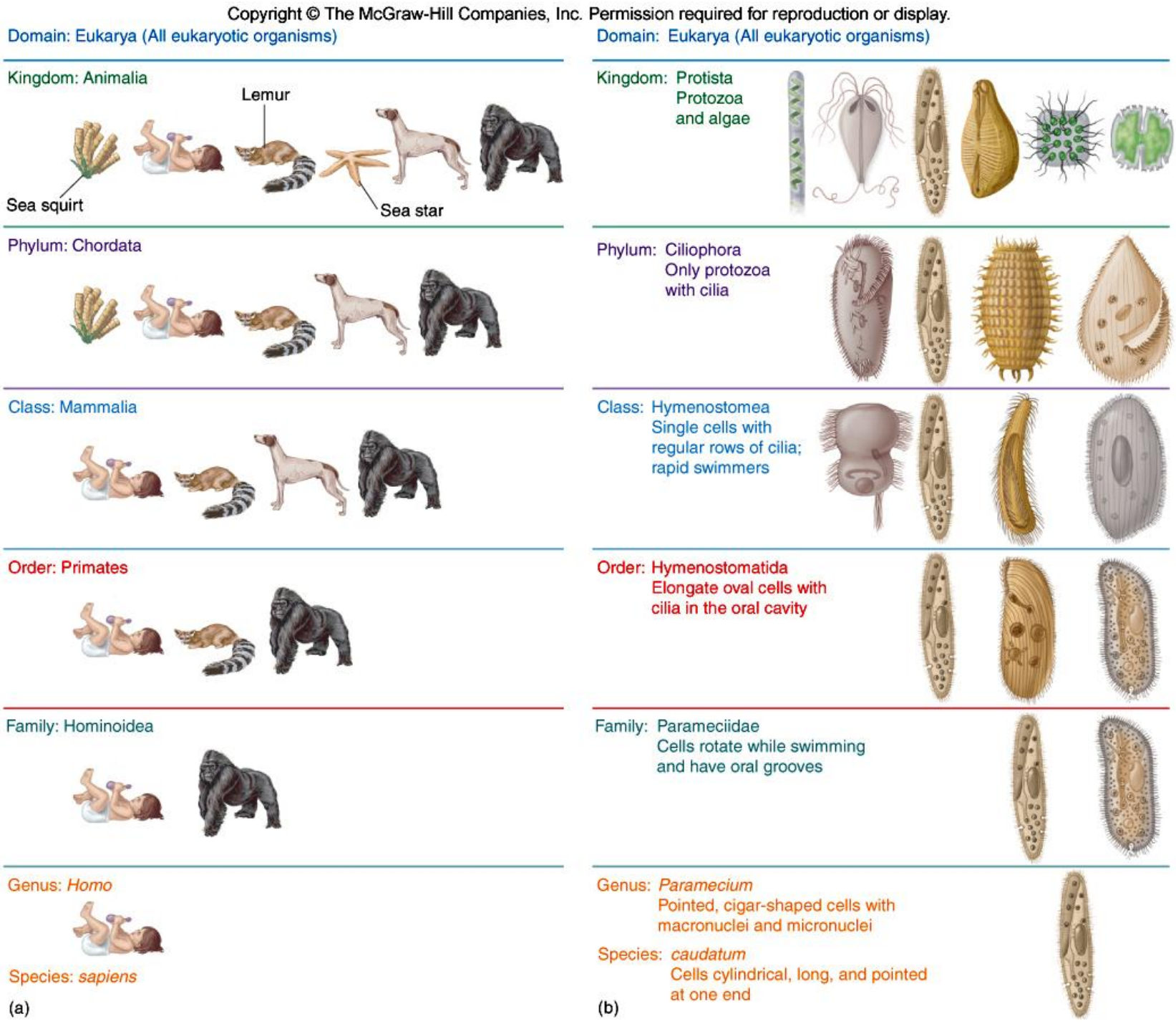


Figure 1.12

Assigning Specific Names

- A standardized nomenclature allows scientists from all over the world to exchange information
- The **binomial system of nomenclature**
  - The generic (genus) name followed by the species name
  - Generic part is capitalized, species is lowercase
  - Both are italicized or underlined if italics aren't available
  - *Staphylococcus aureus*

The Origin and Evolution of Microorganisms

- **Phylogeny**- the degree of relatedness between groups of living things
- Based on the process of **evolution**- hereditary information in living things changes gradually through time; these changes result in structural and functional changes through many generations
  - Two preconceptions:
    - All new species originate from preexisting species
    - Closely related organisms have similar features because they evolved from a common ancestor
- Phylogeny usually represented by a tree- showing the divergent nature of evolution

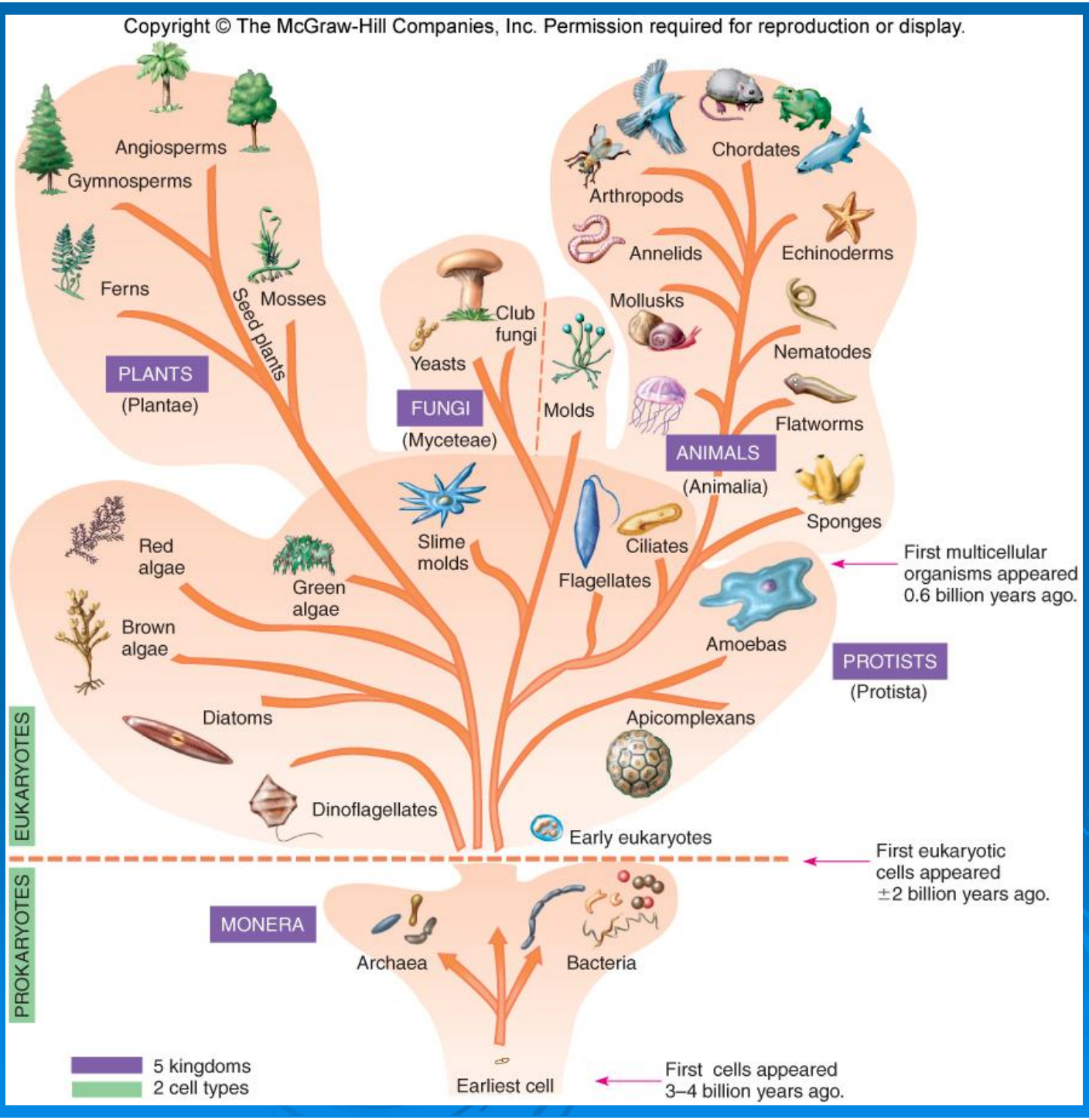
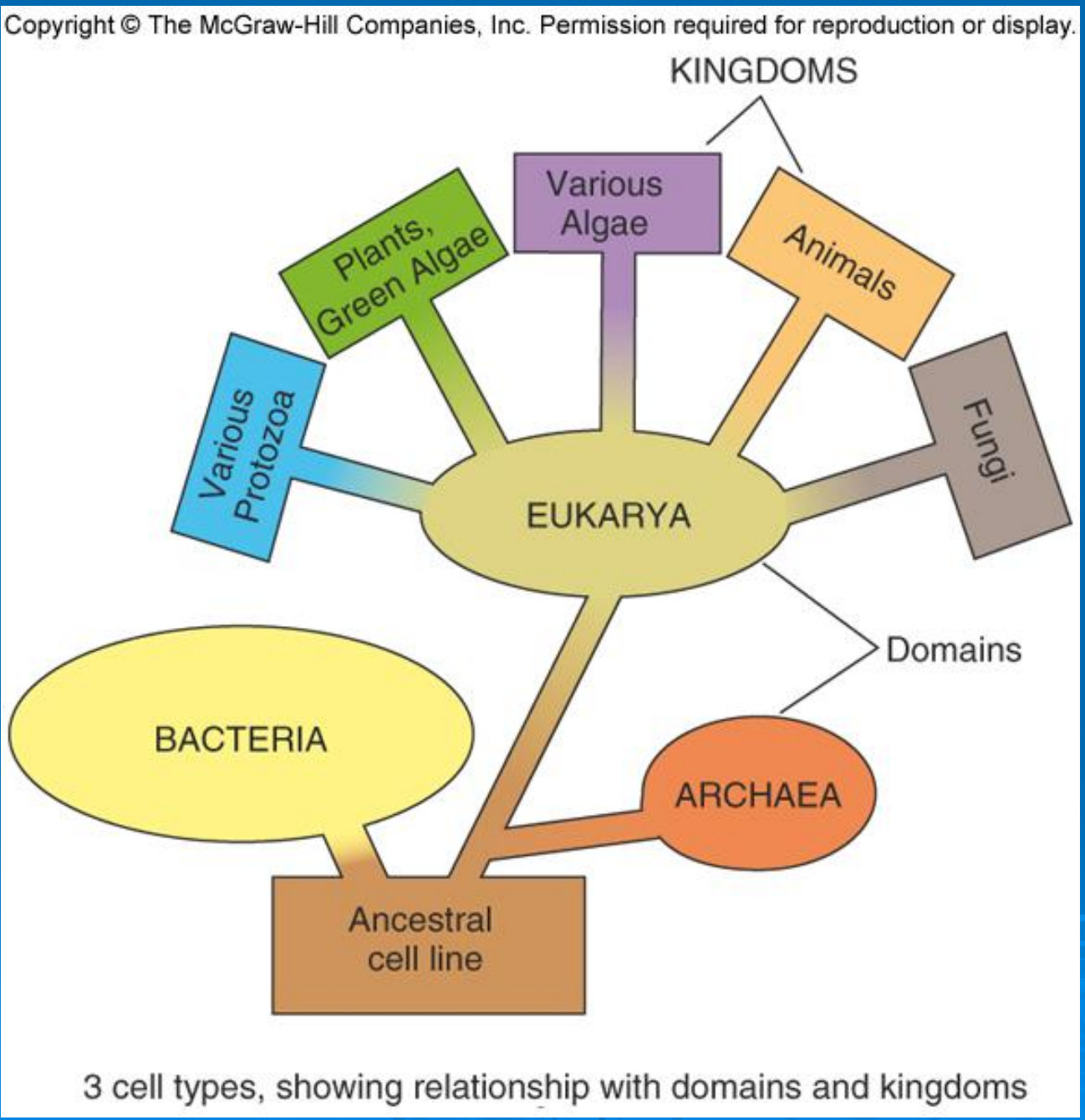


Figure 1.13



3 cell types, showing relationship with domains and kingdoms

Figure 1.14