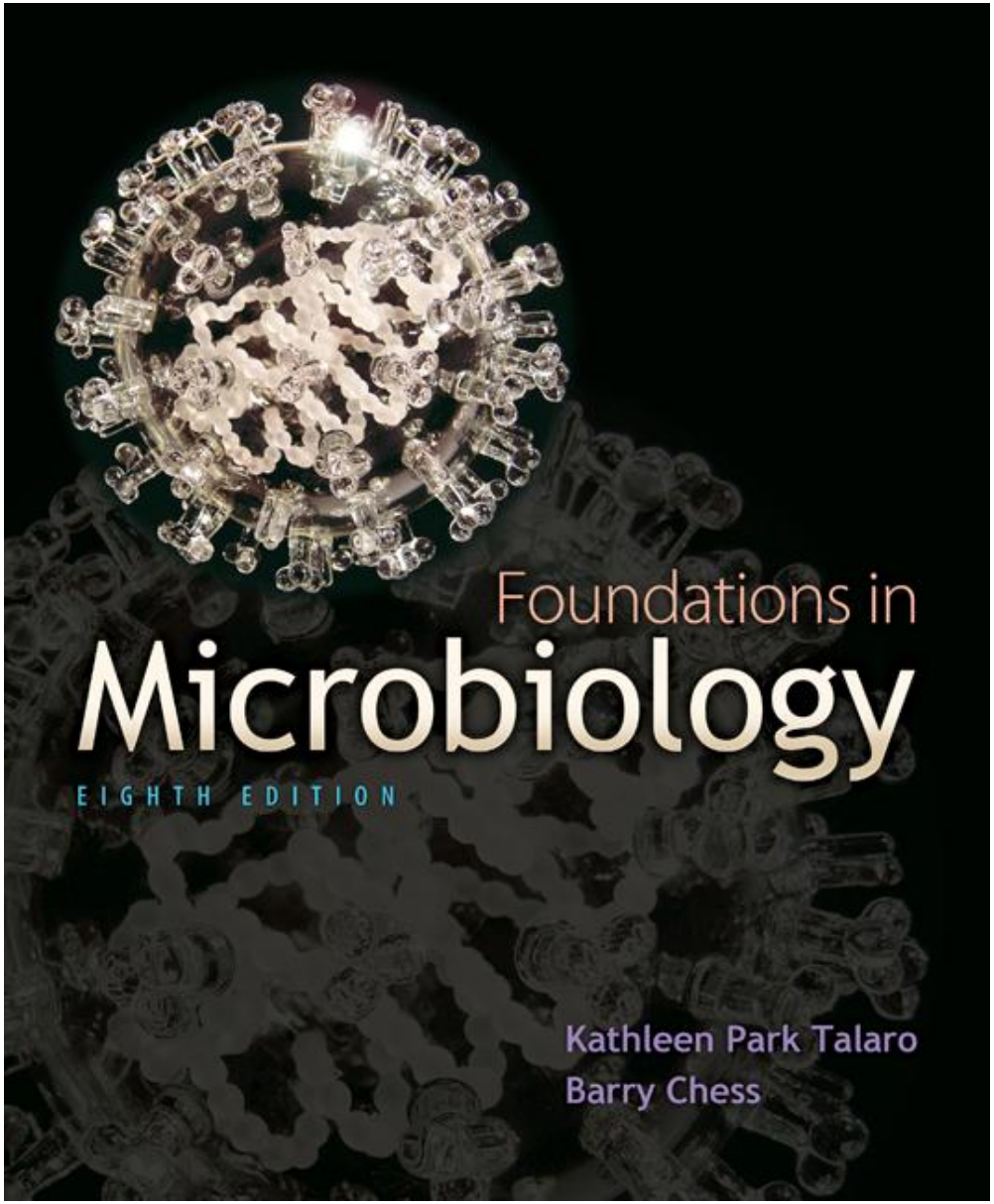
Chapter 1

The Main Themes of Microbiology



1.1 The Scope of Microbiology

- The study of organisms too small to be seen without magnification
- ***microbe***: small; *bios*: life; ubiquitous (everywhere)
- Microorganisms include:
  - Bacteria
  - Viruses
  - Fungi
  - Protozoa
  - Helminths (worms)
  - Algae

Basic and Applied fields of Microbiology

TABLE 1.1 A Sampling of Fields and Occupations in Microbiology

A. Immunology

This branch studies the complex web of protective substances and reactions caused by invading microbes and other harmful entities. It includes such diverse areas as blood testing, vaccination, and allergy (see chapters 15, 16, and 17).

James Gathany/CDC

Figure A A specialist in the CDC special pathogens unit reads a microscopic test to screen for infection that is based on an immune reaction.

B. Public Health Microbiology and Epidemiology

These branches monitor and control the spread of diseases in communities. Some of the institutions charged with this task are the U.S. Public Health Service (USPHS) and the Centers for Disease Control and Prevention (CDC). The CDC collects information and statistics on diseases from around the United States and publishes it in a newsletter, *The Morbidity and Mortality Weekly Report* (see chapter 13).

Photo courtesy of Sartorius Stedim Biotech

Figure B Public health microbiologists examine mice and take samples to determine if they carry the hantavirus, one of the emerging pathogens that concerns the CDC.

C. Biotechnology

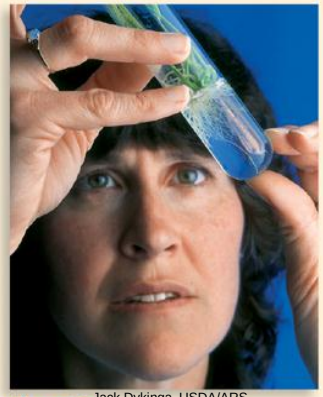
This branch is defined by any process that harnesses the actions of living things to arrive at a desired product, ranging from beer to stem cells. It includes industrial microbiology, which uses microbes to produce and harvest large quantities of such substances as vaccines, vitamins, drugs, and enzymes (see chapters 10 and 27).

CDC

Figure C A biotechnology technician prepares a bioreactor for vaccine production.

D. Genetic Engineering and Recombinant DNA Technology

These interrelated fields involve deliberate alterations of the genetic makeup of organisms to create novel microbes, plants, and animals with unique behavior and physiology. This is a rapidly expanding field that often complements biotechnology (see chapter 10).



Jack Dykinga, USDA/ARS

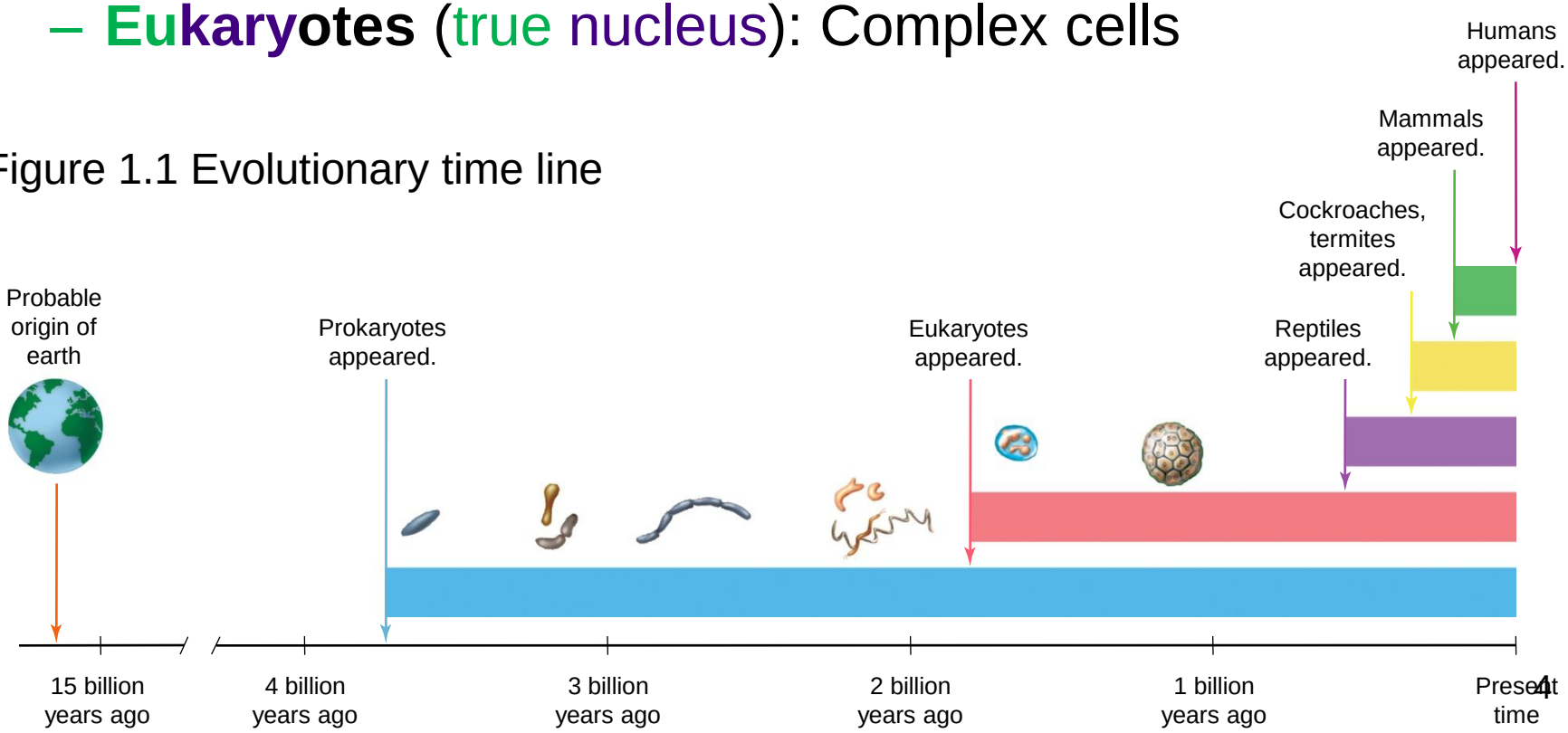
Figure D A geneticist at the US Department of Agriculture examines a wheat plant that has been genetically engineered to resist a fungal pathogen.

The study of microbes established universal concepts concerning life – chemistry, inheritance.

1.2 General Characteristics of Microorganisms and Their Roles in the Earth's Environments

- Bacteria-like organisms have existed on earth for about 3.5 billion years based on fossil records
  - **Prokaryotes** (pre-nucleus): Simple cells, before evolution of the nucleus
  - **Eukaryotes** (true nucleus): Complex cells

Figure 1.1 Evolutionary time line



The Origins of Microorganisms

- Two cell lines (figure 1.2 a)
  - **Prokaryote**: microscopic, unicellular organisms, lack nuclei and membrane-bound organelles
  - **Eukaryote**: unicellular (microscopic) and multicellular, nucleus and membrane-bound organelles
- **Viruses** - *acellular*, parasitic particles composed of a nucleic acid and protein (figure 1.2 b)

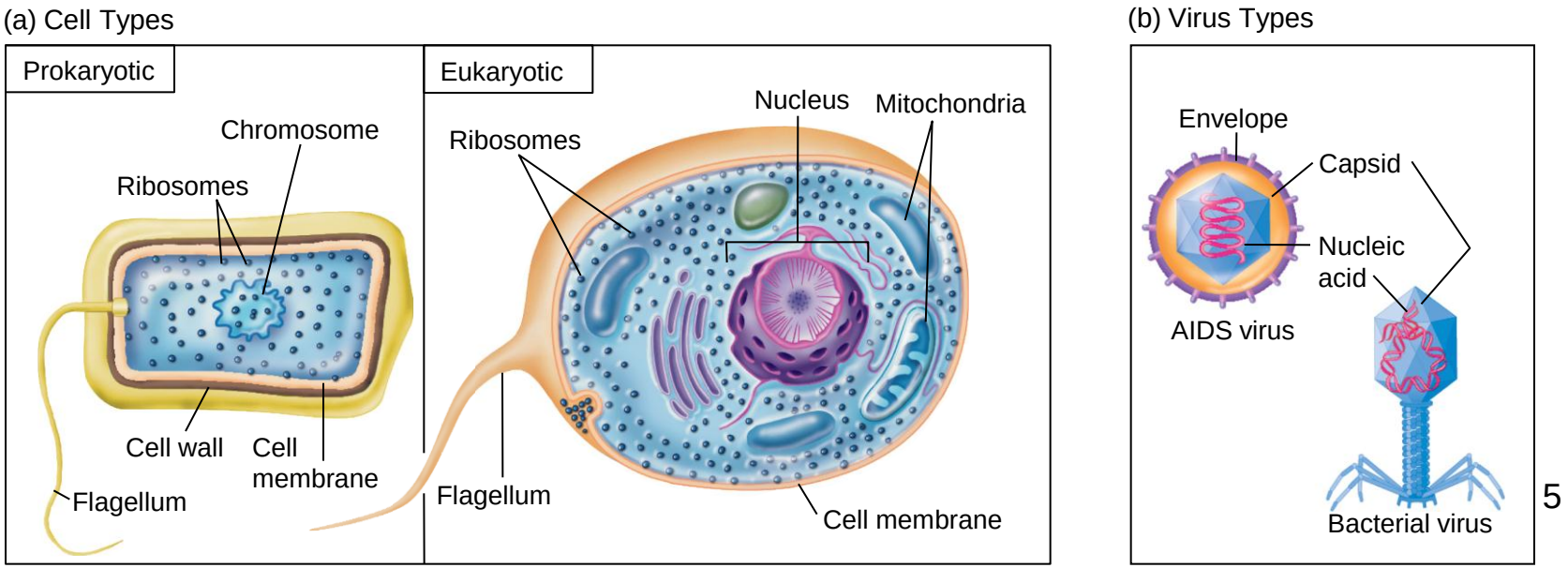
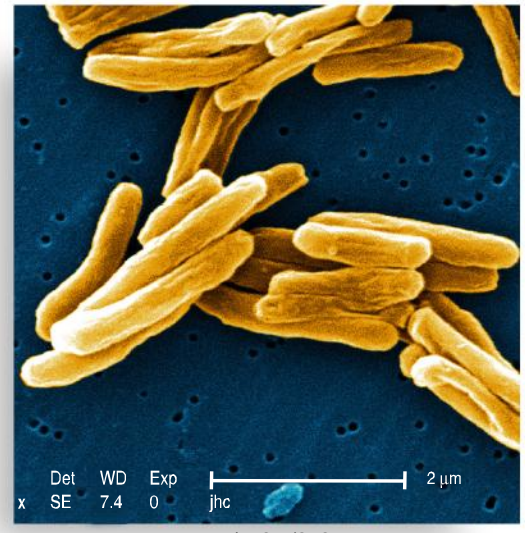
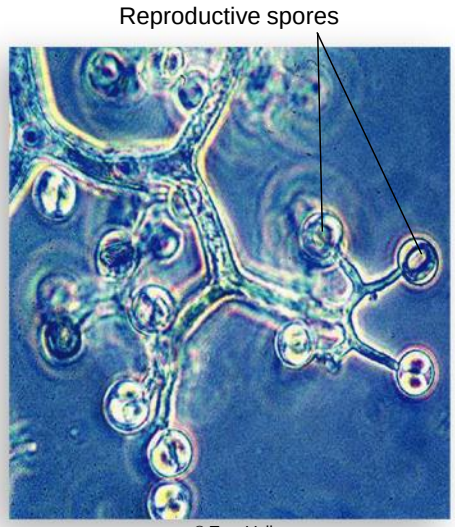


Figure 1.3 - Microbial Diversity: 6 Types of Microbes



Janice Carr/CDC

Bacteria: *Mycobacterium tuberculosis,* a rod-shaped cell (15,500x).



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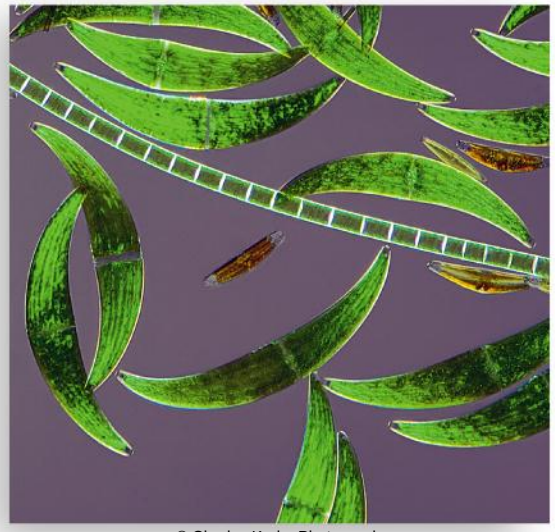
Fungi: *Thamnidium*, a filamentous fungus (400x)



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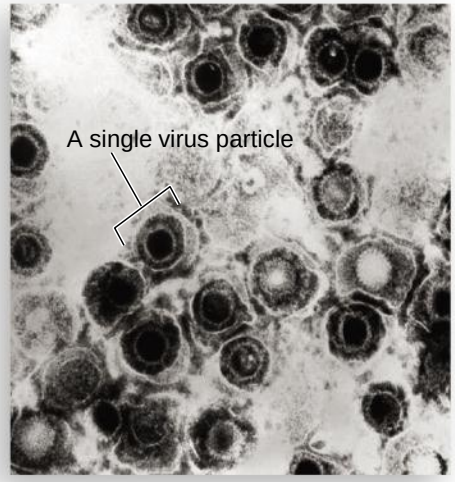
Algae: desmids, *Spirogyra* filament, and diatoms (golden cells) (500x).



CDC

Virus: *Herpes simplex*, cause of cold sores (100,000x).

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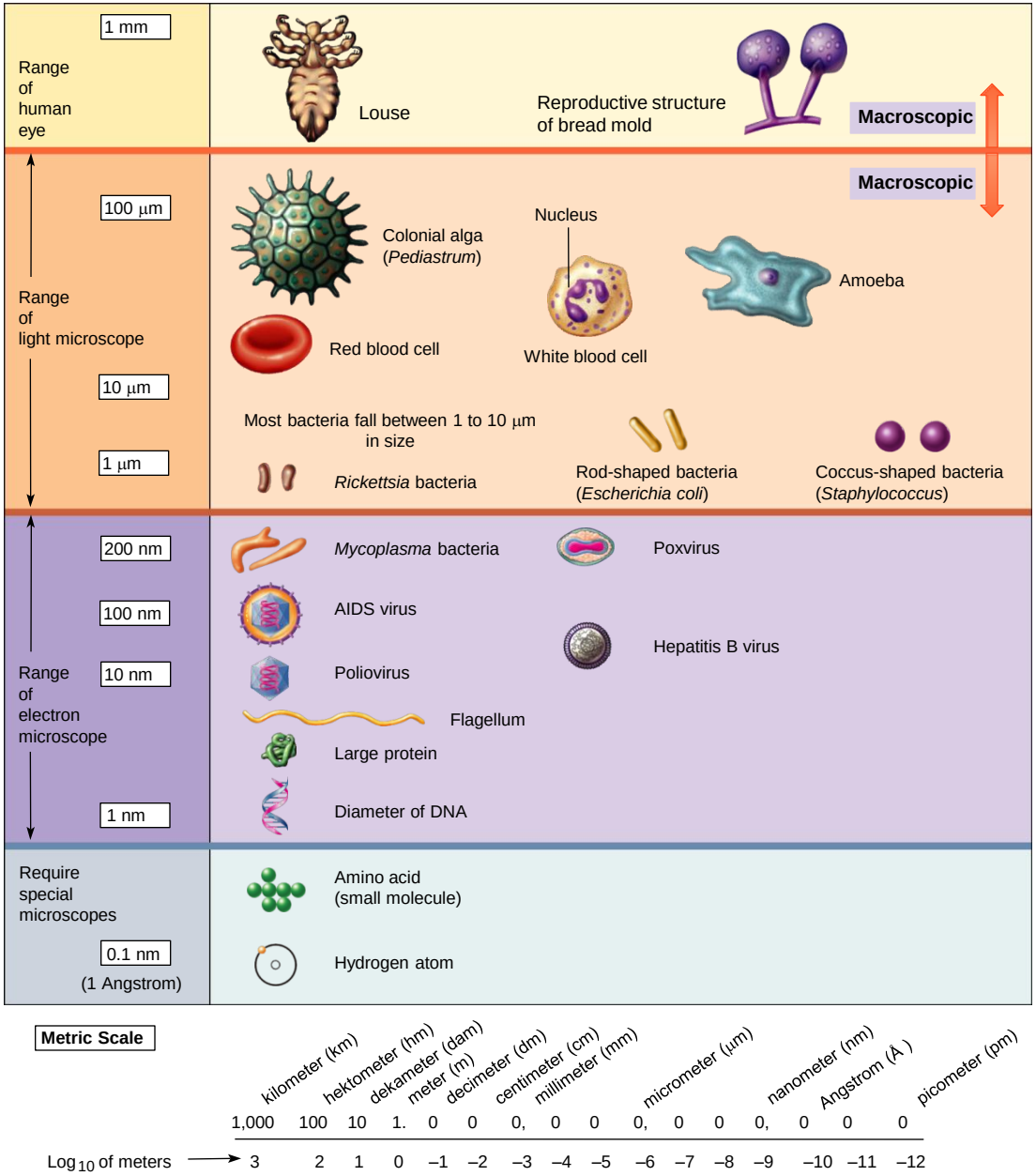
Protozoa: A pair of Vorticella (500x), stalked cells that feed by means of a whirling row of cilia.

CDC

Helminths: Cysts of the parasitic roundworm, *Trichinella spiralis* (250x) embedded in muscle.

Figure 1.4 The Size of Things



Microbial Involvement in Energy and Nutrient Flow

- The flow of energy and food through the earth's ecosystems
  - **Photosynthesis**: Light fueled conversion of carbon dioxide to organic material, plants and algae
  - **Decomposition**: Breakdown of dead matter and wastes into simple compounds, fungi and bacteria
  - **Symbionts**: Organisms that live in partnerships with other living things, beneficial or parasitic.

(a) ©Kathy Park Talaro ©www.microbiological-garden.net

(b) ©Kathy Park Talaro ©University of Adelaide, Australia - Dr. David Ellis

(c) ©Peter Doran/University of Illinois, Chicago Image courtesy of the Priscu Research Group, Montana State University, Bozeman

1.3 Human Use of Microorganisms

- **Biotechnology**: Production of foods, drugs, and vaccines using living organisms

© El Paso Times

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- **Genetic engineering**: Manipulating the genes of organisms to make new products

- **Bioremediation:** Using living organisms to remedy an environmental problem

Courtesy: Pacific Northwest National Laboratory

Courtesy: Pacific Northwest National Laboratory

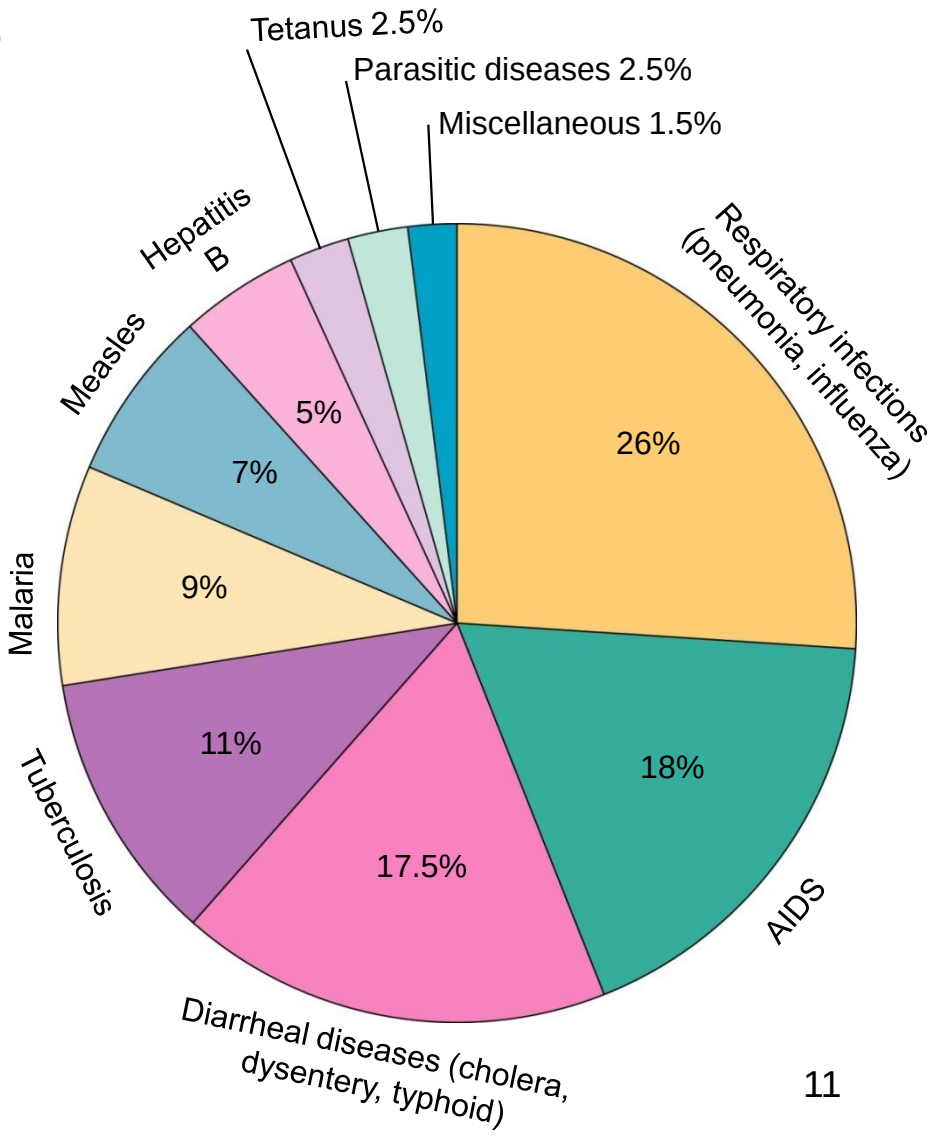
1.4 Microbial Roles in Infectious Diseases

- Majority of microbes live a free existence and are relatively harmless and often beneficial, yet,

- Some microorganisms have close associations with other organisms
  - **Parasites** live on or in the body of another organism called the **host** and it damages the host.
  - Another term for that can be used to specify this type of microbe is **pathogen,** an organism that causes disease.

Figure 1.7Worldwide infectious disease statistics

- **Pathogens**: Microbes that do harm
- Nearly 2,000 different microbes cause diseases
- 10 billion new infections/year worldwide
- 12 million deaths from infections/year worldwide



Top Causes of Death in the United States and Worldwide

TABLE 1.2 Top Causes of Death—All Diseases

United States	No. of Deaths	Worldwide	No. of Deaths
1. Heart disease	696,950	1. Heart disease	8.12 million
2. Cancer	557,270	2. Stroke	5.51 million
3. Stroke	162,670	3. Respiratory infection	3.88 million
4. Chronic lower respiratory disease	124,800	4. Cancer	3.33 million
5. Unintentional injury (accidents)	106,740	5. HIV/AIDS	2.78 million
6. Diabetes	73,250	6. Chronic lower respiratory disease	2.75 million
7. Influenza and pneumonia*	65,680	7. Diarrheal disease	1.80 million
8. Alzheimer disease	58,870	8. Tuberculosis	1.57 million
9. Kidney problems	40,970	9. Malaria	1.27 million
10. Septicemia (bloodstream infection)	33,865	10. Accidents	1.19 million

*Diseases in red are those most clearly caused by microorganisms, although cancer and other diseases may be associated with infections.

1.5 Historical Foundations of Microbiology

- Thousands of microbiologists over 300 years (mid-1600's – today)

- Prominent discoveries include:
  - Microscopy
  - Scientific method
  - Development of medical microbiology
  - Microbiology techniques

Early Concepts:

- **Spontaneous Generation** is an early belief that some forms of life could arise from vital forces present in nonliving or decomposing matter (flies from manure, etc.) (See **Insight 1.2**)

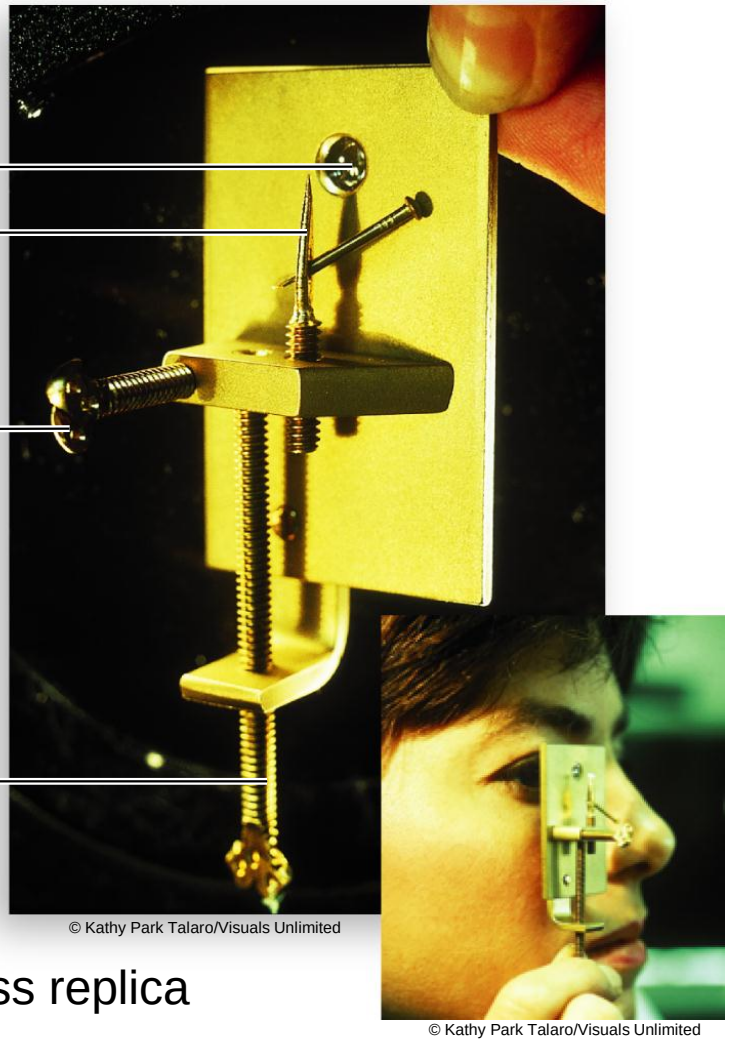
- Louis Pasteur eventually disproved spontaneous generation and proved the **Theory of Biogenesis** - the idea that living things can only arise from other living things, Swan-neck flask experiment

Antonie van Leeuwenhoek (1632-1723)

© Bettmann/Corbis

- First to observe living microbes, developed the microscope
- Single-lens magnified up to 300X

Figure 1.9 Leeuwenhoek's Work



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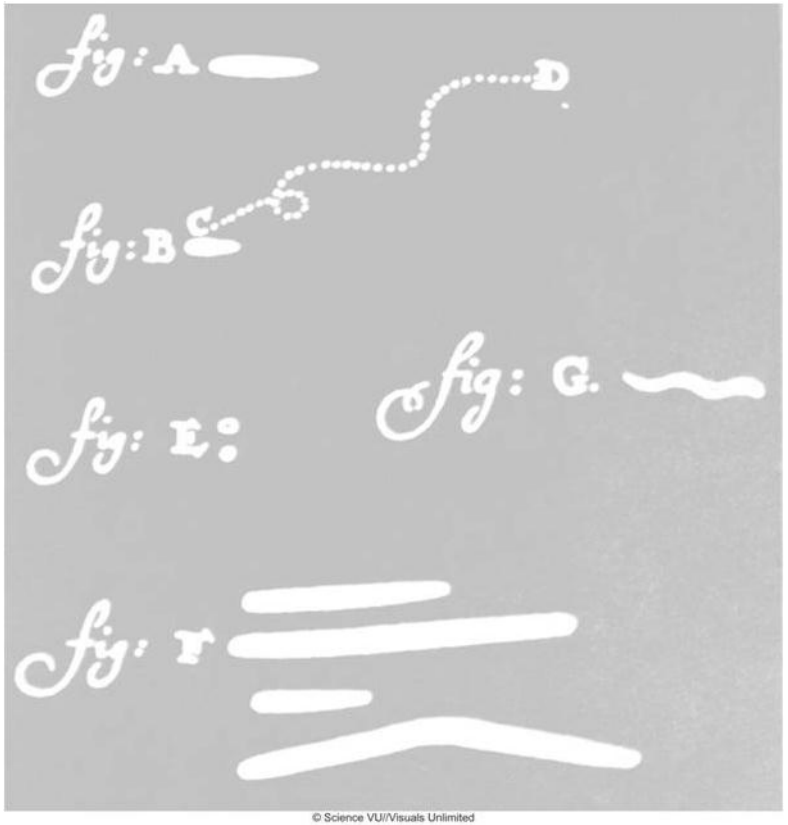
a. A brass replica



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b. Examples of drawings by Leeuwenhoek

The Establishment of the Scientific Method

- Approach taken by scientists to explain a certain natural phenomenon
- Form a **hypothesis** - a tentative explanation that can be supported or refuted
  - Deductive approach "If…, then…."
- A lengthy process of experimentation, analysis, and testing either supports or refutes the hypothesis
- Results must be published and repeated by other investigators.
- If hypothesis is supported by a growing body of evidence and survives rigorous scrutiny, it moves to the next level of confidence - it becomes a **theory*.***
- If evidence of a theory is so compelling that the next level of confidence is reached, it becomes a **Law** or **principle*.***

The Discovery of Spores and Sterilization

- John Tyndall and Ferdinand Cohn each demonstrated the presence of heat resistant forms of some microbes.
  - Cohn determined these forms to be heat-resistant bacterial **endospores.** (Most microbes are easily killed by heat.)

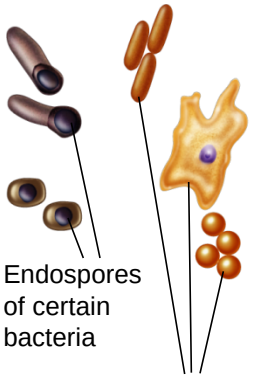
- **Sterility** (**sterile**) requires the elimination of all life forms including endospores and viruses.

Figure 1.10 Using the Scientific Method to Investigate Bacterial Endospores

Start with a *hypothesis*; *predict* an expectation; *test* (experiment); *theory*, has been thoroughly tested

Hypothesis

Bacterial endospores are the most resistant of all cells on earth.



Endospores of certain bacteria

Cells without endospores are ordinary bacteria, fungi, animal cells.

Predictions

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

Testing

Compare endospore formers to non-endospore microbes.

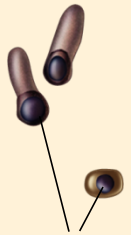
	Survival of endospore former	Survival of non-endospore former
☐ temperature (boiling)	+	–/+*
☐ radiation (ultraviolet)	+	–
☐ lack of water (drying)	+	–/+
☐ chemicals (disinfectants)	+	–/+

*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 cells consistently capable of surviving a wide range of destructive environmental conditions. In order to sterilize, these cells must be eliminated.



Endospores

The Development of Aseptic Techniques

- The human body is a source of infection – observations (mid-late 1800's):
  - **Dr. Oliver Wendell Holmes**: observed that mothers of home births had fewer infections than those who gave birth in hospitals
  - **Dr. Ignaz Semmelweis**: correlated infections with physicians coming directly from the autopsy room to the maternity ward
  - **Joseph Lister**: introduced **aseptic techniques** to reduce microbes in medical settings and prevent wound infections
    - Involved disinfection of hands using chemicals prior to surgery
    - Use of heat for sterilization

The Discovery of Pathogens and the Germ Theory of Disease

- Many diseases are caused by the growth of microbes in the body *and not* by sins, bad character, or poverty, etc.

- Two major contributors, founders of microbiology:

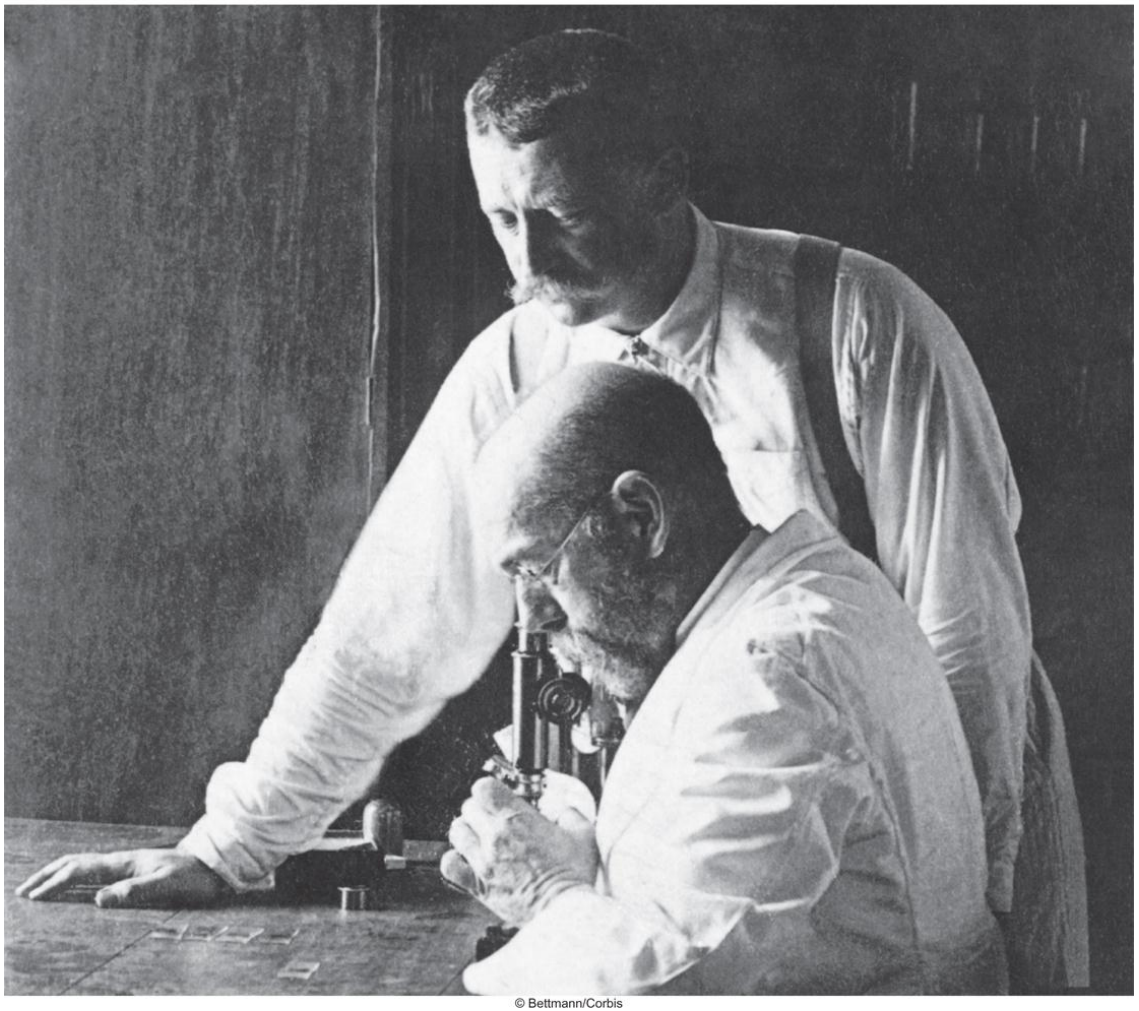
  Louis Pasteur and **Robert Koch**

  - both introduced techniques that are still used today

Louis Pasteur (1822-1895)

- Showed microbes caused fermentation and spoilage
- Disproved spontaneous generation of microorganisms (Insight 1.2)
- Developed pasteurization
- Demonstrated what is now known as Germ Theory of Disease

Robert Koch (1843-1910)



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- Established **Koch's postulates** - a sequence of experimental steps that verified the germ theory (one organism = one disease)
- Identified cause of anthrax, TB, and cholera
- Developed pure culture methods

1.6 Taxonomy: Organizing, Classifying, and Naming Microorganisms

- **Taxonomy**: organizing, classifying, and naming living things
  - Formal system originated by Carl von Linné

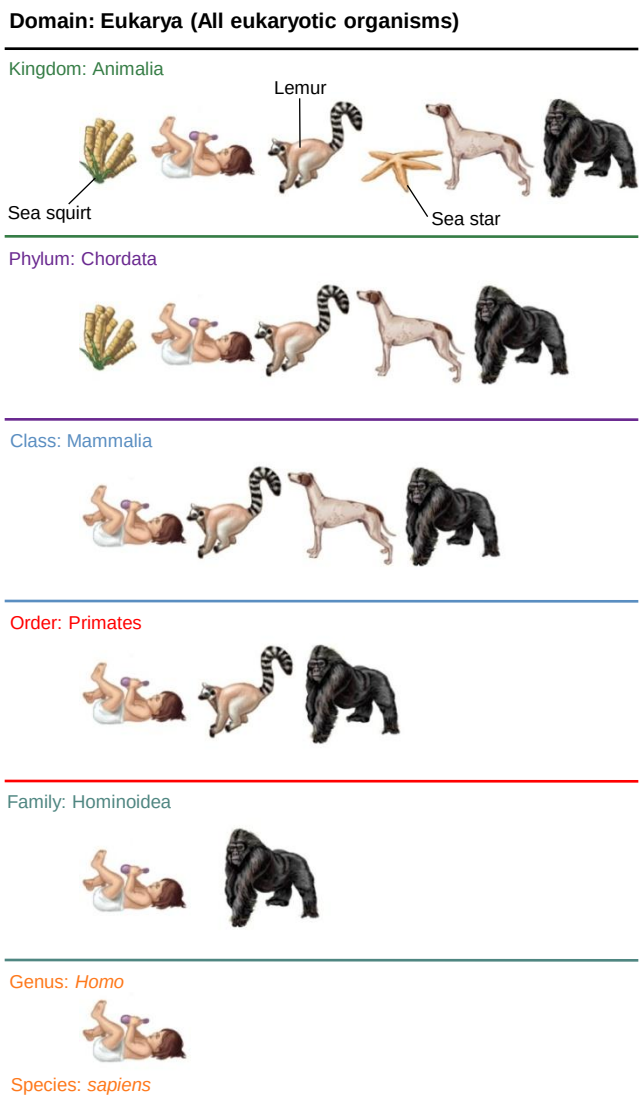
- Concerned with:
  - Classification: orderly arrangement of organisms into groups indicating evolutionary relationships
  - **Nomenclature**: assigning names, genus and species
  - Identification: determining and recording traits of organisms for placement into taxonomic schemes

The Levels of Classification

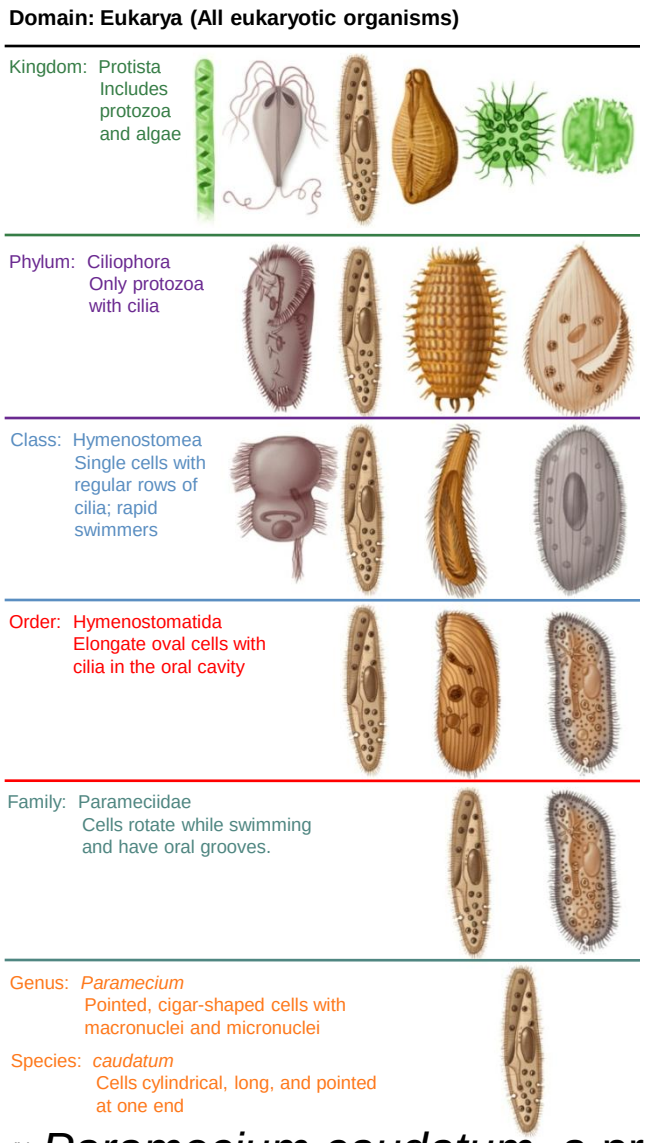
- **Domain** - Archaea, Bacteria, & Eukarya: current method of classification, based on cell type and genome
- **Kingdom** – "old method", mainly based on physical characteristics of organisms
- Phylum or Division
- Class
- Order
- Family
- **Genus**
- **Species**

Used to name the organism

Figure 1.13 Sample Taxonomy



(a) *Homo sapiens*, humans



(b) *Paramecium caudatum*, a protozoan

Assigning Specific Names

- Binomial (two-name system) nomenclature

- Gives each microbe 2 names:
  - **Genus**: capitalized, *Bacillus*
  - **Species**: lowercase, *megaterium*

- Both *italicized* or <u>underlined</u>
  - *Staphylococcus aureus (S. aureus)*
  - <u>Staphylococcus</u> <u>aureus</u> (<u>S.</u> <u>aureus</u>)

  > Many species of bacteria are subdivided into **strains**, a subtype of a species, *E. coli* K12 and *E. coli* O157:H7

- Inspiration for names is extremely varied and often imaginative!

1.7 The Origin and Evolution of Microorganisms

- **Phylogeny**: natural relatedness between groups of organisms, “family tree”

- **Evolution**
  - All new species originate from preexisting species
  - Closely related organism have similar features because they evolved from common ancestral forms

- Evolution usually progresses toward greater complexity

Figure 1.14 Whittaker system of classification – based on cell structure and type, body organization, and nutrition

- **Bacteria** - true bacteria
- **Archaea** - odd bacteria that live in extreme environments, high salt, heat, etc.
- **Eukarya** - have a nucleus and organelles

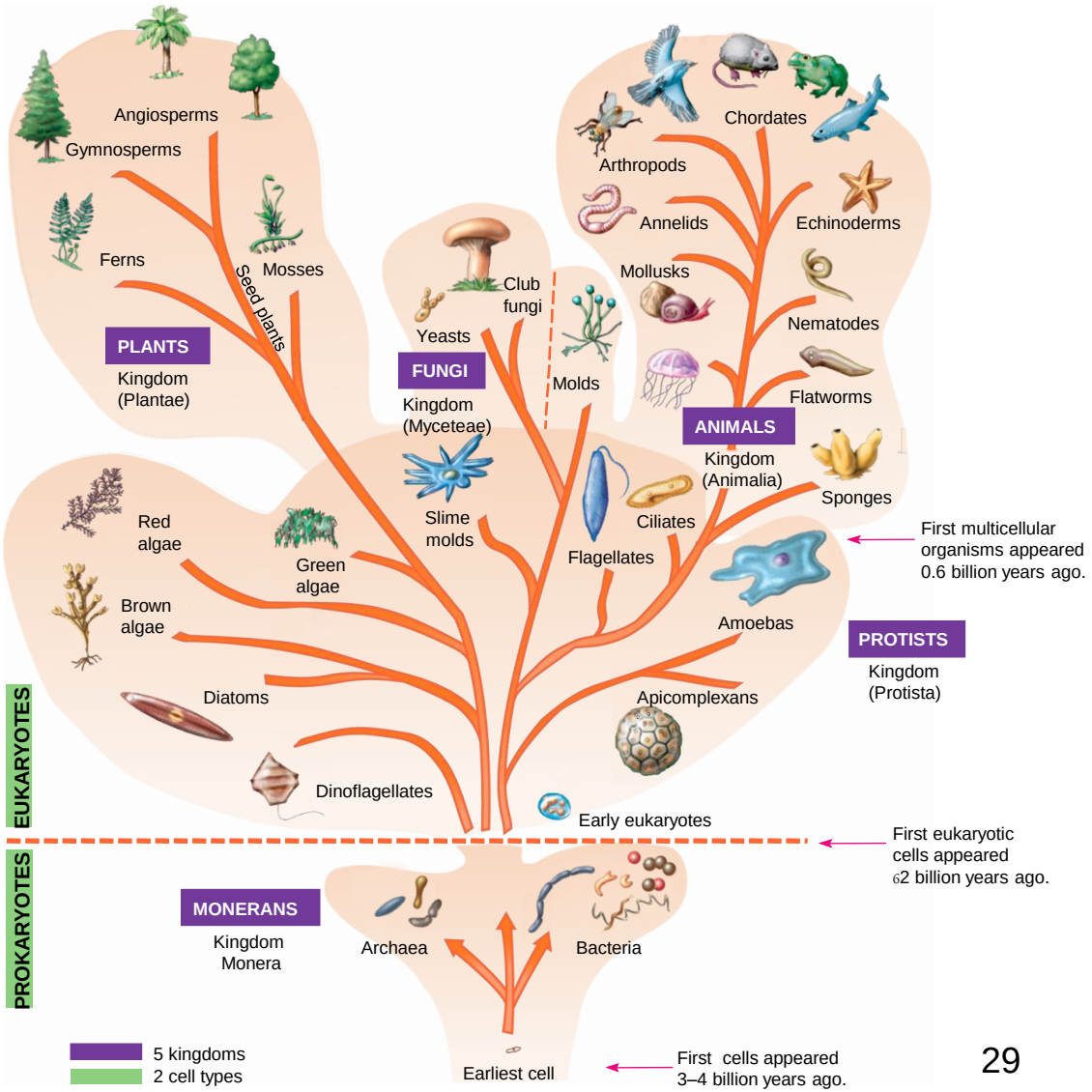


Figure 1.15 Woese-Fox system – three distinct lines