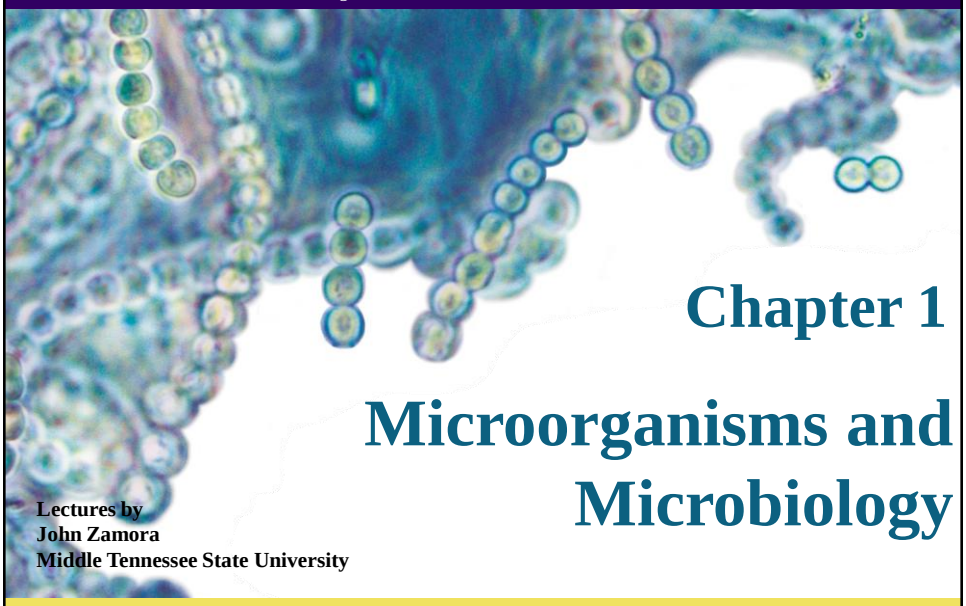
LECTURE PRESENTATIONS

For BROCK BIOLOGY OF MICROORGANISMS, THIRTEENTH EDITION

Michael T. Madigan, John M. Martinko, David A. Stahl, David P. Clark



Chapter 1

Microorganisms and Microbiology

Lectures by
John Zamora
Middle Tennessee State University

I. Introduction to Microbiology

- 1.1 The Science of Microbiology
- 1.2 Microbial Cells
- 1.3 Microorganisms and Their Environments
- 1.4 Evolution and the Extent of Microbial Life
- 1.5 The Impact of Microorganisms on Humans

1.1 The Science of Microbiology

- Microbiology revolves around two themes:
  1. Understanding basic life processes
     - Microbes are excellent models for understanding cellular processes in unicellular *and* multicellular organisms
  2. Applying that knowledge to the benefit of humans
     - Microbes play important roles in medicine, agriculture, and industry

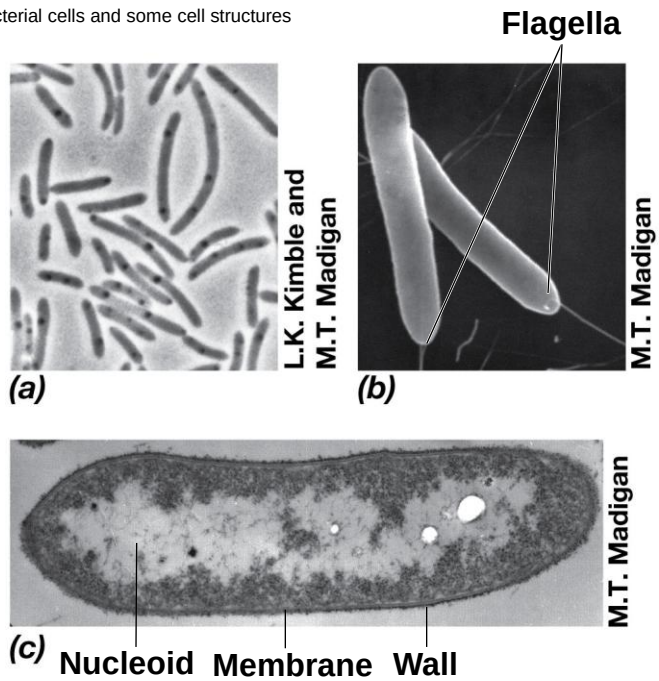
1.1 The Science of Microbiology

- The Importance of Microorganisms
  - Oldest form of life
  - Largest mass of living material on Earth
  - Carry out major processes for biogeochemical cycles
  - Can live in places unsuitable for other organisms
  - Other life forms require microbes to survive

1.2 Microbial Cells

- The Cell
  - A dynamic entity that forms the fundamental unit of life (Figure 1.2)
  - *Cytoplasmic (cell) membrane*
    - Barrier that separates the inside of the cell from the outside environment
  - *Cell wall*
    - Present in most microbes, confers structural strength

Figure 1.2 Bacterial cells and some cell structures



1.2 Microbial Cells

- Characteristics of Living Systems (Figure 1.3)
  - *Metabolism*: chemical transformation of nutrients
  - *Reproduction*: generation of two cells from one
  - *Differentiation*: synthesis of new substances or structures that modify the cell (only in some microbes)
  - *Communication*: generation of, and response to, chemical signals (only in some microbes)
  - *Movement*: via self-propulsion, many forms in microbes
  - *Evolution*: genetic changes in cells that are transferred to offspring

Figure 1.3 The properties of cellular life **(Part 1 of 2)**

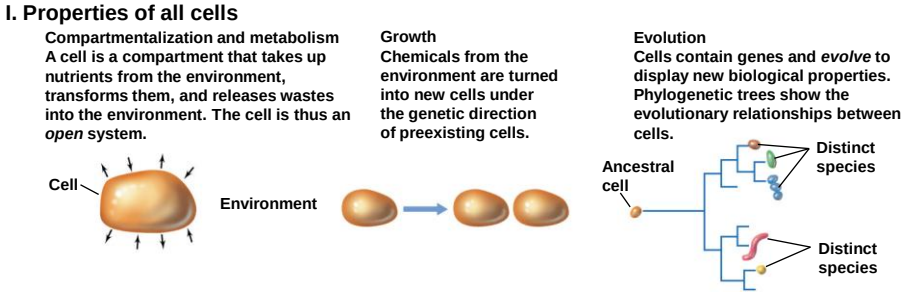
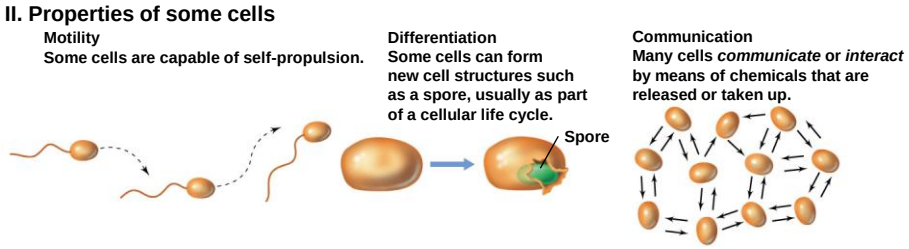


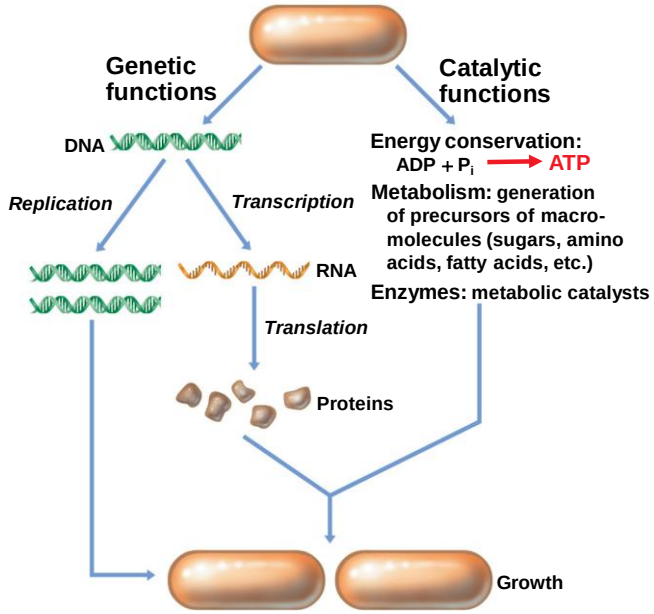
Figure 1.3 The properties of cellular life **(Part 2 of 2)**



1.2 Microbial Cells

- Cells as Catalysts and as Coding Devices
  1. Cells carry out chemical reactions
     - *Enzymes*: protein catalysts of the cell that accelerate chemical reactions (Figure 1.4)
  2. Cells store and process information that is eventually passed on to offspring during reproduction through DNA (deoxyribonucleic acid) and evolution (Figure 1.4)
     - *Transcription*: DNA produces RNA
     - *Translation*: RNA makes protein

Figure 1.4 The catalytic and genetic functions of the cell



1.2 Microbial Cells

- Growth
  - The link between cells as machines and cells as coding devices

1.3 Microorganisms and Their Environments

- Microorganisms exist in nature in populations of interacting assemblages called *microbial communities* (Figure 1.5)
- The environment in which a microbial population lives is its *habitat*
- *Ecosystem* refers to all living organisms plus physical and chemical constituents of their environment
- *Microbial ecology* is the study of microbes in their natural environment

1.3 Microorganisms and Their Environments

- Diversity and abundances of microbes are controlled by resources (nutrients) and environmental conditions (e.g., temp, pH, O_2)
- The activities of microbial communities can affect the chemical and physical properties of their habitats

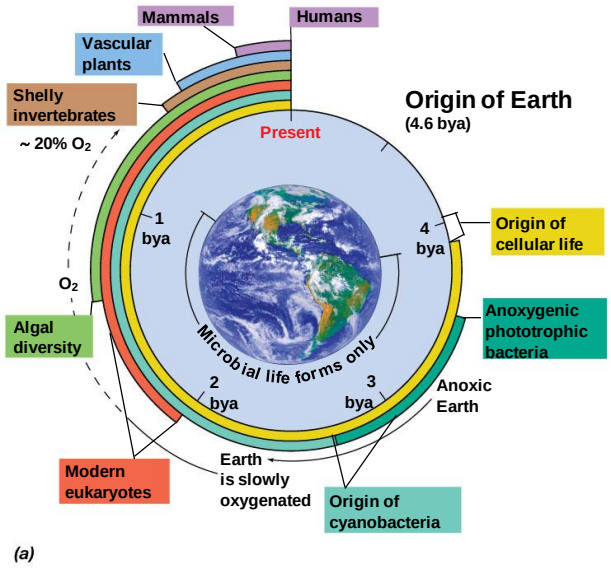
1.3 Microorganisms and Their Environments

- Microbes also interact with their physical and chemical environment
  - Ecosystems greatly influenced (if not controlled) by microbial activities
  - Microorganisms change the chemical and physical properties of their habitats through their activities
    - For example, removal of nutrients from the environment and the excretion of waste products

1.4 Evolution and the Extent of Microbial Life

- Life on Earth through the Ages (Figure 1.6)
  - Earth is 4.6 billion years old
  - First cells appeared between 3.8 and 3.9 billion years ago
  - The atmosphere was anoxic until ~2 billion years ago
    - Metabolisms were exclusively anaerobic until evolution of oxygen-producing phototrophs
  - Life was exclusively microbial until ~1 billion years ago

Figure 1.6 A summary of life on Earth through time and origin of the cellular domains



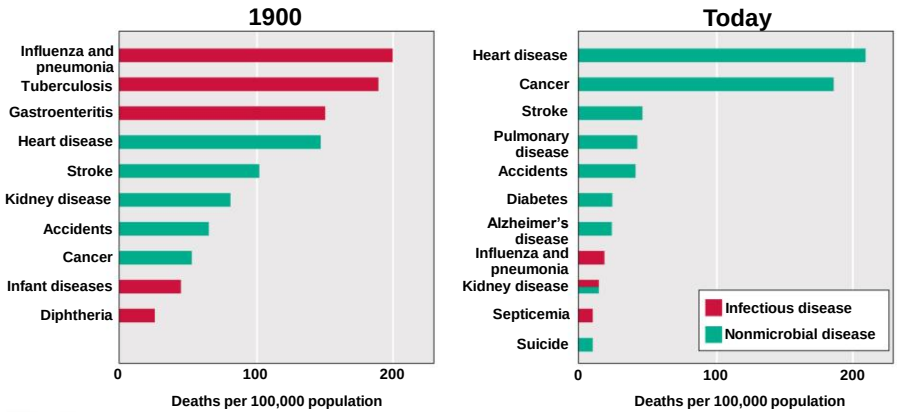
1.4 Evolution and the Extent of Microbial Life

- The Extent of Microbial Life
  - Microbes found in almost every environment imaginable
  - Global estimate of 5×10^{30} cells
    - Most microbial cells are found in oceanic and terrestrial subsurfaces
  - Microbial biomass is significant and cells are key reservoirs of essential nutrients (e.g., C, P, N)

1.5 The Impact of Microorganisms on Humans

- Microorganisms can be both beneficial and harmful to humans
- Emphasis typically on harmful microorganisms (infectious disease agents, or pathogens)
- Many more microorganisms are beneficial than are harmful
- Microorganisms as disease agents
  - Control of infectious disease during last century (Figure 1.8)

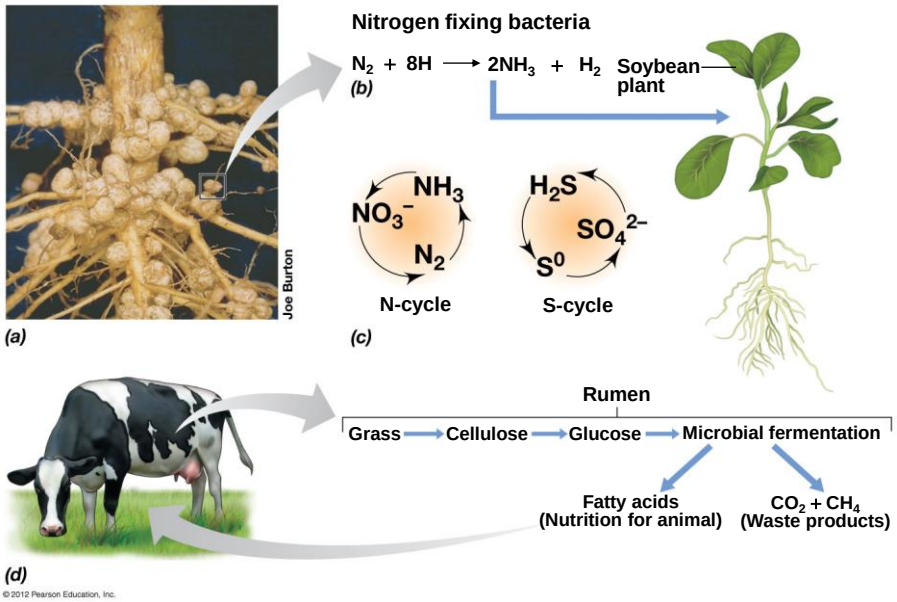
Figure 1.8 Death rates for the leading causes of death in the United States: 1900 and today



1.5 The Impact of Microorganisms on Humans

- Microorganisms and Agriculture
  - Many aspects of agriculture depend on microbial activities (Figure 1.9)
    - Positive impacts
      - nitrogen-fixing bacteria
      - cellulose-degrading microbes in the rumen
      - regeneration of nutrients in soil and water
    - Negative impacts
      - diseases in plants and animals

Figure 1.9 Microorganisms in modern agriculture



1.5 The Impact of Microorganisms on Humans

- Microorganisms and Food
  - Negative impacts
    - Food spoilage by microorganisms requires specialized preservation of many foods
  - Positive impacts
    - Microbial transformations (typically fermentations) yield
      - dairy products (e.g., cheeses, yogurt, buttermilk)
      - other food products (e.g., sauerkraut, pickles, leavened breads, beer)

1.5 The Impact of Microorganisms on Humans

- Microorganisms, Energy, and the Environment (Figure 1.11)
  - The role of microbes in *biofuels* production
    - For example, methane, ethanol, hydrogen
  - The role of microbes in cleaning up pollutants (*bioremediation*)

Figure 1.11 Biofuels

Production of methane

1.5 The Impact of Microorganisms on Humans

- Microorganisms and Their Genetic Resources
  - Exploitation of microbes for production of antibiotics, enzymes, and various chemicals
  - Genetic engineering of microbes to generate products of value to humans, such as insulin (*biotechnology*)

1.5 The Impact of Microorganisms on Humans

- Microbiology as a Career
  - Clinical medicine
  - Research and development – pharmaceutical, chemical/biochemical, biotechnology
  - Microbial monitoring in food and beverage industries, public health, government
- "The role of the infinitely small in nature is infinitely large" – Louis Pasteur

II. Pathways of Discovery in Microbiology

- 1.6 The Historical Roots of Microbiology
- 1.7 Pasteur and the Defeat of Spontaneous Generation
- 1.8 Koch, Infectious Disease, and Pure Culture Microbiology
- 1.9 The Rise of Microbial Diversity
- 1.10 The Modern Era of Microbiology

1.6 The Historical Roots of Microbiology

- Microbiology began with the microscope (Figure 1.12a)
- *Robert Hooke* (1635–1703): the first to describe microbes
  - Illustrated the fruiting structures of molds (Figure 1.12b)
- *Antoni van Leeuwenhoek* (1632–1723): the first to describe bacteria (Figure 1.13)
  - Further progress required development of more powerful microscopes
- *Ferdinand Cohn* (1828–1898): founded the field of bacterial classification and discovered bacterial endospores

Figure 1.12 Robert Hooke and early microscopy

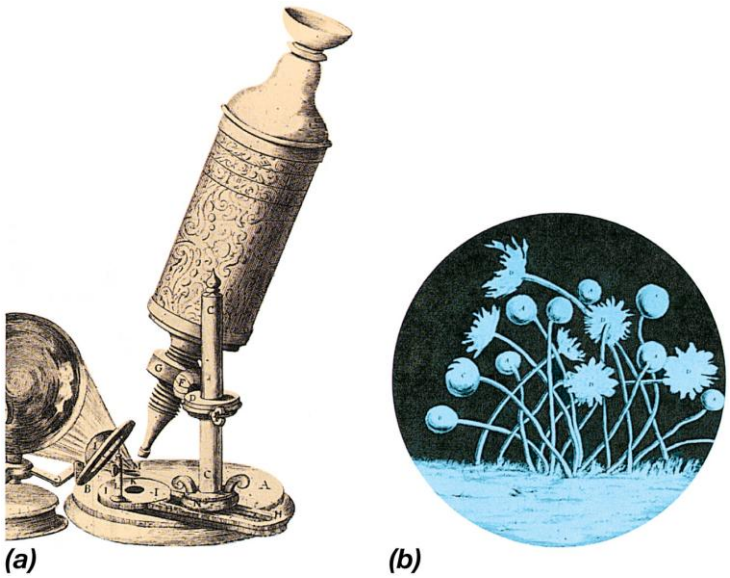
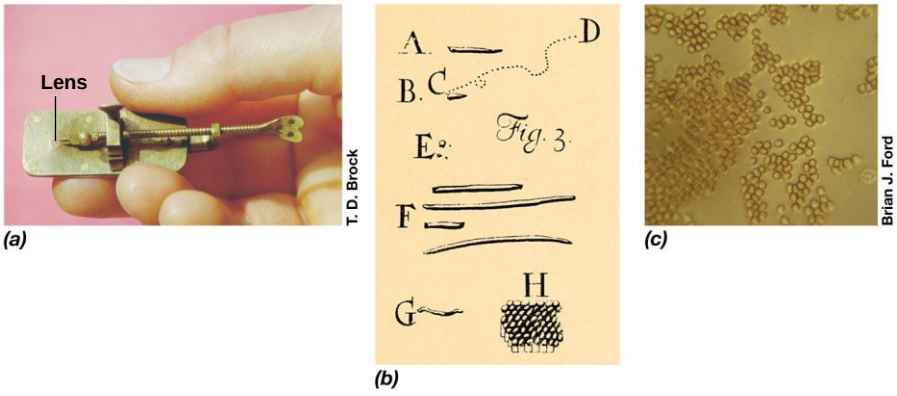


Figure 1.13 The van Leeuwenhoek microscope



1.7 Pasteur and the Defeat of Spontaneous Generation

- *Louis Pasteur* (1822–1895)
  - Discovered that living organisms discriminate between optical isomers
  - Discovered that alcoholic fermentation was a biologically mediated process (originally thought to be purely chemical)
  - Disproved theory of spontaneous generation (Figure 1.16)
    - Led to the development of methods for controlling the growth of microorganisms (aseptic technique)
  - Developed vaccines for anthrax, fowl cholera, and rabies

PLAY Pasteur's Experiment

Figure 1.16a

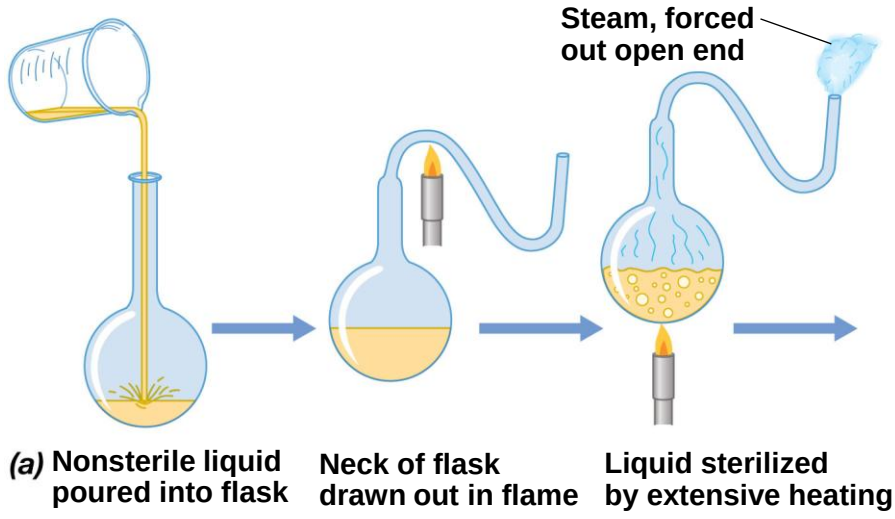


Figure 1.16b

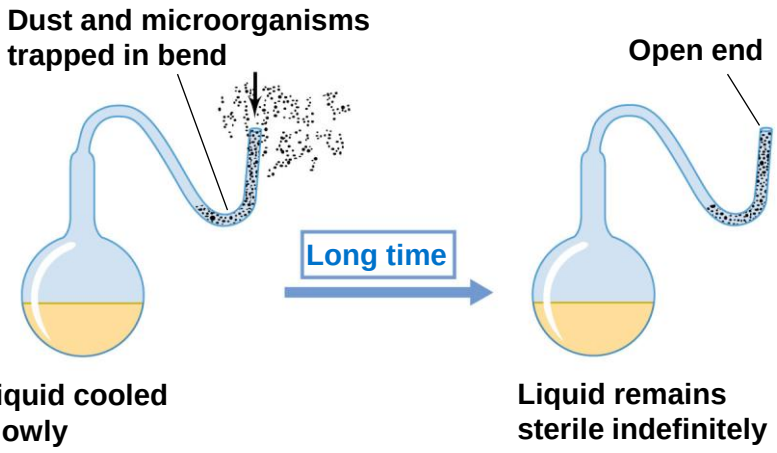
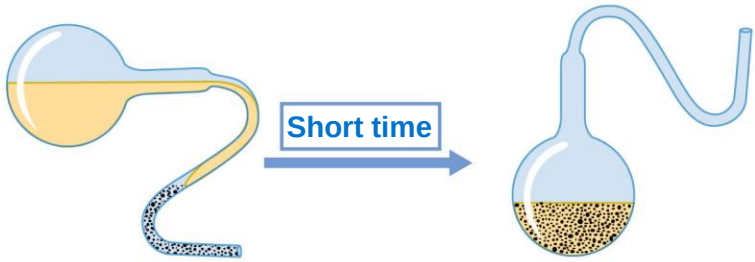


Figure 1.16c



(c) **Flask tipped so microorganism-laden dust contacts sterile liquid**

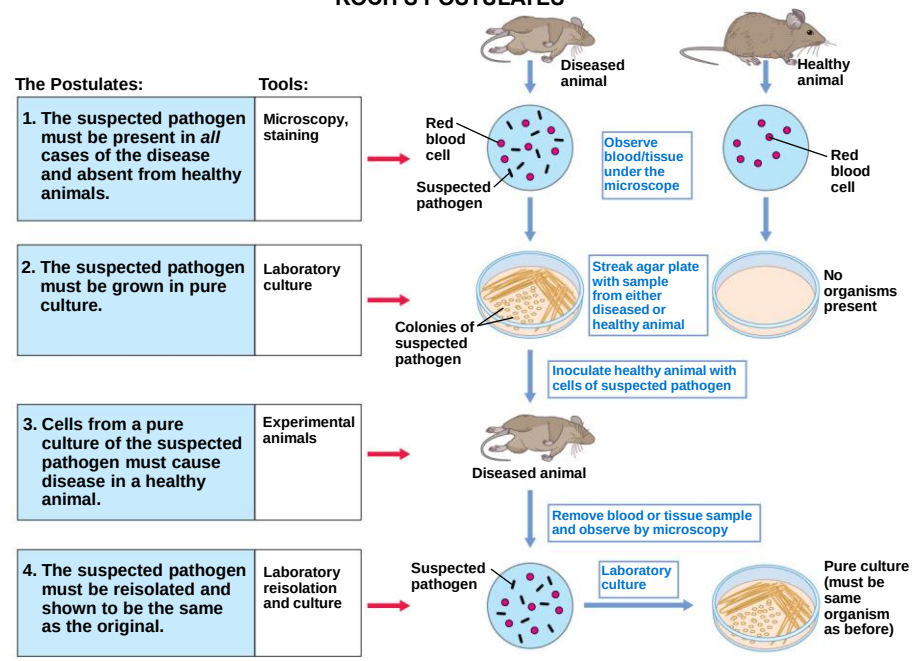
Liquid putrefies

1.8 Koch, Infectious Disease, and the Rise of Pure Cultures

- *Robert Koch* (1843–1910)
  - Demonstrated the link between microbes and infectious diseases
    - Identified causative agents of anthrax and tuberculosis
  - Koch's postulates (Figure 1.19)
  - Developed techniques (solid media) for obtaining *pure cultures* of microbes, some still in existence today
  - Awarded Nobel Prize for Physiology and Medicine in 1905

PLAY Koch's Postulates

Figure 1.19



1.8 Koch, Infectious Disease, and Pure Culture Microbiology

- Koch's Postulates Today
  - Koch's postulates apply for diseases that have an appropriate animal model
  - Remain "gold standard" in medical microbiology, but not always possible to satisfy all postulates for every infectious disease
  - Animal models not always available
    - For example, cholera, rickettsias, chlamydias

1.8 Koch, Infectious Disease, and Pure Culture Microbiology

- Koch and the Rise of Pure Cultures
  - Discovered that using solid media provided a simple way of obtaining pure cultures
  - Began with potato slices, but eventually devised uniform and reproducible nutrient solutions solidified with gelatin and agar

1.9 The Rise of Microbial Diversity

- *Microbial Diversity*
  - Field that focuses on nonmedical aspects of microbiology
  - Roots in 20th century
- Martinus Beijerinck (1851–1931)
  - Developed *enrichment culture technique*
    - Microbes isolated from natural samples in a highly selective fashion by manipulating nutrient and incubation conditions
      - Example: nitrogen-fixing bacteria (Figure 1.21)

1.9 The Rise of Microbial Diversity

- Sergei Winogradsky (1856–1953) and the Concept of Chemolithotrophy
  - Demonstrated that specific bacteria are linked to specific biogeochemical transformations (e.g., S & N cycles)
  - Proposed concept of *chemolithotrophy*
    - Oxidation of inorganic compounds linked to energy conservation

1.10 The Modern Era of Microbiology

- In the 20th century, microbiology developed in two distinct directions:
  - *Applied* and *basic*
- *Molecular microbiology*
  - Fueled by the genomics revolution

1.10 The Modern Era of Microbiology

- Major Subdisciplines of Applied Microbiology
  - *Medical microbiology* and *immunology*
    - Have roots in Koch's work
  - *Agricultural microbiology* and *industrial microbiology*
    - Developed from concepts developed by Beijerinck and Winogradsky
  - *Aquatic microbiology* and *marine microbiology*
    - Developed from advances in *soil microbiology*
  - *Microbial ecology*
    - Emerged in 1960s–70s

1.10 The Modern Era of Microbiology

- Basic Science Subdisciplines in Microbiology
  - *Microbial systematics*
    - The science of grouping and classifying microorganisms
  - *Microbial physiology*
    - Study of the nutrients that microbes require for metabolism and growth and the products that they generate
  - *Cytology*
    - Study of cellular structure

1.10 The Modern Era of Microbiology

- Basic Science Subdisciplines in Microbiology
  - *Microbial biochemistry*
    - Study of microbial enzymes and chemical reactions
  - *Bacterial genetics*
    - Study of heredity and variation in bacteria
  - *Virology*
    - Study of viruses

1.10 The Modern Era of Microbiology

- Molecular Microbiology
  - *Biotechnology*
    - Manipulation of cellular genomes
    - DNA from one organism can be inserted into a bacterium and the proteins encoded by that DNA harvested
  - *Genomics*: study of all of the genetic material (DNA) in living cells
    - *Transcriptomics*: study of RNA patterns
    - *Proteomics*: study of all the proteins produced by cell(s)
    - *Metabolomics*: study of metabolic expression in cells