Introduction to Microbiology

Topics Covered

- Scope of Microbiology
- Importance of Microorganisms
- Characteristics of Microorganisms
- History of Microbiology
- Taxonomy

Scope of Microbiology

Microbiology

- study of organisms too small to be seen by the naked eye.

Microbes or Microorganisms

- commonly referred to as “germs” or “bugs”
- include bacteria, viruses, fungi, algae, protozoa and helminths.
- Prions (“infectious proteins”) are recent addition.

Branches of Study

- **Bacteriology** — study of bacteria
- **Mycology** — study of fungi and yeast
- **Virology** — study of viruses
- **Parasitology** — study of parasitic protozoans and helminths
- **Immunology** — study of the humoral and cellular immune response to disease agents and allergens

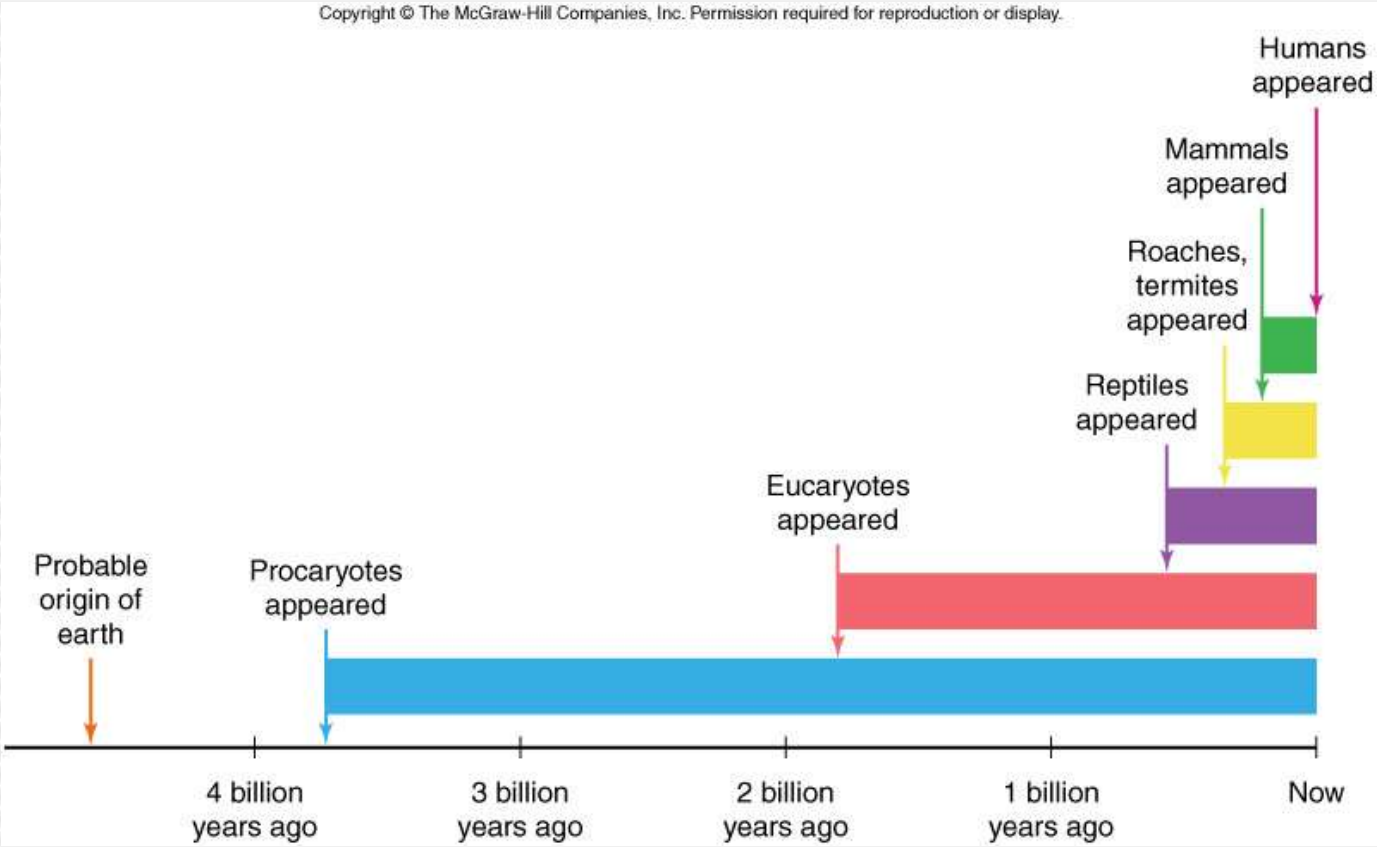
Specializations in Microbiology

- **Epidemiology and Public Health Microbiology**
  distribution and spread of diseases and their control and prevention
- **Food Microbiology**
  use of microbes in the production of food products and drinks
- **Agricultural and Veterinary Microbiology**
  use of microbes to increase crop and livestock yield and control of plant pests and animal diseases
- **Environmental Microbiology**
  study of the beneficial and harmful effects of microbes on the environment

Importance of Microbiology

- First bacteria
- Photosynthesis and decomposition
- Human use of microorganisms
- Infectious diseases

The Progenote



Evolutionary Timeline: Bacteria appeared 3.5 billion years ago

Photosynthetic Microbes

- Microbes are involved in photosynthesis and accounts for >50% of earth's oxygen.
- Also involved in decomposition and nutrient recycling.

Beneficial Uses of Microbes

Extraction of copper from ore

To speed up the process in a biomining lab, scientists use bioleaching. Ores are placed into acid, and then researchers introduce **bacteria** that change the solution so that it dismantles the rock and frees **copper**, in liquid form.

Beneficial Uses of Microbes

Synthesis of drugs, hormones and enzymes

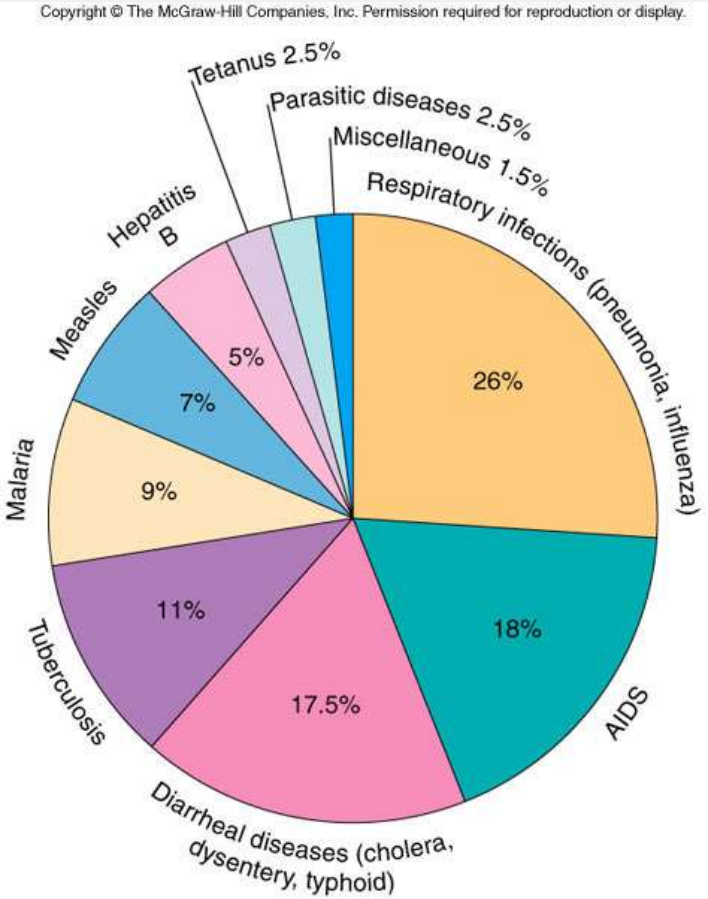
Beneficial Uses of Microbes

Bioremediation is the use of microbes to degrade organic matter in sewage and detoxify pollutants such as oil spills.

Modern Uses of Microbes

- **Biotechnology**, the use of microbes as miniature biochemical factories to produce food and chemicals is centuries old.
- **Genetic engineering** makes use of molecular biology and recombinant DNA techniques as new tools for biotechnology.
- **Gene therapy** replaces missing or defective genes in human cells through genetic engineering.
- **Genetically modified bacteria** are used to protect crops from pests and freezing.

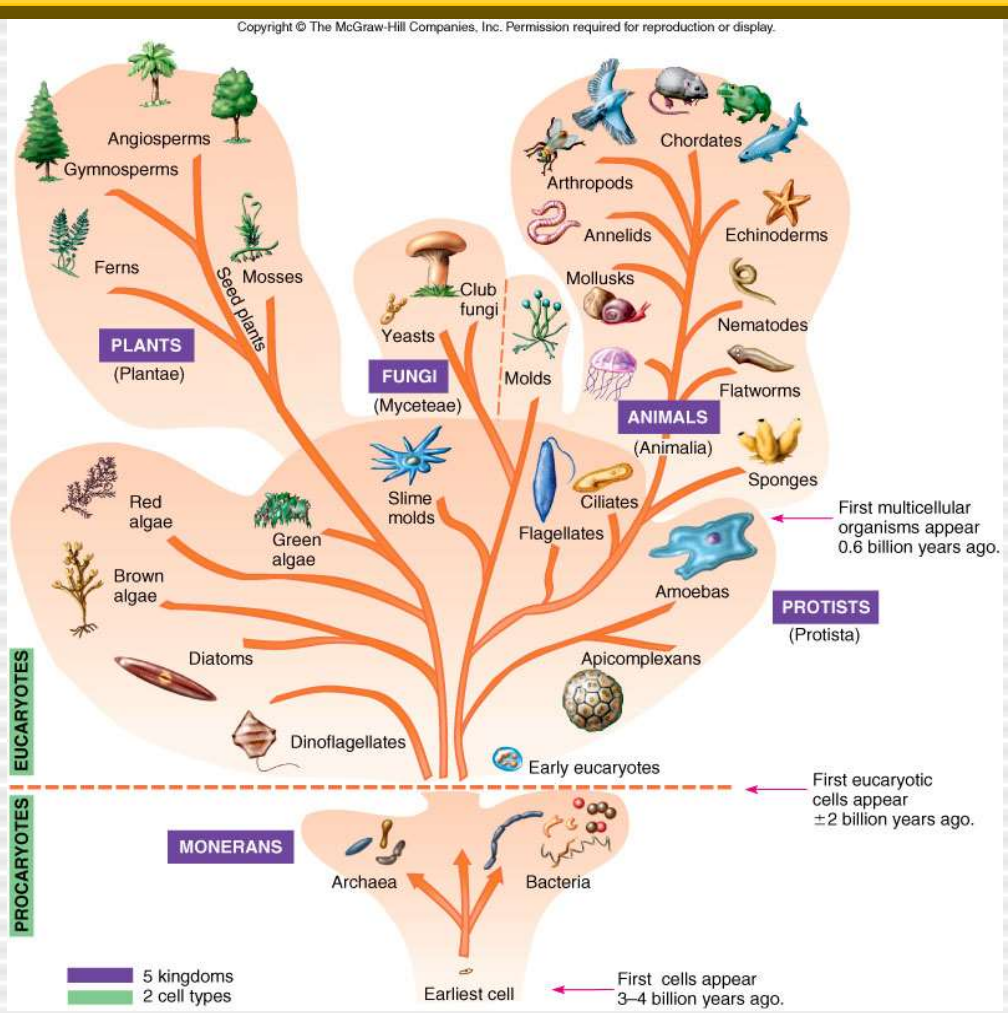
Infectious Diseases



Worldwide infectious disease statistics

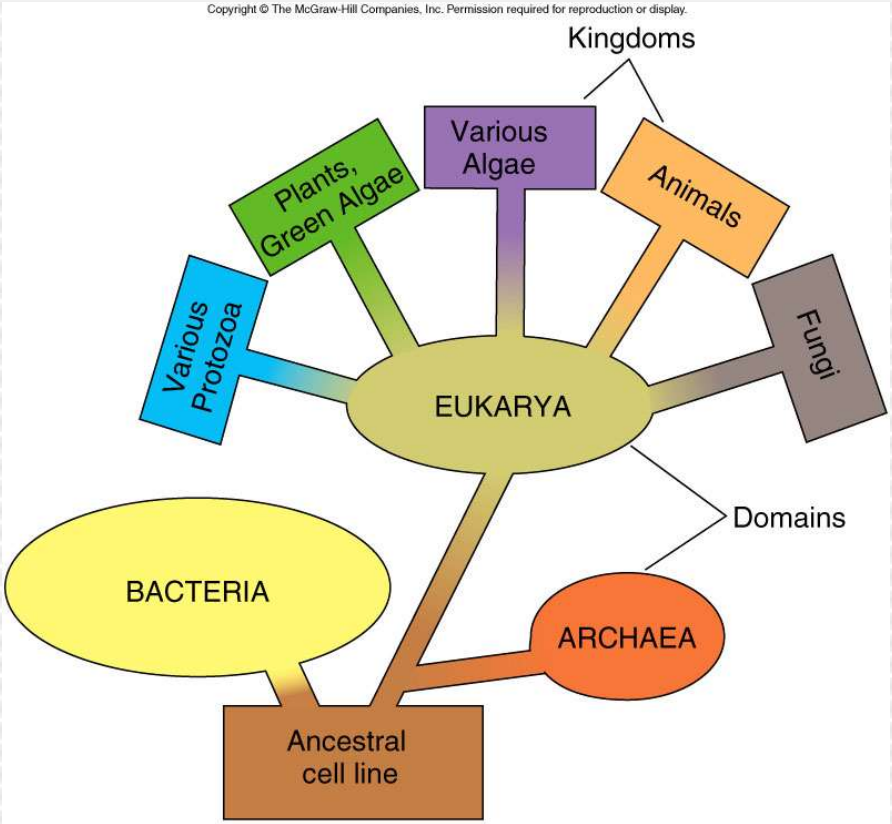
- United States Public Health Service (USPHS) - agency where notifiable diseases are reported
- Centers for Disease Control (CDC)- collects disease data around the U.S. and publishes the MMWR (*Morbidity and Mortality Weekly Report*)
- World Health Organization (WHO)- medical arm of the U.N., monitors diseases worldwide.

Microbial Taxonomy



Traditional Whittaker 5 Kingdom System

Microbial Taxonomy



3 cell types, showing relationship with domains and kingdoms

Woese-Fox 3 Domain System

Nomenclature

- **Linnaeus** introduced the binomial system of scientific nomenclature
- Each organism has two names: the genus and species epithet
- Italicized or underline
- Genus name is capitalized and species in lower case.

Scientific Names

Staphylococcus aureus

describes clustered arrangement of cells and golden yellow color of colonies

Escherichia coli

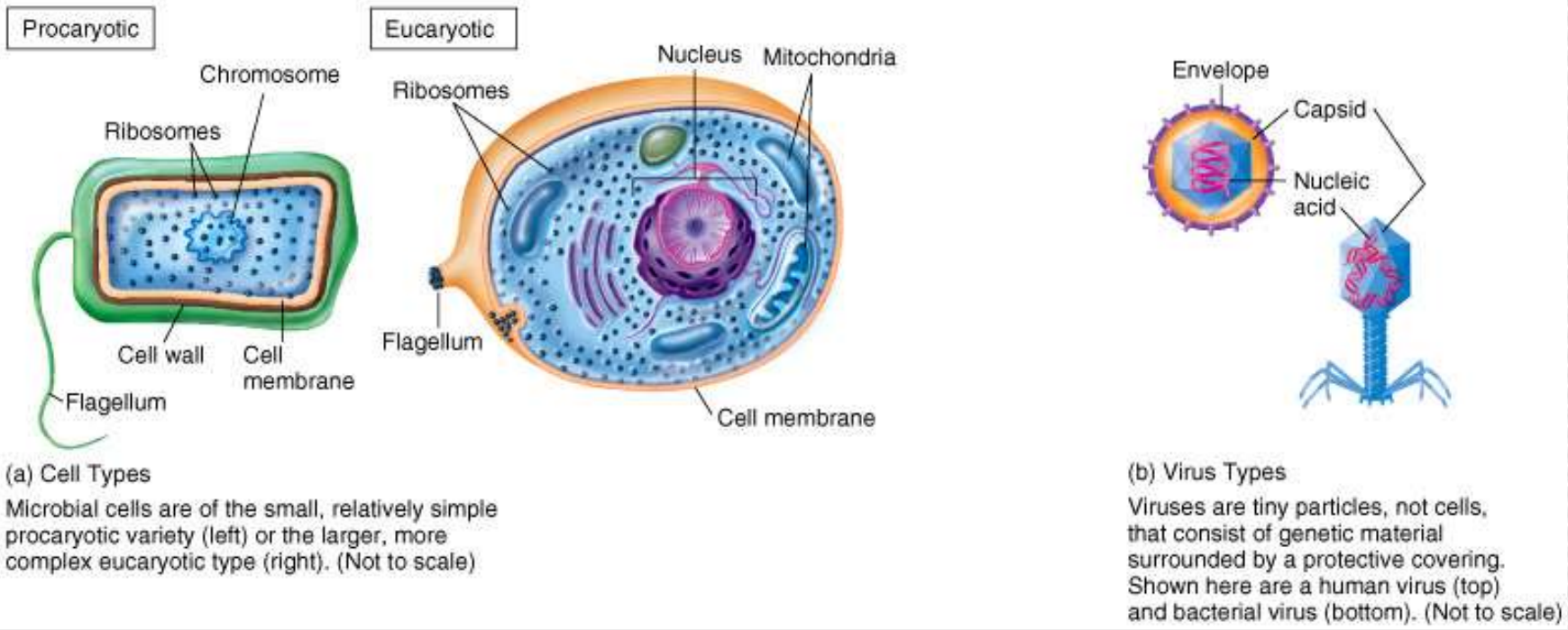
Honors the discoverer, Theodor Escherich and describes its habitat, the colon.

After the first use, scientific names may be abbreviated with the first letter of the genus and full species epithet. (Ex: *E. coli*)

General Characteristics

- Prokaryotes — no nucleus and organelles
- Eukaryotes — membrane bound nucleus and organelles
- Acellular agents — genomes contain either DNA or RNA; newer agent is proteinaceous

Cell Types



(a) Cell Types

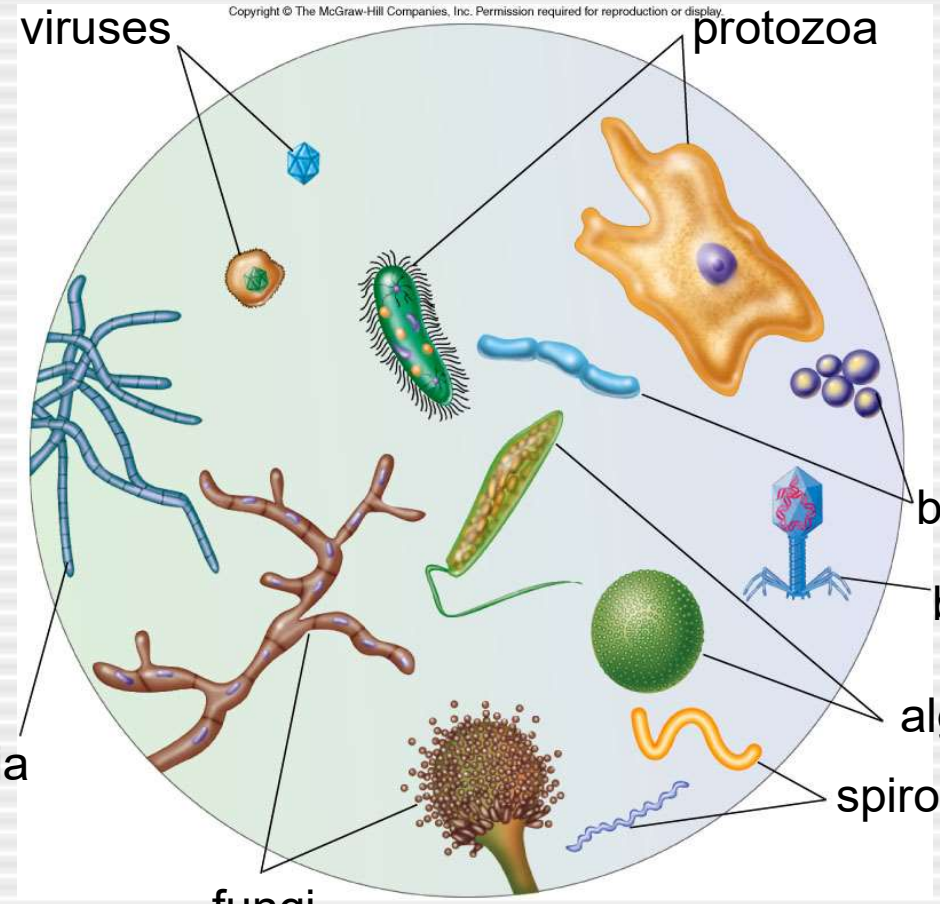
Microbial cells are of the small, relatively simple procaryotic variety (left) or the larger, more complex eucaryotic type (right). (Not to scale)

(b) Virus Types

Viruses are tiny particles, not cells, that consist of genetic material surrounded by a protective covering. Shown here are a human virus (top) and bacterial virus (bottom). (Not to scale)

Comparative cellular structures of microbes

The Microbes



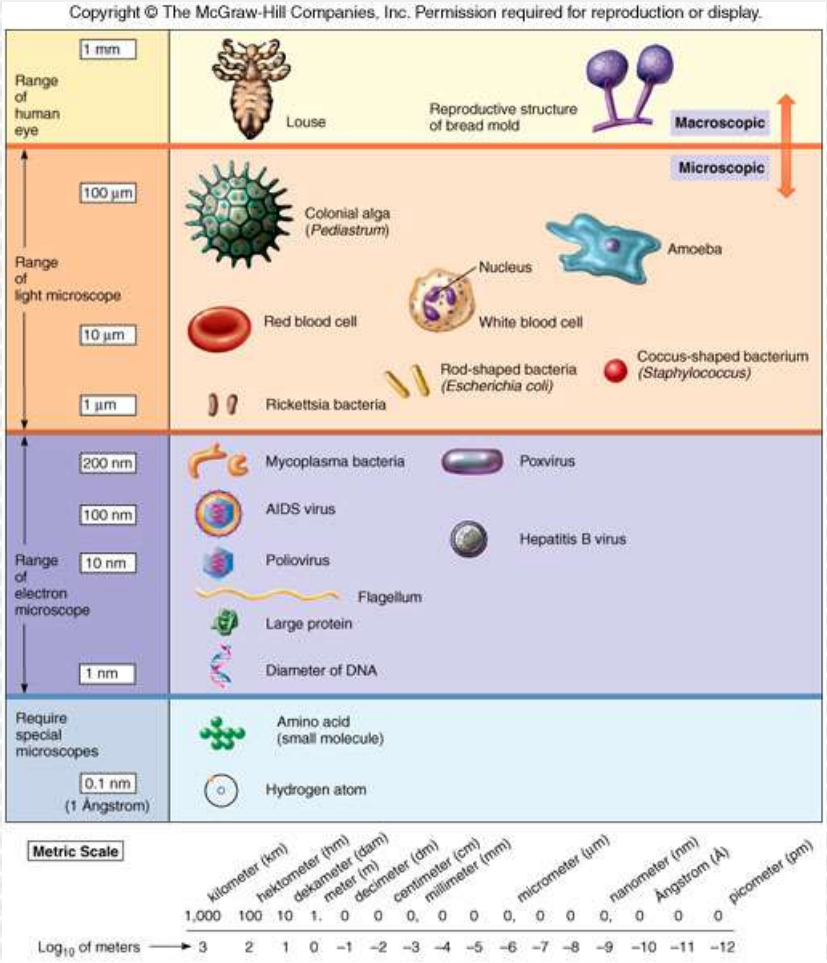
Size of Microbes

Microbes vary in size ranging from 10 **nm** (nanometers) to 100 **mu** (micrometers) to the macroscopic.

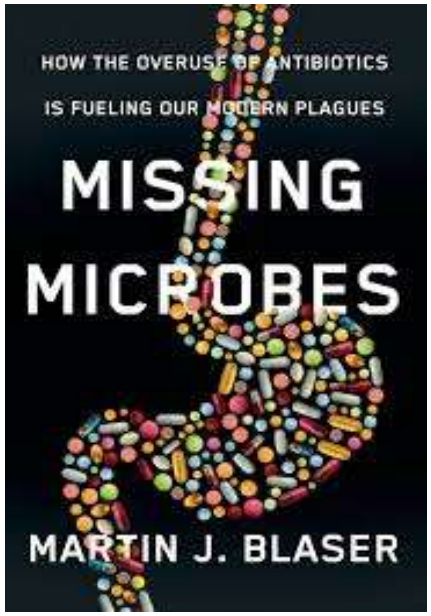
Viruses in **nm** = 10^{-9} **m** (meter)

Bacteria in **um** = 10^{-6} **m**

Helminths in **mm** = 10^{-3} **m**



Types of symbiotic microbe-host relationships



Q: What is the "human microbiome"?

Mutualism * Commensalism * Parasitism

What are the benefits of normal flora?

Benefit to the bacteria = They have a place to eat, survive and multiply.

Benefits to the human =

• Bacteria may produce vitamins (such as B and K), and break down food that host cant normally digest.

• Normal flora protect host against infection by pathogenic organisms:

- take up space, so pathogen has nowhere to set up shop
- may out-compete the invader for available nutrients
- may produce anti-bacterial chemicals (bacteriocins)
- long-term relationship with the human immune system

Image: Arm plate of normal flora, T. Port.

Types of symbiotic microbe-host relationships

Mutualism * Commensalism * Parasitism

- One partner in the relationship benefits. The other neither benefits nor is harmed.

- Pathogens that harm their host.
- Cost to the host can vary from slight to fatal.
- External parasites (ectoparasite) cause *infestation*.
- Internal parasites (endoparasite) cause *infection*.

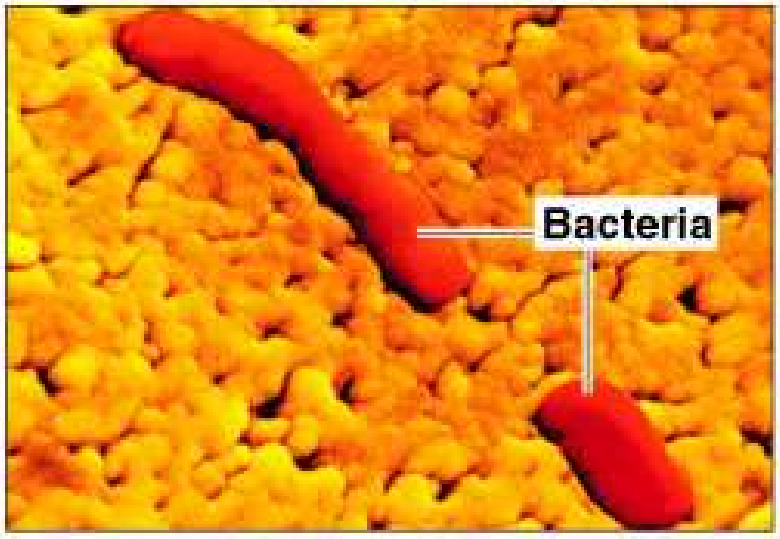
Streptococcus pyogenes, a pathogen that can cause Strep throat, post-partum fever, pneumonia and necrotizing fasciitis.

Image: Blood Agar showing Beta hemolysis from pathogen *Streptococcus pyogenes*, T. Port.

From the Virtual Microbiology Classroom on ScienceProfOnline.com

Bacteria

- Prokaryotes
- Peptidoglycan cell walls
- Binary fission
- Ex: Escherichia coli



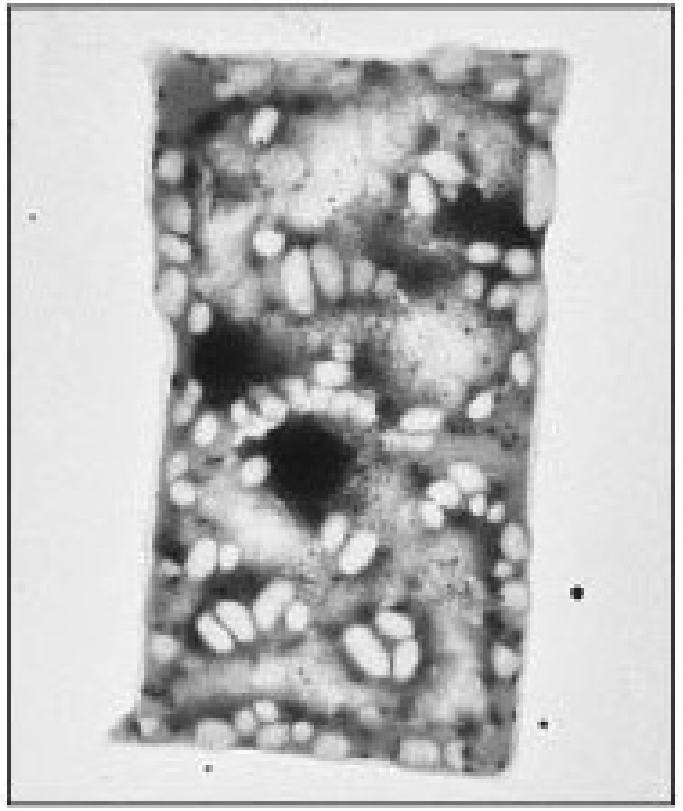
(a)

Archaea

- Prokaryotes
- Lack peptidoglycan
- Live in extreme environments (extremophiles)

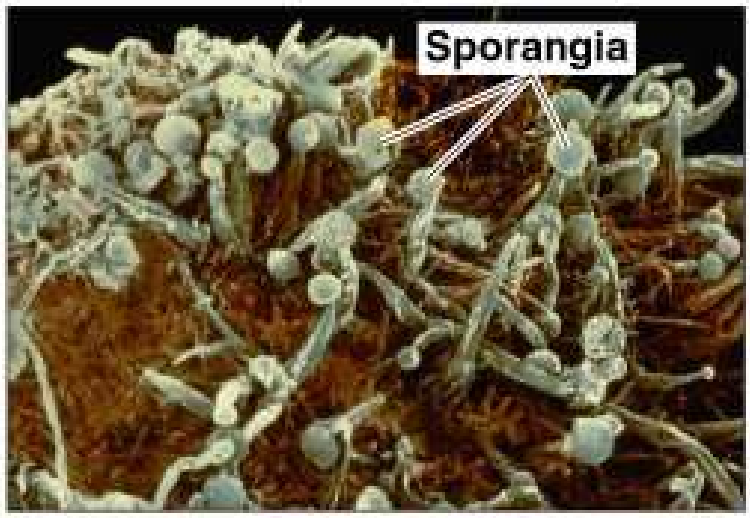
Include:

- Methanogens
- Extreme halophiles
- Extreme thermophiles



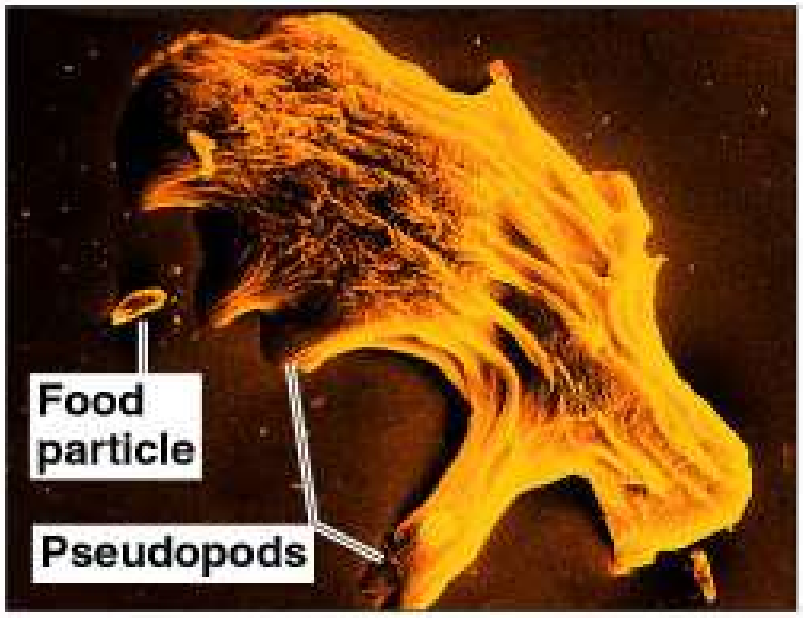
Fungi

- Eukaryotes
- Chitin cell walls
- Molds and mushrooms are multicellular
- Yeasts are unicellular



Protozoa

- Eukaryotes
- Mostly saprobes and commensals
- May be motile by means of pseudopod, cilia or flagella



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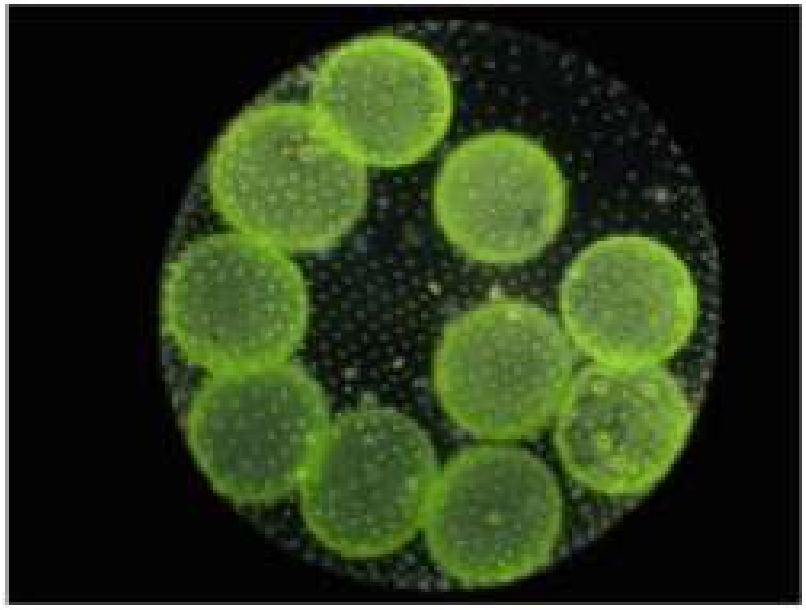
Algae

- Eukaryotes
- Cellulose cell walls
- Photosynthetic
- Produce molecular oxygen and organic compounds
- Part of food chain



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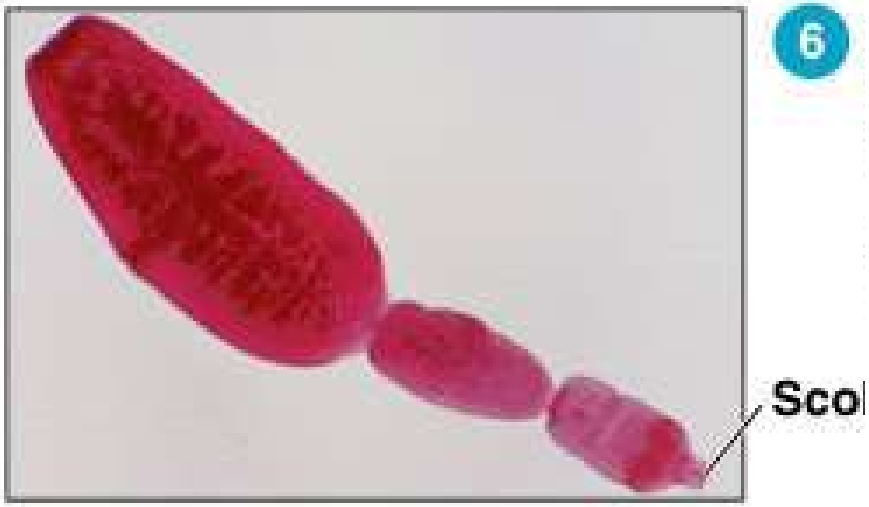
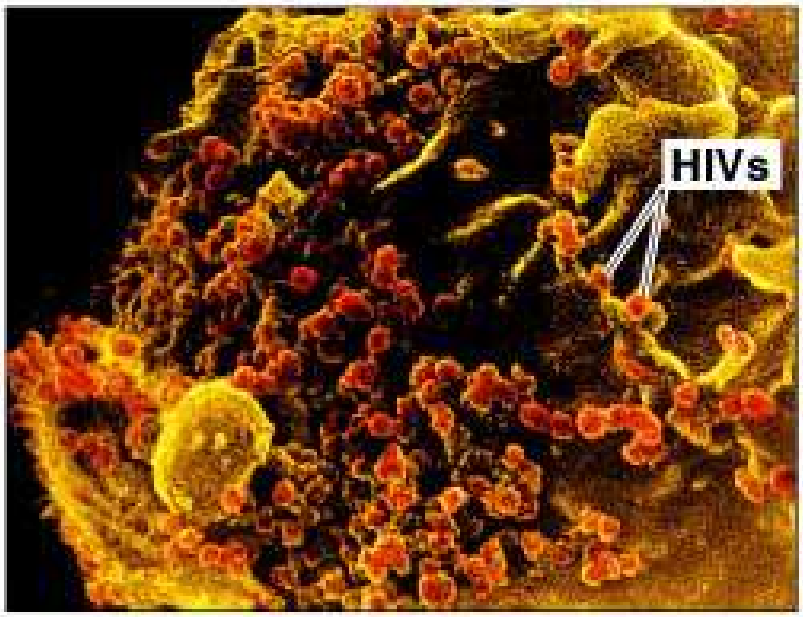
Helminths

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



Viruses

- Acellular
- Obligate intracellular parasites
- Genome consist of DNA or RNA called Core
- Core surrounded by protein coat called Capsid
- Virion may be enclosed in lipid envelope



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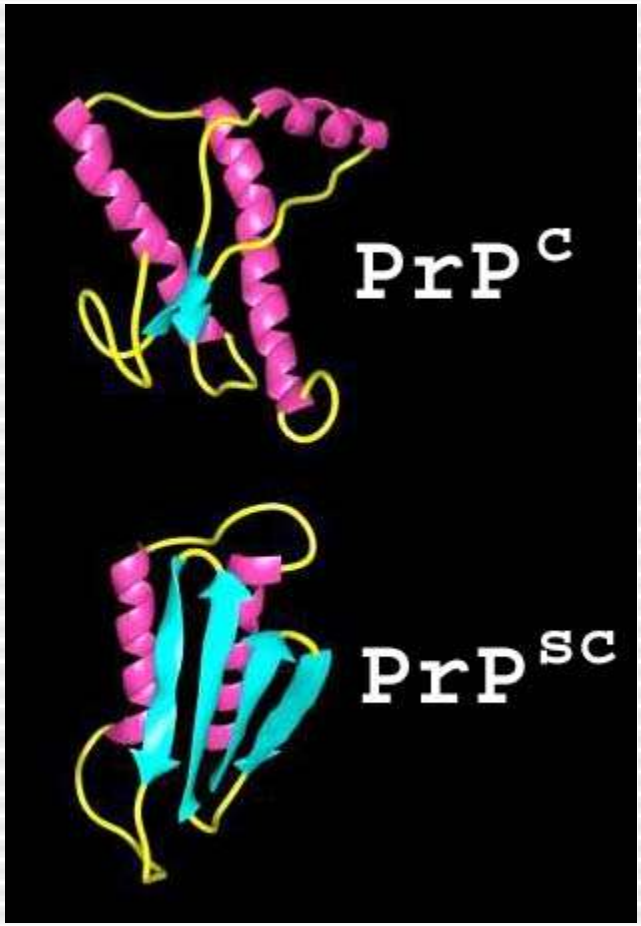
Prions

- Proteinaceous infectious agents
- Causes Bovine Spongiform Encephalopathy (BSE)
- Also causes Creutzfeldt-Jacob Disease (CJD)
- An Emerging Infectious Disease (EID)



Microbiology As A Science

- Science a systematized body of knowledge explaining the occurrence of natural phenomena
- Qualities of a scientist:
  - curiosity
  - open-mindedness
  - skepticism
  - creativity
  - objectivity

Scientific Approach

- Deductive reasoning

  starts with a general idea that are tested to prove or disprove it.

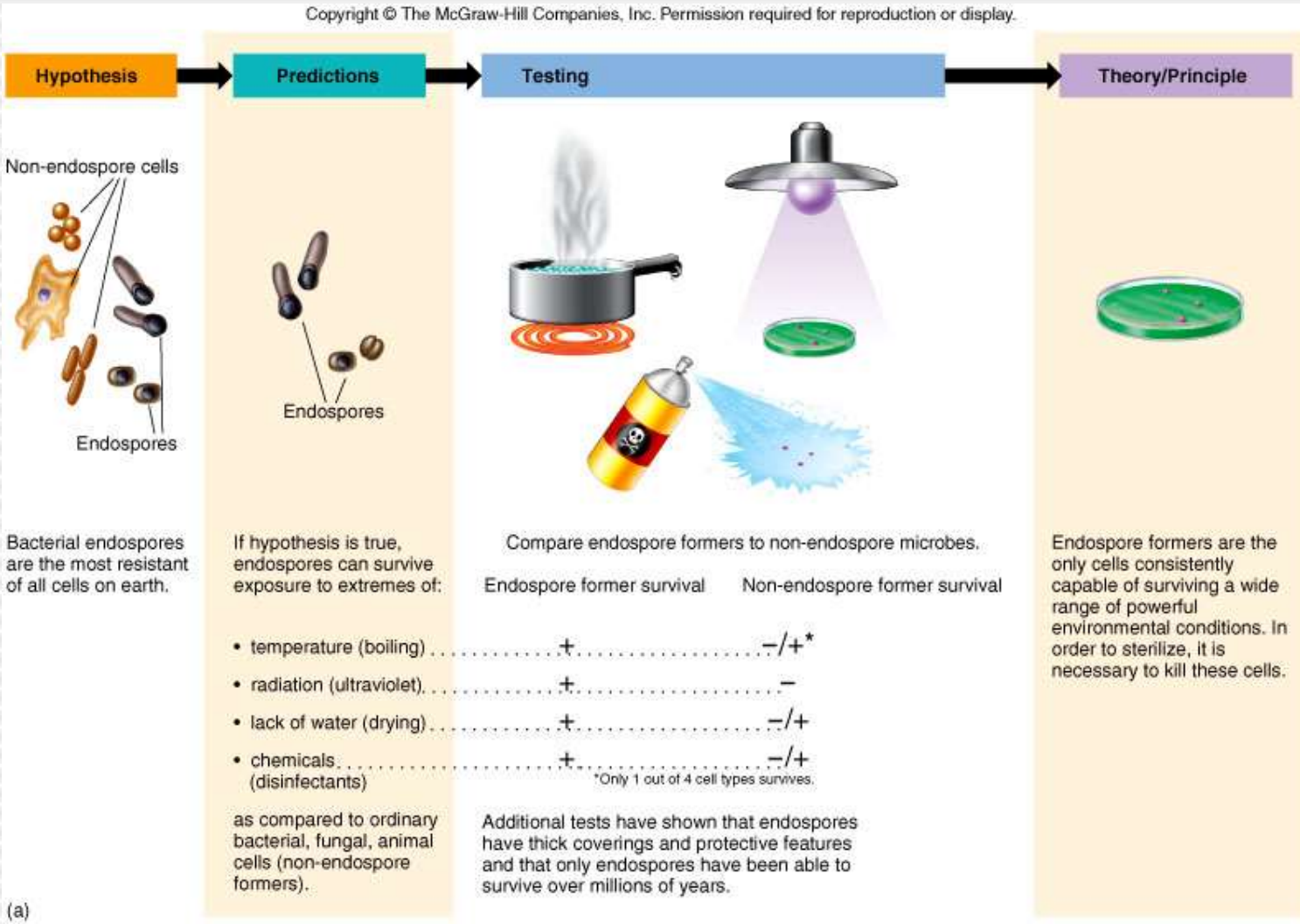
- Inductive reasoning

  starts with drawing patterns from specific observations resulting in generalization.

Scientific Method

- Hypothesis
- Laboratory experimentation or field Studies
- Data collection and analysis
- Conclusion, either reject or accept hypothesis
- Theory or Law

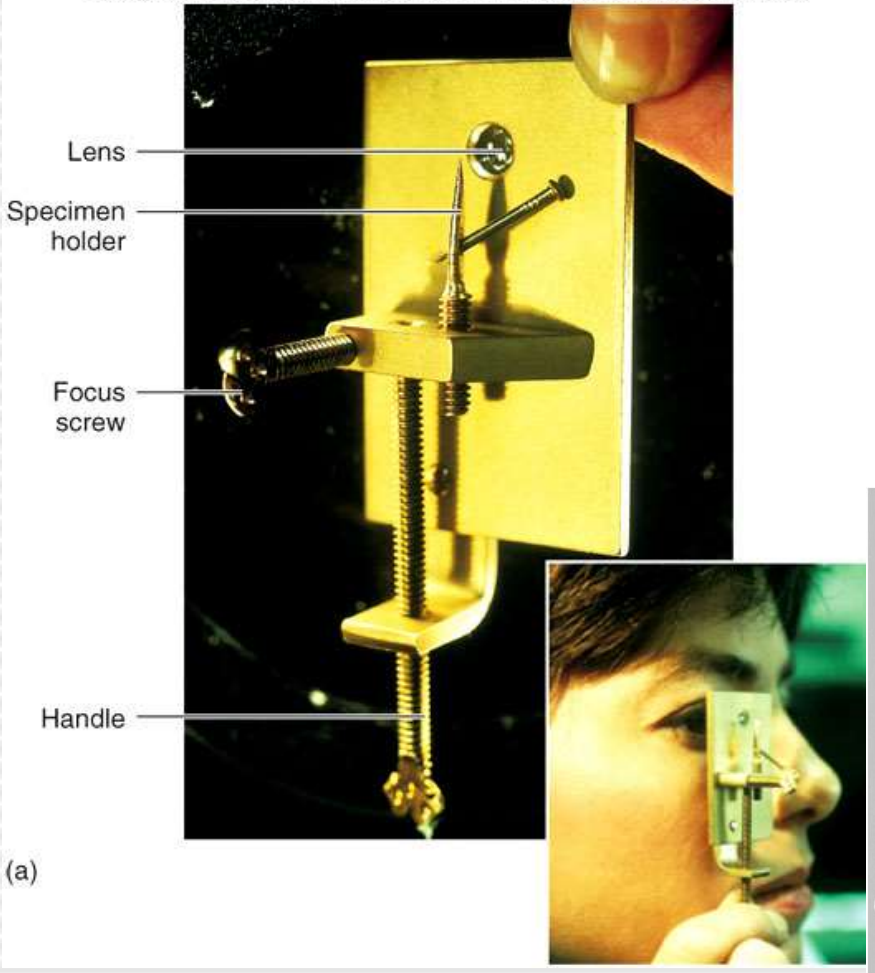
Microbiological Experiment



Brief History of Microbiology

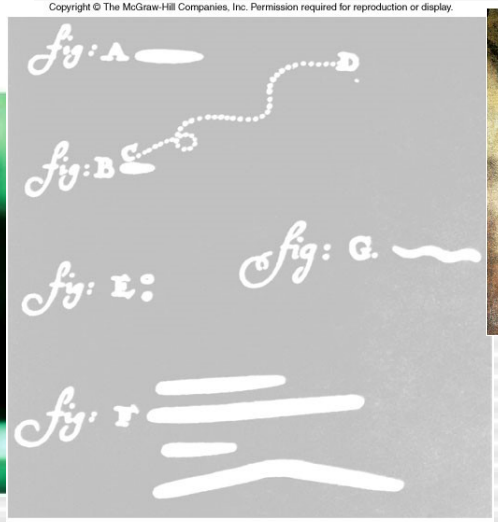
- The Microscope
- Spores and Sterilization
- Spontaneous Generation
- Aseptic Technique
- Germ Theory

The First Microscope



Microbes were first observed by Antonie van Leeuwenhoek using a simple microscope (ca. 1673)

Reported his "animalcules" to the Royal Society of London



(b)

Spores and Sterilization

- **John Tyndall** showed that some microbes in dust and air were resistant to heat.
- **Ferdinand Cohn** discovered and described endospores
- Term **“sterile”** was introduced to mean the complete removal of all life forms including endospores

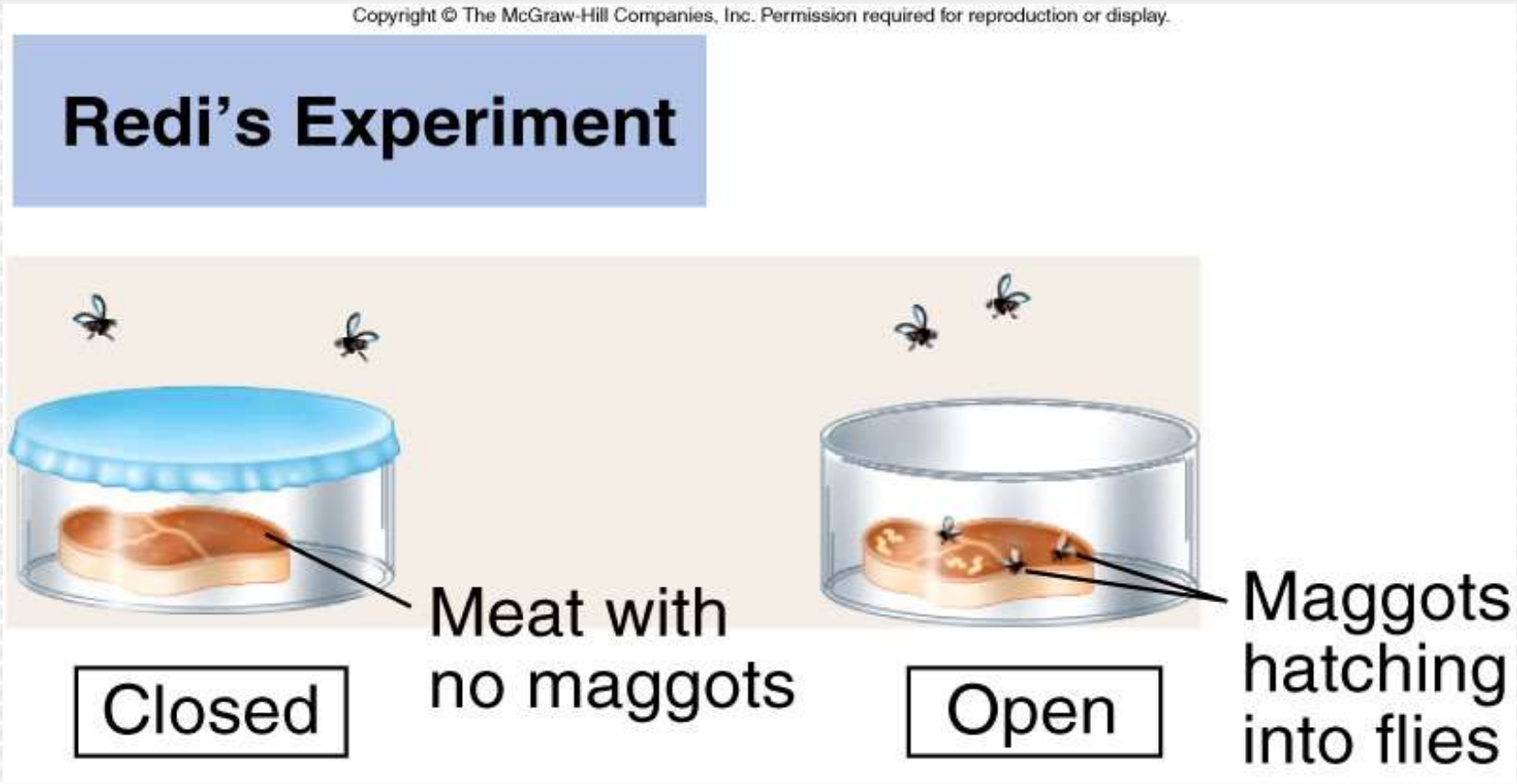
Abiogenesis vs. Biogenesis

- "Spontaneous Generation" was an early belief that living things can arise from vital forces present in nonliving and decaying matter.

  (Ex: maggots from meat or mushrooms from rotting wood

- The alternative hypothesis that living organisms can arise only from preexisting life forms is called "Biogenesis"

The Pros and Cons



Francisco Redi (ca. 1668)

The Pros and Cons

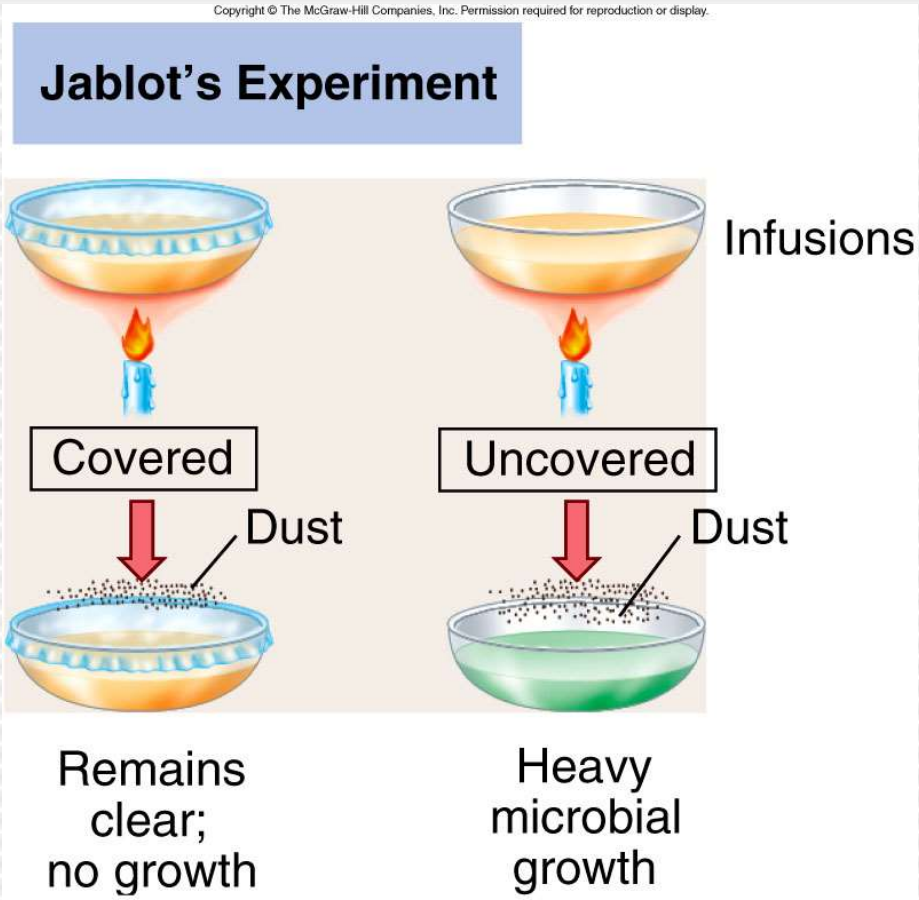
- 1745 -John Needham boiled nutrient broth into covered flasks

Conditions	Results
Nutrient broth heated then placed in sealed flasks	All showed growth

From where did the microbes come?

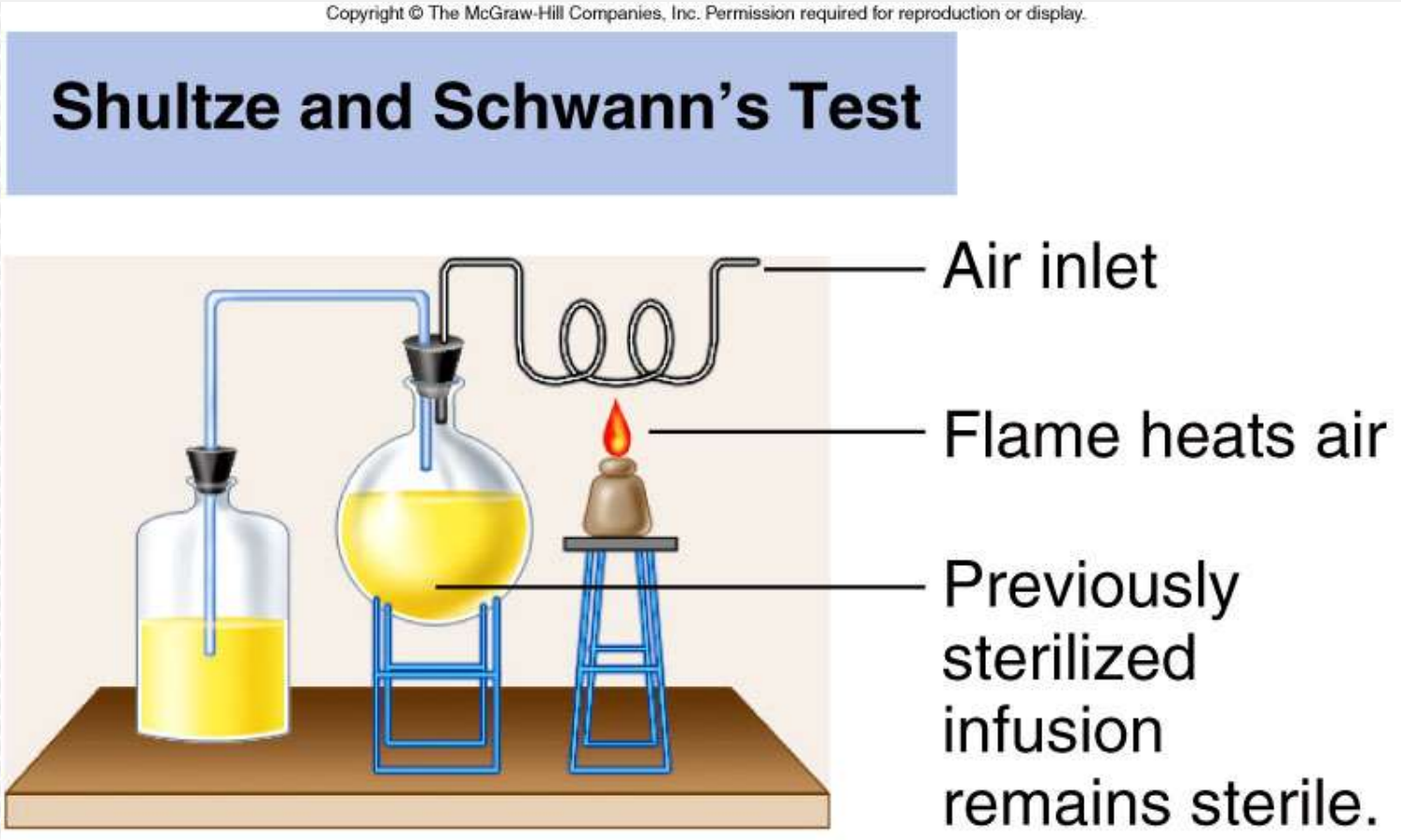
Spontaneous generation or biogenesis?

The Pros and Cons



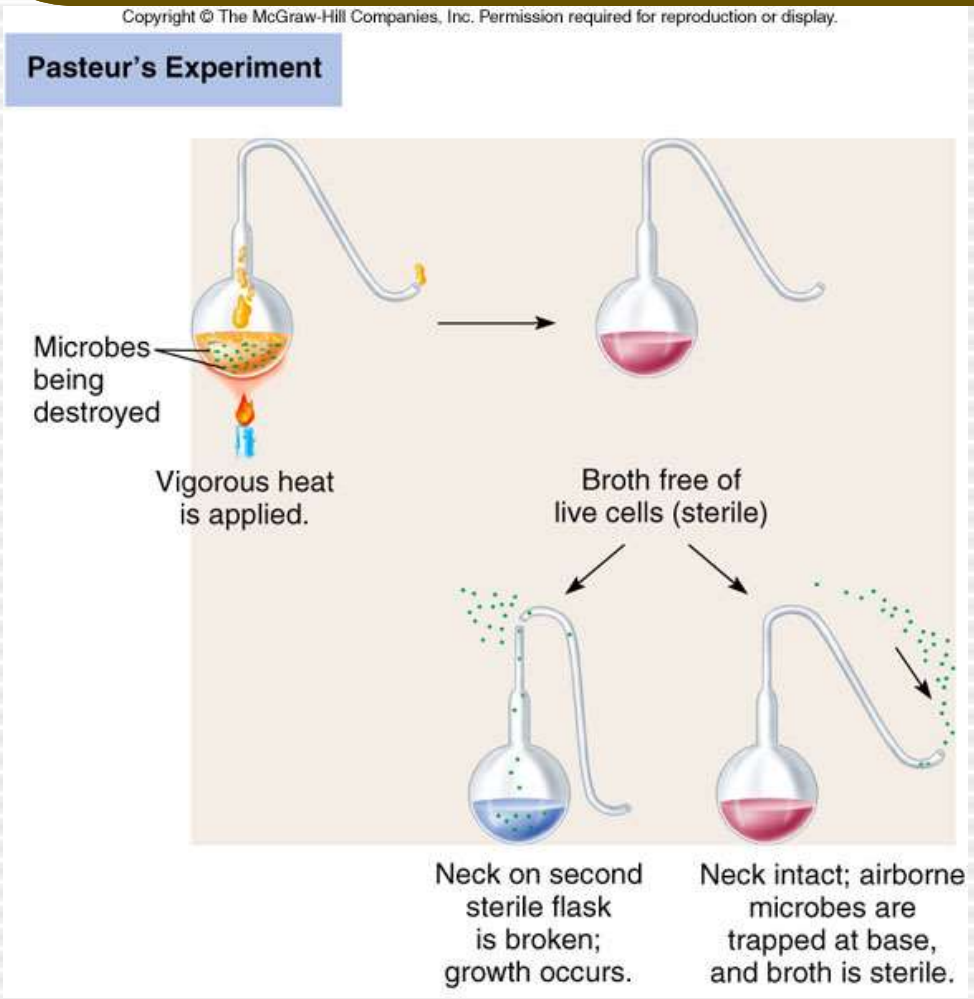
Louis Jablot

The Pros and Cons



Franz Schultze and Theodor Schwann

The Pros and Cons



Louis Pasteur put an end to Abiogenesis debate with his

Goose Neck Flask Experiment

He is the father of Microbiology

Louis Pasteur

- Showed microbes caused fermentation
- Studied spoilage and introduced “Pasteurization” to prevent it
- Used cotton plugs in his cultures to prevent air borne contamination, devised Aseptic Technique.

Antiseptics and Hand Washing

- **1860s - Joseph Lister** used, carbolic acid, a chemical antiseptic to prevent surgical wound infections
- **Ignaz Semmelweis,** a Hungarian physician introduced hand washing as a means of preventing transfer of puerpueral sepsis in obstetrical patients

Germ Theory of Disease

- **1876 - Robert Koch** provided proof that a bacterium causes anthrax using experimental steps now called the **Koch's Postulates**

- He was the first to use agar as solid culture medium in bacteriology.

Koch's Postulates

- The microbe must always be present in every case of the disease
- It must be isolated in pure culture on artificial media
- When inoculated into healthy animal host it should produce the same disease
- It must be isolated from the diseased animal again

Infection and Disease

- **Infection** — the entry of a microbe into the host.
- **Disease** — infection followed by the appearance of signs and symptoms.
- **Pathogen** — an infectious or disease agent.
- **Saprobe** — a microbe that lives on dead or decaying organic matter.
- **Opportunistic pathogen**

  is a microbe that cause disease in immunocompromised hosts or when the normal microbiota is altered.

Emerging Infectious Diseases

- Occurrence of new diseases and increasing incidence of old ones (EID)
- Factors:
  - (a) evolutionary changes in existing organisms
  - (b) spread of known diseases into new geographic areas by modern transportation
  - (c) ecological changes resulting in introduction of unusual agents
  - (d) emergence of antimicrobial resistance

Emerging Infectious Diseases

- **West Nile Encephalitis**, first diagnosed in Uganda in 1937; appeared in New York City in 1999.
- Invasive **Group A Streptococcus**, also known as the “flesh eating bacteria”
- **Escherichia coli 0157:H7**, causes “bloody diarrhea” and hemorrhagic uremic syndrome (HUS)
- **Bovine Spongiform Encephalopathy** (BSE) or “mad cow” disease caused by prions
- **Acquired Immunodeficiency Syndrome** (AIDS) caused by HIV and Africa is hardest hit
- **Anthrax** caused by *Bacillus anthracis* was sensationalized in 2001 when spores were disseminated via the mail