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Microbiology: A Systems Approach

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Chapter 1

The Main Themes of Microbiology

Chapter 1

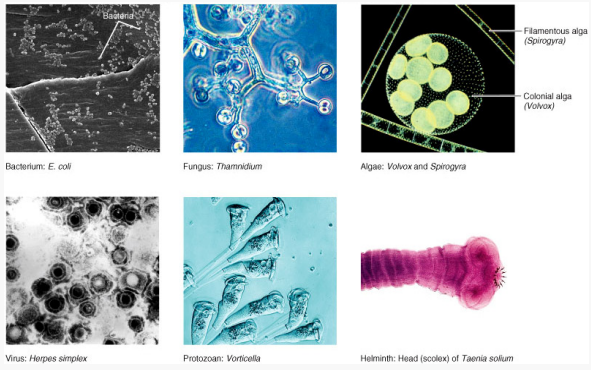
Topics to Cover:

- Scope of Microbiology
- Importance of Microorganisms
  - Human Use of Microbes
- Characteristics of Microorganisms
- History of Microbiology
- Taxonomy

Microbiology

- Specialized area in biology that studies living things too small to be seen by the naked eye
- Microorganisms also called microbes or bugs
- Groups of organism covered:
  - Bacteria, Viruses, Fungi, Protozoa, Algae, and Helminths

There are six main types of microorganisms: 1.) bacterium, 2.) Fungus, 3.) Algae, 4.) Virus, 5.) Protozoan, 6.) Helminth.



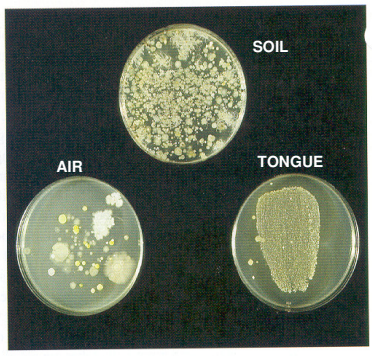
Scope of Microbiology

Many Diverse Disciplines:

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

MICROBIAL HABITATS & ROLES:

- Microorganisms are everywhere.
- Microorganisms reside in animals, plants, soil, on the surfaces of furniture, in dust particles, in water - virtually everywhere!



➢ Figure 1.1 **A simple experiment shows that microorganisms are almost everywhere in our environment.** Soil was added to nutrient agar, a culture medium (dish on top); another dish with agar was exposed to air (bottom left); and a tongue print was made on an agar surface (bottom right). After 3 days of incubation under favorable conditions, abundant microbial growth is easily visible in all three dishes.

UBIQUITOUS!!!

Several reasons to study microbiology - the study (ology) of microorganisms.

Microorganisms are:

- **Are part of our environment.**
- **Important to animal, plant and human health.**
- **Are a source of food or are important in the production of food.**
- **Are important in the recycling of waste.**
- **Are useful for the production of antibiotics, vitamins, amino acids.**
- **Are the stuff of genetic engineering – recombinant DNA technology, gene therapy.**
- **Provide insight into life processes in all life forms**

Microbes are involved in **photosynthesis** - account for >50% of the earth's oxygen. Decomposition – nutrient recycling.

Fig. 1.2 Microbial habitats

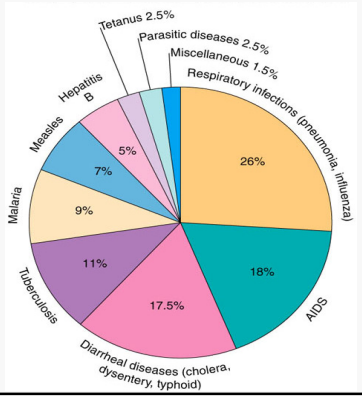
Microbes are used to extract copper from ore, synthesize drugs and enzymes, and bioremediate contaminated water.

Fig. 1.3 Microbes at work

Infectious Diseases

- Only about 1-3% of the microorganisms actually cause disease.
- The remaining 97-99% may be innocuous or have positive benefits.

Most common infectious causes of death worldwide.



Cause of death in USA

TABLE 1.1 Top Causes of Death—All Diseases

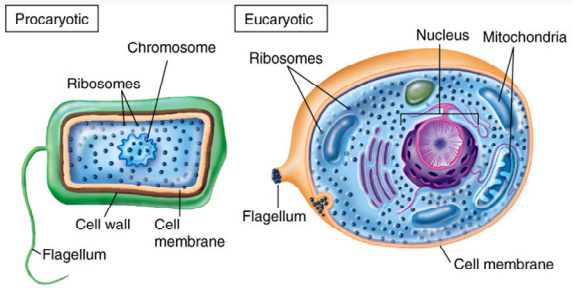
United States	No. of Deaths
1. Heart disease	725,000
2. Cancer	550,000
3. Stroke	167,000
4. Chronic lower-respiratory disease	124,000
5. Unintentional injury (accidents)	97,000
6. Diabetes	68,000
7. Influenza and pneumonia	63,000
8. Alzheimer's disease	45,000
9. Kidney problems	35,000
10. Septicemia (bloodstream infection)	30,000

*Diseases in red are those most clearly caused by microorganisms.
Data adapted from The World Health Report 2002 (World Health Organization).

Characteristics of Microorganisms

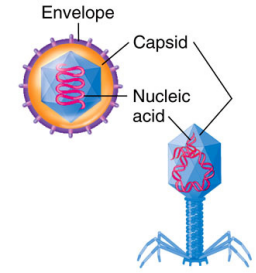
- **Cellular Organization**:
  - **Procaryotic** – no nucleus and organelles
  - **Eucaryotic** – nucleus and organelles (mitochondria, etc.)

There is a difference between the cell structure of a procaryote and eucaryote.



(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)

Viruses are neither but are considered particles.



(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)

Microorganisms vary in size - 1µm to 200 nm.

0.2 um →

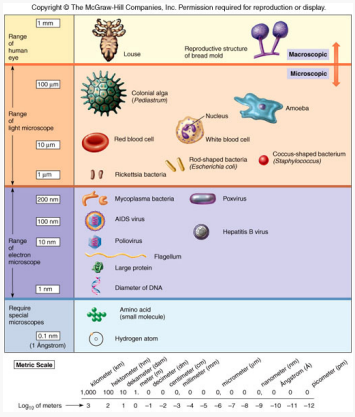


Fig. 1.7 The size of things

History of Microbiology

- Microscopy
- Spores and sterilization
- Spontaneous generation
- Aseptic technique
- Germ theory

The history of microbiology is old. It dates to before the bible.

- Egyptian pharaohs protected their pyramids with *Aspergillus* spores.
- Leprosy was described in the bible.

- The Greeks anticipated microbiology. They could not see microorganisms - only the effect.
  - Hippocrates (~400 BC) set forth an enduring set of ethical standards for the practice of medicine. He also associated signs and symptoms to certain illnesses. He observed potential transmission by person to person or by objects.
  - Thucydides realized that people who survived the plague were protected and could safely care for plague victims.

Microorganisms were first observed by **Antonie van Leeuwenhoek**, using a primitive microscope.

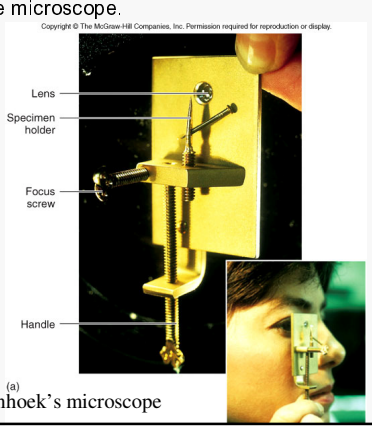
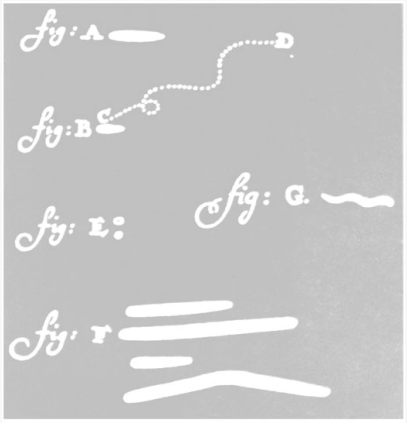


Fig. 1.9 Leeuwenhoek's microscope

- Robert Hooke built the first compound microscope about 1665 and saw cells in a strip of cork.

- Leeuwenhoek- first observed living microorganisms - "animalcules" - using a simple compound microscope. He sampled everywhere and saw protozoa, yeast, fungi and many forms of bacteria. (300X)

Cell Types



Spores and sterilization

- Some microbes in dust and air were resistant to high heat.
- Spores were later identified.
- The term "sterile" was introduced which meant completely eliminating all life forms from objects or materials.

Spontaneous generation

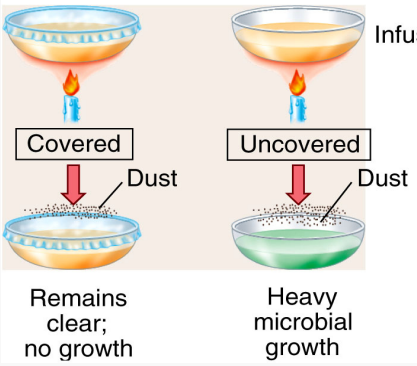
- Early belief that some forms of life could arise from vital forces present in nonliving or decomposing matter (flies from manure, etc)

- Francesco Redi (1600) designed an experiment to refute spontaneous generation. Skepticism reigned.

Redi's Experiment

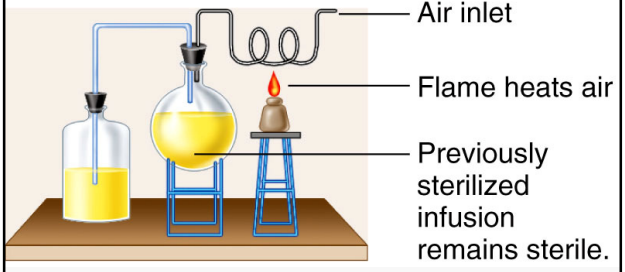
Maggots developed from "flies"

Jablot's Experiment



Microbes originated from "dust in the air"!!

Shultze and Schwann's Test



Results were negated because of "harmful treatment" of air!!!

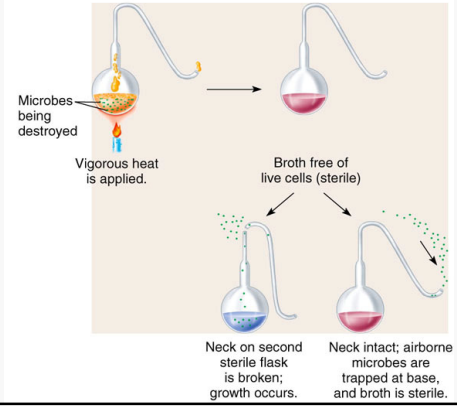
- John Needham refuted these experiments: because they had merely driven off the oxygen which they considered to be required for growth.

- The French Academy of Science held a competition in 1859 to clarify the situation using scientific experiments.

- Louis Pasteur entered the swan-neck flask experiment.

- A difficulty with all of these experiments is that boiling does not necessarily kill all microorganisms…..lucky moment!!!

Pasteur's Experiment



Medical Microbiology

- John Tyndall conducted similar experiments and identify microbes in dust and air with high heat resistance.

- A lucky observation with these experiments is that boiling does not necessarily kill all microorganisms!!!

Louis Pasteur showed microbes caused fermentation & spoilage, and disproved spontaneous generation.

Fig. 1.11 Louis Pasteur

Aseptic technique

-Ignaz Semmelweis and Joseph Lister developed the concept of aseptic technique.

- Ignaz Semmelweis was convinced that when physicians moved from one infected individual to a new individual without adequate washing, disease was transmitted. He was ridiculed.

- Lister continued the work and used carbolic acid to sterilize dressings. He too was ridiculed, but eventually he was recognized for the significance of his contribution.

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.

Robert Koch verified the Germ theory (Koch's postulates).

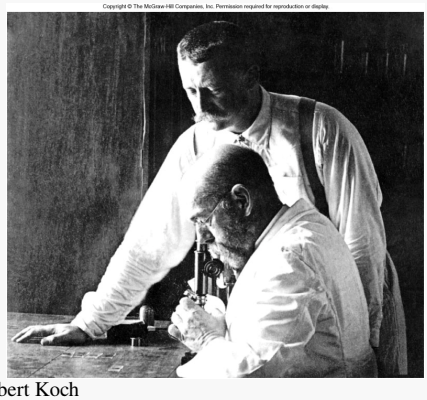


Fig. 1.12 Robert Koch

Medical Microbiology

- Pasteur developed pasteurization (56° C/30 min) in the absence of oxygen) to preserve wine from spoilage.
- Pasteur prepared the first rabies vaccine – made of dried spinal cord from a rabbit infected with rabies virus. Remember that none had any idea of the concept of viruses at that time!!

- In the late 18th century, Jenner noted that milkmaids seldom contracted smallpox. Using this observation he developed the first vaccine
- successful immunization against smallpox.

Robert Koch, a contemporary of Pasteur, made a critical contribution to the field of infectious disease with his formulation of *Koch's postulates*. A corollary of this hypothesis is that one infectious agent causes one disease.

1) The specific causative agent must be found in every case.
2) The infectious agent must be isolated in pure culture.
3) Inoculation of the pure infectious agent into a susceptible animal must result in the same disease.
4) The infectious agent must be recovered from the inoculated animal.

Koch's postulates cannot be applied to all infectious agents - why??

Koch's postulates cannot be applied to all infectious agents - why??

- Some diseases are not cause by microorganisms
- Some microorganisms can not be cultured
- Some microorganisms can cause different diseases
- Some diseases can be cause by different microorganisms.

Vaccination

- Lady Montagu – variolation to treat against smallpox
- Edward Jenner – protected humans against smallpox using the related virus cowpox
- Louis Pasteur – Developed vaccines against rabies and cholera. He introduced the term attenuated vaccines

Chemotheraphy

- Cinchona (quinine) to Europe to treat malaria
- Paul Ehrlich – coined the term chemotheraphy and the concept of magic bullet (selective toxicity)
  - Developed compound 606 (Salvarsan) to treat syphilis
- Alexander Fleming – identified lysozyme and penicillin from the mold *Penicillium*.
- Rene Dubos – discovered two antibiotics produced by the soil bacterium *Bacillus*

Taxonomy

- A system for organizing, classifying & naming living things.
- Primary concerns of taxonomy are ***classification***, ***nomenclature***, and ***identification***.
- **Carl Linnaeus** introduced taxonomic categories or taxa

Nomenclature

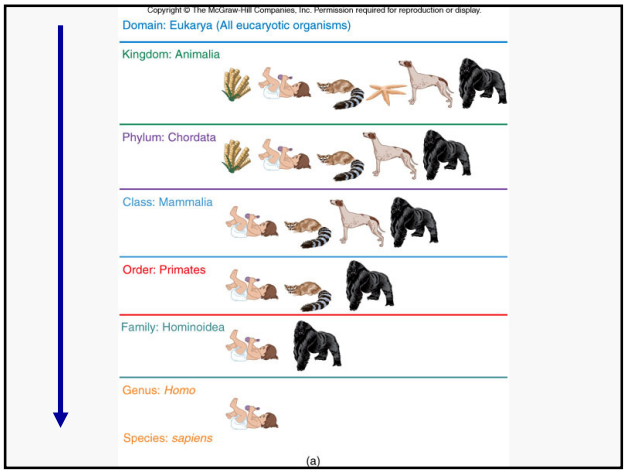
- Binomial (scientific) nomenclature
- **Genus** – *Bacillus,* always capitalized
- **species** - *subtilis*, lowercase
- Both italicized or underlined
  - *Bacillus subtilis* *(B. subtilis)*

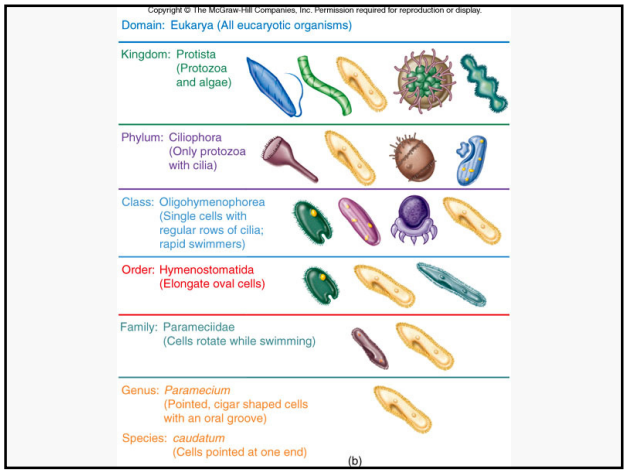
Identification

- The process of discovering and recording the traits (physical, biochemical, genetic) of organisms, thereby, placing them in a taxonomic scheme.

Levels of Classification

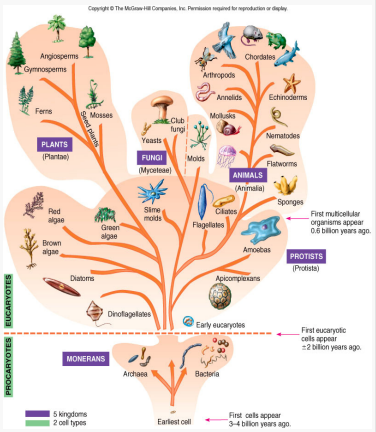
- **Domain**
- Phylum or Division
- Class
- Order
- Family
- Genus
- species





- **Haeckel (1870's) – is credited with the 3 and 4 kingdom system of classification**
- **Robert Whitaker** (1969) - developed after the five-kingdom system of classification

The five-kingdom system became the standard until molecular biology techniques were used to develop the Domain system.



Traditional Whittaker system of classification

Domains

- Developed after the five-kingdom system
- Three domains:
  - **Eubacteria** -true bacteria, peptidoglycan
  - Archaea –odd bacteria that live in extreme environments, high salt, heat, etc
  - Eukarya- have a nucleus, & organelles

The Domain system was developed by Dr. Woese. The basis of the Domain system is the rRNA sequence information.

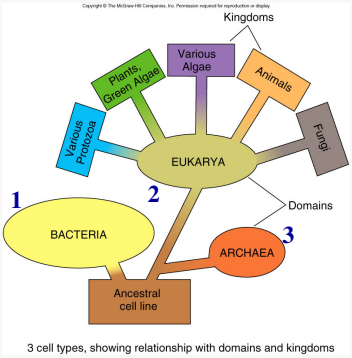


Fig. 1.15 Woese system

Subdivisions or Kingdoms

- Monerans → **Archae and Eubacteria**
- Fungi
- Protists
- Plants
- Animals

Evolution

- Classification schemes allow for a universal tree of life "phylogenetic tree".
- Living things change gradually over millions of years
- Changes favoring survival are retained & less beneficial changes are lost.