The Main Themes of Microbiology

Lecture 1

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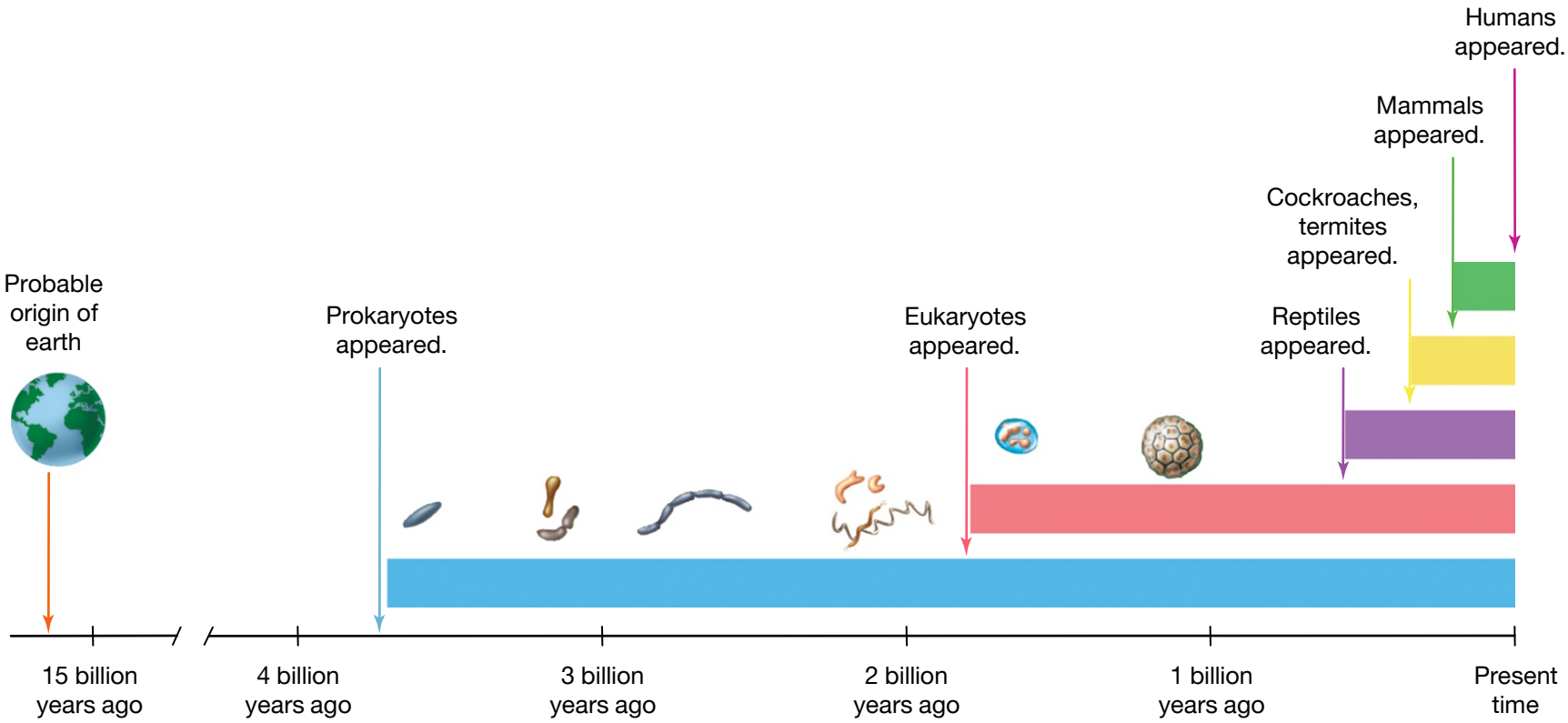
Microbiology

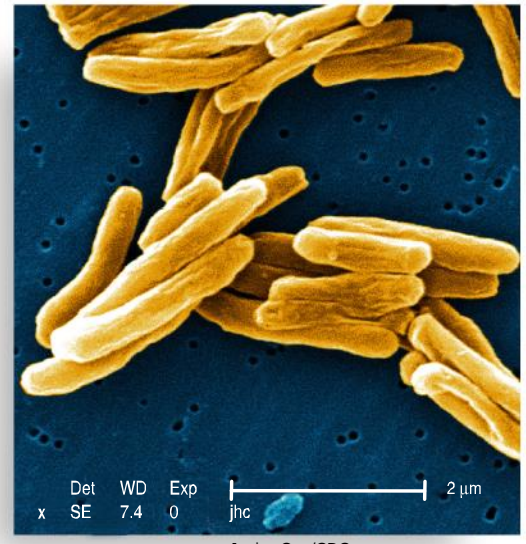
- Micro=small, Bio= Life, Logy= Science
- study of organisms too small and to be seen without microscope.
- Microorganisms include:
  - Bacteria
  - Fungi (molds and yeasts, decomposers, pathogens).
  - Protozoa
  - Helminths (microscopic worms)
  - Algae
  - Viruses

Origins of Microorganisms

- Almost 3.5 billion years ago, Earth was a microbial planet.



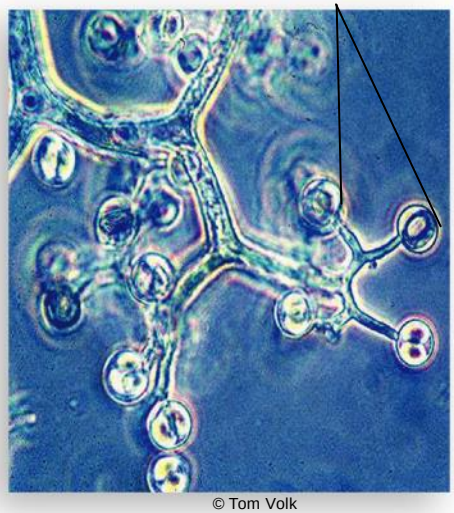
Microbial Diversity: 6 Types of Microbes



Janice Carr/CDC

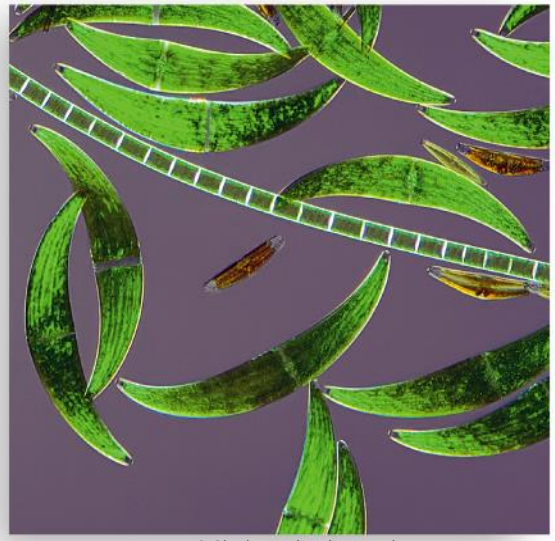
Bacteria: *Mycobacterium tuberculosis,* a rod-shaped cell (15,500x).

Reproductive spores



© Tom Volk

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



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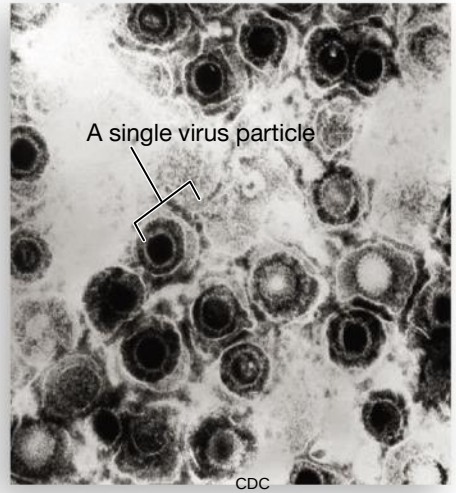
Algae: desmids, *Spirogyra* filament, and diatoms (golden cells) (500x).



CDC

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

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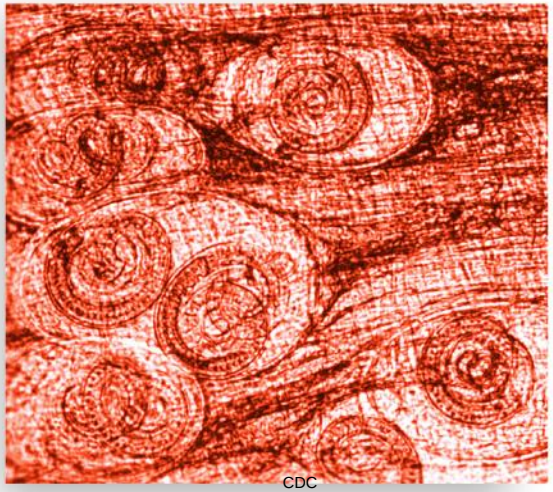
Protozoa: A pair of Vorticella (500x), stalked cells that feed by means of a whirling row of cilia.

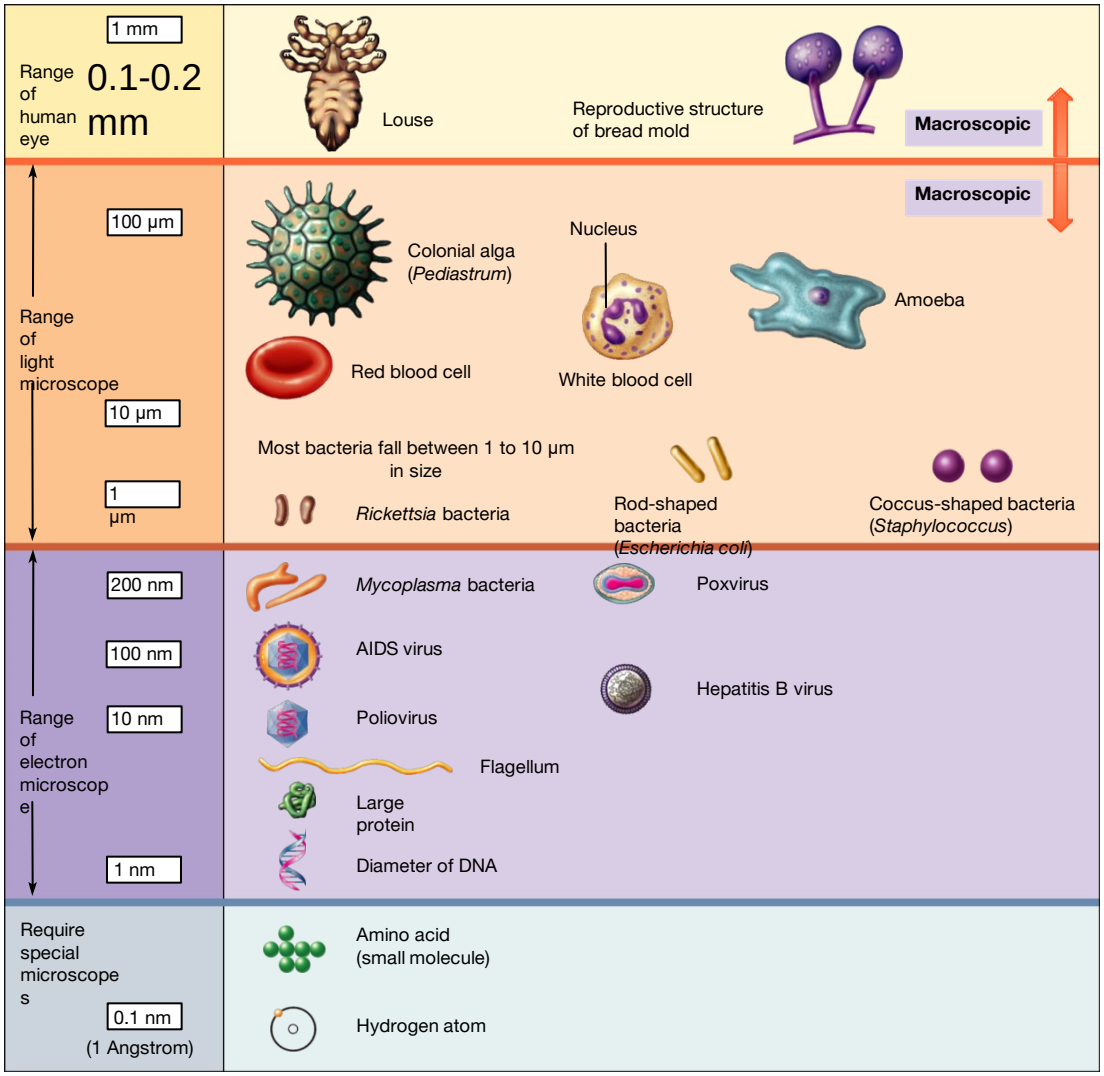


CDC

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

Microbial Dimensions

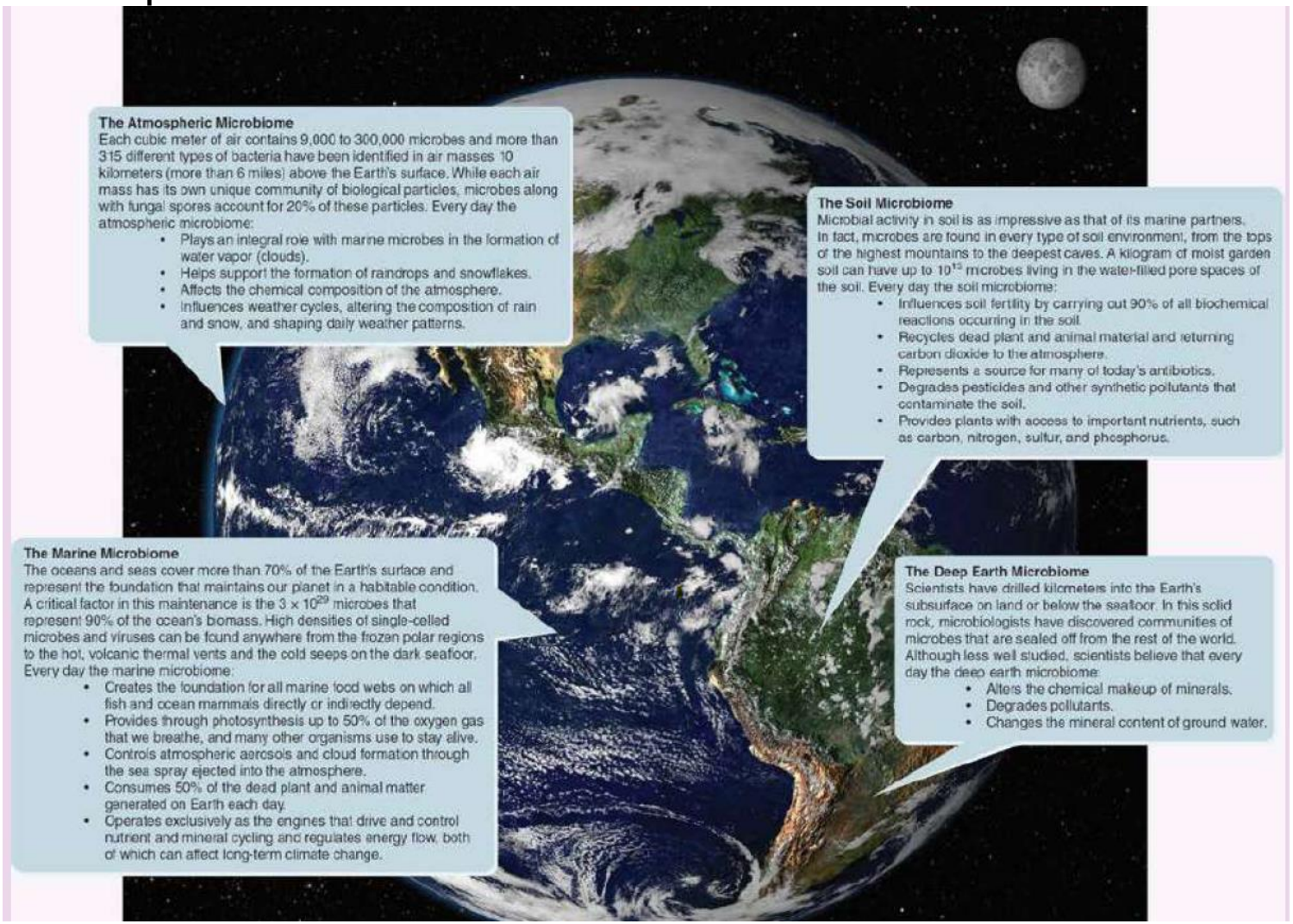
The a person can see smallest object without any magnifying generally considered to be around **100 microns (0.1 mm)**,



The Microbial World: Foundation of the Biosphere

- Space and the universe often appear to be an unlimited frontier.
- An estimated 350 billion large galaxies and more than 10^{24} stars in the known universe.
- However, there is another invisible frontier here on Earth.
- This is the microbial universe, which consists of more than 10^{30} **microorganisms**
- This global community of microbes and their genes forms Earth's microbiome
- Today, microbiologists and scientists from many scientific fields are cataloging the microbial diversity of the biosphere, the regions of the Earth where living organisms are found.
- This effort is called the **Earth Microbiome Project.**
- We will examine Earth's microbiomes and then examine the community of microbes that inhabit the human body.
- We will, learn of the historical events

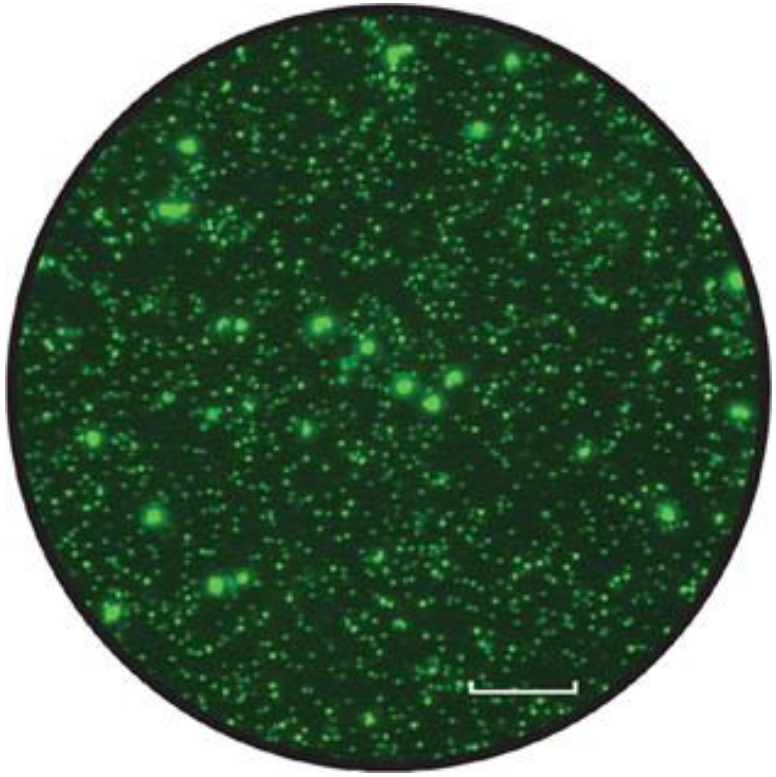
- Almost 4 billion years ago, Earth was a microbial planet.
- The diverse and numerous microorganisms populating the planet were beginning the processes that would create the environment that sustains and shapes our planet and that has made Earth habitable for larger organisms like plants and animals.



Origins of Microorganisms

The Marine Microbiome

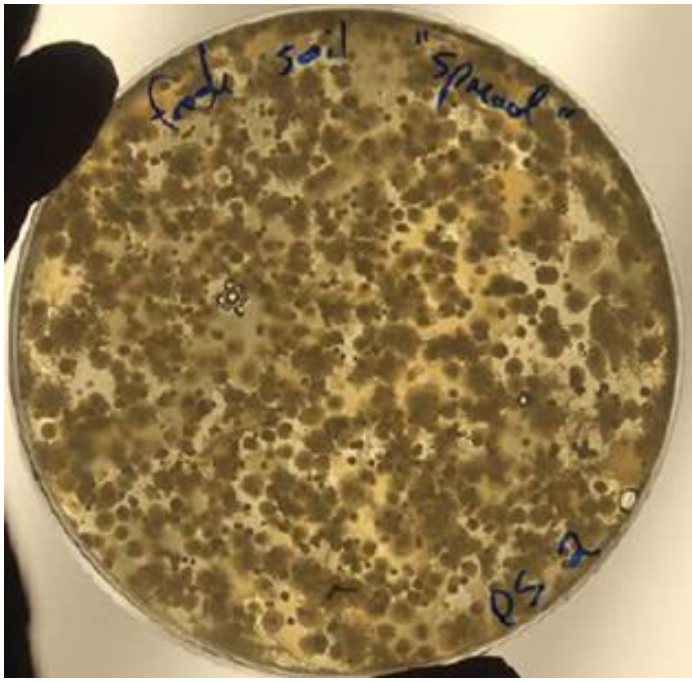
- The Marine Microbiome Is One of the Largest Microbiomes on the Planet.
- Approximately to some 3×10^{29} microbes and represents 90% of the marine biomass (total mass of all organisms in an area).
- Viruses are the most abundant infectious agents on Earth. In the oceans, they outnumber the bacteria 10 to 1.
- Marine viruses kill 20% to 40% of all marine bacteria every day and are responsible for swapping 10^{29} genes between bacteria each day.
- Many scientists believe viruses represent the most dominant agents affecting life on Earth.



Origins of Microorganisms

The Soil Microbiome Shapes the World

- The soil microbiome represents a dynamic group of distinct microbial communities associated with plants, soil animals, and the soil itself.
- Approximately 1kg of moist soil can have up to 10^{13} microbes.
- Up to 5 km into the Earth's they have discovered another microbes that are sealed off from the rest of the world lived in harsh conditions (e.g.,extreme heat, no light, sparse nutrients) might make up 70% of microbes on Earth.
- These relatively slow-growing microbes often are called "zombie" bacteria because they seem to be barely alive. Some might be up to 100 million years old, reproducing only once a century.



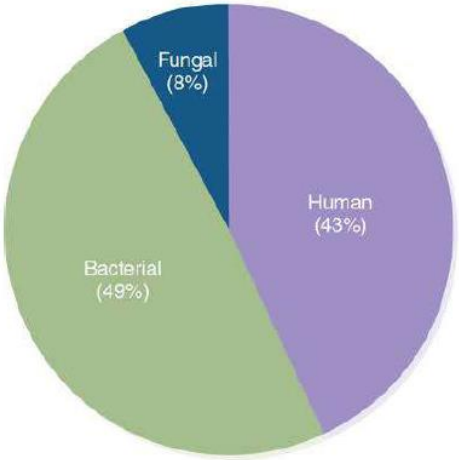
The Atmospheric Microbiome

- In this atmosphere though, events like soil erosion hurl soil microbes, ocean evaporation lifts marine microbes, and coughing and sneezing launch microbes and viruses into the air.
  - In fact, more than 315 different types of bacteria have been identified in air masses 10 kilometers above the Earth's surface.
  - These microbes, along with fungal spores, account for 20% of all particles—biological and nonbiological in the atmosphere

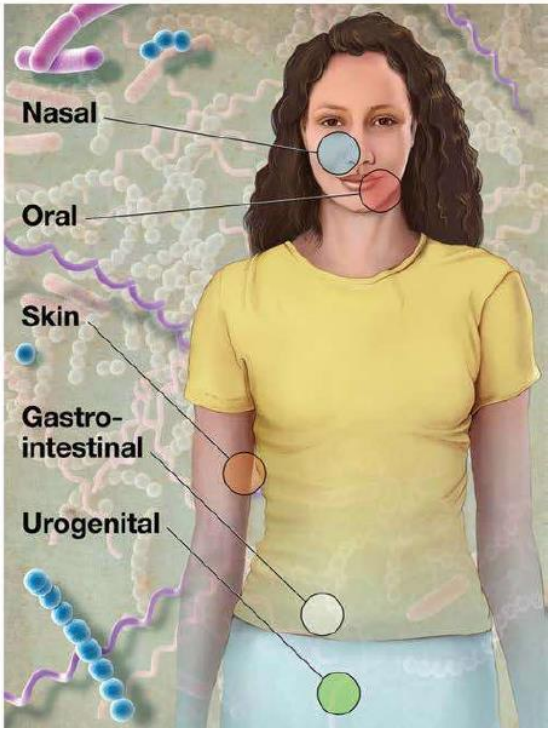
The Human Body Has Its Own Microbiome

- ✓ The human microbiome (formerly and sometimes still called the "microflora") consists of some 38 trillion microbes composing more than 4,000 different types of bacteria and fungi found on and in the human body.
- ✓ This is greater than the number of cells (30 trillion) forming the human body.
- ✓ All human microbiomes do not share the same set of microbes. Each individual has a unique microbiome specific to the skin, the mouth, and the gut that results from physiological differences, age, diet, and geographic location.
- ✓ In fact, the belly button alone has a unique combination of more than 50 types of bacteria

A The cells of the human microbiome (bacterial and fungal) outnumber the human cells in the body.



B Each human possesses several anatomical areas that each contain a unique microbiome.



Microbes in Our Lives

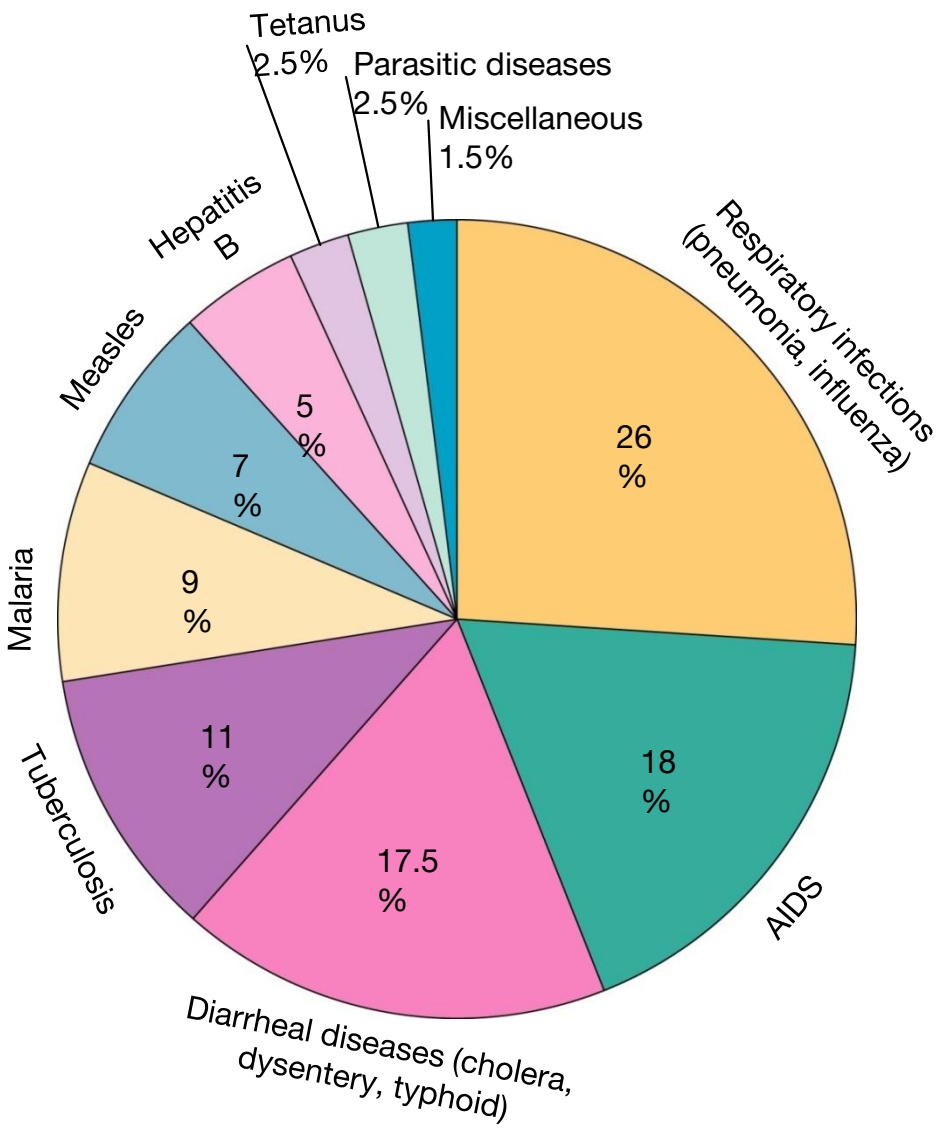
- A few are **pathogenic** (disease-producing)
- Decompose organic waste
- Generate oxygen by photosynthesis
- Produce chemical products such as ethanol, acetone, and vitamins
- Produce fermented foods such as vinegar, cheese, and bread
- Produce products used in manufacturing (e.g., cellulase) and disease treatment (e.g., insulin)

Microbes in Our Lives

- Knowledge of microorganisms allows humans to
  - Prevent food spoilage
  - Prevent disease
  - Understand causes and transmission of disease to prevent epidemics

Microbes & Infectious Diseases

- **Pathogens**: Microbes that do harm, cause disease
- Nearly 2,000 different microbes cause diseases
- 10 B new infections/year worldwide
- 12 M 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.

Lifestyles of Microorganisms

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

- 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.

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Microbes in Energy & Nutrient Flow

- The flow of energy and food through the earth's ecosystems
  - **Photosynthesis**: Light fueled conversion of carbon dioxide to organic material
  - **Decomposition**: Breakdown of dead matter and wastes into simple compounds

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

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Human Use of Microorganisms

- **Biotechnology**: Production of foods, drugs, and vaccines using living organisms
- **Genetic engineering**: Manipulating the genes of organisms to make new products
- **Bioremediation:** Using living organisms to remedy an environmental problem

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Courtesy: Pacific Northwest National Laboratory

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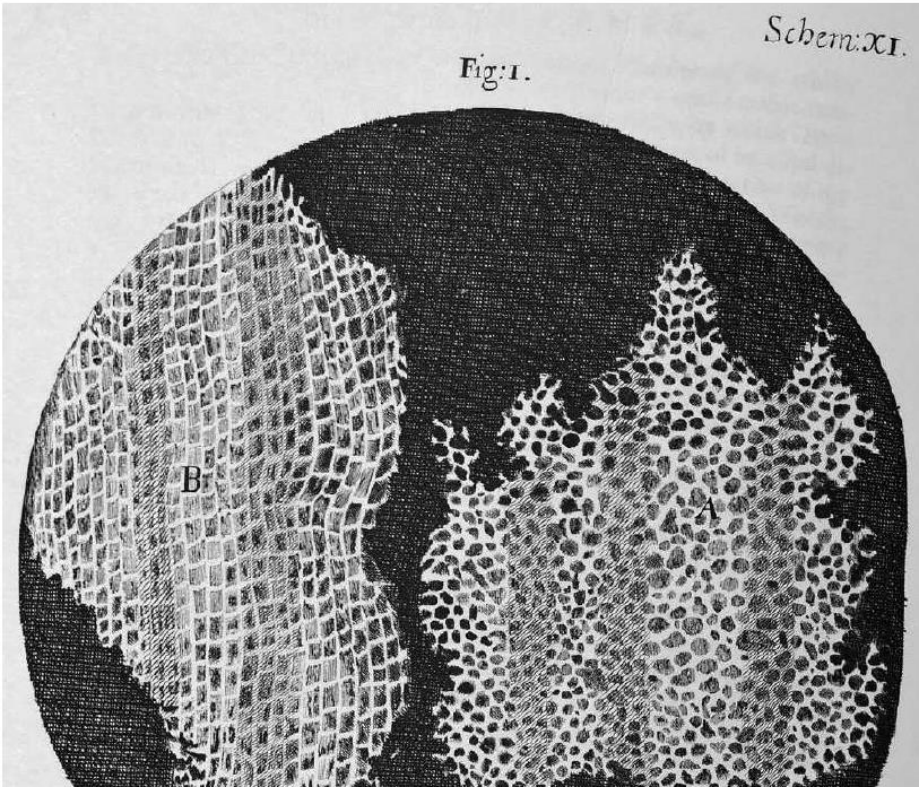
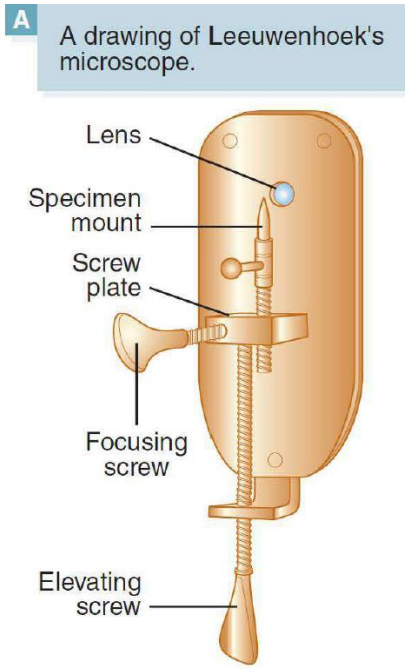
How microbes were first discovered?
(Microbiology Pioneers)

- **Robert Hooke and Leeuwenhoek** Discover the Microbial World 1665.
- ***Micrographia*** was the first important work involving microscopy.
- Hooke's drawing and description of cork was the first use of the word "cell" to describe biological objects.
- At this same time Antoni van Leeuwenhoek was grinding single pieces of glass into fine magnifying lenses.



Antonie van Leeuwenhoek (1632-1723)

- Dutch linen merchant
- First to observe living microbes
- Single-lens magnified up to 300X
- He described hundreds of moving particles.
- He thought they must be tiny living animals, so he called them **animalcules** (cul = "little").



Spontaneous Generation

- **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.)
- in 1861, the French chemist and scientist Louis Pasteur eventually disproved spontaneous generation and proved the **Theory of Biogenesis** - the idea that living things can only arise from other living things.

- Pasteur Proposes That Germs Cause Infectious Disease.
- Pasteurization is a universal method used to kill pathogens and retard spoilage in milk and many other foods and beverages.
- Pasteur reasoned that infections and disease also might be caused by other microorganisms in the environment—what he called germs.

General observations

When studying a problem, the inquiry process usually begins with observations. Pasteur's earlier observations suggested that germs might be in the air.

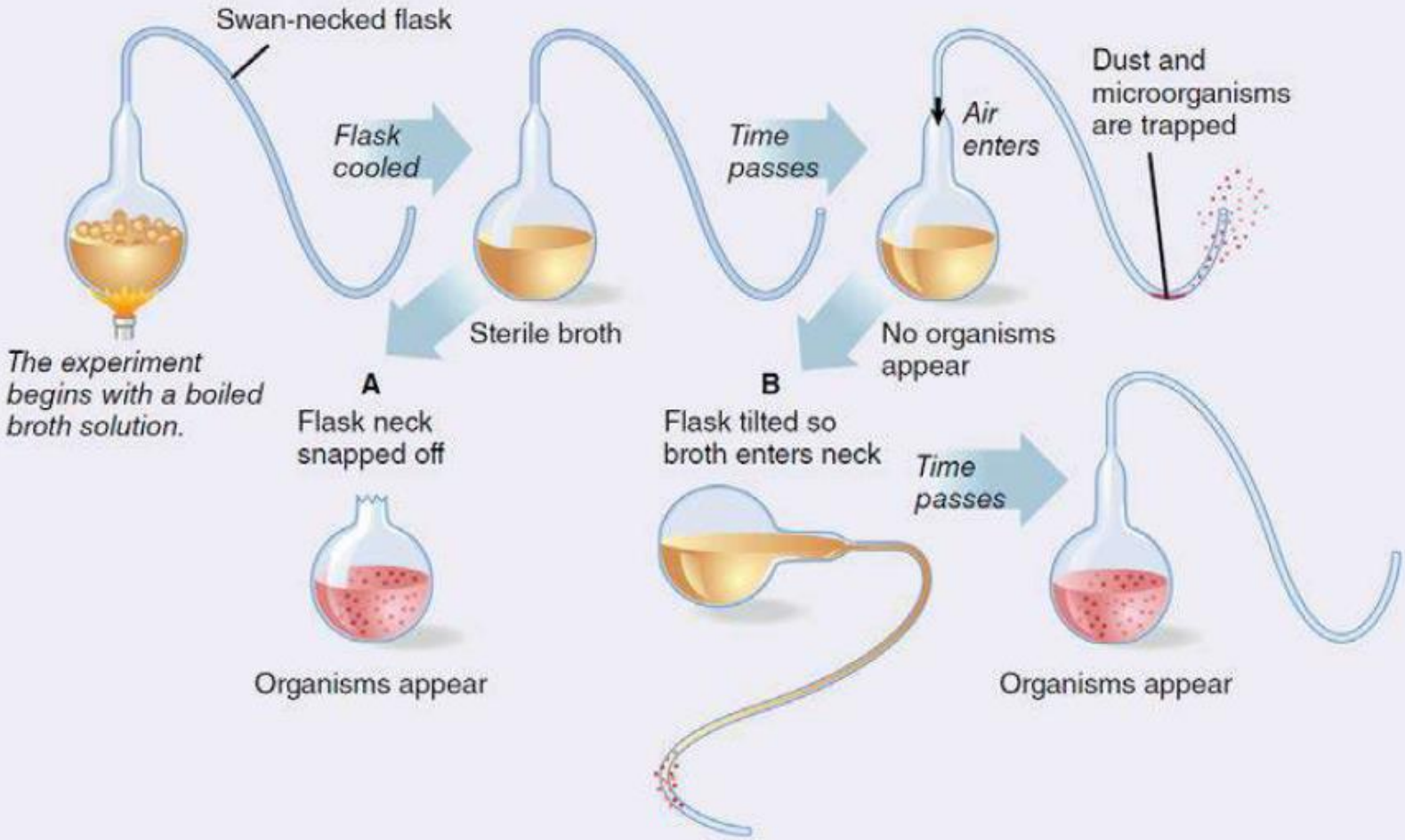
Question

Next comes the question, which can be asked in many ways but usually as a "what," "why," or "how" question. For example, Pasteur asked, "How can I show that microbes are in the air?"

Hypothesis

A hypothesis is a provisional but testable explanation for the question or observation. Pasteur's hypothesis was that "Microbes appearing in the sterile flask come from other germs in the air." If so, then air allowed to enter the sterile flask will contain germs that will grow in such profusion that they will be seen as a cloudy liquid.

Experiments



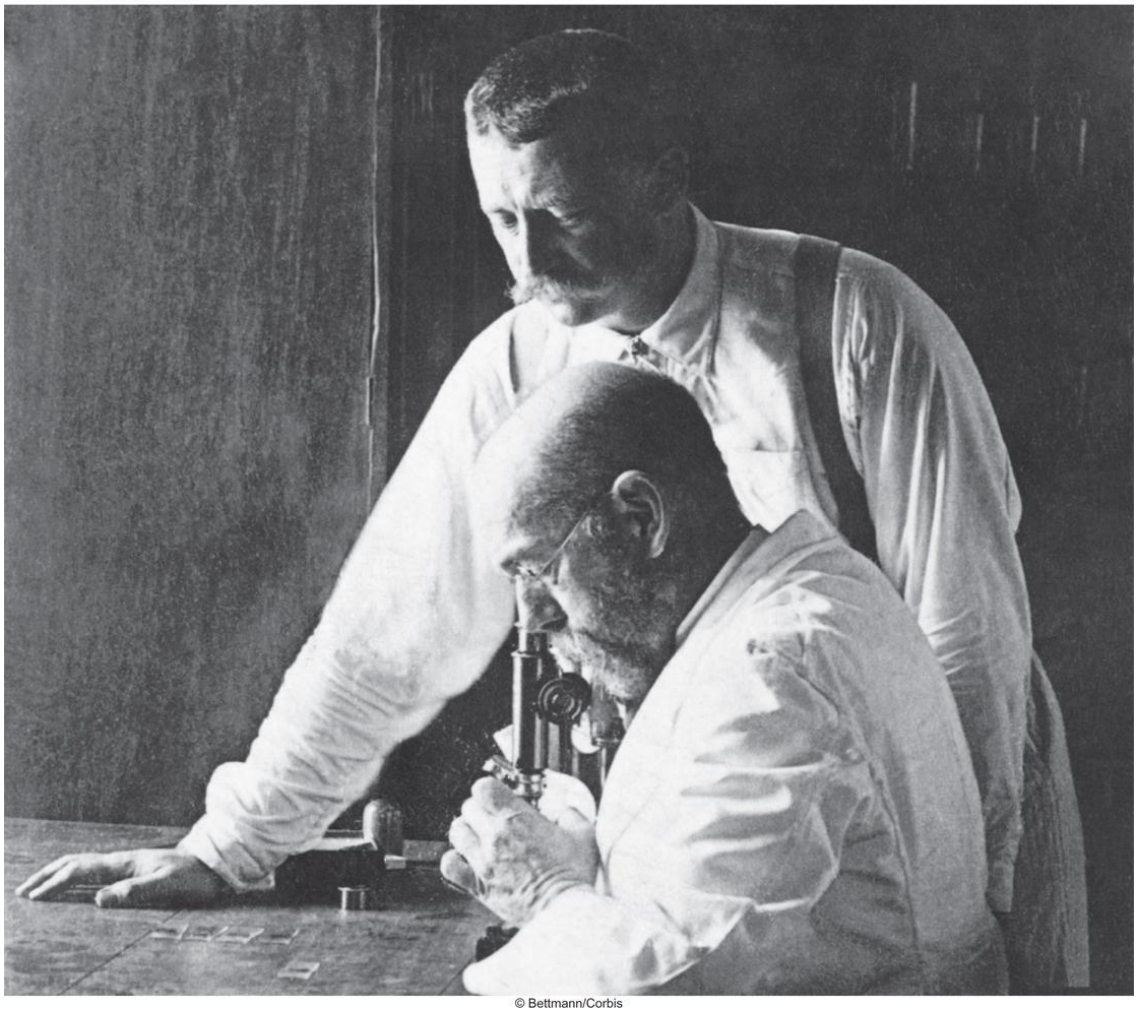
Results

Conclusions

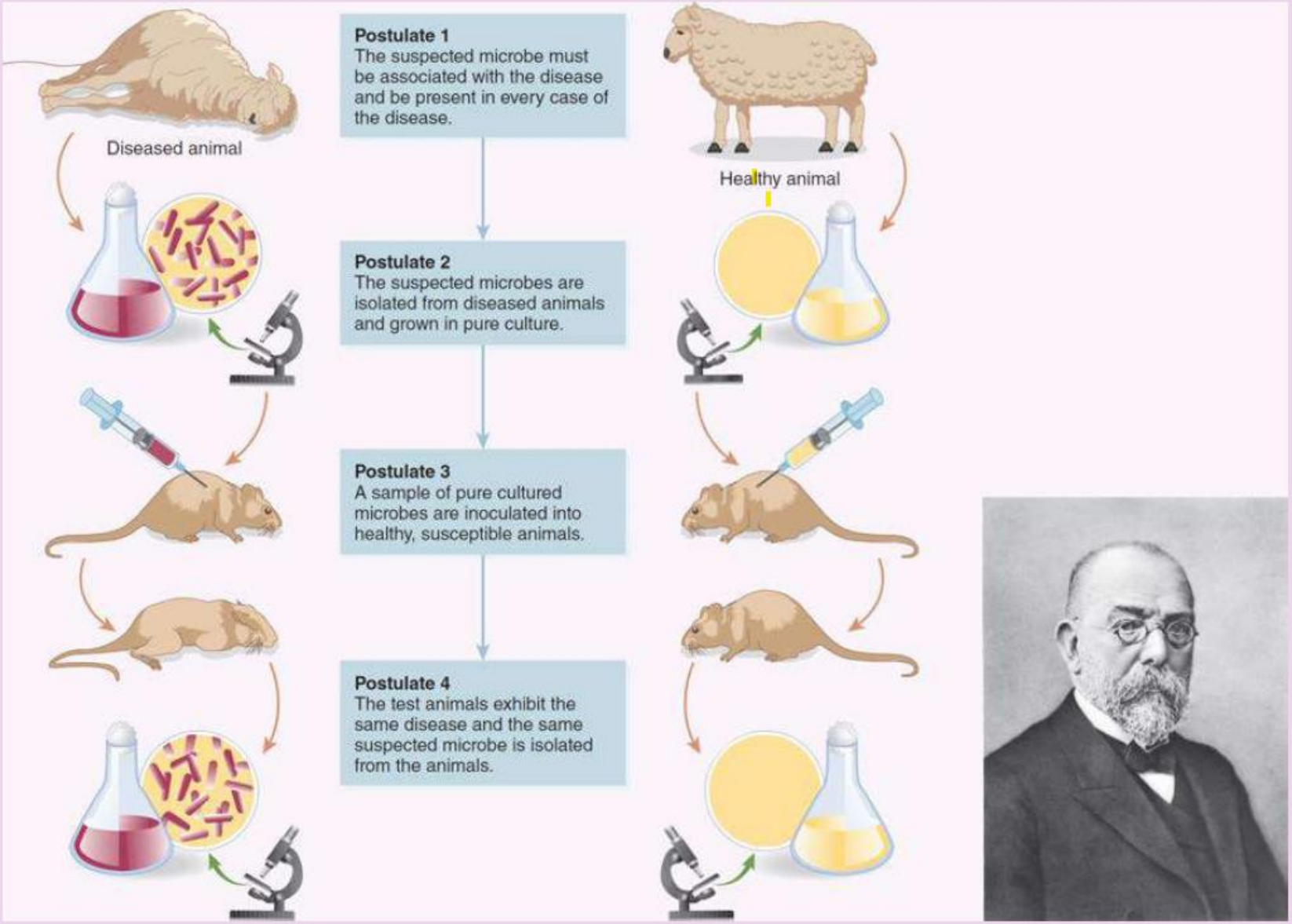
Louis Pasteur (1822-1895)

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

Robert Koch (1843-1910)

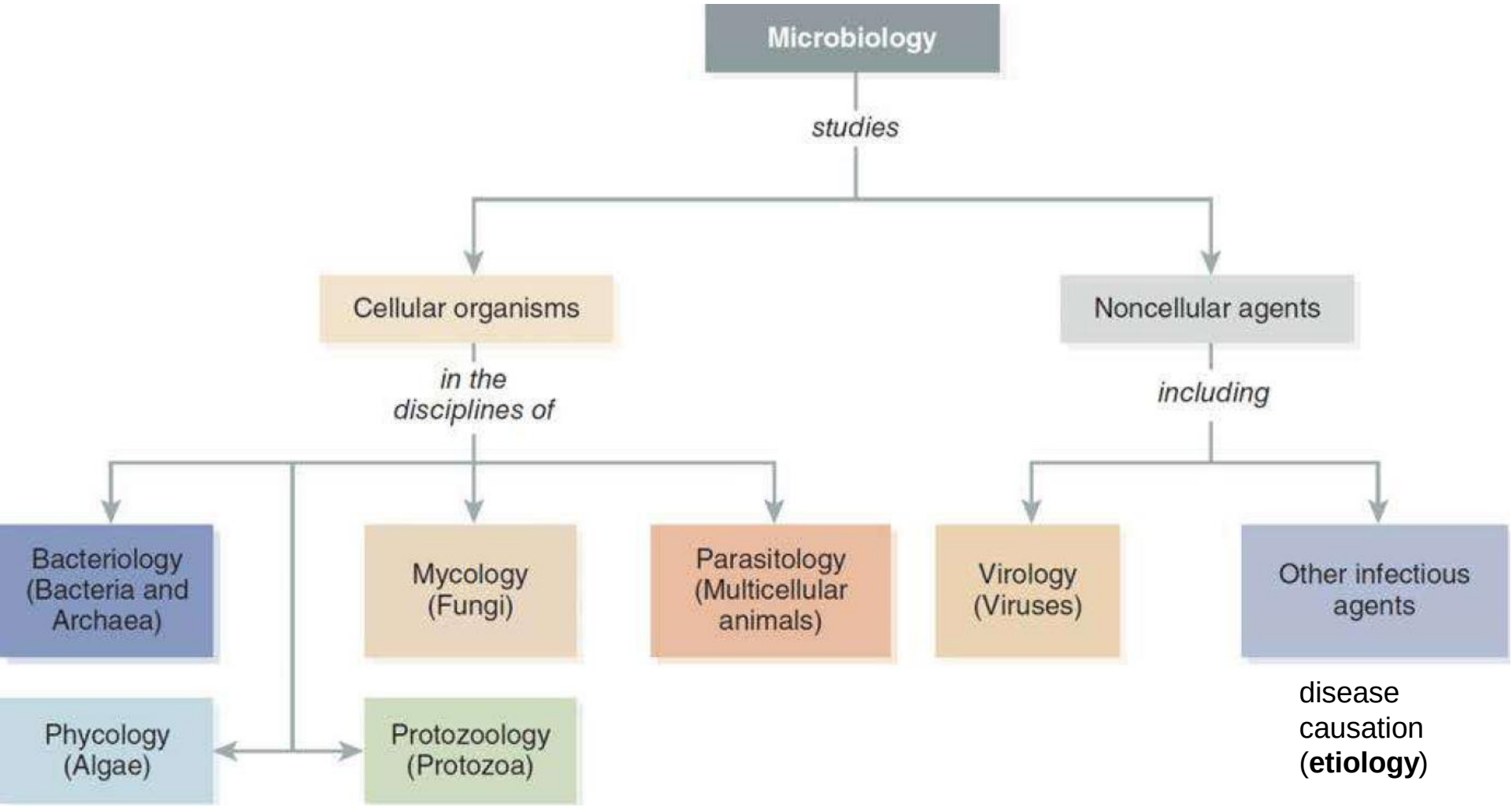


- Established **Koch's postulates** - a sequence of experimental steps that verified the germ theory
- Identified cause of anthrax, TB, and cholera
- Developed pure culture methods



Description

Microbiology disciplines



disease causation (**etiology**)

Other Pioneers

- Ignaz Semmelweis: handwashing reduced childbed fever.
- Joseph Lister: pioneered antiseptic surgery.
- Edward Jenner: first vaccine (smallpox, late 1700s).
- Alexander Fleming (later): discovered penicillin.

Basic characteristics of these microbial groups

❖ Despite their microscopic size, microorganisms share a common set of characteristics, or emerging properties, with all living organisms. These include:

- **Hereditary Material.** Information in the form of DNA is used by all organisms for cell function and reproduction.
- **Complex Biochemical Patterns** (**Metabolism**). The information in an organism's DNA controls metabolism, which also requires the uptake of energy to power these reactions.
- **Reproduction.** During cell division, the complete set of genetic information is replicated and passed to descendant cells.
- **Response to Stimuli.** Cells and organisms seldom live in isolation but rather interact in many different ways by responding to stimuli.
- **Evolutionary Adaptation.** Cell and organism changes (adaptations) over time provide those best suited to the environment the best chance of survival.