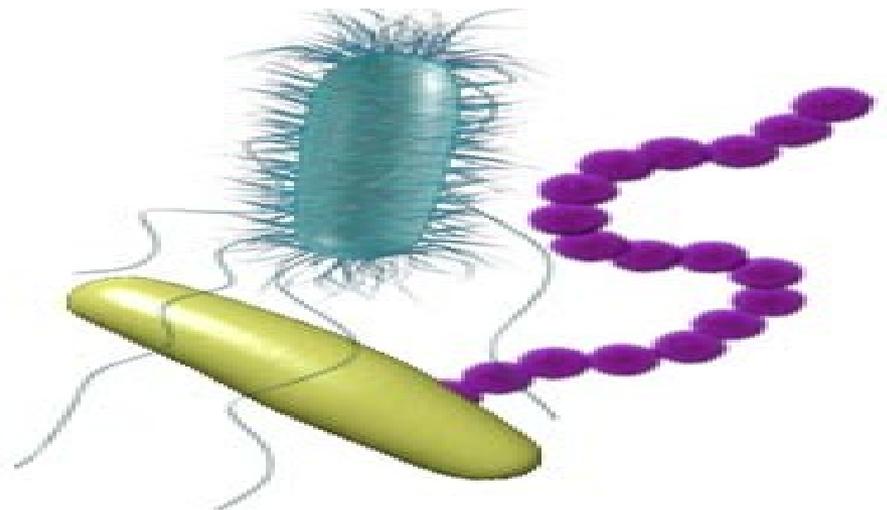


Microbiology for the Health Sciences

An Introduction to Microbiology

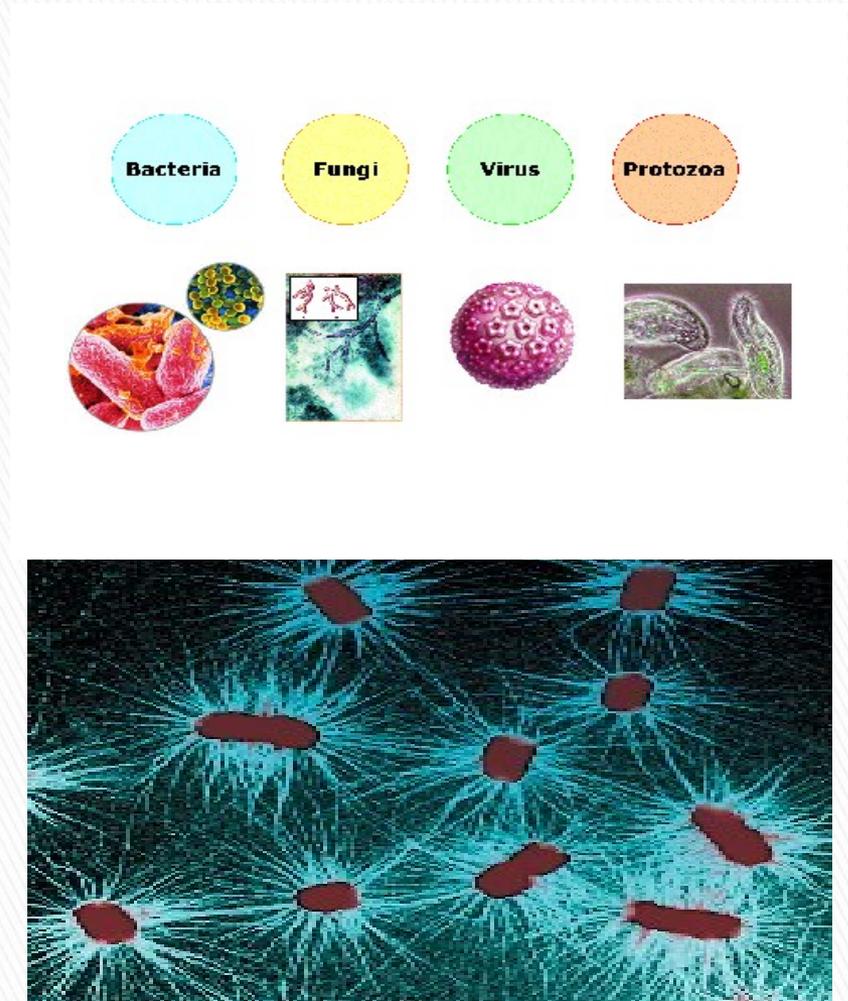


Illustration: Don Smith



The Scope of Microbiology

- ▶ **Microbiology:** The study of living things too small to be seen without magnification
 - **Microorganisms** or **microbes**- these microscopic organisms
 - Commonly called “germs, viruses, agents...” but not all cause disease and many more are useful or essential for human life



Introduction to Microbiology

How Can Microbes Be Classified?

Carolus Linnaeus (Swedish) developed taxonomic system for naming plants and animals and grouping similar organisms together

Leeuwenhoek's microorganisms grouped into six categories as follows:

Fungi

Protozoa

Algae

Bacteria

Archaea

Small animals

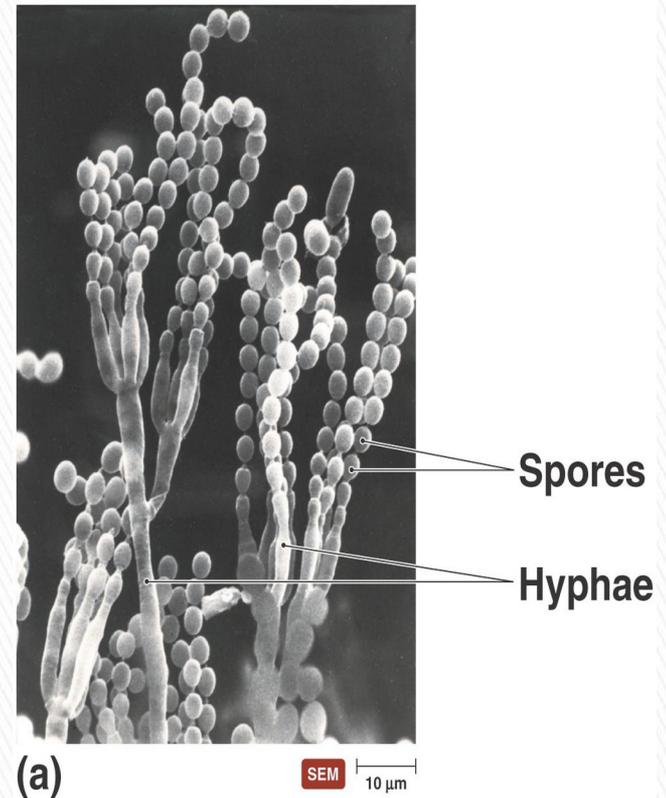


LM 50 μ m

Introduction to Microbiology

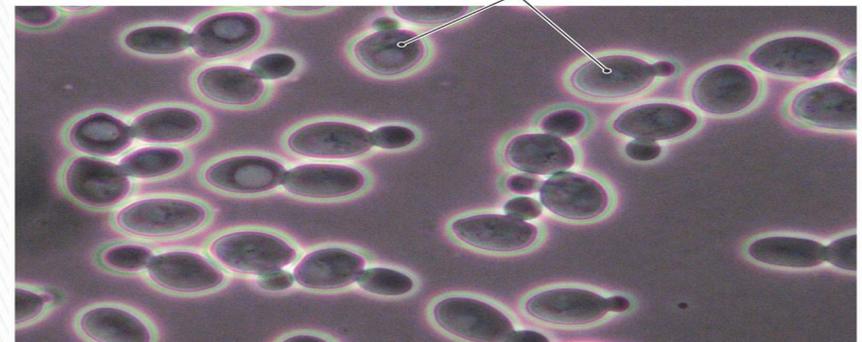
▶ Fungi

- Eukaryotic (have membrane-bound nucleus)
- Obtain food from other organisms
- Possess cell walls
- Composed of
 - ▢ Molds - multicellular; have hyphae; reproduce by sexual and asexual spores
 - ▢ Yeasts - unicellular; reproduce asexually by budding; some produce sexual spores



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Budding cells



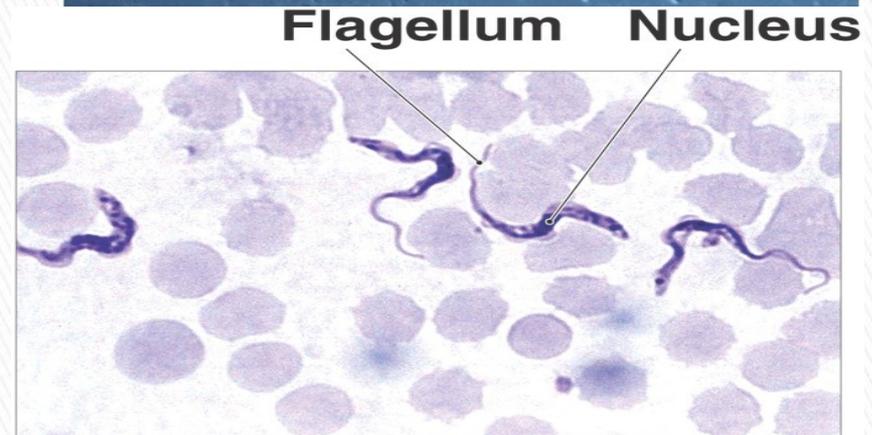
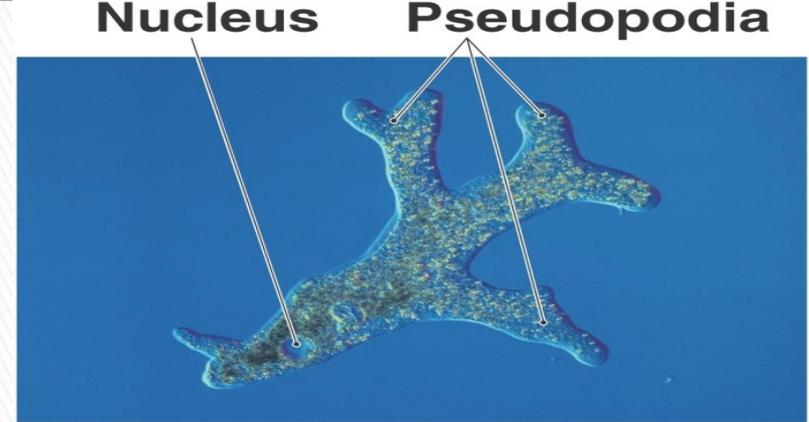
(b)

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Introduction to Microbiology

▶ Protozoa

- Single-celled eukaryotes
- Similar to animals in nutrient needs and cellular structure
- Live freely in water; some live in animal hosts
- Asexual (most) and sexual reproduction
- Most are capable of locomotion by
 - ▢ Pseudopodia - cell extensions that flow in direction of travel
 - ▢ Cilia - numerous, short, hairlike protrusions that propel organisms through environment
 - ▢ Flagella - extensions of a cell that are fewer, longer, and more whiplike than cilia



(c)

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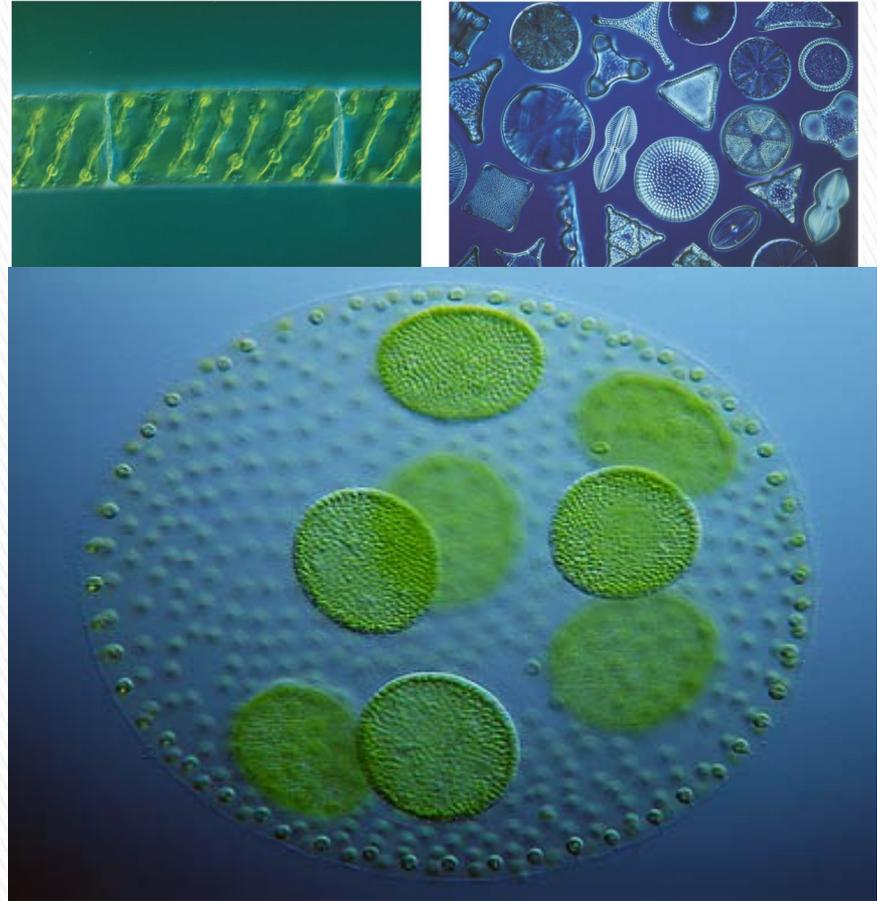
LM

10 μm

Introduction to Microbiology

▶ **Algae**

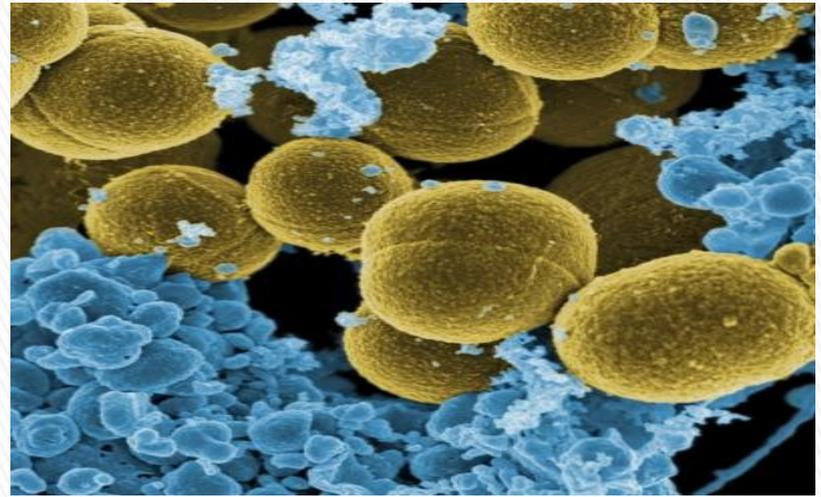
- Unicellular or multicellular
- Photosynthetic
- Simple reproductive structures
- Categorized on the basis of pigmentation, storage products, and composition of cell wall



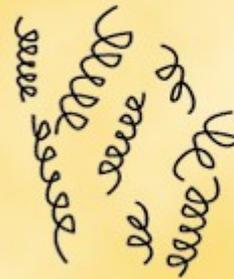
Introduction to Microbiology

▶ **Bacteria and Archaea**

- Unicellular and lack nuclei
- Much smaller than eukaryotes
- Found everywhere there is sufficient moisture; some found in extreme environments
- Reproduce asexually
- Two kinds
 - ▢ Bacteria - cell walls contain peptidoglycan; some lack cell walls; most do not cause disease and some are beneficial
 - ▢ Archaea - cell walls composed of polymers other than peptidoglycan



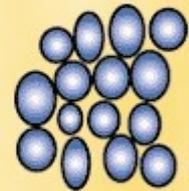
Bacterial Shapes



Spirilla



Bacilli

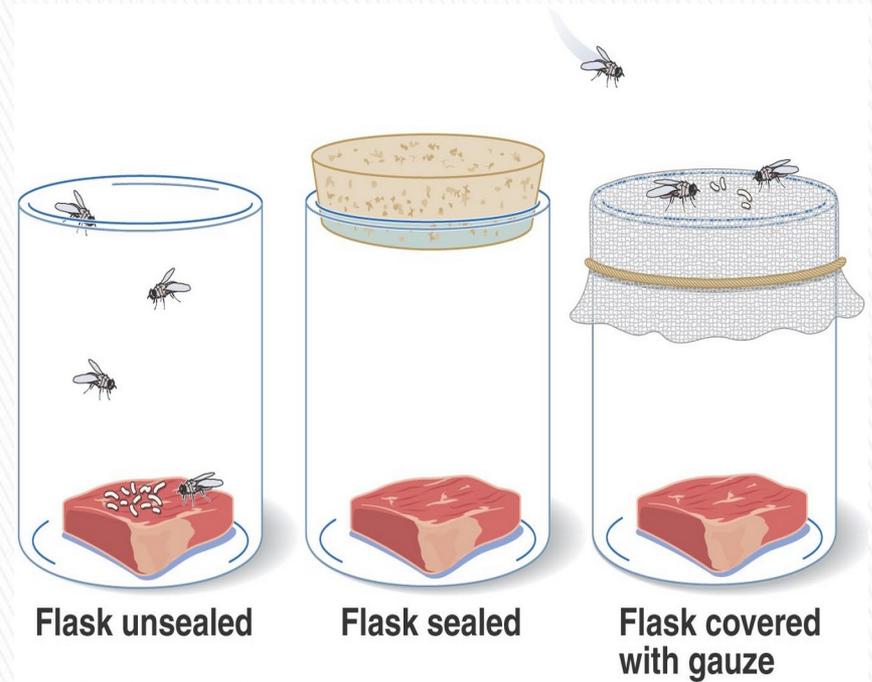


Cocci

The Golden Age of Microbiology

► Redi's Experiments

- When decaying meat was kept isolated from flies, maggots never developed
- Meat exposed to flies was soon infested
- As a result, scientists began to doubt Aristotle's theory

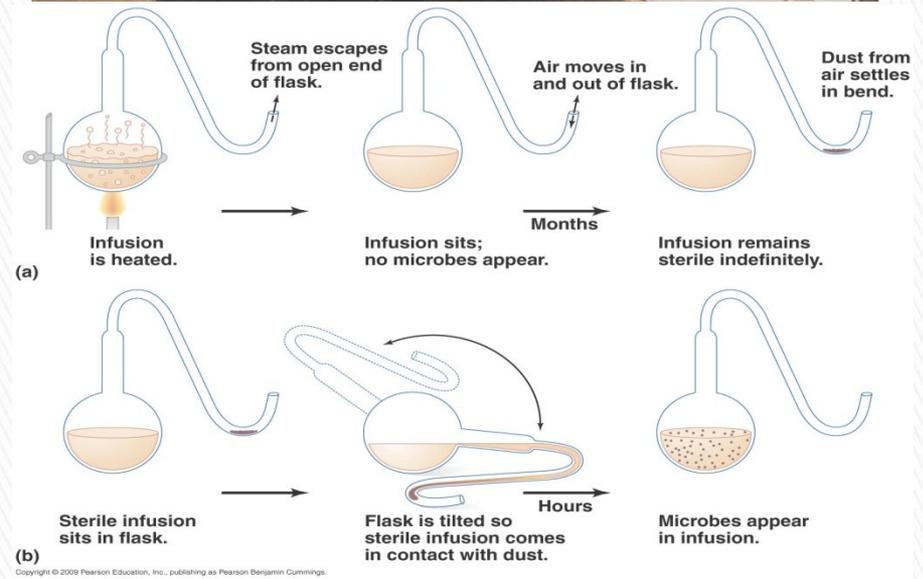


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The Golden Age of Microbiology

▶ Pasteur's Experiments

- When the “swan-necked flasks” remained upright, no microbial growth appeared
- When the flask was tilted, dust from the bend in the neck seeped back into the flask and made the infusion cloudy with microbes within a day



The Golden Age of Microbiology

Table 1.1 Some Industrial Uses of Microbes

Product or Process	Contribution of Microorganism
Foods and Beverages	
Cheese	Flavoring and ripening produced by bacteria and fungi; flavors dependent on the source of milk and the type of microorganism
Alcoholic beverages	Alcohol produced by bacteria or yeast by fermentation of sugars in fruit juice or grain
Soy sauce	Produced by fungal fermentation of soybeans
Vinegar	Produced by bacterial fermentation of sugar
Yogurt	Produced by bacteria growing in skim milk
Sour cream	Produced by bacteria growing in cream
Artificial sweetener	Amino acids synthesized by bacteria from sugar
Bread	Rising of dough produced by action of yeast; sourdough results from bacteria-produced acids

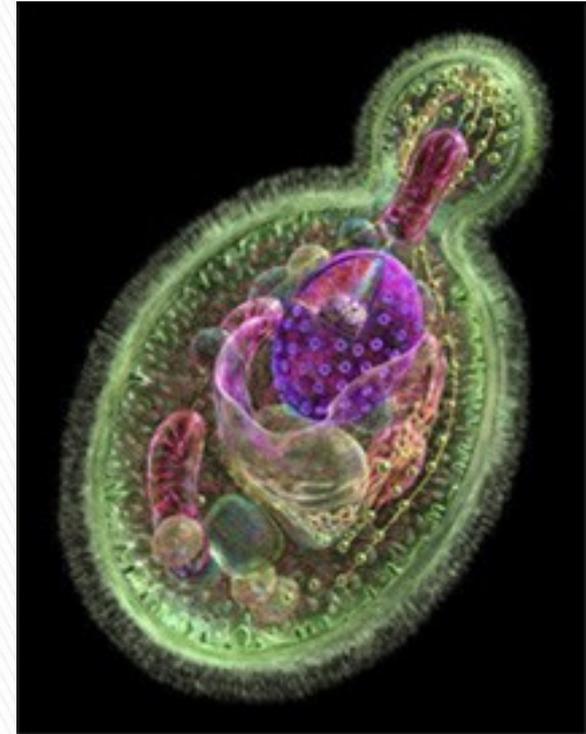


The Golden Age of Microbiology

Table 1.1 Some Industrial Uses of Microbes

Product or Process	Contribution of Microorganism
Other Products	
Antibiotics	Produced by bacteria and fungi
Human growth hormone, human insulin	Produced by genetically engineered bacteria
Laundry enzymes	Isolated from bacteria
Vitamins	Isolated from bacteria
Diatomaceous earth (used in polishes and buffing compounds)	Composed of cell walls of microscopic algae
Pest control chemicals	Insect pests killed or inhibited by bacterial pathogens
Drain opener	Protein-digesting and fat-digesting enzymes produced by bacteria

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The Golden Age of Microbiology

- ▶ **What Causes Disease?**
 - Pasteur developed germ theory of disease
 - Robert Koch studied causative agents of disease
 - ▢ Anthrax
 - ▢ Examined colonies of microorganisms

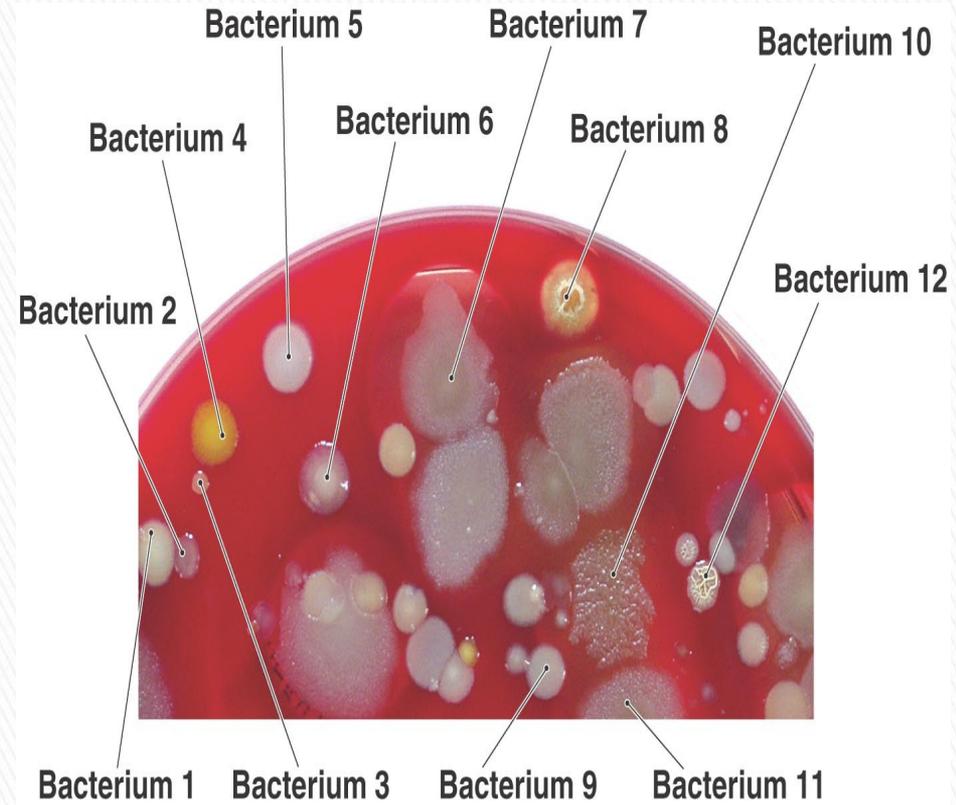


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The Golden Age of Microbiology

▶ Koch's Experiments

- Simple staining techniques
- First photomicrograph of bacteria
- First photomicrograph of bacteria in diseased tissue
- Techniques for estimating CFU/ml
- Use of steam to sterilize media
- Use of Petri dishes
- Aseptic techniques
- Bacteria as distinct species
- Koch's Postulates



The Golden Age of Microbiology

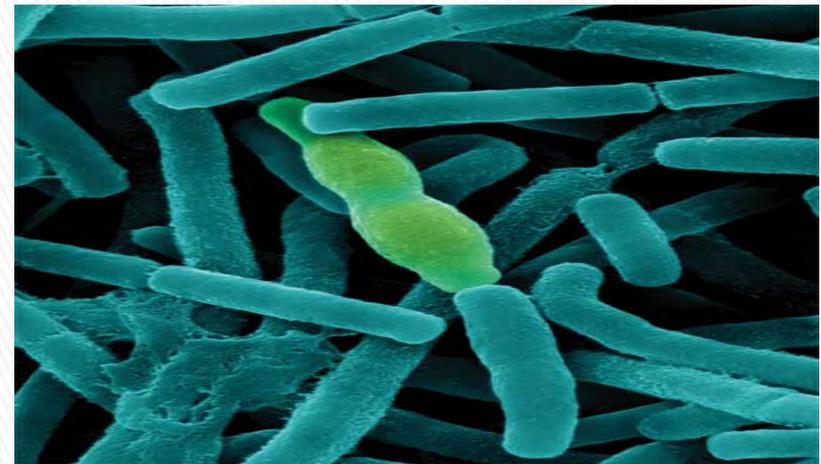
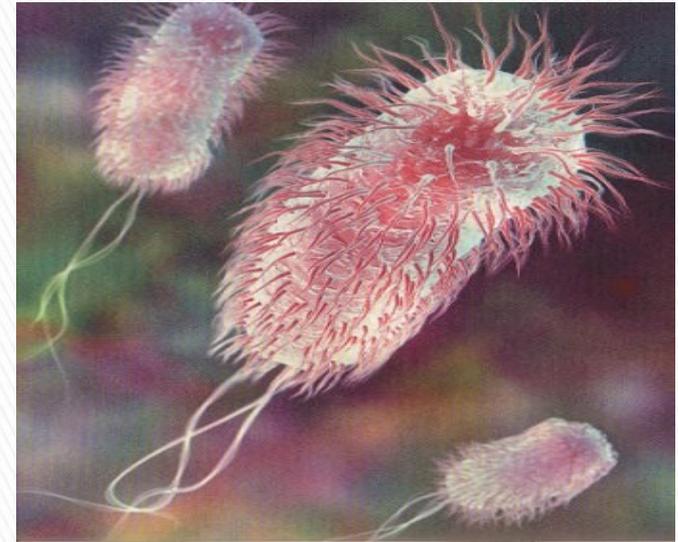


Table 1.2 Some Notable Scientists of the “Golden Age of Microbiology” and the Agents of Disease They Discovered

Scientist	Year	Disease	Agent
Robert Koch	1876	Anthrax	<i>Bacillus anthracis</i> (bacterium)
Albert Neisser	1879	Gonorrhea	<i>Neisseria gonorrhoeae</i> (bacterium)
Charles Laveran	1880	Malaria	<i>Plasmodium</i> species (protozoa)
Carl Eberth	1880	Typhoid fever	<i>Salmonella typhi</i> (bacterium)
Robert Koch	1882	Tuberculosis	<i>Mycobacterium tuberculosis</i> (bacterium)
Edwin Klebs	1883	Diphtheria	<i>Corynebacterium diphtheriae</i> (bacterium)
Theodore Escherich	1884	Traveler's diarrhea Bladder infection	<i>Escherichia coli</i> (bacterium)
Albert Fraenkel	1884	Pneumonia	<i>Streptococcus pneumoniae</i> (bacterium)
Robert Koch	1884	Cholera	<i>Vibrio cholerae</i> (bacterium)
David Bruce	1887	Undulant fever (brucellosis)	<i>Brucella melitensis</i> (bacterium)
Anton Weichselbaum	1887	Meningococcal meningitis	<i>Neisseria meningitidis</i> (bacterium)
A. A. Gartner	1888	Salmonellosis (form of food poisoning)	<i>Salmonella</i> species (bacterium)
Shibasaburo Kitasato	1889	Tetanus	<i>Clostridium tetani</i> (bacterium)
Dmitri Ivanowski and Martinus Beijerinck	1892 1898	Tobacco mosaic disease	<i>Tobamovirus tobacco mosaic virus</i>
William Welch and George Nuttall	1892	Gas gangrene	<i>Clostridium perfringens</i> (bacterium)
Alexandre Yersin and Shibasaburo Kitasato	1894	Bubonic plague	<i>Yersinia pestis</i> (bacterium)
Kiyoshi Shiga	1898	Shigellosis (a type of severe diarrhea)	<i>Shigella dysenteriae</i> (bacterium)
Walter Reed	1900	Yellow fever	<i>Flavivirus Yellow fever virus</i>
Robert Forde and Joseph Dutton	1902	African sleeping sickness	<i>Trypanosoma brucei gambiense</i> (protozoan)

The Golden Age of Microbiology

▶ How Can We Prevent Infection and Disease?

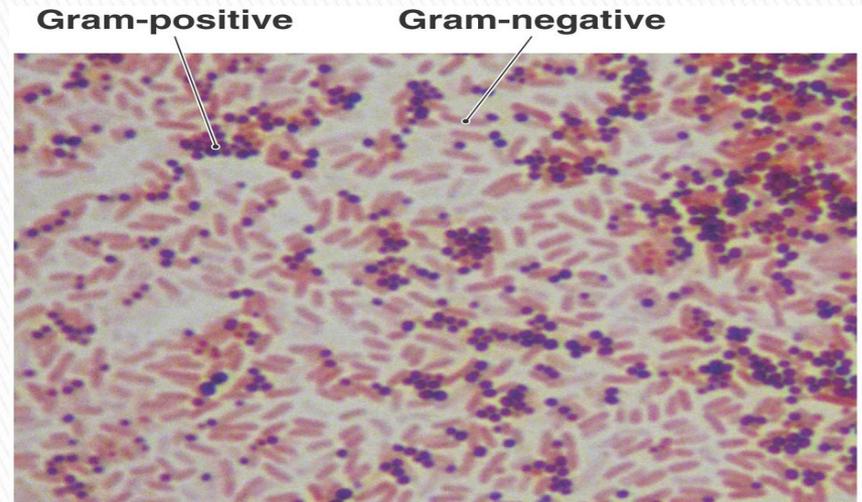
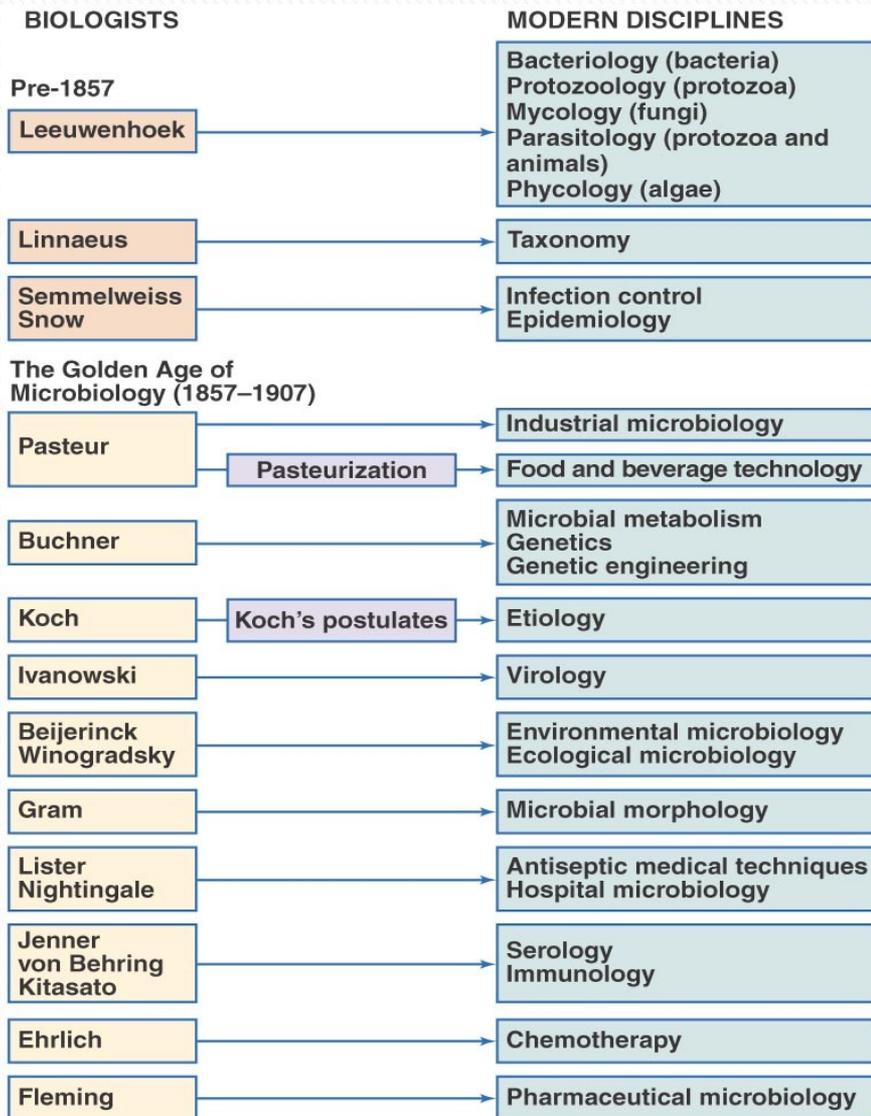
- Semmelweis and handwashing
- Lister's antiseptic technique
- Nightingale and nursing
- Snow - infection control and epidemiology
- Jenner's vaccine - field of immunology
- Ehrlich's "magic bullets" - field of chemotherapy



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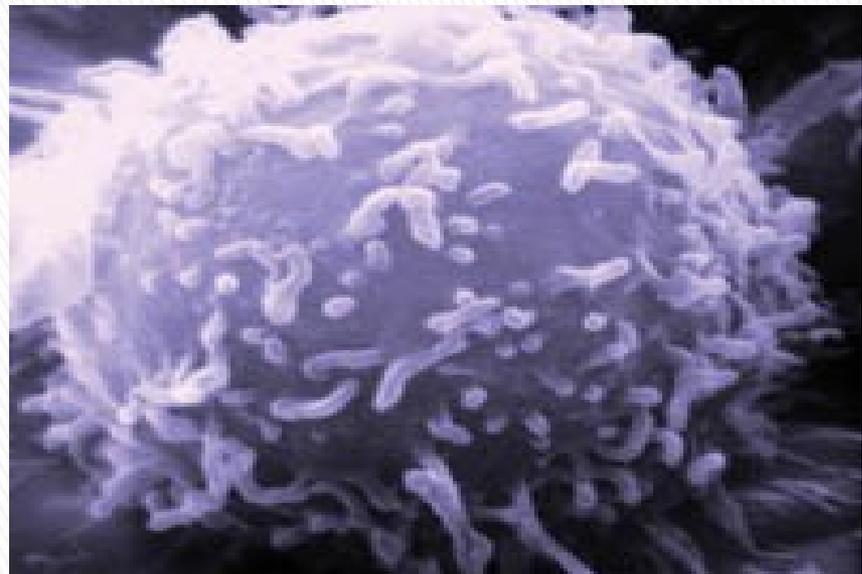


The Golden Age of Microbiology



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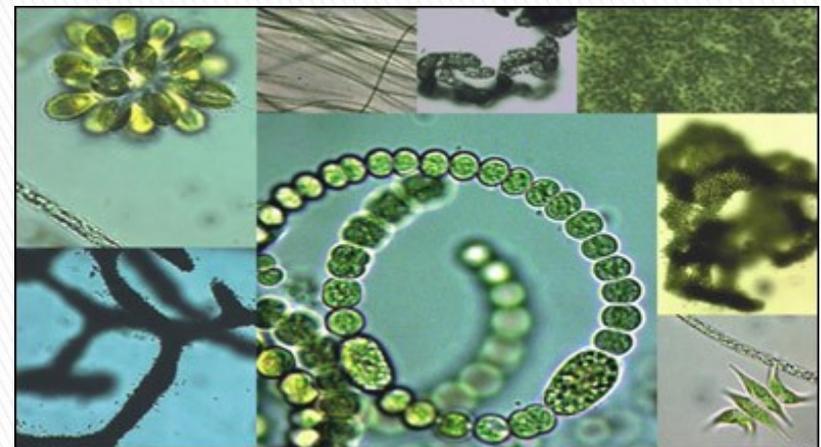
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The Modern Age of Microbiology

Table 1.3 Fields of Microbiology

Disciplines	Subject(s) of Study
Basic Research	
Microbe-Centered	
Bacteriology	Bacteria and archaea
Phycology	Algae
Mycology	Fungi
Protozoology	Protozoa
Parasitology	Parasitic protozoa and parasitic animals
Virology	Viruses
Process-Centered	
Microbial metabolism	Biochemistry: chemical reactions within cells
Microbial genetics	Functions of DNA and RNA
Environmental microbiology	Relationships between microbes, and among microbes, other organisms, and their environment



The Modern Age of Microbiology

▶ What Are the Basic Chemical Reactions of Life?

- Biochemistry
 - ▢ Began with Pasteur's work on fermentation and Buchner's discovery of enzymes in yeast extract
 - ▢ Kluyver and van Niel - microbes used as model systems for biochemical reactions
 - ▢ Practical applications
 - ▢ Design of herbicides and pesticides
 - ▢ Diagnosis of illnesses and monitoring of patients' responses to treatment
 - ▢ Treatment of metabolic diseases
 - ▢ Drug design

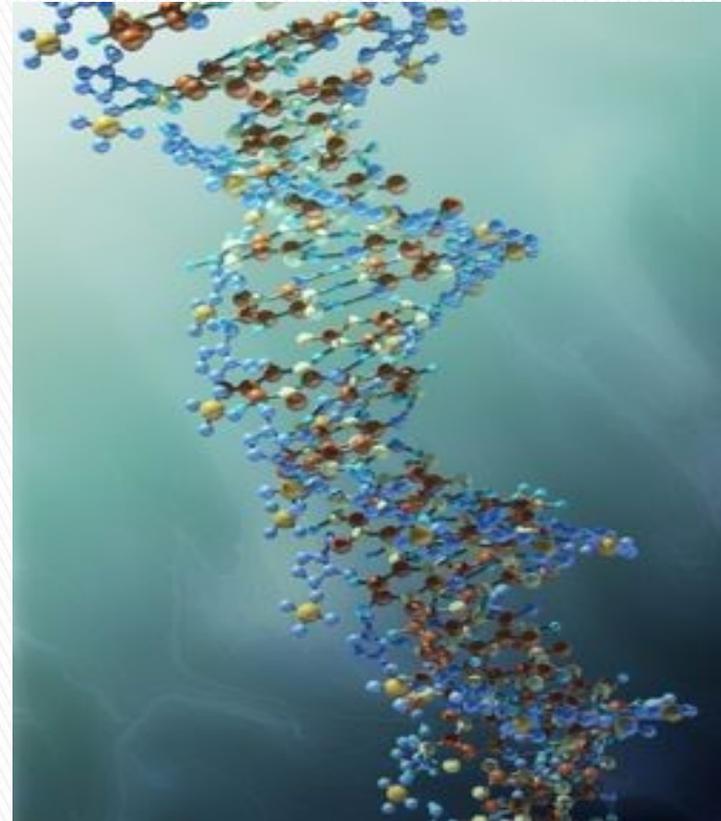
Table 1.3 Fields of Microbiology

Disciplines	Subject(s) of Study
Applied Microbiology	
Medical Microbiology	
Serology	Antibodies in blood serum, particularly as an indicator of infection
Immunology	Body's defenses against specific diseases
Epidemiology	Frequency, distribution, and spread of disease
Etiology	Causes of disease
Infection control	Hygiene in health care settings and control of nosocomial infections
Chemotherapy	Development and use of drugs to treat infectious diseases
Applied Environmental Microbiology	
Bioremediation	Use of microbes to remove pollutants
Public health microbiology	Sewage treatment, water purification, and control of insects that spread disease
Agricultural microbiology	Use of microbes to control insect pests
Industrial Microbiology (Biotechnology)	
Food and beverage technology	Reduction or elimination of harmful microbes in food and drink
Pharmaceutical microbiology	Manufacture of vaccines and antibiotics
Recombinant DNA technology	Alteration of microbial genes to synthesize useful products

The Modern Age of Microbiology

▶ **How Do Genes Work?**

- Microbial genetics
- Molecular biology
- Recombinant DNA technology
- Gene therapy



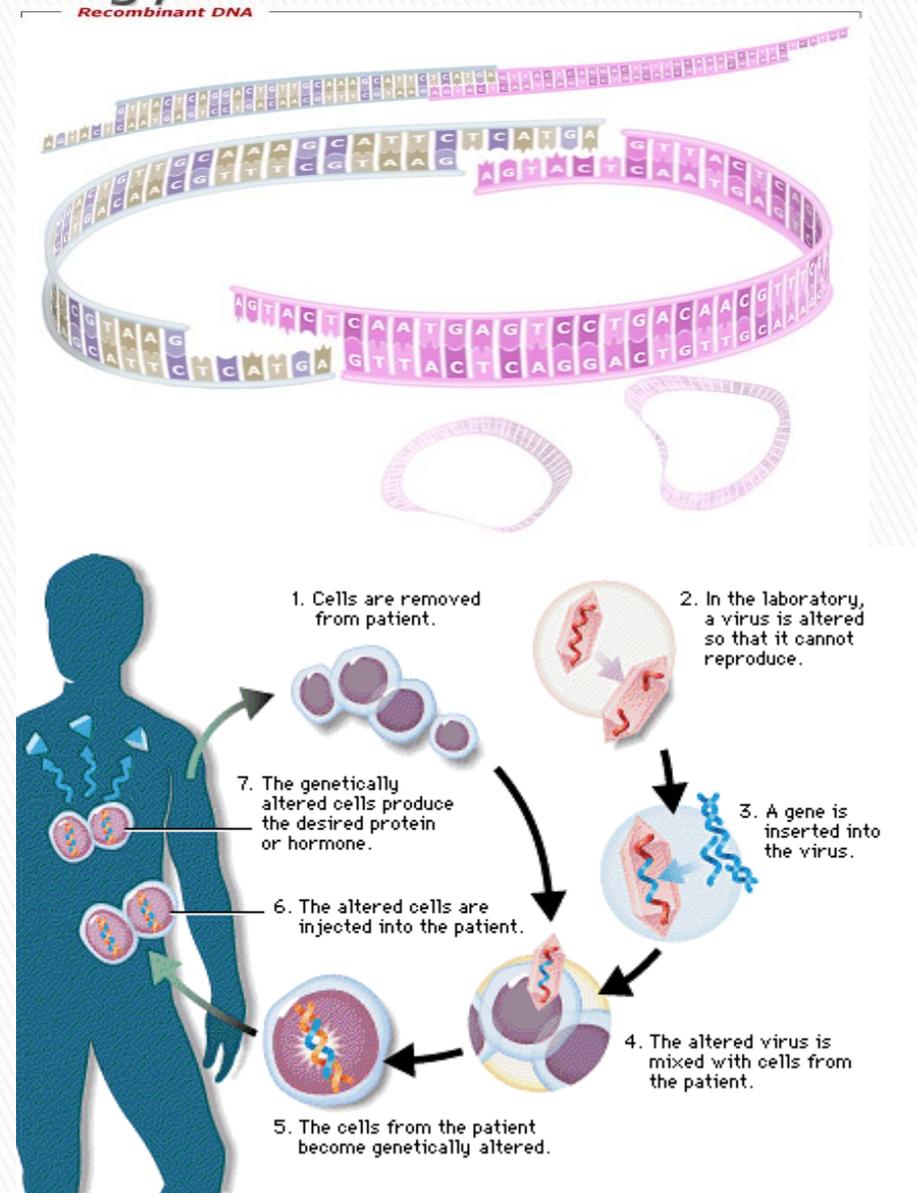
The Modern Age of Microbiology

▶ Recombinant DNA Technology

- Genes in microbes, plants, and animals manipulated for practical applications
- Production of human blood-clotting factor by *E. coli* to aid hemophiliacs

▶ Gene Therapy

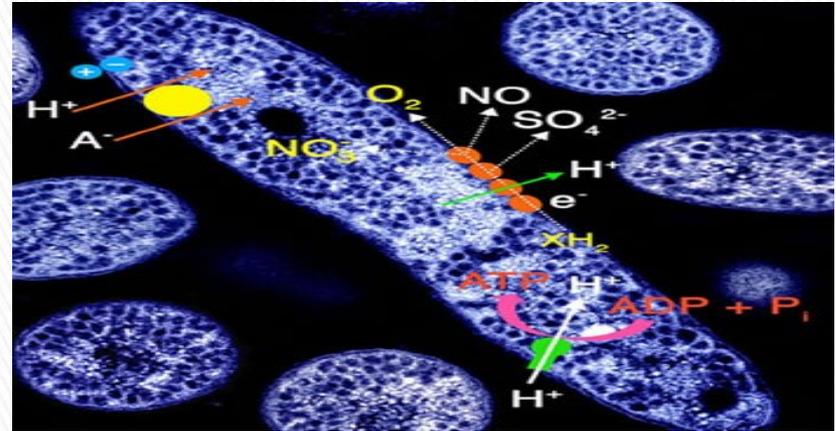
- Inserting a missing gene or repairing a defective one in humans by inserting desired gene into host cells



The Modern Age of Microbiology

▶ **What Role Do Microorganisms Play in the Environment?**

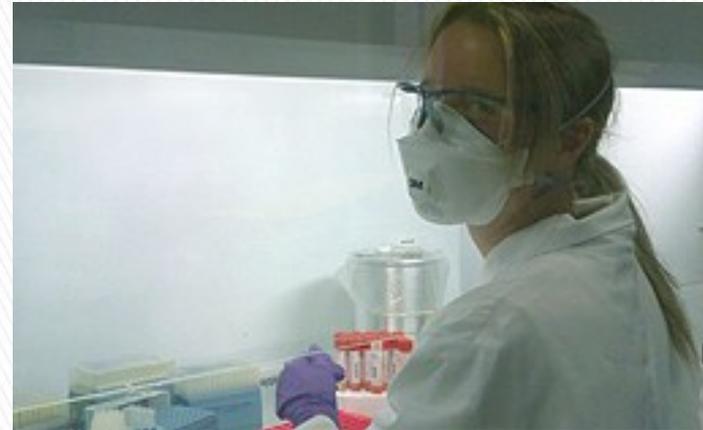
- Bioremediation uses living bacteria, fungi, and algae to detoxify polluted environments
- Recycling of chemicals such as carbon, nitrogen, and sulfur



The Modern Age of Microbiology

▶ How Do We Defend Against Disease?

- Serology
 - ▢ The study of blood serum
 - ▢ Von Behring and Kitasato – existence in the blood of chemicals and cells that fight infection
- Immunology
 - ▢ The study of the body's defense against specific pathogens
- Chemotherapy
 - ▢ Fleming discovered penicillin
 - ▢ Domagk discovered sulfa drugs



• safer food supply
• protect public health
• consumer confidence
• international trade

FDA
USDA **CDC**

NARMS

National Antimicrobial Resistance Monitoring System
Food and Drug Administration • Centers for Disease Control and Prevention • United States Department of Agriculture

The graphic features a central circular element containing a map of the United States. To the left of this circle is a petri dish with several dark, circular colonies on a light-colored agar surface. To the right of the map circle are the logos for the FDA, USDA, and CDC. Below these elements, the word 'NARMS' is written in large, bold, red letters with a white outline. At the bottom, the full name of the system is written in black, followed by the logos of the three partner organizations.

The Modern Age of Microbiology

▶ What Will the Future Hold?

- Microbiology is built on asking and answering questions
- The more questions we answer, the more questions we have

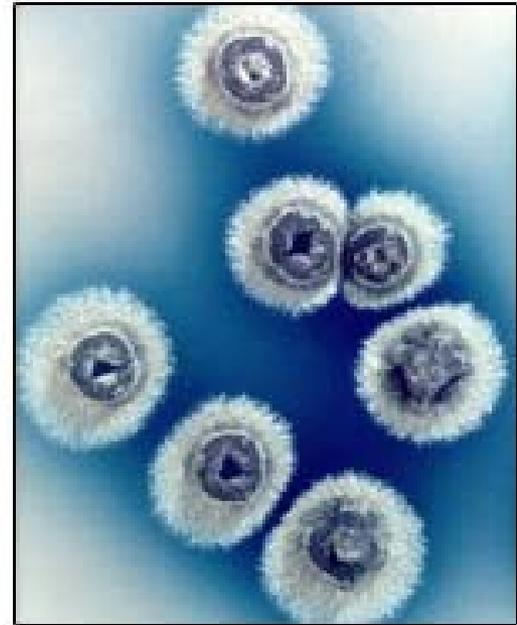
Zone of inhibition



Fungus colony

Bacterial colonies (white dots)

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Streptomyces colonies producing a blue antibiotic. (John Innes Centre)

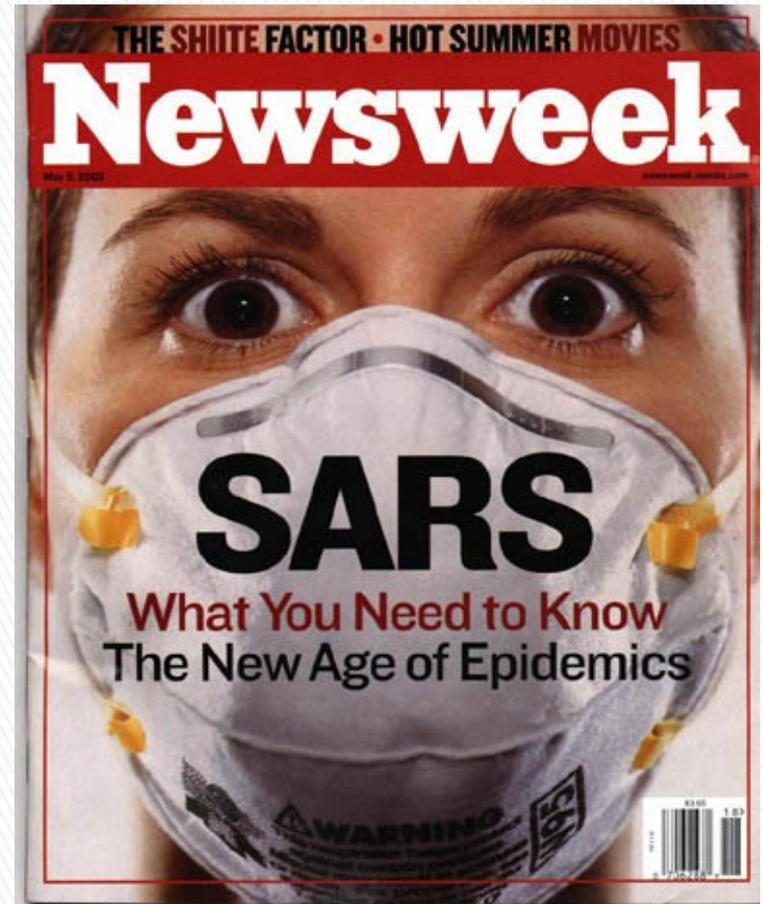
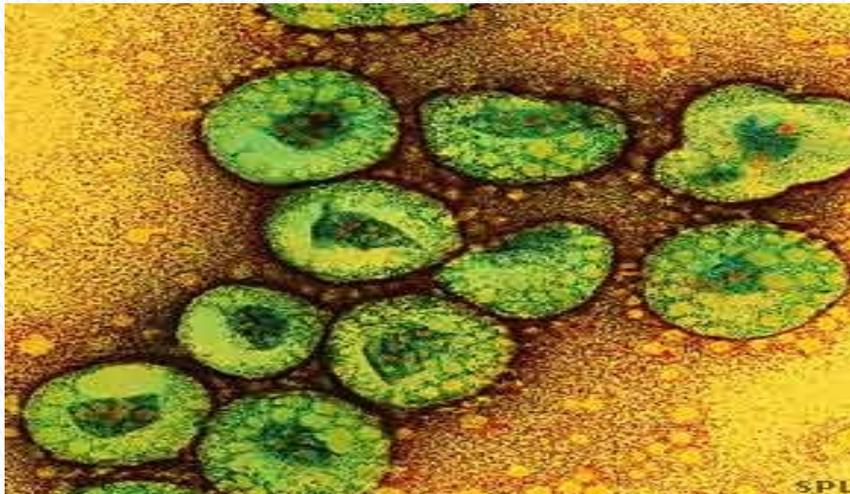


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Worldwide Infectious Diseases Affecting Health Sciences

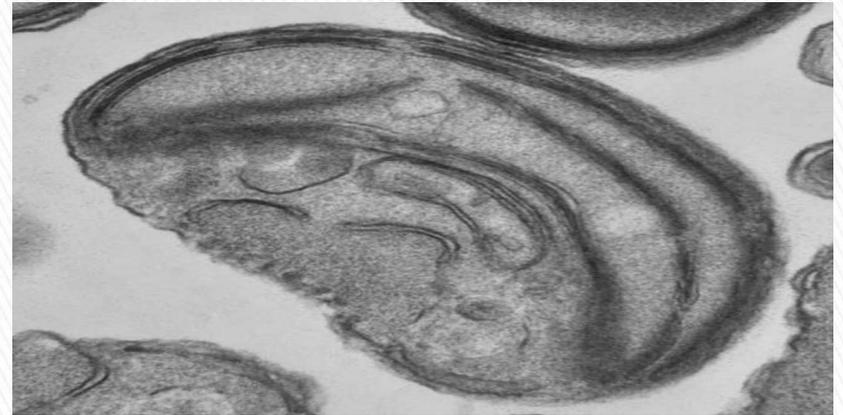
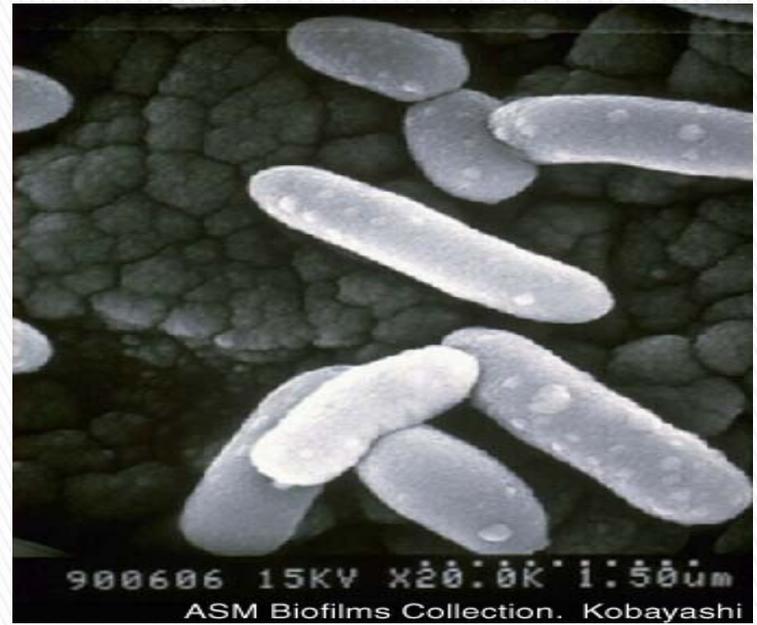
- ▶ Increasing number of emerging diseases (SARS, AIDS, hepatitis C, viral encephalitis)
- ▶ Other diseases previously not linked to microorganisms now are (gastric ulcers, certain cancers, multiple sclerosis)



Cellular Organization

Prokaryotic

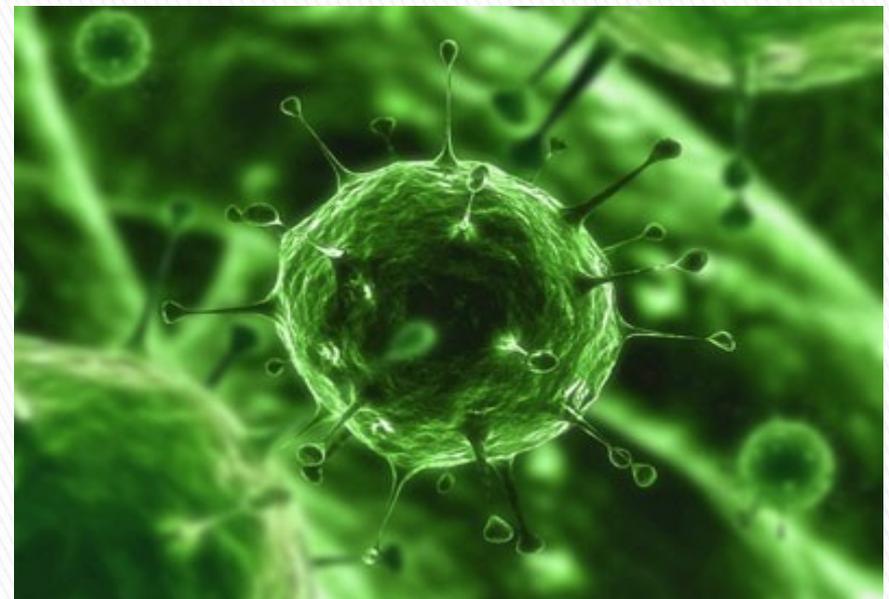
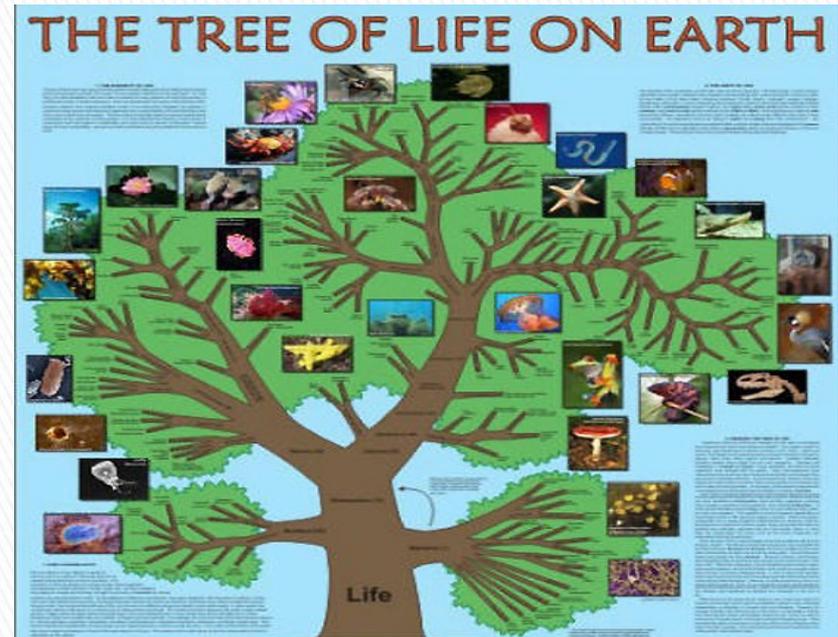
Eukaryotic



Definition of Life

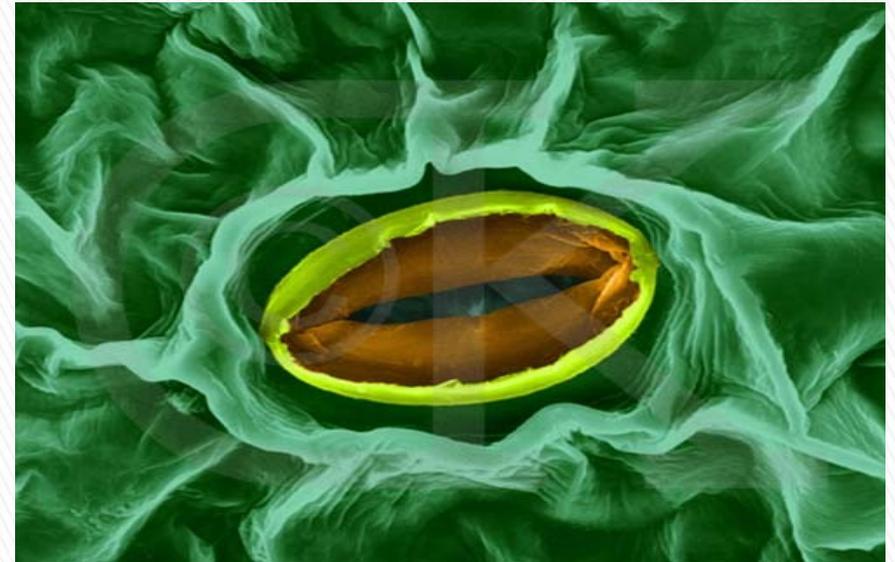
What characteristics must an organism have in order to be considered alive?

- ▶ **Metabolism:** Transformation of energy by converting chemicals and energy into cellular components (anabolism) and decomposing organic matter (catabolism). Living things require energy to maintain internal organization (homeostasis) and to produce the other phenomena associated with life.
- ▶ **Reproduction:** The ability to produce new individual organisms either asexually, from a single parent organism, or sexually, from at least two parent organisms.



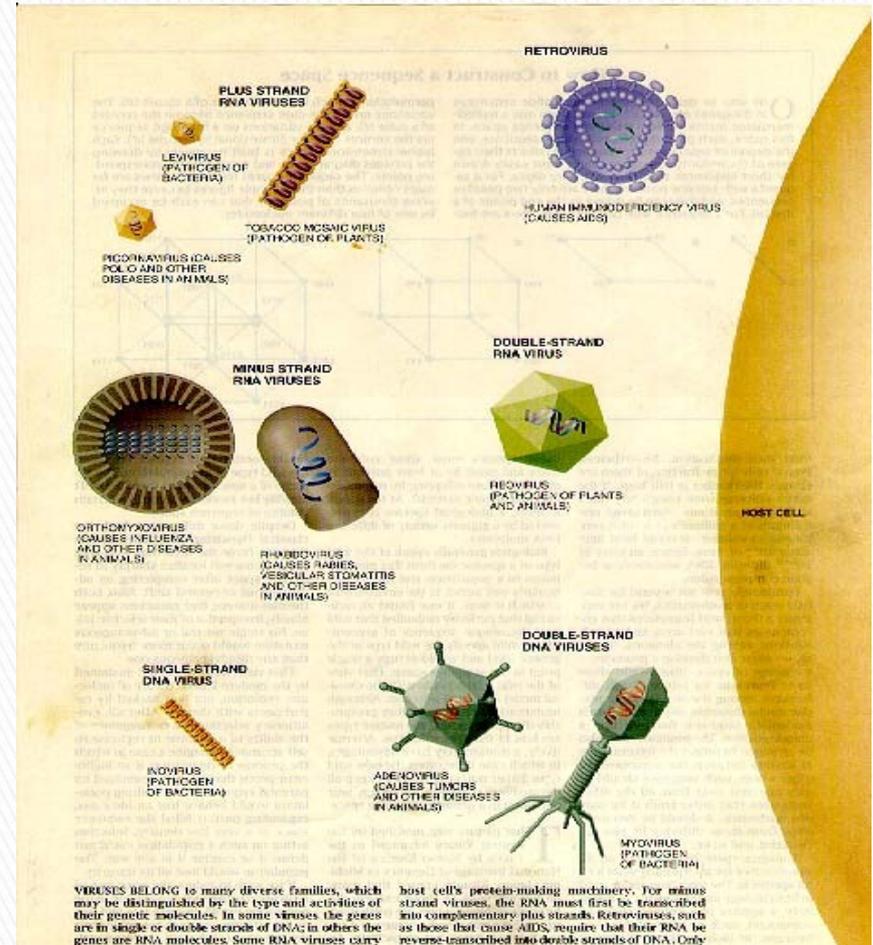
Types of Microorganisms Based on Acquiring Nutrition

- ▶ Autotrophic
- ▶ Heterotrophic
- ▶ Saprophytic or Saprobiic



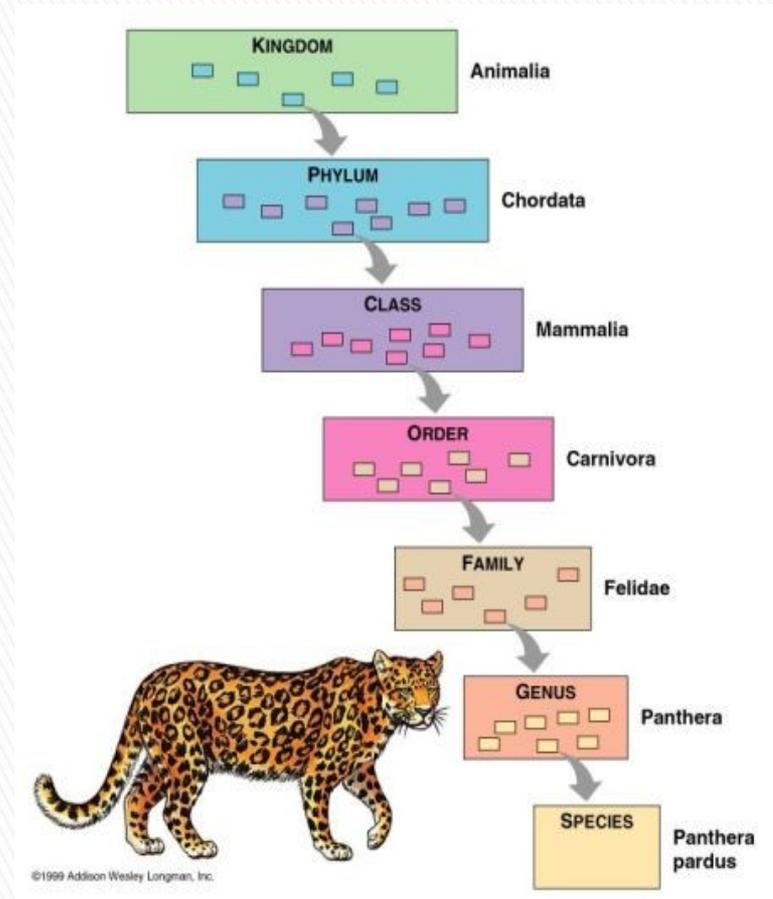
Viruses

- ▶ Not independently living cellular organisms
- ▶ Much simpler than cells- basically a small amount of DNA or RNA wrapped in protein and sometimes by a lipid membrane
- ▶ Individuals are called a **virus particle** or **virion**
- ▶ Depend on the infected cell's machinery to multiply and disperse



Taxonomy: Naming, Classifying, and Identifying Microorganisms

- ▶ **Microbial nomenclature**- naming microorganisms
- ▶ **Taxonomy**- classifying living things
- ▶ **Identification**- discovering and recording the traits of organisms so they can be named and classified



Traditional Whittaker Classification

Five Kingdoms

Prokaryotae (Monera)

Protista

Fungae

Plantae

Animalia

Based on:

Morphology

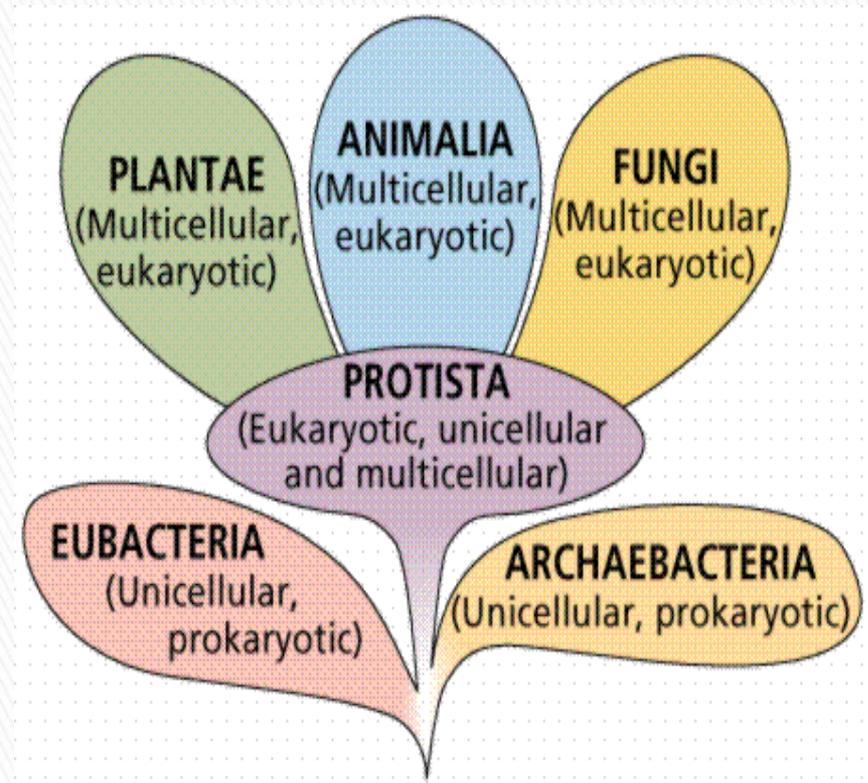
Metabolism (Biochemical Activity)

Molecular Techniques

Fatty Acid Profiles

Protein Differentiation

DNA Finger Printing



Classification

Woese-Fox Classification

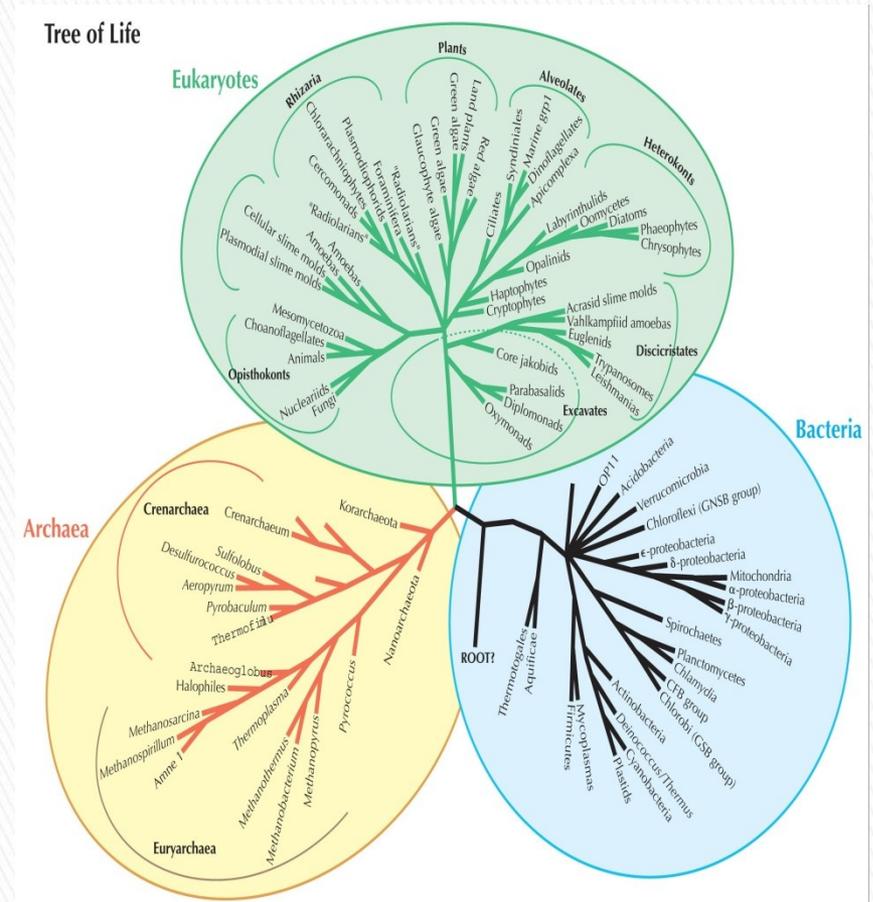
Three Super Kingdoms

Eubacteria

Archaeabacteria

Eukarya

System is based on rRNA.



Assigning Specific Names

- ▶ The **binomial system of nomenclature**
 - The generic (genus) name followed by the species name
 - Generic part is capitalized, species is lowercase
 - Both are italicized or underlined if italics aren't available

▮ *Staphylococcus aureus*



The Origin and Evolution of Microorganisms

- ▶ **Phylogeny**- the degree of relatedness between groups of living things
- ▶ Based on the process of **evolution**- hereditary information in living things changes gradually through time; these changes result in structural and functional changes through many generations
- ▶ Two preconceptions:
 - All new species originate from preexisting species
 - Closely related organisms have similar features because they evolved from a common ancestor
- ▶ Phylogeny usually represented by a tree- showing the divergent nature of evolution

