Lecture 1
6^{th} Jan 2023
BT 206
Microbiology
Prof Manish Kumar

BT 206 Microbiology 3-0-0-6

Syllabus

Introduction to microbiology and study of microorganisms: Scope of Microbiology; History of Microbiology: Spontaneous generation; Germ theory of diseases; Cell theory; Contributions of Antonie van Leuwenhoek, Joseph Lister, Robert Koch, Louis Pasteur, Edward Jenner, John Tyndall, Sergei N. Winogradsky, Alexander Fleming, etc; Microbial cell structure and function: General account of cell size, arrangement, shape; capsule, slime, pili, spores; structure and function of gram negative & gram-positive cell wall and membrane; periplasmic space; brief account of viruses; mycoplasma, eukaryotic microbes.

Microbial taxonomy: Taxonomy: principle and its types; classical approach: numerical, chemical, serological and genetic; bacterial taxonomy: Bergey's manual of Systematic Bacteriology (eubacteria and archaebacteria)

Methods and techniques in Microbiology: Microscopy: Principles; light microscope, phase contrast, dark field, bright field, fluorescent, interference microscope (stereo microscope); confocal microscopy; electron microscope (TEM and SEM).

Nutrition, growth and culturing: Microbiological media, composition and types; selective and differential media; growth curve, growth kinetics; influence of environmental factors on microbial growth; nutritional groups of bacteria; overview estimation of microbes - direct microscopic count, turbidometric assay; indirect method - CO2 liberation, protein estimation; sterilization and disinfection.

Microbial metabolism: Carbohydrate catabolism; anaerobic respiration, fermentation; protein and lipid catabolism; biosynthesis of purines, pyramidines, peptidoglycan, amino acids, lipids.

Microbial genetics: DNA replication in bacteria, fundamentals of gene regulation; mutations and DNA repair; plasmids, transformation, conjugation, transduction; Fundamentals of microbial genomics, metagenomics; Introduction to metagenomics; Scope and applications of genomics and metagenomics;.

Applications/Role of microbes: Applications in agriculture; environment; industry; health and disease. microbe interactions; mechanisms of pathogenicity.

Text Books

1.G. Tortora, B. Funke and C. Case,Microbiology,An Introduction (International Edition), 8th Ed, Pearson Education, 2003.

2. M. Madigan, J. Martinko ad J. Parker, Brock Biology of Microorganisms, 10th Ed, Prentice Hall, 2002.

References

1. R. Y. Stanier, J. L. Ingraham, M.L. Wheelis and P. R. Painter, General Microbiology, 5th Ed, Macmillan Press, 1987.

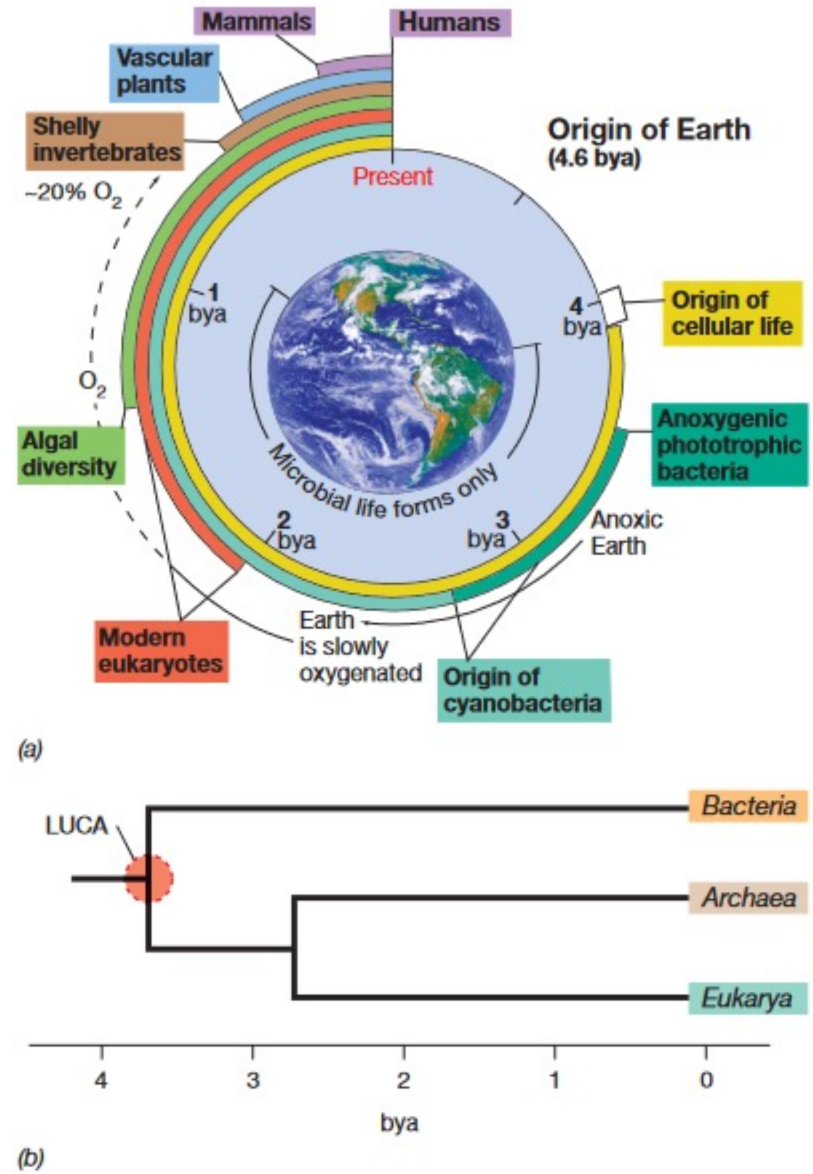
2. L. M. Prescott, J. P. Harley and D. A. Klein, Microbiology, 6th Ed, McGraw Hill, 2005.

3. J. G. Black, Microbiology: Principles & Explorations. 5th Ed, John Wiley & Sons Inc., 2002.Benjamin Lewin, Genes VIII (International Edition), Pearson Education, 2004.

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

(a) Cellular life was present on Earth about 3.8 billion years ago (bya). Cyanobacteria began the slow oxygenation of Earth about 3 bya, but current levels of O2 in the atmosphere were not achieved until 500–800 million years ago. Eukaryotes are nucleated cells and include both microbial and multicellular organisms.

(b) The three domains of cellular organisms : **Bacteria, Archaea, and Eukarya**. The latter two lineages diverged long before nucleated cells with organelles **LUCA, last universal common ancestor**. Note that 80% of Earth's history was exclusively microbial.



Microbes in Our Lives

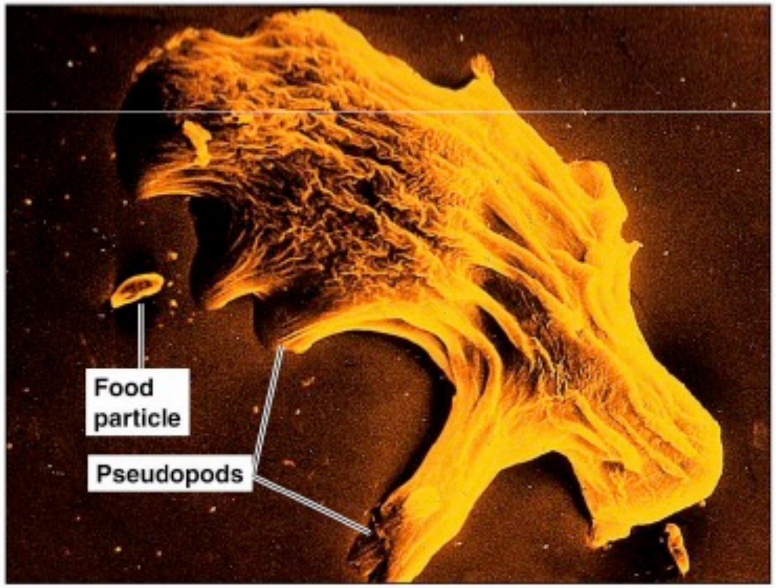
- Microbiology – the study of microbes
- Microbes are organisms that are too small to be seen with the unaided eye
- Aka microorganisms, germs, bugs
- Includes bacteria, fungus, protists, algae, viruses
- Huge diversity in structure, metabolism
- Only common theme is that they are small

Microbes in Our Lives

- Most microbes are beneficial
- Directly beneficial
  - Food (bread, yogurt, beer), make vitamins in human intestines
- Indirectly beneficial
  - Decompose organic matter in soil, clean up sewage, part of food chain

Microbes in our lives

A protist approaching a food particle



(c)

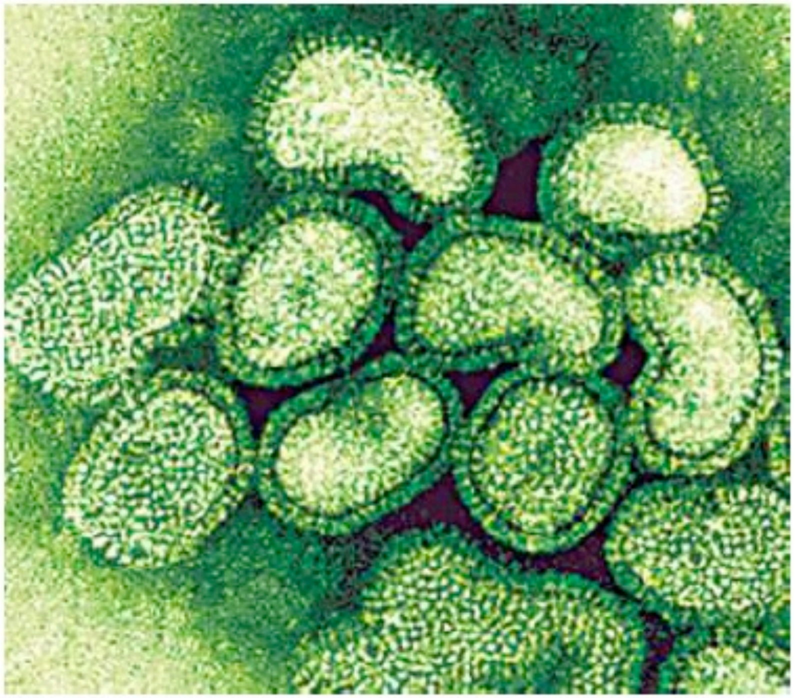
Volvox, a pond algae

(d)

Microbes in our lives

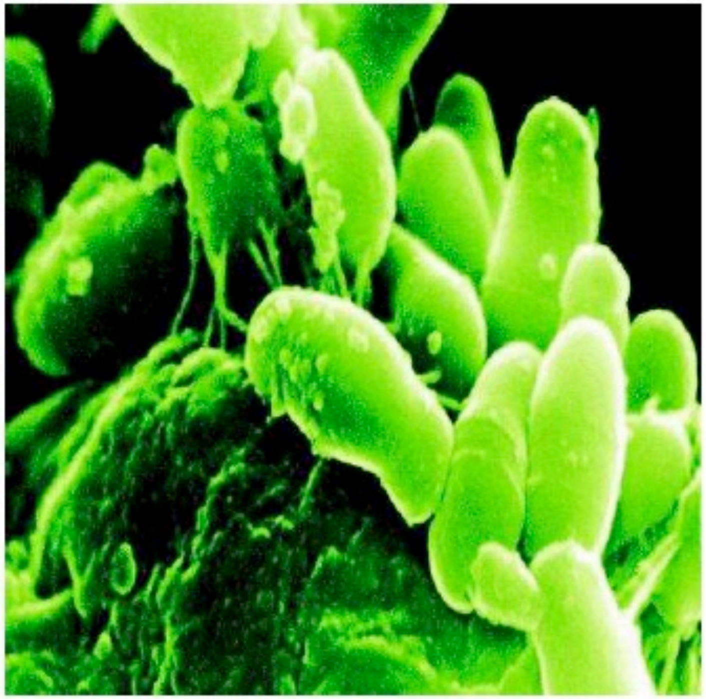
Mycobacterium leprae, the bacterial cause of leprosy

The H1N1 virus, aka Swine Flu Virus

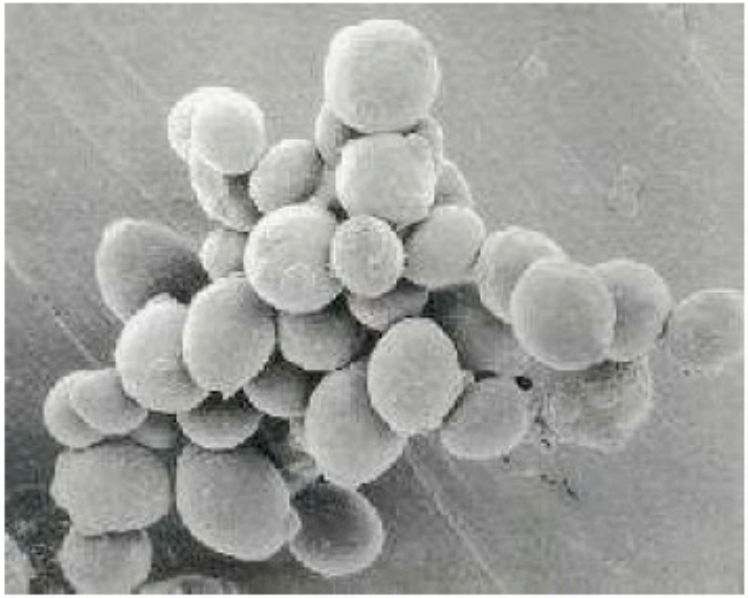


Microbes in our lives

Bifidobacterium, a "probiotic" found in yogurt, in colon



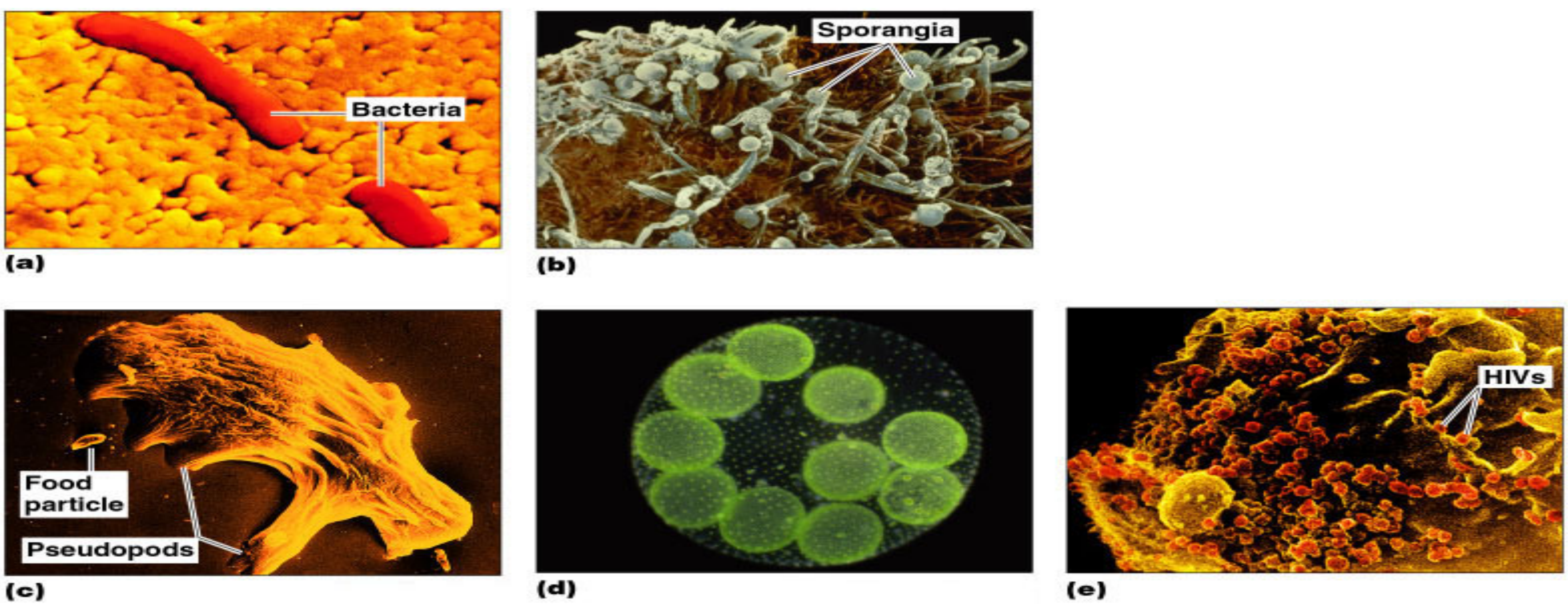
S. cerevisiae, the microbe used in bread and beer production



http://members.aol.com/ChazStone/sem_ady2.jpg

Microorganisms:

- Decompose organic waste
- Are producers in the ecosystem by photosynthesis
- Produce industrial chemicals such as ethyl alcohol and acetone
- Produce fermented foods such as vinegar, cheese, and bread



Microorganisms:

- Produce products used in manufacturing (e.g., cellulase) and treatment (e.g., insulin)
- A few are pathogenic, disease-causing

Lecture 2
12 Jan 2023
BT 206

Knowledge of microorganisms:

- Allows humans to
  - Prevent food spoilage
  - Prevent disease occurrence

- Led to aseptic techniques to prevent contamination in medicine and in microbiology laboratories.

Naming and Classifying Microorganisms

- Carolus Linnaeus (1735) established the system of scientific nomenclature
- Based on Latin
- Two names, the genus and specific epithet (species), which are *italicized* or <u>underlined</u>
- The genus is Capitalized, species is in lower case
  - *Staphylococcus aureus*, *Escherichia coli*
- Genus can be shortened to first letter
  - *S. aureus, E. coli*

Scientific names

- *Staphylococcus aureus*
  - Describes the clustered arrangement of the cells (staphylo-) and the golden color of the colonies.
- *Escherichia coli*
  - Honors the discoverer, Theodor Escherich, and describes the bacterium's habitat, the large intestine or colon.
- After the first use, scientific names may be abbreviated with the first letter of the genus and the specific epithet:

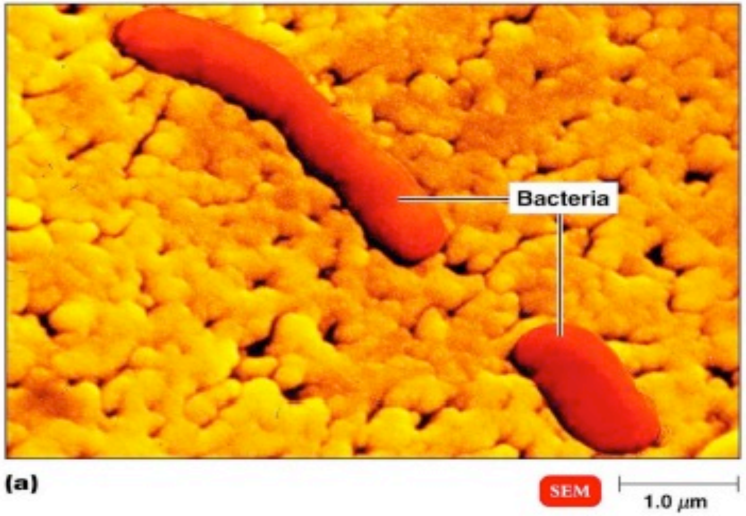
Types of Microorganisms

- Microbes are classified into groups that share similar characteristics
  - Helps organize a very diverse group of organisms
- Grouped into:
  - Bacteria, Archaea, Fungi, Protozoa, Algae, Viruses, Animal parasites

Types of Microorganisms

Bacteria

- Prokaryotic – no nucleus
- Peptidoglycan cell walls
- Divide by binary fission
- Diverse metabolism
  - Organic chemicals, inorganic chemicals, or light as food

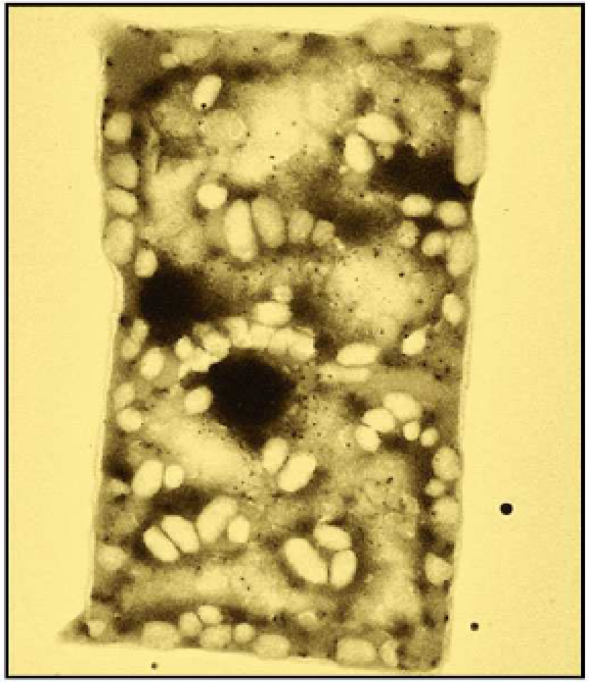


(a)

Types of Microorganisms

Archaea

- Prokaryotic
- Lack peptidoglycan in cell wall
- Live in extreme environments
  - Hot springs, salt lakes
- Classified into 3 major groups:
  - Methanogens – produce methane
  - Extreme halophiles – live in salty environments
  - Extreme thermophiles – live in hot environments



Types of Microorganisms

Fungi

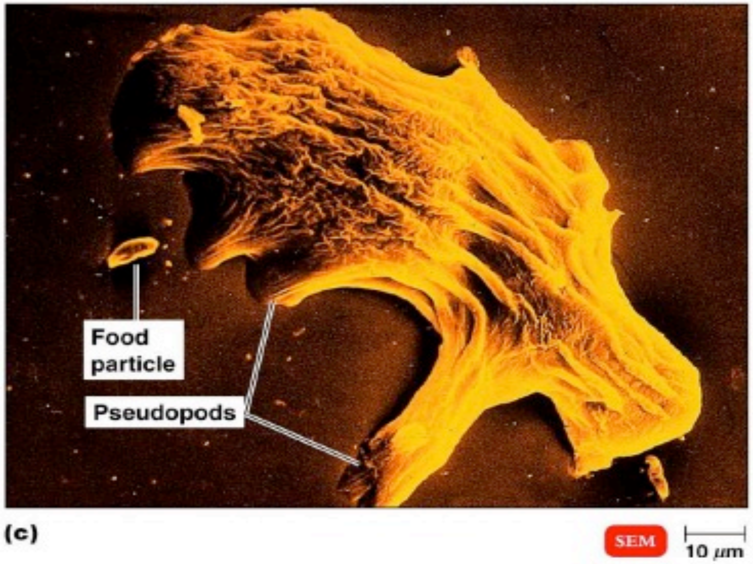
- Eukaryotic – contain nucleus
- Cell walls made of chitin
- Most are multicellular
  - Mushrooms, molds
- Some are single celled
  - Yeasts
- Absorb organic material from environment

(b)

Types of Microorganisms

Protozoa

- Eukaryotic
- Single celled, animal-like cells
- Absorb or ingest organic chemicals
- May be motile via pseudopods, cilia, or flagella



(c)

Types of Microorganisms

Algae

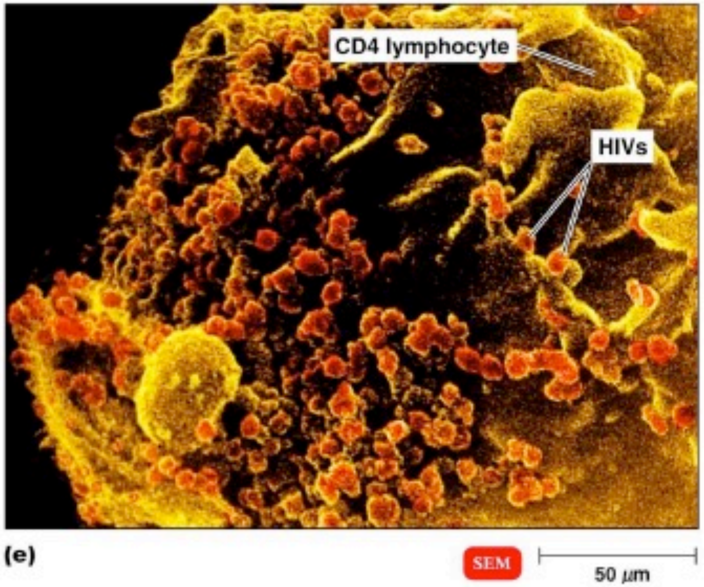
- Eukaryotic
- Cellulose cell walls
- Use photosynthesis for energy
- “Primary producers”
  - Produce oxygen and carbohydrates that other organisms consume

(d)

Types of Microorganisms

Viruses

- Extremely small infectious particles - noncellular
- Consist of DNA *or* RNA core
- Core is surrounded by a protein coat
- Viruses are replicated only when they are in a living host cell

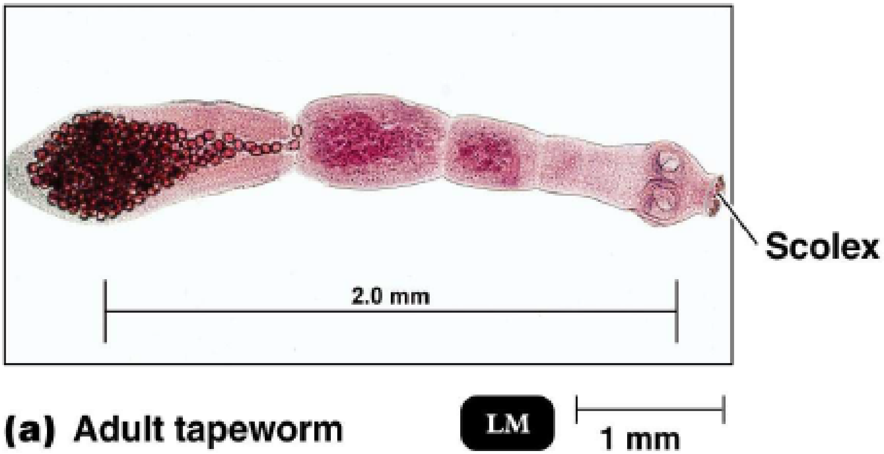


(e)

Types of Microorganisms

Multicellular animal parasites

- Eukaryotic, multicellular animals
- Parasitic flatworms and round worms are called helminths.
- Microscopic stages in life cycles.



(a) Adult tapeworm

Classification of Microorganisms

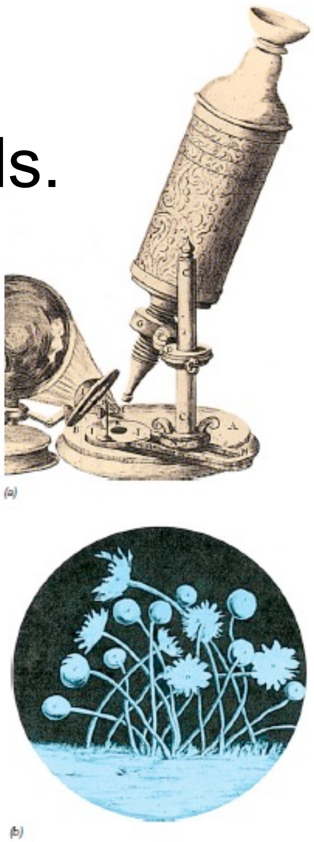
- All organisms are classified into three groups
  - Based on organization of cells
- Grouped into three domains
  - Bacteria, Archaea, Eukarya
- “Bacteria” and “Archaea” are prokaryotic
- “Eukarya” are eukaryotic
- Domain Eukarya includes Kingdoms called:
  - Protists, Fungi, Plants, Animals

A Brief History of Microbiology

- Ancestors of bacteria were the first life on Earth.
- The first microbes were observed in 1673.

The First Observations

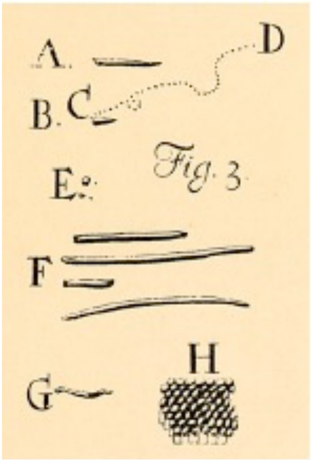
- In 1665, **Robert Hooke** reported that living things were composed of little boxes or cells.
- In 1858, **Rudolf Virchow** said cells arise from preexisting cells.
- Cell Theory. All living things are composed of cells and come from preexisting cells



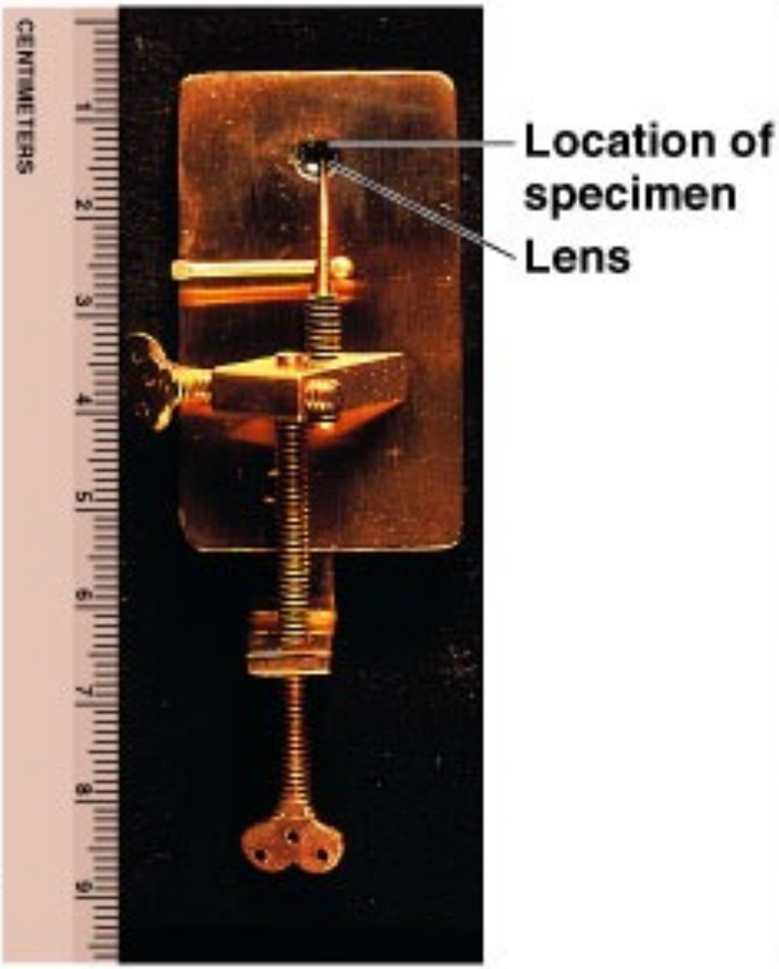
Robert Hooke microscope and his drawings

The First Observations

- 1673-1723, **Antoni van Leeuwenhoek** described live microorganisms that he observed in teeth scrapings, rain water, and peppercorn infusions.



Drawings of microorganisms



(b) Microscope replica

Figure 1.2b

The Debate Over Spontaneous Generation

- The hypothesis that living organisms arise from nonliving matter is called spontaneous generation. According to spontaneous generation, a “vital force’ Forms life.
- The Alternative hypothesis, that the living organisms arise from preexisting life, is called biogenesis.

Lecture 3
13 Jan 2023
BT 206

Evidence Pro and Con

- 1668: Francisco Redi filled six jars with decaying meat.

Conditions	Results
3 jars covered with fine net	No maggots
3 open jars	Maggots appeared
From where did the maggots come? What was the purpose of the sealed jars? *Spontaneous generation or biogenesis?*	

Evidence Pro and Con

- 1745: John Needham put boiled nutrient broth into covered flasks.

Conditions	Results
Nutrient broth heated, then placed in sealed flask	Microbial growth
From where did the microbes come? *Spontaneous generation or biogenesis?*	

Evidence Pro and Con

- 1765: Lazzaro Spallanzani boiled nutrient solutions in flasks.

Conditions	Results
Nutrient broth placed in flask, heated, then sealed	No microbial growth
Spontaneous generation or biogenesis?	

Evidence Pro and Con

- 1861: **Louis Pasteur** demonstrated that microorganisms are present in the air.

Conditions	Results
Nutrient broth placed in flask, heated, not sealed	Microbial growth
Nutrient broth placed in flask, heated, then sealed	No microbial growth
Spontaneous generation or biogenesis?	

The Theory of Biogenesis

- Pasteur's S-shaped flask kept microbes out but let air in.

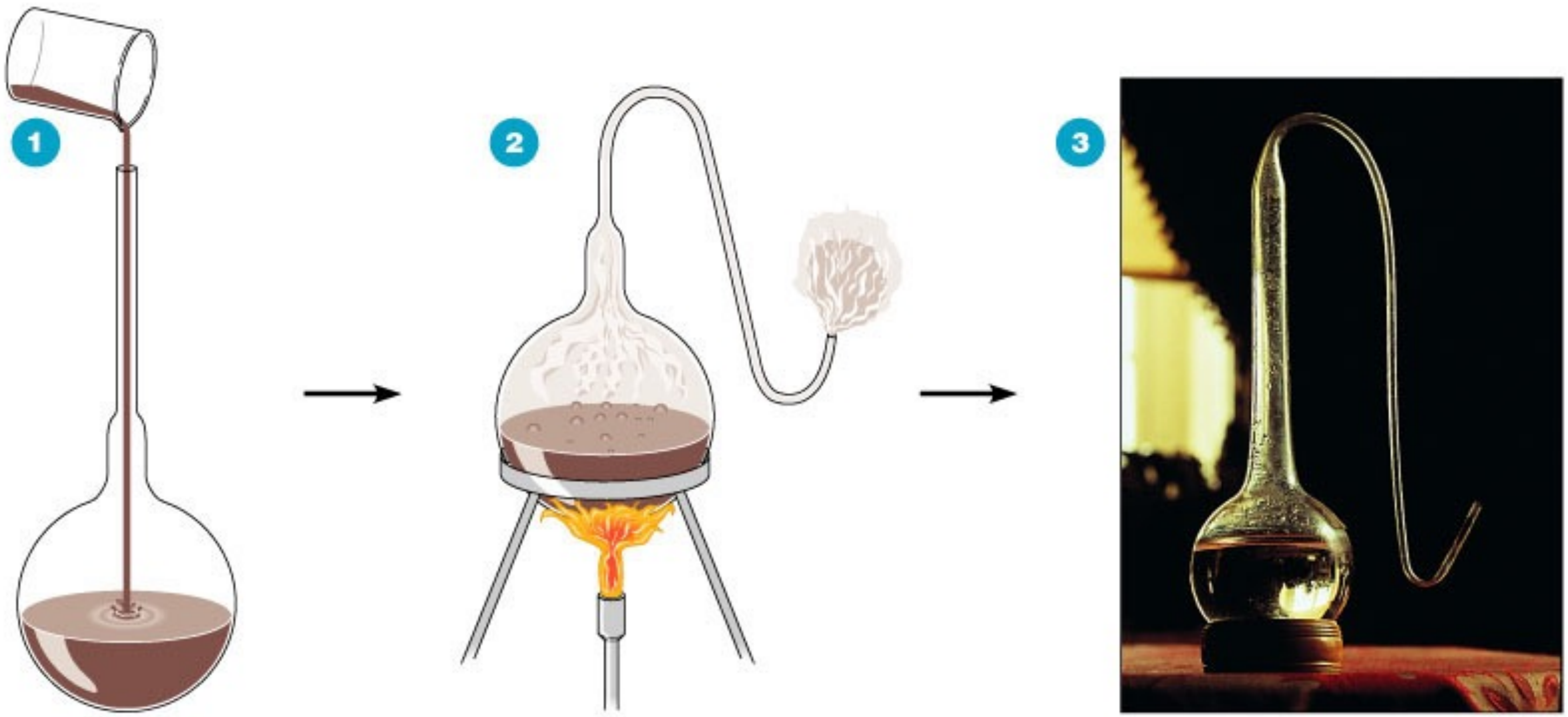


Figure 1.3

The Golden Age of Microbiology

- 1857-1914
- Beginning with **Pasteur's** work, discoveries included the relationship between microbes and disease, immunity, and antimicrobial drugs

Fermentation and Pasteurization

- **Pasteur** showed that microbes are responsible for fermentation.
- Fermentation is the conversation of sugar to alcohol to make beer and wine.
- Microbial growth is also responsible for spoilage of food.
- Bacteria that use alcohol and produce acetic acid spoil wine by turning it to vinegar (acetic acid).

Fermentation and Pasteurization

- **Pasteur** demonstrated that these spoilage bacteria could be killed by heat that was not hot enough to evaporate the alcohol in wine. This application of a high heat for a short time is called pasteurization.

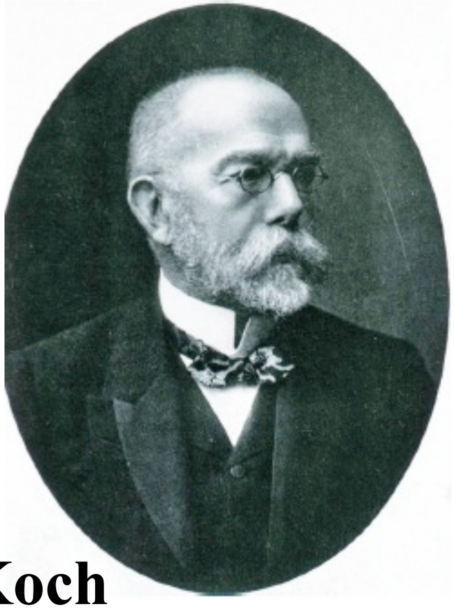
Figure 1.4

The Germ Theory of Disease

- 1835: **Agostino Bassi** showed a silkworm disease was caused by a fungus.
- 1865: **Pasteur** believed that another silkworm disease was caused by a protozoan.
- 1840s: **Ignaz Semmelwise** advocated handwashing to prevent transmission of puerperal fever (**Postpartum infections**) from one obstetrics patient to another.

The Germ Theory of Disease

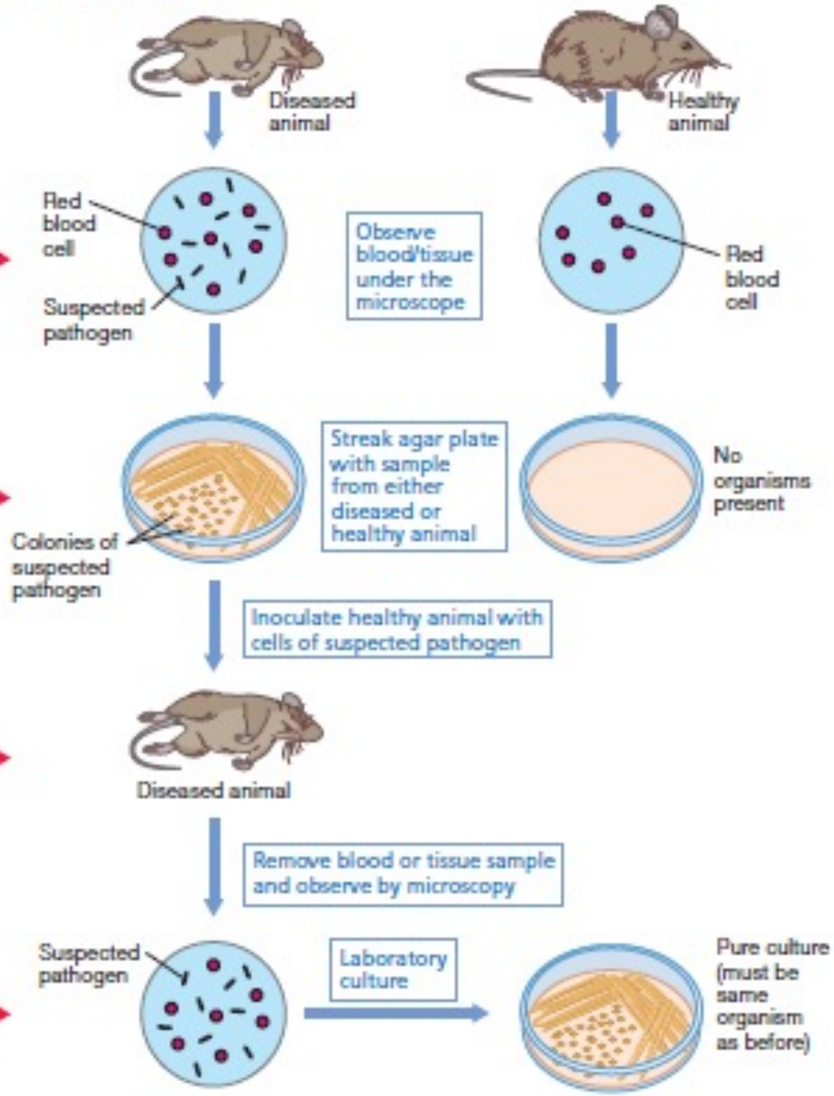
- 1860s: **Joseph Lister** used a chemical disinfectant to prevent surgical wound infections after looking at Pasteur's work showing microbes are in the air, can spoil food, and cause animal diseases.
- 1876: **Robert Koch** provided proof that a bacterium causes anthrax and provided the experimental steps, Koch's postulates, used to prove that a specific microbe causes a specific disease.



Robert Koch

KOCH'S POSTULATES

The Postulates:	Tools:
1. The suspected pathogen must be present in *all* cases of the disease and absent from healthy animals.	Microscopy, staining
2. The suspected pathogen must be grown in pure culture.	Laboratory culture
3. Cells from a pure culture of the suspected pathogen must cause disease in a healthy animal.	Experimental animals
4. The suspected pathogen must be reisolated and shown to be the same as the original.	Laboratory reisolation and culture



Vaccination

- 1796: **Edward Jenner** inoculated a person with cowpox virus. The person was then protected from smallpox.
- Called vaccination from *vacca* for cow
- The protection is called immunity

Table 1.2 ***Giants of the early days of microbiology and their major contributions***

Investigator	*Nationality*	*Dates*[a]	*Contributions*
Robert Hooke	English	1664	Discovery of microorganisms (fungi)
Antoni van Leeuwenhoek	Dutch	1684	Discovery of bacteria
Edward Jenner	English	1798	Vaccination (smallpox)
Louis Pasteur	French	Mid- to late 1800s	Mechanism of fermentation, defeat of spontaneous generation, rabies and other vaccines, principles of immunization
Joseph Lister	English	1867	Methods for preventing infections during surgeries
Ferdinand Cohn	German	1876	Discovery of endospores
Robert Koch	German	Late 1800s	Koch's postulates, pure culture microbiology, discovery of agents of tuberculosis and cholera
Sergei Winogradsky	Russian	Late 1800s to mid-1900s	Chemolithotrophy and chemoautotrophy, nitrogen fixation, sulfur bacteria
Martinus Beijerinck	Dutch	Late 1800s to 1920	Enrichment culture technique, discovery of many metabolic groups of bacteria, concept of a virus

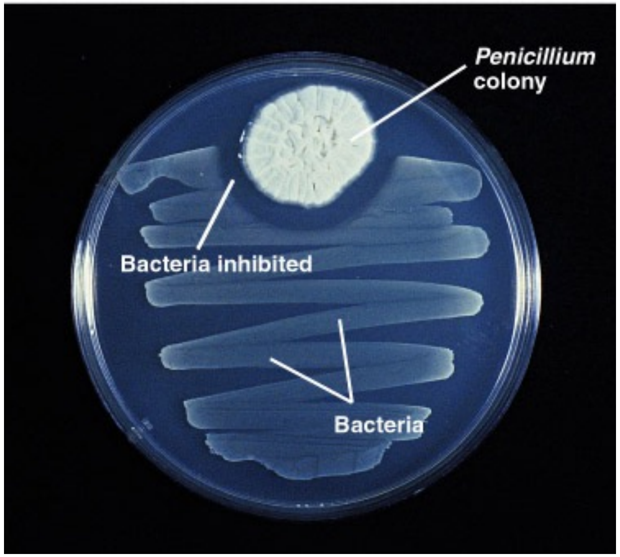
[a]The year in which the key paper describing the contribution was published, or the date range in which the investigator was most scientifically active.

The Birth of Modern Chemotherapy

- Treatment with chemicals is chemotherapy.
- Chemotherapeutic agents used to treat infectious disease can be synthetic drugs or antibiotics.
- **Antibiotics** are chemicals produced by bacteria and fungi that inhibit or kill other microbes.
- **Quinine** from tree bark was long used to treat malaria.
- 1910: **Paul Ehrlich** developed a synthetic arsenic drug, salvarsan, to treat syphilis.
- 1930s: Sulfonamides were synthesized.

The Birth of Modern Chemotherapy

- 1928: **Alexander Fleming** discovered the first antibiotic.
- He observed that *Penicillium* fungus made an antibiotic, penicillin, that killed *S. aureus*.
- 1940s: Penicillin was tested clinically and mass produced.



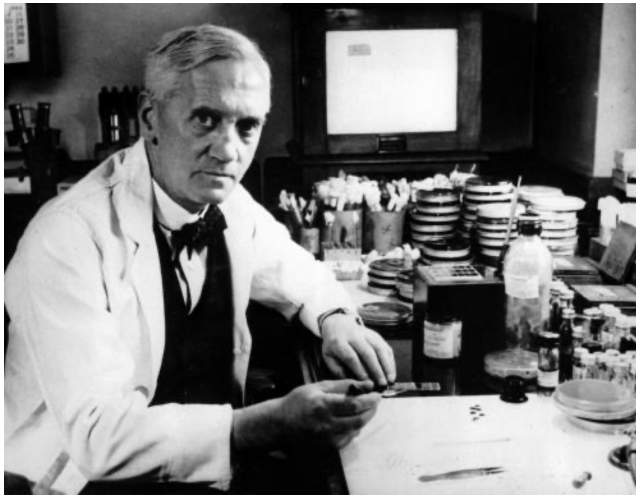


Figure 1.5

Modern Developments in Microbiology

- **Bacteriology** is the study of bacteria.
- **Mycology** is the study of fungi.
- **Parasitology** is the study of protozoa and parasitic worms.
- Recent advances in **genomics**, the study of an organism's genes, have provided new tools for classifying microorganisms.

Modern Developments in Microbiology

- **Immunology** is the study of immunity. Vaccines and interferons are being investigated to prevent and cure viral diseases.
- The use of immunology to identify some bacteria according to serotypes (variants within a species) was proposed by **Rebecca Lancefield** in 1933.

Lecture 4
BT 206
13 Jan 2023

Modern Developments in Microbiology

- **Virology** is the study of viruses.
- Recombinant DNA is DNA made from two different sources. In the 1960s, **Paul Berg** inserted animal DNA into bacterial DNA and the bacteria produced an animal protein.
- Recombinant DNA technology or **genetic engineering** involves microbial genetics and molecular biology.

Modern Developments in Microbiology

- Using microbes
  - **George Beadle and Edward Tatum** showed that genes encode a cell's enzymes (1942)
  - **Oswald Avery, Colin MacLeod, and Maclyn McCarty** showed that DNA was the hereditary material (1944).
  - **Francois Jacob and Jacques Monod** discovered the role of mRNA in protein synthesis (1961).

Selected Novel Prizes in Physiology or Medicine

1901*	von Behring	Diphtheria antitoxin
1902	Ross	Malaria transmission
1905	Koch	TB bacterium
1908	Metchnikoff	Phagocytes
1945	Fleming, Chain, Florey	Penicillin
1952	Waksman	Streptomycin
1969	Delbrück, Hershey, Luria	Viral replication
1987	Tonegawa	Antibody genetics
1997	Prusiner	Prions

* The first Nobel Prize in Physiology or Medicine.

Table 1.4 *Some Nobel laureates in the era of molecular microbiology*[a]

Investigator(s)	*Nationality*	*Discovery/Year*[b]
George Beadle, Edward Tatum	American	One gene–one enzyme hypothesis/1941
Max Delbrück, Salvador Luria	German/Italian	Inheritance of characteristics in bacteria/1943
Joshua Lederberg	American	Conjugation and transduction in bacteria/1946/1952
James Watson, Francis Crick, Maurice Wilkins	American/British	Structure of DNA/1953
François Jacob, Jacques Monod, Andre Lwoff	French	Gene regulation by repressor proteins, operon concept/1959
Sydney Brenner	British	Messenger RNA, ribosomes as site of protein synthesis/1961
Marshall Nirenberg, Robert Holley, H. Gobind Khorana	American/Indian	Genetic code/1966
Howard Temin, David Baltimore, and Renato Dulbecco	American/Italian	Retroviruses and reverse transcriptase/1969
Hamilton Smith, Daniel Nathans, Werner Arber	American/Swiss	Restriction enzymes/1970
J. Michael Bishop, Harold Varmus	American	Cancer genes (oncogenes) in retroviruses/1972
Paul Berg	American	Recombinant DNA technology/1973
Roger Kornberg	American	Mechanism of transcription in eukaryotes/1974
Fred Sanger	British	Structure and sequencing of proteins, DNA sequencing 1958/1977
Carl Woese[c]	American	Discovery of *Archaea*/1977
Stanley Prusiner	American	Discovery and characterization of prions/1981
Sidney Altman, Thomas Cech	American	Catalytic properties of RNA/1981
Barry Marshall, Robin Warren	Australian	*Helicobacter pylori* as cause of peptic ulcers/1982
Luc Montagnier, Françoise Barré-Sinoussi, Harald zur Hausen	French/German	Discovery of human immunodeficiency virus as cause of AIDS/1983
Kary Mullis	American	Polymerase chain reaction/1985
Andrew Fire, Craig Mello	American	RNA interference/1998

[a]This select list covers major accomplishments since 1941. In virtually every case, the laureates listed had important coworkers that did not receive the Nobel Prize.
[b]Year indicates the year in which the discovery awarded with the Nobel Prize was published.
[c]Recipient of the 2003 Crafoord Prize in Biosciences, equivalent in scientific stature to the Nobel Prize.

Microbes and Human Welfare

- Microbial Ecology
- Bacteria recycle carbon, nutrients, sulfur, and phosphorus that can be used by plants and animals.

Bioremediation

- Bacteria degrade organic matter in sewage.
- Bacteria degrade or detoxify pollutants such as oil and mercury

Biological Insecticides

- Microbes that are pathogenic to insects are alternatives to chemical pesticides to prevent insect damage to agricultural crops and disease transmission.
- *Bacillus thuringiensis* infections are fatal in many insects but harmless to other animals including humans and to plants.

Modern Biotechnology and Genetic Engineering

- **Biotechnology**, the use of microbes to produce foods and chemicals, is centuries old.
- **Genetic engineering** is a new technique for biotechnology. Through genetic engineering, bacteria and fungi can produce a variety of proteins including vaccines and enzymes.
- Missing or defective genes in human cells can be replaced in **gene therapy**.
- Genetically modified bacteria are used to protect crops from insects and freezing.

Microbes and Human Disease

- Bacteria were once classified as plants which gave rise to use of the term *flora* for microbes.
- This term has been replaced by *microbiota*.
- Microbes normally present in and on the human body are called normal microbiota.

Normal Microbiota

- Normal microbiota prevent growth of pathogens.
- Normal microbiota produce growth factors such as folic acid and vitamin K.
- Resistance is the ability of the body to ward off disease.
- Resistance factors include skin, stomach acid, and antimicrobial chemicals.

Infectious Diseases

- When a pathogen overcomes the host’s resistance, disease results.
- Emerging Infectious Diseases (EID): New diseases and diseases increasing in incidence

Emerging Infectious Diseases

- **West Nile encephalitis**
  - West Nile Virus
  - First diagnosed in the West Nile region of Uganda in 1937.
  - Appeared in New York City in 1999.
- **Bovine Spongiform Encephalopathy**
  - Prion
  - Also causes Creutzfeldt-Jakob disease (CJD)
  - New-variant CJD in humans related to cattle fed sheep offal for protein.

Emerging Infectious Diseases

- ***Escherichia coli*** **O57:H7**
  - Toxin-producing strain of *E. coli*
  - Fist seen in 1982
  - Leading cause of diarrhea worldwide.
- **Invasive group A *Streptococcus***
  - Rapidly growing bacteria cause extensive tissue damage.
  - Increased incidence since 1995

Emerging Infectious Diseases

- **Ebola hemorrhagic fever**
  - Ebola virus
  - Causes fever, hemorrhaging, and blood clotting
  - First identified near Ebola River, Congo
  - Outbreak every few years

- ***Hantavirus* pulmonary syndrome**
  - *Hantavirus*
  - Fist identified in 1951 in Korea as cause of hemorrhagic fever and named for Hantaan River

Emerging Infectious Diseases

- **Acquired immunodeficiency syndrome** (AIDS)
  - Human immunodeficiency virus (HIV)
  - First identified in 1981.
  - Worldwide epidemic infecting 40 million people; 14,000 new infections everyday.
  - Sexually transmitted disease affecting males and females.
  - In the U.S., HIV/AIDS in people 13-24 years of age: 44% are female and 63% are African American.

Emerging Infectious Diseases

- **Anthrax**
  - *Bacillus anthracis*
  - In 1877, Koch proved *B. anthracis* causes anthrax.
  - Veterinarians and agricultural workers are at risk of cutaneous anthrax.
  - In 2001, dissemination of *B. anthracis* via mail infected 22 people.