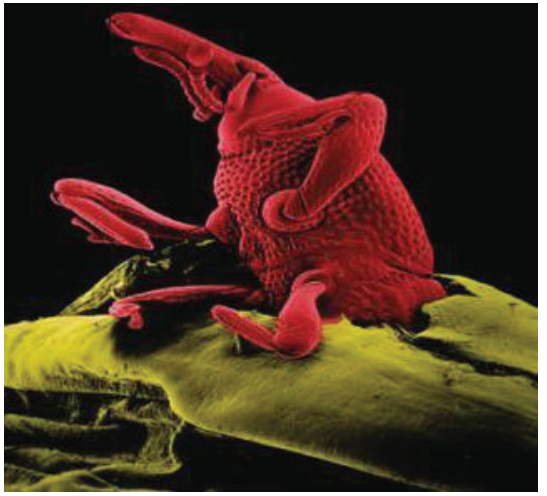
Environmental Microbiology

The Microbial World

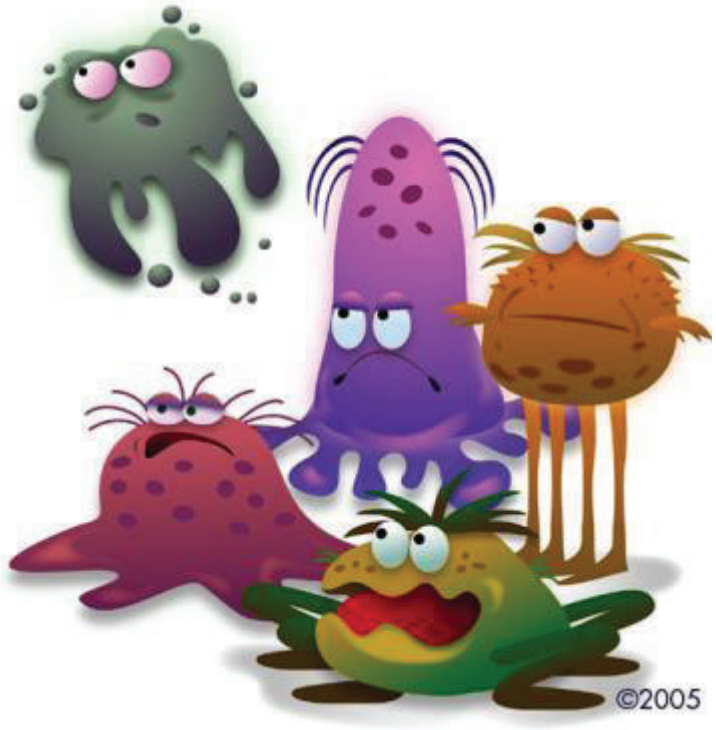
prepared by Prof. Bulent Icgen

Microbes

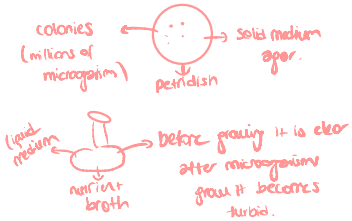
most of the microorganisms are not pathogenic. by means can cause diseases.



- Microorganisms are organisms that are too small to be seen with the unaided eye
- They are not all GERMS!
- GERM refers to a rapidly growing cell that can cause disease



Microorganisms:



Good

- Decompose organic waste (use them as a source of nutrients such as C,N,P) to grow.
- Are producers in the ecosystem by photosynthesis (Ex: cyanobacteri (some calle blue-green algea) green-purple sulfric bacteria algea / phytoplanctons
- Produce industrial chemicals such as ethyl alcohol and acetone
- Produce fermented foods such as vinegar, cheese, and bread

mineral cycle depends on microorganisms.
↳ without them no life.

Bad

- Pathogenic → they have capsule
  - smooth → S type colony
  - ↳ if they are rough mostly non pathogen.

Naming & Classifying Microorganisms

- The basic taxonomic unit is the *species*
- Microrganisms are generally given a genus and species name

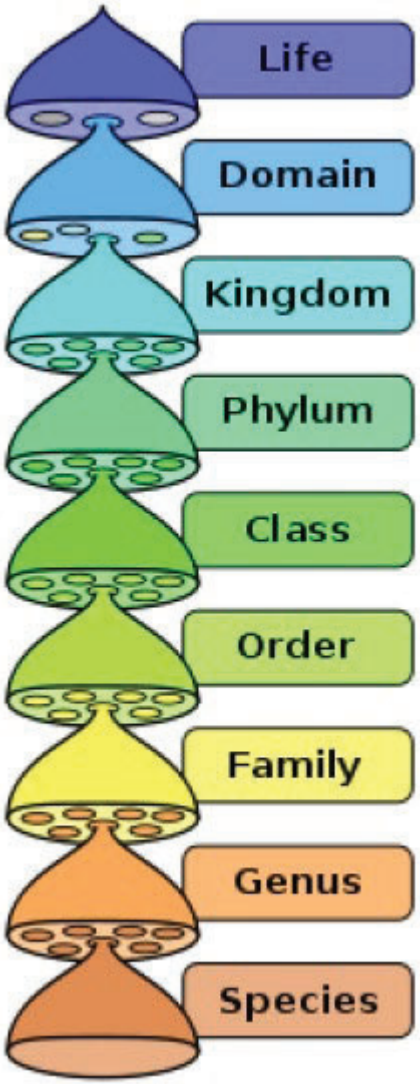
Escherichia coli

Genus Species

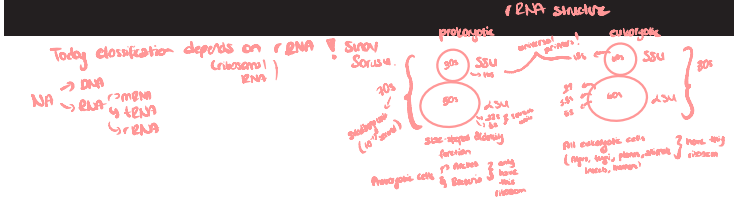
Scientific name (Systematic Name)
Binomial System of Nomenclature

- Genus name + species name
- Italicized or underlined
- Genus name is capitalized and may be abbreviated
- Species name is never abbreviated
- eg: *Bacillus subtilis*

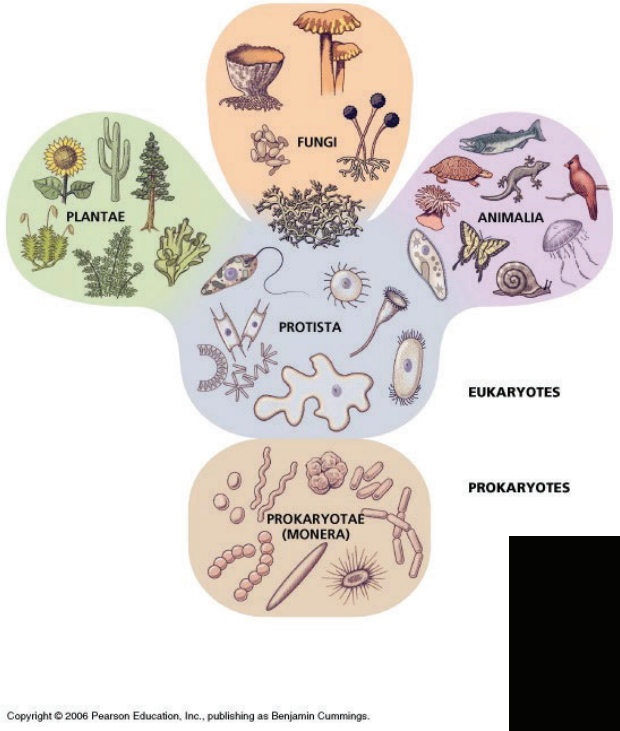
B. subtilis

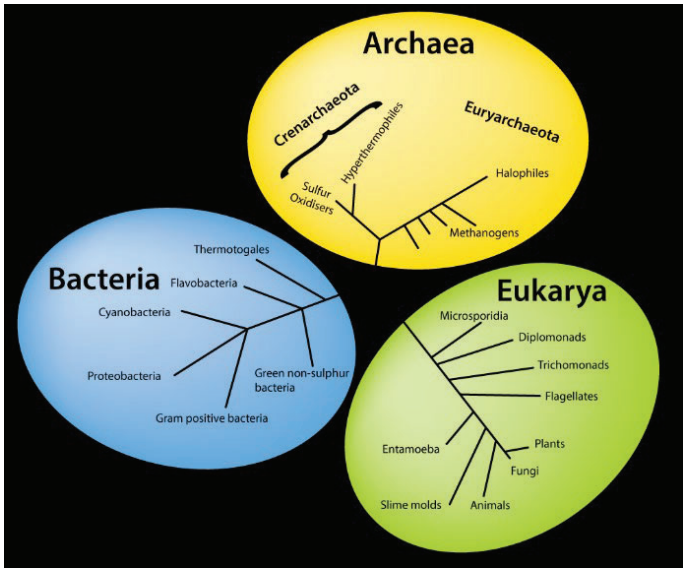


Classification of Microorganisms



- Three domains
  - Bacteria
  - Archaea
  - Eukarya
    - Protists
    - Fungi
    - Plants
    - Animals

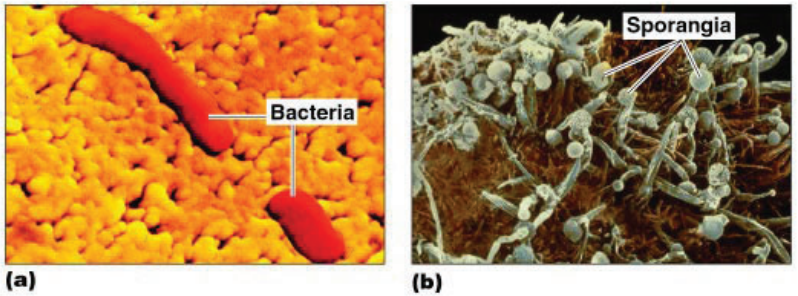




Microorganisms:

Eukaryotic vs. Prokaryotic Cells

- **Eukaryotes**
  - DNA enclosed in a membrane-bound nucleus
  - Cells are generally larger and more complex
  - Contain organelles
- **Prokaryotes**
  - No membrane-enclosed organelles, no nucleus
  - Generally smaller than eukaryotic cells



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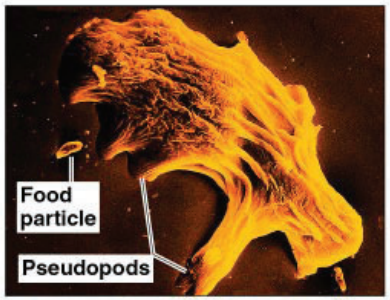

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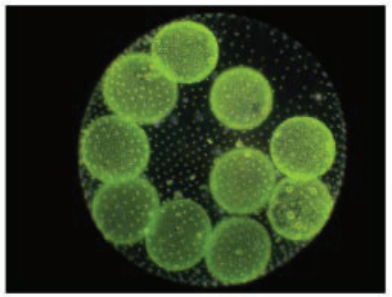
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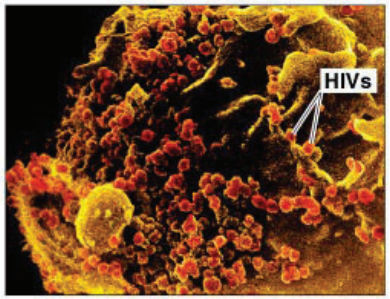

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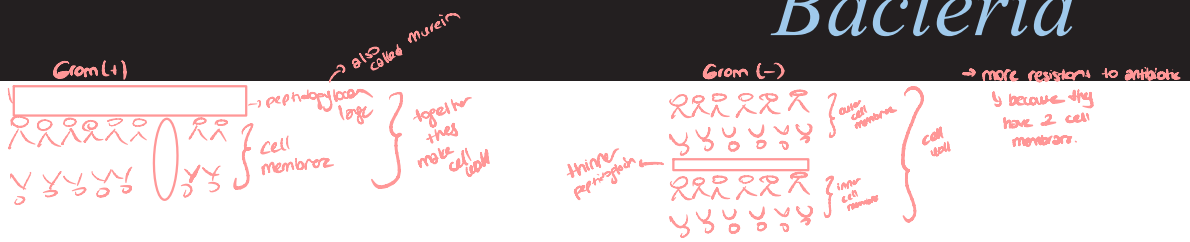
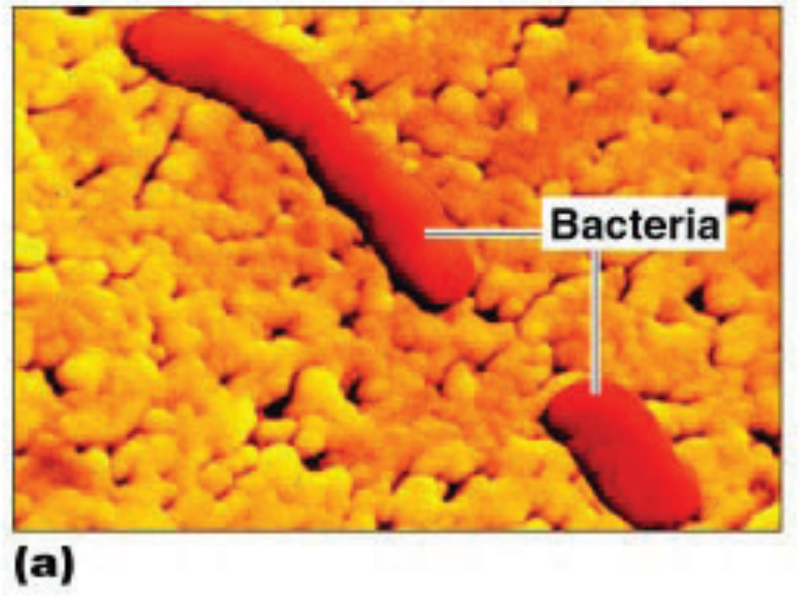
Bacteria

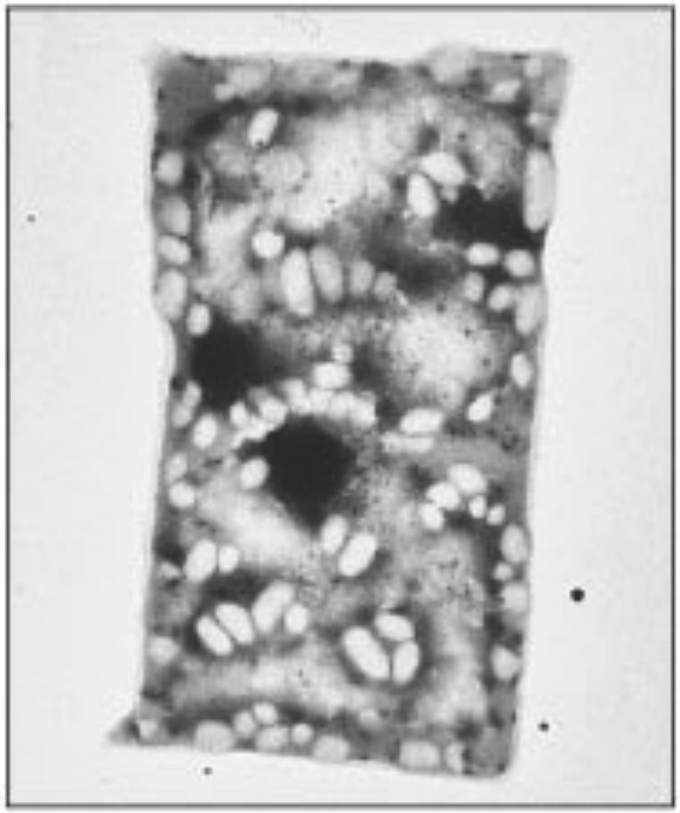


- Prokaryotes
- Peptidoglycan cell walls — can class microorganisms by cell walls
- Binary fission
- For energy, use organic chemicals, inorganic chemicals, or photosynthesis



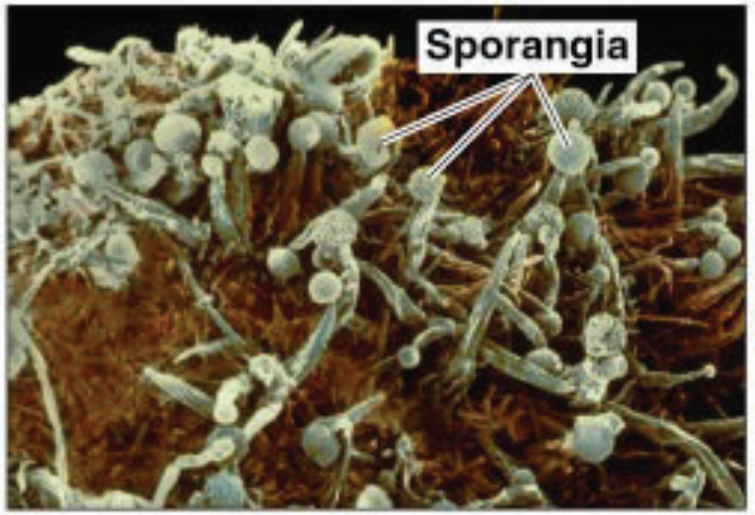
Archaea

- Prokaryotic
- Lack peptidoglycan (murein) → they have pseudo-murein
- Live in extreme environments
- Include:
  - Methanogens (they produce CH_4 & biogas)
  - Extreme halophiles (high salt (NaCl) → destroys cells)
  - Extreme thermophiles



Fungi

- Eukaryotes
- Chitin cell walls
- Use organic chemicals for energy
- Molds and mushrooms are multicellular consisting of masses of mycelia, which are composed of filaments called hyphae
- Yeasts are unicellular

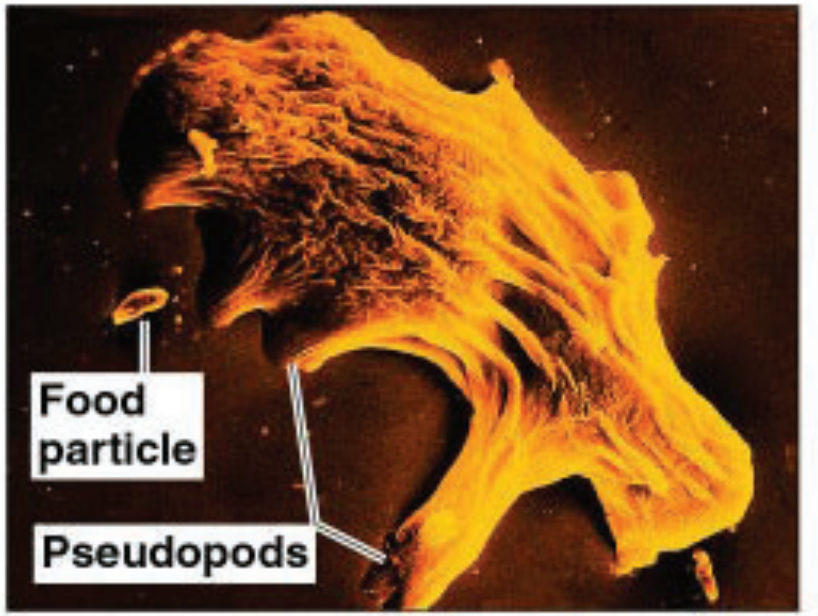


(b)

Protozoa

- Eukaryotes
- Absorb or ingest organic chemicals
- May be motile via pseudopods, cilia, or flagella

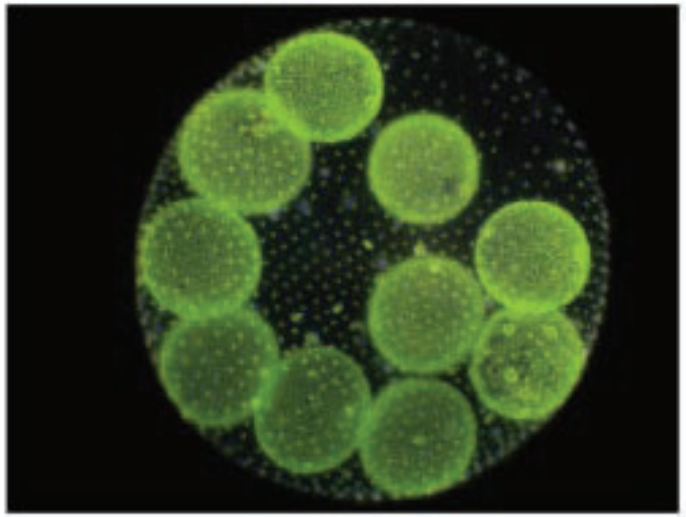
Ameoba



(c)

Algae

- Eukaryotes
- Cellulose cell walls → they look like plants
- Use photosynthesis for energy
- Produce molecular oxygen and organic compounds



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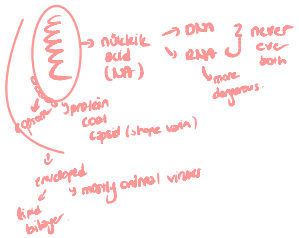
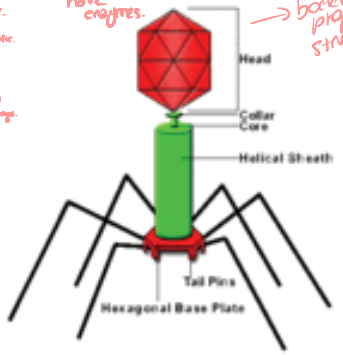
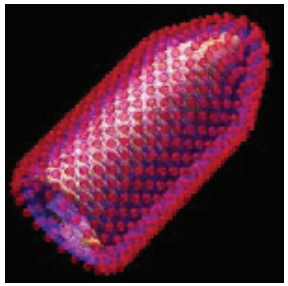
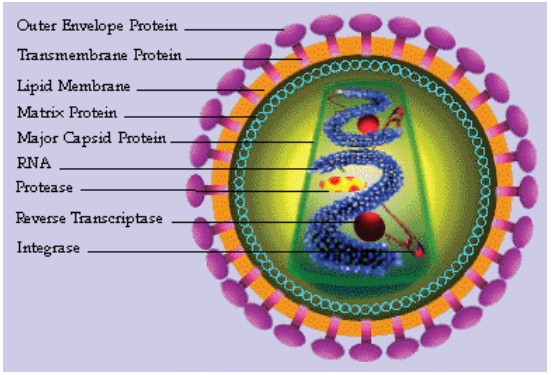
Viruses

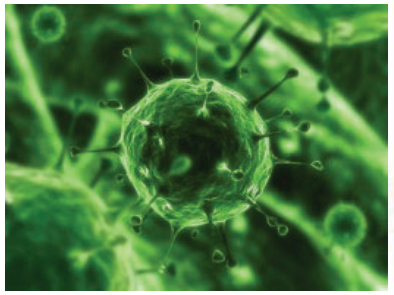


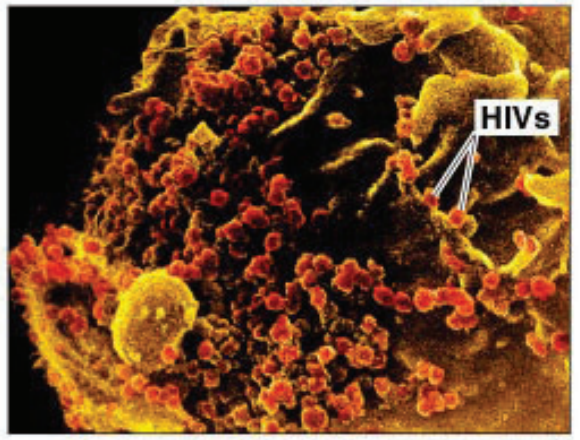


- Acellular
- Consist of DNA *or* RNA core
- Core is surrounded by a protein coat
- Coat may be enclosed in a lipid envelope
- Viruses replicate only when they are in a living host cell







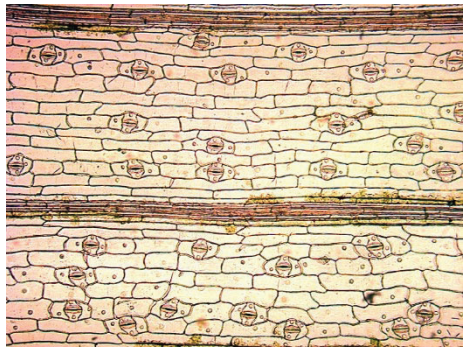


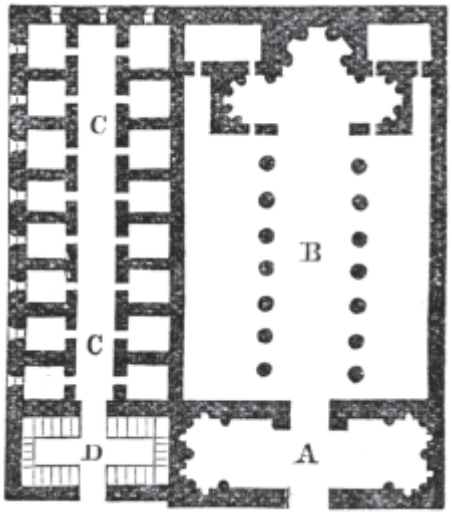
Multicellular Animal Parasites

- Eukaryote
- Multicellular animals
- Parasitic flatworms and round worms are called helminths.
- Microscopic stages in life cycles.

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

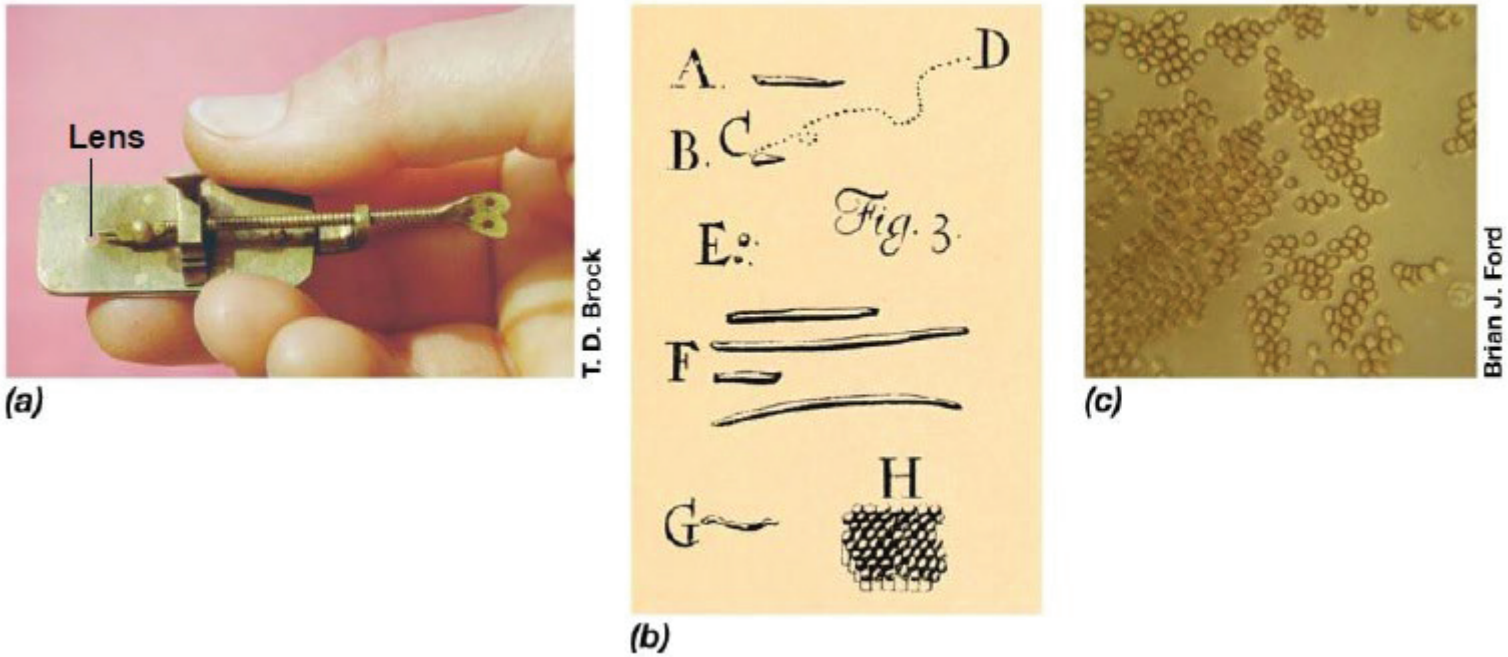




The First Observations

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

The van Leeuwenhoek microscope



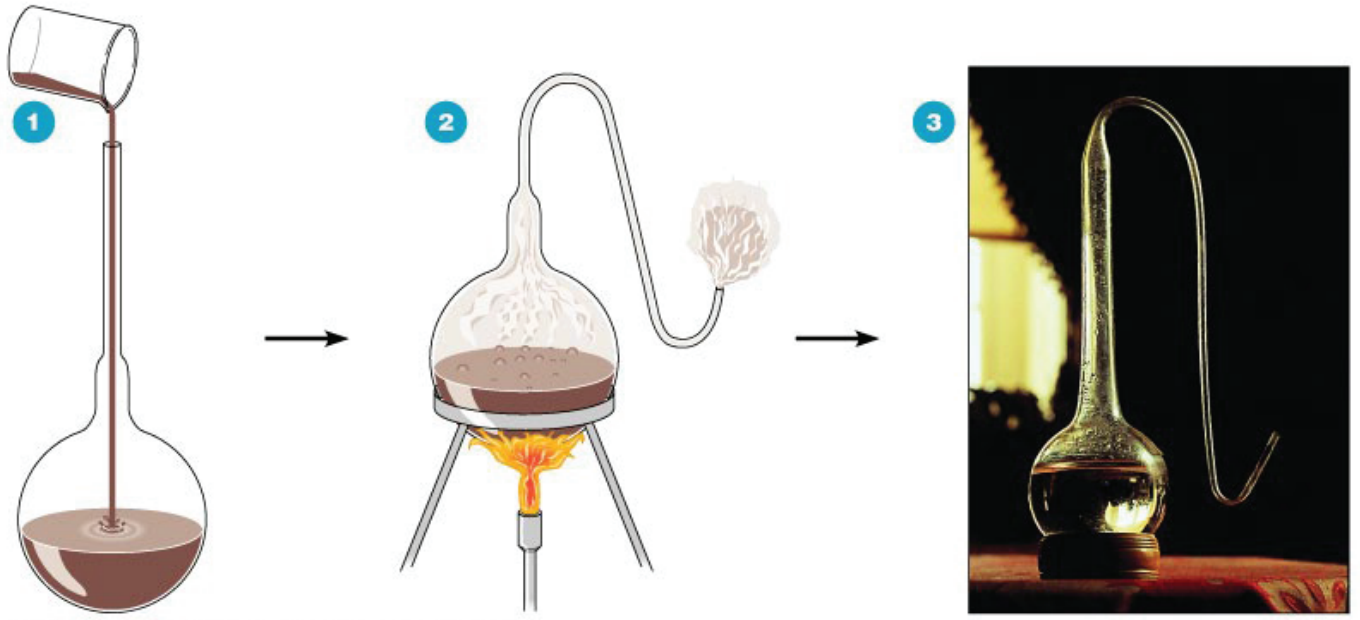
The Debate Over Spontaneous Generation

- 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.

The Theory of Biogenesis

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

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



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.

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 from one OB 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.

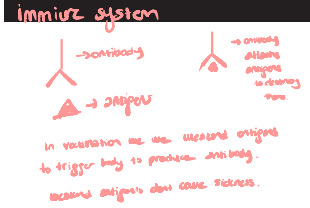
find the relationships btwn microbes and diseases..

The Germ Theory of Disease

Koch's postulates

- Pathogen must be present in all cases of disease
- Pathogen must be isolated and grown in lab in pure culture
- Pathogen from pure cultures must cause disease when inoculated into healthy, susceptible lab animal
- Same pathogen must be isolated from the diseased lab animal

Vaccination



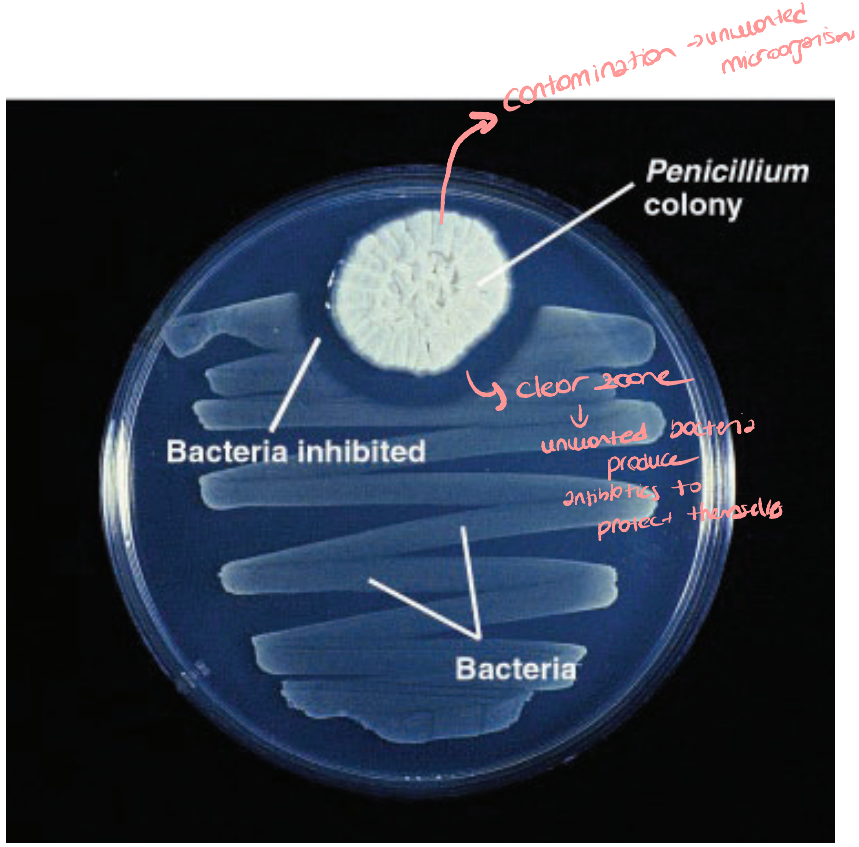
- 1796: Edward Jenner inoculated a person with cowpox virus. The person was then protected from smallpox.
- Called vaccination from *vacca* for cow
- The protection is called immunity

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.



Modern Developments in Microbiology

In the 20th century, microbiology developed in two distinct directions:

- Applied and basic
- Molecular microbiology

Fueled by the genomics revolution

Major Subdisciplines of Applied Microbiology

- Medical microbiology and immunology

Have roots in Koch's work

- Agricultural microbiology and industrial microbiology

Developed from concepts developed by Beijerinck and Winogradsky

- Aquatic microbiology and marine microbiology

Developed from advances in soil microbiology

- Microbial ecology

Emerged in 1960s–70s

Modern Developments in Microbiology

Basic Science Subdisciplines in Microbiology

- Microbial systematics

The science of grouping and classifying microorganisms

- Microbial physiology

Study of the nutrients that microbes require for metabolism and growth and the products that they generate

- Cytology

Study of cellular structure

- Microbial biochemistry

Study of microbial enzymes and chemical reactions

- Bacterial genetics

Study of heredity and variation in bacteria

- Virology

Study of viruses

Modern Developments in Microbiology

Basic Science Subdisciplines in Microbiology

- Molecular Microbiology
- Biotechnology

Manipulation of cellular genomes

DNA from one organism can be inserted into a bacterium and the proteins encoded by that DNA harvested

- Genomics: study of all of the genetic material (DNA) in living cells
- Transcriptomics: study of RNA patterns
- Proteomics: study of all the proteins produced by cell(s)
- Metabolomics: study of metabolic expression in cells
- Recombinant DNA technology or genetic engineering involves microbial genetics and molecular biology.

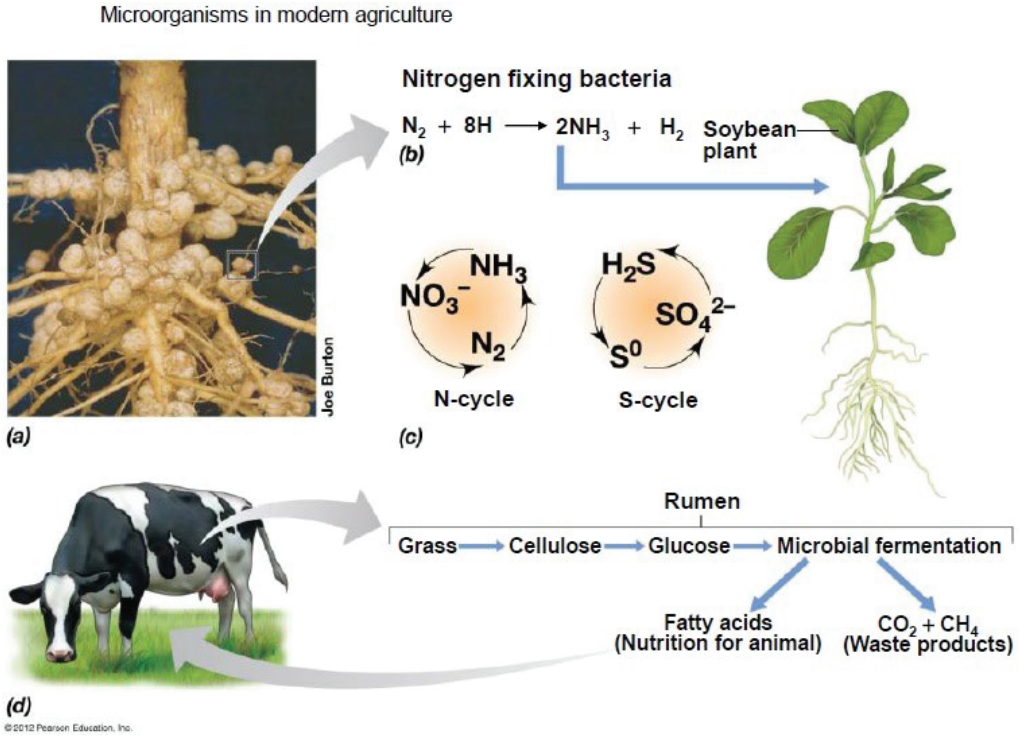
Microbes and Human Welfare

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

Microorganisms and Agriculture

Many aspects of agriculture depend on microbial activities

- ➢ Positive impacts
- • nitrogen-fixing bacteria
- • cellulose-degrading microbes in the rumen
- • regeneration of nutrients in soil and water
- ➢ Negative impacts
- • diseases in plants and animals



Microorganisms and Food

- Negative impacts
- Food spoilage by microorganisms requires specialized preservation of many foods
- Positive impacts
- Microbial transformations (typically fermentations) yield
- dairy products (e.g., cheeses, yogurt, buttermilk)
- other food products (e.g., sauerkraut, pickles, leavened breads, beer)

Microorganisms, Energy, and the Environment

- The role of microbes in biofuels production

•For example, methane, ethanol, hydrogen

- The role of microbes in cleaning up pollutants (bioremediation)

Biofuels

John A. Breznak

(a) (b)

Production of methane

Bioremediation

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

Biological Insecticides

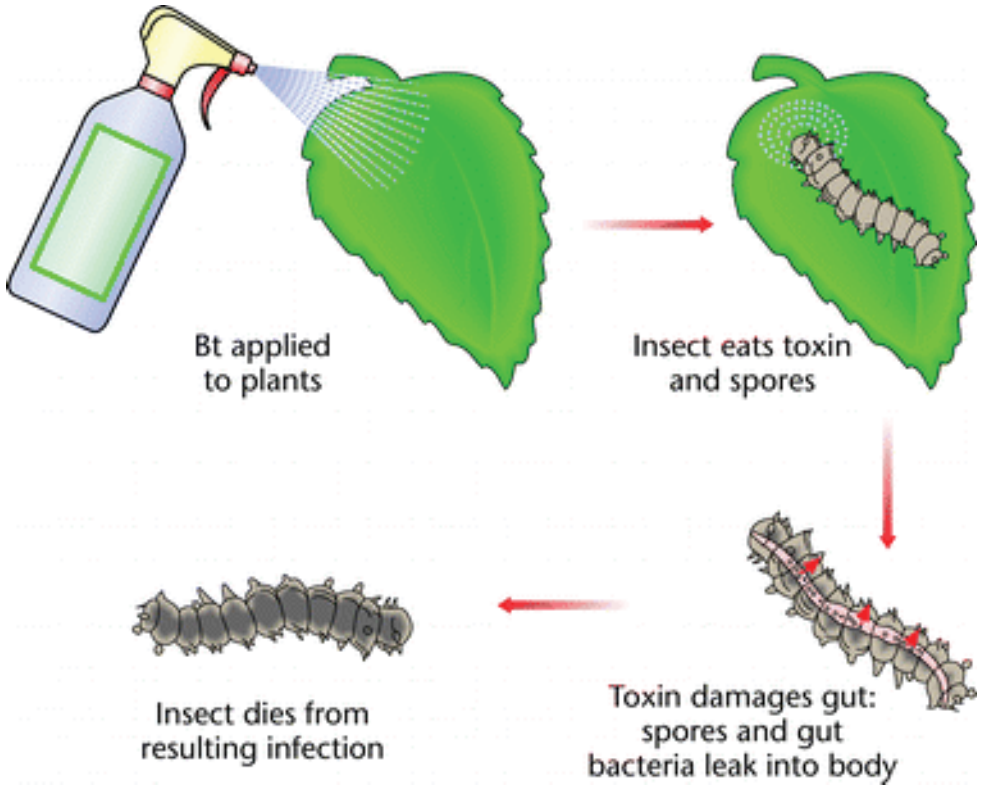
persistant in the environment → after they become pollutant.

Xenobiotics → means man made chemicals.
(pesticide, herbicide, weedicide)

- Microbes that are pathogenic to insects are alternatives to chemical pesticides to prevent insect damage to agricultural crops and disease transmission.

B.t → its produce cry protein (inactive) → active in gut of the insects → because gut is basic. (pH 9) → environmental friendly process. cant harm humans.

- *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 pharmaceuticals, 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.

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

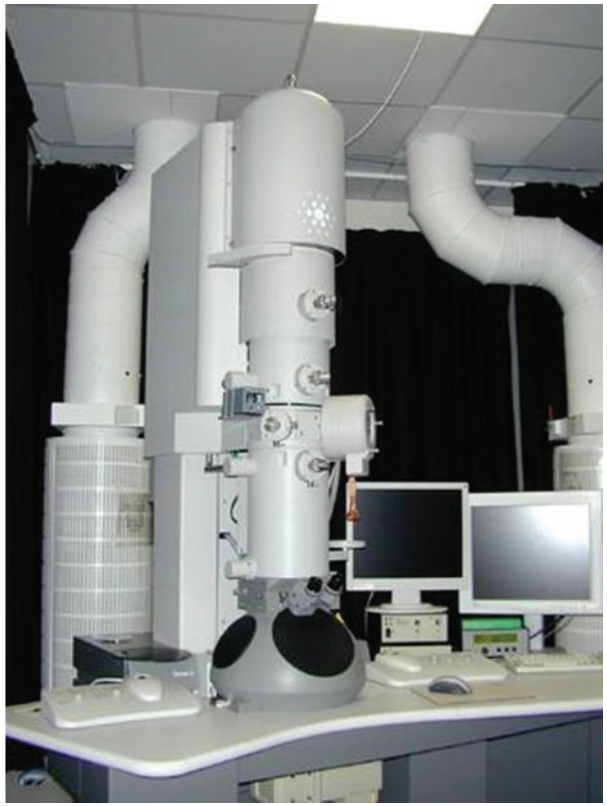
Observing Microorganisms Through a Microscope

most microbes 0,2 µm

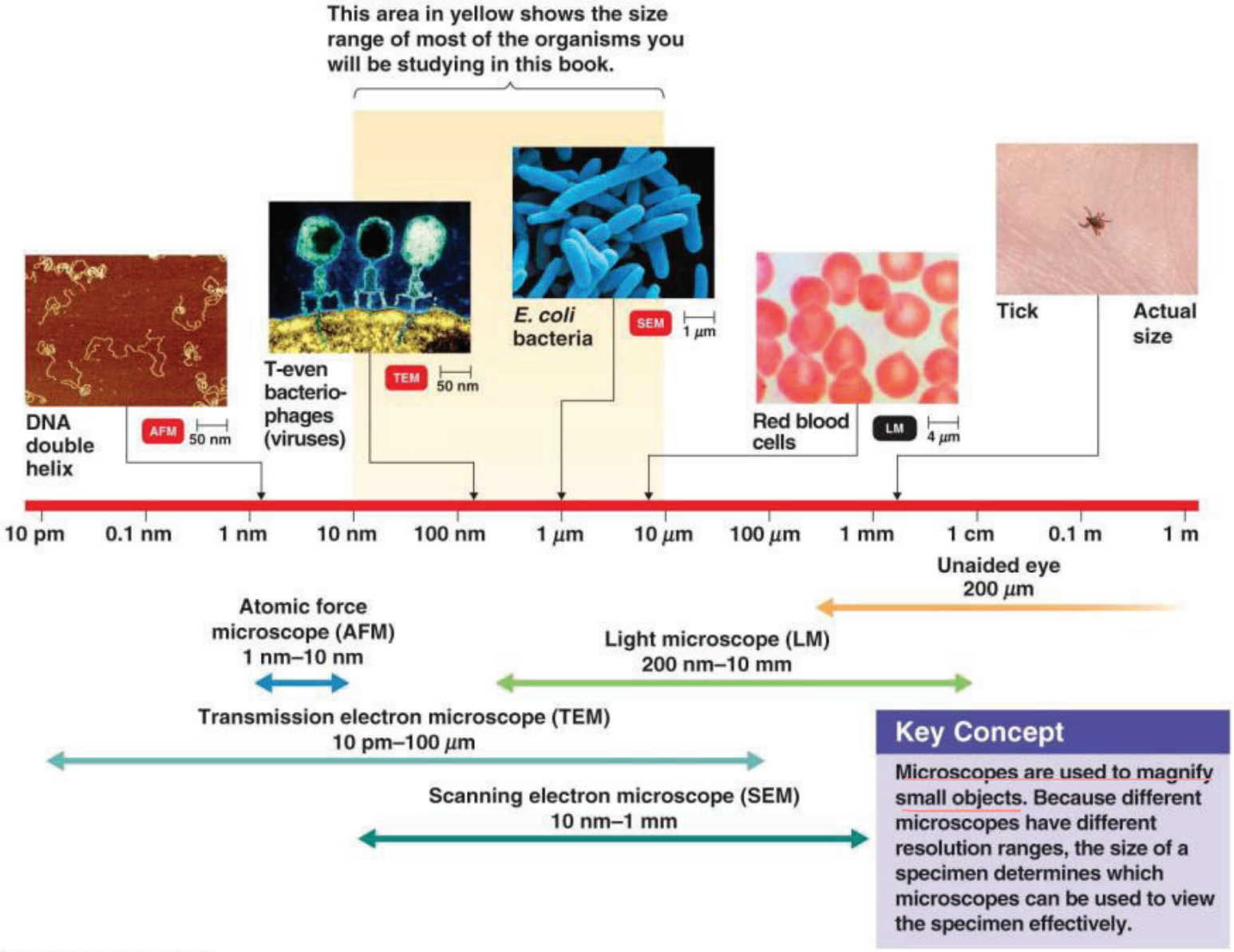
Units of Measurement

- 1 µm = 10^{-6} m = 10^{-3} mm
- 1 nm = 10^{-9} m = 10^{-6} mm
- 1000 nm = 1 µm
- 0.001 µm = 1 nm

Angstroom → Å 10^{-10} m



Observing Microorganisms Through a Microscope



Key Concept

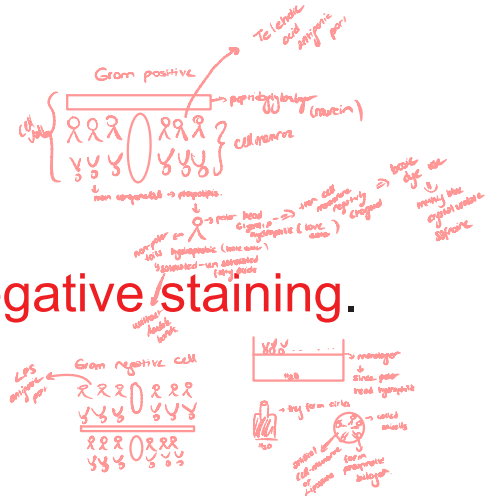
Microscopes are used to magnify small objects. Because different microscopes have different resolution ranges, the size of a specimen determines which microscopes can be used to view the specimen effectively.

Preparing Smears for Staining

- A thin film of a solution of microbes on a slide is a smear.
- A smear is usually fixed to attach the microbes to the slide and to kill the microbes.
  - with air or heat
  - to keep on slide the smear

Preparing Smears for Staining

- Stains consist of a positive and negative ion.
- In a basic dye, the chromophore is a cation.
- In an acidic dye, the chromophore is an anion.
- Staining the background instead of the cell is called negative staining.



Simple Stains

- Use of a single basic dye is called a simple stain.
- A mordant may be used to hold the stain or coat the specimen to enlarge it.

Differential Stains: Gram Stain

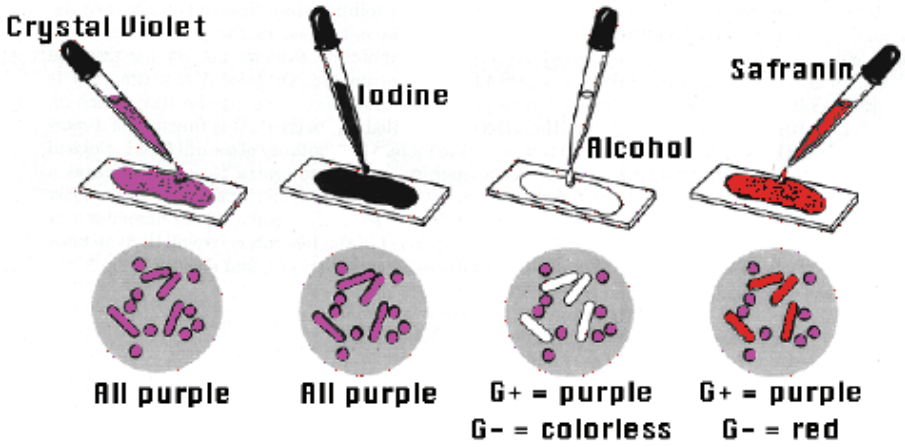
- The Gram stain classifies bacteria into gram-positive and gram-negative.
- Gram-positive bacteria tend to be killed by penicillin and detergents.
- Gram-negative bacteria are more resistant to antibiotics.

Gram Staining Procedure

- A heat-fixed smear is covered with a basic purple dye (usually crystal violet)…the primary stain since it imparts its color to all cells
- The purple dye is washed off and the smear is covered with iodine (the mordant)…after rinsing both will appear purple still
- Slide is washed with alcohol or alcohol-acetone (decolorizing agent)…removes dye from Gram negative bacteria
- Alcohol is rinsed, and the slide is counterstained with safranin (a basic red dye) then rinsed…Gram+ will be purple…Gram- will be red

since gram positive have more thick peptidoglycan layer => it will still have some color

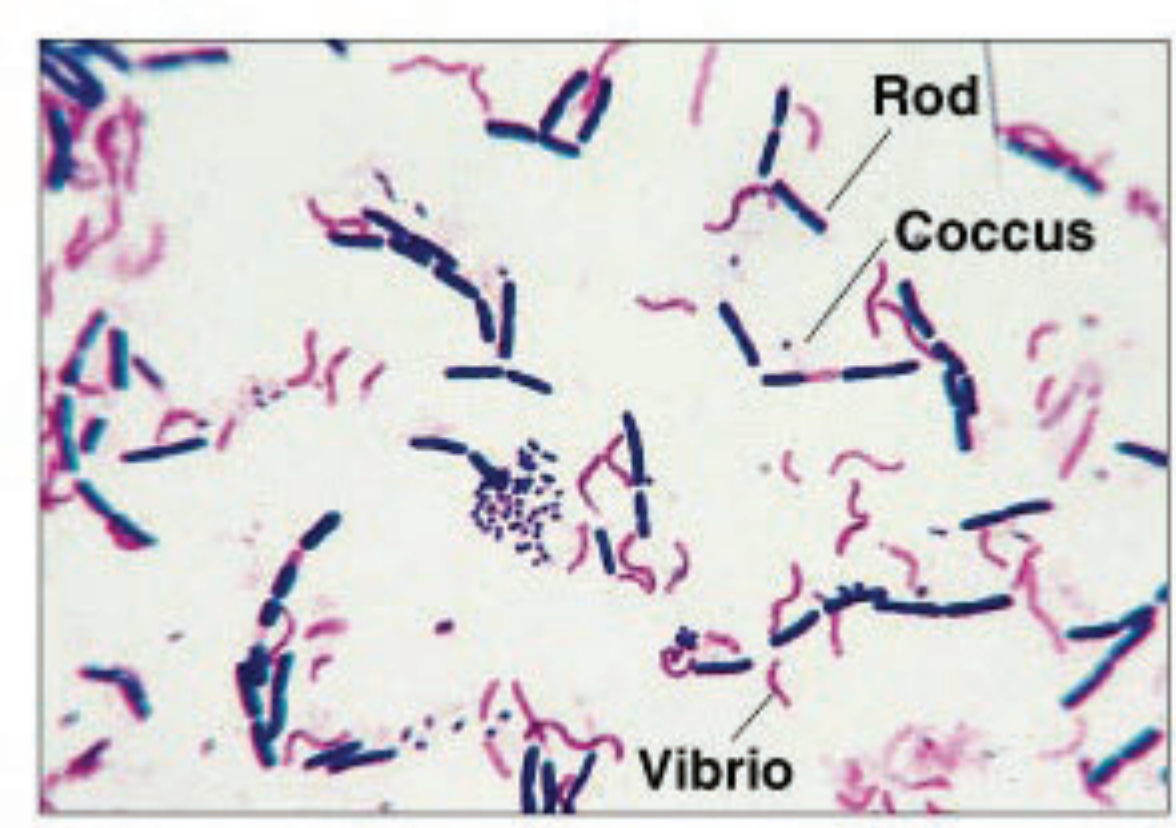
safranin



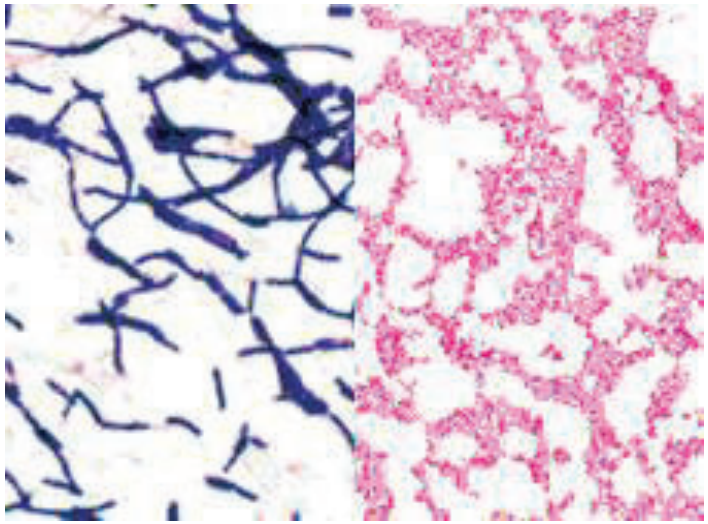
Differential Stains: Gram Stain

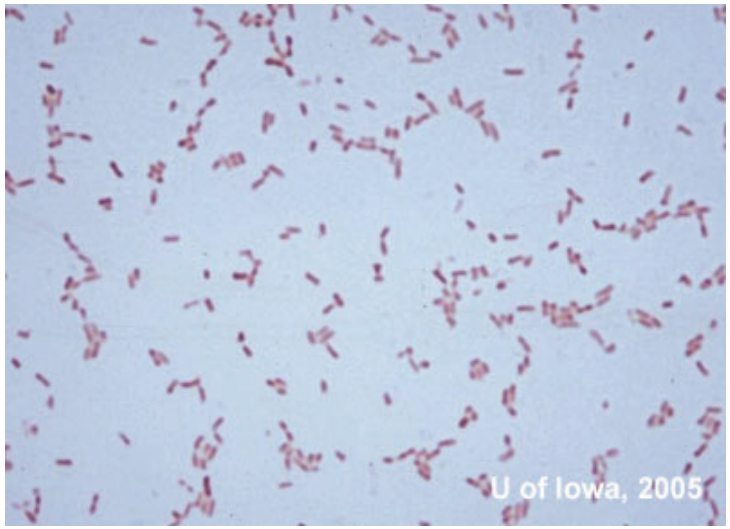
	Color of Gram + cells	Color of Gram – cells
Primary stain: Crystal violet	Purple	Purple
Mordant: Iodine ↳ helps die to stain the cell	Purple	Purple
Decolorizing agent: Alcohol-acetone	Purple	Colorless
Counterstain: Safranin ↳ means secondary stain	Purple	Red

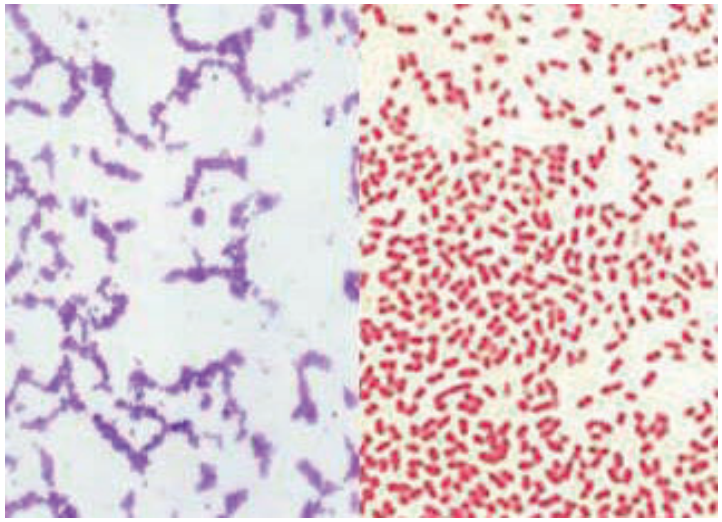
Differential Stains: Gram Stain

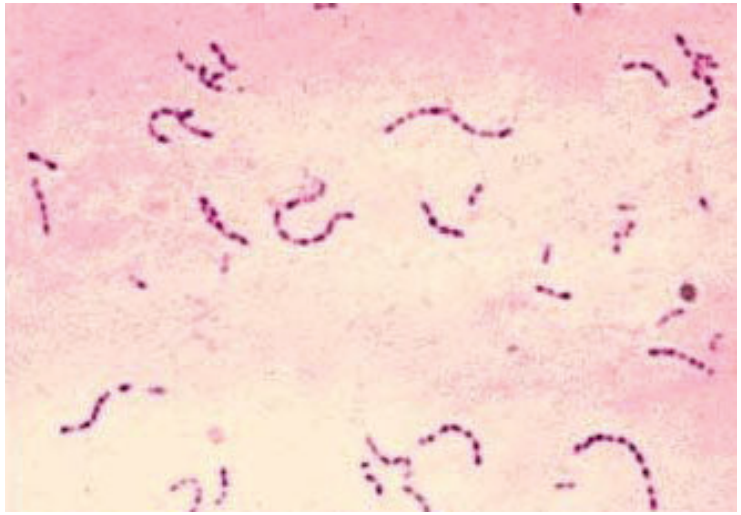


Gram-Stained Bacteria









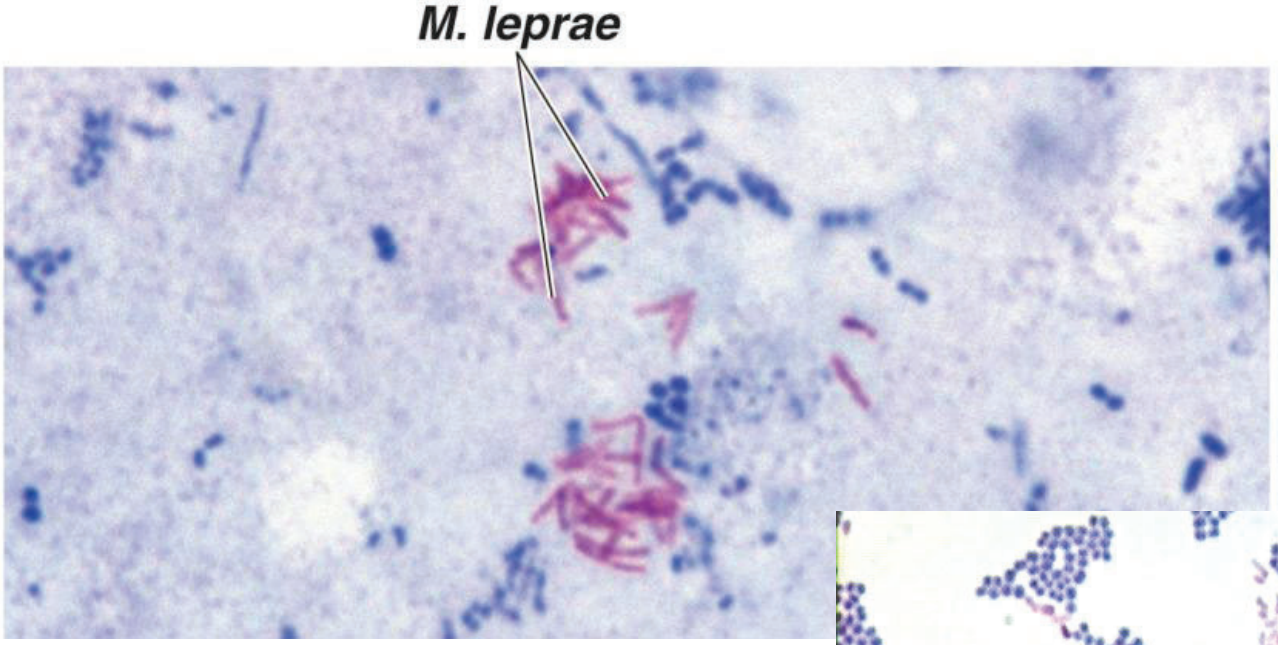
Acid-Fast Stain

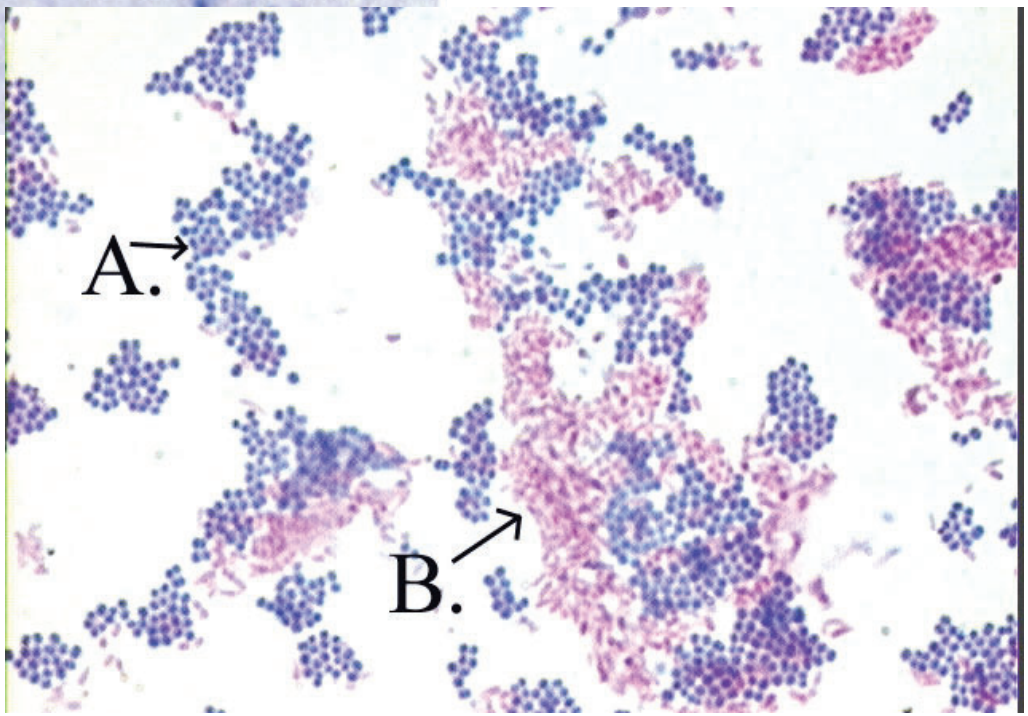
- Another differential staining technique
- Stain binds strongly to bacteria that have waxy material in their cell walls
  - stained waxy cell walls will not decolorized when rinsed with acid-alcohol
  - *Mycobacterium tuberculosis & Mycobacterium leprae*
  - *Nocardia sp.* – causes Nocardiosis a virulent form of pneumonia

Acid-Fast Stain

	Color of Acid-fast	Color of Non–Acid-fast
Primary stain: Carbolfuchsin + Heat	**Red**	**Red**
Decolorizing agent: Acid-alcohol	**Red**	**Colorless**
Counterstain: Methylene blue	**Red**	**Blue**

Acid-Fast Bacteria



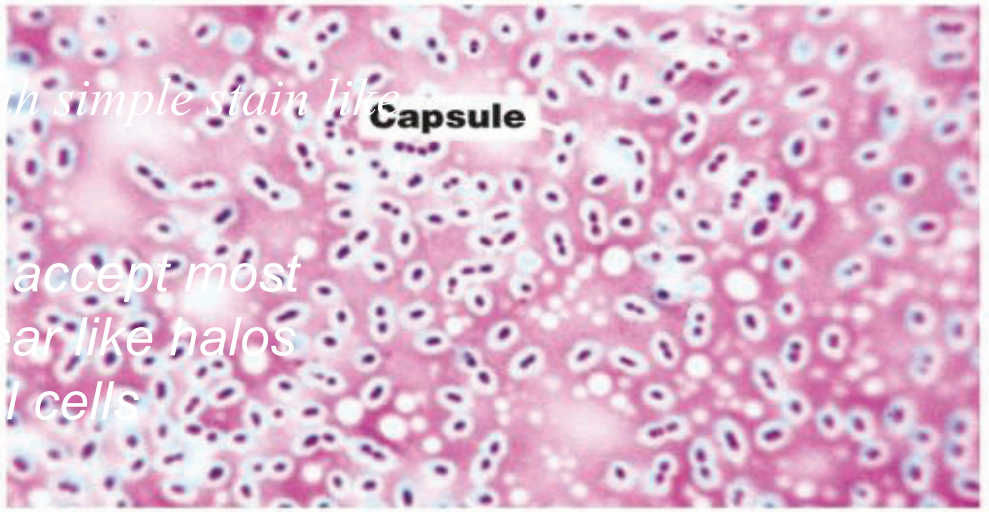


A = non acid fast
B = acid fast

Special Stains to Distinguish Parts of Cells

Negative Staining for Capsules

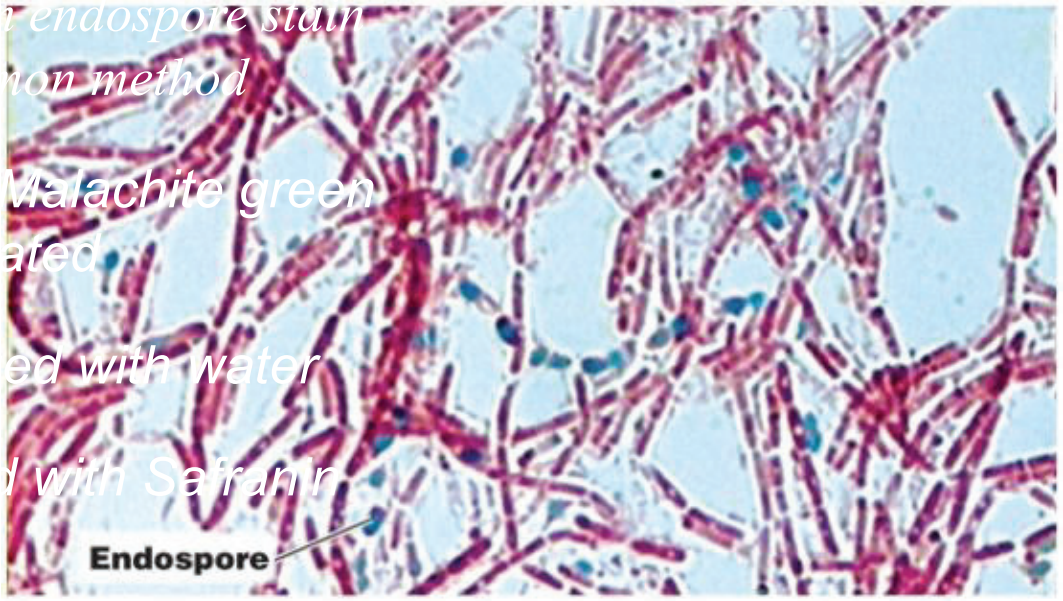
- Many microorganisms have a gelatinous capsules that are difficult to dye
- Helps protect them from host phagocytosis often making them more virulent
- Stain slide with India Ink or Nigrosin for background contrast



Special Stains to Distinguish Parts of Cells

Endospore staining

- Endospores are dormant, resistant structures in some bacterial cells that protect them from adverse environmental conditions
- Cannot be stained with simple stains or Gram staining because dye will not penetrate endospore wall



Special Stains to Distinguish Parts of Cells

Flagella stain

- Flagella are locomotive structures that are typically too small to see with a light microscope
- Using a mordant to enhance their diameter and Carbolfuchsin stain they can be observed

(c) Flagella staining