Lecture 1
Introduction to General Microbiology

Dr Amin Aqel
Associate Professor

What is a Microbe?

- Smaller than 0.1mm
- Includes viruses, protozoan, bacteria, small suckers, others

Nomenclature

- Carolus Linnaeus (1735)
- *Genus species*
- By custom once mentioned can be abbreviated with initial of genus followed by specific epithet. *E. coli*

Why study Microbiology

- Microbes are related to all life.
  - In all environments
  - Many beneficial aspects
  - Related to life processes (nutrient cycling)
  - Only a minority are pathogenic.
  - Most of our problems are caused by microbes

Classification of microorganisms

Bacteria

- Prokaryotes
- Peptidoglycan cell walls
- Binary fission
- For energy, use organic chemicals, inorganic chemicals, or photosynthesis

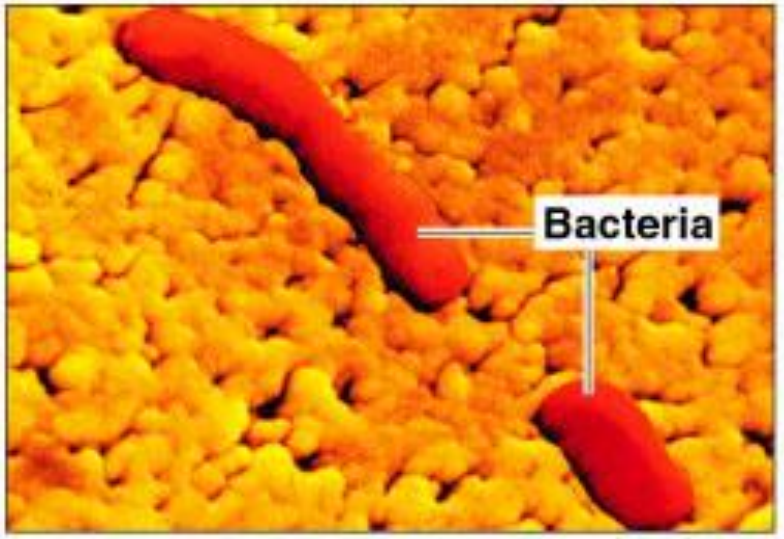
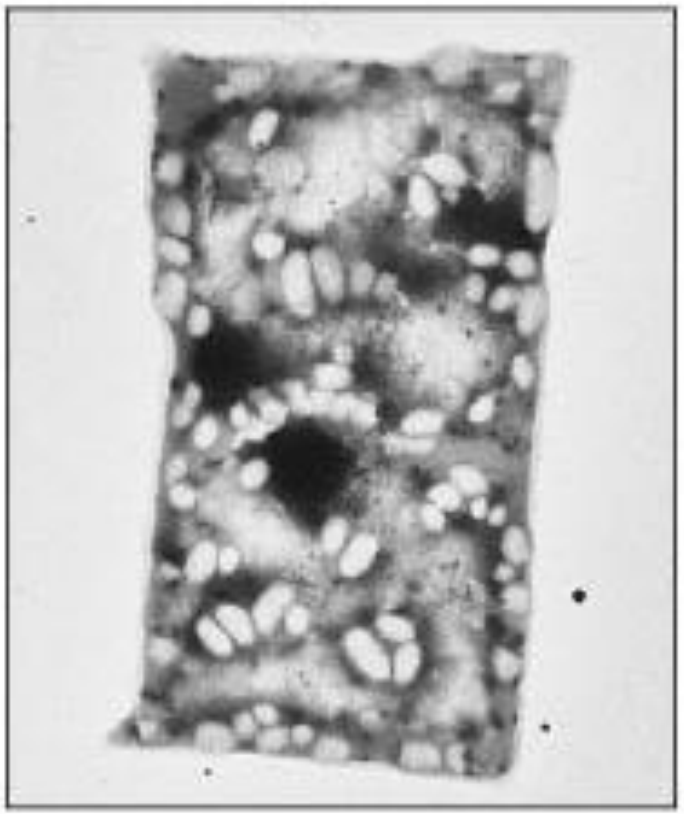


Figure 1.1a

Archaea:

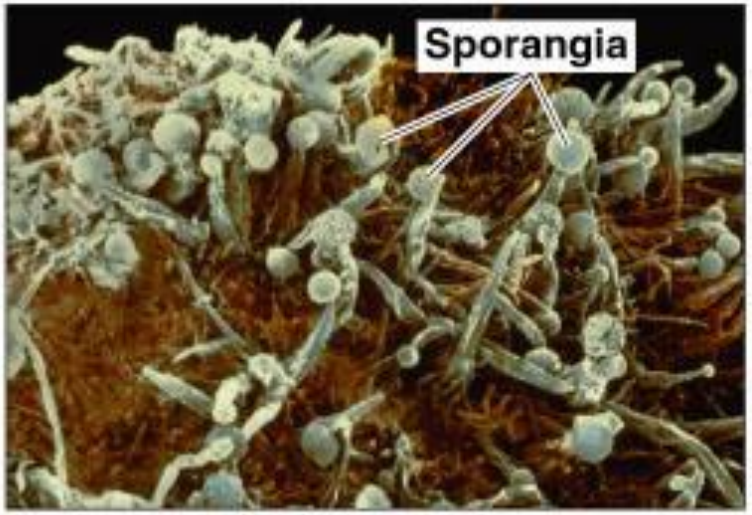
- Prokaryotic
- Lack peptidoglycan
- Live in extreme environments
- Include:
  - Methanogens
  - Extreme halophiles
  - Extreme thermophiles



Halobacteria not from book

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)

Figure 1.1b

Protozoa

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

Figure 1.1c

Algae

- Eukaryotes
- Cellulose cell walls
- Use photosynthesis for energy (primary producers)
- Produce molecular oxygen and organic compounds

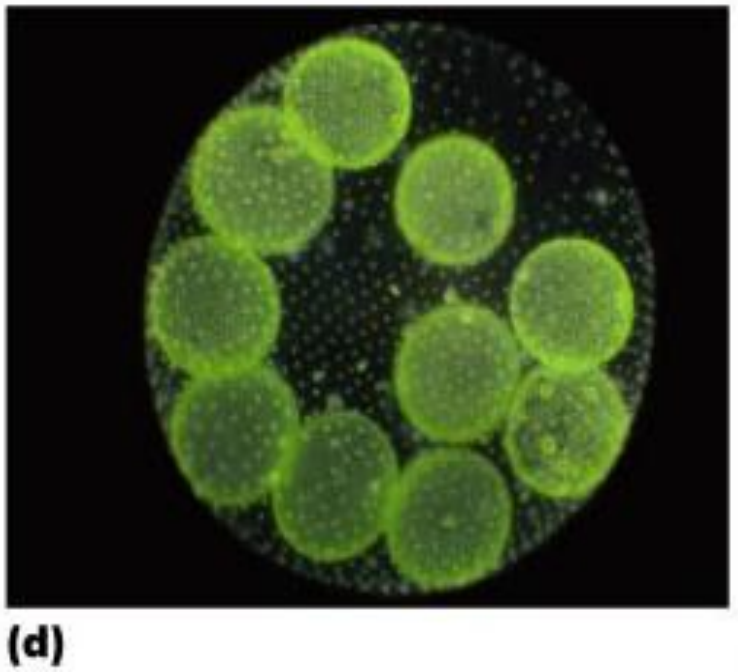


Figure 1.1d

Viruses

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

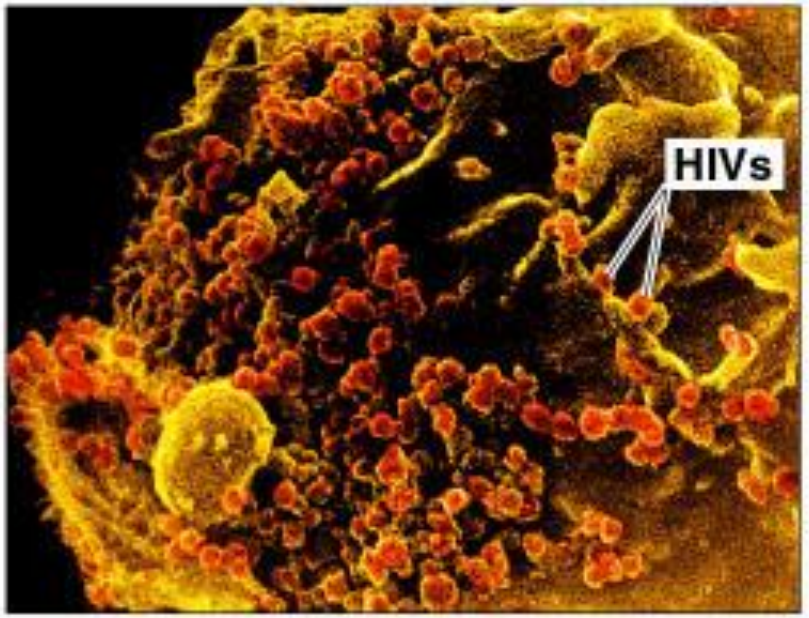


Figure 1.1e

Multicellular Animal Parasites

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

Figure fluke

Knowledge of microorganisms:

- Allows humans to
  - Prevent food spoilage
  - Prevent disease occurrence
  - Others?
- Led to aseptic techniques to prevent contamination in medicine and in microbiology laboratories.

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.

Historical background of Microbiology

- Some highlights
  - 1665 Robert Hooke observed fruiting structures of molds and was the first to describe microorganisms
  - 1673 van Leeuwenhoek's microscopes
  - 1735 Linnaeus Nomenclature
  - 1798 Jenner vaccine
  - 1857 Pasteur Fermentation
  - 1876 Koch germ theory of disease

Adjustment

Lens

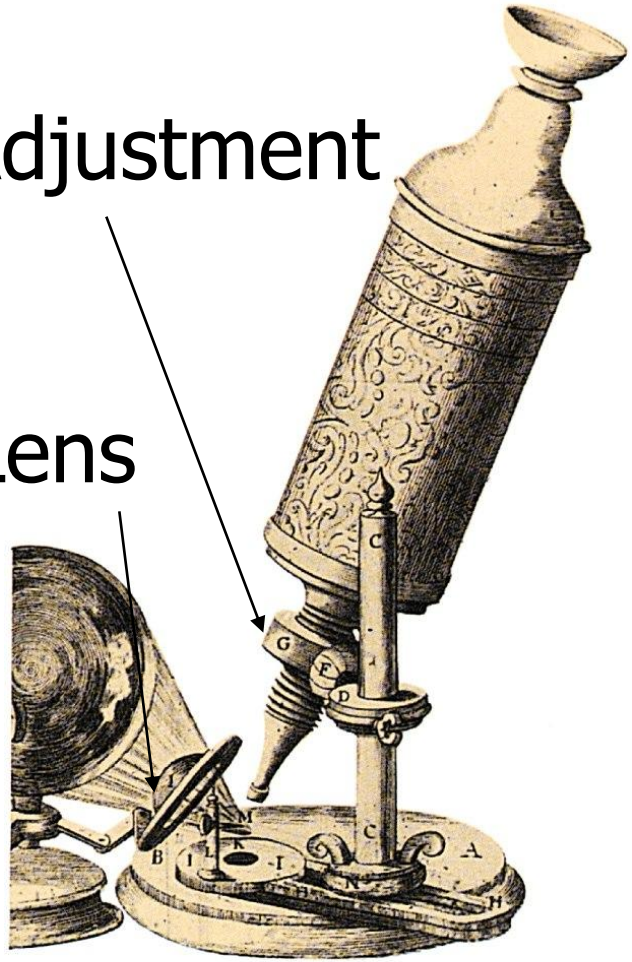


Figure 1-8a Brock Biology of Microorganisms 11/e
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Figure 1-8b Brock Biology of Microorganisms 11/e
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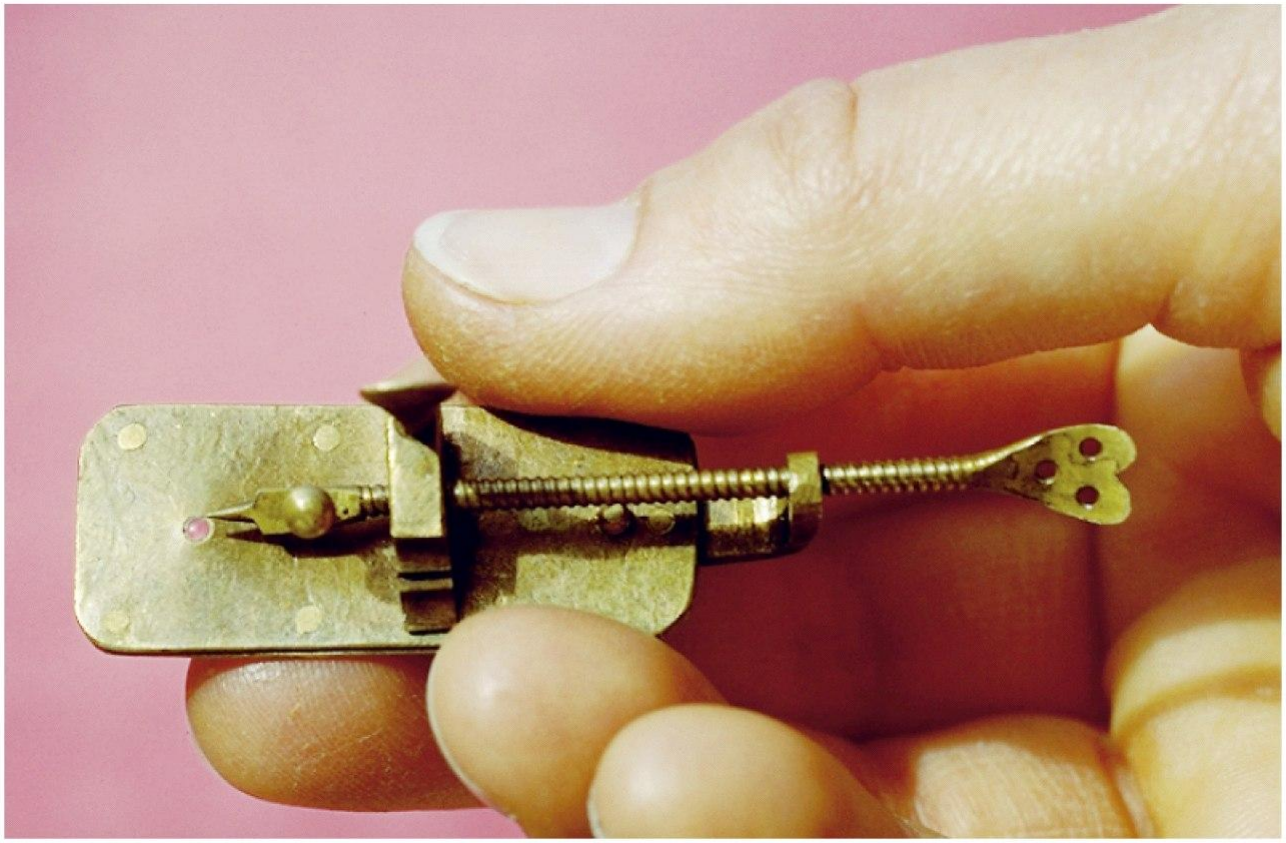
Van Leeuwenhoek's Microscope



T. D. Brock

Figure 1-9a Brock Biology of Microorganisms 11/e

Van Leeuwenhoek's drawing on various organsisms

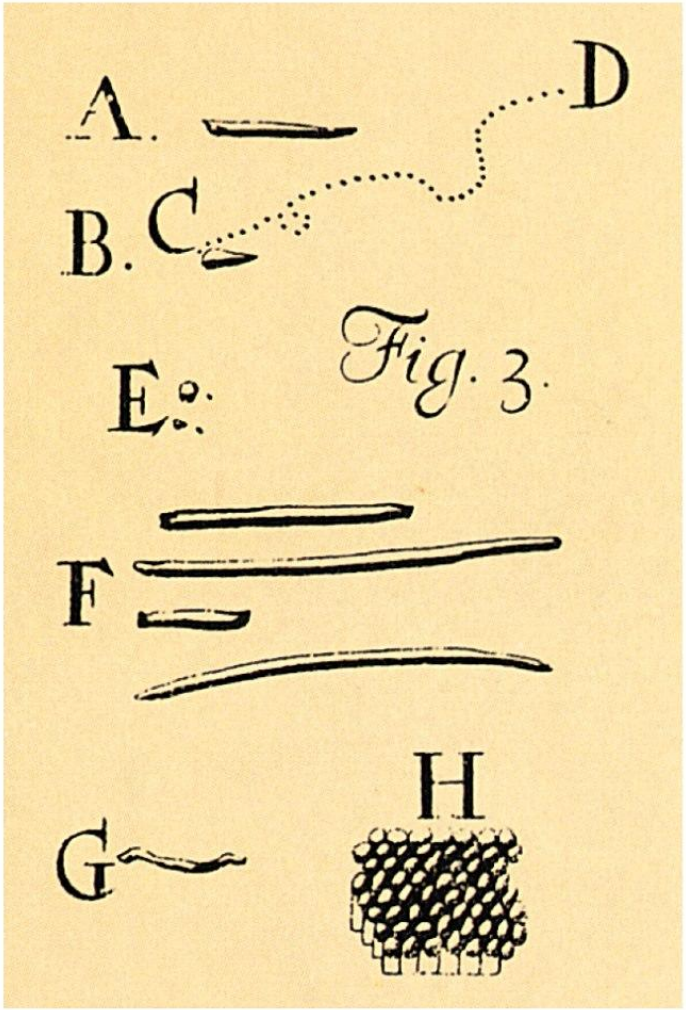


Figure 1-9b Brock Biology of Microorganisms 11/e

The Golden Age of Microbiology

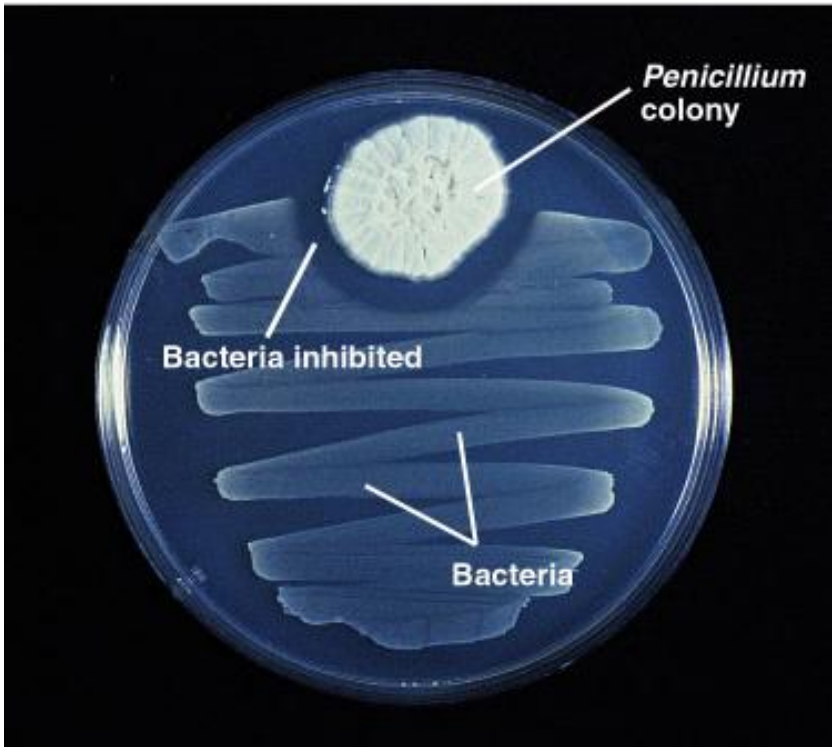
- 1857-1914
- Beginning with Pasteur's work, discoveries included the relationship between microbes and disease, immunity, and antimicrobial drugs

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.

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.



Similar to 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.
- Virology is the study of virus
- Recent advances in genomics, the study of an organism’s genes, have provided new tools for classifying microorganisms.
- Proteomics is looking at the gene products

Taxonomy

- Taxonomy: the Science of Classification
  - The science of Provides a classifying organisms
  - Provides universal names for organisms
  - reference for identifying organisms
  - Groupings of organisms
  - WHY Classify?
  - Establish criteria for ID
  - Arrange related organisms into groups
  - Provide information about evolution of organisms

Levels of Classification

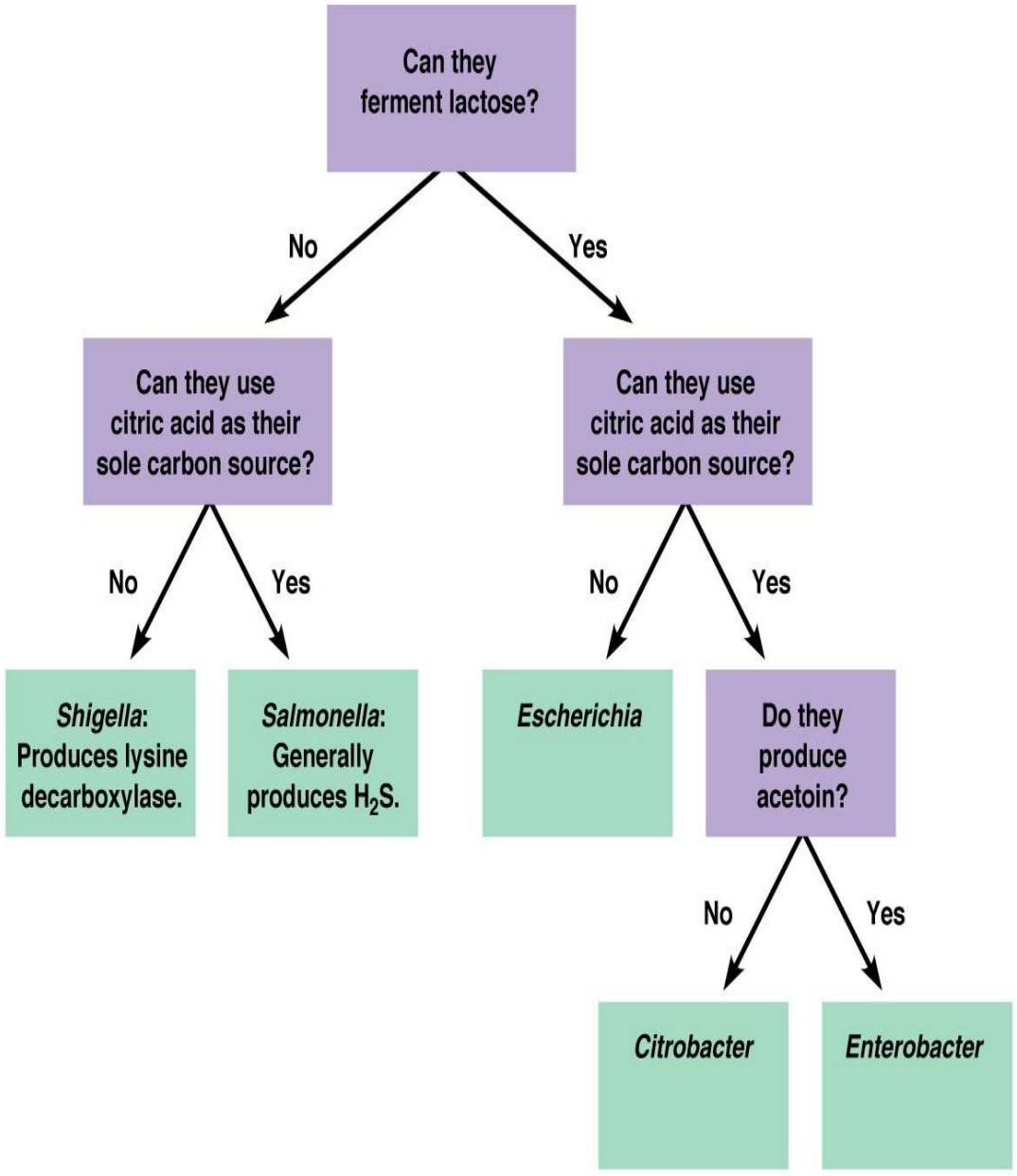
- Kingdom
- Division/Phyta/Phylum
- SubPhylum
- Class
- Order
- Family
- Genus
- Species/Specific Epithet
- Subspecies/Strain

Classification Systems in the Procaryotae

1. Microscopic morphology
2. Macroscopic morphology – colony appearance
3. Physiological / biochemical characteristics
4. Chemical analysis
5. Serological analysis
6. Genetic and molecular analysis
   - G + C base composition
   - DNA analysis using genetic probes
   - Nucleic acid sequencing and rRNA analysis

Identification Methods

- Morphological characteristics: Useful for identifying eukaryotes
- Differential staining: Gram staining, acid-fast staining
- Biochemical tests: Determines presence of bacterial enzymes

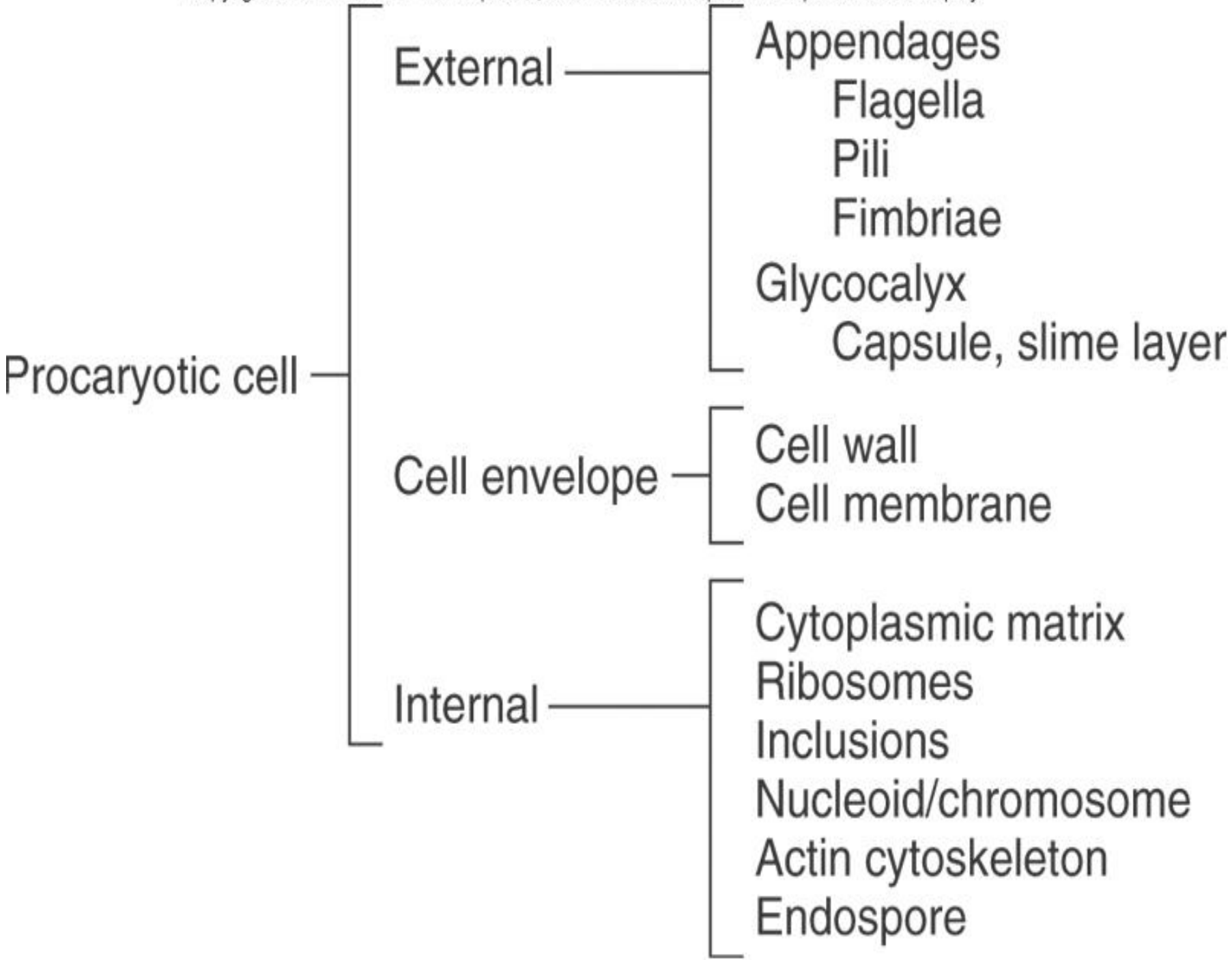


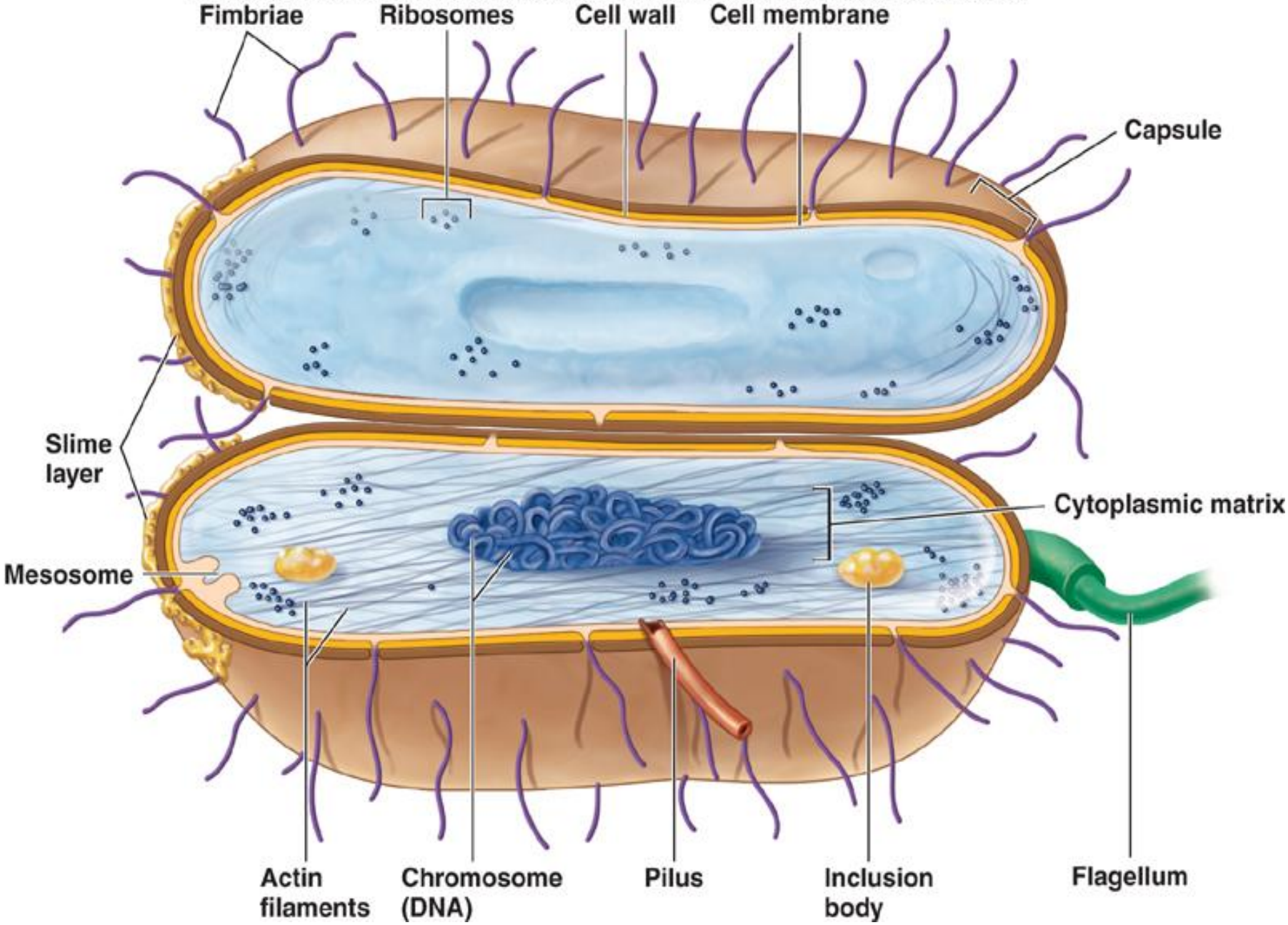
Lecture 2

Morphology / Bacterial Structures

Dr Amin Aqel

Morphology / Bacterial Structures





External Structures

- Appendages
  - two major groups of appendages:
    - Motility – flagella and axial filaments (periplasmic flagella)
    - Attachment or channels – fimbriae and pili
- Glycocalyx – surface coating

Flagella

- 3 parts:
  - **filament** – long, thin, helical structure composed of protein **flagellin**
  - **hook**- curved sheath
  - **basal body** – stack of rings firmly anchored in cell wall

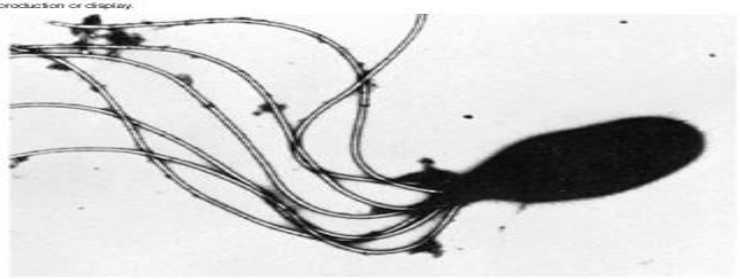
Flagellar Function

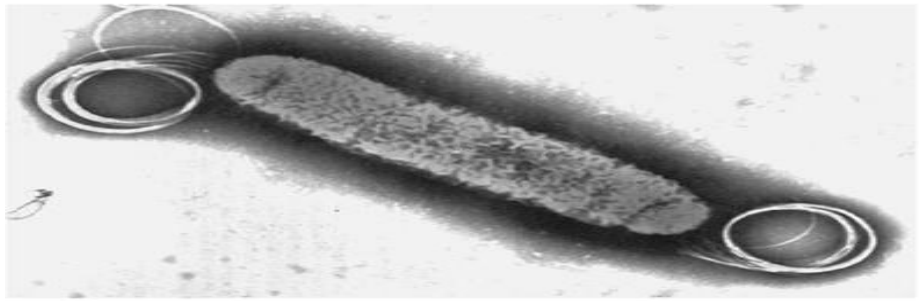
-Functions in motility of cell through environment

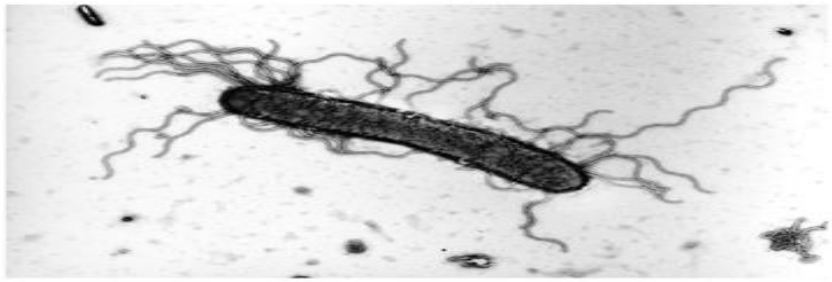
-Guide bacteria in a direction in response to external stimulus:

Flagellar Arrangements

1. Monotrichous – single flagellum at one end
2. Lophotrichous – small bunches arising from one end of cell
3. Amphitrichous – flagella at both ends of cell
4. Peritrichous – flagella dispersed over surface of cell; slowest

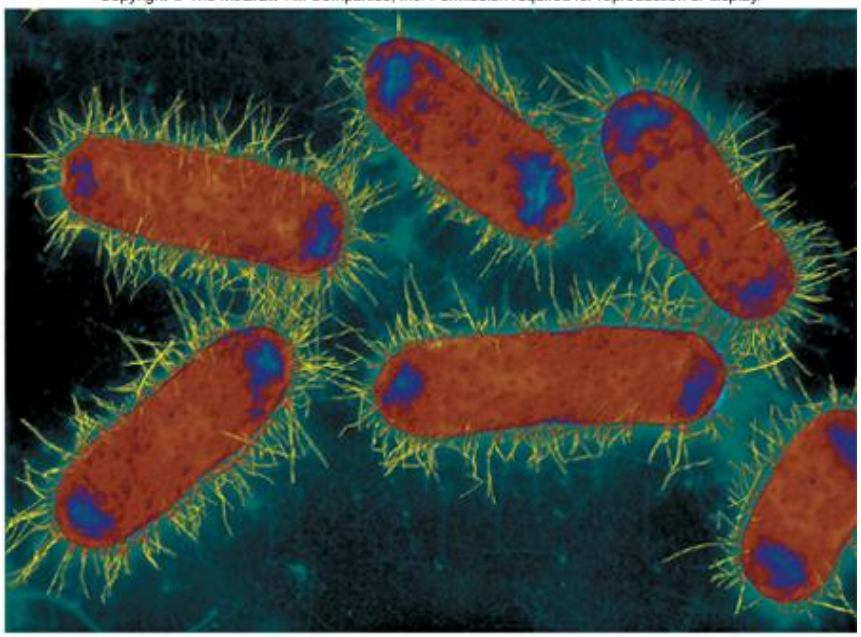






Fimbriae

- Fine, proteinaceous, hairlike bristles from the cell surface
- Function in adhesion to other cells and surfaces



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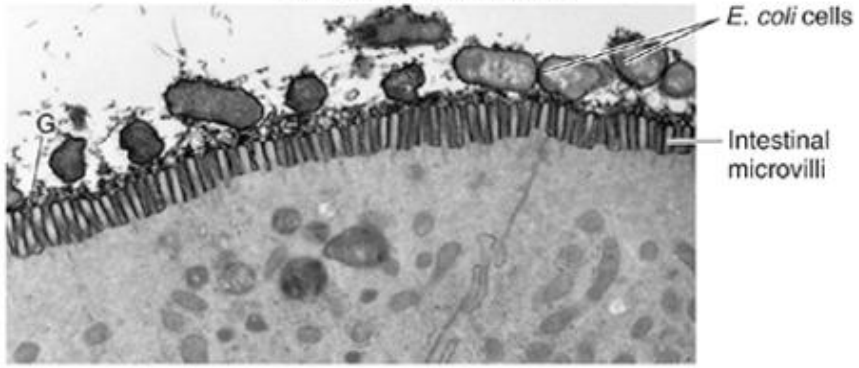

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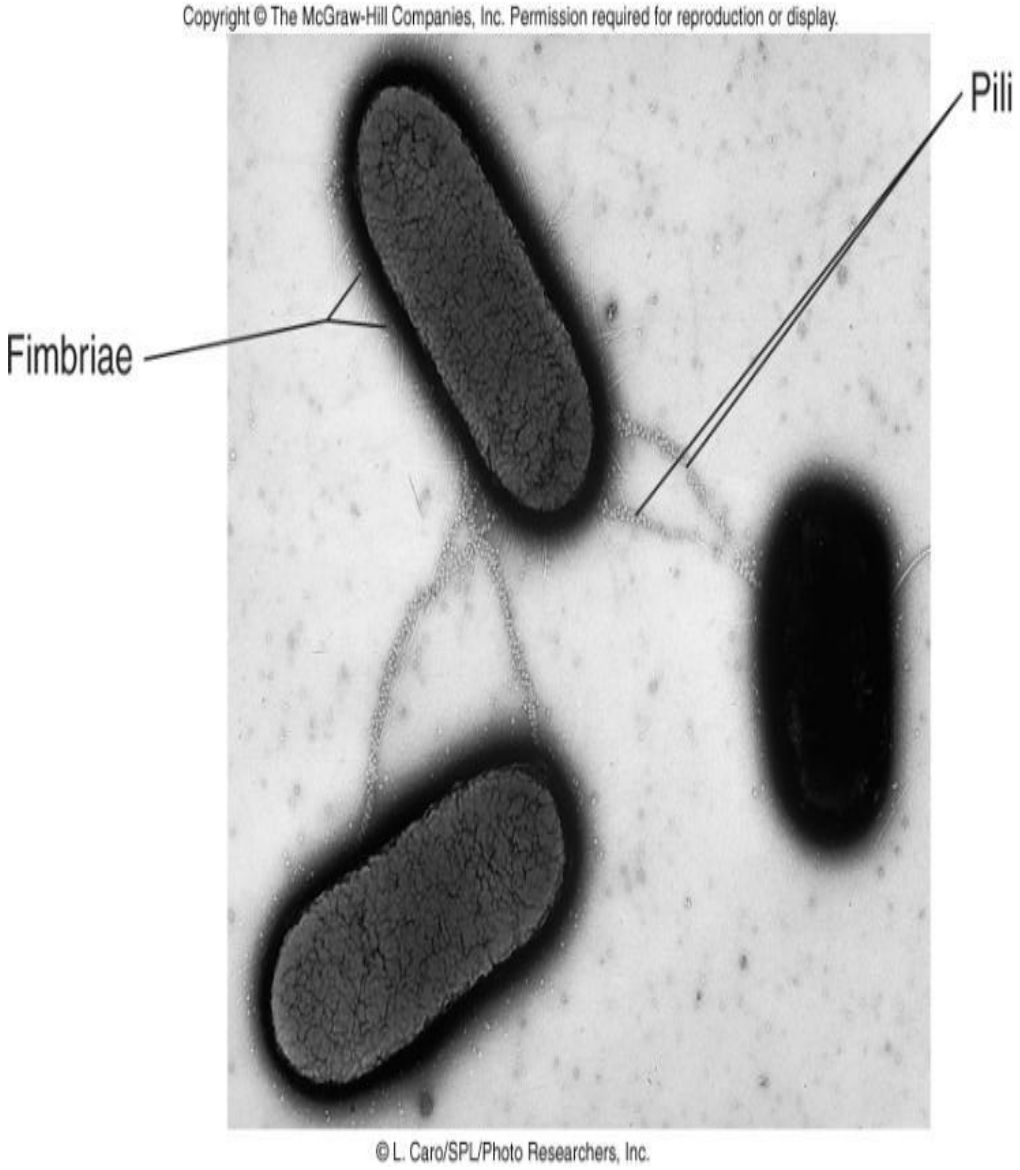
Pili

- Rigid tubular structure made of **pilin** protein
- Found only in Gram negative cells
- Function to join bacterial cells for partial DNA transfer called **conjugation**



Glycocalyx

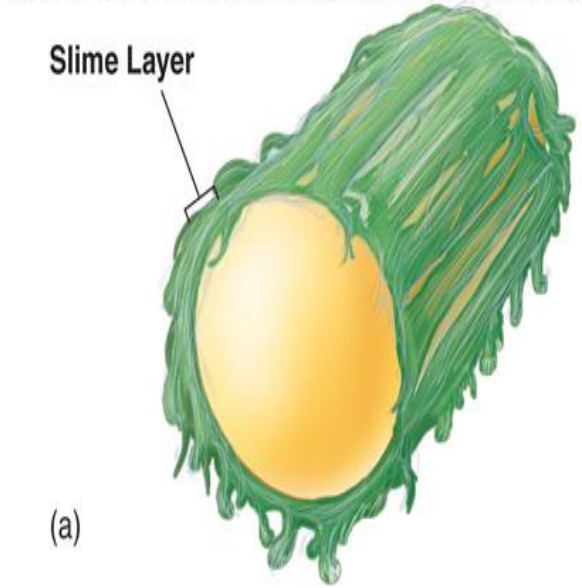
- Coating of molecules external to the cell wall, made of sugars and/or proteins

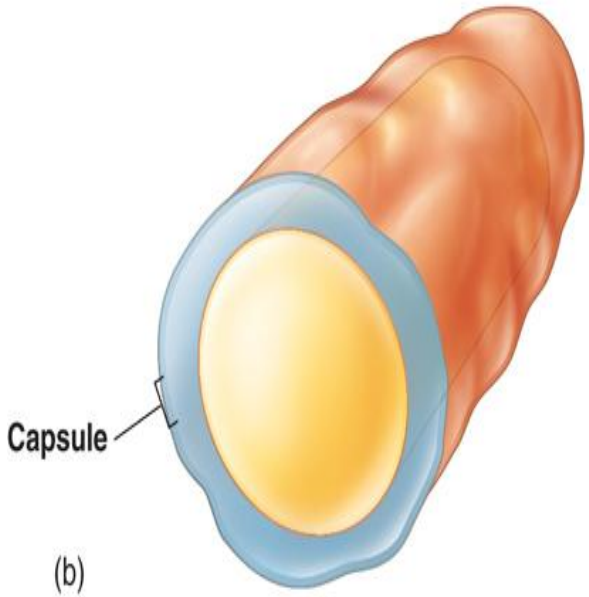
-Two types:

1-slime layer : loosely organized and attached

2-capsule : highly organized, tightly attached

- Functions:
  - -protect cells from dehydration and nutrient loss
  - -inhibit killing by white blood cells by phagocytosis contributing to pathogenicity
  - ◦ attachment - formation of **biofilms**



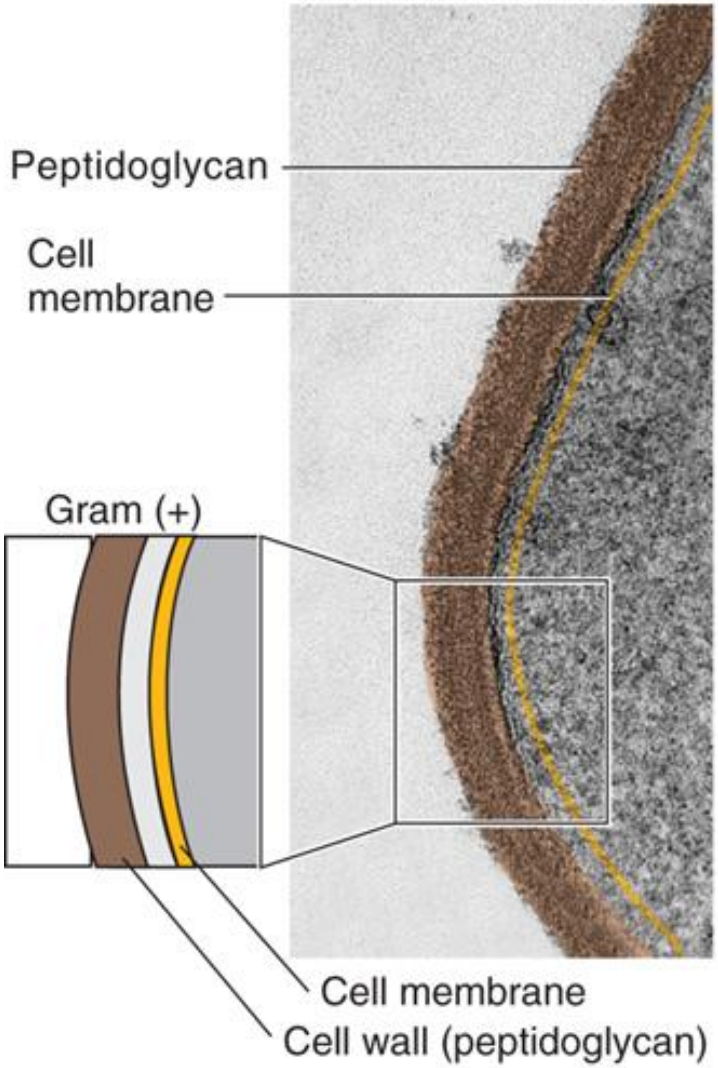


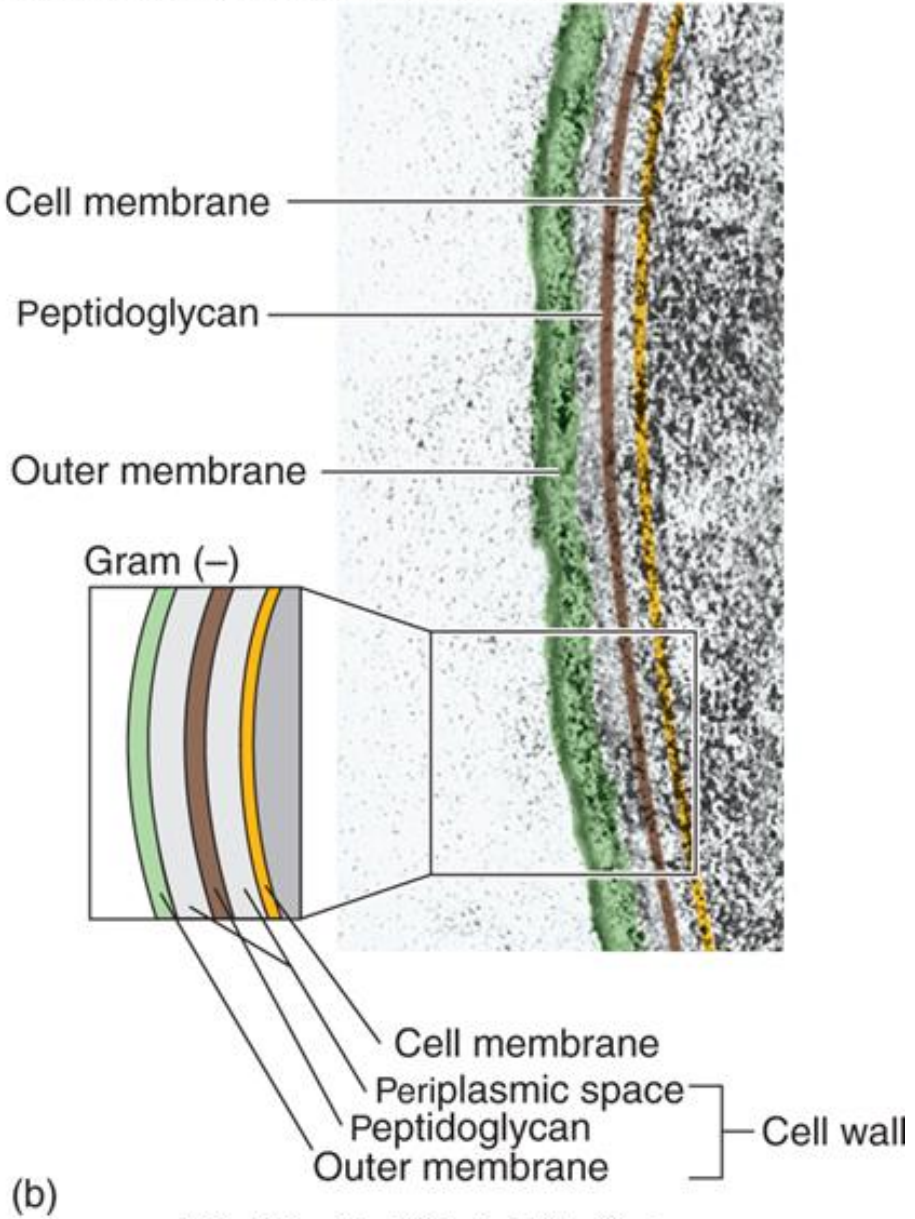
The Cell Envelope

- External covering outside the cytoplasm
- Composed of two basic layers:
  - cell wall and cell membrane
- Maintains cell integrity
- Two generally different groups of bacteria demonstrated by **Gram stain**:

  - **Gram-positive bacteria**: thick cell wall composed primarily of peptidoglycan and cell membrane

  - **Gram-negative bacteria**: outer cell membrane, thin peptidoglycan layer, and cell membrane





Bacterial Internal Structures

- Cell cytoplasm:
  - dense gelatinous solution of sugars, amino acids, and salts
  - 70-80% water
    - serves as solvent for materials used in all cell functions

- Chromosome
  - single, circular, double-stranded DNA molecule that contains all the genetic information required by a cell
  - DNA is tightly coiled around a protein, aggregated in a dense area called the **nucleoid**

Bacterial Internal Structures

- Plasmids
  - small circular, double-stranded DNA
  - free or integrated into the chromosome
  - duplicated and passed on to offspring
  - not essential to bacterial growth and metabolism
  - may encode antibiotic resistance, tolerance to toxic metals, enzymes and toxins
  - used in genetic engineering- readily manipulated and transferred from cell to cell

Bacterial Internal Structures

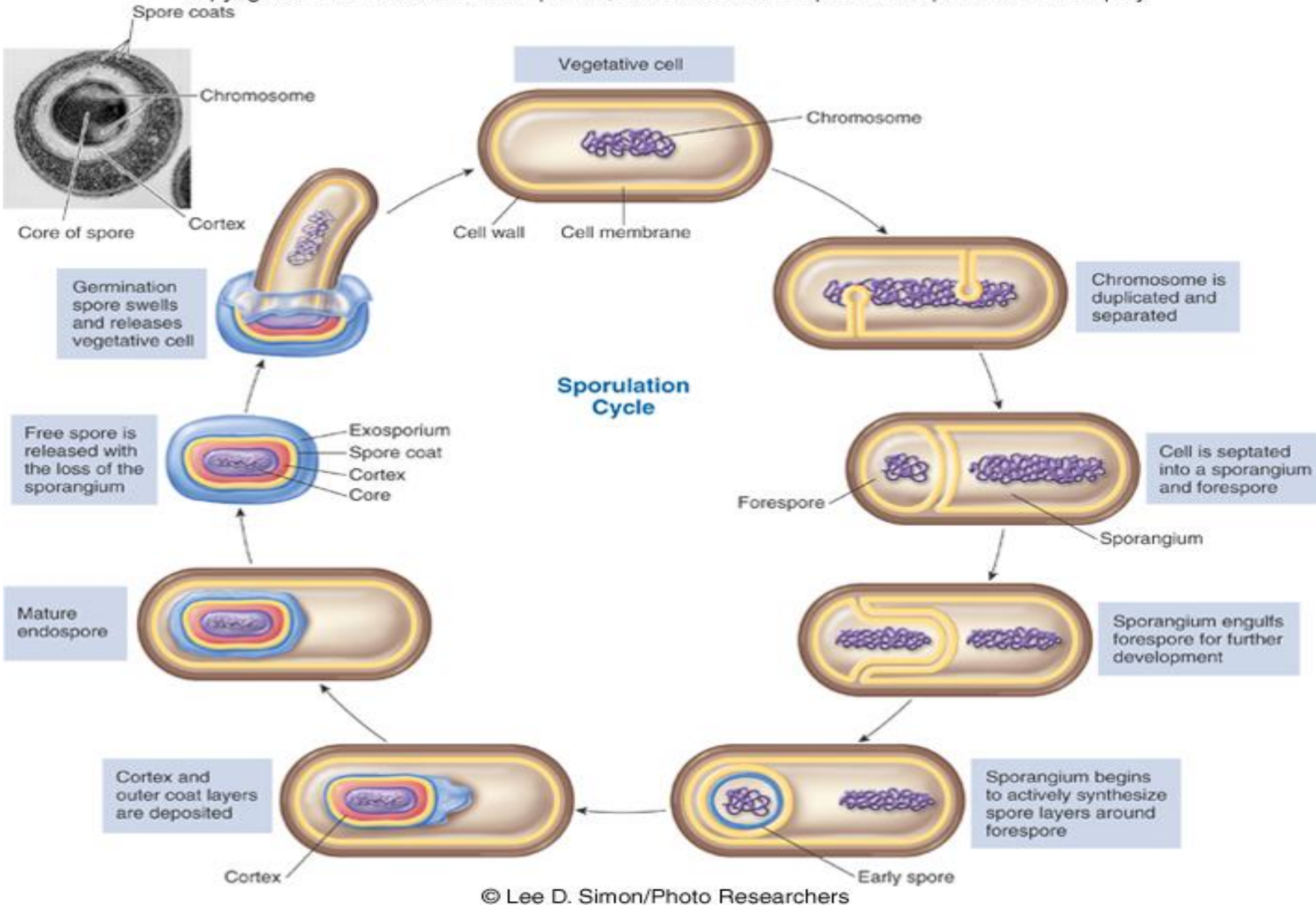
- Ribosomes
  - made of 60% ribosomal RNA and 40% protein
  - consist of two subunits: large and small
  - procaryotic differ from eucaryotic ribosomes in size and number of proteins
  - site of protein synthesis
  - present in all cells

Bacterial Internal Structures

- Inclusions and granules
  - intracellular storage bodies
  - vary in size, number and content
  - Bacterial cell can use them when environmental sources are depleted.
  - examples: glycogen, poly-β-hydroxybutyrate, gas vesicles for floating, sulfur and phosphate granules (metachromatic granules)

Bacterial Internal Structures

- Endospores
  - Inert ,resting, cells produced by some G+ genera: *Clostridium*, *Bacillus and Sporosarcina*
    - have a 2-phase life cycle:
      - vegetative cell – metabolically active and growing
      - endospore – when exposed to adverse environmental conditions; capable of high resistance and very long-term survival
  - **sporulation** : formation of endospores
    - hardiest of all life forms
    - withstands extremes in heat, drying, freezing, radiation and chemicals
    - not a means of reproduction
  - **germination**- return to vegetative growth



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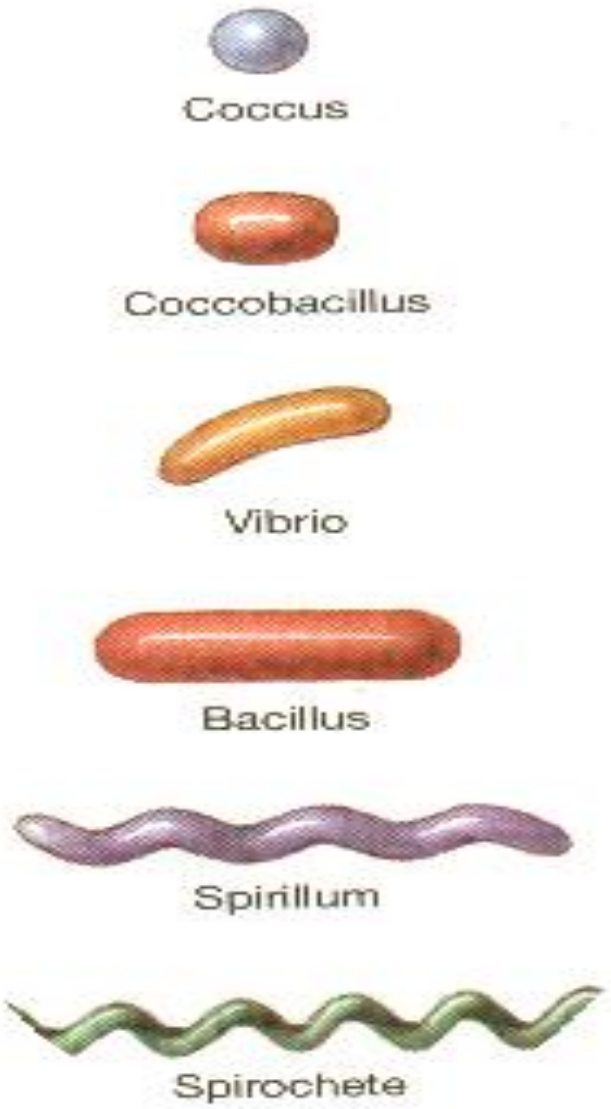
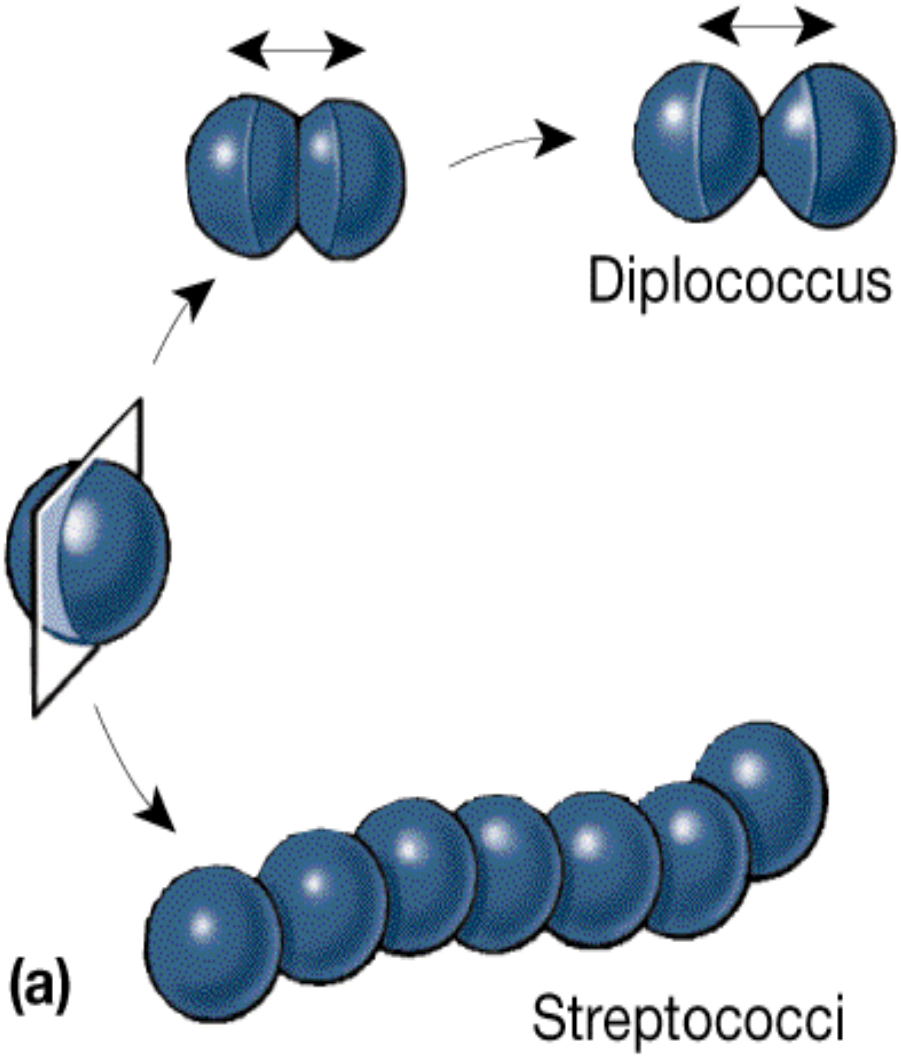
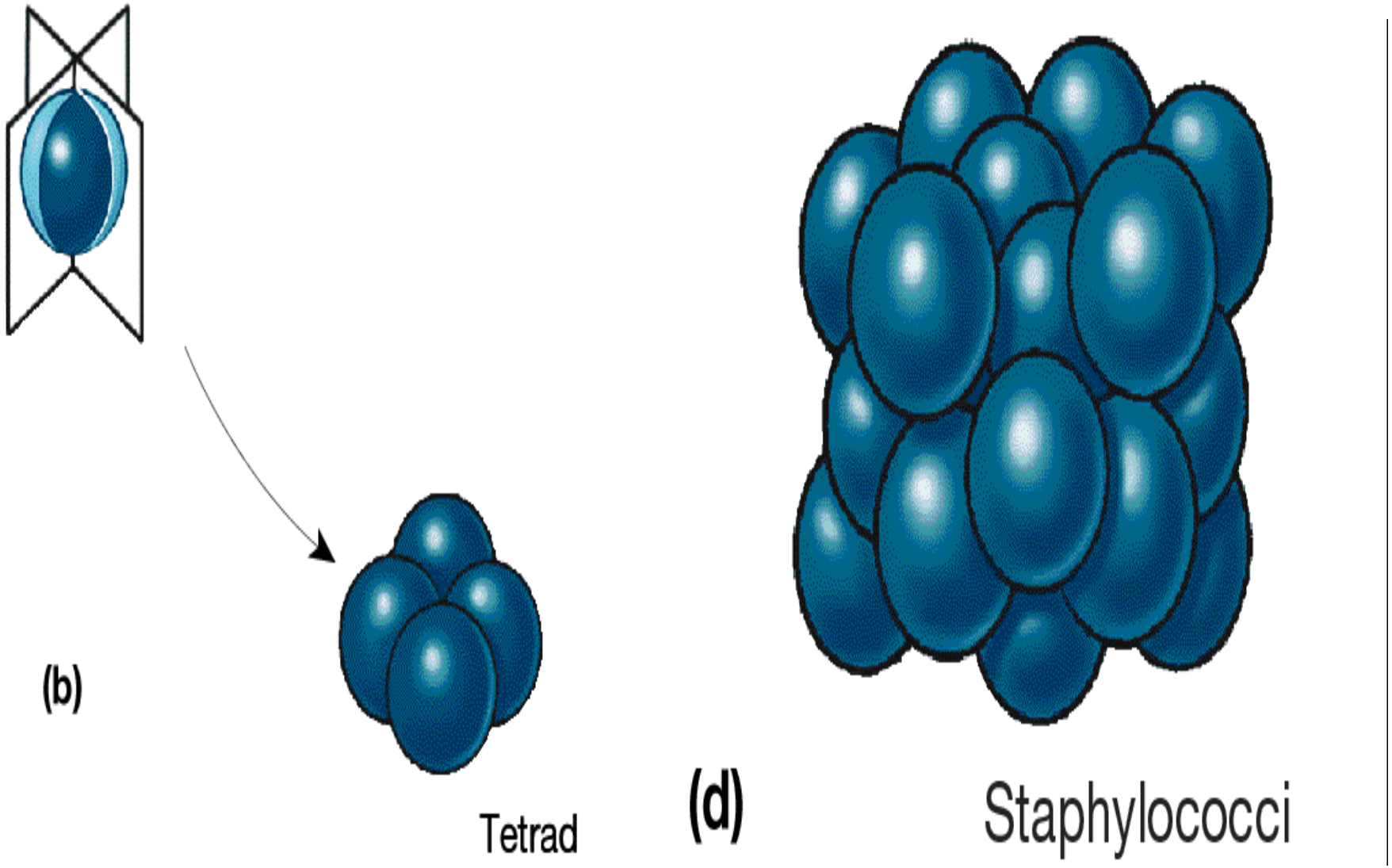
Shapes of Bacteria

- Coccus
  - Chain = Streptoccus
  - Cluster = Staphylococcus
- Bacillus
  - Chain = Streptobacillus
- Coccobacillus
- Vibrio = curved
- Spirillum
- Spirochete
- Square
- Star




Diplococcus
(a)
Streptococci


(b)
Tetrad
(d)
Staphylococci

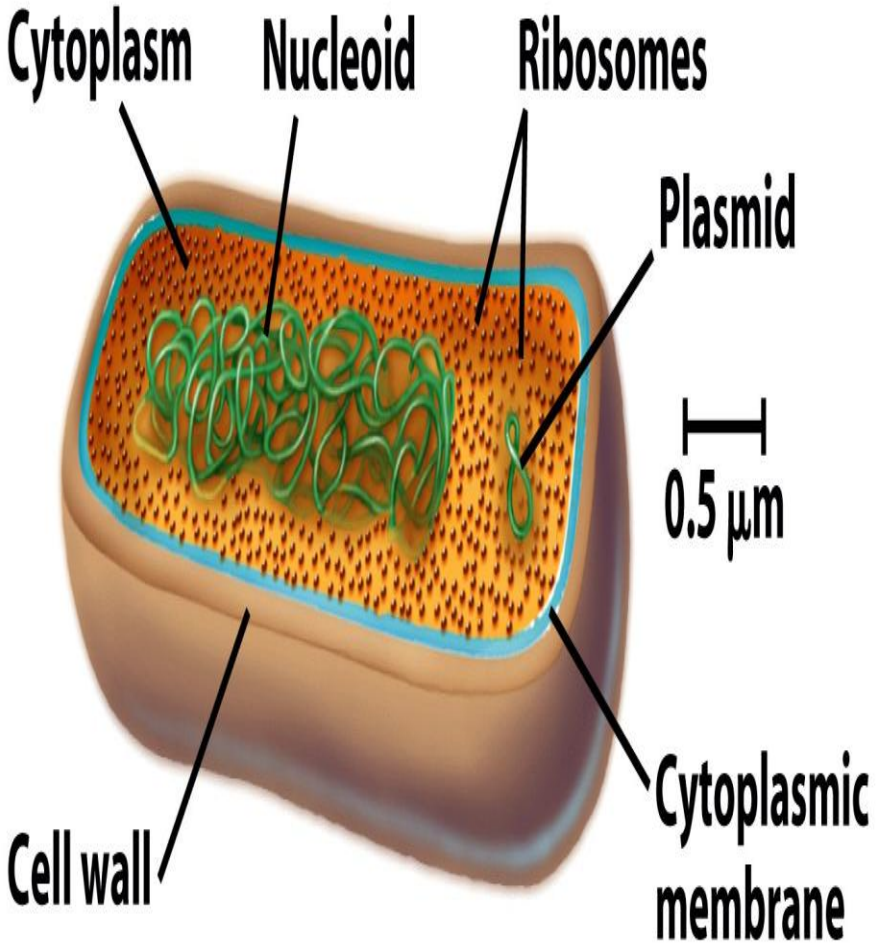
Lecture 3
Bacterial Physiology
Dr Amin Aqel

Bacterial physiology

Cell Structure

• Two structural types of cells are recognized: the **prokaryote** and the **eukaryote**. Prokaryotic cells have a simpler internal structure than eukaryotic cells, lacking membrane-enclosed organelles.

Prokaryote cell



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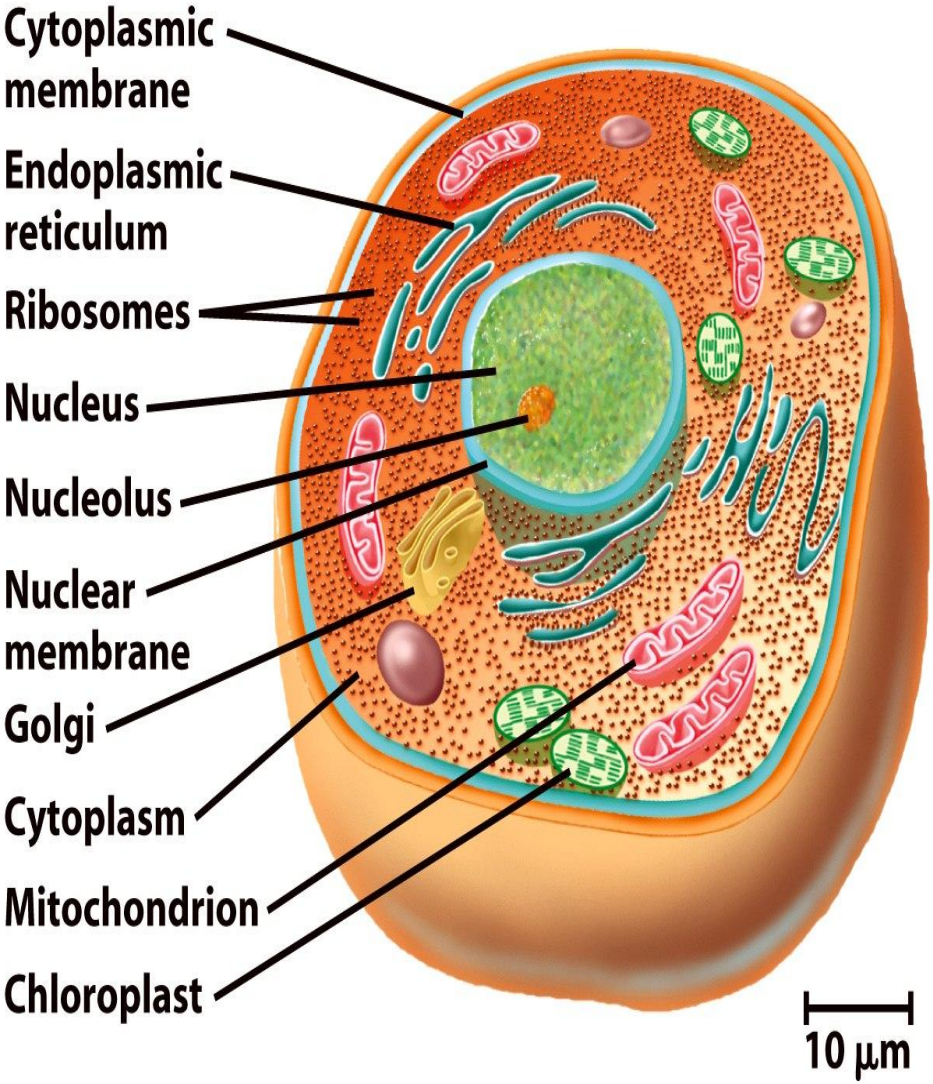
Eukaryote cell



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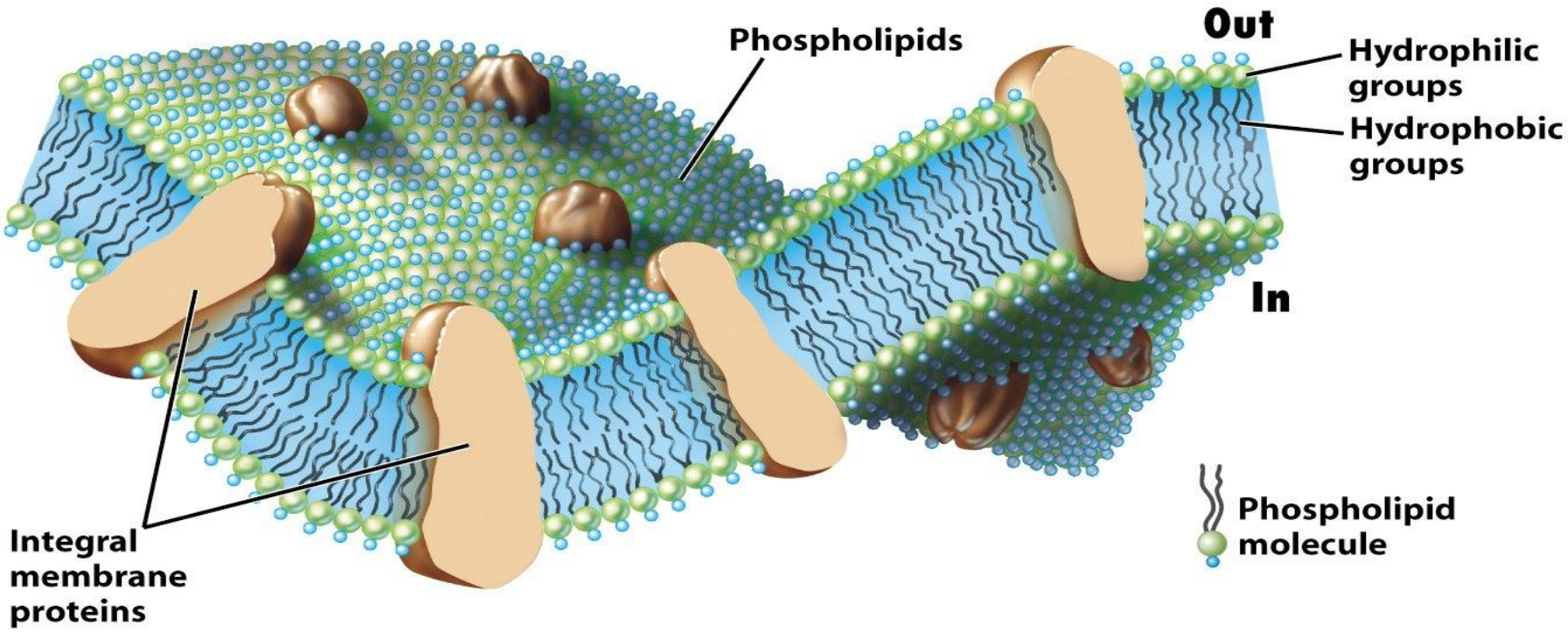
Cytoplasmic Membrane

The **cytoplasmic membrane** is a highly selective permeability barrier constructed of lipids and proteins that forms a bi-layer with hydrophilic exteriors and a hydrophobic interior.



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Movement of Molecules through Cytoplasmic Membrane

- The major function of the cytoplasmic membrane is to act as a permeability barrier, preventing leakage of cytoplasmic metabolites into the environment.
- Several ways for molecules to move through membrane

1. Simple Diffusion
2. Osmosis
3. Facilitated Diffusion
4. Active Transport

Simple Diffusion

- Does not require expenditure of energy
- Process by which some molecules move freely into and out of the cell
- Small molecules such as carbon dioxide and oxygen

Transport proteins (or transporters) responsible for:
Facilitated Diffusion, Active Transport

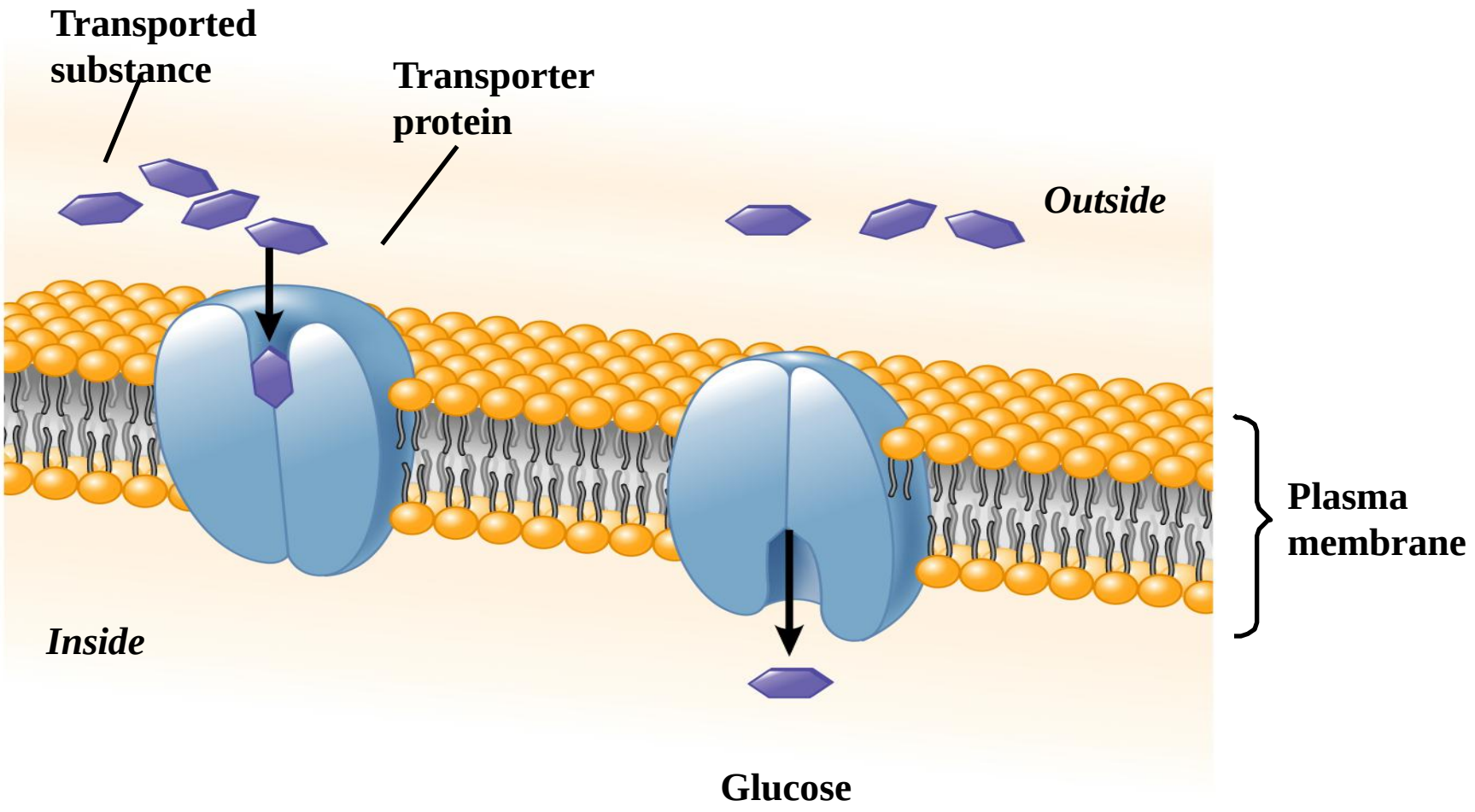


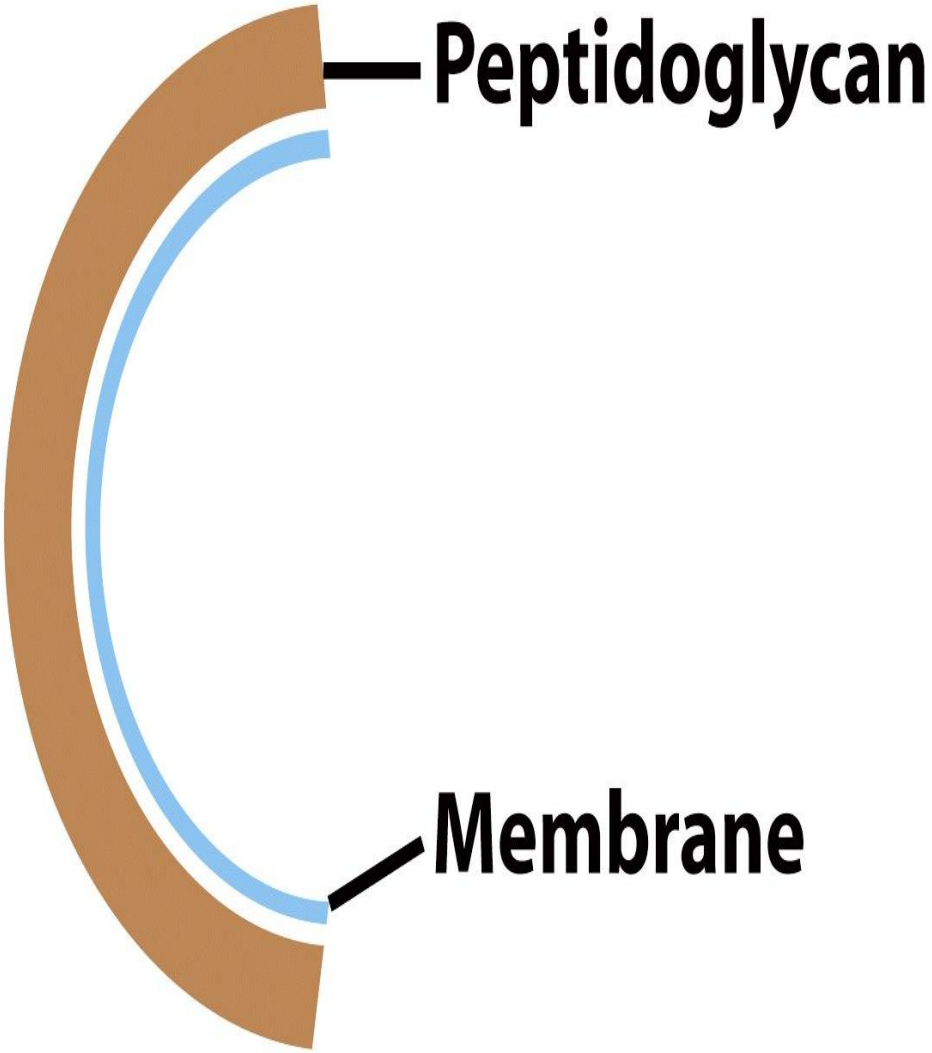
Figure 4.17: Facilitated diffusion.

Cell Wall

• **Gram-negative** *Bacteria* have only a few layers of peptidoglycan , but **Gram-positive** *Bacteria* have several layers.

• In addition to peptidoglycan, gram-negative *Bacteria* contain an **outer membrane** consisting of **lipopolysaccharide (LPS)**, protein, and lipoprotein.

Gram–positive



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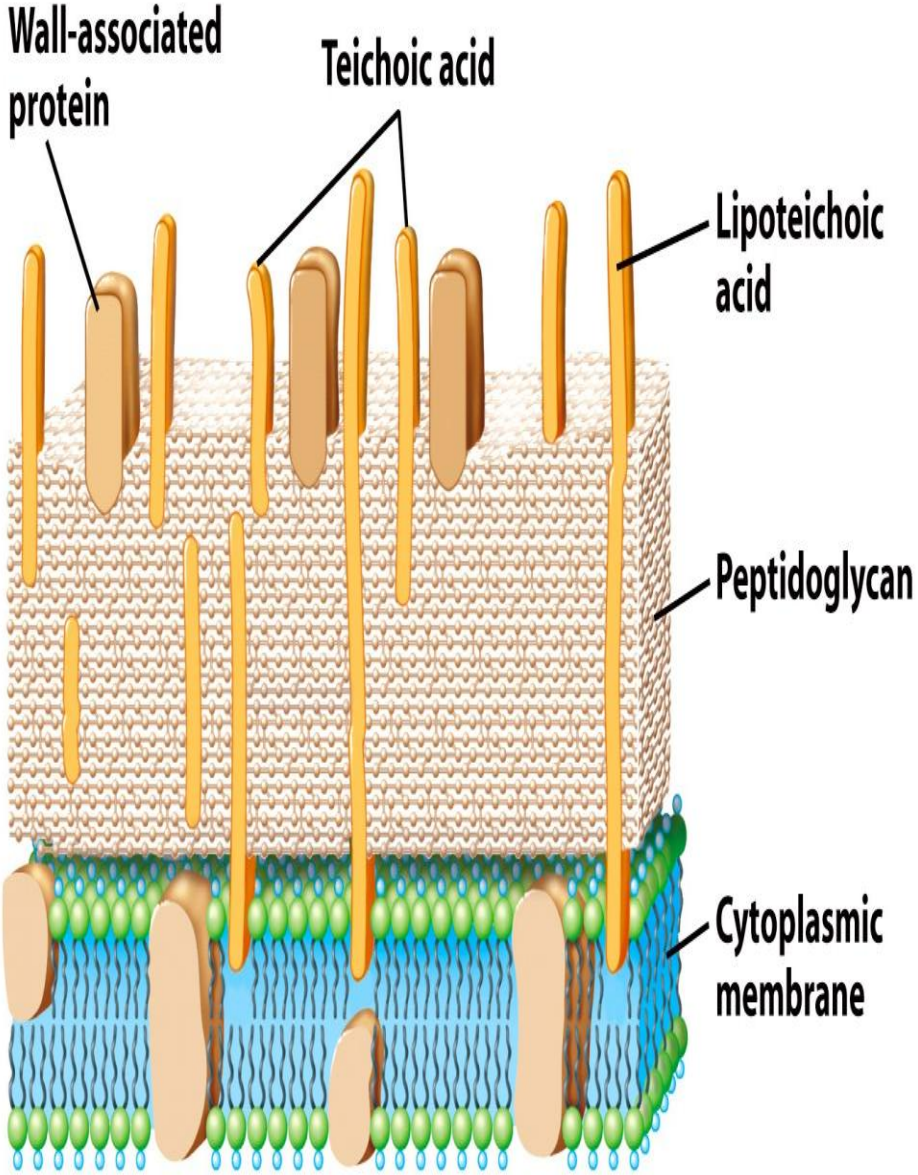

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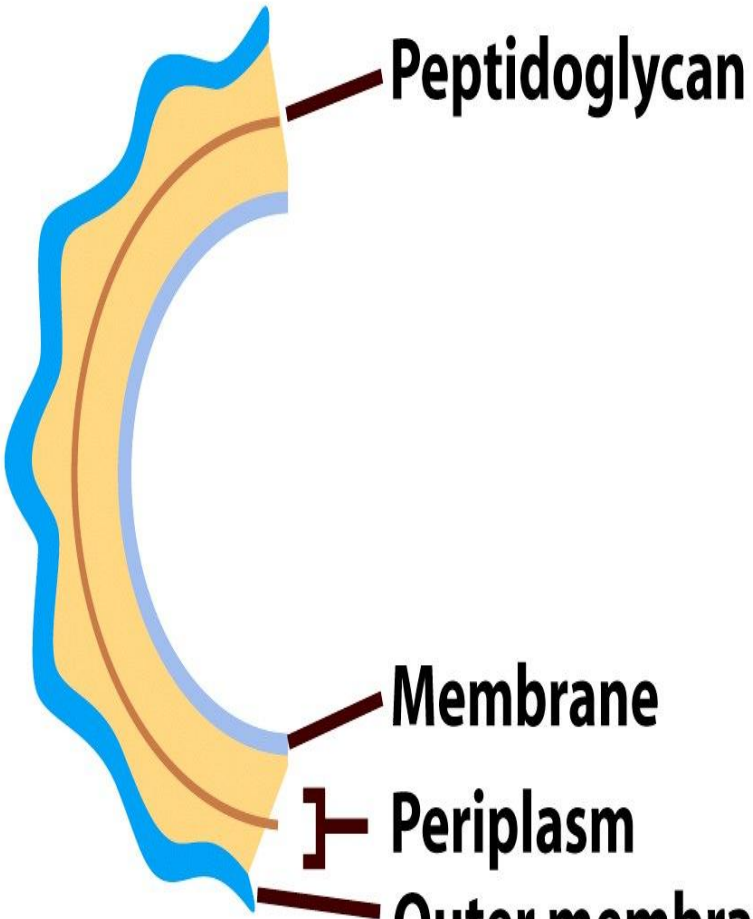
Gram-negative



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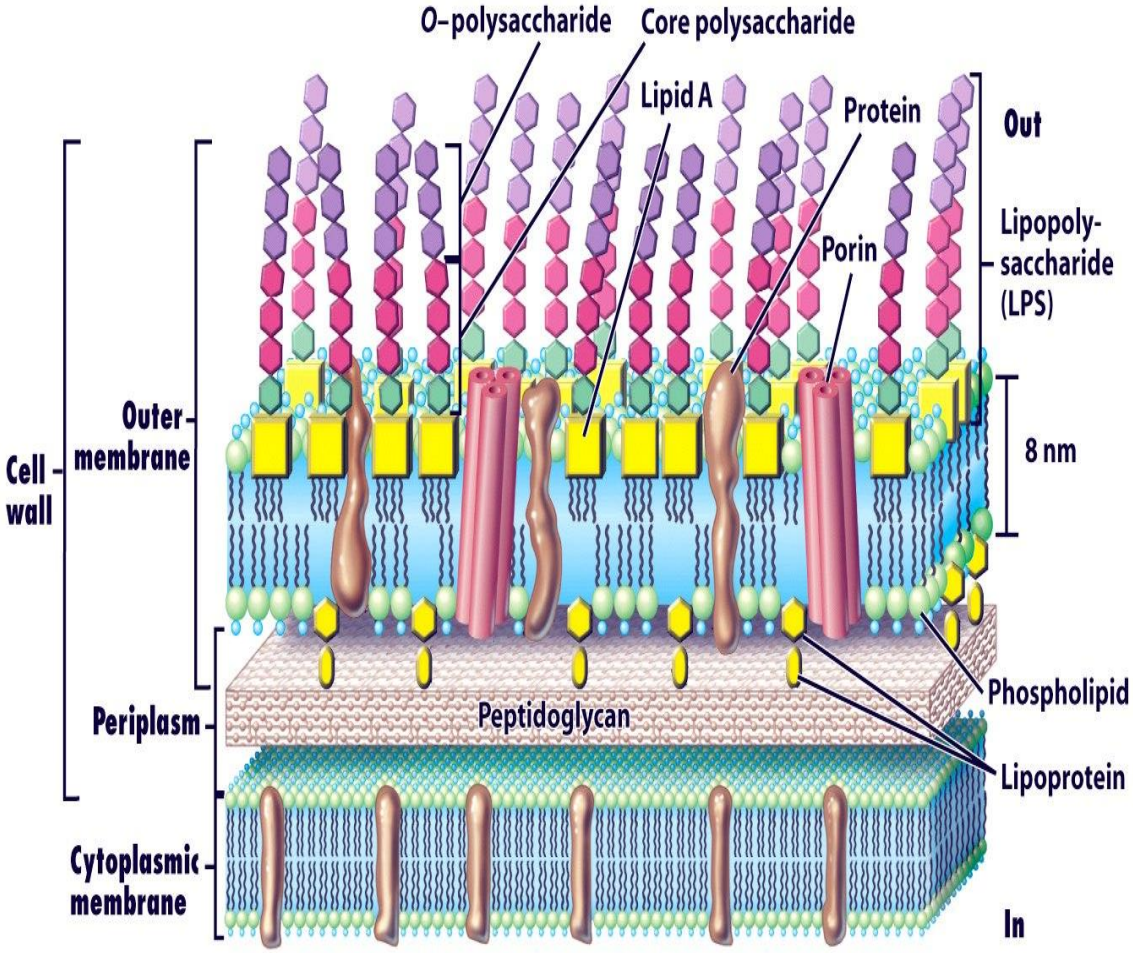

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Bacterial growth

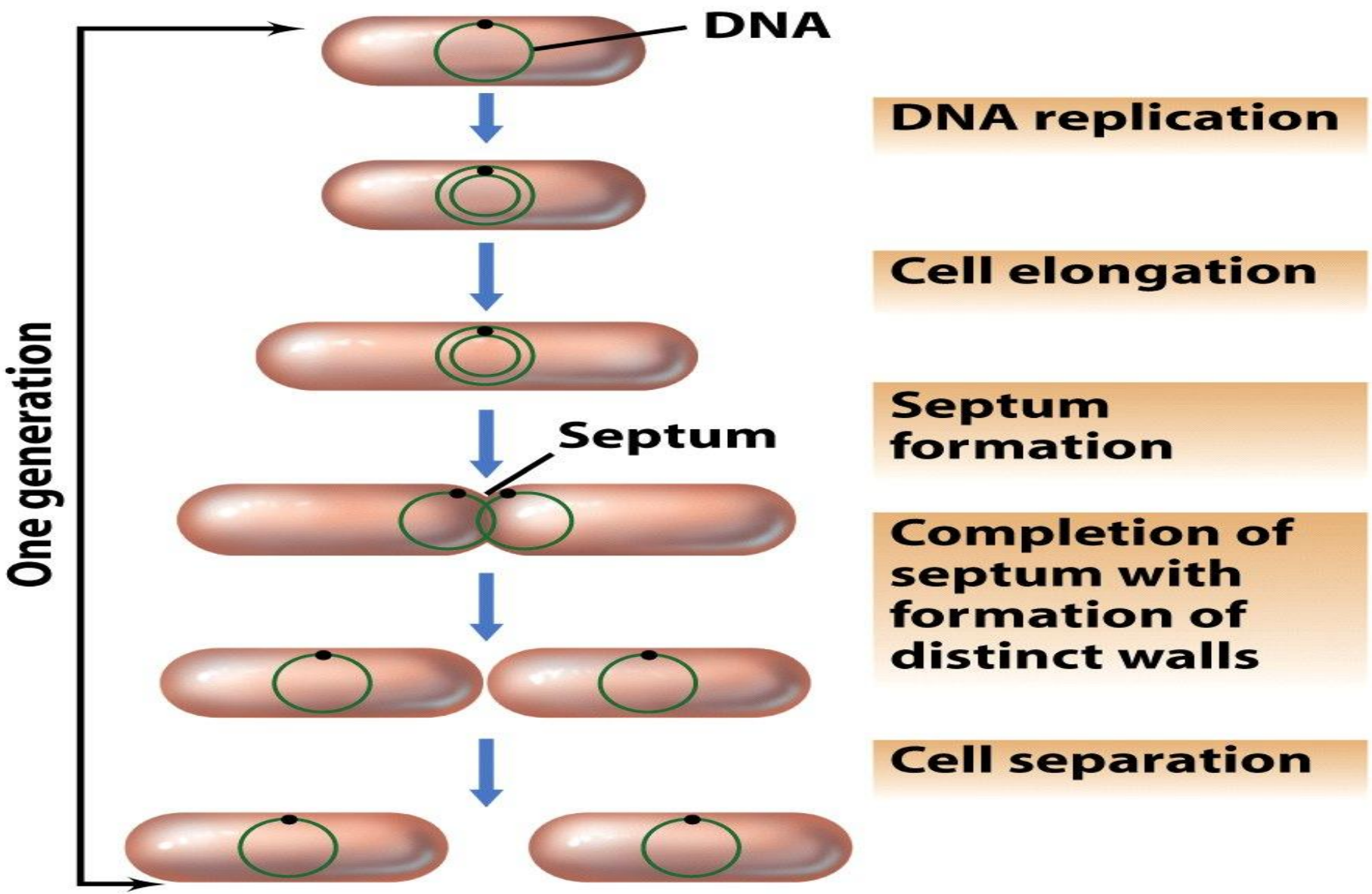

Figure 6-1 Brock Biology of Microorganisms 11/e

Bacterial growth curve

- Lag phase
- Exponential phase
- Stationary phase
- Death phase

The Growth Cycle

- Microorganisms show a characteristic growth pattern when inoculated into a fresh culture medium.

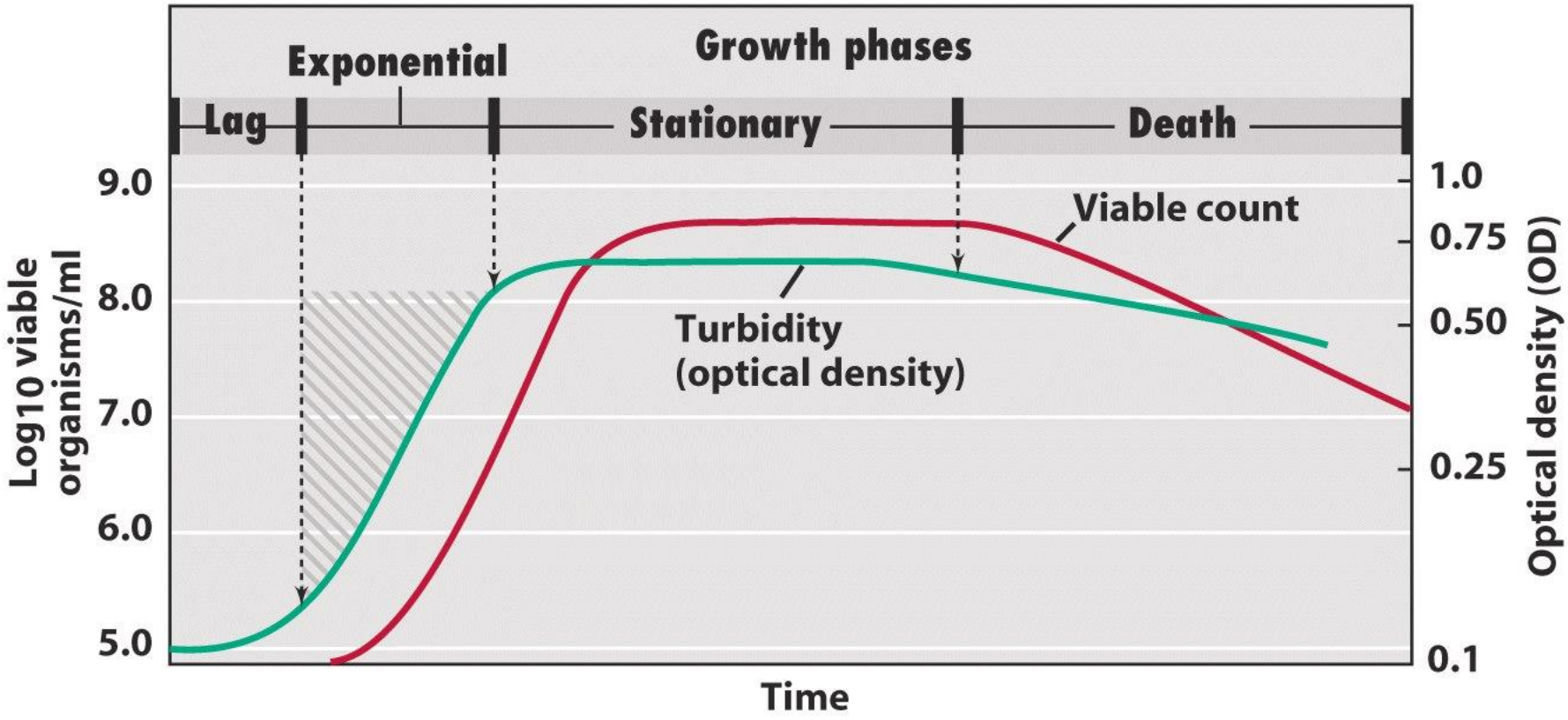

Figure 6-8 Brock Biology of Microorganisms 11/e

Factors affecting growth

1- Temperature
2- pH
3- Salinity
4- Oxygen
5- Nutrition
6- Osmotic Pressure

Temperature

• Temperature is a major environmental factor controlling microbial growth. The **cardinal temperatures** are the minimum, optimum, and maximum temperatures at which each organism grows.

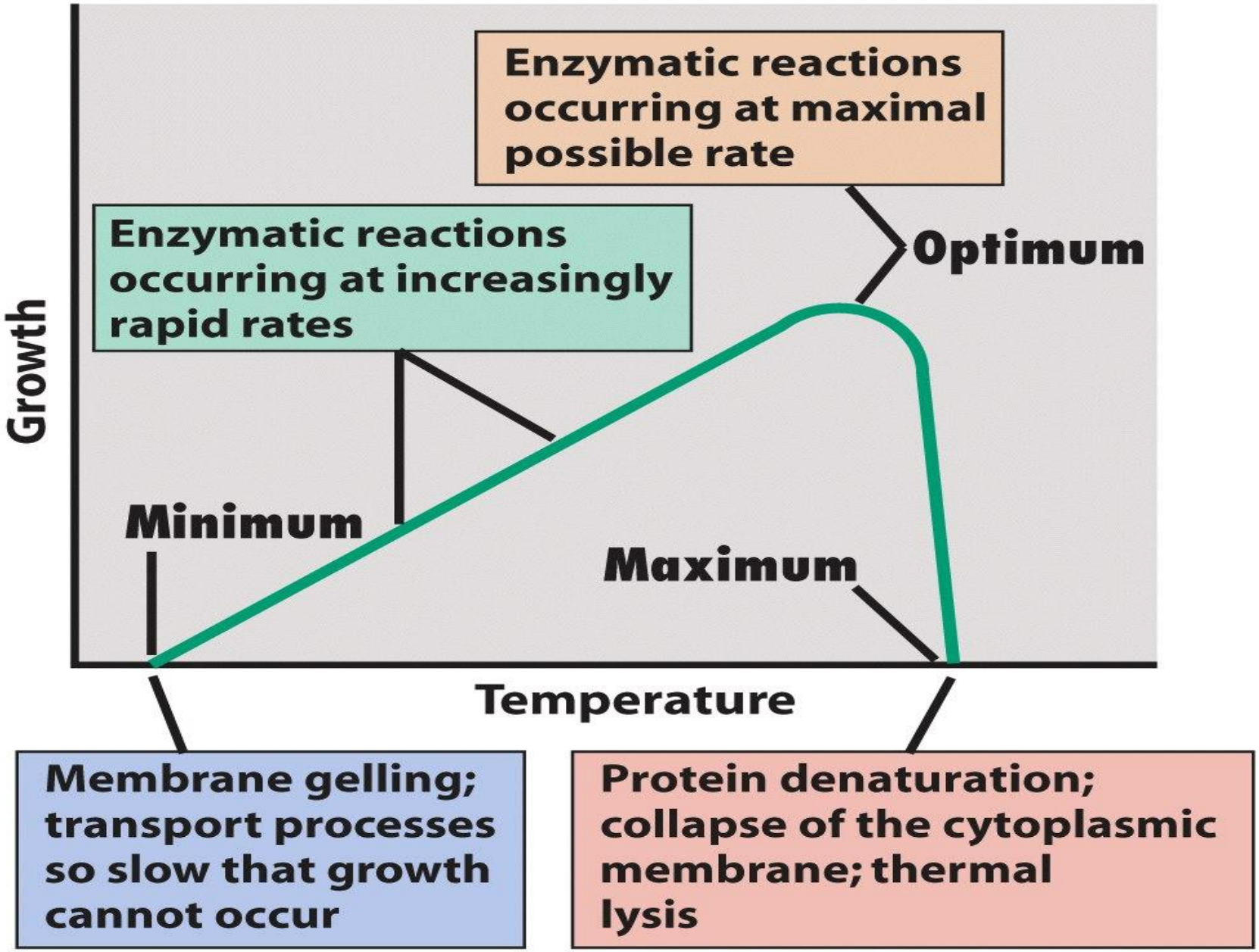

Figure 6-16 Brock Biology of Microorganisms 11/e

Microorganisms can be grouped by the temperature ranges they require.

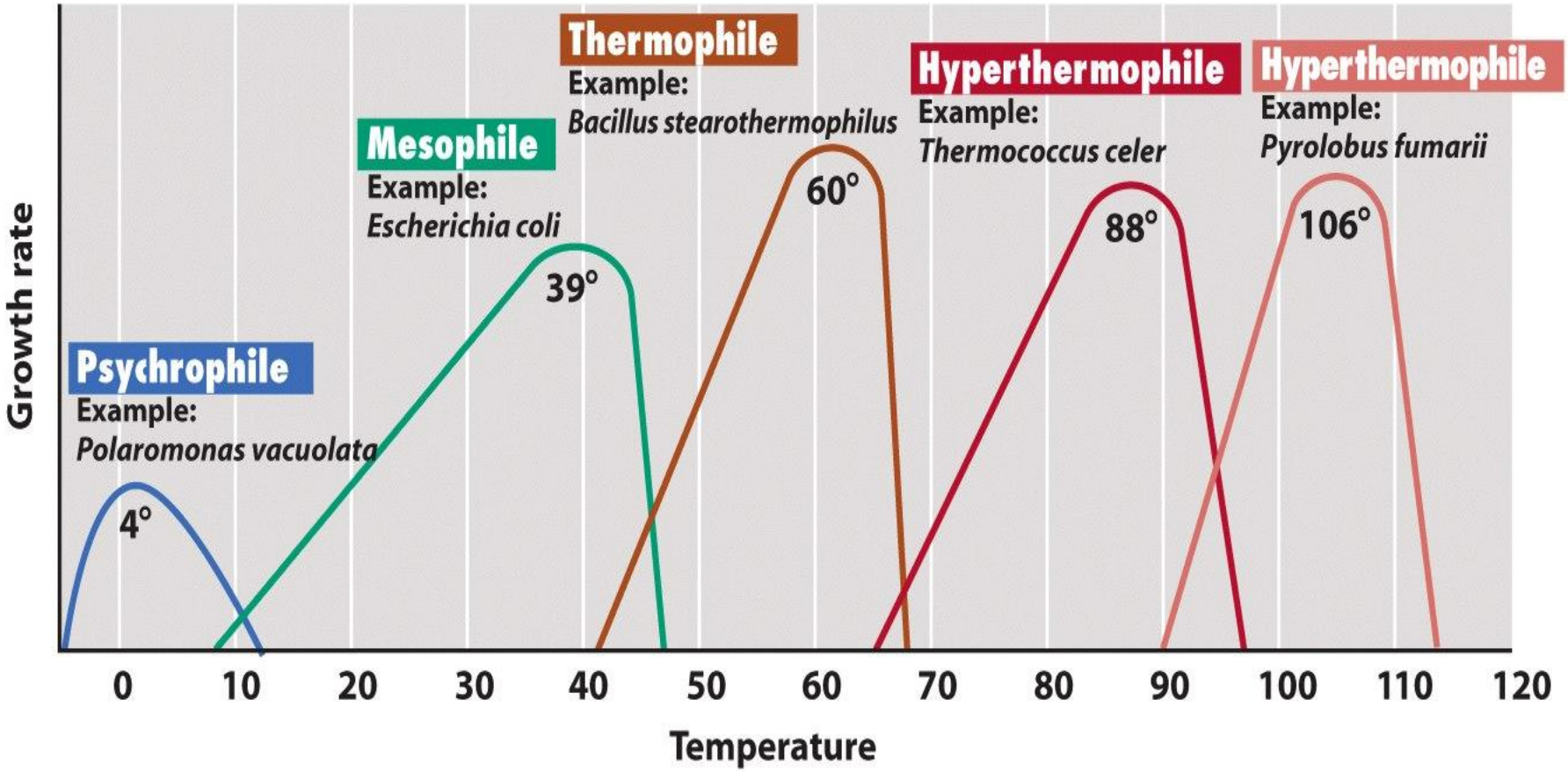

Figure 6-17 Brock Biology of Microorganisms 11/e

Low or High pH

- The acidity or alkalinity of an environment can greatly affect microbial growth.

- Organisms that grow best at low pH are called **acidophiles**; those that grow best at high pH are called **alkaliphiles**.

Salinity

• Some microorganisms (**halophiles**) have evolved to grow best at reduced water potential, and some (**extreme halophiles**) even require high levels of salts for growth.

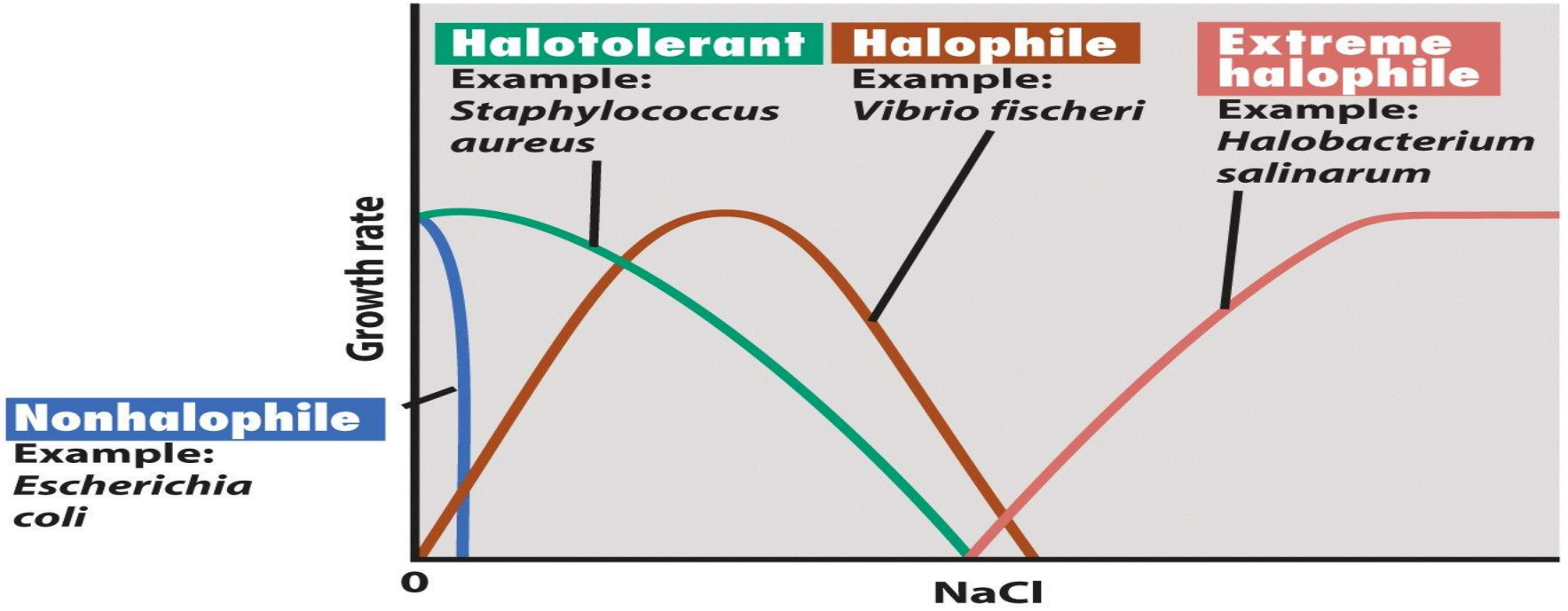

Figure 6-23 Brock Biology of Microorganisms 11/e

Oxygen

- **Aerobes** require oxygen to live, whereas **anaerobes** do not and may even be killed by oxygen.
- **Facultative:** organisms can live with or without oxygen.
- **Aerotolerant anaerobes:** can tolerate oxygen and grow in its presence even though they cannot use it.
- ***Microaerophiles:** are aerobes that can use oxygen only when it is present at levels reduced from that in air.

Bacterial metabolism

Catabolism: substrate breakdown and conversation into usable energy

*Anabolism: synthesis of cellular constituents (cell wall, proteins,fatty acids, nucleic acids

- Bacterial growth requires; a source of energy & raw materials

* To build the proteins, structures and membranes

* That make up the structure and biochemical machines of the cell

- Bacteria should obtain or synthesize:

  - aminoacids, carbohydrates, lipids as building blocks of the cell

The minimum requirement for growth

- Carbon
- Nitrogen
- Energy source
- Water
- Various ions