

## LECTURE 5

### A Survey of Prokaryotic Cells and Microorganisms

## Characteristics of Cells and Life

All living things (single and multicellular) are made of cells that share some common characteristics:

- Basic shape – spherical, cubical, cylindrical
- Internal content – **cytoplasm**, surrounded by a membrane
- DNA chromosome(s), ribosomes, metabolic capabilities

Two basic cell types: **eukaryotic** and **prokaryotic**

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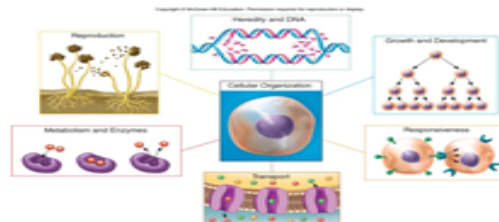
## Characteristics of Cells

Eukaryotic cells: animals, plants, fungi, and protists

- Contain membrane-bound **organelles** that compartmentalize the cytoplasm and perform specific functions
- Contain double-membrane bound **nucleus** with DNA chromosomes

Prokaryotic cells: bacteria and archaea

- No nucleus or other membrane-bound organelles



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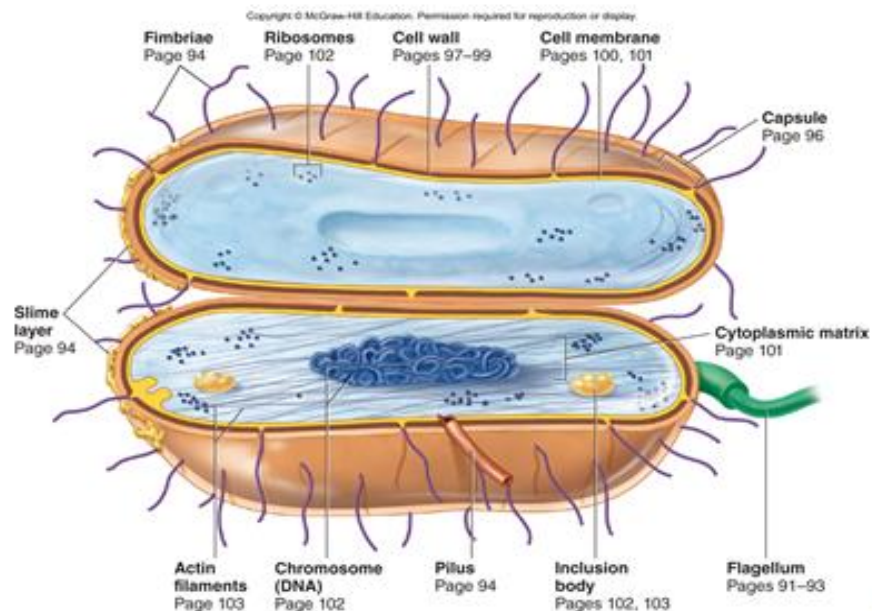
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## Characteristics of Life

- Reproduction and heredity – **genome** composed of DNA packed in chromosomes; produce offspring sexually or asexually
- Growth and development
- Metabolism – chemical and physical life processes
- Movement and/or irritability – respond to internal/external stimuli; self-propulsion of many organisms
- Cell support, protection, and storage mechanisms – cell walls, vacuoles, granules and inclusions
- Transport of nutrients and waste

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## Structure of a bacterial cell



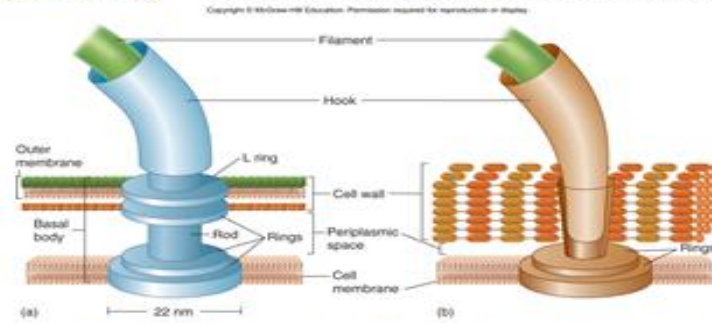
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## External Structures

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

# Flagella

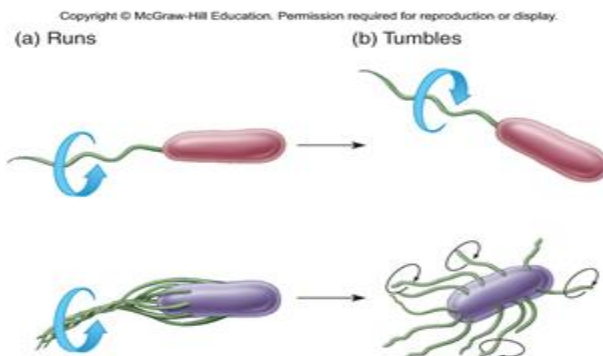
- 3 parts:
  - **Filament** – long, thin, helical structure composed of protein **flagellin**
  - **Hook** – curved sheath
  - **Basal body** – stack of rings firmly anchored in cell wall



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# Flagella

- Rotates 360°
- Functions in motility of cell through environment



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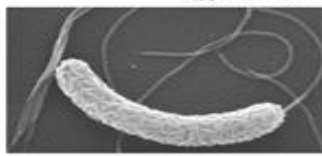
# Flagellar Arrangements

**Monotrichous** – single flagellum at one end

**Lophotrichous** – small bunches emerging from the same site

**Amphitrichous** – flagella at both ends of cell

**Peritrichous** – flagella dispersed over surface of cell

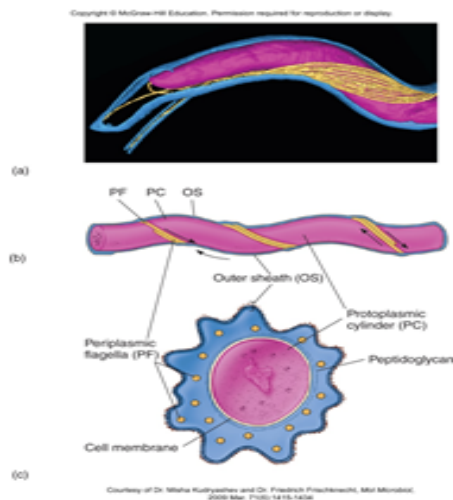


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**Flagellar Responses:** Guide bacteria in a direction in response to external stimulus: Chemical stimuli – **chemotaxis**; positive and negative Light stimuli – **phototaxis**, Signal sets flagella into motion clockwise or counterclockwise: Counterclockwise – results in smooth linear direction – **run** Clockwise – **tumble**.

# Periplasmic Flagella

- Internal flagella, enclosed in the space between the outer sheath and the cell wall peptidoglycan
- Produce cellular motility by contracting and imparting twisting or flexing motion

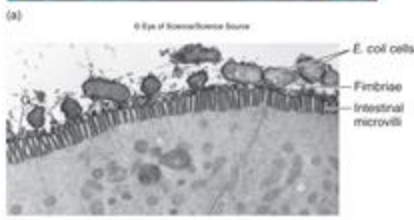
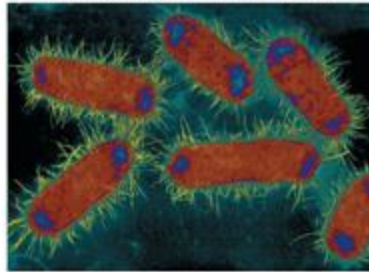


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# Fimbriae

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

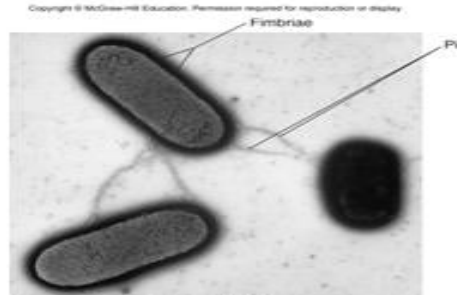


From D.R. Lloyd, S. Kouton, A. McRae, "Identification of a New Fimbrial Structure in Enterohemorrhagic *Escherichia coli* (EHEC) Serotype O157:H7 Which Adheres to Human Intestinal Mucosa: a Potentially New Human EPEC Colonization Factor." *Infection and Immunity*, January 1997, 65(1): 36-42. Fig. 4A & 4B



## 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**

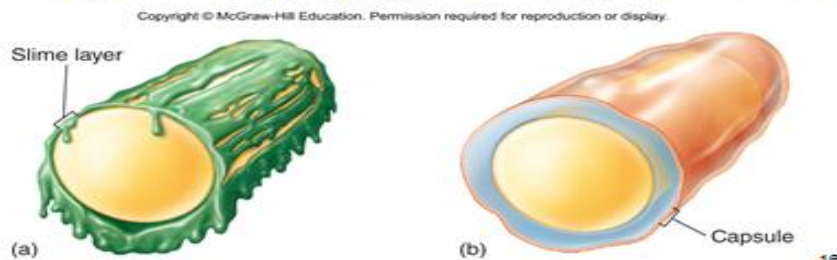


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## Glycocalyx

- 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

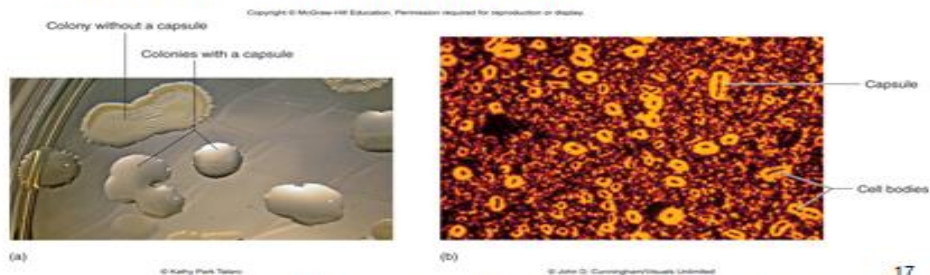


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## Functions of the Glycocalyx

- Protect cells from dehydration and nutrient loss
- Inhibit killing by white blood cells by phagocytosis, contributing to pathogenicity
- Attachment - formation of **biofilms**



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# The Cell Envelope

- External covering outside the cytoplasm
- Composed of two basic layers:
  - Cell wall and cell membrane
- Maintains cell integrity
- Two 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

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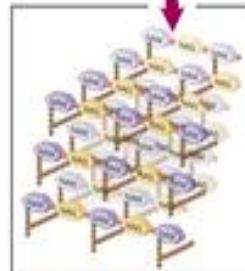
## Structure of Cell Walls

- Determines cell shape, prevents **lysis** due to changing osmotic pressures
- **Peptidoglycan** is the primary component:
  - Unique macromolecule composed of a repeating framework of long glycan chains cross-linked by short peptide fragments

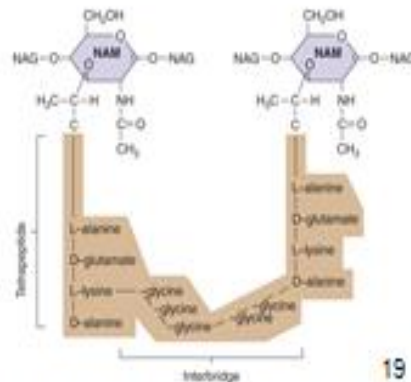
(a) The peptidoglycan of a cell wall is a huge, three-dimensional latticework that is actually one giant molecule to surround and support the cell.



(b) This shows the molecular pattern of peptidoglycan. It has alternating glycans (NAG and NAM) found together in long strands. The NAG stands for N-acetyl glucosamine, and the NAM stands for N-acetyl muramic acid. Adjacent muramic acid molecules on parallel chains are bound by a cross-linkage of peptides (brown spheres).



(c) An enlarged view of the links between the NAM molecules. Tetrapeptide chains branching off the muramic acids are connected by amino acid interbridges. The amino acids in the interbridge can vary or may be lacking entirely. It is this linkage that provides rigidity yet flexible support to the cell.

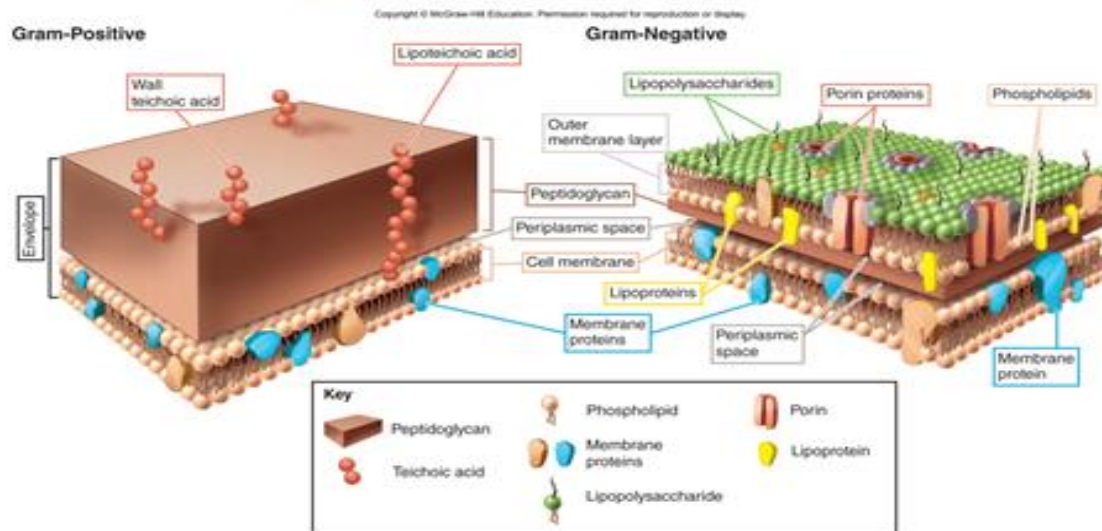


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# Structures of Gram-Positive and Gram-Negative Bacterial Cell Walls



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## The Gram Stain

- Differential stain that distinguishes cells with a gram-positive cell wall from those with a gram-negative cell wall
  - **Gram-positive** - retain crystal violet and stain purple
  - **Gram-negative** - lose crystal violet and stain red from safranin counterstain
- Important basis of bacterial classification and identification
- Practical aid in diagnosing infection and guiding drug treatment

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# The Gram Stain

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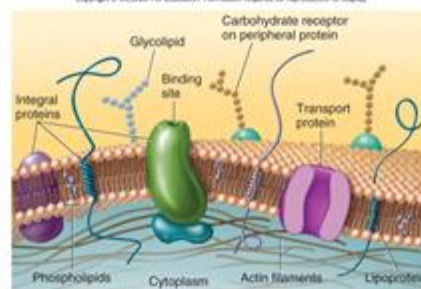
Step	Microscopic Appearance of Cell		Chemical Reaction in Cell (very magnified view)	
	Gram (+)	Gram (-)	Gram (+)	Gram (-)
1 Crystal Violet (primary dye)				
2 Gram iodine (mordant)				
3 Alcohol (decolorizer)				
4 Safranin (red dye counterstain)				

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## Cell Membrane Structure

- Phospholipid bilayer with embedded proteins – **fluid mosaic model**
- Functions in:
  - Providing site for energy reactions, nutrient processing, and synthesis
  - Passage of nutrients into the cell and discharge of wastes
  - Cell membrane is selectively permeable



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



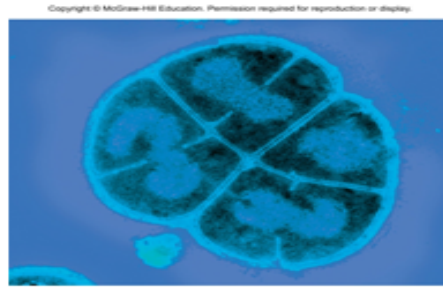
# Nucleoid

- **Chromosome**

- Single, circular, double-stranded DNA molecule that contains all the genetic information required by a cell

- **Plasmids**

- Free small circular, double-stranded DNA
- Not essential to bacterial growth and metabolism
- Used in genetic engineering - readily manipulated and transferred from cell to cell



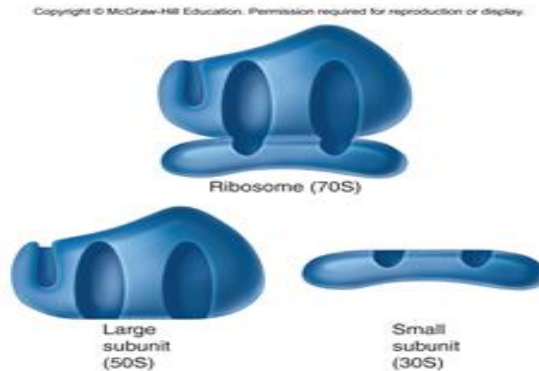
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# Bacterial Ribosome

- **Ribosomes**

- Made of 60% ribosomal RNA and 40% protein
- Consist of two subunits: large and small
- Prokaryotic differ from eukaryotic ribosomes in size and number of proteins
- Site of protein synthesis
- Found in all cells



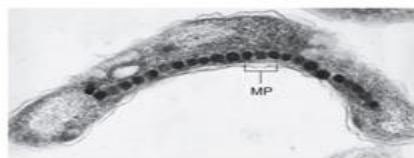
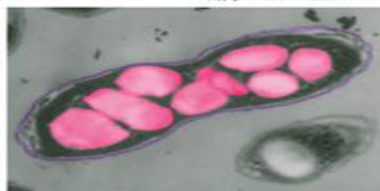
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# Bacterial Internal Structures

- **Inclusions and granules**

- Intracellular storage bodies
- Vary in size, number, and content
- Bacterial cell can use them when environmental sources are depleted



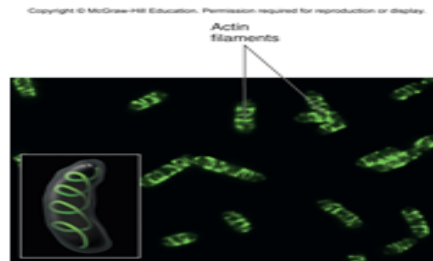
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## Bacterial Internal Structures

- **Cytoskeleton**
  - Many bacteria possess an internal network of protein polymers that is closely associated with the cell wall



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## Bacterial Internal Structures

- **Endospores**
  - Inert, resting, cells produced by some G<sup>+</sup> 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
    - Hardest 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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**Endospores:** Dehydrated, metabolically inactive, Thick coat, Longevity verges on immortality, 250 million years, Resistant to ordinary cleaning methods and boiling, Pressurized steam at 120°C for 20-30 minutes will destroy

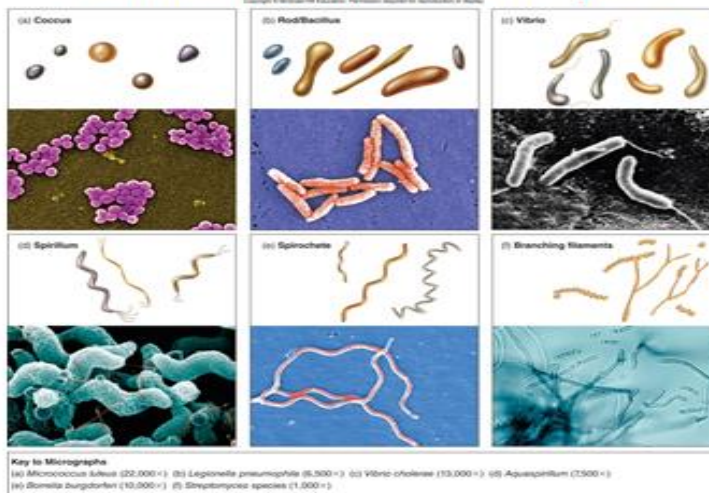
**Bacterial Shapes, Arrangements, and Sizes:**



Vary in shape, size, and arrangement but typically described by one of three basic shapes:

**Coccus** – spherical // **Bacillus** – rod // **Coccobacillus** – very short and plump // **Vibrio** – gently curved // **Spirillum** – helical, comma, twisted rod, // **Spirochete** – spring-like

## Common bacterial shapes

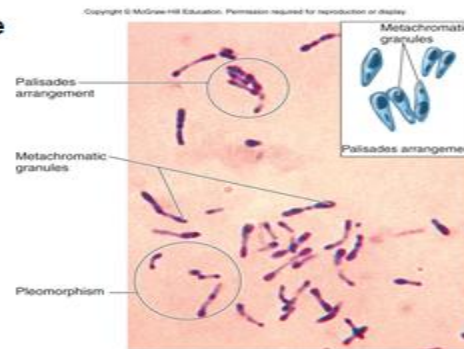


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## Pleomorphism

- Variation in cell shape and size within a single species
- Some species are noted for their pleomorphism



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# Bacterial Arrangements

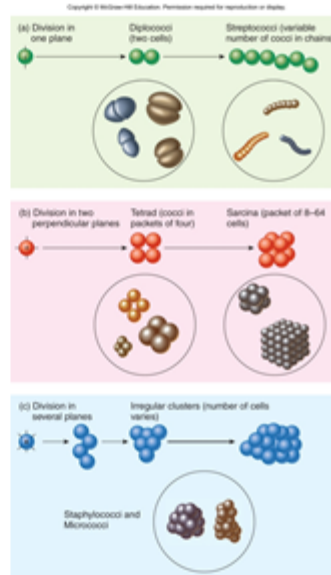
- Arrangement of cells is dependent on pattern of division and how cells remain attached after division:

- Cocci:

- Singles
- Diplococci – in pairs
- Tetrads – groups of four
- Irregular clusters
- Chains
- Cubical packets (sarcina)

- Bacilli:

- Diplobacilli
- Chains
- Palisades



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## Classification Systems for Prokaryotes

- 1-Microscopic morphology
- 2-Macroscopic morphology – colony appearance
- 3-Bacterial physiology
- 4-Serological analysis
- 5-Genetic and molecular analysis

## Bacterial Taxonomy Based on *Bergey's Manual*

- *Bergey's Manual of Determinative Bacteriology* – five volume resource covering all known prokaryotes
  - Classification based on genetic information – **phylogenetic**
  - Two domains: Archaea and Bacteria
  - Five major subgroups with 25 different phyla

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## Major Taxonomic Groups of Prokaryotes

- **Domain Archaea** – primitive, adapted to extreme habitats and modes of nutrition
- **Domain Bacteria:**
  - **Phylum Proteobacteria** – Gram-negative cell walls
  - **Phylum Firmicutes** – mainly Gram-positive with low G + C content
  - **Phylum Actinobacteria** – Gram-positive with high G + C content

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### Diagnostic Scheme for Medical Use

Uses phenotypic qualities in identification Restricted to bacterial disease agents Divides bacteria based on cell wall structure, shape, arrangement, and physiological traits.

## Species and Subspecies

- **Species** – a collection of bacterial cells which share an overall similar pattern of traits in contrast to other bacteria whose pattern differs significantly
- **Strain or variety** – a culture derived from a single parent that differs in structure or metabolism from other cultures of that species (biovars, morphovars)
- **Type** – a subspecies that can show differences in antigenic makeup (serotype or serovar), susceptibility to bacterial viruses (phage type) and in pathogenicity (pathotype)