

Chapter 3

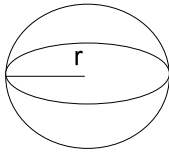
Microbiology Functional Anatomy of Prokaryotic and Eukaryotic Cell

I. Size, Shape & Arrangement of Bacterial Cells

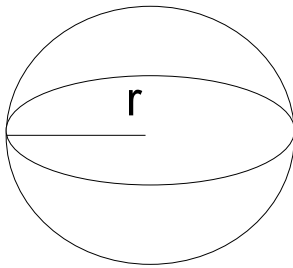
A. Why are bacterial microbes small

1. Diffusion rates affected by surface to volume ratio of cell size

a. Surface area $(4\pi r^2) = \mu\text{m}^2$



$r = 1 \mu\text{m}$ then surface is $12.6 \mu\text{m}^2$
Volume is $4.2 \mu\text{m}^3$
 $S/V = 3$



$r = 2$ surface area is $50.3 \mu\text{m}^2$
volume is $33.5 \mu\text{m}^3$
 $S/V = 1.5$

2. Small cell size permits diffusion of Gases such as O_2 , CO_2 - - - - CH_4

And small molecules like

...Water

& small Nutrients molecules

3. Small cell size permits rapid growth

B. Shape

1. Cocci (round shape)

- a. Diplococci
- b. Streptococci
- c. Tetrad
- d. Sarcinae
- e. Straphylococci

2. Rod

- a. Single Bacillus
- b. Diplobacilli
- c. Streptobacilli
- d. Coccobacillus

II. Appendages

A. Physical structure (Reference Web Site:

http://www.arn.org/mm/mm_movies.htm

<http://www-micro.msb.le.ac.uk/video/motility.html>

1 Three basic parts

- a) Filament
- b) hook (consisting of different proteins)
- c) basal body (which anchors the flagellum to cell membrane)

2. Arrangement of the cell surface of flagella

<http://www.indstate.edu/thcme/micro/flagella.html>

- a) Monotrichous b) Amphitrichous c) Lophotrichous d) Peritrichous

3. Chemical structure

- a) globular spherical Protein structure called flagellin Intertwine hollow helix

4. Mechanism of motility

- a) Hydrogen powered basal body motor proteins
 - b) can alter speed and direction of rotation of flagella
 - 1) movement referred to as "run" or "swim" in one direction
 - 2) random movement "tumble"
 - 3) endoflagella: bundles of fibrils the spiral around the cell
Treponema pallidum agent of syphilis

5. Taxis - Bacterial motility

- a) Either towards or away from stimulus
 - 1) chemotaxis - chemical stimuli

http://www.cfdrc.com/bizareas/biomedlife/comp_med/chemotaxis.html

- b) phototaxis - light stimuli

6. Flagellum used is identification

- a) flagellum protein - H antigen useful as Serovars - O157:H7 serovar of E. coli

B. Other means of movement in prokaryotes

1. Gliding movement and Gliding bacteria: Cyanobacterium

- a) Tracks in outer membrane allow proteins connected to cell membrane to stick to surface and propel bacteria along

2. Axial filaments (endoflagella) Spirochetes

3. Twitching movement in Pseudomonas

- c) Fimbriae and pili

4. General structure

- a. similar in structure to flagella

1) Fimbriae shorter than flagella

2) more numerous

3) Function

- a) Uncertain but thought is - may help bacteria stick to surfaces:
example - biofilms

b. Pili

- 1) One to several presented on the surface of a bacteria

2) Function

- a) As receptor for virus particle information between conjugating bacteria.
- b) Also used to attach to human tissues by some pathogenic bacteria.
- c) Protection against phagotrophic engulfment and or killing

III. Cell Wall

A. Capsules, including slime layers and glycocalyx

1. Composition capsule & slime layer

- a. polysaccharides and polypeptides or both

- b. rigid organized as tight matrix thick and viscous (sticky) material

- c. excludes particles like india ink

2. Slime layer

- a. Less organized layer easily deformed not excluding particles

3. Functions

- a. attachment (adherence) to surfaces animal host tissues

- b. protection against phagotrophic engulfment and killing
 - 1) *Bacillus anthracis* produces a D-glutamic acid
 - 2) difficult for phagocytic cells of the immune system to destroy
- c. protection against desiccation
- d. nutrient reserves
 - 1) inhibits the movement of nutrients from bacterial cell
 - 2) Bacteria can break the this layer down and use the sugars as a source of nutrition
- e. Slime layers and biofilms in medical situation

B. The bacterial cell wall

- 1. General physical properties
 - a. Both Gram (+) & (-) have one cell layer in common
 - b. Both Gram (+) & (-) have cell wall with similar composition
 - Peptidoglycans (or mureins)
 - 1) Each layer is composed of two sugar derivatives N-acetylglucosamine and N-acetylmuramic acid attached to these sugar residues can be found small groups of
 - L-alanine,
 - D-alanine,
 - D-glutamic acid,
 - Lysine
- or
- diaminopimelic acid (DPA).

This cell wall layer is called peptidoglycan region

- 2) N-acetylglucosamine and N-acetylmuramic acid are not found in Archaea and Eukarya
- c. Sugar sheets are held together by peptide cross-links of A.A.'s which provide Strength to the cell wall
- d. A.A. cross-links are characteristically differ between Gram (+) & (-)
 - 1) Gram (-) cross-linkage

Diaminopimelic Acid (DPA) and D-alanine

2) Gram (+) lineage is between peptide interbridge of varying A.A.

Ex.: *Staphylococcus aureus*

e. Gram (+) bacteria - 90% of cell wall is composed of peptidoglycan with small amounts of Teichoic acids

1) May have up to 25 layers of peptidoglycans

f. Gram (-) bacteria: only about 10% of cell wall is peptidoglycan

1) majority of cell wall is cell outer membrane

g. shape of both gram (+) & (-) is thought to be determined by lengths of glycan & manner of cross-linking peptidoglycans.

2. Differences between Gram - positive and negative bacteria

a. most gram (+) bacteria have the A.A. lysine instead of diaminopimelic acid (DAP)

1) A few Gram(+) have other types of A.A.'s serving as cross linkers

2) Unusual configuration of A.A. such as D-alanine D-glutamic acid

3) A.A. never found forming cross-linkage structures Aromatic A.A., sulfur containing A.A., histidine, arginine or Proline.

4) Most Gram (+) bacteria contain Teichoic acid (glycerophosphate or ribitol phosphate residues)

a) These residues are partially responsible for negative cell surface charge

b. Gram (-)

1) Lipopolysaccharide: outer membrane layer

a) constructed of polysaccharides & proteins Lipopolysaccharide layer (LPS)

2) LPS made up of sugars & lipids in an unusual combination

3) Lipoproteins used to anchor outer membrane to peptidoglycan layer (referred to as Periplasm layer)

4) Outer membrane frequently found to be toxic to animals

a) Lipid A elicits toxic response endotoxin refers to toxic component of LPS

5) Relatively permeable to small molecules

a) Porin - channels proteins in outer membrane structure

1) Allows movement in & out of bacteria of small low molecule weight hydrophilic substances

2) Porins are transspanning membrane protein complexes that either are highly specific or non-specific their binding capacity.

6) Outer cell membranes of Gram(-) are not permeable to enzymes or large Molecules

a) Outer membrane keeps periplastic enzymes from diffusing away

1) These enzymes can be hydrolytic or binding in nature or are chemoreceptors which are involved in Chemotaxis

2) Relationship of cell wall structure

a) Bacterial cells uptake crystall violet stain

1) Gram (-) cells loose crystal violet stain following alcohol wash because of thin walls

2) Gram (+) retain stains because alcohol dehydrates the thick cell wall peptidoglycan collapsing the pores within the cell wall trapping the crystal violet in the cell

3. Cell walls of Archaea

a. Majority of Archaea have cell wall some species do not.

b. polysaccharide form the cell wall which are similar to peptidoglycan in their construction

c. Paracrystalline complexity of cell walls varies greatly between species depending on the environment they are found in.

Ex.: Methanosarcina contain (SO_4^{2-}) residues.

d. All Archaea are resistant to lysozyme .

4. Cell wall-less prokaryotes

a. Mycoplasmas: Fire Blight of pear and apples

C. The plasma membrane

1. General properties

- a. About 8 nm thick
- b. Highly selective barrier
- c. Fluid mosaic in nature with viscosity that of light olive oil

2. Basic structure of prokaryota

a. chemical components

1) Phospholipids bilayer (40%)

a) Archaean membrane

1) Lipids monolayer formed by glycerol diether and tetra ether bonds to phytanyl isoprene units

2) Adaptations to extreme environment

2) Protein (60%)

a) Aquaporins: function as water exporter more than water importer

b) Transport proteins

3) Types: Simple; Group; ABC system. Transporter proteins require energy such as ATP, proton motive energy (H^+) or other high energy substances: i.e. PEP.

1) Carrier transporter proteins are highly selective mediating substances in and out of the cell and classically show saturation effects

2) Transport proteins are regulated by the needs of the cell

3) ABC; ATP-Binding cassette transporter protein.

This protein uses periplasmic binding proteins to move substances into the cell in conjunction with membrane spanning protein.

b) Able to bind and transport substances at a concentration of 10^{-6} Molar

c) Even though Gram (+) lack periplasm - ABC-Binding proteins are present.

1) These proteins are anchored to the cytoplasmic membrane

4) Translocase protein (special class)

a) Exports proteins & can also insert proteins into cell membrane in the correct orientation. Sec (secretory) YEG protein. Proteins exported like amylase and cellulase

b) 200 have been described

Transporter Proteins

Transport of nutrients and waste by bacteria (Usually small molecules: ions, amino-acids, sugars, purines and pyrimidines, vitamins, organic acids and alcohols, etc.

1. **Passive diffusion:** In this system of transported molecules move from high concentration on one side of the semipermeable cell membrane (CM) to the other side of lower concentration. In living cells gasses and water diffuse easily through the membrane.

2. **Facilitated diffusion** in cells is similar to passive diffusion but it involves a ligand specific carrier protein (permease) present in the cell membrane. The rate of transport of the substrate is proportional to its concentration gradient and shows saturation kinetics (be able to draw a graph explaining this and passive diffusion).

3. **Active transport.** This system requires chemical energy to be expended. The molecule can be transported with ligand-specific permease and against its concentration gradient. Energy may be ATP; (H⁺) proton gradient or another intermediate molecule inside the cell with high-energy bond, which is, used (phosphoenol pyruvate).

Examples of active transport:

ATP- binding cassette transporter ABC transporter. The molecule to be transported is attached to its specific carrier protein in the periplasm. The complex then binds to its membrane bound transport protein, On the inner side of CM, ATP bound to the transport protein is hydrolyzed, ADP and Pi are formed and the molecule enters the cytoplasm.

Symport and antiport systems where an ion gradient is used to transport a nutrient against its concentration gradient. Often H⁺ gradient is used. When the two molecules move in the same direction the system is a symport. When the two molecules move in opposite direction this is called antiport. Active transport by means of Group translocation or Phosphotransferase system. In some fermenting bacteria some carbohydrates may be transported into cell by this system. The intermediates are called enzyme I, H Pr protein, and enzyme II (may have three subunits one of which is the membrane permease for a specific carbohydrate). The energy is from phosphoenol pyruvate (PEP), which is a high-energy phosphate-carrying molecule and an intermediary molecule from glycolysis. The high-energy phosphate from PEP is transferred by protein intermediates to the membrane; the carbohydrate molecule is phosphorylated at the membrane and is internalized. For example, glucose enters the cytoplasm as glucose-6-phosphate.

Transport of iron. Many different organisms including the bacteria require iron in the cell to form porphyrin ring for heme portion of cytochrome systems for electron transport. Iron salts are insoluble and concentration in the aquatic environment is low, as is in the mammalian host body where iron is bound to transferrin or lactoferrin proteins. Bacteria acquire iron by producing molecules called enterochalins or

siderophores which sequester iron by binding to it and then the complex binds to its transport proteins in cell membrane from where iron ion is internalized.

3) Hapans are present in bacterial membranes acting similar to that of Sterols found in Eukaryotes.

a) Membrane stability imparted

b) To date no hapans have been isolated from Archaea

b. physical arrangement

1) Phospholipid bilayer

2) Fluid mosaic model

3. Functions

a. Osmotic or permeability barrier

b. Location of transport systems for specific solutes (nutrients and ions)

c. Energy generating functions

d. Coordination of DNA replication, cell wall synthesis and septum formation

e. Location of specialized enzyme systems

4. Mesosomes and other membranous structures

a. Relationship to the plasma membrane

b. Functions

IV. Cytoplasmic constituents

A. The cytoplasm

B. The cell genome

1. The bacterial chromosome

a. structure and function

1) Circular Double helix

2) protein synthesis

2. Extra chromosomal DNA: plasmids

a. Not crucial for survival of the bacteria but can carry genes coding for antibiotic resistance and tolerance to toxic metals.

C. Ribosomes

1. Compositions and structure

a. small subunit: 30S & large subunit: 50S make up a complete 70S ribosome

2. Function

a) Transcription of protein synthesis of DNA directly

b) several antibiotics work by inhibiting proteins at this level of control