

Two Different Groups of Prokaryotes

- ***Bacteria*** – mostly unicellular, asexual reproduction, some photosynthetic
- ***Archaea*** – same as for bacteria; adapted to exist in extreme environments

Overview of Prokaryotic Cell Structure:

Microbial Morphology [Size Shape and Arrangement]

- Microbes come in a wide variety of sizes and there is much variation due to differences in their genetics and ecology.
- Viruses are generally considered to be the smallest microorganisms with diameters that range between 8 and 900 nm.
- ***Unicellular*** bacteria range in size between 800 nm and 5000 nm
- The ***Eukaryotic*** microorganisms are generally the largest, with sizes ranging from 8,000-12,000 nm for yeasts and 12,000-100,000 nm for molds algae and protozoa.
- This hierarchy generally holds true, but there are always exceptions. Among the most notable is the bacterium *Epulopsicium fishelsoni*. (***Epulo piscium fishel soni***)
- This giant rod shaped bacterium was recently isolated from the intestines of ***surgeonfish in the red sea***. The organism is roughly 50 μM in diameter and up to 600 μM in length. ***It is more than 1 million times larger than Escherichia coli*** and clearly larger than the normal eukaryotic cell
- *ASM News 59:519-521 (1993)*

On the other extreme, a ***species of green algae has recently been discovered in a lagoon in the Mediterranean sea that is only 700 nm diameter and 1000 nm in length.*** This is an example of a eukaryotic cell that is smaller than the average bacterium.

- *Nature 370:255 (1994)*

Size

- *The size of a microorganism affects a number of its biological properties, one of which is the rate of nutrient uptake and waste elimination*

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- *The transport rates across the cell membrane is a function of the membrane surface area and the relative cell volume. (surface to volume ratio)*
- *A small cell has a greater surface to volume ratio than a larger cell greater surface area available to service a smaller volume*
- *This allows a small cell to transport nutrients and wastes across the membrane at a significantly faster rate, **consequently the small cell has a faster metabolic rate***
- ***This means that a small prokaryotic cell can:***
 - *grow faster*
 - *adapt to environmental changes quicker*
 - *achieve greater population densities than a larger eukaryotic cell*

Shape - Morphology

- *The first thing that we see when we examine a bacteria under the microscope is the overall shape.*

There are roughly 7 general shapes

- (1) Bacteria that appear spherical are called ***coccus (cocci-plural)*** which is the greek word for *berry*.
- (2) Bacteria that appear rod shaped are called ***bacillus (bacilli)*** which is *latin* for *little staff*.
- (3) Bacteria can also assume a rigid spiral shape, these are referred to as ***spirillum (spirilli)*** which is *latin* for *little coil*
- (4) ***Curved rods*** are called *vibrio (vibrios)*
- (5) ***Slender flexible spirals*** are called *spirochete (spirochetes)* which is *greek* for *coil of long hair*
- (6) ***Filamentous***
 - filamentous bacteria which form long multinucleated filaments or hyphae that may branch to produce mycelium. *Ex: Actinomyces*
- (7) ***Pleomorphic***
 - Many bacterium are variable in shape and cannot be characterized by a single form. These are referred to as *Pleomorphic*.
 - Most of the pleomorphic bacteria assume a general rod shaped form, that is considerably different from the classic bacillus morphology, these also include bacteria that assume squares, star shapes, and coccus-bacilli.

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Arrangement

- Bacteria are generally characterized by the way the cells are grouped or arranged
The type of arrangement reflects the manner in which a species divides

A. Arrangements of cocci

- *diplococci* are formed by cells that divide in one plane to form pairs
- *streptococci* are formed by cells that divide on a single plane to form chains of three or more cells
- *tetrads* are formed when cells divide in two planes to generate four cells
- *sheets* are formed by multiple divisions on two planes
- *cube* packets of 8 are formed when cell division occurs on three planes
- Staphylococci are formed by multiple divisions in three planes to form *irregular clusters*

B. Bacilli

Most of the bacilli are not found in special arrangements, although a few species will form:

- *Diplobacilli*
- *Streptobacilli*
- *Pallisades* (*side by side arrangements*)

Prokaryotes:

- *Prokaryotic cells almost are always bound by a chemically complex cell wall and*
- *separated from it by a periplasmic space, lies the plasma membrane*
- *PC does not contain Internal Membrane-Bound Organelles – it's interior appears morphologically simple.*
- *Genetic material is localized in a discrete region, the nucleoid and is not separated from the surrounding cytoplasm by membranes.*
- *Ribosomes and larger masses called inclusion bodies are scattered about in the cytoplasmic matrix.*
- *Both gram + and gram – cells can use flagella for locomotion.*

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- *Many cells are surrounded by a **capsule or slime layer** external to the cell wall.*
- *PC cells are morphologically much simpler than EC.*
- *PC and EC cell differ with respect on their cell walls.*

Cell Membrane – Plasma Membrane

- *Selectively permeable barrier*
- *Mechanical boundary of the cell (retains the cytoplasm)*
- *Nutrient uptake, waste transport, protein secretion and movement of substances across the membrane*
- *Location of many metabolic processes*
 - *(respiration, photosynthesis, and the synthesis of lipids and cell wall constituents)*
- *Detection of environmental cues for chemotaxis*

The **cytoplasmic membrane** is a thin structure 5 – 10 nm thick that completely surrounds the cell and can only be seen with the EM.

- *Functions as a **permeability barrier**, that prevents cytoplasmic contents from leaking out of the cell.*
- *Cytoplasmic membrane is **composed of two layers of phospholipid molecules** that is commonly called the **lipid bilayer***

Phospholipid - lipids containing a substituted at least one phosphate group, often a nitrogenous constituent, and two fatty acid chains on a glycerol backbone. The third glycerol hydroxyl is joined with a phosphate group, and ethanolamine is attached at the phosphate.

Phosphatidyl ethanolamine is an important phospholipid frequently present in bacterial membrane.

Lipid - Water-insoluble organic molecules important in structure of the cytoplasmic membrane and in the cell wall.

- The **polar head** of each phospholipid molecule is **hydrophilic (water loving)** and makes contact with the cytoplasm and periplasm
- The **nonpolar tails (fatty acids)** of the phospholipids are **hydrophobic (water fearing)** point inwards toward each other and are buried within the center of the bilayer.

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- The membrane is additionally stabilized by divalent cations such as Mg²⁺ and Ca²⁺, which interact (ionically) with the negatively charged phospholipids

It is important to emphasize that the cytoplasmic membrane is not a rigid structure, but is very dynamic and fluid like.

(Paint the amoeba experiment)

One of the major differences between prokaryotic and eukaryotic membranes is that prokaryotic membranes do not contain sterols, such as Cholesterol.

- ***Sterols*** are rigid planar molecules that generally make up 5-25% of an eukaryotic membrane. *Sterols strengthen the membrane and make it less flexible, this is needed because most Eukaryotic cells do not have a rigid cell wall.*
- *Some bacterial membranes contain a sterol like compound called hopanoids that serve a similar function (stabilize the membrane).*

Fluid Mosaic Model

- *S. Jonathan Singer and Garth Nicholson*
- *This model distinguishes between two different types of proteins*

Various proteins are inserted into the phospholipid bilayer.

Peripheral proteins:

- *loosely connected to the membrane and can be easily removed.*
- *Soluble in aqueous solutions*
- *Make up 20 to 30% of total protein*
- *do not span both layers.*

Integral proteins:

- *span the bilayer and are arrayed on both the internal and external surface*
- *not easily extracted from membranes and are insoluble in aqueous solutions when freed of lipids*
- *Make up 70 – 80% of MB proteins*
- *The integral membrane proteins typically are **amphipathic***
 - *Amphipathic: structurally asymmetric with polar and nonpolar ends*
 - *have hydrophobic external surfaces in the regions that interact with hydrophilic nonpolar-fatty acid chains of the membrane bilayer*

The Integral proteins have a variety of functions:

- *many serve to transport nutrients into the cell or toxic products out of the cell (H pump or tetA transporter)*

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- *Many of these proteins are **biosynthetic enzymes that are required for synthesis of the cell wall***
- *Some of the proteins are components of the cells energy generating machinery, such as the **electron transport chain***
- *The **motor proteins (mot)** in the flagellar basal body are in the membrane along with the proteins that facilitate replication and segregation of the bacterial chromosome*
- *The membrane also contain a number of **Sensor proteins** which sense the external environment and relay the sensory input to receptor proteins within the cytoplasm (PhoQ, CheY for chemotaxis)*
(Defer discussion on transport to NUTRITION)
- *The plasma membrane is essential to the survival of microorganisms!!*

Mesosomes

- *Internal Membrane Systems*
- *Prokaryotic cytoplasm does not contain complex membranous organelles like mitochondria or chloroplasts, **membranous structures are present.***
- ***Mesosomes:** are invaginations of the plasma membrane in the shape of vesicles.*
- ***Seen in both G+ and G-**, mostly in G-.*
- ***They may be involved in cell wall formation during division or play a role in chromosome replication and distribution to daughter cells.***
- *Believed to be artifacts generated chemical fixation of bacteria for EM. Could possibly represent parts of the plasma membrane that are chemically different and more disrupted by fixatives.*

Cytoplasm – Cytoplasmic Matrix

- ***Unlike the EC, the PC cytoplasm does not contain membrane-bound organelles.***
- *The cytoplasm is a **viscous liquid** that is enclosed by the cell membrane, it lies between the plasma membrane and the nucleoid.*
- *Most of the biological functional that are necessary to sustain life occur in the cytoplasm*
- *Composed of approximately*
 - *70 - 80% **water**,*
 - *the remaining 20% includes the **nucleoid (DNA)***
 - ***ribosomes** for protein synthesis*

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- more than 1500 catabolic and anabolic enzymes, carbohydrates, lipids, amino acids, and inorganic ions.
- *The cytoplasm of a prokaryotic cell is a single compartment, it does not contain mitochondria, chloroplasts, Endoplasmic reticulum, cytoplasmic streaming, microfilaments or microtubules*

Some bacteria do contain **Cytoplasmic inclusion bodies**: used for storage.

(1) **Granules** of materials (starch, glycogen, poly-hydroxybutyrate (PHB), sulfur, and polyphosphate (cellular C, S, and O reserve materials) present in the cytoplasm.

- **Polyphosphate granules**: many bacteria store phosphate and act as an important constituent for nucleic acids.
- **Metachromatic granules**: act as energy reserves, polyphosphate – energy source in reactions.
 - Metachromatic granules: they appear red or a different shade of

(2) **Cyanobacteria** have two distinctive IB

- Cyanophycin
- Carboxysomes

(3) **Gas Vacuole**

- present in cyanobacteria, purple and green photosynthetic bacteria, and few other aquatic forms.
- these bacteria float at or near the surface because GV gives them buoyancy
- gas vacuole are made up of **gas vesicles**
- **Gas vesicles**: are aggregates of enormous numbers of small, hollow, cylindrical structures.
 - GV walls do not contain lipid and are composed entirely of a single small protein
 - Protein subunit form a rigid enclosed hollow cylinder impermeable to water but freely permeable to atmospheric gases.
- A means of motility, allowing cells to float up and down in a water column in response to the environmental factors.
- They are present in the cytoplasm and may number from few to hundred cells.

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(4) Magnetosome

- Used by some bacteria to orient in the earth's magnetic field.
- Magnetosomes are intracellular crystal particles of the iron mineral Magnetite (Fe_3O_4) which gives the cell a permanent magnetic dipole (pos end and a neg end).

Ribosomes

- Found in the cytoplasm
- Loosely attached to the plasma membrane
- Made of protein and (RNA) – ribonucleic acid
- Site of protein synthesis
- Cytoplasmic matrix ribosomes synthesize to remain within the cell
- Plasma ribosomes make proteins for transport outside the cell

Prokaryotic Ribosomes:

Prokaryotic ribosomes are smaller than eukaryotic ribosomes.

- Commonly called 70S ribosomes
 - 14 to 15nm by 20 nm
 - MW of 2.7 million
 - Constructed of a 50S and 30S subunit
- S = Svedberg unit**
- Unit of Sedimentation Coefficient: a measure of the sedimentation velocity in a centrifuge.
 - The faster a particle travels when centrifuged, the greater its Svedberg value or sedimentation coefficient.
 - The S is a function of a particle's weight, volume, and shape.
 - Heavier and more complex particles have larger Svedberg number or sediment faster.

Eukaryotic ribosomes are 80S and 22 nm in diameter.

Nucleoid

- The irregular shaped region of the genetic material (DNA)
- **Other names:** nuclear body, chromatin body, and nuclear region)
- Common Single circle of double stranded DNA (deoxyribonucleic acid)
- But some have linear DNA chromosomes
- DNA is looped and coiled extensively.

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Plasmids

- *Double-stranded DNA molecules*
- *Usually circular, can exist and replicate independently of the chromosome or may be integrated with it*
- *Present in many bacteria alone with chromosomes – inherited or passed on to the progeny.*
- *Not usually attached to the plasma membrane and are sometimes lost to one of the progeny cells during division.*
- *Not required for host growth and reproduction*
- *May carry genes that give their bacterial host a selective advantage*
- ***Advantages:*** *can render bacteria drug-resistant
give them new metabolic abilities
make them pathogenic
or endow them with a number of properties*
- *Plasmids often move between bacteria, they can confer properties through out an entire population.*