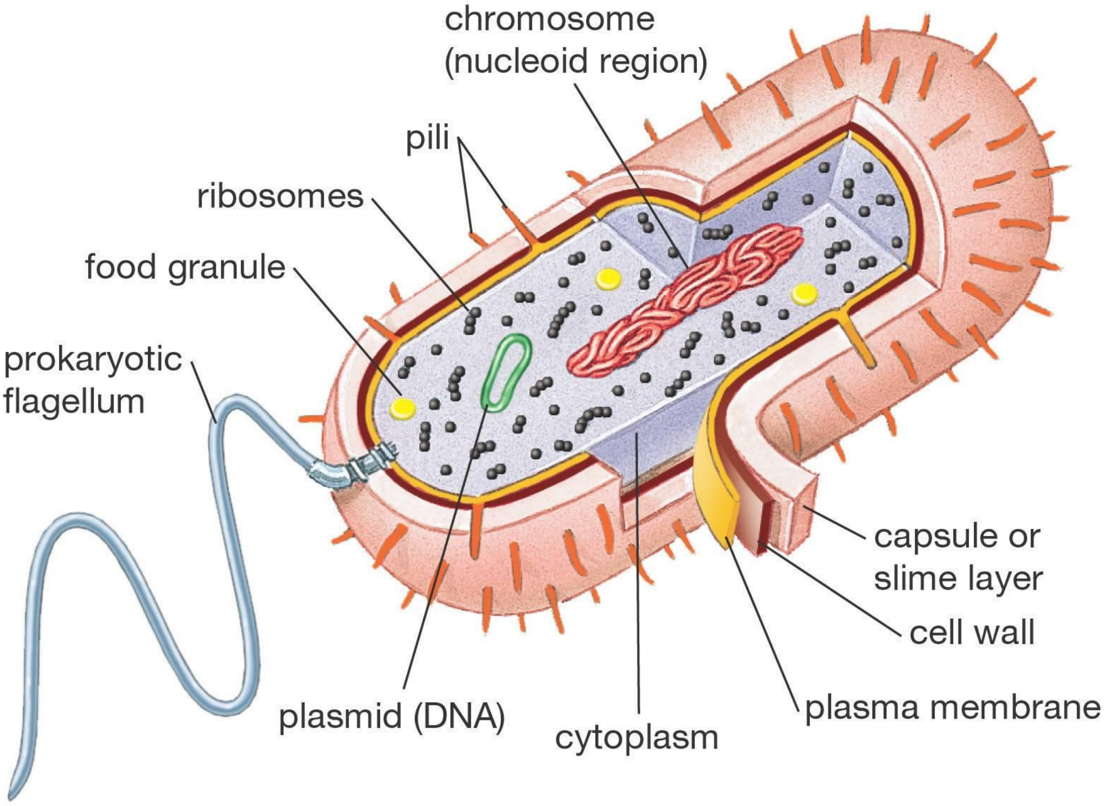
Prokaryotic Cell Structure I

The prokaryotic cell is simpler than the eukaryotic cell at every level, with one exception: the cell envelope is more complex.



The Nucleoid

Prokaryotic have no true nuclei; instead they package their DNA in a structure known as the **nucleoid**. The nucleoid of most bacterial cells consists of a single continuous circular molecule ranging in size from 0.58 to almost 10 million base pairs. However, a few bacteria have been shown to have two, three, or even four dissimilar chromosomes. For example, *Vibrio cholera* and *Brucella melitensis* have two dissimilar chromosomes. There are exceptions to this rule of circularity because some prokaryotes (eg, *Borelia burgdorferi* and

Streptomyces coelicolor) have been shown to have a linear chromosome.

In bacteria, the number of nucleoids, and therefore the number of chromosomes, depends on the growth conditions. Rapidly growing bacteria have more nucleoids per cell than slowly growing ones; however, when multiple copies are present they are all the same(i.e. prokaryotic cells are **haploid**).

Cytoplasmic Structures

Prokaryotic cells lack autonomous plastids, such as mitochondria and chloroplasts; the electron transport enzymes are localized instead in the cytoplasmic membrane. The photosynthetic pigments (carotenoids, bacteriochlorophyll) of photosynthetic bacteria are contained in intracytoplasmic membrane systems of various morphologies. Membrane vesicles (**chromatophores**) or lamellae are commonly observed membrane types. Some photosynthetic bacteria have specialized nonunit membrane-enclosed structures called **chlorosomes**.

Bacteria often store reserve materials in the form of in soluble granules. These so-called **inclusion bodies** almost always function in the storage of energy or as reservoir of structural building blocks. There are many types of these inclusions:

1- The most common inclusion bodies consists of **poly-β-hydroxybutyric acid (PHB),** PHB is produced when the source of nitrogen, sulfur, or phosphorous is limited and there is excess carbon in the medium.

2- Another storage product formed by prokaryotes when carbon is in excess is **glycogen**. PHB and glycogen are used as carbon sources when protein and nucleic acid synthesis are resumed.

3- A variety prokaryotes are capable of oxidizing reduced sulfur compounds and producing intracellular granules of elemental **sulfur.** Many bacteria accumulate large reserves of inorganic phosphate in the form of granules of **polyphosphate**. These granules are sometimes termed **volutin granules** or **metachromatic granules.**

Certain groups of autotrophic bacteria that fix carbon dioxide to make their biochemical building blocks contain polyhedral bodies surrounded by a protein shell (**carboxysomes**) containing the key enzyme of CO_2 fixation, **ribulose-bisphosphate carboxylase**.

Magnetosomes are intracellular crystal particles of the iron mineral magnetite (Fe_3O_4) that allow certain aquatic bacteria to exhibit magnetotaxis.

Gas vesicles are found almost exclusively in microorganisms from aquatic habitats, where they provide buoyancy.

Bacteria contain proteins resembling both the **actin and nonactin cytoskeletal proteins** of eukaryotic cells as additional proteins that play cytoskeletal roles.

The Cell Envelope

Prokaryotic cells are surrounded by complex envelope layers that differ in composition among the major groups. These structures protect the organisms from hostile environments, such as extreme osmolality, harsh chemicals, and even antibiotics.

The Cell Membrane

A. Structure

It is a typical "unit membrane" composed of phospholipids and upward of 200 different kinds of proteins. Proteins account for approximately 70% of the mass of the membrane, which is a considerably higher proportion than that of mammalian cell membranes.

The membranes of prokaryotes are distinguished from those of eukaryotic cells by the absence of sterols, the only exception being mycoplasmas that incorporate sterols, such as cholesterol, into their membranes when growing in sterol-containing media.

The cell membrane of the *Archaea* differ from those of the *Bacteria.* Some Archaeal cell membrane contain unique lipids, **isoprenoids.**

B. Function

The major functions of the cytoplasmic membrane are:

(1) Selective permeability and transport of solutes.

(2) Electron transport and oxidative phosphorylation, in aerobic species.

(3) Excretion of hydrolytic exoenzymes.

(4) Bearing enzymes and carrier molecules that function in the biosynthesis of DNA, cell wall polymers, and membrane lipids.

(5) Bearing the receptors and other proteins of the chemotactic and other sensory transduction systems.

Q/ what are the general mechanisms involved in membrane transport?

The Cell Wall

The bacterial cell wall owes its strength to a layer composed of a substance variously referred to as murein, mucopeptide, or **peptidoglycan** (all are synonyms).

Most bacteria are classified as gram-positive or gram-negative according to their response to the Gram-staining procedure. Gram-positive bacteria look purple under the microscope, and gram-negative bacteria look red.

A- The Peptidoglycan Layer

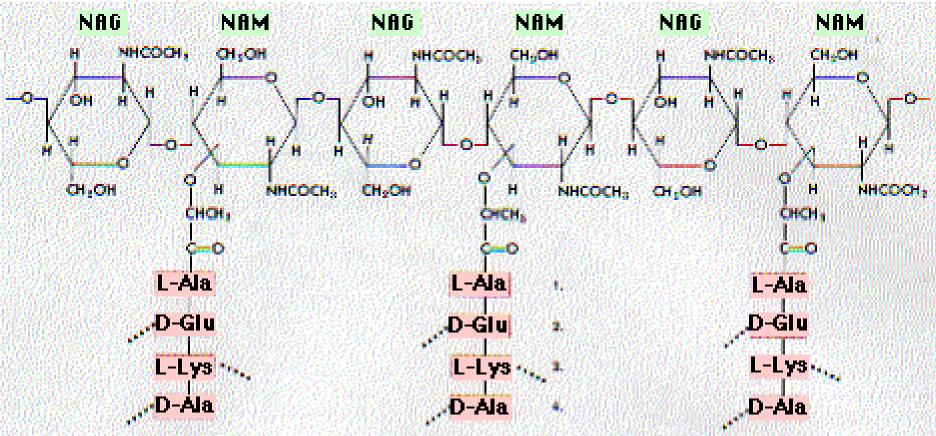
Peptidoglycan is a complex polymer consisting of three parts:
(1) a backbone, composed of alternating *N*-acetylglucosamine**(NAG)** and *N*-acetylmuramic acid**(NAM).**
(2) a set of identical **tetrapeptide side chains** attached to NAM.
(3) a set of identical **peptide cross-bridges**.

The backbone is the same in all bacterial species; the tetrapeptide side chains and the peptide cross-bridges vary from species to species.

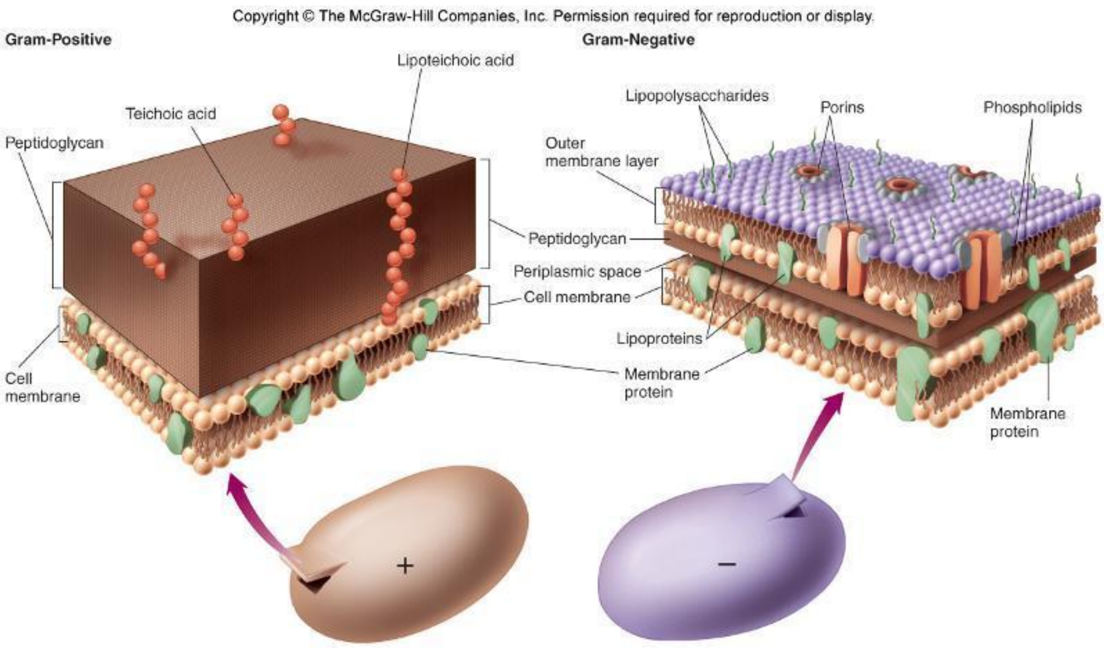
The tetrapeptide side chains of all species have certain important feature in common. Most have **L-alanine** at position 1 (attached to NAM). **D-glutamate** or substituted D-glutamate at position 2. **D-alanine** at position 4. Position 3 is the most variable one: Most gram-negative bacteria have **diaminopimelic acid (DAP)**

at this position. Gram-positive bacteria usually have L-lysine at position 3.

DAP is a unique element of bacterial cell walls. It is never found in the cell walls of *Archaea* or eukaryotes.



The fact that all peptidoglycan chains are cross-linked means that each peptidoglycan layer is a single giant molecule. In gram-positive bacteria, there are as many as 40 sheets of peptidoglycan, comprising up to 50% of the cell wall material; in gram-negative bacteria, there appears to be only one or two sheets, comprising 5-10% of the wall material.



B- Special Components of Gram-Positive Cell Walls

Most gram-positive cell walls contain considerable amounts of **teichoic acids**, and may contain **polysaccharide** molecules.

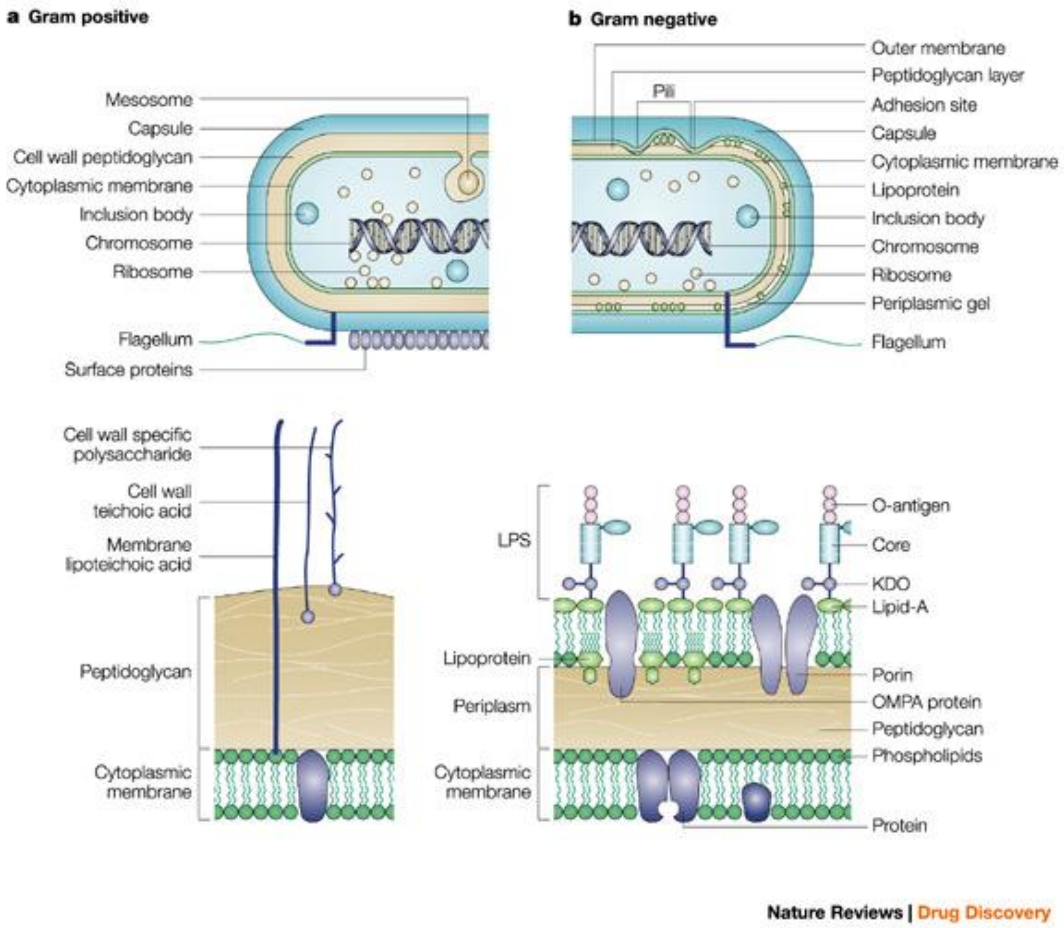
1- Teichoic acids

The term teichoic acids encompasses all wall, membrane, or capsular polymers containing glycerophosphate or ribitol phosphate residues. Because they are negatively charged, teichoic acids are partially responsible for the negative charge of the cell surface as a whole. There are two types of teichoic acids: **wall teichoic acid (WTA)**, covalently linked to peptidoglycan, and **membrane teichoic acid** , covalently linked to membrane glycolipid. Because the latter are intimately associated with lipids, they have been called **lipoteichoic acids (LTA)**.

The teichoic acids constitute major surface antigens of those gram-positive species that possess them, and their accessibility to antibodies has been taken as evidence that they lie on the outside surface of the peptidoglycan.

2- Polysaccharides

The hydrolysis of gram-positive walls has yielded, from certain species, neutral sugars such as mannose, arabinose, rhamnose, and glucosamine and glucosamine and acidic sugars such as glucuronic acid and mannuronic acid. It has been proposed that these sugars exist as subunits of polysaccharides in the cell wall.


a Gram positive
Mesosome
Capsule
Cell wall peptidoglycan
Cytoplasmic membrane
Inclusion body
Chromosome
Ribosome
Flagellum
Surface proteins
Cell wall specific polysaccharide
Cell wall teichoic acid
Membrane lipoteichoic acid
Peptidoglycan
Cytoplasmic membrane
b Gram negative
Outer membrane
Peptidoglycan layer
Pili
Adhesion site
Capsule
Cytoplasmic membrane
Lipoprotein
Inclusion body
Chromosome
Ribosome
Periplasmic gel
Flagellum
LPS
O-antigen
Core
KDO
Lipid-A
Lipoprotein
Periplasm
Porin
OMPA protein
Peptidoglycan
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