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# ORGANIZATIONAL PLAN OF THE LIVING WORLD: PROKARYOTES AND EUKARYOTES

MBOTCC-10
Unit-I

M. Sc. Sem-III
(2018-20)

## Cell as Unit of Structure & Function:

Cell is the fundamental structural and functional unit of living organisms. Destruction of cellular organization by mechanical or other means also leads to destruction of cellular function, although some vital enzymatic activities may persist for some time, and the cell ultimately dies. A high degree of structural and functional coordination is maintained in living organisms by energy transformations based on the constant input and output of matter and energy. The underlying uniformity of the entire living world is further established by biochemical isolation of inorganic components and complex organic molecules of proteins, fats, polysaccharides and nucleic acids from the cells.

The diversity of the living world is ultimately dependent on a genetic programme encoded in the nucleic acids, which is executed through complex regulatory circuits that control the biochemical activities of cells.

## Historical Developments:

(i) Term cell first used by Robert Hooke (1655) to describe the texture of cork by means of magnifying lenses.

(ii) Grew and Malpighi repeated such observations on different plants.

(iii) Leeuwenhoek (1674) discovered free cells and observed some organization within cells, particularly the nucleus in some RBCs.

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## Cell Theory:

(i) The above observations and several subsequent discoveries during the early 19th century finally led to the establishment of the cell theory by Schleiden (1838), a botanist and Schwann (1839), a zoologist in a more definite form, which stated that "all organisms are made up of cells."

(ii) Cell theory was further expanded by Virchow (1855) in his famous aphorism "omnis cellulae e cellula", i.e., all cells arise from preexisting cells. This establishes cell division as the central process of reproduction of organisms.

(iii) Flemming (1880) discovered mitosis and Waldeyer (1890) observed the precise partitioning of chromosomes.

(iv) Hertwig (1875) established fertilization by observing fusion of egg and sperm cells.

All these discoveries led to the modern version of the cell theory which may be put as below:

1. Cells are the morphological and physiological units of all living organisms.

2. Properties of a given organism depend on those of its individual cells.

3. cells orginate from other cells, and continuity is maintained through the genetic material.

4. The smallest unit of life is the cell.

## Prokaryotes and Eukaryotes:

(i) Structurally, two basic types of cell, prokaryotic and eukaryotic, are found among the cellular living world.

(ii) Some microorganisms such as viruses, viroids and prions are acellular. They cannot grow and multiply outside their

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(iii) Cellular organisms are further classified as <u>Prokaryotes</u> (Bacteria, Archaea and Cyanobacteria) and <u>Eukaryotes</u> (Algae, Fungi, Protozoa, Plants and Animals).

(iv) Prokaryotes and eukaryotes share the common basic unit of life, the cell.

(v) Prokaryotes and eukaryotes are chemically similar as both of them contain nucleic acids, proteins, lipids and carbohydrates.

They use identical reactions to metabolise food, build proteins and store energy.

(vi) It is primarily the structure of <u>cell walls</u> and <u>membranes</u>, and the absence of <u>organelles</u> that distinguish prokaryotes from eukaryotes.

(vii) Prokaryotes do not have a membrane bound nucleus. Such a primitive nuclear structure is called <u>nucleoid</u> which contains the DNA usually in a circular form.

Eukaryotes have a well developed membrane bound true nucleus.

(viii) A number of other differences regarding cellular components, wall structure ~~feature~~ and its associated components do exist between prokaryotes and eukaryotes.

<u>Structure of a Prokaryotic cell:</u>

Structure of a prokaryotic cell may be discussed under the following major heads:

(A) Size, Shape and Arrangement of cells
(B) Structures external to the cell wall
(C) Cell Wall
(D) Structures internal to the cell wall

A. <u>SIZE, SHAPE & ARRANGEMENT OF CELLS</u>

(i) Smallest bacterium – 0.3 μm in diameter
e.g., <u>Mycoplasma</u>

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(ii) Most bacteria range in size from 0.2–2.0μm in diameter and 2–8μm in length

E. coli : 1.1–1.5 μm wide and 2.0–6.0 μm long

(iii) Some Spirochetes may be 500μm long

– Cyanobacteria (e.g., Oscillatoria): About 7.0μm in diameter

– Epulopiscium fishelsoni (an intestinal bacterium of brown surgeonfish): 600 by 80μm

(iv) Recently found largest bacterium Thiomargarita namibiensis : 100–750μm in diameter

(v) shape: Spherical (Coccus), rod-shaped (Bacillus), helical (Spirillum), Comma-shaped (Vibrios), filamentous

– Cocci and bacilli are most common.

(vi) Cocci on division may produce pairs (Diplococcus), chains (Streptococcus), tetrads (Micrococcus), cubical packets of eight cells (Sarcina) or grape-like clusters (Staphylococcus).

B. STRUCTURES EXTERNAL TO THE CELL WALL

(a) Glycocalyx – (i) A viscous (sticky) layer of a gelatinous polymer found on the outer surface of the cell wall of many bacterial cells.

(ii) Chemical composition of glycocalyx varies widely with the species.

(iii) Secreted within the cells, and, if firmly attached to the cell wall, it is called capsule.

– If it is loosely attached to the cell wall and is easily removable, the glycocalyx is called slime layer.

(iv) Capsules contribute to bacterial virulence, and also protect

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pathogenic bacteria from phagocytosis by host cells. — Capsules can also protect bacteria against desiccation and from toxic materials.

(v) A specialized glycocalyx made up of sugars is called Extracellular Polysaccharide (EPS). This aids bacterial attachment to the surface of solid objects.

(vi) Many Gram +ve and Gram -ve bacteria have a regularly structured layer called S-layer on their surface. They are very common in Archaea also.

(b) FIMBRIAE & PILI:

(i) Pili are short, fine, hairy and nearly straight appendages mostly in Gram -ve ~~bacteria~~ bacilli.

(ii) Used for attachment of the cells and made up of a protein called pilin.

(iii) Fimbriae are also similar appendages either at the poles of the cells or over the entire cell surface.

(iv) Fimbriae enable bacterial cells to adhere to surfaces.

(v) Pili are usually longer than Fimbriae.

(vi) Sex pili are required for bacterial conjugation.

(c) FLAGELLA: (i) They are slender, helical locomotor appendages extending outward from the plasma membrane and cell wall in motile bacteria, which help in movement.

(ii) Length: 15–20 μm; Diameter: About 20 nm

(iii) Unlike eukaryotic flagellum, they have no definite membrane.

(iv) Flagellar distribution varies in bacterial species. Common patterns are: Monotrichous (Single flagellum at one pole of the cell), Lophotrichous (Numerous flagella at one pole), Amphitrichous (At least one flagellum at each pole) and Peritrichous

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(Flagella all over the cell surface).

(v) Protein molecules of flagellin are found in the flagellar filaments.

(vi) A flagellum consists of three parts: Filament, Basal body and a curved Hook.

Details of the flagellar structure are shown in the diagrams.

(d) AXIAL FILAMENTS:

(i) Spirochetes (helical bacteria) move through flexing and spinning movements of a special axial filament or endoflagellum.

(ii) This is composed of bundles of fibrils.

C. CELL WALL

(i) It is a dense layer surrounding the cell membrane.

(ii) Mycoplasma lack cell walls.

(iii) It acts as a molecular seive preventing passage of large molecules.

(iv) Cell wall components in Gram -ve bacteria may be strongly antigenic.

(v) All peripheral layers including the cell membrane are called cell envelope.

(vi) Rigidity and strength of bacterial cell walls are mainly due to strong fibres of peptidoglycans or mucopeptides.

(vii) Peptidoglycans consist of alternating units of N-acetyl-glucosamine and N-acetyl-muramic acid with β-1,4-linkages. This backbone structure appears to be the same in all prokaryotes.

(viii) Muramic acid, Diaminopimelic acid (DAP) and several D-amino acids are found in the cell wall of prokaryotes.

(ix) Structural rigidity of the peptidoglycans is achieved by cross-linking of the polymers.

The detailed structure of the bacterial cell cell envelope of a Gram -ve bacterial cell is shown in the diagram.

(x) Archaea may lack cell walls or may have unusual walls made up of polysaccharides

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and proteins, but not peptidoglycans.

D. STRUCTURES INTERNAL TO THE CELL WALL:

(a) Protoplast: (i) Entire cell content including the cell membrane but without cell wall is often called protoplast.

(ii) Protoplasts are osmotically fragile.

(b) Spheroplasts: Partially denuded prokaryotic cells (lysozyme or NaOH treated) are called Spheroplasts.

(c) Plasma Membrane

(i) Lipoproteinous selectively permeable boundary layer of the cell protoplast is the cell membrane or plasma membrane.

(ii) Basic structure of the plasma membrane of prokaryons is similar to that of the eukaryotes.
- Prokaryotic plasma membranes usually have a higher proportion of proteins than do eukaryotic membranes.

(iii) A lipid bilayer lies in the middle with proteins attached on the surfaces or traversing the whole thickness of the lipid bilayer. These are called extrinsic and intrinsic proteins respectively.

(iv) Fluid mosaic model of the plasma membrane is most acceptable. It is shown in the diagram.

(d) Internal Membrane Systems:

(i) Infoldings in the plasma membrane of prokaryotic cells produce complex internal structures.

(ii) These intracytoplasmic membranous structures chiefly include Mesosomes and Chromatophores/Thylakoids.

MESOSOMES: (i) They are vesicles, tubules or lamellae found in both Gram +ve and Gram -ve bacteria. They were earlier called peripheral bodies or chondroid.

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(ii) Mesosomes often found next to septa or cross-walls in dividing bacterial cells; sometimes attached to the bacterial genome.

(iii) May be involved in cell wall formation during cell division or play role in chromosome replication.

(iv) Currently many bacteriologists believe that mesosomes are artefacts generated during chemical fixation of bacteria for electron microscopic observations.

(d)

CHROMATOPHORES (THYLAKOIDS):

(i) Infoldings of the plasma membrane bearing pigments and enzymes involved in photosynthesis are called chromatophores or thylakoids.

(ii) Commonly found in Cyanobacteria and Purple bacteria (Rhodospirillaceae, Chromatiaceae).

(iii) Aggregates of spherical vesicles or sometimes flattened vesicles or tubular membranes are found in nitrifying bacteria.

(e) Cytoplasmic Matrix (Cytosol)

(i) Cytoplasmic matrix is the substance lying between the plasma membrane and the nucleoid.

(ii) Unlike eukaryotes, it lacks membrane-bound organelles and cytoskeleton(ER).

(iii) It contains about 70% water and is packed with ribosomes.

(iv) Its actual nature is debatable and still incompletely understood.

(v) It contains a variety of enzymes, coenzymes and metabolites in the form of a fluid matrix.

(vi) Several inorganic ions, amino acids, some proteins, lipocomplexes, peptides, nitrogenous bases, sugars, vitamins, enzymes, coenzymes etc., are found in the cytosol.

(vii) It is thought to provide a favourable chemical millieu for cellular activities.

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(viii) Cytosol is often packed with <u>ribosomes</u> which are the sites of protein synthesis.

- Ribosomes are made up of protein and rRNA (ribosomal RNA).
- Sedimentation co-efficient : 70S
- Size : 15 nm by 20 nm
- Made up of 50S and 30S subunits

(ix) Other inclusions in the cytosol are <u>metachromatic granules</u> or <u>volutin</u>, <u>glycogen granules</u>, <u>cyanophycin granules</u>, etc.

(x) Membrane-bound inclusion bodies are <u>chlorosomes</u> (containing photosynthetic pigments), <u>carboxysomes</u> (site of $CO_2$ fixation), <u>magnetosomes</u> (an intracellular magnet), gas <u>vacuoles</u>, etc.

<u>NUCLEOID (NUCLEAR AREA):</u>

(i) Prokaryotic chromosome containing region is called <u>nucleoid</u> (nuclear area nuclear region).

(ii) Feulgen-stained cells show nucleoid even under the light microscope.

(iii) Prokaryotes usually contain a single circular double-stranded DNA; some may have a linear chromosome.

(iv) <u>Vibrio cholerae</u> cells have more than one chromosome.

(v) Electron micrographs of the nucleoid show a diffuse area of fibrous material without a limiting membrane.

(vi) Nucleoid is composed of about 60% DNA, 30% RNA and 10% protein (mostly RNA polymerase).

(vii) Double-stranded DNA forms a single circular chromosome without any <u>histones</u>. Some basic proteins have been detected recently.

(viii) <u>Nucleoid does not exhibit</u> any <u>mitotic</u> or <u>meiotic phenomena</u>.

(ix) Chromosome of <u>E. coli</u> is the largest molecule discovered so far in any biological system.

(x) Many bacteria, in addition to

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their chromosome, also contain small, circular double-stranded DNA molecules called plasmids. They are extrachromosomal genomes which replicate independent of the chromosomal DNA, and often inherited to the progeny.

These plasmids may carry genes for antibiotic resistance, tolerance to toxic chemicals, production of toxins and synthesis of enzymes.

— Plasmids are used for genetic engineering.

(Figs. below)

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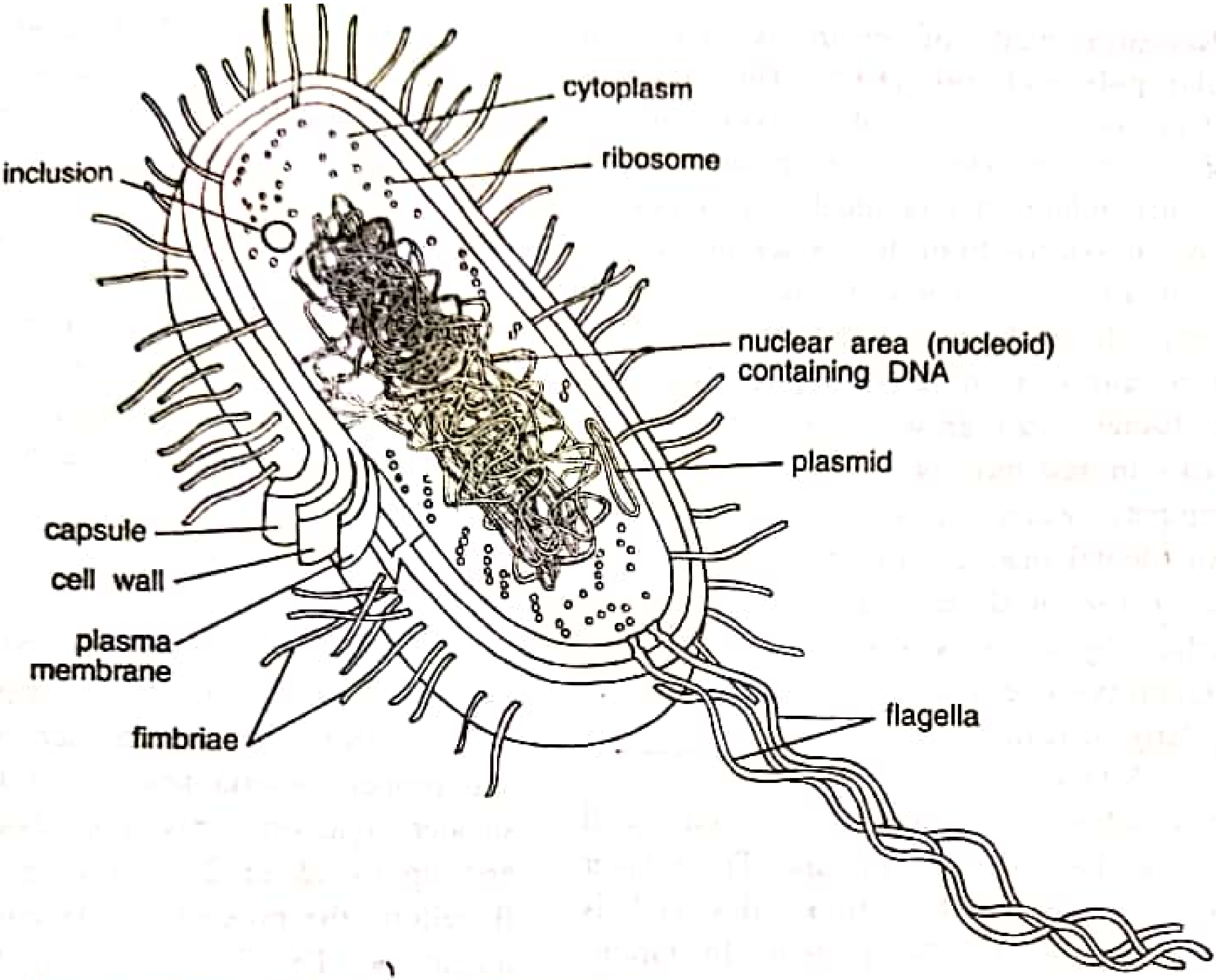


**Fig. 3.4.** A composite diagram showing various structures in bacterial cell, some of which are present only in certain groups of bacteria.

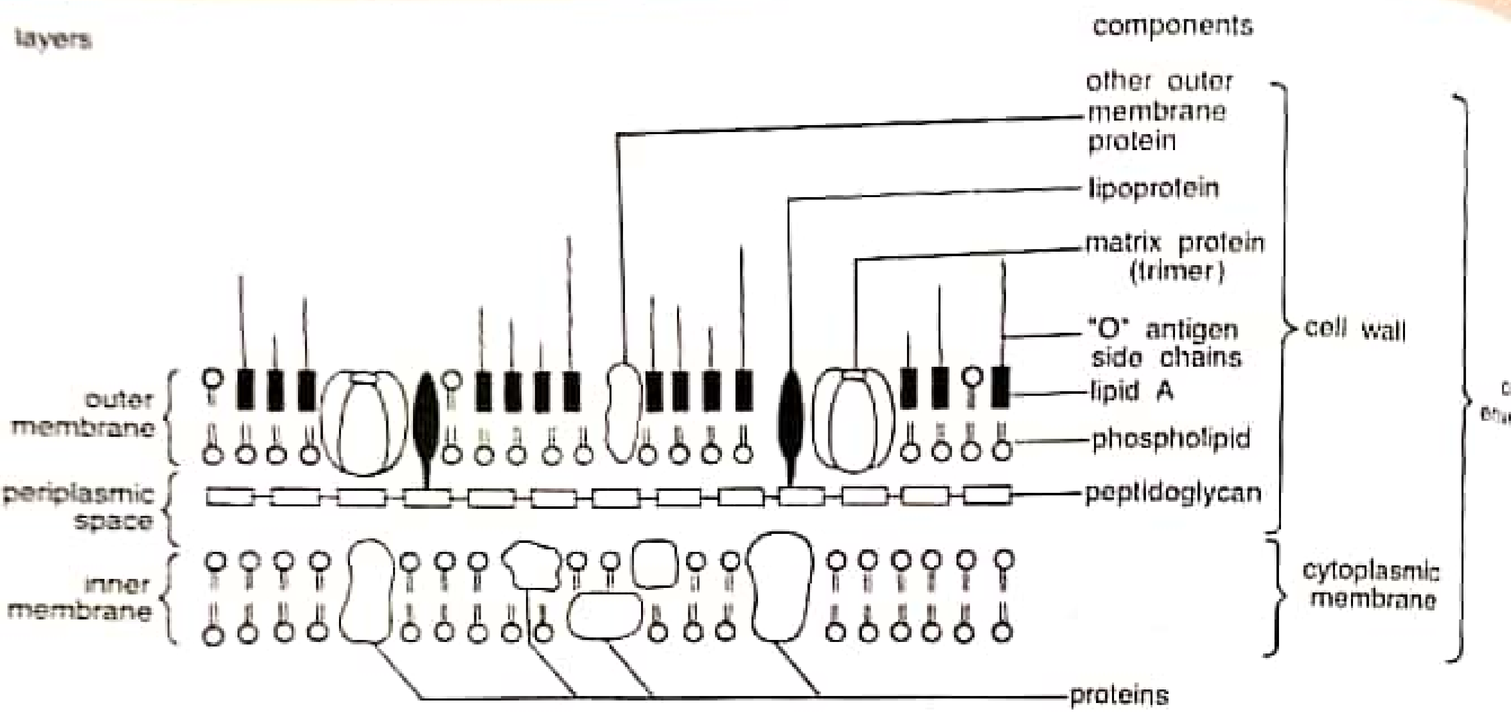


**Fig. 3.12.** Diagram of a Gram-negative cell envelope (cell wall plus cytoplasmic membrane).

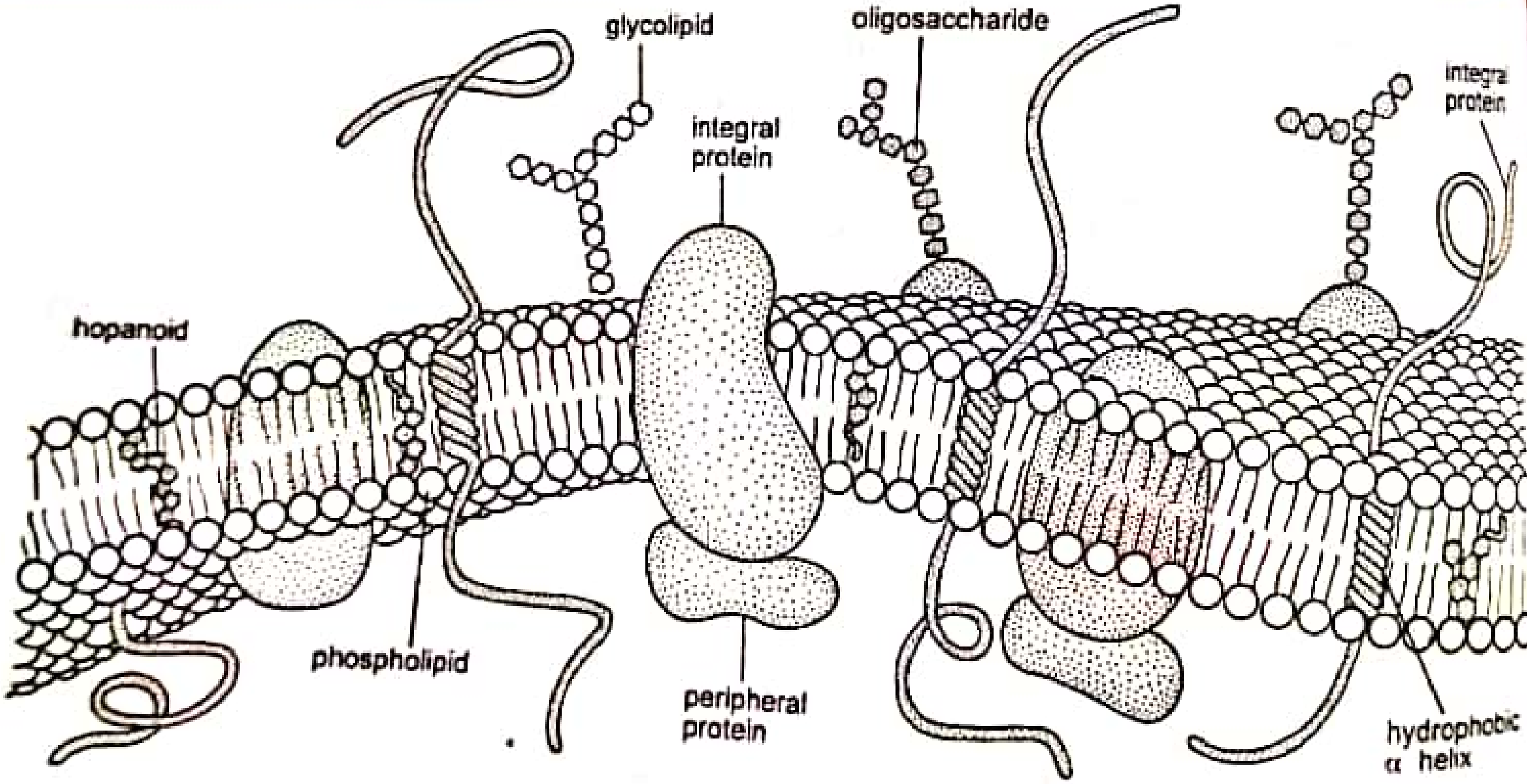


Fig. 3.15. The diagram of the fluid mosaic model of bacterial membrane structure.