Introduction

Biochemistry: **It is the chemistry of living things (matters).**

- **Biochemistry provides fundamental understanding of the molecular basis for the function and malfunction of living things.**
- **Biochemistry provides a broad understanding of the molecular basis of life.**
- **Biochemistry explains what goes wrong to produce disease.**

Examples:

- **The chemical structures of biomolecules.**
- **Interactions leading to formation of super macro-molecules , cells, multi-cellular tissues, and organisms.**
- **Bioenergetics of the reactions in the cell.**
- **Storage and transmission of information.**
- **Chemical changes during reproduction, aging, and death of cells.**
- **Regulation of chemical reactions inside living cells.**

Principal Areas of Biochemistry

Structure-function relationship: **Structural chemistry and functions for proteins, carbohydrates, DNA/RNA, lipids, and every other component in the cell.**

Metabolism:

- **Catabolism: Pathways of chemical reactions leading to the breakdown of molecules**
- **Anabolism: pathways of chemical reactions leading to synthesis of molecules.**
- **Bioenergetics of reaction as well as management of cellular Energy.**

Cellular communication

- **Storage, transmission, and expression of genetic information, DNA replication and protein synthesis.**
- **Cell-cell communication & interaction**
- **Signal transduction**

Living organisms:

1) Living organisms are complicated and highly organized made up of million of cells, containing many kinds of complex molecules (made up of elements C, H, O, N,...). In contrast, Inanimate matter (non-living matter; soil, water and rocks) consists of random mixtures of simple chemical compounds.

2) Each part of living organism appears to have a specific function.

3) Living organism have the capacity to extract and transform energy from their environment and use it to build their body from simple raw materials and to work.

4) Living organisms have the capacity for self-replication (can reproduce themselves hundreds and thousands of generation) While inanimate matter do not have ability to reproduce.

5) Cells are the structural and functional units of all living organisms.

The cellular foundation

- **The cell is the universal building block for living organisms.**
- **Cell is the smallest unit of living matter.**
- **All organisms are composed of one or more types of cells.**
- **All cells come from pre-existing cells by division.**
- **Cell is capable of reproduction.**
- **Cells contains hereditary information which is passed from cell to cell during cell division.**
- **All energy flow (metabolism & biochemistry) of life occurs within cells.**

- **The unity and diversity of organisms become apparent even at the cellular level.**
- **The smallest organisms consist of single cells and are microscopic.**
- **Larger, multicellular organisms contain many different types of cells, which vary in size, shape, and specialized function. All cells of the simplest and most complex organisms share certain fundamental properties, which can be seen at the biochemical level.**

Basic materials in cell:

All cells have these basic common materials:

1) H_2O (solvent of life): All cellular reactions are carried out in aqueous environment.

2) Four Major macromolecules (organic compounds i.e. contain carbon):

- **Proteins (the cell work horses)**
- **Nucleic Acids (genetic materials)**
- **Carbohydrates (many functions)**
- **Lipids (membrane and energy source and depot)**

3) Small amounts of ions & metabolites

There are two broad classes of cells

Eukaryotic cells (Eu = true; kary = nucleus): have a membrane-bound nucleus and a variety of organelles and internal membranes.

Prokaryotic cells (Pro = before) are smaller (a general rule) and lack much of the internal compartmentalization and complexity of eukaryotic cells; No membrane-bound nucleus or other organelles.

All Cells Share Some Common Features

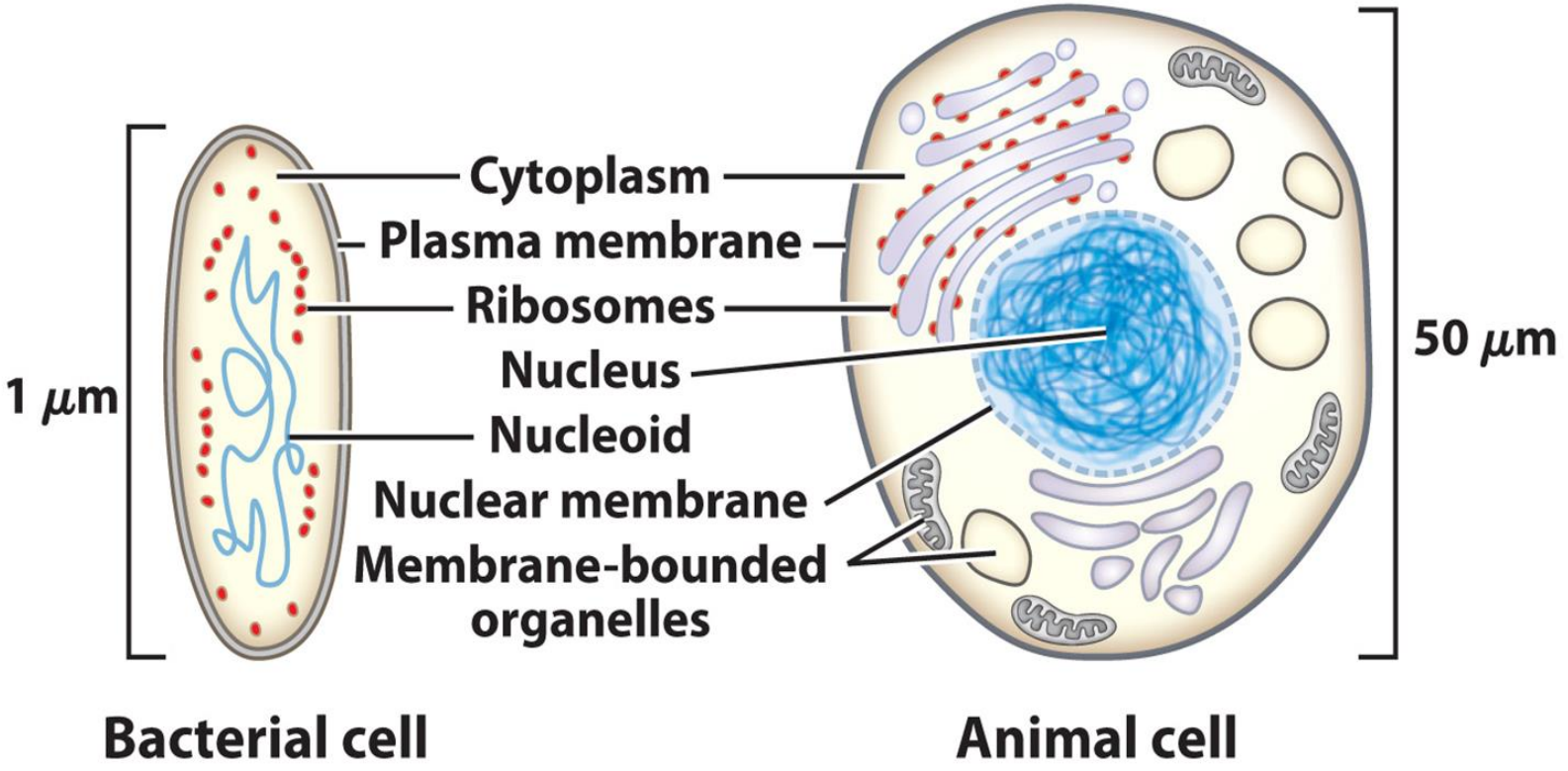


Figure 1-3
Lehninger Principles of Biochemistry, Seventh Edition

Cells of all kinds share certain structural features

The plasma membrane:

- **Defines the periphery of the cell, separating its contents from the surroundings.**
- **It is composed of lipid and protein molecules that form a thin, tough, pliable, hydrophobic barrier around the cell.**
- **Transport proteins in the plasma membrane allow the passage of certain ions and molecules; receptor proteins transmit signals into the cell; and membrane enzymes participate in some reaction pathways.**

Cytoplasm:

- **A portion of a cell's contents outside the nucleus but within the plasma membrane includes organelles such as mitochondria.**
- **Composed of an aqueous solution, the cytosol and a variety of suspended particles with specific functions.**

Cytosol:

- **Continuous aqueous phase of the cytoplasm, with its dissolved solutes; excludes the organelles.**

The cytosol is highly concentrated solution containing:

1- Enzymes and the RNA molecules that encode them.

2- The components (amino acids and nucleotides) from which these macromolecules are assembled.

3- Hundreds of small organic molecules called metabolites, intermediates in biosynthesis and degradative pathways.

4- Coenzymes, compounds essential to many enzyme-catalyzed reactions.

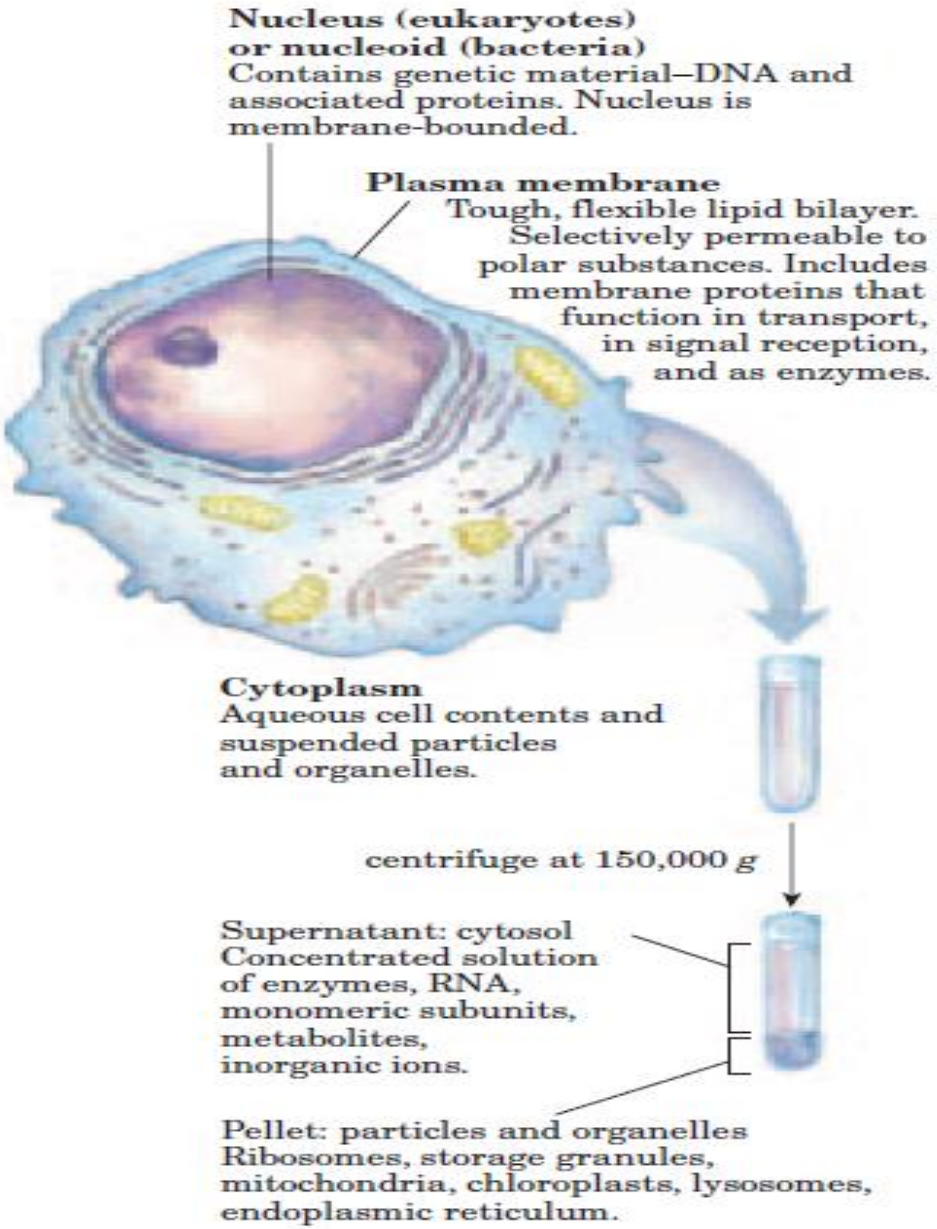
5- Inorganic ions.

Ribosomes

- **Supramolecular structures (group of protein subunits and ribosomal RNA)**
- **The sites of protein synthesis.**

Nucleus or nucleoid

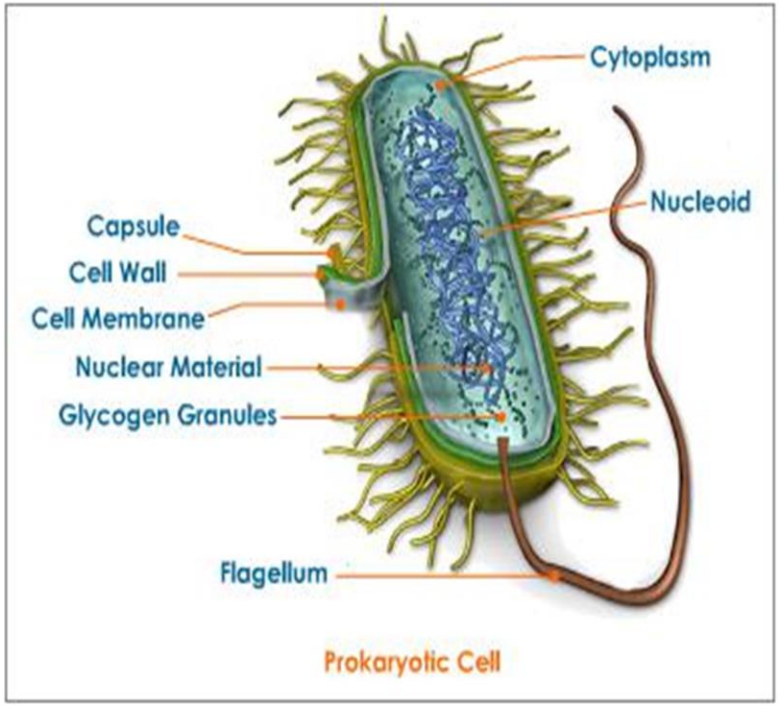
- **The nucleoid in bacteria is not separated from the cytoplasm by a membrane.**
- **The nucleus in eukaryotes consist of nuclear material enclosed within a double membrane (the nuclear envelope).**


Nucleus (eukaryotes)
or nucleoid (bacteria)
Contains genetic material–DNA and
associated proteins. Nucleus is
membrane-bounded.
Plasma membrane
Tough, flexible lipid bilayer.
Selectively permeable to
polar substances. Includes
membrane proteins that
function in transport,
in signal reception,
and as enzymes.
Cytoplasm
Aqueous cell contents and
suspended particles
and organelles.
centrifuge at 150,000 g
Supernatant: cytosol
Concentrated solution
of enzymes, RNA,
monomeric subunits,
metabolites,
inorganic ions.
Pellet: particles and organelles
Ribosomes, storage granules,
mitochondria, chloroplasts, lysosomes,
endoplasmic reticulum.

Prokaryotic cell

Prokaryotes (single-celled organisms): Bacterial cell, blue green algae

- **Do not have true nucleus or organelles.**
- **Most have circular or "looped" DNA.**



Bacterial Cell

Structure	Composition	Function
Cell wall	Carbohydrate + protein	Mechanical support
Cell membrane	Lipid + protein	Permeability barrier
Nucleoid	DNA + protein	Genetic information
Ribosomes	RNA + protein	Protein synthesis
Pili (Capsule)	Protein	Adhesion, conjugation
Flagella	Protein	Motility
Cytoplasm	Aqueous solution	Site of metabolism

Eukaryotic Cells

- **Eukaryotes are found in Animal, Plant, Protists, and Fungi kingdoms.**
- **Few eukaryotes are single-cell but the majority are multicellular organisms.**
- **Complex cells (different sizes, shapes, and structures) and specialized but they all have:**

Membrane-bound nucleus **which contains the cell's genetic material; DNA**

Organelles, each is surrounded by a membrane or two like lysosome, mitochondria, chloroplast and other membranous structures like Golgi bodies, endoplasmic reticulum,, etc.

Eukaryotic DNA **is organized in linear structures (chromosomes), associated with proteins (histones)**

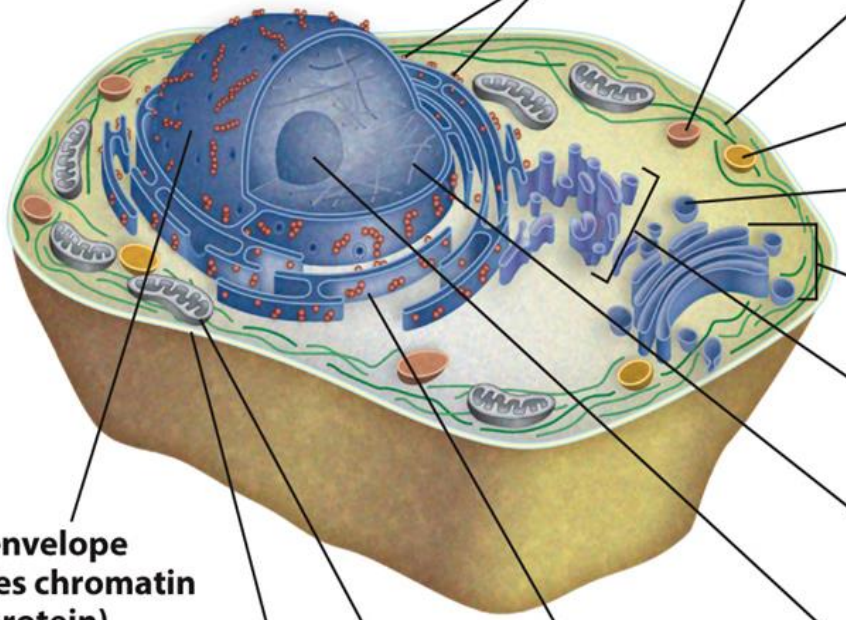
Animal Cell

- **The animal cell is surrounded by lipid bilayer plasma membrane.**
- **The content inside the plasma membrane is called protoplasm. It contains many organelles and subcellular structures as:**

Nucleus, Ribosome, Mitochondria, Lysosome, Golgi Bodies

Endoplasmic reticulum (ER), Centrosome, Cytoskeleton

Animal cell



Ribosomes are protein-synthesizing machines.

Peroxisome oxidizes fatty acids.

Cytoskeleton supports cell, aids in movement of organelles.

Lysosome degrades intracellular debris.

Transport vesicle shuttles lipids and proteins between ER, Golgi, and plasma membrane.

Golgi complex processes, packages, and targets proteins to other organelles or for export.

Smooth endoplasmic reticulum (SER) is site of lipid synthesis and drug metabolism.

Nucleus contains the genes (chromatin).

Nucleolus is site of ribosomal RNA synthesis.

Rough endoplasmic reticulum (RER) is site of much protein synthesis.

Nuclear envelope segregates chromatin (DNA + protein) from cytoplasm.

Plasma membrane separates cell from environment, regulates movement of materials into and out of cell.

Mitochondrion oxidizes fuels to produce ATP.

Figure 1-8a
Lehninger Principles of Biochemistry, Seventh Edition

Plant Cell

Plant cells is larger than animal cells and have some similarity with animal cells and differ in some specific plant structures like:

- **Organelles that present in plant cells but not in animal cells:**

External cell wall; Chloroplast (for photosynthesis); Vacuoles (instead of lysosomes); Starch granules; Thylakoids for ATP synthesis and Glyoxysome for glyoxylate cycle

- **It doesn't have centrosome**

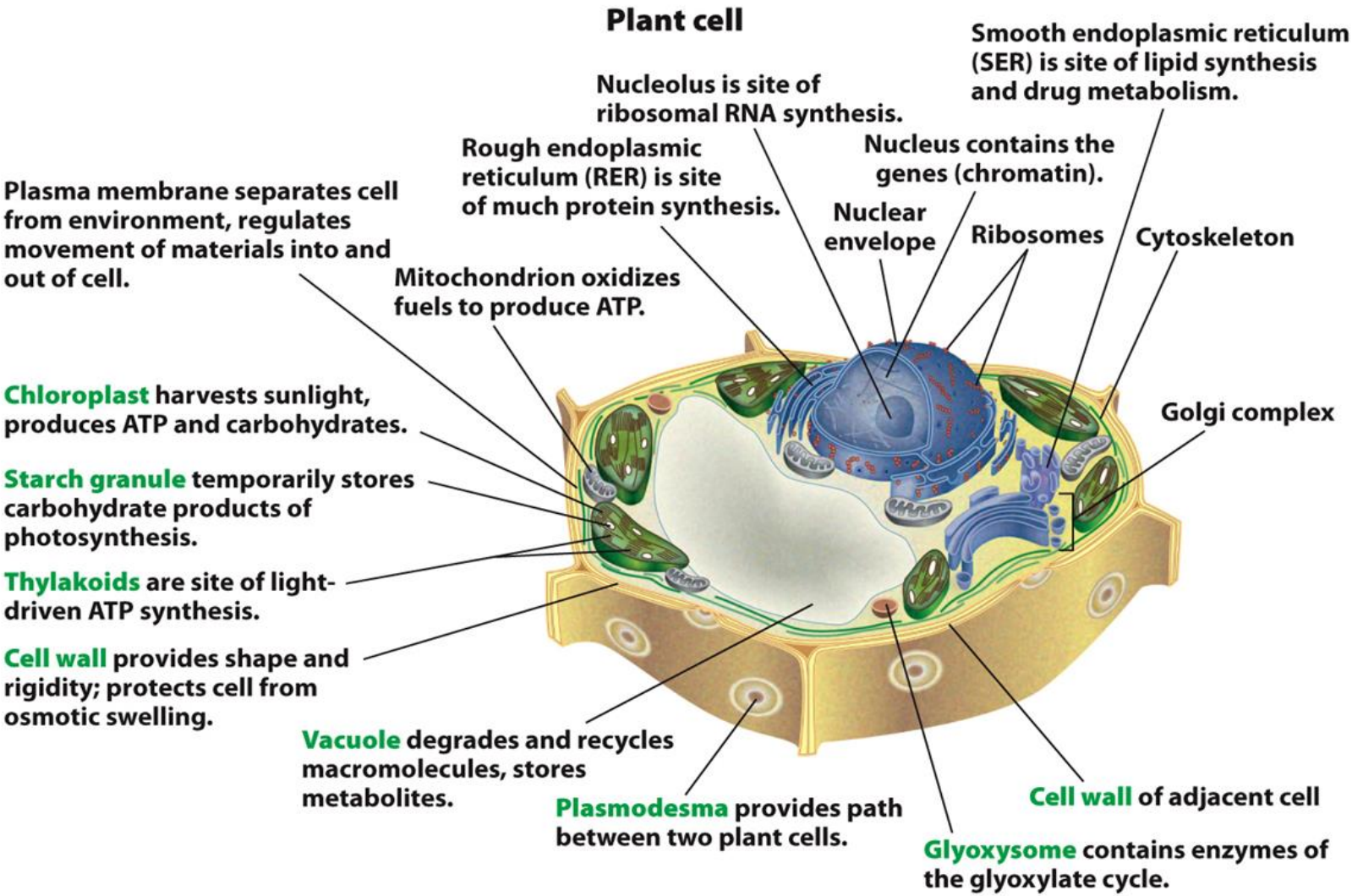


Figure 1-8b
Lehninger Principles of Biochemistry, Seventh Edition

Animal and Plant Cells Contain Identical and Unique Components

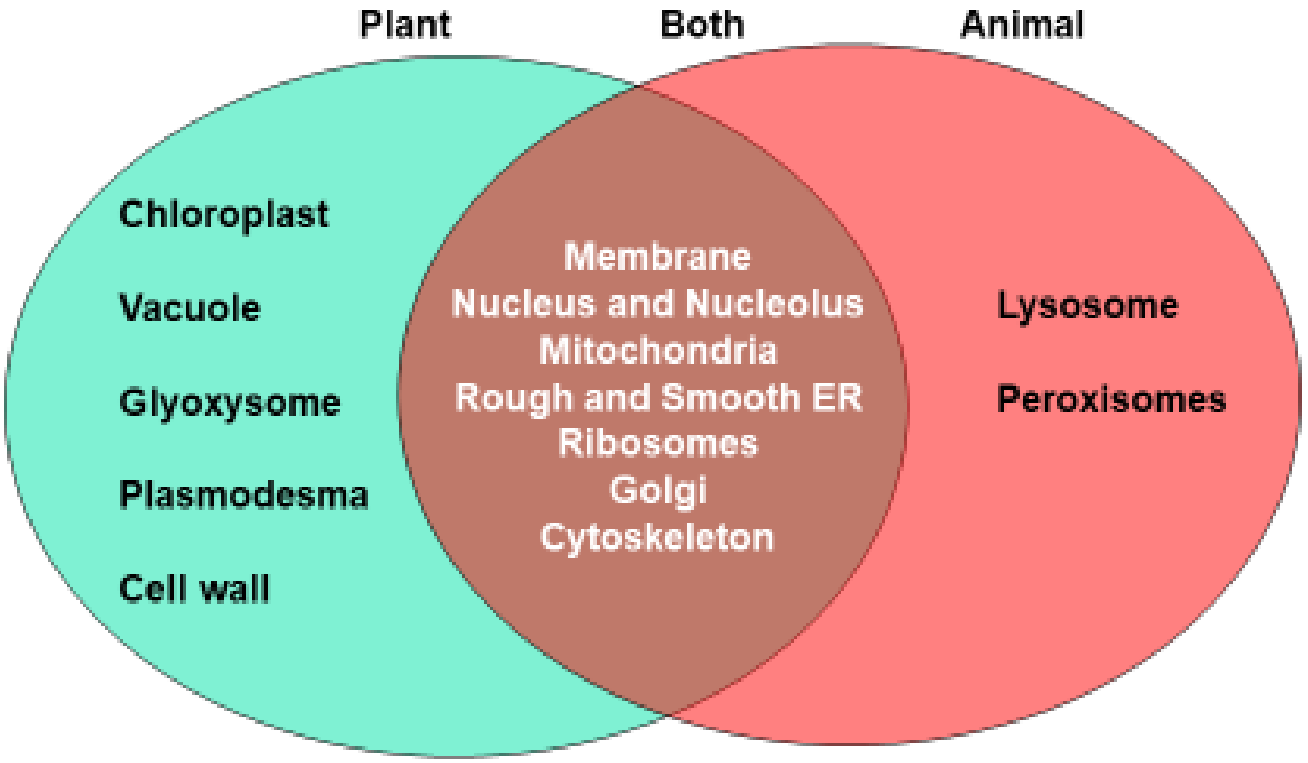


TABLE 4.2 **Principal Differences Between Prokaryotic and Eukaryotic Cells**

Characteristic	Prokaryotic	Eukaryotic
		
Size of cell	Typically 0.2–2.0 μm in diameter	Typically 10–100 μm in diameter
Nucleus	No nuclear membrane or nucleoli	True nucleus, consisting of nuclear membrane and nucleoli
Membrane-enclosed organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria, and chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Glycocalyx	Present as a capsule or slime layer	Present in some cells that lack a cell wall
Cell wall	Usually present; chemically complex (typical bacterial cell wall includes peptidoglycan)	When present, chemically simple
Plasma membrane	No carbohydrates and generally lacks sterols	Sterols and carbohydrates that serve as receptors present
Cytoplasm	No cytoskeleton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming
Ribosomes	Smaller size (70S)	Larger size (80S); smaller size (70S) in organelles
Chromosome (DNA)	Single circular chromosome; lacks histones	Multiple linear chromosomes with histones arrangement
Cell division	Binary fission	Mitosis
Sexual reproduction	No meiosis; transfer of DNA fragments only	Involves meiosis

Cell membrane

- **Biological membranes are sheet – like structures that are composed of lipid and protein molecules held together by non-covalent interactions.**
- **Membrane is a barrier to prevent the contents of the cell from escaping and mixing with the surrounding medium.**

Structure of cell membrane

Cell membrane composed of:

a) lipid bilayer

b) protein

c) carbohydrates in small ratio

a) Lipid bilayer: **The most abundant lipids in cell membrane are the phospholipids.**

- **The phospholipids are amphipathic.**
- **The lipid bilayer is arranged in which the non-polar (hydrophobic tail) towards the interior and the polar (hydrophilic heads) towards the surface.**
- **Cholesterol molecules are embded in the hydrophobic interior of the bilayer.**

b) Protein: **There are two types**

1) Integral proteins (intrinsic proteins)

2) Peripheral proteins (extrinsic proteins)

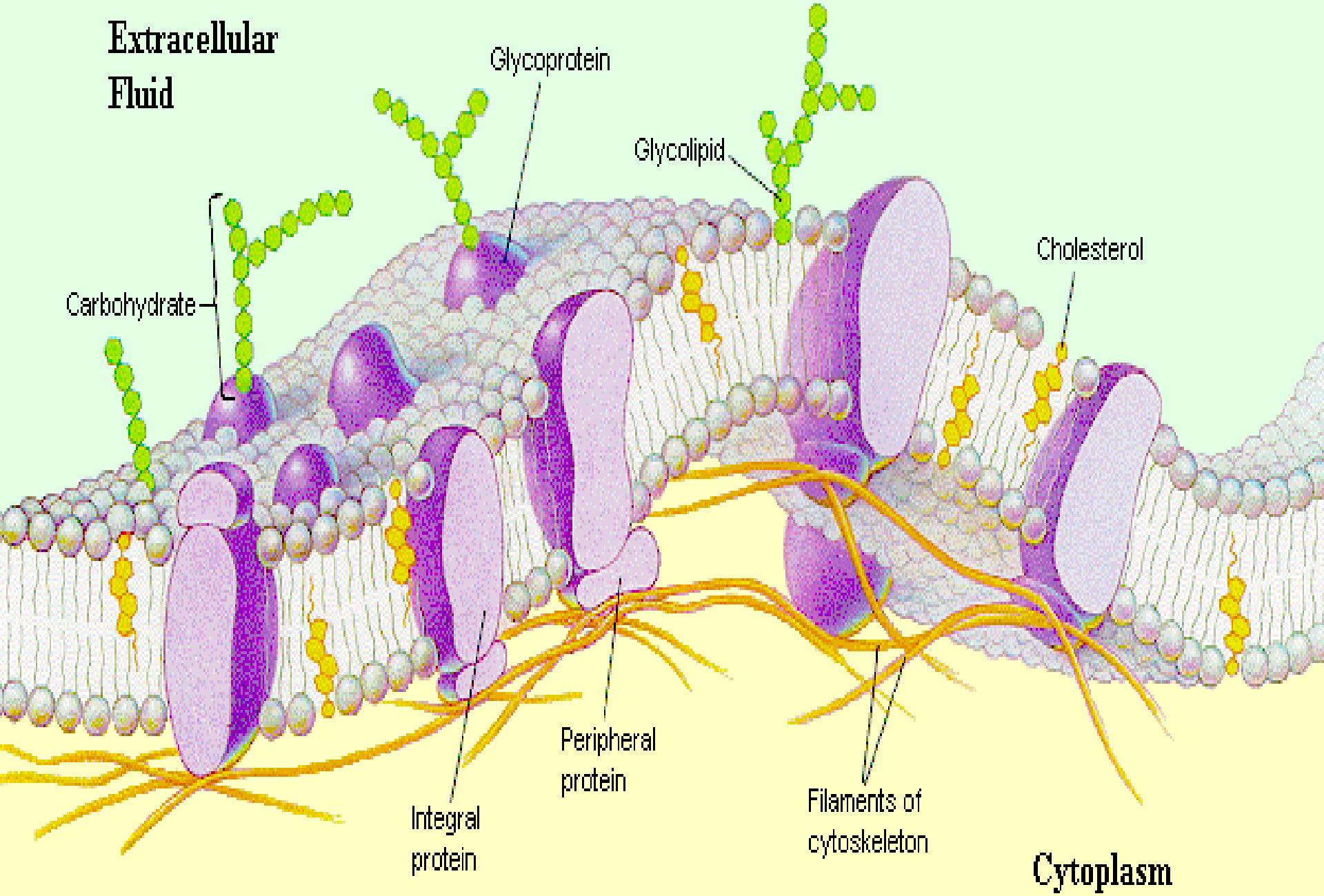
Integral proteins:

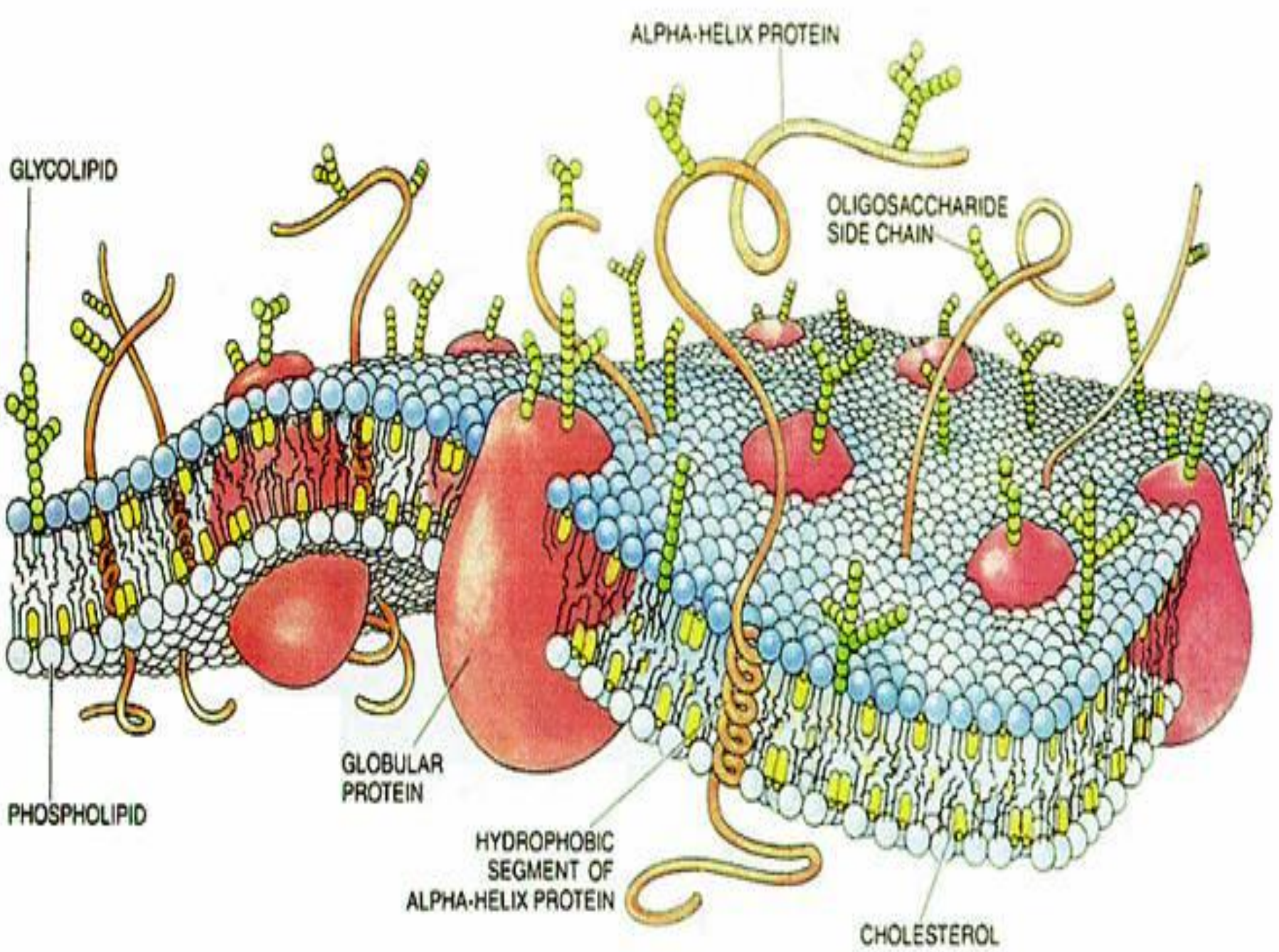
- **They are tightly bound within the membrane.**
- **They are embeded in the membrane.**
- **They are large molecules extend across the lipid bilayer and protrude from both surfaces of the membrane.**
- **Most of integral proteins act as channels.**

Peripheral proteins:

- **Loosely attached to the membrane surface.**
- **Not penetrate the membrane.**
- **They are almost entirely in the inner surface (cytoplasmic surface).**
- **Most of them act as enzymes.**

c) carbohydrates: **Membranes also contain carbohydrates in small ratio (2- 10 %) that are linked to lipids (form glycolipids) and proteins (form glycoproteins). They found on the extracellular side of plasma membrane.**


Extracellular Fluid
Glycoprotein
Glycolipid
Carbohydrate
Cholesterol
Peripheral protein
Integral protein
Filaments of cytoskeleton
Cytoplasm


ALPHA-HELIX PROTEIN
GLYCOLIPID
OLIGOSACCHARIDE
SIDE CHAIN
GLOBULAR
PROTEIN
PHOSPHOLIPID
HYDROPHOBIC
SEGMENT OF
ALPHA-HELIX PROTEIN
CHOLESTEROL

Functions of the plasma membrane:

The main role of plasma membrane is to regulate exchange of materials between the cell and its environment.

Function:

1) Transport

2) Endocytosis

3) Cell recognition and adhesion

4) Hormone receptor

5) Oxidative phosphorylation

6) Transmission of nerve impulses

Transport:

- **Lipid bilayers are highly impermeable to all ions and charged molecules.**
- **Small nonpolar molecules (e.g. O_2 , CO_2) readily dissolve in lipid bilayers and rapidly diffuse across them.**
- **The cell membrane is selectively permeable (i.e the membrane permits the passage of some substances, while blocking the passage of others.**