SECTION ONE CORE UNIT TWO

CELL AND CELL ORGANELLES/CELL CHEMISTRY AND FUNCTION

Major Concept

To study the molecular and functional organisation of a cell and its subcellular organelles

Specific Objectives

1. To know importance of cell, and the types: Prokaryotic and eukaryotic cell.
2. Learn the essential differences of a prokaryotic cell and eukaryotic cell.
3. Draw a diagram of an eukaryotic cell showing different cell organelles.
4. Study the following cellular organelles:
   - Nucleus—its structure and functions.
   - Mitochondrion, the power house of a cell. Learn its structure and functions.
   - Study endoplasmic reticulum, its types, structure and functions.
   - Learn structure and functions of Golgi complexes.
   - Study about lysosomes,
   - Learn about peroxisomes: Their structure and functions.
   - Study the structure and functions of cytoskeleton.

COMMON TERMS ENCOUNTERTED IN CYTOLOGY

TERM(S)	LITERAL MEANINGS/UNDERSTANDING
cytology	Study of cells by means of light and electron microscopes;
Cell theory	All living matter composed of cells; all cell arise from pre-existing cells; all metabolism occurs in cells;
Protoplasm	Living contents of the cell consisting of the cytoplasm and one or more nuclei
Organelle	Structurally and functionally discrete component of a living cell frequently membrane bound
Tissue	A collection of cells physically linked and associated with intercellular substance specialized to perform a particular function;
Cytogenetic	Linking cytology with genetics; relating structure and behaviour of chromosomes during cell division;
Primary lysosome	Refers to the vesicle that has just budded off from the Golgi body containing processed enzymes
Glycosylation	Process of combining carbohydrates with proteins forming glycol-proteins;
*S/Svedberg unit	Related to the rate of sedimentation in a centrifuge/greater the number the greater the rate of sedimentation (70S/80S)
Eukaryotes	Organisms with DNA enclosed by the nuclear envelope
Prokaryotes	Organism with DNA not enclosed by the nuclear membrane
Polyribosomes (polysomes)	Chains of ribosomes
Cytosol	Fluid part of the cytoplasm
Cell inclusions	Structures suspended in the cytoplasm but donot perform any metabolic role
Compartmentation	Refers to the development of separate organelles performing specific roles in a cell
Glycocalyx	Long carbohydrate molecule attached to membrane lipids and proteins

CELL

Cell refers to the basic unit of structure and function in living organism.

The concept of homeostasis at cellular level

Cell is physically separated from its environment by cell membrane/plasma membrane;✓yet capable of exchange with its environment;✓chemicals which are raw materials are acquired✓ and waste products removed;✓in doing work, the system can maintain stability;✓control of enzyme activity allosterically in cells;✓

Thus cell is the fundamental unit of life.

Modern cell theory can be divided into the following fundamental statements:

- Cells make up all living matter
- All cells arise from other cells
- The genetic information required during the maintenance of existing cells and the production of new cells passes from one generation to the Other next generation
- The chemical reaction of an organism that is its Metabolism, both anabolism and catabolism, takes place in the cells.

ORGANISMAL THEORY (REACTIONS TOWARDS THE PROPONENTS OF THE CELL THEORY)

The whole organism is the basic entity and cells are merely incidental sub-units

Looks at an organism as a Utopia of interdependent cells whose function are dictated by the needs of the whole organism.

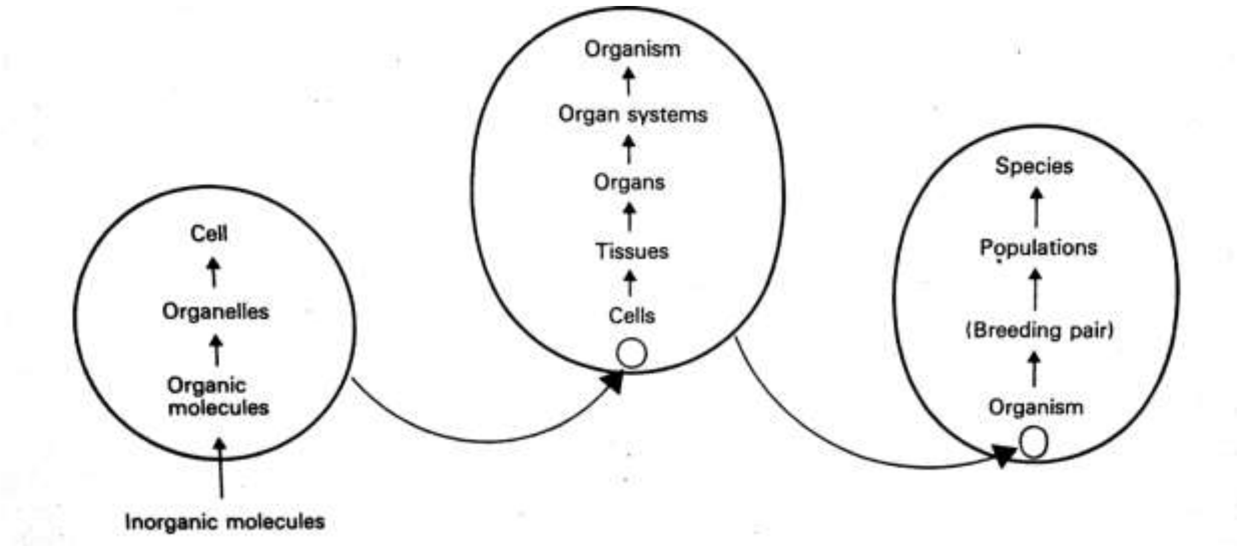
EXCEPTIONS TO THE CELL THEOR Y/DISCREPANCIES

- Mitochondria and chloroplast have their own genetic material and hence are self-replicating✓
- Viruses are considered alive by some but not made up of cells. Viruses have very many features of living things but by definition of cell theory they are not alive✓
- The first cell did not originate from pre-existing cells.

UNITS OF LIFE BEYOND THE CELL

UNIT(S)	NOTES
Tissues	Group of cells, usually of the same type specialized to perform specific functions eg xylem/bone/muscle/epithelium
Organs	Made up of tissues coordinated to perform certain functions eg eye/leaf/kidney
Organ-system	Group of organs which combine to perform a specific function eg endocrine system
Organisms	Depending on their complexity, may each be just one cell eg bacterium or Amoeba or millions of cells with a variety of functional units as above eg oak tree/man.
Populations	Group of organism of the same species occupying a given area at a particular time eg a small herd of cattle
communities	Population of different species living in balance in nature. They form part of the biosphere

SCHEMATA SHOWING DIFFERENT UNITS OF LIFE



TYPES OF CELLS

In general two types of cells exist in nature. They are:

1. Prokaryotic cells
2. Eukaryotic cells

PROKARYOTIC CELLS

Typical prokaryotic cells (Greek: *Pro*-before and *karyon*- nucleus) include the bacteria and cyanobacteria. Most studied prokaryotic cell is *Escherichia coli (E. coli).*

CHARACTERISTICS

- Minimum of internal organisation and smaller in size
- Does not have any membrane bound organelles.
- Genetic material is not enclosed by a nuclear membrane
- DNA is not complexed with histones. Histones are not found in prokaryotic cells
- Respiratory system is closely associated with its plasma membrane and
- Sexual reproduction does not involve mitosis or meiosis.

Morphology of bacterial cells

Size

- Small in size/0.1 to 10 microns/μm;✓

Shape

- Cocci; spherical/oval; eg streptococcus pyogenes;✓
- Bacillus; rods; e.g. bacillus anthrancis;✓
- Filamentous; branched/thin filaments; eg actinomycetes;✓
- Spirillum; curved/spiral; single flagellum; eg treponoma pallidum✓
- Vibrios; comma shaped; eg vibrio cholerae;✓

Arrangement

Cocci

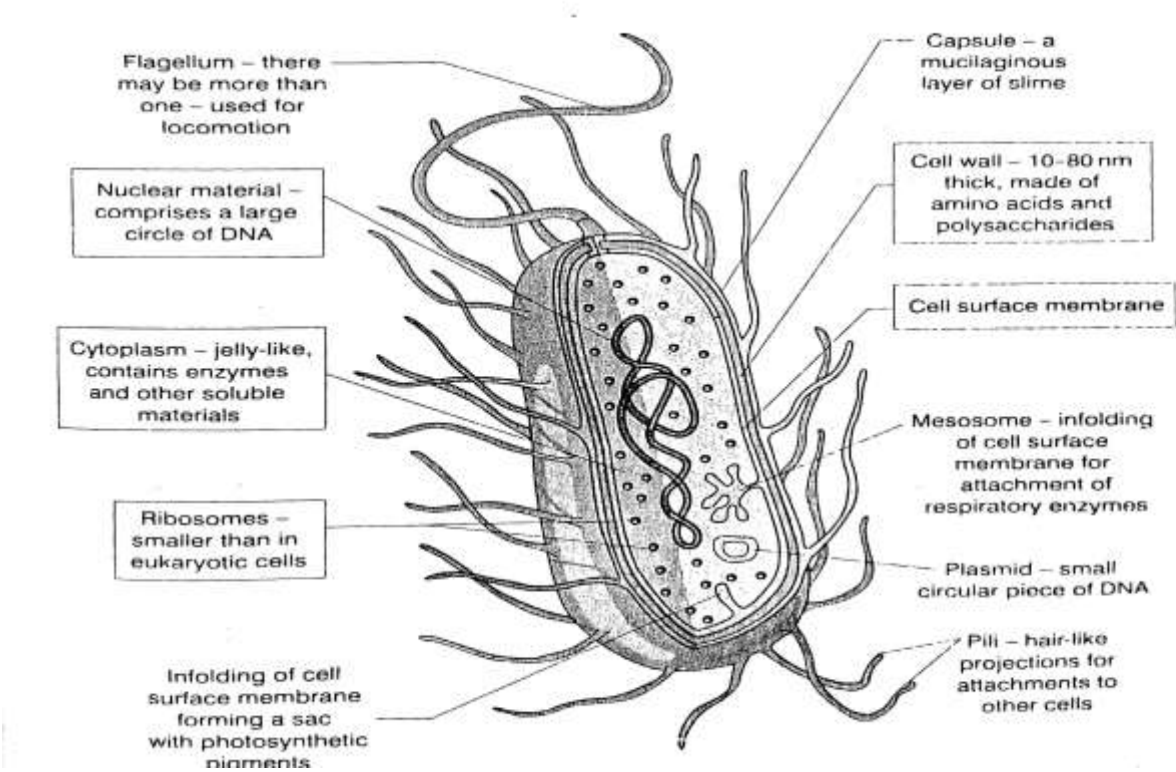
- Streptococci; chains of bacterial cells; eg Streptococcus pneumoniae;✓

- Staphylococci; bunches; eg staphylococcus aureus;✓
- Diplococci; pairs; eg diplococcus pneumoniae;✓
- Tetrad; packets of four; eg pediococcus;✓
- Sarcinae; packets of eight; eg sarcina ureae;✓

Bacillus

- Single bacillus; eg E.coli;✓
- Streptobacillus; chains; e.g. streptobacillus moniliform;✓
- Coccobacilli; short and ovoid; eg haemophilus influenza;✓

Drawing of a prokaryotic cell



KINGDOM PROKARYOTAE/MONERA

Contains two major phyla i.e. eubacteria and cyanobacteria

The Archea-bacteria are not true bacteria/pseudo-bacteria/primitive bacteria and they fall in three categories'.

Methanogens

Thermoacidophils and halophiles

FUNCTONS OF THE PARTS OF A BACTERIUM

PARTS	ROLE(S)
Cell wall	Physical barrier which protects against mechanical damage and exudes certain substances
Capsule	Protects bacterium from other cells eg white blood cells, also helps groups of bacteria to stick together for further protection;
Cellsurface	Differentially permeable layer which controls entry and exit of chemicals;

membrane	
Mesosomes	Provide large surface area for attachment of respiratory enzymes;
Flagellum	For movement of bacterium because its rigid, corkscrew shape and rotating base helps the cell spin through fluids;
Pili	Attachment on surfaces;
Circular DNA	Genetic information for replication of bacteria.
Plasmids	Genes for survival in harsh conditions eg in presence of antibiotics
Ribosomes	70S type for protein synthesis
Glycogen granule	Stores carbohydrate for break down during respiration to provide energy
Lipid droplet	Store lipids as a more concentrated, longer-term, store for conversion to carbohydrate and use in respiration;
Photosynthetic lamellae	Contain enzymes and bacterio- chlorophyll and therefore carry out photosynthesis;

GRAM POSITIVE AND GRAM NEGATIVE BACTERIA

GRAM POSITIVE	GRAM NEGATIVE
Lack lipid layer along their murein;	Have lipid layer along their murein;✓
Affected by antibacterial enzymes/lysozyme;	Not affected by antibacterial enzymes;✓
high concentration of murein	Low concentration of murein
Stain purple with Gram stain/crystal violet solution;	Becomes pink on decolourisation with ethanol;✓
Cell wall is thicker;	Cell wall is thinner;✓

ADAPTATIONS OF BACTERIA

- Capsules and slimy layer/gummy secretions;✓ make them less susceptible to phagocytosis by white blood cells;✓
- Cell wall✓ rigid due to peptidoglycan/murein for support;✓/ prevent osmotic shocks/ Gram negative bacteria have lipid-rich layer covering murein which confers resistance to antibiotics;
- Flagellum;✓long to propel the bacteria along;✓
- Pili/Fimbriae;✓ for cell to surface attachment providing support/cell to cell attachment forming colonies;✓
- Sex pilus;✓sexual reproduction/conjugation;✓
- Mesosomes;✓in folding of the plasma membrane, housing enzymes for respiration/aid in the formation of the new cross wall/facilitates the separation of the two daughter molecules of DNA;✓
- Photosynthetic sacs;✓ tubular/sheet-like containing photosynthetic pigments; for photosynthesis;✓
- Circular DNA;✓containing genes which control the activities of the cell;
- Ribosomes; sites for protein synthesis;✓
- Production of large quantities of spores;✓ which results into rapid multiplications;✓
- Endospores;✓thick walled extremely resistant to harsh condition;✓
- Plasmid;✓extra- chromosomal DNA which confers ability to antibiotics resistance/ use of hydrocarbons/sexual reproduction/ conjugation;✓

- Small in size;✓ decreases nutrient requirements/increasing surface area for diffusion of nutrients into the cell;✓

Endosymbiotic theory/endosymbiogenesis

Evolution of membrane bound organelles is explained by Endosymbiotic theory or endosymbiogenesis;✓Mitochondria and chloroplast were initially independent prokaryotic cells✓ bacteria like organisms which gained access, by accident, to the host cell (larger prokaryotic cell) ✓and entered symbiotic relationship✓Presumably conditions in the cell host were favorable for prokaryote✓ whilst in return the prokaryotes provided increased capacity of cell to form ATP (mitochondria)✓ and chloroplast increased cells capacity to form food.✓

OR

Alternately the organelles may have risen by invaginations of the plasma membrane which became "pinched off" to give separate membrane bound structure within the main cell.

Evidences for the Endosymbiotic theory

- Both mitochondria and chloroplast have naked and circular DNA✓
- Both mitochondria and chloroplast have 70S ribosome✓
- Both mitochondrial and chloroplast protein synthesis are sensitive to antibiotics for example chloramphenical and streptomycin✓
- The ability of the mitochondria and chloroplast to divide themselves/self-replication;✓
- Ribosomes of mitochondria and chloroplasts resemble those of bacteria and cyanobacteria, with respect to size and nucleotide sequence✓
- Mitochondria and chloroplasts reproduce independently of their eukaryotic host cell by a Process similar to the binary fission of bacteria.✓
- The thylakoid membranes of chloroplasts resemble the photosynthetic membranes of cyanobacteria.✓

Advantages conferred due to the presence of membrane organelles

- Potentially harmful reactants or enzymes can be isolated inside organelle✓ so they won't damage the rest of the cell;✓
- The rate of any metabolic pathway inside an organelle can be controlled✓ by regulating the rate at which the membrane surrounding the organelle allows the first reactant to enter.✓
- Containing enzymes for particular metabolic pathway within organelles✓ means product of one reaction will always be at a close proximity to the next enzyme in the sequence.✓
- The organelles increase surface area to volume ratio ✓because as the cells become larger, the proportion of membrane area to cell volume reduced✓.
- Specialization resulting into orderliness and efficiency✓

EUKARYOTIC CELLS

The eukaryotic cells (Greek: *Eu*-true and *karyon*-nucleus) include the protists, fungi, plants and animals including humans. Cells are larger in size.

CHARACTERISTICS

Considerable degree of internal structure with a large number of distinctive membrane enclosed having specific functions

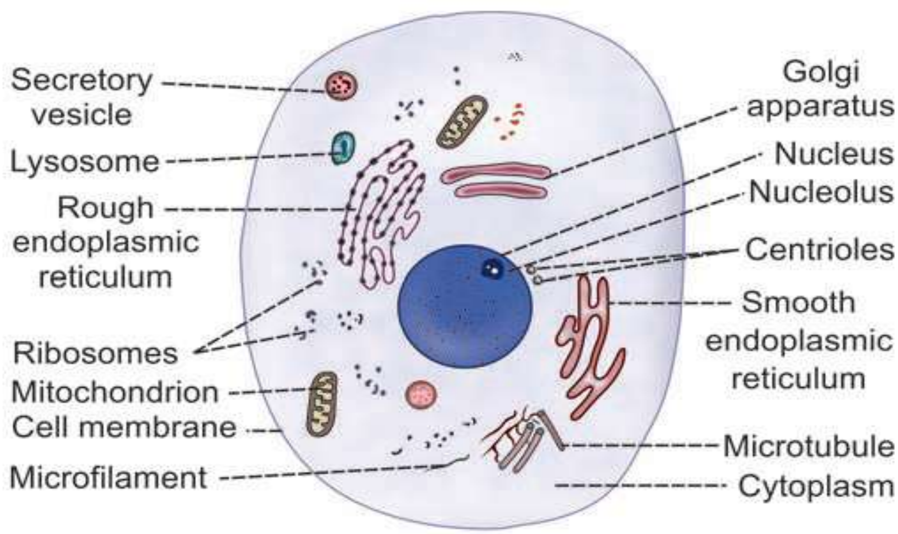
Nucleus is the site for informational components collectively called chromatin

Sexual reproduction involves both mitosis and meiosis

Respiratory site is the mitochondria

In the plant cells, the site of the conversion of radiant energy to chemical energy is the highly structural chloroplasts.

ANIMAL CELL/ULTRASTRUCTURE

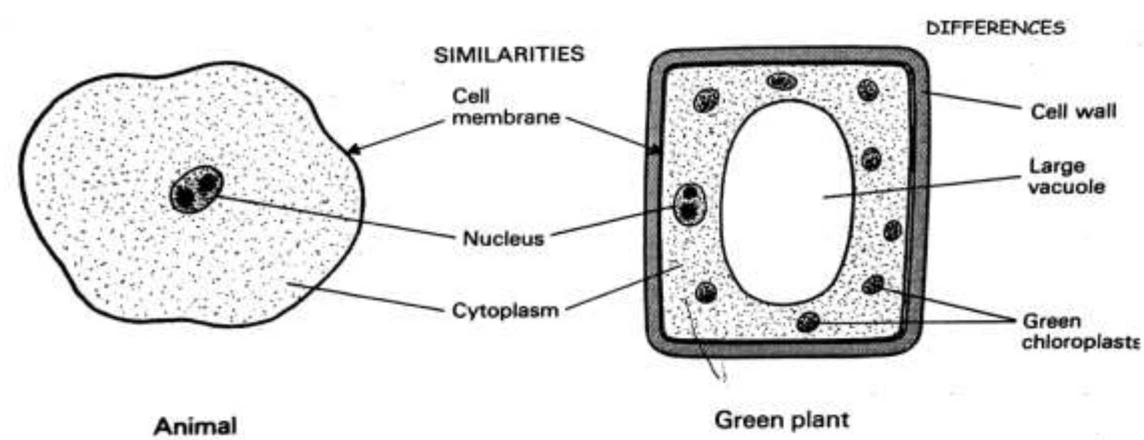


PLANT CELL

These are found in plants

- Cell membrane
- organelles
- Inclusions Cell organelles (i) Nucleus
- Ribosomes
- Endoplasmic reticulum
- (SER/RER)
- Mitochondria (v) Dictyosomes (vi) Microfilaments (vii) Microtubules (viii) Vacuole
- Chloroplasts Cytoplasmic inclusions (i) Starch grains
- Fat droplets

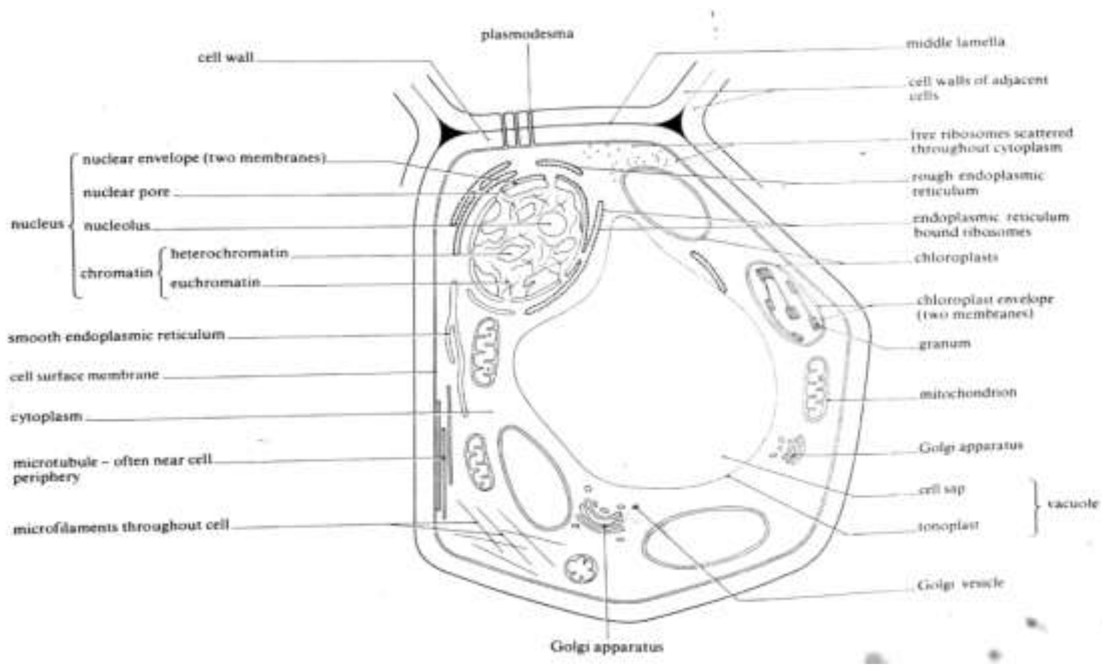
PLANT AND ANIMAL CELL SEEN UNDER LIGHT MICROSCOPE



COMPARISONS

FEATURE	ANIMAL CELL	PLANT CELL
Cell wall	✘	✓
Plastids	✘	✓
Centrioles	✓	✘
Shape	Irregular	✓
Vacuole	small/many	✓/regular
	Glycogen	One large
Food stored	✓	Starch
Vesicles	✓	✘
Cholesterol	✓	✘
Cilia/flagella	✓	✘
plasmodesmata	✘	✓

ULTRA-STRUCTURE OF A PLANT CELL



Comparisons of prokaryotes and eukaryotes

SIMILARITIES

- Both have plasma membrane;✓
- Both have ribosomes;✓
- Both have cytoplasm;✓
- Both are composed of cells;✓
- Both have genetic material, DNA;✓

- Both have cilia and flagella;✓
- Both carry out life processes such as reproduction and photosynthesis;✓
-

DIFFERENCES

	Prokaryotic cell		Eukaryotic cell
1.	Smaller in size 1 to 10 µm	1.	Larger in size 10 to 100 µm or more
2.	Mainly unicellular	2.	Mainly multicellular (with few exceptions). Several different types present
3.	Single membrane, surrounded by rigid cell wall	3.	Lipid bilayer membrane with proteins
4.	Anaerobic or aerobic	4.	Aerobic
5.	Not well defined nucleus, only a nuclear zone with DNA Histones absent	5.	Nucleus well defined, 4 to 6 µm in diameter, contains DNA and surrounded by a perinuclear membrane Histones present
6.	No nuclei	6.	Nucleolus present, rich in RNA
7.	Cytoplasm contains no cell organelles	7.	Membrane bound cell organelles are present
8.	Ribosomes present free in cytoplasm	8.	Ribosomes studded on outer surface of endoplasmic reticulum present
9.	Mitochondria absent. Enzymes of energy metabolism bound to membrane	9.	Mitochondria present Power house of the cell. Enzymes of energy metabolism are located in Mitochondria
10.	Golgi apparatus absent. Storage granules with polysaccharides	10.	Golgi apparatus present—flattened single membrane Vesicles
11.	Lysosomes—absent	11.	Lysosomes present—single membrane vesicle containing packets of hydrolytic enzymes
12.	Cell division usually by fission, no mitosis	12.	Cell division—by mitosis
13.	Cytoskeleton—absent	13.	Cytoskeleton—present
14.	RNA and protein synthesis in same compartment	14.	RNA synthesised and processed in nucleus. Proteins synthesised in cytoplasm
15.	Examples are bacteria, cyanobacteria, rickettsia	15.	Examples: Protists, fungi, plants and animal cells

CELL ORGANELLES

NUCLEUS:

The nucleus contains more than 95 per cent of the cell's DNA and is the control centre of the eukaryotic cell.

- **Nuclear envelope:** A double membrane structure called the nuclear envelope separates the nucleus from the cytosol.
- **Nuclear pore complexes:** These are embedded in the nuclear envelope. These complex structures control the movement of proteins and the nucleic acid ribonucleic acids (RNAs) across the nuclear envelope.
- **Chromatin:** DNA in the nucleus is coiled into a dense mass called chromatin, so named because it is stained darkly with certain dyes. (Euchromatin and heterochromatin)
- **Nucleolus:** A second dense mass closely associated with the inner nuclear envelope is called nucleolus.
- **Nucleoplasm:** Nucleoplasm of nucleus contains various enzymes such as DNA polymerases, and RNA polymerases, for m-RNA and t-RNA synthesis.

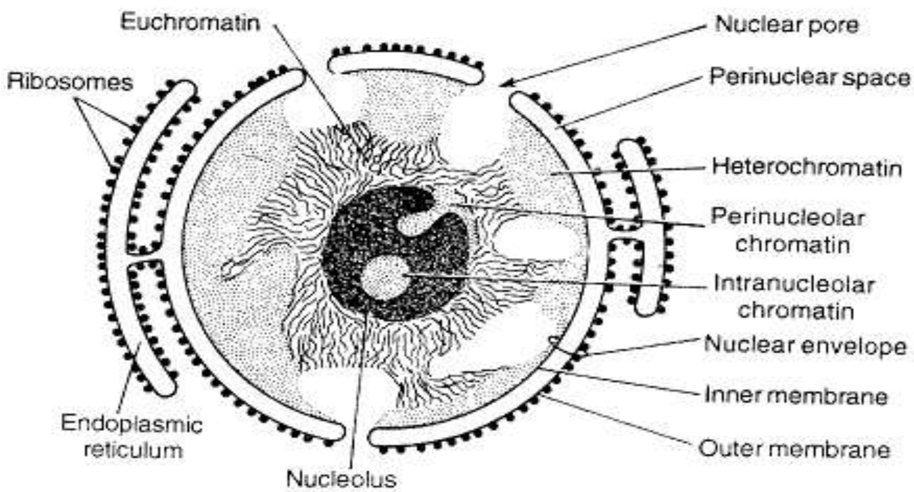
Functions

- DNA replication and RNA transcription of DNA occur in the nucleus. Transcription is the first step in the expression of genetic information and is the major metabolic activity of the nucleus.
- The nucleolus is non-membranous and contains *RNA polymerase*, *RNAase*, *ATPase* and other enzymes but no DNA polymerase. Nucleolus is the site of synthesis of ribosomal

RNA (r-RNA).

- Nucleolus is also the major site where ribosome subunits are assembled.
- Control of the cell division through genes
- Storage of hereditary information (in genes) and transformation of this information from one generation of the species to the next.

Structure of the nucleus



ADAPTATIONS OF THE NUCLEUS

Nuclear envelope; double membrane to regulate materials that enter or leave the nucleus

Nuclear envelope perforated/with pores to allow exchange of materials between the cytoplasm and the nucleus; inner-membrane of the nuclear envelope anchors chromosomes during interphase;

Nucleoplasm; jelly-like material contains chromatins/coils of DNA forming chromosomes that are genetic material/perpetuation of genes;

Nucleolus; spherical bodies; manufacture ribosomal RNA used in assembling of ribosomes

MITOCHONDRION:

Mitochondrion is the power house of cell

VITAL INFORMATION

- Number: The number of mitochondria in a cell varies dramatically. Some algae contain only one mitochondrion, whereas the protozoan Chaos contains half a million. A mammalian liver cell contains from 800 to 2500 mitochondria.
- Size: They vary greatly in size. A typical mammalian mitochondrion has a diameter of 0.2 to 0.8 μ and a length of 0.5 to 1.0 μm.
- Shape: The shape of mitochondrion is not static.
  Mitochondria assume many different shapes under different metabolic conditions.

Structure and Functions

The mitochondrion is bounded by two concentric membranes that have markedly different properties and biological functions

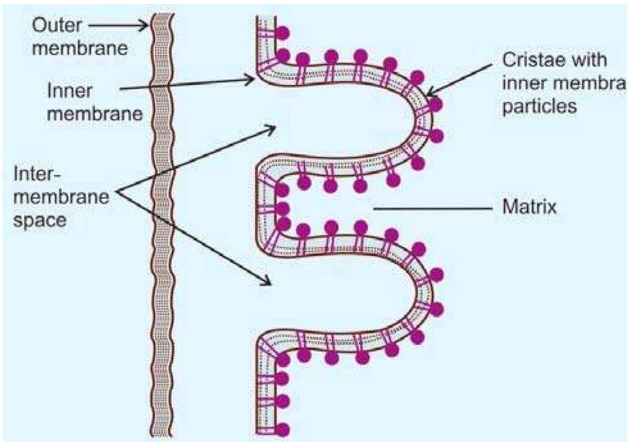
mitochondrial membranes

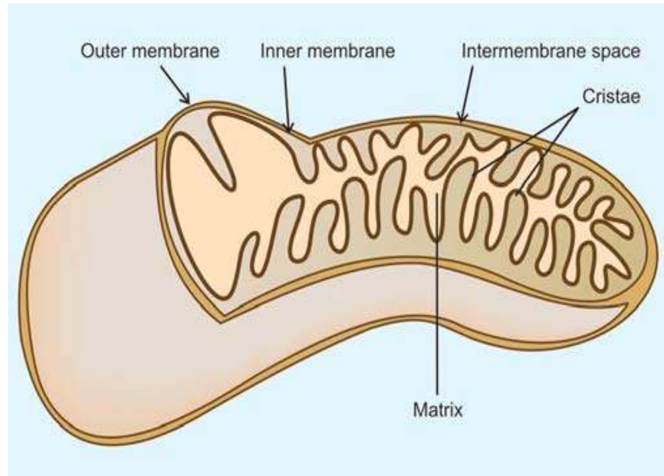
(a) Outer mitochondrial membrane: The outer mitochondrial membrane consists mostly of phospholipids and contains a considerable amount of cholesterol. The outer membrane also contains many copies of the protein called Porin.

functions of Porin and other proteins

(i) These proteins form channels that permit substances with LOW molecular weights of diffuse freely across the outer mitochondrial membrane.

(ii) Other proteins in the outer membrane carry out various reactions in fatty acid and phospholipid biosynthesis and are responsible for some oxidation reactions.





(b) Inner mitochondrial membrane: The inner mitochondrial membrane is very rich in proteins and the ratio of lipid to proteins is only 0.27:1 by weight. It contains high proportion of the phospholipid In contrast to outer membrane; the inner membrane is virtually impermeable to polar and ionic substances. These substances enter the mitochondrion only through the mediation of specific transport proteins.

•**Cristae:** The inner mitochondrial membrane is highly folded. The tightly packed inward folds are called **"Cristae"**.

Functional changes: It is now known that mitochondria undergo dramatic changes when they switch over from resting state to a respiring state. In the respiring state, the inner membrane is not folded into cristae, rather it seems to shrink leaving a much more voluminous inter membrane space.

(c) Intermembrane space: The space between the outer and inner membranes is known as the intermembrane space. Accumulation of hydrogen ions creating EPG forming ATP by chemiosmosis;

(d) Mitochondrial matrix: The region enclosed by the inner membrane is known as the mitochondrial matrix.

COMPOSITION OF MATRIX:

The enzymes responsible for citric acid cycle and fatty acid oxidation are located in the matrix. The matrix also contains several strands of circular DNA, ribosomes and enzymes required for the biosynthesis of the proteins coded in the mitochondrial genome. The mitochondrion is not, however, genetically autonomous, and the genes encoding most mitochondrial proteins are present in nuclear DNA

FUNCTIONS

- Many enzymes associated with carbohydrates, fatty acids and nitrogen metabolism are located within the mitochondrion. Enzymes of electron transport and oxidative phosphorylation are also located in different areas of this cell organelle.
- The mitochondrion is specialized for the rapid oxidation of NADH (reduced NAD) and

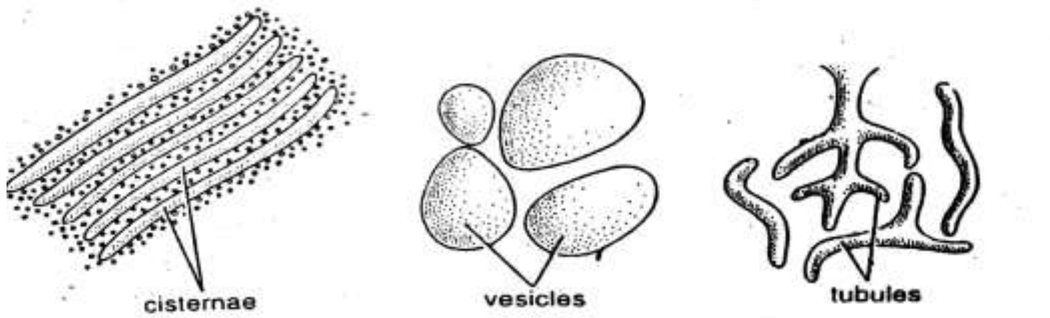
$FADH_2$ (reduced FAD) produced in the reactions of glycolysis, the citric acid cycle and the oxidation of fatty acids. The energy produced is trapped and stored as ATP, for future use of energy in the body

Vital role in Apoptosis; Cytochrome C and second mitochondria-derived activator of caspases (SMAC)/diablo secreted in mitochondria are involved in apoptosis

ENDOPLASMIC RETICULUM

Are the interconnected networks of tubular and flat vesicular structures in the cytoplasm

Morphology of rough endoplasmic reticulum



Morphology of endoplasmic reticulum	Notes
Cisternae	long; flattened; sac-like; straight tubes; arranged in bundles and parallel; exists more in the pancreas/notochord/brain where they perform synthetic roles;
Vesicles;	oval; membrane bound vacuolar structures; abundant in SER;
Tubules	Branched structures forming the reticular system along with cisternae and vesicles;

• Endoplasmic reticulum forms the link between nucleus and cell membrane by connecting the cell membrane at one end and the outer membrane of the nucleus at the other end
• A large number of minute granular particles called ribosomes are attached to the outer surface of many parts of the endoplasmic reticulum, this part of the ER are known as rough or granular ER.
• During the process of cell fractionation, rough ER is disrupted to form small vesicles known as microsomes.
• Part of the ER, which has no attached ribosomes, is known as smooth endoplasmic reticulum

FUNCTIONS OF THE RER

- Production and processing of specific proteins at ribosomal sites, that are later exported
- Folds proteins into three dimensional shape e.g. haemoglobin for further processing e.g. carbohydrates may be added.
- Transports ready proteins to the sites where they are required.
- Checks the quality of proteins formed, especially correct ordering and structure

SER

- **Synthesis of lipids and other steroids like *cholesterol, progesterone and testosterone.***
- **Synthesis and repair of membranes by producing cholesterol and phospholipids,**
- **For metabolism of glycogen in the liver e.g. glucose-6-phosphatase enzyme in SER converts glucose-6-phosphate to glucose.**
- **Contains enzymes that detoxicate lipid- soluble drugs, alcohol and metabolic wastes *from the liver.***
- **SER attaches receptors to cell membrane proteins in plant cells**
- **Sarcoplasmic reticulum regulates muscle contraction through storage and release of calcium ions.**

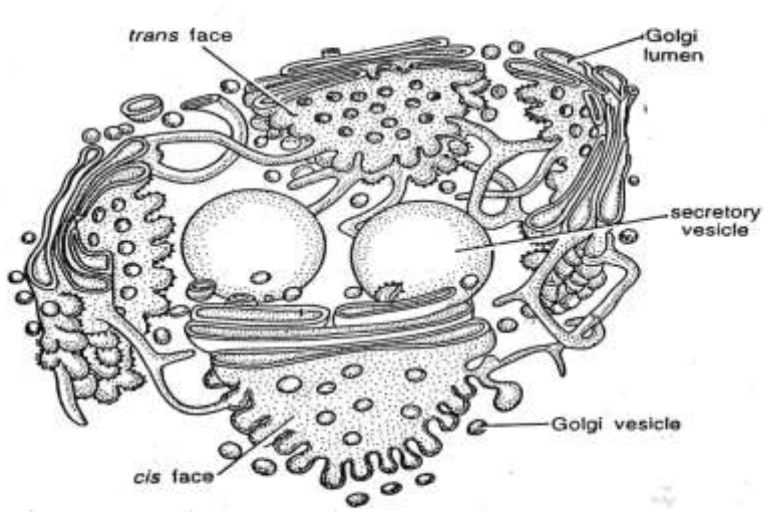
GOLGI COMPLEXES

They are also called Dictyosomes. Each eukaryotic cell contains a unique stack of smooth surfaced compartments or cisternae that make up the Golgi complex. The ER is usually closely associated with the Golgi complexes, which contain flattened, fluid filled Golgi sacs. The Golgi complex has a Proximal or Cis compartment, a medial compartment and a distal or Trans compartment.

FUNCTIONS

(i) **On the proximal or cis side, the Golgi complexes receive the newly synthesised proteins by ER via transfer vesicles.**
(ii) **The post-translational modifications take place in the Golgi lumen (median part) where the carbo hydrates and lipid precursors are added to proteins to form glycoproteins and lipoproteins respectively.**
(iii) **On the distal or Trans side they release proteins via modified membranes called secretory vesicles. These secretory vesicles move to and fuse with the plasma membrane where the contents may be expelled by a process called exocytosis.**

Drawing of the Golgi body



General functions of Golgi body

- To modify, sort and package proteins that are made at the rough
- Endoplasmic reticulum for secretion (export) or for use within the cell.
- To form carbohydrates e.g. polysaccharides are attached to a protein to form proteoglycans present in the extracellular matrix of the animal cell.
- Transport of lipid molecules around the cell.
- Formation of lysosomes containing hydrolytic enzymes.
- Formation of peroxisomes.
- In plant cells, Golgi produces vesicles that join to form cell plates during cell division.
- Secretory vesicles produced by Golgi contain a variety of important substances e.g. neurotransmitters, hormones, mucin, zymogen e.g. pepsinogen, etc.
- Fusion of Golgi vesicles with cell membrane maintains the membrane which is used to form phagocytic vacuoles and Pinocytic vesicles

CELL MEMBRANE

Cell membrane is composed of three types of substances:

1. Proteins (55%)
2. Lipids (40%)
3. Carbohydrates (5%).

MAJOR PROPONENTS OF THE MEMBRANE STRUCTURE

1. Danielli-Davson model

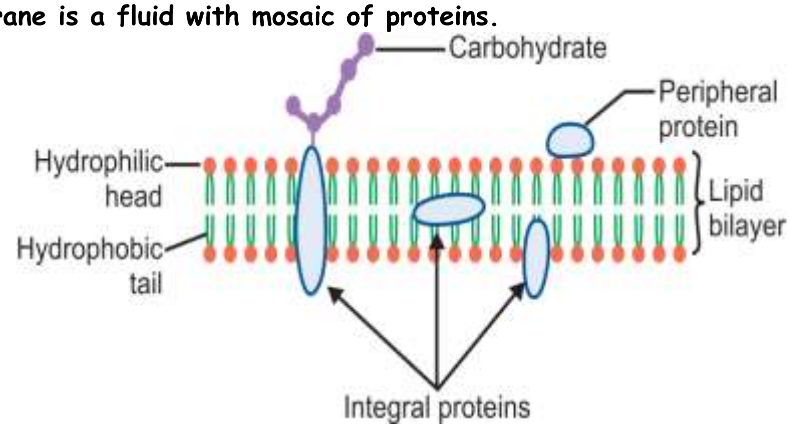
'Danielli-Davson model' was the first proposed basic model of membrane structure. It was proposed by James F Danielli and Hugh Davson in 1935. This model was basically a'sandwich of lipids' covered by proteins on both sides.

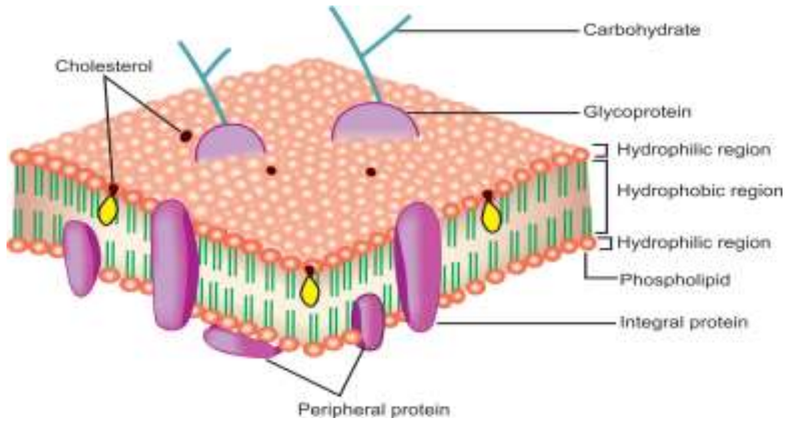
2. Unit membrane model

In 1957, JD Robertson replaced 'Danielli-Davson Model' by 'Unit membrane model' on the basis of electron microscopic studies

3. Fluid mosaic model

Later in 1972, SJ Singer and GL Nicholson proposed 'The fluid mosaic model'. According to them, the membrane is a fluid with mosaic of proteins.





Structure

Bimolecular layer of phospholipids;✓ with inwardly directed hydrophobic tails;✓ and outwardly directed hydrophilic heads;✓ variety of protein molecules with irregular arrangement/mosaic arrangement;✓ some proteins occur on the surface of the phospholipid layer/peripheral/extrinsic;✓ while some extend into it/integral/intrinsic;✓ some extend completely across/transmembrane proteins;✓ present between phospholipids is cholesterol;✓ glycocalyx, glycoproteins and glycolipids;✓ which are antennae like structures at the surface;✓

MEANING OF THE PHRASE "FLUID MOSAIC MODEL "

Fluid because molecules within membrane can move around within their own layer;✓

Mosaic because protein molecules are dotted around within the membrane;✓

Model because no one has seen membrane looking as a diagram and hence it's a representation;✓

EVIDENCES FOR THE FLUID MOSAIC MODEL

Water soluble molecules enter the cell less readily than compounds that dissolve in lipids✓plasma membrane has a higher proportion of lipids;✓

freeze- etching has shown when a membrane is fractured along its mid line globular proteins occur✓ some occur on, some buried in the lipid bilayer, rather than forming sheets of proteins on the surface;✓

Some reactions of proteins in the membrane with enzymes and antibodies✓ have shown that some membrane proteins are exposed on the surface, some are exposed on both surfaces and some inaccessible;✓

Tagging of membrane components with marker substance/fluorescent dye✓ has shown that the molecules of the plasma membrane are on the move membrane is fluid, ever changing;✓

At outer surface of the cell, antennae like carbohydrate molecule form complex with many membrane proteins and lipids✓ and their presence can be shown by addition of non-self-antigen to the cell;✓

DISTRIBUTION AND FUNCTION OF MEMBRANES IN ORGANISMS

- **Plasma membrane;✓ Selective transport in and out of cell/Cell to cell recognition/Antigen presentation/Hormonal signaling/Separating cytoplasm from the rest of the cell✓**
- **Nuclear membrane;✓ Limits DNA/Allows outward diffusion of RNA/Entry of ATP into the nucleoplasm;✓**
- **Mitochondria outer membrane;✓ allows entry of products of glycolysis;✓**

- Mitochondrial inner membrane;✓ Attachment of respiratory enzymes;✓ Attachments of respiratory pigments for electron transport;
- Endoplasmic reticulum membranes;✓ Intracellular transport/Attachment of ribosomes/Synthesis of steroids✓
- Chloroplast outer membrane;✓ allows photosynthetic products out and substrates in✓
- Chloroplast lamellae;✓ Reservoir for photosynthetic pigments;✓
- Golgi membranes;✓ Sorting of ER synthesized material/Synthesis of glycoprotein/Synthesis of polysaccharides e.g. cellulose in plants✓
- Lysosomes;✓ Limiting escape of lytic enzymes✓
- Tonoplast;✓ enclosing cell sap/Selective entry of water and solutes✓
- Phagocytic/ micropinocytic vesicles;✓ Uptake of materials into cells✓
- Root hairs plasma membrane;✓ increasing surface area of epidermal cells✓
- Autolytic/autophagic vacuoles;✓ intracellular digestion✓
- Neurilemma;✓ diffusion of Na+ and K+ allowing electrical polarity✓

FUNCTIONS OF THE CELL MEMBRANE

- Protective function: Cell membrane protects the cytoplasm and the organelles present in the cytoplasm
- Selective permeability: Cell membrane acts as a semipermeable membrane, which allows only some substances to pass through it and acts as a barrier for other substances
- Absorptive function: Nutrients are absorbed into the cell through the cell membrane
- Excretory function: Metabolites and other waste products from the cell are excreted out through the cell membrane
- Exchange of gases: Oxygen enters the cell from the blood and carbon dioxide leaves the cell and enters the blood through the cell membrane
- Maintenance of shape and size of the cell: Cell membrane is responsible for the maintenance of shape and size of the cell.
- Has receptor sites for chemical messengers such as hormones;
- Contain enzymes catalyzing specific reactions;
- Transport proteins carry out transport of molecules such as glucose;

ROLE OF CELL MEMBRANE IN MOVEMENT OF MATERIALS ACROSS IT

- Selective barrier;✓ allowing passage of specific molecules into cells;✓
- Establishment of concentration gradient;✓ determining direction of movement of materials/substances;✓
- Carrier/channel proteins;✓ for movement of materials into and outside cells;✓
- Receptors✓ for binding of materials which have to be moved inside cells;✓
- Non-polar to allow movement of non- polar materials eg steroid hormones;✓
- fluidity/flexibility to allow movement of transport proteins spanning the membrane easily/phagocytosis possible;✓
- Stability to avoid collapse of membrane;✓
- membranes budded off forming vesicles during endocytosis to move materials inside cells;✓
- flexible and fluidity to fuse with other membranes to allow transport of materials✓
- Microvilli;✓ increasing surface area for absorption of materials to be transported;✓

MEMBRANE LIPIDS

The major classes of membrane lipids are:

- Phospholipids
- Glycolipids
- Cholesterol.

They all are amphipathic molecules, i.e. they have both hydrophobic and hydrophilic ends. Membrane lipids spontaneously form bilayer in aqueous medium, burying their hydrophobic tails and leaving their hydrophilic ends exposed to the water

Summary of the functions of the lipids in the plasma membrane

glycolipids	Are involved in cell-to-cell recognition
cholesterol	Stabilizes membrane structure by preventing phospholipids from closely packing together
Lipid bilayer	Being semi-permeable, it controls movement of substances in and out of the cell

Membrane proteins

Channel proteins;✓ provide passageways through the membrane for certain hydrophilic (water-soluble) substances such as polar/charged molecules;✓

Transport proteins/PUMPs;✓ spend energy (ATP) to transfer materials across the membrane active transport/passive transport;✓

Recognition proteins;✓ distinguish the identity of neighboring cells✓

Adhesion proteins;✓ attach cells to neighboring cells/provide anchors for the internal filaments and tubules that give stability to the cell;✓

Receptor proteins;✓ provide binding sites for hormones or other trigger molecules✓

Electron transfer proteins;✓are involved in transferring electrons from one molecule to another during chemical reactions;✓

Integral proteins✓ provide the structural integrity of the cell membrane✓

Enzymes✓ catalyzing specific chemical reactions in membranes✓

Carrier proteins; having receptor sites for binding of molecules to be transported eg glucose;

DATA CONCERNING MEMBRANE COMPONENTS

Membrane	Percentage mass		
	Protein	Lipid	Carbohydrate
A	18	79	3
B	51	49	0
C	52	44	4
D	76	24	0

OBSERVATION

Plasma membrane D has much higher protein content than plasma A

Membrane D is more metabolically active compared to A/membrane A is metabolically inert;✓

COMPARE CELL WALL AND CELL MEMBRANE

Similarities

- Both surround cells;✓
- Both are permeable;✓
- Both are made up of proteins and sugars;✓

Differences

Cell wall	Cell membrane
Thickness normally measured in μm;	Usually measured in nm;✓
Surrounds plant cells/not animal cells;	Surrounds animal cells;✓
Found only outside the cells;	Found either inside or outside cells;✓
Contain cellulose/peptidoglycan/murein in prokaryotes/contain chitin in fungi;	Phospholipids/proteins/cholesterol;✓
Freely permeable;	Partially permeable;✓
Mechanical strength;	Selective barrier;✓
Rigid;	Fluid;✓
Plasmodesmata present	Plasmodesmata absent;
Secondary thickening can occur	No secondary thickening

GLYCOCALYX

Long carbohydrate molecule attached to membrane lipids and proteins

- They play roles such as cell to cell recognition;✓
- Functioning as receptor sites for chemical signals such as hormones;✓
- Binding cells together into tissues;✓
- carbohydrates are negatively charged so limit entry and exit of negatively charged substances;✓

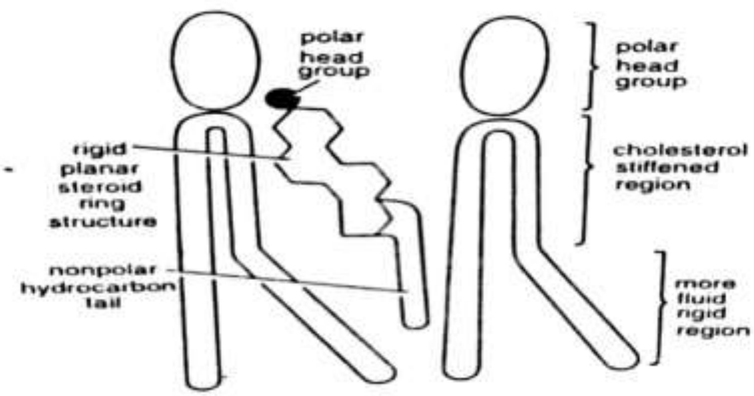
FACTORS AFFECTING FLUIDITY OF THE PLASMA MEMBRANE

- Temperature;✓ high temperature increases fluidity low temperature decreases fluidity;✓
- Length of fatty acids;✓ fluidity increases with decreasing length; long chain decreases fluidity;✓longer chain increases surface area for interactions between adjacent chains increasing vandarwaals forces of attraction
- Unsaturated fatty acids;✓ have kinks in the fatty acid tails which prevents close packing hence increasing fluidity✓ saturated fats lack kinks ;close packing decreasing fluidity;✓
- Cholesterol;✓ between phospholipids inhibits close packing/ at high temperature decreases fluidity low temperature increases fluidity;✓

How cell membrane cholesterol maintains fluidity

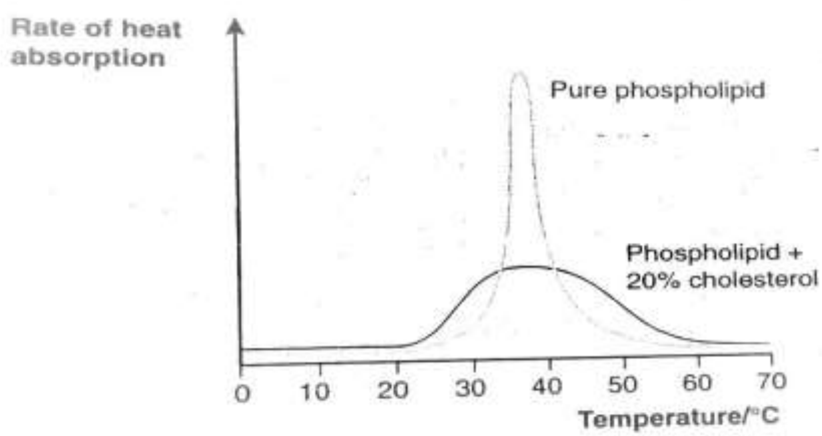
Cholesterol molecules orient themselves in the lipid bilayer in such a way that their hydroxide groups remain close to polar head groups of the phospholipids; their rigid plate-like steroid rings interact with and partly immobilize those regions of hydrocarbon chains that are closet to the polar head groups, leaving chains flexible; cholesterol inhibits phase transition by preventing hydrocarbon chains from coming together and crystallizing.
Cholesterol also tends to decrease the permeability of lipid bilayer to small water-soluble molecules and is thought to enhance both the flexibility and the mechanical stability of bilayer

(Schematic) cholesterol molecules interacting with two phospholipids molecules in a monolayer (after Albert's *etal 1989)*



SYNOPTIC LINK OF MEMBRANE FLUIDITY USING A GRAPH

When phospholipid bilayers are heated, the tail become more mobile at critical transition temperature, they absorb a great deal of heat and become so mobile that they behave like a liquid. The graph below shows the effect of temperature on the heat absorption of a pure phospholipid bilayer and one to which 20% cholesterol has been added.



a) (I) Compare the two graphs one with phospholipids while the other lacking

CLUE: This requires both differences and similarities

Areas of differences and similarities on the graph include

Peak /maximum reached.

- The peak /maximum (do not quote figures)
- How have they reached the peak eg both rise/increase to reach the
- Peak.
- What happens after the peak eg both decline /decrease after the peak?

Trends/patterns which are similar: - Range needed

- Start with the range and units and end with the statement.

Differences:

- Use the words <u>while/ whereas</u> when answering.
- Where range is required write the range and units , then the statement
- Areas of observation recorded as difference include:

<u>The peak/maximum reached</u>

- The levels of the peaks, lower maximum reached and higher maximum reached
- When peaks are reached. (Quote the figure of X-axis and unit) start with statement and then the fig in X-axis/units
- What happens after the peak/maximum reached?

  <u>Trends/patterns which appear different (range needed)</u>
  - The statement must come first and then the range/unit.
  - Levels within a certain range

b (I) how does the phospholipid tail behaving like a liquid affect the permeability of the plasma membrane? (3 marks)

Permeability increases;✓ membrane becomes leaky;✓selectivity of membrane lost;✓

(II) How is this different for the bilayer with 20% cholesterol added?(2 marks)

Permeability reduces with increasing temperature;✓ cholesterol prevents melting of lipids in the membrane;✓

(Iv) Suggest function for cholesterol molecules in plasma membranes. Explain your answer.

Regulating fluidity of the plasma membrane within certain limits;✓ making membrane less fluid at higher temperature✓ and but more fluid at lower ones✓

(V) Importance of fluidity of plasma membrane.

Affects membrane activity✓ such as ease of membranes to fuse;✓ activity of membrane-bound enzymes;✓ and transport proteins✓

<u>PHOSPHOLIPIDS</u>

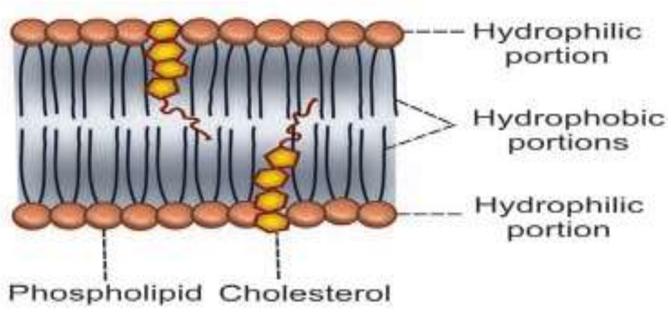
Phospholipids are the lipid substances containing <u>phosphorus</u> and <u>fatty acids.</u>

Phospholipid molecules are arranged in two layers

Each phospholipid molecule resembles the headed pin in shape. The outer part of the phospholipid molecule is called the head portion and the inner portion Is called the tail portion, Head portion is the polar end and it is soluble in Water and has strong affinity for water (hydrophilic). Tail portion is the non-polar end. It is insoluble in water and repelled by water (hydrophobic).

Two layers of phospholipids are arranged in such a way that the hydrophobic tail portions meet in the center of the membrane. Hydrophilic head portions of outer layer face the ECF and those of the inner layer face ICF

<u>PHOSPHOLIPID BI-LAYER STRUCTURE</u>



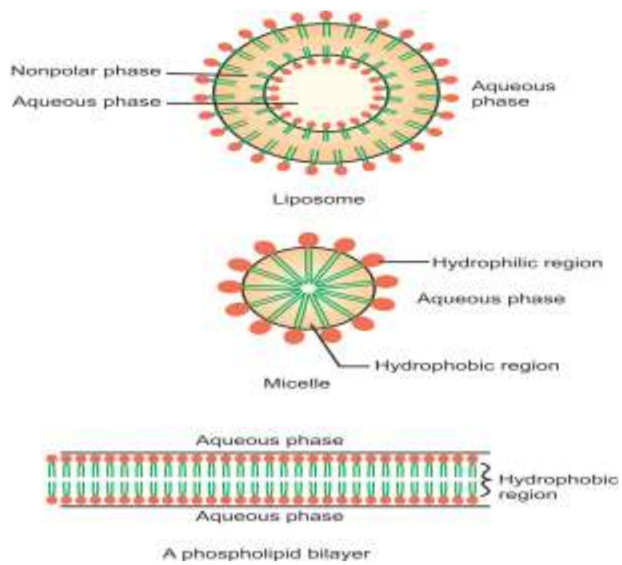
Explain what happens when a thin layer of phospholipids is spread over

Small water quantity

The phospholipid layers orientate themselves in a single monomolecular layer✓ with non-polar hydrophobic tails projecting out of water;✓ whilst the polar hydrophilic heads lie in the surface of water;✓

Large quantities of water and shaken

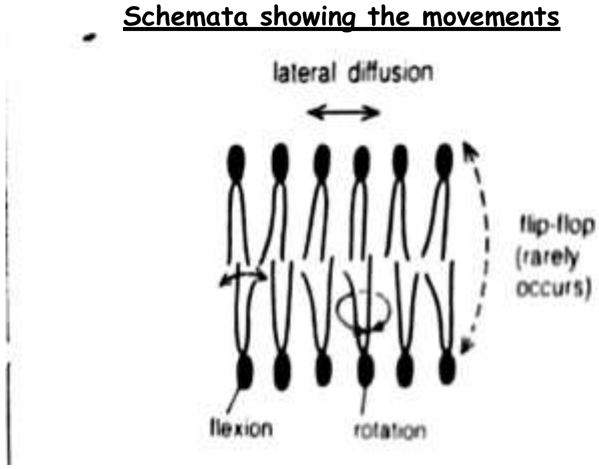
Micelles are formed;✓ in which two layers of lipids occurs/bimolecular layers of phospholipids;✓ with hydrophobic tail pointing inwards away from water and hydrophilic tails projects in water;✓



DESCRIBE THE DIFFERENT TYPES OF MOVEMENTS THAT LIPIDS EXHIBIT IN THE PLASMA MEMBRANE

Flip- flop/transbilayer movement;✓ lipids migrating from one monolayer to another monolayer of lipid bimolecular layer;✓
Lateral diffusion;✓ lipids change places with their neighbors within monolayer;✓
Rotation;✓ rotate rapidly along their longitudinal axes in a monolayer;✓
Flexion;✓ high degree of rotation of lipid hydrocarbons/tails;✓

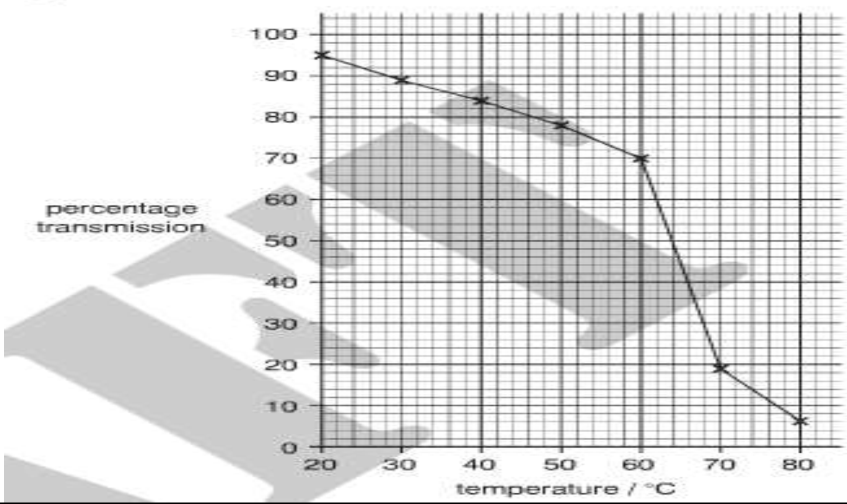
Schemata showing the movements



BACKGROUND OF THE GRAPH

Beetroot tissues contain a carotenoid called Betalain, which escapes on heating due to increased permeability of the cell membrane on heating

Figure 2



RANGE	REASON(S)
From 0^0c to 60^0c; gradual decrease in percentage transmission;	Increased temperature increases KINETIC energy of the proteins and lipids hence move faster and with more energy; leave gaps in the Tonoplast/vacuolar membrane; more permeable hence Betalain is lost making water coloured/red; reducing transmission.
From 60^0c to 70°c; rapid decrease in transmission	Proteins lose their shape due to breakage of hydrogen bond making them; denatured making protein channels bigger; much Betalain is lost; high temperature increases rate of diffusion of Betalain/melting of phospholipids creating big gaps;
From 70°c to 80°c;slight/gradual decrease in transmission	Cell integrity completely lost/structure lost due to very high temperature hence less Betalain lost

Effects of the membrane fluidity

• As membrane fluidity increases, its permeability to water and other small hydrophilic molecules also increases.
• As fluidity increases, the lateral mobility of integral proteins also increases.

Peroxisomes/Microbodies

• These organelles resemble the lysosomes in their appearance, but they differ both in function and in their synthesis.

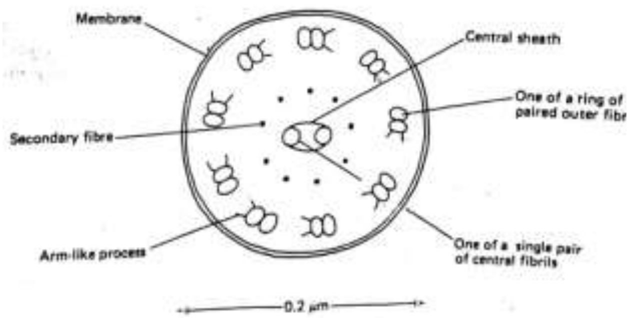
Functions of peroxisomes

• Peroxisomes contain enzymes peroxidases and catalase which are concerned with the metabolism of peroxide. Thus, the peroxisomes are involved in the detoxification of peroxide.
• Peroxisomes are also capable of carrying out β-oxidation of fatty acid.
Glyoxysomes contain enzymes that degrade lipids into sugars during seed germination.

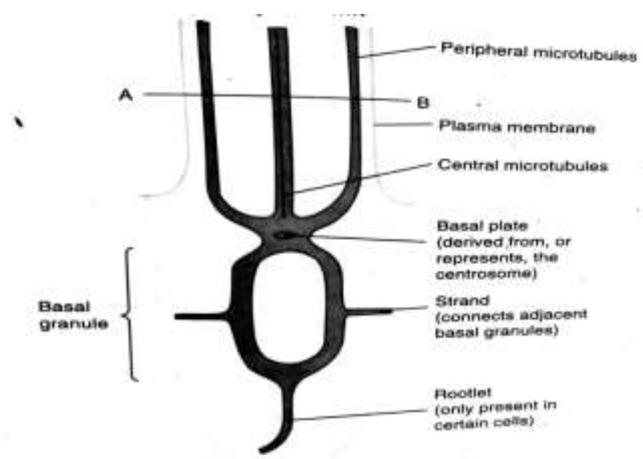
CILIA AND FLAGELLA

structure of cilium

Microtubules;✓ a pair of central singlets;✓ surrounded by nine peripheral doublets/ring of nine paired ones;✓ with arm-like process;✓ 9+2 array/pattern;✓ surrounded by cell surface membrane;✓ each peripheral filaments consists of an A and B microtubule;✓ A microtubule has protein dynein/ATpase;✓ central filaments connected to microtubule A by radial spokes;✓



(CROSS-SECTION)



(LONGITUDINAL-SECTION)

Compare cilia and flagella

Similarities

- Both have 9+2 array/pattern;✓
- Both are used for locomotion;✓
- Both are surrounded by cell membrane;✓
- Both are microscopic;✓
- Both are contractile;✓
- Both are filamentous;✓

Differences

Cilia	Flagella
More Numerous;	Fewer/less in number;✓
May occur throughout the surface of the cell;	Occur at one end of the cell;✓
Shorter processes;	Longer processes;✓
Beat in coordinated rhythm;	Beat independently;✓
Sweeping/pendular motion;	Undulatory motion;✓
Other functions such as feeding/circulation/sensory;	Locomotory functions only;✓

FUNCTIONS OF CILIA AND FLAGELLA

- Ciliary movement enables paramecium to drive food into their gullet.
- In certain mulluscs Ciliary movement facilitates gaseous exchange by passing water currents over the gills
- In echinoderms Ciliary movement enables locomotion by driving water through the water

vascular system.

- Cilia lining the respiratory tract of humans' drives away the microbes and dust particles towards the nose or mouth.
- Cilia in the oviduct or fallopian tubes of human female moves ova towards the uterus.
- Cilia in nephridia of annelids e.g. earthworms moves wastes
- Flagellum of sperms enables their swimming movement.
- Flagellum enables the movement in certain protozoans like euglena

CYTOSKELETONS

The cytoplasm of most eukaryotic cells contains network of protein filaments that interact extensively with each other and with the component of the plasma membrane.

The plasma membrane is anchored to the cytoskeleton. The cytoskeleton is not a rigid permanent framework of the cell but is a dynamic, changing structure.

• The cytoskeleton consists of three primary protein filaments:

1. Microfilaments
2. Microtubules
3. Intermediate filaments.

MICROFILAMENTS

Are about 5 nm in diameter. They are made up of protein actin. Actin filaments form a meshwork just underlying the plasma membrane of cells and are referred to as cell cortex, which is labile. They disappear as cell motility increases or upon malignant transformation of cells. The function of microfilaments to help muscle contraction

MICROTUBULES

are cylindrical tubes,20 to 25 nm in diameter, made up of protein tubulin.

Microtubules are necessary for the formation and function of mitotic spindle.

They provide stability to the cell.

They prevent tubules of ER from collapsing.

These are the major components of axons and dendrites.

INTERMEDIATE

Filaments are so called as their diameter (10 nm) is intermediate between that of microfilaments (5 nm) and of microtubules (25 nm).

Intermediate filaments are formed from fibrous protein which varies with different tissue type.

They play role in cell-to-cell attachment and help to stabilize the epithelium. They provide strength and rigidity to axons/connect adjacent cells through desmosomes

Subclasses of intermediate filaments

Intermediate filaments are divided into five subclasses:

i. Keratins (in epithelial cells)

ii. Glial filaments (in astrocytes)

iii. Neurofilaments (in nerve cells)

iv. Vimentin (in many types of cells)

v. Desmin (in muscle fibers).

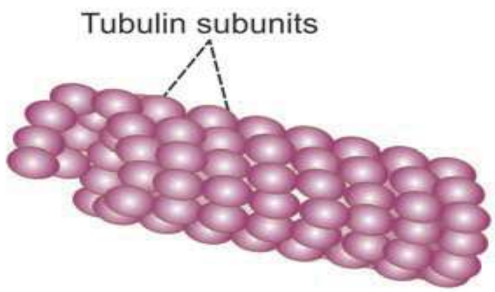
Functions of the cytoskeletons

- The cytoskeleton gives cells their characteristic shape and form, provides attachment points for organelles, fixing their location in cells and also makes communication between parts of the cell possible.
- It is also responsible for the separation of chromosomes during cell division.

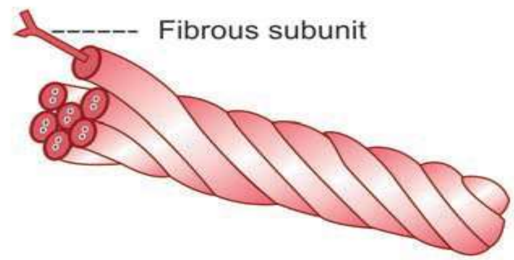
- **The internal movement of the cell organelles as well as cell locomotion and muscle fiber contraction could not take place without the cytoskeleton. It acts as <u>"track"</u> on which cells can move organelles, chromosomes**

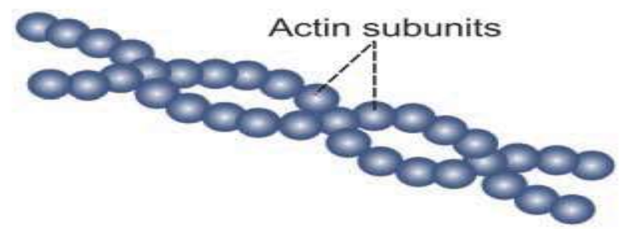
<u>Drawing of a microtubes</u>

Microtubes



intermediate filaments





((Microfilament)

<u>CELL WALL (not an organelle)</u>

The cell wall is differentiated into three layers

- **Primary cell wall**
- **Secondary cell wall**
- **Tertiary cell wall**

<u>COMPARISONS</u>

Primary cell wall	Secondary cell wall	Tertiary cell wall
Outermost layer of cell wall;✓	Found below primary cell wall;✓	Found below secondary cell wall;✓
Comparatively thin and elastic, delicate and permeable;✓	Comparatively thick, and impermeable;✓	Thicker than secondary;✓
Found in meristemic, young and paranchymatous cells;✓	Found in mature and permanent cells;✓	Found in tracheids and mature gymnosperms;✓
Made up of cellulose;✓	Cellulose, pectin, lignin, and other substances;✓	Made up of Xylan;✓
Simple and smooth;✓	Simple;✓	Forms fingerlike process by evagination of the cell wall;✓

DESCRIPTION OF THE CELL WALL STRUCTURE

The cell wall is made up of primary cell wall, middle lamellae, secondary cell wall and tertiary cell wall; primary cell wall consists of cellulose microfibrils running through matrix of polysaccharide; pectates and hemicellulose; deposited on either sides of the middle lamellae; microfibrils run in all directions; portion of the endoplasmic reticulum is trapped across the middle lamellae and forms the plasmodesma; outermost layer; comparatively thin; elastic; delicate and permeable; simple and smooth; secondary cell wall; formed by further deposition of cellulose on the inside of the primary cell wall; microfibrils tightly packed; thicker; impermeable; found below primary cell wall; cellulose cell walls oriented in the direction of the cell elongation; impregnated with cutin/suberin.

Tertiary cell wall; found below secondary cell wall; thicker than secondary and primary; found in tracheids and gymnosperms; impregnated with XYLAN.

CHEMICAL CHANGES THAT OCCUR DURING CELL WALL GROWTH

- Lignifications;✓ deposition of lignin on cell wall;✓
- cutinization;✓ conversion of cellulose into cutin in the cell wall;✓
- suberisation;✓deposition of suberin on the cork cell walls;✓
- Mineralization;✓deposition of mineral substances such as silica, calcium carbonate and calcium oxalate;✓
- mucilaginous changes;✓cellulose cell wall is converted into mucilage; Eg bacteria;✓

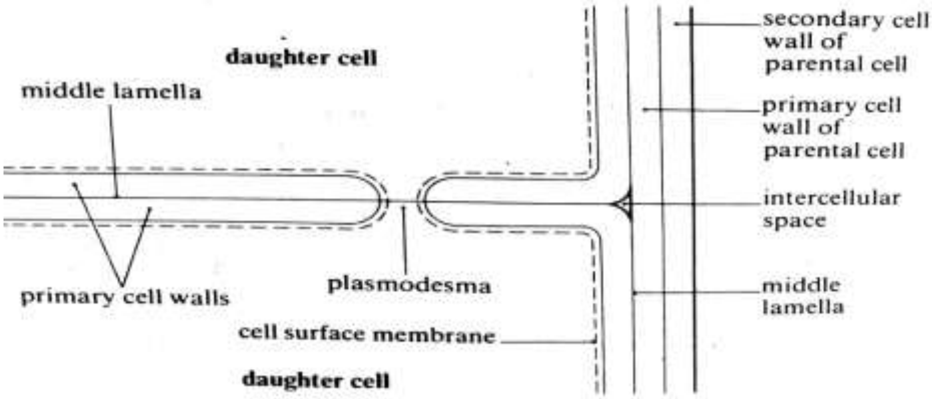
FUNCTIONS OF THE CELL WALL

- Mechanical strength and skeletal support provided for individual cells and for the plant as a whole; due to extensive lignification;
- Cell walls resistant to expansion and allow development of turgidity as a result of osmotic influx of water molecules;
- Orientation of the cellulose microfibrils limits cell growth and shape;
- System of interconnected cellulose cell walls/apoplast; functions as a major pathway of transport of water and dissolved salts; plasmodesmata in cell walls for symplast pathway;
- Develop coating of waxy cutin/cuticle; epidermal cells reducing water loss and risk of infections; cork cells are impregnated by suberin to prevent desiccation;
- Walls of the xylem vessels/tracheids and sieve tubes are adapted for long distance transport of materials through cells;
- Cell walls of endodermal cells are impregnated by suberin forming barrier to water movement;
- Cell walls modified for as food reserves; as in storage of hemicellulose in seeds;
- Cell walls of transfer cells develop an increased surface area for active loading of solutes into sieve tubes;

STAGES OF FORMATION OF THE CELLULOSE CELL WALL

in plant cells the spindle fibres begin to disappear during telophase everywhere except in the region of the equatorial plane; move outwards in diameter and increase in number to form a barrel-shaped phragmoplast; microtubes, ribosomes, mitochondria, endoplasmic reticulum and Golgi body which produce number of fluid filled vesicles, appear in the centre of the cell; coalescence to form a cell plate which grows across equatorial plane; the contents of the vesicles contribute to the new middle lamella and the cell walls of the new daughter cells; membranes form new cell membrane; the spreading cell plate eventually fuses with parent cell walls. The new cell wall formed called primary cell wall; thickened at later stage further with cellulose and other substances such as lignin and suberin to form secondary cell wall; in certain areas the vesicles fail to fuse and cytoplasmic contact remain between daughter cells. These cytoplasmic channels are lined by the cell surface membrane and form plasmodesmata;

Structure of the plant cell wall formed as a result of cytokinesis



ADAPTATIONS OF THE CELL WALL

Cellulose fibres running parallel allowing maximum formation of the hydrogen bonds giving the cell wall high tensile strength/effect is cumulative Thick cell wall made up of three layers making it strong/tough to resists bursting due to osmotic influx of water molecules Secondary walls may be cutinized / suberinised for preventing water loss/desiccation as a result of high temperature The cellulose microfibrils group forming macrofibrils which allow them to give much support Primary cell wall is flexible to allow expansion as water enters by osmosis

LYSOSOMES

Lysosomes are the membrane-bound vesicular organelles found throughout the cytoplasm. The lysosomes are formed by Golgi apparatus. The enzymes synthesized in rough endoplasmic reticulum are processed and packed in the form of small vesicles in the Golgi apparatus. Then, these vesicles are pinched off from Golgi apparatus and become the lysosomes. Among the organelles of the cytoplasm, the lysosomes have the thickest covering membrane. The membrane is formed by a bilayered lipid material. It has many small granules which contain hydrolytic enzymes.

Types of Lysosomes

Lysosomes are of two types:

1. Primary lysosome, which is pinched off from Golgi apparatus. It is inactive in spite of having hydrolytic enzymes
2. Secondary lysosome, which is the active lysosome. It is formed by the fusion of a primary lysosome with phagosome or endosome.

Important lysosomal enzymes

1. Proteases, which hydrolyze the proteins into amino acids
2. Lipases, which hydrolyze the lipids into fatty acids and glycerides
3. Amylases, which hydrolyze the polysaccharides into glucose
4. Nucleases, which hydrolyze the nucleic acids into mononucleotides.

Mechanism of lysosomal function

Lysosomal functions involve two mechanisms:

1. Heterophagy: Digestion of extracellular materials engulfed by the cell via endocytosis
2. Autophagy: Digestion of intracellular materials such as worn-out cytoplasmic organelles.

Specific functions of lysosomes

1. Degradation of macromolecules

Macromolecules are engulfed by the cell by means of endocytosis (phagocytosis, pinocytosis or receptor mediated endocytosis. The macromolecules such as bacteria, engulfed by the cell via phagocytosis are called phagosome or vacuoles. The other macromolecules taken inside via pinocytosis or receptor-mediated endocytosis are called endosomes.
The primary lysosome fuses with the phagosome or endosome to form the secondary lysosome. The pH in the secondary lysosome becomes acidic and the lysosomal enzymes are activated. The bacteria and the other macromolecules are digested and degraded by these enzymes. The secondary lysosome containing these degraded waste products moves through cytoplasm and fuses with cell membrane. Now the waste products are eliminated by exocytosis.

2. Degradation of worn-out organelles

The rough endoplasmic reticulum wraps itself around the worn-out organelles like mitochondria and forms the vacuoles called autophagosomes. One primary lysosome fuses with one autophagosome to form the secondary lysosome. The enzymes in the secondary lysosome are activated. Now, these enzymes digest the contents of autophagosome.

3. Removal of excess secretory products in the cells

Lysosomes in the cells of the secretory glands remove the excess secretory products by degrading the secretory granules.

4. Secretory function – secretory lysosomes having secretory function called secretory lysosomes are found in some of the cells, particularly in the cells of immune system. The conventional lysosomes are modified into secretory
Lysosomes by combining with secretory granules (which contain the particular secretory product of the cell)

Examples of secretory lysosomes:

i. Lysosomes in the cytotoxic T lymphocytes and natural killer (NK) cells secrete perforin and granzymes, which destroy both viral-infected cells and tumor cells. Perforin is a pore-forming protein that initiates cell death. Granzymes belong to the family of serine proteases (enzymes that dislodge the peptide bonds of the proteins) and cause the cell death by apoptosis

ii. Secretory lysosomes of melanocytes secrete melanin

iii. Secretory lysosomes of mast cells secrete serotonin, which is a vasoconstrictor substance and inflammatory mediator.

5. Role in fertilisation; Acrosome in spermatozoa releases enzymes which digest the limiting membrane of the ovum to enable sperm entry and start fertilization. The lysosome in cytoplasm of Ova enables digestion of stored food
6. Role in development; Tadpole metamorphosis (regression of tail) and regression of Wolffian ducts involve shedding of tissues with removal of whole cells and extracellular material by lysosome enzymes during bone development, osteoclasts release lysosomal enzymes that remodel bones.
7. Autolysis. Primary lysosome releases hydrolytic enzymes within a dead cell to digest the whole cell.

ROLE OF LYSOSOMES IN SECRETION OF THYROXINE

The cells making up the thyroid glands are stimulated by the thyroid stimulating hormone to take up thyroglobulin by pinocytosis forming Pinocytic vesicles which fuse with primary lysosome and thyroglobulin is hydrolysed to produce active enzyme thyroxine before lysosomes fuse with the cell surface membrane thus secreting the hormone into the blood

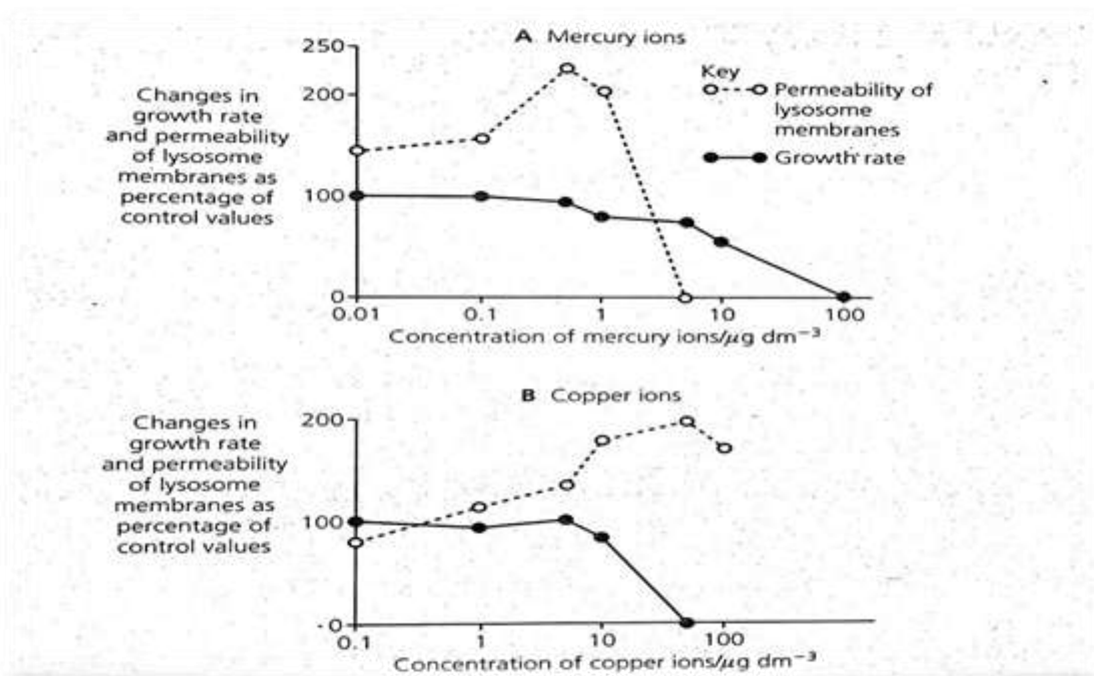
FACTS CONCERNING LYSOSOMES

Size: Mean diameter is approximately 0.4 (varies in between that of microsomes and mitochondria). They are surrounded by a lipoprotein membrane.

- Lysosomes are found in all animal cells, except erythrocytes, in varying numbers and types.
- PH: pH inside the lysosomes is lower than that of cytosol. The lysosomal enzymes have an optimal pH around 5. Acid phosphatase is used as a marker enzyme for this organelle

STUDY THE GRAPH BELOW

The graph below shows changes in the growth rate of C.Hexvosa and in the permeability of its lysosomal membrane following an increase in concentration of copper and mercury ions. The figures are expressed as percentages of those in the controls



a) Compare the effect of the concentration of copper ions and mercury ions on the rate
   (I) growth rate
   (II) Permeability
b) Explain the relationship between the concentration of copper ions and the permeability of the lysosomal membrane
c) Suggest how the controls in the investigation should have been treated
d) It has been suggested that the measuring of the permeability of lysosome membranes may be useful than measuring growth rate when monitoring copper pollution. Describe the evidence from graph B which supports the suggestion
e) From the graph give one disadvantage of using membrane permeability to monitor copper pollution

f)

CHLOROPLAST

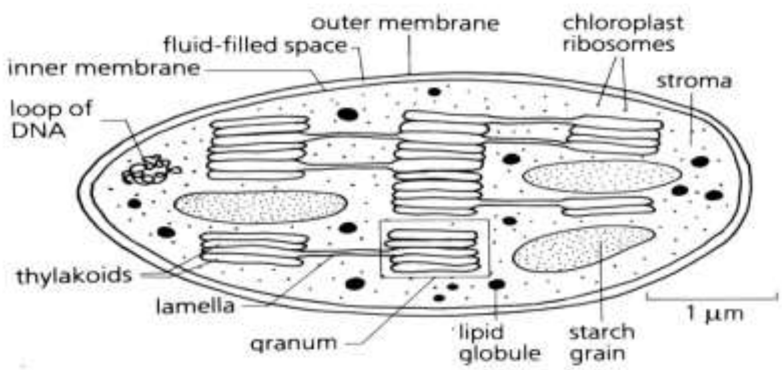
Chloroplast envelope; double membrane; controls entry and exit of materials in and out of the chloroplast;

Stroma; colourless gelatinous matrix containing enzymes responsible for the light independent stage of photosynthesis; Contains 70S ribosome, circular DNA and oil droplets;

Grana; structures look like a stack of coins; 50 grana make up a chloroplast; have flattened discs, thylakoid discs; where chlorophyll molecules are attached; grana carry out light dependent stage of photosynthesis in which energy inform of ATP is made;

Starch granules are temporary store of carbohydrates made during photosynthesis

Structure of the chloroplast



Similarities between the chloroplast and mitochondria

- Both are enclosed by double membranes;✓
- Both contain circular DNA;✓
- Both contain 70S ribosomes;✓
- Both produce ATP by chemiosmosis;✓
- Both lack nuclear envelope;✓
- Both their inner membrane is folded;✓
- Both occur in eukaryotic cells;✓

Differences

CHLOROPLAST	MITOCHONDRION
Site of photosynthesis;	Site for respiration;✓
Contains thylakoid membranes;	Lacks thylakoid membranes;✓
ATP production from light;	ATP production from oxidation of organic compounds;✓
Cristae absent;	Cristae present;✓
Contains photosynthetic pigments;	Lacks photosynthetic pigments;✓
Has starch granules;	Has phosphate granules;✓
Matrix is gelatinous;	Matrix is semi-rigid;✓
Found only higher plants;	Found in both plants and animals;✓

ADAPTATIONS OF THE CHLOPLASTS TO CARRY OUT LIGHT DEPEDENT AND INDEPENDENT STAGE

- Granal membranes✓ provide a large surface area for the attachment of photosynthetic pigments (chlorophyll and carotenoids)/electron carriers and enzymes that carry out dark reaction;✓
- A network of proteins in the grana✓ that hold the photosynthetic pigments in a precise manner forming photosystems allowing maximum absorption of light;✓
- Grana membranes have ATP synthase enzyme✓ which manufacture ATP by chemiosmosis;✓
- The fluid of stroma houses all enzymes needed for Calvin cycle;✓
- The stroma fluid of surrounds the grana✓ so the products of light-dependent reactions in the grana can easily reach/pass into the stroma;✓
- Chloroplasts contain DNA and ribosomes✓ so they can quickly manufacture some proteins needed for photosynthesis;✓

PLASTIDS

Plastids are organelles in plant cells that develop from small bodies, proplastids; found in the meristemic regions;

PLASTIDS	NOTES
Chloroplasts;	Contain chlorophyll and carotenoid pigments; carry out photosynthesis; found mainly in leaves;
Chromoplasts;	Non- photosynthetic colored plastids containing red, green pigments; usually associated with fruits and flowers in which bright colours serve to attract insects/birds and other mammals;
Leucoplasts;	Colorless plastids/ lacking pigments; modified for food storage such as roots/seeds and young leaves; can be further classified basing on stored food eg amyloplasts stores starch; lipdoplast/elaioplasts/oleoplasts store lipids; and proteoplasts store proteins;

VACUOLES

Plant vacuoles are large, sac-like structures in which a single membrane called Tonoplast encloses a fluid called cell sap, containing water and various dissolved substances.

Functions of vacuoles

- The Tonoplast isolates the vacuolar sap from the cytosol, enabling vacuolar pathway of water.
- Vacuoles in some flowers have coloured pigments that give petals bright coloured for attracting pollinators.
- Serve as stores of reserve food, secretory products or waste products.
- It stores salts, nutrients, minerals, pigments, proteins etc.
- It maintains cell turgor by osmotic uptake of water since vacuolar sap has a higher solute concentration than cytosol.
- In meristemic cells, vacuoles bring about growth by initiating cell elongation.

- Serve as stores of waste products like tannins, which are excreted when leaves fall.
- In fresh water protozoans like amoeba and paramecium, contractile vacuoles regulate the water content of cells.
- Food vacuoles formed by phagocytosis (endosomes/phagosome) enable bulk intake of food.

RIBOSOMES

DISTRIBUTION AND OCCURANCE

Ribosomes occur in both prokaryotic and eukaryotic cells; in prokaryotic cells the ribosomes are freely in the cytoplasm and the eukaryotic ribosomes are freely attached on the outer surface of the endoplasmic reticulum; yeast cells/reticulocytes/lymphocytes/meristemic tissues/embryonic nerve cells have large numbers of ribosomes in their cytoplasm;

TYPES OF RIBOSOMES

70S ribosomes; smaller in size and have low sedimentation coefficient; and molecular weight of 2.7x106 Daltons/unit of molecular weight

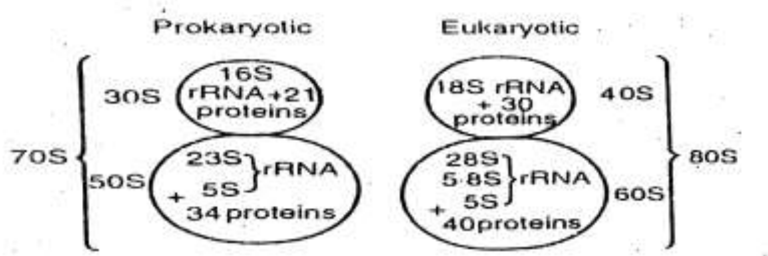
80S ribosome; have sedimentation coefficient of 80S and molecular weight of 40×10^6daltons

Structure of ribosomes

Oblate spheroid structures (hydrated/porous); two subunits; one larger subunit is larger and has dome shape-like shape; while other is smaller with cap-like shape;70S consists of 50S and 30S subunits and 80S consist of60S and 40S subunits;

ROLE: sites for protein synthesis

The diagram below shows the chemical composition of the ribosomes



CYTOPLASM

Jellylike material formed by 80% of water. It contains a clear liquid portion called cytosol and proteins, carbohydrates, lipids or electrolytes in nature. Cytoplasm also contains many organelles with distinct structure

Cytoplasm is made up of two zones:

1. Ectoplasm: Peripheral part of cytoplasm, situated just beneath the cell membrane
2. Endoplasm: Inner part of cytoplasm, interposed between the ectoplasm and the nucleus.

ROLES OF THE CYTOPLASM

Store of vital materials such as salts/sugars/ions/vitamins

Ground substance is a site for metabolic pathway; eg glycolysis/synthesis of fatty acids/nucleotides/aminocids

Movement of organelles by cytoplasmic streaming;

Cytosol also contains free ribosomes often in the polysomes form. They contain many different types of proteins and ribosomal RNA or r-RNA.

ORGANELLES INVOLVED IN THE PRODUCTION AND SYNTHESIS OF ENZYMES

Nucleus;✓contains DNA;✓template for different mRNA coding for different enzymes;✓

Mitochondria;✓supplies energy inform of ATP;✓

Rough endoplasmic reticulum;✓ supports ribosomes;✓transports proteins made by ribosomes;✓ proteins fold into 3-D structure inside membranes;✓

Golgi body;✓modifies proteins ✓;(remolding the carbohydrate antennae to become markers); packages proteins;✓ budded off as vesicles;✓ fuse with plasma membrane to discharge the content to the outside;✓

MICRO-VILLI

Finger-like projections/extensions of the cell membrane of some animal cells; found on the epithelia/simple brush boarded columnar epithelia; increase surface area for absorption of substances such as nutrients. They are lining the intestinal epithelium and kidney tubule epithelium; consists of the actin and myosin forming terminal web; which ensures upright posture and shape; and the interaction between myosin and actin allow movements/backward and forward movement; they can also be associated with enzymes.

Plant cells lack microvilli because their rigid cell walls impose restrictions on extensions of the cell surface membrane but the cell surface membrane area is increased by the intuckings of the transfer cells for transport of materials

CENTROSOME AND CENTRIOLES

Centrosome is the membrane-bound cellular organelle situated almost in the center of cell, close to nucleus. It consists of two cylindrical; hollow; long paired structures called centrioles which are made up of proteins. Centrioles are responsible for the movement of chromosomes during cell division..

Cellular organization - centrosomes are involved in organizing microtubules, whose position determines position of organelles e.g. nucleus (M.T.O.C)

Blepharoplasts/Kinetosomes originate due to replication of the centrioles; and hence vital in formation of cilia and flagella.

Structure: Two cylinders, held at right angle to each other, each about 0.3μm-0.5μm long and 0.24μm in diameter, made of nine triplets of microtubules arranged in a ring in a 9+0 pattern.

PROSIBLE QUESTIONS IN CYTOLOGY AND THEIR RESPONSES

1) Explain how the plasma membrane permits interaction with the outside environment.

plasma membrane is a selectively permeable membrane;✓ Small molecules, like H_2, O_2, and CO_2 readily diffuse through the membrane✓Channel proteins✓ provide passage for certain dissolved substances✓Transport proteins✓ actively transport substances against a concentration gradient;✓glycocalyx/glycolipids/recognition proteins/glycoproteins✓ for cell-to-cell interactions;✓ Receptor proteins✓ recognize hormones and transmit their signals to the interior of the cell;✓ substances exported into the external environment by exocytosis;✓ substances are packaged in vesicles that merge with the plasma membrane contents are released to the outside;✓ food and other substances are imported by endocytosis;✓ plasma membrane encircles the substance and encloses it in a vesicle;✓

2) Explain the different types of vesicular movements

What do we already know?

Vesicular transport uses vesicles or other bodies in the cytoplasm to move macromolecules or large particles across the plasma membrane. Types of vesicular transport are described below.

Solution

- Exocytosis;✓ describes the process of vesicles fusing with the plasma membrane✓releasing their contents to the outside of the cell✓ eg enzyme secretion;✓
- Endocytosis;✓ describes the capture of a substance outside the cell when the plasma membrane emerges to engulf it;✓Phagocytosis ("cellular eating")✓ occurs when un dissolved material enters the cell;✓ plasma membrane wraps around the solid material and engulfs it, forming a Phagocytic vesicle;✓ Phagocytic cells (such as certain white blood cells) attack and engulf bacteria in this manner;✓ Pinocytosis ("cellular drinking") ✓ plasma membrane folds inward to form a channel allowing the liquid to enter cell forming vacoules✓Receptor-mediated endocytosis✓ Molecules such as cholesterol;✓ from extracellular environment bind with specific receptor molecules on the cell surface;✓ receptor sites become filled;✓ the surface folds inwards;✓ until a coated vesicle finally separates from the cell surface membrane into the cytoplasm;✓

3) Explain the importance of vesicles and vacuoles in organisms.

What do we already know?

Vacuoles and vesicles are fluid-filled, membrane-bound bodies.

- Transport vesicles;✓ move materials between organelles/ between organelles and the plasma membrane;✓
- Food vacuoles;✓are temporary receptacles of nutrients;✓
- Storage vacuoles;✓ in plants store starch/pigments/toxic substances;✓ (nicotine, for example).
- Central vacuoles;✓When fully filled, exert turgor/pressure, on the cell walls, thus maintaining rigidity in the cell;✓/also store nutrients/function as lysosomes
- Contractile vacuoles;✓ are specialized organelles in single-celled organisms that collect and pump excess water out of the cell;✓

4) Explain the role of different types of special junctions between animal cells.

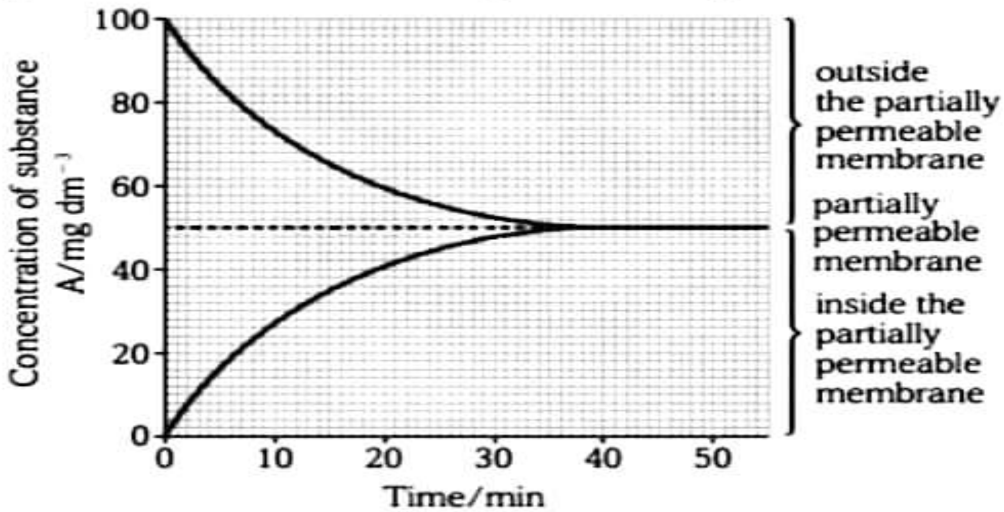
What do we already know?

Cell junctions serve to anchor cells to one another or to provide a passageway for cellular exchange.

Solution

- Desmosomes✓ protein attachments between adjacent animal cells;✓(such as skin or heart muscle).
- Tight junctions✓ are tightly stitched seams between animal cells✓ preventing the movement of material between the cells✓
- Gap junctions✓ are narrow tunnels between animal cells that consist of proteins, connexons✓ The proteins prevent the cytoplasm of each cell from mixing, but allow the passage of ions and small molecules;✓
- Plasmodesmata✓ (singular, plasmodesma) are narrow channels between plant cells✓allows exchange of materials between two plant cells✓

5) **The graph below shows the changes in concentration of substance A on the inside and outside of a partially permeable membrane, during a 50 minute period.**



a) **Explain the relationship between concentration of A inside and outside the membrane**

At 0 minute the concentration of substance A inside is 0 A/mgdm^{-3} while outside is very high;✓ no net movement of substance A by diffusion had occured✓from 0 minute to about 10 minutes concentration of substance A increases rapidly in the inside while decreases rapidly on the outside✓ because of the high concentration gradient✓ substance A diffuses very rapidly to the inside;✓ from 10 minute to about 35 minutes concentration inside increases gradually while outside decreases gradually✓ because the steepness of the concentration gradient decreases✓ as more materials enter the plasma membrane so few materials outside the membrane✓ from 40 minute to 50 minute concentration remains constant✓ because materials inside equals to outside/equilibrium established✓ hence no diffusion✓

b) **Name the process being investigated and evidence**

Diffusion;✓rate of movement of substance A depends on the concentration gradient✓ when the concentration outside is very high and inside low/no substance A; uptake occurs very fast

Multiple Choice Questions (MCQs)

1. The following is the metabolic function of ER:
a) RNA processing
b) Fatty acid oxidation
c) Synthesis of plasma protein
d) ATP-synthesis
2. In biologic membranes, integral proteins and lipids interact mainly by:
a) Covalent bond
b) Both hydrophobic and covalent bond
c) Hydrogen and electrostatic bond
d) None of the above
3. Plasma membrane is made up of:
a) Lipid bilayer
b) Protein bilayer
c) Carbohydrate bilayer
d) Lipid single layer
4. Select the subcellular component involved in the formation of ATP:
a) Nucleus
b) Plasma membrane
c) Mitochondria
d) Golgi apparatus
5. Mitochondrial DNA is:
a) Maternal inherited
b) Paternal inherited
c) Maternal and paternal inherited
d) None of the above
6. All of the following statements about the nucleus are true, *except:*
a) Outer nuclear membrane is connected to ER
b) It is the site of storage of genetic material
c) Nucleolus is surrounded by a bilayer membrane
d) Outer and inner membranes of nucleus are connected at nuclear pores
7. Golgi apparatus is present in all of the following *except:*
a) RBC
b) Parenchymal cells
c) Skeletal muscle cells
d) Pancreatic cell
8. Peroxisomes arise from:
a) Golgi membrane
b) Lysosomes
c) Mitochondria
d) Pre-existing peroxisomes and budding off from the smooth ER
9. Na+ - K+ ATPase is the marker enzyme of:
a) Nucleus
b) Plasma membrane
c) Golgi bodies
d) Cytosol