Cell Biology
(Cell: The unit of Life)

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Syllabus

Cell Biology
(Cell: The unit of Life)

Cell Theory, Types of Cell, Cytoplasm, Cytoskeleton, Cell Wall, Plasma Membrane, Celia and Flagella, Endoplasmic Reticulum(ER), Golgi Apparatus, Lysosomes, Vacuoles, Plastids, Mitochondira, Nucleus, Chromosomes.

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CELL BIOLOGY (Cell : The unit of life)

LEVEL - I

1. The content of nucleolus is continuous with the rest of the nucleoplasm as -
(A) It is the site of active rRNA synthesis
(B) It is spherical
(C) It is membraneless
(D) It is associated with NOR of certain chromosome

2. Number of nucleolus in a nucleus is -
(A) Only one
(B) Many
(C) Dependent on number of SAT-chromosome
(D) One or more

3. Nuclear DNA exists as a complex of proteins called ______ that ______ condenses into ______ during ______
(A) Chromatids, chromosomes, cell division
(B) Chromosomes, chromatin, Interphase
(C) Chromatin, Chromosome, Interphase
(D) Chromatin, Chromosome, Cell division

4. Which of the following cell organelles is directly connected to the outer nuclear membrane ?
(A) Mitochondria (B) Golgi body (C) ER (D) Chromatin

5. An organelle found in all eukaryotic cells during some portion of their lives is the -
(A) Chloroplast (B) Nucleus (C) Flagellum (D) Centriole

6. Material of the nucleus is stained by -
(A) Acidic dye (B) Basic dye (C) neutral dye (D) iodine

7. For the study of structure of nucleus the best cell is -
(A) Cell in the interphase (B) Cell in the late prophase
(C) Cell in the divisional phase (D) Cell in the meiotic phase

8. Which one is correct about the nuclear membranes (NMs)
(A) Both the NMs are never fused
(B) Both the NMs are always parallel to each other and is never fused
(C) Both NMs are parallel to each other and fused to form nuclear pores at a number of places
(D) Inner NM is attached with ribosomes

9. The nuclear pores are the passage for the movement of certain materials between the nucleus and cytoplasm in both the direction. Which one is correct about materials in their respective direction
(A) Proteins, enzymes into the nucleus (B) Ribosomal components out of the nucleus
(C) mRNA out of the nucleus (D) All

10. Actively functional nucleus shows -
(A) Large nucleolus, diffused chromatin and more nuclear pores
(B) Large nucleolus, diffused chromatin and no nuclear pores
(C) Large nucleolus, compact chromatin and many pores
(D) No nucleolus, diffused chromatin and small nuclear pores

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11. Both the nuclear membranes are separated by ______ in perinuclear space

(A) 10 to 50A^0 (B) 1 to 5A^0

(C) 10 to 50 nm (D) 1 to 5nm

12. Cells actively carrying out protein synthesis have -

(A) Smaller and single nucleolus

(B) Smaller and more numerous nucleoli

(C) Large and more numerous nucleoli

(D) Large and single nucleolus

13. Chromatin consists of -

(A) DNA only (B) DNA + Histones

(C) DNA + RNA + histones + Non-histones (D) Ribonucleoproteins only

14. The total length of DNA molecules of 46 chromosomes in a human cell is about ______, where as a typical cell is 10μm in length -

(A) 2mm (B) 2cm (C) 0.2 mm (D) 2m

15. Part of chromosome after secondary constriction is called -

(A) Chromomere (B) Telomere (C) Satellite (D) Primary constriction

16. Structure which provides the shape to chromosomes as called -

(A) Centromere (B) Centriole (C) Satellite (D) Chromomere

17. Which of the following enzymes is absent in lysosome ?

(A) Lipases and proteases (B) carbohydrase

(C) Polymerases (D) Nuclease

18. Which of the following is incorrect about the microbodies ?

(A) They are present in bacteria (B) Minute, membrous vesicles

(C) They are present in plants and animals (D) They have various enzymes

19. The Golgi apparatus (Dictysome) -

(A) Is found in animal cells only (B) Is found in prokaryotes only

(C) Is the site of rapid ATP production (D) Packages and modifies proteins

20. Which one is the important site of synthesis of glycoprotein and glycolipid ?

(A) GB (B) RER (C) Lysosome (D) None

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Answer Key (Level - I)

1.	C	**2.**	D	**3.**	D	**4.**	C	**5.**	B	**6.**	B
7.	A	**8.**	C	**9.**	D	**10.**	A	**11.**	C	**12.**	C
13.	C	**14.**	D	**15.**	C	**16.**	A	**17.**	C	**18.**	A
19.	D	**20.**	A								

LEVEL - II

1. To enter or leave a cell substances must pass through

(A) a microtubule (B) the Golgi apparatus

(C) a ribosome (D) the plasma membrane

2. Bacterial cell are prokaryotic ; in comparison to a typical eukaryotic cell they would

(A) be smaller (B) have a smaller nucleus

(C) lack a plasma membrane (D) have fewer internal membranous compartments

3. Which of the following correctly matches an organelle with its function ?

(A) mitochondrion ... photosynthesis (B) nucleus ... cellular respiration

(C) ribosome ... manufacture of lipids (D) central vacuole ... storage

4. The term "nuclear envelope" is more correct than the term "nuclear membrane" because

(A) The enclosure has pores which membranes do not

(B) The enclosure is made up of two membranes

(C) The chemical composition is inconsistent with cellular membranes

(D) None of the above. The two terms are perfect synonyms.

5. A cell has mitochondria, ribosomes, smooth and rough ER, and other parts. Based on this information, it could not be

(A) a cell from a pine tree (B) a grasshopper cell

(C) a yeast (fungus) cell (D) a bacterium

6. Passage through pores in the nuclear envelope is restricted primarily to

(A) proteins, RNA, and protein-RNA complexes

(B) lipids and glycolipids

(C) DNA and RNA

(D) RNA and protein-carbohydrate complexes

7. Cell fractionation is the most appropriate procedure for preparing ____ for study.

(A) isolated cells which are normally found tightly attached to neighbouring cells

(B) cells without a functional cytoskeleton

(C) isolated organelles

(D) the basic macromolecules

8. Which of the following clues would tell you whether a cell is prokaryotic or eukaryotic ?

(A) The presence or absence of a rigid cell wall

(B) whether or not the cell is partitioned by internal membranes

(C) the presence or absence of ribosomes

(D) whether or not the cell carries out cellular metabolism

9. Choose the correct statement(s) for active transport -

(A) It occurs against the conc. so it needs ATP

(B) A few ions transported by it

(C) Na^+ / K^+ pump is the example of active transport

(D) All

10. Cell wall is -

(A) Nonliving and impermeable (B) Nonliving, rigid and permeable

(C) Living and semipermeable (D) Living and selective permeable

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11. Cell wall forms outer covering for plasmamembrane of -

(A) Only fungi
(B) Only fungi and plants
(C) Only fungi, plants and bacteria
(D) Fungi, bacteria, plants and animals

12. Which is not the function of cell wall ?

I. Provides shape to the cell
II. Protects the cell from mechanical damage and infection
III. Helps in cell to cell interaction
IV. Imbibes water

(A) Only V
(B) Only IV
(C) Only II, IV, and V
(D) None

13. Important site for formation of glycoproteins and glycolipids is

(A) Lysosome (B) Vacuole (C) Golgi apparatus (D) Plastid

14. Peptide synthesis inside a cell takes place in

(A*) Ribosomes
(B) Chloroplast
(C) Mitochondria
(D) Chromoplast

15. In eubacteria, a cellular component that resembles eukaryotic cell is -

(A) Cell wall
(B) Plasma membrane
(C) Nucleus
(D) Ribosomes

16. Microorganisms such as bacteria, viruses etc. are used in genetic manipulation. Bacterial plasmid is an important genetic engineering tool. Which of the following statements about bacterial plasmids is correct ?

(A) They are double-stranded circular nucleic acids
(B) They are recombinant proteins in the cytoplasm
(C) They are cell organelles that contain nucleic acids
(D) They are cell organelles that contain recombinant proteins

17. Which one of the following structures is an organelle within an organelle ?

(A) Ribosome
(B) Peroxisome
(C) ER
(D) Mesosome

18. Which one of the following cellular parts is correctly described ?

(A) Thylakoids - flattened membranous sacs forming the grana of chloroplasts
(B) Centrioles - sites for active RNA synthesis
(C) Ribosomes - those on chloroplasts are larger (80s) while those in the cytoplasm are smaller (70s)
(D) Lysosomes - optimally active at a pH of about 8.5

19. The cell membranes of adjacent cells are fused at

(A) macula adherens
(B) zonula adherens
(C) zonula occludens
(D) nexus

20. Detailed structure of the membrane was studied after the advent of electron microscope during

(A) 1930s (B) 1950s (C) 1970s (D) 1990s

Answer Key (Level - II)

1.	D	**2.**	A	**3.**	D	**4.**	B	**5.**	D	**6.**	A
7.	C	**8.**	B	**9.**	B	**10.**	B	**11.**	C	**12.**	D
13.	C	**14.**	A	**15.**	B	**16.**	A	**17.**	A	**18.**	A
19.	C	**20.**	B								

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LEVEL - III

1. Which one of the following organisms is not an example of eukaryotic cells

(A) Amoeba proteus (B) Paramecium caudatum
(C) Escherichia coli (D) Euglena viridis

2. Which one of the following is not considered as a part of the endomembrane system ?

(A) Golgi complex (B) Peroxisome
(C) Vacuole (D) Lysosome

3. Of the following organelles, which group is involved in manufacturing substances needed by the cell ?

(A) lysosome, vacuole, ribosome (B) ribosome, rough ER, smooth ER
(C) vacuole, rough ER, smooth ER (D) smooth ER, ribosome, vacuole

4. A cell has mitochondria, ribosomes, smooth and rough ER, and other parts. Based on this information, it could not be

(A) a cell from a pine tree (B) a grasshopper cell
(C) a yeast (fungus) cell (D) Actually, it could be any of the above

5. The electron microscope has been particularly useful in studying bacteria, because

(A) electrons can penetrate tough bacterial cell walls
(B) bacteria are so small
(C) bacteria move so quickly they are hard to photograph
(D) with few organelles present, bacteria are distinguished by differences in individual macromolecules.

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6. Which of the following statements are true about Endoplasmic Reticulum ?

I. Smooth Endoplasmic Reticulum makes lipids
II. It is also called the control center of the cell
III. It processes carbohydrates
IV. It modifies chemicals that are toxic to the cell

(A) I, II and III (B) I, III and IV
(C) only I and IV (D) all are correct

7. Which of the following statements are true about Eukaryotes ?

I. They are cells with a nucleus.
II. They are found both in humans and multicellular organisms.
III. Endoplasmic reticulum is present in Eukaryotes.
IV. They have chemically complexed cell wall

(A) I, II and III (B) I, III and IV
(C) I, II and IV (D) all are correct

8. The DNA is located in the _____ of _____ .

(A) Cristae, mitochondria (B) Matrix, mitochondria
(C) Intermembrane space, mitochondria (D) Grana, chloroplast

9. RNA is found in all of the following structures except -

(A) Prokaryotic cell (B) Nucleus, chloroplast and mitochondria
(C) Vacuole (D) Ribosome, HIV, TMV

10. Which of the following cell organelle(s) is/are double membrane bound ?

(A) Nucleus (B) Chloroplast
(C) Mitochondria (D) All

11. Which of the following statement is incorrect ?

(A) Mitochondria, unless specifically stained are not easily visible under the microscope

(B) Physiological activity of cells determines the number of mitochondria per cell

(C) Mitochondrion, a power house of cell has DNA, RNA, ribosomes and enzyme. So it can survive outside the cell

(D) Mitochondria divide by fission

12. Based upon the type of pigment, plastids are of how many type ?

(A) 3 types (B) 4 types

(C) 2 types (D) 5 types

13. Chloroplasts contain -

(A) All types of pigments (B) Chl + Carotene + anthocyanine

(C) Chl + Carotenoids (D) Only Ch

14. In chloroplast, chlorophyll is present in -

(A) thylakoid (B) Stroma

(C) Outer membrane (D) Inner membrane of envelope

15. Stacks of vesicles in chloroplast form -

(A) Stroma (B) Thylakoid

(C) Grana (D) Oxysome

16. Extranuclear genes are found in -

(A) Lysosome and chloroplast (B) GB and ER

(C) Nucleus and mitochondria (D) Mitochondria and chloroplast

17. The number of chloroplast in each mesophyll is -

(A) 100 (B) 100 - 1000

(C) 20 - 40 (D) 104

18. In Chlamydomonas (a green alga) the number of chloroplast per cell is -

(A) 1 (B) 2

(C) 100 (D) 1000

19. The length and width of chloroplast is -

(A) 5 - 10μm, 1-4 mm (B) 50 - 10μm, 2-4 μm

(C) 2 - 4μm, 5-10 μm (D) 5 - 10μm, 2-4 μm

20. In higher plants the chloroplast is -

(A) Spiral (B) Lens - shaped

(C) Cup shaped (D) Reticulate

Answer Key (Level - III)

1.	C	**2.**	B	**3.**	B	**4.**	D	**5.**	B	**6.**	B
7.	A	**8.**	B	**9.**	C	**10.**	D	**11.**	C	**12.**	A
13.	C	**14.**	A	**15.**	C	**16.**	D	**17.**	C	**18.**	A
19.	D	**20.**	B								

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CELL THEORY

Robert Hooke (1665) first discovered the existence of cell in a thin section of cork with the help of a crude microscope. Leeuwenhoek (1675) studied free cells. Schleiden and Schwann propounded the cell theory. Virchow (1855) proposed that cells originate from pre-existing cells [*Ominis Cellule e Cellula*]

The principal features of cell theory are :

1. Cells are the structural unit of all organisms (plants and animals)
2. Cell is the functional unit of life.
3. Cell always arise from pre-existing cells.
4. All organisms are made up of cell and cell products.
5. Organisms are actually cells.
6. The activity of any organism is due to the activity of cells.
7. Cell is the unit of genetics.
8. In multicellular organisms, individual cells are able to maintain their existence and function.

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TYPES OF CELLS

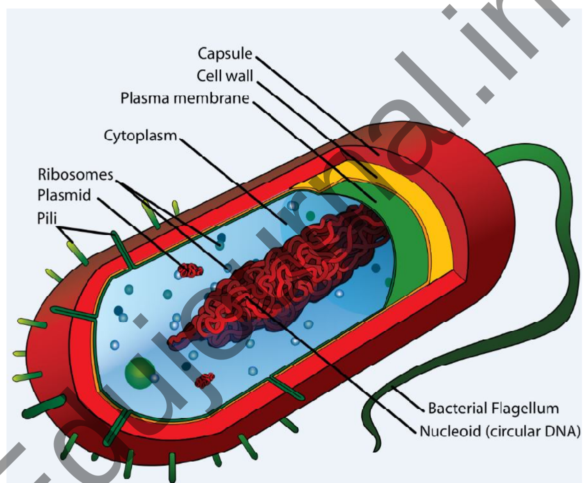
Cells are of two types : Prokaryotes and Eukaryotes.

Prokaryotes

Characteristics

1. Lack of a well-organised nucleus.
2. Nuclear material (Nucleoid) is scattered in the cytoplasm. These contain 700-6000 genes. The genetic material is either DNA or RNA.
3. Presence of membrane-bound enzymes.
4. Membrane composed or proteins, carbohydrates and lipids. Cardiolipin is the principal fat.
5. Absence of histones.
6. Mitchondria absent.
7. No lysosomes.
8. Absence of endoplasmic reticulum.
9. Have 70s (50s + 30s) ribosomes.
10. Fission or budding facilitates increase in the number of cells.

Examples : Bacteria and blue green algae (=cyanobacterea)



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Eukaryote

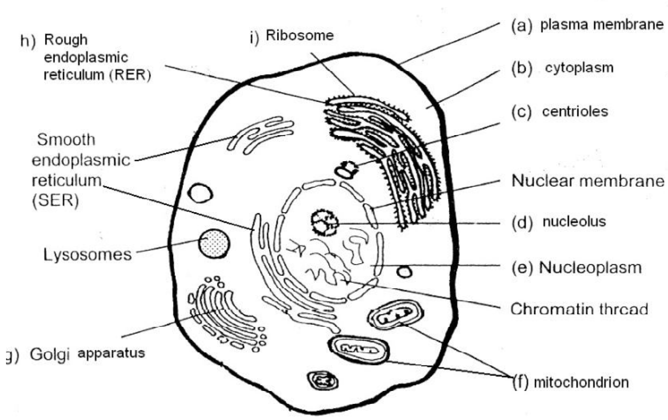
Characteristics and Functions of Animal Cell

1. Bounded by trilayered plasma membrane comprising of lipids, proteins and carbohydrates. It is selective permeable. It may have microvillis, cilia or flagella emanating from its surface. Membrane allows movement of gases, ions and metabolites by diffusion, osmosis, active transport, phagocytosis and pinocytosis. The membrane separates the cytoplasm and cell organelles from the outside environment. The membrane is 75Å — 100Å thick. The protein layer is 20Å — 25Å thick. The pores of the membrane have a diameter of about 8Å — 50Å
2. ***Cytoplasm*** consists of water, organic and inorganic substances. A cytoskeleton of tubulin protein is present which maintains the form and position of the cell and cell organelles.
3. ***Endoplasmic reticulum*** (ER) is made up of tubular, cisternal or vascular forms and occupies substantial space in the cell cytoplasm. It is connected to the plasma membrane and nucleus as well. Its membrane (unit) has a diameter of 50Å — 60Å. Endoplasmic reticulum is of two types :

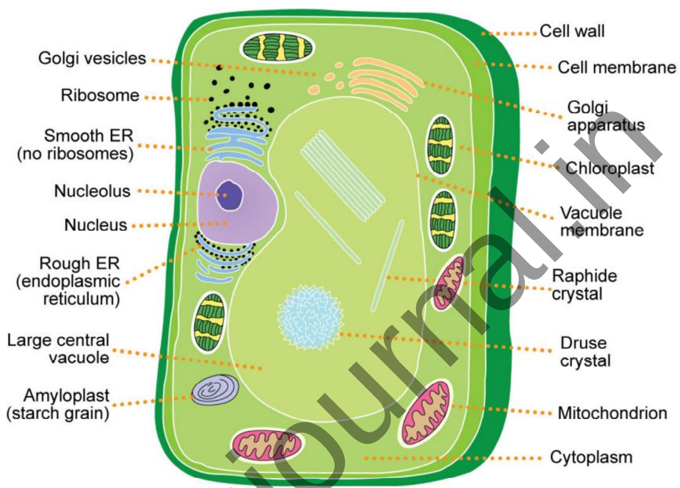
   (a) rough ER (RER) and (b) smooth ER (SER).

   Rough ER is involved with protein synthesis which occurs in ribosomes (80s) attached to mRNA unit. It also facilitates intracellular transport. Smooth ER is involved with steroidogenesis, lipogensis and glycogenesis.
4. ***Mitochondria*** are bound by double membrane and are called 'Power House' of the cell [site of ATP production]. They contain circular DNA ; DNA, 70s ribosome, protein Ca^{2+} Mg^{2+} and can move from one part of the cell to another. Mitochondria contains cristae (finger-likes projection); and mitochondrial

matrix covered by double enclosing a fluid filled space called



Animal Cell



Plant Cell

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perimitochondrial space (80Å — 100Å). External membrane contains many minute particles called oxysomes. Each particle consists of base, shaft and head piece. Mitochondria are the site of Krebs Cycle enzymes (TCA Cycle) ; and Electron transport chain.

5. ***Ribosomes*** are made of ribonucleoprotein. Their diameter is 150Å — 250Å. They are made from 60s and 40s subunits which make 80s ribosomes characteristic of eukaryotes. They lie freely in cytoplasm, or in clusters (called polyribosomes or polysomes) or attached to endoplasmic reticulum. They take part in protein synthesis and are therefore called 'Protein Factor' of cell.

6. ***Golgi Complex*** was discovered by Camillo Golgi (1898). They are in the form of stacks of narrow, flat tubes and are present in the form of one or more groups. They are found in secretory cells and are either cisternal or vesicular in shape. Anabolites synthesized by ER are transfered to Golgi bodies where they undergo maturation and exit as a membrane bound substance. Complex sugars and glycoproteins are also synthesized on RER, etc.

7. **Lysosomes** were discovered by de Duve. They are also called 'suicide bags' of cell. They measure 0.5 — 0.8 μm in diameter. They are bound by a single membrane which is 60Å — 70Å a thick and contain variety of hydrolytic enzymes, e.g., nucleases, lipases glycosidase. Lysosomes are involved in, extracellular and intracellular digestion, cancer ; and in cell division.

8. ***Nucleus*** Majority of cells are mononucleate, some are binucleate (e.g., Paramaecium) or multinucleate (Opalina, skeletal muscle cells), or enucleate (mature RBC of mammals). Nuclear membrane envelops the nucleus. It is a double unit membrane and enclose a space of 100Å — 300Å called perinuclear space. Octagonal nuclear pores (600Å — 700Å diameter) are present in facilitate fluxes of cellular chemicals. Ribosomes are attached to outer nuclear membrane.

Nucleus contains nucleoplasm made up of water, proteins, RNA, etc. Nucleolus and chromosomes are the two principal structural elements of nucleus.

The number of nucleoli may be one or more. They are spherical, made up of RNA and protein. Chromosomes are thread-like structures. Each is made up of DNA and histone protein.

The number of chromosomes is different in different species. Their shape and size of Drosophila and Lamp brush chromosome of amphibian Oocytes. chromosome are of 2 types autosomes and sex-chromosomes or allosomes.

9. ***Centriole*** may be single or double and is present above the nucleus. It is surrounded by cytoplasm and forms the centrosphere. They take part in the formation of nuclear spindle during cell division and of basal bodies of cilia and flagella.

10. ***Cilia and Flagella*** are hair-like structure of varying length and diameter. Although structurally similar, cilia are smaller than flagella and have 9 peripheral fibres and 2 central fibres (9 + 2) made up of microtubules and covered by a membrane. A basal body (called blepharoplast-kinetosplast) is present which determines and regulate their movement. Cilia and flagella are locomotory organelles of many organisms, e.g., Paramaeceni, Euglena, and some cells, e.g., sperm. They contain the contractile proteins, actin and myosin.

Characteristics and Functions of Plant Cells :

Plant cells contain most of the organelles found in animal cell (except centriole). In addition they have

(a) cell wall, (b) plasmodesmata, (c) plastids of various types, and (d) vacuoles.

1. ***Cell wall*** covers the plasma membrane.It is thick and made up of polysaccharides. It protects and gives form to the cell. It prevents entry of large molecules. Like animal cell, movement of material is regulated by plasma membrane. Cellulose is the principal constituent of cell wall of plants.

2. Bridges between two cells occur at few places. These are called *plasmodesmata* and contains channel-like structure formed by cell wall facilitating movement of material.

3. ***Plastids*** are found only in cells (exception Euglena which contains chloroplast). Some plastids are colourless, store starch and are called leucoplast. Other type of plastids have coloured pigments, e.g., chloroplasts contain various types of chlorophyll, and Mg^{2+}, DNA, 70s ribosomes, protein, and enzymes which take part in photosynthesis. Chromoplast contains coloured pigments other than chlorophyll.

4. ***Vacuoles*** are charasteristic of plant cells. However, some animal cells also have them. They are covered by a membrane called tonoplast. Vacuoles serve as storage organs for a variety of biochemicals, pigments, etc.

   In Amoeba, three types of vacuoles are found.

   1. Contractile vacuole with osmoregulatory function.
   2. Food vacuole
   3. Water vacuole.

   Parasitic protozoans and marine animals lack vacuoles in their cells.

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Cell organelles and their functions

1. *Plasma membrane* : Outermost covering of animals cell, 75Å thick, made up of lipoprotein, allows passage of water, gases, ions, organic molecules of various shapes size by diffusion, osmosis, active transport, pinocytosis and phagocytosis, contains surface receptors, enzymes, with catalytic sites.

   Some contain antigens.

2. *Endoplasmic reticulum* : Form internal channel system of cell. Connected to plasma membrane and nuclear membrane, principally of two types

   (a) rough Endoplasmic with attached ribosomes, site for active protein synthesis and

   (b) smooth (without ribosome) site of steroidogenesis ; lipogenesis ; glycogenesis.

3.	*Golgi complex* ;	Present in secretory and metabolically active cells, involved in formation of primary ('Virgin') Lysosomes ; facilitates glyco-lycosidation of lipids and proteins ; bounded by double membrane.
4.	Mitochondria ;	Also called 'Power House' of cell, bounded by double membrane, contain DNA, RNA 70s ribosomes and protein ; contains enzymes of Krebs cycle, and electron transport chain, sites for oxidation of carbohydrates, lipids and amino acids.
5.	*Lysosomes* ;	Also called 'suicide bags', single membrane vesicles ; contain hydrolytic enzyme which are used for extracellular and intracellular digestion. Lysosomes are polymorphic. They are implicated in numerous cell functions.
6.	*Ribosomes* ;	Present in cytoplasm singly or in clusters (polyribosomes), or attached to ER. Two types : prokaryotes have 70s (50s + 30s), while eukaryotes have 80s (60s + 40s) ribosomes, also present in nucleus chloroplast and mitochondria (Both have 70s). Site of protein synthesis.
7.	*Chloroplast* ;	Characteristic of green plants imparting them photosynthetic abilities ; it consists of envelope, stroma and thylakoids. Chlorophyll pigment of several types contains Mg^{2+}. Trap light and use it for photosynthesis.
8.	*Nucleus* ;	Covered by double membrane with nuclear pores (for flux of ions ; metabolites), contain one or more nucleoli (rich in RNA). Chromosomes (number is species-specific) made up of DNA, RNA and histones. Regulator of metabolic and genetic functions ; participates in mitotic and meiotic cell division.

Comparison of prokaryotic and eukaryotic cells

Character	Prokaryote	Eukaryote
Example ; Bacteria. Bluegree algae.		*Example ; Algae, Protists, Metazoans, Higher plants etc.*
1.	Size and shape	
	(a) Microscopic rod-like, spherical, nucleoid without nuclear membrane 0.7 – 2.50 μ.	(a) Large, spherical, well organised nucleus enveloped by nuclear membrane, 4.0 – 75 × 103 μ
	(b) Multiple nucleoid present in a cell.	(b) Mostly mononucleate. Occasionally binucleate and rarely multinucleate.
	(c) Chromosomes absent, instead individual DNA molecule present.	(c) Chromosome present.
2.	Cell division : No mitosis/meiosis. Cell divide by fission.	2. Cell division by mitosis and meiosis, rarely by amitosis and fission.
3.	Endomembranes absent.	3. Endomembranes present.
4.	Mitochondria absent (Respiratory enzymes are present on membrane and on mesosomes).	4. Mitochondria present.
5.	Chloroplasts absent.	5. Chloroplasts present in plant c ells, rarely in animal cell (e.g., *Euglena spp.*)
6.	Cell wall made of non-cellulosic material.	
7.	DNA	6. Cellulose cell wall present only in plant cells.
	(a) Non-histone bound	(a) Bound to histone
	(b) Short and small molecules	(b) Long, linear, double helical molecules.
	(c) Can reanneal rapidly after denaturation.	(c) Reanneals slowly after denaturation.
	(d) Shorter ; and DNA has little redundant base sequence per chromosome	(d) Has more redundant base base sequence per chromosome
	(e) DNA polymerase sensitive to ethidium dibromide.	(e) Not sensitive to ethidium dibromide.
8.	RNA and Ribosomes	

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	(a) 70s (50s + 30s) ribosomes	(a) 80s (60s + 40s) ribosome
9.	Protein synthesis	
	Inhibited by Chloramphenicol	Inhibited by cyclohexamide.
10.	Cardiolipin	
	Present	Absent.
11.	Cholesterol	
	Absent or present in low concentration	Present.
12.	Locomotion	
	By flagella with single fibril	By cilia and flagella. Also by pseudopodia in some.
13.	Exo-and endo-cytosis	
	Absent	Present

Difference between plant and animal cell

	Plant Cell		Animal Cell
1.	Presence of cell wall made of cellulose and other polysaccharides or derivatives.	1.	Absence of cell wall.
2.	Plasmodesmate with channels present.	2.	Plasmodesmata absent.
3.	Vacuoles covered by tonoplast present which act as storage organs.	3.	Vacuoles absent (except in some free living protozoans).
4.	Centriole absent.	4.	Centriole present.
5.	Plastids of various types present and contain DNA, RNA, ribosomes 70s protein and Mg^{2+}.	5.	Plastids absent (except in *Euglena*).
6.	Motile plant cell have cilia or flagella.	6.	Cilia and flagella only present in protozoans, spermatozoa.

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Difference between prokaryote and eukaryote cell

	Prokaryote cell		Eukaryote cell
1.	Cell wall made of aminosugars and muramic acid (peptidoglycan), present.	1.	Absent in animals ; but a cellulose cell wall is presence in plant cell.
2.	Capsule made of mucopolysaccharides is present in many cells.	2.	Absent.
3.	Cell organelles bound by lipoprotein membrane are absent.	3.	Present
4.	Nuclear membrane absent.	4.	Present
5.	DNA naked.	5.	Proteins (histones) are combined with DNA.
6.	Nucleolus absent.	6.	Present (1–2 or more)
7.	Some cells have flagella but lack the 9 + 2 arrangement of fibres.	7.	Cilia and flagella present display characteristic 9+2 arrangement of fibres.
8.	Divide by amitosis (fission)	8.	Divide by mitosis and meiosis. Some forms display amitosis.
9.	70s (50s + 30s) ribosome present.	9.	80s (60s + 40s) ribosomes present.
10.	No mitochondria.	10.	Mitochondria (Power House of cell) present.
11.	No centriole.	11.	Centriole present in animal cell but absent

			in plant cell.
12.	No endoplamic reticulum.	12.	Endoplasmic reticulum present with or without attached ribosomes.
13.	No exocytosis and endocytosis.	13.	Exocytosis and endocytosis are characteristic process.

Various cell types and their size

	Cell type	Size (μm) (Range)
1.	Neurons (Length)	2×10^6
2.	Ostrich egg	75×10^3
3.	Human Oocyte	250.00
4.	Euglena	100.0 – 200.0
5.	Hepatocyte	20.0
6.	Amoeba proteus	8.0 – 15.0
7.	Mammalian RBC	8.0
8.	Small Lymphocytes	0.20 – 2.50
9.	Bacteria	0.10
10.	Pleuropneumonia like Organism (PPLO)	
11.	Viruses	0.07 – 0.10

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CYTOPLASM

Characteristics and Functions of Cytoplasm

1. It is the intricate heterogenous complex of soluble, insoluble colloidal forms of diverse variety of chemicals that fill the interior of cell which contain different types of cell organelles.
2. It forms the internal environment of cells have where numerous biochemical reactions related to cell metabolism occur.
3. The cell matrix contains cytoskeletal elements and organelles. Cell organelles can be removed by ultra centrifugation and the left over soluble fraction is called *cytosol*.
4. Cytoplasm of cell is enveloped externally by plasma membrane and internally by nuclear membrane.
5. Appears to be jelly-like, transparent and colourless fluid
6. Colloidal in nature. Colloids of various shapes and sizes are suspended in water (60–90%).
7. Contains soluble proteins (e.g. some enzymes), inorganic salts, lipids, carbohydrates.
8. Suspended particles exhibit incoherent motion (Brownian movement). Temperature affects this.
9. Cytoplasm exhibits intracellular motion or cyclosis and also amoeboid movement by forming pseudopodia.
10. A proteinaceous cytoskeleton make up of microtubules ; microfilaments and intermediate filaments is present which is aided by intratrabecular system in providing mechanical support.

    These help the cell organelles to maintain their locus.
11. Cytoplasm contains 90% water and 10% organic and inorganic substances. The ratio of elements in cells varies. Carbon, hydrogen, nitrogen and oxygen are abundant elements along with phosphorus and sulphur. They act as precursors for biosynthesis of macromolecules. Inorganic compounds which occur in ionic forms are Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe^{2+}, $Cl^-PO_4^{2-}$, CO_3^{2-} and NO_3^{2-} they have important role in various physiological functions, e.g., electrical properties, electrogenesis by neurons and other excitable cells is due to distribution of Na^+ and K^+ across the membrane. Ca^{2+} is important in (a) blood coagulation. (b) muscle contraction, (c) gelation of cytoplasm. Mg^{2+} is constituent of chlorophyll and Fe^{2+} of Haemoglobin and are also needed as co-factor for catalytic action of enzymes.

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CYTOSKELETON

It forms the internal framework of all cells. It also assists in movement of these structures e.g., mitochondria usually change their position.

Linear structure made up of protein subunit form the fibrous structural component of cell components. These are of 3-types : (a) microtubules, (b) microfilaments and (c) intermediate filaments.

Charactersties and Functions of Microtubules

1. Form the cytoplasmic matrix of all eukaryotic cells.
2. Tube like, 25μm in diameter, occur singly or in aggregate.
3. Microtubules are hollow, devoid of ribosomes, made of 13 sub-units.
4. The protein sub-unit of microtubules is called tubulin.
5. The protein monomers of tubulin are α-tubulin and β-tubulin.
6. The microtubules are specially oriented in relation to the loci of centriole, basal bodies and centromere.
7. Maintains cell shape.
8. Facilitate sperm cell nucleus elongation during spermiogenesis.
9. Involved in cell differentiation.
10. Determines cell polarity and motility.
11. Helps in intracellular transport of macromolecules through the formation of temporary channels.

Characteristics and Functions of Microfilaments

1. Elongated, unbranched and proteinaceous, responsible for cell motility.
2. Filaments arranged in bundles and their thickness varies from 6-10 μm.
3. Actin and myosin present.
4. Microfilaments are found in W.B.C., pseudopodia microvilli of intestinal cells, non-muscle cells, and mitotic spindle.
5. Take part in cytokinesis during mitosis and meiosis.

Characteristics and Functions of Intermediate Filaments

1. Unbranched, diameter of about 100Å.
2. Found in neurons, neuroglial cells, fibroblasts, etc.
3. Contractile in function.
4. Chemically they are of five types and occur in bundles of varying diameter.
   (a) Keratin
   (b) Glial filaments
   (c) Neurofilaments
   (d) Desmin containing filaments
   (e) Vimetin containing filaments

Characteristics and Functions of Microtrabecular System

1. Number to Porter (1976). Consists of microtrabecular filaments.
2. Forms a fine network of filaments that ramify throughout the cell. No definite shape of lattice. It varies with cell shape and environment and contains actin.

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CELL WALL

Cell wall is characteristic of prokaryotes and plant cells. It is absent in animal cells. Cell wall of prokaryotes has been extensively studied and differs in chemical composition from cell wall of lower and higher plants.

Cell Wall of Prokaryotes

Two types of cell walls are found in bacteria recognised by their affinity for crystal violet stain. Bacteria whose cell wall acquire deep purple stain are called Gram (+), while others which take this light pink stain are called gram (–). Gram (+) bacteria (e.g., streptococcus) have very little lipid ; while in Gram (–) bacteria (e.g. E. coli) abundant lipids are present.

Cell wall is rigid, porous, electron dense layer of varying thickness.

Cell Wall of Lower Plants (e.g Fungi)

1. Cell wall is stratified.
2. Cell wall is bilayered. Outer layer is smooth or granular and inner layer is rigid and crystalline Outer wall made of protein and polysaccharides while inner is made of choline.
3. Thickness of wall depends on cell maturity.

Cell Wall of Higher Plants

1. It has three layers, (a) primary wall (b) secondary wall and (3) transitional lamella. Sometimes a thin tertiary wall is also present.
2. It consists of proteins, lignins, polysaccharides, chitinous materials and minerals. Cellulose is the major constituent and provides structural frameworks.
3. Pectins, lignins, hemicellulose, etc. are embeded in the framework.
4. The cell wall also contains hemicellulose.
5. Pectin is present in secondary wall and middle lamella. It is a polysaccharide.
6. Lignin of cell wall makes up about 25% of dry weight of a tree. It is a complex polysaccharide.
7. Cell wall of seaweeds contains a polysaccharide called Agar.
8. The plant cell wall also contains non-polysaccharides, e.g. protein fragments, silicate, calcium carbonate.
9. Cell wall of higher plants provides shape and mechanical support.
10. Many economically important are present in cell wall.
11. Cell wall is porous. Tubular channels called plasmodesmata connect the plasma membrane of adjoining cells. These serve as intercellular routes for transport of water, minerals from root tip to shoot tip and product of photosyntheses from leaf to root by cells. Cell wall is permeable to a variety of substances.
12. Cell wall prevents cells from bursting open as a result of the build up of internal turgor pressure.
13. Plasmodesmata which connect adjacent cells are of several types.

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PLASMA MEMBRANE

Eukaryotic and prokaryotic cells are enclosed by a membrane called plasma membrane (plasmalemma). Plant cells have a cell wall.

Characteristics and Functions of Plasma Membrane

1. It is a dynamic barrier between the cell exterior and cell interior, and regulates fluxes of gases, metabolites, hormones, etc.
2. It is selectively permeable and serves as interphase.
3. It receives exogenous and endogenous signals and translates them into action. (single perception and transduction).
4. Physical and chemical composition of plasma membrane reveals that it is made up of
   (i) proteins (ii) carbohydrates (in varied proportions).
5. Two types of protein are present in membrane
   (a) peripheral protein, (=extrinsic) soluble, free of lipids and
   (b) integral proteins (= intrinsic associated with lipids, and insoluble.
6. Lipids from 40% of the chemical constituent of plasma membrane. Cholesterol, 5 types of phospholipids and glycolipids have been found to be present.
7. Carbohydrates are conjugated to lipids (glycolipids) or to protein (glycoprotein).

Moleculer Models of Plasma Membrane

The arrangement of lipids and proteins in the plasma membrane and manner in which such a membrane functions has been a subject of much investigation and debate. Many models hove been proposed.

Their salient features are as follows :

Danielli-Davson Model (1935)

Plasma membrane is a bilayer of lipids molecules. Proteins (charged groups are attached to polar ends of lipids which are outwardly directed. The total thickness of three layers (2 lipid + 1 protein) to 25 Å. This model fails to explain membrane structure in detail ; and the functions ; and is therefore not accepted.

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Unit Membrane Hypothesis of Robertson (1964)

Unit membrane consists of a core of bimoleculer leaflet of lipids which are flanked on either side by single layer of fully spread out hydrophilic protein or lipid material.

Unit membranes are present in all plant and animal cells and serve as physical and physiological barrier between the environment and cell, and between cell organelles and cell matrix.

Inner and outer layer of proteins are chemically different.

The layer on one side of the lipid core is made up of protein and of the other side of carbohydrate. This leads to asymmetrical state of unit membrane.

Robertson's model fails to explain diversities of membrane and certain aspects of permeability.

Fluid-Mosaic Model of Singer and Nicolson (1972)

This is the most acceptable model. According to this,

1. Lipids occur in the form of a fluid bilayer and the proteins do not form a sandwich covering of hydrophilic lipid bilayer.
2. The membrane proteins are globular in shape and are completely or partially embedded in the lipid bilayer like icebergs in the sea. It presents a mosaic arrangement.

3. Lipids are either phospholipids or glycolipids suspended in water. They aggregate to form micellae of various shapes.

4. Membrane proteins (peripheral and integral) play an important role in structure and act as carriers or channels (serving for transport). Numerous enzymes, antigens and various kinds of receptor molecules are present in plasma membrane.

Functions of Plasma Membrane

Dynamic membrane functions are important in exchange of metabolites, ions, water ingestion of solid materials and fluids, recognition of cell signals, identification of exogenous and endogenous chemicals enzymatic reactions, gaseous change, movement of biochemicals, ions against concentration gradient, etc. The membrane is a living entity, selectively permeable and actively regulates the continuous molecular traffic that are needed, or are to be expelled.

The principal ways in which the membrane functions are -

1. ***Diffusion*** - (passive transport) Diffusion is passage of substance from high concentration to a lower concentration solution. Diffusion dues not require inputs of energy. Small sized, non-polar molecule e.g. water, oxygen and hydrogen can move freely across the membrane. Uncharged polar molecule move rapidly. However, if they are charged they do not diffuse e.g., Na^+. This shows that the plasma membrane is selectively permeable.

2. ***Osmosis*** - When two aqueous solutions of different concentration are separated by the membrane permeable to water but impermeable to solute molecules, water diffuses through the membrane from low concentration until the molal concentration on both sides are equal. This is called *osmosis*.

3. ***Facilitated Transport***
   i. This is aided by carrier molecules embedded in the membrane. A carrier molecule links itself with the substance and transports it across the other side.
   ii. The mobile carrier is considered to be analogus to an enzyme molecule which binds the solute to its active site.

4. ***Active Transport*** - This denote movement of substances against the concentration gradient. salient features of this are as follows.

(i) It is soluble specific.

(ii) It depends on the concentration of substances being transported.

(iii) It is direction specific.

(iv) It can be selectively poisoned e.g. transport of glucose can be inhibited by phlorizen and KCN (also Na. azide)

(v) It facilitates maintenance of internal solute and ion composition of the cell.

(vi) Pumps specific substances against the gradient (substance-specific transport systems).

(vii) Active transport system consists of (a) carrier molecule with binding sites specific to substance to be transported and (b) protein * of protein that transfers energy to first component, facilitating active transport.

(viii) Cell membranes of many cells, e.g. neurons are excitable and respond to exogenous chemicals, temperature change, touch, pressure, etc. and transmit signals in a particular direction. Specific protein receptors are present on membrane.

Nerve cells generate electrical impulses. Na^+ and K^+ play a critical role in this.

(ix) Many membrane proteins play a critical role in detecting foreign material (e.g. toxins, viruses, bacteria, pollen, etc). These are called antigens. When activated they evoke a immune (defensive) reaction by stimulating the formation of antibodies.

(x) Surface carbohydrate of plasma membrane help in cell adhesion to neighbouring cells.

(xi) Surface antigen forms the basis of cell recognition. For example, classification of ABO blood group is based on genetically controlled antigen present on RBC.

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(xii) Cell aggregation occurs due to presence of aggregation factor present on plasma membrane.

(xiii) Flagella and cilia are locomotary organelles on the surface of eukaryotic cells. Other projections are microvilli. Pseudopodia are found in blood cells, e.g. WBC. They are the locomotary organelles of algae and some protozoans where they also help in feeding.

Cell Junctions

Adjacent cells of animal tissues are held together at many sites due to specific types of cell junctions of the plasma membrane. These may be localised or present throughout.

Three types of cell junctions are known as :

Adhering Junction (Desmosomes)

This consists of fine cytoplasmic tonofilaments that run across some regions of cells separated by intercellular space.

Gap Junction (Nexus)

This junction forms cellular adhesion and act as intercellular channels for transport of ions and small molecules. They also facilitate communication via electrical coupling.

Tight Junction

This is formed by fusion of cell membrane of adjacent cells at the point of contact. No intercellular space is across. They have belt or band-like form. They prevent flow of material in either direction and maintain cell polarity.

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CILIA AND FLAGELLA

Cilia and flagella are microscopic, contractile, fibre-like structures emanating from cell cytoplasm. Cilia are smaller than the cell but flagella are longer than its cell. They create water current, collect food material, act as sensory structures, and perform mechanical functions of many types. The number of cilia is much more (3000 – 4000) than flagella (1 – 10). Flagella beat singly, while cilia display synchronous or asynchronous movement. Cilia perform wave-like movement.

Cilia and flagella are found in protozoans and metazoans e.g. Paramecium, nephron of vertebrate kidney, green algae (e.g. *Chlamydomonas* and *Volvox*). zoospores and gametes.

Ultrastructure of Cilia and Flagella

1. Whip-like, cylindrical extensions from the free surface of cells.
2. They arise from basal bodies present in cells which act as centre of motility.
3. They are normally 5-10 μm long. It consists of a basal body, shafts, central axonome, plasma membrane and enterposal cytoplasmic matrix.
4. The basal body (kinetochore) is present below cell membrane and is somewhat similar to centriole. It has a cartwheel-like appearance with 9 peripheral filaments and no central filaments.
5. The shaft is 5 μm – 10 μm long in cilia but in flagella it can be upto 150 μm. Cilia are made of microscopic is characteristic of cilia and flagella of all types of cells that have them.
6. Cilia and flagella contain tubulin protein 20 – 25 secondary proteins.
7. Flagellar activity in eukaryotes is dependent on activity of ATPase. Loss of ATP makes them inert. ATP is provided by mitochondria.

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Functions of Cilia and Flagella

1. **Motility :** Ciliary locomotion is characteristic of protozoa and some planarians. Larval forms of invertebrates are ciliated which help in locomotion in water. Flagella of sperm makes it motile. The ciliary beat may be synchronous or irregular.
2. ***Nutrition :*** Ciliary feeding is characteristic of fresh water mussels, rotifers, herdmania, amphioxus, etc.
3. ***Removal of Excreta :*** Ciliated cells near the oral end of sea-anemones remove undesirable particles.
4. ***Respiration :*** Flagellar and ciliary activity causes water currents. This facilitates gaseous exchange.
5. ***Circulation :*** Movement of coelomic fluid in many annelids and starfishes is faciliated by flagellar activity.
6. Movement of material in uriniferous tubules of kidneys, genital ducts is aided by cilia/flagella.
7. Cilia and flagella act as sensory structures, e.g. macula and cristae hairs serve this function.

ENDOPLASMIC RETICULUM (ER)

Endoplasmic reticulum is a system of endomembranes of the cell cytoplasm with extensive ramification. Thy physical appearance of ER has been studied by electron microscopy. It was discovered by Porter.

ER membrane is similar to plasma membrane i.e. has lipid bilayer, and proteins (integral and peripheral). It is of three types.

1. **Rough Endoplasmic Reticulum (RER)**

(i) Lace-like system appearing as cisternae, running parallel to the nuclear membrane or in parallel rows.

(ii) Cisternae are tubular, closed at both ends, bear ribosomes containing RNA.

(iii) mRNA with attached ribosomes on ER gives it a characteristic spiral or rosette-shaped form.

(iv) RER is the site of protein synthesis which occurs in attached ribosomes.

(v) Nascent peptides/polypeptides are transferred either to cisternae or ER or released in cytoplasm.

(vi) RER is connected to nuclear membrane as well as with plasma membrane. This shows that they also facilitate influx and movement of exogenous material in the nucleus.

2. **Smooth Endoplasmic Reticulum (SER)**

(i) SER is found in continuation with RER and is located in the peripheral part of cytoplasm. SER is though to be derived from RER. It lacks attached ribosomes.

(ii) SER is concerned with lipogenesis and steroidogenesis.

(iii) SER is involved in glycogenesis.

3. **Annulate Endoplasmic Reticulum (AER)**

(i) More or less similar to RER because they have cisternae and ribosomes.

(ii) Differ from RER is not having a constant lamellar surface which in fact is either beaded or moniliform having pores.

(iii) Also concerned with protein synthesis.

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Chemical Composition

(i) ER has a rich variety of phosphatase, cytochromes, reductases, esterases and transferases which are present in its lumen or on the surface facing the cytoplasm.

(ii) ER enzymes catalyse biosynthesis of cholesterol, plasmalogens, bile acids, fatty acids triglycerides, glycolipids, and phosphatides.

(iii) Nearly 60 percent protein and 40 percent phospholipids (by weight) are present in ER.

(iv) The enzymes of electron-transport chain (cytochromes) are involved in electron transfer.

(v) Inner face of ER contain enzymes (peptides) which cut the polypeptide chain two smaller peptides or glycoside and aminoacid residues.

(vi) ER contains the enzymes for biosynthesis of cholesterol, precusor for steroids ; and bile salts.

(vii) ER also facilitates glycogenolysis.

(viii) ER provides mechanical support and functions as a circulatory system of cell facilitating movement of such metabolites as ions, nucleoproteins, RNA, etc.

(ix) ER also has detoxifying enzymes which are triggered into action on administration of hydrocarbons or carcinogens.

GOLGI APPARATUS

First discovered by Camillo Golgi. It occurs in plant and animal cells. Animal cells have various shapes of Golgi complex, e.g. vesicles, cisternae, narrow neck, bowl-like forms or shallow saucer-shaped bodies. Cisternae are the simplest unit of Golgi.

Cisterna of animal cells are of various length and shapes. Plant cell have Golgi consisting of stacks of smooth, double membraneous, lamellar discs (2 – 20) associated with tubules at their edges. At their free end, bulbous dilations may be present. Cisternae are membrane-bound space. They serve as storage sites for secretions of material. Such cisterna are called Dictyosomes and are made up of stacks of flatted discs. Plant cell may have upto 50 dictyosomes scattered in cytoplasm.

Golgi complex comprises of (a) cisternae (b) tubules and small vesicles and (c) large vesicles with amorphous material.

Golgi membrane contains 60 percent protein and 40 percent lipid.

Functions

1. Secretory cells have numerous Golgi which are associated with endoplasmic reticulum. This means that synthetic products of ER are stored in Golgi complex.
2. Golgi complex synthesizes glycoprotein, mucopolysaccharides and glycosphingo-lipids via enzymatic intervention.
3. It synthesizes lipids of yolk in oocytes of many animals.
4. It helps in steroid synthesis in gonads and formation of acrosomal complex in sperm during spermiogenesis.
5. In plant cells they have anabolic function.
6. It aids in cell secretion.
7. Various chemicals are synthesized by Golgi complex in different and cells of animals, e.g.
    - i. Acetylcholine, adrenaline, and peptides by neurons which serve as neurotramsomitters,
    - ii. Milk protein by alveolar epithelium of mammary gland,
    - iii. Enzymes such as lipase, proteases by exocrine cells of pancrease,
    - iv. Hormones,
    - v. Mucigen by goblet cells and
    - vi. Thyroglobulin by thyroid follicle cells.
8. Golgi complex of neuronal cells gives rise to zymogen granules.
9. Formation of cell wall in plant cell is also facilitated by Golgi.

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LYSOSOMES

Lysosomes are cell organelles bound by a single membranes ; de Duve (1955) first gave the term Lysosomes since they contain hydrolytic enzymes. They are also called 'suicide' bags.

Lysosomes are absent in prokaryotes and plant cells but are found in all eukaryotic organisms. Acid phosphatases is used as a cytochemical 'marker' for detecting the site and pattern of distribution of these organelles in a cell. The shape and size (0.1 to 5.0 μm) varies and depends on the metabolic status of the cell.

Lysosomes are polymorphic. Four types are recognised :

1. ***Primary :*** nascent (newly formed) with newly-synthesized enzymes.
2. ***Secondary (Phagolysosome) :*** These are involved in intracellular digestion or breakdown of exogenous material.
3. ***Autolysosomes :*** These arise by fusion of primary lysosomes. If fractured they release their hydrolytic enzymes and cause cell death and autolysis.
4. ***Residual bodies :*** These contain residues of undigested metabolites and/or foreign substances.

Lysosomes are bound by unit membrane which has the unique characteristic of fusion with other membranes.

Origin

1. From endoplasmic reticulum.
2. From focal degradation. Acidic hydrolases synthesized in rough endoplasmic reticulum are translocated to zones of focal degradation where they enlarge and form membrane bound lysosomes.
3. From Golgi complex.
4. Lysosomes synthesized by rough endoplasmic reticulum are translocated to Golgi apparatus from where membrane bound lysosomes are pinched off.

Lysosomal Enzymes

A variety of histochemical, cytochemical and biochemical techniques have been used to localise, extract, and characterise lysosomal enzymes. The fragile lysosomal membrane can be ruptured by surface active agents (detergents), mechanical and osmotic shocks, and enzymes.

The rich repertoire of enzymes (about 40) in lysosomes facilitate digestion of carbohydrates, fats, proteins, nucleic acids and esters. Acidic pH is required for catalytic activity of majority of lysosomal enzymes.

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Functions of Lysosomes

1. In intracellular digestion of endogenous and exogenous material (ingested by cell). Endogenous material may be deformed or broken cell organelles or accumulated end products of catabolism.
2. Digestion of macromolecules and colloids which enter cell by pinocytosis. The left over material in the vesicle forms the residual bodies.
3. ***Autophagy*** Digestion of deformed or fragmented cell organelles or cells/tissues (e.g. during amphibian metamorphosis) etc. Such material is trapped in membrane bound vesicle called autophagic vesicles where it is digested via action of lysosomal hydrolases. Residual bodies thus formed are removed by reverse pinocytosis. They fuse with plasmalemma and expel their contents by exocytosis.
4. ***Crinophagy*** Expulsion of accumulated waste and undigested material. Crinophilic granules fuse with lysosomes to form crinolysosomes. The granules are degraded by hydrolases and the end products diffuse in cytoplasm with the rest expelled from cells residual bodies.
5. ***Lysosomes and Cell Secretion*** Release of hormones from pitutary and thyroid glands is facilitated by lysosomes.

6. Bone resorption is also facilitated by causing breakdown of osteoblast and calcified cells.
7. Sperm acrosomal enzymes of lysosomal origin aid in penetration of sperm into the egg thus helping in fertilisation e.g. hyaluronidase, acrosin ; trypsin-like and neuraminidase.
8. Malfunctions of lysosomes are the cause of many disease in humans, e.g. hexosominidase deficiency causes Tay-Sachs disease ; gout is a disease caused by accumulation of uric acid crystals in joints.
9. ***Role of lysosomes in chemotherapy*** The technique uses neoplastic cells as carriers of drugs. Lysosomes of such cells are loaded with drugs which fuse with Lysosomes. Lysosomes cleave the carrier molecule and the drug is released to the cell interior where it performs its chemotherapeutic role.

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VACUOLES

Vacuoles are characteristic of plant cells particularly in maturing cells. Many protozoan cells also contain them in various forms and function (absent in parasitic and marine protozoans). Other types of animal cells also contain them and they are considered as zones of osmotic differentiation in cytoplasm.

Vacuoles are membrane bound. The membrane is called *tonoplast*. In many plant cells vacuoles are connected by tubular connections extended by neighbouring vacuole. Such tubules may extend even up to nuclear and plasma membrane or reach other cells via plasmodesmata.

In amoeba, three types of vacuoles are present viz., water, food, and contractile vacuole (osmoregulatory). Cyclosis of cytoplasm facilitates their migration.

Function

1. They act as storage organelles for metabolites or toxic secretory products.
2. Cells with large vacuole ensure economy in the synthesis of cytoplasm.
3. Vacuolar membrane (Tonoplast) act as solute pump for such ion flux as Na^+, K^+ and Cl^-.

RIBOSOMES

Ribosomes are found in prokaryotic and eukaryotic cells (absent in mature mammalian RBC). Their number and other characteristics vary. Largest number of ribosomes are found in hepatic cells and secretory cells of pancreas. They occur freely, in clusters, or attached to endoplasmic reticulum.

On the basis of their sedimentation co-efficient, ribosomes have been differentiated into (a) Prokaryotic ribosomes 70S and (b) Eukaryotic ribosomes 80S. 70S ribosomes are also characteristic of chloroplast and mitochondria. Both are made of two unequal sub units. Ribosomes are also found in nucleus and are also found attached to mRNA in the form of string (called polysomes).

Number of ribosomes may be high as 15000, e.g. *Eschrechia coli*.

Ribosomes are concerned with protein synthesis and are made up of uncovered ribonucleoprotein particles (rRNA + protein). The amount of rRNA is approximately 60 percent and of protein 40 percent.

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PLASTIDS

Cells of autotrophic organisms have the ability to synthesize their own food. Plant cells are unique in having special organelles that contain pigments which play a pivotal role in photosynthesis (exception Fungi and Myxomycetes). Some animals, e.g. *Euglena* also have chloroplast and thus are autotrophs. Chloroplast have the green chlorophyll pigments. The two main parts are : Stroma : chlorophyll free protein matrix and (ii) lamellar fraction. Plastids are classified on the basis of (a) presence or absence of pigment and (b) nature of pigment.

Types of Plastids

1. *Amyloplast* develop from proplastid, lack pigments but contain starch, ex. root cells and storage organ cells of some plants like potato.
2. *Leucoplast* are colourless and contain vesicles. ex. white petals and epidermal cells.
3. *Etioplast* contain fats and essential oils develop in dark (lack thylakoids), but develop thylakoids if illuminated.
4. Plastids that store starch, contain pigments (usually chlorophyll) and thylakoids are called *chloroamyloplast.*
5. Chromoplast are of two types :

   (a) On which contain photosynthetically active pigment, e.g., (i) Chloroplast present in green plants and consists of chlorophyll a and b ; (ii) *Phacoplast* contains brown carotenoids chlorophyll a and chlorophyll c pigment characteristic of Dinoflagellates, Brown algae, and diatoms. (iii) rhodoblast contain phycoerythrin (e.g. red algae), chlorophyll a, d and phycobilin protein, and blue (iv) green *chromatophores* (ex. blue green algae) contains chlorophyll a, carotenoids, phycocyanin (accounts for their blue colour).

   (b) Chromoplasts without photosynthetic activity.

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Ultrastructure of Chloroplast

1. Double layered covering
2. A granular stroma or matrix
3. Lamellar system and
4. Plastoglobuli (Osmiophilic granules)

Double Layered Covering

This is somewhat similar to mitochondrial membrane, 50–80 Å thick, has a unit membrane organisation and presence of intermembrane space. Outer membrane is permeable to chemicals of low molecular weight, inner membrane impermeable to nucleotides, sucrose, phosphate but contains specific barriers for translocation of metabolites.

Stroma

Contains (a) granules called grana (b) metabolic enzymes for CO_2 assimilation (c) RNA, proteins, lipids and carbohydrates (d) filled with gel-like fluid.

Lamellar System

This consists of

(a) Flattened disk-like structures called *Thylakoids* which are connected to their lumen and surrounding stroma.

(b) Tightly packed disc form a granum (number 10–100) which looks like stacks of coins.

(c) Stromal lamellae which run between Grana.

(d) Thylakoids contain protein and lipid in a ratio of 50 : 50.

(e) Thylakoids consists of chlorophyll, carotenoids, phospholipids, galactolipids, sulpholipids, and Lipophilic plastid Quinones.

Plastoglobuli

Circular osmiophilic, contain granular lipids, present in stroma as electron-dense bodies, 30μm–300 μm in diameter, their number increases with age of plants. Their size increases during vegetative growth.

Function as storage organs for lipids outside thylakoids.

Characteristics of Chloroplasts

1. Number of chloroplast per cell shows much variation. In angiosperms their number can be 40 per cell. Chlamydomonas has only large chloroplast while an incredible number of chloroplasts have been counted in the leaf of *Ricinus communis* (400,000/mm^2 of surface area)
2. Chloroplast consists of 40–50 percent protein, 5–10 percent chlorophyll a and 2, 1-2 percent carotenoid pigments. Also present are nucleic acids and minerals (free or bound).
3. Chloroplast exhibit contractility and can migrate. Migration is facilitated by cytoplasmic streaming movement in a cell.
4. Shape, size and volume is altered by sun light.
5. Chloroplast store starch.
6. DNA and RNA are associated with the chloroplast.
7. Mg^{+2} is always intimately associated with chlorophyll structure.

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MITOCHONDRIA

These were discovered by Atman (1894) who called them particles resembling bacteria and possessing genetic information apparatus. Benda called them mitochondria. Present in all aerobic eukaryotic cells, they are absent in mammalian mature RBC and prokaryotic cells. Their number varies from one to an astronomical figure of 5×10^5 e.g. *Chaos chaos* (Giant Amoeba). In hepatocytes of rat the number of mitochondria varies between 1000 – 1500. In neoplastic cancer cells, their number is greatly attenuated. Metabolic status of cells largely determines the number of mitochondria and thus it varies from cell to cell also.

Mitochondria contain respiratory enzymes. They can be stained with Janus Green B. They are present in the mitochondrial matrix and cristae.

Position

Found near the nucleus, or aggregated in peripheral cytoplasm. In general, largest concentration of mitochondria occurs near the site of maximal activity or oriented in the direction of activity e.g. sperm cells (mitochondria present in mid-piece), hepatocytes, muscle cells.

Shape

Varies, granular or filamentous (depends on metabolic state of cells). Yeast cells have spherical mitochondria ; elongated shape occurs in hepatocytes ; filamentous in fibroplasts, and elliptical in kidney cells. In rare instances one end of these organelles is swollen.

Size

Varies, but is generally 0.5μ wide and 7μ long (somewhat similar to a bacterial cell). Metabolic state of cells influences size of cells.

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Ultrastructure

Electron microscopic structure of mitchondria was given by Palade. The salient features are :

1. Each organelle is made up of two membrane – an outer smooth membrane and an inner one which has villi like outgrowth of various shapes and sizes called cristae. Membrane resemble unit membrane (70 Å thick).
2. Mitochondrial lumen is enveloped by these two membranes in such a manner so as to give the appearance of a sac within a sac.
3. Presence of an intermembrane space of 60Å – 70Å. The lumen of outer sac has no connection with the inner one.
4. Cristae are heterogenous in shape–some villous, others finger-like and irregular.
5. Mitochondrial matrix is filled with dense granules and proteinaceous material.
6. Dense granules are believed to be site of binding for divalent ions such as Zn^{2+}, Mn^{2+}, and Ni^{2+}.
7. Stalked particles are present on Mitochondrial cristae. These are called elementary particles, which consists of a hexagonal basal plate, stalk and a knob-like structure.
8. Mitochondrial matrix contains circular DNA and ribosomes. DNA-directed protein synthesis occurs here.
9. Lumen of mitochondria contains co-enzymes, e.g. NAD^+, NADH, NADPH Nucleoside mono, di-, and-triphosphates. Inner membrane is impermeable to these.

Functions of Mitochondria

Nearly 70 enzymes and co-enzymes are present on the membrane system, matrix and inter membrane space which catalyse a variety of energy-dependent metabolic functions. In addition to energy transduction, the principal functions are :

1. Ion transport facilitated by permeases

2. Oxidative phosphorylation
3. Tricarboxylic cycle (Krebs cycle)
4. Oxidation of Fatty acids.
5. Electron transport

Origin of Mitochondria

1. do novo origin (From unit membrane or endoplasmic reticulum)’
2. Self-replication of pre-existing mitochondria (by fussion)
3. Transformation of non-mitochondrial system into mitochondria.

   Mitochondria are believed to have originated from aerobic prokaryote i.e. mitochondria represent symbiotic bacteria (= Prokaryote) living in association with eukaryotic cells.

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NUCLEUS

Nucleus was discovered by Robert Brown (1831). Meischer (1869) suggested that nucleus is an important constituent of cells. Waldeyer (1888) designated the rod-like structures in nucleus as chromosomes.

Prokaryotes lack a well-organised and defined nucleus. All eukaryotic cells (except mature RBC of mammals) contain a definitive and well-organised nucleus enveloped by nuclear membrane and contain chromosomes. Prokaryote nucleus is devoid of nuclear membrane and has a single circular chromosome made up of DNA.

Nucleus (a) regulates all metabolic activity of a cell and (b) is store house of all the genetic information ; enucleate cells have short life. The size, shape, and number of nuclei in a cell varies. Most cells, however, are cardiac muscles, *Opalina*. Mostly nucleus is lobed, round, oval, or elliptical. However, it may acquire different shapes.

The position of the nucleus in a cell also varies. It may be central, eccentric, peripheral or basal.

Structure of Nucleus

Nucleus contains the following structures :

Nuclear Membrane

1. Double layered, the two layers are 100 Å – 300 Å apart leaving a discontinuous perinuclear space.
2. Structure of nuclear membrane is similar to plasma membrane.
3. The membrane is derived from endoplasmic reticulum (ER) The outer surface has attached ribosomes.
4. Pores (nuclear pores) present. Their number varies and relates to the species of cells and its metabolic state.
5. Below the inner membrane lies the dense lamellae called the honeycomb layer. This is bordered by lumps of chromatin on the inner surface. The outer membrane communicates with the ER.
6. Nuclear membrane facilitates the transport of macromolecules, ribonucleoprotein, etc.
7. Nuclear membrane contains 20 types of proteins many of them are enzymes. ATPase, glucose-6-phosphatase and cytochrome P-450 are found to be associated with it.

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Nuclear Matrix

1. Jelly-like, composed of nuclear gel or karyolymph and matrix.
2. Nuclear gel is highly granular. It contains proteins, DNA, RNA, and phospholipids.
3. Acidic protein can contract and expand under the influence of Ca^{2+} and Mg^{2+}.
4. Chromatin is present in condensed form called heterochromatin which is made up of network of non-chromatin material.

Nucleolus

1. Present in all eukaryotic cells except sperm, cleaving blastomeres of amphibians and some algae. Number of nucleoli varies from 1 to many. Cells devoid of nucleolus do not synthesize proteins.
2. Nucleolus from shows changes during cell cycle. It disappears during prophase ; and reappears during telophase. Interphase nucleolus is irregular and is prominent.
3. Nucleolus contains a central homogenous region surrounded by a more filamentous region.
4. Nucleolus has three main functions :

   (a) Transcription of the gene that code for rRNA.

   (b) Processing of periribosomal molecule.

   (c) Assembly of ribosomal subunits.

   Nucleolar genes (rDNA) occur in clusters as well as in multiple copies.

Chromatin

1. It is basis of heredity and occurs in the form of viscous substance.
2. Contains DNA, RNA and proteins in a compact form. Proteins are of 2 types (a) histones and (b) Non-histones.
3. During interphase, chromatin is dispersed through the nucleoplasm in the form of reticulum.
4. Feulgen positive dark regions of chromosome is called heterochromatin (forming aggregates called chromomeres), the non-chromatic region is known as euchromatin.
5. Histones are basic proteins and have a 1 : 1 ratio with DNA.
6. Non-histone proteins of chromatin are concerned with gene expression, e.g. RNA polymerse.
7. Eukaryotic chromatin is fibrous.
8. Chromatin consists of *nucleosome* which is connected by a fine thread. A single molecule of H1 and histone is associated with each nucleosome.
9. Nucleosome DNA has two parts (a) core DNA and (b) Linker DNA.
10. Heterochromatic region of chromosomes forms chromocenters during interphase and prophase and contains important genes. It is rich in DNA and is often called satellite or redundant DNA is believed to facilitate separation of chromosomes during anaphase.
11. Chromatin is reproduced during interphase of a growing cell.

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CHROMOSOMES

Chromosomes were named by Waldeyer (1888). They are present in nucleus of eukaryotic cell. They regulate metabolic activities of cells and contain the entire genetic blue print of an organism which is transmitted to the next generation. Fleming observed thread-like structures in chromosomes and called them chromatin.

Prokaryotic chromosomes lie in cytoplasm. Chromosomes of higher plants and animals contain basic proteins called histones. Histones have nothing to do with transmission of heritable traits and information. Roux proposed that units of heredity are present on chromosomes. Beneden and Boveri (1887) stated that each species has fixed number of chromosomes.

The genetic material of majority of organisms is DNA. Some viruses have RNA as the genetic material, e.g. Tobacco mosaic virus, reovirus. Others have DNA. Sutton and Boveri (1902) proposed the chromosome theory of Heredity and Morgan related their role in transmission of character from one generation to other.

The chromosome of prokaryotes, e.g. *Coli* is circular and contains double stranded helix of DNA. It also has small amount of RNA (mRNA) and protein (mostly enzymes). Chromosome is attached to mesosomes. In addition to this, *E. Coli* and other bacteria possess circles of double stranded DNA called plasmids and episomes. Plasmids replicate independently. Episomes first integrate with host chromosomes and then can simultaneously replicate with it. Supercoiled chromosome is found in the bacterium, *Thermoplasma acidophilium.*

Eukaryote Chromosomes : Characteristics and Functions

1. Irregular thread-like, stain with Feulgen technique indicating presence of DNA in them. Highly condensed during metaphase. Form of chromosomes depends on cell cycle.
2. Carriers of genes. Total number of genes present in a haploid or signal set of chromosome in a cell is called genome.
3. Shape and size of chromosomes alters during cell growth and division cyclically. Metaphase chromosome have a primary construction called centromere which divides the chromosomes into two arms.
4. Number of chromosomes is species-specific and can be easily counted during metaphase when they are attached to mitotic spindle by centromere. The smallest diploid number of chromosome in animal is 2 in case of *Ascaris megalocephala* ; in *Drosophila melanogaster* it is 8 and in human it is 46. Table 1.6 gives the information on characteristic chromosome number of plants and animals.

   Somatic cell contain diploid number (2n) while germ cells have haploid number (n) of chromosomes.
5. Chromosomes are classified into 4 types on the basis of position of centromere.

(a) *Telocentric* : Centromere located at one end. Appear to be rod-like. It is of rarest type.

(b) *Acrocentric* : Centromere located in such a way that a very short arm of chromosome is visible.

(c) *Sub-metacentric* : Centromere divides the chromosome into unequal arms. They appear to be L-like in form during anaphase..

(d) *Metacentric* : Centromere divides chromosomes into two equal arms. They appear to be V - like during anaphase.

They are also classified on the basis of number of centromere (a) *Monocentric* : one centromere/chromosome (b) *Dicentric have* 2, (c) Polycentric have more than 2 (d) *Diffuse* : centromere spread along the total length (e) *Acentric* : centromere is absent.

6. Chromosomes are classified into :

(a) *Somatic chromosomes* (autosomes) are present in all somatic cells (body cells). They are more numerous.

(b) *Sex chromosomes* are present in sperm and ovum. They are of 2 types, X and Y (in birds and lepidoptera, they are termed Z and W).

Structure of Autosomes : Each is made up of two chromatids. Chromatids contain coiled chromonema. Chromonema comprises of either a single or multiple strands of nucleoprotein (DNA + histone)

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chromonema is surrounded by chromatin material. Chromatids are held togethers by centromere. During cell division, centromere becomes the focal point for attachment of spindle fibres. Chromatid can be longitudinally split into two halves called chromonema. Thus, each chromosome is a tetrad structure. Chromosomes exhibits banded pattern. Average length 0.5 μ – 30 μm and width 0.2 μm – 3 μm and width 0.2 μm – 3μm. Polytene chromosomes of some insects are 300 μm long 10 μm wide. Chromosomes of plants are longer than that of animals. The beaded structures. present on chromatin are called chromomere. Tobacco chromosomes are largest amongest plants.

The number of centromeres is usually one per chromosome (monocentric). However, in some more than one may be present (polycentric). Centromere divide the chromosome into 2 arms of varying length. The tips of chromosomes are called telomere.

Chromosomes may have one or more constrictions called primary constriction (loci of centromere) and secondary constriction (nucleolar organiser). In addition, some may have a specifically localised satellite chromosome separated from the rest of chromosome.

All somatic cells have a fixed number of chromosomes expressed as diploid or 2n. Their number is reduced to half (haploid = n) during gametogenesis.

Sex Chromosomes (=allosomes) They provide the chromosomal basic of sex determination in animals which manifest sexual dimorphism. Two types of sex chromosomes are found : X and Y . X and Y differ in shape, size, DNA content, and sedimentation rate. In birds and lepidopteran they are called Z and W.

7. Chromosomes contain DNA, RNA, histones, enzymes, some organic phosphorus compounds and inorganic salts.
8. All the chromosomes of a species may have similar size or they may be dissimilar. The size of chromosomes may very from cell to cell in different parts of a plant. In developing stages of insects also, their size exhibits variation.

Special Types of Chromosomes

Lamp Brush Chromosomes

They were discovered by Fleming (1882) in amphibian oocyte.

Characteristics and functions

1. Found in Oocytes of fish, amphibian, reptile, birds and some invertebrates.
2. Hairy appearance, highly elastic, and consists of chromosomes held together by an extremely fine axial fibre (95 per cent DNA). Lateral loops extends from chromomere.
3. Contains alternating regions of high density granules, and low lateral loops which contain 5 per cent DNA.

Polytene Chromosomes

Polytene chromosomes or salivary gland chromosomes of certain dipterans. e.g. *Drosophila* and *Chironomus* larva were disovered by Balbiani (1881).

1. Extremely specialised type found in the larval salivary gland of *Drosophila melanogaster* etc.

   Also found in malpighian tubules, fat bodies and alimentary canal.
2. A large nucleolus is found attached to the common chromocenter.

Human Chromosomes

Characteristics

1. Total diploid number is 46 (23 pairs) in somatic cells.
2. Of the 46 (23 pairs), 44 (22 pairs) are autosomes and 2 (one pair) are sex chromosomes. Males have one X and one Y while females have 2X.
3. The chromosomes are recognised on the basis of position of centromere, size of two arms size of chromosomes and banding pattern (revealed by different staining methods) designated in various ways.

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Chromosomal Abnormalities

Chromosomal abnormalities in humans are due to (a) euploidy (b) aneuploide and (c) structural aberrations. Polyploidy (more than the normal 2n number of chromosome) is rare in humans.

Aneuploidy (less than 2n) may be due to ploidy of sex chromosomes or of autosomes. Thus, *Turner syndrome* is due to presence of only one X chromosome i.e. 2n + XO ; and *Klinefelter syndrome* is due to presence of 1 or more X chromosome (i.e. 2n + XXY).

Autosomal Disorders

1. Down's Syndrome (chromosome was) discovered by Langdown (1866). Number of chromosomes is 47. Three 21st chromosome are present. Persons are mentally retarded and display abnormality of nose, ear and hand (ii) Patau's syndromes (Trisomy of 18th chromosome). Death occurs soon after birth in many cases.

   Structural aberrations due to translocation, deletion, duplication and inversion. Deletion of some genes of chromosome 5 (short arm) leads to Cri-du-chat syndrome ; and of 21st chromosomes causes leukemia.

Characteristic diploid (2n) chromosome number of some plants and animals

	Diploid Number (2n)
I. Plants :	
1. Chlamydomonas [green algae]	16
2. Mucor hemolysis (bread mould fungi)	2
3. Pinus ponderosa (gymnosperm)	24
Angiosperms	
4. Brassica aulerecia (cabbage)	18
5. Raphanus sativus (Radish)	18
6. Carica papaya (Papaya)	18
7. Helianthus annus. (Sunflower)	34
8. Solanum tuberosum (Potato)	48
9. Lycopersicum solanum	24
10. Pisum sativum (Pea)	14
11. Triticum vulgare (Wheat)	42
12. Zea (Maize)	20
13. Oryzae Satius	24
14. Haplopappus gracilies	2
II. Animals	
A. Vertebrates	
1. *Mammals*	
1. Homo sapiens (Humans)	46
2. Chimpanzee (*Pan troglydetro*)	48
3. Gorilla (*Gorilla gorilla*)	48
4. *Rhesus monkey*–Macaca mulatta	42
5. Capra hickers (goat)	60
6. Sheep *Ovis arise*	54
7. Pig–Sus acinus	62
8. Horse–Equs cabalis	64
9. Cat–Felis domesticus	38
10. Dog–Canis familiaries	78
11. Rat–*Mus musculans*	40

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12. Common rat–Rattus rattus	42
13. Rabbit–Oryctolagus cuniculus	44
2. *Birds*	
1. Anser platyrhyncha (Duck)	80
2. Gallus domesticus (Fowl)	78
3. Columba livia	80
3. *Reptila*	
1. Alligator mississipiens	32
4. *Amphibia*	
1. Toad–*Xenopus laevis*	36
2. Toad–Bufo americanus	22
3. Frog–Rana pipiens	26
5. *Pisces*	
1. Goldfish-Carusius aurtaus	100
B. Invertebrates	
1. *Mollusca*	
(a) Helix plamatea (Roman Snail)	54
2. *Arthropoda*	
(a) Mosquito–*Culex pipiens*	6
(b) Honey bee–Apis mellifica	32, 16
(c) Fruitfly–Drosophila melanogaster	8
(d) Housefly–Musca domestica	12
(e) Silk moth–Bombyx mori	56
3. *Nematoda*	
(a) Ascaris Lumbricoides	24
(b) Ascaris megalocephala	2
4. *Platyhelminthes*	
(a) Planaria	16
5. *Cnidaria*	
(a) Hydra vulgaris	32
6. *Protozoa*	
(a) Paramecium aurelia	30–40
(b) Radiolarians	1600

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Chromosomal disorders in humans

Sex chromosome	Sex	No. of Barr body	Result
2n + XO	Female	0	Turner's Syndrome
2n + XX	Female	1	Normal
XXX	Female	2	Super female
XXXX	Female	3	Mentally retarded
XXXXX	Female	4	-do-
XY	Male	0	Normal
XYY	Male	0	Normal
XXY	Male	1	Klinefelter Syndrome
XXYY	Male	1	-do-
XXXY	Male	2	-do-
XXXXY	Male	3	Intense Klinefelter Syndrome.

Autosomes	Sex	Result
Trisomy of 21st chromosomes	Occurs in male or female (47 chromosomes)	Down's Syndrome
Trisomy of 18th chromosome	-do-	Edward's syndrome
Trisomy of 13th chromosome	-do-	Patau's Syndrome
Deletion of some genes (short arm) of 5th chromosome	Male or female	Cri-du-chat syndrome
Deletion of some genes of 21st chromosomes	-do-	Leukemia

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