CELL BIOLOGY

1.1 Tools and Technique

The preparation of the cells or cells parts for their study requires very specialized methods. The search continues for new instruments. So as to provide better understanding of cell structure upto molecular level, the following tools and techniques helped the biologists to know more about the cells.

(1) **Microscopy :** (*Gk. Micros* = small ; *Skopein* = to see) It is practice of using microscopes for the study of finer details of small objects including cells and tissues. Microscope are instruments consisting of lenses (made of glass / Lithium fluoride / electromagnetic lens) which magnify and resolve small objects not visible to unaided eye for the study of their details.

(i) **Magnification :** Is the power of enlargement, which is the ratio of

$$\text{Magnification} = \frac{\text{Size of the image with the instrument}}{\text{Size of the image with unaided eye}}$$

Magnification of a microscope is roughly equal to the multiple of magnifying power of objective lens and ocular lens (eye piece) *e.g.*, if the magnification power of an ocular lens is $10\ X$ and of the objective is $40\ X$, then the total magnifying power of a microscope is $10 \times 40 = 400\ X$ (the magnification power of a microscope is represented by the symbol '*X*').

(ii) **Resolving power :** It is the ability of a system to distinguish two close objects as two distinct objects. Its values is calculated by *Abbe* equation –

$$L_m = \frac{0.61\lambda}{NA}$$

Here, λ – is wavelength of used light, NA – Numerical Aperture, $(NA = n \sin\theta)$

Numerical aperture is multiple of refractive index of medium (n) and $\sin\theta$, which is sine of angle substended by optical axis and outer ray covered by objective. The value for best objective $\text{sine}\, 70° = 0.94$.

The resolving power of a microscope depends on the kind of illumination used. It is equal to one half of the wavelength of the illuminating light. The wavelength of visible light is 3,900 Å to 7,800 Å. Taking the average as 5,850 Å, the resolving power of the light microscope is about 3,000 Å or $0.3\ \mu m$. Therefore, we can not see objects smaller than $0.3\ \mu m$ even with the light microscope. Many cell organelles are smaller than $0.3\ \mu m$. These were unknown till electron microscope was invented.

The resolving power of human eye is $100 \mu m$ or microns (0.1 *mm*). This means that two points less than $100\ \mu m$ apart appear as one point to our eyes.

Father of microscopy is *Leeuwenhoek*. He built first 270 *X* magnification microscope in 1672.

(2) **Types of microscopes**

(i) **Simple microscope :** It is also known as magnifying glass and consists of a convergent lens. The image formed by it is virtual, enlarged and on same side of lens.

Robert Hooke designed a primitive microscope and discovered cells with it. It was the first tool ever used to observe biological objects. Its magnification power was 14 – 42 times only, so it is considered as simple microscope.

(ii) **Compound microscope or Light microscope :** The first compound microscope was assembled by *Zacharias Janseen* and *J. Janseen*, the Dutch spectacles makes in 1590. The first compound microscope was prepared by *Kepler* and *Galileo* in 1611. However, it was not used for laboratory study. It is simplest, widely used microscope having three lens *i.e.* condensor, which collects the light rays and precisely focuses them on the objects; objective lens, which magnifies the image by three objective lenses, *i.e.* low power, high power and oil immersion lenses.

In a compound microscope an object can be magnified upto 1000 times and the magnification is independent of intensity of light, size of microscope and numerical aperture. The light microscope is also called *bright field* microscope because it forms the image when light is transmitted through the object. The specimen formed is darker than the surrounding bright field. The light microscope can be used to examine the live, unstained materials as well as the preserved and stained specimens.

(iii) **Fluorescent microscope :** It was developed by *Coons* (1995). It is observed that when ultraviolet light is irradiated on certain chemical substances, they absorb it and emit visible light. These chemical substances are called fluoro-chromes. The fluorescent substances *e.g.*, quinine sulphate, rhodamine and auramine are used to stain the cellular objects and these objects are easily visible as fluorescent areas when illuminated with ultraviolet light. Property of emission of long wave radiation soon after getting excited by shorter wave called, fluorescence.

(iv) **Polarizing microscope :** It was invented by *Tolbart*. In this microscope the plane polarised light is used as a source of illumination. Unlike the ordinary light, plane polarised light vibrates only in one direction and the cellular objects are easily visible as they appear bright against the dark ground. Polarizing microscope is helpful in studying the spindle fibres in the cells.

(v) **Ultraviolet microscope :** It was invented by *Caspersson*. In this microscope the source of illumination is ultraviolet radiations having shorter wavelengths (1500 Å – 3500 Å) as compared to ordinary visible light. In this microscope, the lenses are made of fluoride, lithium fluoride or quartz instead of glass.

Ultraviolet microscope is helpful in quantitative determination of all those cell components which absorb ultraviolet rays, *e.g.*, those places where high concentration of nucleic acids is found, appear as darker regions than the remaining cell components.

(vi) **Phase contrast microscope**

(a) Discovered by *Dutch man Fredericke Zernicke* (1935).

(b) Source of illumination is visible light.

(c) It is used to study living cells and tissues without staining and effect of chemical and physical agents on the living cells.

(d) The optical system of the phase contrast microscopy converts these phase variations into visible variations in light intensity or contrast.

(e) It also used to study spindle formation, pinocytosis, karyokinesis, cytokinesis etc.

(f) It is draw back is low magnification power so subcellular organelles smaller than $0.2\,\mu$, like ribosomes, lysosomes, ER, cannot be visualised.

(vii) **Interference microscope (Morten et.al.)**

(a) It's principle is similar to that of the phase contrast microscope and gives / studies quantitative data.

(b) Nomarski interference contrast microscope is useful to study mitosis /cell components in living state.

(c) It gives better image of living structures. It also used to measure thickness of the cell and determination of several light absorbing chemicals like nucleic acid, proteins, lipids etc.

(d) It helps to measure dry weight and water contents of the specimen.

(viii) **Dark field microscope**

(a) *Zsigmondy* (1905) invented this microscope.

(b) It is based on the fact that light is scattered at boundaries between regions having different refractive index.

(c) The object smaller than those seen with ordinary light microscope can be detected but can not be resolved.

(d) It makes use of visible light.

(ix) **Electron microscope :** This was developed by *M. Knoll* and *E. Ruska* (1931) in Germany. It is a large sized instrument which has an internal vacuum, high voltage (50,000 – 1,00,000 volts), a cooling system, a fast beam of electrons (0.54 Å wavelength), a cathod filaments of tungsten and electromagnetic lens (which having a coil of wire enclosed in soft iron casing) for focusing.

Thus an electron microscope essentially comprises an electron gun and electron lenses. The electron gun is the source of electrons consisting of a heated tungsten filament. It is preferred because it can be heated upto 3000°C. The electron beam can be reflected by magnetic field. Therefore, a very powerful magnetic coil acts as lens. The focal length of the electromagnetic lenses change with the wavelength of illumination. Since the wavelength is controlled by the voltage, it should be controlled and made constant. Three types of magnetic lenses are used namely projector, objective and condenser. The magnetic field produced is concentrated by soft iron casing. When the filament is heated to incandescence, it emits electron. The electrons then move to positively charged anode. The entire microscope column operates under conditions of high vacuum. It is due to this fact that we can not observe living objects through an electron microscope (EM). For viewing objects under EM, ultrathin sections are prepared through an ultramicrotone.

Electron microscope can magnify the objects upto 2,00,000 times (now possible upto 2,50,000 – 4,00,000) and direct study of objects is possible on this microscope. The resolving power of electron microscope is 10 Å which is 100 times more than the light microscope. The images obtained in electron microscope have usually black gray and white shades. Computer is used to enhance contrast and develop colour. The most recent technique for examining objects through electron microscope is freeze fracture. The material is frozen quickly in liquid nitrogen (–196°C). This material during microtomy tends to along lines of weakness.

Electron microscope are of two types: –

(a) **Transmission electron microscope (TEM) :** It was the first microscope developed by *Ruska* (1932). It produces two dimensional images. Study of living cells can not be done through this microscope because of high voltage, which is required to operate it, kills the living materials.

Magnification of TEM is 1–3 *lakh* and resolving power is 2–10Å. Because of them transmission electron microscope has helped in the discovery of a number of small cell organelles *e.g.*, ER, ribosomes, centrioles, microtubules etc. Details structure of larger cell organelles could also be known only with the help of TEM. *e.g.*, chloroplast (thylakoids), mitochondria (elementary particles, DNA, ribosomes) etc. Study of virus, mycoplasma and other small entities could also be made possible with the advent of electron microscope.

(b) **Scanning electron microscope (SEM) :** This microscope was invented by *Knoll* (1935). It is used to see the surface view of structures by forming an image with the secondary electrons reflected by those structures and it gives three dimensional image. The specimen to be studied is first super cooled (in liquid propane at –180°*C*) and dehydrated in alcohol (at –70°*C*). It is then coated with gold, platinum or some other metal for creating a reflecting surface for electrons. Magnification of SEM varies from 15 – 2,00,000. Resolution power is 5 – 20 *nm.*

Difference between compound and electron microscope

Compound microscope	Electron microscope
Source of illumination is visible part of electromagnetic radiation.	Source of radiation is a beam of electrons.
It does not require vacuum.	The apparatus is enclosed in vacuum chamber.
Glass lenses are used.	Not used.
It does not use magnets.	It uses high power magnets.
High voltage electricity is not required.	High voltage used to generate beam of electrons.
The specimen used may be 6 *mm* or more in thickness.	The specimen must be ultra thin, about 100 Å in thickness.
Contrast is achieved by dyes like heamatoxylin, fast green, saffranin, etc.	Contrast is achieved by using heavy metals likes lead acetate and

	phosphotungstate.
The human eye can directly observe the image formed by the instrument.	Can not be seen directly by eye, instead, a fluorescent screen or a photographic plate is used.
Radiation risk is absent.	Radiation risk is always there.
The specimen or object is kept in liquid medium or a resin.	The specimen must be completely dried.

(x) **Advanced high power microscope**

(a) **Scanning probe microscope :** The microscope is capable of resolving the outer texture of the material to the minutest detail since it has the potential to image even a single atom. Magnification is upto 100 million.

(b) **Scanning tunnelling microscope :** It has a tiny tungsten probe for moving over the surface of specimen. The microscope is used to detect defect in electrical conductors and computer chips.

(c) **Atomic force microscope :** It has an extremely fine diamond probe for moving over the surface of biochemicals. Oscillations produced in the probe are changed into images by a computer. The microscope is useful in viewing detailed structure of biological molecules, *e.g.*, DNA, proteins, etc.

(3) **Units of measurement used in microscopy**

1 micron (μ) = 10^{-6} or one millionth

1 micrometer (μm) = $10^{-6}\,m,\ 10^{-4}\,cm, 10^{-3}\,mm = 1000\ nm$

1 Nanometer (nm) = $10^{-9}m,\ 10^{-7}\,cm, 10^{-6}\,mm, 10^{-3}\,\mu m = 10\,\text{Å}$

1 Angstrom (Å) = $10^{-10}\,m, 10^{-8}\,cm, 10^{-7}\,mm, 10^{-4}\,\mu m, 10^{-1}\,nm, 0.1\,nm$

1 Picometer (pm) = $10^{-12}m, 10^{-3}nm$

1 Fempometer (fm) = $10^{-15}m, 10^{-6}nm$

(4) **Cytochemistry :** A number of dyes or stains are known to colour specific parts. Certain dyes can be used even in case of living materials. They are called vital stains, *e.g.,* neutral red, methylene blue. Fuelgen or Schiff's reaction was developed by *Fuelgen* and *Rossenbeck* (1924). Identification and localization of chemical compounds of a cell is studies in cytochemistry. It is based on four main analytical techniques.

(i) Separation of cell fractionation by conventional bio-chemical techniques.

(ii) Isolation of minute amount of tissue and even single cells by micro and ultramicromethod.

(iii) Direct detection of cell components in the cell by chemical staining.

(iv) Use of measurement of physical parameters.

Cytochemical stains : Some of the important stains are as follows.

Stain	Used for staining	Final colour
Acetocarmine	Chromosomes	Pink
Acid fuchsine	Cortex, cellular walls, mitochondria	Magenta
Aniline blue	Fungal hyphae	Blue
Basic fuchsine	Nucleus	Magenta red
Crystal violet	Bacteria	Violet
Chloro zinc iodine test	Cellulose	
Eosin	Cytoplasm	Pink
Feulgen's stain	DNA	Purple or Red
Geimsa orcein	Nucleus	
Haematoxyline	Nuclei, cell wall and cellulose	Violet
Iodine solution	Starch	Blue
Janus green	Fungi and mitochondria	Green
Methylene blue	Yeast and Glogi complex	Blue
Ninhydrin	Protein and amino acid	
Nephthal yellow	Protein	
Phloroglucinol *+HCl*	Lignin	Red
Pyronin *Y*	RNA	
Ruthenium red	Pectin	Red
Saffranin	Nuclei, lignified tissue	Red
Schiff's reagent	DNA	
Sudan- III or IV	Suberin, cutin, oil	Red
Sudan black	Fatty substance	Black
Toludine blue	RNA	Blue
Cotton blue	Fulngi	Violet

(5) **Cell fractionation :** In isotonic medium cells components are separated, it is two step process.

(i) **Homogenisation :** Cell products are separated in isotonic medium (0.25 *M* sucrose solution) either with the help of homogeniser of ultrasonic vibrations kept at 0 – 4°C. A homogenised cell is called homogenate.

(ii) **Differential centrifugation :** Homogenisation product is rotated (centrifuged) at different speeds. The sediment or pellete of each speed is collected. *e.g.*, nuclei at $1000 \times g$ (*g*= force of gravity) for 10 minutes, chloroplast and mitochondria at $10{,}000 \times g$ for 15 minutes. The particle settle according to their sedimentation ratios. Sedimentation coefficient is expressed in svedberg unit '*S*' related with molecular weight of the particles. For mitochondria it is the best technique.

The various cell organelles and macromolecules sediment in the following order.

Nucleus → Chloroplas t → Mitochondr ia → Ribosome → DNA → mRNA → tRNA

(6) **Chromatography :** Discovered by *Michael Tswett* (1906). This technique is used to separate the molecules of different substances present together. Mixture of molecules is run over an adsorption medium. Chromatography may be following types.

(i) **Adsorption or Column chromatography :** The stationary phase consist of a column of charcoal, silica, alumina, calcium carbonate or magnesium oxide. The solution is made to percolate through this column when different chemicals get adsorb at various levels. The technique is useful for separation of tissue lipids.

(ii) **Thin layer chromatography :** The stationary phase consists of a thin plate of cellulose powder or alumina. As a few drops of mixture are poured over it, the different chemicals spread to different distances. The method is useful in separation of amino acids, nucleotides and other low molecular weight products.

(iii) **Paper chromatography :** A paste of mixture is applied near one end of a chromatographic paper (or Whatman 1). The lower end below the paste is dipped in a solvent. As the solvent rises in chromatographic paper, the different chemicals of the mixture spread to different distances. The paper can be rotated to obtain two dimensional chromatogram.

(iv) **Ion exchange chromatography :** Beads of cellulose and other materials having negative and positive charges are placed in a column. The mixture (mobile phase) is poured over the column. As the mixture passes through the column, its constituents separate according to their charges. The technique is used in purification of insulin, plasma fractionation and separation of proteins.

(v) **Gel fractionation chromatography (Molecular sieve chromatography) :** Dextran gel sephadex is available with various pore size. A mixture is poured over a column of sephadex. The various chemicals pass through the pores and come out of the column with heavier larger molecules do so first followed by progressively smaller sized molecules provided the pores are larger than the size of largest molecules. The technique is used in determining the molecular weight of proteins by calibrating the column with proteins of different molecular weights.

(vi) **Affinity chromatography :** Satationary phase consists of column of ligands (molecules that bind to other specific molecules at particular sites). Mixture is allowed to pass through the column. Chemical linkages are established between ligands and their specific chemicals. Others pass out of the column. The technique is used in separation of enzymes, immunoglobulins, *m*RNA, etc.

(7) **Electrophoresis :** It is an another technique of separation. In which patricles of different charges and sizes are separated under the influence of electric field. *e.g.*, nucleic acids, proteins, amino acid, nucleotides can be separated by this method. The technique was discovered by Russian phyicist *Alexender Reuss* in 1807**.**

A base material is used for the passage of molecules of the mobile phase. In PAGE (ployacrylamide gel electrophoresis) the base material is polyacrylamide or polymer of acrylamide and methylene bisacrylamide. In agarose gel electrophoresis, the base material is agarose. The base material

dip in solution having cathode at one end anode at the other end. As the electric current is switched on, the chemicals of the mixture separate and pass to different distances. The gel functions as a sieve. In two dimensional electrophoresis, molecules are separated in two directions. In immunoelectrophoresis antibodies coupled with radioisotopes, specific enzymes or fluorescent dyes are used in detection of particular proteins. The technique is highly sensitive. It can separate molecules in picogram and nanogram quantities and distinguish proteins which differ from each other in only one amino acid.

(8) **Autoradiography**

(i) It is a technique of studying the route of chemicals in chemical reactions taking place inside the cell and organisms with the help of radioactive isotope.

(ii) Commonly used radio isotopes are $^{14}C, ^{3}H, ^{32}P$.

(iii) In this technique the radioisotopes are incorporated into the precursor molecule. Then the labelled precursor molecules introduced into the cells and their path is followed with the help of their radiation.

(iv) Radioactive precursors emit radiations and their position in the cell is located by bringing the cell in contact with a photographic plate or film.

(v) ^{32}P is used for the study of nucleic acids.

(vi) Melvin Calvin detected the intermediate involved in Calvin cycle of photosynthesis by the use of ^{14}C.

(9) ***X*-ray crystallography :** It was developed by the *Bragg* (1913). The wavelength of *X*–rays depends upon the distance between atoms. Therefore, they can be used as a tool for determining the arrangement of atoms in various biological molecules. When the *X*–rays pass through a molecule, they are scattered by the atoms. The diffraction pattern of the *X*–rays is photographed. The nature of diffraction is related to the orientation of the atoms in the molecule. By using this technique *Wilkins et al.,* 1953 found out details of the DNA molecule for which he was also awarded Nobel Prize along with *Watson* and *Crick* in 1962. *Kendrew*, 1957 by using the same technique studied the molecules of myoglobin.

(10) **Pulse-labelling technique :** Some of the biological molecules undergo changes after their synthesis. We can cite here the case of RNA. The transcription of *hn*RNA from DNA ultimately leads to the formation of *m*-RNA. These changes can be studied through pulse-labelling technique. Here, first the radioactive precursors are introduced in the system for a short time. These precursors are then chased away by non-radioactive precursors by any process of maturation.

(11) **Intracellular electrodes :** The concentration of various ions in different parts is now studies by using a glass microelectrode. It has silver wire dipped in *KCl* solution. This technique is used for studying the movement of ions through ions channels. The ions channels are intrinsic membrane proteins. For studying this passive transport of ions through ion channels *Neher and Sakman* developed a Patch clamp technique for which they are awarded Nobel prize in 1991.

Important Tips

- The term microscope was coined by Faber 1625.
- R.B. Tolles made oil immersion lens in 1830.
- The structure of membrane is observed by freeze fracturing an freeze etching technique.
- Electron microscope is used to study ultrastructure of organelles.
- For microscopic examination of sections are cut with the help of a machine called Microtome or ultramicrotome. It was first developed by W.His.
- X-ray microscope was developed by Kirkpatrick.
- Three dimensional image are obtained with the help of scanning electron microscope and X-ray microscope. Where as all other microscopes give two dimensional image.
- A staining technique, which is used for distinguishing cell structure known as metallic impregnation technique. e.g., golgibody by osmium chloride and silver salts, flagella by silver salts.
- Tracer isotopes / radioactive isotopes : Which functions like normal elements but emit radiations. They can, therefore, be located by Geiger muller counter or scintillalion counter and autoradiography, e.g., $^{3}H, ^{14}C, ^{32}P, ^{35}S,$ etc.

1.2 Cell as a unit of life

(1) **Cytology :** (G.k. *kyios* = cell ; *logas* = study) is the branch of biology. Which comprises the study of cell structure and function. "*Cell is the structure and functional unit of all living beings*".

All living organisms are composed of repeated structural units called cells. Each cell is independent in performing all necessary processes of life and is the least complex unit of matter which can be called living. *Robert Hooke* (1665) discovered hollow cavities (empty boxes) like compartments in a very thin slice of cork (cell wall) under his microscope. He wrote a book "*Micrographia*" and coined the term cellula, which was later changed into cell. *Grew and Malpighi* also observed small structures in slice of plants and animals. *Leeuwenhoek* was the first to see *free cells*. He observed bacteria, protozoa, RBCs, sperms, etc. under his microscope.

(i) **Cell theory :** H.J. Dutrochet (1924) a French worker gave the idea of cell theory.

The actual credit for cell theory goes to two German scientists, a Botanist *M.J. Schleiden* (1838) and a *Zoologist T. Schwann*(1839).They gave the concept "all living organisms are composed of cell". *Schleiden* and *Schwann* both supported the theory of "spontaneous generation". They also mentioned that "the new cell arises from nucleus by budding". Main postulates of cell theory are :

(a) Living beings are made of cells. They may be unicellular, colonial or multicellular.

(b) Cell is a mass of protoplasm having nucleus.

(c) Cells are similar in structure and metabolisms.

(d) The functions of an organism are due to activities and interactions of cells.

(ii) **Exceptions to the cell theory :** Viruses, viroids and prions are an exception to the cell theory as they are obligate parasites (sub–cellular in nature). *Paramecium, Rhizopus, Vaucheria* are some examples, which may or may not be exceptions to the cell theory.

(iii) **Modification of cell theory :** Modification of cell theory was done by *Rudolf Virchow* (1885)**.** He proposed the "law of cell lineage" which states that cell originates from pre-existing cells. *i.e. (omnis cellula-e-cellula)*. It is also called "cell principle" or "cell doctrine". It states : –

(a) Life exists only in cells.

(b) Membrane bound cell organelles of the protoplasm do not survive alone or outside the protoplasm.

(c) Cells never arise *de novo*. The new cells are like the parent cell in all respect.

(d) All cells have similar fundamental structure and metabolic reactions.

(e) Cells display homeostasis and remain alive.

(f) Functions of an organism as a whole are the sums of the activities and interactions of its constituent cell units. An organism can not show functions which is absent in its cells.

(g) Genetic information is stored in DNA and expressed within the cells.

(h) DNA controls structure and working of a cell.

(iv) **The cell as a self contained unit :** Autonomy of a cell is believed due to presence of DNA and its expressibility, otherwise, cell components have different shape and function. It has two positions.

(a) **Autonomy in unicellular organisms :** Unicellular organisms lead to a totally independent life due to different shape, size and role of different organelles shows division of labour. All these display homeostasis. Unicellular organisms are more active due to large surface volume ratio.

(b) **Autonomy in multicellular organisms :** In multicellular organisms life activities are displayed by each of the cells independently. Multicellular organisms have one thing advantage over unicellular organisms is division of labour.

(v) **Cellular totipotency :** Totipotency was suggested by *Haberlandt* (1902)**.** When cells have tendency or ability to divide and redivide the condition of the cell is called totipotent and this phenomenon is called *totipotency*.

(vi) **Steward's experiment :** *Steward et.al.* showed the phenomenon of cellular totipotency in carrot culture. Small fragments (phloem) of mature carrot roots were placed in liquid medium in special containers and growth factors like "coconut milk" was added. The culture developed into clumps or embryoids. When these were shifted to semisolid media, full plants were formed. The plants flowered normally and even bore the seeds.

(vii) **Surface volume ratio :** *Metabolically active cells are small*, as small cells have higher nucleocytoplasmic ratio for better control and higher surface volume ratio for quicker exchange of

materials between the cell and its outside environment. Larger cells have lower surface volume ratio as well as lower nucleocytoplasmic ratio. Surface volume ratio decreases by one half if cell size doubles.

Differences between plant cell and animal cell

Plant cell	Animal cell
Cell wall present.	Cell wall absent.
Nucleus usually lies near periphery due to vacuole.	Nucleus present near the centre.
Centrosome is usually absent from higher plant cells, except lower motile cells.	Usually centrosome is present that helps in formation of spindle fibres.
Plastids are present, except fungi.	Plastids are absent.
Mitochondria is generally spherical or oval in shape.	Generally tubular in shape.
Single large central vacuole is present.	Many vacuoles occurs, which are smaller in size.
Number of mitochondria from 200 – 2000.	Number of mitochondria is approximately 1600 – 16000 in liver cells.
Cytoplasm during cell division usually divides by cell plate method.	Cytoplasm divides by furrowing or cleavage method.
Plant cells are capable of forming all the amino acids coenzymes and vitamins.	Animal cells cannot form all the amino acids, coenzymes and vitamins.
There is no contractile vacuole.	Contractile vacuole may occur to pump excess water.
Sodium chloride is toxic to plant cells.	Tissue fluid containing sodium chloride bathes the animal cells.
Plant cells are generally well over 100 μm long.	Generally much smaller than 100 μm.
Spindle formed during cell division is anastral.	Spindle formed during cell division are amphiastral.
Lysosomes present in less number.	Lysosomes present in more number.
Chromosomes are larger in size.	Chromosomes are smaller in size.

Important Tips

- Jan swammerdam : First to see red blood cells of frog.
- Marcello Malpighi : Observed small utricles in slice of plant and animal tissue.
- N. Grew : Initiated cell concept
- Lamarck : All living beings are formed of cells.
- Corti : First to point out living substance filled inside the cell. It was called "Sarcode" by Dujardin.
- In vivo (in life) study : Study of cells in their natural environment within the intact organism.
- In vitro (cultural condition) study : Study of isolated life system in laboratory and cultural condition .
- Max Shultze proposed protoplasm theory.
- Sachs proposed organismic theory.
- Crystallo : colloidal theory (Fischer), substances dispersed and dissolved in water forming both true solution as well as colloidal solution.
- Energy transducers : Photosynthetic cells are called energy transducers because they convert radiant energy to chemical energy and store it as food energy.
- Intrinsic information is primary while hormonal information is extrinsic and secondary information.
- Largest organelles is nucleus. Largest cytoplasmic organelle is mitochondria in animal cells and chloroplast in plant cell.
- Smallest component is microfilament but smallest organelle is ribosome.
- Viruses do not have cellular structure.
- Monerians and protistians are not divisible into cells they are rather acellular.
- Certain organisms are multinucleated eg., Rhizopus, Vaucheria, etc.
- Fibre of ramie, Boehameria nivea longest plant cell (55 cm in size).
- The shrunken state of RBC caused by exosmosis is called crenation.
- In human beings cell of kidney are smallest and of nerve fibre largest.
- Pyrenoid is a proteinaceous body around which starch is stored in green algae.
- The smallest cell considered so far is of PPLO (Pleuropneumonia like organisms) or Mycoplasma gallisepticum i.e. 0.1 μ.
- The largest cell is an egg of ostrich.
- Acetabularia a unicellular green alga is about 10 cm in length.
- In the alga caulerpa (Siphonales) the length of cell may be up to one metre.
- The bacteriophages or viruses are still smaller in size (but cannot be considered as cells because of sub – cellular nature).

1.3 Structure of the cell

(1) **Introduction**

(i) Study of cell is called cytology.

(ii) Study of metabolic aspects of cell component is called cell biology.

(iii) *Leeuwenhoek* : First to see free cells called them "wild animalcules" and published a book "The secret of nature".

(iv) *Robert Hooke* is known as father of cytology.

(v) *C.P. Swanson* is known as father of modern cytology/ cell doctrine.

(vi) *A.K. Sharma* is known as father of cytology in India.

(vii) Dougherty classified cells based on plan as prokaryotic and eukaryotic.

(2) **Mesokaryon :** *Dodge* gave the term 'Mesokaryon' for dinoflagellates. These are intermediate type of cell organisation in dinophyceae of algae. In mesokaryotic there is present a true or eukaryotic nucleus with definite nuclear membrane and chromosomes. Chromosomes are not well organised and basic proteins or histones are absent. Nuclear membrane is persistent during cell division. Chromosomes are permanently attached to nuclear membrane. They show dinomitosis *e.g.*- Dinophysis Heterocapsa, Dinothrix etc.

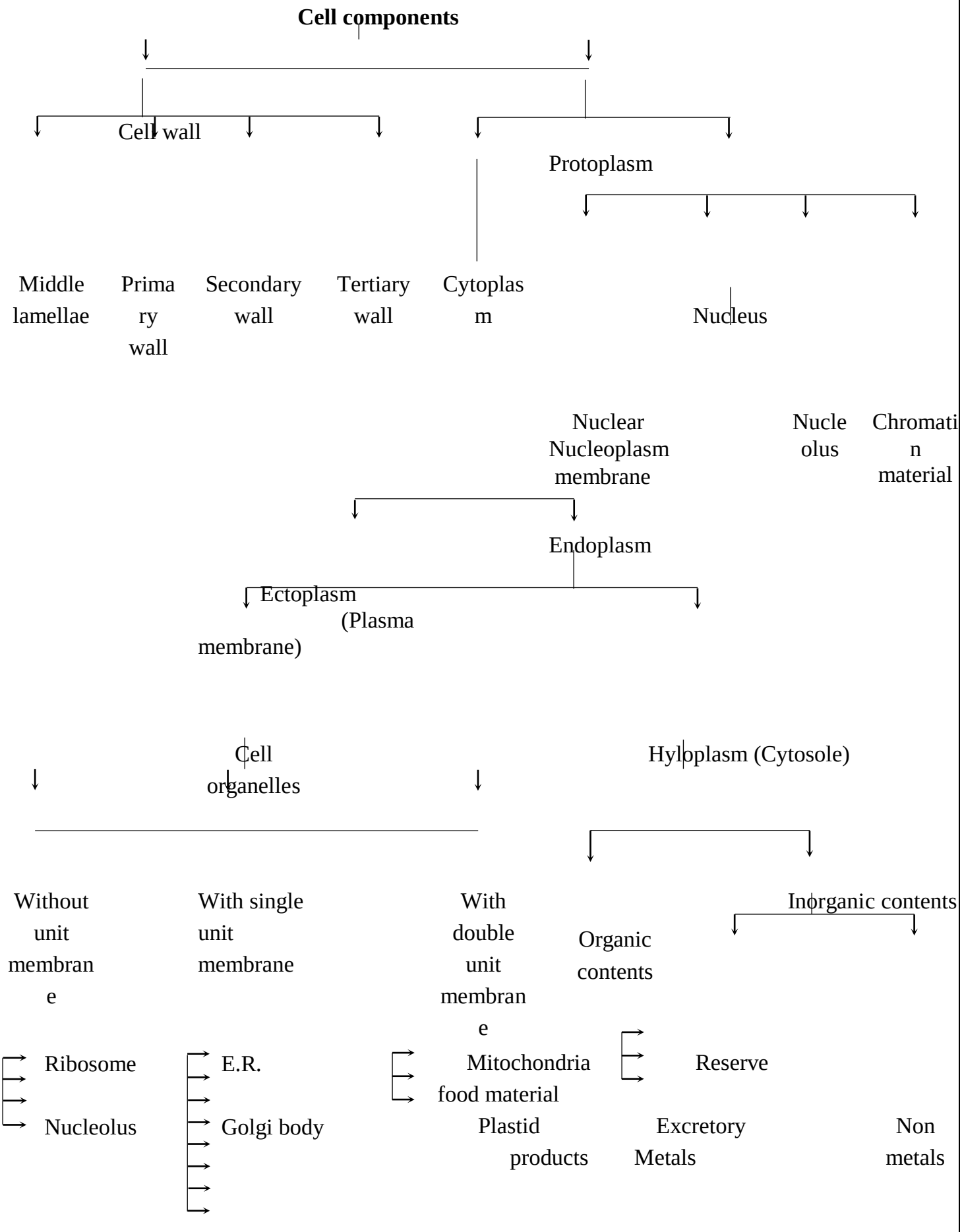
(3) **Types of cell :** Chatton gave the term prokaryote and eukaryote. Depending upon the nature of nucleus cells are classified. A primitive ill defined or incipient nucleus is present in prokaryotes, where as in eukaryotes. Well organised nucleus is present.

Differences between Prokaryotic and Eukaryotic cell

Prokaryotic cell	Eukaryotic cell
It is a single membrane system.	It is a double membrane system.
Cell wall surrounds the plasma membrane.	Cell wall surrounds the plasma membrane in some protists, most fungi and all plant cell. Animal cell lack it.
Cell wall composed of peptidoglycans. Strengthening material is mureir.	It is composed of polysaccharide. Strengthening material is chitin in fungi & cellulose in others plants.
Cell membrane bears *respiratory enzymes*.	It lacks respiratory enzymes.
Cytoplasm lacks cell organelles *e.g.*, Mitochondria, ER, Golgi body etc.	Cytoplasm contains various cell organelles.

Ribosomes are 70 S type.	Ribosomes are 80 S type.
There are no streaming movements of cytoplasm.	Cytoplasm show streaming movements.
Endocytosis and exocytosis do not occur.	Endocytosis and exocytosis occur in animal cells.
Mitotic spindle is not formed in cell division.	Mitotic spindle is formed in cell division.
The mRNA does not need processing.	The mRNA needs processing.
Nuclear material is not enclosed by nuclear envelope and lies directly in cytoplasm. It is called nucleoid.	It is enveloped by nuclear envelope. Nucleus is distinct from cytoplasm.
DNA is circular and not associated with histone proteins.	Nuclear DNA is linear and associated with histone proteins extranuclear DNA is circular and protein free.
Replication of DNA occurs continuously through out cell cycle.	Replication of DNA occurs during *S*-Phase of cell cycle only.
These have small size (0.5 to 10 μm) and have much less DNA.	These are relatively large (10 – 15 μm) and have much more DNA.
Sexual reproduction absent but parasexuality present.	Sexual reproduction is present.
Plasmids and pili occur in many prokaryotes Example – *E. coli*	There are no plasmids and pili in eukaryotic cells Example – *Spirogyra, Chlorella*
Cell division mostly amitotic.	Cell division is typically mitotic.
Plasma invaginates and from finger like process. Mesosome which take part in respiration	Absent

(4) **Cell compartmentation map**



Centriole Lysosome Nucleus Secretory products

Kinetosome Glyoxysome etc.

Sphaerosome

Peroxisome

Vacuole

Microtubule etc.

1.4 CELL WALL

(1) **Discovery :** It was first discovered by *Robert Hooke* in 1665.

Cell wall is the outer most, rigid, protective, non living and supportive layer found in all the plant cells, bacteria, cyanobacteria and some protists. It is not found in animal cells.

(2) **Chemical composition :** Mainly cell wall consists of two parts, matrix and cellulosic fibres (microfibriles). Matrix consists of hemicellulose, pectin, glycoproteins, lipids and water. A cellulose molecule is long unbranched chain of glucose molecules. There are about 6,000 glucose units in each chain. In most of the plants cell wall is made up of cellulose $(C_6H_{10}O_5)_n$, a polymer made-up of unbranched chain of glucose molecule linked by $\beta,1-4$ glycosidic bond. *About* 100 *molecules of cellulose form a micelle,* about 20 *micelle* form a microfibril and *approx* 200 *microfibril* form a fibril. The cell wall of bacteria and the inner layer of blue green algae is made-up of mucopeptide and not of cellulose. The mucopeptide is a polymer of two amino sugars namely N-acetyl glucosamine (NAG) and N-acetyl muramic acid (NAM) held alternately in β –1,4- linkage. In higher fungi, the cell wall is made up of chitin, polymer of glucosamine.

Pectin is a mixture of polymerised and methylated galacturans, galacturonic acid and neutral sugars. Hemicellulose is a mixture of polymerised xylans, mannans, glucomannans, galactans, xyloglucans and arabinogalactans. Glycoproteins are known to influence metabolic activities of the wall. A glycoprotein called extensin or expansin takes part in loosening and expansion of cell was through incorporation of cellulose molecules to cellulose microfibrils.

Plant cell wall may have lignin for strength (*e.g.*, woody tissue), silica for stiffness and protection (*e.g.*, epidermal cells of grasses, *Equisetum*), cutin for preventing loss of water (*e.g.*, epidermal cells), wax as component of cuticle and surface bloom as water repellent (floating leaves) and checking transpiration, suberin for impermeability (*e.g.*, cork cells, endodermal cells), etc.

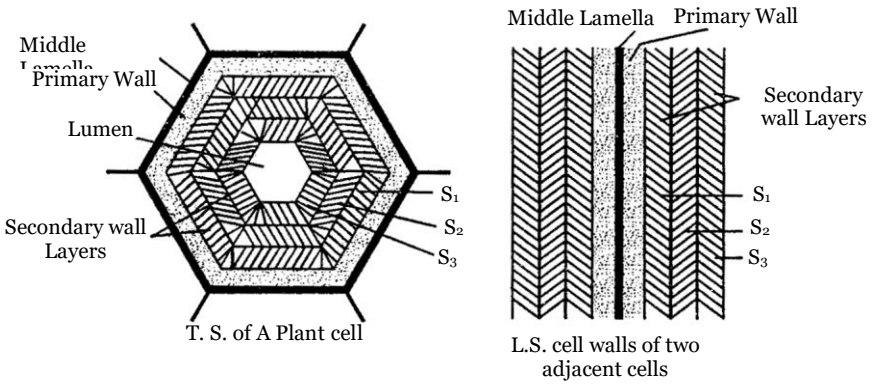


Fig : Layers of cell wall in T.S. and L.S. of a cell

(3) **Structure :** Cell wall consists of middle lamella, primary wall, secondary wall, tertiary wall.

(i) **Middle lamella :** Middle lamella is the outermost region which functions as a cementing layer between two cells. It is absent on the outer free surface. It ruptures to create intercellular spaces. Middle lamella is formed of calcium and magnecium pectate. Fruit softening is due to gelatinisation of pectic compounds of middle lamella. Pectin is used as commercial jellying agent. Which is present outside the primary wall.

(ii) **Primary wall :** A young plant cell forms a single layer of wall material. This layer is known as the primary cell wall. The primary wall is thin, elastic and capable of expansion in a growing cell. It grows by intussusception. Meristematic and parenchymatous cells have primary cell wall only. The cells of leaves and fruits too have only primary wall.

(iii) **Secondary wall :** In mature cell, more layers of wall material are added internal to the primary wall. These are called the secondary cell wall. Growth by addition of new wall material on the primary wall is called accretion. The secondary wall is thick and rigid. It usually consists of three layers, which are often named S_1, S_2 and S_3. It is found in collenchyma and sclerenchyma cells, xylem vesseles.

(iv) **Tertiary wall :** Sometimes tertiary wall is laid down on secondary wall, *e.g.,* tracheids of gymnosperms. It is composed of cellulose and xylan, another ploysaccharides.

(4) **Origin :** A cell wall is organised at telophase stage of cell division. The plane and place of cell wall is determined by the microtubules. Fragments of ER and vesicles of golgi body alligned at the equator, called as *phragmoplast, later which forms the cell plate.* The synthesis of cellulose takes place by the help of enzyme *cellulose synthase* present in the plasma membrane.

The cell plate forms the cell wall. A cell posses three phases of growth namely cell formation, cell elongation and cell maturation. The formation of new cells occurs by mitotic activity. The cell elongation is initiated by an increase in cell turgor. It is brought about by special proteins called *expansion*. They are of two types $\alpha-$expansion and $\beta-$expansion. As a result, lacunae or gaps appear in between the cellulose micelle. There are two possibilities for the deposition of new wall material.

(i) **By intussuception :** As the cell wall stretches in one or more directions, new cell wall material secreted by protoplasm gets embedded within the original wall.

(ii) **By apposition :** In this method new cell wall material secreted by protoplasm is deposited by definite thin plates one after the other.

Differences between primary and secondary cell wall

Primary cell wall	Secondary cell wall
Primary wall is laid inner to middle lamella	Secondary wall is laid inner to primary wall.
It is formed in a growing cell.	It is formed when the cells have stopped growing.

It is capable of extension.	Extensibility is absent except in collenchyma cells.
It is single layered.	It is three or more layered.
Cellulose content is comparatively low (5 – 20%).	Cellulose content is comparatively high (20 – 90%).
Cellulose microfibrils are shorter, wavy and loosely arranged.	They are longer, closely arranged straight and parallel.
Protein content up to 5%.	Protein content up to 1%.
Hemicellulose content is high up to 50%.	It is 25% of the total.
Lipid content up to 5 – 10%.	Lipid is absent.
Primary wall is comparatively thin 1 – 5 μm.	It is comparatively thick 5 – 10 μm

(5) **Thickenings of cell wall :** In many secondary walls specially those of xylem the cell wall becomes hard and thick due to the deposition of lignin. With the increasing amount of lignin, deposition protoplasm is lost. First the lignin is deposited in middle lamella and primary wall and later on in secondary wall. Like cellulose lignin is permeable to water and substances dissolved in it. Lignin is deposited at specific places of the cell walls due to which xylem tracheids and trachea take up following forms:

(i) **Annular thickenings :** Deposition of lignin takes place in the form of rings on the inner surface of protoxylem cells. These rings are placed one above the other leaving some space in between each other.

(ii) **Spiral thickenings :** In these thickenings deposition of lignin takes place in the form of complete spiral bands and are formed in tracheids and trachea of protoxylem.

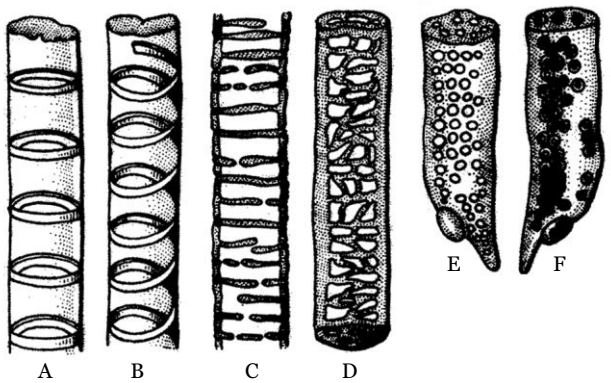


Fig : Different types of secondary wall thickenings – (a) annular (b) spiral (c) scalariform (d) reticulate (e) pitted-simple pits (f) pitted-bordered pit

(iii) **Scalariform (Ladder like) thickenings :** In these thickenings lignin is deposited in the form of transverse rods of the ladder. The unthickened areas between the successive thickenings appear as elongated transverse pits. This type of thickening is common in protoxylem.

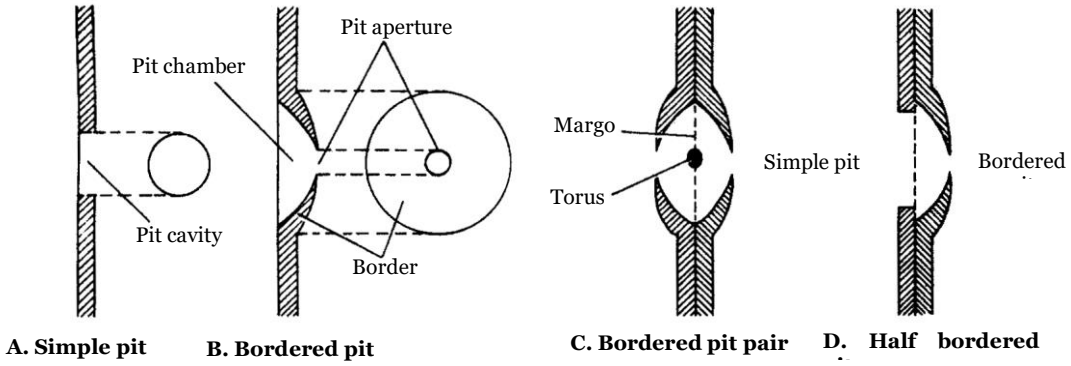
(iv) **Reticulate (Net like) thickenings :** The lignin is deposited in the form of a net or reticulum. The unthickened areas are irregular in shape. These are found in metaxylem.

(v) **Pitted thickenings :** These are found in metaxylem. In such thickening the whole inner wall is more or less uniformly thickened leaving here and there some unthickened areas called pits.

(6) **Pits :** Secondary walls may have irregular thickenings at some places and these places are called pits. Pits are of two types :–

(i) **Simple pit :** In which pit chamber is uniform in diameter.

(ii) **Bordered pit :** In which pit chamber is flask shaped in tracheids of gymnosperm and vessels of angiosperms.



(7) **Plasmodesmata :** *Tangle* (1879) first of all discovered them and were studied elaborately by *Strasburger* (1901). A number of plasmodesmata or cytoplasmic strands are present in pit through which the cytoplasm of one cell is in contact with another. Endoplasmic reticulum plays a role in origin of plasmodesmata.

(8) **Intercellular spaces :** In mature cells certain spaces or cavities are produced which are of 3 types.

(i) **Schizogenous cavities** : In mature cells, the cell walls separate from each other and form a cavity. *e.g.,* resin canals in Pinus.

(ii) **Lysogenous cavities** : It is formed by the break down of cell walls *e.g., Citrus* oil cavities.

(iii) **Schizo-lysogenous cavities :** Both the above processes are involved in this cavity formtion *e.g.,* protoxylem of maize.

(9) **Function of cell wall :** The cell wall serves many functions –

(i) It maintain shape of the cells.

(ii) It protect the cells from mechanical injury.

(iii) It wards off the attacks of pathogens (viruses, bacteria, fungi, protozoans).

(iv) It provides mechanical support against gravity. It is due to the rigid cell walls that the aerial parts of the plants are able to keep erect and expose their leaves to sunlight.

(v) The cell wall prevents undue expansion of the cell when water enters by osmosis to compensate for the lack of contractile vacuole. This prevents bursting of cells.

(vi) It allows the materials to pass in and out of the cell.

(vii) Though permeable, the cell wall plays some regulatory role on the passage of materials into and out of the cell.

(viii) Many enzymic activities associated with metabolism are known to occur in the cell wall.

(ix) Cutin and suberin deposits check loss of water form the cell surface by evaporation.

(x) The cell wall helps in the maintenance of balance of intracellular osmotic pressure with that of its surroundings.

(xi) Pores in the cell walls permit plasmodesmata to link up all the protoplasts into a system called symplast (symplasm).

(xii) The walls of xylem vessels, tracheids and sieve tubes allow movement of materials.

(xiii) The wall in some cases has a role in defence and offence by means of spines.

(xiv) Growth of the cell wall enables the cells to enlarge in size.

(xv) Cell wall and intercellular spaces constitute a nonliving component of plant body known as apoplasm.

Important Tips

- ☞ Peptidoglycane = murein = mucopeptide is the only cell wall material of prokaryotes. It's sugar portion consists of NAG and NAM.
- ☞ In fungi cell wall is made up of chitin (polymer of N- acetyl glucosamine). In bacteria it is composed of protein lipid polysaccharide having N-acetyl glucosamine (NAG) and N-acetyl muramic acid (NAM).
- ☞ **Cell wall proteins –**

  HRGP – Hydroxy proline rich glycoprotein → Phloem and cambium.

  PRP– Proline rich protein → Xylem, fibres, cortex.

  GRP– Glycine rich protein → Xylem.

1.5 Plasma membrane

(1) **Definition :** Every living cell is externally covered by a thin transparent electron microscopic, elastic regenerative and *selective permeable membrane* called plasma membrane. It is quasi fluid in nature. According to *Singer* and *Nicolson* it is "protein iceberg in a sea of lipid". A cell wall lies external to plasmalemma in plant cells, many monerans, some protists and fungal cells. Membranes also occur inside the cells. They are collectively called biomembranes. The term cell membrane was given by *C. Nageli* and *C. Cramer* (1855) for outer membrane covering of the portoplast. It was replaced by the term plasmalemma or plasma membrane by *Plowe* (1931).

(2) **Chemical composition :** Proteins lipoprotein (Lipid +Protein) are the major component forming 60% of the plasma membrane. *Proteins provide* mechanical strength and responsible for transportation of different substances. Proteins also act as enzyme. *Lipids account may* 28%-79% depending upon the type of cell and organism involved (in humans, myelin 79%). Because of the presence of lipids, membranes are always continuous, unbroken structures and are deformable and their over all shape can change. The lipids of plasma membrane are of three types namely *phospholipids*, *glycolipids* and *sterols*. A glycolipid may be cerebroside or ganglioside. The sterol found in the membrane may be cholesterol (Animals), phytosterol (Plants) or ergosterol (Microorganisms). A lipid molecule is distinguishable into a head of glycerol and two tails of fatty acids.

Carbohydrates form 2%–10%. Oligosaccharides are the main carbohydrates present in plasma membrane. The carbohydrates of plasma membrane are covalently linked to both lipid and protein components. The common sugars found in the plasma membrane are *D* – glucose, *D* – mannose, *D* – glactose, *N* – acetyl glucosamine, *N* – acetyl galoactosamine (Both are amino sugars) and sialic acid. Generally the terminal sugar of oligosaccharides is sialic acids (Also known as *N* – acetylneuraminic acid NANA) which gives them a negative charge.

(3) **Ultra structure :** Under electron microscope the plasma membrane appears three layered, *i.e.* trilaminar or tripertite. *One optically light layer* is of lipid and on *both sides two optically dense protein layers* are present.

Generally the plasma membrane is 75 Å thick (75 – 100Å), light layer is 35 Å while dark layers are 20 Å + 20 Å in thickness.

(4) **Molecular structure and different models :** Several models have been proposed to explain the structure and function of the plasma membrane.

(i) **Overton's model :** It suggests that the plasma membrane is composed of a thin lipid bilayer.

(ii) **Sandwich model :** It was proposed by *Davson* and *Danielli* (1935). According to this model the light biomolecular lipid layer is sandwiched between two dense protein layers. This model was also said to be unit membrane hypothesis.

(iii) **Robertson's unit membrane model :** It states that all cytoplasmic membranes have a similar structure of three layers with and electron transparent phospholipid bilayer being sandwiched between two electron dense layer of proteins. All biomembranes are either made of a unit membrane or a multiple of unit membrane. Its thickness is about 75 Å with a central *lipid layer of* 35 *Å thick* and two peripheral *protein layers of* 20 *Å thick.*

(iv) **Fluid mosaic model :** The most important and *widely accepted latest model* for plasma membrane was given by *Singer and Nicolson in* 1972. According to them it is "protein iceberg in a sea of lipids."

According to this model, the cell membrane consists of a highly viscous fluid matrix of two layers of phospholipid molecules. These serve as relatively impermeable barrier to the passage of most water soluble molecules. Protein molecules occur in the membrane, but not in continuous layer; Instead, these occur as separate particles asymmetrical arranged in a mosaic pattern.

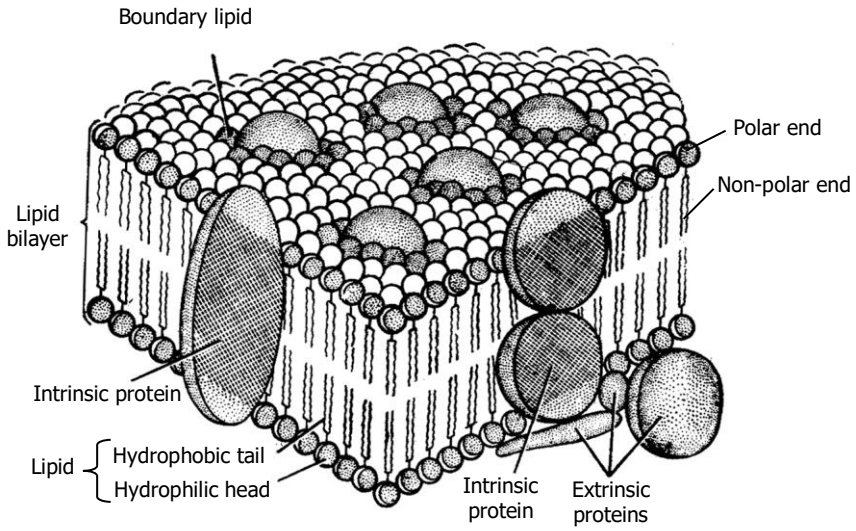


Fig : Fluid-mosaic model of the plasma membrane. Proteins floating in a sea of lipid. Some proteins span the lipid bilayer, others are exposed only to one surface or the other (Modified

Some of these are loosely bound at the polar surfaces of *lipid layers*, called peripheral or *extrinsic proteins*. Others penetrate deeply into the lipid layer called integral or *intrinsic proteins*. Some of the integral proteins penetrate through the phospholipid layers and project on both the surface. These are called trans membrane or tunnel proteins (glycophorins). Singly or in groups, they function as channels for passage of water ions and other solutes. The channels may have gate mechanism for opening in response to specific condition. The carbohydrates occur only at the outer surface of the membrane. Their molecules are covalently linked to the polar heads of some lipid molecules (forming glycolipids) and most of the proteins exposed at outer surface (forming glycoproteins).

The sugar protions of glycolipids and glycoproteins are involved in recognition mechanisms :–

(a) Sugar recognition sites of two neighbouring cells may bind each other causing cell to cell adhesion. This enables cells to orientate themselves and to form tissues.

(b) Through glycoproteins, bacteria recognise each other. *e.g.*, female bacteria are recognised by male bacteria.

(c) These provide the basis of immune response and various control system, where glycoproteins act as antigens. Lipid and integral proteins are amphipathic in nature *i.e.*, they have hydrophilic and hydrophobic groups with in the same molecules. The *NMR* (Nuclear magnetic resonance) and *ESR* (Electron spin resonance) studies showed that the membrane is dynamic. The lipid tails show flexibility. The molecule can rotate or show *flip flop* motion.

Difference between protein types

Extrinsic Protein	Intrinsic Protein
These are associated with surface only.	These lie throughout phospholipid matrix and project on both surfaces, also called transmembrane or tunnel protein.
They form about 30% of the total	They form about 70% of total membrane

membrane protein.	proteins.
Example – Spectrin in red blood cells & ATPase in mitochondria.	Example – Rhodopsin in retinal rod cells.

(5) **Membrane protein can be of following types with different functions**

(i) **Carrier molecules :** These bind with the specific molecules into or out of the cell. This provides selective exchange of materials. The carrier protein molecules are called "permeases" *e.g.*, $Na^+ - K^+$ pump, Na^+– sugar transport.

(ii) **Receptor molecules :** The glycoproteins on the cell surface act as receptors that recognize and bind with specific molecules.

(iii) **Enzyme molecules :** The inner mitochondrial membrane carrier enzyme comprising the electron transport chain for cellular respiration.

(6) **Cell membranes are fluid and dynamic due to**

(i) The constituent molecules can move freely in the membrane.

(ii) The cell membranes are constantly renewed during the cells life.

(iii) They can repair minor injuries.

(iv) They expand and contract during cell movement and during change in shape.

(v) They allow interactions of cells such as recognition of self and fusion of cells.

(7) **Membrane permeability :** According to permeability, membranes are classified as –

(i) **Permeable membrane** : They allow both solvent and solute molecules or ions through them. *e.g.,* cellulose wall, lignified cell walls.

(ii) **Impermeable membrane :** They do not allow solute and solvent molecules. *e.g.,* heavily cutinised or suberinised cell walls in plants.

(iii) **Semi-permeable membrane :** They allow solvent molecules only. *e.g.,* membranes of colloidion, parchment paper and copper ferrocyanide membranes.

(iv) **Differentially permeable membrane :** All membranes found in plants allow some solutes to pass through them along with the solvent molecules. *e.g.,* plasma membrane, tonoplast (vacuolar membrane) etc.

(8) **Intercellular communications/modification of plasma membrane/following structures are derived from plasma membrane**

(i) **Microvilli :** They are fingers like evaginations of 0.1 μm diameter, engaged in absorption. *e.g.*, intestinal cells, hepatic cell, mesothelial cells. The surface having microvilli is called striated border or brush border.

(ii) **Lomasomes :** They are plasmalemma foldings found in fungal cells.

(iii) **Mesosomes :** It serves as site for cellular respiration in prokaryotes.

(iv) **Tight junctions :** Plasma membrane of two adjacent cells are fused at a series of points with a network of ridges or sealing strands. *e.g.*, capillaries, brain cells collecting tubules etc.

(v) **Plasmodesmata :** *They are protoplasmic bridges amongst plant cells*, which occur in area of cell wall pits. It was discovered and reported by *Tangle* and *Strasburger* respectively.

(vi) **Desmosomes :** concerned with cell adherence.

(9) **Functions**

(i) They control the flow of material through them and provides passage for different substances.

(ii) It is differentially permeable, solute particles (1-15 Å) can pass through it.

(iii) It is not only provides *mechenical strength* but also acts as a protective layer.

(iv) Plasma membrane is *responsible for the transportation of materials*, molecules, ions etc.

(v) It helps in osmoregulation.

(vi) Diffusion of gases take place through plasma membrane by simple and facilitated diffusion.

(vii) Transport of ions, small polar molecules through active (energy used) and passive transport (energy not used).

(viii) Gases like O_2 and CO_2 diffuse rapidly in solutions through membranes.

(ix) Ions and small polar molecules diffuse slowly through the membranes.

(x) Some solute molecules or ions first bind with certain specific carrier or transport proteins called permeases.

(xi) Water as well as some solute molecules and ion pass through membranes pores; pores are always bordered by channel proteins.

(xii) When diffusion takes place through channel, called simple diffusion and through carrier proteins, called facilitated diffusion.

(10) **Membrane transport :** It is passage of metabolites, by-products and biochemicals across biomembrane. Membrane transport occurs through four methods–passive, facilitated, active and bulk. Size of the particles passing through plasmalemma is generally 1 – 15 Å.

(i) **Passive transport :** No energy spent. Passive transport occurs through diffusion and osmosis.

(a) **Diffusion :** It is movement of particles from the region of their higher concentration or electrochemical potential to the region of their lower concentration or electrochemical potential. Electrochemical potential operates in case of charged particles like ions. Diffusion can be observed by opening a bottle of scent or ammonia in one corner, placing a crystal of copper sulphate in a beaker of water or a crystal of $KMnO_4$ on a piece of gelatin. Simple diffusion does not require carrier molecules.

Independent Diffusion : In a system having two or more diffusion substances, each individual substance will diffuse independent of others as per gradient of its own concentration, diffusion pressure or partial pressure form region of higher one to region of lower one.

Rate of diffusion is proportional to difference in concentration and inversely to distance between the two ends of the system, inversely to square root of relative density of substance and density of medium, directly to temperature and pressure.

(b) **Osmosis** is diffusion of water across a semipermeable membrane that occurs under the influence of an osmotically active solution.

(c) **Mechanism of passive transport :** Passive transport can continue to occur if the absorbed solute is immobilised. Cations have a tendency to passively pass from electropositive to electronegative side. While anions can pass from electronegative to electropositive side. There are two modes of passive transports.

Lipid matrix permeability : Lipid soluble substances pass through the cell membrane according to their solubility and concentration gradient, *e.g.*, triethyl citrate, ethyl alcohol, methane.

Hydrophillic membrane channels : They are narrow channels formed in the membrane by tunnel proteins. The channels make the membrane semipermeable. Water passes inwardly or outwardly from a cell through these channels according to osmotic gradients. CO_2 and O_2 also diffuse through these channels as per their concentration gradients. Certain small ions and other small water soluble solutes may also do so.

(d) **Ultrafiltration** is fine filtration that occurs under pressure as from blood capillaries, epithelia and endothelia. It is of two types : –

- Paracellular through leaky junctions or gaps in between cells.
- Transcellular through fenestrations in the cells. 'Dialysis' is removal of waste products and toxins from blood by means of diffusion between blood and an isotonic dialysing solution.

(e) **Facilitated transport or Facilitated diffusion :** It is passage of substances along the concentration gradient without expenditure of energy that occurs with the help of special permeating substances called permeases. Permeases form pathways for movement of certain substances without involving any expenditure of energy. At times certain substances are transported alongwith the ones requiring active transport. The latter phenomenon called cotransport. Facilitated transport occurs in case of some sugars, amino acids and nucleotides.

(ii) **Active transport :** It occurs with the help of energy, usually against concentration gradient. For this, cell membranes possess carriers and gated channels.

(a) **Carrier particles or Proteins :** They are integral protein particles which have affinity for specific solutes. A solute particles combines with a carrier to form carrier solute complex. The latter undergoes conformational change in such a way as to transport the solute to the inner side where it is released into cytoplasm.

(b) **Gated channels :** The channels are opened by either change in electrical potential or specific substances, *e.g.*, Calcium channels.

Active transport systems are also called pumps, *e.g.*, H^+ pump, K^+ pump, Cl^- pump, $Na^+ - K^+$ pump. The pumps operate with the help of ATP. $K^+ - H^+$ exchange pump occurs in guard cells.

$Na^+ - K^+$ exchange pump operates across many animal membranes. For every ATP hydrolysed, three Na^+ ions are passed out while two K^+ ions are pumped in. Sea Gulls and Penguins operate $Na^+ - K^+$ pump for excreting *NaCl* through their nasal glands.

Active transport of one substance is often accompanied by permeation of other substances. The phenomenon is called secondary active transport. It is of two main types, cotransport (*e.g.*, glucose and some amino acids alongwith inward pushing of excess Na^+) and counter-transport (Ca^{2+} and H^+ movement outwardly as excess Na^+ passes inwardly).

(iii) **Bulk transport :** It is transport of large quantities of micromolecules, macromolecules and food particles through the membrane. It is accompanied by formation of transport or carrier vesicles. The latter are endocytotic and perform bulk transport inwardly. The phenomenon is called endocytosis. Endocytosis is of two types, pinocytosis and phagocytosis. Exocytic vesicle perform bulk transport outwardly. It is called exocytosis. Exocytosis performs secretion, excretion and ephagy.

(a) **Pinocytosis :** (Lewis, 1931). *It is bulk intake of fluid*, ions and molecules through development of small endocytotic vesicles of 100 – 200 *nm* in diameter. ATP, Ca^{2+}, fibrillar protein clathrin and contractile protein actin are required. Fluid-phase pinocytosis is also called cell drinking. It is generally nonselective. For ions and molecules the membrane has special receptor or adsorptive sites located in small pits. They perform adsorptive pinocytosis. After coming in contact with specific substance, the area of plasma membrane having adsorptive sites, invaginates and forms vesicle. The vesicle separates. It is called pinosome. Pinosome may burst in cytosol, come in contact with tonoplast and pass its contents into vacuole, form digestive vacuole with lysosome or deliver its contents to Golgi apparatus when it is called receptosome.

(b) **Phagocytosis :** (Metchnikoff, 1883). It is cell eating or ingestion of large particles by living cells, e.g., white blood corpuscles (neutrophils, monocytes), Kupffer's cells of liver, reticular cells of spleen, histiocytes of connective tissues, macrophages, Amoeba and some other protists, feeding cells of sponges and coelentrates. Plasma membrane has receptors. As soon as the food particle comes in contact with the receptor site, the edges of the latter evaginate, form a vesicle which pinches off as phagosome.

One or more lysosomes fuse with a phagosome, form digestive vacuole or food vacuole. Digestion occurs inside the vacuole. The digested substances diffuse out, while the residual vacuole passes out, comes in contact with plasma membrane for throwing out its contents through exocytosis or ephagy.

Important tips

- ☞ E. Grater and H. Grendel (1926) : Proposed leaflet model which states that plasma membrane is formed of bilayer sheet of phospholipids.
- ☞ Wolpers (1941) : Proposed lattice model which states lipids are distributed in a framework of proteins.
- ☞ Hilleir and Hoffman (1953) : Proposed micellar model. Plasma membrane is formed of micelles of lipid molecules.

- ☞ Sandwich model of Danielli and Davson (1935) is based on physical and chemical properties.
- ☞ Proteins of plasma membrane provide functional specificity, elasticity and mechanical support.
- ☞ The arrangement of phospholipid molecules in bilayer forms a water resistant barrier.
- ☞ Glycoproteins of plasma membrane determine antigen specificity of cell. These glycoproteins from major histocompatible complex (MHC) which are of specific type in every individual so act as finger print of the cell.
- ☞ Negative charge of the membrane is due to N – acetyl neuraminic acid (NANA)/sialic acid.
- ☞ Lehninger described the percentage of extrinsic and intrinsic protein.
- ☞ Harmone receptor proteins of plasma membrane of target cells act as signal transduction.
- ☞ Phospholipids show asymmetric distribution in plasma membrane lacithin and sphingomycelin mainly found in outer phospholipids layer while cephalin and phosphatidyl serine are mainly present in inner phosphalipid layer.
- ☞ Lomasomes : Infolds of plasma membrane found in fungi. These were reported by Moore and Mclean.
- ☞ Transosomes found in follicular cells of ovary of birds and have triple unit membrane. First reported by Press(1964).
- ☞ Lipid soluble substances pass through the plasma membrane move readily than the water soluble substances.
- ☞ Term biomembrane was coined by Singer and Nicolson.
- ☞ Nehar and Sakmann discovered ion-channels in plasma membrane and they were awarded Noble prize for it in 1971.
- ☞ Pinocytosis and phagocytosis do not take place in prokaryotic cells.
- ☞ Singer and Nicolson's model differs from Robertson's model in the arrangement of proteins.
- ☞ Plasma membrane contains ATPase enzymes.
- ☞ Plasma gel or ectoplasm are the synonyms of plasma membrane.
- ☞ The secondary structure of the integral protein buried in the lipid bilayer of a cell membrane is nature.

1.6 Protoplasm

(1) **Definition :** Protoplasm is a complex, granular, elastic, viscous and colourless substance. It is selectively or differentially permeable. It is considered as "*Polyphasic colloidal system*".

(2) **Discoveries**

(i) *J. Huxley defined it as* "*physical basis of life*".

(ii) *Dujardin* (1835) discovered it and called them "sarcode".

(iii) *Purkinje* (1837) *renamed it as* "*Protoplasm*".

(iv) *Hugo Von Mohl* (1844) gave the significance of it.

(v) *Max Schultz* (1861) gave the protoplasmic theory for plants.

(vi) *Fischer* (1894) and *Hardy* (1899) showed its colloidal nature.

(vii) *Altman* (1893) suggested protoplasm as granular.

(3) **Composition :** Chemically it is composed of

Water	75 – 85%	Carbon	20%
Proteins	10 – 25%	Oxygen	62%
Lipids	2 – 3%	Hydrogen	10%
Inorganic Materials	1%	Nitrogen	3%

Trace elements – 5% (*Ca, P, Cl, S, K, Na, Mg, I, Fe,* etc.)

Maximum water content in protoplasm is found in hydrophytes, *i.e.* 95% where as minimum in seeds, spores (dormant organs) *i.e.* 10 – 15%. In animals water is less (about 65%) and proteins are more (about 15%).

(4) **Physical properties of protoplasm :** *Cyclosis* movement are shown by protoplasm. These are of two types.

(i) **Rotation :** In one direction, either clockwise or anticlockwise *e.g., Hydrilla, Vallisneria*. *Found only in eukaryotes*.

(ii) **Circulation :** Multidirectional movements around vacuole *e.g. Tradescantia*.

(a) It shows stimulation or irritability.

(b) Protoplasm is polyphasic. Colloidal substance or true solution because true solution act as dispersion medium and different colloidal particles constitute dispersed phase.

(c) It shows increased surface area and adsorption.

(d) It shows sol – gel transformation.

(e) It is highly viscous.

(f) It coagulates at $60^{o}\,C$ or above or if treated with concentrated acids or bases.

(g) It shows Brownian movements.

(h) It's specific gravity is slightly more than 1.

(i) It's pH is on acidic side, but different vital activities occur at neutral *pH* which is considered as 7, injury decreases the pH of the cell (*i.e.* 5.2 – 5.5) and if it remains for a long time, the cell dies.

(j) Scattering and dispersion of light is shown by protoplasm *i.e.* Tyndall effect.

1.7 Cytoplasm

The substance occur around the nucleus and inside the plasma membrane containing various organelles and inclusions is called cytoplasm.

(1) The cytoplasm is a semisolid, jelly – like material. It consists of an aqueous, structureless ground substance called cytoplasmic matrix or hyaloplasm or cytosol.

(2) It forms about half of the cell's volume and about 90% of it is water.

(3) It contains ions, biomolecules, such as sugar, amino acid, nucleotide, tRNA, enzyme, vitamins, etc.

(4) The cytosol also contains storage products such as glycogen/starch, fats and proteins in colloidal state.

(5) It also forms crystallo – colloidal system.

(6) Cytomatrix is differentiated into ectoplasm or plasmagel and endoplasm or plasmasol.

(7) Cytomatrix is three dimensional structure appear like a network of fine threads and these threads are called microfilaments (now called actin filaments or microtrabecular lattice) and it is believed to be a part of cytoskeleton. It also contains microtubules and inter mediate cytoplasmic filaments.

(8) Hyaloplasm contains metabolically inactive products or cell inclusions called deutoplast or metaplasts.

(9) Cytoplasmic organelles are plastid, lysosome, sphaerosome, peroxisome, glyoxysomes, mitochondria, ribosome, centrosome, flagellum or cilia etc.

(10) The movement of cytoplasm is termed as *cyclosis* (absent in plant cells).

1.8 MITOCHONDRIA

(1) **Definition :** (Gk – mito = thread ; chondrion = granule) Mitochondria are *semi autonomous* having hollow sac like structures present in all eukaryotes except mature RBCs of mammals and sieve tubes of phloem. These are absent in all prokaryotes like bacteria and cyanobacteria. Mitochondria are also called chondriosome, chondrioplast, plasmosomes, plastosomes and plastochondriane.

(2) **Discoveries**

(i) These were first observed in striated muscles (Voluntary) of insects as granules by Kolliker (1850), he called them "sarcosomes".

(ii) *Flemming* (1882) called them "fila" for thread like structure.

(iii) *Altman* (1890) called them "bioplast".

(iv) *C. Benda* (1897) *gave the term mitochondria*.

(v) *F. Meves* (1904) observed mitochondria in plant (*Nymphaea*).

(vi) *Michaelis* (1898) demonstrated that mitochondria play a significant role in respiration.

(vii) *Bensley* and *Hoerr* (1934) isolated mitochondria from liver cells.

(viii) *Seekevitz* called them "Power house of the cell".

(ix) *Nass* and *Afzelius* (1965) observed first DNA in mitochondria.

(3) **Number of mitochondria :** Presence of mitochondria depends upon the metabolic activity of the cell. Higher is the metabolic activity, higher is the number *e.g.*, in germinating seeds.

(i) Minimum number of mitochondria is one in *Microasterias*, *Trypanosoma*, *Chlorella*, *Chlamydomonas* (green alga) and *Micromonas*. Maximum numbers are found (up to 50,000) in giant *Amoeba* called *Chaos – Chaos*. These are 25 in human sperm, 300 - 400 in kidney cells and 1000 – 1600 in liver cells.

(ii) Mitochondria of a cell are collectively called chondriome.

(4) **Size of mitochondria :** Average size is 0.5–1.00 μm and length up to 1 – 10 μm.

(i) Smallest sized mitochondria in yeast cells $(1 \mu m^3)$.

(ii) Largest sized are found in oocytes of *Rana pipiens* and are 20 – 40 μm.

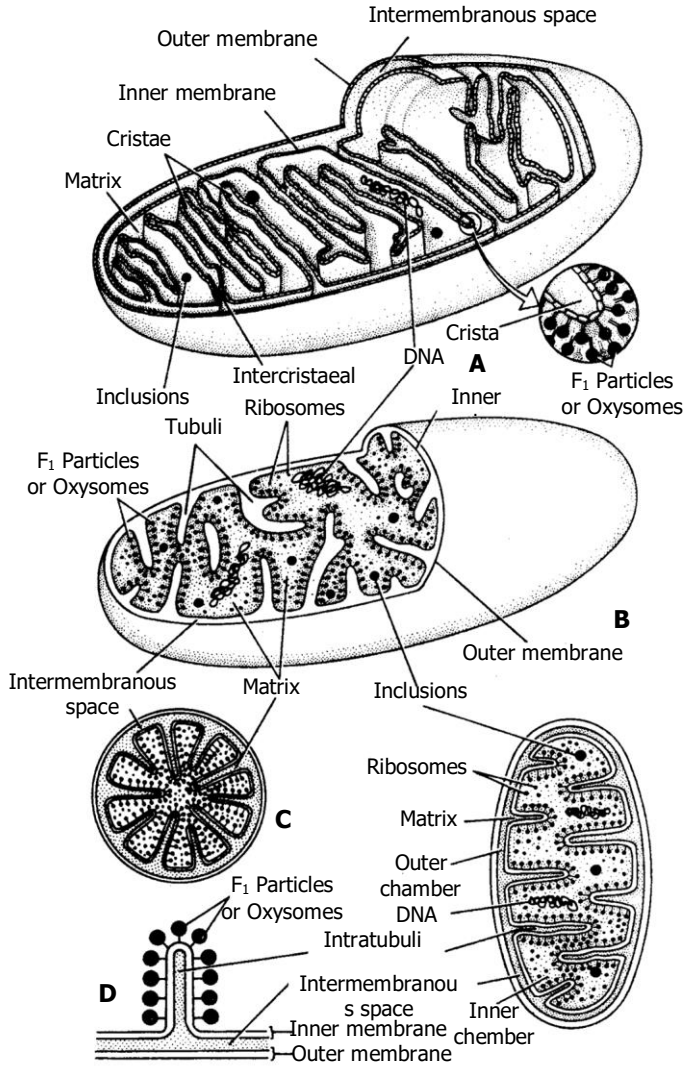


Fig : Three dimentional structure of mitochondrion. A. From an animal cell. B. From plant cell, C. T.S. mitechondrion, D. One tubule

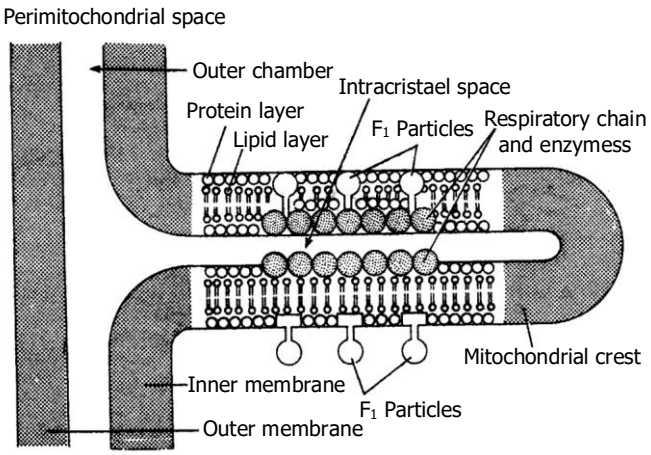


Fig : Molecular organization of inner membrane of mitochondria

(iii) A dye for staining mitochondria is Janus *B* – green.

(5) **Ultrastructure of mitochondria :** Mitochondrion is bounded by two unit membranes separated by perimitochondrial space (60 – 80 Å). The outer membrane is specially permeable because of presence of integral proteins called porins. *The inner membrane is selective permeable*. The inner membrane is folded or convoluted to form mitochondrial crests. In animals these are called *cristae* and in plants these folding are called tubuli or microvili.

The matrix facing face is called 'M' face and face towards perimitochondrial space is called 'C' face. The 'M' face have some small *stalked particles called oxysomes* or *F_1 particle or elementory particle or Fernandez – Moran Particles*. Each particle is made up of base, stalk and head and is about 10*nm* in length. Number of oxysomes varies to 10^4 to 10^5 per mitochondrion and chemically they are made of phospholipid core and protein cortex. *Oxysomes* have ATPase enzyme molecule (Packer, 1967) and therefore, responsible for *ATP synthesis*. These elementary particles are also called $F_0 – F_1$ particles.

In the matrix 2–6 copies of naked, double stranded DNA (circular) and ribosome of 70 S type are present. It is rich in G-C ratio. Basic histone proteins are absent in mitochondrial DNA. The synthesis of ATP in mitochondria is called oxidative phosphorylation, which is O_2 dependent and light independent. Cristae control dark respiration. F_0 particles synthesize all the enzymes required to operate Kreb's cycle. Inner membrane contains cytochrome.

(6) **Semi-autonomous nature of mitochondrion :** Mitochondria contain all requirements of protein synthesis :

(i) 70 *S* ribosomes.

(ii) DNA molecules to form *m*RNA and also replicate.

(iii) ATP molecules to provide energy.

The mitochondria can form some of the required proteins but for most of proteins, these are dependent upon nuclear DNA and cytoplasmic ribosomes, so the mitochondria are called semi-autonomous organelles.

(7) **Two states of mitochondria :** When ATP synthesis is low or the respiratory chain of mitochondrion is inhibited, it is called inactive or orthodox state, and has large amount of matrix and only a few cristae. But when mitochondria are active or condensed state, and have small amount of matrix and highly developed cristae. This shows that the development of mitochondria depends upon the physiological activity of the cell.

(8) **Chemical composition :** *Cohn* gave the chemical composition of mitochondrion:

Proteins = 65 – 70%

Lipids = 25 – 30% (90% phospholipids and 10% cholesterol, Vit. E., etc)

2 – 5% RNA Some amount of DNA

The mitochondrial matrix has many catabolic enzymes like cytochrome oxidase and reductases, fatty acid oxidase, transaminase, etc.

(9) **Enzymes of Mitochondria**

(i) **Outer membrane :** Monoamine oxidase, glycerophosphatase, acyltransferase, phospholipase A.

(ii) **Inner membrane :** Cytochrome b,c_1,c,a, (cyt.b, cyt.c_1, cyt.c, cyt.a, cyt.a_3) NADH, dehydrogenase, succinate dehydrogenase, ubiquinone, flavoprotein, ATPase.

(iii) **Perimitochondrial space :** Adenylate kinase, nucleoside diphosphokinase.

(iv) **Inner matrix :** Pyruvate dehydrogenase, citrate synthase, aconitase, isocitrate dehydrogenase, fumarase, α – Ketoglutarate dehydrogenase, malate dehydrogenase.

(10) **Origin :** Mitochondria are self-duplicating organelles due to presence of DNA molecules so new mitochondria are always formed by growth and division of pre-existing mitochondria by binary fission.

Difference between outer and inner membrane of mitrochondria

Outer membrane	Inner membrane
It is smooth having less area.	It is infolded to form cristae hence large surface area.
It is freely permeable.	Semipermeable, impermeable to coenzyme A and NAD.
It consist 50% lipid and 50% protein.	It consist 80% protein and 20% lipid.
Sialic acid is more (4 – 5 time).	Sialic acid is less.
Near about 14% enzymes are present.	Near about 60 enzymes are present.

(11) **Functions of mitochondria**

(i) Mitochondria are called *power house* or storage batteries or ATP mills as these are sites of ATP formation.

(ii) Intermediate products of cell respiration are used in the formation of steroids, cytochromes, chlorophyll, etc.

(iii) These are also seat of some amino acid biosynthesis.

(iv) Mitochondria also regulate the calcium ion concentration inside the cell.

(v) Site of Krebs cycle and electron transport system.

(vi) Site of thermiogenesis.

(vii) Yolk nucleus (a mitochondrial cloud and golgi bodies) controls vitellogenesis.

(viii) Mitochondria of spermatid form nebenkern (middle piece) of sperm during spermiogenesis.

(ix) It is capable of producing its own DNA.

(x) Mitochondria release energy during respiration.

(xi) Mitochondria contain electron transport system.

Important Tips

- Petite character in yeast and cytoplasmic male sterility in maize are examples of mitochondrial inheritance.
- Mitochondria are believed to be bacterial endosymbionts.
- Mitochondria show a large degree of autonomy or independence in their functioning.
- Mitochondria as a place of cellular respiration were first observed by Hogeboom**.** Enzymes of Kreb's cycle or TCA cycle or citric acid cycle are present in matrix except succinic dehydrogenase which is found attached to inner mitochondrial membrane.
- With the help of phase contrast microscope mitochondria has been studied well.
- Mitochondria can be separated by centrifugation.
- Mitochondria are called as "cell inside cell" by Schiff (1982).
- Life of mitochondria is not more than 5 days.
- Mitochondria are yellowish due to riboflavin.
- 70% of total enzymes of a cell are found in mitochondria.
- Mitochondrial genome has 200 kilobase pairs.
- Mitochondria has the similarity , with bacteria as both have 70 S ribosome, circular DNA and RNA.
- Mitochondria are rich in manganese.
- It has its own electron transport system.
- Mitochondria and chloroplasts have many resemblances.
- According to endosymbiotic origin of mitochondria by Kirns Altman, mitochondria were intially a free living, aerobic bacteria which during to the process of evolution entered an anaerobic cell and become established as mitochondria. This theory is supported by many similarities which exist between bacteria and mitochondria.
- Lehninger discovered oxysomes.
- Percentage of mitochondrial DNA in cells is 1% of the total cellular DNA.
- Parson discovered stalkless and hollow spherical particles present on outer surface of outer mitochondrial membrane.
- When mitochondria treated with detergents like digitonin or lubral, their outer unit membrane is removed and remaining part is called Mitoplast
- The F_1 particle is made up of five types of subunits namely $\alpha, \beta, \gamma, \delta$ and ε. of these α is heaviest and ε is lightest.
- In prokaryotic cell, plasma membrane infolding makes a structure mesosome. Which is analogous structure of mitochondria of eukaryotic cell (both part in respiration).

1.9 Plastids

(1) **Definition :** Plastids are semiautonomous organelles having DNA, RNA, Ribosomes and double membrane envelope which store or synthesize various types of organic compounds as ATP and NADPH + H^+ etc. These are largest cell organelles in plant cell.

(2) **History**

(i) Haeckel (1865) discovered plastid, but the term was first time used by Schimper (1883)**.**

(ii) A well organised system of grana and stroma in plastid of normal barley plant was reported by de Von Wettstein.

(iii) *Park and Biggins* (1964**)** *gave the concept of quantasomes*.

(iv) The term chlorophyll was given by Pelletier and Caventou, and structural details were given by Willstatter and Stall.

(v) The term thylakoid was given by Menke (1962).

(vi) Fine structure was given by Mayer.

(3) **Types of plastids :** According to Schimper**,** Plastids are of 3 types: Leucoplasts, Chromoplasts and Chloroplasts.

Leucoplasts : *They are colourless* plastids which generally occur near the nucleus in nongreen cells and possess internal lamellae. Grana and photosynthetic pigments are absent. They mainly store food materials and occur in the cells not exposed to sunlight *e.g.*, seeds underground stems, roots, tubers, rhizomes etc. These are of three types.

(i) **Amyloplast :** Synthesize and *store starch grains*. *e.g.*, potato tubers, wheat and rice grains.

(ii) **Elaioplast (Lipidoplast, Oleoplast)** : They store lipids and oils *e.g.* castor endosperm, tube rose, etc.

(iii) **Aleuroplast (Proteinoplast) :** *Store proteins e.g., aleurone cells of maize grains*.

Chromoplasts : *Coloured plastids other than green are kown as chromoplasts*. These are present in petals and fruits, imparting different colours (red, yellow, orange etc) for attracting insects and animals. These also carry on photosynthesis.

These may arise from the chloroplasts due to *replacement of chlorophyll* by other pigments *e.g. tomato* and chillies or from leucoplasts by the development of pigments.

All colours (except green) are produced by flavins, flavenoids and cyanin. Cyanin pigment is of two types one is anthocyanin (blue) and another is erythrocyanin (red). Anthocyanin express different colours on different pH value. These are variously coloured *e.g.* in flowers. They give colour to petals and help in pollination. They are water soluble. They are found in cell sap.

Green tomatoes and chillies turn red on ripening because of replacement of chlorophyll molecule in chloroplasts by the red pigment lycopene in tomato and capsanthin in chillies. Thus, chloroplasts are changed into chromatophores.

Chloroplast : Discovered by Sachs and named by Schimper. They are greenish plastids which possess photosynthetic pigments.

(i) **Number :** It is variable. Number of chloroplast is 1 in *Spirogyra indica*, 2 in *Zygnema*, 16 in *S.rectospora*, up to 100 in mesophyll cells. The minimum number of one chloroplast per cell is found in Ulothrix and species of *Chlamydomonas*.

(ii) **Shape :** They have various shapes

Shape	Example
Cup shaped	*Chlamydomonas sp.*
Stellate shaped	*Zygnema.*
Collar or girdle shaped	*Ulothrix*
Spiral or ribbon shaped	*Spirogyra*
Reticulate	*Oedogonium*
Discoid	*Voucheria*

(iii) **Size :** It ranges from 3 – 10 μm (average 5 μm) in diameter. The discoid chloroplast of higher plants are 4 – 10 μm in length and 2– 4 μm in breadth. Chloroplast of spirogyra may reach a length of 1 *mm*. Sciophytes (Shade plant) have larger chloroplast.

(iv) **Chemical composition** :

(a) Proteins 50 – 60%,

(b) Lipids 25 – 30% ,

(c) Chlorophyll – 5- 10 %,

(d) Carotenoids (carotenes and xanthophylls) 1 –2%,

(e) DNA – 0.5%, RNA 2 – 3%,

(f) Vitamins K and E,

(g) Quinines, Mg, Fe, Co, Mn, P, etc. in traces.

(v) **Ultrastructure :** It is double membrane structure. Both membranes are smooth. The inner membrane is less permeable than outer but rich in proteins especially carrier proteins. Each membrane is 90 – 100 Å thick. The inter-membrane space is called the *periplastidial space*. Inner to membranes, matrix is present, which is divided into two parts.

(a) **Grana :** Inner plastidial membrane of the chloroplast is invaginated to form a series of parallel membranous sheets, called lamellae, which form a number of oval – shaped closed sacs, called thylakoids. Thylakoids are structural and functional elements of chloroplasts. These thylakoids contain all the requirements of light reactions *e.g.*, pigments like chlorophyll, carotenoids, plastoquinone, plastocyanin, etc. that are involved in photosynthesis. Each thylakoid has an intrathylakoid space, called loculus (size 10-30Å) bounded by a unit membrane. Along the inner side of thylakoid membrane, there are number of small rounded para-crystalline bodies, called

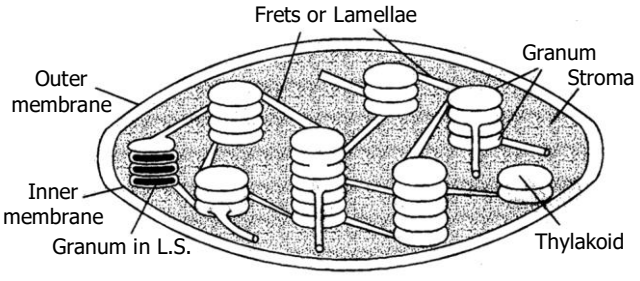


Fig : A chloroplast in section (diagrammatic)

quantasomes (a quantasome is the photosynthetic unit) which can trap a mole of quantum of light and can bring about photosynthetic act. Each quantasome contains about 230 *chlorophyll* molecules and 50 carotenoid molecules.

In eukaryotic plant cells, a number of thylakoids are superimposed like a pile of coins to form a granum. The number of thylakoids in a granum ranges from 10-100 (average number is 20-50). The number of grana per chloroplast also varies widely *e.g.,* one granum per chloroplast in *Euglena* while there are 40-60 grana per chloroplast in spinach. The size of each granum varies from $0.2 - 0.6\,\mu m$ in diameter. But in blue-green algae, the thylakoids are not organised to form granum.

Adjacent grana are interconnected by branched tubules, called stromal lamellae or Fret-channel or Fret membrane's.

(b) **Stroma :** *It is transparent, proteinaceous and watery substance*. Dark reaction of photosynthesis occurs in this portion. Stroma is almost filled with "Rubisco" (about 15% of total enzyme, protein) enzyme CO_2 is accepted by this enzyme. CO_2 assimilation results in carbohydrate formation. It has 20 – 60 copies of naked circular double stranded DNA. Each DNA copy is $40\,\mu$ in length, which can code for 125 amino acids. All plastids of a cell called as "*Plastidome*" (Dangeared 1920) in stroma. Amount of DNA per chloroplast is 10^{-15} *g*. Chloroplast genome has 145 kilobase pairs. It shows semiautonomous nature and ribosomes are of 70 *S* type.

(vi) **Pigments of chloroplast :** Willsttater and Stall observed the following pigments:

(a) **Chlorophyll a :** $C_{55}\ H_{72}\ O_5 N_4 Mg$ (with methyl group)

(b) **Chlorophyll b :** $C_{55}\ H_{70} O_6 N_4 Mg$ (with aldehyde group)

(c) **Chlorophyll c :** $C_{35} H_{32} O_5\ N_4 Mg$

(d) **Chlorophyll d :** $C_{54}\ H_{70}\ O_6 N_4 Mg$

(e) **Carotenes, Xanthophylls :** Carotenoids.

Difference between *Chl. a and Chl. b*

Chl. a	***Chl. b***
Absorption peak at 430, 662.	It is 453, 642.
Bluish green in colour.	Yellowish green.
Soluble in petroleum, ether.	Soluble in methyl alcohol.
Functional group at C_3 position is CH_3	Functional group attached to pyrrol ring is *CHO*.
Present in all green plants excepts autotrophic bacteria.	Present in all green plants except blue green, brown and red algae.
In chloroplast it is 75%.	It is 25%

In reflected light *Chl. a* shows blood red colour while in transmitted light, it shows blue green colour.	In reflected light it show dull brown colour while in transmitted light, it shows yellowish green colour.

(vii) **Chlorophylls and their presence :** Term by Cavantou (1818). It's molecule has tetrapyrollic or porphyrin head ($15\ Å \times 15\ Å$) and phytol tail (20 Å long). Mg^{++} is present in the centre of porphyrin head. If chlorophyll is burnt only Mg is left.

(a) **Chlorophyll *b* :** It is found in members of chlorophyceae.

(b) **Chlorophyll *c* :** It is found in members of phaeophyceae, bacillariophyceae.

(c) **Chlorophyll *d* :** It is found in members of rhodophyceae.

(d) **Chlorophyll *e* :** It is found in members of xanthophyceae.

(e) **Phycoerythrin and phycocyanin** (phycobilins) are the red and blue green pigments in rhodophyceae and cyanophyceae respectively.

(f) **Fucoxanthin** (brown pigment) in phaeophyceae.

(g) **Bacteriochlorophyll** ($C_{55}H_{74}O_6N_4Mg$) or chlorobium chlorophyll present in photosynthetic bacteria. These pigment are red in acidic and blue in alkaline medium.

(viii) **Carotenoids :** These are hydrocarbons, soluble in organic solvents. These are of 2 types:

(a) **Carotenes :** $C_{40}H_{56}$ derivatives of vitamin A. Carrot coloured α, β, γ carotene, lycopene, etc.

(b) **Xanthophyll :** $C_{40}H_{56}O_2$, yellowish in colour, fucoxanthin, violaxanthin. Molar ratio of carotene and xanthophyll in young leaves is 2 : 1.

(ix) **Plastids are interchangeable**

Leucoplast □ Chloroplast

↘ ↙

Chromoplast

(degenerate chloroplast)

<u>The leucoplast and chloroplast are interconvertible</u> but once they have converted into chromoplast, the reverse can not take place. Because, chromoplasts are aged or degenerated form of chloroplast *e.g.* in tomato.

Young ovary (colourless)	–	Leucoplast
Young fruit (green)	–	Chloroplast
Mature fruits (red) (due to Lycopene)	–	Chromoplast.
In carrot leucoplast	–	Chromoplast (carotene) etc.

(x) **Origin of chloroplast :** Plastids, like the mitochondria, are self duplicating organelles. These develop from colourless precursors, called <u>*proplastids*</u>. They are believed to be evolved from endosymbiont origination.

(4) **Function of plastids**

(i) It is the site of photosynthesis, (light and dark reaction).

(ii) Photolysis of water, reduction of NADP to $NADPH_2$ take place in granum.

(iii) Photophosphorylation through cytochrome b_6 *f,* plastocyanine and plastoguinone etc.

(iv) They store starch or *factory of synthesis of sugars*.

(v) Chloroplast store fat in the form of plastoglobuli.

(vi) They can be changed into chromoplasts to provide colour to many flowers and fruits for attracting animals.

(vii) They maintain the percentage of CO_2 and O_2 in atmosphere.

Important Tips

- Murphy and Leech (1978) have reported the synthesis of fatty acids in the spinach chloroplast.
- Proplastids are precursor of all type of plastids.
- Capasanthin is the pigment in carotenoids found in bacteria, fungi and chilly.
- Solar energy is trapped in lamella by chlorophylls but in bacteria trapping centre is B_{890}.
- The chloroplast with nitrogen fixing genes (nif genes) constitute nitroplast.
- Pyrenoids : A proteinaceous core around which starch is deposited mostly found in the chloroplast of algae and in some bryophytes.
- Algal classification is based on pigmentation pattern.
- Eye spot or stigma is photosensitive carotenoid pigment.
- Intact chloroplast can be separated by sugar solution (2.5 M).
- Mitochondria and plastids both have own DNA molecules which is called as Extranuclear/ Extrachromosomal DNA.
- Plastids are absent from monerans, fungi and animals these are also absent from gametes and zoospores of plants.
- Ris and Plaut (1962) reported DNA in chloroplast and was called plastidome. It forms about 0.5% of total cellular DNA and is rich in G-C pairs.
- Plastidoribosomes : Ribosomes of plastids and are of 70S type. These were reported by Jacobson et. al. (1963)
- Thylakoid term was given by Menke (1961).
- Transducers : Structure which are involved in energy transformations e.g. mitochondria and plastids.
- Plastids are the largest cell organelles. The plastids in the order of their increasing size are

  $\text{Chloroplast} \rightarrow \text{Chromoplast} \rightarrow \text{Elaioplast} \rightarrow \text{Aleuroplast} \rightarrow \text{Amyloplast}$

- ☞ Quantasome is formed of 160 chlorophyll a + 70 chlorophyll b molecules and 50 carotenoid molecules.
- ☞ Scattered thylakoids in the cytoplasm of cyanobacteria and photosynthesis bacteria are known as chromatophores.
- ☞ Chromatophore term was given by Schmitz.

1.10 Endoplasmic reticulum (ER)

(1) **Definition :** It is well developed electron microscopic network of interconnected cisternae, tubules and vesicles present throughout the cytoplasm, especially in the endoplasm.

(2) **Discovery :** Garnier (1897) was first to observe the ergastoplasm in a cell. The ER was first noted by *Porter*, Claude, and Fullman in 1945 as a network. It was named by Porter in 1953.

(3) **Occurrence :** The ER is present in almost all eukaryotic cells. A few cells such as ova, embryonic cells, and mature RBCs, however, lack ER. It is also absent in prokaryotic cell.

In muscle cells, it is called sarcoplasmic reticulum, myeloid bodies and nissel granules are believed to be formed from ER. ER is little develop in meristematic cells.

(4) **Chemical composition :** All the components of ER are lipoperoteins and trilaminar like the plasma membrane but differ in following

(i) Thinner $(50-60\ \mathring{A})$ than plasma membrane.

(ii) With less cholesterol.

(iii) With more lipids.

(iv) The lumen is filled with fluid containing 70% phospholipids lecithin and cephalin etc.

(5) **Ultrastructure :** The ER is made up of three components :

(i) **Cisternae :** These are flattened, unbranched, sac like structures. They lie in stacks (piles) parallel to one another. They bear ribosomes. They contain glycoproteins named ribophorin-I and ribophorin-II that bind the ribosomes. Found in protein forming cells.

(ii) **Vesicles :** These are oval or rounded, vacuole like elements, scattered in cytoplasm. These are also studded with ribosomes.

(iii) **Tubules :** Wider, tubular, branched elements mainly present near the cell membrane. They are free from ribosomes. These are more in lipid forming cells.

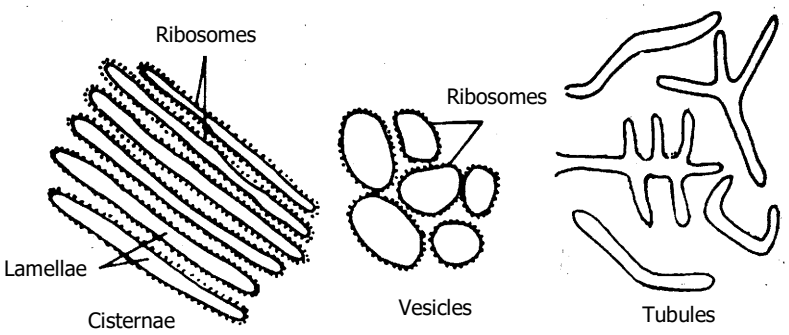


Fig : Elements of Endoplasmic Reticulum

All the three structures are bound by a single unit membrane.

(6) **Types of ER :** Depending upon the presence of ribosomes, the ER has been categorised into two types:

(i) **A smooth or Agranular endoplasmic reticulum (SER) :** It consists mainly of tubules and vesicles. It has no ribosomes associated to it. It is well developed in the muscle cells, adipose tissue cells, interstitial cells, glycogen storing liver cells, etc. and the cells that synthesize and secrete steroids. SER also takes part in synthesis of vitamins, carbohydrates and detoxification. Detoxification of pollutants carcinogens and drugs is carried out SER of liver cells and mitochondria, SER is associated with storage and release of Ca^{2+} ions. It gives rise to spherosomes.

(ii) **Rough or Granular endoplasmic reticulum (RER) :** It mainly consists of cisternae. It has ribosomes attached on its cytoplasmic surface. It is abundant in cells engaged in production and excertion of proteins, *e.g.*, plasma cells, goblets cells, pancreatic acinus cells and certain liver cells. The RER is more stable than SER. The RER is basophilic due to the presence of ribosomes. Ribosomes are attached to ER through hydrophobic interaction.

The proteins synthesised by the ER membrane bound ribosomes pass into the ER lumen, where most of the proteins are glycosylated. For this, an oligosaccharide is always linked to the $-NH_2$ group on side chain of an asparagine residue. The ER lumen serves as a compartment to contain substances which must be kept separate from cytosol. In the ER lumen, the enzymes modify the proteins.

Differences between SER and RER

SER	RER
SER or smooth endoplasmic reticulum does not possesses ribosomes over the surface of its membrane.	RER possesses ribosomes attached to its membrane.
It is mainly formed of vesicles and tubules.	It is mainly formed of cisternae and few tubules.
It is engaged in the synthesis of glycogen lipids and steroids.	The reticulum takes part in the synthesis of proteins.
Pores are absent so that materials synthesised by SER do not pass into its channels.	RER possesses narrow pores below its ribosomes for the passage of synthesised polypeptides into ER channels.
SER is often peripheral. It may be connected with plasmalemma.	It is often internal and connected with nuclear envelope.
Ribophorins are absent.	RER contains Ribophorins I and II for

	providing attachment to ribosomes.
SER gives rise to sphaerosomes.	It helps in the formation of lysosome through the agency of golgi apparatus.

(7) **Origin :** RER is formed from nuclear membrane while SER is formed from RER by loss of ribosomes. Rough vesicles originate only from RER after homogenisation of cell. RER breaks in small fragments (Vesicles) and it is called microsome (This is not a cell organelle). ER constitute cytoskeleton and also help as intracellular transport system. And it is sensitive to irritation.

(8) **Functions**

(i) Synthesis and secretion of specific proteins via – golgi bodies.

(ii) Formation of protein ribophorin. Which helps in attachment of ribosome.

(iii) Give rise to SER.

(iv) Provides surface for synthesis of cholesterol, steroid, ascorbic acid and visual pigments.

(v) It helps in synthesis of harmones *e.g.,* testosterone and estrogen.

(vi) It helps in glycogenolysis in the liver cells and brings about detoxification (SER).

(vii) Gastric cells secreting zymogen have well developed SER.

(viii) ER is a component of cytoskeleton (Spread as a net) of cell and provides mechanical support and shape to the cell.

(ix) ER acts as segregation apparatus and divides the cytoplasm into chambers. Compartmentalisation is most necessary for cellular life.

(x) It participates in the formation of cell-plate during cytokinesis in the plant cells by the formation of phragmoplasts.

(xi) ER has many types of enzymes *e.g.* ATPase, reductases, dehydrogenases and phosphatases.

(9) **Sacroplasmic reticulum :** It is a modified SER striated muscle fibres which forms a network of interconnected tubules in the sarcoplasm. It helps in conduction of motor nerve impulses throughout the muscle fibre and in the removal of lactic acid so prevents muscle fatigue. It is called "ergastoplasm" in muscle and "nisslegranules" in nerve cells.

Important Tips

- Annullated lamellae : It was first reported by Mc Culloch (1952) in the egg of sea urchin. Formed by blebbing of outer nuclear membrane.
- Transitional ER : It is RER without ribosomes.
- Microsome : This term was used by Claude (1941). It probably refers to these fragments of ER which are associated to ribosomes.
- Sjostrand gave the term α – cytomembrane for RER.
- Veratti (1902) reported sacroplasmic recticulum in the muscle fibers.

- Nissl's granules are the masses of RER in the cyton of neurons.
- Myeloid bodies are the masses of tubules (S0 SER) found in retinal cells and are related with photoreception.
- Total ER in the cell – 2/3 RER + 1/3 SER.
- In rapidly dividing cells endoplasmic reticulum is poorly developed.

1.11 GOLGI COMPLEX

(1) **Definition :** Golgi complex is made up of various membranous system e.g. cisternae, vesicles and vacuoles. These are also called golgi bodies, golgisomes, lipochondrion, dictyosomes, Dalton complex, idiosomes or Baker's body. These are also called "traffic police" of the cell.

(2) **Discovery :** First observed by George (1867) but it's morphological details were given by Camillo Golgi (1898), in nerve cells of barn fowl and cat.

(3) **Occurence :** It is present in all eukaryotic cells. They form 2% of total cell volume. In a cell these are found above centriole or near nucleus. *In plants*, these are scattered irregularly in the cytoplasm and called as "*dictyosomes*". These are absent in bacteria and blue green algae, RBCs, spermatozoa of bryophytes and pteridophytes, and sieve tube cells of phloem of angiosperm.

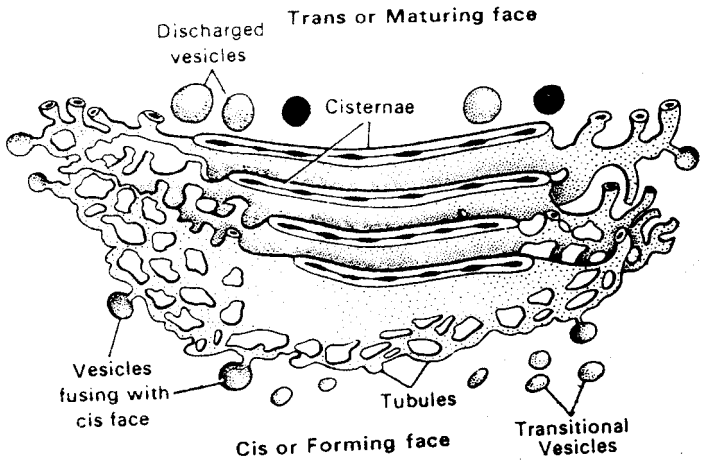


Fig : Arrangement of membrane, tubles and vesicles in golgi complex

(4) **Size and number :** The size of the golgi body varies with the metabolic state of cell and hence it is called pleomorphic. Large in mature functional and secretary cell *e.g.*, germinal cells, goblet cells, but small size in non-secretary cells. There may be 25,000 dictysomes present in rhizoidal cells of *Chara*. Average number 10 – 20 per cell. Number increases during cell division.

(5) **Structure :** Under transmission electron microscope the st. of golgibodies was study by Dalton and Felix (1954), golgi body is made of 4 parts.

(i) **Cisternae :** Golgi apparatus is made up of stack of flat. Sac like structure called cisternae. The margins of each cisterna are gently curved so that the entire golgi body takes on a cup like appearance. The golgi body has a definite polarity. The cisternae at the convex end of the dictyosome comprises forming face (F. face) or cis face. While the cisternae at the concave end comprises the maturing face (M. face) or trans face. The forming face is located next to either the nucleus or endoplasmic reticulum. The maturing face is usually directed towards the plasma membranes. It is the *functional unit of golgi body*.

(ii) **Tubules :** These arise due to fenestration of cisternae and it forms a complex of network.

(iii) **Secretory vesicles :** These are small sized components each about 40 Å in diameter presents along convex surface of edges of cisternae. These are smooth and coated type of vesicles. Smooth or

secretory vesicles, which have a smooth surface and contain secretions of the cell and coated vesicles, that have rough surface. They carry materials to or from the cisternae.

(iv) **Golgian vacuoles :** These are spherical components each about 600 Å in diameter. These are produced by vesiculation of saccules of cisternae. Scattered cisternae are called dictyosomes and condition is called diffused.

(6) **Function**

(i) The main function of golgi body is secretion, so it is large sized among the secretory cells. Secretion are released either by exocytosis or reverse pinocytosis.

(ii) Glycosidation of lipids *i.e.* addition of oligosaccharides to produce glycolipids.

(iii) Glycosylation of proteins *i.e.* addition of carbohydrate to produce glycoproteins.

(iv) Formation of lysosomes.

(v) Golgi body forms the cell plate. During cell division by secreting hemicellulose formation of enzyme and hormones (Thyroxine) etc.

(vi) Matrix of connective tissue is formed by golgi complex.

(vii) In oocytes of animal, golgi apparatus functions as the centre around which yolk is deposited *i.e.* vitellogenesis.

(viii) Membrane of the vesicles produced by golgi apparatus join in the region of cytokinesis to produce new plasmalemma.

(ix) It is also called export house of cell.

(x) Golgi body contains phospholipids, proteins, enzymes and vitamin-c.

(xi) The golgi complex gives rise to the acrosome in an animal sperm.

(7) **Origin :** Most accepted view is that golgi body originates from RER-that has lost its ribosomes from this RER arise transport vesicles that contain Golgi membrane and fuse with the saccule on the forming face of Golgi apparatus. This is why this face is called the forming face.

Important Tips

- According to Camillo Golgi "Apparato reticulare interno" (internal reticular apparatus) is Golgi body.
- Cellulose, hemicellulose and pectin are synthesized by Golgi body.
- Metal silver impregnation technique was used by Camillo Golgi.
- Sperm acrosome is made of golgi apparatus.
- The main enzyme of golgi complex are glycosyl transferase, nucleoside diphosphatase and thiamine pyrophosphatase.
- Zymogen is processed in it.
- Term "trophospongium" given by Holmgen.
- The number of golgi bodies increase during cell division. Phragmoplast is the precursor of cell plate.
- The basophilic ergastoplasm in gland cells indicate the richness of golgi bodies.

- Root cap cells are rich in golgi complex secreting mucilage, which lubricates the root tip.
- Proteins and fats are stored in vacuoles and vesicles of golgi complex.
- In fungi, unicisternal dictyosomes are found.
- Zone of exclusion : A zone of clear cytoplasm with no ribosomes, mitochondria etc. around the golgi body.
- Perner gave the term dictyosome.
- Mollenhaver and Whaley (1963): Reported polarity in golgi complex.
- GERL : Golgi-endoplasmic reticulum-lysosome system.
- GER : Golgi associated endoplasmic reticulum.

1.12 Lysosomes

(1) **Definition :** Lysosomes are electron microscopic, vesicular structures of the cytoplasm, bounded by a *single membrane* which are involved in intracellular digestive activities, contains hydrolytic enzymes, so called lysosomes.

(2) **Discovery :** These were first discovered by a Belgian biochemist, *Christian de Duve* (1995) in the liver cells and were earlier named pericanalicular dense bodies. Terms Lysosome was given by *Novikoff* under the study of electron microscope. Maltile (1964) was first to demonstrate their presence in plants, particularly in the fungus *neurospora*.

(3) **Occurrence :** These are absent from the prokaryotes but are present in all eukaryotic animal cells except mammalian RBCs. They have been recorded in fungi, euglena, cotton and pea seeds.

(4) **Shape :** These are generally spherical in shape but are irregular in plant root tip cells.

(5) **Size :** Size range is 0.2-0.8 μm while size is 0.5 μm (500 *nm*).

(6) **Number :** Lysosomes are more in those cells which are involved in intracellular digestive activities *e.g.*, *WBCs* of blood, *histiocytes* of connective tissue; *phagocytes* of liver and spleen; *osteoclasts*; cells of degenerating tissue like tail of tadpole larva etc.

(7) **Ultrastructure :** Under electron microscope, a lysosome is formed of two parts :

(i) **Limiting membrane :** It is outer, single layered, lipoproteinous and trilaminar unit membrane. It keeps a limit on glycoproteinous digestive enzymes.

(ii) **Matrix :** It is inner, finely granular and highly heterogeneous group substance inside the membrane.

(8) **Types :** The lysosomes change the nature of their contents at different times in the same cell. This variation is referred to as polymorphism. On the basis of their contents, four types of lysosomes are recognised.

(i) **Primary Lysosomes :** A newly formed lysosome contains enzymes only. It is called the *primary lysosomes*. Its enzymes are probably in an inactive state.

(ii) **Secondary Lysosomes :** When some material to be digested enters a primary lysosome, the latter is named the *secondary lysosome*, or *phagolysosome* or *digestive vacuole*, or *heterophagosome*. This commonly occurs by fusion of a primary lysosome with a vacuole (pinosome or phagosome) or a secretory granule.

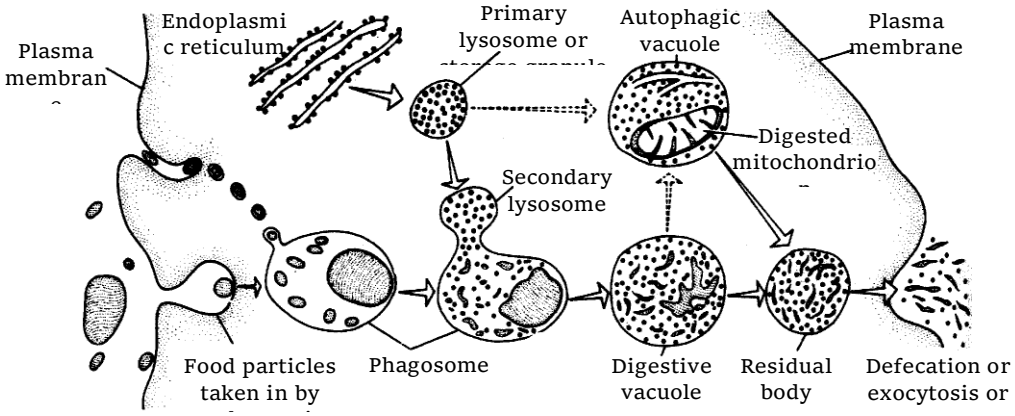


Fig : Different types of lysosomes and their origin

(iii) **Tertiary lysosomes/Residual bodies :** In a secondary lysosome, the enzymes digest the incoming materials. The products of digestion pass through the lysosome membrane into the cytoplasmic matrix for use as a source of nutrition or energy. Indigestible matter remains in the secondary lysosome. A secondary lysosome containing indigestible matter is known as the *residual body* or *tertiary lysosome*. The latter meets the cell by *exocytosis* (*ephagy*).

(iv) **Autophagosomes /Autolysosomes /Autophagic vaculoes :** A cell may digest its own organelles, such as *mitochondria, ER. This process is called autophagy or autolysis*. These are formed of primary lysosomes. The enzymes (hydrolytic) of lysosomes digest the organelles thus enclosed. Therefore, the lysosome are sometimes called disposal units/suicidal bags.

(9) **Chemical composition :** Matrix of primary lysosome is formed of hydrolases, which is involved in hydrolysis or polymeric compounds, that operate in acidic medium at *pH* 5, so called acid hydrolases. Upto now 50 types of enzyme have been reported to be present in latent form in different types of lysosomes. These enzymes are synthesized on RER, transported to cisternae of golgi body where these are packed into the lysosomes. These are as

(i) **Proteases** *e.g.*, cathepsin and collagenase.

(ii) **Nucleases** *e.g.*, DNAse and RNAse.

(iii) **Glycosidases** *e.g.*, β-galactosidase, β-glucoronidase.

(iv) **Phosphatases** *e.g.*, ATPase, acid phosphatase (marker enzyme).

(v) **Sulphatases** *e.g.*, for sulphate-linked organic compounds.

(vi) **Esterases** *e.g.*, phospholipase, acid lipase.

(10) **Origin :** Lysosomes arise from the golgi complex their membrane and hydrolytic enzymes are synthesized on the RER and are transported invesicles to the golgi complex for modification and packaging.

(11) **Functions**

(i) Lysosomes take part in digestion of food through phagosomes, known as intracellular digestion.

(ii) In metamorphosis of many animals certain embryonic parts are digested by it.

(iii) Obstructing structures are destroyed by lysosome.

(iv) Lysosomes perform the function of exocytosis and endocytosis.

(v) Lysosomes of sperms provide enzyme for breaking limiting membrane of egg *e.g.*, hyaluronidase enzyme.

(vi) They cause breakdown of ageing and dead cells.

(vii) Lysosomes functions as trigger of cell division or initiate cell division by digesting repressor molecules.

(viii) Nucleases (DNAse) of lysosomes may cause gene mutations which may cause disease like leukemia or blood cancer (partial deletion of 21^{st} chromosome).

(ix) Sometimes residual bodies accumulate inside the cells leading to storage diseases *e.g.* a glycogen storage disease called Pompe's disease, polynephritis Hurler's disease (deformed bones due to accumulation of mucopolysaccharides).

(x) Lysosomes also engulf the carcinogens.

Important Tips

- Cholesterol, cortisol and cortisone acts as a stablizers of lysosomal membrane, while absence of oxygen, X-rays UV rays and excess of vitamin A and E act as labilizers and weaken the lysosomal membrane.
- Polymorphism in lysosomes were described by De Robertis et. al (1971).
- Lysosomes can hydrolyse all types of organic compounds except cellulose.

1.13 Ribosomes

(1) **Definition :** The ribosomes are smallest known electron microscopic without membrane, ribonucleo–protein particles attached either on RER or floating freely in the cytoplasm and are the sites of protein synthesis.

(2) **Discovery :** In 1943 *Claude* observed some basophilic bodies and named them as microsome. *Palade* (1955) coined the term ribosome (form animal cell). Ribosomes in nucleoplasm were observed by *Tsao* and *Sato* (1959). First isolated by Tissieres and Watson (1958) from *E. coli*. Ribosomes found in groups are termed as polyribosomes or ergosomes (*Rich* and *Warner* 1963 observed first time polyribosomes).

(3) **Occurrence :** These are found in both prokaryotes as well as eukaryotes these are present only in free form in the cytoplasm. While in the eukaryotes the ribosomes are found in two forms in the cytoplasm, free form and bind form (bound on RER and outer nuclear membrane). These are also reported inside some cell organelles like mitochondria and plastids respectively called mitoribosomes and plastidoribosomes.

(4) **Number :** The number of ribosomes depends upon the RNA contents of the cell. These are more in plasma cells, liver cells, Nissl's granules of nerve cells, meristematic cells and cancerous cells.

(5) **Types of ribosomes :** It is determined on the basis of sedimentation coefficient measured in Svedberg unit or 'S' unit and their size. Velocity of sedimentation is 1×10^{-13} *cm* / sec/ *dyne*/*gm*.

(i) **70S ribosomes :** Found in prokaryotes, mitochondria and plastid of eukaryotes. Each is about 200 – 290Å × 170 – 210Å in size and 2.7×10^6 dalton in molecular weight.

(ii) **80S ribosomes :** Found in cytoplasm of eukaryotes. Each is about 300 – 340 Å × 200 – 240 Å in size and $4.5 – 5.0 \times 10^6$ daltons in molecular weight.

(iii) **77S, 60S and 55S ribosomes :** Levine and Goodenough (1874) observed 77S ribosomes in fungal mitochondria 60S ribosomes in animal mitochondria and 55S in mammalian mitochondria.

(6) **Structure :** Each ribosome is formed of two unequal subunits, which join only at the time of protein synthesis. In 70S and 80S ribosomes, 50S and 30S, 60S and 40S are larger and smaller subunits respectively. Larger subunits is dome shaped and attached to ER by glycoproteins called "ribophorins". It has a depression on the flate side which leads into a channel having elongating polypeptide chain. It has a protuberance, a ridge and a stalk. It also has 2 binding sites. Peptidyl or *P* or Donor site and Amino actyl or A or Acceptor site. These sites are for the attachment of charged tRNA molecules. Smaller subunit is oval shaped and fits as a cap on flat side of larger subunit. It has a platform, cleft head and base. It has binding site for mRNA. Delimiting membrane is not found in it. Ribosomes are attached to ER through hydrophobic interactions.

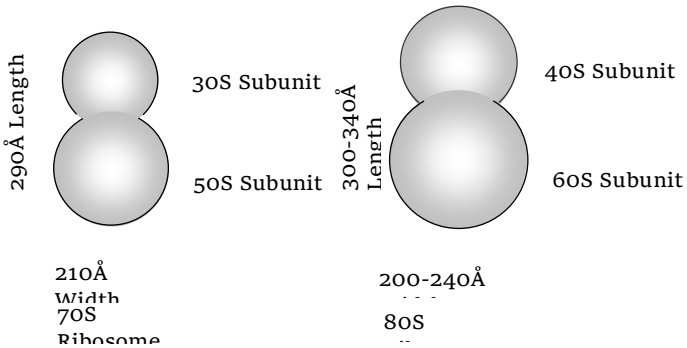


Fig : 70S and 80S ribosome

(7) **Chemical composition :** Ribosomes are chemically composed of rRNA and proteins Ribonucleo-Protein (RNP). Lipids are altogether absent in ribosomes. Ribosomes are strongly negative binding cations and basic dyes. 70*S* ribosomes has 60-65% rRNA and 35-40% proteins (ratio is 1.5 : 1). rRNAs are of three types : 23*S* type and 5*S* type rRNAs in 50*S* and 16S type rRNA in 30S sub-units. There are about 55 types of proteins in 70*S* ribosome out of which 21 proteins are found in 30*S* while 34 proteins are found in 50*S* ribosomal sub-unit and are called *core-proteins*.

80*S* ribosome has 45% rRNA and 55% proteins (ratio is about 1 : 1). r-RNA are of four types : 28*S*, 5*S* and 5.8*S* types of rRNAs in 60*S* and 18*S* type rRNA in 40*S* sub-units. There are about 70 types of proteins in 80*S* ribosome out of which 30 proteins are found in 40*S* while 40 proteins are found in 60*S* ribosomal sub-units. The ribosomal proteins are basic and almost surround the rRNA. Some proteins act as structural proteins while other proteins act as enzymes *e.g.*, *peptidyl transferase* of 50*S* (controls the interlinking of amino acids by peptide bonds).

A 1×10^{-3} (0.001 *M*) molar concentration of Mg^{++} is needed for the structural cohesion of ribosomes i.e., for holding the two subunits together. If this concentration is increased by ten folds, two ribosomes unite to form a *dimer*. The sedimentation coefficient of dimer of 70*S* ribosmes is 100*S* and that of 80*S* is 120*S*. By decreasing the Mg^{++} conc. to normal, the dimer breaks into <u>*monomers* (*single ribosomes*)</u>.

$$\underset{\text{Monomers}}{70S+70S} \underset{-Mg^{++}}{\overset{+Mg^{++}}{\rightleftharpoons}} \underset{\text{Dimer}}{100S}, \quad 80S+80S \underset{-Mg^{++}}{\overset{+Mg^{++}}{\rightleftharpoons}} 120S$$

If the Mg^{++} concentration is decreased to 1×10^{-4} molar, the ribosomes break up into its sub-units. The 70*S* ribosome breaks up into 50*S* and 30*S* sub-units. These 50*S* and 30*S* sub-units further dissociates into RNA and protein components. Similarly, the 80*S* ribosomes dissociates into 60*S* and 40*S* sub-units which further breakup into RNA and protein components.

(8) **Biogenesis of ribosome :**

(i) In eukaryotes the ribosomal RNAs like 18S, 5.8S and 28S are synthesized by nucleolus and 5S RNA out of the nucleus.

(ii) In prokaryotes both rRNA and its protein are synthesized as well as assembled by cytoplasm.

(9) **Polyribosomes or Polysomes :** When many ribosomes (generally 6 – 8) are attached at some mRNA strand. It is called polysome. The distance between adjacent ribosomes is of 90 nucleotides. These are functional unit of protein synthesis.

(10) **Function :**

(i) Ribosomes are also called protein factory of the cell or work branch of proteins.

(ii) Free ribosomes synthesize structural proteins and bounded ribosomes synthesize proteins for transport.

(iii) Ribosomes are essential for protein synthesis.

(iv) Help in the process of photosynthesis.

(v) They are found numerously in actively synthesizing cells like liver cells, pancreas, endocrine, yeast cells and meristematic cells.

(vi) Ribosomes also store the proteins temporarily.

(vii) These also store rRNAs, which helps in protein synthesis.

(viii) Enzyme peptidyl transferase occurs in large subunit of ribosome which helps in protein synthesis.

(ix) Newly formed polypeptide is protected from degradation by cytoplasmic enzymes in large sub-unit of ribosomes before releasing it into RER lumen.

Important tips

- Gunter Blobel and David Sabatini of Rockfeller university proposed signal hypothesis in 1971. Both scientist has been awarded the Nobel prize (1999) for this protein signalling.
- Ultra-structure of ribosomal subunits was given by James A. Lake (1981).
- Palade and Kuff (1966) gave the ultrastructure of ribosomes.
- Chaperons are proteins which assist in proper folding of proteins.

1.14 Microbodies

Microbodies are single membrane bounded small spherical or oval organelles, which take part in oxidation reactions other than those of respiration. They can only be seen by electron microscope. Microbodies posses a crystalline core and granules matrix. They are following types :–

(1) **Sphaerosomes**

(i) **Discovery :** These were first observed by Hanstein (1880) but discovered by Perner (1953). Term sphaerosomes was given by Dangeard.

(ii) **Occurrence :** These are found in all the plant cells which involves in the synthesis and storage of lipids *i.e.* endosperm and cotyledon.

(iii) **Shape, size and structure :** These are spherical or oval in shape about 0.5-2.5 μm in diameter. They contain hydrolytic enzymes like protease, ribonuclease, phosphatase, esterase etc. They are bounded by a single unit membrane.

(iv) **Function :** The main function of sphaerosomes is to help in lipid metabolism. These are also known as plant lysosomes.

(2) **Peroxisomes (Uricosomes)**

(i) **Discovery :** These were first discovered by J. Rhodin (1954) in the cells of mouse kidney with the help of electron microscope, and were called microbodies. De Duve (1965) isolated certain sac like organelles from various types of animals and plants. These were called peroxisomes because these contain peroxide producing enzymes (oxidases) and peroxide destroying enzymes (catalases).

(ii) **Occurrence :** These are found in photosynthetic cells of plants. In animals peroxisomes are abundant in the liver and kidney cells of vertebrates. They are also found in other organs like brain, small intestine, testis and adrenal cortex. They also occur in invertebrates and protozoans *e.g.*, Paramecium.

(iii) **Shape, size and structure :** These are spherical in shape, about 1.5 μm in size. They are bounded by a single unit membrane. They contains granular consents condensing in the centre. Their membrane is permeable to amino acids, uric acids, etc. They contain four enzymes of H_2O_2 metabolism. The enzymes urate oxidase, *d*-amino oxidase, α-hydroxy acid oxidase produce H_2O_2 whereas the catalases plays a significant protective role because H_2O_2 is toxic for cells.

$$\left.\begin{array}{l}\text{Uric acid} + O_2 \xrightarrow{\text{Urate oxidase}} \\ \text{Amino acid} + O_2 \xrightarrow{D\text{–amino oxidase}}\end{array}\right\} \rightarrow H_2O_2 \quad \left.\begin{array}{l}\text{Methyl alcohol} + H_2O_2 \xrightarrow{\text{Catalase}} \\ \text{Formic acid} + H_2O_2 \xrightarrow{\text{Catalase}}\end{array}\right\} \rightarrow H_2O$$

(iv) **Function :** These are involved in the formation and degrading of H_2O_2. Plant peroxisomes are also involved in photorespiration. In which glycolic acid oxidase enzyme oxidises the glycolic acid to glyoxylic acid. In case of plants peroxisomes is also known as glyoxisomes.

(3) **Glyoxysomes**

(i) **Discovery :** These were discovered by Beevers in 1961 and Briedenbach in 1967.

(ii) **Occurrence :** These are found in fungi, some protists and germinating seeds especially in germinating fatty seeds where insoluble lipid food reserves must be turned into soluble sugars.

Animals cannot execute this conversion because they do not posses glyoxylate enzymes.

(iii) **Shape, size and structure :** These are spherical in shape, about 0.5-1 μm in size, they contain enzymes of metabolism of glycolic acid via glyoxylate cycle and bounded by a unit membrane. These are also contain enzymes for β-oxidation of fatty acids.

(iv) **Functions :** The main function of glyoxysomes is conversion of fats into carbohydrates.

(4) **Lomasomes :** These are sac like structures found between cell wall and plasmalemma in the haustoria of fungal hyphae. These were first discovered by *Bowen* and *Berlin*. Webster called them border bodies.

1.15 Centrosome

(1) **Discovery :** Centrosome was first discovered by Van Benden (1887) and structure was given by T. Boveri.

(2) **Occurrence :** It is found in all the animal cell except mature mammalian RBC's. It is also found in most of protists and motile plant cells like antherozoids of ferns, zoospores of algae and motile algal forms *e.g., Chlamydomonas* but is absent in prokaryotes, fungi, gymnosperms and angiosperms.

(3) **Structure :** Centrosome is without unit membrane structure. It is formed of two darkly *stained granules called centrioles*, which are collectively called diplosome. These centrioles are surrounded by a transparent cytoplasmic area called centrosphere or Kinetoplasm. Centriole and centrosphere are collectively called centrosome. Before the cell division the centrioles at each pole of the spindle. The two centrioles are situated at 90^o to each other. Each centriole is a microtubular structure and is formed of microtubules arranged in 9 + 0 manner (all the 9 microtubules are peripheral in position).

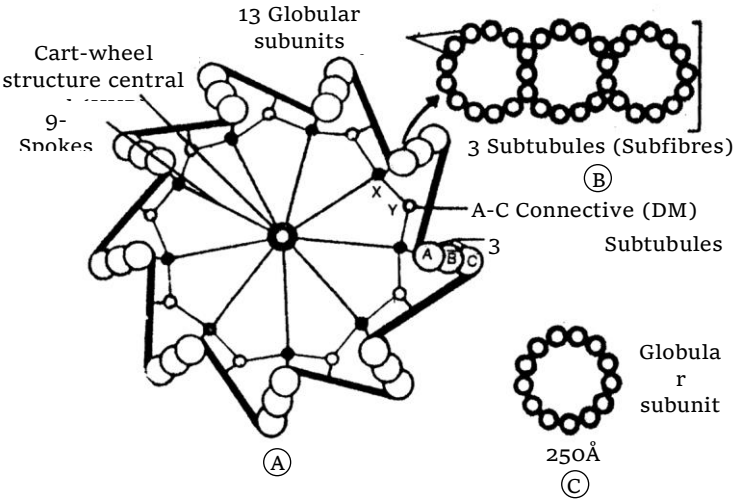


Fig : (A) T.S. Centriole (B) Three subtubules (C) A

Each microtubule is a triplet and is formed of three subtubules which are called A, B and C. A subtubule is about 45*Å* thick and is formed of 13 parallel protofilaments while each of B and C subtubule is formed of 10 parallel protofilaments. Each protofilament is formed of a row of α, β-tubulin dimers. C sub-tubule of each microtubule is linked to A sub-tubule of adjacent microtubule by a dense material (DM) strand called A-C linker, so all the microtubules are tilted at 40^o. Each microtubule is about 250*Å* in diameter.

Inside the microtubules, there is an intra-centriolar or cart-wheel structure which is formed of a central hub (about 25*Å* in diameter) and 9 radial spokes or radial fibres. Each radial spoke ends into a dense material (DM) thickening, called X-body or foot which is further linked to A-subtubule. Between two adjacent X-bodies there is another DM-thickening, called Y-body, which is linked to X-body on either side and to A-C linker on outer side.

Centriole is rich in tubulin and ATPase. Centriole can replicate but has no DNA. Centrioles replicate in G_2 phase of interphase of cell cycle but do not initiate cell division.

(4) **Chemical composition :** Centrosome is lipoproteinaceous structure. The microtubules of centriole are composed of protein tubulin and some lipids. They are rich in ATPase enzyme.

(5) **Origin :** The daughter centriole is formed from the pre-existing centriole in G_2 of interphase so called self-replicating organelle.

(6) **Functions**

(i) The centrioles help organising the spindle fibres and astral rays during cell division. Therefore, they are called microtubules organising centres. The cells of higher plants lack centrioles and still form a spindle.

(ii) They provide basal bodies which give rise to cilia and flagella.

(iii) The distal centriole of a spermatozoan give rise to the axial filament of the tail.

Important Tips

- Centriole is also called microcentrum or cell centre.
- Each centriole is formed of $9 \times 3 = 27$ subtubules or subfibres.

1.16 Cilia and flagella

(1) **Discovery :** Flagellum presence was first reported by *Englemann* (1868). *Jansen* (1887) was first scientist to report the structure of sperm flagellum.

(2) **Definition :** Cilia and flagella are microscopic, hair or thread-like motile structures present extra-cellularly but *originate intra-cellularly from the basal body* and help in movements, locomotion, feeding, circulation etc.

(3) **Occurrence :** Cilia are found in all the ciliate protozoans *e.g.,* Paramecium, Vorticella etc. flame cells of flat worms; in some larval forms *e.g.,* Trochophore larva of *Nereis, Bipinnaria* larva of starfish etc.; in some body structures *e.g.* wind-pipe, fallopian tubes, kidney-nephrons etc.

Flagella are found in all the flagellate protozoans *e.g., Euglena, Trichonympha* etc., collar cells of sponges; gastrodermal cells of coelenterates; spermatozoa of animals and lower plants; zoospores of algae etc. These are absent in red algae, blue-green algae, angiosperms, nematodes, arthropodes etc.

(4) Flagella are 1 – 4 per cell where as cilia are infinity in number.

(5) Cilia are smaller and flagella are longer in size, 5 – 10 μm and 150 μm respectively.

(6) **Structure :** Both cilia flagella are structurally similar and possess similar parts-basal body, rootlets, basal plate and shaft

(i) **Basal body :** These are also termed as blepharoplast (kinetosome) or basal granule. It is present below the plasma membrane in cytoplasm. The structure is similar to centriole made of 9 triplets of microtubules. Out of the 3 fibrils of a triplet first is A which is round and other two B and C are semi-circular. 9 triplets are connected to the centre by spokes. 'C' fibrils disappears as it enters into shaft.

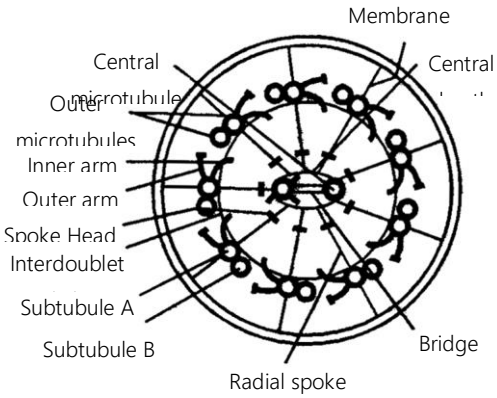


Fig : A diagram of T.S. Cilium or flagellum

(ii) **Rootlets :** Made of microfilament and providing support to the basal body. These are striated fibrillar outgrowths.

(iii) **Basal plate :** Central fibril develop in this area. It is highly dense and lie above plasma-membrane.

(iv) **Shaft :** It is the hair like projecting part of cilia and flagella which remains outside the cytoplasm. It has 9 duplets of microtubules in radial symmetry. These are called axonema. Each axonema has 11 fibrils, 9 in the periphery and 2 in the centre. The arrangement is called 9 + 2 pattern. Central fibrils are singlet fibrils and covered by a central sheath. 9 pheripheral fibrils are duplet and are present at 10^o difference from each other. Inner fibril of duplet is known as subfibre A with two bent arms and the outer one is subfibre-B. Peripheral fibrils are linked with each other by peripheral linkage and with the central fibril by radial linkage.

(7) **Chemical composition :** Chemically, the central tubules are formed of dynein protein while the peripheral microtubules are formed of *tubulin protein*. Dynein is the ATPase enzyme which hydrolyses the ATP to provide free energy for ciliary /flagellar beating. The interdoublet linkers are formed of nexin protein. Quantitatively, it is formed of

Proteins = 74 – 84% Lipids = 13 – 23%

Carbohydrates = 1 – 6% Nucleotides = 0.2 – 0.4%

(8) **Type of flagella :** There are two types of flagella.

(i) **Tinsel – type :** In this, flagellum has lateral hair-like processes, called flimmers or mastigonemes.

(ii) **Whiplash – type :** In this, flagellum has no flimmers.

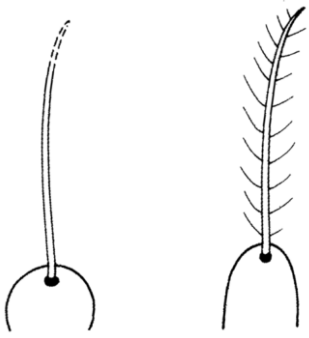


Fig : Types of

(9) **Motion :** Cilia beat in coordinated rhythm either simultaneously

(synchronus) or one after the other (metachronic rhythm). The cilia produce a sweeping or pendular stroke. The flagella beat independently, hence produce undulatory motion.

(10) **Function**

(i) They help in locomotion, respiration, cleaning, circulation, feeding, etc.

(ii) Being protoplasmic structure they can function as sensory organs.

(iii) They show sensitivity to changes in light, temperature and contact.

(iv) Ciliated larvae take part in dispersal of the species.

(v) The cilia of respiratory tract remove solid particles from it. Long term smoking damages the ciliated epithelium, allowing dust and smoke particles to enter the long alveoli.

(vi) The cilia of urinary and genital tracts drive out urine and gametes.

Difference between cilia and flagella

Characters	Cilia	Flagella
Number	More in number (may be upto 14,000 per cell).	Less in number (1-8).
Size	Small sized (5-10 μm).	Large sized (upto 100-200 μm).
Distribution	Generally distributed on whole body.	Generally located at anterior end of body.
Beating	Beat in either metachronous or synchronous coordination.	Beat independently.
Type of motion	Sweeping or rowing motion.	Undulatory motion.
Function	Locomotion, feeding, circulation, etc.	Only locomotion.

Important Tips

- Kinocilia : True or motile cilia e.g. of epithelial cells of respiratory tracct.
- Stereo cilia : Immobile cilia e.g. of epididymis.
- Bacterial flagellum consists of a single fibril composed of flagellin protein.

1.17 Cytoskeleton

In eukaryotic cell, a framework of fibrous protein elements became necessary to support the extensive system of membranes. These elements collectively form cytoskeleton of the cell. There are of three types.

(1) **Microtubules :**

(i) **Discovery :** These were first discovered by *De Robertis* and *Franchi* (1953) in the axons of medullated nerve fibres and were named neurotubules.

(ii) **Position :** The microtubules are electron-microscopic structures found only in the eukaryotic cellular structures *like cilia, flagella*, centriole, basal-body, astral fibres, spindle fibres, sperms tail, neuraxis of nerve fibres etc. These are absent from amoebae, slime-moulds and prokaryotes.

(iii) **Structure :** A microtubule is a hollow cylindrical structure of about 250 *Å* in diameter with about 150 Å luman. Its wall is about 50*Å* thick. Its walls is formed of 13 parallel, proto-tubules, each being formed of a liner series of globular dimeric protein molecules.

(iv) **Chemical composition :** These are mainly formed of tubulin protein. A tubulin protein is formed of 2 sub-units : α – tubulin molecule and β – tubulin molecule which are alternatively in a helical manner.

(v) **Function**

(a) These form a part of cytoskeleton and help in cell-shape and mechanical support.

(b) The microtubules of cilia and flagella help in locomotion and feeding.

(c) The microtubules of asters and *spindle fibres of the mitotic apparatus* help in the movement of chromosomes towards the opposite poles in cell-division.

(d) These help in distribution of pigment in the chromatophores, so help in skin colouration.

(e) These also form micro-circulatory system of the cell which helps in intracellular transport.

(f)These control the orientation of cellulose microfibrils of the cell wall of plants.

(2) **Microfilament**

(i) **Position :** These are electron-microscopic, long, narrow, cylindrical, non-contractile and proteins structures found only in the eukaryotic cytoplasm. These are present in the microvilli, muscle fibres (called myofilaments) etc. But these are absent from the prokaryotes. These are also associated with the pseudopodia, plasma membrane of fibroblats, etc. These are either scattered or organized into network or parallel arrays in the cytoplasmic matrix.

(ii) **Discovery :** These were discovered by Paleviz et. al. (1974).

(iii) **Structure :** Each microfilament is a solid filament of 50-60 Å diameter and is formed of a helical series of globular protein molecules. These are generally grouped to form bundles.

(iv) **Chemical composition :** These are mainly formed of actin-protein.

(v) **Functions**

(a) The microfilaments forms a part of cytoskeleton to support the relatively fluid matrix.

(b) The microfilaments bring about directed movements of particles and organelles along them in the cell.

(c) The microfilaments also produce streaming movements of cytoplasm.

(d) The microfilaments also cause cleavage of animal cells which is brought about by contraction of a ring of microfilaments.

(e) The microfilaments also participate in gliding amoeboid motion shown by amoebae, leucocytes and macrophages.

(f) The microfilaments are also resoponsible for the change in cell shape curing development, motility and division.

(g) Myofilaments bring about muscle contraction.

(h) The microfilaments cause movements of villi to quicken absorption of food.

(i) The microfilaments are responsible for the movement of cell membrane during endocytosis and exocytosis.

(j) The microfilaments cause plasma membrane undulations that enable the firoblasts to move.

(3) **Intermediate filaments**

(i) **Location :** They are supportive elements in the cytoplasm of the eukaryotic cells, except the plant cells. They are missing in mammalian RBCes and in the prokaryotes.

(ii) **Structure :** The IFs are somewhat larger than the microfilaments and are about 10 *nm* thick. They are solid, unbranched and composed of nonmotile structural proteins, such as keratin, desmine, vimentin.

(iii) **Functions**

(a) They form a part of cytoskeleton that supports the fuild cytosol and maintains the shape of the cell.

(b) They stabilize the epithelia by binding to the spot desmosomes.

(c) They form major structural proteins of skin and hair.

(d) They integrate the muscle cell components into a functional unit.

(e) They provided strength to the axons.

(f) They keep nucleus and other organelles in place.

Differences between microtubules and microfilaments

Microtubules	Microfilaments
Are hollow cylinders.	Are solid rods.
About 200 to 270 Å thick.	About 50 to 60 Å thick.
Composed of 13 longitudinal protofilaments each.	Not composed of protofilaments.
Formed of protein tubulin.	Formed of proteins actin and myosin.
Subunits are dimers that have bound GTP and GDP.	Subunits are monomers that have bound ATP and ADP.
Are noncontractile.	Are contractile.
Have no role in cytoplasmic streaming, endocytosis and exocytosis.	Play a role in cytoplasmic streaming, endocytosis and exocytosis.

Important Tips

- Microtubule term was given by Slautterback.
- Tubulin proteins is dimeric protein formed of two globular polypeptides called α – tubulin and β – tubulin.
- Microtubules associated proteins like Tau- protein and kinase control polymerization of tubulin dimer's.
- Hyman (1917) proposed sol-gel-theory for amoeboid locomotion and was supported by Mast.

1.18 Metabolically inactive cell inclusions/Deutoplasmic substances/Ergastic material

Within the cytoplasm of a cell there occur many different kinds of non-living structures which are called inclusions or ergastic substances. They are formed as a result of metabolic activities. They are of following types:

(1) **Vacuoles :** It is a *non-living* reservoir, bounded by a *differentially or selectively permeable membrane*, the *tonoplast*. The structure of tonoplast is similar to that of single unit membrane i.e. tripartite structure. The vacuole is filled with cell sap or tonoplasm**.** The thin layer of protoplasm, pushed towards the wall of the cell is called as primordial utricle. They contain water and minerals.

The vacuole in plants was discovered by *Spallanzani*. The vacuole is not air filled cavity, rather it is filled with a highly concentrated solution the vacuolar sap. It is generally neutral, but at maturity it becomes acidic. The cell sap contains following.

(i) **Gases :** CO_2, O_2 and N_2.

(ii) **Inorganic salts :** Nitrates, chlorides, sulphates, phosphates of K, Na, Ca and *Mg*.

(iii) **Organic acids :** Malic acid, formic acid, acetic acid, oxalic acid or their salts.

(iv) **Sugars :** Cane sugar, glucose and maltose.

(v) **Soluble proteins :** Enzymes.

(vi) **Glycosides :** *Like anthocyanins* (*water soluble pigment*)

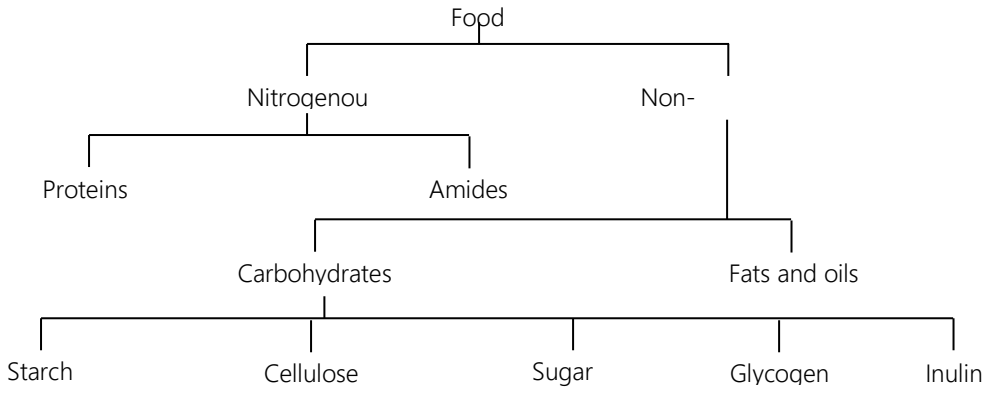
Some protozoans have contractile vacuoles which enlarge by accumulation of fluid or collapse by expelling them from the cell. The vacuoles may be sap vacuoles, contractile vacuoles or gas vacuoles (pseudo vacuoles).

(vii) **Function of vacuoles** : Vacuole maintains osmotic relation of cell which is helpful in absorption of water. They also act as reservoir of cells. Turgidity and flaccid stages of a cell are due to the concentrations of sap in the vacuole.

In animal cell, it is phagocytic, food vacuole, autophagic or contractile in nature.

(2) **Reserve food material**

The reserve food material may be classified as follows :–



(i) **Carbohydrates :** Non-nitrogenous, soluble or non- soluble *important reserve food material*. Starch cellulose and glycogen are all insoluble.

(a) **Starch :** Found in plants in the form of minute solid grains. Starch grains are of two types:

Assimilation starch : It is formed as a result of photosynthesis of chloroplasts. Diastase enzyme converts it into soluble sugar at night time. The conversion of sugar into reserve or storage starch is brought about by leucoplast as amyloplast.

Reserve starch : Thick layers are deposited around an organic centre called hilum. When hilum is situated just at the centre of starch grain, it is said to be concentric *e.g.* pea, bean, wheat etc. While it is situated not at the centre, but nearer the margin it is said to eccentric *e.g.* potato.

(b) **Glycogen :** Glycogen or animal starch occurs only in colourless plants like fungi. It occurs in the cytoplasm as an amorphous body.

(c) **Inulin :** It is a complex type of polysaccharide, soluble found dissolved in cell sap of roots of Dahlia, Jaruslem, Artichoke, Dandelion and members of compositae. When these roots are preserved in alcohol it precipitates in the form of " Sphaerites" or fan shaped crystals.

(d) **Sugars :** A number of sugars are found in solution of cell sap. These include glucose, fructose, sucrose, etc. Glucose and fructose are monosaccharides while can sugar is disaccharide and occurs in beet root and sugar- cane.

(e) **Cellulose :** Chemical formula is $(C_6H_{10}O_5)_n$. The cell wall is made up of cellulose. It is insoluble in water.

(ii) **Fats and Oils :** These are important reserve food material. These are always decomposed into glycerol and fatty acids by enzymatic action. Fat is usually abundant in cotyledons than in the endosperm. *e.g.* flax seed produce linseed oil, castor produce castor oil, cotton seeds produce cottonseed oil, etc.

(iii) **Proteins and Amides (Aleurone grains) :** Storage organ usually contain protein in the form of crystalline bodies known as crystalloids (potato). Proteins may be in the form of aleurone grains as

in pea, maize, castor, wheat, etc. Each aleurone grain consists of a large crystalline grain of protein known as crystalloid associated with it there is a smaller body globoid. It is not a protein but double phosphate of calcium and magnesium.

(3) **Excretory Products :** The organic waste products of plants are by-product of metabolism. They are stored as inclusions. Depending upon chemical composition they are classified as:

(i) **Resins :** They are believed to be aromatic compounds consisting of carbon, hydrogen and oxygen and are acidic in nature. Sometimes they are found in combination with gums and are called gum resin. *e.g. Asafoetida* (heeng). These are used in making varnishes and gums.

(ii) **Tannins :** They are complex nitrogenous compounds of acid nature having an astringent taste. They are used in conversion of hide into leather. With ferric salt they are largely used manufacture of ink. Presence of tannin in plants makes its wood hard durable and germ proof.

(iii) **Alkaloids :** These are organic, basic, nitrogenous substance. They occur in combination with organic acids and most of them are poisonous. From plants, cocaine, hyoscine, morphine, nicotine, quinine, atropine, strychnine and daturine etc. are extracted.

(iv) **Glucosides** : Some glucosides or glycosides function as storage substance e.g. amygdaline of the bitter almond. Erythrocyanins and Anthocyanins are responsible red and blue colour and flavines for cream colour. Carotene is an unsaturated fatty acid and not a glycoside, gives red and orange colour to roots.

(v) **Etherial and Essential oils** : These consist mixture of various hydrocarbons known as tarpenes and their oxygen derivatives. They are responsible for flavor of many fruits and scent of many flowers etc. They are volatile and are soluble in water, ether, petroleum etc. *e.g.* lavender, mint, clove oil, eucalyptus oil, theme oil etc.

(vi) **Mineral matter :** Many minerals are waste products in plants.

(a) **Calcium oxalate :** It occurs in the form of crystals of various shapes.

Raphides : Needle shaped crystals are known as raphides. They are found single or in bundles. e.g. in plants like jamikand, *Colocasia,* water hyacinth (Jal kumbhi), amorphophallus and aroids.

Rosette or Sphaeraphides : Star shaped crystals. They occur in special mucilaginous parenchyma cells of the petiole of arum, water hyacinth, etc. Crystals in the form of cubes are found in tunic of onion bulb. In the leaf of belladona, these crystals are in the form of sand and also called as sand crystals.

Calcium oxalate crystals : In members of family solanaceae. They are found as cubics, rods and prisms.

(b) **Calcium carbonate :** It is deposited in the form of crystalline masses hanging from a cellulose stalk in enlarged epidermal cells of leaves of *Ficus elastica* (Indian rubber plant) and is called as *cystolith*.

(vii) **Latex :** It is an emulsion in water having many substances either in suspension or in true solution. It may contain sugars, alkaloids and oils. It is watery in banana, milky white in *Euphorbia*, yellow or orange red in opium (poppy) is dried latex.

(viii) **Organic acids :** Tartaric acid in tamarind, and grapes, citric acid in lemon, orange etc. malic acid in apple and *Bryophyllum*. Oxalic acid in the form of crystals.

(ix) **Gums :** It is formed by decomposition of cellulose cell wall. Gum arabic of commerce is obtained from *Acacia senegal.*

(4) **Secretory products :** The chief secretion of plants are enzymes nectar, colouring matter, water etc. These secretion are helpful to plants.

1.19 Nucleus

(1) **Definition :** (Karyon = Nucleus) The nucleus also called director of the cell. It is the most important part of the cell which directs and controls all the cellular function.

(2) **Discovery :** The nucleus was first observed by *Robert Brown* (1831). Nucleus plays determinative (in heredity) role in cell and organism, that was experimentally demonstrated by *Hammerling* (1934) by conducting surgical experiments with green marine unicelled algae *Acetabularia*.

(3) **Occurence :** A true nucleus with definite nuclear membrane and linear chromosome, is present in all the eukaryotes except mature mammalian RBCs, *sieve tube cell of phloem*, tracheids and vessels of xylem. The prokaryotes have an incipient nucleus, called nucleoid or prokaryon or genophore or false nucleus or bacterial chromosome.

(4) **Number :** Usually there is a single nucleus per cell i.e. mononucleate condition, e.g. *Acetabularia*.

(i) **Anucleate (without nucleus) :** RBCs of mammals, phloem sieve tube, trachids and vessels of xylam.

(ii) **Binucleate :** *e.g.* Ciliate, Protozoans like Paramoecium.

(iii) **Polynucleate :** *e.g.* fungal hyphae of Rhizopus, Vaucheria. Polynucleate condition may be because of fusion of a number of cells. *i.e.* syncytium, coconut endosperm or by free nuclear divisions without cytokinesis *i.e.* coenocyte.

(5) **Shape :** It varies widely, generally spherical e.g. cuboidal germ cells, oval e.g. columnar cells of intestine, bean shaped in *paramoecium*, horse-shoe shaped in vorticella, bilobed, e.g. WBCs (acidophils), 3 lobed e.g. basophil, multilobed *e.g.* neutrophils, long and beaded form (moniliform) *e.g.* stentor and branched in silk spinning cells of platy phalyx insect larva.

(6) **Size :** The size of nucleus is variable *i.e.* 5 – 30μ. In metabolically active cells size of the nucleus is larger than metabolically inactive cells. The size depends upon metabolic activity of the cells. It is directly proportional to number of chromosomes.

(7) **Chemical composition of nucleus**

Proteins = 80% (65% acidic, neutral and enzymatic proteins; 15% basic proteins-histones)

DNA = 12%

RNA = 5%

Lipids = 3%

Enzymes like polymerases are abundantly present and help in synthesis of DNA and RNA. Minerals like $Ca^{2+}, Mg^{2+}, Na^{+},$ and K^{+} are present in traces.

(8) **Ultrastructure :** The nucleus is composed of following structure

(i) The nuclear membrane

(ii) The nucleous.

(iii) The nuclear sap or nucleoplasm.

(iv) The chromatin fibres.

The nuclear membrane or karyotheca

(i) **Definition :** It is defined as a regulatory envelope which controls the nucleo-cytoplasmic interacitons and exchange of materials.

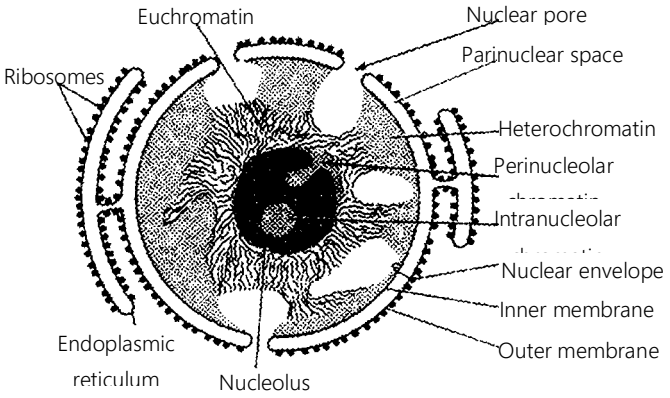


Fig : Electron microscopic structure of nucleus

(ii) **Discovery :** Nuclear membrane, also called nuclear envelope or nucleolemma or karyotheca, was first discovered by *Erclab* (1845).

(iii) **Structure :** It is a bilayered envelope. Each membrane is about 90 Å thick lipoproteinous and trilaminar. Outer membrane, called ectokaryotheca, is studded with ribosomes on its cytoplasmic surface and is continuos with RER at some points. Inner membrane, called endokaryotheca, is without ribosomes and is internally lined by electron-dense material of protein fibres called fibrous or nuclear lamina nuclear cortex or hoeny comb layer (about 300 Å thick). Two membranes are separated by a fluid-filled intermembranous perinuclear space (about 100-300Å). Nuclear membrane contains following structure.

(a) **Nuclear pore :** Nuclear membrane is porous and has 1,000-10,000 octagonal nuclear pores. Each nuclear pore is about 400-1,000 Å in diameter (average size is 800 Å). The number and size of the nuclear pores depend upon the needs of the cell. Nuclear pores are interspaced at about 1000-1500 Å. Each nuclear pore is fitted with a cylindrical structure, called annulus (with a lumen of 500 Å) and both

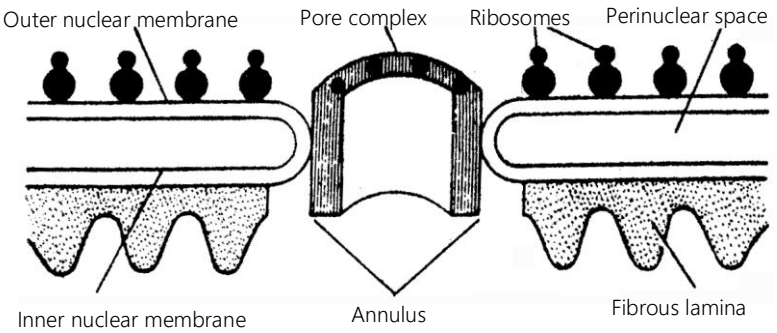


Fig : V.S. of nuclear envelope showing nuclear pore, Ribosomes and fibrous lamina

collectively form the pore complex or pore basket. Annulus has 8 micro-cylinders (each about 200 Å in diameter and with a lumen of 50 Å) in its wall. It also encloses a channel having nucleoplasmin for the movement of substances. Annulus acts as a diphragm and regulates the size of the nuclear pore.

(b) **Nuclear blebbing :** The nuclear envelope shows evagination. As a result, blebs are formed which are pinched off. This phenomenon is called blebbing. The nuclear vesicles so formed are thought to give rise to mitochondria, plastids, etc. Blebbing may also occur from the outer unit membrane only. A row of these blebs move towards the periphery. As a result of deposition of matrix material in between these blebs, and annulate lamella is formed. The annulate lamellae is thought to give rise to ER cisternae.

(iv) **Origin :** It is formed by the fusion of ER elements during the telophase of cell division.

(v) **Functions**

(a) It regulates the nucleo-cytoplasmic interactions.

(b) It allows the passage of inorganic ions and small organic molecules.

(c) It helps in pinocytosis and phagocytosis of large sized molecules .

(d) It allows passage of ribosomal subunits, RNAs and proteins through nuclear pores.

(e) It maintains the shape of the nucleus.

(f) Fibrous lamina strengthens the nuclear envelope. It also helps in dissolution and reformation of nuclear membrane during cell division.

The nucleolus (Little nucleus)

(i) **Discovery :** Nucleolus was first observed by *Fontana* (1781) in the skin cells of an eel. Term 'nucleous' was coined by *Bowman* (1840). Its light microscopic structure was given by *Wagner* (1840).

(ii) **Position :** It is generally associated with nucleolar organizer region (NOR) of the nucleolar chromosomes. It is absent in muscle fibres, RBC, yeast, sperm and prokaryotes.

(iii) **Number :** Generally, a diploid cell is with two nucleoli but there are five nucleoli in somatic cell of man and about 1000 nucleoli in the oocytes of Xenopus.

(iv) **Structure :** (*De Robertis et. al* 1971). A nucleolus is distinguishable into following regions :-

(a) **Chromatin :** The nucleolus is surrounded by perinucleolar chromatin. Heterochromatic intrunsions are also seen in the nucleolus which constitutes the intranucleolar chromatin.

(b) **Pars fibrosa :** Fibrils of 80 – 100 Å size form a part of the nucleolus.

(c) **Pars granulosa :** Granules of 150 – 200 Å diameter constitute the granular part of the nucleolus. They appear like

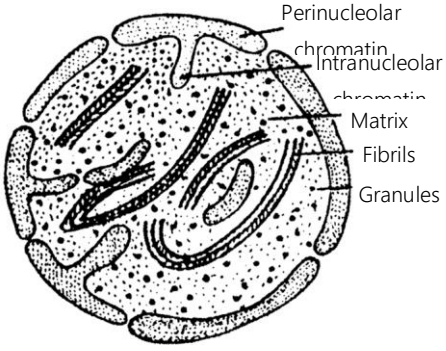


Fig : Ultrastructure of a Nucleolus

vesicle with a light central core. The granules may be joined by filament forming a beaded primary nucleolonema. The fibrils may also be associated to it. The primary nucleolonema may further coil to form the secondary nucleolonema.

(d) **Pars amorpha :** The granules and the fibrils lie dispered in an amorphous proteinaceous matrix. Nucleolus contains large amount of proteins mainly phosphoproteins. There are no histones proteins. RNA methylase, an enzyme that transfers methyl groups to the RNA bases has been localized in nucleolus. Nucleolus is stained by "pyronine". It is not bounded by any limiting membrane. Fibrillar region of nucleolus is called secondary constriction or nucleolar organising region (NOR) and this region directs the synthesis of rRNA. Ribosomes are assembled here as such it is also called ribosome producing machine or factory. Ribosomal units so formed are joined together by thin filament (rRNA) forming a structure like string of beads and it is called "*nucleonema*".

(v) **Chemical composition :** Nucleolus is mainly formed of RNA and non histone acidic proteins. It is a *storehouse of RNA.*

(vi) **Origin :** A nucleolus is formed at specific sites, called the nucleolar organizers, present on certain chromosomes region (NOR).

(vii) **Functions**

(a) It is seat of biogenesis of rRNA and also stores rRNA.

(b) It plays important role in spindle formation during cell division.

(c) It receives the ribosomal proteins from the cytoplasm, combines the rRNAs and ribosomal proteins to form ribosomal subunits.

Nucleoplasm : It is also called karyolymph. It is transparent, homogenous, semifluid, colloidal, ground substance present inside the nuclear membrane in which nuclear chromatin and nucleoli are embedded. Chemically it contains. Nucleoplasm is also known as protoplasm of nucleus.

(i) **Nucleic acid :** Monomer nucleotides of DNA and RNA

(ii) **Proteins** : Basic proteins (nuclear protamines and nucleohistones and acidic proteins (non-histone)

(iii) **Enzymes :** DNA polymerase, RNA polymerase, NAD synthetase, nucleoside triphosphatase, and pyruvic acid kinase, etc.

(iv) **Minerals :** Phosphorus, potassium, sodium, calcium, magnesium, etc.

(v) **Ribonucleoproteins :** Contain perichromatin granules and interchromatin granules. Histone proteins are basic because they contain arginine in much amount *e.g.* H_1, H_2A, H_2B, H_3 and H_4 .

The nucleoplasm helps in maintaining the shape of nucleus formation of spindle protein of NAD, ATP, DNA, RNAs and ribosomal subunits. Plasmosome and karyosome combindly called "*amphinucleoli*".

Chromatin fibres /Nuclear chromatin : The nucleoplasm contains many thread like, coiled and much elongated structures which take readily the basic stains such as "basic fuschin". These thread like

structures are known as chromatin fibre. They are uniformly distributed in the nucleoplasm. They are observed only in the "interphase stage". Chromatin fibres are made of chromosomes. In resting nondividing eukaryotic cells the genome is nucleoprotein complex and it is called chromatin.

1.20 Chromosome

(1) **Definition :** During interphase, chromatin threads are present in the form of a network called *chromatin* reticulum. At the time of cell division, these thread like structures of chromatin become visible as independent structures, called chromosomes.

(2) **Structure of chromosome :** Each chromosome consists of two coiled filaments throughout its length called chromonemata by *Vejdovsky*. These have *bead like* structures called *chromomeres which bear genes*. Chromatid is a half chromosome or daughter chromosome. The *two chromatids are connected at the centromere or primary constriction*. Primary constriction (centromere) and secondary constriction gives rise to satellite. The secondary constriction consists of genes which code for ribosomal RNA and nucleolus hence it is called as "nucleolar organizer region". Chromosomes having satellite are called SAT chromosomes.

The ends of chromosomes are called "telomeres" (which do not unite with any other structure). A tertiary constriction is also present in chromosomes, which perhaps helps in recognition of chromosomes.

In 1928 *Emile Heitz* developed a technique for stainning of chromosomes. Chromosomes can be stainned with acetocarmine or fuelgen (basic fuschin) there are two types of regions are seen :–

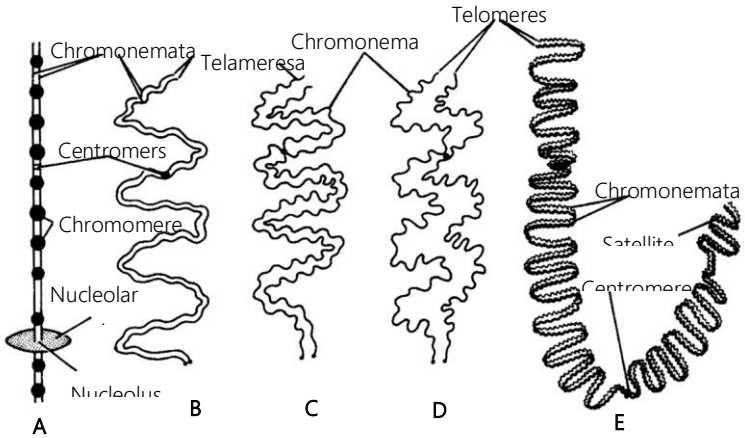


Fig : Chromosomes A. Diagrammatic B, C, D, E-Different parts

(i) **Heterochromatin :** It is formed of thick regions which are more darkly stained than others areas. It is with condensed DNA which is transcriptionally inactive and late replicating. It generally lies near the nuclear lamina. Heterochromatin are of two types : –

(a) **Facultative heterochromatin :** Temporarily inactivated chromatin and forms 2.5% of the genome.

(b) **Constitutive hetrochromatin :** Permanently inactivated chromatin and generally ground near centromeres.

(ii) **Euchromatin :** It is true chromatin and is formed of thin, less darkly stained areas. It is with loose DNA which is transcriptionally active and early replicating.

(3) **Chemical chomposition :** DNA - 40%. Histone – 50%. Other (acid) Proteins – 8.5%. RNA – 1.5%. Traces of lipids, *Ca, Mg* and *Fe.* Histone are low molecular weight basic proteins which occur alongwith DNA in 1 : 1 ratio. Nonhistone chromosomal or NHC proteins are of three types– structural,

enzymatic and regulatory. Structural NHC proteins form the core or axis of the chromosome. They are also called scaffold proteins. Enzymatic proteins form enzymes for chemical transformation, *e.g.*, phosphates, RNA polymerase, DNA polymerase. Regulatory proteins control gene expression. HMG (high mobility group) proteins get linked to histones for releasing DNA to express itself.

(4) **Ultrastructure and Models of chromosomes** : (See in genetics).

Important Tips

- Syncytium is multinucleate condition formed by the fusion of cells e.g. in plasmodium of slime moulds.
- Coenocytic is multinucleate condition by repeated Karyokinesis but not followed by cytokinesis e.g. in vaucheria, rhizopus.
- Callan and Tamlin (1950) first to observe nuclear pore in nuclear membrane.
- Staining property of chromosomes is called as heteropycnosis.
- Satellite is also called trabant.
- Centromere or kinetochore is responsible for chromosomal movement during cell division.
- Idiogram : Karyotype of a species is represented with the help of a diagram called idiogram.
- Genome : It is defined as the haploid set of chromosomes.
- Plasmon : Genes present in cytoplasm are called "plasmons"
- Non histone proteins (acidic proteins) are rich in nucleus and less chromosome.

1.21 Micromolecules

(1) **Definition :** These are molecules of low molecular weight and have higher solubility. These include minerals, water, amino acid, sugars and nucleotides. All molecules or chemicals functional in life activity are called *biomolecules*.

(2) **Elements** : They are naturally occuring and they are classified on the basis of their property into metals and non-metals. Again on the basis of presence and requirement in plants and animals, they are grouped into major and minor bioelements. Which are required in large amount are major bioelements *e.g. Ca, P, Na, Mg, S, K, N*, etc., while those are required in small amount are called minor bioelements e.g. *Fe, Cu, Co, Mn, Mo, Zn, I*, etc.

On the basis of function, they may be of following types :–

(i) **Framework elements :** Carbon, oxygen and hydrogen.

(ii) **Protoplasmic elements :** Protein, nucleic acid, lipids, chlorophyll, enzymes, etc.

(iii) **Balancing elements :** *Ca, Mg* and *K*. counteract the toxic effect of other minerals by ion-balancing. There are 17 essential elements in plants and 24 in animals. 14 elements are non-essential :–

(iv) **Proportion of elements in a cell**

Oxygen - *O* - 62%	Chlorine- *Cl*	0.16%
Carbon - *C*- 20% major elements (95%)	Sulphur - *S*	0.14%
Hydrogen- *H*- 10%	Potassium- *K*	0.11%
Trace elements- 0.75% minor elements (4.25%)	Sodium - *Na*	0.10%
Calcium – *Ca*- 2.5%	Magnesium – *Mg*	0.07%
Phosphorous- *P*- 1.14%	Iodine- *I*	0.14%
	Iron - *Fe*	0.10%

(3) **Biological compounds :** These involve two kinds of compounds.

(i) **Inorganic compounds :** Characterised by absence of carbon, simple structure with low molecular weights *e.g.* water, minerals, ions and gases etc. Water 80% and inorganic salts 1-3%.

(ii) **Organic compounds :** Characterised by presence of carbon bonded to form a straight chain or ring structure.

Carbohydrates	Lipids	Proteins	Nucleotides	Other compounds
1.0%	3.5%	12.0%	2.0%	0.5%

(4) **Cellular pool :** Aggregated and interlinked various kinds of biomolecules in a living system. So cell is called cellular pool. It includes over 5000 chemicals. Inorganic chemicals are present mostly in aqueous phase while organic in both. The aqueous phase may be moleculer solution in which dissolved particles are smaller than 0.000001 *mm* and colloidal phase in which particle size varies between 0.0001 – 0.000001 *mm*. Cellular pool comprises of both crystelloid and colloidal particles. Hence called as crystal colloids the non-aqueous phase comprises of organic molecules present in cell compartments like plasma membrane, mitochondria, chloroplast, etc.

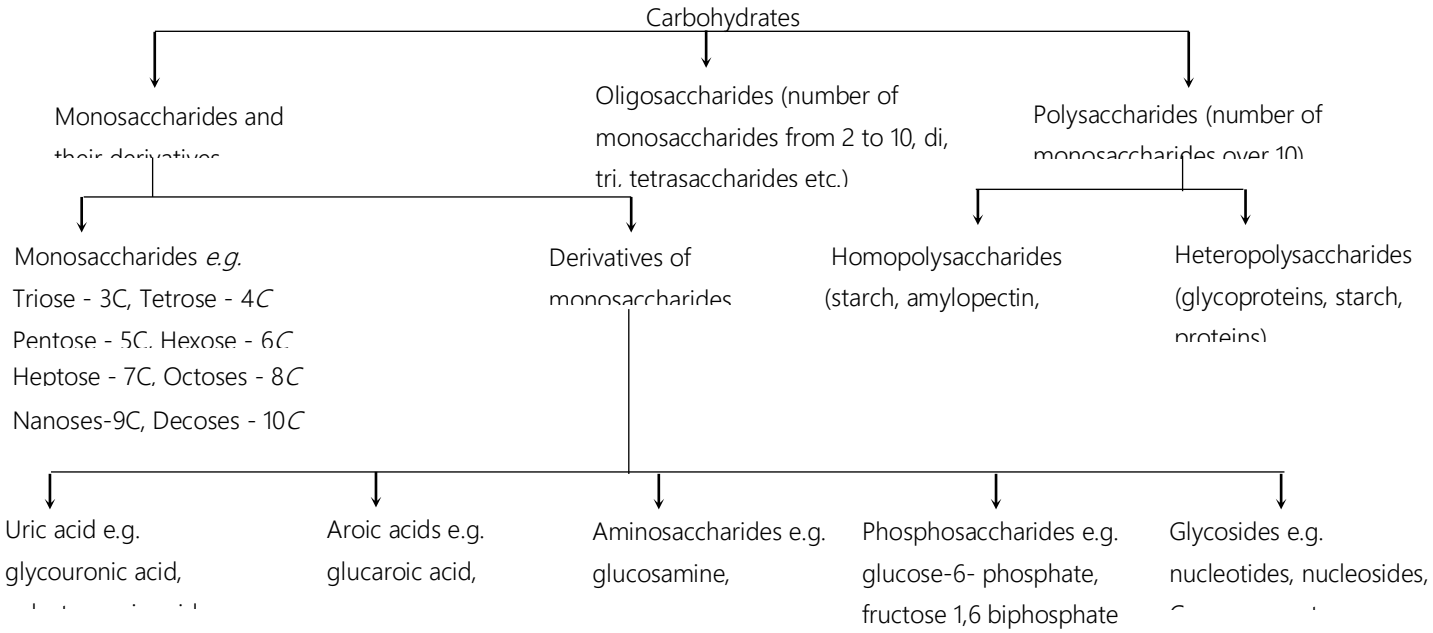
(5) **Water :** Liquid of life, major constituent of cell (about 60-90%) and exists in intracellular, intercellular and in vacuoles. In cells it occurs in free state or bound state (*KOH, CaOH* etc.).

(i) **Properties of water :** It is colourless, transparent, tastless and odourless, neutral (pH-7) liquid. It is universal solvent, as it can dissolve both polar and non-polar solutes. High boiling point due to hydrogen bonding. Shows high degree of cohesion and adhesion. It can undergo three states of matter *i.e.* solid□ liquid□ gas. It is dense and heaviest at 4*C* and solid below it.

(6) **Carbohydrates :** *e.g.* sugars, glycogen (animal starch), plant starch and cellulose.

(i) **Source of carbohydrate :** Mainly photosynthesis. It exists only in 1% but constitutes 80% of the dry weight of plants.

(ii) **Composition :** It consists of carbon, hydrogen and oxygen in the ratio $C_nH_{2n}O_n$. It is also called saccharide and sugars are their basic components. Classification of carbohydrates can be summarised as :–



Monosaccharides : These are single sugar units which can not be hydrolysed furthur into smaller carbohydrates. General formula is $C_nH_{2n}O_n$, *e.g.* Triose-3C, glyceraldehyde, dihydroxyacetone, etc., *tetrose*, *pentose*, *hexose*, etc. About 70 monosaccharides are known, out of which only 20 are present in plants and animals.

(i) **Important Hexoses**

(a) **Glucose :** $C_6H_{12}O_6$. Grape sugar is dextrose. Grape is sour due to presence of tartaric acid. Fructose is called fruit sugar (sweetest among natural sugars) and glucose is called " sugar of body". Normal level of blood glucose is 80-120mg/100ml. If it exceeds then condition is called "glucosuria".

(b) **Fructose :** Occurs naturally in fruit juices and honey. Hydrolysis of cane sugar in body also yields fructose.

(c) **Galactose :** It is called as brain sugar. It's an important constituent of glycolipids and glycoproteins.

(d) **Mannose :** It is obtained on hydrolysis of plant mannans and gums. It is constituent of albumins, globulins and mucoproteins.

(ii) **Structure of monosaccharides**

(iii) **Properties of monosaccharide**

(a) Monosaccharides are colourless, sweet tasting, solids.

(b) Due to asymmetric carbon, they exist in different isomeric forms. They can rotate polarized light hence they are dextrorotatory and leavorotatory.

(c) D-glucose after reduction gives rise to a mixture of polyhydroxy alcohol, sorbitol or mannitol.

(d) The sugars with a free aldehyde or ketone group reduce Cu^{++} to Cu^{+} (cupric to cuprous)

(e) Sugars show oxidation, esterification and fermentation.

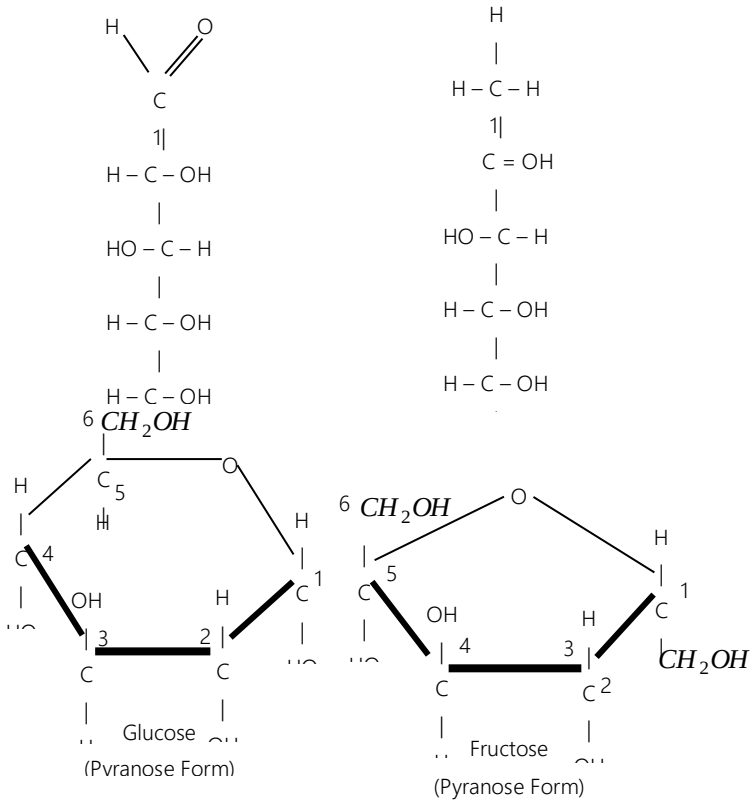


Fig : Open chain and ring forms of three hexoses

(f) The aldehyde or ketone group of a simple sugar can join an alcoholic group of another organic compound bond *C-O-C* the process involves loss of water and is called condensation (*H-O-H*) or $H+OH \rightarrow H_2O$.

(iv) **Functions of monosaccharides**

(a) Glucose is the ultimate source of ATP in the cell respiration.

(b) It is used in formation of vitamin C.

(c) The intermediate compounds for the formation of glucose in photosynthesis are triose, tetrose, pentose and heptose, etc.

(d) Galactose is a constituent of agar-agar.

(e) Glucose is a blood sugar and xylose is a non nutritive sweetner.

(f) Polymerisation of these molecules forms macromolecules.

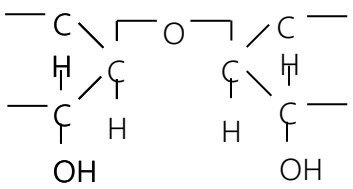
(g) Ribose and deoxyribose are constituent of nucleic acids and nucleotides

(h) Glyceraldehyde and dihydroxyacetone are trioses.

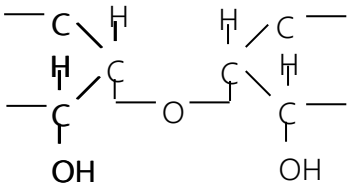
(i) Sugars have free aldehyde or ketone group which can reduce Cu^{++} to Cu^{+} and are called reducing sugars. Benedicts or fehling's test are used to confirm the presence of reducing sugars.

Oligosaccharides : Formed due to condensation of 2-10 monosaccharide units, the Oxygen bridge is known as "glycoside linkage" and water molecule is eliminated.

The bond may be α and β.



α-glycosidic linkage



β-glycosidic linkage

(i) **Disaccharides :** Composed of two molecules of same or different monosaccharide units. Also called "double sugars". Molecular formula is $C_{12}H_{22}O_{11}$.

(a) **Maltose :** Also called "malt sugar" stored in germinating seeds of barley, oat, etc. It is formed by enzymatic (enzyme amylase) action on starch. It is a reducing sugar.

(b) **Sucrose :** "Cane sugar" or " table-sugar". Obtained from sugarcane and beet root and on hydrolysis splits into glucose and fructose.

(c) **Lactose :** Milk sugar or 5% in mammalian milk. On hydrolysis yields glucose and galactose. *Streptococus lacti* converts lactose in to lactic acid and causes souring of milk.

(ii) **Trisaccharides :** Composed of three molecules of sugars. Molecular formula is $C_{18}H_{32}O_{16}$.

(a) **Raffinose :** Found in sugar beet, cotton and in some fungi. It is made up of glucose, fructose and galactose.

(b) **Gentianose :** Found in rhizomes of gentian species, made up of glucose and fructose.

(iii) **Tetrasaccharides :** Composed of four molecules of same or different sugars. Stachyose is found in *Stachys tubefera*. It is made up of two unit of galactose, one unit of glucose and one unit of fructose.

(iv) **Polysaccharides :** General formula is $(C_6H_{10}O_5)_n$ formed by condensation of several molecules (300-1000) of monosaccharides, (Described under " Macromolecules").

(v) **Reducing and Non-reducing carbohydrates :** Those which reduce Tollen's reagent or fehling solution are called reducing sugars and those do not reduce are called non-reducing sugars. All monosaccharides and disaccharides except sucrose are reducing. While all polysaccharides are non-reducing sugars.

(7) **Lipids :** Term lipid was coined by <u>*Bloor*</u>. These are esters of fatty acids and alcohol. They are hydrophobic insoluble in water but soluble in benzene, ether and chloroform. Lipids are classified into three groups:–

(i) **Simple lipids :** These are the esters of fatty acids and glycerol. Again they are typed as :–

(a) **Fats and Oils :** (Natural lipids or true fats). These triglycerides of fatty acid and glycerol. Fats which are liquid at room temperature are called oils. Oils with polyunsaturated fatty acids are called polyunsaturated e.g. sunflower oil, lower blood cholesterol.

(b) **Fatty acids :** Obtained by hydrolysis of fats. Formic acid is simplest fatty acid (*HCOOH*). These are of 2 types :–

Saturated fatty acids : The fatty acids which do not have double bond in between carbon atoms.e.g. butyric acid, palmitic acid,hexanoic acid, etc. They have high melting points, solid at room temperature and increase blood cholesterol.

Unsaturated fatty acids : The fatty acids which have double bonds in carbon atoms. *e.g.* 8 hexadecanoic acid, 9 octadecanoic acid etc. They have lower melting points mostly found in plant fats, liquid at room temperature and lower the blood cholesterol.

(c) **Waxes :** These are simple lipids composed of one molecule of long chain fatty acid and long chain monohydric alcohol. Waxes have high melting point, insoluble in water, resistant to atmospheric oxidation, chemically inert and not digested by enzymes. They reduce rate of transpiration by making plant tissue water proof and work as excellent lubricant.

Types of waxes

- **Plant wax :** Forms coating.
- **Bee's wax :** It is secretion of abdominal glands of worker honeybee. It consist of palmitic acid and myricyl alcohol.
- **Lanolin or Wool fat :** It is secreted by cutaneous glands, also obtained from wool of sheeps. It consists of palmitic acid, oleic or stearic acid and cholesterol.
- **Sebum :** It is secretion of sebaceous gland of skin.
- **Paraffin wax :** Obtained from petrolium.

(ii) **Compound lipids :** They contain some additional or element. Group with fatty acid and alcohol on the basis of group they may be of following types:

(a) **Phospholipids :** These contain phosphoric acid. It helps in transport, metabolism, blood clotting and permeability of cell membrane. It is a bipolar molecule i.e. phosphate containing end is hydrophilic whereas fatty acid molecules represent hydrophobic (non-polar tail). Phospholipids again comprises.

Lecithin : These are yellowish grey solids, soluble in ether and alcohol but insoluble in acetone. On hydrolysis they yield glycerol, fatty acid, phosphoric acid and choline. Lecithins are broken down by enzyme lecithinase to lysolecithin. The enzyme is found in venom of bee and cobra.

Cephalins : Found in animal tissue and soyabean oil. Cephalin contains choline or serine sometimes and stearic acid, oleic acid, linoelic and arachidonic acid.

(b) **Glycolipids :** These contain nitrogen and carbohydrate beside fatty acids. Generally found in white matter of nervous system. *e.g.* sesocine frenocin.

(c) **Chromolipids :** It includes pigmented lipids *e.g.* carotene.

(d) **Aminolipids :** Also known as sulpholipids. It contains sulphur and amino acids with fatty acid and glycerol. Cutin and suberin are also compound lipids resistant to water and also provide mechanical support in plants.

(iii) **Derived lipids :** These are obtained by hydrolysis of simple and compound lipids. Derived lipids include following components :–

(a) **Sterols :** Lipids without straight chains are called sterols. They are composed of fused hydrocarbon rings and a long hydrocarbon side chain. Best known sterol is cholesterol, present in high concentration in nervous tissue and in bile. Cholesterol is also the precursor of hormones like progesterone, testosterone, estradiol and cortisol and vitamin D**.** Diosgenin is obtained from yam plant (*Dioscorea*) used in making anti- infertility pills.

(b) **Digitalin :** It is prepared from leaves of Foxglove *(Digitalis lantana)* is a heart stimulant.

(c) **Ergosterol :** Present in food, found in ergot and yeast. It is precursor of another form of vitamin D, ergocalciferol (D_2).

(d) **Coprosterol :** It is found in faeces. It is formed as a result of the reduction by bacteria in intestine from the double bond of cholesterol between C_5 and C_6.

(e) **Tarpens :** It is essential oil and present mostly in oils of camphor, eucalyptus, lemon and mint. Phytol is a terpenoid alcohol present in Vitamin A, K, E and in pigments like chlorophyll carotenoid. Other forms are licopene, gibberellins and natural rubber.

(f) **Prostaglandin :** It is hormone like compound derived from arachidonic acid. Mostly present in secretion of seminal vesicles in males and menstrual cycle fluid in females.

(g) **Blubber :** A very thick layer of subcutaneous fat in whale.

(iv) **Functions of lipids**

(a) Oxidation of lipids yields comparatively more energy in the cell than protein and carbohydrates. 1gm of lipids account for 39.1 *KJ*.

(b) The oil seeds such as groundnut, mustard, coconut store fats to provide nourishment to embryo during germination.

(c) They function as structural constituent *i.e.* all the membrane system of the cell are made up of lipoproteins.

(d) Amphipathic lipids are emulsifier.

(e) It works as heat insulator.

(f) Used in synthesis of hormones.

(g) Fats provide solubility to vitamins *A, D, E,* and *K*.

(8) **Amino acids :** Amino acids are normal components of cell proteins (called amino acid). They are 20 in number specified in genetic code and universal in viruses, prokaryotes and eukaryotes. Otherwise amino acids may be termed rare amino acids, which take part in protein synthesis e.g. hydroxyproline and non- protein amino acids do not take part in protein synthesis *e.g.* Ornithin, citrullin, gama-aminobutyric acid (GABA) a neurotransmitter, etc.

(i) **Structure and Composition :** Amino acids are basic units of protein and made up of *C, H, O, N* and sometimes S. Amino acids are organic acids

$$NH_2 - \underset{\displaystyle R}{\overset{\displaystyle H}{\underset{|}{\overset{|}{C}}}} - COOH$$

with a carboxyl group (*–COOH*) and one amino group $(-NH_2)$ on the α -carbon atom. Carboxyl group attributes acidic properties and amino group gives basic ones. In solution, they serve as buffers and help to maintain *pH*. General formula is $R-CHNH_2.COOH$.

Amino acids are amphoteric or bipolar ions or Zueitter ions. Amino acids link with each other by peptide bond and long chains are called polypeptide chains.

(ii) **Classification**

Based on R-group of amino acids.

(a) **Simple amino acids** : These have no functional group in the side chain. *e.g.* glycine, alanine , leucine, valine etc.

(b) **Hydroxy amino acids** : They have alcohol group in side chain. *e.g.* threonine, serine, etc.

(c) **Sulphur containing amino acids** : They have sulphur atom in side chain. *e.g.* methionine, cystenine.

(d) **Basic amino acids** : They have basic group $(-NH_2)$ in side chain. *e.g.* lysine, arginine.

(e) **Acidic amino acids** : They have carboxyl group in side chain. *e.g.* aspartic acid, glutamic acid.

(f) **Acid amide amino acids :** These are the derivatives of acidic amino acids. In this group, one of the carboxyl group has been converted to amide $(-CO.NH_2)$. *e.g.* asparagine, glutamine.

(g) **Heterocyclic amino acids :** These are the amino acids in which the side chain includes a ring involving at least one atom other than carbon. *e.g.* tryptophan, histidine.

(h) **Aromatic amino acids :** They have aromatic group (benzene ring) in the side chain. *e.g.* phenylalanine, tyrosine, etc.

On the basis of requirements : On the basis of the synthesis amino acids in body and their requirement, they are categorized as :–

(a) **Essential amino acids :** These are not synthesized in body hence to be provided in diet *e.g.* valine, leucine, isoleucine, theronine ,lysine, etc.

(b) **Semi-essential amino acids :** Synthesized partially in the body but not at the rate to meet the requirement of individual. *e.g.*, arginine and histidine.

(c) **Non-essential amino acids :** These amino acids are derived from carbon skeleton of lipids and carbohydrate metabolism. In humans there are 12 non- essential amino acids *e.g.* alanine, aspartic acid, cysteine, glutamic acid etc. Proline and hydroxyproline have, *NH* (imino group) instead of NH_2 hence are called imino acids. Tyrosine can be converted into hormone thyroxine and adrenaline and skin pigment melanin. Glycine is necessory for production of heme. Tryptophan is the precursor of vitamin nicotinamide and auxins. If amino group is removed from amino acid it can form glucose and if *COOH* group is removed, it forms amines e.g. histamine.

(iii) **Functions of amino acids**

(a) Amino acids are building blocks of proteins and enzymes.

(b) By glycogenolysis, they form glucose.

(c) Hormones like adrenaline and thyroxine are formed with the help of tyrosine.

(d) Antibiotics often contain non-protein amino acids.

(e) They are precursour of many substances.

(9) **Nucleotides** : Structurally a nucleotide can be regarded as a phosphoester of a nucleoside. A combination of nitrogens base and a sugar is called nucleoside and combination of a base, a sugar and phosphate group is known as nucleotide.

Types of nitrogen base	Nucleoside	Nucleotide
Adenine	Adenosine	Adenylic acid
Guanine	Guanosine	Guanylic acid
Cytosine	Cytidine	Cytidilic acid
Thymine	Thymidine	Thymidylic acid
Uracil	Uridine	Uridylic acid

There are two types of pentose sugars, ribose found in RNA and deoxyribose found in DNA. Nucleotides form 2% of the cell component.

N_2 base + Pentose sugar $\rightarrow$ 'Nucleoside'

Nucleoside + Phosphoric acid $\rightarrow$ 'Nucleotide' + H_2O .

There are two types of bases which occur in the nucleic acids.

(i) **Purines :** Purines are 9 membered *double ringed* nitrogenous bases which possess nitrogen at 1' ,3' ,7' and 9' positions. They are *adenine* (A) and *guanine* (G).

(ii) **Pyrimidines :** They are smaller molecule than purines. These are 6 membered *single ringed* nitrogenous bases that contain nitrogen at 1' and 3' positions like cytosine (C), thymine (T) and uracil (U). In DNA adenine pairs with thymine by two H_2 bond and cytosine pairs with guanine by three H_2 bond.

A nucleotide may have one, two or three phosphates, as one in AMP (adenosine monophosphate), two in ADP (adenosine diphosphate). The phosphate bond is called high energy bond and it release about 8 K cal. ATP was discovered by *Karl Lohmann* (1929). Formation of ATP is endergonic reaciton.

(iii) **Functions of nucleotides :** Following are the major functions of nucleotides.

(a) **Formation of nucleic acids :** Different nucleotides polymerize together to form DNA and RNA.

(b) **Formation of energy carrier :** They help in formation of *ATP,AMP, ADP, GDP, GTP, TDP,TTP, UDP,* etc. which on breaking release energy.

(c) **Formation of Coenzymes :** Coenzymes like NAD, NADP, FMN, FAD, CoA, etc are formed. Coenzymes are non-proteinaceous substance necessory for the activity of the enzymes.

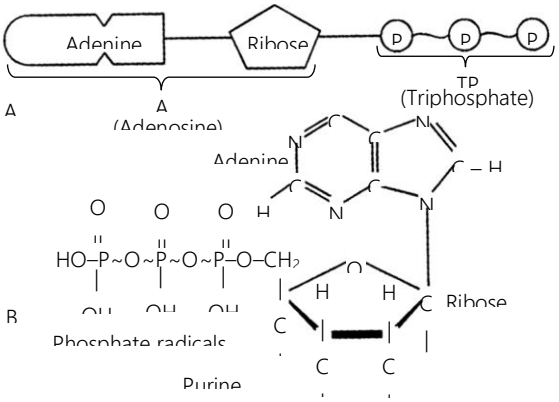


Fig : Structure of ATP molecule

(iv) **Some important Coenzymes**

(a) **NAD^+** (Nicotinamide adenine dinucleotide) or Code hydrogenase-I is involved in many hydrogen transferring reaction. It is Coenzyme I (Vit B_5).

(b) **Coenzyme II** or Code hydrogenase II or $NADP^+$; TPN (triphopyridine) etc. it is similar in functioning to Coenzyme-I.

(c) **Coenzyme A :** It is a complex thiol derivative unlike Co-I and Co-II, Co-A is not a oxidising-reducing Coenzyme but is acylating *i.e.* Co-A accepts acetyl groups from one metabolite and denotes them to another in the presence of specific enzymes. Most important Co-A compound is acetyl Co-A (activated acetate). Beside acylation Coenzyme-A can also undergo phosphorylation.

(d) **Flavonucleotides :** FMN (flavin mononucleotide) and FAD (flavin adenine dinucleotide) take part in oxidation reaction and also function as dehydrogenase. FMN is vitamin B_2 or riboflavin.

(v) **Important points**

(a) On the basis of presence of aldehyde or ketone groups glyceraldehyde may be termed as an aldotriose and dihydroxyacetone is then called ketotriose.

(b) General formula of oligosaccharide is $C_n(H_2O)_{n-1}$.

(c) Isomaltose has α-1-6 linkage.

(d) Musein is a polysaccharide.

(e) Cobalt is constituent of vit.B_{12} and required for synthesis of phytochromes and auxins.

(f) Copper is a constituent of plastocyanine and co-factor of respiratory enzymes.

(g) Boron is necessory for plants in sugar translocation.

(h) Galactose is a constituent of 'gum arabic'.

(i) Sweetest protein is monellin.

(j) Lipidosis in born or acquired characteristic syndrome due to lipid metabolism.

(k) Cellulose nitrite is used in propellant explosis.

(l) Nickle is required for activity of urease.

1.22 Macromolecules

Macromolecules are polymerisation product of micromolecuels, have high molecular weight and low solubility. They include mainly polysaccharide, protein and nucleic acids.

Polysaccharide : They are branched or unbranched polymers of monosaccharides jointed by glycosidic bond. Their general formula is $(C_6H_{10}O_5)_n$. They are also called glycans polysaccharides are amorphous, tasteless and insoluble or only slightly soluble in water and can be easily hydrolysed to monosaccharide units.

(1) **Types of polysaccharides**

On the basis of structure

(i) **Homopolysaccharides :** These are made by polymerisation of single kind of monosaccharides. *e.g*. starch, cellulose, glycogen, etc.

(ii) **Heteropolysaccharide :** These are made by condensation of two or more kinds of monosaccharides. *e.g.* chitin, pectin, etc.

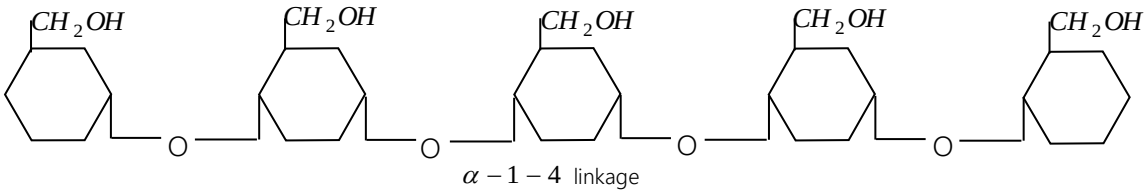
On the basis of functions

(i) **Food storage polysaccharides :** They serve as reserve food. *e.g.* starch and glycogen.

(ii) **Structural polysaccharides :** These take part in structural framework of cell wall *e.g.* chitin and cellulose.

(2) **Description of some polysaccharides**

(i) **Glycogen :** It is a branched polymer of glucose and contain 30,000 glucose units. It is also called *animal starch*. Their general formula is $(C_6H_{10}O_5)_n$. It is also found as storage product in blue green algae, slime moulds, fungi and bacteria. It is a non-reducing sugar and gives red colour with iodine. In glycogen, glucose molecule are linked by 1 – 4 glycosidic linkage in straight part and 1 – 6 linkage in the branching part glycogen has branch points about every 8-10 glucose units.



(ii) **Starch :** Starch is formed in photosynthesis and function as energy storing substance. Generally found in the form of grains, which contain 20% water. It is found abundantly in rice, wheat, legumes, potato (oval and ecentric shaped), banana, etc. Starch is of two types. Straight chain polysaccharides known as amylose and branched chain as amylopectin. Both composed of D – glucose units jointed by $\alpha-1-4$ linkage and $\alpha-1-6$ linkage. It is insoluble in water and gives blue colour when treated with iodine. Amylose consists of 200 – 500 *glucose units*. It is stored inside chloroplast or spherical leucoplast and known as amyloplasts.

(iii) **Inulin :** Also called "dahlia starch"(found in roots). It has unbranched chain of 30 – 35 fructose units linked by $\beta-2-1$ glycosidic linkage between 1 and 2 of carbon atom of D – fructose unit.

(iv) **Cellulose :** An important constituent of cell wall (20 – 40%), made up of *unbranched chain* of 6000 *β–D glucose units linked by* 1 – 4 *glycosidic linkage*. It is fibrous, rigid and insoluble in water. Wood (20 – 50%) and cotton (90%) contain large amount of it. Rayon (artificial fibre) cellulose, nitrate (used as explosive) and carboxyl methyl cellulose (used as cosmetics and ice cream) are obtained by activity of "cellulase" enzyme. It doesn't give any colour when treated with iodine.

(v) **Chitin :** It is a polyglycol consisting of N-acetyl–D–glucosamine units connected with $\beta-1,4$ glycosidic linkage. Mostly it is found in hard exoskeleton of insects and crustaceans and some times in fungal cell wall. Second most abundant carbohydrate.

(vi) **Agar-Agar :** It is a galactan, consisting of both D and L galactose and it is used to prepare bacterial cultures. It is also used as luxative and obtained from cell wall of red algae *e.g.* Gracilaria, Gelidium, etc.

(vii) **Pectin :** It is a cell wall material in collenchyma tissue may also be found in fruit pulps, rind of citrus fruits etc. It is water soluble and can undergo sol gel transformation. It contain arabinose, galactose and galacturonic acid.

(viii) **Neutral sugars :** It is found associated with cellulose in cell wall. The common sugars in hemicellulose are D-xylose, L–arabinose, D-galactose, D-mannose and D-glucusonic acid. *e.g.* hemicellulose.

(ix) **Gum :** It secreted by higher plants after injury or pathogenic attacks. It is viscous and seals the wound. It involves sugars like L-arabinose, D-galactose, D-glucusonic acid. *e.g.* gum arabic.

(x) **Mucopolysaccharides :** These are gelatinous substance, containing amino sugars, uronic acid, etc. All slimy substances of plant are mucopolysaccharide. *e.g.* hyaluronic acid, vitreous humour, chondridine sulphate, heparin, husk of isabgul and mucilage of also.

(xi) **Glycoproteins :** They include some plasmaprotein and blood group substances. They doesn't contain uronic acid.

(xii) **Murein :** It is a peptidoglycan, linked to short chains of peptides. It is constituent of cell wall of bacteria and blue green algae.

(3) **Properties of polysaccharides**

(i) They are tasteless and colourless solids.

(ii) Insoluble in water, soluble in alcohol and more soluble in ether.

(iii) Can be easily hydrolyzed into their monosaccharide.

(iv) Their molecular weight is high.

(v) They do not diffuse through plasma membrane.

(4) **Functions**

(i) Cellulose pectin and chitin are constituents in cell wall of higher plants but peptidoglycan in the cell wall of prokaryotes.

(ii) They are reserve food material.

(iii) They form protective covering.

(iv) They can be used as culture medium.

(v) Being insoluble they do no exert osmotic or chemical influence in the cell.

(vi) Fibres are obtained used in making cloth and rope.

(vii) Nitrocellulose and trinitrate cellulose (gun-cotton) used as explosive.

$$-NH-\overset{\overset{O}{\|}}{C}-$$
Peptide linkage.

Protein : The word protein was coined by *Berzelius* in 1838 and was used by *G. J. Mulder* first time 1840. 15% of protoplasm is made up of protein. *Average proteins contain* 16% *nitrogen*, 50–55% *carbon, oxygen* 20–24%, *hydrogen* 7% and *sulphur* 0.3 – 0.5%. Iron, phosphorous, copper, calcium, and iodine are also present in small quantity.

(1) **Structure of proteins :** It is due to different rearrangement of amino acids. When carboxyl group $(-COOH)$ of one amino acid binded with amino group ($-NH_2$) of another amino acid the bond is called peptide bond. A peptide may be dipeptide, tripeptide and polypeptide. The simplest protein is Insulin. According to *Sanger* (1953) insulin consists 51 amino acids. A protein can have up to four level of conformation.

(i) **Primary structure :** The primary structure is the covalent connections of a protein. It refers to linear sequence, number and nature of amino acids bonded together with peptide bonds only. e.g. ribonuclease, insulin, haemoglobin, etc.

(ii) **Secondary structure :** The folding of a linear polypeptide chain into specific coiled structure (α – helix) is called secondary structure and if it is with intermolecular hydrogen bonds the structure is known as β – pleated sheet. α – helical structure is found in protein of fur, keratin of hair claws, and feathers. β – pleated structure is found in silk fibres.

(iii) **Tertiary structure :** The arrangement and interconnection of proteins into specific loops and bends is called tertiary structure of proteins. It is stabilized by hydrogen bond, ionic bond, hydrophobic bond and disulphide bonds. It is found in myoglobin (globular proteins).

(iv) **Quaternary structure :** It is shown by protein containing more than one peptide chain. The protein consists of identical units. It is known as homologous quaternary structure e.g. lactic dehydrogenase. If the units are dissimilar, it is called as heterogeneous quaternary structure *e.g.* hemoglobin which consists of two α – chains and two β – chains.

(2) **Classification of proteins :** Proteins are classified on the basis of their shape, constitution and function.

On the basis of shape

(i) **Fibrous protein/Scleroprotein :** Insoluble in water. Animal protein resistant to proteolytic enzyme is spirally coiled thread like structure form fibres. e.g. *collagen* (in connective tissue), actin and myosin, keratin in hairs, claws, feathers, etc.

(ii) **Globular proteins :** Soluble in water. Polypeptides coiled about themselves to form oval or spherical molecules e.g. albumin insulin hormones like ACTH, oxytosin, etc.

On the basis of constituents

(i) **Simple proteins :** The proteins which are made up of amino acids only. *e.g.* albumins, globulins, prolamins, glutelins, histones, etc.

(ii) **Conjugated proteins :** These are complex proteins combined with characterstic non–amino acid substance called as prosthetic group. These are of following types :–

(a) **Nucleoproteins :** Combination of protein and nucleic acids, found in chromosomes and ribosomes. *e.g.* deoxyribonucleoproteins, ribonucleoproteins, etc.

(b) **Mucoproteins :** These are combined with large amount (more than 4%) of carbohydrates *e.g.* mucin.

(c) **Glycoproteins :** In this, carbohydrate content is less (about 2 – 3%) *e.g.* immunoglobulins or antibiotics.

(d) **Chromoproteins :** These are compounds of protein and coloured pigments. *e.g.* haemoglobin, cytochrome, etc.

(e) **Lipoproteins :** These are water soluble proteins and contain lipids. e.g. cholesterol and serum lipoproteins.

(f) **Metalloprotein :** These are metal binding proteins, AB_1–globin known as transferring is capable of combining with iron, zinc and copper e.g. chlorophyll.

(g) **Phosphoprotein :** They composed of protein and phosphate e.g. casein (milk) and vitellin (egg).

(iii) **Derived proteins :** When proteins are hydrolysed by acids, alkalies or enzymes, the degredation products obtained from them are called derived proteins. On the basis of progressive cleavage, derived proteins are classified as primary proteoses, secondary proteoses, peptones, polypeptides, amino acids, etc.

On the basis of nature of molecules

(i) **Acidic proteins :** They exist as anion and include acidic amino acids. e.g. blood groups.

(ii) **Basic proteins :** They exist as cations and rich in basic amino acids e.g. lysine, arginine etc.

(3) **Function of Proteins**

(i) Proteins occur as food reserves as glutelin, globulin casein in milk.

(ii) Proteins are coagulated in solutions, alkaline to the isoelectric *pH* by positive ions such as $Zn^{2+}, Cd^{2+}, Hg^{2+}$ etc. Casein – *pH* 4.6, cyt. C – 9.8, resum globulin 5.4, pepsin 2.7, lysozyme 11.0 etc.

(iii) Proteins are the most diverse molecule on the earth.

(iv) Proteins work as hormone as insulin and glucagon.

(v) Antibiotics as gramicidin, tyrocidin and penicillin are peptides.

(vi) They are structural component of cell.

(vii) They are biological buffers.

(viii) Monellin is the sweetest substance obtained from African berry (2000 time sweeter than sucrose).

(ix) Proteins helps in defence, movement activity of muscles, visual pigments receptor molecules, etc.

(x) Natural silk is a polyamide and artificial silk is a polysaccharide. Nitrogen is the basic constituent.

1.23 Nucleic acid

(1) **Definition :** Nucleic acids are the polymers of nucleotide made up of carbon, hydrogen, oxygen, nitrogen and phosphorus and which controls the basic functions of the cell. These were first reported by *Friedrich Miescher* (1871) from the nucleus of pus cell. *Altmann* called it first time as nucleic acid. They are found in nucleus. They help in transfer of *genetic information*.

(2) **Types of nucleic acids :** On the basis of nucleotides *i.e.* sugars, phosphates and nitrogenous bases, nucleic acids are of two types which are further subdivided. These are DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid).

DNA (Deoxyribonucleic acids)

(i) **Types of DNA :** It may be linear or circular in eukaryotes and prokaryotes respectively.

(a) **Palindromic DNA :** The DNA helical bears nucleotide in a serial arrangement but opposite in two strands.

$-T-T-A-A-C-G-T-T-A-A$.....

$-A-A-T-T-G-C-A-A-T-T$.....

(b) **Repetitive DNA** : This type of arrangement is found near centromere of chromosome and is inert in RNA synthesis. The sequence of nitrogenous bases is repeated several times.

(c) **Satellite DNA** : It may have base pairs up to 11 – 60*bp* and are repetitive in nature. They are used in DNA matching or finger printing (Jefferey). In eukaryotes, DNA is deutrorotatory and sugars have pyranose configuration.

(ii) **Chargaff's rule :** Quantitatively the ratio of adenine (A) to thymine (T) and guanine (G) to cytosine (C) is equal. *i.e.* "Purines are always equal to pyrimidine".

(iii) **C value :** It is the total amount of DNA in a genome or haploid set of chromosomes.

(iv) **Sense and Antisense strand :** Out of two DNA strand one which carries genetic information in its cistrons is called sense strand while the other strand does not carry genetic information, therefore, doesn't produce mRNA. The non-functional DNA strand is called antisense strand.

(v) **Heteroduplex DNA :** Hybrid DNA formed as a result of recombination is called heteroduplex DNA. It contains mismatched base pair of heterologous base sequence.

(a) **X-Ray crystallography study of DNA :** It was done by Wilkins. It shows that the two polynucleotide chains of DNA show helical configuration.

(b) **Single stranded DNA (ssDNA) :** It is single helixed circular. And isolated from bacteriophage $\phi \times 174$ by *Sinsheimer* (1959). It does not follow chargaff's rule. The replicative form (RF) has plus – minus DNA helix. e.g. parvovirus.

(c) **Double helical model of DNA:** It is also known as Watson and Crick model.

RNA or Ribonucleic acid : RNA is second type of nucleic acid which is found in nucleus as well as in cytoplasm *i.e.* mitochondria, plastids, ribosomes etc. They carry the genetic information in some viruses. They are widely distributed in the cell.

Important Tips

- **ds DNA :** All eukaryotes, bacteria, polyoma virus and small pox virus.
- **ss DNA :** Bacteriophage $\phi \times 174$ and parvovirus.
- **ds RNA :** Reogroup of viruses, wound tumour virus.
- **ss RNA :** TMV, TNV Poliomyelitis.
- **Single genome :** virus, bacteria, F_2 and R_{17}.
- **Segmented genome :** Orthomyxovirus (influenza virus).
- Natural silk is a polyamide and have nitrogen in high amount.
- **Cairns** noticed process of replication of DNA in bacteria and said to be "theta mode".
- **S. Ochoa** (1967) synthesized RNA in vitro.
- Actinomycin D prevents transcription.
- Genomic RNA was discovered by **Franklin and Conrat** (1957).
- DNA end with no unpaired base is called blunt end.
- Portion of DNA that codes for the final mRNA is exon.
- **Pribnow box :** The sequence of boxes that orient RNA polymerase so that synthesis proceeds left to right.
- **Hogness box :** (TATA box). The hypothesized eukaryotic RNA polymerase II promoter. Analogous to the pribnow box.
- **Nick –** A single strand scission of the DNA.
- Bacteriophage T_2 infects E. coli (bacteria).
- Width of DNA helix is 2nm (20 Å).

- DNA polymerase-III makes mistake about every 1 in 10^4 bases and joins an incorrect deoxyribonucleotide to growing chain.
- The two dimensional structure of tRNA is clover leaf like, but three dimensional form is L-shaped.
- Initiation of polypeptide chain is done by methionine.
- Term DNA was given by **Zacharis**.
- The mitochondria DNA differs from nuclear DNA because of lacking binding histones.

1.24 Cell division/Cell reproduction/Cell cycle

(1) **Introduction :** It is the process by which a mature cell divides and forms two nearly equal daughter cells which resemble the parental cell in a number of characters.

"*Continuity of life*" is an important intrinsic characteristic of living organisms and is achieved through the process of reproduction. The reproduction may be asexual or sexual. Both of these involve the division and replication of cells. Even the growth and development of every living organism depends on the growth and multiplication of its cells.

In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organism also, new individual develop from a single cell. The zygote, by the cell division. Cell division is central to life of all cell and is essential for the perpetuation of the species.

(2) **Discovery :** Prevost and Dumas (1824) first to study cell division during the cleavage of zygote of frog.

Nagelli (1846) first to propose that new cells are formed by the division of pre-existing cells.

Rudolf virchow (1859) proposed "omnis cellula e cellula" and "cell lineage theory".

A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/Nucleoplasmic ratio (NP)/Kernplasm connection. Two processes take place during cell reproduction.

(a) **Cell growth :** (Period of synthesis and duplication of various components of cell).

(b) **Cell division :** (Mature cell divides into two cells).

(3) **Cell cycle :** *Howard* and *Pelc* (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps:

(i) Interphase

(ii) *M*-phase/Dividing phase

(i) **Interphase :** It is the period between the end of one cell division to the beginning of next cell division. It is also called *resting phase* or not dividing phase. But, it is actually highly metabolic active phase, in which cell prepares itself for next cell division. In case of human beings it will take approx 25 hours. Interphase is completed in to three successive stages.

***G_1* phase/Post mitotic/Pre-DNA synthetic phase/Gap I^{st} :** In which following events take place.

(a) Intensive cellular synthesis.

(b) Synthesis of rRNA, mRNA ribosomes and proteins.

(c) Metabolic rate is high.

(d) Cells become differentiated.

(e) Synthesis of enzymes and ATP storage.

(f) Cell size increases.

(g) Decision for a division in a cell occurs.

(h) Substances of G stimulates the onset of next S – phase.

(i) Synthesis of NHC protein, carbohydrates, proteins, lipids.

(j) Longest and most variable phase.

(k) Synthesis of enzyme, amino acids, nucleotides etc. but there is no change in DNA amount.

_S_-phase/Synthetic phase

(a) DNA replicates and its amount becomes double (2C - 4C).

(b) Synthesis of histone proteins.

(c) Euchromatin replicates earlier than heterochromatin.

(d) Synthesis of NHC (non-histone chromosomal proteins).

(e) Each chromosome has 2 chromatids.

G_2-phase/Pre mitotic/Post synthetic phase/gap-IInd

(a) Intensive cellular synthesis.

(b) Increase in energy store.

(c) Mitotic spindle protein (tubulin) synthesis begins.

(d) Chromosome condensation factor appears.

(e) Synthesis of 3 types of RNA and NHC proteins.

(f) Synthesis of ATP molecule and storage.

(g) Duplication of mitochondria, plastids and other cellular macromolecular complements.

(h) Damaged DNA repair occur.

(ii)**_M_-phase/Dividing phase/Mitotic phase**

(a) Nuclear division *i.e.* karyokinesis occurs in 4 phases – prophase, metaphase, anaphase and telophase. It takes 5-10% (shortest phase) time of whole division.

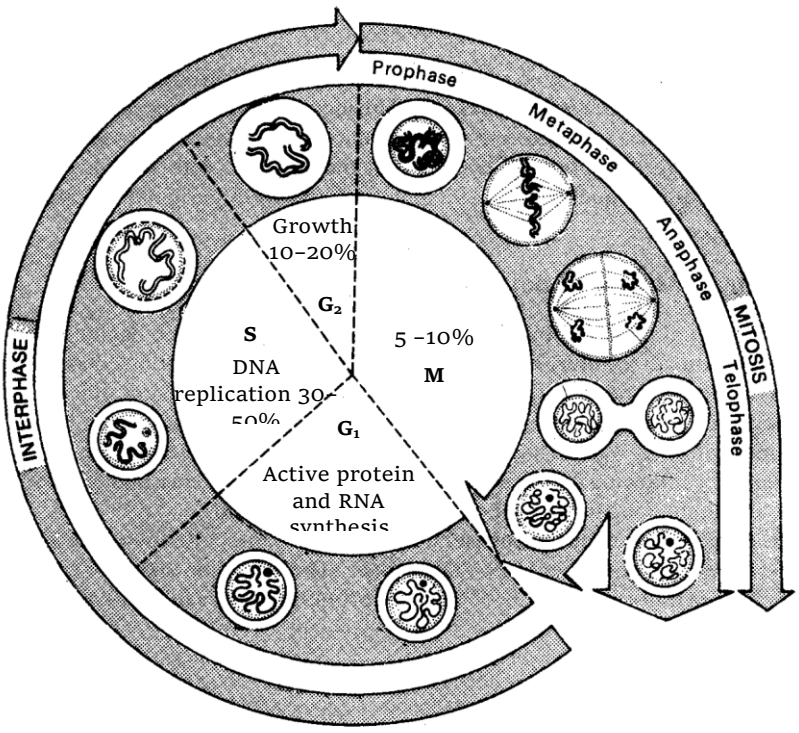


Fig : Different stages of cell cycle (Mitotic cycle).

(b) **Cytokinesis :** Division of cytoplasm into 2 equal parts. In animal cell, it takes place by cell furrow method and in plant cells by cell plate method.

(4) **Duration of cell cycle :** It depends on the type of cell and external factors such as temperature, food and oxygen. Time period for G_1, *S*, G_2 and *M*-phase is species specific under specific environmental conditions. *e.g.* 20 minutes for bacterial cell, 8-10 hours for intestional epithelial cell, and onion root tip cells may take 20 hours.

(5) **Regulation of cell cycle :** Stage of regulation of cell cycle is G_1 phase during which a cell may follow one of the three options.

(i) It may start a new cycle, enter the *S*-phase and finally divide.

(ii) It may be arrested at a specific point of G_1 phase.

(iii) It may stop division and enter G_0 quiscent stage. But when conditions change, cell in G_0 phase can resume the growth and reenter the G_1 phase.

Types of cell division : It is of three types, Amitosis, Mitosis and Meiosis.

Important tips

- G_0 – phase : The cells, which are not to divide further, do not proceed beyond the G_1 phase and start undergoing differentiation into specific type. such cells are said to be in G_0 phase.
- **Generation time :** Period between 2 successive generation (range 8 hr – 100 days).
- **Mitogens :** Chemicals which enhance or stimulate cell division e.g. lymphokinase (in man)
- **Cell cycle duration :** 20 minutes in bacteria , 20 hrs in root tip of onion, 2-3 hrs in yeast, 24 hrs in man.
- **G_0 phase :** Cell only starts dividing when the period is favorable otherwise, it remain viable for months or years as such in G_0 phase.
- During the mitosis of He-La cells, the longest period is gap I phase or G_1.
- DNA replication occurs in S-phase.
- In a cell cycle the condensation of chromosome with visible centromere occurs during M-phase.
- Sequence in cell cycle is G_1, S, G_2, M .
- M-phase is of shortest duration of cell cycle.
- In G_2 , the damaged DNA is repaired.
- Histone protein and RNA synthesis occurs in S-phase.
- Duplication of chromosome occurs at S- phase.

Amitosis : (Gk amitos = without thread, osis = state) It is also called as direct cell division. It was discovered by *Remak* (1855) in RBC of chick embryo. In this division there is no differentiation of chromosomes and spindle. The nuclear envelope does not

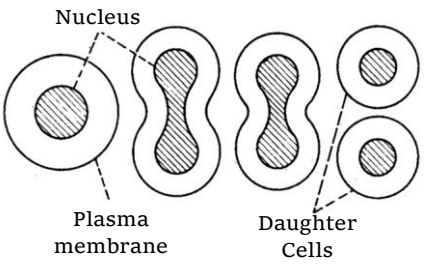


Fig : Amitosis

degenerate.The nucleus elongates and constricts in the middle to form two daughter nuclei. This is followed by a centripetal constriction of the cytoplasm to form two daughter cells. It is primitive type of division occuring in prokaryotes, protozoans, yeasts, foetal membrane of mammals, cartilage of mammals, degenerating cells of the diseased tissues and in the old tissues.

Mitosis : (Gk. Mitos = thread; osis = state)

(1) **Definition :** It is also called indirect cell division or somadtic cell division or equational division. In this, mature somatic cell divides in such a way that chromosomes number is kept constant in daughter cells *equal to those in parent cell*, so the daughter cells are quantitatively as well as qualitatively similar to the parental cell. So it is called equational division.

(2) **Discovery :** Mitosis was first observed by *Strasburger* (1875) and in animal cell by *W.fleming* (1879) term mitosis was given by *Fleming* (1882).

(3) **Occurrence :** Mitosis is the common method of cell division. It takes place in the somatic cells in the animals. Hence, it is also known as the somatic division. It occurs in the gonads also for the multiplication of undifferentiated germ cells. In plants mitosis occurs in the meristematic cells *e.g.* root apex and shoot apex.

(4) **Duration :** It ranges from 30 minutes to 3 hours time is species-specific but also depends upon type of tissues, temperature.

(5) **Process of mitosis :** Mitosis is completed in two steps

Karyokinesis : (Gk. karyon = nucleus; kinesis = movement) *Division of nucleus*. Term given by *Schneider* (1887).

Cytokinesis : (Gk –kitos = cell; kinesis = movement) *Division of cytoplasm*, Term given by *Whitemann* (1887).

Karyokinesis : It comprises four phases *i.e.* Prophase, Metaphase, Anaphase, Telophase.

(i) **Prophase :** It is largest phase of karyokinesis.

(a) Chromatin fibres thicken and shorter to form chromosomes which may overlap each other and appears like a ball of wool. *i.e.* Spireme stage.

(b) Each chromosome divides longitudinally into 2 chromatids which remain attached to centromere.

(c) Nuclear membrane starts disintegrating except in dinoflagellates.

(d) Nucleolus starts disintegrating.

(e) Cells become viscous, refractive and oval in outline.

(f) Spindle formation begins.

(g) Cell cytoskeleton, golgi complex, ER, etc. disappear.

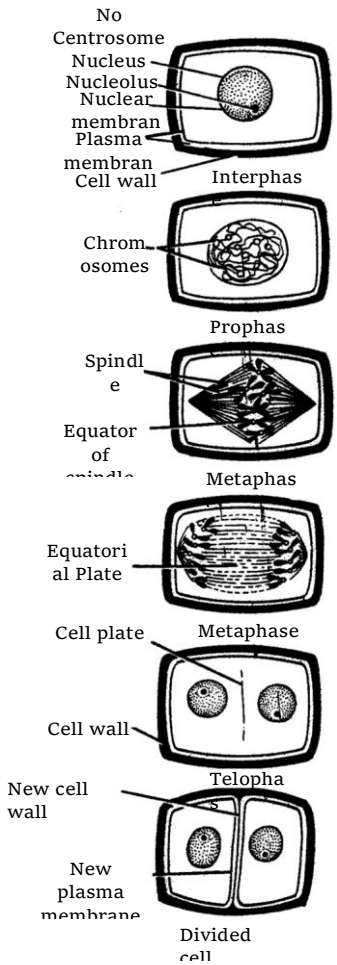


Fig : Various stages of mitosis

(h) In animal cells, centrioles move towards opposite sides.

(i) Lampbrush chromosomes can be studied well.

(j) Small globular structure (beaded) on the chromosome are called chromomeres.

(ii) **Metaphase**

(a) Chromosomes become maximally distinct *i.e.* size can be measured.

(b) A colourless, fibrous, bipolar spindle appears.

(c) Spindle is formed from centriole (in animal cells) or MTOC (microtubule organising centre) in plant cells successively called astral and anastral spindle.

(d) Spindle has 3 types of fibres.

- Continuous fibre (run from pole to pole).
- Discontinuous fibre (run between pole to centromeres).
- Interzonal fibre (run between 2 centromere).

(e) Spindle fibre are made up of 97% tubulin protein and 3% RNA.

(f) Chromosomes move towards equatorial plane of spindles called congression and become arranged with their arms directed towards pole and centromere towards equator.

(g) Spindle fibres attach to kinetochores.

(h) Metaphase is the best stage for studying chromosome morphology.

(iii) **Anaphase**

(a) Centromere splits from the middle and two chromatids gets separated.

(b) Both the chromatids move towards opposite poles due to repulsive force called anaphasic movement.

(c) Anaphasic movement is brought about by the repolymerisation of continuous fibres and depolymerisation of chromosomal fibres.

(d) Different shape of chromosomes become evident during chromosome movement viz. metacentric acrocentric etc.

(e) Chromosomes takes V, J, I or L shapes.

(f) The centromere faces towards equator.

(g) The chromatids are moved towards the pole at a speed of 1 μm/*minute*. About 30 ATP molecules are used to move one chromosome from equator to pole.

(iv) **Telophase**

(a) Chromosomes reached on poles by the spindle fibers and form two groups.

(b) Chromosomes begin to uncoil and form chromatin net.

(c) The nuclear membrane and nucleolus reappear.

(d) Two daughter nuclei are formed.

(e) Golgi complex and ER etc., reform.

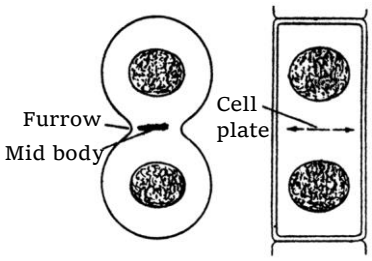


Fig : Furrowing (In animals) Cell plate formation (In plants)

Cytokinesis : It involves division of cytoplasm in animal cells, the cell membrane develops a constitution which deepens centripetally and is called *cell furrow method.*

In plant cells, cytokinesis occurs by cell plate formation.

(6) **Significance of mitosis**

(i) It keeps the chromosome number constant and genetic stability in daughter cells, so the linear heredity of an organism is maintained. All the cells are with similar genetic constituents.

(ii) It helps in growth and development of zygote into adult through embryo formation.

(iii) It provides new cells for repair and regeneration of lost parts and healing of the wounds.

(iv) It helps in asexual reproduction by fragmentation, budding, stem cutting, etc.

(v) It also restores the nucleo-plasmic ratio.

(vi) Somatic variations when maintained by vegetative propagation can play important role in speciation.

(7) **Types of Mitosis**

(i) **Anastral mitosis :** It is found in plants in which spindle has no aster.

(ii) **Amphiastral mitosis :** It is found in animals in which spindle has two asters, one at each pole of the spindle. Spindle is barrel-like.

(iii) **Intranuclear or Promitosis :** In this nuclear membrane is not lost and spindle is formed inside the nuclear membrane *e.g.* Protozoans (*Amoeba*) and yeast. It is so as centriole is present within the nucleus.

(iv) **Extranuclear or Eumitosis :** In this nuclear membrane is lost and spindle is formed outside nuclear membrane *e.g.* in plants and animals.

(v) **Endomitosis :** Chromosomes and their DNA duplicate but fail to separate which lead to polyploidy *e.g.* in liver of man, both diploid (2N) and polyploid cells (4N) have been reported. It is also called endoduplication and endopolyploidy.

(vi) **Dinomitosis :** In which nuclear envelope persists and microtubular spindle is not formed. During movement the chromosomes are attached with nuclear membrane.

Important tips

- **Pericentriolar cloud *:*** A clear cytoplasmic area with no cell organelle between the centriole pair and astral rays.
- Root tips of onion are best material for studying mitosis.

- **Kinetochore :** A discoidal area on each chromatid and is the site of attachment of spindle fibres.
- In mitosis, plectonemic coiling takes place, in which sister chromatids are tightly coiled upon each other and are not easily separable. Paranemic coiling found in meiosis.
- Chromosomal fibres are also called tractile fibres, while continuous fibres are also called interpolar fibres.
- **Mitogens :** The agents which stimulate cell division e.g., cytokinins, auxins, gibberllins, insulin, temperature, steroids.
- **Mitotic poision :** The agents which inhibit cell division.

(a) **Azides and Cyanides :** Inhibit prophase.

(b**) Colchicine :** Inhibits spindle formation at metaphase.

(c) **Mustard gas :** Agglutinates the chromosomes.

(d) **Chalones :** These were first reported by Laurence and Bullough (1960). They are peptides and glycoproteins secreated by extracellular fluid of healthy cells and inhibit cellular division.

- **Karyochoriosis :** A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.
- **C-mitosis :** Colchicine induced mitosis.
- After undergoing certain divisions, cells die. This is called as " Hayflick limit".
- Actinomycin D and tetracyclin inhibit cell division.
- 7 mitotic divisions occur to form embryosac in angiosperms.
- Mitosis index is the ratio of dividing and non-dividing cells.

Meiosis : (Gk. meioum = to reduce, osis = state)

(1) **Definition :** It is a special type of division in which the chromosomes duplicate only once, but cell divides twice. So one parental cell produces 4 daughter cells; each having half the chromosome number and DNA amount than normal parental cell. So meiosis is also called reductional division.

(2) **Discovery :** It was first demonstrated by *Van Benden* (1883) but was described by *Winiwarter* (1900). Term "meiosis" was given by *Farmer* and *Moore* (1905).

(3) **Occurrence :** It is found in special types and at specific period. It is reported in diploid germ cells of sex organs (*e.g.* primary spermatocytes of testes to form male gametes called spermotozoa and primary oocytes to form female gametes called ova in animals) and in pollen mother cells (microsporocytes) of anther and megasporocyte of ovule of ovary of flowers in plant to form the haploid spores. The study of meiosis in plants can be done in young flower buds.

(4) **Process of meiosis :** Meiosis is completed in two steps, meiosis I and meiosis II

Meiosis I : In which the actual chromosome number is reduced to half. Therefore, meiosis I is also known as reductional division or heterotypic division. It results in the formation of two haploid cells from one diploid cell. It is divided into two parts, karyokinesis I and cytokinesis I.

Karyokinesis I : It involves division of nucleus. It is divided into four phases *i.e.* prophase, metaphase, anaphase, telophase.

Prophase I : It is of longest phase of karyokinesis of meiosis. It is again divisible into five subphases *i.e.* leptotene, zygotene, pachytene, diplotene and diakinesis.

(i) **Leptotene/Leptonema**

(a) Chromosomes are long thread like with chromomeres on it.

(b) Volume of nucleus increases.

(c) Chromatin network has half chromosomes from male and half from female parent.

(d) Chromosome with similar structure are known as homologous chromosomes.

(e) Leptonemal chromosomes have a definite polarization and forms loops whose ends are attached to the nuclear envelope at points near the centrioles, contained within an aster. Such peculiar arrangement is termed as *bouquet stage* (in animals) and *syndet knot* (in plants).

(f) E.M. (electron microscope) reveals that chromosomes are composed of paired chromatids, a dense proteinaceous filament or axial core lies within the groove between the sister chromatids of each chromosome.

(g) Lampbrush chromosome found in oocyte of amphibians is seen in leptotene.

(ii) **Zygotene/Zygonema**

(a) Pairing or "synapsis" of homologous chromosomes takes place in this stage.

(b) Synapsis may be of following types.

- **Procentric :** Starting at the centromere.
- **Proterminal :** Starting at the end.
- **Localised random** : Starting at various points.

(c) Paired chromosomes are called bivalents, which by furthur molecular packing and spiralization becomes shorter and thicker.

(d) Pairing of homologous chromosomes in a zipper-fashion. Number of bivalents (paired homologous chromosomes) is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome (*i.e.* one chromosome derived from each parent).

(e) Under EM, a filamentous ladder like nucleoproteinous complex, called synaptinemal. Complex between the homologous chromosomes which is discovered by "*Moses*" (1953).

(iii) **Pachytene/Pachynema**

(a) In the tetrad, two similar chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are termed non-sister chromatids.

(b) Crossing over *i.e.* exchange of segments between non-sister chromatids of homologous chromosome occurs at this stage.

It takes place by breakage and reunion of chromatis segments. Breakage called nicking, is assisted by an enzyme endonuclease and reunion termed annealing is added by an enzyme ligase. Breakage and reunion hypothesis proposed by *Darlington* (1937).

(c) Chromatids of pachytene chromosome are attached with centromere.

(d) *A tetrad consists of two sets of homologous chromosomes each with two chromatids*. Each tetrad has four kinetochore (two sister and two homologous).

(e) A number of electron dense bodies about 100 *nm* in diameter are seen at irregular intervals within the centre of the synaptonemal complex, known as recombination nodules.

(f) DNA polymerase is responsible for the repair synthesis.

(iv) **Diplotene/Diplonema**

(a) At this stage the paired chromosomes begin to separate (desynapsis).

(b) Cross is formed at the place of crossing over between non-sister chromatids.

(c) *Homologous chromosomes move apart they remain attached to one another at specific points called chiasmata*.

(d) At least one chiasma is formed in each bivalent.

(e)Chromosomes are attached only at the place of chiasmata.

(f) Chromatin bridges are formed in place of synaptonemal complex on chiasmata.

(g) This stage remains as such for long time.

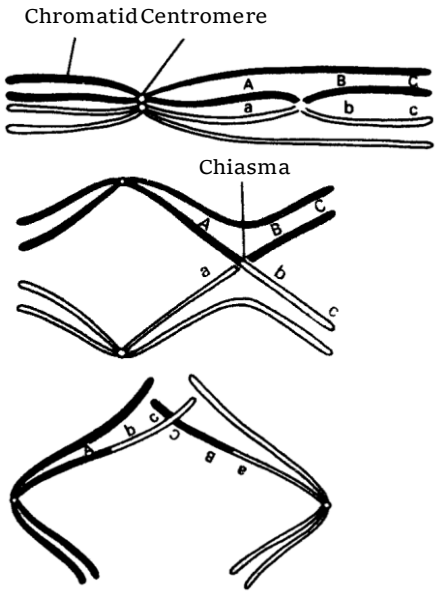


Fig : Showing crossing over during meiosis

(v) **Diakinesis**

(a) Chiasmata moves towards the ends of chromosomes. This is called *terminalization*.

(b) Chromatids remain attached at the place of chiasma only.

(c) Nuclear membrane and nucleolus degenerates.

(d) Chromosome recondense and tetrad moves to the metaphase plate.

(e) Formation of spindle.

(f) Bivalents are irregularly and freely scattered in the nucleocytoplasmic matrix.

When the diakinesis of prophase-I is completed than cell enters into the metaphase-I.

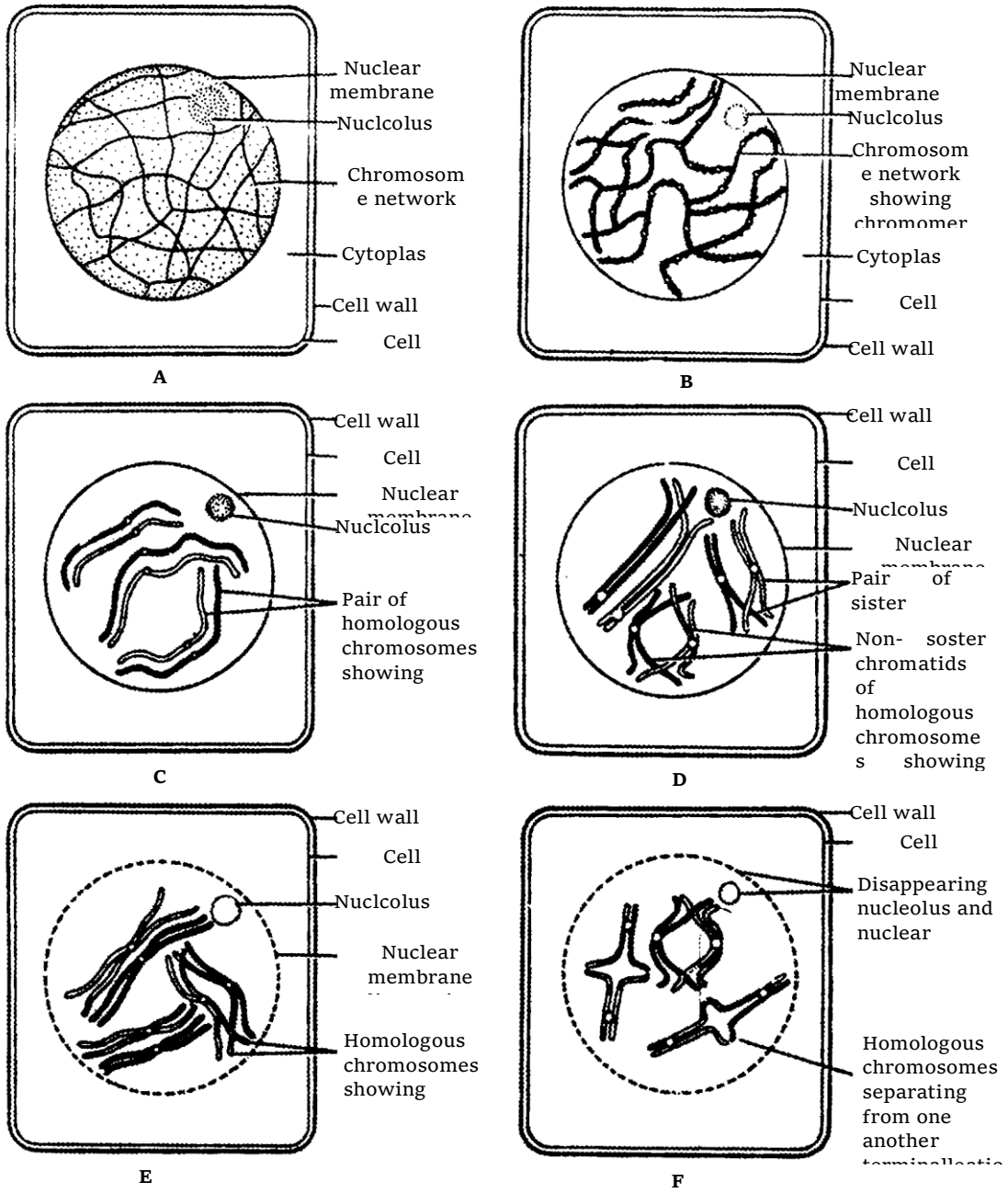


Fig : A-F Meiosis : Prophase I. A. Cell before entering leptotene, B. Leptotene, C. Zygotene, D. Pachytene, E. Diplotene, F. Diakinesis.

Metaphase I : It involves;

(i) Chromosome come on the equator.

(ii) Due to repulsive force the chromosome segment get exchanged at the chiasmata.

(iii) Bivalents arrange themselves in two parallel equatorial or metaphase plates. Each equatorial plate has one genome.

(iv) Centromeres of homologous chromosomes lie equisdistant from equator and are directed towards the poles while arms generally lie horizontally on the equator.

(v) Each homologous chromosome has two kinetochores and both the kinetochores of a chromosome are joined to the chromosomal or tractile fibre of same side.

Anaphase-I

(i) It involves separartion of homologous chromosomes which start moving opposite poles so each tetrad is divided into two daughter dyads. So anaphase-I involves the reduction of chromosome number, this is called *disjunction.*

(ii) The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.

(iii) Segregation of mendalian factors or independent asortment of chromosomes take place. In which the paternal and maternal chromosomes of each homologous pair segregate during anaphase-I which introduces genetic variability.

Telophase-I

(i) Two daughter nuclei are formed but the chromosome number is half than the chromosome number of mother cell.

(ii) Nuclear membrane reappears.

(iii) After telophase I cytokinesis may or may not occur.

(iv) At the end of Meiosis I either two daughter cells will be formed or a cell may have two daughter nuclei.

(v) Meiosis I is also termed as reduction division.

(vi) After meiosis I, the cells in animals are reformed as secondary spermatocytes or secondary oocytes; with haploid number of chromosomes but diploid amount of DNA.

(vi) Chromosomes undergo decondensation by hydration and despiralization and change into long and thread like chromation fibres.

Interphase : Generally there is no interphase between meiosis-I and meiosis-II. A brief interphase called interkinesis, or intermeiotic interphase. There is no replication chromosomes, during this interphase.

Cytokinesis-I : It may or may not be present. When present, it occurs by cell-furrow formation in animal cells and cell plate formation in plant cells.

Significance of meiosis-I :

(i) It separates the homologous chromosomes to reduce the chromosome number to the haploid state, a necessity for sexual reproduction.

(ii) It introduces variation by forming new gene combinations through crossing over and randon assortment of paternal and maternal chromosomes.

(iii) It may at times cause chromosomal mutation by abnormal disjunction.

(iv) It induces the cells to produce gametes for sexual reproduction or spores for asexual reproduction.

Meiosis-II : It is also called equational or homotypical division because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into two parts, Karyokinesis-II and Cytokinesis-II.

Karyokinesis-II : It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in four phases *i.e.*, Prophase-II, Metaphase-II. Anaphase-II and Telophase-II.

Almost all the changes of Karyokinesis-II resembles to mitosis which involves.

(i) It starts just after end of telophase I.

(ii) Each daughter cell (nucleus) undergoes mitotic division.

(iii) It is exactly similar to mitosis.

(iv) At the end of process, cytokinesis takes place.

(v) Four daughter cells are formed after completion.

(vi) The sister kinetochores of one chromosome are separated.

(vii) The four daughter cells receive one chromatid each of the tetravalent.

(viii) Centromere divide at anaphase II.

(ix) Spindle fibres contract at prophase II.

Cytokinesis-II : It is always present and occurs by cell furrow formation in animal cell and cell plate formation in plant cell.

So by meiosis, a diploid parental cell divides twice forming four haploid gametes or sex cells, each having half the DNA amount than that of the parental cell and one-fourth of DNA present in the cell at the time of beginning of meiosis.

(5) **Significance of meiosis**

(i) Constancy of chromosome number in successive generation is brought by process.

(ii) Chromosome number becomes half during meiosis.

(iii) It helps in introducing variations and mutation.

(iv) It brings about gamete formation.

(v) It maintains the amount of genetic informative material.

(vi) Sexual reproduction includes one meiosis and fusion.

(vii) The four daughter cells will have different types of chromatids.

(6) **Why the necessity of meiosis-II :** The basic aim of meiosis is to reduce the number of chromosomes to half. The chromosomes that separate in the anaphase of meiosis-I are still double. Each consist of two chromatids and has 2n amount of DNA. Thus reduction of DNA content does not occur in meiosis-I. Truely haploid nuclei in terms of DNA contents as well as chromosome number are formed in meiosis-II. When the chromatids of each chromosome are separated into different nuclei. Thus meiosis-II is necessary.

Difference between Mitosis and Meiosis

S.No.	Characters	Mitosis	Meiosis
I. General			
(1)	Site of occurrence	Somatic cells and during the multiplicative phase of gametogenesis in germ cells.	Reproductive germ cells of gonads.
(2)	Period of occurrence	Throughout life.	During sexual reproduction.
(3)	Nature of cells	Haploid or diploid.	Always diploid.
(4)	Number of divisions	Parental cell divides once.	Parent cell divides twice.
(5)	Number of daughter cells	Two.	Four.
(6)	Nature of daughter cells	Genetically similar to parental cell. Amount of DNA and chromosome number is same as in parental cell.	Genetically different from parental cell. Amount of DNA and chromosome number is half to that of parent cell.
II. Prophase			
(7)	Duration	Shorter (of a few hours) and simple.	Prophase-I is very long (may be in days or months or years) and complex.
(8)	Subphases	Formed of 3 subphases : early-prophase, mid-prophase and late-prophase.	Prophase-I is formed of 5 subphases: leptotene, zygotene, pachytene, diplotene and diakinesis.
(9)	Bouquet stage	Absent.	Present in leptotene stage.
(10)	Synapsis	Absent.	Pairing of homologous chromosomes in zygotene stage.
(11)	Chiasma formation and crossing over.	Absent.	Occurs during pachytene stage of prophase-I.
(12)	Disappearance of nucleolus and	Comparatively in earlier part.	Comparatively in later part of prophase-I.

	nuclear membrane		
(13)	Nature of coiling	Plectonemic.	Paranemic.
III. Metaphase			
(14)	Metaphase plates	Only one equatorial plate	Two plates in metaphase-I but one plate in metaphase-II.
(15)	Position of centromeres	Lie at the equator. Arms are generally directed towards the poles.	Lie equidistant from equator and towards poles in metaphase-I while lie at the equator in metaphase-II.
(16)	Number of chromosomal fibres	Two chromosomal fibre join at centromere.	Single in metaphase-I while two in metaphase-II.
IV. Anaphase			
(17)	Nature of separating chromosomes	Daughter chromosomes (chromatids with independent centromeres) separate.	Homologous chromosomes separete in anaphase-I while chromatids separate in anaphase in anaphase-II.
(18)	Splitting of centromeres and development of inter-zonal fibres	Occurs in anaphase.	No splitting of centromeres. Inter-zonal fibres are developed in metaphase-I.
V. Telophase			
(19)	Occurrence	Always occurs	Telophase-I may be absent but telophase-II is always present.
VI. Cytokinesis			
(20)	Occurrence	Always occurs	Cytokinesis-I may be absent but cytokinesis-II is always present.
(21)	Nature of daughter cells	2N amount of DNA than 4N amount of DNA in parental cell.	1 N amount of DNA than 4 N amount of DNA in parental cell.
(22)	Fate of daughter cells	Divide again after interphase.	Do not divide and act as gametes.
VII. Significance			
(23)	Functions	Helps in growth, healing, repair and multiplication of somatic cells. Occurs in both asexually and sexually reproducing	Produces gametes which help in sexual reproduction.

		organisms.	
(24)	Variations	Variations are not produced as it keeps quality and quantity of genes same.	Produces variations due to crossing over and chance arrangement of bivalents at metaphase-I.
(25)	In evolution	No role in evolution.	It plays an important role in speciation and evolution.

(7) **Types of meiosis :** On the basis of time and place, meiosis is of three types

(i) **Gametic/Terminal meiosis :** In many protozoans, all animals and some lower plants, meiosis takes place before fertilization during the formation of gametes. Such a meiosis is described as gametic or terminal.

This type of life cycle with diploid adult and gametic meiosis is known as the diplontic cycle.

(ii) **Zygotic or Initial Meiosis :** In fungi, certain protozoan groups, and some algae fertilization is immediately followed by meiosis in the zygote, and the resulting adult organisms are haploid. Such a meiosis is said to be zygotic or initial. This type of life cycle with haploid adult and zygotic meiosis is termed the haplontic cycle.

(iii) **Sporogenetic Meiosis**

(a) Diploid sporocytes or spore mother cells of sporophytic plant, undergo meiosis to form the haploid spores in the sporangia.

(b) Haploid spore germinates to form haploid gametophyte which produces the haploid gametes by mitosis.

(c) Haploid gametes fuse to form diploid zygote which develops into diploid sporophyte by mitotic divisions. *e.g.* In higher plants like pteridophytes, gymnosperms and angiosperms.

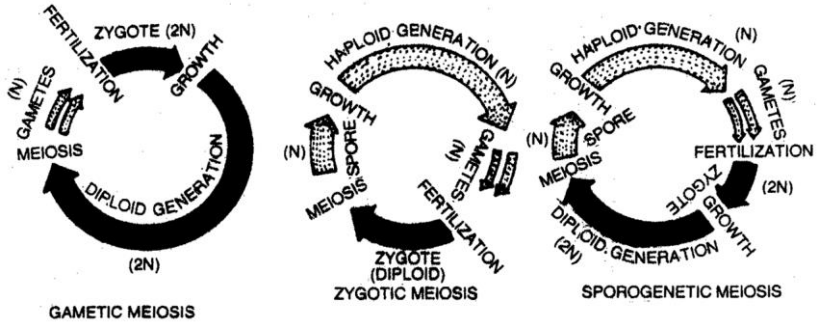


Fig : Three types of Meiosis

Important tips

- **Brachymeiosis :** Failure of meiosis-II. It is characteristic feature of fungi.
- Meiosis-II is not mitosis as it occurs haploid number of chromosomes and chromatids formed may not be similar to each other.
- **Restitution nucleus :** A colchicine treated cell has the nucleus with double sets of chromosomes.
- In cyperus, one meiosis produce only one pollen instead of four so that meiotic division required to produce fruits will be = number of fruits $\times$ 2.
- Chiasmata first observed by **Janseens** (1909).
- When sister chromatids are loosely arranged and are easily separate. It is found in meiotic chromosomes.
- Mitosis ends in 1- 2 hours while meiosis may take 24 hrs to few years.
- Neuron cells are always in interphase.
- When the chromosome duplicates but karyokinesis does not take place the number of chromosome per cell will increases, it is called endomitosis or endoduplication.
- Process of inducing mitosis into a cell – mitogenesis.
- To study mitosis root tips are fixed in 1: 3 acetic acid and methanol.
- Colchicine inhibits spindle formation and enhance duplication in number of chromosomes.
- At the time of cell division electrostatic force is responsible for terminalization.
- Mitotic crossing over takes place in parasexual cycle.

ASSIGNMENT

TOOLS AND TECHNIQUE

Basic Level

1. Who invented the "electron microscope"

(a) Knoll and Ruska (b) Robert Brown (c) Correns (d) Janssen and Janssen

2. Resolving power of light microscope is

(a) 0.3 μm (b) 0.1 μm (c) 2 μm (d) 100 μm

3. Differentiation capacity of compound microscope is

(a) 0.275 μm (b) 2.75 μm (c) 27.5 μm (d) None of these

4. Types of lenses in a compound microscope are

(a) 3 (b) 4 (c) 2 (d) 1

5. The smallest size of a cell which can be seen with unaided eye is or differentiation capacity of human eye is

(a) 1 micron (b) 10 micron (c) 100 micron (d) 1000 micron

6. Angstrom is equal to

(a) $10^{-10} m$ (b) $10^{-12} m$ (c) $10^{-6} m$ (d) $10^{-3} m$

7. 1 nm is equal to

(a) 10 Å (b) $10^{-3} mm$ (c) $10^{-8} m$ (d) 100 μm

8. Electron microscope is used for

(a) Viewing structure of the cell (b) Whole mount study

(c) Cell division study (d) Structure of the pollen grain

9. Which of the following statements is false

(a) An angstrom is one- hundredth of a micron

(b) Separation of proteins can be brought about by electrophoresis

(c) The image produced by a compound microscope is virtual and erect

(d) Unstained living cells and tissues studied under phase contrast microscope

10. Tracer elements are

(a) Vitamins (b) Radioisotopes (c) Microelements (d) Macroelements

11. The unit of measurement for size of cell is

(a) *nm* (b) μm (c) *mm* (d) Å

12. 1 $m\mu$ (millimicron) is equal to

(a) $10^{-5} mm$ (b) $10^{-6} mm$ (c) $10^{-7} mm$ (d) $10^{-8} mm$

13. The minimum cell size that can be seen by light microscope is

(a) 1 μ (b) 0.5 μ (c) 0.25 μ (d) 0.1 μ

14. Resolving power of an electron microscope is

(a) 1.0Å (b) 2.0Å (c) 5.0Å (d) 100Å

15. In which of the following units the sedimentation constant of a subcellular particle is expressed

(a) $gm\ ml^{-1}$ (b) Newton (c) Svedberg (d) Dalton

16. The most important property of a microscope is

(a) Its magnification (b) Its resolution

(c) Its ability to show in three dimensions (d) Its ability to use larger wave lengths

17. In electron microscope higher magnification is due to the use of

(a) Higher wavelenghts of light (b)High velocity electrons

(c) A chromatic lenses (d) Magnetic system

18. The only microscope which gives 3D images is

(a) Compound microscope (b)Electron microscope

(c) Scanning electron microscope (d)Fluorescent microscope

19. Resolving power of microscope means capacity to

(a) Magnify the image (b) Distinguish between two organelles

(c) Distinguish between two objects (d) Distinguish between two close points

20. Magnification of a compound microscope does not depend upon

(a) Focal length of objective (b) Focal length of eyepiece

(c) Tube length of microscope (d) Numerical aperture of objective

21. Autoradiography technique was used to

(a) Find out the absorption maximum of chlorophyll pigments

(b) Study photorespiration in certain plants

(c) Trace the path of carbon in photosynthesis

(d) Establish that the oxygen evolved during photosynthesis is by photolysis of water molescules

22. Metabolic processes can be studied by means of

(a) Light/Compound microscope (b)Autoradiography

(c) Phase contrast microscope (d)Electron microscope

23. Intact chloroplasts of green cells can be isolated with the help of

(a) Acetone (b) Alcohol

(c) Carbon sulphide (d) 0.5solution of sucrose

24. A living cell can not be studied under

(a) Light microscope (b) Compound microscope

(c) Electron microscope (d) All of these

25. Which technique other than electron microscopy is used in the fine structure of a cell

(a) Plasmolysis (b) Chromatography

(c) Crystallography (d) Obleteraturs

26. Interference microscopy is used
(a) To localise a cellular organelle
(b) To study cells and their components in a living state using phase difference of light rays
(c) For obtaining X-ray diffraction patterns of DNA
(d) For increasing resolving power of microscope

27. Dark field microscopy is used to detect bacteria. It makes use of
(a) Invisible far red light (b)Invisible UV light
(c) Visible light (d)Does not use any light

28. Which of the following isotope is non radioactive
(a) C^{14} (b) H^{3} (c) P^{31} (d) O^{18}

29. For the study of cell, the technique used to other than microscopy is
(a) Plasmolysis (b) Obliteration (c) Autoradiography (d) All the above

30. Which of the following is basic stain
(a) Methylene blue (b) Safranin (c) Both (a) and (b) (d) Acid fuchsin

31. Cellulosic cell wall can be specifically stained by
(a) Methylene blue (b) Sudan IV (c) Schultz reagent (d) Janus green

32. The technique of chromatography was introduced by
(a) Tswett (b) Zernicke (c) Wilkins (d) Svedberg

33. X-ray crystallography was developed by
(a) Bragg (b)Kirkpatrick
(c) Astbury and Franklin (d)Astbury and Franklin

34. A scientist wants to study the structure of a protein. What technique would be useful
(a) Electrophoresis (b) X-ray crystallography
(c) Density gradient centrifugation (d) Microspectrophotometry

35. Ability to distinguish two closely placed points is
(a) Resolving power (b)Video power
(c) Distinguishing power (d)Magnifying power

36. The unit of measurement of light microscope is
(a) Milimetre (b) Svedberg unit (c) Micron (d) Angstrom

37. What is the lowest limit of resolution of a light microscope
(a) 1Å (b) 4Å (c) 200Å (d) 2000Å

38. Resolving power of an electron microscope is
(a) About 10 times of light microscope (b) About 50 times of light microscope
(c) More than 100 times of light microscope (d) More than 100 times of visible microscope

39. Maximum magnification of scanning electron microscope (SEM) are usually around
(a) 200 times (b) 2,000 times (c) 20,000 times (d) 2,00,000 times

40. Magnification of common oil immersion lens is
(a) 45X (b) 100 X (c) 450 X (d) 1000X

41. Which of the following statements is correct phase microscopy is
(a) Used for the study of living cells
(b) Based on the scattering of light and uses a dark field condenser
(c) Related to retardation and to the thickness of the object
(d) The best method for studying nonliving ultrasturcture

42. The X-ray crystallographic studies to get diffraction picture of DNA molecule was made by
(a) Watson and Crick (b) Wilkins and Franklin (c) Beadle and Tatum (d) Jacob and Monad

43. The limit of resolution of an instrument is
(a) Diractly related to its resolving power (b) Inversely related to its resolving power
(c) Not related to its resolving power (d) Same as its resolving power

44. In centrifugation which one settles as sediment I
(a) Ribosomes (b) Mitochondria (c) Nuclei (d) None of these

45. Living cells cannot be observed in an electron microscope because
(a) They lose water vapour and disturb the vacuum of the microscope
(b) The heat generated by electrons injurious to cell and its organelles
(c) They are transparent and therefore remains invisible
(d) They are killed by fast beam of electron

46. The technique used to study the five details of surface features of cell and organisms, is
(a) Transmission electron microscope (b) Scanning electron microscope
(c) Interference microscope (d) Fluorescence microscope

47. To destruct cell boundary, the tissues are homogenized in
(a) 0.25 M sucrose solution (b) 1.0 M sucrose solution
(c) 1.0 M salt solution (d) 0.25 M salt solution

48. Materials are separated by density gradient by centrifugation on the basis of
(a) Size (b) Density (c) Size and density (d) None of these

49. Who among the following scientists developed cytochemical technique for the presence of DNA
(a) Johannsen (b) Fuelgen and Rossenbeck (c)Mc clintock (d) Hammerling

50. A cell homogenate is subjected to ultra centrifugation. What fraction would be separated at $10{,}000g \times 20$ minutes
(a) Ribosome and Microsome (b)Mitochondria and Lysosome
(c) Nucleus and Nucleolus (d) Endoplasmic reticulum

51. The finest resolution achieved with a light microscope in visible light with oil-immersion and with out oil immersion is respectively
(a) 3.0 μm and 30 μm (b) 0.3 μm and 10 μm (c) 3.0 μm and 2.0 μm (d) 0.2 μm and 0.3 μm

52. Interference microscope was invented by
(a) Morten et al. (b) Knoll and Ruska
(c) Leeuwenhoek (d) Zernike

53. Dark field microscope was invented by
(a) Zsigmondy (b) Zernicke (c) Morten et al (d) Caspersson

54. One micrometre (micron, μm) is equal to

(a) 0.1 *mm* (b) 0.01*mm* (c) 0.001 *mm* (d) 0.0001*mm*

55. A nanometre (nm) is

(a) $10^{-9} m$ (b) $10^{-7} cm$ (c) 10 Å (d) All the above

56. The term microscope was coined by

(a) Janssen and Janseen (b) Faber (c) Robert Hooke (d) Leeuwenhoek

57. Which one is the most important in microscopy

(a) Resolving power (b) Magnification

(c) Study of living cells (d) Study of biochemicals

58. Reflector of classroom microscope is

(a) Convex lens (b) Concave lens

(c) Concavo-convex lens (d) Plano concave lens

59. Microtome was invented by

(a) Abbe (b) Tolles (c) His (d) Malpighi

60. Microtomy is

(a) Surgery of tissues (b) Surgery of endocrine glands

(c) A new technique of surgery where incision is not visible

(d) Fine sectioning by machine

61. Fast green stains

(a) Cellulose wall green (b) Cytoplasm green (c) Mitochondria orange (d)Both (a) and (b)

62. Which one is a redox dye

(a) Janus green (b) Methylene blue (c) Neutral red (d) Aniline blue

63. Janus green dye is specific for

(a) Mitochondria (b) Golgi apparatus (c) Cell walls (d) Cytoplasm

64. Iodine solution is used for testing the presence of

(a) Carbohydrates (b) Proteins (c) Fats (d) Starch

65. Iodine test was developed by

(a) Feulgen and Rossenbeck (b) F.V Raspail

(c) Zernike (d) Flemming and Brown

66. Fuelgen test is specific for

(a) RNA (b) DNA (c) Proteins (d) Lipids

67. Dyes that make cellullar structures glow under UV-radiations are

(a) Fluorescent (b) Fluorochromes

(c) Autofluorescent (d) Phosphorescent

68. C^{14} uridine is used to determine

(a) Carbohydrate synthesis (b)Photosynthesis (c) RNA synthesis (d) DNA synthesis

Advance Level

69. Electron microscope has revealed the presence of OR which among the following can be seen only under electron microscope

(a) Ribosome (b) Chromosome (c) Chloroplast (d) Leucoplast

70. The transmission electron microscope has a resolution of

(a) 2,000 nanometres (b) 200 nanometres (c) 2 nanometres (d) 0.2 nanometre

71. A magnification of up to 100 million times is possible

(a) Scanning electron microscope (b)Electron transmission microscope

(c) Scanning probe microscope (d)Photon tunneling microscope

72. Ultrastructure of cell can be best studied by

(a) Autoradiography (b) X-ray diffration method

(c)Phase contrast microscope (d) None of these

73. Ultrastructure of a cell organelle can best be studied through

(a) Microdissection (b) Electron microscope

(c) Phase –contrast microscope (d) Autoradiography

74. A living cell can be best studied by means of

(a) Dark field microscope (b)Electron microscope

(c) Phase contrast microscope (d)Compound microscope

75. A living cell is to be studied without staining a microscope useful for it

(a) Phase contrast microscope (b) TEM

(c) SEM (d) Fluorescent microscope

76. Organelles can be separated from cell homogenate through

(a) Chromatography (b) X-ray diffraction

(c) Differential centrifugation (d) Auto- radiography

77. Sub-cellular components are separated with the help of

(a) Electrophoresis (b) Autoradiography (c) Chromatography (d) Cell fractionation

78. A student wants to study metaphasic behaviour of chromosomes/ chromosomes in a living cell. The technique most suitable is

(a) Phase contrast microscope (b) X-ray microscope

(c) Cell fractionation (d) Scanning electron microscope

79. Wavelength of radiation used in electron microscope is

(a) More than light (b) Less than light (c) Like X-rays (d) Equal to light

80. High wavelength UV rays are used in

(a) Fluorescent microscope (b)Polarising microscope

(c) Ultra-violet microscope (d) Phase-contrast microscope

81. Electrons used in electron microscope have a wavelength of

(a) 0.05Å (b) 0.1Å (c) 0.15 Å (d) 0.5Å

82. Resolving power of electron microscope is
(a) 1000 Å (b) 100 Å (c) 1 Å (d) 10Å

83. Electron microscope has a high resolution power. This is due to
(a) Electromagnetic lenses (b)Very low wavelength of electron beam
(c) Low wavelength of light source used (d) High numerical aperture of glass lenses used

84. Electron microscope is more advantageous than light microscope because it
(a) Requires no light (b) Has higher magnification (c)Gives depth focus (d)Uses vacuum

85. Highest resolving power is that of
(a) Fluorescent microscope (b)Polarising microscope
(c)Ultraviolet microscope (d)Electron microscope

86. Which German phycist invented the electron microscope which one him the 1986 Nobel Prize in physics
(a) Erst Ruska (b) Van't Hoff (c) J.A.D Jensen (d) Eugene P. Wigner

87. Fluorescence microscope is useful for
(a) Localisation of structures having affinity for fluorochromes
(b) Study of cell components in living state
(c) Obtaning X- ray diffraction photographs
(d) Its very high resolving power.

88. X-ray crystallography is useful in the study of
(a) Lipid structure (b) Three dimensional structure of proteins
(c) Arrangement of proteins (d) Composition of nucleic acids and proteins

89. Technique useful for studying synthesis of molecules and tracing metabolic pathways is
(a) Chromatography (b) Autoradiography
(c) Micro spectrophotometry (d) Cytochemistry

90. Path of carbon assimilation can be traced with the help of
(a) Chromatography (b) Electrophoresis (c) Radioisotopes (d) Fractionation

91. Autoradiography is employed for knowing
(a) Photorespiration
(b) Pathway of carbon assimilation
(c) Absorption maxima of photosynthetic pigments
(d) Evolution of oxygen during photo-synthesis due to photolysis of water

92. Arrangement of atoms and molecular groups in DNA and RNA can be studied through
(a) Spectrophotometer (b) X-ray diffraction (c) Histochemistry (d) Centrifugation

93. The process by which the amount of DNA, RNA and protein can be known at a time is
(a) Cell fractionation (b) Autoradiography
(c) Phase contrast microscopy (d) Tissue culture

94. Transparent living cells can be properly studied under the microscope called
(a) Ordinary optical microscope (b) Electron microscope
(c) X-ray microscope (d) Phase contrast microscope

95. The order of sedimentation of subcellular structures during differential centrifugation is

(a) Lysosome, mitochondria, ribosome (b) Mitochondria, nucleus, lysosome

(c) Nucleus, mitochondria, lysosome (d) Ribosome, nucleus, mitochondria

96. If a biochemical analysis of mitochondria is to be done, the best procedure would be

(a) Grind the cell and filter out the mixture and take the debris

(b) Subject the cells to cell fractionation

(c) Select cells which have a large number of mitochondria

(d) Plasmolyse the cells, filter it and take the debris

97. DNA synthesis can be specifically measured by estimating the incorporation of radioactive labelled

(a) Uracil (b) Thymidine (c) Adenine (d) Deoxyribose sugar

98. In recent years considerable attention is being given to DNA protein interactions, because expression of genes is regulated thought binding of specific proteins on regulatory DNA sequences. The pattern of protein binding on DNA can be studied by

(a) Light microscope (b) X-ray crystallography (c) Electron microscope (d) Ultracentrifugation

99. The fuelgen nuclear reaction includes the following

(a) Removal of purines at the level of the purine deoxyribose glucosidic bond of DNA by hydrolysis

(b) Reaction of the deoxyribose with leucofuchsin to give purple colur to DNA

(c) Reaction of the free aldehyde groups with schiff's reagent to stain DNA

(d) Both (a) and (c)

100. The resolution of light microscope could be improved to 1.5 times by using

(a) Red light + immersion oil between the specimen and objective

(b) Blue light + glycerine between the specimen and objective

(c) Blue light + immersion oil between specimen and objective

(d) Day light + air between the specimen and objective

101. Separation of proteins on the basis of their being polyelectrolytes can be brought about by

(a) Centrifugation (b) Electrophoresis (c) Chromatography (d) Crystallography

102. Technique by which subcellular components are separated on the basis of their physical properties

(a) Chromatography (b) Tracer technique

(c) Microtomy and Centrifugation (d) Microscopy

103. A particular cell from a mixture can be separated by

(a) Flow cytometry (b) Chromatography

(c) Microscopy (d) Fractionation

104. Scanning electron microscope is important for its images which are

(a) Very large and sharp (b) Three- dimensional

(c) Fluorescent (d) Two-dimensional

105. Taylor (1958) studied chromosome replication by using radioactive

(a) Uridine (b) Thymidine (c) Histones (d) Phosphate

106. Homogenisation is

(a) Breaking a tissue into cells

(b) Crushing a tissue to separate cells from intercellular substances

(c) Breaking of cells and suspending them in 0.25 M sucrose solution

(d) Separation of different cellular components

107. In homogenisation the suspension is kept at a temperature of

(a) 15 – 20° C (b) 25 –35° C (c) –4° to 0° C (d) 0° – 4° C

108. Organelle not possible to observe without electron microscope is

(a) Chloroplast (b) Ribosome (c) Mitochondrion (d) Nucleolus

109. Details of mitochondrial structure could be studied only after the discovery of

(a) Oil immersion lens (b) Fluorescent microscope

(c) Electron microscope (d) All the above

110. Which of the following microscope is best for studying the process of mitosis

(a) Dark field microscope (b)Phase contrast microscope

(c) Ultraviolet microscope (d)Electron microscope

111. Which one is a new structure obtained during Cell fractionation

(a) Microsomes (b) Microbodies

(c) Endoplasmic raticulum (d) Ribosome subunits

112. Schultze's reagent is

(a) Safranin (b) Fast green

(c) Phloroglucinol + HCl (d) Chlor-zinc-iodine

113. Sudan III is used for identification of

(a) Glycogen (b) Protein (c) DNA (d) Fat

114. What stains are used in fluorescent microscopy

(a) Orcein (b) Safranin (c) Rhodamine (d) Eosine

115. Which of the following is used for vital staining of the components of a living cell

(a) Wrights stain (b) Malachite green

(c) Safranin (d) Acetocarmine

116. Osmium tetroxide is used in

(a) Light microscopy (b) Electron microscopy

(c) Phase contrast microscopy (d) X-ray diffraction microscopy

CELL THEORY AND GENERAL INFORMATION

Basic Level

117. Who proposed the "cell theory

(a) Schleiden and Schwann (b)Watson and Crick (c) Mendel and Morgan (d) Robert Hooke

118. T. Schwann and M. Schleiden were

(a) Dutch biologists (b) English biologists (c) Austrian biologists (d) German biologists

119. Who proposed the theory that "cells arise only from the pre –existing cells

(a) Mohl (b) Virchow (c) Haeckel (d) Brown

120. Which of the following is the exception of cell theory

(a) Bacteria (b) Fungi (c) Lichen (d) Virus

121. The cell theory states that

(a) All cells have nuclei (b) All cells are totipotent

(c) Cells reproduce by mitosis (d) Cells are the basic structural units of living

122. Living cells were seen for the first time by

(a) Leeuwenhoek (b) Robert Hooke (c) Waksman (d) Flemming

123. Cell was discovered by and given the term

(a) Grew (b) Brown (c) Robert Hooke (d) Darwin

124. What Robert Hooke had discovered in the thin section of the cork

(a) Cellulose (b) Cell wall (c) Nuclei (d) Protoplasm

125. Robert Hooke

(a) Lived in the 17^{th} century (b) Observed cork cells

(c) Invented lens (d) constructed a microscope

126. How many types of cells are known

(a) One (b) Two (c) Three (d) Four

127. The branch which deals with the study of cell structure is known as

(a) Histology (b) Ecology (c) Morphology (d) Cytology

128. The word "Prokaryote" means a cell

(a) With many nuclei (b) With one nucleus

(c) With diffused nucleus (d) Without chloroplast

129. Which one of the following is a prokaryote

(a) Agaricus (b) Salmonella (c) Green algae (d) Bacteriophage

130. Basic unit of life is

(a) Cell (b) Tissue (c) Organ (d) Organ system

131. Omnis cellula e cellula is generalisation given by

(a) Leeuwenhoek (b) Dutrochet (c) Lamarck (d) Virchow

132. Cellular totipotency is demonstrated by

(a) Only gymnosperm cells (b) All plant cells

(c) All eukaryotic cells (d) Only bacterial cells

133. Totipotency is evident in

(a) Meristem (b) Xylem sclerenchyma

(c) Phloem sieve tube (d) Phellum

134. The division of the plant kingdom into Prokaryota and Eukaryota is based on the characters of

(a) Nucleus only (b) Chromosomes only

(c) Cell organelles only (d) All the above

135. Which of the following is absent in prokaryotes

(a) Nuclear membrane (b) Golgi bodies (c) Endoplasmic reticulum (d)All the above

136. Difference between the prokaryotic and eukaryotic cells in having

(a) Cell wall (b) Nuclear membrane (c) Ribosome (d) None

137. Which of the following is absent in prokaryotes

(a) DNA (b) RNA (c) Plasma membrane (d) Mitochondria

138. Intracellular compartments are not found in cells of

(a) Lower plants (b) Prokaryotes (c) Higher plants (d) Eukaryotes

139. The inherent capacity of a cell to regenerate a new whole organism is called

(a) Ontogeny (b) Totipotency (c) Phycogeny (d) Differentiation

140. Cell organelles found only in plants

(a) Golgi complex (b) Mitochondria (c) Plastids (d) Ribosomes

141. A plant cell usually differs from an animal cell in the absence of

(a) Ribosomes (b) Centriole (c) Mitochondria (d) E.R

142. The main difference between plant and animal cell is

(a) Animal cells lack cell wall (b)Plant cell has no cell wall

(c) Animal cell has a rigid cell wall (d) Plant cells lack cell membrane

143. Smallest known cell is

(a) Acetabularia (b) Nostoc

(c) Chlamydomonas (d) Pleuropneumonia like organism

144. Smallest cell organelle is

(a) Lysosome (b) Dictyosome (c) Polysome (d) Monosome

145. Plant cells lack

(a) Spindle fibres (b) Centrioles (c) Asters (d)Centrioles and asters

146. A mature plant cell has

(a) Cell wall (b) Vacuole (c) Protoplasm (d) All of the above

147. A prokaryotic cell is characterised by

(a) Distinct nucleus (b) Distinct chromosomes

(c) Absence of nuclear membrane (d) Distinct DNA

148. The smallest living cells with the cell wall are

(a) Viroids (b) Protistans (c) Mycoplasma (d) Bacteria

149. A prokaryotic structure is

(a) Bacteria and Archaebacteria (b) Blue green algae and Mycoplasma

(c) Ricketts (d) All of these

150. Name the correct order of relative size

(a) Nucleus, cell, chromosome oxygen atom and water molecule

(b) Cell, nucleus, water molecule, oxygen atom, chromosome

(c) Chromosome, cell, nucleus, water molecule and oxygen atom

(d) Cell, nucleus, chromosome, water molecule and oxygen atom

151. Cell recognition is due to

(a) Lipid portion of cell membrane (b)Carbohydrate portion of glycoproteins

(c) Protein portion of glycoprotein (d) Both carbohydrate and protein portion of glycoprotein

152. Cell is a unit of life and all cells in a tissue remain united was idea of

(a) Steward (b) Schleiden (c) Schwann (d) Dutrochet

153. Raphides are found in

(a) Dahlia (b) Asparagus (c) Nut (d) Guava

154. Cystolith is made up of

(a) Calcium oxalate (b) Calcium carbonate (c) Calcium hydroxide (d) Calcium oxide

155. The main difference between the living and non living is

(a) In the growth (b) In the size

(c) In the movement (d) In the presence of protoplasm

156. Plant cell is differ from animal cell because of

(a) The presence of cell wall and absence of chlorophyll in plant cell

(b) The presence of cell wall and chlorophyll in plant cell

(c) The absence of cell wall and presence of chloroplast in animal cell

(d) The absence of cell wall and presence of chlorophyll in plant cell

157. The correct order of sedimentation of sub-cellular structure during differential centrifugation is

(a) Lysosome $\rightarrow$ Mitochondria $\rightarrow$ Nucleus $\rightarrow$ Ribosome

(b) Mitochondria $\rightarrow$ Nucleus $\rightarrow$ Lysosome $\rightarrow$ Ribosome

(c) Nucleus $\rightarrow$ Mitochondria $\rightarrow$ Lysosome $\rightarrow$ Ribosome

(d) Lysosome $\rightarrow$ Ribosome $\rightarrow$ Mitochondria $\rightarrow$ Nucleus

158. Ephagy refers to

(a) Removal of metabolic waste by exocytosis (b) Removal of metabolic waste by endocytosis

(c) Exudation of secretory products (d) None of these

159. Mesokaryotic condition was distinguised by

(a) Whittaker (b) Dodge (c) Capeland (d) Haeckel

160. Usual size of eukaryotic cell varies from 3 to 30 μ. The volume of an eukaryotic cell

(a) 100 -10000 μm^3 (b) 1000–10000 μm^3 (c) 100–4000 μm^3 (d) 3 to 5 μm^3

161. The size and volume of prokaryotic wall is

(a) 0.1 to 5 μ; 0.2 to 10 μm^3 (b) 0.1 to 1 μ; 0.2 to 1 μm^3

(c) 0.1 to 1 μ; 0.2 to 10 μm^3 (d) 0.1 to 0.3 μ; 0.2 to 0.3 μm^3

162. A typical eukaryotic cell is approximately ——times larger than a bacterium

(a) 100 times (b) 10 times (c) 1000 times (d) 10000 times

163. First modification in cell theory was done by

(a) Virchow (b) Strasburger (c) Flemming (d) Sachs

164. The term cytology (Gr. *Kytos = hollow vessel* (cell); *logos* = study of) for the study of structure of cell and its components was coined by

(a) Bridges (b) Robert Hooke (c) Schwann (d) Hertwig

165. No body can have life if its constituents are not formed of cells. This was remarked by

(a) Dutrochet (b) Leeuwenhoek (c) Schwann (d) Lamarck

166. Haploid plants can be obtained by culturing

(a) Root tips (b) Young leaves (c) Endosperms (d) Anthers/pollen grains

167. The largest unicellular animal and plant are

(a) Amoeba (1mm), Acetabularia (10 *cm*) (b) Amoeba (1 mm), vaucheria (40 cm)

(c) Paramecium, chara (d) Plasmodium, bacteria

168. Prokaryotes do not have histone but polyamine type of basic protein are present to

(a) Neutralize acidity of DNA (b)Acidic RNA

(c) Bases (d) None of the above

169. Lignified cells are stained by

(a) Saffranin (b) Methyle blue (c) Acetocarmine (d) Light green

170. Differentiation on the basis of karyon is done between

(a) Anaima and Enaima (b) Prokaryota and Eukaryota

(c) Protista and monera (d) None of the above

171. Father of modern cytology is

(a) Schleiden (b) Schwann (c) Swanson (d) Bridges

Advance Level

172. **Assertion A :** Eukaryotic cells have more DNA than prokaryotic cells

Reson R : Eukaryotes are genetically more complex than prokaryotes

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is not the correct explanation

(c) A is true but R is False

(d) A is false but R is true

173. From which part of the plant haploid cells can be obtained

(a) Leaf (b) Stem (c) Seed (d) Anther

174. Generally the smaller cell

(a) The larger the nucleus (b) The smaller the nucleus

(c) It will be more metabolically active (d) It will be less metabolically active

175. The size of most of the cells is best expressed in

(a) Å (b) Milimeters (*mm*) (c) Nanometers (*nm*) (d) Micrometers (μm)

176. If we separate the cell organelles of a living cell, then which part should be alive

(a) Endoplasmic reticulum (b)Chloroplast (c) Cell wall (d) Ribosome

177. The cell organelles are found in

(a) Bacterial cells (b) Cyanobacterial cells (c) Procaryotic cells (d) Eucaryotic cells

178. Which of the following is not a cell organelle

(a) Mitochondria (b) Ribosome (c) Golgi complex (d) Microsome

179. Which of the following chemical characteristics is not common to all living beings

(a) Similar triplet code for amino acids (b) Energy is stored by high phosphate bonds

(c) Type of protein present in the body (d) Ribosomes are the sites of protein synthesis

180. Raphides are needle-like crystals made up of

(a) Calcium carbonate (b) Calcium sulphate (c) Calcium oxalate (d) Calcium pectate

181. Cytochrome are found in

(a) Chloroplasts (b) Bacteria (c) Mitochondria (d) All of these

182. Chemiosmotic hypothesis was proposed by

(a) Mitchell (b) Metcalf (c) Hans kreb (d) Calvin

183. Which of the following pairs is correct

(a) Svedberg unit – Biomembranes (b)Polyribosomes – RNA

(c) Dictyosomes – Suicidal sacs (d)Cisternae – Mitochondria

184. Which one of the following pairs is correctly matched

(a) Microsomes Participate in the process of photosynthesis

(b) Lysosomes Involved in synthesizing amino acids

(c) Endo. Reticulum Plays role in the formation of a new nuclear membrane during cell division

(d) Centrosome Provide enzymes required in the digestive process

185. Match List I and List II and select the correct answer using the code given below the list

List I	**List II**
a. Lysosome	1. Bacteria without cell walls
b. Mycoplasma	2. A virus that infact bacterial cells
c. Thylakoid	3. Flattened sacs in a chloroplast
d. Bacteriophage	4. A vesicle in which hydrolytic enzymes are stored

Code

(a) a b c d
3 1 2 4

(b) a b c d
4 1 3 2

(c) a b c d
2 3 4 1

(d) a b c d
1 4 2 3

186. The site of EMP pathway in cell is

(a) Peroxisome (b) Matrix of mitochondria (c)Cytoplasm (d) None of these

CELL WALL

Basic Level

187. Cell wall consist of

(a) Lignin, hemicellulose, pectin and lipid (b) Hemicellulose, pectin, protein and lipid

(c) Cellulose, hemicellulose, pectin and lipid (d) Cellulose, hemicellulose, tubulin and lignin

188. Cell wall shows

(a) Complete permeability (b)Semipermeability

(c) Differential permeability (d) Impermeability

189. The wall of cork cell is mostly impregnated with

(a) Cellulose (b) Suberin (c) Cutin (d) Lignin

190. Cell wall in higher plants is made up of

(a) Cellulose + Lignin (b) Cellulose + Pectin (c) Cellulose+ Suberin (d) Cellulose + Lipid

191. Cellulose and hemicellulose the constituent of cell wall are synthesized by

(a) Lysosome (b) Microbodies (c) SER (d) Golgi bodies

192. Middle lamella is the part of

(a) Cell wall (b) Nucleoplasm (c) Cytoplasm (d) Cell membrane

193. Middle lamella is made up of

(a) Cellulose (b) Suberin

(c) Calcium and magnesium pectate (d) Lignin

194. The chemical substance most abundantly present in the middle lamella is

(a) Pectin (b) Lignin (c) Suberin (d) Cutin

195. Outermost layer of cell wall is

(a) Plasmalemma (b) Secondary wall (c) Middle lamella (d) Primary wall

196. Which one of the following plant cells are devoid of wall

(a) Root hair (b) Stem hair (c) Epidermal cell (d) Gamete

197. Cell wall substance affected in ripe fruits is

(a) Cellulose (b) Chitin (c) Suberin (d) Pectin

198. Cell wall in bacteria and cyanobacteria is made up of

(a) Murein or mucopeptide (b) Peptidoglycan and amino sugars

(c) Cellulose (d) Chitin

199. Cell wall is permeable and has

(a) Cellulose (b) Proteins (c) Hemicellulose (d) All correct

200. The smallest structural unit of cell wall is

(a) Fibril (b) Microfibril (c) Micelle (d) Cellulose

201. The primary function of cell wall is associated with
(a) Controlling volume (b) Providing shape
(c) Its selective permeability (d) Protection against bursting

202. Formation of layers in secondary wall is called
(a) Intussuception (b) Lamellation (c) Apposition (accertion) (d)All correct

203. Which one forms the matrix of cell wall
(a) Cellulose (b) Hemicellulose (c) Pectins (d) Both (b) and (c)

204. The plane of cell wall formation is determined by
(a) Dictyosomes (b) ER (c) Microtubules (d) Microfilaments

205. Cell wall is thin in
(a) Xylem (b) Collenchyma (c) Cytoplasm (d) Parenchyma

206. A cell lacking cell wall would also lack
(a) Chloroplast (b) ER (c) Mitochondria (d) Biomembrane

207. The material in plant cell wall impervious to gases and water is
(a) Pectin (b) Hemicellulose (c) Suberin (d) Chitin

208. The chemical substance in cork cell wall is
(a) Lignin (b) Chitin (c) Cutin (d) Suberin

209. What is absent in matrix of cell wall
(a) Protein (b) Lipid (c) Cellulose (d) Pectin

210. Glucuronic acid, galacturonic acids are found as chief components of
(a) Lignin (b) Pectin (c) Suberin (d) Glucose

211. Cell wall of the fungus may contain
(a) Pectin and cellulose (b) Cellulose and chitin
(c) Chitin and pectin (d) Chitin and silica

212. The tertiary wall of plant cell is composed of
(a) Suberin (b) Xylan (c) Cutin (d) Lignin

213. Cell wall is the secretion product of
(a) Middle Lamella (b) Plasmalemma (c) Cytoplasm (d) Plasmodesmata

214. All plant cells normally possess
(a) Middle lamella (b) Primary wall (c) Lysosomes (d) Centrioles

215. The layer of cellulose deposited on middle lamella by cytoplasm on its outside during cell wall formation is
(a) Primary wall (b) Secondary wall (c) Tertiary wall (d) None of these

216. Which layer has more cellulose
(a) Primary wall (b) Secondary wall (c) Tertiary wall (d) Middle lamella

217. Animal cells do not have cell wall because
(a) They are adapted to move their body (b) They have muscles and nerves
(c) They have to change the size of their body during locomotion (d) All correct

218. Point out the correct statement
(a) 100 cellulose chains from a microfibril (b) 20 microfibrils form a cellulose micelle
(c) 250 microfibrils form a macrofibril (d) 250 micelle form a macrofibril

219. How many glucose molecules make one cellulose chain in cell wall
(a) 3000 glucose (b) 6000 glucose (c) 100 glucose (d) 20 glucose

220. Tonofibrils are related to
(a) Nuclear membrane (b) Chloroplast
(c) Mitochondria (d) Plasmodesmata

221. What is absent in plasmodesmata
(a) Middle lamella (b) Cell wall (c) Primary wall (d) Secondary wall

222. The cementing layer of pectin between adjacent plant cells is called
(a) Middle lamella (b) Secondary wall (c) Ectoplast (d) Primary wall

223. A small thickening found in the middle of pit membrane in a bordered pit is called
(a) Nucleolous (b) Torus (c) Tyloses (d) Callus

224. Torus in bordered pit is made up of
(a) Pectin (b) Cellulose (c) Suberin (d) Chitin

225. Symplast
(a) Is living component of cell (b) consists of cytoplasm and cell membrane
(c) Both correct (d) only (b) is correct

226. Apoplast
(a) Is nonliving part of cell (b) Consists of cell wall and intercellular spaces
(c) Both correct (d) Both wrong

227. A micelle is made up of
(a) 250 microfibrils (b) 100 cellulose chains (c) 20 macrofibils (d)3000cellulose chains

Advance Level

228. Ripening fruits soften due to
(a) Jelly formation of acidic *pH* (b)Solubilisation of pectate of middle lamellae
(c) Conversion of starch into sugar (d) Incorporation of pectate in middle lamella

229. Which organelle of plant cells secretes polysaccharide and protein to make cell walls
(a) Golgi bodies (b) Lysosome (c) Mitochondria (d) Chloroplast

230. The addition of new cell wall particle among those already in position is known as
(a) Intrussusception (b) Apposition (c) Deposition (d) Plasmation

231. The plant cell wall is made up of cellulose. This is believed to be
(a) A liquid (b) A protein (c) A polysaccharide (d) An amino acid

232. The strength and rigidity of a cell wall is due to the substance known as
(a) Suberin (b) Cellulose (c) Lignin (d) pectin

233. Lignified cell wall is the characteristic feature of
(a) Phloem (b) Epidermal cells (c) Cambrial cells (d) Xylem cells

234. The possibility of being outermost layer of cell is highest for which of the following
(a) Plasmalemma (b) Cell membrane (c) Middle lamella (d) Primary wall

235. In the middle lamella of plant cell walls, one of the main elements is
(a) Iron (b) Calcium (c) Magnesium (d) Potassium

236. The internal layer joining the primary walls of the two adjacent cells is known as
(a) Plasmodesmata (b) Middle lamella (c) Periderm (d) Casparian strip

237. Macromolecule most common in plant cell walls is
(a) Glycogen (b) Starch (c) Protein (d) Cellulose

238. Cytoplasm of one cell is connected with other through
(a) Cytoplasmic strands (b) Plasmodesmata (c) Torus (d) Pit membrane

239. The minute protoplasmic connections between cells are called
(a) Chiasmata (b) Plasmodesmata (c) Tractile fibres (d) Ultra-cellular stands

240. Tertiary wall consists of
(a) Lignin and cellulose (b) Cellulose and xylans
(c) Cellulose (d) Suberin and xylans

241. Cell wall generally present in water conducing tissues are represented by swollen nodules is called
(a) Secondary wall (b) Tertiary wall (c) Middle lamella (d) None of the above

242. In bacteria cell wall, NAM and NAG are 2 amino sugars arranged alternately. A short chain of four amino acids is attached to
(a) NAM (b) NAG (c) Carbohydrate (d) Protein

243. The most abundant component of plant cell wall is
(a) Pentosan polysaccharide (b)Mucopolysaccharide
(c) Hexose polysaccharide (d)Disaccharide

244. The component of plant collenchyma cell wall, an acid carbohydrate, is the polymer of
(a) Glucose (b) Mannose (c) Galacturonic acid (d) Alginic acid

245. Polygalactronoids are the major constituents of
(a) Middle lamella (b) Primary cell wall (c) Secondary cell wall (d) Cell membrane

246. Pectin acts are filler substance in matrix of cell wall Hemi cellulose helps in
(a) Binding microfibils (b) Strenghtening (c) Hardness (d)Protection from injury

247. Xylans are present in
(a) Middle lamella (b) Microfibrils of primary wall
(c) Innermost layer of secondary wall (d) Absent in all of the above

248. Middle lamella is
(a) Present inside the primary wall (b)Present inside the secondary wall
(c) Present outside the primary wall (d)Present in between secondary and tertiary walls

249. A pit is unthickened area in cell wall, It lacks
(a) Primary wall (b) Middle lamella
(c) Secondary wall (d) Cell wall and cell membrane

250. Pit in cell wall are found in pairs. Some times pit is found single. It is called
(a) Blind pit (b) Half bordered pit (c) Simple pit (d) Bordered pit

251. Intussusception is shown by primary cell wall. It is
(a) Deposition of cell wall materials from inside to cause growth
(b) Deposition of wall materials from outside as layers
(c) Hardening of cell wall
(d) None of the above

252. The method of intercalation of new wall material in between the old component of the cell wall is called growth by
(a) Layering (b) Apposition (c) Interssuception (d) Multinet theory

PLASMA MEMBRANE

Basic Level

253. Which is the latest model that is proposed to explain the structure of plasma membrane
(a) Fluid mosaic model (b) Molecular model
(c) Unit membrane model (d) None of the above

254. Who proposed "fluid mosaic model" for plasma membrane
(a) C. Cramer and C. Nageli (b) Singer and Nicholson
(c) Denielli and Davson (d) J.D. Robertson

255. Singer and Nicholson's model of plasma membrane differs from Robertson's model in the
(a) Number of lipid layers (b)Arrangement of lipid layers
(c) Arrangement of proteins(d)Absence of protein in singer and Nicholson's model

256. According to mosaic model, Plasma membrane is made up of
(a) Cellulose and hemicellulose (b) Phospholipid and integrate protein
(c) Phospholipid, extrinsic and intrinsic protein (d) Phospholipid and hemicellulose

257. According to the 'unit membrane model' the thickness of the cell membrane is about
(a) 200 *nm* (b) 7.5 *nm* (c) 150 *nm* (d) 1.0 *nm*

258. Plasma membrane is made up of
(a) A protein layer between two lipid layers (b) A lipid layer between two protein layers
(c) A protein, a lipid and a cellulose layer
(d) Bimolecular lipid layer surrounded by protein layers

259. Which of the following is not constituent of unit membrane
(a) Phosphoprotein (b) Protein and lipids (c) Phospholipids (d) Cellulose

260. Carbohydrates are present in the plasmalemma in the form of
(a) Starch
(b) Cellulose
(c) Hemicellulose
(d) Phospholipids (glycolipids) and phosphoproteins (glycoproteins)

261. Which of the following organelles is bounded by two unit membranes
(a) Golgi complex (b) Peroxisome (c) Chloroplast (d) Lysosome

262. Which of the following cell organelles is having single layered unit membrane
(a) Centrosome (b) Lysosome (c) Mesosome (d) Nucleus

263. Which of the following has a single unit membrane
(a) Ribosome (b) Peroxisome (c) Nucleolus (d) Centrosome

264. Phagocytosis was first discovered by
(a) Huxley (b) Haeckel (c) Metchinkoff (d) Strasburgers

265. The process of cell eating is called
(a) Pinocytosis (b) Phagocytosis (c) Endocytosis (d) Exocytosis

266. The process of cell drinking is called
(a) Pinocytosis (b) Phagocytosis (c) Endocytosis (d) Exocytosis

267. One of the fundamental characteristic of cell membrane is
(a) Amino acid regulation (b)Fat regulation (c) Glucose regulation (d) Ion regulation

268. Which of the following structures controls the transport of the material into and out of living cells
(a) Centrosome (b) Cell membrane (c) Cell wall (d) Ribosome

269. Every living cell has a
(a) Membrane (b) Food vacuole (c) Chloroplast (d) Cell wall

270. Plasmalemma is another term for
(a) Cell wall (b) Middle lamella (c) Microfibrils (d) Plasma-membrane

271. The protoplasmic strands connecting the two adjacent plant cells are called
(a) Plasmalemma (b) Plasmodesmata (c) Tonofibrils (d) Spindle fibres

272. Who proposed the concept of unit membrane for tripartite structure of lipoproteins
(a) Seifriz (b) Buvat (c) Davson and Danielli (d) Robertson

273. The mosaic model of plasma membrane can better explain permeability by
(a) Osmosis (b) Diffusion
(c) Carrier process (d) Electrochemical gradient

274. Cell membrane is
(a) Premeable (b) Impermeable (c) Selectively permeable (d)Semi permeable

275. The number of the components present in the biomembranes are
(a) 3 (b) 4 (c) 5 (d) 8

276. Plasmodesmamta help in
(a) Food translocation (b) Mineral translocation
(c) Translocation of phytohormones (d) All above

277. The proteins in biomembranes are responsible for
(a) Mosaiceness (b) Antigen specificity (c) Cell to cell recognition (d) All above

278. Correct sequence of protein (P) and lipid (L) in cell membrane is
(a) L – P – L – P (b) L – P– P– L (c) P – L – L – P (d) P– P – L – L

279. Plasma membrane, particularly in animal cells, is elastic due to
(a) Carbohydrates (b) Proteins (c) Lipids (d) None of these

280. Out of proteins, lipids and carbohydrates present in a cell membrane, what is true
(a) Carbohydrates are minimum (b) Carbohydrates are maximum
(c) Lipids are minimum (d) All the three are in equal proportion

281. Cell recognition and adhesion occur due to biochemicals of cell membrane named
(a) Proteins (b) Lipids
(c) Proteins and lipids (d) Glycoproteins and glycolipids

282. The plasma membrane of an animal cell is composed of
(a) Lipids, proteins, oligosaccharides (b) Lipids, proteins, Polysaccharides
(c) Lipids, proteins, disaccharides (d) Lipids, proteins, monosaccharides

283. The basic unit of plasma membrane is
(a) Protein and phospholipid (b)Cellulose and carbohydrate
(c)Protein and carbohydrate (d) Protein and cellulose

284. Protein tubulin is absent in
(a) Flagella (b) Cilia (c) Microtubules (d) Plasma membrane

285. Cellular membranes occur in
(a) Bacteria and cyanobacteria (b)All eukaryotes (c) Prokartyotes (d) All above

286. Membrane bound organelles occur in
(a) Eukaryotes (b) Prokaryotes (c) Akaryotes (d) All of these

287. Membranes are found in
(a) Cytoplasm, mitochondria and chloroplasts (b) Cytoplasm, nuclei and starch grains
(c) Chromosomes, nuclei and mitochondria (d)Chromosomes, chloroplasts and starch grains

288. Single membrane bound cell organelles include
(a) Endoplasmic reticulun (b)Lysosomes (c) Spherosomes (d) All of these

289. Chemical nature of carrier molecules facilitating transport across plasma membrane is
(a) Starchy (b) Sugary (c) Proteinaceous (d) Fatty acidic

290. Size of molecules that can pass through plasma membrane is
(a) 1–15 Å (b) 8–10 Å (c) 10–13 Å (d) 15–75 Å

291. The active transport mechanism is against concentration gradient and
(a) Requires ATP (b) Does not require ATP
(c) Requires protein (d) Does not require protein

292. Active transport involves
(a) Use of metabolic energy (b)Passive diffusion (c)Simple osmosis (d) Any of the above

293. The entry of mineral ions in a plant cell during diffusion is by
(a) Passive absorption (b) Active absorption (c) Osmosis (d) Endocytosis

294. Pinocytosis is
(a) Ingestion of solid particles by plasma membrane (b)Ingestion of liquid particles
(c) Changed permeability of plasmalemma towards ions (d)Both (a) and (b)

295. Term plasmalemma was coined by
(a) Nageli and Cramer (b) J.Q. Plowe (c) Robertson (d) Robert Hooke

296. J. Singer and G.Nicolson proposed their model in
(a) 1968 (b) 1972 (c) 1971 (d) 1964

297. The most satisfactory model of cell membrane explaining its functional aspects has been given by
(a) Robertson (b) Danialli (c) Davson (d)Singer and Nicholson

298. One of the model of cell membrane was described as " Protein icebergs in a sea of lipids" by its authors. They are
(a) Danielli and Davson (b)Robertson (c) Singer and Nicolson (d)Lucy

299. According to the lamellar model the correct sequence in plasma-membrans is
(a) Lipid-protein –protein-lipid (b) Lipid-protein -lipid –protein
(c) Protein -lipid –protein-lipid (d) Protein-lipid-protein

300. The model given by Wolpers was
(a) Trilaminar model (b) Unit membrane (c) Lattice model (d) Fluid mosaic

301. The first lipid model of cell membrane showing that cell membrane is made up of a lipid layer was given by
(a) Garter and Grendel (b) Overton (c) Danielli and Davson (d)Lucy

302. Bimolecular leaflet model was given by
(a) Robertson (b) Singer and Nicholson (c) Wolpers (d) Garter and Grendel

303. Who among the following proposed unit membrane model for cell membrane
(a) Davson and Danielli (b) Robertson (c) Singer and Nicholson (d)Overton

304. The thickness of phospholipid bilayer of a typical plasma membrane is
(a) 75 A^o (b) 100 A^o (c) 45 A^o (d) 35 A^o

305. Basic structure of all cell membranes is provided by
(a) Lipid (b) Protein (c) Oligosaccharide (d) RNA

306. Lipid molecules (Phospholipids) are amphiatic, Each molecule has
(a) One nonpolar and 2 polar tails (b)One polar head and 2 nonpolar chains
(c) One polar head and one nonpolar chain (d) Two heads and one chain

307. Frame work molecules in biomembranes are
(a) Glycolipids (b) Phospholipids (c) Glycoproteins (d) Oligosaccharides

308. Proteins iceberge in a sea of lipids is related with
(a) Unit membrane model (b)Fluid mosaic model
(c) Lamellar/ sandwich model (d)Micellar model

309. Hydrophobic end of phospholipid has
(a) Affinity for water (b) Non affinity for water
(c) Affinity for metabolites (d) Non affinity for metabolites

310. Carbohydrate molecules attached to lipid and protein molecules form Glycocalyx (extraneous coat). These carbohydrates are usually
(a) Monosaccharides (b) Polysaccharides (c) Oligosaccharides (d) Starches

311. According to Robertson's unit membrane, Lamellar model, the proteins are

(a) Extended and fibrous (b) Asymmetric

(c) Each protein layer is of 20Å thickness (d) All correct

312. A membrane is held together primarily by

(a) Hydrophobic attractions (b) Hydrophilic attractions

(c) Covalent bonds (d) Ionic bonds

313. Lipids and protein contents in all membrane are in ratio of

(a) 40:58 (b) 58:40 (c) 60:40 (d) 50:50

314. Transmembrane proteins are

(a) Intrinsic proteins (b) Extrinsic proteins (c) Glycocalyx (d) Tunnel proteins

315. An enzyme carries protein associated with cell membrane is

(a) Lipase (b) amylase (c) Permease (d) Catalase

316. The channels and pumps that control molecular traffic in and out of a cell are collectively known as

(a) Intrinsic proteins (b) Permeases (c) Carriers (d) Cytochromes

317. One of the following does not support facilitated diffusion

(a) This requires energy input (b)This is passive process

(c) Solutes are moved by a change in shape in the carrier protein

(d) The solute can move in either direction

318. Which of the following can diffuse easily through non-polar membrane

(a) CO_2 (b) Proteins (c) Lipids (d) Pb^+

319. Ions enter the cell through plasma membrane by

(a) Some carriers present in the membrane (b) Cytochrome pump across the membrane

(c) Phosphatidic acid cycle (d)All the above

320. Which does not require active transport (*i.e.* ATP)

(a) Pinocytosis (b) Phagocytosis

(c) Ephagy (d) Facilitated transport

321. An input of energy is needed for a process called

(a) Active transport (b) Diffusion (c) Osmosis (d) imbibition

322. Secondary active transport is

(a) Co-transport (b) Symport (c) antiport (d) All above

323. Active transport involves

(a) Production of ATP (b) Requirement of energy

(c) Production of toxin (d) Release of energy

324. The materials are carried across the cell membrane by

(a) Proteins (b) Fatty acids (c) Phosphates (d) Lipids

325. Selective permeability identifies the process of

(a) Diffusion (b) Osmosis (c) Imbibition (d) Plasmolysis

326. Which does not pass across membrane by diffusion

(a) CO_2 (b) O_2 (c) H_2O (d) H^+

327. Cell wall and cell membrane are two distinct layers. It can be proved by

(a) Plasmolysis (b) Osmosis (c) Imbibition (d) All of these

328. Land plants grow in soil that is relative to their cells

(a) Hypotonic (b) Isotonic (c) Hypertonic (d) Ultratonic

329. Microvilli are found in

(a) Call wall (b) Cell membrane

(c) Mitrochondria (d) Salivary chromosome

330. Microvilli are

(a) Outfolds of cell membrane (b) Infolds of cell membrane

(c) Both (a) and (b) (d) None of these

331. Microvill are meant for

(a) Slowing down of cell movements (b)Helping in cell movements

(c) Rapid osmosis (d) Increasing absorptive area

332. Plasmalemma of two adjecent cells are fused in case of

(a) Terminal bars (b) Tight junctions (c) Microvilli (d) Desmosomes

333. The process by which substances in bulk are taken in by the plasmamembrane is

(a) Endocytosis (b) Exocytosis (c) Karyokinesis (d) Cytokinesis

334. The secretion of macromolecules by fusing a transport vesicle to the plasma membrane is

(a) Pinocytosis (b) Phagocytosis (c) Endocytosis (d) Exocytosis

335. Cells send out their wastes secretion through

(a) Pinocytosis (b) Exocytosis (c) Phagocytosis (d) Lysosomes

336. Pinocytosis was first observed by

(a) Metchnikoff (b) Lewis (c) Robertson (d)Holleir and Hoffman

337. Outfolds of plasmamembrane in a fungal hyphal cell are called

(a) Lomasomes (b) Lysosomes (c) Mesosomes (d) Tonofibrils

338. Thickened parts of plasma membrane with radiating protein tubules are called

(a) Terminal bars (b) Desmosomes

(c) Interdigitations (d) Tight junctions

339. Biological membranes are composed of

(a) 40% proteins and 60% lipids (b)50% proteins and 50% lipids

(c) 70% proteins and 30% lipids (d)60% proteins and 40% lipids

340. Which one enzyme of plasma membrane gets inactivated in the absence of lipids

(a) ATPase (b) Alkaline phosphatase

(c) Acid phosphomonoesterase (d) RNAase

341. Which one of the following activator remains attached with ATP in plasma membrane

(a) Mg^{++} (b) Ca^{++} (c) K^{+} (d) Na^{+}

342. According to Robertson, thickness of lipid zone in the cell membrane ranges from

(a) 10–20 Å (b) 25–35 Å (c) 50– 60 Å (d) 35–50Å

Advance Level

343. Fluid mosaic model of cell membrane proposed that

(a) A lipid bilayer is coated by a layer of proteins on each surface

(b) A lipid bilayer is coated by a layer of proteins on the outer surface only

(c) A lipid bilayer has both embedded in itself and none on the surface

(d) A lipid bilayer has both embedded and outer protein

344. Lipid molecule in plasma membrane are arranged in

(a) Scattered (b) Series (c) Alternate (d) Head parallel

345. Which of the following layer is present nearest to plasma membrane in plant cell

(a) Secondary wall (b) Middle lamella (c) Primary wall (d) Tonoplast

346. Thickness of plasma membrane is

(a) 10 Å to 30 Å (b) 30 Å to 50 Å (c) 50 Å to 70 Å (d) 70 Å to 100 Å

347. When a cell engulfs or surrounds a particle and forms a vesicle around it, the phenomenon is known as

(a) Exocytosis (b) Phagocytosis (c) Endocytosis (d) None of these

348. Bulk drinking of fluid by cells is termed as

(a) Phagocytosis (b) Pinocytosis (c) Cyclosis (d) Osmosis

349. Which one of the following is a non-protoplasmic cell inclusion

(a) Ribosomes (b) Mitochondria (c) Lysosomes (d) Cystoliths

350. In fluid mosaic model of plasma membrane

(a) Polar layer is hydrophobic (b)Phospholipids form bimoleculer layer

(c) Proteins form a middle layer (d)Upper layer is non – polar and hydrophilic

351. Fluid mosaic model exhibits amphipathic because of

(a) Glycoproteins (b) Phospholipids (c) Lipids (d) Glycolipids

352. According to fluid mosaic model plasmamembrane is composed of

(a) Phospholipid, extrinsic and intrinsic proteins (b) Phospholipid and hemicellulose

(c) Phospholipid and oligosaccharides (d) Phospholipid and integral glycoproteins

353. Most of the substances in the living world are transported across the membrane through the phenomenon of

(a) Diffusion (b) Osmosis (c) Both (a) and (b) (d) Active transport

354. Active transport of ions by the cell requires

(a) High temperature (b) ATP (c) Alkaline *pH* (d) Salts

355. Ion carries are located in

(a) Nucleus (b) Cell wall (c) Cellular space (d) Plasma membranes

356. Plasma membrane (plasmalemma) prevents the escape of Na^+ and K^+ to

(a) Cause disruption in neighbouring cells through desmosomes

(b) Maintain electrostatic neutrality of the cell

(c) Maintain cells (d) All of the above

357. Desmosomes are concerned with

(a) Cell division (b) Cellular excretion (c) Cytolysis (d) Cell adherence

358. Which one of the following pairs is not correctly matched

(a) Cristae The " shelves" formed by the folding of the inner membrane of the mitochondrion

(b) Plasmodesmata The membrane surrounding the vacuole in plants

(c) Grana Membrane bound discs in chloroplasts that contain chlorophylls and carotenoids

(d) Middle lamella Layer between adjacent cell walls in plants derived from cell plate

359. Beet root if kept in cold water anthocyanin does not come out due to plasma membrane

(a) Differentially permeable (b) Impermeable to anthocyanins

(c) Permeable to anthocyanins (d) Lose of fluidity

360. Which of the following does not require carrier molecules during transport through cell membranes

(a) Simple diffusion (b) Facilitated diffusion

(c) $Na^+ - K^+$ transport (d) Active transport of sugars and amino acids

361. Which of the following pair lack the unit membrane

(a) Nucleus and E.R (b) Mitochondria and chloroplast

(c) Ribosome and nucleolus (d) Golgi body and lysosome

362. Sialic acid is a constituent of

(a) Cell membrane (b) Cell wall (c) Chromosome (d) Dictyosome

363. RNA is absent in

(a) Plasmalemma (b) Cytoplasm (c) Chromosomes (d) Ribosomes

364. Which is not correct

(a) Na^+ ions help retain water

(b) Na^+ ions help conduct nerve impulse

(c) Na^+ ions help in transport of substances across membranes

(d) Na^+ ions are important components of blood plasma

365. A dominant intracellular cation is

(a) Na^+ (b) K^+ (c) Ca^{2+} (d) Chlorine

366. Carrier proteins take part in

(a) Passive transport of ions (b)Active transport of ions

(c) Water transport (d)Water evaporation

367. Active transport occurs

(a) Against concentration gradient and requires ATP

(b)Against concentration gradient but does not require ATP

(c) Along concentration gradient but requires ATP

(d) Along concentration gradient but does not require ATP

368. In the resting state of the nutral membrane, diffusion due to concentration gradients, If allowed, would drive

(a) Na^+ in to the cell (b) Na^+ out of the cell

(c) K^+ in to the cell (d) K^+ and Na^+ out of the cell

369. In Singer and Nicholson (1972) fluid mosaic model, extrinsic proteins are

(a) Superficially arranged and can be separated easily

(b) Superficially arranged and cannot be separated easily

(c) Tightly attached to intrinsic proteins and can not be separated easily

(d) Tightly attached to intrinsic proteins and can be separated easily

370. Plasmodesmata were discovered and named respectively by

(a) Tangl and Strasburger (b)Strasburger and plowe

(c)Altman and Benda (d)Strasburger and Golgi

371. Robertson's model of cell membrane is similar to that of Danielli and Davson's in

(a) Types of proteins (b) Lamellar structure (c) Permeases (d) Carrier Particles

372. Singer and Nicolson's fluid mosaic model of biomembrane differs from Robertson's unit membrane in

(a) Arrangement of lipids (b)Number of lipid layers

(c)Arrangment of proteins (d)Absence of proteins

373. The osmosis is a process in which two weak and strong solutions are separated by the semipermeable membrane' which of the following is not mentioned in the statement

(a) DPD (b) Exact concentration

(c) Nature of particles (d) Nature of semipermeable membrane

374. Facilitated diffusion involves

(a) Carriers but no energy (b)Receptors and energy

(c)Enzymes and energy (d)Carriers and energy

375. Difference between active and passive modes of membrane transport is

(a) Active transport is confined to cations while passive is connected to anions

(b) Active transport is nonselective while passive one is selective

(c) Active transport requires metabolic energy while passive transport requires concentration gradient

(d) Active transport is more rapid

376. The difference between permeable and bulk transport across the cell membrane is related to

(a) Molecular weight of substance (b)Solvent system

(c) Structure of molecules allowed passage (d)Solvent system as well as structure of molecules

377. During symport or cotransport of sugar or amino acid Na^+ moves

(a) Opposite its concentration gradient (b) Along its concentration gradient

(c) In both directions (d) Not involved

378. Poisons like cyanide inhibit Na^+ efflux and K^+ influx. The effect is reversed by injection of ATP indicating that

(a) $Na^+ - K^+$ pump operates in cells

(b) ATP is hydrolysed by ATP-ase to release energy

(c) Energy for $Na^+ - K^+$ pump comes from ATP (d) None of these

379. The main difference between pinocytosis and phagocytosis is

(a) Taking in of fluid substances and engulfing of food material and foreign bodies

(b) Taking in of small and large particles respectively

(c) Taking in of small amount of liquid and large volume of liquids

(d) None of these

380. Recycling of plasma membrane is carried out by

(a) Golgi apparatus (b) Cell wall

(c) Lysosomes (d) Endoplasmic reticulm

381. Kavanau's lipid pillar model can not explain

(a) Passive transport (b) Active transport (c) Phagocytosis (d) None of these

382. Of about 30 different enzymes isolated from plasma membrane which one occurs in more quantity

(a) ATPase (b) Alkaline phosphatase

(c) Acid phosphomonoesterase (d) RNAase

383. Which one statement regarding plasma membrane is correct

(a) It outer and inner layer are electron dense while middle layer is electron transparent

(b) It outer and middle layer are transparent while inner layer is electron dense

(c) It outer and inner layer are electron transparent while middle one is electron dense

(d) All layers are electron dense

384. For the transport of ions, protein-lecithin theory (Phosphatidic cycle) was given by

(a) Lundegardh (b) Bennet Clarke (c) Davson and Danielli (d) Robertson

385. One of the following model of plasma membrane suggested that molecules show globular arrangement

(a) Lattice model (b) Fluid mosaic (c) Bimolecular leaflat (d) Micellar model

386. The first micellar model was proposed by

(a) Robertson (b) Danielli and Davson

(c) Singer and Nicolson (d) Helleir and Hoffmann

387. Which of the following statement is incorrect regarding cell membranes

(a) In general smaller molecules pass through cellular membranes more readily than larger molecules

(b) Water soluble substances pass through cell membranes more readily as compared to lipid soluble substances

(c) Membranes are selectively permeable

(d) Membranes permeability depends upon physical nature and electrical charge of solute

388. According to an accepted model of plasma membrane transport during 'symport' or 'co-transport' of sugar or amino-acids through cell membrane is when

(a) *Na* ions move in both directions irrespective of concentration gradient

(b) *Na* ions move in the directions of it's con-centration gradient

(c) *Na* ions move against the direction of it's concentration gradients

(d) No movement of Na ions is involved

389. The major driving force for formation of membrane lipid bilayer is

(a) Vander Waal forces (b) Electrostatic forces

(c) Hydrophobic interactions (d) Hydrogen bonding

390. A phospholipid molecule is amphipathic and produces 2 layers coming in contact with H_2O. The head of phospholipid molecule is

(a) At the outer surface (b) Between the surfaces

(c) At an angle of 40^o (d) Embedded in protein molecules

391. Lipid bilayers in biomembranes are barrier to

(a) Polar molecules (b) Non polar molecules

(c) Both polar and non polar molecules (d) None

392. Plasma membrane helps in cell movements through

(a) Undulation (b) Extensions

(c) Formation of pseudopodia (d) All correct

393. The term which can be used for covering of slime moulds, mycoplasmas or Amoeba is plasmalemma which is also called as

(a) Cell wall (b) Micro- fibrils (c) Plasma membrane (d) Middle lamella

394. The fluid mosaic model explains

(a) Structural aspects of cell membrane (b) Functional aspects of cell membrane

(c) Structural and functional aspects both (d) None of these

395. Biomembranes are

(a) Asymmetric (b) Symmetric (c) Asymmetric fluid (d) symmetric fluid

396. In trilaminar arrangement of biomembrane, which is true

(a) Inner layer is transparent (b)Outer layer is transparent

(c) Middle layer is opaque (d)Middle layer is transparent

397. Capability of plasma membrane to change its permeability by lateral shifting of peripheral proteins is called

(a) Dynamism (b) Polarity (c) Active transport (d) Permeability

398. Ion channels in cell membranes were discovered by Nobel prize winners of 1991 who are

(a) Singer and Nicolson (b) Nehar and Sakmann

(c) Garter and Grendel (d) Metchniknoff

399. Glycocalyx is found

(a) In the cytoplasmic matrix (b) On cell surface

(c) Around nucleus (d) On the periphery of nucleoplasm

400. Cell coat consists of

(a) Glycocalyx (b) Cellulose

(c) Cellulose+Hemicellulose+ Pectin (d) Protein

401. Amphipathy means

(a) Presence of hydrophillic and hydrophobic ends (b)Presence of hydrophobic end

(c) Presence of hydrophillic end (d)None of above

402. Cell membrane has proteins, lipids and carbohydrates. With respect to their mutual proportions, which statement is correct

(a) All the three are in equal proportion (b) Lipids are in least proportions

(c) Carbohydrates are in least proportions (d) Proteins are in least amount

403. The thickness of three layers of cell membrane is variable but usually

(a) 20: 35: 20 (b) 35: 20: 35 (c) 20: 40: 20 (d) 15: 45: 15

404. Main function of plasmamembrane is to

(a) Prevent water from entering/ leaving (b) Control what goes into and out of the cell

(c) Act as sieve (d) Help the cell to move

405. The purple cabbage leaves do not loose their colour in cold water but do so in the boiling water because

(a) Boiling water enters the cell easily (b) Plasmalemma killed in boiling water

(c) Pigment is not soluble in cold water (d) Cell wall is coagulated in boiling water

406. Glycocalyx (Glycolipids and Glycoproteins) is cell coat lying outside cell membrane. It act as

(a) Recognition centre (b) Insulating coat (c) Protective coat (d) All correct

407. Glycoproteins are known to play an important role in cell recognition, the specificity of this recognition is largely provided by

(a) Lipid portion of glycoproteins

(b) Protein portion of glycoproteins

(c) Carbohydrate portion of glycoproteins

(d) Both carbohydrate and protein components of glycoproteins

408. One of the following methods for transporting substances across a membrane does not involve a change in extrinsic and intrinsic proteins

(a) *Na-K* pump (b) Active transport

(c) Simple diffusion (d) facilitated diffusion

409. The movement of substances across the cell membrane from lower to higher concentration with the utilisation of energy is known as

(a) Osmosis (b) Passive transport

(c) Active transport (d) Facilitated transport

410. Which process does not involve a change in shape of the transport protein in a cell membrane

(a) Facilitated diffusion (b) Active transport (c) Simple diffusion (d) Na^+K^+

411. A selective (differential) permeable membrane allows passage of

(a) Solutes only (b) Solvents only

(c) Some solvents and all solutes (d) Some solutes and all solvents

412. When the fluid outside a cell has a greater concentration of a given molecule than the fluid inside the cell, the external fluid is

(a) Isotonic (b) Hypertonic (c) Hypotonic (d) Ultratonic

413. 'Ultraphagocytosis' is intake by cell of

(a) Solid particles (b) Colloid particles

(c) Water (d) It is very quick phagocytosis

414. Emelocytosis is another term for

(a) Pinocytosis (b) Phagocytosis (c) Reverse endocytosis (d) All above

415. Which of the following cell surface differentiation is not likely to play a role in iner cellular communication

(a) Desmosome (b) Gap junction (c) Tight junction (d) None above

416. Phagosome is

(a) Carrier vesicle carrying solid food particle

(b) Carrier vesicle carrying fluid matter

(c) A carrier vesicle formed by evagination of plasma membrane around the food particle

(d) Both (a) and (c) correct

PROTOPLASM AND CYTOPLASM

Basic Level

417. Which of the following is the "*physical basis of life*"

(a) DNA (b) Protoplasm (c) Nucleus (d) Sex chromosome

418. Protoplasm was regarded as the "physical basis of life" by

(a) Huxley (1868) (b) Corti (1772) (c) Hardy (1899) (d) Malphighi (1903)

419. The name 'Protoplasm" was given by
(a) Purkinje (b) Hooke (c) A.K Sharma (d) Schwann

420. The amount of which of the element is greatest in protoplasm
(a) Hydrogen (b) Oxygen (c) Nitrogen (d) Carbon

421. Normal *pH* of Protoplasm is
(a) 7.8 (b) 6.8 (c) 5 (d) 6.5

422. Protoplasm is a
(a) True solution (b) Suspension
(c) Emulsion (d) Polyphasic colloidal system

423. Protoplasm found inside the nucleus is known as
(a) Nucleoplasm (b) Amyloplast (c) Elaioplast (d) Cytoplasm

424. Protoplasm is
(a) Non living matter (b) Bearer of hereditary characters
(c) Living matter without function (d) Physical basis of life

425. Both plants and animals are provided with
(a) Cell wall (b) Golgi body (c) Chloroplast (d) Protoplasm

426. Cyclosis is
(a) Circular movement of cytoplasm inside the cell (b)Up and down movement of protoplasm
(c) To and fro movement of nucleoplasm (d) None of the above

427. The protoplasm theory was established in plant cell by
(a) Strasburger (b) Robert Brown (c) De Bary (d) Max Schultze

428. The four principal organic constituents of protoplasm are
(a) Proteins, carbohydrates, fats and nucleic acids
(b) Proteins, amino acids, fats and carbohydrates
(c) Carbohydrates, proteins, vitamins and hormones
(d)Amino acids, sugars, nucleic acids and hormones

429. Term protoplast was given by
(a) Hanstein (b) Dodge (c) Fischer (d) Strasburger

430. Which best explains protoplam structure
(a) Colloidal theory of Fishcher (b)Alveolar theory of Butochl
(c) Fibriller theory of Velton (d)Granular theory of Altman

431. In which one of the following states the constituents of the protoplasm are found
(a) Dissolved (b) Colloidal (c) Insoluble (d)Dissolved and colloidal

432. Which one of the following sets of elements is always present in protoplasm
(a) Hydrogen, carbon, oxygen, phosphorus, nitrogen and sulphur
(b) Hydrogen, carbon, nitrogen, oxygen, phosphorus and sodium
(c) Hydrogen, carbon, nitrogen, oxygen, iron and sulphur
(d) Hydrogen, carbon, nitrogen, oxygen, calcium and phophorus

433. Trace elements in protoplasm are functionally important as
(a) Enzymes (b) Coenzymes (c) Antibodies (d) Cofactors

434. The substances of protoplasm present in the least quantity are
(a) Non-metals (b) Proteins (c) Trace elements (d) Lipids

435. If protoplasm is subjected to higher temperature it will first bring about the denaturation of
(a) Lipid (b) Protein (c) Carbohydrate (d) Water

436. When a beam of light is passed through a colloidal solution, it becomes visible and called
(a) Brownian movement (b)Cyclosis (c) Tyndall effect (d) None of these

437. Movement of particles of protoplasm in a regular path is termed as
(a) Amoeboid (b) Brownian (c) Tyndall (d) Streaming

438. The random movement of particles within protoplasm is called
(a) Active transport (b) Brownian movement (c) Passive transport (d) Cyclosis

439. Cytoplasm is a crystallo-colloidal polyphasic solution, discovered by Kollikar. It is actually
(a) Protoplasm (b) Protoplasm – Nucleus
(c)Hyaloplasm – Organelle (d) Protoplasm – Organelle

440. When cytoplasm moves around a central vacuole, this is called
(a) Rotaion (b) Cyclosis (c) Circulation (d) Pinocytosis

441. Brownian movement in cytoplasm is shown by
(a) Proteins (b) Lipids (c) Colloidal solution (d) Suspension

442. Which is true for cytoplasm
(a) Ectoplasm shows brownian movement (b) Endoplasm shows brownian movement
(c) Both show brownian movement (d) None of the above

443. ———— is known as cytoplasm minus all inclusions and organelles
(a) Hyaloplasm (b) Cytoplasm (c) Cytosol (d) Matrix

444. The ground substance of cytoplasm is called
(a) Hyaloplasm (b) Endoplasm (c) Karyoplasm (d) Ergastoplasm

445. The ground substance of a living cell is
(a) Cytoplasm (b) Protoplasm (c) Nucleoplasm (d) Endoplasm

446. *pH* of cytoplasm is
(a) Acidic (b) Slightly acidic (c) Alkaline (d) Extremely acidic

447. Sol ⇌ gel nature of cytoplasm is due to
(a) Water in cytoplasm (b) Salts in cytoplasm
(c) Proteins and organelles (d) Colloidal nature of cytoplasm

448. "Plasma gel" is the name of
(a) Ectoplasm (b) Endoplasm (c) Protoplasm (d) None of these

449. Non-living substance in protoplasm is
(a) Carbohydrate (b) Ribosome (c) Mitochondria (d) Plastids

450. Jelly like semifluid complex of cytoplasm is called
(a) Endoplast (b) Cytosol (c) Cytoplasmic matrix (d) Both (b) and (c)

451. Cyclosis is caused by activity of
(a) Microtubules (b) Microfilaments (c) Intermediate filament (d)All the above

452. The term cytoplasm was coined by

(a) Sachs (b) Strasburger (c) Hanstein (d) Flemming

453. Viscocity of cytoplasm is

(a) 2 centipoise (b) 100 centipoise (c) 10 centipoise (d) 20 centipoise

454. The conversion of plasmasol to plasmagel is

(a) Physical phenomenon (b)Chemical phenomenon

(c) Physio-chemical phenomenon (d)Biochemical phenomenon

455. The portion of cytoplasm in which centriole formation take place is called

(a) Centromere (b) Centrosome (c) Desmosome (d) Microsome

456. Hyloplasm contains

(a) Cytoplasm and water (b) Protoplasm and water

(c) Minerals and water (d) None of the above

Advance Level

457. The movement of cytoplasm is termed as

(a) Brownian movement (b)Endocytosis (c) Cyclosis (d) Cytokinesis

458. Contribution of protoplasm to the total weight of the body is

(a) 10% (b) 45% (c) 7% (d) 95%

459. The substance which makes up about 80% of cytoplasm and has unique structure

(a) Proteins (b) Fats (c) Minerals (d) Water

460. Number of amino acids present in protoplasm is

(a) 20 (b) 12 (c) 10 (d) 8

461. Content of nucleic acid in protoplasm is

(a) 35% (b) 29% (c) 10% (d) 2%

462. Non-living substances of the protoplasm are collectively known as

(a) Deutoplasm (b) Plasma gel (c) Mesoplasm (d) Cytoplasm

463. The best material for demonstrating streaming movement of protoplasm within living cells is

(a) Onion peel (b) Staminal hairs of Tradescantia

(c) Pith cells (d) Cortical cells

464. Protoplasm undergoes coagulation which result in total stoppage of physiological activities at

(a) 60^{o}C (b) 50^{o}C (c) 70^{o}C (d) 75^{o}C

465. Crystallo-colloidel nature of protoplasm was suggested by

(a) Altman (b) Butschilli (c) Fischer (d) Kolliker

466. Protoplasm is called mixture of mixtures. The Alveolar theory about nature of protoplasm was given by

(a) Fischer (b) Altman (c) Butschli (d) Velton

467. Who among the following proposed the colloidal theory of protoplasm

(a) Bowman (b) Boveri (c) Fischer (d) Sutton

468. All cells contain a living substance which is called protoplasm It was first observed by
(a) Purkinge (b) Von Mohl (c) Max Schultze (d) Corti

469. Circulation cyclosis is commonly seen in
(a) Hydrilla leaves (b) Cell of staminal hair of Tradescantia
(c) Lotus leaf (d) All of above

470. Cyclosis is not required in
(a) Undulation of cell membrane (b) Formation of pseudopodia
(c) Movement of chloroplast (d) All of the above

471. Reduction of oxygen contest from the environment of protoplasm will
(a) Increase energy out put (b)Decrease energy output
(c) Increase endosmosis (d) Decrease endosmosis

472. The water contains in protoplasm are
(a) Upto a quarter of it (b) Upto a half of it
(c) Upto three quarters of it (d) More than three quarter of it

473. Which of the following properties is attributed to the respones to changes in external and internal environment by protoplasm
(a) Irritability (b) Mutability
(c) Reproducibility (d) Adaptability

474. What electrical changes take place when the sol structure is converted in to gel
(a) All positive charges become converted in to negative
(b) All positive charges become converted in to positive
(c) All positive and negative charges become neutralised
(d) Neulralized state is converted in to charged state

475. The theory strongly advocating the morphological nature of protoplasm is
(a) Granular theory of Altman (b)Fibrical theory of Flemming
(c) Nuclear theory of Altman (d)Colloidal theory of Wilson Fischer and Hardy

476. Amici studied cyclosis for the first time in
(a) *Hydrilla* (b) *Amoeba* (c) *Chara* (d) *Acetabularia*

477. In rotation type of cyclosis, the cytoplasmic matrix flows in
(a) One direction (b) Two opposite direction (c)Different directions (d)Side ways

478. In circulation streaming protoplasm moves in
(a) One direction (b) Two opposite direction around a vacuole
(c) Different directions around different vacuole (d) Both (a) and (b)

479. Cyclosis was first studied by
(a) Robert Brown (b) Dalton and Felix (c) Amici (d) Sachs

MACRO ORGANELLES OF CELL

Basic Level

480. Who first introduced the term "mitochondrion"

(a) Kolliker (b) Robert Brown (c) Benda (d) Altman

481. The size of mitochondrion is

(a) $5-10\,\mu$ (b) $50-100\,\mu$ **(c)** $0.5-1.0\,\mu$ (d) $150-300\,\mu$

482. Single mitochondrion is found in

(a) *Microsteria* (b) *Rhizopus* (c) *Nostoc* (d) *Ulothrix*

483. Mitochondria are non-existent in

(a) Red algae (b) Some bacteria (c) Green algae (d) Brown algae

484. The number of mitochondria increases in cells of

(a) Dormant seeds (b) Germinating seeds

(c) Dry seeds (d) Dead seeds

485. Which of the following is present in mitochondria

(a) Polysome (b) Monosome (c) Quantasome (d) Oxysome

486. Elementary particles (Oxysomes) are present in

(a) Chloroplasts (b) Mitochondria

(c) Golgi bodies (d) Endoplasmic reticulum

487. F_1 particles are also called

(a) Electron transport particles (b) Elementary particles

(c) Cytochromes (d) Cristae

488. Oxysomes are located inside

(a) Mitochondria (b) Plastids (c) Lysosomes (d) Golgi body

489. Electron transport system in mitochondria is located in

(a) Outer membrane (b) Inter-cristae space

(c) Inner membrane (d) Inner membrane space

490. Cytochrome is found in

(a) Cytoplasm (b) Golgi body (c) Nucleus (d) Plasmalemma

491. DNA is present in

(a) Carboxysomes (b) Ribosomes (c) Lysosomes (d) Mitochondria

492. Cytochromes are

(a) Oxygen acceptors (b) Electron acceptors (c) Carbon acceptors (d) Both (a) and (b)

493. Mitochondria are the site for

(a) Photophosphorylation (b) Oxidative phosphorylation

(c) Transpiration (d) Carboxylation

494. The reaction of ATP formation is

(a) Exergonic (b) Endergonic (c) Spontaneous (d) None of these

495. Function of mitochondria is

(a) To provide CoA (b) To synthesize PGA

(c) To release energy during respiration (d) All the above

496. The fine network of single membrane distributed extensively throughout the cytoplasm in a cell is referred to as

(a) Golgi bodies (b) Peroxisome

(c) Lysosome (d) Endoplasmic reticulum

497. Respiratory enzymes are present in
(a) Mitochondria (b) Chloroplasts (c) Golgi bodies (d) Lysosomes

498. Oxidative enzymes occurs mostly in
(a) Lysosomes (b) Golgi bodies (c) Mitochondria (d) Ribosomes

499. Glycogen occurs in
(a) Mitochondria (b) Krab's cycle (c) Cytoplasm (d) None of these

500. What is the energy coin of a cell
(a) DNA (b) RNA (c) ATP (d) Minerals

501. Which of the following contains DNA
(a) Mitochondria (b) Lysosomes (c) Golgi bodies (d) Ribosomes

502. Chondrisome was discovered by
(a) Tatum (b) Palade (c) Sutton (d) Benda

503. Foldings of inner mitochondrial membrane are called
(a) Grana (b) Thylakoids (c) Cristae (d) $F_0 - F_1$ Structures

504. Cristae control
(a) Photo-oxidation (b) Photosynthesis (c)Absorption (d) Dark respiration

505. Mitochondrial cristae are sites of
(a) Breakdown of macromolecules (b) Protein synthesis
(c) Phosphorylation of flavoproteins (d) Oxidation – reduction reactions

506. Inner membrane of mitochondria have
(a) TCA enzyme (b) $F_1 - F_0$ particle (c) ATPase (d) All above

507. ATP is formed in
(a) Mitochondria (b) Nucleus (c) Nucleoius (d) Ribosomes

508. One of the following organelle is concerned with photorespiration
(a) Glyoxisomes (b) Ribosomes (c) Mitochondria (d) Lysosomes

509. If the contents of a leaf tissue are carefully fractionated, which of the fractionate could be called alive
(a) Mitochondrion (b) Endoplasmic reticulum (c)Cell wall (d) Ribosome

510. Which one separates the mitochondrial core from outside
(a) Outer membrane (b) Inner membrane (c) Perimitochondrial space (d)All the above

511. The enzymes for Kreb's cycle in mitochondria are located
(a) On the outer membrane (b)On inner membrane
(c) In the mitochondrial matrix (d)Both (b) and (c)

512. Cell organelle which has electron transport system is
(a) Nucleus (b) Mitochondria (c) Endoplasmic reticulum (d) Centriole

513. ETS is component of
(a) Golgi apparatus (b) Mitochondrion (c) Nucleus (d) Microtubule

514. Membrane bound Kreb's cycle enzyme is

(a) Fumarase (b) Cis-aconitase

(c) Succinic dehydrogenase (d)Malate ochydrogenase

515. Centre of phosphorylation is

(a) Oxysome (b) Peroxisome (c) Ribosome (d) Mitochondria

516. Which of the following developments was most instrumental in enabling us to determine mitochondria

(a) Technique of culturing bacteria (b)The electron microscope

(c) The phase constrast microscope (d)All above

517. Presence of DNA in chloroplasts and mitochondria indicates that

(a) Glycolysis occurs in them (b)They originated as independent free living organisms

(c) They undergo meiosis and mitosis independent of nucleus

(d) They take part in ATP synthesis

518. Transformation of chemical energy into utilisable form occurs in

(a) Mitochondria (b) Lysosomes (c) Endoplasmic reticulum (d)Microsomes

519. First plant cell in which mitochondria were observed

(a) Lily (b) Nymphea (c) Nelumbium (d) Nerium

520. Mitochondria are usually found in

(a) Reproductive cells (b) Vegetative cells

(c) Both reproductive and vegetative cells (d) None of these

521. Mesosomes were taken as

(a) Golgi bodies (b) Plastids

(c) Mitochondria (d) Endoplasmic reticulum

522. Mitochondria without its outer membrane is called

(a) Chondriome (b) Chondriole (c) Mitoplast (d) Chondrioide

523. Percentage of mitochondrial DNA in the cells is

(a) 10% of total cellular DNA (b) 1% of total cellular DNA

(c) 2.5% of total cellular DNA (d) None of the above

524. The mitochondrial DNA differs from the nuclear DNA because of

(a) Being linear (b) Having A = T and C ≡ G

(c) Lacking binding histones (d) Being highly twisted

525. Which is absent in Mitochondrial DNA

(a) Basic histone proteins (b)Acidic proteins (c) Protamines (d) All correct

526. Mitochondrial matrix contains

(a) Enzymes (b) DNA and RNA (c) Ribosomes (d) All the above

527. Mitochondrial membranes are

(a) Laminate membranes (b)Bilaminate membranes

(c) Trilaminate membranes (d) None of the above

528. Number of Mitochondria in Trypanosoma chlorella is
(a) 1 (b) 2 (c) 4 (d) Many

529. Mitochondria are yellowish due to
(a) β – carotene (b) Riboflavin (c) Xanthophyll (d) Proplastid

530. The term thylakoid was coined by
(a) Arnon (b) Park and Biggins (c) Menke (d) Willstatter

531. The term plastid was coined by
(a) Haeckel (b) Strasburger (c) Virchon (d) Flemming

532. In which plastids are not found
(a) Blue green algae (b) Bacteria (c) Fungi (d) All of the above

533. Plastids present in unilluminated cells are
(a) Chloroplasts (b) Chromoplasts (c) Leucoplasts (d) Proplastids

534. Plastids possess
(a) Cristae (b) Thylakoids (c) Microtubules (d) Porous membranes

535. All plastids have similar structure because they can
(a) Store starch, lipids and proteins (b)Get transformed form one type to another
(c) Perform same function (d)Be present together

536. Cup shaped chloroplast is found in
(a) Spirogyra (b) Chlamydomonas (c) Ulothrix (d) All above

537. Solar energy is converted into ATP by
(a) Mitochondrion (b) Peroxisome (c) Ribosome (d) Chloroplast

538. Factory for synthesis of sugars in autotrophic eucaryotes in
(a) Chloroplast (b) Mitochondrion (c) Endoplasmic reticulum (d)Ribosome

539. The chloroplasts of algae usually lack
(a) Grana (b) Pigments (c) Quantasomes (d) Lamellae

540. Which one of the following pigments does not occur in the chloroplast
(a) Carotene (b) Chlorophyll 'b' (c) Xanthophyll (d) Anthocyanin

541. Green pigment presents in plants is
(a) Chromoplast (b) Chloroplast (c) Ribosome (d) Lysosome

542. A flattened disc-like sac in a chloroplast is called a
(a) Loculus (b) Thylakoid (c) Stroma (d) Margin

543. Thylakoids are constituents of
(a) Chloroplasts (b) Mitochondria (c) ER (d) Ribosomes

544. Thylakoids are found commonly in the plastids of
(a) Bacteria (b) Blue green algae (c) Higher plants (d) All of these

545. Stroma is the ground material of which of the following
(a) Lysosomes (b) Ribosomes (c) Chloroplasts (d) Mitochondria

546. Chromoplast may be of
(a) Orange colour (b) Red colour (c) Yellow colour (d) All the above

547. The amyloplasts look like

(a) Proplastids (b) Elioplast (c) Aleuroplast (d) Chloroplast

548. Agranal chloroplast are found in some

(a) Succulents (b) Hydrophytes (c) C_4 plants (d) C_3 plants

549. Where do you find cytochromes B_6 and f

(a) Chloroplast (b) Lysosomes (c) Ribosomes (d) Mitochondria

550. The cell within cell organelle is

(a) Amyloplast (b) Aleuroplast (c) Elalioplast (d) Chloroplast

551. Chloroplast, has three membranes, outer inner and

(a) Middle layer (b)Periplastidial space

(c) Thylakoid membrane (d)Stroma lamella

552. Starch in chloroplast is

(a) Assimilatory starch (b) Reserve starch (c) Storage starch (d) Structural

553. Chloroplasts are present in

(a) Companion cell (b) Latex cell (c) Complementary cell (d) Guard cell

554. Star shaped chloroplasts are present in cells of

(a) Zygnema (b) Cladophora (c) Vaucheria (d) Chara

555. Pigment free plastids are

(a) Chloroplasts (b) Chromoplasts (c) Lysosomes (d) Leucoplasts

556. Starch grains in potato tuber are located

(a) Ribosomes (b) Nucleus (c) Leucoplasts (d) Golgi bodies

557. Cell organelles meant for the storage of fats are known as

(a) Amyloplasts (b) Elaioplasts (c) Leucoplasts (d) Aleuroplasts

558. A plant is kept in dark for few days. The cells of leaves in this plant will show

(a) Amyloplast (b) Chromoplast (c) Anthocyanin (d) Etioplast

559. Starch is commonly stored in

(a) Chloroplasts (b) Amyloplasts (c) Chromoplast (d) Leucoplast

560. Which membrane converts the light energy into chemical energy

(a) Thylakoid (b) Biomembrane (c) Nuclear membrane (d) Fret

561. For the synthesis of glucose, source of H atoms is

(a) $NADPH_2$ (b) H_2O (c) H_2S (d) $FADH_2$

562. The chlorophyll pigments are located in the chloroplast in its

(a) Membrane part (b) Grana region (c) Stroma region (d) Intergrana part

563. The role of chlorophyll in photosynthesis is

(a) Dark assimilation (b) Photolysis of water

(c) To absorb light (d) Photochemical conversion

564. Pigment absent in chromoplast

(a) Chlorophyll (b) Carotene (c) Xanthophyll (d) Anthocyanin

565. Carotenes and chlorophyll pigment types can be traced in
(a) Matrix (b) Lamellae (c) Stroma (d) Grana

566. P_{700} is pigment molecule of
(a) Chlororphyll *a* (b) Chlorophyll *b* (c) Carotenoid (d) None of these

567. The pigment which comes out to leaf on boiling in H_2O is
(a) Xanthophyll (b) Carotene (c) Anthocyanin (d) Chlorophyll

568. "Endoplasmic reticulum" was discovered by
(a) Porter (b) Altmann (c) Golgi (d) Benda

569. The endoplasmic reticulum often bears
(a) Lysosomes (b) Centrioles (c) Peroxisome (d) Ribosomes

570. In rapidly dividing cells, endoplasmic reticulum is
(a) Poorly developed (b) Highly developed (c) Absent (d) Non- functional

571. In endoplasmic reticulum the following processes take place
(a) Lipid synthesis (b) Channeling of biosynthetic processes
(c) Steroid synthesis (d) All of the above

572. In plants cells, the dictysomes are derived from
(a) ER (b) Plasma membrane (c) Mitochondria (d) Tonoplast

573. The transfer vesicle from RER fuse with which region of Golgi complex
(a) Cis (b) Medial (c) Trans (d) Protein arms

574. RER is well developed in cells engaged in synthesis of
(a) Nucleotides (b) Proteins (c) Lipids (d) Secretory products

575. RER differs form SER in presence of
(a) Ribosome (b) Ergastic substances (c) Nucleus (d) DNA

576. The name 'cisterna' to lamellae of ER was given by
(a) Porter (b) Claude (c) Sjostrand (d) Kurosumi

577. The term tubule to the network of ER was given by
(a) Sjostrand (b) Porter (c) Kurosumi (d) Claude

578. The word 'ergastoplasm' was coined by
(a) Porter (b) Claude (c) Garnier (d) Sjostrand

579. Sarcoplasmic reticulum is related with
(a) Protein synthesis (b)Hormone synthesis
(c) Release of Ca^{++} ions and contraction of muscles (d)None of these

580. Basophilic region of matrix having granular ER is called
(a) Sarcoplasm (b) Ergastoplasm (c) Phragmoplast (d) Polysome

581. The basophilic staining property of RER is due to
(a) Proteins (b) Ribosomes (c) GERL system (d) DNA

582. SER mainly consists of

(a) Cisternae and tubules (b)Cisternae and vesicles

(c) Vesicles only (d) Tubules and vesicles

583. SER is concerned with

(a) Wall synthesis (b) Protein synthesis (c) Detoxification (d) All of these

584. Endoplasmic reticulum arises form

(a) Nuclear membrane (b) Golgi system (c) Cell membrane (d) ER itself

585. ER increases surface area and give mechanical support to cell by acting as cytoskeleton. It forms

(a) > 25% of total membranes in cell (b) > 50% of total membranes in cell

(c) > 10% of total membranes in cell (d) Hardly 1% of total membranes

586. The proteins synthesized on RER are packaged into transport vesicles by SER. These vesicles are modified and packaged into secretory vesicles by

(a) Golgi complex (b) Lysosomes (c) Ribosomes (d) Cell membrane

587. Proteins (export proteins) that are to be used outside the cell are synthesized

(a) In mitochondria (b) On SER (c) On RER (d) On free ribosomes

588. Golgi body originated from

(a) Lysosome (b) Endoplasmic reticulum

(c) Mitochondria (d) Cell membrane

589. Main function of which organelle is secretory

(a) Lysosomes (b) Mesosomes (c) Golgi apparatus (d) Microtubules

590. The major role of Golgi bodies is

(a) Fermentation (b) Phosphorylation (c) Glycosidation (d) Translocation

591. Golgi bodies are absent in

(a) Plants (b) Bacteria (c) Animals (d) Eukaryotic cells

592. Golgi bodies are maximum in

(a) Calyptrogen (b) Root cap (c) Root tip (d) None of these

593. The golgi apparatus contains

(a) DNA (b)RNA

(c) Phospholipids, protiens enzymes and vitamin C (d)Protein-lipid-protein

594. Dictyosomes are

(a) Class of ribosomes (b) Place of flagellar organelles

(c) Respiratory particles (d) Golgi bodies (of plant cells)

595. GERL is associated with

(a) Lysosomes (b) Golgi body (c) Mitochordria (d) Lomasomes

596. The functional unit of golgi apparatus is

(a) Thylakoid (b) Oxysomes (c) Cristae (d) Cisternae

597. Other than acrosomal synthesis golgi bodies are concerned with synthesis of
(a) Photosynthetic pigments
(b) Hydrolytic enzymes as hyaluronidase
(c) Cell plate (d) All above

598. The cell organelle containing the flattened membrane bounded cisternae are located near the nucleus are
(a) Mitochondrion (b) Golgi (c) Centrioles (d) Nucleolus

599. Golgi apparatus serves as the centre of
(a) Protein production (b) Enzyme production
(c) Fat production (d) Carbohydrate metabolism

600. Golgi bodies are connected with
(a) Grana (b) Cell plate (c) Plastids (d) Lomosomes

601. Golgi complex is specialised for
(a) Glycosidation of lipids and proteins (b)Conversion of light energy into chemical energy
(c) Energy transduction (d)Digestion of carbohydrates and proteins

602. Cellulose and hemicellulose the constituents of cell wall are synthesized by
(a) Lysosomes (b) Microbodies
(c) Smooth endoplasmic reticulum (d) Golgi apparatus

603. Golgi appratus was first seen by
(a) George (b) Golgi (c) Cajal (d)Robinson and Brown

604. Who studied golgi apparatus for the first time
(a) Golgi (b) George (c) Cajal (d) Koltzoff

605. Golgi complex is not found in
(a) Nerve cells (b) RBCs (c) Germ cells (d) All the above

606. Golgi apparatus is found in
(a) Cryptogams only (b) Phanerogams only
(c) Procaryotic only (d) Eucaryotic cells

607. Cell organelle specialised in forming acrosome part of sperm is
(a) Mitochondrion (b) Centriole (c) Peroxisome (d) Golgi apparatus

608. Golgi apparatus receives biochemicals with the help of transition vesicles formed by
(a) E.R (b) Plasmalemma (c) Lysosomes (d) Nuclear blebs

609. A cell organelle with a definite polarity is
(a) Ribosome (b) Mitochondrion (c) Golgi apparatus (d) Chloroplast

610. Isolated units of Golgi apparatus found in plant cells are called
(a) Golgisomes (b) Dictyosomes (c) Lipochondria (d) Cisternae

611. Which one is the function of Golgi apparatus
(a) Cell plate formation (b) Matrix formation of connective tissue
(c) Secretion of tears (d) All the above

612. The term 'dictyosome' was coined for golgi because it means
(a) Globular body (b) Spherical bodies (c) Stack like bodies (d) Flattened bodies

613. One of the organelle showing polarity is
(a) Ribosomes (b) DNA (c) Golgi bodies (d) Lysosomes

614. The main enzyme in dictyosomes is
(a) Raphides (b) Nucleoside diphosphatase
(c) Glucose 6-phosphatase (d) None of the above

615. An organel rich in fat is
(a) ER (b) Golgi complex (c) Lysosome (d) Centriole

616. Dictyosomes are scattered and unconnected in
(a) Plant cells (b) Animal cells (c) Bacteria (d) Blue green algae

617. The Golgi apparatus is mainly concerned with the synthesis of
(a) Cellulose (b) Hemicellulose (c) Pectin (d) All above

618. Cell organelle connected with cell plate formation/ phragmoplast is
(a) ER (b) GERL (c) Lomasomes (d) Dictyosomes

619. Golgi apparatus is connected with
(a) Photosynthesis (b) Protein synthesis (c) Egg synthesis (d) Cellular synthesis

620. Besides giving out secretory vesicles, Golgi apparatus has important role in formation of
(a) Grana of chloroplasts (b) Lysosomes
(c) Plastids (d) Cell plate formation during cell division

621. The golgi apparatus is bounded by
(a) Cellulose (b) Hemicellulose (c) Pectin (d) None of the above

622. The secretory material is discharged the golgi vesicles, from the surface of cell membrane by
(a) Pinocytosis (b) Endocytosis
(c) Reverse pinocytosis (d) Dissolving the cell membrane

Advance Level

623. Prokaryotic origin of mitochondria was proposed by
(a) Rabinowitch (b) Altmann and schimper (c)Salton (d) Morrison

624. Importance of mitochondria in respiration was first discovered by
(a) S. Madani (b) Meves (c) Michaelis (d) Barbergan

625. Mitochondria are the store- houses of or power house of
(a) Fats (b) ATP (c) Glucose (d) Glycogen

626. In which part of mitochondria, ATP is generated
(a) Matrix (b) Cristae
(c) Outer membrane (d) F_1 particles (oxysomes)

627. ATP is

(a) Adenosine D-ribose three phosphate (b) Adenosine L- ribose three phosphate

(c) Adenine D- ribose three phosphate (d) Adenine L-ribose three phosphate

628. The site for cellular respiration is

(a) Nucleus (b) Ribosome (c) Mitochondria (d) ER

629. In prokaryotes, the mitochondria are absent even then Kreb's cycle takes place. What is the site of Kreb's cycle in bacteria

(a) Ribosomes (b) Nucleoid (c) Cytoplasm (d) Plasma membrane

630. In which of the following parts of mitochondria succinic dehydrogenase enzymes is located

(a) Outer membrane (b) Inner membrane

(c) Perimitochondrial space (d) Matrix

631. Mitochondria are similar to

(a) Prokaryotes (b) Plasmids (c) Plastids (d) Viruses

632. If living cells similar to those found on earth, were found on another planet, where there was no oxygen. Which cell organelle would most probably be absent

(a) Cell membrane (b) Ribosomes (c) Mitochondria (d) Chromosomes

633. Mitochondria supply most of the necessary biological energy by

(a) Breaking down of sugar (b)Oxidizing substrates of TCA cycle

(c) Reducing NADP (d) Breaking down of protein

634. The presence of DNA in mitochondria and chloroplast supports the hypothesis that

(a) Mitochondria and chloroplast both originated as independent free living organisms

(b) Glycolysis occurs in mitochondria and chloroplast both

(c) ATP is produced in mitochondria and chloroplast both

(d) Mitchondria and chloroplast undergo meiosis and mitosis independent of nucleus

635. Autonomic genome system is present in

(a) Ribosomes and chloroplasts (b)Mitochondria and ribosomes

(c) Mitochondria and chloroplasts (d) Golgi bodies and mitochondria

636. If a biochemical analysis of mitochondria is to be done the best procedure would be

(a) Grind the cell and filter out the mixture and take the debris

(b) Subject the cells to cell differentiation (centrifuge)and obtain mitochondria

(c) Select cells which have a large number of mitochondria

(d) Plasmolyse the cell, filter it and take the debris

637. Which one of the following is attached to the surface of mitochondrial cristae

(a) Ribosomes (b) Oxysomes (c) Peroxysomes (d) Mesosomes

638. DNA is present in

(a) Nucleus only (b) Mitochondrion only (c) Chloroplast only (d) All the above

639. Which of the cell organelles are devoid of deoxy ribonuleic acid

(a) Mitochondria and nucleus (b)Chloroplast and mitochondria

(c) Nucleus and chloroplast (d)Lysosome and dictyosome

640. Which of the following cell organelle is considered to be rich in catabolic enzymes

(a) Endoplasmic reticulum (b)Lysosome (c) Golgi body (d) Mitochondria

641. An organelle shows a highly folded inner wall ultrasonic disruption of the organelle yeild fragments which are capable of synthesising ATP the organelle must be

(a) Mitochondrion (b) Chloroplast

(c) Ribosome (d) Mitochondria and chloroplast

642. The diameter of mitochondria is

(a) $0.5-2\,\mu m$ (b) $5-20\,\mu m$ (c) $500-1000\,\mu m$ (d) $150-300\,\mu m$

643. The inner membrane of mitochondria bears foldings/finger like projections called cristae. These cristae

(a) Increase the thickness of wall (b)Increase surface area

(c) Increase ATP Supply (d) Keep external substance away

644. Outer and inner membranes of mitochondria are

(a) Structurally and functionally similar (b) Structurally and functionally dissimilar

(c) Structurally similar but functionally different

(d) Structurally different but functionally similar

645. Inner mitochondrial membrane possesses enzymes

(a) ATP-synthetase, succinate dehydrogenase and respiratory chain enzymes

(b) NADH-cytochrome reductase and monomeric oxidase

(c) Malate and isocitrate dehydrogenases, fumarate, aconitase and citrate synthetase

(d) Adenylate kinase and nucleoside diphosphokinase

646. Reduced coenzymes are regenerted in electron transport system by

(a) Loss of hydrogen (b) Addition of hydrogen (c) Loss of electrons (d) Gain of electrons

647. Besides nucleus, DNA is also present in

(a) Mitochondrion outer surface (b)Golgi apparatus

(c) In perimitochondrial space (d)In mitochondrial matrix

648. Mitochondria are absent in

(a) Fungi (b) Methanobacteria

(c) Pteriodophytes (d) Angiosperms

649. Mitochondria arises

(a) By growth and division of pre-existing mitochondria

(b) From non- mitochondrial membranes

(c) From precursors of the cytoplasm (d) None of these

650. Mitochondria are numerous and densely packed in

(a) Inactive tissues (b) Less active tissues (c) Very active tissues (d) Damaged tissues

651. Mitochondria in the living cell can readily be identified from other organelles of the cell through light microscope by using

(a) Cotton blue (b) Osmic acid (c) Janus green (d) Lead citrate

652. Which of the following observations most strongly support the view that mitochondria contain electron transfer enzymes aggregated into compact association

(a) Mitochondria have a highly folded inner wall

(b) Disruption of mitochondria yields membrane fragments which are able to synthesize ATP

(c) Mitochondria in animal embryos have a tendency to concentrate in cells which are to become a part of locomotory structure

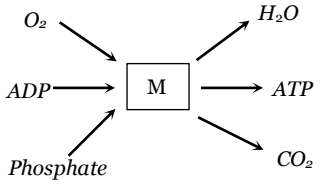
(d) A contractile protien capable of utilising ATP has been obtained from mitochondria

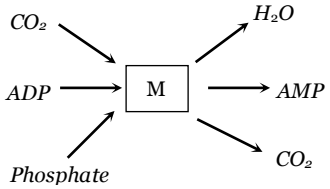
653. Chondriospheres are formed due to

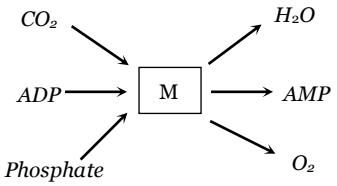
(a) Fusion of mitochondria (b)Division of mitochondria

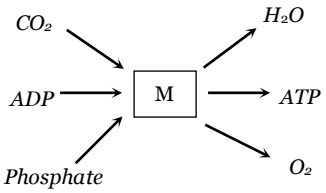
(c) DNA replication (d)Transcription

654. Which of the following representation correctly explain the function of mitochondrion

(a) 

(b) 

(c) 

(d) 

655. The mitochondrial membranes are not permeable to

(a) Pyruvic acid (b) Coenzyme A (c) NAD (d) Both (b) and (c)

656. The base piece of F_1 particles contains the enzymes of electron transfer chain (respiratory chain), while the head piece contians the enzymes of ATPase system (ATP synthetase), was suggested by

(a) Maclenan (b) Green (c) Baum (d) all above

657. Which of the following sets of cell organelles contains DNA

(a) Mitochondria, ribosomes and chloroplasts (b) Nucleus, ribosomes and chlororplasts

(c) Nucleus, ribosome and mitochondria (d) Nucleus, mitochondria and chloroplasts

658. If a living cell is placed under anaerobic condition

(a) Mitochondria will multiply (b) Mitochondria will disappear

(c) ER will disappear (d) None of these

659. From recent studies it has been found that pre-existing plastids arise from

(a) Bodies called proplastids (b) The nucleus

(c) The vacuole (d) The cell wall

660. All plastids have essentially same structure because

(a) They have to perform same function

(b) They are localized in aerial parts of plant

(c) All plastids store starch, lipid and proteins

(d) One type of plastids can be differentiated into another type of plastid depending on cell requirements

661. The thylakoid in chloroplast are arranged as

(a) Interconnected disc (b) Interconnected sacs (c) Stacked discs (d) None of these

662. If the leaf tissue are carefully fractionated what parts should we get alive

(a) Endoplasmic reticulum (b)Chloroplasts (c) Cell wall (d) Ribosomes

663. The main difference between chlorophyll '*a*' and '*b*' is

(a) Chlorophyll '*a*' is linear chain compound and '*b*' is branched chain

(b) Chlorphyll '*a*' has no Mg^{+} ion in centre of molecule

(c) In chlorophyll '*a*' there is CH_3 group whereas in '*b*' it is *–CHO* group

(d) All of the abve

664. The presumed size of chlorophyll molecules is

(a) Head–15 × 15Å, Tail –20 Å (b)Head–10 × 12Å, Tail –15 Å

(c) Head–20 × 20Å, Tail –25 Å (d)Head–15 × 15Å, Tail –25 Å

665. The term chromatophore was coined by

(a) Schmitz (b) Comparethi

(c) W. Pfeffer (d) Singer and Nicolsan

666. The colour of chromatoplast can be

(a) Yellow (b) Red (c) Orange (d) All of these

667. Anthocyanins are grouped under

(a) Phenols (b) Tannins (c) Carbohydrates (d) Alkaloids

668. When green tomatoes fruits turn to red, then

(a) Chloroplasts are disintegrated and get converted into chromoplasts

(b) New chromoplasts are formed

(c) Chromoplasts are changed to chloroplasts

(d) None of these

669. The bright colours of ripe fruits are due to

(a) Leucoplasts (b) Chloroplasts (c) Amyloplasts (d) Chromoplasts

670. A typical parenchyma cell does not contain

(a) Nucleus (b) Chloroplast (c) Central vacuole (d) Cell wall

671. Extranuclear DNA is found in

(a) Chloroplast (b) Ribosome (c) Endoplasmic reticulum (d)Golgi apparatus

672. Orange yellow colours of flowers and fruits are due to

(a) Chloroplasts (b) Leucoplasts (c) Aleuroplasts (d) Chromoplasts

673. Chloroplast fix

(a) N_2 (b) H_2 (c) O_2 (d) CO_2

674. In chloroplast, chlorophyll is present in the

(a) Thylakoids (b) Stroma (c) Outer membrane (d) Inter membrane

675. Quantasome discovered by Park and Biggins (1964) has

(a) 100 chl molecules (b) 300 chl molecules

(c) 230 chl molecules (d) 230 chl and 50 carotenoid molecules

676. Solar energy is trapped in

(a) Stroma (b) Lamellae (c) DNA (d) Oxysomes

677. Which element forms nucleus of porphyrin ring of chlorophyll

(a) Fe^{++} (b) Fe^{+++} (c) N (d) Mg^{++}

678. Pyrenoids are centre of

(a) Fat storage (b) Starch storage (c) Protein formation (d) Enzyme formation

679. Chlorophyll '*b*' is characterised by the side group

(a) Methyl (b) aldehyde (c) Phytol (d) Formyl

680. Chlorophyll '*a*' is characterised by the side group

(a) Methyl (b) Aldehyde (c) Phytol (d) Ketone

681. A piece of carrot and an flower is put in water separately. The water becomes purple in case of carrot but remain colourless in flower case. It is because

(a) In carrot, Anthocyanin pigments are found in cell sap which are water soluble

(b) In flowers, carotenoid pigments are fat soluble and found in chromoplast and not come out in water

(c) In flowers pigments are found in cytoplasm while in carrot, pigments are localized in vaculoes

(d) Both (a) and (b)

682. Green plants obtain energy from sun though chloroplasts. These cell organelle provide energy to plants by absorbing from the solar spectrum

(a) Green and blue colours (b)Violet and blue colours

(c) Violet and green colours (d) Green and red colours

683. A pigment in carotenoid is found in Bacteria and Fungi. It is

(a) Fucoxanthin (b) Lycopene (c) Capsanthin (d) Xanthophyll

684. A granum has a stack of how many thylakoids

(a) 40–100 (b) 20–40 (c) 4–30 (d) 40–60

685. The amount of DNA per chloroplast is

(a) 100–200 g (b) $100^{-15}\,g$ (c) $10^{-15}\,g$ (d) 10% of dry weight

686. Chloroplast is semiautonomous body. It has naked prokaryotic type of double stranded circular DNA, which was observed by

(a) Nass and Nass (b) Ris and Plaut (c) Watson and Crick (d) Meyer

687. Structural and functional part of chloroplast is respectively

(a) Stroma and grana (b) Grana and thylakoids

(c) Thylakoids and quantasomes (d) Grana and quantasomes

688. The parallel layering of membranes in chloroplast is suited for

(a) Maximum light absorption

(b) Maximum exposure of enzymes

(c) Minimum light absorption so that the cells can maintain their temperture

(d) All the above

689. Anthocyanins are pigments which are

(a) Water soluble and located in chromoplasts (b) Water insoluble and located in chromoplasts

(c) Water insoluble and located in cell sap (d) Water soluble and located in cell sap

690. Some metallic ions present in chloroplast are

(a) *Fe, Br, I* and *k* (b) *F, K ,I* and *Fe* (c) *Fe, Cu, Mn,* and *Zn* (d) *Cu, K, I* and *P*

691. The chloroplast of polyploid cells are comparatively

(a) Larger than the chloroplast of diploid cells (b) Smaller than the normal diploid cells

(c) Do not show any change (d) Chloroplast is deleted

692. Fret channels are associated with

(a) Two grana of a chloroplast (b)Two lamellae of a granum

(c) Two plastids of a cell (d)Two quantasomes

693. Pigment anthocyanin is located in

(a) Chloroplast (b) Chromoplast (c) Cytoplasm (d) Vacuole

694. Number of thylakoids per granum is one in

(a) Red algae (b) Green algae (c) Leaf of pea plant (d) Leaf of gram

695. Which of the following is related to glycosylation of protein

(a) ER (b) Peroxisome (c) Lysosome (d) Mitochondria

696. Endoplasmic reticulum is more developed in

(a) Green cells (b) Young cells (c) Mature cells (d) Bacteriophage

697. RER endoplasmic reticulum is mainly concerned with

(a) Proteolysis (b) Fatty acids synthesis

(c) Peptide bond formation (d) Chloesterol synthesis

698. SER produces

(a) Protein (b) Carbohydrate (c) Lipid (d) Nucleic acid

699. When the region of endoplasmic reticulum are studded by ribosome on their outer surface of the cisternae, It is called

(a) Sarcoplasmic reticulum (b)Smooth endoplasmic reticulum
(c) Granular endoplasmic reticulum (d)None of these

700. One of the following serves as a temporary storage place for proteins and other compounds synthesized by endoplasmic reticulum

(a) Lysosomes (b) Sphaerosomes (c) Microsomes (d) Dictyosomes

701. The most important function of endoplasmic reticulum is

(a) Protein synthesis (b)Nourishing the nucleus
(c)Secretion of materials (d)To give shape to the cell

702. Disulphide bonds which acts as atomic staples to reinforce the conformation of proteins are found in

(a) Endoplasmic reticulum (b)Lysosome (c) Golgi apparatus (d) Cytosol

703. In plant cells the number of golgi bodies increases during

(a) Cell division (b) Food synthesis (c) Translocation (d) Respiration

704. The enzyme present in golgi bodies is

(a) PEP carboxylase (b) Peptidyl transferase (c) Thymine ligase (d) Glycosyl transferase

705. Which is not function of golgibody

(a) Secretion (b) Formation of plasmamembrane
(c) Fat synthesis (d) Cell wall formation

706. Secretory and membrane proteins are processed

(a) Peroxysomes (b) Glyoxysomes (c) Golgi complex (d) Sphaerosomes

707. Zone of exclusion is associated with

(a) Golgi complex (b) Endoplasmic reticulum (c)Mitochondria (d) Chloroplast

708. Which of the following is responsible for mechanical support enzyme transport and protein synthesis

(a) Dictyosomes (b) Cell membrane (c) Mitochondria (d) Endoplasmic reticulum

709. Golgi apparatus is commonly present in

(a) Near mitochondria (b) Near chloroplast (c) Perinuclear area (d) Germ cells

710. Export house of cell is

(a) E.R (b) Golgi body (c) Nucleus (d) lysosome

711. Golgi was able to differntiate Golgi apparatus through

(a) Phase contrast microscopy (b)Metallic impregnation technique
(c) Electron microscopy (d) Special redox dye

712. Metallic stain used by Golgi was

(a) Lead acetate (b) Osmium chloride and silver salts

(c) Phosphotungstate (d) Palladium

713. Golgi apparatus was first seen under electron microscope by

(a) Novikoff (b) Dalton and Felix (c) Rhodin (d)De Robertis and Franchi

714. On which side of Golgi apparatus are the membranes thin

(a) Concave distal side (b) Concave proximal side

(c) Convex distal side (d) Convex proximal side

715. Golgian vacuoles develop from

(a) Tubules (b) Convex proximal cisterna

(c) Concave distal cisterna (d) Transition vesicles

716. Amongst plants, golgi apparatus is absent in

(a) Sieve tube cells (b) Sperms of bryophytes

(c) Sperms of pteridophytes (d)All of these

717. The term 'trophospongium' for golgi complex was given by

(a) Dalton (b) Camillo (c) Holmgren (d) Sjostrand

718. Golgi bodies were discovered by Golgi from nerve cells of born owl and cats by a technique of

(a) Cell fractination (b) Metal silver impragnation

(c) Janus green (d) Osmium tetraoxide

719. Secrotory vesicles are pinched off as zymogen granules from —— side of dictyosomes

(a) Convex (b) Concave (c) Plain (d) All sides

720. The number of cisternae in each stack of Golgi apparatus of animals cells is

(a) 1 (b) 4-8 (c) 1-50 (d) 10-30

721. The maximum number of cisternae in plant cells can be

(a) 20 (b) 5 (c) 2 (d) 10

722. Chemicals of Golgi complex comprises

(a) Proteins (b) Phospholipids

(c) Cephaline (d) Protiens and Phospholipids

723. Flattened sacs of Golgi are separated from each other by a space which is

(a) 13Å (b) 130 Å (c) 115 Å (d) 300 Å

724. The number of Golgi bodies during cell division of plants and animals

(a) Increases (b) Decreases

(c) Remains constant (d) Increases many folds

MICRO CELLORGANELLES

Basic Level

725. Lysosomes as known as suicidal bags because of
(a) Phagocytic activity (b) Hydrolytic enzymes (c) Parasitic on nucleus (d) Proteolytic enzymes

726. Which of the following cell organelle lacks DNA and bounding membrane
(a) Ribosome (b) Plastid (c) Nucleolus (d) Plasmid

727. Lysosome along with the food content is called
(a) Primary lysosome (b) Secondary lysosome (c) Residual bodies (d) Cytosome

728. Secondary lysosomes are also called
(a) Autophagic vacuoles (b)Lipofuscin granules (c)Residual body (d) Heterophagosomes

729. Lysosomes are so called because these contain
(a) Carboxylating enzymes (b) Respiratory enzymes
(c) Oxidizing enzymes (d) Digestive enzymes

730. Which is concerned with autolysis
(a) Ribosome (b) Golgi bodies (c) Lysosome (d) Oxysome

731. Lysosomes are surrounded by how many membranes
(a) One (b) Two (c) Three (d) Four

732. The main function of lysosomes is
(a) Digestion (b) Replication (c) Translation (d) Translocation

733. What would happen if lysosomes get ruptured inside the cells in which they are present
(a) Cells will swell (b) Cells will shrink (c) Cells will die (d)Nothing would happen

734. Lysosomes were discovered by de Duve accidently. Who gave the term lysosome and examined under election microscope
(a) Fitz James (b) Novikoff (c) Palade (d) Robertson

735. Which cell organelle reduces the number of other organelles
(a) Oxysome (b) Lysosome (c) Mitochondria (d) None of these

736. Lysosomes contain
(a) Acid phosphatase (b) Hormones (c) Various enzymes (d) Both (a) and (c)

737. Most of hydrolytic enzymes of lysosomes function at
(a) Acidic *pH* (b) Basic *pH* (c) Neutral *pH* (d) Any *pH*

738. The membrane bag of hydrolytic enzymes used for the controlled intracellular digestion molecules is a
(a) Phagosome (b) Nucleosome
(c) Lysosome (d) Endoplasmic reticulum

739. Which lysosomes are scavenging in function
(a) Primary (b) Secondary (c) Tertiary lysosomes (d) Autolysosomes

740. The size of lysosome varies from
(a) $1.2-1.8\,\mu m$ (b) $2.5-3.5\,\mu m$ (c) $0.1-0.5\,\mu m$ (d) $0.2-0.8\,\mu m$

741. Cathepsins are a type of enzymes in lysosomes, that help in digestion of
(a) Proteins (b) Fats (c) glycosides (d) Sulphates

742. Which organel converts cellular polymers into monomers
(a) Lysosomes (b) Golgi bodies (c) SER (d) Plastide

743. Lysosomes arise through the
(a) Golgi complex (b) SER (c) RER (d) GERL system

744. Lysosomes containing inactive enzymes are called
(a) Primary lysosomes (b) Secondary lysosomes (c) Autophagosomes (d) Residual bodies

745. Sphaerosomes are commonly present in
(a) Prokaryotic cells (b) All eukaryotic cells
(c) Lipid secreting and storing cells (d) Fast respiring cells

746. Sphaerosomes found in lipid storing cells originate form
(a) Mitochondria (b) SER (c) RER (d) Golgi complex

747. Spherosome have affinity for
(a) Suden III (b) Eosin stains (c) Leishman's stain (d) Giemso's stains

748. Which one of the following is present outside the plasma membrane but inside the cell wall
(a) Sphaerosome (b) Peroxisome (c) Lomasome (d) Golgi body

749. Who discovered "ribosomes" in animal cells
(a) Watson (b) Talvim (c) Cowdry (d) Palade

750. All are membrane bound cell organelles except

Or

Which of the following cell organelles lacks a unit membrane
(a) Mitochondria (b) Lysosomes (c) Sphaerosomes (d) Ribosomes

751. The functional unit in the synthesis of protein is
(a) Peroxisome (b) Dictyosome (c) Lysosome (d) Polysome

752. The site of protein synthesis in plants is the
(a) Chloroplast (b) Ribosome (c) Pyrenoids (d) Mitochondria

753. Ribosomes are the site for
(a) Photosynthesis (b) Protein synthesis (c) Respiration (d) Fat synthesis

754. The proteins are synthesized at
(a) Ribosomes (b) Mitochondria (c) Centrosomes (d) Golgi bodies

755. Which of the following statements is wrong for ribosome
(a) Formed by two sub units
(b) Formed by ribo-protein
(c) Formed in chain (d)Both sub-units are bounded by a membrane

756. Which of the cell organelles is smallest
(a) Nuclei (b) Ribosome (c) Microsomes (d) Vacuole

757. Ribosomes are made up of
(a) DNA and protein (b) DNA alone (c) RNA and protein (d) RNA and DNA

758. The 80S ribosomes are present in
(a) Eucaryotic cells (b) Procaryotic cells (c) Bacterial cells (d) Cyanobacterial cells

759. The larger sub-unit in 80S ribosome is
(a) 50S (b) 60S (c) 40S (d) 0 S

760. Eukaryotic 80S breaks into
(a) 40S and 40S (b) 60S and 40S (c) 60S and 50S (d) 50S and 30S

761. 70S type of ribosome shows two units whose sedimentation constants are
(a) 40S and 30S (b) 50S and 20S (c) 50S and 30S (d) 60 S and 20S

762. Which type of ribosomes are found in Nostoc cells
(a) 50S (b) 60S (c) 70S (d) Eukaryotic

763. The bacterial ribosomes are of
(a) 50S type (b) 70S type (c) 30S type (d) 80S type

764. Ribosomes are produced in
(a) Nucleolus (b) Mitochondria (c) Cytoplasm (d) Golgibody

765. The most abundant ribosomes amongst the following will be in..... plant cells
(a) Meristematic (b) Dead (c) Parenchymatous (d) Lignified

766. Delimiting membrane is absent in
(a) Mitochondria (b) Chloroplast (c) Nucleus (d) Ribosome

767. Ribosomes form association with mRNA to form
(a) Polyribosomes (b) Protein ribosome complex
(c) Ribosomal complex (d) All of these

768. The site of protein synthesis in an animal cell is
(a) Ribosomes attached to mRNA (b)Ribosomes attached to RER
(c) Ribosomes attached to nuclear envelope (d) Both (a) and (b)

769. Ribosomes in nucleoplasm were discovered by
(a) Tsao and Sato (b) Brown and Strasburger (c)Palade and Robinson (d)Meyer

770. The cytoplasm of bacteria is granular due to
(a) Glycogen granules (b) Volutin particles (c) Ribosomes (d) Chromatin network

771. The size of ribosomes varies from
(a) 100–150 Å (b) 60 –100Å (c) 150–250Å (d) 200–300Å

772. The ribosome are
(a) Positively charged (b) Negatively charged (c) Amphipathied (d) None of these

773. Ribosomes are synthesized in
(a) Nucleus (b) Nucleolus (c) Cytoplasm (d) Nucleoplasm

774. Which of the following statement is correct with respect to ribosomes
(a) They remain united in absence of protein synthesis
(b) *Mg* concentration affects the binding of two subunits
(c) More important for protein synthesis is larger subunit (d) None of these

775. Ribosomes are attached to ER through
(a) rRNA (b) Hydrophobic attraction (c)Ribophorins (d) tRNA

776. Ribosomes differ from cell to cell/species to species in
(a) Types of proteins (b) Types of rRNA (c) Mg^{++} concentration (d) All of these

777. On the basis of sedimentation value, how many types of RNA are present in 70 S ribosome
(a) Two types (b) One type (c) Three types (d) Four types

778. rRNA protein ratio of 80 S ribosome is
(a) 40–44: 56–60 (b) 45–50 : 50-55 (c) 50 – 55 : 45 – 50 (d) 60 – 65 : 35 –40

779. rRNA present in 40S subunit of ribosome is
(a) 5S (b) 5.8S (c) 16S (d) 18S

780. rRNA present in 40S subunit of ribosome is
(a) 5S (b) 5.8S (c) 28 S (d) None of these

781. rRNA present in 50S subunit of ribosome is
(a) 23S (b) 5S (c) Both (a) and (b) (d) 23S, 5.8S and 5.8

782. Sedimentation unit of ribosome is
(a) μ(micron) (b) $m\mu$(mili micron) (c) Å (Angstrom) (d) S (Svedberg)

783. The only organelle found in PPLO is
(a) Nucleus (b) Ribosomes (c) Plastids (d) Vacuoles

784. Which one of the following pairs is membraneless
(a) Lysosomes and Ribosomes (b)Ribosomes and Microtubules
(c) Ribosomes and Flagella (d)Ribosomes and Dictyosomes

785. Plants can convert fatty acids into sugar by
(a) Glycolysis (b) Glyoxylate cycle (c) Photorespiration (d) Kreb's cycle

786. 'Glyoxysome' term was coined by
(a) Kreb (b) Breiden back and Beevers (c)Rhodin (d) Both (b) and (c)

787. Series of reactions which convert fatty acids to sugars in plants but not in animals is
(a) Krebs cycle (b) Glyoxylate cycle (c) Ornithine cycle (d) Glycolysis

788. Glyoxylate cycle occurring in glyoxysomes is a modified form of
(a) Kreb's cycle (b) Calvin cycle (c) Glycolysis (d) Glycolate cycle

789. Glyoxysome occur in
(a) Both plant and animal cells (b)Plant cells only (c)Animal cells only (d) All types of cells

790. Fat storing microbodies are
(a) Peroxisomes (b) Glyoxysomes (c) Lysosomes (d) Residual bodies

791. Glyoxysomes are seat of ..... metabolism
(a) Fat (b) Carbohydrate (c) Protein (d) All of these

792. β-oxidation of fatty acids in liver cells is mainly carried by
(a) Lysosomes (b) Glyoxysomes (c) Autophagic vacuoles (d)Peroxisomes

793. Glyoxysomes are abundant in germinating seeds of
(a) Pea (b) Castor (c) Maize (d) Wheat

794. Urate oxidase occurs in
(a) Lomasomes (b) Peroxisomes (c) Mitochondria (d) Glyoxysomes

795. Peroxisomes, in plant cells, are involved in
(a) Photooxidation (b) Photorespiration
(c) Photophosphorylation (d) Photolysis of water

796. What is degraded by peroxisomes
(a) Carbon dioxide (b) Hydrogen peroxide (c) Hydrogen (d) Carbon monoxide

797. Peroxisomes are rich in
(a) DNA (b) RNA (c) Catalytic enzymes (d) Oxidative enzymes

798. Glycolate metabolism occurs in
(a) Lysosome (b) Ribosomes (c) Glyoxysomes (d) Peroxisome

799. Peroxisomes contain
(a) Hydrolysing enzymes (hydrolases) (b) Oxidising enzymes (oxidases)
(c) Transferases (d) Isomerases

800. During photorespiration, hydrogen peroxide is broken down with the help of three organalles into water and oxygen with the help of
(a) Peroxidases (b) Oxidases (c) Catalases (d) None of these

801. Who among the following discovered role of peroxisomes in plant
(a) Tolbert (b) Porter (c) Palade (d) Lutz

802. Which organelle protects the cell from the effect of hydrogen peroxide
(a) Lysosomes (b) Peroxisomes (c) Glyoxysomes (d) Sphaerosomes

803. The organelle involved in photorespiration are
(a) Mitochondria, chloroplast and peroxisomes (b) Mitochondria, nucleus and ribosomes
(c) Mitochondria glyoxysomes and peroxisomes (d) Mitochondria, chloroplat and glyoxysomes

804. Rhodin in 1995 discovered peroxisomes in
(a) Germinating seeds (b) Fat storing cells (c) Kidney tissue (d) Brain cells of mouse

805. Enzymes concerning H_2O_2 metabolism are present in
(a) Golgi bodies (b) rRNA (c) Peroxisomes (d) Chloroplasts

806. Peroxisome do not have
(a) *D*-amino acid oxidase (b)*B*-hydroxy acid oxidase(c)Urate oxidase (d) Amylase

807. Which of the following parts of a cell is non-living
(a) Centriole (b) Vacuole (c) Ribosomes (d) Mitochondria

808. Hyaloplasm of vacuole contains
(a) Air (b) Water (c) Water and Minerals (d) Nothing

809. In plant cells the site of storage of minerals is
(a) Golgi body (b) Mitochondria (c) Peroxisomes (d) Vacuole

810. Most of the water in turgid plant cells occurs chiefly
(a) In the nucleus (b) In the vacuole (c) In the cell wall (d) In the cytoplasm

811. Cell vacuole contains

(a)Water (b) Metabolic gasses

(c) Water and dissolved substances (d) Cytoplasm

812. Water soluble pigment present is cell sap of rose petal is

(a) Anthocyanin (b) Carotene (c) Xanthophyll (d) Chlorophyll

813. Colour of rose petal is due to water soluble pigment present in

(a) Cytoplasm (b) Intracellular spaces (c) Nucleus (d) Vacuoles

814. The pigment in flower petals equal to melannin of animals can be traced in

(a) Cell sap of epidermal cells (b) Vacuoles

(c) Intercellular spaces (d) Both (a) and (b)

815. Anthocyanin occurs in

(a) Cell sap (b) Vacuoles (c) Chloroplasts (d) Both (a) and (b)

816. Vacuole is surrounded by

(a) Plasmalemma (b) Cell wall (c) Tonoplast (d) Plasmodesmata

817. Vacuoles help in

(a) Storing wastes and food particles (b) Separating water from cytoplasm

(c) Making cell light (d) None of these

818. A large and mature plant cell has

(a) Many vacuole (b) No vacuole

(c) A large vacuole (d) Many small vacuoles and a large vacuole

819. pH of vacuolar cell sap is

(a) Acidic and hypertonic (b) Alkaline and hypotonic

(c) Neutral and isotonic (d) Equal to cytoplasm and isotonic

820. The contents of food vacuoles in *Amoeba* are

(a) Acidic (b) Alkaline

(c) First acidic and then alkaline (d) First alkaline and then acidic

821. Most common element and organic acid in sap vacuole

(a) K^+, acetic acid (b) Ca^{++}, citric acid (c) K^+, oxaloacetic (d) Ca^{++}, acetic acid

822. The main structure of centriole is

(a) 9 + 3 fibrils (b) 9 + 2 fibrils (c) Nine triplets (d) 13 globular subunits

823. Centrosome is found in

(a) Nucleus (b) Nucleolus (c) Cytoplasm (d) Chromosomes

824. Centrioles and centrosomes are present in cells of

(a) Bacteria (b) Cyanobacteria (c) Green plants (d) Animals

825. Which of the following has centrioles

(a) Chromosomes (b) Spindle fibres (c) Centrosomes (d) Centromeres

826. The number of membranes that surround centrioles structure is

(a) 3 (b) 0 (c) 1 (d) 2

827. Which one is without an external covering

(a) Lysosome (b) Golgi apparatus (c) Centrosome (d) Centriole

828. The organelle has no DNA but replicates

(a) Flaellum (b) Cilia (c) Centrosome (d) All of these

829. Which cell structure occurs in epidermal cells of human but not in the epidermal cells of leaves

(a) Centriole (b) Mitochondria (c) Cell membrane (d) Glyoxisomes

830. Centrioles are found

(a) Singly (b) Pairs (c) Triplets (d) Quadruplets

831. Cell organelle multiplying through sort of replication is

(a) DNA (b) RNA (c) Centriole (d) Mitochondrion

832. Centrosome is rich in

(a) ATP (b) RNA (c) DNA (d) Enzymes

833. The principal protein of cilia and flagella is

(a) Tubulin (b) Albumin (c) Globulin (d) Gliadin

834. Basal bodies are associated with the development of

(a) Cilia and flagella (b) Cell plate (c) Phragmoplast (d) Kinetochore

835. Basal bodies of cilia and flagella are derived from

(a) Plasma membrane (b) Genes (c) Centrioles (d) Lysosomes

836. Pattern of organisation of cilia and flagella is

(a) 9 + 0 (b) 9 + 1 (c) 9 + 2 (d) 9 + 3

837. The arrangement of central and outer microtubules in a cilium is called the

(a) 9 + 2 pattern (b) 2 + 9 pattern (c) 9 + 0 pattern (d) 0 + 9 pattern

838. Cilia are formed by

(a) Peroxisomes (b) Centrioles (c) Dictyosomes (d) Microfilaments

839. Microtubules were discovered by

(a) De Roberties and Franchi (b) Robert Brown

(c) Koliker (d) Palade

840. Microtubule is involved in the

(a) Cell division (b) DNA recognition

(c) Muscle contraction (d) Membrane architecture

841. The protein not associated with the flagella is

(a) Tubulin (b) Dyenin (c) Flagellin (d) Pilin

842. When two flagella in a cell are dissimilar it is called

(a) Isokont (b) Heterokont (c) Akont (d) Anisogamy

843. The basal bodies at the base of Flagella and cillia are

(a) Ribosome (b) Kinetoplast (c) Kinetosome (d) Dictyosome

844. The side arms of a subfibril '*A*' in cilium are made of

(a) Tubulin (b) Actin (c) Myosin (d) Dynein

845. 9 + 2 arrangement is absent in

(a) Flagellum of *Chlamydomonas* (b)Flagellum of *Euglena*

(c) Flagellum of *Paramecium* (d)Flagellum of bacterium

846. Sweeping type of rhythmic movements are shown by

(a) Flagella (b) Cilia (c) Both (a) and (b) (d) Centrosome

847. Which of the following show 9 + 0 arrangement

(a) Centriole and basal bodies (b) Cilia

(c) Centriole (d) Cilia and flagella

848. The term microtubule was introduced by

(a) Watson (b) Porter (c) Franchi (d) Slautterback

849. The cellular role for microtubule is

(a) Portein synthesis (b) Intracellular communication

(c) Digestion of aged organelles (d) Cell destruction during development

850. Tubulin protein occurs in

(a) Rough endoplasmic reticulum (b) Microtubules

(c) Thylakoids (d) Digestive enzymes

851. Arrangement of microtubules in basal bodies is

(a) 9 pairs in circle (b) 9 triplets in circle

(c) 9 pairs in circle + 2 axial (d) 2 in circle and 9 in periphery

852. Microtubules are formed largely of a protein called

(a) Tubulin (b) Actin (c) Flagellin (d) Myosin

853. Microtubules are madeup of tubulin and microfilaments of

(a) Actin (b) Myosin (c) Both (a) and (b) (d) None of these

854. The plane of cell wall is determined by

(a) Microfilaments (b) Microsomes (c) Microbodies (d) Microtubules

855. B-subfibres of flagella contain.....sub-units

(a) 13 (b) 9 (c) 2 (d) 9–10

Advance Level

856. "Lysosomes" were discovered by

(a) Haekel (b) De Duve (c) De Vries (d) Purkinje

857. The "marker" enzyme of lysosome is

(a) Lysozyme (muramidase) (b) Acid protease

(c) Acid phosphatase (d) Beta-galactosidase

858. Which of the following statements is incorrect with reference to lysosomes

(a) They are filled acid hydrolase and other enzymes

(b) They are monomorphic and uniform in structure and function

(c) They may be autophagic

(d) They can digest proteins, nuclei acids, lipids and polysaccharides

859. Which of the following organ has single membrane

(a) Nucleus (b) Cell wall (c) Mitochondria (d) Spherosomes

860. Lysosomes are rich in

(a) Polyribosome (b) Lipoproteins (c) DNA ligase (d) Hydrolytic enzymes

861. Lysosomes are generally found in

(a) Animal cells only (b) Animal cell and in some plant cells

(c) Plant cells only (d) Bacterial cells

862. Which of the function is performed by lysosome

(a) Breakdown of cell substances (b) Photosynthesis

(c) Breakdown of water (d) Synthesis of protein

863. At which *pH* enzymes of Lysosomes are usually active

(a) *pH* 5 (b) *pH* 7 (c) *pH* 8 (d) In any *pH*

864. The organelles whose major function is storage of hydrolytic enzymes are

(a)Centrioles (b) Chromoplasts (c) Lysosomes (d) Chloroplasts

865. A lysosome in which intracellular organells is getting digested is called

(a) Primary lysosome (b) Secondary lysosome (c) Autophagosome (d) None of these

866. Release of lysosomal enzymes may be brought about by

(a) Extremes of pH (b) Ag^{+} (c) Hg^{++} and Cu^{++} (d) All of these

867. When are lysosomes extra active

(a) Seed maturalion (b) Seed germination (c) Flowering (d) Fruiting

868. Heterophagy means

(a) Digestion of fat by glyoxysomes (b)Activity of catalase of peroxisome

(c) Photorespiration by peroxisome (d)Lysosomal digestion of endocylosed material

869. De Duve discovered lysosomes from

(a) Orchid root cells (b) Rat liver cells (c) Rat kidney cells (d) Leaf cells

870. Electron microscopy has revealed that the golgi complex is involved in the

(a) Formation of primary lysosomes (b)Development of ribosomes

(c) Accumulation of lipoproteins (d)Accumulation of proteins

871. Labilizers are the elements responsible for

(a) Causing instability to membrane of lysosome (b) Causing stability to membrane of lysosome

(c) Strengthen the membrane of lysosome (d) None of these

872. Ribosomes are attached to E.R. through

(a) Riboplasm (b) rRNA

(c) tRNA (d) Hydrophobic interaction

873. Ribosomes, similar to those of bacteria, are found in

(a) Plant nuclei (b) Pancreatic mitochondria

(c)Liver endoplasmic reticulum (d) Cardiac muscle cytoplasm

874. Which of the following affects the association and dissociation of sub-units of ribosomes

(a) *Mg* (b) *Ca* (c) *Fe* (d) *K*

875. Polyribosomes are aggregation of

(a) Ribosomes and rRNA

(b) Only rRNA

(c) Peroxisomes

(d) Several ribosomes held together by a stearing of mRNA

876. If all the ribosomes of a cell are destroyed

(a) Respiration will not take place (b)Photosynthesis will not occur

(c) Fat will not be stored (d)Protein will not be formed

877. Ribosomes of bacteria, mitochondria, prokaryotes and chloroplast are of

(a) 50 S type (b) 80 S type (c) 70 S type (d) 30 S type

878. Below a certain level of Mg^{++} the two sub units of the ribosome

(a) Separates (b) Fuses (c) Divides (d) None of these

879. Two molecules of RNA occur in each ribosome having molecular weight respectively

(a) 0.7×10^6 and 0.7×10^6 (b) 1.6×10^6 and 0.6×10^6 (c) 1.6×10^5 and 0.6×10^3 (d) 1.6×10^6 and 0.7×10^6

880. Number of proteins associated with 60 S ribosome sub-unit is

(a) 40 (b) 34 (c) 30 (d) 21

881. Ergasomes are

(a) ER (b) Golgi bodies (c) Polyribosomes (d) Microbodies

882. Polysomes are formed by

(a) More than 4 ribosomes on ER (b)More than > 5 ribosomes

(c) More than > 5 ribosomes on mRNA (d) mRNA + ribosomes + microsomes

883. 'P' site (Peptidyl site) containing peptidyl transferase is present on

(a) Smaller unit of ribosome (b) Larger unit of ribosome

(c) Entire ribosome (d) mRNA

884. During protein synthesis, mRNA is attached to

(a) Smaller unit of ribosome (b) Larger unit of ribosome

(c) ER (d) RER

885. Ribosomal 'dimer' is formed by

(a) Increasing *Mg* concentration (b) Decreasing *Mg* concentration
(c) Increasing *NaCl* concentration (d) Both (a) and (b)

886. The types of amino acids in highest quantity in ribosomes are
(a) Glycine and tryptophan (b)Leusine and arginine
(c) Histidine and threonine (d)Lysine only

887. DNA remains absent in
(a) Chloroplast (b) Nucleus (c) Peroxisomes (d) Chromosomes

888. The organelle associated with photorespiration is called as
(a) Lysosome (b) Peroxisome (c) Glyoxysome (d) Mesosome

889. Some of the enzymes, which are associated in converting fats into carbohydrates, are present in
(a) Liposomes (b) Golgi bodies (c) Microsome (d) Glyoxysomes

890. Peroxisomes are involved in the synthesis of
(a) Glucose (b) Fatty acids (c) Glycine and serine (d) Nucleotides

891. One of the most common enzyme found in peroxisome is
(a) Hydrolase (b) Catalase (c) Dehydrogenase (d) Reductase

892. Tonoplast is a
(a) Covering layer of golgi complex (b)Covering layer of vacuoles
(c) Covering layer of microbodies (d)Non-living cytoplasmic content

893. The fluid part of cell called *cell sap* is the
(a) Non-living contents of a cell
(b) Living contents of a cell
(c) Non-living contents of the vacuole of cell (d) Living contents of the vacuole of cell

894. Young plant cells possess sap vacuoles
(a) One, large and central (b) Many, large and dispersed
(c) Many and small (d) None of these

895. A vacuole without a regular covering membrane is
(a) Contractile vacuole (b) Food vacuole (c) Sap vacuole (d) Gas vacuole

896. Which one passes only a protein membrane
(a) Feeding canals of contractile vacuole (b) Vesicle of gas vacuole
(c) Contractile vacuole (d) Gas vacuole

897. Residual vacuole throw their undigested material by
(a) Pinocytosis (b) Phagocytosis (c) Ephagy (d) Diffusion

898. Centriole/centrosome takes part in
(a) Nucleolus formation (b) Start of cell division
(c) Cell plate formation (d) Spindle formation

899. Centrioles replicate during
(a) Interphase (b) Early prophase (c) Late prophase (d) Late telophase

900. Centrioles and centrosomes can be traced in the cells of

(a) Green plants (b) Animals

(c) Prokarotic cells of bacteria and cyanobacteria (d) Both (a) and (b)

901. Basal body could be another name of centriole in view of internal structures when

(a) It gives rise to spindle fibres (b)It divides during mitosis

(c) It gives rise to cilia or flagella (d)It gives basic reactions

902. A centrosome is

(a) A cytoplasmic organelle present in plant cells

(b) A cytoplasmic organelle present in animal cells

(c) A cytoplasmic organelle present in plant and animal cells

(d) A nuclear structure present in animal cells

903. The function of centrosome is

(a) Inhibition of cell division (b)Initiates cell division

(c) To increase protein synthesis (d)None of these

904. In ultra structure blepharoplasts resemble

(a) Centrioles (b) Flagella (c) Cilia (d) None of these

905. Each peripheral fibril on the centriole is made up of

(a) 1 microtubule (b) 2 microtubule (c) 3 microtubule (d) 4 microtubule

906. The diameter of centriole is

(a) 25 nm (b) 0.15μ (c) 15μ (d) 25 $\mathring{A}$

907. Flagella with single strand and composed of flagellin is found in

(a) Prokaryotes (b) Eukaryotes (c) Both (a) and (b) (d) None of these

908. The filaments associated with cilia and flagella are constituted by

(a) Microtubules (b) Microfilaments (c) Microfibrils (d) Microvilli

909. Prokaryotic flagella possess

(a) Helically arranged protein molecule (b) Protein membrane enclosed fibre

(c) Unit membrane enclosed fibre

(d) Microtubular 9 + 2 membrane enclosed structure

910. Microtubule is involved in the

(a) Cell division (b) DNA recognition

(c) Muscle contraction (d) Membrane architecture

911. Match List I and List II and select the correct answer using the code given below the lists

List I	**List II**
1. Microtubules	Structural components of cilia
2. Centrioles	Store hydrolytic enzymes
3. Peroxisomes	Store oil protein and starch in plants

(a) 1, 2 and 3 are correct (b)1 and 2 are correct, 3 is false

(c) 1 is correct, 2 and 3 are false (d)1 and 3 are correct, 2 is false

912. Flagella of prokaryotic and eukaryotic cells differ in
(a) Microtubular organization and type of movement (b)Microtubular organisation and function
(c) Type of movement and placement in cell (d) Location in cell and mode of functioning

913. In cilia, microtubular fibrils are of doublet nature and are tilted by 10^o so that subfibril *A* is close to centre. In centriole, microtubular fibrils are of triplet nature and are tilled by
(a) 10^o (b) 30^o (c) 40^o (d) 45^o

914. Stereocilia are
(a) Mobile without blepharoplast (b)Immobile with bleharoplast
(c) Immobile without basal body (d)Mobile with basal body

915. The 11-stranded flagellum of eucaryote possesses
(a) Nine triplet and two doublet fibrils (b) Eleven doublet fibrils
(c) Nine doublet and two singlet fibrils (d) Nine singlet and two doublet fibrils

916. Peripheral duplet fibrils in a flagella are interconnected by A – B linker which is made up of protein
(a) Tubulin (b) Dyenin (c) Nexin (d) Myelin

917. Flagella is present in following except
(a) *Pinus* (b) *Funaria* (c) *Dryopteris* (d) All correct

918. Microfilaments were discovered by Paleviz *et al*, 1974. These are formed of
(a) Actin and myosin (b) Actinogen (c) Myoglobin (d) Myosin

919. Microfilaments are long, thin, contractile rods (solids) of 6-10 *nm* diameter. These help in
(a) Movement of cell membrane during mobility and endocytosis
(b) Contraction of muscles, functioning of microvilli and undulation of cell membrane
(c) Cytoplasmic streaming, cleavage of animal cell, formation of pseudopodia
(d) All of these

920. Calmodulin is a calcium protein complex in microtubules and microfilaments. It is involved in
(a) Cell differentiation (b) Synthesis of ATP (c) Breakdown of ATP (d) Cell motility

921. Diameter of microtubules is
(a) 250 Å (b) 100 Å (c) 50 Å (d) 10 Å

922. One of the following is not a cellular role of microtubules
(a) Intracellular communication (b)Digestion of aged organelles
(c) Destruction during development (d)Protein synthesis

923. The mesh of fibres of microtubulets and microfilaments is called
(a) Cytoskeleton (b) Sclerenchyma (c) Centrosomes (d) None of these

924. Microbodies differ from lysosomes in that
(a) Microbodies are surrounded by a single unit membrane while lysosome membrane is double
(b) Microbodies are surrounded by double membrane while lysosomes membrane is single unit
(c) Microbodies contain lytic enzymes while lysosomes do not

(d) Lysosome contain lytic enzymes while microbodies do not

925. Eukaryotic cells possess a cytoskeleton of
(a) Microtubules, microfilaments and cytoplasm
(b) Microtubules, microfilaments and protoplasm
(c) Microtubules, microfilaments and proteins (d) None of these

NUCLEUS

Basic Level

926. Nucleus was discovered by
(a) Purkinje (b) Nageli (c) Brown (d) Hofmeister

927. Controlling centre of cell is
(a) Nucleus (b) Nucleolus (c) Mitochondria (d) Ribosome

928. The nucleus has
(a) One membrane with pores
(b) Two membranes with pores
(c) Two membranes with pores through which substances do not pass
(d) Two membranes with pores through which macromolecules may pass

929. True nucleus is absent in
(a) Green algae (b) Fungi (c) Lichens (d) Bacteria

930. Karyolymph is a
(a) Nuclear sap (b) SPM membrane (c) Nuclear pore (d) None of these

931. Karyokinesis differ from cytokinesis because it involves
(a) Division of cytoplasm (b)Division of the nucleus and cytoplasm
(c) Division of the nucleus (d)Division of the cell

932. Which of the following regulates and governs the physiological processes of the cell
(a) Protoplast (b) Nucleolus (c) Mitochondria (d) Nucleus

933. Nucleus is enclosed in
(a) Double and non-porous layer (b)Double and porous layer
(c) Single and non-porous layer (d)Single and porous layer

934. Nucleolus is found in
(a) Protoplasm (b) Nucleus (c) Cytoplasm (d) None of these

935. Nucleosome consists of
(a) Nucleolus (b) Genes (c) Microfilaments (d) Histones + DNA

936. The nucleoplasm is continuous with the cytoplasm of a cell through
(a) Centriole (b) Endoplasmic reticulum (c)Nuclear pores (d) Golgi apparatus

937. Nuclear material without nuclear membrane is observed in
(a) Bacteria and green algae (b)Cyanobacteria and red algae
(c) Bacteria and cyanobacteria (d)Mycoplasmas and green algae

938. Nucleoproteins of a cell are synthesized in
(a) Nucleolus (b) Nucleoplasm (c)Nuclear membrane (d)Outside the nucleolus

939. DNA is mainly found in
(a) Nucleus only (b) Nucleus and cytoplasm
(c) Cytoplasm only (d) All of these

940. Cytoplasm and nucleus are separated by a membrane which is
(a) Single layered (b) Double layered (c) Triple layered (d) Multi layered

941. The continuation of endoplasmic reticulum is with
(a) Ribosome (b) Golgi body (c) Mitochondria (d) Nuclear membrane

942. Fibrillar nucleus without clear boundaries is unique to
(a) Bacteria and cyanobacteria (b) Eukaryotes
(c) Plant cells (d) Animal cells

943. Nucleocytoplasmic traffic through nuclear pore is facilitated by
(a) Protein nucleoplasmin (b)Protein rhodopsin
(c) Nuclear lamina (d) Lipid bilayer of cell membrane

944. Role of nucleus in morphological differentiation was discovered in
(a) *Acetabularia* by Hammerling (b)*Drosophila* by Morgan
(c) *Neurospora* by Bedle and Tatum (d)Garden Pea by Mendel

945. Experiments on *Acetabularia* by Hammerling proved the role of
(a) Cytoplasm in controlling differentiation (b) Nucleus in heredity
(c) Chromosomes in heredity (d) Nucleo-cytoplasmic ratio

946. Genophore is
(a) Single molecule of double stranded naked DNA (b)A single stranded DNA
(c) RNA + histone (d)DNA + histone

947. Study of nuclear cytology is called
(a) Neurology (b) Karyology (c) Mycology (d) Rhinology

948. The structure of the nuclear membrane facilities
(a) Organisation of the spindle (b)Synapsis of homologous chromsomes
(c) Nucleo-cytoplasmic exchange of materials (d)Anaphasic separation of daughter chromosomes

949. Interphase nucleus is enclosed by
(a) Nonporous nuclear membrane (b)Porous double nuclear membrane
(c) Nonporous double discontinuous nuclear membrane
(d) A single porous unit membrane

950. Who showed that the nuclear membrane has many pores or circular structures or annuli
(a) Fawcell (b) Strasburger (c) Butchen (d) Callan and Tomlin

951. Hammerling prove the importance of nucleus in heriditary characters on the basis of the following alga
(a) *Neurospora* (b) *Peziza* (c) *Drosophila* (d) *Acetabularia*

952. The term 'nucleoplasm' was given by
(a) Strasburger (b) Flamming (c) Harris and James (d) Bowman

953. Nucleolus contains
(a) No membrane covering (b) Amorphous matrix and granular zone
(c) Fibrillar zone and chromatin (d) All of these

954. Nucleolus is formed from
(a) Nucleus (b) Nuclear sap (c) Sat chromosomoses (d) Giant chromosomes

955. Granulas of nucleolus are precursors of
(a) Chromosomes (b) Ribosomes (c) RNA (d) All of these

956. The first satisfactory account of the structure of nucleus and its mode of division was given by
(a) Robert Brown (b) Watson and Crick (c) Schleiden and Schwann (d)Strasburger

957. Which protein of nucleoplasm activates DNA to replicate and transcribe
(a) Histone (b) Nonhistone (c) Phosphoprotoeins (d) Nucleoproteins

958. Fibrillar region of nucleolus which contains fibrils of ribonucleoprotein is called
(a) NOR (b) Fibronema (c) Nucleonema (d) Pars amorpha

959. Nucleus of bacteria is called
(a) Mesosome (b) Genophore (c) Nucleolus (d) Gonophore

960. Nuclear envelope is porous. These pores control the passages of
(a) mRNA (b) Nucleoproteins (c) mRNA + proteins (d) All correct

961. Number of nucleoli in the nucleus is equal to
(a) Only one (b) One or more than one
(c) Depends upon number of genomes (d) Equal to pairs of sat. chromosomes

962. Which part of the cell is important for growth and synthesis of protoplasm
(a) Chloroplast (b) Chromosomes (c) Mitochondria (d) Nucleus

963. An undefined or undifferentiated fibrillar nucleus is seen in
(a) Eukaryotic cells (b) Prokaryotic cells
(c) Cells of higher organisms (d) Cells of higher plants

Advance Level

964. Pars amorpha is associated with
(a) Nucleus (b) Chloroplast (c) Mitochondria (d) Nucleolus

965. "*Nu body*" was shown by
(a) Darlington (b) Johansen (c) Woodcock (d)Temin and Baltimore

966. The term 'nucleolus' was coined by

(a) R. Brown (b) H. Hooks (c) Bowman (d) Hanstein

967. The function of nucleolus is the synthesis of

(a) DNA (b) m-RNA (c) r-RNA (d) t-RNA

968. In nucleoplasm, a conspicuous body of spherical shape attached to a particular chromosome on a definite position is called

(a) Plasmid (b) Karyolymph (c) Nucleolus (d) Nuclear reticulum

969. Histone proteins found in nuclei of eukaryotes are

(a) Acidic (b) Basic (c) Neutral (d) Amphoteric

970. The core of nucleosome is made up of

(a) H_1, H_2A, H_2B, H_3 (b) H_1, H_2A, H_2B, H_4 (c) $H_1, H_2A, H_2B, H_3, H_4$ (d) H_2A, H_2B, H_3, H_4

971. Chromatin consist of

(a) DNA (b) RNA (c) RNA and Histones (d) DNA and Histones

972. Nucleosomes are

(a) Units of DNA (b) Units of RNA (c) Units of protein (d) Units of chromatin

973. Nucleoli are rich in

(a) DNA and RNA (b) DNA, RNA and proteins (c)DNA (d) RNA

974. Nucleoid is

(a) A single inactive nucleus having double stranded DNA and proteins

(b) A group of chromosomes associated with proteins

(c) A nucleus without nuclear membrane and nucleolus or genetic material of prokaryotes

(d) A chromosome associated with proteins

975. Protein synthesis is an animal cell, takes place

(a) Only in the cytoplasm (b)In the nucleolus as well as in the cytoplasm

(c) In the cytoplasm as well as in mitochondria (d) Only on ribose attached to nucleon

976. If nucleus represents its large size in proportion to cytoplasm of cell, it indicates that

(a) Cell is dying (b) The nucleus is in resting phase

(c) The nucleus has entered *S*-phase of interphase (d) Cell is about to die

977. Which of the following is the best explanation for the early discovery of nucleus

(a) Nucleus is more important than cytoplasm

(b) The nucleus is a visible body while cell theory was absolute generalization

(c) Nuclei are stained darker than other cell organelles

(d) The english scientists had better microscopes than other

978. What will happen if nucleus is removed

(a) The metabolism will increase (b)The cell will die

(c) The metabolism will decrease (d)None of these

979. Histone proteins found in the nuclei of eukaryotes are rich in

(a) Glycine and phenylalanine (b)Lysine and arginine
(c) Glycine and arginine (d)Phenylalanine and lysine

980. Which of the following functions would stop first when the nucleus remove from the mesophyll cell of a leaf
(a) Phosphorylation (b) Osmosis
(c) Photosynthesis (d) Synthesis of cytoplasmic protein

MICRO AND MACRO MOLECULES

Basic Level

981. Which one of the following is the sweetest sugar
(a) Fructose (b) Glucose (c) Galactose (d) Sucrose

982. Which of the following is a disaccharide
(a) Ribose (b) Maltose (c) Glucose (d) Cellulose

983. Lipids are insoluble in water, because lipids molecules are
(a) Neutral (b) Zwitter ions (c) Hydrophobic (d) Hydrophillic

984. Proteins consist of
(a) Carbon, hydrogen, chlorine, sulphure (b) Carbon, hydrogen, oxygen, nitrogen
(c) Carbon, manganese, phosphorus, nitrogen
(d) Carbon, iodine, oxygen and inorganic phosphate

985. Largest physical and chemical molecules are
(a) Carbohydrates (b) Lipids (c) Proteins (d) Nucleic acids

986. No cell could live without
(a) Phytochrome (b) Enzyme (c) Chloroplasts (d) Protein

987. Which of the following is the characteristics of plants
(a) Glucose and cellulose (b)Pyruvic acid and glucose
(c) Cellulose and starch (d)Starch and pyruvic acid

988. Starch and cellulose are the compounds made of many units of
(a) Simple sugar (b) Fatty acid (c) Glycerol (d) Amino acid

989. Oval shaped and eccntric starch particles are found in
(a) Wheat (b) Maize (c) Potato (d) Rice

990. What are the most diversed molecules in the cell
(a) Lipids (b) Proteins (c) Carbohydrates (d) Mineral salts

991. The form in which sugar is present in sugarcane
(a) Maltose (b) Sucrose (c) Fructose (d) Glucose

992. Cane sugar hydrolyses to form
(a) Glucose + Fructose (b) Glucose + Glucose (c) Glucose + Galactose (d) Glucose + Maltose

993. A trisaccharide is
(a) Galactose (b) Maltose (c) Raffinose (d) Mannose

994. Two fatty acid monomers are joined by
(a) Hydrogen bond (b) Peptide bond (c) Phosphodiester bond (d)Ester bond

995. The most essential of the fatty acids is
(a) Arachidonic acid (b) Linolenic acid (c) Linoleic acid (d) Oleic acid

996. Which one is phosphoprotein
(a) Ferritin (b) Casein (c) Mucin (d) Albumin

997. Peptide bond is formed between two amino acids through
(a) Addition of water (b) Loss of water (c) Decarboxylation (d) Deamination

998. A basic amino acid is
(a) Leucine (b) Methionine (c) Aspartic acid (d) Lysine

999. Most abundant organic compound on earth is
(a) Cellulose (b) Protein (c) Lipids (d) Steriods

1000. Most common monosaccharides found in nucleus are
(a) Trioses (b) Tetroses (c) Pentoses (d) Hexoses

1001. Hydrolysis of nucleic acid yields
(a) Only sugar (b) Phosphoric acid only (c) NItrogenous base only (d)All of the above

1002. Nucleic acids were discovered by
(a) Watson and Crick (b) Khorana (c) Wilkins (d) Miescher

1003. A nucleoside differs from a nucleotide in not having
(a) Phosphate (b) Sugar (c) Phosphate and sugar (d) Nitrogen base

1004. DNA was first discovered by
(a) Beadle and Tatum (b) Watson and Crick (c) Friedrich Miescher (d) Kornberg

1005. DNA is a polymer of
(a) Nucleotide (b) Nucleoside (c) Amino acids (d) All of the above

1006. Purines (bases) of DNA are represented by
(a) Uracil and guanine (b) Guanine and adenine (c) Adenine and cytosine (d)None of these

1007. In DNA guanine pairs with
(a) Cytosine (b) Thymine (c) Uracil (d) Adenine

1008. The number of hydrogen that bound guanine and cytosine
(a) 1 (b) 2 (c) 3 (d) 4

1009. Strands of DNA are bonded by
(a) Hydrogen (b) Carbon (c) Oxygen (d) Nitrogen

1010. DNA is concentrated in
(a) Chromatin as DNA-protein complex (b) Ribosomes
(c) Golgi bodies (d) Plastids

1011. The similarity between DNA and RNA is that both are

(a) Double stranded (b) Having similar sugars

(c) Polymers of nucleotides (d) Having similar pyrimidines

1012. DNA differs from RNA

(a) In the nature of sugar alone (b) In the nature of purine alone

(c) In the nature of sugar and pyrimidines (d) None of these

1013. DNA differs from RNA

(a) In having cytosine but no guanine (b) In having thymine but no cytosine

(c) In having uracil but no thymine (d) In having thymine but no uracil

1014. Which one of the following is widely distributed in a cell

(a) DNA (b) RNA (c) Chloroplast (d) Chromoplast

1015. Which of the following bases is present in RNA in place of thymine

(a) Uracil (b) Adenine (c) Guanine (d) Water

1016. *t*-RNA is also called

(a) Microsomal RNA (b) Messenger RNA (c) Soluble RNA (d) *r*RNA

1017. The function of *t*RNA is

(a) Production of *m*RNA (b)Production of ribosomes

(c) Production of microsomes (d) Selection of amino acids

1018. Number of nitrogen bases found in RNA

(a) Two (b) Eight (c) Six (d) Four

1019. A nucleotide is formed of

(a) Purine, pyrimidine and phosphate (b) Purine, sugar and phosphate

(c) Nitrogen base, sugar and phosphate (d) Pyrimidine, sugar and phosphate

Advance Level

1020. Which of the following forms more than 1/2 of cell

(a) Water (b) Mineral (c) Protein (d) Carbohydrate

1021. Corn is immersed in the boiling water. It is then cooled, the solution becomes sweet. It is due to

(a) Enzymes are inactivated in boiling water

(b) Disaccharides are converted to monosaccharides

(c) Monosaccharides are converted to disaccharides (d)None of these

1022. Pentoses and hexoses are the most common

(a) Disaccharides (b) Monosaccharides (c) Oligosaccharides (d) Polysaccharides

1023. Phospholipids are

(a) Amphipathic (b) Amphibolic (c) Hydrophobic (d) None of these

1024. Inulin found in plant cell is a

(a) Lipid (b) Protein (c) Polysaccharide (d) Vitamin

1025. Which one of the following is a conjugate protein

(a) Globulin (b) Albumin (c) Histone (d) Flavoprotein

1026. Glycoproteins contain

(a) Protein and fat (b) Protein and salt

(c) Protein and vitamin (d) Protein and carbohydrates

1027. Aleurone grains are

(a) Enzymes (b) Carbohydrates (c) Protein (d) Fat

1028. Cellulose, the most important constituent of plant cell wall is made up of

(a) Branched chain of glucose molecules linked by α 1, 6 glycosidic bond at the site of branching

(b) Unbranched chain of glucose molecules linked by α 1, 4 glycosidic bond

(c) Branched chain of glucose molecules linked by β 1, 4 glycosidic bond in straight chain and α 1, 6 glycosidic bond at the site of branching

(d) Unbranched chain of glucose molecules linked by β 1, 4 glycosidic bond

1029. Most of water found in young cell occurs in

(a) Cell wall (b) Nucleus (c) Cytoplasm (d) Vacuoles

1030. Glycosidic linkage in maltose is

(a) $\alpha 4 \rightarrow 1$ (b) $\beta 4 \rightarrow 1$ (c) $\alpha 1 \rightarrow 4$ (d) $\beta 1 \rightarrow 4$

1031. Mucilage present in 'Bhindi' (Okra, Lady's Finger) contains

(a) Mannose (b) Galactose (c) Lactose (d) Both (a) and (b)

1032. Macromolecule chitin is

(a) Sulphur containing polysaccharide (b) Phosphorus containing polysaccharide

(c) Nitrogen containing polysaccharide (d) Simple polysaccharide

1033. Highest content of linoleic acid is found in

(a) Sunflower oil (b) Coconut oil (c) Groundnut oil (d) Cotton oil

1034. Number of fatty acid residues present in one molecule of fat is

(a) 4 (b) 3 (c) 2 (d) 1

1035. Unsaturated fats are made saturated by

(a) Polymerisation (b) Hydrogenation (c) Dehydrogenation (d) Hybridisation

1036. Calmodulin is

(a) Carotene binding protein (b) Cadmium binding protein

(c) Calcium binding protein (d) Chlorophyll binding protein

1037. Cellulose is homopolymer of

(a) Fructose (b) Mannose (c) Galactose (d) Glucose

1038. Glucose is

(a) Pyranose pentose sugar (b)Furanose pentose sugar

(c) Ketose hexose sugar (d)Aldose hexose sugar

1039. Starch and cellulose are compounds consisting of many units of

(a) Amino acids (b) Fatty acids (c) Glycerol (d) Simple sugars

1040. The chemical formula of starch is

(a) $(C_6H_{10}O_5)_n$ (b) $(C_6H_{12}O_6)_n$ (c) $C_{12}H_{22}O_{11}$ (d) CH_3COOH

1041. Final product of starch digestion is

(a) Maltose (b) Sucrose (c) Lactose (d) Glucose

1042. Which of the following is capable of self replication

(a) An enzyme (b) A carbohydrate molecule

(c)A water molecule (d) A nucleic acid

1043. A ribose (but not deoxyribose) nucleotide is

(a) Cytosine – pentose sugar – phosphate (b) Guanine – pentose sugar – phosphate

(c) Thymine – pentose sugar – phosphate (d) Uracil – pentose sugar – phosphate

1044. Artificial synthesis of DNA was first accomplished by

(a) Khorana (b) Watson and Crick (c) Nirenberg (d) Kornberg

1045. Structure of DNA helix was given by

(a) Watson and Kornberg (b)Watson and Crick

(c) Nirenberg and Khorana (d)Halley and Nirenberg

1046. How many nucleotides are present in one turn of DNA helix

(a) 4 (b) 8 (c) 10 (d) 9

1047. In DNA molecule, which of the following base pair is present

(a) Cytosine and adenine (b)Adenine and thymine

(c)Adenine and guanine (d)Cytosine and thymine

1048. The base pairs of DNA are correctly shown as

(a) $A \equiv T$ and $C = G$ (b) $A = T$ and $C = G$ (c) $A = T$ and $C \equiv G$ (d) $A \equiv T$ and $C \equiv G$

1049. DNA synthesis can be specifically measured in estimating the incorporation of radio labelled

(a) Uracil (b) Adenine (c) Thymidine (d) Deoxyribose sugar

1050. Feulgen reaction a technique has been developed by Feulgen and Rossenbeck to study or to strain

(a) Proteins (b) Lipids (c) DNA (d) RNA

1051. If an isolated strain of DNA is kept at $82-90^oC$, then

(a) It changes into RNA (b) It divides into one million pieces

(c) No effect (d) It uncoild in to helixes

1052. Who was awarded Nobel Prize for synthesis of RNA in 1959

(a) S. Ochoa (b) A. Kornberg (c) H. Khorana (d) Nirenberg

1053. Which type of RNA is most abundant in cell

(a) *m* RNA (b) *t* RNA (c) *r* RNA (d) Catalytic RNA

1054. Which RNA is having least age

(a) *m* RNA (b) *t* RNA (c) *r* RNA (d) None of these

1055. Which site of a *t*-RNA molecule hydrogen bonds to a *m*-RNA molecule

(a) Codon (b) Anticodon

(c) 5' end of the *t*-RNA molecule (d) 3' end of the *t*-RNA molecule

1056. Which of the character is not applicable to *t*-RNA

(a) It is the smallest of the RNAs (b)Its acts as an adapter for amino acids

(c) It has a clover leaf like structure (d)It is the largest of the RNAs

1057. Which one of the following pairs is not correctly matched

(a) Recombinant DNA DNA formed by the joining of segments of DNA from different sources

(b) Purine Nitrogenous bases-cytosine, thymine and uracil

(c) ATP The principal energy carrying compound in the cell

(d) *r*-RNA RNA molecules found in ribosomes

1058. Break through of the year 2002

(a) *c*DNA (b) 16 *Sr*RNA (c) *r*DNA (d) *mi*RNA

1059. ATP is

(a) Nucleotide (b) Nucleoside (c) Purine base (d) Nucleosome

1060. Maximum number of nitrogen atoms occur in

(a) Guanine (b) Uric acid (c) Urea (d) Ammonia

1061. Ultraviolet light absorbed by nucleic acids is

(a) 26 *nm* (b) 75 *nm* (c) 260 *nm* (d) 1500 *nm*

1062. Which type of protein is found in nucleus

(a) Simple protein (b) Structural protein (c) Conjugated protein (d) Derived protein

1063. How many microfibrils combine to form a fibril of cellulose

(a) 50 (b) 100 (c) 200 (d) 250

1064. The enzyme for conversion of fats into carbohydrate are provided by

(a) Golgi complex (b) Lysosomes (c) Glyoxysomes (d) Lomasomes

CELL DIVISION

Basic Level

1065. Which one connected with the cell division

(a) *ER* (b) Peroxysomes (c) Ribosomes (d) Microtubules

1066. Cell division is initiated by

(a) Centrosome (b) Centriole (c) Centromere (d) Chromomere

1067. Cell division in blue-green algae is more or less similar to that in

(a) Red algae (b) Green algae (c) Brown algae (d) Bacteria

1068. Which one of the following forms the spindle apparatus during cell division

(a) Chromosome (b) Centrosome (c) Ribosome (d) Kinetosome

1069. The replication of nuclear DNA occurs in

(a) G_1 phase (b) G_2 phase (c) *S* phase (d) *M* phase

1070. Duplication of chromosomes take place in

(a) G_1 phase (b) G_2 phase (c) *S* phase (d) In all of the above

1071. The number of DNA in chromosome at G_2 stage of cell cycle

(a) One (b) Two (c) Four (d) Eight

1072. The decision for division occurs in a cell at

(a) *S* phase (b) G_2 phase (c) G_1 phase (d) None of these

1073. During interphase, RNA and proteins are synthesized in

(a) *S* phase (b) G_1 phase (c) G_2 phase (d)In both G_1 and G_2 phases

1074. Mitosis results in

(a) Reduction in chromosome number (b) Doubling of chromosome number

(c) Constant chromosome number (d) Increase in cell volume

1075. The process of mitosis is divided into 4 phases. Identify the correct order in which these phases appear in mitosis

(a) Anaphase, metaphase, telophase and prophase

(b) Telophase, anaphase, metaphase and prophase

(c) Metaphase, prophase, anaphase and telophase

(d) Prophase, metaphase, anaphase and telophase

1076. Between mitosis a cell is called to be in the

(a) Resting stage (b) Sleeping stage (c) Active stage (d) None of these

1077. Which is not the character of mitosis

(a) Leptotene (b) Zygotene (c) Pachytene (d) All of the above

1078. Which out of the following is not a divisional stage

(a) Telophase (b) Interphase (c) Metaphase (d) Prophase

1079. In which phase of mitosis the chromosomes are arranged around the equator of the spindle

(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

1080. During mitosis chromosomes go to their poles in a stage called

(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

1081. Centromere is concerned with

(a) Splitting of chromosomes (b) Formation of spindle fibres

(c) Movement of chromosomes to poles (d) Duplication of DNA

1082. In mitosis the duplication of chromosomes occurs during

(a) Early prophase (b) Late prophase (c) Interphase (d) Late telophase

1083. In mitosis nucleolus and nuclear membrane disappear at

(a) Interphase (b) Prophase (c) Metaphase (d) Telophase

1084. Which of the following structure will not be common to mitotic cell of a higher plant

(a) Cell plate (b) Centromere (c) Centriole (d) Spindle fibre

1085. During cell division in apical meristem nuclear membrane reappears in

(a) Interphase (b) Telophase (c) Prophase (d) *S* phase

1086. Spindle apparatus is formed during which stage of mitosis

(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

1087. The nuclear spindle consists of

(a) One type of fibre (b) Two types of fibres (c) Three types of fibres (d) Four types of fibres

1088. Spindle fibres are made up of

(a) Proteins (b) Cellulose (c) Lipids (d) Pectin

1089. Phragmoplast is precursor of

(a) Cell plate (b) Chloroplast (c) Chromoplast (d) Colourless plastid

1090. In mitosis then movement of chromosomes requires

(a) Presence of centromere (b) Plasmalemma (c) Spindle fibres (d) Nucleotides

1091. What is the stage of mitosis when chromosomes separate and move towards poles

(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

1092. In the somatic cell cycle

(a) A short interphase is followed by along mitotic phase

(b) G_2 phase follows mitotic

(c) In G_1 phase DNA content is double the amount of DNA present in the original cell

(d) DNA replication takes place in *S* phase

1093. Chromosome start separating at which stage of mitosis

(a) Early metaphase (b) Late metaphase (c) Early anaphase (d) Early telophase

1094. The stage of mitosis in which chromosomes are arranged on the equator of spindle

(a) Anaphase (b) Metaphase (c) Prophase (d) Late prophase

1095. A diploid somatic cell can divide by

(a) Mitosis but not meiosis (b) Meiosis but not mitosis

(c) Meiosis or mitosis (d) Amitosis only

1096. The best stage to view structure, size and to count the number of chromosome is

(a) Metaphase (b) Late prophase (c) Early anaphase (d) *I-phase*

1097. In mitosis, anaphase differ from metaphase in having

(a) Same number of chromosomes and half number of chromatids

(b) Half number of chromosomes and half number of chromatids

(c) Half number of chromosomes and same number of chromatids

(d) Same number of chromosomes and same number of chromatids

1098. A drug called colchicine interferes in mitosis during the spindle microtubule formation; it does so by

(a) Arresting chromosome movement (b) Breaking microtubules

(c) Thickening microtubule (d)Arresting centriole movement

1099. In the flowering plants, a mature female gametophyte is derived from megaspore cell by

(a) Three mitotic divisions (b)One meiotic and two mitotic divisions

(c) Two mitotic divisions (d)A single meiotic division

1100. The term "mitosis" was proposed by

(a) Fleming (b) Farmer (c) Moore (d) Boveri

1101. In mitotic cell division

(a) Number of chromosomes is doubled at the end

(b)Number of chromosomes is reduced to half

(c) Number of chromosomes remain unchanged (d) There is no division of chromosomes

1102. Prophase in onion root tip takes place in

(a) 71 minutes (b) 6.5 minutes (c) 2.4 minutes (d) 3.8 minutes

1103. Mitotic crossing over takes place in

(a) Normal mitosis (b) Normal sexual cycle (c) Parasexual cycle (d) Lytic cycle

1104. An acentric chromosome at metaphase will be

(a) Condensed and lie near the equator (b) Irregularly shaped and lie at one of the poles

(c) Condensed and lie at poles (d) Coiled and get attached to spindle fibre

1105. Which one of the following are mainly concerned with the spindle fibre formation

(a) Sphaerosomes (b) Microtubules (c) Golgi bodies (d)Endoplasmic reticulum

1106. Meiosis was discovered by

(a) Strasburger (b) Hofmeister (c) Sutton (d) Amici

1107. In which of the following meiosis takes place

(a) Pollen grains (b) Pollen tube (c) Pollen mother cells (d) Generative cells

1108. The significance of meiosis lies in

(a) Reduction of the diploid number of chromosomes to haploid

(b) Maintaining constancy in the number of diploid chromosomes during sexual reproduction

(c) Production of genetic variability in the population of a species

(d) All of the above

1109. Prophase of reduction division is divided into number of stages. The correct chronological sequence is

(a) Leptotene – pachytene – zygotene – diplotene – diakinesis
(b) Leptotene – diplotene – pachytene – zygotene – diakinesis
(c) Leptotene – zygotene – diplotene – pachytene – diakinesis
(d) Leptotene – zygotene – pachytene – diplotene– diakinesis

1110. When during the meiotic division, do the homologous chromosomes pair with each other
(a) Leptotene (b) Pachytene (c) Zygotene (d) Metaphase-I

1111. Repulsion of homologous chromosomes takes place in
(a) Zygotene (b) Leptotene (c) Diakinesis (d) Diplotene

1112. Chiasmata formation occurs during
(a) Diplotene (b) Leptotene (c) Pachytene (d) Diakinesis

1113. In pachytene stage of meiosis the chromosomes appear
(a) Single stranded (b) Double stranded (c) Three stranded (d) Four stranded

1114. Pacytene occurs during
(a) Meiosis (b) Mitosis
(c) Growth of a cell (d) Formation of endosperm

1115. Chromonemata start associating into bivalent chromosomes during**.**
(a) Zygotene (b) Leptotene (c) Pachytene (d) Diplotene

1116. In which of the following stage, the chromosome is thin and like long thread
(a) Leptotene (b) Zygotene (c) Pachytene (d) Diakinesis

1117. Prophase is longer in
(a) Mitosis (b) Meiosis (c) Equal in both (d) Amitosis

1118. In meiosis, the centromere divides during
(a) Prophase-I (b) Metaphase-I (c) Anaphase-I (d) Anaphase-II

1119. Chromosome number is halved in meiosis during
(a) Metaphase-I (b) Anaphase-I (c) Metaphase-II (d) Telophase-I

1120. Synapsis is pairing of
(a) Any two chromosomes (b)Non homologous chromosomes
(c) Acentric chromosomes (d)Homologous chromosomes

1121. Synapsis is characteristic of
(a) Leptotene (b) Pachytene (c) Zygotene (d) Diplotene

1122. Crossing over is advantageous because it brings about
(a) Variation (b) Linkage (c) Inbreeding (d) Stability

1123. The meiotic process by which homologous chromosomes are paired during prophase I is called
(a) Interkinesis (b) Crossing over (c) Chiasma (d) Synapsis

1124. The number of chromosome groups at the equatorial plate in metaphase-I of meiosis in a plant with $2n = 50$ shall be
(a) 50 (b) 25 (c) 30 (d) 100

1125. Centromere divides at

(a) Prophase I of reduction division (b)Metaphase I of reduction division

(c) Anaphase II of reduction division (d)Telophase I of reduction division

1126. Spindle fibres attach to chromosomes at their

(a) Telomeres (b) Chromomeres (c) Kinetochores (d) Centromeres

1127. The spindle fibre contracts in

(a) Metaphase I (b) Anaphase II (c) Prophase II (d) Telophase II

1128. Assuming no linkage and no crossing over, segregation of Mendelian factors during meiosis occurs at

(a) Anaphase I (b) Anaphase II (c) Diplotene (d) Metaphase I

1129. How many meiotic divisions would be required to produce 101 female gametophytes in an angiosperm

(a) 26 (b) 101 (c) 127 (d) None of these

1130. Meiosis occurs in Neurospora, at the time of

(a) Gemetic fusion (b) Ascospore formation

(c) Gamete formation (d) Fertilization

1131. Number of cells undergo meiotic divisions to produce 216 gametes in gymnosperm is

(a) 54 (b) 216 (c) 108 (d) 432

1132. In flowering plants, meiosis takes place at the time of

(a) Seed germination (b) Bud formation

(c) Formation of pollen grains (d) Formation of root tip

1133. How many reduction divisions are necessary for the formation of 100 grains of wheat

(a) 125 (b) 50 (c) 25 (d) 36

1134. Meiosis differs from mitosis as

(a) It takes place in vegetative cells (b) It shows crossing over

(c) It forms two cells (d) Number of chromosomes remain unchanged

1135. Meiosis is significant because

(a) It produces identical cells

(b) It restores the original number of chromosomes (after fertilization)

(c) There is doubling of DNA contents in the cell

(d) It occurs only in vegetative cells

Advance Level

1136. The function of centrosome is

(a) Inhibition of cell division (b)Initiates cell division

(c) To increase protein synthesis (d)None of these

1137. Which type of cell division occurs in the gonads

(a) Mitosis only (b) Meiosis (c) Both (a) and (b) (d)Amitosis and meiosis

1138. Coiling of chromatids in mitotic and meiotic division is

(a) Paranemic in both (b) Plectonemic in both

(c) Paranemic in mitosis and plectonemic in meiosis

(d)Plectonemic in mitosis and paranemic in meiosis

1139. DNA replication takes place in

Or

DNA molecule of each chromosome become double in

(a) G_1 phase (b) G_2 phase (c) *S* phase (d) Mitotic phase

1140. G_2 phase of mitosis takes

(a) 50% time of cell cycle (b)25 to 33% time of cell cycle

(c) 12 to 16% time of cell cycle (d) 4% time of cell cycle

1141. At G_1 stage which phenomenon takes place

(a) DNA synthesis (b) RNA synthesis (c) Reverse transcription (d)All of the above

1142. Regarding the sequence of cell cycle, which one is correct

(a) G_1, G_2, *S* and *M* (b) *S*, G_1, G_2 and *M* (c) G_1, *S*, G_2 and *M* (d) G_2, *S*, G_1 and *M*

1143. Phase of cell cycle when DNA polymerase is active

(a) G_1 (b) *S* (c) G_2 (d) *M*

1144. Histone protein synthesis occurs during

(a) G_1 phase (b) G_2 phase (c) *S* phase (d) Prophase

1145. '"Go" state of cells in eukaryotic cell cycle denotes

(a) Check point before entering the next phase

(b) Pausing in the middle of a cycle to cope with a temporary delay

(c) Death of a cell

(d) Exit of cells from cell cycle

1146. The process by which the chromosomes are separated in the sex cells and their number reduced from the diploid to haploid condition is known as

(a) Division (b) Mitosis (c) Conjugation (d) Meiosis

1147. Constancy of the chromosome number in successive generations is brought by the process of

(a) Mitosis (b) Meiosis (c) Conjugation (d) None of these

1148. The process of mitosis can be studied in

(a) Onion root tip (b) Garlic root tip (c) Tendrit tip (d) All of the above

1149. Mitosis occurs in

(a) Haploid individuals (b) Diploid individuals (c) Both (a) and (b) (d) In bacteria only

1150. Period of active mitosis ranges from

(a) 10 minutes to a few hours (b) A few hours to a one day
(c) One day to a week (d) Less than a minute

1151. Which cell division is found during cleavage
(a) Amitosis (b) Mitosis (c) Closed mitosis (d) Meiosis

1152. In cancer cells
(a) Meiosis takes place (b) Mitosis takes place
(c) Sometimes meiosis and sometimes mitosis take place (d) Cell division stops

1153. Cancer cells are more easily damaged by radiation than normal cells because they are
(a) Different in structure (b)Non-dividing
(c) Starved of mutation (d)Undergoing rapid division

1154. Cyclin is associated with which one of the following
(a) Glycolysis (b) Clyclosis (c) Haemolysis (d) Mitosis

1155. Which of the following stage is affected by colchicum
(a) Metaphase (b) Prophase (c) Interphase (d) Anaphase

1156. DNA replication occurs during
(a) Prophase (b) Metaphase (c) Anaphase (d) Interphase

1157. An anaphase chromosome contains
(a) 1 DNA molecule (b) 3 DNA molecule (c) 2 DNA molecule (d) 4 DNA molecule

1158. How many ATP is required during anaphase to move chromosomes from equator to the poles
(a) 38 ATP (b) 5 ATP (c) 30 ATP (d) 76 ATP

1159. The number of chromatids in a chromosome at anaphase is
(a) 2 in mitosis and 1 in meiosis (b)1 in mitosis and 2 in meiosis
(c) 2 each in mitosis and meiosis (d)2 in mitosis and 4 in meiosis

1160. In which of the following stages chromosomes are attached on equatorial plate
(a) Metaphase (b) Anaphase (c) Telophase (d) None of these

1161. Recombinant nodules are found during which of the following
(a) Anaphase (b) Prophase (c) Telophase (d) Metaphase

1162. Cellular structure always disappears during mitosis is
(a) Cell wall (b) Cell membrane (c) Nucleolus (d) All of the above

1163. Which one of the following precedes reformation of the nuclear envelop during *M* phase of the cell cycle
(a) Formation of contractile ring and formation of phragmoplast
(b) Formation of contractile ring and transcription from chromosome
(c) Decondensation from chromosomes and reassembly of the nuclear lamina
(d) Transcription from chromosome and reassembly of the nuclear lamina

1164. The nuclear membrane disappears in

(a) Metaphase (b) Early prophase (c) Late prophase (d) Anaphase

1165. Phragmoplast is

(a) Cell plate formed by endoplasmic reticulum and products of dictyosome during cytokinesis

(b) Cell membrane formed by endoplasmic reticulum, golgi bodies and secretory vesicles during cytokinesis

(c) Plastid capable of fragmentation

(d) Plastid capable of duplication

1166. Cell plate is referred as

(a) Germplast (b) Idioblast (c) Phragmoplast (d) Middle lamella

1167. Mitosis is the process by which eukaryotic cells

(a) Expose the genes for protein synthesis

(b) Become specialized in structure and function

(c) Multiply (d) Grow

1168. Normal cellular activities, such as protein synthesis occur primarily during

(a) Interphase (b) Anaphase (c) Metaphase (d) Prophase

1169. How many mitotic divisions must occur in a cell of root tip to form 128 cells

(a) 128 (b) 127 (c) 64 (d) 32

1170. How many mitotic divisions are needed for a single cell to make 128 cells

(a) 7 (b) 14 (c) 28 (d) 32

1171. The best stage to count the number of chrormosomes during mitosis is or structure of chromosomes can be best seen at

(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

1172. Bivalents in meiosis are

(a) Tetrad (b) Pairs of non-homologous chromosomes

(c) Pairs of several chromatids (d) Pairs of homozygous chromosomes

1173. Mitosis and meiosis take place respectively in

(a) Meristem and gametangia (b) Gametangia and meristem

(c) Permanent tissue and secretory tissue (d) Secretory tissue and permanent tissue

1174. Which of the following will show simple cell division

(a) Microspore mother cells (b) Megaspore mother cells

(c) Archesporial cells (d) All of the above

1175. As there occurs more and more condensation of chromatin during cell division, there occurs

(a) Increase in heterochromatin

(b) Increase in euchromatin

(c) Differentiation of heterochromatin and euchromatin decreases

(d) Differentiation of heterochromatin and euchromatin increases

1176. Amorphous and filamentous part of the interphase nucleolus is called as

(a) Nucleolar organizers (b)Nucleolonema
(c) Nucleolar zone (d)Nucleolar chromosomes

1177. A cell in prophase of mitosis can be distinguished from a cell in prophase-I of meiosis by
(a) The presence of only half as many chromosomes in the meiotic cell
(b) The formation of tetrads in the meiotic cell
(c) The presence of twice as many chromosomes in the meiotic cell
(d) None of these

1178. "Endomitosis" refers to
(a) Division of nucleus without chromosomal division
(b) Division of chromosome without nuclear division
(c) Division of cytoplasm (d)None of these

1179. Mitotic index means
(a) Rate of mitotic division (b) Ratio of mitotic and meiotic division
(c) Ratio of dividing and non-dividing cells (d) None of these

1180. The term meiosis was coined by
(a) Farmer and Moore (b) Flemming (c) Blackman (d) Robertson

1181. Meiosis occurs in
(a) Embryo sac (b) Megaspore
(c) Megaspore mother cell (d) Nucellus

1182. The role of meiosis
(a) Formation of gametes (b)Bringing haplophase
(c)Bringing diplophase (d)Completing life cycle

1183. Four daughter cells formed after meiosis are
(a) Genetically similar (b) Genetically different (c) Anucleate (d) Multinucleate

1184. Meiosis can be observed in
(a) Root tips (b) Cambium (c) Anther (PMC) (d) Pollen grains

1185. Which stage connecting link between Meiosis I and Meiosis II
(a) Interphase I (b) Interphase II (c) Interkinesis (d) Anaphase I

1186. The second division in meiosis is called
(a) Equational division (b) Reduction division (c) Multiplied division (d) None of these

1187. The homologous chromosomes follow the process of synapsis in the stage

Or

Pairing of homologous chromosome takes place in
(a) Leptotene (b) Zygotene (c) Diplotene (d) Pachytene

1188. Four chromatids and two centromeres which are homologous occurs in
(a) Zygotene (b) Diplotene (c) Diakinesis (d) Pachytene

1189. The replication of centrioles occurs during
(a) Early prophase (b) Late prophase (c) Late telophase (d) Interphase

1190. In an organism, if the normal diploid number of chromosomes is 8, how many chromatids are present in each daughter cell at the end of meiosis I

(a) 2 (b) 4 (c) 8 (d) 16

1191. How many meiotic divisions will be necessary to produce two hundred pollen grains

(a) 50 (b) 100 (c) 199 (d) 150

1192. If at the end of meiosis, the 4 daughter cells have 4 chromosomes. How many chromosomes were in the mother cell

(a) 8 (b) 16 (c) 2 (d) 4

1193. If there were 4 chromosomes present during prophase I. How many chromosomes are there in each cell at the end of anaphase II

(a) 16 (b) 4 (c) 2 (d) 8

1194. At what phase of meiosis are there two cells, each with sister chromatids aligned at the spindle equator

(a) Anaphase II (b) Metaphase II (c) Metaphase I (d) Anaphase I

1195. Recombination of genes occur at

(a) Prophase in mitosis (b)Prophase I in meiosis

(c) Prophase II in meiosis (d)Metaphase II in meiosis

1196. Which one of the following pairs is correctly matched

(a) Anaphase I Homologous chromosomes are separated

(b) Metaphase I Pairing of maternal and paternal homologous chromosomes takes place

(c) Interphase I A nuclear envelope encloses each haploid set of chromosomes

(d) Prophase I Non-homologous chromosomes are separated

1197. Match list I and list II and select the correct answer using the code given below in the lists

List I (Phase of meiosis)	**List II** (Event that occurs)
(1) Prophase I	Crossing over occurs
(2) Metaphase I	Sister chromatids migrate to opposite poles
(3) Anaphase I	Homologous line up at equator in pairs

Code :

(a) 1, 2 and 3 are correct (b)1 and 2 are correct, 3 is false

(c) 1 is correct, 2 and 3 are false (d)1 and 3 are correct, 2 is false

1198. The number of chromosomes after I phase of meiotic division in reduction division

(a) Remain unchanged (b) Become doubled (c) Become halved (d) None of these

1199. Meiosis I is reductional division. Meiosis II is equational division due to

(a) Separation of chromatids (b) Pairing of homologous chromosomes

(c) Terminalization (d) Disjunction of homologous chromosomes

1200. A plant has number of chromosome groups arranged at equatorial plane of metaphase-I whose $2n = 50$; the number of chromosomes visible will be

(a) 100 (b) 25 (c) 50 (d) 75

1201. In Neurospora crassa 8 ascospores are formed instead of 4, this is by

(a) One meiosis (b) Two meiosis (c) Two mitosis (d) Meiosis followed by mitosis

1202. In algae meiosis occurs during

(a) Spore formation (b) Spore germination (c) Zygote formation (d) Zygote germination

1203. During the first metaphase of meiosis the centromeres

(a) Undergo division (b) Do not divide

(c) Divide but do not separate (d) Are not identical

1204. When during the meiotic division, do the centromeres divide

(a) Diplotene (b) Metaphase-I (c) Pachytene (d) Anaphase-II

1205. Exchange of chromosome segments between maternal and paternal chromatids during meiosis is called

(a) Linkage (b) Dominance (c) Crossing over (d) DNA multiplication

1206. For viewing diakinesis which one of the following would be a suitable material

(a) Onion root tip (b) Leaf of Dichanthium (c) Rat tail (d) Flower bud

1207. The study of chromosomes at meiotic diplotene shows that

(a) The intimately paired chromosomes repel each other and begin to separate

(b) The pairing of homologous chromosomes which had initiated in the earlier stage is completed

(c) The homologous chromosomes remain united by chiasmata

(d) None of these

1208. Synaptonemal complex is formed during

(a) Meiosis (b) Amitosis (c) Mitosis (d) Cytokinesis

1209. Synaptonemal complex was discovered in

(a) 1953 (b) 1950 (c) 1935 (d) 1980

1210. The points at which crossing over has taken place between homologous chromosomes are called

(a) Protein axes (b) Synaptonemal complexes (c)Chiasmata (d) Centromeres

1211. If for a species $2n = 16$, then during Ist prophase and IInd prophase of meiotic division of a cell, how many tetrads and diads will be formed

(a) 4 and 4 (b) 8 and 4 (c) 8 and 8 (d) 4 and 8

1212. In pollen mother cells cytokinesis during meiosis is

(a) Successive type

(b) Simultaneous type

(c) In some cases successive type while in others simultaneous type

(d) No cytokinesis takes place

1213. A repeated cycle of DNA replication without separation of daughter chromatids leads to the formation of

(a) Pachytene chromosome (b)Leptotene chromosomes

(c) Polytene chromosome (d)Zygotene chromosomes

1214. The force responsible for the terminalization at the time of cell division is

(a) Chemostatic (b) Galvanostatic (c) Electrostatic (d) None of these

1215. Meiosis and mitosis differ from each other because in meiosis

(a) The four nuclei formed are not similar to parental ones

(b) Homologous chromosomes pair are exchange parts

(c) Number of chromosomes gets halved (d) All of the above

ANSWER

ASSIGNMENT (BASIC & ADVANCE LEVEL)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
a	a	a	a	c	a	a	a	a	b	b	b	c	b	c	b	d	c	d	d
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
c	b	d	c	c	b	c	c	c	c	c	a	a	b	a	c	d	c	c	b
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
a	b	b	c	d	b	a	b	b	b	d	a	a	c	d	b	a	d	c	d
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
d	a	a	d	b	b	b	c	a	d	c	d	b	c	a	c	c	a	c	a
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
d	d	b	b	d	a	a	b	b	c	b	b	b	d	c	b	b	b	a	c
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
b	a	a	b	b	d	d	b	c	b	a	d	d	c	b	b	a	d	b	d
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
d	a	c	b	b	c	d	c	b	a	d	b	c	d	d	b	d	b	b	c
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
b	a	d	d	d	d	c	d	d	d	b	d	b	b	d	b	c	a	b	b
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
a	b	a	d	d	d	a	a	a	b	c	a	d	c	d	b	d	d	c	c
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
d	a	b	c	b	c	c	c	b	b	d	a	c	a	c	d	d	b	d	c
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
b	c	d	c	d	a	c	d	c	b	b	b	c	b	a	b	d	c	a	d
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240

b	a	b	c	c	c	b	b	a	b	c	c	d	c	b	b	d	b	b	b
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
d	c	c	c	a	a	c	c	c	a	a	b	a	b	c	c	b	d	d	d
261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
c	b	b	c	b	a	d	b	a	d	b	d	c	c	a	d	a	c	b	a
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
d	a	a	d	d	a	a	d	c	a	a	a	a	b	b	b	d	c	d	c
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
b	d	b	d	a	b	b	b	b	c	d	a	a	d	c	b	a	a	d	d
321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340
a	d	b	a	b	d	a	a	b	a	d	b	a	d	b	b	a	b	d	a
341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
b	b	d	d	a	d	b	b	d	b	b	a	c	b	d	b	d	b	d	a
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380
c	a	a	c	b	b	a	a	a	a	b	c	a	a	c	c	b	c	a	d
381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
b	a	c	b	d	d	b	c	c	a	a	d	c	c	c	d	d	a	b	a
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
a	c	a	b	b	d	d	c	c	c	d	b	b	c	b	c	b	a	a	a
421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440
b	d	a	d	d	a	d	a	a	a	d	a	d	c	b	c	d	b	b	a
441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460
c	b	a	a	a	b	d	a	a	d	b	b	d	c	b	c	c	d	d	a
461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
d	a	b	a	d	c	c	d	b	c	b	d	a	c	d	c	a	c	c	c
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
a	a	b	b	d	b	b	a	c	a	d	d	b	b	c	d	a	c	a	c
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520
a	d	c	d	d	d	a	c	a	a	d	b	b	c	a	c	b	a	b	c
521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
c	c	b	c	a	d	c	a	b	c	a	d	c	b	b	b	d	a	a	d
541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560
b	b	a	c	c	d	a	c	a	d	c	a	d	a	d	c	b	d	b	a
561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580
a	b	c	a	d	a	a	a	d	a	d	a	a	b	a	c	c	c	c	b
581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
b	d	c	a	b	a	c	b	c	c	b	b	c	d	a	d	c	b	d	b
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620

a	d	a	a	b	d	d	a	c	b	d	c	c	b	b	a	d	d	d	d
621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640
d	c	b	c	b	d	a	c	d	b	c	c	b	a	c	b	b	d	d	d
641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
a	a	b	c	a	c	d	b	a	c	c	b	a	a	d	b	d	b	a	d
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680
c	b	c	a	a	d	b	a	c	b	a	d	d	a	d	b	d	b	b	a
681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
d	b	c	d	c	b	a	a	d	c	a	a	d	a	a	b	c	c	c	d
701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
d	a	a	d	c	c	a	d	c	b	b	b	b	d	c	d	c	b	b	b
721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740
a	d	d	d	b	a	b	d	d	c	a	a	c	b	b	d	a	c	c	d
741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760
a	a	d	a	c	b	a	c	d	d	d	b	b	a	d	b	c	a	b	b
761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780
c	c	b	c	a	d	d	d	a	c	c	b	b	b	c	b	c	a	d	d
781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800
c	d	b	b	b	b	b	a	b	b	a	b	b	b	b	b	d	d	b	c
801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820
a	b	a	c	c	b	b	c	d	b	c	a	d	d	d	c	a	c	a	c
821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840
a	c	c	d	c	b	c	c	a	b	c	a	a	a	c	c	b	b	a	a
841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860
d	b	b	d	d	b	a	d	b	b	b	a	c	d	d	b	c	b	d	d
861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880
b	a	a	c	c	b	b	d	b	a	a	d	b	a	d	d	c	a	d	a
881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900
c	c	b	a	a	b	c	b	d	c	b	b	c	c	d	b	c	d	a	b
901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920
a	b	b	a	c	b	a	a	a	a	c	a	c	c	c	c	a	a	d	d
921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940
a	b	a	d	a	c	a	d	d	a	c	d	b	b	d	c	c	a	a	b
941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960
d	a	c	a	b	a	b	c	b	c	d	a	d	c	b	d	b	c	b	d
961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980
b	d	b	d	c	c	c	c	b	d	d	d	b	c	b	c	c	b	b	d

981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
a	b	c	b	c	d	c	a	c	b	b	a	c	d	c	c	b	d	a	c
1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020
d	d	a	c	a	a	a	c	a	a	c	c	d	b	a	c	d	d	c	a
1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040
b	b	a	a	d	d	c	d	c	c	d	c	a	b	b	c	d	d	d	a
1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060
d	d	d	d	b	c	b	c	c	c	d	a	c	a	b	d	b	d	a	a
1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080
c	c	d	c	d	a	d	d	c	c	b	c	d	c	d	a	d	b	b	c
1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100
c	c	b	c	b	b	c	a	a	c	a	d	c	b	a	a	a	b	a	a
1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120
c	a	c	a	b	a	c	d	d	c	d	a	d	a	a	a	b	d	b	d
1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140
c	a	d	b	c	c	b	a	b	b	a	c	a	b	b	b	c	d	c	c
1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160
b	c	b	c	a	d	b	d	c	a	c	b	d	d	a	d	a	c	d	a
1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180
b	c	a	c	a	c	c	a	b	a	b	a	a	c	c	a	b	b	c	a
1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200
c	b	b	c	c	a	b	a	d	c	a	a	c	b	b	a	b	c	a	c
1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215					
d	d	b	d	c	d	c	a	a	c	c	c	c	c	d					