12 Nucleus

The ***nucleus*** is defined as any *formation surrounded by cytoplasm from which chromosomes arise during cell division.* Nucleus is the most important part of the cell. It controls all the cellular activities. So it is referred to as the ***controlling centre*** of the cell. It functions as the ***heart*** of a cell. The nucleus acts as the ***brain*** of a cell. It is the ***administrative office*** of the cell.

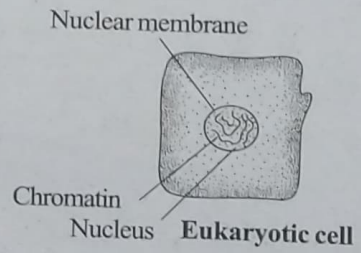

Fig.12.1: A cell with nucleus.

It was first discovered by ***Robert Brown*** (1831) in plant cells. The study of nucleus is termed ***karyology.*** Nucleus is the ***largest or- ganelle*** of the cell.

The nucleus is present in all eukaryotic cells. However, it is absent from RBC of man and some lens cells of eye. The ***sieve tubes*** of plants also lack nucleus.

In eukaryotes, the nucleus is surrounded by a ***nuclear membrane***. But in prokaryotes, the nucleus is not surrounded by a nuclear membrane. Such a nucleus without a nuclear membrane is called a ***nucleoid.***

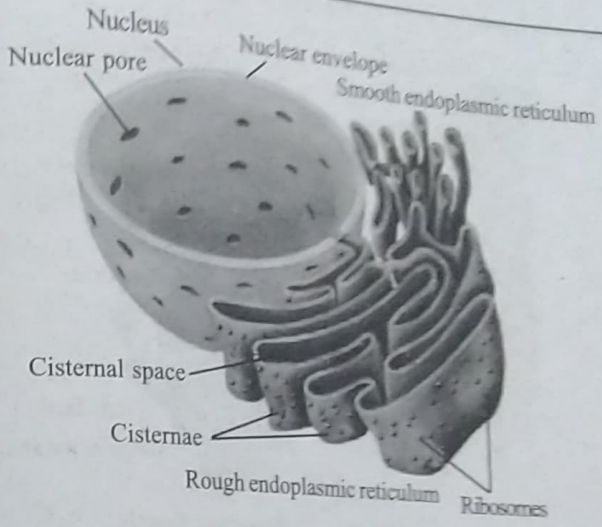

Fig.12.2: Nucleus with endoplasmic reticulum.

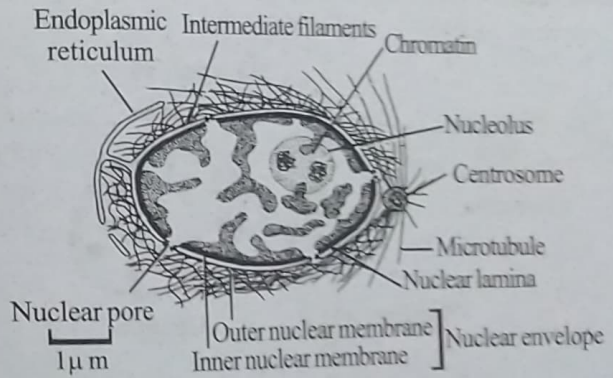

Fig.12.3: Nucleus showing nuclear lamina.

The nucleus occurs in two phases. They are ***mitotic phase*** nucleus and ***interphase nucleus.*** *The nucleus which is involved in division* is called ***mitotic phase nucleus.*** During interphase, the nucleus is involved in metabolic activities. This phase is also called ***resting phase.***

Generally, a cell contains only one nucleus. But sometimes two or more nuclei are present. Based on the number of nucleus, the cells are classified into the following types:

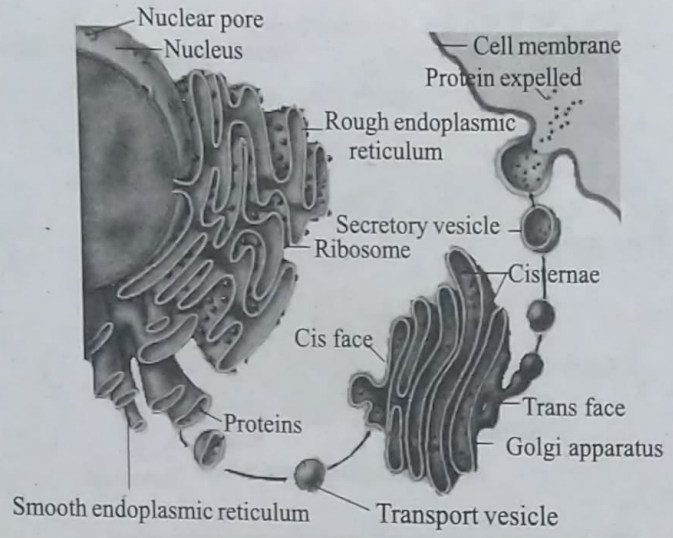

Fig.12.4: A cell showing nucleus.

1. Anucleate cell: In ***anucleate cells***, the nucleus is absent. Eg. *RBC of man.*

2. Mononucleate cell: In ***mononucleate cells***, a single nucleus is present. Eg. *Amoeba, a typical cell,* etc.

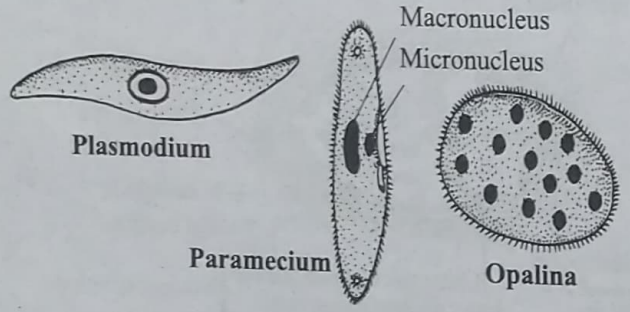

Fig.12.5: Cells showing nuclei.

3. Binucleate cell: In ***binucleate cell,*** two nuclei are present. Of these, one nucleus is small and called ***micronucleus*** and the other nucleus is large and called ***macronucleus.*** Eg. *Paramecium.*

4. Multinucleate cell: Multinucleate cell contains many nuclei. Eg. *Opalina.* The multinucleate animal cells are called ***syncytial cells.*** (Eg. *Epidermal cells of Ascaris*) and the multi-nucleate plant cells are called ***coenocytes.***

The position of the nucleus in a cell is variable. Usually it is situated in the centre of the cell. But in adipose cells and eggs rich in yolk, the nucleus is forced to

lie on the periphery. In glandular cells and in *Acetabularia,* it lies in the ***basal region***. In some plant cells and epithelial cells, it is ***peripheral.***

The shape of the nucleus varies considerably. In most of the cells, it is ***spherical*** in shape. In cylindrical cells, it is ***elliptical***. In human neutrophils, it is ***trilobed***. In *Paramecium*, the macronucleus is kidney shaped. The nucleus of spinning gland cells of insects is highly ***branched***. In *Vorticella,* it is ***horse-shoe*** shaped. In *Stentor,* it is ***beaded.***

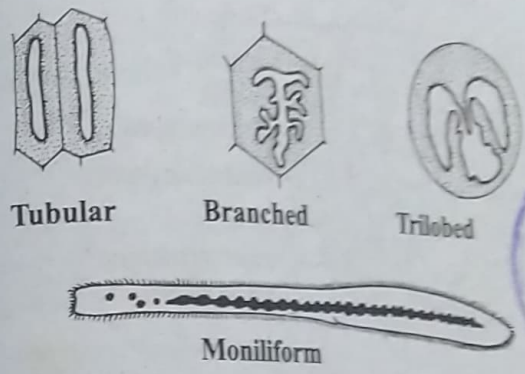

Fig.12.6: Different shapes of nucleus.

The size of the nucleus is not constant. It varies from 11 to 25 mm. The size of the nucleus is directly proportional to the volume of cytoplasm. The more the volume of the cytoplasm, the larger is the size of the nucleus. ***R. Hertwig*** has formulated a relationship between the nuclear volume and the cytoplasmic volume which is called the ***nucleocytoplasmic index*** (NP). The increase in NP acts as a stimulus to the cell division.

$$NP = \frac{Vn}{Vc\text{-}Vn}$$

Vn = Volume of the nucleus

Vc = Volume of the cytoplasm

The size is also correlated with the number of chromosomes and the DNA content. The nuclei having triploid and tetraploid sets of chromosomes are larger in size than those having diploid sets of chromosomes.

Structure of the Interphase Nucleus

Interphase is the period of the cell between two divisions. It is the longest phase. In a typical human cell, the interphase lasts for 89 hrs and the period of division lasts for 1 hr. The interphase cell is metabolically active.

The nucleus of the interphase cell is called ***interphase nucleus.***

The interphase nucleus is surrounded by an envelope called ***nuclear membrane.*** The nuclear membrane encloses a granular semi solid substance called ***nucleoplasm.*** It is also called ***nuclear sap, nuclear matrix*** or ***karyolymph.***

The nucleoplasm contains ***chromatin reticulum*** and ***nucleolus.***

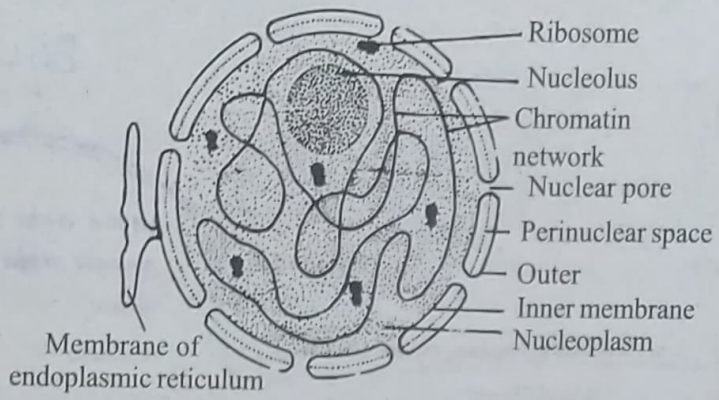

Fig.12.7: A typical nucleus.

1. Nuclear Membrane

The nucleus is separated from the cytoplasm by a semi permeable membrane, the ***nuclear membrane.*** It is also called ***nuclear envelope*** or ***karyotheca***.

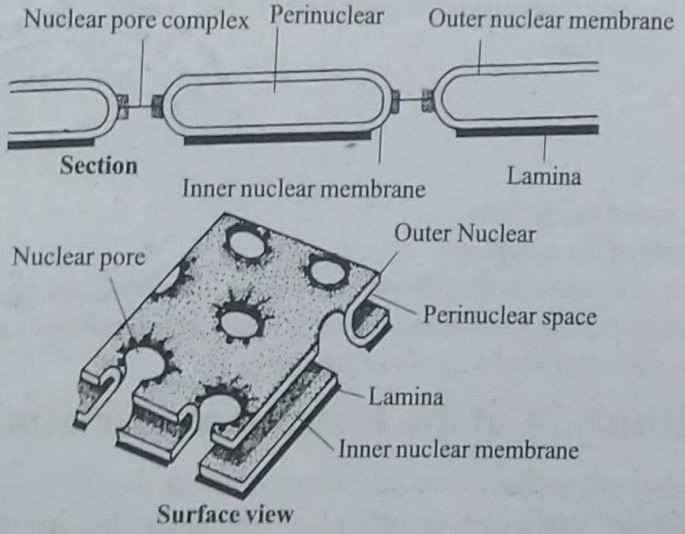

Fig.12.8: Nuclear membrane with pores.

It is ***double layered*** and ***lipoprotein*** in nature as the plasma membrane. The outer layer is called ***ecto karyotheca*** and the inner layer is called ***endo karyotheca.*** They are separated by a ***perinuclear space*** which is about 150 to 300 A°. Each layer is about 70 to 80 A° thick.

The nuclear membrane is a ***unit membrane*** similar to plasma membrane.

The inner nuclear membrane is lined by a fibrous material called ***nuclear lamina***. It composed of an intermediate filament protein called ***lamin*** (A and B type).

The outer membrane is also surrounded by lamins, but they are not well organised like the nuclear lamina.

The outer nuclear membrane is beset with ribosomes. The outer membrane communicates with endoplasmic reticulum at several points.

The outer membrane is often continuous with membranes of the Golgi, endoplasmic reticulum, mitochondrion and plasma membrane. The outer membrane is rough owing to the presence of ribosomes, while the inner membrane is smooth.

The nuclear membrane contains many pores called ***nuclear pores***. These pores are arranged in rows in plant cells or in cluster in lymphocytes but usually are randomly distributed. Nuclear pores form passage ways between the nucleoplasm and cytoplasm.

Nuclear Pore Complex

The nuclear membrane contains many openings called ***nuclear pores***. The nuclear pores form passage ways between nucleoplasm and cytoplasm.

The nuclear pores are arranged randomly in most of animal cells, in ***clusters*** in lymphocytes and oocytes (Fig.23.2) and in definite ***rows*** in plant cells.

The nuclear pore has a complex organization. So the entire structure of nuclear pore is called ***nuclear pore complex***.

The nuclear pore is circular in surface view. In the centre of the pore, there is the passage called ***central channel***. The central channel is surrounded by a central hub called ***transporter***. The transporter is made up of two proteinaceous rings called ***irises***. The two irises are placed one above the other. Each iris is made up of 8 arms. The two irises open sequentially like the diaphragm of a camera.

On the cytoplasmic side, the nuclear pore is provided with an octagonal ring called ***cytoplasmic ring***. It is connected to the transporter by ***8 spokes***.

Similarly, on the nuclear side, the nuclear pore is provided with another octagonal ring called ***nucleoplasmic ring***. It is also connected to the transporter by ***8 spokes***.

The space between the spokes is called an ***aqueous channel***.

On the nucleoplasm side, the nuclear pore is provided with a ***basket***. The basket consists of a ***small ring***, ***8 filaments*** connecting the small ring and the nucleoplasmic ring.

A number of ***cytoplasmic granules*** and ***cytoplasmic filaments*** are attached to the cytoplasmic ring.

Functions of Nuclear Pore Complex

- Nuclear pores function *export* and *import* pathways. Export is the sending out of molecules from the nucleoplasm to the cytoplasm. Import is the transport of molecules from the cytoplasm into the nucleoplasm
- ***Proteins*** and ***metabolites*** diffuse through the aqueous channels.
- ***tRNAs*** and ***mRNAs*** are exported from the nucleus into the cytoplasm.
- All the ***nuclear proteins*** are imported into the nucleus from the cytoplasm.

Pore Complex

The nuclear membrane contains many pores. They are circular in shape. Each pore is 200 to 400 A° in diameter.

At the rims of the pores, the inner and outer membranes are continuous. Each pore is fitted with an apparatus called ***pore complex.*** The pore complex is a cylindrical structure called ***annulus.*** It lies inside the pore. The actual opening of the nuclear pore is the cavity of the annulus.

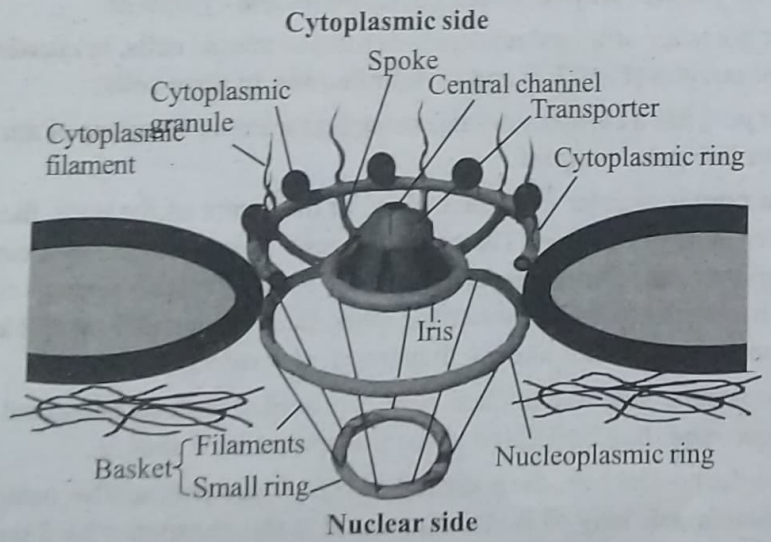

Fig.12.9: Nuclear pore complex.

The outer end of the annulus extends into the cytoplasm and the inner end extends into the nucleoplasm. *The projections of the annulus into the cytoplasm and the nucleoplasm* are called ***blebs***. The annulus is made up of eight radially arranged ***microtubules*** or ***microcylinders.***

The pores can be opened and closed. Exchange of materials between the nucleoplasm and cytoplasm occurs through the nuclear pores. The annulus regulates the exchange of macromolecules in relation to their size and chemical nature.

During cell division the nuclear membrane breaks and disappears. It reappears again at the end of cell division.

2. Nucleoplasm

The nucleus is filled with a homogenous, transparent acidophilic substance known as the ***nucleoplasm*** or ***nuclear sap*** or ***karyolymph.*** There are one or more definite structures called ***nucleoli.*** The ***chromatin threads*** remain suspended in the nucleoplasm. In addition, there may be larger bodies which stain like chromatin threads and hence they are known as ***chromatin nucleoli*** or ***false nucleoli.*** The nuclear sap contains organic and inorganic substances like ***nucleic acids, proteins, enzymes*** and ***minerals.***

3. Chromatin Reticulum

There are lightly stained thread-like bodies embedded in the nucleoplasm called the ***chromonemata,*** which form a network called the ***chromatin reticulum.*** They represent ***chromosomes. Chrome*** in Greek means ***colour*** because they are coloured during staining. The chromatin network readily stains with basic dyes. The chromatin net work is condensed to form thick ribbon-like bodies called ***chromosomes*** during cell division. At certain stages of cell-division, the chromatin reticulum may show bead-like structures called ***chromomeres***.

4. Nucleolus

Fontona (1874) discovered the presence of round oval bodies called ***nucleoli*** embedded in the nucleoplasm. Nucleoli are distinct in the interphase nucleus. They disappear at prophase, remain indistinct during metaphase and anaphase and reappear only during telophase.

Nucleoli occupy a fixed position. They are often associated with the nucleolar organizing portion of the chromosomes. The number of nucleoli varies from species to species. It depends on the number of chromosome sets. The size of the nucleoli is related to the synthetic activities of the cell. Under the light microscope, the

nucleolus appears as a fluid or semi solid body of homogenous consistency. Under the electron microscope, it shows the following parts:

1. Granular Portion: It occurs at the periphery of the nucleolus. It consists of dense granules of 150 to 200 A° diameter. It is composed of RNA and proteins.

2. Fibrillar Portion: It consists of many fibrils of 50 to 80 A° long. These fibrils are called ***nucleolonema***, formed of ribonucleo proteins.

3. Amorphous Portion: This portion has low electron density and it is found only in certain nucleoli.

4. Nucleolus Associated Chromatin: It consists of fibrils of 100 A° thickness situated around the nucleolus extending into it. It contains DNA.

The important function of the nucleolus is the synthesis of ribosomal RNA and protein. The RNA produced inside the nucleolus passes first into nucleoplasm and from there it is passed into the cytoplasm.

5. Chromocentres

In certain cells, such as salivary gland cells of *Drosophila* and *Sciara* one or more areas of nucleus stain very dark with basic dyes. Such areas are called ***chromocentres.*** The chromocentres differ from the heterochromatin by their large size.

Chemistry of the Nucleus

Nucleus mainly consists of ***nucleoproteins***. Besides, enzymes, inorganic salts and lipids occur in smaller amounts. The nucleoproteins are resolved into three groups. They are

1. Basic proteins

2. Acidic proteins and

3. Nucleic acids

Nucleic acids are the most important constituents of the nucleus. They are of two types, namely ***deoxyribo nucleic acid*** and ***ribonucleic acid.*** DNA is present in chromatin net and RNA is present in the nucleolus and in small quantity in chromosomes. Lipids occur in the form of lipoprotein and phospholipids. It comprises about 3.1% of the total weight of the nucleus. Numerous enzymes have been observed. A few important enzymes are nucleoside phosphorylase, ribonuclease, etc. The inorganic compounds usually found in the nucleus are salts of ***calcium, iron*** and ***zinc.***

Functions of Nucleus

1. Metabolism: Nucleus controls majority of the activities of cells. It is a regulatory organelle in cell metabolism.

2. Heredity: Since the nucleus contains DNA molecules in its chromosomes, it plays a significant role in heredity.

3. Differentiation: It controls cell differentiation during the embryonic development. The presence of nuclear enzymes such as DNA polymerase, DPN synthetase, etc. points to the fact that DNA replication and transcription (synthesis of RNA) occur mainly in the nucleus.

4. RNA Synthesis: The synthesis of ribosomal RNA takes place in the nucleolus.

5. Exchange of Materials: Nuclear membrane is concerned with the exchange of materials between the cytoplasm and nucleoplasm.

6. Support: Nuclear membrane provides a surface for the attachment of structural elements of the cytoplasm such as microtubules and microfilaments.

7. Genetic code: Nucleus contains the master plan for protein synthesis.

Nucleolus

Nucleolus *is the deeply staining spherical body concerned with rRNA synthesis, lying inside the nucleus.*

It was first discovered by ***Fontana*** in 1874.

Nucleolus is absent from lower organisms like ***bacteria, yeasts, some algae, cleaving cells, mammalian RBC, reticulocytes, spermatozoa***, etc. In all other cells, nucleolus is present.

The number of nucleoli depends upon the number of sets of chromosomes. Usually one nucleolus is present for each chromosome set. A diploid cell contains two nucleoli. A haploid cell contains only one nucleolus. Thus the sperm and ovum contain only one nucleolus. However, the amphibian oocyte contains 600 to 1200 nucleoli (Fig.23.3).

The nucleolus is located on the ***nucleolar organizer region (secondary constriction)*** of the nucleolar chromosome.

Frequently the nucleolus is attached with the nuclear membrane.

The size of the nucleolus depends upon the synthetic activity of the cell. The nucleoli are small or absent in cells exhibiting little protein synthesis. They are very

large in cells where protein synthesis is going on actively as in oocytes, neurons, secretory cells, etc.

The nucleolus is surrounded by a thick covering called ***perinucleolar chromatin.*** It may be continuous or with holes.

Here and there, the perinucleolar chromatin projects into the nucleolus to form ***intranucleolar chromatin.***

The perinucleolar chromatin and the intranucleolar chromatin are rich in DNA. The DNA serves as the template for the synthesis of RNA.

The interior of the nucleolus is filled with a proteinaceous ground substance called ***matrix*** or ***pars amorpha***.

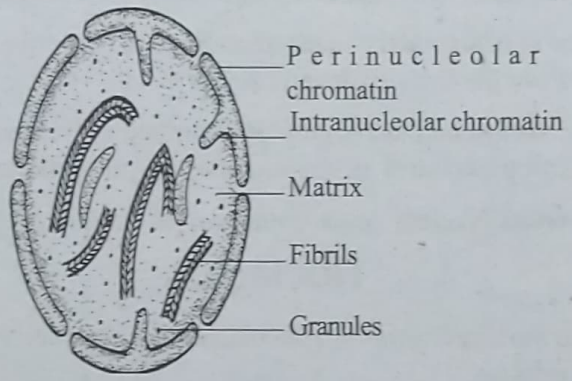

Fig.23.10: Ultrastructure of nucleolus.

The matrix contains a number of ***fibrils*** and ***granules.*** The fibrils contain RNA. They are the precursors of granules. The granules contain protein and RNA.

Nucleolus is composed of RNA, DNA, proteins and enzymes. The RNA is similar to rRNA. The enzymes include ***acid phosphatase, nucleoside phosphorylase, RNA methylase*** and enzymes for the synthesis of NAD.

The nucleoli are classified into three types based on the distribution of granules. They are the following:

1. Homogenous Nucleolus: The granules are uniformly distributed throughout the nucleus.

2. Heterogenous Nucleolus: The granules are occurring in groups.

3. Ring Nucleolus: The granules are arranged along the periphery of the nucleolus in the form of a ring.

The nucleolus exists throughout the interphase period of the cell. When the cell begins to divide, the nucleolus disappears. It reappears when cell division is completed.

Generally nucleolus disappears during prophase and reappears by the end of telophase.

Nucleolar organizer *is a constricted area of a chromosome where nucleolus is formed.* This region of the chromosome is also called ***secondary constriction.*** The chromosome containing the nucleolar organizer is called the ***nucleolar chromosome.***

Generally, a diploid cell contains two nucleolar chromosomes and a haploid cell contains one nucleolar chromosome.

The nucleolar organizer contains genes for the synthesis of ribosomal RNAs such as 18S and 28S. These genes are named as rDNAs.

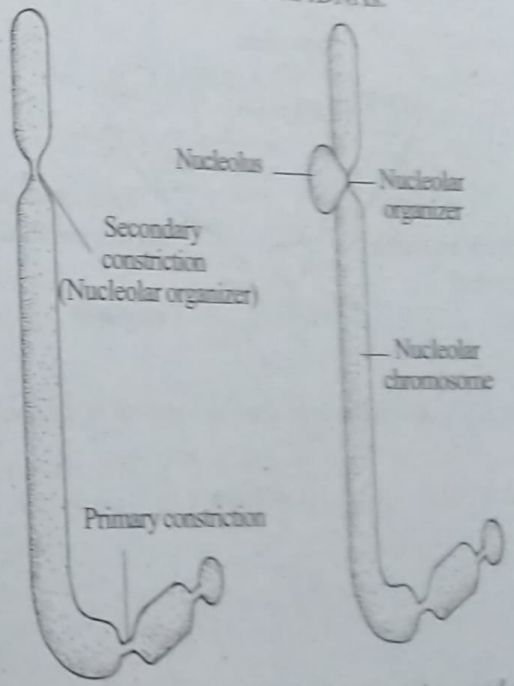

Fig.12.11: Nucleolar chromosome, nucleolar organizer and nucleolus.

Functions of Nucleolus

The nucleolus has the following functions:

1. RNA Synthesis: The nucleolus is the active site for RNA synthesis. The nucleolus synthesizes 70-90% of rRNA in the cell.

2. Ribosome Formation: The nucleolus contains rDNA. The rDNA produces 45S rRNA. It is broken to form 28S and 18S rRNA. Another rDNA outside the nucleolus produces 5S rDNA.

The 28S rRNA combines with 5S rRNA and 5.8S rRNA and proteins to form 60S ribosomal sub-unit. Similarly 18S rRNA combines with proteins to form 40S sub-unit of the ribosome. The two sub-units pass out of the nucleolus and reach the cytoplasm. Thus nucleolus is the site where ribosomal sub-units are synthesized.

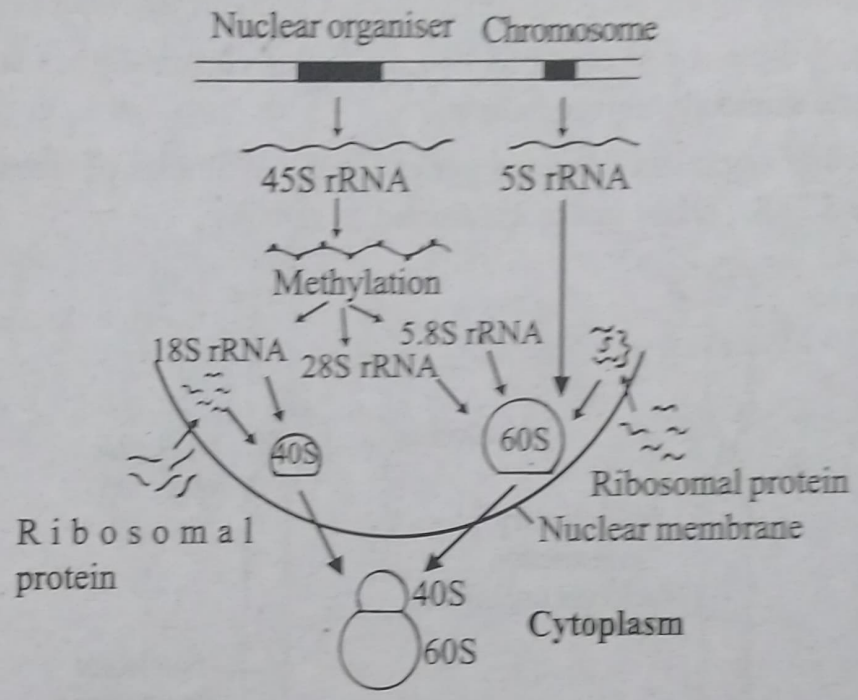

Fig.12.12: Biosynthesis of ribosomal subunit in the nucleolus.