CELL AND MOLECULAR BIOLOGY
UNIT III
NUCLEUS

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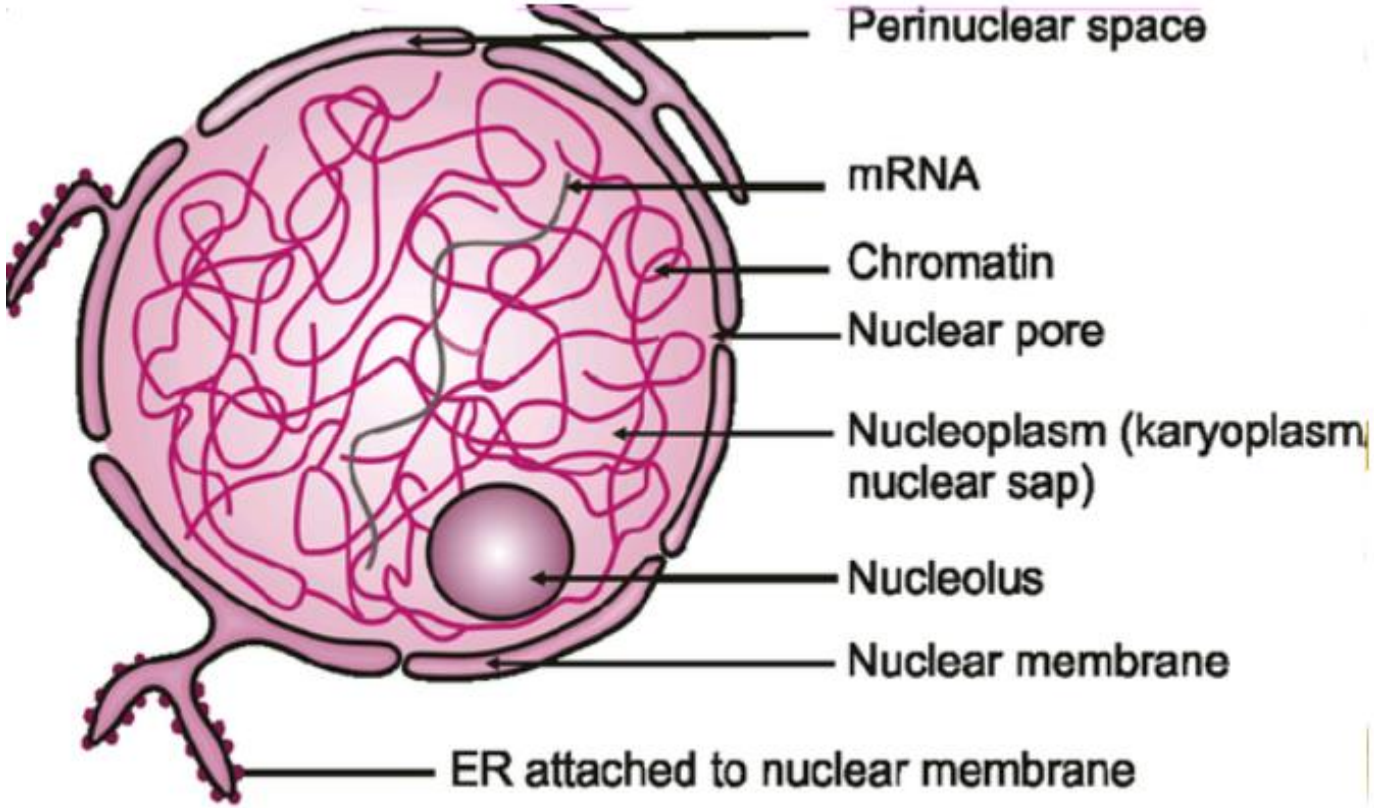
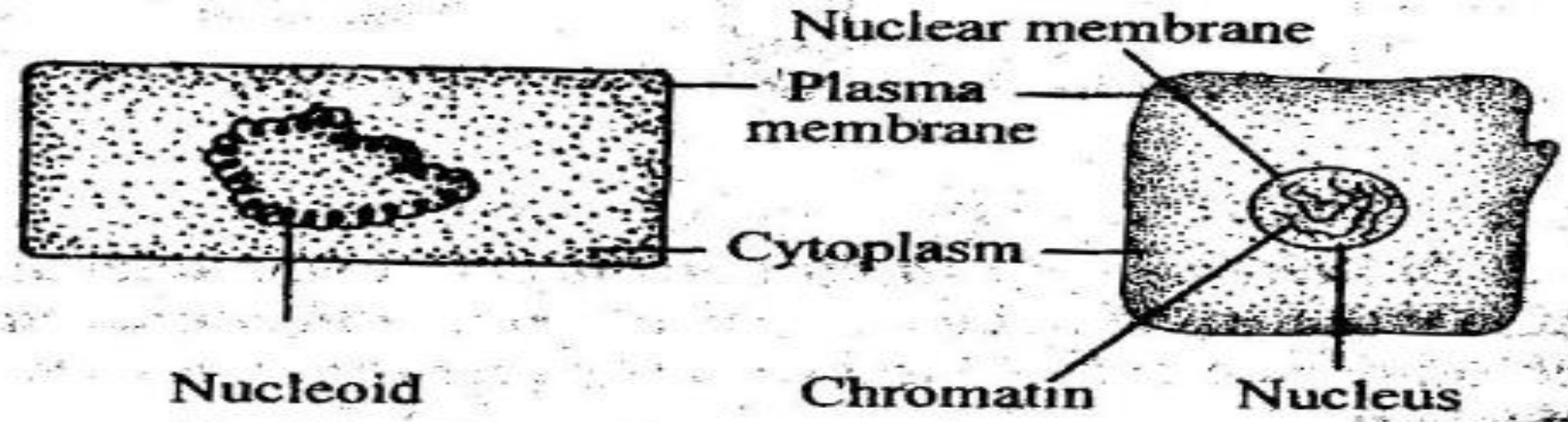


Structure of nucleus

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 was first discovered by ***Robert Brown*** in 1831 in flowering plants. The study of nucleus is termed ***karyology.***

The nucleus is present in all eukaryotic cells. However, it is absent from RBC of man and some lens cells of eye.



Prokaryote and Eukaryote cells.

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.***

The nucleus occurs in two phases. They are ***mitotic phase*** nucleus and ***interphase.*** 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 some times two or more nuclei are present. Based on the number of nucleus, the cells are classified into the following types:

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.

Cells showing nuclei.

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

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***.

Different shapes of nucleus.

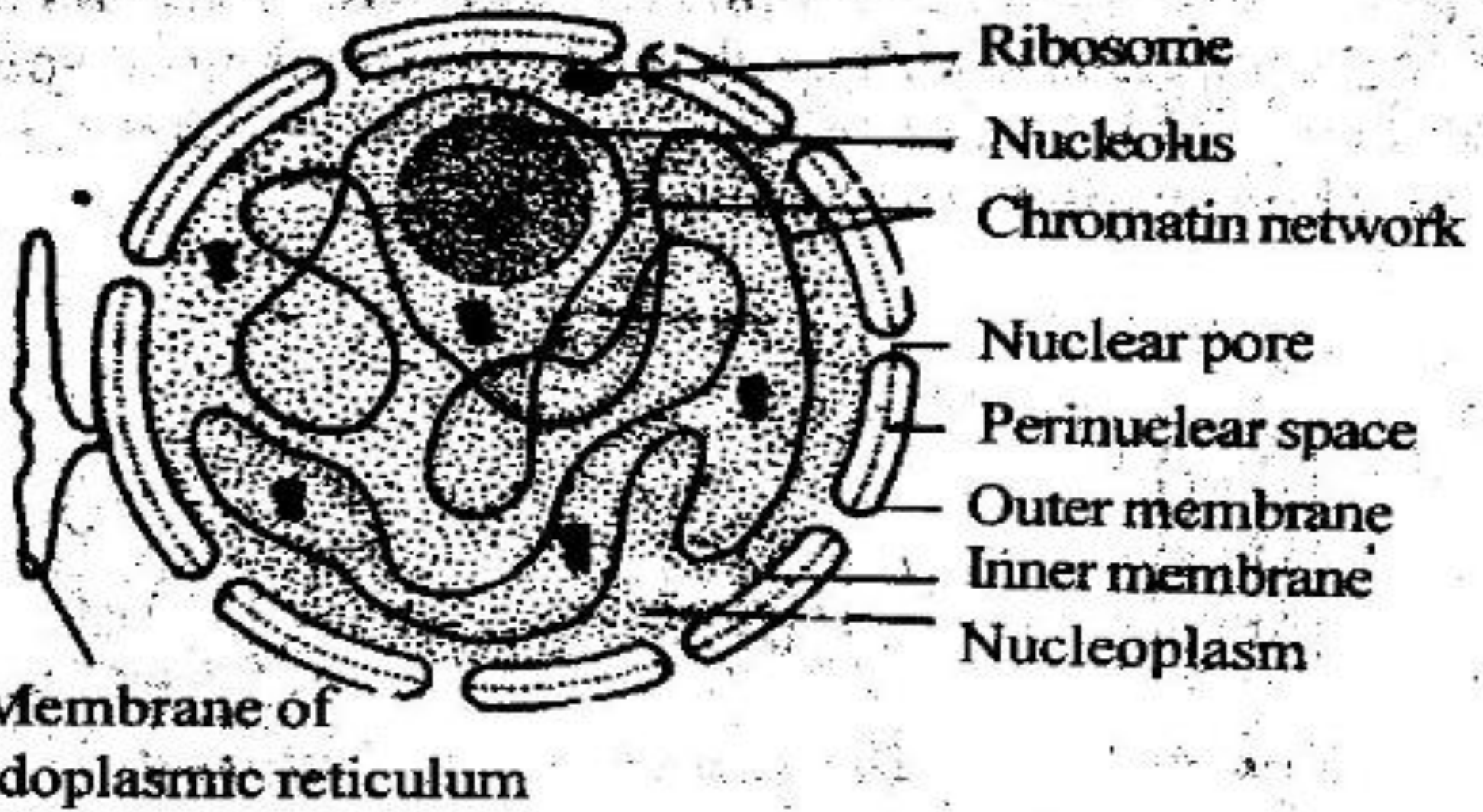
The size of the nucleus is not constant. It is variable. The size of the nucleus is directly proportional to the cytoplasm. The more the volume of the cytoplasm the larger is the size of the nucleus. ***R. Hertwig*** has formulated a relationship between the nuclear volume and the cytoplasmic volume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

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

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.



: *A typical nucleus.*

Structure of the Interphase Nucleus

A cell has two phases, namely an ***interphase*** or ***period*** of non-division and ***period of division***.

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

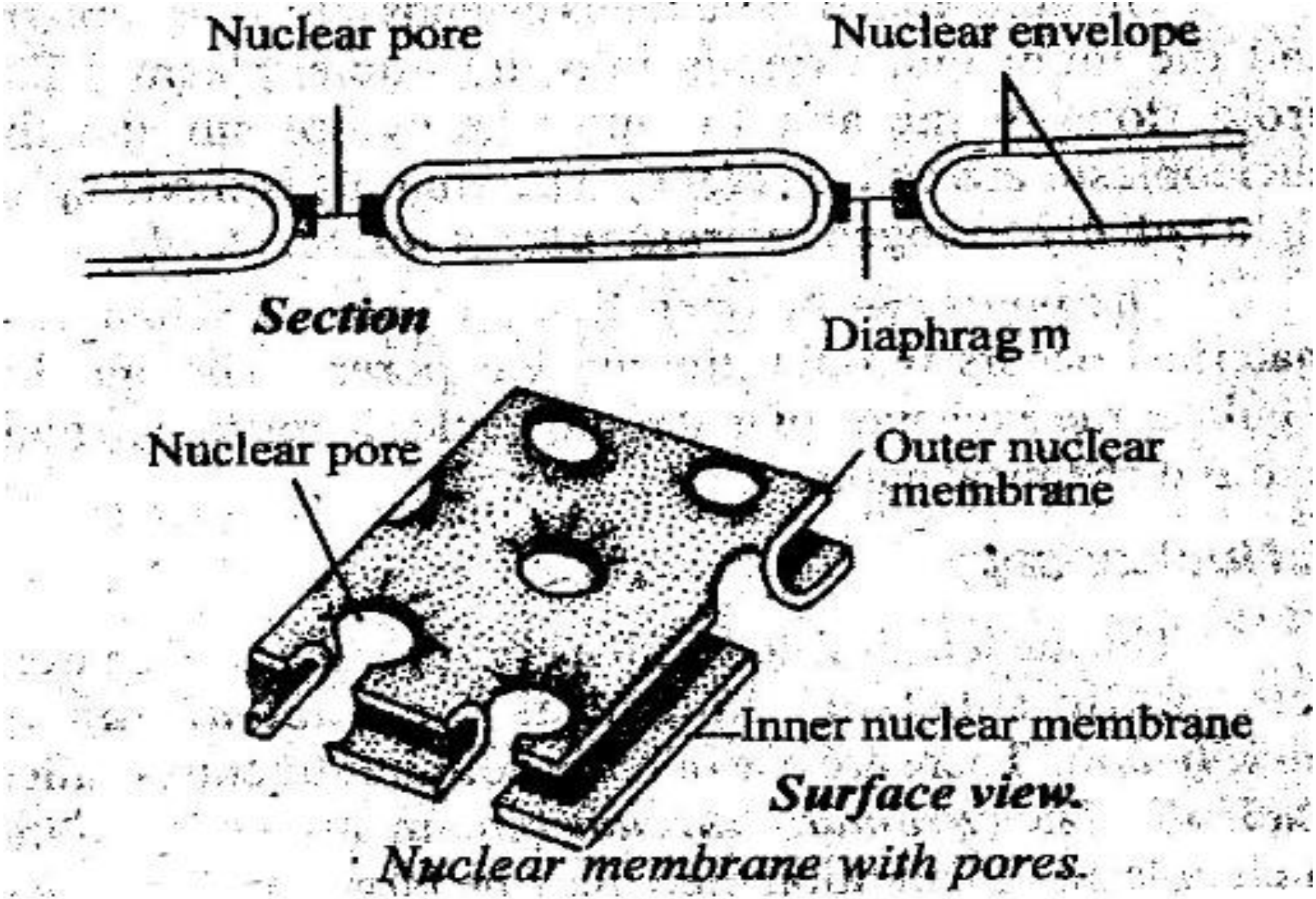
The nucleus of the interphase cell is called ***interphase nucleus.***

The interphase nucleus has the following parts:

1. *Nuclear envelope or karyotheca*
2. *Nuclear sap or karyolymph*
3. *Chromatin net or nuclear reticulum*
4. *Nucleolus and*
5. *Chromocentres.*

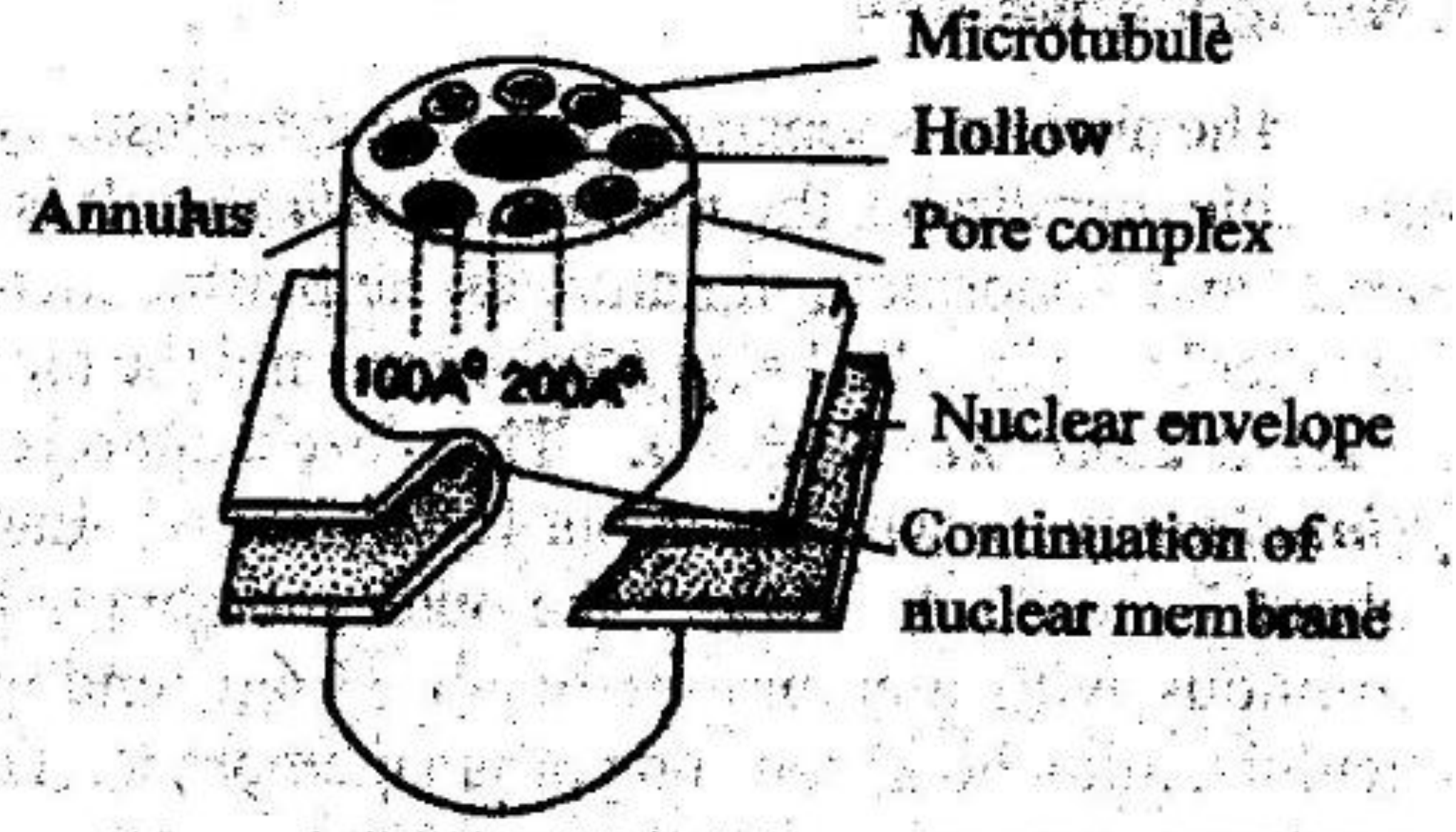
1. Nuclear envelope

The nucleus is separated from the cytoplasm by a semi permeable membrane, the ***nuclear membrane.*** 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 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.



Nuclear membrane with pores.

Pore complex: The nuclear membrane contains many pores. They are circular in shape. Each pore is 200 to 400 Å 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.



Nuclear membrane with 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 occurs through the nuclear pores. The annulus regulates the exchange of macromolecules in relation to their size and chemical nature.

2. *Nuclear sap*

The nucleus is filled with a homogenous, transparent acidophilic substance known as the ***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*

These are lightly stained thread-like bodies embedded in the nucleoplasm called the ***chromonemata***, which form a net work called the ***chromatin reticulum.*** This net work readily stains with basic dyes. The chromatin net work readily stains with basic dyes. The chromatin net work is condensed to form thick ribbon-like bodies called ***chromosomes*** during cell division. At certain places, the chromatin net remains condensed as darkly stained chromatin mass. These regions are called ***heterochromatin***. They contain small amount of DNA and large amount of RNA. At certain stages of cell-division, the chromatin reticulum may show bead-like structures called ***chromomeres.***

4. Nucleolus

Fontona (1784) 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 nucleus. 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.

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 nucleus.

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 1781.

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

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

Frequently the nucleolus is attached with the nuclear membrane.

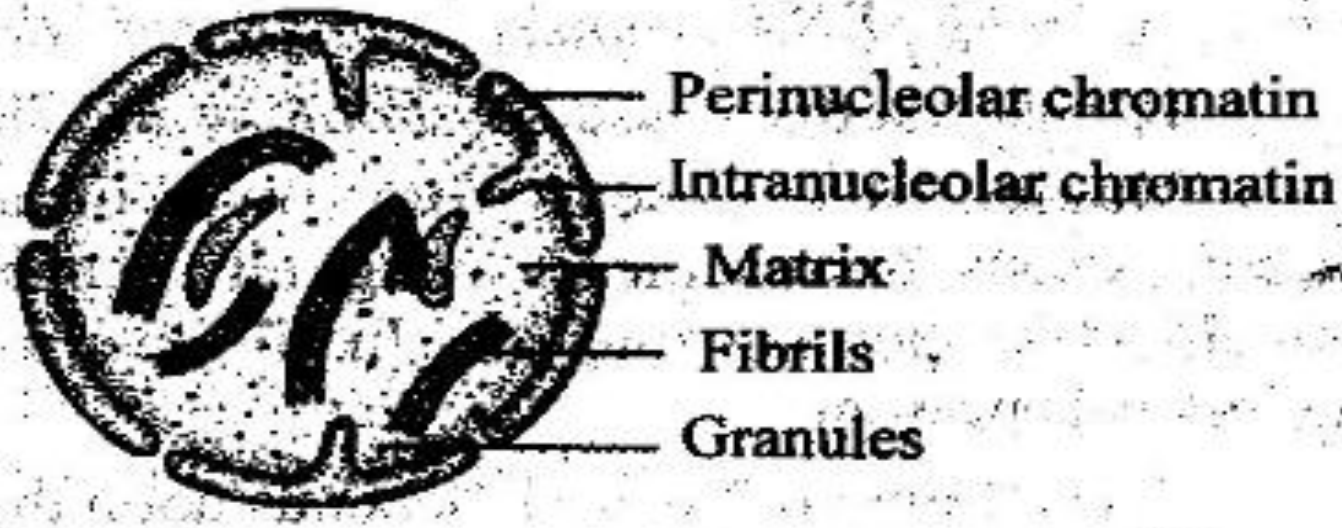
The size of the nucleolus depends upon the synthetic activity of the cell. The nucleoli are small or absent in cells exhibiting little protein synthesis. They are very large in cells where protein synthesis is going on actively as in oocytes, neurons, secretory cells, etc.

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***.



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.

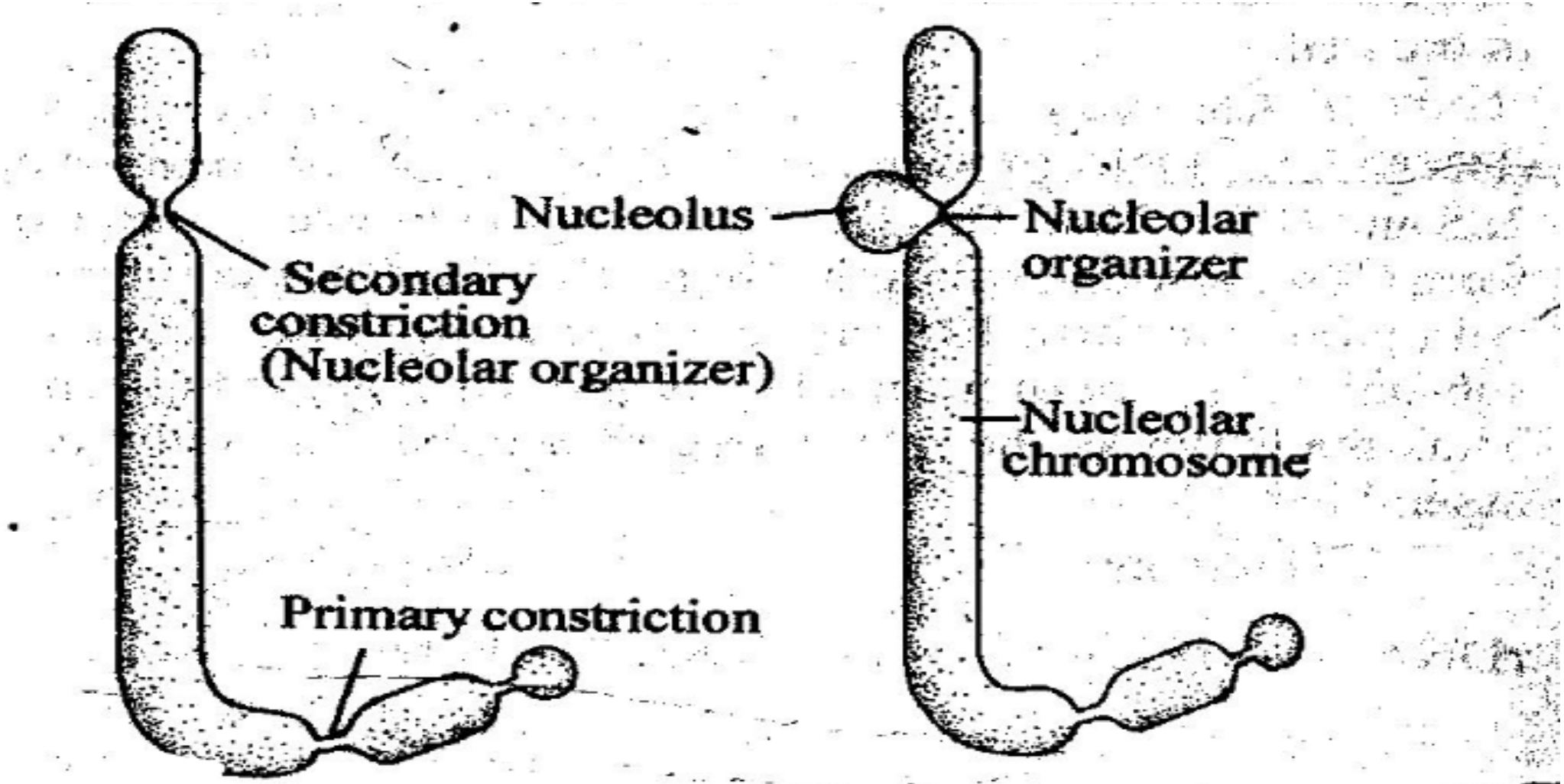
The nucleoli are classified into three types based on the distribution of granules. They are the following:

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 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.



Nucleolar chromosome, nucleolar organizer and nucleolus.

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.

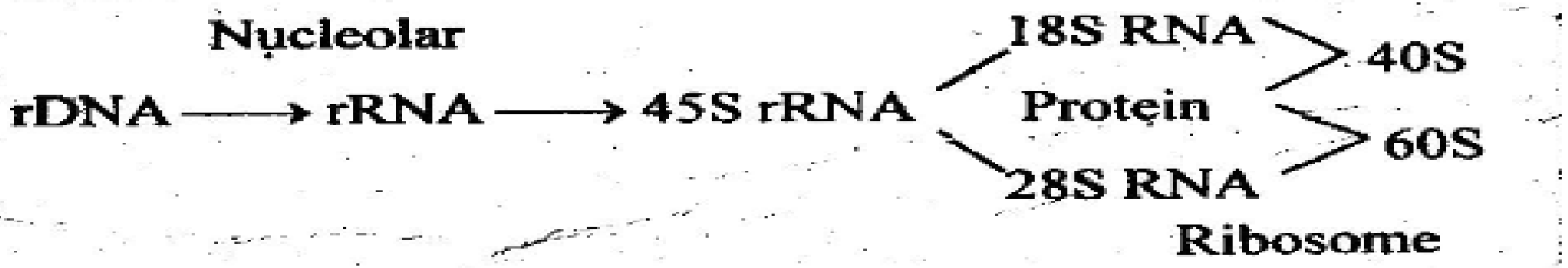
The nucleolar organizer contains genes for the synthesis of ribosomal RNAs such as 18S and 28S. These genes are named as rDNA.

Functions of Nucleolus

The nucleolus has the following functions:

1. RNA synthesis: The nucleolus is the active site for RNA synthesis. The nucleolus synthesises 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. The 28S rRNA combines with protein to form 60S ribosomal sub-unit. Similarly 18S rRNA combines with protein 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 assembled.



Biosynthesis of ribosomal subunit in the nucleolus.