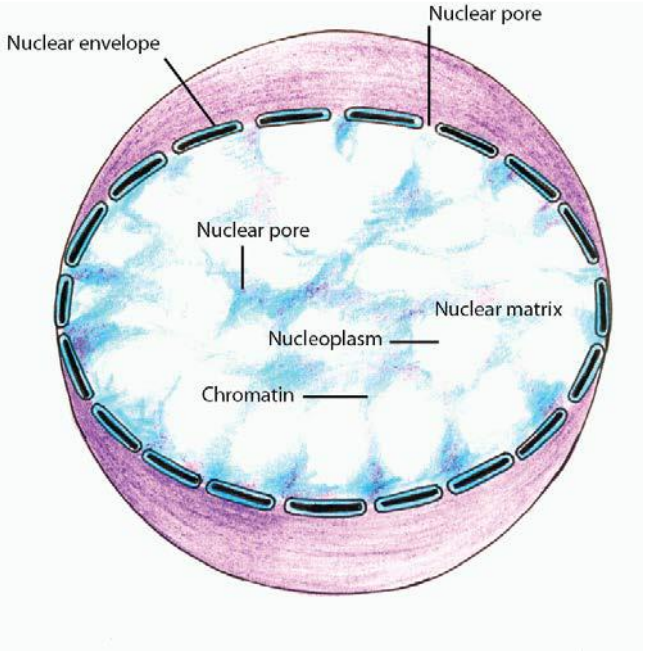
Nucleus


Nuclear pore
Nuclear envelope
Nuclear pore
Nuclear matrix
Nucleoplasm
Chromatin

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Nucleus is the most important component of a cell, enclosed by specialized double membrane which controls cellular metabolism and contains all the genetic materials.

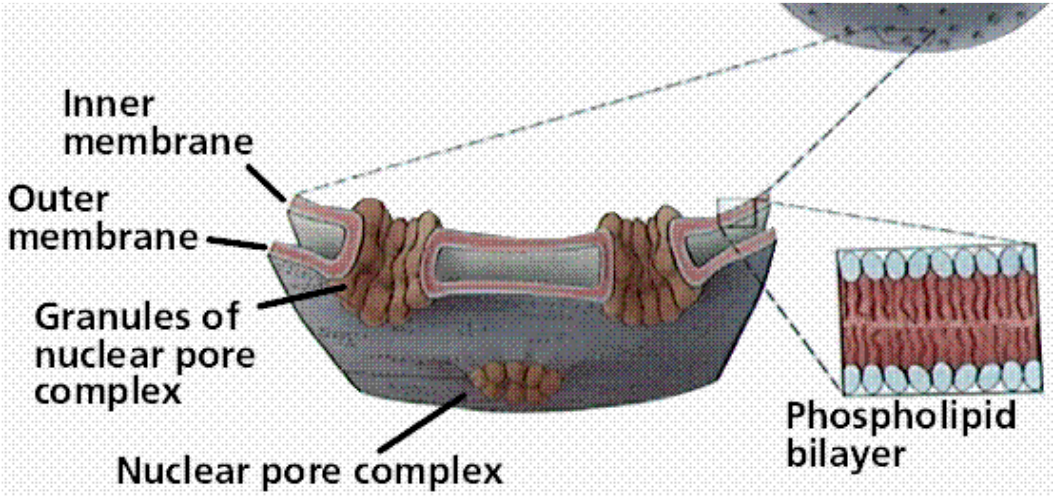
A nucleus is called an interphase nucleus when it is in the non-dividing or metabolic phase. Leeuwenhoek first observed nucleus in the red blood corpuscles of fish. But Robert Brown was the first to study nucleus in orchid root cells in 1831.

Nucleus is present universally in all eukaryotic cells of plant and animals but no nucleus is present in prokaryotic cells.

Most of the cells of plants and animals are uninucleate i.e., they contain single nucleus. Some cells however contain two nuclei. For example cells which are present in protozoans like *Paramecium*. The larger macronucleus is responsible for controlling metabolic activities while the smaller micronucleus possesses the genetic information. Cells of bone marrow, striated muscle, latex vessels, several fungi and algae contain numerous nuclei and are called multinucleate cells. Multinucleate cells of plants and animals are termed as coenocytic cells.

Nucleus is usually placed at the center of cell though its position may vary according to the cell type. The nucleus is located at the peripheral position of the plant cell due to presence of large central vacuole. The shape of nucleus is generally spherical in shaped but it may be of ellipsoid or flattened in some other cells. Although the shape of nucleus is constant, the size may vary at different times. The chromatin material present in the nucleus does not change and remain constant for a particular species even though the shape and size of nucleus change in a cell. The different components of the nucleus are nuclear envelop or nuclear membrane, cytoplasmic extrusion, chromatin, nucleoplasm or karyolymph and nucleus.

The **nuclear envelope** encloses the nucleus demarcating it from the cytoplasm of the cell. It is a differentiation of rough endoplasmic reticulum and is composed of two membranes. Each membrane is about 75-90Å thick and lipoprotein in nature and they are separated by a space of 100-150 Å called the **perinuclear space**. The outer nuclear membrane may be smooth or rough (when ribosomes are bound on to it) but the inner membrane is always smooth and contain no ribosome but sometimes associated with chromatin. The nuclear membrane is broken at regular interval by nuclear pores which are octagonal orifices about 80 nm (10nm - 100 nm) in diameter. These are not freely communicating openings but are plugged by a cylindrical of protein materials. The inner membrane of the nuclear membrane is attached to a layer of fibrous proteins 50 to 80 nm thick that is known as the nuclear lamina. The lamina proteins become phosphorylated during mitosis which led to the dissembling of the nuclear envelop. But during telophase, the lamina proteins bind strongly to chromatin and are thought to be important in reassembling the nucleus. The nuclear envelop regulates the passage of ions and macromolecules. The nuclear pores present in envelop play an important role in the transfer of macromolecules between the nucleus and the cytoplasm and vice versa.
Cytoplasmic extrusions are present between the cytoplasm and the nucleus in the pores. They connect the nuclear membrane and endoplasmic reticulum of the cytoplasm. The outer membrane of the nuclear envelop is continuous with the endoplasmic reticulum.



Nucleoplasm:

The space between the nuclear envelope and the nucleolus is filled by a transparent, semi-solid, granular and slightly acidophilic ground substance or the matrix known as the nuclear sap or nucleoplasm or karyolymph.

The nuclear components such as the chromatin threads and the nucleolus remain suspended in the nucleoplasm which is composed mainly of nucleoproteins but it also contains other inorganic and organic substances, namely nucleic acids, proteins, enzymes and minerals. The most common nucleic acids of the nucleoplasm are the DNA and RNA.

The nucleoplasm contains many types of complex proteins categorized into:

(i) Basic proteins. The proteins which take basic stain are known as the basic proteins. The most important basic proteins of the nucleus are nucleoprotamines and the nucleohistones.

(ii) Non-histone or Acidic proteins. The acidic proteins either occur in the nucleoplasm or in the chromatin.

The most abundant acidic proteins of the euchromatin (a type of chromatin) are the phosphoproteins. The nucleoplasm contains many enzymes which are necessary for the synthesis of the DNA and RNA. Most of the nuclear enzymes are composed of non-histone (acidic) proteins. The most important nuclear enzymes are the DNA polymerase, RNA polymerase, NAD synthetase, nucleoside triphosphatase, adenosine diaminase, nucleoside phosphorylase, guanase, aldolase, enolase, 3-phosphoglyceraldehyde dehydrogenase and pyruvate kinase. The nucleoplasm also contains certain cofactors and coenzymes such as ATP and acetyl CoA. The nucleoplasm has small lipid content. The nucleoplasm also contains several inorganic compounds such as phosphorus, potassium, sodium, calcium and magnesium. The chromatin comparatively contains large amount of these minerals than the nucleoplasm.

The nucleoplasm contains many thread-like, coiled and much elongated structures which take readily the basic stains such as the basic fuchsin. These thread-like structures are known as the chromatin (*chrome*=colour) substance or chromatin fibres.

Thread like, coiled and much elongated structures are present inside the nucleus of cells at interphase stage. These thread like structures are called **chromatin** or nuclear reticulum and they are a complex of DNA and histone proteins. But the chromatin fibers become thick, short and ribbon like structures called **chromosomes** during cell division. The chromatic fibers are distributed throughout the nucleoplasm and are differentiated into two regions – **euchromatin and heterochromatin**. Euchromatin is narrow about 10-30 nm thick lightly stained and diffused part which form the bulk of chromatin. It however takes deep stain during cell division and contains maximum DNA and is genetically very important. Heterochromatin is wider about 100nm thick and coiled tightly. There is a greater density of chromatin material and thus stained darker in interphase nucleus. This region is genetically inert as it contains relatively little DNA and large amount of RNA.

Nucleoplasm or karyolymph is a transparent semifluid and colloidal substance which fills the space between the nuclear envelope and the nucleolus. It is also termed as matrix in which the chromatin thread and nucleolus remain suspended. Nucleoplasm is mainly composed of nucleoprotein and it contains various inorganic and organic substances such as nucleic acids, proteins, enzymes etc. The enzymes essential for the synthesis of DNA and RNA are also present along with many cofactors and coenzymes like $NAD^{+,}$ ATP and acetyl CoA. Basic and acidic proteins are also found in the nucleoplasm. Nucleo-protamines and nucleo histones are the important basic proteins while phosphoproteins are the most important acid proteins in nucleoplasm. It also contains many inorganic compounds of P, K, Ca, Na and Mg.

The **nucleolus** is large spherical body found inside the nucleus and was first discovered by Wagner in 1982. The number of nucleolus present in a nucleus varies with species. Nucleus of some cells of plant and animals may contain one or two nucleolus or even more. In human, there is two pair of nucleoli in each diploid nucleus.

The nucleolus is found to be in contact with heterochromatic regions of chromosomes in certain cells and these regions are called the **nucleolar organizing region** of the chromosomes.

The nucleolus is chemically composed of proteins and nucleic acid (DNA and RNA). The RNA present in nucleolus is closely similar with the ribosomal RNA. It is believed that nucleolus ***helps in the synthesis of ribosomal RNA***. The DNA present in the nucleolus guides the synthesis of RNA. The RNA after synthesis passes from the nucleolus to the nucleus and then to ribosomes in the cytoplasm. The most important protein of nucleolus is *phosphoproteins* but it also contains certain enzymes required for the biosynthesis of coenzymes, nucleotides and ribosomal RNA.

Nucleolus:

Most cells contain in their nuclei one or more prominent spherical colloidal *acidophilic* bodies, called nucleoli. However, cells of bacteria and yeast lack nucleolus.

The nucleolus is mainly involved in the **assembly of ribosomes**. After being produced in the nucleolus, ribosomes are exported to the cytoplasm where they translate mRNA. Some of the eukaryotic organisms have nucleus that contains up to four nucleoli. The nucleolus plays an indirect role in protein synthesis by producing ribosomes. Nucleolus disappears when a cell undergoes division and is reformed after the completion of cell-division. The size of the nucleolus is found to be related with the synthetic activity of the cell. Therefore, the cells with little or no synthetic activities, sperm cells, blastomeres, muscle cell, etc., are found to contain smaller or no nucleoli, while the oocytes, neurons and secretory cells which synthesize the proteins or other substances contain comparatively large-sized nucleoli. The number of nucleoli in nucleus may be 1, 2 or 4, depending on spps.

A nucleolus is often associated with the nucleolar organizer (NO) which represents the secondary constriction of the nucleolar organizing chromosomes, and are 10 in number in human beings. Nucleolar organizer consists of the genes for 18S, 5.8S and 28S rRNAs. The genes for fourth type of r RNA, *i.e.*, 5S rRNA occur outside the nucleolar organizer.

The nucleolus is composed of four regions - **granular, fibrillar, amorphous and chromatin regions**. The *granular region* occurs at the periphery and consists of granules having a diameter of about 150-200Å. This region is mainly composed of ribonucleoprotein. The *fibrillar region* on the other hand is composed of many fibrils of 50-80Å long and also contains ribonucleoprotein. *Amorphous region* is also called *pars amorpha* and is composed of proteins which can be easily hydrolyzed by pepsin enzymes. This region surrounds the granules and fibrils of nucleolus. The *chromatin region* is located at the periphery and is composed of DNA which serves as template for RNA synthesis.

Nucleolus is not bounded by any limiting membrane; calcium ions are supposed to maintain its intact organization.

Nucleolus also contains some enzymes such as acid phosphatase, nucleoside phosphorylase and NAD_+ synthesizing enzymes for the synthesis of some coenzymes, nucleotides and ribosomal RNA. RNA methylase enzyme which transfers methyl groups to the nitrogen bases occurs in the nucleolus of some cells. Functionally nucleolus is the site where biogenesis of ribosomal subunits (40S and 60S) takes place.

In it three types of rRNAs, namely 18S, 5.8S and 28S rRNAs, are transcribed as parts of a much longer precursor molecule (45S transcript) which undergoes processing (RNA splicing) by the help of two types of proteins such as nucleolin and U3 sn RNP (U3 is a 250 nucleotide containing RNA, sn RNP represents small nuclear ribonucleoprotein).

The 5S r RNA is transcribed on the chromosome existing outside the nucleolus and the 70S types of ribosomal proteins are synthesized in the cytoplasm. All of these components of the ribosomes migrate to the nucleolus, where they are assembled into two types of ribosomal subunits which are transported back to the cytoplasm. The smaller (40S) ribosomal subunits are formed and migrate to the cytoplasm much earlier than larger (60S) ribosomal subunits; therefore, nucleolus contains many more incomplete 60S ribosomal subunits than the 40S ribosomal subunits. Such a time lag in the migration of 60S and 40S ribosomal subunits, prevents functional ribosomes from gaining access to the incompletely processed heterogeneous RNA (hn RNA; the precursor of m RNA) molecule inside the nucleus.

Functions of the nucleus

Speaking about the functions of a cell nucleus, it controls the hereditary characteristics of an organism. This organelle is also responsible for the protein synthesis, cell division, growth, and differentiation. Some important functions carried out by a cell nucleus are:

1. Storage of hereditary material, the genes in the form of long and thin DNA (deoxyribonucleic acid) strands, referred to as chromatins.
2. Storage of proteins and RNA (ribonucleic acid) in the nucleolus.
3. Nucleus is a site for transcription in which messenger RNA (mRNA) are produced for the protein synthesis.
4. Exchange of hereditary molecules (DNA and RNA) between the nucleus and rest of the cell.
5. During the cell division, chromatins are arranged into chromosomes in the nucleus.
6. Production of ribosomes (protein factories) in the nucleolus.
7. Selective transportation of regulatory factors and energy molecules through nuclear pores.

As the nucleus regulates the integrity of genes and gene expression, it is also referred to as the control center of a cell. Overall, the cell nucleus stores all the chromosomal DNA of an organism.