INTERPHASE NUCLEUS

Nucleus- Definition, Structure, Functions and Diagram

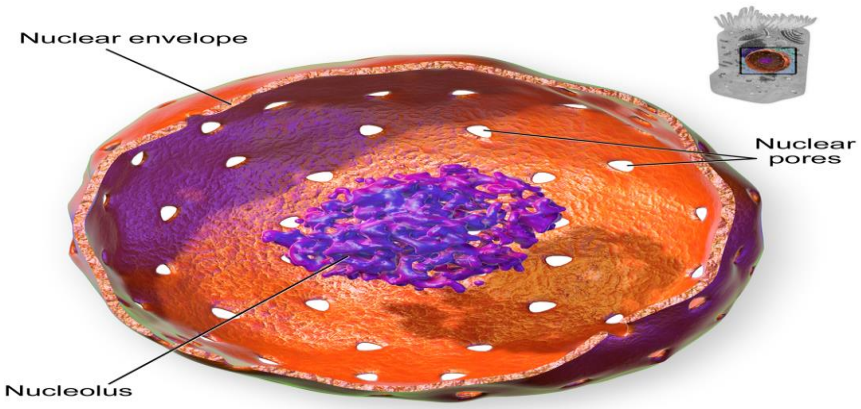
Definition

- The cell nucleus is a membrane-bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction.
- It is the command center of a eukaryotic cell and is commonly the most prominent organelle in a cell accounting for about 10 percent of the cell's volume.
- In general, a eukaryotic cell has only one nucleus. However, some eukaryotic cells are enucleated cells (without a nucleus), for example, red blood cells (RBCs); whereas, some are multinucleate (consists of two or more nuclei), for example, slime **molds**.
- The nucleus is separated from the rest of the cell or the **cytoplasm** by a nuclear membrane.

As the nucleus regulates the integrity of genes and gene expression, it is also referred to as the control center of a cell.

Structure of Nucleus

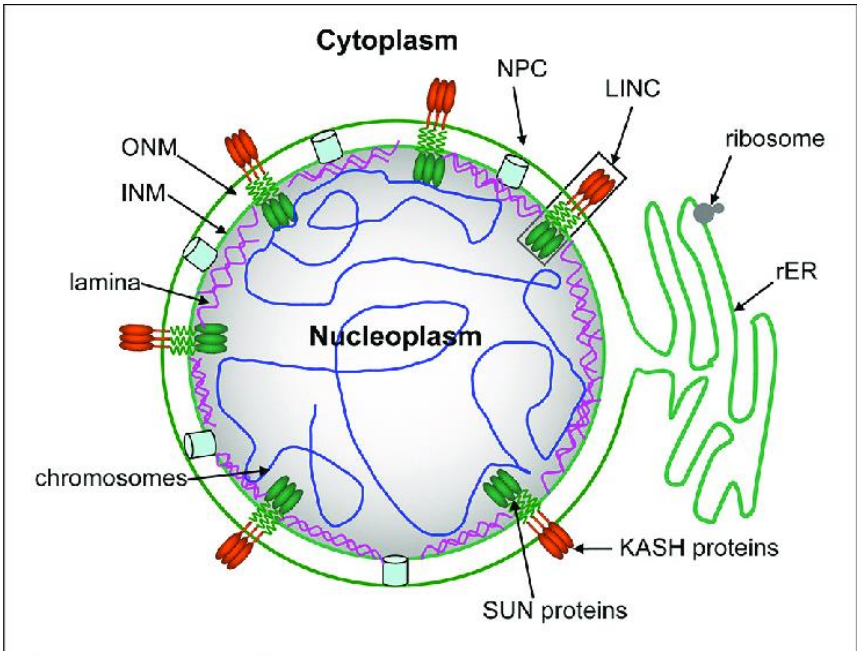
- **Nucleus** is a membrane bound structure that contains the cell's hereditary information and controls the cell's growth and reproduction.
- Nucleus is present in all eukaryotic cells, they may be absent in few cells like the mammalian RBCs.
- The shape of the nucleus is mostly round, it may be oval, disc shaped depending on the type of cell.
- It is the command center of a eukaryotic cell and is commonly the most prominent organelle in a cell.
- The nuclear envelope is a double membrane that separates the nucleus from the cytoplasm.
- All traffic into and out of the nucleus passes through nuclear pores that bridge the double membranes.
- Inbound traffic includes all nuclear proteins and ribosomal proteins destined for the nucleolus.
- The nuclear envelope consists of phospholipids that form a lipid bilayer.
- The nuclear envelope is perforated with numerous pores called nuclear pores.
- The envelope helps to maintain the shape of the nucleus and assists in regulating the flow of molecules into and out of the nucleus through nuclear pores.
- The nuclear envelope is connected with the endoplasmic reticulum (ER) in such a way that the internal compartment of the nuclear envelope is continuous with the lumen of the ER.
- **Chromosomes** consist of DNA, which contains heredity information and instructions for cell growth, development, and reproduction.
- When a cell is "resting" i.e. not dividing, the chromosomes are organized into long entangled structures called **chromatin** and not into individual chromosomes.
- **Nucleoplasm** is the gelatinous substance within the nuclear envelope.
- **The nucleolus** is not surrounded by a membrane, it is a densely stained structure found in the nucleus.



Nucleus

Functions of Nucleus

1. It controls the heredity characteristics of an organism.
2. It main cellular metabolism through controlling synthesis of particular enzymes.
3. It is responsible for protein synthesis, cell division, growth and differentiation.
4. Stores heredity material in the form of deoxy-ribonucleic acid (DNA) strands. Also stores proteins and ribonucleic acid (RNA) in the nucleolus.
5. It is a site for transcription process in which messenger RNA (mRNA) are produced for protein synthesis.
6. It helps in exchange of DNA and RNA (heredity materials) between the nucleus and the rest of the cell.
7. Nucleolus produces ribosomes and are known as protein factories.
8. It also regulates the integrity of genes and gene expression.



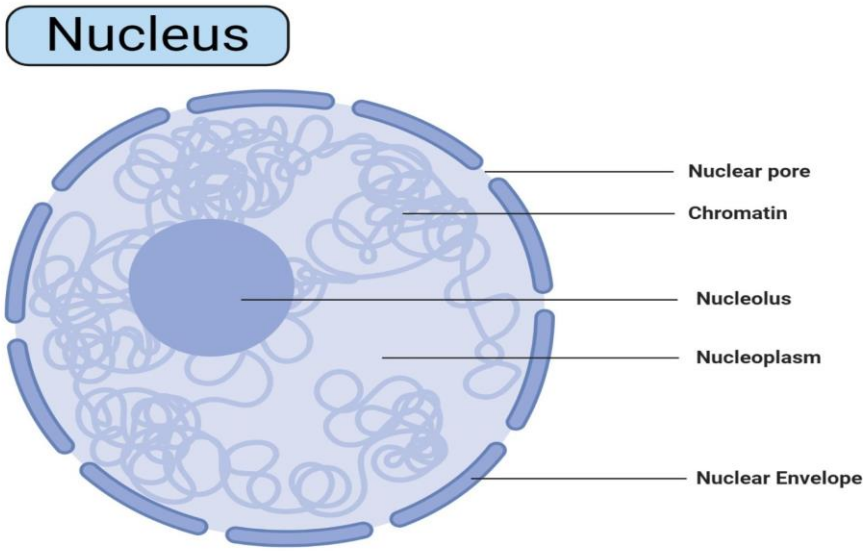
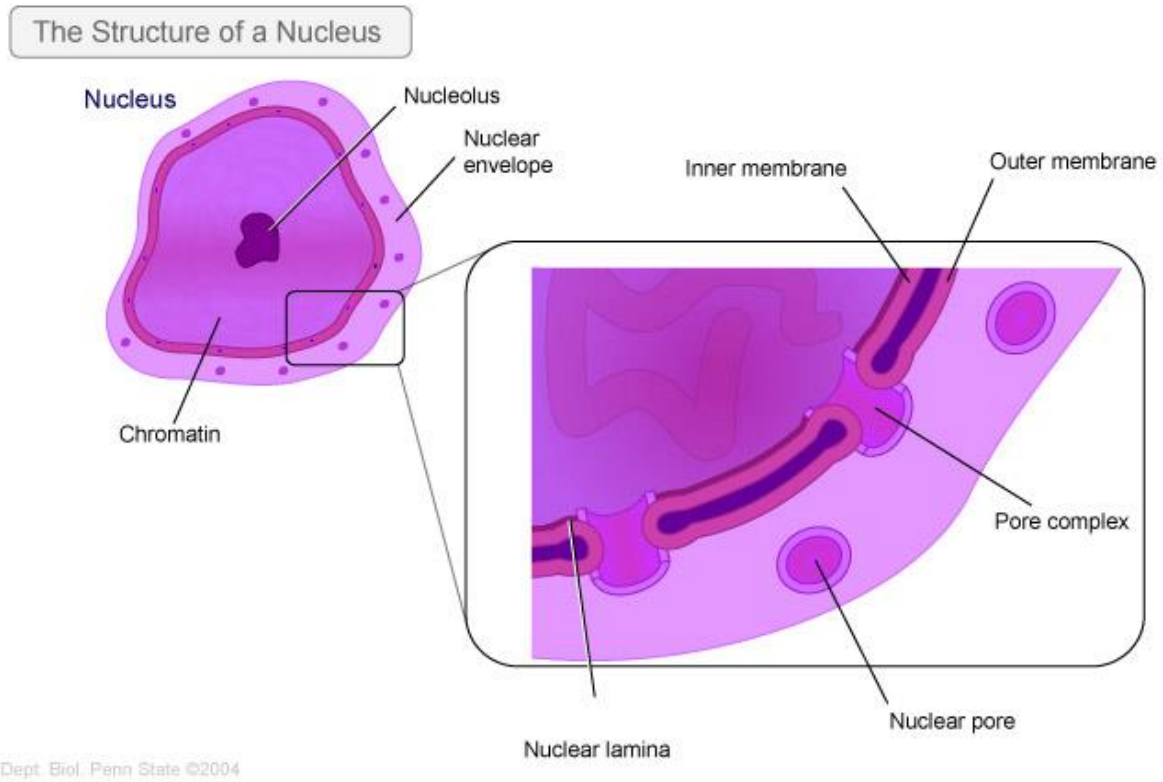
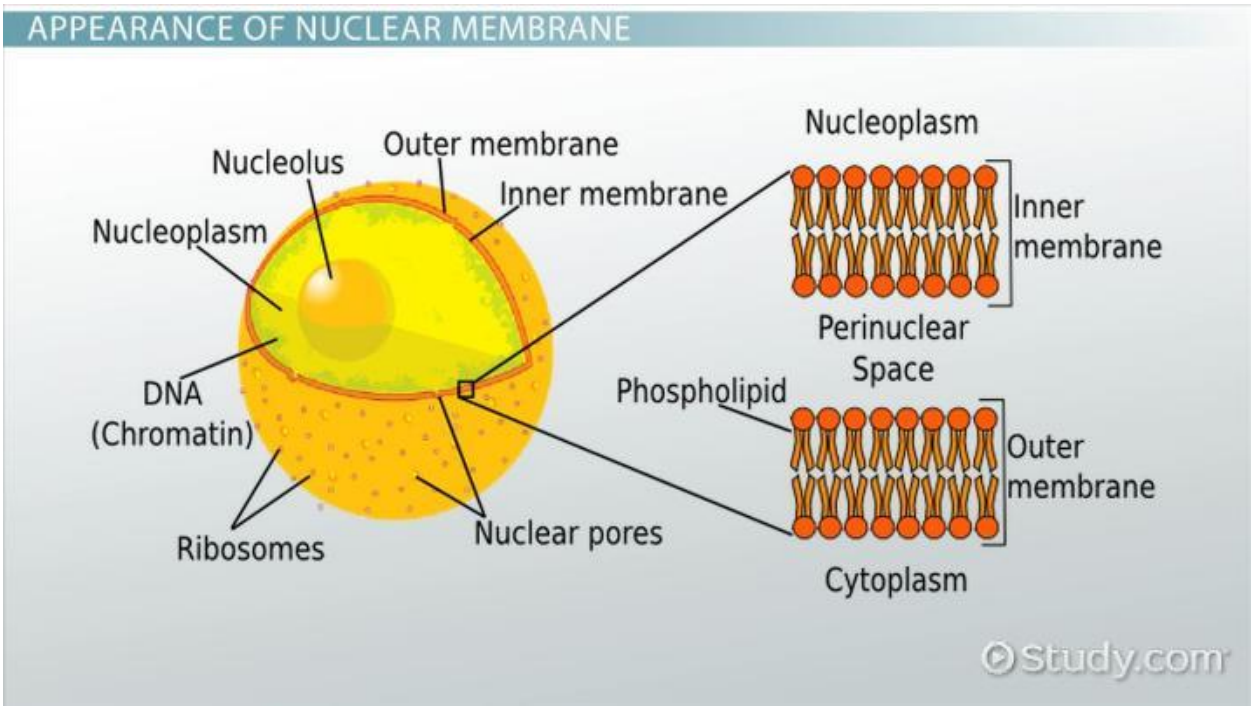


Figure: Nucleus, Image Copyright © Sagar Aryal, www.microbenotes.com

1. NUCLEAR MEMBRANE





1. NUCLEAR ENVELOPE OR KARYOTHECA

- ✓ The **nuclear membrane or karyotheca** form an envelope-like structure around the nuclear contents and is commonly known as **nuclear envelope**.
- ✓ The nuclear membrane in higher plant and animal disappears in late prophase during mitosis and re-forms around the daughter chromosomes during telophase.
- ✓ In lower eukaryotes, the nuclear envelope remains intact throughout mitosis.
- ✓ It separates nucleus from cytoplasm and functions to facilitate and regulate nucleocytoplasmic interaction.
- ✓ **Under electron microscope** the nuclear envelope in **the interphase or prophase stage** appears to consist of two concentric membranes, viz., inner nuclear membrane and outer nuclear membrane.

Table 9.1: Number of nucleus/cell in different organisms

Number of nucleus	Organism/cell
True *Nucleus absent*	Prokaryotic organism like bacteria, PPLO, Spirochaeta, blue-green algae
True nucleus present in early stage but absent in mature stage	Plant-sieve tube; Animal—RBC of mammals
Single nucleus (Mononucleate)	Most of the eukaryotic cells or organisms
Two nuclei (Binucleate)	*Paramoecium*, liver cell, cartilage cell
Many nuclei (Polynucleate/multinucleate)	Animal—Cells of bone marrow. Plant—Fungus, *Vaucheria* (algae), endosperm cells

- ✓ Each membrane is about 75 to 90 A thick and lipoproteinous in nature.
- ✓ The outer and inner membranes are separated by perinuclear space of 100-170 A^0.
- ✓ The inter-membrane space is known as perinuclear cisternae (Fig. 9.4).
- ✓ The inner membrane defines the content of nucleus itself and it contains specific proteins that act as binding sites for the nuclear lamina.
- ✓ The outer membrane is rough due to presence of ribosomes (25 nm in diameter) attached with it. The ribosomes are engaged in protein synthesis. The proteins made on these ribosomes are transported into the space between the inner and outer nuclear membrane.
- ✓ In many cells, the outer nuclear membrane is continuous with rough endoplasmic reticulum. The space between the inner and outer nuclear membrane is continuous with the lumen or inner cavity of the rough endoplasmic reticulum.

(III) FUNCTIONS OF NUCLEAR ENVELOPE

1. The nuclear envelope acts as a shield and protects the inner contents of the nuclear compartment.
2. One of the main functions of the nuclear envelope is to prevent the entrance of active ribosomes and other cytoplasmic components.

- The nuclear membrane is very selective for the exchange of materials between nucleus and cytoplasm through nuclear pore complexes.
- The nuclear envelope is very conservative and it does not allow to enter any large cytoplasmic protein or components.
- It has been demonstrated by injecting labelled molecules into the cytoplasm and measuring their rate of diffusion into the nucleus.
    - But the nucleus imports many large proteins that it needs such as DNA and RNA polymerase, histone which are synthesised in the cytoplasm.

2. NUCLEOLUS

The nucleolus is the dominant internal feature of the cell nucleus and was among the first subcellular organelles described by microscopy.

The nucleolus is not separated from the remaining nucleoplasm by a membrane, but in many cells its margins are associated with chromatin.

The nucleolus is composed of RNA and proteins and is the site of formation of ribosomal constituents.

In cells that are actively engaged in protein synthesis and which therefore have greater demands for ribosomes, the nucleoli are larger and more numerous.

When the cell undergoes nuclear division, protein synthesis is decreased and ribosome production is halted.

These changes are accompanied by a reduction in the size and number of nucleoli. In fact, at the metaphase stage of mitosis, no nucleoli can be distinguished.

Parts of one or more chromosomes are looped into a nucleolus forming what is known as a nucleolar organizing region (NOR).

These regions contain the genes that are transcribed into rRNA. Dense fibrillar regions surrounding the NOR are associated with small ribonucleoprotein particles and frequently reveal mature ribosomes.

Four chief components have been observed:

- An amorphous matrix or pars amorpha.
- Chromatin containing abundant DNA.
- Fibrils containing RNA, 80-100 Å in diameter, precursor of granules.
- Granules- Ribonucleoprotein granules 150-200 Å in diameter.

Composition:

(*i*) DNA
(*ii*) RNA — Nucleic acid
(*iii*) Protein

Functions of Nucleolus:

(i) Ribosome formation or biogenesis of ribosomes.

(ii) Synthesis and storage of RNA:

It produces 70-90% of cellular RNA in many cells. It is source of RNA.

(iii) Protein synthesis:

In eukaryotes the gene coding for RNA contains a chain of at-least 100-1000 repeating copies of DNA.

This DNA is given off from the chromosomal fibre in the forms of loops.

The DNA loops are associated with proteins to form nucleoli.
The DNA seems as a template for 45S rRNA. Half the 45S rRNA is broken down to form 28S and 18S RNA.

3. NUCLEOPLASM

1. It is the general mass of nucleus.
2. Nucleoplasm is covered on the outside by double membrane envelope called nuclear envelope.
3. Sol-gel differentiation is not clear.
4. Nucleoplasm contains a fibrous matrix. Its outer part is dense and forms fibrous lamina in contact with nuclear envelope.
5. The nucleoplasm contains three structures- chromatin, matrix and nucleolus.
6. Cyclosis or streaming is absent.
7. Nucleoplasm possesses small amount of minerals, sugar and amino acids. There are abundant nucleosides, nucleotides, proteins and enzymes.
8. Endomembrane are absent.
9. It is site of ribosome formation.
10. Nucleoplasm is part of cell, that contains genetic material for controlling cytoplasmic structure and function.
11. It forms a small part of cell.

Functions

The main function of the nucleoplasm is to serve as a suspension substance for the organelles inside the nucleus.

It also helps maintain the shape and structure of the nucleus, and plays an important role in the transportation of materials that are vital to cell metabolism and function.

Many substances such as nucleotides and enzymes are dissolved in the nucleoplasm.

4. THE STRUCTURE AND FUNCTION OF CHROMATIN

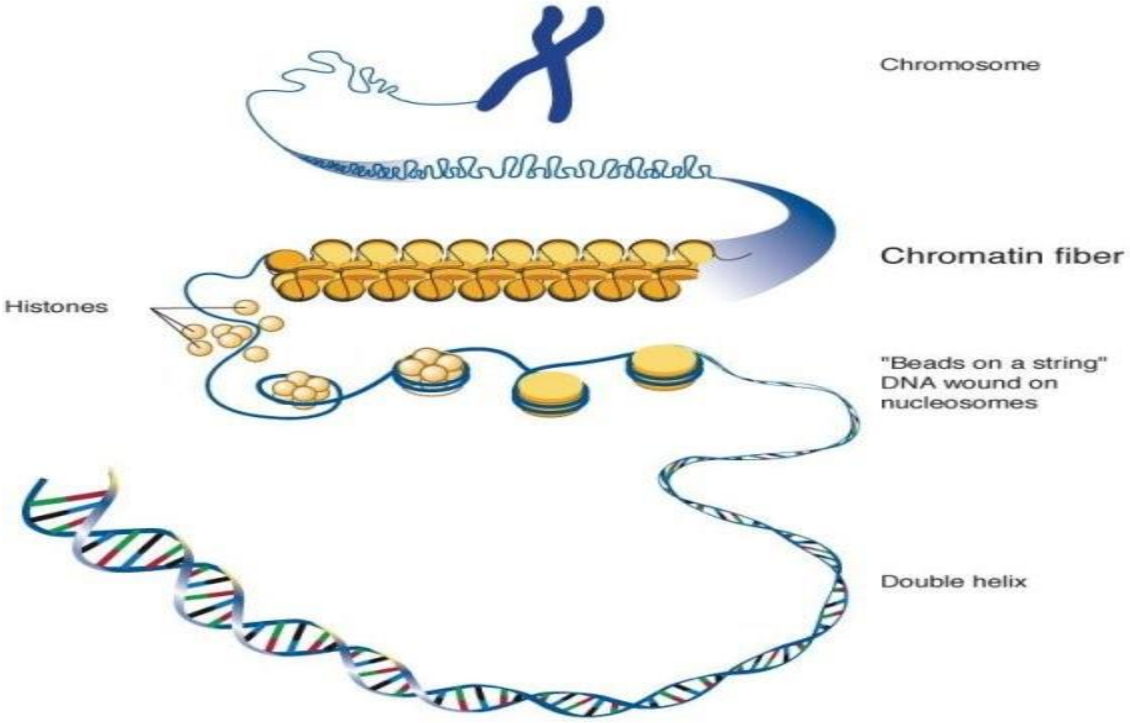
Chromatin is a complex of macromolecules composed of DNA, RNA, and protein, which is found inside the nucleus of eukaryotic cells. Chromatin exists in two forms: heterochromatin (condensed) and euchromatin (extended).

The primary protein components of chromatin are histones that help to organize DNA into "bead-like" structures called nucleosomes by providing a base on which the DNA can be wrapped around.

A nucleosome consists of 147 base pairs of DNA that is wrapped around a set of 8 histones called an octomer.

The nucleosome can be further folded to produce the chromatin fiber.

Chromatin fibers are coiled and condensed to form chromosomes. Chromatin makes it possible for a number of cell processes to occur including DNA replication, transcription, DNA repair, genetic recombination, and cell division.



Chromatin, Chromosomes and Chromatids

- People often confuse these three terms: chromatin, chromosome, and chromatid. While all of those three structures are composed of DNA and proteins within the nucleus, each is uniquely defined.

- As mentioned above, chromatin is composed of DNA and histones that are packaged into thin, stringy fibers.
- The chromatin undergoes further condensation to form the chromosome.
- So the chromatin is a lower order of DNA organization, while chromosomes are the higher order of DNA organization.
- Chromosomes are single-stranded groupings of condensed chromatin.
- During the cell division processes of mitosis and meiosis, chromosomes replicate to ensure that each new daughter cell receives the correct number of chromosomes.
- A duplicated chromosome is double-stranded and has the familiar X shape. The two strands are identical and connected at a central region called the centromere.
- A chromatid is either of the two strands of a replicated chromosome. Chromatids connected by a centromere are called sister chromatids.
- At the end of cell division, sister chromatids separate and become daughter chromosomes in the newly formed daughter cells.

The Function of Chromatin

DNA Packaging

This is the most fundamental function of chromatin: compactification of long DNA strands.

The length of DNA in the nucleus is far greater than the size of the compartment in which it is stored.

To fit into this compartment the DNA has to be condensed in some manner.

Transcription Regulation

Transcription is a process in which the genetic information stored in DNA is read by proteins and then transcribed into RNA, and the RNA will later be translated into functional proteins.

Chromatin and DNA Repair

Chromatin relaxation occurs rapidly at the site of a DNA damage, which allows the repair proteins to bind to DNA and repair it.

Structure of chromatin

- Chromatin is a mass of genetic material composed of DNA and proteins that condense to form chromosomes during eukaryotic cell division.
- Chromatin is located in the nucleus of our cells.
- The primary function of chromatin is to compress the DNA into a compact unit that will be less voluminous and can fit within the nucleus. Chromatin consists of complexes of small proteins known as histones and DNA.
- Histones help organize DNA into structures called nucleosomes by providing a base on which the DNA can be wrapped around.
- A nucleosome consists of a DNA sequence of about 150 base pairs that is wrapped around a set of eight histones called an octamer.**1**
- The nucleosome is further folded to produce a chromatin fiber. Chromatin fibers are coiled and condensed to form chromosomes. Chromatin makes it possible for many cell processes to occur including DNA replication, transcription, DNA repair, genetic recombination, and cell division.

Euchromatin and Heterochromatin

- Chromatin within a cell may be compacted to varying degrees depending on a cell's stage in the cell cycle.
- In the nucleus, chromatin exists **as euchromatin or heterochromatin**. During interphase of the cycle, the cell is not dividing but undergoing a period of growth.
- Most of the chromatin is in a less compact form known as euchromatin. More of the DNA is exposed in euchromatin allowing replication and DNA transcription to take place.
- During transcription, the DNA double helix unwinds and opens to allow the genes coding for proteins to be copied. DNA replication and transcription are needed for the cell to synthesize DNA, proteins, and organelles in preparation for cell division (mitosis or meiosis).
- A small percentage of chromatin exists as heterochromatin during interphase. This chromatin is tightly packed, not allowing gene transcription. Heterochromatin stains more darkly with dyes than does euchromatin.