

The Nucleus and Its Functions

The Control Center of the Cell

Dr Abdul Samad Khan

Senior Lecturer-DIKIOHS

Dow University of Health Sciences



Learning objectives

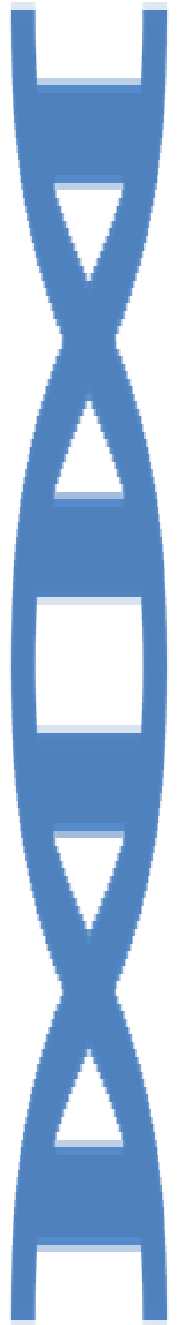
By the end of this lecture, student will be able to:

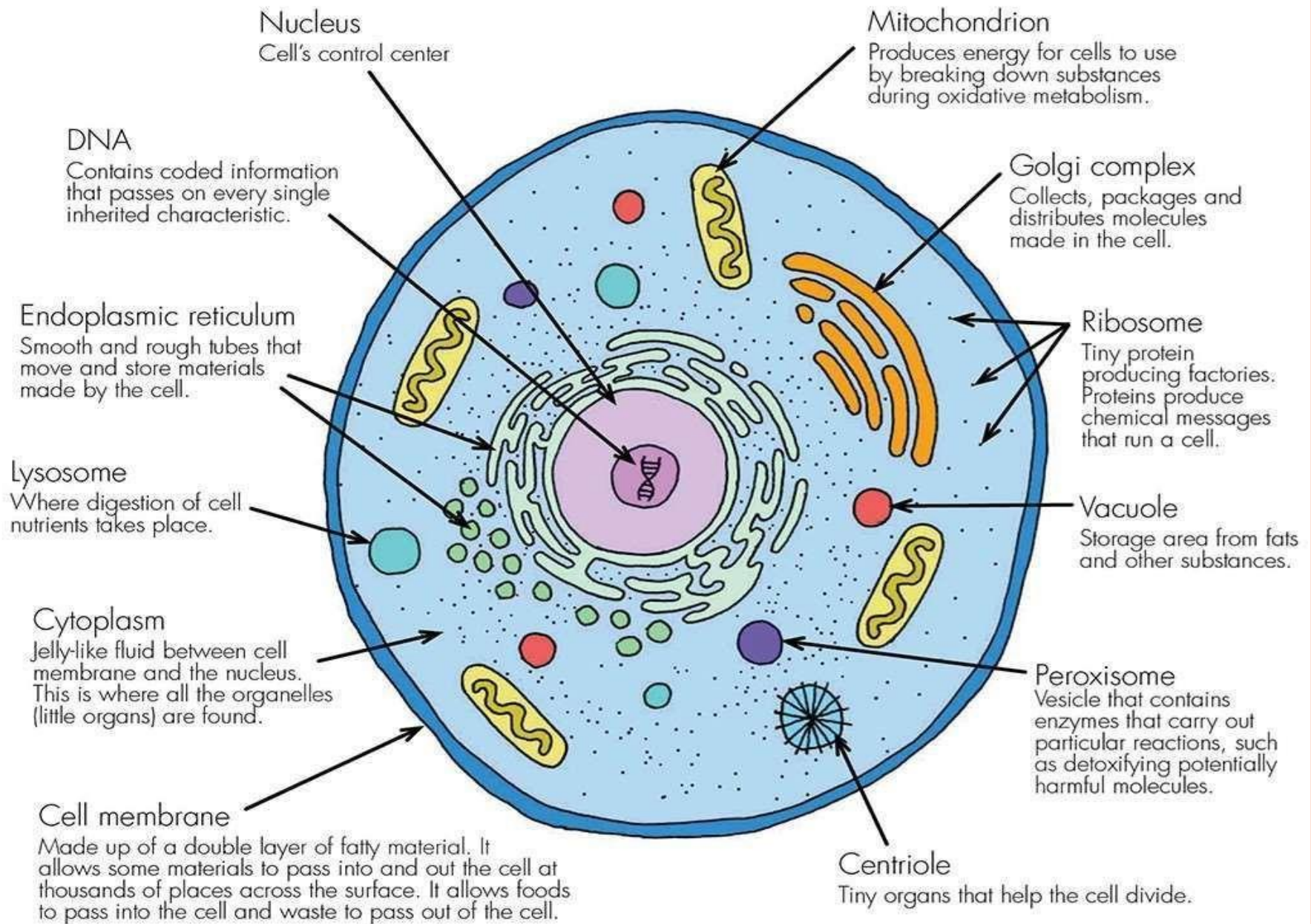
- Describe the structure and components of the nucleus.
- Explain the role of the nucleus in cell function and gene expression.
- Understand the process of transcription and RNA processing.
- Identify the significance of the nucleus in cell division and protein synthesis.
- Discuss diseases related to nuclear dysfunction

Introduction

The nucleus is a membrane-bound organelle found in cells.

- It contains most of the cell's genetic material, organized with multiple, long, linear, DNA molecules in complex including a large variety of proteins, such as histones, to form chromosomes.
- Essential for growth, reproduction, and gene expression.
- It functions as the control center, regulating cell activities and storing genetic material.





Structure of the Nucleus



- **Nuclear Envelope**: A double membrane with nuclear pores.



- **Nucleoplasm**: Gel-like substance inside the nucleus.



- **Chromatin**: DNA and protein complex.



- **Nucleolus**: Site of ribosome synthesis.



- **Nuclear Pores**: Regulate transport of molecules in and out.

STRUCTURE OF NUCLEUS

Nuclear envelope

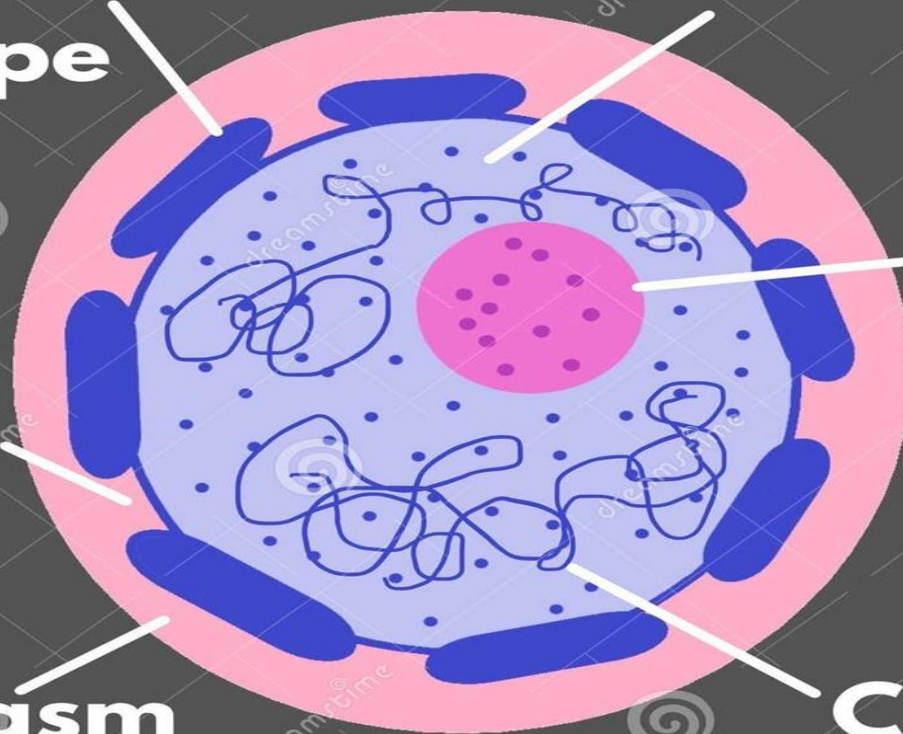
Nucleoplasm

Nucleolus

Pores

Cytoplasm

Chromatin



Cell-Structure

Nucleus

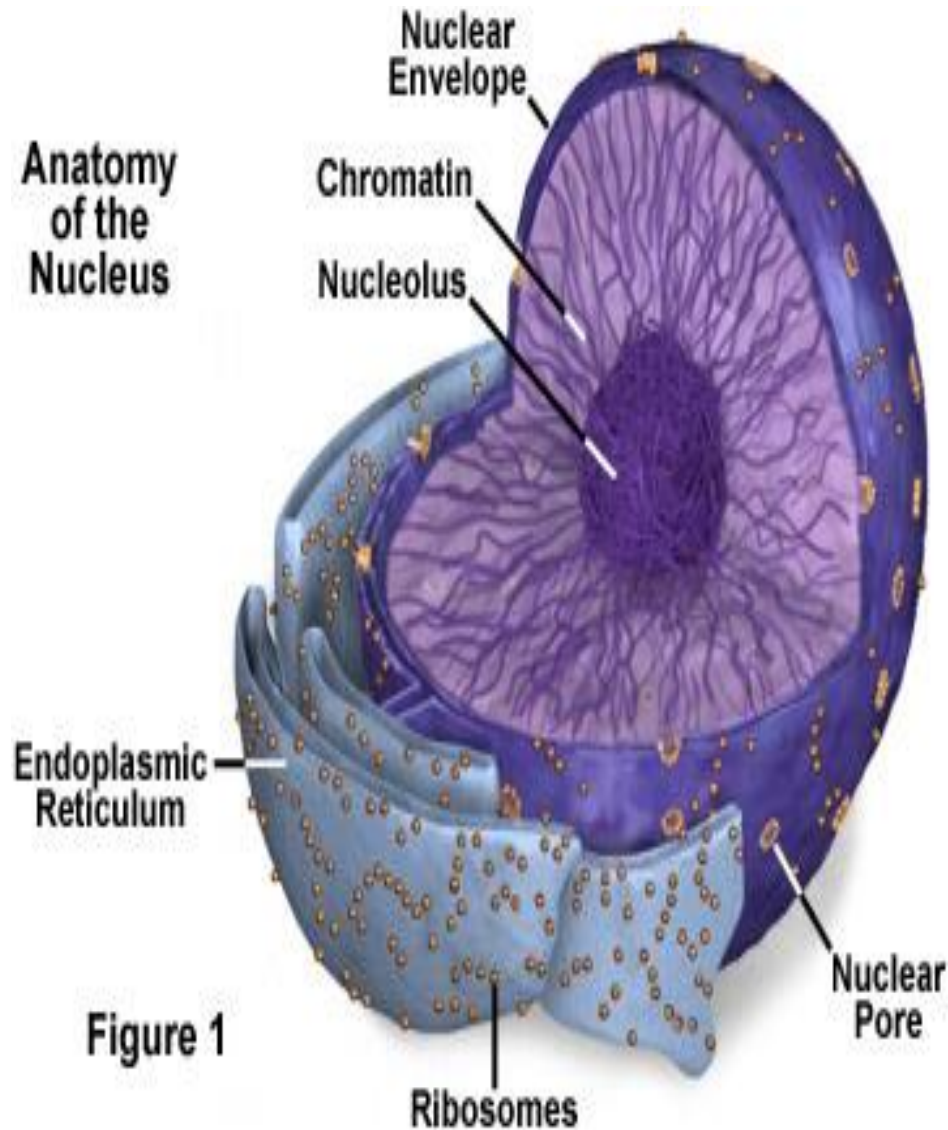
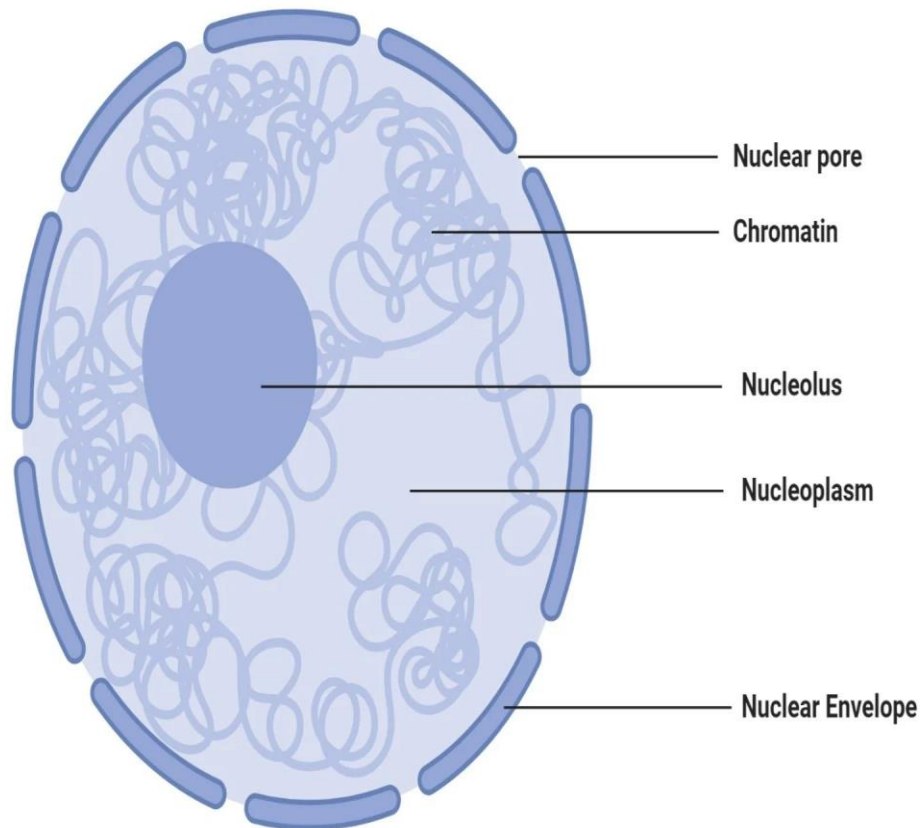


Figure 1

Nuclear Envelope

- A double-layered membrane that encloses the nucleus.
- Separates the nucleus from the cytoplasm.
- Contains nuclear pores for selective exchange of materials.

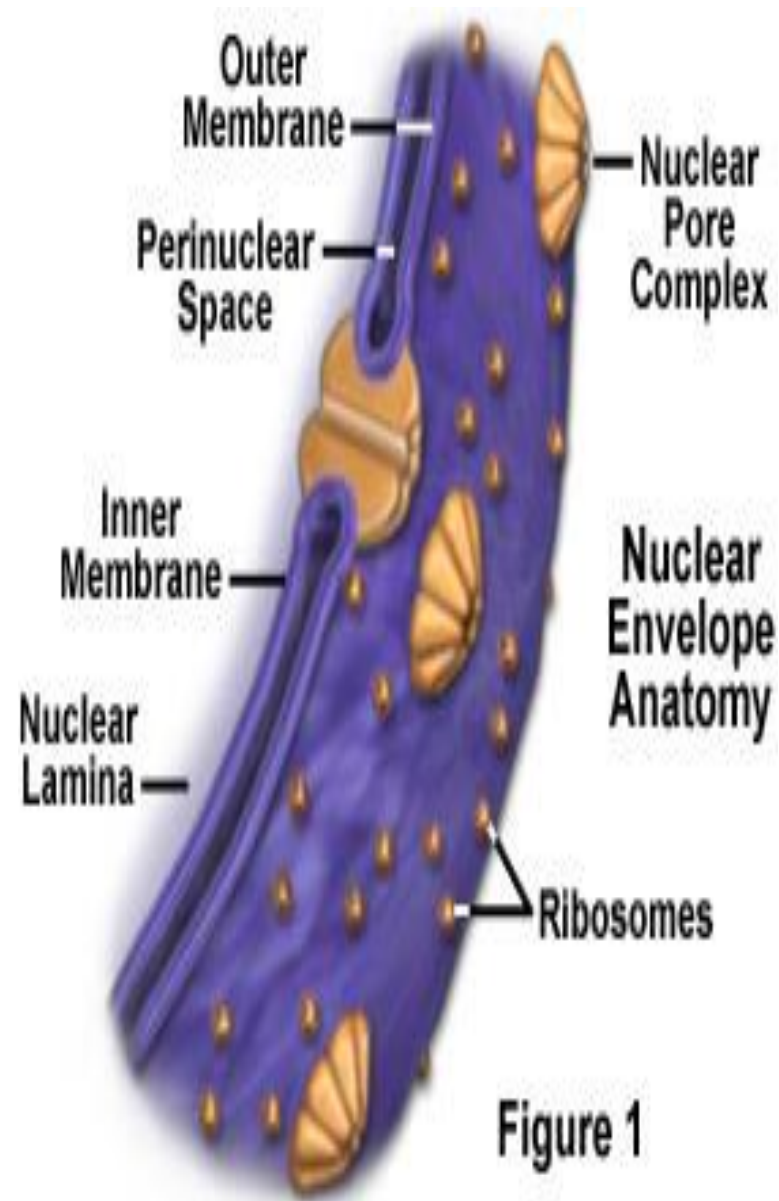
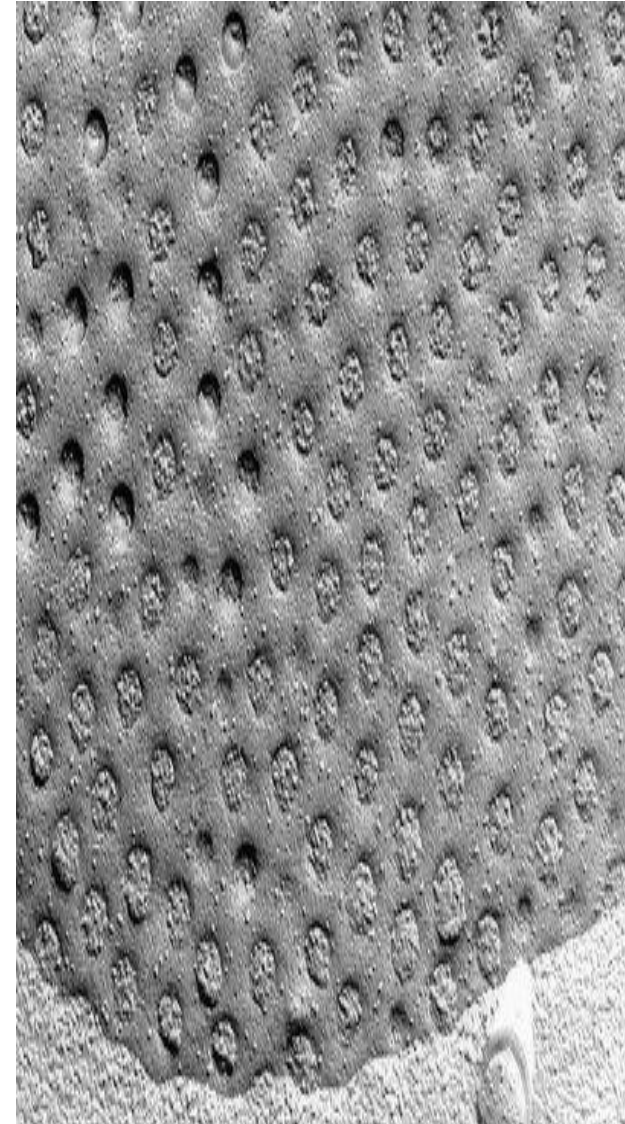


Figure 1

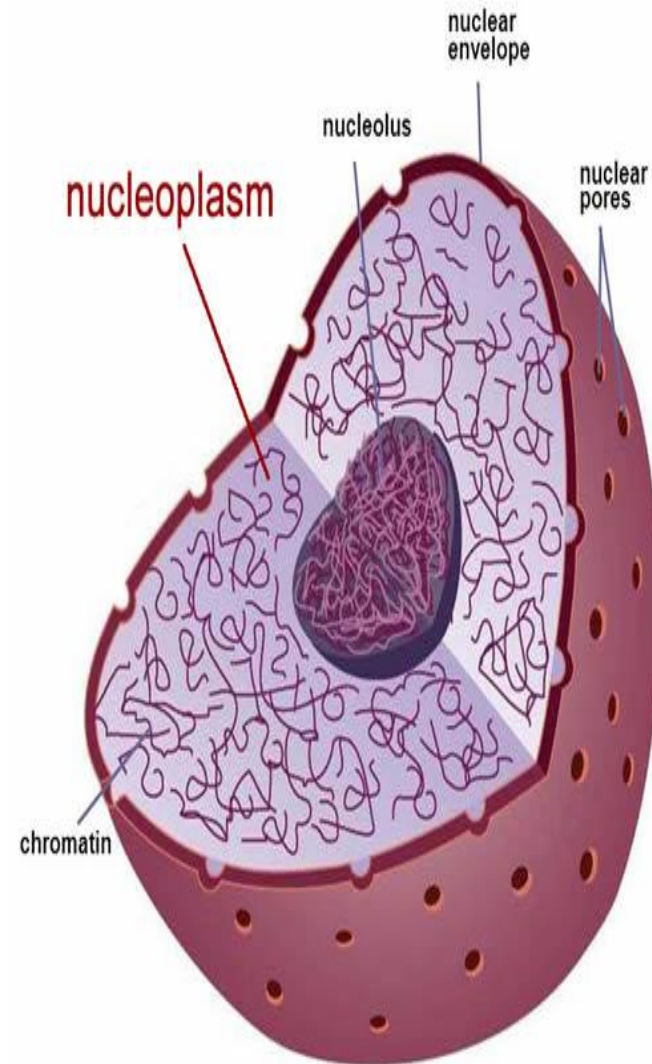
Nuclear Pores

- Tiny openings in the nuclear envelope.
- Allow controlled exchange of RNA, proteins, and ions.
- Maintain communication between the nucleus and cytoplasm.



Nucleoplasm

- Nucleoplasm is the viscous fluid found within the nucleus of cells
- Contains dissolved enzymes, nucleotides, and chromatin.
- Provides a medium for molecular movement inside the nucleus.
- The nucleoplasm is present inside the nucleus and is similar to the cytoplasm in consistency
- The nucleoplasm is responsible for maintaining the shape of the nucleus and also providing optimal conditions for genetic processes.
- Some components of the nucleoplasm include proteins, enzymes, ions, nucleotides, and nucleic acid.



Chromatin and Chromosomes

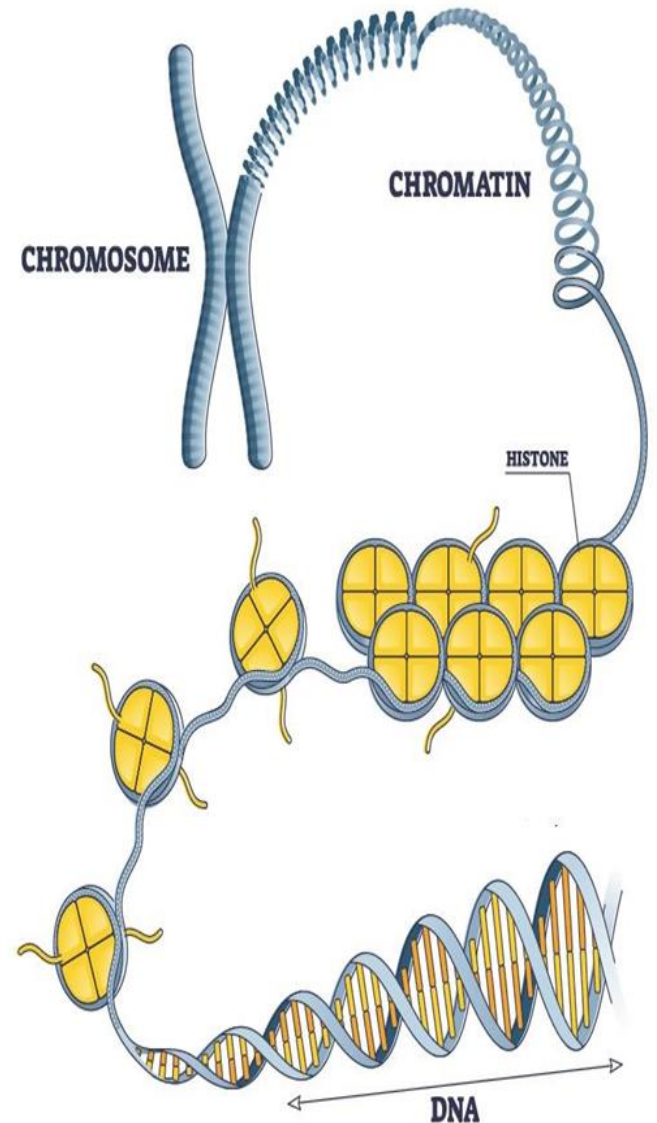
Chromatin is a complex formed by histones (A histone is a protein that provides structural support for a chromosome) packaging the DNA double helix.

Chromosomes are structures of proteins and nucleic acids found in the living cells and carry genetic material.

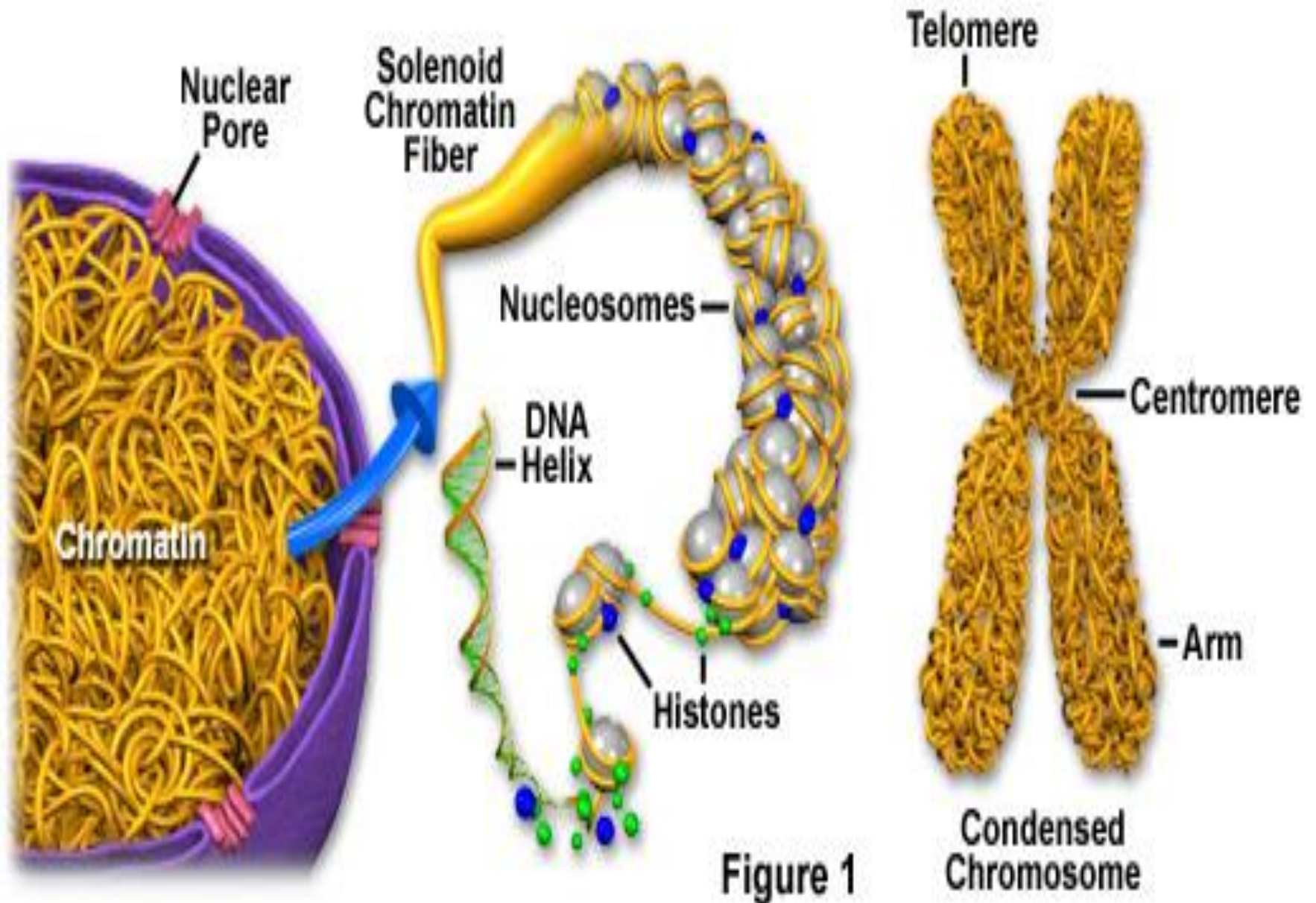
Chromosomes carry genetic information for inheritance.

Humans have 23 pair of chromosome (46 in total)

Chromatin is composed of nucleosomes. Chromosomes are composed of condensed chromatin fibers.



Chromatin and Condensed Chromosome Structure



The Nucleolus

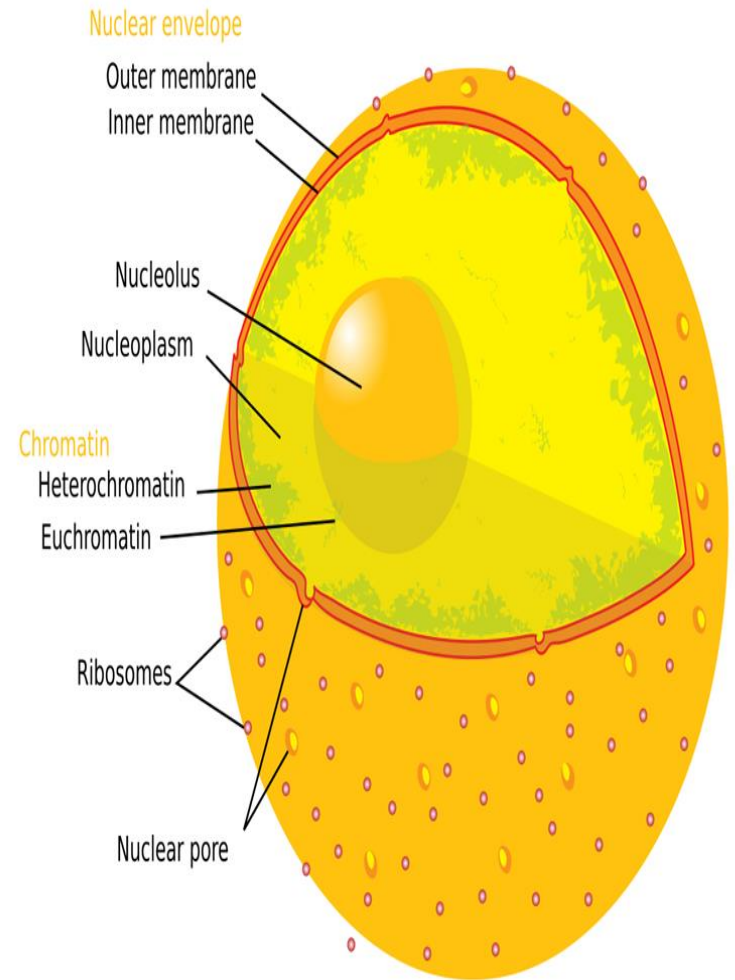
The most prominent substructure within the nucleus is the nucleolus

Main function

Synthesis of ribosomal RNA (rRNA).

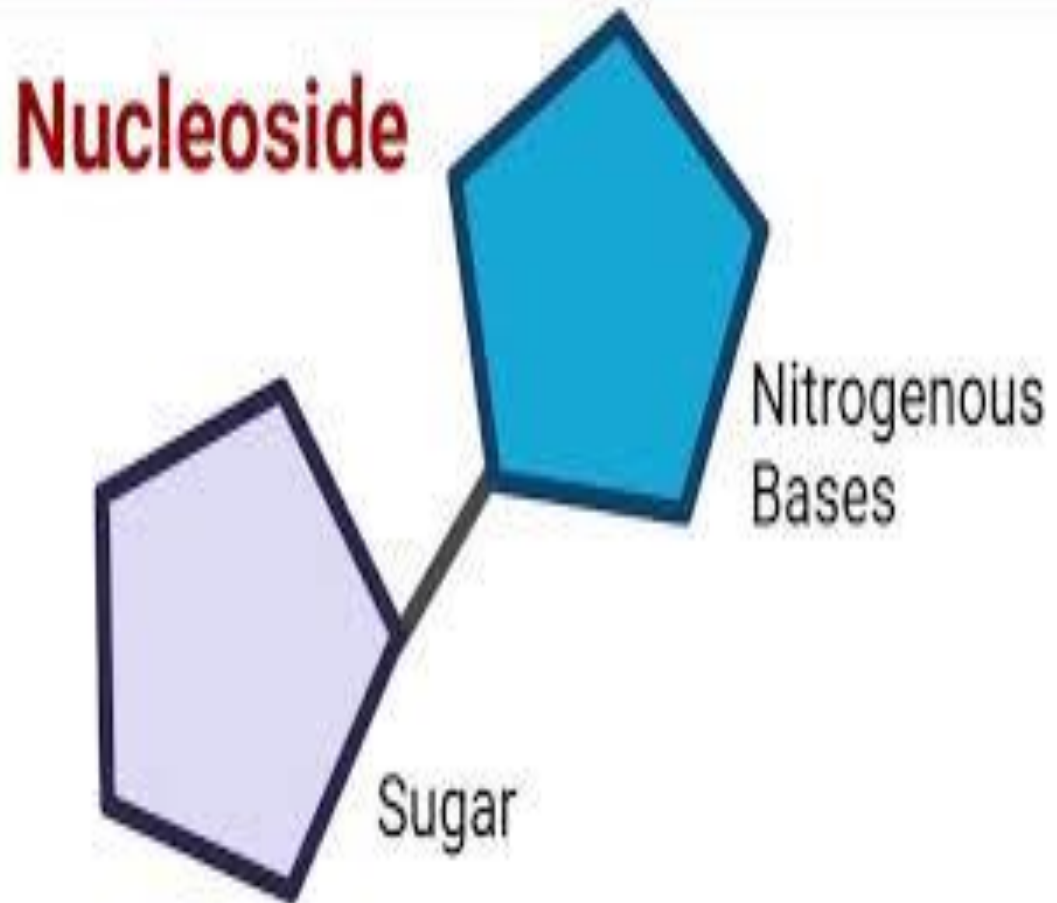
It is the site of rRNA transcription and processing

Plays a key role in the production of ribosomes and of ribosome assembly.



Nucleosides

A unit consisting of a nitrogen base bonded to a sugar



Nitrogen bases

NITROGENOUS BASES

- **Purine**

adenine (A)

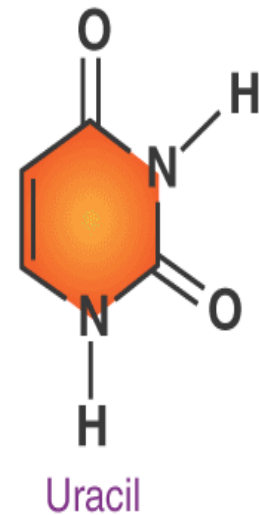
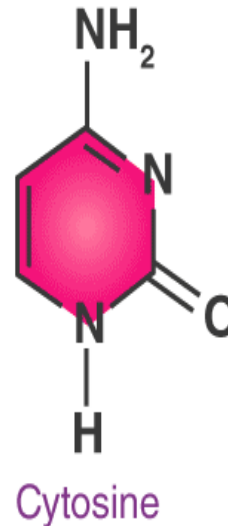
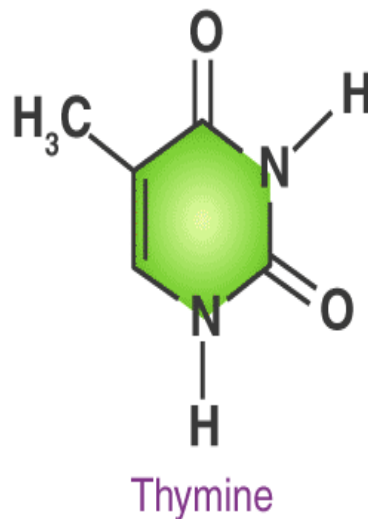
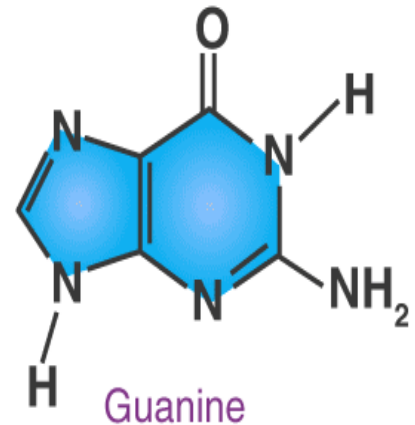
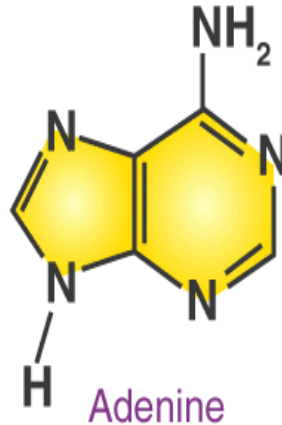
guanine (G)

- **Pyrimidine**

cytosine (C)

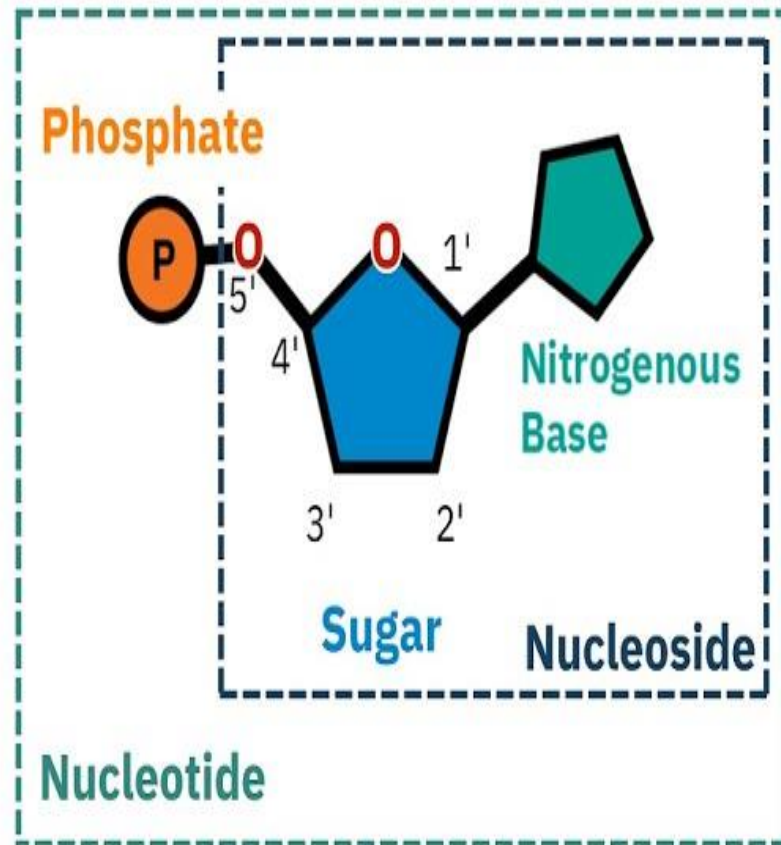
Thymine(T)

Uracil (U)



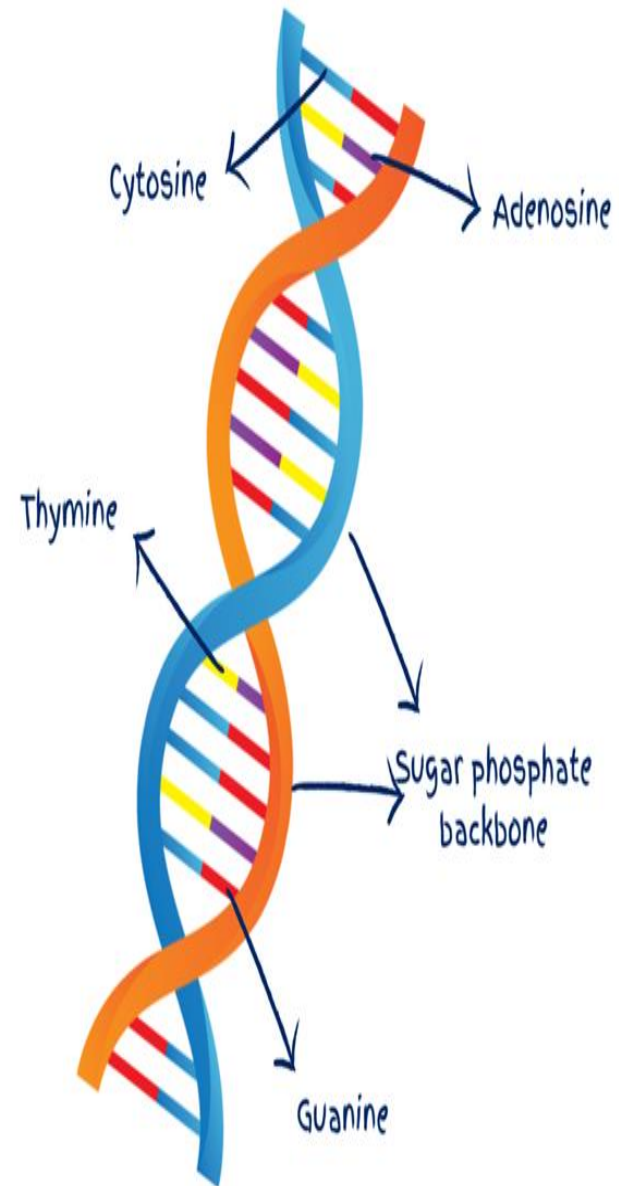
Nucleotide

A nucleotide is a nucleoside with phosphate groups linked by an ester bond.



DNA: The Genetic Blueprint

- **DNA (Deoxyribonucleic Acid)** carries genetic instructions.
- **Structure:** Double helix composed of:
 - **Nitrogenous bases** (Adenine, Thymine, Cytosine, Guanine).
 - **Sugar-phosphate backbone.**
- **Functions of DNA:**
 - Stores genetic information.
 - Guides **protein synthesis** through RNA.
 - Replicates before cell division.



RNA:

- RNA are nucleotide polymers like DNA combine called nucleic acids both carry information in a form that can be passed from one generation to the next.

It primarily converts DNA genetic instructions into proteins.

Types of RNA:

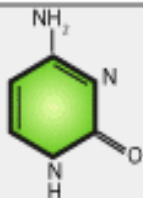
- **mRNA (Messenger RNA):** Carries genetic code from DNA to ribosomes.
- **tRNA (Transfer RNA):** Brings amino acids for protein synthesis.
- **rRNA (Ribosomal RNA):** Component of ribosomes, aids in translation.

DIFFERENCES BETWEEN DNA & RNA

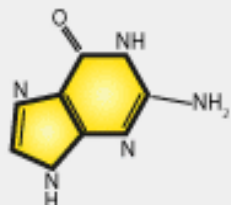
DIFFERENCES	DNA	RNA
Nucleotides	Adenine, guanine, cytosine and thymine	Adenine, guanine, cytosine and uracil
Number of chains	2	1
Location	Mostly in the nucleus or nucleoid, but also in mitochondria	Mainly in the cytoplasm
Composition	Deoxyribose	Ribose
Shape	Storing genetic information	Transform and transport proteins

DIFFERENCE BETWEEN DNA AND RNA

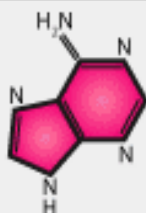
CYTOSINE **C**



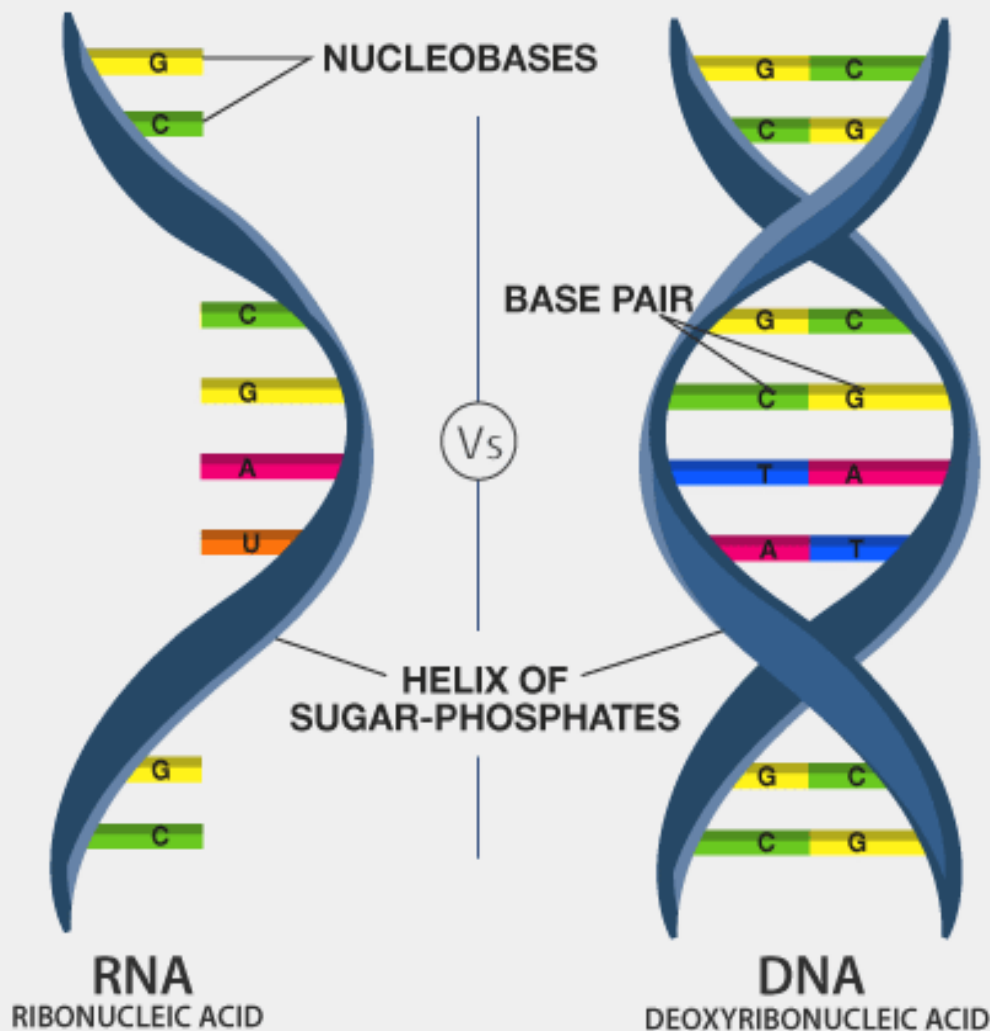
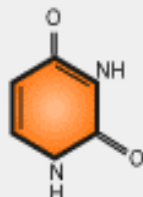
GUANINE **G**



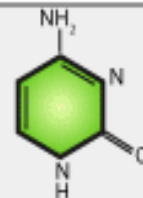
ADENINE **A**



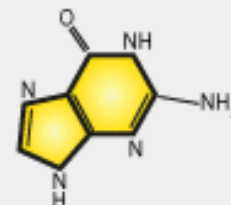
URACIL **U**



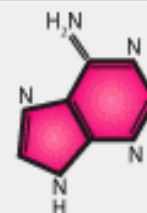
CYTOSINE **C**



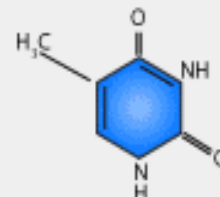
GUANINE **G**



ADENINE **A**



THYMINE **T**



Functions of the Nucleus

1. Genetic Material Storage: Contains DNA, the blueprint of life.

2. Gene Expression Regulation: Controls transcription and protein synthesis.

3. Cell Division: Essential for mitosis and meiosis.

4. Ribosome Production: Nucleolus synthesizes ribosomal RNA.

5. Cell Growth & Differentiation: Regulates cellular functions and development.

DNA Replication

DNA replication is the process by which a cell makes exact copies of its DNA.

DNA replication ensures that each of the newly divided daughter cells receives its own copy of each DNA molecule

Steps of DNA replication:

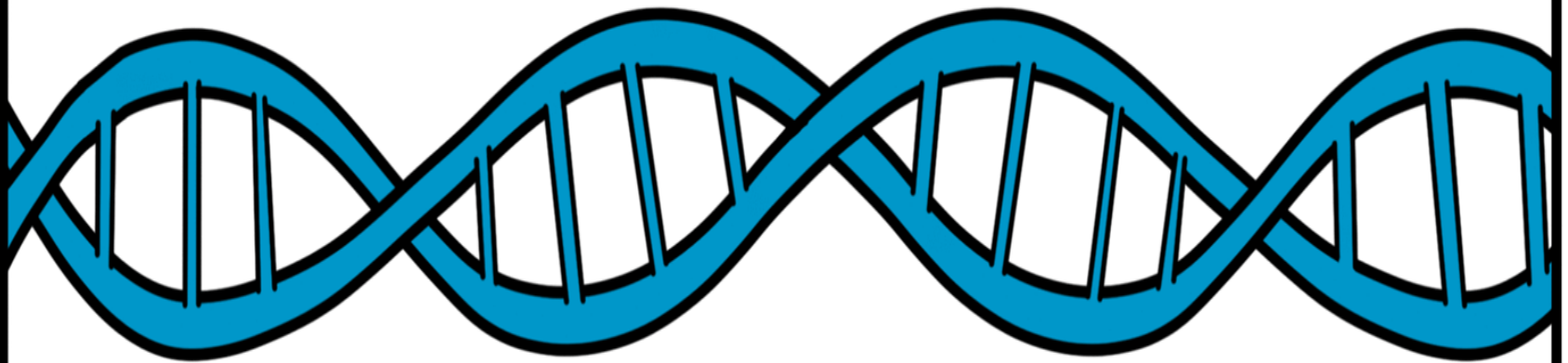
- **Initiation:** Helicase enzyme unwinds the double helix.
- **Elongation:** DNA polymerase adds complementary nucleotides.
- **Termination:** Two identical DNA strands are formed.

Ensures genetic continuity during cell division.

Amoeba Sisters

Helicase

#AmoebaGIFs



The unzipping enzyme in DNA replication

The genetic code:

The genetic code is the set of rules used by living cells to translate information encoded within genetic material (DNA or RNA sequences of nucleotide triplets or codons) into proteins

Codon:

A codon is a trinucleotide sequence of DNA or RNA that corresponds to a specific amino acid.

Gene Expression:

Gene expression is the process by which information from a gene is used to synthesize functional gene products (proteins or RNA).

It involves two main stages:

- **Transcription** and
- **Translation.**

Overview of Transcription-27

Transcription is the process of copying genetic information from DNA to RNA.

Occurs in the nucleus before translation.

Involves three main stages:

Initiation,

Elongation,

and Termination.

Overview of Translation

- Translation is the process of synthesizing proteins from mRNA.
- Takes place in the **ribosome**
- Requires **mRNA, tRNA, ribosomes, and amino acids.**
- Occurs in three stages:
 - **Initiation,**
 - **Elongation,**
 - **Termination.**

The Nucleus and Cell Division

- **Mitosis**: Cell division for growth and repair.
- **Meiosis**: Formation of gametes for reproduction.
- Nucleus ensures proper DNA replication and segregation.

Mitosis

A type of cell division producing two identical daughter cells.
Essential for growth, tissue repair, and asexual reproduction.

- **Stages of Mitosis:**
- **Prophase:** Chromosomes condense, spindle fibers form.
- **Metaphase:** Chromosomes align at the cell's equator.
- **Anaphase:** Sister chromatids separate and move to opposite poles.
- **Telophase:** Nuclear membrane reforms, chromosomes de-condense.
- **Cytokinesis:** Division of cytoplasm, completing cell division.

Meiosis

- A type of cell division that produces four genetically distinct gametes.
- Essential for sexual reproduction and genetic variation.
- **Stages of Meiosis:**
 - **Meiosis I:** Homologous chromosomes come close
 - **Prophase I:** Crossing over occurs.
 - **Metaphase I:** Homologous chromosomes align at the equator.
 - **Anaphase I:** Homologous pairs separate to opposite poles.
 - **Telophase I & Cytokinesis:** Two haploid cells form.
 - **Meiosis II:** Sister chromatids separate.
 - **Prophase II:** Chromosomes condense again.
 - **Metaphase II:** Chromosomes align at the equator.
 - **Anaphase II:** Sister chromatids separate.
 - **Telophase II & Cytokinesis:** Four genetically unique haploid cells result.

Mitosis

Parent cell



DNA replicates



2 daughter cells



Meiosis

Parent cell



DNA replicates



2 daughter cells



4 daughter cells



Diseases Related to Nuclear Dysfunction

- Cancer: Uncontrolled cell growth due to genetic mutations.
- Progeria: Premature aging caused by nuclear instability.
- Huntington's Disease: Genetic disorder affecting the nervous system.

Importance of the Nucleus

- The nucleus is essential for gene expression and cellular function.
- Protects and organizes genetic material.
- Coordinates growth, metabolism, and reproduction.

Summary

- The nucleus is the control center of the cell.
- It regulates genetic material and protein synthesis.
- Plays a vital role in growth, division, and cell differentiation.

- **Which of the following structures regulates the exchange of materials between the nucleus and the cytoplasm?**
 - a) Nucleolus
 - b) Nuclear envelope
 - c) Nuclear pores
 - d) Chromatin

Answer: c) Nuclear pores

- **What is the primary function of the nucleolus?**
 - a) DNA replication
 - b) RNA processing
 - c) Ribosomal RNA (rRNA) synthesis
 - d) Protein synthesis

Answer: c) Ribosomal RNA (rRNA) synthesis

- **Which stage of transcription involves RNA polymerase binding to the promoter region?**
 - a) Initiation
 - b) Elongation
 - c) Termination
 - d) Splicing

Answer: a) Initiation

- **During which phase of mitosis do sister chromatids separate and move to opposite poles?**
 - a) Prophase
 - b) Metaphase
 - c) Anaphase
 - d) Telophase

Answer: c) Anaphase

- **Which of the following diseases is caused by nuclear dysfunction leading to premature aging?**
 - a) Huntington's disease
 - b) Progeria
 - c) Cancer
 - d) Alzheimer's disease

Answer: b) Progeria

- **Which of the following is the correct start codon for translation?**
 - a) UAA
 - b) AUG
 - c) UGA
 - d) UAG

Answer: b) AUG