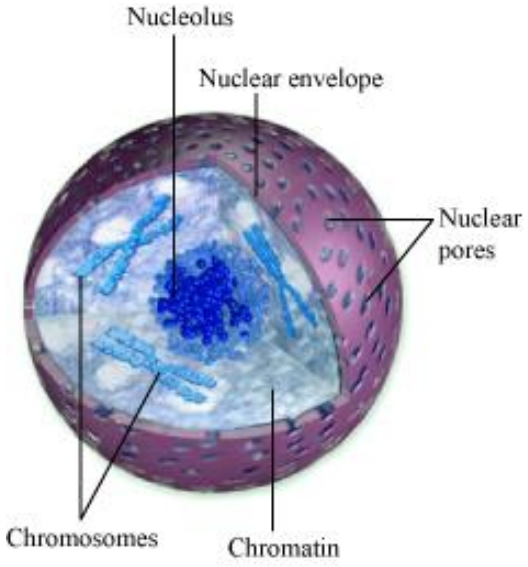
Structure of Chromosomes, Cell Cycle & Cell Division

Nucleus and Chromosomes

Nucleus



- Every cell has a nucleus, except some such as the RBCs of mammals and the sieve tube cells in vascular plants.

  A cell usually has one nucleus, except some variations.

- Nucleus is bound by a *nuclear envelope* which consists of two membranes with *perinuclear space* (10 − 50 nm) between them

- Perinuclear space acts as a barrier for the flow of materials between the inside of the nucleus and the cytoplasm. So, to facilitate the transfer of RNA and proteins, *nuclear pores* are present. Nuclear pores are formed at places where the two membranes fuse.

- *Nuclear matrix* (*Nucleoplasm* consists of the nucleolus and the chromatin.)

- Nucleolus (pl. nucleoli): Site of active rRNA synthesis; not bound by membrane; its contents are continuous with the nucleoplasm

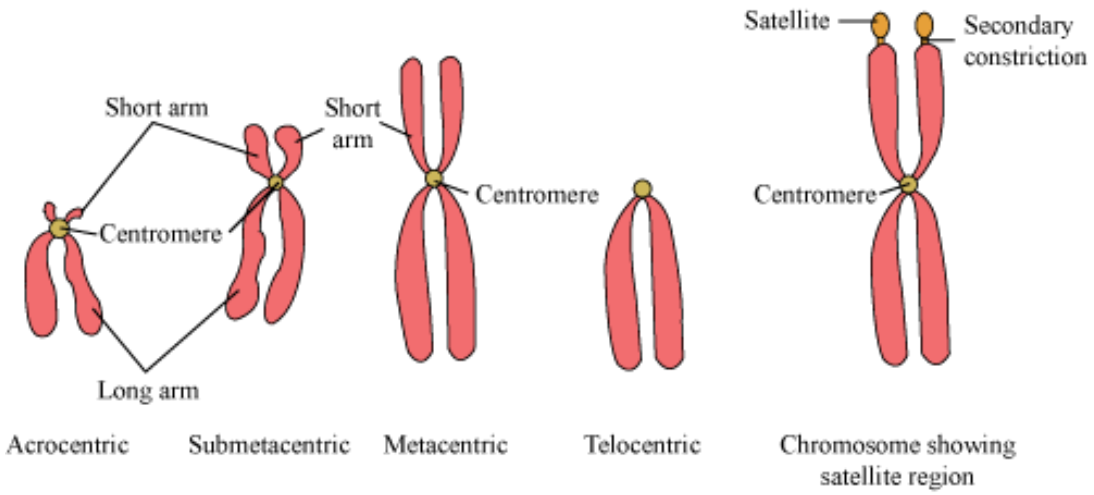
- Chromatin: Loose, indistinct network of nucleoprotein fibres (present in the interphase)

- Chromosomes: Chromatin structures develop into distinct chromosomes during cell division.

- Contains DNA, histone proteins, non-histone proteins, and also RNA
- DNA is distributed among 23 pairs (46) of chromosomes
- A chromosome has a primary constriction called *centromere***.** On the sides of the centromere, disc-shaped kinetochores are present.

Classification of Chromosomes

- Based upon the position of the centromere, chromosomes are of four types:
- *Metacentric* − centromere located in the middle, forming two equal arms of the chromosome
- *Sub-metacentric* − centromere located slightly away from the middle, resulting in one arm being longer than the other
- *Acrocentric* − centromere located close to the end, resulting in one arm being extremely longer than the other
- *Telocentric* − centromere located at the terminal point



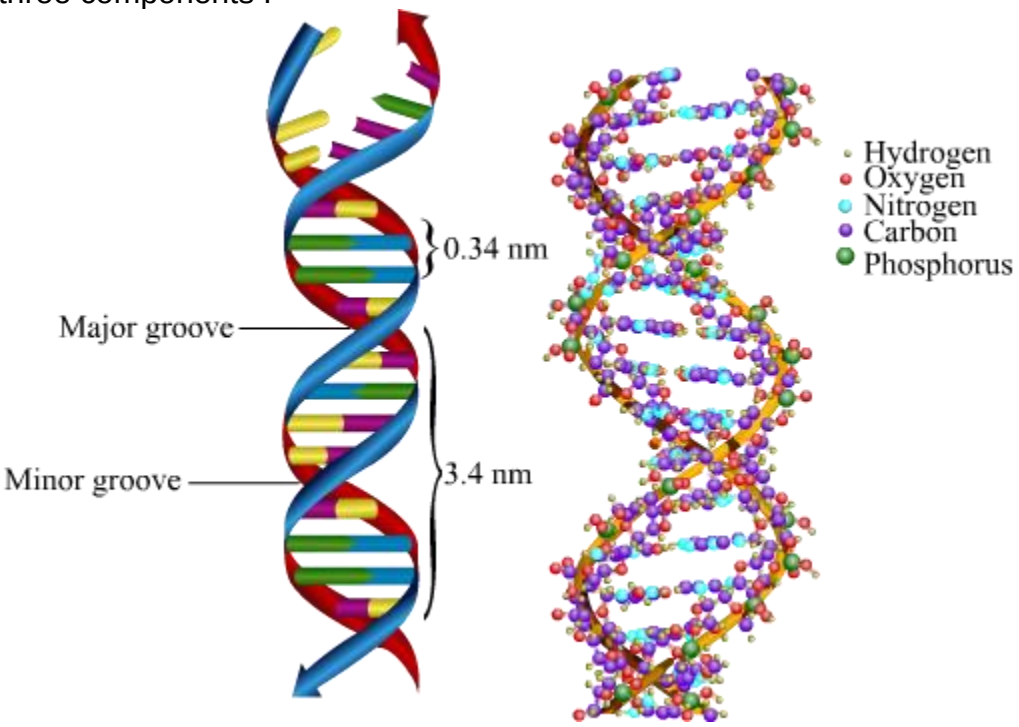
Types of chromosomes

- *Satellites*: Small fragments that appear due to the non-staining secondary constrictions present at a constant location on the chromosomes

DNA and Its Structure

Deoxyribonucleic acid or DNA is a macromolecule found inside the nucleus. It has a double helical structure, similar to a ladder, which is twisted at both ends. A DNA molecule is made up of repeating units of **nucleotides.** Each nucleotide is made up of

three components :



- A pentose sugar (ribose)
- Phosphate group
- A nitrogen base

There are four nitrogenous bases found in DNA. These are :

- Adenine (A)
- Guanine (G)
- Cytosine (C)
- Thymine (T)

Adenine pairs with Thymine with the help of two hydrogen bonds, while Guanine pairs with Cytosine with the help of three hydrogen bonds.

Each DNA molecule has a property to duplicate, or **replicate**, itself. This replication process takes place during mitosis, in which the helical structure of DNA gets open at one end and the free strands give rise to new, complementary strands.

Genes

A gene is a functional unit of DNA. It is located on a chromosome and controls the development of one or more traits through proteins encoded by it. It is the basic unit through which the genetic information is transferred from parent to their offspring. Every person has two copies of each gene, one inherited from each parent. Genes can acquire mutations in their sequence that lead to different variants, known as **alleles**, in population.

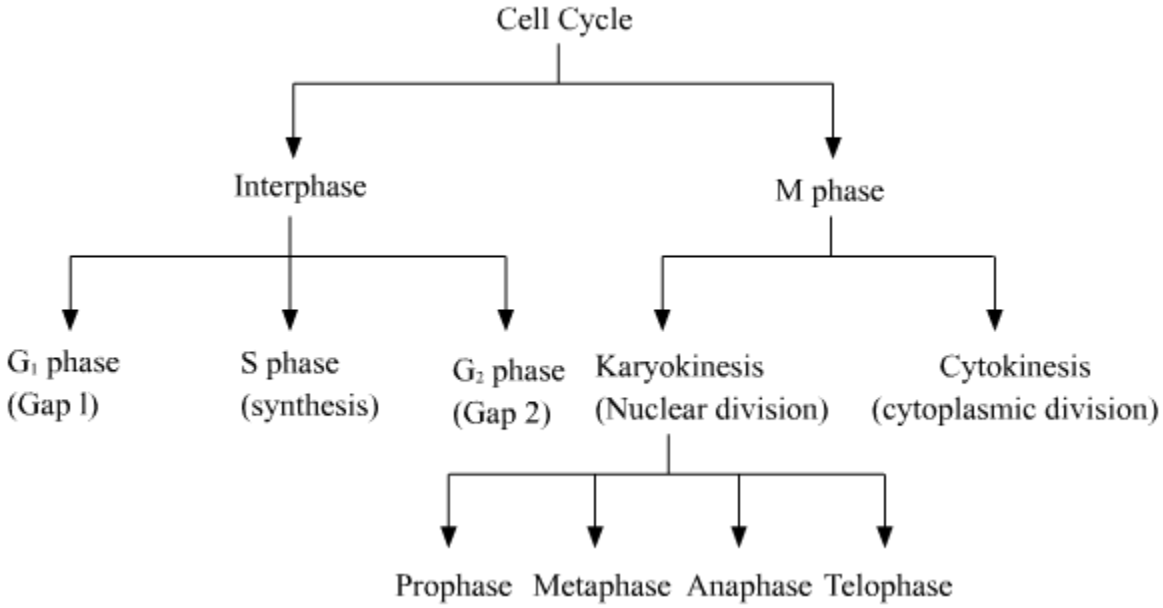
Phases of Cell Cycle

Cell Cycle

- The sequence of events by which a cell duplicates its genome, synthesises other cell constituents, and eventually divides into two daughter cells.
- The events of the cell cycle are under genetic control.

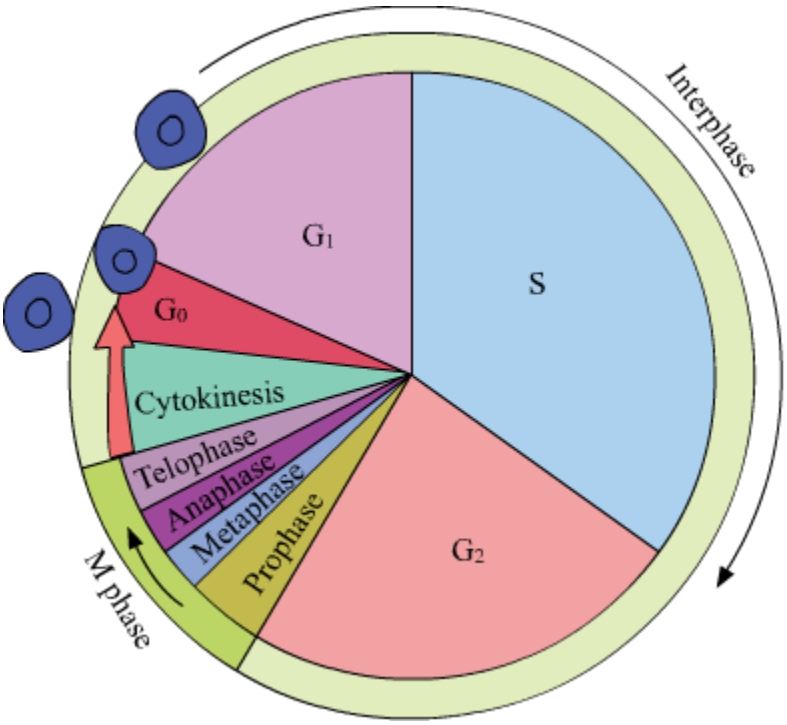
Phases of Cell Cycle

- Duration of the cell cycle varies from organism to organism, and from cell to cell. Duration of the cell cycle in humans is 24 hrs, and in yeast is 90 min.
- Phases of the cell cycle are:



- **Interphase** represents the phase during which a cell prepares itself for division, grows and DNA is replicated in it. Interphase occupies more than 95% of the duration of the cell cycle.
- It is divided into three phases − G_1, S and G_2.
- **G_1 (Gap 1) phase** is the phase between the end of mitosis and the initiation of DNA replication. The growth of the cell takes place in this phase.
- **S (synthesis) phase** is the phase of DNA replication. DNA content doubles (from 2C to 4C), but chromosome number remains the same. (remains diploid; 2*n* only). In this phase, the centriole also duplicates in animal cells.

- **G_2 (Gap 2) phase** is the phase in which the proteins needed for mitosis are synthesised. Cell growth continues in this phase.



- **G_0 phase** is the quiescent stage in which the cells that do not divide further enter after exiting from the G_1 phase. In this phase, the cells do remain metabolically active, but do not proliferate unless required.

- **M phase** represents the phase where the cell actually divides. It starts with nuclear division and ends with the division of the cytoplasm.

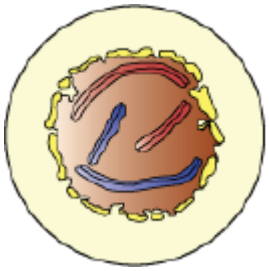
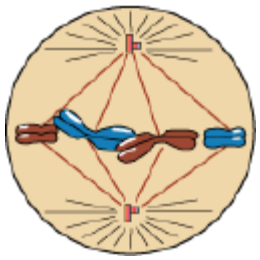
Significance of Cell Division

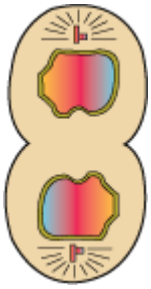
- It is the mean of asexual reproduction in unicellular organisms.
- It is essential for the growth of a single celled zygote into a whole new multicellular organism.
- It helps in the repair of injuries and worn out tissues.
- It replaces dead cells of the body and thus is essential for growth of organism.
- In sexual reproduction, meiosis occurs. This type of cell division not only results in production of gametes, but also brings new combinations of genes, thus resulting in variations among a population. This also leads to evolution of a species.

Mitosis - Events and Significance

Mitosis (M Phase)

- Also called **equational division** as number of chromosomes in parent and progeny remain the same
- Mitosis (M phase) is divided into 4 stages.
- Prophase (1st stage)
- Metaphase
- Anaphase
- Telophase (Last stage)

Phase	Characteristic features
Prophase 	→ Follows S and G2 phases of interphase → Chromosome material condenses and untangles. → Centriole, duplicated during S phase, starts moving towards opposite poles. → Mitotic spindle starts assembling. → Microtubules appear.
Metaphase 	→ Chromosomes condense completely. → Sister chromatids held together by centromere → At the surface of centriole, kinetochore appears. Here, spindle fibres attach. → Chromosomes lie at centre (equator) with each sister chromatid attached to spindle fibre of their respective poles with the help of kinetochore. [The plane of alignment of the chromosomes at metaphase is called Metaphase plate]

Anaphase 	→ Here, chromosome splits and daughter chromatids separate. → Chromatids move towards opposite poles. → Centromere leads and arms follow.
Telophase 	→ Chromosomes reach at opposite poles. → Chromosomes start losing their individuality. → Chromatin material collects at poles. → Nuclear envelope appears around chromosome clusters. → Cell organelles such as ER, Golgi complex, etc reappear. → This phase is followed by interphase of next cycle.

Cytokinesis

- *Cyto* (cell) *kinesis* (division) follows the process of karyokinesis (nuclear division).
- Process of cytokinesis in plant cell:
- New cell wall begins to form with precursor cell plate equivalent to middle lamella.
- This new cell wall grows outwards.
- Organelles such as mitochondria and plastids also get distributed between two daughter cells at the same time.
- Process of cytokinesis in animal cell:
- Furrow appears in the cell membrane.

- This furrow deepens and joins in the centre to divide the cytoplasm into two.
- If cytokinesis does not follow karyokinesis, then cell becomes multinucleate, leading to the formation of syncytium.

Significance of mitosis

- Results in formation of diploid genetically identical daughter cells
- Growth in multicellular organisms takes place by mitosis.
- Cell repair and replacement of worn out tissues
- Maintenance of nucleo-cytoplasmic ratio
- Vegetative reproduction in plants takes place by mitosis.

Meiosis and Its Significance

Meiosis

- It is a type of cell division that produces gametes.
- It occurs in the reproductive organs of various organisms. In humans, it occurs in testis and ovary to produce sperm and ova, respectively, whereas in plants, it occurs in anthers and ovules to produce pollen grains and egg, respectively.

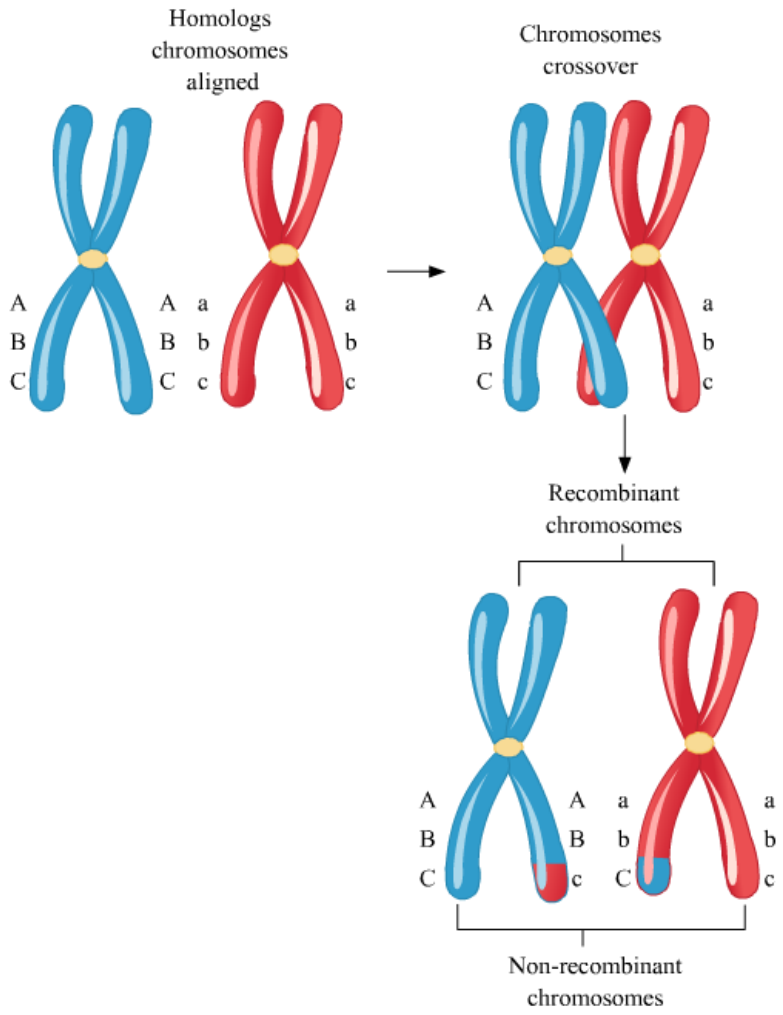
Important characteristic:

- In normal body cells, or **somatic cells**, the chromosomes are present in the form of pairs; each set of a pair comes from each parent. Such a cell is said to be **diploid**, represented as **2n**.
- During meiosis, the number of chromosomes is halved, so that the daughter cells thus formed contain single set of the chromosome pair. The cells thus formed (or gametes) are said to be **haploid**, represented as **n**.
- This reductional nature of meiosis is important to maintain the genetic makeup of an organism undergoing sexual reproduction. In sexual reproduction, the haploid male and female gametes produced through meiosis get fused together during fertilisation. As a result, the chromosome number in the zygote remains equal to that of the parents, and thus the diploid nature is restored.

Significance of meiosis:-

- Chromosome number is halved.
- It helps in mixing up of genes. This occurs in two ways:

- The maternal and paternal chromosomes mix at the time of first division, when they separate from homologous pairs.
- Cross joining : When maternal and paternal chromosomes separate, chromatid material often gets exchanged between the members of homologous pair, resulting in genetic recombination.



Differences between Mitosis and Meiosis

Mitosis	Meiosis
It occurs in the somatic cells throughout life.	It occurs in the reproductive cells during reproductive age.

Parent chromosome and genes in daughter cell are identical.	Parent chromosome and genes in daughter cell are randomly assorted, causing genetic variation.
It helps in growth and replacement.	It helps in gamete formation.
Complete set of chromosome is passed.	Half the number of chromosomes is passed.
Two daughter cells are produced.	Four daughter cells are produced.
Single nuclear division occurs after duplication of chromosome.	Double nuclear division occurs after duplication of chromosome.