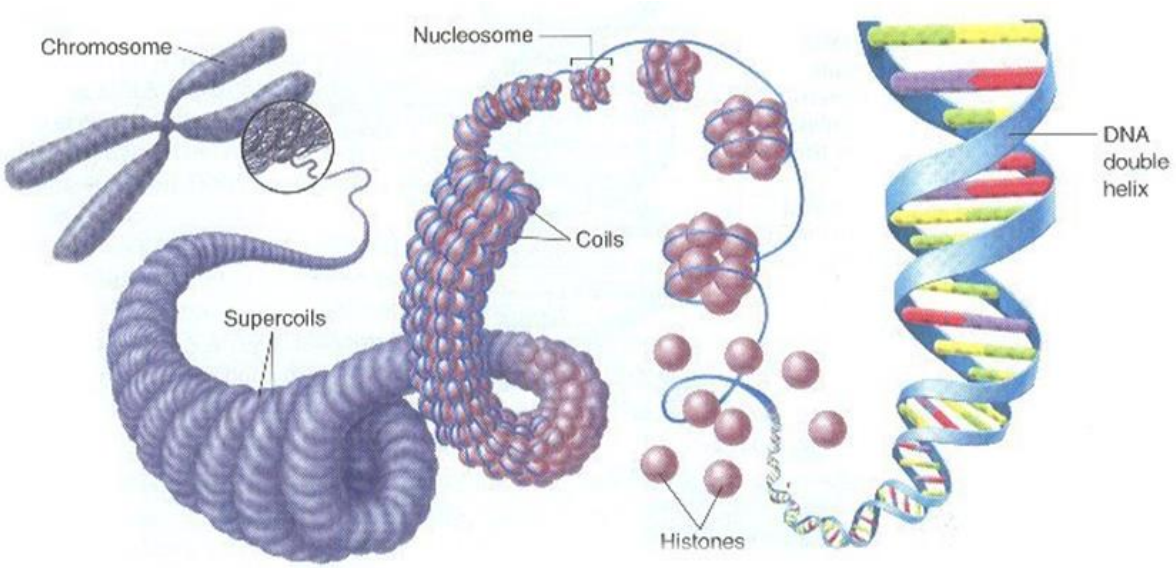
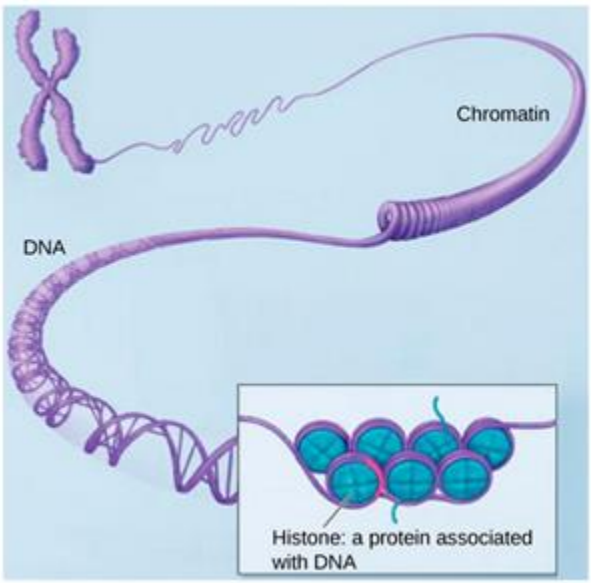
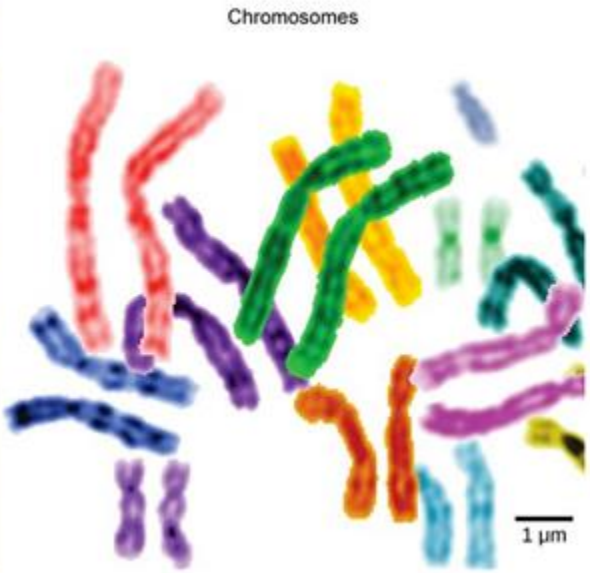
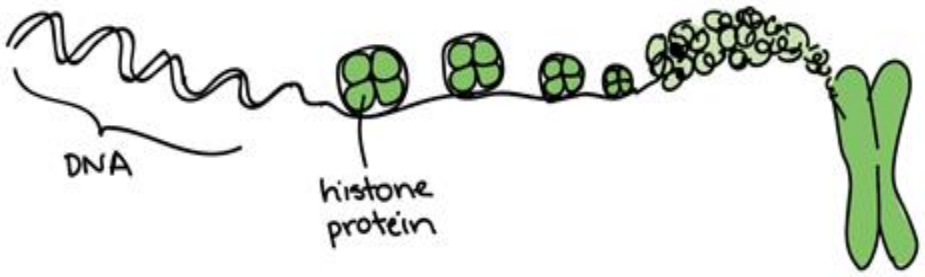
Chromosome- Structure, Types and Functions

- In the nucleus of each cell, the **DNA** molecule is packaged into thread-like structures called chromosomes.
- Each chromosome is made up of DNA tightly coiled many times around proteins called histones that support its structure.
- Chromosomes were first described by **Strasburger (1815),** and the term 'chromosome' was first used by **Waldeyer in 1888.**
- They appear as rod shaped dark stained bodies during the metaphase stage of mitosis when cells are stained with a suitable basic dye and viewed under a light microscope.









Structure of Chromosome

1. In eukaryotic cells, chromosomes are composed of single molecule of DNA with many copies of five types of histones.
2. Histones are proteins molecules and are rich in lysine and arginine residues, they are positively charged. Hence, they bind tightly to the negatively-charged phosphates in the DNA sequence.
3. A small number of non-histone proteins are also present, these are mostly transcription factors. Transcription factors regulate which parts of DNA to be transcribed into RNA.
4. During most of the cell's life cycle, chromosomes are elongated and cannot be observed under the microscope.
5. During the S phase of the mitotic cell cycle the chromosomes are duplicated.
6. At the beginning of mitosis, the chromosomes are duplicated and they begin to condense into short structures which can be stained and observed easily under the light microscope.
7. These duplicated condensed chromosomes are known as dyads.
8. The duplicated chromosomes are held together at the region of centromeres.
9. The centromeres in humans are made of about 1-10 million base pairs of DNA.
10. The DNA of the centromere are mostly repetitive short sequences of DNA, the sequences are repeated over and over in tandem arrays.
11. The attached, duplicated chromosomes are commonly called sister chromatids.
12. Kinetochores are the attachment point for spindle fibers which helps to pull apart the sister chromatids as the mitosis process proceeds to anaphase stage. The kinetochores are a complex of about 80 different proteins.
13. The shorter arm of the two arms of the chromosome extending from the centromere is called the p arm and the longer arm is known the q arm.

Structurally, each chromosome is differentiated into three parts—

- Pellicle
- Matrix
- Chromonemata

Pellicle

- It is the outer envelope around the substance of chromosome.
- It is very thin and is formed of achromatic substances.

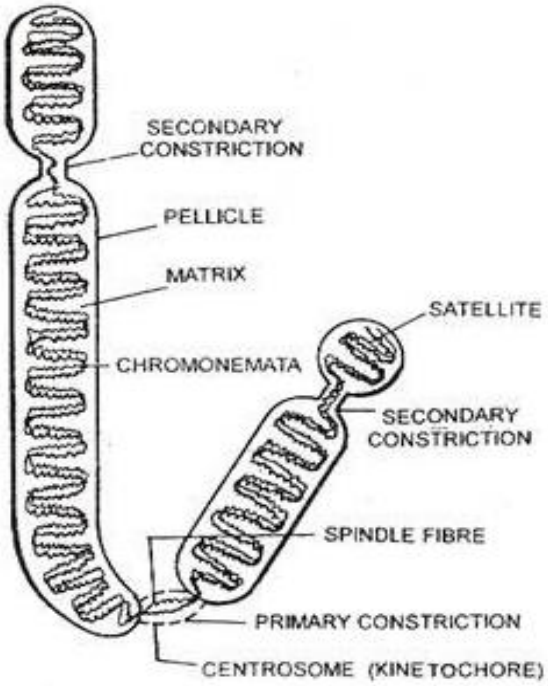
Matrix

- It is the ground substance of chromosome which contains the Chromonemata.
- It is also formed of non-genic materials.

Chromonemata

- Embedded in the matrix of each chromosome are two identical, spirally coiled threads, the chromonemata.
- The two chromonemata are also tightly coiled together that they appear as single thread of about 800A thickness.
- Each chromonemata consists of about 8 microfibrils, each of which is formed of a double helix of DNA.

In mitotic metaphase chromosomes, the following structural feature (except chromomere) can be seen under the light microscope:
(1) Chromatid,
(2) Chromonema,
(3) Chromomeres,
(4) Centromere,
(5) Secondary constriction or Nucleolar organizer,
(6) Telomere and
(7) Satellite.



Structure of chromosome at anaphase stage of mitosis.

Centromere

- A small structure in the chromonema, marked by a constriction which is recognised as permanent structure in the chromosome is termed as the centromere.
- At this point the two chromonemata are joined together.
- It is known as centromere or kinetochore or primary constriction.

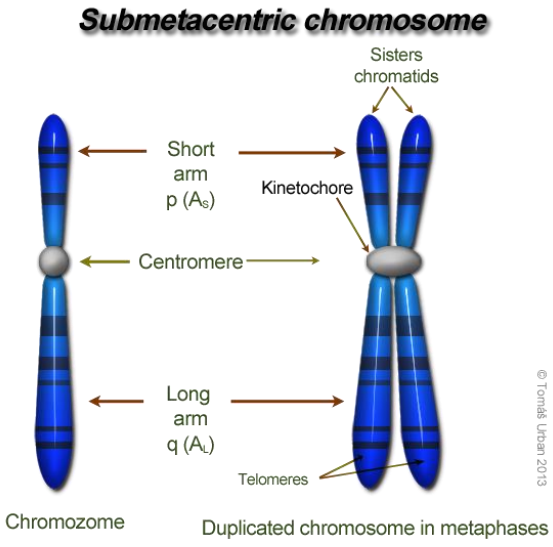
- It divides the chromosome into two sections, or “arms.” The short arm of the chromosome is labelled the “p arm.” The long arm of the chromosome is labelled the “q arm.”
- Its position is constant for a given type of chromosome and forms a feature of identification.
- In thin electron microscopic sections, the kinetochore shows a trilaminar structure, i.e., a 10 nm thick dense outer protein aceous layer, a middle layer of low density and a dense inner layer tightly bound to the centromere.
- The chromosomes are attached to spindle fibres at this region during cell division.

Secondary Constriction or Nucleolar Organiser

- The chromosome besides having the primary constriction or the centromere possesses secondary constriction at any point of the chromosome.
- Constant in their position and extent, these constrictions are useful in identifying particular chromosomes in a set.
- The chromosome region distal to the secondary constriction i.e., the region between the secondary constriction and the nearest telomere is known as satellite.
- Therefore, chromosomes having secondary constrictions are called satellite chromosomes or sat-chromosomes.
- Nucleolus is always associated with the secondary constriction of sat-chromosomes. Therefore, secondary constrictions are also called nucleolus organiser region (NOR) and sat-chromosomes are often referred to as nucleolus organiser chromosomes.

Telomeres

- These are specialized ends of a chromosome which exhibits physiological differentiation and polarity.
- Each extremity of the chromosome due to its polarity prevents other chromosomal segments to be fused with it. The chromosomal ends are known as the telomeres.
- If a chromosome breaks, the broken ends can fuse with each other due to lack of telomere.



Types of Chromosomes

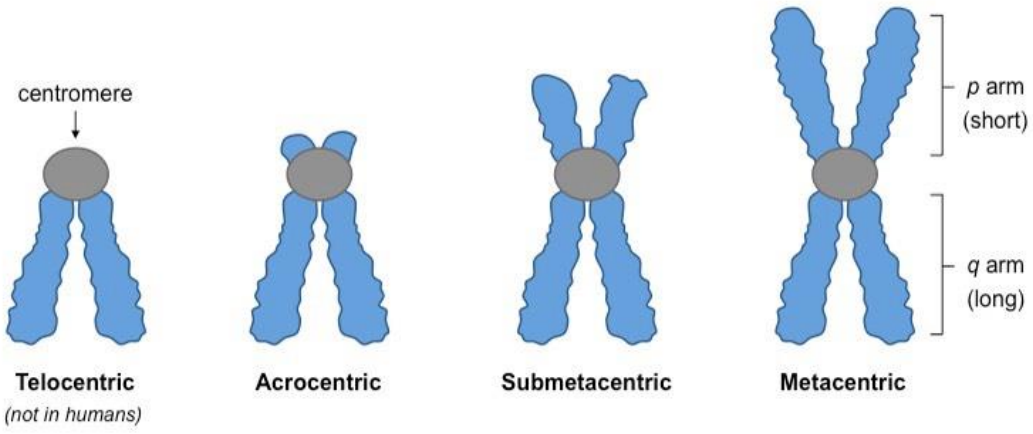
A. Autosomes and Sex Chromosomes

- Human chromosomes are of two types autosomes and sex chromosomes.
- Genetic traits that are linked to the sex of the person are passed on through the sex chromosomes. The rest of the genetic information is present in the autosomes.
- Humans have 23 pairs of chromosomes in their cells, of which 22 pairs are autosomes and one pair of sex chromosomes, making a total of 46 chromosomes in each cell.

B. On the Basis of Number of Centromeres

- **Monocentric** with one centromere.
- **Dicentric** with two centromeres.
- **Polycentric** with more than two centromeres
- **Acentric** without centromere. Such chromosomes represent freshly broken segments of chromosomes which do not survive for long.

C. On the Basis of Location of Centromere



Chromosomes are divided into two parts (p and q arms) with a constriction point called a centromere in the middle.
The centromere can be located in different positions and this forms the basis for the four different classes of chromosome:

- **Metacentric** – centromere is in middle, meaning p and q arms are of comparable length (e.g., chromosomes 1, 3, 16, 19, 20)
- **Submetacentric** – centromere off-centre, leading to shorter p arm relative to q arm (e.g., chromosomes 2, 4 – 12, 17, 18, X)
- **Acrocentric** – centromere severely off-set from centre, leading to much shorter p arm (e.g., chromosomes 13 – 15, 21, 22, Y)
- **Telocentric** – centromere found at end of chromosome, meaning no p arm exists (chromosome not found in humans)

Function and Significance of Chromosomes

- The number of the chromosomes is constant for a particular species. Therefore, these are of great importance in the determination of the phylogeny and taxonomy of the species.
- **Genetic Code Storage**: Chromosome contains the genetic material that is required by the organism to develop and grow. DNA molecules are made of chain of units called genes. Genes are those sections of the DNA which code for specific proteins required by the cell for its proper functioning.
- **Sex Determination:** Humans have 23 pairs of chromosomes out of which one pair is the sex chromosome. Females have two X chromosomes and males have one X and one Y chromosome. The sex of the child is determined by the chromosome passed down by the male. If X chromosome is passed out of XY chromosome, the child will be a female and if a Y chromosome is passed, a male child develops.
- **Control of Cell Division:** Chromosomes check successful division of cells during the process of mitosis. The chromosomes of the parent cells ensure that the correct information is passed on to the daughter cells required by the cell to grow and develop correctly.
- **Formation of Proteins and Storage:** The chromosomes direct the sequences of proteins formed in our body and also maintain the order of DNA. The proteins are also stored in the coiled structure of the chromosomes. These proteins bound to the DNA help in proper packaging of the DNA.