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The chromosomes
History-structure number karyotyping

History:

In a series of experiments beginning in the mid-1880s, Theodor Boveri gave the definitive demonstration that chromosomes are the vectors of heredity; his two principles or postulates were the ***continuity*** of chromosomes and the ***individuality*** of chromosomes.

- Wilhelm Roux suggested that each chromosome carries a different genetic configuration , and Boveri was able to test and confirm this hypothesis.
- The number of human chromosomes was published in 1923 by Theophilus Painter.
- By inspection through the microscope, he counted 24 pairs, which would mean 48 chromosomes.
- His error was copied by others and it was not until 1956 that the true number, 46, was determined by Indonesia-born cytogeneticist Joe Hin Tjio.

What is a chromosome?

- Chromosomes are thread-like structures located inside the nucleus of animal and plant cells. Each chromosome is made of protein and a single molecule of deoxyribonucleic acid (DNA). Passed from parents to offspring, DNA contains the specific instructions that make each type of living creature unique.
- The term chromosome comes from the Greek words for color (chroma) and body (soma). Scientists gave this name to chromosomes because they are cell structures, or bodies, that are strongly stained by some colorful dyes used in research.

Chromosome structure

In M-phase the long eukaryotic DNA molecules have to be packed in small chromosomes to be able to accurately halve without breaks. Meanwhile, the original length of the DNA (several cm) is reduced by ten thousands fold (few µm). The molecular mechanism of this packaging is still not known in detail. The major points of a widely accepted model are described below (Figure 2.1).

Chromosomes also contain DNA-bound proteins, which serve in packaging the DNA and control its functions. Chromosomes vary both in number and structure among

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organisms and the number of chromosomes is characteristic of every species.

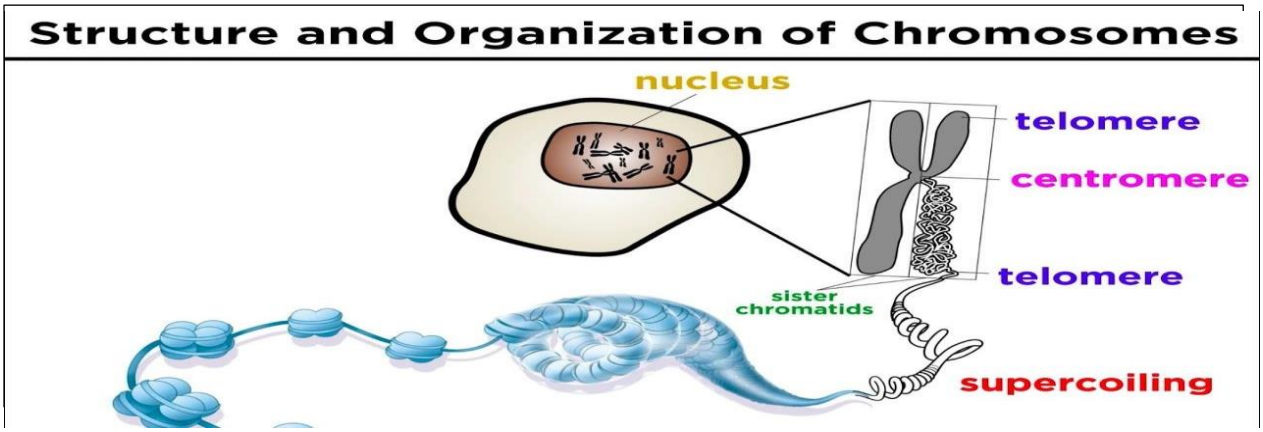

Figure 2.1 Chromosome structure

Two nm wide DNA double helix wraps the octamers of histones (2 of each H2A, H2B, H3 and H4 histone molecules) forming nucleosomes, disc-like structures connected by the continuous DNA molecule (figure 2.2). It is called nucleosomal structure having a diameter of 11 nm. H1 histone folds six nucleosomes in one plane to give a diameter of 30 nm fiber called chromatin or solenoid.

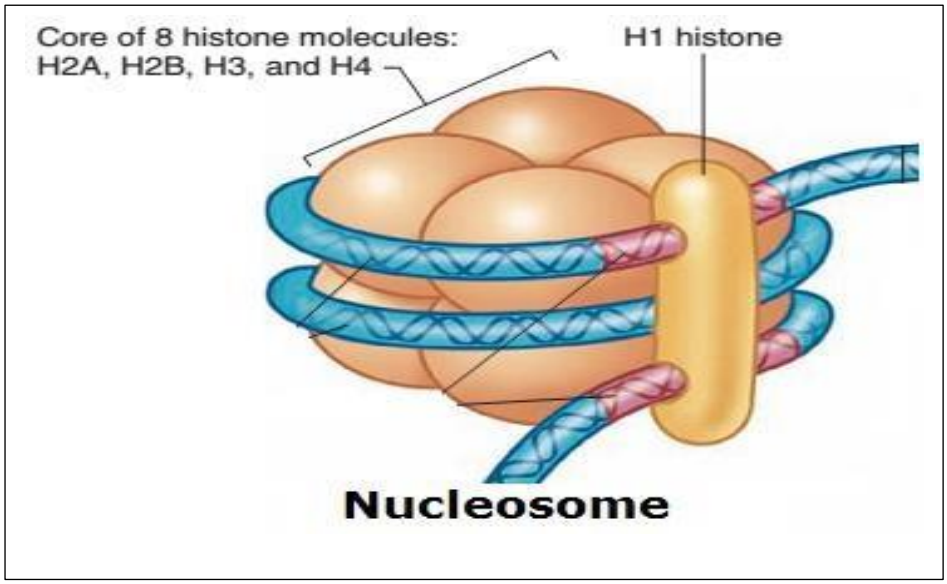

Figure: 2.2 Nucleosome structure

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The chromatin fiber is attached to a protein scaffold and forms loops. These loops are the basic unit of replication and transcription, and this structure is 300 nm wide. Finally, it is further compressed and folded to produce the chromatids of 1400 nm wide metaphase chromosome (figure 2.3).

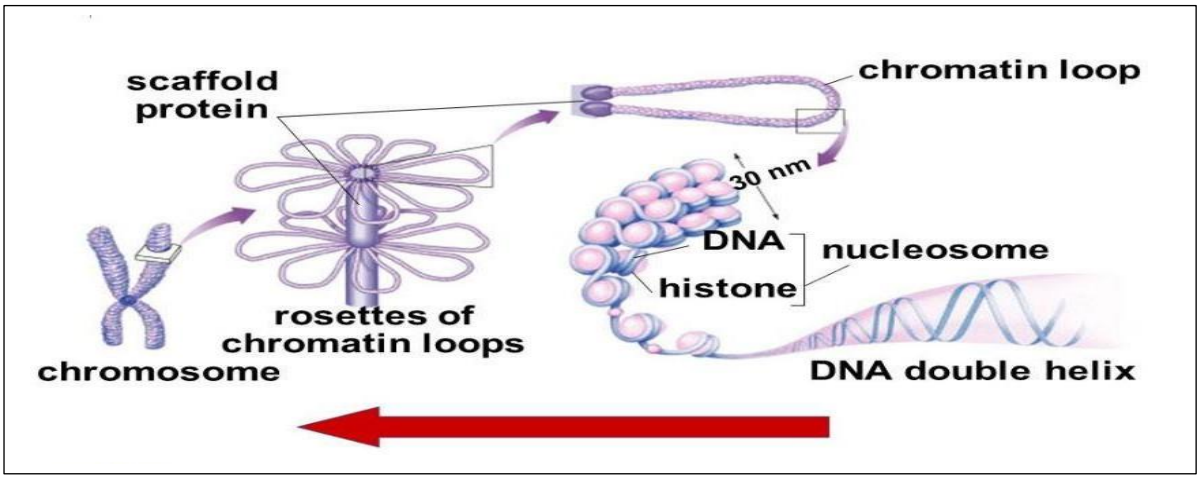

Figure: 2.3 The chromatin structure

The final step of chromosome condensation induced by the MPF (mitosis-promoting factor) activated condensins. There are two protein complexes of similar structure influencing different DNA functions: the condensins and the cohesins. They are composed of different SMC (structural maintenance of chromosomes) proteins having ATPase activity and regulatory functions, all associate in a ring- like structure (Figure 2.4).

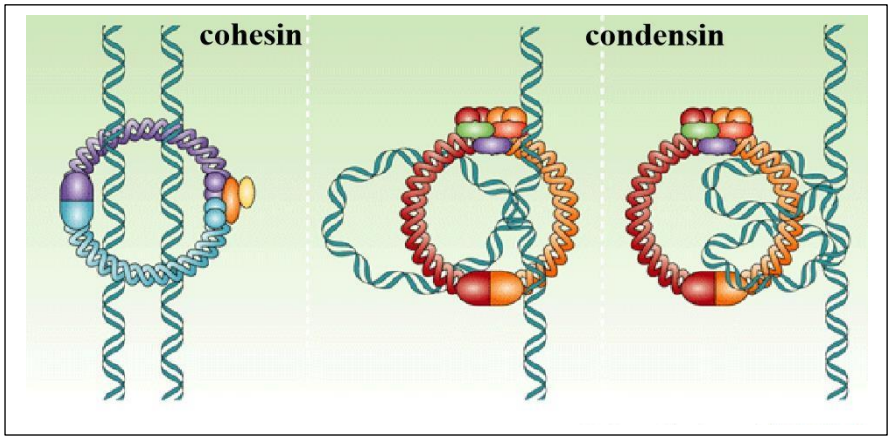

Figure 2.4 Structure of cohesin and condensing

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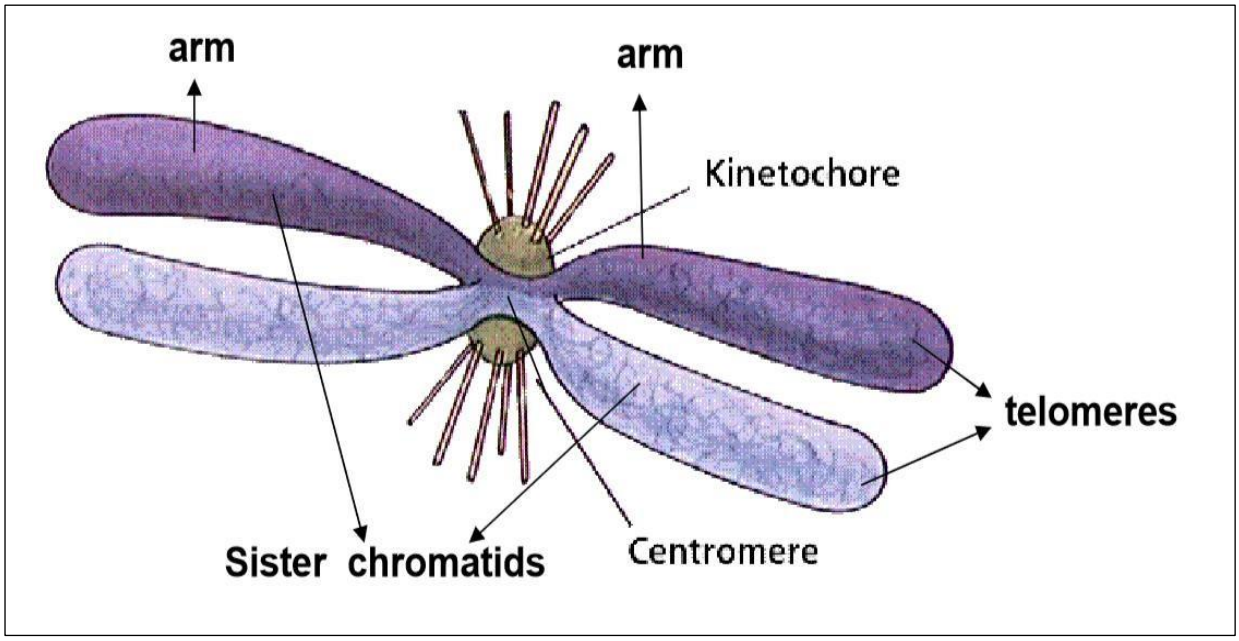
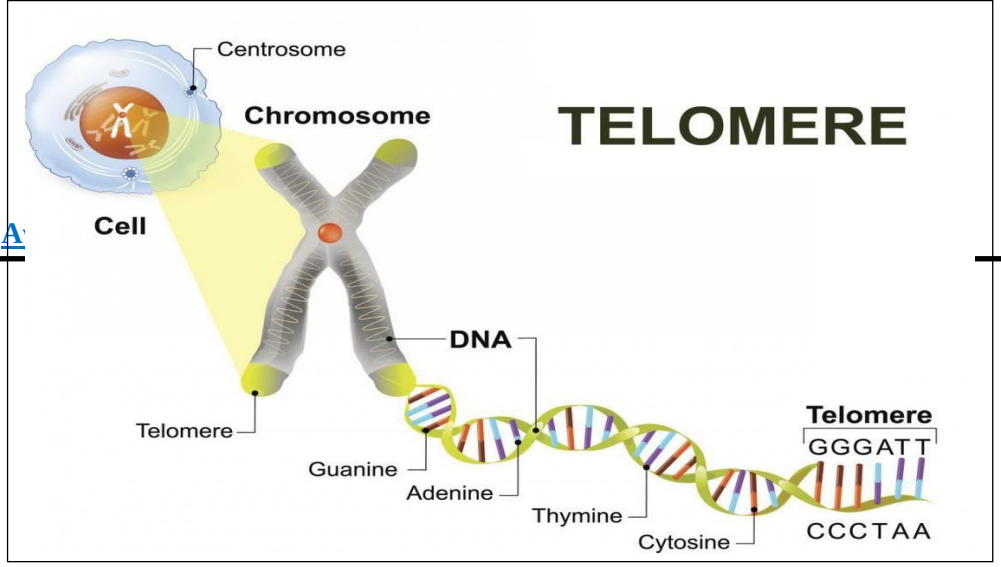


Figure 2.4 Eukaryotic chromosome

Telomeres are protein structures located at the ends of each eukaryotic DNA chromosomal arm. These chromosomal caps are 1 of the most important structures that preserve the structural integrity of linear DNA during each cycle of replication.[1] Functions of telomeres include protecting the ends of the DNA from binding to one another and to itself, allowing for complete chromosomal replication, and serving as a molecular timer by controlling the lifespan of a eukaryotic cell. Telomeres also prevent the free ends of the chromosome from appearing as DNA double-stranded breaks, which in turn safeguards the ends from accidental DNA repair.[2] Telomeres play a significant role in cellular senescence in humans and have made major contributions to human aging. Pathologically, dysregulated expression of



the telomere synthesis mechanism causes cellular immortality, leading to potential oncogenesis and tumorigenesi

A telomere structure consists of repeats of non-coding nitrogenous bases (5'-TTAGGG-3').

Function : The main functions of a telomere are to maintain chromosomal stability and prevent chromosomal degradation. Additionally, telomeres protect the ends of the chromosome from DNA end-joining to one another, damage response to DNA, and accidental DNA recombination.[6] The longer 3' G-rich end overhang that creates the T-loop protects the end of that chromosome from appearing as a double-stranded break in the DNA strand, thus preventing unwanted DNA repair.[17] For these reasons, telomeres and their maintenance are essential to eukaryotic genomic stability and the longevity of cellular information.

Karyotyping:

is defined as the process of pairing and ordering all the chromosomes of an organism to provide a genome-wide overview of an individual's chromosomes, allowing for the analysis of chromosomal anomalies and structural features. It is utilized in the study of chromosome number changes and minute chromosomal alterations associated with genetic disorders and cancers.

What is Karyotyping and Why is it Important?

At its core, cytogenetics is a branch of genetics that studies the DNA structure within the cell's nucleus. **Karyotyping** is a tool or technique that cytogeneticists use to study the structure of DNA in the nucleus. These approaches can vary from staining/imaging, sequencing, microarray, or polymerase chain reaction (PCR) based applications.

All these methods have their respective advantages and disadvantages that we will highlight in this blog.

What is a karyotype test?

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A karyotype test uses blood or body fluids to analyze your chromosomes. Chromosomes are the parts of our cells that contain genes, which consist of DNA. You inherit genes from your parents. Genes determine your traits, such as eye and skin color.

Most people have 23 pairs of chromosomes (46 chromosomes total). Each biological parent contributes half. But sometimes, people are missing chromosomes or have extra chromosomes. Or their chromosomes might be an abnormal size, shape or sequence (order). Unusual chromosomes can mean that you have a genetic disease or disorder.

When is a karyotype test needed?

Adults may need this type of genetic testing if they:

- **Are having trouble getting pregnant or getting their partner pregnant.** Sometimes male or female infertility is the result of a genetic disorder.
- **Have certain cancers or blood disorders.** Diseases such as anemia, leukemia, lymphoma or multiple myeloma can change your chromosomes. Finding these abnormalities with karyotyping can guide your treatment.
- **Have a family history of certain genetic diseases.** A chromosome analysis can determine if you have abnormal chromosomes and what the chances are of passing them to your children.