10.1C: Eukaryotic Chromosomal Structure and Compaction

Chromosomes must coil to pack DNA into the cell during cell division, a process involving 3 levels of compaction.

Learning Objectives

• Describe the levels of chromosomal structure and compaction

Key Points

• During some stages of the cell cycle, the long strands of DNA are condensed into compact chromosomes to fit in the cell’s nucleus.

• In the first level of compaction, short stretches of the DNA double helix wrap around a core of eight histone proteins at regular intervals along the entire length of the chromosome.

• The DNA surrounding the histone core is called a nucleosome; the DNA-histone complex is called chromatin.

• The second level of compaction occurs as the nucleosomes and the linker DNA between them are coiled into a 30-nm chromatin fiber, which shortens the chromosome so it’s about 50 times shorter than the extended form.

• After replication, the chromosomes are composed of two linked sister chromatids; when fully compact, the pairs of identically-packed chromosomes are bound to each other by cohesin proteins.

• The connection between the sister chromatids is closest in a region called the centromere; this region is highly condensed.

Key Terms

• nucleosome: any of the subunits that repeat in chromatin; a coil of DNA surrounding a histone core
• **histone**: any of various simple water-soluble proteins that are rich in the basic amino acids lysine and arginine and are complexed with DNA in the nucleosomes of eukaryotic chromatin

• **chromatin**: a complex of DNA, RNA, and proteins within the cell nucleus out of which chromosomes condense during cell division

### Eukaryotic Chromosomal Structure and Compaction

If the DNA from all 46 chromosomes in a human cell nucleus was laid out end to end, it would measure approximately two meters. However, the diameter would be only 2 nm. Considering that the size of a typical human cell is about 10 µm (100,000 cells lined up to equal one meter), DNA must be tightly packaged to fit in the cell's nucleus. At the same time, it must also be readily accessible for the genes to be expressed. During some stages of the cell cycle, the long strands of DNA are condensed into compact chromosomes. There are a number of ways that chromosomes are compacted to fit in the cell's nucleus and be accessible for gene expression.

In the first level of compaction, short stretches of the DNA double helix wrap around a core of eight histone proteins at regular intervals along the entire length of the chromosome. The DNA-histone complex is called chromatin. The beadlike, histone DNA complex is called a nucleosome. DNA connecting the nucleosomes is called linker DNA. A DNA molecule in this form is about seven times shorter than the double helix without the histones. The beads are about 10 nm in diameter, in contrast with the 2-nm diameter of a DNA double helix. The next level of compaction occurs as the nucleosomes and the linker DNA between them are coiled into a 30-nm chromatin fiber. This coiling further shortens the chromosome so that it is now about 50 times shorter than the extended form. In the third level of packing, a variety of fibrous proteins is used to pack the chromatin. These fibrous proteins also ensure that each chromosome in a non-dividing cell occupies a particular area of the nucleus that does not overlap with that of any other chromosome.
Levels of DNA Compaction: Double-stranded DNA wraps around histone proteins to form nucleosomes that have the appearance of “beads on a string.” The nucleosomes are coiled into a 30-nm chromatin fiber. When a cell undergoes mitosis, the chromosomes condense even further.

DNA replicates in the S phase of interphase. After replication, the chromosomes are composed of two linked sister chromatids. When fully compact, the pairs of identically-packed chromosomes are bound to each other by cohesin proteins. The connection between the sister chromatids is closest in a region called the centromere. The conjoined sister chromatids, with a diameter of about 1 µm, are visible under a light microscope. The centromeric region is highly condensed and will appear as a constricted area.

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