Nucleosome and packaging of DNA into chromosome

In order to fit DNA into the nucleus, it must be packaged into a highly compacted structure known as chromatin. In the first step of this process DNA is condensed into an 11 nm fiber that represents an approximate 6-fold level of compaction. This is achieved through nucleosome assembly.

The nucleosome is the smallest structural component of chromatin, and is produced through interactions between DNA and histone proteins. A histone octamer is formed from the histones H2A, H2B, H3 and H4; although in some cases other histone variants may also be found in the core. A 147bp segment of DNA then wraps around the histone octamer 1.75 times, thus completing the formation of a single nucleosome.

Multiple nucleosomes form in a linear fashion along the DNA molecule. This produces 11 nm fibers, which is described as beads on a string whrere adjacent nucleosomes are connected via linker DNA, which is usually bound to the H1 histone and is between 20-80 bps long. The level of compaction attained through the formation of the 11 nm nucleosome fiber is insufficient to package the whole genome into the nucleus. Instead, this fiber forms the basis for other higher order chromatin structures that are established through additional folding and bending events.

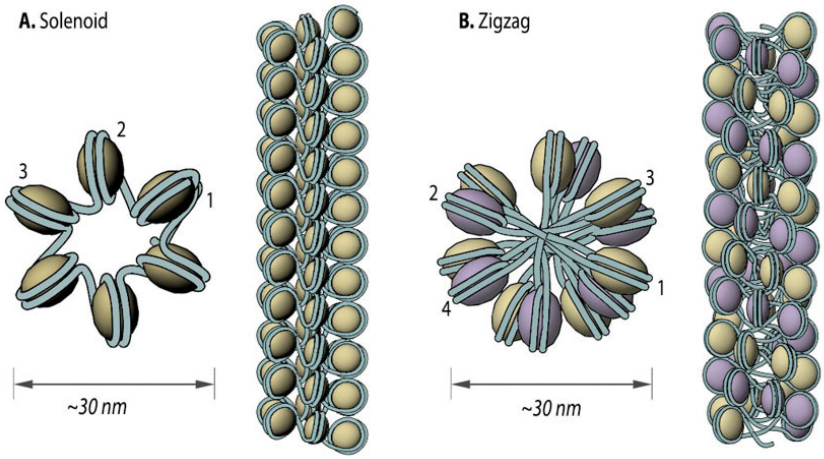
Intermediate chromatin structures

Two models that were proposed are solenoid and zigzag. In each case, 11 nm nucleosome fibers undergoes additional folding to form a 30 nm fiber with the manner of folding for a particular region depending on the internucleosomal linker length and the presence of linker histone H17.

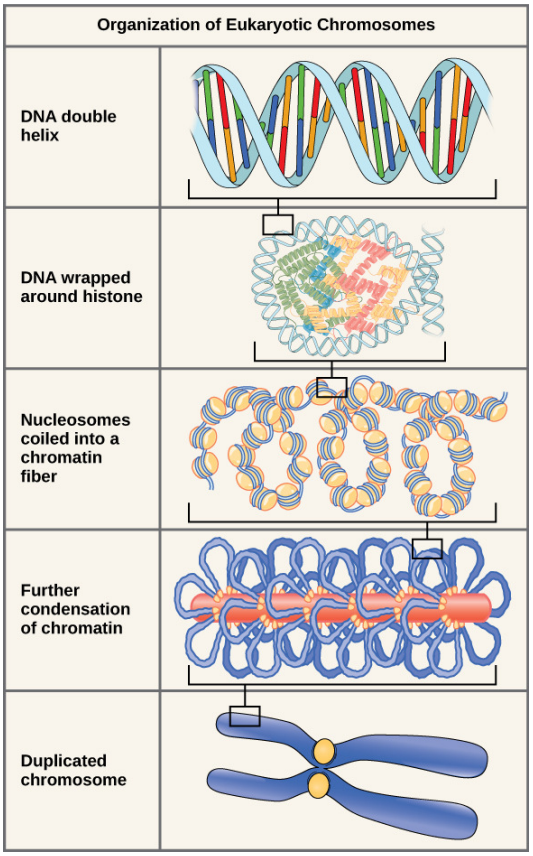
In the one-start solenoid model, bent linker DNA sequentially connects each nucleosome cores, creating a structure where nucleosomes follow each other along the same helical path.

In the two-start zigzag model, straight linker DNA connects two opposing nucleosome cores, creating the opposing rows of nucleosomes that form so called two-start helix. In this model, alternate nucleosomes (for example, N1 and N3) become interacting partners.

Some studies offer a model, where intermediate 30 nm fibers contain both solenoid and zigzag conformations. New models have been proposed (e.g., chromonema, chromatin hub, hybrid chromonema/chromatin hub, fractal), but no common conclusion has been reached yet.



In the first level of compaction, short stretches of DNA double helix wrap around a core of eight histone proteins at regular intervals along the entire length of the chromosome. The beadlike, histone DNA complex is called a nucleosome, and DNA connecting the nucleosomes is called linker DNA. A DNA molecule in this form is about seven times shorter than the double helix without histones, and the beads are about 10 nm in diameter, in contrast with the 2 nm diameter of a DNA double helix. The second level of compaction occurs as nucleosomes and linker DNA are coiled into 30 nm chromatin fiber. This coiling further shortens the chromosome so that it is about 50 times shorter than the extended form. In the third level of packing, 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 nucleus that does not overlap with that of any other chromosome. DNA replicates in the S phase of interphase. After replication, chromosomes are composed of two linked sister chromatids. When fully compact, pairs of identically packed chromosomes are bound to each other by cohesin proteins. Connection between sister chromatids is closest in a region called centromere. Sister chromatids are visible under light microscope. Centromeric region is highly condensed and appears as a constricted area.



Source: https://www.mechanobio.info/genome-regulation/what-are-nucleosomes/

Source: https://courses.lumenlearning.com/suny-wmopen-biology1/chapter/chromosomes-and-dna-packaging/

Further reading: https://www.ncbi.nlm.nih.gov/books/NBK26834/

Further reading: https://www.easybiologyclass.com/nucleosome-model-of-chromosomes-in-eukaryotes-short-notes/