Deoxyribonucleic acid (DNA) is a macromolecule that consists of deoxyribonucleotide monomers linked to each other by phosphodiester bonds. The sequence of these nucleotides contains translates into a genetic blueprint by which a cell can synthesize proteins.

**Mechanics**

In cells, DNA exists as a double-stranded molecule that twists around its axis to form a helical structure. Each strand is a complement to the other; the nucleotides on one strand hydrogen-bond with complementary nucleotides on the opposite strand. The double helical “twist” occurs because of the angular geometry of each bonded nucleotide.

Uncoiled DNA can exist in either a linear form or as a closed-loop molecule (plasmid). Yet each complete turn of the double-helix spans either 10.7 base pairs (A-DNA) or 10.5 base pairs (B-DNA), so in order for a plasmid to close stably it must be a multiple of 10.7 or 10.5 base pairs in length.

**A-DNA, B-DNA, Z-DNA**

There are three major geometric configurations of DNA:

B-DNA is the “generic” double helical form of DNA that is typically presented in introductory biology textbooks and on television. It is the form that predominates in vivo (in live cells), and is unmethylated. Every complete turn of the helix spans ~10.5 base pairs. B-DNA is right-handed, and has a barely noticeable tilt from its vertical axis. B-DNA has a wide major groove at which proteins can bind.

Unlike B-DNA, A-DNA has a narrower major groove and a wider minor groove. Consequently, A-DNA binds proteins at the minor groove. A-DNA also has a significant tilt from its vertical axis and each helical rotation requires 10.7 base pairs. A-DNA typically forms either when DNA duplexes with RNA, or at low water concentrations.

Z-DNA earns its name from a zigzag-like appearance. It is narrower than either B-DNA or A-DNA, and is left-handed unlike the other two forms (both right-handed). Z-DNA also has a tilt from its vertical axis, but not as great as A-DNA. Z-DNA is sometimes formed in vivo, often due to alternating guanine and cytosine nucleotides or as a result of methylation.

**Supercoiling**

Without supporting proteins, DNA undergoes “supercoiling” and collapses onto itself. This is because its double-helical nature creates a torsional strain, similar to a twisted piece of rope.

**CHROMATIN PACKAGING**

In eukaryotic cells, linear DNA is packaged into a dense material called chromatin. This prevents supercoiling, keeps the DNA precisely organized, and prevents disastrous shearing during cell division. Specifically, DNA is wrapped around a histone pentamer (tetramer in some cases), forming a nucleosome. Below is a visual representation of the first degree of
DNA packaging where multiple nucleosomes span the DNA molecule like beads on a string:

Histones interact with each other to form what is called the 30-nm fiber (referring to the thickness of the structure). Typically, less active genes are packed in a 30-nm fiber. When cell division occurs, the 30-nm is scaffolded to more structural proteins, until eventually the chromatin is packed into structures known as chromosomes.

### Plasmids

Plasmids are typically found in bacteria, however some eukaryotes such as the yeast *Saccharomyces cerevisiae* also contain plasmids. Histones are not found in prokaryotes, and DNA is not packaged the way it is in eukaryotic cells. Therefore, plasmids are typically found in supercoiled form. Two common shapes are the toroid and the plectoneme:

### SIGNIFICANCE

DNA shape affects how/whether proteins can bind to it, which has important consequences for gene transcription and regulation since condensed DNA cannot bind polymerases. DNA shape also affects its molecular mobility. This is an important consideration in gel electrophoresis, where linear DNA travels faster than plasmids of the same length in base pairs, and supercoiled plasmids travel faster than uncoiled plasmids.

### References


### Contributors

- Dmitry Ratner (UCD)