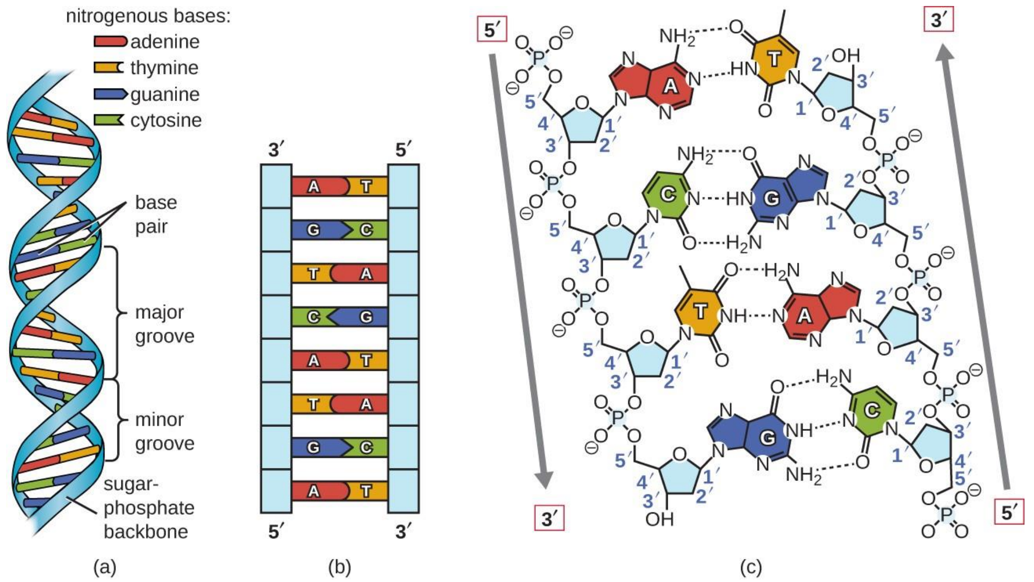
DNA- Structure, Properties, Types and Functions

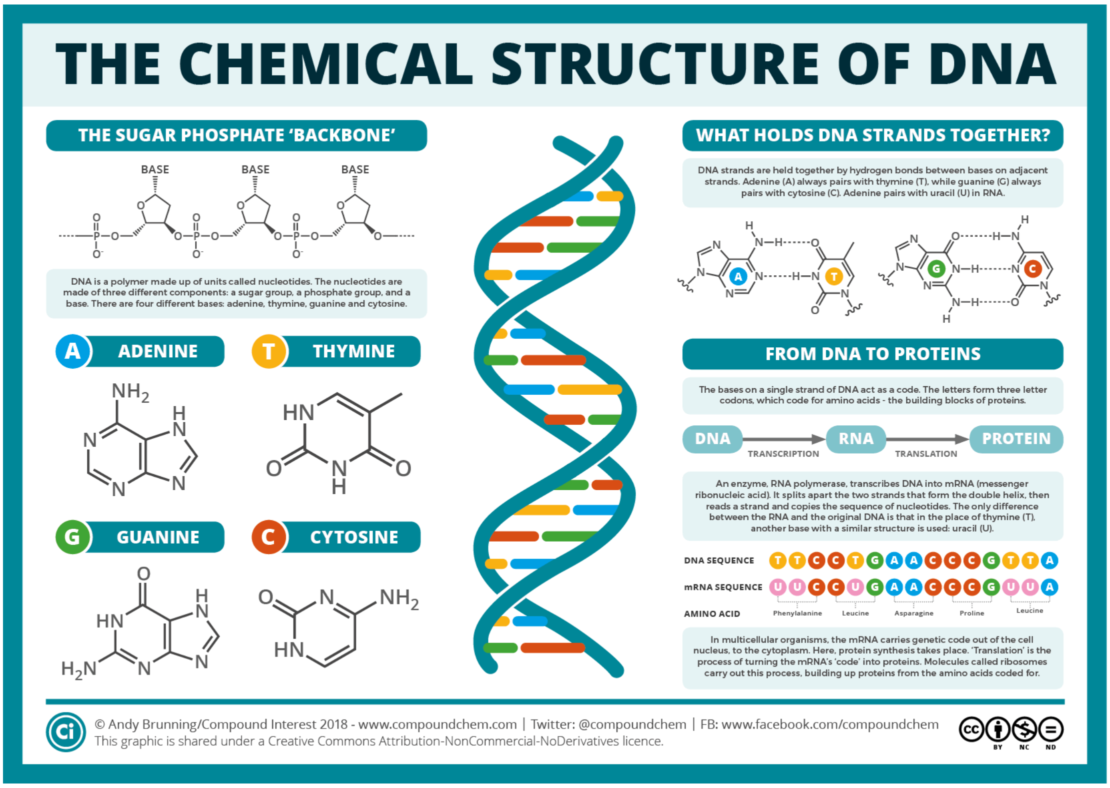
- **DNA** stands for Deoxyribonucleic Acid which is a molecule that contains the instructions an organism needs to develop, live and reproduce.
- These instructions are found inside every cell and are passed down from parents to their children.
- It is a nucleic acid and is one of the four major types of macromolecules that are known to be essential for all forms of life.
- DNA is found in the nucleus, with a small amount of DNA also present in mitochondria in the eukaryotes.

DNA Structure



- In 1953, James Watson and Francis Crick discovered the **structure of DNA**.
- The works of Rosalind Franklin lead to Watson and Crick's discovery. Franklin first had pointed out that the DNA is made up of two spirals.
- The structure of DNA is a double helix structure because it looks like a twisted ladder.
- The sides of the ladder are made of alternating sugar (deoxyribose) and phosphate molecules while the steps of the ladder are made up of a pair of nitrogen bases.
- There are 4 types of nitrogen bases Adenine (A) Thymine (T) Guanine (G) Cytosine (C) DNA Pairing. The nitrogen bases have a specific pairing pattern.
- This pairing pattern occurs because the amount of adenine equals the amount of thymine; the amount of guanine equals the amount of cytosine. The pairs are held together by hydrogen bonds.

Detailed Structure and Composition of DNA



- DNA is a double-stranded helix. That is each DNA molecule is comprised of two biopolymer strands coiling around each other to form a double helix structure. These two DNA strands are called polynucleotides, as they are made of simpler monomer units called nucleotides.
- Each strand has a 5′end (with a phosphate group) and a 3′end (with a hydroxyl group).
- The strands are antiparallel, meaning that one strand runs in a 5′to 3′direction, while the other strand runs in a 3′ to 5′ direction.
- The two strands are held together by hydrogen bonds and are complimentary to each other.
- Basically, the DNA is composed of deoxyribonucleotides.
- The deoxyribonucleotides are linked together by 3′ – 5′phosphodiester bonds.
- The nitrogenous bases that compose the deoxyribonucleotides include adenine, cytosine, thymine, and guanine.
- The complimentary of the strands are due to the nature of the nitrogenous bases. The base adenine always interacts with a thymine (A-T) on the opposite strand via two hydrogen bonds and cytosine always interacts with guanine (C-G) via three hydrogen bonds on the opposite strand.
- The shape of the helix is stabilized by hydrogen bonding and hydrophobic interactions between bases.
- The diameter of double helix is 2nm and the double helical structure repeats at an interval of 3.4nm which corresponds to ten base pairs.

Major and Minor Grooves of the DNA

- As a result of the double helical nature of DNA, the molecule has two asymmetric grooves. One groove is smaller than the other.
- This asymmetry is a result of the geometrical configuration of the bonds between the phosphate, sugar, and base groups that forces the base groups to attach at 120-degree angles instead of 180 degree.
- The larger groove is called the major groove, occurs when the backbones are far apart; while the smaller one is called the minor groove, occurs when they are close together.
- Since the major and minor grooves expose the edges of the bases, the grooves can be used to tell the base sequence of a specific DNA molecule.
- The possibility for such recognition is critical, since proteins must be able to recognize specific DNA sequences on which to bind in order for the proper functions of the body and cell to be carried out.

Properties of DNA

- DNA helices can be right-handed or left-handed. But the B – conformation of DNA having the right-handed helices is the most stable.
- On heating the two strands of DNA separate from each other and on cooling these again hybridize.
- The temperature at which the two strands separate completely is known as melting temperature (Tm). Melting temperature is specific for each specific sequence.
- The B sample of DNA having higher melting point must have more C-G content because C-G pair has 3 hydrogen bonds.
- The sequence of bases along the DNA molecule encodes for the sequence of amino acids in every protein in all organisms.

Types of DNA

Eukaryotic organisms such as animals, plants and fungi, store the majority of their DNA inside the cell nucleus and some of their DNA in organelles such as mitochondria.
Based on the location DNA may be:

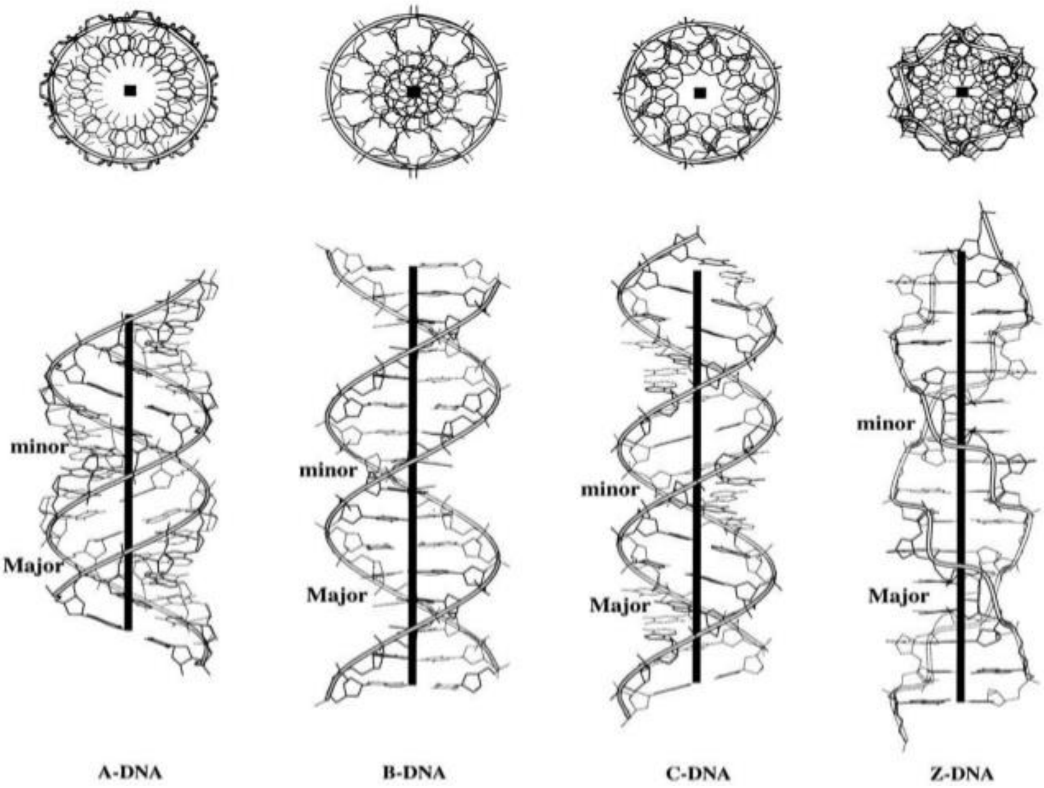
Nuclear DNA

- Located within the nucleus of eukaryote cells.
- Usually has two copies per cell.
- The structure of nuclear DNA chromosomes is linear with open ends and includes 46 chromosomes containing 3 billion nucleotides.
- Nuclear DNA is diploid, ordinarily inheriting the DNA from two parents. The mutation rate for nuclear DNA is less than 0.3%.

Mitochondrial DNA

- Mitochondrial DNA is located in the mitochondria.
- Contains 100-1,000 copies per cell.
- Mitochondrial DNA chromosomes usually have closed, circular structures, and contain for example 16,569 nucleotides in human.
- Mitochondrial DNA is haploid, coming only from the mother.
- The mutation rate for mitochondrial DNA is generally higher than nuclear DNA.

Forms of DNA



- Most of the DNA is in the classic Watson-Crick model simply called as B-DNA or B-form DNA.
- In certain condition, different forms of DNAs are found to be appeared like A-DNA, Z-DNA, B- DNA.
- This deviation in forms is based on their structural diversity.
- **B-DNA**
  Most common, originally deduced from X-ray diffraction of sodium salt of DNA fibres at 92% relative humidity.
- **A-DNA**
  Originally identified by X-ray diffraction of analysis of DNA fibres at 75% relative humidity.

3. **Z-DNA**
   Left-handed double helical structure winds to the left in a zig- zag pattern.

Functions of DNA

DNA has a crucial role as genetic material in most living organisms. It carries genetic information from cell to cell and from generation to generation.
Thus its major functions include:

- Storing genetic information
- Directing protein synthesis
- Determining genetic coding
- Directly responsible for metabolic activities, evolution, heredity, and differentiation.

It is a stable molecule and holds more complex information for longer periods of time.