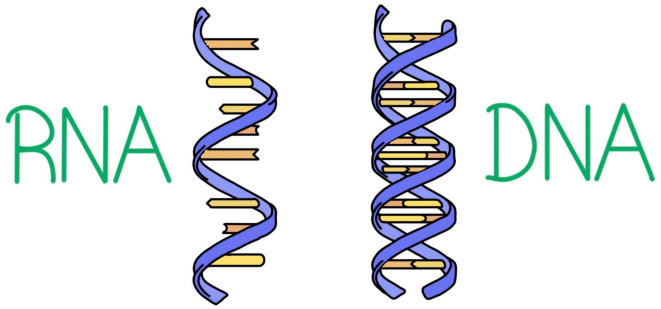


Lecture: DNA and RNA

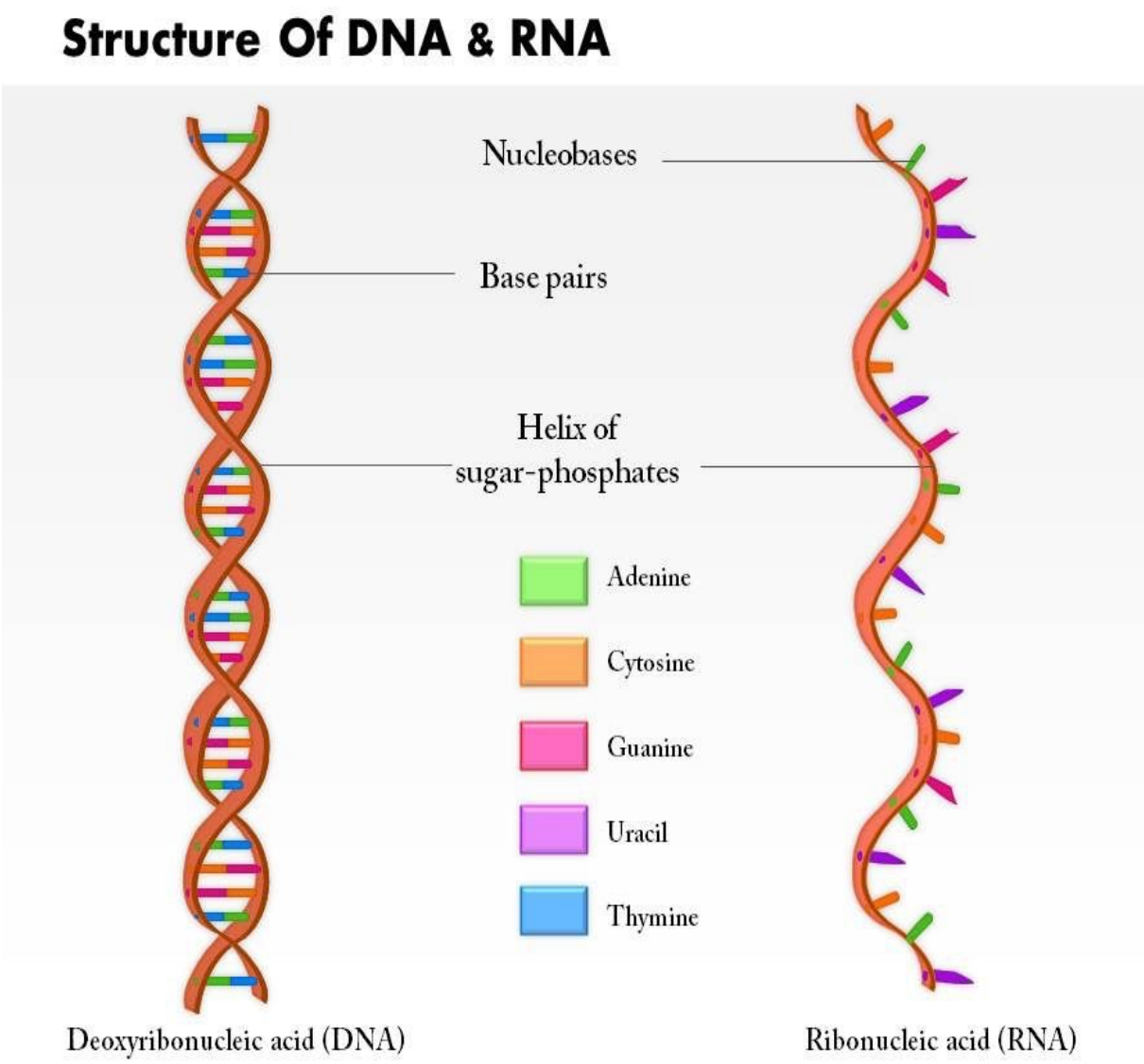
Ref book: Biology for Engineers - Arthur T. Johnson [2nd edition]
Biology for Engineers – G. K. Suraishkumar

Prepared by **Nipa Roy**
Institute of Natural Sciences
United International **University**

Web ref provided on slides
Images: From google image
Further reading:https://www.genome.gov/genetics-glossary/Base-Pair
https://www.sciencedirect.com/topics/nursing-and-health-professions/pentose

Introduction: DNA and RNA

- Genetics mainly deals with the study of genes, heredity, and genetic variation. Genes exist on chromosomes and chromosomes are comprised of DNA and proteins. DNA is a molecule that carries genetic information in all living organisms and viruses where it is used in reproduction, functioning, growth, and development. It is a long polymer of deoxyribonucleotides.
- Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two types of nucleic acids found in living systems. DNA acts as the genetic material in most of the organisms. RNA though it also acts as a genetic material in some viruses, mostly functions as a messenger.



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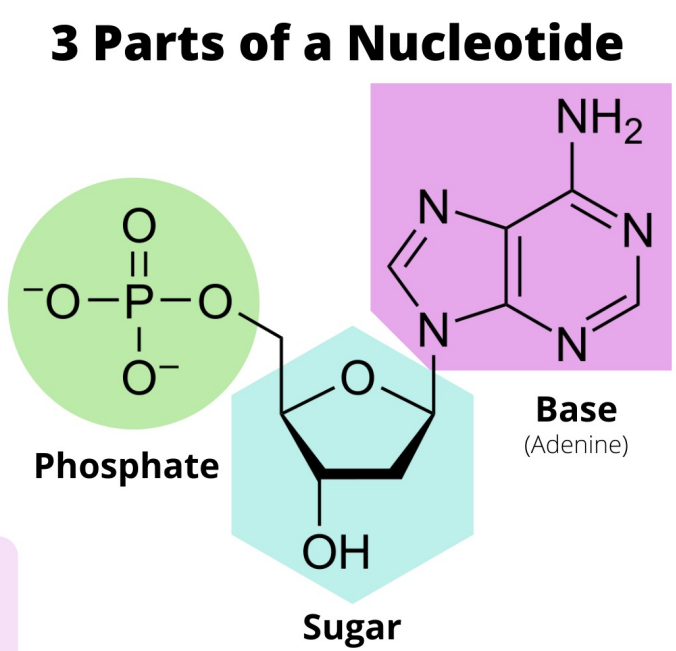
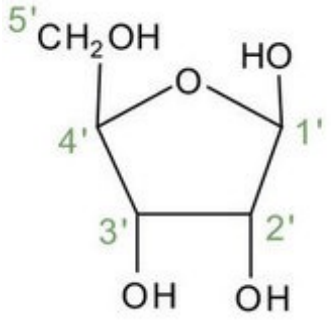
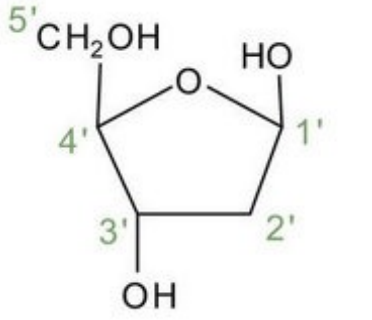
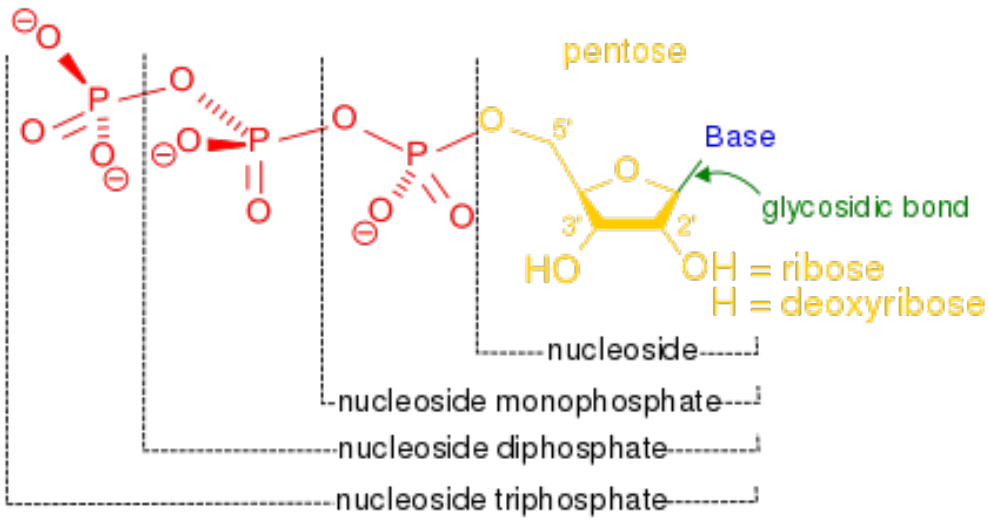
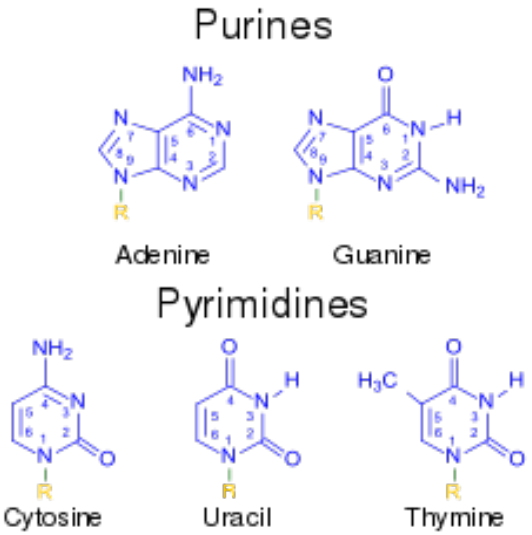
Introduction: DNA and RNA



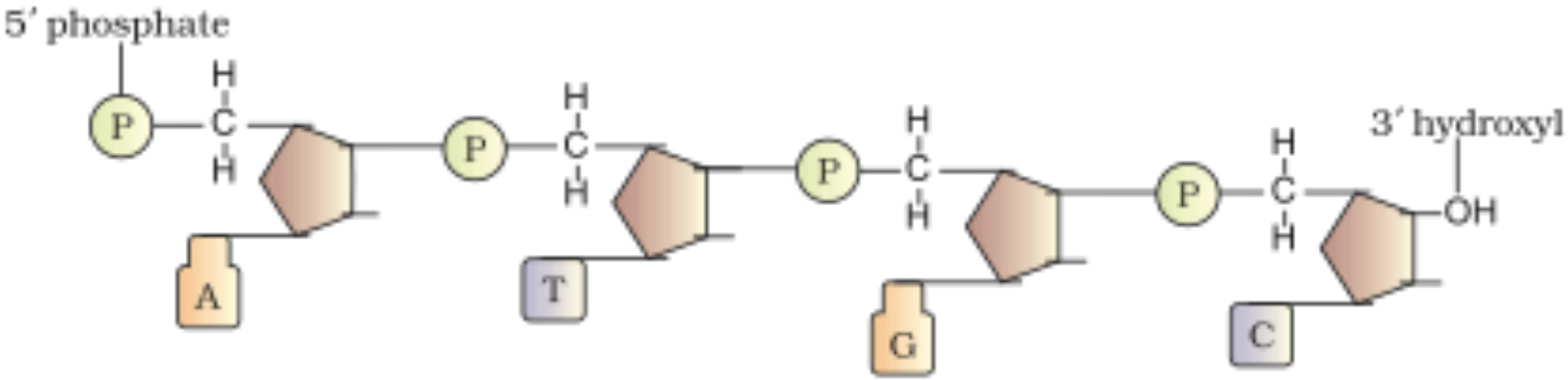








Introduction: DNA and RNA



- A nucleotide has three components – a nitrogenous base, a pentose sugar (ribose in case of RNA, and deoxyribose for DNA), and a phosphate group. There are two types of nitrogenous bases – Purines (Adenine and Guanine), and Pyrimidines (Cytosine, Uracil and Thymine). Cytosine is common for both DNA and RNA and Thymine is present in DNA. Uracil is present in RNA at the place of Thymine.
- A nucleotide combines a nucleobase, a pentosesugar (ribose or deoxyribose), and at least one phosphate group.

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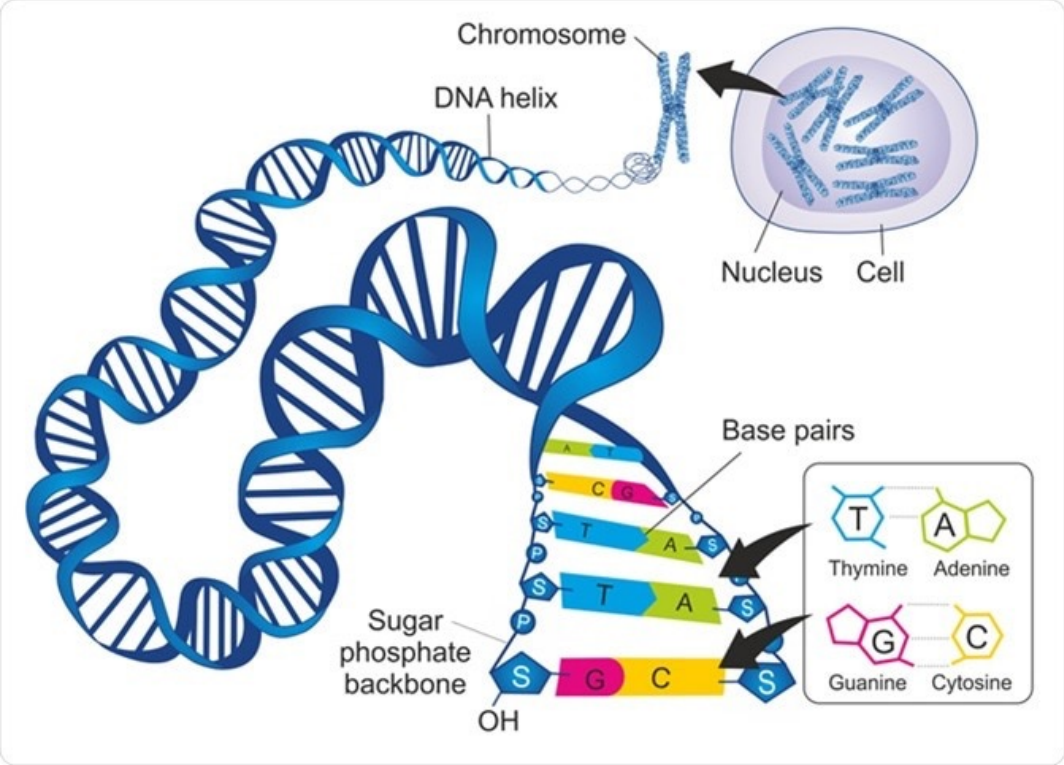
Introduction: DNA

DNA

- DNA is a double-helical structure that carries all the genetic information. Its length is determined by the number of nucleotide pairs present in it. It is an acidic substance in the nucleus identified by Friedrich Meischer. Its double helical structure was given by Watson and Crick.



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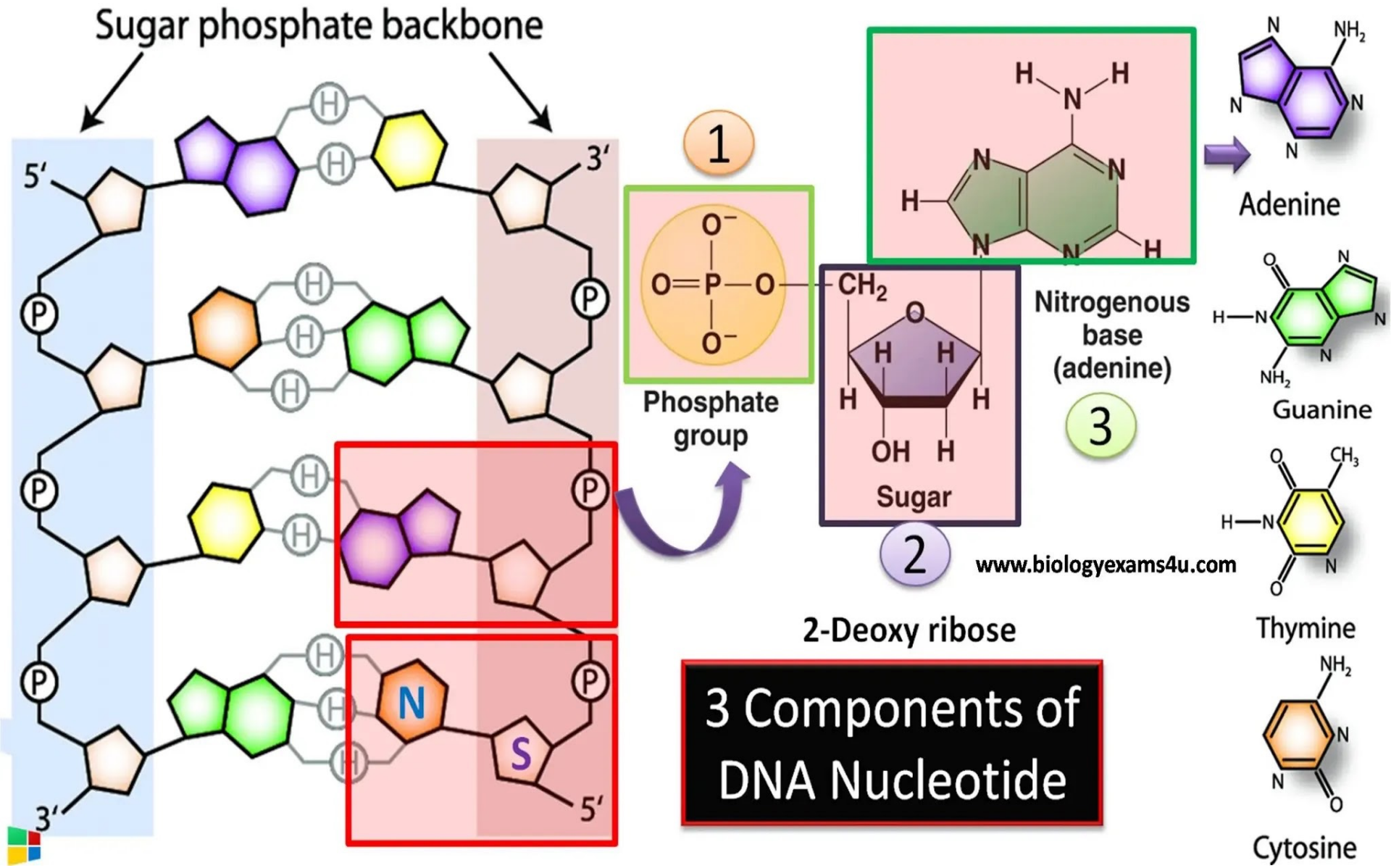
Introduction: DNA



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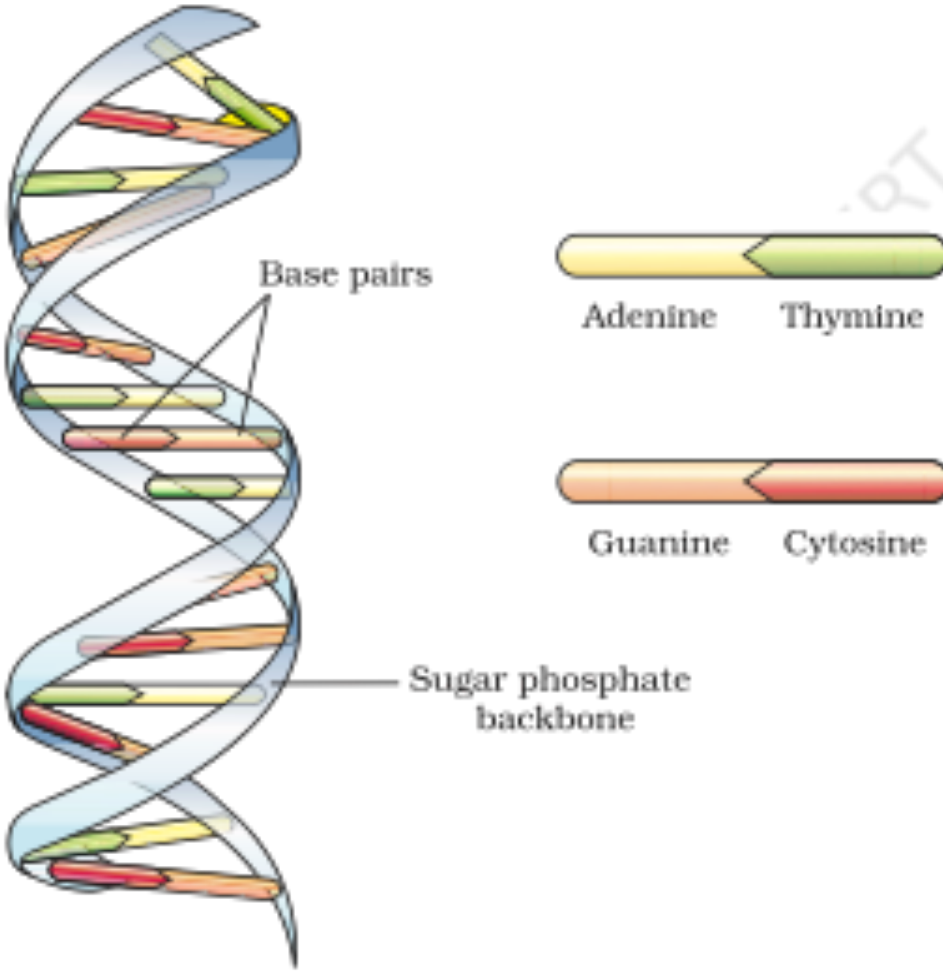
Introduction: DNA

Structure

- DNA is made up of 6 molecular structures that comprise of one phosphate molecule and five carbon sugar termed deoxyribose. A nucleotide is a basic building block of DNA. A nucleotide is comprised of one of the 4 bases, one sugar molecule, and one phosphate molecule. A sugar-phosphate chain act as a backbone and bases are on the inside. Nucleotide subunits are linked together to form a DNA strand thus providing polar stability.
- The three-dimensional structure of DNA arises from chemical and structural features of 2 polynucleotide chain. A purine base pairs up with pyrimidine base. For instance guanine pairs with cytosine. So the two strands that are held together by a hydrogen bond are complementary to each other and they run in the antiparallel direction.



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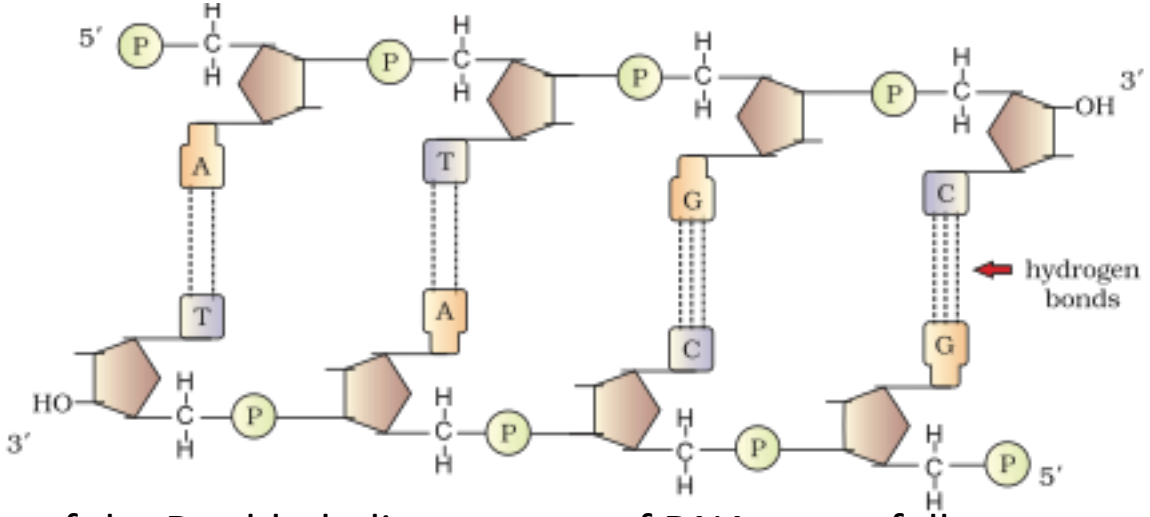
Introduction: DNA



The salient features of the Double-helix structure of DNA are as follows:

- It is made of two polynucleotide chains, where the backbone is constituted by sugar-phosphate, and the bases project inside.
- The two chains have anti-parallel polarity. It means, if one chain has the polarity 5′ *to* 3′, the other has 3′ *to* 5′.
- The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with Thymine from opposite strand and vice-versa. Similarly, Guanine is bonded with Cytosine with three H-bonds. As a result, always a purine comes opposite to a pyrimidine. This generates approximately uniform distance between the two strands of the helix.
- The two chains are coiled in a right-handed fashion. The pitch of the helix is 3.4 nm (a nanometre is one billionth of a metre, that is 10^{-9} m) and there are roughly 10 bp in each turn. Consequently, the distance between a bp in a helix is approximately 0.34 nm.
- The plane of one base pair stacks over the other in double helix. This, in addition to H-bonds, confers stability of the helical structure.

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Introduction: DNA

Central Dogma

- The central dogma was proposed by Crick. The central dogma states that the DNA is converted into RNA and the RNA is converted into proteins. In retroviruses, the flow of information is opposite, i.e., RNA to DNA to mRNA to Protein.

Central dogma

DNA Packaging

- The negatively charged DNA is packaged by surrounding the positively charged histone octamer. A structure called nucleosome is formed. The DNA is packed in chromatin of eukaryotes.

Taken the distance between two consecutive base pairs as 0.34 nm (0.34×10^{-9} m), if the length of DNA double helix in a typical mammalian cell is calculated (simply by multiplying the total number of bp with distance between two consecutive bp, that is, 6.6 × 109 bp × 0.34 × 10-9m/bp), it comes out to be approximately 2.2 metres. A length that is far greater than the dimension of a typical nucleus (approximately 10–6 m). How is such a long polymer packaged in a cell?

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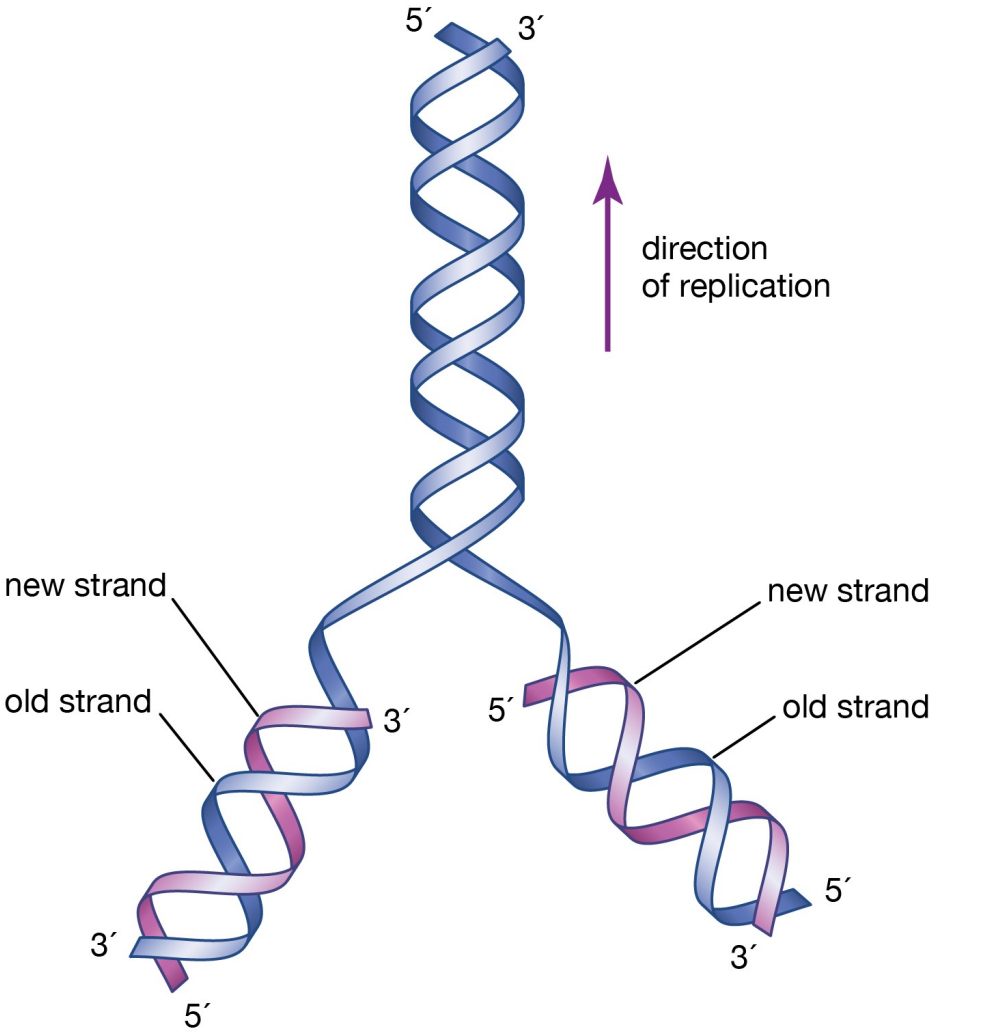
Introduction: DNA

DNA Replication

- DNA is self-replicative. It occurs in the S-phase of the life cycle. It takes only a few minutes in prokaryotes but hours in eukaryotes. DNA undergoes semi-conservative replication, i.e., two strands of DNA are formed. One strand is the same as one of the strands while the other is complementary to the parent strand. The replication occurs in 5′-3′ direction.

Reading: DNA Replication



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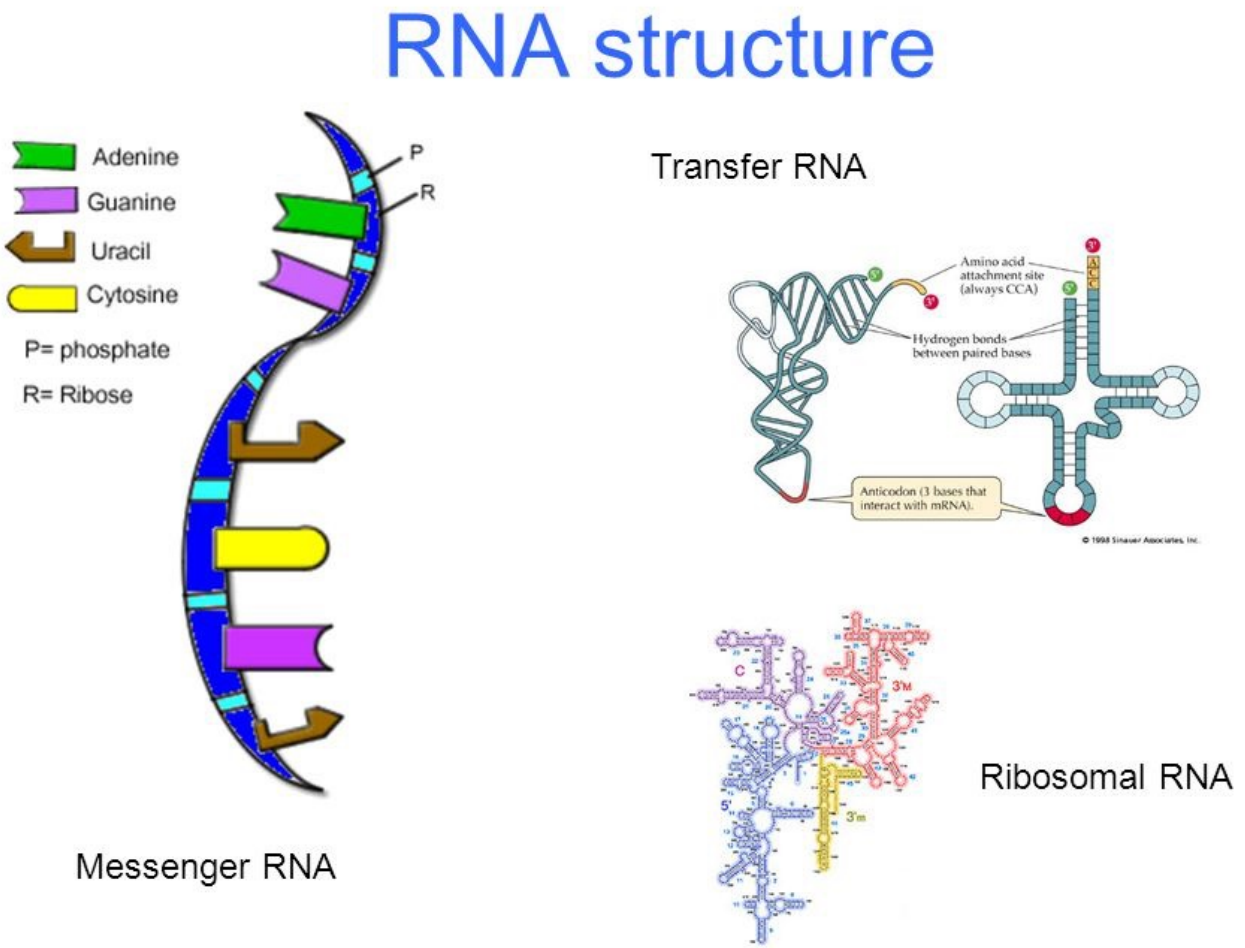
Introduction: RNA

Ribonucleic acid or RNA is a vital molecule with a long chain of nucleotides. It is the first genetic material. A nucleotide chain comprises a phosphate, a ribose sugar, and nitrogenous base. RNA acts as a catalyst and as genetic material. There are two types of RNA, that is genetic and non-genetic.



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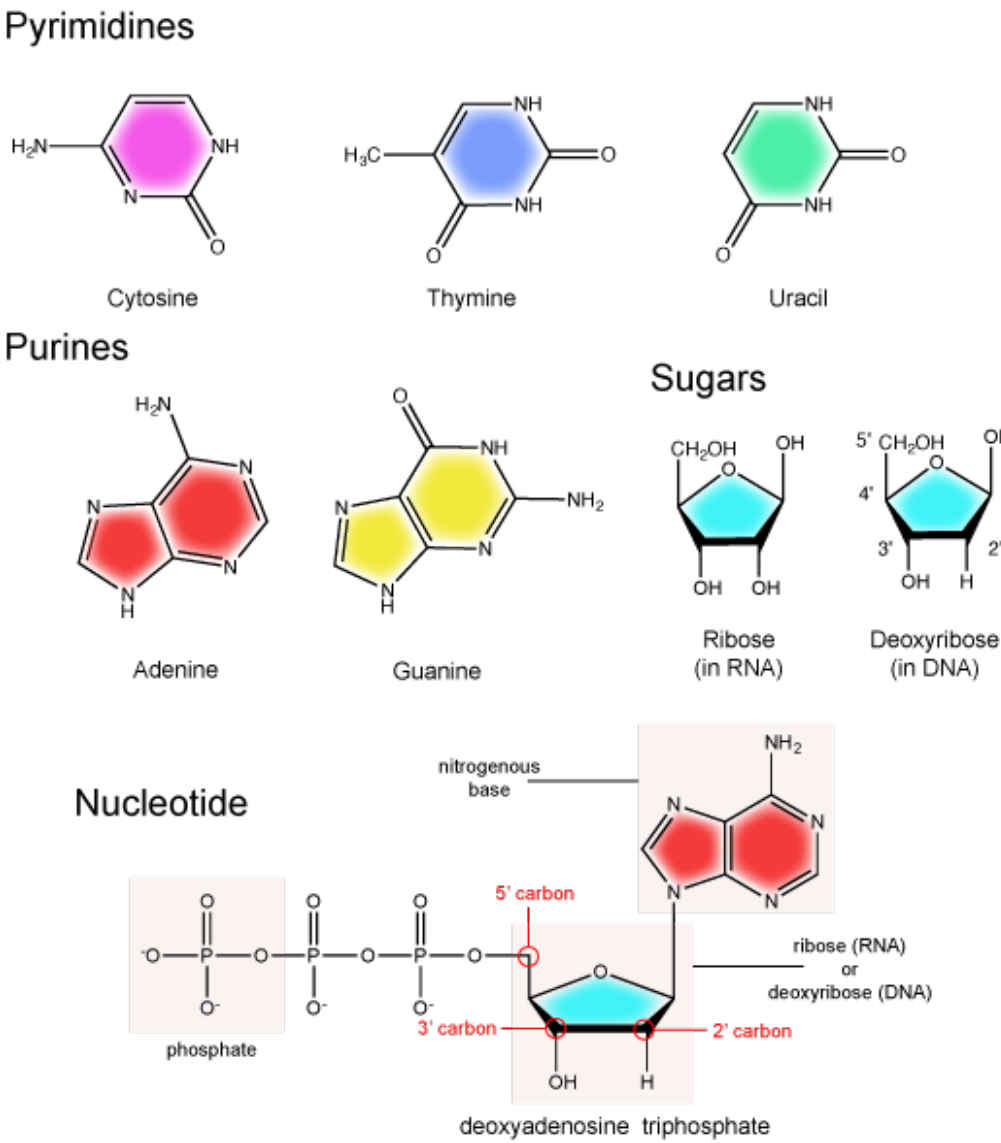
DNA or RNA

A molecule that can act as a genetic material must fulfill the following criteria:

- It should be able to generate its replica (Replication).
- It should be stable chemically and structurally.
- It should provide the scope for slow changes (mutation) that are required for evolution.
- It should be able to express itself in the form of 'Mendelian Characters'.



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DNA or RNA

- If one examines each requirement one by one, because of rule of base pairing and complementarity, both the nucleic acids (DNA and RNA) have the ability to direct their duplications. The other molecules in the living system, such as proteins fail to fulfill first criteria itself.
- DNA chemically is less reactive and structurally more stable when compared to RNA. Therefore, among the two nucleic acids, the DNA is a better genetic material. In fact, the presence of thymine at the place of uracil also confers additional stability to DNA.
- Both DNA and RNA are able to mutate. In fact, RNA being unstable, mutate at a faster rate.
- RNA can directly code for the synthesis of proteins, hence can easily express the characters. DNA, however, is dependent on RNA for synthesis of proteins.
- DNA being more stable is preferred for storage of genetic information. For the transmission of genetic information, RNA is better.

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Introduction: Genetic Code

Genetic Code: DNA

- The genetic code can be defined as a set of rules wherein the information encoded in genetic materials are translated into proteins by living cells. The code defines how codons specify which amino acids will be added next during protein synthesis.
- The frequency of codon is termed as codon usage bias. It varies from species to species in terms of functional implications for the control of translation.
- The genetic code can also be defined as a relationship between the sequence of amino acids in a nucleotide chain of mRNA or DNA and amino acid in a polypeptide chain.

First position	Second position: U	Second position: C	Second position: A	Second position: G	Third position
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

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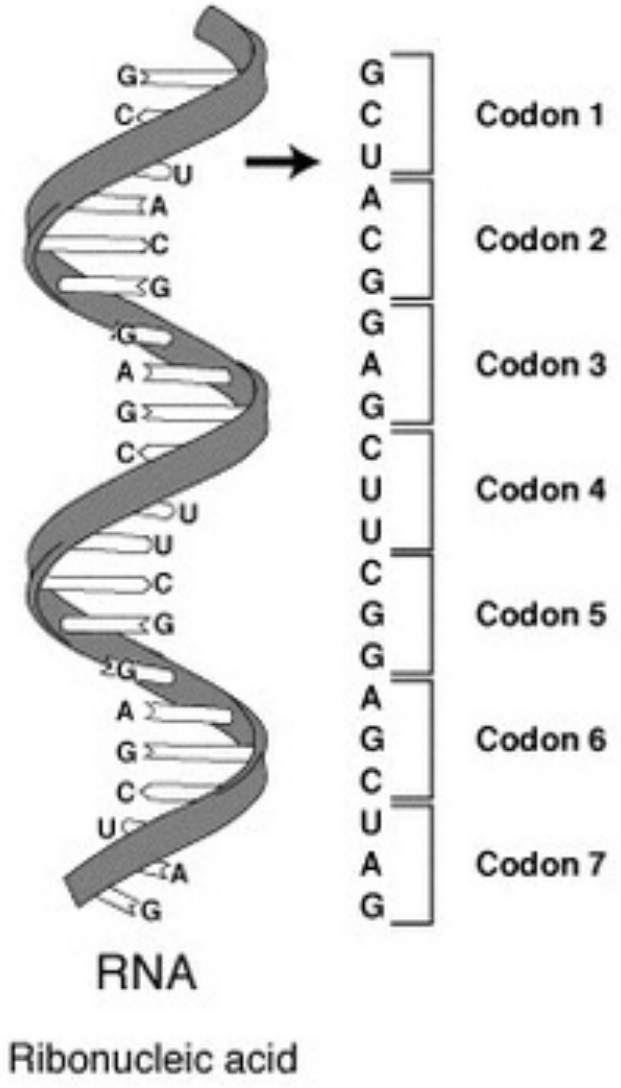
Genetic Code

Nearly **twenty** types of amino acids participate in protein synthesis. **Sixty-one** codons out of sixty-four codons **code only for amino acids**. The characteristics of the genetic code are stated below:

- Degeneracy of genetic code.
- Non-overlapping.
- Universality.
- Triplet in nature.
- Comma-less.
- Non-ambiguous.



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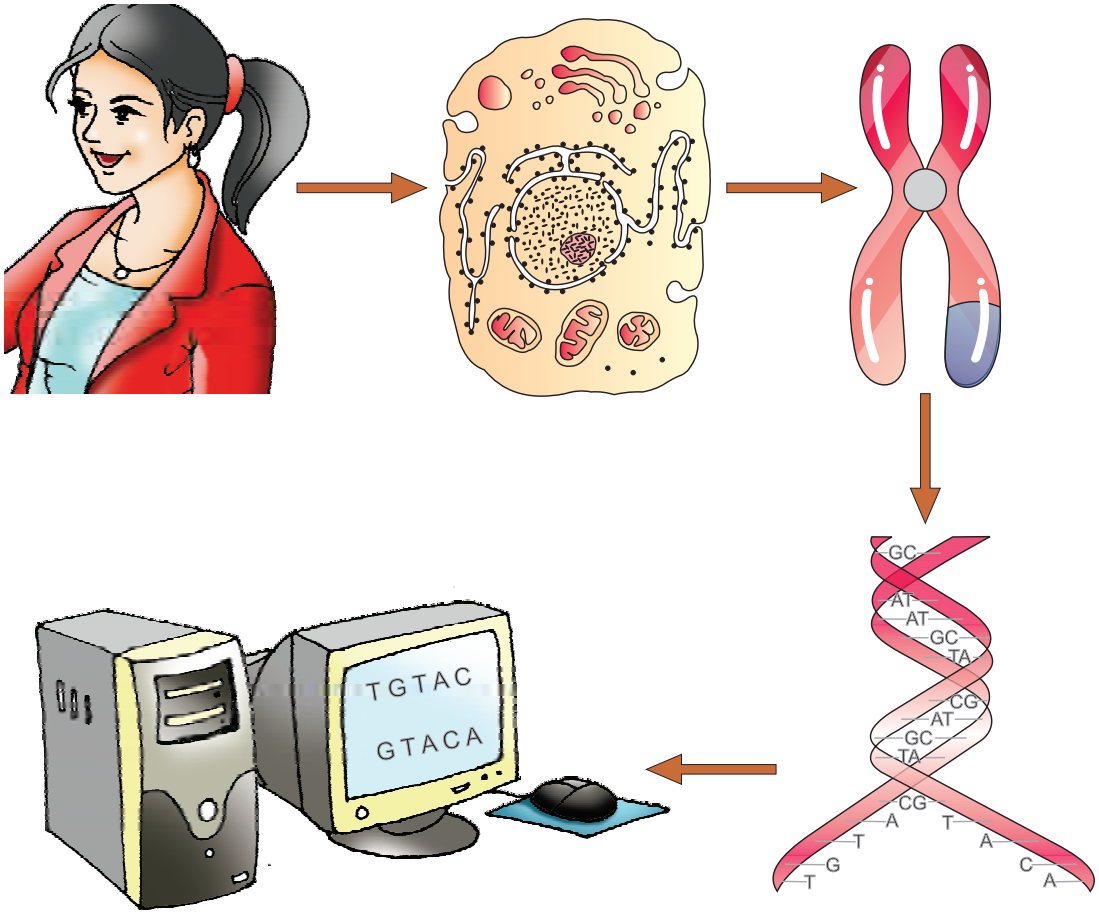
Introduction: Human Genome Project

- The human genome project was launched to sequence the entire human genome of 2.75 billion base pairs. The main goals of the human genome project are:
- To provide a complete sequence of 3 billion base pairs that make up the human genome.
- To sequence the genome of other organisms that are used in medical research. For eg, mouse, flies, etc.
- To develop new tools to obtain and analyse the data and to make this data widely available.
- It holds prospects for healthier living, a database of knowledge about designer drugs, genetically modified diets, and genetic identity.



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Human Genome Project

Some of the important goals of HGP were as follows:

(i) Identifyalltheapproximately20,000-25,000genesinhumanDNA;

(ii) Determinethesequencesofthe3billionchemical basepairsthat make up human DNA;

(iiii) Store this information in databases;

(iv) Improve tools for data analysis;

(v) Transfer related technologies to other sectors, such as industries;

(vi) Address the ethical, legal, and social issues (ELSI) that may arise from the project.

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