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Introduction to Nucleic Acid

- Nucleic acids are long chain polymers of Nucleotides present in nuclei of cell,so they are also called as polynucleotide.whereas nucleic acid like proteins,the repeating unit is α-Amino acid.
- Nucleic acids occur in all living cells as a major component of the nucleus.
- Nucleic acids are generally associated with proteins to form Nucleoproteins.
- Nucleic acids are colourless complex compounds which are made up of three units : Bases (Purine or Pyrimidine),Sugar and Phosphoric acid.
- These are obtained by the careful hydrolysis of nucleoproteins.

Classification of Nucleic Acids

- Two types of nucleic acids have been known for a long time,

1. Deoxyribonucleic acid (DNA).
2. Ribonucleic acid (RNA).

- DNA is found predominantly in the Nucleus while RNA is predominant in the Cytoplasm.

- DNA also synthesizes RNA, and RNA in turn is responsible for the synthesis of Proteins.

Structure of Nucleosides:

- Nucleosides are the condensation products of a Sugar and a Base.
- These are obtained by hydrolysis of nucleotides (or nucleic acids)with aqueous ammonia at 175°C.
- The nucleosides on further hydrolysis with inorganic acids yields sugar and bases.
- Therefore to know the structure of nucleosides,we must know the structures of the various bases and sugars present in the nucleosides.

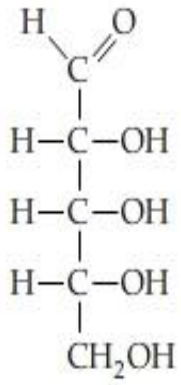
- **Sugars**:

- In the hydrolysates of nucleic acids,only two sugars have been isolated.

- Both are pentoses,D(-)-ribose and 2-deoxyD(-)ribose.

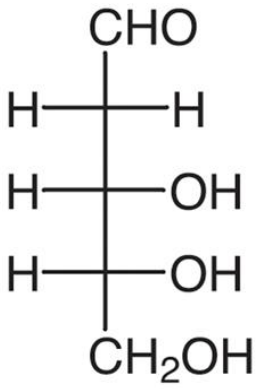
- The ribose is Present only in the ribonucleic acids (RNA) while deoxyribose is present only in the deoxyribonucleic acids (DNA).

- The open-chain and cyclic structures of these sugars may be represented as follows:

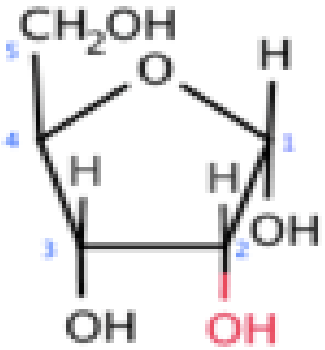


D-ribose

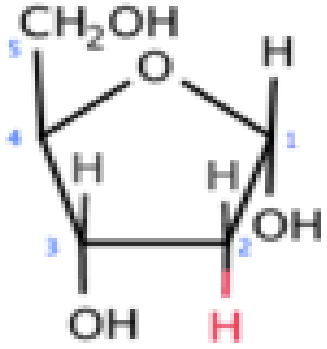
Open chain structure of D(-)-ribose



Open chain structure of 2-deoxy-D(-)-ribose



Ribose



Deoxyribose

Ring structure of D(-)-ribose and Ring structure of 2-deoxy-D(-)-ribose

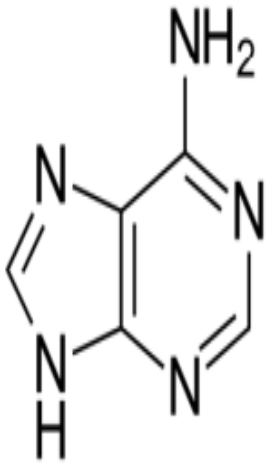
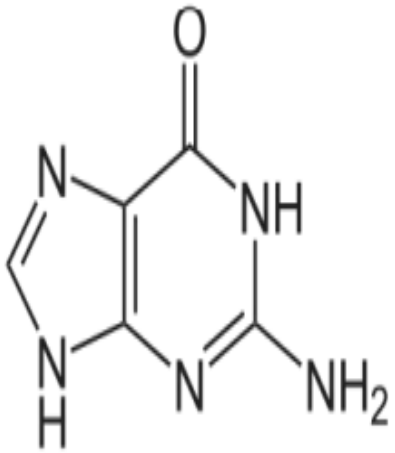
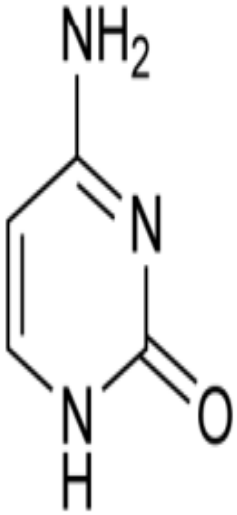
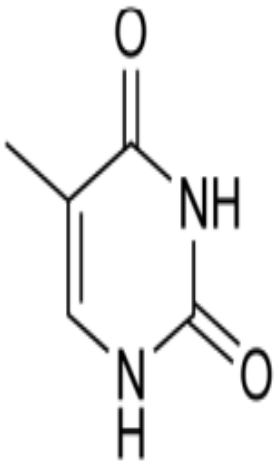
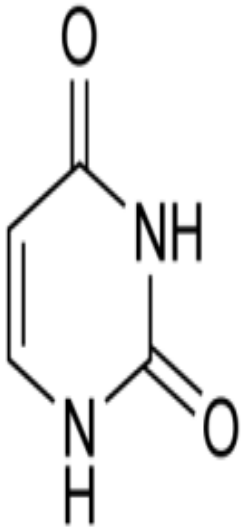
- **Bases**:

➢ In the hydrolysates of nucleic acids,two types of bases have been isolated :

- Purines
- Pyrimidines

➢ The most common purine bases are Adenine & Guanine. Many other purines like, 1-, 2-, 3-methyladenine, 3-methylguanine etc., have been isolated.

➢ The most common pyrimidine bases are Uracil,Thymine and Cytosine.Other pyrimidine like 5-methylcytosine can be isolated.

Purines		Pyrimidines		
Adenine	Guanine	Cytosine	Thymine	Uracil
				

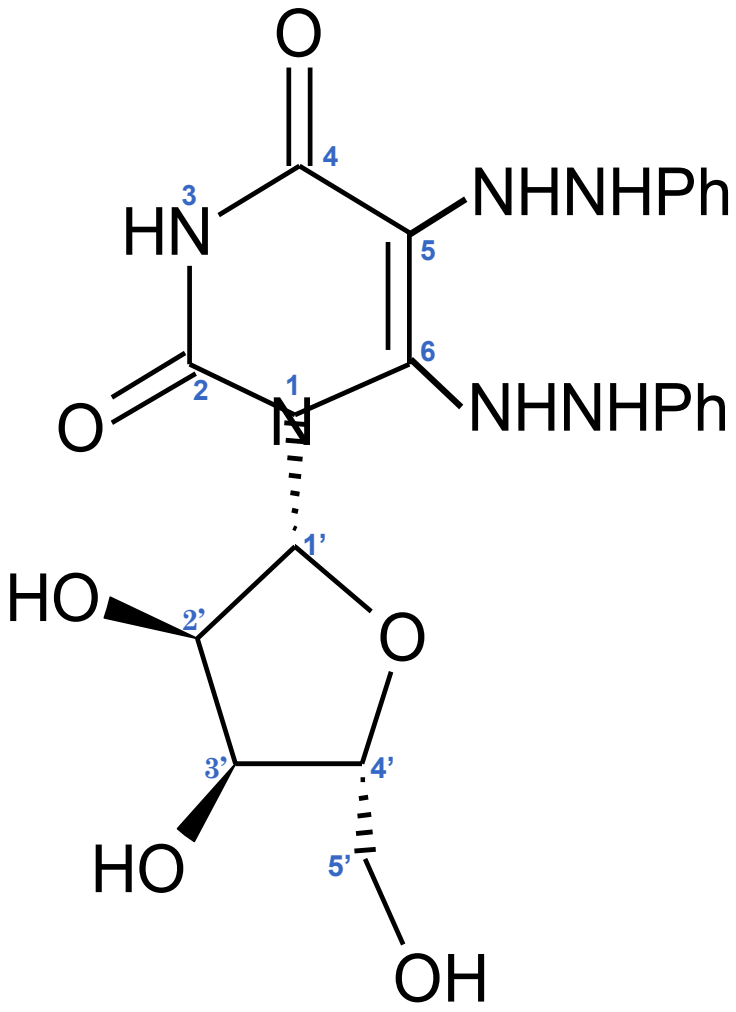
Nucleosides containing pyrimidine bases:

- Consider Nucleosides containing pyrimidine bases.Eg:Cytidine,to determine the point of linkages between sugar and base.

- Cytidine when treated with nitrous acid is converted into Uridine (-NH_2 in cytidine + HNO_2 $\longrightarrow$ -OH in uridine).

- Uridin,when treated with an excess of bromine,followed by addition of phenylhydrazine,is converted into a Uridine derivative which contains two Phenyl- hydrazine groups. This Uridine derivative was given in Structure (I).

- Thus the compound (I) could be only obtained if uracil is substituted in position 1 & position's 5 & 6 are free.Thus, the sugar is attached to N-1.

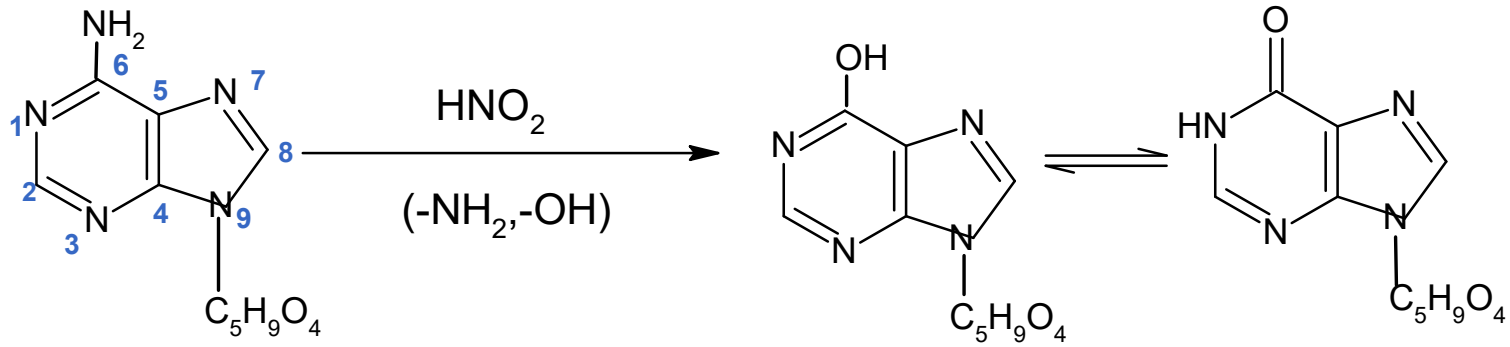


Structure(I)
Uridine derivative

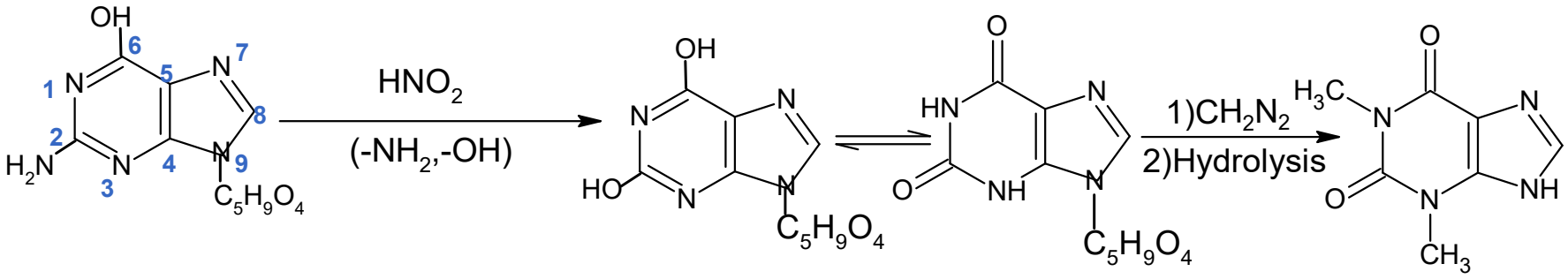
Nucleosides containing purine bases :

- Now consider nucleosides containing purine bases, eg:Adenine and Guanine.
- As Adenosine has a free amino-group at position 6,it means that Sugar cannot be present at C-6 or N-1.
- Further,Guanosine possesses a free amino-group at position 2.Therefore the sugar cannot be present at C-2 or N-3.
- It was found by *Levene* that adenosine & guanosine are equally readily hydrolysed by dilute acids and by the same enzyme.
- This reveals that the sugar residue is linked at the same place in both nucleosides.

- Only two positions 7 or 9 are free.This has been supported by the following evidence:



Adenosine **Inosine**



Guanosine **Xanthosine** **Theophylline**

- The formation of the latter compound reveals that the sugar must be attached at position 7 or 9

- The above evidence does not make a decision between the Position 7 or 9 because the system is tautomeric.

- However,this position has been found to be 9 on the basis of the ultraviolet absorption spectrum.

Sequence of Nucleic acids:

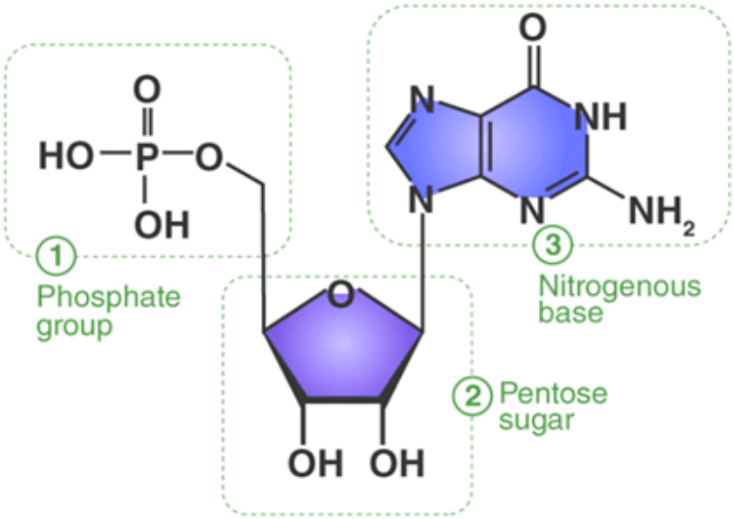
- Nucleic acids are polynucleotides,i.e.,polymeric structures in which repeating units are either Ribonucleotides Or Deoxyribonucleotides.

- The difference between the 2 structures is that in ribonucleotides there is an -OH group in position-2'.

- Depending upon the repeating units, there are 2 types of nucleic acids;

- RNA : In RNA, the repeating units are Ribonucleotides.
- DNA : In DNA, the repeating units are Deoxyribonucleotides.

- Structure of Nucleotide is as follows,

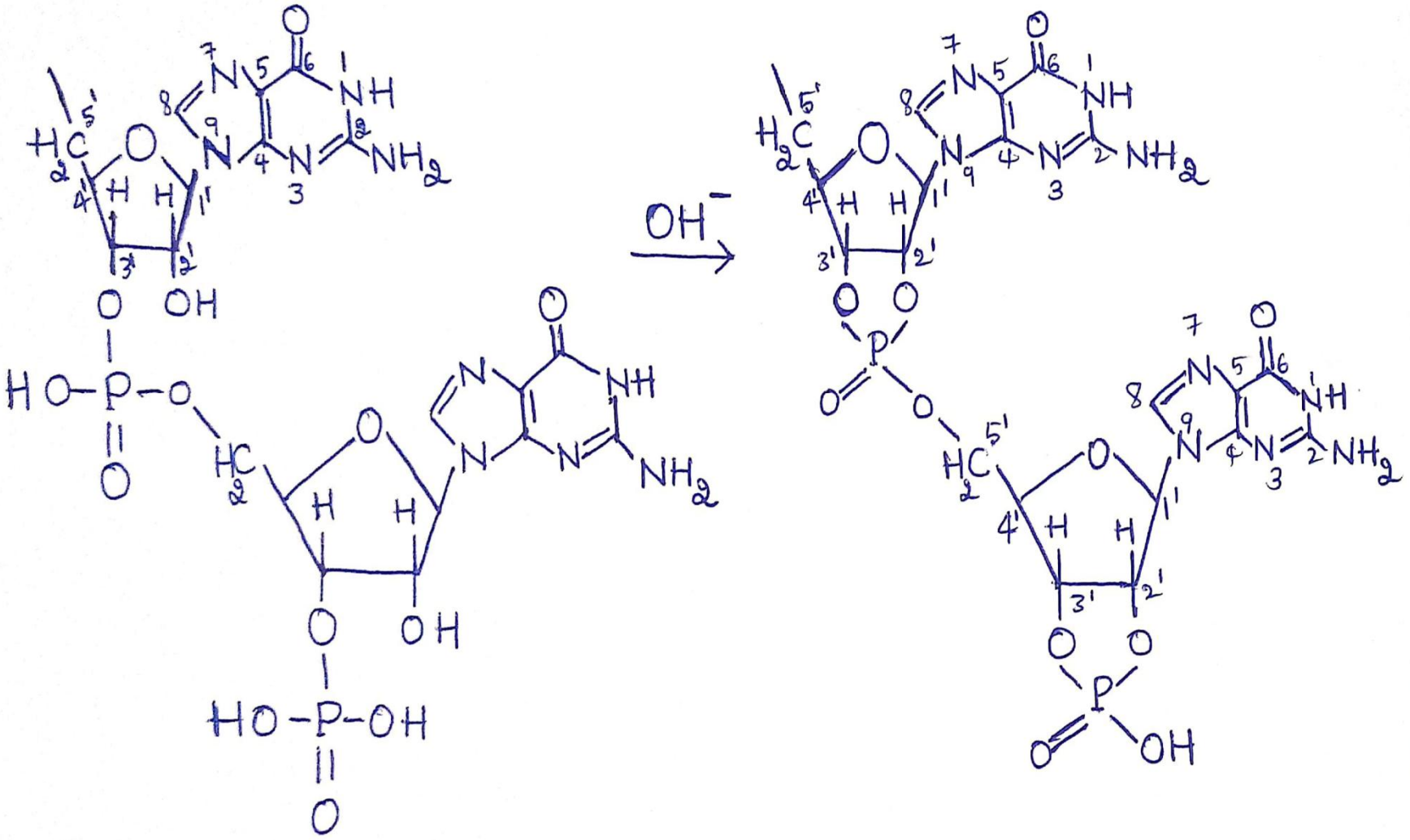


- Thus, the nucleotides are connected by pentose phosphate bond.

- **Internucleotide Bond in RNA**:

- when hydrolysed with dilute alkalis, RNA yields a mixture of 2' and 3'-phosphoesters.

- It is already described that alkalis cause cyclisation of the Phosphoesters in nucleotides; in RNA cyclisation precedes hydrolysis as shown below:

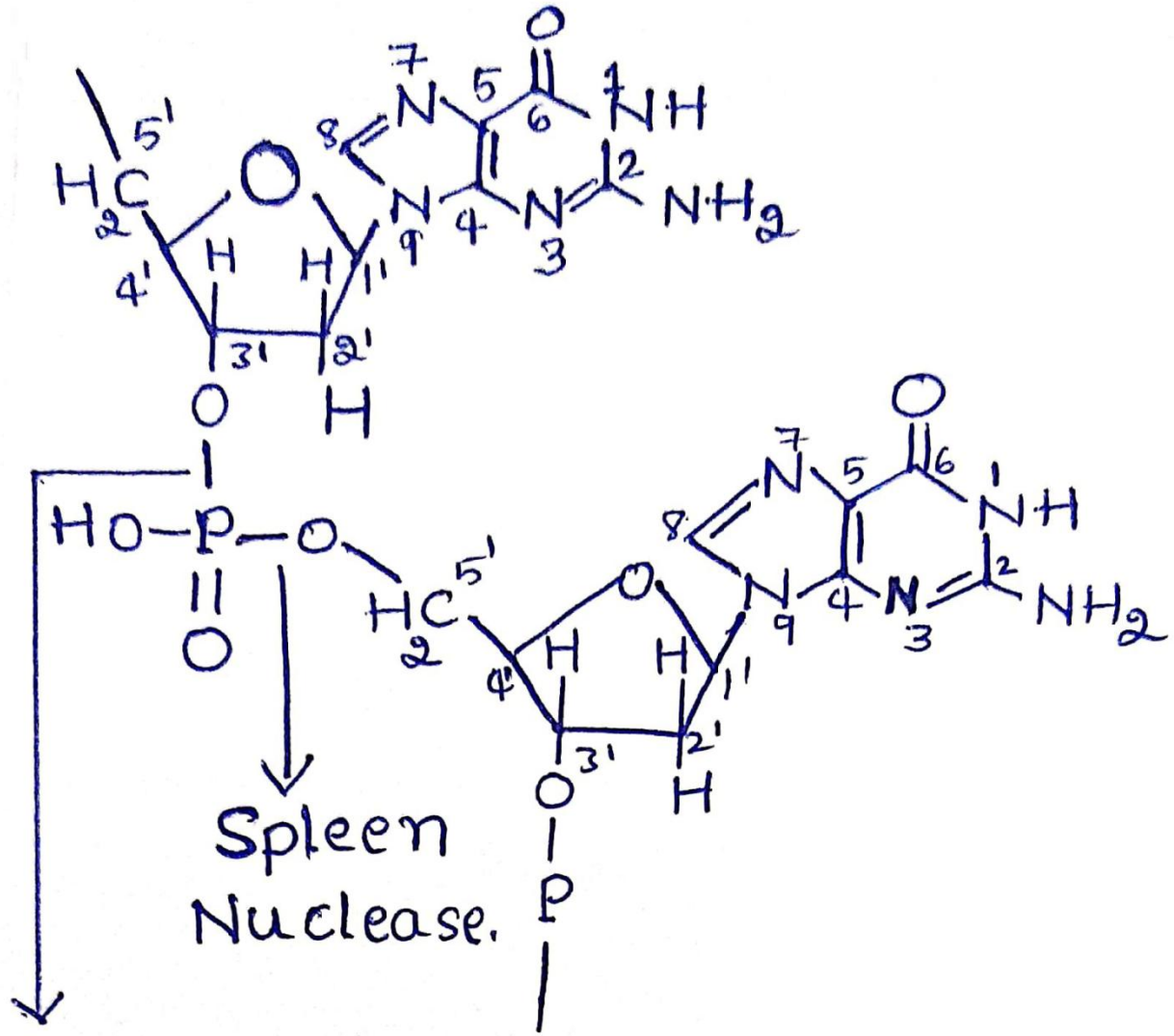

OH⁻

- **Internucleotide Bond in DNA :**

- Deoxyribonucleotides do not contain any -OH group in position 2', they are not able to form cyclic phosphoesters. So that the DNA is stable to the action of dilute alkalis.

- Hydrolysis by specific enzymes which should yield predictable results.Fortunately, two nucleases have been found, one in Pancreas & the other in Spleen.Both of these catalyse specifically the cleavage of one or the other phosphoester bonds.

- When Pancreatic nuclease attacks DNA, the products obtained are mainly 5'-phosphoesters;when spleen nuclease attacks DNA, the products are mainly 3'-phosphoesters. This can only happen if the ester bond between Deoxyribonucleotides in DNA is 3'-5'.

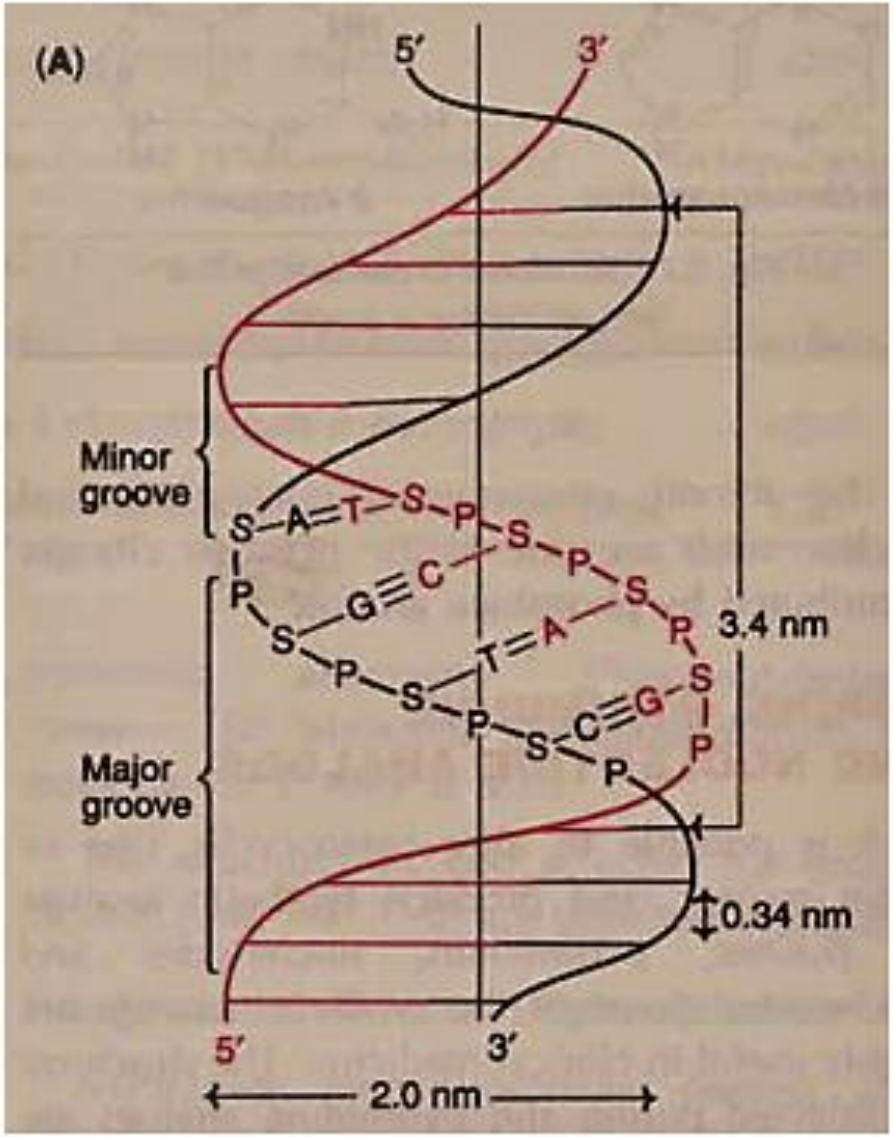

Spleen
Nuclease.
Pancreatic
Nuclease.

Structure of DNA

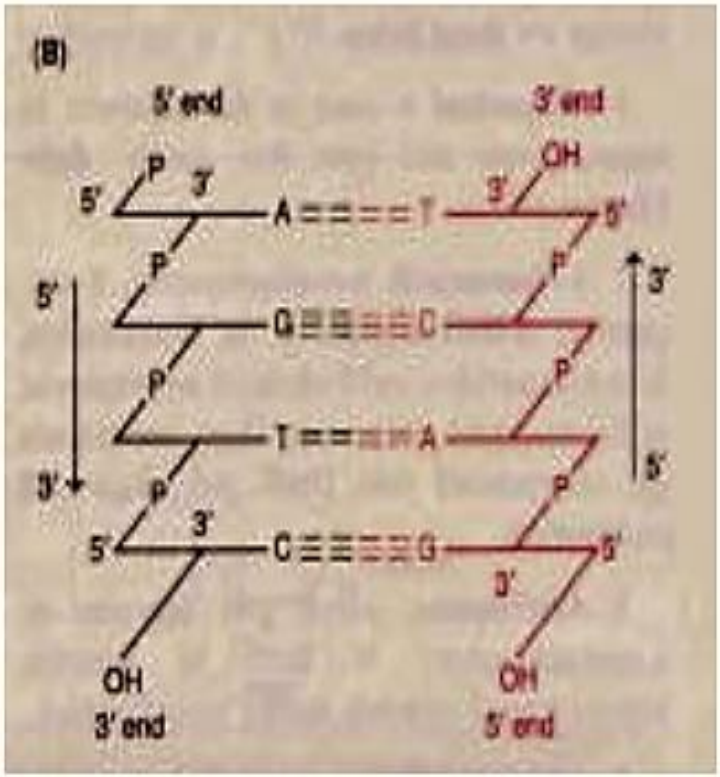
- DNA is composed of two polynucleotide chains that are coiled around each other to form a structure called **Double Helix.**

- In order to explain how a DNA molecule can replicate, **Watson and Crick** first constructed a model to represent the macromolecular shape of DNA.

- They proposed the 3-D model of physiological DNA.



A) Watson-Crick model of DNA helix



B) Complementary base pairing in DNA helix

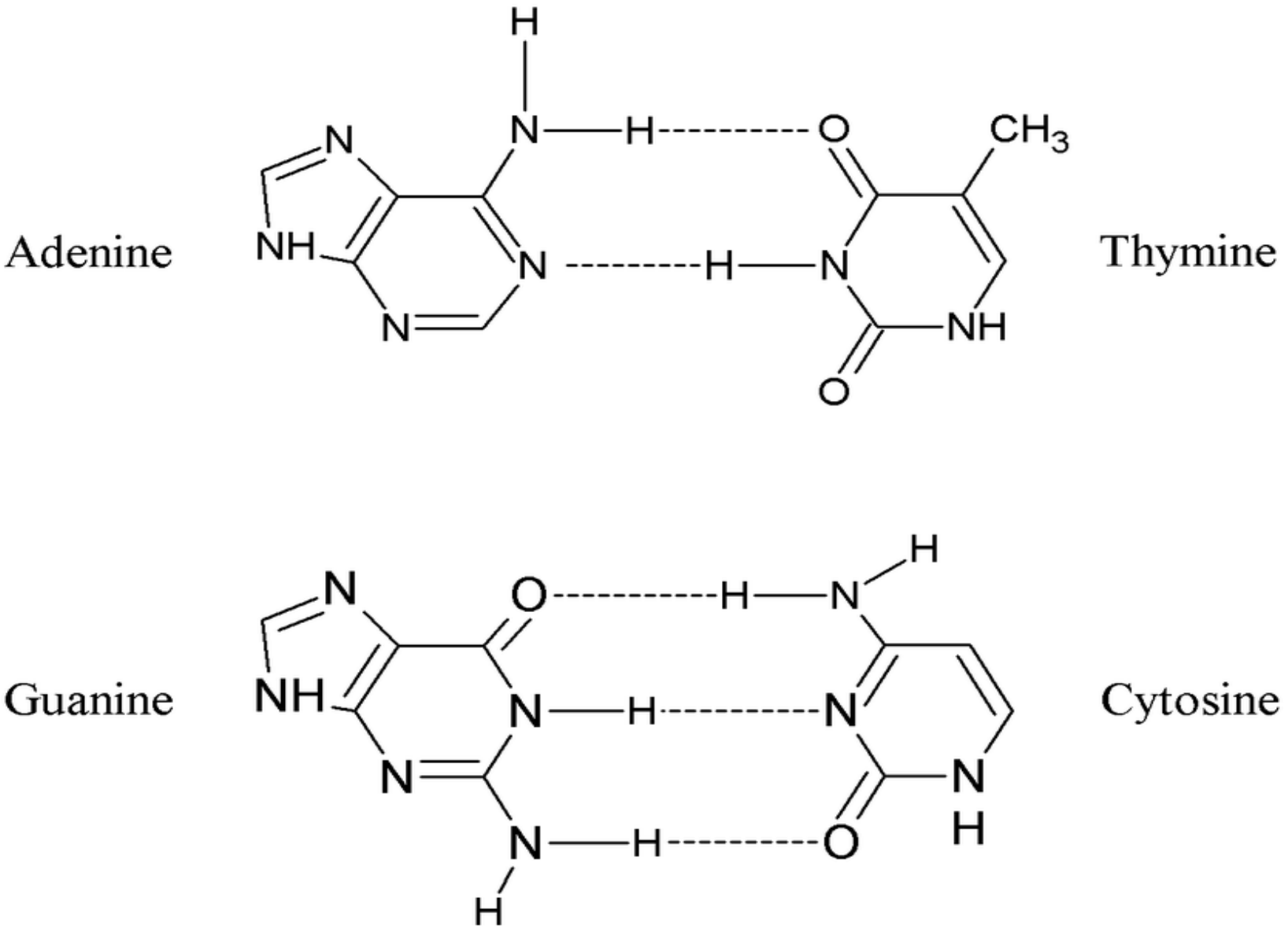


Fig : Thymine pairs with Adenine by 2 hydrogen bond , Cytosine pairs with Guanine by 3 hydrogen bond

Structure of RNA:

- It is also a polynucleotide but the pentose ribose has a free hydroxyl group in position 2'.
- It is a long-chain polynucleotide which does not exist in a regular conformation like a double-chain DNA although some viruses have double standed RNA.
- In regions where purine-pyrimidine pairing takes place, Adenine pairs with Uracil and Guanine with Cytosine.All normal RNA chains either start with Adenine or Guanine.

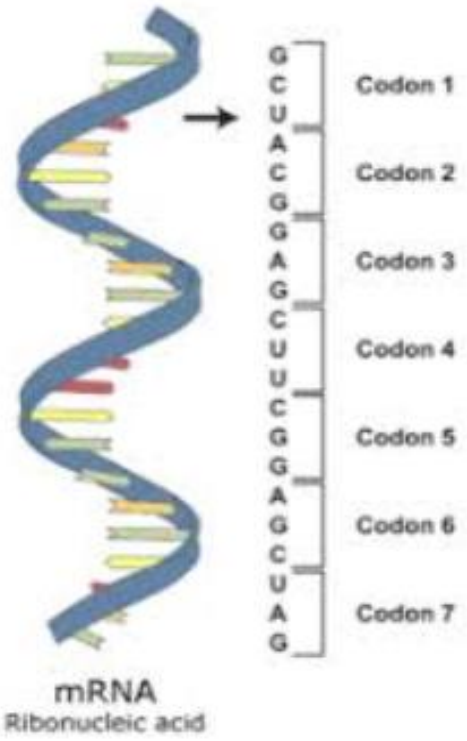
Types of RNA, There are three distinct RNA species :

1. Messenger RNA (mRNA) or template RNA : (5-10%):

- mRNA is always Single stranded.It contains the bases,no base pairing takes place.

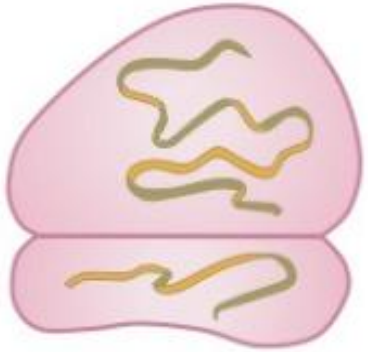
- Functions as a carrier of genetic information from the DNA in the cell nucleus to the site of protein synthesis in the cytoplasm.

- mRNA has a short lifetime (usually less than 1 hour); it is synthesized as it is needed, then rapidly degraded to the constituent nucleotides.



2. Ribosomal RNA (rRNA) : (80-85%) :

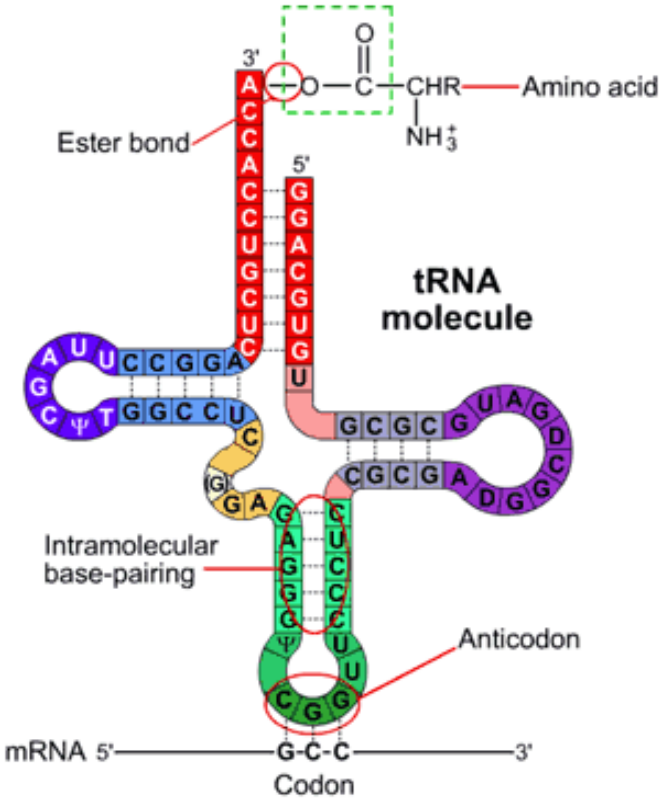
- RNA of ribosome is called r-RNA.
- The main component of ribosomes that are the site of protein synthesis.
- rRNA accounts for 80-85% of the total RNA of the cell.
- rRNA accounts for 65% of a ribosome's structure (the remaining 35% is protein).



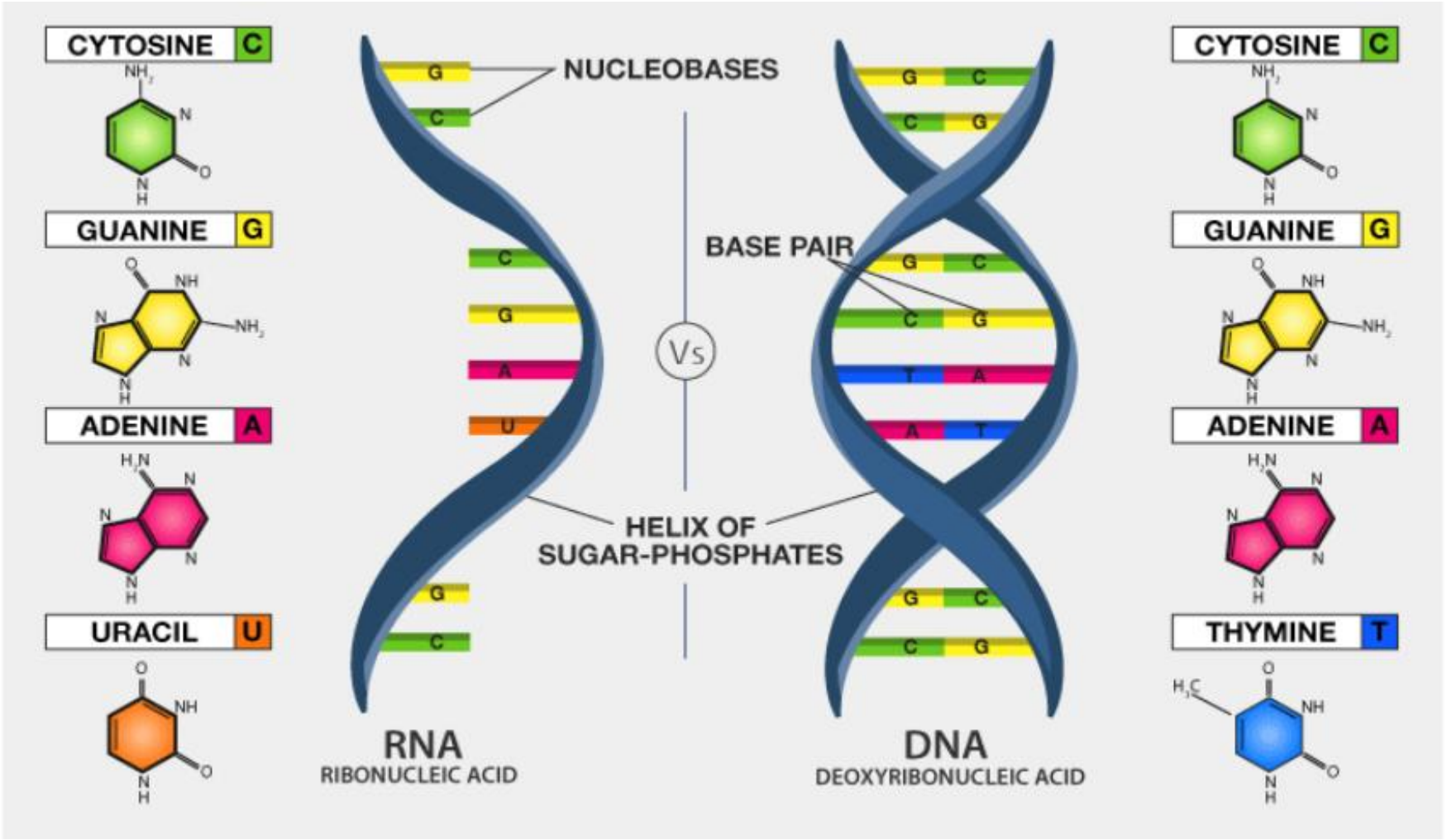
Ribosomal RNA (rRNA)

3.Soluble RNA (sRNA) or **Transfer RNA (tRNA)** : (10-20%):

- Delivers individual amino acids to the site of protein synthesis.
- tRNA is specific to one type of amino acid; cells contain at least one specific type of tRNA for each of the 20 common amino acids.
- tRNA is the smallest of the nucleic acids, with 73-93 nucleotides per chain.



Differences Between DNA and RNA



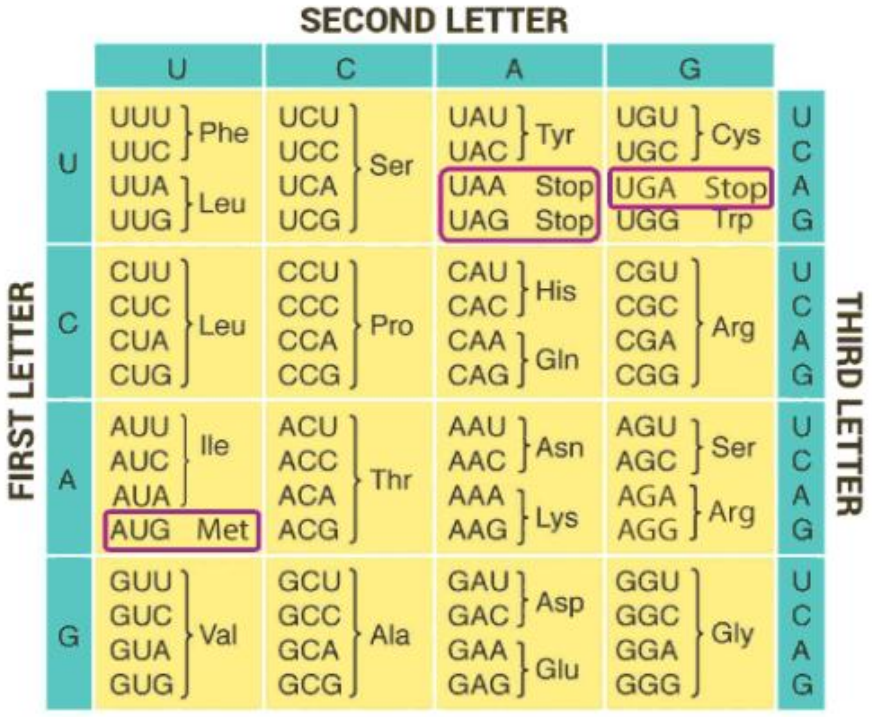
Genetic code

- The genetic code can be defined as the set of certain rules using which the living cells translate the information encoded within genetic material (DNA or RNA sequences) OR The collection of codon is called **Genetic code.**

- A **codon** is a sequence of three nucleotides which together form a unit of genetic code in a DNA or RNA molecule.

Genetic code table

- The complete set of relationships among **amino acids** and **codons** is said to be a genetic code which is often summarized in a table.
- There are 64 possible codons,3 of which do not code for Amino acid but indicate end of protein,the remaining 61 codon specify 20 Amino acids for specific codon.



Genetic Code-salient features:

- Genetic code is Triplet in nature.
- Genetic code is Non-overlapping.
- Genetic code is Commaless.
- Genetic code is Degenerate.
- Genetic code is Universal.

Conclusion

While studying Nucleic Acids we come to know that,they are the most essential part of all living beings and nucleotides act as the building block of both the DNA and the RNA.

A nucleotide is formed by a nitrogenous base,a pentose sugar,and a phosphate group.

A Nucleic acid sequence indicates the order of nucleotide forming alleles within a DNA(using GATC) or RNA(GAUC) molecule.

And we studied about the structure of DNA with the help of Watson and Crick model and also the structure of RNA with their classifications,also we discussed about Genetic code and their salient features.

References

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- Organic chemistry–Natural products, O.P. Agarwal, Vol. I, GOEL Publishing House,Meerut,India,2003.

Thank You