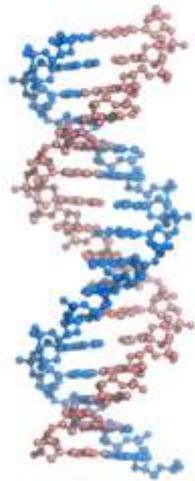


THE NUCLEIC ACIDS



MOOHAMMAD SHAHRUKH
M.Sc. Medical Biochemistry
(Ph.D. Scholar)

HISTORY

Friedrich Miescher in 1869

- Isolated what he called **nuclein** from the nuclei of pus cells
- Nuclein was shown to have acidic properties, hence it became called **nucleic acid**



TYPES OF NUCLEIC ACID

Two types of nucleic acid are found

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

The distribution of nucleic acids in the eukaryotic cell

- DNA is found in the nucleus
 - with small amounts in mitochondria and chloroplasts
- RNA is found throughout the cell

NUCLEIC ACID STRUCTURE

- Nucleic acids are **polynucleotides**
- Their building blocks are **nucleotides.**
- Nucleotides are **phosphate esters of nucleosides**

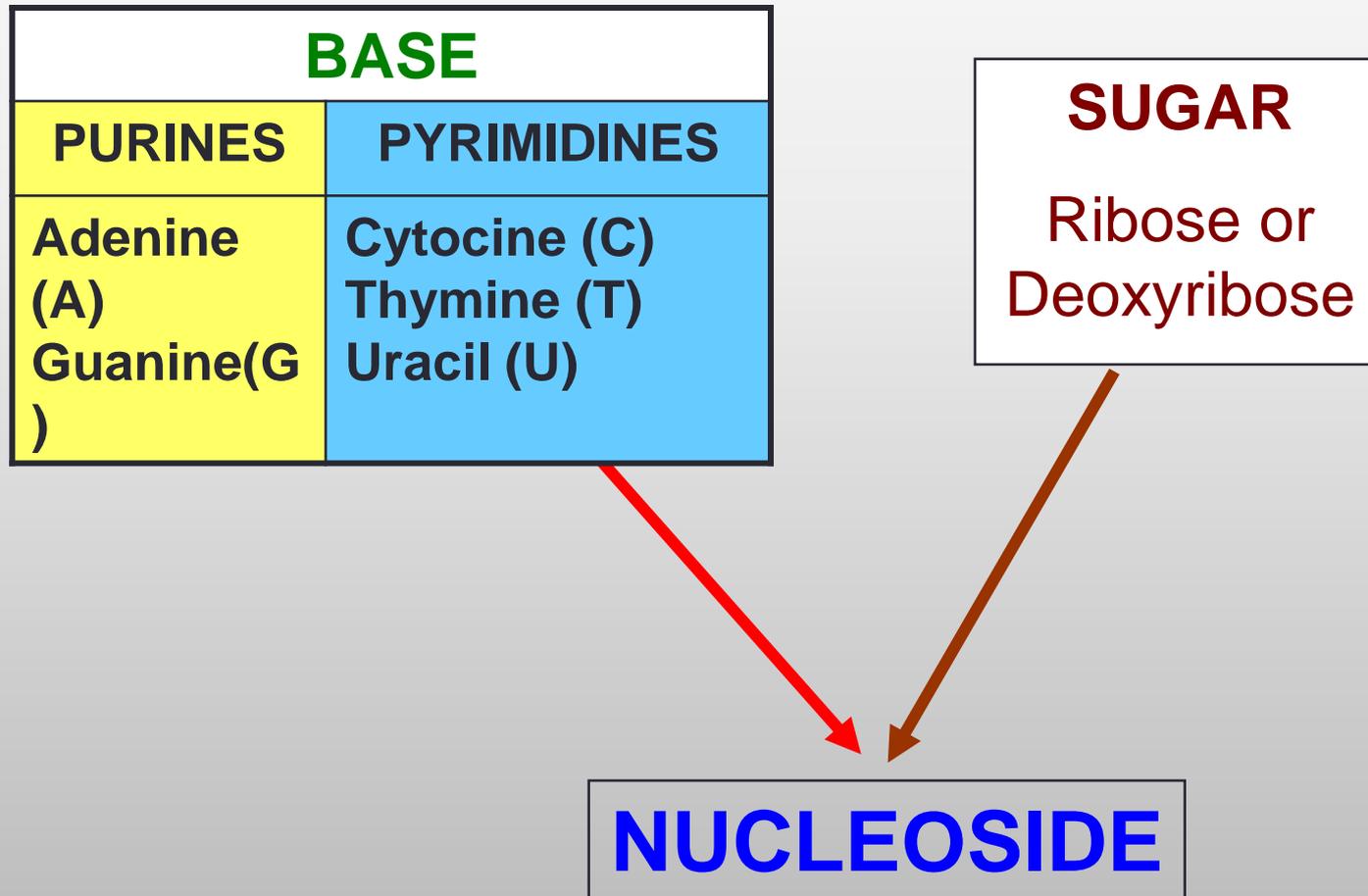
FUNCTIONS OF NUCLEIC ACIDS

- DNA is the chemical basis of heredity and may be regarded as the reserve bank of genetic information.
- DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years.
- The **DNA is organized into genes, the fundamental units of genetic information.**
- **The genes control the protein synthesis.**

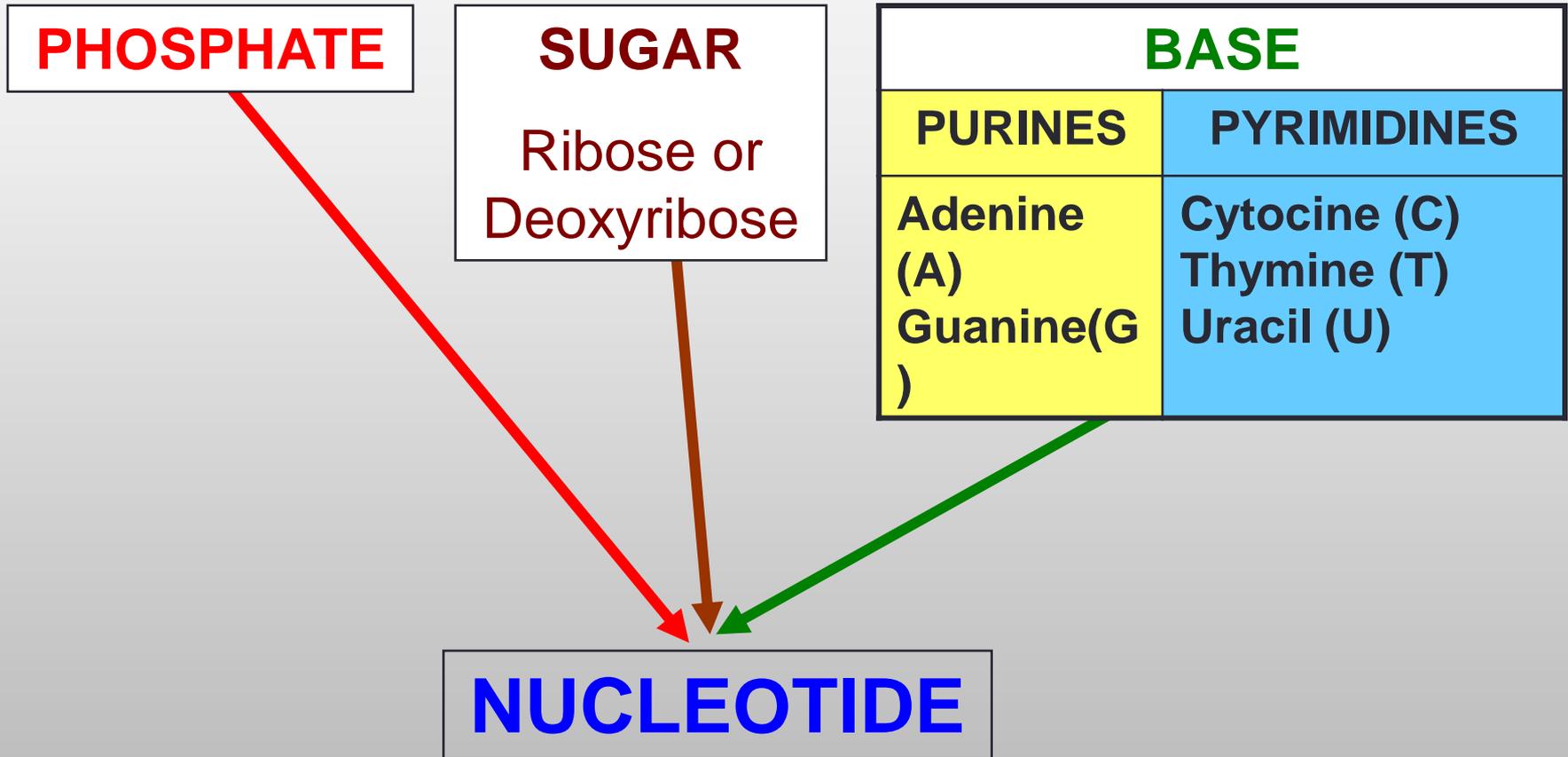


- The interrelationship of these three classes of biomolecules (DNA, RNA and proteins) constitutes the **central dogma of molecular biology or more commonly the central dogma of life.**

NUCLEOSIDE STRUCTURE



NUCLEOTIDE STRUCTURE



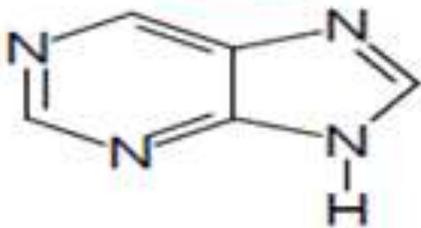
Nucleotide

Nucleoside

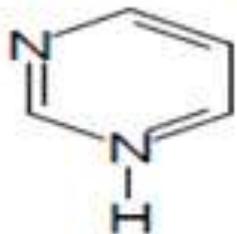
Base

Sugar

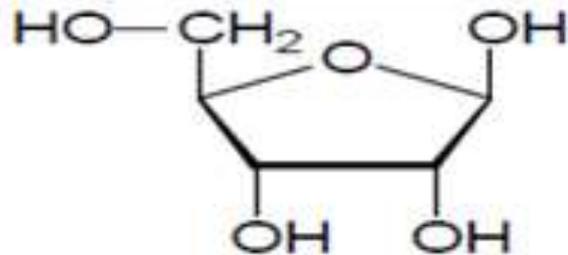
Phosphate(s)



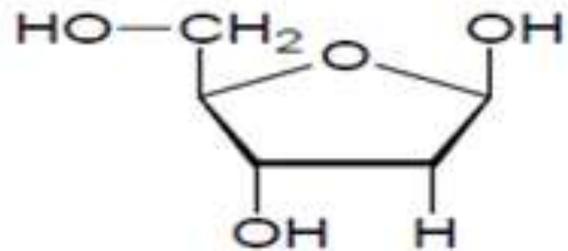
purine



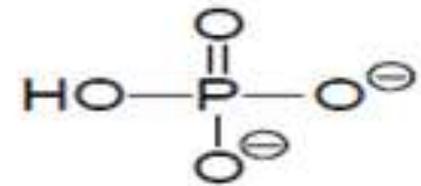
pyrimidine



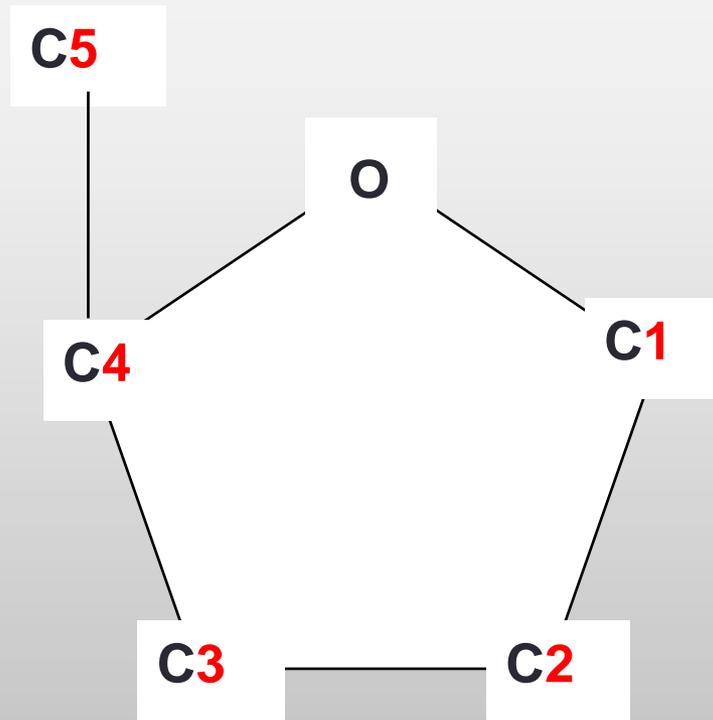
ribose



deoxyribose

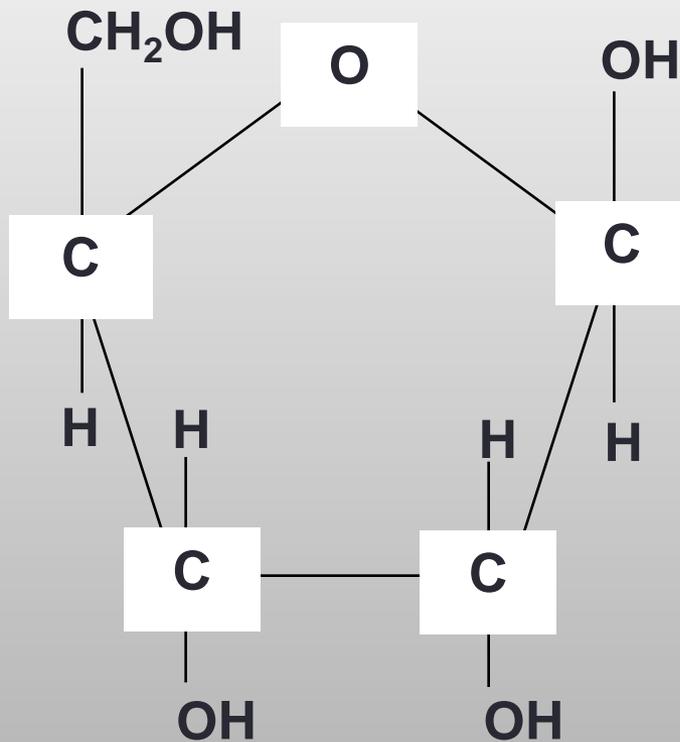


Ribose is a pentose

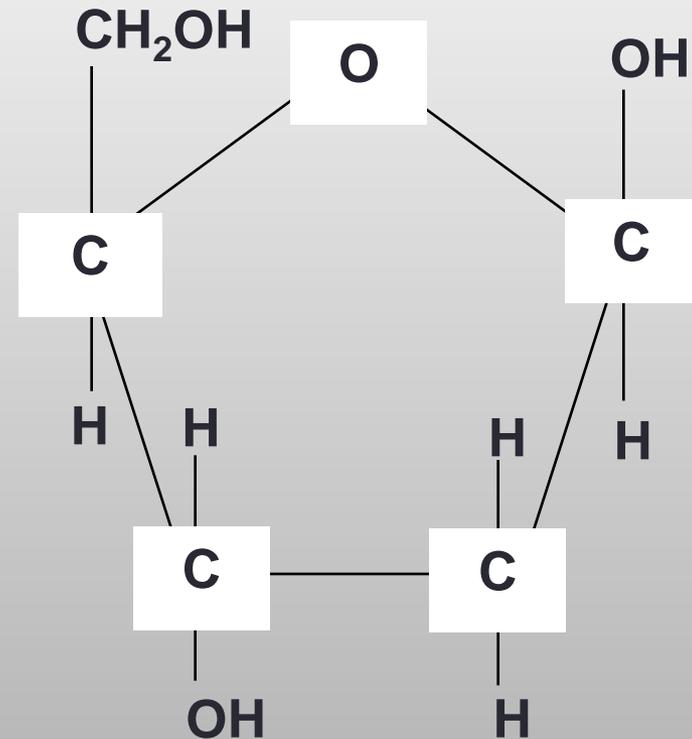


Spot the difference

RIBOSE

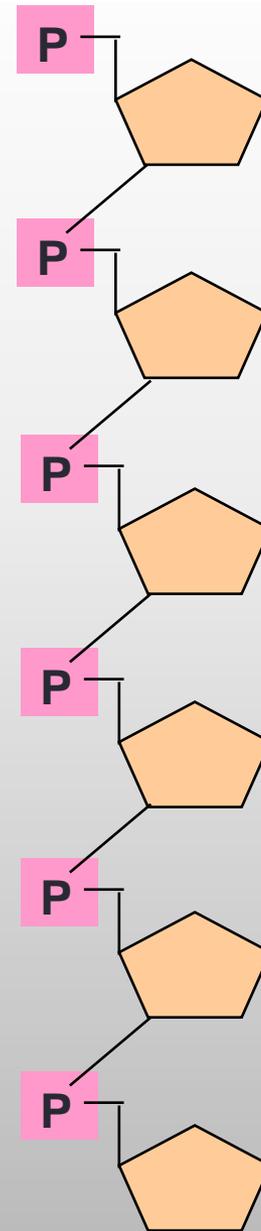


DEOXYRIBOSE



THE SUGAR-PHOSPHATE BACKBONE

- The nucleotides are all orientated in the same direction
- The phosphate group joins the 3rd Carbon of one sugar to the 5th Carbon of the next in line.



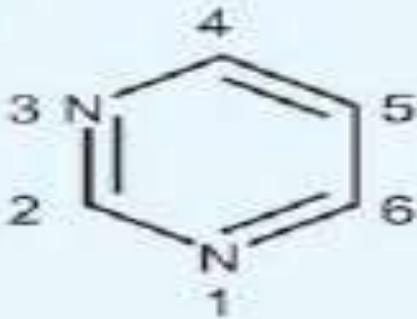
MAJOR NITROGENOUS BASES

□ PURINES-

- **Adenine (A)** : 6-aminopurine
- **Guanine (G)**: 2-amino 6-oxypurine

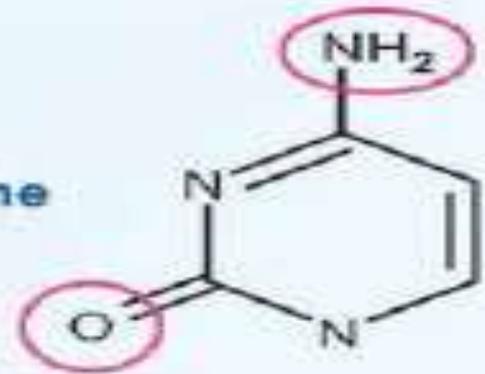
□ PYRIMIDINES-

- **Cytosine (C):** 2-oxy 4-aminopyrimidine
- **Uracil (U)** : 2,4- dioxypyrimidine
- **Thymine (T)** : 2,4- dioxo 5-methylpyrimidine



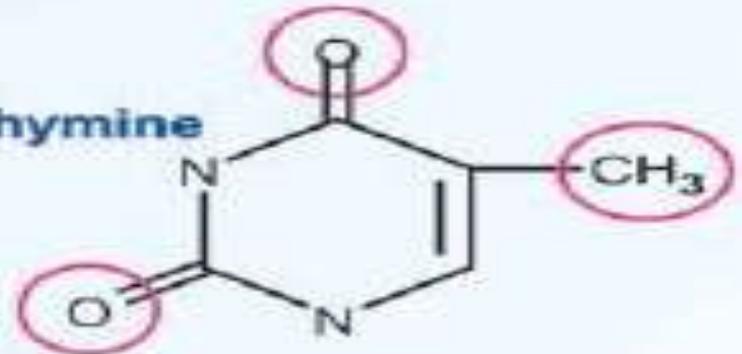
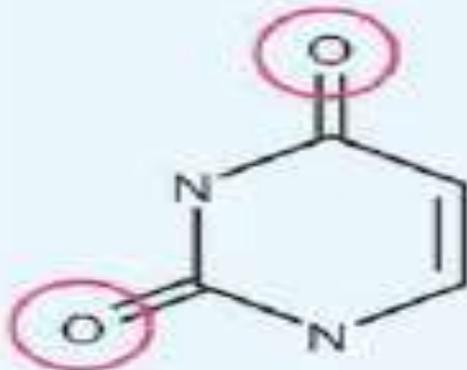
Pyrimidine

Cytosine



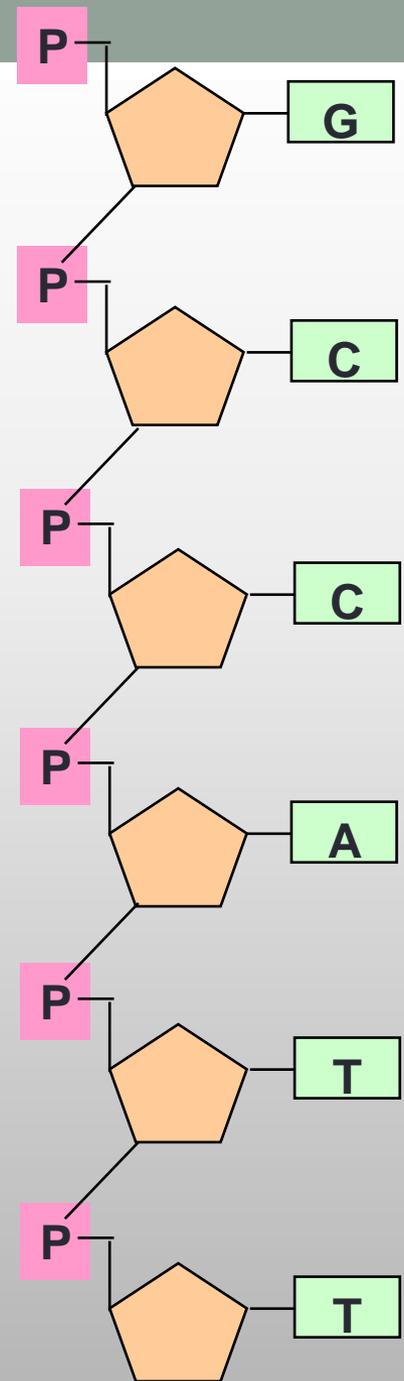
Uracil

Thymine



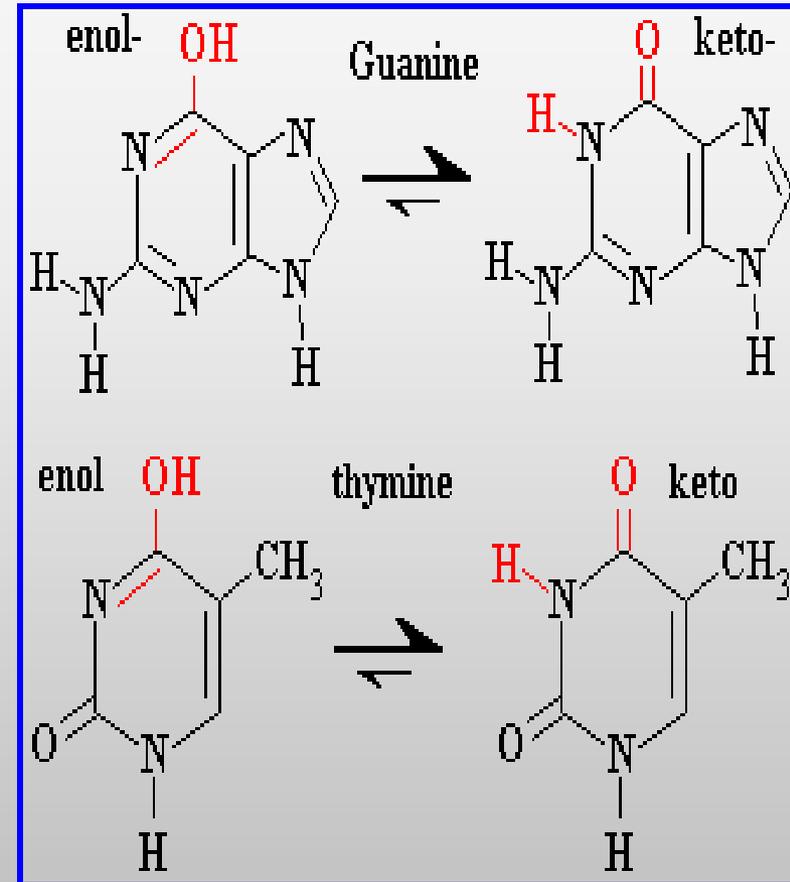
ADDING IN THE BASES

- The bases are attached to the 1st Carbon
- Their order is important
It determines the genetic information of the molecule



Properties of bases

- Tautomerization of bases:
Keto/Lactam & Enol/Lactim forms
 - The keto form predominates at physiological pH
- Purine and pyrimidine bases absorb uv light
 - Strong absorbance of UV light at 260 nm



NOMENCLATURE OF NUCLEOSIDES

- Ribonucleosides

- Purine nucleosides end with “-osine”

Adenine + Ribose

Adenosine

Guanine + Ribose

Guanosine

Hypoxanthine + Ribose

Inosine

Xanthine + Ribose

Xanthosine

- Pyrimidine nucleosides end with “-idine”

Uracil + Ribose

Uridine

Cytosine + Ribose

Cytidine

Nomenclature of nucleosids.....

- **Deoxyribonucleosides**
- Deoxynucleosides are denoted by adding the prefix “**d**”- before the nucleoside—

Adenine + deoxyribose → Deoxyadenosine (d-Adenosine)

Guanine + deoxyribose → Deoxyguanosine (d-Guanosine)

Cytosine + deoxyribose → Deoxycytidine (d-Cytidine)

Thymine + deoxyribose → Deoxythymidine (d-thymidine)

NOMENCLATURE OF NMPs

(NMP= Nucleoside + phosphate)

• Ribonucleotides

- Adenosine + Pi \longrightarrow Adenosine monophosphate
(AMP / Adenylate / Adenylic acid)
- Guanosine + Pi \longrightarrow Guanosine monophosphate
(GMP / Guanylic acid)
- Cytidine + Pi \longrightarrow Cytidine monophosphate
(CMP / Cytidylic acid)
- Uridine + Pi \longrightarrow Uridine monophosphate
(UMP / Uridylic acid)
- Inosine + Pi \longrightarrow Inosine monophosphate
(IMP / Inosinic acid)
- Xanthosine + Pi \longrightarrow Xanthosine monophosphate
(XMP)

NOMENCLATURE OF NMPs

(NMP= Nucleoside + phosphate)

- Deoxyribonucleotides

- dAdenosine + Pi dAMP
- dGuanosine + Pi dGMP
- dCytidine + Pi dCMP
- dThymidine + Pi dTMP

TABLE 5.1 Principal bases, nucleosides and nucleotides

<i>Base</i>	<i>Ribonucleoside</i>	<i>Ribonucleotide (5'-monophosphate)</i>	<i>Abbreviation</i>
Adenine (A)	Adenosine	Adenosine 5'-monophosphate or adenylyate	AMP
Guanine (G)	Guanosine	Guanosine 5'-monophosphate or guanylyate	GMP
Cytosine (C)	Cytidine	Cytidine 5'-monophosphate or cytidylate	CMP
Uracil (U)	Uridine	Uridine 5'-monophosphate or uridylate	UMP
<i>Base</i>	<i>Deoxyribonucleoside</i>	<i>Deoxyribonucleotide (5'-monophosphate)</i>	<i>Abbreviation</i>
Adenine (A)	Deoxyadenosine	Deoxyadenosine 5'-monophosphate or deoxyadenylate	dAMP
Guanine (G)	Deoxyguanosine	Deoxyguanosine 5'-monophosphate or deoxyguanylyate	dGMP
Cytosine (C)	Deoxycytidine	Deoxycytidine 5'-monophosphate or deoxycytidylate	dCMP
Thymine (T)	Deoxythymidine	Deoxythymidine 5'-monophosphate or deoxythymidylate	dTMP

FUNCTIONS OF NUCLEOTIDES

- They supply **monomeric units of nucleic acids**
- Nucleotides play important role as **energy currency** in the cells
 - **ATP** is central to energy metabolism,
 - **GTP** drives protein synthesis.
 - **CTP** drives lipid synthesis.
 - **UTP** drives carbohydrate metabolism

Functions of nucleotides.....

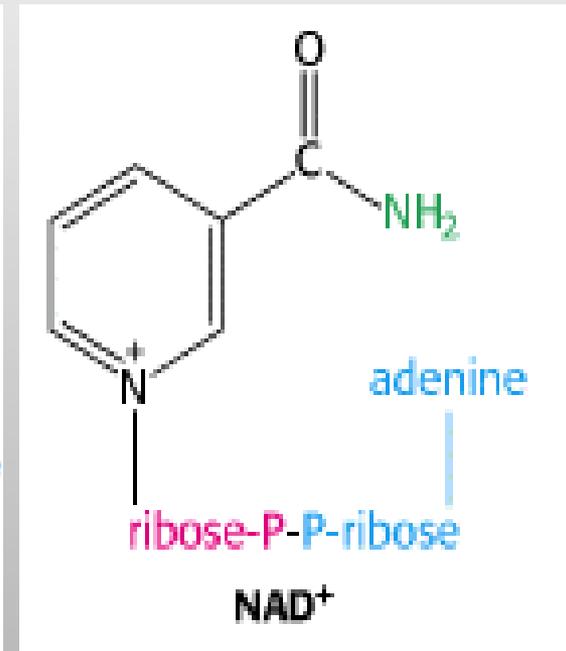
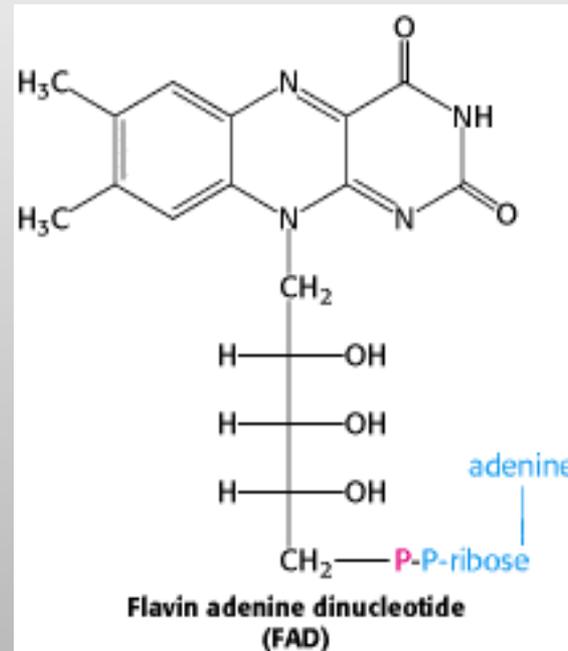
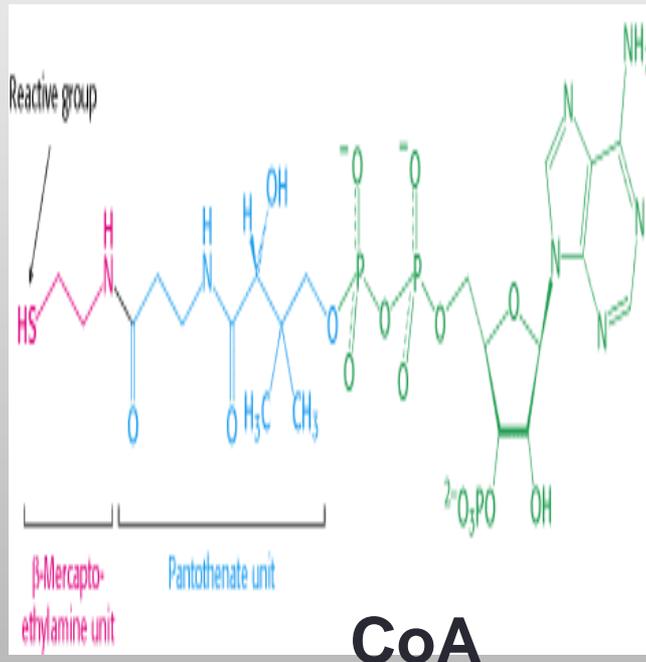
- Nucleotides such as cyclic adenosine monophosphate (**cAMP**) & cyclic guanosine monophosphate (**cGMP**) serve as **second messengers** in signal transduction pathways
- Nucleotides serve as **carriers of activated intermediates** in biosynthetic reactions
 - **UDP Glucose** in glycogen synthesis
 - **UDP Galactose** in synthesis of ceramide
 - **CTP Choline** in phospholipid synthesis

Functions of nucleotides.....

- Nucleotides act as **allosteric modulators** of metabolic pathways
 - Enzyme: **Phosphofructokinase** of glycolysis has
 - **AMP** as positive modulator
 - **ATP** as negative modulator

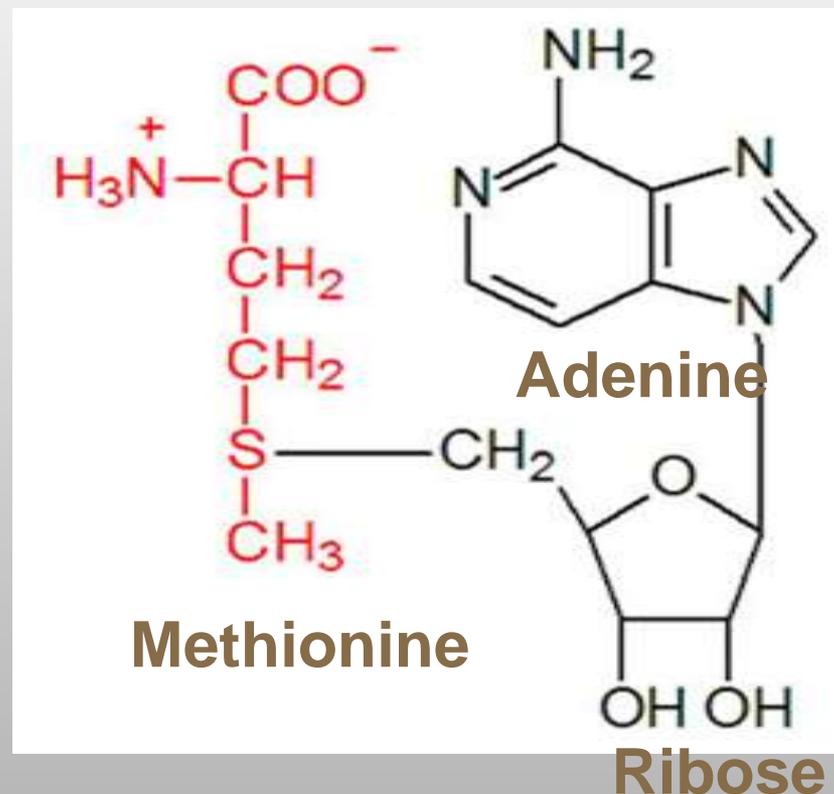
Functions of nucleotides.....

- Nucleotides are structural components of several essential **coenzymes** → **CoA, FAD, NAD⁺, NADP⁺**



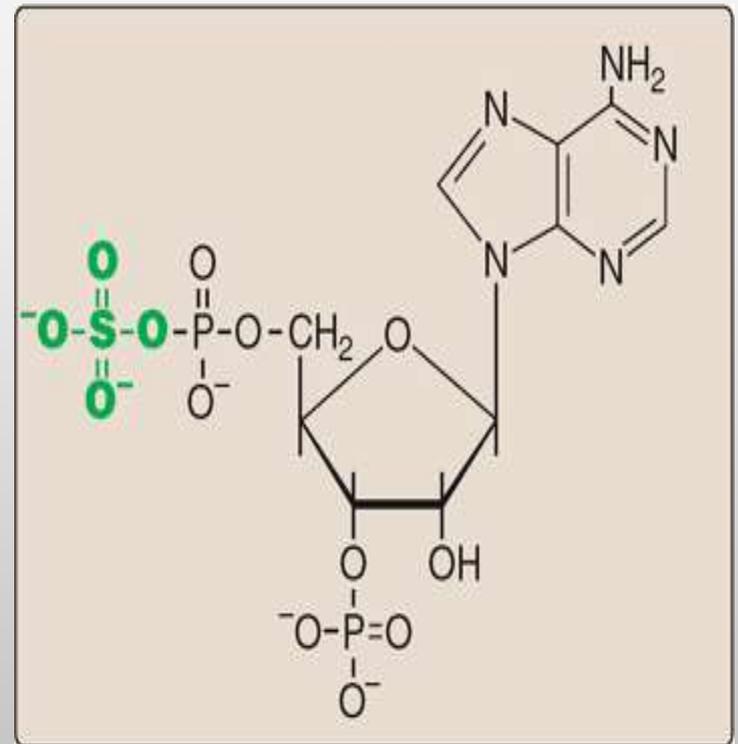
Functions of nucleotides.....

- **S-adenosylmethionine (SAM):** Active methionine- serves as a **methyl donor** in methylation reactions



Functions of nucleotides.....

- **Phosphoadenosine phosphosulphate (PAPS):** Active sulphate-acts as a **sulphate group donor** for the formation of—
 - Sulphated mucopolysaccharides
 - Sulphatides &
 - In detoxication reactions



DEOXYRIBONUCLEIC ACID (DNA)

- DNA is a **polymer of deoxyribonucleotides** (or simply deoxynucleotides).
-
- It is composed of monomeric units namely deoxyadenylate (dAMP), deoxyguanylate (dGMP), deoxycytidylate (dCMP) and deoxythymidylate (dTMP).
- It may be noted here that some authors prefer to use TMP for deoxythymidylate, since it is found only in DNA.

DNA IS MADE OF TWO STRANDS OF POLYNUCLEOTIDE

- The sister strands of the DNA molecule run in opposite directions (**antiparallel**)
- They are joined by the bases
- Each base is paired with a specific partner:

A is always paired with **T**

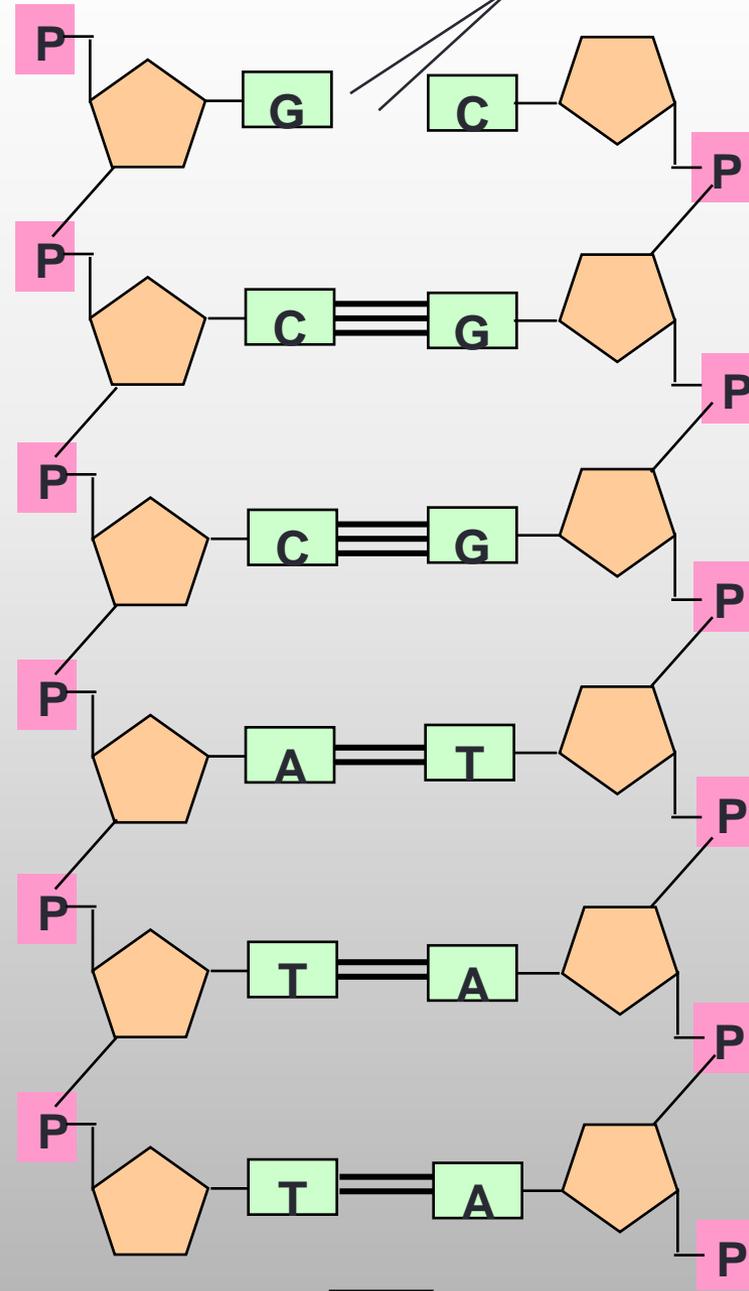
G is always paired with **C**

Purine with Pyrimidine

- Thus the sister strands are **complementary** but not identical
- The bases are joined by **hydrogen bonds**, individually weak but collectively strong.

Hydrogen bonds

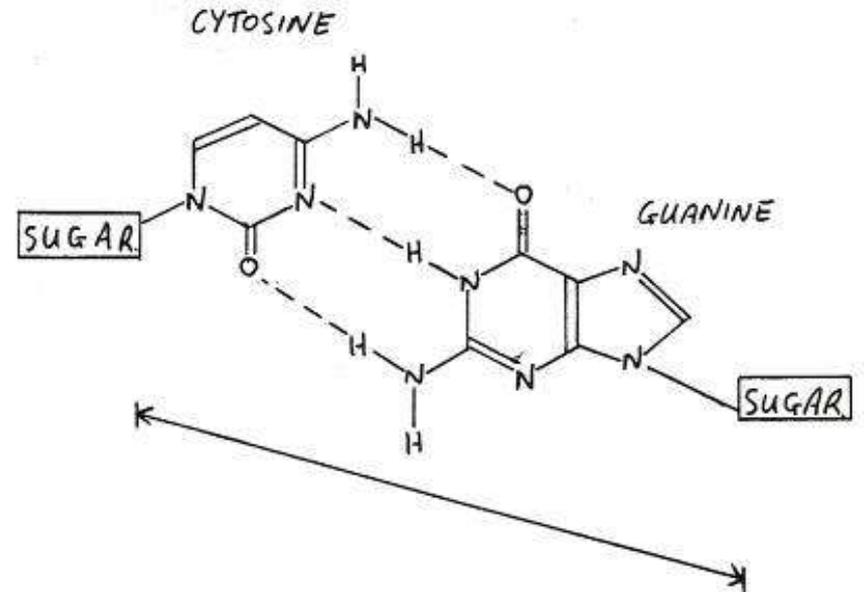
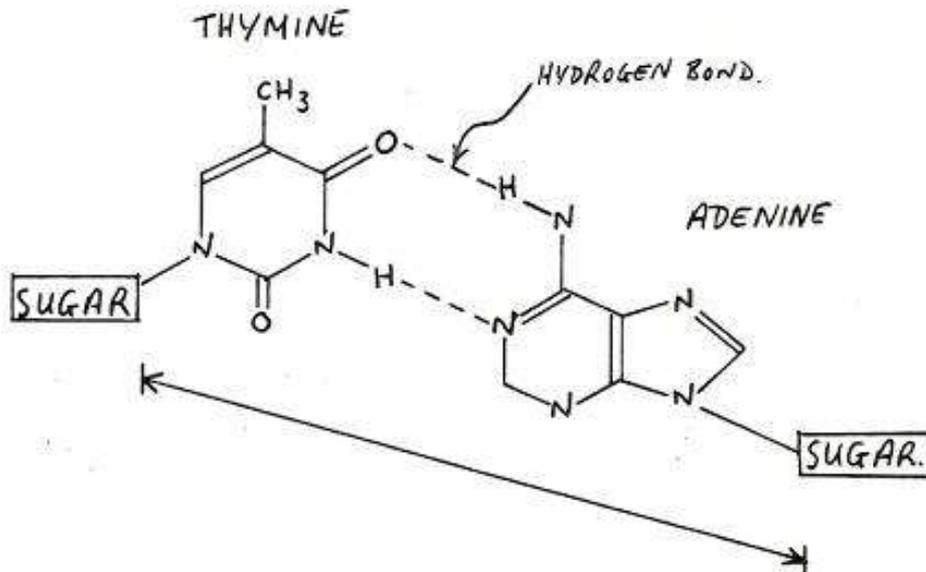
**DNA IS MADE OF
TWO STRANDS OF
POLYNUCLEOTIDE**



Chargaff's rule of DNA composition

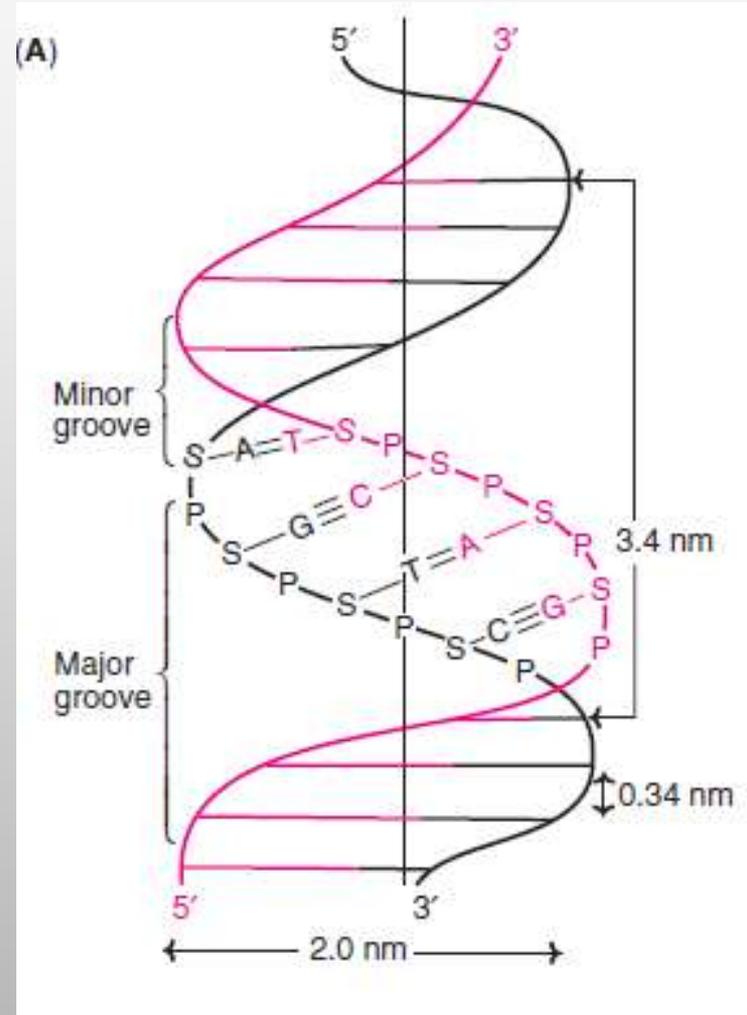
- Erwin Chargaff in late 1940s quantitatively analysed the DNA hydrolysates from different species.
- He observed that in all the species he studied, DNA had equal numbers of adenine and thymine residues ($A = T$) and equal numbers of guanine and cytosine residues ($G = C$).
- This is known as Chargaff's rule of **molar equivalence between the purines and pyrimidines in DNA** structure.

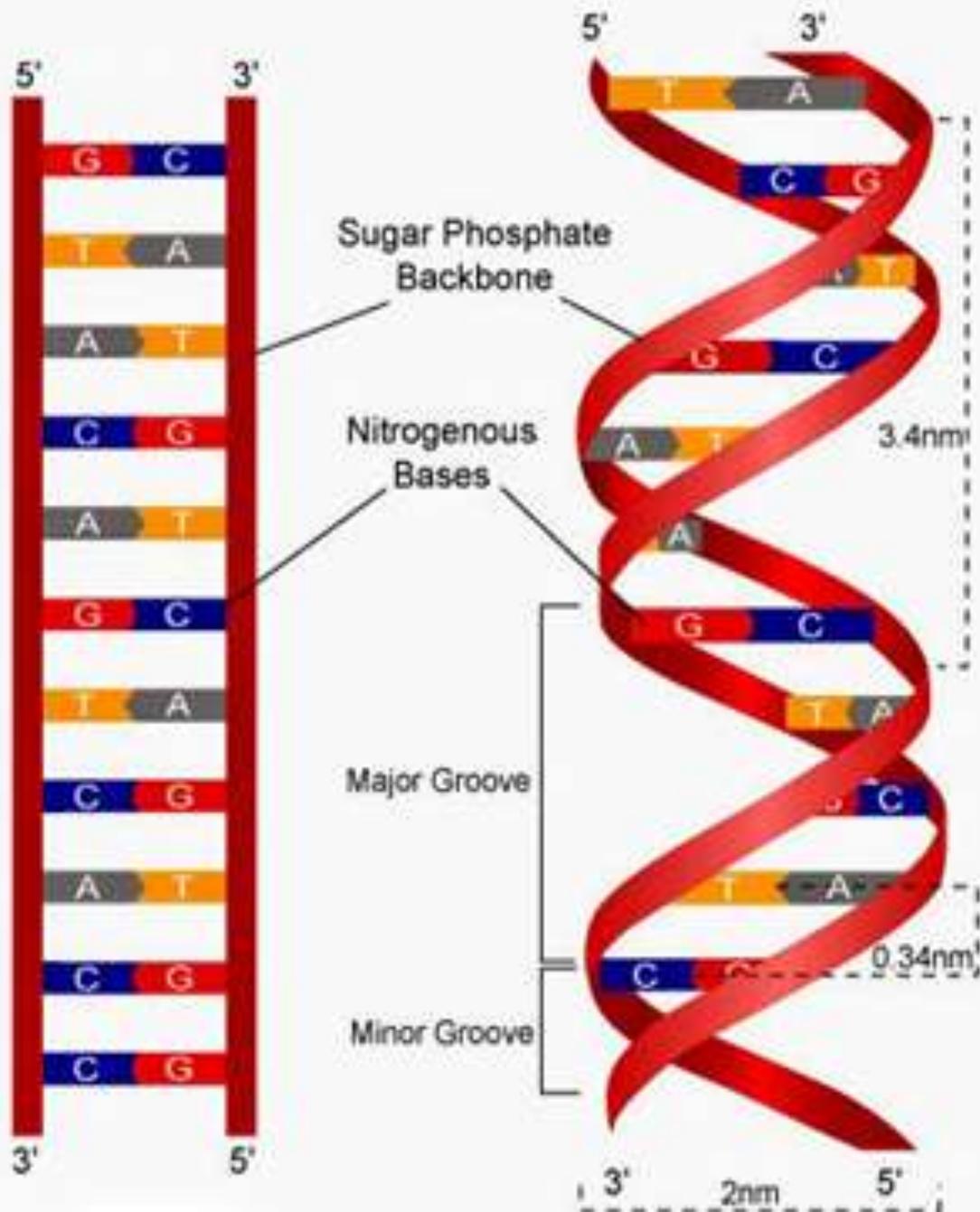
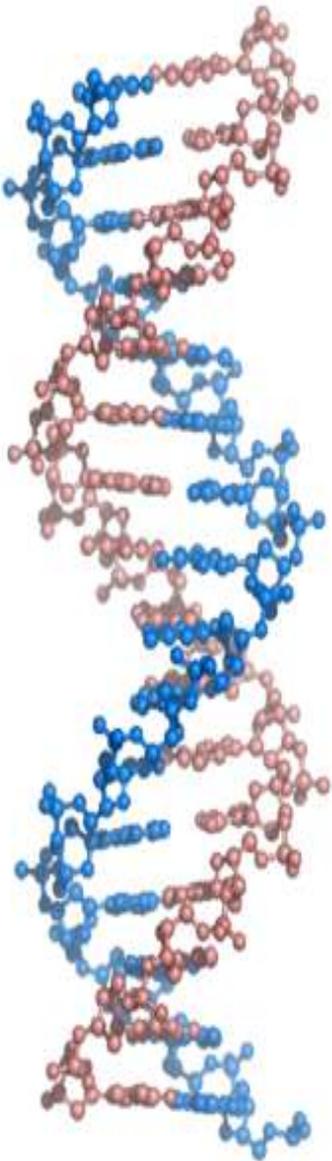
DNA DOUBLE HELIX (Watson & Crick MODEL)



DNA DOUBLE HELIX (Watson & Crick MODEL)

- The double helical structure of DNA was proposed by **James Watson and Francis Crick** in 1953 (Nobel Prize, 1962).
- The structure of DNA double helix is comparable to a twisted ladder.





SILENT FEATURES OF DNA MODEL

- ❖ The DNA is a right handed double helix. It consists of **two polydeoxyribonucleotide chains** (strands) twisted around each other on a common axis.
- ❖ The two strands are **antiparallel, i.e., one** strand runs in the 5'to 3' direction while the other in 3'to 5'direction. This is comparable to two parallel adjacent roads carrying traffic in opposite direction.
- ❖ The width (or diameter) of a double helix is 20 A (2 nm).
- ❖ Each turn (pitch) of the helix is 34 A° (3.4 nm) with **10 pairs of nucleotides, each pair** placed at a distance of about 3.4 A° .

SILENT FEATURES OF DNA MODEL

❖ Each strand of DNA has a hydrophilic deoxyribose phosphate backbone (3'-5' phosphodiester bonds) on the outside (periphery) of the molecule while the hydrophobic bases are stacked inside (core).

❖ The **two polynucleotide chains are not identical but complementary to each other due to base pairing.**

The two strands are **held together by hydrogen bonds formed by complementary base pairs. The A-T pair has 2 hydrogen bonds** while G-C pair has 3 hydrogen bonds. The G -C is stronger by about 50% than A = T.

SILENT FEATURES OF DNA MODEL

- ❖ The complementary base pairing in DNA helix proves **Chargaff's rule**. The **content of** adenine equals to that of thymine ($A = T$) and guanine equals to that of cytosine ($G = C$).
- ❖ The **genetic information resides on one of** the two strands known as **template strand or** sense strand. The opposite strand is antisense strand. The double helix has (wide) major grooves and (narrow) minor grooves along the phosphodiester backbone. Proteins interact with DNA at these grooves, without disrupting the base pairs and double helix.

Conformations of DNA double helix

- ❖ Variation in the conformation of the nucleotides of DNA is associated with conformational variants of DNA.
- ❖ The double helical structure of DNA exists in at least 6 different forms-A to E and Z. Among these, B, A and Z forms are important.
- ❖ **The B-form of DNA double helix, described by Watson and Crick (discussed above), is the most predominant form under physiological conditions.**
- ❖ **Each turn of the B-form has 10 base pairs** spanning a distance of 3.4 nm. The width of the double helix is 2 nm.

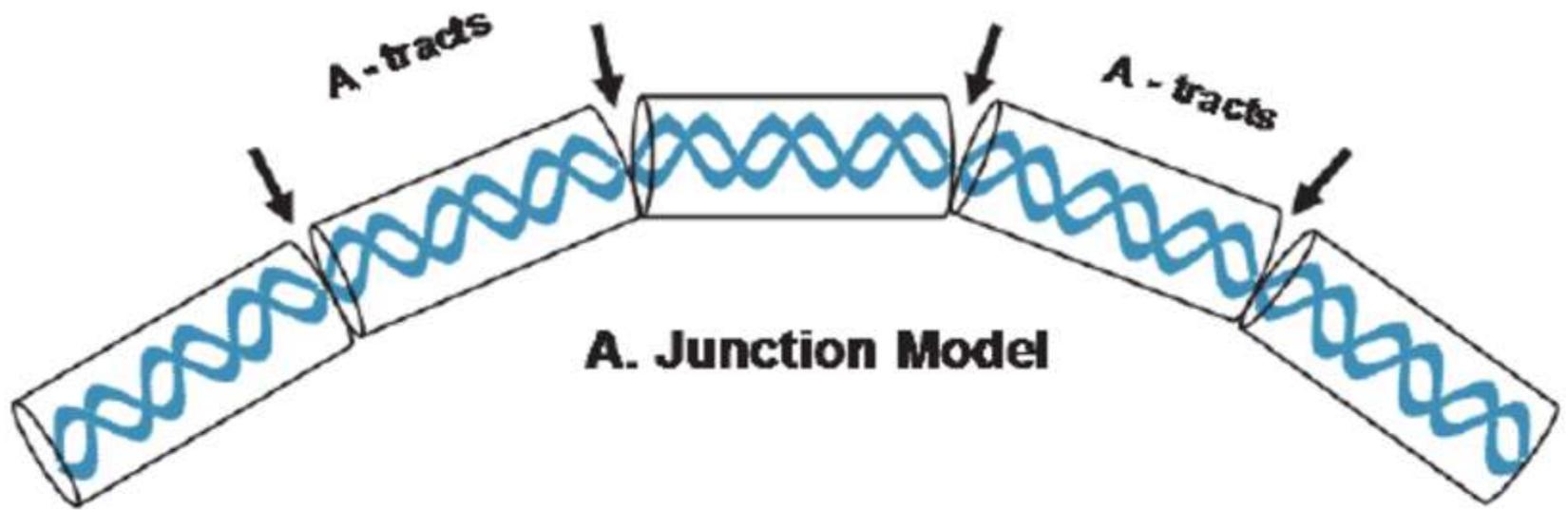
Conformations of DNA double helix

- ❖ The A-form is also a right-handed helix. It contains 11 base pairs per turn. There is a tilting of the base pairs by 20° away from the central axis.
- ❖ The Z-form (Z-DNA) is a left-handed helix and contains 12 base pairs per turn. The polynucleotide strands of DNA move in a somewhat 'zig zag' fashion, hence the name Z-DNA.

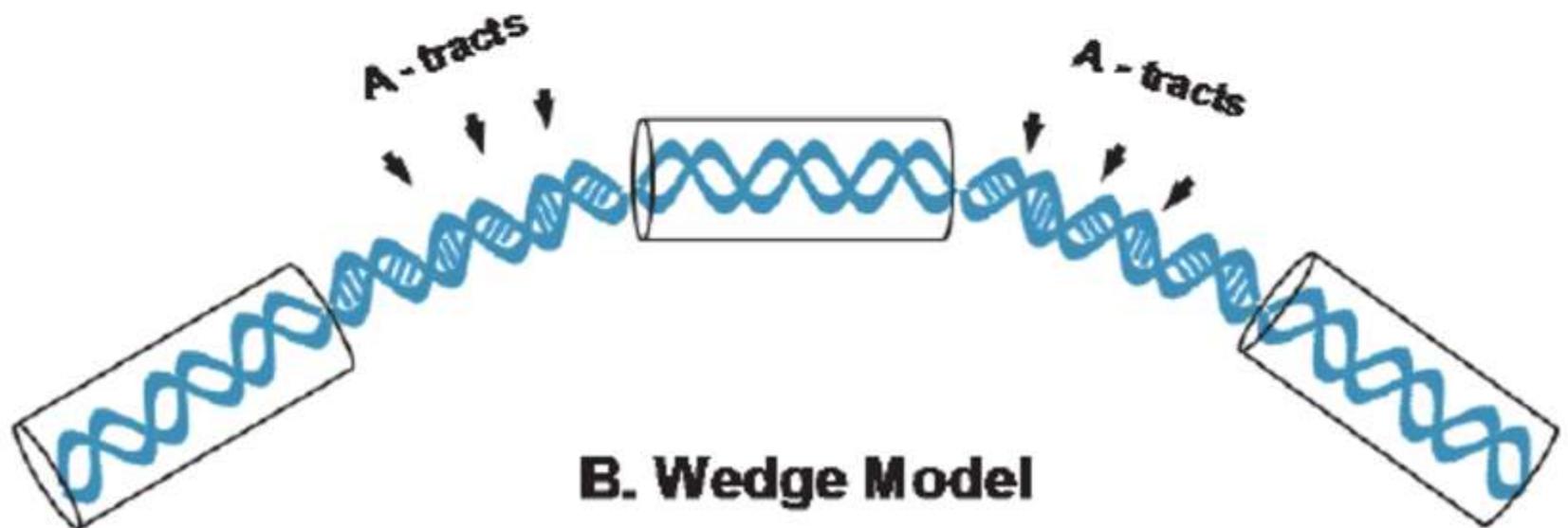
OTHER TYPES OF DNA STRUCTURE

DNA also exists in certain unusual structures. Some selected **unusual structures of DNA** are

- **Bent DNA:** Bent conformation of DNA occurs when A-tracts are replaced by other bases or a collapse of the helix into the minor groove of A-tract. Bending in DNA structure has also been reported due to photochemical damage or mispairing of bases.
- Certain antitumor drugs (e.g. cisplatin) produce bent structure in DNA. Such changed structure can take up proteins that damage the DNA.



A. Junction Model



B. Wedge Model

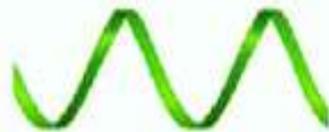
Triple-stranded DNA

- Triple-stranded DNA formation may occur due to additional hydrogen bonds between the bases. Thus, a thymine can selectively form two **Hoogsteen hydrogen bonds to the adenine of A-T pair to form T-A-T.**
- **Likewise, a protonated** cytosine can also form two hydrogen bonds with guanine of G–C pairs that results in C–G–C.
- Triple-helical structure is less stable than double helix. This is due to the fact that the three negatively charged backbone strands in triple helix results in an increased electrostatic repulsion.

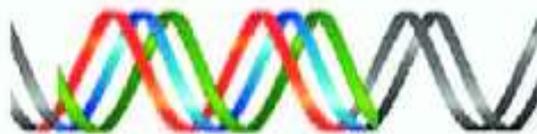
double-helix (duplex-DNA)



third strand (TFO)



+



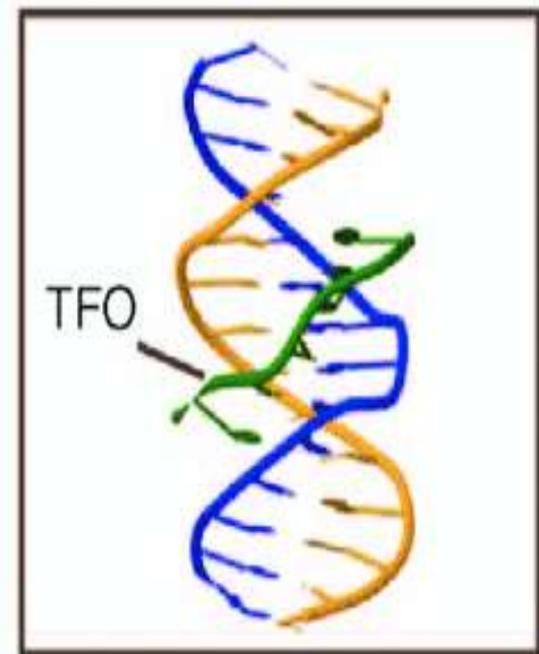
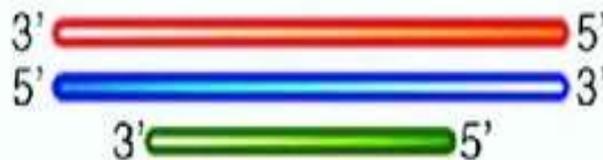
triple-helix

-  Purine track of the duplex
-  Pyrimidine track of the duplex
-  Triplex-forming oligonucleotide (TFO)

Parallel oriented binding:



Anti-parallel oriented binding:



Four-stranded DNA

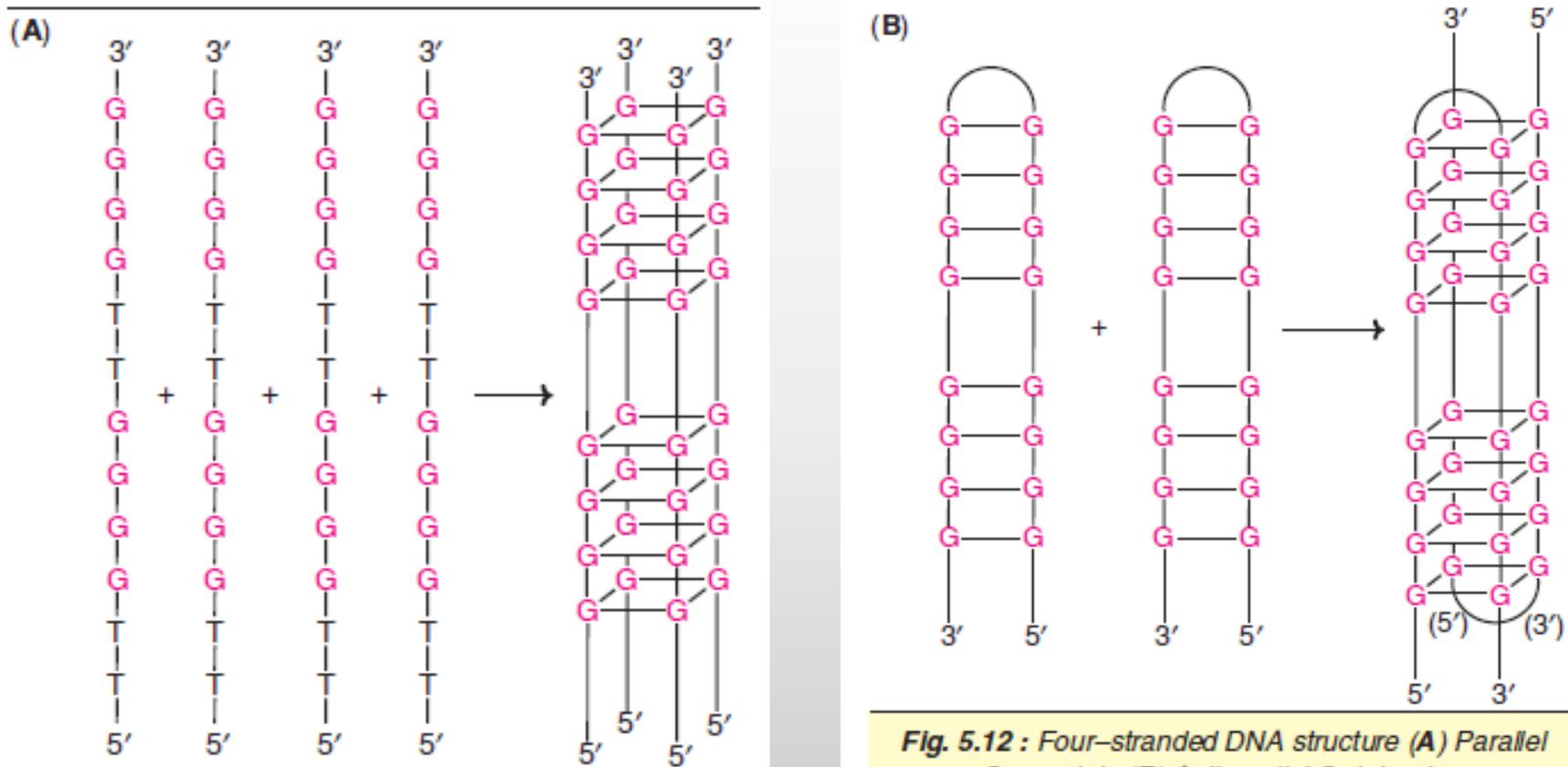


Fig. 5.12 : Four-stranded DNA structure (A) Parallel G-quartets (B) Antiparallel G-tetraplex.

- Polynucleotides with very high contents of guanine can form a novel tetrameric structure called **G-quartets**.
- **These structures are planar** and are connected by Hoogsteen hydrogen bonds.
- **Antiparallel four-stranded** DNA structures, referred to as **G-tetraplexes** have also been reported.

THE SIZE OF DNA MOLECULE —UNITS OF LENGTH

- DNA molecules are huge in size. On an average, a pair of B-DNA with a thickness of 0.34 nm has a molecular weight of 660 daltons.
- For the measurement of lengths, DNA doublestranded structure is considered, and expressed in the form of **base pairs (bp)**. A **kilobase pair (kb)** is **10³ bp**, and a **megabase pair (Mb)** is **10⁶ bp** and a **gigabase pair (Gb)** is **10⁹ bp**.

$$1 \text{ kb} = 1000 \text{ bp}$$

$$1 \text{ Mb} = 1000 \text{ kb} = 1,000,000 \text{ bp}$$

$$1 \text{ Gb} = 1000 \text{ Mb} = 1,000,000,000 \text{ bp}$$

THE SIZE OF DNA MOLECULE

—UNITS OF LENGTH

- The length of DNA varies from species to species, and is usually expressed in terms of base pair composition and **contour length**.
- **Contour** length represents the total length of the genomic DNA in a cell. Some examples of organisms with bp and contour lengths are listed.
 - λ phage virus — 4.8×10^4 bp — contour length 16.5 μm .
 - *E. coli* — 4.6×10^6 bp — contour length 1.5 μm .
 - Diploid human cell (46 chromosomes) — 6.0×10^9 bp — contour length 2 meters.
- In humans, a 2-meter long DNA is packed in a nucleus of about 10 μm diameter!

DNA as genetic material: The circumstantial evidence

1. Present in all cells and virtually restricted to the nucleus
2. The amount of DNA in somatic cells (body cells) of any given species is constant (like the number of chromosomes)
3. The DNA content of gametes (sex cells) is half that of somatic cells.
In cases of polyploidy (multiple sets of chromosomes) the DNA content increases by a proportional factor
4. The mutagenic effect of UV light peaks at 253.7nm.
The peak for the absorption of UV light by DNA

Organization of prokaryotic DNA

- In prokaryotic cells, the DNA is organized as a single chromosome in the form of a doublestranded circle.
- These bacterial chromosomes are packed in the form of nucleoids, by interaction with proteins and certain cations (polyamines).

Organization of eukaryotic DNA

- In the eukaryotic cells, the DNA is associated with various proteins to form **chromatin** which then gets **organized into compact structures** namely **chromosomes**.
- The DNA double helix is wrapped around the core proteins namely **histones which are basic in nature**.
- The core is composed of two molecules of histones (H2A, H2B, H3 and H4).
- Each core with two turns of DNA wrapped round it (approximately with 150 bp) is termed as a **nucleosome, the basic unit of chromatin**.
- Nucleosomes are separated by spacer DNA to which histone H1 is attached.

Organization of eukaryotic DNA

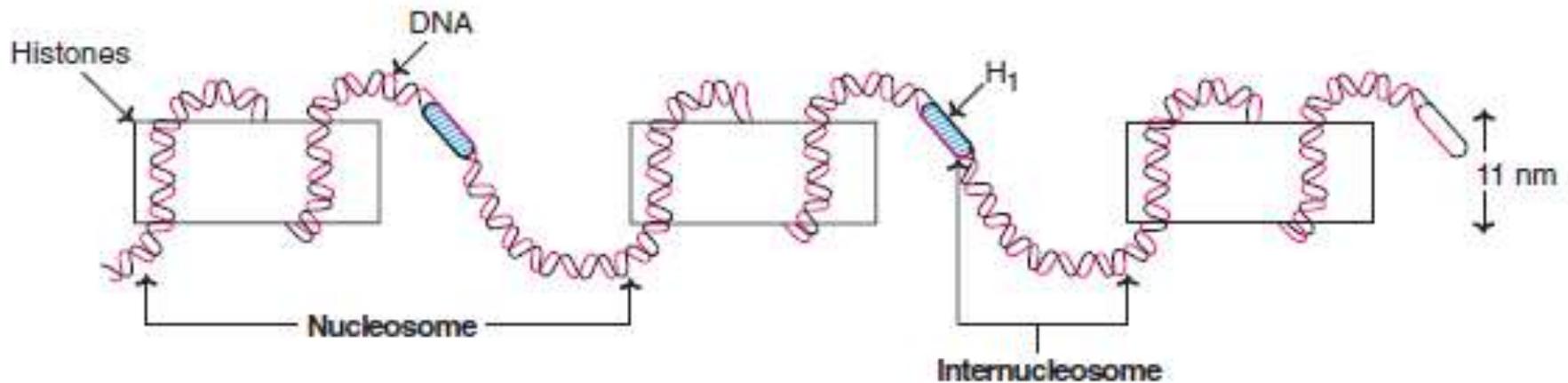


Fig. 5.15 : Structure of nucleosomes.

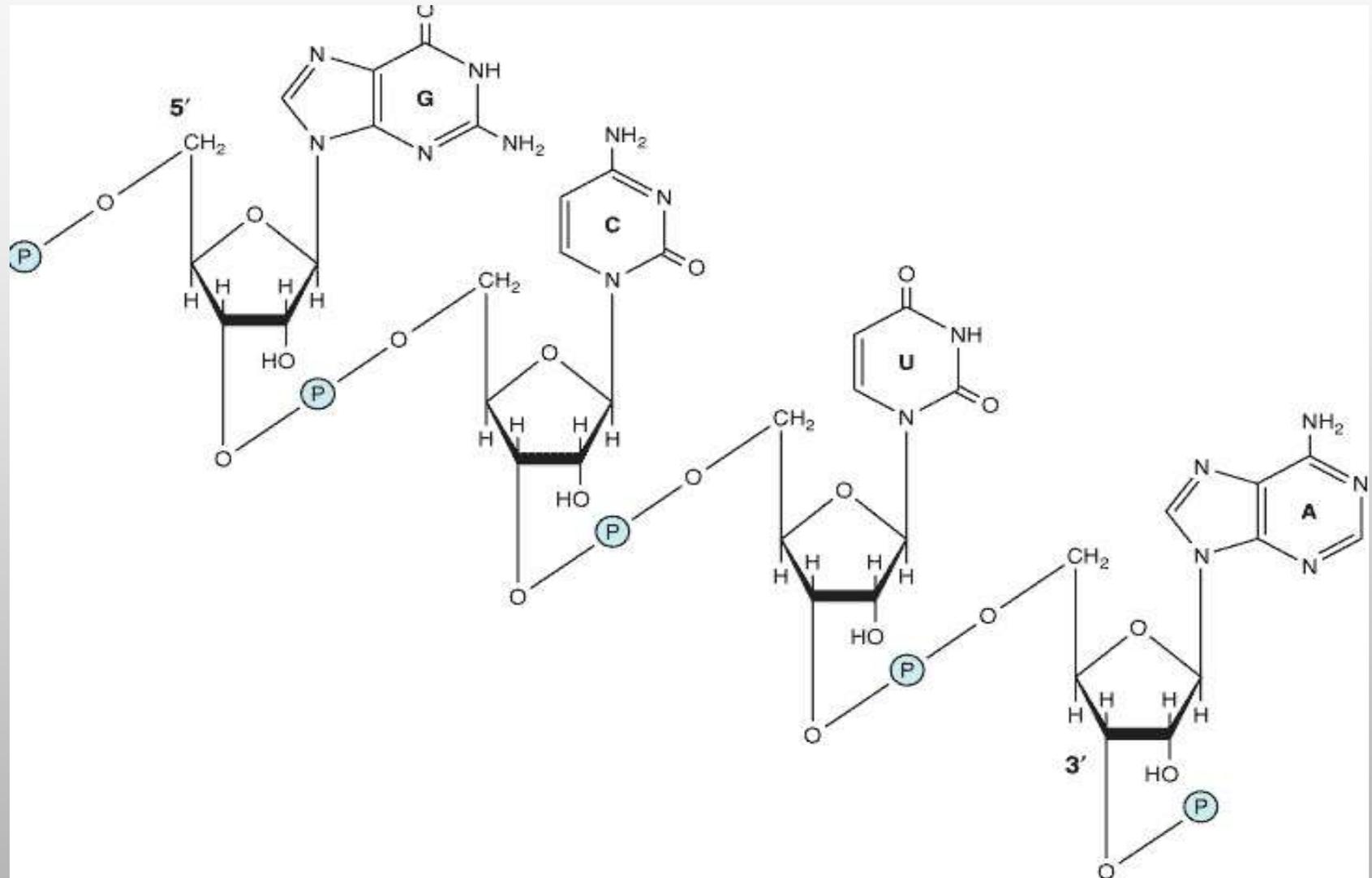
THANK YOU!



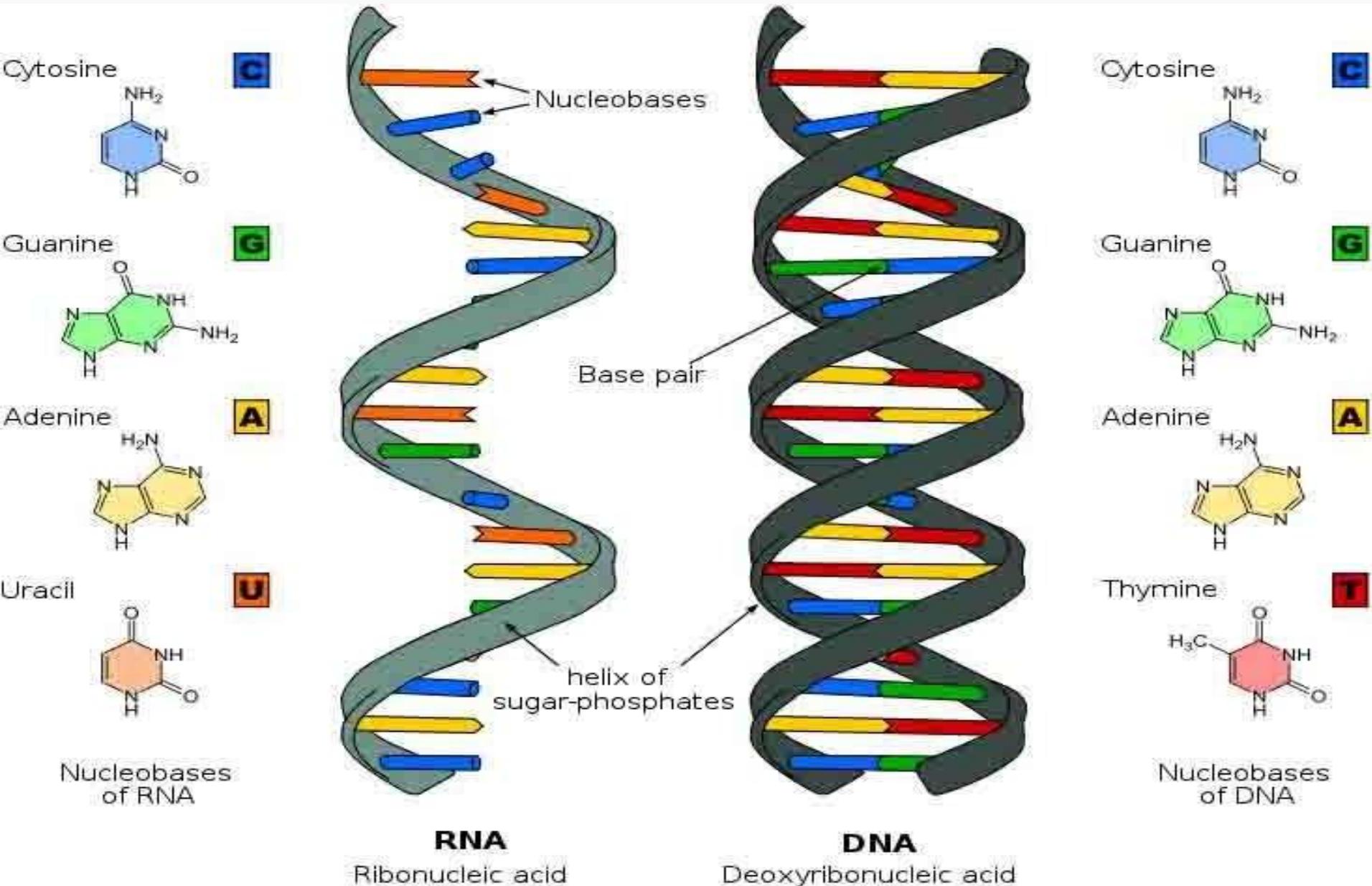
RIBONUCLEIC ACID (RNA)

- Ribonucleic acid is ***a polymer of ribonucleotides of Adenine, Uracil, Guanine and Cytosine, joined together by 3' – 5' phosphodiester bonds.***
- ***Thymine is absent in RNA.***
- ***RNA is found in the nucleolus, Nissl granules, ribosomes, mitochondria and cytoplasm.***
- **The pentose sugar of the nucleotide is D-ribose.**

RIBONUCLEIC ACID (RNA)



RNA V/S DNA



Differences between RNA and DNA

S.No.	RNA	DNA
1)	Single stranded mainly except when self complementary sequences are there it forms a double stranded structure (Hair pin structure)	Double stranded (Except for certain viral DNA s which are single stranded)
2)	Ribose is the main sugar	The sugar moiety is deoxy ribose
3)	Pyrimidine components differ. Thymine is never found(Except tRNA)	Thymine is always there but uracil is never found
4)	Being single stranded structure- It does not follow Chargaff's rule	It does follow Chargaff's rule. The total purine content in a double stranded DNA is always equal to pyrimidine content.

Differences between RNA and DNA

S.No.	RNA	DNA
5)	RNA can be easily destroyed by alkalies to cyclic diesters of mono nucleotides.	DNA resists alkali action due to the absence of OH group at 2' position
6)	RNA is a relatively a labile molecule, undergoes easy and spontaneous degradation	DNA is a stable molecule. The spontaneous degradation is very 2 slow. The genetic information can be stored for years together without any change.
7)	Mainly cytoplasmic, but also present in nucleus (primary transcript and small nuclear RNA)	Mainly found in nucleus, extra nuclear DNA is found in mitochondria, and plasmids etc
8)	The base content varies from 100-5000. The size is variable.	Millions of base pairs are there depending upon the organism

Differences between RNA and DNA

S.No.	RNA	DNA
9)	There are various types of RNA – mRNA, r RNA, t RNA, Sn RNA, Si RNA, mi RNA and hn RNA. These RNAs perform different and specific functions.	DNA is always of one type and performs the function of storage and transfer of genetic information.
10)	No variable physiological forms of RNA are found. The different types of RNA do not change their forms	There are variable forms of DNA (A to E and Z)
11)	RNA is synthesized from DNA, it can not form DNA(except by the action of reverse transcriptase). It can not duplicate (except in certain viruses where it is a genomic material)	DNA can form DNA by replication, it can also form RNA by transcription.
12)	Many copies of RNA are present per cell.	Single copy of DNA is present per cell.

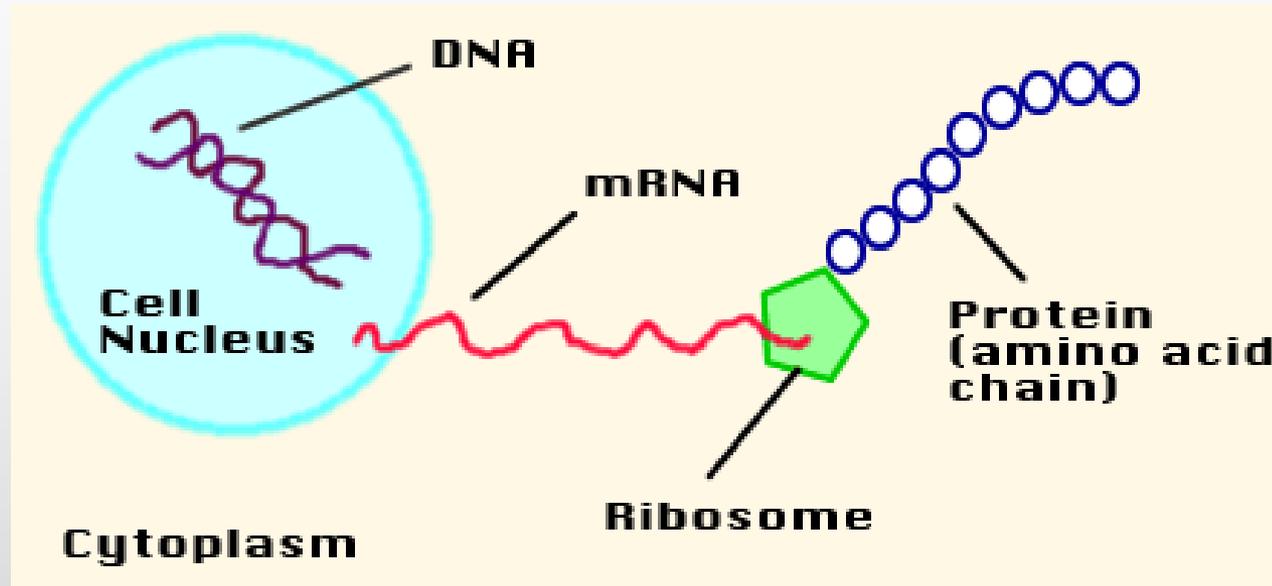
TYPES OF RNA

- The three major types of RNAs with their respective cellular composition are given below

1. **Messenger RNA (mRNA) : 5–10%**
2. **Transfer RNA (tRNA) : 10–20%**
3. **Ribosomal RNA (rRNA) : 50–80%**

Other RNAs are also present in the cells. These include heterogeneous nuclear RNA (hnRNA), small nuclear RNA (snRNA), small nucleolar RNA (snoRNA) and small cytoplasmic RNA (scRNA).

Messenger RNA (mRNA)



- The mRNA is synthesized in the nucleus (in eukaryotes) as **heterogeneous nuclear RNA (hnRNA)**. hnRNA, on **processing, liberates the functional mRNA** which enters the cytoplasm to participate in **protein synthesis**.
- **mRNA has high** molecular weight with a short half-life.

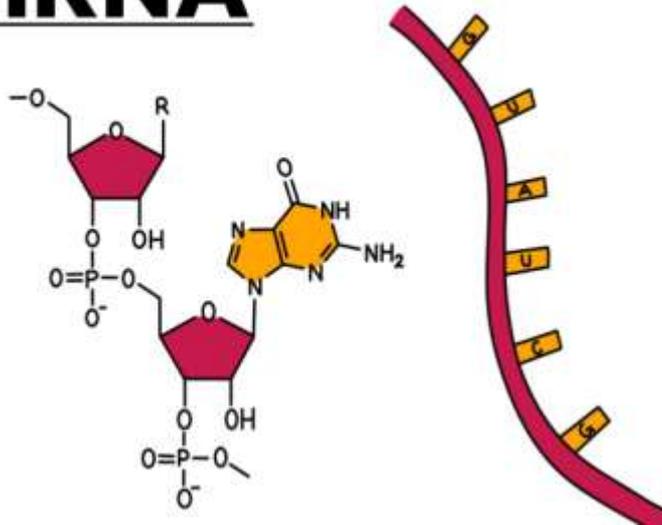
Messenger RNA (mRNA)

- In general, mRNA of eukaryotes is more stable with longer half-life, compared to prokaryotic mRNA.
- All members of the class function as messengers carrying the information in a gene to the protein synthesizing machinery.
- the 5'-terminal end by 7-methylguanosine triphosphate.
- It is believed that this cap helps to prevent the hydrolysis of mRNA by 5'-exonucleases. Further, the cap may be also involved in the recognition of mRNA for protein synthesis.

Messenger RNA (mRNA)

- The 3'-terminal end of mRNA contains a polymer of adenylate residues (20-250 nucleotides) which is known as **poly (A) tail**.
- This tail may provide stability to mRNA, besides preventing it from the attack of 3'-exonucleases. mRNA molecules often contain certain modified bases such as 6-methyladenylates in the internal structure.

mRNA



A = Adenine
U = Uracil
G = Guanine
C = Cytosine

Transfer RNA (t-RNA)

- Transfer RNA (**soluble RNA**) **molecule** contains 71-80 nucleotides (mostly 75) with a molecular weight of about 25,000.
- There are at least 20 species of tRNAs, corresponding to 20 amino acids present in protein structure.
- The structure of tRNA (for alanine) was first elucidated by Holley.
- The structure of tRNA, resembles that of a clover leaf. tRNA contains mainly four arms, each arm with a base paired stem.

Transfer RNA (t-RNA)

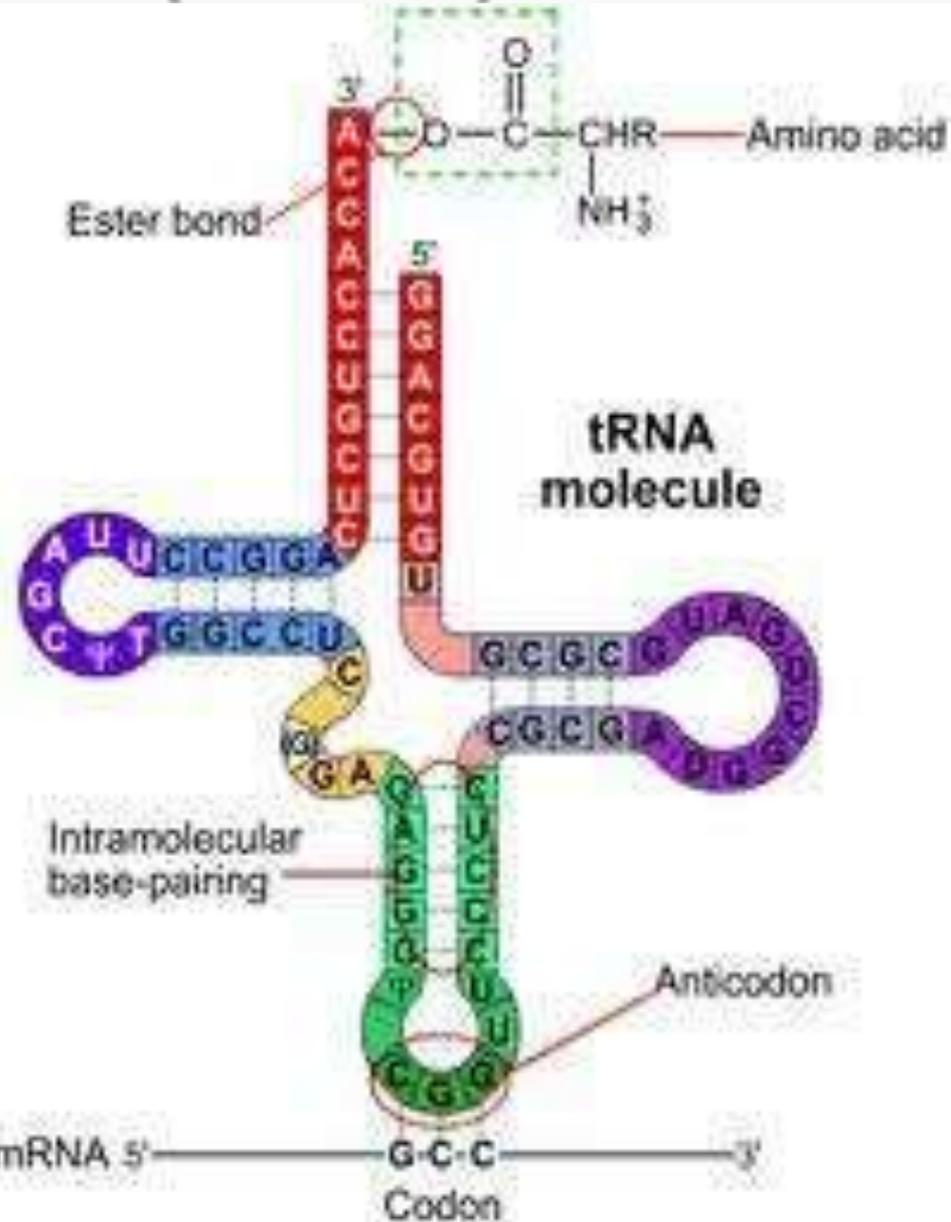
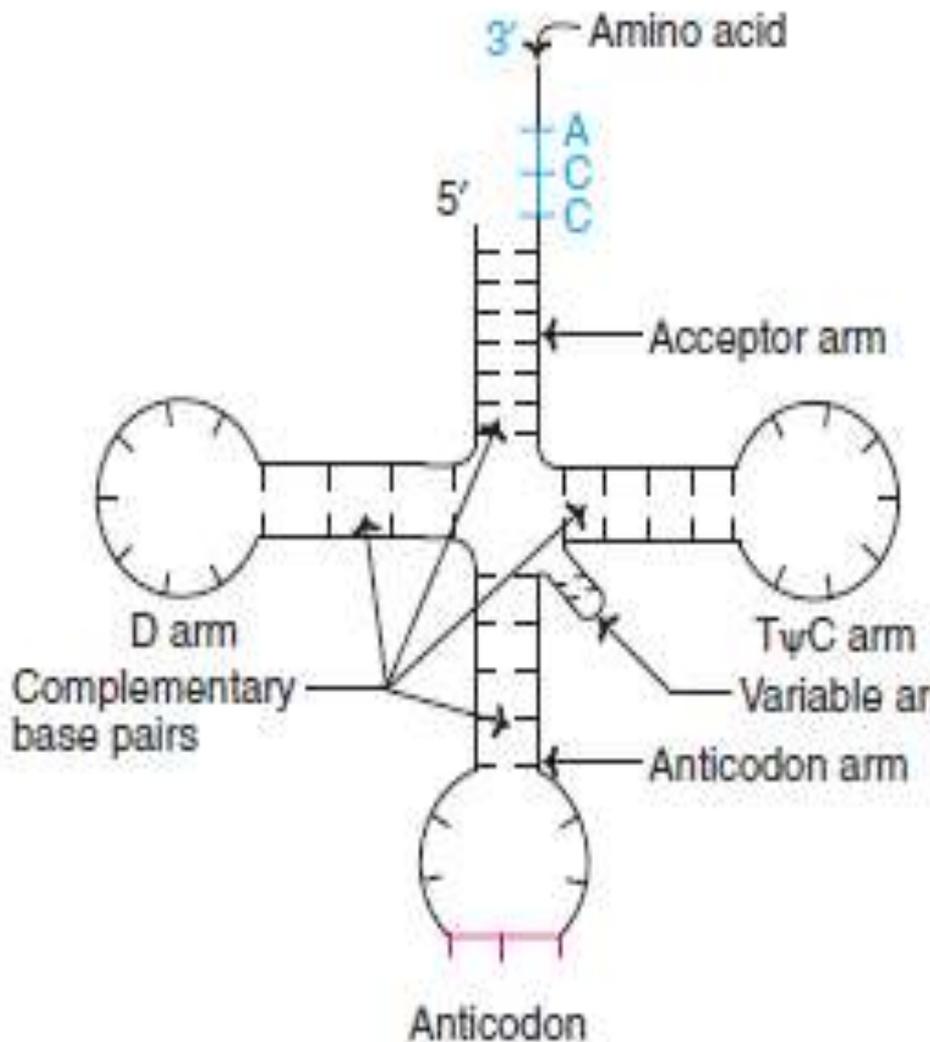


Fig. 5.16 : Structure of transfer RNA.

Transfer RNA (t-RNA)

1. **The acceptor arm** : This arm is capped with a sequence CCA (5'to 3'). The amino acid is attached to the acceptor arm.
2. **The anticodon arm** : This arm, with the three specific nucleotide bases (anticodon), is responsible for the recognition of triplet codon of mRNA. The codon and anticodon are complementary to each other.
3. **The D arm** : It is so named due to the presence of dihydrouridine.
4. **The T ψ C arm** : This arm contains a sequence of T, pseudouridine (represented by psi, ψ) and C.

Transfer RNA (t-RNA)

- **The variable arm** : This arm is the most variable in tRNA. Based on this variability, tRNAs are classified into 2 categories :

(a) **Class I tRNAs** : The most predominant (about 75%) form with 3-5 base pairs length.

(b) **Class II tRNAs** : They contain 13-20 base pair long arm.

Base pairs in tRNA : The four arms with their respective base pairs are given below

The acceptor arm – 7 bp

The T ψ C arm – 5 bp

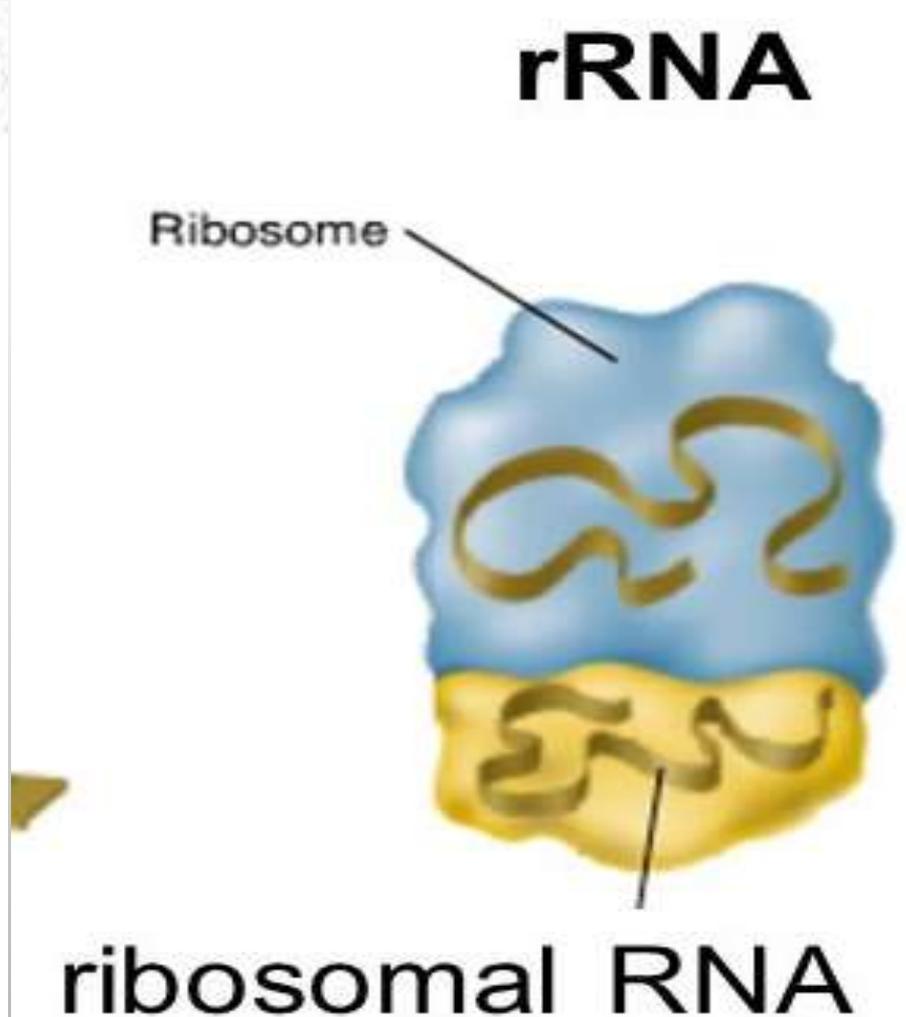
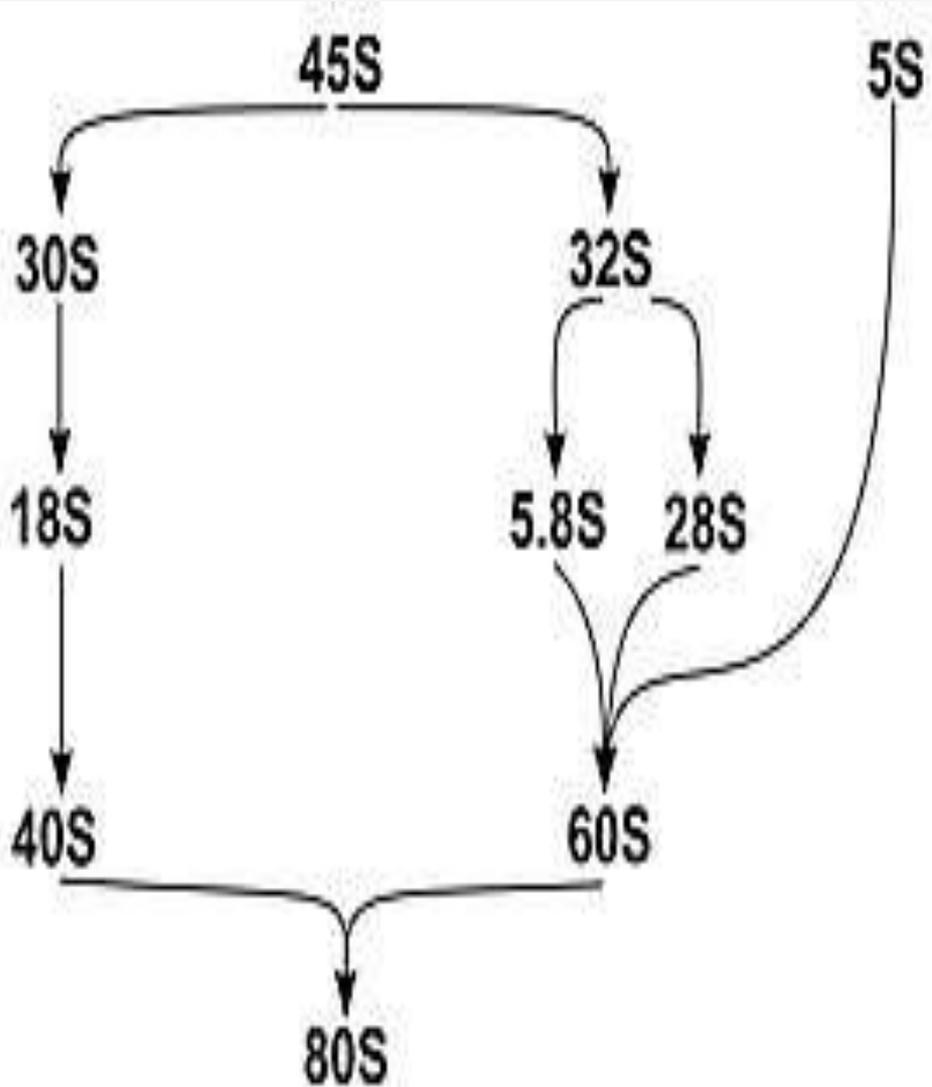
The anticodon arm – 5 bp

The D arm – 4 bp

Ribosomal RNA (rRNA)

- ❖ The ribosomes are the factories of protein synthesis.
- ❖ The eukaryotic ribosomes are composed of two major nucleoprotein complexes—60S subunit and 40S subunit.
- ❖ The 60S subunit contains 28S rRNA, 5S rRNA and 5.8S rRNA while the 40S subunit contains 18S rRNA.
- ❖ The function of rRNAs in ribosomes is not clearly known. It is believed that they play a significant role in the binding of mRNA to ribosomes and protein synthesis.

Ribosomal RNA (rRNA)



Cellular RNAs and their function(s)

TABLE 5.3 Cellular RNAs and their function(s)

<i>Type of RNA</i>	<i>Abbreviation</i>	<i>Function(s)</i>
Messenger RNA	mRNA	Transfers genetic information from genes to ribosomes to synthesize proteins.
Heterogeneous nuclear RNA	hnRNA	Serves as precursor for mRNA and other RNAs.
Transfer RNA	tRNA	Transfers amino acid to mRNA for protein biosynthesis.
Ribosomal RNA	rRNA	Provides structural framework for ribosomes.
Small nuclear RNA	snRNA	Involved in mRNA processing.
Small nucleolar RNA	snoRNA	Plays a key role in the processing of rRNA molecules.
Small cytoplasmic RNA	scRNA	Involved in the selection of proteins for export.
Transfer-messenger RNA	tmRNA	Mostly present in bacteria. Adds short peptide tags to proteins to facilitate the degradation of incorrectly synthesized proteins.

CATALYTIC RNAs—RIBOZYMES

- In certain instances, the RNA component of a ribonucleoprotein (RNA in association with protein) is catalytically active. Such RNAs are termed as ribozymes.

TABLE 5.4 A selected list of ribozymes and the corresponding biochemical reactions

<i>Ribozyme(s)</i>	<i>Biochemical reaction(s)</i>
rRNA	Peptide bond formation in protein biosynthesis
RNase P	RNA cleavage and ligation
Self-splicing RNAs	DNA cleavage
RNAs of spliceosome	RNA splicing
<i>In vitro</i> selected RNAs	RNA polymerization, RNA phosphorylation RNA aminoacylation Glycoside bond formation Oxidation-reduction reactions Disulfide exchange

THANK YOU

