Unit-VII : Genetics and Evolution

Chapter 5

MOLECULAR BASIS OF INHERITANCE

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NUCLEIC ACIDS (DNA/RNA)

- In 1869, Friedrich Miescher discovered Nucleic Acids
- He found it in a cellular substance from nuclei of pus cells
- He named it Nuclein
- Nuclein showed acidic properties hence it got renamed as Nucleic Acid

DNA

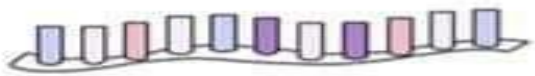
- DNA is a long polymer of Deoxyribonucleotides
- The length of DNA is defined as no. of nucleotides (in base pairs)

  - Bacteriophage ϕ x 174 → 5386 nucleotides
  - Escherichia coli (E.coli) → 4.6×10^6 bp
  - Lambda phage (λ) → 48502 bp
  - Human DNA (haploid) → 3.3×10^9 bp

- Offsprings inherit genes from their parents
  - DNA → Deoxyribonucleic acid
- Nucleic acids are polymers of Nucleotides
- 2 types of Nucleic acids → DNA & RNA → Ribonucleic acid
- Genetic material: DNA → Mostly in all living organisms
  RNA → In Viruses

- Types of RNA

Messenger



Messenger RNA (mRNA)

Structural

Ribosomal RNA (rRNA)

Adapter

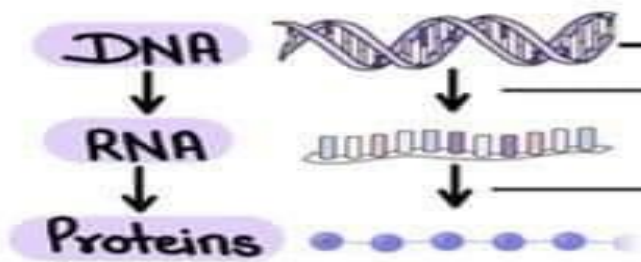
Transfer RNA (tRNA)

Catalytic

Ribozymes

- DNA is the genetic material of living organisms
  - Criteria for it to be genetic material
    1. Chemically stable
    2. Expresses accurately
    3. Replicate with minimum error
    4. Scope for mutation

- DNA → Can Replicate
- RNA → Transcription → In nucleus
- Proteins → Translation → In cytoplasm



Belief

CENTRAL DOGMA OF PROTEIN SYNTHESIS

By Francis Crick in 1958

He proposed that DNA determines the sequence of amino acids in a polypeptide (protein) through mRNA

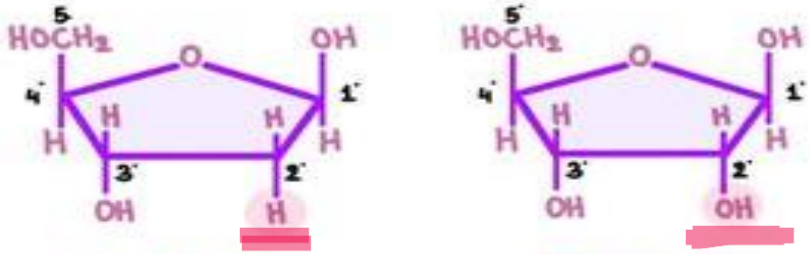
STRUCTURE OF POLYNUCLEOTIDE CHAIN

- Structural units of Nucleic Acids are NUCLEOTIDES

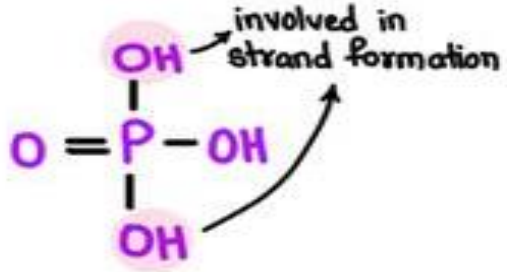
3 Components

Pentose Sugar (S)

- Deoxyribose — $C_5H_{10}O_4$
- Ribose — $C_5H_{10}O_5$



Phosphate Group (P)



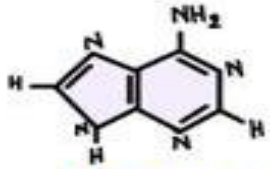
H_3PO_4

Phosphoric Acid

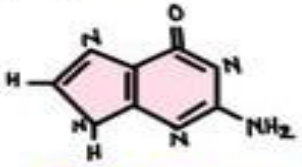
3 active OH groups

Nitrogen Bases (N)

Cyclic compounds containing C, H, O, N

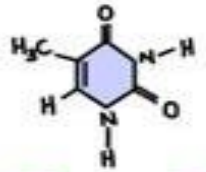


Adenine (A)

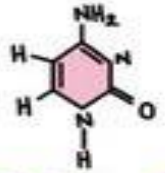


Guanine (G)

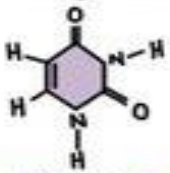
PURINES



Thymine (T)



Cytosine (C)

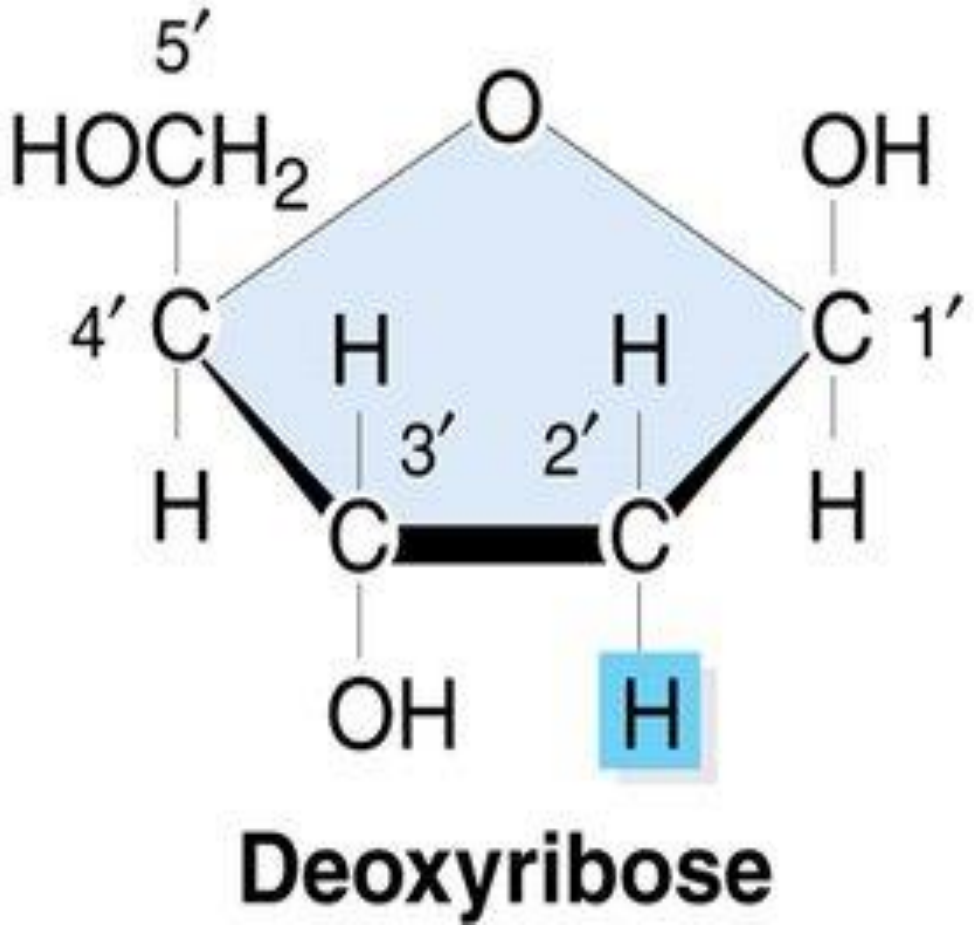


Uracil (U)

Only in RNA

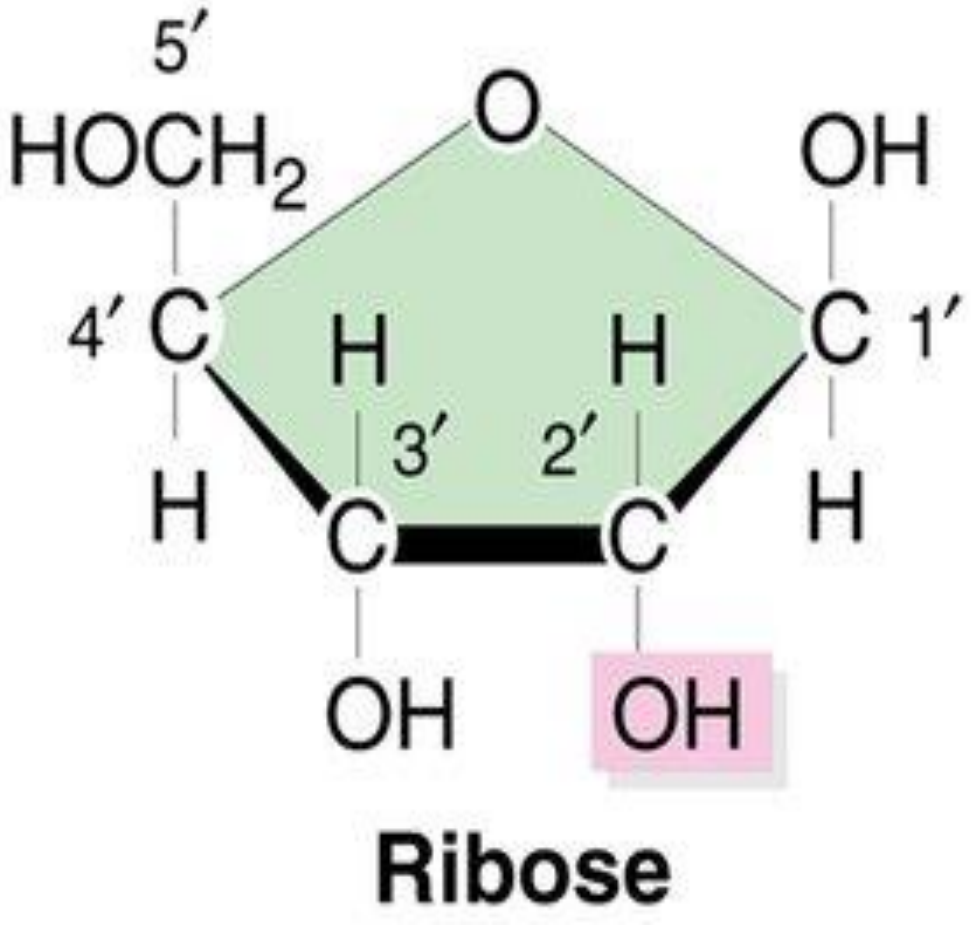
PYRIMIDINES

COMPONENT 1: SUGAR



Deoxyribose

Deoxyribose Sugar Present in DNA



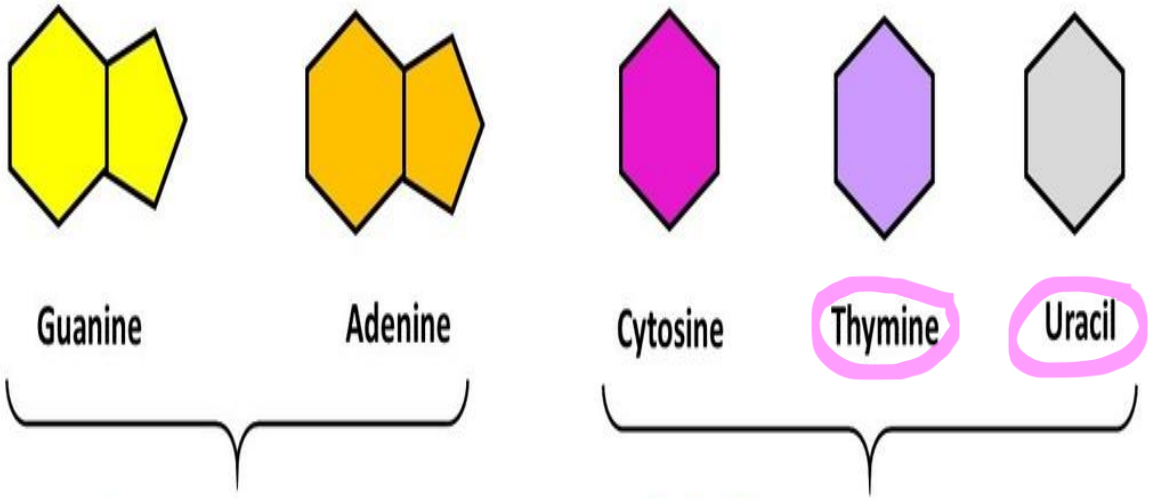
Ribose

Ribose Sugar Present in RNA

COMPONENT 2: NITROGENOUS BASE

There are five nitrogenous bases in total:

Guanine	Adenine	Cytosine	Thymine	Uracil
Found in: DNA RNA	Found in: DNA RNA	Found in: DNA RNA	Found in: DNA	Found in: RNA

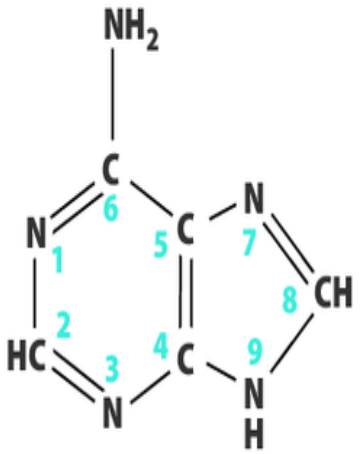


Purines = double ring structures

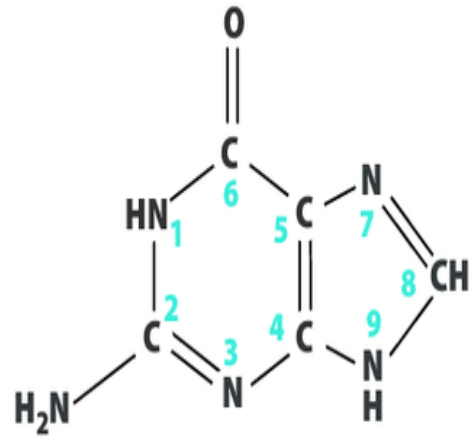
Pyrimidines = single ring structures

PURINES

adenine (A)



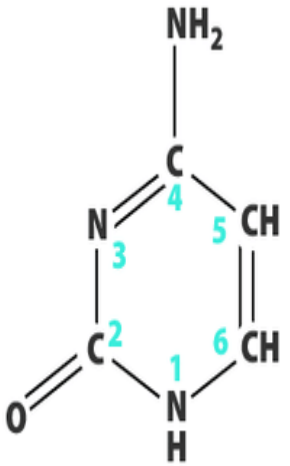
guanine (G)



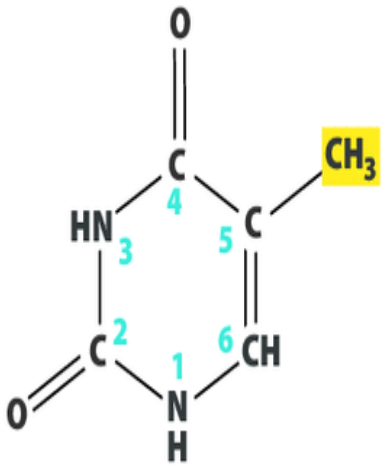
RNA

PYRIMIDINES

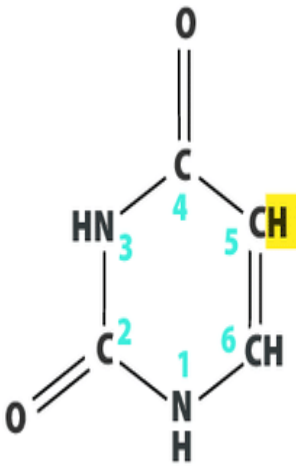
cytosine (C)

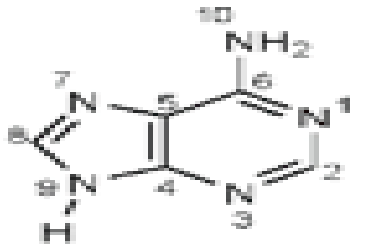
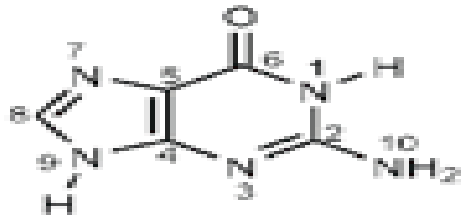
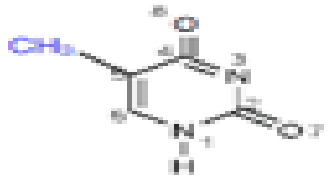
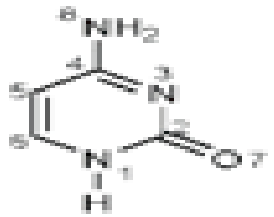
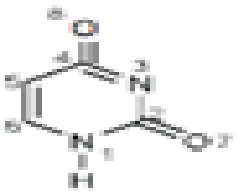


thymine (T)

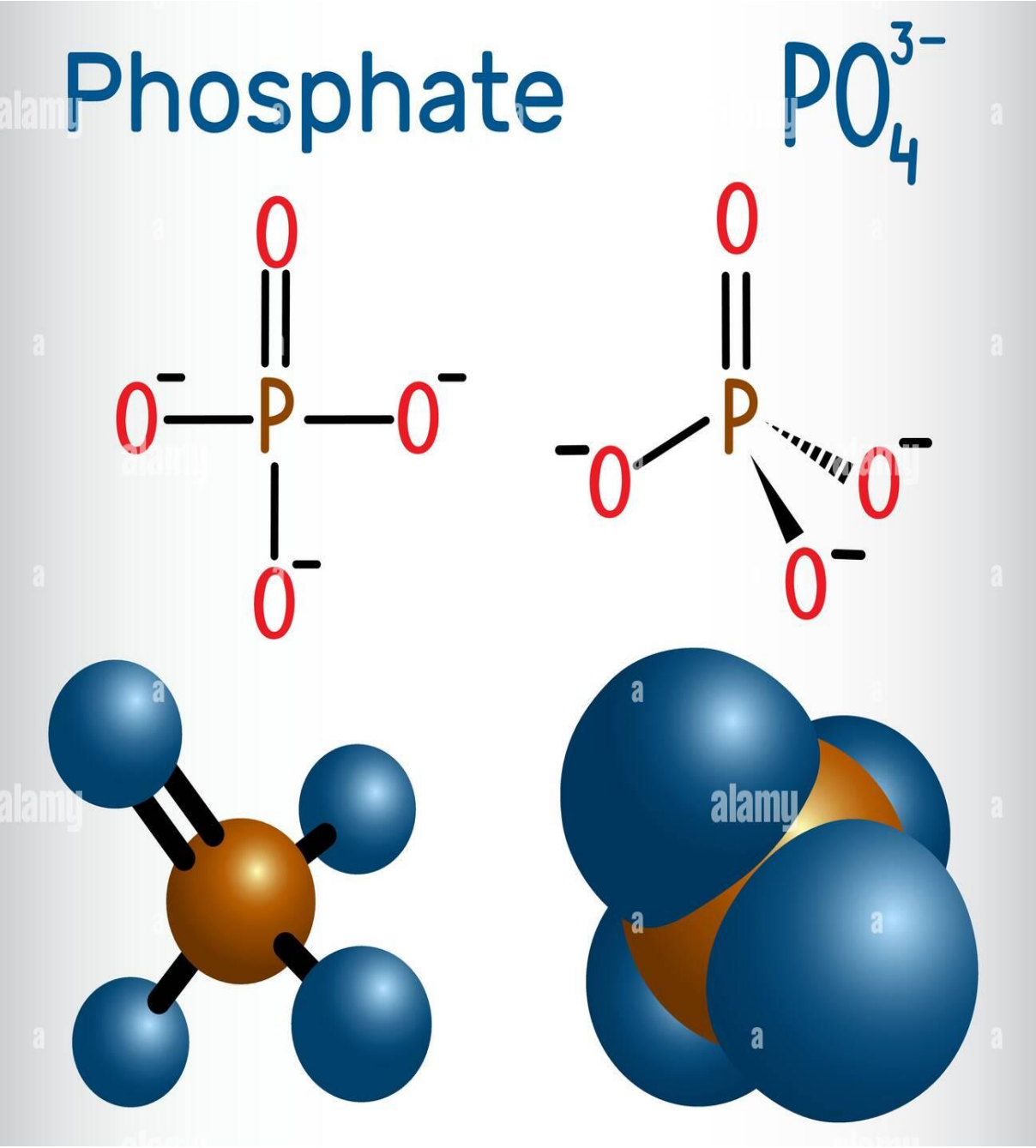


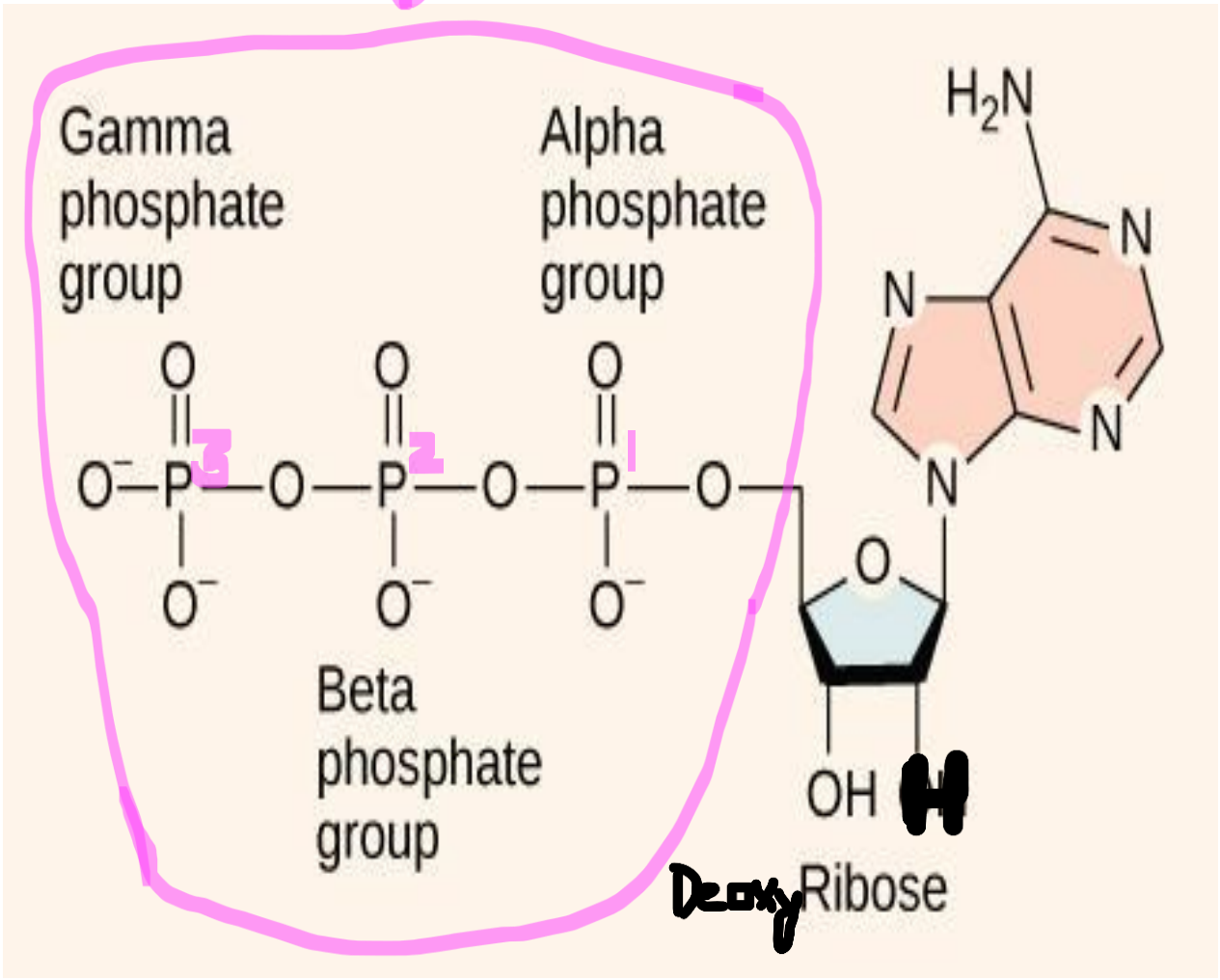
uracil (U)



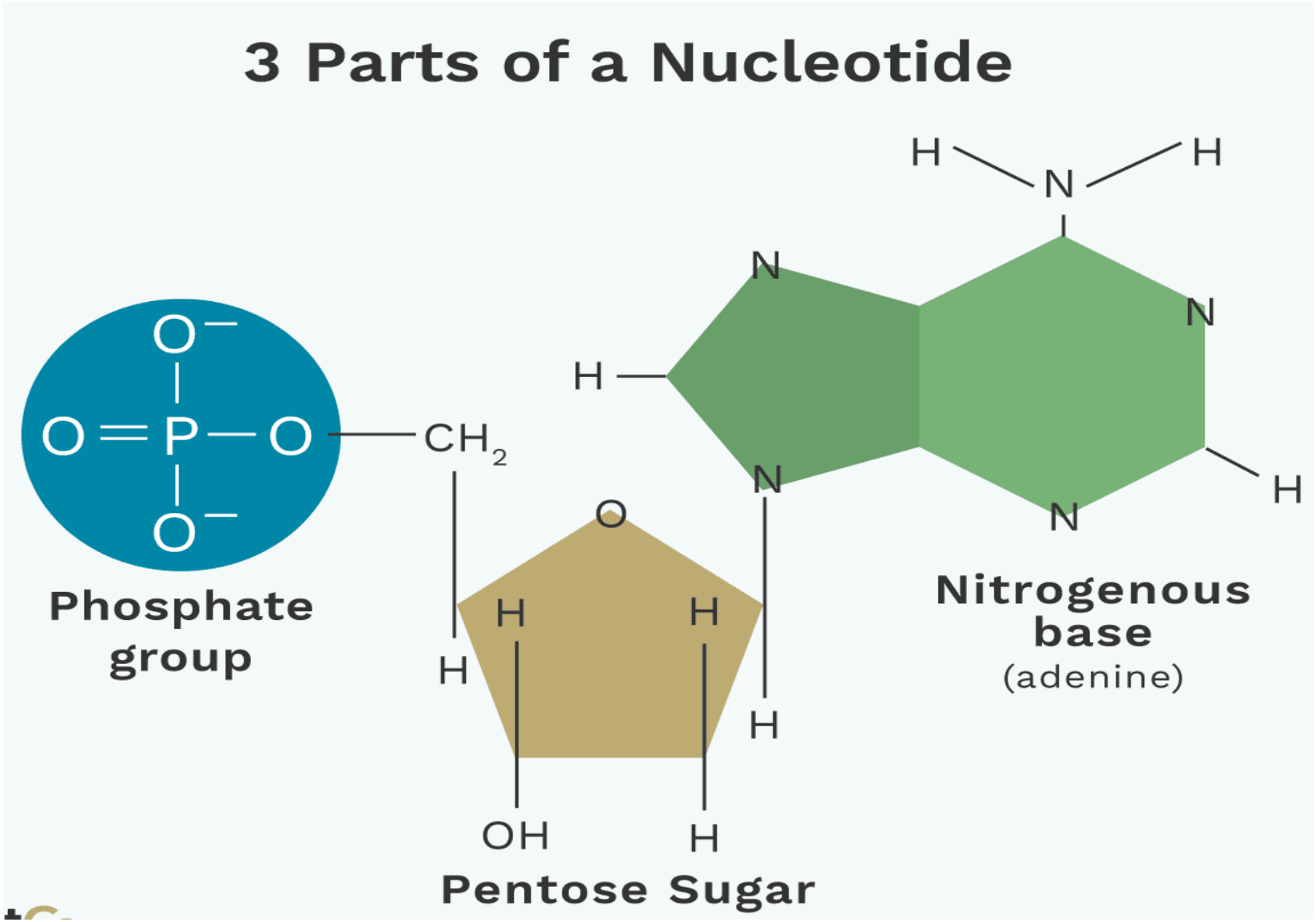
Nitrogen bases		IUPAC name	Structure
Purine	Adenine	6-amino purine	
	Guanine	2-amino, 6- oxy purines	
Pyrimidine	Thymine	2, 4- dioxy, 5 methyl pyrimidine	
	Cytosine	4-amino 2-oxy pyrimidine	
	Uracil	2, 4- dioxy pyrimidine	

COMPONENT 3: PHOSPHATE GROUP





Structure of a *Nucleotide*

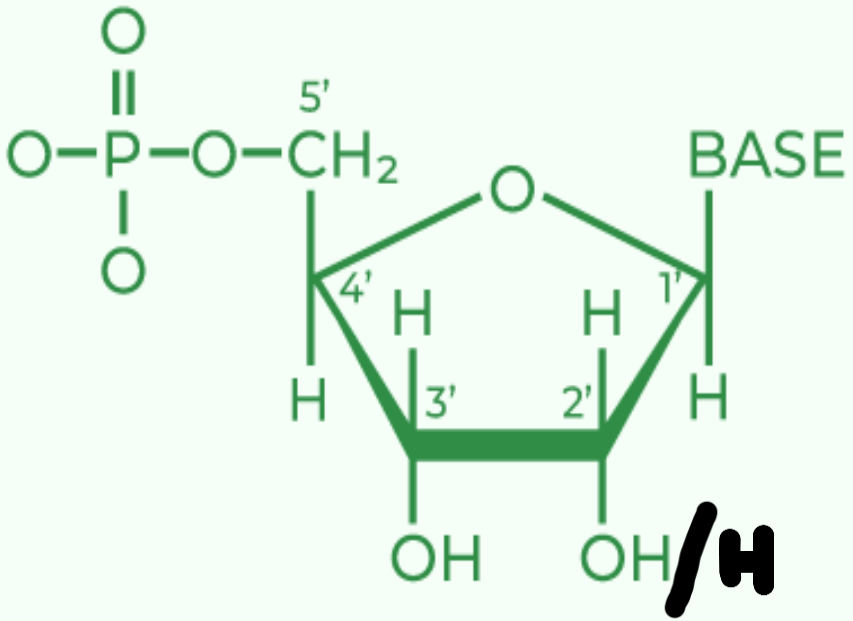


3 Parts
Or
Components Combine
To Form A Nucleotide

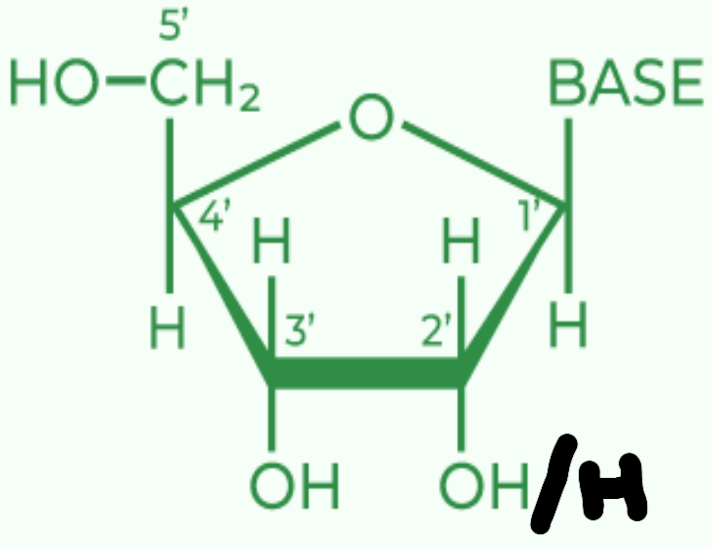
NUCLEOTIDE

A nucleotide is an organic molecule consisting of a nitrogenous base, pentose sugar, and one or more phosphate groups.

Difference between
Nucleotide & Nucleoside

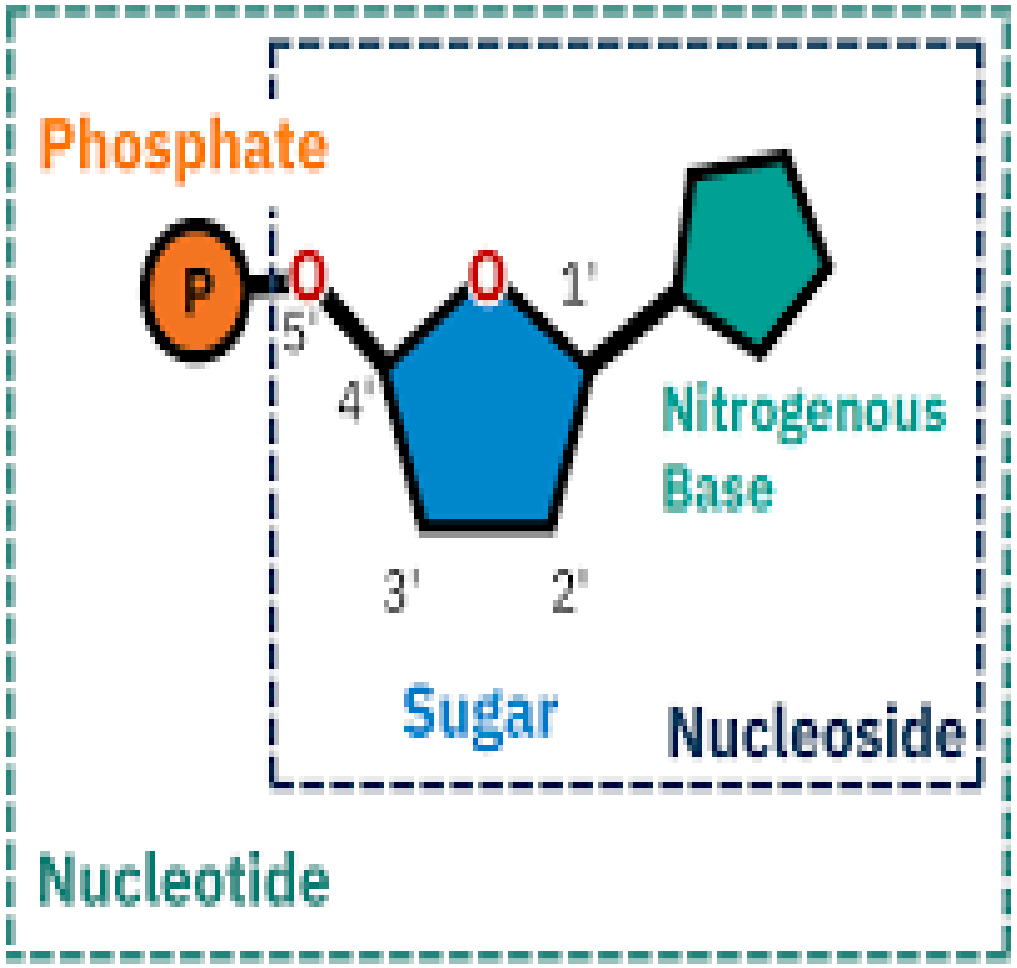


Nucleotide



Nucleoside

NUCLEOSIDE AND NUCLEOTIDE



RNA contains Ribose while DNA contains 2'deoxy-D-Ribose

Nucleoside: Nitrogenous base + ribose:

Nucleotide and Nucleic Acid Nomenclature

Base	Nucleoside*	Nucleotide*	Nucleic acid
Purines			
Adenine	Adenosine	Adenylate	RNA
	Deoxyadenosine	Deoxyadenylate	DNA
Guanine	Guanosine	Guanylate	RNA
	Deoxyguanosine	Deoxyguanylate	DNA
Pyrimidines			
Cytosine	Cytidine	Cytidylate	RNA
	Deoxycytidine	Deoxycytidylate	DNA
Thymine	Thymidine or deoxythymidine	Thymidylate or deoxythymidylate	DNA
Uracil	Uridine	Uridylate	RNA

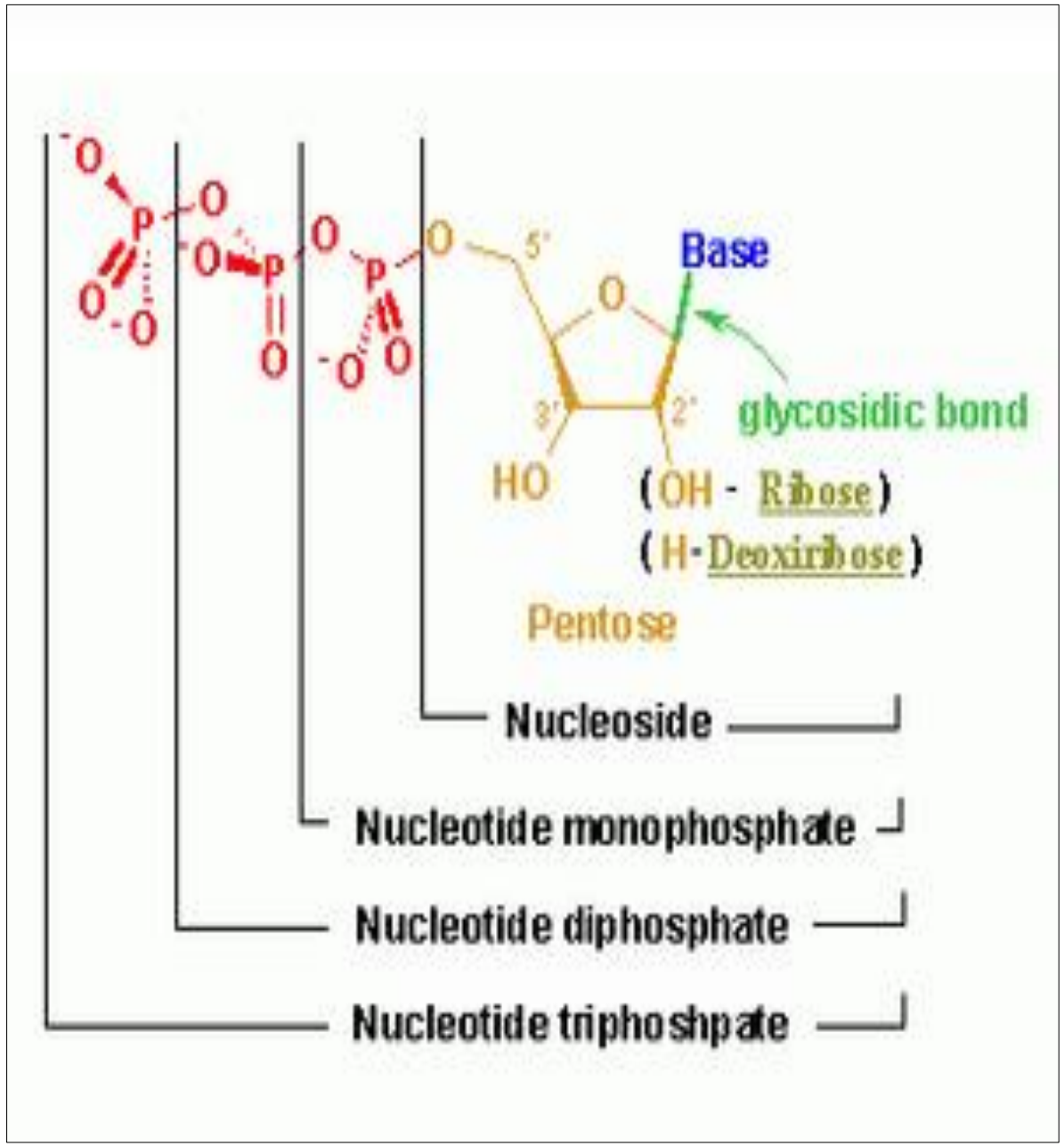
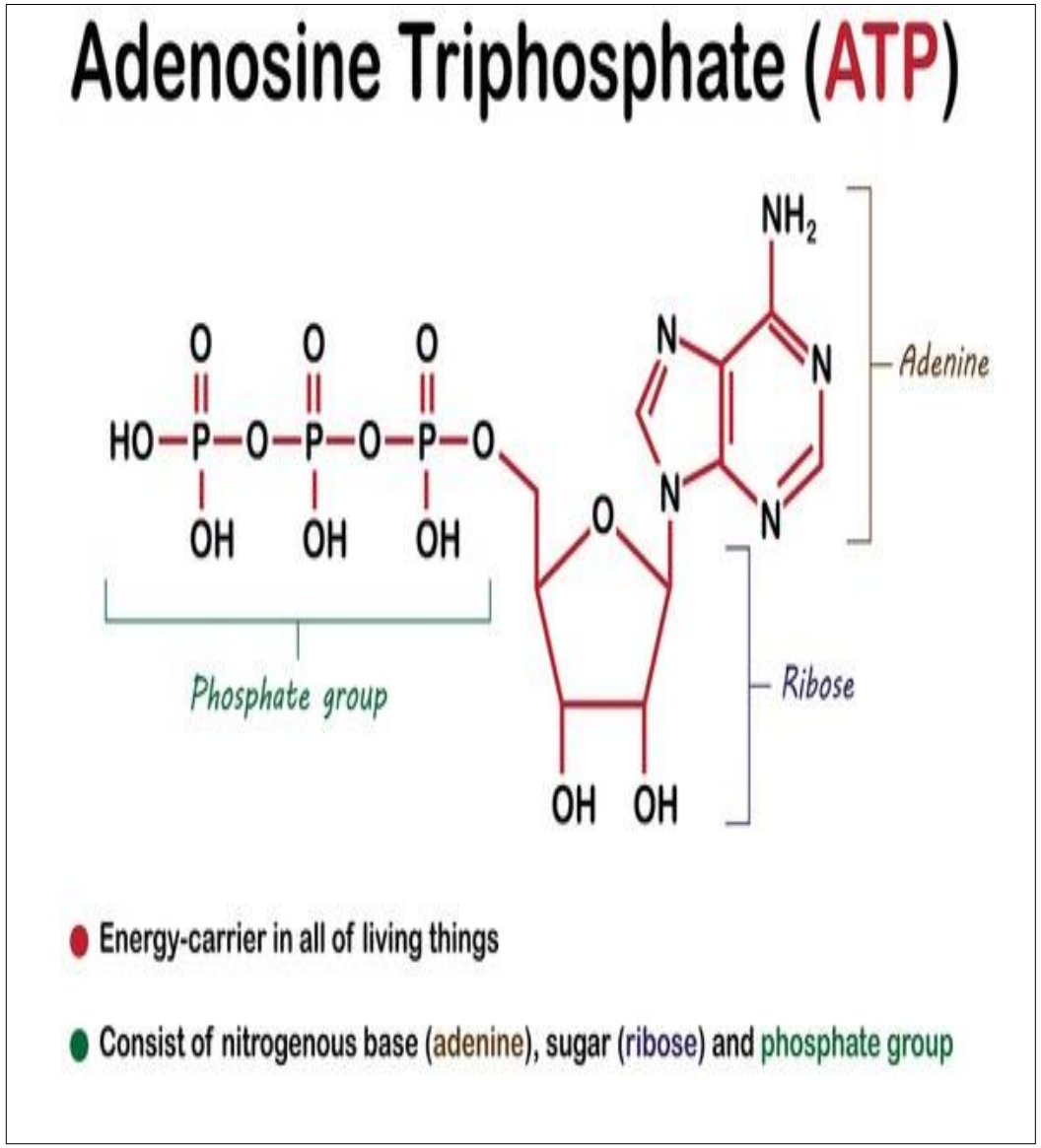
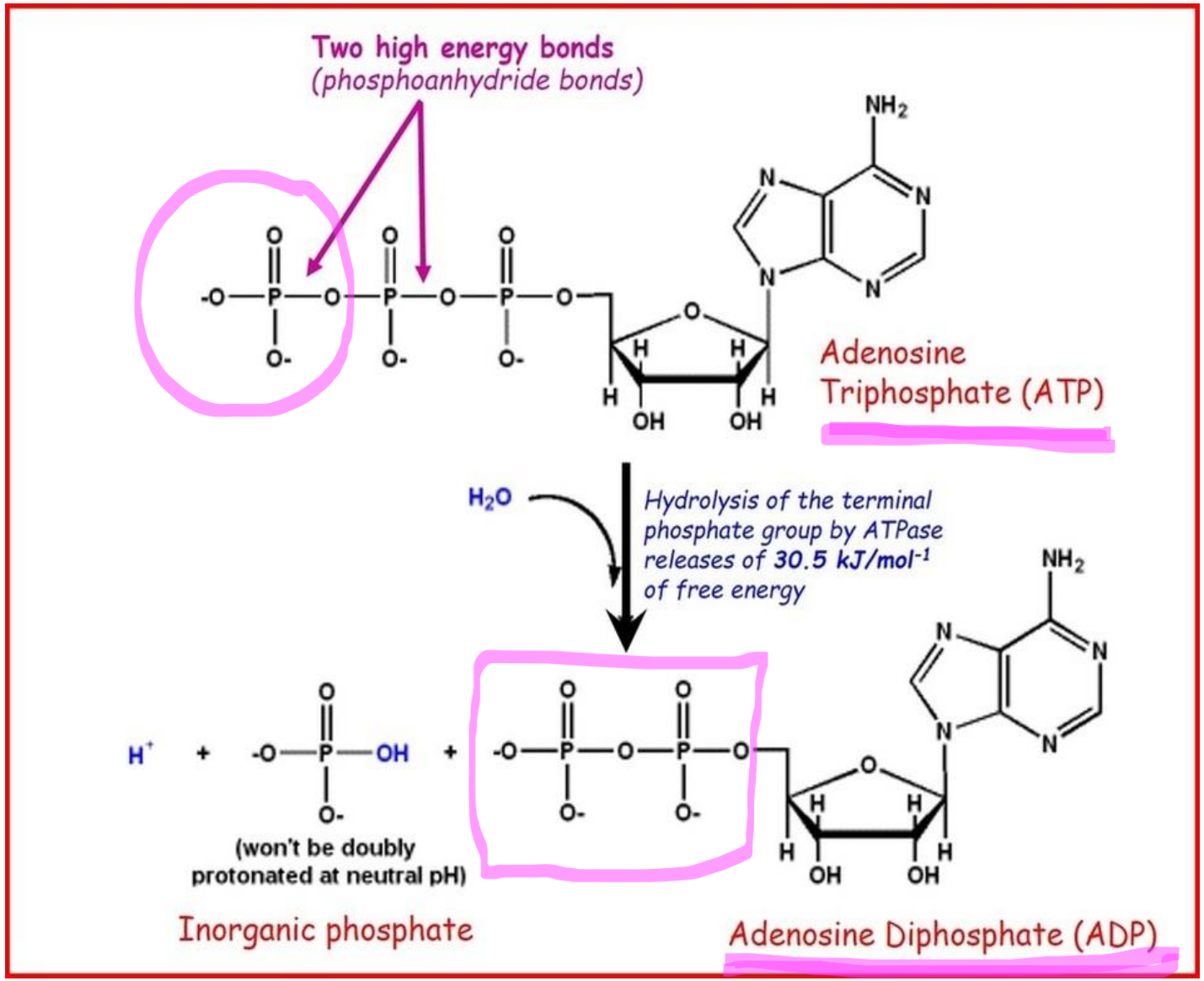


Table Bases, their nucleosides and nucleotides

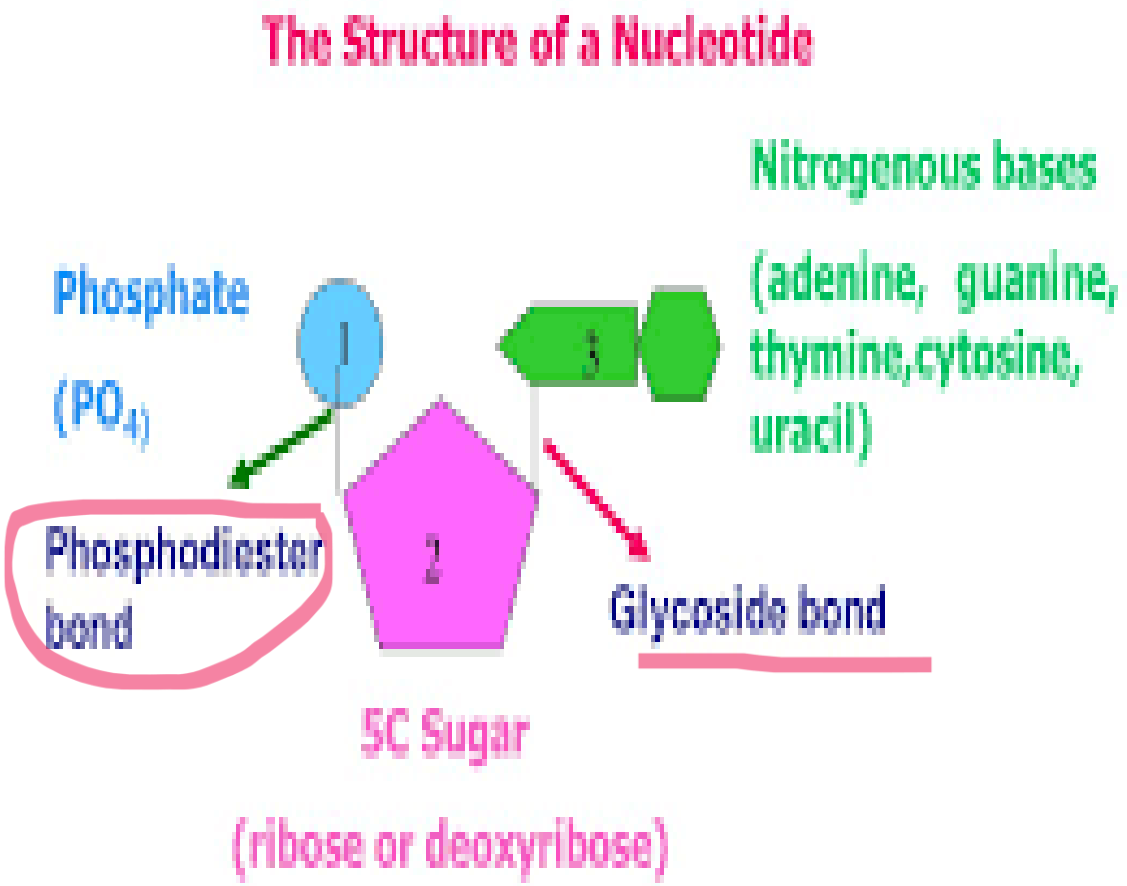
Name of the base	Sugar	Nucleoside	No. of Phosphate Groups	Nucleotide
Adenine	Ribose	Adenosine	1	AMP
			2	ADP
			3	ATP
	Deoxyribose	Deoxy Adenos-ine	1	dAMP
			2	dADP
			3	dATP
Guanine	Ribose	Guanosine	1	GMP
			2	GDP
			3	GTP
	Deoxyribose	Deoxy Guano-sine	1	dGMP
			2	dGDP
			3	dGTP
Cytosine	Ribose	Cytidine	1	CMP
			2	CDP
			3	CTP
	Deoxyribose	Deoxy Cytidine	1	dCMP
			2	dCDP
			3	dCTP
Uracil	Ribose	Uridine	1	UMP
			2	UDP
			3	UTP
	Deoxyribose	Deoxy Uridine	1	dUMP
			2	dUDP
			3	dUTP
Thymine	Ribose	Thymidine	1	TMP
			2	TDP
			3	TTP
	Deoxyribose	Deoxy Thymi-dine	1	dTMP
			2	dTDP
			3	dTTP

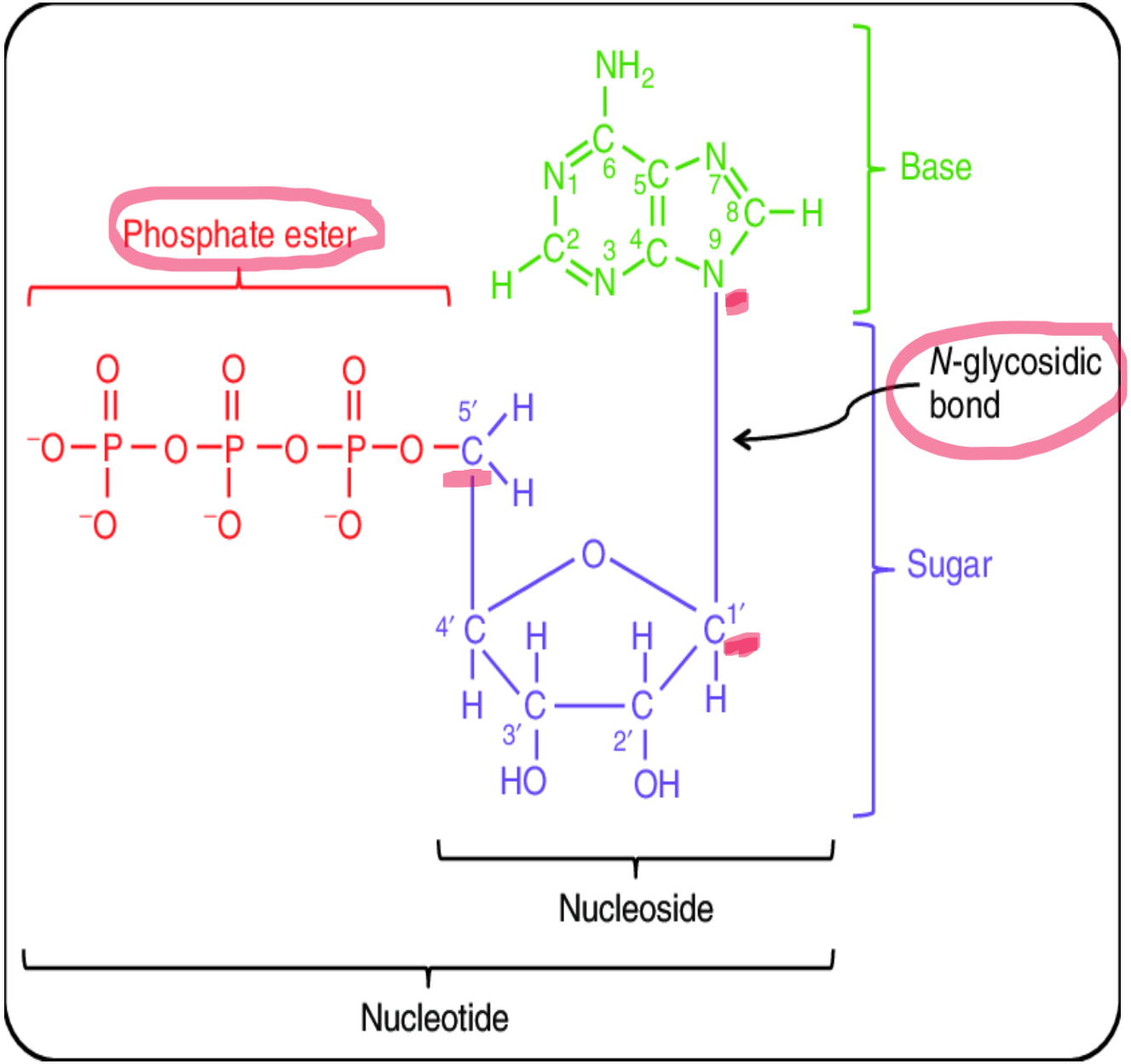
EXAMPLE OF A NUCLEOTIDE





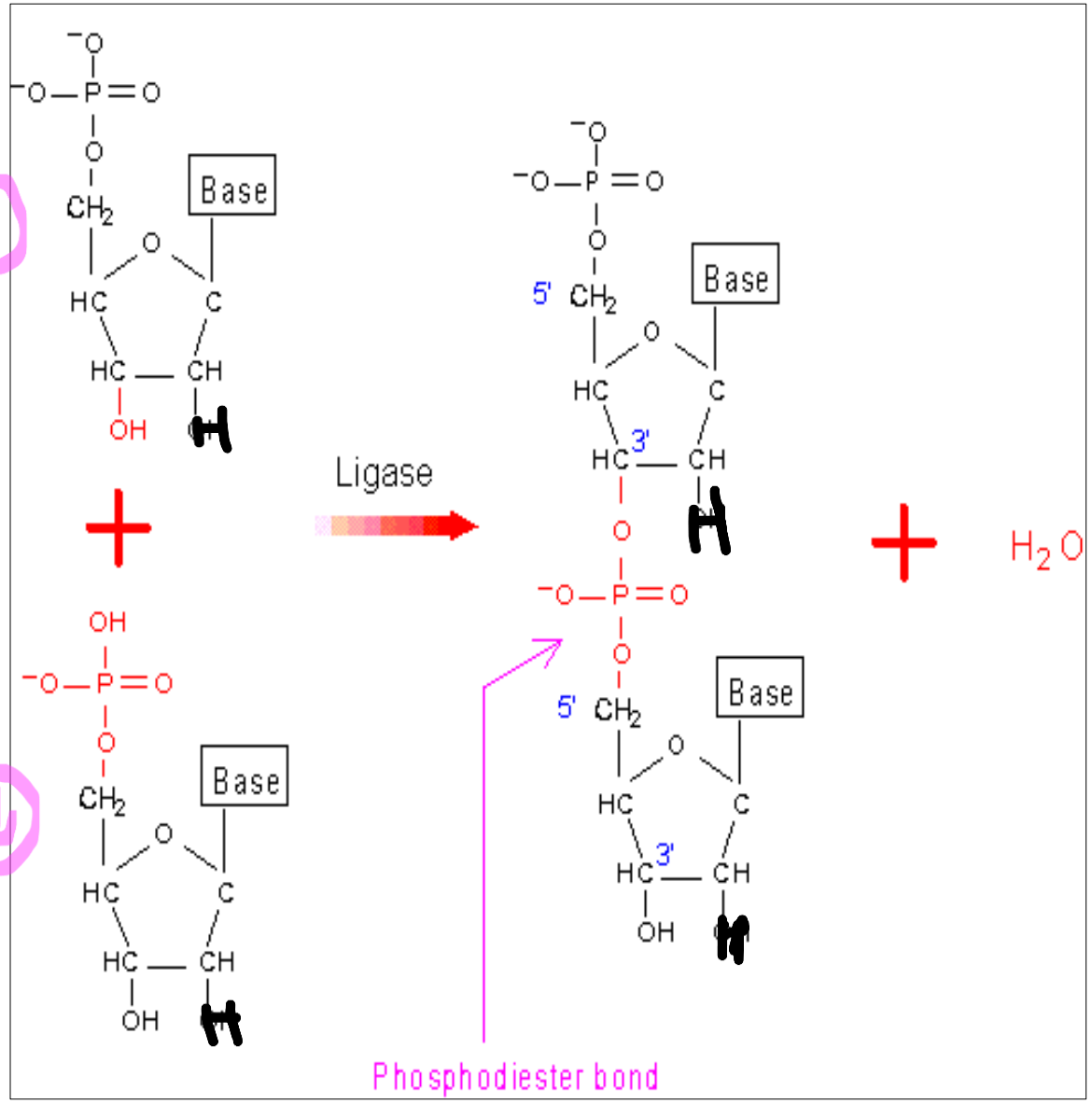
Linkages or Bonds present in a Nucleotide

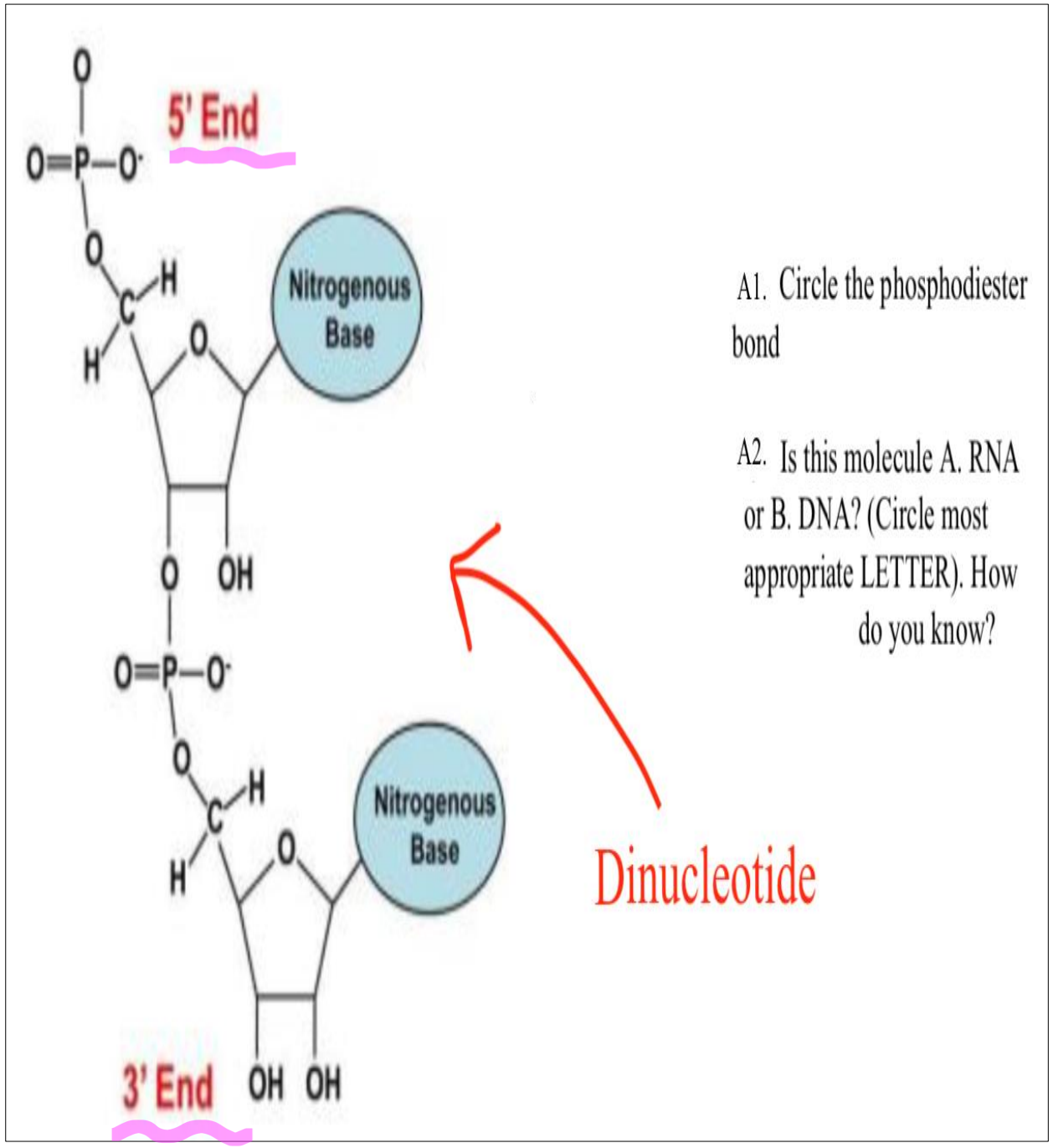




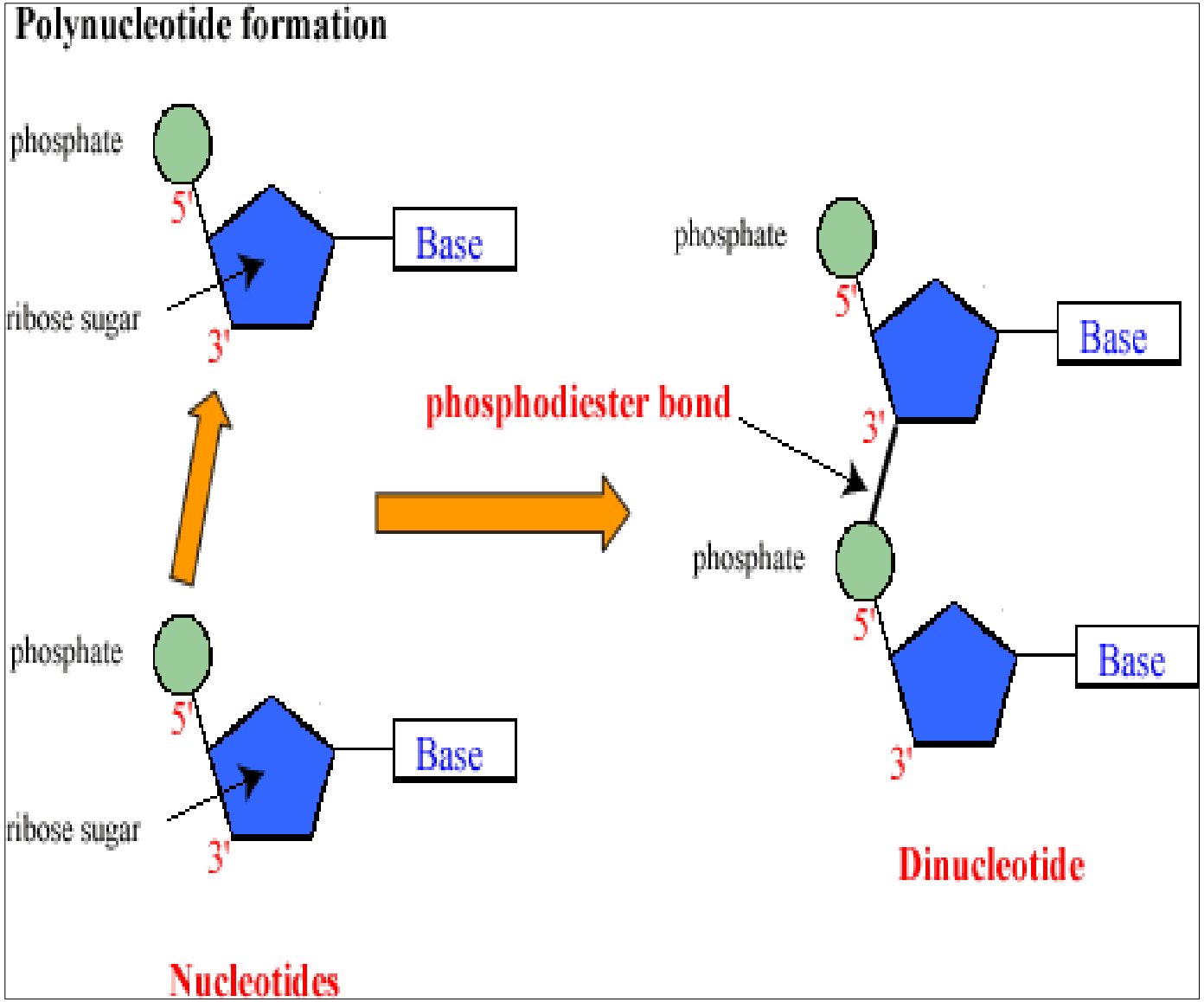
Nucleic acids are polymers of nucleotides.

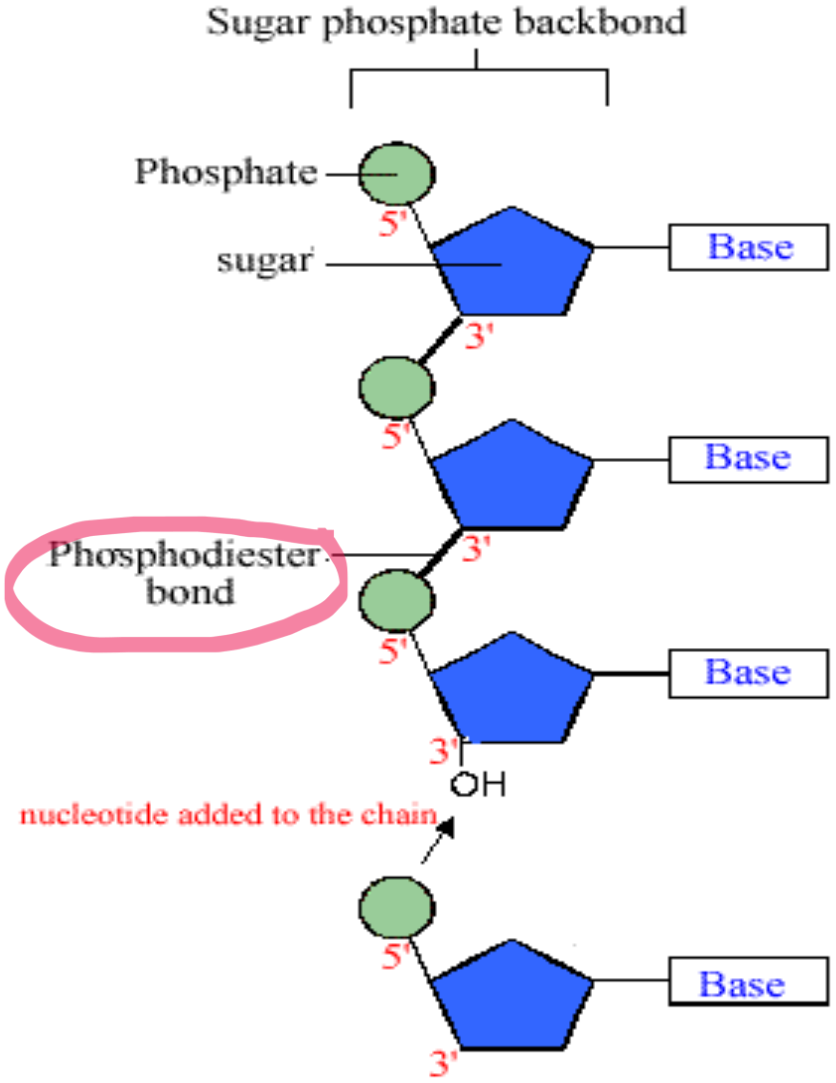
Dinucleotide

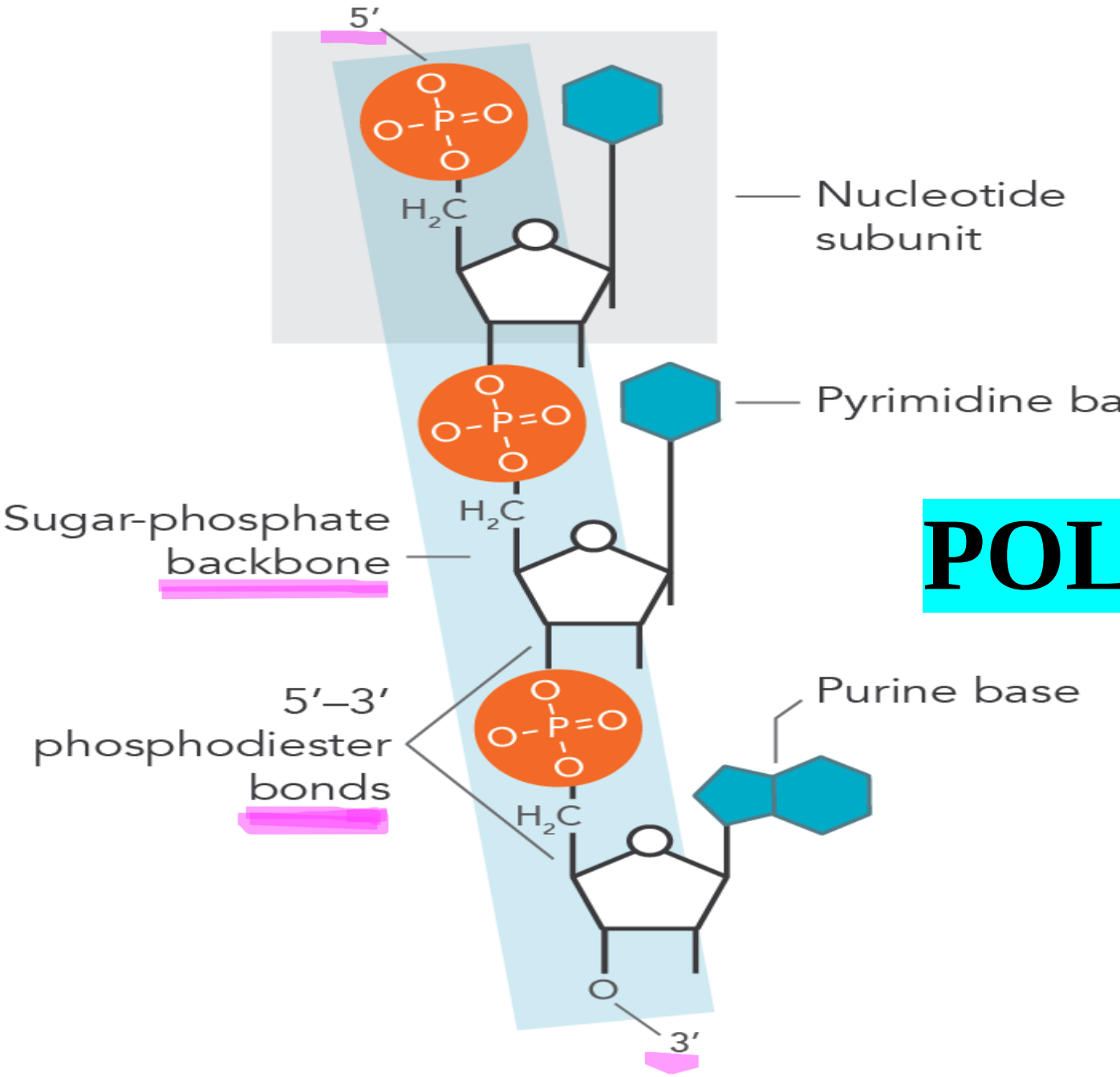




POLYNUCLEOTIDE CHAIN FORMATION & BOND





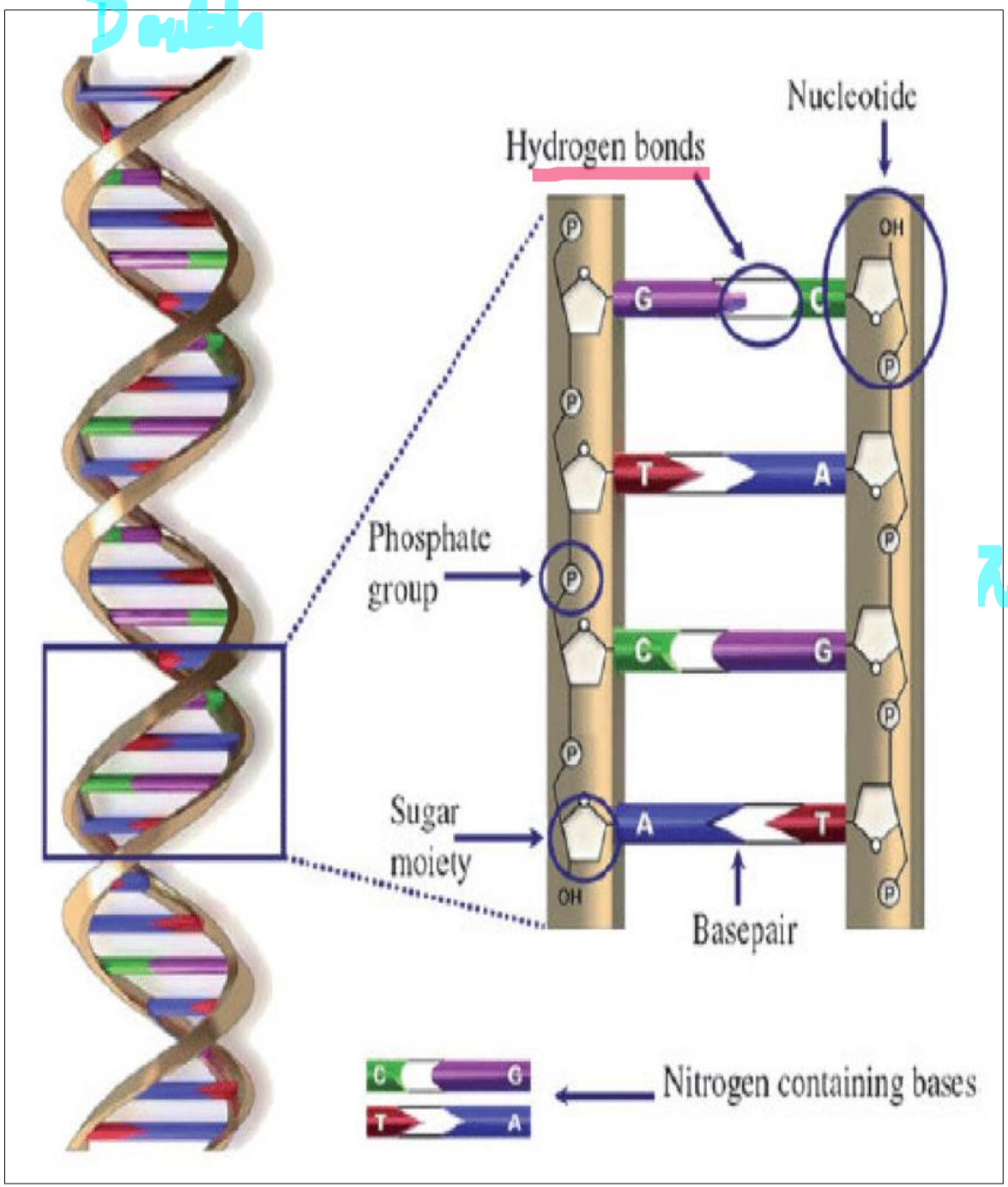


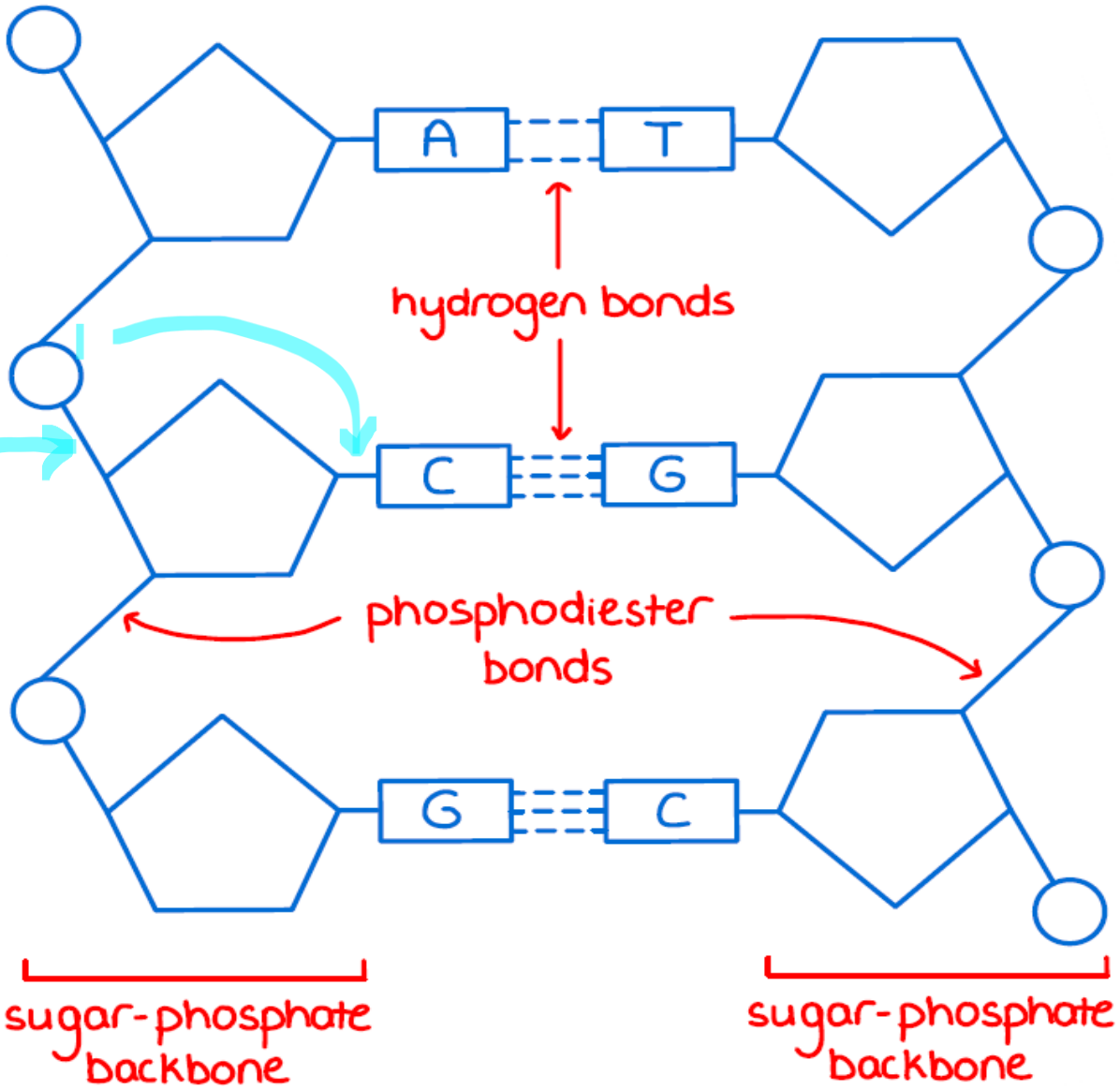
POLYNUCLEOTIDE CHAIN

(2 free ends)

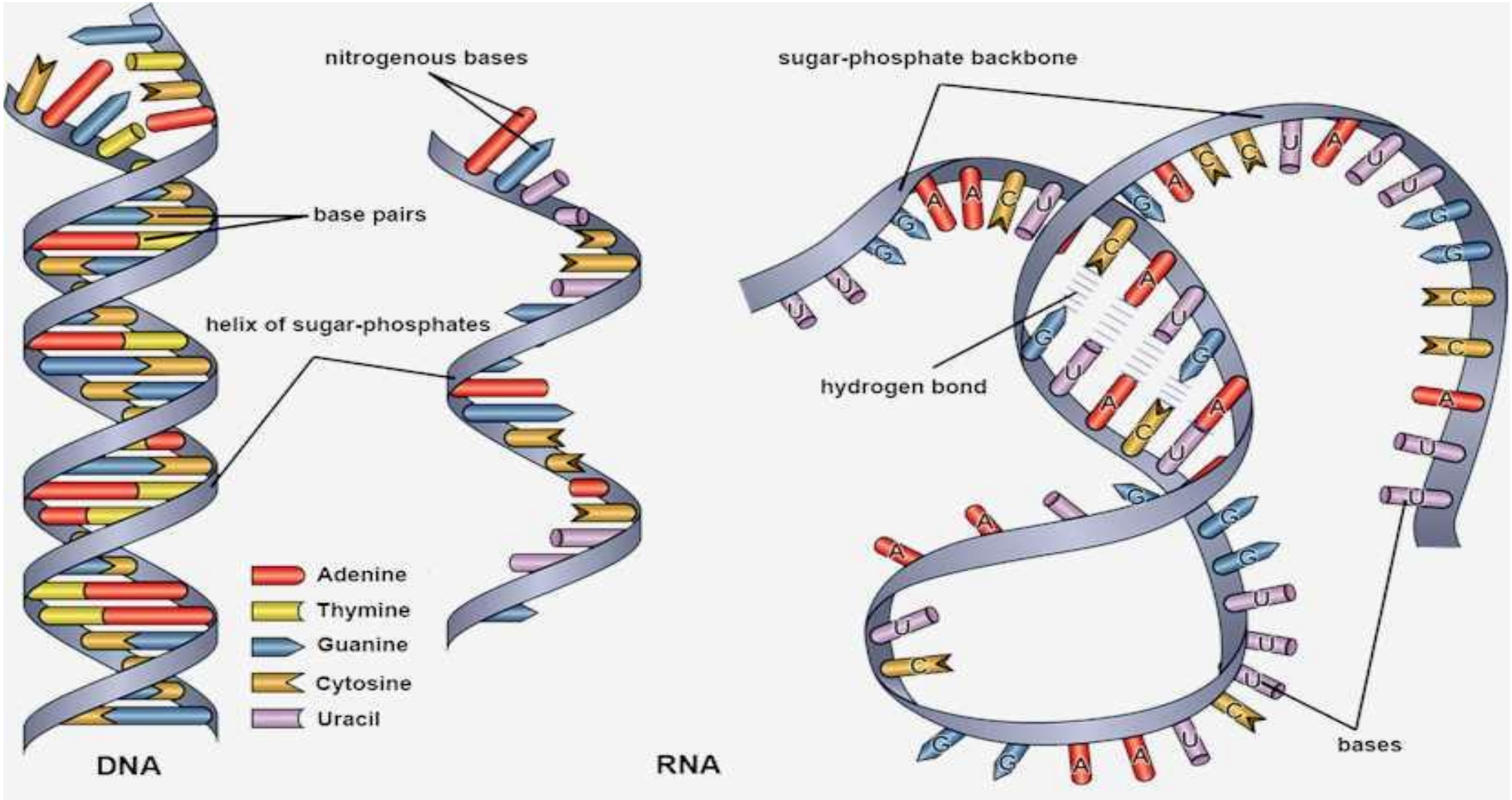
- **5’ end**
- **3’ end**

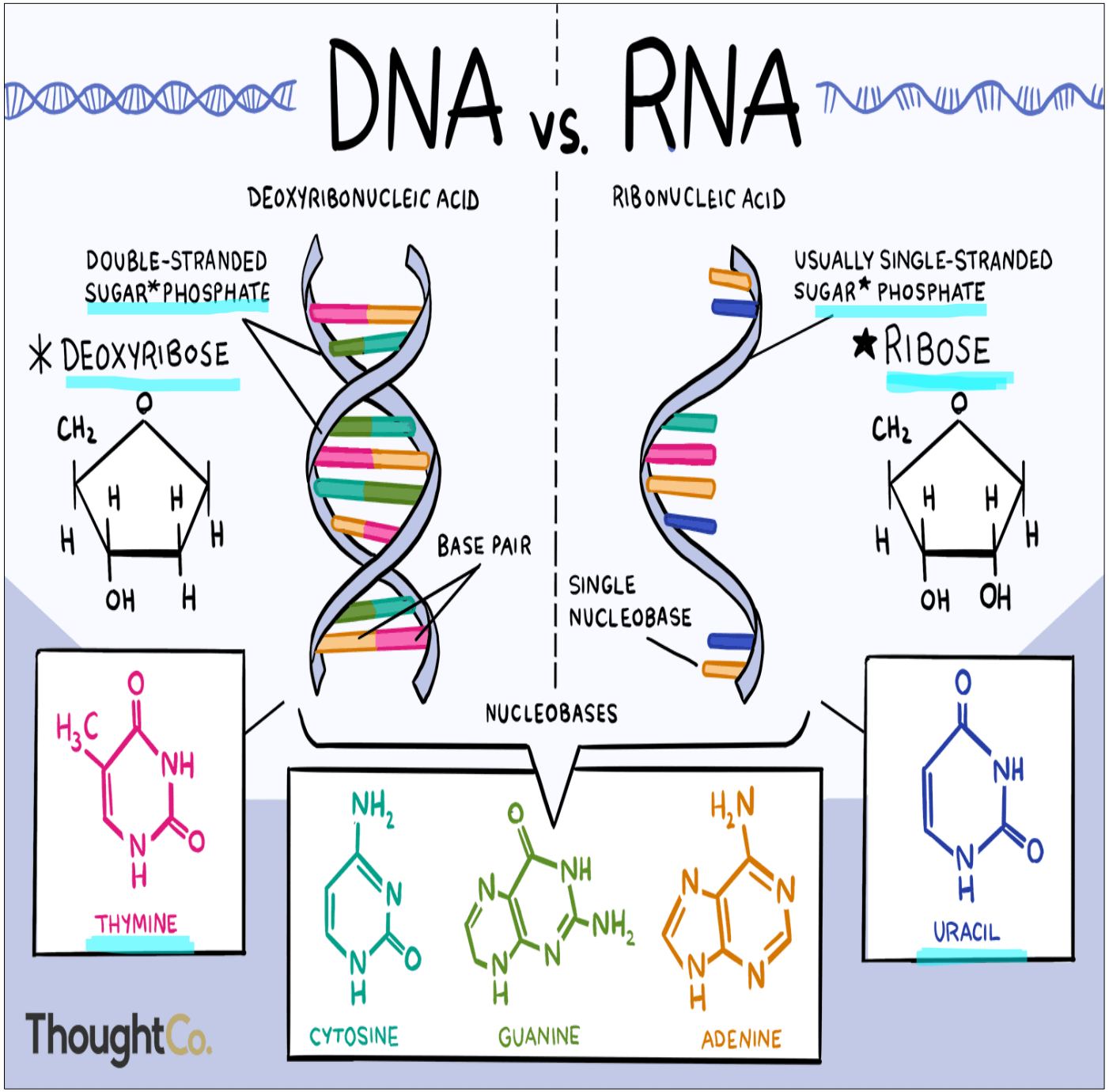
Bonds present in a DNA





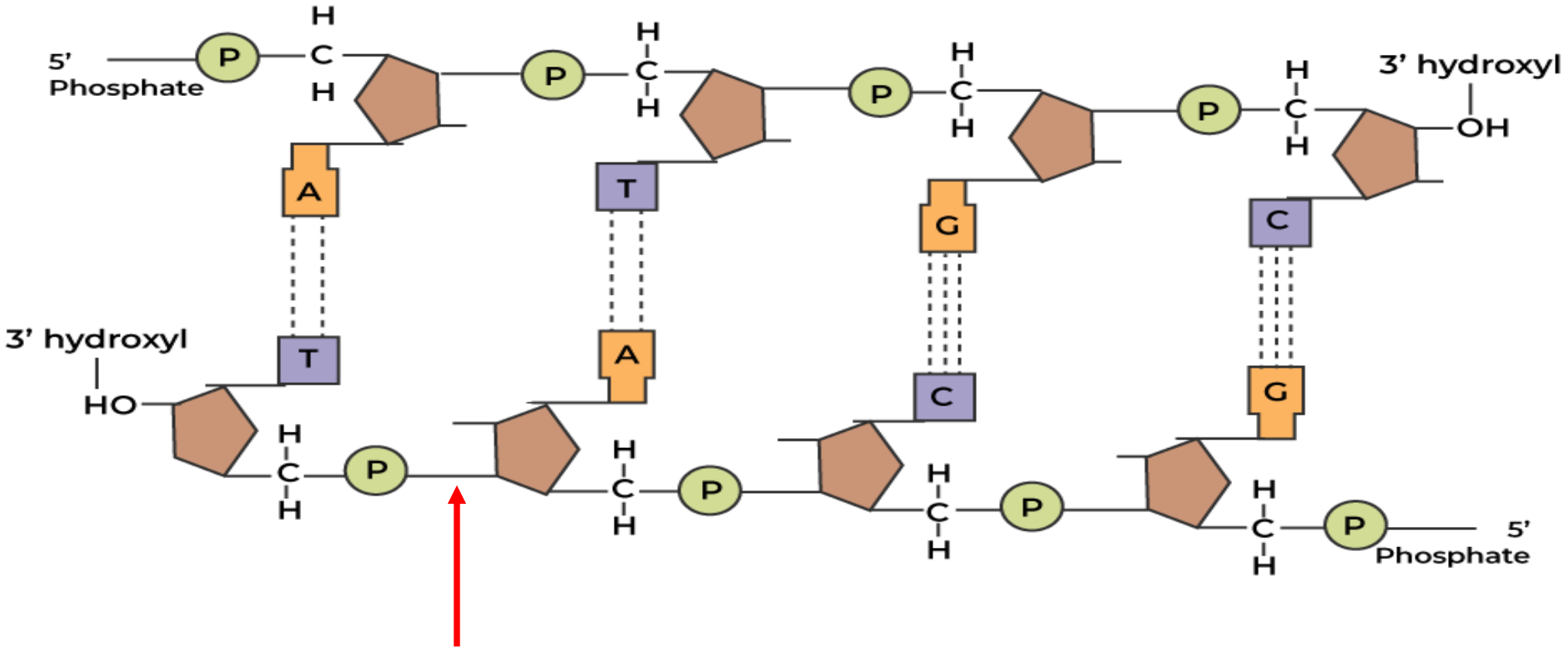
RNA (Ribonucleic Acid)



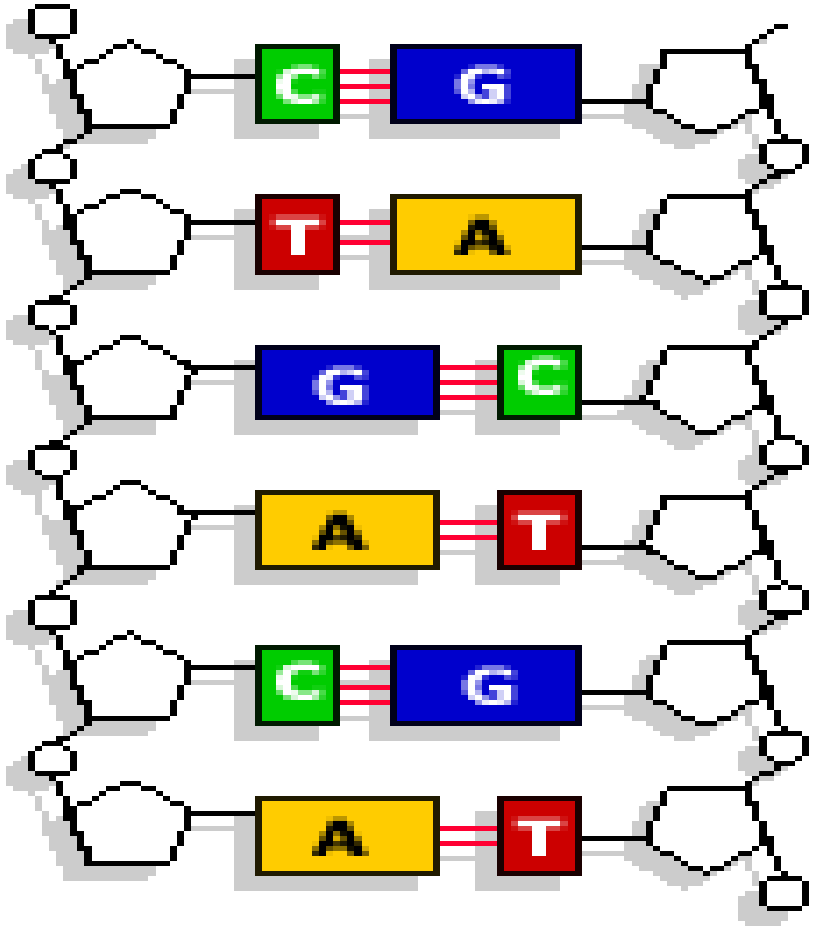


DNA	VERSUS	RNA
DNA is mostly found in nucleus and nucleoid		RNA is mostly found in the cytoplasm
Stands for deoxyribonucleic acid		Stands for ribonucleic acid
Deoxyribose is the sugar where the bases are A, T, C and G		Ribose is the sugar where the bases are A, U, C and G
A long polymer		Shorter than DNA
A pairs with T and C pairs with G		A pairs with U and C pairs with G
Double-stranded and it exhibits a double-helix structure		Single-strand, sometimes it forms secondary and tertiary structures
Prefers B-form		Prefers A-form
More prone to UV damage		Less prone to UV damage
Carries the genetic information necessary for the development, functioning, and reproduction		Mainly involved in protein synthesis, sometimes it regulates the gene expression

DNA



Backbone of Polynucleotide chain
(Phosphate & Sugar)



Base pairs are complementary to each other.

Therefore, if the sequence of one strand is known. The other strand sequence can be predicted. Because of this, the structure of DNA became clear.

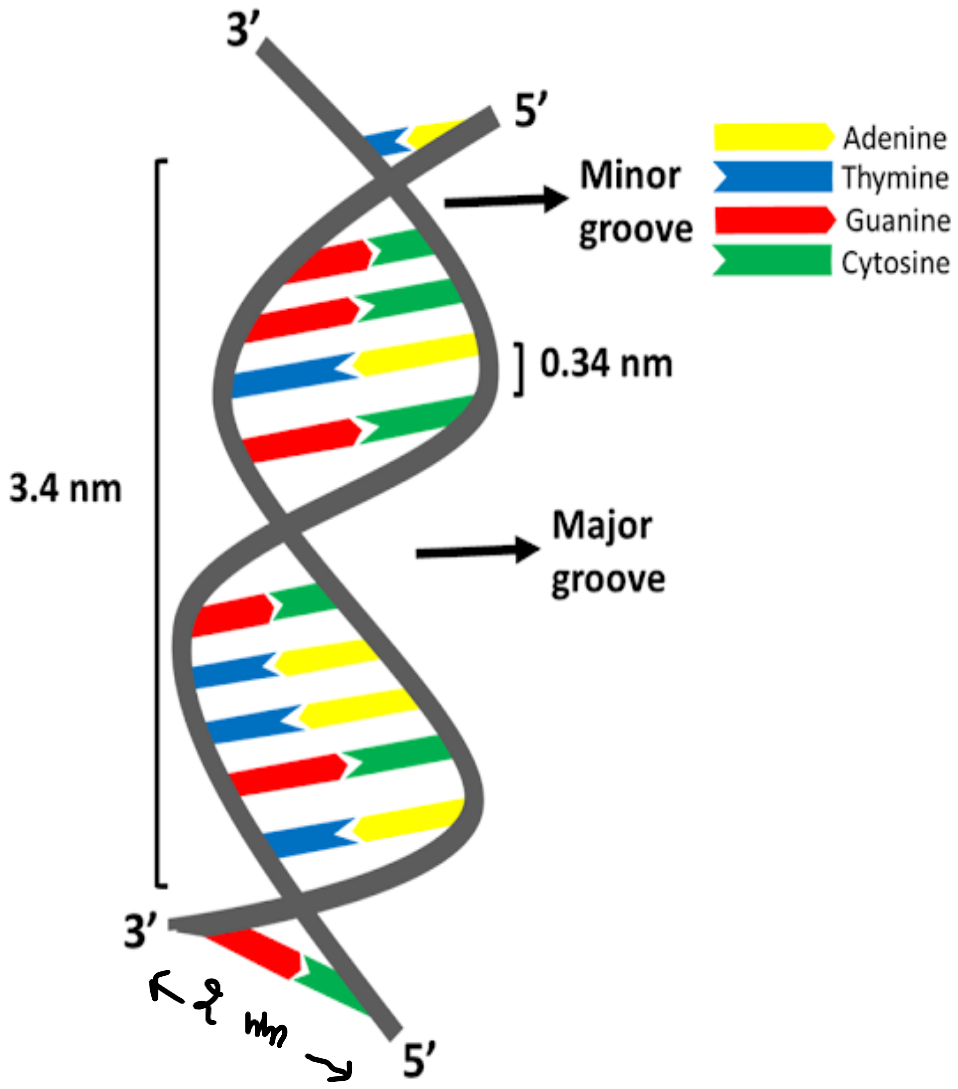
DNA as an acidic substance present in nucleus was first identified by F. Miescher in 1869. However, due to limitation in isolation of such a long polymer intact, structure of DNA remain elusive for a long time.

It was only in 1953, James Watson and Francis crick based on the X-ray diffraction data produce by Maurice Wilkins & Rosalind Franklin, proposed the famous double helix model of structure of DNA.

Proportion of the base pairing between 2 strands of polynucleotide chains was based on observation of Erwin Chargaff.

(Ratio between A & T, G & C are constant and equal)

Double helical structure of DNA



Watson and Crick DNA

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

1. The DNA double helix is made of two polynucleotide chains of deoxyribosenucleo
2. Each chain of the double helix comprises of the **backbone of sugar-phosphate** and the **nitrogenous bases** projecting inside.
3. The two chains have **anti-parallel polarity**. It means, if one chain has the polarity 5′⟶3′, the other has 3⟶5′.
4. 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.**

   Thus, always **a purine comes opposite to a pyrimidine**. This **generates approximately uniform distance between the two strands of the helix** of **2.0 nm.**
5. 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 equal to **0.34 nm.**
6. 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**