Nucleic Acid and its Structure - DNA, RNA, DNA as Genetic Material

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Nucleic Acids

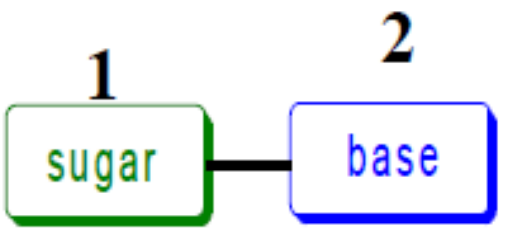
- Nucleic acid is an important class of macromolecules found in all cells and viruses. The functions of nucleic acids have to do with the storage and expression of genetic information. **Deoxyribonucleic acid (DNA)** encodes the information the cell needs to make proteins. A related type of nucleic acid, called **ribonucleic acid (RNA)**, comes in different molecular forms that participate in protein synthesis.
- Nucleic acids are polynucleotides
- Their building blocks are nucleotides

Nucleic Acids

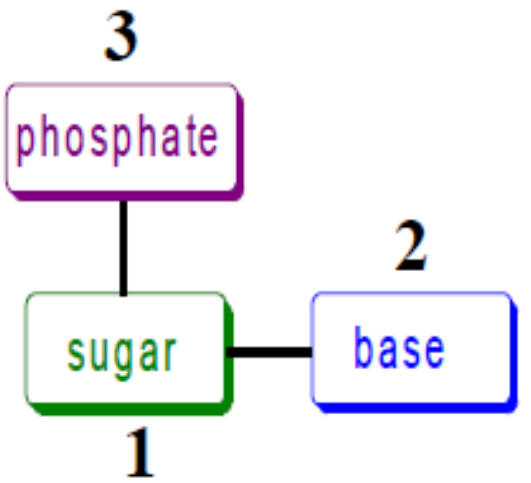
- The nucleic acids are vital biopolymers found in all living organisms, where they function to encode, transfer, and express genes. The nucleic acids are of two types, namely **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**

HISTORY:

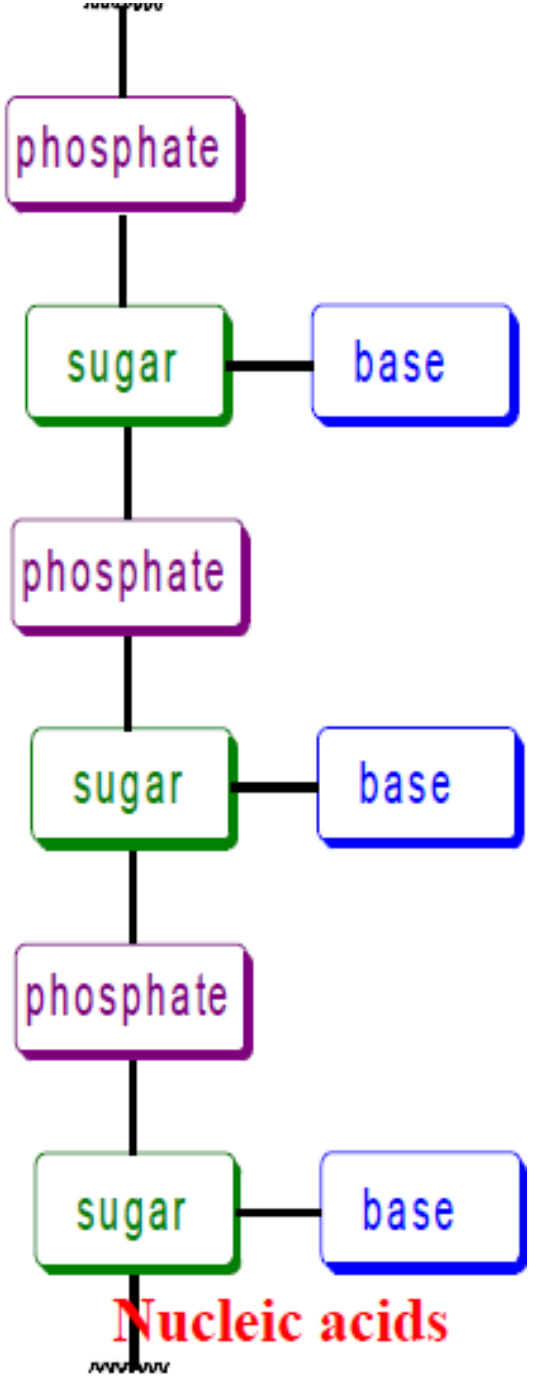
- Friedric Miescher (1868) discovered an acidic substance from pus cells and named it as Nuclein
- Altman (1889) coined the term Nucleic Acids



Nucleoside



Nucleotides



Nucleic acids

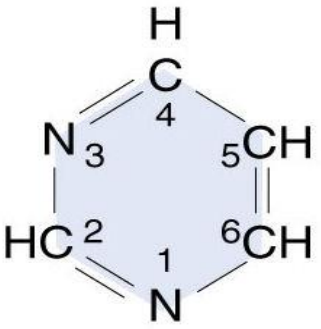
NITROGEN BASES

Purines

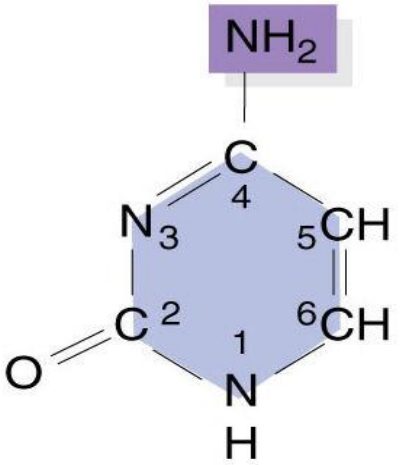
- Adenine, Guanine
- Dicyclic molecules
- 4 N atoms at 1,3,7,9 positions
- Glycosidic bond formed between 1 C of pentose sugar and N (9) of purine

Pyrimidines

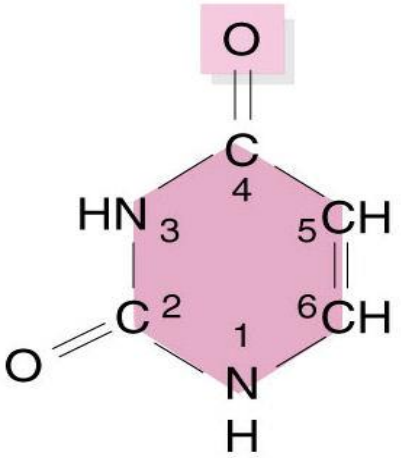
- Cytosine,Thymine, Uracil
- Monocyclic molecules
- 2 N atoms at 1,3 positions
- Glycosidic bond formed between 1 C of pentose sugar and N (1) of pyrimidine



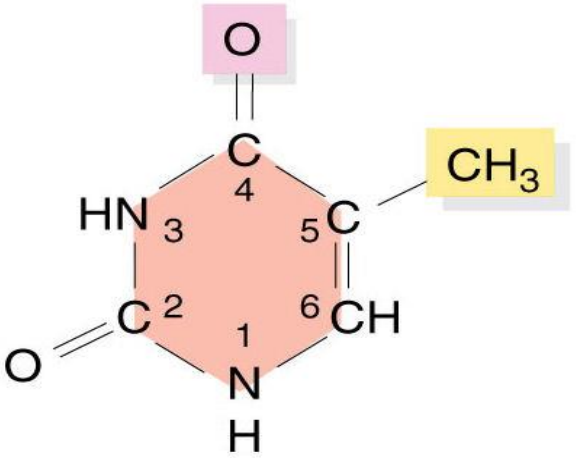
Pyrimidine



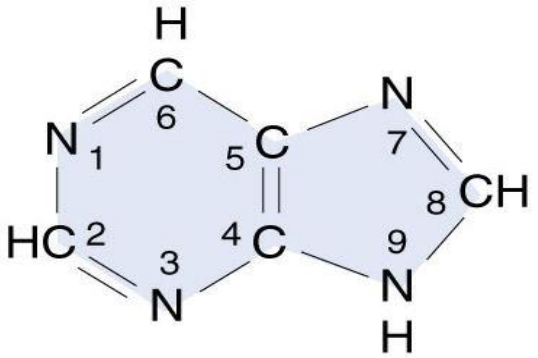
Cytosine (C)



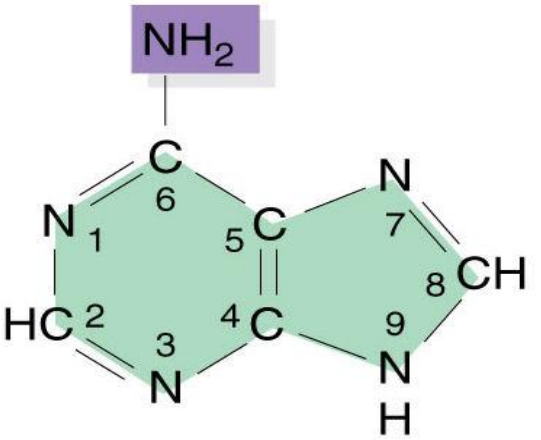
Uracil (U)
(found in RNA)



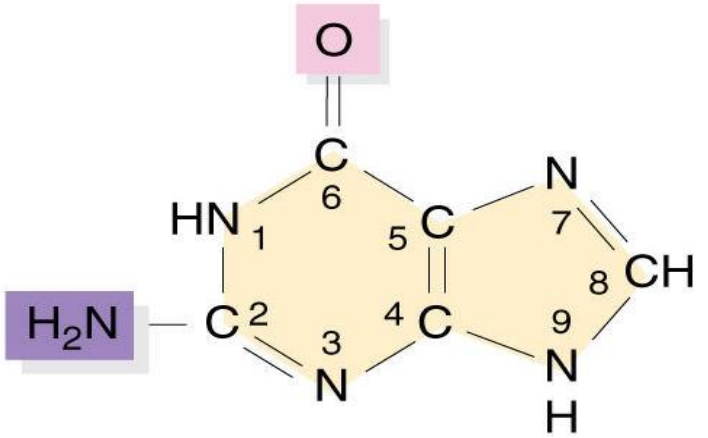
Thymine (T)
(found in DNA)



Purine



Adenine (A)



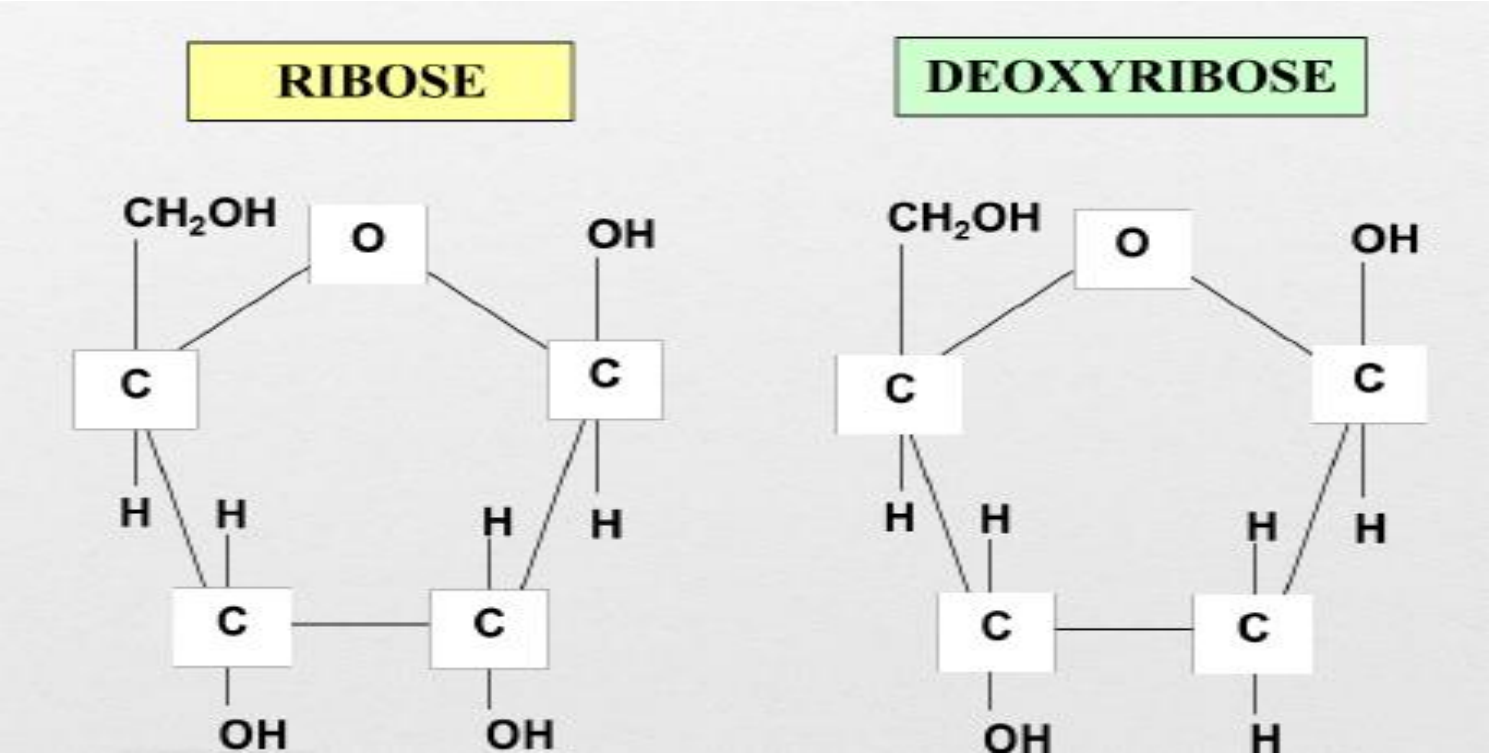
Guanine (G)

Pentose sugar:

Form glycosidic bond

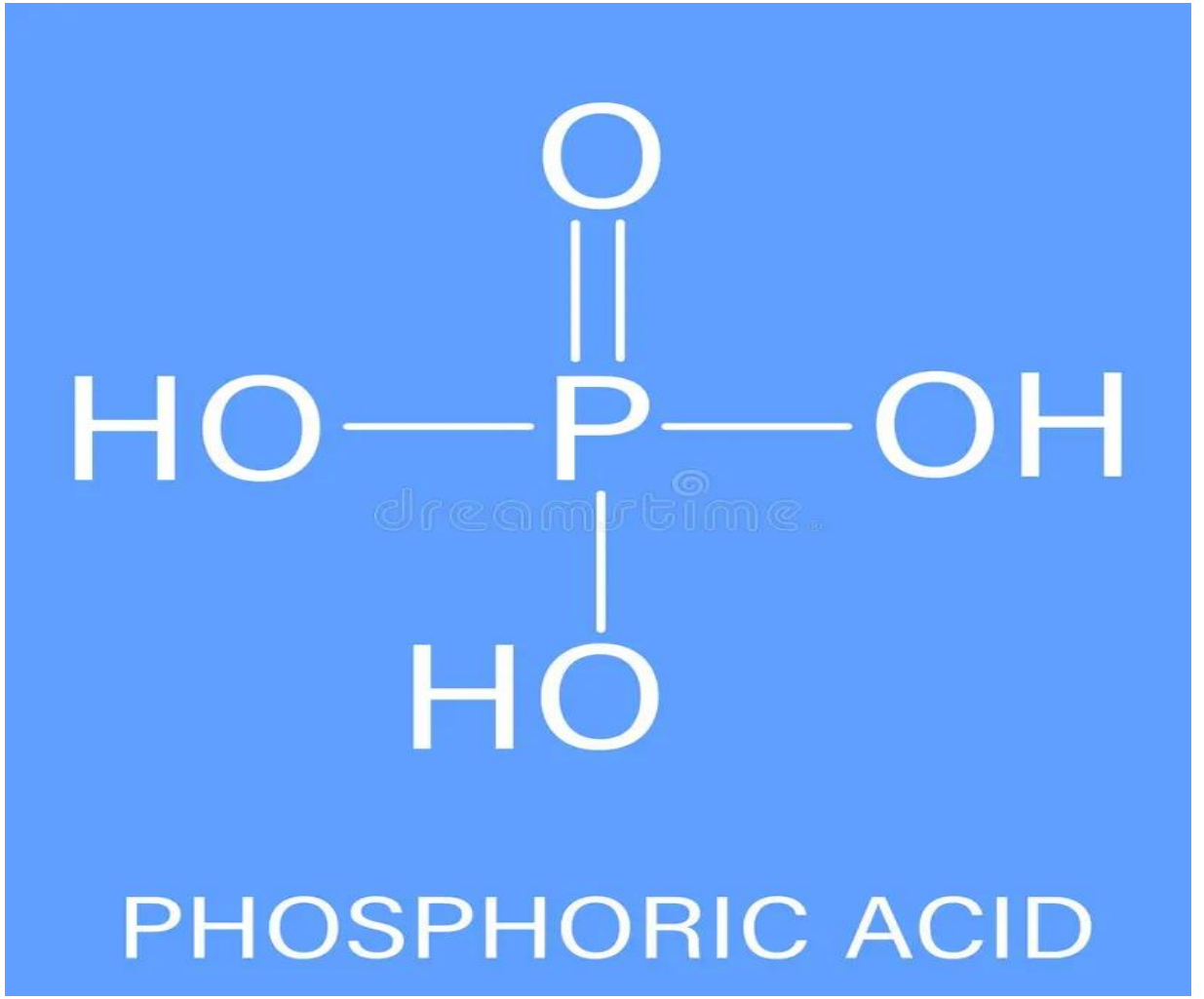
RNA – Ribose sugar

DNA – Deoxyribose sugar

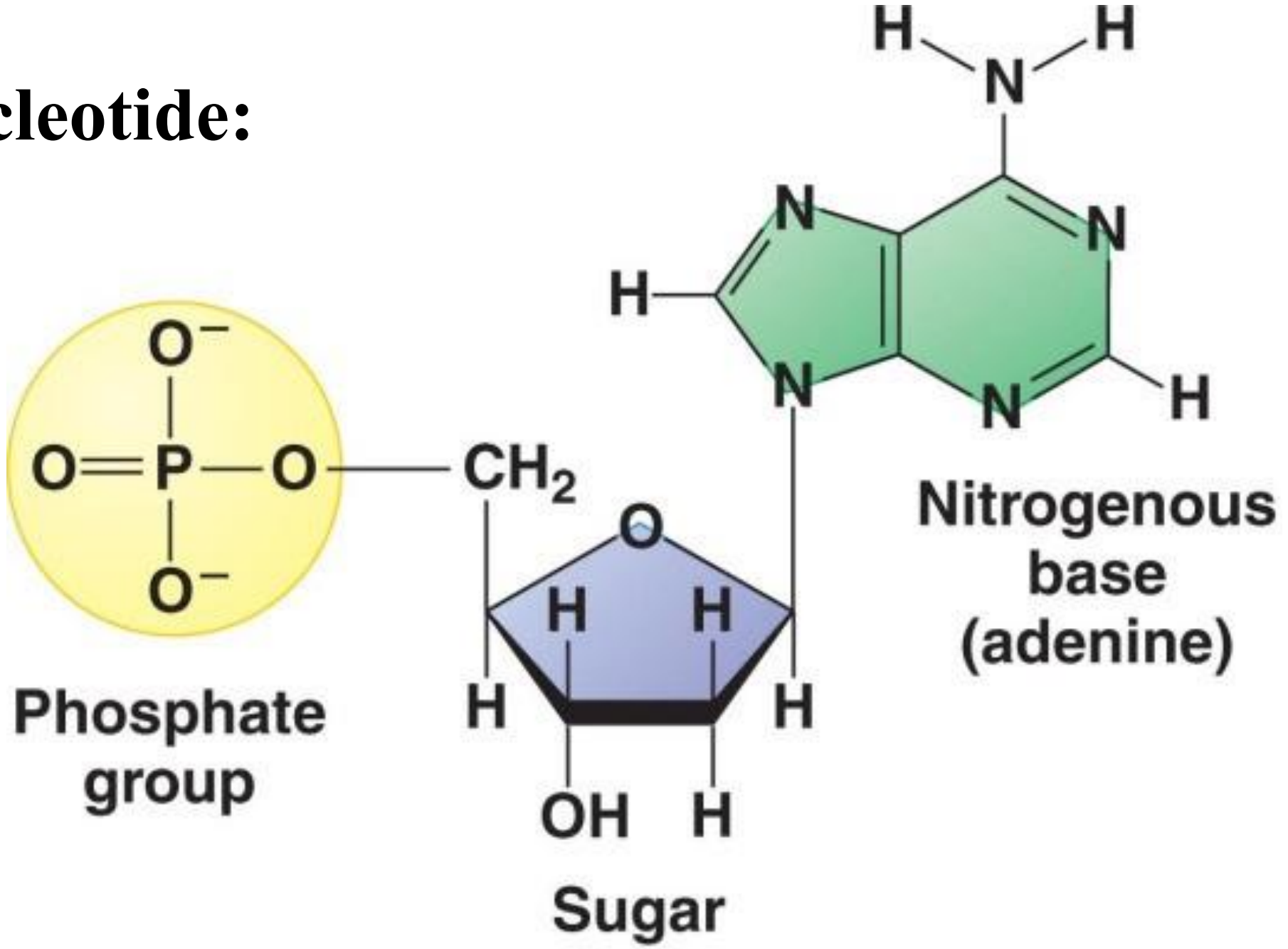


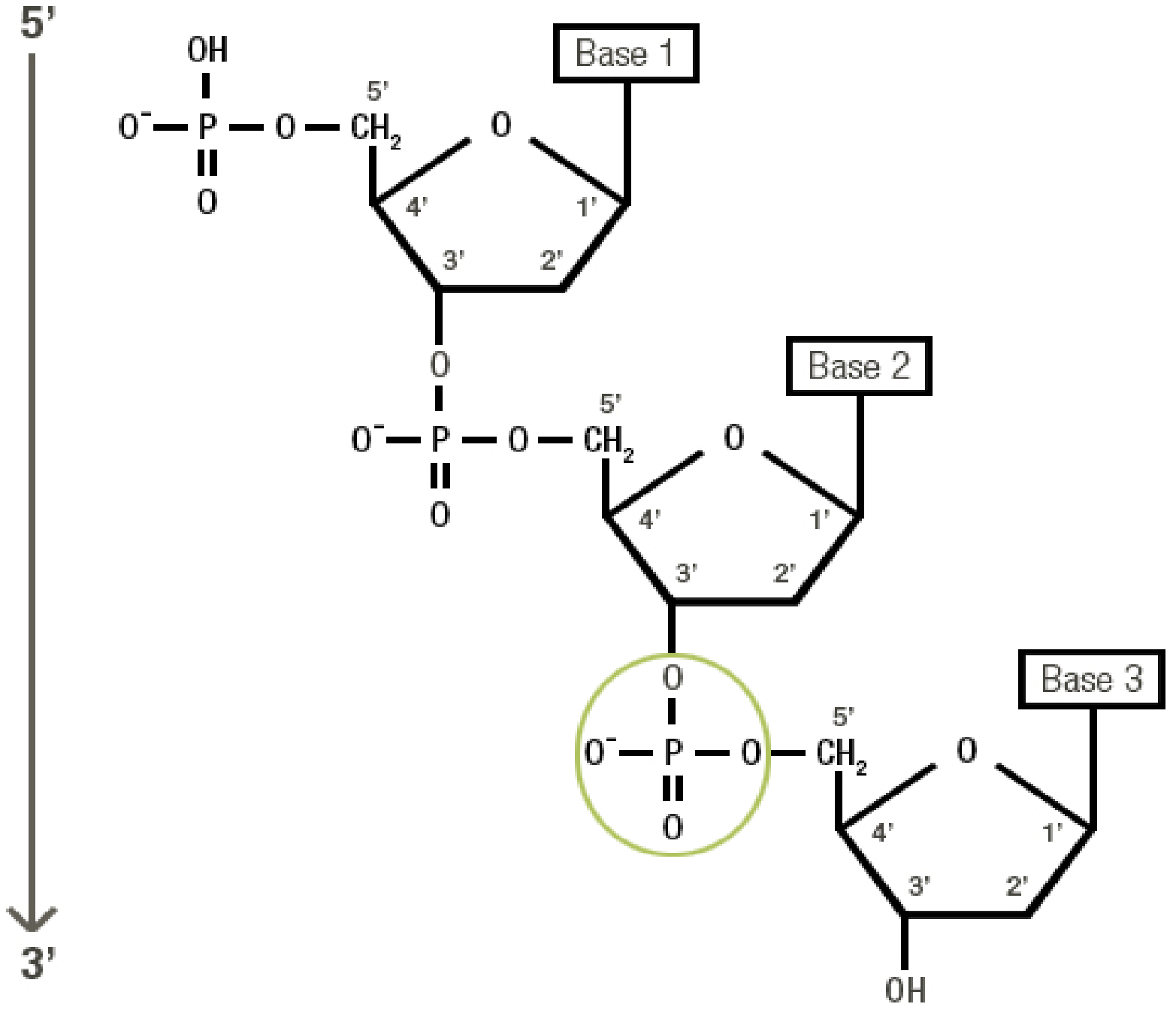
Phosphoric acid

Attached to 5 C of pentose sugar by phosphodiester bond



Nucleotide:




5'
3'
OH
O⁻
P
O
O
CH2
5'
4'
1'
3'
2'
Base 1
Base 2
Base 3
OH

Minor bases

Several minor & unusual bases are often found in DNA & RNA

- These include 5-methylcytosine, N4-acetylcytosine, N6 methyl adenine, N6 dimethyl adenine, dihydrouracil & N7 methylguanine

Importance:

- The unusual bases in nucleic acids help in the recognition of specific enzymes.

DNA

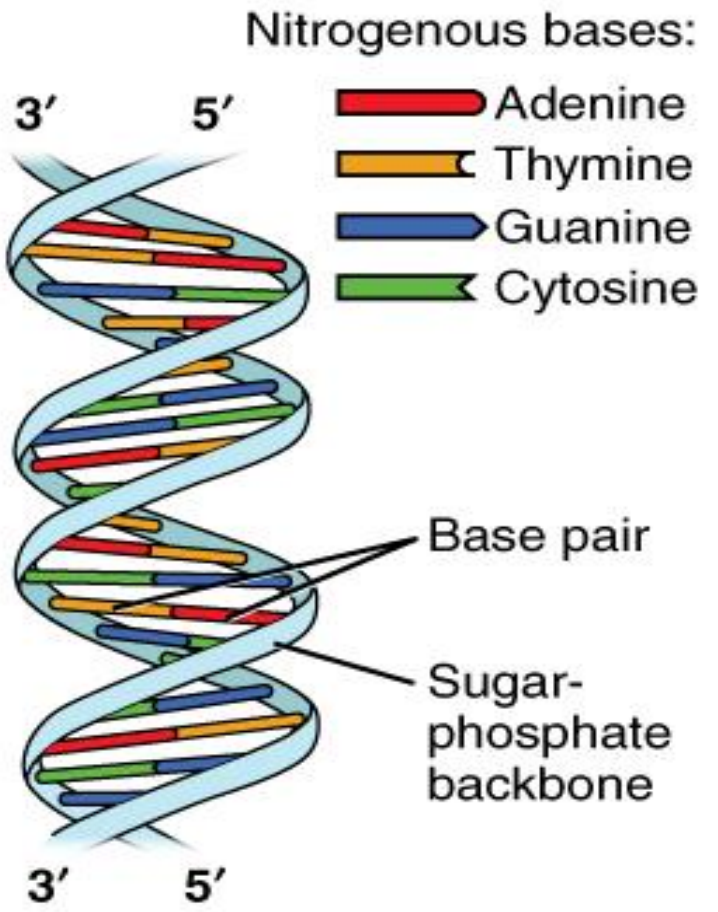
- **Location**: In eukaryotes it is present in nucleus (chromosomes) and lesser amounts in mitochondria and chloroplasts.

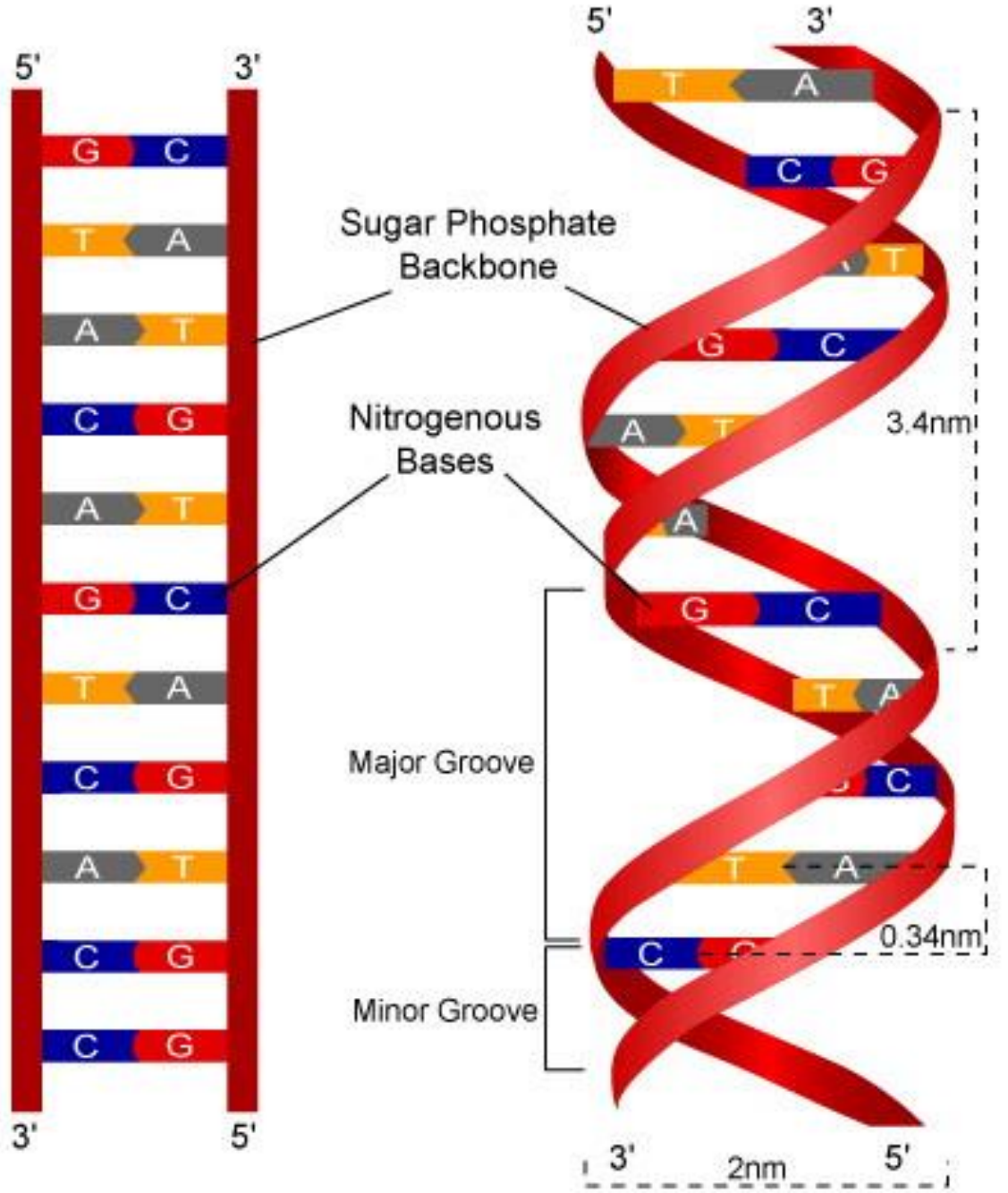
  In prokaryotes it is found in cytoplasm.
- **Structure**: Double stranded structure, however in some viruses it is single stranded.
- **Shape**: In eukaryotes, DNA is of linear shape. In prokaryotes and mitochondria DNA is circular.
- **Replication**: **Semi-conservative manner**.
- **Types**: A , B, and Z forms of DNA.
- **Functions**: **Stores and transforms genetic information and involved in mRNA synthesis**.

STRUCTURE OF DNA: Watson and Crick proposed double helix structure in 1953 (term DNA - Zacharis)

Features of DNA double helix structure:

- Double helix structure
- Each strand is made up of a chain of nucleotides
- 2 strands run antiparallel to each other
- Purine always pairs with pyrimidine
- The diameter of the helix is **20 Å.** Pitch of the helix is **34 Å (Angstrom)** and **10 bp** in each turn. Adjacent bases are separated by **3.4 Å.**
- The two chains are held together by **hydrogen bonds** between the nitrogen bases. (A=T, C≡G)
- Helix in clockwise (righthanded)

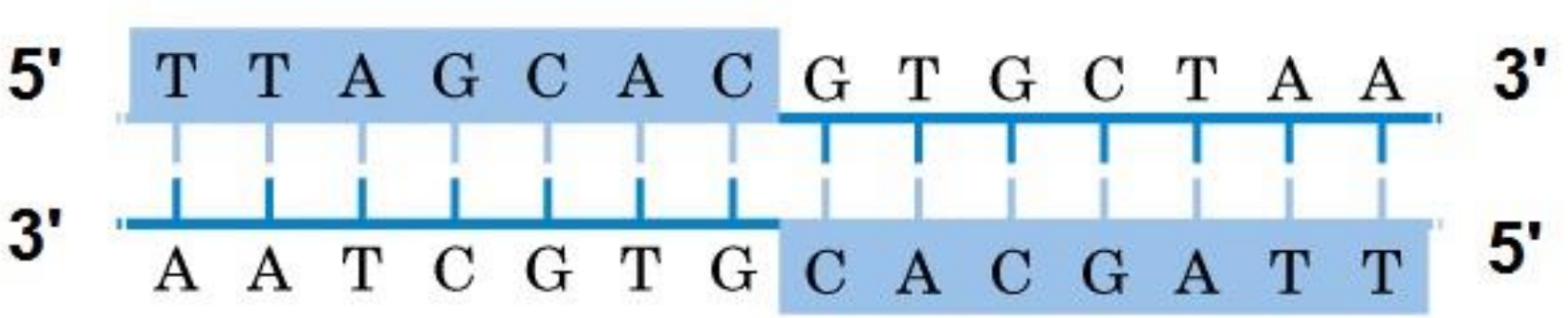



5'
3'
G C
T A
A T
C G
A T
G C
T A
C G
A T
C G
C G
3'
5'
Sugar Phosphate Backbone
Nitrogenous Bases
Major Groove
Minor Groove
5'
3'
3.4nm
0.34nm
3'
2nm
5'

- **CHARGAFF'S RULE**

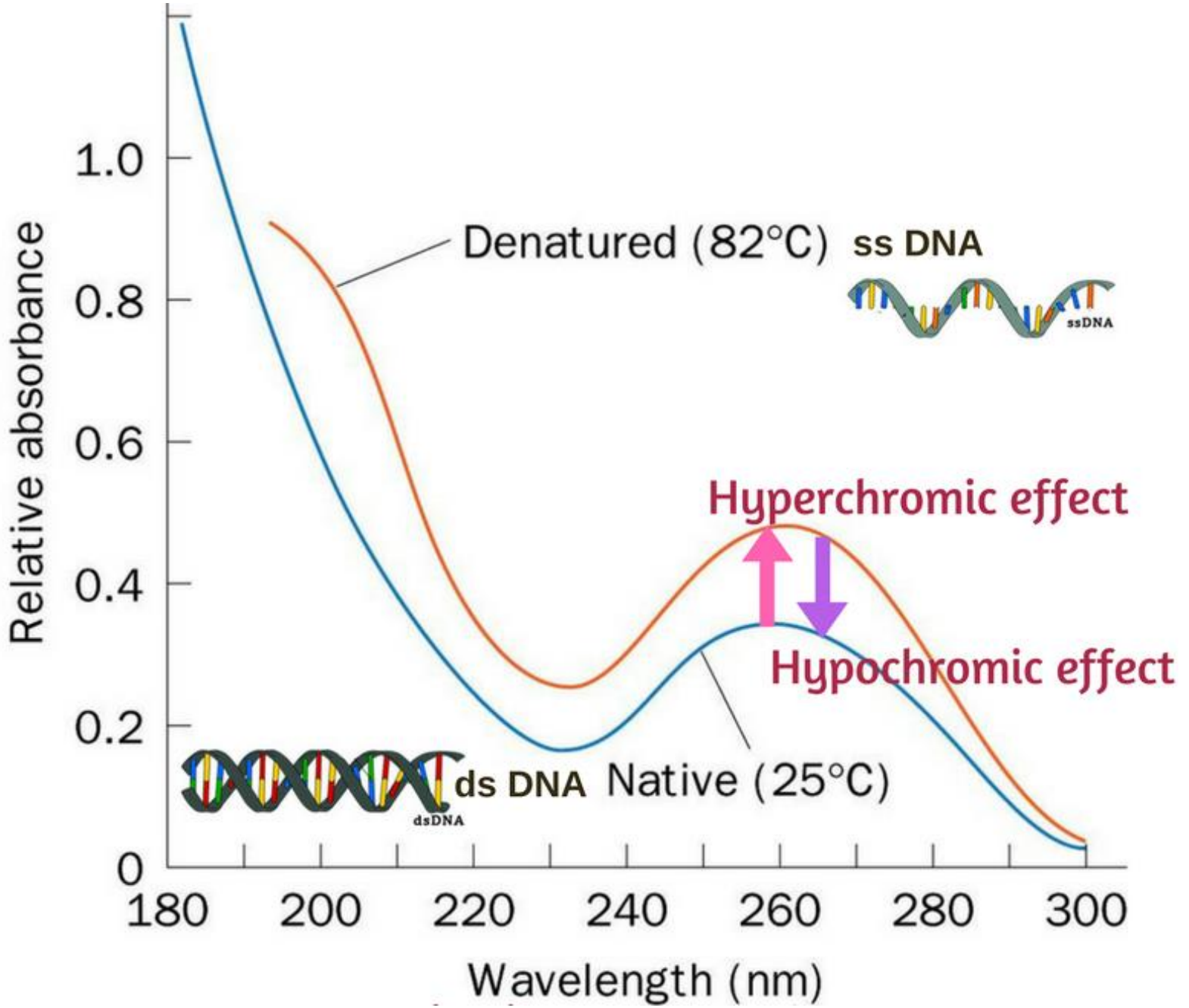
- **Purine = Pyrimidine.**
- **A = T & G = C**
- **A + G / C + T = 1.**
- **CG Rule:** The overall G+C content is species specific, it tends to be higher in exons than the introns

- **PALINDROME SEQUENCE**



- **HYPERCHROMATIC EFFECT**

It is the striking increase in absorbance of DNA upon denaturation


Relative absorbance
1.0
0.8
0.6
0.4
0.2
0
180
200
220
240
260
280
300
Wavelength (nm)
Denatured (82°C)
ss DNA
ssDNA
Hyperchromic effect
Hypochromic effect
ds DNA
dsDNA
Native (25°C)

Which Came First?
RNA OR DNA

- Most scientists believe RNA evolved before DNA. RNA has a simpler structure and is needed in order for DNA to function. Also, RNA is found in prokaryotes.
- RNA on its own can act as a catalyst for certain chemical reactions.

Why DNA evolved if RNA existed?

- Having a double-stranded molecule helps protect the genetic code from damage. If one strand is broken, the other strand can serve as a template for repair.

RNA

- A nucleic acid that carries the genetic message from DNA to ribosomes and is involved in the process of protein synthesis is referred to as RNA. It contains:
- Ribose sugar
- Nitrogen base (A, G, U, C)
- Phosphoric acid

Heterogeneous RNA (hnRNA):

- Precursor RNA synthesized from DNA through transcription. Contains both exons and introns.

Messenger RNA (mRNA) :

- It constitutes about 5% of total RNA in the cell.
- Role: carries the information for the protein synthesis.
- mRNA is formed after processing of hnRNA. Processed through the process of capping (7-methyl guanosine is added to the 5' terminal end), tailing, splicing and base modifications.

Transfer RNA (tRNA) (soluble RNA or adapter molecules)

- Smallest of all the 3 major RNA (mRNA, rRNA, tRNA)
- Role : transfers amino acids from cytoplasm to protein synthesis machinery.
- **The first nucleic acid to be completely sequenced was tRNA (tRNA alanine), by HOLLEY and Co-workers.**

Ribosomal RNA(rRNA) :

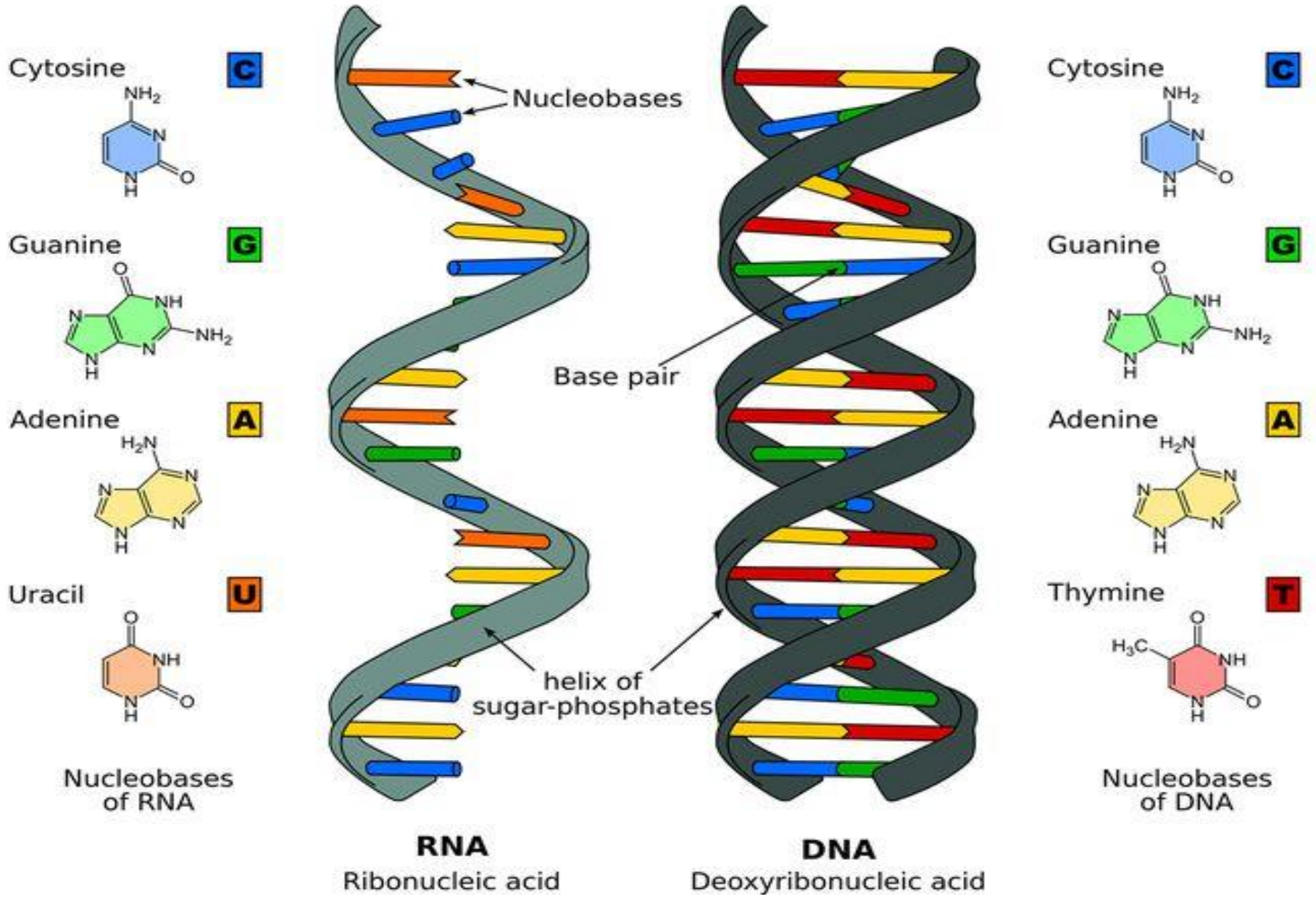
- rRNA is synthesized in nucleolus.
- Role: Plays an important role in binding of mRNA to ribosome and its translation.

Functions of RNA:

- Storage function: Many viruses have RNA as genetic material, it may be ssRNA or dsRNA.
- Structural RNA: rRNA is the major component of ribosome.
- Transfer function: mRNA encodes for protein synthesis involved in transfer of genetic information.
- Catalytic function: RNA in ribosomes has peptidyl transferase activity which is responsible for formation of peptide bond between the amino acids. Ribozymes have catalytic activity.
- Regulatory function: siRNA (short interfering RNA), miRNA (micro RNA) are involved in plant defense mechanism.

Differences between DNA and RNA:

Particulars	DNA	RNA
Location	Nucleus (chromosome), mitochondria, chloroplast, cytoplasm	Nucleolus, cytoplasm and ribosomes
Replication	Self replication	Self replication is rare
Types	A,B and Z forms	mRNA, tRNA, and rRNA
Strands	Usually two, rarely one	Usually one , rarely two
Bases	A,G,C and T	A, G, C and U
Base pairing	AT and GC	AU and GC
Sugar	Deoxyribose	Ribose
Size	Upto 4.3 million nucleotides	Upto 12000 nucleotides
Function	Genetic role	Protein synthesis. Genetic in some viruses


Cytosine
C
Guanine
G
Adenine
A
Uracil
U
Nucleobases of RNA
Nucleobases
Base pair
helix of sugar-phosphates
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
Cytosine
C
Guanine
G
Adenine
A
Thymine
T
Nucleobases of DNA

CHARACTERISTICS OF GENETIC MATERIAL

- Replication
- Storage information for the expression of the trait
- Control expression of traits
- Change in controlled way (Undergo Mutation)
- Must be stable

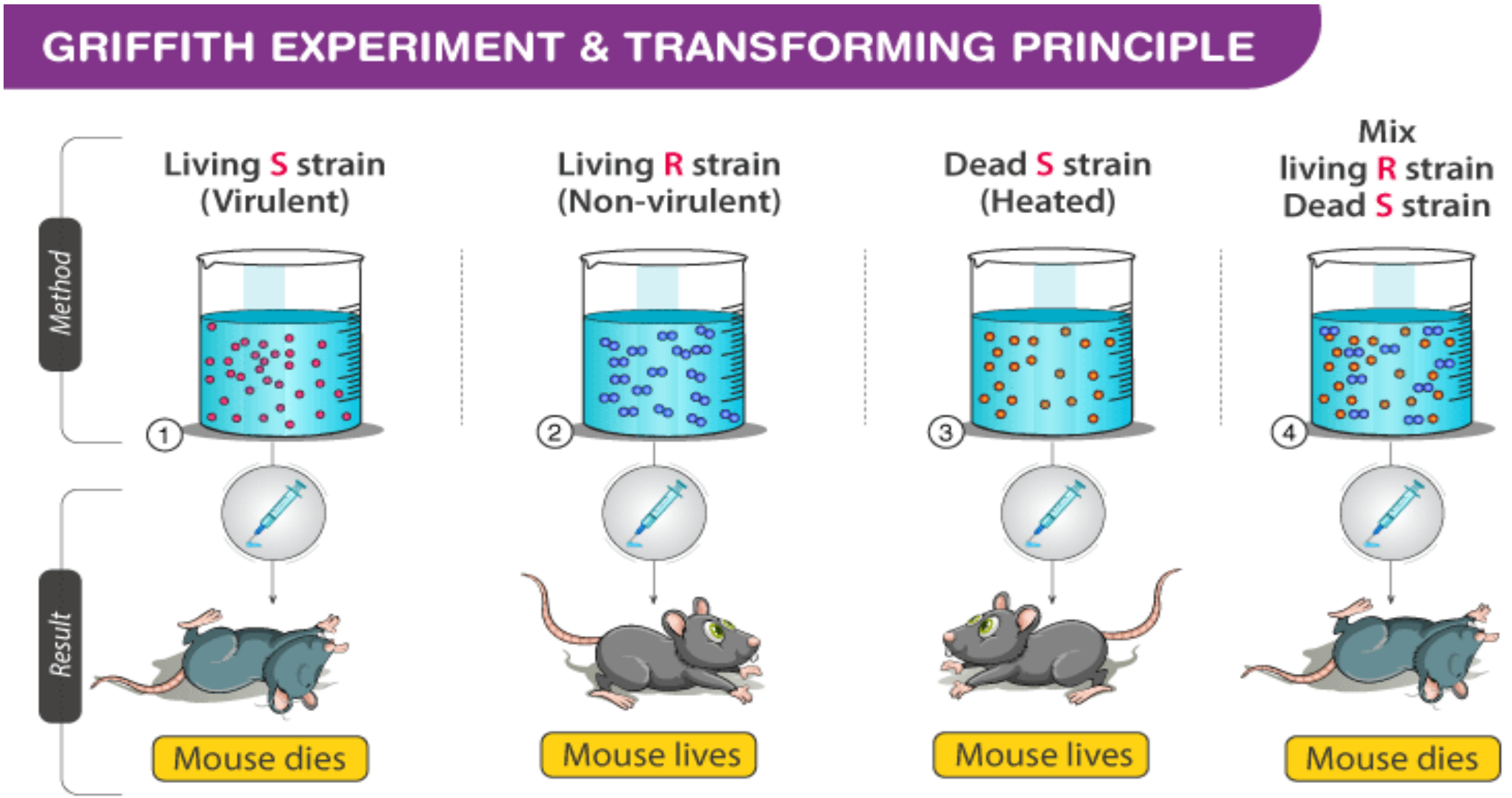
Is the Genetic Material Protein or DNA?

- Until 1940 Proteins were considered as genetic material as proteins are polymer of 20 protein amino acids and present in larger quantity, encode more and variety of information.
- DNA is polymer of only 4 different deoxyribonucleotides (ATP, CTP, GTP & TTP) and is present in smaller quantity

Evidences which prove DNA as Genetic Material

- Frederick Griffith's (1928) experiment on Bacterial Transformation
- Oswald Avery, Colin Macleod and Maclyn McCarty's (1944) experiment on Transformation
- Alfred D. Hershey and Martha Chase (1952) experiment on T- Even (2,4) Bacteriophage

GRIFFITH'S EXPERIMENT ON BACTERIAL TRANSFORMATION (1928)



- It was postulated that some of the cells of R type had changed into S type due to the influence of the dead S cells present in the mixture

- **This phenomenon was called transformation.**
- **The components of the S cells which induced the conversion of R cells into S cells was named the transforming principle.**

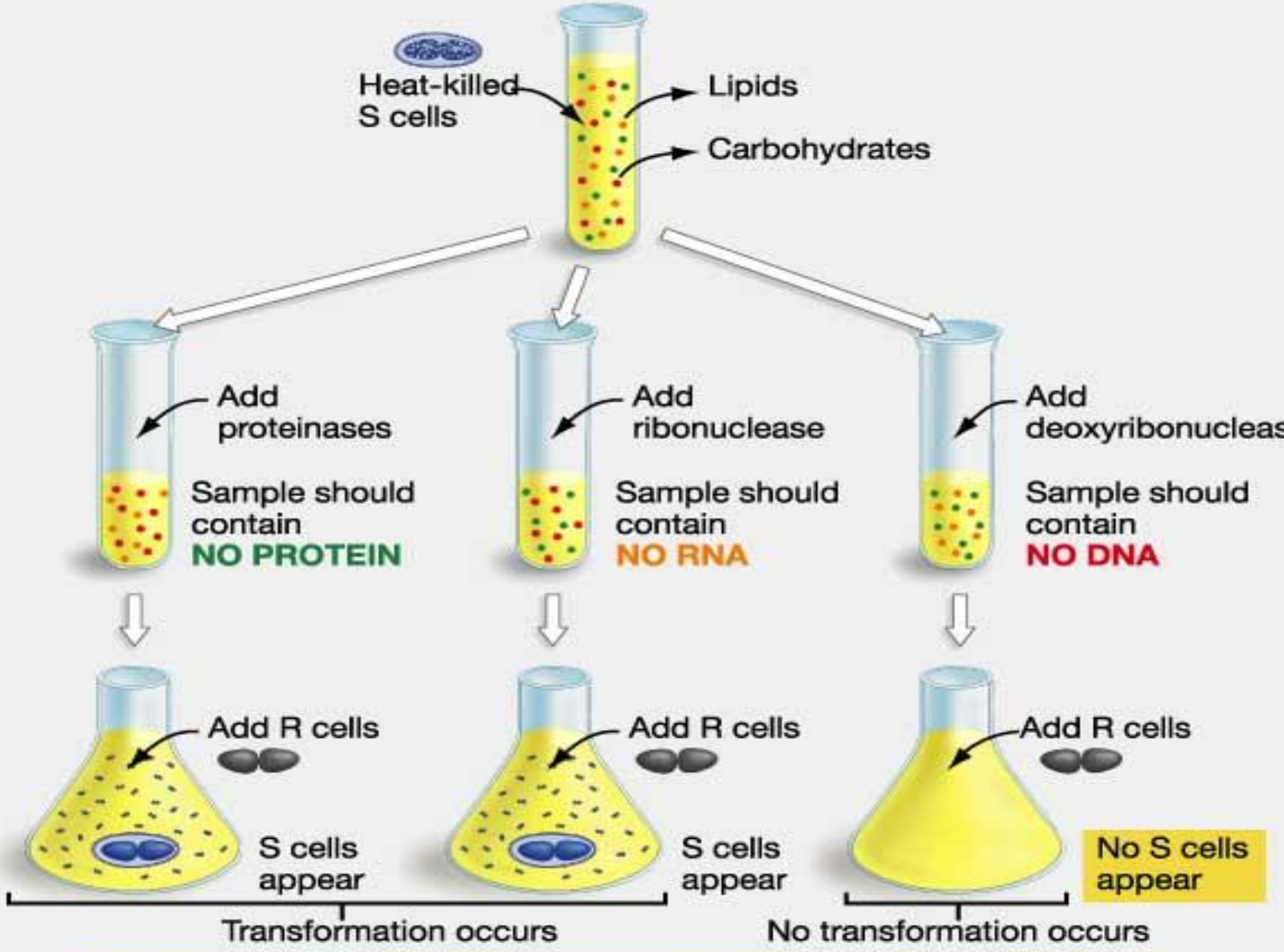
Avery, Macleod and Mc Carty (1944)

experiment on Transformation

- Carried out the experiments of Griffith *in vitro*

- They concluded that DNA was the genetic material and not the proteins. Because the transformation occurred when the DNA was present in the extract and there was no transformation when DNA was digested with DNAase enzyme

DETERMINING THAT DNA IS THE HEREDITARY MATERIAL



1. Remove the lipids and carbohydrates from a solution of heat-killed S cells. Proteins, RNA, and DNA remain.

2. Subject the solution to treatments of enzymes to destroy either the proteins, RNA, or DNA.

3. Add a small portion of each sample to a culture containing R cells. Observe whether transformation has occurred by testing for the presence of virulent S cells.

Conclusion: Transformation cannot occur unless DNA is present. Therefore, DNA must be the hereditary material.

THANK YOU