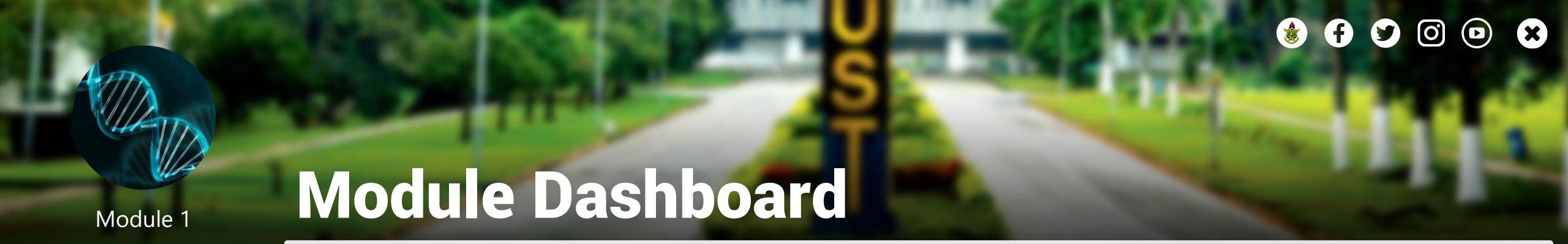

Kwame Nkrumah University of
Science & Technology, Kumasi, Ghana
Module 1
Structure
Prof. Matthew Glover Addo
Start Module



Module 1

DNA Structure

Module Dashboard

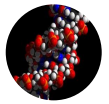
- Dashboard
- Introduction
- Lessons
- Assignments

Lessons
3

Assignments
4

Start Learning

Pick a Lesson

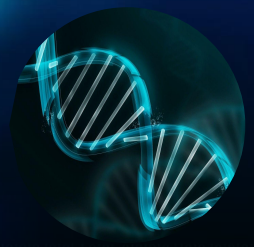


Lesson 1
DNA Structure

Lesson 2
Denaturation & Renaturation

Lesson 3
DNA Functions

2



Module 1

DNA Structure

Module Objectives

1. To know and appreciate the structure of DNA in terms of its components (i.e. nucleotides:- phosphate, pentose sugar, and a base)

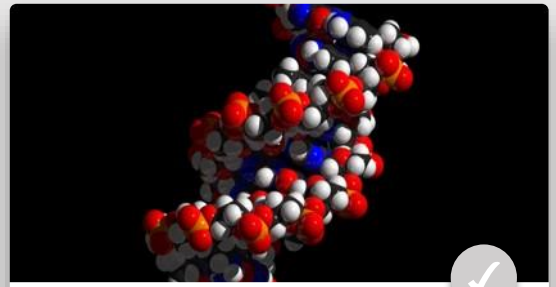
2. To know certain properties of DNA like denaturation, renaturation, bouyant density etc.

Module 1

DNA Structure

Module Lessons

- Dashboard
- Introduction
- Lessons
- Assignments



Lesson 1

DNA Structure

Learn about the discovery and components of DNA structure

Start ▸

Lesson 2

Denaturation & Renaturation

Start ▸

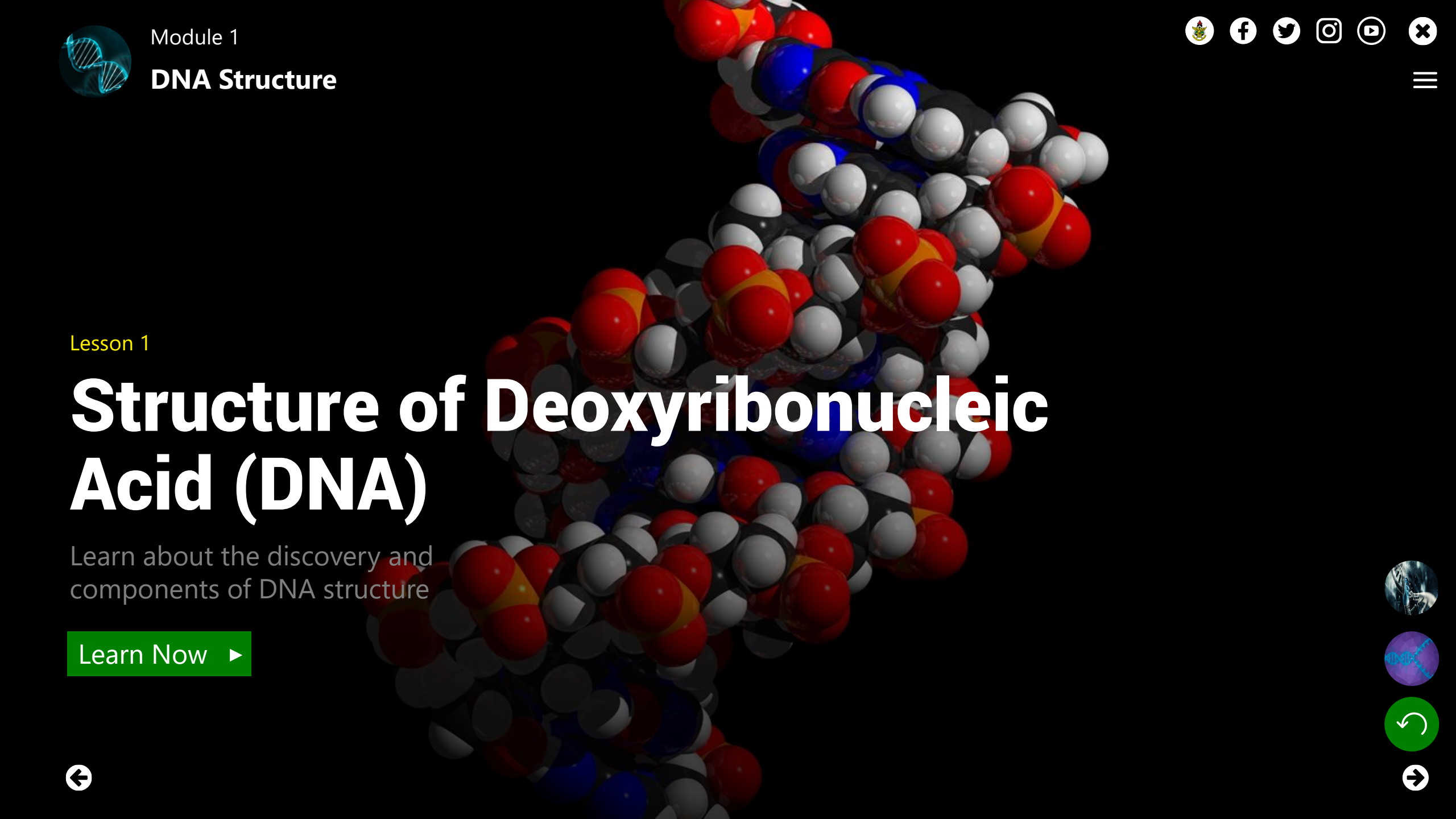
Lesson 3

DNA Functions

Learn the important roles of DNA

Start ▸

4



Lesson 1

Structure of Deoxyribonucleic Acid (DNA)

Learn about the discovery and components of DNA structure

Learn Now ▸

Structure of Deoxyribonucleic Acid (DNA)

All experiments described so far point to nucleic acid (DNA or RNA) as the carrier of genetic information

DNA Discovery

Early 1950's

DNA structure elucidated

DNA Discovery

This was achieved through effective investigation of scientists like:

Rosalind Franklin

X-ray Crystallographer

Learn More

Maurice Wilkins

X-ray Crystallographer

Learn More

Francis Crick

Molecular Biologist

Learn More

James Watson

Molecular Biologist

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Erwin Chargaff

Biochemist

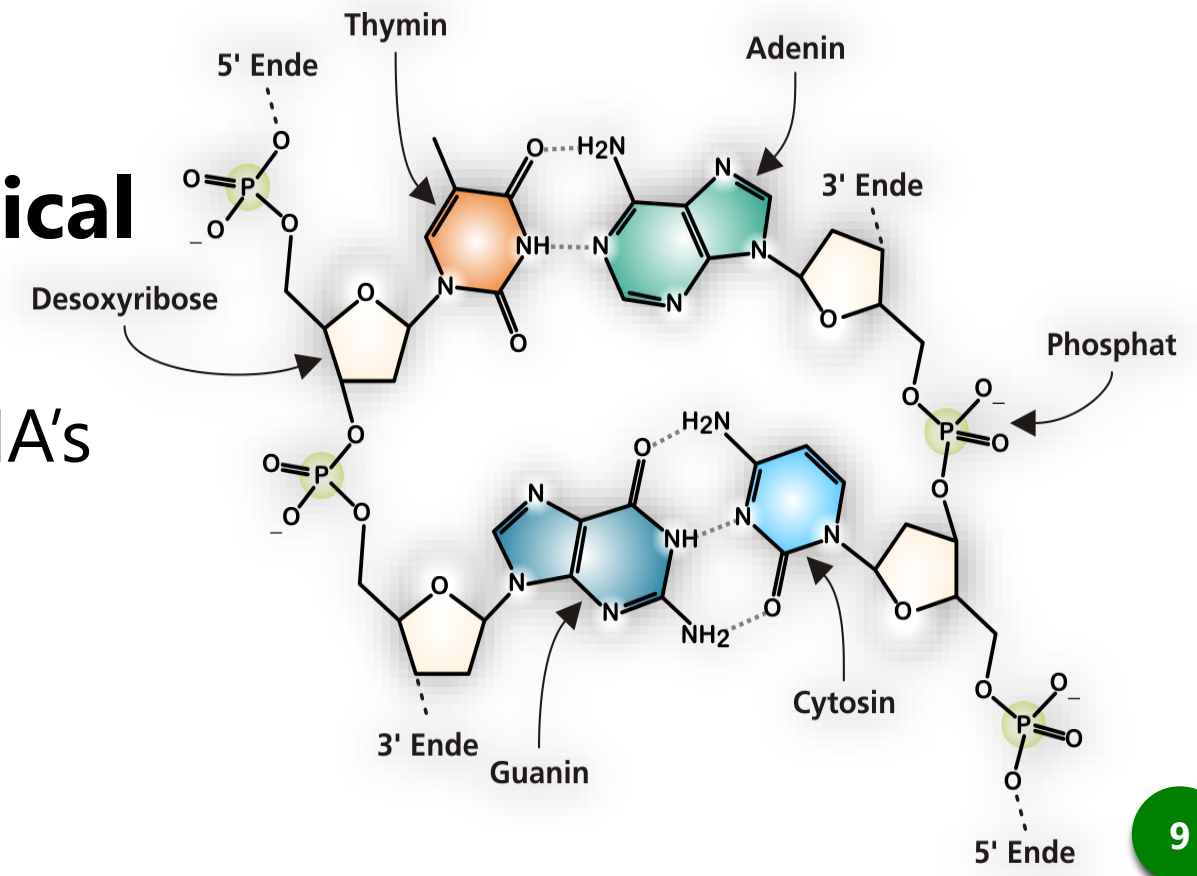
Learn More

DNA Discovery

Foundations on which the DNA structure were based:

1. **Structural and Theoretical Chemistry Analysis**

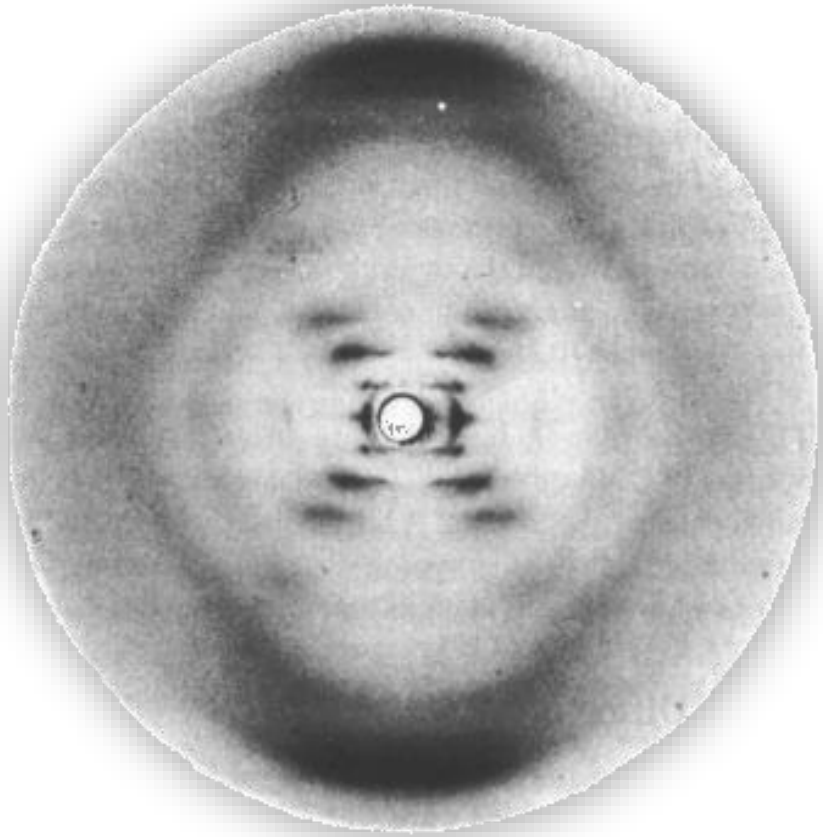
   of base compositions of DNA's from a variety of species



DNA Discovery

Foundations on which the DNA structure were based:

1. Structural and Theoretical Chemistry Analysis
2. **X-ray Crystallographic Data**



DNA Discovery

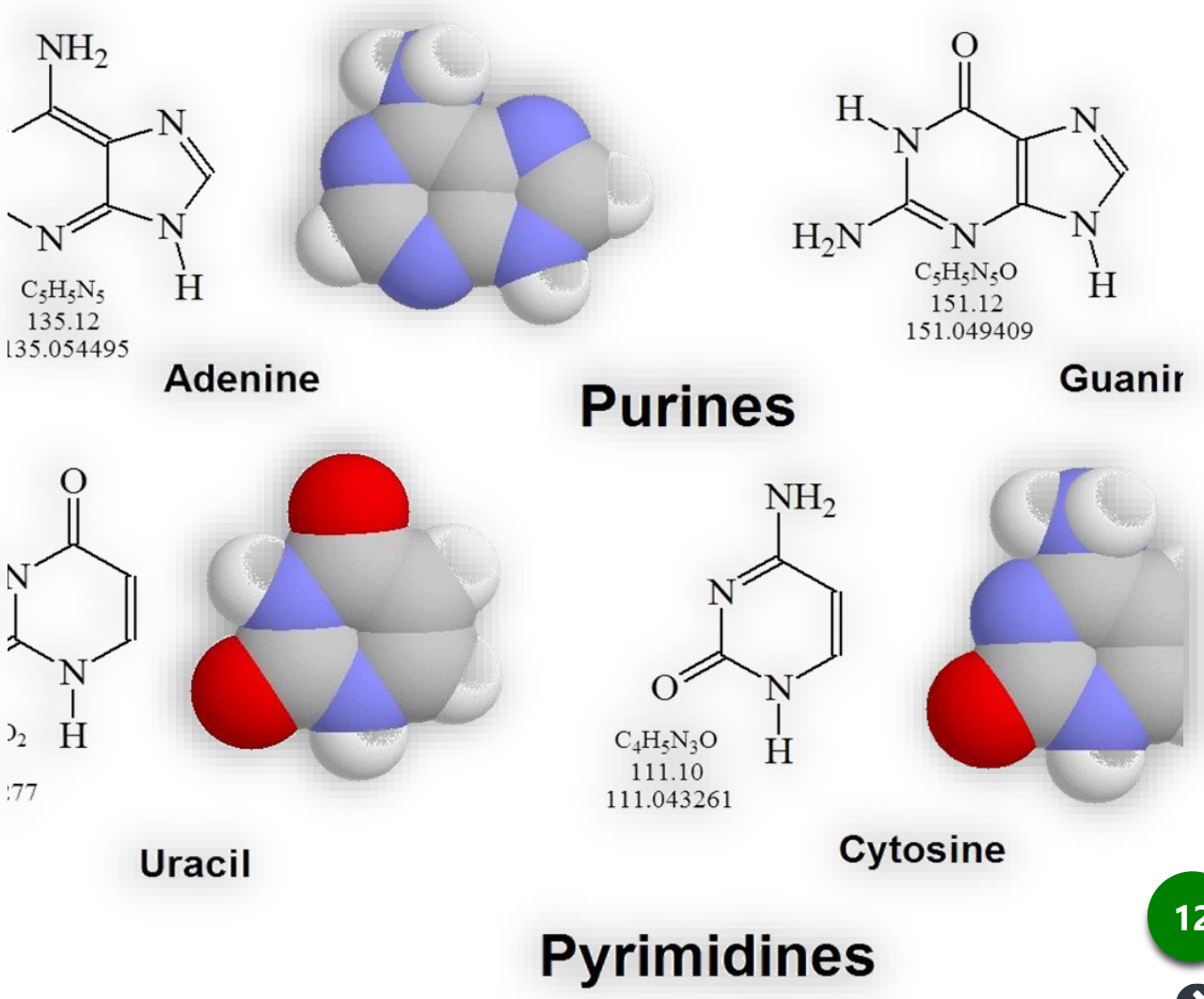
Foundations on which the DNA structure were based:

3 **Structural Models**

The ability of Watson and Crick to build structural models that were consistent with the chemical and physical data

DNA Discovery

Aaron Levene provided important information about the chemical composition of DNA and concluded that, it is a polymer of **purine** and **pyrimidine** nucleotides



DNA Discovery

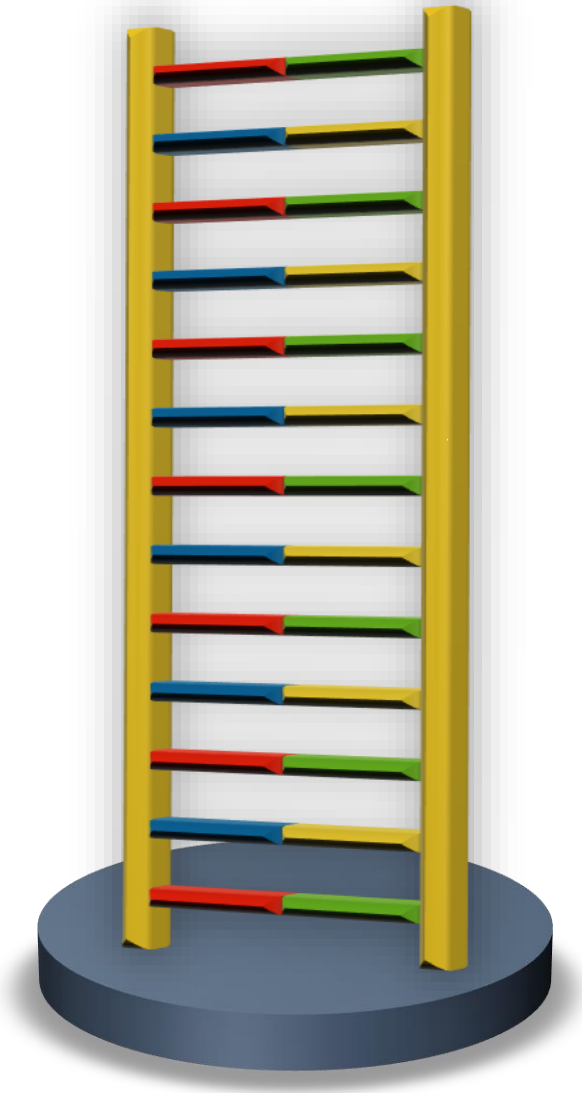
Using an x-ray crystallographic picture of DNA made by Franklin, Watson and Crick were able to propose a model for the structure of DNA

DNA is a Double Helix

According to the model, DNA is composed of two long, unbranched polymers of deoxynucleotides lying side by side

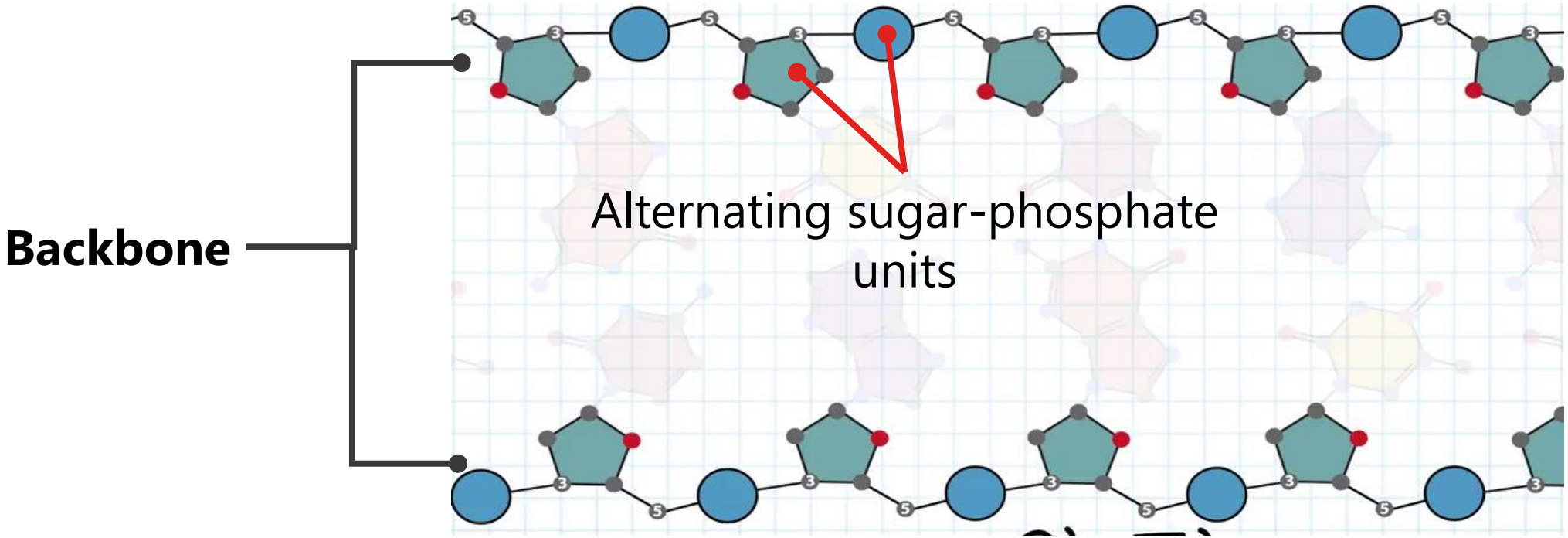
DNA is a Double Helix

It is a high molecular weight polymeric compound which consists of two molecules that are arranged into a ladder-like structure called a **Double Helix**



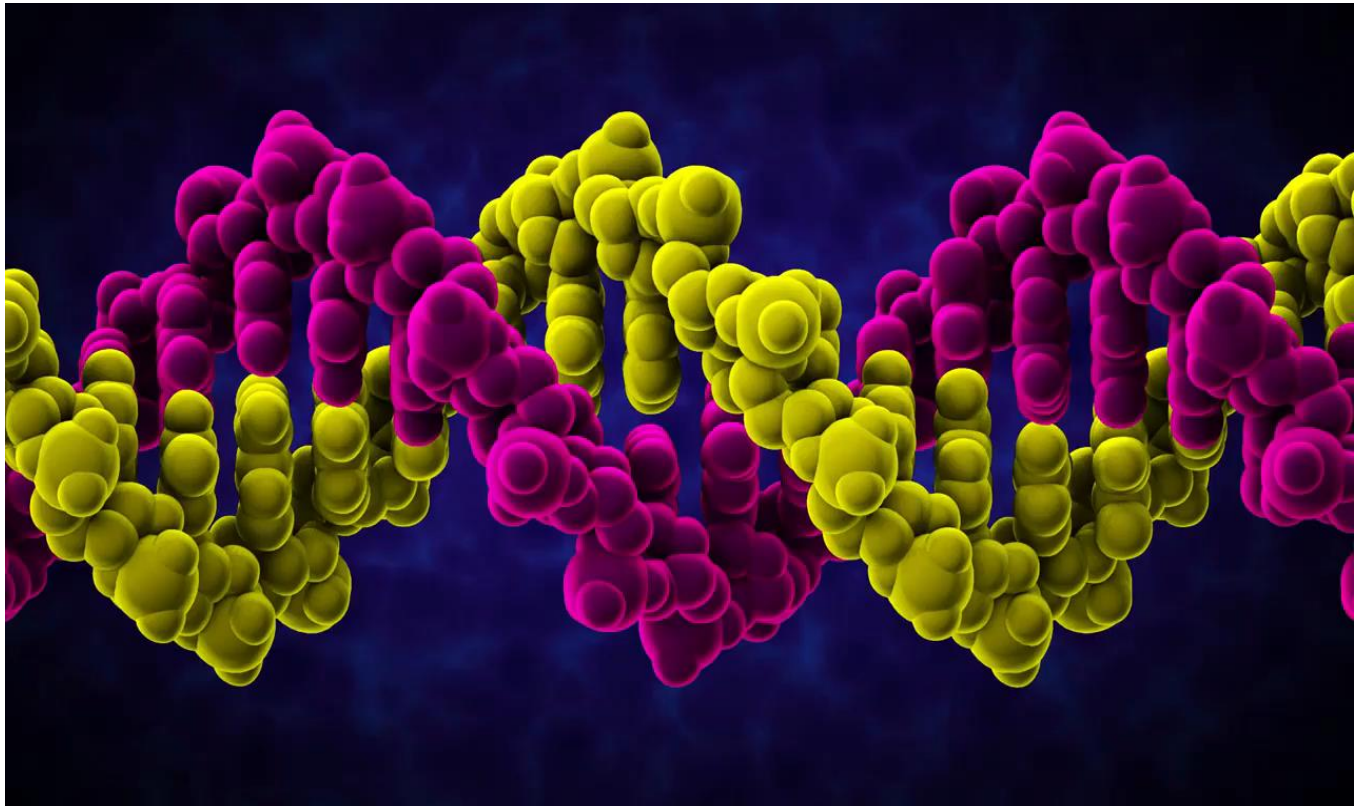
DNA is a Double Helix

The backbone of the helix is composed of two chains with alternating sugar-phosphate units



Nucleotides

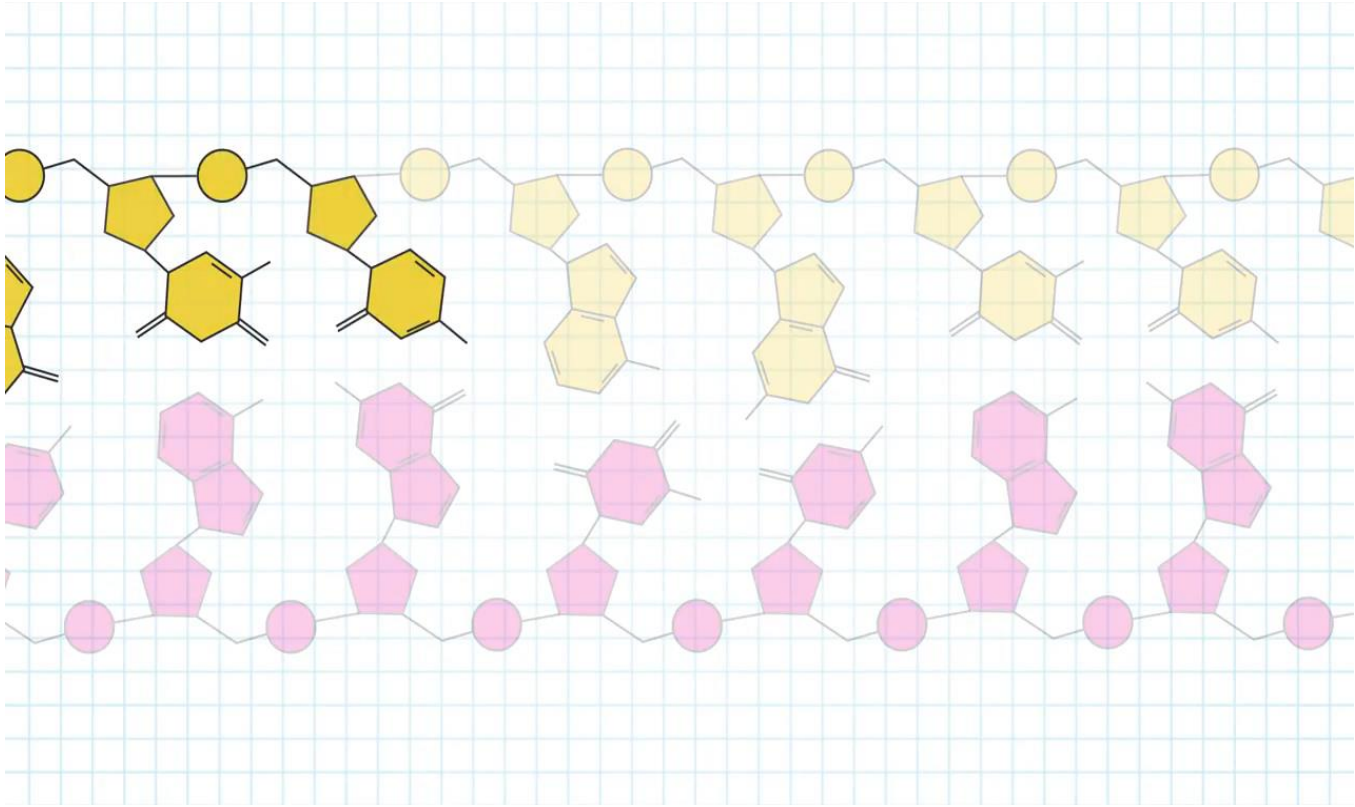
A molecule of DNA is made up of millions of tiny subunits called **Nucleotides**



Nucleotides

Each nucleotide consists of:

1. **Phosphate group**
2. **Pentose sugar**
3. **Nitrogenous base**



Structure of DNA

Nucleotides

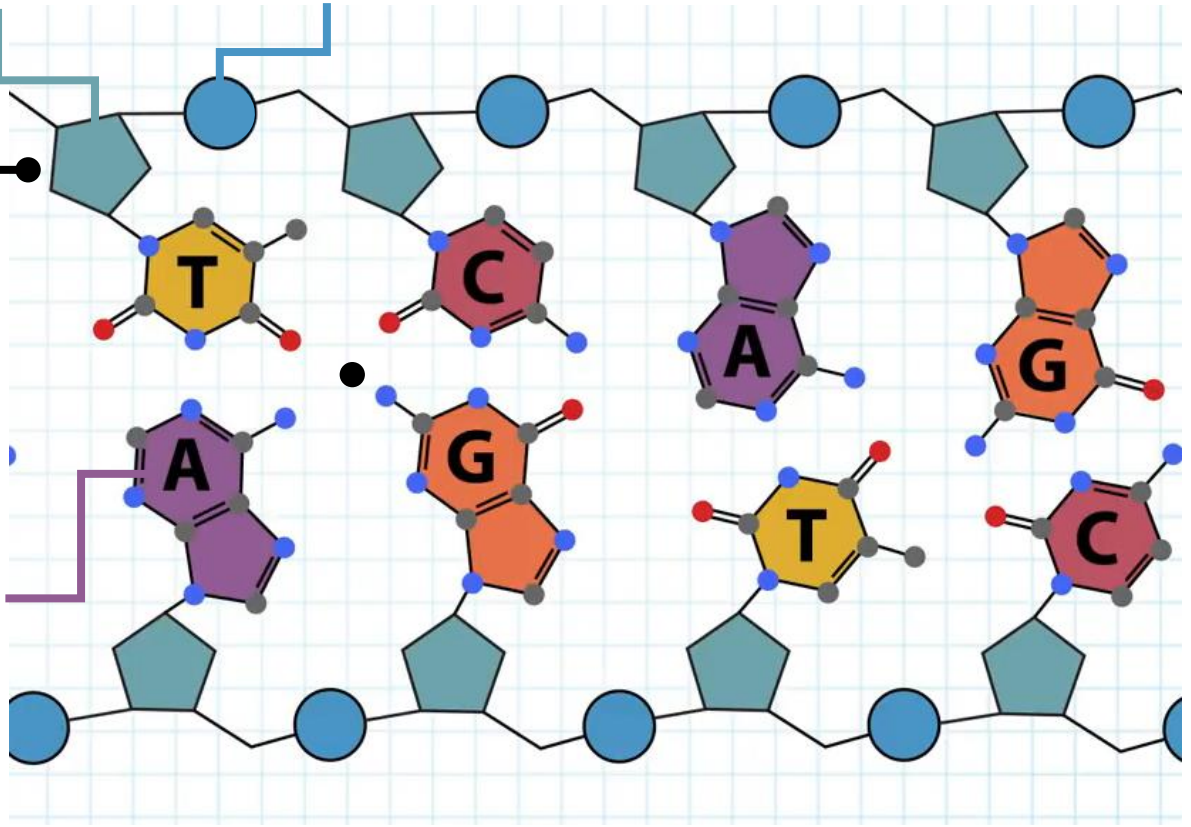
Backbone

"Rungs"

Bases

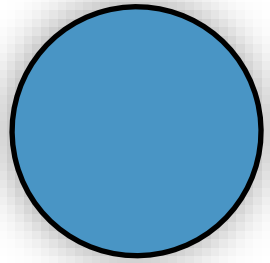
Sugar

Phosphate

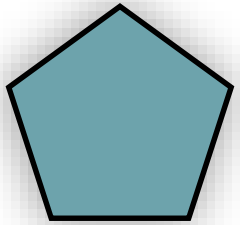


Nucleotides

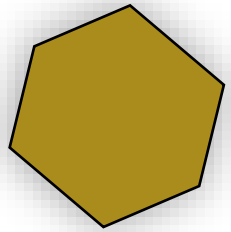
Complete hydrolysis of DNA yield



Phosphate Group



Pentose Sugar

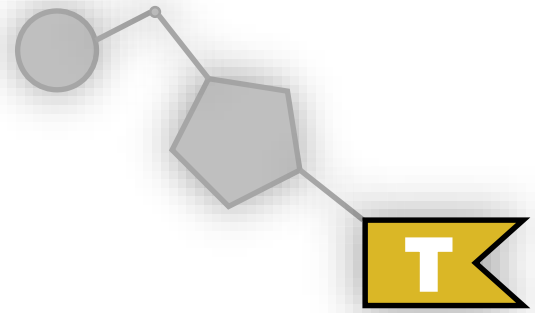


Pyrimidine & Purine Bases

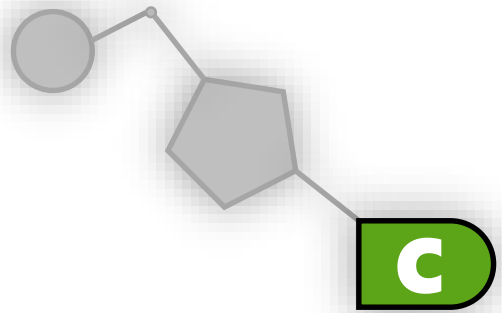
Nucleotides › Nitrogenous Bases › Types

1. Adenine

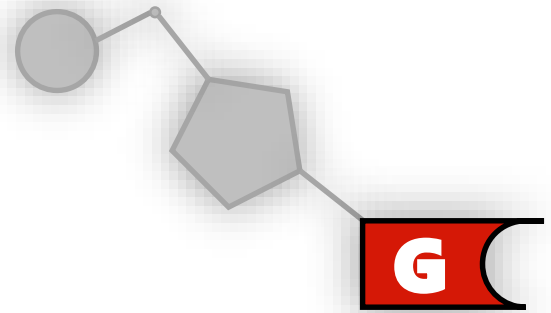
2. Thymine



3. Cytosine



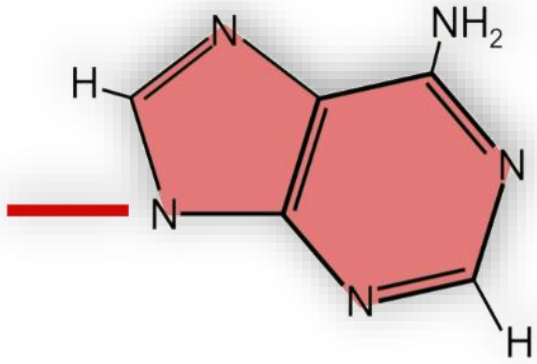
4. Guanine

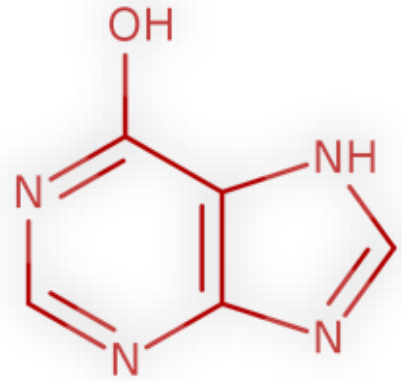


Nucleotides › Nitrogenous Bases › Purines

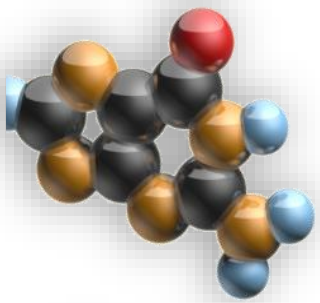
Purines are **heterocyclic ring** of carbon and nitrogen atoms

Adenine

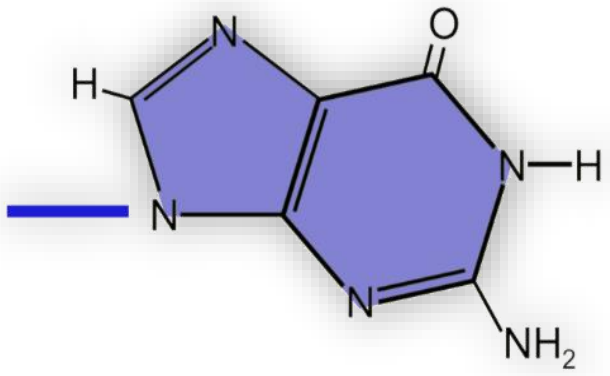


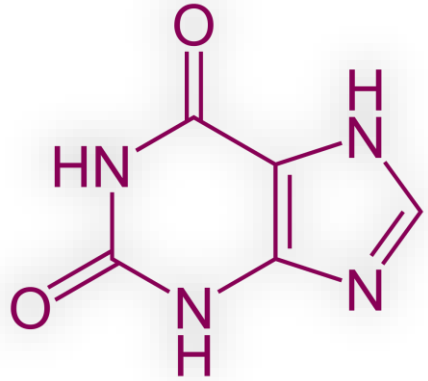


Hypoxanthine



Guanine

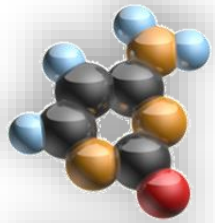




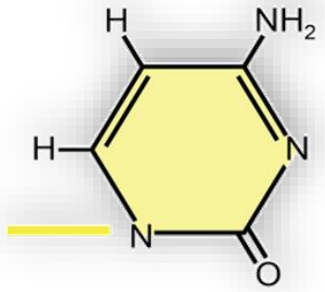
Xanthine

Nucleotides › Nitrogenous Bases › Pyrimides

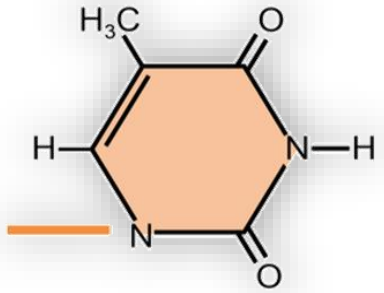
Pyrimidines are **cyclic ring** of carbon and nitrogen atoms

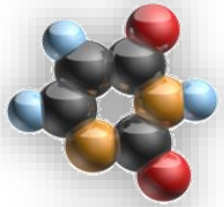


Cytosine

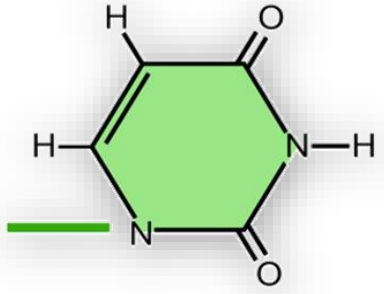


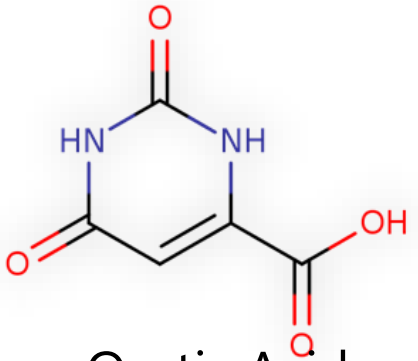
Thymine
(DNA Only)





Uracil
(RNA Only)



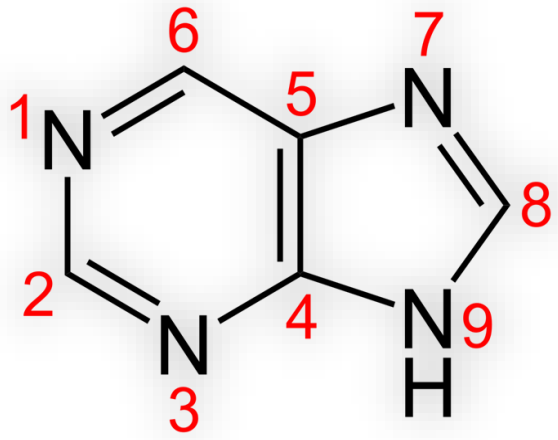


Orotic Acid

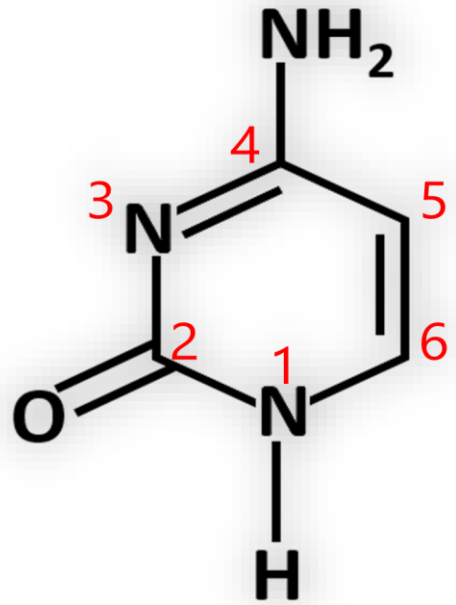
Nucleotides › Nitrogenous Bases

Note

The style of numbering of the pyrimidine ring in the purines differs from that used for the pyrimidines themselves



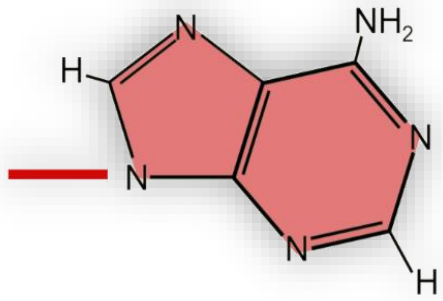
Adenine



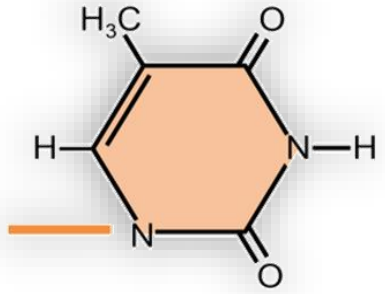
Cytosine

Nucleotides › Nitrogenous Bases › Major Bases

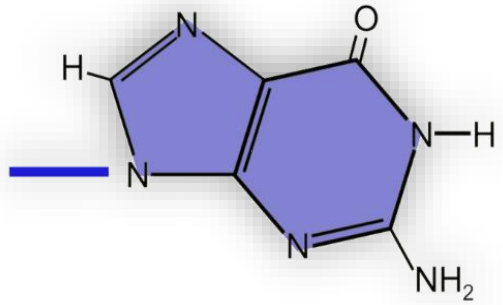
Major bases found in DNA & RNA



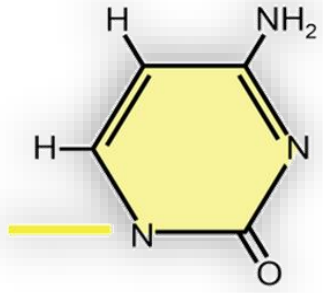
Adenine



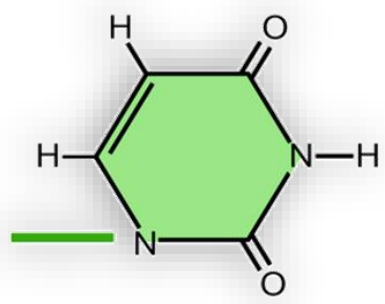
Thymine
(DNA only)



Guanine

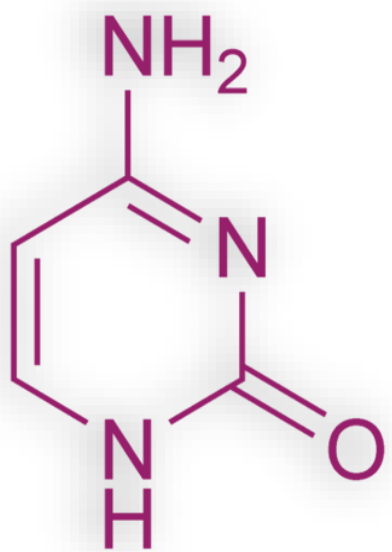


Cytosine

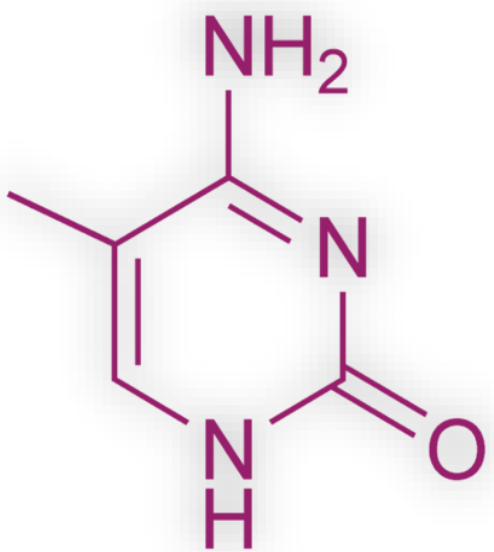


Uracil
(RNA only)

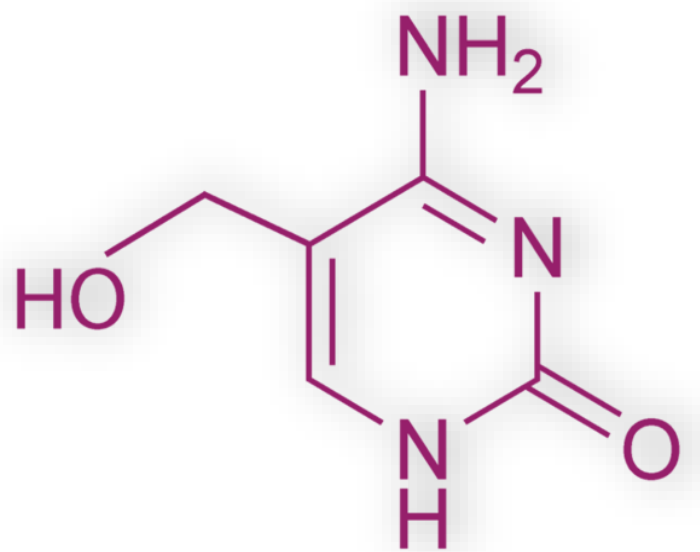
In certain bacterial viruses, cytosine is replaced by **5-methylcytosine** or **5-hydromethylcytosine**



Cytosine



5-methylcytosine



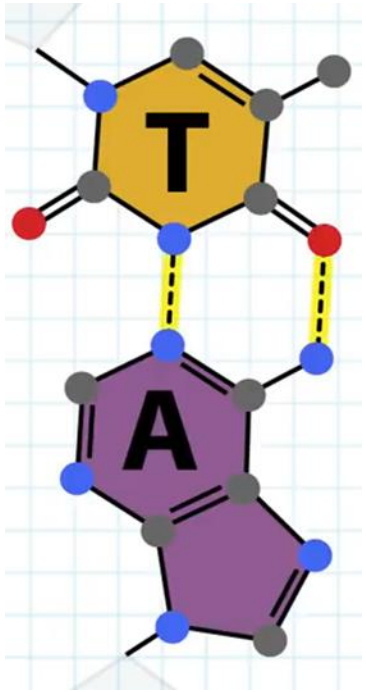
5-hydromethylcytosine

Nucleotides › Nitrogenous Bases › Base Pairing

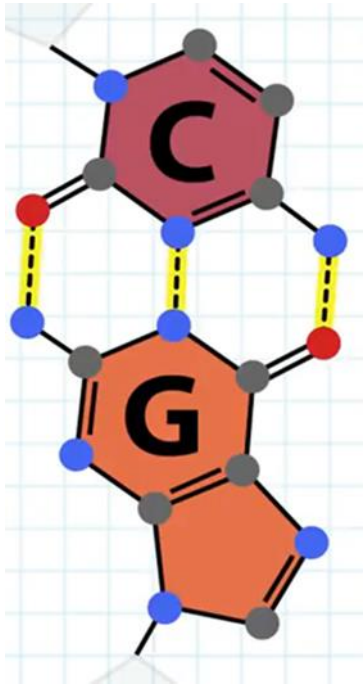
Each base will only **bond with one** other specific base

Thymine (T)

Adenine (A)



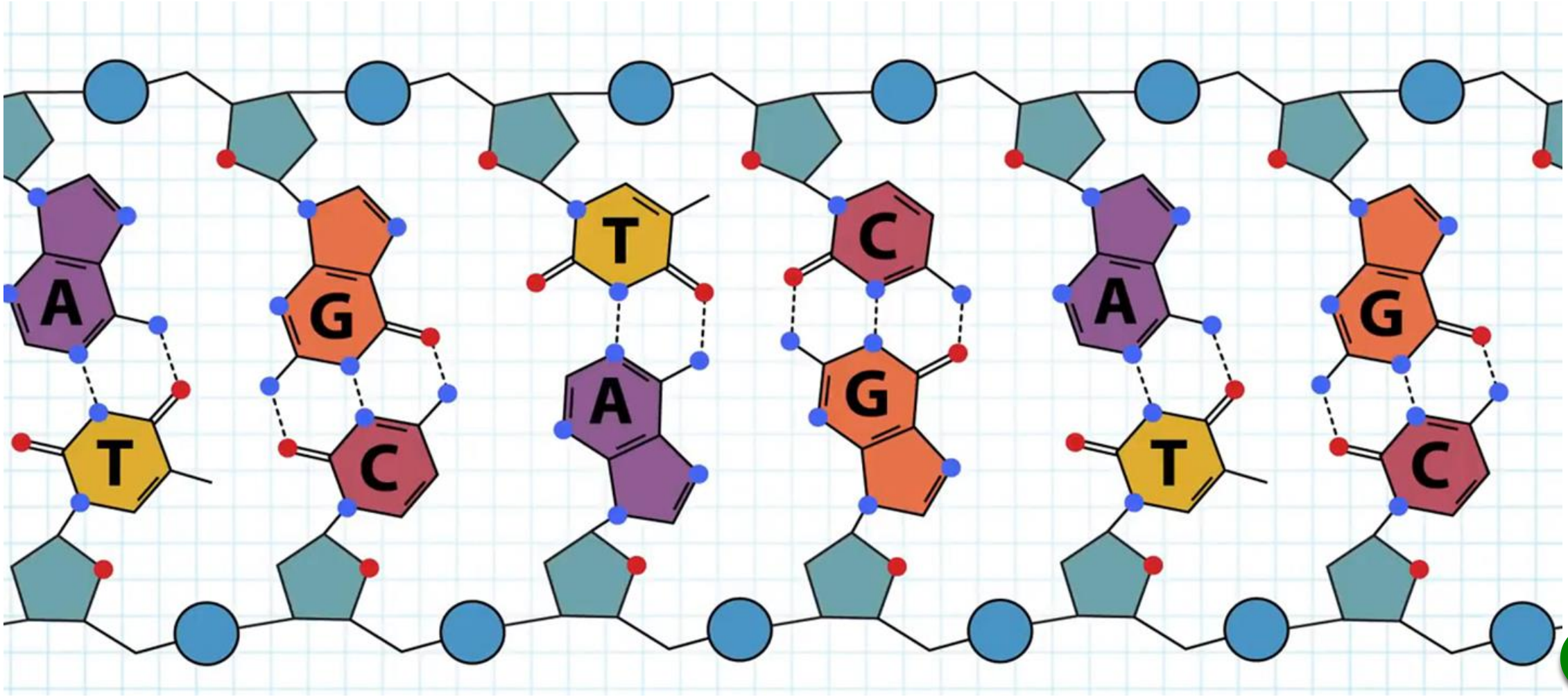
Base Pair



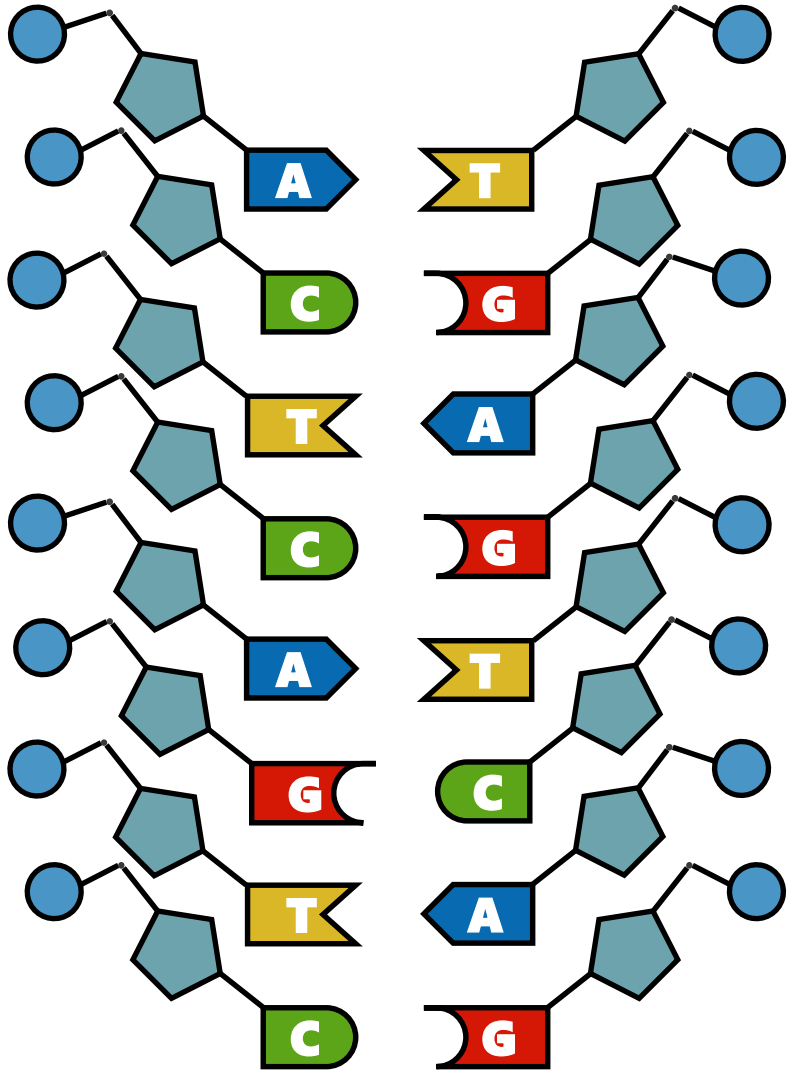
Cytosine (C)

Guanine (G)

Nucleotides › Nitrogenous Bases › Base Pairing

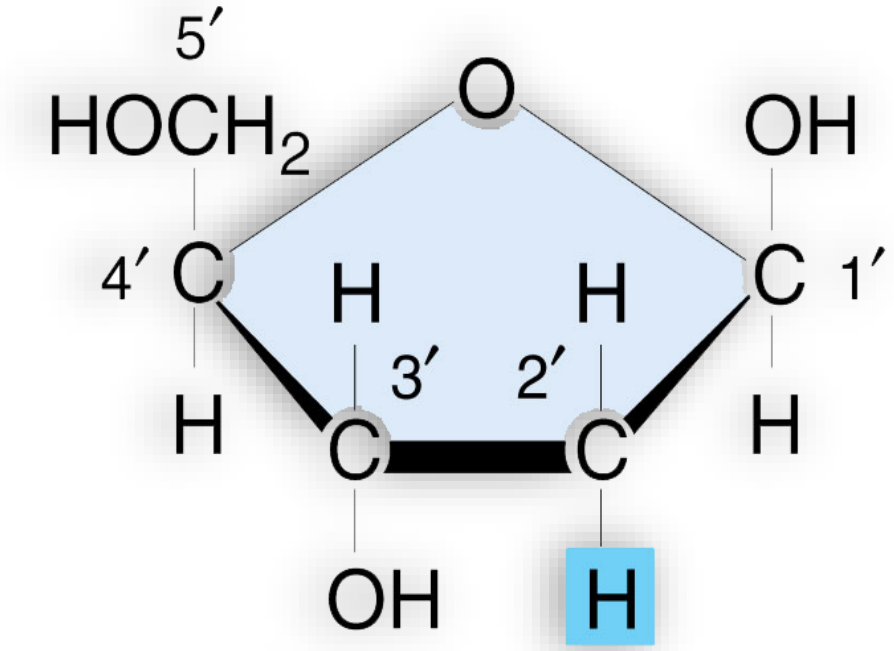


Because of this **complementary** base pairing, the order of the bases in one strand determines the order of the bases in the other strand

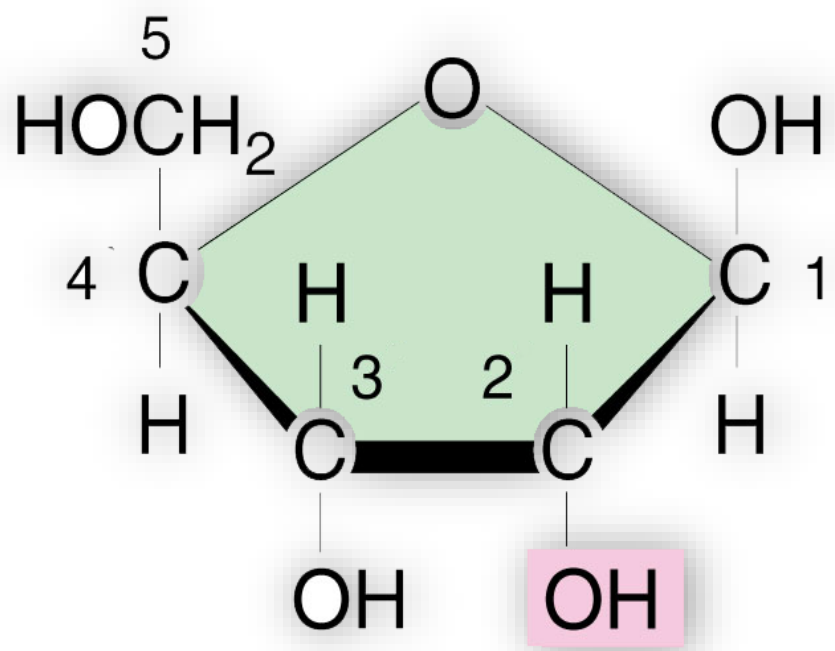


Nucleotides › Pentose Sugar

A Pentose sugar is a 5-carbon sugar in a ring form



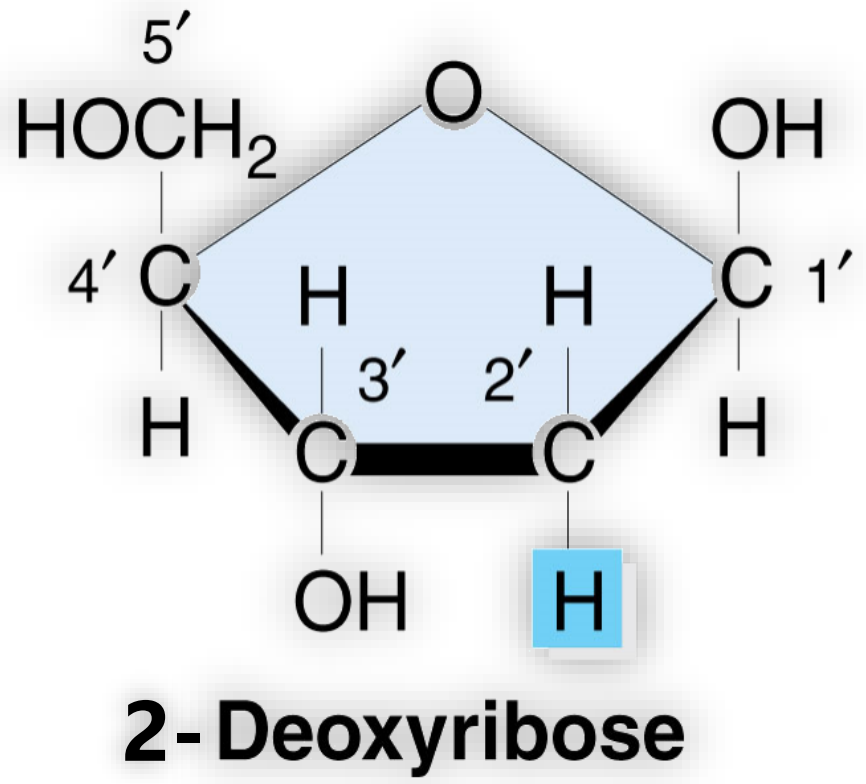
Deoxyribose



Ribose

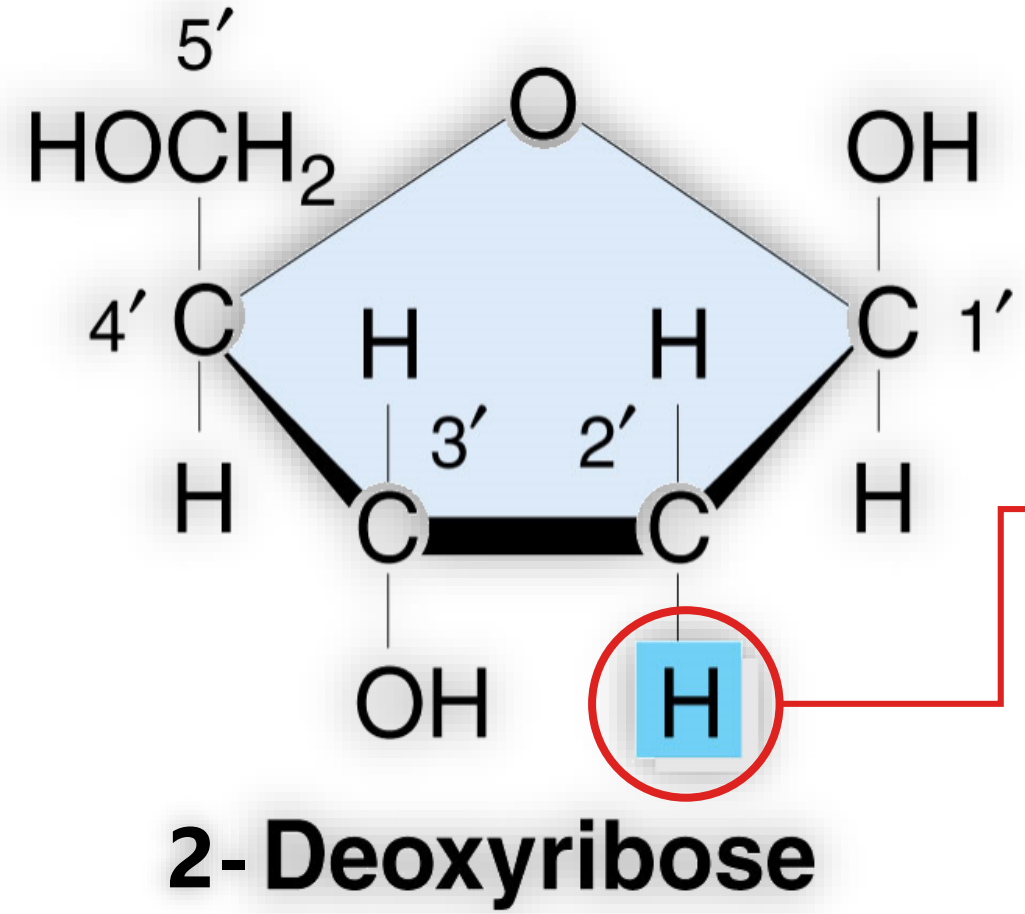
Nucleotides › Pentose Sugar › The Sugar Component

The sugar component of DNA is **2-deoxyribose**



2-Deoxyribose

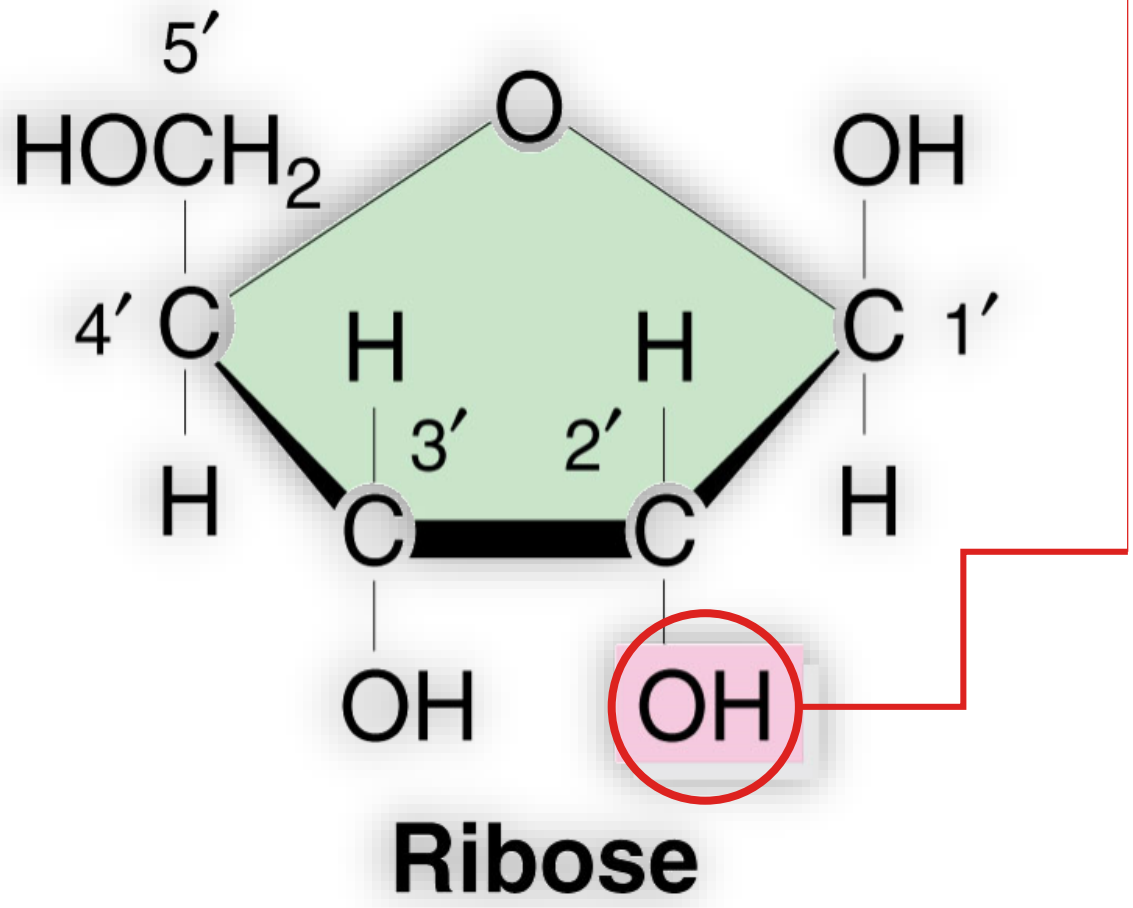
Nucleotides › Pentose Sugar › The Sugar Component



2-Deoxyribose

The absence of OH- at carbon 2 has wide ranging effects on both their chemistry and structure

Nucleotides › Pentose Sugar › The Sugar Component

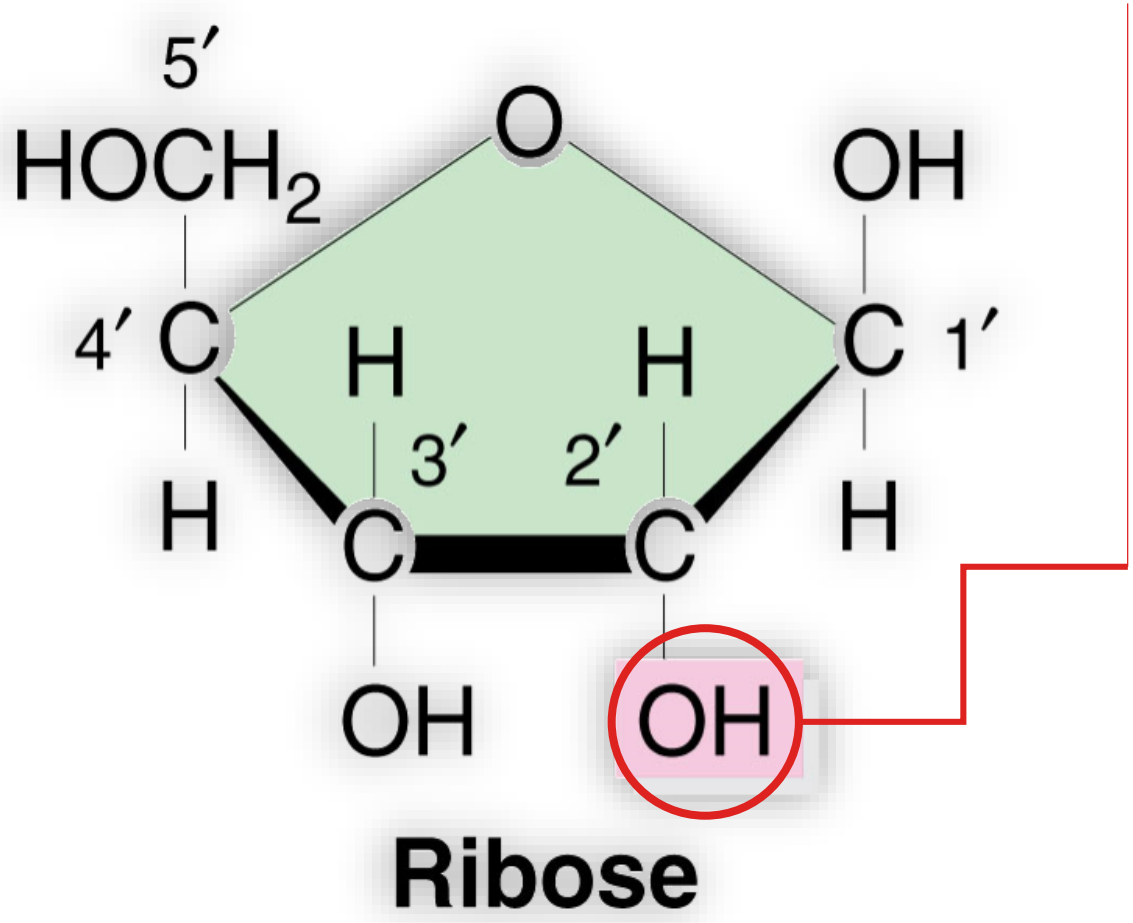


Ribose

The presence of the bulky hydroxyl group on the 2-position

1. Limits the range of possible secondary structures available to the RNA molecule

Nucleotides › Pentose Sugar › The Sugar Component



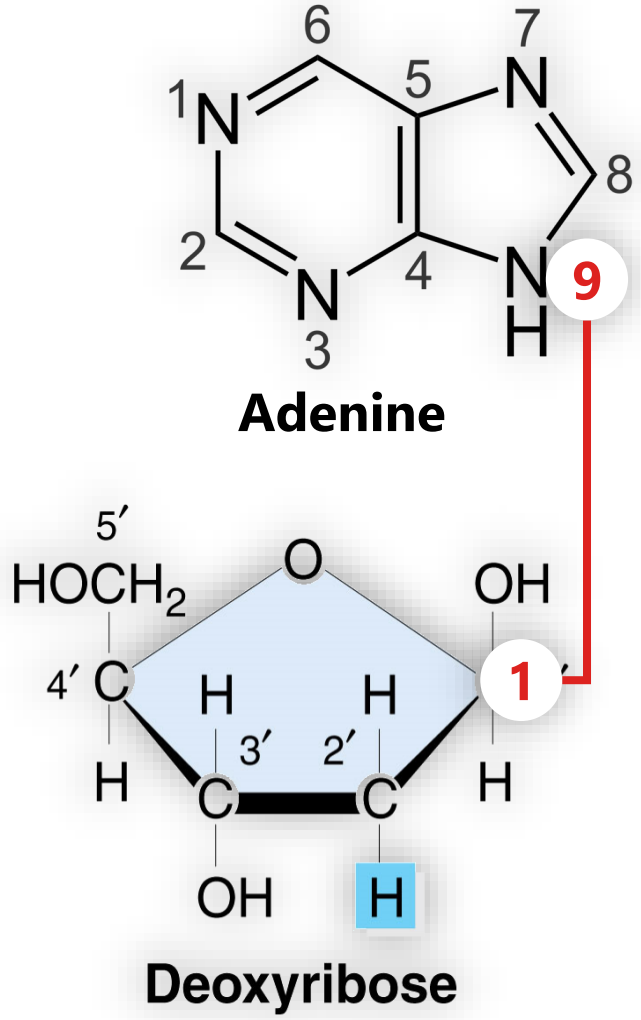
Ribose

The presence of the bulky hydroxyl group on the 2-position

2. Makes it more susceptible to chemical and enzymatic degradation

Nucleotides › Pentose Sugar › Nitrogenous Base Link

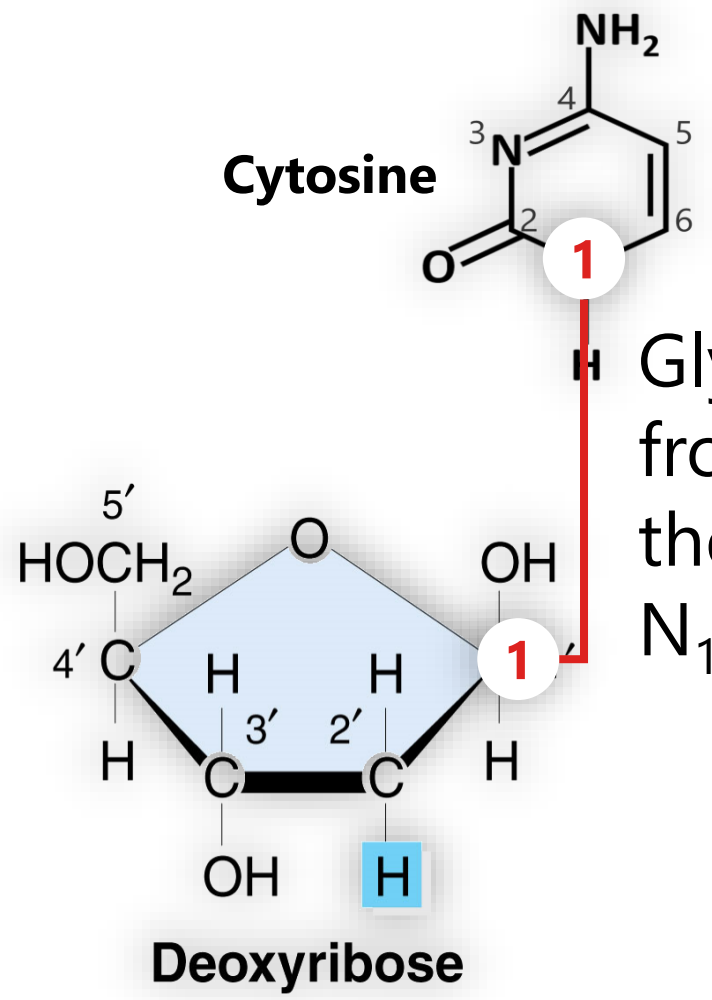
Pentose Sugar – Purine bond



Glycosidic bond from position 1 on the pentose ring to N_9 of purines

Nucleotides › Pentose Sugar › Nitrogenous Base Link

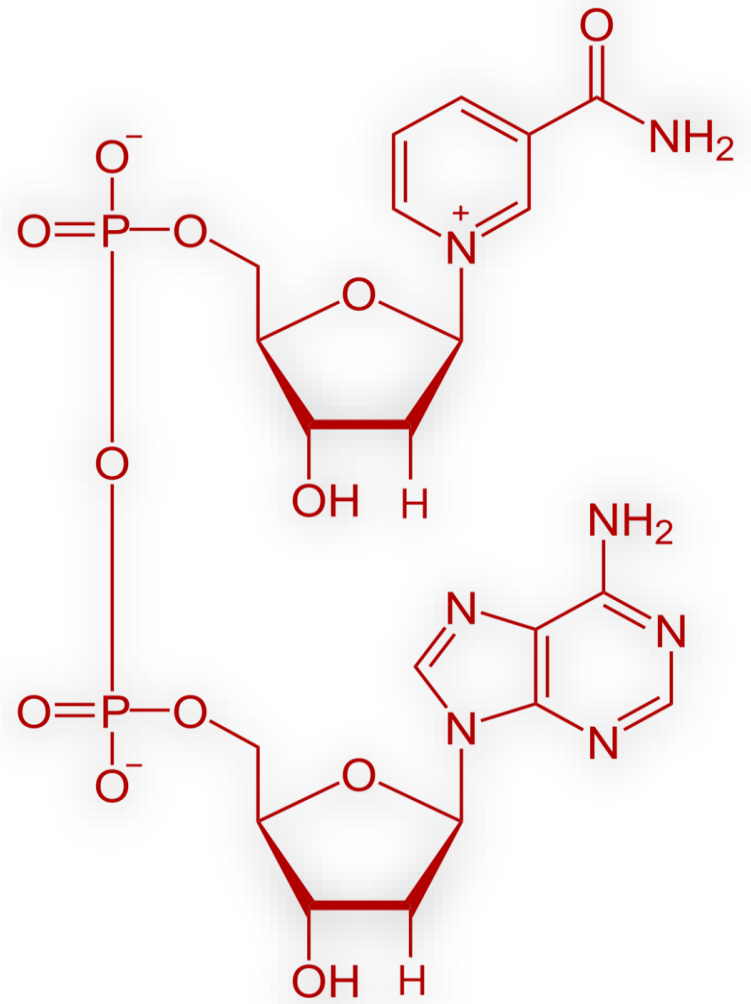
Pentose Sugar – Pyrimidine bond



Glycosidic bond from position 1 on the pentose ring to N_1 of pyrimidines

Nucleotides › Pentose Sugar › Nitrogenous Base Link

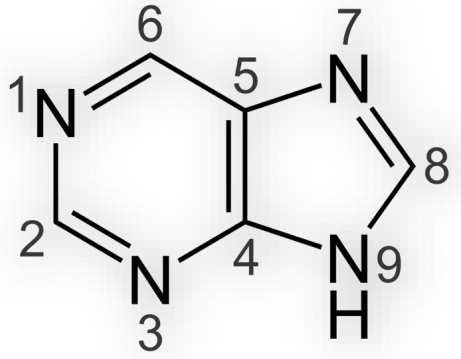
Nucleotide Diagram



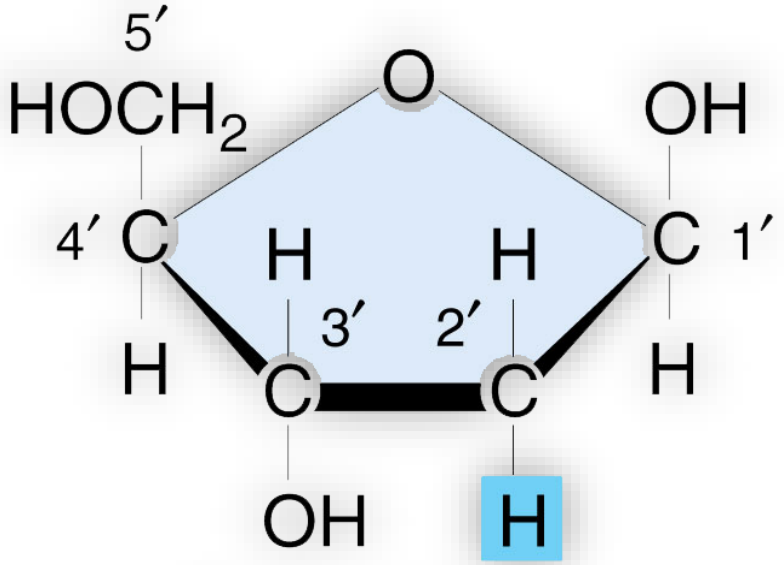
Nucleotides › Pentose Sugar › Nitrogenous Base Link

Note

To avoid ambiguity between the numbering systems of the heterocyclic rings and the sugar, positions on the pentose are given a prime (′)



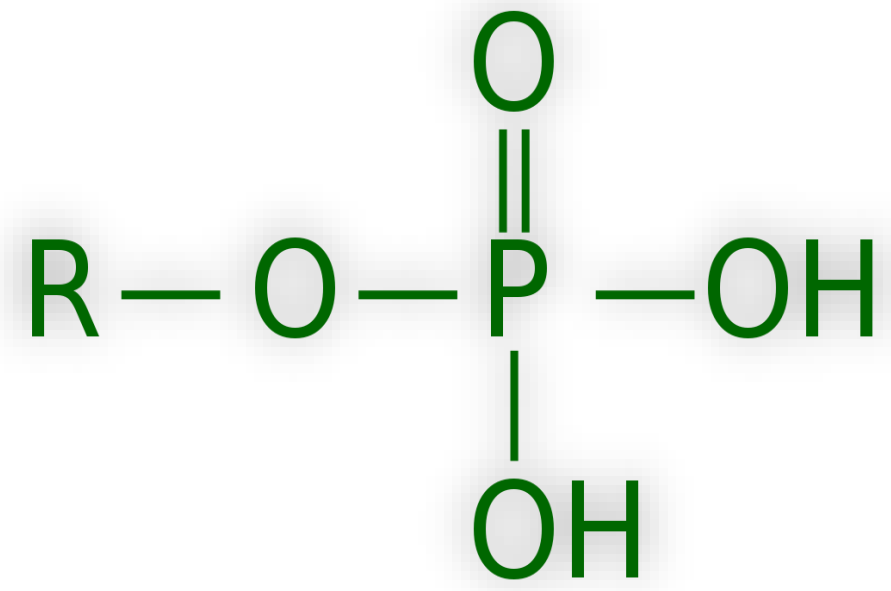
Base



Deoxyribose

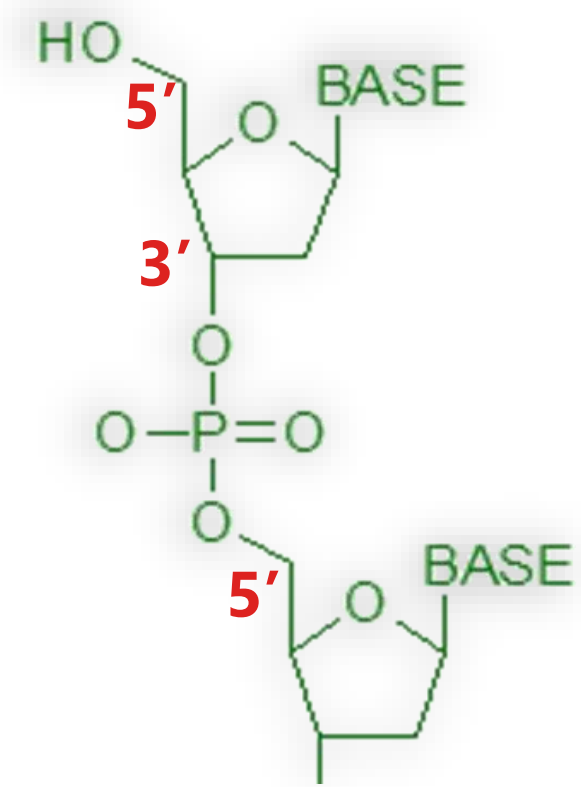
Nucleotides › Phosphate Group

HPO_4^{2-}



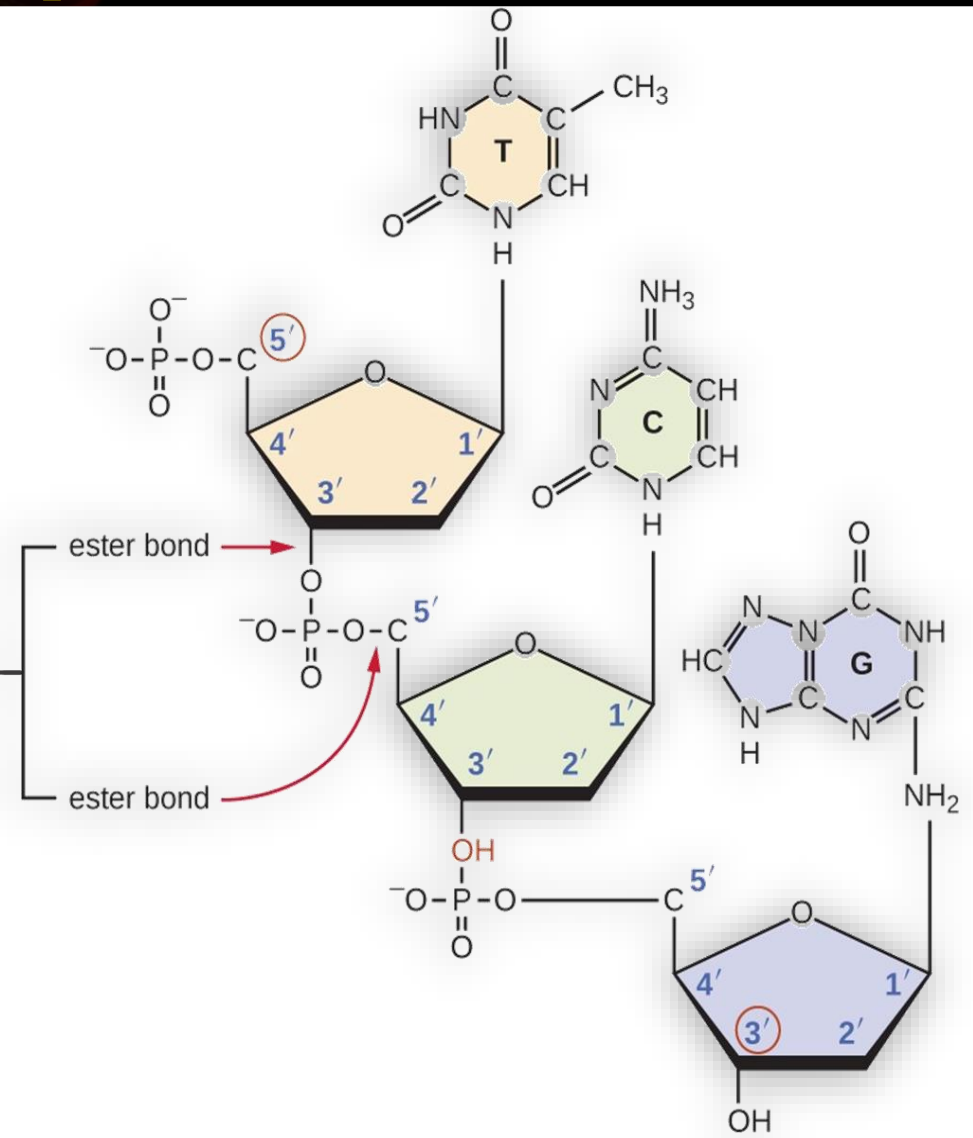
Nucleotides › Phosphate Group

The 5′ position of one pentose ring is connected to the 3′ position of the next pentose via a phosphate

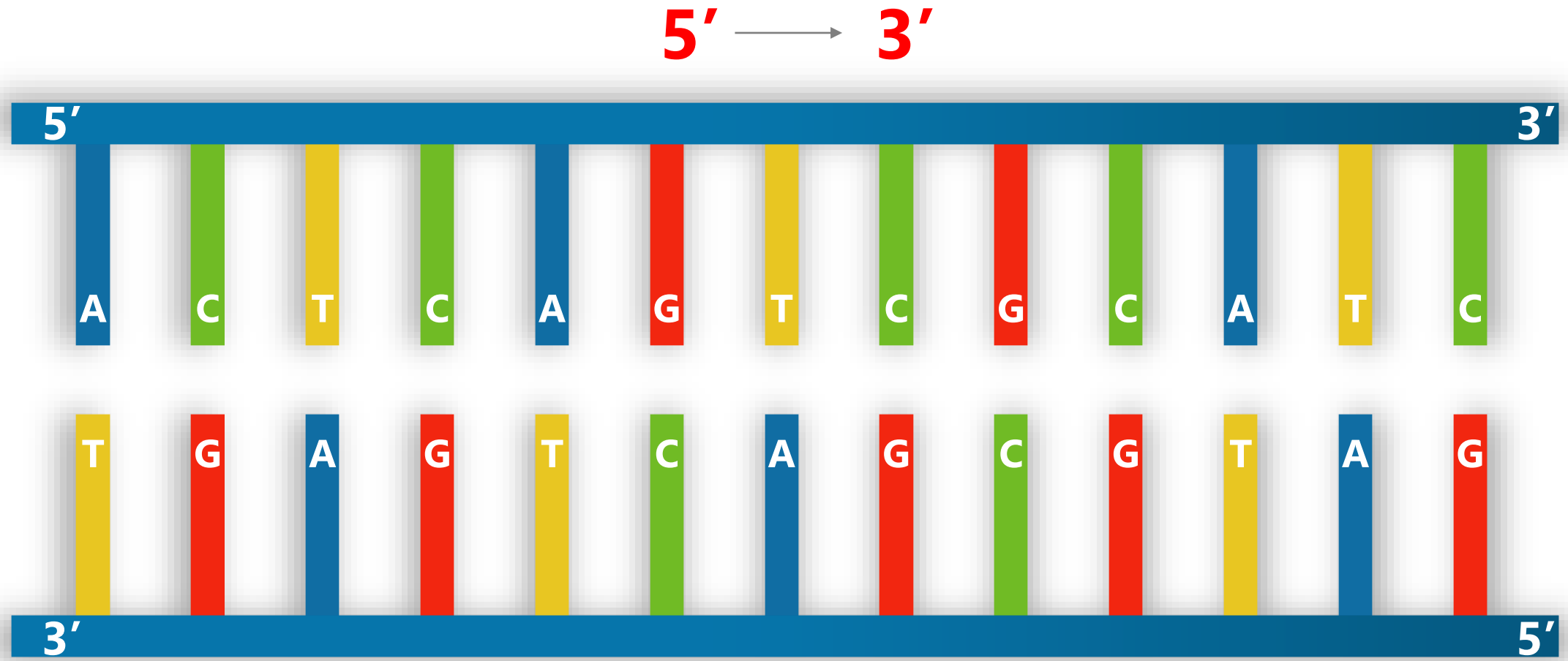


Nucleotides › Phosphate Group

Thus, the sugar - phosphate backbone is said to consist of 5′ – 3′ **phosphodiester bond** or linkages

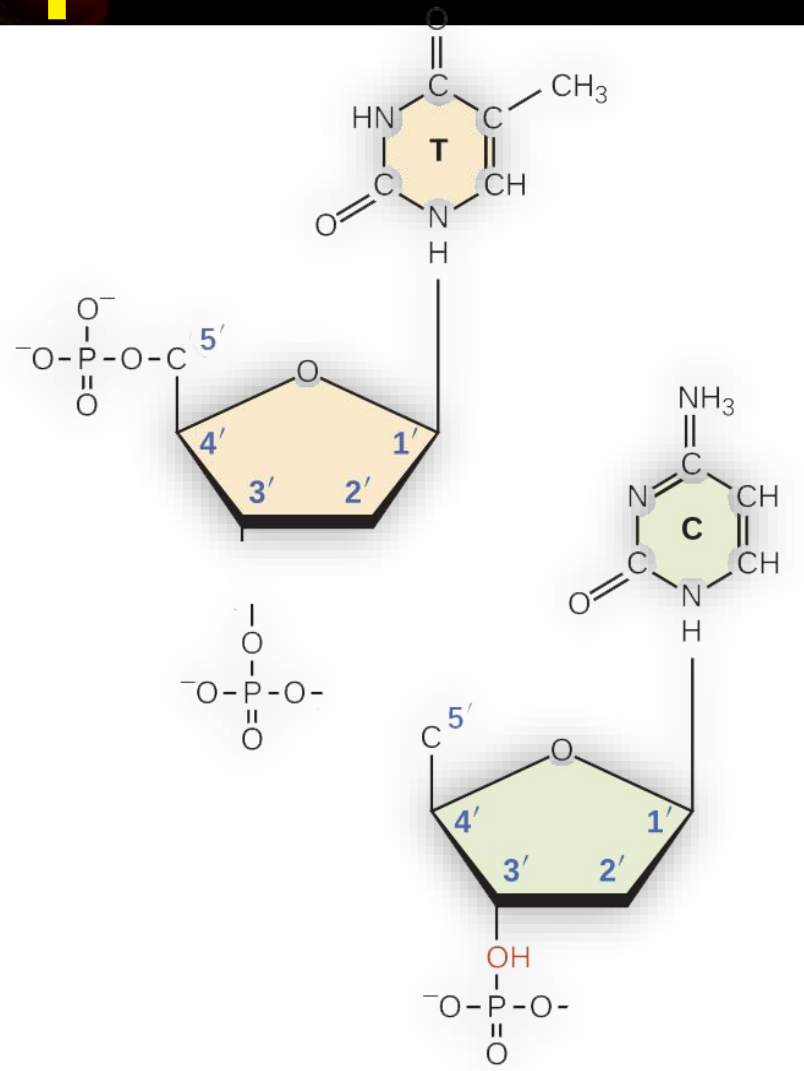


Nucleotides › Phosphate Group



Nucleotides › Phosphate Group

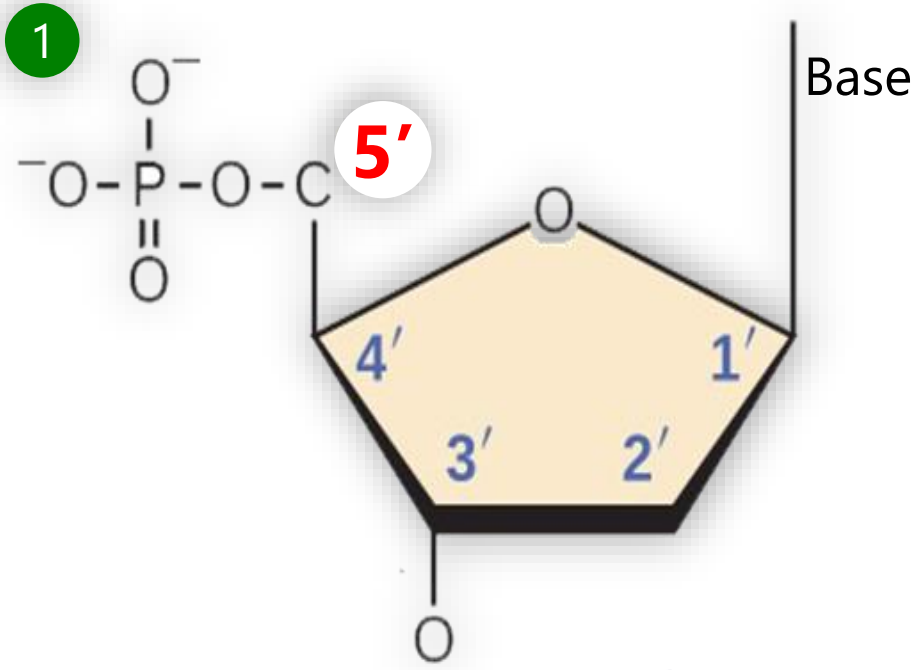
When DNA (RNA) is broken into its constituent nucleotides, the cleavage may take place on either side of the **phosphodiester bonds**



Nucleotides › Phosphate Group

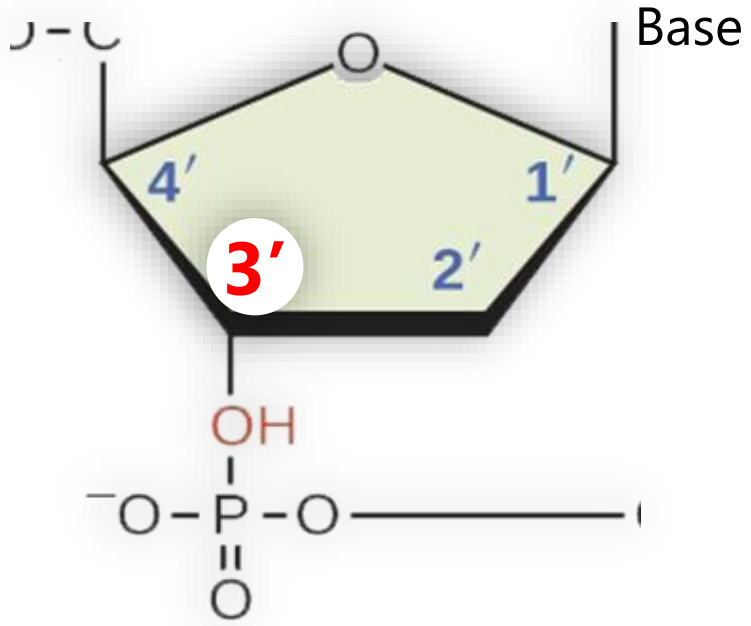
2 types of nucleotides released from N.A.

1



Nucleoside-5′-monophosphate

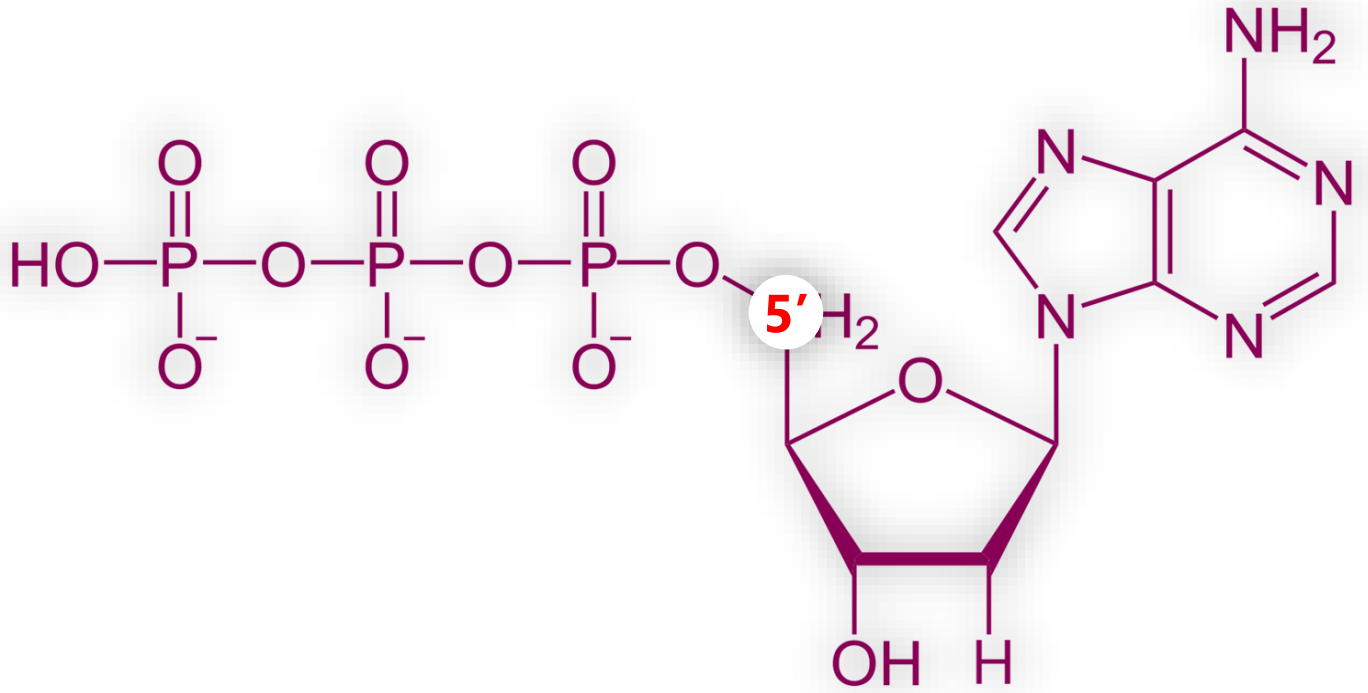
2



Nucleoside-3′-monophosphate

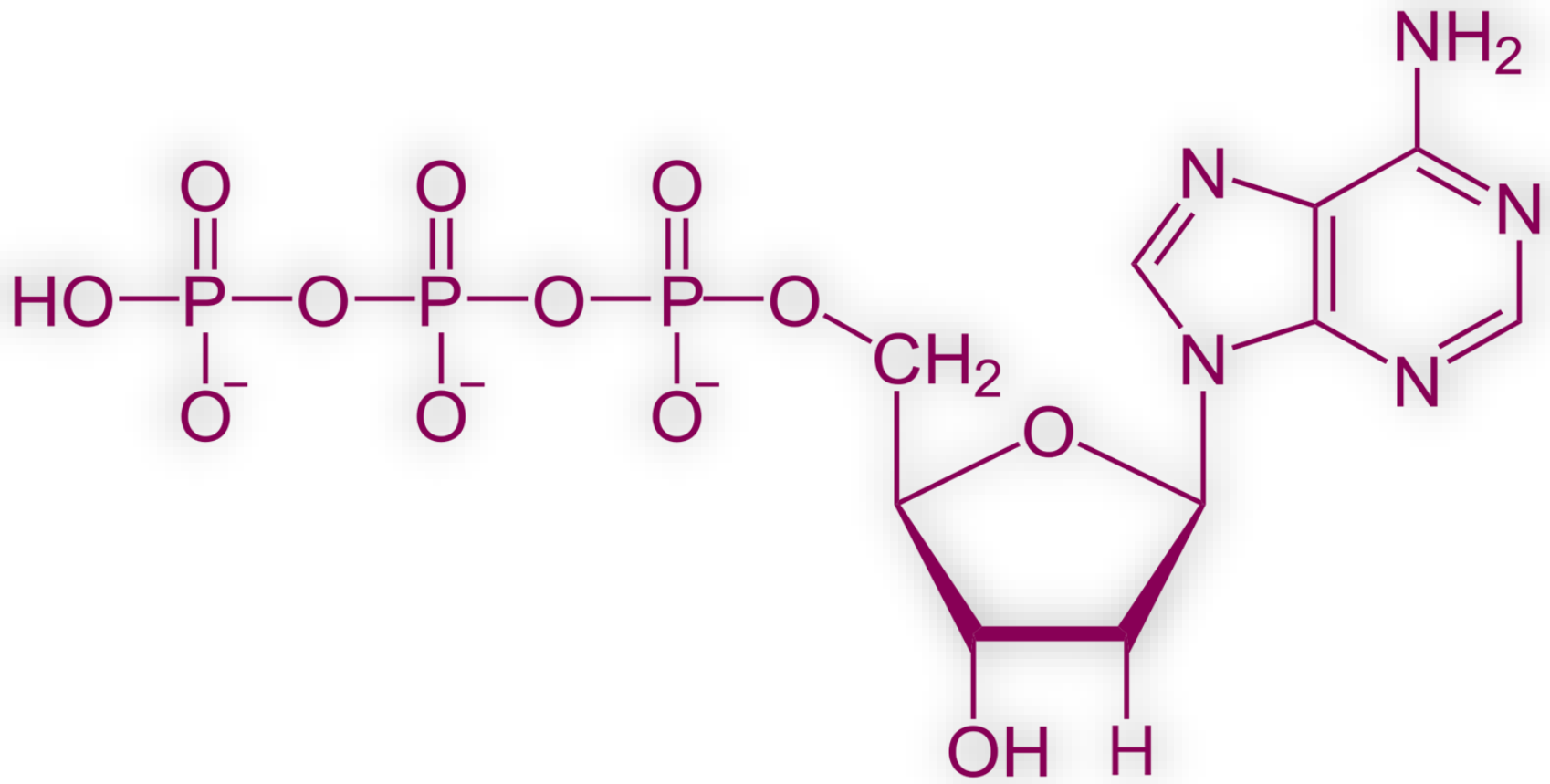
Nucleotides › Phosphate Group

All the nucleotides can exist in a form in which there is more than one phosphate group linked to the 5′ position



Nucleoside-5′-triophosphate

Nucleotides › Phosphate Group

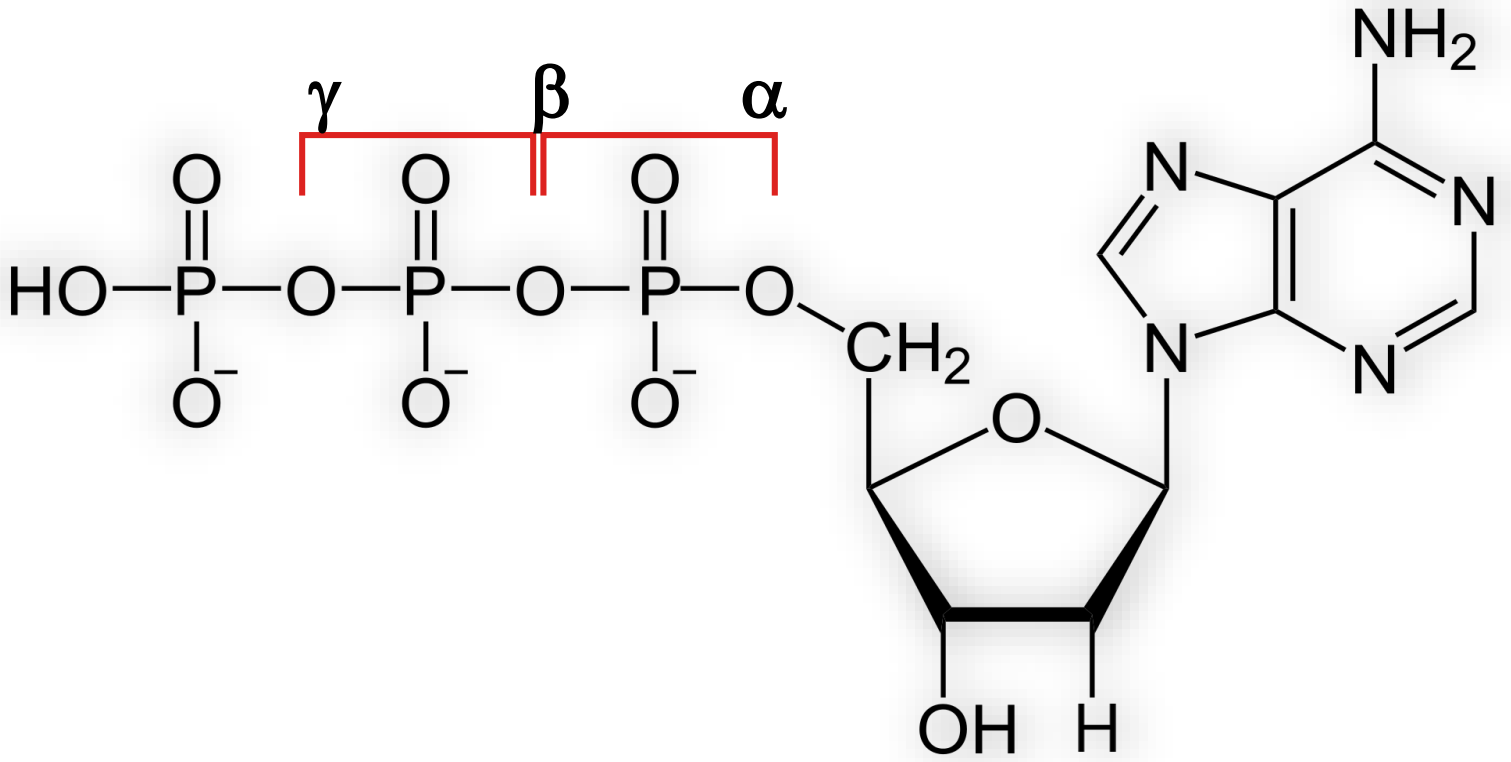


Adenosine-5-triophosphate

Nucleotides › Phosphate Group

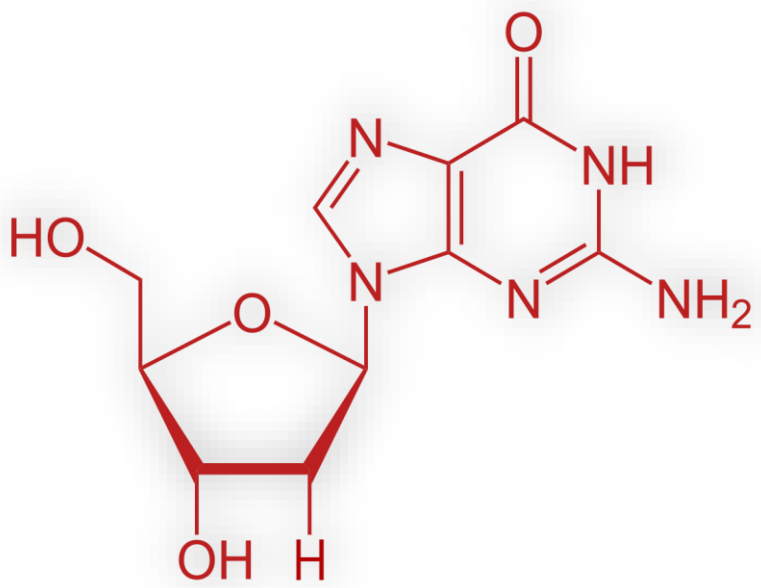
Energy-rich Bonds

used to provide an energy source for various cellular activities

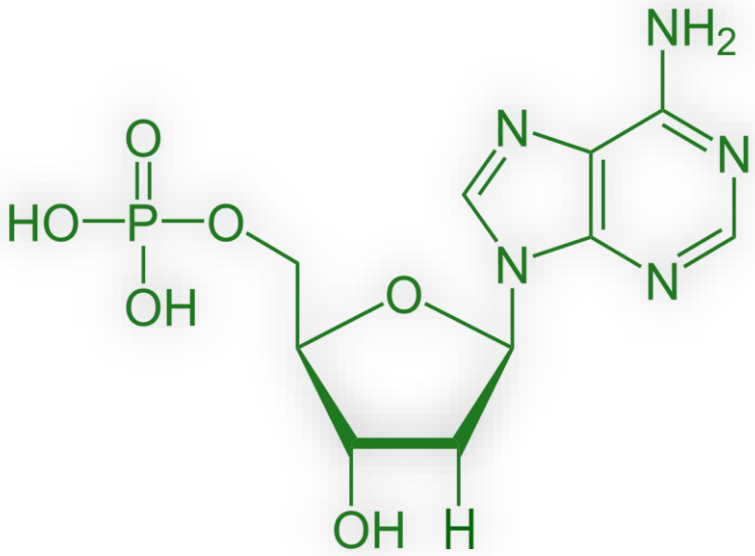


Nucleotides › Phosphate Group

Partial hydrolysis yields nucleosides and nucleotides compounds



Nucleoside

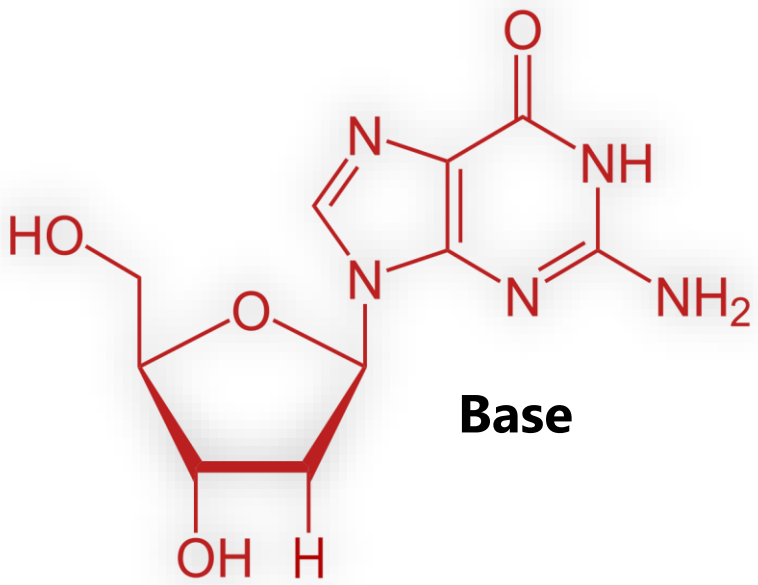


Nucleotide

Nucleotides › Phosphate Group

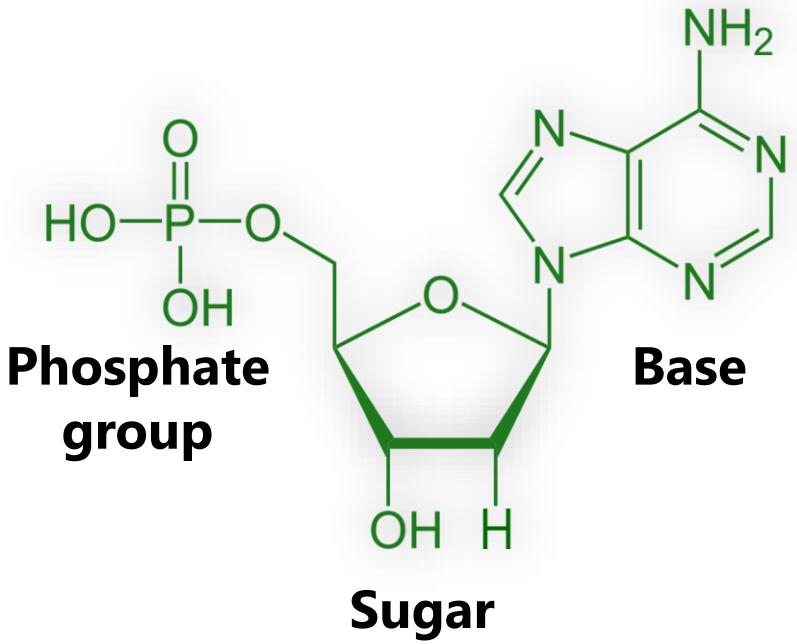
Nucleoside

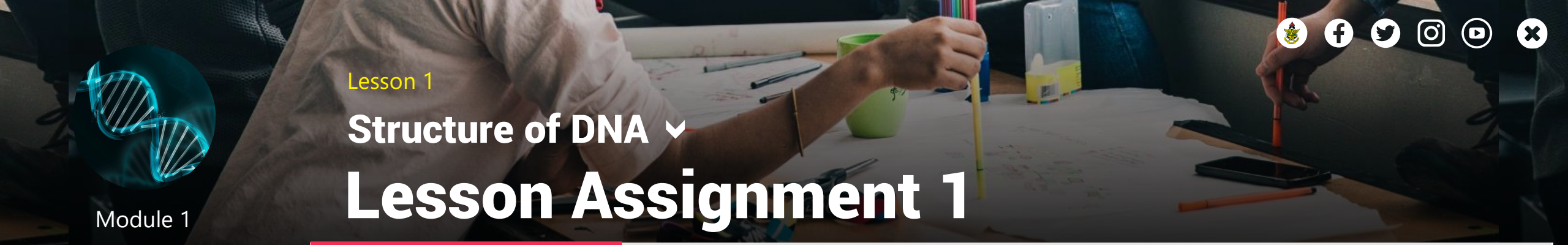
A base linked to a sugar



Nucleotide

When a phosphate group is added to a base-sugar





Lesson Assignment 1

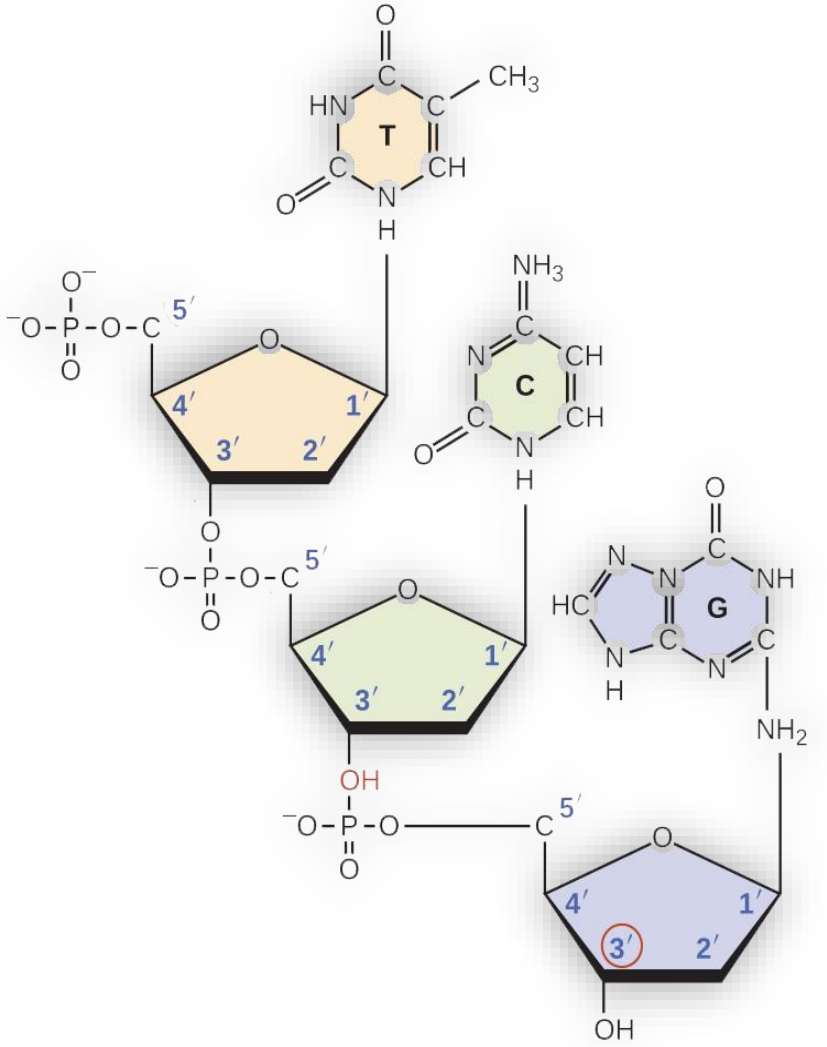
Bases, nucleosides, and nucleotides have related names. Learn these nomenclature depending on the base present.

Example:

adenine- adenosine-adenylic acid-dAMP

Nucleotides › Shorthand Notation

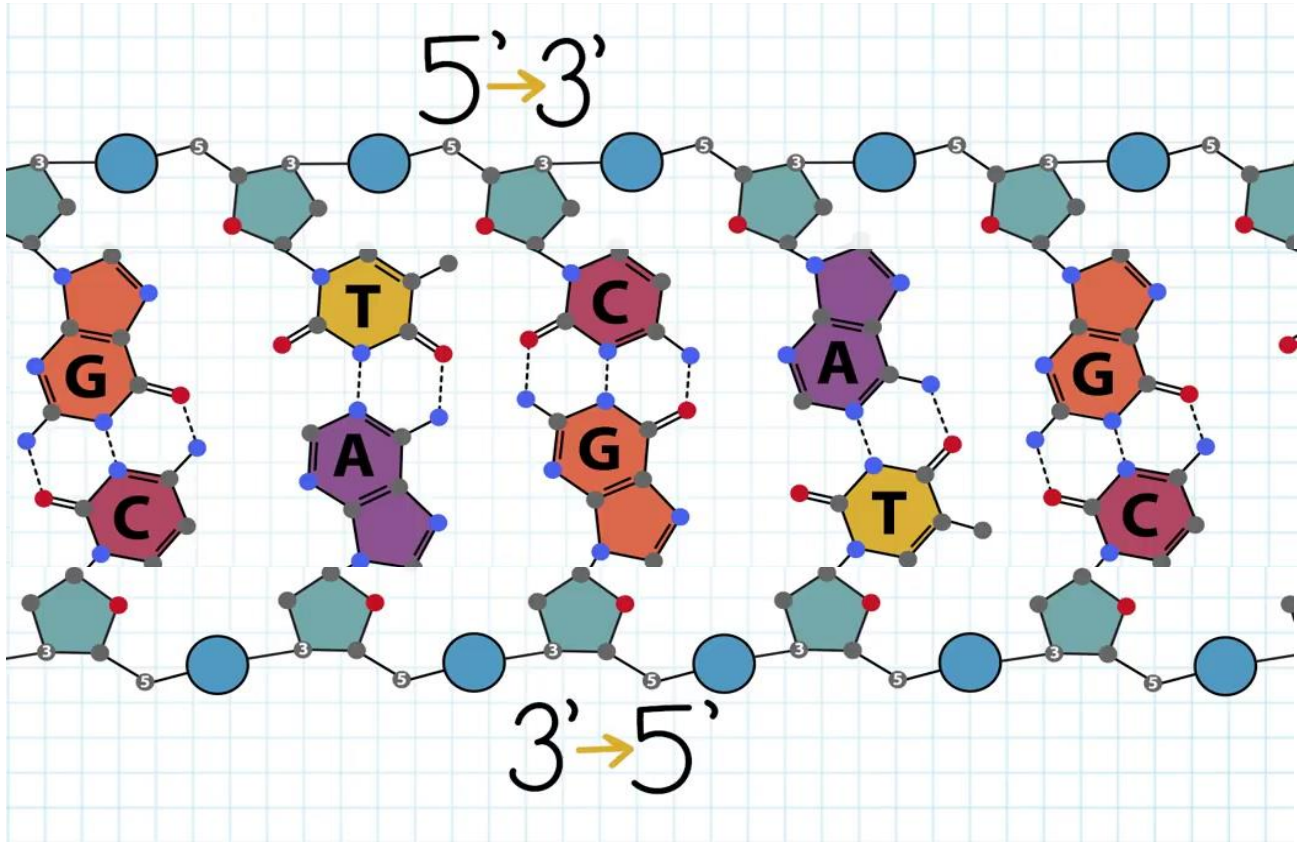
The representation of polynucleotide chains by complete formulae is clumsy and therefore has become necessary to use schematic systems



Nucleotides › Shorthand Notation

5′ → 3′ polarity on the top line of the sequence with the complementary strand of opposite polarity lying below

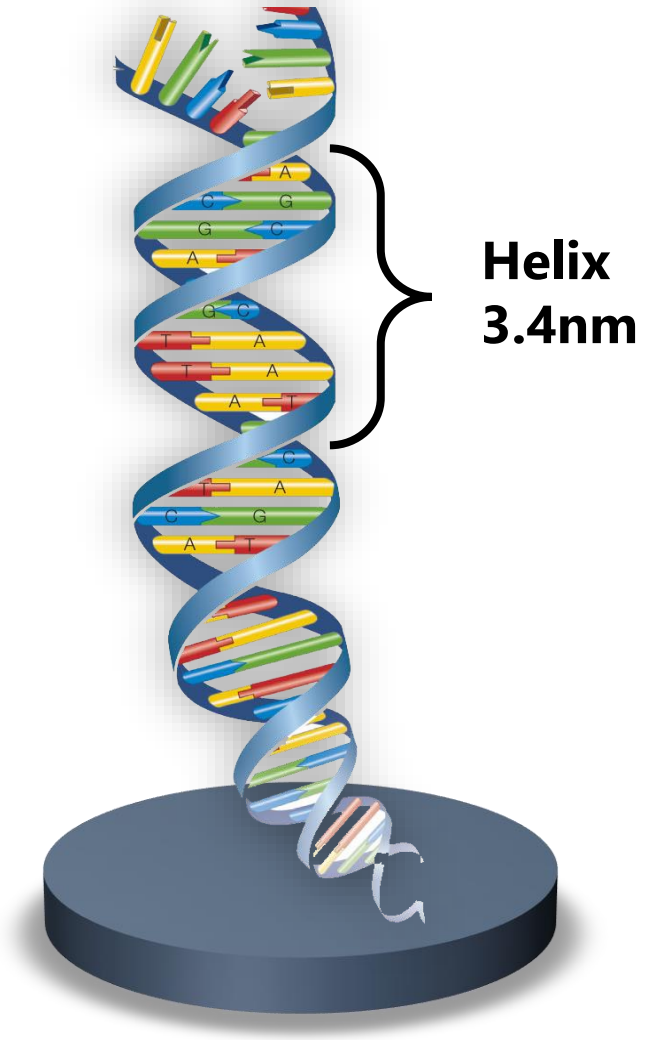
5′- GTCAG - 3′
3′- CAGTC - 5′



The Double-Helix › Some Characteristics

1 Helix

Regular Helix has complete turn (pitch) of **34Å** or (3.4nm)

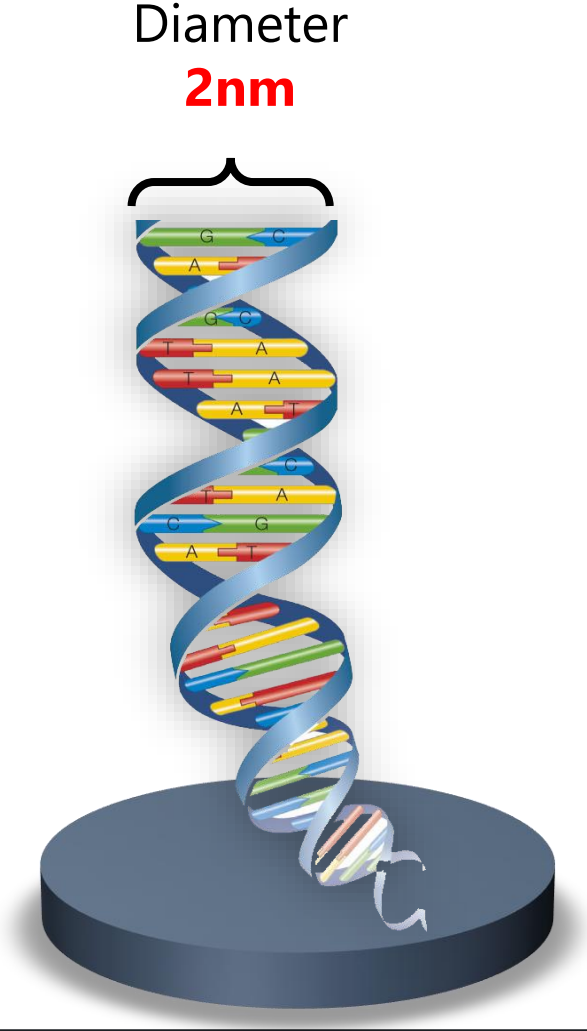


The Double-Helix › Some Characteristics

1. Helix = 3.4nm

2. **Diameter**

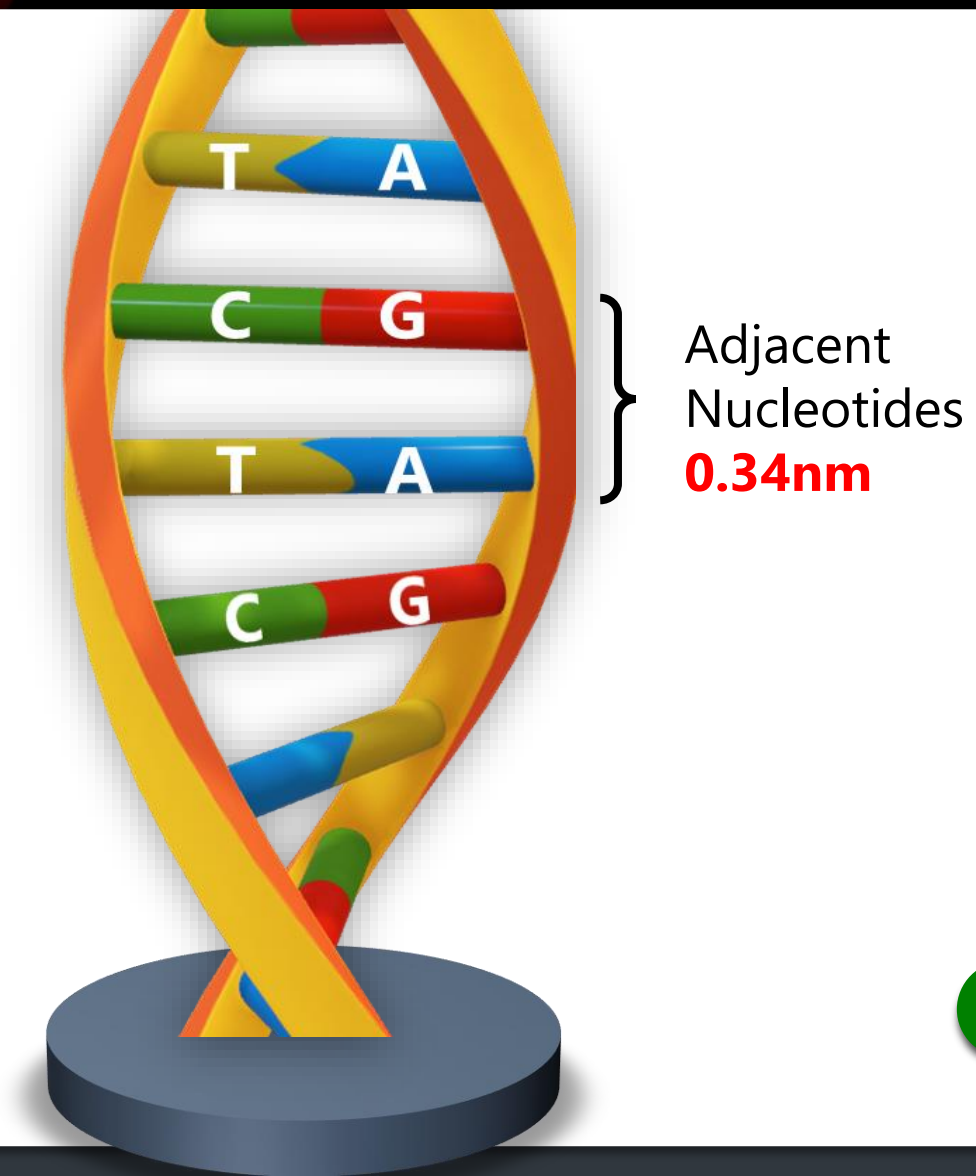
   Has a diameter of
   ≈ **20Å** or (**2nm**)



The Double-Helix › Some Characteristics

1. Helix = 3.4nm
2. Diameter = 2nm
3. **Nucleotides Distance**

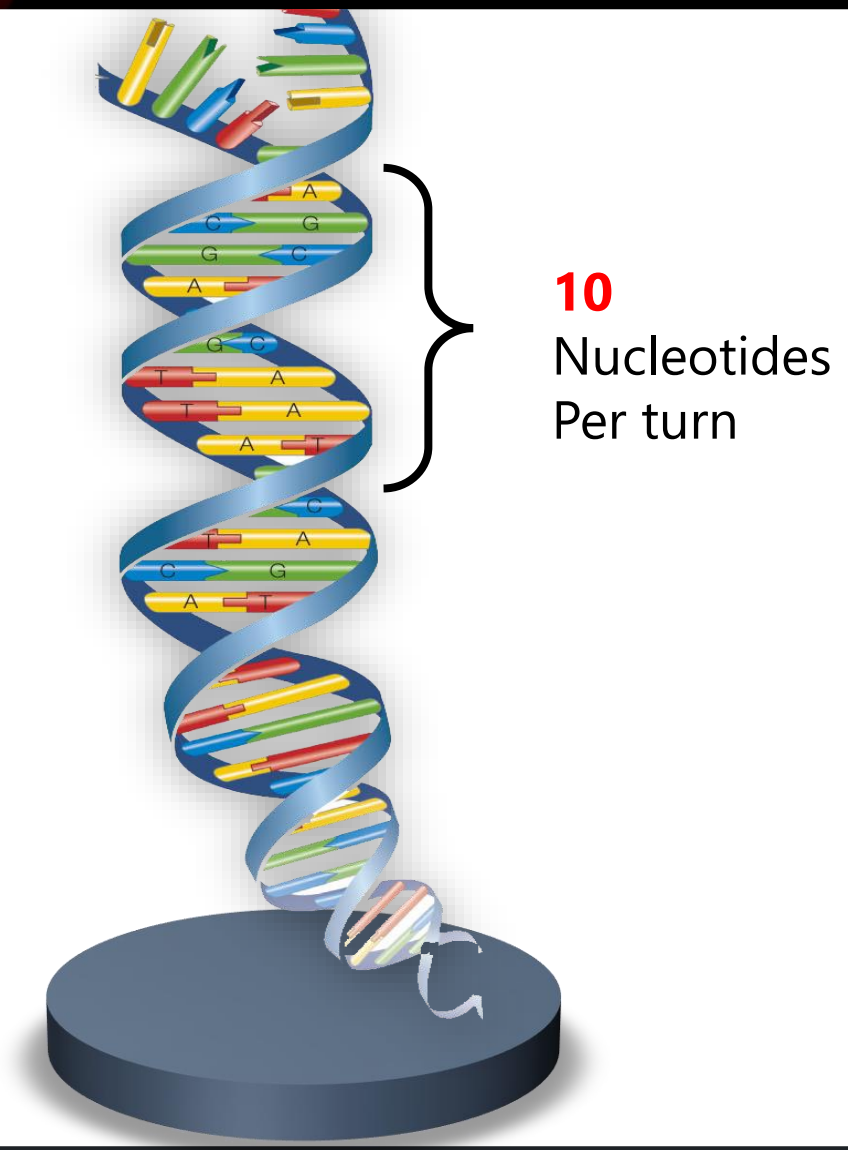
The distance between adjacent nucleotides is **3.4Å** or **(0.34nm)**



The Double-Helix › Some Characteristics

1. Helix = 3.4nm
2. Diameter = 2nm
3. Nucleotides Distance = 0.34nm
4. **Nucleotides Per Turn**

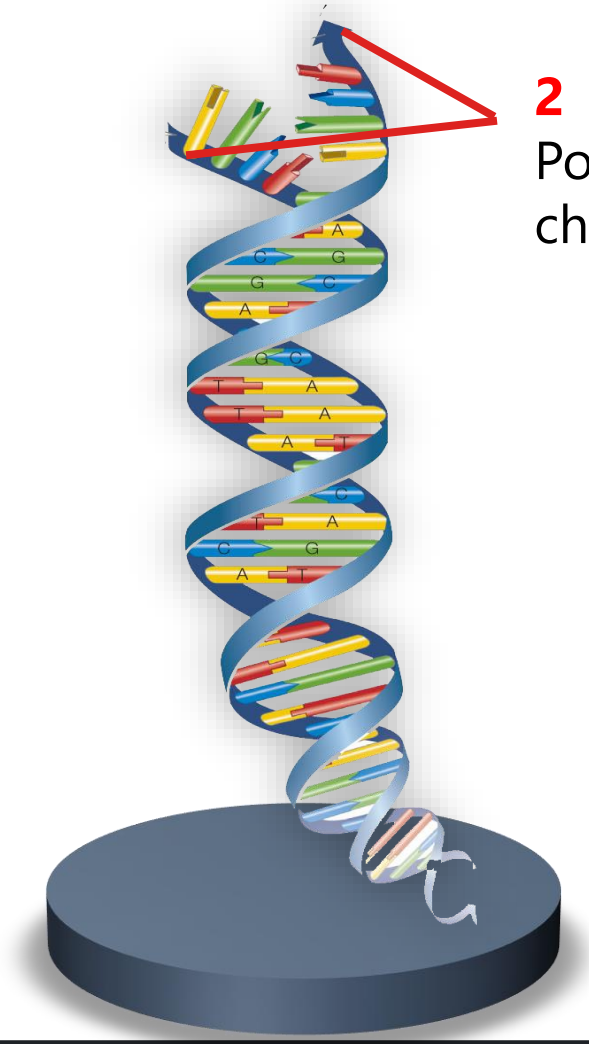
There must be
10 nucleotides
per turn



The Double-Helix › Some Characteristics

1. Helix = 3.4nm
2. Diameter = 2nm
3. Nucleotides Distance = 0.34nm
4. Nucleotides Per Turn = 10
5. **Polynucleotide Chains**

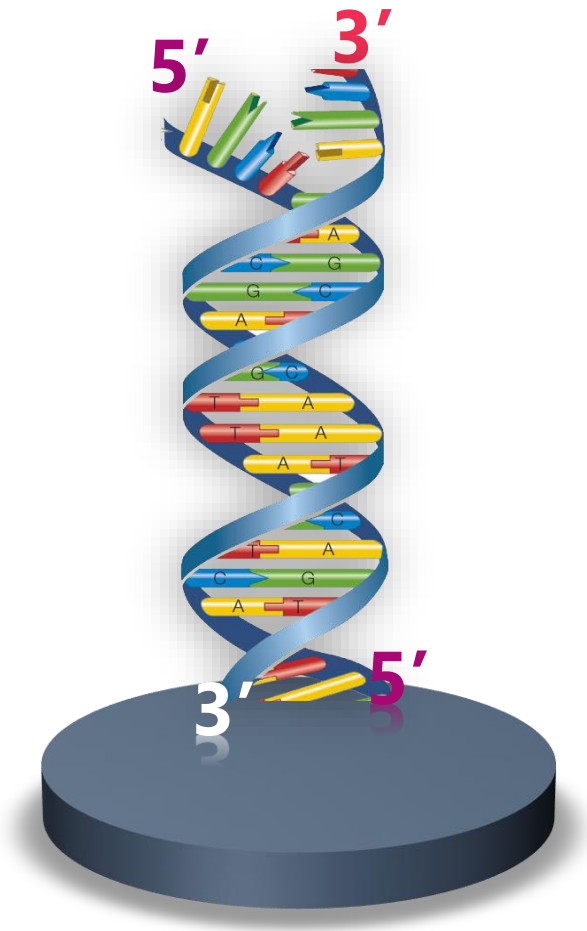
The density of DNA suggests that, the helix must contain **2** polynucleotide chains



The Double-Helix › Some Characteristics

Polynucleotide Chains

The two chains are anti-parallel which means if one strand has 5′→3′ polarity from top to bottom, then, the other must have 3′→5′ polarity from top to bottom



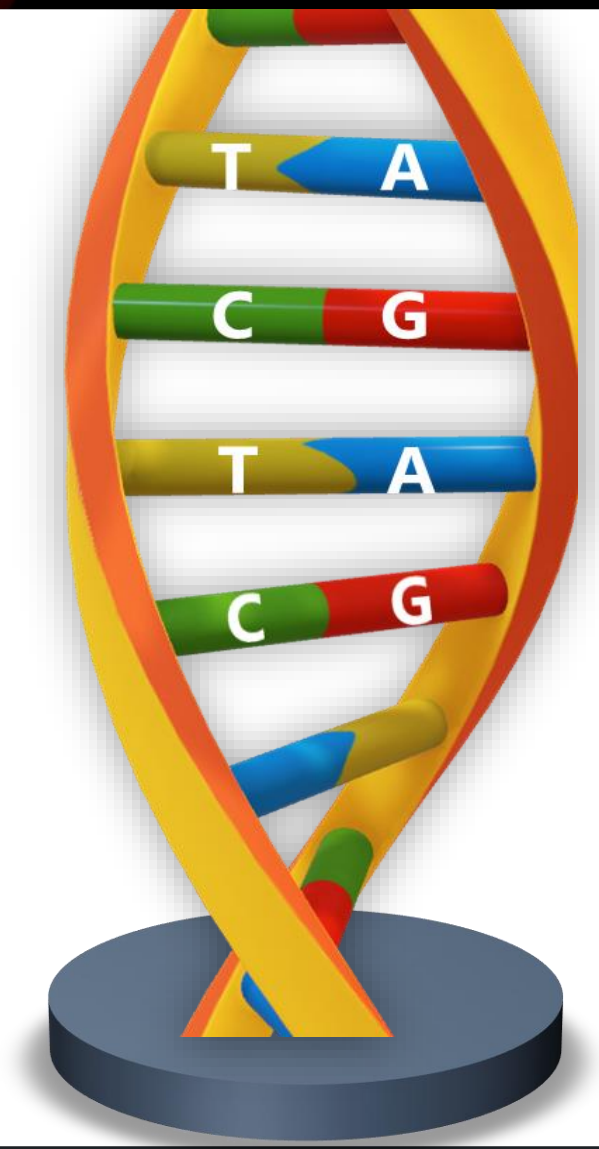
The Double-Helix › Some Characteristics

1 2 3 4

5 Polynucleotide Chains = 2

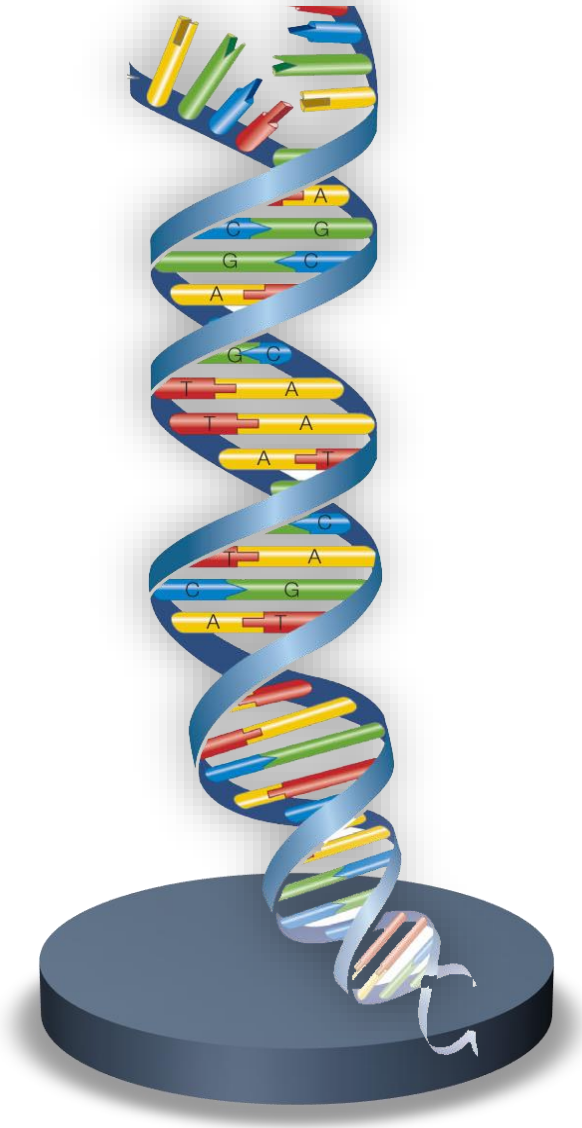
6 Proportion of Bases

Irrespective of the actual amounts of each base, the proportion of G is always the same as the proportion of C in DNA, and that of A is always the same as T



The Double-Helix › Some Characteristics

1. Helix = 3.4nm
2. Diameter = 2nm
3. Nucleotides Distance = 0.34nm
4. Nucleotides Per Turn = 10
5. Polynucleotide Chains = 2
6. Proportion of Bases = G=C, A=T



Module 1

DNA Structure

Lesson 1

Structure of DNA

Lesson Assignment 2

Assignment 1 | **Assignment 2** | Assignment 3 | Assignment 4

- Dashboard
- Introduction
- Lessons
- Assignments

Read on Chargaff's Rule

Contributions of the Base Pairs

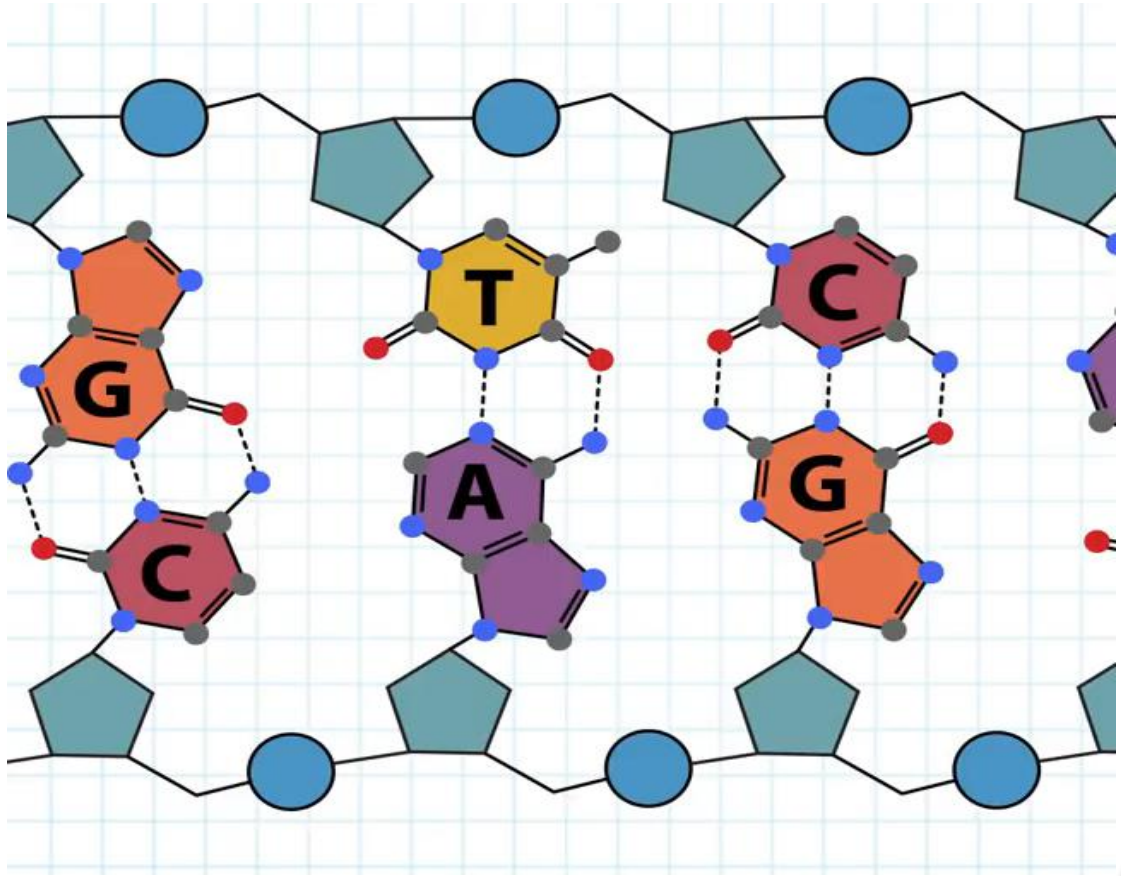
The base pairs affect the thermodynamic stability of the double helix in two ways:

1. **Hydrogen Bonding**
2. **Hydrophobic base-stacking**

Contributions of the Base Pairs

1 Hydrogen Bonding

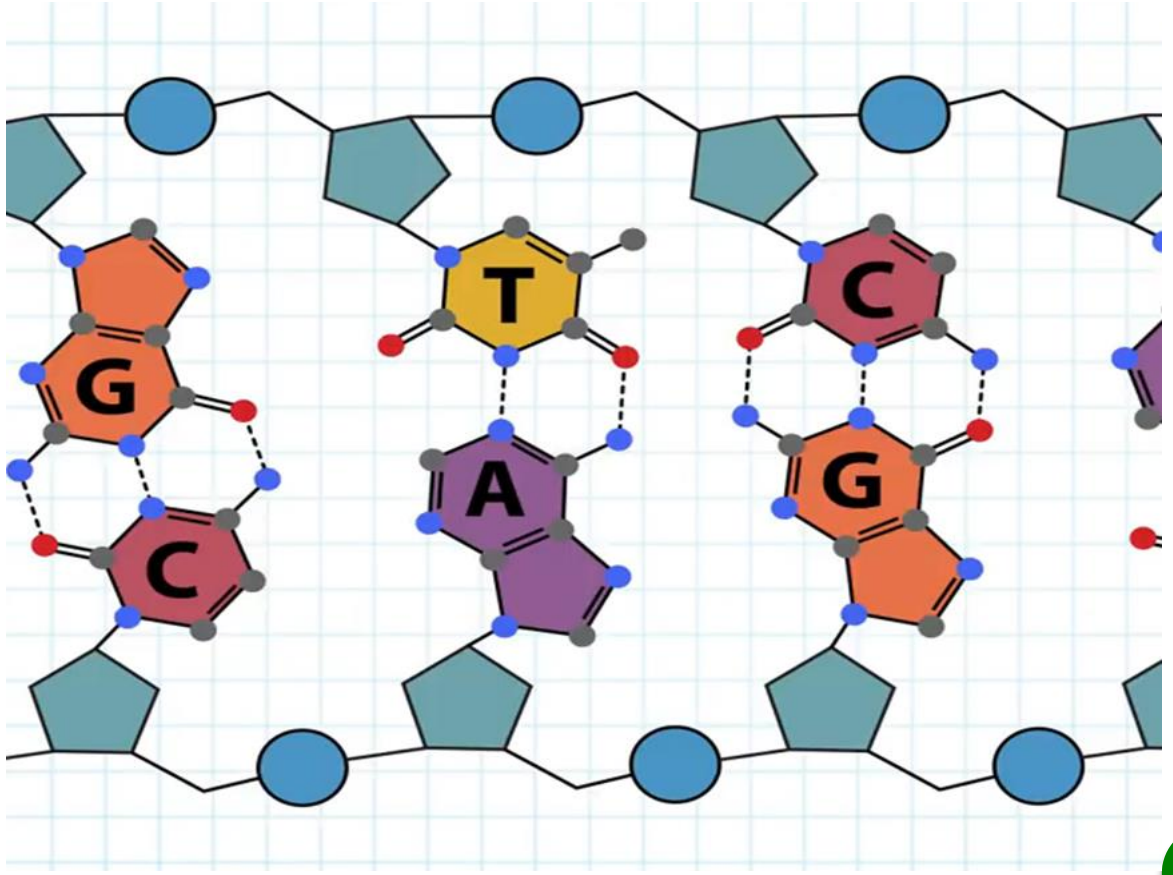
between the bases in each pair releases energy corresponding to 3 H-bonds per G-C and 2H-bonds per A - T pair



Contributions of the Base Pairs

1 Hydrogen Bonding

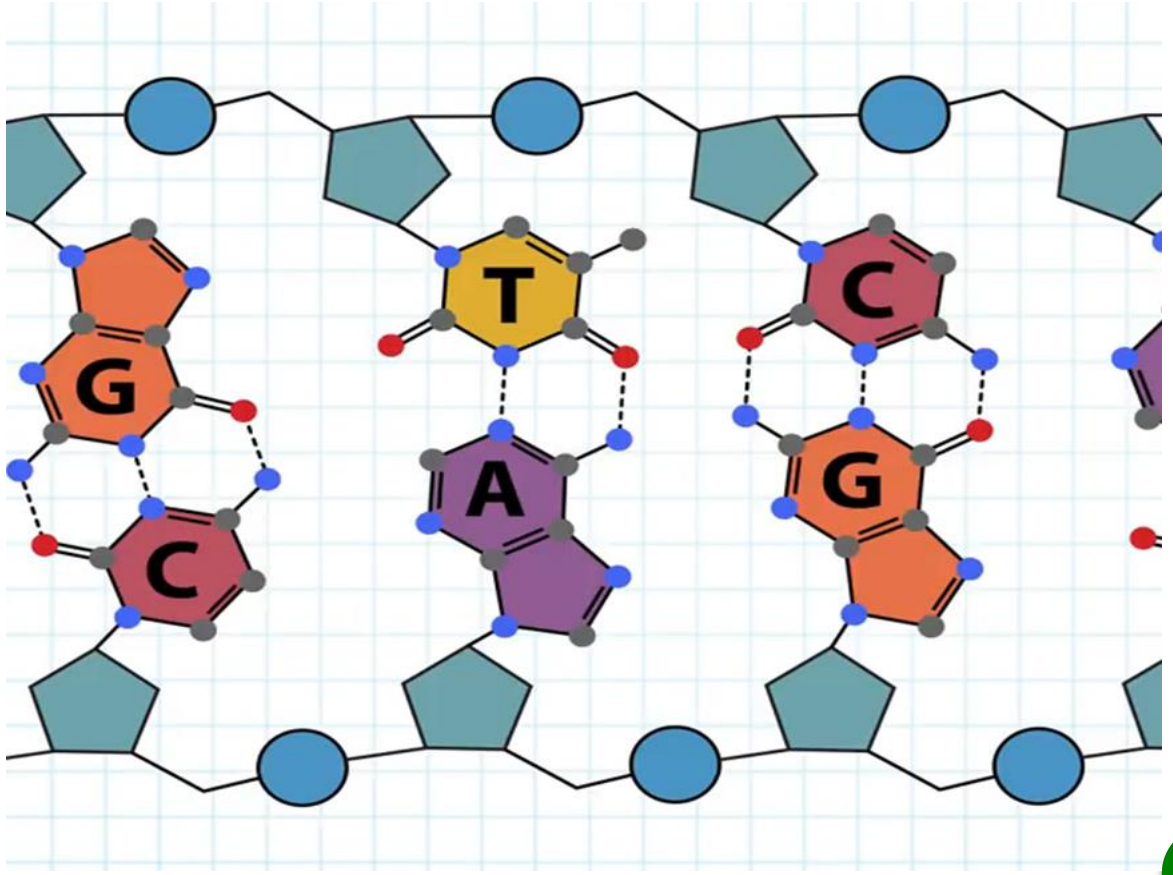
Due to the increased number of hydrogen bonds holding together a G:C nucleotide pair, regions of DNA rich in G + C are more stable than regions rich in A + T.



Contributions of the Base Pairs

1 Hydrogen Bonding

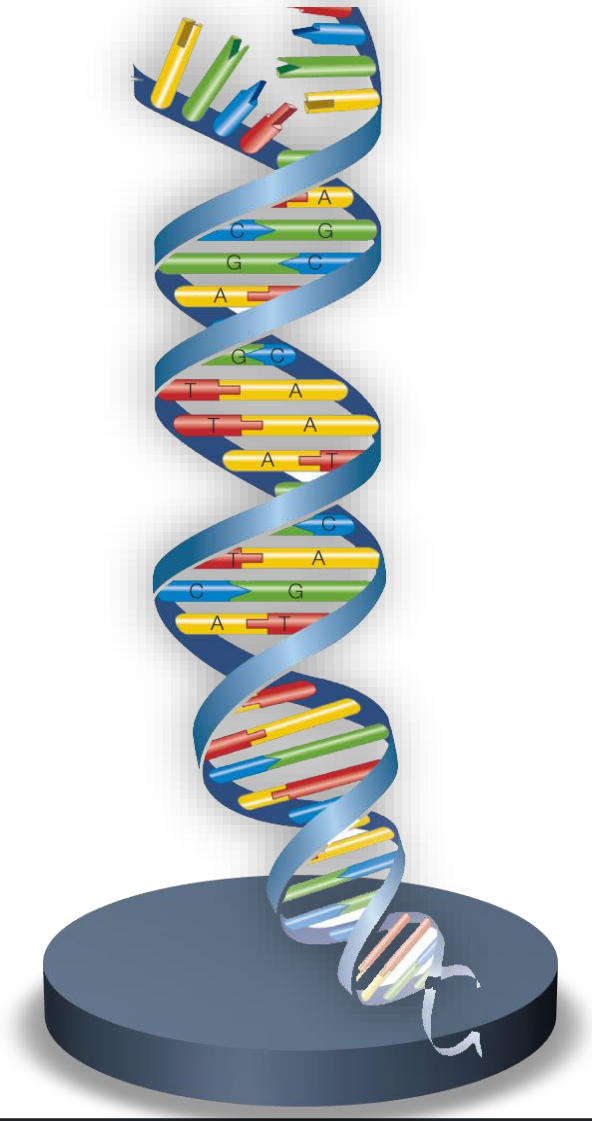
On denaturation, the A + T-rich regions will melt first



Contributions of the Base Pairs

1. Hydrogen Bonding
2. **Hydrophobic base-stacking**

The interaction between the electron systems of the base pairs also results in hydrophobic base-stacking

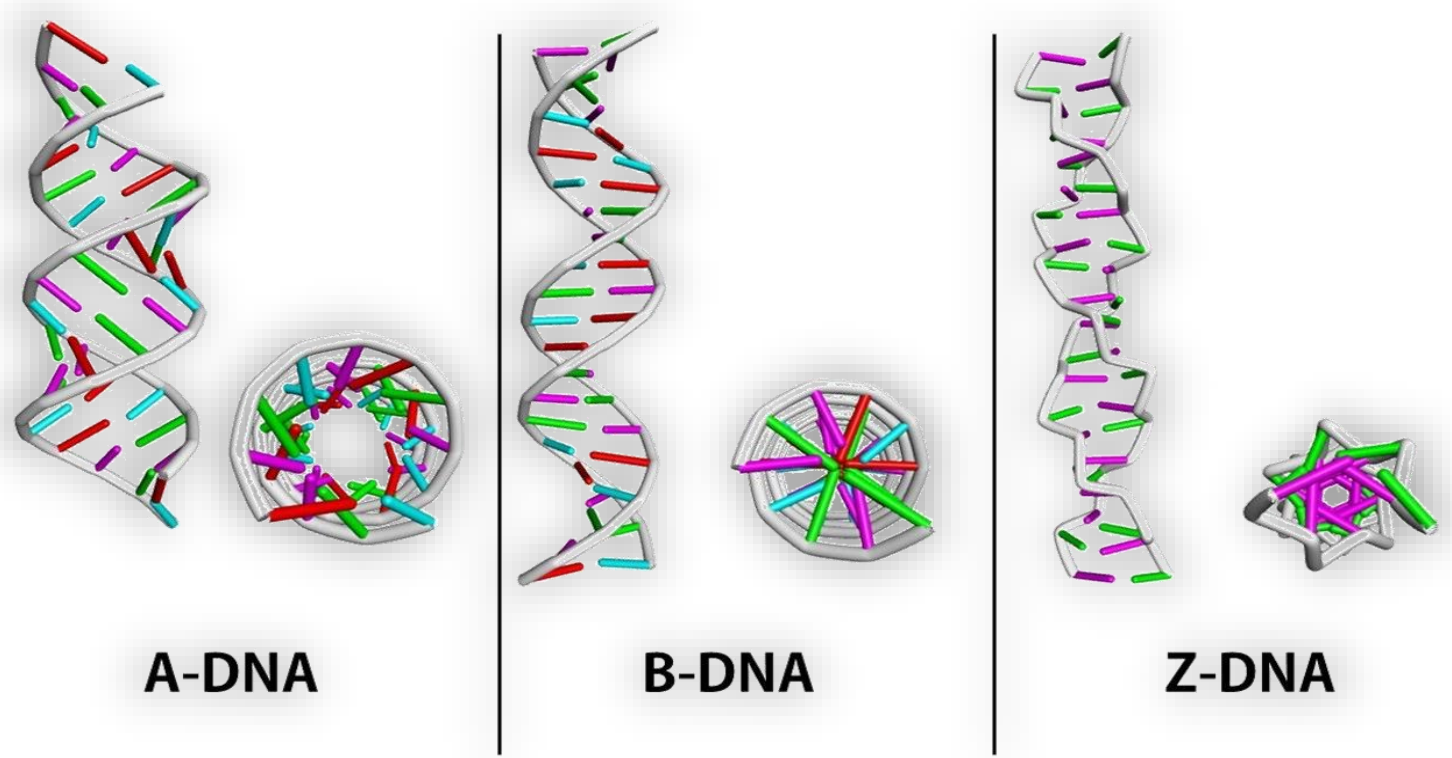


Different Forms of DNA

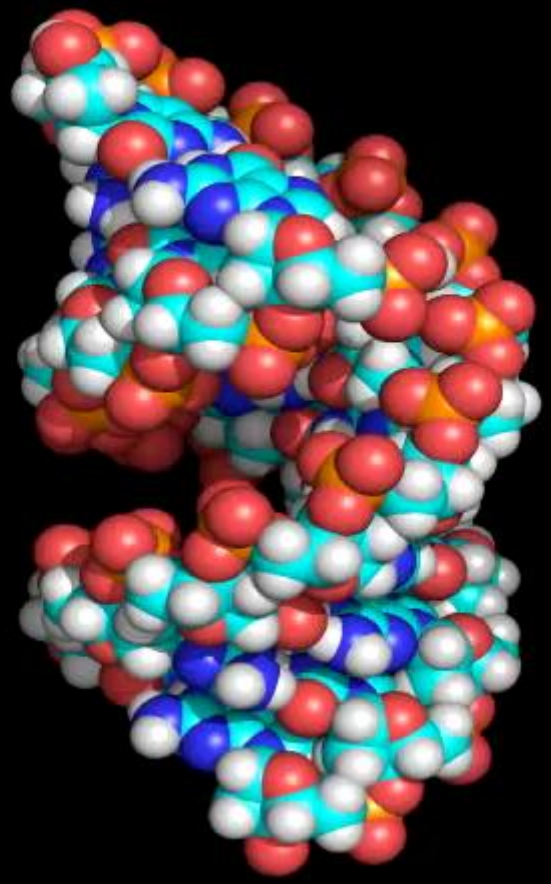
Although the basic model put forward by Watson and Crick remains close to the accepted structure of the DNA molecule in solution, varieties exist

Different Forms of DNA

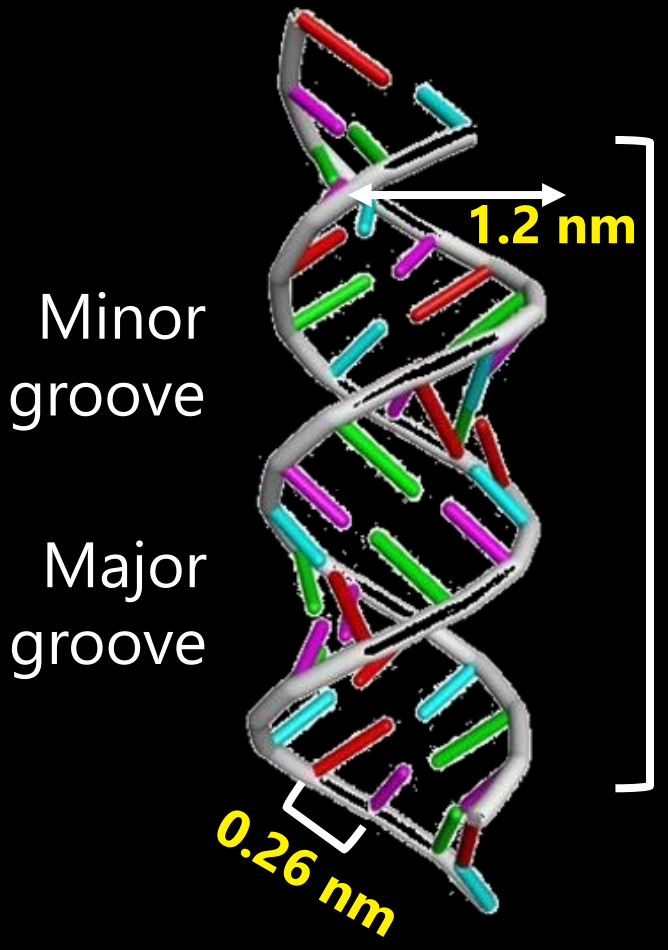
Refined X-ray studies show a variety of possible structures like **A-**, **B-**, **C-**, and **Z-** forms, depending on the **conditions** chosen to produce the DNA



Different Forms of DNA › A DNA



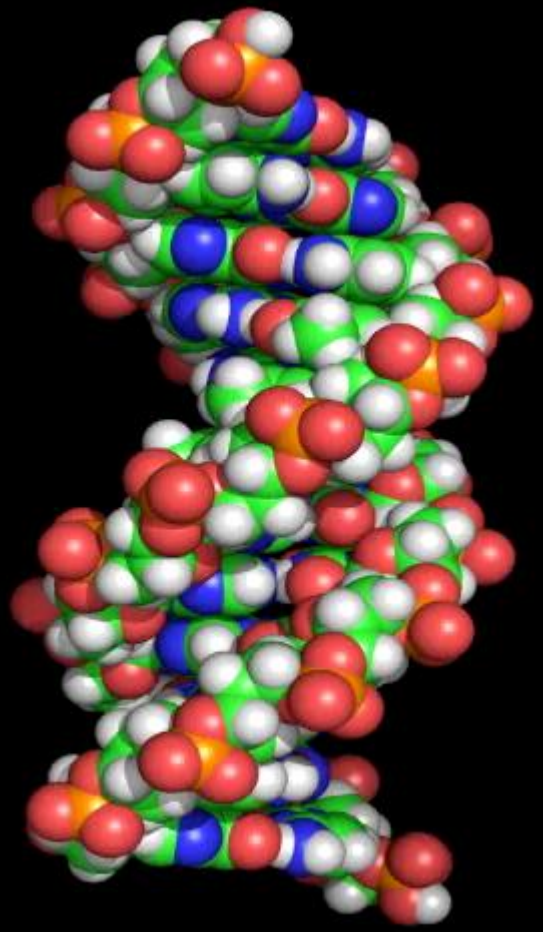
A DNA



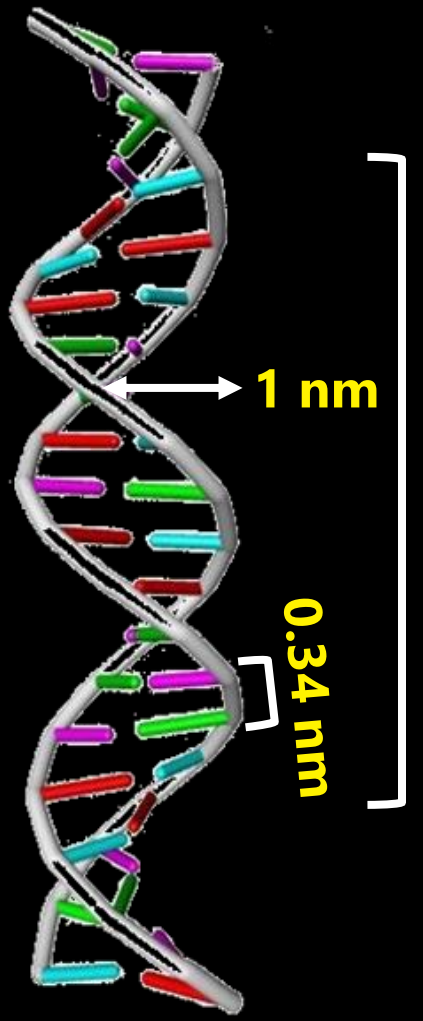
11 Bp/turn

+34.7° Rotation/Bp

Different Forms of DNA › B DNA



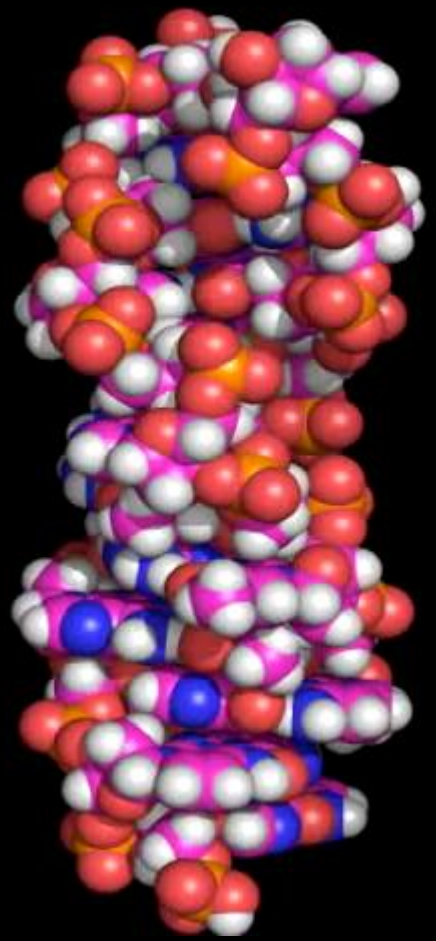
B DNA



10.4 Bp/turn

+34.6° Rotation/Bp

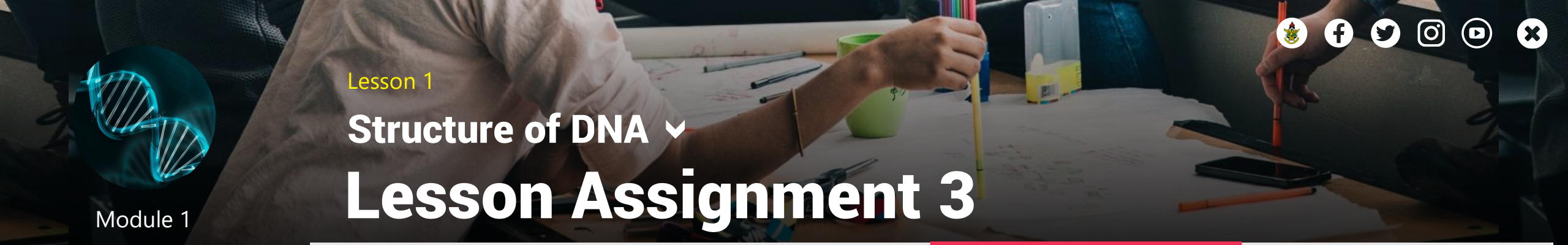
Different Forms of DNA › Z DNA



Z DNA

12 Bp/turn

-30.0° Rotation/Bp



Lesson 1

Structure of DNA

Lesson Assignment 3

Module 1

DNA Structure

Dashboard
Introduction
Lessons
Assignments

Read and summarize the different forms of DNA under the following headings:

1. Relative Humidity
2. Pitch in nm
3. Residues per turn and
4. Inclination of b.p. from horizontal

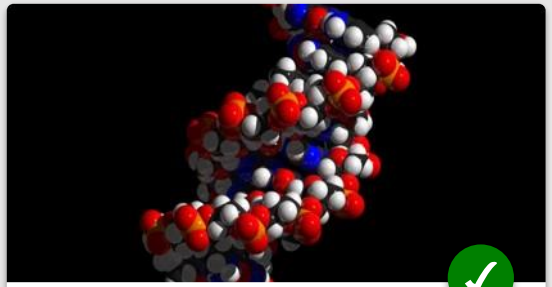
Example: The B-form under R.H of 92% has a pitch of 3.4nm, 10 bases per turn and has 0º angle of inclination to the horizontal.

Module 1

DNA Structure

Module Lessons

- Dashboard
- Introduction
- Lessons
- Assignments

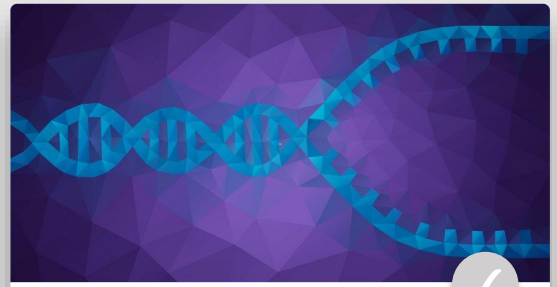


Lesson 1

DNA Structure

Learn about the discovery and components of DNA structure

Start ▸



Lesson 2

Denaturation & Renaturation

Start ▸

Lesson 3

DNA Functions

Learn the important roles of DNA

Start ▸

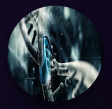
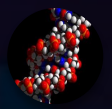
73

Lesson 2

DNA Denaturation & Renaturation

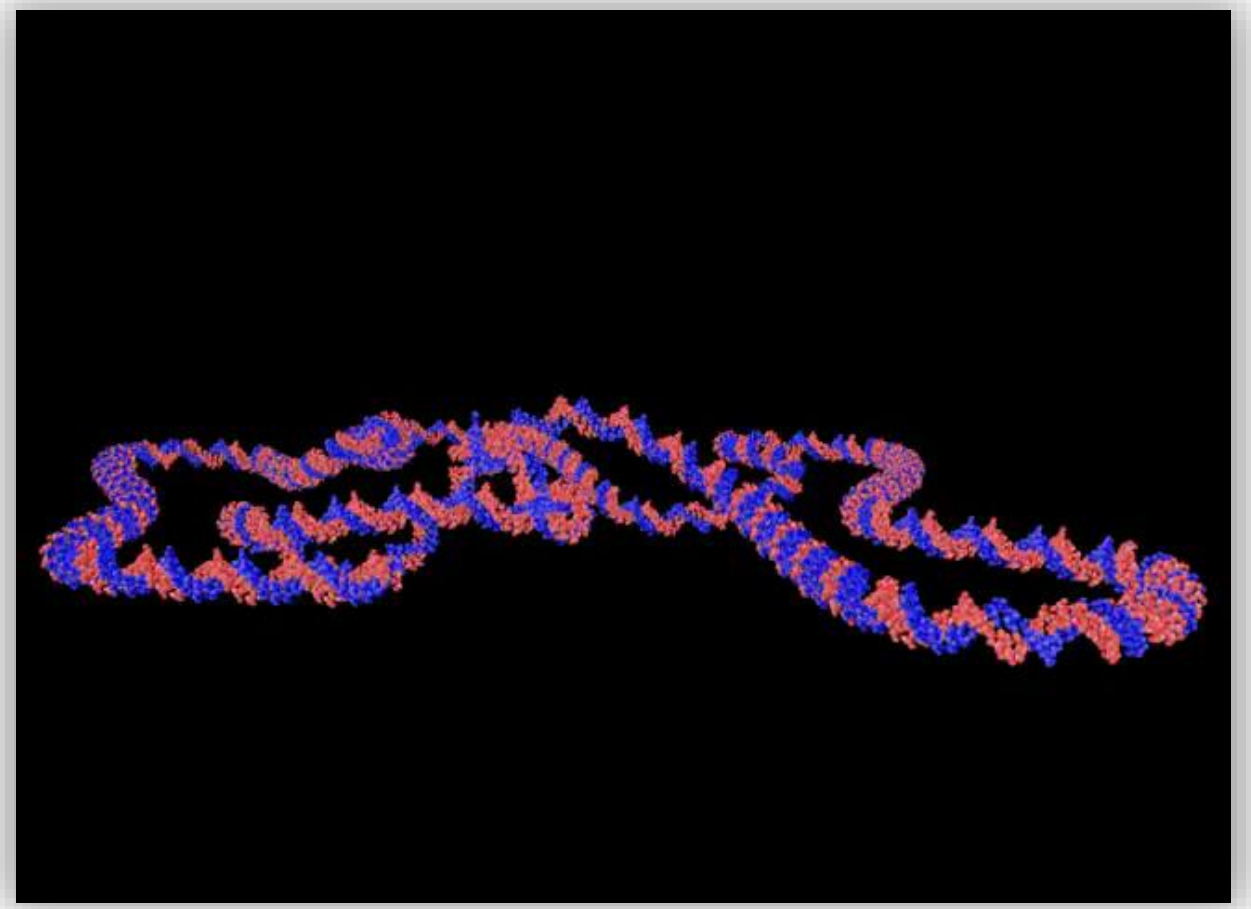
Learn how DNA changes from a double helix to a single stranded DNA random coil

Learn Now ▶

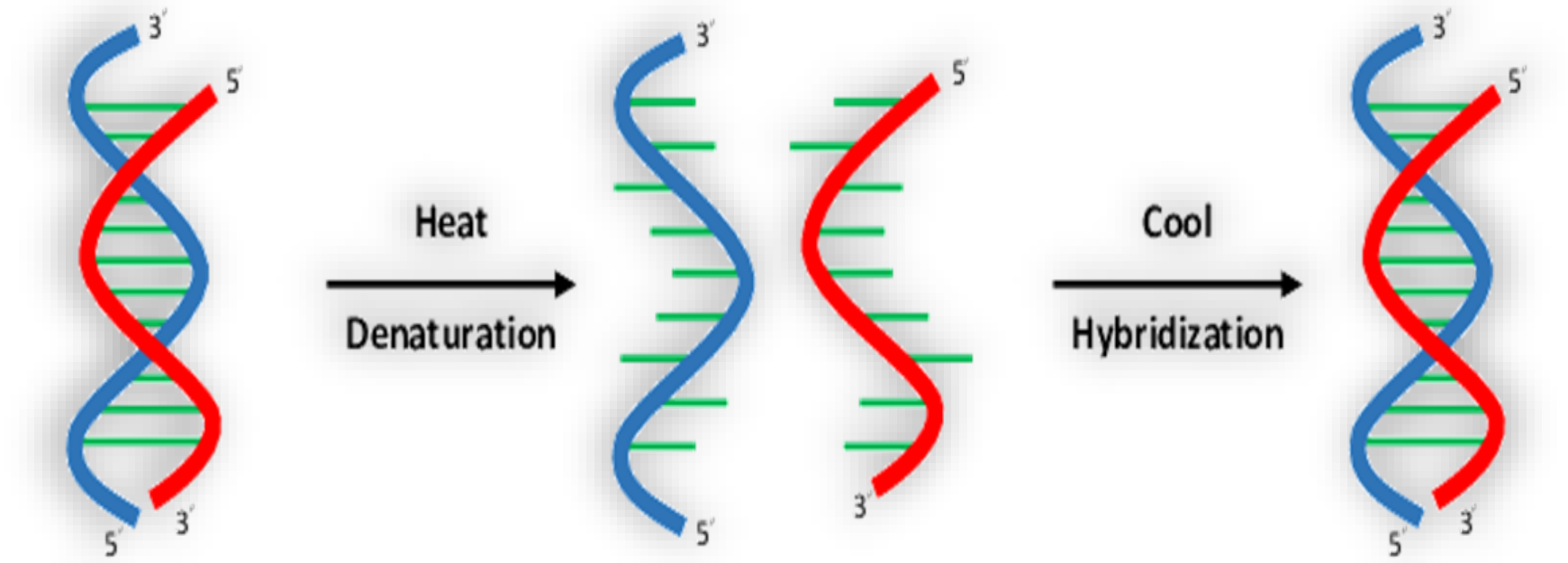
DNA Denaturation and Renaturation

When double-stranded DNA molecules are subjected to extremes of temperature or pH, the hydrogen bonds of the double helix are rupture and the two strands no longer hold together



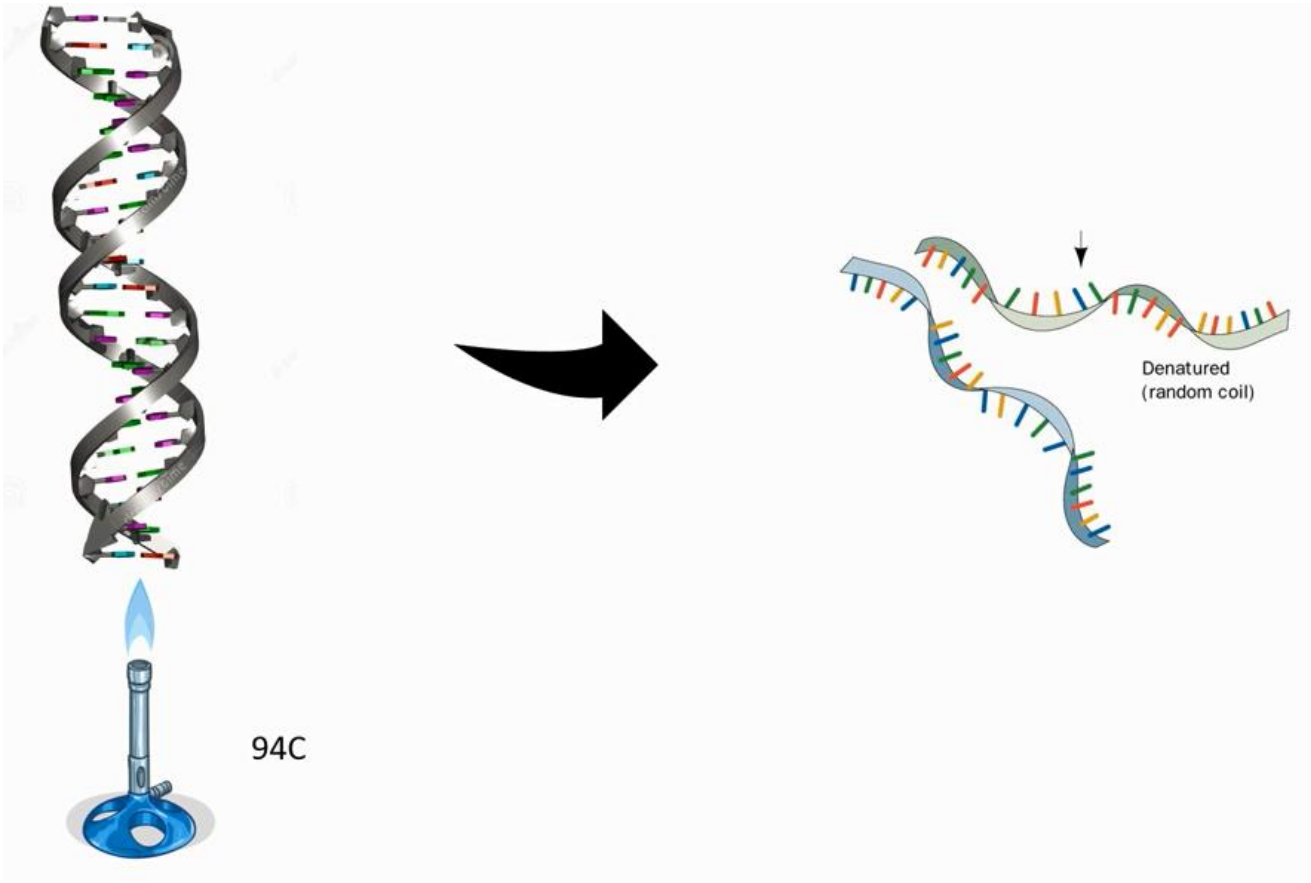
DNA Denaturation and Renaturation

The DNA is said to denature and changes from a double helix to a single stranded DNA random coil



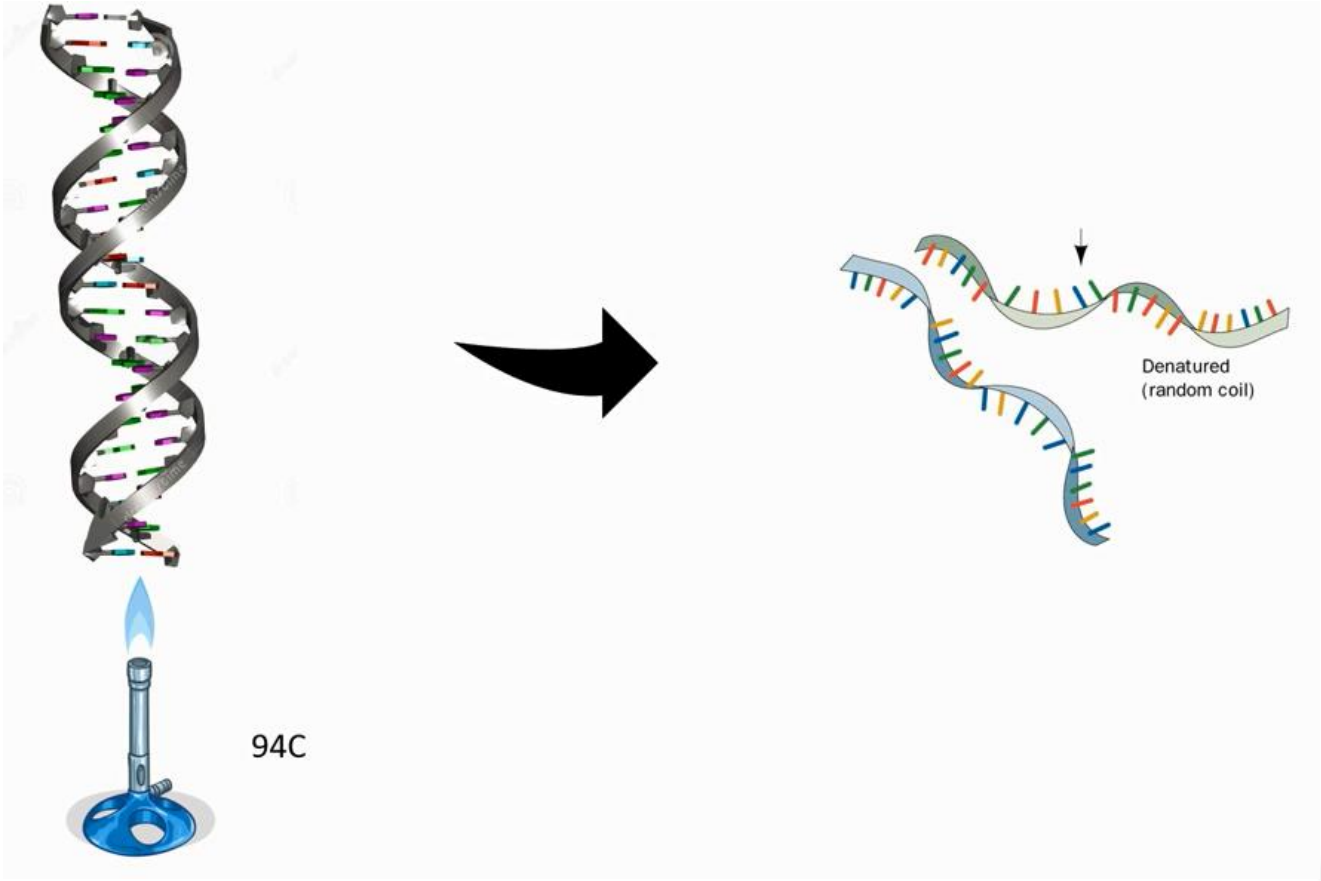
DNA Denaturation and Renaturation

When heat is used as the denaturant, the DNA is said to **melt** and the temperature at which the strands separate is the **melting temperature** or **transition temperature** (**Tm**)



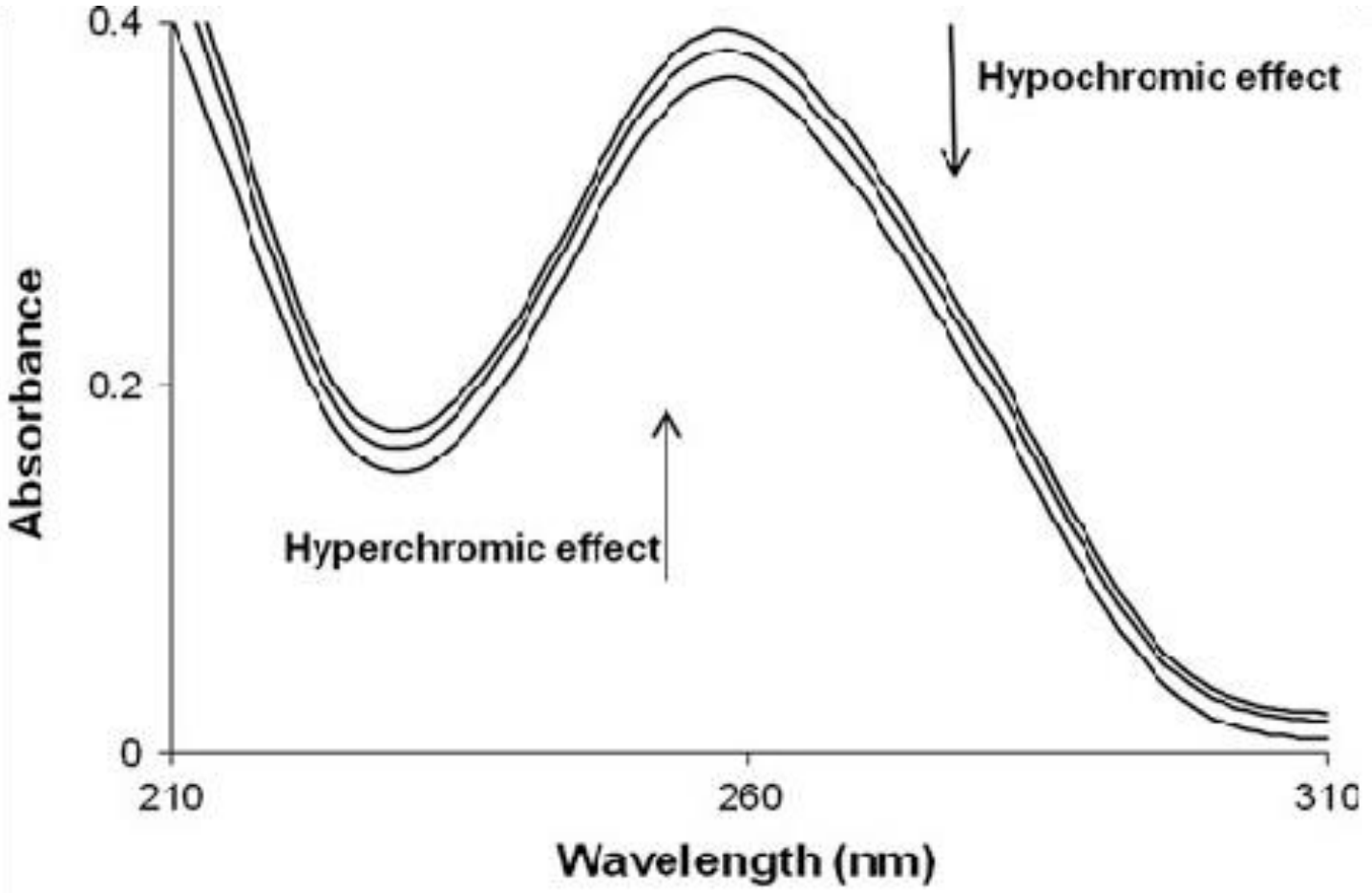
DNA Denaturation and Renaturation

When duplex DNA melts, the hydrogen bonds break and the bases unstack with the consequence that the absorption at 260 nm rises by 30-40% (20-30%)



DNA Denaturation and Renaturation

This rise in absorption is the **hyperchromic effect** or **shift** and is used to monitor the melting of DNA



DNA Denaturation and Renaturation

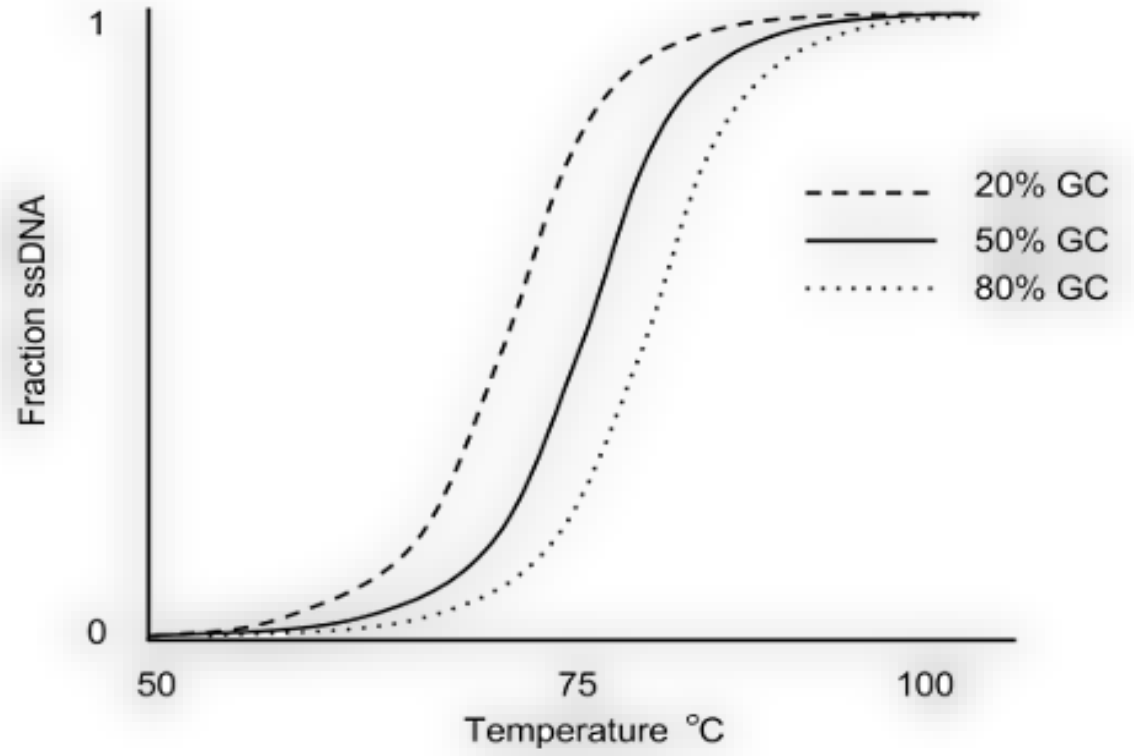
The nature of the melting transition is affected by several factors:

1. **G + C Content**
2. **The nature of the solvent**
3. **The nature of the DNA**

DNA Denaturation and Renaturation

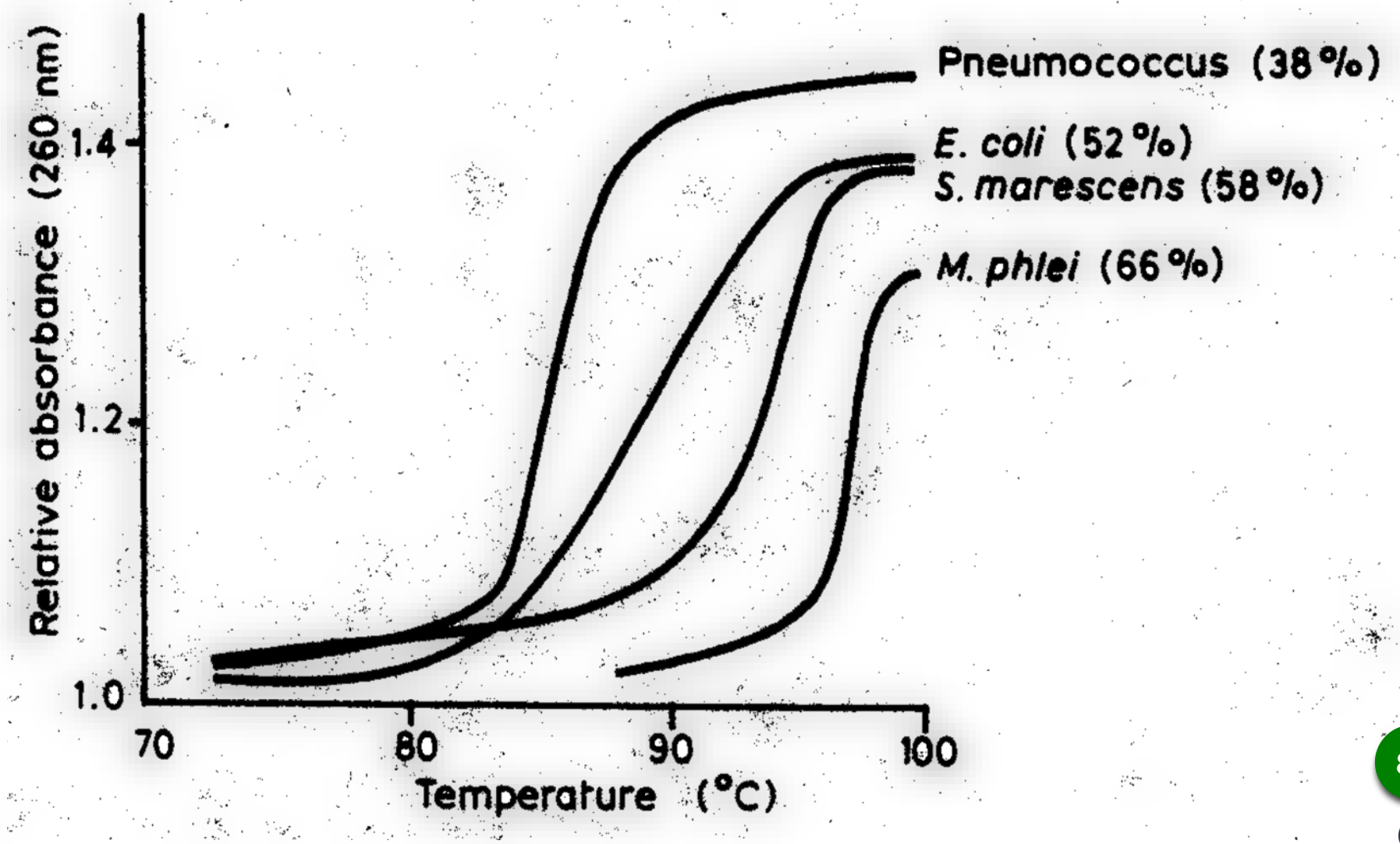
1 G + C Content

The higher the G+C content of DNA, the more stable the molecule will be and hence, the higher the melting temperature



DNA Denaturation and Renaturation

Denaturation by heat of DNAs from different organisms



Lesson Assignment 4

Read and make notes on the other factors

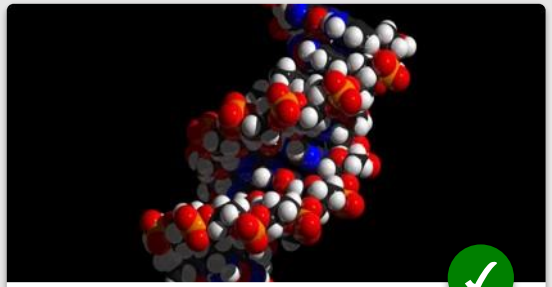
2. **The nature of the solvent**
3. **The nature of the DNA**

Module 1

DNA Structure

Module Lessons

- Dashboard
- Introduction
- Lessons
- Assignments



Lesson 1

DNA Structure

Learn about the discovery and components of DNA structure

Start ▸

Lesson 2

Denaturation & Renaturation

Start ▸

Lesson 3

DNA Functions

Learn the important roles of DNA

Start ▸

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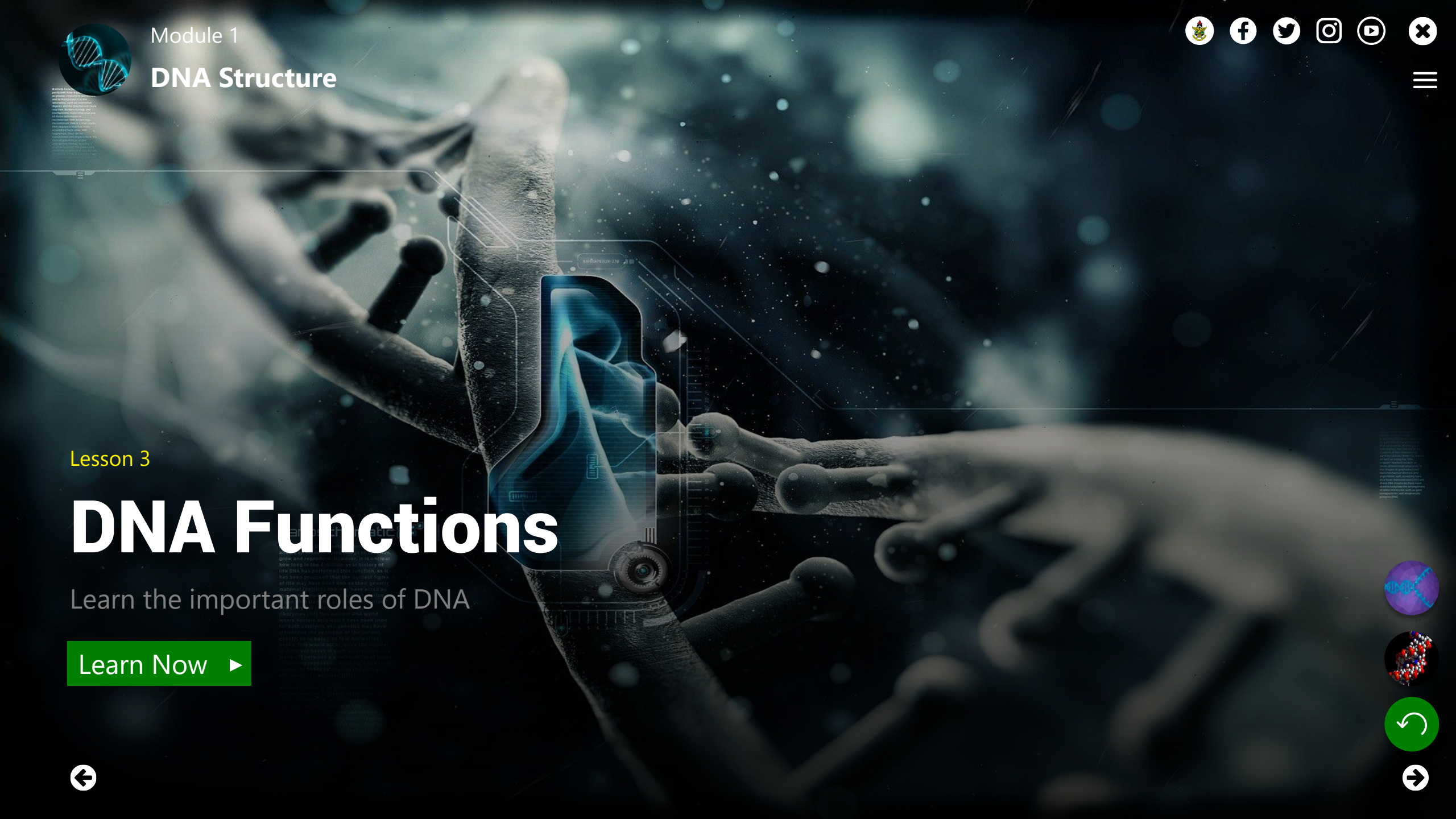


Lesson 3

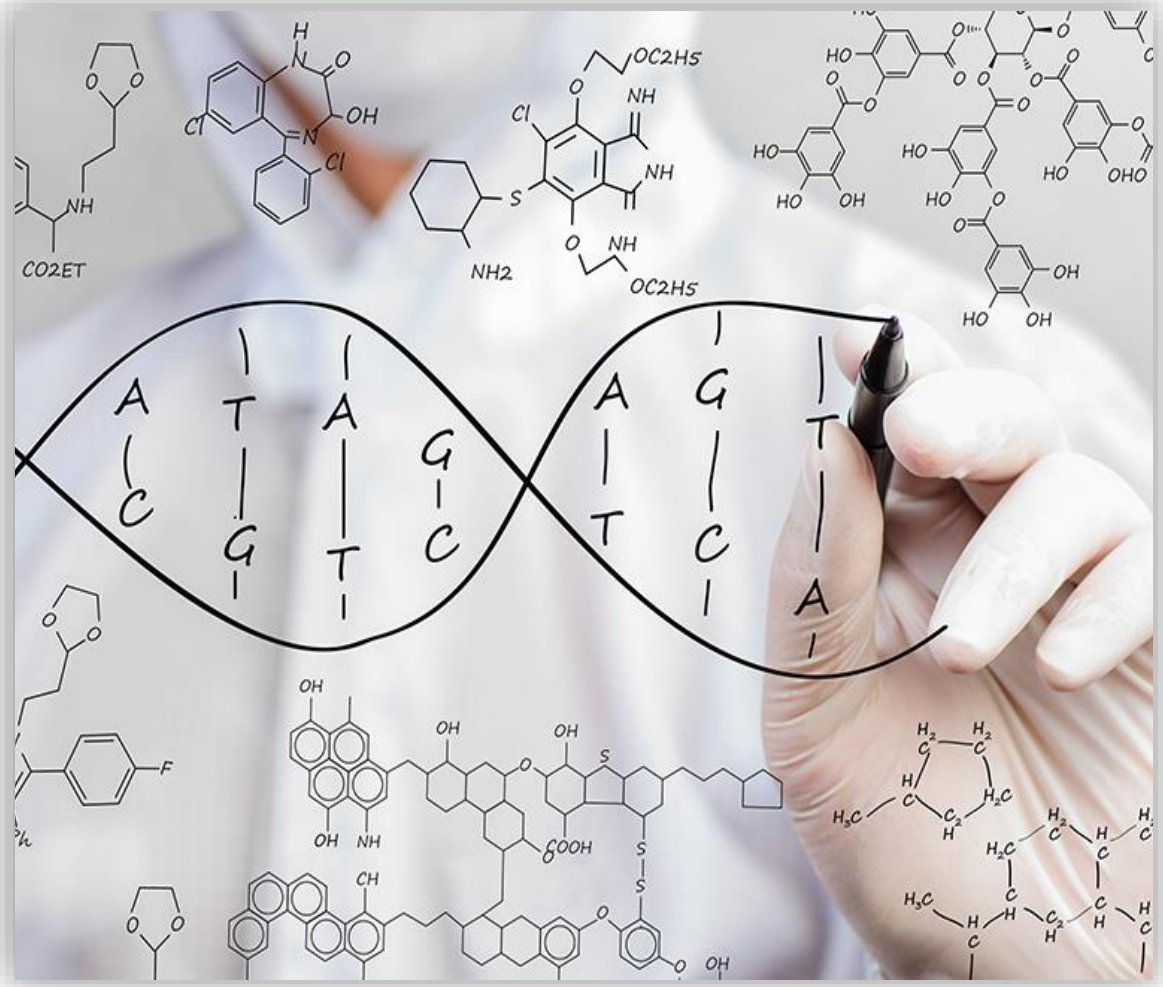
DNA Functions

Learn the important roles of DNA

Learn Now ▸

DNA Functions

1. Storage of genetic information
2. **Self-duplication (replication)** & inheritance
3. Expression of the genetic message



DNA Functions

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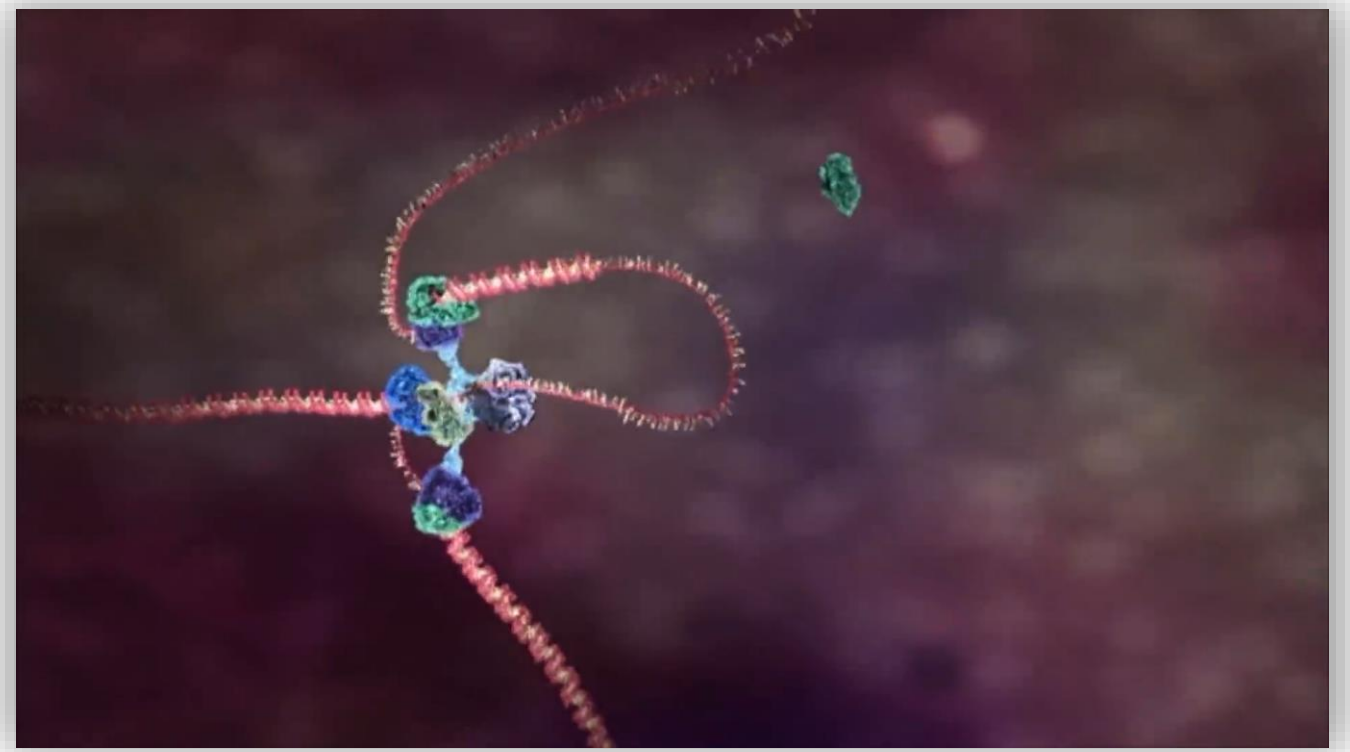


DNA Functions

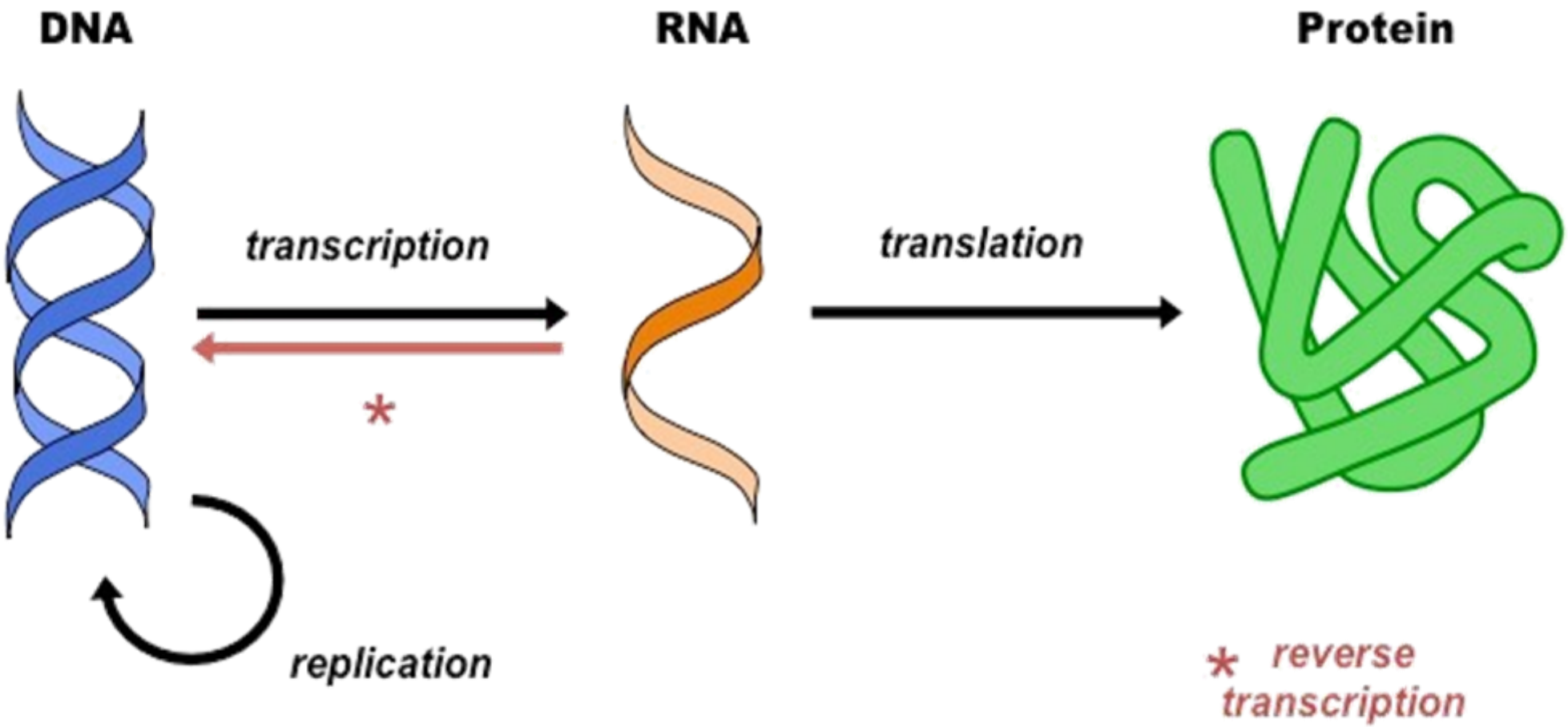
1. Storage of genetic information
2. **Self-duplication (replication)** & inheritance
3. Expression of the genetic message

DNA Functions › Major Function

DNA's major function:

Code for Proteins

The Central Dogma of Gene Expression

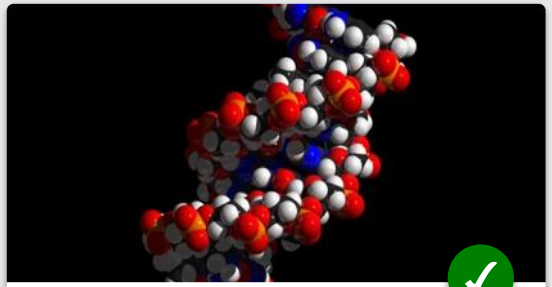


Module 1

DNA Structure

Module Lessons

- Dashboard
- Introduction
- Lessons
- Assignments



Lesson 1

DNA Structure

Learn about the discovery and components of DNA structure

Start ▸

Lesson 2

Denaturation & Renaturation

Start ▸

Lesson 3

DNA Functions

Learn the important roles of DNA

Start ▸

End of Module 1

End Class

Next Module