DNA

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What is DNA?

DNA, or deoxyribonucleic acid, is a molecule that carries the genetic instructions used in the development, functioning, and reproduction of all known living organisms and many viruses.

DNA → RNA → proteins

Proteins compose: hairs, nails, skin, blood, enzymes, muscles, eye color etc..!

Examples of proteins:

Keratin – nails and hairs.

Hemoglobin – found in red blood cells; binds and transports O_2 in our body.

Enzymes – processes different biochemical reactions in our body; especially digestion.

Protein pumps – transport molecules through the cell membrane.

Brief overview of key milestones in understanding DNA as the genetic material

1. **Friedrich Miescher (1869):** Miescher first identified DNA in 1869 while studying the chemical composition of white blood cells. He called the substance "nuclein."

2. **Avery, MacLeod, and McCarty (1944):** In a landmark experiment, Oswald Avery, Colin MacLeod, and Maclyn McCarty demonstrated that DNA was the substance responsible for the transfer of genetic information in bacteria. They showed that when they destroyed the DNA in a virulent strain of bacteria, its ability to transform non-virulent bacteria into virulent ones was lost. (https://www.youtube.com/watch?v=LPms5JQcwCA)

3. **Hershey-Chase Experiment (1952):** Martha Chase and Alfred Hershey conducted an experiment using bacteriophages (viruses that infect bacteria) to confirm that DNA, not protein, is the genetic material. The experiment provided strong evidence that DNA carries genetic information. (https://www.youtube.com/watch?v=B1jDNSEnfIA)

4. **Watson and Crick (1953):** James Watson and Francis Crick, with significant input from Rosalind Franklin's X-ray diffraction images, proposed the double-helix structure of DNA. This model explained how DNA could serve as a template for the replication of genetic information.

Double stranded model of DNA – Watson and Crick, and……..?

Many know that James Watson and Francis Crick are commonly credited as the sole contributors to the current model of DNA. However, the narrative is more complex than that. Behind the scenes, another crucial figure played a significant role in this discovery.

Watch this video featuring Rosalind Franklin, a woman integral to the story.

https://youtu.be/BIP0lYrdirI

NUCLEOTIDES AND NUCLEIC ACIDS

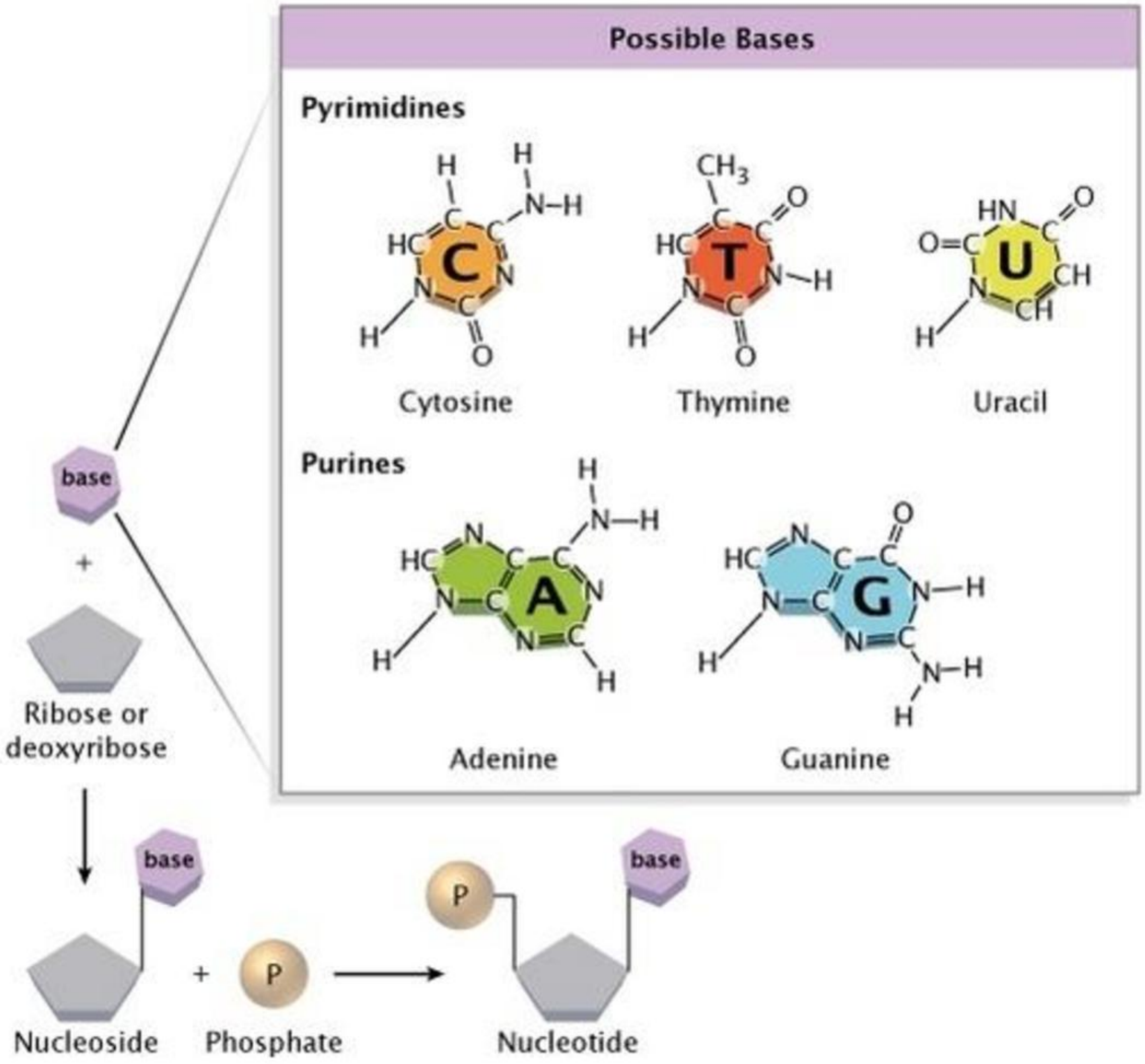
Nucleotides – monomers

Nucleic Acids – polymers

DNA is a nucleic acid composed of nucleotides.

A nucleotide is composed of:

1. Nitrogenous Bases
2. Phosphate group
3. Ribose in RNA, or Deoxyribose in DNA (sugar molecule)



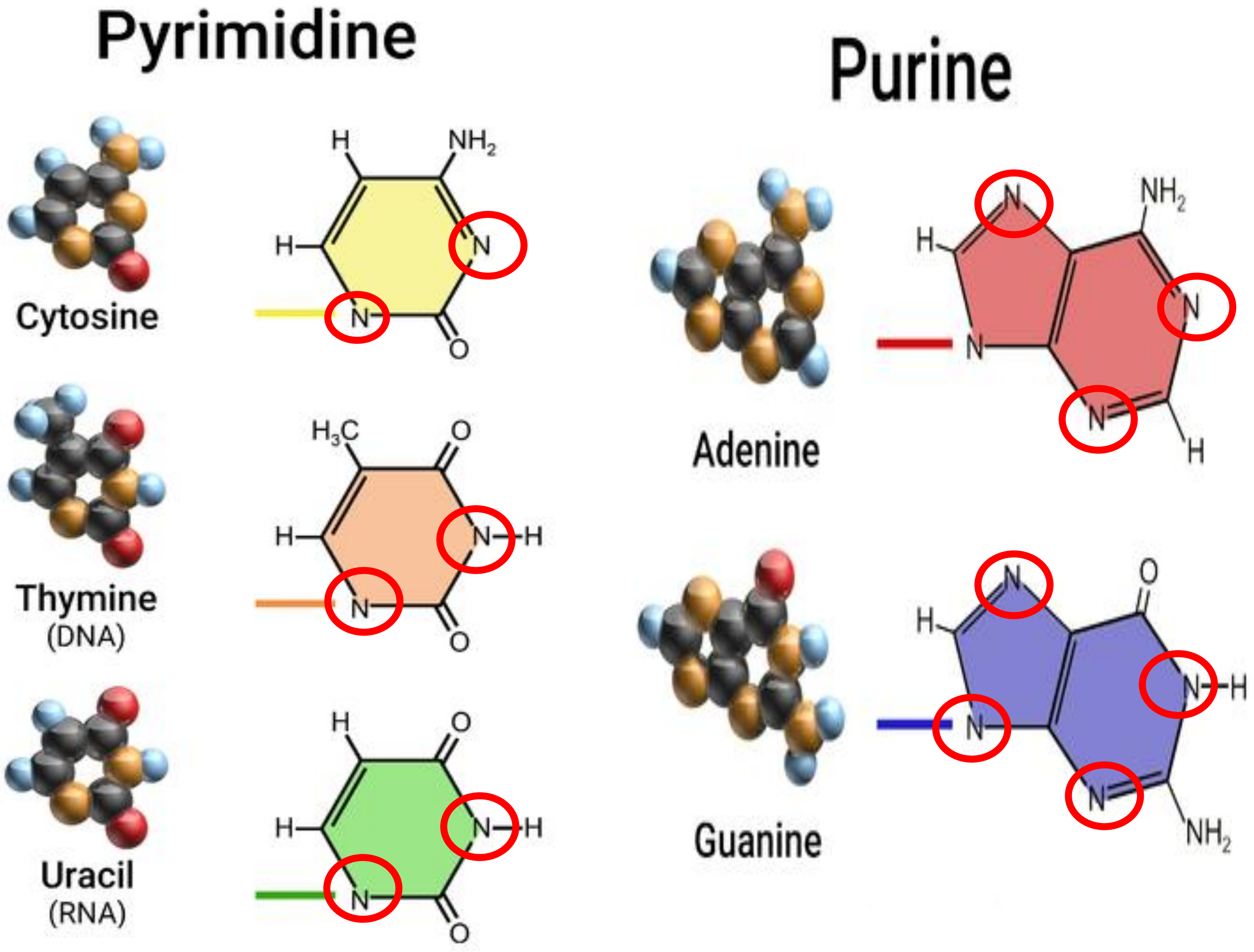
NITROGENOUS BASES

The nitrogenous bases are so named because they contain **nitrogen atoms** in their molecular structure.

There are four types of nitrogenous bases found in DNA: adenine (A), thymine (T), cytosine (C), and guanine (G).

In RNA, thymine is replaced by uracil (U), so the four bases in RNA are adenine (A), uracil (U), cytosine (C), and guanine (G).

The specific sequence of these nitrogenous bases along a DNA or RNA strand encodes genetic information. **The complementary base pairing between adenine and thymine (or uracil in RNA) and between cytosine and guanine is a key feature of the double-helix structure of DNA.**

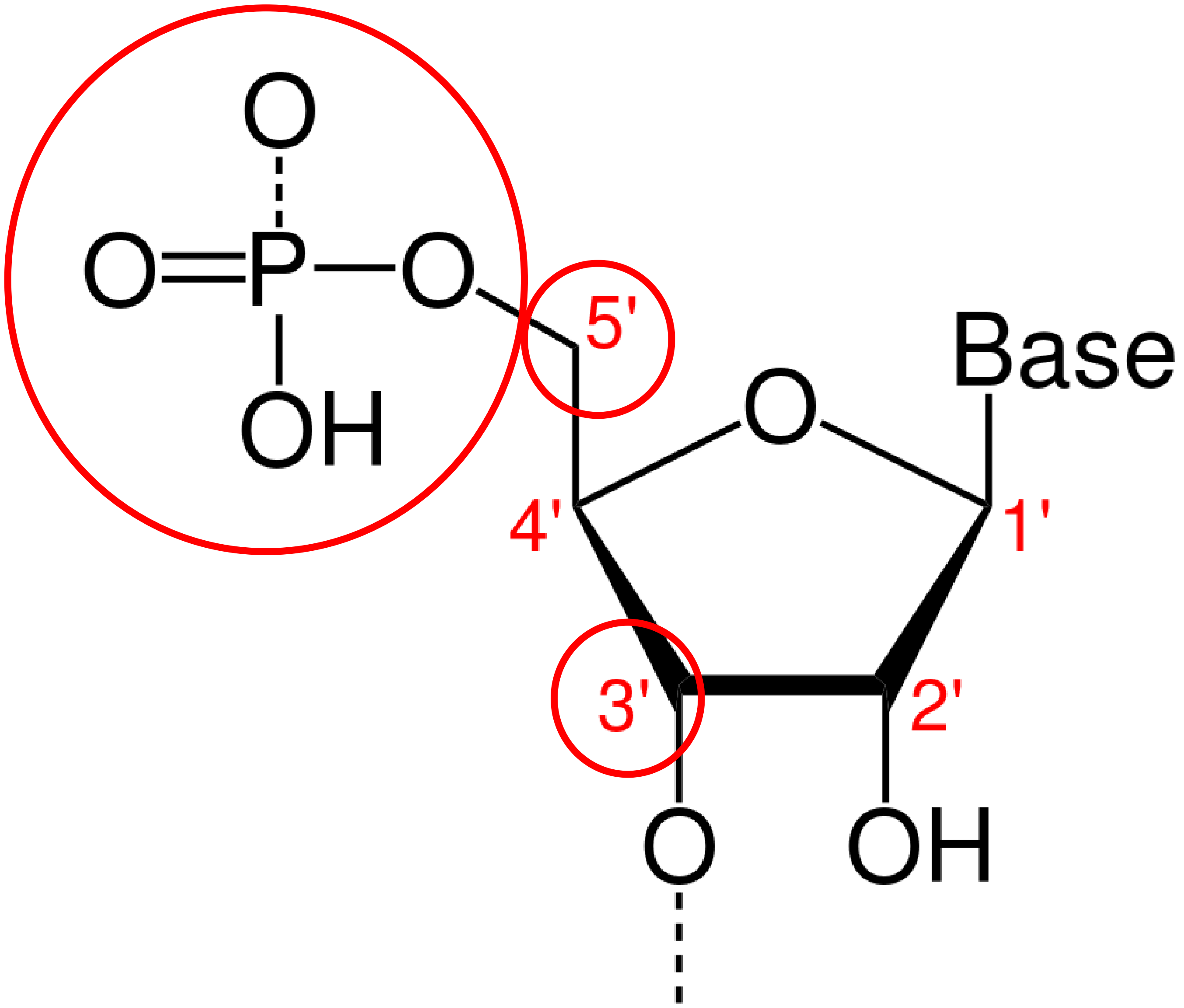


PHOSPHATE GROUP

The phosphate group is bonded to the **5' carbon** of the sugar molecule within a nucleotide.

Together, the phosphate group and the sugar molecule form the **phosphate-sugar backbone** of DNA or RNA.

The 5' phosphate and the 3' hydroxyl (OH) groups are crucial components, playing a significant role during the process of DNA replication.

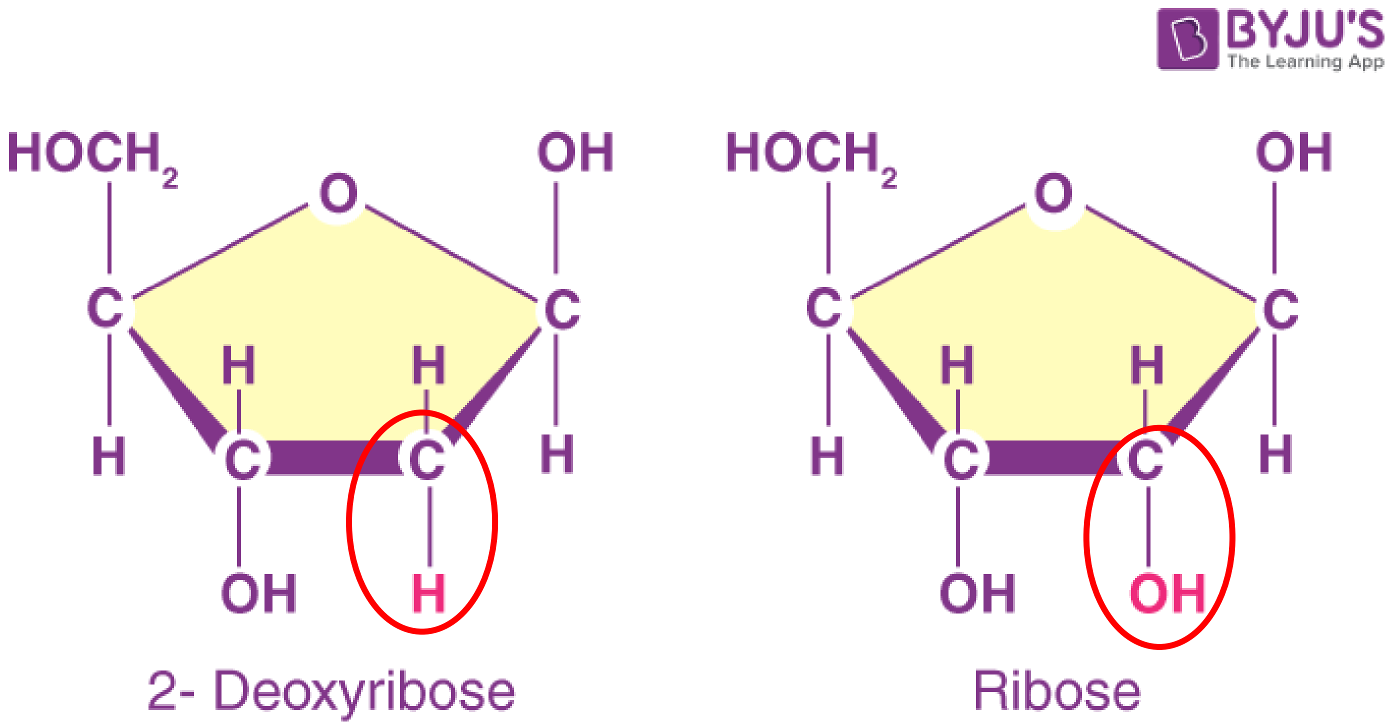


RIBOSE, OR DEOXYRIBOSE (SUGAR MOLECULE)

The sugar molecule can either be deoxyribose or ribose.

Deoxyribose is found in DNA, while ribose is present in RNA.

The sole distinction between deoxyribose and ribose **lies in the absence of an oxygen atom in the second carbon atom of deoxyribose**, which is why it is termed "deoxy."



Antiparallel structure of DNA (5' end and 3' end)

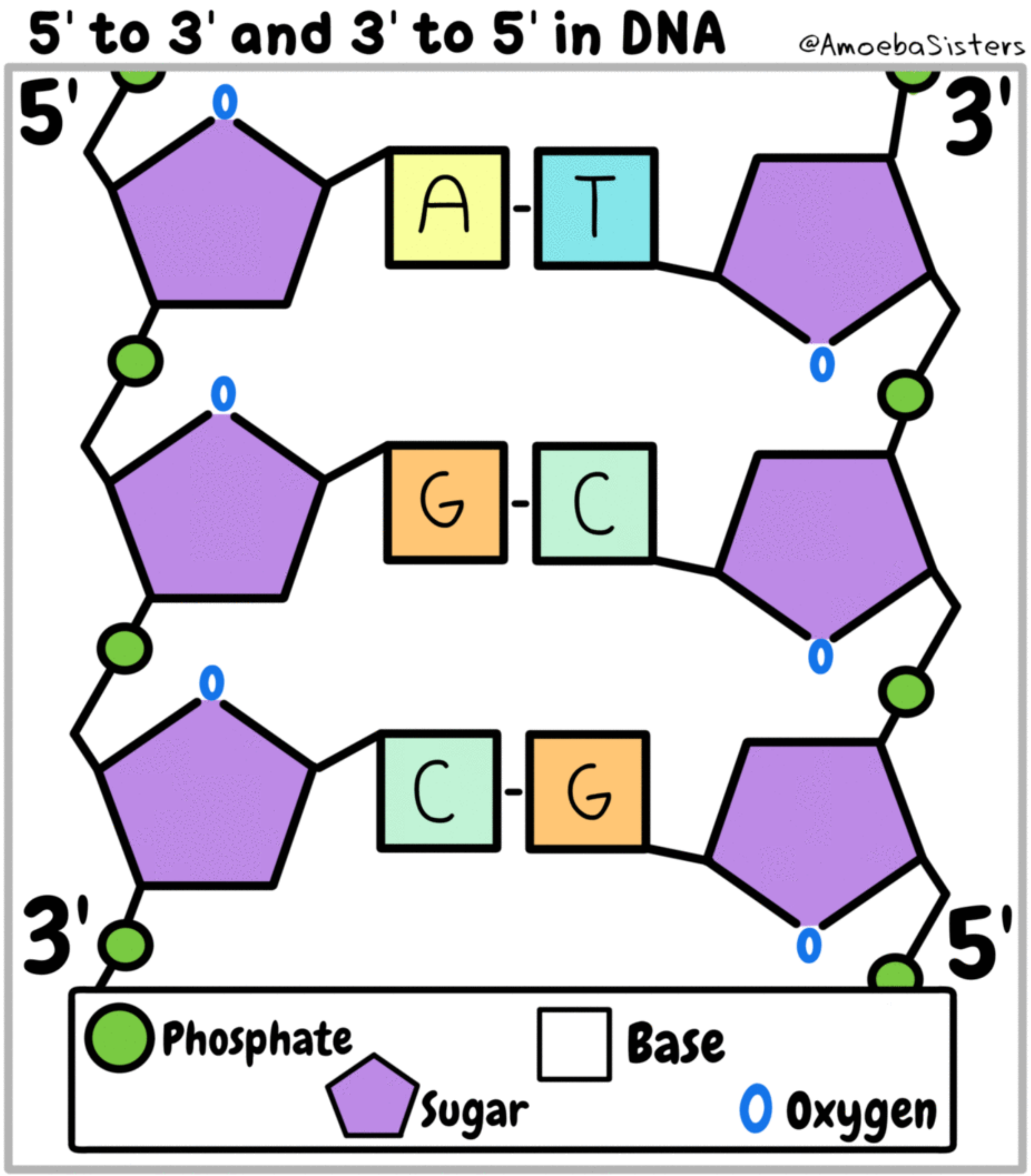
In DNA, the two strands are oriented in opposite directions, and **this is often described as having one strand running in the 5' to 3' direction and the other running in the 3' to 5' direction**. The orientation is based on the numbering of carbon atoms in the sugar molecules of the DNA backbone.

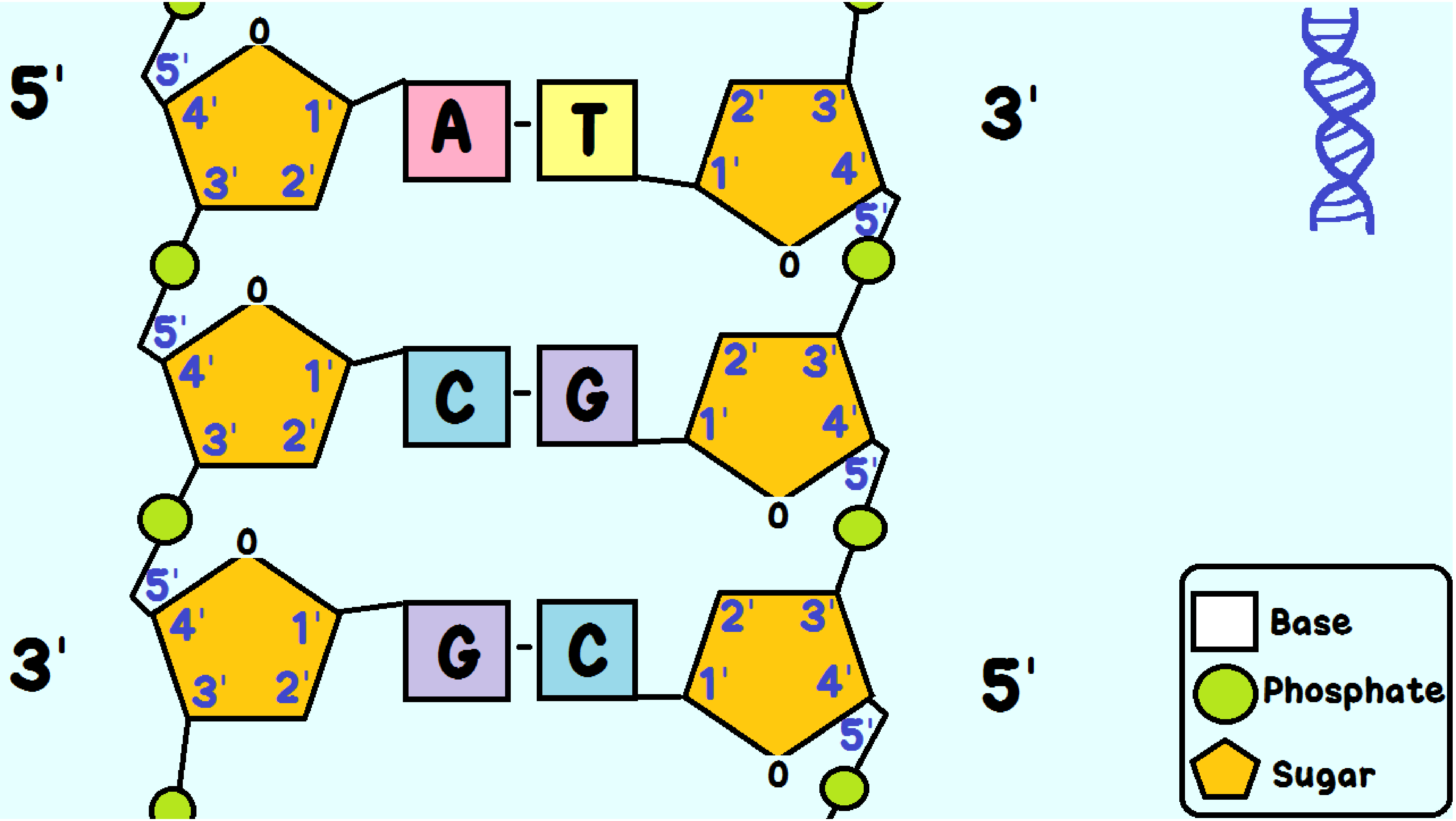
Here's a simple way to understand the antiparallel nature of DNA:

1. Each DNA strand has two ends: a 5' end and a 3' end.

2. The orientation of the sugar-phosphate backbone runs from the 5' end to the 3' end.

3. In an antiparallel arrangement, one DNA strand runs from 5' to 3', while the complementary strand runs from 3' to 5'.




5'
3'
3'
5'
A
T
C
G
G
C
Base
Phosphate
Sugar

BASE PAIRING

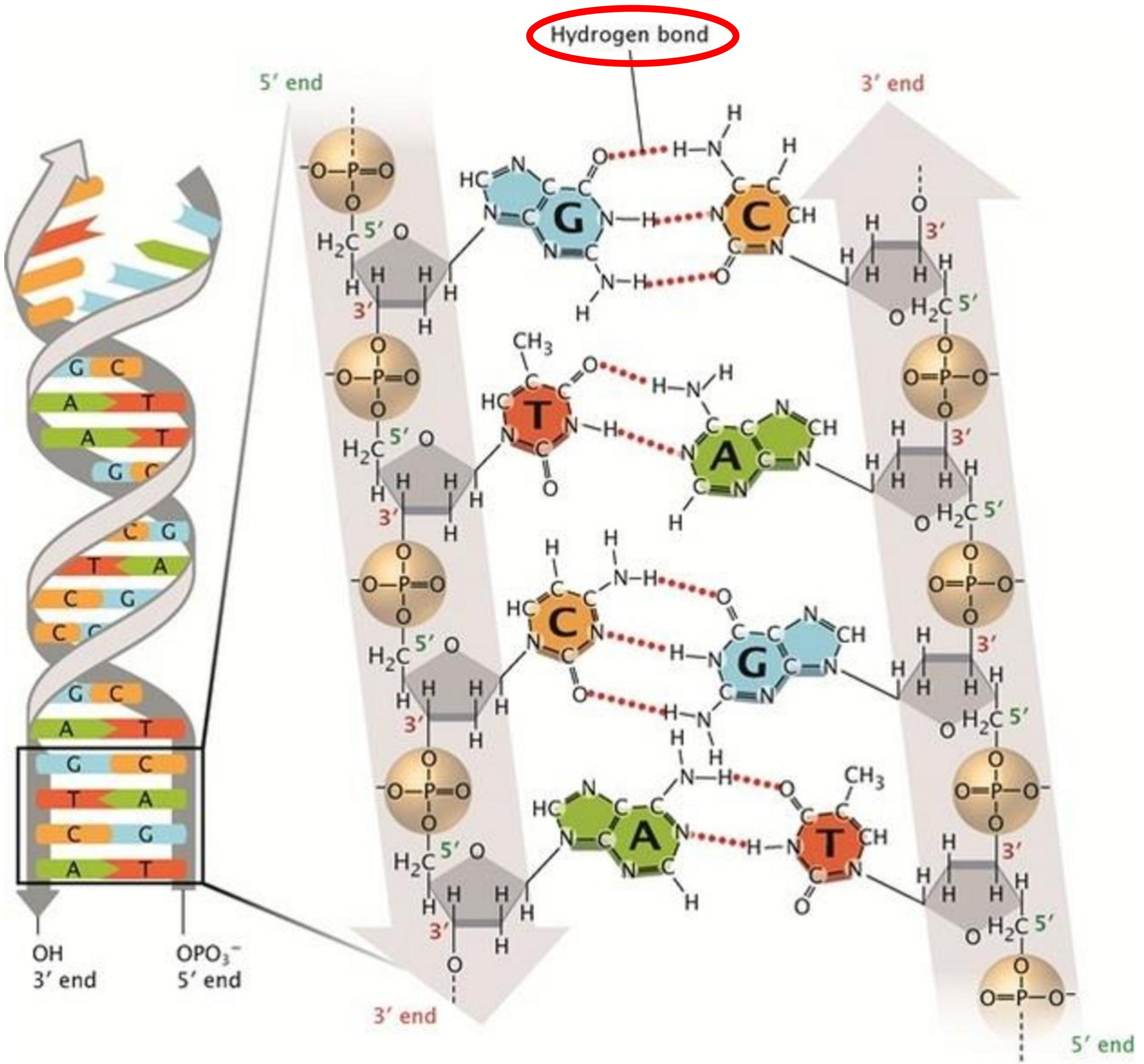
Base pairing adheres to a specific set of rules. Guanine forms pairs with Cytosine through the assistance of 3 hydrogen bonds, while Thymine pairs with Adenine with the aid of 2 hydrogen bonds.

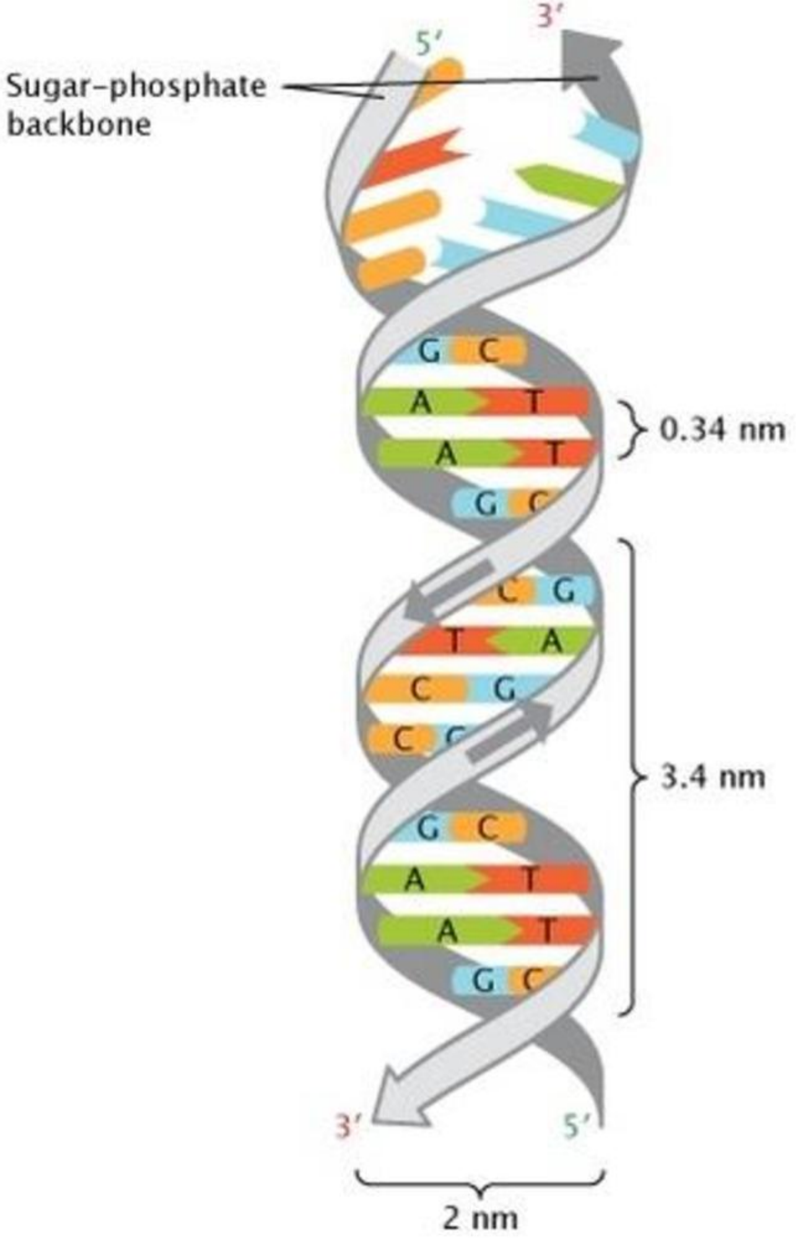
In summary, the base pairs are as follows:

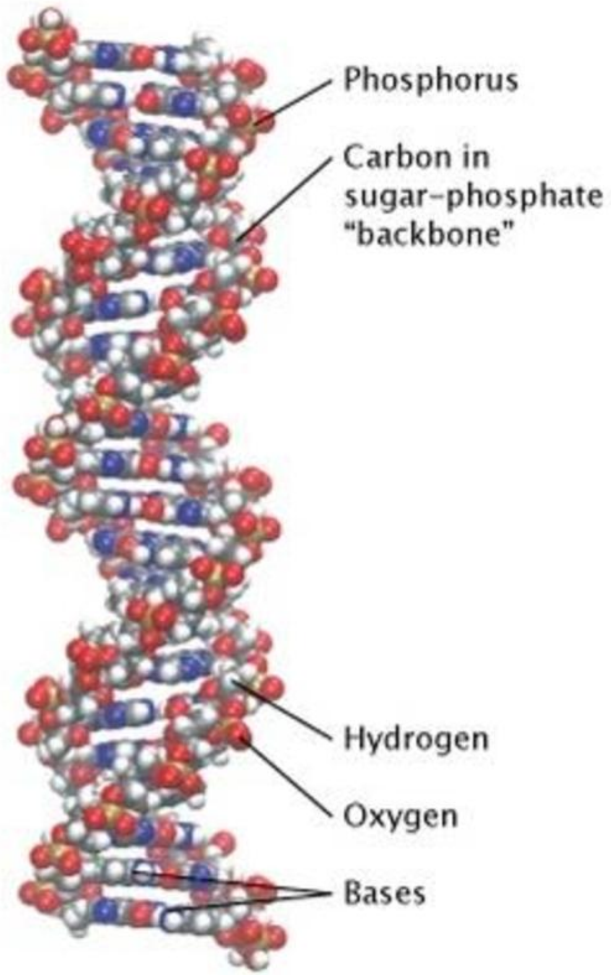
G ≡ C and T = A.

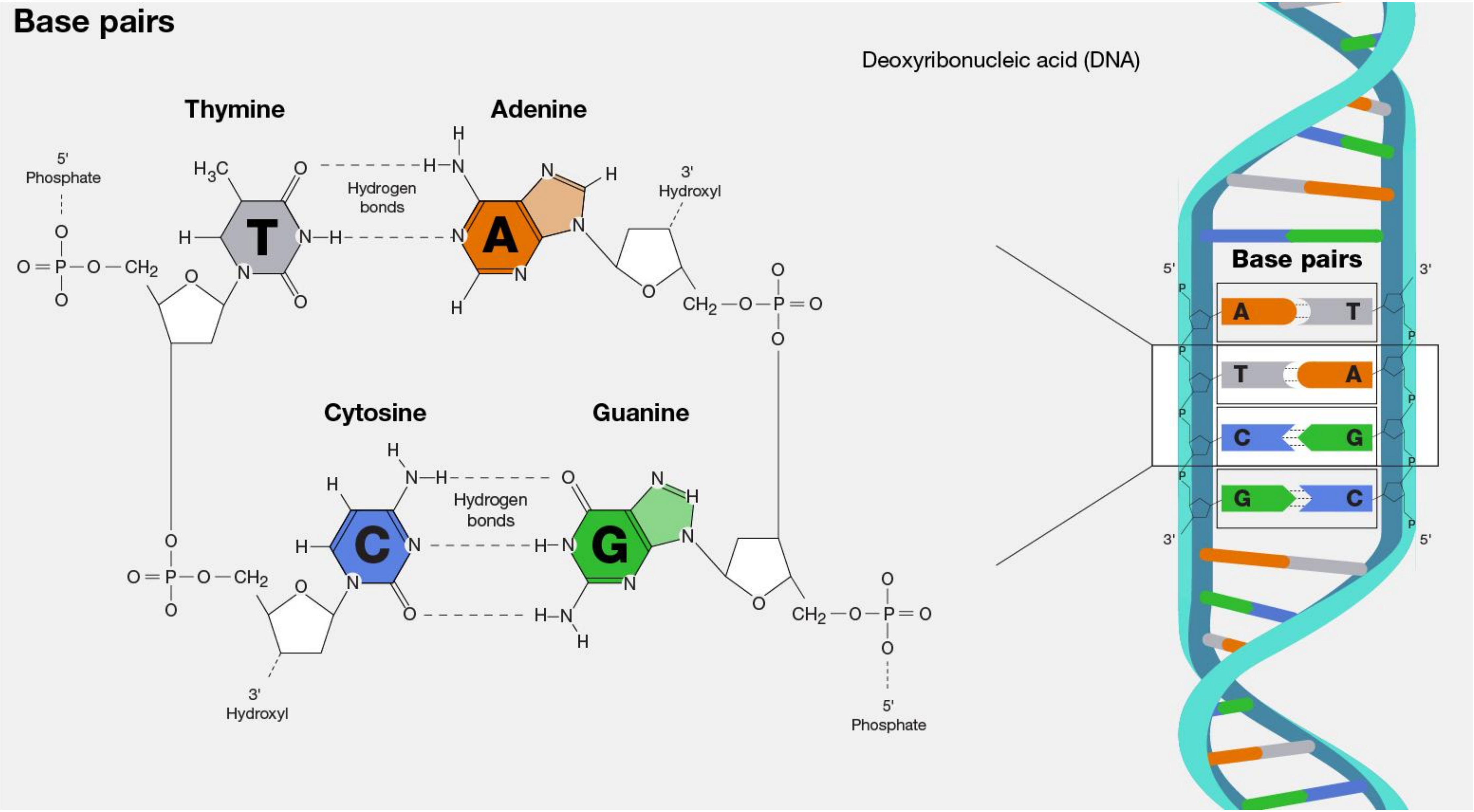
The hydrogen bonds established between these nitrogenous bases play a crucial role in maintaining the stability of the DNA molecule.

In RNA, the pairing rules remain the same, except for one distinction: Adenine pairs with Uracil instead of Thymine. Therefore, in RNA, the base pair is A - U.




5′
3′
Sugar-phosphate backbone
G C
A T
A T
G C
0.34 nm
C G
T A
C G
C G
G C
A T
A T
G C
3.4 nm
3′
5′
2 nm


Phosphorus
Carbon in sugar-phosphate “backbone”
Hydrogen
Oxygen
Bases


Base pairs
Thymine
Adenine
Cytosine
Guanine
5' Phosphate
3' Hydroxyl
Hydrogen bonds
Deoxyribonucleic acid (DNA)
Base pairs
5'
3'
A T
T A
C G
G C

ATP and ADP

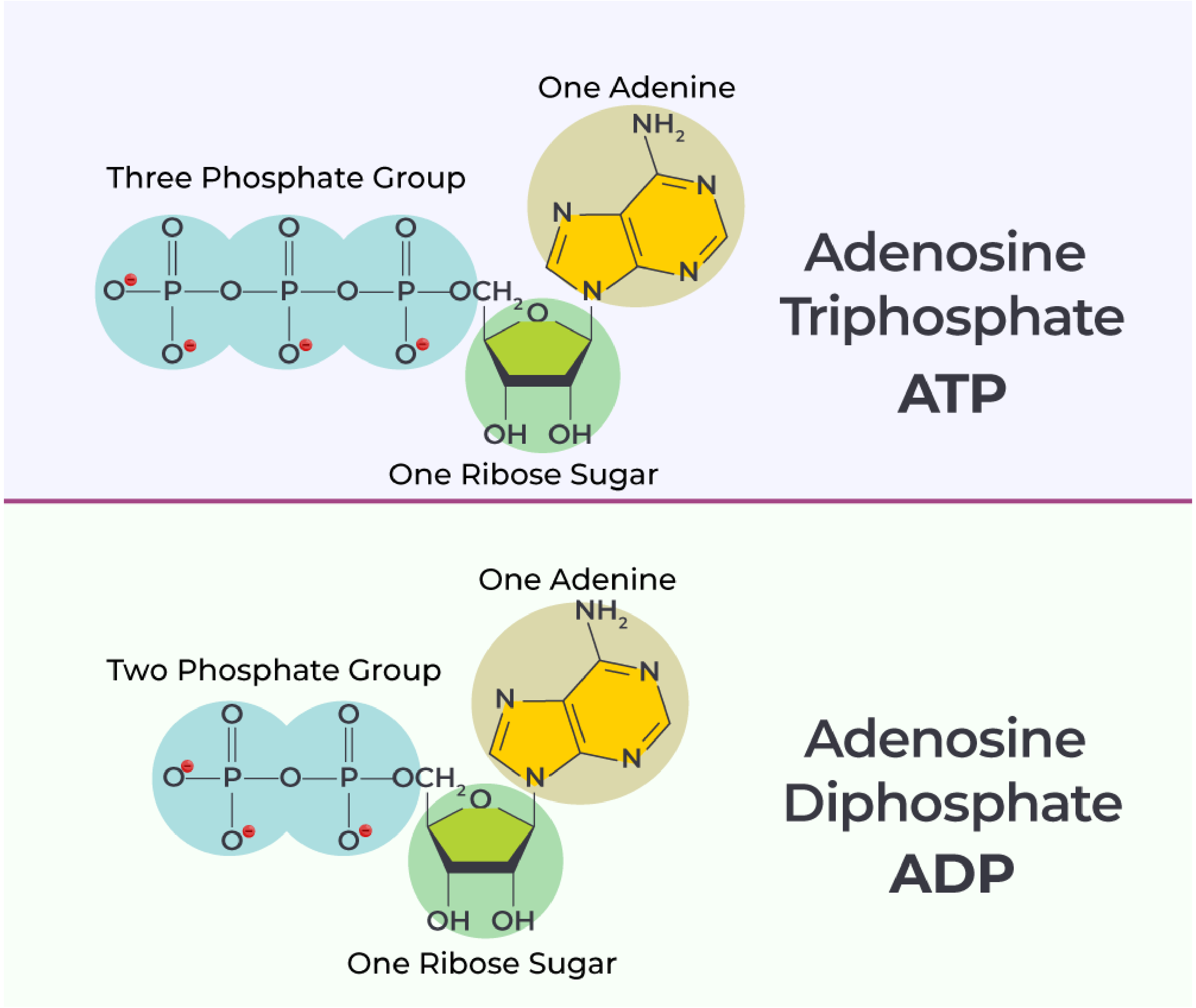
The formation of ATP (adenosine triphosphate) from ADP (adenosine diphosphate) and inorganic phosphate (Pi) is an **endothermic process**. This means that it requires **an input of energy** to build ATP from its precursor molecules.

The overall reaction for ATP synthesis is:

ADP+Pi+energy→ATP

This process is coupled with energy-absorbing reactions, such as those that occur during cellular respiration or photosynthesis. In cellular respiration, for example, the energy released during the breakdown of nutrients (like glucose) is used to drive the synthesis of ATP from ADP and Pi.

In summary, while the breakdown of ATP to ADP and inorganic phosphate releases energy (**an exothermic process**), the synthesis of ATP from ADP and Pi requires an input of energy and is therefore **endothermic.**



Summary

DNA (Deoxyribonucleic Acid): DNA is the genetic material found in the cells of living organisms. It consists of two complementary strands forming a double helix structure. The four nitrogenous bases—adenine (A), thymine (T), cytosine (C), and guanine (G)—pair in a specific manner (A=T and C≡G) and encode genetic information. DNA serves as a blueprint for the synthesis of proteins and is essential for the inheritance of traits.

ATP (Adenosine Triphosphate) and ADP (Adenosine Diphosphate): ATP is the primary energy currency of cells. Comprising three phosphate groups, a ribose sugar, and an adenine base, ATP stores energy in its high-energy phosphate bonds. During cellular activities, ATP is hydrolyzed to ADP and inorganic phosphate, releasing energy for various processes. ADP, with two phosphate groups, can be phosphorylated back to ATP, requiring an input of energy. The ATP/ADP cycle is fundamental to cellular energy metabolism, supporting activities such as muscle contraction, active transport, and biosynthesis.

Stimulation

https://www.labxchange.org/library/items/lb:LabXchange:feb8ec5b:lx_simulation:1