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Nucleic Acids

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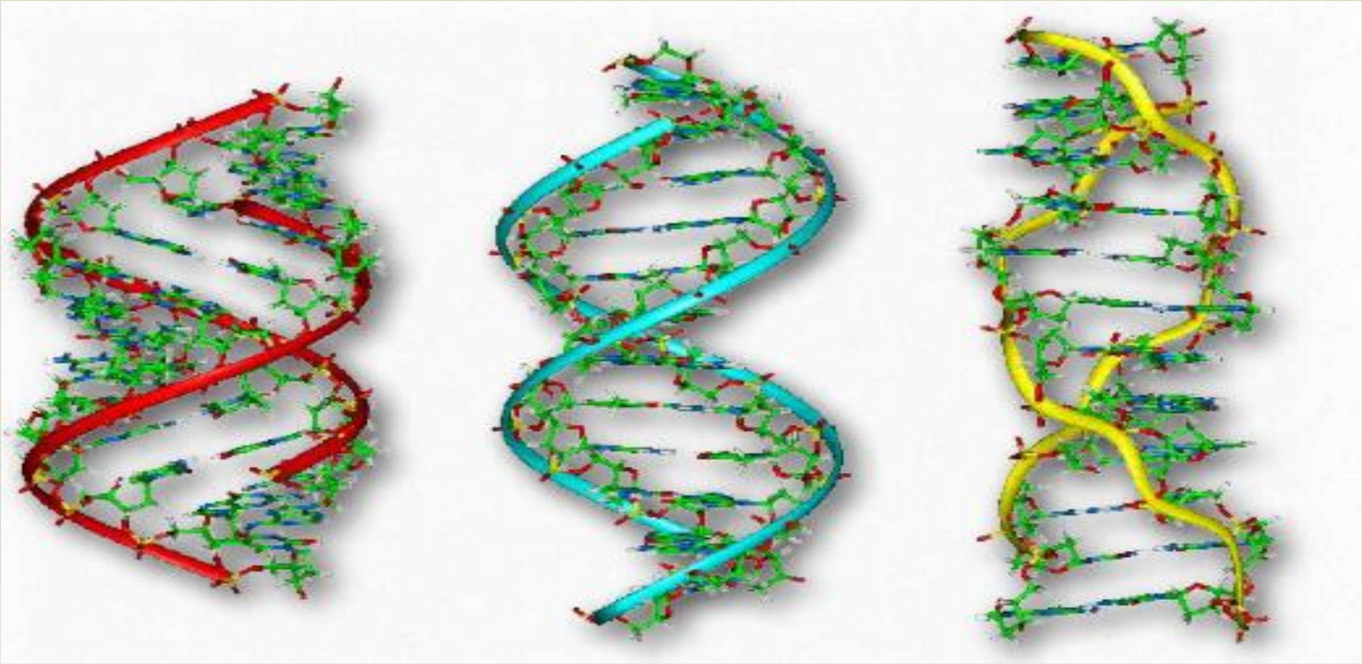


Nucleic acids are the biopolymers, or small biomolecules , essential to all known forms of life . The term *nucleic acid* is the overall name for DNA and RNA. They are composed of nucleotides , which are the monomers made of three components: a 5-carbon sugar , a phosphate group and a nitrogenous base. If the sugar is a compound ribose , the polymer is RNA (ribonucleic acid); if the sugar is derived from ribose as deoxyribose the polymer is DNA (deoxyribonucleic acid).Nucleic acids are the most important of all biomolecules.

The term nucleic acid is the overall name for DNA and RNA, members of a family of biopolymers and is synonymous with polynucleotide .Nucleic acids were named for their initial discovery within the nucleus, and for the presence of phosphate groups (related to phosphoric acid. Although first discovered within the nucleus of eukaryotic cells, nucleic acids are now known to be found in all life forms including within bacteria, archaea, virusis. All living cells contain both DNA and RNA (except some cells such as mature red blood cells), while viruses contain either DNA or RNA, but usually not both. The basic component of biological nucleic acids is the nucleotide, each of which contains:

1-pentose sugar (ribose or deoxyribose)

2-phosphate group

3-nucleoase .

A nucleic acid is a chain of nucleotides which stores genetic information in biological systems. It creates DNA and RNA, which store the information needed by cells to create proteins. This information is stored in multiple sets of three nucleotides, known as codons.

How Nucleic Acids Work

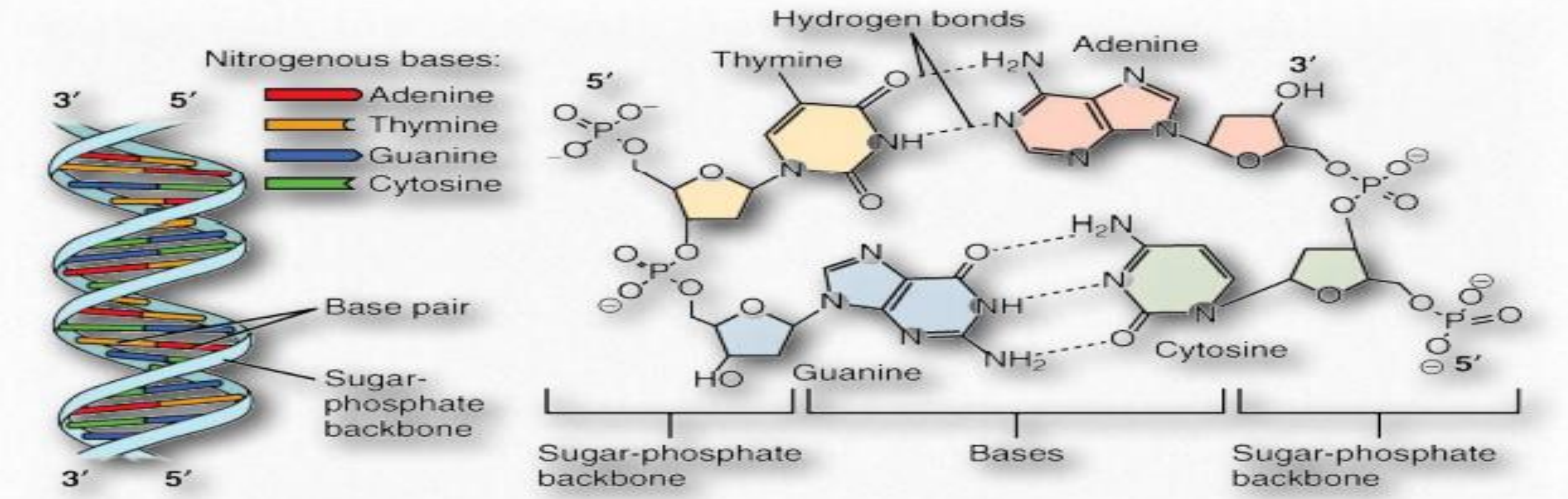
The name comes from the fact that these molecules are acids – that is, they are good at donating protons and accepting electron pairs in chemical reactions – and the fact that they were first discovered in the nuclei of our cells

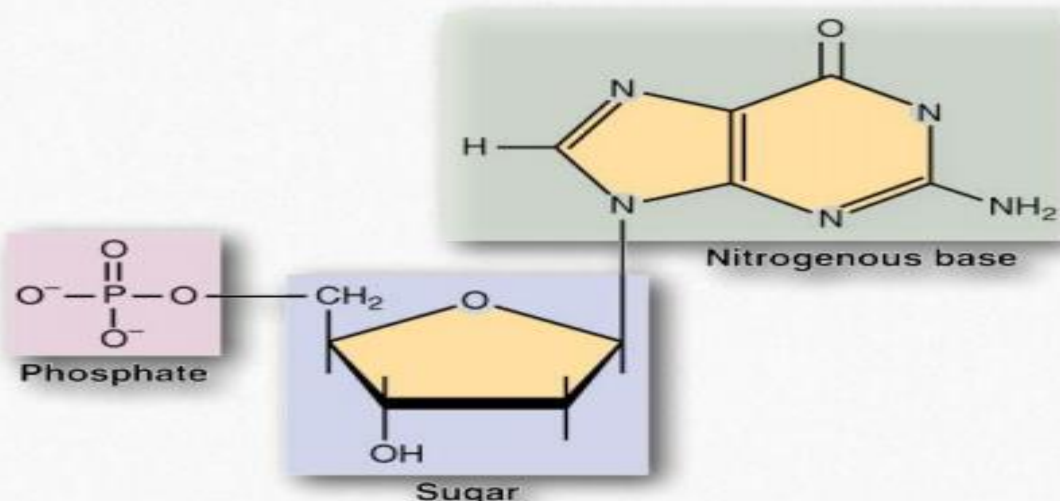
- All life on Earth uses nucleic acids as their medium for recording hereditary information – that is nucleic acids are the hard drives containing the essential blueprint or “source code” for making cells.
- For many years, scientists wondered how living things “knew” how to produce all the complex materials they need to grow and survive, and how they passed their traits down to their offspring.
- Scientists eventually found the answer in the form of DNA – deoxyribonucleic acid – a molecule located in the nucleus of cells, which was passed down from parent cells to “daughter” cells.
- When the DNA was damaged or passed on incorrectly, the scientists found that cells did not work properly. Damage to DNA would cause cells and organisms to develop incorrectly, or be so badly damaged that they simply died.
- Later experiments revealed that another type of nucleic acid – RNA, or ribonucleic acid – acted as a “messenger” that could carry copies of the instructions found in DNA. Ribonucleic acid was also used to pass down instructions from generation to generation by some viruses.

DNA

the structure of DNA was one of the greatest stories of 20th century science. Discovered in 1869 by Friedrich Miescher, DNA was identified as the genetic material in experiments in the 1940s led by Oswald Avery, Colin MacLeod, and Maclyn McCarty. X-ray diffraction work of Rosalind Franklin and the observations of Erwin Chargaff were combined by James Watson and Francis Crick to form a model of DNA that we are familiar with today.

The double helix, made up of a pair of DNA strands, has at its core, bases joined by hydrogen bonds to form base pairs - adenine always paired with thymine, and guanine invariably paired with cytosine. Two hydrogen bonds are formed between adenine and thymine, but three hydrogen bonds hold together guanine and cytosin


Nitrogenous bases:
Adenine
Thymine
Guanine
Cytosine
3′
5′
Base pair
Sugar-phosphate backbone
3′
5′
Hydrogen bonds
Thymine
Adenine
5′
3′
OH
Guanine
Cytosine
HO
5′
Sugar-phosphate backbone
Bases
Sugar-phosphate backbone


Nitrogenous base
Phosphate
Sugar

The complementary structure immediately suggested to Watson and Crick how DNA might be (and in fact, is) replicated and it further explains how information is DNA is transmitted to RNA for the synthesis of proteins. In addition to the hydrogen bonds between bases of each strand, the double helix is held together by hydrophobic interactions of the stacked, non-polar bases. Crucially, the sequence of the bases in DNA carry the information for making proteins. Read in groups of three, the sequence of the bases directly specifies the sequence of the amino acids in the encoded protein.

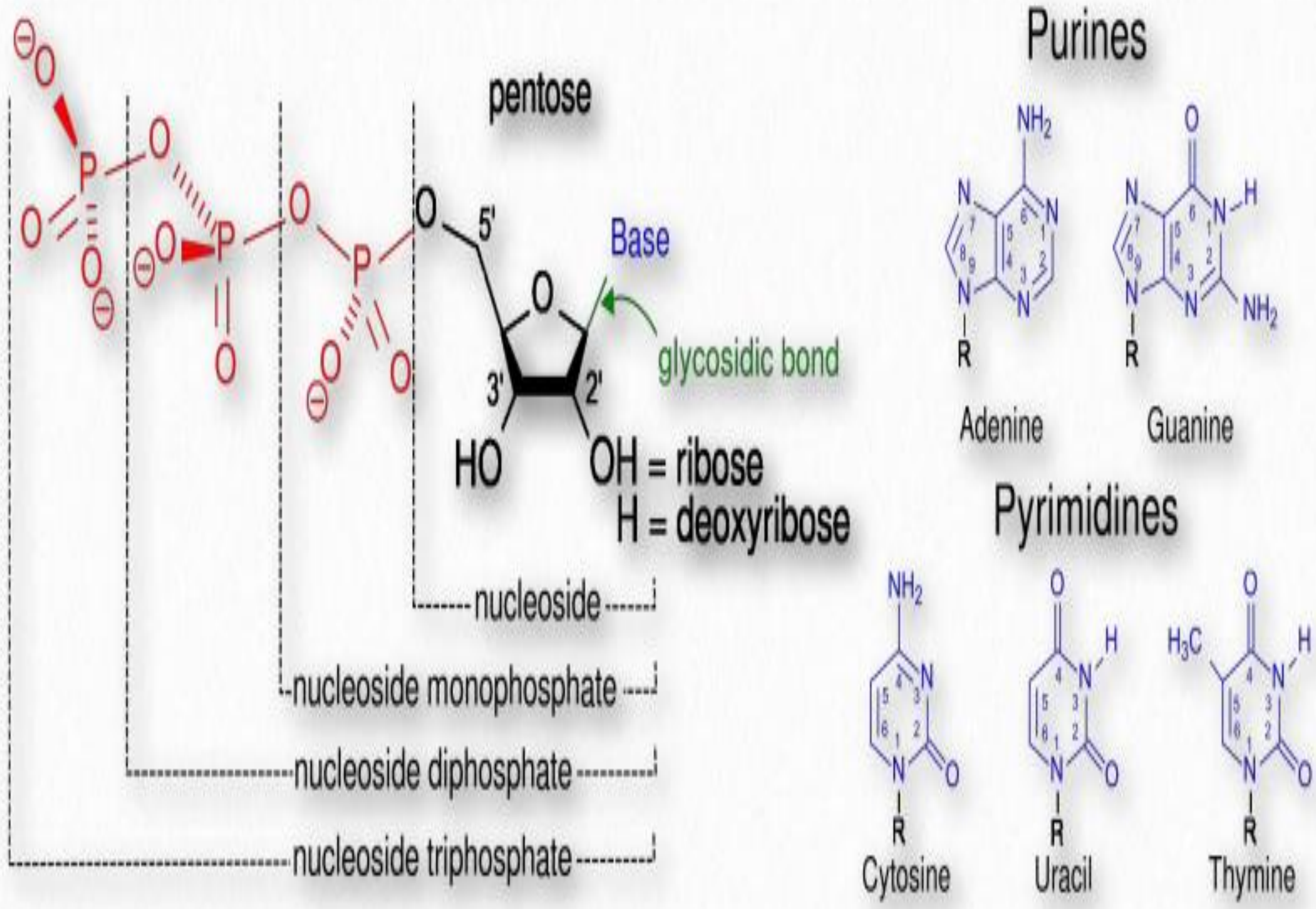
Structure

A DNA strand is a polymer of nucleoside monophosphates held together by phosphodiester bonds. Two such paired strands make up the DNA molecule, which is then twisted into a helix. In the most common form, the DNA helix has a repeat of 10.5 base pairs per turn, with sugars and phosphate forming the covalent phosphodiester “backbone” of the molecule and the adenine, guanine, cytosine, and thymine bases oriented in the middle where they form the now familiar base pairs that look like the rungs of a ladder.

Building blocks

The term nucleotide refers to the building blocks of both DNA (deoxyribonucleoside triphosphates, dNTPs) and RNA (ribonucleoside triphosphates, NTPs). In order to discuss this important group of molecules, it is necessary to define some terms.

Nucleotides contain three primary structural components. These are a nitrogenous base, a pentose sugar, and at least one phosphate. Molecules that contain only a sugar and a nitrogenous base (no phosphate) are called nucleosides. The nitrogenous bases found in nucleic acids include adenine and guanine (called purines) and cytosine, uracil, or thymine (called pyrimidines). There are two sugars found in nucleotides - deoxyribose and ribose). By convention, the carbons on these sugars are labeled 1’ to 5’. (This is to distinguish the carbons on the sugars from those on the bases, which have their carbons simply labeled as 1, 2, 3, etc.) Deoxyribose differs from ribose at the 2’ position, with ribose having an OH group, where deoxyribose has H.


pentose
Base
glycosidic bond
5'
3'
2'
HO
OH = ribose
H = deoxyribose
nucleoside
nucleoside monophosphate
nucleoside diphosphate
nucleoside triphosphate
Purines
Adenine
Guanine
Pyrimidines
Cytosine
Uracil
Thymine

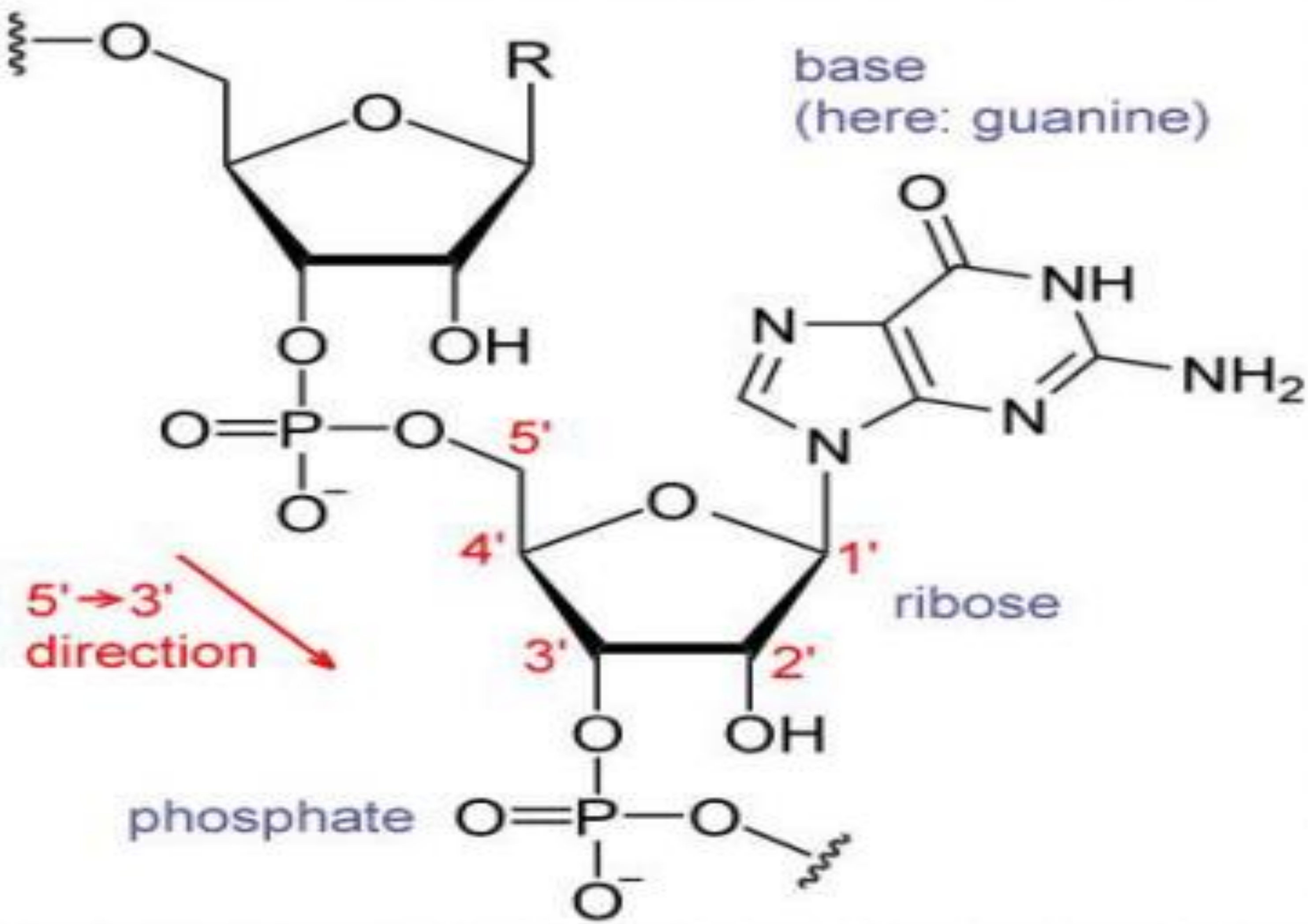
Nucleotides containing deoxyribose are called deoxyribonucleotides and are the forms found in DNA. Nucleotides containing ribose are called ribonucleotides and are found in RNA. Both DNA and RNA contain nucleotides with adenine, guanine, and cytosine, but with very minor exceptions, RNA contains uracil nucleotides, whereas DNA contains thymine nucleotides. When a base is attached to a sugar, the product, a nucleoside, gains a new name.

- **uracil-containing** = uridine (attached to ribose) / deoxyuridine (attached to deoxyribose)
- **thymine-containing** = ribothymidine (attached to ribose) / thymidine (attached to deoxyribose)
- **cytosine-containing** = cytidine (attached to ribose) / deoxycytidine (attached to deoxyribose)
- **guanine-containing** = guanosine (attached to ribose) / deoxyguanosine (attached to deoxyribose)
- **adenine-containing** = adenosine (attached to ribose) / deoxyadenosine (attached to deoxyribose)

Of these, deoxyuridine and ribothymidine are the least common. The addition of one or more phosphates to a nucleoside makes it a nucleotide. Nucleotides are often referred to as nucleoside phosphates, for this reason. The number of phosphates in the nucleotide is indicated by the appropriate prefixes (mono, di or tri)

RNA

- The structure of RNA is very similar to that of a single strand of DNA. Built of ribonucleotides, joined together by the same sort of phosphodiester bonds as in DNA, RNA uses uracil in place of thymine. In cells, RNA is assembled by RNA polymerases, which copy a DNA template in the much same way that DNA polymerases replicate a parental strand. During the synthesis of RNA, uracil is used across from an adenine in the DNA template. The building of messenger RNAs by copying a DNA template is a crucial step in the transfer of the information in DNA to a form that directs the synthesis of protein. Additionally, ribosomal and transfer RNAs serve important roles in “reading” the information in the mRNA codons and in polypeptide synthesis. RNAs are also known to play important roles in the regulation of gene expression.


R
base
(here: guanine)
O
NH
N
NH_2
N
N
O
OH
O=P—O
5'
O⁻
O
4'
1'
ribose
5'→3'
direction
3'
2'
O
OH
phosphate
O=P—O
O⁻

RNAs are more varied than their DNA. Created by copying regions of DNA, cellular RNAs are synthesized as single strands, but they often have self-complementary regions leading to “foldbacks” containing duplex regions. These are most easily visualized in the ribosomal RNAs (rRNAs) and transfer RNAs (tRNAs) ,though other RNAs, including messenger RNAs (mRNAs), small nuclear RNAs (snRNAs), microRNAs ,and small interfering RNAs (siRNAs) may each have double helical regions as well.

Base pairing

- Base pairing in RNA is slightly different than DNA. This is due to the presence of the base uracil in RNA in place of thymine in DNA. Like thymine, uracil forms base pairs with adenine, but unlike thymine, uracil can, to a limited extent, also base pair with guanine, giving rise to many more possibilities for pairing within a single strand of RNA.
- These additional base pairing possibilities mean that RNA has many ways it can fold upon itself that single-stranded DNA cannot. Folding, of course, is critical for protein function, and we now know that, like proteins, some RNAs in their folded form can catalyze reactions just like enzymes. Such RNAs are referred to as ribozymes. It is for this reason scientists think that RNA was the first genetic material, because it could not only carry information, but also catalyze reactions. Such a scheme might allow certain RNAs to make copies of themselves, which would, in turn, make more copies of themselves, providing a positive selection.

- **Stability**

RNA is less chemically stable than DNA. The presence of the 2’ hydroxyl on ribose makes RNA much more prone to hydrolysis than DNA, which has a hydrogen instead of a hydroxyl. Further, RNA has uracil instead of thymine. It turns out that cytosine is the least chemically stable base in nucleic acids. It can spontaneously deaminate and in turn is converted to a uracil. This reaction occurs in both DNA and RNA, but since DNA normally has thymine instead of uracil, the presence of uracil in DNA indicates that deamination of cytosine has occurred and that the uracil needs to be replaced with a cytosine. Such an event occurring in RNA would be essentially undetectable, since uracil is a normal component of RNA. Mutations in RNA have much fewer consequences than mutations in DNA because they are not passed between cells in division.