BCH-201:Nucleotides and Nucleic acids

Nucleotides and Nucleic acids are compounds containing Nitrogen bases (aromatic cyclic structures possessing nitrogen atoms) as part of their structure.N**ucleic acids** are linear, unbranchedpolymers of nucleotides.

Nucleotides consist of three parts:

1. A five-carbon sugar (hence a **pentose**). Two kinds are found:

- **Deoxyribose**, which has a hydrogen atom attached to its #2 carbon atom (designated 2'), and
- **Ribose**, which has a hydroxyl group there.

Deoxyribose-containing nucleotides, the **deoxyribonucleotides**, are the monomers of deoxyribonucleic acids **(<u>DNA</u>)**.

Ribose-containing nucleotides, the **ribonucleotides**, are the monomers of ribonucleic acids **(<u>RNA</u>)**.

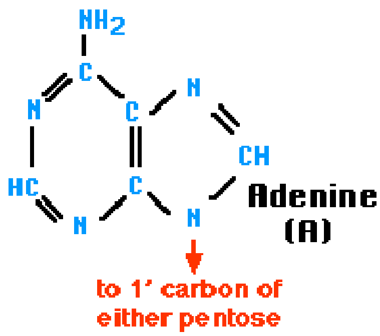
2. A nitrogen-containing ring structure called a **base**. The base is attached to the 1' carbon atom of the pentose. In **DNA**, four different bases are found:

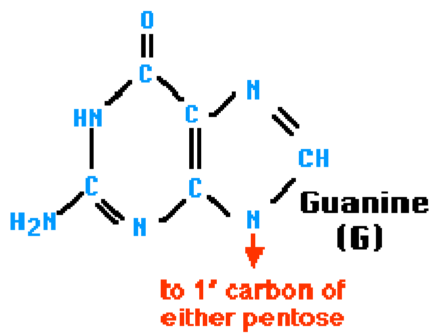
1. two **purines**, called **adenine** (**A**) and **guanine** (**G**)
2. two **pyrimidines**, called **thymine** (**T**) and **cytosine** (**C**)

RNA contains:

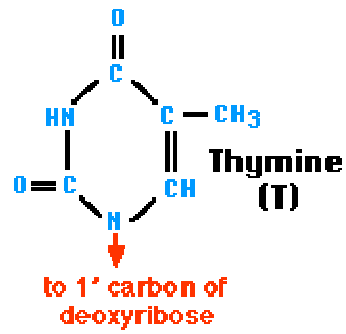
1. The same purines, **adenine** (**A**) and **guanine** (**G**).
2. RNA also uses the pyrimidine **cytosine** (**C**), but instead of thymine, it uses the pyrimidine **uracil** (**U**).

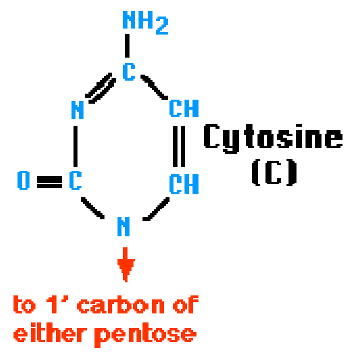
The Purines

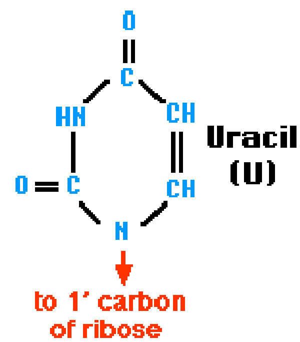




The Pyrimidines







The combination of a base and a pentose is called a **nucleoside**.

The pentose sugar of the nucleotides is joined to the bases by **β-N-glycosidic bonds**. The β-N-glycosidic linkage is between **N^9-C^1** for purine bases and **N^1-C^1** for pyrimidine bases.

3. One (as shown in the first figure), two, or three **phosphate** groups. These are attached to the 5' carbon atom of the pentose. The product in each case is called a **nucleotide**.

Both DNA and RNA are assembled from **nucleoside triphosphates**.

For **DNA**, these are **dATP**, **dGTP**, **dCTP**, and **dTTP**.

For **RNA**, these are **ATP**, **GTP**, **CTP**, and **UTP**.

In both cases, as each nucleotide is attached, the second and third phosphates are removed.

The nucleosides and their mono-, di-, and triphosphates

	Base	**Nucleoside**	**Nucleotides**		
DNA	Adenine (A)	Deoxyadenosine	dAMP	dADP	dATP
	Guanine (G)	Deoxyguanosine	dGMP	dGDP	dGTP
	Cytosine (C)	Deoxycytidine	dCMP	dCDP	dCTP
	Thymine (T)	Deoxythymidine	dTMP	dTDP	dTTP
RNA	Adenine (A)	Adenosine	AMP	ADP	ATP
	Guanine (G)	Guanosine	GMP	GDP	GTP
	Cytosine (C)	Cytidine	CMP	CDP	CTP
	Uracil (U)	Uridine	UMP	UDP	UTP

Function of Nucleotides:

- Participate in the majority of biochemical reactions

- ATP - - energy currency (also ADP, AMP)

- UDP-glucose - - glycogen biosynthesis

- CoA, NAD+, NADP+, FAD are derivatives of nucleotides

- cAMP - - regulation of cellular processes (signaling)

- Nucleoside triphosphates (NTP) - - RNA

- Deoxynucleoside triphosphates (dNTP) - - DNA

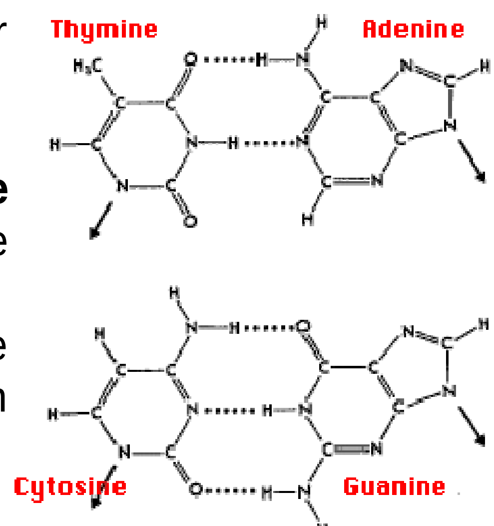
NUCLEIC ACIDS.

Nucleic acids are defined as biopolymers that are involved in the preservation/storage and transmission of genetic information from one generation to another. The nucleotides that make up the nucleic acids are linked by phosphodiester bonds between 3' and 5' positions of the sugars. The linkage is called **a 3'-5' phosphodiester bond.**

Base Pairing

The rules of base pairing (or nucleotide pairing) are:

- **A** with **T**: the purine **adenine** (A) always pairs with the pyrimidine **thymine** (T)
- **C** with **G**: the pyrimidine **cytosine** (C) always pairs with the purine **guanine** (G)



This is consistent with there not

being enough space (20 Å) for two purines to fit within the helix and too much space for two pyrimidines to get close enough to each other to form hydrogen bonds between them.

But why not A with C and G with T?

The answer: only with A & T and with C & G are there opportunities to establish hydrogen bonds (shown here as dotted lines) between them (two between A & T; three between C & G). These relationships are often called the rules of **Watson-Crick** base pairing, named after the two scientists who discovered their structural basis.

The rules of base pairing tell us that if we can "read" the sequence of nucleotides on one strand of DNA, we can immediately deduce the complementary sequence on the other strand.

The rules of base pairing explain the phenomenon that whatever the amount of adenine (A) in the DNA of an organism, the amount of thymine (T) is the same (called Chargaff's rule). Similarly, whatever the amount of guanine (G), the amount of cytosine (C) is the same.

RIBONUCLEIC ACID (RNA)

Several types of RNA are synthesized in the nucleus of eukaryotic cells. Of particular interest are:

- messenger RNA (**mRNA**). This will later be translated into a polypeptide.
- ribosomal RNA (**rRNA**). This will be used in the building of ribosomes: machinery for synthesizing proteins by translating mRNA.
- transfer RNA (**tRNA**). RNA molecules that carry amino acids to the growing polypeptide.

- small nuclear RNA (**snRNA**). DNA transcription of the genes for mRNA, rRNA, and tRNA produces large precursor molecules (**"primary transcripts"**) that must be processed within the nucleus to produce the functional molecules for export to the cytosol. Some of these processing steps are mediated by snRNAs.
- small nucleolar RNA (**snoRNA**). These RNAs within the nucleolus have several functions (described below).
- microRNA (**miRNA**). These are tiny (~22 nucleotides) RNA molecules that regulate the expression of messenger RNA (mRNA) molecules. [Discussion]
- **XIST** RNA. This inactivates one of the two X chromosomes in female vertebrates. [Discussion]

Messenger RNA (mRNA)

Messenger RNA comes in a wide range of sizes reflecting the size of the polypeptide it encodes. Most cells produce small amounts of thousands of different mRNA molecules, each to be translated into a peptide needed by the cell.

Many mRNAs are common to most cells, encoding "housekeeping" proteins needed by all cells (e.g., the enzymes of glycolysis). Other mRNAs are specific for only certain types of cells. These encode proteins needed for the function of that particular cell (e.g., the mRNA for hemoglobin in the precursors of red blood cells).

Ribosomal RNA (rRNA)

There are 4 kinds. In eukaryotes, these are

- **18S rRNA**. One of these molecules, along with some 30 different protein molecules, is used to make the **small subunit** of the ribosome.

- **28S, 5.8S, and 5S rRNA**. One each of these molecules, along with some 45 different proteins, are used to make the **large subunit** of the ribosome.

The S number given each type of rRNA reflects the rate at which the molecules sediment in the ultracentrifuge. The larger the number, the larger the molecule (but not proportionally).

The 28S, 18S, and 5.8S molecules are produced by the processing of a single primary transcript from a cluster of identical copies of a single gene. The 5S molecules are produced from a different cluster of identical genes.