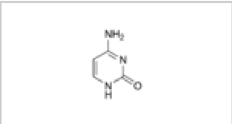
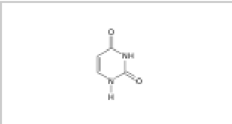
Basic components of nucleic acids

Mononucleotide contains three components, namely **a pentose, a phosphate and a nitrogenous base.** The pentose has a central position among them, it is either β-D-ribofuranose (**ribose**) or 2'-deoxy-β-D-ribofuranose (**deoxyribose**). In nucleotides, the pentose carbons are numbered with an apostrophe (C2'..c two with a dash) to distinguish them from the base carbons. Depending on the type of pentose, we distinguish ribonucleic acids (**RNA**) and deoxyribonucleic acids (**DNA**). Pentose occurs in various conformations. If C2' protrudes above the plane of the furanose ring in the same way as C5', it is a 2'-endo conformation, if C3' protrudes like this, the conformation is called 3'-endo. The conformation of pentoses changes during functionally significant changes in the higher structure of nucleic acids.

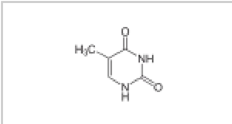
A base is attached to C1 of pentoses by an N-β-glycosidic bond. Bases are derived either from a pyrimidine (**cytosine, uracil, thymine**) or from a purine (**adenine, guanine**). In RNA thymine occurs rarely, DNA does not contain uracil. The basic character of these compounds is given by heterocyclic nitrogens, which, however, are not protonated in the cell at pH close to 7.



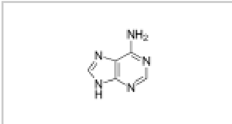
Cytosine



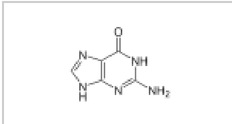
Uracile



Thymine

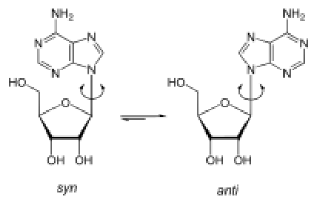


Adenine



Guanine

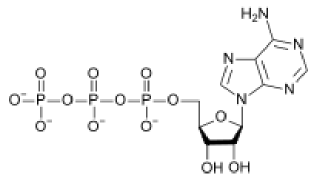
The compound of a nitrogenous base with a saccharide is called a **nucleoside**, according to the pentose a ribonucleoside (specifically cytidine, uridine, thymidine) or a deoxyribonucleoside (adenosine, guanosine). The heterocycles of the bases are flat, their plane is approximately perpendicular to the plane of the furanose ring of the pentose. At first glance, it appears that the base can rotate around the glycosidic bond relative to the pentose. However, steric hindrances allow only the syn- or anti-conformation to be adopted, depending on whether the base around the glycosidic bond is turned over the pentose face (syn-) or to the opposite side (anti-). In natural dsDNA, the anti-conformation of purines and pyrimidines predominates.



Syn- and anti-conformations of adenosine nucleoside

A nucleotide is formed from a nucleoside by **esterification** of a saccharide with **trihydrogenphosphoric acid**. In ribonucleotides, phosphate can be attached in the 2', 3' or 5' position, in deoxyribonucleotides in the 3' or 5' position.

Due to the complexity of the formulas and the length of the names of the components of nucleic acids, the nomenclature commission of the **International Union of Pure and Applied Chemistry (IUPAC)** established rules for the use of names, abbreviations, one- or three-letter symbols. The table shows the most used of them:



Chemical structure of ATP

Nomenclature, symbols and abbreviations of nucleic acids and their components

Base	**Ribonucleoside**				**Deoxyribonucleoside**		
	N				**dN**		
Pyrimidins	**Pyr**	**-idine**	**Y**	**Pyd**	**Deoxy- -idine**	**dY**	**dPyd**
Cytosine	Cyt	Cytidine	C	Cyd	Deoxycytidine	dC	dCyd
Uracile	Ura	Uridine	U	Urd	Deoxyuridine	dU	dUrd
Thymine	Thy	Ribosylthymine	T	Thd	(Deoxy)thymidine	dT	dThd
Purins	**Pur**	**-osine**	**R**	**Puo**	**Deoxy- -osine**	**dR**	**dPud**
Adenine	Ade	Adenosine	A	Ado	Deoxyadenosine	dA	dAdo
Guanine	Gua	Guanosine	G	Guo	Deoxyguanosine	dG	dGuo
Hypoxanthine	Hyp	Inosine	I	Ino			
Xanthine	Xan	Xanthosine	X	Xao			
Orotate	Oro	Orotodine	O	Ord			

Examples

Uridine-5'-phosphate	Urd-5'-P	UMP
Uridine-3'-phosphate	Urd-3'-P	
Adenosine-5'-diphosphate	Ado-5'-PP	ADP
Adenosine-5'-triphosphate	Ado-5'-PPP	ATP
Cyclic adenosine-3',5'-phosphate	Ado-3',5'-P	cAMP
Deoxycytidine-5'-phosphate	dCyd-5'-P	dCMP
Isoacceptor RNAs	$tRNA_1^{AA}$, $tRNA_2^{AA}$, $tRNA_5^{AA}$	
Aminoacyl-tRNA	AA-tRNA	
Heterogeneous nuclear RNA	hnRNA	
Small nuclear RNA	snRNA	
Small nucleolar RNA	snoRNA	
Complementary DNA (to mRNA)	cDNA	

Table notes:

1. The IUPAC Commission has reserved single-letter symbols C, T, A, G, etc. for nucleosides included in an oligo- or polynucleotide. It is written CpUpGpAp or C–U–G–Ap in the case of RNA and d(pApGpT) or d(pA–G–T) in the case of DNA. Phosphates (and terminal phosphates) are marked with the lowercase letter p. If the polarity of the chain is not indicated by numbers or arrows between the letters, then the 5'-end of the chain is on the left and the 3'-end is on the right. If there is a p symbol at either end, it means that the terminal 5'- or 3'-OH group is esterified with phosphate. Single-letter symbols are not used for mononucleotides; these can only be described with three-letter symbols, and phosphate is written as a capital letter P.
2. The prefix deoxy- is usually omitted for thymidine, so dT is thymidine. T is ribosylthymine, found for example in transfer RNAs.
3. The abbreviations ATP, CDP, dGMP are reserved only for nucleoside 5'-phosphates, not 3'- or 2'-phosphates. The first phosphate, referred to as α, is connected to the pentose by an ester bond, the second (β) and third (γ) phosphates form an anhydride with the previous phosphate.
4. Phosphate can bind to two carbons of the same pentose through a phosphodiester bond, creating another heterocycle in the compound, which is why the compound is called a cyclic nucleotide. The abbreviations cAMP and cGMP denote the respective 3',5'-phosphates; have an important signaling function in the cell.

In addition to the listed basic components, nucleic acids also contain other so-called **minor bases** and **nucleosides**. They are mostly formed by additional methylation of a base or pentose after their incorporation into a polynucleotide, there are, for example, N-6-methyladenosine (m^6A), 5-methylcytosine (m^5C), 2'-O-methylguanosine (Gm). Dihydrouracil and thymine riboside are found in transfer RNAs. Minority bases and nucleosides probably participate in the formation of signal sites or their substituents protect the nucleic acid from cleavage by nucleases. Other bases are metabolites of basic bases, for example hypoxanthine (6-oxopurine), xanthine (2,6-dioxopurine) and uric acid (2,6,8-trioxopurine). Methylxanthines caffeine (1,3,7-trimethylxanthine), theophylline (1,3-dimethylxanthine) and theobromine (3,7-dimethylxanthine) are pharmacologically active substances of plant origin.

Among the properties of bases, their **tautomerism** is significant, where isomers differ in the distribution of electrons and protons in the molecule.

Tautomerism of bases

In the cell at pH around 7, the lactam form predominates for uracil, guanine and thymine, and the lactim form for cytosine and adenine. Tautomerism is important for correct base pairing in double-stranded nucleic acids. Another property of the bases is their characteristic spectrum with a maximum at λ=260 nm. It is used in a number of methodological approaches to the study of nucleic acids (purity of the nucleic acid preparation, their concentration, denaturation, etc.)

Links

Related articles

- Structure of DNA
- Denaturation of nucleic acids, molecular hybridization
- Topology of DNA
- Interaction of DNA with proteins
- Bacterial chromosome
- Eukaryotic Chromosomes

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