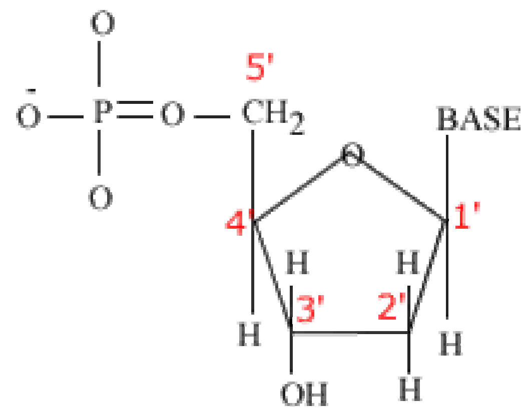
NUCLEIC ACIDS

Nucleic acids are, among other things, the stuff of which genes are made. In beginning biology, there are three nucleic acids of primary importance: deoxyribonucleic acid (DNA); ribonucleic acid (RNA); and adenosine triphosphate (ATP).



A nucleotide. Note the numbering of the carbons.

Nucleotides

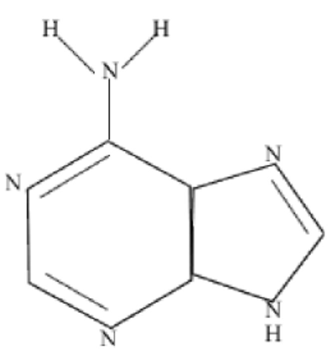
Just as polysaccharides have building blocks of monosaccharides, just as lipids have building blocks of glycerol and fatty acids, just as proteins have building blocks of amino acids, nucleic acids have building blocks – called nucleotides.

Nucleotides are composed of three parts: (1) a pentose sugar (2) a phosphate group, and (3) a base.

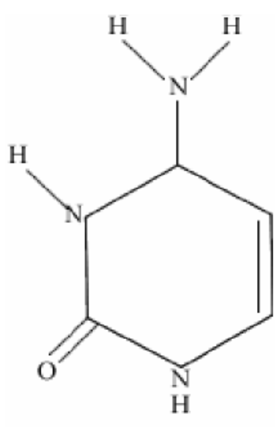
Bases of Nucleic Acids

There are five important bases for nucleic acids. Remember, bases taste bitter, turn red litmus blue, are indicated by the presence of hydroxide ions, and they neutralize acids. The bases of nucleic acids are

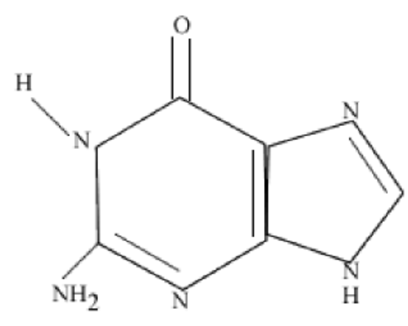
(1) adenine (A)
(2) thymine (T)
(3) cytosine (C)
(4) guanine (G)
(5) uracil (U).



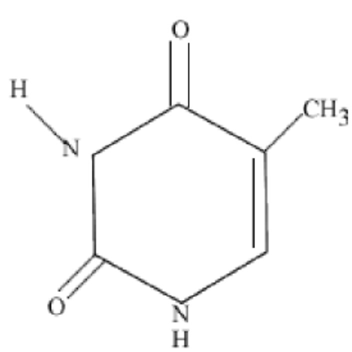
adenine



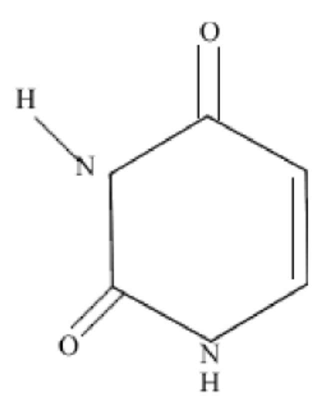
cytosine



guanine



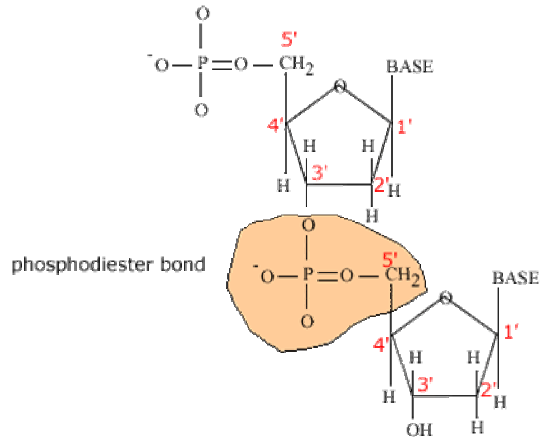
thymine



uracil

NUCLEIC ACIDS

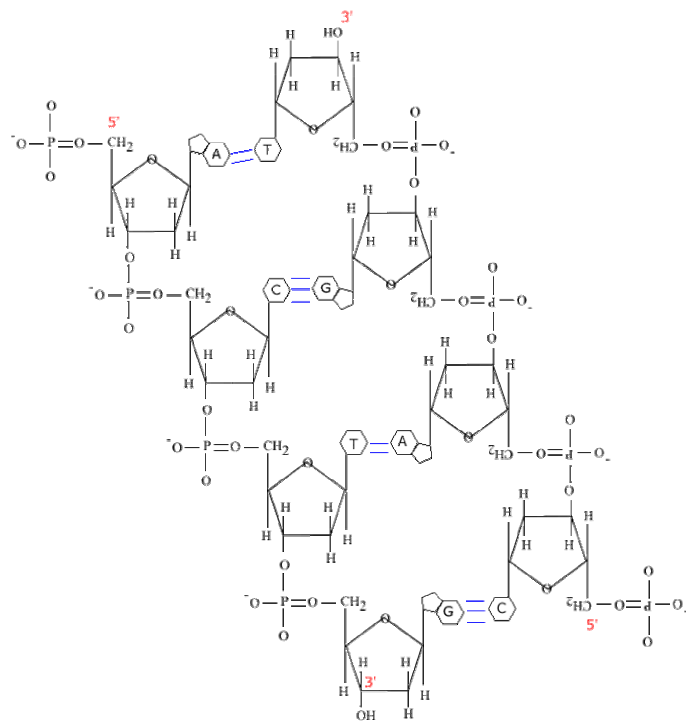
The pentose sugar is centrally located in the nucleotide. The phosphate group attaches left of the pentose and the base attaches to the right of the pentose.



DNA and RNA are strands of nucleotides joined together by dehydration synthesis (or condensation synthesis) at a phosphate group. A bond forms between the phosphate group from the # 5 carbon on one nucleotide and the # 3 carbon of another nucleotide. It is referred to as a phosphodiester bond because the phosphate group forms two ester bonds, one at the # 3 carbon and one at the # 5. Consequently, all nucleic acids have a free end composed of the 5' phosphate group and a 3' hydroxyl group. The nucleic acid strands have a 5'←→ 3' orientation.

DNA

DNA is a double strand of nucleotides with the bases pointing toward each other from each strand. There are only 4 of the 5 possible bases in DNA. DNA contains the bases adenine, thymine, cytosine and guanine. DNA does not contain the base uracil. The arrangement of the bases is significant. The biochemist Erwin Chargaff studied different species' DNA and came to the conclusion the DNA in all species was very consistently arranged so that the amount of adenine in a species was, in essence, the same as the amount of thymine and the amount of cytosine was equivalent to the amount of guanine. In other words, A = T, G = C.



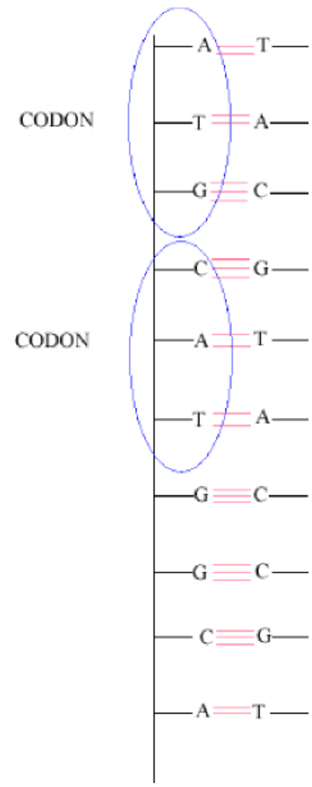
For Chargaff 's rule to be obeyed, the base adenine must pair opposite thymine in a DNA molecule. The base cytosine must always pair opposite guanine. Even though base pairs are restricted to Chargaff's rule, the uniqueness of every organism's DNA is based on the arrangement of those pairs within the molecule. For example, my DNA sequence (of one side of the strand) may read ATTCGCCGC and yours may read AGTCGCCGC.

The base pairs are joined by hydrogen bonds. There are two hydrogen bonds between adenine and thymine and three between cytosine and guanine. DNA looks very much like a circular staircase with the base pairs (and hydrogen bonds) the rungs, the pentose sugars as the "rails" of the with phosphate groups sticking outside the rails. Imagine your ladder

twisted into an α helix. Extend your staircase to a length of over 100,000 “rungs” and you will have one of the smaller DNA molecules in existence. No wonder these are often referred to as “macromolecules.” The two strands of nucleotides run antiparallel to each other. 5’-------------------------3’
3’-------------------------5’

Codons

A sequence of three base pairs along the strand of a nucleotide is called a codon. Codons code for something – amino acids. We make proteins from amino acids and pretty much everything about you is determined from your proteins. Therefore, in simple terms, DNA is the genetic code of much of the life on this planet (viruses may have RNA and early life forms may have been RNA) and DNA codes for proteins by stipulating the 1° structure of the protein. The great news is scientists have broken the genetic “code”.



Standard Genetic Code

First Position 5' End	**U**	**Second C**	**Position A**	**G**	**Third position 3' end**
U	**Phe** **Phe** **Leu** **Leu**	**Ser** **Ser** **Ser** **Ser**	**Tyr** **Tyr** **UAA (Stop)** **UAG (Stop)**	**Cys** **Cys** **UGA (Stop)** **Trp**	**U** **C** **A** **G**
C	**Leu** **Leu** **Leu** **Leu**	**Pro** **Pro** **Pro** **Pro**	**His** **His** **Gln** **Gln**	**Arg** **Arg** **Arg** **Arg**	**U** **C** **A** **G**
A	**Ile** **Ile** **Ile** **Met (Start)**	**Thr** **Thr** **Thr** **Thr**	**Asn** **Asn** **Lys** **Lys**	**Ser** **Ser** **Arg** **Arg**	**U** **C** **A** **G**
G	**Val** **Val** **Val** **Val**	**Ala** **Ala** **Ala** **Ala**	**Asp** **Asp** **Glu** **Glu**	**Gly** **Gly** **Gly** **Gly**	**U** **C** **A** **G**

The way you read the genetic code is to first substitute thymine (T) for U (uracil). More about that later in the course. The codon ACA codes for the amino acid Threonine. Glycine may be coded for by four combinations: GGU, GGC, GGA, and GGG.

There are several significant features to the genetic code. First, it is universal. By this, scientists mean ACA codes for Threonine in dogs, cats, bacteria, viruses, frogs, snakes, fish, jellyfish, and yes, even humans. ACA codes for Threonine in every living thing on this planet.

The second feature is the genetic code is degenerate. There is more than one way to code for Glycine, *i.e.* GGU, GGC, GGA, and GGG. The reason is very simple. *If* the genetic code consisted of *one* base pair, and since there are only 4 bases in DNA, it would only be possible to code for (4^1) or 4 of the 20 amino acids. That not enough. *If* the genetic code was composed of *two* base pairs, it would be possible to code for (4^2) or 16 of the 20 amino acids. We are still 4 amino acids short. However, since the genetic code seems to be *three* base pairs, the number of amino acids for which can be coded is (4^3) or 64. We only have 20 amino acids, so that leaves 44 potential codes. The genetic code then repeats some of the amino acids – to build in a redundancy.

The third feature of the genetic code is it is a good grammarian. It begins sentences with a capital letter and puts a period at the end of the sentence. Note that AUG codes for Methionine or Start. The genetic code tells where to begin to code for a protein and then with UAA, UAG or UGA, it tells where to stop the code for the protein. It tells us the beginning and end of the gene product.

RNA

Ribonucleic Acid is different from DNA in several ways. Perhaps the best way to illustrate RNA is to compare it to DNA

Characteristic	**RNA**	**DNA**
Bases	RNA does not contain the base thymine; instead, it substitutes the base uracil	DNA does not contain the base uracil; instead it substitutes the base thymine
Strands of Nucleotides	RNA is *typically* single stranded	DNA is *typically* double stranded
Oxygens	RNA has one more oxygen in the ribose than DNA	DNA has one less oxygen in the ribose than RNA

There are three primary types of RNA. They are

(1) messenger RNA (m-RNA)
(2) ribosomal RNA (r-RNA)
(3) transfer RNA (t-RNA).

More will be discussed later about the three primary types of RNA and the other types of RNA in the cell.

Adenosine Triphosphate

ATP is considered the energy "currency" of the cell. It is the method by which cells "pay" for their activities. The ribose sugar and the base adenine together are referred to as the adenosine unit. Add three phosphate groups to the left of the ribose sugar and you have ATP. The third phosphate group is difficult to attach. It takes a lot of energy to add the third unit. This means once the bond on the third phosphate group is broken, the energy stored there is released to do work in the cell. ATP is manufactured in the cell from ADP (adenosine diphosphate) and ADP is manufactured from AMP (adenosine monophosphate.

$$AMP + P_i \leftrightarrow ADP + P_i \leftrightarrow ATP$$

The cell is constantly breaking ATP apart and rebuilding it according to its energy needs.