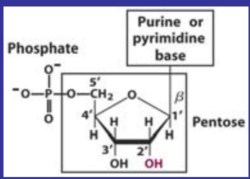
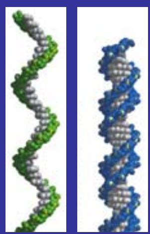
Nucleotides and nucleic acids

Nucleotides are the building blocks of nucleic acids



Nucleotide



RNA DNA

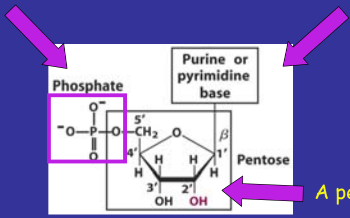
Nucleotides also play other important roles in the cell

Structure of nucleotides

Nucleotides have three characteristic components:

A phosphate group

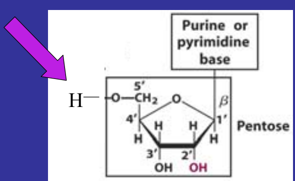
A nitrogenous base
(pyrimidines or purine)



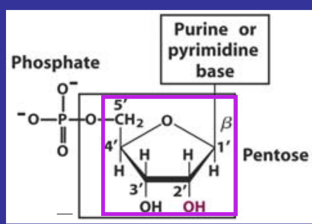
A pentose sugar

Structure of nucleosides

Remove the phosphate group, and you have a nucleo**side**.

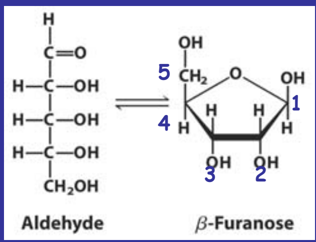


The ribose sugar



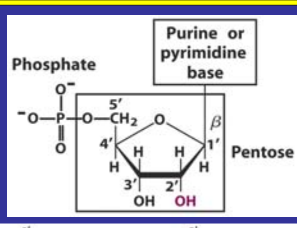
Ribose

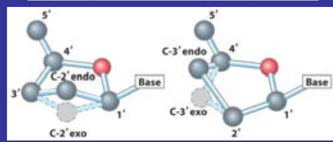
- Ribose (β-D-furanose) is a pentose sugar (5-membered ring).
- Note numbering of the carbons. In a nucleotide, "prime" is used (to differentiate from base numbering).



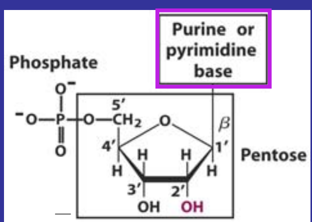
Ribose

- An important derivative of ribose is 2'-deoxyribose, or just deoxyribose, in which the 2' OH is replaced with H.
- Deoxyribose is in DNA (deoxyribonucleic acid)
- Ribose is in RNA (ribonucleic acid).
- The sugar prefers different puckers in DNA (C-2' endo) and RNA C-3' endo).



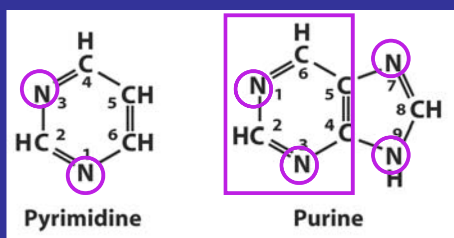


The purine or pyrimidine base

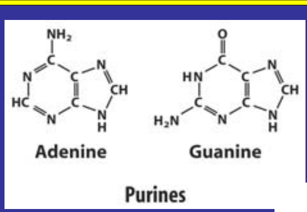


Pyrimidine and purine

Nucleotide bases in nucleic acids are pyrimidines or purines.

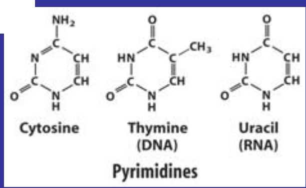


Major bases in nucleic acids



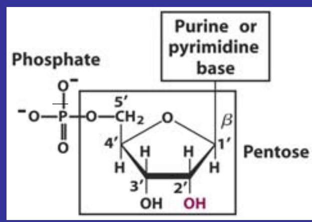
- The bases are abbreviated by their first letters (*A, G, C, T, U*).
- The purines (*A, G*) occur in both RNA and DNA

- Among the pyrimidines, *C* occurs in both RNA and DNA, but
- T occurs in DNA, and
- U occurs in RNA



Nucleotides in nucleic acids

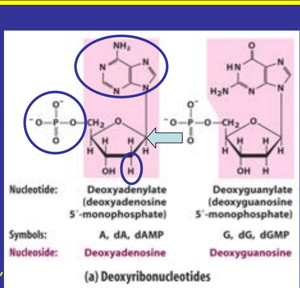
- Bases attach to the *C*-1' of ribose or deoxyribose
- The pyrimidines attach to the pentose via the N-1 position of the pyrimidine ring
- The purines attach through the N-9 position
- Some minor bases may have different attachments.



Deoxyribonucleotides

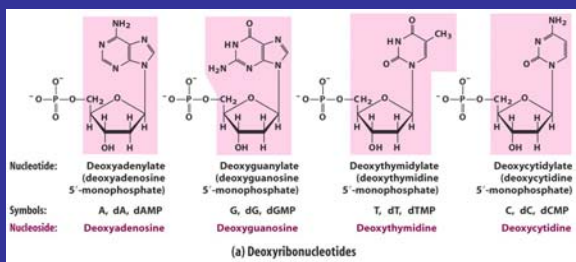
2'-deoxyribose sugar with a base (here, a purine, adenine or guanine) attached to the *C*-1' position is a deoxyribonucleoside (here deoxyadenosine and deoxyguanosine).

Phosphorylate the 5' position and you have a nucleotide(here, deoxyadenylate or deoxyguanylate)



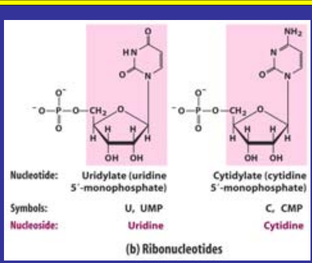
Deoxyribonucleotides are abbreviated (for example) A, or dA (deoxyA), or dAMP (deoxyadenosine monophosphate)

The major deoxyribonucleotides



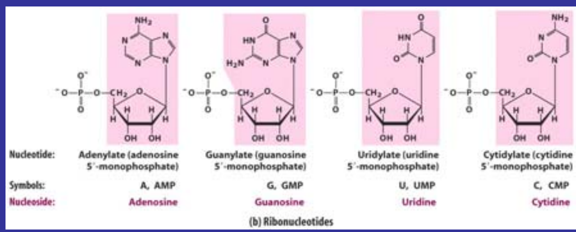
Ribonucleotides

- The ribose sugar with a base (here, a pyrimidine, uracil or cytosine) attached to the ribose *C*-1' position is a ribonucleoside (here, uridine or cytidine).
- Phosphorylate the 5' position and you have a ribonucleotide (here, uridylate or cytidylate)



- Ribonucleotides are abbreviated (for example) U, or UMP (uridine monophosphate)

The major ribonucleotides



Nucleotide nomenclature

TABLE 8-1 Nucleotide and Nucleic Acid Nomenclature

Base	Nucleoside	Nucleotide	Nucleic acid
Purines			
Adenine	Adenosine	Adenylate	RNA
	Deoxyadenosine	Deoxyadenylate	DNA
Guanine	Guanosine	Guanylate	RNA
	Deoxyguanosine	Deoxyguanylate	DNA
Pyrimidines			
Cytosine	Cytidine	Cytidylate	RNA
	Deoxycytidine	Deoxycytidylate	DNA
Thymine	Thymidine or deoxythymidine	Thymidylate or deoxythymidylate	DNA
Uracil	Uridine	Uridylate	RNA

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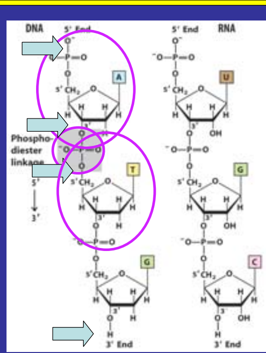
Nucleic acids



Nucleotide monomers can be linked together via a phosphodiester linkage

formed between the 3' -OH of a nucleotide

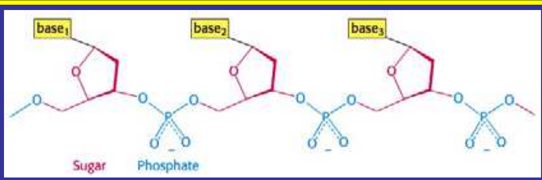
and the phosphate of the next nucleotide.

Two ends of the resulting poly- or oligonucleotide are defined:

The 5' end lacks a nucleotide at the 5' position,

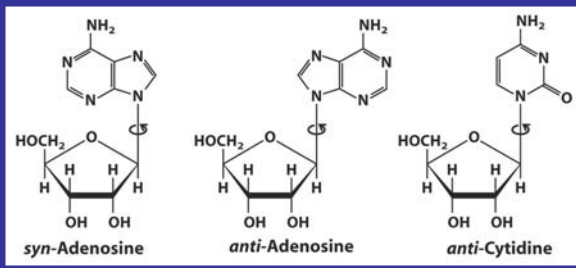
and the 3' end lacks a nucleotide at the 3' end position.

Sugar-phosphate backbone



- The polynucleotide or nucleic acid backbone thus consists of alternating phosphate and pentose residues.
- The bases are analogous to side chains of amino acids; they vary without changing the covalent backbone structure.
- Sequence is written from the 5' to 3' end: 5'-ATGCTAGC-3'
- Note that the backbone is polyanionic. Phosphate groups pKa ~ 0.

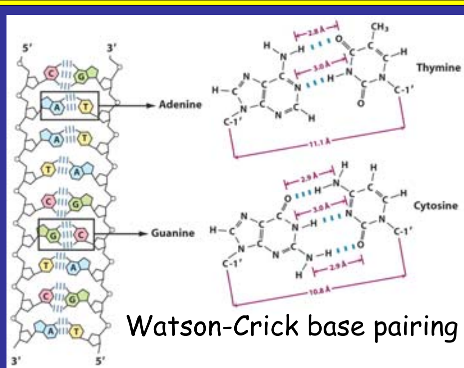
The bases can take syn or anti positions



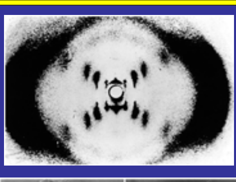
Compare polynucleotides and polypeptides

- As in proteins, the sequence of side chains (bases in nucleic acids) plays an important role in function.
- Nucleic acid structure depends on the sequence of bases *and* on the type of ribose sugar (ribose, or 2'-deoxyribose).
- Hydrogen bonding interactions are especially important in nucleic acids.

Interstrand H-bonding between DNA bases



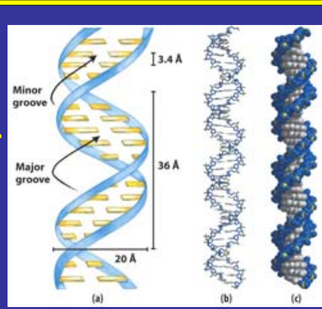
DNA structure determination



- Franklin collected x-ray diffraction data (early 1950s) that indicated 2 periodicities for DNA: 3.4 Å and 34 Å.
- Watson and Crick proposed a 3-D model accounting for the data.

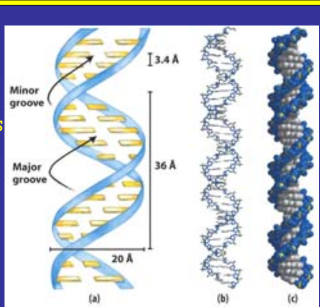
DNA structure

- DNA consists of two helical chains wound around the same axis in a right-handed fashion aligned in an antiparallel fashion.
- There are 10.5 base pairs, or 36 Å, per turn of the helix.
- Alternating deoxyribose and phosphate groups on the backbone form the outside of the helix.
- The planar purine and pyrimidine bases of both strands are stacked inside the helix.

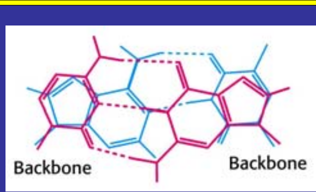


DNA structure

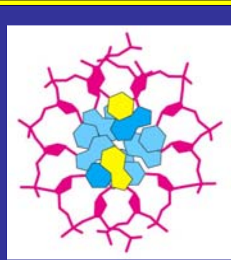
- The furanose ring usually is puckered in a C-2' endo conformation in DNA.
- The offset of the relationship of the base pairs to the strands gives a major and a minor groove.
- In B-form DNA (most common) the depths of the major and minor grooves are similar to each other.



Base stacking in DNA

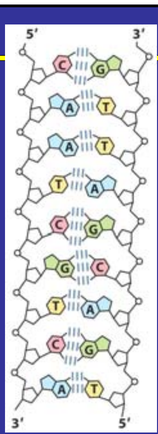


- C-G (red) and A-T (blue) base pairs are isosteric (same shape and size), allowing stacking along a helical axis for any sequence.



•Base pairs stack inside the helix.

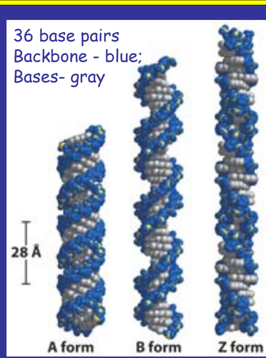
DNA strands



- The antiparallel strands of DNA are not identical, but are complementary.
- This means that they are positioned to align complementary base pairs: C with G, and A with T.
- So you can predict the sequence of one strand given the sequence of its complement.
- Useful for information storage *and* transfer!
- Note sequence conventionally is given from the 5' to 3' end

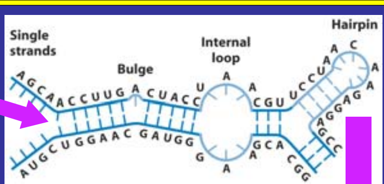
Nucleic acids

- B form - The most common conformation for DNA.
- A form - common for RNA because of different sugar pucker. Deeper minor groove, shallow major groove
- A form is favored in conditions of low water.
- Z form - narrow, deep minor groove. Major groove hardly existent. Can form for some DNA sequences; requires alternating syn and anti base configurations.



RNA has a rich and varied structure

Watson-Crick base pairs (helical segments; Usually A-form). Helix is secondary structure. Note A-U pairs in RNA.

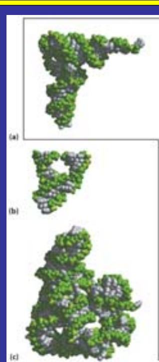


RNA can form structures like this as well.

RNA displays interesting tertiary structure

Single-stranded RNA right-handed helix

Fig. 8-25



Yeast tRNA^{Phe} (1TRA)

Hammerhead ribozyme (1MME)

T. thermophila intron, A ribozyme (RNA enzyme) (1GRZ)

Fig. 8-28

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