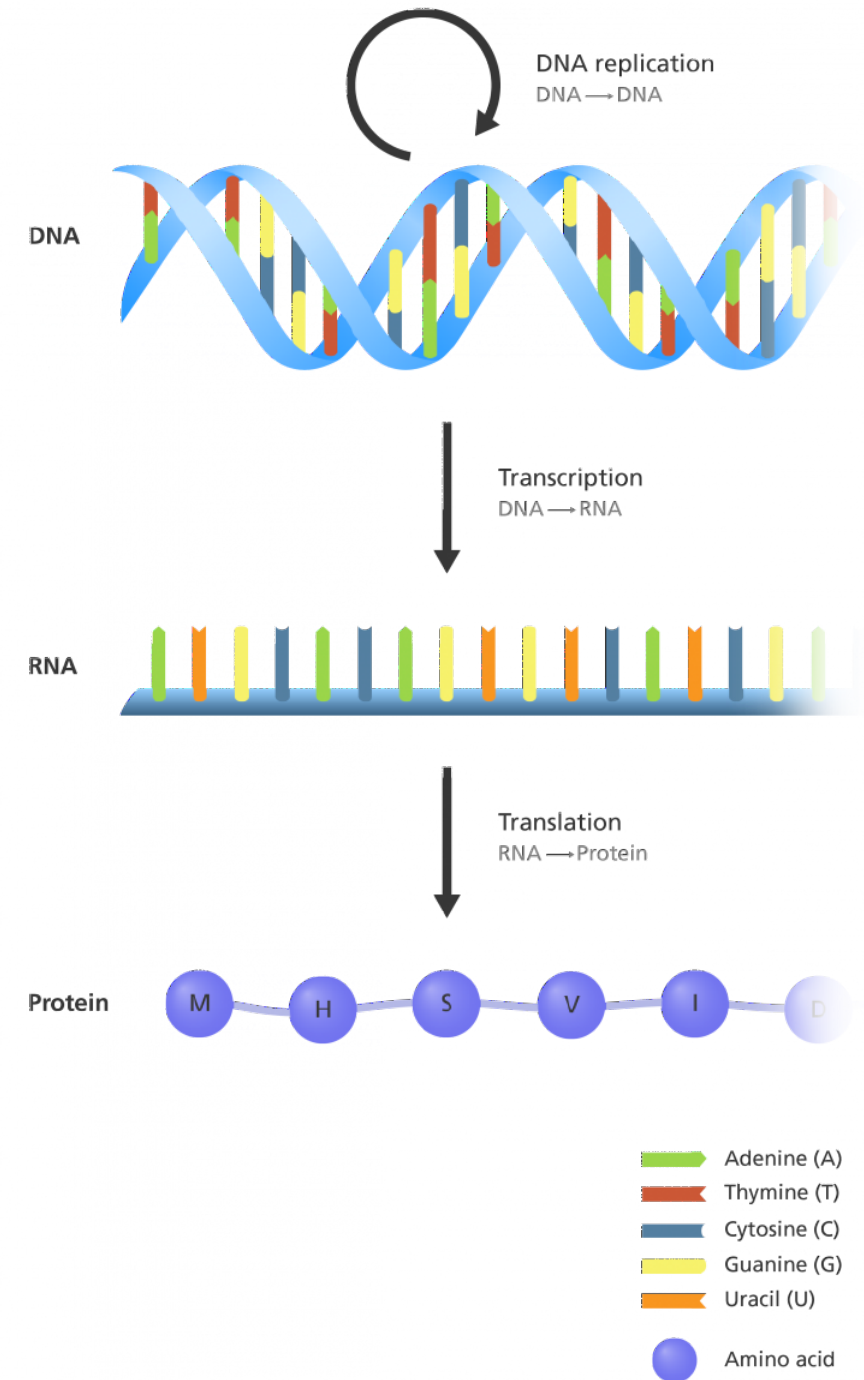


L4: Overview of DNA, RNA and Protein

Central Dogma of Molecular Biology

- Flow of information.
- What an organism can do with the information in DNA ?



Three Key players

❖ DNA

❖ RNA

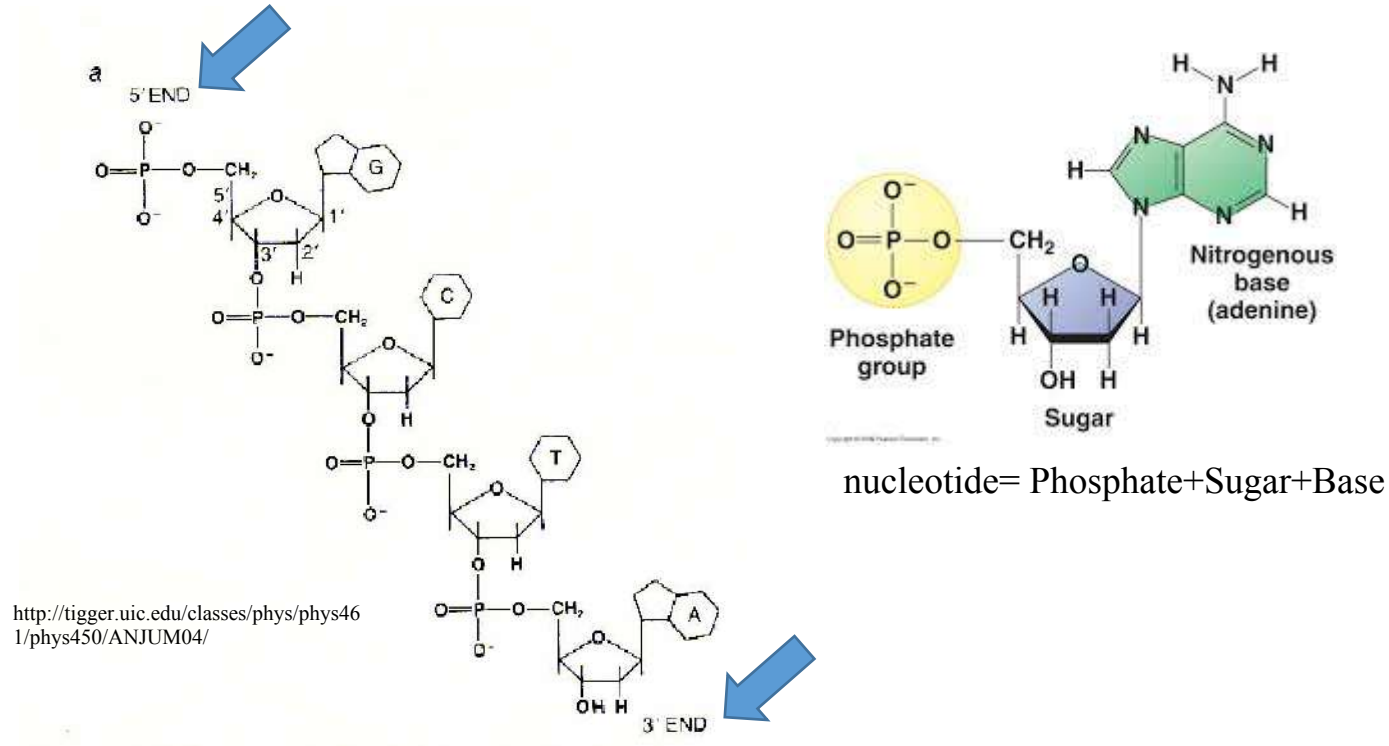
❖ Protein

❖ Quick overview of
the structure of DNA

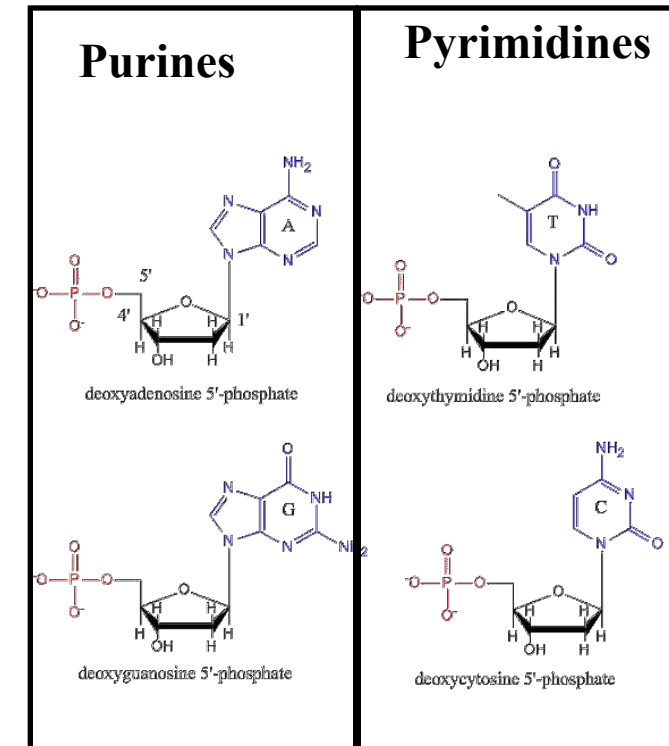
Structure of DNA

DNA (deoxyribonucleic acid)

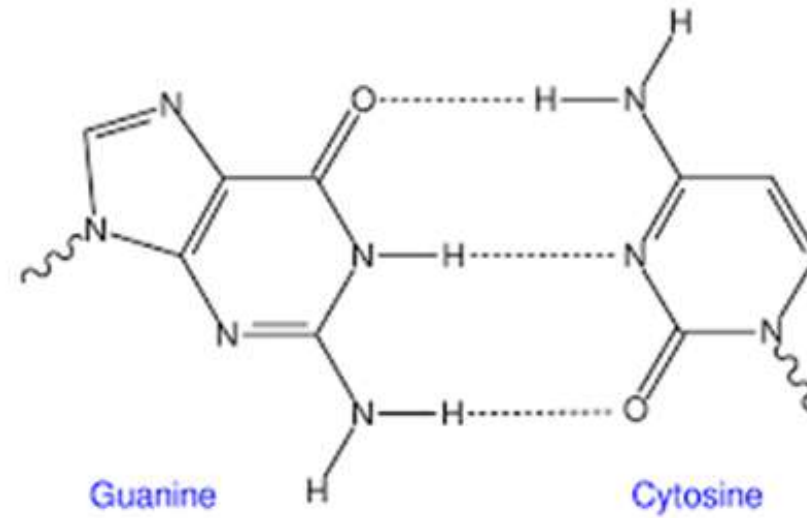
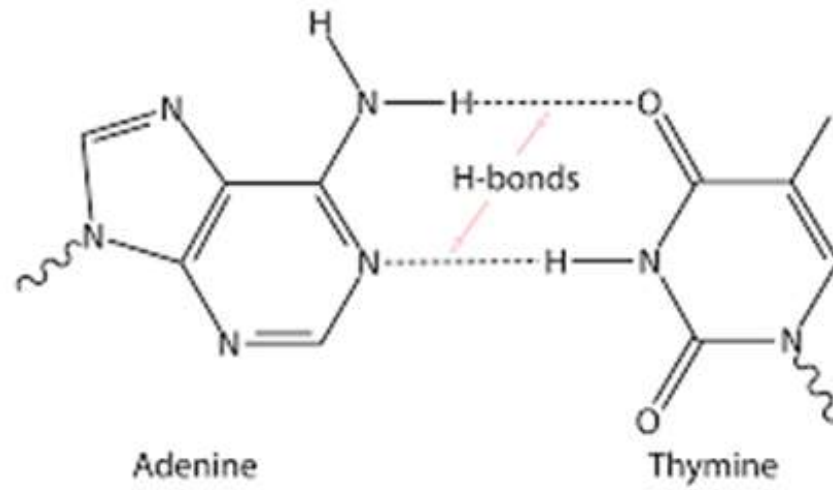
- Usually double stranded (Single stranded viral DNA are also known)
- Each chain is a polymer of subunits called nucleotides (Hence Polynucleotide).

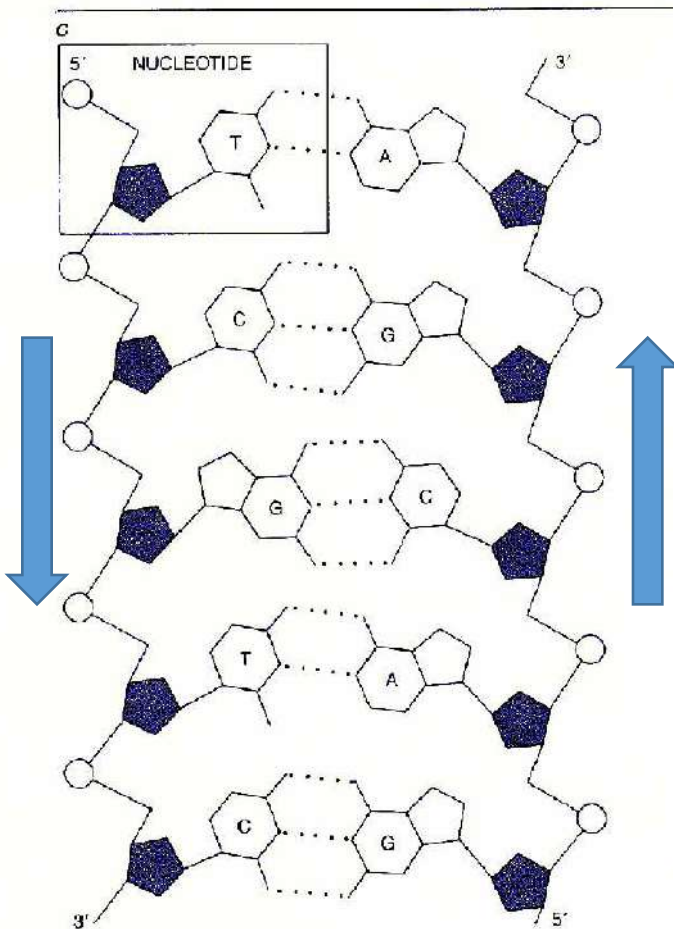


- 4 possible bases (Adenine, Guanine, Cytosine and Thymine)
- Deoxyribose = Missing 2'-OH
- Initial discovery in the nucleus (Nucleic)
- Presence of phosphate group (related to phosphoric acid).



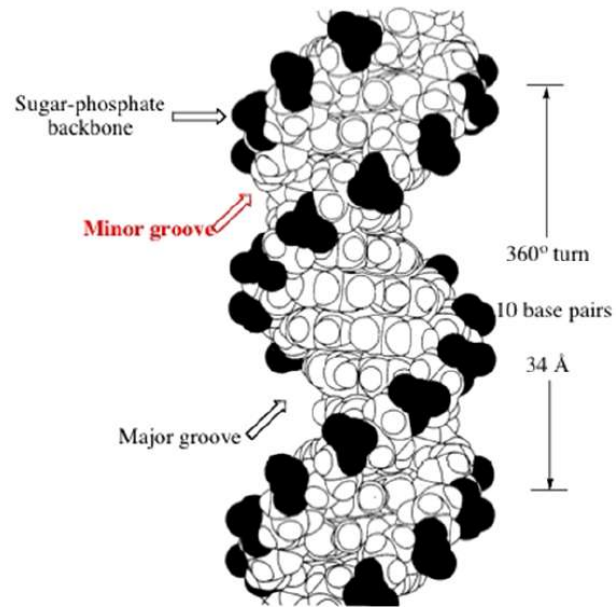
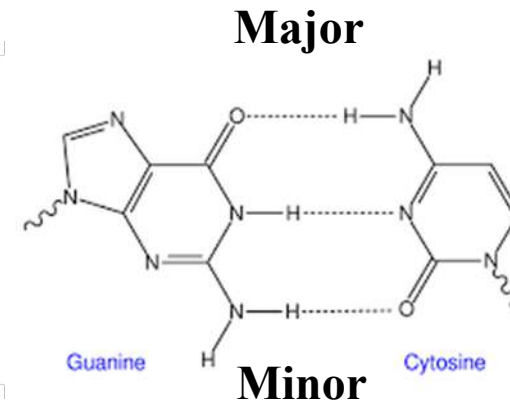
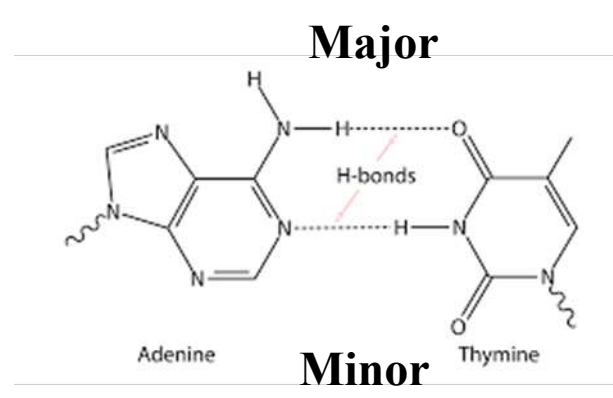
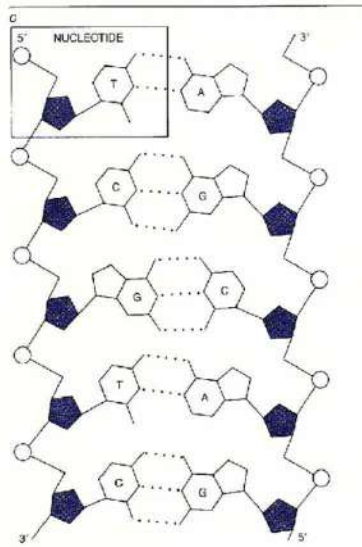
Base pairing in DNA





<http://tigger.uic.edu/classes/phys/phys461/phys450/ANJUM04/>

- **DNA is a double-stranded helix with antiparallel strands [Watson and Crick].**
- **The amounts of $A = T$, $G = C$, and purines = pyrimidines [Chargaff's Rule].**
- **A-T base-pair 2 hydrogen bonds**
- **G-C base-pair has 3 hydrogen bonds.**
- **G-C interaction is therefore stronger than A-T, and A-T rich regions of DNA are more prone to thermal fluctuations.**



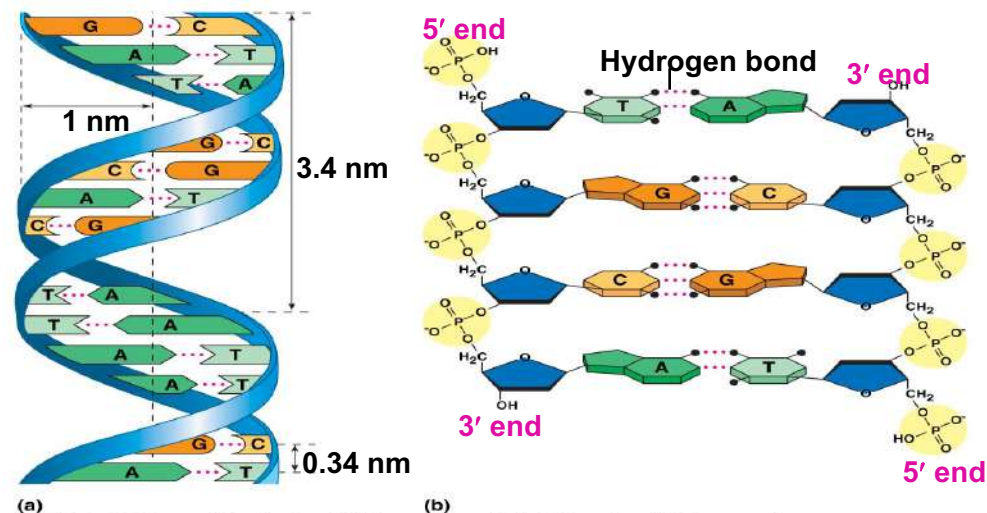
Source: Internet

CONCLUSION:

- Double Helix
- Broad Major groove
- Two chains runs opposite ($5' \rightarrow 3'$ and $3' \rightarrow 5'$)

Factors stabilizing the helix

- ❖ H- bonding between the bases
- ❖ Hydrophobicity. Bases are perpendicular to helix axis. **HYDROPHOBIC** in the direction perpendicular to the plane of the base.
- ❖ Stacking (Electrostatic, Vander Waals forces). **DISPLACED PARALLEL**.
- ❖ Tetrahedral phosphate
- ❖ Changed backbone (strong repulsions between two strands are stabilized by counter ions) essential for double helical structure.



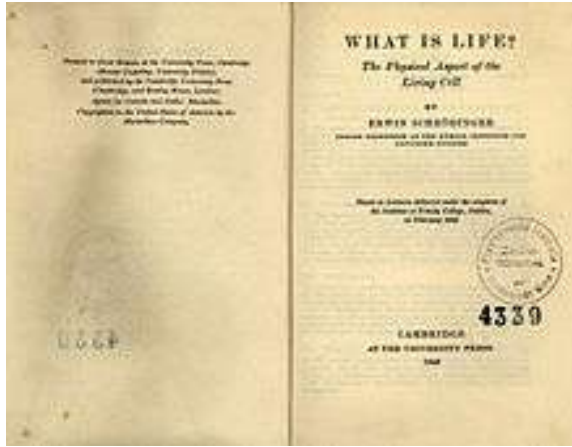
Stacking is very important ?

Even in single stranded DNA, bases prefer to be stacked. Single stranded chain can also have regions of helical conformations.

Handedness of helix?



Impact of DNA structure in biology :



Source: Wiki

“...living matter, while not eluding the "laws of physics" as established up to date, is likely to involve "**other laws of physics**" hitherto unknown, which however, once they have been revealed, will form just as integral a part of science as the former.” – **Schrödinger**

Watson, J.D. and F.H. Crick, “Molecular Structure of Nucleic Acids: A Structure for Deoxynucleic Acids”. *Nature* 171 (1953), p. 738.

Life could be understood in terms of atoms...

How the information stored could be copied ...

How the DNA is packaged ?

<http://www.sciencephoto.com/media/209697/view>



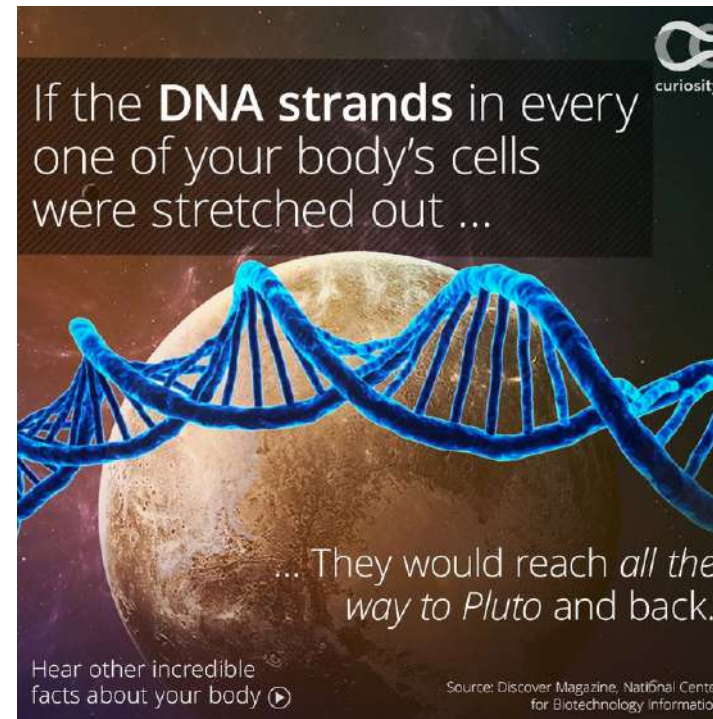
Coloured TEM of DNA from E. coli bacterium

The total length of DNA is 1.5 millimetres, 1000 times the length of the bacterium itself.

How long is DNA if you stretch it out?

Ans: DNA in a single cell ~ **2m** long

Packed in side nucleous ~ **6×10^{-6} m**



Levels of Chromatin Structure

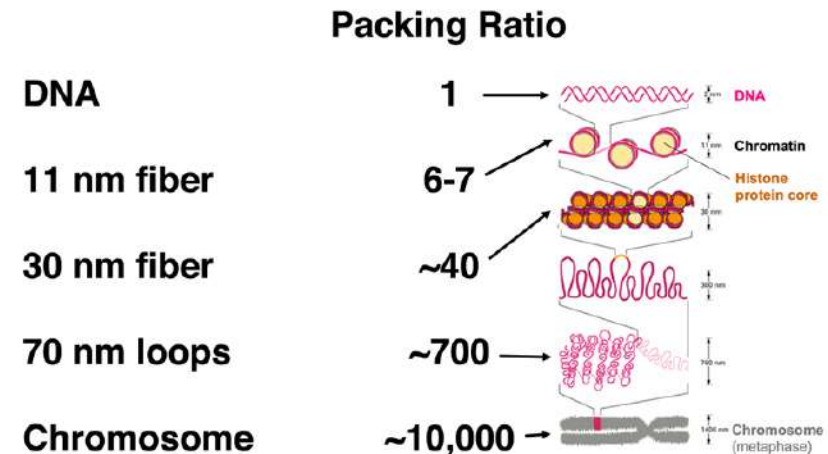


Genetics: A Conceptual Approach, Fourth Edition
© 2012 W.H. Freeman & Company

<https://www.youtube.com/watch?v=prYd9nE0Rks>

**The Best packaging
company is
biological CELL**

Chromatin packing

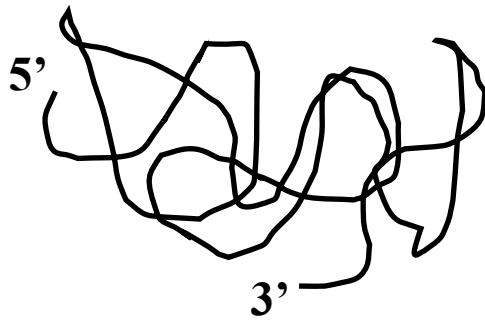


❖ Quick overview of
the structure of RNA

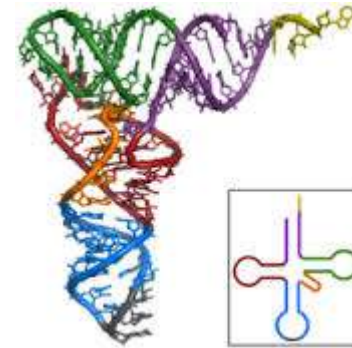
RNA (ribonucleic acid)

Structure

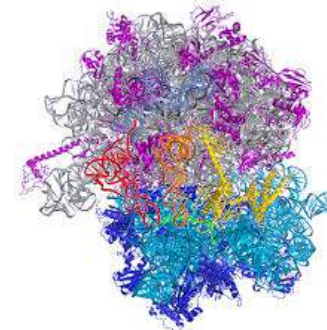
**Unstructured
(e.g, mRNA)**



**Intricate/elabolare structures
(e.g, tRNA, ribosomal RNA,
Ribozymes..)**



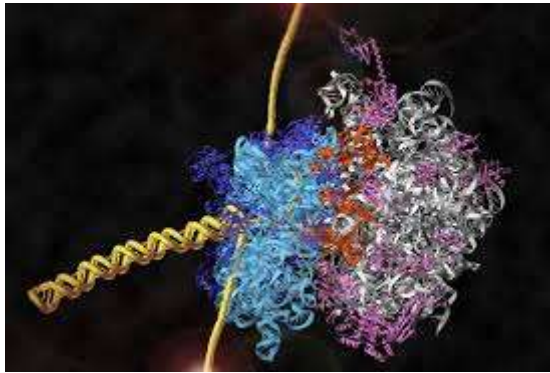
tRNA



Ribosome

RNA : Complex structural architecture.
Involved in all aspect of gene expression.

Few examples:



Ribosome: Protein
Synthesis Machinery

<http://www.wired.com/2009/10/ribosomes/>



tRNA:
Transport aminoacids

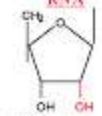
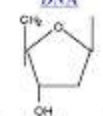
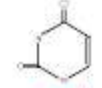
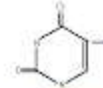


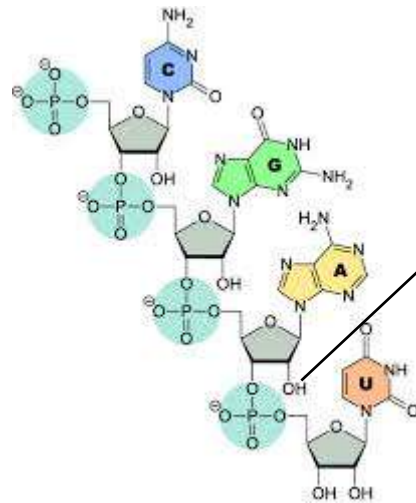
Group II intron:
self splicing

Science, 2008, 320, 77-82

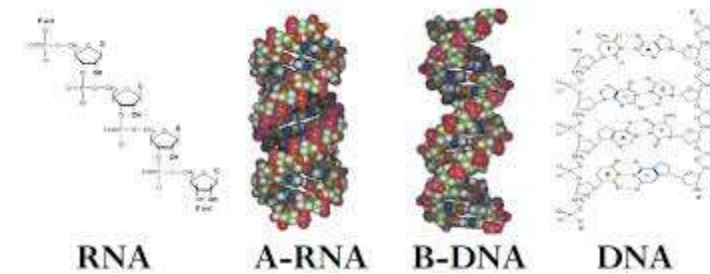
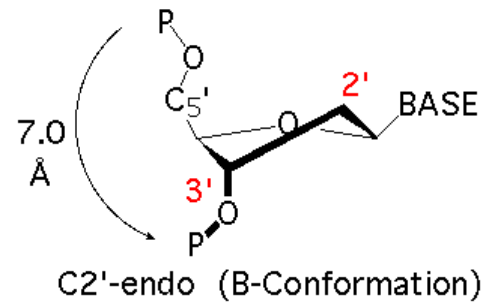
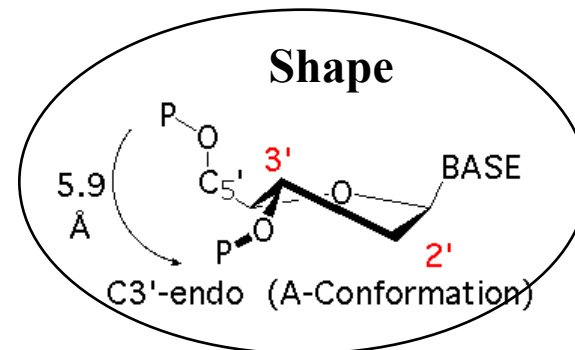
- single-stranded
- Ribose sugar
- Thymine in DNA is replaced by Uracil in RNA.

DNA and RNA = Chemical cousins

Differences between RNA and DNA		
	RNA	DNA
1) ribose sugar	 (ribonucleic acid)	 (deoxy ribonucleic acid)
2) T and U	 uracil	 thymine
3) strand	single	double



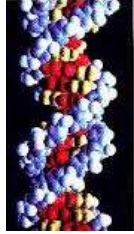
Donate and accept h-bond
“Sticky”



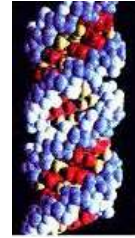
RNA duplex
Squashed
and compact

Compare DNA vs RNA

DNA=B form



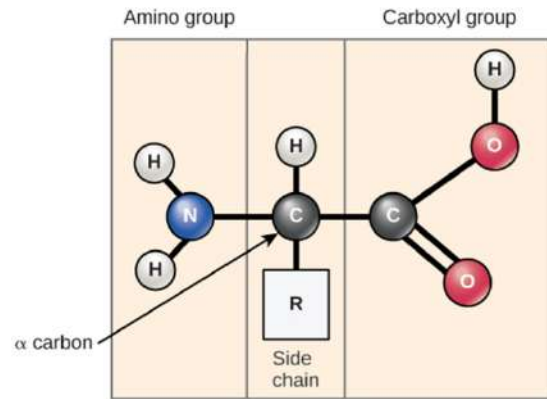
RNA=A form



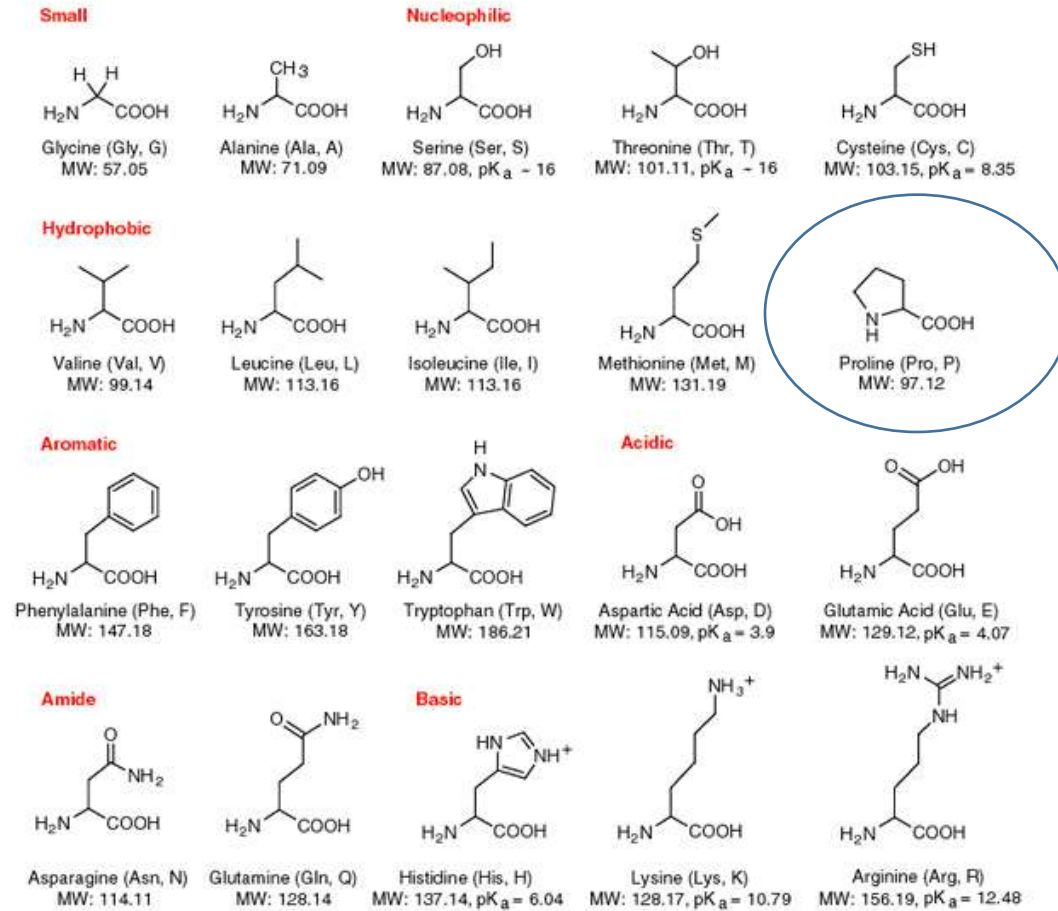
Major Groove	11.7Å(w), 8.5Å(d)	3Å(w), 13Å(d)
Minor Groove	5.7Å(w), 7.5Å(d)	11Å(w), 3Å(d)
Base Pair/turn	10	11
Rise/bp	3.4Å	2.6Å
Sugar Pucker	C2' endo	C3' endo

❖ Quick overview of
the structure of
proteins

Proteins are one or multiple chains of amino acid residues.

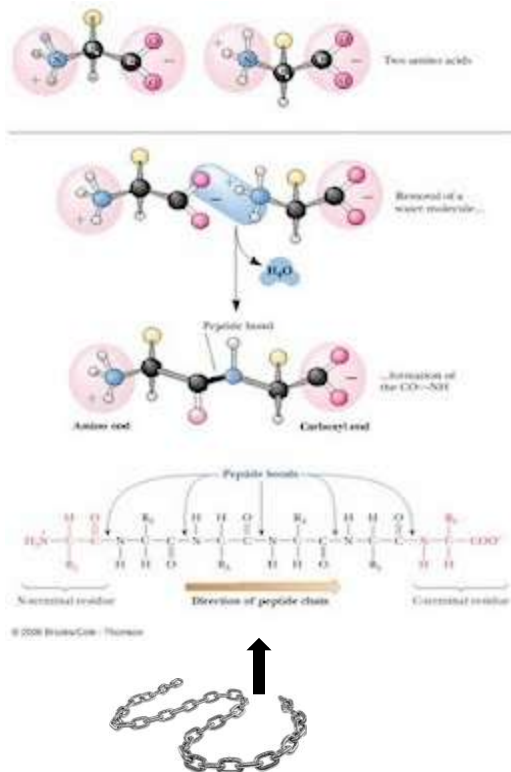


20 amino acid



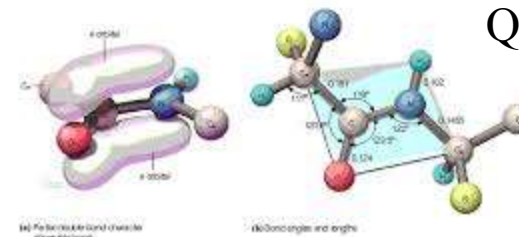
<https://www.neb.com/tools-and-resources/usage-guidelines/amino-acid-structures>

Formation of peptide bond

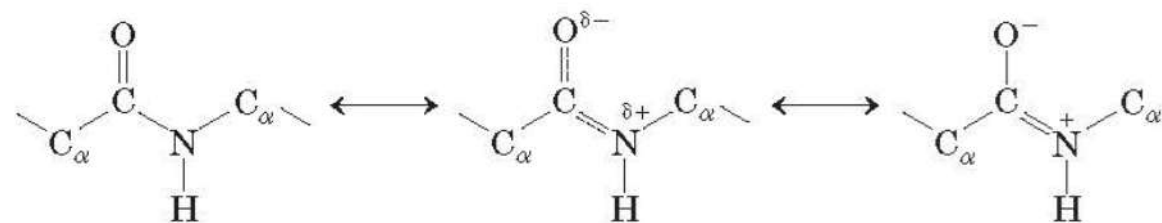


Nature of peptide bond: Planer

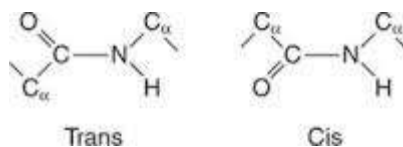
Electronic structure of peptide bond



Quantum mechanical..

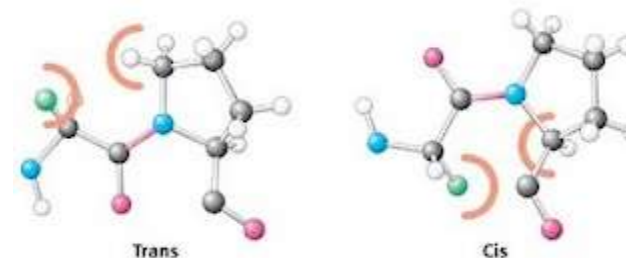


Why peptide is Trans:



CIS: Lot of possibility of R groups to hit into each other in space- **Steric effect**.

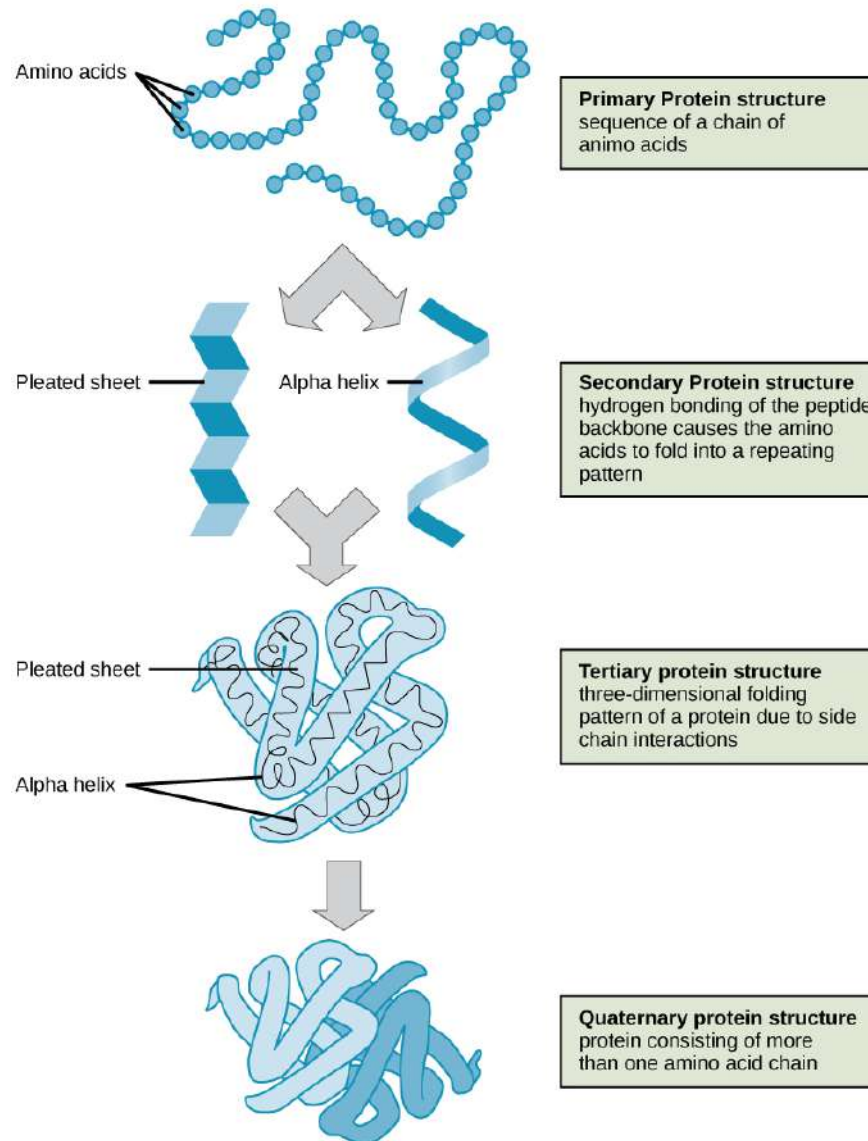
Strongly prefer Trans over Cis



Proline: cyclic nature of the side chain.

Mordatrely prefer Trans over Cis

Protein Structure in Four levels



Secondary structural motif : Alpha-helix, Beta sheet etc.

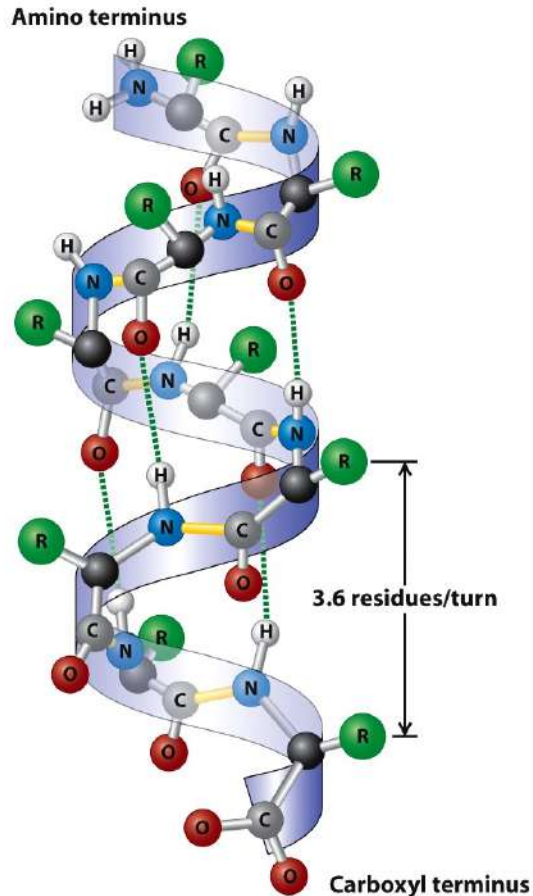


Figure 3-4
Molecular Cell Biology, Sixth Edition
© 2008 W.H. Freeman and Company

Alpha-helix

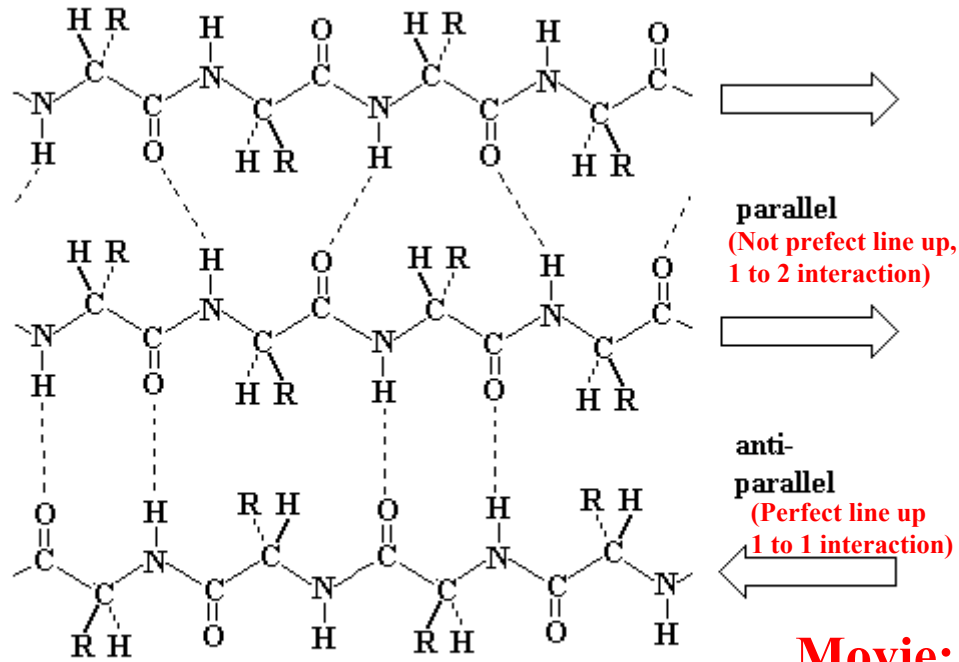
- Very stable linear arrangement of atoms involved in H bonding.
- C-O of each amino acid is H-bonded to the N-H group of the amino acid 4 residues away (see picture).
- 3.6 residues for each turn
- H bonds are parallel to helix axis.
- R groups are pointed outward

α -helix disruptions

- proline: creates bend in backbone (NO N-C α rotation, NO H bonding from α -NH group).
- electrostatic repulsion from closeness of multiple charged group of same sign
- steric repulsion of bulky side chains(i.e., I,V,T)

Movie : <https://www.youtube.com/watch?v=eUS6CEn4GSA>

Beta sheet

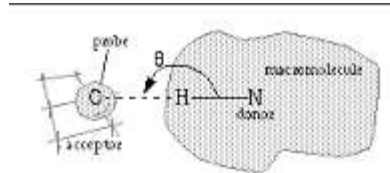


mixture-beta sheet

- Repeated zig-zag structure of H bonds.
- H bonds are perpendicular to direction of chain (not parallel, as in α -helix).
- Inter chain and intra chain β -pleated sheet
- Parallel, antiparallel

Movie: <https://www.youtube.com/watch?v=wM2LWCTWlrE>

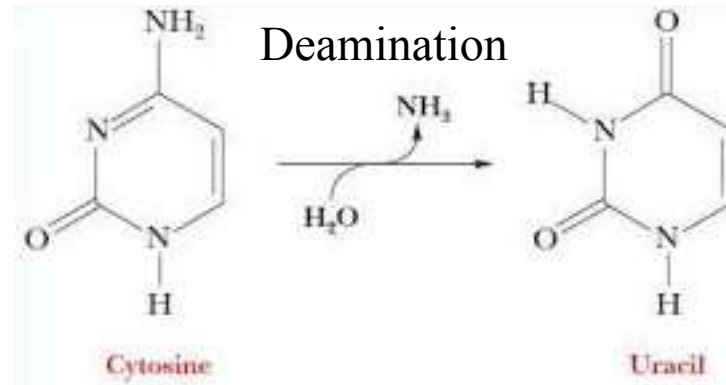
Which one do you think is more stable ?



Interesting question ?

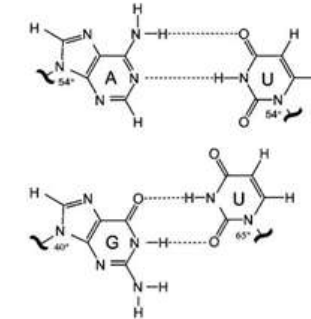
- Why DNA use Thymine instead of Uracil ?

Answer: Error correction



Deeper question ?

- Why RNA happily tolerate mismatches (e.g, G-U) , not in DNA (~~G-T~~) ?



PUZZLE...

Why DNA is right handed ?