Lec. 3+4

DNA Backbone + Ribonucleic Acid RNA

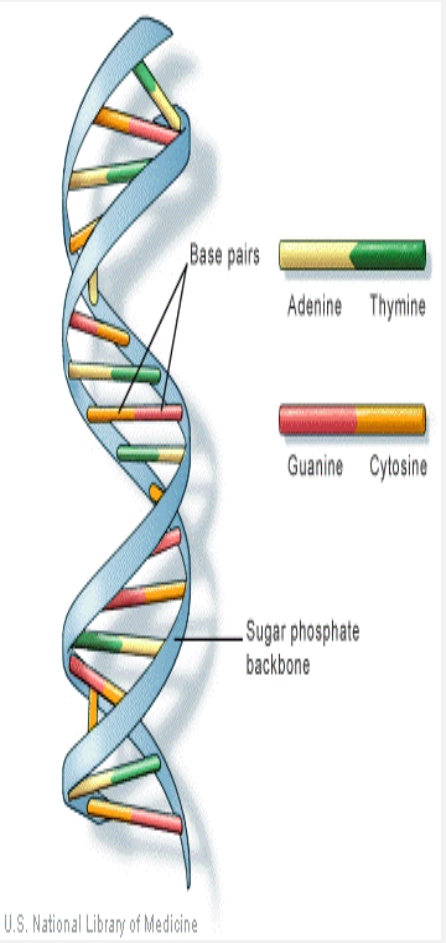
Lecture questions

- What is the DNA backbone ?
- What is the double helix and hydrogen bonding
- What is the ribonucleic acid (RNA) ?
- What is the structure of RNA?

DNA Backbone

The **backbone** of the polynucleotide is a chain of **sugar and phosphate molecules**.

Each of the sugar groups in this sugar-phosphate backbone is linked to one of the four nitrogenous bases.



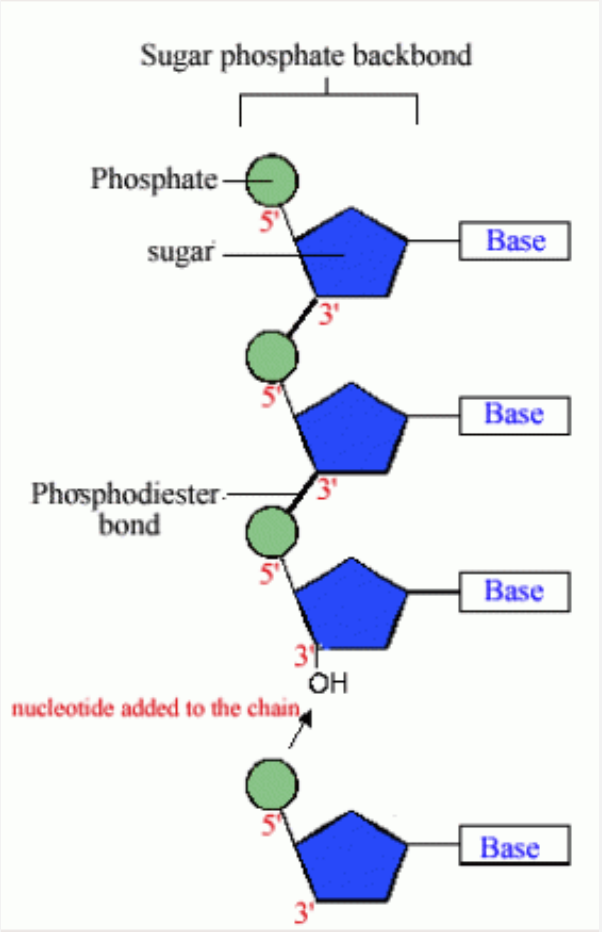
Features of the DNA Backbone

1- Alternating backbone of deoxyribose and phosphodiester groups
2-Chain has a direction (known as polarity), 5'- to 3'- from top to bottom
3-Oxygens of phosphates are polar and negatively charged
4- A, G, C, and T bases can extend away from chain, and stack atop each other
5- Bases are hydrophobic

Polynucleotide formation

Two nucleotides are joined by phosphodiester bond. Between a phosphate group (of a nucleotide) and 3rd C in a pentose (of the other nucleotide).

Nucleotides are linked together by covalent bonds called **phosphodiester linkage**



DNA Double Helix

The ‘backbones’ of DNA molecules are made of alternating sugar and phosphates

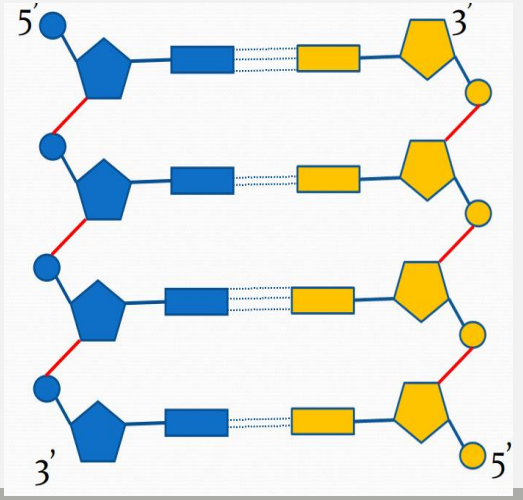
The ‘rungs on the ladder’ are made of bases that are hydrogen bonded to each other

Advantages to Double Helix

- Stability---protects bases from attack by H_2O soluble compounds and H_2O itself.
- Provides easy mechanism for replication

Antiparallel strands:

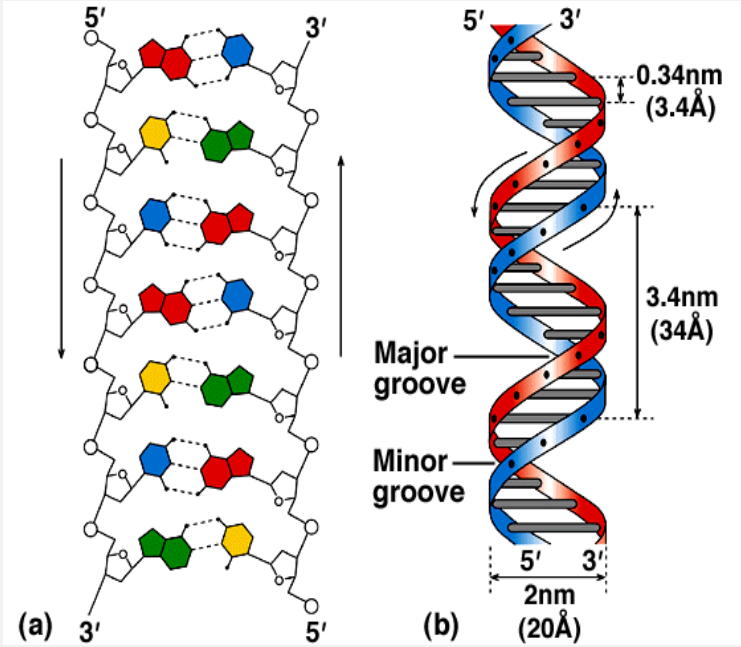
The strands run opposite of each other. The 5’ end always has the phosphate attached.



Physical Structure

Each strand of DNA has a “direction” at one end, the terminal carbon atom in the backbone is the 5’ carbon atom of the terminal sugar at the other end, the terminal carbon atom is the 3’ carbon atom of the terminal sugar therefore we can talk about the 5’ and the 3’ ends of a DNA strand in a double helix, the strands are **antiparallel** (arrows drawn from the 5’ end to the 3’ end go in opposite directions)

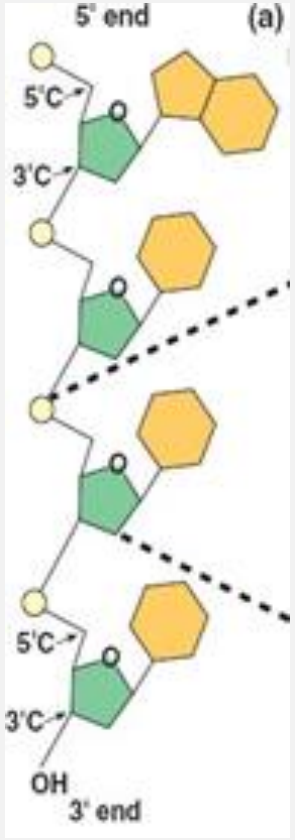
Chains are anti-parallel (i.e in opposite directions).

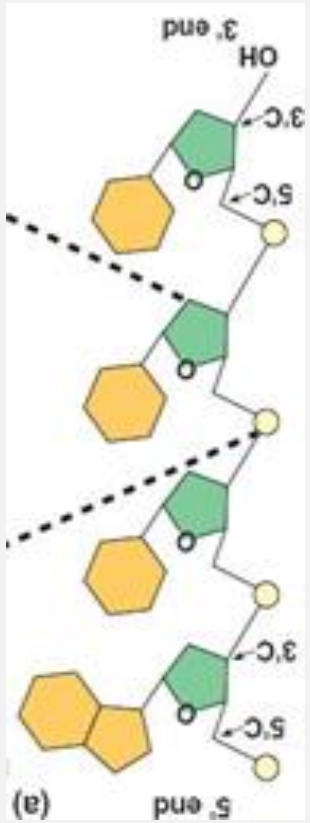


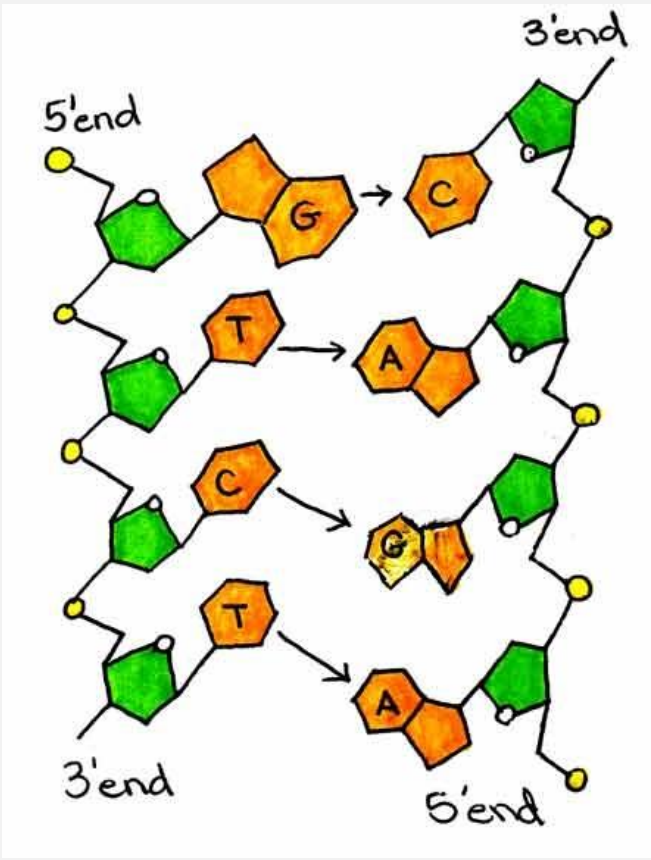
Features of the DNA Double Helix:

-Two DNA strands form a helical spiral, winding around a helix axis in a right-handed spiral
-The two polynucleotide chains run in opposite directions
-The sugar-phosphate backbones of the two DNA strands wind around the helix axis like the railing of a spiral staircase
- The bases of the individual nucleotides are on the inside of the helix, stacked on top of each other like the steps of a spiral staircase.
The double helix makes a complete turn in just over 10 nucleotide pairs, so each turn takes a little more) 35.7 Å to be exact) than the 34 Å shown in the diagram .
•There is an average of 25 hydrogen bonds within each complete turn of the double helix providing a stability of binding about as strong as what a covalent bond would provide .

Antiparallel strands







Forms of DNA

- The **A-DNA** conformation (left) is favored when DNA is dehydrated.
- **B-DNA** (center) is the conformation normally found inside cells.
- the **Z-DNA** conformation (right) is favored in certain GC-rich sequences.

Summary of Nucleic Acids Structure

https://www.youtube.com/watch?v=apaP9a079po

https://www.youtube.com/watch?v=C1CRrtkWwu0

What is the Ribonucleic acid (RNA)?

- With the discovery of the molecular structure of the DNA double helix in 1953, researchers turned to the structure of ribonucleic acid (RNA).
- **Ribonucleic acid**, or RNA is a type of molecule that consists of a long chain of nucleotide units.
- RNA is transcribed from DNA by enzymes called RNA polymerases.
- RNA is very similar to DNA, but differs in a few important structural details.
- RNA is central to the synthesis of proteins.
- There are many type of RNAs involved in the protein synthesis.

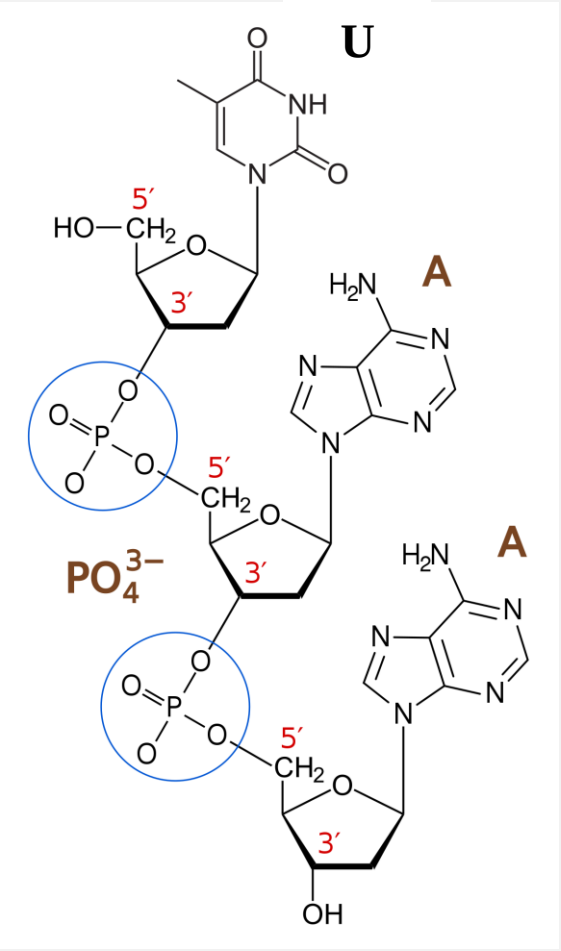
RNA Structure

❖Each nucleotide in RNA contains **ribose sugar**, **nitrogen bases** and **phosphate group**.

❖A ribose sugar (the pentose sugar), with carbons numbered 1' through 5'.

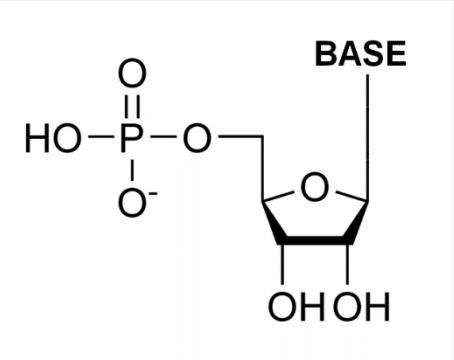
❖A base is attached to the 1' position, in general, **adenine (A), cytosine (C), guanine(G), and uracil (U).**

❖It has usually single strand, but some viruses have double stranded RNA.

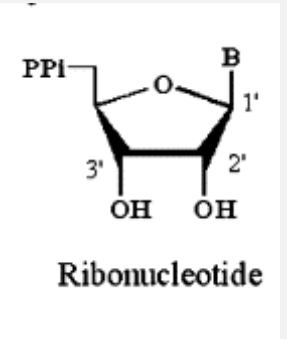


RNA is a polymer of ribonucleotides linked together by 3'-5' phosphodiester linkage.

RNA Structure



1. Like DNA, RNA is a long polymer consisting of nucleotides.
2. RNA is a single-stranded helix.
3. The sugar in RNA is **ribose** rather than **deoxyribose** as in DNA.
4. It is composed of ribonucleotides.
5. The strand has a 5′end (with a phosphate group) and a 3′end (with a hydroxyl group).
6. The ribonucleotides are linked together by 3′ –> 5′ phosphodiester bonds.
7. The nitrogenous bases that compose the ribonucleotides include adenine, cytosine, uracil, and guanine. Thus, thymine in DNA is replaced by uracil in RNA.

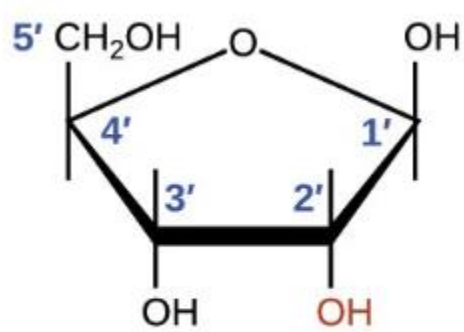


Ribonucleotide

Chemical Structure of RNA

1- Ribose sugar

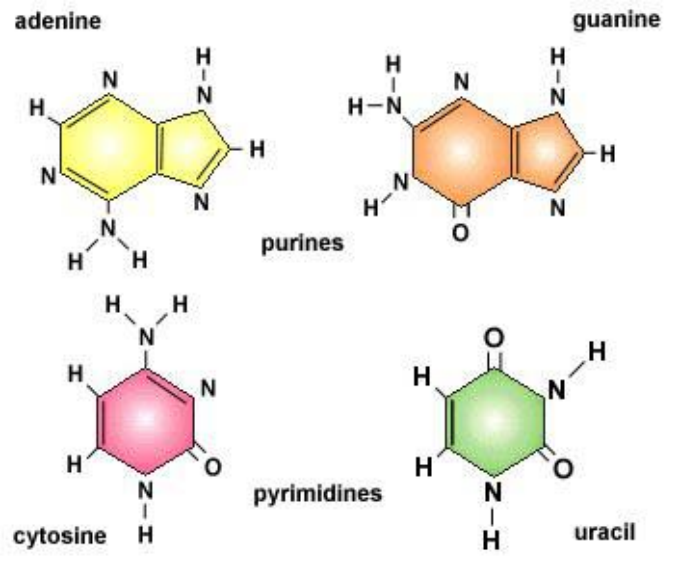
- It is a "normal" sugar, with one oxygen atom attached to each carbon atom.
- An important structural feature of RNA that distinguishes it from DNA is the presence of a hydroxyl group at the 2 'position of the ribose sugar.
- The presence of the 2'-hydroxyl group is that in conformationally flexible regions of an RNA molecule (that is, not involved in formation of a double helix).



ribose (in RNA)

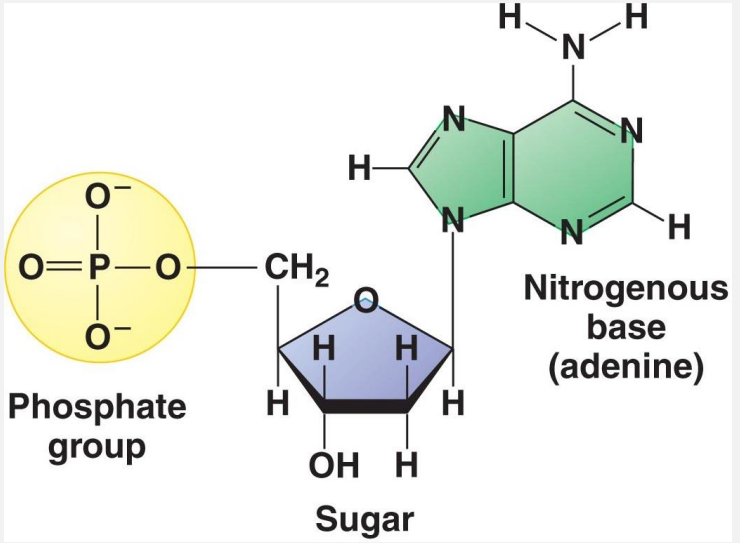
2- Nitrogenous base:

Ribonucleic acid (RNA) is composed of four types of bases: adenine (A), cytosine (C), guanine (G), and uracil (U).



3-Phosphate group:

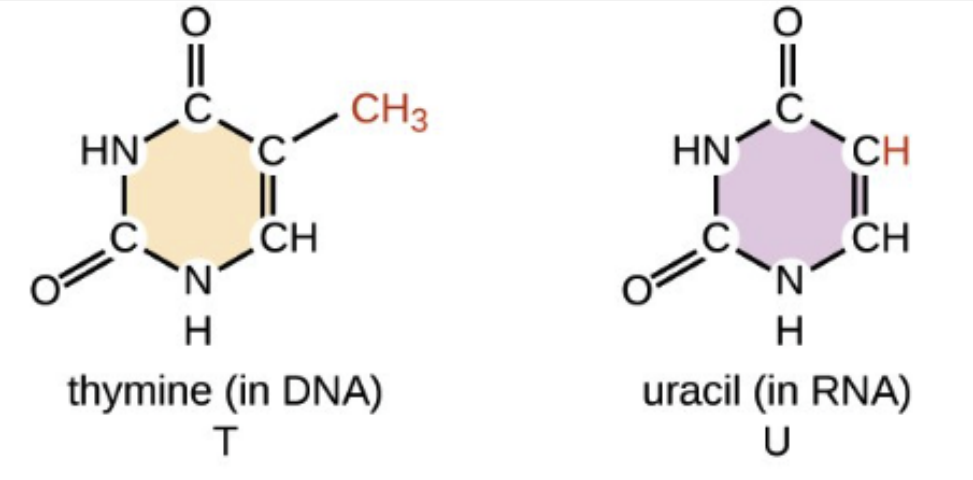
A phosphate group is attached to the 3' position of one ribose and the 5' position of the next. The phosphate groups have a negative charge each, making RNA a charged molecule (polyanion).



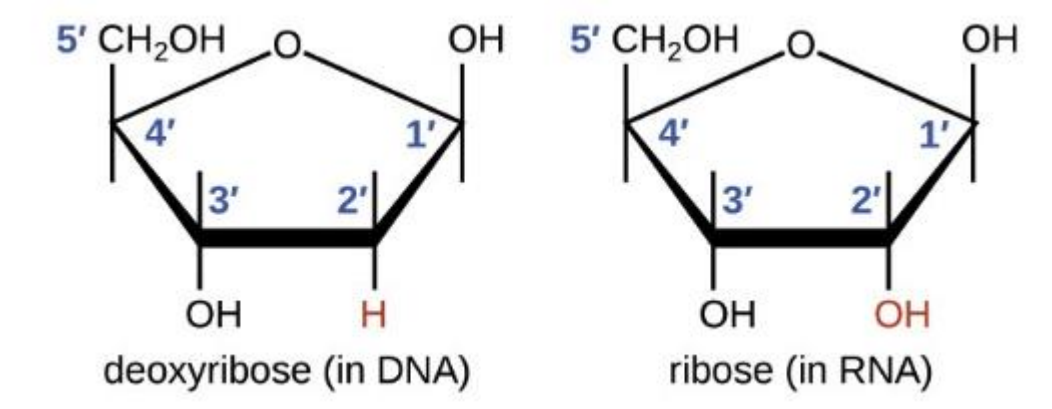
There are several important differences between RNA and DNA:

RNA is much more abundant than **DNA**

1. the pentose sugar in RNA is ribose, in DNA it's deoxyribose
2. in RNA, uracil replaces the base thymine (U pairs with A)
3. RNA is single stranded while DNA is double stranded
4. RNA molecules are much smaller than DNA molecules



RNA contains the pyrimidine uracil in place of thymine found in DNA.

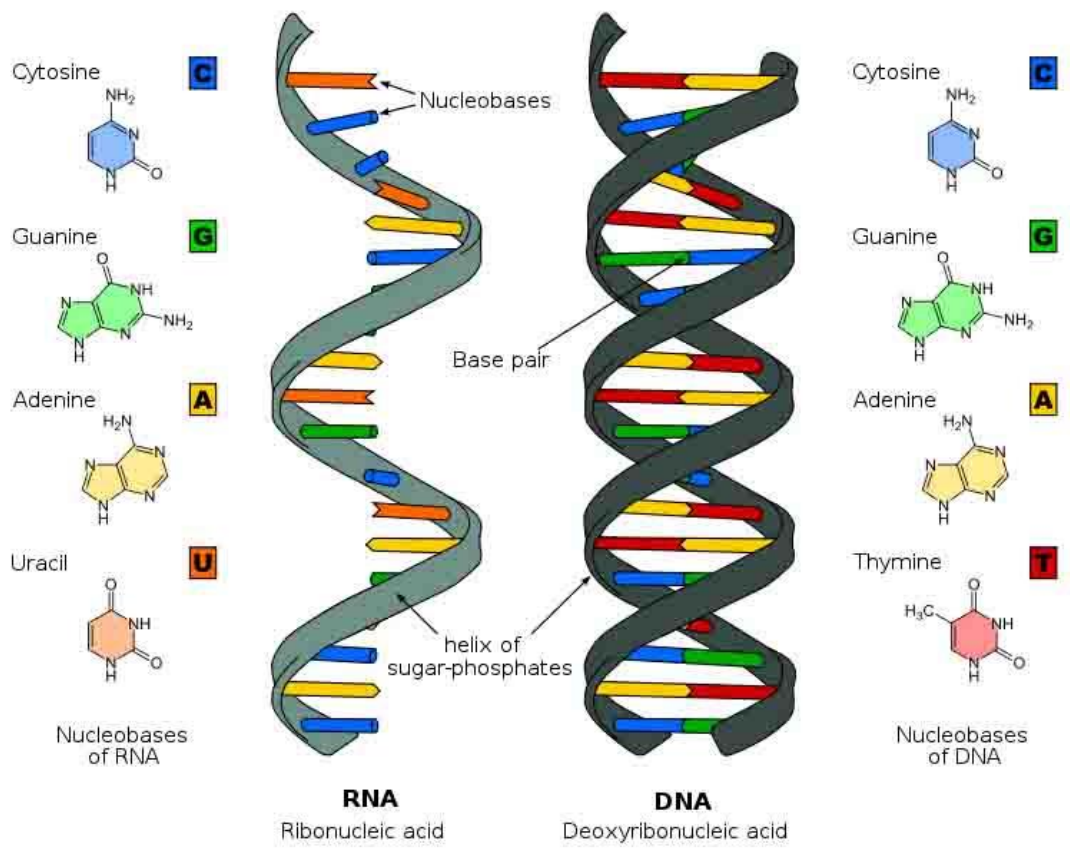


Ribonucleotides contain the pentose sugar ribose instead of the deoxyribose found in deoxyribonucleotides which is a modified sugar, lacking one oxygen atom (hence the name "deoxy").

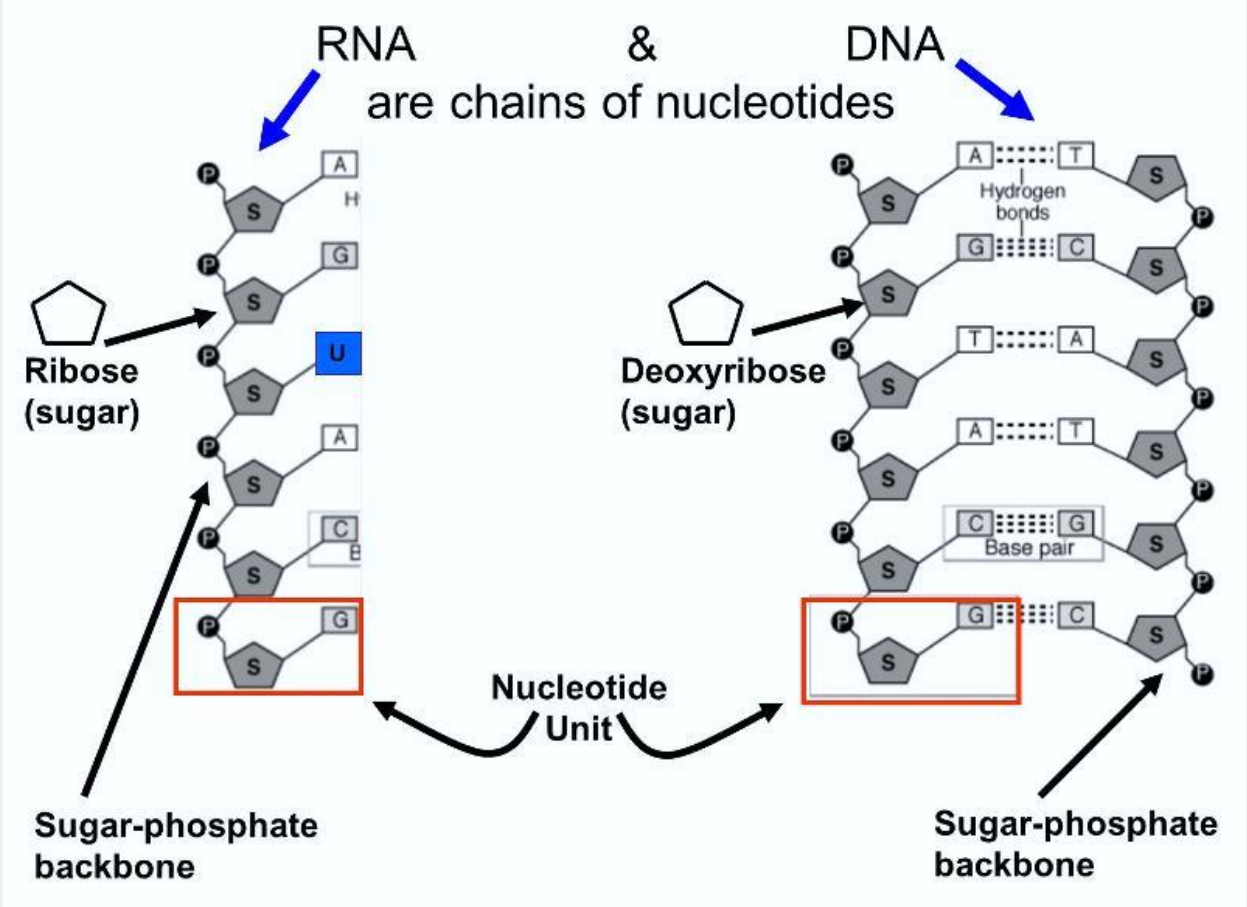
This difference of one oxygen atom is important for the enzymes that recognize DNA and RNA, because it allows these two molecules to be easily distinguished inside organisms.

Comparison	DNA	RNA
Name	DeoxyriboNucleic Acid	RiboNucleic Acid
Function	Long-term storage of genetic information; transmission of genetic information to make other cells and new organisms.	Used to transfer the genetic code from the nucleus to the ribosomes to make proteins. RNA is used to transmit genetic information in some organisms and may have been the molecule used to store genetic blueprints in primitive organisms.
Structural Features	molecule consisting helix DNA is a double-stranded of a long chain of nucleotides.	RNA usually is a single-strand helix consisting of shorter chains of nucleotides.
Composition of Bases and Sugars	deoxyribose sugar phosphate backbone adenine, guanine, cytosine, thymine bases	ribose sugar phosphate backbone adenine, guanine, cytosine, uracil bases
Propagation	DNA is self-replicating.	RNA is synthesized from DNA on an as-needed basis.
Base Pairing	AT (adenine-thymine) GC (guanine-cytosine)	AU (adenine-uracil) GC (guanine-cytosine)
Reactivity	The C-H bonds in DNA make it fairly stable, plus the body destroys enzymes that would attack DNA. The small grooves in the helix also serve as protection, providing minimal space for enzymes to attach.	The O-H bond in the ribose of RNA makes the molecule more reactive, compared with DNA. RNA is not stable under alkaline conditions, plus the large grooves in the molecule make it susceptible to enzyme attack. RNA is constantly produced, used, degraded, and recycled.
Ultraviolet Damage	DNA is susceptible to UV damage.	Compared with DNA, RNA is relatively resistant to UV damage.

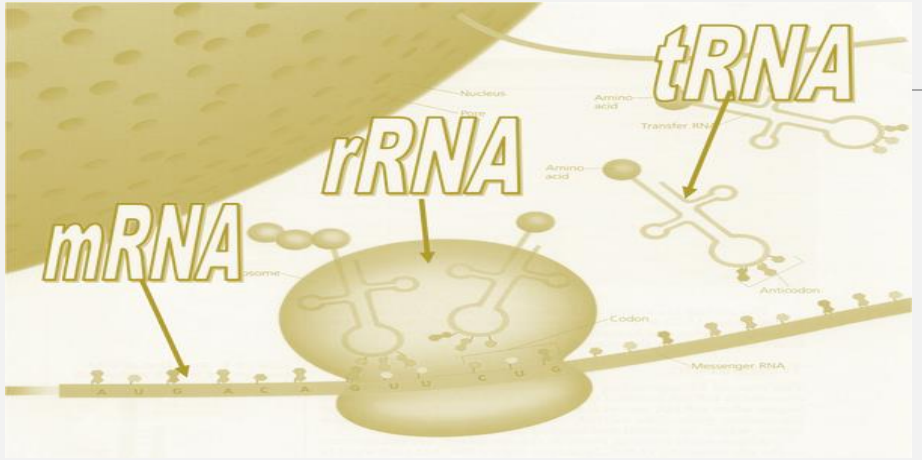
RNA V/S DNA



Differences between DNA and RNA



The Types Of RNA



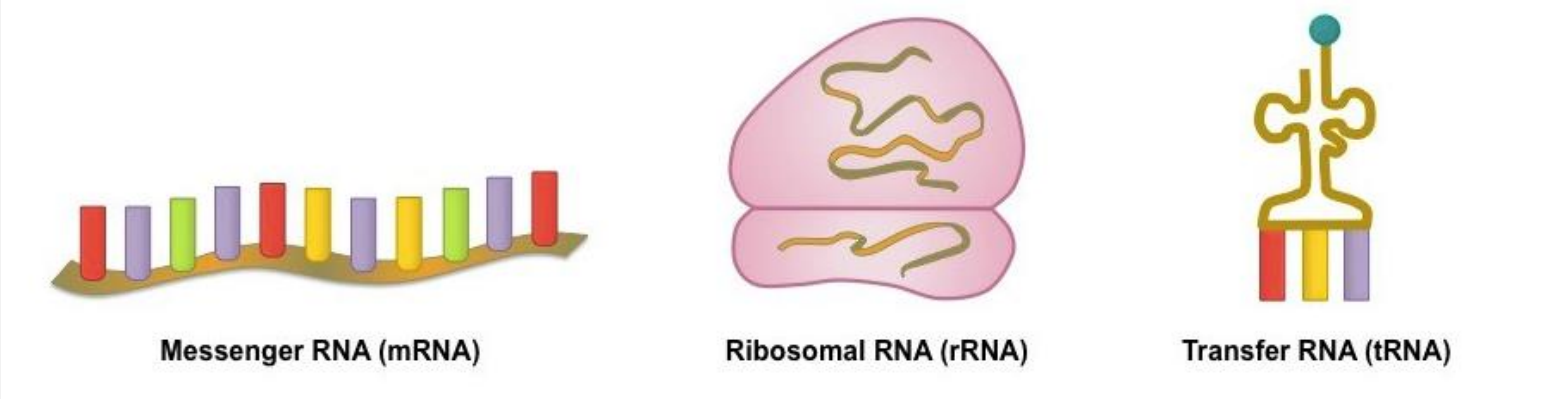
Lecture question?

What are the types of RNA and how do they Structure and function?

Types of RNA

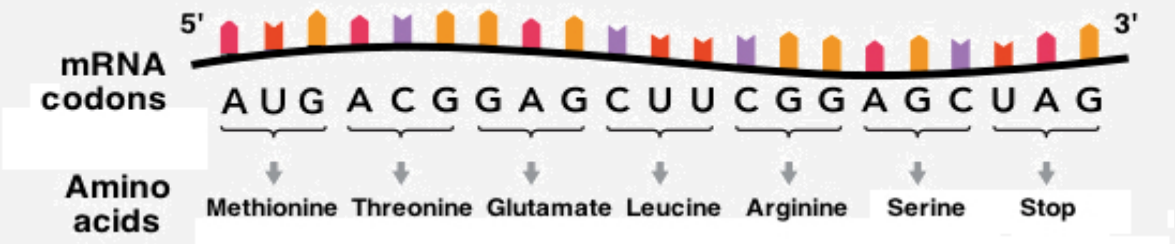
There are three main types of RNA:

- messenger (mRNA)
- ribosomal (rRNA)
- transfer (tRNA)



Messenger RNA (mRNA)

- mRNA - Jacob and Monod (1961) proposed the name.
- It consists of only 3 to 5% of the total RNA in the cell.
- The cell does not contain large quantities of mRNA.
- It is synthesized from DNA template chain by a process called transcription.



Structure and Function of mRNA

-Structure of mRNA

- Messenger RNA is always single stranded.
- The genetic message is in the form of three bases called triplet codons.

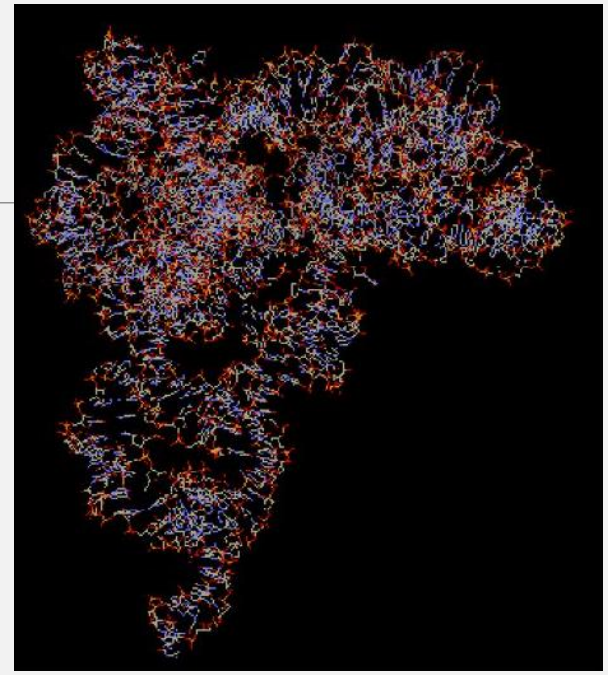
-Function of mRNA

- It carries genetic information required for synthesis of a specific protein from DNA to ribosomes.

Ribosomal RNA (rRNA)

- As the name suggests, is found in the ribosomes.
- It comprises about 80% of the total RNA of the cell.
- The ribosome binds mRNA and carries out protein synthesis.
- It consists of a single strand twisted upon itself in some regions.
- The base sequence of rRNA is complementary to that of the region of DNA where it is synthesized.
- In eukaryotes ribosomes are formed in the nucleolus.

Structure and Function of rRNA



-Structure of Ribosomal RNA

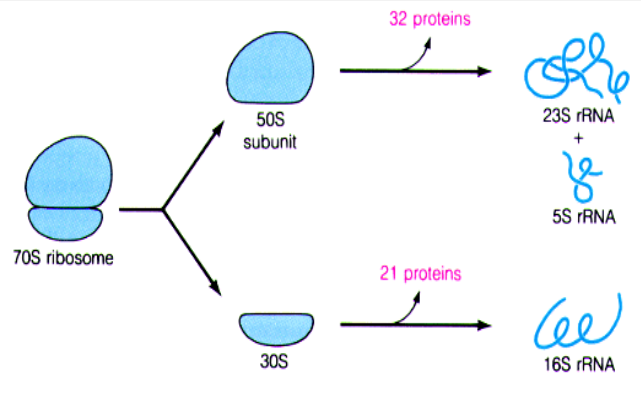
❖In the helical region most of the base pairs are complementary, and are joined by hydrogen bonds.

❖In the unfolded single strand regions the bases have no complements.

❖Ribosomal RNA contains the four major RNA bases with a slight degree of methylation.

- Function of rRNA

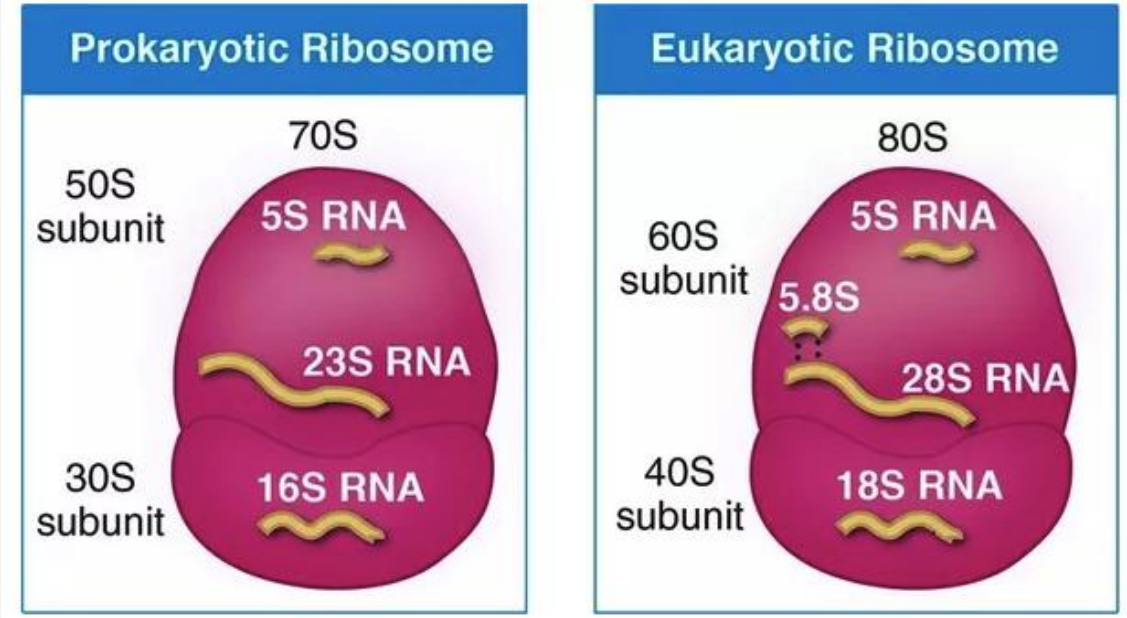
❖These ribosomes are made from proteins and ribosomal RNAs, which come together to form a molecular machine that can read messenger RNAs and translate the information they carry into proteins

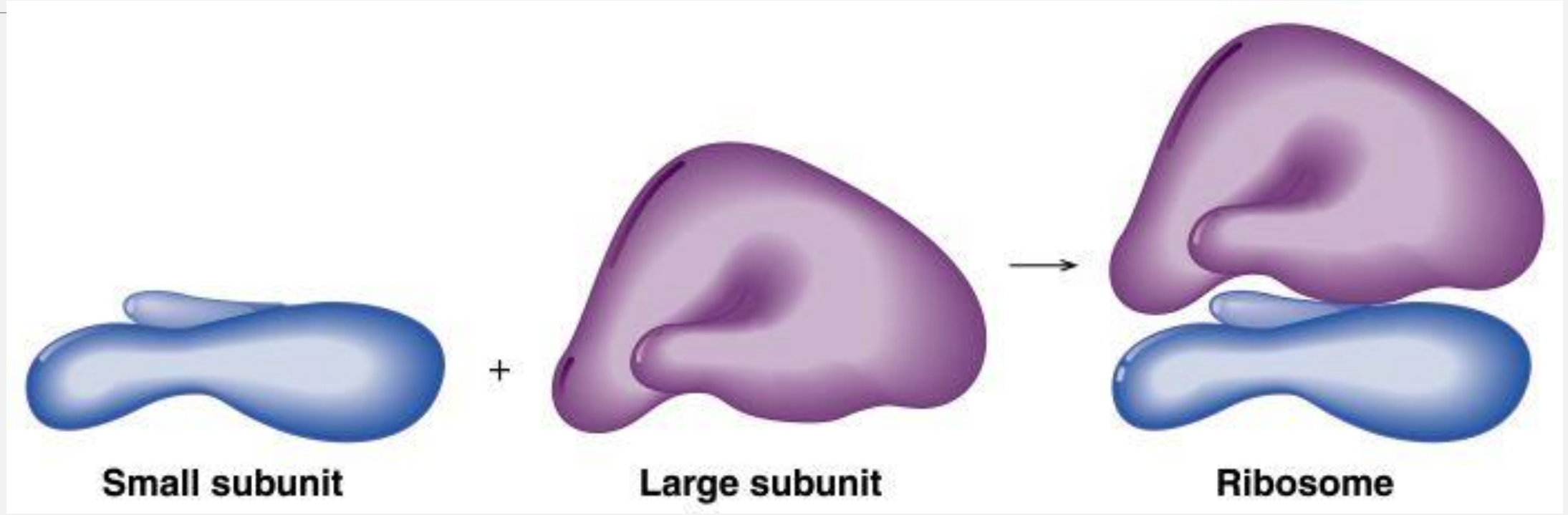


Ribosomes

Ribosomes are organelles present in both prokaryotic and eukaryotic cells. Their main function is to synthesize proteins and coding of genes.

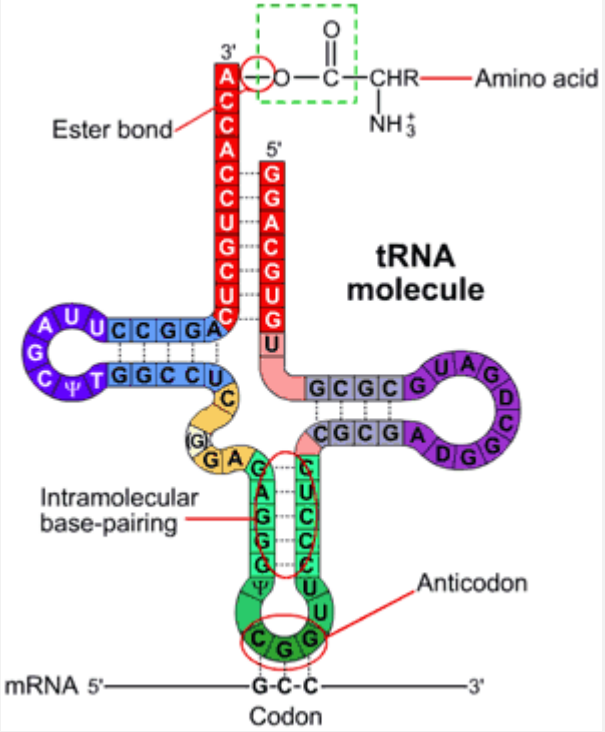
Ribosomes have two sub units. Out of this one is smaller than other one. In prokaryotic cells two subunits are present 50s and 30s separately but when they combine to generate proteins and for coding they form single unit of 70s while in eukaryotic cells 60s and 40s two subunits are present and after combination they form 80s single subunit.




Small subunit
+
Large subunit
Ribosome

Transfer RNA (tRNA)

- It is called as **transfer RNA (tRNA)**
- It is easily soluble , hence called “Soluble RNA or sRNA.
- It constitutes about 15% of total RNA of cells
- It is composed of 80-90 nucleotides.
- It is the smallest of three major species of RNA molecules



Structure and Function of tRNA

-Structure of Transfer RNA – tRNA

❖It is composed of single strand which is folded forming 5 arms, called Clover leaf model

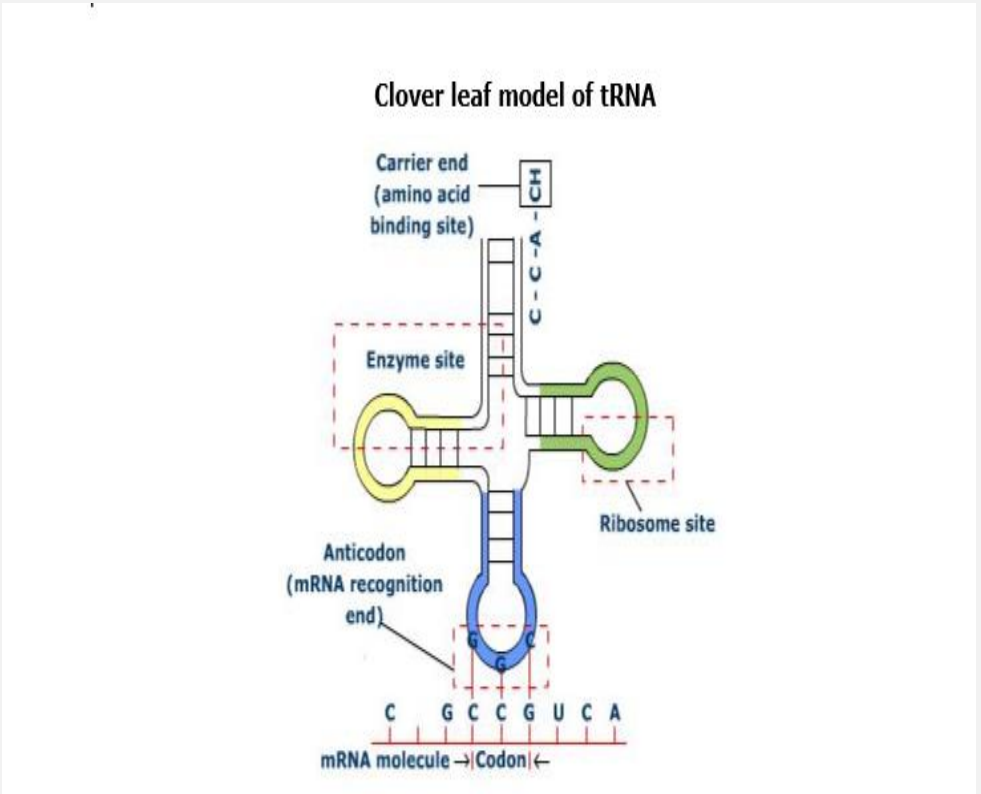
-Function of t-RNA

❖tRNAs transfer the amino acids from cytoplasm to the protein synthesizing machinery, hence the name tRNA.

❖During protein synthesis by ribosomes, tRNAs deliver the correct amino acids through interactions of their anticodon region with the complementary codons on the messenger RNA.

The Cloverleaf Model

Several models of the secondary structure of tRNA have been proposed, and of these the cloverleaf model of Holley is the most widely accepted.



tRNA Structure

The secondary structure of most tRNA is composed of four helical stems arranged in a cloverleaf structure and an central four-way junction.

One end of the tRNA contains an anticodon loop which pairs with a mRNA specifying a certain amino acid.

The other end of the tRNA has the amino acid attached to the 3' OH group via an ester linkage.

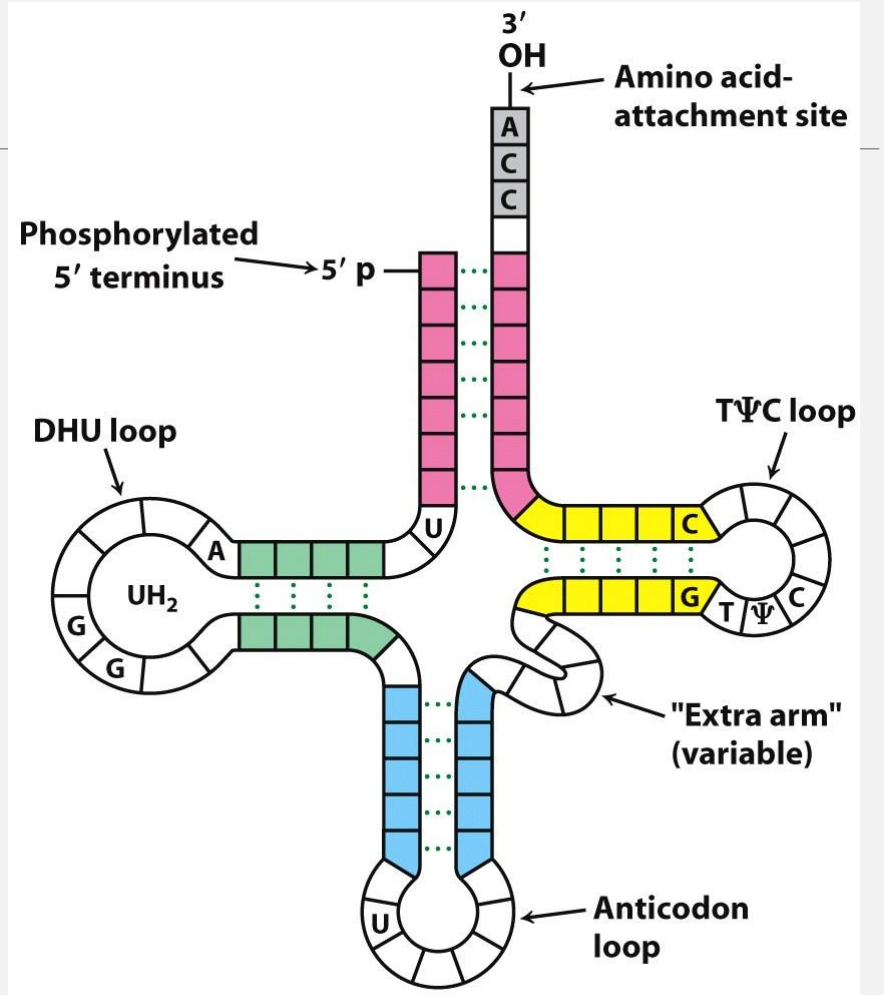
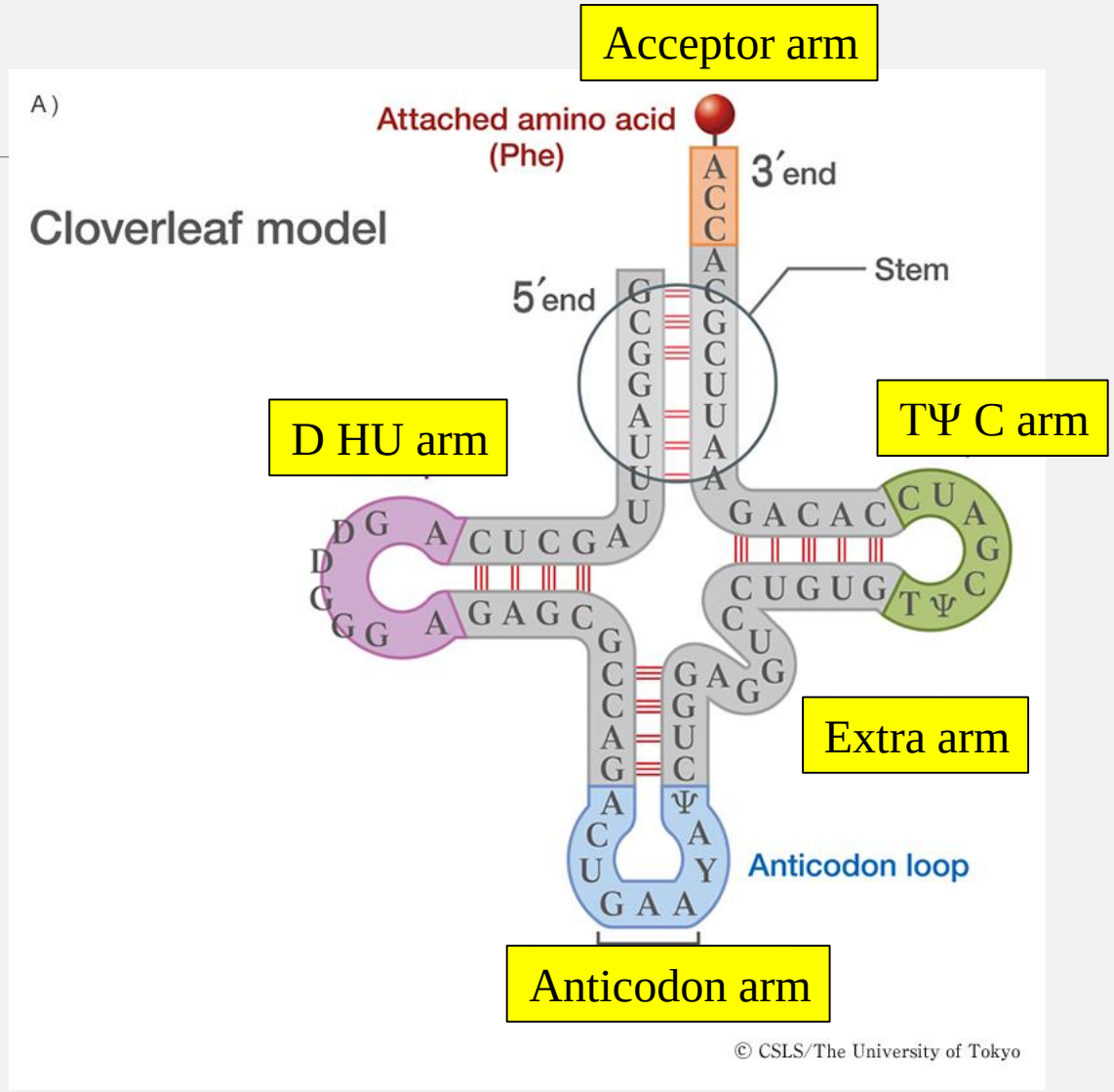


Figure 30.3
***Biochemistry*, Seventh Edition**

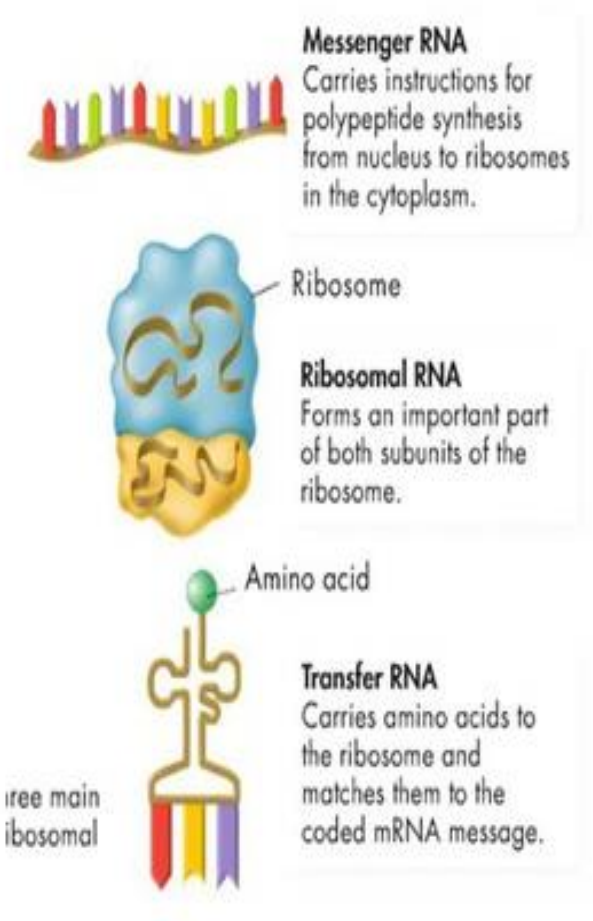
- Secondary structure (Clover leaf structure)
- All t-RNA contain 5 main arms or loops which are as follows-
- Acceptor arm
- Anticodon arm
- D HU arm
- TΨ C arm
- Extra arm



RNA types & functions

Types of RNAs	Primary Function(s)
mRNA - messenger	translation (protein synthesis) regulatory
rRNA - ribosomal	translation (protein synthesis) <catalytic>
t-RNA - transfer	translation (protein synthesis)
hnRNA - heterogeneous nuclear	precursors & intermediates of mature mRNAs & other RNAs
scRNA - small cytoplasmic	signal recognition particle (SRP) tRNA processing <catalytic>
snRNA - small nuclear snoRNA - small nucleolar	mRNA processing, poly A addition <catalytic> rRNA processing/maturation/methylation
regulatory RNAs (siRNA, miRNA, etc.)	regulation of transcription and translation,

- Three different types of RNA:
  - mRNA (messenger) used as template to make proteins
  - rRNA (ribosomal) makes up ribosomes
  - tRNA (transfer) matches amino acids to mRNA to help make proteins



outline