Ministry of Public Health of Ukraine
Poltava State Medical University

Nucleotides,
Nucleic acids

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Lecture plan

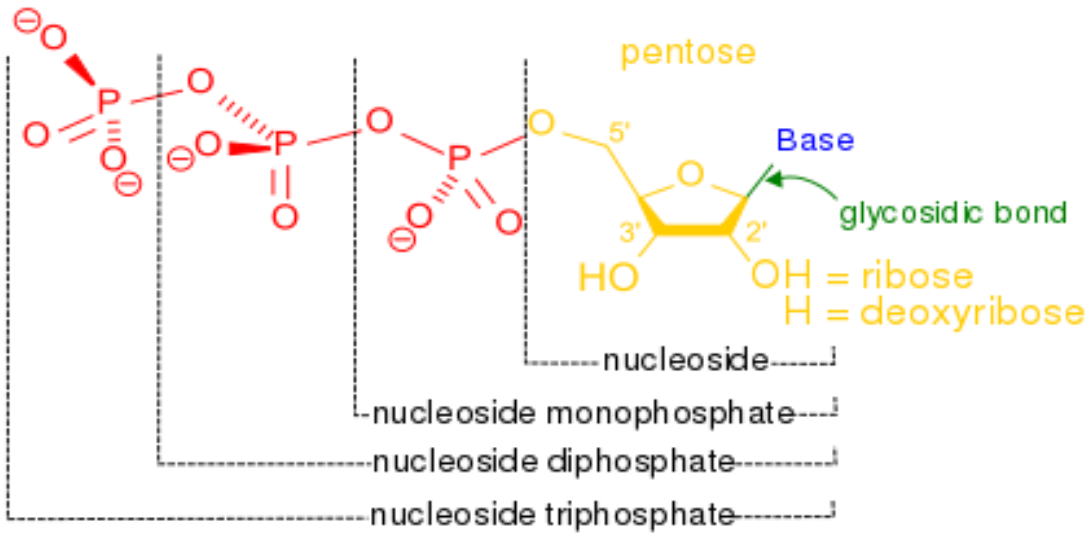
- Nucleosides
- Nucleotides
- Nucleic acids

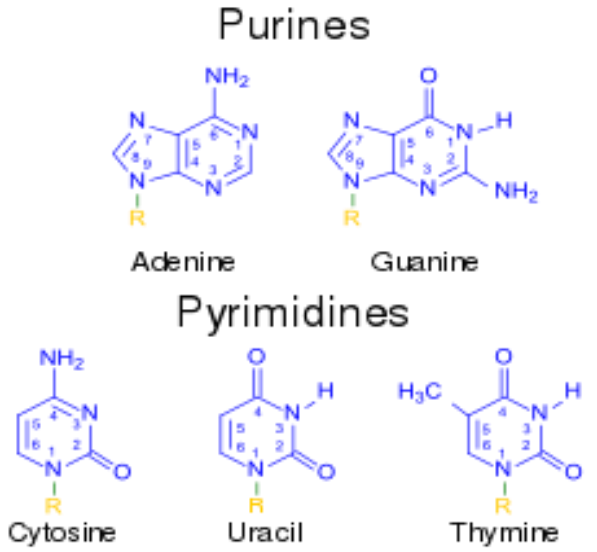
Nucleosides

- A nucleoside consists of a nitrogenous base (purine or pyrimidine) and a five-carbon sugar (ribose or 2'-deoxyribose). In a nucleoside, the anomeric carbon is linked through a glycosidic bond to the N9 of a purine or the N1 of a pyrimidine. Examples of nucleosides include adenosine, guanosine, inosine, cytidine, uridine, thymidine.

Nucleotides

- Nucleotide is composed of nitrogenous base (purine or pyrimidine), a five-carbon sugar (ribose or 2'-deoxyribose) and one or more phosphate groups.





https://en.wikipedia.org/wiki/Nucleotide

Nitrogenous base	Ribonucleoside	Deoxyribonucleoside	Ribonucleotide	Deoxyribonucleotide
Adenine A	Adenosine	Deoxyadenosine dA	Adenosinemono phosphate (AMP)	Deoxyadenosine monophosphate (dAMP)
Guanine G	Guanosine	Deoxyguanosine dG	Guanosinemono phosphate (GMP)	Deoxyguanosine monophosphate (dGMP)
Thymine T	5-Methyluridine or thymidine	Deoxythymidine dT	Thymidine monophosphate (TMP)	Deoxythymidine monophosphate (dTMP)
Uracil U	Uridine	Deoxyuridine dU	Uridine monophosphate (UMP)	Deoxyuridine monophosphate (dUMP)
Cytosine C	Cytidine	Deoxycytidine dC	Cytidine monophosphate (CMP)	Deoxycytidine monophosphate (dCMP)

The nucleotides functions

- Monomers of nucleic acids (DNA and RNA).
- Nucleotside diphosphates and triphosphates, especially ATP are high-energy molecules
- Activated intermediates in many biosyntheses: e.g UDP-glucose ® glycogen, CDP-choline ® phosphoglycerides, S-adenosylmathionine as methyl donor, etc.
- Components of the coenzymes, $NAD(P)^+$, FAD, and CoA-SH.
- Second messengers of hormonal action (c-AMP, c-GMP).
- Allosteric regulators of enzymes.

Nucleic acids

- Nucleic acids are long polymers of nucleotides: DNA (deoxyribonucleic acid) or RNA (ribonucleic acid).

	DNA	RNA
Pentose sugar	Deoxyribose	Ribose
Base Composition	Adenine (A) Guanine (G) Cytosine (C) **Thymine (T)**	Adenine (A) Guanine (G) Cytosine (C) **Uracil (U)**
Number of strands	Double stranded (forms a double helix)	Single stranded

https://ib.bioninja.com.au/standard-level/topic-2-molecular-biology/26-structure-of-dna-and-rna/dna-versus-rna.html

RNA	DNA
RNA is single stranded except in some viruses	DNA is double stranded except in few viruses
RNA have ribose sugar	DNA have deoxyribose sugar
Bases present are adenine, guanine, cytosine and uracil.	Bases present are adenine, guanine, cytosine and thymine.
Adenine pairs with uracil	Adenine pairs with thymine
Purine is not equal to pyrimidine	Purine is equal to pyrimidine (Chargaff's rule)
Regions having complementary nucleotides, pairs, and form hair pin loop like structure and helical.	Complementary nucleotides are present throughout the length of the DNA.
RNA is genetic material in some viruses.	DNA is the genetic material in all living organisms.
Length of RNA is short consisting of only few thousands nucleotides.	Length of DNA is quite large consisting of millions of nucleotides.
Three types of RNA are present in an organism: mRNA, rRNA, tRNA.	DNA occurs only in one form in an organism.
mRNA occurs in nucleolus, rRNA and tRNA occur in cytoplasm.	DNA occurs in nucleus, nucleolus, and extrachromosomal DNA in mitochondria and chloroplast.

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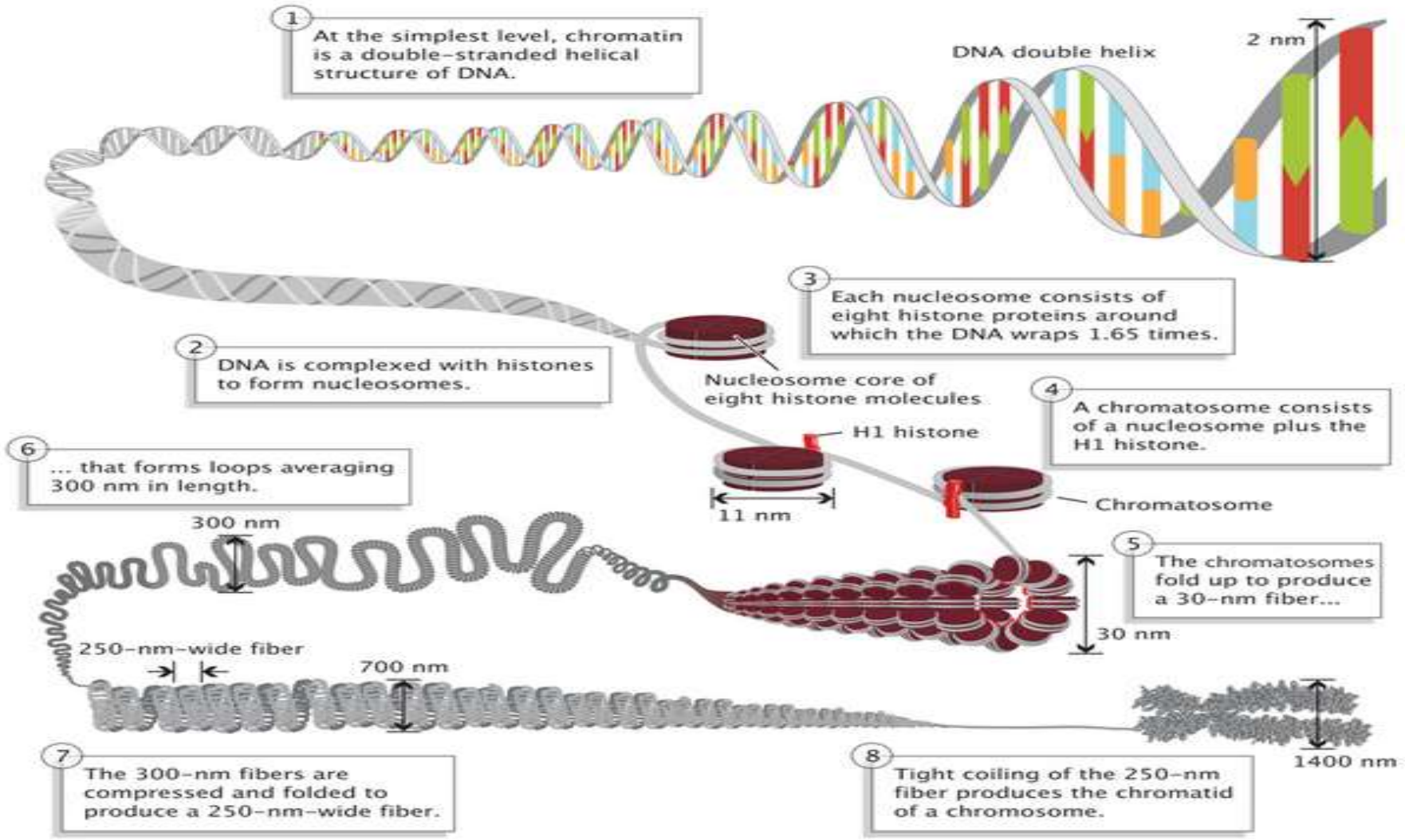
DNA (deoxyribonucleic acid)

DNA contains information about the structure of various types of **proteins.**

Deoxyribonucleic acid (DNA) is a macromolecule that provides storage, transmission from generation to generation and implementation of the genetic program
for the development and functioning of living organisms.
A DNA molecule stores biological information in the form of a genetic code consisting of a sequence of nucleotides.

3 nucleotides = 1 amino acid.
1 structural gene = information about primary structure of proteins.

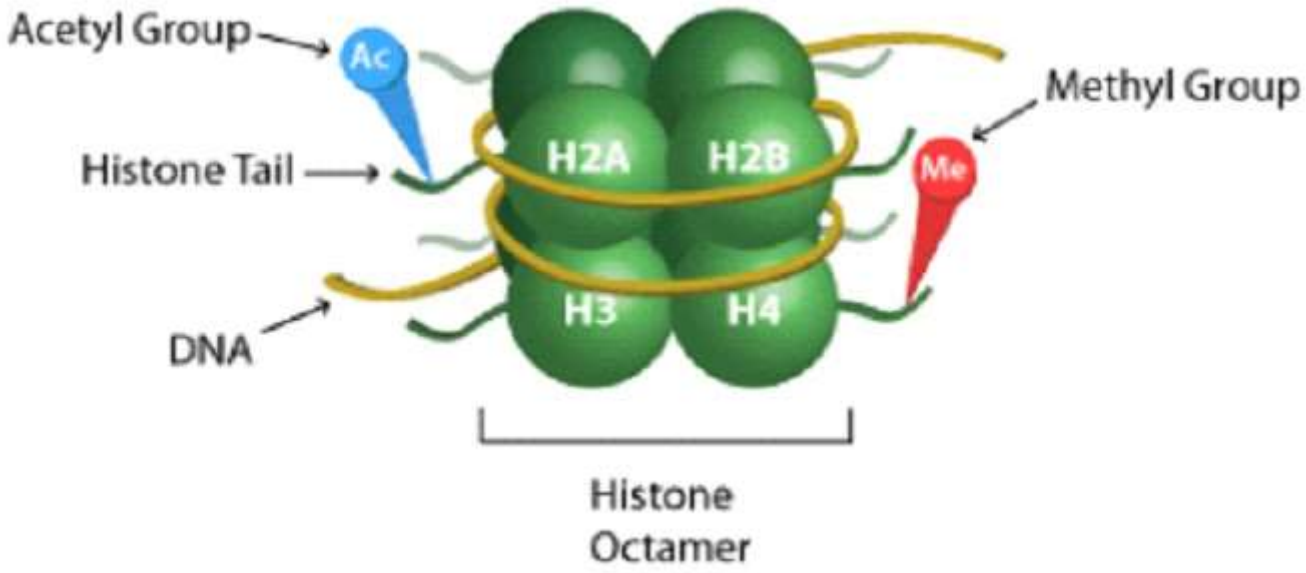
DNA levels of organization



https://www.nature.com/scitable/topicpage/eukaryotic-genome-complexity-437/

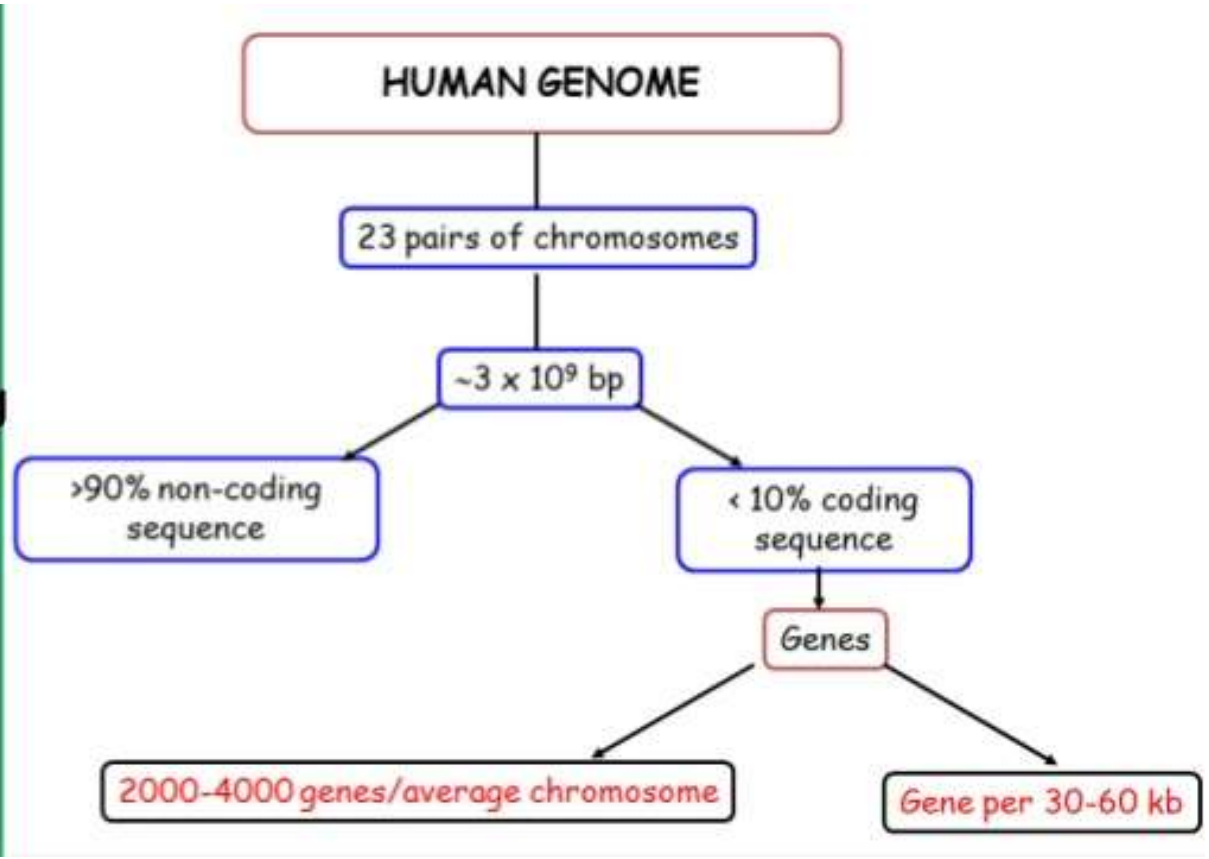
Histones

- **H1** is the main among histone protein which have a components of chromatin in eukaryotes. H1 cannot make up the nucleosomes beads. It sits on the top of the structure, where the DNA that has wrapped around the nucleosomes. It is present in half of the other 4 histone, which contribute 2 molecules to each nucleosomes bead.
- **H2A** is very important for packaging DNA into chromatin. H2A package DNA molecules into chromatin, the packaging process will effect gene expression. H2A has been correlated with DNA modification. H2A plays a crucial role in determining the overall structure of chromatin. H2A has been found to regulate gene expression.
- **H2B** is also involves in the structure of the nucleosomes of the beads on a string structure.
- **H3** is involves in the forming of shape of chromatin in eukaryotes. Gives feature of a main globular domain and have an extended N-terminal tail. H3 is an important protein in the emerging feild of epigenetics, where its sequence varients and variables modification states are thought to play a role in the dynamic and long term regulation of gene.
- **H4** is involves in the structure of chromatin in eukaryotes. H4 includes **acetylation** and **methylation**, which can alter expression of genes located on DNA related to its parent histone octamers.
- In the core of nucleosomes the 2 dimer H2A and H2B and tetramer H3 and H4 are involve and form the tertiary structure. Histone are highly positively charge and have lysine and arginine residues.
- **Histone modification**
  All the histone protein are chemically modified. Chemically modification of histones are associated with structural change that occurs at the time of replication and transcription. The 3 most common types of chemical modification are:
- **Acetylation**
- **Methylation**
- **Phosphorylation**



https://microbiologynotes.org/histones/

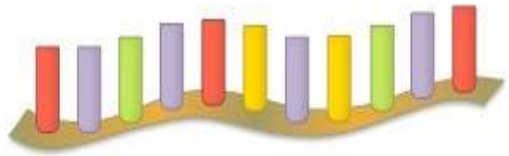
Human Genome Sequencing completed in 2001!!



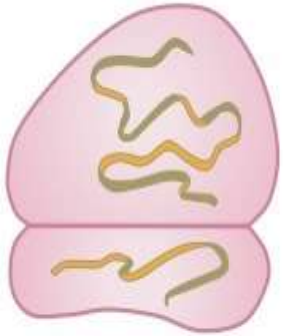
https://www.slideshare.net/biruthapa/dna-organization-or-genetic-makeup-in-prokaryotic-and-eukaryotic-systems

RNA (ribonucleic acid)

- n both prokaryotes and eukaryotes, there are three main types of RNA –
- **rRNA (ribosomal)**
- **tRNA (transfer)**
- **mRNA (messenger)**



Messenger RNA (mRNA)



Ribosomal RNA (rRNA)

Transfer RNA (tRNA)

https://microbenotes.com/rna-properties-structure-types-and-functions/#:~:text=FUNCTIONS%20OF%20RNA,-RNA%20is%20a&text=Messenger%20RNA%20(mRNA)%20copies%20DNA,are%20joined%20to%20form%20proteins.

Messenger RNA (mRNA)

- Accounts for about 5% of the total RNA in the cell.
- Most heterogeneous of the 3 types of RNA in terms of both base sequence and size.
- It carries the genetic code copied from the DNA during transcription in the form of triplets of nucleotides called codons.
- As part of post-transcriptional processing in eukaryotes, the 5’ end of mRNA is capped with a guanosine triphosphate nucleotide, which helps in mRNA recognition during translation or protein synthesis.
- Similarly, the 3’ end of an mRNA has a poly A tail or multiple adenylate residues added to it, which prevent enzymatic degradation of mRNA. Both 5’ and 3’ end of an mRNA imparts stability to the mRNA.
- **Function**
- mRNA transcribes the genetic code from DNA into a form that can be read and used to make proteins. mRNA carries genetic information from the nucleus to the cytoplasm of a cell.

Ribosomal RNA (rRNA)

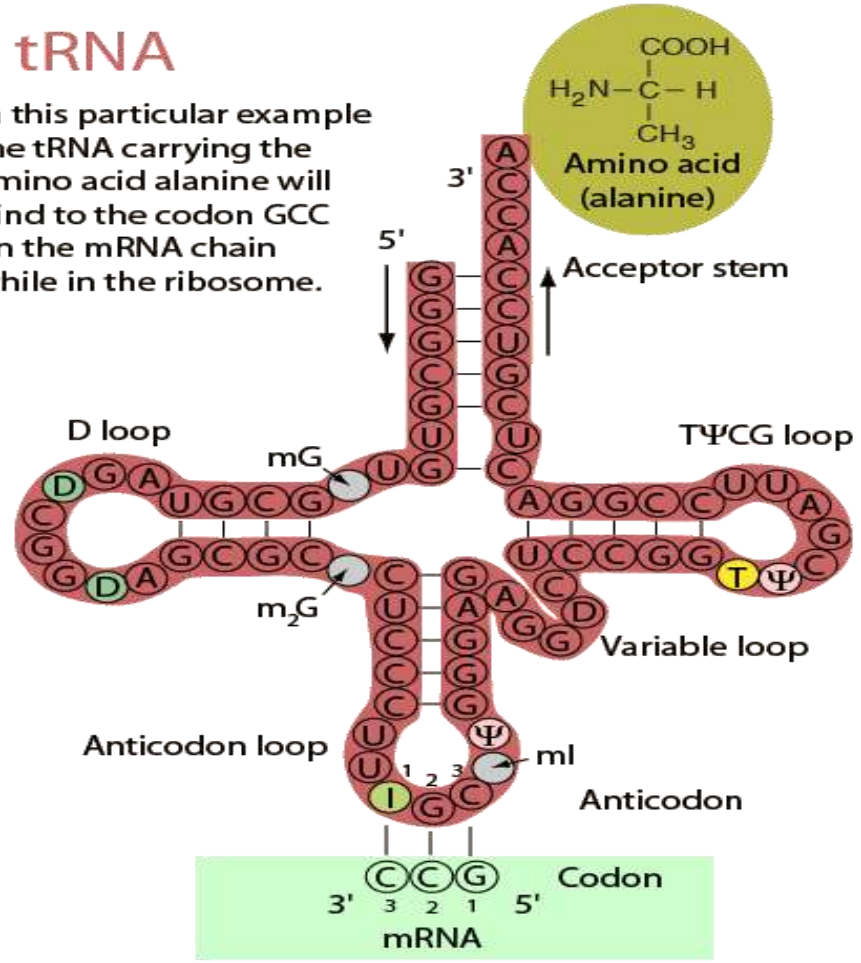
- Found in the ribosomes and account for 80% of the total RNA present in the cell.
- Ribosomes consist of two major components: the small ribosomal subunits, which read the RNA, and the large subunits, which join amino acids to form a polypeptide chain.
  Each subunit comprises one or more ribosomal RNA (rRNA) molecules and a variety of ribosomal proteins (r-protein or rProtein).
- Different rRNAs present in the ribosomes include small rRNAs and large rRNAs, which denote their presence in the small and large subunits of the ribosome.
- rRNAs combine with proteins in the cytoplasm to form ribosomes, which act as the site of protein synthesis and has the enzymes needed for the process.
- These complex structures travel along the mRNA molecule during translation and facilitate the assembly of amino acids to form a polypeptide chain. They bind to tRNAs and other molecules that are crucial for protein synthesis.
- **Function**
- rRNA directs the translation of mRNA into proteins.

Transfer RNA (tRNA)

- tRNA is the smallest of the 3 types of RNA having about 75-95 nucleotides.
- tRNAs are an essential component of translation, where their main function is the transfer of amino acids during protein synthesis. Therefore they are called transfer RNAs.
- Each of the 20 amino acids has a specific tRNA that binds with it and transfers it to the growing polypeptide chain. tRNAs also act as adapters in the translation of the genetic sequence of mRNA into proteins. Therefore they are also called adapter molecules.
- **Structure of tRNA**
- tRNAs have a clover leaf structure which is stabilized by strong hydrogen bonds between the nucleotides. Apart from the usual 4 bases, they normally contain some unusual bases mostly formed by methylation of the usual bases, for example, methyl guanine and methylcytosine.
- Three structural loops are formed via hydrogen bonding.
- The 3′ end serves as the amino acid attachment site.
- The center loop encompasses the anticodon.
- The anticodon is a three-base nucleotide sequence that binds to the mRNA codon.
- This interaction between codon and anticodon specifies the next amino acid to be added during protein synthesis.
- **Function**

tRNA

In this particular example the tRNA carrying the amino acid alanine will bind to the codon GCC on the mRNA chain while in the ribosome.



http://hyperphysics.phy-astr.gsu.edu/hbase/Organic/trna.html

RNA types & functions

Types of RNAs	Primary Function(s)
mRNA - messenger	Transfers genetic information from genes to ribosomes to synthesize protein
rRNA - ribosomal	Provides structural framework for ribosomes & catalytic role
t-RNA - transfer	Transfers a.a to mRNA for synthesis of protein.
hnRNA - heterogeneous nuclear	precursors for mRNAs & other RNAs
scRNA - small cytoplasmic	involved in selection of protein for export ,signal recognition particle (SRP)
snRNA - small nuclear snoRNA - small nucleolar	mRNA processing, poly A addition <catalytic> rRNA processing/maturation/methylation
regulatory RNAs RNA	regulation of transcription and translation, other??

https://slideplayer.com/slide/12937363/

Sources of information

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