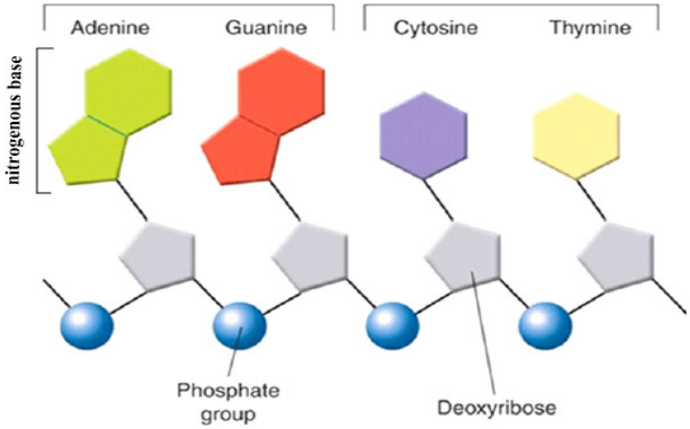
DNA

The full name of DNA is deoxyribonucleic acid. DNA is a polymer of deoxyribonucleotides. It is double stranded and helical in nature. DNA is found in chromosomes, mitochondria and chloroplasts. It carries the genetic information.



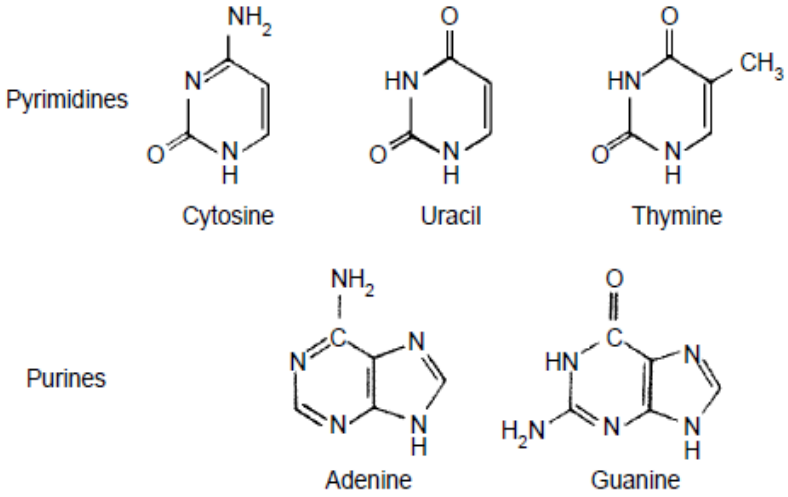
Nitrogenous bases:

Two types:

(1) Pyrimidine base: Thymine, Cytosine and Uracil

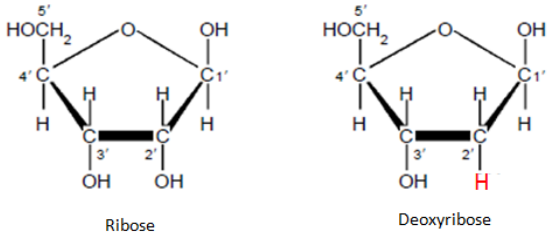
(2) Purine base: Adenine and Guanine

These bases are called nucleic acid bases. A,T,G,C are present in DNA and A,T,G,U are present in RNA.



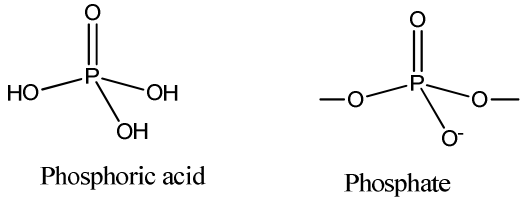
Sugar:

There are two types of pentose sugar. (1) Ribose, present in RNA and (2) Deoxyribose, present in DNA.



Phosphate:

There is a phosphate group (PO_4) derived from phosphoric acid called inorganic phosphate (Pi).



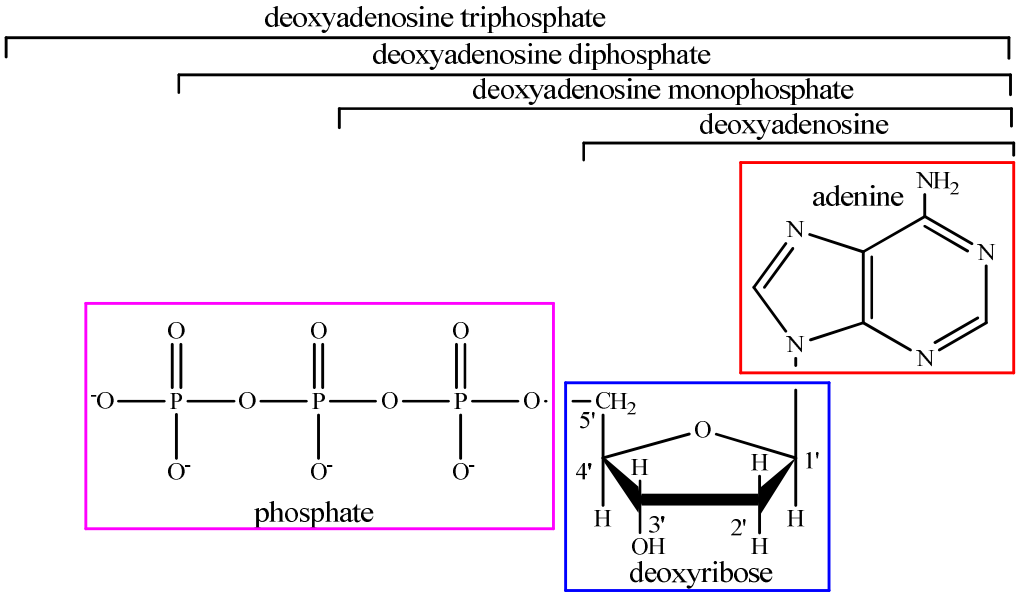
Formation of monomeric unit (Building block)

Nucleoside: The combination of one of the sugar with one of the nitrogenous base formed nucleoside. Nucleoside = Base + sugar. Depending on the sugar, it may be ribonucleoside or deoxyribonucleoside. For example:

Adenine + ribose = Adenosine, Adenine + deoxyribose = Deoxyadenosine

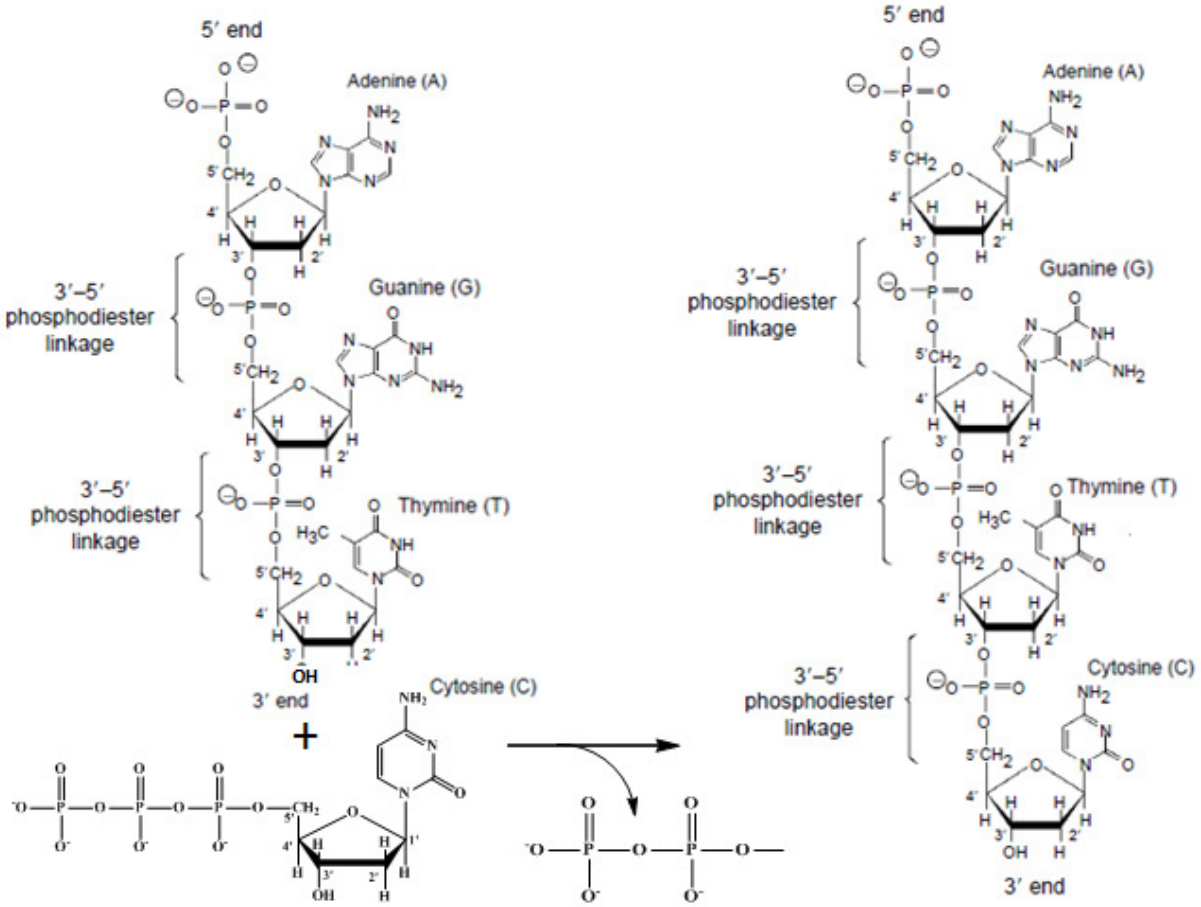
Nucleotide: The addition of phosphate group to sugar residue of nucleoside produces nucleotide. Nucleotide = Base + sugar + phosphate. For example:

Deoxyadenosine monophosphate (dAMP), Deoxyadenosine diphosphate (dADP)



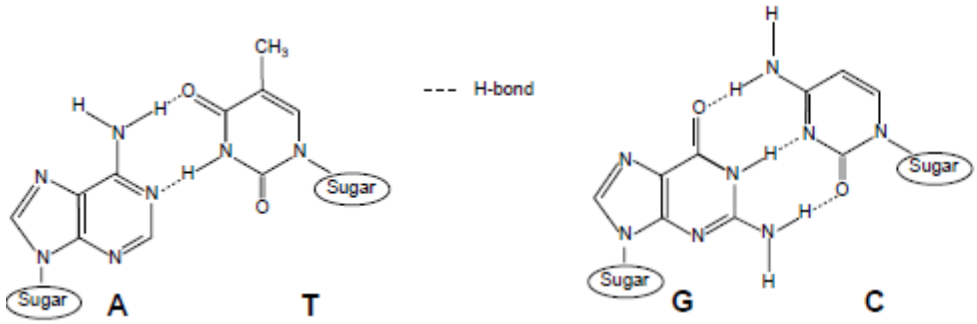
Structure of Nucleic acid:

Nucleic acids are the polynucleotides. Nucleotides are joined through the sugar–phosphate bond known as phosphodiester linkage. It is formed between 5′ carbon of one sugar residue and 3′ carbon of the next sugar residue.



H-bonds between the bases:

The bases are complementary to each other. Adenine is H-bonded with thymine whereas, guanine forms H-bond with cytosine. There are two H-bond in AT pair and three in GC pair.



Structure of DNA:

In 1953, James Watson and Francis Crick described a very simple but famous Double Helix model for the structure of DNA.

1) DNA is a double stranded polynucleotide. Two strands are twisted to each other forms double helical structure. Helix may be either right handed or left handed.

2) Two strands runs antiparallel i.e., one is 5′→3′ and another is 3′→5′.

3) The sugar residue and phosphate forms the backbone of the strand, and bases are positioned inside the helix.

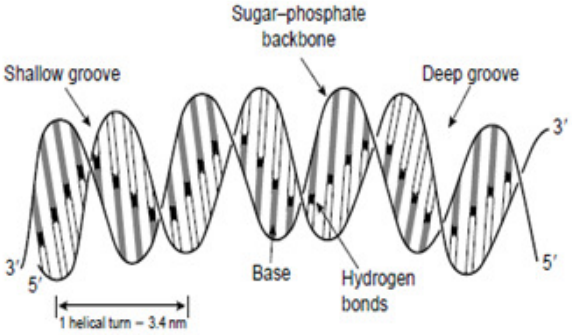
4) Two strands are joined together by H-bond. Adenine of one strand is being H-bonded to thymine of another strand and similarly guanine being H-bonded to cytosine.

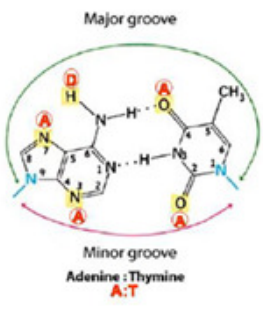
5) The base pairing is very specific which make the two strands complementary to each other.

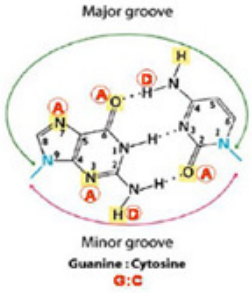
6) The plane of the bases are perpendicular to the fibre axis and also sugar molecules.

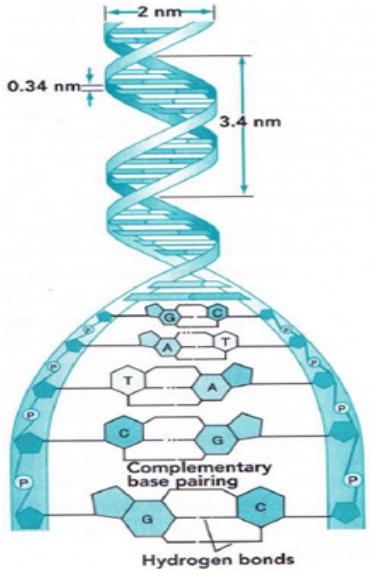
7) The pitch of the helix is 3.4 nm and there are roughly 10 base pair in each turn. Consequently, the distance between a base pair in a helix is approximately equal to 0.34 nm.

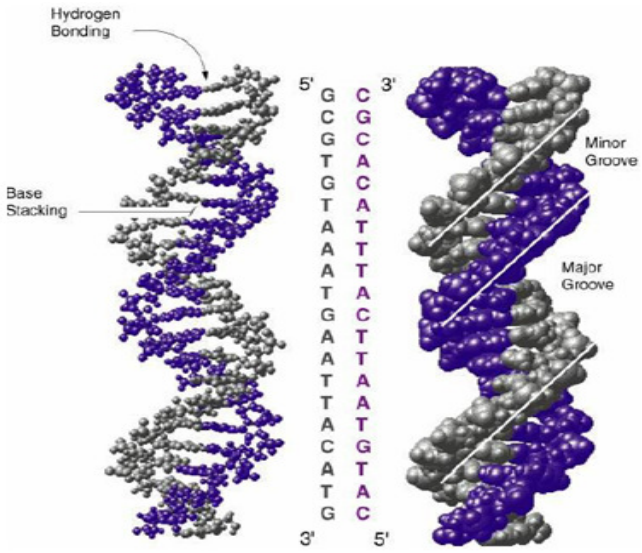
8) The DNA helix contains two grooves named as major and minor groove. Through this grooves protein and other molecules interacts with DNA.



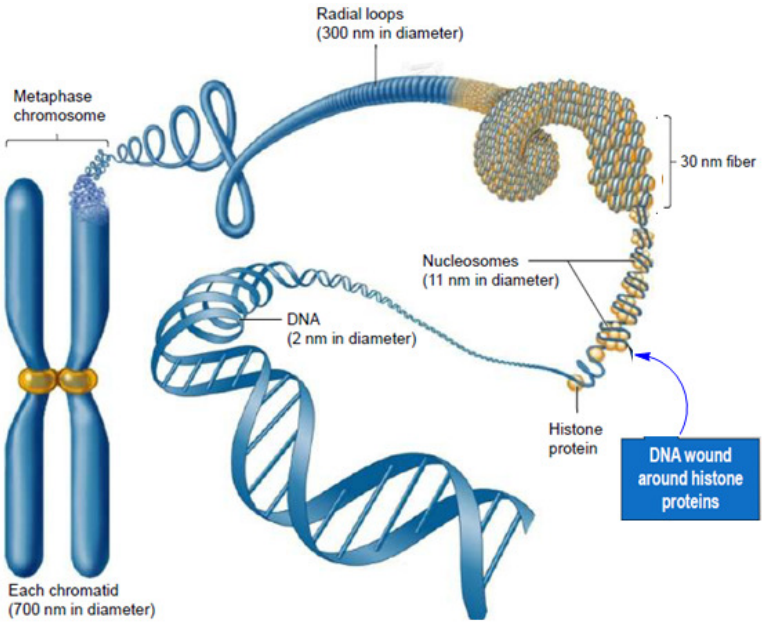








Supercoiling of DNA



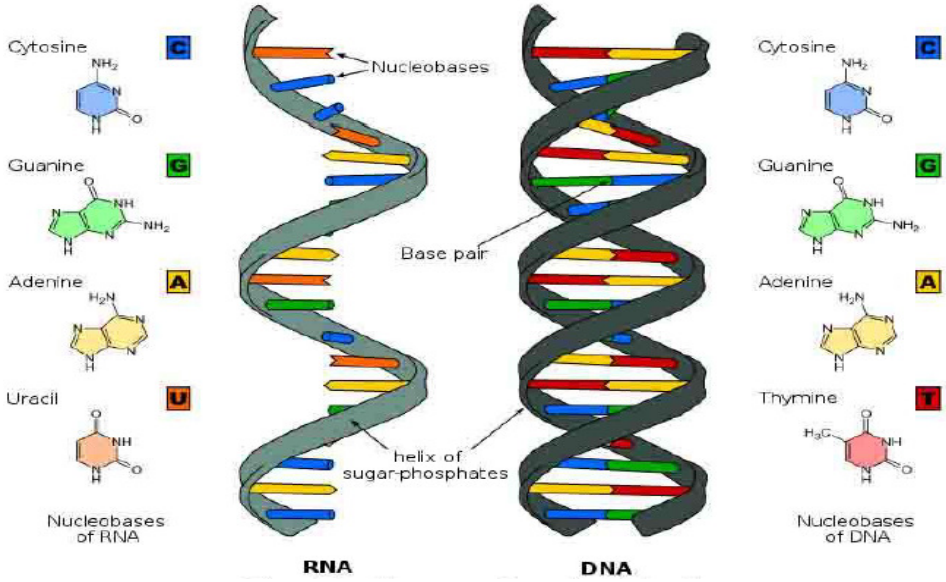
- There is a set of positively charged basic proteins called histones.
- DNA is negatively charged due to PO_4^{3-} group. The negatively charged DNA is wrapped around the positively charged histone to form a structure called nucleosome.
- Nucleosomes constitute the repeating unit of a structure in nucleus called chromatin.
- The DNA and Protein are electromagnetically attracted to each other to form chromatin.

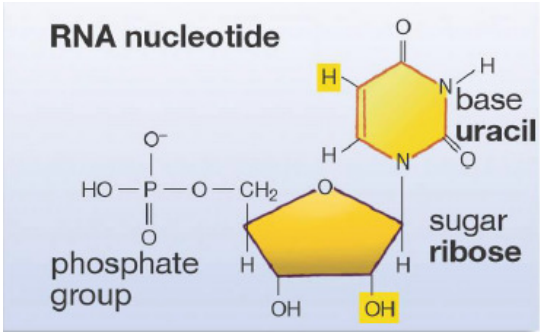
Biological role of DNA

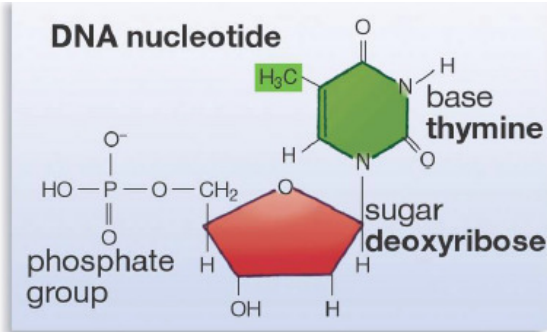
1. DNA acts as the genetic material of the organisms.
2. DNA is pivotal to our growth, reproduction, and health.
2. DNA dictates how a human or animal develops and reproduces, and eventually dies.
3. Every cell contains DNA, where is the complete genetic material stored. It is coping during the cell division and transfer to the daughter cells.
4. In all living things, DNA is essential for inheritance, coding for proteins, and providing instructions for life and its processes.
5. The main roles of DNA include replication, encoding information, mutation/recombination and gene expression.
6. It contains the instructions to produce proteins that affect many different processes and functions in your body.

RNA

RNA means ribonucleic Acid. RNA is a polymer of ribonucleotides linked together by phosphodiester linkage. Ribonucleotide is formed by the condensation of ribose sugar, phosphate and one of the nitrogenous bases. RNA is single stranded and helical in structure.







Biological roles of RNA

1. RNA is the genetic material of some viruses.
2. It directly or indirectly involved in protein synthesis or its regulation.
3. RNA functions as the intermediate (mRNA) between the gene and the protein-synthesizing machinery.
4. It functions as messenger (mRNA), adapter (tRNA), structural (rRNA) and in some cases as a catalytic molecule (Ribozyme).
4. RNA functions as an adaptor (tRNA) between the codons in the mRNA and amino acids.
6. RNA serves as a regulatory molecule, which through sequence complementarity binds to, and interferes with the translation of certain mRNAs.
7. Some RNAs are enzymes that catalyze essential reactions in the cell (RNase P ribozyme, large rRNA, self-splicing introns, etc).

Types of RNA:

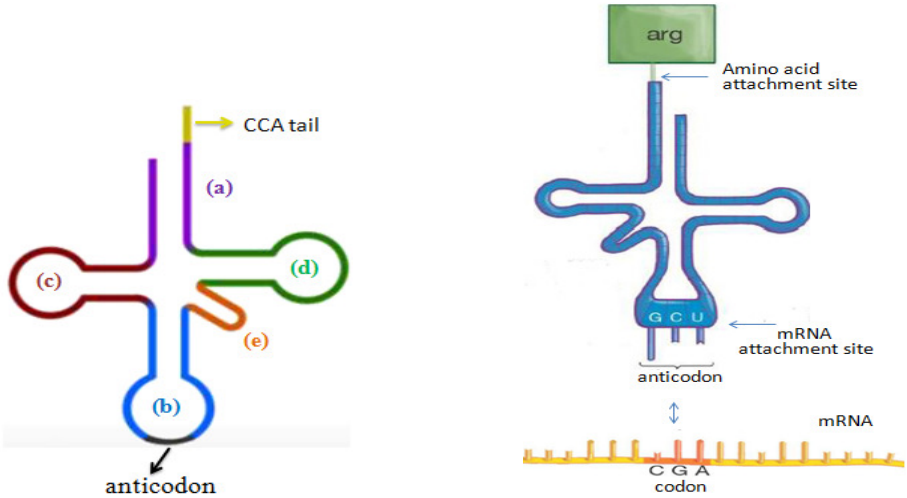
(1) Messenger RNA (mRNA):

- ❖ It Carries genetic information copied from DNA in the form of a series of 3-base code, each of which specifies a particular amino acid.
- ❖ mRNA carries the genetic code to the ribosome, the protein synthesizing machinery.
- ❖ mRNA that are complementary to the DNA of the gene for the protein to be synthesized.

(2) Transfer RNA (tRNA):

- ❖ tRNA read the code on the mRNA.
- ❖ They transfer the amino acids from cytoplasm to the protein synthesizing machinery, hence the name tRNA. Each amino acid has its own tRNA.
- ❖ They are also called adapter molecules, since they act as adapters for the translation of the sequence of nucleotides of the mRNA into specific amino acids.

Structure of tRNA: Each single t-RNA shows extensive internal base pairing and acquires a clover leaf like structure. The structure is stabilized by hydrogen bonding between the bases and is a consistent feature. In clover leaf structure, tRNA has 5 main arms or loops which are as follows: (a) Acceptor arm (b) Anticodon arm (c) DHU arm (DihydroUracil) (d) TΨC arm (Thymidine Pseudouridine Cytosine) (e) Extra arm



(3) Ribosomal RNA (r RNA):

- ❖ Ribosomal ribonucleic acid (rRNA) is the RNA component of the ribosome, and is essential for protein synthesis in all living organisms.
- ❖ They are necessary for ribosomal assembly and plays key roles in the binding of mRNA to ribosomes and its translation.
- ❖ Large rRNA subunit of ribosome acts as an enzyme called ribozyme, catalysing peptide bond formation and shows peptidyl transferase activity.

Replication

1. DNA replication is process in which a duplicate DNA is produced from parent DNA.

2. The original DNA molecule is split into two strands and each strand acts as a template on which a new strand is synthesized.

3. The site where two strand of DNA is separated and replication process starts is called replication fork.

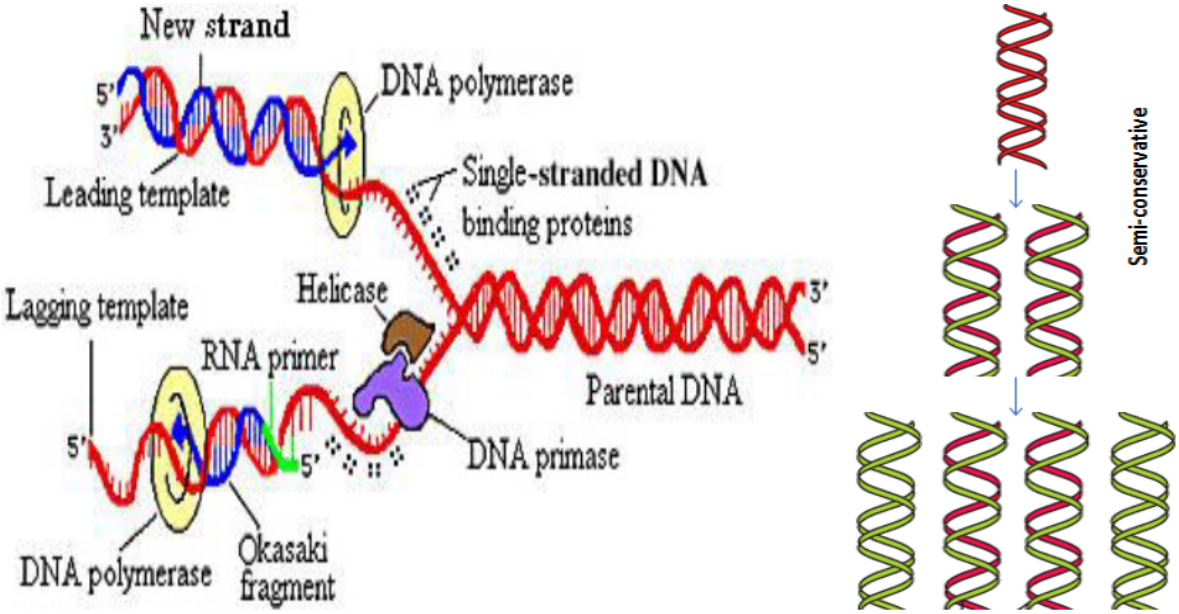
3. Two parent strands are called either leading strand (3′→5′) or lagging strand (5′ → 3′).

4. In leading strand, new DNA strand is synthesized continuously in the direction 5′ → 3′ whereas in the lagging strand synthesis occur in discontinuous way as a series of short lengths of DNA, each of which is called Okazaki fragment. The Okazaki fragments are later joined by the enzyme DNA ligase.

5. The process is catalysed by the enzyme DNA polymerase.

6. DNA polymerases catalyse polymerisation only in one direction, that is 5′→3′.

7. There are five theoretically possible modes of replication. Conservative, Semi-conservative, Non-conservative, Dispersive and End-to-end.



Transcription

1. The process of copying genetic information from one strand of the DNA into RNA is termed as transcription.

2. Only a segment of one strand of DNA is copied into RNA.

3. The strand that has the polarity 3′→5′ acts as a template strand. The other strand which has the polarity (5′→3′) is referred to as coding strand. For example:

3′-ATGCATGCATGCATGCATGCATGC-5′ Template Strand

5′-TACGTACGTACGTACGTACGTACG-3′ Coding Strand

3. Synthesized mRNA is complementary to the template strand of DNA.

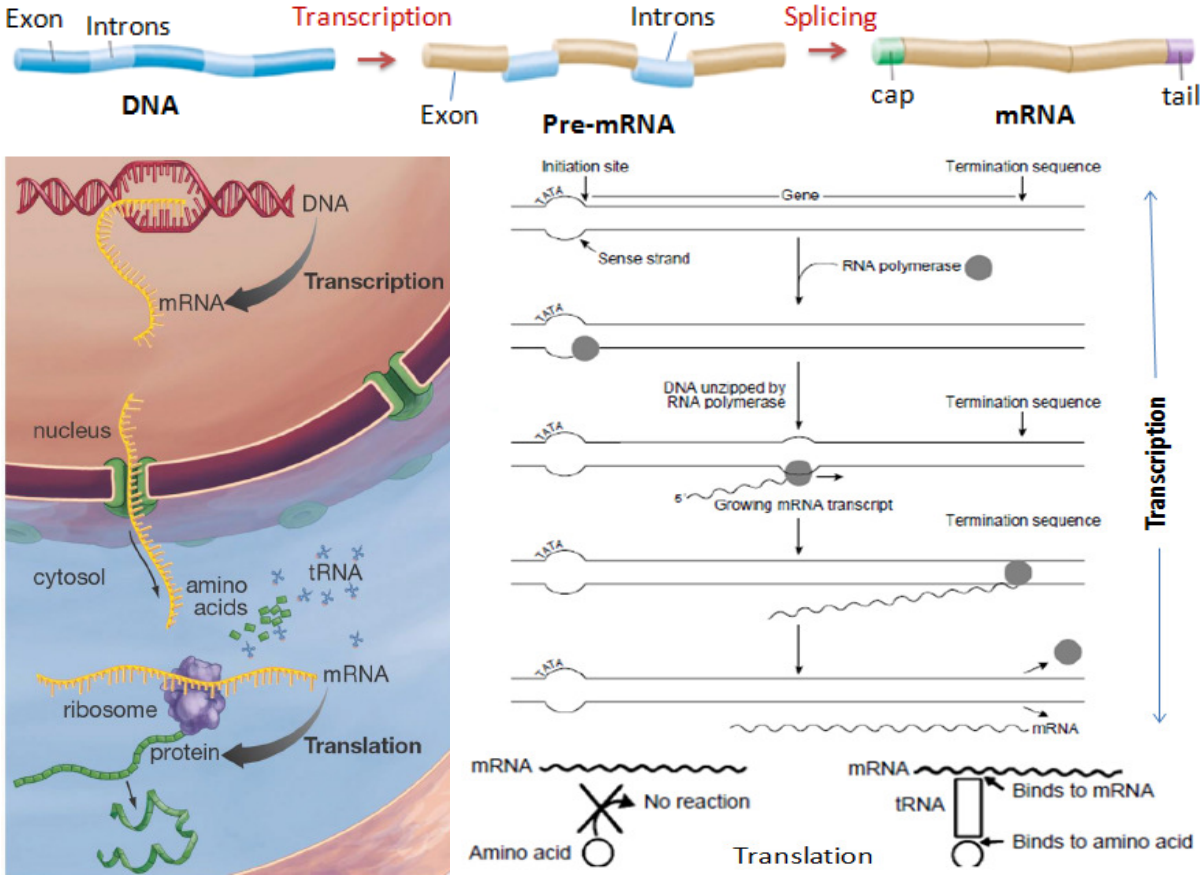
4. It requires basic building blocks for RNA i.e. free RNA nucleotides and ATP molecule for energy together with a DNA molecule acts as DNA template.

5. Transcription starts and stops at distinct sites at the ends of a gene.

6. This process is catalysed by RNA polymerase. It binds to DNA and separates the DNA strands. The sites where RNA polymerase binds to DNA are called **promoters**.

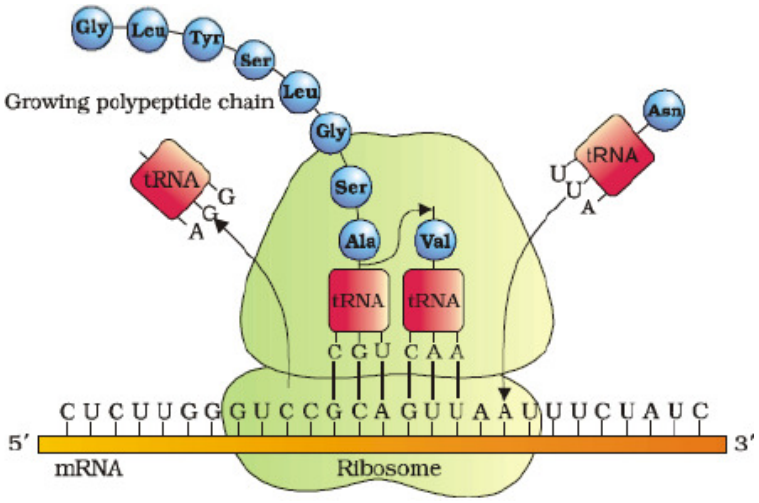
7. The process occurs in nucleus of the cell.

8. The segments of nucleotide are not involved in coding for protein are known as **introns** and segments are involved in coding for proteins are known as **exons**.



Translation

1. Translation, in which the genetic information coded as a sequence of bases in mRNA is translated or converted into a sequence of amino acids to form a discrete polypeptide chain.
2. The process is catalyzed by the enzyme amino acyl-tRNA synthetase.
3. It requires mRNA for coding sequence, tRNA for bind and transfer amino acids and ATP for energy.
4. This process occurs in ribosome present in cytoplasm.
5. mRNA molecule is attached to ribosome and each codon of mRNA molecule moves through the ribosome, the proper amino acid is brought into the ribosome by tRNA.
6. Each tRNA molecule carries only one kind of amino acid and each tRNA has anticodon complementary to codon in mRNA.
5. Translation of mRNA strand is started from the 5′ end at a specific triplet codon and process is stopped at stop codon.

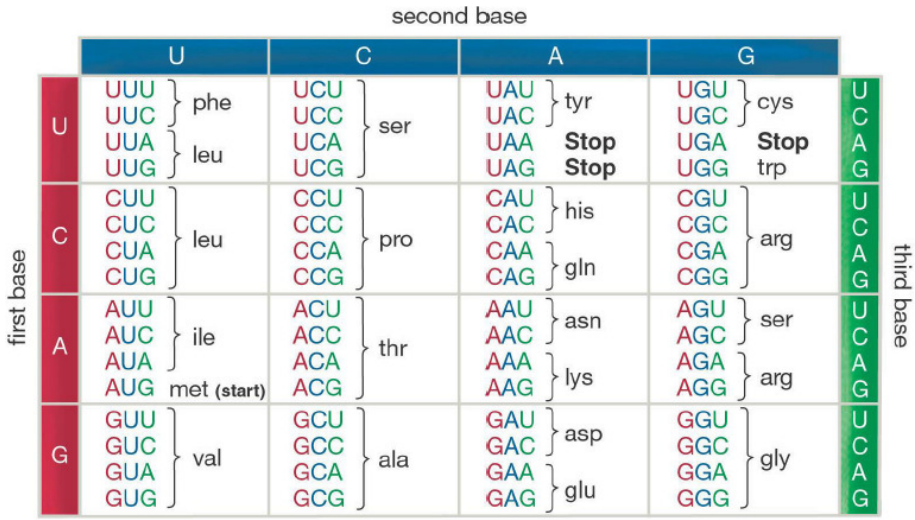


Genetic Code

There is no complementary relation exists between nucleotide and amino acid. It is evident that changes in nucleic acids (genetic material) were responsible for change in amino acids in proteins. Therefore, the transfer of genetic information from DNA to a sequence of amino acid that constitute a polypeptide through transcription followed by translation is occurred by some embedded rule is known as genetic code.

The salient features of genetic code:

- Genetic code is a set of rules that maps codons to amino acids.
- The language of the genetic code contains only 4 letters (A,U,G,C).
- The three consecutive nucleotides on mRNA is termed as codon which specifies a particular amino acid. So, codon is triplet.
- Some amino acid can be specified by more than one codon, hence codon is degenerate.
- There are 64 codons. 61 codons for amino acid and 3 codons do not code for any amino acid and function as stop codons and called non-sense codon.
- The codon in mRNA is read in continuous manner. There are no punctuations.
- The code is nearly universal. For example, from bacteria to human UUU would code for Phenylalanine (phe).
- The code is not just a random association of codons and amino acids. There seems to be an intriguing underlying order. For example, all codons with U in the second place code for hydrophobic amino acids.
- XYU and XYC always code the same amino acid.
- XYA and XYG often code the same amino acid.
- AUG has dual functions. It codes for Methionine (met), and also acts as start codon.
- UAA, UAG, UGA are act as stop codon.



Gene therapy

Gene therapy is a medical field which focuses on the genetic modification of cells to produce a therapeutic effect or the treatment of disease by repairing or reconstructing defective genetic material. Gene Therapy is a new tool to cure human diseases.

Gene therapy is broadly two types:

1) Somatic gene therapy: In somatic gene therapy, the therapeutic effects are restricted to the actual patient and are not passed on to next generation. All gene therapy to date on humans has been directed at somatic cells.

This therapy again two types: ex vivo, which means exterior (where cells are modified outside the body and then transplanted back in again). in vivo, which means interior (where genes are changed in cells still in the body). This form of gene therapy is called in vivo, because the gene is transferred to cells inside the patient's body.

2) Germline gene therapy: The therapeutic effects are passed down to subsequent generations. The germline engineering in humans remains controversial and prohibited in for instance.

Example:

Introduction of gene for adenosine deaminase in persons suffering from severe combined immuno-deficiency (SCID)