BIOMOLECULES

Topic:4

NUCLEIC ACIDS - CHEMICAL COMPOSITION AND STRUCTURE OF DNA AND RNA, TRANSCRIPTION AND TRANSLATION

VERY SHORT ANSWER QUESTIONS

1. What are nucleic acids?

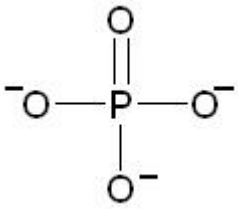
Ans: Nucleic acids are biologically important polymers which are present in all living cells, also called as polynucleotides because repeating structural unit is nucleotide.
There are two types of nucleic acids
(i) **DNA** (deoxyribonucleic acid)
(ii) **RNA** (Ribonucleic acid)

2. What do nucleic acids contain?

Ans: Composition of nucleic acids
1. A phosphate group
2. Sugar
3. Nitrogenous bases

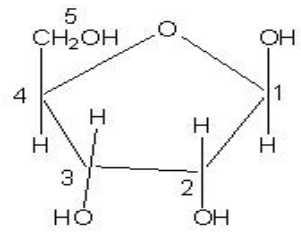
3. What is the structure of sugar group?

Ans: . Phosphate Group: Phosphate group in nucleic acid is:

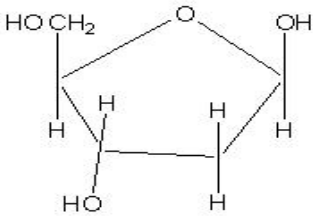


4. What are the sugar groups present in nucleic acid?

Ans: Sugar: Two types of sugars present in nucleic acids.
RNA (D – ribose)
DNA (D – deoxyribose)



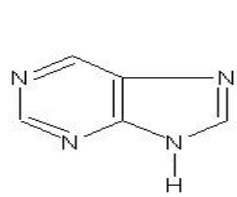
D-ribose



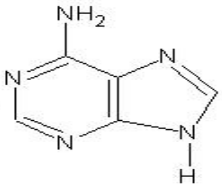
D-deoxyribose

5. **What are the nitrogen bases present in nucleic acids?**

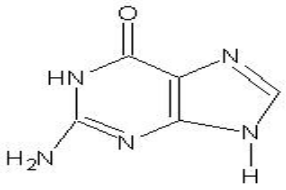
Ans: Nitrogenous bases: Two types
(i) Purines – Adenine (A) and Guanine (G)
(ii) Pyrimidines – Cytosine (C), thymine (T) and uracil (U)



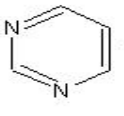
Purines



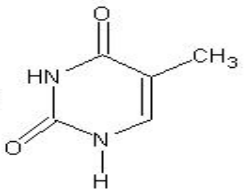
Adenine (A)



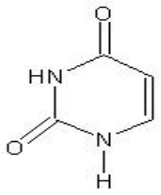
Guanine (G)



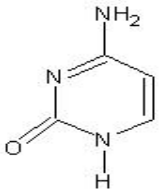
Pyrimidines



Thymine (T)



Uracil (U)



Cytosine (C)

SHORT ANSWER QUESTIONS

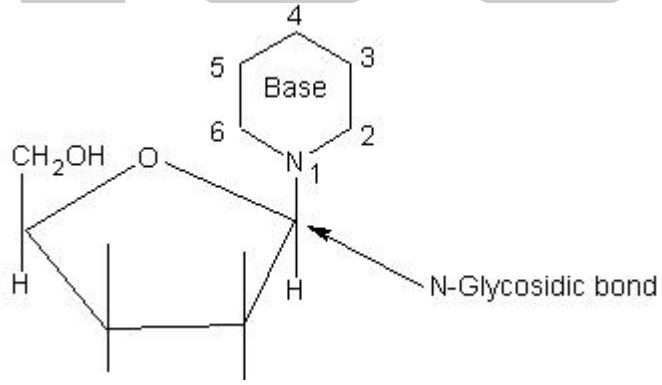
1. **Write the differences between DNA and RNA.**

Ans: DNA and RNA

	DNA		RNA
1.	Sugar present in DNA is 2-deoxyribose.	1.	Sugar is D-ribose.
2.	It contains cytosine and thymine as pyrimidine.	2.	It contains cytosine and uracil as pyrimidine.
3.	It has double stranded a - helix structure.	3.	It has single stranded a - helix.
4.	DNA occurs in the nucleus of cell.	4.	RNA occurs in cytoplasm of the cell.
5.	Controls transmission of hereditary material.	5.	It controls the synthesis of proteins.

2. **Explain what are nucleosides?**

Ans: Nucleosides: Nucleoside contains only two basic components of nucleic acids (a pentose sugar and a nitrogenous base). During their formation, 1- position of pyrimidine or 9 – position of purine moiety is linked to C_1 of sugar (ribose or deoxyribose) by α - linkage.



General structure of a nucleoside

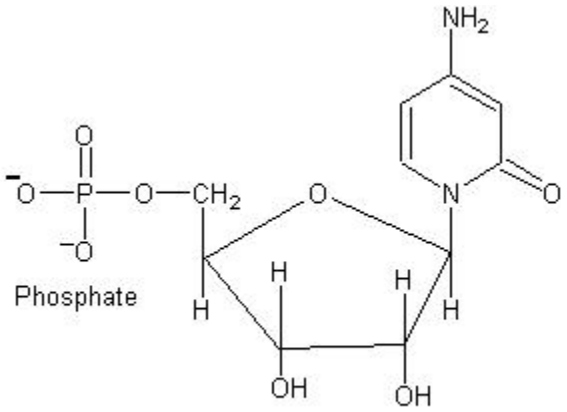
Depending upon the type of sugar present, nucleosides are of two types:

(i) Ribonucleosides and

(ii) Deoxyribonucleosides

3. What are nucleotides?

Ans: Nucleotides: Nucleotides contains all the three basic components of nucleic acids. Nucleotides are nucleoside monophosphates.
They are of two types depending upon the type of sugar – Ribonucleotides and Deoxyribonucleotides. Nucleotide may be represented as follows.

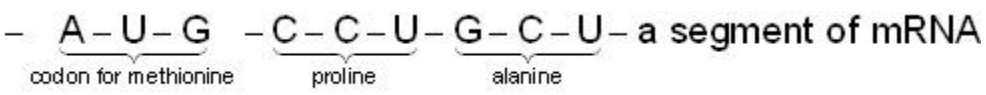


E.g: Structure of cytidine monophosphate

4. Explain how protein is synthesized?

Ans: Protein synthesis: It is a fast process and about 20 amino acids are added in one second. It may be noted that translation is always unidirectional but transcription can sometimes be reversed. (RNA is copies into DNA) This is called reverse transcription (occurs in Retroviruses).
Genetic Code
Segment of DNA is called gene and each triplet of nucleotides is called a codon that specifies one amino acid. This relationship between nucleotide triplets and amino acids is called genetic code.

E.g.



LONG ANSWER QUESTIONS

1. Explain the structure of DNA.

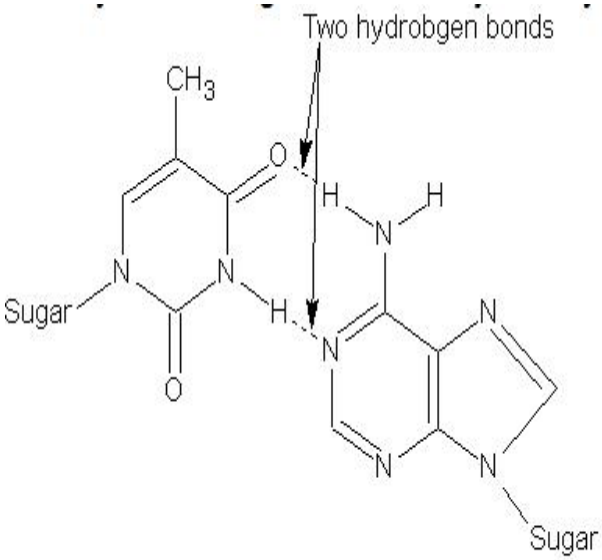
Structure of DNA: Primary structure and its double helix: Sequence in which four nitrogen bases are attached to the sugar phosphate backbone of a nucleotide chain is called primary structure.

Watson and crick in 1953 proposed that DNA polymers form a duplex structure consisting of two strands of polynucleotide chain coiled around each other in the form of a double helix. Bases of one strand of DNA are paired with bases on the other strand by means of hydrogen bonding. According to Chargaff rule – Thymine and adenine can be joined by 2 hydrogen bonds (T = A) while cytosine and guanine can be joined by three hydrogen bonds.

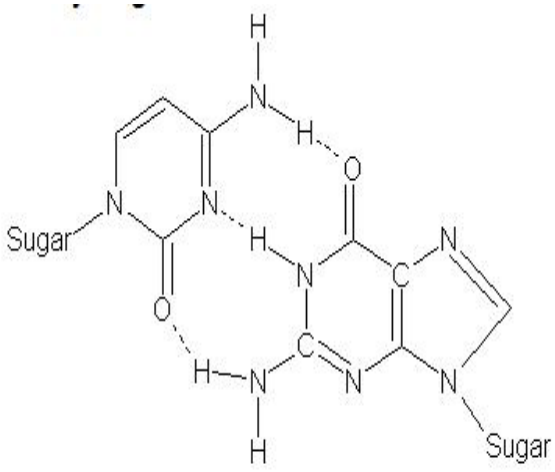
Deoxyribonucleic acid or **DNA** is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms (with the exception of RNA viruses). The main role of DNA molecules is the long-term storage of information. DNA is often compared to a set of blueprints, like a recipe or a code, since it contains the instructions needed to construct other components of cells, such as proteins and RNA molecules. The DNA segments that carry this genetic information are called genes, but other DNA sequences have structural purposes, or are involved in regulating the use of this genetic information. Along with RNA and proteins, DNA is one of the three major macromolecules that are essential for all known forms of life.

DNA consists of two long polymers of simple units called nucleotides, with backbones made of sugars and phosphate groups joined by ester bonds. These two strands run in opposite directions to each other and are therefore anti-parallel. Attached to each sugar is one of four types of molecules called nucleobases (informally, *bases*). It is the sequence of these four nucleobases along the backbone that encodes information. This information is read using the genetic code, which specifies the sequence of the amino acids within proteins. The code is read by copying stretches of DNA into the related nucleic acid RNA, in a process called transcription.

Within cells, DNA is organized into long structures called chromosomes. These chromosomes are duplicated before cells divide, in a process called DNA replication. Eukaryotic organisms (animals, plants, fungi, and protists) store most of their DNA inside the cell nucleus and some of their DNA in organelles, such as mitochondria or chloroplasts. In contrast, prokaryotes (bacteria and Achaea) store their DNA only in the cytoplasm. Within the chromosomes, chromatin proteins such as histones compact and organize DNA. These compact structures guide the interactions between DNA and other proteins, helping control which parts of the DNA are transcribed.

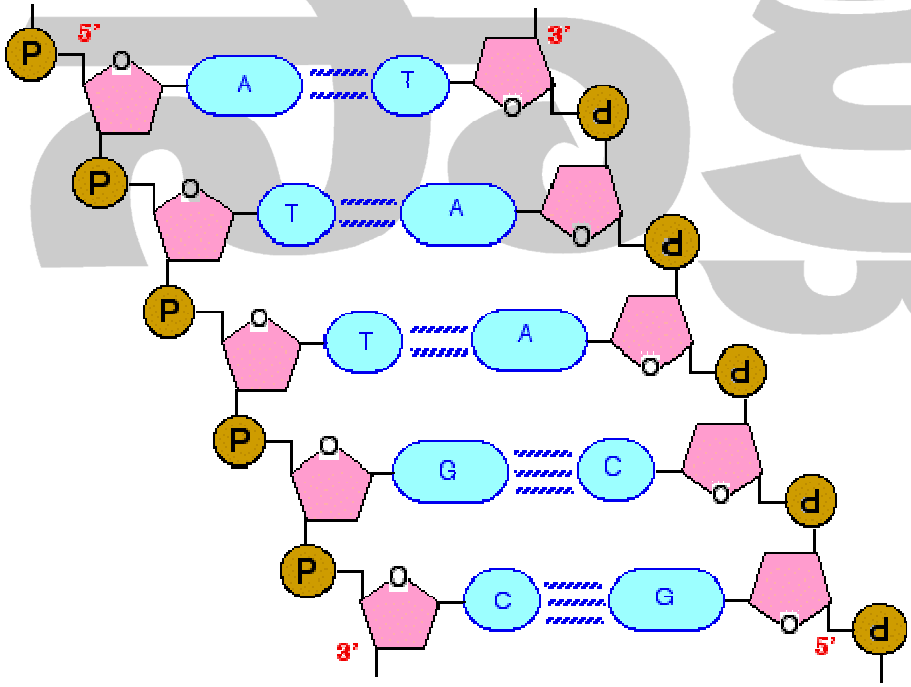


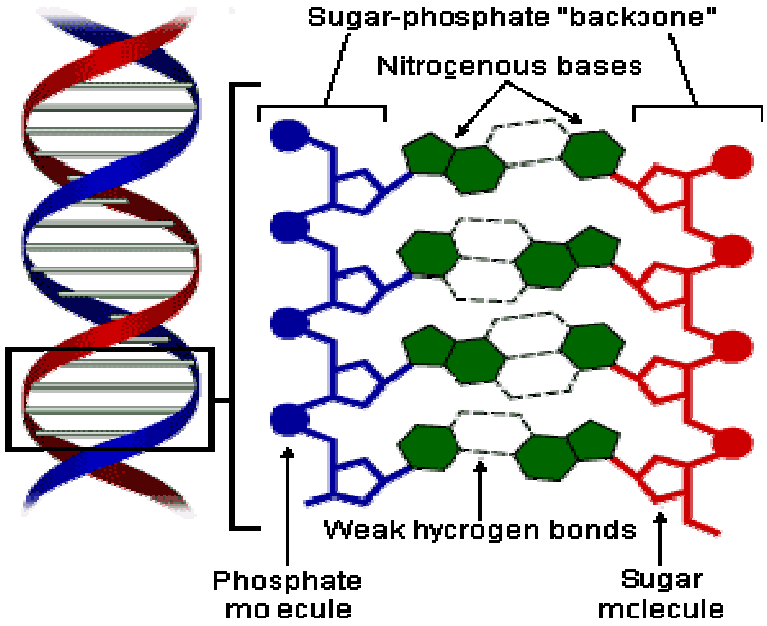
(Thymine = Adenine)



Pairing of cytosine and guanine

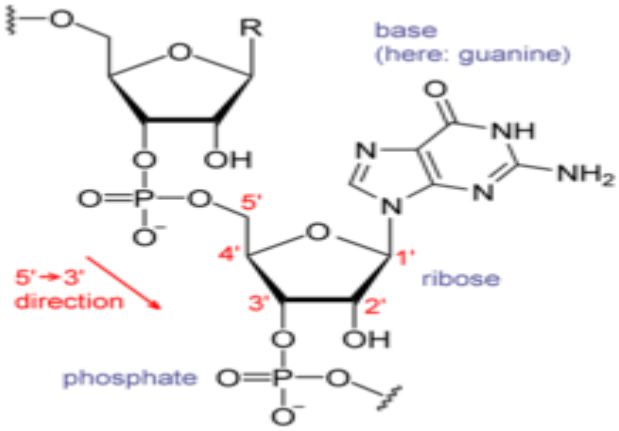
(C≡G)





2. **Explain the structure of RNA.**

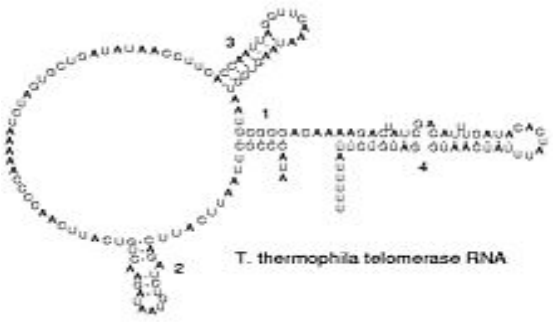
Ans: Structure of RNA: Each nucleotide in RNA contains a ribose sugar, with carbons numbered 1' through 5'. A base is attached to the 1' position, in general, adenine (A), cytosine (C), guanine (G), or uracil (U). Adenine and guanine are purines, cytosine, and uracil are pyrimidines. A phosphate group is attached to the 3' position of one ribose and the 5' position of the next. The phosphate groups have a negative charge each at physiological pH, making RNA a charged molecule (polyanion). The bases may form hydrogen bonds between cytosine and guanine, between adenine and uracil and between guanine and uracil. However, other interactions are possible, such as a group of adenine bases binding to each other in a bulge, or the GNRA tetraloop that has a guanine–adenine base-pair.



Chemical structure of RNA

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 this functional

group causes the helix to adopt the A-form geometry rather than the B-form most commonly observed in DNA. This results in a very deep and narrow major groove and a shallow and wide minor groove. A second consequence of 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), it can chemically attack the adjacent phosphodiester bond to cleave the backbone.

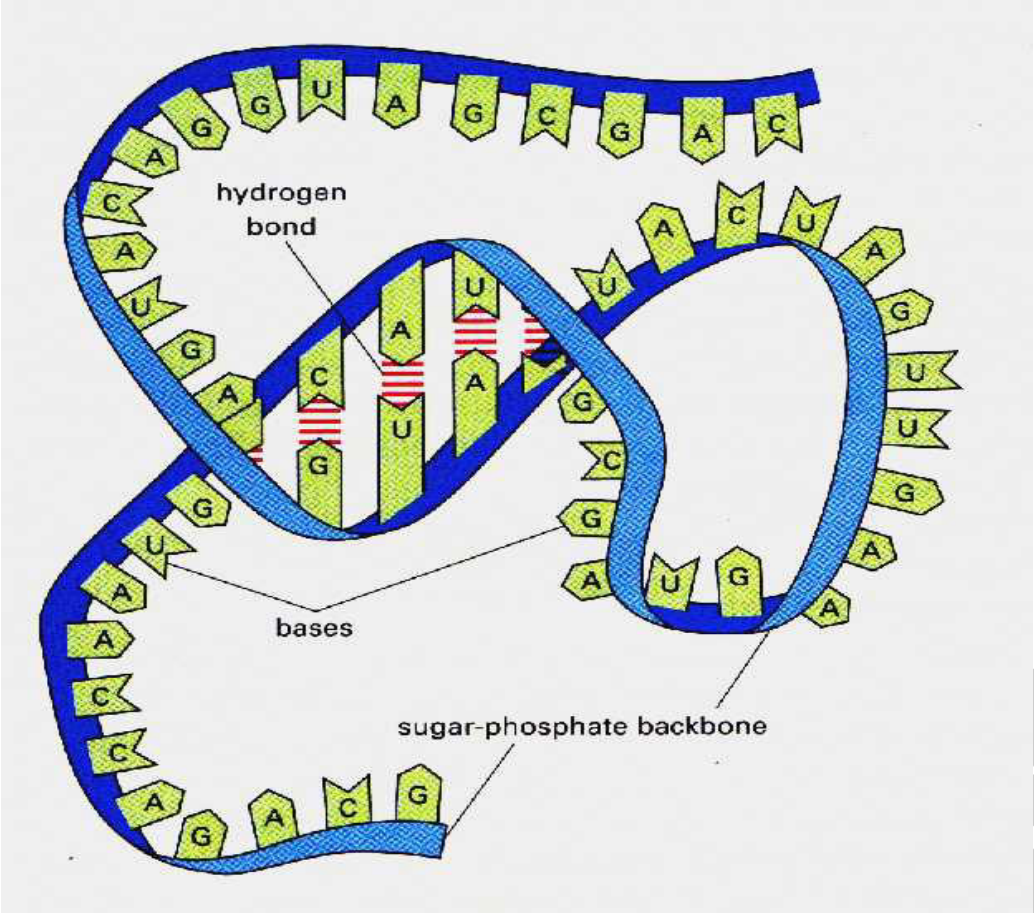


Secondary structure of a telomerase RNA

RNA is transcribed with only four bases (adenine, cytosine, guanine and uracil), but these bases and attached sugars can be modified in numerous ways as the RNAs mature. Pseudouridine (Ψ), in which the linkage between uracil and ribose is changed from a C–N bond to a C–C bond, and ribothymidine (T) are found in various places (the most notable ones being in the TΨC loop of tRNA). Another notable modified base is hypoxanthine, a deaminated adenine base whose nucleoside is called inosine (I). Inosine plays a key role in the wobble hypothesis of the genetic code.

There are nearly 100 other naturally occurring modified nucleosides, of which pseudouridine and nucleosides with 2'-O-methylribose are the most common. The specific roles of many of these modifications in RNA are not fully understood. However, it is notable that, in ribosomal RNA, many of the post-transcriptional modifications occur in highly functional regions, such as the peptidyl transferase center and the subunit interface, implying that they are important for normal function.

The functional form of single stranded RNA molecules, just like proteins, frequently requires a specific tertiary structure. The scaffold for this structure is provided by secondary structural elements that are hydrogen bonds within the molecule. This leads to several recognizable "domains" of secondary structure like hairpin loops, bulges, and internal loops. Since RNA is charged, metal ions such as Mg^{2+} are needed to stabilize many secondary and tertiary structures.



3. **Explain the biological functions of nucleic acids.**

Ans: **<u>Biological functions of nucleic acids</u>**

Important functions are

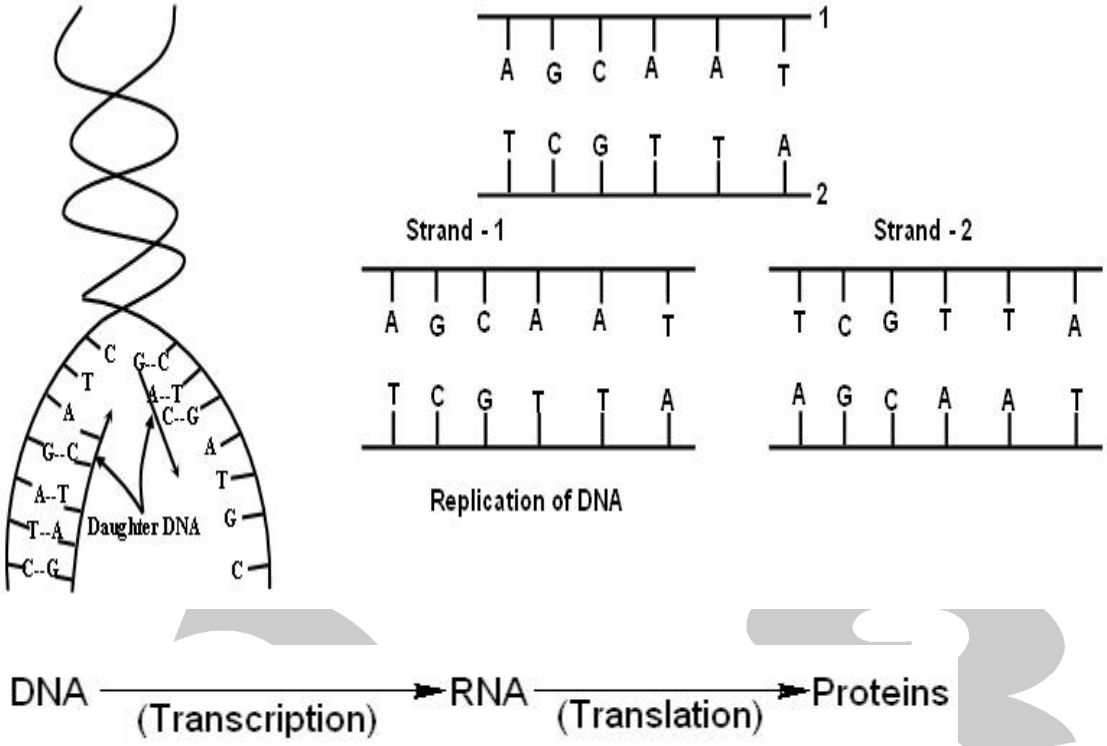
(1) Replication

(2) Protein synthesis → Transcription

(2) Protein synthesis → Translation

1. <u>Replication</u>

Process by which a single DNA molecule produces two identical copies of itself is called replication. Replication of DNA is an enzyme catalyzed process. In this process, two strands of DNA helix unwind and each strand serves as a template or pattern for the synthesis of a new strand. Newly synthesized complementary strand is an exact copy of the original DNA. In this way hereditary characteristics are transmitted from one cell to another.



Transcription:

- It is the process of synthesis of RNA (mRNA) by using DNA as template. This process is similar to replication process. Differ in following ways.
- In transcription, ribose nucleotide assemble along the uncoiled template instead of deoxyribose nucleotide and base uracil (U) is substituted for the base thymine (T).
- Synthesis of RNA or DNA always takes place in 5' - 3' direction. Process is catalyzed by an enzyme RNA polymerase. In this way DNA transfers its genetic code to mRNA.
- After synthesis, RNA detaches from DNA and moves from nucleus to the cytoplasm where it acts as template for protein synthesis. DNA returns to its double helix structure.

Translation:

- It is the process of synthesis of protein. This process is directed by mRNA in the cytoplasm of cell with the help of tRNA (transfer RNA) and ribosomal particles (RNA – protein complex).
- The process occurs with the attachment of mRNA to ribosome particle mRNA then gives the message of the DNA and dictates the specific amino acid sequence for the synthesis of protein.

- 4 bases in mRNA act in the form of triplets and each triplet acts as a code for a particular amino acid. This triplet is called codon. There may be more than one codon for same amino acid. E.g. amino acid methionine has code AUG while glycine has 4 codons GGU, GGC, GGA, GGG.
- These codon expressed in mRNA is read by tRNA carrying anticodon and is translated into an amino acid sequence. This process is repeated again and again thus proteins are synthesized. After completion, it is released from ribosome.