MOLECULAR BASIS OFINHERITANCE

1. Nucleic Acids

These are long polymers of nucleotides. Two types of nucleic acids are found in living systems, i.e. RNA and DNA.

2. Search for Genetic Material

Frederick Griffith, carried out a series of experiments with Streptococcus pneumoniae and discovered the genetic material as the transforming principle. Avery, Macleod and McCarty worked to determine the biochemical nature of Griffith's transforming principle. They proved that DNA is the hereditary material. Hershey-Chase experiment with bacteriophage porved that DNA is the genetic material that is passed from one generation to the next.

(i) **DNA** acts as the genetic material in most organisms. It is a long polymer of deoxyribonucleotides. It codes for all the metabolic processes of life.

(ii) **RNA** helps in the transfer and expression of information. It functions as messenger RNA (mRNA) for the translation of proteins.

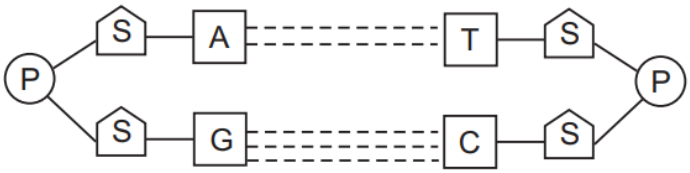
(iii) **Nucleoside and nucleotide**A nucleoside is formed when a nitrogenous base is linked to a pentose sugar through N-glycosidic linkage. A nucleotide is the basic unit of DNA and RNA, composed of a nitrogenous base, a pentose sugar and a phosphate group.

(iv) **Nitrogenous bases** are of two types, i.e. purines (adenine, guanine) and pyrimidines (cytosine, uracil, thymine).

RNA contains uracil in place of thymine. Two types of sugars are present in RNA and DNA, i.e. ribose and deoxyribose, respectively.

- RNA functions as an adapter, structural and a catalytic molecule.
- RNA also acts as a genetic material in some viruses.
- Although both RNA and DNA can act as genetic material, but DNA being chemically and structurally more stable is a better choice.

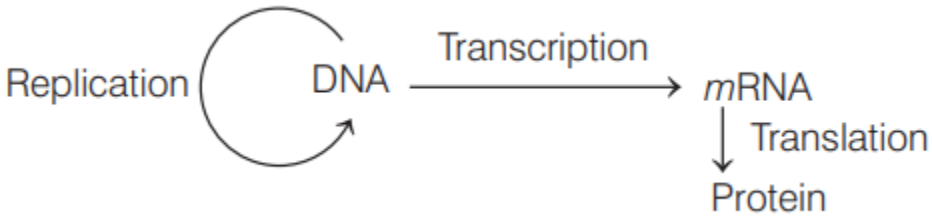
■ RNA was the first to evolve and DNA was derived from RNA. In DNA, adenine pairs with thymine through two H-bonds, while the guanine pairs with cytosine through three H-bonds. This makes one strand complementary to the other.



Polynucleotide chain

3. Central Dogma of Molecular Biology

Francis Crick proposed the 'Central dogma' in molecular biology which states that genetic information flows in the following manner.



4.Genetic Material in Prokaryotic and Eukaryotic Cells

(i) In **prokaryotic cells**, DNA (negatively charged) is held together with some proteins (positively charged) in a region known as nucleoid.

(ii) In **eukaryotic cells**, there is a set of positively charged proteins called histones which are organised to form a unit of eight molecules called histone octamer. The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called nucleosome which is the unit of compaction.

5. Packaging of Chromatin

The packaging of chromatin at higher level requires additional set of proteins that are collectively called as Non-Histone Chromosomal (NHC) proteins.

6. Euchromatin and Heterochromatin

Some regions of chromatin which are loosely packed (stain light) are called euchromatin (active chromatin). In some regions, chromatin is densely packed (stain dark), it is called heterochromatin (inactive chromatin).

7. Replication of DNA

The DNA replicates semiconservatively. According to this scheme, the two strands of double-helix would separate and act as a template for the synthesis of new complementary strands. The process is guided by complementary H-bonding. The process is catalysed by various sets of enzymes which are as follows

(i) DNA dependent DNA polymerase, uses DNA template to catalyse the polymerisation of deoxynucleotides.

(ii) DNA helicase, unwinds DNA strand for the formation of a replication fork.

(iii) DNA ligase, facilitates the joining of DNA strands together by catalysing the formation of phosphodiester bond. On 3 5 ′ → ′ strand, replication is continuous and

on 5 3 ′ → ′ strand, it is discontinuous. DNA replication begins at a specific and fixed position of DNA molecule known as **origin of replication**.

8. Types of RNA

There are following three types of RNA, i.e. messenger RNA (mRNA) which provides the template for transcription, transfer RNA (tRNA), which brings amino acids and reads the genetic code and ribosomal RNA (rRNA), which plays structural and catalytic role during translation.

Note tRNA is an adapter molecule which can read the code on one end and on the other end could bind to the specific amino acid. tRNA has five loops, i.e. anticodon loop, amino acid acceptor end, T-loop, D-loop and variable loop. It is a clover leaf-shaped molecule.

Transcription in Eukaryotes and Prokaryotes Transcription is the process of copying genetic information from one strand of the DNA into RNA. In this only a segment of DNA or only one out of the two strands is copied into RNA.

(i) In prokaryotes, like bacteria, the transcribed mRNA is functional, so it can be directly translated.

(ii) In eukaryotes, the genes are split. The coding sequences, i.e. exons are interrupted by non-coding sequences, i.e. introns. Introns are removed and exons are joined together to produce functional RNA. This is called splicing. A transcription unit in DNA has three regions, i.e. a promoter, the structural gene and a terminator.

9. Post Transcriptional Modifications

Heteronuclear RNA (hnRNA) The hnRNA undergoes two additional processes

(i) Capping, where methyl guanosine triphosphate, is added to the 5 ′ end of hnRNA.

(ii) Tailing, where adenylate residues (200-300) are added at 3 ′ end in a template independent manner.

10. Genetic Code

It is the relationship between the sequence of nucleotides on mRNA and the sequence of amino acids in the polypeptide.

(i) Artificial synthesis of genetic code Dr. Har Gobind Khorana, developed a chemical method for the synthesis of RNA molecule with defined base combination to develop a genetic code.

(ii) Important features of genetic code It has following features

- Genetic code is unambiguous and specific, i.e. one codon codes for only one amino acid.
- Codon is triplet and degenerate.
- The genetic code is universal, i.e. one codon codes for the same amino acid in all organisms.
- AUG codon has dual function, i.e. it codes for the amino acid methionine (met) and also acts as an initiation codon.
- Three codons do not code for any amino acid, hence they function as stop codon, e.g. UAA, UGA, UAG.

11. Translation

The process of polymerisation of amino acids to form a polypeptide is known as translation. In this process, proteins are synthesised from mRNA with the help of ribosomes.

(i) Ribosome exists as two subunits in inactive state, i.e. small subunit and large subunit.

(ii) Different phases of translation are

- Initiation of polypeptide synthesis
- Elongation of polypeptide chain
- Termination of polypeptide synthesis

12. Gene Expression in Prokaryotes and Eukaryotes

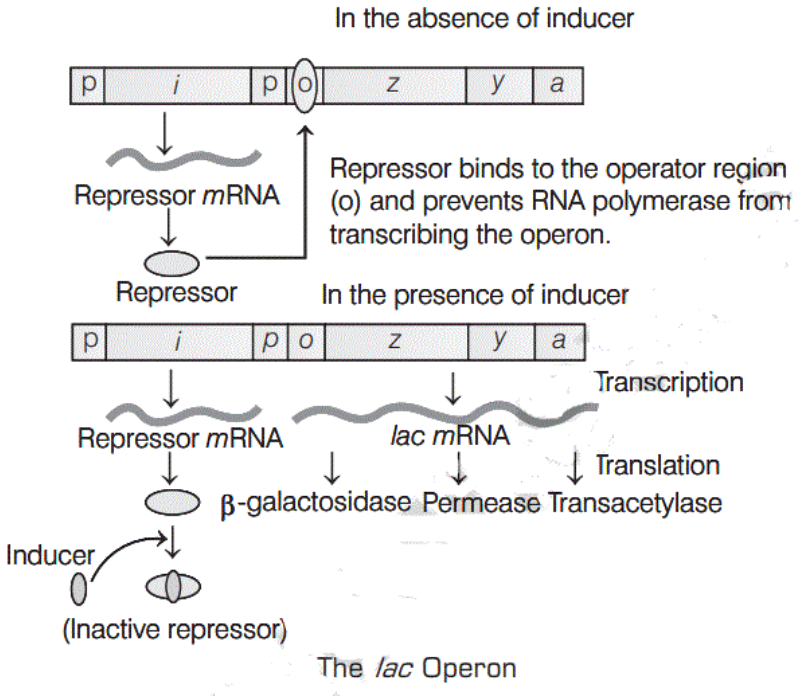
Regulation of gene expression occurs at various levels. Gene expression results in the formation of a polypeptide.

(i) In prokaryotes, it is regulated by the rate of initiation of transcription and in eukaryotes, regulation is achieved at the following four levels

- Transcriptional level (formation of primary transcript).
- Processing level (regulation of splicing).
- Transport of mRNA from nucleus to the cytoplasm.
- Translational level.

(ii) Operon is a transcriptionally regulated system, where a polycistronic structural gene is regulated by a common promoter and regulatory genes, e.g. lac (lactose) operon, ara (arabinose) operon, his (histidine) operon, val (valine) operon, etc. Lac operon was proposed by Francois Jacob and Jacque Monod.

(iii) Lac operon is the prototype (inducible) operon in bacteria, which codes for genes responsible for the metabolism of lactose.



The *lac* Operon

- The operon is regulated by the amount of lactose in the medium, where the bacteria are grown. Therefore, this regulation can also be viewed as regulation of enzyme synthesis by its substrate.

13. Human Genome Project

It was a mega project of 13 years. It was aimed to sequence every base in human genome. This project has yielded a lot of new information. Many new areas and avenues have opened up as a consequence of this project.

14. Rice Genome Project

Rice was the first crop whose genome was sequenced. It was a project of 10 years. It provided an excellent opportunity to illustrate the impact on plant biology and breeding. The knowledge of genetic code of rice helps breeders to develop strains of the crop with specific characteristics (e.g. stress tolerance, disease resistance or high yield).

15. DNA Fingerprinting

It is a technique used to find out variations in individuals of a population at DNA level. It works on the principle of polymorphism in DNA sequences. It has immense applications in the field of forensic science, genetic biodiversity, evolutionary biology and kinship relationships. (The technique has the following steps)

(i) DNA isolation

(ii) Amplification

(iii) Separation of DNA fragments by electrophoresis

(iv) Blotting (transfer of the separated DNA fragments to synthetic membranes like nylon or nitrocellulose)

(v) Hybridisation

(vi) Autoradiography