Chapter-10 Molecular Basis of Inheritance

1. Distinguish between heterochromatin and euchromatin. Which of the two is transcriptionally active?

A: Densely packed and dark stained chromatic regions are called Heterochromatin. Loosely packed light stained regions are called Euchromatin. Euchromatin is transcriptionally active.

2. Who proved that DNA is the genetic material? What is the organism they worked on?

A: Alfred Hershey and Martha Chase.

They worked on bacteriophages that infect bacteria.

3. What is the function of DNA polymerase?

A: 1.It catalyzes polymerisation of deoxyribonucleotides in 5'→3' direction.

2. It separates two strands of DNA by breaking hydrogen bonds between them.

3. It proof reads mismatching during polymerization. (in 3'→5' direction).

4. What are the components of a nucleotide?

A: Nitrogen base, Pentose sugar and Phosphate.

5. Given below is the sequence of coding strand of DNA in a transcription unit.

5'A A T G C A G C T A T T A G G-3'

Write the sequence of

a) Its complementary strand.

b) The mRNA.

A: a) 3'T T A C G T C G A T A A T C C-5' b) 5'A A U G C A G C U A U U A G G-3'

6. Name any three viruses which have RNA as genetic material?

A: Tobacco Mosaic Virus, QB bacteriophage, HIV, Polio etc

7. What are the components of a transcriptional unit?

A: Promoter, Terminator and Structural genes are the components of transcriptional unit.

8. What is the difference between exons and introns?

A: In a transcriptional unit the coding sequences or expressing sequences are exons. Exons appear in mature or processed RNA.

Introns are the intervening or interrupting sequences that do not appear in mature or processed RNA.

9. What is meant by capping and tailing?

A: In post transcriptional changes of mRNA addition of methyl gaunosine triphosphate to the 5' end is called as capping.

Addition of adenylated residues(200-300) to the 3' end is called as tailing.

10. What is meant by point mutation? Give an example?

A: Mutations involving a single base pair of DNA are called as point mutations.

E.g. Sickle cell anemia in humans.

11. What is meant by charging of tRNA?

A: In the first phase or translation phase, amino acids are activated by ATP. The linking of activated amino acid to the cognate tRNA is called charging of tRNA or amino acylation of tRNA.

12. What is the function of the codon AUG?

A: AUG is the starting codon. It codes for methionine.

13. Define stop codon. Write the codons?

A: Stop codon is a terminating codon. They do not code for any amino acids, hence they stop the protein synthesis. They are UAA, UAG and UGA.

14. What is the difference between the template strand and a coding strand in a DNA molecule?

A: One of the two strands i.e. 5'→3' which is having genetic code is called coding strand. The complementary strand i.e. 3'→5' strand is called template strand.

15. Write any two differences between DNA and RNA?

A: 1. Sugar in DNA is 2'deoxyribose sugar and in RNA it is ribose sugar.

2. Thymine is present in DNA and in RNA it is replaced with Uracil.

16. In a typical DNA molecule, the proportion of Thymine is 30% of the N bases. Find out the percentages of other N bases?

A: If Thymine is 30% Adenine must also be 30% as both are complementary. Guanine will be 20% and Cytosine also 20%. (A+G = C+T).

17. The proportion of nucleotides in a given nucleic acid are: Adenine 18%, Guanine 30%, Cytosine 42% and Uracil 10%. Name the nucleic acid and mention the number of strands in it?

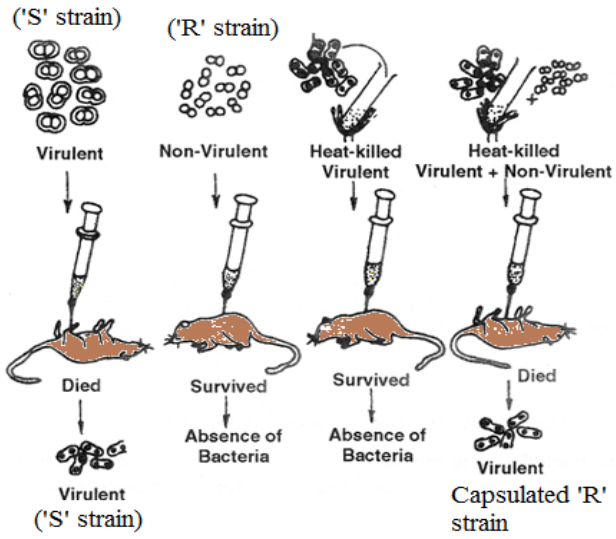
A: It is a single stranded RNA as Uracil is present.

Nucleic acids are Adenosine triphosphate, Guanosine triphosphate, Cytosine triphosphate and Uridine triphosphate.

Short Answer Type Questions

1. Define transformation in Griffith's experiment. Discuss how it helps in the identification of DNA as genetic material?

Ans: Genetic alteration resulting from the transfer of genetic material from one bacterium to the other bacterium through the medium without any physical contact between the bacteria is called as transformation. In molecular it is the uptake of external genetic material by any cell.



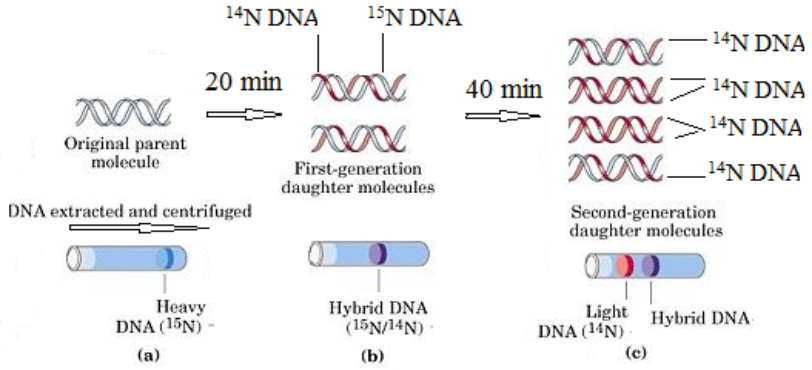
Bacterial transformation experiments conducted by Griffith

In Griffith's experiment when heat killed 'S' strain and 'R' strain together injected into mice the mice developed disease and died. He found 'R' strain with capsule in the body of mice. He concluded that 'R' strain somehow transformed by the heat killed 'S' strain. The biochemical nature of genetic material was not defined from his experiments. It is left to the Oswald Avery, MacLeod, McCarthy in 1944 to prove the biochemical nature of 'transforming principal' of Griffith's experiment. The genetic material was thought to be a protein prior to their work.

They purified the biochemicals from heat killed 'S' strain and found to contain protein, DNA, RNA etc. They also found that protein-digesting enzymes, proteases, and RNA-digesting enzymes, RNases, did not affect transformation, so the transforming substance was not a protein or RNA. Digestion with DNase inhibited transformation, suggesting that the DNA caused the transformation. They concluded that DNA is the hereditary material.

2. Discuss the significance of heavy isotope of nitrogen in Meselson and Stahl's experiment.

Ans: Isotopes are variants of a particular element with **different mass number** but same atomic number. In biological sciences isotopes of many elements are used in various laboratory **techniques**. Isotopes are **used in labeling** a specific chemical compound so that they can be identified in metabolic processes.



DNA is composed of **Nitrogen Bases**, Sugar and phosphate. Nitrogen bases can be labeled with heavy isotopes of nitrogen **^{15}N**.As these molecules are heavier than normal **^{14}N** molecule they can be distinguished by **density gradient centrifugation**.

Meselson and Stahl used this technique in proving that replication of DNA is semiconservative.

They grew ***E. coli*** in a medium containing $^{15}NH_4Cl$ as the only nitrogen source for many generations. The result was that **^{15}N** was incorporated into newly synthesised DNA. This heavy DNA molecule could be distinguished from the normal DNA by centrifugation in a cesium chloride (CsCl) density gradient which settles at the bottom.

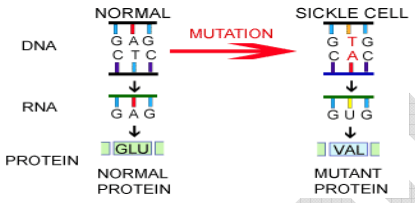
Then they transferred the cells into a medium with normal $^{14}NH_4$ Cl. The DNA that was extracted from the culture after one generation (20 min) after the transfer from **^{15}N** to ^{14}N medium was a **hybrid** or intermediate density. DNA extracted from the culture after another generation [that is after 40 minutes, II generation] was composed of **equal amounts of this hybrid DNA and of 'light' DNA**.

The experiments proved that the DNA in chromosomes also **replicate semiconservatively**.

3. A single base mutation in a gene may not always result in loss or gain of function. Do you think the statement is correct? Defend your answer.

Ans: The **statement is correct**.

Loss or Gain of Function:A single base pair mutation are called point mutations. The mutation may involve addition or deletion. This results loss or gain in the function. A classical example of such a mutation is sickle cell anemia. Due to mutation in a single nucleotide of the gene for haemoglobin, from **GAG to GUG**, this results in **Glutamic acid** replaced with **Valine** in the 6th codon. Deletions and insertions of base pairs of DNA, causes **frame-shift mutations**.



No **Loss or Gain of Function:** One of the important features of the Genetic Code is **'degeneracy'** of the code. Usually one codon codes for one amino acid . But some amino acids are coded by more than one codon. This is called as 'degeneracy' of the code.

e.g. **Leusine** coded by **6 codons**, **Valine** coded by **4 codons.**

In triplet codons of these amino acids point mutation, in the third base of these codons, do not result in a change in the sequence of amino acids in the protein during translation.

GUU, GUC, GUA, GUG all code for Valine.

Hence we can say 'A single base mutation in a gene may not always result in loss or gain of function'.

4. How many types of RNA polymerases exist in cells? Write their names and functions.

Ans: RNA polymerase is the enzyme responsible for the synthesis of RNAs. This enzyme is present in both prokaryotes and eukaryotes.

In Eukaryotes there are at least **three RNA polymerases in the nucleus**, in addition to the RNA polymerase found in the organelles.

RNA polymerase I,

RNA polymerase II,

RNA polymerase III.

There is a clear cut division of labour.

RNA polymerase I: The enzyme RNA polymerase I present in the nucleolus is responsible for transcribing the genes coding for rRNAs (**28S, 18S, and 5.8S**).

RNA polymerase II: The other major enzyme is RNA polymerase II present in nucleoplasm is responsible for synthesizing **heterogenous nuclear RNA (hnRNA), the precursor for mRNA.**

RNA polymerase III: The RNA polymerase III is present in nucleoplasm responsible for transcription of **tRNA**, **5srRNA**, and **snRNAs** (small nuclear RNAs).

In addition to these a distinct RNA polymerase is present in cell organelles mitochondria and chloroplasts with their small genomes.

In prokaryotes a single type of RNA polymerase is responsible for all synthesis of mRNA, rRNA and tRNA

5. What are the contributions of George Gamow, H.G.Khorana, and Marshall Nirenberg in deciphering the genetic code?

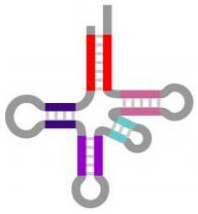
Ans: **George Gamow**, a physicist, proposed that since there are **only 4 bases** and if they have to code for 20 amino acids, the code should constitute a combination of bases. He suggested that in order to code for all the 20 amino acids, the code should be made up of three nucleotides. This was a very important proposition, because a permutation combination of $\mathbf{4^3}$ **(4 × 4 × 4)** would generate 64 codons; generating many more codons than required. Single nucleotide 4^1 or combinations of two nucleotides 4^2(4×4) fell short of required 20.

Har Gobind Khorana provided proof that the codon was a triplet. The chemical method developed by Har Gobind Khorana was instrumental in synthesising RNA molecules with defined combinations of similar bases such as UUU or GGG (homopolymers) and different bases such as UUC or CCA (copolymers). He elucidated the codons of all the amino acids.

Marshall Nirenberg's adopted a different method. He developed cell-free system for protein synthesis and finally helped the code to be deciphered.

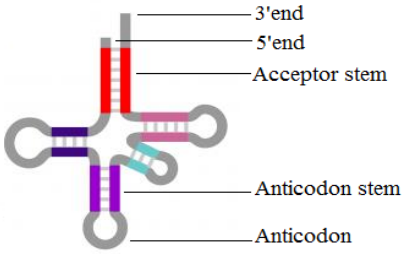
Severo Ochoa enzyme (polynucleotide phosphorylase) was also helpful in polymerising RNA with defined sequences in a template independent manner (enzymatic synthesis of RNA). Finally a checker-board for genetic code was prepared.

6. On the diagram of the secondary structure of tRNA shown below, label the location of the following parts:



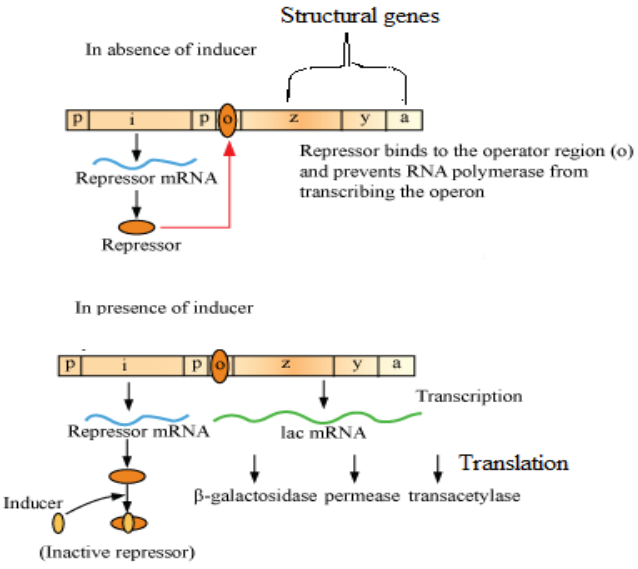
a) Anticodon b) Acceptor stem c) Anticodon stem d)5' end e) 3' end

Ans:



7. Draw the schematic/ diagrammatic presentation the operon.

Ans:



8. What are the differences between DNA and RNA.

Ans:

	DNA	RNA
1	Consists of **two strands** of nucleotides	Consists of only **one strand** of nucleotides
2	Most of the DNA is present in Nucleus and very little in the cytoplasm in chloroplasts and mitochondria	Most of the RNA is present in cytoplasm and very little inside the nucleus
3	Sugar is the Deoxyribose sugar ($C_5H_{10}O_4$)	Sugar is the Ribose sugar ($C_5H_{10}O_5$)
4	Pyrimidines are '**Thymine and Cytosine'**.	Pyrimidines are **'Uracil and Cytosine'**.
5	DNA is made up of **several nucleotides**(more than 4 million)	RNA is made up of **few nucleotides** (75-2000 or more in mRNA)
6	DNA undergoes **self replication**.	RNA **does not undergo self replication**. Exception in RNA viruses.
7	DNA is the genetic material.	RNA is non-genetic material.(Except in RNA viruses).In some biochemical reactions it acts as a catalyst.
8	DNA **does not participate directly in protein synthesis.**	RNA participates directly in protein synthesis.
9	Metabolically DNA is of **one type**.	Metabolically RNA is of three types.(mRNA, rRNA, tRNA)
10	The base pairing is **A= T** and G ≡ C	The base pairing is **A = U** and G ≡ C

11	DNA can be damaged by exposure to ultra-violet rays.	RNA is **more resistant** to damage by Ultra-violet rays.
12	Deoxyribose sugar in DNA is less reactive because of C-H bonds.(More stable)	Ribose sugar is more reactive because of C-OH (hydroxyl) bonds. (Less stable)

9. Write the important features of Genetic code.

Ans: The important features of Genetic code are as follows:

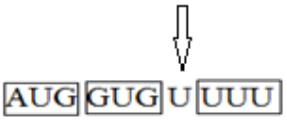
1. The codon is **triplet.** Three nitrogen bases specify one amino acid.

2. 61 codons code for amino acids and 3 codons do not code for any amino acids, hence they function as **stop codons or termination codons.** These are **UAA, UAG UGA**.

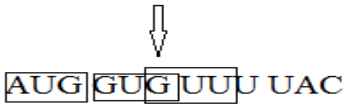
3. One codon codes for only one amino acid, hence, it is **unambiguous** and **specific**.

4. Some amino acids are coded by more than one codon, hence the code is **degenerate**.

5. The codon is read in mRNA in a contiguous fashion. There are no punctuations. i.e every nucleotide participate in a codon. No nuclcleotide is left without participating in any codon.



6. Code is non-over lapping. One nitrogen base is not a part of more than one codon.



7. The code is nearly **universal**: for example, from bacteria to human UUU would code for Phenylalanine (phe). Some exceptions to this rule have been found in mitochondrial codons, and in some protozoans.

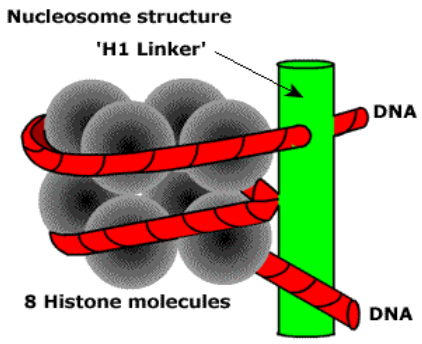
8. AUG has dual functions. It codes for **Methionine** (met) , and it also act as **initiator** codon.

10. Write briefly on Nucleosomes.

Ans: In eukaryotes, the organization of DNA is complex.

There is a set of **positively charged**, basic proteins called **histones**.

Histones are rich in the basic amino acid residues **lysines** and **arginines**. Both the amino acid residues carry positive charges in their side chains.



Histones are organised to form a unit of eight molecules called as **histone octamer**.

The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called **nucleosome** .

A typical nucleosome contains **200 bp of DNA helix**.

Nucleosomes constitute the repeating unit of a structure in nucleus called **chromatin,** thread-like stained (coloured) bodies seen in nucleus.

The nucleosomes in chromatin are seen as **'beads-on-string'** structure when viewed under electron microscope.

The beads-on-string structure in chromatin is packaged to form chromatin fibers that are further coiled and condensed at **metaphase stage** of cell division to form chromosomes.