UNIT II

Chapter 5

MOLECULAR GENETICS

CHAPTER SNAPSHOT

Chapter 5

Evaluation

1. Hershey and Chase experiment with bacteriophage showed that
(a) Protein gets into the bacterial cells
(b) DNA is the genetic material
(c) DNA contains radioactive sulphur
(d) Virusus undergo transformation
[Ans. (b) DNA is the genetic material]

2. DNA and RNA are similar with respect to
(a) Thymine as a nitrogen base
(b) A single-stranded helix shape
(c) Nucleotide containing sugars, nitrogen bases and phosphates
(d) The same sequence of nucleotides for the amino acid phenyl alanine
[Ans. (c) Nucleotide containing sugars, nitrogen bases and phosphates]

3. A mRNA molecule is produced by
(a) Replication (b) Transcription
(c) Duplication (d) Translation
[Ans. (b) Transcription]

4. The total number of nitrogenous bases in human genome is estimated to be about
(a) 3.5 million (b) 35000
(c) 35 million (d) 3.1 billion
[Ans. (d) 3.1 billion]

5. *E. coli* cell grown on ^{15}N medium are transferred to ^{14}N medium and allowed to grow for two generations. DNA extracted from these cells is ultracentrifuged in a cesium chloride density gradient. What density distribution of DNA would you expect in this experiment?
(a) One high and one low density band
(b) One intermediate density band
(c) One high and one intermediate density
(d) One low and one intermediate density band
[Ans. (d) One low and one intermediate density band]

6. What is the basis for the difference in the synthesis of the leading and lagging strand of DNA molecules?
(a) Origin of replication occurs only at the 5' end of the molecules.
(b) DNA ligase works only in the 3' → 5' direction
(c) DNA polymerase can join new nucleotides only to the 3' end of the growing stand.
(d) Helicases and single-strand binding proteins that work at the 5' end.
[Ans. (c) DNA polymerase can join new nucleotides only to 3' end of the growing stand.]

7. Which of the following is the correct sequence of event with reference to the central dogma?
(a) Transcription, Translation, Replication
(b) Transcription, Replication, Translation
(c) Duplication, Translation, Transcription
(d) Replication, Transcription, Translation
[Ans. (d) Replication, Transcription, Translation]

8. Which of the following statements about DNA replication is not correct?
(a) Unwinding of DNA molecule occurs as hydrogen bonds break.
(b) Replication occurs as each base is paired with another exactly like it.
(c) Process is known as semi conservative replication because one old strand is conserved in the new molecule.
(d) Complementary base pairs are held together with hydrogen bonds.
[Ans. (b) Replication occurs as each base is paired with another exactly like it]

9. Which of the following statements is not true about DNA replication in eukaryotes?
(a) Replication begins at a single origin of replication.
(b) Replication is bidirectional from the origins.
(c) Replication occurs at about 1 million base pairs per minute.
(d) There are numerous different bacterial chromosomes, with replication ocurring in each at the same time.
[Ans. (d) There are numerous different bacterial chromosomes, with replication ocurring in each at the same time]

10. **The first codon to be deciphered was _____ which codes for _____.**

(a) AAA, proline (b) GGG, alanine
(c) UUU, Phenylanine (d) TTT, arginine

[Ans. (c) UUU, Phenylanine]

11. **Meselson and Stahl's experiment proved**

(a) Transduction
(b) Transformation
(c) DNA is the genetic material
d) Semi-conservative nature of DNA replication

[Ans. (d) Semi-conservative nature of DNA replication]

12. **Ribosomes are composed of two subunits; the smaller subunit of a ribosome has a binding site for _____ and the larger subunit has two binding sites for two _____.**

[Ans. (mRNA, tRNA)]

13. **An operon is a:**

(a) Protein that suppresses gene expression
(b) Protein that accelerates gene expression
(c) Cluster of structural genes with related function
d) Gene that switched other genes on or off

[Ans. (c) Cluster of structural genes with related function]

14. **When lactose is present in the culture medium:**

(a) Transcription of *lac y*, *lac z* a genes
(b) Repressor is unable to bind to the operator
(c) Repressor is able to bind to the operator
d) Both (a) and (b) are correct

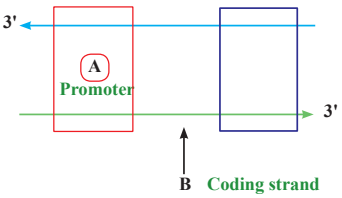
[Ans. (d) Both (a) and (b) are correct]

15. **Give reasons: Genetic code is 'universal'.**

Ans. The genetic code is universal. It means that all known living systems use nucleic acids and the same three base codons (triplet codon) direct the synthesis of protein from amino acids. For example, the mRNA (UUU) codon codes for phenylalanine in all cells of all organisms. Some exceptions are reported in prokaryotic, mitochondrial and chloroplast genomes. However similarities are more common than differences. Most part of the genetic code is universal in prokaryotes and eukaryotes.

16. **Name the parts marked 'A' and 'B' in the given transcription unit.**

Ans.



17. **Differentiate - Leading strand and lagging strand.**

Ans. During DNA replication, One acts as the leading strand and the other is the lagging strand.

Leading Strand	Lagging Strand
1) During DNA replication among the two strands of DNA one strand acts as the template strand in which the replication continuous and called leading strand.	1) During DNA replication among the two strands of DNA one strand acts as the coding strand and replication, is discontinuous in this strand known as lagging strand.
2) The polarity of this strand is $3' \rightarrow 5'$	2) The polarity of this strand is $5' \rightarrow 3'$
3) No okazaki fragments are formed.	3) Discontinuous fragments called okazaki fragments are formed which are joined by the enzyme DNA ligase.

18. **Differentiate - Template strand and coding strand.**

Ans.

Template Strand	Coding Strand
1) In transcriptional unit in DNA, one strand has with DNA - dependent RNA polymerase catalysing the polymerisation in only one direction, This strand acts as a template, known as template strand.	1) In transcriptional unit in DNA, one strand with a sequence same as RNA (except thymine at the place of uracil) and is displaced during transcription, is known as coding strand.
2) This strand has the polarity is $3' \rightarrow 5'$ direction.	2) This strand has the polarity $5' \rightarrow 3'$ direction

27. What are the three structural differences between RNA and DNA?

Ans. Structural difference between DNA and RNA.

DNA	RNA
1) It contains De oxyribose sugar	1) It contains Ribose sugar
2) DNA structure is a double helix	2) RNA has a single strand
3) The nitrogenous bases consist of Adenine, Guanine, Thymine, Cytosine	3) The nitrogenous bases consist of Adenine, Guanine, Uracil and Cytosine.

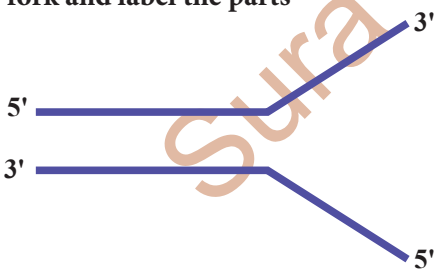
28. Name the anticodon required to recognize the following codons: AAU, CGA, UAU, and GCA.

Ans.

CODON	Anticodon
1) AAU	1) UUA
2) CGA	2) GCU
3) UAU	3) AUA
4) GCA	4) CGU

29. a) Identify the figure given below

b) Redraw the structure as a replicating fork and label the parts

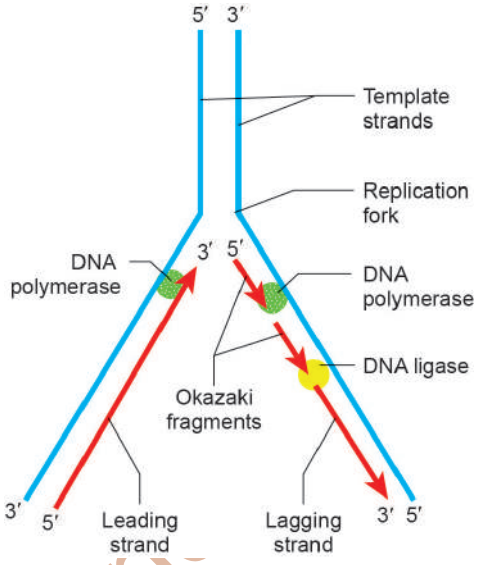


(c) Write the source of energy for this replication and name the enzyme involved in this process.

(d) Mention the differences in the synthesis of protein, based on the polarity of the two template strands.

Ans. (a) The figure shows the semiconcervative mode of DNA Replication - A Replication fork is seen.

(b)



(c) Source of energy for the replication is Deoxy nucleotide triphosphate provides energy for the process. The enzymes required for replication are different types of DNA polymerase. DNA helicase helps in unwinding of DNA. DNA ligase helps to join broken DNA fragments.

(d) During transcription process, the DNA dependent RNA polymerase enzyme catalyses the polymerisation in only one direction (3' → 5') which acts as template and is called template strand. The other strand with polarity 5' → 3' is displaced during transcription. Therefore the mRNA base sequence is complementry to the template strand only. mRNA brings the information for the formation of proteins. Thus the synthesis of protein is based on the sequence of the template strand of DNA with polarity 3' → 5'.

30. If the coding sequence in a transcription unit is written as follows:
5'TGCATGCATGCATGCATGCATGC 3'
Write down the sequence of mRNA.

Ans. Sequence of mRNA for the given coding unit
3' ACGUACGUACGUACGUACGUACG 5'

31. How is the two stage process of protein synthesis advantageous?

Ans. (i) Protein synthesis comprises two major parts - transcription and translation. The process involves ribonucleic acid (RNA), deoxyribonucleic acid (DNA), and a

set of enzymes. All types of ribonucleic acids, namely messenger ribonucleic acid (mRNA), ribosomal ribonucleic acid (rRNA), and transfer ribonucleic acid (tRNA) are required for protein synthesis.

(ii) Accordingly, protein synthesis of a specific amino acid sequence takes place. Overall, the process of protein synthesis involves transcription of DNA to mRNA, which is then translated into proteins. This process requires proper coordination of RNA, DNA, enzymes, and ribosomes.

32. Why did Hershey and Chase use radioactively labelled phosphorous and sulphur only? Would they have got the same result if they use radiolabelled carobon and nitrogen?

Ans. *(i)* **Alfred Hershey** and **Martha Chase** (1952) conducted experiments on bacteriophages that infect bacteria.

(ii) Hershey and Chase wanted to observe whether it was DNA or protein that entered the bacteria.

(iii) All nucleic acids contain phosphorus and contain sulphur (in the amino acid cysteine and methionine)

(iv) Hershey and Chase used radioactive isotopes of Sulphur (^{35}S) and phosphorus (^{32}P) to keep separate track of the viral protein and nucleic acids during the infection process.

(v) The phages were allowed to infect bacteria in culture medium which contained the radioactive isotopes ^{35}S or ^{32}P.

(vi) The bacteriophage that grew in the presence of ^{35}S had labelled proteins and bacteriophages grown in the presence of ^{32}P had labelled DNA.

(vii) The differential labelling thus enabled them to identify DNA and proteins of the phage.

(viii) Hershey and Chase mixed the labelled phages with unlabelled *E. coli* and allowed bacteriophages to attack and inject their genetic material.

(ix) It was observed that only ^{32}P was found associated with bacterial cells and ^{35}S was in the surrounding medium and not in the bacterial cells. When phage progeny was studied for radioactivity, it was found that it carried only ^{32}P and not ^{35}S.

(x) Hershey and Chase thus conclusively proved that it was DNA, not protein, which carries the hereditary information from virus to bacteria.

(xi) If they had used radioactive labelled carbon and nitrogen they would have not got the same result because carbon and nitrogen are found in DNA and protein.

(xii) If they had used radioactive labelled carbon and nitrogen these labelled molecules would have been found in DNA and proteins and they would never be able to prove whether DNA or protein of a virus causes the heredity information

33. Explain the formation of a nucleosome.

Ans. *(i)* In eukaryotes, chromatin is formed by a series of repeating units called **nucleosomes.**

(ii) Korenberg proposed a model for the nucleosome, in which 2 molecules of the four histone proteins H2A, H2B, H3 AND H4 are organized to form a unit of eight molecules called **histone octamere.**

(iii) 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.

(iv) The histone octameres are in close contact and DNA is coiled on the outside of nucleosome.

(v) Neighbouring nucleosomes are connected by linker DNA (H1) that is exposed to enzymes. The DNA makes two complete turns around the histone octameres and the two turns are sealed off by an H1 molecule

(vi) Chromatin lacking H1 has **beads on a string** appearance in which DNA enters and leaves the nucleosomes at random places.

(vii) H1 of one nucleosome can interact with H1 of the neighbouring nucleosomes resulting in the further folding of the fibre.

5. There are no tRNA for stop codons.

Ans. The stop codons serve to indicate the termination of protein synthesis. Therefore when any one of the stop codons (UAA, UAG, UGA) appear on the mRNA. It will signal the action of GTP-dependent release factor which cleaves the polypeptide chain from the terminal tRNA. The tRNA will further be released from ribosomes.

6. Human Genome Project can aim at a 'Perfect Race'.

Ans. Human Genome Project has identified all the genes in Human DNA and can create lot of possibilities for new gene therapies. Attempts will be made to "breed out" certain genes from the human population with the aim to create a "Perfect race" of humans. This can have lot of disastrous consequences.

7. VNTR can serve as genetic markers.

Ans. In DNA short repetitive nucleotide sequences are specific for a person. These nucleotide sequences are called as Variable and Number Tandem repeats (VNTR). The VNTRs of two persons generally show variations and are useful as genetic markers. This is applicable to DNA finger printing technique.

8. PCR is an important part of DNA finger printing technique.

Ans. PCR stands for Polymerase chain reaction. In many situations, there is only a small amount of DNA available for DNA finger printing. If needed many copies of the DNA can be produced by a method of DNA amplification called as PCR.

9. AUG has dual functions.

Ans. The codon AUG acts as a initiator codon and also codes for the amino acid methionine. Thus it is said to have dual functions.

10. HGT could have played a major role in evolution of life on earth.

Ans. In eukaryotic genes, the expressed sequences are called exons and intervening non-coding sequences are called introns. Introns or mobile DNA sequence can splice themselves out of, as well as into specific 'target sites' acting like mobile transposon-like elements (mediating transfer of genes between organisms). Such transfer is called as HGT-Horizontal Gene Transfer. This could have occurred between different lineages of cells and played a major role in the evolution of life on earth.

11. The genetic code is said to be Non-ambiguous.

Ans. ***(i)*** Non-ambiguous code means that one codon will code for one amino acid.

(ii) There are specific codons for each amino acid. **Eg:** AUG codes for methionine.

12. The triplet codon is described as 'degenerate code'.

Ans. .A degenerate code means that more than one triplet codon could code for a specific amino acid. For example: codons GUU, GUC, GUA and GUG code for valine.

Very Short Answers — 2 Marks

1. Differentiate between purines and pyrimidines.

Ans.

Purines	Pyrimidines
Purines have double carbon-nitrogen ring structures. **Eg:** Adenine and Guanine.	Pyrimidines have single ring structure. **Eg:** Thymine, Cytosine and Uracil.

2. Why is the term nucleic acid used for DNA and RNA?

Ans. The phosphate functional group (PO_4) present in DNA and RNA gives the property of an acid (releasing H^+ ion or proton in solution) at physiological pH. Hence the name nucleic acid.

3. What are nucleotides?

Ans. In nucleic acids (DNA and RNA), the nitrogenous base is chemically linked to one molecule of sugar forming a nucleotide.

When a phosphate group is attached to the nucleoside, it becomes a nucleotide. The nucleotides are polymerised to form a polynucleotide chain (DNA and RNA)

4. What is base pair rule?.

Ans. Erwin Chargaff changes observed that in DNA, Adenine pairs with Thymine (A = T) with two hydrogen bonds and Guanine pairs with Cytosine (G ≡ C) with three hydrogen bonds.

The ratios between Adenine with Thymine and Guanine with Cytosine are constant and equal. This base pairing gives a unique property to DNA.

5. What does 'RNA world' refer to?

Ans. The term 'RNA world' first used by **Walter Gilbert** in 1986, hypothesizes RNA as the first genetic material on earth. There is now enough evidence to suggest that essential life processes (such as metabolism, translation, splicing etc.,) evolved around RNA. RNA has the ability to act as both genetic material and catalyst.

6. What is genophore?

Ans. The DNA as a nucleoid is organized into large loops held by protein. DNA of prokaryotes is almost circular and lacks chromatin organization, hence termed **genophore.**

7. What is a nucleosome?

Ans. In eukaryotes, chromatin is formed by a series of repeating units called nucleosomes. It consists of a histone octamer. The negatively charged DNA is wrapped around the positively charged histone octamer to form a nucleosome.

8. Distinguish heterochromatin and euchromatin.

Ans.

Heterochromatin	Euchromatin
1) The Chromatin that is tightly packed (stains darkly) is called heterochromatin.	1) The Chromatin that is loosely packed (lightly straned) is called euchromatin.
2) It is transcriptionally inactive	2) It is transcriptionally active

Short Answers — 3 Marks

1. Mention any 3 rules as defined by classical concept of gene

Ans. According to the classical concept of gene introduced by Sutton in 1902, genes have been defined as discrete particles that follow Mendelian rules of inheritance, occupy a definite locus in the chromosome and are responsible for the expression of specific phenotypic character. They show the following properties:

(i) Number of genes in each organism is more than the number of chromosomes, hence several genes are located on the same chromosome.

(ii) The genes are arranged in a single linear order like beads on a string.

(iii) Each gene occupies a specific position called locus.

(iv) Genes may exist in several alternate forms called alleles.

2. State one gene one enzyme hypothesis.

Ans. The experiments of **George Beadle and Edward Tatum** in the early 1940's on *Neurospora crassa* (the red bread mould) led them to propose one gene-one enzyme hypothesis, which states that one gene controls the production of one enzyme. This is called one gene one enzyme hypothesis.

3. Differentiate DNA and RNA.

Ans.

DNA	RNA
1) It stands for De Oxyribo Nucleic acid.	1) It stands for Ribo Nucleic acid.
2) It contains De Oxyribose Sugar	2) It contains Ribose Sugar
3) The nitrogenous bases are adenine, guanine, thymine and cytosine.	3) The nitrogenous bases are adenine, guanine, uracil and cytosine.
4) It is a double stranded molecule.	4) It is a single stranded molecule.
5) DNA is the hereditary material in all living organisms.	5) RNA is the hereditary material only in some viruses.

4. Distinguish replication and transcription.

Ans.

Replication	Transcription
1) Replication is a process by which a DNA molecule makes as a copy of itself.	1) The process of copying genetic information from one strand of DNA into RNA is called transcription.
2) It takes place during 's' phase of cell cycle.	2) It takes place during protein synthesis.
3) It requires DNA and enzymes like DNA polymerases and Ligases.	3) It requires DNA and enzymes like RNA Polymerases.