314en23

23

MOLECULAR INHERITANCE AND GENE EXPRESSION

A cell contains the nucleus. Nucleus contains chromosomes, Chromosomes bear genes. Genes carry the hereditary information. A zygote has the information for development and differentiation of the embryo in its genes. Cells of an individual have the genes for maintaining their structure and function. What are these genes and how do they function? Genes are made of segments of the DNA. This lesson deals with the study of DNA as the genetic material, its structure and functioning at the molecular level.

OBJECTIVES

After completing this lesson, you will be able to :

- *discuss the concept of one gene one enzyme hypothesis;*
- *give the history of discovery of DNA as geneticc material;*
- *describe the general structure of DNA by referring to the terms nucleotides, nucleosides, purincs and pyrimidines;*
- *list the differences between DNA and RNA;*
- *mention the various categories of RNA and explain their functions;*
- *describe the modes of gene transfer, transformation, transduction and conjugation;*
- *explain the steps of DNA replication;*
- *explain the concept of central dogma;*
- *describe the sequence of steps during transcription and translation during protein sysnthcsis;*
- *trace the major steps in regulation of gene expression;*
- *define house-keeping genes and explain their role;*
- *categorise various types of mutations;*
- *define mutagen and list their different categories;*
- *highlight the useful and harmful effects of mutation.*

23.1 THE CONCEPT OF THE ONE GENE ONE ENZYME HYPOTHESIS

The British biochemist and physician Archibald Garrod had mentioned in his book named "Inborn errors of metabolism" that there are inherited genetic disorders such as **phenylketonuria** and **alkaptonuria** which are caused by the absence of particular enzymes. Beadle and Tatum working with the mutants of the fungus *Neurospora* showed that the absence of a gene in a mutant leads to absence of an enzyme in a metabolic pathway (chain of biochemical reactions) midway. Thus was proposed that **one gene was responsible for the production of one enzyme** and this was called the **one gene one enzyme hypothesis**. Later, it was found that an enzyme (a protein) may be made of more than one polypeptide and one gene controlled production of one polypeptide (chain of amino acids in a protein).

In the following sections you will learn about the nature of the genetic material, DNA, and its role in the synthesis of proteins. You will also learn about gene mutation because of which a normal protein is not manufactured in the body and results in genetic disorders.

23.2 DISCOVERY OF DNA AS THE GENETIC (HEREDITARY) MATERIAL

That genes, located on chromosomes, are the hereditary material was known to scientists in the early twentieth century. That genes are segments of DNA became evident from the work of Griffith on **bacterial transformation.**

Bacterial transformation

The bacterium *Streptococcus pneumoniae* when grown in the lab forms smooth colonies and when injected into mice kill them. A mutant of this bacterium forms rough colonies and is harmless to mice. In 1928, Frederick Griffith found that if the *smooth virulent* form of *Streptococcus* is killed and mixed with the *harmless rough* form of *Streptococcus* the latter becomes virulent (killer). This change (or transformation) of the bacteria from harmless to virulent is termed **bacterial transformation.** (Fig. 23.1).

In 1944, Avery, Mcleod and McCarty extracted DNA from the virulent smooth *Streptococcus* and mixed it with the non-virulent rough variety. The non-rough variety became *virulent* and had a *smooth coat*. This did not happen when DNA of the virulent form was digested with the enzyme DNase and then mixed. Thus it became clear that **DNA was the transforming principle.**

Later Hershey and Chase in 1952 used T_2 bacteriophage, a virus which infects bacteria for their experiments. They labelled the protein coat of the virus with radioactive isotope of sulphur ^{35}S. When the virus was introduced into the bacteria, no radioactivity was found inside the bacteria as the viral coat was left outside. When they labelled viral DNA with $^{52}P_{32}$ or radioactive phosphorus, radioactivity was found inside the bacteria. It bacame clear that new generations of the virus were reproduced inside bacteria because of viral DNA (Fig. 23.2).

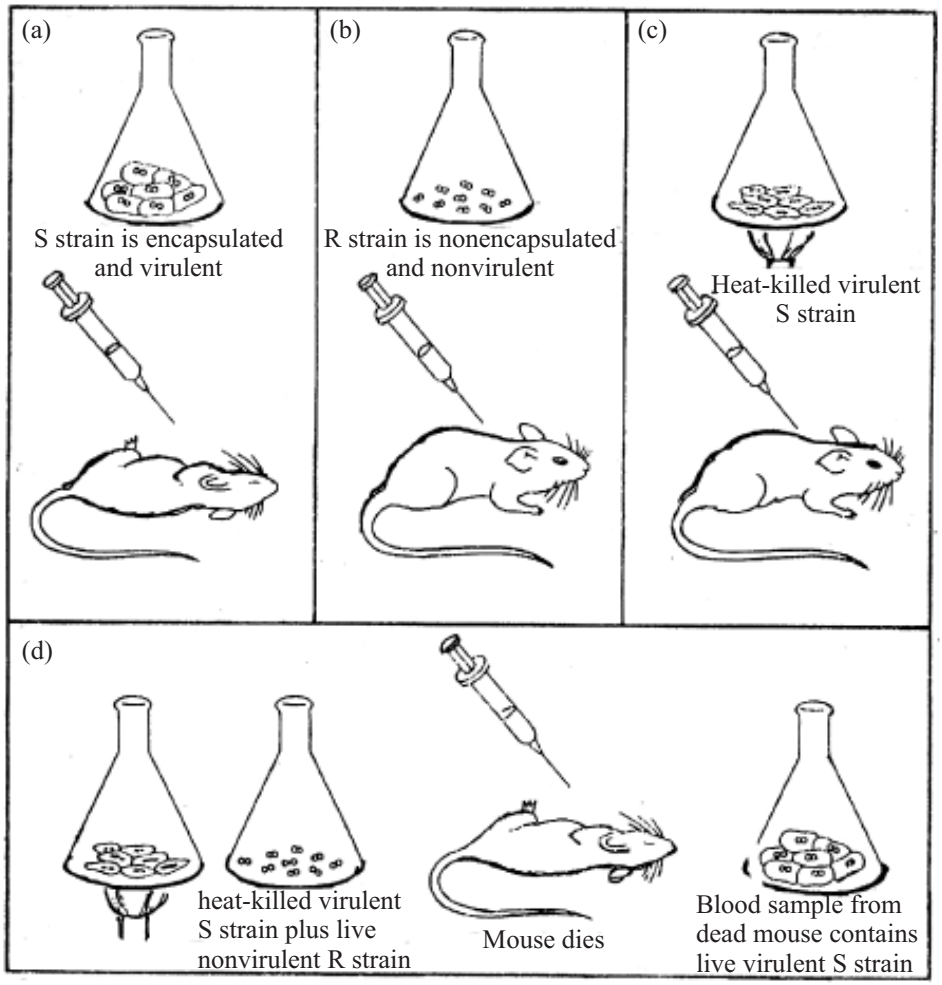


Fig. 23.1 Griffith's bacterial transformation experiment.

These experiments confirmed that DNA is the genetic material and genes are made of Deoxyribonucleic Acid or DNA.

23.3 STRUCTURE OF DNA, THE GENETIC (HEREDITARY) MATERIAL

23.3.1 Chemical nature of DNA or Deoxyribonucleic acid

DNA is a polynucleotide, a macromolecule (macro = large) made of units called **nucleotides.**

Each nucleotide consists of three subunits.

(i) a pentose (5 carbon) sugar called **deoxyribose**

(ii) 4 nitrogenous bases Adenine (A), and Guanine (G) are purine bases and Thymine (T) and Cytosine (C) are pyrimidine bases

(iii) a phosphate group (PO_4) positioned on the sugar (Fig. 23.3)

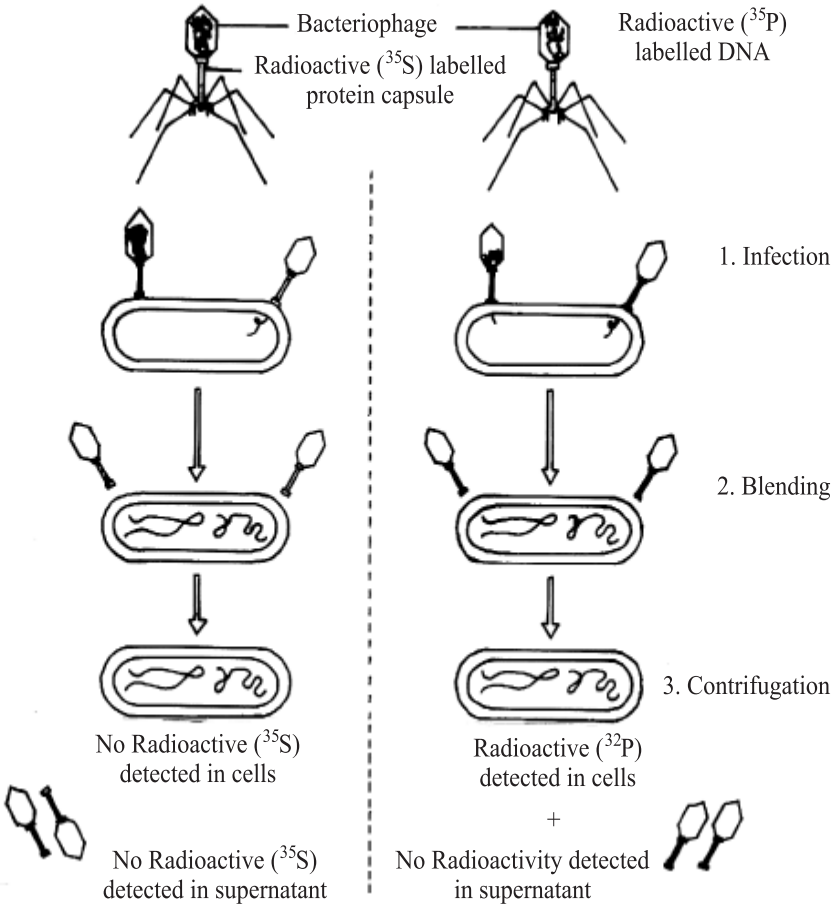
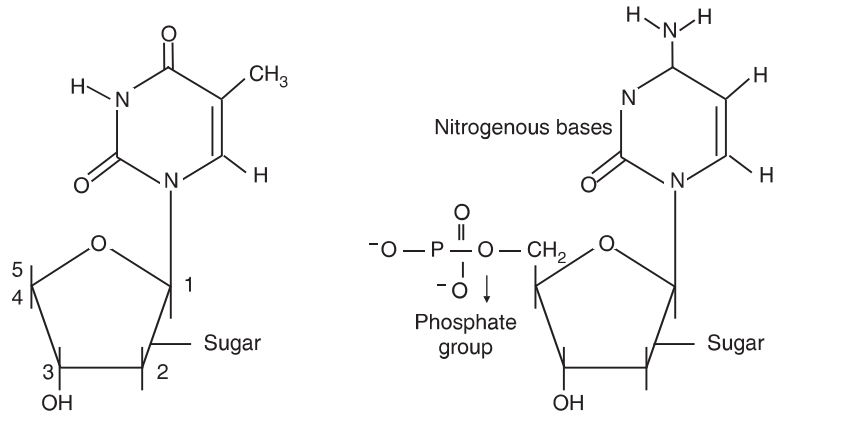


Fig. 23.2 The Hershey Chase experiment

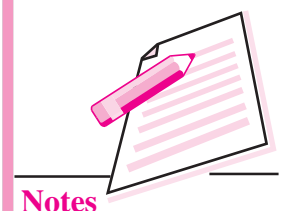


(a) (Base + Sugar = Nucleoside)

(b) (Base + Sugar + Phosphate = Nucleotide)

Fig. 23.3 Component of nucleoside and nucleotide

A base and a sugar combine to form a nucleoside, while it becomes a **nucleotide** when a phosphate group gets attached to the **nucleoside**.



Base + sugar = nucleoside

Base + sugar + Phosphate = nucleotide

So there are **four nucleotides** in DNA formed of sugar and nitrogenous base and phosphate.

Chargaff's rule

The four nucleotides are not present in equal amounts in a DNA molecule. But the amount of purines (A + G) and that of pyrimidines (T + C) is always equal. In other words, A = T and G = C. This is called Chargaff's rule.

23.3.2 Physical structure of DNA– The DNA double helix

A DNA molecule is **three dimensional** and made of **two strands** helically coiled around each other. Franklin and Wilkins first showed through X-ray diffraction studies of DNA that it is a double helix.

In 1953, James Watson and Francis Crick were awarded the Nobel Prize for working out the structure of DNA.

According to the Watson and Crick model

- DNA molecule is a **double helix** consisting of two strands of DNA
- The arrangement of the two strands is **antiparallel**, which means that the sequence of nucleotides goes up in 5′ to 3′ direction in one strand and other strand comes down in 3′ to 5′ direction. (3′ and 5′ refer to the carbon atom to which the phosphate group is attached) see Fig. 23.4.

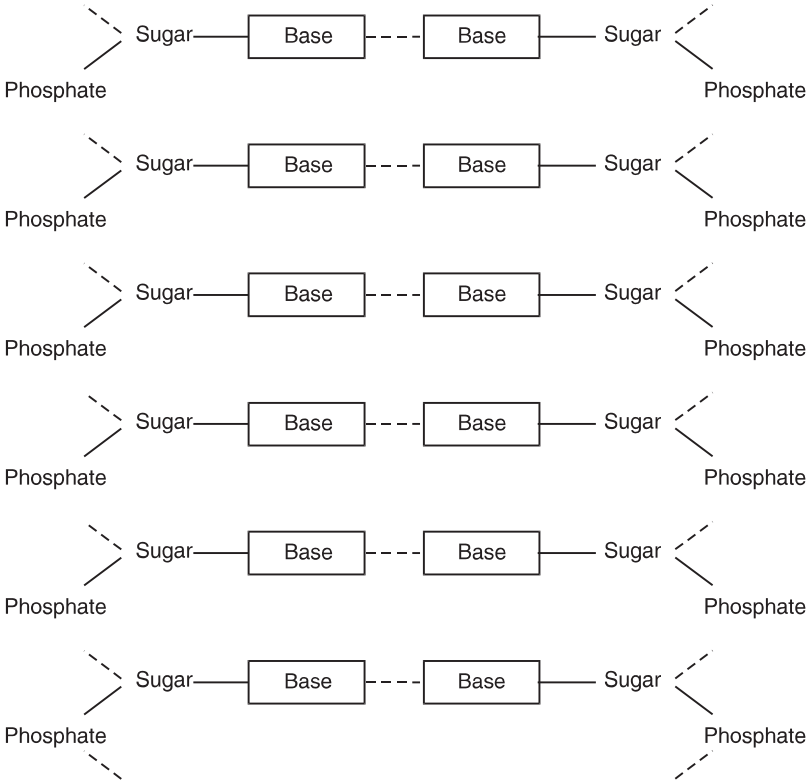


Fig. 23.4a Components of a DNA double helix

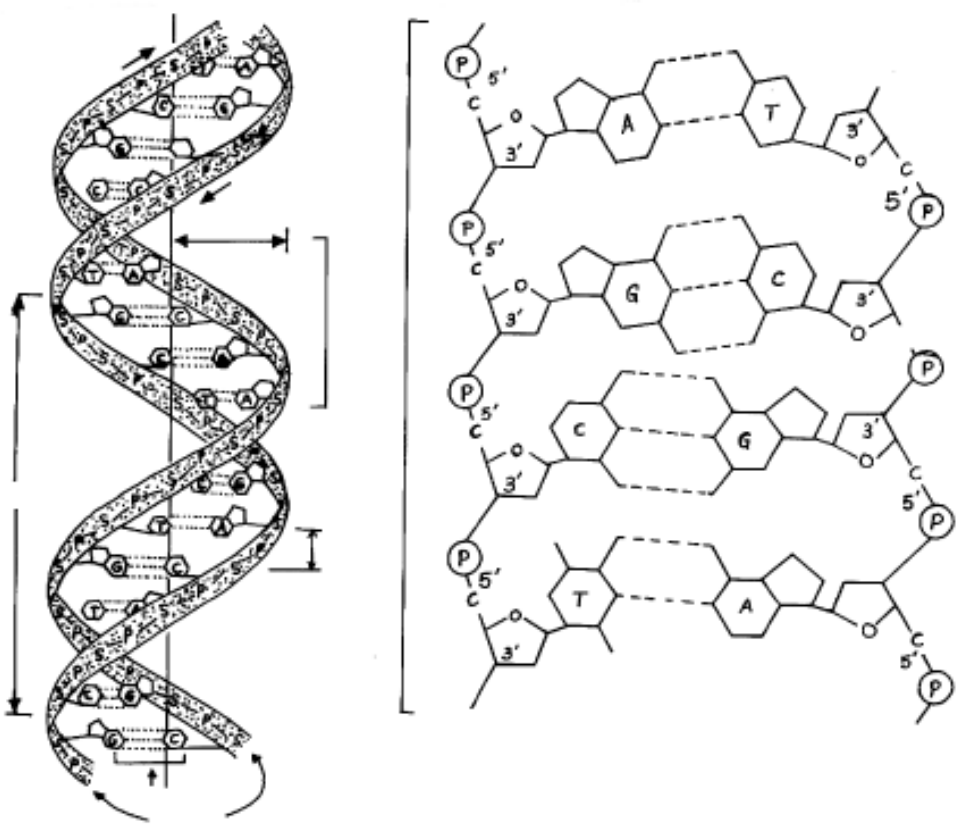


Fig. 23.4b-c DNA double helix

- The **backbone** of the helix is made of **sugar and phosphate.** Nitrogenous bases are linked to the **sugar**. (Fig. 23.4a and 23.4b)
- The bases of the two strands are linked by hydrogen bonds.
- Base pairing is very specific as per Chargaff's rule. Adenine, a purine base always pairs with thymine, a pyrimdine base. The purine base Guanine pairs with the pyrimidine, Cytosine. These pairs of bases are called **complementary bases.**

There are **two** hydrogen bonds between A and T and **three** hydrogen bonds between G and C. A and T are complementary bases and so are G and C.

In the DNA helix, a complete helical turn occurs after 3.4 nm (or 34Å). This complete turn encloses 10 base pairs. Each base pair lies 0.34 nm (3.4 Å) apart. The diameter of the double helical DNA molecule is 2.0 nm (Fig. 23.4c).

Watson and Crick model explains well how the two strands of a DNA molecule may separate at replication and transcription and then rewind.

The hereditary material must be capable of (i) replication (ii) storage of information (iii) transmission of information (iv) expression of information and (v) regulation of gene expression.

Packaging of DNA in Eukaryotic chromosome

In the bacteria (prokaryotes), ***only one double stranded DNA molecule*** constitutes the chromosome. Eukaryotes have many chromosomes and also many genes. One chromosome, however, is made up of one long double stranded DNA molecule. So how does this long molecule get accommodated in the chromosome seen as small mircoscopic entities during cell division? Fig. 23.5 shows how a long DNA molecule is packaged.

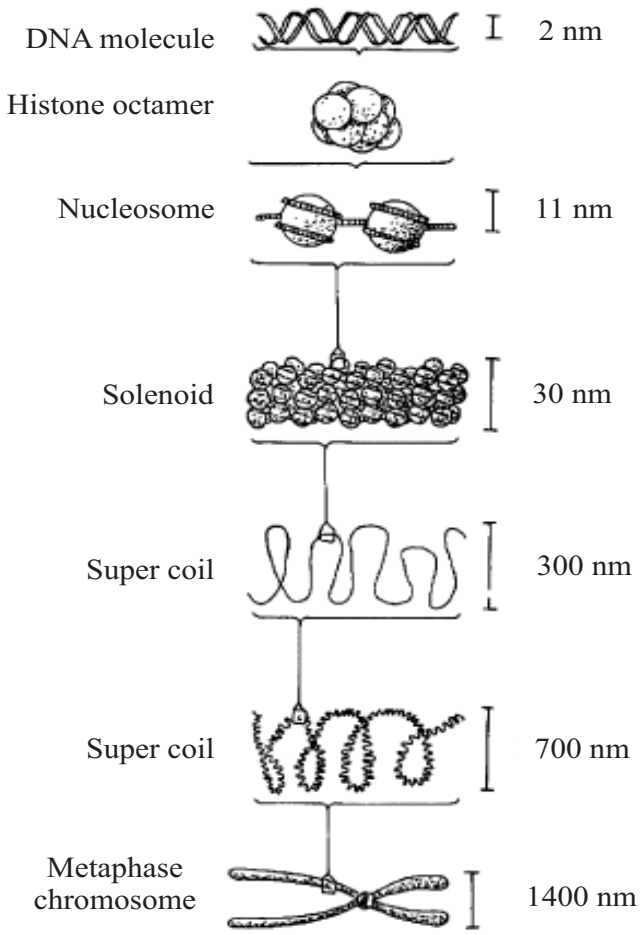


Fig. 23.5 Packaging of the DNA molecule.

- At intervals DNA molecule is coiled around a "core particle" which is an **octamer**, that is made of 8 histone proteins forming a ball like structure.
- Each core particle with DNA around it is called a **nucleosome.** Under the electron microscope the eukaryotic chromosome looks like a string of beads (string being the DNA molecule and beads the nucleosomes).
- The string is then coiled to form a **solenoid** and the solenoid is coiled again (**supercoiling**) ultimately to form the chromosome.
- In this way the long DNA molecule becomes thicker and thicker and shorter and shorter as shown in the figure.

Notes

23.4 RNA OR RIBONUCLEIC ACID

Apart from DNA, RNA or Ribonucleic acid is the other important nucleic acid present inside the cell. Table 23.1 gives the differences between DNA and RNA.

Table 23.1 Differences between DNA and RNA

DNA	RNA
1. *Double* stranded molecule	1. Single stranded molecule
2. Contains **deoxyribose** sugar	2. contains **ribose** sugar.
3. Pyrimidine base complementary to Adenine is **Thymine**	3. Pyrimiine base complementary to adenine is **Uracil** No thymine in RNA
4. DNA has only one function, that is to bear hereditary in formation	4. Many species of RNA such as mRNA, tRNA, rRNA with different functions. RNA is the genetic material in retroviruses.
5. DNA can duplicate **on its own**	5. RNA is synthesized **on a DNA template**

Functions of various type of RNA

mRNA or messenger RNA

mRNA or messenger RNA is transcribed in the nucleus to carry information for the protein to be synthesized, from DNA to site of protein synthesis in the cytoplasm.

mRNA is transcribed as a strand of complementary bases of one of the DNA strands and carries the information for the synthesis of a particular protein or polypeptide.

tRNA or transfer RNA

tRNA or transfer RNA, also called soluble RNA has a clover leaf structure (Fig. 23.6) with loops. One loop recognises the ribosome, the top loop has an 'anticodon' to recognise the codon (triplet nucleotide sequence coding for an amino acids) on mRNA. tRNA "transfers" the amino acids to their respective positions during synthesis of protein.

There are many t-RNAs which differ in their anticodon. Each tRNA is specific for an amino acid and can carry that amino acid to the ribosome during protein synthesis.

The 3' end of every t RNA ends in the bases CCA and the 5' end of the tRNA end in G. Amino acid is carried at 5' end.

tRNA contains unusual bases like inosine, dihydrouridine etc.

rRNA or ribosomal RNA

rRNA is a component of ribosome which are ribonucleoprotein particles containing RNA and proteins. rRNA is synthesized from the information in ribosomal genes in a chromosome. rRNA has a role in protein synthesis

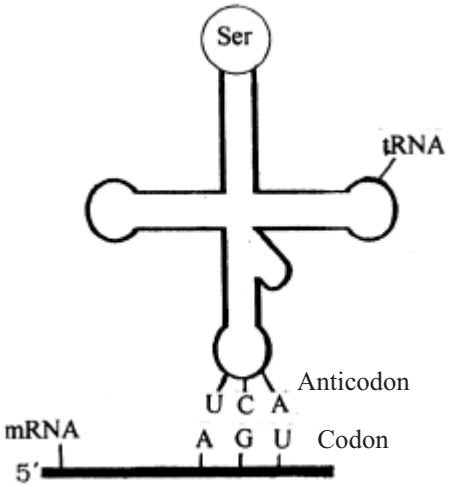


Fig. 23.6 RNA showing anti codon and codon pairing.

23.5 MECHANISMS OF DNA TRANSFER IN BACTERIA

Bacteria are prokaryotes and possess a single DNA molecule as their single chromosome. The DNA molecule is double stranded and helically coiled. Among bacteria, genes may be transferred from one bacterium to the other. DNA transfer or gene transfer can occur among bacteria by any one of the three processes, 1. Conjugation, 2. Transformation and 3. Transduction

Conjugation

Two bacteria may come together for **conjugation**. In conjugation, a plasmid containing a few genes passes from one bacterium into the other. The transfer (also called horizontal gene transfer) may also happen through a break in the single strand of the chromosome of **donor bacterium** and then that broken one strand is transferred to the **recipient bacterium**. The single strand left behind in the donor as well as the single strand donated to the recipient cell then become double stranded by adding a strand with complementary bases. The transferred DNA gets integrated into recipient chromosome. This is called **recombination.** Conjugation occurs between two strains of bacteria F^+ and F^-. The transferred DNA is from F^+ called F factor. Since F factor from F^+ is integrated into bacterial chromosome, there is high frequency of recombination, hence the strain is now known as H fr strain.

Transformation

Recall from the earlier part of this lesson (21.2) that DNA from one bacterium may integrate into DNA of another bacterium as in case of *Streptococcus pneumoniae*. Transformation is defined as the **ability of extracellular DNA to enter a bacterial cell** and recombine with the bacterial genome. The bacterial genome acquires new properties on account of the foreign DNA that had entered.

Transduction

Transduction refers to transfer of DNA from one bacterial cell into another bacterium through the agency of a virus (bacteriophage). A phage may undergo **lysogeny**, that

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is the virus enters the bacterium and divides along with bacterial genome. So a number of viral particles can form. Meanwhile viral DNA integrates and becomes part of bacterial DNA which is now a new **recombinant DNA**. Sometimes the viral genome may become independent and carry host bacterial genes to another new host bacterium and recombine into its genome. This process of gene transfer is called **transduction.**

INTEXT QUESTIONS 23.1

1. Expand the abbreviation DNA.

   .....

2. Name the scientists who confirmed that DNA was the genetic material in bacterial transformation.

   .....

3. Name the sugar and the nitrogenous bases found in DNA

   .....

23.6 DNA REPLICATION

DNA duplicates itself with complete fidelity for passing on genetic information to the next generation of cells. Replication may thus be defined as a mechanism for transmission of genetic information generation after generation.

You have learnt in the lesson on 'cell' that the cell passes through the cell cycle and DNA replication or DNA duplication takes place during S-phase.

Mechanism of replicaiton

Replication occurs through the following steps :

1. Unwinding of DNA double helix

The two strands of the replicating DNA molecule separate by the action of the enzyme **Helicase. Topoisomerase** enzyme keeps it open. The opened part is the replicaiton fork as shown in Fig. 23.7a.

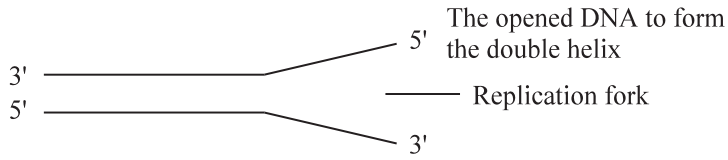
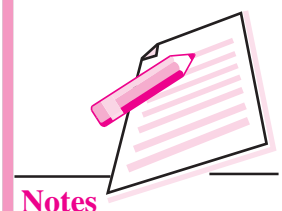


Fig. 23.7a Replication fork

2. Synthesis of the primer

Primer is a short RNA molecule of about 5 to 10 bases. It is formed in the presence of the enzyme **primase**. The primer provides a 3'-OH group for attachment of the new DNA strand.



3. Synthesis of new DNA strand

The opened strands of DNA form the template. New strands complementary to template get synthesized. At the replication fork, a new DNA strand begins to synthesise, attaching itself to the primer, in the presence of the enzyme **DNA polymerase**. It begins synthesis from its 5' end and a DNA strand complementary to one of the unwound parental DNA strand gets synthesized. The new strand of DNA **continues to be synthesized uninterrupted** and is termed as the **leading strand.**

Synthesis of the other new DNA strand

DNA synthesis always takes place along 5' to 3' direction. Therefore, the other new DNA strand gets synthesised in the direction opposite to the leading strand. This new strand called **Lagging strand** builds up in small pieces as shown in the figure, in the presence of enzyme **DNA polymerase**. Thus, the synthesis of the lagging strand is **discontinuous** (Fig. 23.7b). The new pieces of DNA are termed **Okazaki fragments**. In the presence of the enzyme **ligase** and the energy source ATP, the okazaki pieces get joined together to form a DNA strand

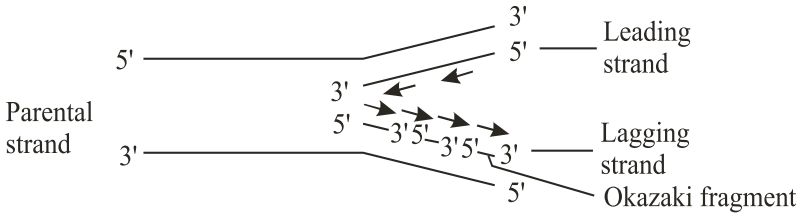


Fig. 23.7b Formation of new DNA strands

- DNA replication is remarkably accurate so that the parental DNA molecule gets an exact duplicate copy. Any mistake gets chipped and repaired. This is at the end of DNA replication and is called DNA **proof reading**.
- After **DNA replication,** two identical DNA molecules are formed which are identical to the parent molecule.
- DNA replication is thus **semidiscontinuous**, that is, one strand of the new DNA molecule builds up continuously and the other in pieces.
- DNA replication is **semiconservative**, since in the two new molecules formed, one parental strand is conserved and the other strand is newly synthesised The semiconservative mode of DNA replication was experimentally proven by Messelson and Stahl.

INTEXT QUESTIONS 23.2

1. In which direction does DNA polymerase proceed to catalyse DNA replicaiton 5′ to 3′ or 3′ to 5′?

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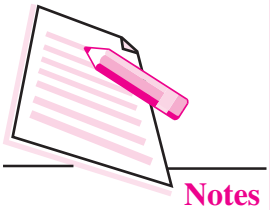


Notes

2. What is a primer ..... a DNA molecule or an RNA molecule?

.....

3. Name the four enzymes needed for DNA replication.

.....

4. Which enzyme joins the okazaki pieces to form a complete DNA strand?

.....

23.7 GENES AND PROTEIN SYNTHESIS

The genes of an individual is the **genotype**, and the expression of genes results in the **phenotype**. This you have already learnt in the previous lesson. There are different **structural proteins** e.g. Haemoglobin in blood, enzymes e.g. pepsin, almost all of which are proteins. There are **carrier proteins** in the cell membrane about which you have learnt in lesson 1, on cell. So there are various proteins and the information for the formation of these proteins is present in the genes, which you know are sequences of bases in the DNA molecule.

For the study of protein synthesis you have to first understand the following

1. Central dogma
2. Genetic code

23.7.1 Central Dogma

Genes are in the nucleus and proteins are synthesised in the cytoplasm of the cell. **The transfer of information from genes to the site of protein synthesis constitutes the Central Dogma.** The central dogma operates in the following sequence. Information flows from DNA (particular gene) to the particular protein through RNA.

$$\text{DNA} \xrightarrow{\text{Transcription}} \text{RNA} \xrightarrow{\text{Translation}} \text{Protein}$$

For protein synthesis, first the information coded in DNA is copied as a complementary messenger RNA molecule. This is termed as **Transcription**. Messenger RNA carrying information moves out of nucleus into the cytoplasm, attaches to the ribosomes to translate the information in the form of a protein. This is termed **Translation** as shown.

In retroviruses, the genetic material is RNA. Therefore, during protein synthesis it is first 'transcribed into a DNA molecule in the presence of the enzyme **Reverse Transcriptase** and then the path of central dogma is followed as shown below.

$$\underset{\text{(genetic material of retrovirus)}}{\text{RNA}} \xrightarrow[\text{transcription}]{\text{Reverse}} \text{DNA} \longrightarrow \text{mRNA} \longrightarrow \text{Protein}$$

23.7.2 Genetic Code

The information for the synthesis of proteins is present in the DNA in a sequence of nucleotides. This coded information was discovered by Nirenberg, Mathais and Ochoa.

The genetic code refers to the information in DNA responsible for the amino acid sequence of a particular protein to be synthesised. The information is coded as sequence of nitrogen bases in the DNA molecule. The particular gene or fragment of DNA which carries the code for synthesis of a complete polypeptide (protein) is termed a **cistron**.

The genetic code has the following characteristics:

1. Genetic code is a **triplet** code. This means that sequence of 3 bases called **codon** has the information of a particular amino acid. The **sequence of** codons determine the sequence of amino acids in a protein.
2. Genetic code is **unambiguous,** that is a particular codon can code for only one amino acid.
3. Genetic code is **commaless** and **non-overlapping**. This means that it is read continuously from beginning to end.
4. Genetic code is **degenerate**. There are 20 amino acids only that form the various proteins of living beings. But if 3 out of 4 nucleotides (each containing one of the four bases) form a codon, there can be $4^3 = 64$ codons. Hence more than one codon codes for a particular amino acid that is, the code is degenerate. In fact as you can see from the table 23.1 first two bases of the codons for the same amino acid are common and the third one changes or wobbles. This is called **Wobble hypothesis**.
5. The genetic code is read on the transcribed mRNA during protein synthesis.
6. AUG codon, codes for Methionine and is the **initiation** codon as it is the first one to be transcribed from a cistron.
7. UAA, UAG and UGA are stop codons and anticodons of one of these three codons is present at the end of every cistron to terminate protein synthesis.
8. Genetic code is universal and common for almost all organisms on earth. (Table 23.1).

23.7.3 Transcription in Prokaryotes (Bacteria)

The flow of genetic information from cistronic DNA to mRNA is called Transcription. It occurs in the following steps–

1. Cistronic DNA which carries the information for the protein to be synthesised unwinds in the presence of enzymes helicase and topoisomerase.
2. RNA polymerase begins to catalyse synthesis of mRNA signalled by a protein called **sigma** factor.
3. mRNA is synthesised complementary to cistronic DNA and a Rho factor signals RNA polymerase to complete transcription.
4. The strand of DNA which bears the code for transcription of the specific protein is called **sense strand of DNA** opposed to the **antisense strand** which is not transcribed. (Fig 23.8)

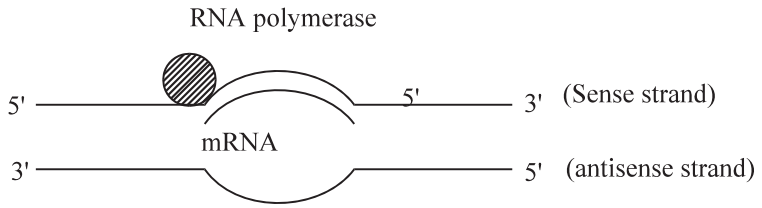


Fig. 23.8 Transcription in prokaryotes

In Eukaryotes a large molecule of RNA called hn RNA is synthesised in the nucleus when its sense strand is exposed. Catalysed by enzyme RNA polymerase, hn RNA is processed to form mRNA which gets a cap at 5' end and a poly A tail, before leaving the nucleus.

Processsing of mRNA

hnRNA is large because eukaryotic genes contain coding sequences called **exons** and non coding sequences called introns (I) in between exons. Both introns and exons (E) are transcribed in mRNA. During processing of mRNA, introns are cut off and exons join to form mRNA.

- A nucleoside (recall from section 23.3) called methyl guanosine comes and attaches at the 5' end of mRNA. This is called capping.
- A small piece of RNA having only nucleotides containing the base Adenine is attached at the 3' end. This is called the poly A tail.
- The m RNA with cap and tail moves out of the pores in the nuclear membrane.

The process of formation of functional mRNA from hnRNA is termed **RNA processing** (Figs. 23.9)

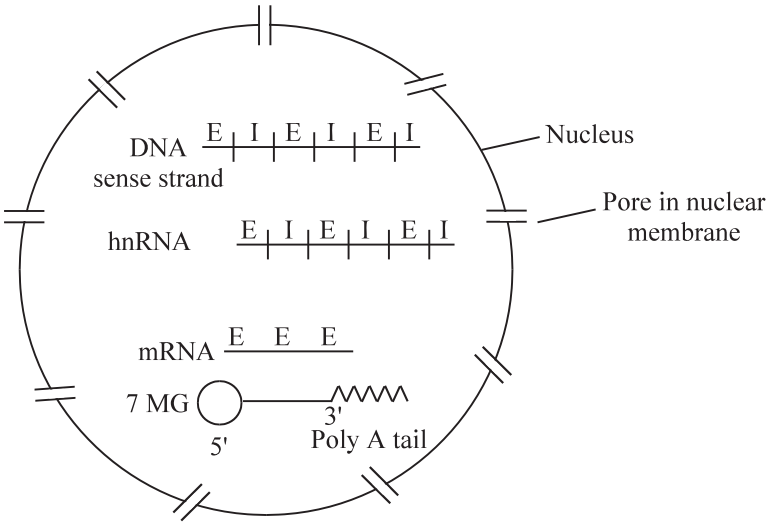


Fig. 23.9 Schematic drawing showing transcription and processing of hnRNA in eukaryotes

23.7.4 Translation

A series of events follows transcription in which the language of nucleotides transcribed (copied) in mRNA is **translated** into the language of amino acids to form a protein. These events are

1. Activation of amino acid
2. Formation of mRNA ribosome complex and chain initiation
3. Chain elongation
4. Chain termination

Activation of amino acid

A specific t RNA attaches to specific amino acid in the presence of the enzyme **amino acyl-tRNA synthetase** in two steps given below. This requires energy

$$\text{Amino acid} + \text{ATP} \xrightarrow[\text{tRNA synthetase}]{\text{aminoacyl}} \underset{\text{(Amino acyl adenylate)}}{\text{aa} \sim \text{AMP}} + \underset{\text{(Inorganic phosphate)}}{\text{Pi}}$$

$$\text{aa}\sim\text{AMP} + \text{tRNA} \xrightarrow[\text{tRNA synthetase}]{\text{aminoacyl}} \underset{\text{(Amino acid attached to its tRNA)}}{\text{aa} \sim \text{tRNA}} + \text{AMP}$$

Formation of mRNA ribosome complex and chain initiation

- mRNA binds to small ribosomal subunit

- Larger subunit of ribosome attaches to complete the ribosome.
- The mRNA ribosomal complex contains two codons so that at a time two amino acids can be accommodated in the ribosome.
- In the presence of some proteins called **initiation factors** methionine (an amino acid is carried to the mRNA ribosome complex and enters at the A site in the large subunit of ribosome. Recall that tRNA has an **anticodon** a sequence of three bases complementary to the codon for methionine.

Chain elongation

The second amino acid is carried by its tRNA to the ribosome according to the second codon on at the P site in large ribosomal unit. Peptidyl transferase enzyme then helps to establish a bond between the first two amino acids. The first amino acid loses its tRNA which moves out. Ribosome then moves over the m-RNA towards 3' end. The dipeptide made of the two amino acids shifts towards 5' end such that the second amino acid occupies the A site with methionine attahed to it. The third amino acid then enters through P site carried by its tRNA according to third codon. In the presence of peptidyl transferase, a peptide bond is formed between second and third amino acids and tRNA of second amino acid becomes free. In this way the peptide chain is synthesized. (Fig. 23.10).

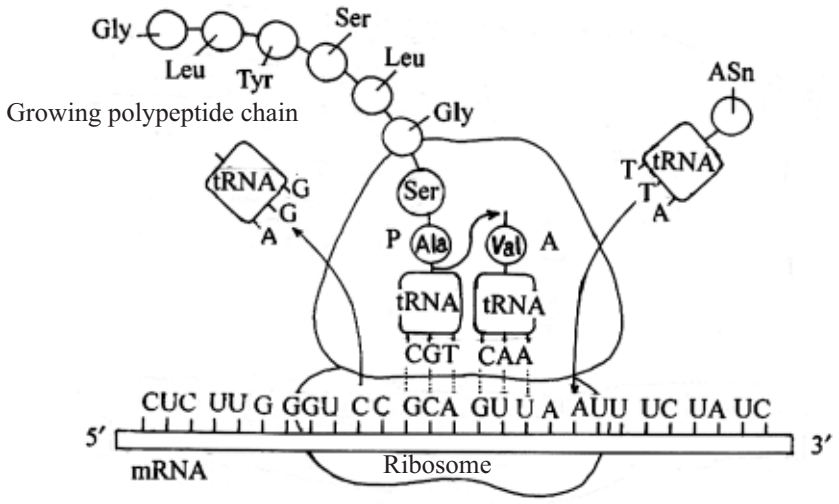


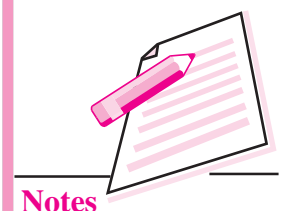
Fig. 23.10 Translation of mRNA Polysome assembly

- **Polysome assembly**

  When mRNA has shifted ahead such that about ten amino acid long peptide is synthesised, a second ribosome attaches to form ribosome mRNa complex. Thus at one point of time a number of ribosomes are seen attached to mRNA one molecule of the polypeptide continues synthesis in each ribosome till the termination codon is reached (Fig. 23.10).

Chain termination

When the stop codon on mRNA is reached, the polypeptide is synthesised. It leaves the ribosome and the ribosome dissociates into its two subunits.



INTEXT QUESTIONS 23.3

1. What is central dogma in molecular Biology?

   .....

2. Which molecule is synthesised during transcription?

   .....

3. What is a codon? What is meant by 'code is degenerate'?

   .....

4. Where in the cell does translation occur?

   .....

5. Name the three types of RNA that participate in protein synthesis.

   .....

23.8 HOUSE KEEPING GENES

In multicellular organisms, all cells contain all genes but only those genes function which are required to be active. In other words the expression of genes is regulated by switching on and switching off genes when required.

Certain genes, however, bear the code for proteins needed in the cell all the time. These are the genes needed for survival and maintenance of the cells and need to be expressed all the time. Such genes which are expressed all the time in all cells are termed **housekeeping genes. Inducible genes** are the genes which are switched on when a particular substance is present in the environment. **Repressible genes** are those which are shut off in the presence of a specific substance in the environment.

23.9 REGULATION OF GENE EXPRESSION

In Prokaryotes, the Lac-operon is an excellent example of control of gene expression in prokaryotes (bacteria). It is an inducible system and is switched on in the presence of the substrate **lactose**. Enzymes for metabolising lactose are galactosidase, permease and transacetylase and genes that code for them get switched on. In the absence of lactose, they remain switched off.

Jacob and Monod received the Nobel prize for showing that bacterium *Escherichia coli* has a set of genes forming an "operon" which regulate expression of genes coding for enzymes needed to breakdown lactose. The operon includes certain genes lying close together on the chromosome next to the regulator gene i, and includes promoter gene p which RNA polymerase identifies at the time of transcription; operator gene, o which switches on structural genes z, y, a coding for the enzymes, Galactosidase, Permease and Transacetylase.

The working of the operon system is given in Fig. 23.11a-b.

In absence of the substrate lactose

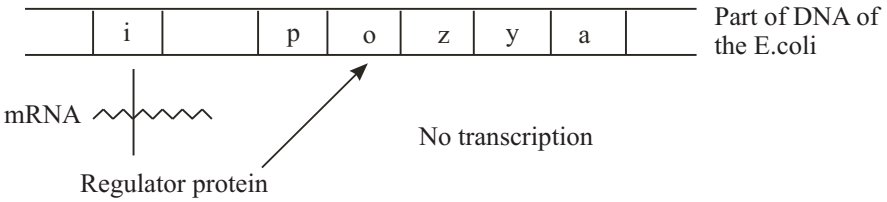


Fig. 23.11a Lac operon switched off

Regulator protein blocks o, RNA polymerase cannot find p and z, y, a remain switched off.

In the presence of lactose

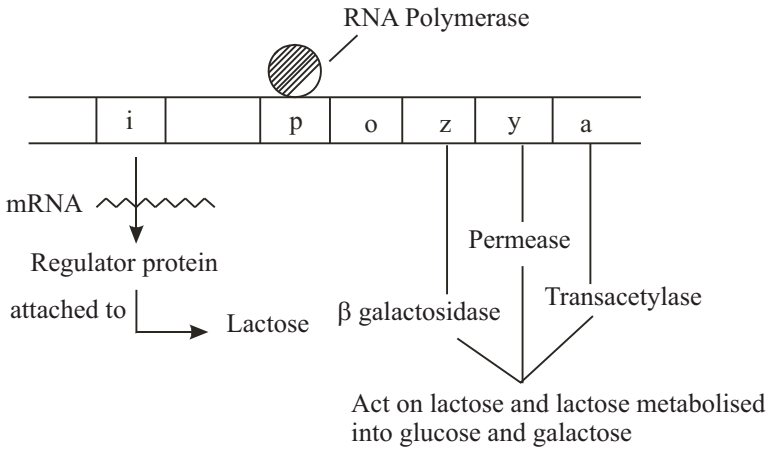


Fig. 23.11b Lac operon switched on

Regulator protein is attracted to lactose, o site opens; RNA polymerase finds promoter; genes z, y, a switched on, transcription begins and the three enzymes are synthesized inside the cell.

The above is an example of inducible system. Repressible systems are also found in prokaryotes.

Gene regulation in eukaryotes is more complex, Gene expression can be regulated at level of transcription or processing of hnRNA into mRNA or at translation or post translation. (Fig. 23.12).

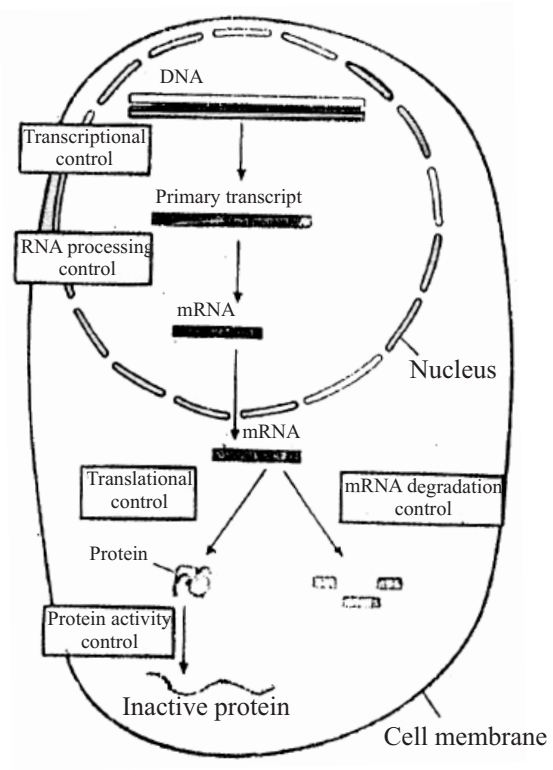


Fig. 23.12 Levels of gene control in eukaryotes

A heritable change in the structure, content and organization of the genetic material that can be passed down to the next generation is termed **mutation**. Mutation may occur in **one gene** when it is termed **point mutation** or may affect a number of genes on a part of chromosome when it is termed **chromosomal mutation**.

Chromosomal mutation

Involves a number of genes. It is of two types, (1) Change in number of chromosomes and (2) Change in structure of chromosomes.

The number of chromosomes in individuals of a species is fixed. For example humans have 2n = 46 chromosomes. But sometimes one or more chromosomes may be lost or added and such a change in number is termed **Aneuploidy** when 2n = 45 or 2n = 47 is found is an individual. Sometimes the whole set of chromosomes may be duplicated so that instead of 2n, an individual way possess 3n or 4n chromosomes. This is **polyplocdy**.

Chromosomal change in structure is also termed as **chromosomal aberration**. It is of four types 1. **Deletion**, in which a piece of a chromosome may be lost. 2. **Inversion**, a piece of a chromosome breaks off and rejoins in the reverse direction. 3. **Duplication** A part of the chromosome may get represented twice and 4. **Translocation** a piece from another chromosome may get attached.

Genes mutation or Point Mutation

A change which affects only one gene is called gene mutation or point mutation. You already know that gene is a segment of DNA and is made of a sequence of nucleotides. Whenever one nucleotide is changed within a gene, it may cause a change in the phenotype.

Gene mutation is of the following types :

1. Transition : When a purine base is replaced by another purine base or a pyrimidine base by another pyrimidine
   ATGCATGC ⟶ A**G**GC AGGC
2. Transversion : When a purine base is replaced by pyrimidine base and similarly a pyrimidine base by a purine
   ATGC ATGC ⟶ ATG**T** ATGC
3. Frameshift : Sometimes due to loss or gain of one nucleotide the reading frame of the genetic code for an entire protien changes
   CAT CAT CAT CAT ⟶ CAT ATC ATC ATC
   when C gets lost after CAT
4. Missense : A change in the genetic code due to replacement of a nucleotide (base) may give rise to a different protein e.g. sickle cell haemoglobin.
5. Nonsense : If a genetic code changes such that it becomes a stop codon mid way, no protein is formed e.g.
   GAAGAAGAA ⟶ GAA**UAA**AA
   synthesis stops as UAA in stop condon
6. Silent : When the changed nucleotide does not bring about any phenotypic change because it also codes for same amino acid.

Mutagens

Agents that cause mutation in the genetic material are called **mutagens**. Mutagens belong to two categories

1. Radiations : x-ray, UV rays, α radiations.
2. Chemical : Mustard gas, Actinomycin D

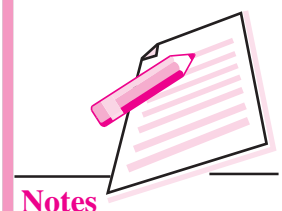
INTEXT QUESTIONS 23.4

1. Name the components of an operon.

   .....

2. What is mutation? When is a mutation called a transition mutation?

   .....



3. Why is "silent mutation" called so?

.....

4. What are mutagens?

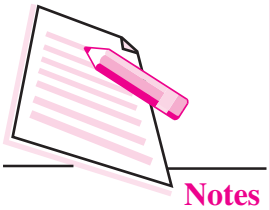
.....

5. Name a chemical which causes mutation in the heredity material.

.....

WHAT YOU HAVE LEARNT

- One gene was found to be responsible for the production of one enzyme, and this was called one gene one enzyme hypothesis.
- The transformation of the bacteria from harmless to virulent is termed bacterial transformation.
- DNA is a polynucleotide, made up of nucleotides. Each nucleotide consists of three subunits (i) deoxyribose sugar (ii) any one of 4 nitrogenous bases (Adenine, Guanine, Thymine and cytosine (iii) a phosphate group.
- RNA is the other important nucleic acid present inside the cell. RNA has pentose sugar ribose and base uracil instead of cytosine. Many species of RNA such as mRNA, tRNA, rRNA have different functions.
- Transformation means the ability of extracellular DNA to enter a bacterial cell and recombine with the bacterial genome.
- Transduction refers to transfer of DNA from one bacterial cell into another bacterium through the agency of a virus.
- Replication may be defined as a mechanism for transmission of genetic information generation after generation.
- The transfer of information from genes to the site of protein synthesis constitutes the central dogma.
- The information for genetic coded was discovered by Nirenberg, Mathair and Ochoa.
- The flow of genetic information from cistronic DNA to mRNA is called transcription.
- A single triplet (three bases) is called codon.
- Mutation is a sudden change in genes or chromosomes resulting in alteration of protien/phenotype.



Notes

TERMINAL EXERCISES

1. How did Hershey and Chase prove that DNA is the hereditary material?
2. Explain (i) Transduction and (2) Lysogeny
3. Describe the Watson and Crick model of DNA.
4. Explain how replication takes place.
5. Write a note on Central Dogma
6. State the properties of the genetic code.
7. Explain transcription in Eukaryotes and processing of hnRNA.
8. What do you mean by regulation of genes?
9. Explain how the lac operon gets switched on in the presence of lactose in *E.coli*.
10. Name three levels at which regulation takes place in a eukaryotic cell.
11. Write notes on :
    (i) Types of mutations
    (ii) Okazaki fragments
    (iii) Chain termination during translation.

ANSWERS TO INTEXT QUESTIONS

23.1
1. Deoxyribonucleic acdi
2. Avery, Mcleod and McCarty
3. Deoxyribose, Adenine, Guanine, Thymine, Cytosine

23.2
1. In 5'-3' direction
2. RNA molecule
3. Helicase, DNA polymerase, DNA ligase, Topoisomerase
4. DNA ligase

23.3
1. The transfer of information from genes to the site of protein synthesis constitutes the central dogma.
2. Cistronic DNA
3. Sequence of three bases in the genes.
4. Nucleus
5. mRNA, tRNA, hnRNA

23.4
2. A heritable change in the structure, content and organization of genetic material when in a DNA sequence a purine is replaced by purine and pyrimidine is replaced by pyrimidine.
3. A silent mutation ina gene does not bring about a change in the synthesis of the coded protien.