Principles of Inheritance and Variation

CHAPTER 5

EXAM DRILL

ANSWERS

1. **(c) :** Gregor Johann Mendel chose pea plants for his experiments because the garden pea is an ideal subject in the study of genetics for the following reasons:

(i) presence of observable traits with contrasting forms

(ii) produces many offspring in one cross

(iii) short life cycle

(iv) though self pollinated but ease in cross-pollination.

2. **(c) :** The principle of segregation describes how pairs of gene variants called alleles are separated into reproductive cells. Mendel crossed two heterozygous pea plants, which means that each plant had two different alleles at a particular genetic position and he discovered that the traits in the offspring of his crosses did not always match the traits in the parental plants. This meant that the pair of alleles encoding the traits in each parental plant had separated or segregated from one another during the formation of the reproductive cells.

OR

(a) : Emasculation is the process of removing anthers from bisexual flowers without affecting the female reproductive part (pistil), which is used in various plant hybridisation techniques. To remove the anthers, the flowers are covered with a bag before they open. This ensures that the flower is pollinated by pollen grains obtained from desirable varieties only.

3. **(c) :** The cross performed by the plant breeder is a dihybrid cross. The axial flowers and inflated pods are dominant characters whereas the terminal flowers and constricted pods are recessive characters. The ratio obtained by plant breeder is similar to the dihybrid cross ratio obtained by Mendel where the cross between dominant and recessive parents lead to the production of heterozygous dominant progeny which further on selfing produce the parental and recombinants in the ratio of 9:3:3:1.

4. **(b) :** Linkage can be determinated by a test cross which is somewhat different from a regular test cross. In the former case, the genotypes of both of the parents are known. The parent with the dominant phenotype is known to be a heterozygote (for example, AaBb) and the tester parent is known to be completely homozygous recessive (aabb). The heterozygous parent with the dominant phenotype, if the genes showed independent assortment, should make four gametes AB, Ab, aB and ab in equal frequencies. Linkage will be detected if there are more testcross progeny who got the parental gametes from the dominant individual that you would expect by chance alone.

5. **(d) :** In birds, sex is determined by two chromosomes *viz*. Z and W. In birds, females are heterogametic (ZW) and males are homogametic (ZZ). In this case, the total numbers of chromosomes are same in both males and females but two different types of gametes in terms of the sex chromosomes, are produced by females, *i.e.*, female heterogamety.

OR

(a) : Epistasis is a type of non-allelic interaction where one gene controls the phenotype of another gene for a trait. Both genes have an influence on the physical appearance of the trait, but the one that shows epistasis masks the effect of the other. Dominant epistasis happens when the dominant allele of one gene masks the expression of all alleles of another gene and the mendelian dihybrid cross ratio deviates to 12 : 3 : 1. In recessive epistasis; the recessive allele of one gene masks the effects of either allele of the second gene and the mendelian ratio deviates from 9 : 3 : 3 : 1 to 9 : 3 : 4. Complementary gene interaction results in 9 : 7 ratio.

6. Significance of linkage is as follows:

(i) Linkage produces parental combination therefore limits variability among individuals.

(ii) It helps to maintain the important trait of newly developed variety.

(iii) Some of the early expressing genes can be used as marker genes to know the late expressing linked genes.

7. The UV-radiations cause base deletion, strand breakage, cross-linking and generation of nucleotide dimers such as, thymine-thymine dimer and thymine-cytosine dimers.

8. To find the genotype of a pea plant bearing violet flowers, test cross must be performed.

9. During anaphase of meiosis I segregation of an independent pairs of chromosomes occur.

10. Sickle cell anaemia is due to inheritance of a defective allele coding for β-globin. It results in the transformation of Hb^A into Hb^S in which glutamic acid is replaced by valine at sixth position in each of two β-chains of haemoglobin. The substitution of amino acid in the globin protein results due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG.

11. **(b)**

12. **(c) :** Human skin colour is a polygenic trait.

13. **(c) :** The pink colour flower appear in F_1 generation due to incomplete dominance of red (dominant) over white (recessive).

14. **(b) :** Phenylketonuria is an inherited error of metabolism caused by a deficiency in the enzyme phenylalanine hydroxylase. It is an autosomal recessive trait. It is a hereditary human condition resulting from the inability to convert phenylalanine into tyrosine. This leads to over production of phenylalanine and its conversion to phenylpyruvic acid and other derivatives. These are then excreted in urine due to poor absorption by kidneys.

15. **(i) (d)**

(ii) **(a) :** On inbreeding walnut combed chickens, all four types of combs will be obtained in the ratio of 9 walnut : 3 pea : 3 rose : 1 single.

(iii) **(a) :** This can be explained as follows:

Walnut (PpRr) × ppRR (rose)

↓

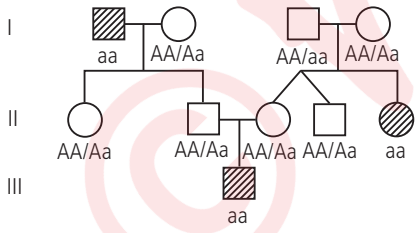
	PR	Pr	pR	pr	1 : 1 ratio
pR	PpRR Walnut	PpRr Walnut	ppRR Rose	ppRr Rose	

(iv) **(c) :** When pure pea combed and pure rose combed birds are crossed, all the offspring of F_1 individuals have walnut comb.

(v) **(d) :** Collaborative supplementary genes are pair of non-allelic genes present on different loci on the chromosomes.

16. **(i) (b)**

(ii) **(d) :**



(iii) **(b)**

(iv) **(b)**

(v) **(b) :** Alzheimer's disease is an autosomal dominant trait.

17. In single crossing over, there is only one chiasma from where chromatids of homologous chromosomes contact. The chromosomes break only at one point along their entire length whereas in double crossing over, the crossing over occurs at two points in the same chromosome pair, *i.e.*, the chromatids break and rejoin at two points.

OR

Down's syndrome is the most common human condition due to aneuploidy, which results in trisomy (an extra chromosome) at chromosome 21 due to non-disjunction of two homologous chromosomes. The offspring has 47 chromosomes instead of 46. It is characterised by rounded face, protruding tongue, short neck, palmar crease etc.

18. If Mendel would have taken *Mirabilis jalapa*, he would not be able to formulate the law of dominance as the flower colour genes in *Mirabilis jalapa* do not show complete dominance as pea flowers do. According to the law of dominance, when the cross is made in plants homozygous dominant and homozygous recessive for flower colour, in F_1 generation the plants with heterozygous genotype are produced where the dominant allele completely masks the effect of recessive allele, whereas in *Mirabilis jalapa*, the plants in F_1 generation show an intermediate phenotype.

19 Pedigrees are used to analyse the pattern of inheritance of a particular trait throughout a family. Pedigrees show the presence or absence of a trait as it relates to the relationship among parents, offspring and siblings. By analysing a pedigree, we can determine genotypes, identify phenotypes, and predict how a trait will be passed on in the future. The information from a pedigree makes it possible to determine how certain alleles are inherited: whether they are dominant, recessive, autosomal or sex-linked.

20. Gene mutations are stable changes in genes *i.e.* DNA chain which leads to the alteration in the expression of gene. Not every time, a change in a gene or nucleotide pair produce detectable mutation.

Transition is a type of substitution mutation and it involves the replacement of a purine base [A] with another purine base [G] or a pyrimidine base [T] with a pyrimidine base [C] whereas transversion is a type of substitution mutation where a purine base (A,G) is replaced by a pyrimidine base (T,C) or *vice versa*.

21. Aneuploidy is a phenomenon which occurs due to non-disjunction of chromosomes resulting in gain or loss of one or more chromosomes during meiosis. In hypoploidy, the organisms have less number of chromosomes, however the hyper-aneuploids have extra number of chromosomes. In aneuploidy one gamete receives an extra chromosome and the other becomes deficient in one chromosome. On the basis of extra or less number of chromosomes, the anueploidy is of various types *viz*. monosomy, nullisomy, trisomy, tetrasomy, pentasomy, etc.

22. **(a)** (i) Green (ii) Yellow (iii) Inflated (iv) Constricted

(b) (i)Humans have 46 chromosomes *i.e.* 23 pairs of chromosomes therefore the linkage groups in human are 23.

(ii) *Drosophila* have 8 chromosomes *i.e.* 4 pairs of chromosomes therefore the linkage groups in *Drosophila* are 4.

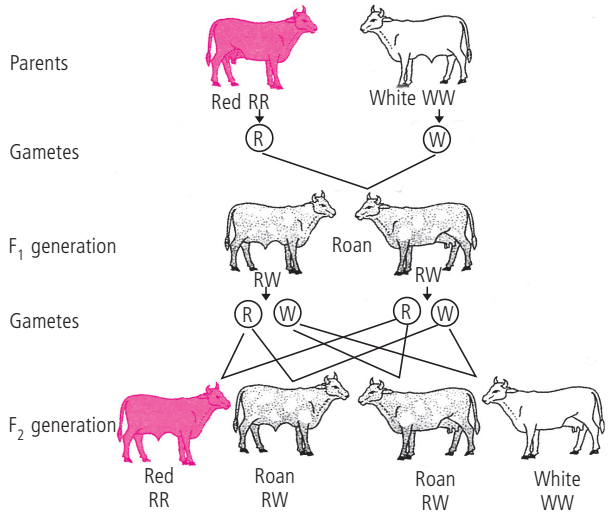
23. The percentage of recombinants produced in a cross is called recombination frequency which can be calculated using the number of recombinant produced in progeny out of total number of progeny.

$$\text{Recombination frequency} = \frac{\text{Recombinant in the progeny}}{\text{Total offsprings}} \times 100\%$$

Recombination frequency = (430+390)/(135 + 120 + 390 + 430) × 100 = 76.3

Therefore, the frequency of recombination is 76%.

24. Inheritance of hair colour in cattle show incomplete dominance. It can be illustrated as follows:



25.

Parents : RR (Pure red snapdragon) × rr (Pure white snapdragon)

Gametes : R, r

F_1 generation : Rr

All pink snapdragon

Selfing

F_2 generation	R	r
R	RR Red	Rr Pink
r	Rr Pink	rr White

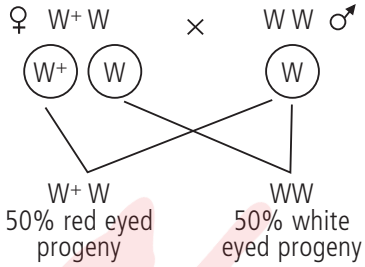
Phenotypic ratio - 1 : 2 : 1

Genotypic ratio - 1 : 2 : 1

In Snapdragon, one allele is incompletely dominant over the other allele. Therefore, all pink snapdragon plants are obtained in F_1 generation. Further, the selfing of F_1 individual lead to the production of red, pink and white snapdragon plants in the ratio of 1 : 2 : 1. The genotypic ratio obtained in F_2 generation is RR : Rr : rr is 1 : 2 : 1.

26. The gene for eye colour in fruit flies is sex-linked on the X chromosome. Only the cross between a heterozygous red eyed female with white eyed male would lead to the production of 50% red eyed progeny (25% male and 25% female)and 50% white eyed progeny (25% male and 25% female).

The cross given below represents a cross between a heterozygous red-eyed female and a white-eyed male. The symbol W^+ is the dominant allele for red eyes, and the symbol W represents the recessive allele for white eyes. Only females can be homozygous or heterozygous for red eye colour. The males have only one allele for eye colour on their X-chromosomes. This cross would produce 50% red-eyed male and female fruit flies, and 50% white-eyed male and female fruit flies.

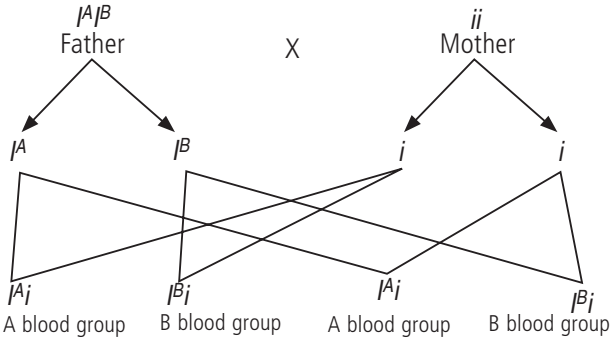


27. Klinefelter's syndrome is one of the genetic disorders in males that occurs when a male baby is born with an extra X chromosome resulting into a karyotype of 47 chromosomes. Klinefelter's syndrome is found in one out of 1000 males. The unwanted additional sex chromosome is a result of a random error in the formation of sperm or the egg. Women with pregnancies after the age of 35 have slightly more chances of having a baby with this syndrome.

Klinefelter's syndrome may adversely affect testicular growth, resulting in smaller than normal testicles, which can lead to lower production of testosterone. The syndrome may also cause enlarged breast, *i.e.*, gynaecomastia and sterility.

OR

Within the ABO blood group system, the I^A and I^B genes are codominant, *i.e.* these will be expressed whenever the gene is present. The *i* gene is silent and is only expressed when neither I^A nor I^B is present. Father's genotype for blood group is I^AI^B and mothers' genotype for blood group is *ii* (recessive).



50% of children would have blood group A and 50% children would have blood group B.

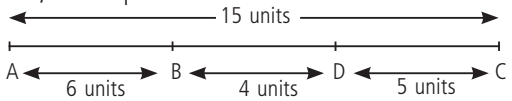
(a) There is 0% probability of having father's blood group.

(b) There is 0% probability of having mother's blood group.

28. **(a)** Linked genes are those genes that are physically close to one another on the same chromosome and are likely to be inherited together. They do not show independent assortment at the time of gamete formation.

(b) Map distance between A and B- 6 units, A and C -15 units, C and D- 5units and B and D-4units.

Therefore, the sequence would be

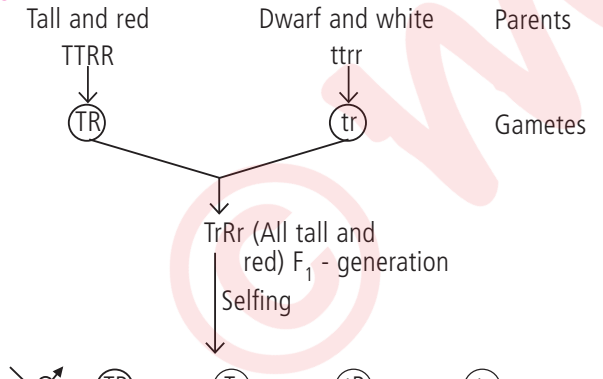


The distance between B and C would be 4 + 5 = 9 units

(c) Differences between linkage and crossing over are as follows:

S. No.	Linkage	Crossing over
(i)	It is tendency of genes in a chromosome to remain together and pass as such to the next generation.	It is exchange of genes/ chromosomal parts to break established linkages and formation of new linkages.
(ii)	It produces parental types.	It produces recombinations.
(iii)	Strength of linkage between two genes increases if they are closely placed in a chromosome.	Frequency of crossing over between two genes decreases if they are closely placed.
(iv)	It helps to maintain a newly improved variety.	It is the source of variations for producing new varieties.
(v)	With increase in age linkage increases.	Crossing over decreases with age.

29.



♀ \ ♂	TR	Tr	tR	tr Gametes
TR	TTRR Tall red	TTRr Tall red	TtRR Tall red	TtRr Tall red
Tr	TTRr Tall red	TTrr Tall white	TtRr Tall red	Ttrr Tall white
tR	TtRR Tall red	TtRr Tall red	ttRR Dwarf red	ttRr Dwarf red
tr	TtRr Tall red	Ttrr Tall white	ttRr Dwarf red	ttrr Dwarf white

F_2-generation

Genotypic ratio: 1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1

OR

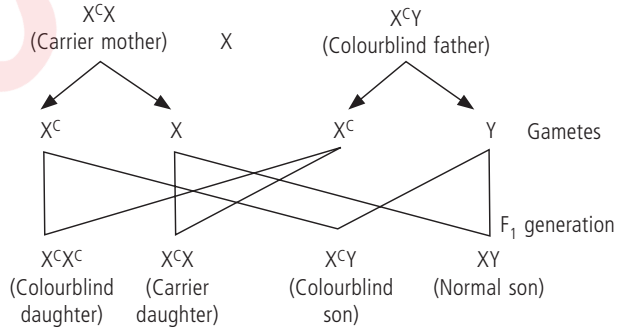
The alteration in genetic material through loss, gain or rearrangement of a particular segment of chromosome is called chromosomal aberrations that bring about chromosomal mutations which are very rare in nature. Chromosomal aberrations can be induced artificially by X rays, atomic radiation and chemicals, etc.

Translocation involves the transfer of a section of a chromosome to non homologous chromosome. It produces imperfect or faulty pairing during meiosis. It also produces duplication deficiencies and wrong segregations of chromosomes resulting in sterility of large section of gametes.

30. (a) The given pedigree shows the inheritance of X-linked traits. The genes for X linked traits are located on non-homologous segment of X chromosome. The genes for these characters show criss-cross inheritance as the gene for these characters are inherited from mother to his son and from son to his daughter in F_2 generation.

(b) Haemophilia and colourblindness are two diseases that are X linked and are inherited through the similar pattern.

(c) If both the parents are suffering from the X linked disease, then the probability of having disease in F_1 generation would be 50% as explained by the cross.



The F_1 progeny would have 25% healthy, 25% carrier and 50% diseased offspring.

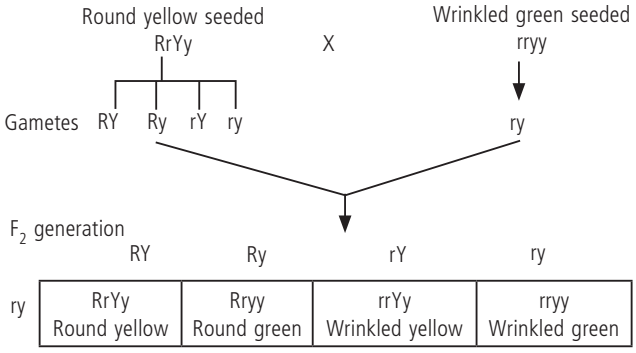
31. The given cross represents the dihybrid cross. The total number of seeds produced in F_2 generation are 1600.

(i) The analysis of cross reveals that the number of seeds heterogenous for yellow colour and homogenous for round seed shape are 2 out of 16.

Therefore, the total number of seeds heterogenous for yellow colour and homogenous for round seed shape are:

$= 2/16 \times 1600 = 200$

(ii) The cross between F_1 hybrids with wrinkled green seeded plants (rryy) can be explained with the help of following cross :



The phenotypic ratio obtained in F_2 generation is 1:1:1:1 and the genotypic ratio obtained in F_2 generation is 1:1:1:1.

(iii) According to the given cross, the seeds homogenous for round seed shape and green colour are 1/16. Therefore, the total number of round green seeds obtained is 100.

Homogenous round green seeds = 1/16 × 1600 = 100

OR

The starch synthesis in pea seeds is controlled by a single gene. It has two alleles B and b. Homozygous for BB produced large starch grains as compared to that produced by plants which are homozygous for bb. After maturation it was observed that BB seeds were round and bb were wrinkled. When they were crossed the resultant progeny were of intermediate size seeds showing round seeds (Bb). The cross involved is:

Parents: BB (Large starch grain with round seed) × bb (Small starch grain with wrinkled seed)

F_1: Bb (Intermediate sized starch grain with round seed)

↓ Selfing

F_2:

♀ \ ♂	B	b
B	BB Large and round	Bb Intermediate and round
b	Bb Intermediate and round	bb Small and wrinkled

Genotypic : BB : Bb : bb

Ratio : 1 : 2 : 1

Phenotypic Ratio : 1 Large : 2 Intermediate : 1 Small

But in case of seed shape the phenotype is 3 : 1; Round : Wrinkled.

Deviation from Mendel's law of dominance : If starch grain size is considered as the phenotype, then the alleles show incomplete dominance. Thus, dominance is not an autonomous feature of a gene, it depends on gene product and production of particular phenotype of product.

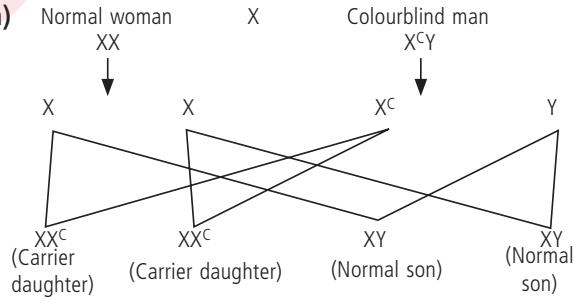
32. (a) In grasshoppers, the sex determination is of XX-XO type. Males are heterogametic and females are homogametic. The males have only one X-choromosomes (XO) whereas females have a pair of X-chromosomes (XX). It is the most common method of sex determination in a large number of insects where all eggs bear an additional X-chromosome besides the other chromosomes (autosomes). On the other hand, some of the sperms bear the X-chromosome whereas some do not. Eggs fertilised by sperm having an X-chromosome become females and those fertilised by sperms that do not have an X-chromosome become males.

(b) The sex dermination in birds is done by two chromosomes *viz*. Z and W. Females are heterogametic (ZW) and males are homogametic (ZZ). In this case, the total number of chromosome are same in both males and females but two different types of gametes (in terms of the sex chromosomes) are produced by females, *i.e.*, female heterogamety.

In case of humans, sex determination is XX-XY type. The males are heterogametic and females are homogametic. All males and females have 23 pairs of chromosomes out of which 22 pairs of autosomes are exactly same. Females have a pair of X chromosomes and males have an X and Y chromosome. Y chromosomes are determinant of the male characteristic. The sex determination in humans is completely determined by male's Y chromosome.

OR

(a)



The colourblindness is a X linked disease which shows criss-cross inheritance. The son receives X chromosome from mother and Y chromosome from father. Therefore, there is 0% probability that the daughter would suffer from colourblindness.

(b) Haemophilia is sex-linked disease, also known as bleeder's disease as the patient will continue to bleed even from minor cut due to absence of antihaemophilic globulin or factor VIII and plasma thromboplastin factor IX. The genes associated with these conditions are located on the X chromosome. In males (who have only one X chromosome), one altered copy of the gene in each cell is sufficient to cause the condition. In females (who have two X chromosomes), a mutation would have to occur in both copies of the gene

to cause the disorder. Because it is unlikely that females will have two altered copies of this gene, it is very rare for females to have haemophilia. In X-linked recessive inheritance, a female with one altered copy of the gene in each cell is called a carrier.

(c) Alzheimer's disease is an autosomal dominant disorder whereas sickle cell anaemia is an autosomal recessive disorder. In autosomal dominant disorders, a single copy of the disease-associated mutation is enough to cause the disease, however in contrast, an autosomal recessive disorder, two copies of the mutation are needed to cause the disease.

33. In dominant epistasis, the dominant allele of one gene masks the expression of alleles of another gene. It is even effective in heterozygous condition. ***e.g.,*** Fruit colour in plants such as summer squash is an example of dominant epistasis. There are 3 colours in summer squash fruits ***i.e.*** yellow, white and green and it is controlled by more than one gene (polygenic). The white fruit colour is controlled by a dominant gene (WW) and the yellow fruit colour is also controlled by dominant gene (GG) however, green fruit colour is governed by recessive gene (wg).

Parents: White Fruit WWgg × Yellow Fruit wwGG

F_1 Generation: WwGg White Fruit

F_2 Generation

	WG	Wg	wG	wg
WG	WWGG [W]	WWGg [W]	WwGG [W]	WwGg [W]
Wg	WWGg [W]	WWgg [W]	WwGg [W]	Wwgg [W]
wG	WwGG [W]	WwGg [W]	wwGG [Y]	wwGg [Y]
wg	WwGg [W]	Wwgg [W]	wwGg [Y]	wwgg [G]

W = White fruit, Y = Yellow fruit, G = Green fruit

The normal dihybrid modified to 12 : 3 : 1 in F_2 generation. When the dominant gene for white colour occurs in combination with the recessive gene of green colour, the phenotypic expression would be white due to its dominance over green colour. Similarly, the dominant gene for yellow colour show dominance over the recessive gene of green colour and the resulting phenotype would be yellow, but when both dominant genes of white and green colour occur together, the phenotypic expression of yellow coloured gene is masked by the expression of white coloured genes.

OR

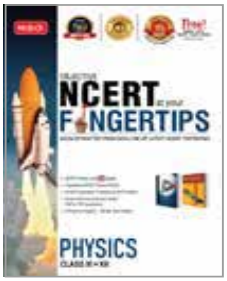
Mutagens are any chemical and physical factors which have capacity to induce mutations. The various mutagens includes physical and chemical mutagens.

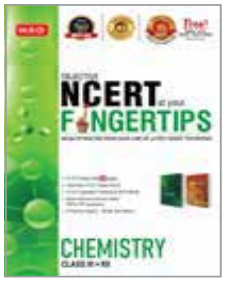
Physical mutagens include radiations, heat, etc. Different types of radiations such as UV rays, X-rays, alpha rays and other ionising and non-ionising radiations are mutagenic as they can directly damage the DNA or nucleotide structure. The UV-radiation cause base deletion, strand breakage, cross-linking and generation of nucleotide dimers such as, thymine-thymine dimer and thymine-cytosine dimers. The high dose of X-ray breaks the phosphodiester bonds between the DNA and thus results in the strand breakages. Heat also works as mutagen. At high heat, the DNA becomes denatured, ***i.e.***, two single-stranded DNA generated from the dsDNA and extreme heat also damages DNA and breaks the phosphodiester bonds too.

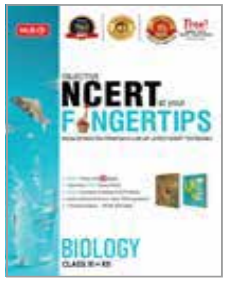
The chemical mutagens involves base analogues, alkylating agents, intercalating agents and metals etc. The base analogues structurally resemble the DNA bases. Bromouracil and aminopurine are two common base analogues incorporated into DNA instead of normal bases, during the process of replication.

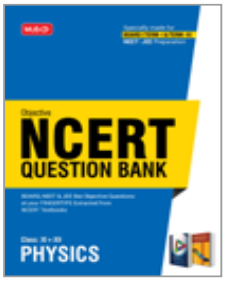
The alkylating agents cause base-pairing errors by increasing ionisation and produces gaps in the DNA strand. Mustard gas and vinyl chloride are common alkylating agents which add alkyl group to the DNA and damages it. The intercalating agents intercalate between the bases of DNA and disrupt its structure. If it is incorporated during the replication, it can cause frameshift mutation. It may also block transcription. ***e.g.***, ethidium bromide, acridine orange. Some metal ions also cause mutations by producing ROS, hindering DNA repair pathway, cause DNA hypermethylation or may directly damage the DNA.

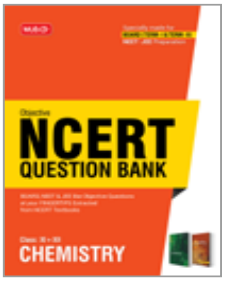
mtG BEST SELLING BOOKS FOR CLASS 12

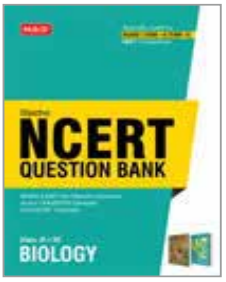


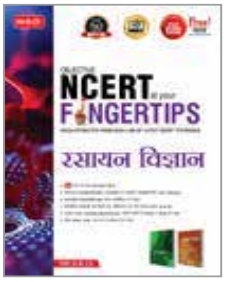


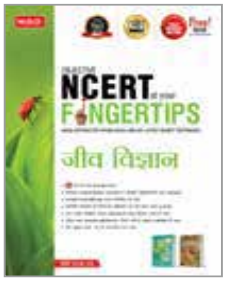


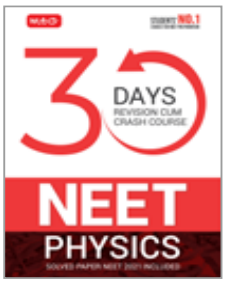


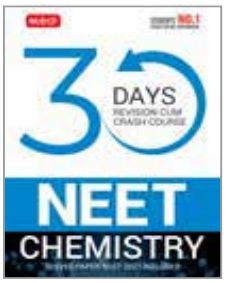


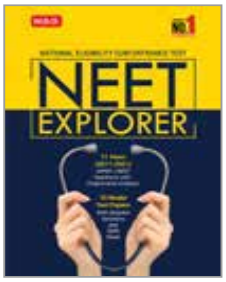


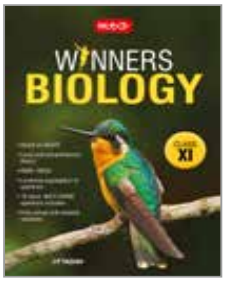


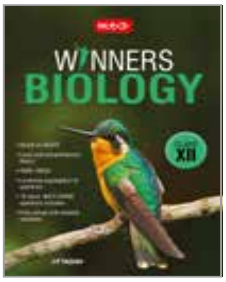












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