5

Principle of Inheritance and Variations

Multiple Choice Questions (MCQs)

Q. 1 All genes located on the same chromosome

(a) form different groups depending upon their relative distance
(b) form one linkage group
(c) will not from any linkage group
(d) form interactive groups that affect the phenotype

Ans. ***(b)*** All the genes, present on a particular chromosome form a linkage group. The number of linkage group of a species correspond to the total number of different chromosomes of that species. It is not simply the number of chromosomes in haploid set.

e.g., in human male=22 pairs of autosomes + 1X-chromosome + 1Y-choromosme *i.e.,* 24 linkage groups and in female = 22 pairs autosomes + 2X-chromosomes *i.e.,* 23 linkage groups.

While options (a), (c) and (d) are incorrect.

Q. 2 Conditions of a karyotype $2n \pm 1$ and $2n \pm 2$ are called

(a) aneuploidy
(b) polyploidy
(c) allopolyploidy
(d) monosomy

Thinking Process

Numerical changes in chromosome number are referred to as changes in ploidy.

Ans. ***(a)*** Aneuploidy involves changes in chromosome number by additions or deletions of less than a whole set. In this case organism gains or loses one or more chromosomes but not a complete set. Polyploidy is defined as the addition of entire set of chromosome. The polyploidy can be triploidy ($3n$), tetraploidy ($4n$), pentaploidy ($5n$), etc.

Allopolyploidy is the polyploidy in which chromosome sets are non-homologous. In other words we can say that the allopolyploids are derived from a stock which is heterozygous. Monosomy is the process in which one chromosome is removed from diploid set of chromosome ($2n$-1).

Q. 3 Distance between the genes and percentage of recombination shows

(a) a direct relationship
(b) an inverse relationship
(c) a parallel relationship
(d) no relationship

Thinking Process

Crossing over (recombination) is the mutual exchange of the corresponding segments of the adjacent paternal and maternal chromatids of the synapsed homologous chromosomes producing new combinations of genes.

Ans. ***(a)*** Crossing over separates genes away from each other. So, the distance between the genes and percentage of recombination shows an direct relationship, *i.e.,* when genes are close together they have high linkage and exhibit low recombination frequencies.

Thus, the other option are wrong as it does not show parallel or inverse relationship.

Q. 4 If a genetic disease is transferred from a phenotypically normal but carrier female to only some of the male progeny, the disease is

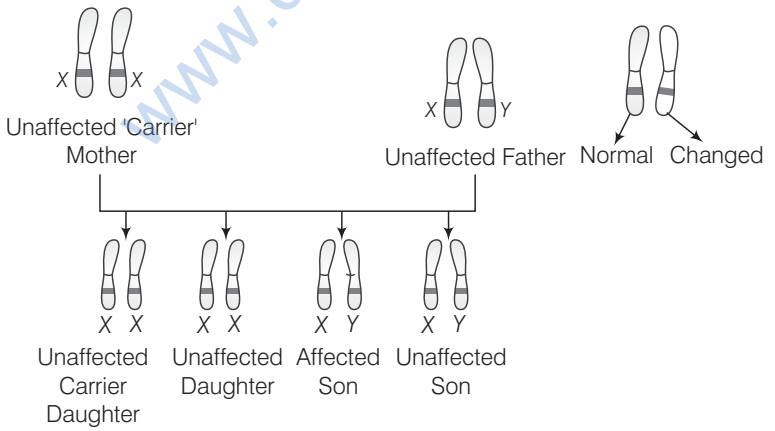
(a) autosomal dominant
(b) autosomal recessive
(c) sex-linked dominant
(d) sex-linked recessive

Thinking Process

Sex-linked disorders are those genetic diseases where the defective genes are carried on either the X or Y-chromosomes.

Ans. ***(d)*** Most sex-linked (X-linked) conditions are recessive. This means that in a person with two X-chromosomes (females), both copies of a gene (*i.e.,* one on each X-chromosome), must have a change or mutation whereas in a person with one X-chromosomes (males), only one copy of a gene must have a mutation.

A female with a mutation in one copy of a gene on the X-chromosome is said to be a 'carrier' for an X-linked condition.



For X-linked recessive disorders, an unaffected carrier mother who has a mutation in a gene on the X-chromosome can transmit either the X-chromosome with this mutation or a normal X-chromosome to her children.

Autosomal dominant inheritance refers to the pattern of inheritance of a condition directly or indirectly due to a dominant faulty gene located on autosome.

Autosomal recessive inheritance is the condition caused directly or indirectly due to a recessive faulty gene copy on autosome.

Sex-linked dominant is a rare trait that is caused by a single abnormal gene on the X-chromosome.

Q. 5 In sickle-cell anaemia glutamic acid is replaced by valine. Which one of the following triplet codes for valine?

(a) G G G (b) A A G (c) G A A (d) G U G

Ans. ***(d)*** Sickle-cell anaemia is an autosome linked recessive trait. This disease is controlled by a single pair of allele Hb^A and Hb^S only the homozygous individuals for Hb^S, *i.e.,* $Hb^S Hb^S$ shows the diseased phenotype. The heterozygous individuals are carriers ($Hb^A Hb^S$).

Due to point mutation, glutamic acid (Glu) is replaced by valine (Val) at sixth position of β-chain of haemoglobin molecule. This substitution occurs due to the single base substitution of the beta globin gene from GAG (Glu) to GUG (Val).

Whereas, the other codes GGG, AAG, GAA do not codes for valine.

Q. 6 Person having genotype $I^a I^b$ would show the blood group as AB. This is because of

(a) pleiotropy (b) codominance

(c) segregation (d) incomplete dominance

Thinking Process

The alleles which are able to express themselves independently when present together are called codominant alleles and this biological phenomenon of expressing together is called codominance.

Ans. ***(b)*** A B O blood grouping in humans is an example of codominance. A B O blood groups are controlled by gene I. Gene I has three alleles I^A, I^B and $I^{oi.}$ I^A and I^B are the dominant alleles. When I^A and I^B are present together, both express equally and produce the surface antigens A and B, whereas I is the recessive allele and does not produce any antigen.

Pleiotropy referred the genetic effect of a single gene on multiple phenotypic traits.

Incomplete dominance is a genetic term in which does not completely dominate another allele.

Segregation is the separation of allele during the process of gametogenesis. This is the basis of reappearance of recessive character in F_2-generation.

Q. 7 ZZ/ZW type of sex determination is seen in

(a) platypus (b) snails (c) cockroach (d) peacock

Thinking Process

In birds the ZW case i.e., ZZ/ZW type of sex determination is seen.

Ans. ***(d)*** In ZZ/ZW case, the female has heteromorphic (ZW) sex chromosomes and the male has homomorphic (ZZ) sex chromosomes. Thus, peacock shows ZZ/ZW sex determination type.

In platypus the sex determination is of XX-XY type. Both male and females has ten sex chromosome each. The male has XY, XY, XY, XY, XY and female has XXXXXXXXXX.

In snails the sex determination is environmentally induced, while in cockroaches it is of XX-XO types.

In this type Y-chromosome is completely lacking. In this the presence pf unpaired X-chromosomes determines the masculine sex.

Q. 8 A across between two tall plants resulted in offspring having few dwarf plants. What would be the genotypes of both the parents?

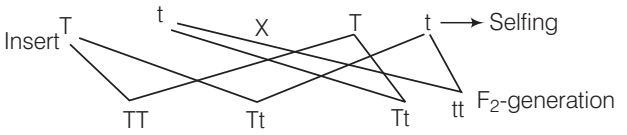
(a) TT and Tt (b) Tt and Tt (c) TT and TT (d) Tt and tt

Thinking Process

On the basis of monohybrid cross (a cross involving only one trait) Mendel formulated the law of segregation.

Ans. ***(b)*** Tt and Tt let's use Mendel's cross of tall and dwarf pea plants as an example.

The F_1 plants of genotype Tt are self-pollinated.(both tall (T) but with dwarf (t) alleles).



Phenotypic ratio : Tall : Dwarf

3 : 1

Genotypic ratio : Pure tall : Hybrid : Pure dwarf

1 : 2 : 1

The letters T and t are used to represent the alleles of the gene that determine plant height by conventions. The upper case letter (T) represents the dominant allele and the recessive allele (t) is represented by the same letter in lower case.

Thus, the tall parents plants having heterozygous alleles, results in offsprings which comprises of both tall and dwarf plants.

For the parental cross, both the parents are true breeding plants, the tall plant is homozygous for the tall allele 'T' while the dwarf plant is homozygous for the dwarf allele 't'. Mendel tracked each trait through two generations.

When true breeding plants were crossed to each other, this is called a parental cross and offspring comprise the first filial or F_1-generation. When the members of the F_1-generation were crossed, this produced the F_2-generation or second filial generation.

A cross between true breeding tall and dwarf plants of the parent generation yield phenotypically tall plants.

The cross between TT and Tt is called **back cross**, which results into two homozygous and two heterozygous dominant gametes. The cross between Tt and tt is called **test cross** which results into 1:1 ratio of gametes.

Q. 9 In a dihybrid cross, if you get 9 : 3 : 3 : 1 ratio it denotes that

(a) the alleles of two genes are interacting with each other

(b) it is a multigenic inheritance

(c) it is a case of multiple allelism

(d) the alleles of two genes are segregating independently

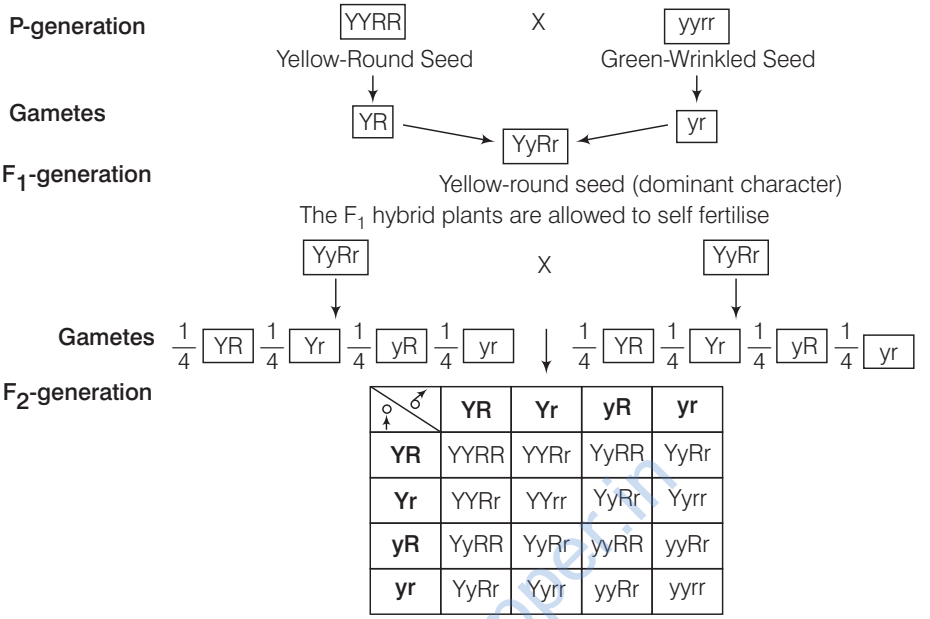
Thinking Process

A cross that involves the analysis of two independent traits is termed a dihybrid cross. The law of independent assortment was deduced from Mendel's experiment with dihybrid cross.

Ans. ***(d)*** Alleles of two genes are segregating independently. It can be explained as. Suppose crosses are made between a pea plant with round and yellow seeds and one with wrinkled and green ones.

All F_1 hybrids give yellow and round seeds. Since yellow colour is dominant over the green and the round shape is dominant over the wrinkled.

When the F_1-hybrid plants are crossed to each other or allowed to self fertilise, an F_2-*generation form as represented in the following figure*



♀ \ ♂	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

Phenotypic ratio – 9 : 3 : 3 : 1

The outcome of the dihybrid cross make it very clear that segregation of the seed colour is independent of the seed shape and both the parental and new combinations of the characters appear in the F_2 offspring, *i.e.,* assortment of genes of one pair is independent of the other pair.

When the alleles of two genes are interacting with each other one may dominate over other or become recessive. During a multigenic inheritance we describe a characteristics that is specified by a combination of multiple genes. Multiple allelism is a type of non-mendelian inheritance pattern that involves more than just the typical two alleles.

Q. 10 Which of the following will not result in variations among siblings?

(a) Independent assortment of genes (b) Crossing over
(c) Linkage (d) Mutation

Thinking Process

Linkage refers to the physical association of genes on chromosome.

Ans. *(c)* Linkage will not result in variations among siblings. Morgan carried out several dihybrid crosses in *Drosophila* to study genes that were sex-linked.

Morgan came to know that the genes were located on the X-chromosome and also observed that when the two genes in a dihybrid cross were situated on the same chromosome, the proportion of parental gene combinations were much higher than the non-parental type.

It indicates that due to the physical association of the two genes. There will be no variations among siblings. Independent assortment of genes means that allele pair separate during the formation of gametes independently. It means that traits are transmitted to offspring independently of one another.

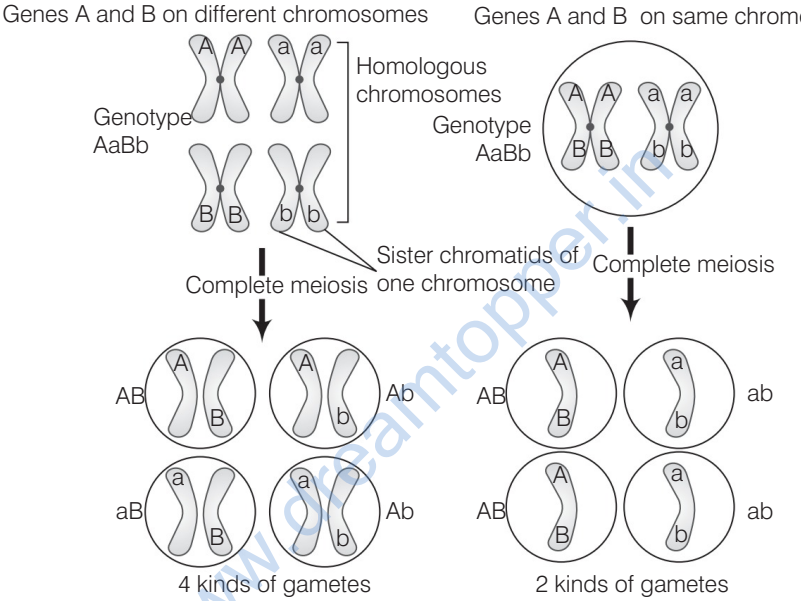
Crossing over is the exchange of genetic material between homologous chromosomes. It is one of the final phases of genetic recombination. Mutation is the sudden inheritable change in genetic material of an organism which transfers to next generation.

Q. 11 Mendel's law of independent assortment holds good for genes situated on the

(a) non-homologous chromosomes (b) homologous chromosomes
(c) extra nuclear genetic element (d) same chromosome

Ans. *(a)* **Non-homologous Chromosome** The law of independent assortment holds true as long as two different genes are on separate chromosomes. When the genes are on separate chromosom, the two alleles of one gene (A and a) will segregate into gametes independently of the two alleles of the other gene (B and b).

Equal numbers of four different gametes will form AB, aB, Ab,ab. But if the two genes are on the same chromosome, then they will be linked and will segregate together during meiosis, producing only two kinds of gametes.



Homologous chromosomes are similar but not identical. Each carries the same gene in same order but the alleles for each trait may not be the same. Extranuclear genetic elements are also called as plasmids and shows the pattern of maternal inheritance.

Q. 12 Occasionally, a single gene may express more than one effect. The phenomenon is called

(a) multiple allelism (b) mosaicism
(c) pleiotropy (d) polygeny

Ans. *(c)* Occasionally, a single gene may express more than one trait. This phenomenon is called pleiotropy. Sometimes, one trait will be very evident and others will be less evident, *e.g.,* a gene for white eye in *Drosophila* also affect the shape of organs in male responsible for sperm storage as well as other structures.

Similarly, sickle-cell anaemic individuals suffer from a number of problems, all of which are pleiotropic effects of the sickle-cell alleles.

Multiple allelism is a seies of three or more alternative or allelic forms of a gene, only two of which can exist in any normal diploid individual, *e.g.,* genes of blood groups in humans.

Mosaicism describes the occurrence of cells that differ in thier genetic component from other cells of the body.

Polygeny refers to a single characteristic that is controlled by more than two genes. (it is also known as multifactorial inheritance).

Q. 13 In a certain taxon of insects some have 17 chromosomes and the others have 18 chromosomes. The 17 and 18 chromosome-bearing organisms are

(a) males and females, respectively
(b) females and males, respectively
(c) all males
(d) all females

Ans. *(a)* In certain insects, such as cockroach, and some roundworms, the Y-chromosome is missing so that the male has only one sex chromosome, *i.e.,* 'X'. The condition in the male is XO (O means absence of one sex chromosome) and in the female it is XX., thus males showing 17 chromosomes while females show 18 chromosome.
All the other option given are wrong.

Q. 14 The inheritance pattern of a gene over generations among humans is studied by the pedigree analysis. Character studied in the pedigree analysis is equivalent to

(a) quantitative trait
(b) Mendelian trait
(c) polygenic trait
(d) maternal trait

Thinking Process

A pedigree is a family tree that diagrams the relationships among parents and children across several generations which shows the inheritance pattern of a particular phenotyphic character.

Ans. *(b)* Mendelian inheritance in humans is difficult to study. Current understanding of mendelian inheritance in humans is gained by analysis of family pedigrees or the results of matings that have already occured. By analysing a pedigree, we may be able to predict how the trait is inherited.

It is a visual tool for documenting the biological relationship in families and to determine the mode of inheritance (dominant, recessive etc.,) of genetic diseases.

Whereas quantitative trait, polygenic trait and maternal traits are not studied by pedigree analysis.

Continuous traits are often measured and given a quantitative value, they are often referred as quantitative traits, *e.g.,* crop yield, weight, gain in animals, IQ, etc.

Polygenic traits are another exception to mendels rule, which occurs when a trait is controlled by more than one gene. This means that each dominant allele adds to the expression of the next dominant allele.

Maternal traits are the traits inherited and expressed from the maternal parent to the subsequent offsprings.

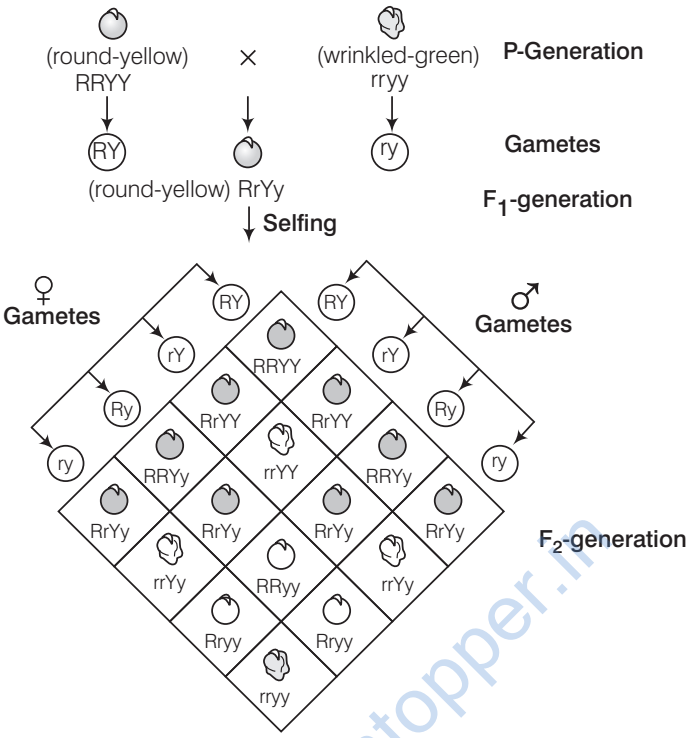
Q. 15 It is said that Mendel proposed that the factor controlling any character is discrete and independent. This proposition was based on the

(a) results of F_3-generation of a cross
(b) observations that the offspring of a cross made between the plants having two contrasting characters shows only one character without any blending
(c) self-pollination of F_1 offsprings
(d) cross-pollination of F_1-generation with recessive parent

Thinking Process

Law of segregation states that the factors or alleles of a pair segregate from each other during gamete formation, such that a gamete receives only one of the two factors. They do not show any blending.

Ans. *(b)*



Phenotypic ratio	Round yellow			:	Round green			:	Wrinkled yellow			:	Wrinkled green			
		9		:		3		:		3		:		1		
Genetypic ratio	1	:	2	:	2	:	4	:	1	:	2	:	1	:	2	: 1

Results of a dihybrid cross where the two parents differed in two pairs of contrasting traits seed colour and seed shape

Rest of the options does not support the Mendel's low of segregation.

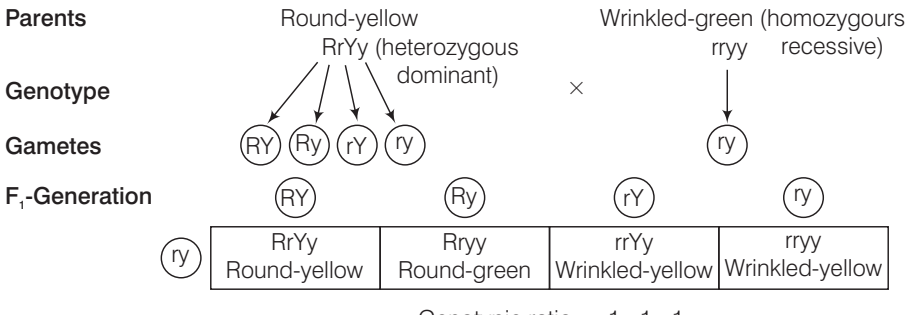
Q. 16 Two genes 'A' and 'B' are linked. In a dihybrid cross involving these two genes, the F_1 heterozygote is crossed with homozygous recessive parental type (aa bb). What would be the ratio of offspring in the next generation?

(a) 1 : 1 : 1 : 1 (b) 9 : 3 : 3 : 1 (c) 3 : 1 (d) 1 : 1

Thinking Process

When a progeny of F_1 is crossed with the homozygous recessive parent, it is called test cross.

Ans. *(a)* **1:1** It can be explained by the following test cross.



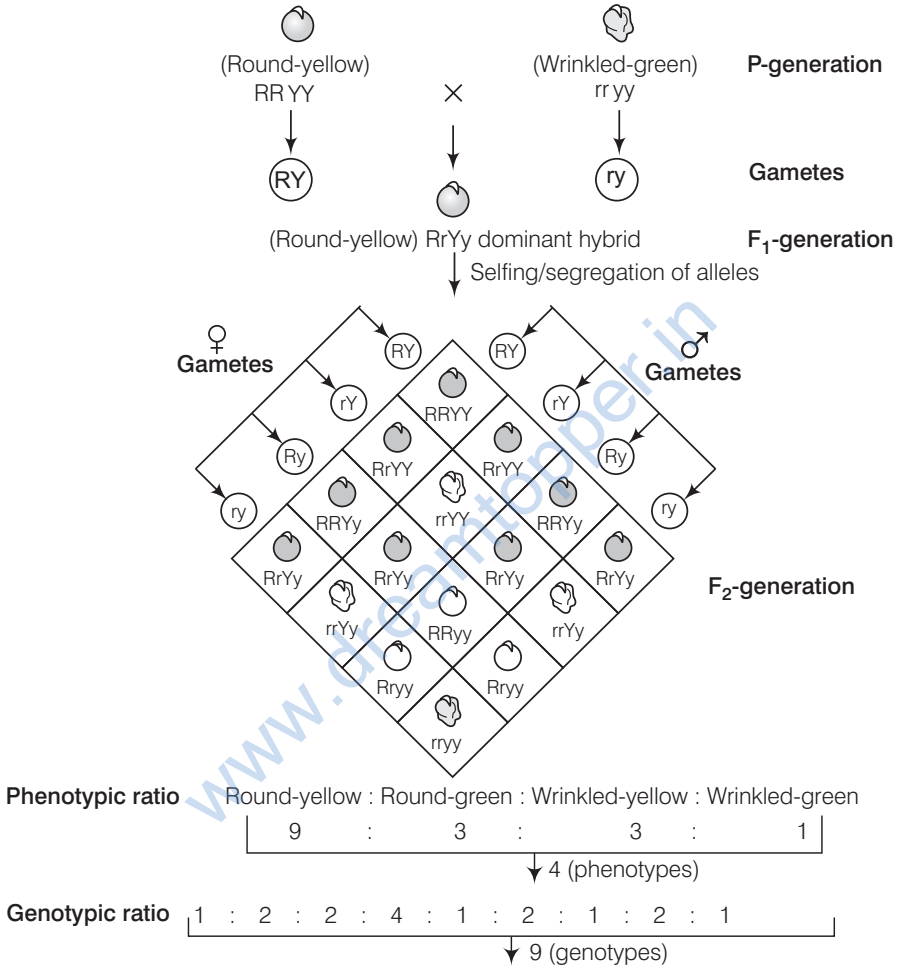
Genotypic ratio — 1 : 1 : 1

The other options are incorrect.

Q. 17 In the F_2-generation of a Mendelian dihybrid cross the number of phenotypes and genotypes are

(a) phenotypes-4, genotypes-16 (b) phenotypes-9, genotypes-4
(c) phenotypes-4, genotypes-8 (d) phenotypes-4, genotypes-9

Ans. *(d)* Mendel's dihybrid cross



Results of a dihybrid cross where the two parents differed in two pairs of contrasting traits : seed colour and seed shape

Other combinations do not show dihybrid cross ratio of mendelien inheritance.

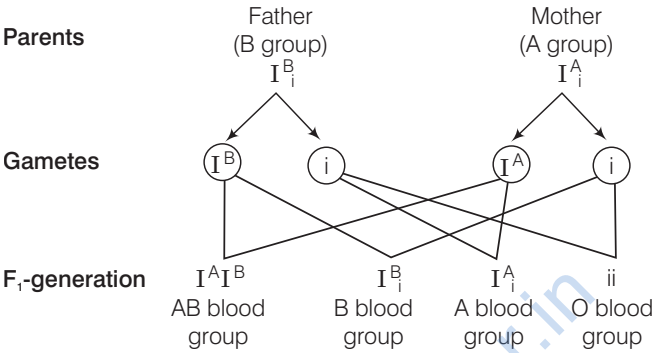
Q. 18 Mother and father of a person with 'O' blood group have 'A' and 'B' blood group respectively. What would be the genotype of both mother and father?

(a) Mother is homozygous for 'A' blood group and father is heterozygous for 'B'
(b) Mother is heterozygous for 'A' blood group and father is homozygous for 'B'
(c) Both mother and father are heterozygous for 'A' and 'B' blood group respectively
(d) Both mother and father are homozygous for 'A' and 'B' blood group respectively

Thinking Process

The child with blood group O will have homozygous recessive alleles. Therefore, both the parents should be heterozygous, i.e., the genotype of father will be $I^A i$ *and of mother will be* $I^B i$.

Ans. *(c)* When a cross is carried out between heterozygous father (for blood group B) and heterozygous mother (of blood group A) to get four children with different blood groups.



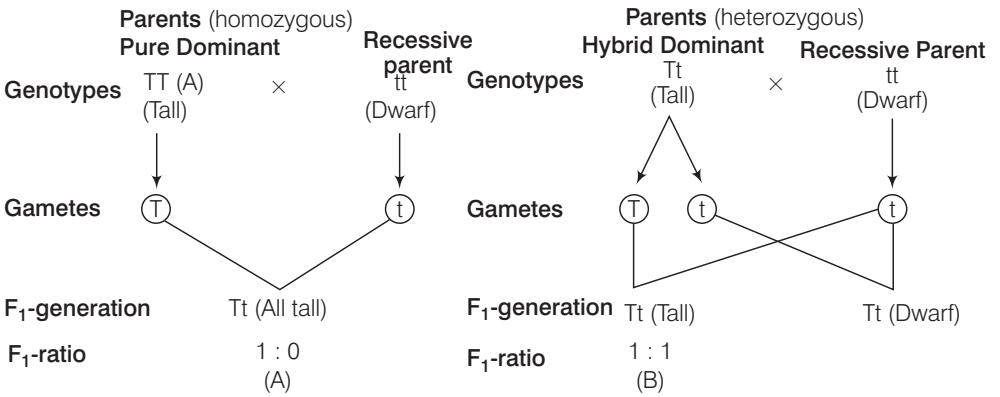
All the four blood groups are controlled by three allelic genes I^A, I^B, i and thus it shows phenomenon of multiple allelism. Both I^A and I^B is dominant over i. However , when together, both are dominant and show the phenomenon of codominance forming the blood group AB. Six genotypes are possible with combination of these three alleles. Thus, other option are wrong or incorrect.

Very Short Answer Type Questions

Q. 1 What is the cross between the progeny of F_1 and the homozygous recessive parent called? How is it useful?

Ans. When a progeny of F_1 is crossed with the homozygous recessive parent, it is called test cross.

Test cross between pure dominant (A) and hybrid dominant (B) individuals with recessive parent is shown below



Such a cross is useful to determine the genotype of an unknown trait, *i.e.,* whether it is heterozygous or homozygous dominant for the trait.

Q. 2 Do you think Mendel's Laws of inheritance would have been different in the characters that he chose were located on the same chromosome.

Ans. If the characters are present on the same chromosome they would not assort independently as they are linked on the same chromosome. Percentage of linkage depends on the distance between the genes. With linkage no conclusive laws can be drown.

Q. 3 Enlist the steps of controlled cross-pollination. Would emasculation be needed in a cucurbit plant? Give reasons for your answer.

Thinking Process

Controlled cross-pollination is one of the major approaches of crop improvement programme. In such experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen).

Ans. *Steps of controlled cross-pollination are*

(i) Selection of parents with desired characters.

(ii) Emasculation, *i.e.*, if the female parent bears bisexual flowers, before dehiscence anther should be removed by forceps.

(iii) Bagging, *i.e.,* emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen.

(iv) When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma

(v) The flowers are rebagged and the fruits are allowed to develop.

Emasculation is not always needed in a cucurbit plant. Emasculation is essential only in case of bisexual flowers to prevent self-pollination. In case of cucurbit plant, female parent produces usually unisexual flowers but may sometimes have bisexual flowers.

Note *If the female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.*

Q. 4 A person has to perform crosses for the purpose of studying inheritance of a few traits/characters. What should be the criteria for selecting the organisms?

Ans. *The criteria for selecting the organism to study inheritance are*

(i) Easily visible and different traits

(ii) Short life span

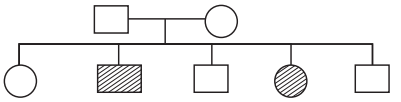
(iii) Simple pollination procedure

(iv) Organisms must be true breeds

(v) Mating of gametes has to be random

(vi) Can be easily manipulated

Q. 5 The pedigree chart given below shows a particular trait which is absent in parents but present in the next generation irrespective of sexes. Draw your conclusion on the basis of the pedigree.



Ans. The pedigree chart shows that the trait is autosome linked and recessive in nature. But, the parents are carriers (*i.e.,* heterozygous) hence, among the offsprings only few show the trait irrespective of sex. The other offsprings are either normal or carrier.

Q. 6 In order to obtain the F_1-generation Mendel pollinated a pure-breeding tall plant with a pure-breeding dwarf plant. But for getting the F_2-generation, he simply self-pollinated the tall F_1 plants. Why?

Ans. Characters segregate during gamete formation. Pure-breeding parents give rise to F_1 with heterozygous conditions. Only self-pollination of heterozygotes can result in all possible recombinations of characters in progeny as mating is random.

Q. 7 'Genes contain the information that is required to express a particular trait.' Explain.

Ans. Genes contain the information required to express a particular trait can be explained by the following experiment.

G Beadle and **E Tatum** set an experiment to prove that one gene possess a particular trait and is responsible for the production of one enzyme or protein. They performed their experiment on *Neurospora crassa* which were nutritionally mutant.

It was proved that a single protein contains several polypeptide and each polypeptide is controlled by separate gene. Thus, each gene expresses a particular trait. This theory was called one-gane-one enzyme or one gene-one polypeptide hypothesis.

But after the discovery of cistron (the functional unit of gene), the theory was named as one-cistron-one polypeptide hypothesis.

Q. 8 How are alleles of particular gene differ from each other? Explain its significance.

Ans. Alleles are polymorphs that differ in their nucleotide sequence resulting in contrasting phenotype expression. Alleles are the alternative forms of a same gene for, *e.g.,* genes for height have two allele, one for dwarfness (t) and one for tallness (T).

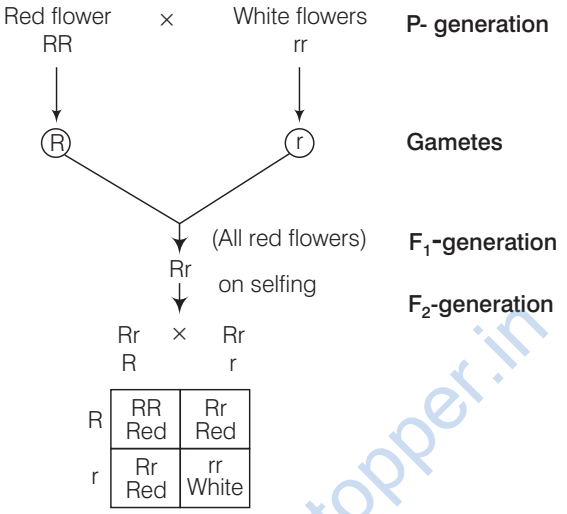
Significance

(i) A character may have two or more contrasting phenotypic expression, thus resulting variation in the population.

(ii) These are used in the studies of inheritance and in understanding their behaviour.

Q. 9 In a monohybrid cross of plants with red and white flowered plants. Mendel got only red flowered plants. On self-pollinating these F_1 plants got both red and white flowered plants in 3:1 ratio. Explain the basis of using RR and rr symbols to represent the genotype of plants of parental generation.

Ans.



Phenotypic ratio Red flower : White flower 3 : 1
Genotype ratio RR : Rr : rr 1 : 2 : 1

Generally, upper case letters are used as symbols for dominant and lower case for recessive traits of the same gene (alleles). Experiment shows that it is a monohybrid cross with 3 : 1 ratio in F_2-generation.

This shows parents must be true-breeds. As parents are diploid and homologous chromosomes carry alleles with similar type they are represented with RR and rr.

Q. 10 For the expression of traits genes provide only the potentiality and the environment provides the opportunity. Comment on the veracity of the statement.

Thinking Process

Phenotype = Genotype + Environment
(Trait) (potentiality) (opportunity)

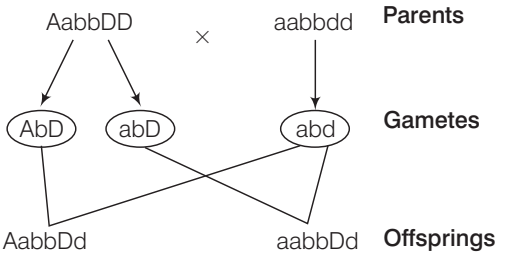
Ans. Obviously, genes are not the only factors that determine phenotype. Environment also plays an important role in the expression of traits. Genes are actually quite active throughout our lives, switching their expression on and off in response to the environment.

Besides the effect of internal factors like hormones and metabolism on gene expression, external factors like temperature, light, nutrition, etc., also affect the gene expression and ultimately exhibiting phenotypic changes.

So, we can say that genes provide only the potentiality and the environment provides the opportunity for the expression of traits.

Q. 11 A, B, D are three independently assorting genes with their recessive alleles a, b, d, respectively. A cross was made between individuals of Aa bb DD genotype with aa bb dd. Find out the type of genotypes of the offspring produced.

Ans. The given cross Aa bb DD X aa bb dd, is a trihybrid cross, Accordingly the type of offspring produced would be,



Q. 12 In our society a woman is often blamed for not bearing male child. Do you think it is right? Justify.

Thinking Process

The sex determining chromosome in case of humans is of XY type.

Ans. It is unfortunate that in our society women are blamed for giving birth to female children and have been ostracised and ill-treated because of this false notion. Out of 23 pairs of chromosomes present, 22 pairs are exactly same in both males and females, these are the autosomes.

A pair of X-chromosomes are present in the female, whereas the presence of an X and Y-chromosome are determinant of the male characteristic. During spermatogenesis among males, two types of gametes are produced.

50 per cent of the total sperm produced carry the X-chromosome and the rest 50% has Y-chromosome besides the autosomes. Females, however, produce only one type of ovum with an X-chromosome. There is an equal probability of fertilisation of the ovum with the sperm carrying either X or Y-chromosome.

In case when the ovum fertilises with a sperm carrying X-chromosome the zygote develops into a female (XX) and the fertilisation of ovum with Y-chromosome carrying sperm results into a male offspring. Thus, it is evident that it is the genetic makeup of the sperm (male) that determines the sex of the child.

It is also evident that in each pregnancy there is always 50% probability of having either a male or a female child.

Q. 13 Discuss the genetic basis of wrinkled phenotype of pea seed.

Ans. Seed shape is determined by a single gene, with the allele (R) for round peas dominant over the allele (r) for wrinkled peas (recessive trait).

It the alleles for the gene controlling the seed shape are homozygous in a plant, it will show the character or phenotype of same alleles, *i.e.,*-RR- round seed, rr-wrinkled seed.

On the other hand, if the alleles of gene are heterozygous. They will express the phenotype of dominant allele.

Rr - Round seed (r- wrinkled is recessive)
This is the genetic basis of wrinkled phenotype of pea seed.

Q. 14 Even if a character shows multiple allelism, an individual will only have two alleles for that character. Why?

Ans. Multiple alleles are the multiple forms of a gene which occur on the same gene locus, but distributed in different organisms in the gene pool with an organism, which carry only two alleles and the gamete have only one allele.

Despite multiple allelism, an individual will have only two alleles because an individual develops from a zygote which is the result of fusion of sperm (carrying father set of (*n*)haploid chromosomes) and an egg (carrying mother set of haploid chromosomes).

Sperm and an egg have only one gene (allele) for each trait. A zygote when becomes diploid, have two alleles for each trait. It is the maximum number of alleles an individual can have. *e.g.,* genes of blood groups.

Q. 15 How does a mutagen induce mutation? Explain with example.

Ans. Mutagens may be physical, *i.e.,* ionising radiations X-ray,UV rays, gamma rays, DNA reactive chemicals, *i.e.,* hydroxyl radicals, H_2O_2, etc., or biological such as virus.
A mutagen can induce mutation by inducing, a change in the base sequence by insertion, deletion or substitution.

e.g., a single base sequence substitution at the sixth codon of the β-globin gene changes the codon from GAG to GUG. This results in the substitution of glutamic acid (Glu) by valine (Val) at the sixth position of the β-globin chain of the haemoglobin molecule.

The mutant haemoglobin molecule undergoes polymerisation under low oxygen tension causing the change in the shape of the RBC from biconcave disc to the elongated sickle, *i.e.*, like structure which is not functional.

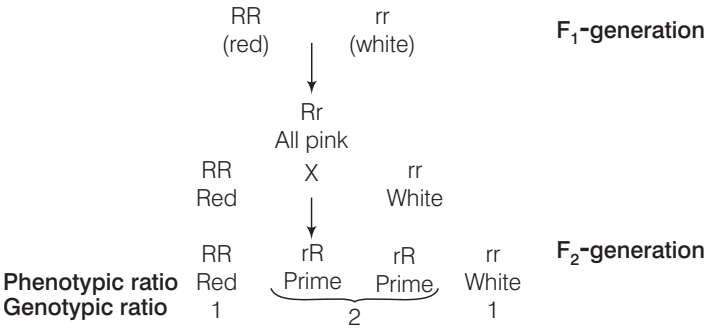
Short Answer Type Questions

Q. 1 In a Mendelian monohybrid cross, the F_2-generation shows identical genotypic and phenotypic ratios. What does it tell us about the nature of alleles involved? Justify your answer.

Thinking Process

In a monohybrid cross starting with parents which are homozygous dominant and homozygous recessive, F_1 would be heterozygous for the trait and would express the dominant allele. But in case of incomplete dominance the result will be different.

Ans. In case of incomplete dominance, a monohybrid cross shows the result as follows



Here, the phenotypic and genotypic both ratios are the same. So, we can conclude that when genotypic and phenotypic ratios are the same, alleles show incomplete dominance. *i.e.,* none of the two alleles shows dominance thus producing hybrid intermediate from the expression of two homozygous alleles.

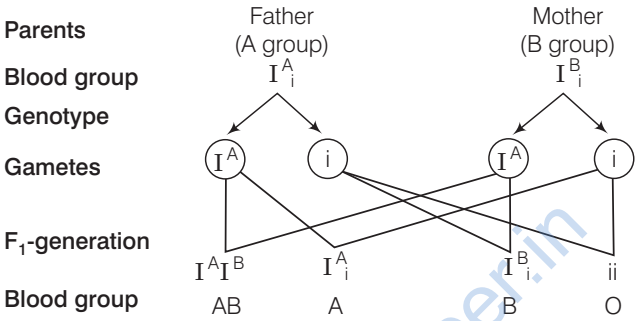
Q. 2 Can a child have blood group 'O' if his parents have blood group 'A' and 'B' Explain.

Thinking Process

The child with blood group O will have homozygous recessive alleles. Therefore, both the parents should be heterozygous, i.e., genotype of father will be $I^A i$, or $I^B i$ and of mother will be $I^A i$ or $I^B i$.

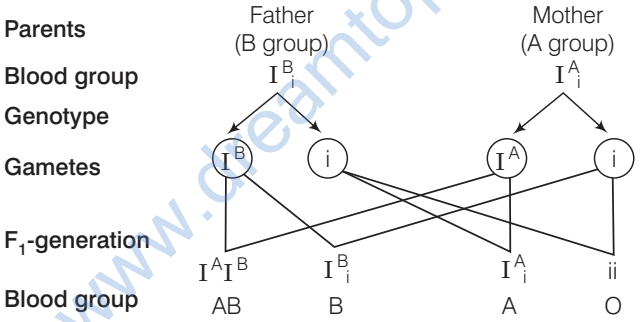
Ans. A child have blood group O in the following two cases

Case I When father is $I^A i$ and mother is $I^B i$.



The offsprings will have the above possible blood groups. *i.e.,* AB, A, B and O

Case II When father is $I^B i$ and mother is $I^A i$.



The offsprings will have the above possible blood groups, *i.e.,* AB, A, B and O. Thus, a child can have blood group 'O' if parents have heterozygous alleles for group 'A' and 'B'.

Q. 3 What is Down's syndrome? Give its symptoms and cause. Why is it that the chances of having a child with Down's syndrome increases if the age of the mother exceeds forty years?

Ans. Down's syndrome is a human genetic disorder caused due to trisomy of chromosome number 21. Such individuals are aneuploid and have 41 chromosomes, *i.e.,* $(2n+1)$

Symptoms of down's syndrome are

(i) Mental retardation

(ii) Growth abnormalities

(iii) Constantly open mouth

(iv) Dwarfness, etc., gonads and genitalia under developed

The reason for the disorder is the non-disjunction (failure to separate) of homologous chromosome (a pair 21 during meiotic division. The chances of having a child with Down's syndrome increases with the age of the mother (+40) because age adversely affects meiotic chromosome behaviour.

Meiosis in the egg cells is not completed, until after fertilisation. During this long gap (till meiosis is not completed) egg cells are arrested in prophase I and chromosomes are unpaired. The greater the time they remain upaired greater the chance for unpairing and chromosome non-disjunction.

Q. 4 How was it concluded that genes are located on chromosomes?

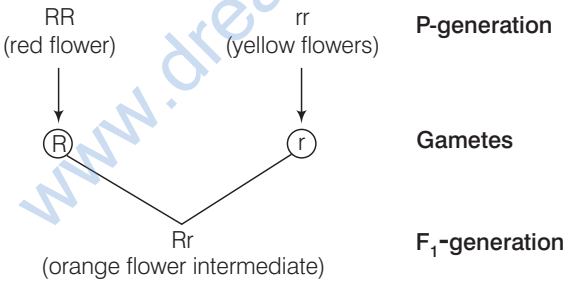
Ans. Chromosome theory of inheritance was proposed by **Sutton** and **Boveri** independently in 1902. The theory believes that chromosomes are vehicles of heriditary information, possess Mendelian factors or genes and it is the chromosomes which segregate and assort independently during transmission from one generation to the next.

Q. 5 A plant with red flowers was crossed with another plant with yellow flowers. If F1 showed all flowers orange in colour, explain the inheritance.

Thinking Process

If any of the alleles does not fully dominate in a heterozygous condition, it is called incomplete dominance.

Ans. Incomplete dominance is the phenomenon where neither of the two alleles shows dominance thus producing intermediate hybrid between the expression of two alleles in homozygous state. In this case, a new phenotype in between the two original phenotype appears.



Q. 6 What are the characteristic features of a true-breeding line?

Ans. True breeding is a stable trait inheritance and expression for several generations as a result of continuous self-pollination.

Characteristic features of a true-breeding line

(i) They are used as parents in artificial hybridisation as they provide gametes with all similar traits.

(ii) Homozygous recessive plants are used in test cross to determine the genotype.

Q. 7 In peas,tallness is dominant over dwarfness, and red colour of flowers is dominant over the white colour. When a tall plant bearing red flowers was pollinated with a dwarf plant bearing white flowers, the different phenotypic groups were obtained in the progeny in numbers mentioned against them

Tall, Red = 138
Tall, White = 132
Dwarf, Red = 136
Dwarf, White = 128

Mention the genotypes of the two parents and of the four offspring types.

Ans. The result shows that the four types of offspring are in a ratio of 1:1:1:1. Such a result is observed in a test cross progeny of a dihybrid cross.

The cross can be represented as

Parents Tall and red (TtRr) × Dwarf and white (ttrr)

Offsprings

♀ \ ♂	**TR**	**Tr**	**tR**	**tr**
tr	TtRr (tall and red)	Ttrr (tall and white)	ttRr (dwarf and red)	ttrr (dwarf and white)

Q. 8 Why is the frequency of red-green colourblindness is many times higher in males than that in the females?

Ans. Colourblindness is a X-inked sex inheritance. For becoming colourblind, the female must have the allele for it in both her X-chromosomes and if only one X-chromosome of female possess allele for colour blind character she becomes the carrier for this characteristics But males develop colourblindness when their sole X- chromosome has the allele for it. Thus males are more prone to colour blindness while females are carriers.

Q. 9 If a father and son are both defective in red-green colour vision, is it likely that the son inherited the trait from his father? Comment.

Ans. Gene for colourblindness is X-chromosome linked, and sons receive their sole X-chromosome from their mother, not from their father. Male to male inheritances is not possible for X-linked traits in humans.

In the given case the mother of the son must be a carrier (heterozygous) for colour blindness gene, thus transmitting the gene to her son.

Q. 10 Discuss why *Drosophila* has been used extensively for genetical studies?

Ans. **Morgan** worked with the tiny fruit flies, *Drosophila melanogaster*, which were found to be suitable for genetical studies due to the following characteristics

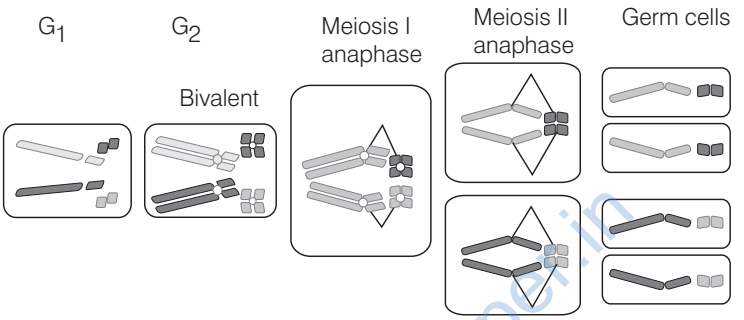
(i) They could be grown on simple synthetic medium in the laboratory.
(ii) They complete their life-cycle in about two weeks.
(iii) A single mating could produce a large number of progeny flies.
(iv) A clear differentiation of the sexes– the male and female flies are easily distinguishable.
(v) It has many types of variations (hereditary) that can be seen with low power microscopes.

Q. 11 How do genes and chromosomes share similarity from the point of view of genetical studies?

Ans. By 1902, the chromosome movement during meiosis had been worked out.

Walter Sutton and **Theodore Boveri**, (1902) noted that the behaviour of chromosomes was parallel to the behaviour of genes and used chromosome movement to explain Mendel's Laws.

They studied the behaviour of chromosomes during mitosis (equational division) and during meiosis (reduction division). The chromosomes as well as genes occur in pairs and the two alleles of a gene pair are located of homologous sites of homologous chromosomes.



Chromosome movement in meiosis and germ cell formation in a cell with four chromosomes. Chromosomes segregate when germ cells are formed

Q. 12 What is recombination? Discuss the applications of recombination from the point of view of genetic engineering.

Ans. Recombination refers to the generation of new combination of genes which is different from the parental types. It is produced due to crossing over that occurs during meiosis prior to gamete formation.

Applications of Recombination

(i) It is a means of introducing new combinations of genes and hence new traits.

(ii) It increases variability which is useful for natural selection and under changed environment.

(iii) Since, the frequency of crossing over depends upon the distance between the two genes, the phenomenon is used for preparing linkage chromosome maps.

(iv) It has proved that genes lie in a linear fashion in the chromosome.

(v) Breeders have to select small or large population for obtaining the required cross-overs. For obtaining cross-overs between closely linked genes, a very large population is required.

(vi) Useful recombinations produced by crossing over are picked up by breeders to produce useful new varieties of crop plants and animals. Green revolution has been achieved in India due to this selective picking up of useful recombinations. Operation flood or white revolution is also being carried out on the similar lines.

Q. 13 What is artificial selection? Do you think it affects the process of natural selection? How?

Ans. Artificial selection (or selective breeding) describes intentional breeding for certain traits or combination of traits by humans, for exploiting the variations existing among species. It is of three types-mass selection, pure-line selection and clonal selection.

Yes, it affects the process of natural selection. Natural selection selects for/or against traits based on their effect on the fitness of the organism. In artificial selection, traits are selected based on human preference for improving traits.

The process of natural selection leads to evolutionary change in the expression of the trait in the population, whereas the artificial selection, though being the same process, involves the traits preferred by humans for its own benefit. It is a much faster process than the natural selection but it may impose threat on diversity in long run making it unfit to the environment.

Q. 14 With the help of an example differntiate between incomplete dominance and co-dominance.

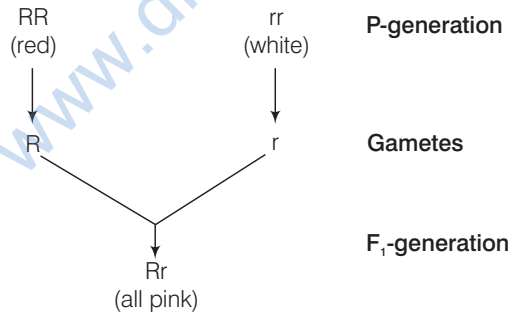
Ans. Incomplete dominance is a phenomenon where two contrasting alleles are present together but neither of the alleles is dominant over other and the phenotype formed is intermediate of the two alleles.

e.g., the kind of inheritance in the dog flower (Snapdragon or *Antirrhinum* species) in which the intermediate trait is expressed in F_1-generation.

Codominance is a phenomenon in which when two contrasting alleles are present together and both of the alleles express themselves.

e.g., AB blood group in humans where both the alleles are expressed to produce RBC surface antigens A and B.

(i) **Coss showing incomplete dominance**



(ii) **Blood group showing co-dominance**

Genotype	Surface Antigen	Blood Group
I^Ai (dominance)	A	A
I^AI^A	A	A
I^Bi (dominance)	B	B
I^BI^B	B	B
I^AI^B (co-dominance)	AB	AB
ii	—	O

Q. 15 It is said, that the harmful alleles get eliminated from population over a period of time, yet sickle-cell anaemia is persisting in human population. Why?

Ans. Sickle-cell anaemia is an autosomal recessive disease caused by haemoglobins an oxygen carrying protein in blood cells.

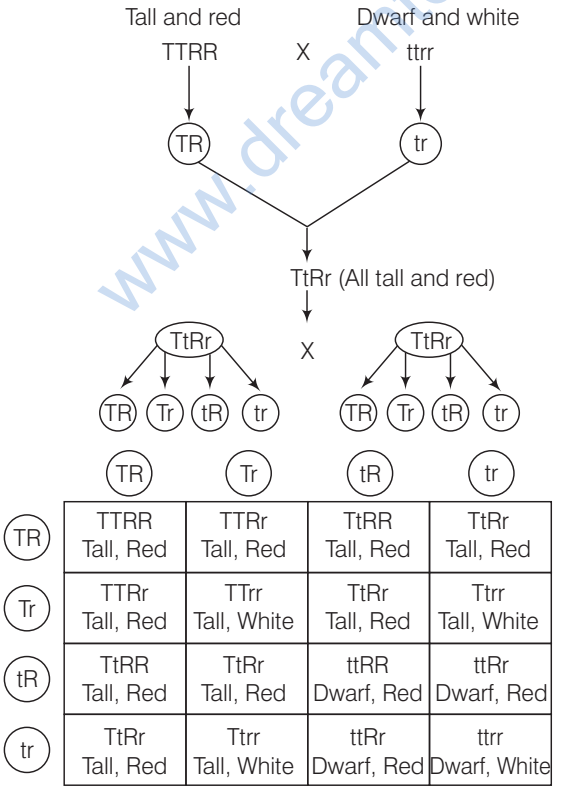
Despite the disease's lethal symptoms, it protects the carrier from malaria. Its allele are most common in the people of African descent (about 7% people of African descent carry an allele) and some other are as where malaria in prevalent.

It provides the vital protection from malaria. Individuals with HbAS heterozygotes tend to survive better than individuals with HbSS (homozygotes) as they are not exposed to the same severity of risk.

Long Answer Type Questions

Q. 1 In a plant tallness is dominant over dwarfness and red flower is dominant over white. Starting with the parents work out a dihybrid cross. What is standard dihybrid ratio? Do you think the values would deviate if the two genes in question are interacting with each other?

Ans.



The standard dihybrid ratio is 9:3:3:1. Yes, the values will show deviation if the two genes in the above case are interacting with each other. When the genes are linked, they do not assort independently but remain together in the gametes and the offsprings, give a dihybrid ratio of 3:1 and show a test cross ratio of 1:1 instead of 1:1:1:1.

Q. 2 (a) In humans, males are heterogametic and females are homogametic, Explain. Are there any examples where males are homogametic and females heterogametic?

(b) Also describe as to, who deterrmines the sex of an unborn child? Mention whether temperature has a role in sex determination.

Ans. **(a)** The term homogametic and heterogametic refers to the organism depending upon whether all the gametes contain one type of sex chromosome (*homo* same) or two different types of sex chromosomes (*hetero* different).

Humans show XX/XY type of sex determination, *i.e.,* females contain 2 copies of X-chromosome and males contain 1 X and 1 Y-chromosome. Therefore, ova produced by females contain the same sex chromosome, *i.e.,* X.

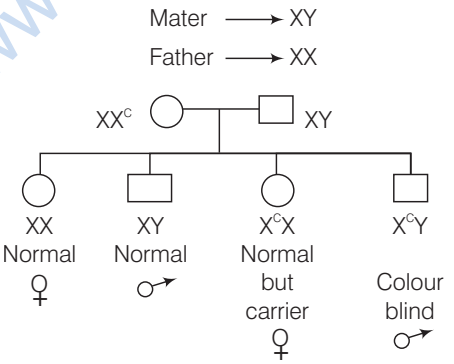
On the other hand the sperms contain 2 different types of chromosomes, *i.e.,* 50% sperms have X and 50% have Y-chromosomes (meiosis). Therefore, the sperms are different with respect to the composition of sex chromosome.

In case of humans, females are considered to be homogametic while males are heterogametic. Yes, there are examples where males are homogametic and females are heterogametic. In some birds the mode of sex determination is denoted by ZZ (males) and ZW (females). Certain moths and butterflies also show homogametic males and heterogametic females.

(b) As a rule the heterogametic organism determines the sex of the unborn child. In case of humans, since males are heterogametic it is the father and not the mother who decides the sex of the child. In some animals like crocodiles, lower temperature favour hatching of female offsprings and higher temperatures lead to hatching of male offsprings.

Q. 3 A normal visioned woman, whose father is colour blind, marries a normal visioned man. What would be probability of her sons and daughters to be colour blind? Explain with the help of a pedigree chart.

Ans. *The genotype of parents are*



50% daughters are normal visioned but 50% will be carries and 50% of sons are likely to be colour blind and 50% are normal visioned.

Q. 4 Discuss in detail the contributions of Morgan and Sturvant in the area of genetics.

Ans. **T H Morgan** (1866-1945) was given the Nobel Prize in 1933.

His contributions are

(i) Morgan worked on fruit fly *Drosophila melanogaster* and proposed the chromosomal theory of linkage.

(ii) He stated and established that genes are located on the chromosome.

(iii) He established the principle of linkage, crossing over, sex-linked inheritance and discovered the relation between gene and chromosome.

(iv) He established the technique of chromosome mapping.

(v) He observed and worked on mutation.

Alfred Henry Sturtevant (1891-1970) student of morgan was given the National Medal of Science in 1967. *His contributions are*

(i) He constructed the first genetic map of a chromosome while working on the *Drosophila* genome.

(ii) His main contributions to science include his analysis of genetic 'linkage groups,' which became classical method of chromosome mapping that is still used today. In 1913, he determined that genes were arranged on chromosomes in a linear fashion, like beads on a necklace. He also showed that the gene for any specific trait was in a fixed location (locus).

(iii) His work on *Drosophila* proved that two closely related species showed newly recurring mutations that were allelic and thus probably identical. His work also helped to determine genetic role in sexual selection and development and displayed the importance of chromosomal crossing over in mutations.

(iv) One of Sturtevant's principal contributions was his introduction to the concept that the frequency of crossing over between two genes could help to determine their proximity on a linear genetic map. His experiments determined that the frequency of double crossing over can be used to deduce gene order.

Q. 5 Define aneuploidy. How is it different from polyploidy? Describe the individuals having following chromosomal abnormalities.

(a) Trisomy of 21st Chromosome (b) XXY (c) XO

Ans. Aneuploidy is a phenomenon which occurs due to non-disjunction, resulting in gain or loss of one or more chromosomes during meiosis.

Aneuploidy is different from polyploidy. Polyploidy is a phenomenon in which the organisms contain more than two monoploid value or basic sets of chromosomes. *i.e.,* –3*n*, 4*n*etc. Example of such organisms are certain fish and salamanders and is commonly found in plants like grapes, banana.

Chromosomal Abnormalities

(a) Down's syndrome is an autosomal disorder that is caused by the trisomy of chromosome 21.

The individual is short statured with round head, open mouth, protruding tongue, short neck, slanting eyes, and broad short hands. The individual also shows retarded mental and physical growth,under developed gonads and genitats, etc.

(b) Klinefelter's syndrome is the chromosomal disorder that is caused by the presence of an additional copy of X-chromosome resulting in the karyotype 45+XXY.

In this disorder sex of the individual is masculine but possess feminine characters also. The individual shows gynaecomastia, *i.e.,* development of breasts. The individual will be often sterile having poor beard growth and feminine pitched voice.

(c) Turner's syndrome is the chromosomal disorder that is caused by the absence of one of the X-chromosomes, resulting in the karyotype 45+XO.

In this disorder the individual (female) will be sterile with rudimentary ovaries. Other symptoms include shield-shaped thorax, webbed neck, poor development of breasts, short stature, small uterus and puffy fingers.