1. Genetic Basis of Inheritance

1.0 : Introduction

Q.1. Explain the concept "Like begets like".

Ans: i) Living organisms produce young ones similar to them.
ii) A dog gives puppies and a mango tree gives mango seeds.
iii) This basic principle of life giving rise to life of 1its own kind is called "Like begets like".
iv) Reproduction, a fundamental characteristic of life, becomes possible due to replication of DNA (genetic material) and its transmission to next generation.

Q.2. Define the terms :

i) Heredity
ii) Variation
iii) Genetics

Ans:i) Heredity : The transmission of characters from one generation to the next or from parents to offsprings is called heredity.

ii) Variation : The differences between parents and offsprings or among the offsprings of the same parents and among individuals of the same species is called variation.

iii) Genetics : It is a branch of biology which deals with the study of heredity and variations. The term 'genetics' was coined by William Bateson in 1906.

Q.3: Who is called as the Father of genetics ?

Ans: Gregor Johann Mendel is called as the Father of Genetics.

1.1 : Mendelian Inheritance

Q.4: Define or explain the following terms :

1) Clone	**2) Factor**
3) Gene	**4) Alleles or Allelomorphs**
5) Homozygous	**6) Heterozygous**
7) Genotype	**8) Phenotype**
9) Monohybrid cross	**10) Dihybrid cross**
11) Monohybrid	**12) Monohybrid ratio**
13) Dihybrid ratio	**14) Dihybrid**
15) F_1 generation	**16) F_2 generation**
17) Dominant	**18) Recessive**
19) Offsprings	**20) Progeny**
21) Hybrid	**22) Character**
23) Trait	**24) Homologous chromosomes or Homologues**
25) Emasculation	**26) Genome**
27) Pure line	

Ans:1) Clone : Organisms produced by asexual reproduction or plants produced by vegetative propagation which are identical to their parents are called clones.

2) Factor : Particles present in an organism which is responsible for the inheritance and expression of the characters is called as Factor.

3) Gene : (coined by Johannsen)
Specific segment of DNA which determines a particular character of an organism.

OR

It is a particular segment of DNA which is responsible for the inheritance and expression of that character.

4) **Alleles or Allelomorphs :** (coined by Bateson)
Two or more alternative forms of a gene present at the same loci of homologous chromosomes and controlling the same character are called as alleles or allelomorphs.

5) **Homozygous :** An individual having identical alleles for a particular character is homozygous for that character. It is pure or true breeding. e.g. TT, tt.

6) **Heterozygous :** An individual having dissimilar alleles for a particular character is heterozygous for that character. It is a hybrid. e.g. Tt

7) **Genotype :** It is the genetic constitution of an individual with respect to a single character or a set of characters. e.g. Tall (IT or Tt), Dwarf (tt).

8) **Phenotype :** The external appearance of an individual for a given trait. e.g. tallness, dwarfness.

9) **Monohybrid cross :** A cross between two pure (homozygous) parents differing in a single pair of contrasting character is called monohybrid cross. The ratio for this cross is 3 : 1.

10) **Dihybrid cross :** A cross between two pure parents differing in two pairs of contrasting characters is called dibybrid cross. The ratio for such cross is 9 : 3 : 3 : 1.

11) **Monohybrid :** It is heterozygous for one trait and produced by crossing two pure parents differing in a single pair of contrasting characters. ego Cross between pure tall (IT) and dwarf (tt) parent gives rise to hybrid tall (Tt).

12) **Monohybrid ratio :** The phenotypic ratio of different types of offsprings (dominant and recessive) obtained in F_2 generation of a monohybrid cross is called Monohybrid ratio. In all Mendelian crosses, the monohybrid ratio is 3 : 1.

13) **Dihybrid ratio :** The phenotypic ratio of different types of offsprings (having different combinations) obtained in F_2 generation of dihybrid cross is called Dihybrid ratio. In all Mendelian crosses, the dihybrid ratio is 9 : 3 : 3 : 1.

14) **Dihybrid :** It is heterozygous for two traits and produced in a cross between two parents differing in two pairs of contrasting characters.

15) **F_1 generation :** The hybrid individuals obtained by a cross between two pure parents with contrasting characters is called F_1 generation or first filial generation.

16) **F_2generation :** The generation of offsprings obtained by selfing of F_1 individuals is called F_2 generation or second filial generation.

17) **Dominant :** The character expressed in F_1 generation is called dominant character.

OR

It is an allele that expresses even in presence of an alternative allele.

18) **Recessive :** The character which is not expressed in F_1 generation is called recessive character.

OR

It is an allele which is not expressed in presence of an alternative allele.

19) **Offsprings :** The individuals produced by sexual reproduction are called offsprings.

20) **Progeny :** All offsprings produced by the parents are called progeny.

21) **Hybrid :** Heterozygous individual produced by parents having contrasting characters. e.g. Tt.

22) **Character :** A visible feature is a character. e.g. height, seed colour.

23) **Trait :** One form of the visible feature. e.g. tallness or dwarfness, yellow or green.

24) **Homologous chromosomes or Homologues :** Morphologically, physiologically and genetically similar chromosomes present in a diploid cell are called homologues or homologous chromosomes. In each pair of homologous chromosomes, one chromosome is maternal and the other is paternal.

25) **Emasculation :** Removal of stamens well before anthesis is called emasculation. It is done in bud condition to prevent self-pollination.

26) **Genome :** Entire genetic constitution of an organism is called genome.

27) **Pure line :** An individual or a group of individuals (population) that is homozygous or true breeding for one or more traits.

Q.5. Which term did Mendel use for gene ?

Ans: Mendel used the term 'factor' for the unit of heredity which is now called as gene.

Q.6. What is Punnett square/Checker Board ?

Ans: Punnett square is a graphical representation to calculate the probability of all possible genotypes and phenotypes of offsprings in a genetic cross. It was developed by Reginald C. Punnett.

Q.7. Distinguish between :

i) Homozygous and Heterozygous

Ans:

No.	Homozygous	Heterozygous
a.	Organisms having identical alleles for a character are homozygous.	Organisms having dissimilar alleles for a character are heterozygous.
b.	It is pure or true breeding.	It is hybrid.
c.	They form only one type of gamete.	They form more than one type of gametes.
d.	e.g. Tall (TT), Dwarf (tt).	e.g. Tt.

ii) Dominant and Recessive character

Ans:

No.	Dominant character	Recessive character
a.	The characters that are expressed in F_1 generation are dominant.	The characters that are not expressed in F_1 generation are recessive.
b.	It is expressed in presence of dominant as well as recessive allele. e.g. Tt, TT = tall.	It is expressed only when both the recessive alleles of a gene are present. e.g. tt = dwarf
c.	In pea plant, tallness and red flowers are dominant characters	In pea plant, dwarfness and white flowers are recessive characters.
d.	Dominant character can express both homozygous as well as heterozygous condition.	Recessive character can be expressed only in homozygous condition.

iii) Phenotype and Genotype

Ans:

No.	Phenotype	Genotype
a.	It is the physical appearance of an organism.	It is the genetic constitution of an organism.
b.	It can be directly seen.	It is determined by inheritance pattern.
c.	Phenotype can be determined from genotype. e.g. Tt = tall	Genotype cannot be determined from phenotype e.g.Tall can be either Tt or TT.
d.	e.g. Tallness, dwarfness.	e.z. TT, Tt, tt.

Q.8. Why did Mendel select garden pea for his experiments? Explain the characteristics of pea.

Ans: Mendel selected garden pea plant (*Pisum sativum*) for his experiments because of the following characteristics :

i) The pea plant (*Pisum sativum*) is an annual plant with short life cycle.
ii) The flowers are bisexual and naturally self pollinating.
iii) They can be artificially cross-pollinated.
iv) The offsprings produced after cross pollination are fertile.
v) Pea plant has several pairs of contrasting characters.
vi) Flowers of pea plant are large enough for easy emasculation.
vii) It is a small herbaceous plant, so he could grow large number of plants.

Q.9. Enlist seven traits in pea selected by Mendel.

Ans:

No.	Character	Contrasting form / traits	
		Dominant	Recessive
i)	Height of stem	Tall (TT)	Dwarf(tt)
ii)	Colour of flower	Colored (CC)	White (cc)
iii)	Position of flower	Axial (AA)	Terminal (aa)
iv)	Pod shape	Inflated (II)	Constricted (ii)
v)	Pod colour	Green (GG)	Yellow (gg)
vi)	Seed shape	Round (RR)	Wrinkled (rr)
vii)	Seed colour (cotyledon)	Yellow (YY)	Green (yy)

Q.10.What are the reasons for Mendel's success ?

Ans: The reasons for Mendel's success are :

i) Mendel chose garden pea plant for his experiments which was an annual, naturally self-pollinating plant with several pairs of contrasting characters.
ii) Mendel concentrated only on one character at a time.
iii) He kept accurate records (both qualitative and quantitative).
iv) He used statistical methods for analyzing the results.
v) The characters selected by Mendel were present on different chromosomes.
vi) All the seven pairs of contrasting traits selected by him showed complete dominance.

Q.11.What is the genotype of a "true breeding tall" and "true breeding dwarf' pea plant ?

Ans: The genotype of a "true breeding tall" pea plant is "TT" and that of a "true breeding dwarf' pea plant is "tt".

Q.12.Describe the steps or procedure of Mendel's experiment with suitable example.

Ans: The steps or procedure of Mendel's experiments are as under :

i) Selection of material : Mendel selected garden pea (*Pisum sativum*) as the experimental material for his experiments.

ii) Selection of characters : Mendel selected seven pairs of contrasting characters in garden pea which are listed in the table given below.

No.	Character	Dominant trait	Recessive trait
i)	Stem height	Tall (T)	Dwarf (t)
ii)	Seed colour	Yellow (Y)	Green (y)
iii)	Seed shape	Round (R)	Wrinkled (r)
iv)	Pod colour	Green (G)	Yellow (g)
v)	Pod shape	Inflated (I)	Constricted (i)
vi)	Flower position	Axial (A)	Terminal (a)
vii)	Flower colour	Coloured (C)	White (c)

iii) Procedure of Experiments :

a) Mendel was very methodical in carrying out his experiments.
b) First, he studied only one trait at a time, unlike others who had considered the organism as a whole.
c) Then, he studied two traits and three traits at a time by performing monohybrid, dihybrid and trihybrid crosses.
d) He started his experiments with true breeding (pure line) plants and maintained a complete record of the actual number of each type of offsprings.
e) He conducted several crosses to eliminate chance factor.

Mendel conducted experiments in the following three steps :

Step 1 - Selection of parents and obtaining pure lines.

Mendel started with pure lines that were available. He also ensured that the selected male and female parent plants are breeding true for the selected trait/traits by selfing them for three generations. (Breeding true or 'true breeding' means they produce offsprings with the same selected trait/traits only).

Step 2 - Artificial cross of the selected parents to raise F_1 generation.

Mendel first emasculated the flowers of the plant which he had selected as a female parent. Then, pollens from the flower of selected male parent were dusted on the stigma of the emasculated flower, i.e. artificial-cross. Mendel crossed many flowers, collected seeds and raised the hybrids that represent first filial generation or F_1 generation.

Step 3 - Selfing of F_1 hybrids to raise F_2 generation.

Mendel allowed the natural self-pollination in each F_1 hybrid; collected seeds separately and raised F_2 generation, i.e. second filial generation. (F_2 generation was obtained by selfing of F_1 hybrids.)

Q.13.Explain monohybrid cross with an example.

Ans: Monohybrid cross : The cross between two pure parents differing in a single pair of contrasting character is called monohybrid cross. The ratio for the cross is 3 : 1.

e.g. Monohybrid cross between pure tall pea plant and pure dwarf pea plant.

Phenotype of parents → Pure Tall × Pure Dwarf

Genotype → TT tt

Gametes → T t

F_1 generation → Tt

Hybrid tall

Selfing of F_1 hybrid → ×

Gametes → Tt Tt

F_2 generation →

♀ \ ♂	T	t
T	TT Tall	Tt Tall
t	Tt Tall	tt Dwarf

Q.14.State Mendel's first law of inheritance or law of dominance.

Ans: Law of dominance states that "in a cross between two homozygous organisms differing in a single pair of contrasting character, the character which is expressed in the F_1 generation is called dominant character and the character which is not expressed is the recessive character".

Q.15.State Mendel's second law of inheritance or law of segregation or law of purity of gametes.

Ans: Law of segregation states that "when the two. alleles for a contrasting character are brought together in a hybrid, they do not mix or contaminate but segregate or separate out from each other during gamete formation". Law of segregation is also known as law of purity of gametes, as gametes have only one allele.

Q.16.State Mendel's third law of inheritance or law of independent assortment.

Ans: The law of independent assortment states that "when two homozygous parents differing from each other in two or more pairs of contrasting characters are crossed, then the inheritance of one pair of characters is independent of the other pair of characters".

Q.17.Explain law of dominance using a monohybrid cross.

Ans: Law of dominance states that "in a cross between two homozygous organisms differing in a single pair of contrasting character, the character which is expressed in the F_1 generation is called dominant character and the character which is not expressed or suppressed is the recessive character". e.g. Tallness in pea plant is a dominant character. while dwarfness is a recessive character.

Phenotype of parents → Pure Tall × Pure Dwarf

Genotype → TT tt

Gametes → T t

F_1 generation → Tt

Hybrid tall

Explanation :

i) In a cross between pure tall and pure dwarf pea plant, only tall character is expressed in all the individuals of F_1 generation.

ii) Hence, it can be inferred that in pea plants, tallness is the dominant character, while dwarfness is a recessive character.

iii) Tallness in F_1 hybrid is determined by genotype Tt in which the dominant allele 'T' suppresses the recessive allele 't', thereby suppressing its expression in the phenotype.

Q.18. Explain why law of segregation is also called law of purity of gametes.

Ans: i) In F, hybrid (Tt), the two alleles Tall (T) and dwarf (t) present would segregate during gamete formation.

ii) Due to segregation, the two types of gametes produced, i.e. T and t would be pure for the trait they carry.

iii) Example:

F_1 hybrid → Tt

Gametes → T, t

Thus, law of segregation is also called law of purity of gametes.

Q.19.State and explain Mendel's second law of inheritance.

Ans: Law of segregation states that "when the two alleles for a contrasting character are brought together in a hybrid union, they do not mix or contaminate but segregate or separate out from each other during gamete formation".

Explanation :

i) Each organism contains two factors for each trait in its diploid cells and the factors segregate during the formation of gametes.

ii) Each gamete then contains only one factor from each pair of factors.

iii) When fertilization occurs, the new organism has two factors for each trait, one from each parent.

iv) When Mendel crossed a homozygous tall plant (TT) with a homozygous dwarf plant (tt), the offspring was found to be a hybrid tall (Tt).

v) The hybrid tall thus produced has two alleles, viz. 'T' (tallness) and 't' (dwarfness). During gamete formation, the two alleles, viz. 'T' and 't' segregate as shown below :

Phenotype of parents → Pure Tall × Pure Dwarf

Genotype → TT × tt

Gametes → T, t

F_1 generation → Tt (Hybrid tall)

Selfing of F_1 generation → Tt × Tt

Gametes → T, t × T, t

The two alleles (contrasting characters) do not mix, alter or dilute each other and the gametes formed are 'pure' for the characters which they carry. Hence, this law is also called the law of purity of gametes.

Q.20.A pea plant with purple flowers was crossed with white flowers producing 50 plants with only purple flowers. On selfing, these plants produced 482 plants with purple flowers and 162 with white flowers. What genetic mechanism accounts for these results? Explain.

Ans: In pea plant: Purple colour of flower is dominant and white is recessive trait.

Phenotype of parents → Purple flower × White flower

Genotype → PP × Pp

Gametes → P, p

F_1 generation → Pp (Purple flower)

Selfing of F_1 generation → Pp × Pp

Gametes → P, p × p, p

F_2 generation →

♀ \ ♂	**P**	**p**
P	PP Purple	Pp Purple
p	Pp Purple	pp White

Phenotypic ratio → 3:1(482 purple flowers:162 white flowers)
Genotypic ratio → 1:2:1 (1PP: 2Pp:1pp)
In F_2 generation, the ratio comes to 3 : 1 between purple and white flowers. It is a monohybrid cross involving one pair of contrasting character. It explains law of dominance and law of segregation. The characters are controlled by factors that occur in pairs. Only the dominant factor expresses in F_1 generation.

Q.21.Using a Punnett square, workout the distribution of phenotypic features in the first filial generation after a cross between a homozygous female and heterozygous male for a single locus.

Ans: Female can be represented as TT (homozygous tall) and male can be represented as Tt (heterozygous tall). Thus, using Punnett square, their cross can be given as follows :

Phenotype of parents → Homozygous tall female × Heterozygous tall male
Genotype → TT Tt
Gametes → (T) (T) (T) (T)
F_1 generation →

♀ \ ♂	**T**	**t**
T	TT Tall	Tt Tall
T	TT Tall	Tt Tall

Thus, in the first filial generation, all offsprings will be phenotypically dominant, i.e. tall, whereas genotypically 50% will be homozygous tall and 50% will be heterozygous tall.

Q.22.Explain dihybrid cross with suitable example. **[Oct 2013]**

Ans: Dihybrid cross : A cross between two pure (homozygous) parents in which the inheritance pattern of two pairs of contrasting characters is considered simultaneously is called Dihybrid cross. The phenotypic ratio of different types of offsprings (with different combinations) obtained in F_2 generation of dihybrid cross is called dihybrid ratio. It is 9 : 3 : 3 : 1. For example, when we cross a yellow round seed pea plant with a green wrinkled seed pea plant, we get 9 yellow round, 3 yellow wrinkled, 3 green round and 1 green wrinkled plants in the F_2 generation.

Phenotype of parents → Yellow Round × Green Wrinkled
Genotype → YYRR yyrr
Gametes → (YR) (yr)

YyRr
(Yellow Round)

F_1 generation →
Selfing of F_1 generation → YyRr × YyRr
Gametes → (YR)(Yr)(yR)(yr) (YR)(Yr)(yR)(yr)
F_2 generation →

♀ \ ♂	**YR**	**Yr**	**yR**	**yr**
YR	YYRR Yellow round	YYRr Yellow round	YyRR Yellow round	YyRr Yellow round
Yr	YYRr Yellow round	YYrr Yellow wrinkled	YyRr Yellow round	Yyrr Yellow wrinkled
yR	YyRR Yellow round	YyRr Yellow round	yyRR Green round	yyRr Green round
yr	YyRr Yellow round	Yyrr Yellow wrinkled	yyRr Green round	yyrr Green wrinkled

Result : Yellow round = 9 ;Yellow wrinkled = 3; green round = 3; green wrinkled = 1
Dihybrid ratio → 9 : 3 : 3 : 1

Q.23.State and explain the 'Law ofIndependent Assortment' with a suitable example. [Mar 2014]

Ans: The law of independent assortment states that "when two parents differing from each other in two or more pairs of contrasting characters are crossed, then the inheritance of one pair of character is independent of the other pair of character." For example, when we cross a pure tall,red flowered pea plant with a pure dwarf white flowered pea plant, we get 9 tall red, 3 tall white, 3 dwarf red and 1 dwarf white plants in the F_2 generation. A cross between two homozygous individuals differing in two pairs of contrasting characters is called dihybrid cross.

Phenotype of parents → Tall Red × Dwarf White

Genotype → TTRR × ttrr

Gametes → TR, Tr

F_1 generation → TtRr (Tall Red)

Selfing of F_1 generation → TtRr × TtRr

Gametes → TR, Tr, tR, tr × TR, Tr, tR, tr

F_2 generation →

♀ \ ♂	**TR**	**Tr**	**tR**	**tr**
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	ttRr Dwarf red
tr	TtRr Tall red	Ttrr Tall white	ttRr Dwarf	ttrr Dwarf white

Result: Tall red = 9 ;Tall white = 3; Dwarf red = 3; Dwarfwhite = 1
Phenotypic ratio → 9 : 3 : 3 : 1
Genotypic ratio → 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
TTRR TTRr TtRR TtRr ttRR ttRr TTrr Ttrr ttrr

From the above results, it is obvious that the inheritance of character of tallness in no way linked with the red colour of the flower. Similarly, the character of dwarfness is not linked with the white colour of the flower. This is due to the fact that in the above cross, the two pairs of characters segregate independently. In other words, there is independent assortment of characters during inheritance.

Q.24.Describe the cross between a homozygous tall, round-seeded pea plant and a dwarf, wrinkled-seeded pea plant. What will be the types of progeny in the F_2 generation of this cross and in what proportion will it be?
Name and state the law which is explained by this example. [Oct 2014]

Ans: Let the gene for tall habit of pea plant be represented by 'T' and dwarf habit be represented by 't'.
Let the gene for round-seed be represented by 'R' and that of wrinkled seed be represented by gene 'r'.
Then, the genotypes of the parents would be :

i) Homozygous tall, round-seeded - TTRR
ii) Homozygous dwarf, wrinkled seeded - ttrr

Phenotype of parents → Tall Red × Dwarf White
Genotype → TTRR ttrr
Gametes → (TR)(TR) (tr)(tr)

F_1 generation →

♀ \ ♂	**TR**	**TR**
tr	TtRr Tall round	TtRr Tall round
tr	TtRr Tall round	TtRr Tall round

Phenotype of F_1 generation → All Tall round
Genotype of F_1 generation → TtRr
Selfing of F_1 → TtRr × TtRr
Gametes → (TR)(Tr)(tR)(tr) (Tr)(Tr)(tR)(tr)
F_2 generation →

♀ \ ♂	**TR**	**Tr**	**tR**	**tr**
TR	TTRR Tall Round	TTRr Tall Round	TtRR Tall Round	TtRr Tall Round
Tr	TTRr Tall Round	TTrr Tall Wrinkled	TtRr Tall Round	Ttrr Tall Wrinkled
tR	TtRR Tall Round	TtRr Tall Round	ttRR Dwarf Round	ttRr Dwarf Round
tr	TtRr Tall Round	Ttrr Tall Wrinkled	ttRr Dwarf Round	ttrr Dwarf Wrinkled

Phenotypic ratio → 9 : 3 : 3 : 1
Genotypic ratio → 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
TTRR TTRr TtRR TtRr ttRR ttRr TTrr Ttrr ttrr

The above example of a dihybrid cross between homozygous tall, round-seeded pea plant and dwarf, wrinkled-seeded pea plant explains the 'Law of Independent Assortment'.

The law of independent assortment states that "when two parents differing from each other in two or more pairs of contrasting characters are crossed, then the inheritance of one pair of character is independent of the other pair of character."

Q.25.Why law of independent assortment is not universally applicable ?

Ans: i) When the two homozygous parents differing in two pairs of contrasting traits are crossed, the inheritance of one pair is independent of the other. In other words, when a dihybrid forms gametes, assortment (distribution) of alleles of different traits is independent of their original combinations in the parents.

ii) Many genes are located on one chromosome, i.e. they are linked. Therefore, they pass through gametes in the form of a linkage group. However, recombinations are due to the crossing over that takes place during meiosis.

iii) Therefore, the law of independent assortment is applicable only for the traits which are located on different chromosomes. Thus, law of independent assortment is not universally applicable.

Q.26.A true breeding pea plant homozygous for axial violet flowers (AAVV) is crossed with terminal white flowersI aavv).

i) What would be the phenotype and genotype of F_1 and F_2 generations?

ii) Give the phenotypic ratio of F_2 generation.

iii) List Mendel's generalisation that can be derived from the above cross.

Ans:i)

Phenotype of parents → Axial violet × Terminal white

Genotype → AAVV aavv

Gametes → (AV) (AV) (av) (av)

F_1 generation →

♀ \ ♂	**AV**	**AV**
av	AaVv Axial violet	AaVv Axial violet
av	AaVv Axial violet	AaVv Axial violet

Phenotype of F_1 generation - All Axial Violet

Genotype of F_1 generation - AaVv

ii) Selfing of F_1 → AaVv × AaVv

Gametes → (AV) (Av) (aV) (av) (AV) (Av) (aV) (av)

F_2 →

♀ \ ♂	**AV**	**Av**	**aV**	**av**
AV	AAVV Axial Violet	AAVv Axial Violet	AaVV Axial Violet	AaVv Axial Violet
Av	AAVv Axial Violet	AAvv Axial White	AaVv Axial Violet	Aavv Axial White
aV	AaVV Axial Violet	AaVv Axial Violet	aaVV Terminal Violet	aaVv Terminal Violet
av	AaVv Axial Violet	Aavv Axial white	aaVv Terminal Violet	aavv Terminal White

F_2 phenotypic ratio → 9 Axial Violet; 3 Axial White ; 3 Terminal Violet, 1 Terminal White.

iii) Mendel proposed " The law of independent assortment" from the above cross. In a dihybrid cross, the segregation of one pair of traits is independent of the other.

Q.27.When a cross is made between tall plant with yellow seeds (TtYy) and tall plant with green seeds (Ttyy), what proportions of phenotype in the offspring could be expected to be :

i) Tall and green ii) Dwarf and green

Ans:

Phenotype of parents → Tall plant with × Tall plant with yellow seeds green seeds

Genotype → TtYy TYty

Gametes → (TY) (Ty) (tY) (ty) (Tt) (yy)

F_1 Generation →

♀ \ ♂	TY	Ty	tY	ty
Ty	TTYy Tall yellow	TTyy Tall green	TtYy Tall yellow	Ttyy Tall green
ty	TtYy Tall yellow	Ttyy Tall green	ttYy Dwarf yellow	ttyy Dwarf green

Thus,

i) Offsprings with phenotype tall and green are 3.

ii) Offspring with phenotype dwarf and green is 1.

Q.28.Distinguish between Monohybrid cross and Dihybrid cross.

Ans:

No.	Monoh brid cross	No.	Monoh brid cross
i)	The cross between two pure parents differing in a single pair of contrasting character is called Monohybrid corss.	i)	The cross between two pure parents differing in two pairs of contrasting characters is called dihybrid cross.
ii)	Phenotypic ratio is 3 : 1	ii)	Phenotypic ratio is 9 : 3 : 3 : 1
iii)	Genotypic ratio is 1 : 2 : 1	iii)	Genotypic ratio is 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
iv)	The law of segregation is explained by this cross.	iv)	The law of independent assortment is explained by this cross.

Q.29.Answer the following :

i) What is a back cross ?

Ans: The cross between F_1 hybrid and anyone of the parents is called back cross.

ii) Define the term Test cross.

Ans: The cross between F_1 hybrid and the recessive parent is called test cross.

iii) When is back cross not a test cross ?

Ans:A back cross with dominant parent is not a test cross.

Q.30.Explain the statements.

i) Test cross is a back cross but back cross is not necessarily a test cross.

ii) Law of dominance is not universally applicable.

iii) Law of segregation is universally applicable.

Ans:i) Test cross is a backcross but back cross is not necessarily a test cross : It is because; in backcross F_1 generation can be crossed with either dominant or recessive parent. But in test cross, F_1 generation is crossed with recessive parent only. Thus, test cross is a backcross but back cross is not necessarily a test cross.

ii) Law of dominance is not universally applicable : In a cross between two organisms pure for any pair (or pairs) of contrasting characters, the character that appears in F_1 generation is called dominant and the one which is suppressed is called recessive. In many cases, the dominance is not complete or absent. Phenomenon of dominance is significant as the harmful recessive traits are masked, i.e. not expressed in the presence of its normal dominant allele. e.g. In humans a form of idiocy, diabetes and haemophilia are recessive characters. Thus, law of dominance is significant and true, but it is not universally applicable.

iii) Law of segregation is universally applicable : Member of allelic pair in a hybrid remain together without mixing with each other and separate or segregate during gamete formation. Thus gametes

receive only one of the two factors and are pure for a given trait. Therefore, this is also known as law of segregation.

All sexually reproducing higher organisms are diploid (2n), i.e. with ,two sets of chromosomes and gametes are haploid (n), i.e. with one set of chromosome. Therefore, law of segregation is universally applicable.

Q.31.Explain briefly the back cross and test cross.

Ans:i) When the F_1 hybrid is crossed back with anyone of the parents, it is called a back cross. Cross of F_1 hybrid with homozygous recessive parent is **test cross.**

ii) A back cross can be a test cross, but all test crosses need not be back crosses. A back cross with dominant parent is not a **test cross.**

iii) Back cross can be a dominant or recessive back cross.

iv) In dominant back cross, F_1 individual is crossed with dominant parent and all progeny shows dominant character.

v) F_1 hybrid tall plant (Tt) is crossed with dominant parent (TT), progeny will be TT or Tt. Genotypically and phenotypically all offsprings would be tall.

vi) In recessive back cross, F_1 individual is crossed with recessive parent (tt).

vii) If progeny is Tt or tt genotypically and 50 % tall and 50 % dwarf phenotypically, then one can infer that F_1 generation is heterozygous, i.e Tt.

viii) If progeny is TT genotypically, i.e all tall phenotypically, then one can infer that F_1 generation is homozygous, i.e. TT

Phenotype of Parents → Pure Tall × Pure Dwarf

Genotype → TT × tt

Gametes → (T) × (t)

Tt

F_1 Generation → Hybrid tall plants

Back cross : F_1 Generation × Dominant parent

Parent →

♀ \ ♂	**T**	**t**
T	TT	Tt
T	TT	Tt

← F_1

50% offsprings are tall and 50% dwarf.

Thus, test cross produced progeny with both dominant and recessive characters in equal to proportion.

Q.32.A heterozygous tall plant of pea is crossed with a dwarf plant of pea. Calculate the phenotypic ratio of the progeny. [Oct 2013]

Ans: When a heterozygous tall plant of pea (Tt) is crossed with a dwarf plant of pea (tt), it can be represented as follows :

Q.33.What is the ratio of dlhybrld test cross? Give a graphical representation with the help of Punnett square.

Ans: The ratio of dihybrid cross can be explained with the help of a cross between tall pea plant with red flowers and dwarf pea plant with white flowers.

Phenotype of Parents → Pure tall with Red flowers × Pure Dwarf with white flowers

Genotype → TTRR × ttrr

Gametes → TR × t

TtRr

F_1 Generation → Hybrid tall with Red flower

Test cross : → TtRr ttrr

F_1 Generation → (F_1 hybrid) (Recessive parent)

Gametes → TR Tr tR tr × tr

F_2 generation →

♀ \ ♂	**TR**	**Tr**	**tR**	**tr**
tr	TtRr Tall Red	Ttrr Tall White	ttRr Dwarf Red	ttrr Dwarf White
	TtYy Tall yellow	Ttyy Tall green	ttYy Dwarf yellow	ttyy Dwarf green

Test cross ratio → 1 : 1 : 1 : 1

Q.34.What is test cross? Explain the significance of test cross.

Ans: The cross between FI hybrid and the recessive parent is called test cross.

Example :

Parents → TT (Tall) × tt (Dwarf)

T × t

Tt

F_1 Generation →

Test cross

F_1 generation (Tt) × Recessive parent (tt)

F_2 generation →

♀ \ ♂	**T**	**t**
t	Tt	tt
t	Tt	tt

← F_1

Recessive parent →

Thus, in the F_2 generation of a test cross, 50% are heterozygous tall plants (Tt) and 50% are homozygous dwarf plants (tt).

Significance of test cross:

i) It helps to determine whether individuals exhibiting dominant character are genotypically homozygous or heterozygous.

ii) Purity of the parents can be determined.
iii) It helps to determine the genotype of the individual.
iv) It has wide application in plant breeding experiments.

Q.35.Give the significance of back cross.
Ans: Significance of back cross:

i) It is a rapid method of improving crop variety.
ii) It helps to verify laws of inheritance.
iii) Back cross with dominant parent always produce dominant characters.
iv) Continuous back cross never produce recessive trait, hence recessive trait cart be eliminated from progeny.

Q.36. Distinguish between Test cross and Back cross.
Ans:

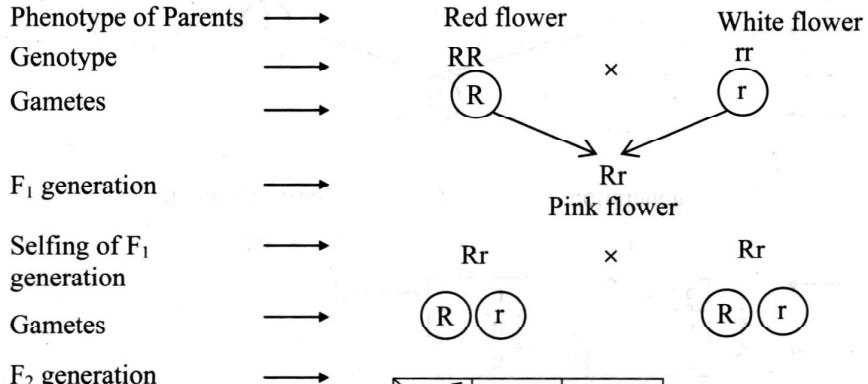
No.	Test cross	Back cross
i)	The cross between F_1 hybrid and its recessive parent is called test cross.	The cross betwen F_1 hybrid and any one of its parents (either dominant or recessive) is called back cross.
ii)	A test cross is always a back cross.	A back cross is not always a test crops.
iii)	Test cross determines the genetic constitution of an organism.	Back cross helps in improving and obtaining desirable charcters.
iv)	Test cross produces both dominant and recessive dominant character.	Back cross with dominant parent produces all

1.2 : Deviations from Mendelian ratios

Incomplete Dominance

Q.37. Explain incomplete dominance with an example.
Ans: Incomplete dominance :

i) Incomplete dominance can be defined as a phenomenon in which neither of the alleles of a gene is completely dominant over the other and hybrid is intermediate between the two parents.
ii) Incomplete dominance is a deviation of Mendel's law of dominance which states that out of two contrasting allelomorphic factors, only one expresses itself in an individual in F_1 generation called as dominant, while other which has not shown its effect is called as recessive, however this recessive hidden character reappeared, unchanged in F_2 generation.
iii) Thus, according to incomplete dominance, F_1 phenotype is intermediate between the parental traits. Incomplete dominance is demonstrated in Mirabilis jalapa (four o'clock plant) as given below :



♀ \ ♂	R	r
R	RR Red	Rr Pink
r	Rr Pink	rr White

Phenotypic ratio → 1:2:1 (1 Red: 2 Pink : 1 White)
Genotypic ratio → 1:2:1 (1 RR: 2 Rr: 1 IT)
This indicates the following facts:

i) Pink is the phenotype of the heterozygous genotype (Rr).
ii) This pattern of inheritance is due to non-blending of the characters, because one-fourth of the F_2 progeny are red-flowered and another one-fourth are white-flowered: which are the parental combinations.
iii) The phenotypic and genotypic ratios are the same.
iv) This type of observation has resulted from incomplete dominance of the alleles.

Q.38.Name two plants showing incomplete dominance.
Ans: Snapdragon (*Antirrhinum majus*) and Four o'clock plant (*Mirabilis jalapa*) show incomplete dominance.

Co-dominance

Q.39. Explain co-dominance with suitable examples.
Ans: Co-dominance is a condition in which both alleles of a gene pair in heterozygous condition are fully expressed, with neither one being dominant or recessive to the other. Thus, in co-dominance, we get a blending of dominant and recessive traits resulting in different phenotype.

Example 1:
Blood group 'AB' in humans is an example of co-dominance.

i) Blood .group character is controlled by gene I, that exists in three allelic forms I^A, I^B and 1°.
ii) In I^A and I^B, superscripts A and B stand for glycoproteins (sugar polymers) that are found projecting from the surface of RBCs.
iii) The allele r^A produces glycoprotein A, while I^B produces glycoprotein B, allele 1^O does not produce any of them.
iv) The allele I^A is dominant over 1^O. I^B is also dominant over 1^O. Allele I^A and I^B are co-dominant and express themselves when present together. Such RBCs have both the types of glycoproteins and blood group will be AB.

Example 2:
Roan coat colour in Cattle.

i) There are two types, one with red coat (skin with red colour hair) and the other with white coat (with white hair).
ii) When red cattle (RR) is crossed with white cattle (WW), F_1 hybrids (RW) have roan colour. Roans have the mixture of red and white colour hair.
iii) Thus, both the traits are expressed equally. In F_2 generation (produced by interbreeding of roans), red (RR), roans (RW) and white (WW) are produced in the ratio 1:2:1.
iv) Thus, in co-dominance also, genotypic and phenotypic ratios are identical.

Q.40. Distinguish between the following :
i) Complete dominance and Incomplete dominance. ii) Dominance and Co- dominance iii) dominance and Co-dominance.

Ans: i) Complete dominance and Incomplete dominance.

No.	complete Dominance	Incomplete Domiance
a.	Dominant trait always dominates recessive trait or character.	Neither of the traits/characters is completely dominant over the other.
b.	When we cross two homozygous parents for one or more paris of contrasting characters, the hybrid of F_1 is always dominant. It is termed as complete dominance.	When a cross is made between two homozygous parents for one or more pairs of traits, the hybrid of F_1 is intermediate. It is called incomplete dominance, when dominance is not complete.
c.	Dominant allele is stronger than the recessive allele in it.	Both alleles of one contrasting pair have equal strength. They express themselves incompletely in it.
d.	Exaple : Height of Pea plant. P_1 → Tall Plant × Dwarf plant TT × tt F_1 ⟶ T_t Tall plant	Example : Flower colour in M. *jalapa* P_1 → Red flower × White flower RR × rr F_1 ⟶ Rr Pink Flower

ii) Dominance and Co-dominance.

No.	Dominance	Co- dominace
a.	In a pair of genes with contrasting characters, only one of the traits (dominant) is expressed in hybrid.	In a pair of genes with contrasting characters, both traits are expressed in hybrid.
b.	Dominant allele is stronger than recessive allele.	Both alleles possess equal strength.
c.	Only the product of dominant allele is observed in phenotype.	Product of both alleles are observed in phenotype.
d.	Example: Hybrid tall pea plant (Tt)	Example: AB blood group in humans.

iii) Incomplete dominance and Co-dominance.

No.	Incomplete dominance	Co- dominace
a.	It is the phenomenon in which neither of the alleles of a gene is completely dominant over the other.	It is the phenomenon in which two alleles of a gene are equally dominant and express themselves in the presence of the other, when they are together.
b.	In case of incomplete dominance, the phenotype of hybrids is intermediate between phenotypes of parents.	In codominance, both the genes are expressed equally.
c.	e.g. Pink colour flower of *Mirabilis jalapa*	e.g. Roan coat colour in cattle.

Q.41.'In incomplete dominance and co-dominance, genotypic and phenotypic ratios are identical.' Explain how co-dominance differs from incomplete dominance in phenotypic nature of their hybrids. [Mar 2013]

Ans:i) **Co-dominance** is a condition in which both alleles of a gene pair in heterozygous condition are fully expressed, with neither one being dominant or recessive to the other.
Genotypic ratio of Co-dominance → 1:2:1
Phenotypic ratio of Co-dominance → 1:2:1

ii) **Incomplete dominance** can be defined as a phenomenon in which neither of the alleles of a gene is completely dominant over the other and hybrid is intermediate between the two parents.
Genotypic ratio ofIncomplete dominance → 1:2:1
Phenotypic ratio ofIncomplete dominance → 1:2: 1

iii) In incomplete dominance, the phenotype of hybrid is intermediate between the phenotypes of parents, whereas in co-dominance, there is no intermediate expression as both the alleles express themselves independently.

Multiple Alleles and Inheritance of blood groups

Q.42.What is multiple allelism? Explain with example of ABO blood group system in humans.

Ans: Multiple Allelism :

i) More than two alternative forms (alleles) of gene in a population occupying the same locus on a chromosome or its homologue are known as multiple alleles.

ii) ABO blood group system in humans is an example of multiple allelism, because gene I exists in threeallelic forms I^A, I^B and 1^O.

iii) Here, allele I^A codes for type A blood, allele I^B codes for type B blood and allele 1^Ocodes for type Oblood.

iv) Allele 10 is recessive to the alleles I^A and I^B.

v) Thus, with these three alleles, we can have 6 different genotypes and 4 different phenotypes for blood groups.

vi)

No.	Genotype	Phenotype (Blood group)
i)	I^AIA or $I^A I^O$	Type A
ii)	I^BI^B or $I^B I^O$	Type B
iii)	I^AI^B	Type AB
iv)	I^OI^O	Type O

Q.43. A child has blood group O. If the father has blood group A and mother has blood group B. Work out the genotypes of the parents and the possible genotypes of the other offsprings.

Ans: Possible genotype of father = $I^A I^A$ or $I^A 1^O$

Possible genotype of mother = I^BI^B or $I^B 1^O$

The blood group of child is 'O'. So, its genotype must be $I^O 1^O$ because it has recessive alleles of a gene. Since the genotype of child I^O, so the genotype of father and mother should be $I^A 1^O$ and $I^B 1^O$ respectively because both parents are contributing their recessive allele (I^O) to the child.

Phenotype of parents → Male × Female

Genotype → $I^A I^O$ $I^B I^O$

Gametes → I^A I^O I^B I^O

F_1 generation →

♀ \ ♂	I^A	I^O
I^B	I^AI^B (AB)	I^BI^O (B)
I^O	I^AI^O (A)	I^OI^O (O)

Therefore, the blood groups of the other children in the future will be AB or A or B.

Q.44. Give multiple aUeles of the different wings in Drosophila.

Ans:

Phenotype	Genotype
Normal wings	Vg+
Nicked wings	Vgni
Notched wings	Vgno
Strap wings	vz''
Vestigial wings	vg

Pleiotropy

Q.45.Write a note on pleiotropy.

Ans: Pleiotropy :

i) When a single gene controls two (or more) different traits, it is called pleiotropic gene and this phenomenon is called pleiotropy or pleiotropism. The ratio is 2: 1 instead of 3: 1.

ii) According to Mendel's principle of unit character, one gene (factor) controls one character (trait), but sometimes single gene produces two related or unrelated phenotypic expressions.

iii) For example, the disease, sickle cell anaemia is caused by a gene Hb^8. Normal or healthy gene is Hb^A and is dominant.

iv) The carriers (heterozygotes – Hb^A/Hb^s) show signs of mild anaemia as their RBCs become sickleshaped (half-moon shaped) in oxygen deficiency. They are said to have sickle-cell trait and are normal in normal conditions.

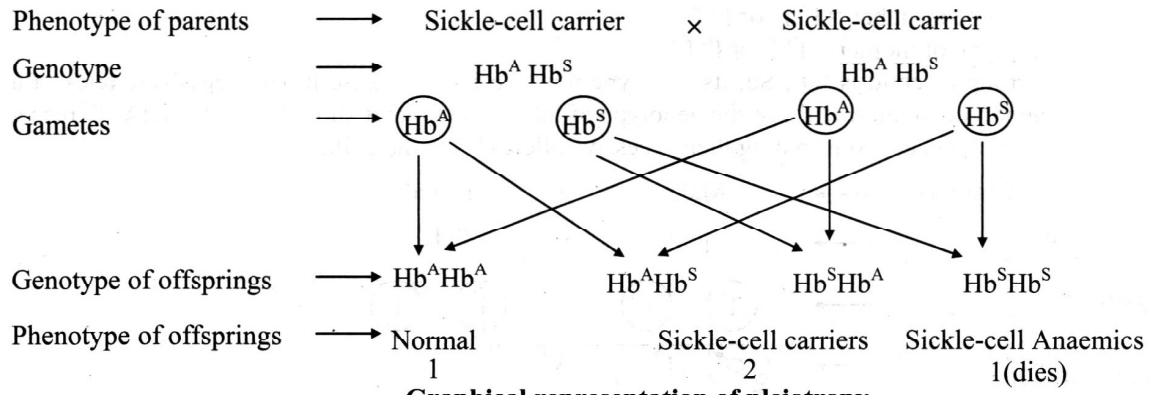
v) The homozygotes with recessive gene Hb^8 however, die of fatal anaemia.

vi) Thus, the gene for sickle-cell anaemia is lethal in homozygous condition and produces sickle cell trait in heterozygous carrier.

vii) Two different expressions are produced by a single gene.

Q.46.Why is marriage between sickle cell anaemic carriers discouraged? Explain with graphical representation.

Ans: A marriage between two carriers will produce normal, carriers and sickle-cell anaemic children in 1:2: 1 ratio. But, sickle-cell anaemics who are homozygous for gene Hbs will die, as Hbs is a lethal gene causing death of the bearer.



Graphical representation of pleiotropy

Polygenic (Quantitative) inheritance

Q.47. What are polygenes? Explain with suitable example.

Ans:Polygenes :

Characters are determined by two or more gene pairs, and they have additive or cumulative effect. Such genes are called cumulative genes or polygenes or multiple factors.

Example 1:

Human skin colour

i) Population derived from marriage between negro and white show intermediate skin colour and are called mulattoes.

ii) When such individuals marry each other, all shades of colour are observed in the population in the ratio, 1:6:15:20:15:6:1.
From this, it can be concluded that skin colour in humans is controlled by three pairs of genes, Aa, Bb, and Cc.

iii) The presence of melanin pigment in the skin determines the skin colour. Each dominant gene is responsible for the synthesis of fixed amount of melanin.

iv) The effect of all the genes is additive and the amount of melanin synthesized is always proportional to the number of dominant genes.

v) Genotype of negro parent is AABBCC, and that of albino (pure white, melanin is not produced at all) is aabbcc.

vi) Genotype of their offspring (mulatto) is AaBbCc.

vii) Mulattoes (F_1 offspring) produce eight different types of gametes, and total sixty four combinations are possible in the population of next generation (F_2); but there are seven different phenotypes due to the cumulative effect of each dominant gene as follows,

i)	Pure black (negro)	6)	dominant genes	1/64
ii)	Black (less dark than negro parent)	5)	dominant genes	6/64
iii)	Lesser black or brown	4)	dominant genes	15/64
iv)	Mulatto (intermediate- 'Sanwla')	3)	dominant genes	20/64
v)	Fair	2)	dominant genes	15/64
vi)	Very fair	1)	dominant genes	6/64
vii)	Pure white (albino)	No dominant gene		1/64

Example 2 :

Kernel colour in Wheat

i) A variety of wheat with red kernel was crossed with wheat having white kernel.

ii) The F_1 generation plants had red kernel, but of a shade intermediate between the red and white of the

parental generation.

iii) When F_1 plants were self-pollinated,' the F2 individuals produced were of five different phenotypes, in the ratio of 1:4:6:4: 1.

iv) 1116 of the individuals of the progeny were darkest red (as red as a parent plant) resembled one of the parents and another 1116 individuals were white (as white as a parent plant).

v) 4/16 of the individuals were medium red (less than parent but more than F_1 hybrids), 6116 of the individuals were intermediate red (as F_1 hybrids) and 4116 of the individuals were light red (less than F_1 hybrids).

vi) It was concluded that the kernel colour is under control of two pairs of alleles. The two pairs of alleles segregate independently of each other as in Mendel's dihybrid crosses. The two genes contribute in the production of pigment and a graded phenotype is produced.

Phenotype of parents → Red kernel × White kernel

Genotype → AABB × aabb

Gametes → (AB) (ab)

F_1 generation → AaBb Intermediate red

Selfing of F_1 generation → AaBb × AaBb

Gametes → (AB) (Ab) (aB) (ab) (AB) (Ab) (aB) (ab)

F_2 generation →

♀ \ ♂	AB	Ab	aB	ab
AB	AABB ●●●●	AABb ●●●○	AaBB ●●●○	AaBb ●●○○
Ab	AABb ●●●○	AAbb ●●○○	AaBb ●●○○	Aabb ●○○○
aB	AaBB ●●●○	AaBb ●●○○	aaBB ●●○○	aaBb ●○○○
ab	AaBb ●●○○	Aabb ●○○○	aaBb ●○○○	aabb ○○○○

Phenotypic ratio → 1 ●●●● Darkest Red : 4 ●●●○ Medium Red : 6 ●●○○ Intermediate Red : 4 ●○○○ Light Red : 1 ○○○○ White

Additional Theory Questions :

Q.1. Mention the advantages of selecting pea plant for his experiment by Mendel. ***Refer Q.8.***

Q.2. Enlist the seven pairs of contrasting characters in pea plant selected by Mendel. ***Refer Q.9.***

Q.3. Why was Mendel successful in his experiment on pea plant? Refer ***Q.10.***

Q.4. What was Mendel's experimental procedure? Refer ***Q.12.***

Q.5. Give graphic representation of monohybrid cross. Refer ***Q.13.***

Q.6. State and explain Mendel's first law or law of dominance. Refer ***Q.17.***

Q.7. State and explain the Law of dominance with suitable example. Refer ***Q.17.***

Q.8. State and explain Mendel's second law of inheritance or law of segregation or law of purity of gametes.
Refer Q.19.

Q.9. What is dihybrid cross? Explain with suitable example and checker board method. Refer Q.22.

Q.10. What is independent assortment? Explain with suitable example. Refer Q.23.

Q.11. State Mendel's third law of inheritance or law of independent assortment and explain it with a dihybrid cross. Refer Q.23.

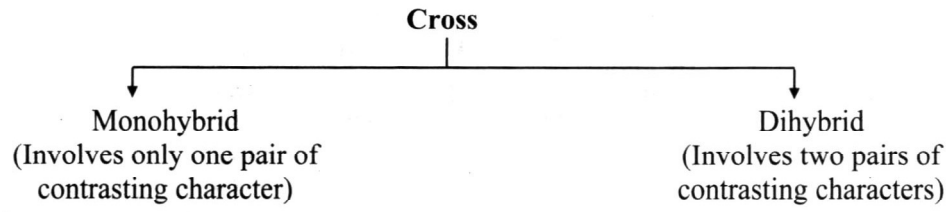
Q.12.Explain deviation of Mendel's law with an example of Mirabilis jalapa /4 o'clock plant. Refer Q.37.

Q.13. What is pleiotropy? Explain with suitable example. Refer Q.45.

Quick Review :

- **7 Pairs of contrasting characters studied by Mendel in pea plant :**

No.	Character	Contrasting form / traits	
		Dominant	Recessive
i)	Height of stem	Tall (IT)	Dwarf (tt)
ii)	Colour of flower	Co loured (CC)	White (cc)
iii)	Position of flower	Axial (AA)	Terminal (aa)
iv)	Pod shape	Inflated (II)	Constricted (ii)
v)	Pod colour	Green (GG)	Yellow (gg)
vi)	Seed shape	Round (RR)	Wrinkled (rr)
vii)	Seed colour(cotyledon)	Yellow (YY)	Green (yy)



- **Result of monohybrid cross experiments :**

No.	Cross	F_1	F_2	Ratio
i)	Tall × dwarf	Tall	787 Tall, 277 dwarf	2.84:1
ii)	Yellow × green seeds	Yellow seed	6022 Yellow,2001 green	3.01:1
iii)	Round × wrinkled seeds	Round seed	5474 Round, 1850 wrinkled	2.96:1
iv)	Green × yellow pods	Green pods	428 Green, 152 yellow	2.82:1
v)	Inflated × constricted pods	Inflated pods	882 Inflated, 299 constricted	2.95:1
vi)	Axial × terminal flower	Axial flower	651 Axile, 207 terminal	3.14 :1
vii)	Violet × white flower	Violet flower	705 Violet, 224 white	3.15 :1
viii)	Grey × white seed coat	Grey seed coat	705 Grey, 224 white	3.15. 1

* Monohybrid Phenotypic ratio = 3 : 1
  Monohybrid Genotypic ratio = 1 : 2 : 1
* Dihybrid Phenotypic ratio = 9 : 3: 3 : 1
* Dihybrid Genotypic ratio = 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
* Back cross: F_1 hybrid × parent (Dominant / Recessive)
* Test cross: F_1 hybrid × parent (Recessive)
* Deviation from Mendelian ratio:
  a. Incomplete dominance
  b. Co-dominance
  c. Multiple alleles

Mendel's Laws

- Law of dominance (First law of inheritance)
- Law of Segregation (Second Law of inheritance Law of purity or of gametes)
- Law of Independent assortment (Third law of inheritance)

Gene interactions

- Intragenic (Interallelic)
  eg. Incomplete dominance
  Co-dominance
  Multiple alleles
- Intergenic (Non-allelic)
  eg. Pleiotropy
  Polygenes
  Epistasis

- **Blood group and its inheritance :**

Father		Mother		Children
Phenotype	Genotype	Phenotype	Genotype	Phenotype
A	I^AI^A I^AI^O	A	I^AI^A I^AI^O	A,O
B	I^BI^B I^BI^O	B	I^BI^B I^BI^O	B,O
A	I^AI^A I^AI^O	B	I^BI^B I^BI^O	A,B,AB,O
A	I^AI^A I^AI^O	O	I^OI^O	A,O
B	I^BI^B I^BI^O	O	I^OI^O	B,O
AB	I^AI^B	A	I^AI^A I^AI^O	A,AB,B
AB	I^AI^B	B	I^BI^B I^BI^O	B,AB,A
O	I^OI^O	O	I^OI^O	O

- **Scientists and their contribution :**

No.	Scientist	Contribution	Year
i)	Mendel	Father of genetics	1908
ii)	William Bateson	Coined the word genetics	1906
iii)	Hugo De Veries (Holland) Kari Correns (Germany) Erich Tschermark (Austria)	Rediscovered Mendel's findings	1901
iv)	Johannsen	Coined the word gene	–
v)	Bateson	Coined the word Allele or Allelomorphs	–
vi)	Reginald C.Punnett	Devised Punnett square	
	H. Nilsson - Ehle	Discovered Polygenic inheritance	1908
viii)	Davenport and Davenport	Studied the inheritance of skin colour in Negroes and albinos	

Multiple Choice Questions

1. The functional unit of heredity is
a) chromosome b) Protein
c) nucleus d) gene

2. The factors which represent pairs of characters are called
a) dominant and recessive
b) alleles
c) homologous pairs
d) determinants

3. The first work on genetics was done by
a) Lamarck b) Hugo de Vries
c) Mendel d) Darwin

4. Mendel's laws were rediscovered by
a) Lamarck, de Vries and Corrensy
b) Hugo De Vries, Correns and Tschermak
c) Morgan, Beadle and Tatum
d) Hugo de Vries, Morgan and Correns

5. Mendel's principles are related to
a) evolution b) reproduction
c) variations d) heredity

6. Mendel performed experiments on
a) Pigeon Pea b) Cow Pea
c) Garden Pea d) Chick Pea

7. Emasculation is
a) removing pollen grains.
b) removing stamens before anthesis.
c) removing stamens after anthesis.
d) removing stamens from male parent.

8. The term 'genetics' was coined by
a) Mendel b) Bateson
c) Muller d) Morgan

9. The character which appears in F_1 generation in a hybrid cross is called
a) recessive b) dominant
c) co-dominant d) fillial

10. Which of the following pair does not represent a contrasting character ?
a) Tall and Dwarf stem
b) Axial and Terminal flower
c) Green and Yellow seed colour
d) Round and Light seed

11. The offspring of a cross between two individuals differing in at least one set of characters is called
a) polyploid b) mutant
c) hybrid d) variant

12. Mendel selected pea plant as material for his experiments because
a) it is an annual plant with short life cycle.
b) the flowers are naturally self-pollinated.
c) flowers can be artificially cross pollinated.
d) all of these.

13. First generation after a cross is called
a) first filial generation
b) F_1 hybrid
c) second filial generation
d) both a) and b)

14. F_2 generation is produced as result of
a) crossing F_1 individual with dominant individuals.
b) crossing F_1 individual with recessive individuals.
c) crossing F_1 individuals amongst themselves.
d) crossing F_1 individuals with their dominant parents.

15. In *Pisum sativum*, which of the following traits is dominant ?
a) White flowers b) Green seeds
c) Yellow pods d) Inflated pods

16. Which one of the following is an incorrect pair in Mendelian characters ?

	Character	Dominant	Recessive
A)	Pod colour	Green	Yellow
B)	Seed shape	Round	Wrinkled
C)	Flower position	Terminal	Tall
D)	Shape of pod	Inflated	Constricted

17. A pure tall pea plant was crossed with a pure dwarf pea plant. All the plants of F_1 were found to be tall. This is due to
a) dominance.
b) disappearance of factor for dwarfness in F_1 generation.
c) segregation of factors.
d) incomplete dominance.

18. A monohybrid cross is the one in which
a) only a single plant is involved for the experiment.
b) a single pair of contrasting characters is considered for the cross.
c) a hybrid is crossed to a homozygous plant,
d) F_1 hybrid is crossed back with recessive parent.

19. In Mirabilis jalapa, when two F_1 pink flowered plants were crossed with each other, the F_2 generation produced 40 red, 80 pink and 40 white flowering plants. This is a case of
a) duplicate genes
b) lethal genes
c) incomplete dominance
d) epistasis

20. For a given character, a gamete is always
a) homozygous b) pure
c) hybrid d) heterozygous

21. How would you test a pea plant whether it is a pure or hybrid for tallness ?
a) Crossing it with another tall pea plant of unknown genotype.
b) Crossing it with a pure tall pea plant.
c) Crossing with a homozygous dwarf pea.
d) Crossing it with any pea plant.

22. A cross between F_1 hybrid and its parent is
a) back cross b) reciprocal cross
c) monohybrid cross d) dihybrid cross

23. Test cross is a cross between
a) hybrid × dominant parent (Tt × IT)
b) hybrid × recessive parent (Tt × tt)
c) hybrid × hybrid (Tt × Tt)
d) hybrid × unknown parent

24. A cross between an individual with unknown genotype for a trait with recessive plant for that trait is
a) Back cross b) Reciprocal cross
c) Test cross d) Monohybrid cross

25. Genetically identical progeny is produced when individuals
a) perform cross fertilization.
b) produce identical gametes.
c) inbreed without meiosis.
d) exhibit sexual reproduction.

26. Tall plant with round seeds is crossed with dwarf plant having wrinkled seeds. This type of cross is
a) dihybrid b) monohybrid
c) test cross d) back cross

27. Genes do not occur in pairs in
a) zygote b) somatic cell
c) brain cells d) gametes

28. Pisum sativum is
a) strictly a self fertilizing plant.
b) naturally self fertilizing but cross fertilizable plant.
c) naturally cross fertilizing but self fertilizable plant.
d) strictly cross fertilizing plant.

29. The phenotypic ratio in incomplete dominance is
a) 3: 1 c) 9: 3 : 3 : 1
b) 1: 2 : 1 d) 1: 1

30. In a dihybrid cross, F_2 generation offsprings show four different phenotypes, while the genotypes are
a) Six b) Nine
c) Eight d) Sixteen

31. Pea plant with double hybrid yellow round seeds (YyRr) is crossed with pea plant having single hybrid green round seeds (yyRr). The progeny shall be
a) 3: 3 : 1 : I b) 1: 1 : 1 :1
c) 9: 3 : 3 : 1 d) 3: 1 : 3 : 1

32. The ratio of phenotypes in F2 generation of a monohybrid cross is
a) 3: 1 b) 1: 2 : 1
c) 9: 3 : 3 :1 d) 2: 1

33. Heterozygous tall plant is selfed. It produced both tall and dwarf plants. This confirmed
a) dominance
b) segregation
c) independent assortment
d) incomplete dominance

34. 'R' is dominant red flower trait, while 'r' is recessive white flower trait. Heterozygous Rr (red) is crossed with homozygous red (RR) flowered plant. In all, 64 offsprings are produced. Number of white flowered plants is
a) 64 b) 32
c) 16 d) 0

35. Heterozygous tall (Tt) is crossed with homozygous tall (IT). Percentage of heterozygous tall in the progeny would be
a) 25% b) 50%
c) 75% d) 100%

36. Hybrid pea plant with yellow round seeds (YyRr) is self pollinated. Phenotypic ratio of next generation would be
a) 13: 3 b) 9: 7
c) 1: 4 : 6 : 4 : 1 d) 9: 3 : 3 : 1

37. In a cross between heterozygous tall (Tt) and homozygous tall (TT), there is a progeny of

38. In red-white flowered cross of Mirabilis *jalapa,* F_2 generation has red, pink and white flowered plants in the ratio of
a) 1: 2 :1 a) 1: 0 : 1
c) 2: 1 : 1 d) 1: 1 : 2

39. The gene which controls many characters is called
a) Codominant gene b) Polygene
c) Pleiotropic gene d) Multiple gene

40. In an experiment on pea plant, pure plants with yellow round seeds (YYRR) were crossed with plants producing green wrinkled seeds (yyrr). What will be the phenotypic ratio of F_1 progeny ?
a) 9 yellow round : 3 round green : 3 wrinkled yellow : 1 green wrinkled
b) All yellow round
c) 1 round yellow : 1 round green wrinkled yellow : 1 wrinkled green
d) All wrinkled green

41. A pea plant with yellow and round seeds is crossed with another pea plant with green and wrinkled seeds produced 51 yellow round seeds and 49 yellow wrinkled seeds. Genotype of plant with yellow round seeds must be
a) YYRr b) YyRr
c) YyRR. d) YYRR

42. In a cross, 45 tall and 14 dwarf plants were obtained. Genotype of parents was
a) TT × TT a) TT × Tt
c) Tt × Tt d) TT × tt

43. Tallness (T) is dominant over dwarfness (t), while red flower colour (R) is dominant over white colour (r). A plant with genotype TtRr is crossed with plant of genotype ttrr. Percentage of progeny having tall plants with red flower is
a) 25% b) 50%
c) 75% d) 100%

44. "Gametes are never hybrid". It is a statement of law of
a) dominance
a) segregation
c) independent assortment
d) unit character

45. Inheritance of skin colour in humans is an example of
a) Point mutation
b) Polygenic inheritance
c) Co-dominance
d) Chromosomal aberration

46. Blood grouping in humans is controlled by
a) 4 alleles in which A is dominant.
b) 3 alleles in which AB is co-dominant.
c) 3 alleles in which none is dominant.
d) 3 alleles in which A is dominant.

47. Genes located on same locus but show more than two different phenotypes are called
a) polygenes a) multiple alleles
c) co-dominants d) pleiotropic genes

48. Which one of the following is an example of multiple alleles ? **[Oct 2013]**
a) Height in pea plant
b) Hair colour in cattle
c) Petal colour in four o'clock plant
d) Wing-size in Drosophila

49. Genotype of blood group 'A' will be
a) I^AI^A b) I^BI^B
c) I^AI^A or I^AI^O d) I^AI^O

50. When phenotypic and genotypic ratio is the same, then it is an example of
a) Incomplete dominance
b) Cytoplasmic inheritance
c) Quantitative inheritance
d) Incomplete or Co-dominance

51. Which one of the following is true pleiotropic gene? **[Oct 2014]**
a) Hb^A b) Hb^s
c) Hb^D d) Hb^P

52. When two genes control single character and have cumulative effect, the ratio is
a) 1 : 1 : 1 : 1 b) 1 : 4 : 6 : 4 : 1
c) 1 : 2 : 1 d) 1 : 6 : 15 : 20 : 15 : 6:1

53. If cattle with black coat is crossed with white coat, the F_1 hybrids posses roan coat. This is an example of
a) epistasis
b) co-dominance
c) incomplete dominance
d) law of segregation

54. When single gene produces two effects and one of it is lethal, then ratio is
a) 2 : 1 b) 1 : 1
c) 1 : 2 : 1 d) 1 : 1 : 1 : 1

Answer Keys

1. d)	**2.** b)	**3.** c)	**4.** b)	**5.** d)	**6.** c)	**7.** b)	**8.** b)	**9.** b)	**10.** d)
11. c)	**12.** d)	**13.** d)	**14.** c)	**15.** d)	**16.** c)	**17.** a)	**18.** b)	**19.** c)	**20.** b)
21. c)	**22.** a)	**23.** b)	**24.** c)	**25.** b)	**26.** a)	**27.** d)	**28.** b)	**29.** b)	**30.** b)
31. d)	**32.** a)	**33.** b)	**34.** d)	**35.** b)	**36.** d)	**37.** d)	**38.** a)	**39.** c)	**40.** b)
41. b)	**42.** c)	**43.** a)	**44.** b)	**45.** b)	**46.** b)	**47.** b)	**48.** d)	**49.** c)	**50.** d)
51. b)	**52.** b)	**53.** b)	**54.** c)						