XII
5

PRINCIPLES OF INHERITANCE AND VARIATION

SYLLABUS

Mendelian Inheritance; Deviations from Mendelism-Incomplete dominance, Co-dominance, Multiple alleles and Inheritance of blood groups, Pleiotropy; Elementary idea of polygenic inheritance; Chromosome theory of inheritance; Chromosomes and genes; Sex determination-In humans, birds, honey bee; Linkage and crossing over; Sex linked inheritance-Haemophilia, Colour blindness; Mendelian disorders in humans-Thalassemia; Chromosomal disorders in humans; Down's syndrome, Turner's and Klinefelter's syndromes.

KEY CONCEPTS

INTRODUCTION

* Genetics term was given by W. Bateson (Father of Modern Genetics).
* Genetics = Collective study of heredity & Variations.
* Heredity = Transmission of genetic characters from parent to offsprings.
* **Variation** = Individuals of same species have some differences, these are called variation.

(i) **Somatic (Non inheritable)**

(ii) **Germinal (Blastogenic):** transfer from generation to generation (Inheritable)

(a) **Continuous variation :** due to crossing over

(b) **Discontinuous variation :** due to mutation

* G.J. Mendel – Father of Genetics.
* W. Bateson – Father of Modern Genetics.
* Morgan - Father of Experimental genetics
* A. Garrod = Father of human genetics and biochemical genetics. Garrod discovered first human Metabolic genetic disorder which is called alkaptonuria (black urine disease).
  Gave the concept 'One mutant gene one metabolic block'.

BASIC TERMS

1. **Factors :** Unit of heredity which is responsible for inheritance and appearance of characters.
These factors were referred as genes by Johannsen(1909). Mendel used term "element" for factor. Morgan first used symbol to represent the factor. Dominant factors are represented by capital letter while recessive factor by small letter.

2. **Allele :** Alternative forms of a gene which are located on same position (loci) on the homologous chromosome is called Allele. Term allele was coined by Bateson.

3. **Homozygous :** A zygote is formed by fusion of two gametes having identical factors is called homozygote and organism developed from this zygote is called homozygous.
Ex. TT, RR, tt

4. **Heterozygous :** A zygote is formed by fusion of two different types of gamete carrying different factors is called heterozygote (Tt, Rr) and individual developed from such zygote is called heterozygous.

The term homozygous and heterozygous are coined by Bateson.

5. **Hemizygous :** If individual contains only one gene of a pair then individual said to be Hemizygous. Male individual is always Hemizygous for sex linked gene.
6. **Phenotype :** It is the external and morphological appearance of an organism for a particular character.
7. **Genotype :** The genetic constitution or genetic make-up of an organism for a particular character. Genotype & phenotype terms were coined by Johannsen.
8. **Phenocopy :** If different genotypes are placed in different environmental conditions then they produce same phenotype. Then these genotypes are said to be Phenocopy of each other.
9. **Hybrid vigour/Heterosis :** Superiority of offsprings over its parent is called as Hybrid vigour & it develops due to Heterozygosity.

MENDELISM

* Experiments performed by Mendel on genetics and description of mechanisms of hereditary processes and formulation of principles are known as **Mendelism**.
* Mendel postulated various experimental laws in relation of genetics.
* Gregor Johann Mendel (1822 - 1884) : He started his historical experiments of heredity on pea (Pisum sativum) plant.
* The results of his experiments were published in the science journal. "Nature For schender varein" in 1866.
* This journal was in German language. Title was "Verschue uber Pflangen Hybridan".

Mendel's Experiment

* Gregor Mendel(Father of Genetics). Conducted hybridization experiments on garden peas for seven years (1856 - 1863) and proposed laws of inheritance.
* Mendel conducted artificial pollination/cross pollination experiments using several true-breeding pea lines.
* A true breeding line is one that, having undergone continuous self-pollination for several generations.
* Mendel selected 14 true-breeding peas' plant varieties, as pair's which were similar except for one character with contrasting traits.
  - True breed selected by Mendel
  - Stem height- Tall / dwarf
  - Flower color- Violet/white
  - Flower position - Axial / terminal
  - Pod shape- Inflated / beaded or constricted
  - Pod color- Green / yellow
  - Seed color- Yellow/ green
  - Seed shape - round / wrinkled

* **Selection of pea plant:** The main reasons for adopting garden pea (*Pisum sativum*) for experiments -
  - Pea has many distinct contrasting characters.
  - Life span of pea plant is short.
  - Flowers show self pollination, reproductive whorls being enclosed by corolla.
  - It is easy to artificially cross pollinate the pea flowers. The hybrids thus produced were fertile.

* **Working method:** Mendel's success was also due to his meticulous planning and method of work -
  - He studied only one character at a time.
  - He hybridised plants with alternate forms of a single trait (**Monohybrid cross**). The seeds thus produced were grown to develop into plants of **first filial generation (F_1).**
  - Mendel then self-pollinated the F_1 plants to generate plants of **second filial generation (F_2).**
  - Later, Mendel also crossed pea plants that differed in two characters (**Dihybrid cross**).
  - He applied mathematics and statistics to analyse the results obtained by him.

Basic outline of Mendels cross :

1. Pure breeding parents for a pair of contrasting character (allelic Pair) is taken. e.g, Tall pure-bred pea plants (TT) & short pure-bred pea plants (tt) ↓
2. Gamete formation (Meiosis) ↓

3. Hybridization (crossing is done)
↓
4. **F_1 generation** - the product of the above cross (are called hybrids)
↓
5. **Selfing** (allowed to self fertilize / self breeding)
↓
6. Gamete formation (Meiosis)
↓
7. **F_2 generation** - the product of the above selfing
↓
8. Analysis of result (Phenotype and Genotype)

MENDEL'S LAWS OF INHERITANCE

1. **Mendel's first law (Law of dominance):** This law states that when two contrasting genes for a character come together in an organism, only one is expressed externally and shows visible effect. It is called dominant and the other gene of the pair which does not express and remains hidden is called recessive. (Can be explained by monohybrid cross)

2 **Mendel's second law (Law of segregation):** The two alleles received, one from each parent, segregate independently in gamete formation, so that each gamete receives one or the other with equal probability. (Can be explained by monohybrid cross)

3. **Mendel's third law (Law of Independent assortment):** The law of independent assortment states that inheritance of two or more genes when occur at one time, their distribution in the gametes and in the progeny of subsequent generations is independent of each other. (To prove this, he did a dihybrid cross. He crossed homozygous dominant smooth and yellow seeded (YYRR) with homozygous recessive wrinkled and green seeded (yyrr) plants. The F_1 hybrid was self pollinated and F_2 generation was obtained with the phenotypic ratio of 9:3:3:1 and genotypic ratio of 1:2:1:2:4:2:1:2:1.).

INHERITANCE OF ONE GENE

* Mendel crossed tall and dwarf pea plants to study the inheritance of one gene.
* When we consider the inheritance of one character at a time in a cross this is called **monohybrid cross**.
* He collected the seeds produced as a result of this cross and grew them to generate plants of the first hybrid generation. This generation is called **filial progeny or the F_1.**
* Mendel observed that all the F_1 progeny plants were tall, like one of its parents; none were dwarf.
* He made similar observations for the other pairs of traits - he found that the F_1 always resembled either one of the parents, and that the trait of the other parent was not seen in them.
* Mendel then self - pollinated the tall F_1 plants and to his surprise found that in the **F_2 generation** some of the offsprings were dwarf; the character that was not seen in the F_1 generation was now expressed.
* The proportion of plants that were dwarf was 1/4th of the F_2 plants while 3/4th of the F_2 plants were tall.
* The tall and dwarf traits were identical to their parental type and did not show any blending, that is all the offsprings were either tall or dwarf, none were of in between height.
* Similar results were obtained with the other traits that he studied: only one of the parental traits was expressed in the F_1 generation while at the F_2 stage both the traits were expressed in the proportion of 3:1.
* The contrasting traits did not show any blending at either F_1 or F_2 stage.

Monohybrid cross :

* When we consider the inheritance of one character at a time in a cross this is called monohybrid cross.
* First of all, Mendel selected tall and dwarf plants.

Parent Tall (Pure) × Dwarf (Pure)
↓
F_1-Generation All tall (impure)
↓ Self pollination
Tall Dwarf (Phenotypic ratio or basic ratio or Mendelian ratio)

F_2-Generation 3 : 1

1 tall (pure) 2 tall (impure) 1 Dwarf (pure)

Sefling ↓ Sefling ↓ Sefling ↓

F_3- Generation

All tall 3 tall : 1 dwarf All dwarf

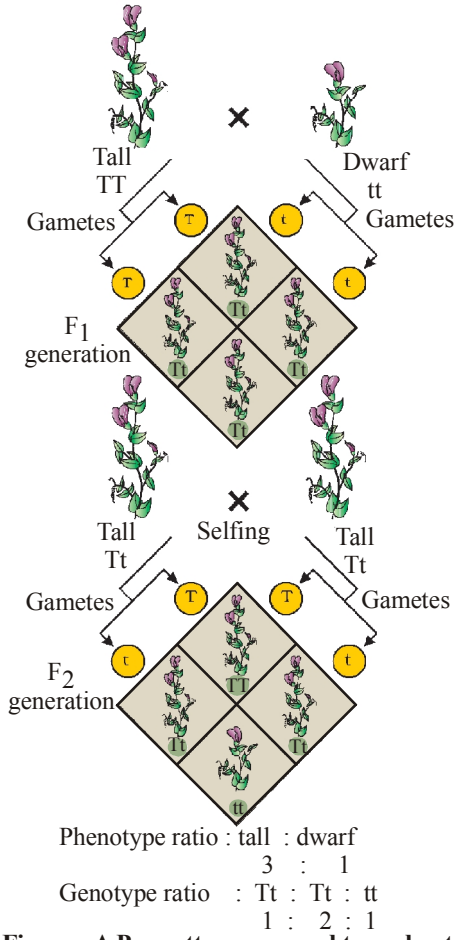
Genotype ratio :

Pure tall (1) : Impure tall (2) : Pure dwarf (1)

Mendelian ratio : Tall (3) : Dwarf (1)

Checker Board Method :

* First time, it was used by Reginald. C. Punnett (1875-1967).
* Different combinations of gametes are theoretically represented in a square tabular form known as **'Punnett Square'.**
* Male gametes lie horizontally and female gametes lie vertically.



Phenotype ratio : tall : dwarf
3 : 1

Genotype ratio : Tt : Tt : tt
1 : 2 : 1

Figure : A Punnett square used to understand a typical monohybrid cross conducted by Mendel between true-breeding tall plants and true-breeding dwarf plants

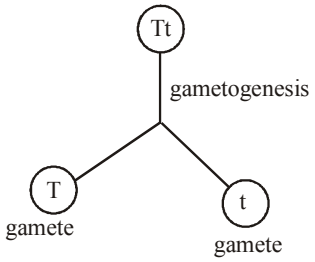
TT = Tall (dominant homozygous),
Tt = Tall (dominant heterozygous),
tt = Dwarf (recessive homozygous).

Conclusions (results) of Monohybrid Cross :

* **Ist Conclusion :** According to Mendel each genetic character is controlled by a pair of unit factor. It is known as conclusion of paired factor or unit factor.
* **IInd Conclusion :** This conclusion is based on F_1-generation. When two different unit factors are present in single individual. only one unit factor is able to express itself and known as dominant unit factor. Another unit factor fails to express is the recessive factor. In the presence of dominant unit factor recessive unit factor can not express and it is known as conclusion of dominance.

  Tall × Dwarf
  TT ↓ tt
  F_1 gen. (Tt) All tall

* **IIIrd Conclusion :** During gamete formation ; the unit factors of a pair segregate randomly and transfer inside different gamete. Each gamete receives only one factor of a pair; so gametes are pure for a particular trait. It is known as conclusion of purity of gametes or segregation.



Dihybrid cross

* A cross in which study of inheritance of two pairs of contrasting traits.
* Mendel selected traits for dihybrid cross for his experiment as follows :

(1) Seed form → Round (R) and Wrinkled (r)

(2) Colour of cotyledons → Yellow (Y) & Green(y)

* When F_1 plants were self pollinated to produce four kinds of plants in F_2 generation such as yellow round, yellow-wrinkled, green round and green wrinkled, there were in the ratio of 9 : 3 : 3 : 1. This ratio is known as dihybrid ratio.

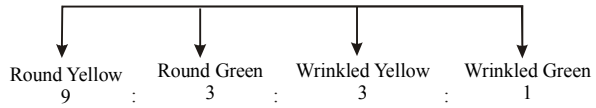
Round - Yellow × Wrinkled - Green

↓

F_1 - Generation All round - yellow

↓ selfing

F_2 - Generation



Conclusion : The F_2 generation plant produce two new phenotypes, so inheritance of seed coat colour is independent from the inheritance of shape of seed. Otherwise it can not possible to obtain yellow wrinkled and green round type of seeds.

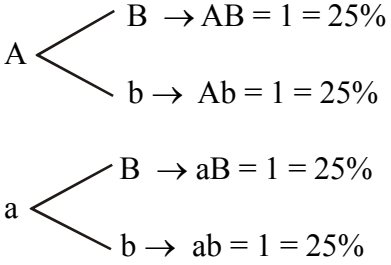
This observation leads to the Mendel's conclusion that different type of characters present in plants assorted independently during inheritance.

This is known as Conclusion of Independent Assortment.

Fork line method :

* To find out the composition of factors inside the gamete, we use fork line method.

AaBb = 4 types of gamete

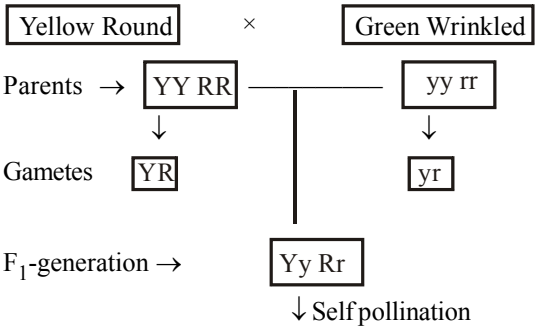


* Type of gamete /phenotypic category = 2^n
* n = No of hybrid character or heterozygous pair.
* Type of genotype = 3^n

eg in dihybrid cross = $3^2 = 9$ genotype

* No. of zygote produced by selfing of a genotype = 4^n

Demonstration by checker board method :



F_2-generation →

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

Phenotype :

Yellow Round = 9/16

Yellow Wrinkled = 3/16

Green Round = 3/16

Green Wrinkled = 1/16

Thus, Phenotypic Ratio = 9 : 3 : 3 : 1

Genotype:

YYRR	YYRr	YyRR	YyRr	YYrr	Yyrr	yyRR	yyRr	yyrr
1	2	2	4	1	2	1	2	1

Thus, Genotypic Ratio = 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

Back cross

* . . . . . $_1$ individuals are crossed with any of their parents.
* When F_1 individual is crossed with dominant parent then it is termed **out cross**. The generations obtained from this cross, all possess dominant character, so any analysis can not possible in F_1 generation.
* When F_1 progeny is crossed with recessive parent then it is called **test cross.**
* **Monohybrid Test Cross :** The progeny obtained from the monohybrid test cross are in equal proportion, means 50% is dominant phenotypes and 50% is recessive phenotypes.

It can be represented in symbolic forms as :

F 1 progeny(hybrid) × Recessive parent

Tt ↓ t t

	t
T	Tt
t	tt

Monohybrid test cross ratio = 1 : 1

* **Dihybrid Test Cross :** The progeny is obtained from dihybrid test cross are four types and each of them is 25%.

F_1-dihybrid Recessive parent

T t R r × t t r r

↓

	RT	Tr	Rt	tr
tr	TtRr	Ttrr	ttRr	ttrr

The ratio of Dihybrid test cross = 1: 1: 1: 1

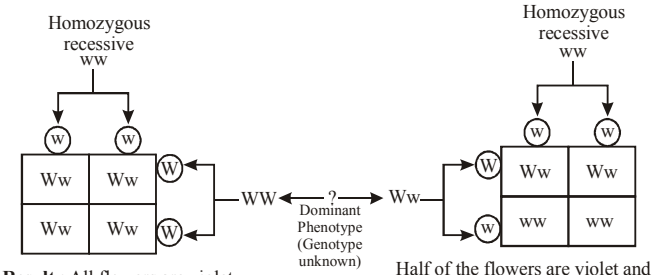


Figure : Diagrammatic representation of a Test cross

Conclusion: In test cross phenotypes and genotypes ratio are same. Helps to determine genotype of test organism.

* **Reciprocal Cross :** When two parents are used in two experiments in such a way that in one experiment "A" is used as the female parent and "B" is used as the male parent, in the other experiment "A" will be used as the male parent and "B" as the female parent such type of a set of two experiments is called Reciprocal cross. Characters which are controlled by karyogene are not affected by Reciprocal cross. In case of cytoplasmic inheritance result change by Reciprocal cross.

(a) TT × tt (b) TT × tt

(a) TT × tt
(Female) (Male)
↓
All tall

(b) TT × tt
(Female) (Male)
↓
All tall

* **Summarised account of Mendel's experiments**

No. of traits / hybrid (n)	Experiment	Types of gametes (2^n)	Number of zygotes / offsprings $(gametes)^2$	Number of Phenotype (2^n)	Number of genotype (3^n)	Phenotypic ratio	Genotypic ratio
1.	Monohybrid cross (Aa × Aa)	$2^n = 2^1 = 2$	$2^2 = 4$	$2^n = 2^1 = 2$	$3^1 = 3$	3 : 1	1 : 2 : 1
2.	Dihybrid cross (AaBb × AaBb)	$2^2 = 4$	$4^2 = 16$	$2^2 = 4$	$3^2 = 9$	$(3 : 1)^2 = 9 : 3 : 3 : 1$	$(1 : 2 : 1)^2 = 2:4:2:1:2$ 1 : 1 : 2 : 1
3.	Trihybrid cross [AaBbCc × AaBbCc]	$2^3 = 8$	$8^2 = 64$	$2^3 = 8$	$3^3 = 27$	$(3 : 1)^3$	$(1 : 2 : 1)^3$

ALLELIC GENE INTERACTION

* Allelic gene interaction takes place between allele of same gene which are present at same locus. eg, Incomplete dominance, Co-dominance.

Incomplete dominance :

* According to Mendel's law of dominance, dominant character must be present in F_1 generation.

* But in some organisms, F_1 generation is different from the both parents.

* Both factors such as dominant and recessive are present in incomplete dominance but dominant factors are unable to express their character completely, resulting different type of generation is formed which is different from the both parents.

* **Examples :**

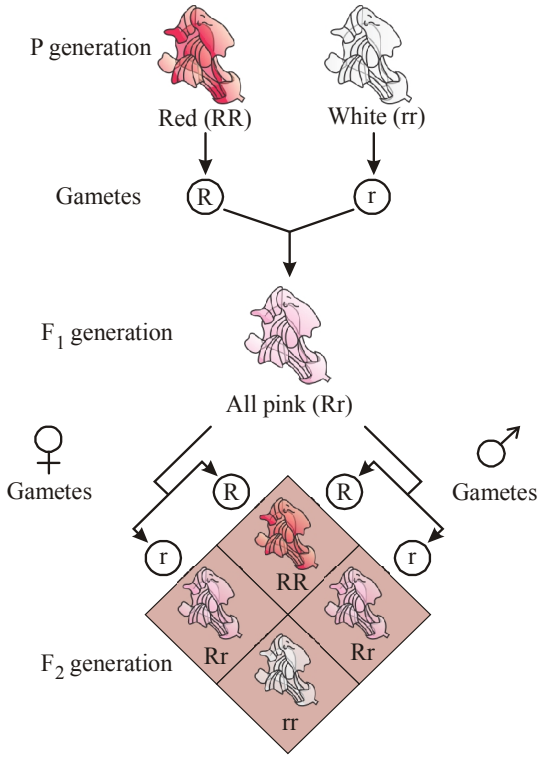
(a) Incomplete dominance was first discovered by Correns in Mirabilis jalapa. This plant is called as '4 O' clock plant' or 'Gul-e-Bans'.

Three different types of plant are found in Mirabilis on the basis of flower colour, such as red, white and pink.

When plants with red flowers is crossed with white flower plants, with pink flower obtained in F_1 generation the reason of this is that the genes of red colour incompletely dominant over the

genes of white colour.

When, F_1 generation of pink flower is self pollinated then the phenotypic ratio of F_2 generation is red, pink, white=1: 2:1 in place of normal monohybrid cross - 3 : 1.



Phenotype ratio : red : pink : white
1 : 2 : 1
Genotype ratio : RR : Rr : rr
1 : 2 : 1

Figure : Results of monohybrid cross in the plant Snapdragon, where one allele is incompletely dominant over the other allele.

The ratio of phenotype and genotype of F_2 generation in incomplete dominance is always same.

NOTE :

Cross	Result of F_2 generation	
	Phenotypic ratio	Genotypic ratio
Monohybrid Tt X Tt	3:1	1:2:1
Dihybrid cross YyRr X YyRr	9:3:3:1	1:2:1:2:4:2:1:2:1
Incomplete dominance Rr X Rr	1:2:1	1:2:1

(b) **Antirrhinum majus :** Incomplete dominance is also seen in this plant. This plant is also known as ''Snapdragon' or 'Dog flower'. Incomplete dominance is found in this plant which is the same as Mirabilis.

(c) **Andalusian Fowls :** Incomplete dominance is present for their feather colour. When a black colour fowl is crossed with a white colour fowl, the colour of F_1 generation is blue.

Co-dominance :

* In this phenomenon, both the gene expressed for a particular character in F_1 hybrid progeny.
* In the case of co-dominance the F_1 generation resembles both parents
* There is no blending of characters, whereas both the characters expressed equally.
* In incomplete dominance, characters are blended phenotypical, while in co-dominace, both the genes of a pair exhibit both the characters side by side and effect of both the character is independent from each other.
* When a black parent is crossed with white parent, a roan colour F_1 progeny is produced.
* When we obtain F_2 generation from the F_1generation, the ratio of black; black-white (Roan) ; white of animals is 1 : 2 : 1

Note : F_2 generation is obtained in animals by sib-mating cross.

Black × White
R_1R_1 × R_2R_2
↓
F_1-generation R_1R_2 (Roan)
↓ Sib-mating cross
R_1 R_2

F_2-generation

	R_1	R_2
R_1	R_1R_1	R_1R_2
R_2	R_1R_2	R_2R_2

R_1R_1 = Black -1
R_1R_2 = Roan-2
R_2R_2 = White-1

* It is obvious by above analysis that the ratio of phenotype as well as genotype is 1 : 2 : 1 in co-dominance.

Note : In incomplete dominance, characters are blended phenotypical, while in co-dominace,

both the genes of a pair exhibit both the characters side by side and effect of both the character is independent from each other.

Examples of Co-dominance :

(i) AB blood group inheritance (I^AI^B)

* ABO blood groups are controlled by the gene I.
* The plasma membrane of the red blood cells has sugar polymers that protrude from its surface and the kind of sugar is controlled by the gene.
* The gene (I) has three alleles I^A, I^B and i.
* The alleles I^A and I^B produce a slightly different form of the sugar while allele i doesn't produce any sugar. Because humans are diploid organisms, each person possesses any two of the three I gene alleles.
* I^A and I^B are completely dominant over i, in other words when I^A and i are present only I^A expresses (because i does not produce any sugar), and when I^B and i are present I^B expresses. But when I^A and I^B are present together they both express their own types of sugars: this is because of co-dominance.
* Red blood cells have both A and B types of sugars. Since there are three different alleles, there are six different combinations of these three alleles that are possible, and therefore, a total of six different genotypes of the human ABO blood types (Table).

Allele from Parent 1	Allele from Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	$I^A I^A$	A
I^A	I^B	$I^A I^B$	AB
I^A	i	$I^A i$	A
I^B	I^A	$I^A I^B$	AB
I^B	I^B	$I^B I^B$	B
I^B	i	$I^B i$	B
i	i	i i	O

(ii) Carrier of Sickle cell anaemia ($Hb^A Hb^S$)

Multiple allele :

* More than 2 alternative forms of same gene called as multiple allele.
* Multiple allele is formed due to mutation.
* Multile allele located on same locus of homologous chromosome.
* A diploid individual contains two alleles and gamete contains one allele for a character. Ex. Blood group - 3 alleles

Coat colour in rabbit - 4 alleles

* If n is the number of allele of a gene then number of different possible genotype $= \frac{n(n+1)}{2}$

Example of multiple allele :

1. ABO blood group : ABO blood groups are determined by allele I^A, allele I^B, allele I^O

I^A = dominant ; I^B = dominant ; I^O = recessive

Possible phenotypes - A, B, AB, O

Blood group	Genotype	Antigen or agglutinogen	Antibody or agglutinin
A	I^AI^A, I^AI^O	A	b
B	I^BI^B, I^BI^O	B	a
AB	I^AI^B	A&B	None
O	I^OI^O	none	a & b

Possible genotype number $= \frac{3(3+1)}{2} = 6$ genotype

2. Coat colour in rabbit.

3. Eye colour in Drosophila.

4. Self incompatibility genes in plants.

Lethal Gene :

* Gene which causes death of individual in early stage when it comes in homozygous condition called lethal gene.
* It may be dominant or recessive both, but mostly recessive for lethality.
* Lethal gene was discovered by L. Cuenot in coat colour of mice.
* Gene of yellow body colour of mice is lethal. So homozygous yellow mice are never obtained in population. It dies in embryonal stage.
* When yellow mice were crossed among themselves segregation for yellow and brown body colour was obtained in 2 : 1 ratio.

Yy × Yy

	Y	y
Y	YY	Yy
y	Yy	yy

YY - death in embryonal stage modified ratio = 2 : 1

* In plant lethal gene was first discovered by E. Baur in Snapdragon (Antirrhinum majus)

Snapdragon (i) Golden leaves (G),
(ii) Green leaves (g)

Golden × Golden
Gg Gg

	G	g
G	GG	Gg
g	Gg	gg

Modified Ratio: 2 : 1

* Homozygous golden leaves are never obtained.

Sickle cell anaemia in human : In human, gene of sickle cell anaemia Hb^S is the example of lethal gene. When two carrier individuals of sickle cell anaemia are crossed then offsprings are obtained in 2 : 1 ratio.

$Hb^S\ Hb^A \times Hb^S\ Hb^A$

	Hb^S	Hb^A
Hb^S	$Hb^S\ Hb^S$	$Hb^S\ Hb^A$
Hb^A	$Hb^S\ Hb^A$	$Hb^A\ Hb^A$

Sublethal gene but ratio 2 : 1

Pleiotropic gene :

* Gene which controls more than one character is called pleiotropic gene.
* This gene shows multiple phenotypic effect. For example : In Pea plant :
* Single gene influences (i) Seed coat colour, (ii) Red spot on leaf, (iii) Flower colour.
* In Drosophila recessive gene of vestigial wings also influence some another characters :
  - Structure of reproductive organs
  - Longevity (Length of Body)
  - Bristles on wings.
  - Reduction in egg production.

Examples of pleiotropic gene in human

Sickle cell anaemia :

* Gene Hb_β^S provide a classical example of pleiotrophy.
* It not only causes haemolytic anaemia but also results increased resistance to one type of malaria that caused by the parasite Plasmodium falciparum.
* The sickle cell Hb_β^S allele also has pleiotropic effect on the development of many tissues and organs such as bone, lungs, kidney, spleen, heart.

NONALLELIC GENE INTERACTION

* When interaction takes place between non allele is called non allelic gene interaction. It changes or modifies other non allelic gene.
* **Examples of nonallelic interaction :**

Epistasis : When, a gene prevents the expression of another non-allelic gene, then it is known as epistatic gene and this phenomenon is known as Epistasis.

Gene which inhibit the expression of another non alleleic gene is called epistatic gene and expression of gene which is suppressed by epistatic gene called hypostatic gene.

Example : Hair Colour in Dog.

* **Complementary Gene :** Two pair of non allelic genes are essential in dominant form to produce a particular character.

Such genes that act together to produce an effect that neither can produce, it's effect separately are called complementary genes. Both types of gene must be present in dominant form.

Example : Colour of flowers in Lathyrus odoratus

* **Supplementary gene or Recessive Epistasis**

A pair of gene change the effect of another non allelic gene, is called supplementary gene.

Example : Coat colour in Mice.

POLYGENIC INHERITANCE

* Inheritance of characters in which one character is controlled by many genes and intensity of character depends upon the number of dominant allele.
* Polygenic inheritance first described by Nilsson-Ehle in kernal colour of wheat.
* Nilsson-Ehle said that kernal colour of wheat is regulated by two pairs of gene.

	RRBB			×		rrbb			
	Red					White			
				↓					
F_1-gen.				RrBb (intermediate)					
				↓					
F_2-gen.	1	:	4	:	6	:	4	:	1
	Full red		light red		Intermediate red		very light		white
No. of dominant gene	4		3		2		1		0

1 Red : 14 intermediate : 1 white

Another example : Colour of the skin in human.

CYTOPLASMIC INHERITANCE

* Inheritance of characters which are controlled by cytogene or cytoplasm is called cytoplasmic inheritance.
  Genes which are present in cytoplasm called **'cytogene'** or **'plasmagene'** or extra nuclear gene.
* Total cytogen present in cytoplasm is called **plasmon**.
* A gene which is located in the nucleus is called **karyogene**.
* Inheritance of cytogene in higher plants only through the female. Because female gamete has karyoplasm, simultaneously it has cytogene because of more cytoplasm.
* The male gamete of higher plant is called male nucleus. It has very minute [equivalent to nil) cytoplasm, so male gamete only inherited karyogene.
* Thus, inheritance of cytogene only through female.
  (also called maternal inheritance)
* If there is a reciprocal cross in this condition, then results may be effected.

Cytoplasmic inheritance of three types :

1. Maternal effect depending indirectly on nuclear genes and involving no known cytoplasmic hereditary unit called as **predetermination**. In this maternal effect is determine before fertilization.
Example : Shell coiling in snail (Limnaea peregra)

2. Cytoplasmic inheritance involving dispensable and infective hereditary particle in cytoplasm which mayor may not depend on nuclear genes called as **Dauermodification.**
Example : Sigma particle in Drosophila, Kappa particle in Paramecium.

3. Cytoplasmic inheritance involving essential organelles like, Chloroplast and mitochondria called as organellar genetics.
Example of Organellar Genetics: (True examples of cytoplasmic inheritance)

(a) **Plastid inheritance in *Mirabilis jalapa*** - Cytoplasmic inheritance first discovered by Correns in Mirabilis jalapa.
In *Mirabilis jalapa* plastid inheritance i.e. branch colour is example of cytoplasmic inheritance.
Branch colour

(i) Pale ♀ × Green ♂ → F_1-Pale

(ii) Green ♀ × Pale ♂ → F_1-Green

(iii) Variegated ♀ × Pale or Green or Variegated ♂ → F_1-Pale,Green and Variegated

(b) **Male sterelity in maize plant :** Gene of male sterelity present in mitochondria. If a normal male plant crossed with a female plant which has genes of male sterelity then all the generation of male become sterile, because a particular gene was present with female which inherited by female and male plant of the progeny are sterile.

CHROMOSOMAL THEORY OF INHERITANCE

* This theory was proposed by Walter, Sutton and Theodor Roveri (1902). Following are the main points of this theory

1. Gametes serve as the bridge between two successive generations.

2. Male and Female gametes play an equal role in contributing hereditary components of future generation.

3. Only the nucleus of sperm combines with ovum. Thus, the hereditary information is contained in the nucleus.

4. Chromatin in the nucleus is associated with the cell division in the form of chromosomes.

5. Any type of deletion or addition in the chromosomes can cause structural and functional changes in living beings.
6. A sort of parallelism is observed between Mendelian factors and chromosomes.
7. A number of genes or Mendelian factors are found in each chromosome. .
8. Determination of sex in most of the animals and plants is affected by specific chromosomes. These chromosomes
are called sex chromosomes.

Parallelism between Gene and Chromosomes :

1. Chromosomes are also transferred from one generation to the next as in' the case of genes (Mendelian factors).
2. The number of chromosomes is fixed in each living species. These are found as homologous pairs in diploid cells. One chromosome from father and the other contributed by the mother constitute a homologous pair.
3. Before cell division, each chromosome as a whole and the alleles of genes get replicated and are separated during mitotic division.
4. Meiosis takes place during gamete formation. Homologous chromosomes form synapses during prophase-I stage which in later course get separated and transferred to daughter cells. Each gamete or a haploid cell has only one allele of each gene present in the chromosome.

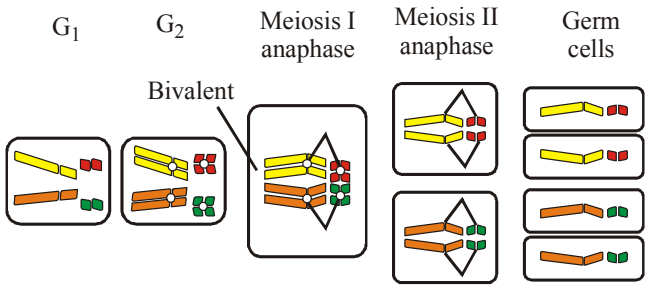


Figure : Meiosis and germ cell formation in a cell with four chromosomes.

During Anaphase of meiosis I, the two chromosome pairs can align at the metaphase plate independently of each other. To understand this, compare the chromosomes of four different colour in the left and right columns. In the left column (Possibility I) orange and green is segregating together. But in the right hand column (Possibility II) the orange chromosome is segregating with the red chromosomes.

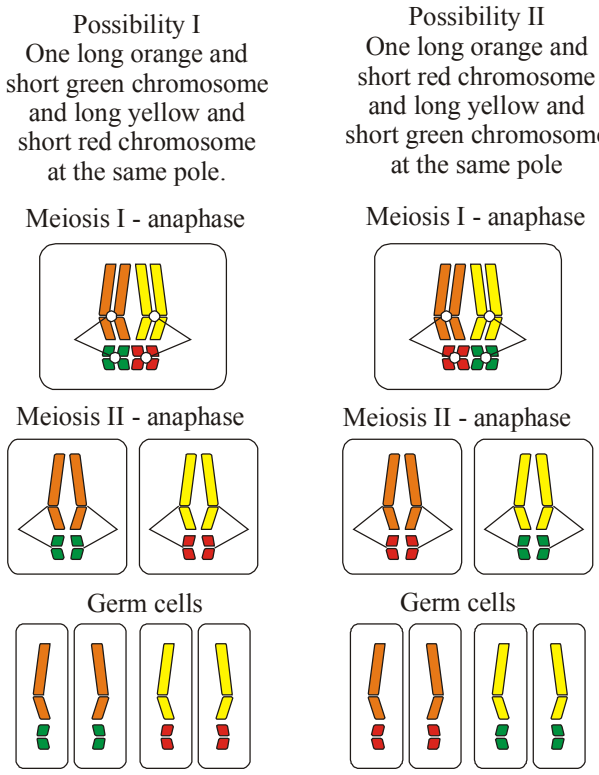


Figure : Independent assortment of chromosomes

5. A characteristic diploid number is again established by the union of the two haploid gametes.
6. Both chromosomes and the alleles (Mendelian factors) behave in accordance to Mendel's law of segregation.
7. Experimental verification of the chromosomal theory of inheritance by Thomas Hunt Morgan and his colleagues, led to discovering the basis for the variation that sexual reproduction produced. Morgan worked with the tiny fruit flies, Drosophila melanogaster, which were found very suitable for such studies. They could be grown on simple synthetic medium in the laboratory.

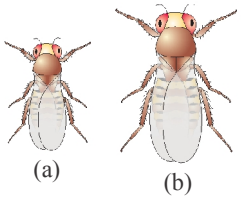


Figure : *Drosophila melanogaster* (a) Male (b) Female

They complete their life cycle in about two weeks, and a single mating could produce a large number

of progeny flies. Also, there was a clear differentiation of the sexes – the male and female flies are easily distinguishable. Also, it has many types of hereditary variations that can be seen with low power microscopes.

Salient features of chromosome theory:

* Both chromosomes as well as genes occur in pairs in the somatic or diploid cells.
* A gamete contains only one chromosome of a type and only one of the two alleles of a character.
* The paired condition of both chromosomes as well as Mendelian factor is restored during fertilization.

LINKAGE AND RECOMBINATION

* Collective inheritance of character is called linkage. Linkage first time seen by Bateson and Punnett in Lathyrus odoratus and gave coupling and repulsion phenomenon. But they did not explain the phenomenon of linkage.
* Sex linkage was first discovered by Morgan in Drosophila & coined the term linkage. He proposed the theory of linkage.
* Linkage and independent assortment can be represented in dihybrid plant.
* 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. Morgan attributed this due to the physical association or linkage of the two genes and coined the term **linkage** to describe this physical association of genes on a chromosome and the term **recombination** to describe the generation of non-parental gene combinations.
* Morgan and his group also found that even when genes were grouped on the same chromosome, some genes were very tightly linked (showed very low recombination) (Figure, Cross A) while others were loosely linked (showed higher recombination) (Figure, Cross B). For example he found that the genes white and yellow were very tightly linked and showed only 1.3 per cent recombination while white and miniature wing showed 37.2 per cent recombination.
* Alfred Sturtevant (Student of Morgan) used the frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome.

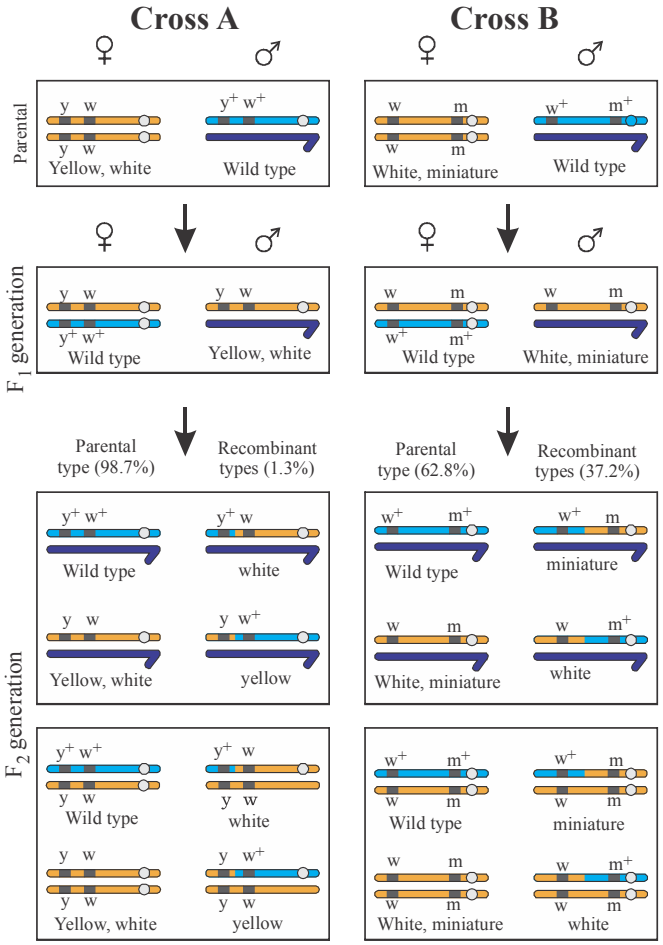


Figure : Linkage: Results of two dihybrid crosses conducted by Morgan. Cross A shows crossing between gene y and w; Cross B shows crossing between genes w and m. Here dominant wild type alleles are represented with (+) sign in superscript. Note:The strength of linkage between y&w is higher than w&m.

Theory of linkage :

1. Linked genes are linearly located on same chromosome. They get separated if exchange (crossing over) takes place between them.
2. **Strength of linkage** $\propto$ (1/distance) between the genes. It means, if the distance between two genes is increased then strength of linkage is reduced and it proves that greater is the distance

between genes, the greater is the probability of their crossing over.

Crossing over obviously disturbs or degenerates linkage. Linked genes can be separated by crossing over.

3. **Linkage group :** All the genes which are located on one pair of homologous chromosome form one linkage group. Genes which are located on homologous chromosomes are allelic so we consider one linkage group.

Linkage group = haploid no. of homologous chromosomes.

	2n	n	Pair	Linkage group
Pea	14	7	7	7
Maize	20	10	10	10
Drosophila	8	4	4	4
Barley	14	7	7	7
Mouse	42	21	21	21

Types of Linkage :

There are two types of linkage

1 **Complete linkage :** Linkage in which genes always show parental combination. It never forms new combination.

Crossing over is absent in it. Such genes are located very close on the chromosomes. Such type of linkage very rare in nature. e.g. male Drosophila, female silk moth.

2. **Incomplete linkage :** When new combinations also appear along with 'parental combination in offsprings, this type of linkage is called incomplete linkage, the new combinations form due to crossing over. The % of new combination is equal to the percentage of crossing over. (< 50%)

Application of Linkage :

Distance can be identified by the incomplete linkage. It's unit is centi Morgan.

Strength of linkage

$$\propto \frac{1}{\text{Distance b/w linked gene}} \propto \frac{1}{\text{Crossing Over}}$$

Genetic map/Linkage map/Chromosome map :

* In genetic map different genes are linearly arranged according to % of crossing over ($\propto$ Distance) between them.
* With the help of genetic map we can find out the position of a particular gene on chromosome. Genetic map is helpful in the study of genome.

SEX DETERMINATION

* Establishment of sex through differential development in an individual at an early stage of life, is called sex determination.
* Various methods operate in sex determination like environmental, non-allosomic genetic determination, allosomic sex determination and haplodiploidy.

Sex Determination on the basis of fertilization.

1. **Progamic -** Sex is determined before fertilization. eg. - drone in honey bee
2. **Syngamic -** Sex is determined during fertilization. eg. - most of plants & animals
3. **Epigamic -** Sex is determined after fertilization. eg. - Female in honey bee.

Allosomic determination of sex

* Allosome chromosomes are associated with sex determination. Term "Allosome" & "Heterosome" were given by Montgomery.
* Sex chromosomes first discovered by Mc Clung in grass hopper.
* X-Chromosome discovered by Henking and called x-body.
* Wilson & Stevens proposed cnromosomal theory for sex determination.

(1) XX - XY type or Lygaeus type : This type of sex determination first observed by Wilson & Stevens in Lygaeus insect.

(a) XX female and XY male : In this type of sex determination female is Homogametic i.e. produces only one type of gamete

2A + XX (Female) $\rightarrow$ Gametes :

(i) A + X (ii) A + X

Male is heterogametic (male produces two types of gamete)

2A + XY (Male) $\rightarrow$ Gametes :

(i) A + X (ii) A + Y

In male X-chromosome containing gametes is called **Gymnosperm** and Y-chromosome containing gamete is called **Androsperm.** eg. Man and dioecious plants like Coccinea, Melandrium.

(b) XY female and XX male or ZW female and ZZ male :

* In this type of sex determination female is Heterogametic i.e. produces two types of gamete and male individual is homogametic i.e produces one type of gamete.
* It is found in some insects like butterflies, moths and vertebrates like birds, fishes and reptiles.
* In plant kingdom this type of sex determination is found in Fragaria elatior.

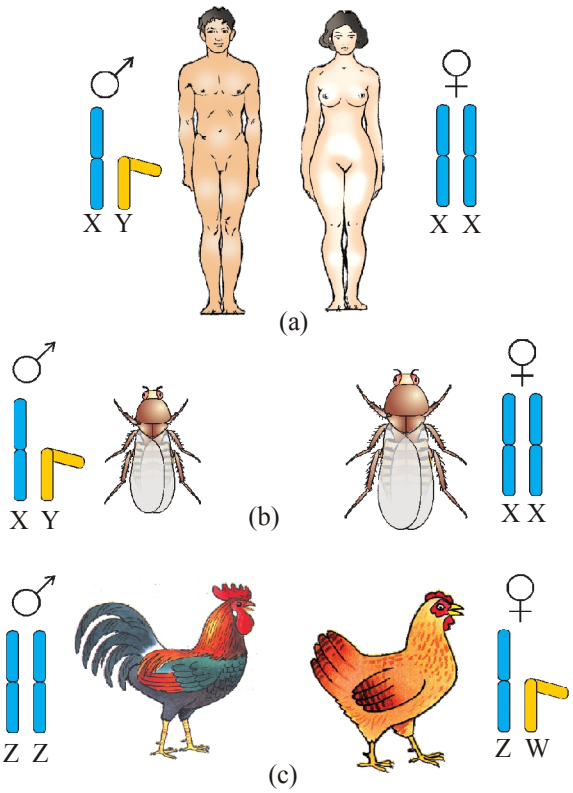


Figure : Determination of sex by chromosomal differences: (a,b) Both in humans andin Drosophila, the female has a pair of XX chromosomes (homogametic) and the male XY (heterogametic) composition; (c) In many birds, female has a pair of dissimilar chromosomes ZW and male two similar ZZ chromosomes

(2) XX female and XO male or Protenor type :

In this type of sex determination deficiency of one chromosome in male. In this type, female is homogametic and male is heterogametic.

Female (2A + XX) :

(i) A + X (ii) A + X (homogametic)

Male (2A + XO) :

(i) A + O (ii) A + X (heterogametic)

Example : * Grass hopper * Sqash bug Anasa * Cockroach, * Ascaris and in plants like - Dioscorea sinuta & Vallisneria spiralis.

Sex determination in Honey bee (Haploid - diploid mechanism) :

* In insects of order Hymenoptera which includes ants, honey bees, wasps etc.
* Sex determination takes place by sets of chromosomes.
  Diploid (two sets) → Female ; Haploid (One set) → Male
* In honey bee male individual (Drone) develops from unfertilized eggs (Haploid).
* Male is always parthenote.
* Queen and worker bees develop from diploid eggs i.e. fertilized egg.
  Fertilized egg → Diploid larva -
  (i) Feed on Royal jelly : Queen (Fertile female)
  (ii) Bee bread : Worker (Sterile female)

Genic balance theory :

* C.B. Bridges proposed genic balance theory for sex determination in Drosophila.
* According to Bridges in Drosophila Y-chromosome is heterochromatic so it is not active in sex determination.
* In Drosophila sex determination takes place by sex index ratio.

$$\text{Sex index ratio} = \frac{\text{No. of x chromosomes}}{\text{No. of set of Autosomes}} = \frac{X}{A}$$

* In Drosophila gene of femaleness (Sxl- gene) (Sxl = Sex lethal gene) is located on x-chromosome and gene of maleness is located on autosome.
* Gene of male fertility is located on y-chromosome and in Drosophila, y-chromosome plays additional role in spermatogenesis and development of male reproductive organ, so y-chromosome is essential for the production of fertile male.

Sex index ratio

(a) $\frac{X}{A} = 1 \rightarrow$ female (2A + XX), (3A + XXX)

(b) $\frac{X}{A} = 0.5 \rightarrow$ male (i) (2A + XY) = Fertile male

(ii) (2A + XO) = Sterile male

(c) $\frac{X}{A} = 1.5 \rightarrow$ Super female or meta female (Sterile) (2A + XXX)

(d) $\frac{X}{A}$ = less than $0.5 \rightarrow$ Super male or meta male (Sterile) (3A+XY)

(e) $\frac{X}{A}$ = In between 0.5 and 1 $\rightarrow$ Intersex (Sterile) (3A+XX)

Cytological basis of sex determination :

* Barr body technique or Lyon's hypothesis.
* Interphasic nucleus of human female contains two X-chromosomes. Out of two, one X-chromosome becomes heterochromatin and other X-chromosome is euchromatin.
* By staining X-heterochromatin, it appears as a dense body which is called **Barr body**. (Facultative heterochromatin)
* No. of Barr body $\Rightarrow$ (No. of X chromosomes – 1)
  So in a Normal female (2A + XX) $\rightarrow$ One Barr body.
* Normal male (2A + XY) $\rightarrow$ Barr body absent .
* Turner syndrome (Sterile female) (2A + XO) $\rightarrow$ No. Barr body
* Kinefelter syndrome (Sterile male)(2A+XXY)$\rightarrow$ One Barr body.
* Drum stick which occurs in blood of female of mammals, is also a type of barr body. Drum stick is absent in neutrophils of male.

Sex determination in human :

* The sex determining mechanism in case of humans is XY type. 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 per cent 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 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 that determines the sex of the child.
* It is also evident that in each pregnancy there is always 50 per cent probability of either a male or a female child.

Sex determination in plant

* H.E. Warmke discovered sex determination in Melandrium plant.
* In Melandrium Y-chromosome is long as compareto X- chromosome.
* In plant sex chromosomes are found only in unisexual plant.
  Pro. R.P. Roy gave the importance of Y-chromosome in plant.
* He discovered sex determination in Coccinea indica (Family- cucurbitaceae)
* Y-chromosome contains four region and X-chromosome contains two regions.

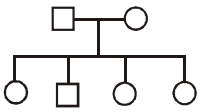
MUTATION

* Mutation is a phenomenon which results in alteration of DNA sequences and consequently results in changes in the genotype and the phenotype of an organism. In addition to recombination, mutation is another phenomenon that leads to variation in DNA.
* One DNA helix runs continuously from one end to the other in each chromatid, in a highly supercoiled form. Therefore loss (deletions) or gain (insertion/duplication) of a segment of DNA, result in alteration in chromosomes. Since genes are known to be located on chromosomes, alteration in chromosomes results in abnormalities or aberrations. Chromosomal aberrations are commonly observed in cancer cells.

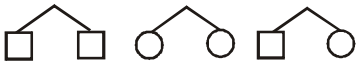
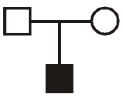
* Mutation also arise due to change in a single base pair of DNA. This is known as **point mutation**. A classical example of such a mutation is sickle cell anemia.
* Deletions and insertions of base pairs of DNA, causes **frame-shift mutations.**
* There are many chemical and physical factors that induce mutations. These are referred to as mutagens. UV radiations can cause mutations in organisms – it is a mutagen.

GENETIC DISORDERS

Pedigree Analysis :

* Study of ancestoral history of man of transmission of genetic characters from one generation to next, is pedigree analysis.
* Dwarfism, albinism, colour blindness, haemophilia etc. are genetically transmitted characters.
* To study and analyse them a pedigree of genetic facts/data and following symbols are used.
* **Symbol used in Pedigree:**
  1. □ - Normal Male
  2. ○ - Normal Female
  3. □—○ - Mating (marriage)
* Usual practice is to place the males first, on the left if one parent is not shown in a pedigree, it indicates that this individual was phenotypically normal.
  4. 
* The siblings are indicated in chronological order of birth
  5. ◇ Sex unspecified
  6. Twin

     If monozygotic 

     If dizygotic 
  7. ● ■ Affected male and female individual
  8. ◧ ◐ Heterozygous for autosomal recessive
  9. ⊙ Carrier female of sex linked recessive character or disease
  10. ⊠ ∅ Death of individual
  11. | Abortion or still birth (sex unspecified)
  12. □—○ Consanguineous marriage
  13.  Parent with male child affected with disease
  14. ◇5 Five unaffected offsprings
* Pedigree analysis provides valuable informations regarding genetical make up of human beings.
* If any genetic disease is occurring in a family, then pedigree analysis provides guidance to forthcoming parents about their future progenies for example- polydactyly in humans.
* **Human Karyotype :** Humans have 23 pairs (46) chromosomes. In this method, the chromosomes (autosomes and sex chromosomes) are arranged according to their size and structure. Based on the position of centromere and relative lengths of both arms of chromosome, three types of chromosomes are found in human-metacentric, submetacentric and acrocentire. Karyotype helps to know the relative structures (morphology) of chromosomes. Besides, it helps in chromosomal identification and it's nomenclature. It is also used in studying chromosomal abnormalities.

Mendelian Disorders :

* Broadly, genetic disorders may be grouped into two categories–Mendelian disorders & Chromosomal disorders.
* Mendelian disorders are mainly determined by alteration or mutation in the single gene. These disorders are transmitted to the offspring on the same lines as we have studied in the principle of inheritance. The pattern of inheritance of such Mendelian disorders can be traced in a family by the pedigree analysis. Most common and prevalent Mendelian disorders are Haemophilia, Cystic fibrosis, Sickle-cell anaemia, Colour blindness, Phenylketonuria, Thalassemia, etc.
* Mendelian disorders may be dominant or recessive. By pedigree analysis one can easily understand whether the trait in question is dominant or recessive.

* The trait may also be linked to the sex chromosome as in case of haemophilia. It is evident that this X-linked recessive trait shows transmission from carrier female to male progeny.

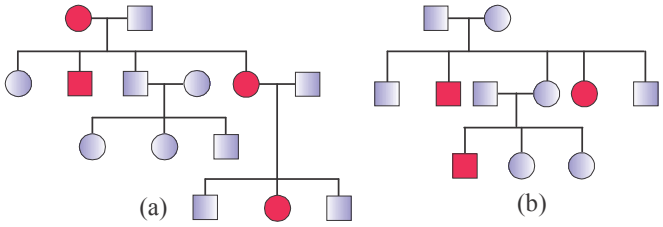


Figure : Representative pedigree analysis of (a) Autosomal dominant trait (for example: Myotonic dystrophy) (b) Autosomal recessive trait (Sickle-cell anaemia)

(a) Haemophilia :

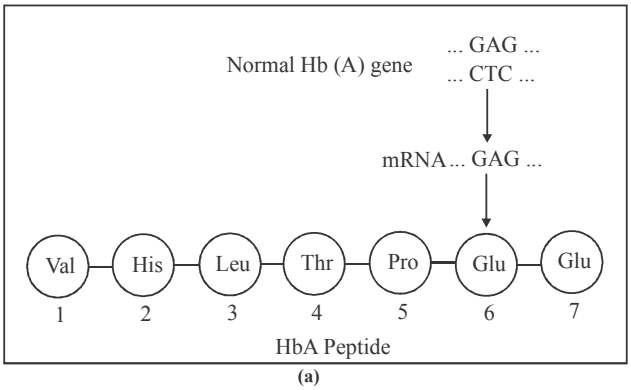
* This sex linked recessive disease, which shows its transmission from unaffected carrier female to some of the male progeny has been widely studied.
* First discovered by John Otto (1803).
* In this disease, a single protein that is a part of the cascade of proteins involved in the clotting of blood is affected. Due to this, in an affected individual a simple cut will result in non-stop bleeding.
* The heterozygous female (carrier) for haemophilia may transmit the disease to sons. The possibility of a female becoming a haemophilic is extremely rare because mother of such a female has to be at least carrier and the father should be haemophilic (unviable in the later stage of life).
* The family pedigree of Queen Victoria shows a number of haemophilic descendents as she was a carrier of the disease.
* Haemophilia -A → due to lack of factor -VIII (Antihaemophilic globulin AHG)
* Haemophilia B or Christmas disease - due to lack of factor-IX (Plasma thromboplastin component)
* Haemophilia - C → due to lack of factor - XI (Plasma Thromboplastin antecedent)

(b) Cystic fibrosis :

* Hereditary metabolic disorder that is controlled by a single autosomal recessive gene.
* The gene specifies an enzyme that produces a unique glycoprotein. This glycoprotein results in the production of mucous.
* More mucous interfere with the normal functioning of several exocrine glands including those in the skin, lungs, liver and pancreas.

(c) Sickle-cell anaemia :

* This is an autosome linked recessive trait that can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous).
* The disease is controlled by a single pair of allele, Hb^A and Hb^S. Out of the three possible genotypes only homozygous individuals for Hb^S (Hb^SHb^S) show the diseased phenotype.
* Heterozygous (Hb^AHb^S) individuals appear apparently unaffected but they are carrier of the disease as there is 50 per cent probability of transmission of the mutant gene to the progeny, thus exhibiting sickle-cell trait (Figure).
* The defect is caused by the substitution of Glutamic acid (Glu) by Valine (Val) at the sixth position of the beta globin chain of the haemoglobin molecule.
* The substitution of amino acid in the globin protein results due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG.
* The mutant haemoglobin molecule undergoes polymerisation under low oxygen tension causing the change in the shape of the RBC from biconcave disc to elongated sickle like structure (Figure).



(a)

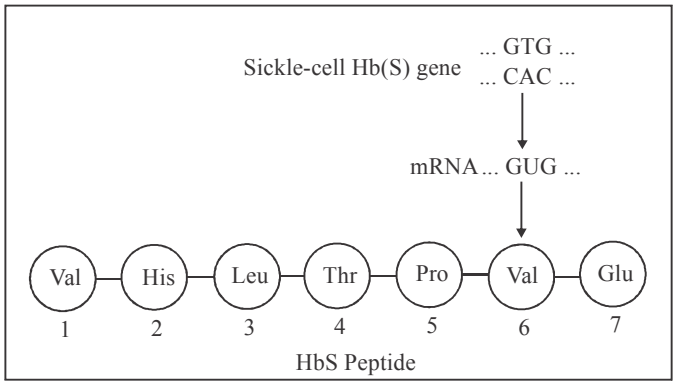


Figure : Micrograph of the red blood cells and the amino acid composition of the relevant portion of β-chain of haemoglobin: (a) From a normal individual; (b) From an individual with sickle-cell anaemia

(d) Phenylketonuria :

* This inborn error of metabolism is also inherited as the autosomal recessive trait.
* The affected individual lacks an enzyme that converts the amino acid phenylalanine into tyrosine. As a result of this phenylalanine is accumulated and converted into phenylpyruvic acid and other derivatives. Accumulation of these in brain results in mental retardation. These are also excreted through urine because of its poor absorption by kidney.
* **Table : Mendelian disorders**

S.N.	Disorder	Dominant / Recessive	Autosomal / Sex linked
1.	Haemophilia	Recessive	X-linked
2.	Colour blindness	Recessive	X-linked
3.	Sickle cell anaemeia	Recessive	Autosomal
4.	Phenylketo-nuria	Recessive	Autosomal
5.	Cystic fibrosis	Recessive	Autosomal
6.	Thalassemia	Recessive	Autosomal
7.	Myotonic dystrophy	Dominant	Autosomal

Chromosomal disorders:

* Caused due to absence or excess or abnormal arrangement of one or more chromosome.
* Failure of segregation of chromatids during cell division cycle results in the gain or loss of chromosome(s), called **Aneuploidy.**
* Failure of cytokinesis after telophase stage of cell division results in an increase in a whole set of chromosome in an organism and this phenomenon is called **polyploidy.**
* **Trisomy:** additional copy of a chromosome may be included in an individual (2n+1).
* **Monosomy:** an individual may lack one of any one pair of chromosomes (2n-1)

Down syndrome:

* It was first described by Langdon Down (1866).
* It is due to trisomy of 21st chromosome, arising from non-disjunction.
* As the maternal age increases, the instances of nondisjunction increase.
* When such an ovum containing two 21st chromosomes (24) is fertilized by a normal sperm (23), the zygote (47) comes to possess three copies of 21st chromosome.
* **Symptoms:** Short statured with small round mouth, palm is broad with characteristic palm crease, physical, psychomotor and mental development is retarded.

Klinefelter's syndrome:

* It arises due to non-disjunction of X-chromosomes during ova formation. When an ovum containing two X-chromosomes is fertilized by a Y-carrying sperm, XXY individual (47) appears.(karyotype)
* **Symptoms:** A male with underdeveloped breasts (gynaecomastia), sparse body hair, mentally retarded and sterile.

Turner's syndrome:

* It arises due to non-disjunction of X-chromosomes(45 with XO) during ova formation.
* When an ovum carrying no X-chromosome is fertilized by a sperm carrying X- chromosome, a zygote with XO appears.
* **Symptoms:** A female with rudimentary ovaries, short stature, lack of secondary sexual characters, they are sterile.

CONCEPT REVIEW

* **Mendelian Inheritance** (Mendelism)

(i) Mendel proposed that something was being stably passed down, unchanged, from parent to offspring through the gametes, over successive generations. He called these things as 'factors'.

(ii) The dominant characters are expressed when factors are in heterozygous condition (Law of Dominance).

(iii) The characters never blend in heterozygous condition.

(iv) The recessive characters are only expressed in homozygous condition.

(v) A recessive trait that was not expressed in heterozygous condition may express again when it become homozygous. Hence, characters segregate while formation of gametes (Law of Segregation).

(vi) Mendel also studied the inheritance of two characters together and he found that the factors independently assort and combine in all permutations and combinations (Law of Independent Assortment).

* The factors on chromosomes regulating the characters are called the **genotype** and the physical expression of the characters is called **phenotype.**
* Genes which code for a pair of contrasting traits are known as alleles.
* A cross between F_1 hybrid (Tt) and its homozygous recessive parent (tt) is called test cross.
* If F_1 phenotype does not resemble either of the two parents and is in between the two, it is called incomplete dominance.
* Presence of more than two alleles for a gene is known as **multiple allelism.**
* If F_1 phenotype resembles both of the parents, it is called **co-dominance.**
* If more than one phenotype is influenced by the same gene, it is called **pleiotropy.**
* If two genes present on different loci produce the same effect when present alone but interact to form a new trait when present together, they are called **complementary genes.**
* A gene which masks the action of another gene (non-allelic) is termed as epistatic gene. The process is called **epistasis.**
* Walter Sutton and Theodore Boveri noted that the behaviour of chromosomes was parallel to the behaviour of genes and used chromosome movement to explain Mendel's laws.
* Mendel's law of independent assortment is not true for the genes that were located on the same chromosomes *(i. e.,* **linked genes).**
* Closely located genes assorted together, and distantly located genes, due to recombination, assorted independently.
* **Frequency of recombination** between gene pairs on the same chromosome is a measure of the distance between genes.
* Polygenic inheritance is controlled by 2 or more genes in which the dominant alleles have cumulative effect, with each dominant allele expressing a part of functional phenotype and full trait is shown when all the dominant alleles are present.
* The tendency of some of the genes to inherit together is called as **linkage.**
* Sex-limited traits are autosomal and found in both sexes but expressed in one sex only.
* Sex-influenced traits are autosomal and appear more frequently in one sex than in the other.
* **Mutation** is defined as change in the genetic material. A **point mutation** is a change of a single base pair in DNA. Some mutations involve changes in whole set of chromosomes (polyploidy) or change in a subset of chromosome number (aneuploidy).
* Failure of segregation of chromatids during cell division cycle results in the gain or loss of a chromosome(s), called **aneuploidy.**
* Failure of cytokinesis after telophase stage of cell division results in an increase in a whole set of chromosomes in an organism and, this phenomenon is known as **polyploidy.**
* Sickle-cell anaemia is caused due to change of one base in the gene coding for beta-chain of haemoglobin.
* Inheritable mutations can be studied by generating a **pedigree** of a family.

* **Down's syndrome** is due to trisomy of chromosome 21. In **Turner's syndrome,** one X-chromosome is missing and the sex chromosome is as XO.
* In **Klinefelter's syndrome,** the condition is XXY.
* **Formula chart**

1. Types of gametes = 2^n

2. Number of zygotes / offsprings = $(\text{Gametes})^n$

3. Number of phenotype = 2^n

4. Number of genotype = 3^n

where n = Number of traits / hybrid (n)

5. Number of genotypes for multiple allelism

$= \frac{n}{2}(n+1)$, here n = Number of alleles

6. Recombination frequency or cross over value

$= \frac{\text{Number of recombinant}}{\text{Total number of offsprings}} \times 100$

IMPORTANT POINTS

* Principles of segregation and independent assortment can be explained on the basis of chromosomal theory of Inheritance.
* It is the chromosomes that undergo segregation and independent assortment at the time of gamete formation i.e., meiosis.
* The position of a gene on the chromosome, is called a locus.
* Tall red flowered pea plant crossed to dwarf white flowered plant yields only tall red flowered plants. A test cross shall give a ratio of 1 : 1 : 1 : 1.
* In a genetic cross having recessive epistasis, F_2 phenotypic ratio would be 9 : 3 : 4.
* Segregation of Mendelian factors (no linkage, no crossing over) occurs during Anaphase I.
* A polygenic inheritance in human beings is skin colour.
* Different form of a gene are called Alleles.
* Phenotypic dihybrid ratio is 9 : 3 : 3 : 1.
* Phenomenon of an allele of one gene suppressing the activity of allele of another gene is called epistasis.
* Mendel's law of independent assortment is based on F_2 ratio of 9 : 3 : 3 : 1.
* Mendel's laws of heredity can be explained with the help of meiosis.
* Incomplete dominance is found in *Antirrhinum/ Mirabilis*.
* Out of two alleles of the same gene, one finds morphological expression. The phenomenon is dominance.
* Sickle cell anaemia is autosomal heritable disease.
* Alleles are alternate forms of a gene.
* Epistasis is an interaction of genes.
* Independent assortment can be deduced from dihybrid cross.
* The number of phenotypes in ABO blood groups is 4.
* Independent assortment = Segregation of factors.
* Multiple phenotype is seen in polygenic inheritance.
* Ovum producing Klinefilter's syndrome shall have chromosome number 24.
* XO and XXX is responsible for mental abnormalities in humans.
* Linkage in plants was first shown in *Lathyrus odoratus*.
* Genes for colour blindness / sex linked traits are located on X-chromosome.
* One barr body is found in man of genotype XXY.
* Klinefilter's syndrom has 44 + XXY.
* Autosomes in humans are 22 pairs.
* Linkage was discovered by Morgan.
* The substance which causes a definite change in genes is called mutagen.
* A mutation results in change in sequence of amino acids in a protein.
* Haemophilia is a genetic disorder in which there is delayed coagulation of blood.
* Down's syndrome is due to trisomy of 21st chromosome caused by nondisjunction either during egg formation or sperm formation.
* Down' syndrome = Presence of an extra chromosome.
  Klinefilter's syndrome = An additional sex chromosome.
  Turner's syndrome = Absence of sex chromosome.
* Strength of linkage is related inversely to distance between genes.

* Christmas disease is another name of haemophilia B. The Christmas disease patient lacks antihaemophilic Factor IX.
* Crossing over results in recombination between linked genes.
* Tay Sach's disease is due to autosomal recessive gene.
* Number of linkage groups in *Escherichia coli* is 1.
* Clotting factor VIII is absent in haemophilia A.
* Monoploidy = n Monosomy = 2n – 1
  Nullisomy = 2n – 2 Trisomy = 2n + 1
  Tetrasomy = 2n + 2
* XX – XO type of sex determination is found in grasshopper.
* 44 + XYY chromosome condition is Jacob syndrome.
* Dr. Karl Landsteiner got Nobel Prize in. 1930 , for discovery of blood groups.
* If one parent has AB blood group (I^AI^B) and other parent is with O blood group (i i) then none of their offspring can have blood groups of any parent i.e., AB and O.
* If both parents are with blood group A and any of their offspring has blood group O, it means both parents are heterozygous (I^Ai).
* If one parent has AB blood group (I^AI^B) then none of their offspring can have O blood group.
* If one parent has O blood group (i i) then none of their offspring can have AB blood group.
* Human Y-chromosome was discovered by Painter in 1923.
* X-chromosome is submetacentric.
* Y chromosome is one of the smallest chromosomes; it is acrocenbic and included in group 'G' of autosome.
* For X linked character (colour blindness and haemophilia) a man will be either normal or show the trait (colourblind)
* Albinism is a hereditary disease.
* In sickle-cell anaemia glutamic acid (glutamine) is replaced by valine at the sixth position in P chain of haemoglobin.
* Thalassemia is due to an autosomal mutant gene.

* **Table : Major Milestones in Genetics**

Year	Scientific Advance
1866	Mendel proposed existence of hereditary factors now known as genes
1869	Nucleic acids discovered
1953	Structure of DNA determined
1960s	Genetic code explained (how proteins are made from DNA)
1977	DNA sequencing began
1986	DNA sequencing automated
1995	Sequencing of first genome (bacterium *Haemophilus influenzae)* completed
1996	Sequencing of first eukaryotic genome (yeast *Saccharomyces cerevisiae)* completed
1998	Sequencing of first multicellular eukaryotic genome (nematode worm *Caenorhabditls elegans)* completed
2001	Draft sequence of entire human genome published
2003	Final completion of DNAsequencing of human genome

* **Table : Chromosome Abnormalities: Disorders Produced by Aneuploidie**

Karyotype	Common Name	Clinical Description
Trisomy 13	Patau syndrome	Multiple defects, with death typically by age 3 months.
Trisomy 18	Edwards syndrome	Ear deformities, heart defects, spasticity, and other damage; death typically by age I year, but some survive much longer.
Trisomy 21	Down syndrome	Overall frequency is about 1 in 800 live births. True trisomy is most often found among children of older (age 35+) mothers, but translocation resulting in the equivalent of trisomy is not age-related. Trisomy 21 is characterized by a fold of skin above the eye, varying degrees of mental retardation, short stature, protruding furrowed tongue, transverse palmar crease, cardiac deformities, and increased risk of leukemia and Alzheimer's disease.
XO	Turner syndrome	Short stature, webbed neck, sometimes slight mental retardation; ovaries degenerate in late embryonic life, leading to rudimentary sexual characteristics; gender is female; no Barr bodies.
XXY	Klinefelter syndrome	Male with slowly degenerating testes, enlarged breasts; one Barr body per cell.
XYY	XYY karotype	Many males have no unusual symptoms; others are unusually tall, with heavy acne, and some tendency to mild mental retardation.
XXX	Triplo-X	Despite three X chromosomes, usually fertile females with normal intelligence; two Barr bodies per cell.

* Monohybrid cross
  Phenotypic ratio = 3 : 1
  Genotypic ratio = 1 : 2 : 1
  Test cross ratio = 1: 1
* Dihybrid cross
  Phenotypic ratio = 9 : 3 : 3 : 1
  Genotypic ratio = 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
  Test cross ratio = 1 : 1 : 1 : 1
* Complementary gene = 9 : 7
  Dominant epistasis = 12 : 3 : 1
  Recessive epistasis = 9 : 3 : 4
* Coupling = 7 : 1 : 1 : 7
  Repulsion = 1 : 7 : 7 : 1
* Incomplete dominance (Monohybrid cross)
  Phenotypic ratio = 1 : 2 : 1
  Genotypic ratio = 1 : 2 : 1
* Co-dominance (Monohybrid cross)
  Phenotypic ratio = 1 : 2 : 1
  Genotypic ratio = 1 : 2 : 1
* Trihybrid phenotypic ratio
  = 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1
* Modified ratio of lethal gene in monohybrid cross
  = 2 : 1
* Polygenic inheritance
  1 : 4 : 6 : 4 : 1 (For two gene)
  1 : 6 : 15 : 20 : 15 : 6 : 1 (For three gene)
* Type of phenotype in polygenic intheritance
  = (2n + 1)
* Contribution of each dominant allele

$$= \frac{\text{Maximum expression} - \text{Minimum expression}}{\text{Total number of dominant allele}}$$

* **Different systems based on chromosomal mechanism of sex-determination can be summarised as:**

Type	System	Gametes		Zygotes	
		Sperms	Eggs	Males	Females
Male heterogametic	XO ♂ e.g., Grasshopper	A + X (50%) A + O (50%)	A + X (100%)	AA + XO	AA + XX
	XY ♂ e.g., *Drosophila, Homo sapiens* (Humans)	A + X (50%) A + Y (50%)	A + X (100%)	AA + XY	AA + XX
Female heterogametic	ZW ♀ e.g., Birds	A + X (100%)	A + Z (50%) A + W (50%)	AA + ZZ	AA + ZW
	ZO ♀ eg, Butterflies	A + X (100%)	A + Z (50%) A + O (50%)	AA + ZZ	AA + ZO

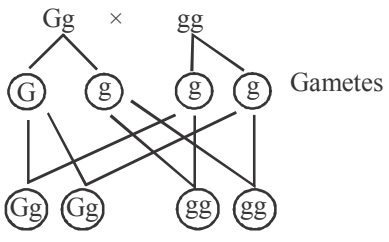
EXAMPLES

Example 1 :

In *Pisum sativum*, the pods may be green (G) or yellow (g). What proportion of the offspring in the following crosses would be expected to be homozygous green?

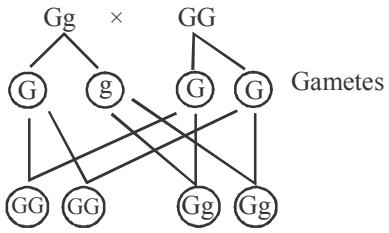
(i) Gg × gg (ii) Gg × GG

Sol. (i)



∴ GG = 0%

(ii)



$\therefore$ GG = $\frac{2}{4}$ = 50%

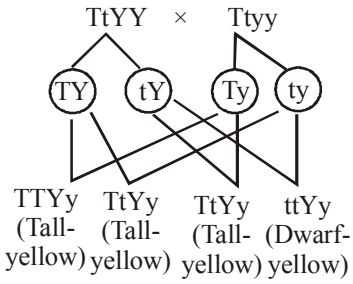
Example 2 :

In a cross between two pea plants with genotypes Tt YY (tall plant with yellow seeds) and Ttyy (tall plants with green seeds), what proportion of the offsprings could be expected to be :

(i) Tall and yellow

(ii) Dwarf and green

Sol.

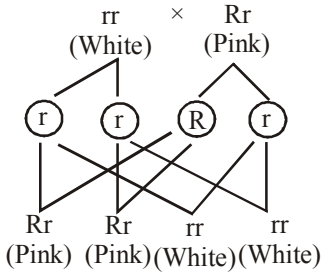


$\therefore \frac{3}{4} = 75\%$

Example 3 :

When a cross is made between white and pink flowered *Antirrhinum* plants, what phenotypic ratio is obtained in the resulting generation?

Sol.



$\therefore$ Phenotypic ratio = 2 : 2

Example 4 :

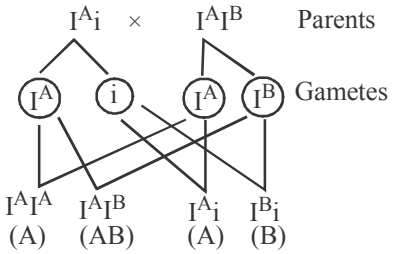
(i) Human beings have three alleles for ABO blood grouping; I^A, I^B and I^O. How many of these alleles will be present in one individual and a gamete?

(ii) A child has blood group B. If the mother has blood group AB and father blood group A, workout the genotypes of the parents and the possible genotypes of the other offsprings.

Sol. (i) Individual (diploid), $\therefore$ 2 alleles

Gamete (haploid), $\therefore$ 1 allele

(ii) A child can have blood group B if he or she has genotype I^BI^Bor I^Bi. For this the father with blood group A must be heterozygous (I^Ai). Mother has AB blood group, therefore she will have genotype I^AI^B.



i.e., other offspring can have A or AB blood groups.

Example 5 :

Calculate the sum total of phenotypes and genotypes in F_2 generation if a character is controlled by 2 pair of polygenes.

Sol. Number of phenotype for polygenes

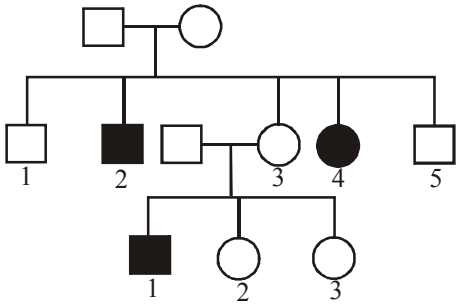
$= 2n + 1 = 2 \times 2 + 1 = 5$

Number of genotype for polygenes = 3^n

$\therefore \quad 3^2 = 9$ i.e., 5 + 9 = 14

Example 6 :

Study the given pedigree chart and answer the questions that follow :



(i) Trait is autosomal recessive (True/False).

(ii) Give the genotype of the members 3 and 4.

Sol. (i) True (e.g., sickle cell anaemia)

(ii) 3 → Aa, 4 → aa

Example 7 :

In a cross between a yellow and a green seeded pea plants, all F_1 members are yellow. But F_2 generation raised by crossing two such F_1 consists of approximately 75% yellow and 25% green seeded pea plants. (i) What will be the offspring be like if two F_2 greens are mated? (ii) What will be genotypic ratio in the population of yellow-seeded plants in F_2 generation?

Sol. It is monohybrid cross.

YY × yy

↓

Yy F_1 generation

↓ Selfing

Yellow [YY, Yy, Yy] Green [yy] F_2 generation

(i) yy × yy

↓

yy

i.e., All green-seeded pea plants are obtained.

(ii) Genotypes of yellow-seeded pea Plants

YY = 1

Yy = 2

∴ Genotypic ratio = 1 : 2

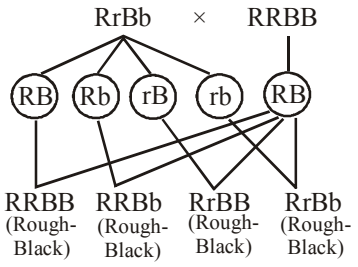
Example 8 :

In an animal, assume that rough coat (R) is dominant over smooth coat (r) and the black (B) is dominant over white (b). Consider that these two pairs of alleles assort independently then

(i) What proportion of the offspring from the cross RrBb × RRBB would be rough and black?

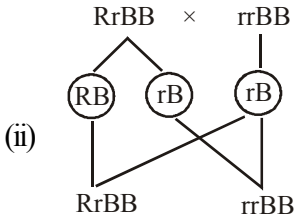
(ii) From the cross RrBB × rrBB, how many progeny will be homozygous for both of the characters?

Sol. (i)



∴ 100% offspring will be rough-black.

(ii)

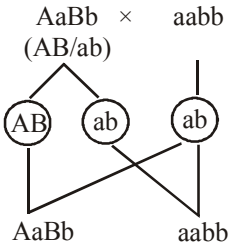


∴ Progeny with homozygous for both of the characters (rrBB) = 1/2 = 50%

Example 9 :

Two heterozygous parents (AaBb) are crossed. If the two loci are completely linked (AB/ab), what would be the distribution of phenotypic features in resulting generation of test cross?

Sol. If two loci are linked (i.e., genes are located closely on the same chromosome), there would be no segregation of alleles/traits due to absence of crossing over.



∴ Phenotypic ratio = 1 : 1

QUESTION BANK

EXERCISE - 1 (LEVEL-1) [NCERT EXTRACT]

SECTION - 1 (VOCABULARY BUILDER)

Choose one correct response for each question.
For Q.1-Q.5
Match the column I with column II.

Q.1 Match the following columns.

	Column I	Column II
a.	Monohybrid cross	i. T and t
b.	Test cross	ii. TT
c.	Alleles	iii. Tt × Tt
d.	Homozygous tall	iv. tt
		v. Tt × tt

Codes
(A) (a) – (iii), (b) – (v), (c) – (iv), (d) – (ii)
(B) (a) – (v), (b) – (iii), (c) – (ii), (d) – (iv)
(C) (a) – (iii), (b) – (v), (c) – (i), (d) – (ii)
(D) (a) – (iii), (b) – (i), (c) – (v), (d) – (ii)

Q.2 Match the following columns.

	Column I	Column II
a.	Autosomal linked recessive trait	i. Down's syndrome
b.	Sex linked recessive disease	ii. Phenylketonuria
c.	Metabolic error linked to autosomal recessive trait	iii. Haemophilia
d.	Additional 21st chromosome	iv. Sickle-cell anaemia

Codes
(A) (a) – (iv), (b) – (i), (c) – (ii), (d) – (iii)
(B) (a) – (iv), (b) – (iii), (c) – (ii), (d) – (i)
(C) (a) – (ii), (b) – (i), (c) – (iv), (d) – (iii)
(D) (a) – (iii), (b) – (iv), (c) – (i), (d) – (ii)

Q.3 Match the following columns.

	Column I	Column II
a.	Linkage	i. Recombination of genes
b.	Mutation	ii. More than two set of chromosomes
c.	Crossing over	iii. Morgan
d.	Polyploidy	iv. de Vries

Codes
(A) (a) – (iii), (b) – (iv), (c) – (i), (d) – (ii)
(B) (a) – (i), (b) – (ii), (c) – (iii), (d) – (iv)
(C) (a) – (iv), (b) – (iii), (c) – (i), (d) – (ii)
(D) (a) – (i), (b) – (ii), (c) – (iv), (d) – (iii)

Q.4 Match the following columns.

	Column I	Column II
a.	XX-XO method of sex determination	i . Female heterogametic
b.	1.5 X/A ratio	ii. Tumer's syndrome
c.	Karyotype 45	iii. Hemiptera
d.	ZW-ZZ method of sex determination	iv. Meta female

Codes
(A) (a) – (ii), (b) – (iv), (c) – (i), (d) – (iii)
(B) (a) – (iii), (b) – (iv), (c) – (ii), (d) – (i)
(C) (a) – (iv), (b) – (i), (c) – (ii), (d) – (iii)
(D) (a) – (i), (b) – (iv), (c) – (ii), (d) – (iii)

Q.5 Match the following columns.

	Column I	Column II
a.	Sickle-cell anaemia	i. Sex-linked
b.	Colour blindness	ii. Autosomal chromosome-7
c.	Phenylketonuria	iii. Autosomal chromosome-11
d.	Cystic fibrosis	iv. Autosomal chromosome-4
e.	Huntington's disease	v. Autosomal chromosome-12

Codes
(A) (a)-(i), (b)-(ii), (c)-(iii), (d)-(iv), (e)-(v)
(B) (a)-(iii), (b)-(v), (c)-(i), (d)-(ii), (e)-(iv)
(C) (a)-(ii), (b)-(i), (c)-(v), (d)-(iii), (e)-(iv)
(D) (a)-(iii), (b)-(i), (c)-(v), (d)-(ii), (e)-(iv)

SECTION - 2 (BASIC CONCEPTS BUILDER)

For Q.6 to Q.44 :

Choose one word for the given statement from the list.

Frame-shift mutations, heterozygous, Genes, Back cross, Homozygous, GAG, GUG, Low oxygen, Sickle cell anaemia, less; more, 1, 2, 9, Female, Male, Large, one, Meiosis; Variation, Segregate, Large, Low, Sex chromosomes

Q.6 Unit of inheritance that required to express a particular trait of organism is called _____.

Q.7 If the genotype of an individual consists of only one type of genes at same locus. It is called ___

Q.8 Deletions and insertions of base pair of DNA, causes _____.

Q.9 A classical example of point mutation is _____.

Q.10 The crossing of F_1 to any one of the parents is called _____.

Q.11 Frequency of crossing over is ____ in linked gene ____ in unlinked gene.

Q.12 The substitution of amino acid in the globin protein results due to the single base substitution at the 6^{th} codon of the β-globin gene from ___ to ___. The mutant haemoglonbin molecule undergoes polymerisation under ____ tension causing the change in the shape of the RBC from biconcave disc to elongated sickle-like structure.

Q.13 The recessive parental trait is expressed without any blending in the F_2-generation, we can infer. That F_1-plant produce gamete by the process of ____ and allele of parental pair separate ___ from each other and only one gamete is transmitted a gamete.

Q.14 In chicks, ____ individual produces two different types of gametes.

Q.15 In butterflies, all ___ gametes contain autosomes as well as sex chromosome.

Q.16 Types of gametes possible from a diploid organism having genotype AaBBCC is ____.

Q.17 _____ gene produces all gametes that are similar, while a _____ produces two kinds of gametes each having one allele with equal proportion.

For Q.18-Q.20

Fill in the blanks (w.r.t. experimental material used by Morgan)

Q.18 Females are easily distinguishable from the male by the _____ body size.

Q.19 It has many types of hereditary variations that can be seen with _____ power microscope.

Q.20 Male individuals have heteromorphic _____.

Q.21 ____ is the degree by which progeny differs from their parents.

Q.22 *Pisum sativum* produces a _____ number of offspring and completes its life cycle in ____ season.

Q.23 Types of genotype observed in a dihybrid cross are _____.

Q.24 The types of gametes produced by a heterozygous allelic pair is/are _____.

Q.25 The transfer of characters from parents to offspring is known as inheritance. **[True / False]**

Q.26 A true breeding line shows stable trait inheritance and expression for several generations.

[True / False]

Q.27 In total, Mendel selected 7 true-breeding pea plant varieties. **[True / False]**

Q.28 A gamete carries only one factor of a character. **[True / False]**

Q.29 Starch synthesis in wrinkled seeded pea plants is most efficient. **[True / False]**

Q.30 Modified allele is always the recessive allele. **[True / False]**

Q.31 In fruit fly, genes of white eye and normal wing are X-linked recessive. **[True / False]**

Q.32 Loosely linked genes show high recombination. **[True / False]**

Q.33 In birds, both the sexes possess two sex chromosomes. **[True / False]**

Q.34 In butterflies, sex determination is exactly opposite the condition found in grasshoppers. **[True / False]**

Q.35 Chromosomal aberrations are commonly observed in cancer cells. **[True / False]**

Q.36 Mutation is the only phenomenon that leads to variation in DNA. **[True / False]**

Q.37 Heterozygous female for haemophilia may transmit the disease to sons. **[True / False]**

Q.38 Affected individuals with phenylketonuria lack an enzyme that converts the amino acid phenylalanine into phenylpyruvic acid. **[True / False]**

Q.39 Klinefelter's syndrome is caused due to the presence of an additional copy of X-chromosome resulting into a karyotype of 47, XXX. **[True / False]**

Q.40 Failure of segregation of homologous pair of chromosomes during cell division cycle results in Turner's syndrome. **[True / False]**

For Q.41-Q.44

State **True or False** (w.r.t. Chromosomal theory of inheritance)

Q.41 Both chromosomes as well as genes occur in pairs in the somatic cells.

Q.42 Both chromosomes as well as genes segregate at the time of gamete formation such that complete pair is transmitted to a gamete.

Q.43 Chromosomes are the carriers of Mendel's factors.

Q.44 The paired condition of both chromosomes as well as Mendelian factors is restored during microsporogenesis.

SECTION - 3 (ENHANCE PROBLEM SOLVING SKILLS)

Choose one correct response for each question.

PART - 1 : MENDEL'S LAWS OF INHERITANCE

Q.45 Mendel's experimental material was –

(A) *Pisum sativum* (B) *Lathyrus odoratus*
(C) *Oryza sativa* (D) *Mirabilis jalappa*

Q.46 Mendel selected *Pisum sativum* for hybridisation experiments because of

(A) Clear contrasting characters and short life span.
(B) Long life span and non-fertile hybrids.
(C) Presence of unisexual flowers
(D) Infertile hybrids and production of large number of seeds by each plant.

Q.47 Which is correct about traits choosen by Mendel for his experiment on pea plant?

(A) Terminal pod was dominant
(B) Constricted pod was dominant
(C) Green coloured pod was dominant
(D) Tall plants were recessive

Q.48 Gametes produced by a homozygous individual is/are of _____ types.
(A) 1 (B) 2
(C) 3 (D) Many

Q.49 Mark the odd one (w.r.t. dominant trait in garden pea)
(A) Yellow pod (B) Inflated pod
(C) Axial flower (D) Yellow seed

Q.50 Out of 7 contrasting trait pairs selected by Mendel, how many traits were dominant and recessive?
(A) 7 and 7 (B) 8 and 6
(C) 6 and 8 (D) 5 and 9

Q.51 Transmission of genetic characters from parents to offsprings is
(A) Variation (B) Heredity
(C) Blending (D) Somatoplasm

Q.52 If genes of an allelic pair are not-same. This condition is called
(A) homozygous (B) heterozygous
(C) diallelic (D) polyallelic

Q.53 Which of the following trait of garden pea is present on 7th chromosome?
(A) Pod shape (B) Pod colour
(C) Seed shape (D) Stem height

PART - 2 : INHERITANCE OF ONE GENE

Q.54 The first hybrid progenies obtained by Mendel were called –
(A) F_1-progeny (B) F_0-progeny
(C) F_2-progeny (D) F_3-progeny

Q.55 Mendel observed that _____ generation always shows phenotype of dominant parent.
(A) F_4 (B) F_2
(C) F_1 (D) F_0

Q.56 The allele which expresses itself in both homozygous and heterozygous condition is called
(A) dominant allele
(B) recessive allele
(C) incomplete dominant allele
(D) split allele

Q.57 The phenotype of F_1 hybrid resembles either of the two parents in
(A) Dominance
(B) Incomplete dominance
(C) Co-dominance
(D) Intermediate inheritance

Q.58 When F_1-generation progeny resembles both the parents this is called
(A) codominance
(B) incomplete dominance
(C) Both (A) or (B)
(D) Complete dominance

Q.59 The factors which expresses only in homozygous condition is
(A) dominant (B) recessive
(C) hidden (D) cryptic

Q.60 Mendel did not include in his laws –
(A) Segregation (B) Dominance
(C) Purity of gametes (D) Linkage

Q.61 Mendel proposed law of dominance and law of segregation based on his observations on
(A) Monohybrid crosses (B) Dihybrid crosses
(C) Test crosses (D) Out crosses

Q.62 Which of the following law was discovered first by Mendel ?
(A) Law of dominance
(B) Law of segregation
(C) Law of independent assortment
(D) Law of sex determination

Q.63 Alleles are
(A) alternative form of a gene.
(B) alternative form of a gene that govern similar character of trait.
(C) which govern only single character of trait.
(D) All of the above

Q.64 Mendel's law were first published in the year –
(A) 1875 (B) 1890
(C) 1928 (D) 1866

Q.65 Blood grouping is the example of –
(A) multiple allele
(B) codominance
(C) Both (A) and (B)
(D) independent assortment

Q.66 All of this obeys Mendel's laws except.
(A) Codominance
(B) Independent assortment
(C) Dominance
(D) Purity of gametes

Q.67 The ABO blood group are controlled by
(A) I-gene (B) c-gene
(C) B-gene (D) n-gene

Q.68 A cross between F_1 hybrid and its homozygous recessive parent is called
(A) Out cross (B) Test cross
(C) Monohybrid cross (D) Dihybrid cross

Q.69 When a tall pea plant (TT) is crossed with dwarf plant (tt) what will be the phenotype in F_2-generation?
(A) All tall plants
(B) All dwarf plants
(C) Both tall and dwarf plants in 1 : 1 ratio
(D) Both tall and dwarf plants in 3 : 1 ratio

Q.70 The phenotypic ratio of a monohybrid cross in F_2-generation is
(A) 3: 1 (B) 1 : 2 : 1
(C) 2 : 1 : 1 (D) 9 : 3 : 3 : 1

Q.71 The law of segregation of characters is also called the law of purity of gametes because
(A) gametes have only one of the two alleles for each characters.
(B) gametes cannot be contaminated.
(C) gametes are very different type of cells.
(D) Both tall and dwarf plants in 1 : 2.

Q.72 Codominance is found in –
(A) plants (B) animal
(C) Both (A) and (B) (D) prokaryote

Q.73 Select the correct option w.r.t. law of independent assortment
(A) It can be explained by using monohybrid cross
(B) Inheritance of one character is dependent on another character
(C) This law is not applicable universally
(D) It was proposed by Bateson

Q.74 Chances of segregation of alleles in gametes are
(A) 25% (B) 35%
(C) 50% (D) 75%

Q.75 Leaf colour in *Mirabilis jalapa* is an example of
(A) non-Mendelian inheritance
(B) Mendelian inheritance
(C) chemical inheritance
(D) Both (B) and (C)

Q.76 Example of interagenic gene interaction is/are –
(A) incomplete dominance (B) codominant
(C) multiple alleles (D) All of the above

Q.77 Which of the following is best suited for codominance? The genes involved in codominance.
(A) Both are recessive (B) Both are dominant
(C) One is recessive (D) One is dominant

Q.78 Test cross is –
(A) recessive F_1-plant crosses with dominant F_2-plant.
(B) recessive F_2-plant crosses with dominant F_3-plant.
(C) dominant F_2-plant crosses with recessive parent plants.
(D) dominant F_2plant crosses with heterozygous parent plants.

Q.79 If heterozygous dominant (tT) crossed with homozygous dwarf plant, then the percentage of progeny having dwarf character is
(A) 60% (B) 40%
(C) 50% (D) 70%

Q.80 F_3-generation is obtained by
(A) selfing of F_1
(B) selfing of F_2
(C) crossing of F_1 and F_2
(D) None of these

Q.81 When there are more than two allele controlling the same character. These are called –
(A) many alleles (B) polyalleles
(C) multiple alleles (D) All of these

Q.82 Incomplete dominance is shown by
(A) Primrose (B) *Mirabilis*
(C) *Helianthus* (D) China rose

Q.83 The character that is expressed in the F_1-generation is called the –
(A) recessive character
(B) dominant character
(C) codominant character
(D) None of these

Q.84 If mendel has chosen to study traits determined by linked genes he would not have discovered
(A) Law of segregation
(B) Law of dominance
(C) Law of independent assortment
(D) Law of unit character

PART - 3 : INHERITANCE OF TWO GENES

Q.85 Ratio observed in dihybrid cross (phenotypically)
(A) 3 : 1 (B) 1 : 2 : 1
(C) 9 : 7 (D) 9 : 3 : 3 : 1

Q.86 In which phase of meiosis-I the two chromosome can align at the metaphase plate independently of each other
(A) metaphase-II (B) metaphase I
(C) anaphase-I (D) telophase-I

Q.87 Walter Sutton is famous for his contribution to
(A) genetic engineering
(B) totipotency
(C) quantitative genetics
(D) chromosomal theory of inheritance

Q.88 Select the odd one out w.r.t. chromosomal theory of inheritance
(A) It was proposed by Sutton and Boveri.
(B) Behaviour of chromosomes is parallel to behaviour of genes.
(C) Chromosomes and genes occur in pairs in diploid and haploid cells respectively.
(D) The paired condition of both chromosomes as well as Mendelian factors is restored during fertilization.

Q.89 Who was fly man of genetics?
(A) Sutton (B) Pasteur
(C) Robert Hooke (D) TH Morgan

Q.90 Rrrr (progeny) : Red (dominant) flowers (heterozygous) were crossed with white flower. The result will be –
(A) 350 → Red : 350 → white
(B) 450 → Red : 250 → white
(C) 380 → Red : 320 → white
(D) None of the above

Q.91 The chromosomal number in meiocytes of housefly are –
(A) 8 (B) 12
(C) 21 (d) 23

Q.92 Morgan used *Drosophila* as experimental material because
(A) It cannot be reared and bred under lab conditions.
(B) A single mating produces very few offsprings
(C) It has high number of morphologically similar chromosomes.
(D) It has a short life span.

Q.93 Which of the following is true about linkage
I. It is phenomenon in which more recombinants are produced in F_2generation.
II. More parental combination are produced in F_2 -generation.
III. Genotype which are present in F_1 hybrid. Reappear in high frequency in F_2-generation.
IV. It is a phenomenon in which two chromosome are linked.
(A) only I (B) only II
(C) I and III (D) III and IV

Q.94 Which cross was used to study the independent assortment?
(A) Monohybrid cross (B) Dihybrid cross
(C) Trihybrid cross (D) Tetrahybrid cross

Q.95 What is genotypic ratio in a dihybrid cross?
(A) 1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1
(B) 2 : 4 : 2 : 1 : 2 : 1 : 1 : 2 : 1
(C) 1 : 4 : 2 : 1 : 1 : 1 : 2 : 1
(D) 4 : 2 : 1 : 1 : 1 : 1 : 2 : 1 : 1

Q.96 Who carried out several dihybrid crosses in *Drosophila* to study genes that were sex-linked?
(A) Morgan (B) Sutton
(C) Bateson (D) Punnet

Q.97 Morgan worked with tiny fruit fly named as –
(A) *Drosophila melanogaster*
(B) *Mangifera indica*
(C) *Mirabilis jalapa*
(D) *Drosophila indica*

Q.98 Dihybrid ratio of test cross 1 : 1 : 1 : 1proves that –
(A) F_1-hybrid produces four different progenies
(B) F_1-hybrid produces two different progenies
(C) parents produces two different progenies
(D) None of the above

Q.99 Find the odd one out w.r.t. complete linkage
(A) 100% parental combinations in F_2 generation
(B) F_2 phenotypic ratio is 3 : 1 in dihybrid cross
(C) Dihybrid test cross ratio is 1 : 1 in F_2 generation
(D) Linked genes tend to separate frequently.

Q.100 Who proposed the chromosomal theory of inheritance?
(A) Sutton and Mendel (B) Boveri and Morgan
(C) Morgan and Mendel (D) Sutton and Boveri

Q.101 Linkage gene do not shows
(A) independent assortment
(B) 9 : 3 : 3 : 1
(C) segregation
(D) All of the above

Q.102 Who proposed chromosomal theory of linkage?
(A) Morgan (B) Castle
(C) Both (A) and (B) (D) Bateson

Q.103 How many linkage groups are present in human male?
(A) 24 (B) 23
(C) 46 (D) 22

Q.104 In law of independent assortment. How many factors are involved? (for a dihybrid cross)
(A) 2 (B) 3
(C) 4 (D) 1

Q.105 Dihybrid ratio of the linked gene is
(A) 1 : 1 (B) 1 : 1 : 1 : 1
(C) 9 : 3 : 3 : 1 (D) 3 : 1

Q.106 In cross between yellow round (YYRR) and pure breeding pea plants having green wrinkled (yyrr) find out the total seeds (plants) having yellow colour in F_2-generation
(A) 12 (B) 10
(C) 14 (D) 11

Q.107 7 : 1 : 1 : 7 as linkage ratio in case of dihybrid test cross means that there are
(A) 2 parental & 14 recombinant plants
(B) 14 parental & 2 recombinant plants
(C) 9 parental & 7 recombinant plants
(D) 8 parental & 8 recombinant plants

Q.108 Experimental evidences of chromosomal theory of inheritance was given by –
(A) HT Morgan (B) TH Morgan
(C) H de Vries (D) DH Vries

Q.109 Find the incorrect statement w.r.t. chromosomal mapping
(A) Crossing over is important in locating genes on chromosome.
(B) Recombination frequency depends upon the distance between the genes.
(C) Recombination frequency is inversely proportional to distance between genes.
(D) The sequences and the relative distances between various genes is graphically represented in terms of recombination frequencies.

PART - 4 : SEX DETERMINATION

Q.110 In XX and XY type of sex determination, the males are –
(A) homogametic (B) heterogametic
(C) Both (A) and (B) (D) isogametic

Q.111 Hypertrichosis is an example of which inheritance
(A) holandric (B) incomplete sex-linked
(C) sex-influenced (D) sex-limited

Q.112 Mark the incorrect pair (w.r.t. sex determination)
(A) ZW-ZZ type – Fishes
(B) ZO-ZZ type – Birds
(C) XX-XO type – *Dioscorea*
(D) XX-XY type – *Melandrium*

Q.113 The genes located in the same chromosome do not separate and are inherited together over its generations due to the phenomenon of –
(A) complete linkage
(B) incomplete linkage
(C) incomplete recombination
(D) complete recombination

Q.114 If the ratio between X-chromosomes and complete set of autosome is 0.5. Then the individual will be –
(A) female (B) super female
(C) male (D) super male

Q.115 In bugs and cockroaches, the sex determination takes place by
(A) XX and XO chromosomes
(B) XX and XY chromosomes
(C) ZZ-ZW chromosomes
(D) ZO-ZZ chromosomes

Q.116 Linkage groups are always present on the
(A) homologous chromosomes
(C) sex chromosomes
(B) analogous chromosomes
(D) heterologous chromosomes

Q.117 Which of the following statement about Barr body is incorrect?
(A) Observed by Barr and Bertram
(B) Can be seen in neutrophils of females as drumstick
(C) Number of Barr body is one less than the number of autosomes
(D) Normal male has no Barr body

Q.118 Which of the following is not a correct match?
(A) Sex determination – A chromosomal phenomenon
(B) Y-chromosome – Autosomal
(C) Red-green colour blindness in human character. – A sex-linked
(D) An abnormal chromosome number in each cell – A case of olyploidy

Q.119 Sex linked traits are the traits determined by –
(A) sex chromosome (B) autosomes
(C) allosomes (D) All of these

Q.120 The chromosomal denotation for heterogametic female and homogametic males are
(A) ZW and ZZ (B) ZO-ZZ
(C) XX-XO (D) Both (A) and (B)

Q.121 Barr body is observed in
(A) basophils of male (B) neutrophils of female
(C) basophils of female (D) eosinophils

Q.122 When the number of recombinant progeny is usually less than the number expected in independent assortment it is called –
(A) complete linkage
(B) incomplete linkage
(C) complete recombination
(D) complete independent assortment

Q.123 XO type of sex determination is seen in
(A) man (B) grasshopper
(C) *Drosophila* (D) birds

Q.124 In the XX-XO type of sex determination
(A) Females produce only one type of eggs
(B) Females have only one X-chromosome
(C) Males have two X-chromosomes
(D) Males are homogametic

Q.125 Haploid-diploid mechanism of sex determination (haplodiploidy) takes place in –
(A) bees (B) wasps
(C) Ants (D) All of these

Q.126 Genic balance theory of sex determination, stated by CB Bridges, is related to –
(A) *Drosophila melanogaster* (B) Rumex
(C) Snapdragon (D) None

Q.127 Barr body in mammals represent –
(A) all the heterochromatin in female cells.
(B) one of the two X-chromosomes in somatic cells females.
(C) all the heterochromatin in male and female cells.
(D) the Y-chrornosorne in somatic cells of male

Q.128 Identify the wrong statement.
(A) In male grasshoppers, 50% of the sperms have no sex chromosome.
(B) Usually, female birds produce two types of gametes based on sex chromosome.
(C) The human males have one of their sex chromosomes much shorter than other.
(D) In domesticated fowls, the sex of the progeny depends on the type of sperm rather than the egg.

Q.129 Select the odd one out w.r.t. genic balance theory of sex-determination in *Drosophila*
(A) Y-chromosome plays no role in sex-determination
(B) Given by C.B. Bridges
(C) If X/A ratio is one, superfemales are produced
(D) If X/A ratio is less than 0.5, supermales are produced.

Q.130 The traits which are not expressed due to a particular gene but are expressed by products of sex hormones are –
(A) sex influenced traits (B) autosomal traits
(C) allosomic traits (D) sex linked traits

PART - 5 : MUTATION

Q.131 Which phenomena leads to the variation in DNA
(A) Mutation (B) Linkage
(C) Both (A) and (B) (D) Mitosis

Q.132 Loss of chromosomal segment occurs due to
(A) polyploidy (B) deletion
(C) duplications (D) inversion

Q.133 Mutation can't change
(A) RNA (B) enzyme
(C) DNA (D) None of these

Q.134 How many pairs of autosomal chromosomes are found in human?
(A) 23 pairs (B) 1 pair
(C) 22 pairs (D) 46 pairs

Q.135 Point mutation arises due to change in –
(A) single base DNA
(B) single base pair of DNA
(C) segment of DNA
(D) double base pair of DNA

Q.136 Mutation are generally –
(A) recessive (B) polymorphic
(C) lethal (D) dominant

Q.137 Harmful mutation does not get eliminated from the gene pool because they are mainly
(A) recessive, which have beneficial effect on population and carried by heterozyous individuals.
(B) dominant, which have beneficial effect on population and carried by homozygous individuals.
(C) carried from one generation to another generation through autosomal chromosomes
(D) they show genetic drift.

Q.138 Frameshift mutation arises due to
(A) deletion of base pair of DNA.
(B) insertion of base pair of DNA.
(C) Both (A) and (B).
(D) change in single base pair of DNA.

Q.139 Which of the following type of mutation involves the reverse order of genes in a chromosome?
(A) Deletion
(B) Duplication
(C) Inversion
(D) Reciprocal translocation

PART - 6 : GENETIC DISORDERS

Q.140 In pedigree analysis, the square, blackened and horizontal lines represents
(A) female, healthy individual, parents
(B) female, affected individual, parents
(C) male, affected individual, parents
(D) male, affected individual, progeny

Q.141 21 trisomy in humans causes
(A) Klinefelter's syndrome (B) Down's syndrome
(C) Turner's syndrome (D) Patau's syndrome

Q.142 The enzyme missing in phenylketonuria is
(A) phenylalanine hydroxylase
(B) phenylalanine reductase
(C) phenylalanine oxidase
(D) phenylalanine oxidoreductase

Q.143 Haemophilia is also called –
(A) bleeders disease (B) blood disease
(C) RBC disease (D) All of these

Q.144 Select the odd one out w.r.t. haemophilia
(A) X-linked dominant disorder
(B) Bleeder's disease
(C) Criss-cross inheritance
(D) X-linked recessive disorder

Q.145 In sickle-cell anaemia, glutamic acid (glu) is replaced by –
(A) valine (B) leucine
(C) isolucine (D) methionine

Q.146 Colour blindness is
(A) sex-linked recessive disease
(B) sex-linked dominant disease
(C) autosomal dominant disease
(D) autosomal recessive disease

Q.147 Phenylketonuria disease is a –
(A) autosomal dominant (B) autosomal recessive
(C) sex linked recessive (D)sex linked dominant

Q.148 I. Trisomy of sex (X) chromosome.
II. XXY + 44 III. 21st trisomy
IV. Sterile male V. Gynaecomastia
Choose the correct option for Klinefelter's syndrome.
(A) I, II, III and IV (B) I, II, IV and V
(C) II, III, IV and V (D) I, III, IV and V

Q.149 Select the correct match
(A) Sex-limited trait Colour blindness
(B) Sex-limited trait Express in both sexes
(C) Sex-influenced trait More frequent in one sex than in the other
(D) Sex-influenced trait Porcupine skin

Q.150 In sickle-cell anaemia, GAG is replaced by
(A) GGA (B) GUG
(C) AAG (D) GGG

Q.151 Genes for colour blindness is carried by –
I. abnormal development II. father
III. mother IV. autosomes
(A) I and II (B) II and III
(C) III and I (D) I and IV

Q.152 Night blindness is
(A) genetic disease
(B) nutritional deficiency disease
(C) generally found in male
(D) generally found in female

Q.153 More man suffers from colour blindness than women because –
(A) women have more resistance.
(B) male sex hormone testosterone causes the disease.
(C) the colourblind gene is carried by Y-chromosome.
(D) man are hemizygous and one defective gene is enough to make colourblind.

Q.154 If a normal man marries a girl who is carrier for haemophilia, then
(A) All sons will be haemophilic.
(B) All daughters will be haemophilic.
(C) 75% of the offsprings will be haemophilic.
(D) 50% of the sons will be haemophilic.

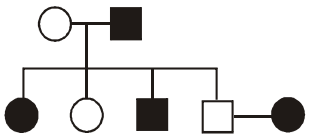
Q.155 Klinefelter's syndrome results from
(A) XX egg of Y sperm
(B) XX egg and XY sperm
(C) X egg and YY sperm
(D) XY egg and X sperm

Q.156 Select the incorrect statement w.r.t. pedigree analysis
(A) Solid symbol shows the unaffected individual
(B) It is useful for genetic counsellors
(C) Proband is the person from which case history starts
(D) It is an analysis of traits in a several generations of a family.

Q.157 Choose the correct option for the chromosomal disorders
I. Colour blindness II. Down's syndrome
III. Phenylketonuria IV. Turner's syndrome
V. Thalassaemia
(A) I, II and III (B) II, IV and V
(C) III, IV and V (D) II and IV

Q.158 Turner's syndrome caused due to the absence of –
(A) one X-chromosome (44 with XO)
(B) one Y-chromosome
(C) one X- and Y-chromosome
(D) two X-chromosomes

Q.159 Find out the genotype of father and mother is the given pedigree chart.



(A) Mother-AA, Father-AA
(B) Mother-Aa, Father-Aa
(C) Mother-AA, Father-aa
(D) Mother-aa, Father-Aa

Q.160 The mutant haemoglobin molecule undergoes polymerisation under low oxygen tension causing the change in the shape of RBC from biconcave to elongated structure. This property of RBC is found in –
(A) Haemophilia (B) Colour blindness
(C) Phenylketonuria (D) β-thalassaemia

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

Q.1 Cross devised by Mendel to prove that F_1 individual is heterozygous is
(A) Self cross (B) Out cross
(C) Reciprocal (D) Test cross

Q.2 Calculate the number of possible genotypes if a character is controlled by 10 alleles of a gene
(A) 516 (B) 55
(C) 21 (D) 24

Q.3 As a result of marriage of curly hair mother and straight hair father, 8 children are born. The ratio of curly and straight haired will be
(A) 6 : 2 (B) 2 : 6
(C) 4 : 4 (D) 3 : 5

Q.4 Gene frequency for free car lobed persons is 0.6, calculate the percentage of heterozygous individuals out of 6000 population
(A) 2880 (B) 2450
(C) 2860 (D) 3000

Q.5 In snail (Limnaea) F_1 obtained from a cross between dextral (DD) female and sinistral (dd) male are all dextral When F_1 progenise are selfed the F_2 shows
(A) All sinistral (B) All dextral
(C) 3 dextral : 1 sinistral (D) 1 dextral : 1 sinistral

Q.6 A haemophilic man married to a woman whose father was haemophitc, what will be the percentage of normal male individual in the progeny ?
(A) 75% (B) 25%
(C) 50% (D) 37%

Q.7 In ABC/abc X abc/abc, if no double crossover occur how many types of gametes will be formed, when ABC genes are present in linear order on same chromosome?
(A) 18 (B) 4
(C) 6 (D) 16

Q.8 Three genes are placed in an order i – j – k on the chromosome, if crossover value of i – j and j – k are 20% and 40% respectively, then what is the expected value of double crossovers in i – k region ?
(A) 6% (B) 8%
(C) 2% (D) 20%

Q.9 In a trihybrid cross of pure tall yellow round seeded pea plant with dwarf green wrinkled seeded plant the percentage of tall yellow wrinkled recombinants in F_1 generation is
(A) 25% (B) 14 %
(C) 12.5% (D) 75%

Q.10 A husband and wife have normal vision but fathers of both of them were colour blind. Probability of their first daughter to be colour blind is –
(A) 25% (B) 50%
(C) 75% (D) 0%

Q.11 In snapdragon, a dihybrid cross between broad leaves and red flowers plant with narrow leaves and white flower plant, the total number of phenotypes and genotypes in the F_2 generation are
(A) 9 (B) 18
(C) 13 (D) 20

Q.12 In the case of balanced lethality in Drosophila, the surviving phenotype is
(A) Dominant homozygous
(B) Heterozygous
(C) Heterozygous and Dominant homozygous
(D) Heterozygous and Recessive homozygous

Q.13 In Mirabilis & Antirrhinum plant the appearance of the pink hybrid (Rr) between cross of a red (RR) and white (rr) flower parent indicates :
(A) Incomplete dominance (B) Segregation
(C) Dominance (D) Heterosis

Q.14 Exception to mendel's law is found in flower colour of –
(A) Mirabilis (B) Sweet - pea
(C) Garden-pea (D) Beans

Q.15 RR(red) is crossed with ww (white). All Rw offsprings are pink. This indicates that R-gene is
(A) Hybrid (B) Incompletely dominant
(C) Recessive (D) Mutant

Q.16 In case of incomplete dominance the monohybrid ratio of phenotypes in F_2 generation is –
(A) 1 : 2 : 1 (B) 3 : 1 : 1
(C) 9 : 3 : 3 : 1 (D) 2 : 3 : 1

Q.17 A white flowered mirabilis plant rr was crossed with red coloured RR, If 120 plants are produced in F_2 generation the result would be –
(A) 90 uniformly coloured & 30 white
(B) 90 Non-uniformly coloured & 30 white
(C) 60 Non-uniformly coloured & 60 white
(D) All coloured & No white

Q.18 When the phenotypic and genotypic ratios resemble in the F_2 generation it is an example of
(A) Independent assortment
(B) Qualitative inheritance
(C) Segregation of factors
(D) Incomplete dominance

Q.19 Which one carries extra nuclear genetic material–
(A) Plastids (B) Ribosomes
(C) Chromosomes (D) Golgi-complex

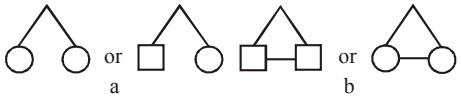
Q.20 When certain character is inherited only through the female parent, it probably represents the case of –
(A) Mendelian nuclear inheritance
(B) Multiple plastid inheritance
(C) Cytoplasmic inheritance
(D) Incomplete dominance

Q.21 Cytoplasmic male sterility is inherited :
(A) Maternally
(B) Paternally
(C) Both
(D) Bacteriophage multiplication

Q.22 A couple has 6 children, 5 of which are girls and 1 a boy. The percentage of having a girl child on next time is –
(A) 10% (B) 20%
(C) 50% (D) 100%

Q.23 I. Haemophilia II. Cystic fibrosis
III. Sickle-cell anaemia IV. Colour blindness
V. Cancer VI. Plague
VII. Phenylketonuria VIII. Thalassaemia
Choose the correct options for Mendelian disorders.
(A) I, II, III, IV, VI, VIII
(B) I, II, III, IV, VII, VIII
(C) I, II, III, IV, V, VI
(D) I, II, III, IV, V, VIII

Q.24 The given diagram a and b indicates.



(A) a-Zygotic twins; b-Dizygotic twins
(B) a-Dizygotic twins; b-Identical twins
(C) a-Zygotic twins; b-Identical twins
(D) a-Identical twins; b-Dizygotic twins

Q.25 Which law would have been violated if mendel had chosen eight characters in garden-pea –
(A) Law of dominance
(B) Law of segregation
(C) Principle of independent assortment
(D) Law of purity of gametes

Q.26 Mendel had a difficulty in explaining the linked characters
(A) Law of dominance
(B) Law of segregation
(C) Law of independent assortment
(D) All the above

Q.27 In Mirabilis jalapa when homozygous red flowered and white flowered plants are crossed, all F_1 plants , have pink coloured flowers. In F_2 produced by selfing of F_1 plants, red, pink, white flowered plants would appear respectively in the ratio of –
(A) 1 : 1 : 2 (B) 2 : 1 : 1
(C) 1 : 0 : 1 (D) 1 : 2 : 1

Q.28 The main aim of plant breeding is –
(A) To produce improved varieties
(B) To make soil fertile
(C) To control pollution
(D) To become more progressive

Q.29 Which of the character is dominant in pea plant
(A) Wrinkled seeds containing tall plants
(B) Red flower containing dwarf plant
(C) Both (A) and (B)
(D) Neither (A) nor (B)

Q.30 Plants having similar genotypes produced by plant breeding are called –
(A) Clone (B) Haploid
(C) Autopolyploid (D) Genome

Q.31 If mendel might have studies 7 pairs of characters in a plant with 12 chromosomes instead of 14, then –
(A) He could not discover independent assortment
(B) He might have not discovered linkage
(C) He might have discovered crossing-over
(D) He might have not observed dominance

Q.32 The first attempt to show linkage in plants was done
(A) Pisum satiwm
(B) Lathyrus odoratus
(C) Zea mays
(D) Oenothera lamarckiana

Q.33 In case of incomplete dominance, F_2 generation has –
(A) Genotypic ratio equal to phenotypic ratio
(B) Genotypic ratio is 3 : 1
(C) Phenotypic ratio is 3 : 1
(D) None of these

Q.34 The segregation of paired hereditary factors that Mendel postulated occurs during –
(A) Anaphase of first meiotic division.
(B) Metaphase of second meiotic division.
(C) During interphase between two meiotic divisions.
(D) Prophase of first meiotic division.

Q.35 Genes controlling seven traits in pea studied by mendel were actually located on –
(A) Seven chromosomes
(B) Six chromosomes
(C) Four chromosomes
(D) Five chromosomes

Q.36 With increasing age the linkage becomes :
(A) Strong (B) Weak
(C) Terminates (D) Remains unchange

Q.37 Coupling and Repulsion theory produced by :
(A) Morgan (B) Bateson
(C) Muller (D) De vries

Q.38 In which type of inheritance the results are affected by reciprocal cross :
(A) Nuclear (B) Cytoplasmic
(C) Blending (D) All the above

Q.39 If there were only parental combinations in F_2 of a dihybrid cross then mendel might have discovered –
(A) Independent assortment (B) Atavism
(C) Linkage (D) Repulsion

Q.40 From a cross AABb x aaBb, the genotypes AaBB : AaBb : Aabb : aabb will be obtained in the ratio –
(A) 1: 1 : 1 : 1 (B) 1: 2 : 1 : 0
(C) 0: 3 : 1 : 0 (D) 1: 1 : 1 : 0

Q.41 Plants similar to mother plant can be obtained from
(A) Seeds (B) Stem cutting
(C) Both of these (D) None of these

Q.42 Linkage discovered in Drosophila by :
(A) Bateson (B) Morgan
(C) Muller (D) Correns

Q.43 Mendelian dihybrid and dihybrid with linkage are respectively related with how many chromosomes
(A) 1 pair & 2 pair (B) 2 pair & 2 pair
(B) 2 pair & 1 pair (D) 1 pair & 1 pair

Q.44 Incomplete dominance occurs in –
(A) Mirabilis (B) Antirrhinum
(C) Andulasion fowl (D) All of the above

Q.45 A dihybrid plant with incomplete linkage on test cross may produce how many types of plants –
(A) 2 (B) 4
(C) 8 (D) 1

Q.46 In an organism, pink spot is a sex-linked recessive trait and black hair is dominant to white. If a pink spotted black heterozygous female is mated to a white male which is not spotted, the phenotypic ratio of the offspring would be
(A) 1/4 spotted black; 1/4 pink spotted white; 1/4 unspotted black; 1/4 unspotted white
(B) 1/2 pink spotted black; 1/2 pink spotted white
(C) 3/4 pink spotted black; 1/4 pink spotted white
(D) 3/4 unspotted black; 1/4 pink spotted white

Q.47 How many linkage group are there in nucleoid of bacteria :
(A) One (B) Two
(C) Four (D) None

Q.48 Which cross yields red, white & pink flowers variety of dog flower :
(A) RR X Rr (B) Rr X RR
(C) Rr X Rr (D) Rr X rr

Q.49 What shall be ratio in offspring when a roan cow is crossed with a white bull –
(A) 1 : 2 : 1 (B) 3 : 1
(C) 1 : 1 (D) All roan

Q.50 If distance between gene on chromosome is more, then gene shows –
(A) Weak linkage (B) Strong linkage
(C) Less crossing (D) 1 & 3 both

Q.51 Linked gene shows –
(A) Always parental combination
(B) Sometimes new combinations
(C) Always new combination
(D) New combination more

Q.52 In a certain plant, red flowers (R) are dominant to white flowers (r) and tallness (T) is dominant to dwarfness (t). A heterozygous plant (RrTt) is backcrossed with a double recessive plant (rrtt). If the gene loci for colour and size and situated very close together on the same chromosome, the expected percentage of offsprings could be approximately

	tall red	tall white	dwarf red	dwarf white
(A)	25%	25%	25%	25%
(B)	49%	49%	1%	1%
(C)	49%	1%	1%	49%
(D)	1%	1%	49%	49%

Q.53 The number of linkage groups in a cell having 10 pairs of chromosomes are :
(A) 5 (B) 10
(C) 15 (D) 20

Q.54 Cytology + genetics were merged into "Cytogenetics" by one of following –
(A) Bateson (B) Punnet
(C) Morgan (D) Muller

Q.55 Phenotypic ratio in codominance –
(A) 1 : 2 : 1 (B) 3 : 1
(C) 2 : 1 (D) 2 : 1 : 3

Q.56 Which of the following is exception to Mendel's laws
(A) Linkage (B) Incomplete dominance
(C) Co-dominance (D) All of the above

Q.57 A roan bull is bred to three cows. Cow A has the same genotype as the roan bull cow B is red and cow C is white what proportions of roan cows are expected in the offsprings of each group of cows :
(A) 2, 1, 1 (B) 1, 2, 1
(C) 1, 1, 2 (D) 3, 1

Q.58 A tobacco plant which is heterozygous for albinism (a recessive character) is self pollinated if 1200 seeds are subsequently germinated, how many of the seedlings would have the parental genotype –
(A) 300 (B) 600
(C) 900 (D) 1200

Q.59 The association of parental characters combinations in the offsprings of a dihybrid is excess to nonparental combinations is said to be due to :
(A) Co-dominance (B) Blending inheritance
(C) Linkage (D) Duplicate genes

Q.60 Complete linkage is found in :
(A) Birds (B) Snakes
(C) Female- Drosophila (D) Male - Drosophila

Q.61 A phenomenon which works opposite to the linkage is –
(A) Independent assortment (B) Crossing-over
(C) Segregation (D) Mutation

Q.62 The scientist who first discovered cytoplasmic inheritance was –
(A) Correns (B) Rhoades
(C) Mendel (D) Morgan

Q.63 Shell coiling in Limnaea (Snail) is an example of
(A) Maternal inheritance
(B) Biparental inheritance
(C) Predetermination
(D) Dauermodification

Q.64 Probability of genotype TTrr in F_2 generation of a dihybrid cross is –
(A) 1/16 (B) 3/16
(C) 9/16 (D) 6/16

Q.65 A woman of blood group 'O' presented a baby of blood group 'O' which she claimed as her child. She brought a suit against a man of . AB group as the father of the child. Which statement is correct as per your judgement –
(A) The father and mother claimed are the true persons.
(B) Father is true and mother is not the true person.
(C) Both the parentage claims are false.
(D) Mother is the true person and father claimed is not true.

Q.66 A man with blood group 'AB' marries a woman with 'O' blood group. In this situation
(A) The blood groups of their children will be the same as that of the mother.
(B) The blood group of the children differs from both the parents.
(C) While 50% of children will have father's blood group, the remaining will have mother's blood group.
(D) None of the above

Q.67 Pure homozygous offsprings in a dihybrid cross in the F_2 generation will be –
(A) 1/2 (B) 1/4
(C) 1/8 (D) 1/16

Q.68 A black dog heterozygous for the colour is crossed with white bitch, recessive homozygous. Progeny will show black to white offsprings in the ratio of –
(A) All black (B) All albino
(C) 1 : 1 (D) 3 : 1

Q.69 Exchange of one part of a chromosome to the other part of same or another chromosome is –
(A) Inversion (B) Mutation
(C) Translocation (D) Linkage

Q.70 Recessive characters are expressed
(A) Only when they are present on X chromosomes of male.
(B) Only when they are present on X chromosomes of female.
(C) On any autosome.
(D) On both the chromosomes of female.

Q.71 Persons with the following syndrome have a tendency of tall structure, mental defects and a strong antisocial behaviour –
(A) XYY syndrome
(B) Down's syndrome
(C) Klinefelter's syndrome
(D) Turner's syndrome

Q.72 You perform the following dihybrid cross AAbb × aaBB, where A = Tall (dominont), a = Dwarf (recessive), B = Dark (dominant) b = Light (recessive). In the F_1 generation all the progeny are Tall & Dark. Self the F_1 progeny, How many of the F_2 progeny would you expect to be Tall & light?
(A) 1/16 (B) 1/4
(C) 3/16 (D) 9/16

Q.73 A normal woman whose father was albino, marries an albino man, what proportion of normal and albino are expected among their offsprings
(A) All normal (B) 2 normal : 1 Albino
(C) All albino (D) 1 normal : 1 Albino

Q.74 What is the inheritance of colour blindness of both parents having a normal vision but mother has a recessive gene for colour blindness –

	Son	Daughter
(A)	50%	Nil
(B)	100%	Nil
(C)	Nil	100%
(D)	Nil	Nil

Q.75 What would be the nature of children if a colour blind woman marries a normal man –
(A) Colourblind daughter & normal sons
(B) Colourblind sons and carrier daughters
(C) Normal sons & carrier daughters
(D) Normal sons & Normal daughters

Q.76 One of the parents of a cross has a mutation in its mitochondria. In that cross, that parent is taken as a male. During segregation of F_2 progenies that mutation is found in–
(A) All the progenies
(B) Fifty percent of the progenies
(C) One-third of the progenies
(D) None of the progenies

Q.77 A colourblind man marries a normal lady whose father was colour blind. If it produces two sons & two daughters, how many of them would be suffer –
(A) Both sons
(B) Both daughters
(C) One son & one daughter
(D) Both sons & both daughters

Q.78 Inheritance of skin colour in human beings is an example of –
(A) Complementary gene
(B) Monogenic inheritance
(C) Polygenic inheritance
(D) Mendelian inheritance

Q.79 Imagine that in a plant, green leaves are dominant to yellow leaves and blue flowers are dominant to white flowers. You cross a pure breeding green leaved, blue flowered plant with a pure breeding yellow leaved, white flowered plant, you allow the offspring to self fertilize and observe that the F_2 offsprings are 70% green leaved & blue flowered, 20% yellow leaved & white flowered, 5% green leaved & white flowered and 5% yellow leaved & blue flowered. Based on these observations you can conclude that the two genes
(A) Are in the same biological pathway
(B) Segregate independently
(C) Exibit typical Mendelian ratios
(D) Are on the same chromosomes

Q.80 A gene which suppresses the effect of another gene not located on the similar locus of the homologous chromosomes –
(A) Duplicate gene (B) Complementary gene
(C) Epistatic gene (D) Supplementary gene

Q.81 The phenomenon in which an allele of one gene suppresses the expression of an allele of another gene is known as –
(A) Dominance (B) Inactivation
(C) Epistasis (D) Suppression

Q.82 When a cell with 40 chromosomes undergoes meiosis, each
of the four resulting cells has
(A) 20 chromosomes (B) 40 chromosomes
(C) 80 chromosomes (D) 10 chromosomes

Q.83 When two independently assorting dominant genes interact with each other to produce particular phenotype but when they present alone they did not produce phenotype they are called
(A) Complementary gene
(B) Supplementary gene
(C) Duplicate gene
(D) Inhibitory gene

Q.84 Polygenic genes show –
(A) Identical phenotype
(B) Identical biochemistry
(C) Different phenotype
(D) Identical genotype

Q.85 AB - Blood group shows –
(A) Co-dominance
(B) Complete dominance
(C) Mixed inheritance
(D) Composite inheritance

Q.86 ABO blood group is an example of –
(A) Epistasis (B) Multiple allelism
(C) Pleotropism (D) Complementary genes

Q.87 A child is blood group is 'O'. His parents blood group cannot
(A) B & O (B) A & O
(C) AB (D) A & B

Q.88 A recessive gene is one which
(A) Occurs less frequently than a dominant one
(B) Occurs only in heterozygotes
(C) Produces large amounts of RNA
(D) Produces very less or no mRNA

Q.89 If selfing occurs in the plant having genotype RrYy, then ratio of given genotype will be RRYY, RrYY, RRYy, RrYy
(A) 1 : 2 : 2 : 4 (B) 1 : 2 : 2 : 1
(C) 1 : 1 : 1 : 1 (D) 2 : 2 : 2 : 1

Q.90 If one parent has blood group A and the other parent has blood group B. The offsprings have which blood group –
(A) AB (B) O
(C) BO (D) A, B, AB, O

Q.91 A colourblind daughter is born when –
(A) Father is colourblind, mother is normal.
(B) Mother is colourblind, father is normal.
(C) Mother is carrier, father is normal.
(D) Mother is carrier, father is colourblind.

Q.92 The process of mating between closely related individuals is –
(A) Out-breeding (B) Inbreeding
(C) Hybridisation (D) Heterosis

Q.93 How many different genotypes can be expected in the F_2 of the crossing AABB × aabb when [A] the genes are completely coupled and [B] the genes inherit independently
(A) [A]-3 ; [B]-4 (B) [A]-3 ; [B]-9
(C) [A]-4 ; [B]-9 (D) [A]-4 ; [B]-16

Q.94 Chromosomal number in a cell of a flowering plant is –
(A) Only haploid (B) Only diploid
(C) Many types (D) None of these

Q.95 A man of A blood group marries a woman of AB blood group, which type of progeny would indicate that man is heterozygous A –
(A) AB (B) A
(C) O (D) B

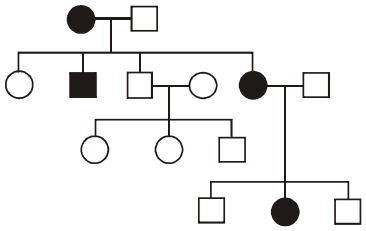
Q.96 A child of O blood group, has B-blood group father, the genotype of father would be –
(A) I^OI^O (B) I^BI^B
(C) I^AI^B (D) I^BI^O

Q.97 Identical twins are produced when –
(A) One fertilized egg divided into 2 blastomeres and both separate.
(B) One sperm fertilizes two eggs.
(C) One egg fertilized with two sperms.
(D) Two eggs are fertilized.

Q.98 In a trihybrid cross which plant will produce eight types of gametes
(A) Any plant of F_1 generation
(B) 25% plants of F_1 generation
(C) Recessive plant of F_1 generation
(D) Any plant except a plant of F_1 generation

Q.99 How many genome types are present in a typical green plants cell –
(A) Two (B) Three
(C) More than five (D) More than ten

Q.100 In the following pedigree chart, the mutant trait is shaded black. The gene responsible for the trait is



(A) Dominant and X-linked
(B) Dominant and autosomal or dominant and X-linked
(C) Recessive and X-linked
(D) Recessive and Y-linked

Q.101 In cross between yellow round (YYRR) and green wrinkled (yyrr) find out the ratio between seeds having yellow and green seed colour.
(A) 3 : 2 (B) 3 : 1
(C) 9 : 7 (D) 7 : 9

Q.102 In previous question find out the ratio between round and wrinkled seed texture
(A) 3 : 1 (B) 2 : 2
(C) 1 : 1 (D) 9 : 6 : 1

Q.103 Which of the followng statement for grasshopper is **incorrect** ?
(A) Male individual heterogametic due to two heteromorphic sex chromosomes.
(B) Sperms determines the sex of offsprings
(C) Similar number of autosomes are found in male and female individuals both.
(D) All eggs contain autosomes as well as X-chromosome.

Q.104 What shall be the ratio of heterozygous, homozygous and hemizygous in offsprings of a colour blind husband & a carrier wife –
(A) 1 : 1 : 2 (B) 1 : 1 : 1
(C) 2 : 1 : 1 (D) 1 : 2 : 1

Q.105 Which of the following is not a sex linked characters
(A) Haemophilia (B) Colour blindness
(C) Hypertrichosis (D) Baldness

Q.106 RR (Red) is crossed with ww (white), all the Rw offsprings
are pink. This is an indication that R gene is –
(A) Hybrid (B) Recessive
(C) Incompletely dominant (D) Mutant

Q.107 How many different kinds of gametes will be produced by a plant having genotype AABbcc?
(A) Three (B) Four
(C) Nine (D) Two

Q.108 Phenylketonuria, Huntington's disease and sickle cell anaemia are caused due to the disorder associated with –
(A) chromosome-7, chromosome-11, chromosome-12
(B) chromosome-11, chromosome-4, chromosome-12
(C) chromosome-7, chromosome-12, chromosome-11
(D) chromosome-12, chromosome-4, chromosome-11

Q.109 When one sex chromosome is lacking in female and males are homogametic, in that condition, the sex chromosomal representation is –
(A) ZO-ZZ (B) XY-XX
(C) XX-XO (D) ZW-ZZ

Q.110 Which of the following genotype will produce 4 different types of gametes?
(A) AAbbccddEE (B) aaBbCCdd
(C) AaBbCC (D) Aabb

Q.111 In *Mirabilis*, a hybrid for red (RR) and white(rr) flower produces pink (Rr) flower. A plant with pink flower is crossed with white flower, the expected phenotypic ratio is –
(A) red : pink : white (1 : 2 : 1)
(B) pink : white (1 : 1)
(C) red : pink (1 : 1)
(D) red : white (3 : 1)

EXERCISE - 3 (LEVEL-3)

Choose one correct response for each question.

Q.1 One of the autosomal loci controlling eye color in fruit flies has two alleles, one for brown eyes and the other for red eyes. Fruit flies from a true-breeding line with brown eyes were crossed with flies from a true-breeding line with red eyes. The F_1 flies had red eyes. What conclusion can be drawn from this experiment?
(A) these alleles underwent independent assortment.
(B) these alleles underwent segregation.
(C) these genes are X-linked.
(D) the allele for red eyes is dominant to the allele for brown eyes.

Q.2 The F_1 flies described in above question were mated with brown-eyed flies from a true-breeding line. What phenotypes would you expect the offspring to have?
(A) all red eyes
(B) all brown eyes
(C) half red eyes and half brown eyes
(D) red-eyed females and brown-eyed males

Q.3 The type of cross described in above question is a(an)
(A) F_2 cross (B) dihybrid cross
(C) test cross (D) two-point test cross

Q.4 If the 2N number is 6 and one homologous pair underwent nondisjunction, how many chromosomes would be present in the daughter cells of that division?
(A) Both daughter cells would have 3.
(B) One would have 2 and the other 3.
(C) One would have 1 and the other 5.
(D) One would have 2 and the other 4.

Q.5 You have a new puppy, a yellow lab. The parents of your new puppy were both black labs. The only way this could have occurred is that both parents must have been __ .
(A) heterozygous for black and the Epistasis gene
(B) heterozygous for black and the pleiotropic gene
(C) homozygous recessive for black
(D) heterozygous for black

Q.6 If 75% of the offspring have a genetic condition, it can be concluded the condition is –
(A) autosomal recessive
(B) sex-linked autosomal recessive
(C) autosomal dominant
(D) sex-linked autosomal dominant

Q.7 A man who has a sex-linked allele will pass it on to
(A) all his daughters (B) all his sons
(C) 1/2 of his daughters (D) 1/2 of his sons

Q.8 Harry knew that he was adopted. He was 6 ft 2 in, and both parents were under 5 ft 6 in. In fact, Harry checked his pedigree for 3 generations and no one was over 5 ft 8 in. How would you counsel Harry?
(A) Harry is correct, he must be adopted.
(B) Height is determined by polygenic inheritance.
(C) Height is a result of the product rule.
(D) Height is due to multiple alleles.

Q.9 Bob has blood type A and his children all have blood type O. Bob is very upset with his wife, who is also blood type A. You come to the rescue and explain to Bob that he is getting the __ confused with the ____.
(A) phenotype, genotype
(B) dominance, recessive
(C) monohybrid, dihybrid
(D) homozygous, heterozygous

Q.10 Assume the DNA content of a cell about to undergo mitosis is X. Immediately after crossing over has occurred, the amount of DNA present is –
(A) 0.5 X (B) 0.75 X
(C) X (D) 2X

Q.11 Following Mendel's experiment patterns for a monohydrid cross, if the F_1 generation was a different phenotype than either of the parental individuals, which would be the simplest explanation?
(A) codominance or incomplete dominance.
(B) multiple alleles
(C) pleiotropy
(D) sex linkage

Q.12 Betty Sue and Barney just had a baby. The doctor comes in and tells the happy couple the child is a carrier for red-green color blindness. The sex of the child is –
(A) male
(B) female
(C) impossible to tell
(D) not one child but two males

Q.13 You are analyzing karyotypes of two patients, a male and a female. The phone rings and you are distracted for a few minutes. When you return you know you are looking at the female karyotype because you clearly see –
(A) mitochondria
(B) centrioles
(C) a barr body
(D) only one Y chromosome

Use the following information to answer questions 14 through 17:

In peas, the allele for round seeds (R) is dominant to that for wrinkled seeds (r); the allele for yellow seeds (Y) is dominant to that for green seeds (y). These loci are unlinked. Plants from a true-breeding line with round, green seeds are crossed with plants from a true-breeding line with wrinkled, yellow seeds. These parents constitute the P generation.

Q.14 The genotypes of the P generation are –
(A) RRrr and Yyyy (B) RrYy
(C) RRYY and rryy (D) RRyy and rrYY

Q.15 What are the expected genotypes of the F_1 hybrids produced by the described cross?
(A) RRrr and YYyy (B) all RrYy
(C) RRYY and rryy (D) RRyy and rrYY

Q.16 What kinds of gametes can the F_1 individuals produce?
(A) RR and YY (B) Rr and Yy
(C) RR, rr, YY, and yy (D) RY, Ry, rY, and ry

Q.17 What is the expected proportion of F_2 wrinkled, yellow seeds?
(A) 9/16 (B) 1/16
(C) 3/16 (D) 1/4

Q.18 A photomicrograph of the stained metaphase chromosomes present in a given cell is called a
(A) karyotype
(B) nucleotide triplet repeat
(C) pedigree
(D) DNA microarray

Q.19 Individuals with trisomy 21, or ____, are mentally and physically retarded and have abnormalities of the face, tongue, and eyelids.
(A) Down syndrome
(B) Klinefelter syndrome
(C) Turner syndrome
(D) Huntington's disease

Q.20 An inherited disorder caused by a defective or absent enzyme is called a(an)
(A) karyotype
(B) trisomy
(C) reciprocal translocation
(D) inborn error of metabolism

Q.21 In __, a genetic mutation codes for an abnormal hemoglobin molecule that is less soluble than usual and more likely than normal to deform the shape of the red blood cell.
(A) Down syndrome (B) Tay-Sachs disease
(C) sickle cell anemia (D) PKU

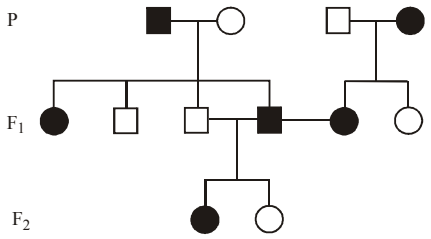
Q.22 *Drosophila* is a particularly good model for developmental studies because
(A) a large number of developmental mutants are available
(B) it has a fixed number of somatic cells in the adult
(C) its embryos are transparent
(D) it is a vertebrate

Q.23 The anterior-posterior axis of a Drosophila embryo is first established by certain
(A) homeotic genes
(B) maternal effect genes
(C) segmentation genes
(D) chronogenes

Q.24 You discover a new Drosophila mutant in which mouth parts appear where the antennae are normally found. You predict that the mutated gene is most likely a
(A) homeotic gene (B) gap gene
(C) pair rule gene (D) maternal effect gene

Q.25 In an individual with ___, the mucus is abnormally viscous and tends to plug the ducts of the pancreas and liver and to accumulate in the lungs.
(A) Down syndrome (B) Tay-Sachs disease
(C) sickle cell anemia (D) cystic fibrosis

Q.26 The figure below shows a pedigree for a family that carries the gene for Huntington's disease. Individuals who express a particular trait are shown shaded in.



What is the genotype of the daughter in the F_2 generation who does not have the disease?
(A) H/H (B) H/h
(C) h/h (D) X-X

Q.27 In peas, the trait for tall plants is dominant (T) and the trait for short plants is recessive (t). The trait for yellow seeds is dominant (Y) and the trait for green seeds is recessive (y). A cross between two plants results in 292 tall yellow plants and 103 short green plants. Which of the following are most likely to be the genotypes of the parents?
(A) TtYY × Ttyy (B) TTYy × TTYy
(C) TTyy × TTYy (D) TtYy × TtYy

Q.28 A child is born with blood type O. All of the following could be the blood type of the parents EXCEPT
(A) A and B (B) A and A
(C) O and O (D) AB and O

Q.29 Gene R controls the formation of feathers on a bird. In addition, it seems to be responsible for traits in several other body systems. What is the best explanation for this type of inheritance?
(A) blending inheritance (B) codominance
(C) pleiotropy (D) epistasis

Q.30 In one strain of mice, fur color ranges from white to darkest brown with every shade of brown in between. This pattern of inheritance for fur color is probably controlled by
(A) multiple genes
(B) a single gene with many alleles
(C) pleiotropy
(D) one gene with hundreds of incidences of crossover

Q.31 How is Huntington's disease inherited?
(A) It is caused by a virus inherited from either parent.
(B) It is sex-linked recessive.
(C) It is autosomal recessive.
(D) It is autosomal dominant.

Q.32 Two traits, A and B, are linked, bur they are not always inherited together. The most likely reason is –
(A) they are not on the same chromosome.
(B) they are not sex-linked.
(C) they are on the same chromosome but are far apart.
(D) they are close together on the same chromosome.

Q.33 A cross was made between two fruit flies, a white-eyed female and a wild male (red eyed). One hundred F_1 offspring were produced. All the males were white eyed and all the females were wild. When these F_1 flies were allowed to mate, the F_2 flies were observed and the following data was collected.

	Females		Males
P:	White eyed	×	Wild (red eyed)
F_1 :	59 wild		51 white eyed
F_2 :	24 wild		23 wild
	26 white eyed		27 white eyed

What is the most likely pattern of inheritance for the white-eyed trait?

(A) autosomal dominant (B) autosomal recessive
(C) sex-linked dominant (D)sex-linked recessive

For Q.34-Q.35

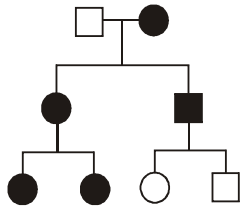
(A) Statement-1 is True, Statement-2 is True, Statement-2 is a correct explanation for Statement -1
(B) Statement-1 is True, Statement-2 is True ; Statement-2 is NOT a correct explanation for Statement - 1
(C) Statement - 1 is True, Statement- 2 is False
(D) Statement -1 is False, Statement -2 is False

Q.34 **Statement 1 :** Most of experiments regarding sex determination were done on Drosophila.
Statement 2 : It is fruit fly.

Q.35 **Statement 1 :** In humans, most sex-linked genes are present on the X-chromosome.
Statement 2 : X-chromosome contains a large number of genes with major effects on phenotype.

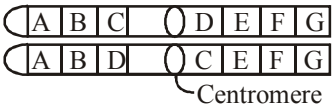
Q.36 If two pea plant having red (dominant) coloured flowers with unknown genotype are crossed, 75% of the flowers are red and 25% are white. The genotypic constitution of the parents having red coloured flowers will be –
(A) both homozygous
(B) one homozygous and other heterozygous
(C) both heterozygous
(D) both hemizygous

Q.37 Identify the type of inheritance in the given diagram.



(A) Dominant X-linked
(B) Recessive X-linked
(C) Dominant Y-linked
(D) Cytoplasmic or mitochondrial inheritance

Q.38 The type of chromosomal abbreviation indicated in the diagram is



(A) interstitial translocation
(B) reciprocal translocation
(C) pericentric inversion
(D) paracentric inversion

Q.39 Cri-du-chat syndrome in humans is caused by –
(A) fertilisation of an XX egg by normal of bearing sperm.
(B) loss of half of the short arm of chromosome-5
(C) loss of half of the long arm of chromosome-5
(D) trisomy of 21st chromosome.

Q.40 Gamete mother cells of the chromosome 44 + XY suffers from non-disjunction at first meiotic division. Which of the following set of gametes would result?
(A) 22 + XX, 22 + XY, and 22, 22
(B) 22 + XY, 22 + XY, and 22, 22
(C) 22 + X, 22 + Y, and 22 + Y, 22
(D) 22 + X, 22 +XY, and 22 + Y, 22 +Y

EXERCISE - 4 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Choose one correct response for each question.

Q.1 If both parents are carriers for thalassaemia, which is an autosomal recessive disorder, what are the chances of pregnancy resulting in an affected child ? **[NEET 2013]**
(A) 25% (B) 100%
(C) No chance (D) 50%

Q.2 Which idea is depicted by a cross in which the F_1 generation resembles both the parents ? **[NEET 2013]**
(A) Inheritance of one gene
(B) Codominance
(C) Incomplete dominance
(D) Complete dominance

Q.3 Select the incorrect statement with regard to haemophilia **[NEET 2013]**
(A) It is a dominant disease
(B) A single protein involved in the clotting of blood is affected
(C) It is a sex-linked disease
(D) It is a recessive disease

Q.4 If two persons with 'AB' blood group marry and have sufficiently large number of children, these children could be classified as 'A' blood group. 'AB' blood group : 'B' blood group in 1 : 2 : 1 ratio. Modern technique of protein electrophoresis reveals presence of both 'A' and 'B' type proteins in 'AB' blood group individuals. This is an example of **[NEET 2013]**
(A) Partial dominance
(B) Complete dominance
(C) Codominance
(D) Incomplete dominance

Q.5 Which of the following statements is not true of two genes that show 50% recombination frequency ? **[NEET 2013]**
(A) The gene show independent assortment
(B) If the genes are present on the same chromosome, they undergo more than one crossovers in every meiosis
(C) The genes may be on different chromosomes
(D) The genes are tightly linked.

Q.6 Fruit colour in squash is an example of **[AIPMT 2014]**
(A) Recessive epistasis
(B) Dominant epistasis
(C) Complementary genes
(D) Inhibitory genes

Q.7 A man whose father was colour blind marries a woman who had a colour blind mother and normal father. What percentage of male children of this couple will be colour blind ? **[AIPMT 2014]**
(A) 25% (B) 0%
(C) 50% (D) 75%

Q.8 A human female with Turner's syndrome **[AIPMT 2014]**
(A) has 45 chromosomes with XO.
(B) Has one additional X chromosome.
(C) Exhibits male characters.
(D) Is able to produce children with normal husband.

Q.9 Alleles are **[AIPMT 2015]**
(A) Different molecular forms of a gene
(B) Heterozygotes
(C) Different phenotype
(D) True breeding homozygotes

Q.10 Multiple alleles are present **[AIPMT 2015]**
(A) At the same locus of the chromosome
(B) On Non-sister chromatids
(C) On different chromosomes
(D) At different loci on the same chromosome

Q.11 A man with blood group 'A' marries a woman with blood group 'B'. What are all the possible blood groups of their offsprings **[AIPMT 2015]**
(A) A, B, AB and O (B) O only
(C) A and B only (D) A, B and AB only

Q.12 How many pairs of contrasting characters in pea plants were studied by Mendel in his experiments **[AIPMT 2015]**
(A) Eight (B) Seven
(C) Five (D) Six

Q.13 An abnormal human baby with 'XXX' sex chromosomes was born due to **[AIPMT 2015]**
(A) Fusion of two ova and one sperm
(B) Fusion of two sperms and one ovum
(C) Formation of abnormal sperms in the father
(D) Formation of abnormal ova in the mother

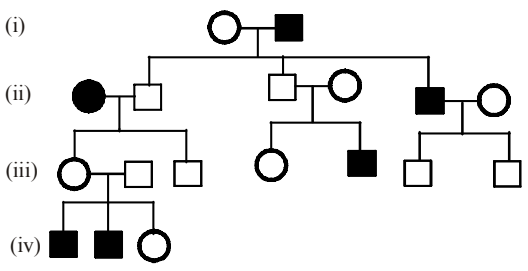
Q.14 A gene showing codominance has **[RE-AIPMT 2015]**
(A) Alleles that are recessive to each other.
(B) Both alleles independently expressed in the heterozygote.
(C) One allele dominant on the other.
(D) Alleles tightly linked on the same chromosome.

Q.15 In his classic experiments on pea plants, Mendel did not use **[RE-AIPMT 2015]**
(A) Seed shape (B) Flower position
(C) Seed colour (D) Pod length

Q.16 A colour blind man marries a woman with normal sight who has no history of colour blindness in her family. What is the probability of their grandson being colour blind ? **[RE-AIPMT 2015]**
(A) Nil (B) 0.25
(C) 0.5 (D) 1

Q.17 A pleiotropic gene **[RE-AIPMT 2015]**
(A) Controls a trait only in combination with another gene
(B) Controls multiple traits in an individual
(C) Is expressed only in primitive plants
(D) Is a gene evolved during Pliocene

Q.18 In the following human pedigree, the filled symbols represent the affected individuals. Identify the type of given pedigree. **[RE-AIPMT 2015]**



(A) Autosomal recessive (B) X-linked dominant
(C) Autosomal dominant (D) X-linked recessive

Q.19 The term "linkage" was coined by **[RE-AIPMT 2015]**
(A) G. Mendel (B) W. Sutton
(C) T.H. Morgan (D) T. Boveri

Q.20 Which of the following most appropriately describes haemophilia? **[NEET 2016 PHASE 1]**
(A) Recessive gene disorder
(B) X-linked recessive gene disorder
(C) Chromosomal disorder
(D) Dominant gene disorder

Q.21 A tall true breeding garden pea plant is crossed with a dwarf true breeding garden pea plant. When the F_1 plants were selfed the resulting genotypes were in the ratio of **[NEET 2016 PHASE 1]**
(A) 1 : 2 : 1 : : Tall homozygous : Tall heterozygous : Dwarf
(B) 1 : 2 : 1 : : Tall heterozygous : Tall homozygous : Dwarf
(C) 3 : 1 : : Tall : Dwarf
(D) 3 : 1 : : Dwarf : Tall

Q.22 Match the terms in Column I with their description in Column II and choose the correct option **[NEET 2016 PHASE 1]**

	Column I		Column II
(a)	Dominance	(i)	Many genes govern a single character
(b)	Codominance	(ii)	In a heterozygous organism only one allele expresses itself.
(c)	Pleiotropy	(iii)	In a heterozygous organism both alleles express themselves fully.
(d)	Polygenic inheritance	(iv)	A single gene influences many characters.

(A) a-(ii), b-(i), c-(iv), d-(iii)
(B) a-(ii), b-(iii), c-(iv), d-(i)
(C) a-(iv), b-(i), c-(ii), d-(iii)
(D) a-(iv), b-(iii), c-(i), d-(ii)

Q.23 Pick out the correct statements : **[NEET 2016 PHASE 1]**

(a) Haemophilia is a sex-linked recessive disease.
(b) Down's syndrome is due to aneuploidy.
(c) Phenylketonuria is an autosomal recessive gene disorder.
(d) Sickle cell anaemia is an X-linked recessive gene disorder.

(A) (a) and (d) are correct
(B) (b) and (d) are correct
(C) (a), (c) and (d) are correct
(D) (a), (b) and (c) are correct

Q.24 In a testcross involving F_1 dihybrid flies, more parental-type offspring were produced than the recombinant-type offspring. This indicates **[NEET 2016 PHASE 1]**

(A) The two genes are located on two different chromosomes.
(B) Chromosomes failed to separate during meiosis.
(C) The two genes are linked and present on the same chromosome.
(D) Both of the characters are controlled by more than one gene.

Q.25 If a colour-blind man marries a woman who is homozygous for normal colour vision, the probability of their son being colour-blind is **[NEET 2016 PHASE 2]**

(A) 0 (B) 0.5
(C) 0.75 (D) 1

Q.26 A disease caused by an autosomal primary non-disjunction is **[NEET 2017]**

(A) Down's syndrome
(B) Klinefelter's syndrome
(C) Turner's syndrome
(D) Sickle cell anemia

Q.27 Thalassemia and sickle cell anemia are caused due to a problem in globin molecule synthesis. Select the correct statement. **[NEET 2017]**

(A) Both are due to a qualitative defect in globin chain synthesis.
(B) Both are due to a quantitative defect in globin chain synthesis.
(C) Thalassemia is due to less synthesis of globin molecules.
(D) Sickle cell anemia is due to a guantitative problem of globin molecules.

Q.28 Which one from those given below is the period for Mendel's hybridization experiments? **[NEET 2017]**

(A) 1856 - 1863 (B) 1840 - 1850
(C) 1857 - 1869 (D) 1870 - 1877

Q.29 The genotypes of a Husband and Wife are I^AI^B and I^Ai. Among the blood types of their children, how many different genotypes and phenotypes are possible **[NEET 2017]**

(A) 3 genotypes ; 3 phenotypes
(B) 3 genotypes ; 4 phenotypes
(C) 4 genotypes ; 3 phenotypes
(D) 4 genotypes ; 4 phenotypes

Q.30 Among the following characters, which one was not considered by Mendel in his experiments on pea? **[NEET 2017]**

(A) Stem-Tall or Dwarf
(B) Trichomes-Glandular or non-glandular
(C) Seed-Green or Yellow
(D) Pod-Inflated or Constricted

Q.31 Select the correct match **[NEET 2018]**

(A) T.H. Morgan - Transduction
(B) F_2 × Recessive parent - Dihybrid cross
(C) Ribozyme - Nucleic acid
(D) G. Mendel - Transformation

Q.32 Which of the following pairs is wrongly matched? **[NEET 2018]**

(A) XO type sex determination : Grasshopper
(B) ABO blood grouping : Co-dominance
(C) Starch synthesis in pea : Multiple alleles
(D) T.H. Morgan : Linkage

Q.33 Select the correct statement **[NEET 2018]**
(A) Spliceosomes take part in translation
(B) Punnett square was developed by a British scientist
(C) Franklin Stahl coined the term "linkage"
(D) Transduction was discovered by S. Altman

Q.34 A woman has an X-linked condition on one of her X chromosomes. This chromosome can be inherited by **[NEET 2018]**
(A) Only grandchildren
(B) Only sons
(C) Only daughters
(D) Both sons and daughters

Q.35 Select the incorrect match : **[NEET 2018]**

(A) Submetacentric – chromosomes	L-shaped chromosomes
(B) Allosomes –	Sex chromosomes
(C) Lampbrush – chromosomes	Diplotene bivalents
(D) Polytene – chromosomes	Oocytes of amphibians

Q.36 Which of the following characteristics represent 'Inheritance of blood groups' in humans? **[NEET 2018]**
a. Dominance b. Co-dominance
c. Multiple allele d.Incomplete dominance
e. Polygenic inheritance
(A) b, d and e (B) a, b and c
(C) b, c and e (D) a, c and e

Q.37 Which of the following muscular disorders is inherited? **[NEET 2019]**
(A) Tetany (B) Muscular dystrophy
(C) Myasthenia gravis (D) Botulism

Q.38 Select the incorrect statement. **[NEET 2019]**
(A) Male fruit fly is heterogametic.
(B) In male grasshoppers 50% of sperms have no sex-chromosome.
(C) In domesticated fowls, sex of progeny depends on the type of sperm rather than egg.
(D) Human males have one of their sex chromosome much shorter than the other.

Q.39 What map unit (Centimorgan) is adopted in the construction of genetic maps? **[NEET 2019]**
(A) A unit of distance between two expressed genes representing 10% cross over.
(B) A unit of distance between two expressed genes representing 100% cross over.
(C) A unit of distance between genes on chromosomes, representing 1% cross over.
(D) A unit of distance between genes on chromosomes, representing 50% cross over.

Q.40 In *Antirrhinum* (Snapdragon), a red flower was crossed with a white flower and in F_1 generation pink flowers were obtained. When pink flowers were selfed, the F_2 generation showed white, red and pink flowers. Choose the **INCORRECT** statement from the following : **[NEET 2019]**
(A) This experiment does not follow the Principle of Dominance.
(B) Pink colour in F_1 is due to incomplete dominance.
(C) Ratio of F_2 is 1/4 (Red) : 2/4 (Pink) : 1/4 (White)
(D) Law of Segregation does not apply in this experiment.

Q.41 A gene locus has two alleles A, a. If the frequency of dominant allele A is 0.4, then what will be the frequency of homozygous dominant, heterozygous and homozygous recessive individuals in the population? **[NEET 2019]**
(A) 0.36(AA); 0.48(Aa); 0.16(aa)
(B) 0.16(AA); 0.24(Aa); 0.36(aa)
(C) 0.16(AA); 0.48(Aa); 0.36(aa)
(D) 0.16(AA); 0.36(Aa); 0.48(aa)

Q.42 The frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes was explained by : **[NEET 2019]**
(A) T.H. Morgan (B) Gregor J. Mendel
(C) Alfred Sturtevant (D) Sutton Boveri

Q.43 What is the genetic disorder in which an individual has an overall masculine development gynaecomastia, and is sterile ? **[NEET 2019]**
(A) Turner's syndrome (B) Klinefelter's syndrome
(C) Edward syndrome (D) Down's syndrome

ANSWER KEY

EXERCISE-1 (SECTION-1&2)

(1) (C) **(2)** (B) **(3)** (A) **(4)** (B)
(5) (D) **(6)** Genes **(7)** Homozygous
(8) Frame-shift mutations **(9)** Sickle cell anaemia
(10) Back cross **(11)** less; more
(12) GAG, GUG, Low oxygen
(13) Mmeiosis; segregate **(14)** Female
(15) Male
(16) **2.** Type of gametes = 2^n (n = number of hybrid)
n = 1, $\therefore$ $2^1 = 2$ type of gametes
(17) Homozygous; heterozygous
(18) Large **(19)** Low
(20) Sex chromosomes **(21)** Variation
(22) Large, one **(23)** 9 **(24)** 2
(25) True **(26)** True **(27)** False
(28) True **(29)**) False **(30)** False
(31) False **(32)** True **(33)** True
(34) True **(35)** True **(36)** False
(37) True **(38)** False **(39)** False
(40) True **(41)** True **(42)** False
(43) True **(44)** False

EXERCISE - 1 [SECTION-3]

Q	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
A	A	A	C	A	A	A	B	B	C	A	C	A	A	A	B	D	A	B	A	D	C	A	A	B
Q	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
A	D	A	A	C	C	C	A	D	B	C	C	B	C	B	B	C	D	B	D	C	D	A	B	D
Q	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
A	A	B	A	A	A	A	D	D	D	C	A	A	D	A	B	B	C	B	A	B	A	C	A	A
Q	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
A	C	B	A	D	B	B	B	A	D	A	B	D	C	A	A	B	D	C	A	A	A	C	C	C
Q	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160				
A	B	A	A	A	A	A	B	B	C	B	B	B	D	D	A	A	D	A	D	A				

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A	D	B	C	A	B	B	C	B	B	D	B	B	A	A	B	A	B	D	A	C	A	C	B	B	C	C	C	A	D	A
Q	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
A	A	B	A	A	C	A	B	B	C	B	B	B	B	D	B	A	A	B	C	A	B	C	B	D	A	D	A	B	C	D
Q	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
A	B	A	C	A	D	B	C	C	C	A	A	C	D	A	B	D	C	C	D	C	C	A	A	C	A	B	C	D	A	D
Q	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111									
A	D	B	B	C	D	D	A	A	A	B	B	A	A	B	B	C	D	D	A	C	B									

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	C	C	D	A	C	A	B	A	C	A	B	C	D	B	D	C	A	A	D	C	A	B	A	D
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40										
A	C	D	D	C	A	D	C	D	B	A	C	D	D	B	B										

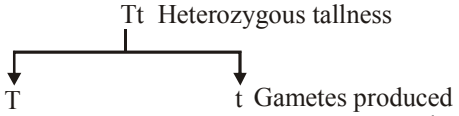
EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	A	B	A	C	D	B	C	A	A	A	A	B	D	B	D	C	B	A	C	B	A	B	D	C	A
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43							
A	A	C	A	C	B	C	C	B	D	D	B	B	C	C	D	C	C	B							

SOLUTIONS

EXERCISE-1

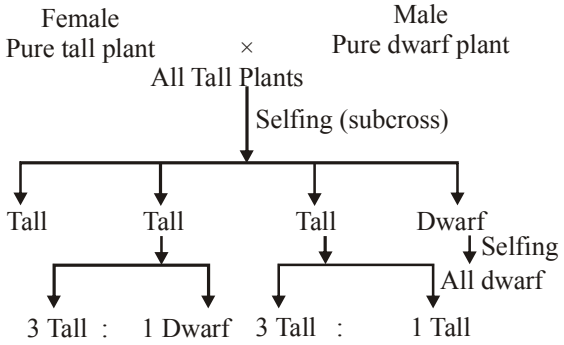
(1) (C) **(2)** (B) **(3)** (A) **(4)** (B)
(5) (D) **(6)** Genes **(7)** Homozygous
(8) Frame-shift mutations **(9)** Sickle cell anaemia
(10) Back cross **(11)** less; more
(12) GAG, GUG, Low oxygen
(13) Mmeiosis; segregate **(14)** Female
(15) Male
(16) **2.** Type of gametes = 2^n (n = number of hybrid)
n = 1, $\therefore 2^1 = 2$ type of gametes
(17) Homozygous; heterozygous
(18) Large **(19)** Low
(20) Sex chromosomes **(21)** Variation
(22) Large, one
(23) **9.** Dihybrid genotype ratio.
1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1 total nine types of genotype and four types of phenotype.
(24) **2.** As heterozygous alleles have two different types of chromosomes, so they produce two types of genes.



(25) True **(26)** True **(27)** False
(28) True **(29))** False **(30)** False
(31) False **(32)** True **(33)** True
(34) True **(35)** True **(36)** False
(37) True **(38)** False **(39)** False
(40) True **(41)** True **(42)** False
(43) True **(44)** False **(45)** (A)
(46) (A) **(47)** (C)
(48) **(A).** As homozygous have only one type of alleles, so they produce only one kind of gamete. **(49)** (A)
(50) **(A).** 7 dominant traits, 7 recessive traits total 14 traits or 7 opposing pairs of traits.

Characters	Dominant Traits	Recessive Traits
Seed shape	Round	Wrinkled
Seed colour	Yellow	Green
Flower colour	Violet	White
Pod shape	Full	Constricted
Pod colour	Green	Yellow
Flower position	Axial	Terminal
Stem height	Tall	Dwarf

(51) (B) **(52)** (B) **(53)** (C)
(54) **(A).** Mendel cross-pollinated a pure tall pea plant (100-120 cm height) and a pure dwarf pea plant. (only 22 to 44 cm height). He called them parental generation, expressed now-a-days by symbol P. This hybridisation popularly called as monohybrid cross.



(55) (C) **(56)** (A) **(57)** (A) **(58)** (A)
(59) **(B).** The allele which does not show its effect in heterozygous individual is called recessive factor or recessive allele. It shows its phenotype only in absence of dominant factor or dominant allele.
(60) (D) **(61)** (A)
(62) **(B).** Originally Mendel proposed two laws, firstly law of segregation and then law of independent assortment.
(63) **(A).**
(64) **(D).** He published his findings in 1866 in the "Annual proceedings of the Natural History society of Brunn".
(65) (C) **(66)** (A)
(67) **(A).** The ABO blood group are controlled by I gene, which have three alleles(I^A, I^B, I^O).
(68) (B)
(69) **(D).** When a tall plant (TT) is crossed with dwarf plant (tt) the F_1-progeny shows all plants hybrid tall (Tt) and on selfing of F_1 the progeny the F_2-generation shows both tall and dwarf plant in the ratio of 3 : 1. Out of three tall plant one is pure tall and two are hybrid.

(70) **(A).** Phenotypic ratio Tall : Dwarf
3 : 1
Genotypic ratio TT : Tt : It
1 : 2 : 1
A Punnett square used to understand a typical monohybrid cross conducted by Mendel between true-breeding tall plants and true-breeding dwarf plants.

(71) (A) **(72)** (C) **(73)** (C)

(74) **(C).** During rnerosis or gametogenesis each chromosome/gene in allele has equal (50%) chances for separation. That is also called law of segregation.

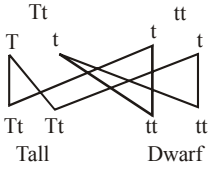
(75) **(A).** The inheritance due to the genes found in cytoplasm (mitochondria and chloroplast) is called cytoplasmic inheritance or non-Mendelian inheritance. The leaves of *Mirabilis jalapa* may be green, white or variegated. This is due to cytoplasmic inheritance.

(76) **(D).** In the intragenic interaction the two alleles (present on the same gene locus on the two homologous chromosome) of a gene interact in such a way as to produce a phenotypic expression different from typical dominant-recessive phenotype, e.g., incomplete dominance, codominance multiple alleles. In intergenic or non-allelic interaction, two or more independent gene present on the same or different chromosomes interact to produce different expression, e.g., epistasis, duplicate genes, complementary genes, supplementary genes, lethal genes, inhibitory genes, etc.

(77) **(B).** In codominance both the genes of an allelomorphic pair express themselves equally by F_1 hybrid. The ratio in F_2-generation is 1 : 2 : 1 both genotypically as well as phenotypically, e.g., codominance of coat colour in cattle and codominance of blood alleles in man.

(78) **(C).**

(79) **(C).** (Heterozygous tall) × (Homozygous dwarf)



(80) **(B).** F_3-generation obtained by selfing of F_2-generation.

(81) **(C).** Human blood (ABO) is example of multiple alleles in which three alleles I^A, I^B, I^O governing the same trait.

(82) (B) **(83)** (B) **(84)** (C) **(85)** (D)

(86) (B) **(87)** (D) **(88)** (C) **(89)** (D)

(90) **(A).** (Red dominant) Rrrr × (White dominant) rrrr

	rr	rr
Rr	Rrrr (Red)	Rrrr (Red)
rr	rrrr (White)	rrrr (White)

Ratio Red : White
1 : 1
350 : 350

(91) **(B).** Chromosomal number in meiocytes of house fly is 12 and chromosomal pair is six.

(92) (D) **(93)** (A) **(94)** (B) **(95)** (A)

(96) (A)

(97) **(A).** Thomas Hunt Morgan (the father of experimental genetics) selected fruitfly (*Drosophila melanogaster*) is also called Jackpot of genetics as experimental material.

(98) **(A).** Dihybrid cross is a cross involving two pairs of contrasting characters. A dihybrid test cross gives 1 : 1 : 1 : 1. Ratio indicating that when F, hybrid is crossed with recessive parent the two pairs of factors segregate and assorting independently and produce four type of progenies.

(99) (D) **(100)** (D)

(101) **(D).** Linked gene don't show any accordance with Mendel's law because Mendel's law can be applied only on unlinked gene.

(102) (C) **(103)** (A) **(104)** (A) **(105)** (D)

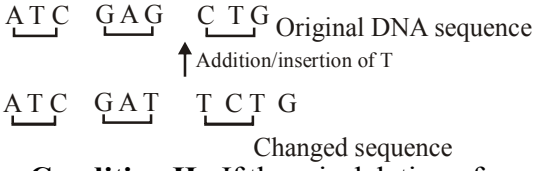
(106) **(A).** A dihybrid cross in pea plant between yellow round (smooth) seeded and green wrinkled seeded plant. The cross proves the principle of independent assortment.

(107) (B) **(108)** (B) **(109)** (C) **(110)** (B)

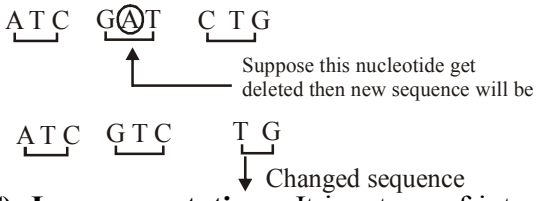
(111) **(A).** Hypertrichosis is the excessive growth of hair on the body.

It is an example of holandric inheritance. Genes responsible for this are located on Y-chromosomes only which are also known as holandric genes. Y-linked holandric genes are transmitted directly from father to son.

(112) (B) **(113)** (A) **(114)** (C) **(115)** (A)
(116) (A) **(117)** (C) **(118)** (B) **(119)** (A)
(120) **(D).** ZW and ZZ and ZO-ZZ.
(121) **(B).** Barr body can be observed in neutrophils of females.
(122) **(B).** In the incomplete linkage we get some recombinant progeny but in complete linkage the recombinant progeny percentage is very less as compared to incomplete linkage.
(123) (B) **(124)** (A)
(125) **(D).** Haploid diploid mechanism of sex determination (haplodiploidy) .
Hymenopterous insect such as bees, wasps ants show unique phenomena in which an unfertilised egg develops into male and female develops from fertilised egg.
In honeybee, the quality of food determines whether a diploid larva will become a fertile queen or a sterile worker female. A larva fed on royal jelly a secretion from the mouth of mussing workers grows into a queen, whereas a larva fed on pollen and nectar grows into a worker bee.
(126) (A)
(127) **(B).** Barr body in mammals represents one of the two X-chromosomes in somatic cells of female. Females have two X-chromosome and males have one X-chromosome. So,inactivation of one of the X in female also called dosage compensation. At the time of gametogenesis both 'X' of female get activated. So, the 'X' is also called facultative heterochromatin.
(128) **(D).** In birds the determination of sex depend on the female not male because the female is heterogametic.
(129) (C) **(130)** (A) **(131)** (A)
(132) **(B).** Deletion is the way through, which loss of a chromosome takes place. In polyploidy and duplication, there is increase in chromosomal content. In inversion and transversion, there is only rearrangement of base pairs in chromosome takes place.
(133) **(D).** Sudden inheritable change in DNA (mutation) can change the RNA, enzyme, protein but it can't change the environment.
(134) **(C).**
(135) **(A).** Mutation that takes place due to change in single base pairis called point mutation, e.g., Sickle-cell anaemia.
(136) **(A).** Mutation are generally recessive. That is the only cause due to which they survive in population otherwise they have been eliminated.
(137) **(A).** Harmful mutation does not get eliminated from the gene pool because most of the harmful mutations are recessive and they carried by heterozygous condition in the individual.
If they (mutation) are dominant then they easily get eliminated by the death of an organism.
(138) **(C).** Deletion and insertion of one base leads to entire changeof DNA base pair sequence.
DNA base pair sequence is called reading frame.
Condition I: If there is insertion of one base



Condition II : If there is deletion of one base



(139) **(C).** **Inverse mutation :** It is a type of intra chromosomal modification in which the segment of chromosome separate and rejoints in reverse position.
(140) **(C).** In pedigree, square represents male blackened square or circle represents affected individual.
Horizontal line represents-parents.

(141) (B).

Disorders	Autosomal/ Sex linked	Symptoms	Effects
Down's syndrome	Autosomal aneuploidy (trisomy, +21)	Mongolian eyefold (epicanthus), open mouth, protruded tongue, projected lower lip, many loops on finger tip, palm crease.	Retarded mental development IQ (below 40)
Turner's syndrome	Sex chromosomal monosomy 44 + XO	Short stature females (<5'), webbed neck, body hair absent menstrual cycle absent. Sparse pubic hair, under developed breasts narrow lips puffy fingers.	Sterile hearing problem
Klinefelter's syndrome	Sex chromosomal aneuploidy (tri/ tetrasomy of X chromosome) 44 + XXY. 44 + XXXY	The males are tall with long legs, testes small, sparse body hair, Barr body present, breast enlargement.	Gynaecomastia azospermia sterile

(142) (A) **(143)** (A) **(144)** (A) **(145)** (A)

(146) (A). Colour Blindness

(i) It is a sex-linked recessive disorder.

(ii) It results in defect in either red or and green cone cells of eye resulting in failure to discriminate between red and green colour.

(iii) The gene for colour blindness is present on X-chromosome.

(iv) It is observed more in males (X^cY) because of presence of only one X-chromosome as compared to two chromosomes in females.

(147) (B) **(148)** (B) **(149)** (C)

(150) (B). GAG code for glutamic acid in haemoglobin mRNA replaced by GUG code which code for valine in haemophilic haemoglobin mRNA.

(151) (B). Colour blindness is the sex-linked recessive disease in which the defective gene carried by the X-chromosome. So, if a person is colour blind then it is due to the defective gene present in the father and mother.

(152) (B). Night blindness is nutritional deficiency disease generally happens due to deficiency of vitamin-A.

(153) (D) **(154)** (D)

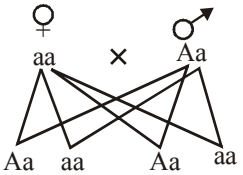
(155) (A). The genotype of Klinefelter syndrome is XXY. In this, there is one extra X-chromosome. This extra chromosome comes when there is non-disjunction of X-chromosome in ova-or-sperm fuses with Y or X-chromosome of sperm or ova resulting XXY genotype.

(156) (A)

(157) (D). Chromosomal Disorders : These genetic disorders are caused due to absence or excess or abnormal arrangement of one or more chromosomes. These are non-heritable and pedigree analysis of a family does not help in tracing the pattern of inheritance of such chromosomal disorders. These are of two types abnormalities due to aneuploidy and aberrations either autosomes or in sex chromosomes.

(158) (A). Absence of one X-chromosome (44 with XO).

(159) (D).



The pedigree given in question is the most probable autosomal disease.

(160) (A)

EXERCISE-2

(1) (D). In test cross F_1 individual is back crossed with homozygous recessive parent.

(2) (B). Number of genotypes in multiple allelism is $\frac{n}{2}(n+1)$. Where n = number of alleles.

(3) (C). In human beings, curly hairs is dominant and straight hair is recessive.

(4) (A). $p = 0.6$; $q = 1 - 0.6 = 0.4$
Heterozygous = 2 x p x q = 0.48

(5) (B). Coiling of shell in case of small is a maternal effect, in which the genotype of female parent will effect the penotype of progeny.

(6) (B). X^CY–Haemophilic man, XX^Carrier woman.

(7) (C). 6 gametes

A	a	A	a	A	a
B	b	b	B	B	b
C	c	c	C	c	C

(8) **(B).** Double crossovers = 0.2(20%) × 0.4 (40%) = 0.08 (8%)

(9) **(B).** Frequency of tall yellow wrinkled = $\frac{9}{64}$

Percentage of tall yellow wrinkled

$= \frac{9}{64} \times 100 = 14\ \%$

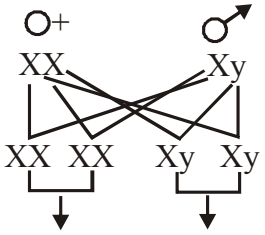
(10) **(D).** Probability of their first (or any) daughter being colourblind is nil as the daughter of normal father can never be colourblind.

(11) **(B).** Snapdragon shows incomplete inheritance for leaf shape and flower colour
Number of genotype = 3^2 =9
Number of phenotype = 9

(12) **(B).** In balanced lethality both homozygous dominant and recessive will die.

(13) (A) **(14)** (A) **(15)** (B) **(16)** (A)
(17) (B) **(18)** (D) **(19)** (A) **(20)** (C)
(21) (A)

(22) **(C).** Probability of child being boy or girl is 50%.



2 girls 2 boys
50% girl and 50% boys

(23) **(B).** Haemophilia, cystic fibrosis, thalassaemia. sickle-cell anaemia, colour blindness, phenylketonuria.

(24) **(B).** a-Dizygotic twins are the twins, which results from the fusion of two sperm with two ova. It is very rare in case of human beings.
b-Monozygotic twins are the twins, which results from the fusion of one sperm with one ova leads to zygote. This zygote later on divide and give rise to two or more zygote. In this cells of all progeny have the identical genome.

(25) (C) **(26)** (C)
(27) (C) **(28)** (A)

(29) **(D).** Round seeds containing tall plants and red flower containing tall plants is dominant in pea plant.

(30) (A) **(31)** (A) **(32)** (B) **(33)** (A)

(34) **(A).** Anaphase divides the paired hereditary factors in to two equal and similar halves.

(35) (C) **(36)** (A) **(37)** (B) **(38)** (B)
(39) (C)

(40) **(B).** AABb × aaBb

	AB	Ab	AB	Ab
aB	AaBB	AaBb	AaBB	AaBb
ab	AaBb	Aabb	AaBb	Aabb
aB	AaBB	AaBb	AaBB	AaBb
ab	AaBb	Aabb	AaBb	Aabb

AaBB : AaBb: Aabb: aabb
4 : 8 : 4 : 0
AaBB = 1; AaBb = 2; Aabb = 1; aabb = 0

(41) (B) **(42)** (B) **(43)** (B) **(44)** (D)
(45) (B)

(46) **(A).**
Bbrr × bbRr
(Female) (Male)
Pink spotted black White not spotted
Heterozygous
Gametes - Br, br bR, br

♀ / ♂	bR	br
Br	BbRr Black unspotted	Bbrr Black pink spotted
br	bbRr White unspotted	bbrr White pink spotted

$\frac{1}{4}$ Black unspotted, $\frac{1}{4}$ Black pink spotted

$\frac{1}{4}$ White unspotted, $\frac{1}{4}$ White, pink spotted

Here B is dominant over band R is dominant over r.

(47) (A) **(48)** (B) **(49)** (C) **(50)** (A)
(51) (B)

(52) **(C).** Due to linkage new combinations are minimum.

(53) (B) **(54)** (D) **(55)** (A) **(56)** (D)
(57) (A)

(58) **(B).** XX × Xx Parents
↓
XX Xx Xx xx F_1 hybrid
In F_1 generation half of the total offsprings represent parental genotype i.e., Xx.

Therefore out of 1200 seedling 600 will have parental genotype.

(59) (C) **(60)** (D) **(61)** (B) **(62)** (A)
(63) (C)
(64) **(A).**

♀ / ♂	TR	Tr	tR	tr
TR	TTRR	TTRr	TtRR	TtRr
Tr	TTRr	TTrr	TtRr	Ttrr
tR	TtRR	TtRr	ttRR	ttRr
tr	TtRr	Ttrr	ttRr	ttrr

In F_2 generation (TTrr is 1/16)

(65) **(D).** The mother can be true but father is not exactly true.

(66) **(B).** When a man with blood group AB marries a woman with "O" blood group then blood group of children will be A or B which is differ from parental blood group.

(67) **(C).** In F_2 generation of dihybrid cross two type of YYRR and yyrr pure homozygous offsprings are found out of 16. offsprings, so Number of Pure homozygous offspring

$$= \frac{\text{Pure homozygous}}{\text{Total Number of offspring}} = \frac{2}{16} = \frac{1}{8}$$

(68) **(C).** It is a test cross ratio whenever a dominant heterozygous (Xx) is crossed with recessive homozygous (xx), the ratio in their progeny is 1 : 1.

(69) **(C).** Translocation is a kind of chromosomal rearrangement in which a block of genes from one linkage group is transferred to another linkage group.

(70) **(A).** Recessive characters are expressed in the subsequent generation only when present on the X chromosome of male.

(71) **(A).** The extra y-chromosome is strongly male determining. The extra y-chromosome leads to over production of male hormone, which causes over aggressiveness. So XYY men are prone to violence, criminality and antisocial behaviour.

(72) (C) **(73)** (D) **(74)** (A) **(75)** (B)
(76) **(D).** Because mitochondrial genes also show maternal inheritance because all the mitochondria a zygote has come from the cytoplasm of the ovum.

(77) (C) **(78)** (C) **(79)** (D) **(80)** (C)
(81) (C)
(82) **(A).** 20 chromosomes; because in meiosis cell division chromosome number becomes halved.

(83) (A) **(84)** (C) **(85)** (A) **(86)** (B)
(87) (C)
(88) **(D).** A recessive gene is one which is not able to synthesize a functional polypeptide and hence it is not expressed phenotypically, therefore that part of DNA does not transcribe mRNA or very little of mRNA.

(89) (A) **(90)** (D) **(91)** (D) **(92)** (B)
(93) (B)
(94) **(C).** Haploid in germinal cell, diploid in somatic cell and triploid in endosperm cells.

(95) (D) **(96)** (D)
(97) **(A).** Identical twins are formed when one sperm fertilizes one egg to form a single zygote. They have the same genotype and phenotype and are of same sex.

(98) **(A).** In trihybrid cross, three genes are involved.

AA BB CC × aa bb cc

↓

F_1 - Aa Bb Cc

$2 \times 2 \times 2 = 8$ gametes

In heterozygous condition 2 gametes and in homozygous condition 1 gamete is produced.

(99) **(A).** Since a typical green plant is diploid, therefore it has two sets of chromosome. So the number of genome will be two because genome is a set of chromosomes.

(100) (B) **(101)** (B) **(102)** (A)
(103) **(A).** Male individual = (AA + XO) i.e., only one type of sex chromosome

(104) (B) **(105)** (B)
(106) **(C).** This is an example of incomplete dominance in which the genes from both the parents are accumulated in F_1 which show pink phenotype (This is an exception of Mendel's law).

(107) **(D).** The types of gametes produced by a plant depend upon the number of heterozygous pair. Number of types of gametes = 2^n

n = number of heterozygous pair

$2^1 = 2$; The gametes are ABc and Abc.

(108) **(D).** Phenylketonuria – Chromosome-12
Huntingnton disease – Chromosome-4
Sickle-cell anaemia – Chromosome-11

(109) **(A).** ZO and ZZ type of sex determination. This mechanism occurs in certain butterflies and moths. The female is heterogametic and produces two types of eggs half with Z and half without Z-chromosome. The males have homomorphic sex chromosomes and is homogametic. It forms only one kind of sperms, each with Z-chromosome.

Parents	Phenotypes	Male	Female
	Genotypes	AA + ZZ	AA + ZO
Gametes		A+ Z, A+ Z	A+ Z, A + O

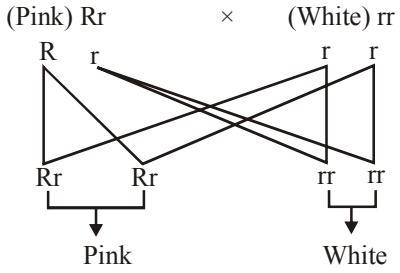
F_1-generation

	A + Z	A + O
A + Z	AA + ZZ	AA + ZO
A + Z	AA + ZZ	AA + ZO
	Males	Females

ZO-ZZ type of sex determination.

(110) (C)

(111) **(B).** *Mirabilis jalapa* shows incomplete dominance.



The ratio of pink and white flower will be 1 : 1.

EXERCISE-3

(1) (D) **(2)** (C) **(3)** (C)

(4) **(D).** Nondisjunction is when a homologous pair doesn't separate; one daughter cell of meiosis I would have two chromosomes and the other would have 4. Each of these chromosomes would be composed of two sister chromatids.

(5) **(A).** In order to get a yellow lab puppy, each of the parents must have a recessive allele for both color and the E gene (epistasis gene), since the genotype of a yellow lab puppy is bbee]

(6) **(C).** Given the information, it can be concluded that both the homozygous dominant as well as the heterozygous genotypes have the phenotype, since the phenotype is not associated with the sex of the individual, this is an autosomal condition.

(7) **(A).** A man gives his sons the Y chromosome and passes sex-linked traits to all his daughters.

(8) **(B).** There are multiple genes with multiple alleles that determine height. In addition, external factors such as nutritional factors also play a significant role in growth or height of an individual.

(9) **(A).** The phenotype is the expression or in this example the blood type, while the genotype are the actual alleles that are present. In this example both the mom and dad are type A - phenotype and their genotypes must be AO to have type O children. Blood typing is an example of codominance, if the allele is present, it will be expressed.

(10) **(C).** Crossing over is only an exchange of DNA between homologous chromosomes, so the DNA amount would not increase or decrease.

(11) **(A).** The parental cross is between a homozygous dominant and a homozygous recessive. If the offspring has a different phenotype than either of the parents, the most likely explanation would be codominance or incomplete dominance. In either case the phenotypic expression is either both alleles are present and expressed, or there is a blending of the alleles.

(12) **(B).** Red-green color blindness is a X-linked trait. Males are more likely to have this condition since they only have 1 X chromosome. Females can be carriers since they can be heterozygous with 2 X chromosomes.

(13) **(C).** One of the X-chromosomes in females will become inactive (condensed) to form a barr body. This can be observed in a karyotype of a female.

(14) (D) **(15)** (B) **(16)** (D)
(17) (C) **(18)** (A) **(19)** (A)
(20) (D) **(21)** (C) **(22)** (A)
(23) (B) **(24)** (A) **(25)** (D)

(26) **(C).** Females are represented as circles; males as squares unless otherwise stated. You should know that Huntington's disease is inherited as autosomal dominant. The F_2 daughter who does not have the condition must have inherited one healthy gene from each parent. She must be h/h, normal.

(27) **(D).** Since there are four genes (T, t, Y, and y) but only two phenotypes in the offspring, the traits for height and seed color must be linked, that is, on the same chromosome. So solve the problem this way. Consider the traits separately at first. The phenotype ratio in the offspring for height is 3: 1, tall to short. Therefore, the parents must be Tt and Tt. The phenotype ratio in the offspring for seed color is 3: 1, yellow to green. Therefore, the parents must be Yy and Yy. Now, put both genotypes together. The parents must be TtYy and TtYy.

(28) **(D).** Blood type O is homozygous recessive, ii or I^OI^O. The child must receive an O allele from each parent. Blood type AB has no O allele. Therefore, choice (D) is excluded as a parent.

(29) **(C).** When one gene seems to control the expression of several traits, the pattern of inheritance is pleiotropy. A classic example of pleiotropy in humans is Marfan's syndrome.

(30) **(A).** Examples of polygenic inheritance in humans are genes for skin color and height.

(31) **(D).** Although the trait is autosomal dominant, symptoms do not usually appear until later in life, long after the person with the condition has passed the trait on to children and, perhaps, grandchildren.

(32) **(C).** If genes are on the same chromosome but far apart, they will often be inherited separately because they will often be separated by crossover.

(33) **(D).** Here is the first cross.

	X	Y
X–	X–X	X–Y
X–	X–X	X–Y

All the female offspring are carriers (X-X), and all the male offspring have white eyes (X-Y).

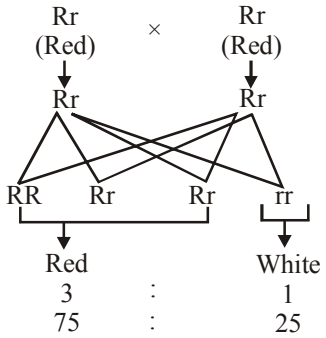
Here is the second cross.

	X–	Y
X–	X–X–	X–Y
X	X–X	XY

There is a 50 percent chance that a male will be white eyed and a 50 percent chance he will be red eyed. There is a 50 percent chance a female will be white eyed and a 50 percent chance she will be red eyed (a carrier).

(34) (B) **(35)** (A)

(36) **(C).** Homozygous and heterozygous



(37) **(D).** Cytoplasmic or mitochondrial inheritance is the inheritance in which the trait pass only from mother to all of their offspring. The genes of that inheritance is present in the cytoplasm of ova that's why these genes goes to all of their offspring. As sperm have very less cytoplasm, so this inheritance doesn't apply to males.

(38) **(D).** **Inversion :** A piece of chromosomes is removed and rejoined in reverse orientation. It can be two types

(i) **Pericentric inversion :** The inverted segment does not contains centromere.

(ii) **Paracentric inversion :** The inverted segment contains centromere.

(39) **(B).** Cri-du chat is a syndrome in which deletion on short, arm of 5th chromosome takes place.

(40) **(B).** Non-disjunction is the condition in which the separationof chromosome doesn't take place during cell division. In 44 + XY non-disjunction, there is non-separation of XY gene, which leads to the formation of sperm having genotypes, 22 + XY and 22.

EXERCISE-4

(1) **(A).** Thalassaemia is an autosomal recessive blood disorder.

Parents : Tt × Tt

genotype

Offspring genotype : TT : Tt : tt

1 : 2 : 1

Normal Carriers Affected

25% 50% 25%

(2) **(B).** In codominance, both the alleles are able to express themselves independently when present together resulting in a phenotype that is intermediate between both the parental homozygous phenotypes, thereby resembling both of them.

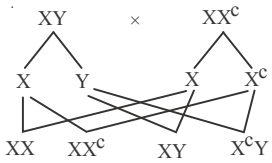
(3) **(A).** Haemophilia is sex-linked disease which is also known as bleeder's disease as the patient will continue to bleed even from a minor cut since he or she does not possess the natural phenomenon of blood clotting due to absence of antihaemophiliac globulin or factor VIII (haemophilia - A) and plasma thromboplastin factor IX (haemophilia - B, Christmas disease) essential for it.

(4) **(C).** The phenomenon of expression of both the alleles in a heterozygote is called codominance. Alleles for blood group A(I^A) and B(I^B) are codominant so when they come together in an individual, they produce blood group AB characterized by presence of both antigens A and B over the surface of erythrocytes.

(5) **(D).** The two genes that show 50% recombinant frequency are tightly linked. These are called linked genes. Linked genes occur in same chromosome and lie in a linear sequence.

(6) **(B).** Dominant epistasis is the phenomenon of masking or supressing the expression of a gene by a dominant non-allelic gene. eg, fruit colour in *Cucurbita pepo* (Summer squash)

(7) **(C).**



50% of male children of this couple will be colour blind.

(8) **(A).** Turner's syndrome is caused due to the absence of one of the X chromosomes i.e. 45 with XO
(or 44+ XO).

(9) **(A).** Genes are the units of inheritance and contain the information that is required to express a particular trait in an organism. Alternating forms of a single gene which code for a pair of contrasting traits are known as alleles. for example, two alleles determine the height of pea plant (tall and dwarf).

(10) **(A).**

(11) **(A).** ♂ I^AI^O ♀ I^BI^O

♀ \ ♂	I^A	I^O
I^B	I^AI^B	I^BI^O
I^O	I^AI^O	I^OI^O

Blood of offsprings may be A, B, AB, O

(12) **(B).** Characters studied by Mendel are given as :

	Trait studied	Dominant	Recessive
1	Plant height	Tall (T)	Dwarf(t)
2	Flower position	Axial (A)	Terminal (a)
3	Pod colour	Green (G)	Yellow (g)
4	Pod shape	Full or inflated (I)	Constricted (i)
5	Flower colour	Violet (V)	White (v)
6	Seed shape	Round (R)	Wrinkled (R)
7	Seed colour	Yellow (Y)	Green (y)

(13) **(D).** Formation of an abnormal ova usually occurs as an event during the formation of reproductive cells.

An error in cell division called non-disjunction can result in reproductive cells with additional chromosomes. Any of these cells if contributes in the genetic make up of child leads to trisomy of X-chromosome i.e. the child will have an extra X-chromosome. ZZ + XX in mother will lead to birth of a XXX genotype baby

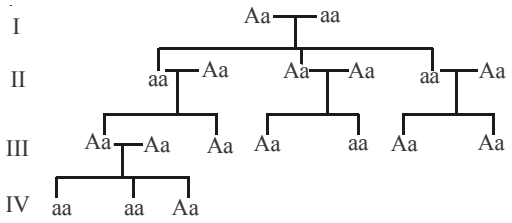
(14) **(B).** Both alleles are independently expressed in heterozygote during codominance.

(15) **(D).** Pod length did not use by mendel for his experiment.

(16) **(C).** Father (Colourblind) → Daughter (Carrier) → Grandson [50% Probability (0.5)]

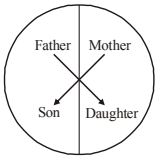
(17) **(B).** The gene which controls multiple traits in an individual.

(18) **(A).** The given pedigree represents inheritance of Autosomal recessive trait

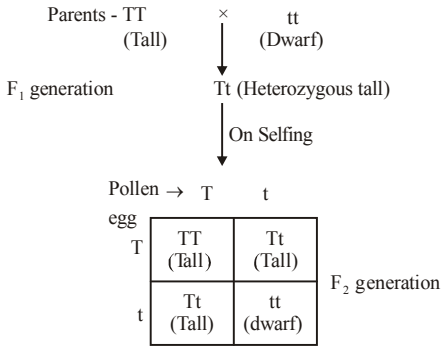


(19) **(C).** The term "linkage" was coined by T.H. Morgan.

(20) **(B).** Haemophilia is X-linked recessive gene disorder. It is a blood clotting disorder and shows criss-cross inheritance.



(21) **(A).**



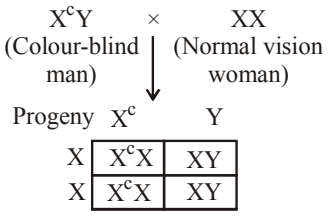
Phenotypic ratio = 3 : 1 [Tall : Dwarf]
Genotypic ratio ⇒ 1 : 2 : 1
[Homozygous tall : Heterozygous tall : Dwarf]

(22) **(B).** Dominance - Expression of only one allele in heterozygous organism.
Codominance - Side by side full expression of both alleles. F_1 resembles both parents.
Pleiotropy - Single gene can exhibit multiple phenotypic expression e.g., Phenyl ketonuria.
Polygenic inheritance - Many genes govern a single character e.g., Human skin colour.

(23) **(D).** Sickle cell anaemia is autosomal recessive gene disorder.

(24) **(C).** When two genes in a dihybrid cross are situated on the same chromosome, the proportion of parental gene combinations are much higher than the nonparental or recombinant type.

(25) **(A).** Colourblindness is X-linked recessive disease and shows criss-cross inheritance.



100% - carrier daughters (Phenotypically normal)
100% - Normal son

(26) **(A).** Down's syndrome is caused by non-disjunction of 21st chromosome.

(27) **(C).** Thalassemia differs from sickle-cell anaemia in that the former is a quantitative problem of synthesising too few globin molecules while the latter is a qualitative problem of synthesising an incorrectly functioning globin.

(28) **(A).** Mendel conducted hybridization experiments on Pea plant for 7 years between 1856 to 1863 and his data was published in 1865.

(29) **(C).**

♀ \ ♂	I^A	I^B
I^A	I^AI^A	I^AI^B
i	I^Ai	I^Bi

Number of genotypes = 4
Number of phenotypes = 3
I^AI^A and I^Ai = A
I^AI^B = AB ; I^Bi = B

(30) **(B).** During his experiments Mendel studied seven characters.
Nature of trichomes i.e., glandular or non-glandular was not considered by Mendel.

(31) **(C).** Ribozyme is a catalytic RNA, which is nucleic acid.

(32) **(C).** Starch synthesis in pea is controlled by pleiotropic gene.
Other options (A, B & D) are correctly matched.

(33) **(B).** Punnett square was developed by a British geneticist, Reginald C. Punnett.
– Franklin Stahl proved semi-conservative mode of replication.
– Transduction was discovered by Zinder and Laderberg.
– Spliceosome formation is part of posttranscriptional change in Eukaryotes.

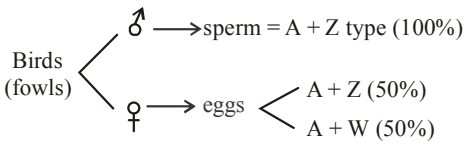
(34) **(D).** Woman is a carrier
Both son & daughter inherit X–chromosome
Although only son be the diseased.

(35) **(D).** Polytene chromosomes are found in salivary glands of insects of order Diptera.

(36) **(B).** I^AI^O, I^BI^O - Dominant–recessive relationship
I^AI^B - Codominance
I^A, I^B & I^O - 3-different allelic forms of a gene (multiple allelism).

(37) **(B).** Progressive degeneration of skeletal muscle mostly due to genetic disorder is muscular dystrophy where as tetany is muscular spasm due to low calcium in body fluid. Myasthenia gravis is an anto immume disorder leading to paralysis of skeletal muscles. Botulism is rare and dangerous type of food poisoning caused by bacterium *Clostridium Botulinum*.

(38) **(C).** In birds female heterogamety is found thus sex of progeny depends on the types of egg rather than the type of sperm. eg.



(39) **(C).** 1 map unit represent 1 % cross over.
Map unit is used to measure genetic distance.
This genetic distance is based on average number of cross over frequency.

(40) **(D).** Genes for flower colour in snapdragon shows incomplete dominance which is an exception of Mendel's first principle i.e. Law of dominance. Whereas Law of segregation is universally applicable.

(41) **(C).** Frequency of dominant allele (say p) = 0.4
Frequency of recessive allele (say q)
$= 1 - 0.4 = 0.6$
Frequency of homozygous dominant individuals (AA) $= p^2 = (0.4)^2 = 0.16$
Frequency of heterozygous individuals (Aa)
$= 2pq = 2\ (0.4)\ (0.6) = 0.48$
Frequency of homozygous recessive individuals (aa) $= q^2 = (0.6)^2 = 0.36$

(42) **(C).** Alfred Sturtevant explained chromosomal mapping on the basis of recombination frequency which is directly proportional to distance between two genes on same chromosome.

(43) **(B).** Individuals with Klinefelter's syndrome have trisomy of sex chromosome as 44 + XXY (47). They show overall masculine development, gynaecomastia and are sterile.