

Class: 12th

Subject: Biology

Chapter 22: VARIATION AND GENETICS

Important MCQs:

1. The basic unit of biological information is:

(a) Chromosome

(b) Gene

(c) Protein

(d) Trait

2. The position of a gene on the chromosome is called its:

(a) Allele

(b) Phenotype



(c) Locus

(d) Genotype

3. The physical appearance of a trait is called its:

(a) Genotype

(b) Phenotype

(c) Allele

(d) Gene pool

4. A red or white flower represents:

(a) Two genotypes

(b) Two phenotypes

(c) Two loci

(d) Two populations

5. Partners of a gene pair located on homologous chromosomes are called:

- (a) Traits
- (b) Loci
- (c) Alleles
- (d) Genotypes

6. Allele "R" determines:

- (a) Whiteness
- (b) Redness
- (c) Recessive trait
- (d) Mutation

7. A population that interbreeds and exists together in time and space is called:

- (a) Family

(b) Gene pool

(c) Population

(d) Trait group

8. The total genetic information in a breeding population at a given time is called:

(a) Genome

(b) Gene pool

(c) Chromatin

(d) Phenotype



9. The concept of “beanbag genetics” is used to explain:

(a) Crossing over

(b) Gene pool

(c) DNA replication

(d) Mutation process

10. Jumping genes are those which:

(a) Remain fixed on one locus

(b) Move from one locus to another

(c) Are found only in plants

(d) Never express themselves

11. The founder of classical genetics was:

(a) Charles Darwin

(b) Gregor Johann Mendel

(c) Thomas Morgan

(d) Watson and Crick

12. Mendel performed his experiments on:

(a) Sunflower

(b) Garden pea (*Pisum sativum*)

(c) Wheat

(d) Corn

13. The law of segregation and law of independent assortment were given by:

(a) Charles Darwin

(b) Mendel

(c) Lamarck

(d) Hugo de Vries



14. In Mendel's monohybrid cross, the F_1 generation showed:

(a) Both parental traits

(b) Only dominant trait

(c) Only recessive trait

(d) Intermediate traits

15. The phenotypic ratio of F_2 generation in Mendel's monohybrid cross was:

(a) 1:1

(b) 3:1

(c) 2:1

(d) 9:3:3:1

16. Mendel used the term "Elementen" for:

(a) Chromosomes

(b) Hereditary factors

(c) Alleles

(d) Traits

17. The term "Gene" was first used by:

-
- (a) Gregor Mendel
- (b) Johannsen
- (c) Darwin
- (d) Morgan

18. Hereditary factors are transmitted from parents to offspring through:

- (a) Blood
- (b) Gametes
- (c) Cytoplasm
- (d) Chromosomes



19. A true-breeding round seed plant has the genotype:

- (a) rr
- (b) RR

(c) Rr

(d) R

20. A true-breeding wrinkled seed plant has the genotype:

(a) RR

(b) Rr

(c) rr

(d) R

21. When both alleles of a gene pair are the same, the organism is called:

(a) Heterozygous

(b) Homozygous

(c) Dominant

(d) Hybrid

22. When both alleles of a gene pair are different, the organism is:

- (a) Homozygote
- (b) Heterozygote**
- (c) Recessive
- (d) Dominant

23. The genotype of F₁ generation in Mendel's monohybrid cross is:

- (a) RR
- (b) Rr**
- (c) rr
- (d) None

24. The phenotype of F₁ generation in Mendel's experiment was:

- (a) Wrinkled

(b) Round

(c) Mixed

(d) Intermediate

25. In a dihybrid cross, Mendel studied the inheritance of:

(a) One trait

(b) Two traits simultaneously

(c) Three traits

(d) Four traits

26. In Mendel's dihybrid cross, the F_2 generation showed a phenotypic ratio of:

(a) 3:1

(b) 9:3:3:1

(c) 1:2:1

(d) 1:1

27. The new phenotypic combinations (round green and wrinkled yellow) in F_2 were due to:

(a) Mutation

(b) Independent assortment of alleles

(c) Segregation of alleles

(d) Linkage

28. The law derived from the dihybrid cross is called:

(a) Law of Segregation

(b) Law of Independent Assortment

(c) Law of Dominance

(d) Law of Probability

29. In a dihybrid cross, four types of gametes (RY, Ry, rY, ry) are produced in the ratio of:

- (a) 3:1
- (b) 1:1:1:1
- (c) 9:3:3:1
- (d) 2:1:1

30. Independent assortment occurs only when genes are located on:

- (a) Same chromosome
- (b) Non-homologous chromosomes
- (c) Homologous chromosomes
- (d) Linked loci

31. The principle used to calculate combined probabilities of independent events is called:

- (a) Product rule
- (b) Law of dominance

(c) Test cross

(d) Cross fertilization

32. When one allele completely hides the effect of another, it is called:

(a) Codominance

(b) Incomplete dominance

(c) Complete dominance

(d) Over dominance

33. Incomplete dominance was discovered by:

(a) Mendel

(b) Carl Correns

(c) Morgan

(d) De Vries

34. In codominance, the phenotype of heterozygote:

- (a) Is intermediate between parents
- (b) Shows both alleles equally expressed**
- (c) Shows only the dominant allele
- (d) Shows blending of traits

35. The MN blood group system was discovered by:

- (a) Karl Landsteiner and Weiner
- (b) Landsteiner and Levine**
- (c) Bernstein and Morgan
- (d) Mendel and De Vries

36. The M phenotype in humans has which antigen on RBCs?

- (a) N antigen
- (b) Both M and N antigens**

(c) M antigen

(d) No antigen

37. A person with MN blood group has which genotype?

(a) LM LM

(b) LN LN

(c) LM LN

(d) None of these

38. In the MN blood group system, the M and N alleles show:

(a) Complete dominance

(b) Recessiveness

(c) Codominance

(d) Incomplete dominance

39. When a man with M blood group marries a woman with N blood group, the children will have:

- (a) M blood group
- (b) N blood group
- (c) MN blood group
- (d) All of the above

40. Overdominance refers to:

- (a) Homozygote being superior
- (b) Heterozygote exceeding both homozygotes in phenotype
- (c) Codominant alleles expressing equally
- (d) Mutation of alleles

41. In fruit fly *Drosophila*, overdominance is shown by:

- (a) Eye shape

(b) Wing size

(c) Fluorescent pigment quantity

(d) Body color

42. The ABO blood group system was discovered by:

(a) Levine

(b) Bernstein

(c) Karl Landsteiner

(d) Morgan

43. The gene controlling the ABO blood group system is located on:

(a) Chromosome 7

(b) Chromosome 9

(c) Chromosome 11

(d) Chromosome 19

44. In ABO blood groups, alleles I^A and I^B are:

(a) Dominant to each other

(b) Recessive to each other

(c) Codominant to each other

(d) Mutually exclusive

45. A person with genotype $I^A i$ has which blood group?

(a) A

(b) B

(c) AB

(d) O

46. The blood group O individual has:

(a) Both A and B antigens

-
- (b) Only A antigen
 - (c) Only B antigen
 - (d) No antigen

47. Blood group O individuals are called universal:

- (a) Recipients
- (b) Donors
- (c) Agglutinators
- (d) Secretors



48. A person with blood group AB is known as:

- (a) Universal donor
- (b) Universal recipient
- (c) Secretor
- (d) Agglutinator

49. The gene responsible for secretion of blood group antigens in saliva is:

- (a) IA
- (b) IB
- (c) i
- (d) Se

50. The Rh blood group system was named after:

- (a) Rabbit
- (b) Rhesus monkey
- (c) Rat
- (d) Rhinoceros

51. The Rh factor was first discovered by Landsteiner in the:

- (a) 1920s

(b) 1930s

(c) 1940s

(d) 1950s

52. The Rh blood group system is controlled by how many genes?

(a) One

(b) Two

(c) Three

(d) Four



53. The most important gene locus in the Rh blood group system is:

(a) C locus

(b) E locus

(c) D locus

(d) F locus

54. Persons with genotype DD or Dd are:

(a) Rh-

(b) Rh+

(c) ABO-

(d) Codominant

55. A person with genotype dd will have which Rh type?

(a) Rh+

(b) Rh-

(c) Both

(d) None of these

56. Anti-Rh antibodies are produced:

(a) Naturally at birth

(b) Only after exposure to Rh antigen

(c) Only in Rh+ individuals

(d) Never

57. The disease caused by maternal–foetal Rh incompatibility is:

(a) Anaemia

(b) Erythroblastosis foetalis

(c) Haemophilia

(d) Jaundice

58. In erythroblastosis foetalis, which type of mother is at risk?

(a) Rh+ mother with Rh+ baby

(b) Rh– mother with Rh+ baby

(c) Rh– mother with Rh– baby

(d) Rh+ mother with Rh- baby

59. To prevent Rh sensitization, an Rh- mother is given an injection of:

(a) Rh+ blood

(b) Rh antiserum

(c) Anti-A serum

(d) Anti-B serum

60. The phenotype of an organism results from interaction between:

(a) Genes and environment

(b) Alleles only

(c) Chromosomes only

(d) Enzymes only

61. Traits showing large and obvious differences are called:

-
- (a) Quantitative traits
 - (b) Qualitative traits**
 - (c) Polygenic traits
 - (d) Dominant traits

62. The traits showing small, gradual differences over a range are called:

- (a) Qualitative
- (b) Quantitative**
- (c) Simple
- (d) Mendelian



63. Human height, weight, and skin colour are examples of:

- (a) Discontinuous variation
- (b) Continuous variation**

(c) Dominant traits

(d) Monogenic traits

64. A continuously varying trait is controlled by:

(a) A single gene

(b) Two alleles only

(c) Two or more gene pairs

(d) One dominant allele

65. The genes controlling quantitative traits are called:

(a) Alleles

(b) Polygenes

(c) Codominant genes

(d) Recessive genes

66. Polygenic traits show:

(a) Discontinuous variation

(b) Continuous variation

(c) Single gene control

(d) Simple dominance

67. In polygenic inheritance, each gene has a:

(a) Large effect

(b) Small additive effect

(c) No effect

(d) Recessive effect

68. The colour of wheat grains shows:

(a) Discontinuous variation

(b) Continuous variation

(c) Codominance

(d) Epistasis

69. Nilsson-Ehle studied the genetics of:

(a) Human height

(b) Wheat grain colour

(c) Skin colour

(d) Eye colour

70. In Nilsson-Ehle's experiment, crossing dark red and white wheat gave F_1 grains that were:

(a) White

(b) Red

(c) Light red

(d) Pink

71. Wheat grain colour is controlled by how many gene pairs?

-
- (a) One
 - (b) Two
 - (c) Three
 - (d) Four

72. In wheat grain colour, alleles A, B, and C produce:

- (a) White pigment
- (b) Red pigment
- (c) No pigment
- (d) Yellow pigment



73. A plant with genotype AABBCC will produce:

- (a) White grains
- (b) Dark red grains
- (c) Light pink grains

(d) Pink grains

74. The genotype aabbcc produces which phenotype?

(a) Light red

(b) White

(c) Pink

(d) Dark red

75. The phenotype of polygenic traits depends on:

(a) Only genes

(b) Only environment

(c) Both genes and environment

(d) Mutations only

76. Human skin colour depends on the number of:

(a) Chromosomes

(b) Pigment-producing genes

(c) Dominant alleles only

(d) Melanin molecules

77. The distribution curve of human height forms a:

(a) Flat line

(b) Bell-shaped curve

(c) Zigzag curve

(d) Inverted curve



78. The ability to roll the tongue is an example of:

(a) Continuous variation

(b) Discontinuous variation

(c) Polygenic trait

(d) Quantitative trait

79. The frequency diagram of human height shows:

- (a) Two separate peaks
- (b) Smooth bell-shaped curve**
- (c) Straight line
- (d) Uneven steps

80. The phenomenon of genes located on the same chromosome staying together is called:

- (a) Mutation
- (b) Linkage**
- (c) Segregation
- (d) Recombination

81. Gene linkage represents a _____ between genes.

- (a) Functional relationship

(b) Physical relationship

(c) Chemical reaction

(d) Temporary bond

82. The number of linkage groups in humans is:

(a) 22

(b) 23

(c) 24

(d) 46



83. Genes for colour blindness, haemophilia, and gout form a linkage group on:

(a) Chromosome 11

(b) Chromosome X

(c) Chromosome Y

(d) Chromosome 9

84. Linked genes do not obey which of Mendel's laws?

(a) Law of dominance

(b) Law of segregation

(c) Law of independent assortment

(d) Law of purity of gametes

85. The exchange of segments between non-sister chromatids of homologous chromosomes is called:

(a) Mutation

(b) Crossing over

(c) Linkage

(d) Replication

86. The closer two genes are on a chromosome, the:

-
- (a) Higher the recombination frequency
 - (b) Stronger the linkage
 - (c) Greater the mutation rate
 - (d) Weaker the linkage

87. Recombination frequency is directly proportional to:

- (a) Chromosome number
- (b) Distance between linked genes
- (c) Mutation rate
- (d) Number of alleles

88. If two linked genes show 20% recombination frequency, they are how many map units apart?

- (a) 2 units
- (b) 10 units

(c) 20 units

(d) 40 units

89. Crossing over is important because it:

(a) Reduces variation

(b) Increases genetic variation

(c) Destroys chromosomes

(d) Produces identical offspring

90. The XO-XX type of sex determination is found in:

(a) Man

(b) Drosophila

(c) Grasshopper

(d) Bird

91. In XO-XX system, the male is:

-
- (a) XX
 - (b) XO
 - (c) XY
 - (d) YY

92. In XO-XX type, the male is called heterogametic because:

- (a) It forms only one type of gamete
- (b) It forms two types of sperms
- (c) It has two X chromosomes
- (d) It produces only female offspring

93. A gamete without any sex chromosome is known as:

- (a) Null gamete
- (b) Fertile gamete
- (c) Mutant gamete

(d) Recessive gamete

94. In *Drosophila*, the male is:

(a) XX

(b) XY

(c) XO

(d) ZZ

95. In humans, the male has:

(a) XX chromosomes

(b) XY chromosomes

(c) YY chromosomes

(d) XO chromosomes

96. The sex of the offspring in humans is determined by:

(a) Mother's egg

(b) Father's sperm

(c) Both equally

(d) Environment

97. In birds, butterflies, and moths, the sex determination system is:

(a) XY-XX

(b) ZZ-ZW

(c) XO-XX

(d) XX-YY



98. In ZZ-ZW type, female is:

(a) ZZ

(b) ZW

(c) XY

(d) Xz

99. In birds, the sex of offspring is determined by:

(a) The sperm

(b) The egg

(c) Both equally

(d) Environmental factors

100. In *Drosophila*, sex depends on:

(a) Presence of Y chromosome

(b) X to autosome ratio

(c) Number of chromosomes

(d) Hormones

101. In humans, SRY gene determines maleness. It is located on:

(a) X chromosome

(b) Y chromosome

(c) 11th chromosome

(d) Z chromosome

102. In humans, XO condition produces:

(a) Klinefelter's male

(b) Turner's female

(c) Normal male

(d) Normal female



103. In Drosophila, XO individual is:

(a) Female

(b) Sterile male

(c) Fertile male

(d) Normal female

104. In humans, XXY individual is known as:

(a) Turner's syndrome

(b) Klinefelter's syndrome

(c) Down's syndrome

(d) Edwards syndrome

105. In Drosophila, XXY individual is:

(a) Sterile male

(b) Fertile female

(c) Sterile female

(d) Normal male

106. In plants like Ginkgo, male and female flowers occur on separate plants. Such plants are called:

-
- (a) Monoecious
 - (b) Dioecious
 - (c) Bisexual
 - (d) Asexual

107. In dioecious plants, sex determination is often based on:

- (a) Environmental factors
- (b) X-Y chromosome system
- (c) Hormonal balance
- (d) Genetic recombination

108. Correns (1907) discovered that in certain plants, sex is determined by:

- (a) Egg
- (b) Pollen

(c) Temperature

(d) Water

109. In yeast, sex determination depends on:

(a) X and Y chromosomes

(b) Simple allelic differences

(c) Hormones

(d) Environmental cues



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110. The white-eyed trait in Drosophila was first discovered by:

(a) Calvin Bridges

(b) T.H. Morgan

(c) Mendel

(d) Correns

111. The gene for eye colour in Drosophila is located on:

- (a) Y chromosome
- (b) X chromosome**
- (c) Autosomes
- (d) Both X and Y chromosomes

112. male Drosophila with one X and one Y chromosome is called:

- (a) Diploidnk
- (b) Hemizygous**
- (c) Heterozygous
- (d) Homozygou

113. The reciprocal cross between a white-eyed female and a red-eyed male in Drosophila produced:

- (a) All red-eyed males

(b) All red-eyed females

(c) All white-eyed females

(d) All white-eyed male

114. A gene present only on X chromosome with no counterpart on Y is called:

(a) Autosomal gene

(b) X-linked gene

(c) Pseudoautosomal gene

(d) Y-linked gene

115. X-linked traits are inherited in:

(a) Direct father-to-son manner

(b) Crisscross pattern

(c) From mother to all sons

(d) From both parents equally

116. Y-linked traits are transmitted:

(a) From father to son only

(b) From mother to daughter

(c) From both parents

(d) From father to daughter

117. Example of a Y-linked gene in humans is:

(a) Colour blindness

(b) Haemophilia

(c) SRY gene

(d) Opsin gene

118. Genes found on both X and Y chromosomes are known as:

- (a) X-linked genes
- (b) Y-linked genes
- (c) Pseudoautosomal genes
- (d) Autosomal genes

119. Haemophilia is caused due to:

- (a) Dominant autosomal gene
- (b) Recessive X-linked gene
- (c) Y-linked gene
- (d) Polygenic inheritance

120. Haemophilia A is caused by abnormality of:

- (a) Factor IX
- (b) Factor VIII
- (c) Factor XI

(d) Factor X

121. Haemophilia B is caused by defect in:

(a) Factor VIII

(b) Factor IX

(c) Factor XI

(d) Factor VII

122. Haemophilia C differs from A and B because it is:

(a) X-linked dominant

(b) Autosomal recessive

(c) Autosomal dominant

(d) Y-linked

123. Colour blindness is more common in males because:

(a) They have two X chromosomes

(b) They have one X chromosome

(c) They lack Y chromosome

(d) It is an autosomal trait

124. Red-green colour blindness is caused by mutation in genes for:

(a) Opsins on X chromosome

(b) Enzymes on Y chromosome

(c) Proteins on autosome 7

(d) Hormones on chromosome 11

125. Testicular feminization syndrome is a result of:

(a) Excess testosterone

(b) Androgen insensitivity

(c) Lack of estrogen

(d) Mutation in Y-linked gene

126. Hypophosphatemic rickets is an example of:

(a) X-linked recessive

(b) X-linked dominant

(c) Y-linked

(d) Autosomal dominant

127. Pattern baldness is an example of:

(a) Sex-limited trait

(b) Sex-influenced trait

(c) Autosomal dominant

(d) X-linked trait

128. MODY (Maturity Onset Diabetes of the Young) is caused by mutation in:

(a) Glucokinase gene ✓

(b) Insulin receptor gene

(c) Factor IX gene

(d) SRY gene

Q2: Exercise Short Questions

(i) **Phenotype and Genotype**

Answer:

Phenotype: The observable traits or characteristics of an organism, such as eye color, height, or flower color. It is the physical expression of genes.

Genotype: The genetic makeup or allelic combination of an organism that determines a trait, e.g., AA, Aa, or aa.

(ii) **Homozygous and Heterozygous**

Answer:

Homozygous: An individual has two identical alleles for a gene (AA or aa). Both alleles contribute the same trait.

Heterozygous: An individual has two different alleles for a gene (Aa). The dominant allele usually masks the recessive allele.

(iii) Autosome and Sex Chromosome

Answer:

Autosome: Any chromosome that does not determine sex. Humans have 22 pairs of autosomes.

Sex Chromosome: Chromosome that determines sex (X or Y in humans). Females have XX, males have XY.

Explanation: **Autosomes** carry most genes unrelated to sex, while **sex chromosomes** determine male or female characteristics.

(iv) Allele and Multiple Allele

Answer:

Allele: Alternative form of a gene at the same locus (e.g., A or a).

Multiple Allele: More than two allelic forms of a gene exist in a population (e.g., ABO blood group system: IA, IB, i).

Explanation: Allele = single variant; Multiple alleles = many variants possible for a single trait.

(v) Incomplete Dominance and Codominance

Answer:

Incomplete Dominance: Heterozygote shows a blending of two alleles (e.g., red × white → pink flowers).

Codominance: Both alleles in heterozygote are fully expressed without blending (e.g., AB blood group shows both A and B antigens).

Explanation: Incomplete dominance = mixture of traits; Codominance = both traits fully visible.

(vi) Continuous and Discontinuous Variations

Answer:

Continuous Variation: Traits show a range of intermediate forms (e.g., human height, skin color).

Discontinuous Variation: Traits appear in distinct, separate categories with no intermediates (e.g., blood groups, tongue rolling).

Explanation: **Continuous** = gradual spectrum; **Discontinuous** = distinct categories only.

(vii) Gene and Allele

Answer:

Gene: A segment of DNA that codes for a specific trait or protein. **Example:** gene for flower color.

Allele: Different forms of the same gene found at the same locus on homologous chromosomes. **Example:** A (red) and a (white) are alleles of the flower color gene.

(viii) Monohybrid and Dihybrid

Answer:

Monohybrid: Cross between parents differing in one trait only. Example: AA × aa for seed shape.

Dihybrid: Cross between parents differing in two traits. Example: AaBb × AaBb for seed shape and seed color.

Explanation: **Monohybrid** = single trait; **Dihybrid** = two traits simultaneously.

(ix) Dominance and Epistasis

Answer:

Dominance: One allele masks the expression of another allele at the same locus. Example: In Aa, A is dominant and a is recessive.

Epistasis: An allele of one gene masks the expression of another gene at a different locus. Example: In labrador coat color, the E gene masks B/b gene effect.

Explanation: Dominance = within same gene; Epistasis = between different genes.

(x) X-linked trait and Y-linked trait

Answer:

X-linked trait: Gene is located on X chromosome. **Example:** hemophilia, red-green color blindness.

Y-linked trait: Gene is located on Y chromosome and appears only in males. **Example:** SRY gene determines maleness.

Explanation: X-linked = may appear in both sexes, more in males; Y-linked = only in males.

(xi) Sex-limited and Sex-influenced trait

Answer:

Sex-limited trait: Expressed in only one sex due to anatomical differences. **Example:** Milk production in cows, beard growth in men.

Sex-influenced trait: Expressed in both sexes but dominant in one and recessive in the other due to hormones. **Example:** Pattern baldness (dominant in males, recessive in females).

Explanation: **Limited** = appears in one sex only; **Influenced** = appears in both, expression differs by sex.

(xii) Dominant trait and Recessive trait

Answer:

Dominant trait: Expressed even if only one allele is present (heterozygous or homozygous). **Example:** Red flower in Aa.

Recessive trait: Expressed only when both alleles are recessive (homozygous recessive). **Example:** White flower in aa.

Explanation: Dominant hides recessive; recessive shows only if dominant absent.

(xiii) Wild type and Mutant

Answer:

Wild type: The normal, most common phenotype in natural populations. **Example:** Red-eyed Drosophila.

Mutant: Any variation that differs from the wild type due to mutation. **Example:** White-eyed Drosophila.

Explanation: Wild type = standard/normal form; Mutant = altered form due to genetic change.

2. What is a gene pool?

Answer:

A gene pool is the total set of all genes and their different alleles present in a population of a species at a given time.

Explanation: It represents the genetic diversity of a population, and the variation within it provides raw material for evolution and adaptation.

3. Was pea a lucky choice for Mendel? What would have happened if he had studied an eighth character?

Answer:

- Yes, the pea was a lucky choice because it has easily distinguishable traits, short generation time, and can be self- or cross-pollinated.
- If Mendel had studied an eighth character, the dihybrid and trihybrid ratios would have been more complex, making it difficult for him to detect clear patterns of inheritance. His simplicity in choosing seven characters allowed him to observe Mendelian ratios clearly.

4. What is a test cross? Why did Mendel devise this cross?

Answer:

- A test cross is the mating of an individual showing a dominant phenotype (unknown genotype) with a homozygous recessive individual for the same trait.
- **Purpose:** Mendel devised this to determine the genotype of the dominant phenotype, whether it is homozygous dominant or heterozygous.

5. What would happen if alleles of a pair do not segregate at meiosis? How would it affect the purity of gamete?

Answer:

- If alleles of a pair do not segregate (non-disjunction), gametes would not be pure. Some gametes may carry both alleles or no allele for a trait, instead of just one.
- **Effect:** This would violate Mendel's law of segregation and could produce abnormal zygotes or unexpected phenotypes in offspring.

6. If the alleles do not assort independently, which type of combination is missing in the progeny?

Answer:

If alleles do not assort independently, some recombinant combinations are missing.

Explanation: Only parental allele combinations are produced, while combinations that would arise from independent assortment (new allele pairings) do not appear. This happens in linked genes on the same chromosome.

7. Why has each gamete equal chance of getting one or the other allele of a pair?

Answer:

During meiosis, homologous chromosomes separate randomly. Each gamete receives one allele from each gene pair, giving all gametes an equal 50% chance of inheriting either allele.

Explanation: This is the physical basis of Mendel's law of segregation.

8. Does the dominant allele modify the determinative nature of its recessive partner?**Answer:**

No, the dominant allele does not alter the nature of the recessive allele.

Explanation: The recessive allele remains the same, but its expression is masked in heterozygous condition. It can still be passed to the next generation unchanged.

9. What sort of relationship do they have?**Answer:**

Linked genes have a physical relationship because they are located on the same chromosome and tend to be inherited together.

Explanation: The closer the genes are on a chromosome, the stronger their linkage and the less likely they are to separate during meiosis.

10. Which type of traits can assort independently?

Answer:

Traits whose genes are located on different chromosomes or are far apart on the same chromosome can assort independently.

Explanation: These genes follow Mendel's law of independent assortment during gamete formation.

11. Why does the blood group phenotype of a person remain constant throughout life?

Answer:

Blood group phenotype remains constant because the genes controlling blood groups are fixed and do not change after birth.

Explanation: ABO blood group alleles (A, B, O) are autosomal and inherited, and their expression does not vary with age.

12. What is a universal blood donor?

Answer:

A person with O negative (O-) blood group is a universal blood donor.

Explanation: Their red blood cells lack A, B, and Rh antigens, so they can be safely transfused to any recipient without causing an immune reaction.

13. How can you protect the baby against Rh-incompatibility?

Answer:

The baby can be protected by giving the Rh-negative mother an injection of anti-Rh antibodies (Rho(D) immune globulin) during pregnancy and after delivery.

Explanation: This prevents the mother from producing antibodies against Rh-positive fetal blood cells, avoiding hemolytic disease of the newborn.

14. Which type of genes do not obey law of independent assortment?

Answer:

Linked genes do not obey the law of independent assortment because they are located on the same chromosome and are inherited together.

15. How can linked genes be separated from each other?

Answer:

Linked genes can be separated by crossing over during meiosis.

Explanation: Homologous chromosomes exchange segments at chiasmata, producing recombinant gametes with new allele combinations.

16. What is multifactorial inheritance?

Answer:

Multifactorial inheritance is when a trait is influenced by multiple genes (polygenic) and environmental factors.

Examples: Height, intelligence, susceptibility to diabetes or heart disease.

17. What is MODY?

Answer:

MODY (Maturity Onset Diabetes of the Young) is a type of diabetes that occurs at a young age (<25 years), caused by mutations in a single gene affecting insulin production.

Explanation: It is usually inherited in an autosomal dominant pattern.

18. Can a child have more intelligence (IQ score) than his parents?

Answer:

Yes, a child can have a higher IQ than parents due to polygenic inheritance and environmental influences such as education, nutrition, and stimulation.

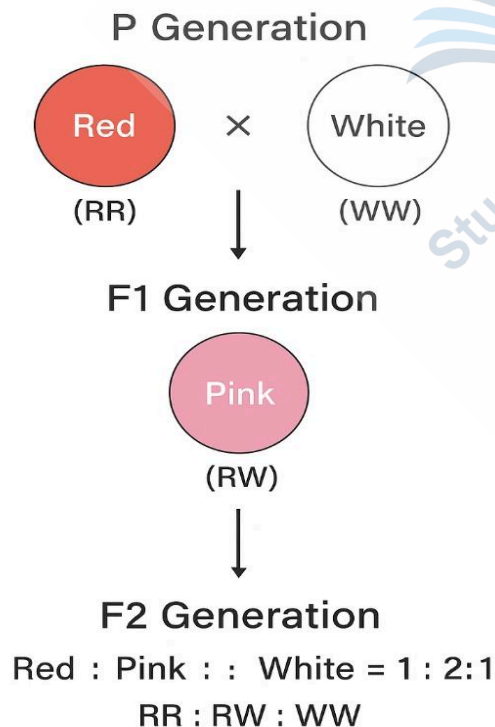
Explanation: Intelligence is a multifactorial trait, so both genes and environment contribute to the final IQ.

Q4: Extensive Questions

☀ Q1: What is incomplete dominance? Explain it with an example.

❖ **Definition:**

Incomplete dominance is a type of genetic inheritance where the heterozygous offspring shows a phenotype that is intermediate between the phenotypes of the two homozygous parents. In other words, neither allele completely dominates the other, so the traits “blend” in the offspring.



◆ **Key Features of Incomplete Dominance:**

1. Heterozygote exhibits a blended or intermediate trait.
2. No allele is completely dominant over the other.
3. F₂ generation shows 1:2:1 ratio both phenotypically and genotypically.
4. It is different from complete dominance, where the dominant allele completely masks the recessive allele.

Example:

Flower color in Snapdragon (*Antirrhinum majus*):

Parental generation (P):

- Red flowers (RR) × White flowers (WW)

F₁ generation (heterozygotes):

- All offspring are pink (RW) → intermediate between red and white.

F₂ generation (F₁ × F₁):

- **Cross:** RW × RW

Offspring genotypes and phenotypes:

Explanation:

- Each allele contributes partially to the phenotype.
- Pink color is blend of red and white.

This demonstrates the principle of incomplete dominance, where heterozygotes have a unique intermediate trait.

✨ **Q2: Define Mendel's Law of Segregation. Explain it with an example.**

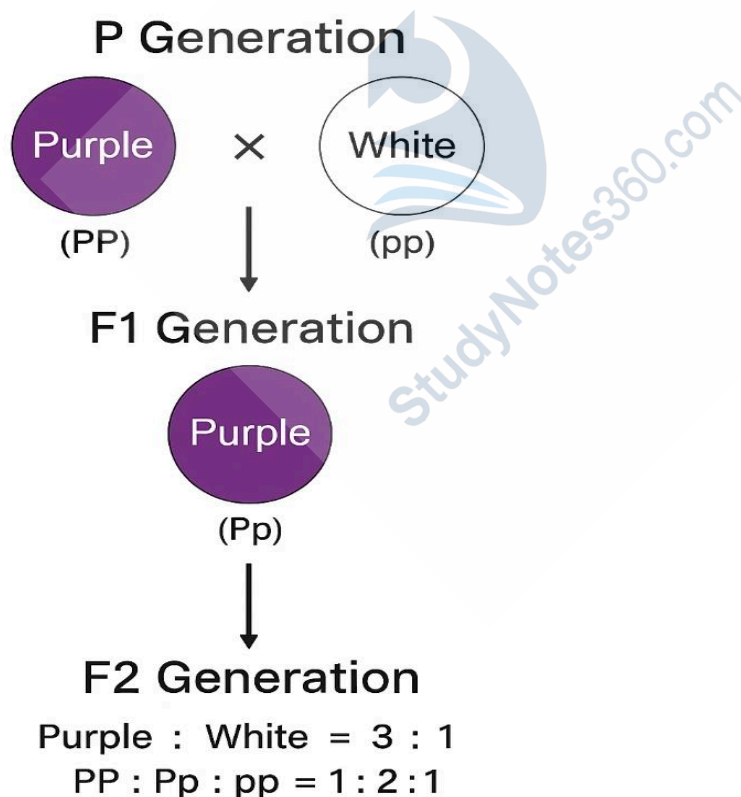
❖ **Definition:**

Mendel's Law of Segregation states that each individual has two alleles for a trait, which segregate (separate) during gamete formation, so that each gamete receives only one allele. Upon fertilization, the offspring inherits one allele from each parent, restoring the pair of alleles.

◆ **Key Points:**

1. Organisms have two alleles for each trait (homozygous or heterozygous).

2. During meiosis, these alleles segregate into separate gametes.
3. Each gamete receives only one allele.
4. Fertilization restores the two-allele condition in offspring.
5. Explains why offspring may show both dominant and recessive traits.



Example:

Flower color in pea plants (Mendel's experiment):

Parental generation (P):

- Purple flowers (PP) × White flowers (pp)

F1 generation:

All offspring are heterozygous (Pp) → show purple flowers (dominant trait).

F2 generation (F1 × F1):

- **Cross:** Pp × Pp
- Punnett square:

 **Gametes**

P p

P | PP | Pp |

p | Pp | pp |

Genotypic ratio (F2): 1 PP : 2 Pp : 1 pp

Phenotypic ratio (F2): 3 Purple : 1 White

Explanation:

- Each gamete receives only one allele (P or p) from the parent.
- The F2 generation shows both homozygous and heterozygous combinations.
- This law explains the predictable pattern of inheritance of dominant and recessive traits.

★ Q3: Define Mendel's Law of Independent Assortment. Explain it with an Example.

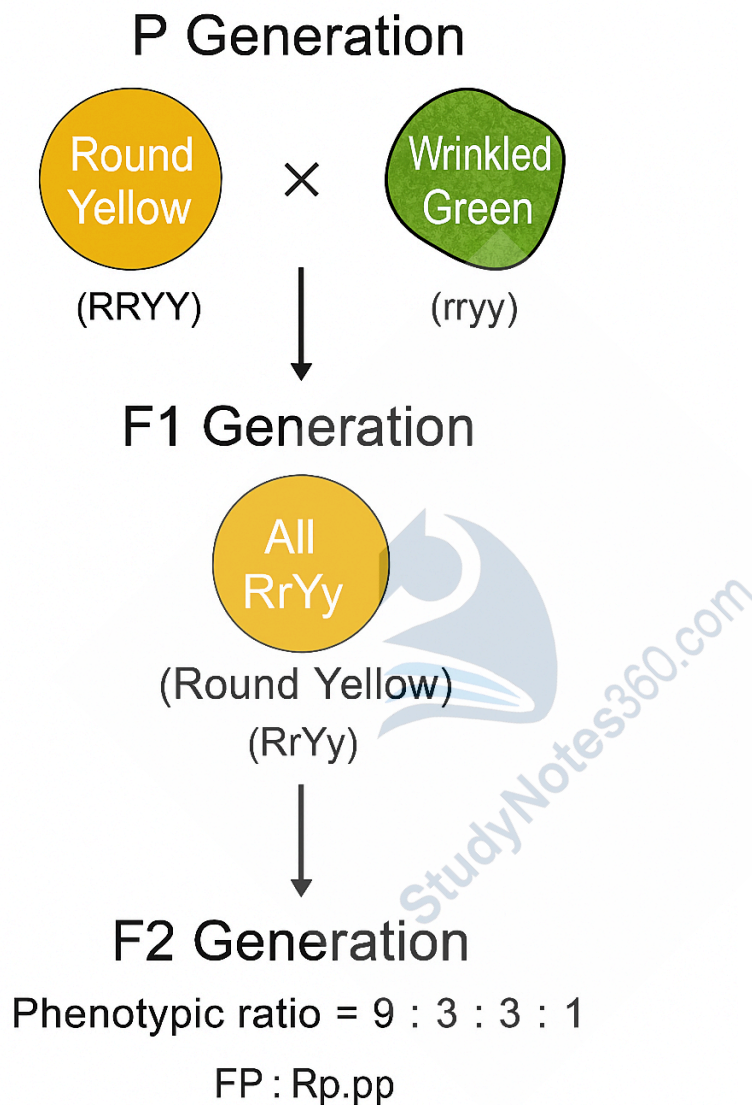
❖ Definition:

Mendel's Law of Independent Assortment states that:

> "Alleles of different genes segregate independently of each other during gamete formation."

This means the inheritance of one trait does not affect the inheritance of another trait, provided the genes are on

different chromosomes or are far apart on the same chromosome.



◆ **Key Points to Remember:**

1. Applies when studying two or more traits simultaneously.

2. Each pair of alleles segregates independently during meiosis.
3. Leads to new combinations of traits in the offspring (genetic variation).
4. Produces predictable phenotypic ratios, like 9:3:3:1 in a dihybrid cross.

Example:

Traits in Pea Plant:

- **Seed Shape:** Round (R) is dominant, Wrinkled (r) is recessive
- **Seed Color:** Yellow (Y) is dominant, Green (y) is recessive

Parental Generation (P):

- Round Yellow (RRYY) × Wrinkled Green (rryy)

F1 Generation:

- All offspring are heterozygous RrYy → Round Yellow seeds

F2 Generation (F1 × F1 cross):

- Gametes formed by F1: RY, Ry, rY, ry

Punnett square (4 × 4):

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

F2 Phenotypic Ratio:

- Round Yellow: 9
- Round Green: 3
- Wrinkled Yellow: 3
- Wrinkled Green: 1

Explanation:

- The seed shape does not influence seed color.
- Each trait is inherited independently.
- New combinations arise because different gametes combine randomly.

Important Notes:

1. Law applies only to genes on different chromosomes or far apart on the same chromosome.

2. Linked genes (genes close together on the same chromosome) do not follow this law.

★ Q4: Define probability. Derive 9:3:3:1 F₂' ratio of independent assortment through product rule.

❖ Definition:

Probability is the chance of an event occurring. In genetics, it predicts the likelihood of offspring showing a particular trait.

Formula:

Probability = Number of favorable outcomes ÷ Total number of possible outcomes

- Deriving 9:3:3:1 F₂ Ratio Using Product Rule

- **Example:** Dihybrid cross in pea plants

Traits:

- **Seed shape:** Round (R) dominant, Wrinkled (r) recessive
- **Seed color:** Yellow (Y) dominant, Green (y) recessive

Step 1: F1 Generation

- **Cross:** $RrYy \times RrYy$
- F1 offspring are heterozygous for both traits.

Step 2: Gametes

- Each parent produces four types of gametes: RY, Ry, rY, ry

Step 3: Product Rule

- Probability of a combination = Probability of one trait \times Probability of the other trait

Step 4: Probabilities for individual traits

- Round (R_{-}) = $3/4$
- Wrinkled (rr) = $1/4$
- Yellow (Y_{-}) = $3/4$
- Green (yy) = $1/4$

Step 5: Using Product Rule

- Round Yellow ($R_Y_$) = $3/4 \times 3/4 = 9/16$
- Round Green (R_yy) = $3/4 \times 1/4 = 3/16$
- Wrinkled Yellow ($rrY_$) = $1/4 \times 3/4 = 3/16$
- Wrinkled Green ($rryy$) = $1/4 \times 1/4 = 1/16$

Step 6: F2 Phenotypic Ratio

- Round Yellow = 9
- Round Green = 3
- Wrinkled Yellow = 3
- Wrinkled Green = 1

✓ Phenotypic ratio: 9 : 3 : 3 : 1

★ Q5: What is codominance? Explain the phenomenon of codominance with an example.

What is Codominance?

In codominance, neither allele is recessive, and both contribute equally and independently to the organism's traits. This differs from:

- Complete dominance, where one allele masks the other.
- Incomplete dominance, where the phenotype is a blend of both alleles.

◆ **Example:** ABO Blood Group System

One of the most well-known examples of codominance in humans is the AB blood type:

- The ABO gene has three alleles: I^A , I^B , and i .
- I^A and I^B are codominant, while i is recessive.
- If a person inherits I^A from one parent and I^B from the other, their blood type is AB.
- This means both A and B antigens are expressed equally on the surface of red blood cells – not a blend, but a full expression of both traits.

★ **Q6: Define multiple alleles. Describe multiple allelic blood group system of man.**

❖ **Definition of Multiple Alleles:**

- When a single gene exists in more than two alternative forms (alleles) in a population, these are called multiple alleles.
- Although a person can have only two alleles of a gene (one from each parent), many alleles may exist in the population for that same gene.

👉 **In short:**

> Multiple alleles are different forms of a gene that control the same trait and occupy the same locus on homologous chromosomes.

★ **Key Point:**

- Each individual = only two alleles (one from each parent).
- Population = many alleles for that gene.

Example: Human ABO blood group system – controlled by three alleles.

🔴 **Multiple Allelic Blood Group System in Humans (ABO System)**

🧬 **Discovery:**

- The ABO blood group system was discovered by Karl Landsteiner in 1901.
- It is a classic example of multiple alleles and codominance.

⚙️ **Genes and Alleles:**

- The blood group is controlled by a single gene (I) located on chromosome number 9.

This gene has three alleles:

- I^A → produces antigen A
- I^B → produces antigen B
- i → produces no antigen

Dominance Relationship:

- I^A and I^B are codominant → both express equally when together.
- i is recessive to both I^A and I^B .

Possible Genotypes and Blood Groups

- If a person has the genotype $I^A I^A$ or $I^A i$, the blood group will be A, because the antigen A is produced on the surface of red blood cells and the plasma contains anti-B antibodies.
- If a person has the genotype $I^B I^B$ or $I^B i$, the blood group will be B, with antigen B on red blood cells and anti-A antibodies in the plasma.
- If both I^A and I^B alleles are present together (genotype $I^A I^B$), the blood group will be AB, as both antigens A and B appear on red blood cells and there are no antibodies in plasma.

- If the genotype is ii , the blood group will be O, with no antigens on red blood cells but both anti-A and anti-B antibodies present in the plasma.

Importance of ABO Blood Group System:

1. It ensures safe blood transfusions by matching donor and recipient groups correctly.
2. It helps in paternity testing and population studies.
3. It demonstrates codominance and multiple allelism in genetics.

◆ **Summary:**

- Multiple alleles are more than two forms of the same gene found in a population.
- The ABO blood group system is controlled by three alleles: I^A , I^B , and i .
- I^A and I^B are codominant, while i is recessive.
- The four main blood groups are A, B, AB, and O.
- This system clearly illustrates how multiple alleles increase genetic variation in humans.

★ **Q7: What is Rh factor? Describe the genetic basis of Rh-blood group system of man.**

❖ **Definition of Rh Factor:**

👉 The Rh factor is a type of protein found on the surface of red blood cells (RBCs).

- If this protein (antigen) is present, the person is Rh positive (Rh^+);
- if absent, the person is Rh negative (Rh^-).

Genetic Basis of Rh Blood Group System:

1. Genes Controlling Rh Factor:

- The Rh blood group is controlled by a pair of allelic genes located on chromosome number 1.
- These genes are known as D and d.

D gene → produces Rh antigen (Rh^+)

d gene → does not produce Rh antigen (Rh^-)

2. Genotypes and Phenotypes:

Genotype	Phenotype (Blood Type)
DD	Rh positive (Rh^+)
Dd	Rh positive (Rh^+)
dd	Rh negative (Rh^-)

◆ Thus, the presence of at least one D allele makes the person Rh⁺, while absence (dd) results in Rh⁻ blood.

3. Inheritance Pattern:

- Rh factor follows the Mendelian law of dominance.
- When an Rh⁺ person (with genotype Dd) marries an Rh⁻ person (dd), their children may be either Rh⁺ or Rh⁻ depending on the combination of alleles.

4. Medical Significance (Erythroblastosis fetalis):

- If an Rh⁻ mother carries an Rh⁺ fetus, the Rh antigen from the fetus can enter the mother's bloodstream.
- The mother's body then produces anti-Rh antibodies, which may attack the RBCs of the next Rh⁺ fetus.
- This condition is called Erythroblastosis fetalis and can cause severe anemia in the baby.

◆ Summary:

- Rh factor = protein antigen on RBCs
- Controlled by D/d genes on chromosome 1
- D = dominant (Rh⁺), d = recessive (Rh⁻)

Important in blood transfusion and pregnancy safety.

☀️ **Q8: What is Erythroblastosis foetalis? Discuss this adverse effect of Rh incompatibility. Also suggest a therapy to avoid Rh sensitization of an Rh⁻ mother married to an Rh⁺ man.**

❖ **Definition:**

👉 Erythroblastosis foetalis (also called Hemolytic Disease of the Newborn) is a serious condition in which the red blood cells (RBCs) of a developing foetus are destroyed by antibodies produced by the Rh⁻ mother against the Rh antigen of the foetus.

💧 **Cause: Rh Incompatibility**

1. Rh incompatibility occurs when:

- The mother is Rh⁻ (dd)
- The father is Rh⁺ (DD or Dd)
- The foetus inherits the D gene and becomes Rh⁺

2. During first pregnancy:

- Some Rh⁺ foetal RBCs may leak into the mother's bloodstream (especially during childbirth).
- The Rh⁻ mother's immune system identifies these cells as foreign and produces anti-Rh antibodies (IgG).

3. During subsequent pregnancies:

If the next baby is again Rh⁺, these maternal antibodies cross the placenta and destroy the baby's RBCs, causing:

- Severe anaemia
- Jaundice
- Brain damage
- Even death of the foetus in severe cases

! Adverse Effects of Rh Incompatibility:

- Destruction of foetal red blood cells (haemolysis)
- Accumulation of bilirubin in blood (jaundice)
- Enlargement of liver and spleen
- Fluid accumulation in body tissues (hydrops foetalis)
- Stillbirth or death shortly after birth in severe cases

💊 Therapy to Prevent Rh Sensitization:

👉 The condition can be prevented by giving the mother an Rh immunoglobulin injection (anti-Rh serum), known as Rho(D) Immunoglobulin or RhoGAM.

Mechanism:

- The RhoGAM injection destroys any Rh⁺ foetal RBCs that may have entered the mother's blood before her immune system can react.
- This prevents the formation of anti-Rh antibodies in the mother.

Time of Administration:

- Within 72 hours after the delivery of an Rh⁺ baby.
- Also given after miscarriage, abortion, or amniocentesis if the foetus may be Rh⁺.

🌟 Q9: Define Epistasis and Explain with an Example.

❖ Definition of Epistasis:

- Epistasis is a type of gene interaction in which one gene masks or suppresses the effect of another gene at a different locus.
- The gene that suppresses or masks the effect of another gene is called the epistatic gene,
- while the gene whose effect is suppressed is called the hypostatic gene.

🧬 In simple words:

➔ One gene “hides” the expression of another gene in the phenotype.

Epistasis Interaction

Gene C (Pigment Production)

|— C_— → Colour formed
|— cc → No colour (Albino)

Gene A (Pigment Type)

|— A_— → Agouti (Gray)
|— aa → Black

AaCc × AaCc



F₂ Phenotypes:

9 Agouti : 3 Black : 4 Albino

✚ Explanation with Example: Coat Colour in Mice

In mice, coat colour is controlled by two genes:

- ◆ **Gene C (Colour gene):** Responsible for the production of pigment.

- C = allows pigment (dominant)
- c = no pigment (recessive → albino)

◆ **Gene A (Agouti gene): Determines the distribution of pigment.**

- A = agouti (grayish coat due to mixture of black and yellow bands)
- a = black coat

🧠 **How Epistasis Works:**

◆ If a mouse has at least one dominant C allele (C-), pigment is produced, and gene A can show its effect:

- A-C- → Agouti (gray)
- aaC- → Black

◆ But if the genotype is cc, no pigment is produced regardless of A or a:

- AA^{cc} or aa^{cc} → Albino (white)

➔ So, gene C is epistatic to gene A because when cc is present, it masks the effect of gene A completely.

⚖️ **Phenotypic Ratio (F₂ Generation):**

When two double heterozygotes (AaCc × AaCc) are crossed, the phenotypic ratio obtained is:

👉 **9 Agouti : 3 Black : 4 Albino**

This 9:3:4 ratio is the classical ratio of recessive epistasis.

☀️ Q10: What is a Pleiotropic Gene? Discuss Pleiotropy with Examples.

❖ Definition of Pleiotropic Gene:

- A pleiotropic gene is a single gene that affects two or more different traits in an organism.
- This phenomenon is called pleiotropy.

🧬 In other words:

- ➡ One gene controls multiple characters or phenotypic effects at the same time.

🧠 Explanation:

- Normally, each gene influences only one trait.
- But sometimes, a single gene can affect several unrelated features, because the product of that gene (like a protein or enzyme) is used in different parts of the body or multiple biological processes.

Thus, a mutation in such a gene produces a chain of effects on various organs or functions.

✚ Types of Pleiotropy:

1. Primary Pleiotropy (Direct):

- The gene product directly affects multiple traits.

2. Secondary Pleiotropy (Indirect):

- The gene affects one trait, which in turn influences other traits indirectly.

Examples of Pleiotropy:

(1) Sickle Cell Anemia in Humans:

- Caused by a mutation in the β -globin gene of hemoglobin (HBB gene).
- The mutant gene changes the structure of hemoglobin, leading to sickle-shaped red blood cells.
- ◆ This single gene mutation causes multiple effects, such as:
 - Decreased oxygen transport
 - Anemia
 - Damage to heart, kidney, and spleen
 - Resistance to malaria

➔ **Conclusion:** One gene → Many symptoms = Pleiotropy

(2) Phenylketonuria (PKU):

- Caused by a mutation in the gene for enzyme phenylalanine hydroxylase.
- This enzyme normally converts phenylalanine → tyrosine.
- ◆ When the gene is defective, phenylalanine accumulates, leading to:

- Mental retardation
- Reduced skin pigmentation
- Growth failure

➔ A single gene defect leads to several disorders – a clear case of pleiotropy.

(3) White Eye Gene in Drosophila:

◆ The same gene that produces white eyes in fruit flies also affects:

- The color of testis sheath
- Shape of sperm

➔ Thus, one gene influences multiple unrelated traits.

★ Q11: What are Polygenes? Explain Polygenic Inheritance.

❖ Definition of Polygenes:

- Polygenes are a group of two or more genes that collectively control a single trait in an organism.
- Each of these genes has a small additive effect on the expression of that trait.

➔ **In simple words:**

Polygenes = Many genes controlling one character.

❖ Definition of Polygenic Inheritance:

- Polygenic inheritance is the type of inheritance in which a trait is controlled by several genes, and the combined effect of these genes produces a continuous variation in the trait.

◆ **Explanation:**

- In monogenic inheritance, one gene controls one trait (e.g., flower color in peas).
- But in polygenic inheritance, multiple genes (polygenes) contribute additively to one trait (e.g., height, skin color, intelligence).
- Each dominant allele contributes a small unit of effect, while the recessive allele contributes nothing.
- The total number of dominant alleles present determines the degree or intensity of the trait.

Thus, traits governed by polygenes do not show clear-cut categories, but rather a range of variations (continuous variation).

 **Characteristics of Polygenic Traits:**

1. Controlled by two or more genes.
2. Show continuous variation (no distinct classes).
3. Environment also influences their expression.

4. Example traits:

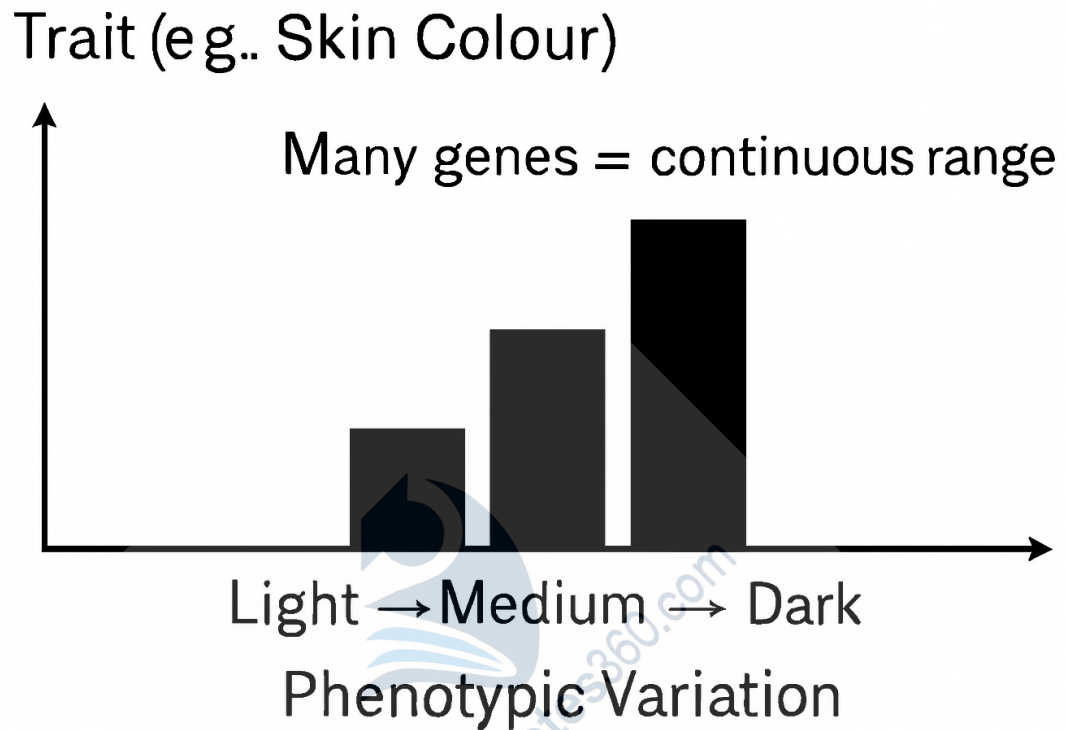
- Human height
- Skin color
- Weight
- Intelligence
- Milk production in cattle

Example: Human Skin Colour

- Human skin color is determined by three pairs of genes (A, B, and C).
- Each dominant allele (A, B, or C) adds a unit of pigment to the skin.
- The total pigment depends on the number of dominant alleles present.

Genot ype	Numbe r of Domin ant	Phenot ype
AABB CC	6	Very dark
AaBbC c	3	Mediu m
aabbcc	0	Very light

➔ The offspring show a continuous range of skin tones, not just light or dark.



🌱 Another Example: Height in Humans

- Human height depends on the additive effect of several genes.
- The more dominant alleles for height an individual has, the taller he/she will be.
- Environmental factors like nutrition also affect height – showing that polygenic traits are influenced by both genes and environment.

◆ Summary:

-
- Polygenes = many genes influencing one trait.
 - Polygenic inheritance = continuous variation of traits.
 - Each dominant allele adds to the expression of the character.
 - Environment affects polygenic traits.

Examples: skin color, height, intelligence, weight, milk yield.

★ **Q12: What is Crossing Over? Define Recombination Frequency and Explain its Significance**

❖ **Definition of Crossing Over:**

- Crossing over is the exchange of genetic material between non-sister chromatids of homologous chromosomes during prophase I of meiosis.

➔ It results in the recombination of genes, producing new combinations of traits that are different from parents.

Homologous Chromosomes Pairing (Prophase I)

Parent Chromosomes:



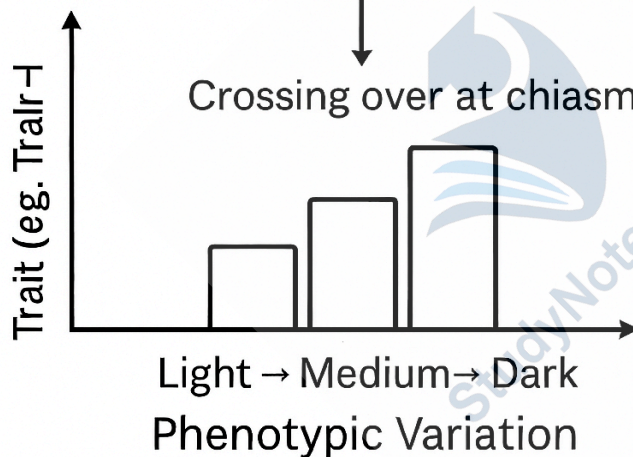
(Crossing over at chiasma)



$aancC \times AaCc$



Crossing over at chiasma



Process of Crossing Over:

1. During prophase I, homologous chromosomes pair up to form bivalents (tetrads).
2. The non-sister chromatids of these homologous chromosomes cross over at points called chiasmata.

3. At these points, chromatid segments are exchanged, resulting in new gene combinations.
4. After meiosis, the resulting gametes contain recombinant chromosomes – different from parental types.

Definition of Recombination Frequency:

- Recombination frequency is the percentage of recombinant offspring produced due to crossing over between two linked genes.

It is calculated using the formula:

Recombination Frequency (%) = (Number of Recombinant Offspring / Total Number of Offspring) × 100

Significance of Recombination Frequency:

1. Measures the distance between genes:

- Genes that are far apart on a chromosome have a higher recombination frequency.
- Genes that are close together show low recombination.

2. Used for constructing genetic maps:

- The unit of distance on a chromosome is called a map unit or centimorgan (cM).
- 1% recombination = 1 map unit = 1 centimorgan.

3. Provides evidence for gene linkage:

- Helps in identifying which genes are linked and inherit together.

4. Source of genetic variation:

- Produces new gene combinations leading to variation among offspring – an important factor in evolution.

◆ Example:

In *Drosophila*, if the genes for eye color and wing shape show 10% recombination, it means:

➔ These two genes are 10 map units apart on the same chromosome.

☀ Q13. What are Sex Chromosomes? Discuss the Chromosomal Patterns of Sex Determination in Organisms.

❖ Definition of Sex Chromosomes:

- Sex chromosomes are the chromosomes that determine the sex (male or female) of an organism.
- They are also called allosomes, while the remaining chromosomes are called autosomes.
- **In humans**, there are 46 chromosomes (23 pairs).
- **Out of these**, 22 pairs are autosomes, and 1 pair (XX or XY) is the sex chromosome pair.

Types of Sex Chromosomes:

1. X chromosome – Large chromosome carrying many genes related to body and sex traits.
2. Y chromosome – Smaller chromosome carrying genes responsible for male characteristics (like the SRY gene).

⚙️ **Chromosomal Patterns of Sex Determination:**

- Sex determination is the process by which the sex of an individual (male or female) is decided at fertilization.
- Different organisms have different chromosomal mechanisms of sex determination.

1. **XX–XY Type (Humans and Many Animals)**

- **Males:** XY (heterogametic, produce two types of sperms – X and Y)
- **Females:** XX (homogametic, produce only X-type eggs)

At fertilization:

- X sperm + X egg → XX → Female
- Y sperm + X egg → XY → Male

Hence, the male determines the sex of the offspring.

2. **XX–XO Type (Grasshoppers and Some Insects)**

- **Males:** XO (only one X chromosome, no Y)
- **Females:** XX

Males produce two types of sperms – one with X, and one without X (O).

Fertilization pattern:

- X sperm + X egg \rightarrow XX \rightarrow Female
- O sperm + X egg \rightarrow XO \rightarrow Male

3. ZZ–ZW Type (Birds, Reptiles, Moths, etc.)

- **Males:** ZZ (homogametic, produce one type of sperm)
- **Females:** ZW (heterogametic, produce two types of eggs – Z and W)

Fertilization pattern:

- Z sperm + Z egg \rightarrow ZZ \rightarrow Male
- Z sperm + W egg \rightarrow ZW \rightarrow Female

👉 Here, the female determines the sex of the offspring (opposite of humans).

4. Haplo–Diploid Type (Bees, Ants, Wasps)

- **Males:** Haploid (develop from unfertilized eggs)
- **Females:** Diploid (develop from fertilized eggs)

This system is found in honeybees, where queens and workers are diploid females, and drones (males) are haploid.

◆ Summary:

- Sex chromosomes control the sex of an individual.

- Different organisms have evolved different systems of sex determination such as XX–XY in humans, XX–XO in insects, ZZ–ZW in birds, and haplo-diploid in bees.

In humans, the male's sperm determines the sex of the offspring.

☀ Q14. Compare Chromosomal Determination of Sex between *Drosophila* and Humans.

❖ Introduction:

- Sex determination is the biological process by which an organism develops as a male or female.
- This determination depends upon the combination of sex chromosomes present in the individual.
- Both humans and *Drosophila* (fruit flies) possess X and Y chromosomes, but the mechanism of sex determination is different in the two.

Sex Determination in Humans (XX–XY System):

- Humans have 46 chromosomes, including 44 autosomes and 2 sex chromosomes.
- In this system, the presence or absence of the Y chromosome determines the sex of the individual.
- A female has two X chromosomes (XX).
- A male has one X and one Y chromosome (XY).
- The Y chromosome carries a special gene known as the SRY gene (Sex-determining Region of Y).

- This gene controls the development of testes, which produce male hormones (androgens).
- These hormones bring about the development of male sexual characteristics.
- If the SRY gene is absent, the embryo develops ovaries and becomes female.
- **Therefore**, the Y chromosome plays a key role in male determination.

During gamete formation:

- Males produce two types of sperms – one carrying X and the other carrying Y chromosome.
- Females produce only one type of egg – all carrying X chromosome.

At fertilization:

- If a sperm carrying X chromosome fertilizes the egg → the zygote becomes XX → Female.
- If a sperm carrying Y chromosome fertilizes the egg → the zygote becomes XY → Male.

Thus, in humans, the male determines the sex of the child.

Sex Determination in Drosophila (Fruit Fly):

- Drosophila has 8 chromosomes in total, including 6 autosomes and 2 sex chromosomes.

- Both males and females have an X and Y chromosome, but the Y chromosome does not determine sex as it does in humans.
- **Instead**, sex in *Drosophila* depends on the ratio of X chromosomes to the sets of autosomes, called the X/A ratio.
- When the ratio of X chromosomes to autosomes is 1 (X:A = 1), the individual is female.
- When the ratio is 0.5 (X:A = 0.5), the individual is male.

For example:

- A fly with 2 X chromosomes and 2 sets of autosomes (XX:2A) develops as a female.
- A fly with 1 X chromosome and 2 sets of autosomes (XY:2A) develops as a male.
- The Y chromosome in *Drosophila* is not responsible for sex determination – it is only important for male fertility.

⚙️ **Main Difference Between Humans and *Drosophila*:**

- In humans, sex is determined by the presence of the Y chromosome.
- If Y is present, the individual is male; if Y is absent, the individual is female.

- In *Drosophila*, sex is determined by the ratio of X chromosomes to autosomes, and the Y chromosome only affects fertility, not sex.

◆ **Summary:**

- **In humans**, the Y chromosome and its SRY gene decide maleness.
- **In *Drosophila***, the ratio between X chromosomes and autosomes determines sex, while the Y chromosome has no role in sex determination except in sperm formation.

Thus, both species use X and Y chromosomes, but their mechanisms of sex determination are entirely different.

✨ **Q15. Define Gene Pool. Explain the Concept of Gene Pool in a Sample Population.**

❖ **Definition of Gene Pool:**

- A gene pool is the total collection of all the genes and their different alleles present in all the individuals of a population at a given time.
- In simple words, it represents the complete set of genetic information available in a population that can be passed on to the next generation.

🌿 **Explanation:**

- Every species consists of many individuals, and each individual carries a unique combination of genes.

- All these genes – including their dominant and recessive alleles – form the gene pool of that species.
- The larger and more diverse the gene pool, the greater the genetic variation in a population.
- Genetic variation allows a population to adapt to changing environmental conditions and survive better.
- If a population has a small gene pool (less variation), it becomes more vulnerable to diseases, environmental changes, or genetic disorders.

Example (Concept in a Sample Population):

- Let's take a population of 100 rabbits.
- Each rabbit has two alleles for fur color: B (black) and b (white).
- Some rabbits are BB (black), some are Bb (gray), and some are bb (white).
- Now, all these alleles (B and b) from all 100 rabbits make up the gene pool for fur color in that rabbit population.
- If the frequency of B and b alleles changes over generations due to natural selection, mutation, migration, or genetic drift, it means the gene pool has evolved.

Factors Affecting the Gene Pool:

1. Mutation: Creates new alleles, increasing genetic variation.

2. Migration (Gene flow): Brings new genes into a population or removes existing ones.

3. Natural Selection: Favors some alleles over others, changing their frequency in the gene pool.

4. Genetic Drift: Random changes in allele frequencies, especially in small populations.

5. Non-random Mating: Alters the proportion of certain genotypes.

 **Significance of Gene Pool:**

- Represents the genetic health and diversity of a population.
- Helps in understanding evolutionary processes.
- Provides a basis for natural selection and adaptation.
- Larger gene pools mean greater chances of survival against environmental pressures.

◆ **Summary:**

- The gene pool includes all genes and alleles present in a population.
- It reflects the genetic variation of that population.
- Changes in the gene pool over time indicate evolution.
- A diverse gene pool provides greater adaptability and survival advantage.

🌟 Q16: What is Sex Linkage? Explain T. H. Morgan's Study of Sex Linkage in Drosophila.

❖ Definition of Sex Linkage:

- Sex linkage is the inheritance of genes that are located on sex chromosomes (X or Y chromosomes) rather than on autosomes.
- Traits controlled by these genes are called sex-linked traits because their inheritance depends on the sex of the individual.

👉 In simple words, sex-linked inheritance means that some traits are passed from parents to offspring through the X or Y chromosome.

⚙️ Explanation:

- Males have XY chromosomes.
- Females have XX chromosomes.

The X chromosome carries many important genes, but the Y chromosome has very few genes.

Therefore, X-linked traits are more common and usually appear more in males because they have only one X chromosome.

🧑🔬 **T. H. Morgan's Experiment on *Drosophila melanogaster* (Fruit Fly):**

Thomas Hunt Morgan (1910) was the first scientist to discover sex linkage while studying eye color in the fruit fly, *Drosophila melanogaster*.

Observation:

- Normally, *Drosophila* has red eyes (wild type).
- But Morgan found a white-eyed male fly (mutant).
- He wanted to know how this white eye trait was inherited.

Experiment Steps:

Step 1:


- Morgan crossed a white-eyed male (X^wY) with a red-eyed female (X^+X^+).

Parental cross:

- X^+X^+ (female) \times X^wY (male)

F₁ generation:

- All offspring (both males and females) had red eyes.

 This showed that the white-eye gene (X^w) is recessive to the red-eye gene (X^+).

Step 2:

- Morgan then crossed the F₁ red-eyed female (X^+X^w) with a red-eyed male (X^+Y).

F₂ generation obtained:

- Red-eyed females (X^+X^+)
- Red-eyed females (X^+X^w)
- Red-eyed males (X^+Y)
- White-eyed males (X^wY)

👉 The white-eyed trait appeared only in males.

◆ Summary:

- Sex linkage refers to the inheritance of genes on sex chromosomes.
- T. H. Morgan discovered this phenomenon while studying eye color in fruit flies.
- The white-eye trait is X-linked recessive.
- Males show the trait more often because they have only one X chromosome.
- Morgan's discovery provided strong evidence for the chromosomal theory of inheritance.

🌟 Q17: Compare the Pattern of Inheritance of an X-linked Dominant Trait with an X-linked Recessive Trait in Humans.

❖ Introduction:

- In humans, many traits are controlled by genes located on the X chromosome.
- These traits are called X-linked traits.

◆ **They can be of two main types:**

1. **X-linked dominant traits**
2. **X-linked recessive traits**

Their inheritance patterns differ because of how dominant and recessive alleles express in males (XY) and females (XX).

⚙️ 1 X-Linked Dominant Traits

Definition:

- An X-linked dominant trait is caused by a dominant allele on the X chromosome.
- Only one copy of the dominant allele is enough to express the trait, even in females.

Examples:

- Hypophosphatemic rickets (Vitamin-D resistant rickets)
- Fragile-X syndrome (in some forms)

Inheritance Pattern:

- Affected father ($X^A Y$) passes the dominant X^A to all daughters, so all daughters are affected, but none of the sons receive it (since sons get Y from father).
- Affected mother ($X^A X$ or $X^A X^A$) passes the trait to 50% of sons and 50% of daughters (if heterozygous).

Key Points:

- Appears in every generation (no skipping).
- More females are affected (because they have two X chromosomes).

Example Cross:

- **Father:** $X^A Y$ × Mother: $X X$
- **Offspring:** $X^A X$ (affected daughter), XY (normal son)

⚙️ 2 X-Linked Recessive Traits

Definition:

- An X-linked recessive trait is caused by a recessive allele on the X chromosome.
- It is expressed only when no dominant allele is present.

Examples:

- Hemophilia A and B
- Red-green color blindness
- Duchenne muscular dystrophy

Inheritance Pattern:

- Affected males ($X^a Y$) usually inherit the trait from carrier mothers ($X^a X$).
- Affected females ($X^a X^a$) are rare because they need two copies of the recessive allele.
- The trait zigzags from maternal grandfather → carrier daughter → grandson.

Key Points:

- More males are affected.
- Trait often skips generations through carrier females.
- Father-to-son transmission does not occur (because the Y chromosome comes from father).

Example Cross:

- **Father:** X^aY × **Mother:** XX
- **Offspring:** X^aX (carrier daughter), XY (normal son)

◆ Summary:

- Both traits are inherited through the X chromosome.
- Dominant X-linked traits appear in both sexes, often more in females.
- Recessive X-linked traits appear mostly in males, passed through carrier females.
- No father-to-son transmission occurs in either case.
- The pattern of inheritance helps in pedigree analysis and genetic counseling.

☀ Q18. Explain Diabetes Mellitus and Its Genetic Basis.

❖ Definition of Diabetes Mellitus:

- Diabetes mellitus is a metabolic disorder in which the level of glucose (sugar) in the blood becomes abnormally

high (hyperglycemia) due to defective insulin production, secretion, or action.

- It mainly affects how the body uses carbohydrates, fats, and proteins for energy.

Normal Function of Insulin

- Insulin is a hormone secreted by the β -cells (beta cells) of the Islets of Langerhans in the pancreas.
- It helps body cells absorb glucose from the blood and convert it into energy (ATP) or store it as glycogen in the liver and muscles.
- When insulin is absent or ineffective, glucose cannot enter cells, leading to high blood sugar.

Types of Diabetes Mellitus:

Type I Diabetes Mellitus (Insulin-Dependent Diabetes Mellitus – IDDM)

- Usually occurs in childhood or adolescence.
- It results from the autoimmune destruction of β -cells of the pancreas.
- As a result, little or no insulin is produced.
- Patients require regular insulin injections.

Genetic Basis:

- Linked to specific genes in the HLA (Human Leukocyte Antigen) region on chromosome 6.

- Inheritance is polygenic – meaning many genes contribute.
- Both genetic susceptibility and environmental triggers (like viral infections) play a role.

2 Type II Diabetes Mellitus (Non-Insulin-Dependent Diabetes Mellitus – NIDDM)

- Usually develops in adults (above 40 years), but now also seen in younger people due to obesity and poor lifestyle.
- The pancreas produces insulin, but body cells become resistant to it – this is called insulin resistance.
- Often managed with diet, exercise, and oral drugs rather than insulin injections.

Genetic Basis:

- Strong familial inheritance (runs in families).
- Defects in multiple genes affecting insulin receptor, glucose transporter, and signal pathways.
- Variants in genes such as TCF7L2, PPARG, and KCNJ11 are associated with increased risk.
- Environmental factors like obesity, lack of exercise, and high-calorie diet trigger expression of these genes.

Symptoms of Diabetes Mellitus:

- Excessive urination (polyuria)
- Excessive thirst (polydipsia)
- Increased hunger (polyphagia)

- Weakness and fatigue
- Weight loss (especially in Type I)
- Slow healing of wounds and infections

Complications of Untreated Diabetes

If untreated, long-term high blood sugar can cause:

- Retinopathy (eye damage → blindness)
- Nephropathy (kidney failure)
- Neuropathy (nerve damage)
- Heart diseases and stroke
- Gangrene in limbs

Q19: Discuss the Genetics of Colour-Blindness or Haemophilia.

❖ Introduction:

- Some genetic disorders are caused by defective genes located on the X-chromosome.
- Such traits are called X-linked traits, and they usually affect males more than females.

Two classic examples of X-linked recessive disorders are:

1. Colour-Blindness
2. Haemophilia

1. Haemophilia (Bleeder's Disease)

Definition:

Haemophilia is a hereditary bleeding disorder in which the blood fails to clot normally due to the absence or deficiency of clotting factors (proteins that help stop bleeding).

Even small injuries can cause excessive bleeding that may be life-threatening.

Genetic Basis

- The gene responsible for haemophilia is located on the X chromosome.
- It is recessive, so it appears only when no normal allele is present.
- ◆ **There are two main types:**
 - **Haemophilia A:** Deficiency of Factor VIII (anti-hemophilic factor).
 - **Haemophilia B:** Deficiency of Factor IX (Christmas factor).

Gene Location:

Located on the X chromosome → hence, called an X-linked recessive disorder.

Why Haemophilia is More Common in Males:

- Males have one X and one Y chromosome (XY).
- If the X chromosome carries a defective gene → no normal allele on Y to mask it.

- So, disease appears in males.
- ◆ Females have two X chromosomes (XX).
 - If one X has the defective gene, the other X with the normal gene compensates → female becomes a carrier but not diseased.

Carrier Mother Cross

Let's take:

- X^H = Normal allele
- X^h = Haemophilic allele

Parents	$X^H X^h$ (carrier female) × $X^H Y$ (normal male)
Possible Offspring	$X^H X^H$ (normal girl), $X^H X^h$ (carrier girl), $X^H Y$ (normal boy), $X^h Y$ (haemophilic boy)

Result:

- 50% sons have a chance to be haemophilic.
- 50% daughters have a chance to be carriers.

Example: Queen Victoria's Family

- Queen Victoria of England was a carrier of haemophilia.
- She passed the gene to her descendants, including the royal families of Russia, Spain, and Germany – hence it was called “Royal Disease.”

2. Colour-Blindness

Definition:

- Colour-blindness is an inability to distinguish between certain colours, especially red and green.
- It results from defective cone cells in the retina of the eye.

Genetic Basis

- The genes responsible for red and green colour vision are located on the X chromosome.
- The defect is X-linked recessive, similar to haemophilia.
- Caused by mutation in the gene producing photopigments (opsins).

Inheritance Pattern:

- Males (XY) are affected if their single X carries the defective gene.
- Females (XX) are affected only if both X chromosomes carry the defective gene – very rare.
- Females with one defective and one normal X are carriers.

Carrier Mother Cross Example

Let's take:

- X^N = Normal vision

- X^n = Colour-blindness allele

Parents	$X^N X^n$ (carrier female) \times $X^N Y$ (normal male)
Possible Offspring	$X^N X^N$ (normal girl), $X^N X^n$ (carrier girl), $X^N Y$ (normal boy), $X^n Y$ (colour-blind boy)

Result:

- 50% sons = colour-blind
- 50% daughters = carriers

Types of Colour-Blindness

1. Red–Green Colour-Blindness → Most common
2. Blue–Yellow Colour-Blindness → Rare
3. Total Colour-Blindness (Monochromacy) → Very rare (see only shades of grey)

◆ Summary:

- Both haemophilia and colour-blindness are X-linked recessive disorders.
- Males are more affected because they have only one X chromosome.
- Females are usually carriers.
- Haemophilia affects blood clotting, while colour-blindness affects colour vision.

-
- Carrier mothers can transmit the disorder to sons, while daughters may become carriers.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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