













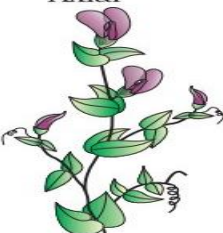

CHAPTER – 5

# PRINCIPLE OF INHERITANCE & VARIATION

**Introduction**

- Genetics: is the branch of biology that studies heredity and variation in organisms.
- Gregor Mendel a scientist and the monk was first to study *Pisum sativum* (garden pea) scientifically. He observed that pea plants inherit traits by way of discrete “units of inheritance” and published his work in 1865. The experimental results were described mathematically.

**Contrasting characters:**

Character	Dominant trait	Recessive trait
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

**Figure 5.1** Seven pairs of contrasting traits in pea plant studied by Mendel

A single character that exhibits two opposite different character.

- Contrasting characters of plant height is tall and dwarf.
- Seven pair of contrasting characters is observed in pea plants.

**Dominating characters:**

- A character that is controlled by a particular allele of a gene and which is displayed when the individual is homozygous or heterozygous for a allele.
- The phenotypic characters that gets expressed in F1 generation.

**Recessive characters:**

- A character that is controlled by a particular allele of a gene and the gets expressed only when the individual is homozygous for this allele.
- Stem height-dwarf, Flower colour-white, Flower position-terminal, Pod shape-constricted, Pod colour-yellow , Seed shape-wrinkled, Seed colour-green.

**Monohybrid cross:**

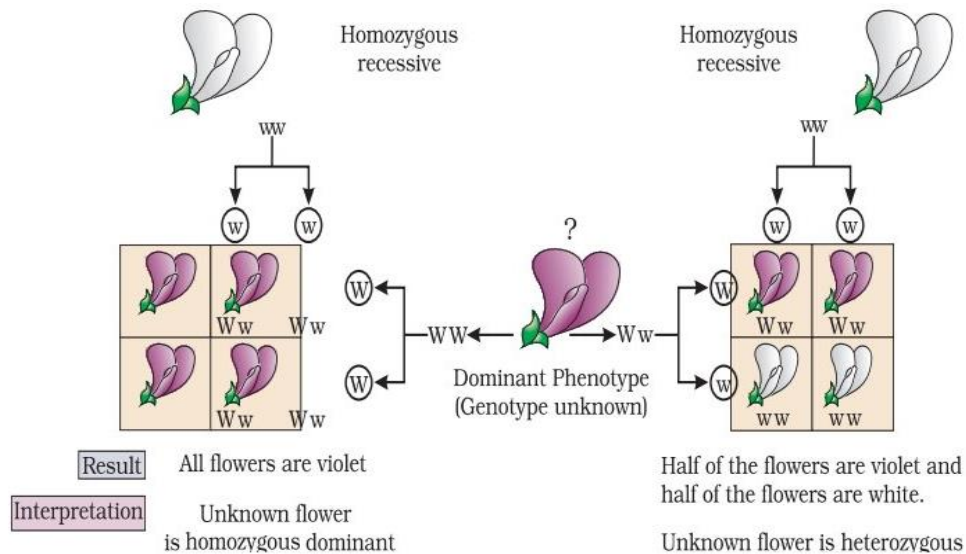
- A cross which determines the allele combination of offspring for a particular gene.

- Tall X Dwarf  
(homozygous) (homozygous) **(Punnett Square to be drawn)**

F1 Tall (heterozygous)

**Test cross:**

- A cross in which breeding of an individual is carried out with phenotypically recessive individual; in order to determine the zygosity of an individual by analyzing the proportions of offspring phenotypes.



**Figure 5.5** Diagrammatic representation of a test cross

**The Law of Dominance:**

- (i) Characters are controlled by discrete units called factors.
- (ii) Factors occur in pairs.
- (iii) In a dissimilar pair of factors one member of the pair dominates (dominant) the other (recessive).
- The law of dominance is used to explain the expression of only one of the parental characters in a monohybrid cross in the F1 and the expression of both in the F2. It also explains the proportion of 3:1 obtained at the F2.

**Law of Segregation:**

- The law is based on the fact that the alleles do not show any blending and that both the characters are recovered as such in the F2 generation though one of these is not seen at the F1 stage.
- Though the parents contain two alleles during gamete formation, the factors or alleles of a pair **segregate** from each other such that a gamete receives only one of the two factors. Of course, a homozygous parent produces all gametes that are similar while a heterozygous one produces two kinds of gametes each having one allele with equal proportion.

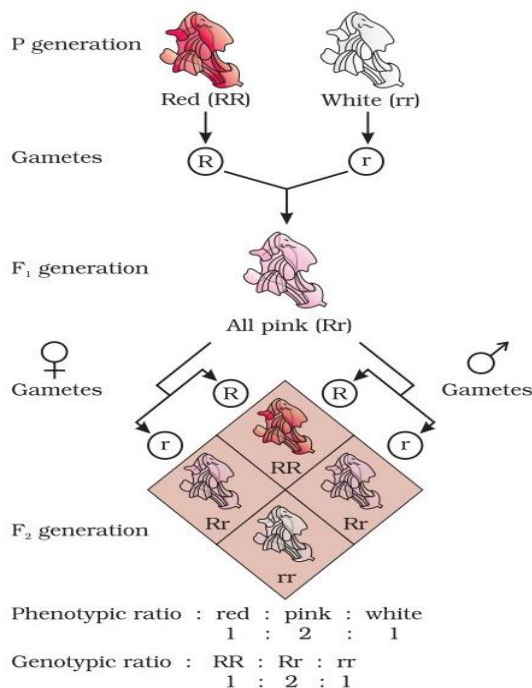
**Inheritance of Two Genes:**

- Mendel worked with and crossed pea plants that differed in two characters, as is seen in the cross between a pea plant that has seeds with yellow colour and round shape and one that had seeds of green colour and wrinkled shape.
- $RRYY \times rryy$  Fig.5.7 (page 79)
- Phenotypic ratio of dihybrid cross is 9:3:3:1
- 

**Law of Independent assortment:**

Law states that ‘when two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair of characters’.

**Incomplete dominance:**



**Figure 5.6** Results of monohybrid cross in the plant Snapdragon, where one allele is incompletely dominant over the other allele

Incomplete dominance is a form of **intermediate inheritance** in which one allele for a specific trait is not completely expressed over its paired allele. The phenotypic expression is a combination of both the alleles.

- When experiments on peas were repeated using other traits in other plants, it was found that sometimes the F1 had a phenotype that did not resemble either of the two parents and was in between the two.
- The inheritance of flower colour in the dog flower (*Mirabilis jalapa* or *Antirrhinum* sp.) show **incomplete dominance**.
- In a cross between **true-breeding** red-flowered (RR) and truebreeding white-flowered plants (rr), the **F1** (Rr) was **pink** (Figure 5.6). When the F1 was self-pollinated the F2 resulted in the following ratio 1 (RR) Red: 2 (Rr) Pink: 1 (rr) White.
- Here the genotype ratios were exactly same as seen in Mendelian monohybrid cross, but the phenotype ratios had changed i.e. 1:2:1 (1 Red: 2 Pink: 1 White).

### Co-dominance:

- Co-dominance is a form of inheritance where the pair of alleles of a gene in heterozygous condition are fully expressed. As a result the phenotype of the offspring is a combination of the phenotype of the parents.
- The trait is neither dominant nor recessive.
- In the case of co-dominance the F1 generation resembles both parents.
- A good example is different types of red blood cells that determine ABO blood grouping in human beings. ABO blood groups are controlled by the gene I (isohaemagglutinin).
- 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  $i$  ( $I^o$ ).
- The alleles  $I^A$  and  $I^B$  produce a slightly different form of the sugar while allele  $I^o$  does not 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. Hence 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 5.2: Table Showing the Genetic Basis of Blood Groups in Human Population**

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

**Multiple allelism:**

- The state of having more than two alternative contrasting characters controlled by multiple alleles at a single genetic locus.
- The ABO blood group in humans is a good example of multiple allelism. Gene I has three alleles  $I^A$ ,  $I^B$  and  $I^O$ .

**Pleiotropy:**

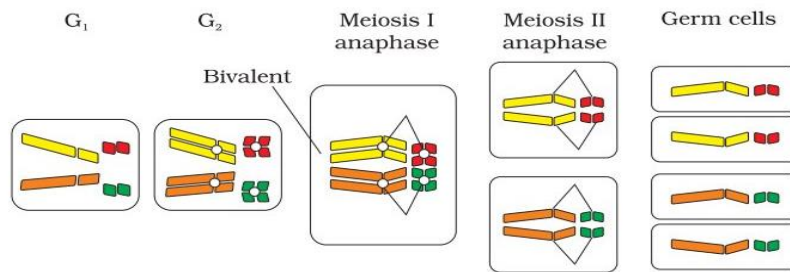
- A single gene expressing multiple phenotypic traits.
- Such a gene that exhibits multiple phenotypic expressions is called a pleiotropic gene.
- Examples:
  - i) starch synthesis in pea seeds and shape of the seeds.
  - ii) phenylketonuria
- Starch synthesis in pea seeds and shape of the seeds is controlled by one gene. It has two alleles (**B and b**). Starch is synthesized effectively by **BB homozygotes** and therefore, **large starch grains** are produced.
- In contrast, **bb homozygotes** have lesser efficiency in starch synthesis and produce **smaller starch grains**. After maturation of the seeds, **BB seeds** are round and the **bb seeds** are wrinkled.
- Heterozygotes produce round seeds, and so B seems to be the dominant allele. But, the starch grains produced are of intermediate size in Bb seeds. So if starch grain size is considered as the phenotype, then from this angle, the alleles show incomplete dominance.

**Rediscovery of Mendel's Laws:**

- In 1900, three Scientists (**de Vries, Correns and von Tschermak**) independently rediscovered Mendel’s results on the inheritance of characteristics.

**Chromosomal Theory of Inheritance**

- The advancements in microscopy in early 20<sup>th</sup> century that were taking place, scientists were able to carefully observe cell division. This led to the discovery of structures in the **nucleus** that appeared to **double** and **divide** just before each **cell division**.
- These were called **chromosomes** (colored bodies, as they were visualised by staining). By 1902, the chromosome movement during meiosis had been worked out. 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.



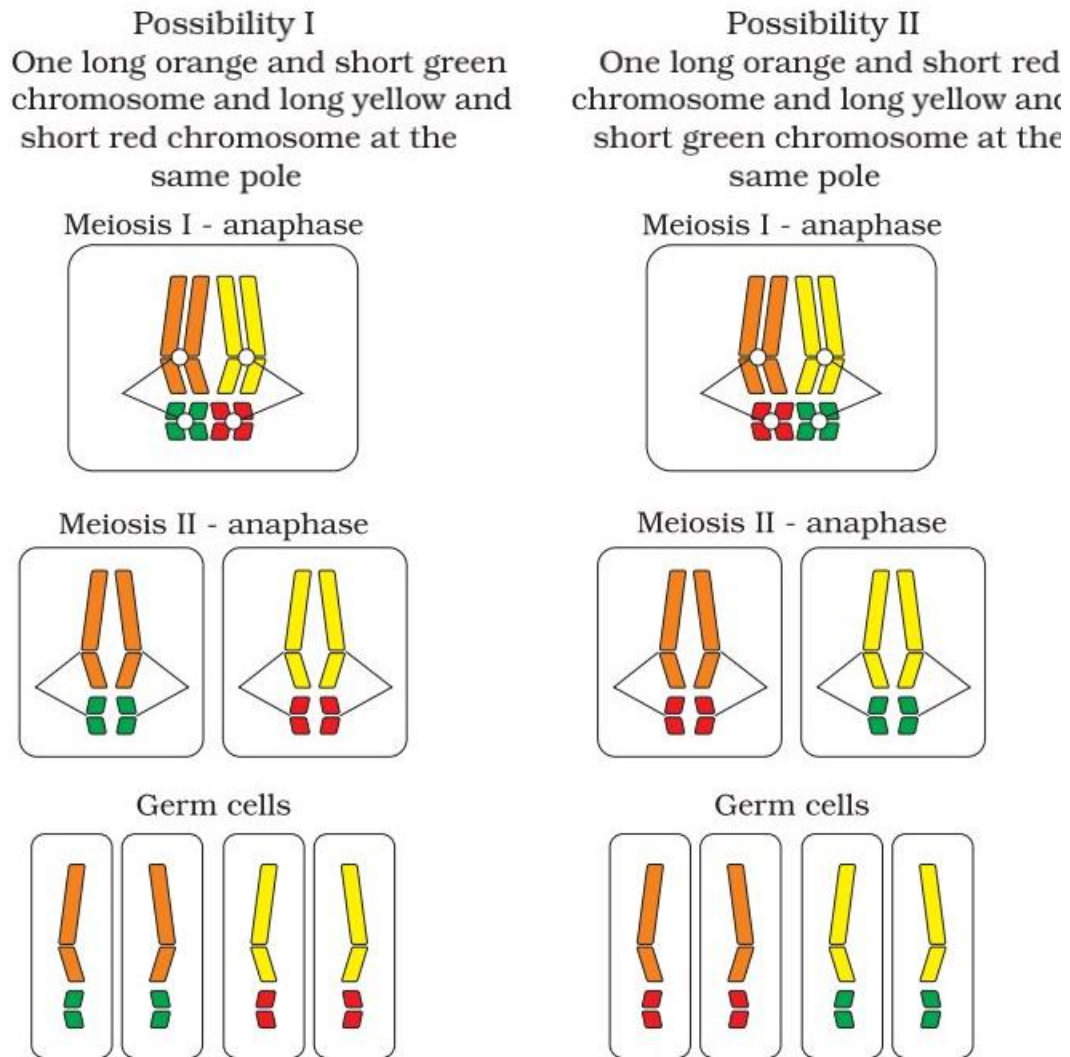
**Figure 5.8** Meiosis and germ cell formation in a cell with four chromosomes. Can you see how chromosomes segregate when germ cells are formed?

**Table 5.3: A Comparison between the Behaviour of Chromosomes and Genes**

<b>A</b>	<b>B</b>
<i>Occur in pairs</i>	<i>Occur in pairs</i>
<i>Segregate at the time of gamete formation such that only one of each pair is transmitted to a gamete</i>	<i>Segregate at gamete formation and only one of each pair is transmitted to a gamete</i>
<i>Independent pairs segregate independently of each other</i>	<i>One pair segregates independently of another pair</i>
<i>Can you tell which of these columns A or B represent the chromosome and which represents the gene? How did you decide?</i>	

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

- During Anaphase of meiosis I, the two chromosome pairs can align at the metaphase plate independently of each other. The pairs of chromosome get segregated independently of the other. As shown in Possibility -I and Possibility-II.



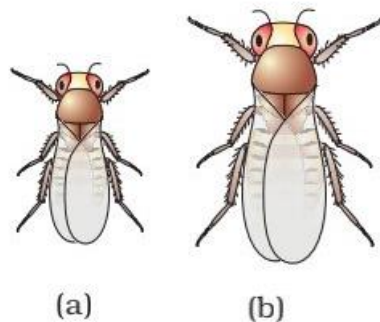
**Figure 5.9** Independent assortment of chromosomes

- *Sutton and Boveri* argued that the pairing and separation of a pair of chromosomes would lead to the segregation of a pair of factors they carried. Sutton united the knowledge of chromosomal segregation with Mendelian principles and called it the chromosomal theory of inheritance.



Linkage and Recombination:

- 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*.
- Fruit flies could be grown on simple synthetic medium in the laboratory. They complete their lifecycle in about two weeks, and a single mating could produce a large number of progeny flies.
- 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.

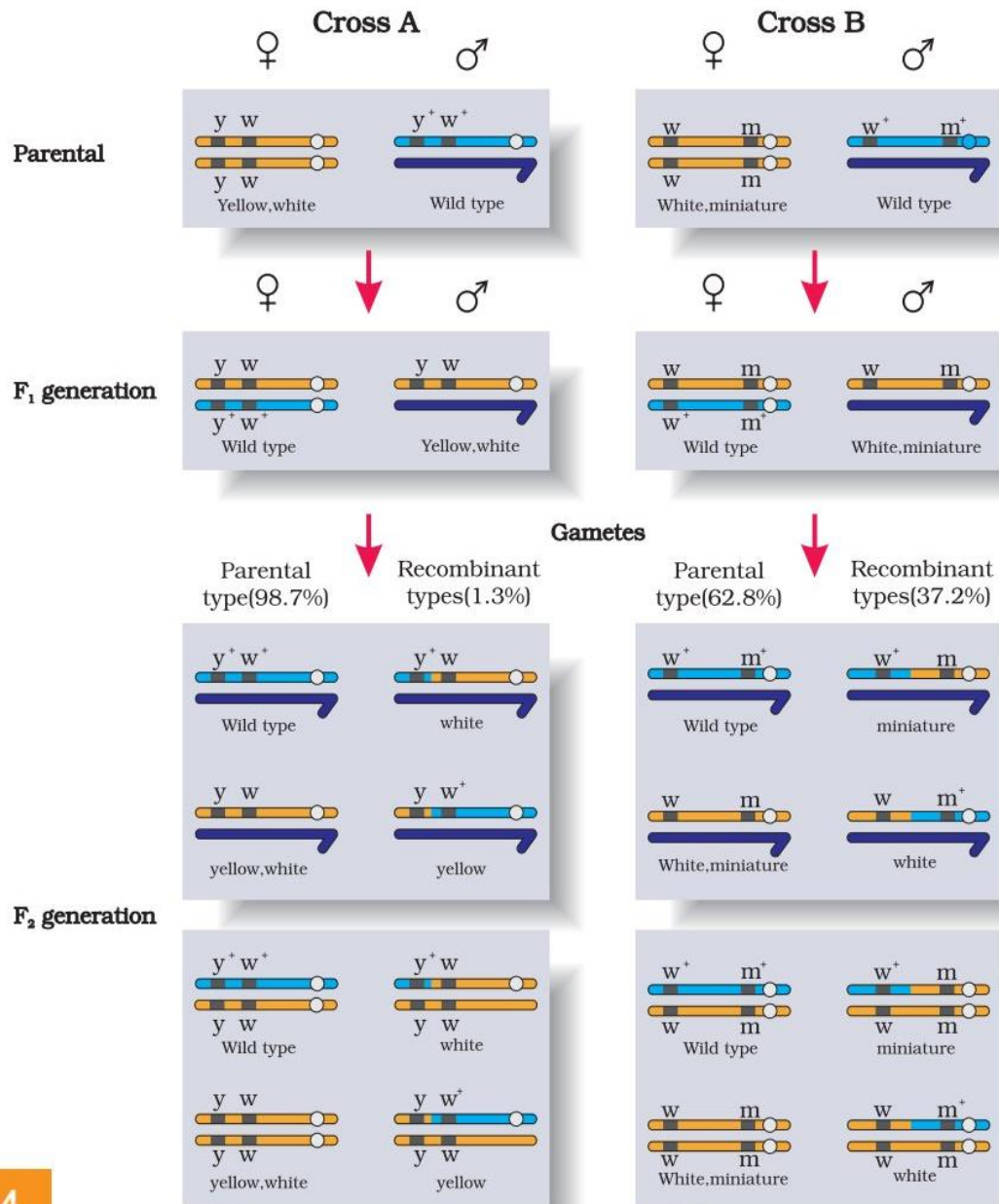


**Figure 5.10** *Drosophila melanogaster* (a) Male  
(b) Female

- Morgan carried out several dihybrid crosses in *Drosophila* to study genes that were sex-linked. The crosses were similar to the dihybrid crosses carried out by Mendel in peas. Morgan hybridised yellow-bodied, white-eyed females to brown-bodied, red-eyed males and intercrossed their F1 progeny. He observed that the two genes did not segregate independently of each other and the F2 ratio deviated very significantly from the 9:3:3:1 ratio.
- Morgan and his group knew that the genes were located on the X chromosome (Section 5.4) and saw quickly that when the two genes in a dihybrid cross were situated on the same chromosome, the proportion of parental gene combinations were much higher than the non-parental type.
- 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.
- 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 5.11, Cross A) while others were loosely linked (showed higher recombination) (Figure 5.11, Cross B).

- He found that the genes white and yellow were very tightly linked and showed only 1.3 per cent recombination while white and miniature showed 37.2 per cent recombination.



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**Figure 5.11** 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* and *w* is higher than *w* and *m*.

### Gene mapping

- Morgan's student Alfred Sturtevant used the frequency of recombination between genes on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome.

### Map distance

- The distance between the position of two genes on a chromosome.
- A genetic map unit (m.u.) is sometimes referred to as a centimorgan (cM).

### Mechanism of Sex Determination:

#### Chromosomal basis of sex determination:

- **Henking's X-body:** determination. Henking (1891) could trace a specific nuclear structure all through spermatogenesis in a few insects, and it was also observed by him that 50 per cent of the sperm received this structure after spermatogenesis, whereas the other 50 per cent sperm did not receive it.
- Henking gave a name to this structure as the X body. Further investigations by other scientists led to the conclusion that the 'X body' of Henking was in fact a chromosome sex chromosomes, that is why it was given the name X-chromosome.

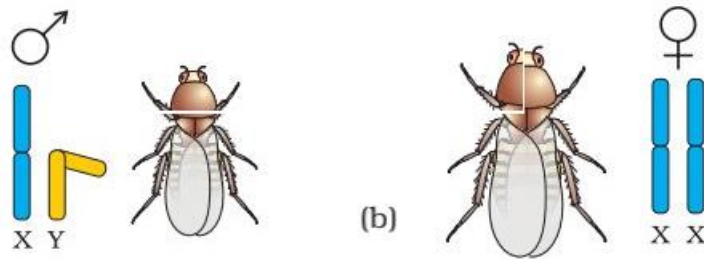
#### XO-type of sex determination:

- Grasshopper is an example of XO type of sex determination in which the males have only one X-chromosome besides the autosomes, whereas females have a pair of X-chromosomes.
- In Grasshopper it was observed that the females lay eggs bear an additional X-chromosome besides the other chromosomes (autosomes).
- On the other hand, some of the sperms bear the X-chromosome whereas some do not.
- Eggs fertilised by sperm having an X-chromosome become females and, those fertilised by sperms that do not have an X-chromosome become males.
- Due to the involvement of the **X-chromosome** in the determination of sex, it was designated to be the **sex chromosome**, and the rest of the chromosomes were named as autosomes.

#### Male Heterogamety:

- Males produce two different types of gametes, (a) either with or without X-chromosome or (b) some gametes with X-chromosome and some with Y-chromosome. Such types of sex determination mechanism is designated to male heterogamety.

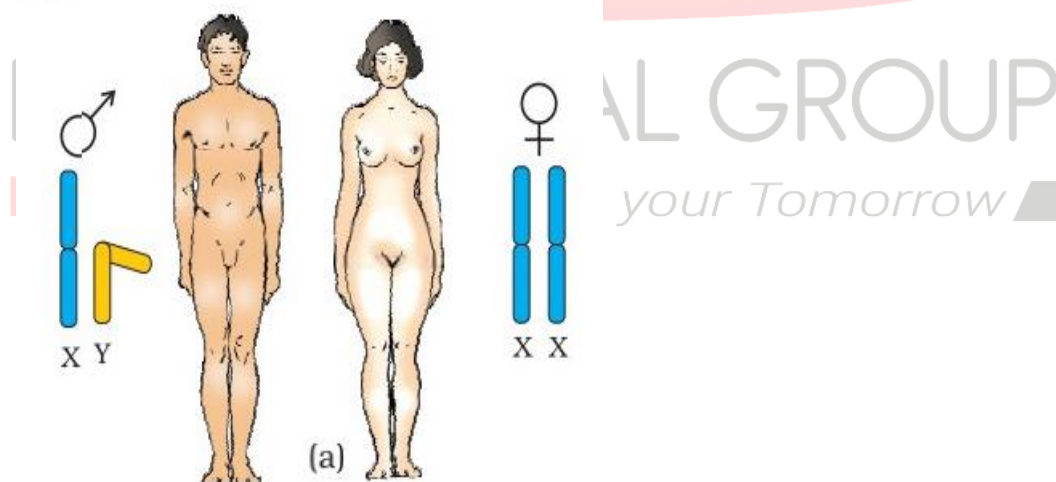
XY-type of sex determination in *Drosophila* fig



In a number of other **insects and** mammals including man, XY type of sex determination is seen where both male and female have same number of chromosomes.

- Among the males an X-chromosome is present but its counterpart is distinctly smaller and called the Y-chromosome. Females, however, have a pair of X chromosomes.
- Both males and females bear same number of autosomes. Hence, the males have autosomes plus XY, while female have autosomes plus XX.

XY-type of sex determination in Human fig

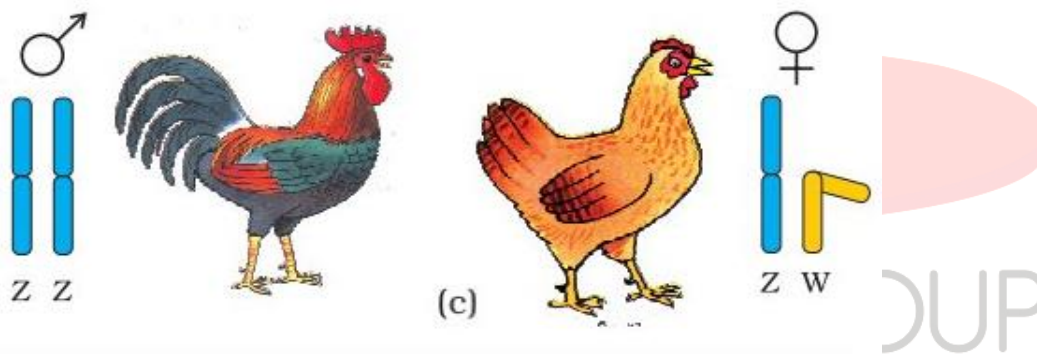


- In human beings males have one X and one Y chromosome, whereas females have a pair of X-chromosomes besides autosomes. In this case the total number of chromosome is same in both males and females. But two different types of gametes are produced in terms of the sex.
- Out of 23 pairs of chromosomes 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.

#### Female Heterogamety:



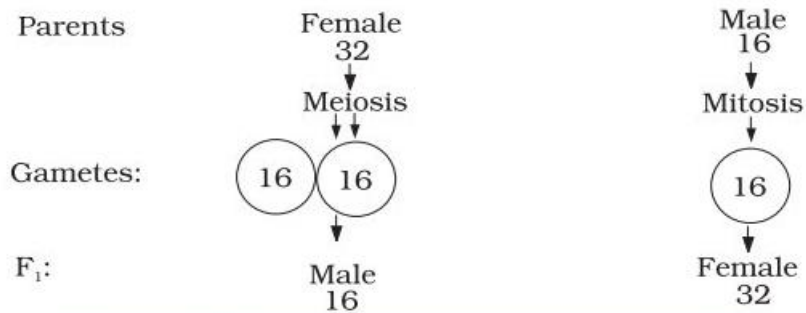
*Changing your Tomorrow*

- In some organisms two different types of gametes in terms of the sex chromosomes, are produced by females, i.e., female heterogamety.

ZZ-ZW type of sex determination in rooster and hen

- The two different sex chromosomes of a female bird has been designated to be the Z and W chromosomes. In these organisms the females have one Z and one W chromosome, whereas males have a pair of Z chromosomes besides the autosomes.

#### [The sex determination in honey bee](#)



**Figure 5.13** Sex determination in honey bee

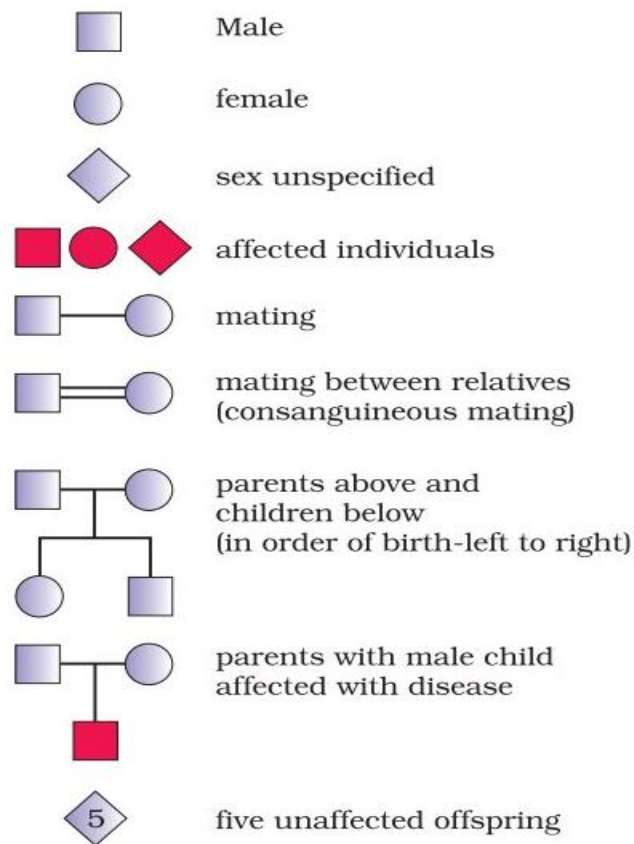
- The sex determination in honey bee is based on the number of sets of chromosomes an individual receives.
- An offspring formed from the union of a sperm and an egg develops as a female (queen or worker), and an unfertilized egg develops as a male (drone) by means of parthenogenesis.
- Thus the males have half the number of chromosomes than that of a female. The females are diploid having 32 chromosomes and males are haploid, i.e., having 16 chromosomes.
- This is called as **haplodiploid** sex-determination system has special characteristic features such as the males produce sperms by mitosis they do not have father and thus cannot have sons, but have a grandfather and can have grandsons.

#### 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.
- The 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. In addition to the above, mutation also arises 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.

#### Pedigree Analysis:

- Study of the family history about inheritance of a particular trait in a several of generations of a family is called the pedigree analysis.
- In the pedigree analysis the inheritance of a particular trait is represented in the family tree over generations.
- In human genetics, pedigree study provides a strong tool, which is utilised to trace the inheritance of a specific trait, abnormality or disease.
- Some of the important standard symbols used in the pedigree analysis have been shown in the figure.

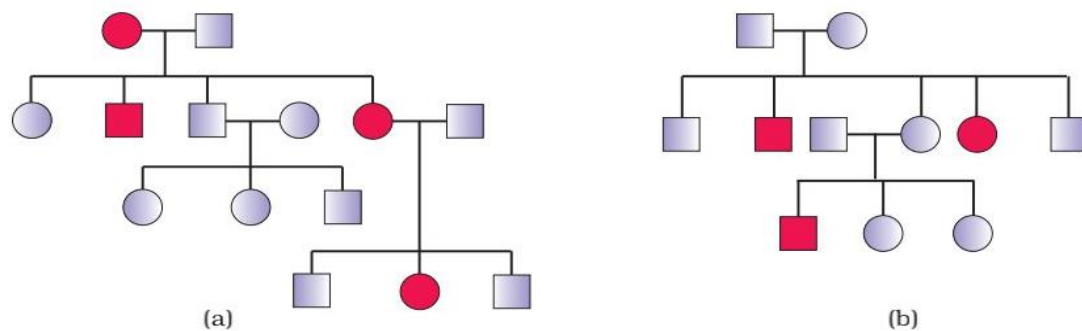


**Figure 5.13** Symbols used in the human pedigree analysis

Mendelian disorders:

- Mendelian disorders are mainly determined by alteration or mutation in the single gene. These disorders are transmitted to the offspring abiding 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.
- A representative pedigree is shown in Figure 5.14 for dominant and recessive traits.



**Figure 5.14** Representative pedigree analysis of (a) Autosomal dominant trait (for example: Myotonic dystrophy) (b) Autosomal recessive trait (for example: Sickle-cell anaemia)

colour blindness

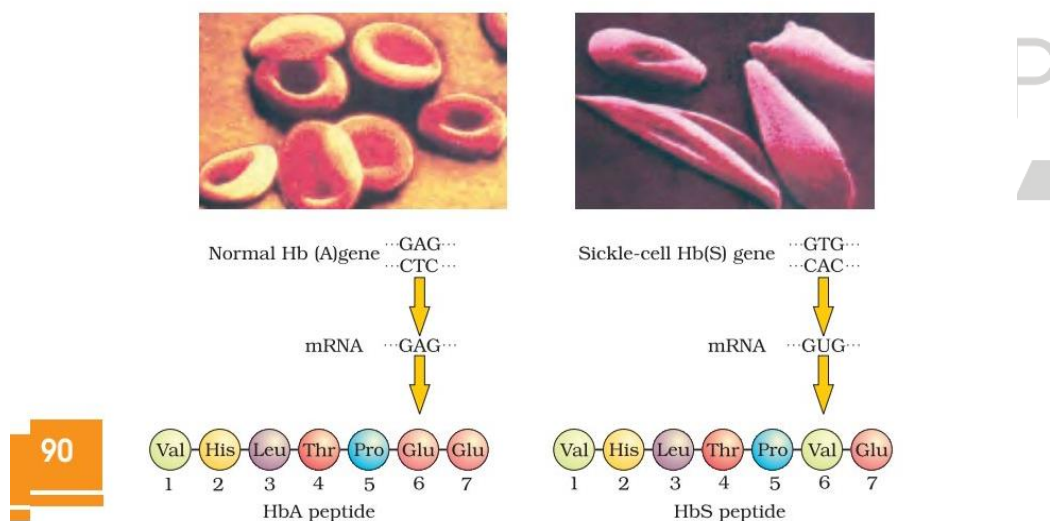
- It is a sex-linked recessive disorder due to defect in either red or green cone of eye resulting in failure to discriminate between red and green colour.
- This defect is due to mutation in certain genes present in the X chromosome. It occurs in about 8 per cent of males and only about 0.4 per cent of females. This is because the genes that lead to red-green colour blindness are on the X chromosome.
- Males have only one X chromosome and females have two.
- The son of a woman who carries the gene has a 50 per cent chance of being colour blind. The mother is not herself colour blind because the gene is recessive. That means that its effect is suppressed by her matching dominant normal gene.
- A daughter will not normally be colour blind, unless her mother is a carrier and her father is colour blind.

Hemophilia:

- This sex linked recessive disease, which shows its transmission from unaffected carrier female to some of the male progeny has been widely studied.
- 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).
- Sickle cell anemia
- 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, HbA and HbS. Out of the three possible genotypes only homozygous individuals for HbS (HbSHbS) show the diseased phenotype.
  - Heterozygous (HbAHbS) 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 5.15).
  - 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 5.15** Micrograph of the red blood cells and the amino acid composition of the relevant portion of  $\beta$ -chain of haemoglobin: (a) From a normal individual; (b) From an individual with sickle-cell anaemia

### 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 molecules in brain results in mental retardation. These are also excreted through urine because of its poor absorption by kidney.

### Thalassemia :

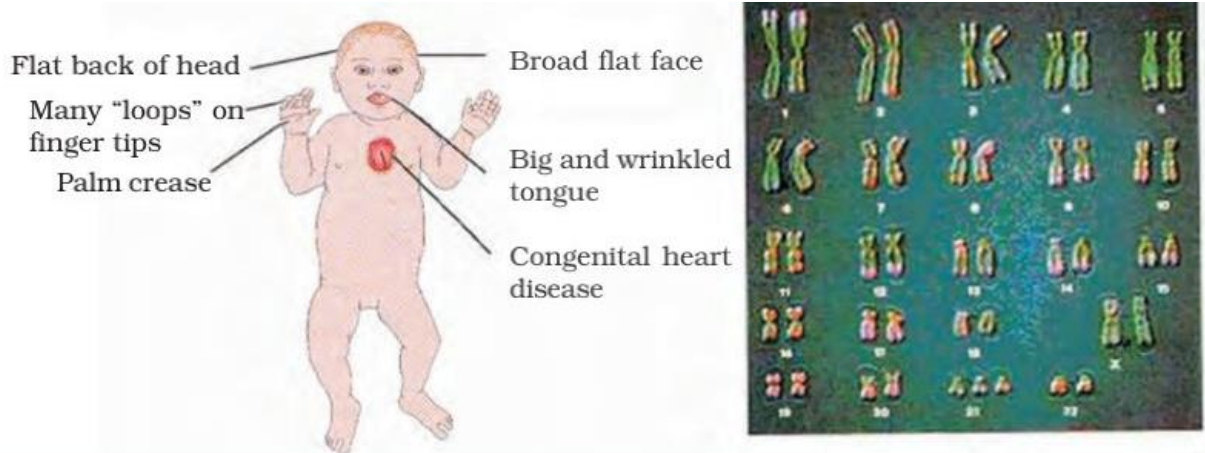
- This is also an autosome-linked recessive blood disease transmitted from parents to the offspring when both the partners are unaffected carrier for the gene (or heterozygous).
- The defect could be due to either mutation or deletion which ultimately results in reduced rate of synthesis of one of the globin chains (a and b chains) that make up haemoglobin.
- This causes the formation of abnormal haemoglobin molecules resulting into anaemia which is characteristic of the disease.
- Thalassemia can be classified according to which chain of the haemoglobin molecule is affected.
- In a Thalassaemia, production of a globin chain is affected while in b Thalassaemia, production of b globin chain is affected.
- a Thalassaemia is controlled by two closely linked genes HBA1 and HBA2 on chromosome 16 of each parent and it is observed due to mutation or deletion of one or more of the four genes.
- The more genes affected, the less alpha globin molecules produced. While b Thalassaemia is controlled by a single gene HBB on chromosome 11 of each parent and occurs due to mutation of one or both the genes.
- Thalassaemia 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.

### Chromosomal Disorders

- The chromosomal disorders on the other hand are caused due to absence or excess or abnormal arrangement of one or more chromosomes. Failure of **segregation** of chromatids during cell division cycle results in the gain or loss of a chromosome(s), called **aneuploidy**.
- For example, Down's syndrome results in the gain of extra copy of chromosome 21.
- Similarly, Turner's syndrome results due to loss of an X chromosome in human females.
- 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. This condition is often seen in plants.

- The total number of chromosomes in a normal human cell is 46(23 pairs). Out of these 22 pairs are autosomes and one pair of chromosomes are sex chromosome.
- Sometimes, though rarely, either an additional copy of a chromosome may be included in an individual or an individual may lack one of any one pair of chromosomes.
- These situations are known as trisomy or monosomy of a chromosome, respectively. Such a situation leads to very serious consequences in the individual. Down's syndrome, Turner's syndrome, Klinefelter's syndrome are common examples of chromosomal disorders.

Down's Syndrome



**Figure 5.16** A representative figure showing an individual inflicted with Down's syndrome and the corresponding chromosomes of the individual

- The cause of this genetic disorder is the presence of an additional copy of the chromosome number 21 (trisomy of 21). This disorder was first described by Langdon Down (1866).
- The affected individual is short statured with small round head, furrowed tongue and partially open mouth.
- Palm is broad with characteristic palm crease. Physical, psychomotor and mental development is retarded.
- Klinefelter's Syndrome



(a)  
Tall stature  
with feminised  
character

- This genetic disorder is also caused due to the presence of an additional copy of X chromosome resulting into a karyotype of 47, XXY.
- Such an individual has overall masculine development, however, the feminine development (development of breast, i.e., **Gynaecomastia**) is also expressed. Such individuals are sterile.
- Turner's Syndrome :



(b)  
Short stature and  
underdeveloped  
feminine character

- Such a disorder is caused due to the absence of one of the X chromosomes, i.e., 45 with XO.
- Such females are sterile as ovaries are rudimentary besides other features including lack of other secondary sexual characters.

**IMPORTANT TERMS**

sl No.	Terms	Explanation
1	Heredity	Transmission of characters from one generation to next generation.
2	Alleles	The various forms of a gene are called alleles
3	Phenotype	The external characteristic of an organism
4	Genotype	The genetic constitution of organism.
5	Homozygote	Individuals with similar alleles for one trait
6	Heterozygote	Individuals with dissimilar alleles for one trait
7	Dominant	The form of character expressed in F-1 generation
8	Recessive	The form of character suppressed in presence of dominant character but expresses itself when present in double doses.
9	Monohybrid cross	Cross where inheritance of contrasting pairs of one trait is considered.
10	Dihybrid cross	Cross where inheritance of contrasting pairs of two traits are considered.
11	Linkage	The tendency of gene to remain together.
12	Recombination	Exchange of genetic segments between non-sister chromatids during pachytene.
13	Genetic maps	Location of genes upon the chromosomes as per their recombination frequency