Chapter - 36
Chromosomal Aberrations in Humans

Chromosome – In the previous chapter we have studied Mendel's laws related to genetics. In this chapter, we would study chromosomal aberration along with common knowledge about chromosomes known as physical basis of heredity. Chromosomes are thread like structured capable of automatic generation. These are situated in nucleus. These can be studied after easily staining. They carry hereditary characters from one generation to other generation so these are known as carriers of heredity. These are also known as basis of heredity.

History – First of all in 1848, **Hofmeister** observed chromosomes in pollen grain mother cell of *Tradescantia*. In 1888, **Waldeyer** called these structures as chromosomes.

First of all **Strasburger** described them. In 1903, **Sutton** and **Boveri** told that particles of heredity are present on chromosomes. This hypothesis is called **Sutton and Boveri hypothesis**.

Type of chromosomes

Different types of living beings are found in whole living world which have different types of chromosomes, i.e.-

1. Viral chromosomes
2. Prokaryotic chromosomes
3. Eukaryotic chromosomes

1. **Viral chromosome –** All types of viruses have only one chromosome. Chemically it is made of DNA or RNA. DNA is found in the chromosomes of bacteriophage which may be of linear or circular type. Most of animal viruses and tobacco mosaic virus etc. have RNA molecule of single chain. These chromosomes are found inside capsid shell made of protein.

2. Prokaryotic chromosomes – Prokaryotic cells like bacteria have only one chromosome in number. Their shape is circular and its size is up to 25 to 100 μ.

3. Eukaryotic chromosomes – In eukaryotic cells like animals, plants and kingdom –Fungi the chromosomes are found inside the nucleus. It has a large quantity of DNA as genetic material and these are affiliated with histone and non-histoneprotein. The number of DNA molecules is fixed in different species. Their number may be from 2 (i.e. Nematode animal) to 1600 (i.e. some members of phylum protozoa).

Autosomes and Sex chromosomes

23 pairs of chromosomes means 46 chromosomes are found in human. Out of these 46 chromosomes 44 chromosomes are similar is male and female which are known as somatic or asexual chromosomes or autosomes. Out of remain two chromosomes one chromosome is smaller and other is bigger in males. These are respectively known as X and Y chromosomes. In female human both the chromosomes are similar and are known as XX chromosomes. Thus in human species total 44+XY = 46 chromosomes are found in males and 44+XX = 46 chromosomes in females. These two additional chromosomes which determine the sex (male or

female) are known as sex chromosomes or allosomes. Sometimes there may be some difference in the set number of chromosomes; these additional chromosomes are called supernumerary chromosomes.

On the basis of their size the chromosome pairs of human are arranged in a sequence and each pair is known by its number. Such type of diagram of karyotype is known as ideogram. Due to this the detection of any type of disorder and its elimination become easy.

Human chromosomal Aberrations

Abnormal children may are born due to difference in the number of chromosomes by any reason during embryonic development in human. Abnormal condition may occur due to change in number of both types of chromosomes- autosomes or sex chromosomes. Abnormalities developed by to any type of change in common number and structure. Some examples of genetically disorders in human are as follows.

(a) Autosomal abnormalities

(i) Mongolism or Down-syndrome – First of all Langdon Down described this abnormality of Mongol childrenin 1866. Scientists found that person suffering from Mongolism or Down-Syndrome has 47 chromosomes which are due to one additional chromosome in 21st pair (Trisomy of 21st chromosome).

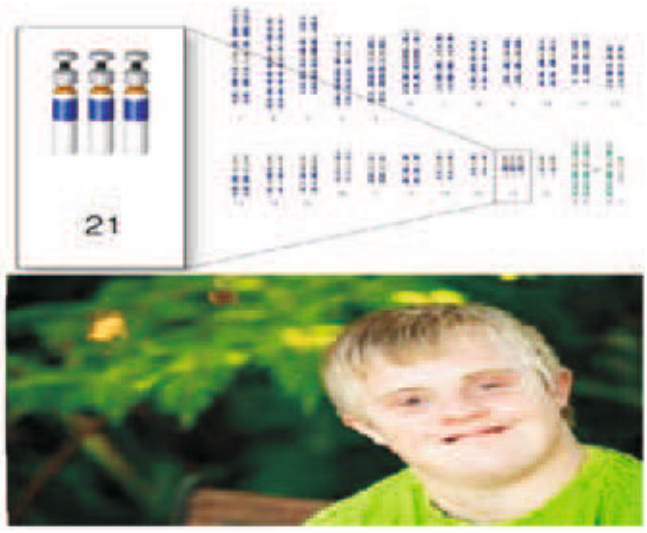

Fig. 36.1 Chromosome in Mongolism or Down-sysdrome

This innate disease of Down's syndrome is found in the ratio of one from every 600 children. Generally this type of disorder is found in children taking birth from ladies of more than 40 years of age. In these women one additional chromosome comes in ovum by error in meiosis during oogenesis. Therefore chromosome count becomes 24 as compared to 23 in ovum of the woman and abnormalities are developed in children taking birth.

These children are with physical abnormalities since birth. They have following symptoms-

Broad cranium of child, short neck, flat hands, and stubby fingers, always opened mouth, lower lip budging below, tongue also sticks out of mouth, and less developed intellectual ability.

2. Edward-syndrome – This abnormality is due to addition of one additional chromosome in 18th pair.

3. Different structural abnormalities- Such type of abnormalities are developed due to deletion of some specific part of the chromosome. Example-comparing with 45 chromosomes due to deletion of smaller arm of chromosome number 5, cri-du-chat syndrome is caused.

(b) Abnormalities related to sex chromosomes

Numerical changes in sex chromosomes are much more as compared to numerical changes in autosomal chromosomes by which many abnormalities and deformations are found in children taking birth which are as follows-

1 Turner-Syndrome – This person is always female. This female has only one x chromosome instead of two. Their chromosome number is 45 (44+XO). It is called Turner's syndrome. These female have less length and their sexual development is also delayed. These females are sterile. One Turner-syndrome girl is born with among per 3000 births. Main symptoms of this are-

Mentally retarded, weblike skin on neck, imperfectly developed breast

2. Klinefilter-syndrome – This disease is caused in males. Their cells may have 47,48 or 49 chromosomes rather than 46. This additional number may be of X or Y chromosome. Klinefelter

males may have following type of chromosomes-

1. 44+ XXY (one additional X chromosome) = 47
2. 44+ XXXY (Two additional X chromosome) = 48
3. 44+ XXXXY (Three additional X chromosomes) = 49
4. 44+ XXYY (One additional X and one additional Y chromosome) = 48
5. 44+ XXXYY (Two additional X and one additional Y chromosome) = 49

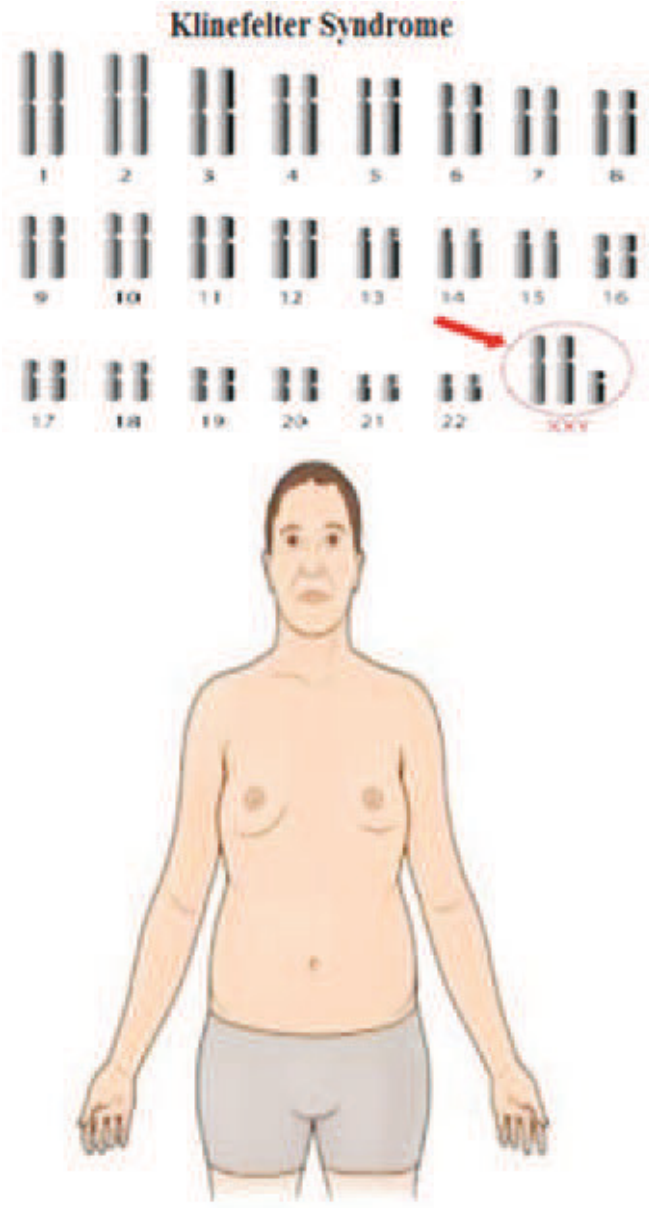

Fig. 36.2 Chromosome in Klinefelter Syndrome

In these males with abnormal chromosome number symptoms of female are observed. Specific symptoms of Klinefelter are as follow-

Tall, less intelligent male, hand and legs are more long, sterile and female like breast developed in male gynecomastia (gynae = female + massere = male + mammary)

3. Status of additional chromosomes in females – It may also be the total number of chromosomes from 47 to 49 but it has increased due to extra X chromosomes means 44 + XXX, 44 + XXXX, 44 + XXXXX. Development of sexual characters delayed in such female and they are less intelligent.

4. Additional chromosomes in males - In such males total chromosomes are 47(44 +XYY). In these males the development of sex organs is abnormal. Their specific symptoms are as follow-

Abnormal tall, less mental ability, criminal mentality

Linkage

Mendel's law of independent assortment is proved true for both genes and chromosomes. Genes are found in various numbers on each of the chromosome of an organism. According to Mendel, each character is determined by a factor which is later on called gene. At first German Scientist Sutton dissevered linkage describing the correlation between factors and chromosomes. According to him the paternal and maternal members of each pair of chromosomes are independently distributed in gametes during meiosis. Due to this the genes situated on separate chromosomes are independently assorted. Number of genes are more in comparison of number of chromosomes in most of the organisms as in **Drosophila,** there are four pairs of chromosomes, while the number of genes is in thousands. It means several genes are present on a chromosome. These are called linked genes and the character controlled by these is known as linked character. These characters are inherited together from one generation to another. Thus genes situated on one chromosome are not always assorted independently.

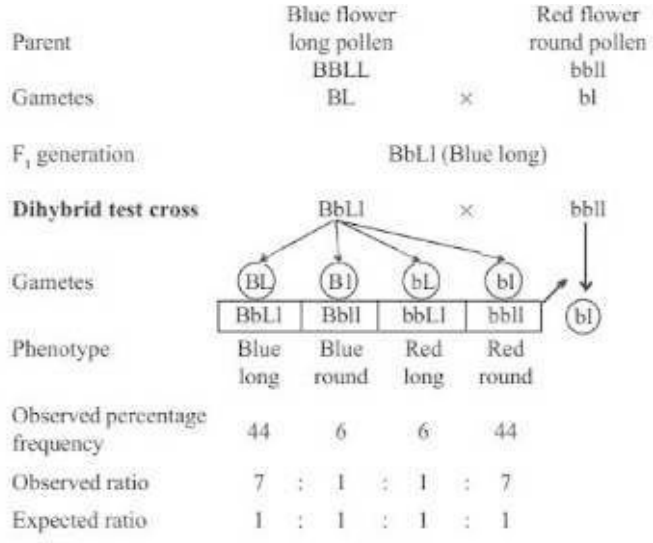

Fig. 36.3 Machanism of linkage
(Bateson and Punnet's experiment on sweet pea)

Thus genes present on a chromosome have a tendency of inheritance together, these genes are called linked and this phenomenon is known as linkage. The group of genes present on a chromosome, which have a tendency of inheriting together that, is called linkage group.

Types of Linkage - Linkage is of two types –

(a) Complete linkage - When the genes present on a chromosome are so close that their inheritance from generation to generation happens without forming new combinations. This is called complete linkage.

(b) In complete linkage – Linked genes do not inherit always in the same combination. At the time of meiosis, the homologous chromosomes exchange them by crossing over. The genes located away on chromosomes are incompletely linked, because much possibility of segregation by crossing over.

Crossing over – Some recombinant forms were also found during Bateson and Punnet's experiments. This was due to another phenomenon which is called crossing over.

Crossing over is that phenomenon in which genes are exchanged between heterologous chromatid of homologous chromosomes and new combination of recombinant gene or genes are obtained.

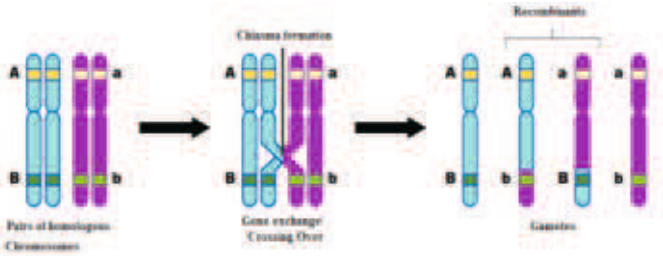

Fig. 36.4 Machanism of gene exchange / crossing over

Crossing over happens at pachytene stage of prophase first of meiosis first at the time of gamete formation. The point where the crossing over happens that is known as chiasmi. The linked gene segregates from each other by the process of crossing over by which new combinations are formed (Fig.36.4).

Types of crossing over – On the basis of formation of number of chiasma crossing over in chromosome are divided under three types-

(a) Single crossing over – Only one chromatid of homologous chromosome takes part in the process of crossing over and only one chiasma is formed in its pair. This is called single crossing over.

(b) Double crossing over – Two- three or all the four chromatids may take part in this process and two chiasmas are formed in them. So it is called double crossing over.

(c) Multiple crossing overs - When more than two chiasma formed in two non-sister chromatids then it is known as multiple crossing overs.

Main characteristics of crossing over –

(a) This process takes place in pachytene during meiosis or gametogenesis.

(b) This process takes place between non-sister chromatids of homologous chromosomes.

(c) Exchange of segments or genes in between non-sister chromatids is called crossing over.

(d) The number of points at which crossing over take place on one chromosome pair at a time it depends upon the length of chromosomes. The percentage of crossing over increases with increases in length.

(e) The distance of genes between each other on

chromosomes also tells the probability of crossing over. More distance between the genes increase the probability and less distance between the genes diminish the probability.

Sex-linked inheritance– According to scientific discoveries in ancient times it was supposed that sex chromosomes are meant only for sex determination. After wards on the basis of various researches, it is well known that sex chromosomes have many genes which express traits of various body characters.

Such characters of which the genes are found on sex chromosomes and inherited with them from one generation to another are known as sex linked characters and their inheritance is called sex linked inheritance. The genes found on X chromosome may be expressed in both male and female therefore the expression of these genes is known as criss-cross genetics. In such inheritance the character of parent generation is transferred into next generation through daughter. Genes for about 20 characters are found on X-chromosomes of human, which are sex-linked characters. The information about facts for important characters out of these is as follows-

Colour blindness- The person suffering from this disease could not identify various colours. Such personis called colour blind. Different persons have different type of colour blindness but the patient of colour blindness of red and green colour are found more i.e. those who could not those who cannot distinguish red and green colour.

The genes forming cones are found on X chromosome of human. The genes control the formation of cells of colour in retina. If in place of this gene its recessive allele appears then colour differentiating cells are not formed by this the person is suffered from disease of colour blindness.

This disease is found more in males because males have only single X- chromosome if the gene forming pigmented cells (cones) on this chromosome is recessive allele then the cones could not be formed while women have two X chromosomes, so woman could not suffer from this disease however she plays the role of carrier.

The inheritance of this disease is as follows.

(i) Inheritance of colour blindness in normal woman and colour blind man - If normal woman is married with colour blind man then their all sons and daughters are normal, but the daughter of this colour blind father is married with normal vision man then sons are colour blind among their generation. It is clear from above example shows that the specific character of colour blindness is transferred by daughter in second generation; this type of inheritance is called crisscross inheritance. Such woman who is not diseased herselfbut becomesas a medium of transfer of the genes of diseaseto next generation,that is known as carrier.

(ii) Father of a colour blind woman should always be colour blind and her mother is carrier of the disease.

Conclusions from the above mentioned examples and their explanations regarding the inheritance of colour blindness disease are as follow-

- Identification of colour in vision is a sex linked character whose gene is located on x chromosome but the allele of this is absent on chromosome.
- Disease of colour blindness is generally found in males. Males have only single X chromosome, so by the absence of common gene for colour differentiation this disease is caused. Males are not carrier of this disease.
- While two XX chromosomes are present in females means the gene for expression of character of identification of colours in male is present on only single chromosome whereas in females genes for it are present on both chromosomes. The female which has this gene on only single X chromosome would be the carrier of this disease.
- The character of identifying colour is dominant over colour blindness so, female would only be colour blind when both chromosomes have the genes of colour blindness, while male with single gene would be colour blind.

- Father and son of colour blind female are colour blind. If husbands of colour blind female are colour blind then their daughter will be colour blind.
- The daughters with normal vision of colour blind father would give birth to half of the boys colour blind and other half are of normal vision.

Haemophilia or Bleeder's Disease

There is lack of blood clotting factor in persons suffering from this disease. Resulting to this if such person has any small injury then blood flows out continuously and at last he die. If the blood flow is not stopped for more than 5-7 minutes then that is said to be haemophilia disease. This disease is also found only in men, women are carrier of this disease. This disease lasts several generations in many families. Former queen Victoria of England was also carrier of this disease. This disease was carried over in her progeny for many generations in males. To avoid death of the patients of haemophilia an injection of blood coagulation factor is given.

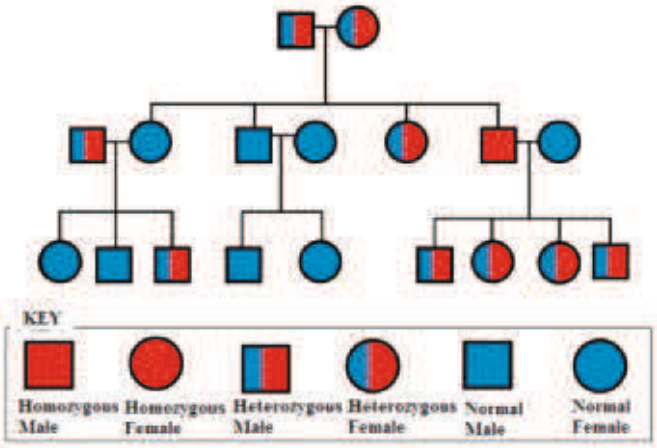

Fig. 36.5 Inheritance of colour blindness and haemophilia

This disease is also caused by sex linked recessive gene which is located on X-chromosome. The inheritance of this disease is also like colour blindness. This disease is caused in males, due to single X chromosome whereas due to two X-chromosomes in female the presence of recessive allomorphic genes is necessary. If any woman has both recessive allomorphic genes then she could not survive because of them one X-chromosome is derived from father and the gene for disease is present on this chromosome. These carrier daughters are married with normal persons than half of progeny of sons become haemophilia disease.

Sickle cell anaemia –

It is a hereditary abnormality. It is due to mutation in autosomal gene. In β - chain of haemoglobin sixth amino acid- glutamic acid is substituted by valine in it. In this red blood corpuscles change their normal shape and distorted into sickle – shaped. This is due to defected haemoglobin. This could not transport oxygen.

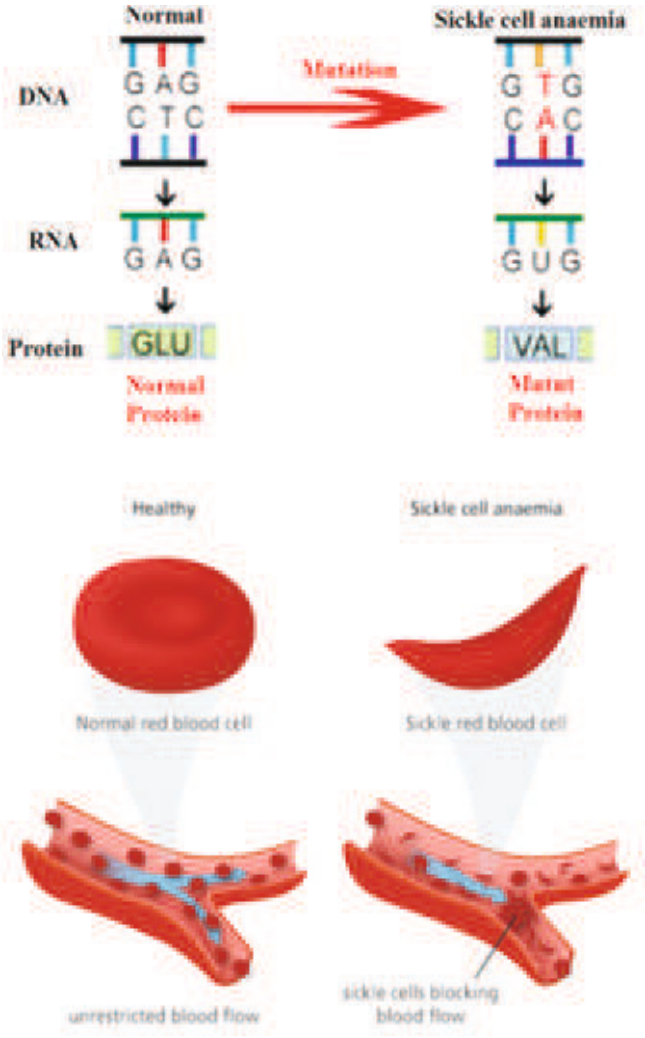

Fig. 36.6 Sickle cell anaemia

Persons with two defected genes (homozygous, recessive) could not survive. Heterozygous persons have one gene normal so half of the total red blood corpuscles have normal haemoglobin while other half is defected; Malaria is less effective in heterozygous persons with sickle cell gene because malaria parasite could not grow in defected red blood corpuscles. So such children who have this gene, this gene is like a boom against malaria among them.

Phenylketonuria –

This disease is also due to recessive mutation in autosomal chromosome.

The person suffered from this disease could not synthesis enzyme phenylalanine hydroxylase which decomposes phenylalanine into tyrosine. As a result of this phenylalanine aggregates and this phenyl is converted into phenyl pyruvic acid and other derivatives. Due to aggregation of these, brain is not developed and mental retardation comes in suffered person. Due to less absorption of it by kidneys, these are also excreted with urine

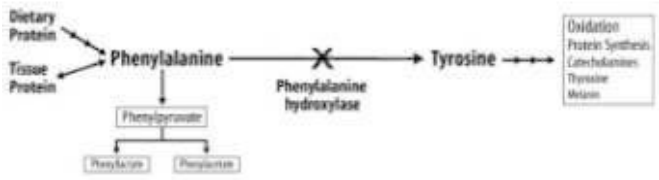

Fig. 36.7 Phenyl ketonuria

Important points

1. Human has 22 pairs of autosomes and one pair of sex chromosomes.
2. Down syndrome, Edward syndrome and other disease are caused due to abnormalities in autosomes.
3. Turner's syndrome and klinefelter syndrome diseases occur due to abnormalities in sex chromosomes.
4. The genes located on one chromosome are known as linked genes. These are called linkage groups.
5. The distance between genes determines the percentage of linkage. Less distance offers more percentage of linkage and linkage percentage is less in more distance.
6. New combinations of genes or recombinants are formed by crossing over process in human.
7. Crossing over happens at the time of meiosis and gamete formation. As a result of this new characters are expressed in progeny.
8. Those characters whose genes are found on sex-chromosomes are known as sex linked genes and inheritance of these characters is called inheritance of sex-linked characters. Some diseases like colour blindness and haemophiliaetc. are its examples.
9. Defected haemoglobin could not transport oxygen in sickle cell anaemia.
10. Phenylketonuria disease is caused due to recessive mutation in autosomal chromosome. Due to this the person suffers with mental retardation.
11. Bleeding is continuously due to small wound in person suffering fromhaemophilia and at last he may die.
12. The person suffering from colour blindness could not identify different colours. Such person is called colour blind.

Practice Questions

Multiple choice Questions-

1. The number of autosomes in human is –
   (a) 42 (b) 44
   (c) 46 (d) 48
2. Which of the following disease is caused due to change in number of autosomes ?
   (a) Turner-syndrome
   (b) Klinfelter-syndrome
   (c) Triple female
   (d) Down-syndrome
3. The progeny of normal woman and colour blind father will be-

(a) All children are of normal vision and none is carrier

(b) Boys colour blind but girls normal

(c) Girls carrier but boys are normal

(d) All children colour blind

4. The number of chromosomes in turner syndrome is –

(a) 44 (b) 45

(c) 46 (d) 47

5. Which of the following is sex linked disease -

(a) Cholera

(b) Edward-syndrome

© Mongolism

(d) Haemophilia

6. The progeny of haemophilic father and carrier mother will be-

(a) Half boys are normal but half are haemophilic

(b) All boys haemophilic

(c) All girls haemophilic

(d) Half girls are normal and half are diseased

7. When a group of genes shows linkage then they-

(a) Do not show independent assortment

(b) Induce cell division

(c) Do not show chromosomal map

(d) Show recombinants during meiosis

8. Crossing over due to which there is genetic recombination in higher organisms is found in between which of following-

(a) Sister chromatids of any bivalent.

(b) Non sister chromatids of any bivalent.

(c) Two daughter nuclei.

(d) Two different bivalent

9. Which enzyme is not synthesized in phenylketonuria disease-?

(a) Phenylalanine hydroxylase

(b) Phenylalanine dehydrogenase

(c) Phenyl oxygenate

(d) Phenyl hydroxylase

10. Sickle cell anaemia is caused-

(a) Due to mutation in autosomal gene

(b) Due to more sex chromosomes.

(c) Due to lack of sex chromosome

(d) None of above

Very Short Answer Questions-

1. What is Down-syndrome?
2. What is the functions of phenylalanine hydroxylase
3. Which type of mutation occurs in heamoglobin in sickle cell anaemia?
4. How many chromosomes may be in Klinefelter syndrome?
5. In which division and when crossing over occurs?
6. What is linkage group?
7. What is haemophilia?
8. Write the number of chromosomes in female and male human.

Short Answer Questions-

1. What is colour blindness?
2. Mention the heredity of disease in progeny of carrier of colour blindness mother and normal father.
3. What is Turner's syndrome?
4. Explain the experiment of Bateson and Punnet.
5. Explain different types of linkage.
6. What is sex linked character and explain their inheritance?

Essay type Questions-

1. What do you understand by sex linked inheritance? Explain it with reference of colour blindness and haemophilia.
2. Explain by clearing the difference between linkage and crossing over.

3. Explain in detail different type of chromosomal abnormalities in human.

Answer Key-

1. (b)	2. (d)	3. (c)
4. (b)	5. (d)	6. (a)
7. (a)	8. (b)	9. (a)
10. (a)		