

Chromosomal theory of inheritance

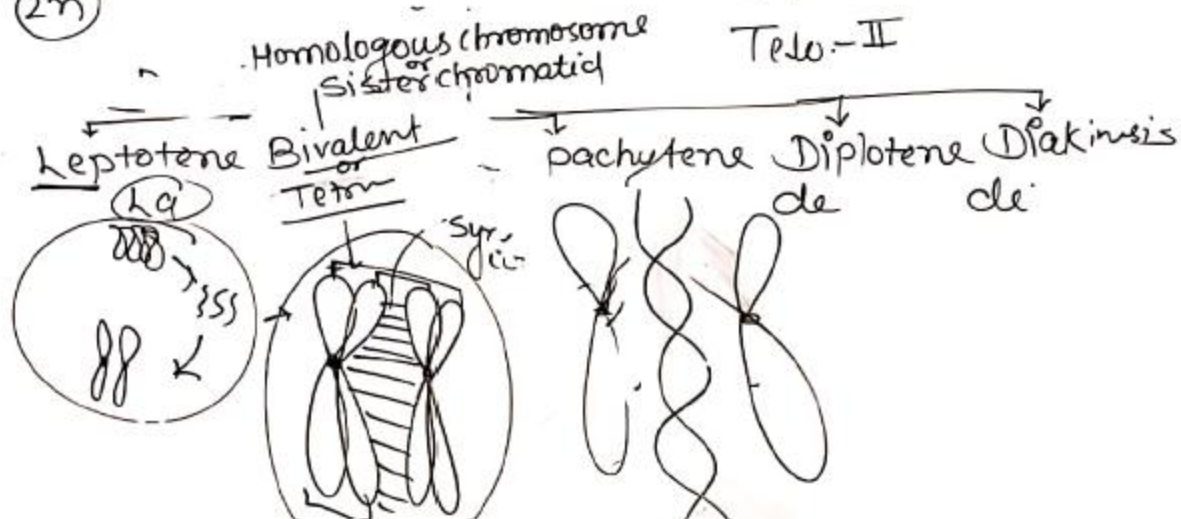
G_1
2C
(2n)

S
↓
2C
↓
4C
(2n)

G_2 ⇒
4C
(2n)

Meiosis-I
↳ prophase-I
Metaphase-I

Meiosis-II
Pro. - II
Met. - II
An. - II
Telo. - II



communication was not easy (as it is now) in those days and his work could not be widely publicised. Secondly, his concept of **genes** (or **factors**, in Mendel's words) as stable and discrete units that controlled the expression of traits and, of the pair of alleles which did not 'blend' with each other, was not accepted by his contemporaries as an explanation for the apparently continuous variation seen in nature. Thirdly, Mendel's approach of using mathematics to explain biological phenomena was totally new and unacceptable to many of the biologists of his time. Finally, though Mendel's work suggested that factors (genes) were discrete units, he could not provide any physical proof for the existence of factors or say what they were made of.

In 1900, three Scientists (de Vries, Correns and von Tschermak) independently rediscovered Mendel's results on the inheritance of characters. Also, by this time due to advancements in microscopy 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 (Figure 5.8) to explain Mendel's laws (Table 5.3). Recall that you have studied the behaviour of chromosomes during mitosis (equational division) and during meiosis (reduction division). The important things to remember are that chromosomes as well as genes occur in pairs. The two alleles of a gene pair are located on homologous sites on homologous chromosomes.

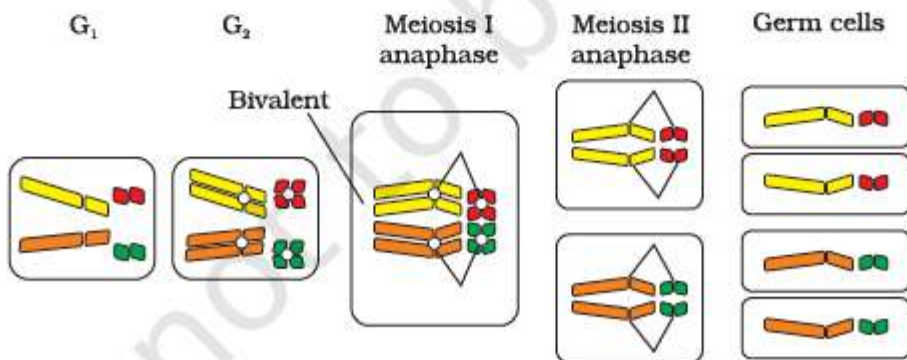


Figure 5.8 Meiosis and germ cell formation in a cell with four chromosomes. Can you see how chromosomes segregate when germ cells are formed?

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

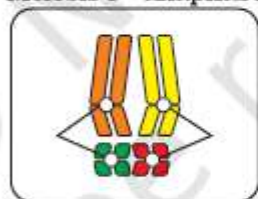
| A | B |
|--|---|
| <i>Occur in pairs</i> | <i>Occur in pairs</i> |
| <i>Segregate at the time of gamete formation such that only one of each pair is transmitted to a gamete</i> | <i>Segregate at gamete formation and only one of each pair is transmitted to a gamete</i> |
| <i>Independent pairs segregate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

During Anaphase of meiosis I, the two chromosome pairs can align at the metaphase plate independently of each other (Figure 5.9). To understand this, compare the chromosomes of four different colour in the left and right columns. In the left column (Possibility I) orange and green is segregating together. But in the right hand column (Possibility II) the orange chromosome is segregating with the red chromosomes.

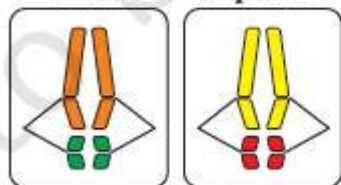
Possibility I

One long orange and short green chromosome and long yellow and short red chromosome at the same pole

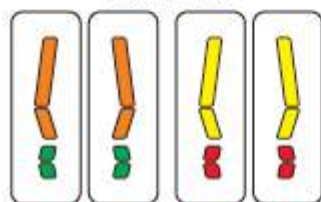
Meiosis I - anaphase



Meiosis II - anaphase



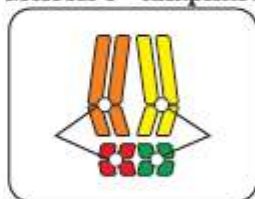
Germ cells



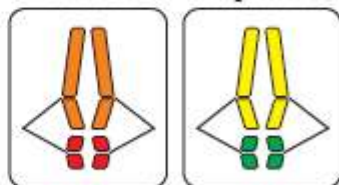
Possibility II

One long orange and short red chromosome and long yellow and short green chromosome at the same pole

Meiosis I - anaphase



Meiosis II - anaphase



Germ cells

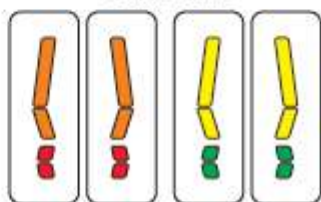


Figure 5.9 Independent assortment of chromosomes

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**.

Following this synthesis of ideas, experimental verification of the chromosomal theory of inheritance by Thomas Hunt Morgan and his colleagues, led to discovering the basis for the variation that sexual reproduction produced. Morgan worked with the tiny fruit flies, *Drosophila melanogaster* (Figure 5.10), which were found very suitable for such studies. They could be grown on simple synthetic medium in the laboratory. They complete their life cycle in about two weeks, and a single mating could produce a large number of progeny flies. Also, there was a clear differentiation of the sexes – the male and female flies are easily distinguishable. Also, it has many types of hereditary variations that can be seen with low power microscopes.

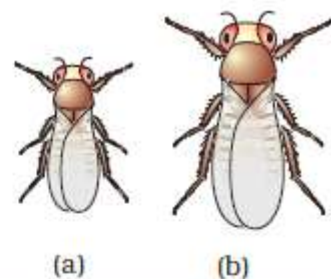


Figure 5.10 *Drosophila melanogaster* (a) Male (b) Female

5.3.3 Linkage and Recombination

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. For example Morgan hybridised yellow-bodied, white-eyed females to brown-bodied, red-eyed males and intercrossed their F_1 progeny. He observed that the two genes did not segregate independently of each other and the F_2 ratio deviated very significantly from the 9:3:3:1 ratio (expected when the two genes are independent).

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 and the term **recombination** to describe the generation of non-parental gene combinations (Figure 5.11). 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). For example he found that the genes white and yellow were very tightly linked and showed only 1.3 per cent recombination while white and miniature wing showed 37.2 per cent recombination. His student Alfred Sturtevant used the frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome. Today genetic maps