Crossing Over

In the chapter of linkage, we have stated that the geneslocated in the same chromosome show linkage. Theselinked genes may either remain together during the process of inheritance and, thus, showing complete linkage or they may be segregated or separated during gametogenesis and, thus, displaying the incomplete linkage. The incomplete linkage takes place due to the occurrence of new combinations or recombinations of linked genes. The recombination in its turn is accomplished through a process known as **crossing over** in which the non-sister chromatids of homologous chromosomes exchange the chromosomal parts or segments.

Characteristics of Crossing Over

1. Crossing over or recombination occurs at two levels (i) at gross chromosomal level, called **chromosomal crossing over** and (ii) at DNA level, called **genetic recombination**.
2. A reciprocal exchange of material between homologous chromosomes in heterozygotes is reflected in crossing over.

3. The crossing over results basically from an exchange of genetic material between non-sister chromatids by break-and-exchange following replication.
4. The frequency of crossing over appears to be closely related to physical distance between genes on chromosome and serves as a tool in constructing genetic maps of chromosomes.

TYPES OF CROSSING OVER

According to its occurrence in the somatic or germ cells following two types of crossing over have been recognized :

1- Somatic or Mitotic Crossing Over

When the process of crossing over occurs in the chromosomes of body or somatic cells of an organism during the mitotic cell division it is known as**somatic** or**mitotic crossing over**. The somatic crossing over is rare in its occurrence and it has no genetical significance.

2- Germinal or Meiotic Crossing Over

Usually the crossing over occurs in germinal cells during the gametogenesis in which the meiotic cell division takes place. This type of crossing over is known as **germinal** or **meiotic crossing over**. The meiotic crossing over is universal in its occurrence and is of great genetic significance.

MECHANISM OF MEIOTIC CROSSING OVER

The process of crossing over includes following stages in it, viz., synapsis, duplication of chromosomes, crossing over and terminalization. The chromosomes which tend to undergo recombination due to meiotic crossing over necessarily complete two functions :

1. 99.7 per cent replication of DNA and 75 per cent synthesis of histones, both of which take place prior to onset of prophase 1, and

2. attachment of each chromosome by its both ends (**telomeres**) to the nuclear envelope (to nuclear lamina) via the specialized structure, called **attachment plaques**.

This event occurs during the **leptotene** stage of prophase I and though each chromosome at this stage is visually long and thin thread, but contains material of two sister chromatids (two DNA molecules plus almost duplicated amount of histones).

1. **Synapsis**

   Synapsis or intimate pairing between the two homologous chromosomes (one maternal and another paternal) is initiated during **zygotene** stage of prophase I of meiosis I. Synapsis often starts when the homologous ends of the two chromosomes are brought together on the nuclear envelope and it continues inward in a zipper-like manner from both ends, aligning the two homologous chromosomes side by side (e.g., mammals).

2. **Duplication of Chromosomes**

   The synapsis is followed by duplication of chromosomes (in **pachytene**). During this stage, each homologous chromosome of bivalents splits longitudinally and form two identical sister chromatids which remain held together by an unsplitted centromere.

3. **Crossing Over by Breakage and Union**

   It is well evident that crossing over occurs in the homologous chromosomes only during the four stranded or tetrad stage. Homologues continue to stay in synapsis for days during pachytene stage and chromosomal crossing over occurs due to exchange of chromosomal material between non-sister chromatids of each tetrad. In pachytene, the recombination nodules become visible between synapsed chromosomes.

4. **Terminalisation**

   After the occurrence of process of crossing over, the non-sister chromatids start to repel each other because the force of synapsis attraction between them decreases. During **diplotene**, desynapsis begins, synaptonemal complex dissolves and two homologous chromosomes in a bivalent are pulled away from each other.

   During **diakinesis**, chromosomes detaches from the nuclear envelope and each bivalent is clearly seen to contain four separate chromatids with each pair of sister chromatids linked at their centromeres, while non-sister chromatids that have crossed over are linked by chiasmata. The chromatids separate progressively from the centromere towards the chiasma and the chiasma itself moves in a zipper fashion towards the end of the tetrad. The movement of chiasma is known as **terminalisation**. Due to the terminalisation the homologous chromosomes are separated completely.

KINDS OF CROSSING OVER

According to the number of chiasma following types of crossing over have been described.

1. **Single crossing over.** When the chiasma occurs only at one point of the chromosome pair then the crossing over is known as **single crossing over**. The single crossing over produces two cross over chromatids and two non-cross over chromatids.
2. **Double crossing over.** When the chiasmata occur at two points in the same chromosome, the phenomenon is known as **double crossing over**. In the double crossing over, the formation of each chiasma is independent of the other and in it four possible classes of recombination occur.