Faculty Name: Dr. Kumari Sushma Saroj

Department: Zoology

College: Dr. L. K. V. D College, Tajpur, Samastipur

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Topic: Crossing Over

Crossing Over

Crossing over is the process of exchange of genetic material or segments between non-sister chromatids of two homologous chromosomes. Crossing over occurs due to the interchange of sections of homologous chromosomes.

The chromosomes usually undergo breakage during gametogenesis. Thus, a mechanism does exist by which a group of genes on the same chromosome changes with the similar group of genes on the homologous chromosome.

The percentage of crossing-over which is obtained between different linked genes varies according to distance between the genes on the chromosomes.

Further, the two genes are apart on a chromosome, more likely is the occurrence of crossing-over between them. At a particular point only two of the four chromatids are involved in the exchange of their parts and to produce 50 per cent recombinant gametes.

The genes in such a case should be located so much apart on the same chromosome as to allow crossing-over in all the mother cells during reductional division.

Under such conditions genes behave as if located on different chromosomes. Mendel's law of Independent Assortment holds good only under the following conditions:

(a) When the genes are located on different chromosomes.

(b) If the genes are located on the same chromosome but the distance between them is so good as to produce 50 per cent recombinant gametes due to crossing-over.

Mechanism of crossing-over:

(i) Synapsis:

The homologous chromosomes pair lengthwise due to a force of mutual attraction in zygote of prophase-I in meiosis. The pairing starts at one or more points and proceeds along the whole length in a zipper fashion. The process of pairing is called synapsis.

The paired homologous chromosomes are called bivalents. During synapsis, a molecular scaffold called synaptonemal complex aligns the DNA molecule of two homologous chromosomes side by side.

(ii) Duplication of chromosomes:

Synapsis is followed by the duplication of chromosomes which changes the bivalent nature of chromosome to four- stranded stage or tetravalent. Four stranded stage of chromatids occurs due to splitting of homologous chromosomes into sister chromatid attached with un-splitted centromeres.

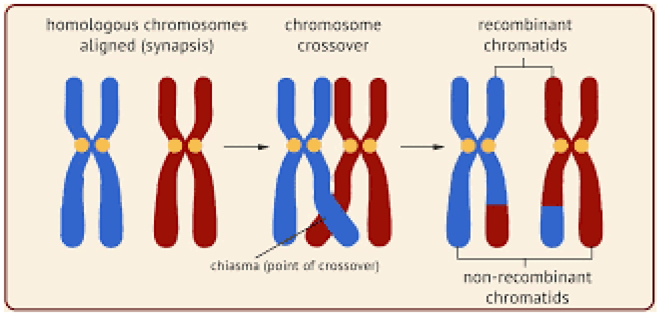

Fig. Chiasma Formation

(iii) Crossing-over:

In pachytene, crossing over occurs. Non-sister chromatids of homologous pair twist over each other due to action of enzyme endonuclease. The chromatids get connected with each other at points known as chiasmata.

The crossing over can take place at several points. The number of chiasmata formed is proportional to the length of chromatids. The genes at distant loci undergo crossing-over but closely placed genes fail to cross-over and exhibit the phenomenon of linkage.

During diakinesis of prophase-I chiasmata move towards the end of bivalent by a process called terminalization. Thus twisting chromatids separate so that the homologous chromosomes are separated completely.

At anaphase –1 of meiosis, the homologous chromosomes separate. It is evident that one of the chromatids of each chromosome carries a portion of chromatid from its homologous chromosome.

At the end of meiosis, four types of gametes are formed. Two will be of parent types and two will contain chromosomes with recombination of genes formed during crossing- over.

Janssens (1909) was the first to correctly understand the process of chiasma formation. What actually causes the breakage and reunion of chromatids still remains obscure. According to Stem and Hota (1978) breaks or nicks appear in the chromatids due to enzyme endonuclease.

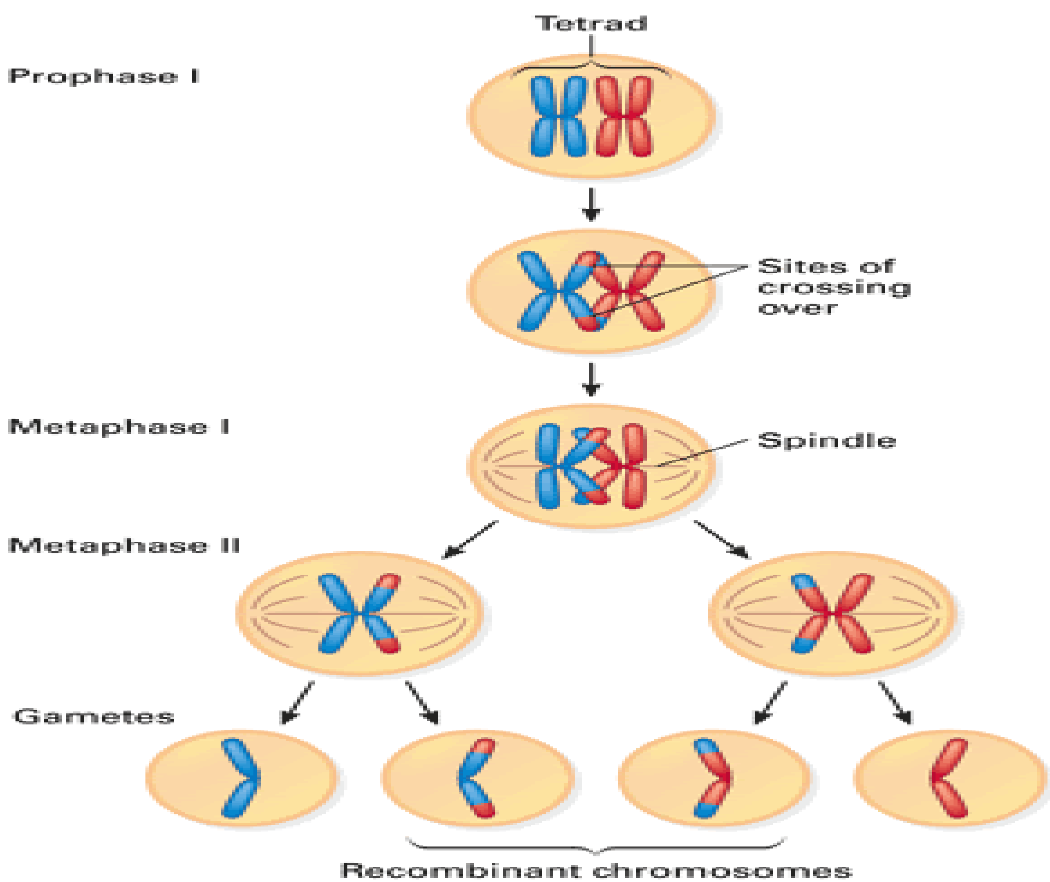

Fig. Crossing-over

Crossing-over and chiasmata:

There are two theories regarding relationship between crossing over and chiasmata formation.

1. Chiasma type theory (Jenssen, 1909):

According to this theory, the act of crossing-over is followed by chiasma formation. Here the chiasma formation is the consequence of crossing-over.

This view states that adjacent loops are organised in one plane and hence it is called one plane theory. According to this theory, crossing-over takes place at the pachytene stage and chiasma appear at diplotene.

2. Classical theory (Sharp, 1934):

According to this theory, crossing-over the result of chiasma formation. Adjacent loops are organised at right angles to each other and hence it is called two plane theory.

Chiasmata are organised at pachytene and crossing-over takes place at diplotene stage. This theory has been considered to be untenable and hence rejected.

Types of Crossing-over:

Depending upon the number of chiasmata formed.

(i) Single cross-over:

In this case, only one chiasma is formed which leads to formation of single cross-over gametes. It is most common type of cross-over.

(ii) Double cross-over:

In double cross-over, two chiasmata develop. These chiasmata may appear between the same chromatids or between different chromatids. This type of crossing over forms double crossing-over gametes.

(iii) Multiple cross-over:

Here, more than two chiasmata are constituted. It may be further classified into triple (3 chiasmata), quadruple (4 chiasmata) and so on. Multiple crossing-overs are of rare occurrence.

Factors influencing crossing-over:

Distance between the genes. More the distance between two genes on same chromosome, higher the frequency of crossing over.

Significance of crossing-over:

(i) This process provides an inexhaustible store of genetic variability in sexually reproducing organisms.

(ii) Useful recombinations are used by plant and animal breeders. Breeders try to break up the linkages by crossing-over to get combinations of useful traits in the progeny.

(iii) This process produces new combination of genes (recombination). Green revolution and white revolution are mainly due to selective picking up of useful genetic recombination developed by the process of crossing-over.