UNIT 17 MEIOSIS AND CELL DIVISION

Structure

17.1 INTRODUCTION

In the previous unit (16) you have studied about mitosis, cell cycle and factors that determine and control cell cycle and cell division. You have also read about the chromosomal events taking place during mitosis. Mitosis gives rise to daughter cells, each of them receiving exactly the same **number** and **kind** of chromosomes that the parent cell had. During the late 1800s, it became apparent that another, modified form of cell division must occur in the life cycle of sexually reproducing organisms in order to ensure the constancy of the chromosome number in the successive generations. The term meiosis is taken from the Greek word **meioun,** which means 'to diminish'. This unit deals with the process of meiosis.

In addition to reducing the chromosome number of the daughter cells, meiosis also brings about **recombination**, a mechanism by which segments of chromosomes are physically exchanged to mix the gene sequence into new combinations. Recombination provides a variety of genetic types to meet the demands of a changing environment. Here you will study chromosomal behaviour during meiosis, genetic recombination and also about division of the cytoplasm,i.e., **cytokinesis.**

Objectives

After reading this unit you shall be able to:

- draw diagrams to show chromosomal behaviour in various phases of meiotic prophase
- explain the molecular theory of genetic recombination
- list the chromosomal and genetic differences in daughter cells produced by mitosis and meiosis
- give distinctive features of cytokinesis in plant cells compared with those in the animal cells.

17.2 MEIOSIS

You must be aware that organisms reproduce basically in two different ways: i) **Asexual** reproduction, and ii) **Sexual** reproduction. In asexual reproduction, a single parent usually splits, buds, or fragments to give rise to two or more individuals. The individuals produced by the ways mentioned above is through the process of mitosis, and therefore have the same number of chromosomes as that of their parent. They also have identical genes and therefore inherit traits similar to those of their parent organism.

In contrast, sexual reproduction involves two parents, each of which contributes a specialised sex cell, or **gamete.** In the case of animals and plants, the male gamete is called **sperm** and the female gamete is called an **ovum** or **egg**. At the time of

fertilisation the male and the female gametes fuse to form a **zygote.** The zygote divides through a series of mitotic divisions to give rise to a new individual.

You must be aware that the number of chromosomes carried by the cells in an individual, and all the individuals of a species is constant. Chromosomes normally exist in pairs; there are two of each kind in the somatic (body) cells of higher plants and animals. Thus, the 46 chromosomes in human cells constitute 23 different pairs. The member of a pair, called **homologous chromosomes** are similar in size, in shape, and in the position of their centromere. A set containing two of each kind of chromosome is said to have the **diploid** number or **2n.**

You have learnt above that, at the time of fertilisation male and the female gamete fuse to form a zygote. Let us consider that in an organism four is the diploid number of chromosomes and the gametes too carry four chromosomes. In this case, when the gametes fuse to form a zygote, the chromosomal number in the zygote will be 8 (4+4=8) and all the cells derived from the zygote would contain 8 chromosomes. Thus chromosome number would increase at the turn of each generation by the square of number of chromosomes of the previous generation. This would consequently lead to an untenable situation. There would remain no significance to the number of chromosomes an organism carries. But in nature this is not so. We see that chromosome number is constant no matter how many generations succeed one another. The constancy of the chromosomal number in successive generations of sexually reproducing organisms is ensured by the process of **meiosis.** Gametes have only one homologue of each homologous pair and thus have the **haploid** or **n** number of chromosomes. At the time of fertilisation when the sperm and egg fuse, each gamete contributes its haploid number of chromosomes; the diploid number is thereby restored in the fertilised egg (zygote). When the zygote divides by mitosis to form the first two cells of the embryo, each cell receives a diploid set of chromosomes; thus most body cells are diploid. Now we will study about the behaviour of chromosomes during meiosis.

17.2.1 Chromosomal Events

Meiosis consists of a series of nuclear and cell divisions, designated as the first and second meiotic divisions, or simply **meiosis I** and **meiosis II.** Each of these includes prophase, metaphase, anaphase and telophase. During the first meiotic division, the members of each of the homologous chromosomes separate and are distributed into separate cells. In the second meiotic division, the chromatids that make up each chromosome separate and are distributed to the daughter cells. In this way the number of chromosomes is reduced by half, which gives rise to four haploid cells at the end of meiosis. The meiotic division takes place at the end of the G2 phase of the interphase, as in the case of mitotic cell division.

The essential processes that take place during meiosis are:
- pairing (synapsis) of the homologous chromosomes
- formation of chiasmata, and
- segregation of homologous chromosomes.

From the morphological point of view the prophase of the first meiotic division is a long process during which homologous chromosomes pair closely and interchange hereditary material. For convenience the first meiotic prophase is divided into the following five stages:
- Leptotene (Leptonema)
- Zygotene (Zygonema)
- Pachytene (Pachynema)
- Diplotine (Diplonema)
- Diakinesis

However these stages are not sharply demarcated. Now we will study about each of these stages in detail.

Leptotene: Leptotene stage begins when each chromosome is first seen to have condensed from its interphase conformation to produce a long thread with a proteinaceous central axis. Each chromosome is attached at both of its end to the nuclear envelope via a specialised structure called an **attachment plate.** Although each chromosome has replicated and consists of two **sister chromatids,** these chromatids are closely opposed and therefore appears to be single (Fig. 17.1A).

Zygotene: Leptotene is considered to end and the zygotene stage begins as soon as intimate pairing between the two homologous chromosomes is initiated by the process called **synapsis** or zygotene pairing. The homologous chromosomes which pair are coming from different sexes (father and mother). Synapsis often starts when the homologous ends of the two chromosomes are brought together on the nuclear envelope and continues inwards in a zipper-like manner from both ends, aligning the two homologous chromosomes side by side (Fig. 17.1B). The pairing is completed in three different ways, as follows:

i) **Proterminal Pairing**: The two homologous chromosomes start pairing at the ends or terminals, which gradually progress towards the centromere.

ii) **Procentric Pairing**: The pairing starts at the centromere and proceeds towards the end.

iii) **Random or Intermediate Pairing**: The pairing may be at many points towards the ends.

As a result of synapsis each gene is thus thought to be brought into close contact with its homologous gene on the opposite chromosome. The two homologous chromosomes are brought together to form a characteristic ladder-like structure, called **synaptonemal complex**. Each homologous chromosome pair in meiotic prophase I consists of two closely opposed sister chromatids, thus each pair containing four replicas known as **tetrads**.

Pachytene: As soon as the synapsis is complete all along the chromosome, the cells are said to have entered the pachytene stage of prophase, where they may remain for days. At this stage large **recombination nodules** appear at intervals on the synaptonemal complex. These recombination nodules mediate for chromosomal changes. The **non-sister chromatids** (chromatids of different chromosomes) twist around each other. This process is called **crossing over** (Fig. 17.1C).

Diplotene: The beginning of diplotene stage is marked by the beginning of separation of non-sister chromatids and the tight pairing is relaxed. This process is known as **desynapsis**. The separation of homologous chromosomes is however not completed. They remain attached at one or more points where crossing over has occurred. These points of attachment are called **chiasmata**. In oocytes, diplotene can last for months or years, since it is at this stage that the chromosomes decondense and engage in RNA synthesis. In some cases the chromosomes expand enormously, producing the **lampbrush chromosomes**, found in amphibians and some other organisms (Fig. 17.1D).

Diakinesis: Diplotene stage merges into diakinesis. At this stage RNA synthesis stops and the chromosomes condense, thicken, and become detached from the nuclear envelope. Each bivalent is clearly seen to contain four separate chromatids, with each pair of sister chromatids attached at their centromeres, whereas non-sister chromatids that crossed over are linked by chiasmata (Fig. 17.1E).

Prometaphase I: During this phase the bounding membrane of centrosome degenerates, leaving behind two centrioles along with astral rays. Then both of them move apart and take their final position at opposite poles of the cell. Each centriole is provided with its own astral rays. Nuclear membrane also breaks down and results in the formation of spindle fibres.

Metaphase I: During metaphase-I, the bivalent chromosomes arrange themselves in the plane of the equator forming equatorial plate. The centromere of each chromosome is directed towards the opposite poles and the arm of chromosomes is faced towards the equatorial plate (Fig. 17.1F).

Anaphase I: All the bivalent chromosomes repel each other towards opposite poles. Thus each pole receives half the number of haploid set of the chromosomes. Thus, actual reduction occurs at this stage. The movements of chromosomes is brought by the spindle fibres, which is similar to the mitotic movements (Fig. 17.1G).

Telophase I: At this stage, the nuclear membranes are formed by the endoplasmic reticulum around the groups of chromosomes which disappear with the appearance of nucleolus or nucleoli (Fig. 17.1H).

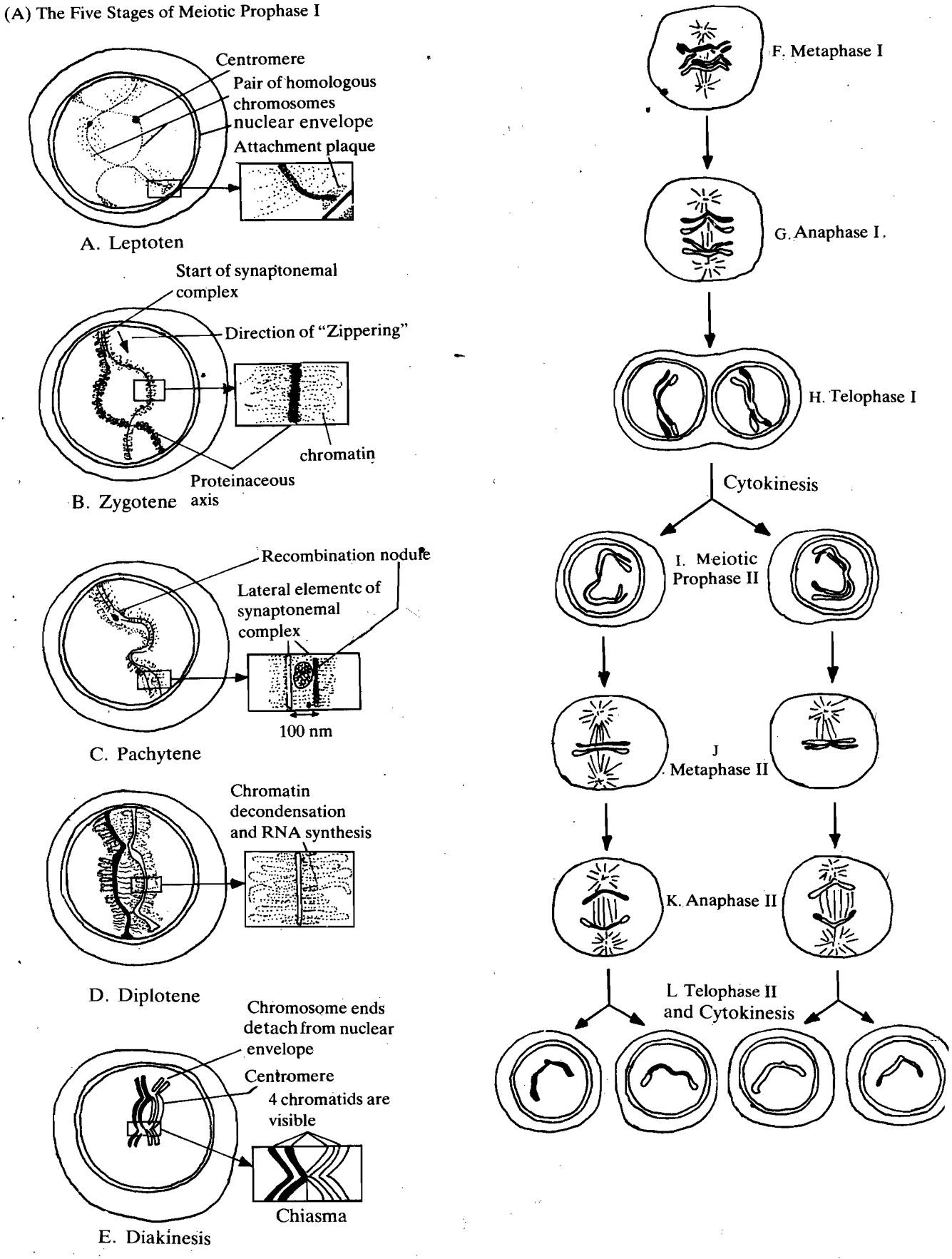

Fig. 17.1 Stages of Meiosis

Intrameiotic Interphase: This is the stage between the telophase of the first meiotic division and the prophase of the second meiotic division. In the previous unit you have studied that replication of chromosomal DNA takes place during this phase. But in meiosis, no replication of DNA takes place during the interphase.

The Second Meiotic Division: The second meiotic division is essentially similar to mitosis. It divides each haploid cell into two daughter haploid cells. Like mitotic division it can be studied under four phases:

Prophase II: Prophase II does not show the complex nuclear behaviour of prophase I. The chromatids of prophase II have widely separated rims, and in this respect differ from the chromatids of the mitosis, which are close together. Spindle formation takes place in prophase II as in mitosis, and the nuclear membrane disappears (Fig. 17.1I).

Metaphase II: The chromosomes become oriented on the equatorial plate and have the same relationship to the spindle as in mitosis (Fig. 17.1J).

Anaphase II: The centromeres divide and the two chromatids of each chromosome separate and move to the poles. After separation, the chromatids are called chromosomes (Fig. 17.1K).

Telophase II: At this stage reconstruction of the nuclei takes place as in mitosis. The nucleus, centriole and the chromosomes return to the interphase condition. Each nucleus contains the haploid number of chromosomes (Fig. 17.1L).

In animal oocytes, anaphase II and telophase II are again asymmetrical. A **second polar body** is formed. The first polar body may also undergo a meiosis II to give rise to two haploid daughter polar bodies. Thus at the end of meiosis II we find 4 haploid cells, three polar bodies and the **ovum** (Fig. 17.2).

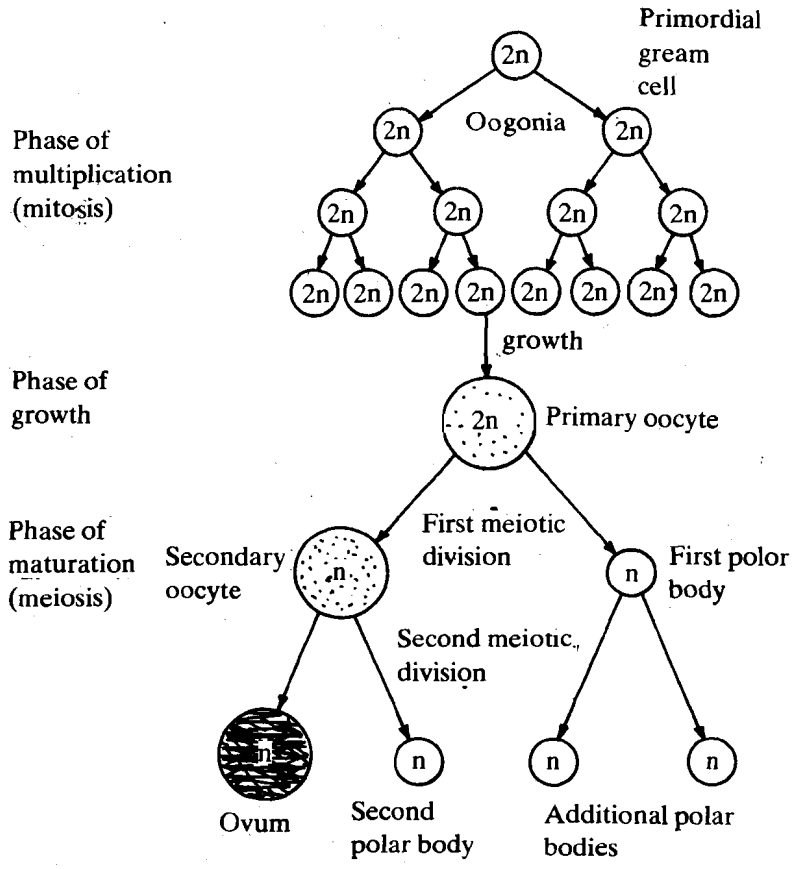

Fig. 17.2 Meiotic Division in Animal Oocyte

SAQ 1

Fill in the blanks with suitable words.

a) Meiois is a special type of cell division in which the chromosomal number is reduced to ..... of the original number.

b) The essential processes that take place during meiosis are ..... of homologous chromosomes, formation of ....., and ..... of homologous chromosomes.

c) Crossing over takes place during ..... stage of the first meiotic prophase.

d) ..... is the point of attachment of non-sister chromatids during crossing over.

e) In amphibians chromosomes expand enormously during diplotene stage producing the .....

17.3 GENETIC RECOMBINATION

In the previous section you have learnt that at the end of the meiosis, four haploid daughter cells are produced from one diploid germ cell, maintaining constancy of chromosome number in the species. In addition to maintaining the constancy of chromosomal number in the species, meiosis also brings about genetic variability in the population.

Genetic variability is brought about by genetic recombination. You have learnt in the previous section that the genetic recombination takes place by the process of crossing over during pachytene. In this process the precise pairing of the homologous chromosomes plays a very important role and this is brought about by the development of synaptonemal complex. Synaptonemal complex provides the structural framework necessary for recombination events. The actual recombination is mediated by recombination nodules, which are either spherical, ellipsoidal, or bar-like protein—containing assemblies with a diameter of about 90 mm. These nudules sit at intervals on the synaptonemal complex, placed like basketballs on a ladder between the two homologous chromatids (Fig. 17.3). There are about as many recombination nodules as crossover events. Since recombination nodules initiate the process of crossing over, it implies that recombination nodules must be extremely efficient in causing the chromatids on opposite homologues to recombine.

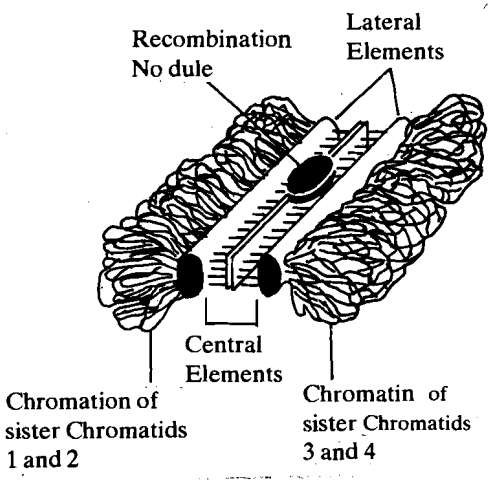

Fig. 17.3 Synaptonemal Complex

Recombination of genetic material results from physical exchanges between homologues, which involve a process of breakage and reunion of chromosome segments. Figure 17.4 clearly illustrates the process of recombination of genetic material between the homologous chromosomes (Fig. 17.4).

You can see in Fig. 17.4 that a homologous pair of chromosomes contain the genes A,a, and B,b, at different sites on the chromosome arm (Fig. 17.4A). One member of the pair has the alleles A and B at these locations. As a result of replication of premeiotic interphase, both chromatids of the chromosomes will have the A and B alleles at these sites. The opposite member of the homologous pair has the alleles a and b at the corresponding locations. At this stage, these chromosomes are identical in sequence of chromosomes of the same homologous pair in any cell of the organism. During prophase I of meiosis, the homologous pair closely. If recombination occurs between these genes (Fig. 17.4B), two of the four chromatids

at the close of meiosis will contain the new combinations A-b and a-B (Fig. 17.4C) As a result, the products of recombination consists of two chromatids of unchanged sequence (the parentals) and two with altered sequence (the recombinants). In the subsequent section we will study about the molecular mechanism involved in the process of recombination.

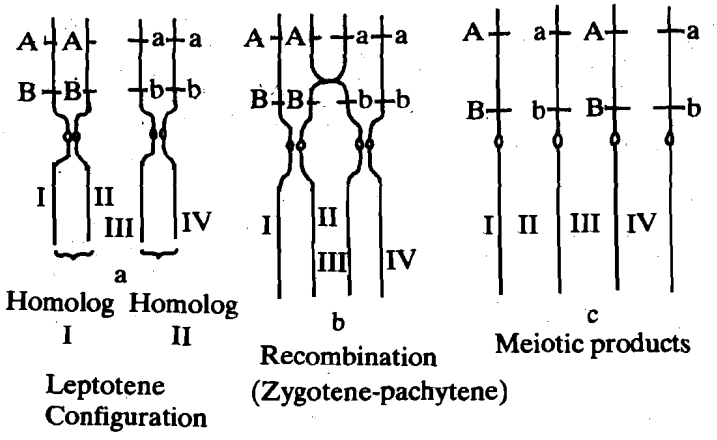

Fig. 17.4 The effect of recombination in mixing the alleles of the chromatids entering meiosis into the new combinations.

17.3.1 Molecular Theory of Recombination

Whitehouse (1963), Holliday (1964), Meselson (1964) and others proposed models to explain recombination of genetic material at the molecular level. However, all of these models share several basic assumptions about the molecular events taking place in the breakage and exchange mechanisms.

As per the molecular model, two of the four chromatids, or two DNA molecules of opposite parentage approach and pair in such a way that homologues are opposite to each other (Fig. 17.5A). In the subsequent step, openings are made (by DNA endonuclease enzyme) in each of the nucleotide chains of the two DNA molecules (Fig. 17.5B). These openings are called **nicks**.

Following the openings of the nicks, the two DNA molecules unwind to expose four single-stranded DNA (Fig. 17.5C). Unwinding is promoted by DNA-binding proteins that stabilise and protect DNA in the single-stranded form, and possibly by unwinding enzymes and DNA gyrases. These enzymes are identical to those involved in DNA replication.

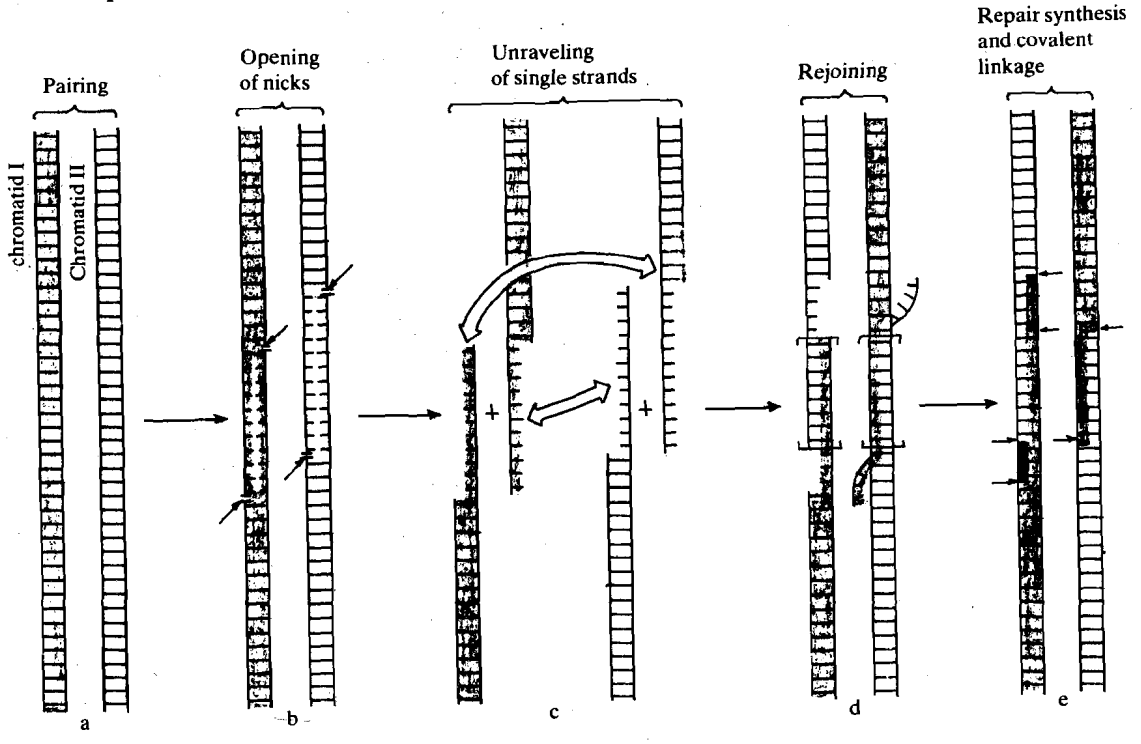

Fig. 17.5 A simplified model for the molecular steps in recombination by breakage and exchange.

While the segments are rewound, one or more of the exposed single-stranded ends may be "nibbled" or shortened by DNA exonuclease. The complementary nucleotide chains from opposite chromatids then pair by alignment of complementary bases and wind into double helices producing hybrid DNA (Fig. 17.5D). The hybrid DNA may not be completely complementary and may contain sequences originating from opposite alleles. At the ends of the hybrid regions, gaps or overlaps may be produced because of inexact location of the single-strand nicks and because of nibbing. The overlaps are then excised by DNA exonuclease, and the gaps filled in by DNA polymerases. Finally, the remaining nicks in the recombined DNA molecule are covalently linked by the enzymes DNA ligase (Fig. 17.5E). Table 16.3 summarises the enzymes involved in the process of recombination.

Table 17.1 Enzymes and Factors Active in Recombination

Enzymes or Factors	Possible Role in Recombination
DNA endonuclease	Opening initial nicks in the homologous DNA molecules.
DNA-binding proteins, unwinding enzymes, DNA gyrase	Unwinding and stabilising single nucleotide chains after nicking; Promoting invasion of homologous helix.
DNA exonuclease	Nibbling ends of exposed single nucleotide chains.
DNA polymerase	Gap filling after formation of hybrid helix.
DNA ligase	Sealing nicks after gap filling.

Experimental results from the variety of sources indirectly support the molecular model for recombination and indicate that the proposed mechanism, or one very much like it, probably operates in the breakage and exchange of chromosome segments during meiotic prophase I. All of these enzymes required including DNA endonuclease, DNA exonuclease, binding proteins, unwinding enzymes and DNA gyrases, and DNA polymerases and ligases are known and well characterised. There is also evidence from the work of Stern and Hotta (1973) that these enzymes increase in activity during the recombination stage.

17.3.2 How does Meiosis Differ from Mitosis?

The events of meiosis are similar to the events of mitosis, but there are several important differences. Let us study these differences following Table 17.2.

Table 17.2 Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. The cell divides only once.	1. There are two cell divisions, the first and the second meiotic divisions.
2. Mitosis takes place in the somatic cells of the body.	2. Meiosis takes place in the germ cells.
3. Occurs in both sexually as well as asexually reproducing organisms.	3. Occurs only in sexually reproducing organisms.
4. DNA replication takes place during interphase I.	4. DNA replication takes place during interphase I but not interphase II.
5. The DNA replicates once for one cell division.	5. The DNA replicates once for two cell divisions.
6. The duration of prophase is short, usually of a few hours.	6. Prophase is comparatively longer and may take days.
7. Prophase is comparatively simple.	7. Prophase is complicated and is divided into leptotene, zygotene, pachytene, diplotene and diakinesis.
8. The cell divides only once and the chromosomes also divide only once.	8. There are two cell divisions but the chromosomes divide only once.
9. There is no synapsis.	9. Synapsis of homologous chromosomes takes place during prophase.
10. The two chromatids of a chromosome do not exchange segments during prophase.	10. Chromatids of two homologous chromosomes exchange segments during crossing-over.
11. Each chromosome consists of two chromatids united by a centromere.	11. The two homologous chromosomes from bivalents or tetrads. Each bivalent has four chromatids and two centromers.
12. The arms of the prophase chromatids are close to one another.	12. The arms of the chromatids are separated widely in prophase II.

Mitosis	Meiosis
13. Chromosomes are already duplicated at the beginning of prophase.	13. When prophase I commences the chromosomes appear single (although DNA replication has taken place in interphase I).
14. In the metaphasic plate all the centromeres line up in the same plane.	14. In metaphase I the centromeres are lined up in two planes which are parallel to one other.
15. The metaphasic plate is made up of chromosome pairs.	15. The metaphasic plate is made up of paired chromosome pairs.
16. Division of centromeres takes place during anaphase.	16. There is no centromeric division during anaphase I. Centromeres divide only during anaphase II.
17. The chromosomes separate simultaneously during anaphase.	17. Short chromosomes separate early; separation of long chromosomes is delayed.
18. Spindle fibres disappear completely in telophase.	18. Spindle fibres do not disappear completely during telophase I.
19. Nucleoli reappear at telophase	19. Nucleoli do not reappear in telophase I.
20. The chromosome number remains constant at the end of mitosis.	20. The chromosomal number is reduced from the diploid to the haploid.
21. The genetic constitution of the daughter cells is identical to that of parent cells.	21. The genetic constitution of the daughter cells differs from that of the parent cell. The chromosomes of daughter cells usually contain a mixture of maternal and paternal genes.

SAQ 2

Explain in just one line the role of the enzymes listed below, in the process of recombination

a) DNA Endonuclease: .....

.....

b) DNA gyrase: .....

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c) DNA exonuclease: .....

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d) DNA polymerase: .....

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e) DNA ligase: .....

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17.4 CYTOKINESIS

In Unit 16 and the earlier sections of this unit you have been studying the chromosomal events taking place during mitosis and meiosis. In this section we will study about division of the cytoplasm, cytokinesis in both animals and plants.

The nuclear division and cytokinesis usually occur together; however, this is not always the case. For example in **Drosophila** eggs, early development consists of many successive and synchronous nuclear divisions in the fertilised egg without accompanying cytokinesis. This creates a single cytoplasmic mass with several thousand nuclei. Occasionally even in animal cells cytokinesis may fail to occur, creating binucleated cells.

Cytoplasmic division in most cells begins during late anaphase and continues during telophase, when the daughter nuclei have reached the G1 stage. Division of the cells occurs in a plane at the right angle to the long axis of the spindle, midway between the separated groups of daughter chromosomes. The process of cytokinesis in animal cells differs from the process in plant cells. The two mechanisms of cytokinesis are described in the following sub-sections.

17.4.1 Cytokinesis in Animal Cells

Cytokinesis in animal cells is a contractile process. The contractile mechanism is

contained in a **contractile ring** located just inside the plasma membrane. The ring forms around the circumference of the cell at the edge of the metaphase plate. The contractile ring consists of a bundle of microfilaments of actin and myosin. An interaction between actin and myosin, accompanied by hydrolysis of ATP to ADP and Pi generates a contractile force that draws the contractile ring inwards, forming a furrow in the cell surface and pinching the cell in two. To accomplish cytokinesis the contractile ring must be attached to the inside of the plasma membrane. As the ring contracts, actin and myosin are released from the ring. The contractile ring reduces the connection between the two daughter cells to a narrow bridge that contains a compressed bundle of microtubules of the spindle. This compact bundle, called the **mid-body,** persists as the last remnant of the spindle (Fig. 17.6) and then disappears as the two cells finally break apart from each other. In animal cells cytokinesis takes place within a few minutes. In amoeba, **Acanthamoeba,** the contractile ring contracts extremely rapidly, and all of cytokinesis takes place in 40 to 50 seconds.

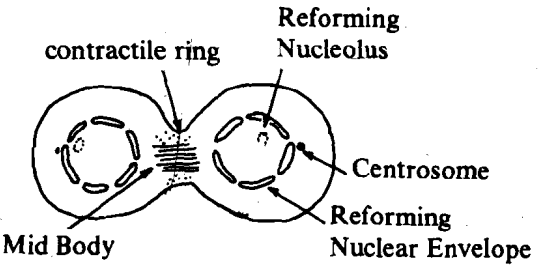

Fig. 17.6 Cytokinesis in Animal Cell

17.4.2 Cytokinesis in Plant Cells

Plant cells do not divide by means of contractiled ring. Instead they assemble plasma membranes and cell walls between the two daughter cells in the plane of the metaphase plate. When the daughter chromosomes have left the metaphase plate as a result of their anaphase movements, membranous vesicles derived from the golgi complex accumulate in the plane of the metaphase plate. The vesicles are drawn into the plane from both sides of the spindle by the action of microtubules. The small vesicles fuse to form a large, flat vesicle that grows perpendicular to the spindle until it reaches the plasma membrane. The accumulated vesicular material is called the **phargmoplast**. By their fusion the vesicles of the phargmoplast form a double plasma membrane. The two plasma membranes fuse peripherally with the main plasma membrane of the cell, thereby forming two separate daughter cells. Therefore, a double cell wall is formed between the two plasma membranes by the daughter cells. The new cell wall, at first very thin and highly flexible, is gradually thickened by the secretion of additional layers of wall material. Narrow openings called **plasmodesmate** persist in the new cell wall and remain as direct cytoplasmic connections between the daughter cells. When the plasma membrane and new cell wall between the daughter cells are fully formed, the partition at the middle region is termed the **cell plate** Complete formation of the cell plate may take from 30 minutes to 2 hours in different species. Figure 17.7 illustrates the process of cytokinesis in a higher plant cell with a rigid cell wall (Fig. 17.7).

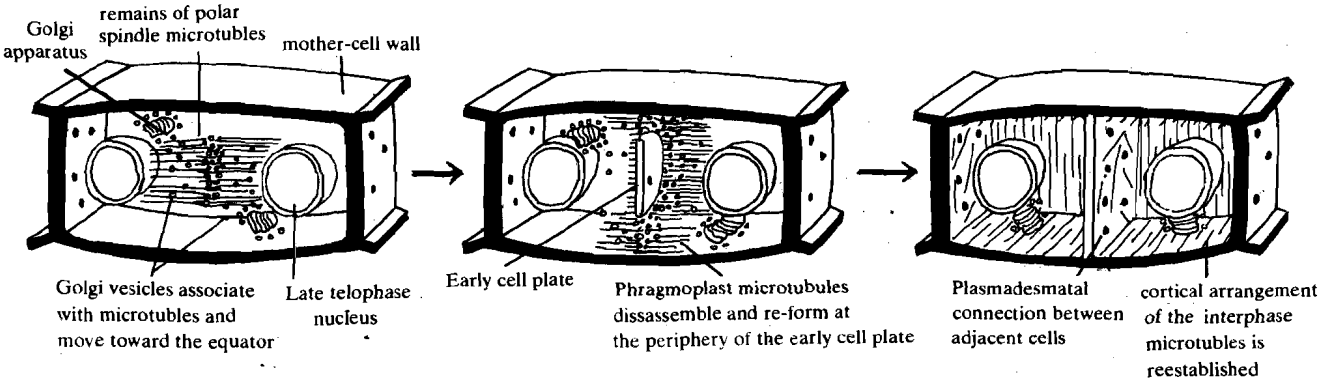

Fig. 17.7 Cytokinesis in Plant Cell

17.4.3 Distribution of Cytoplasmic Components

In the earlier sections you had studied about the events of nuclear division and cytoplasmic division. In this sub-section we will study about the distribution of cytoplasmic components during cytokinesis.

In most instances cytokinesis divides a cell into roughly equal-sized daughters. Exceptions occur in early cleavage stages of embryos of many species, where cytokinesis produces large and small daughter cells in precisely defined patterns. Even in the usual case of equal division, cytokinesis often does not divide a cell into two exactly equal parts. One cell receives slightly more of the cytoplasm than the other. This unequal distribution of the cytoplasm is not a matter of major consequence since most cytoplasmic organelles like mitochondria and ribosomes are present in many copies and each cell always receives some of these. Failure of a daughter cell to receive at least one mitochondrion (and at least one chloroplast for plant cell) is likely to be lethal. Since DNA-containing organelles form by fission of pre-existing organelles, they cannot be formed in the cell. However a golgi complex or a contractile vacuole can be formed inside the cell.

SAQ 3

Fill in the blanks with suitable words.

a) Cytokinesis in animal cell is a ..... process. An interaction between ..... and ..... accompanied by hydrolysis of ..... generates contractile force that draws the contractile ring involves, forming a furrow in the cell surface, pinching the cell in two.

b) During cytokinesis in plant cells, ... is formed by the fusion of vesicular material derived from the ..... which later fuses with the plasma membrane of the cell, forming two separate daughter cells.

17.5 SUMMARY

In this unit you have studied that:

- Meiosis is a special type of division that occurs during the formation of gametes in animals and spores in plants. It involves two successive cell division (meiosis I and meiosis II), during which the chromosome number is reduced to one-half of its original number.
- The prophase of the first meiotic cell division is a long process during which homologous chromosomes pair and interchange genetic material. During anaphase of the first meiotic division, two chromatids of each homologous chromosomes separate, and one is distributed in each daughter cell. When zygote is formed, one member of each homologous pair is contributed by one parent and the other member by the other parent. Therefore, each parent contributes half of the chromosomes of the zygote.
- Recombination involves physical exchange of chromosome segments between the homologues.The sites of breakage and exchange of chromatids become visible as chiasmata.
- Recombination occurs within the framework of the synaptonemal complex in which DNA molecules from opposite homologues loop out and undergo close molecular pairing. The breakage and exchange of chromatids involves enzymatic steps, these include (1) nicking by endonucleases; (2) unwinding promoted by binding proteins, unwinding enzymes, and DNA gyrases; (3) nibbing of unwound chains, catalysed by exonucleases; (4) rewinding, possibly promoted by DNA gyrases; (5) gap filling and chain extension by DNA polymerases; and (6) nick sealing by DNA ligases.
- Cytokinesis in animal cells is a contractile process. Microfilaments of actin and myosin form the contractile ring. An interaction between actin and myosin accompanied by hydrolysis of ATP generates contractile force that draws the contractile ring inwards, forming a furrow in the cell surface, pinching the cell in two.
- Cytokinesis in plants involves accumulation of vesicular material in the plane of the metaphase plate, perpendicular to the spindle. Fusion of vesicles form phragmoplast which fuses with the main plasma membrane of the cell, thereby forming two separate cells.

17.6 TERMINAL QUESTIONS

1) Explain diagrammatically the behaviour of chromosomes during various phases of meiotic prophase I.

a. Leptotene b. Zygotene c. Pachytene d. Diplotene e. Diakinesis

2) Explain briefly in the space given below the molecular mechanism involved in the genetic recombination.

.....

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3) List five chromosomal and genetic differences in daughter cells produced by mitosis and meiosis.

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4) Explain briefly in the space given below, the process of cytokinesis in animal and plant cells.

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17.7 ANSWERS

Self-assessment Questions

1 a) one-half.
b) pairing, chiasmata, segregation
c) Pachytene
d) chiasmata
e) Lampbrush chromosomes

2 Please refer Table. 17.1

3 a) contractile, actin, myosin, ATP
b) Phragmoplast, Golgi complex.

Terminal Questions

1) Please refer Fig. 17.1A, 17.1B, 17.1C, 17.1D, 17.1E and 17.1F.

2) Please refer sub-section 17.3.1

3) Please refer Table 17.2.

4) Please refer Section 17.4.