MEIOSIS

Dr. M. Roy

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Unit-II

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Introduction:

Meiosis is a specialized and rather complicated type of cell division occurring in diploid germ cells and results in the formation of haploid sex cells or gametes. Thus, meiosis is a kind of reduction division which produces haploid (n) gametes in higher plants and animals with a chromosome number exactly half of the parental gametocytes.

In bryophytes and pteridophytes, meiosis occurs during the formation of spores, while in most of the algae, zygotes divide meiotically to produce haploid cells that develop into the thallus.

Higher RNA/DNA ratio in the cell leads to meiosis. There is always a premeiotic interphase like the one found in mitosis. However, G_2 phase is very short or altogether absent in meiosis.

Stages of Meiosis:

(i) Meiosis comprises a sequence of events which are repeated twice, with or without a short interphase in between them. Thus meiosis consists of two successive divisions of a cell so that as a result of one complete meiotic division, four cells will be formed.

(ii) First meiotic division is accompanied with reduction in chromosome number without any division of chromosomes, while second division involves separation of chromatids of the chromosomes.

(iii) Consequently, number of chromosomes which is reduced to haploid (n) condition in the first division remains unchanged

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(haploid, n) during the second division.

(iv) Hence, for convenience meiosis can be described in two parts: First Meiotic Division (Meiosis-I) and Second Meiotic Division (Meiosis-II).

I. First Meiotic Division (Meiosis-I)

This is a reduction division and consists of the usual four stages - Prophase, Metaphase, Anaphase and Telophase.

(a) Prophase-I

(i) This is of very long duration and is also complex.

(ii) On account of several chromosomal changes, this is further sub-divided into five substages - Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

These stages and substages are only for the convenience of description, otherwise the whole division process is a continuous unpunctuated event which passes on from one stage to the next one without any stop or gap in between.

This involves the following sub-stages:

(i) Leptotene (Leptonema)

(i) Chromosomes appear as long thread-like structures which are loosely interwoven.

(ii) Bead-like structures called chromomeres are found all along the length of chromosomes.

(ii) Zygotene (Zygonema)

(i) Pairing (synapsis) of homologous chromosomes occurs at this stage.

(ii) Pairing proceeds in a zipper-like fashion and may start at any point on the entire length of chromosomes.

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(iii) Pairing takes place between homologous segments even if they are present in non-homologous chromosomes, as in case of translocations.

(iv) Pairing is allowed only between chromosomes in one region. For example, in an autotetraploid, where there will be four homologous chromosomes, in a particular region only two chromosomes will pair.

(v) Stern and Hotta (1969) have shown that 0.3% of DNA replicates at about zygotene and is believed to control chromosome pairing.

(iii) Pachytene (= Pachynema)

(i) Chromosomes become shortened and coiled.

(ii) Chromosomes appear as thickened thread-like structures, haploid in number. – Paired chromosomes are called bivalents.

(iii) Each chromosome in a bivalent has two chromatids. Thus, a bivalent consists of four chromatids and is called a tetrad.

(iv) Crossing over or exchange of segments of chromatids is brought about at this stage. This exchange occurs between non-sister chromatids.

(v) Nucleolus still persits. Nucleolar organizing bivalent is seen attached to the nucleolus.

(iv) Diplotene (= Diplonema)

(i) Further thickening and shortening of chromosomes takes place.

(ii) Homologous chromosomes start separating from each other; thus dual nature of bivalents becomes distinct (so the name diplotene).

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(iii) Crossing over points become distinct and they are known as Chiasmata.

(iv) Number of chiasmata per bivalent is normally dependent on the length of chromosomes.

(v) Chiasmata are not the cause but are the consequences of crossing over.

(vi) Mechanism of crossing over and chiasma formation have been explained variously by different workers.

(v) Diakinesis

(i) Chromosomes continue to undergo further contraction.

(ii) Thus diakinesis is the more contracted state of bivalents.

(iii) Nucleolus may not be seen at this stage.

(iv) Due to further separation and contraction, bivalents appear evenly distributed throughout the cell.

(v) Chiasmata are largely terminalized.

(b) Metaphase-I

(i) Chromosomes are most condensed.

(ii) Spindle apparatus starts appearing and bivalents become attached to spindle through centromeres.

(iii) Further, bivalents become arranged on the equatorial region of the spindle apparatus forming the equatorial plate.

(c) Anaphase-I

(i) Chromosomes from the bivalents start moving towards the poles from the equatorial plate towards the poles.

(ii) As sister chromatids move to the same pole, this is a reductional or disjunctional division.

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(d) Telophase-I and Interphase

(i) Nuclear membranes are formed around the groups of chromosomes at the two poles.

(ii) Chromosomes undergo a small interphase before the second meiotic division starts.

(iii) In some cases, Telophase-I and Interkinesis may be absent and chromosomes at the two poles after Anaphase-I may directly pass on to Metaphase-II.

(iv) Meiosis-I after the end of Telophase-I may be followed by cytokinesis giving rise to a dyad. Such a division is called successive division. However, cytokinesis may be postponed till the end of Meiosis-II, when four daughter cells are formed due to simultaneous division.

II. Second Meiotic Division (Meiosis-II)

(i) Second meiotic division may or may not be preceded by an intervening interphase.

(ii) Meiosis-II is essentially a mitotic division.

(iii) At Prophase-II chromosomes are already double, each having two sister chromatids with a single functional centromere.

(iv) These chromosomes soon arrange at metaphase plate during Metaphase-II. The centromere then splits and two chromatids, which may now be called chromosomes, pass on to the opposite poles during Anaphase-II. This is soon followed by Telophase-II and cytokinesis.

(v) Thus at the end of Telophase-II four haploid cells are formed.

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Significance of Meiosis:

1. Meiosis is a logical and essential component in the life cycle of sexually reproducing organisms since it leads to the formation of haploid gametes or sex cells, that participate in fertilization.

Thus numerical constancy of chromosomes is maintained over successive generations and basic genetic traits of a species are maintained.

2. Meiosis involves recombination of genetic materials of male and female contributions of the previous generation leading to genetic variations. These variations are the raw materials of the evolutionary process.

Meiosis thus contributes to the origin of variations and forms a significant process for evolutionary speculations.

(Figs. below)

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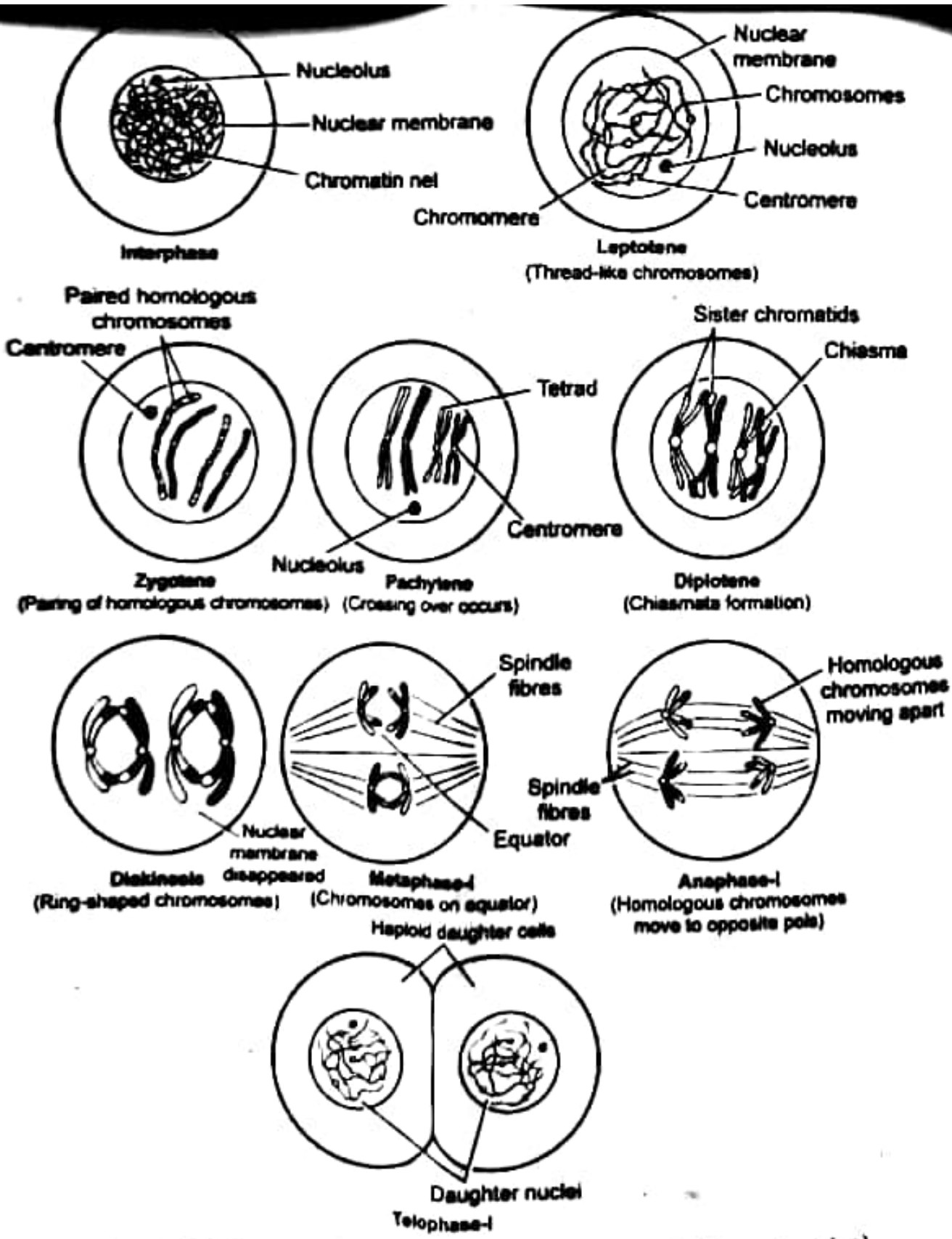

Fig. 5.20 Different stages in the first meiotic division (Reduction division).

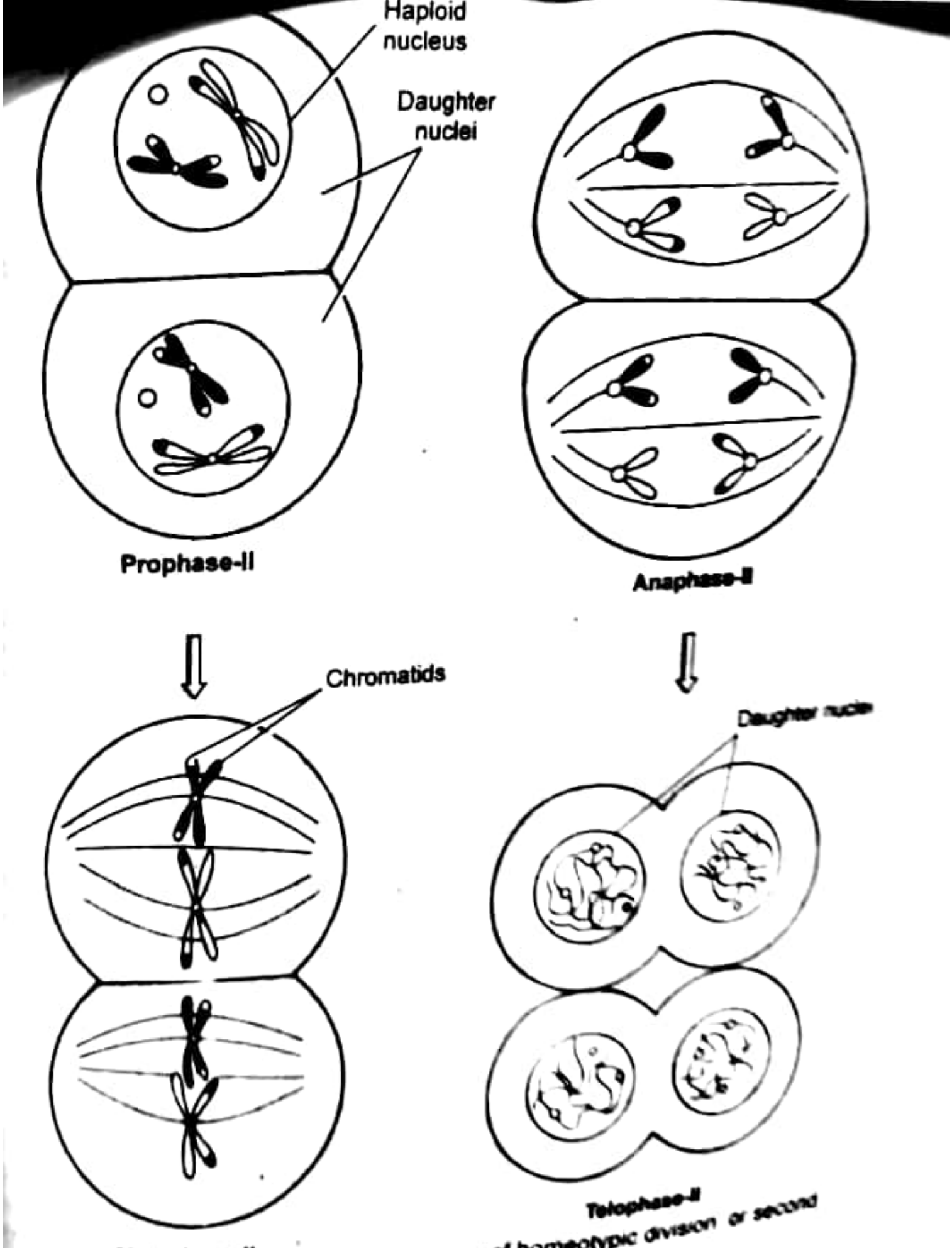

Fig. 5.23 Diagrammatic representation of homeotypic division or second meiotic division of meiosis.