Human Development
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Supplementary Material: Meiosis

MEIOSIS

Ploidy refers to the numbers of chromosomes a cell has. Human cells are typically diploid (2n) because they contain 2 sets of 23 chromosomes (total =46 chromosomes). Their DNA content is referred to as 2C. One set of the chromosomes is the sex chromosomes XX (female) or XY (male). The remaining 22 chromosomes are also referred to as autosomes. Cells usually reproduce by mitosis with each daughter cell being a replicate of the mother cell. Meiosis only occurs in sexual cells where they reproduce in the gonads (ovaries or testes). During the formation of the gametes (sperm and eggs), the genomic DNA content and the corresponding chromosome number of the gametes must be reduced by half. Thus gametes are haploid (n) with a DNA content of 1C. During fertilization the joining of two haploid gametes will re-establish the diploid number of chromosomes and the 2C DNA content of the zygote genome ($n + n = 2n$; $C + C = 2C$). Humans receive one set of chromosomes from each parent.

Chromosomes with the same complement of genes are called homologous chromosomes. When the alleles on the homologous chromosomes differ, the person is heterozygous for the trait specified by those genes. If the alleles are the same the person is homozygous.

Meiosis will separate the pairs of chromosomes so that one copy of each homologous chromosome will become part of the haploid gamete genome.

Phases of Meiosis

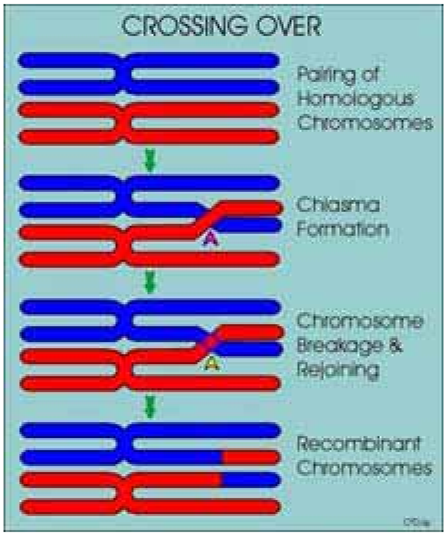
Meiosis occurs in two phases: Meiosis I (Reduction Division) and Meiosis II (Division). The end product will be 4 haploid cells. Prior to beginning the division process, the DNA in each chromosome has been duplicated so that each chromosome consists of two sister chromatids. Thus at this point the cell contains 4C DNA but it the chromosome number is still considered 2n because the sister chromatids are joined at the centromere and thus comprise a single chromosome. During Meiosis I the homologous chromosomes will be separated from each other. During Meiosis II, the sister chromatids will be separated from each other.

Prophase I

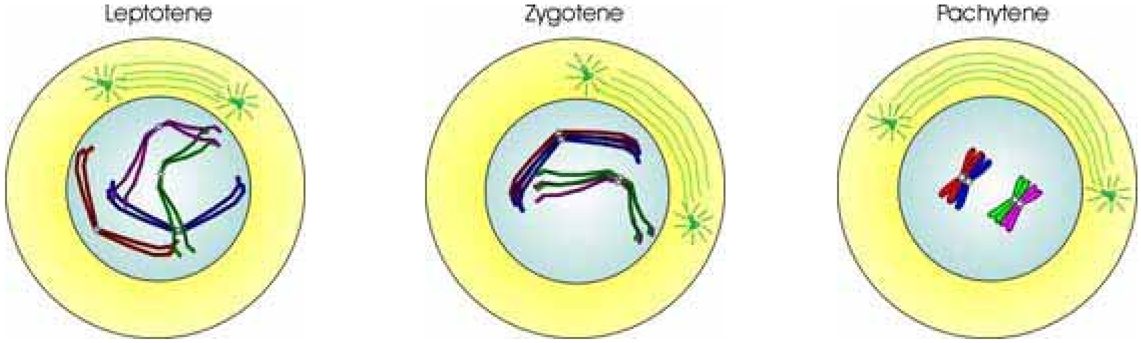
Prophase I is divided into 5 stages: Leptotene, Zygotene, Pachytene, Diplotene, Diakinesis.

Before looking at each one, let's just summarize what will happen. During prophase I, the nucleolus will disappear, the nuclear envelope will break down and the chromatin will condense into visible chromosomes as the spindle apparatus begins to form. Homologous chromosomes will pair up in a process called synapsis. Since each chromosome is made up of two sister chromatids, the resulting pair is called a terad. At this point the pairs of sister chromatids intertwine and crossing-over can occur. Crossing over involves breaks in each of the paired chromosomes which then can rejoin with the opposite homologous chromosome.

Crossing-over is visualized by the appearance of a special structure called a chiasma. More than one chiasma is referred to as chiasmata. Chromosome breakage and rejoining occurs resulting in recombinant chromosomes (genetic material has been exchanged between sister chromatids).



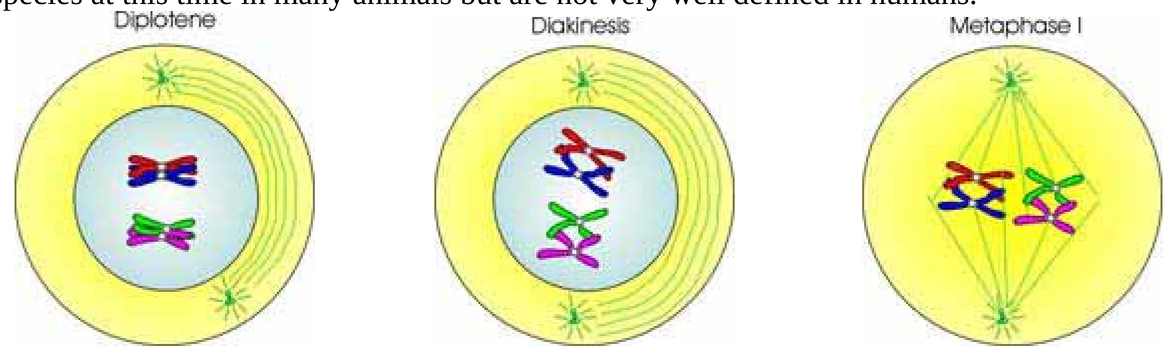
Leptotene (from the Greek: "thin thread"). DNA synthesis occurs in the S phase of the cell cycle, prior to the actual events of mitosis. As a result the sister chromatids of each chromosome are already present. At this stage the thread-like chromatin has not condensed, so it is impossible to actually see individual chromosomes.



Zygotene ("yoked threads"). The homologous chromosomes, align side-by-side in a process of pairing called synapsis. A special structure called a synaptonemal complex forms at the regions where the chromosomes are aligned. This relationship is called a tetrad or a bivalent.

Pachytene ("thick thread"). Condensation of the chromosomes has occurred so that the individual chromatids are now visible under the light microscope. Crossing over can be detected first at this stage.

Diplotene ("double threads"). The synaptonemal complexes begin to disappear and the homologous chromosomes begin to separate remaining attached at areas called chiasmata. Active gene transcription occurs at this stage. Special "lampbrush chromosome" configurations of chromosomes are visualized in various species at this time in many animals but are not very well defined in humans.



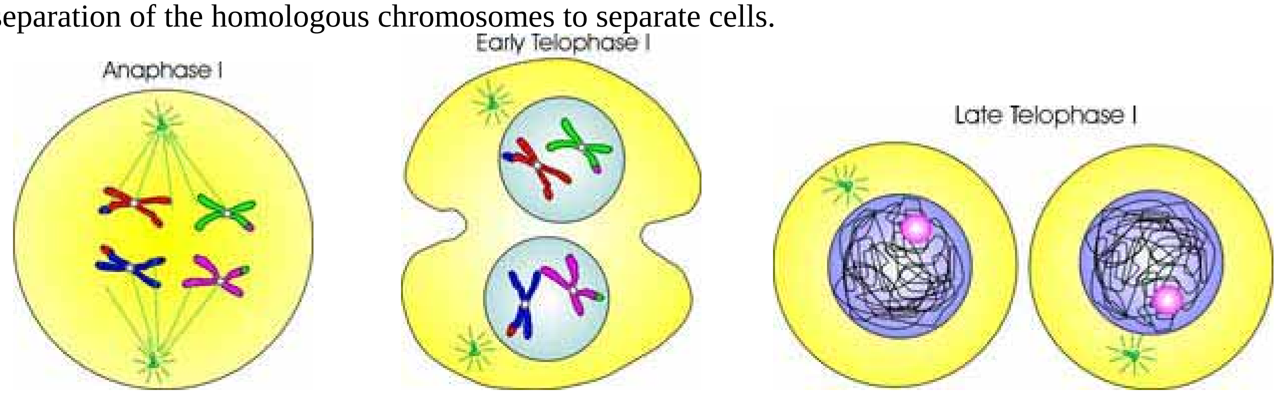
Diakinesis ("moving apart"). the centromeres move away from each other leaving the chromosomes attached only at their tips. At this point the nuclear envelope breaks down as a prelude to the chromosomes moving to the metaphase plate.

Metaphase I

By metaphase I, the asters have moved to opposite sides of the cell and have formed the spindle apparatues (meiotic spindle) that is comprised of microtubules (green). The chromosomes align along the equator of the cells with microtubules attached to their centromeres.

Anaphase I

The homologous chromosomes are pulled to the poles by active sliding of the microtubules. This results in the separation of the homologous chromosomes to separate cells.

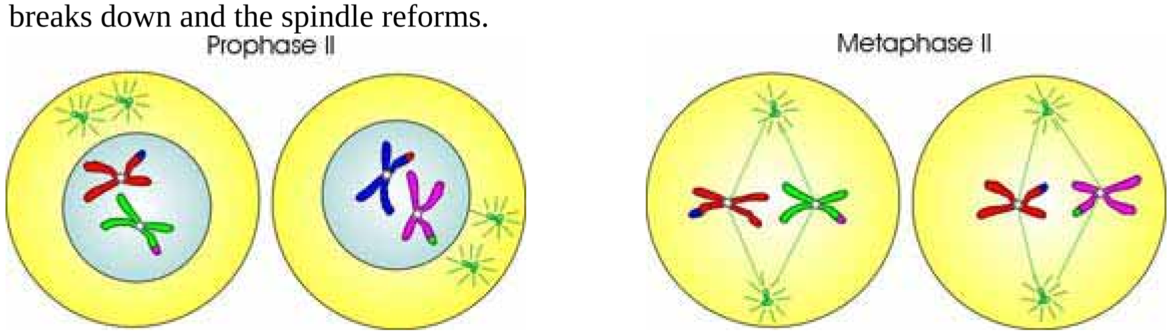


Telophase I

Two daughter cells are formed each containing one partner of each of the homologous chromosome pairs. The nuclear envelope reforms as the chromosomes decondense and a nucleolus reappears.

Prophase II

Following a short interkinesis, in which no DNA synthesis occurs, the second meiotic division begins with a prophase II which lacks the complexity of prophase I. Here the chromosomes condense as the nuclear envelope breaks down and the spindle reforms.

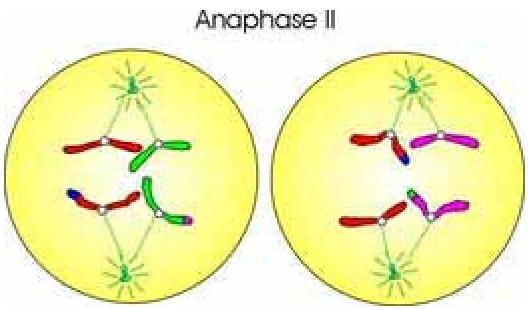


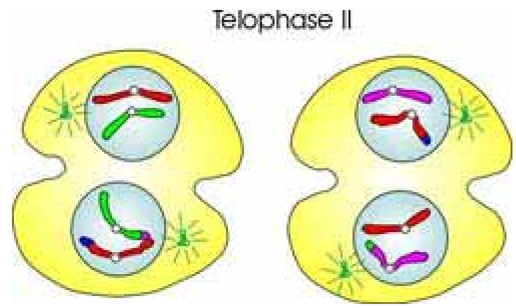
Metaphase II

The condensed chromosomes align along the metaphase plate with the centromeres attached to the spindle microtubules.

Anaphase II

The chromosomes are pulled to the poles resulting the division of the centromere so that each the sister chromatids goes to the opposite poles.





Telophase II

Each sister chromatid is know a single chromosome. Thus the resulting haploid cells (gametes) each contain a haploid genome of 23 chromosomes. Each is also different due to the events of crossing-over and the various combinations of chromatid complements that are possible.

The chromosomes have separated. The spindle disappears as the nuclear envelope reforms and the cell membrane begins to pinch in to separate the cells as individual entities.

Once the cells are separate, they are individual haploid cells. In some cases they need to complete their differentiation into the gametes.