# Meiosis

Meiosis is the special form of cell division used to produce gametes. It has two important functions:

* To form haploid cells with half the normal chromosome number
* To re-arrange the chromosomes with a novel combination of genes (genetic recombination)

Meiosis comprises two successive divisions, without DNA replication in between. The second division is a bit like mitosis, but the first division is different in many important respects. The details are shown in this diagram for a hypothetical cell with 2 pairs of homologous chromosomes (n=2):

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| --- | --- | --- | --- |
| **First Division** | | **Second Division** | |
| **Interphase I**   * chromatin not visible * DNA & proteins replicated |  | **Interphase II**   * Short * no DNA replication * chromosomes remain visible. |  |
| **Prophase I**   * chromosomes visible * homologous chromosomes join together to form a bivalent |  | **Prophase II**   * centrioles replicate and move to new poles. |  |
| **Metaphase I**   * bivalents line up on equator |  | **Metaphase II**   * chromosomes line up on equator. |  |
| **Anaphase I**   * chromosomes separate (not chromatids- centromere doesn’t split) |  | **Anaphase II**   * centromeres split * chromatids separate. |  |
| **Telophase I**   * nuclei form * cell divides * cells have 2 chromosomes, not 4 chromatids. |  | **Telophase II**   * 4 haploid cells, each with 2 chromatids * cells often stay together to form a tetrad. |  |

## Genetic Variation in Sexual Reproduction

The whole point of meiosis and sex is to introduce genetic variation, which allows species to adapt to their environment and so to evolve. There are three sources of genetic variation in sexual reproduction:

* Independent assortment in meiosis
* Crossing over in meiosis
* Random fertilisation

**1. Independent Assortment**

This happens at metaphase I in meiosis, when the bivalents line up on the equator. Each bivalent is made up of two homologous chromosomes, which originally came from two different parents (they’re often called maternal and paternal chromosomes). Since they can line up in any orientation on the equator, the maternal and paternal versions of the different chromosomes can be mixed up in the final gametes.



In this simple example with 2 homologous chromosomes (n=2) there are 4 possible different gametes (22). In humans with n=23 there are over 8 million possible different gametes (223). Although this is an impressively large number, there is a limit to the mixing in that genes on the same chromosome must always stay together. This limitation is solved by crossing over.

**2. Crossing Over**

This happens at prophase I in meiosis, when the bivalents first form. While the two homologous chromosomes are joined in a bivalent, bits of one chromosome are swapped (crossed over) with the corresponding bits of the other chromosome.



The points at which the chromosomes actually cross over are called chiasmata (singular chiasma), and they involve large, multi-enzyme complexes that cut and join the DNA. There is always at least one chiasma in a bivalent, but there are usually many, and it is the chiasmata that actually hold the bivalent together. The chiasmata can be seen under the microscope and they can give the bivalents some strange shapes at prophase I. There are always equal amounts crossed over, so the chromosomes stay the same length.

Crossing over means that maternal and paternal alleles can be mixed, even though they are on the same chromosome.

**3. Random Fertilisation**

This takes place when two gametes fuse to form a zygote. Each gamete has a unique combination of genes, and any of the numerous male gametes can fertilise any of the numerous female gametes. So every zygote is unique.