Module 3B – Meiosis and Sexual Life Cycles

- In this module, we will examine a second type of cell division used by eukaryotic cells called meiosis.
- In addition, we will see how the 2 types of eukaryotic cell division, mitosis and meiosis, are involved in transmitting genetic information from one generation to the next during eukaryotic life cycles.

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Objective # 12

Explain the role of mitosis, meiosis, and fertilization in the life cycle of animals and plants.

2

Objective 12

- Unlike prokaryotes, which are almost always haploid (each cell has one set of genetic instructions), most eukaryotes have a life cycle that alternates between haploid and diploid stages.

3

Objective 12

- In eukaryotic life cycles:
  - Mitosis keeps the number of chromosomes in each cell the same.
  - Meiosis reduces the number of chromosomes from 2 sets to 1 set.
  - Fertilization doubles the number of chromosomes from 1 set to 2 sets.

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Objective 12

- Alternation of meiosis and fertilization makes possible the development of life cycles that alternate between haploid and diploid stages.
- These life cycles involve sexual reproduction where two parents each contribute half the genetic material needed to form a new individual.

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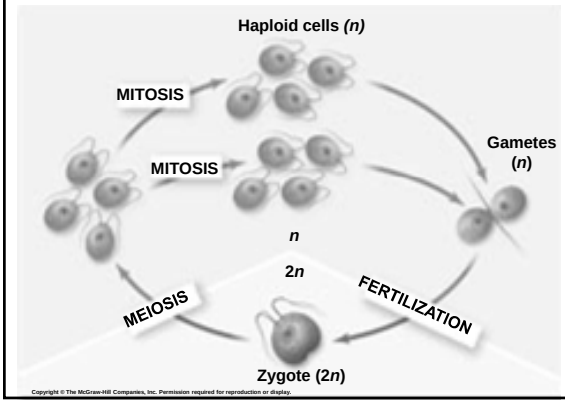
Typical Life Cycle of Algae and Fungi



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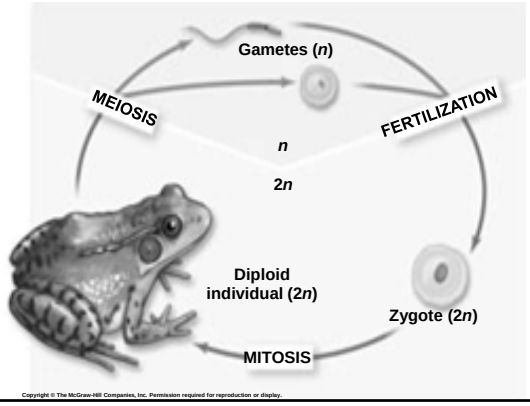
Typical Animal Life Cycle



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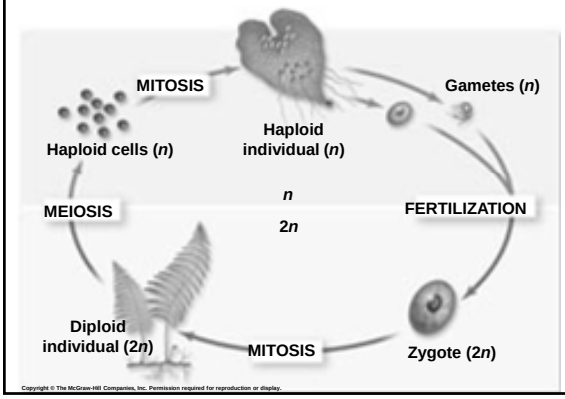
Typical Plant Life Cycle



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Objective # 13

List, describe, diagram, and identify the stages of meiosis.

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Objective 13

- Only diploid cells can divide by meiosis.
- Meiosis involves 2 consecutive cell divisions. Since the DNA is duplicated prior to the first division only, the final result is 4 haploid cells.
- We will examine the stages of meiosis in a diploid cell where 2N = 6:

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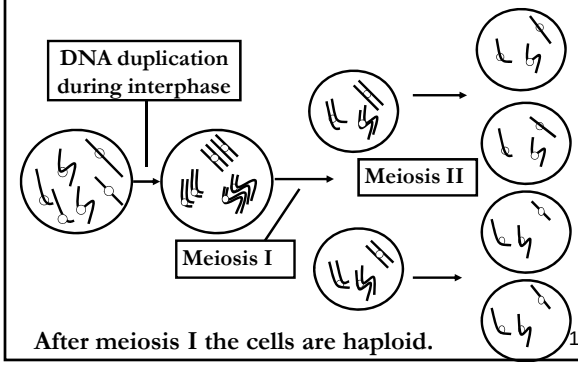
Objective 13

Overview of meiosis in a cell where 2N = 6



After meiosis I the cells are haploid.

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Prophase I:

- Chromosomes condense. Because of replication during interphase, each chromosome consists of 2 identical chromatids joined by cohesin proteins.
- Synapsis – the 2 members of each pair of homologous chromosomes line up side-by-side and are closely associated by a synaptonemal complex to form a bivalent (2 associated chromosomes), also called a tetrad (4 chromatids):

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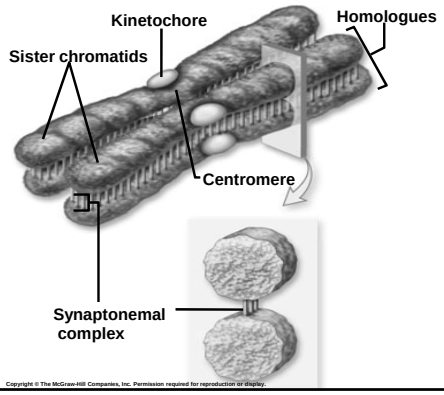
Synapsis Produces Bivalents or Tetrads:



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Prophase I:

- During synapsis, sometimes chromatids break and there is an exchange of homologous parts between non-sister chromatids. This exchange is called crossing over.
- Evidence of crossing over can be seen under the microscope as X-shaped structures called chiasmata.

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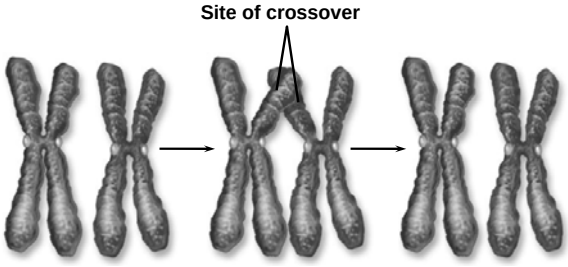
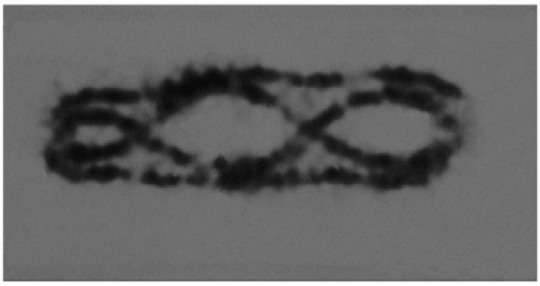
Crossing Over between Non-sister Chromatids



Chiasmata



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Prophase I:

- Chiasmata hold homologous chromosomes together as they move within the cell.
- The cytoskeleton is disassembled and a spindle of microtubules begins to form.
- The Golgi and ER are dispersed.
- The nuclear envelope disintegrates.

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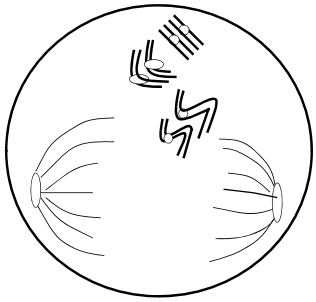
Prophase I



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Prometaphase I:

- The kinetochores of sister chromatids fuse and function as one. A kinetochore microtubule from one pole of the cell attaches to one member of each homologous pair of chromosomes while a kinetochore microtubule from the other pole attaches to the other member.
- Homologous chromosomes remain paired as they move toward equator of the cell.

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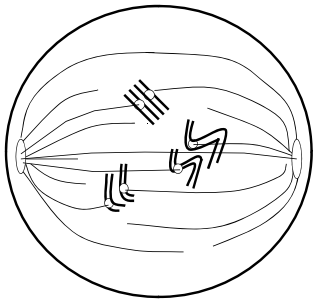
Prometaphase I



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Metaphase I:

- Homologous chromosomes line up along the equatorial plate in pairs.
- Alignment of each pair of chromosomes relative to the poles of the cell is random and independent of the other pairs. This is referred to as independent assortment.

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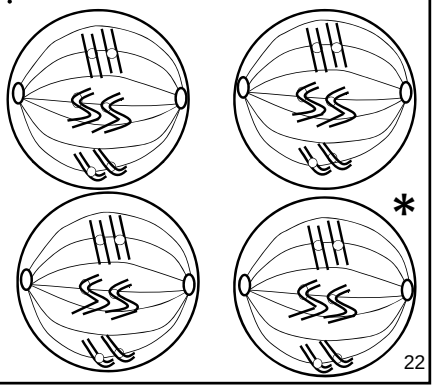
Possible Alignment of Chromosomes during Metaphase I :

***We will follow this alignment. There are actually 8 possibilities, the other 4 being the reverse of those shown.**



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Anaphase I:

- Kinetochore microtubules contract, pulling the 2 members of each homologous pair of chromosomes to opposite poles of the cell.
- Centromeres do NOT split and sister chromatids remain attached.
- When the kinetochore microtubules have fully contracted, each pole has one complete set of duplicated chromosomes.

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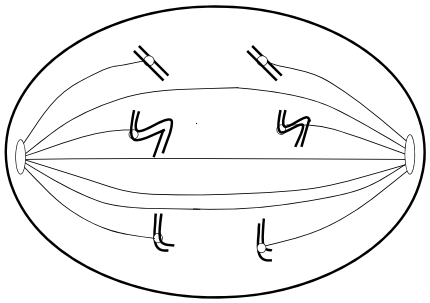
Anaphase I



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Telophase I:

- A nuclear membrane reforms around each set of duplicated chromosomes
- Cytokinesis divides the original cell into 2 haploid, non-identical, daughter cells.
- Each chromosome is still duplicated and consists of 2 chromatids, but the sister chromatids are not identical due to crossing over during prophase I.

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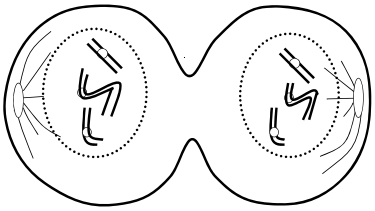
Telophase I



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Prophase II:

- Following a typically brief interphase, with no S phase, meiosis II begins.
- In each daughter cell, the nuclear envelope breaks down and a new spindle of microtubules starts to form.

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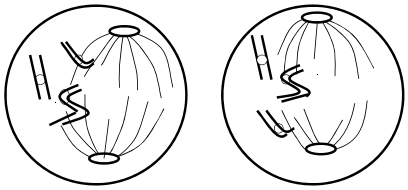
Prophase II



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Prometaphase II:

- For each chromosome, a kinetochore microtubule from one pole of the cell attaches to the kinetochore on one chromatid while a kinetochore microtubule from the other pole attaches to the kinetochore on the other chromatid.
- Duplicated chromosomes begin to move towards the equatorial plate.

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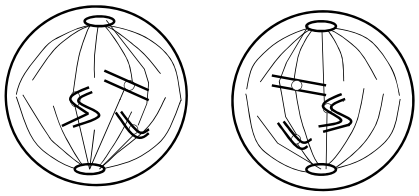
Prometaphase II



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Metaphase II:

- Duplicated chromosomes line up along the equatorial plate in single file.

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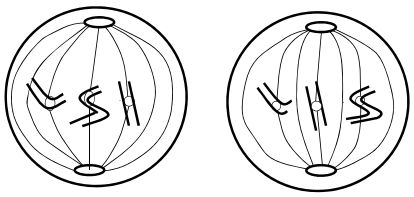
Metaphase II



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Anaphase II:

- Centromeres split and each former chromosome becomes 2 separate chromosomes.
- Kinetochore microtubules contract pulling the 2 members of each pair of chromosomes (that were formerly sister chromatids) to opposite poles of the cell.

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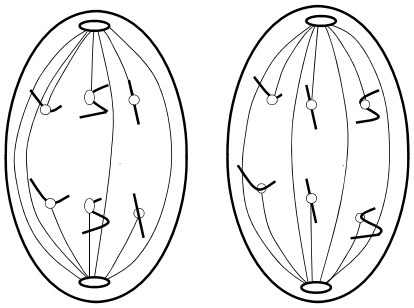
Anaphase II



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Telophase II:

- Nuclear envelope reforms around each group of daughter chromosomes.
- Chromosomes uncoil.
- Cytokinesis divides the 2 cells from meiosis I into 4 haploid cells.
- No two cells are alike due to crossing over during prophase I and independent assortment of homologous pairs during metaphase I.

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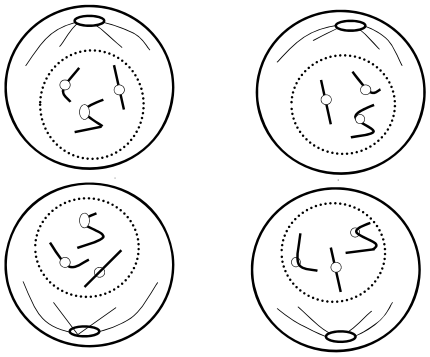
Telophase II



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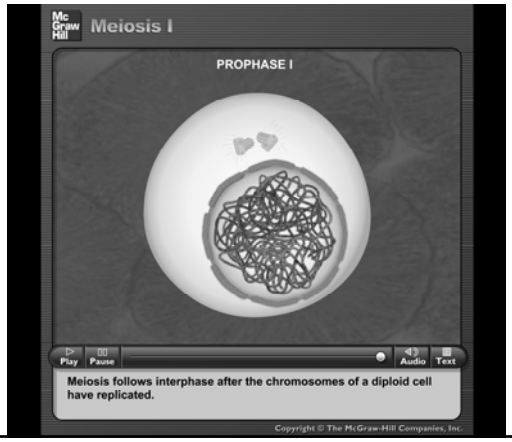

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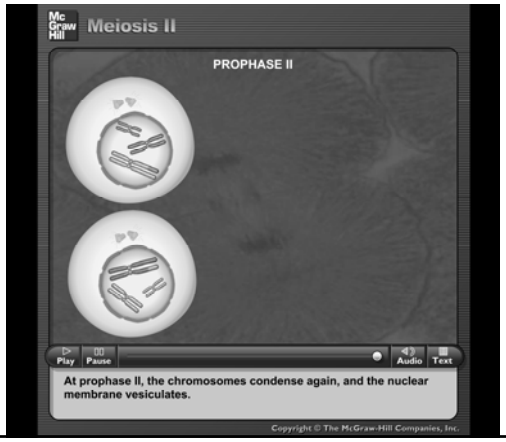

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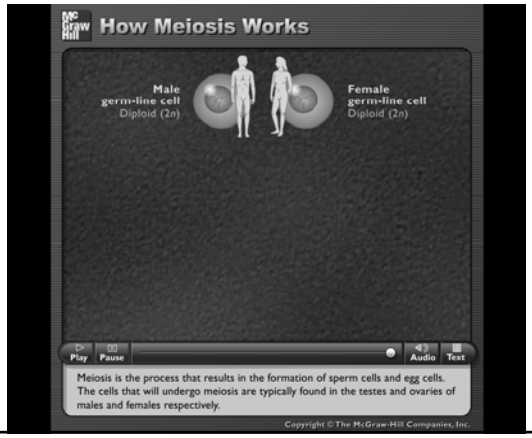

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Objective # 14

Describe the processes of independent assortment and crossing over and explain their biological significance.

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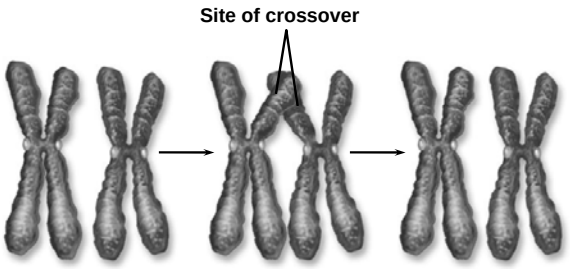
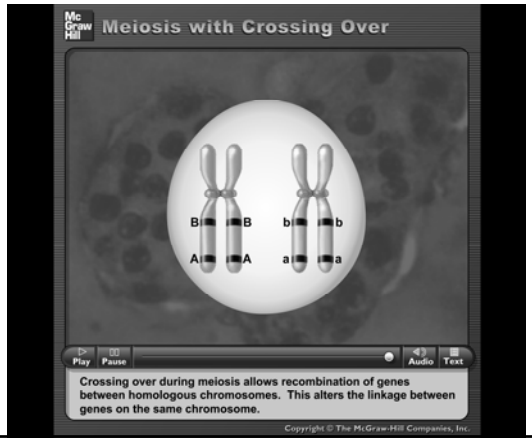
Crossing Over between Non-sister Chromatids





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Objective 14

- Independent assortment and crossing over increase genetic variability among the daughter cells produced during meiosis.
- If there are n pairs of chromosomes in the original cell, independent assortment produces 2^n possible chromosome combinations in the daughter cells.

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Objective 14

- In addition, almost every cross over produces chromosomes with a new combination of maternal and paternal genes.
- Therefore, as a result of independent assortment and crossing over, an almost unlimited number of gene combinations are possible in the daughter cells produced by meiosis.

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Objective # 15

Compare mitosis with meiosis and explain the importance of each.

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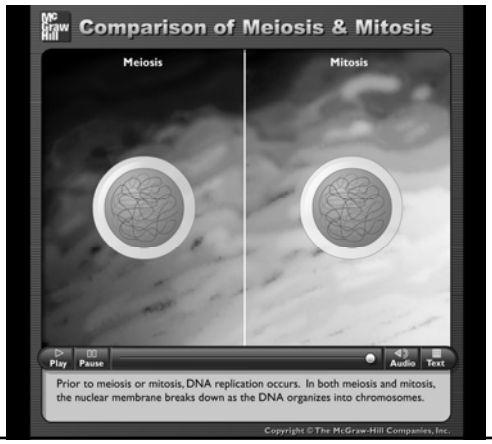

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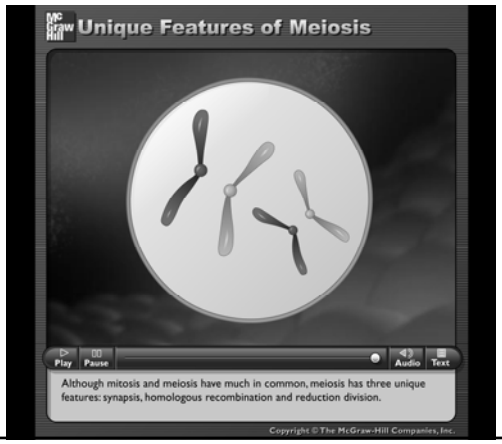

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Objective 15

Mitosis	Meiosis
Homologous chromosomes do not pair up	Synapsis
No genetic exchange between homologous chromosomes	Crossing over
DNA duplication followed by 1 cell division	DNA duplication followed by 2 cell divisions

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Objective 15

Mitosis	Meiosis
One diploid cell produces 2 diploid cells OR one haploid cell produces 2 haploid cells	One diploid cell produces 4 haploid cells
New cells are genetically identical to original cell (except for mutation)	Each new cell has a unique combination of genes

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Objective 15

Importance:

- Mitosis allows a cell to produce more identical copies of itself. This is the basis for asexual reproduction.
- Meiosis reduces the number of chromosomes from 2 sets to 1 set. This is the basis for life cycles where each parent contributes half the genes needed to produce a new individual.

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