

**DNA Part V**  
**Meiosis**

### Advantages of Asexual Reproduction

- Eliminates the need to find a mate
- May reproduce at a faster rate
- May produce larger number of offspring using less overall energy and resources
- Optimum in stable unchanging environments
- Uses mitosis



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### Advantages of Sexual Reproduction

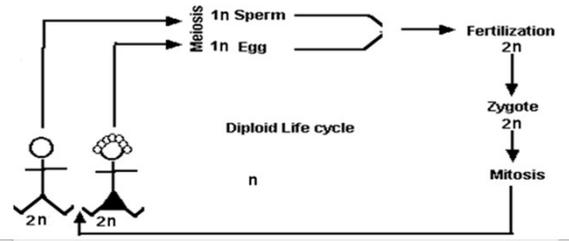
- Varied number phenotypic offspring.
- Better response to varying environment.

Sexual reproduction involves the union of two haploid cells from different parents to produce a diploid zygote.



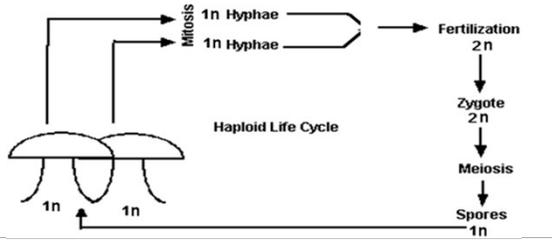

Meiosis is a special type of cell reproduction found in organisms that reproduce sexually.

### Diploid Life Cycle



- The advantage of being diploid is that deleterious genes can be masked if they are recessive.
- The disadvantage is that with more chromosomes to manage, there is an increased likelihood that something will go awry!

### Haploid Life Cycle



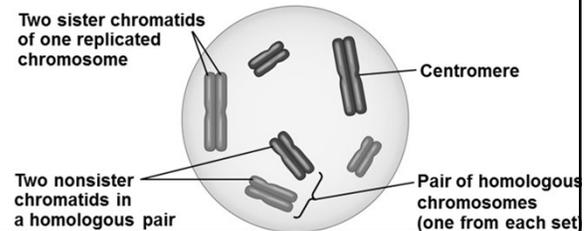
- Disadvantage of being haploid is that all the genes are expressed. "What you see is what you get."
- Advantage of being haploid is that it is easier to reproduce with fewer chromosomes.

### A Diploid Cell

Key

- Maternal set of chromosomes ( $n = 3$ )
- Paternal set of chromosomes ( $n = 3$ )

$2n = 6$



Two sister chromatids of one replicated chromosome

Two nonsister chromatids in a homologous pair

Centromere

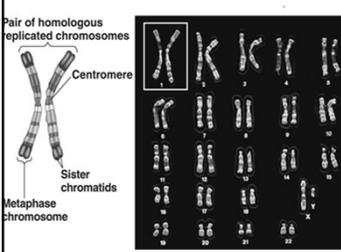
Pair of homologous chromosomes (one from each set)

### Human Somatic Chromosomes

- Humans have 23 pairs of chromosomes in their somatic cells.
- These chromosomes have been stained and certain banding patterns appear.
- The two chromosomes in each pair are called **homologous chromosomes**, or homologs.
- Chromosomes in a homologous pair are the same length and carry genes controlling the same inherited characters.



### Human Karyotype



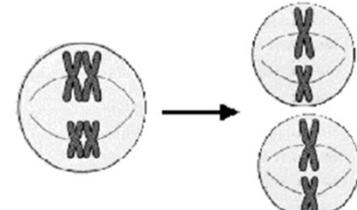
- A **karyotype** is an ordered display of the pairs of chromosomes from a given cell arranged from longest to shortest.
- Autosomes are non-sex chromosomes.

- Notice that the sex chromosomes in this karyotype are not homologous. What does that signify?

### Meiosis Overview (Caution! More Details Coming...)

- This is a special type of cell division where ONE diploid cell produces FOUR haploid cells that are genetically *different* from one another.
- There are TWO cell division events, and they are called meiosis I and II.
- Meiosis I produces 2 haploid cells with *double stranded* chromosomes (chromosomes have 2 chromatids). The cells are genetically different.
- Meiosis II produces 4 haploid cells that separate the hybrid chromatids.

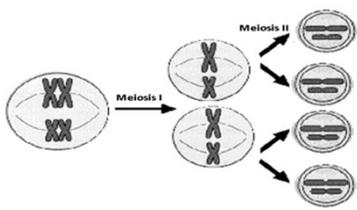
### Meiosis I: Cut Chromosome Number in Half



This cell division results in *two genetically different haploid* cells that *contain double stranded* chromosomes.

1 cell (4 double-stranded chromosomes) → 2 cells (2 double-stranded chromosomes)

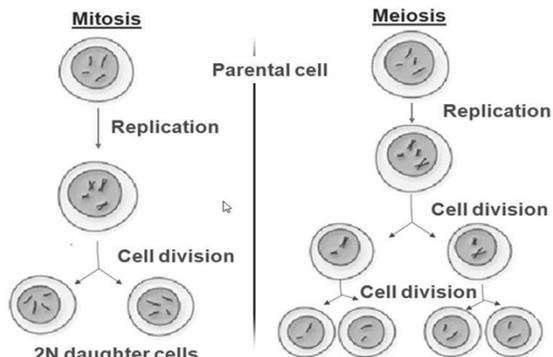
### Meiosis II: Produce 4 Haploid Gametes



Results in **four haploid** cells by separating the 2 cells with double-stranded chromosomes into 4 cells with 2 *single-stranded* chromosomes.

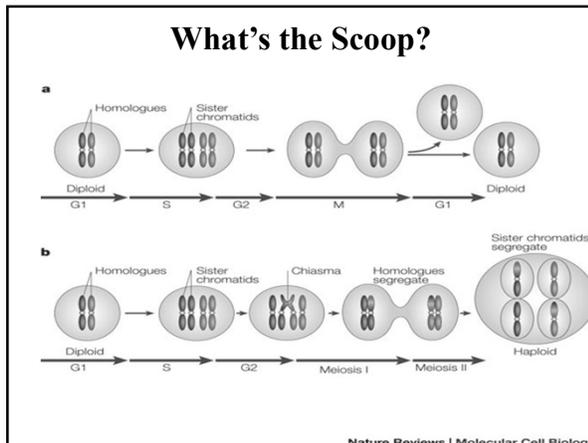
2 cells (2 double-stranded, haploid chromosomes) → 4 cells (2 single-stranded, haploid chromosomes)

### Mitosis vs. Meiosis Side By Side



**Mitosis**  
Parental cell → Replication → Cell division → 2N daughter cells

**Meiosis**  
Parental cell → Replication → Cell division → Cell division → Cell division → 4 haploid cells



### Interphase

- $G_1$ , S,  $G_2$  of the cell cycle (DNA is replicated in S)
- Centrosomes with a pair of centrioles (not in higher plant cells) replicate.
- Centrosomes are microtubules organizing centers

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### Prophase/Prometaphase I

Prophase I

- Chromosomes are visible as long separated filaments
- Homologous chromosomes pair and align as long well-separated filaments.
- Recombination nodules attach and crossing over occurs.

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### Prophase I

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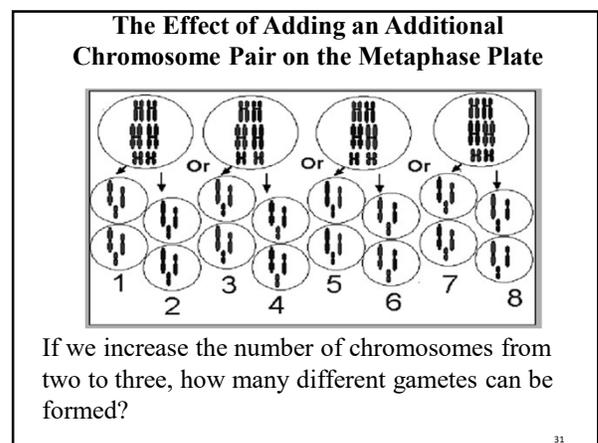
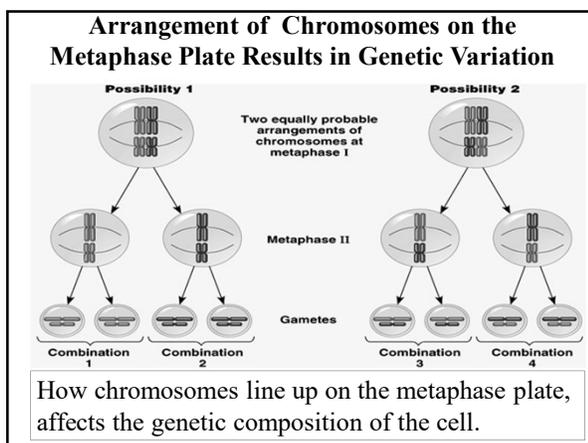
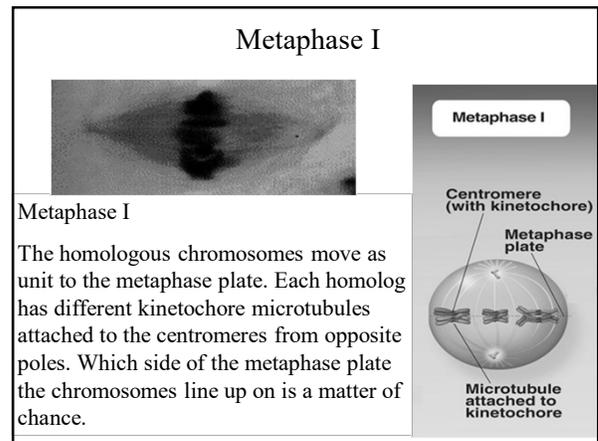
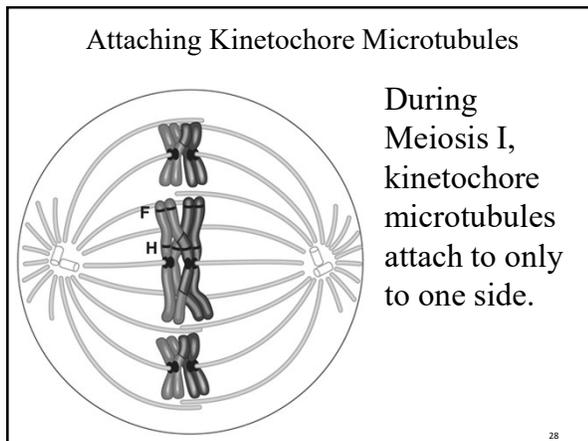
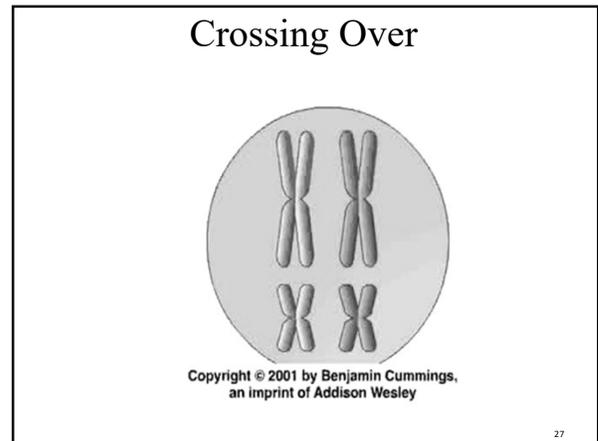
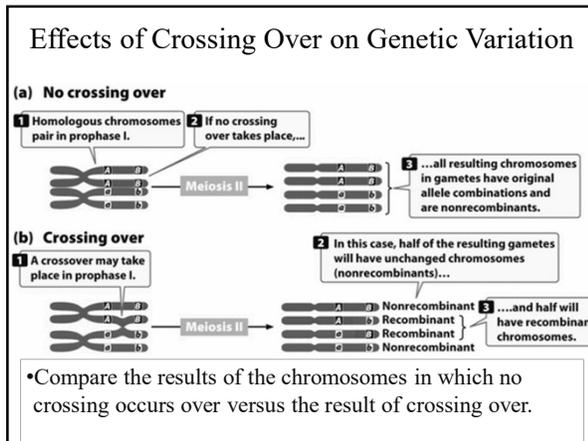
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### Synapsing

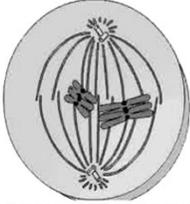
- Homologous pairs form a protein structure between them called the synaptonemal complex. This keeps the homologs as a tetrad.
- Places where crossing over occurs is called a chiasma.
- In mitosis, kinetochore microtubules attach to both sides of

### Forming the Tetrad

- When synapsing occurs, the chromosomes do not lie side by side but rather on top of each other with a protein called the synaptonemal complex holding them together.



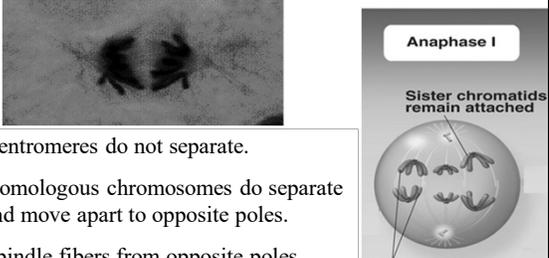
### Metaphase I



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### Anaphase I

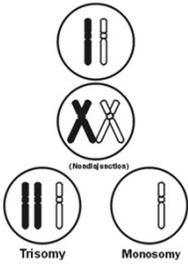


- Centromeres do not separate.
- Homologous chromosomes do separate and move apart to opposite poles.
- Spindle fibers from opposite poles interact to force poles apart.

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### Nondisjunction

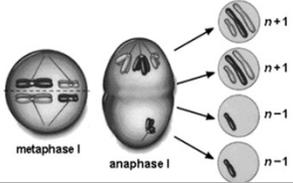
- Nondisjunction occurs when problems with the meiotic spindle cause errors in daughter cells.
- This may occur if tetrad chromosomes do not separate properly during meiosis I.
- Alternatively, sister chromatids may fail to separate during meiosis II.



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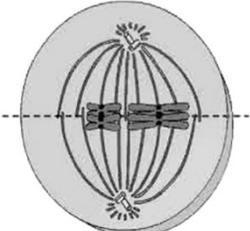
### Aneuploidy

- If the gamete is fertilized, the resulting cells will not have the proper number of chromosomes and is called aneuploidy.



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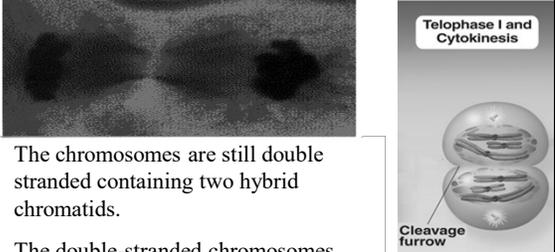
### Anaphase I



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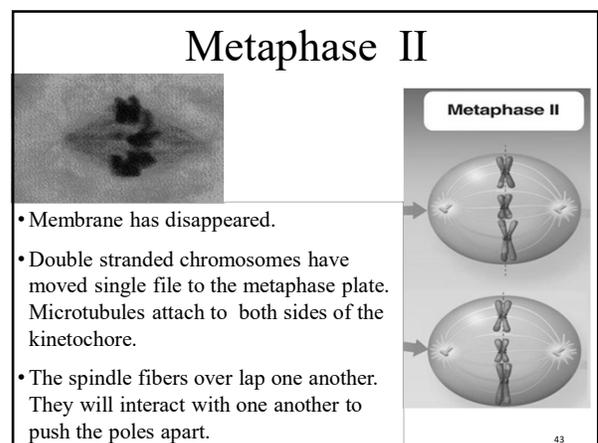
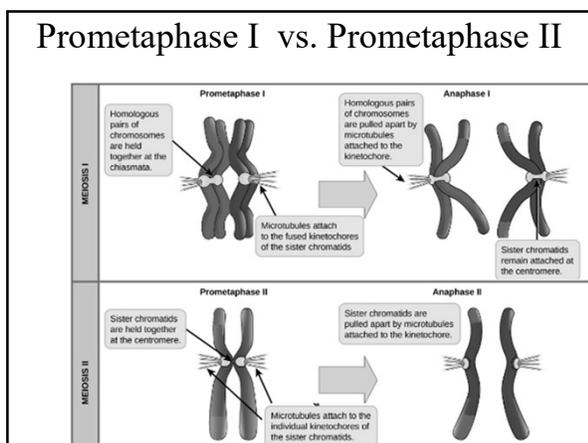
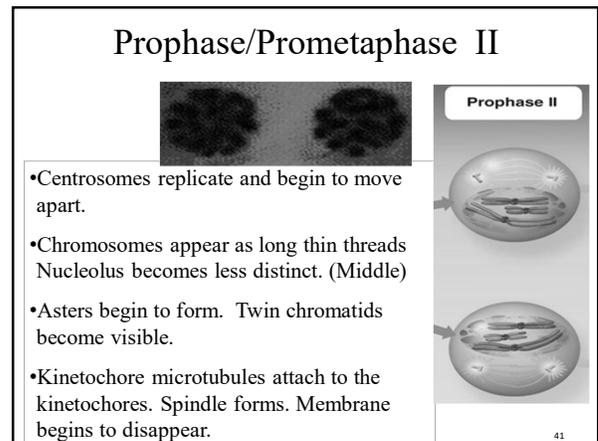
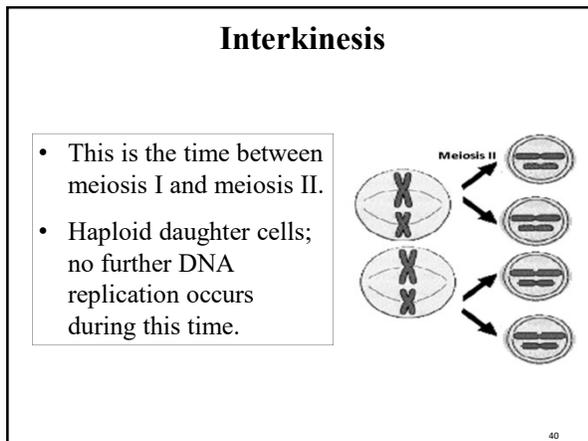
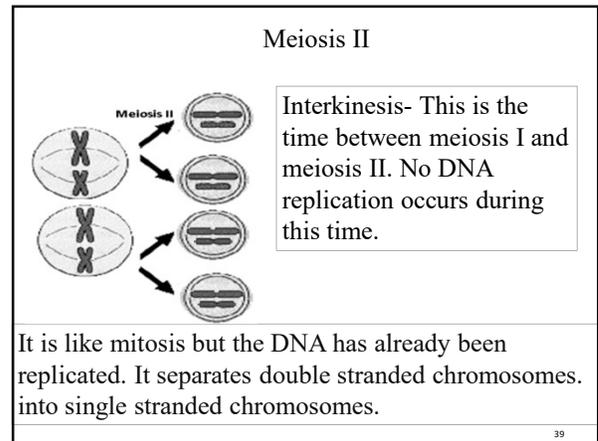
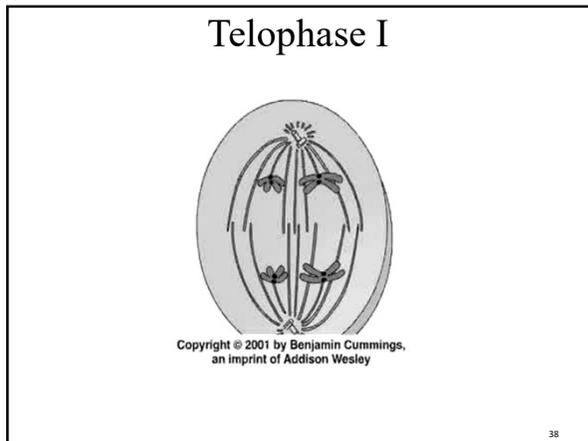
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### Telophase I



- The chromosomes are still double stranded containing two hybrid chromatids.
- The double-stranded chromosomes have migrated to the poles.
- The number of chromosomes is the haploid number of chromosomes.

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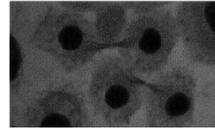
### Anaphase II

- Centromeres have separated and move the single stranded chromosomes toward opposite poles.
- Overlapping spindle microtubules from opposite poles interact and to pull the poles apart.
- Cytokinesis may begin.

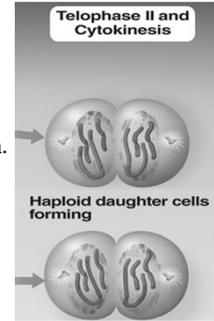


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### Telophase II

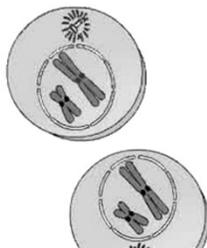


- Nuclear membrane begins to form. Chromosomes begin to uncoil, become thinner.
- Nucleolus becomes less distinct. Cytokinesis is nearly complete.



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### Meiosis II and Cytokinesis

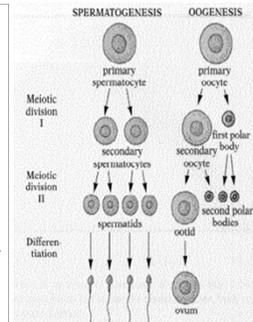


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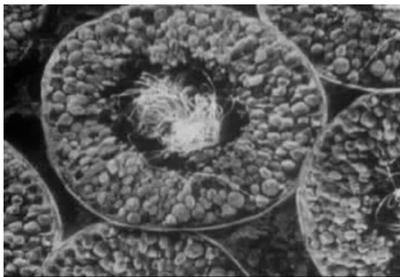
### Gametogenesis in Humans

- Spermatogenesis: The four equal sized cells produced in meiosis will differentiate and become sperm cells.
- Oogenesis: During cytokinesis, there is unequal division of the cytoplasm with usually one large cell and three smaller cells.



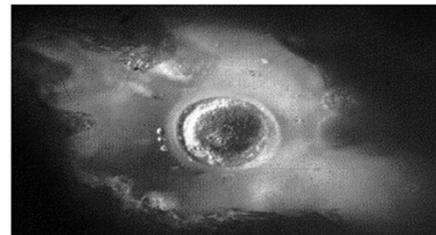
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### Review of Meiosis



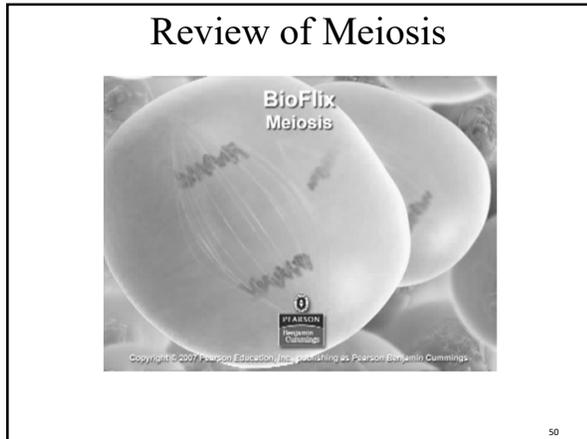
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### Oogenesis



Human ovum with three polar bodies.

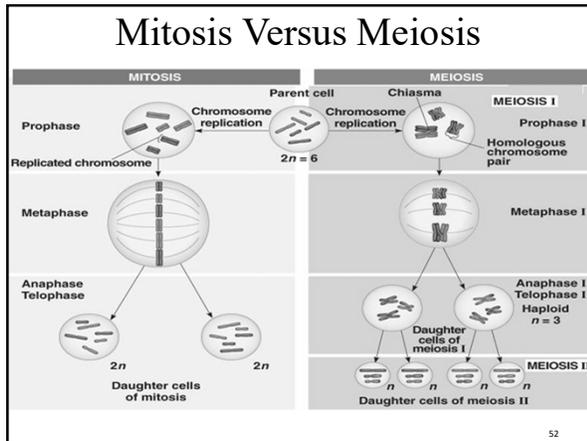
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### Mitosis Versus Meiosis

SUMMARY		
Property	Mitosis	Meiosis
DNA replication	Occurs during interphase before mitosis begins	Occurs during interphase before meiosis I begins
Number of divisions	One, including prophase, metaphase, anaphase, and telophase	Two, each including prophase, metaphase, anaphase, and telophase
Synapsis of homologous chromosomes	Does not occur	Occurs during prophase I along with crossing over between nonsister chromatids; resulting chiasmata hold pairs together due to sister chromatid cohesion
Number of daughter cells and genetic composition	Two daughter cells that are genetically identical to each other and also to the mother cell. The original cell can start with any number of chromosomes	Four, each haploid (n), containing half as many chromosomes as the parent cell; genetically different from the parent cell and from each other
Role in the animal body	Enables multicellular adult to arise from zygote; produces cells for growth, repair, and, in some species, asexual reproduction	Produces gametes; reduces number of chromosomes by half and introduces genetic variability among the gametes

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- ### Sexual Reproduction Provides Genetic Variability to Population
- Crossing over
  - Random arrangement of chromosome when lining up on the metaphase plate
  - Random fertilization of gametes
  - Choice of mates
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