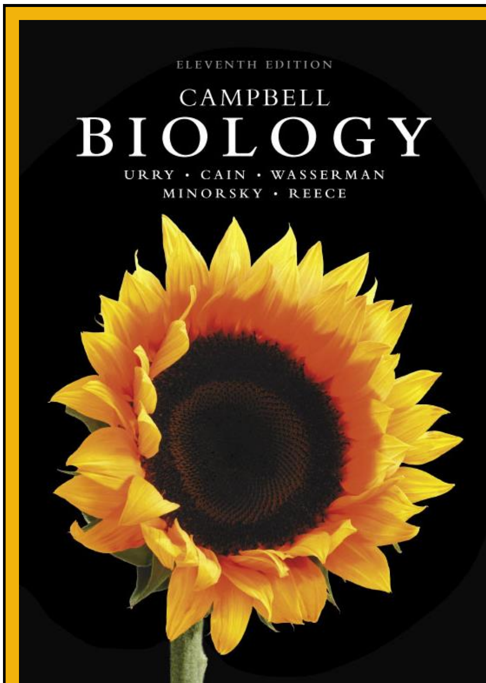

Chapter 13

Meiosis and Sexual Life Cycles

Lecture Presentations by
Nicole Tunbridge and
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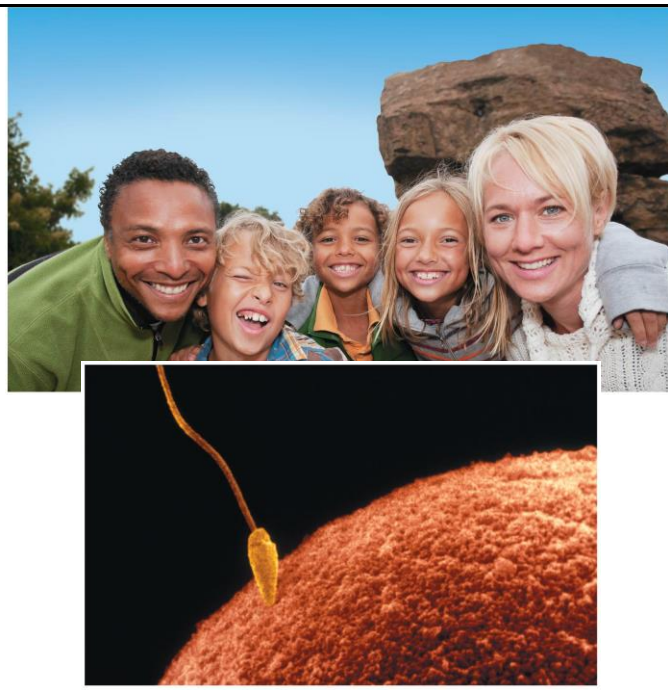
Variations on a Theme

- Offspring resemble their parents more than they do unrelated individuals
- **Heredity** is the transmission of traits from one generation to the next
- **Variation** is demonstrated by the differences in appearance that offspring show from parents and siblings
- **Genetics** is the scientific study of heredity and variation

Figure 13.1



A sperm fertilizing an egg

Concept 13.1: Offspring acquire genes from parents by inheriting chromosomes

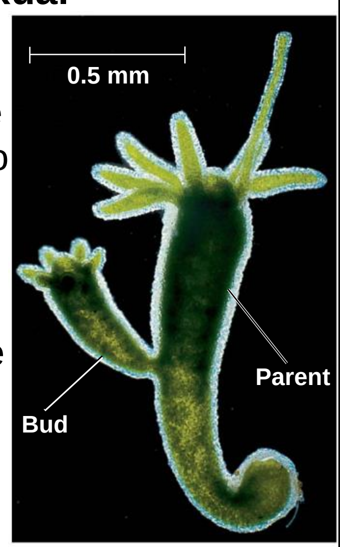
- In a literal sense, children do not inherit particular physical traits from their parents
- *It is genes that are actually inherited*

Inheritance of Genes

- **Genes** are the units of heredity and are made up of segments of DNA
- Genes are passed to the next generation via reproductive cells called **gametes** (sperm and eggs)
- Most DNA is packaged into chromosomes
- Humans have 46 chromosomes in the nuclei of their **somatic cells**, all cells of the body except gametes and their precursors
- A gene's specific position along a chromosome is called its **locus**

Comparison of Asexual and Sexual Reproduction

- In **asexual reproduction**, a single individual passes all of its genes to its offspring without the fusion of gametes
- A **clone** is a group of genetically identical individuals from the same parent
- In **sexual reproduction**, two parents give rise to offspring that have unique combinations of genes inherited from the two parents



(a) Hydra

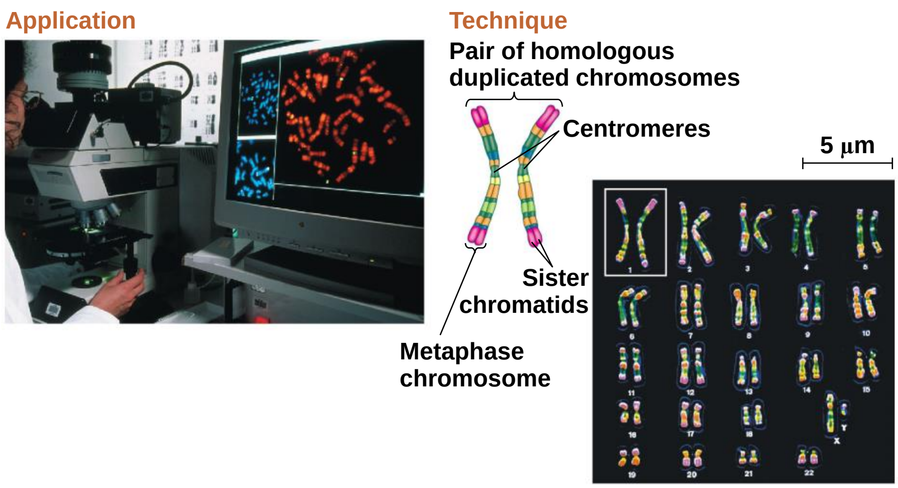
Concept 13.2: Fertilization and meiosis alternate in sexual life cycles

- A **life cycle** is the generation-to-generation sequence of stages in the reproductive history of an organism

Sets of Chromosomes in Human Cells

- Human somatic cells have **23 pairs** of chromosomes
- A **karyotype** is an ordered display of the pairs of chromosomes from a cell
- The two chromosomes in each pair are called **homologous chromosomes**, or **homologs,** one coming from the mother and the other from the father
- Chromosomes in a homologous pair are the *same length and shape and carry genes controlling the same inherited characters*

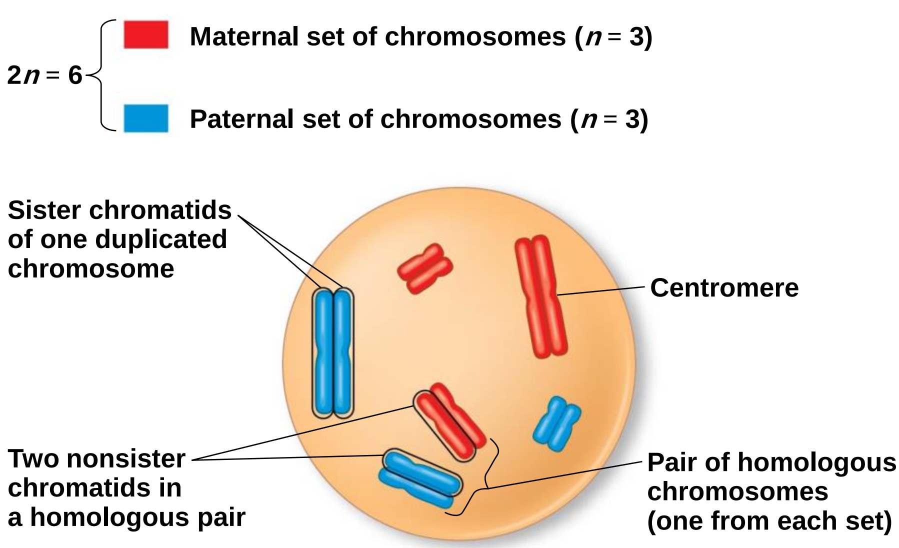
Figure 13.3



- The **sex chromosomes**, which determine the sex of the individual, are called X and Y
- Human females have a homologous pair of X chromosomes (XX)
- Human males have one X and one Y chromosome
- The remaining 22 pairs of chromosomes are called **autosomes**

- Each pair of homologous chromosomes includes one chromosome from each parent
- The 46 chromosomes in a human somatic cell are two sets of 23: one from the mother and one from the father
- A **diploid cell** (2*n*) has two sets of chromosomes
- *For humans, the diploid number is 46 (2n = 46)*
- *Remember:* In a cell in which DNA synthesis has occurred, each chromosome is replicated
- Each replicated chromosome consists of two identical sister chromatids

Figure 13.4



- A gamete (sperm or egg) contains a single set of chromosomes and is thus a **haploid cell** (*n*)
- *For humans, the haploid number is 23 (n = 23)*
- *Each set of 23 consists of 22 autosomes and one sex chromosome*
- In an unfertilized egg (ovum), the sex chromosome is X
- In a sperm cell, the sex chromosome may be either X or Y

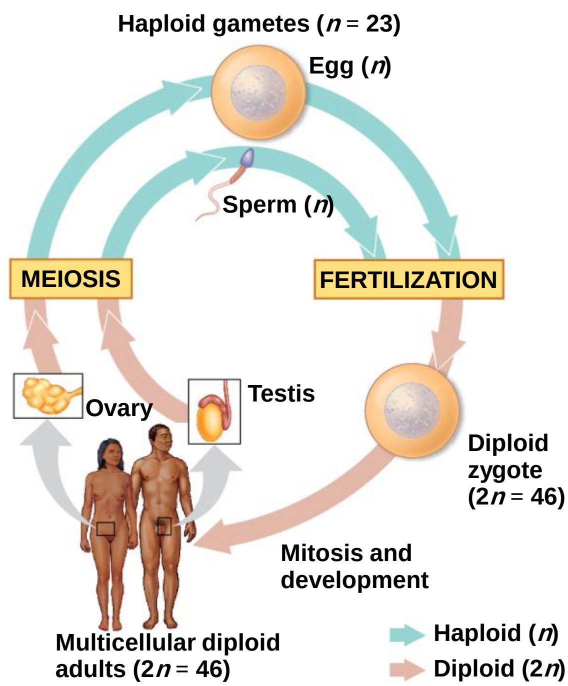
Behavior of Chromosome Sets in the Human Life Cycle

- **Fertilization** is the union of gametes (the sperm and the egg)
- The fertilized egg is called a **zygote** and has one set of chromosomes from each parent
- *The zygote produces somatic cells by mitosis and develops into an adult*

- **At sexual maturity, the ovaries and testes produce haploid gametes**
- *Gametes are the only types of human cells produced by **meiosis**, rather than mitosis*

- Meiosis results in one set of chromosomes in each gamete
- Fertilization and meiosis alternate in sexual life cycles to maintain chromosome number

Figure 13.5



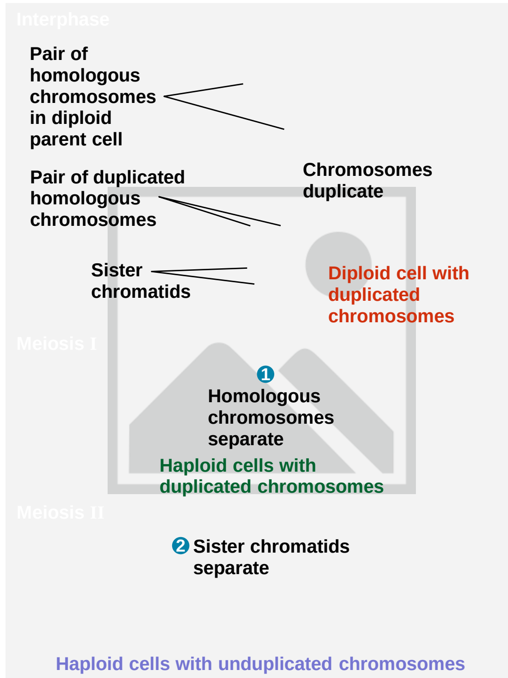
Concept 13.3: Meiosis reduces the number of chromosome sets from diploid to haploid

- Like in mitosis, replication of chromosomes happens before meiosis
- Meiosis takes place *in two consecutive cell divisions*, called **meiosis I** and **meiosis II**
- The two cell divisions result in four daughter cells, rather than the two daughter cells in mitosis
- Each daughter cell has only half as many chromosomes as the parent cell

The Stages of Meiosis

- Chromosomes duplicate before meiosis
- The resulting sister chromatids are closely associated along their lengths
- This is called sister chromatid cohesion
- The chromatids are sorted into four haploid daughter cells

Figure 13.7



- Division in meiosis I occurs in four phases:
    - prophase I
    - metaphase I
    - anaphase I
    - telophase I and cytokinesis

Prophase I

- In early prophase I, each chromosome pairs with its homolog and **crossing over** occurs
- X-shaped regions called **chiasmata** are sites of crossovers

Metaphase I

- In metaphase I, pairs of homologs line up at the metaphase plate, with one chromosome facing each pole
- Microtubules from one pole are attached to the kinetochore of one chromosome of each pair
- Microtubules from the other pole are attached to the kinetochore of the other chromosome

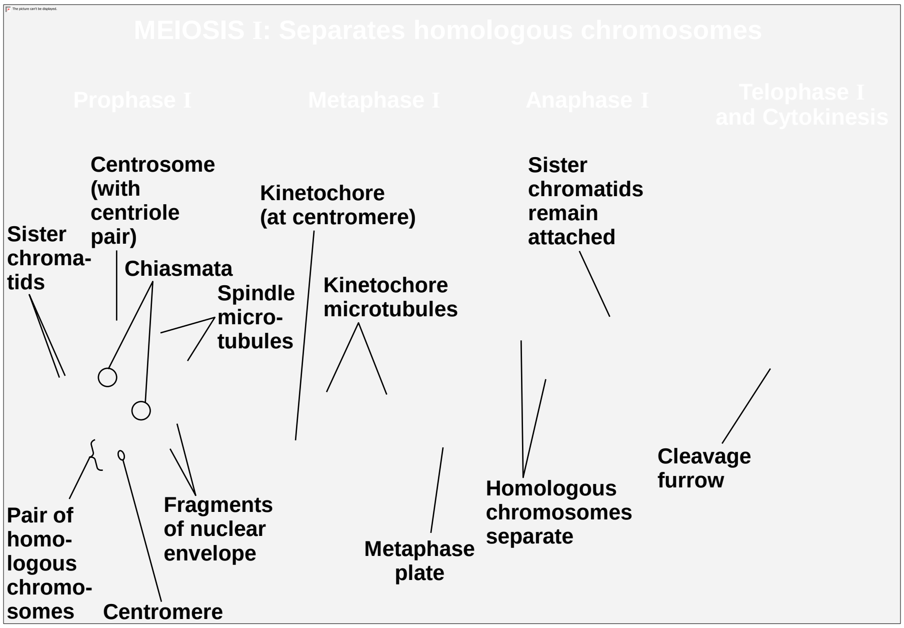
Anaphase I

- In anaphase I, pairs of homologous chromosomes separate
- One chromosome of each pair moves toward opposite poles, guided by the spindle apparatus
- *Sister chromatids remain attached at the centromere and move as one unit toward the pole*

Telophase I and Cytokinesis

- In the beginning of telophase I, *each half of the cell has a haploid set of chromosomes; each chromosome still consists of two sister chromatids*
- Cytokinesis usually occurs simultaneously, forming two haploid daughter cells
- In animal cells, a cleavage furrow forms; in plant cells, a cell plate forms
- *No chromosome replication occurs between the end of meiosis I and the beginning of meiosis II* because the chromosomes are already replicated

Figure 13.8a



- Division in meiosis II also occurs in four phases:
  - prophase II
  - metaphase II
  - anaphase II
  - telophase II and cytokinesis
- *Meiosis II is very similar to mitosis*

Prophase II

- In prophase II, a spindle apparatus forms
- In late prophase II, chromosomes (each still composed of two chromatids) move toward the metaphase plate

Metaphase II

- In metaphase II, the sister chromatids are arranged at the metaphase plate
- *Because of crossing over in meiosis I,* ***the two sister chromatids of each chromosome are no longer genetically identical***
- The kinetochores of sister chromatids attach to microtubules extending from opposite poles

Anaphase II

- In anaphase II, the sister chromatids separate
- The sister chromatids of each chromosome now move as two newly individual chromosomes toward opposite poles

Telophase II and Cytokinesis

- In telophase II, the chromosomes arrive at opposite poles
- Nuclei form, and the chromosomes begin decondensing
- Cytokinesis separates the cytoplasm
- At the end of meiosis, there are four daughter cells, each with a haploid set of unreplicated chromosomes
- Each daughter cell is *genetically distinct* from the others and from the parent cell

Figure 13.8b

MEIOSIS II: Separates sister chromatids

Prophase II | Metaphase II | Anaphase II | Telophase II and Cytokinesis

Sister chromatids separate

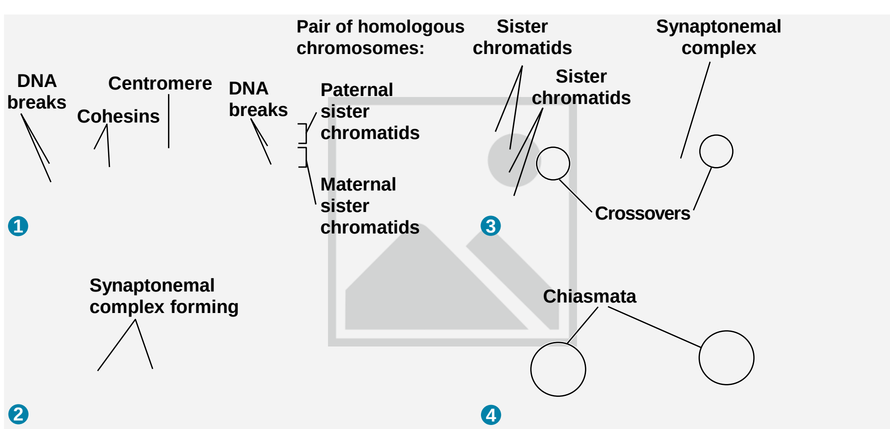
Haploid daughter cells forming

BioFlix Animation: Meiosis

Crossing Over and Synapsis During Prophase I

- After interphase, the sister chromatids are held together by proteins called cohesins
- The nonsister chromatids are broken at precisely corresponding positions
- A zipper-like structure called the **synaptonemal complex** holds the homologs together tightly
- During **synapsis**, DNA breaks are repaired, joining DNA from one nonsister chromatid to the corresponding segment of another

Figure 13.9



A Comparison of Mitosis and Meiosis

- Mitosis **conserves the number of chromosome sets**, producing cells that are **genetically identical to the parent cell**
- Meiosis **reduces the number of chromosomes sets** from two (diploid) to one (haploid), producing cells that **differ genetically** from each other and from the parent cell
- Three events are unique to meiosis, and all three occur in meiosis I
  - *Synapsis and crossing over in prophase I:* Homologous chromosomes physically connect and exchange genetic information
  - *Homologous pairs at the metaphase plate*
  - *Separation of homologs during anaphase I*

Figure 13.10a

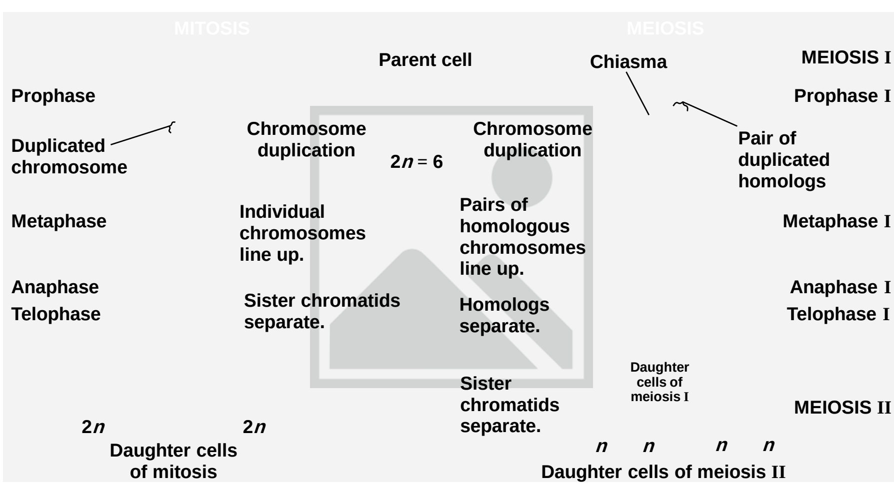


Figure 13.10b

- Sister chromatid cohesion allows sister chromatids to stay together through meiosis I
- In mitosis, cohesins are cleaved at the end of metaphase
- In meiosis, cohesins are cleaved along the chromosome arms in anaphase I (separation of homologs) and at the centromeres in anaphase II (separation of sister chromatids)

Concept 13.4: Genetic variation produced in sexual life cycles contributes to evolution

- Mutations (changes in an organism's DNA) are the original source of genetic diversity
- Mutations create different versions of genes called alleles
- Reshuffling of alleles during sexual reproduction produces genetic variation

Origins of Genetic Variation Among Offspring

- The behavior of chromosomes during meiosis and fertilization is responsible for most of the variation that arises in each generation
- Three mechanisms contribute to genetic variation:
  - *Independent assortment of chromosomes*
  - *Crossing over*
  - *Random fertilization*

Independent Assortment of Chromosomes

- Homologous pairs of chromosomes orient randomly at metaphase I of meiosis
- In independent assortment, *each pair of chromosomes sorts maternal and paternal homologs into daughter cells independently of the other pairs*

- The number of combinations possible when chromosomes assort independently into gametes is 2^n, where n is the haploid number
- For humans ($n = 23$), there are more than 8 million (2^{23}) possible combinations of chromosomes

Figure 13.11_1

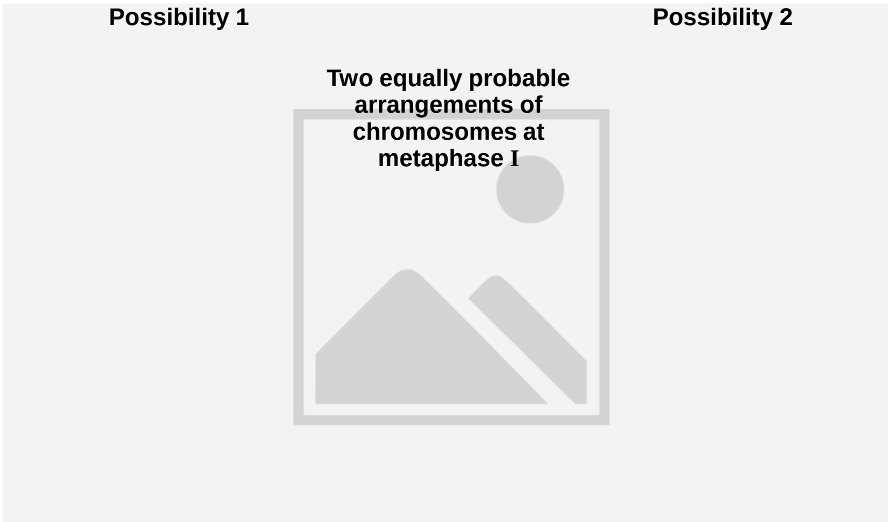


Figure 13.11_2

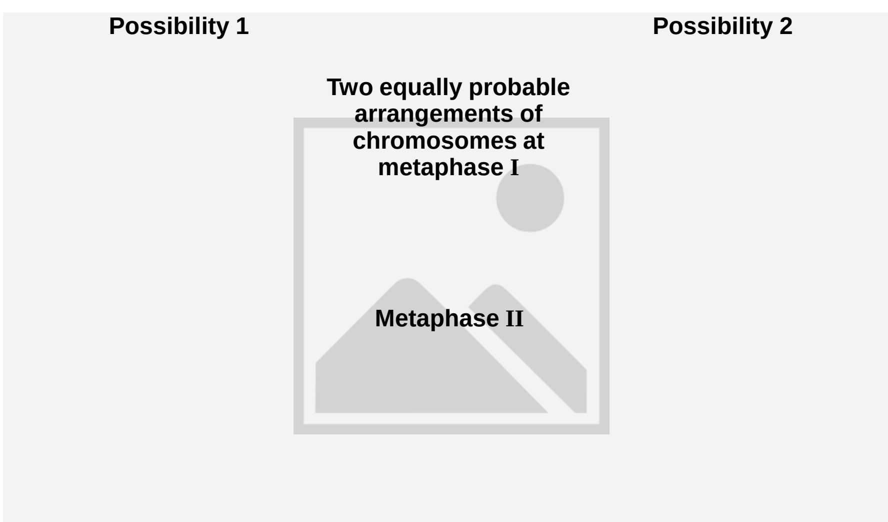
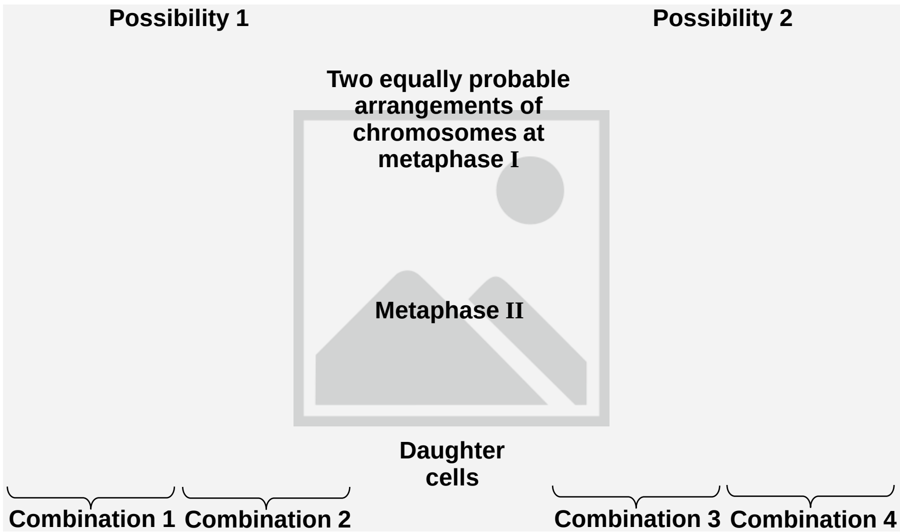


Figure 13.11_3



Crossing Over

- Crossing over produces **recombinant chromosomes**, which *combine DNA inherited from each parent*
- Crossing over contributes to genetic variation by combining DNA from two parents into a single chromosome
- In humans, an average of one to three crossover events occurs per chromosome

Figure 13.12_1

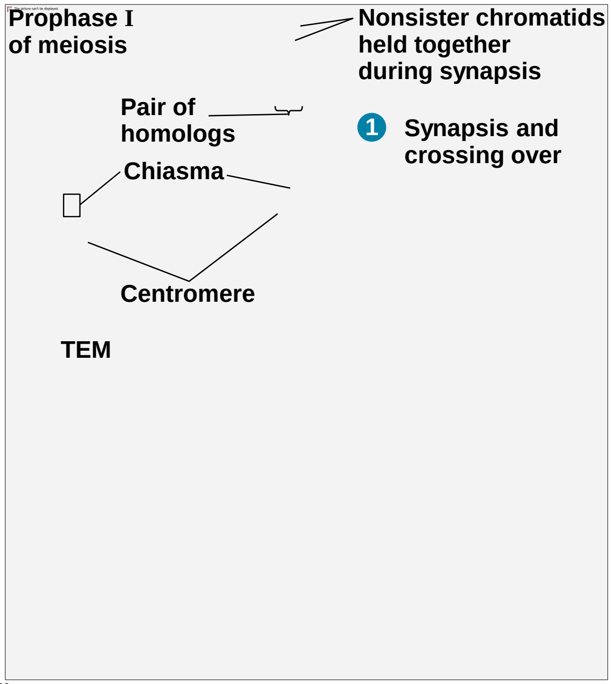


Figure 13.12_2

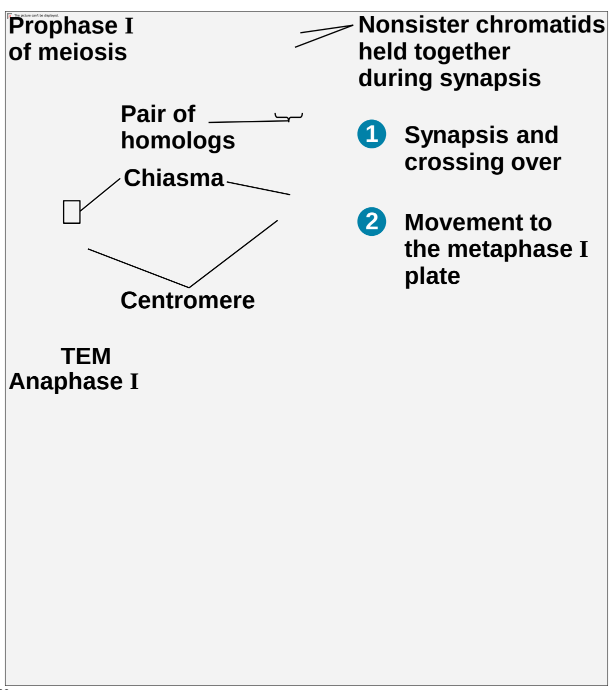


Figure 13.12_3

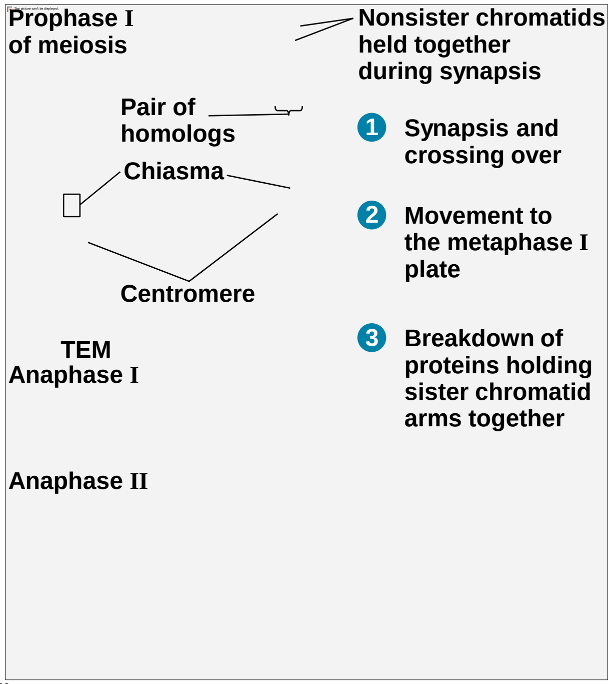
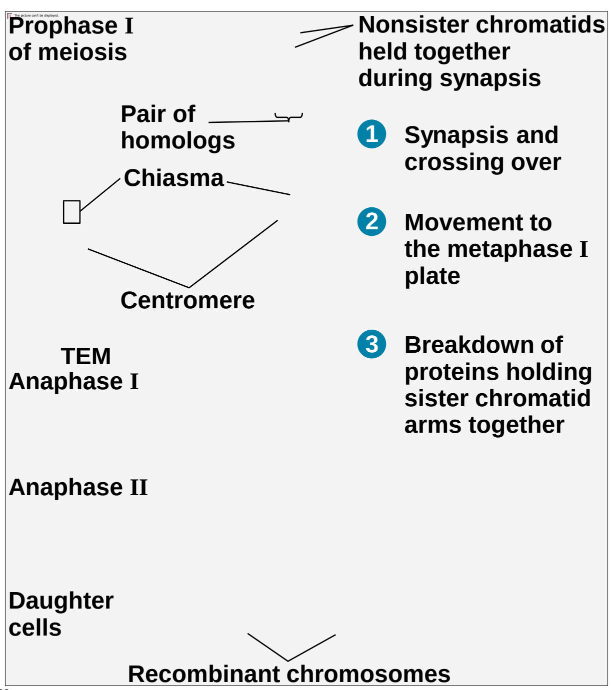


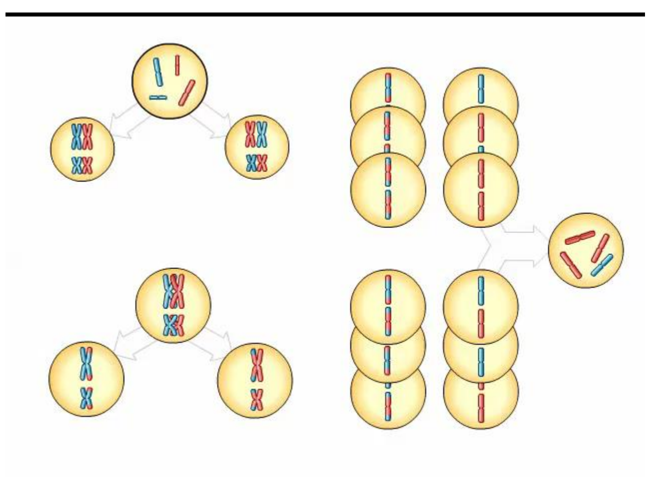
Figure 13.12_4



Random Fertilization

- Random fertilization adds to genetic variation because *any sperm can fuse with any ovum* (unfertilized egg)
- The fusion of two gametes (each with 8.4 million possible chromosome combinations from independent assortment) produces a zygote with any of about 70 trillion diploid combinations
- Crossing over adds even more variation
- Each zygote has a unique genetic identity

Animation: Genetic Variation



Class activity!

- After the synaptonemal complex disappears, how would the two homologs be associated if crossing over did not occur?
- What effect might this ultimately have on gamete formation?

Class activity!

- A human cell containing 22 autosomes and a Y chromosome is
  a. A sperm
  b. An egg
  c. A zygote
  d. A somatic cell of a male

- Homologous chromosomes move toward opposite poles of a dividing cell during
  a. Mitosis
  b. Meiosis I
  c. Meiosis II
  d. Fertilization