Chapter 13

Meiosis and Sexual Life Cycles

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Variations on a Theme

- Living organisms are distinguished by their ability to reproduce their own kind
- **Genetics** is the scientific study of heredity and variation
- **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

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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

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Inheritance of Genes

- **Genes** are the units of heredity, and are made up of segments of DNA
- Genes are passed to the next generation through reproductive cells called **gametes** (sperm and eggs)
- Each gene has a specific location called a **locus** on a certain chromosome
- Most DNA is packaged into chromosomes
- One set of chromosomes is inherited from each parent

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Comparison of Asexual and Sexual Reproduction

- In **asexual reproduction**, one parent produces genetically identical offspring by mitosis
- 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

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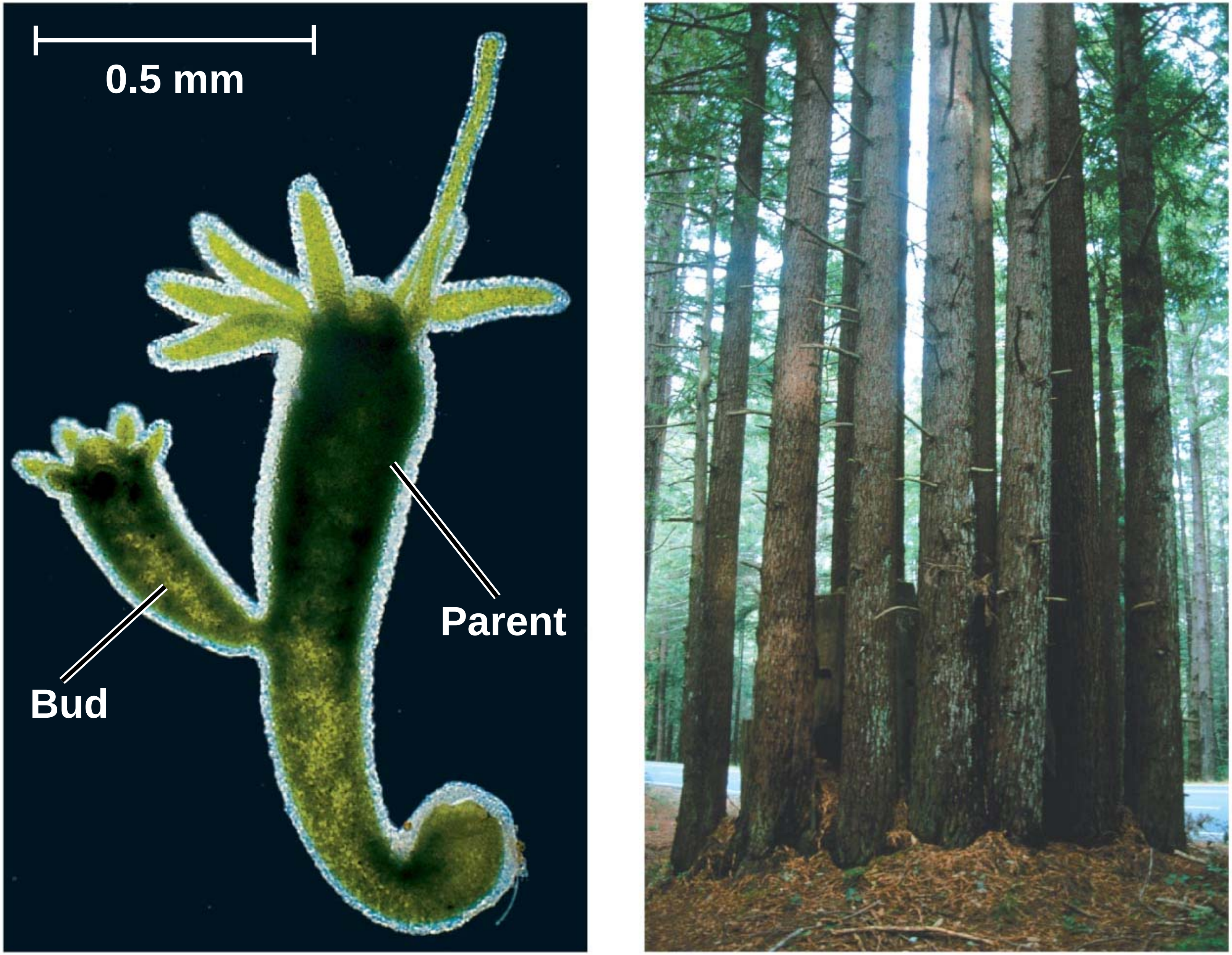
Fig. 13-2



(a) Hydra

(b) Redwoods

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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

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Sets of Chromosomes in Human Cells

- Human **somatic cells** (any cell other than a gamete) 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
- Chromosomes in a homologous pair are the same length and carry genes controlling the same inherited characters

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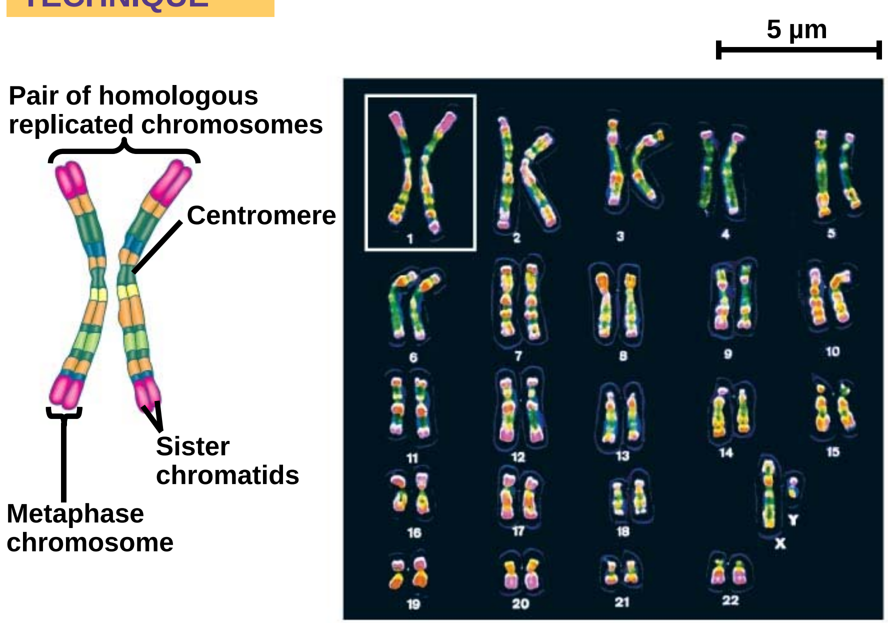
Fig. 13-3

Preparing a karyotype

APPLICATION

TECHNIQUE



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- The **sex chromosomes** 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 22 pairs of chromosomes that do not determine sex are called **autosomes**

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- 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** ($2n$) has two sets of chromosomes
- For humans, the diploid number is 46 ($2n = 46$)

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- In a cell in which DNA synthesis has occurred, each chromosome is replicated
- Each replicated chromosome consists of two identical sister chromatids

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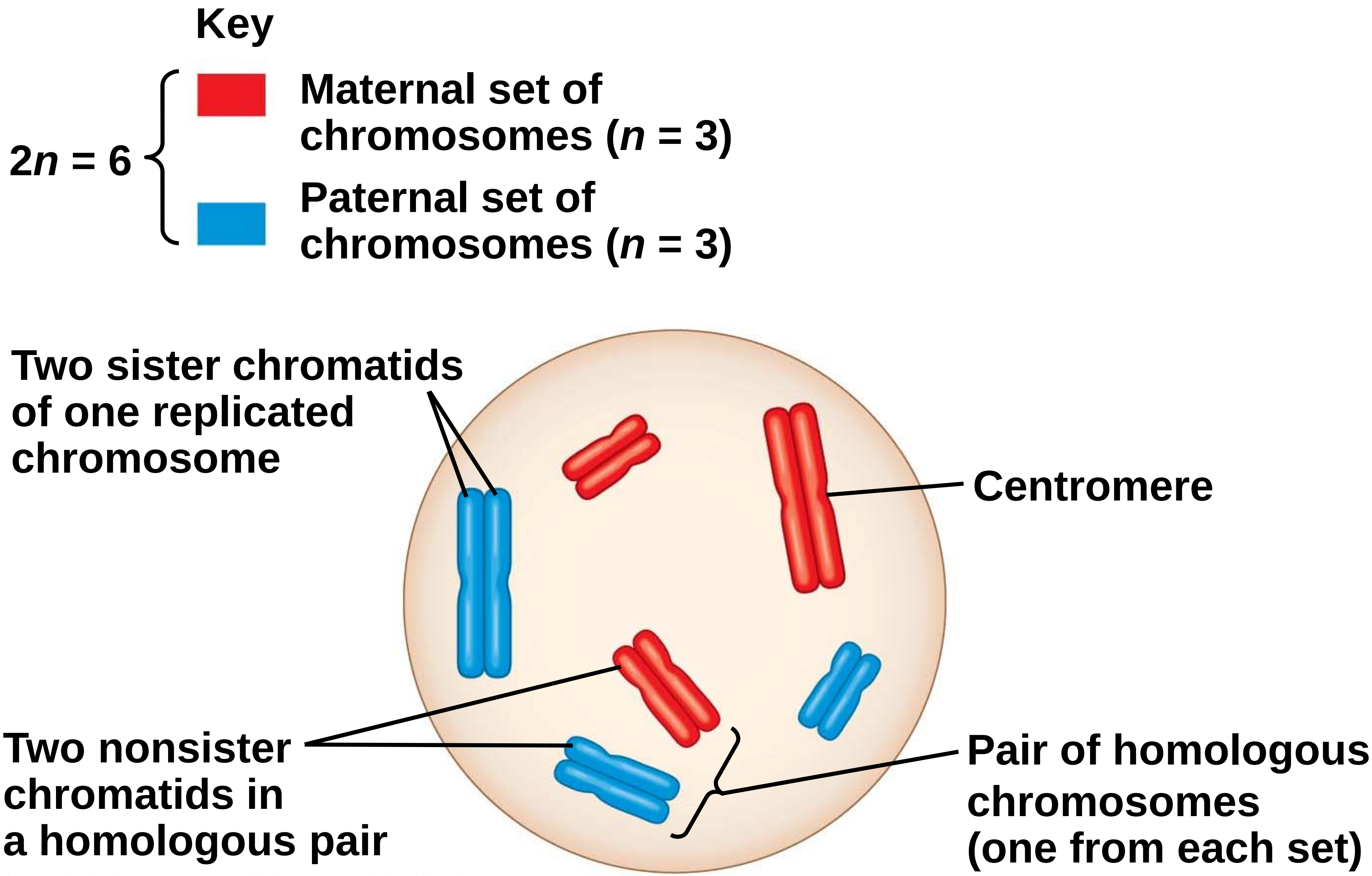
Fig. 13-4

Describing chromosomes



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- A gamete (sperm or egg) contains a single set of chromosomes, and is **haploid** (*n*)
- For humans, the haploid number is 23 (n = 23)
- Each set of 23 consists of 22 autosomes and a single 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

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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

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- 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

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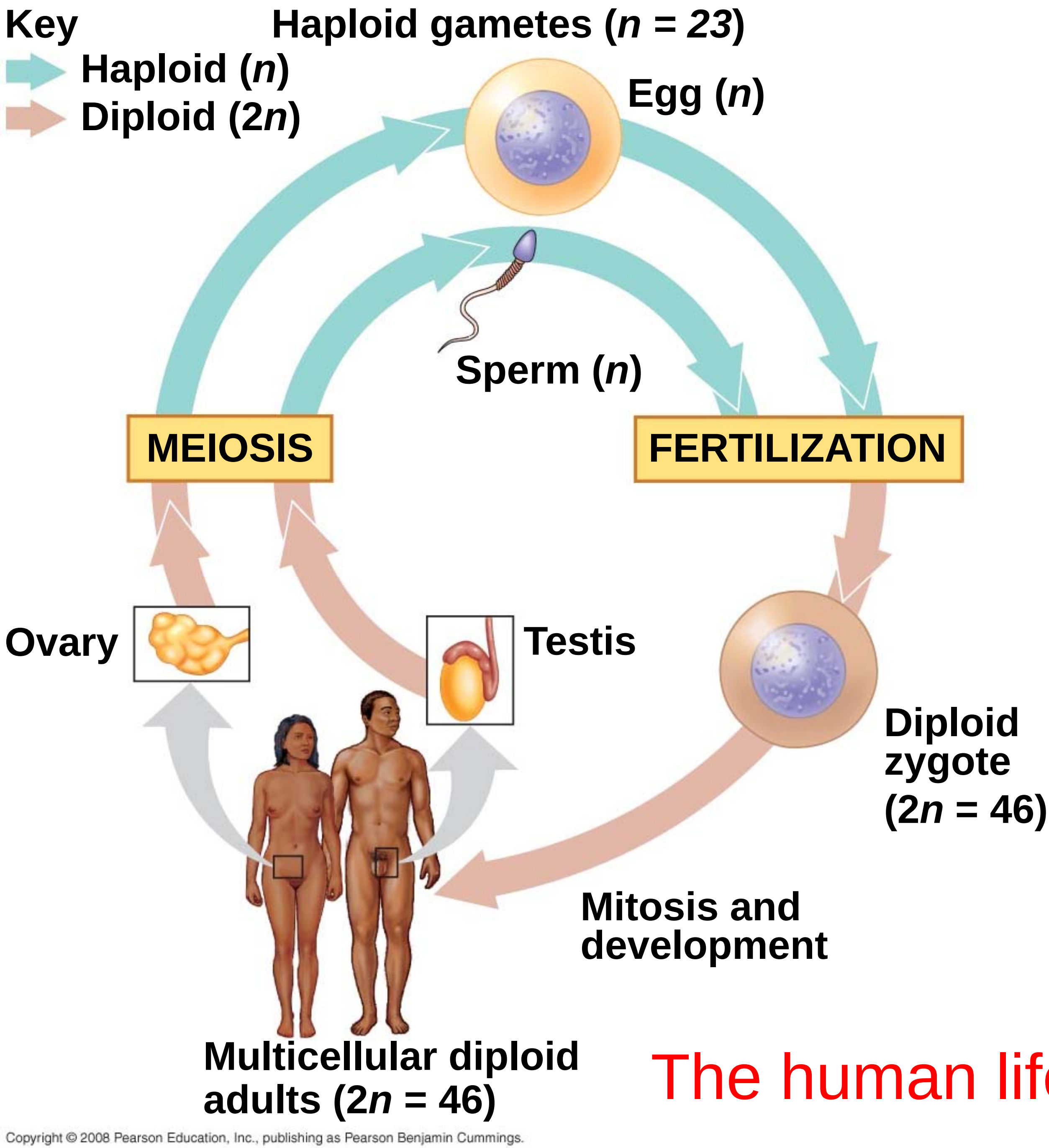
Fig. 13-5



The human life cycle

The Variety of Sexual Life Cycles

- The alternation of meiosis and fertilization is common to all organisms that reproduce sexually
- The three main types of sexual life cycles differ in the timing of meiosis and fertilization

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- In animals, meiosis produces gametes, which undergo no further cell division before fertilization
- Gametes are the only haploid cells in animals
- Gametes fuse to form a diploid zygote that divides by mitosis to develop into a multicellular organism

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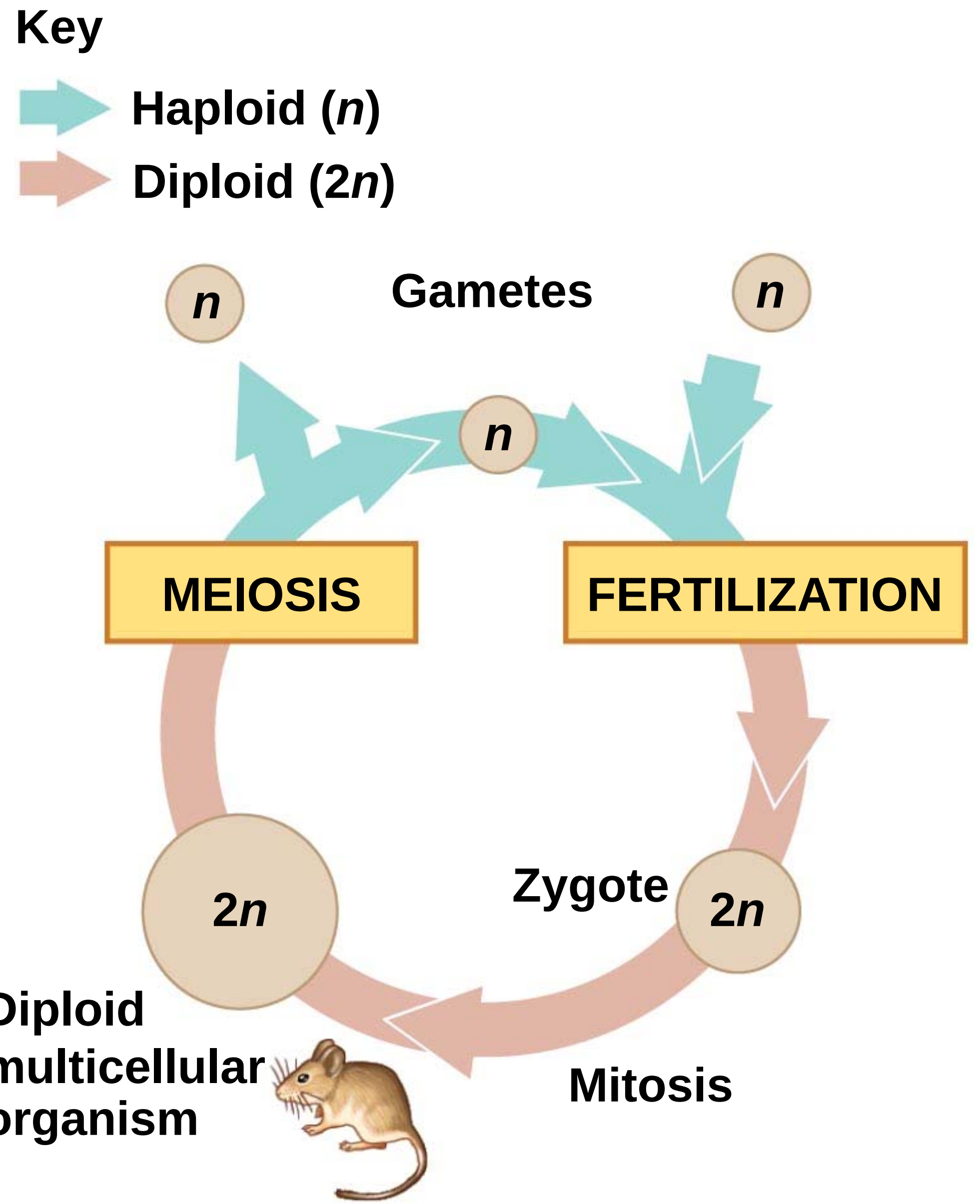
Fig. 13-6a



(a) Animals

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- Plants and some algae exhibit an **alternation of generations**
- This life cycle includes both a diploid and haploid multicellular stage
- The diploid organism, called the **sporophyte**, makes haploid **spores** by meiosis

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- Each spore grows by mitosis into a haploid organism called a **gametophyte**
- A gametophyte makes haploid gametes by mitosis
- Fertilization of gametes results in a diploid sporophyte

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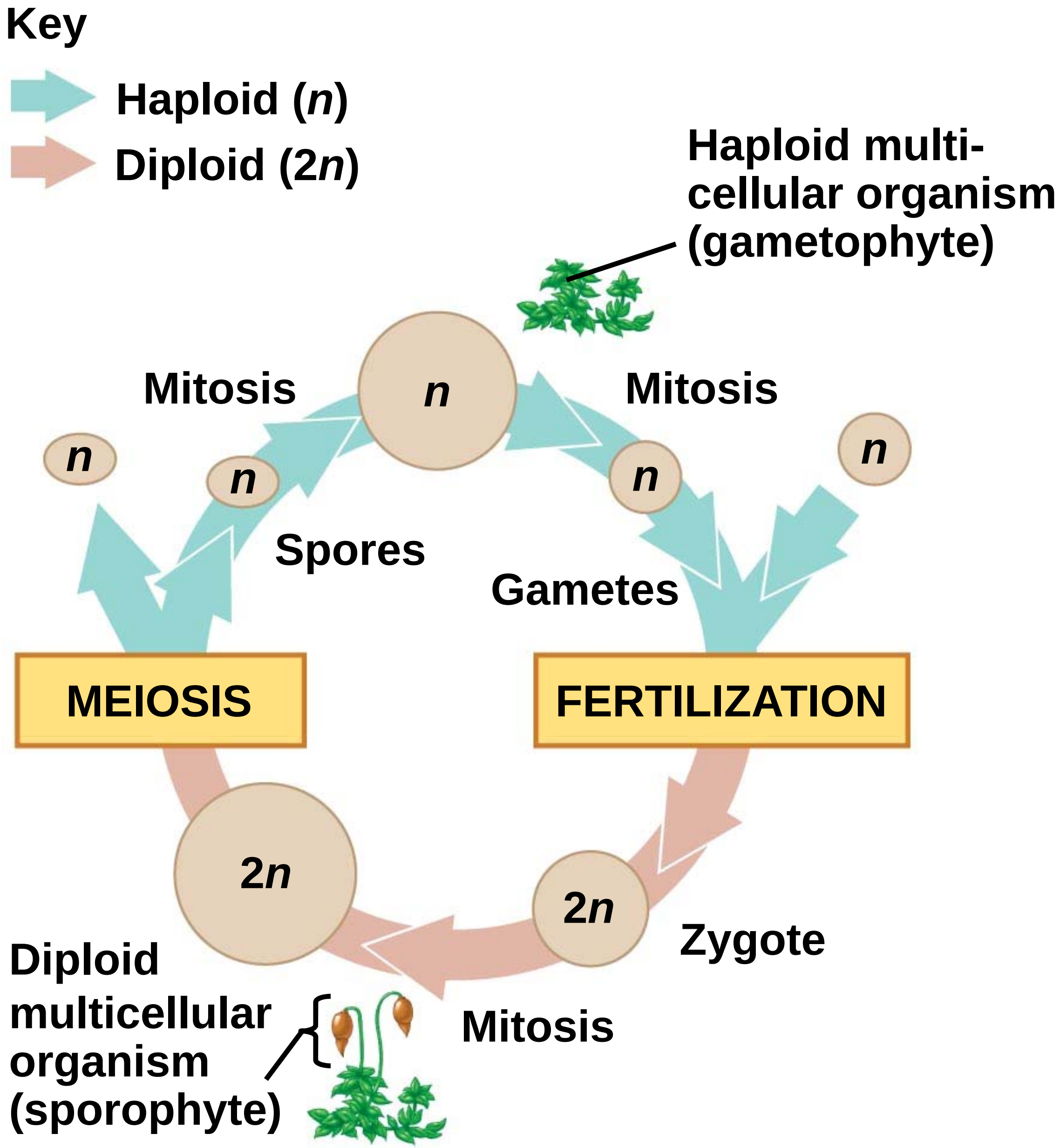
Fig. 13-6b



(b) Plants and some algae

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- In most fungi and some protists, the only diploid stage is the single-celled zygote; there is no multicellular diploid stage
- The zygote produces haploid cells by meiosis
- Each haploid cell grows by mitosis into a haploid multicellular organism
- The haploid adult produces gametes by mitosis

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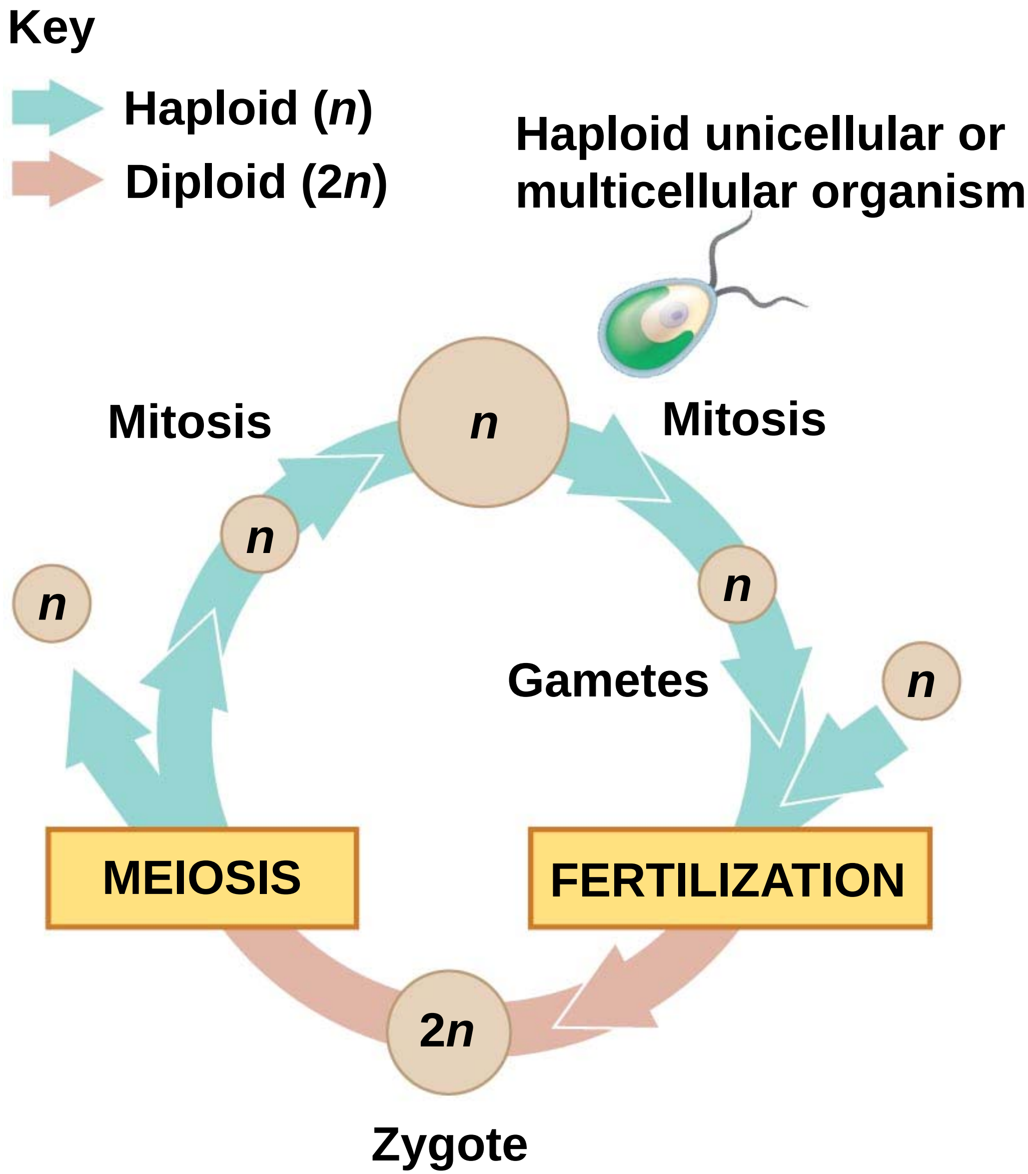
Fig. 13-6c



(c) Most fungi and some protists

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- Depending on the type of life cycle, either haploid or diploid cells can divide by mitosis
- However, only diploid cells can undergo meiosis
- In all three life cycles, the halving and doubling of chromosomes contributes to genetic variation in offspring

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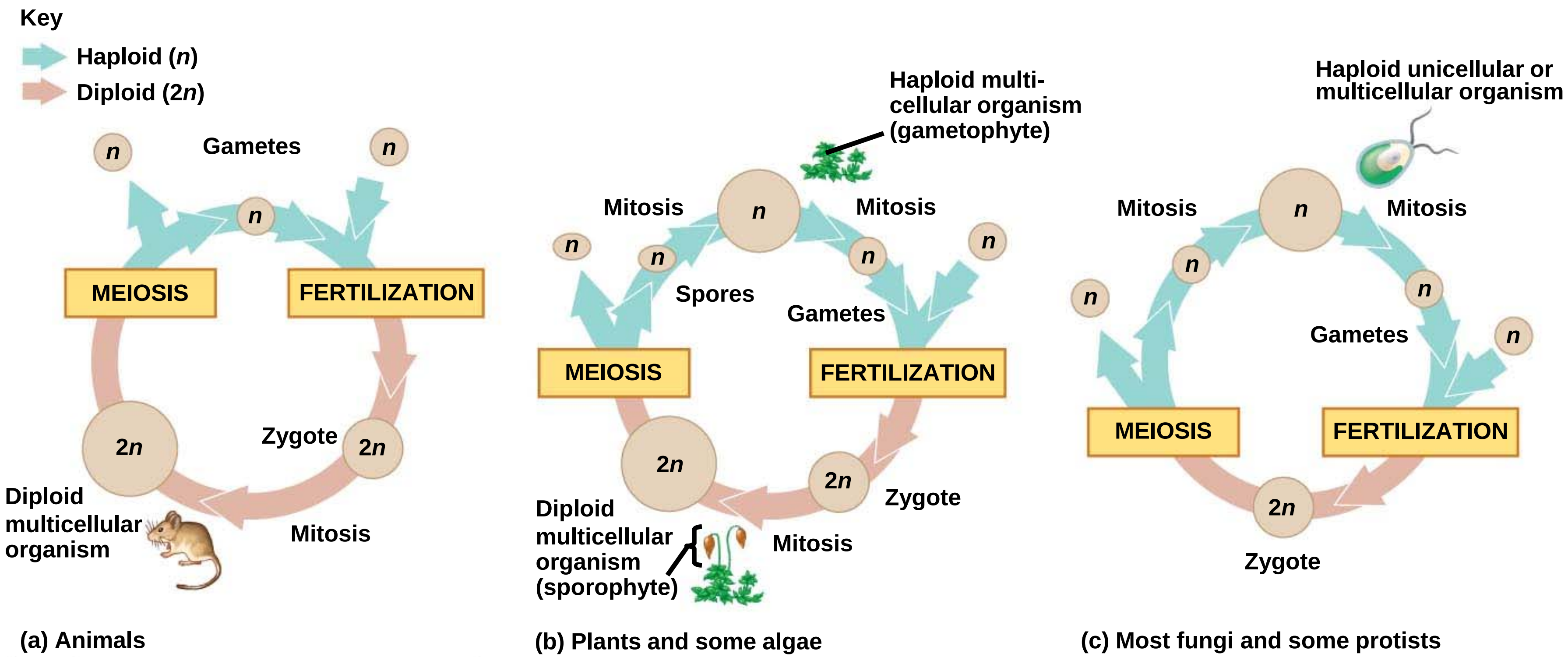
Fig. 13-6

Three types of sexual life cycles



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

- Like mitosis, meiosis is preceded by the replication of chromosomes
- Meiosis takes place in two sets of 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

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The Stages of Meiosis

- In the first cell division (meiosis I), homologous chromosomes separate
- Meiosis I results in two haploid daughter cells with replicated chromosomes; it is called the reductional division
- In the second cell division (meiosis II), sister chromatids separate
- Meiosis II results in four haploid daughter cells with unreplicated chromosomes; it is called the equational division

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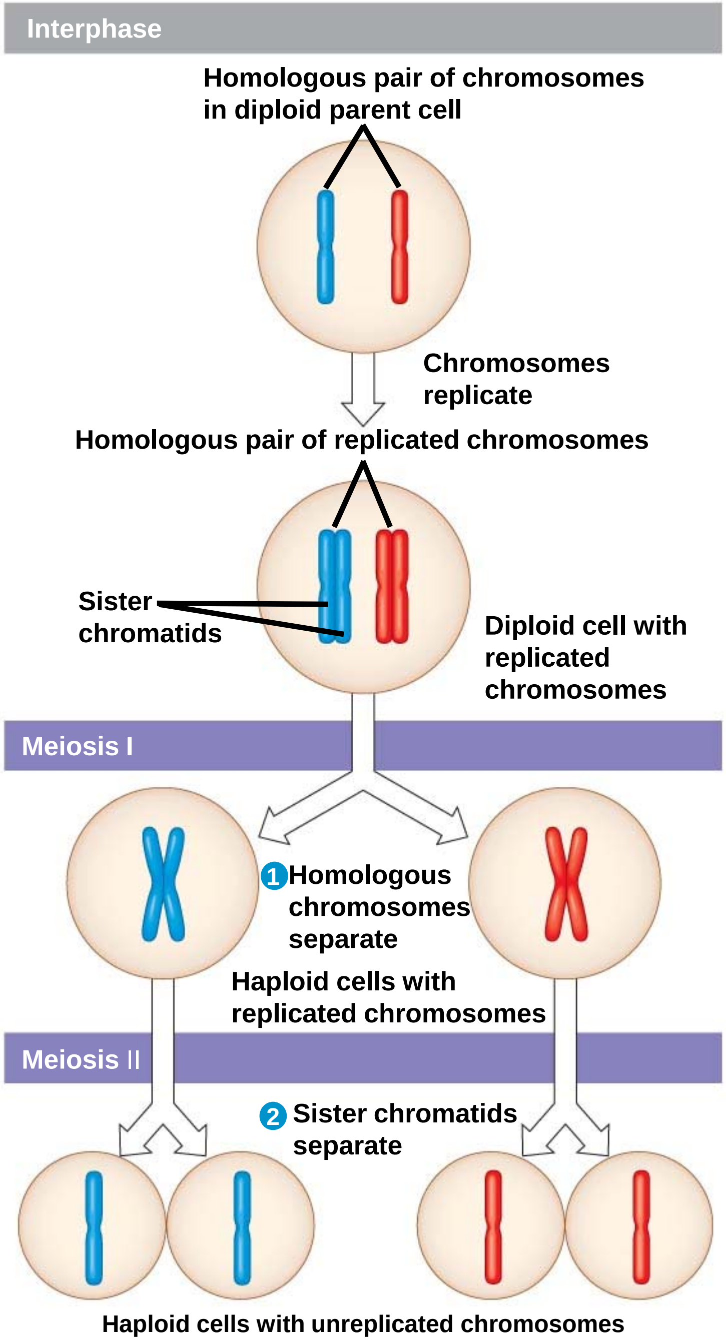
Fig. 13-7-3



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- Meiosis I is preceded by interphase, in which chromosomes are replicated to form sister chromatids
- The sister chromatids are genetically identical and joined at the centromere
- The single centrosome replicates, forming two centrosomes

PLAY BioFlix: Meiosis

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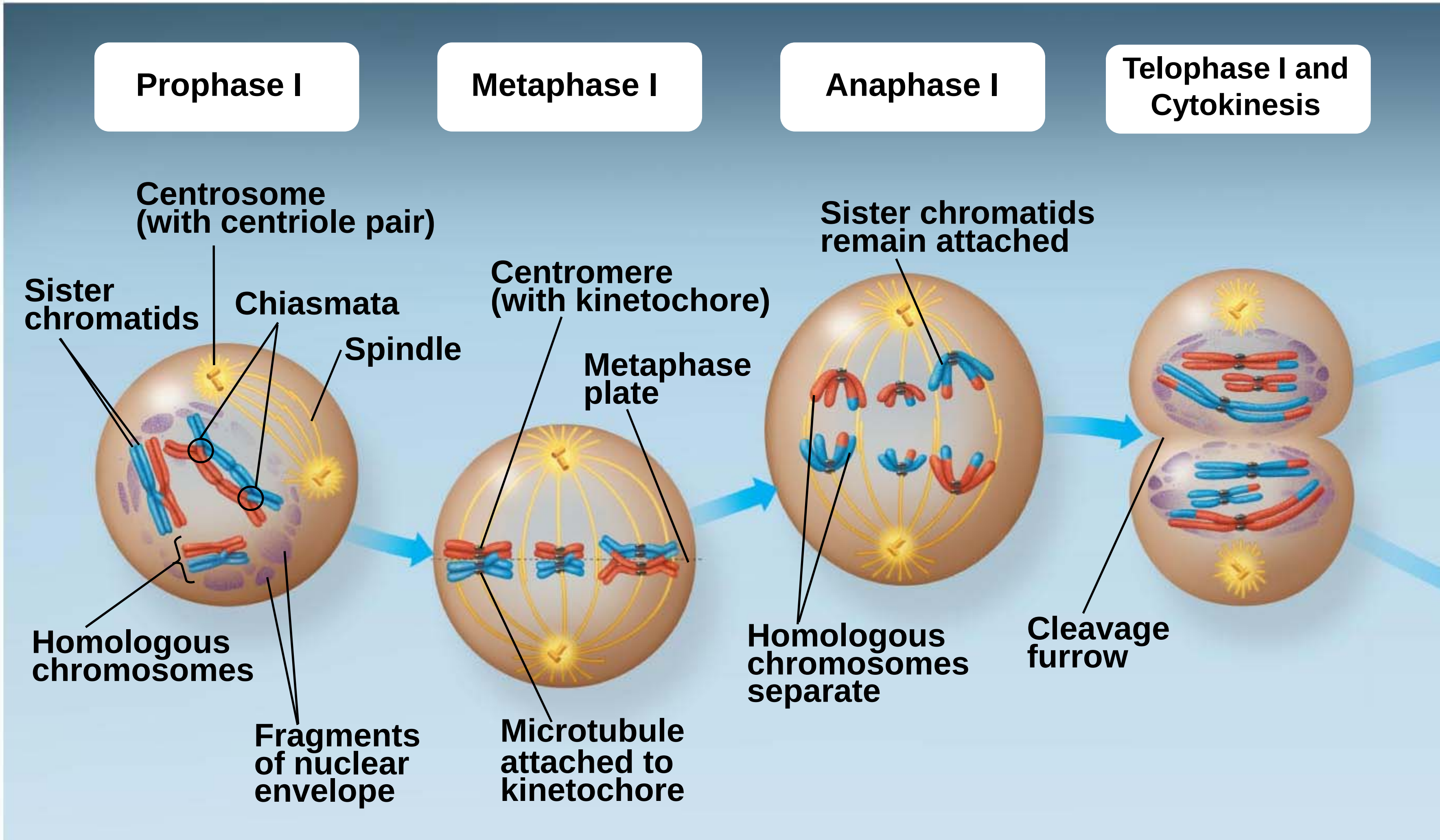
Fig. 13-8a



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Prophase I

- Prophase I typically occupies more than 90% of the time required for meiosis
- Chromosomes begin to condense
- In **synapsis**, homologous chromosomes loosely pair up, aligned gene by gene

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- In **crossing over**, nonsister chromatids exchange DNA segments
- Each pair of chromosomes forms a tetrad, a group of four chromatids
- Each tetrad usually has one or more **chiasmata**, X-shaped regions where crossing over occurred

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Metaphase I

- In metaphase I, tetrads 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 tetrad
- Microtubules from the other pole are attached to the kinetochore of the other chromosome

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Anaphase I

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

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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

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- 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

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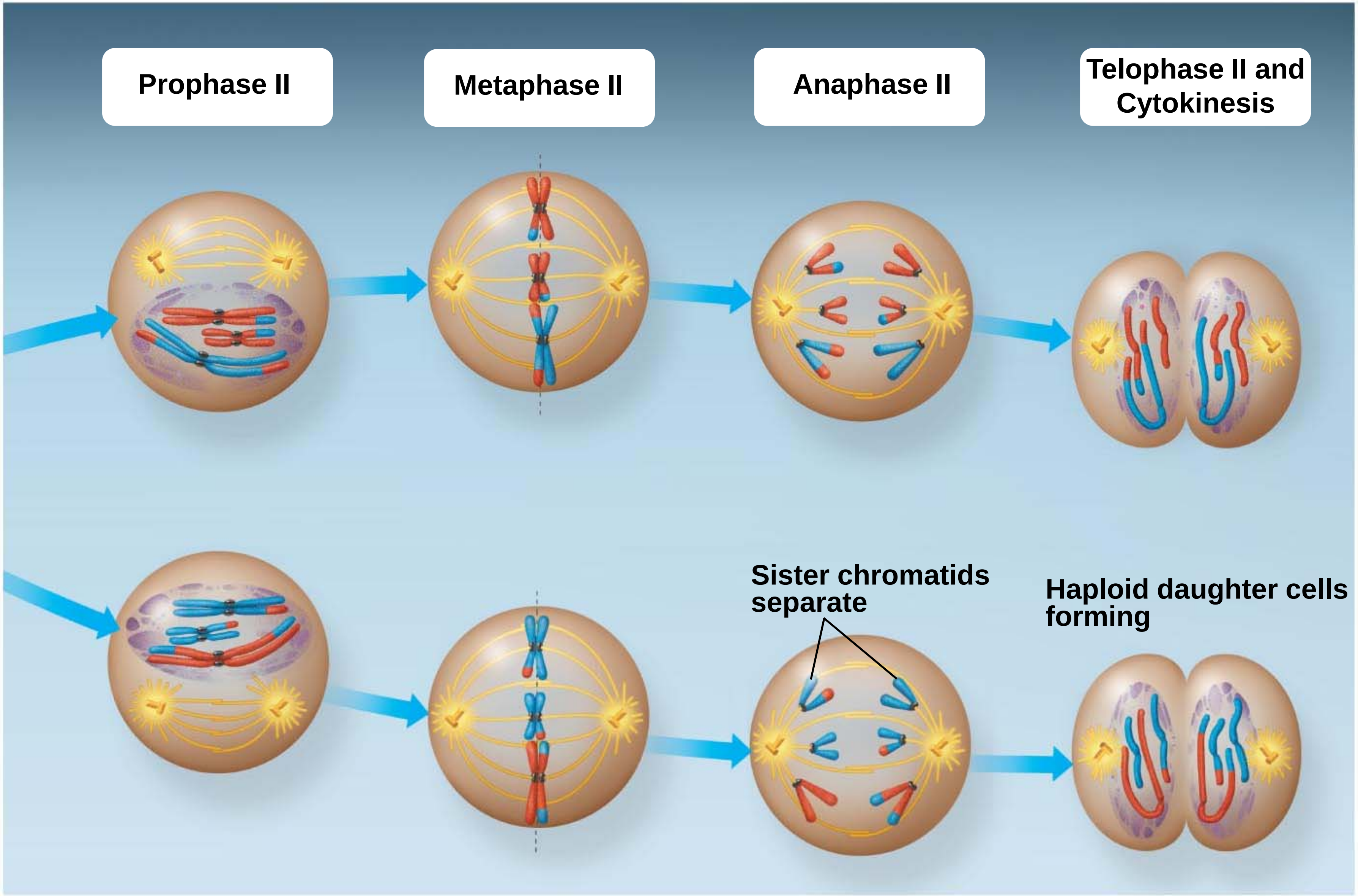
Fig. 13-8d



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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

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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

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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

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Telophase II and Cytokinesis

- In telophase II, the chromosomes arrive at opposite poles
- Nuclei form, and the chromosomes begin decondensing

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- 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

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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
- The mechanism for separating sister chromatids is virtually identical in meiosis II and mitosis

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Fig. 13-9a

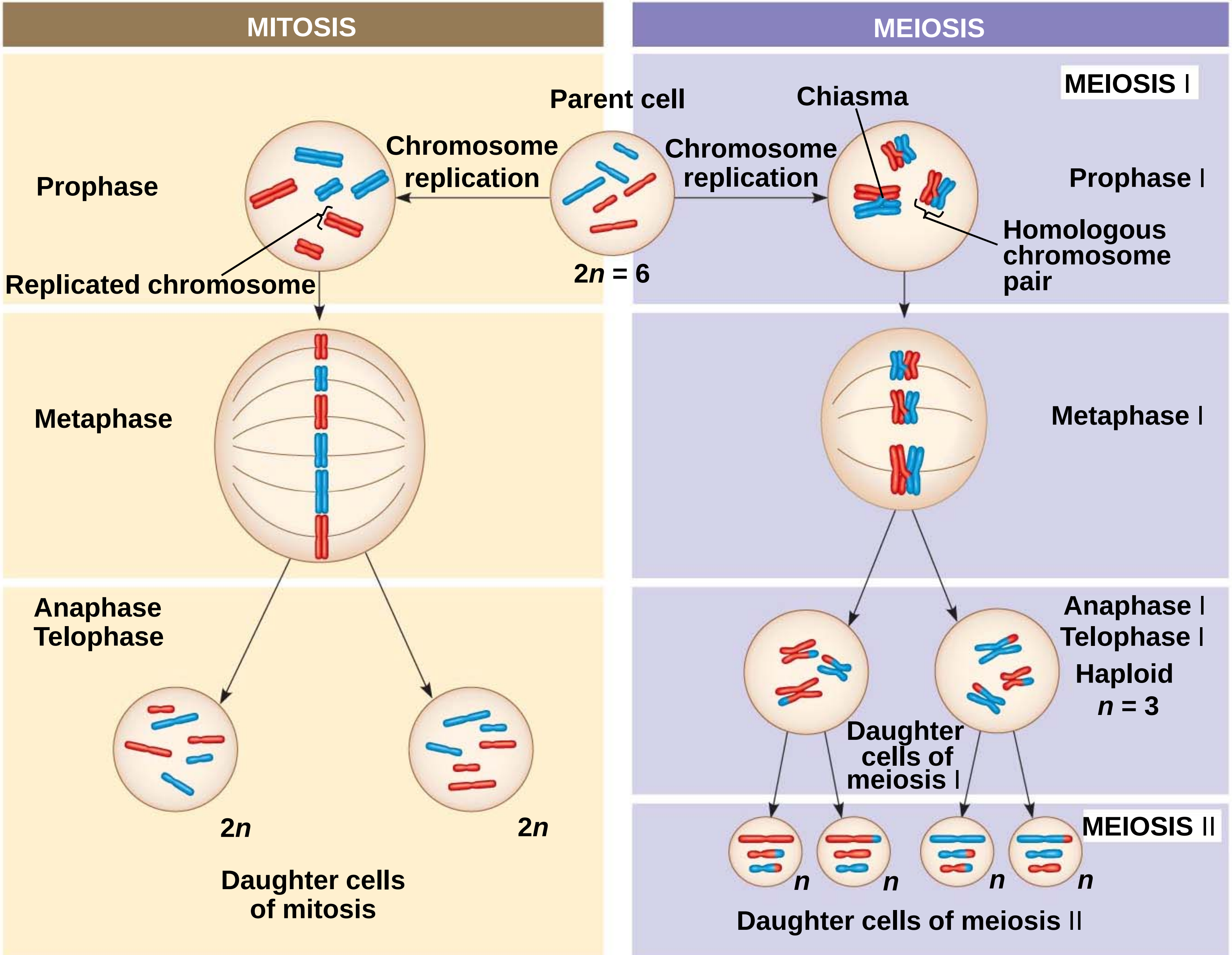

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Fig. 13-9b

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, each diploid (2*n*) and genetically identical to the parent cell	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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- 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
  - At the metaphase plate, there are paired homologous chromosomes (tetrads), instead of individual replicated chromosomes
  - At anaphase I, it is homologous chromosomes, instead of sister chromatids, that separate

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- Sister chromatid cohesion allows sister chromatids of a single chromosome to stay together through meiosis I
- Protein complexes called cohesins are responsible for this cohesion
- 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)

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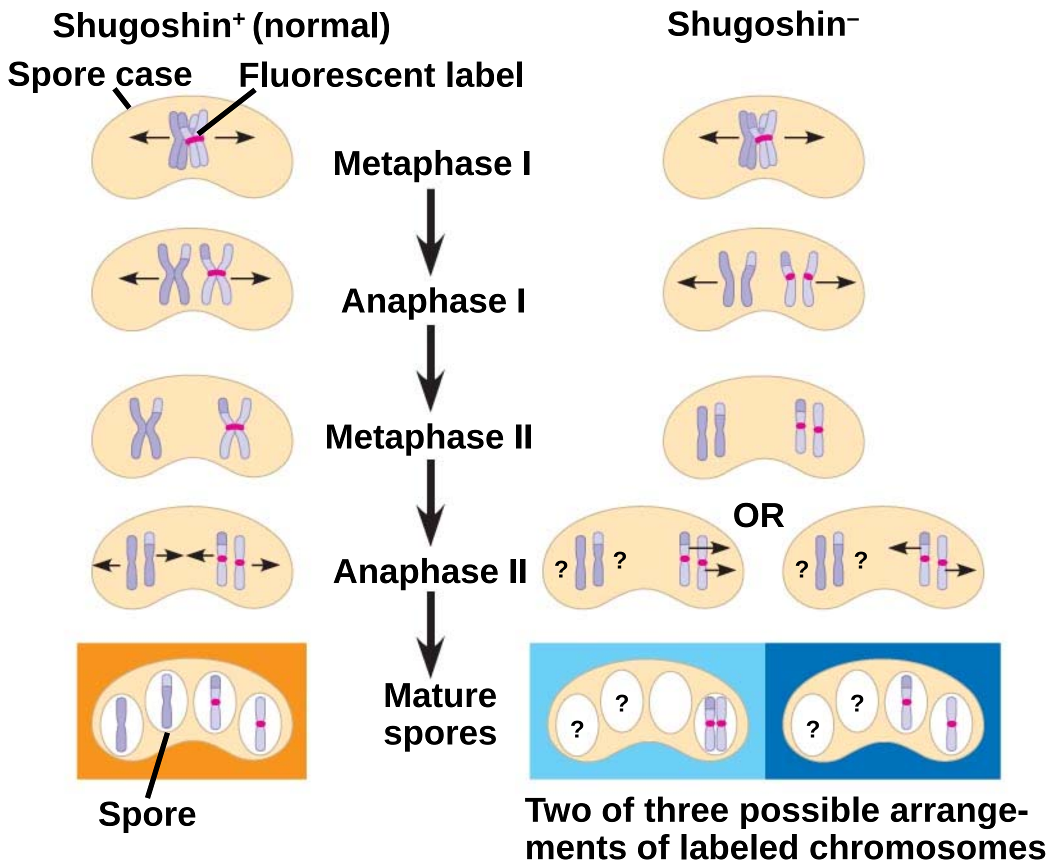
Fig. 13-10

EXPERIMENT



RESULTS

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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

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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

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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 homologues into daughter cells independently of the other pairs

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- 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

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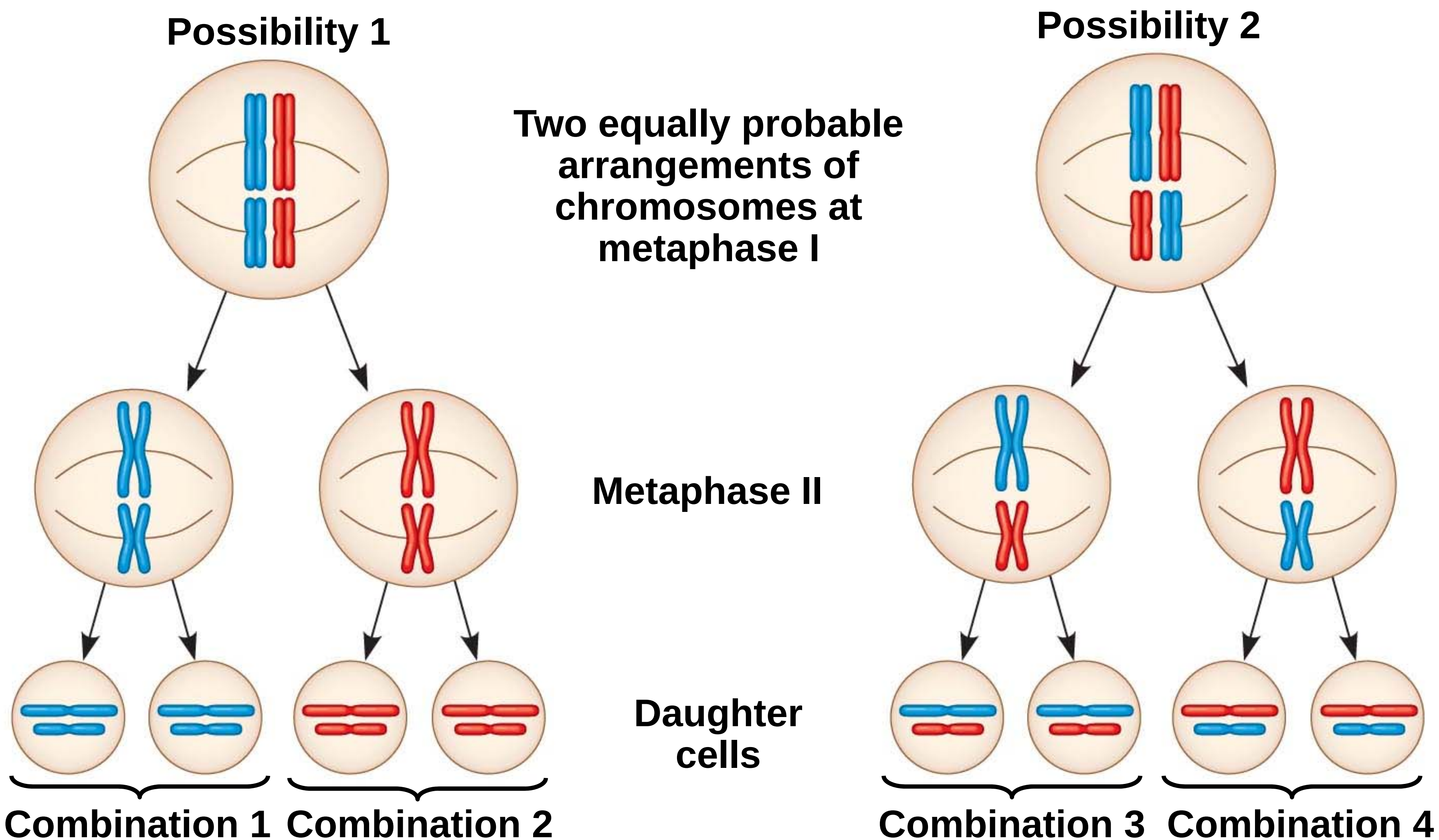
Fig. 13-11-3

The independent assortment of homologous chromosomes in meiosis



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Crossing Over

- Crossing over produces **recombinant chromosomes**, which combine genes inherited from each parent
- Crossing over begins very early in prophase I, as homologous chromosomes pair up gene by gene

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- In crossing over, homologous portions of two nonsister chromatids trade places
- Crossing over contributes to genetic variation by combining DNA from two parents into a single chromosome

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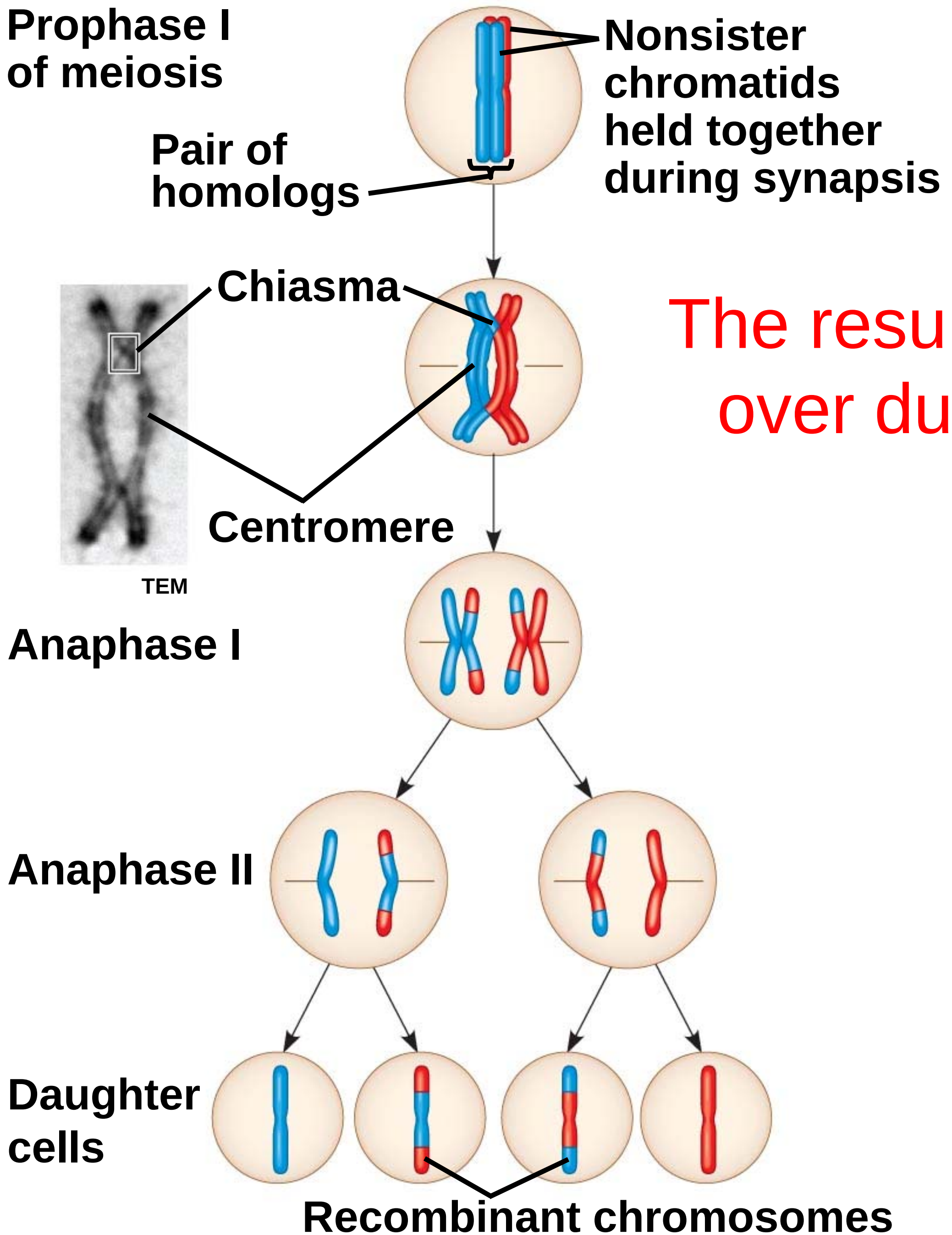
Fig. 13-12-5

The results of crossing over during meiosis



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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

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- Crossing over adds even more variation
- Each zygote has a unique genetic identity

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The Evolutionary Significance of Genetic Variation Within Populations

- Natural selection results in the accumulation of genetic variations favored by the environment
- Sexual reproduction contributes to the genetic variation in a population, which originates from mutations

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You should now be able to:

1. Distinguish between the following terms: somatic cell and gamete; autosome and sex chromosomes; haploid and diploid
2. Describe the events that characterize each phase of meiosis
3. Describe three events that occur during meiosis I but not mitosis
4. Name and explain the three events that contribute to genetic variation in sexually reproducing organisms

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