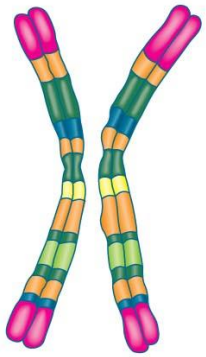
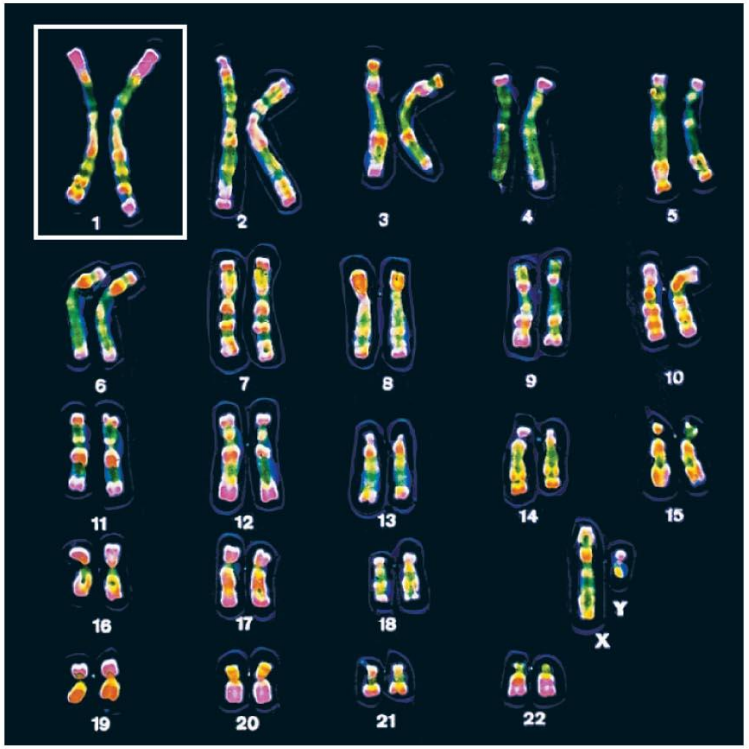
Chapter 13
Meiosis and Sexual Life Cycles





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

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 through reproductive cells called gametes (sperm and eggs)**
- **Each gene has a specific location called a locus on a certain chromosome**
- **One set of chromosomes is inherited from each parent**

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

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** (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**

Fig. 13-3b

TECHNIQUE

Karyotyping

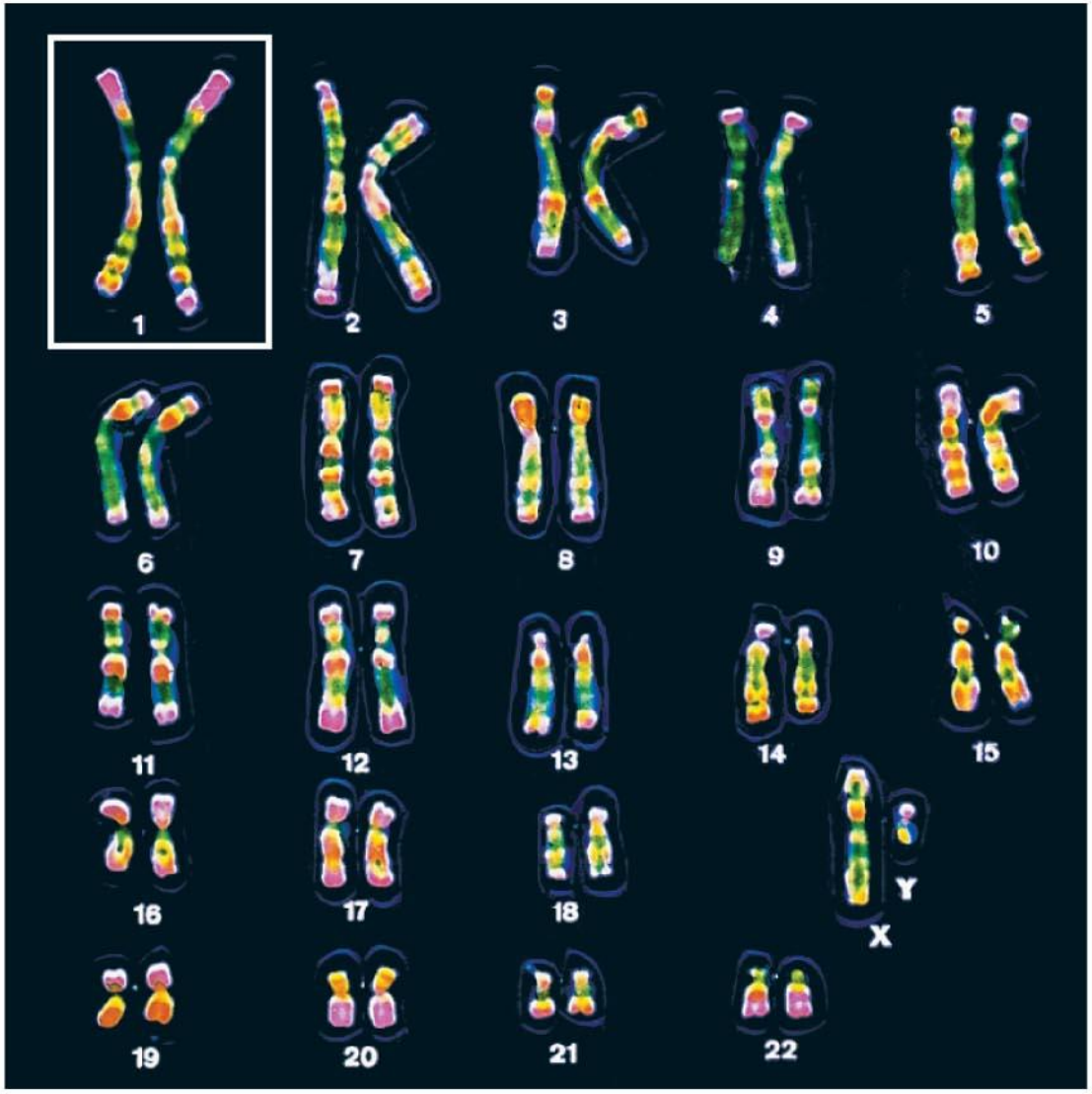
5 µm

Pair of homologous replicated chromosomes

Centromere

Sister chromatids

Metaphase chromosome



- 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 (XY)
- The 22 pairs of chromosomes that do not determine sex are called autosomes

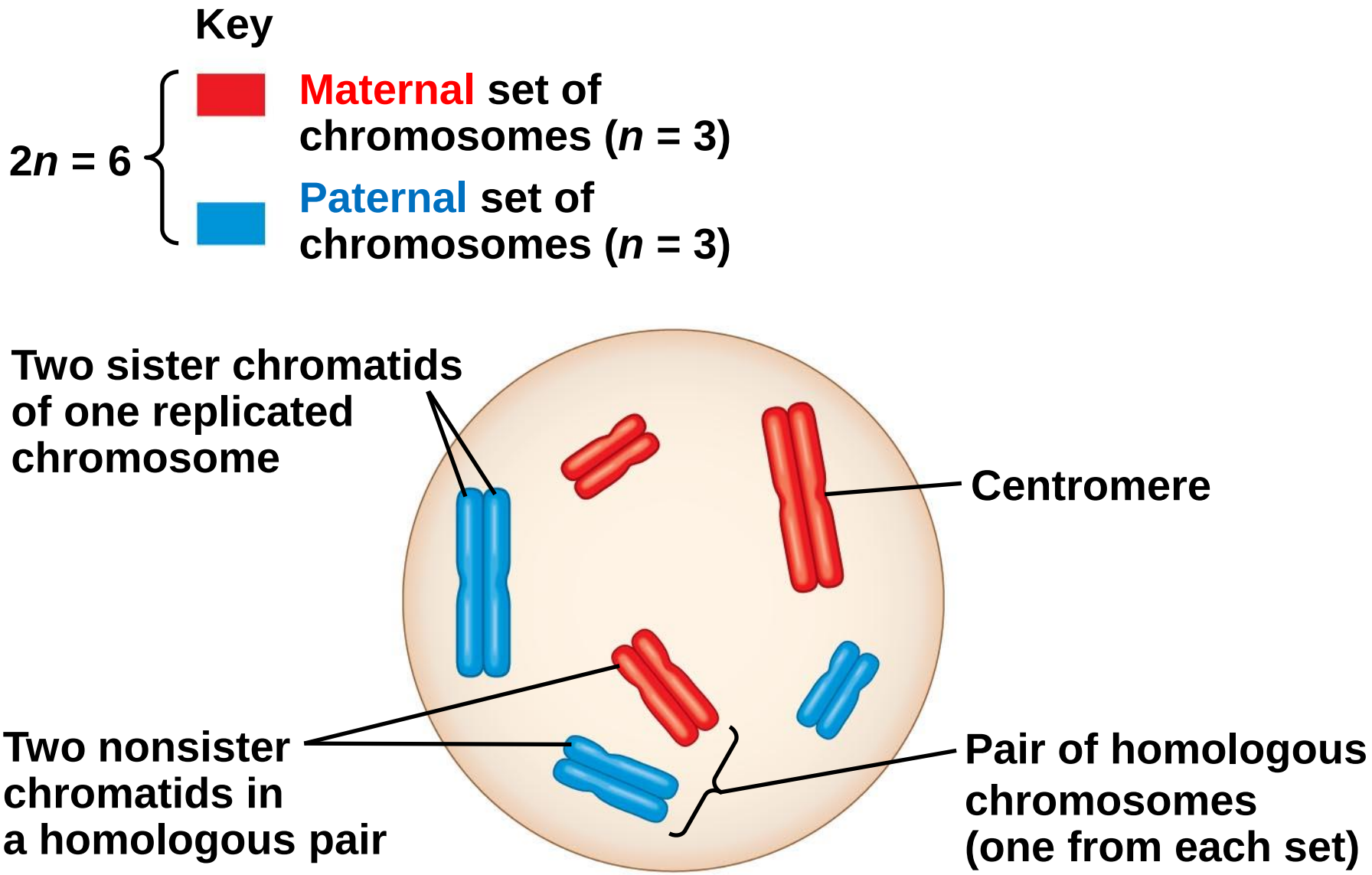
- **Each pair of homologous chromosomes includes one chromosome from each parent**

- **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, diploid number is 46 (2*n* = 46)**

Fig. 13-4



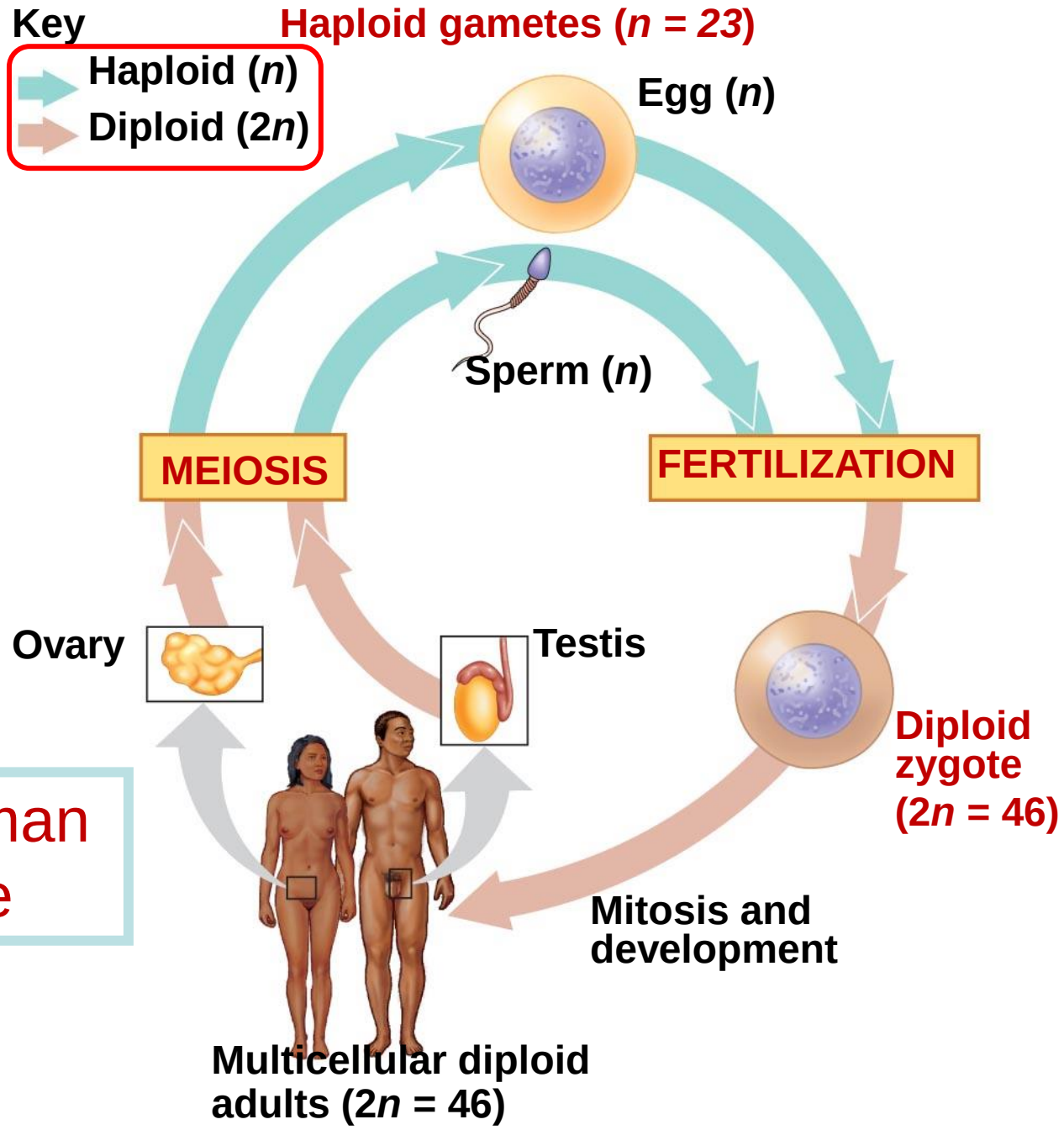
- A **gamete** (sperm or egg) contains a single set of chromosomes, and is **haploid (*n*)**
- For humans, the **haploid number is 23 (*n* = 23)**
- Each set of 23 chromosomes consists of **22 autosomes** and a **single sex chromosome**
- Other example: Drosophila melanogaster: 2n-8, 1n=4
- Dogs: 2n=78, 1n=39

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

Fig. 13-5



The human life cycle

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

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**

Fig. 13-7-1

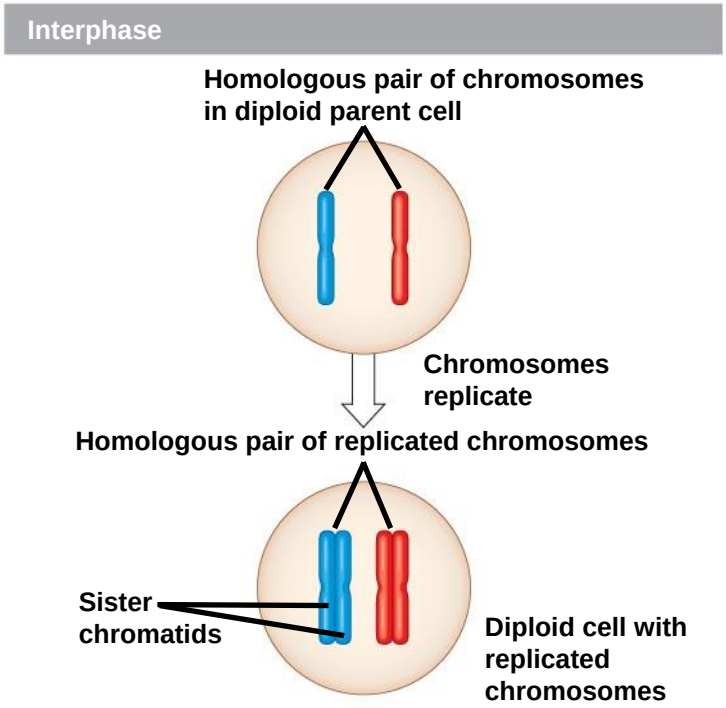


Fig. 13-7-2

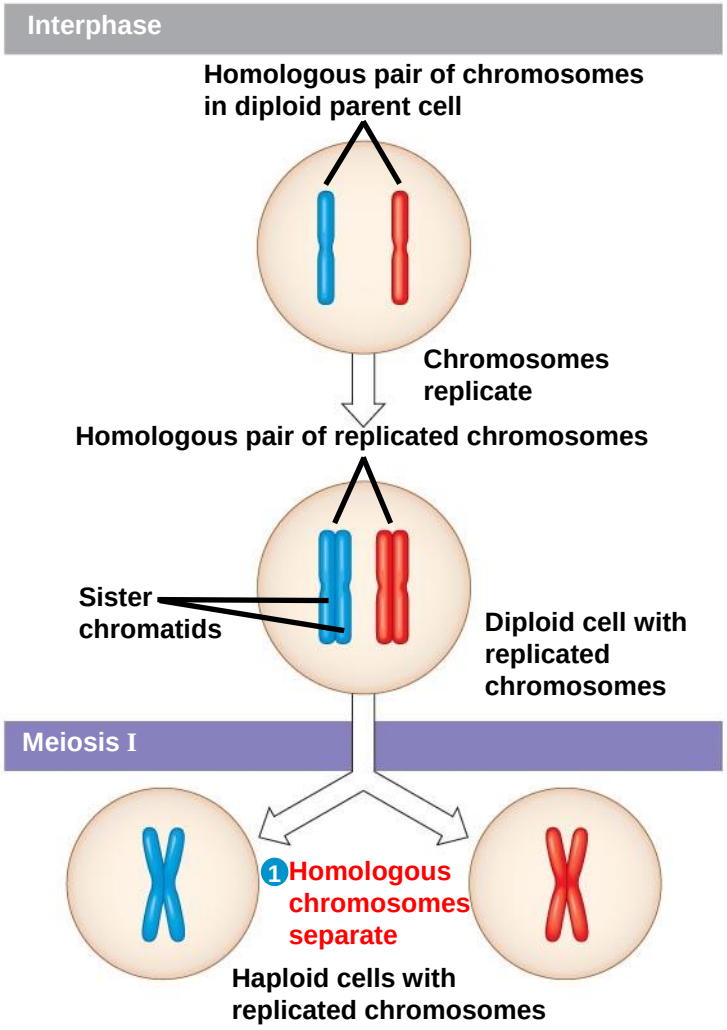


Fig. 13-7-3

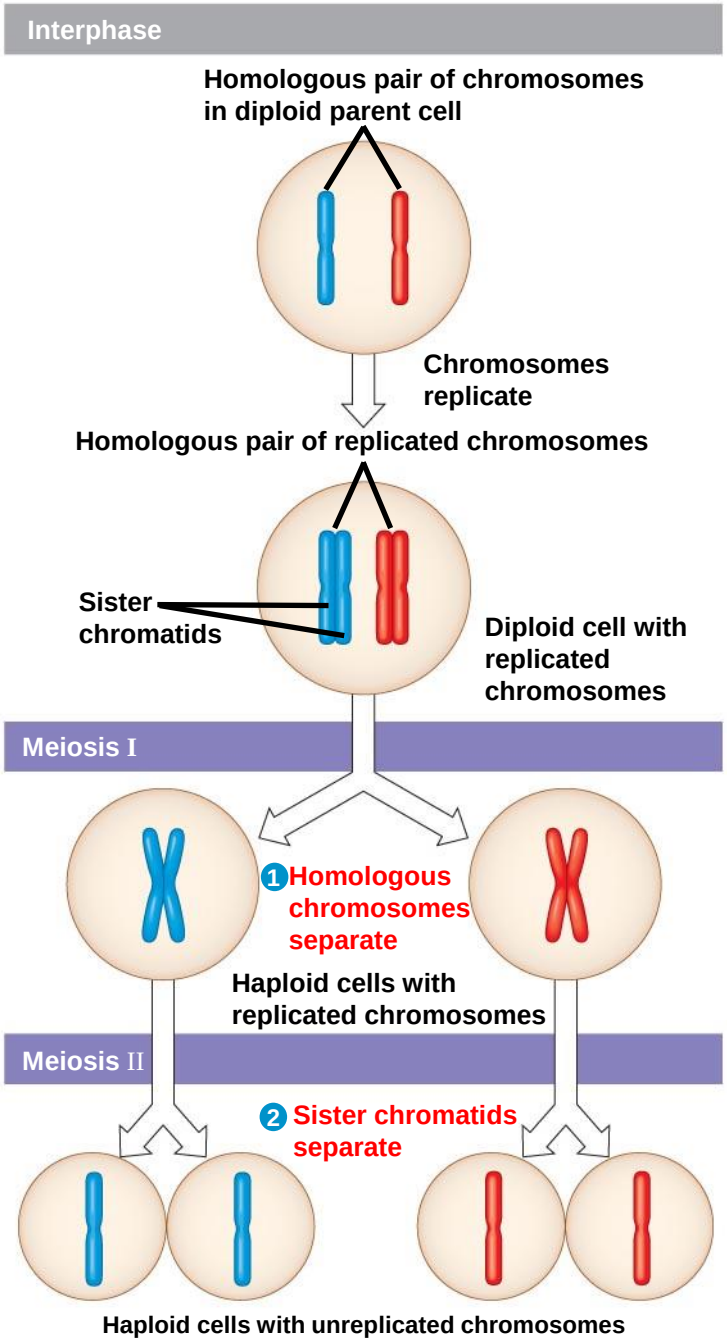
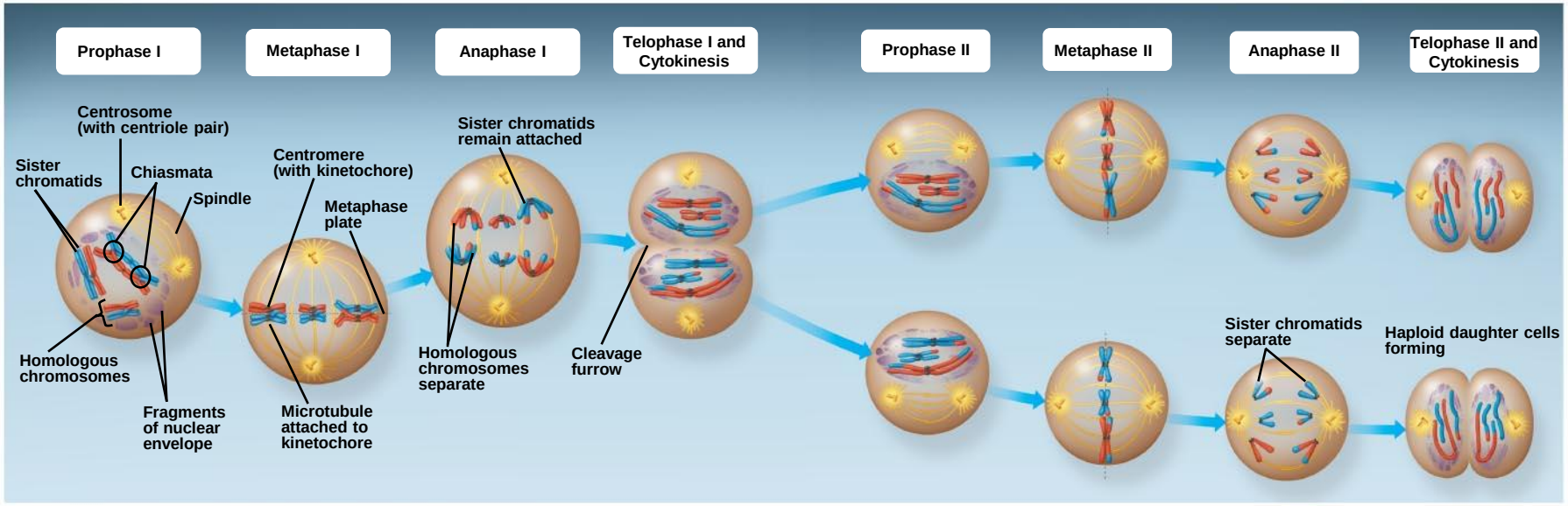
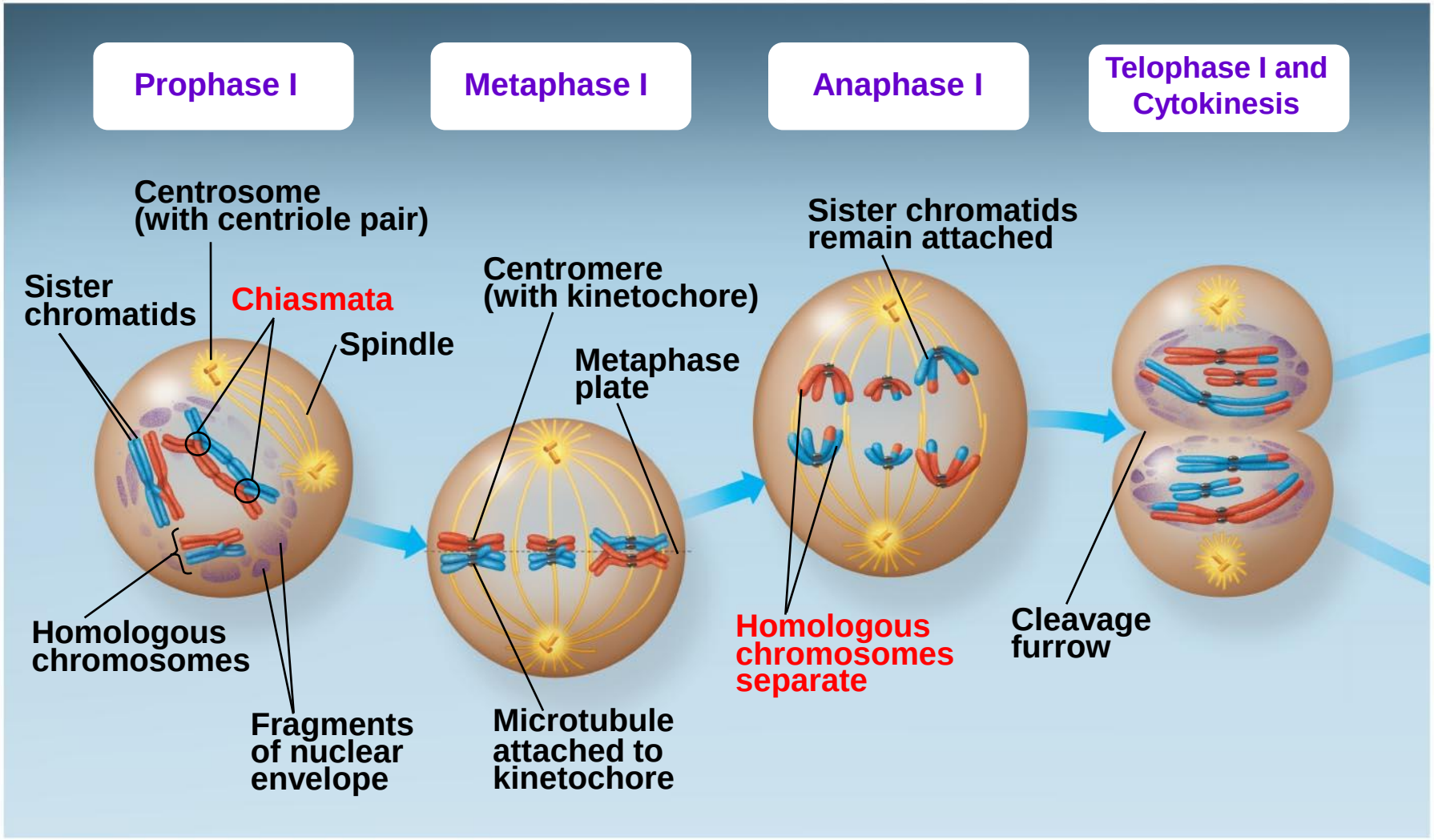


Fig. 13-8



- **Division in meiosis I occurs in four phases:**
  - **Prophase I**
  - **Metaphase I**
  - **Anaphase I**
  - **Telophase I and cytokinesis**

Fig. 13-8a



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**

- In **crossing over**, nonsister chromatids **exchange** DNA segments

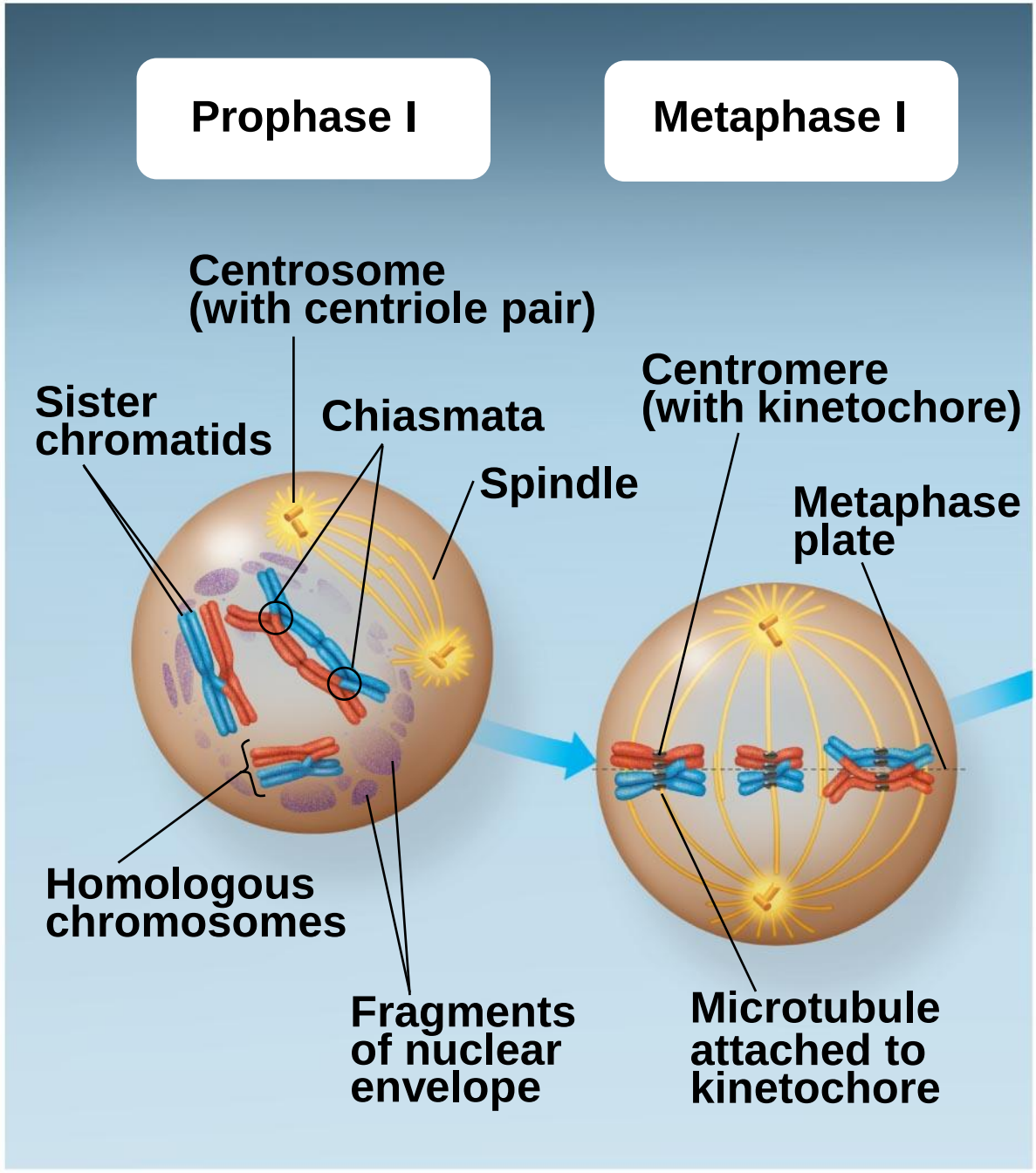
- Each pair of chromosomes forms a **tetrad**, a group of four chromatids

- Each tetrad usually has one or more **chiasmata**, *X-shaped regions where crossing over occurred*

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

Fig. 13-8b



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

Telophase I and Cytokinesis

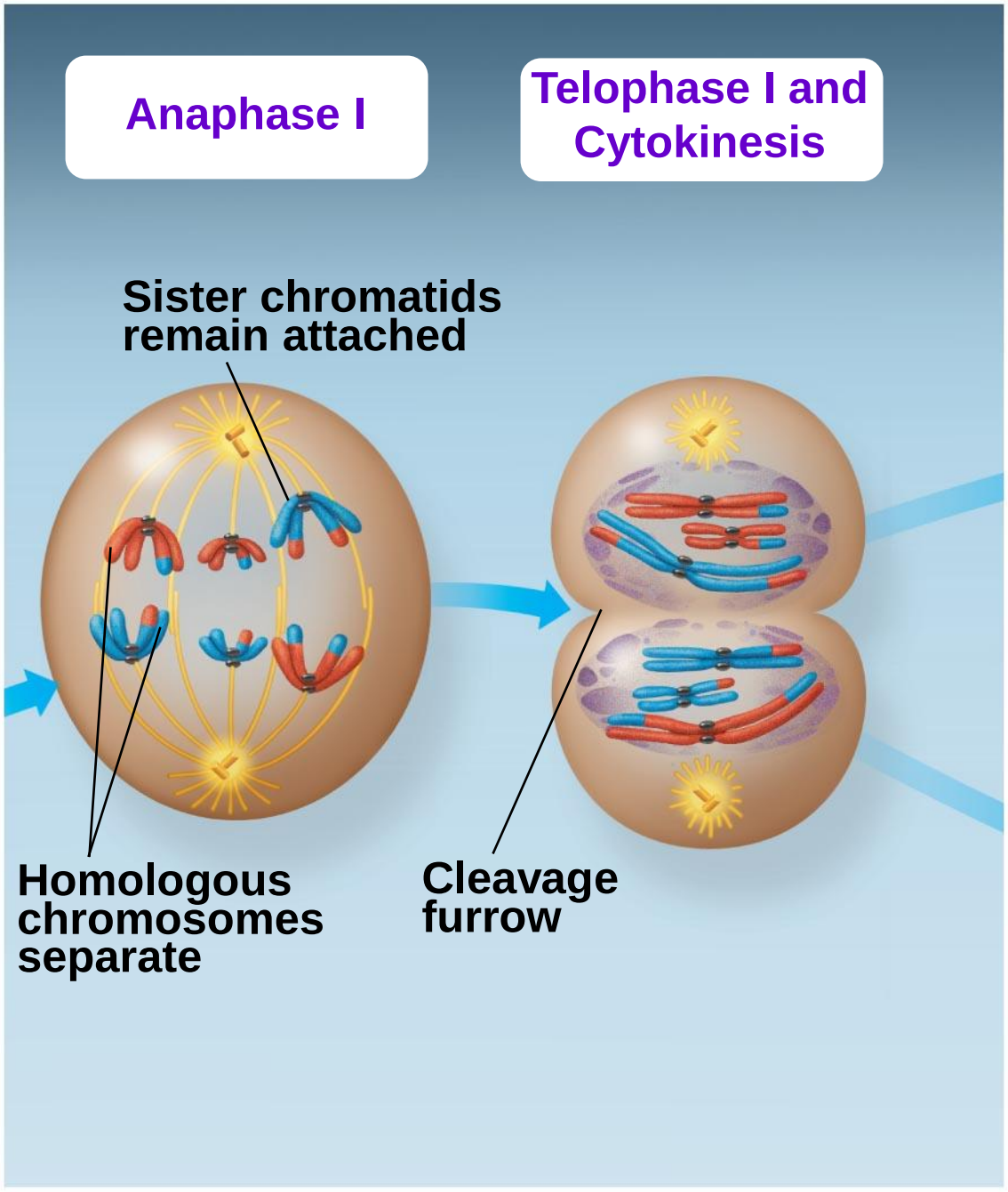
- In the beginning of telophase I, each half of the cell has a haploid set of chromosomes; **each chromosome still consists of two sister chromatids**

- **Cytokinesis** usually occurs simultaneously, forming **two haploid daughter cells**

- **In animal cells, a cleavage furrow forms; in plant cells, a cell plate forms**

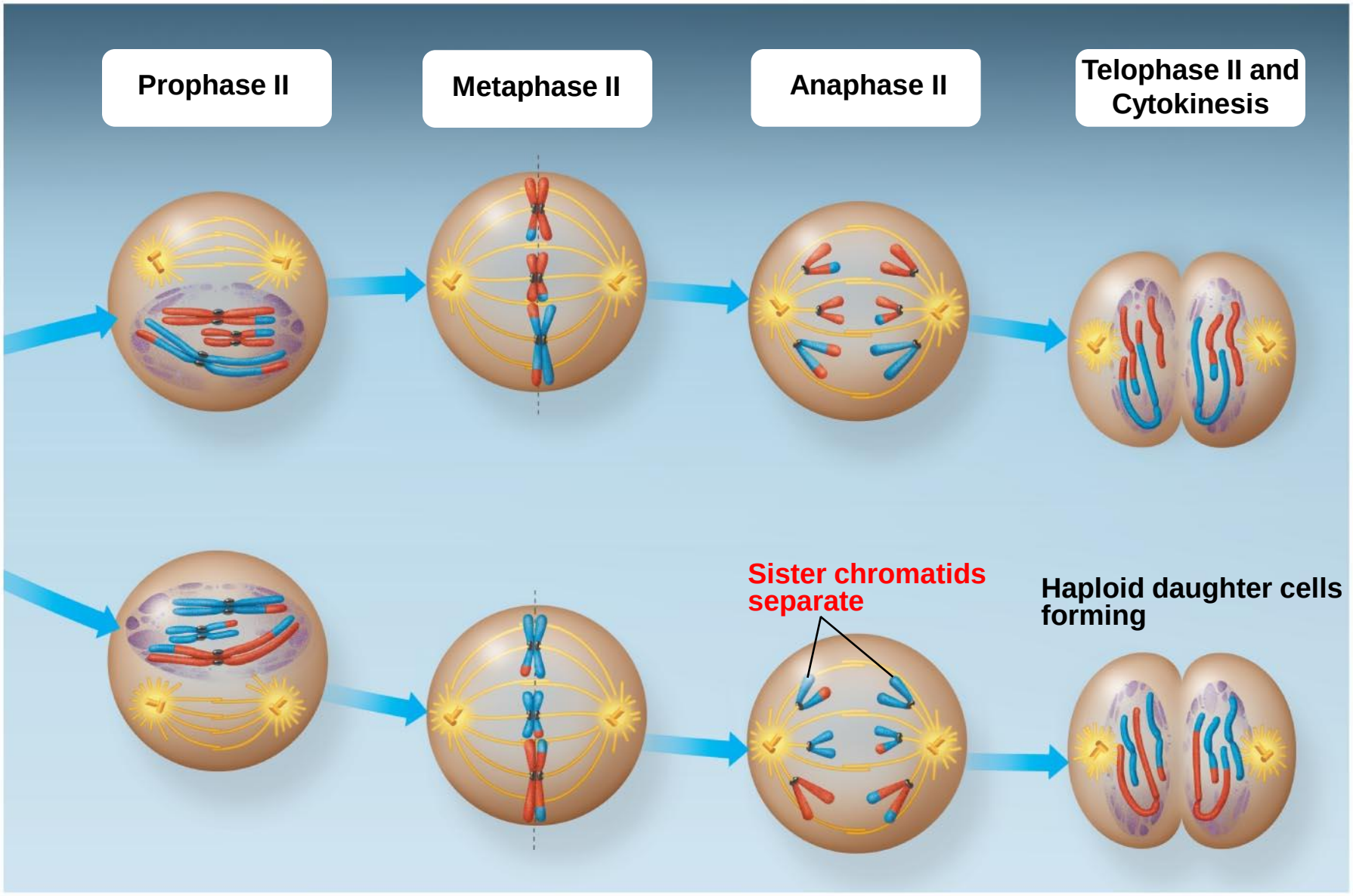
- ***No chromosome replication occurs between the end of meiosis I and the beginning of meiosis II***

Fig. 13-8c



- **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**

Fig. 13-8d



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

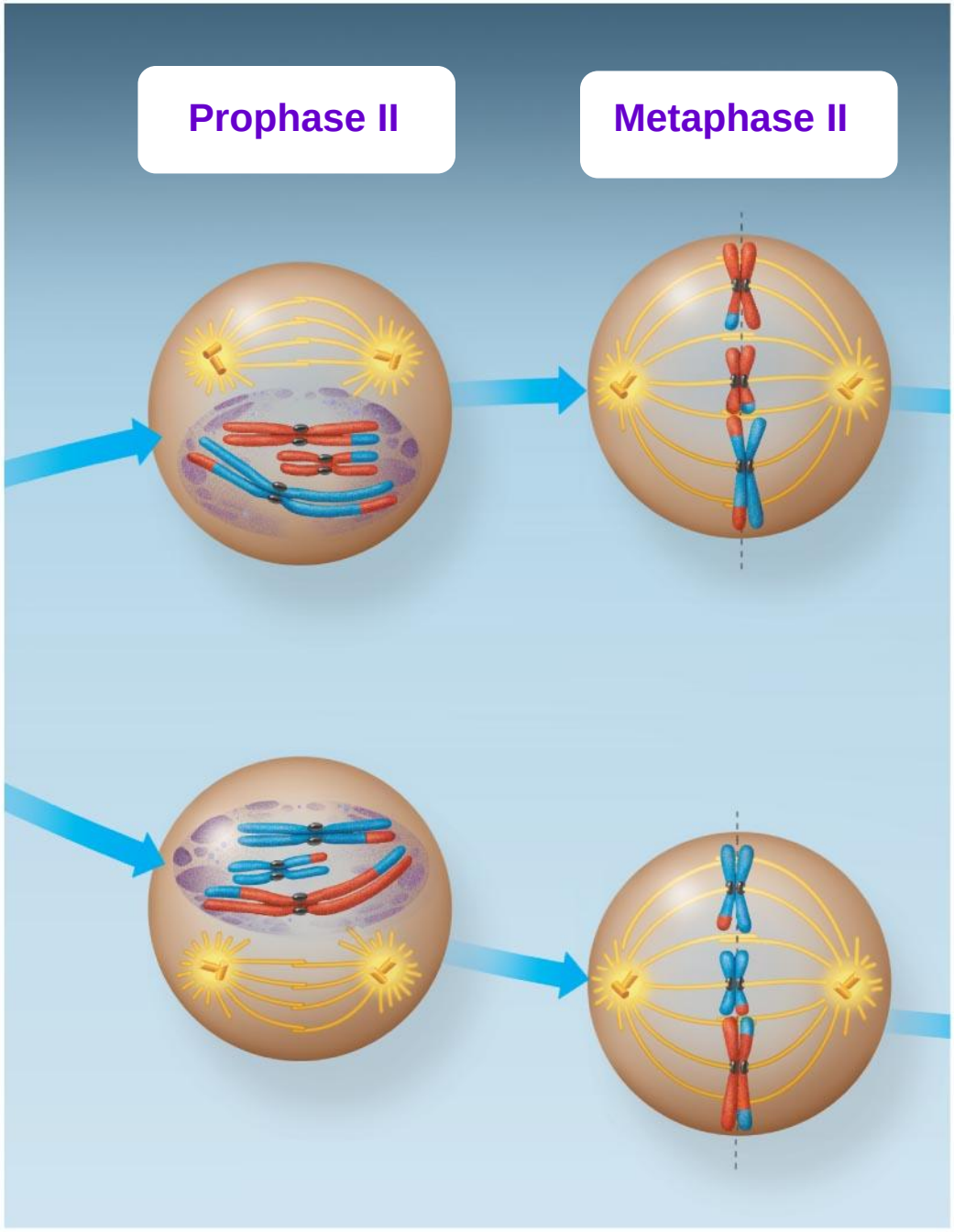
Metaphase II

- 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

Fig. 13-8e



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

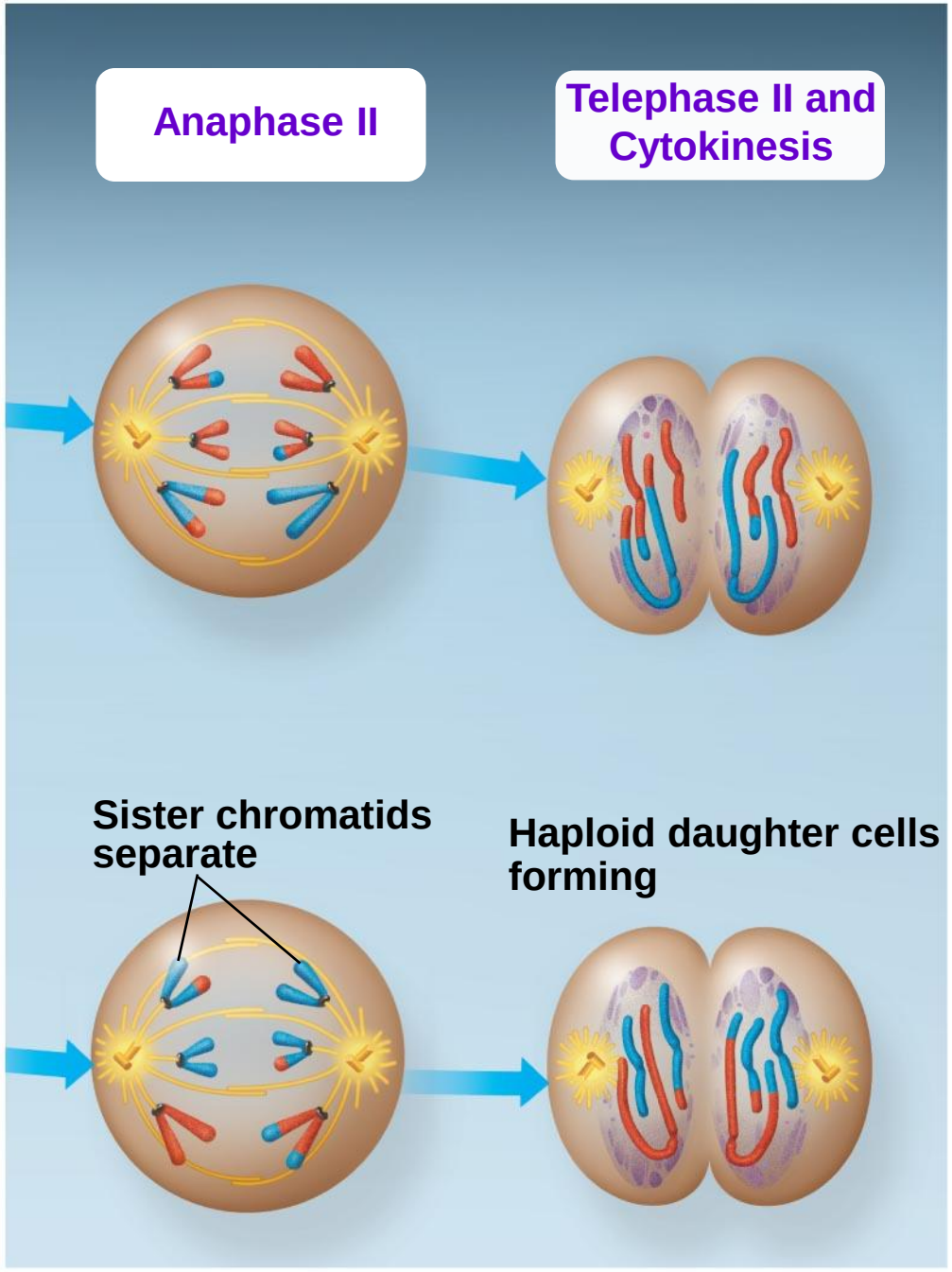
- **In telophase II, the chromosomes arrive at opposite poles**
- **Nuclei form, and the chromosomes begin decondensing**

- Cytokinesis **separates** the cytoplasm

- At the end of meiosis, there are four daughter cells, each with a **haploid set** of chromosomes

- **Each daughter cell is genetically distinct from the others and from the parent cell**

Fig. 13-8f

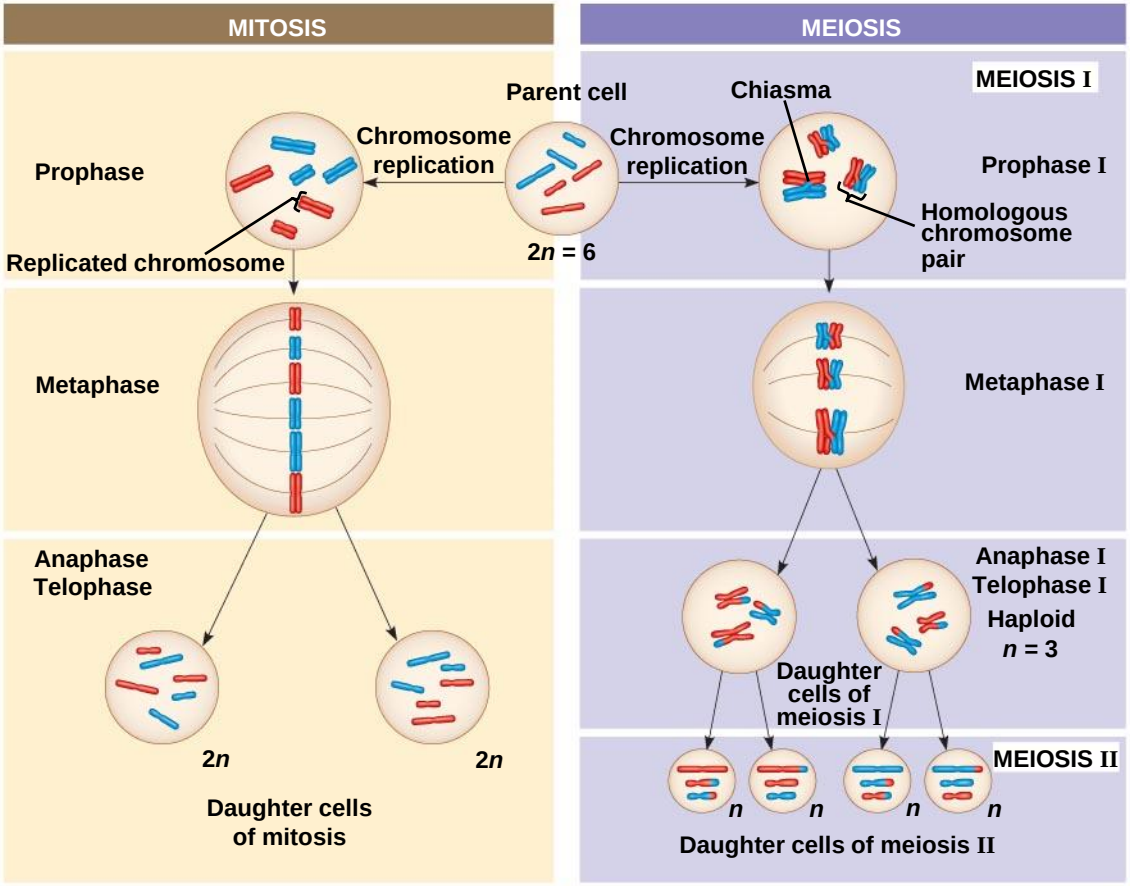


A Comparison of Mitosis and Meiosis

- 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

Fig. 13-9



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, anahase, 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 amoung the gametes

Fig. 13-9a

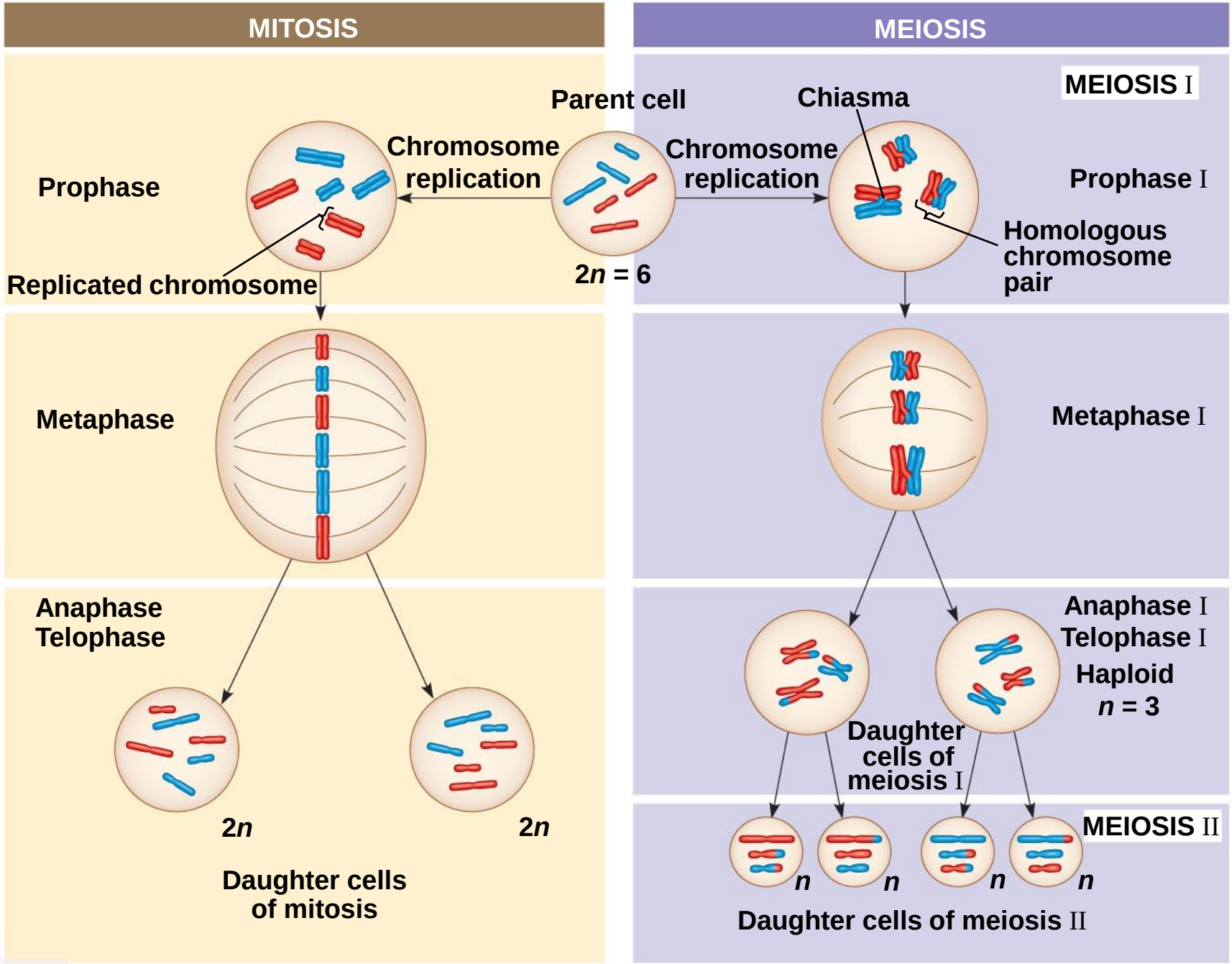


Fig. 13-9b

SUMMARY

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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

*** 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**