Meiosis, the basis of sexual reproduction

- In sexual reproduction (= Meiosis), offspring does not exactly look like their parents because they inherit a unique combination of genes from their two parents, and this combined set of genes programs a unique combination of traits.
- As a result, sexual reproduction can produce tremendous variety among offspring.
- Sexual reproduction depends on the cellular processes of meiosis and fertilization.

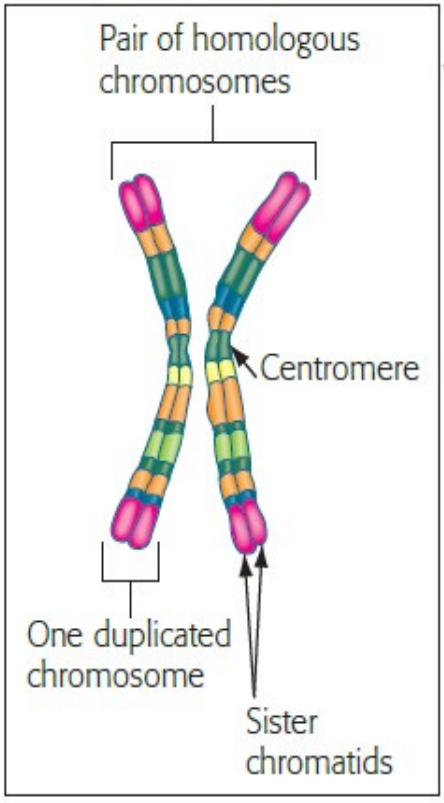
Homologous chromosomes

- Cells in same species & sex has the same number & types of chromosomes.
- Somatic cell or body cell (= non-sexual cell) has 46 chromosomes in human.

Karyotype

Is a technique which can:

- break open a human cell in metaphase of mitosis.
- stain the chromosomes with dyes.
- take a picture with the aid of a microscope.
- arrange the chromosomes in matching pairs by size.



Each chromosome is duplicated, with two sister chromatids joined along their length.

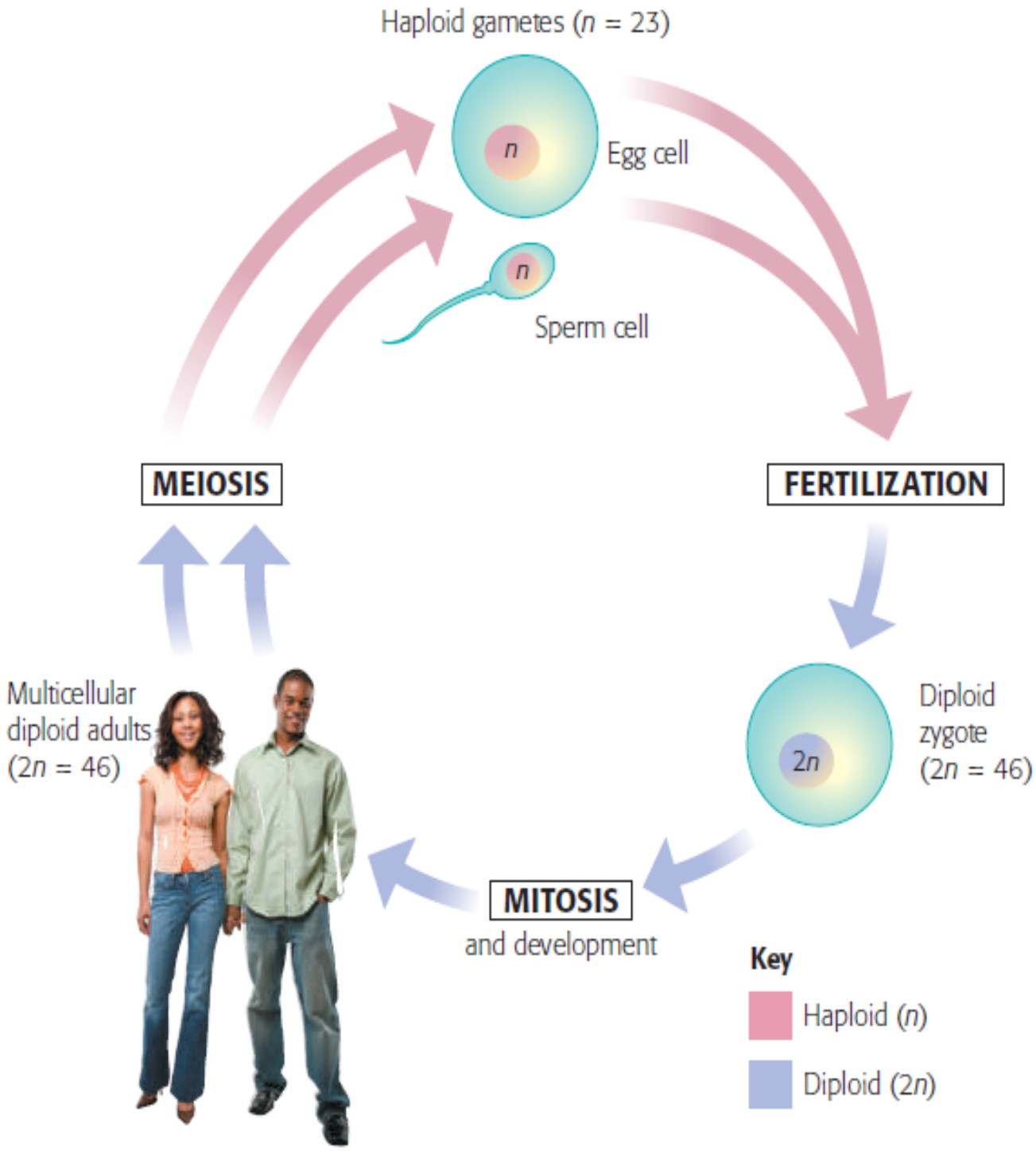
- **Homologous chromosomes: are two (twin) chromosomes that resembles it in (1) length, (2) centromere position and (3) staining pattern, which carry genes controlling the same inherited characteristics.**
- **The two homologous chromosomes may have different versions of the same gene.**

Briefly:

- **A pair of homologous chromosomes has two nearly identical chromosomes, each of which consists of two identical sister chromatids after chromosome duplication.**

Homologous chromosomes

- **In human: 44 autosome chromosomes + 2 sex chromosomes.**
- **In human male: Only 44 chromosomes are homologous chromosomes + one pair (= sex chromosomes) consist of X & Y chromosomes.**
- **In human female: All 46 chromosomes are homologous chromosomes. Sex chromosomes consist of two X chromosomes.**



Life cycle

Gametes and the life cycle of a sexual organism

- **Life cycle of a multicellular organism is the sequence of stages leading from the adults of one generation to the adults of the next generation.**
- **Have two sets of chromosomes, one inherited from each parent.**

Cell Division

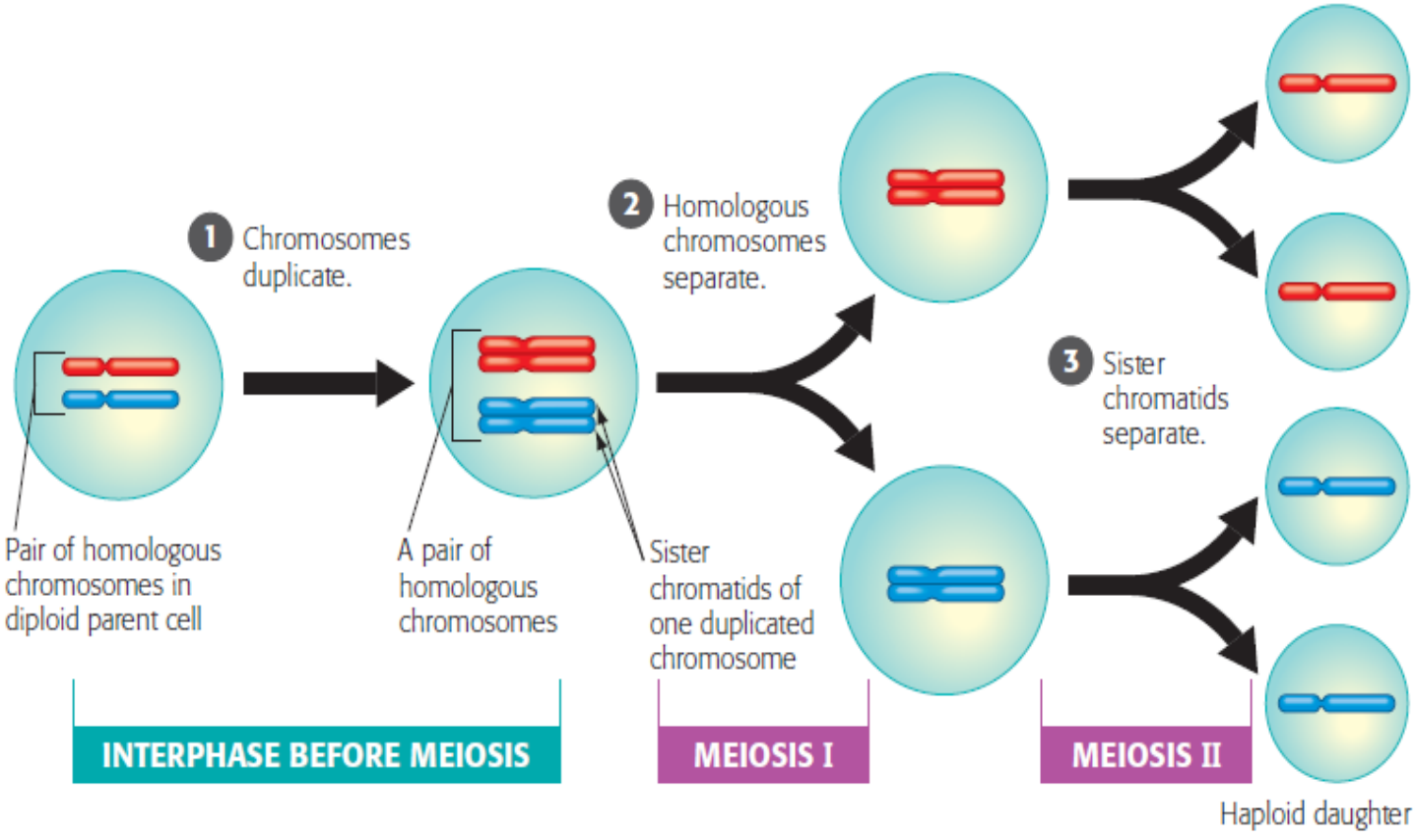
- **All human (also most animal & plants) body cells are diploid (2*n*) organisms because they contain pairs of homologous chromosomes.**
- **In human sexual cells (= egg & sperm gametes) are haploid (1*n*) made by meiosis in ovary and testis.**
- **Each gamete has a single set (1*n*) of chromosomes: 22 autosome chromosomes + two sex chromosomes (either X or Y) = 23 chromosomes.**

Life cycle

1 haploid sperm + 1 haploid egg **fertilisation** →

diploid zygote.

How meiosis halves chromosome number?



- **By tracking one pair of homologous chromosomes:**

① Each of the chromosomes is duplicated during interphase (before mitosis).

② the first division, meiosis I, segregates the two chromosomes of the homologous pair, packaging them in separate (haploid) daughter cells. But each chromosome is still doubled.

③ Meiosis II separates the sister chromatids. Each of the four daughter cells is haploid and contains only a single chromosome from the pair of homologous chromosomes.

Process of Meiosis

- **Meiosis, the process of cell division that produces haploid gametes in diploid organisms.**
- **Two differences between mitosis & meiosis:**

First, in meiosis:

1. Number of chromosomes is cut in half.

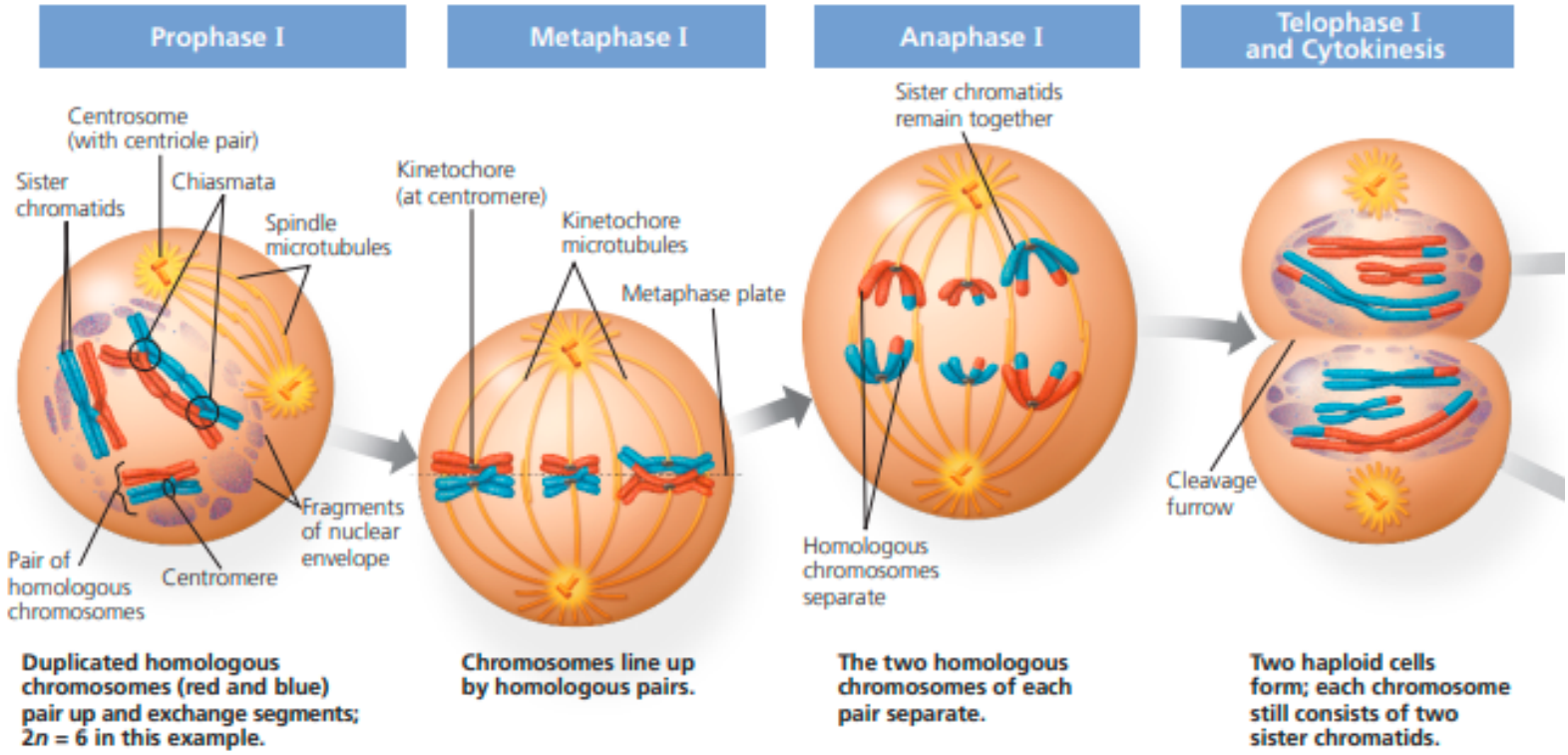
2. Cell that has duplicated its chromosomes undergoes two consecutive divisions, called meiosis I and meiosis II and produce 4 haploid gametes.

Second, in meiosis:

- **Exchange of genetic material - pieces of chromosomes — between homologous chromosomes.**
- **This exchange process, called crossing over, occurs during the first prophase of meiosis.**

▼ Figure 13.8 Exploring Meiosis in an Animal Cell

MEIOSIS I: Separates homologous chromosomes



Prophase I

- Centrosome movement, spindle formation, and nuclear envelope breakdown occur as in mitosis. Chromosomes condense progressively throughout prophase I.
- During early prophase I, before the stage shown above, each chromosome pairs with its homolog, aligned gene by gene, and **crossing over** occurs: The DNA molecules of nonsister chromatids are broken (by proteins) and are rejoined to each other.
- At the stage shown above, each homologous pair has one or more X-shaped regions called **chiasmata** (singular, *chiasma*), where crossovers have occurred.
- Later in prophase I, microtubules from one pole or the other attach to the kinetochores, one at the centromere of each homolog. (The two kinetochores on the sister chromatids of a homolog are linked together by proteins and act as a single kinetochore.) Microtubules move the homologous pairs toward the metaphase plate (see the metaphase I diagram).

Metaphase I

- Pairs of homologous chromosomes are now arranged at the metaphase plate, with one chromosome of each pair facing each pole.
- Each pair has lined up independently of other pairs. (This arrangement is called *independent assortment*, to be discussed later.)
- Both chromatids of one homolog are attached to kinetochore microtubules from one pole; the chromatids of the other homolog are attached to microtubules from the opposite pole.

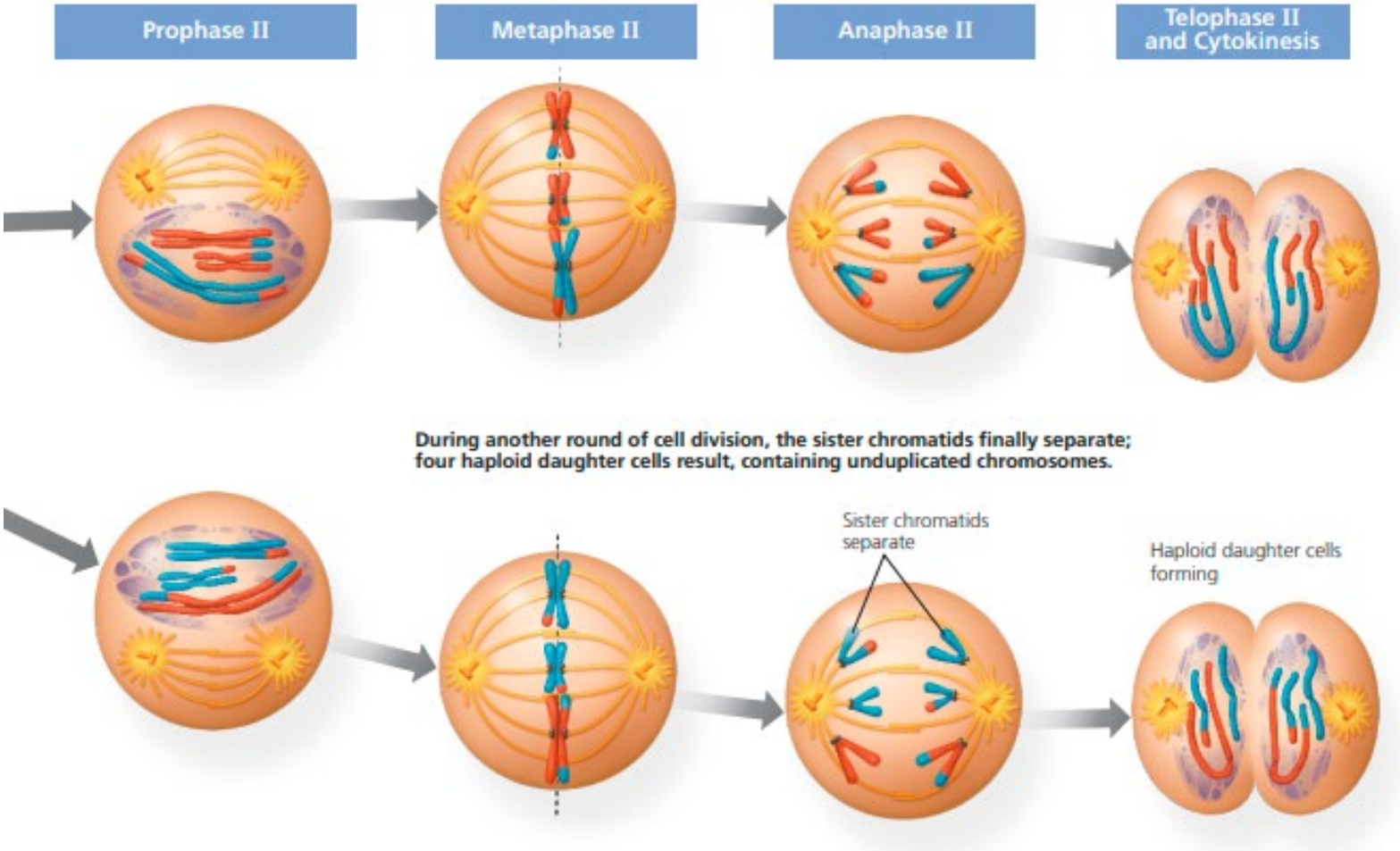
Anaphase I

- Breakdown of proteins that are responsible for sister chromatid cohesion along chromatid arms allows homologs to separate.
- The homologs move toward opposite poles, guided by the spindle apparatus.
- Sister chromatid cohesion persists at the centromere, causing the two chromatids of each chromosome to move as a unit toward the same pole.

Telophase I and Cytokinesis

- When telophase I begins, each half of the cell has a complete haploid set of duplicated chromosomes. Each chromosome is composed of two sister chromatids; one or both chromatids include regions of nonsister chromatid DNA.
- Cytokinesis (division of the cytoplasm) usually occurs simultaneously with telophase I, forming two haploid daughter cells.
- In animal cells like these, a cleavage furrow forms. (In plant cells, a cell plate forms.)
- In some species, chromosomes decondense and nuclear envelopes form.
- No chromosome duplication occurs between meiosis I and meiosis II.

MEIOSIS II: Separates sister chromatids



Prophase II

- A spindle apparatus forms.
- In late prophase II (not shown here), chromosomes, each still composed of two chromatids associated at the centromere, are moved by microtubules toward the metaphase II plate.

Metaphase II

- The chromosomes are positioned at the metaphase plate as in mitosis.
- Because of crossing over in meiosis I, the two sister chromatids of each chromosome are not genetically identical.
- The kinetochores of sister chromatids are attached to microtubules extending from opposite poles.

Anaphase II

- Breakdown of proteins holding the sister chromatids together at the centromere allows the chromatids to separate and move toward opposite poles. Each chromatid has now become an individual chromosome.

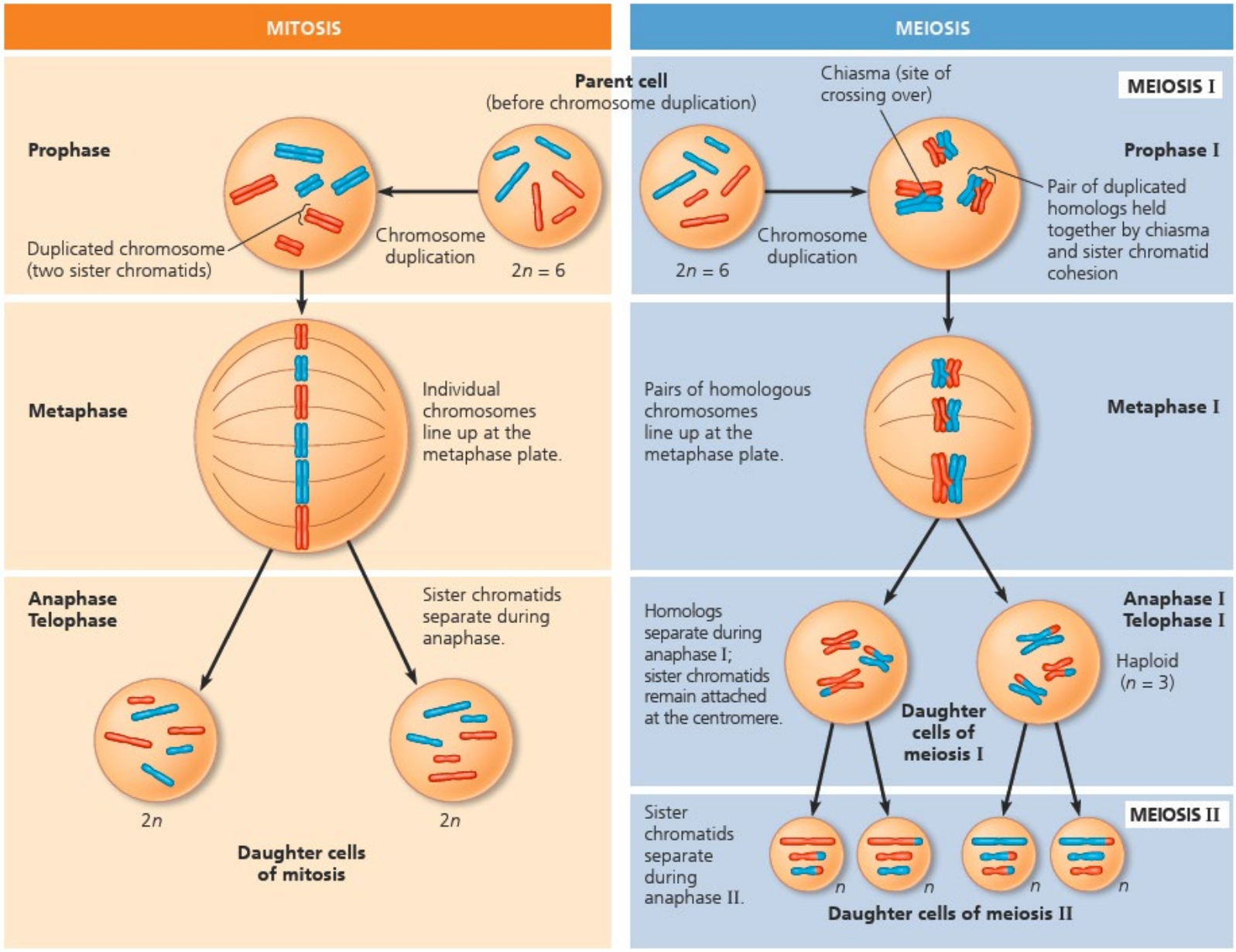
Telophase II and Cytokinesis

- Nuclei form, the chromosomes begin decondensing, and cytokinesis occurs.
- The meiotic division of one parent cell produces four daughter cells, each with a haploid set of (unduplicated) chromosomes.
- The four daughter cells are genetically distinct from one another and from the parent cell.

Review: Comparing Mitosis and Meiosis

- **In mitosis and meiosis, the chromosome duplicates only once during interphase.**
- **Mitosis includes one nuclear and cytoplasmic division (duplication, then division in half) producing two diploid cells.**
- **Meiosis includes two nuclear and cytoplasmic division. (duplication, division in half, then division in half again) producing four haploid cells.**

comparison of mitosis and meiosis.



SUMMARY		
Property	**Mitosis** (occurs in both diploid and haploid cells)	**Meiosis** (can only occur in diploid cells)
DNA replication	Occurs during interphase, before mitosis begins	Occurs during interphase before meiosis I but not before meiosis II
Number of divisions	One, including prophase, prometaphase, 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 genetically identical to the parent cell, with the same number of chromosomes	Four, each haploid (*n*); genetically different from the parent cell and from each other
Role in animals, fungi, and plants	Enables multicellular animal, fungus, or plant (gametophyte or sporophyte) to arise from a single cell; produces cells for growth, repair, and, in some species, asexual reproduction; produces gametes in the plant gametophyte	Produces gametes (in animals) or spores (in fungi and in plant sporophytes); reduces number of chromosome sets by half and introduces genetic variability among the gametes or spores

Definition

Nucleosome: consists of DNA wound around several histone proteins.

Cell cycle is the ordered sequence of events that extends from the time a cell is first formed from a dividing parent cell until its own division into two cells.

Cytokinesis is the division of the cytoplasm into two cells.

Karyotype: A technique that breaks open a human cell in the metaphase of mitosis, stains the chromosomes with dyes, takes a picture with the aid of a microscope, and arranges the chromosomes in matching pairs by size.

Homologous chromosomes: The two chromosomes of such a matching pair, carry genes controlling the same inherited characteristics.

Meiosis is the process of cell division that produces haploid gametes in diploid organisms, with two important differences.

Crossing over is an exchange of genetic material between homologous chromosomes during meiosis.