Essentials of Biology

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Chapter 9
Lecture Outline

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9.1 The Basics of Meiosis

- Animals and plants practice sexual reproduction, with parents passing chromosomes to their offspring.

- Because each child receives unique combinations of chromosomes from the parents, each child differs from the parents.

- Meiosis is the process of cell division that contributes to sexual reproduction and the resulting variation in the offspring.

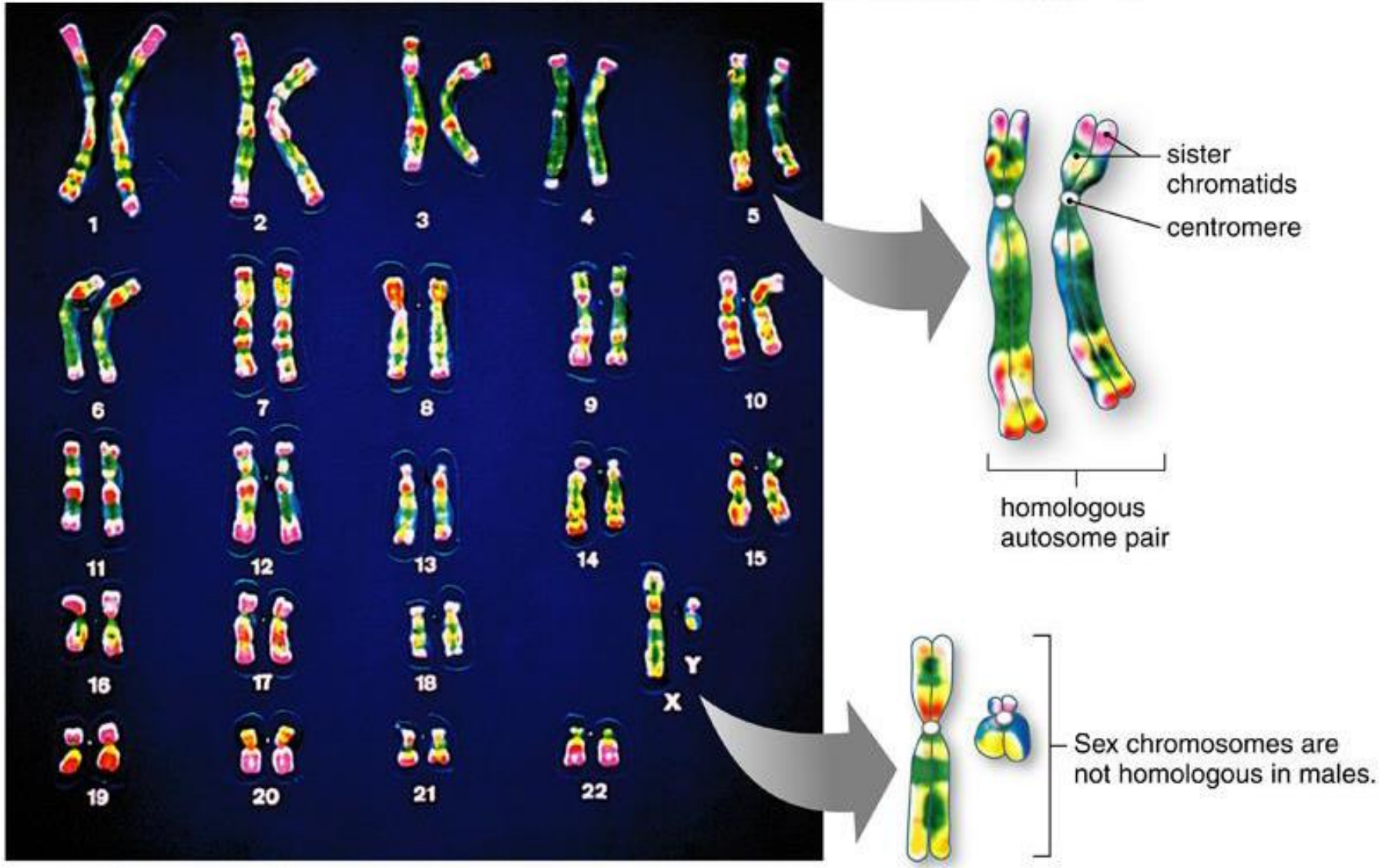
9.1 The Basics of Meiosis (cont.)

- The chromosomes of each parent exist in pairs called homologues, or homologous chromosomes.

- The pairs are identical in size, shape, construction, and the genes they contain.

- However the homologues within an organism may contain different versions, or alleles, of those genes.

9.1 The Basics of Meiosis (cont.)



The 46 chromosomes of a male

9.1 The Basics of Meiosis (cont.)

- In humans, there are 23 pairs of homologous chromosomes.
- There are 22 pairs of autosomes.
- The sex chromosomes comprise the last pair.
  - Males have an X and a smaller Y chromosome.
  - Females have two equal X chromosomes.

9.1 The Basics of Meiosis (cont.)

- With 23 pairs of chromosomes, humans have a total of 46 chromosomes.
- This total number of chromosomes is called the diploid number.
- The number of chromosome pairs an organism has is its haploid number.

The Human Life Cycle

- The life cycle of a sexually reproducing organism includes all the reproductive events from one generation to the next.

- The human life cycle involves two types of cell division.
  - Mitosis
  - Meiosis

The Human Life Cycle (cont.)

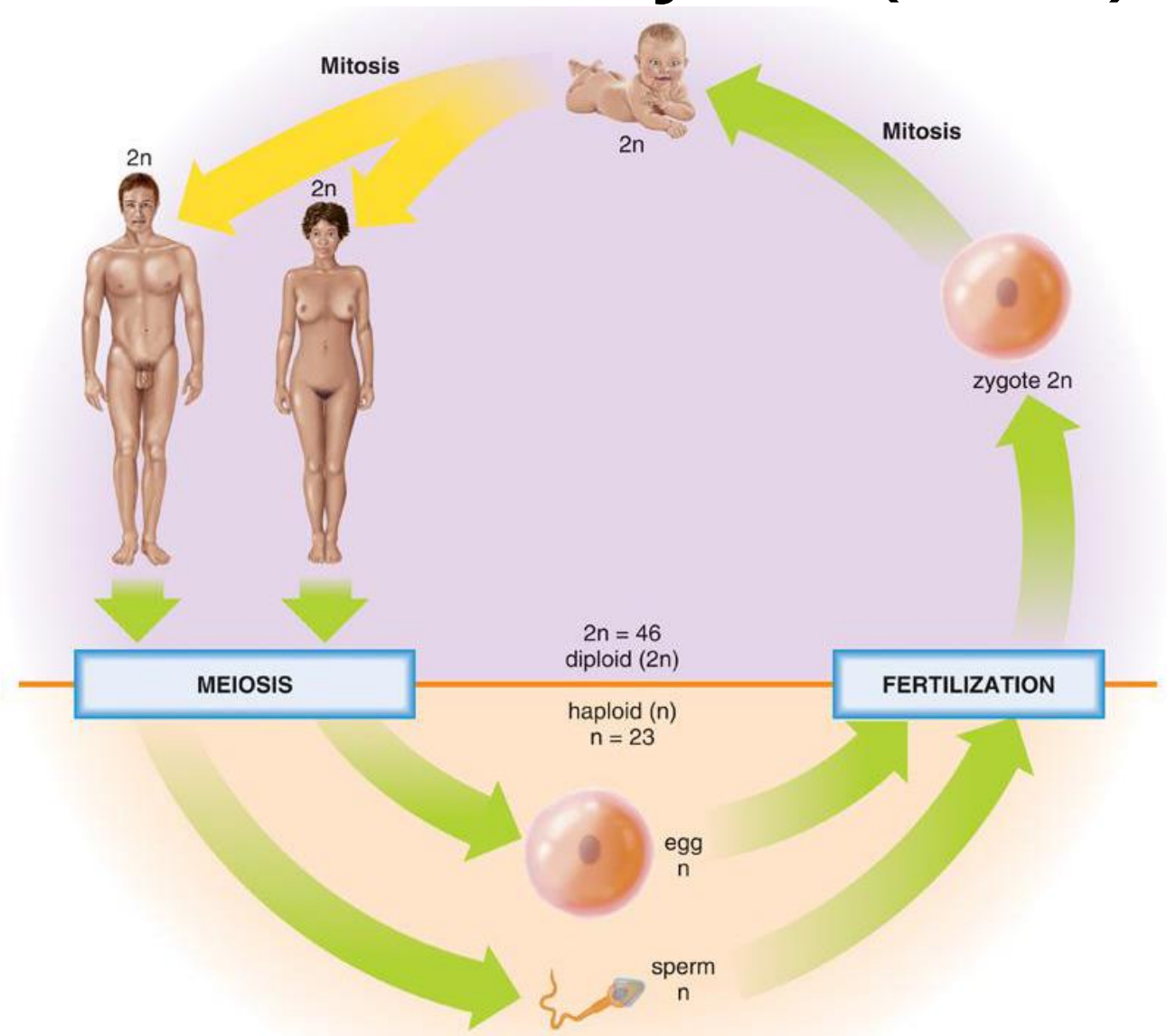
- Mitosis is involved in the growth of a child and repair of tissues.

- Meiosis is a special form of cell division associated with sexual reproduction.
  - Meiosis produces special reproductive cells called gametes (eggs and sperm in humans).
  - Gametes have only one chromosome of each chromosome pair (e.g., 23 instead of 46).

The Human Life Cycle (cont.)

- In males, meiosis is part of sperm production (spermatogenesis).
- In females, meiosis is part of egg production (oogenesis).
- During fertilization, an egg and sperm unite to form a zygote, restoring the chromosomes to 46 total.

The Human Life Cycle (cont.)



Overview of Meiosis

- Meiosis involves two cellular divisions.
  - Meiosis I
  - Meiosis II

- These two cellular divisions produce four daughter cells, each with one chromosome of each pair.

Overview of Meiosis (cont.)

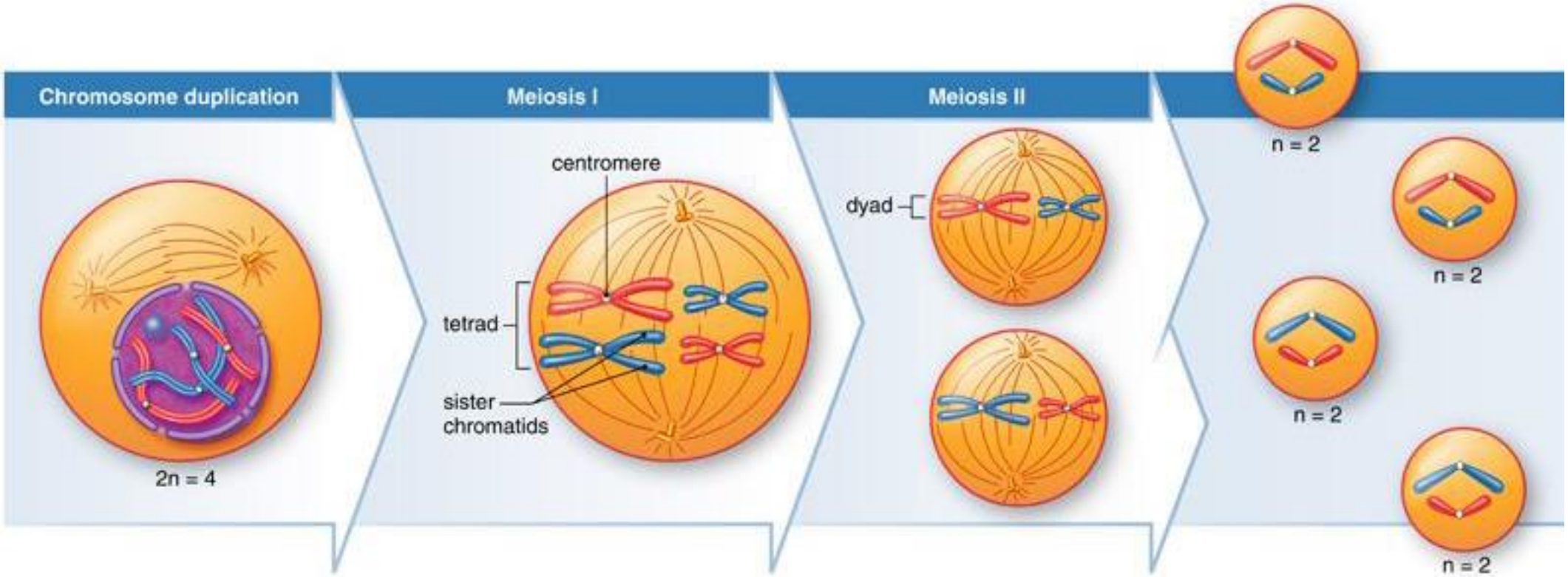
- During meiosis I, the homologous chromosomes pair up in synapsis to form a tetrad (sister chromatids of two homologous chromosomes).
- Later in meiosis I, the homologous pairs separate to provide one member of each homologous pair to each daughter cell.
- After meiosis I, the daughter cells have half the number of chromosomes, but each chromosome consists of two sister chromatids (dyads).

Overview of Meiosis (cont.)

- During meiosis II, the sister chromatids (dyads) are separated.

- The two divisions of meiosis insure that the gametes produced by an individual have unique combinations of homologous chromosomes.

Overview of Meiosis (cont.)

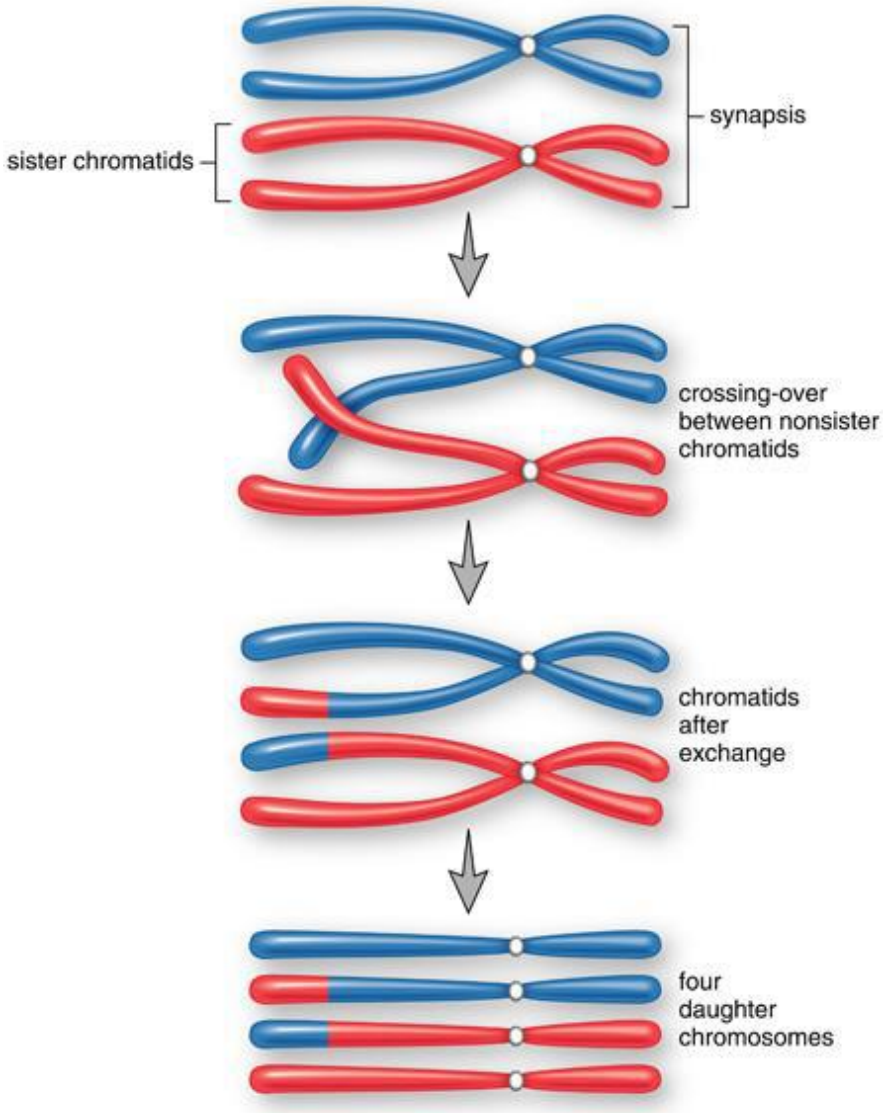


Crossing-Over

- While a tetrad is formed during the synapsis of meiosis I, the homologues may exchange genetic material by crossing-over.

- Crossing-over recombines the alleles of the homologous chromosomes, creating new combinations and increasing the genetic variability of the gametes.

Crossing-Over (cont.)



The Importance of Meiosis

- One reason meiosis is important is that it maintains the same number of chromosomes in each new generation.

- Another reason meiosis is important is that it contributes new combinations of alleles to each new generation.

- Crossing-over can produce different alleles on the sister chromatids of homologous chromosomes.

The Importance of Meiosis

- Meiosis produces gametes with many different combinations of homologous chromosomes.

- Fertilization to form a zygote produces one of >70 trillion possible combinations of chromosomes.

9.2 The Phases of Meiosis

- The same four stages of mitosis occur during meiosis.
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase

- The four stages occur twice, once during meiosis I and again during meiosis II.

The First Division – Meiosis I

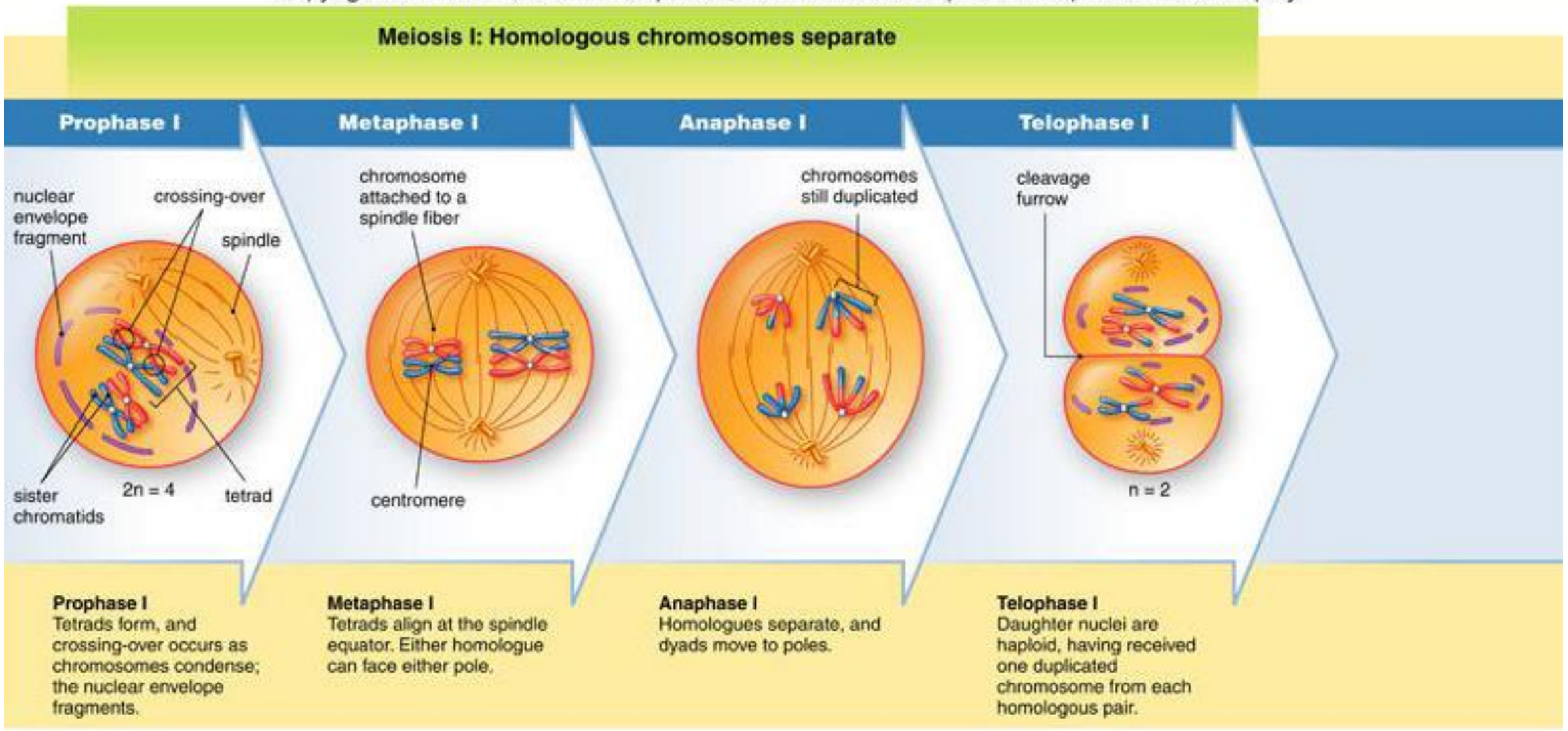
- Significant events occur during prophase I of meiosis.
  - The spindle appears between the separating centromeres.
  - The homologous chromosomes undergo synapsis as they condense.
  - Crossing-over between homologous chromosomes may occur.

- At metaphase I, the tetrads attached to the spindle are aligned at the spindle equator.

The First Division – Meiosis I (cont.)

- The homologous chromosomes are separated during anaphase I.
- Anaphase I is the point at which the diploid cell becomes haploid.
- During telophase I, the nuclear envelope reforms around the now haploid nuclei.

The First Division – Meiosis I (cont.)



The Second Division – Meiosis II

- The events that occur during meiosis II are essentially the same as those that occur during mitosis.

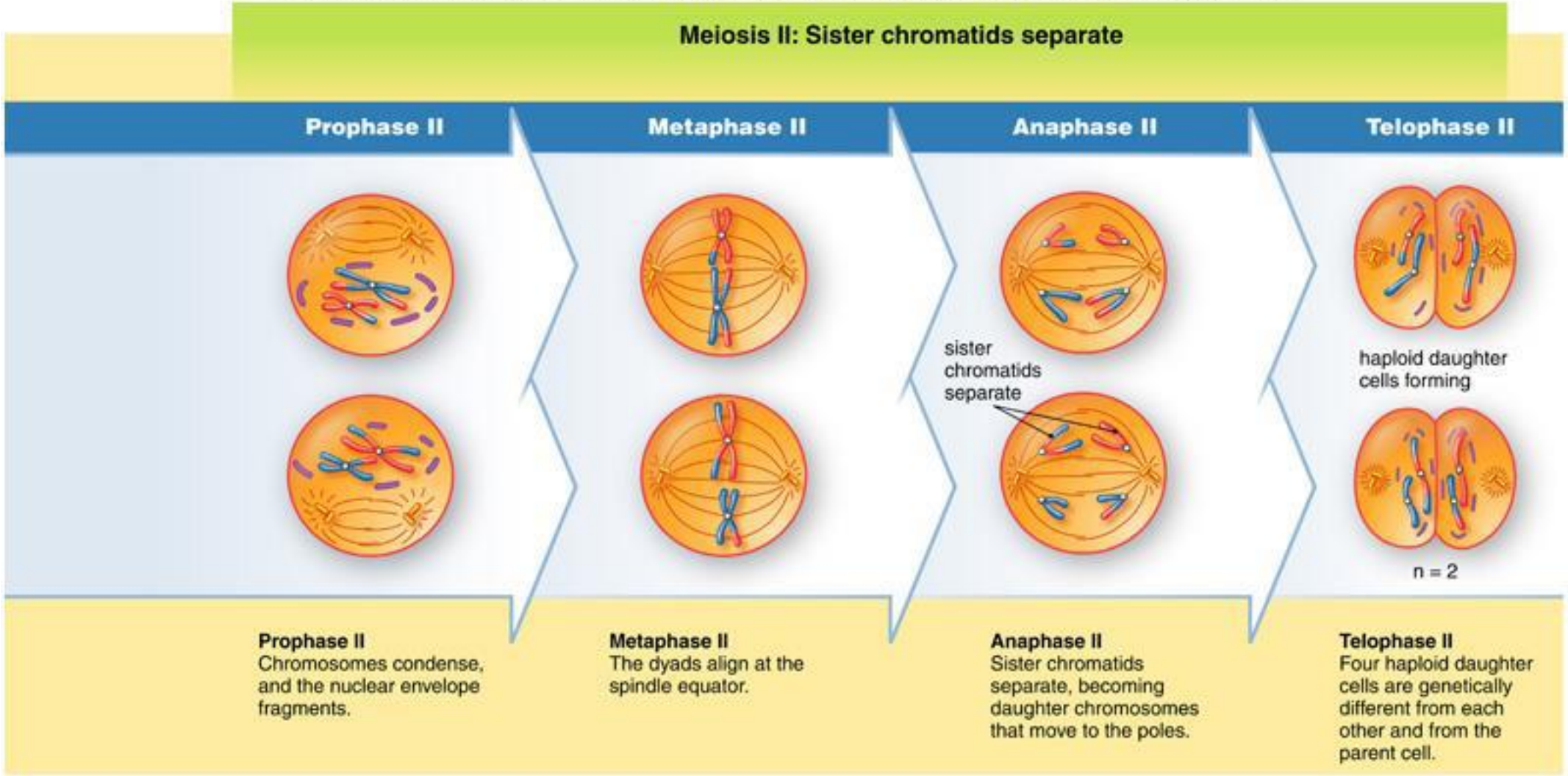
- As prophase II begins, a spindle appears and the nuclear envelope and nucleolus disappear.

- During metaphase II the dyads line up at the spindle equator.

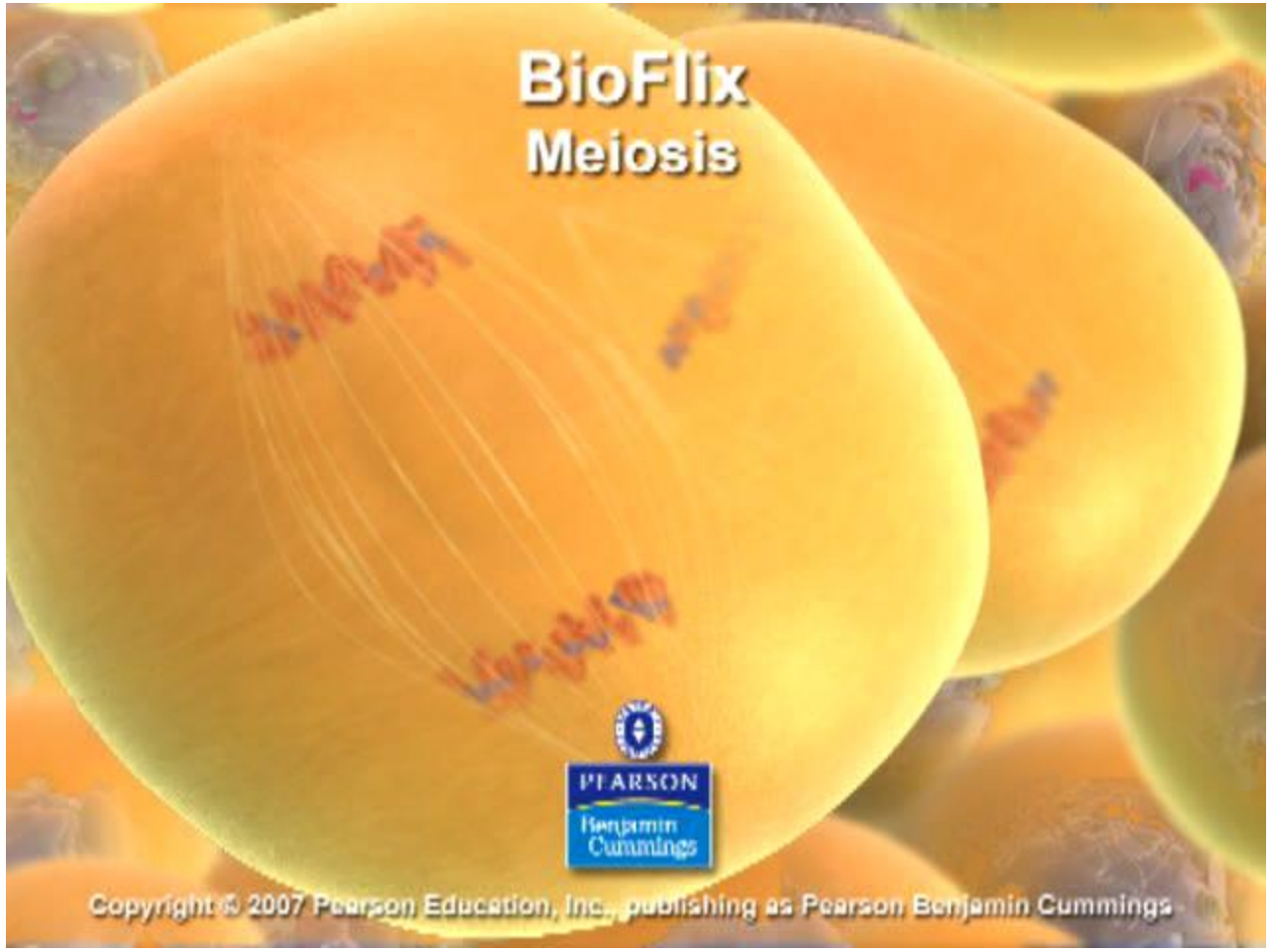
The Second Division – Meiosis II (cont.)

- The sister chromatids of the dyad separate during anaphase II and begin migrating towards the poles.
- The spindle disappears and the nuclear envelope reforms in telophase II.
- Cytokinesis occurs to complete the meiosis.
- In summary, a single diploid cell undergoes meiosis to produce four haploid gametes.

The Second Division – Meiosis II (cont.)



BioFlix: Meiosis



9.3 Meiosis Compared to Mitosis

- Meiosis requires two nuclear divisions while mitosis requires only one.
- Meiosis produces four daughter nuclei while mitosis produces only two.
- Both meiosis and mitosis are typically followed by cytokinesis.

9.3 Meiosis Compared to Mitosis (cont.)

- After meiosis, the daughter nuclei are haploid and contain half the chromosome number of the parent cell.

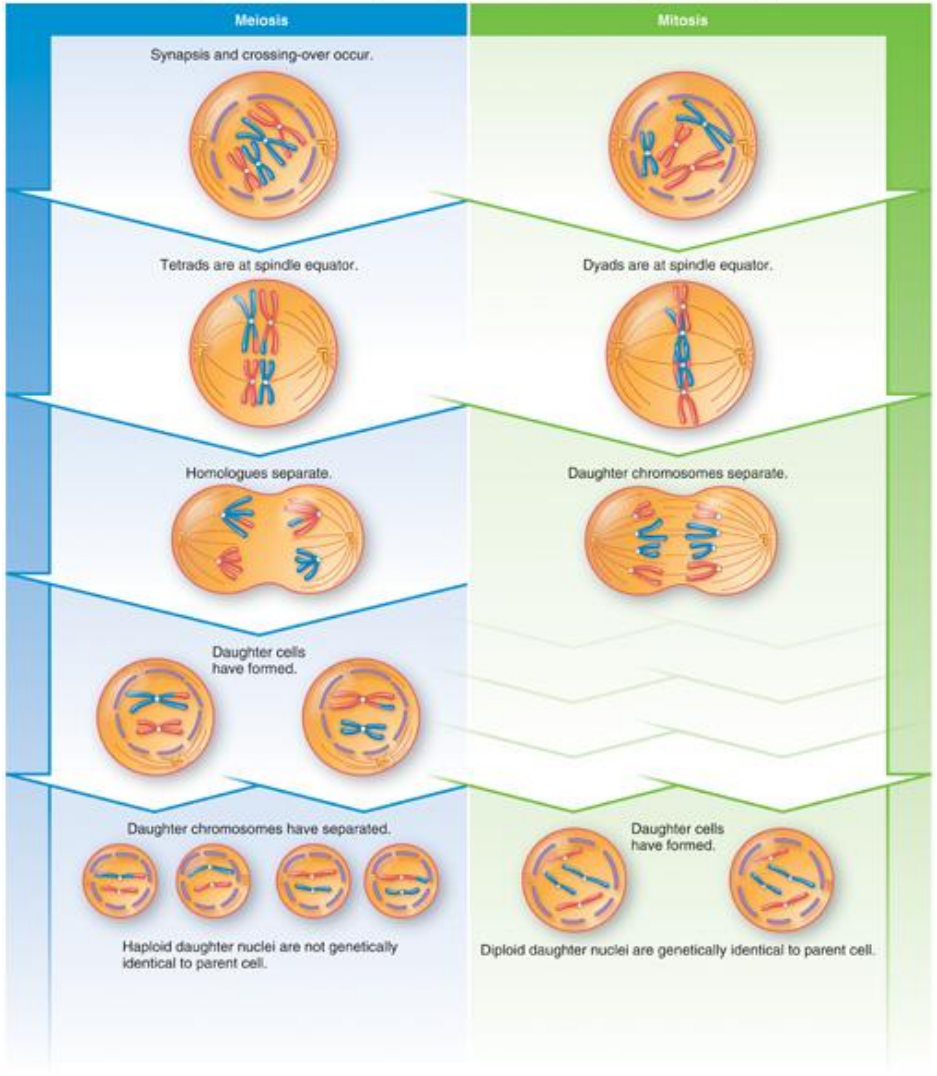
- Following mitosis, the daughter cells have the same chromosome number as the parent cell.

9.3 Meiosis Compared to Mitosis (cont.)

- The daughter cells of meiosis are genetically dissimilar from the parent cell.

- The daughter cells of mitosis are genetically identical to the parent cell.

9.3 Meiosis Compared to Mitosis (cont.)



Occurrence

- Meiosis occurs only at specific times during the life cycle of sexually reproducing organisms.
- Meiosis in humans occurs only in the testes and ovaries.
- Mitosis is common and occurs throughout the body.

Process

- There are several events that distinguish meiosis I from mitosis.

- Tetrads form during meiosis and crossing-over can occur during prophase I. This does not occur during mitosis.

Process

- The tetrads align at the spindle equator during metaphase I of meiosis. In mitosis, the dyads align during metaphase.

- During anaphase I, the homologous chromosomes separate while in anaphase of mitosis, the sister chromatids of the dyad separate.

Process (cont.)

Table 9.1 Meiosis I Compared to Mitosis

Meiosis I	Mitosis
Prophase I	***Prophase***
Pairing of homologous chromosomes; crossing-over	No pairing of chromosomes
Metaphase I	***Metaphase***
Tetrads at spindle equator	Dyads at spindle equator
Anaphase I	***Anaphase***
Homologues of each tetrad separate, and dyads move to poles	Sister chromatids separate, becoming daughter chromosomes that move to the poles
Telophase I	***Telophase***
Two haploid daughter cells not identical to parent cell	Two diploid daughter cells, identical to the parent cell

Process (cont.)

- The events of meiosis II are the same as mitosis.

Process (cont.)

Table 9.2 Meiosis II Compared to Mitosis

Meiosis II	Mitosis
Prophase II	***Prophase***
No pairing of chromosomes	No pairing of chromosomes
Metaphase II	***Metaphase***
Haploid number of dyads at spindle equator	Diploid number of dyads at spindle equator
Anaphase II	***Anaphase***
Sister chromatids separate, becoming daughter chromosomes that move to the poles	Sister chromatids separate, becoming daughter chromosomes that move to the poles
Telophase II	***Telophase***
Four haploid daughter cells, not genetically identical to each other or the parent cell	Two daughter cells, genetically identical to the parent cell

9.4 Abnormal Chromosome Inheritance

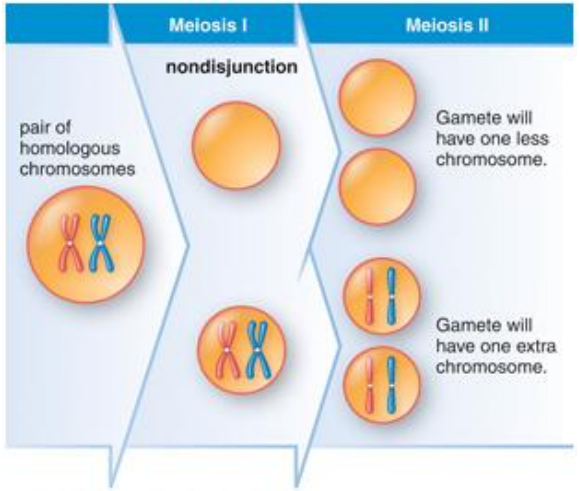
- Humans can occasionally be born with an abnormal number of chromosomes.
- This results because meiosis did not occur properly in one of the parents and a gamete has an abnormal number of chromosomes.
- This error in meiosis is called nondisjunction.

9.4 Abnormal Chromosome Inheritance (cont.)

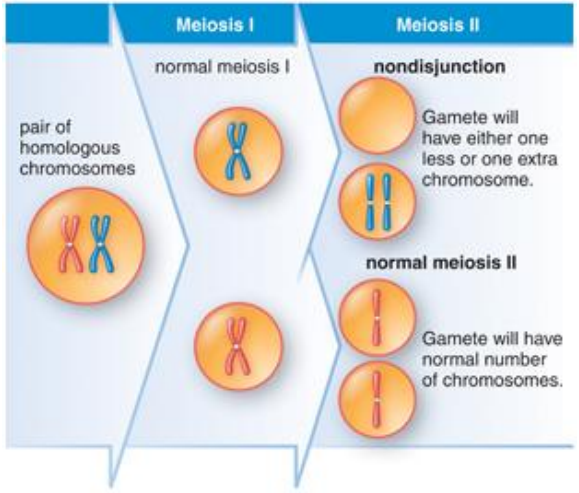
- There are two causes of nondisjunction.
  - Both members of a homologous pair go into the same daughter cell in meiosis I.
  - Both sister chromatids go into the same daughter cell in meiosis II.

- Nondisjunction can lead to two types of chromosome abnormalities.
  - In trisomy, a third chromosome of one type is present.
  - In monosomy, one chromosome of a pair is absent.

9.4 Abnormal Chromosome Inheritance (cont.)



a. Nondisjunction during meiosis I



b. Nondisjunction during meiosis II

Down Syndrome

- Down syndrome is trisomy for chromosome 21.

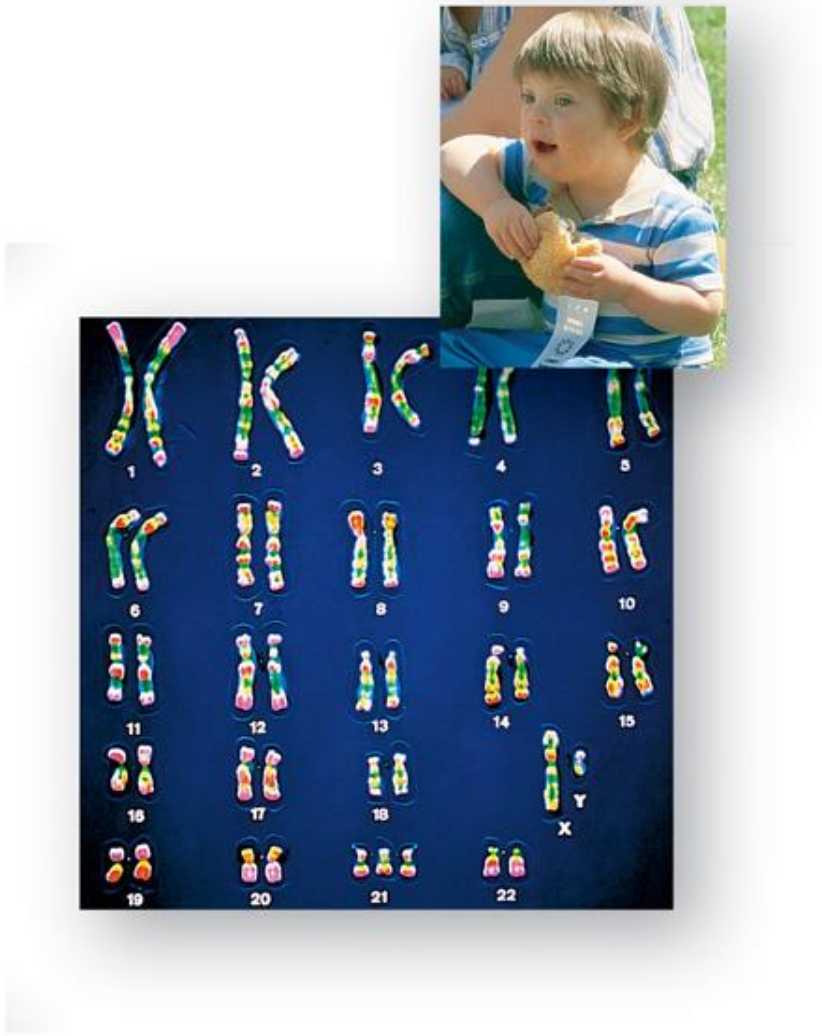
- Down syndrome produces several recognizable characteristics in the child.
  - Short stature
  - Eyelid folds
  - Stubby fingers
  - A wide gap between the first and second toes.
  - A fissured tongue
  - A round head
  - Palm crease (the Simian line)
  - Mental Retardation

Down Syndrome (cont.)

- The probability that a woman will have a Down syndrome child increases rapidly with age beginning at age 40.

- The frequency of Down syndrome varies as a function of maternal age.
  - The frequency is 1 in 800 births for women under 40.
  - The frequency is 1 in 80 births for women over 40.

Down Syndrome (cont.)



Abnormal Sex Chromosome Number

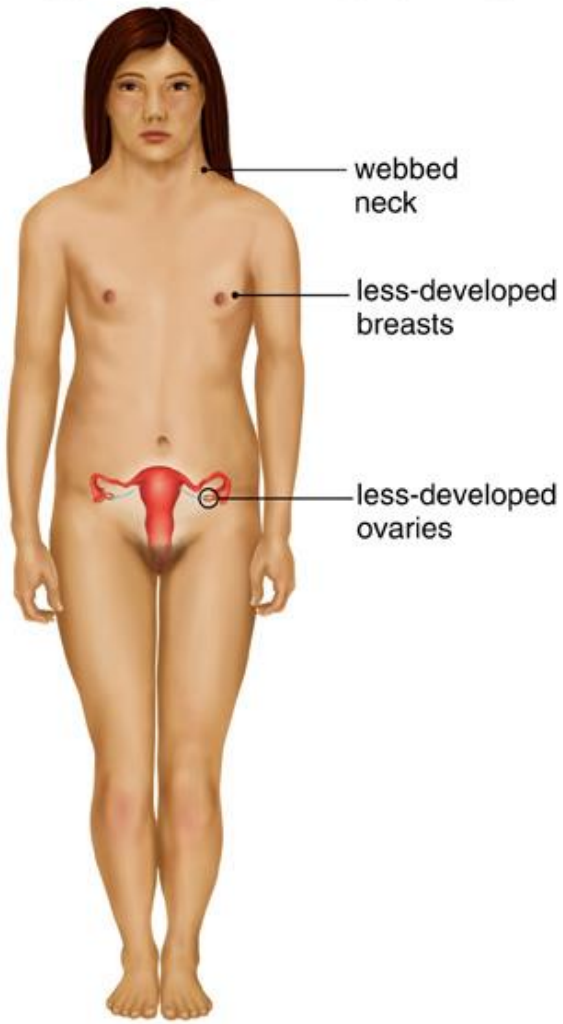
- In normal human females with two X chromosomes, one is functional and the other becomes an inactive Barr body.

- Nondisjunction can cause trisomy or monosomy of the sex chromosomes, typically with detrimental effects.

Abnormal Sex Chromosome Number (cont.)

- A Turner syndrome female has monosomy for the sex chromosomes (XO).
  - The female is short in stature with a broad chest and webbed neck.
  - The ovaries, oviducts, and uterus are small and underdeveloped.
  - Puberty and menstruation do not occur.
  - Turner syndrome females can live normal lives with hormonal therapy.

Abnormal Sex Chromosome Number (cont.)

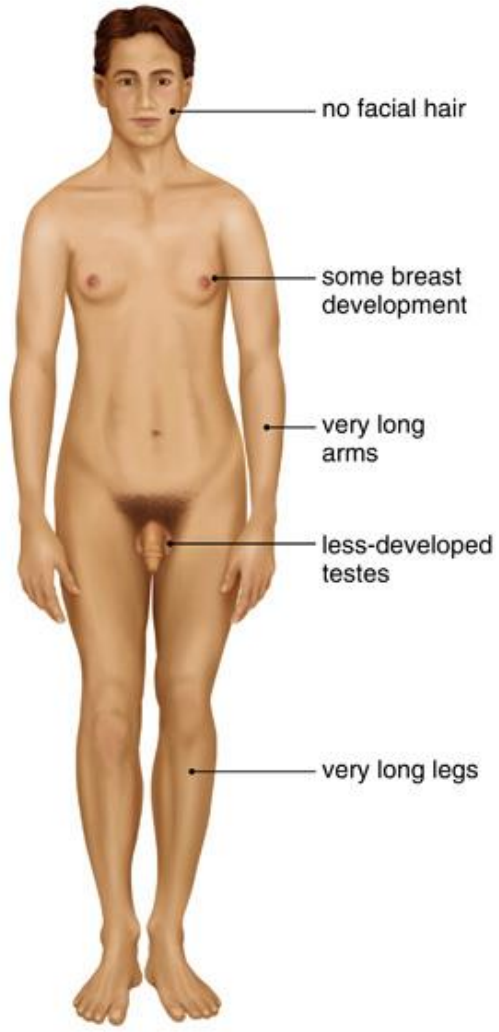


a. A female with Turner (XO) syndrome

Abnormal Sex Chromosome Number (cont.)

- A person with Klinefelter syndrome is an XXY male.
  - The extra X becomes a Barr body.
  - The testes and prostate gland are underdeveloped.
  - Facial hair is absent.
  - Breasts may develop.
  - Hands and feet are large.
  - Legs and arms are long.
  - Children are slow to learn but not mentally retarded.
  - With early identification, a normal life is possible.

Abnormal Sex Chromosome Number (cont.)



b. A male with Klinefelter (XXY) syndrome