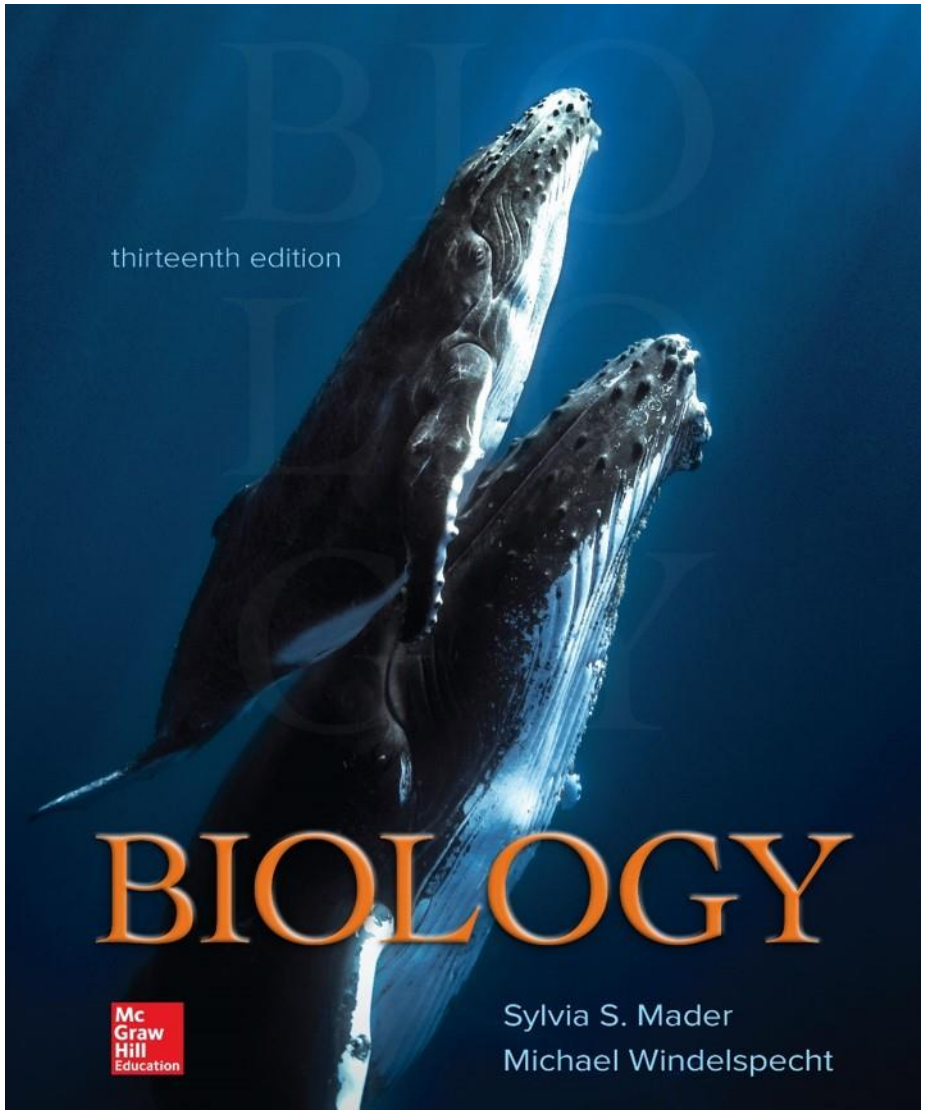

Biology

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Chapter 10
Meiosis and Sexual Reproduction
Lecture Outline

See separate FlexArt PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.

Outline

10.1 Overview of Meiosis

10.2 Genetic Variation

10.3 The Phases of Meiosis

10.4 Meiosis Compared to Mitosis

10.5 The Cycle of Life

10.6 Changes in Chromosome Number and Structure

The Importance of Meiosis

Meiosis

- It introduces an enormous amount of diversity.
- There are more than 70 trillion different genetic combinations possible from the mating of two individuals.
- Males and females differ in the way they form gametes.
- In males, sperm production begins at puberty, but in the female, the process of producing eggs starts before birth and ends at menopause.

10.1 Overview of Mitosis

Meiosis

- Special type of cell division
- Used only for **sexual reproduction**
- Chromosomes are replicated in S phase of interphase and then halved prior to fertilization.
  - Parents are diploid (2n).
  - Meiosis produces haploid (n) gametes.
    - Haploid cells contain a single set of chromosomes.
    - If there were no reduction of chromosomes in meiosis, the number of chromosomes would double each generation.
  - **Gametes** fuse in fertilization to form a diploid (2n) **zygote**.
    - The zygote becomes the next diploid (2n) generation.
    - If events in meiosis go wrong, gametes contain the wrong number of chromosomes.

Overview of Mitosis – Homologous Pairs of Chromosomes

In diploid body cells, chromosomes occur in pairs.

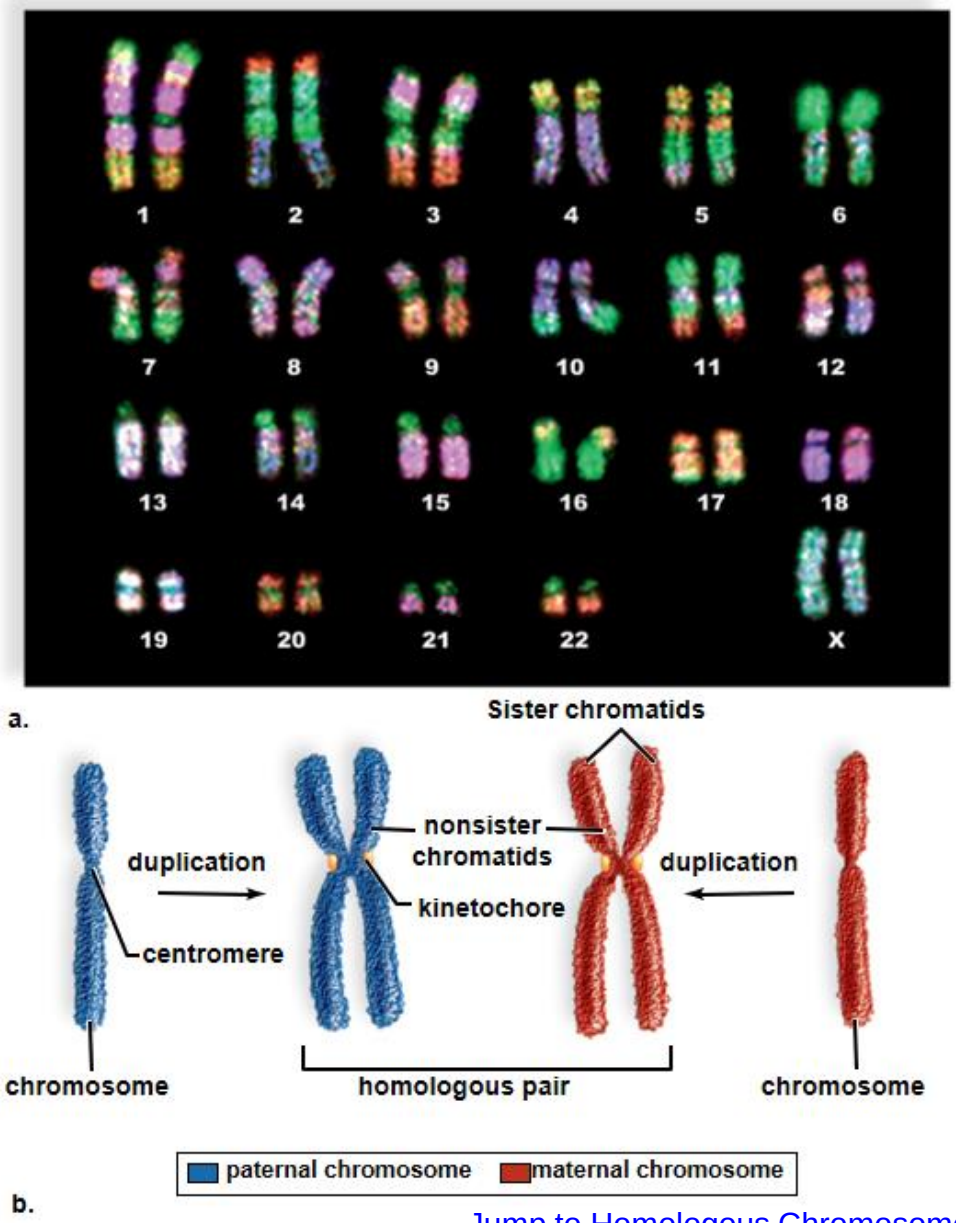
Humans have 23 different types of chromosomes.

Diploid (2n) cells have two chromosomes of each type.

Chromosomes of the same type are said to be **homologous chromosomes (homologues)**.

- They have the same length.
- Their centromeres are positioned in the same place.
- One came from the father (the paternal homologue); the other from the mother (the maternal homologue).
- When stained, they show similar banding patterns.

Homologous Chromosomes (1)



Jump to Homologous Chromosomes (1) Long Description

Homologous Chromosomes (2)

Homologous chromosomes have genes controlling the same trait at the same position.

- Gene occurs in duplicate
- A maternal copy from the mother
- A paternal copy from the father

Many genes exist in several variant forms in a large population.

Homologous copies of a gene may encode identical or different genetic information.

The variants that exist for a gene are called **alleles**.

An individual may have:

- Identical alleles for a specific gene on both homologues (homozygous for the trait), or
- A maternal allele that differs from the corresponding paternal allele (heterozygous for the trait).
- Example: a gene coding for short fingers on one homologue and a gene coding for long fingers at the same location on the other

Meiosis Is Reduction Division

Meiosis involves two nuclear divisions.

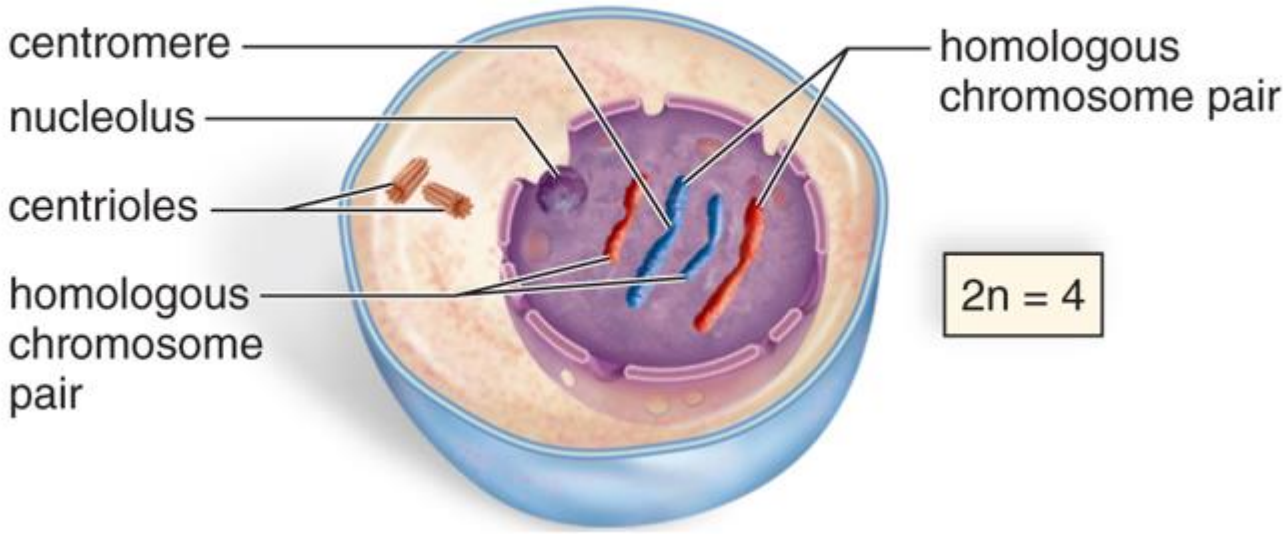
Meiosis I:

- Chromosomes are replicated prior to meiosis I.
  - Each chromosome consists of two identical sister chromatids.
- Homologous chromosomes pair up in **synapsis**.
  - Chromosomes may recombine or exchange genetic material.
- Homologous pairs align themselves against each other, side by side at the metaphase plate.
- The two members of a homologous pair separate.
- Each daughter cell receives one duplicated chromosome from each pair.
  - Chromosome number is reduced from 2n to n.

Meiosis II:

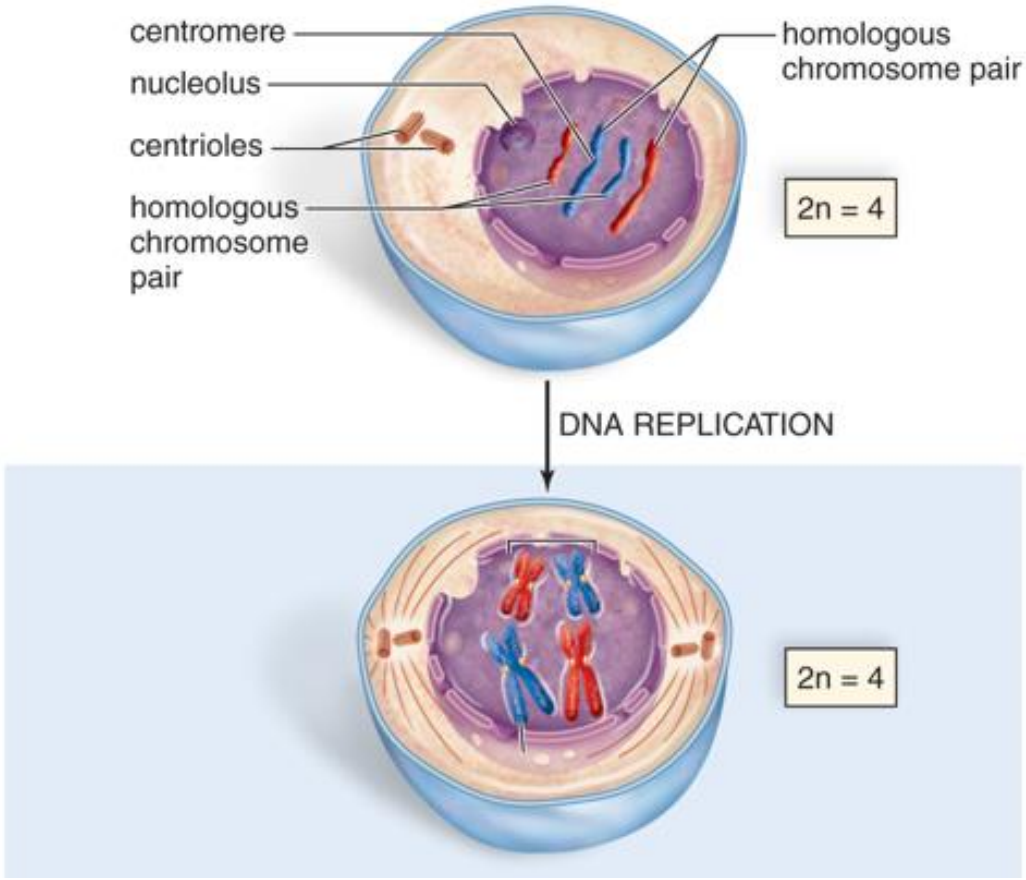
- DNA is not replicated between meiosis I and meiosis II.
- Sister chromatids separate and move to opposite poles.
- The four daughter cells contain one daughter chromosome from each pair.
- Each daughter chromosome consists of a single chromatid.
- The daughter cells are haploid.

Overview of Meiosis (1)

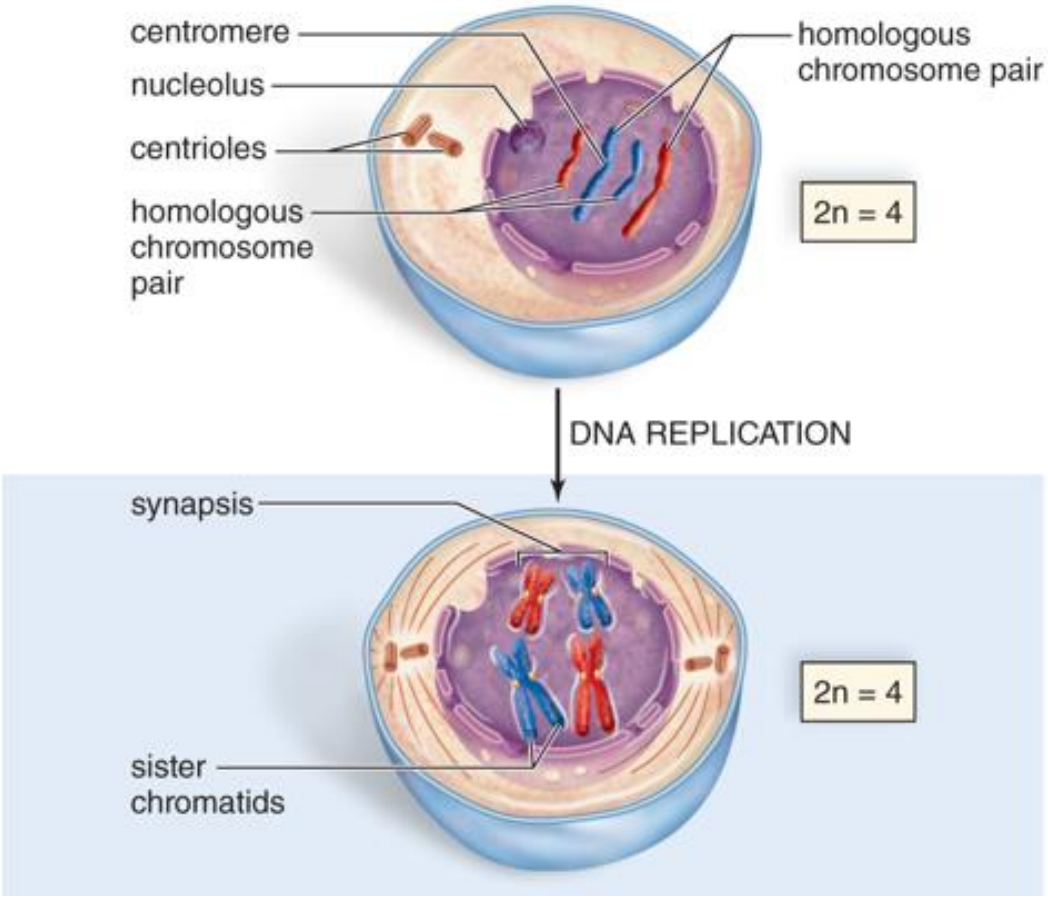


Jump to Overview of Meiosis (1) Long Description

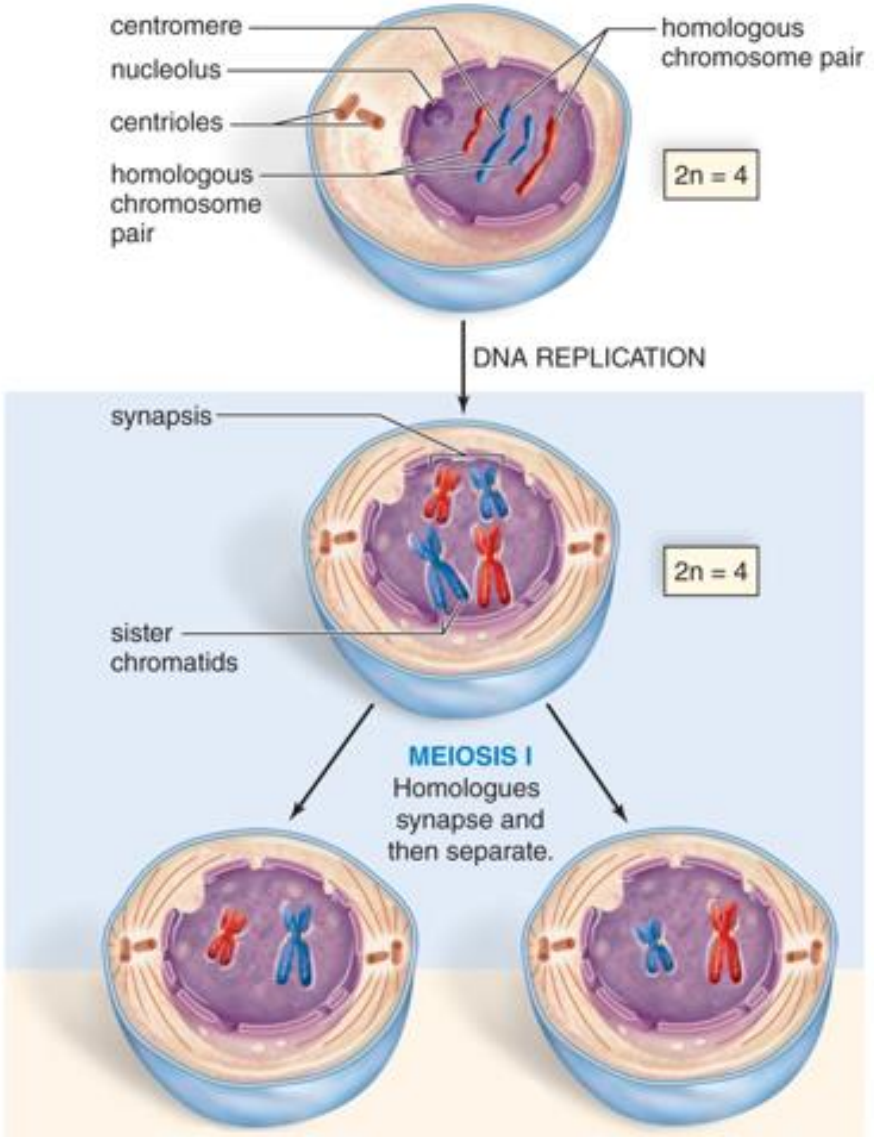
Overview of Meiosis (2)



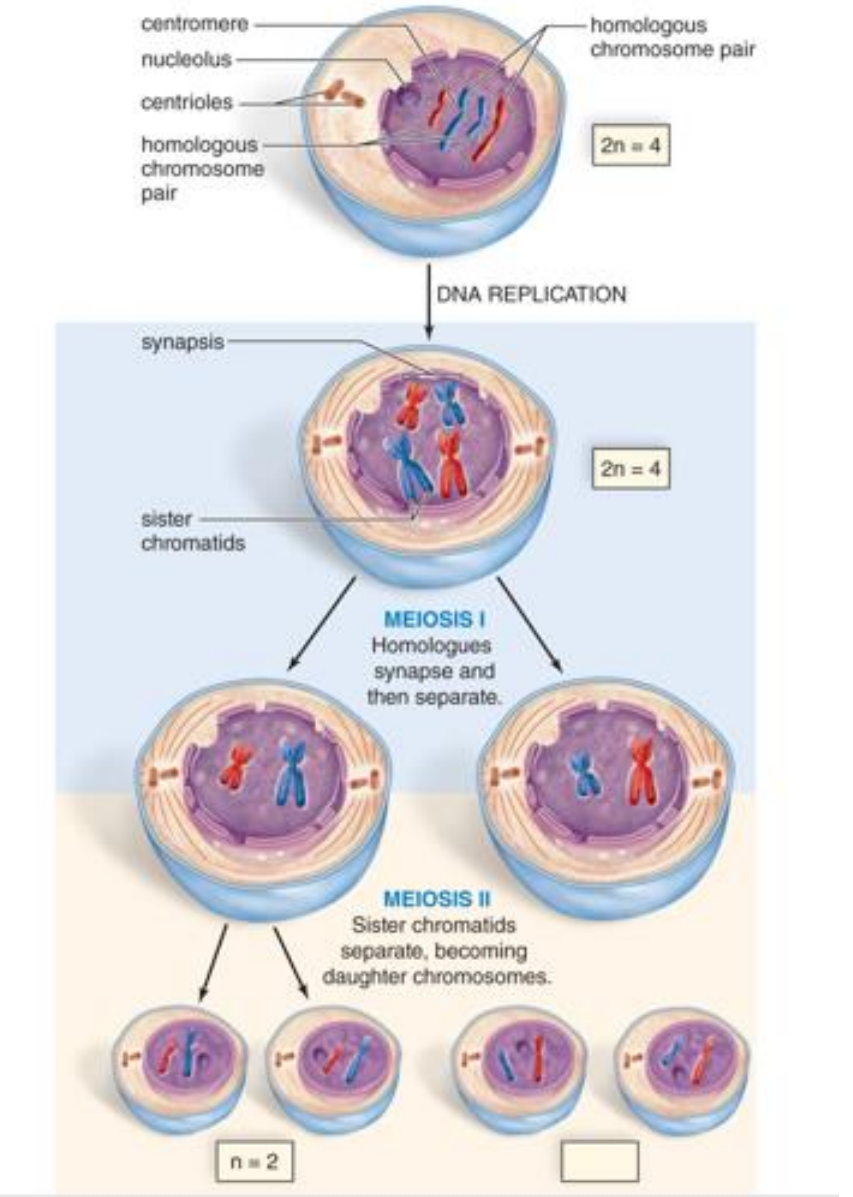
Overview of Meiosis (3)



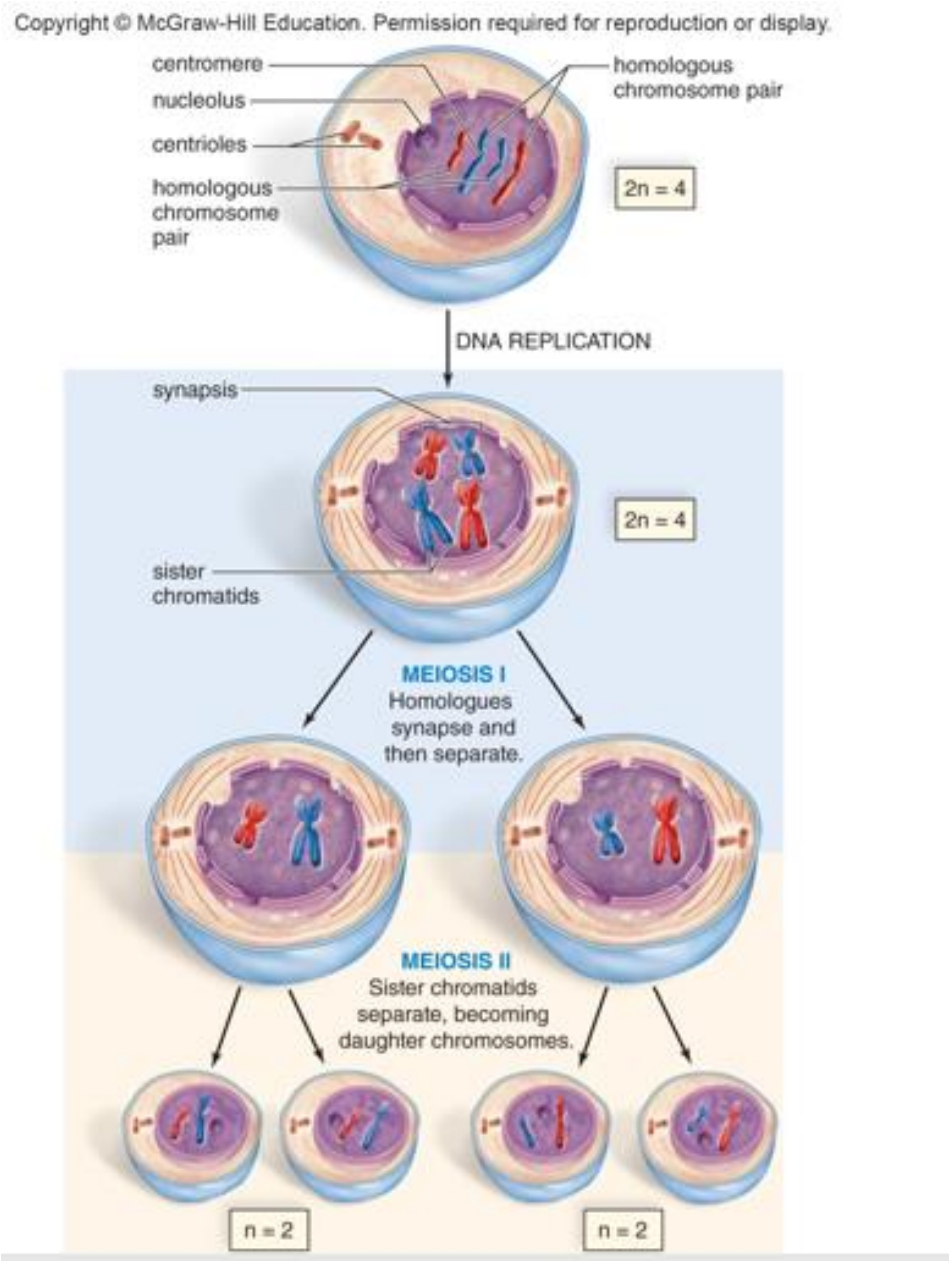
Overview of Meiosis (4)



Overview of Meiosis (5)



Overview of Meiosis (6)



10.2 Genetic Variation

Genetic variation is essential for a species to evolve and adapt in a changing environment.

- Asexually reproducing organisms depend on mutations to generate variation in offspring.

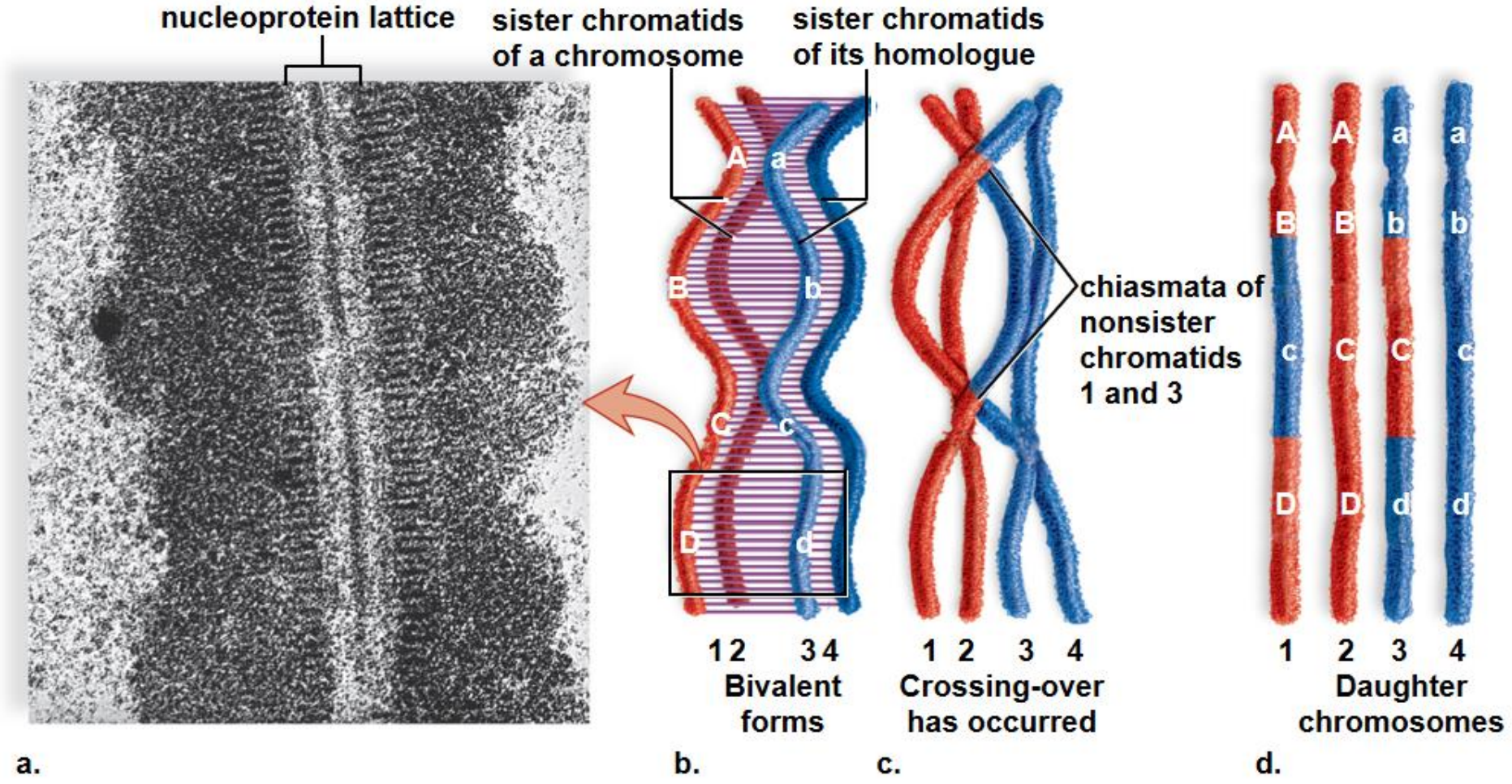
Meiosis brings about genetic variation in two key ways:

- **Crossing over** between homologous chromosomes, and
- **Independent assortment** of homologous chromosomes

Crossing-Over:

- It involves exchange of genetic material between nonsister chromatids during meiosis I.
- At synapsis, a nucleoprotein lattice (called the **synaptonemal complex**) appears between homologues.
  - Holds homologues together
  - Aligns DNA of non-sister chromatids
  - Allows crossing-over (exchange of genetic material) to occur
- Then, homologues separate and are distributed to different daughter cells.

Crossing Over Occurs During Meiosis I



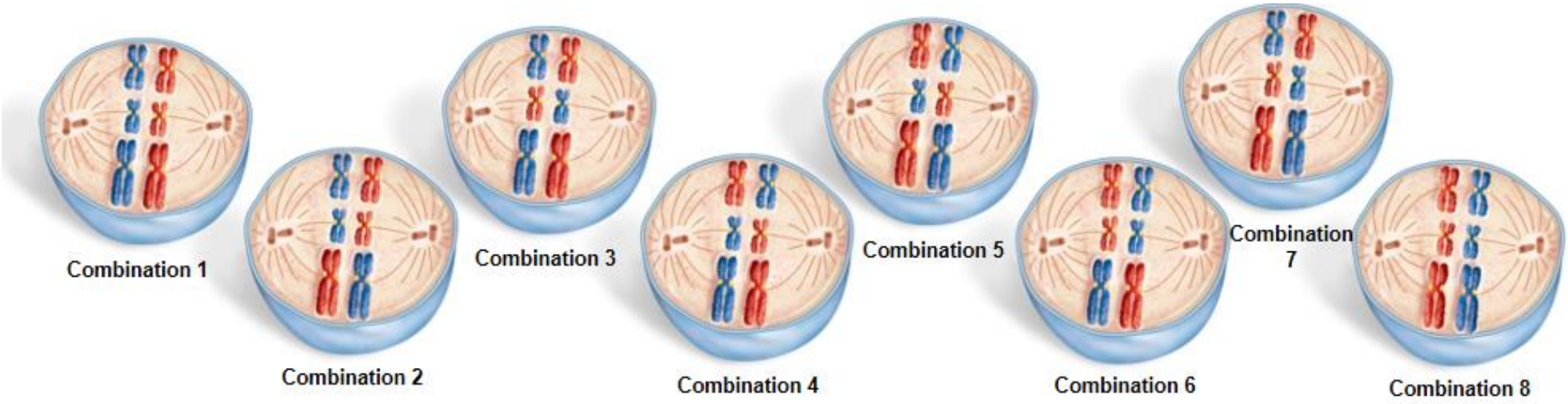
Jump to Crossing Over Occurs During Meiosis I Long Description

Genetic Variation (1)

Independent assortment of homologous chromosomes

- When homologous chromosome pairs align at the metaphase plate:
  - They separate in a random manner.
  - The maternal or paternal homologue may be oriented toward either pole of mother cell.
- It causes random mixing of blocks of alleles into gametes.
- The possible chromosome orientations for a cell with three pairs of homologous chromosomes is 2^3 or 8 combinations of maternal and paternal chromosomes.

Independent Assortment



Jump to Independent Assortment Long Description

Genetic Variation (2)

Fertilization: union of male and female gametes

- Chromosomes donated by the parents are combined.
- In humans, $(2^{33})^2 = 70{,}368{,}744{,}000{,}000$ chromosomally different zygotes are possible.

If crossing-over occurs only once

- $(4^{23})^2$, or 4,951,760,200,000,000,000,000,000,000 genetically different zygotes are possible.

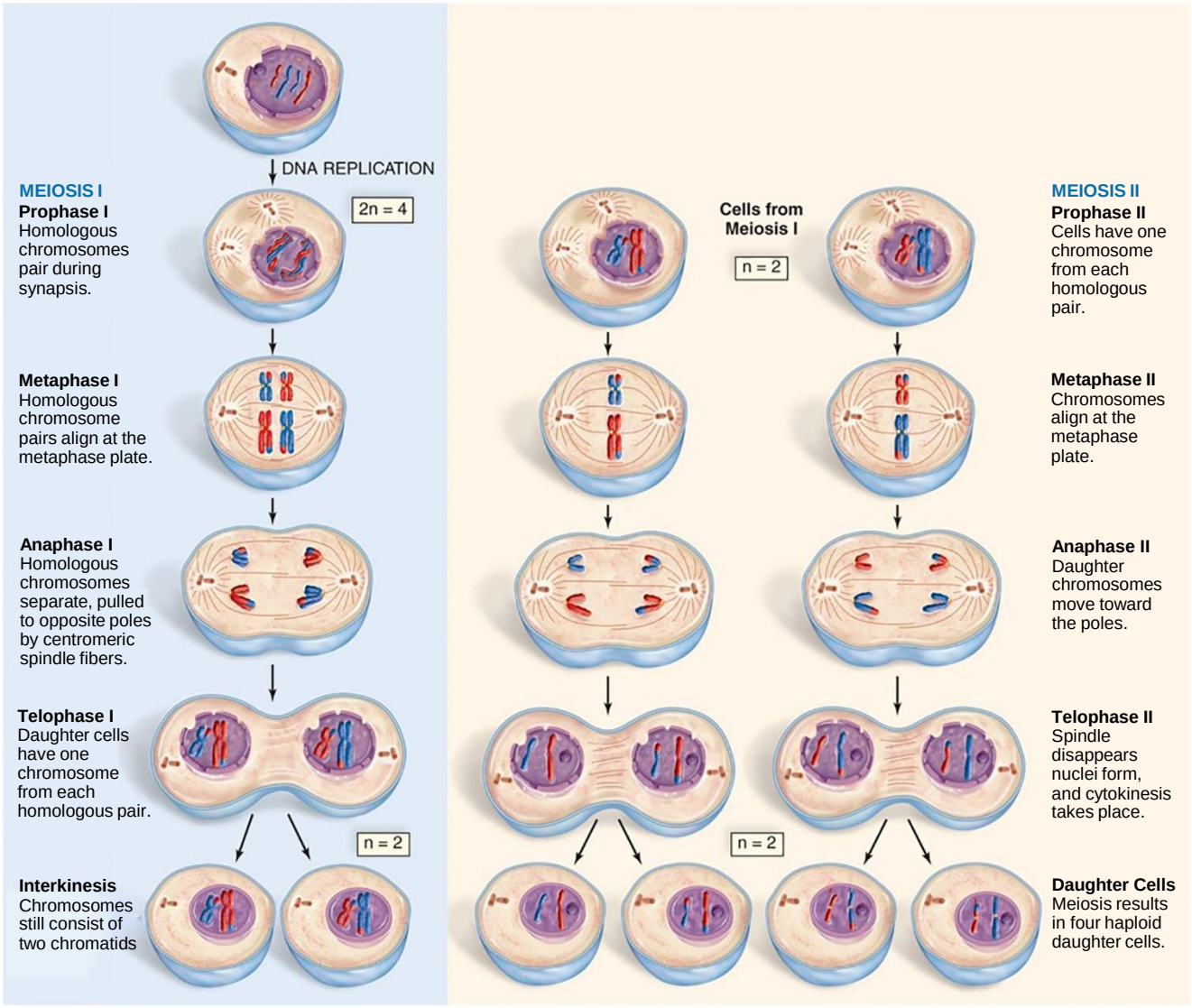
Crossing-over may occur several times in each chromosome.

Genetic Variation (3)

Significance of genetic variation:

- Asexual reproduction produces genetically identical clones.
- Sexual reproduction causes genetic recombinations among members of a population.
  - In humans with 23 pairs of chromosomes, the possible chromosomal combinations is 2^{33} or 8,388,608, assuming no crossing-over has occurred.
- Asexual reproduction is advantageous when the environment is stable.
- However, if the environment changes, genetic variability introduced by sexual reproduction may be advantageous.
  - Some offspring may have a better chance of survival.
  - Example: If the temperature rises due to climate change, an animal with less fur or reduced body fat would have an advantage.

Stages of Meiosis



Jump to Stages of Meiosis Long Description

Meiosis Compared to Mitosis (1)

Table 10.1 Meiosis I Compared to Mitosis

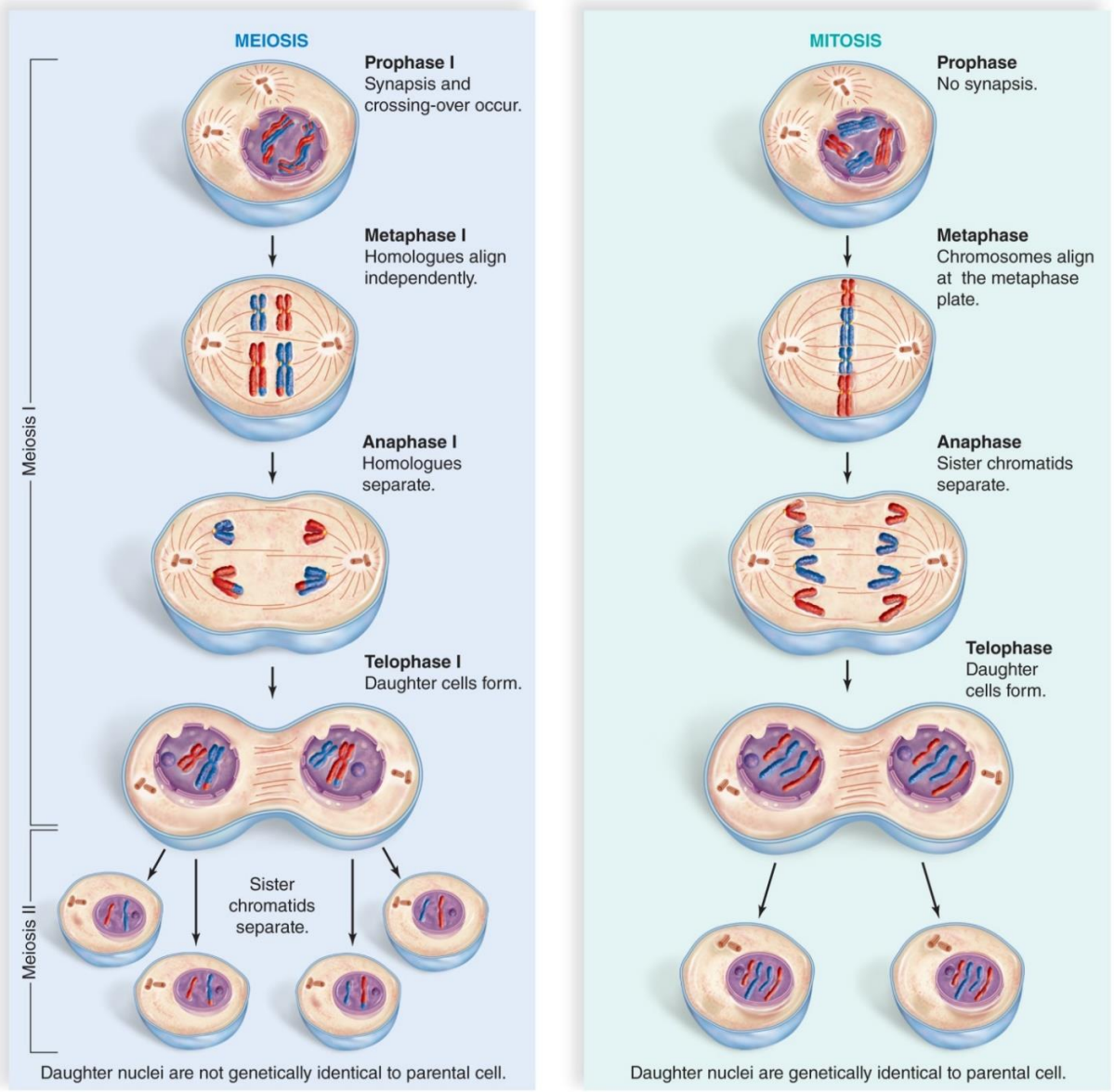
Meiosis I	Mitosis
Prophase I	**Prophase**
Pairing of homologous chromosomes	No pairing of chromosomes
Metaphase I	**Metaphase**
Bivalents at metaphase plate	Duplicated chromosomes at metaphase plate
Anaphase I	**Anaphase**
Homologues of each bivalent separate and duplicated chromosomes move to poles	Sister chromatids separate, becoming daughter chromosomes that move to the poles
Telophase I	**Telophase**
Two haploid daughter cells, not identical to the parent cell	Two diploid daughter cells, identical to the parent cell

Meiosis Compared to Mitosis (2)

Table 10.1 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 duplicated chromosomes at metaphase plate	Diploid number of duplicated chromosomes at metaphase plate
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**
Two haploid daughter cells, not genetically identical	Two diploid daughter cells, identical to the parent cell

Meiosis Compared to Mitosis (3)



Jump to Meiosis Compared to Mitosis (3) Long Description

10.6 Changes in Chromosome Number and Structure

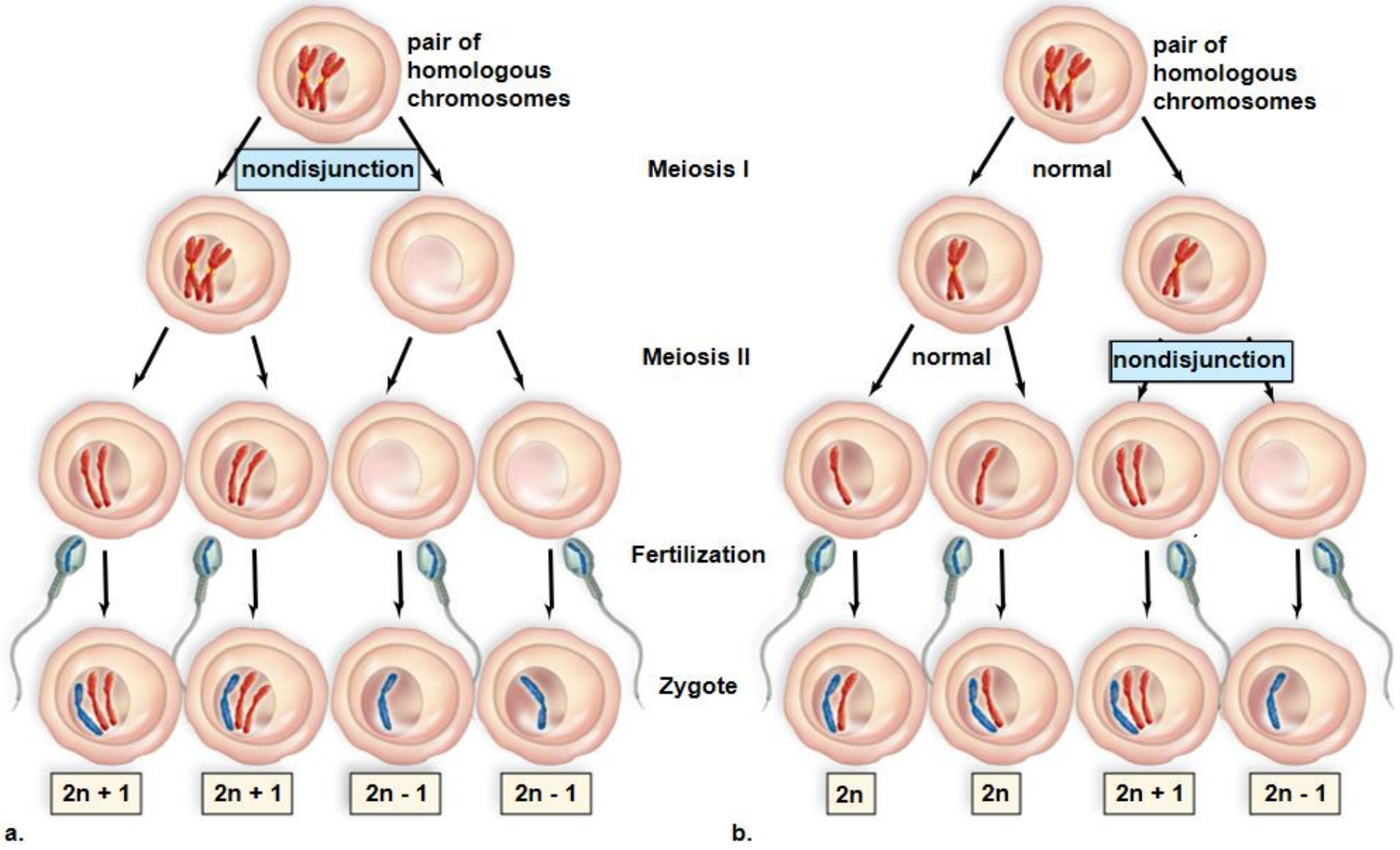
Meiosis almost always proceeds normally.

Euploidy is the correct number of chromosomes in a species.

Aneuploidy is a change in the chromosome number.

- A **karyotype** is a display of chromosomes arranged by size, shape, and banding pattern for observing aneuploidies.
- Aneuploidy results from **nondisjunction**—failure of chromosomes to separate.
  - Nondisjunction can occur in meiosis I or meiosis II.
  - It may result in gain or loss of chromosomes.
    - **Monosomy** – only one of a particular type of chromosome
    - **Trisomy** – three of a particular type of chromosome

Nondisjunction (4)



Jump to Nondisjunction (4) Long Description

Changes in Chromosome Number and Structure (1)

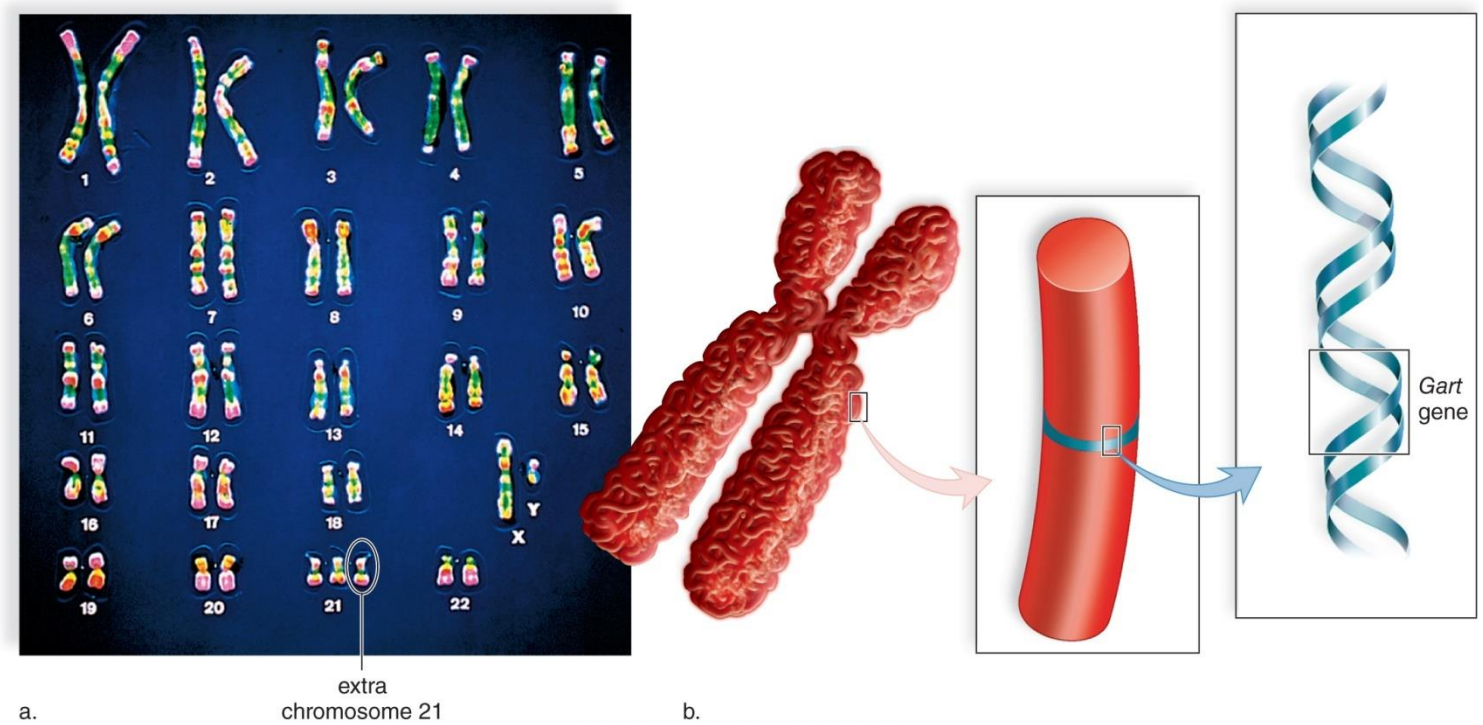
Trisomy occurs when an individual has three of a particular type of chromosome.

- In humans, three autosomal trisomies are viable beyond birth.

The most common autosomal trisomy seen among humans is trisomy 21.

- Also called Down syndrome
  - The chance of a woman having a child with Down syndrome increases with her age.
    - The longer the oocytes are stored, the greater the chances of nondisjunction occurring.
- Recognized by these characteristics:
  - Short stature
  - Eyelid fold
  - Flat face
  - Stubby fingers
  - Wide gap between first and second toes

Trisomy 21



a. b.

a. © CNRI/SPL/Science Source

Jump to Trisomy 21 Long Description

Changes in Chromosome Number and Structure (2)

Changes in sex chromosome number:

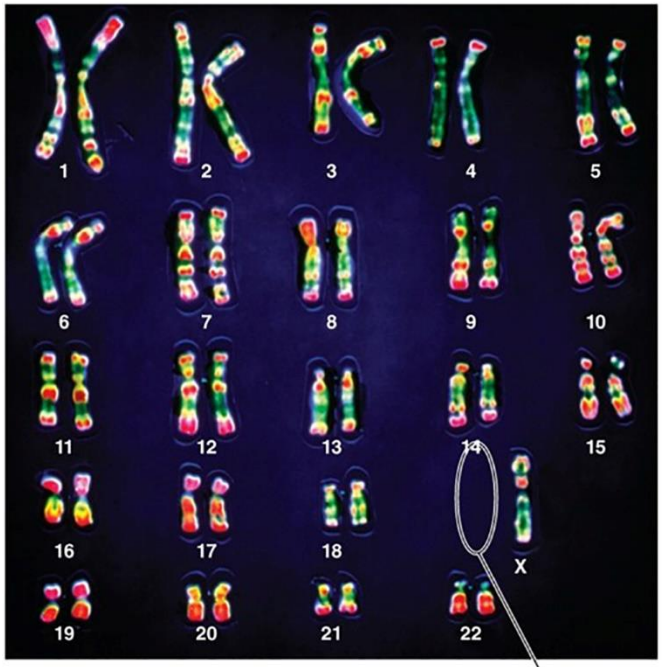
- Results from inheriting too many or too few X or Y chromosomes
  - Extra copies of sex chromosomes are more easily tolerated than autosomes.
- Nondisjunction during oogenesis or spermatogenesis
- Turner syndrome (XO)
  - Female with a single X chromosome
  - Short, with broad chest and widely spaced nipples
  - Can be of normal intelligence and function with hormone therapy

Changes in Chromosome Number and Structure (3)

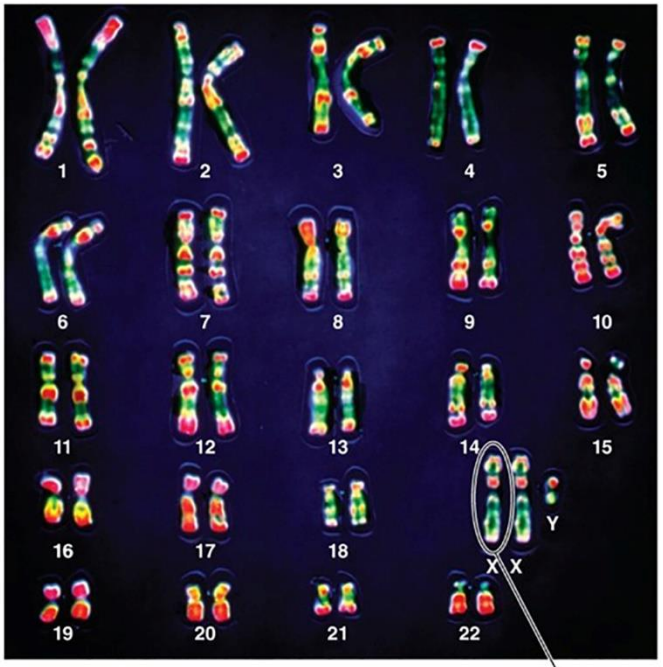
Changes in sex chromosome number:

- Klinefelter syndrome (XXY)
  - Male with underdeveloped testes and prostate; some breast overdevelopment
  - Long arms and legs; large hands
  - Near-normal intelligence unless XXXY, XXXXY, etc.
  - No matter how many X chromosomes are present, the presence of a chromosome Y renders the individual male.
- Deletion of the *SRY* gene results in XY female.
  - Lack of testis-determining factor, which plays a role in male genital development
  - Presence of *SRY* determines maleness.

Changes in Sex Chromosome



a. Turner syndrome



b. Klinefelter syndrome

Jump to Changes in Sex Chromosome Long Description