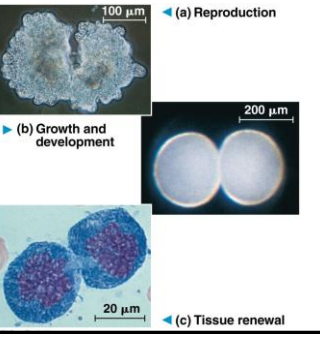
Chapter 12

The Cell Cycle

Functions of Cell Division



Concept 12.1: Cell division results in genetically identical daughter cells

- Most cell division results in daughter cells with identical genetic information, DNA
- A special type of division produces nonidentical daughter cells (gametes, or sperm and egg cells)

Cellular Organization of the Genetic Material

- All the DNA in a cell constitutes the cell's **genome**
- A genome can consist of a single DNA molecule (common in prokaryotic cells) or a number of DNA molecules (common in eukaryotic cells)

- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells
- Eukaryotic **chromosomes** consist of **chromatin**, a complex of DNA and protein that condenses during cell division

Distribution of Chromosomes During Eukaryotic Cell Division

- In preparation for cell division, DNA is replicated and the chromosomes condense
- Each duplicated chromosome has two **sister chromatids**, which separate during cell division
- The **centromere** is where the two chromatids are most closely attached

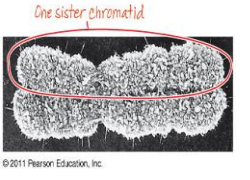
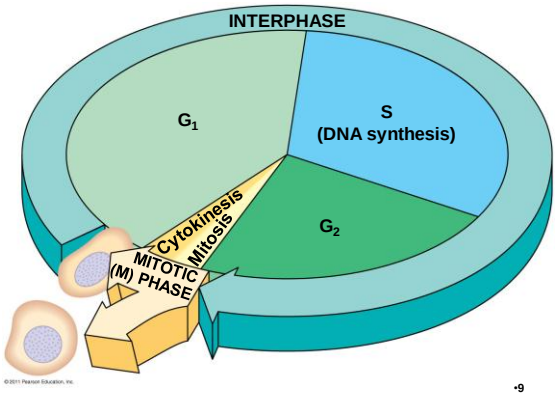


Fig. 12-UN3

- Interphase (about 90% of the cell cycle) can be divided into subphases:
  - **G_1 phase** ("first gap")
  - **S phase** ("synthesis")
  - **G_2 phase** ("second gap")
- The cell grows during all three phases, but chromosomes are duplicated only during the S phase

- Eukaryotic M phase consists of:
  - **Mitosis**, the division of the nucleus
  - **Cytokinesis**, the division of the cytoplasm

Figure 12.6



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- Mitosis is conventionally divided into five phases:
  - **Prophase**
  - **Prometaphase**
  - **Metaphase**
  - **Anaphase**
  - **Telophase**
- Cytokinesis is well underway by late telophase

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Figure 12.7a

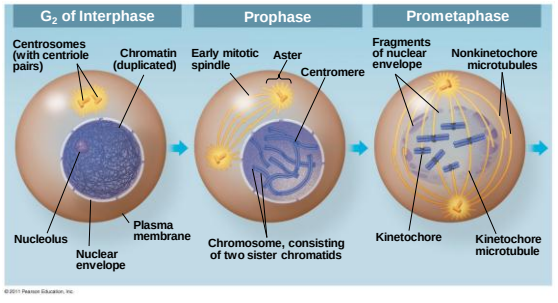

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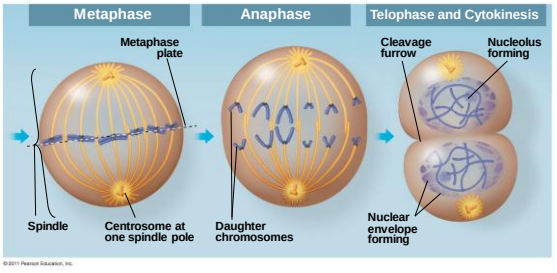
Figure 12.7b



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Cytokinesis of Animal Cells

- Cytokinesis occurs by a process known as **cleavage**, forming a **cleavage furrow**

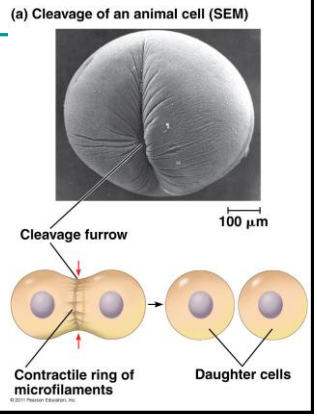


Fig. 12-9a

Cytokinesis in Plant Cells

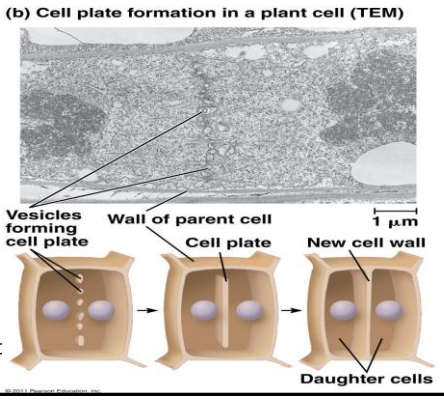
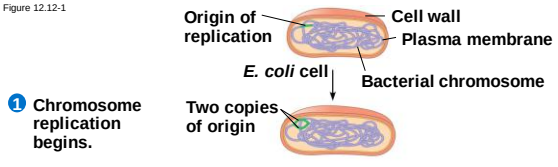


Fig. 12-9b

Binary Fission

- Prokaryotes (bacteria and archaea) reproduce by a type of cell division called **binary fission**
- In binary fission, the chromosome replicates (beginning at the **origin of replication**), and the two daughter chromosomes actively move apart



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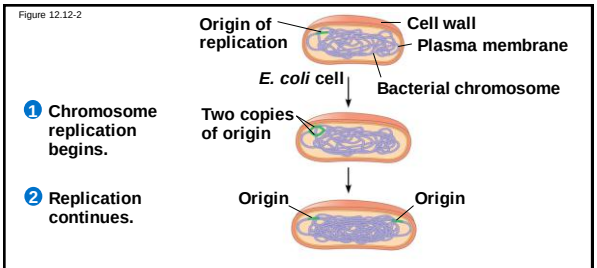

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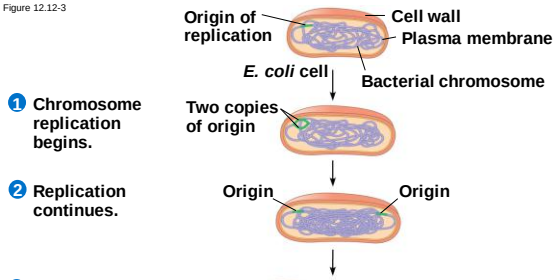

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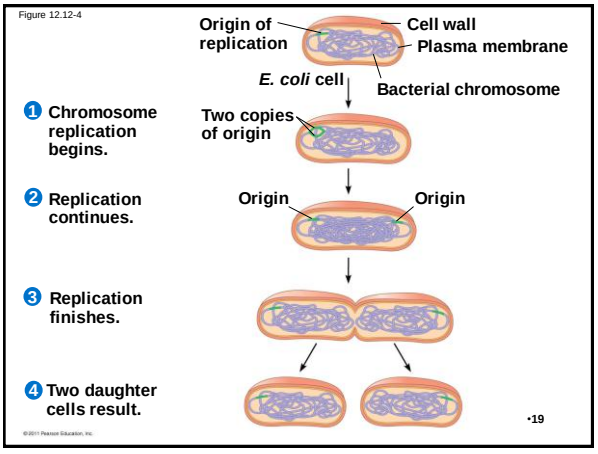
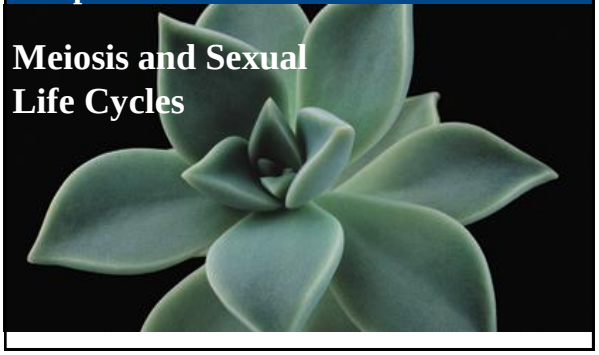


The Evolution of Mitosis

- Since prokaryotes evolved before eukaryotes, mitosis probably evolved from binary fission
- Certain protists exhibit types of cell division that seem intermediate between binary fission and mitosis

Chapter 13

Meiosis and Sexual Life Cycles



Overview: Variations on a Theme

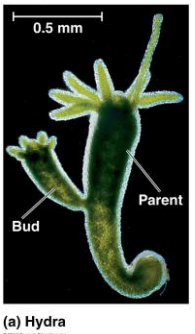
- **Genetics** is the scientific study of heredity and variation
- **Heredity** is the transmission of traits from one generation to the next
- **Variation** is demonstrated by the differences in appearance that offspring show from parents and siblings

Concept 13.1: Offspring acquire genes from parents by inheriting chromosomes

- **Genes** are the units of heredity, and are made up of segments of DNA

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

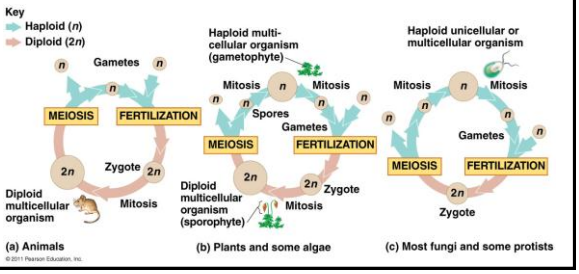


(a) Hydra

- 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

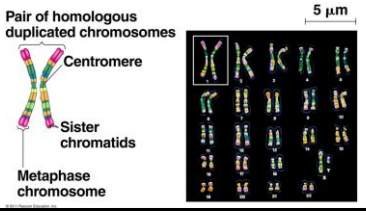


Sets of Chromosomes in Human Cells

- A **diploid cell** (2*n*) has two sets of chromosomes. 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

Homologous Chromosomes

- The two chromosomes in each pair are called **homologous chromosomes**, or homologs.
- Each pair of homologous chromosomes includes one chromosome from each parent

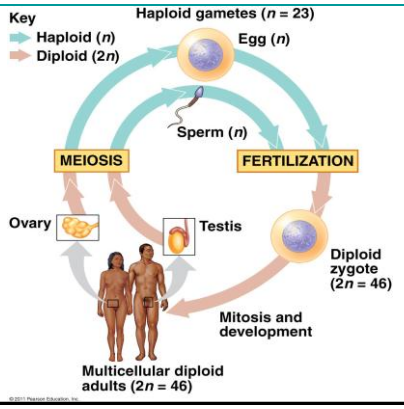


Sex Chromosomes and Autosomes in Humans

- 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**

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

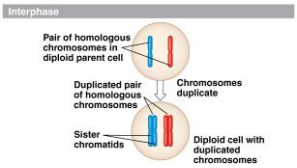
Human Life Cycle



- Depending on the type of life cycle, either haploid or diploid cells can divide by mitosis
- However, only diploid cells can undergo meiosis

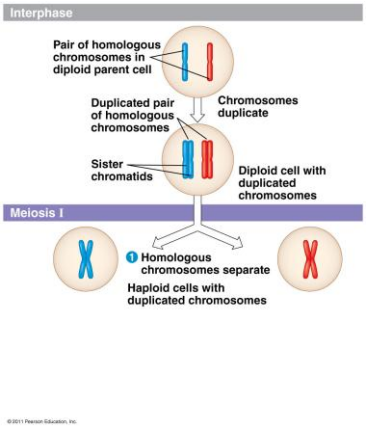
Concept 13.3: Meiosis reduces the number of chromosome sets from diploid to haploid

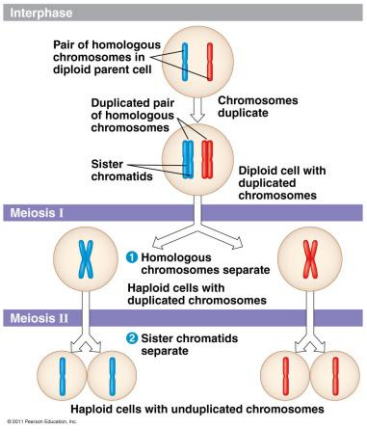
- Like mitosis, meiosis is preceded by the replication of chromosomes



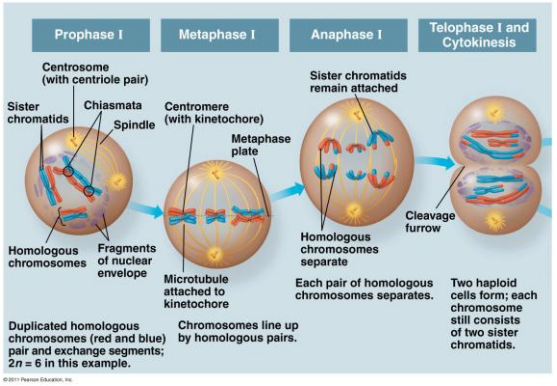
The Stages of Meiosis: Meiosis I

- Meiosis takes place in two sets of cell divisions, called **meiosis I** and **meiosis II**
- 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

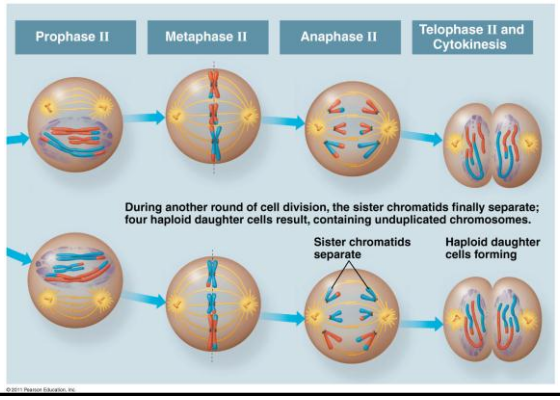




Meiosis I



Meiosis II



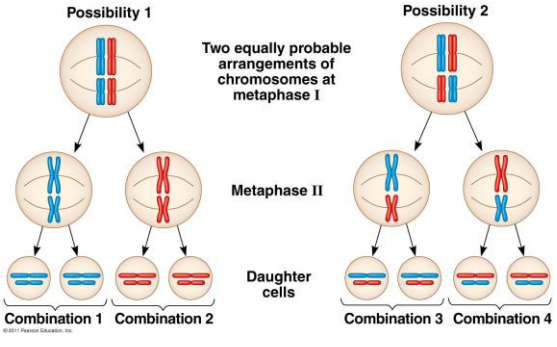
Concept 13.4: Genetic variation produced in sexual life cycles contributes to evolution

- 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

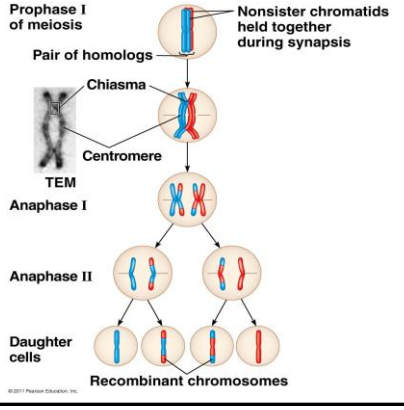
Origins of Genetic Variation Among Offspring

- Three mechanisms contribute to genetic variation:
  - Independent assortment of chromosomes
  - Crossing over
  - Random fertilization

Independent Assortment



Crossing Over



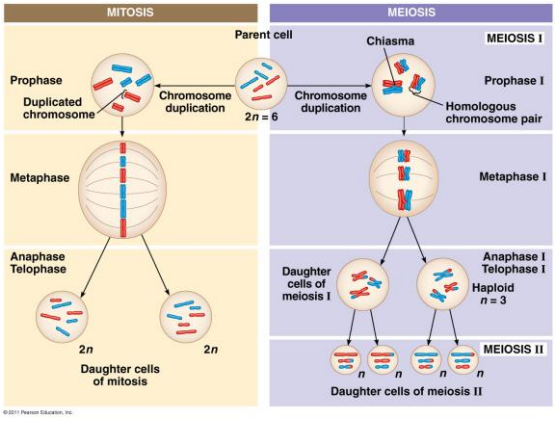
- Three events are unique to meiosis, and all three occur in meiosis I:
  - Synapsis and crossing over in prophase I: Homologous chromosomes physically connect and exchange genetic information
  - At the metaphase plate, there are paired homologous chromosomes (tetrads), instead of individual replicated chromosomes
  - At anaphase I, it is homologous chromosomes, instead of sister chromatids, that separate

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

Comparison of Mitosis and Meiosis

- Mitosis
  - Is the separation of sister chromatids
  - Maintains the same chromosome number
  - Yields clones.
- Meiosis
  - Reduces chromosomes number by half and produces genetically different gametes



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 ($2n$) 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