

## Lecture Series 5 Cell Cycle & Cell Division

## Cell Cycle & Cell Division

- A. Systems of Cell Division
- B. Interphase and the Control of Cell Division
- C. Eukaryotic Chromosomes
- D. Mitosis: Distributing Exact Copies of Genetic Information
- E. Cytokinesis: The Division of the Cytoplasm

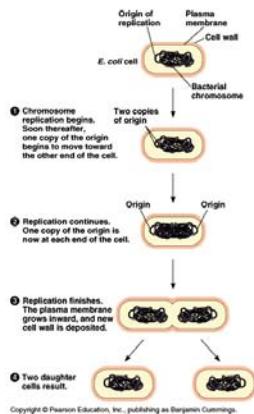
## Cell Cycle & Cell Division

- F. Mitosis: Asexual Reproduction and Genetic Constancy
- G. Meiosis: Sexual Reproduction and Diversity
- H. Meiosis: A Pair of Nuclear Divisions
- I. Meiotic Errors: Source of Chromosomal Disorders
- J. Cell Death

## A. Systems of Cell Division

- Cell division is necessary for reproduction, growth, and repair of an organism.
- Cell division must be initiated by three steps: DNA replication, DNA separation, and then division of the cytoplasm.
- In prokaryotes, cellular DNA is a single molecule, or chromosome. Prokaryotes reproduce by cell fission aka binary fission.

Bacterial cell division (binary fission):

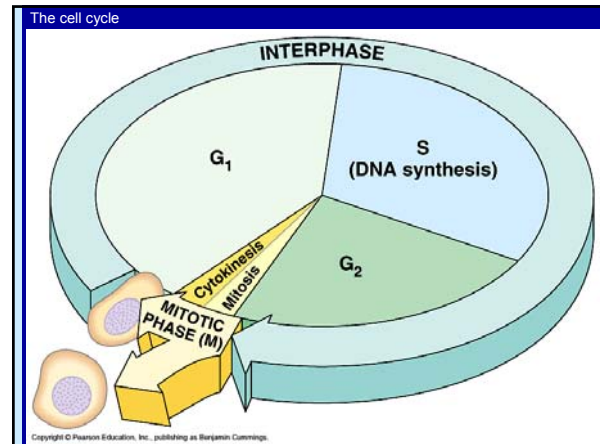


## A. Systems of Cell Division

- In eukaryotes, nuclei divide by either mitosis or meiosis.

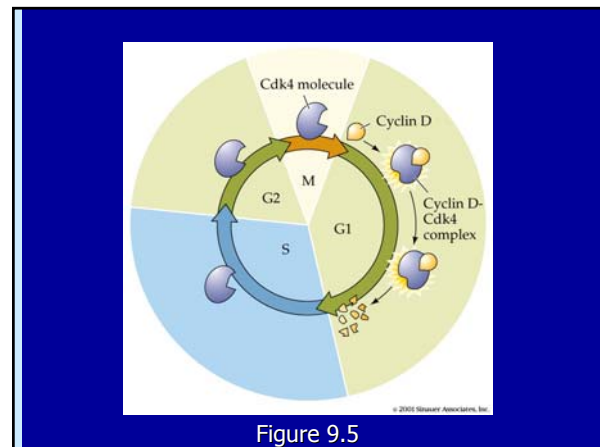
## B. Interphase and the Control of Cell Division

- The mitotic cell cycle has two main phases: interphase and mitosis.
- Interphase is the period between divisions in the cytoplasm.
- During most of the cell cycle the cell is in interphase, which is divided into three subphases: S, G<sub>1</sub>, and G<sub>2</sub>.
- DNA is replicated during S phase.



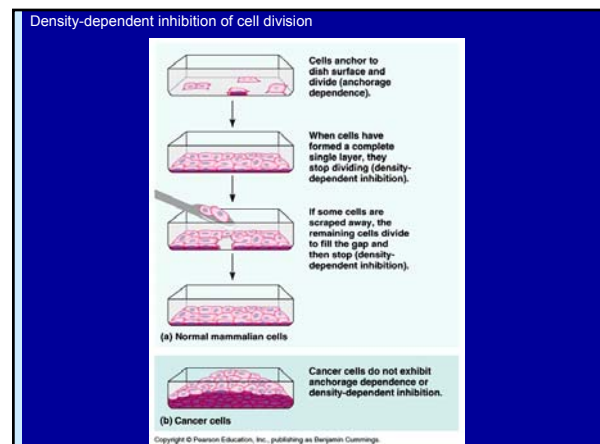
## B. Interphase and the Control of Cell Division

- Cyclin-Cdk complexes regulate the passage of cells from G<sub>1</sub> into S phase and from G<sub>2</sub> into M phase.
- Cyclin binding to Cdk exposes the active site of the kinase but breaks down quickly.
- These complexes act as checkpoints regulating the cells progression through the cell cycle.



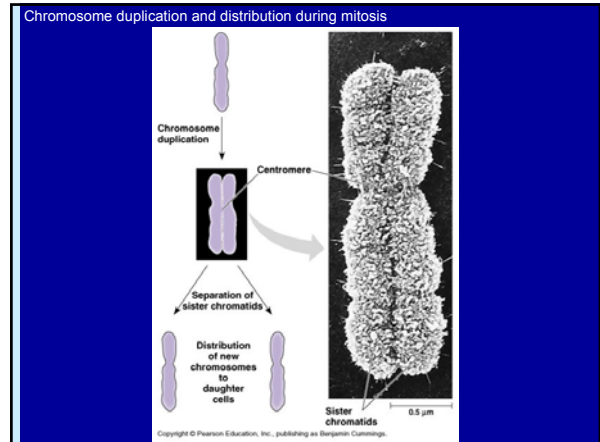
## B. Interphase and the Control of Cell Division

- In addition to the **internal** cyclin-Cdk complexes, controls **external** to the cell, such as growth factors and hormones, can also stimulate a division cycle.
- Cancer cells often have defective Cyclin-Cdk complexes or lose control over their growth factors.



## C. Eukaryotic Chromosomes

- Chromosomes contain DNA and proteins. At mitosis, chromosomes initially appear double because two sister chromatids are held together at the centromere. Each sister chromatid consists of one double-stranded DNA molecule complexed with proteins and referred to as chromatin.



## C. Eukaryotic Chromosomes

- During interphase, DNA in chromatin is wound around histone core proteins to form nucleosomes. DNA folds repeatedly, packing within the nucleus. When mitotic chromosomes form, it supercoils and condenses even more.

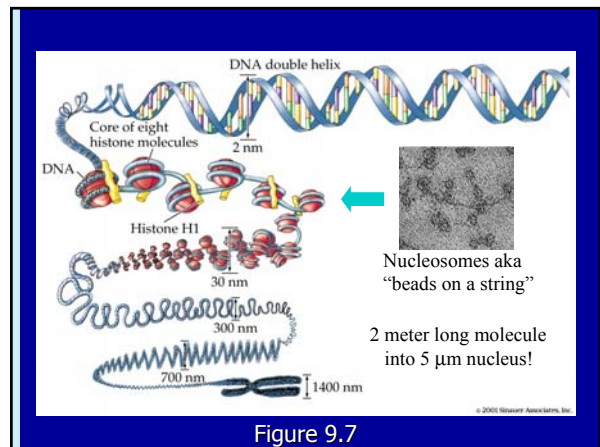


Figure 9.7

## D. Mitosis: Distributing Exact Copies of Genetic Information

- After DNA is replicated during S phase, the first sign of mitosis is the separation of centrosomes, which initiate microtubule formation for the spindle.

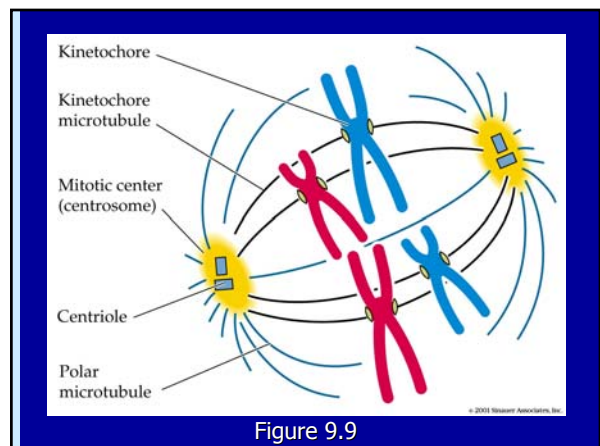
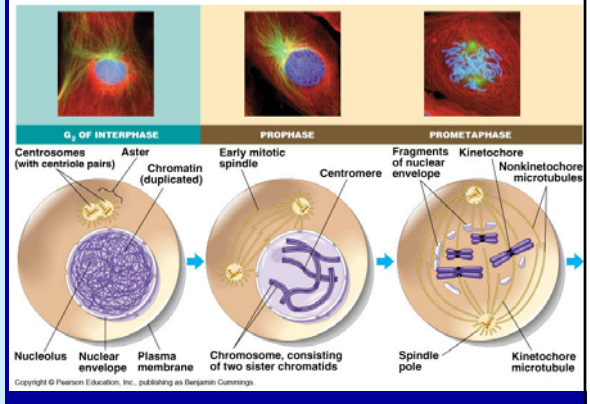


Figure 9.9

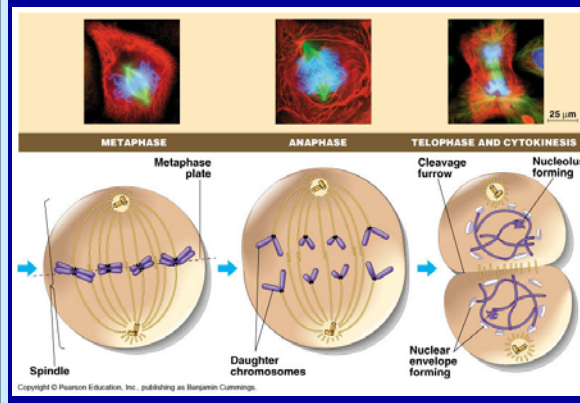
## D. Mitosis: Distributing Exact Copies of Genetic Information

- Mitosis can be divided into phases: prophase, prometaphase, metaphase, anaphase, and telophase.

Mitotic cell division stages (animal cell): Interphase; prophase; prometaphase.



Mitotic cell division stages (animal cell): metaphase; anaphase; telophase & cytokinesis.



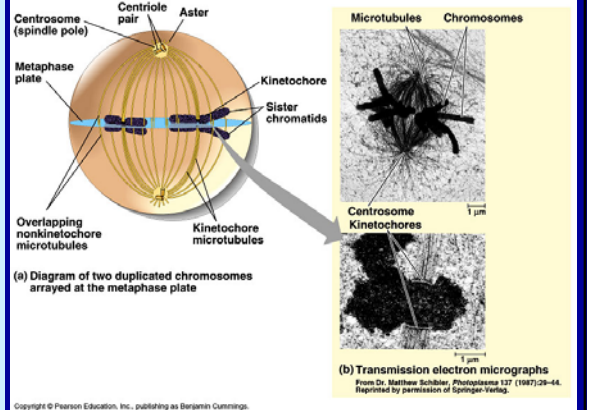
## D. Mitosis: Distributing Exact Copies of Genetic Information

- During prophase, the chromosomes condense and appear as paired chromatids.
- During prometaphase, the chromosomes move toward the middle of the spindle. The nuclear envelope breaks down. Kinetochore microtubules appear and attach the kinetochores to the centrosomes.

## D. Mitosis: Distributing Exact Copies of Genetic Information

- In metaphase, chromatids gather at the middle of the cell, their centromeres on the metaphase plate.
- In anaphase, the centromeres holding the chromatid pairs together separate. Each member of the pair, now called a daughter chromosome, migrates to its pole along the microtubule track.

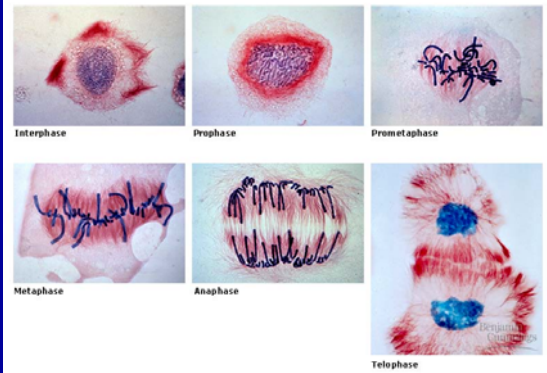
The mitotic spindle at metaphase



## D. Mitosis: Distributing Exact Copies of Genetic Information

- During telophase, the chromosomes become less condensed. The nuclear envelopes and nucleoli re-form, producing two nuclei whose chromosomes are identical to each other and to those of the cell that began the cycle.

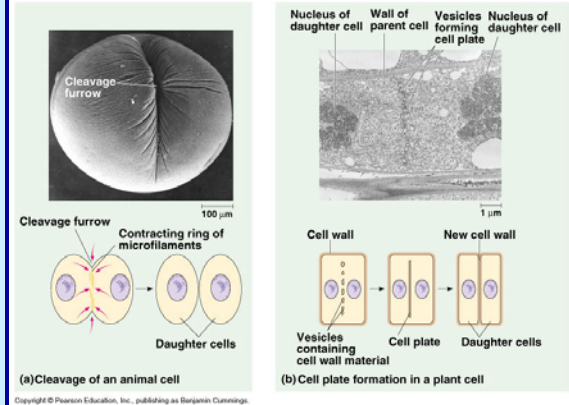
Mitosis in a plant cell



## E. Cytokinesis: The Division of the Cytoplasm

- Cytokinesis usually follows nuclear division. Animal cell cytoplasm usually divides by plasma membrane furrowing caused by contraction of cytoplasmic microfilaments.
- In plant cells, cytokinesis is accomplished by vesicle fusion and the synthesis of new cell wall material.

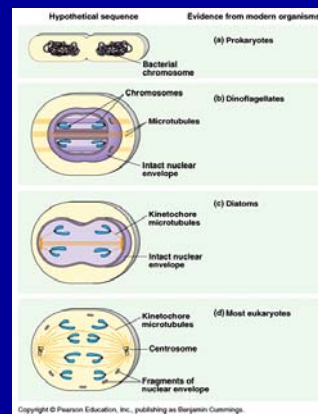
Cytokinesis in animal and plant cells



Mitosis in an onion root



A hypothesis for the evolution of mitosis



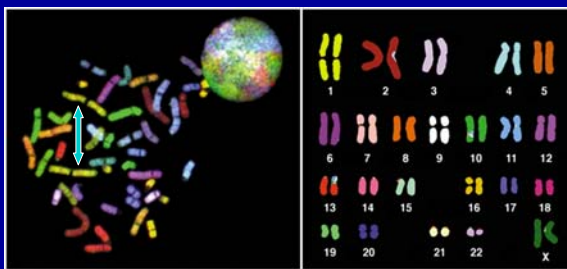
## F. Mitosis: Asexual Reproduction and Genetic Constancy

- The cell cycle can repeat itself many times, forming a clone of genetically identical cells.
- Asexual reproduction produces an organism genetically identical to the parent. Any genetic variety is the result of mutations.

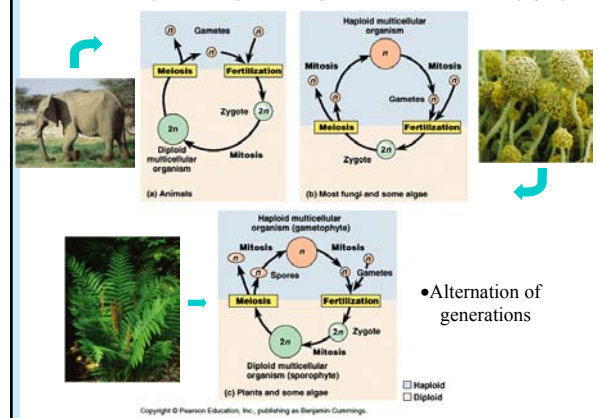
## G. Meiosis: Sexual Reproduction and Diversity

- In sexual reproduction, two haploid gametes—one from each parent—unite in fertilization to form a genetically unique, diploid zygote.
- The number, shape and size of metaphase chromosomes constitute a karyotype.
- Humans have 23 pairs of chromosomes.

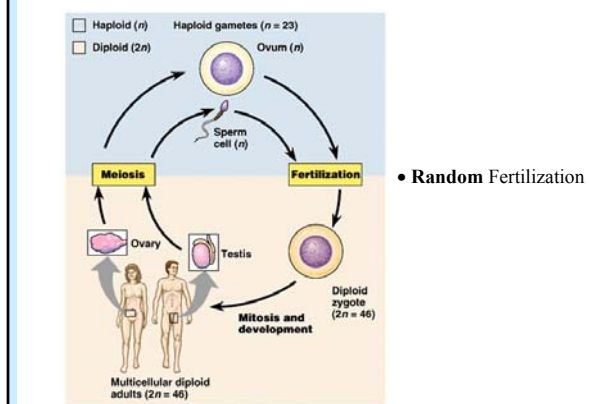
Chromosome Painting and respective Karyotype  
Figure 9.13



Three sexual life cycles differing in the timing of meiosis and fertilization (syngamy)



The human life cycle



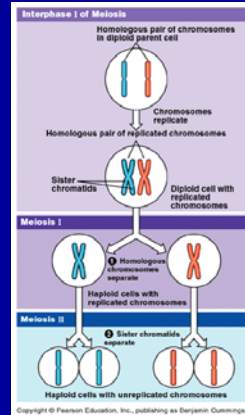
## G. Meiosis: Sexual Reproduction and Diversity

- In sexually reproducing organisms, certain cells in the adult undergo meiosis, whereby a diploid cell produces haploid gametes.
- Each gamete contains a random mix of one of each pair of homologous chromosomes from the parent.
- Zygotes are formed by random fertilization which increases diversity.

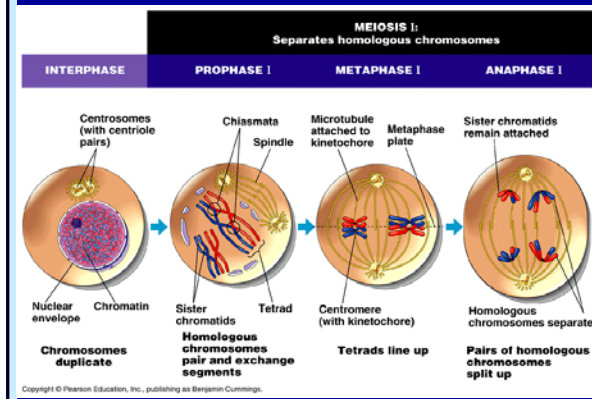
## H. Meiosis: A Pair of Nuclear Divisions

- Meiosis reduces the chromosome number from diploid to haploid and ensures that each haploid cell contains one member of each chromosome pair. It consists of two nuclear divisions.
- We often refer to meiosis as reduction-division.

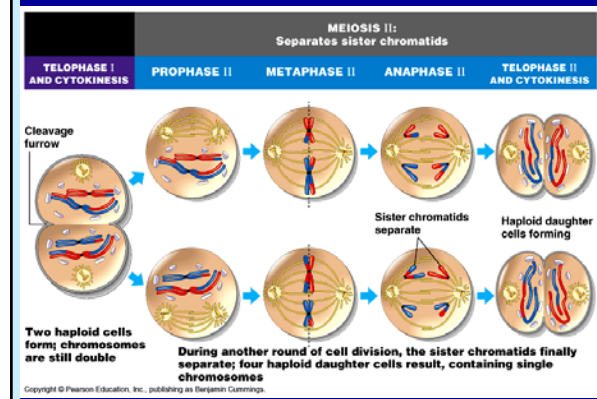
Overview of meiosis: how meiosis reduces chromosome number



The stages of meiotic cell division: Meiosis I

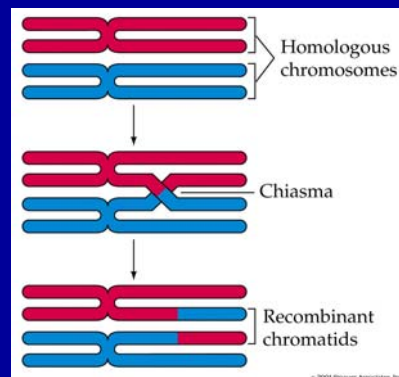


The stages of meiotic cell division: Meiosis II



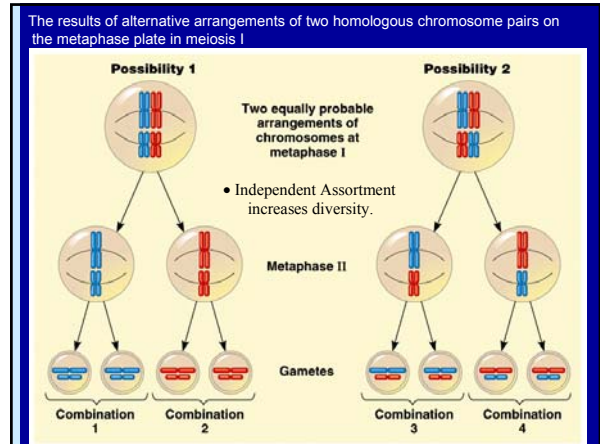
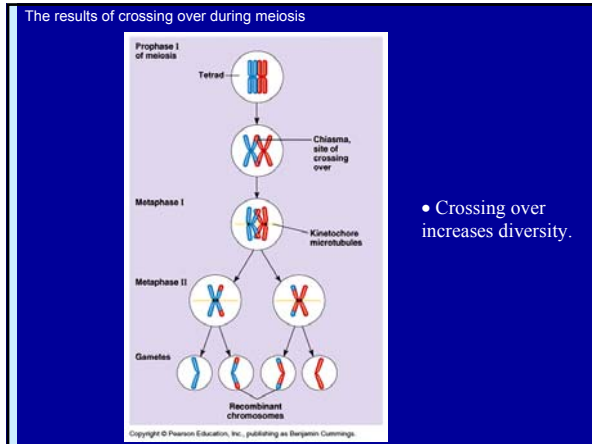
## Meiosis: A Pair of Nuclear Divisions

- During prophase I of the first meiotic division, homologous chromosomes pair, and material may be exchanged by crossing over between nonsister chromatids of two adjacent homologs.
- In metaphase I, the paired homologs gather at the equatorial plate. Each chromosome has one kinetochore and associates with polar microtubules for one pole.
- In anaphase I, entire chromosomes, each with two chromatids, migrate to the poles. By the end of meiosis I, there are two nuclei, each with the haploid number of chromosomes but with two sister chromatids.



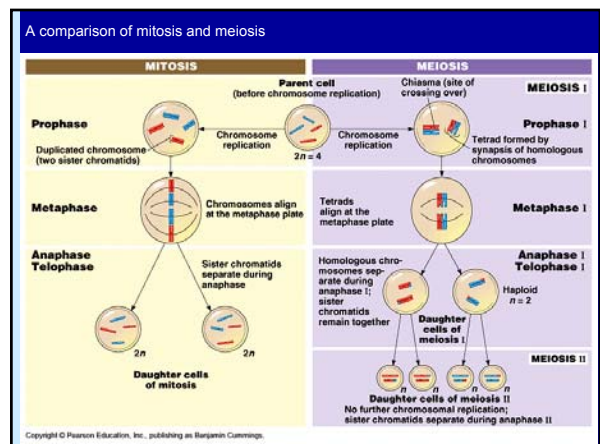
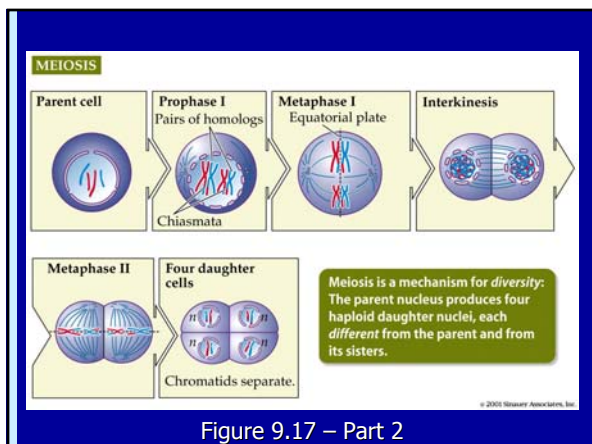
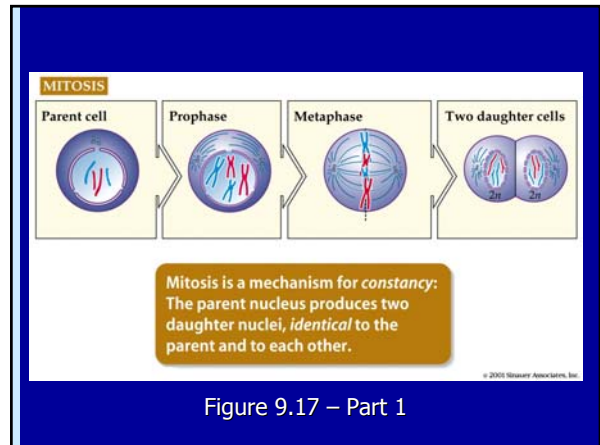
Synapsis: Crossing over of nonsister chromatids.

Figure 9.16



## H. Meiosis: A Pair of Nuclear Divisions

- In meiosis II, the sister chromatids separate. No DNA replication precedes this division, which in other aspects is similar to mitosis. The result of meiosis is four cells, each with a haploid chromosome content.



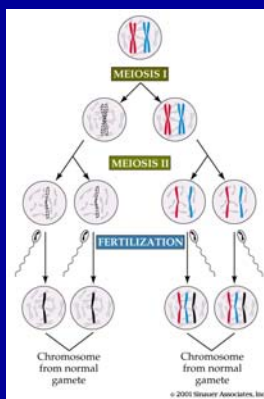


## H. Meiosis: A Pair of Nuclear Divisions

- Both crossing over during prophase I and the random selection of which homolog of a pair migrates to which pole during anaphase I ensure that the genetic composition of each haploid gamete is different from that of the parent AND from that of the other gametes.
- The more chromosome pairs there are in a diploid cell, the greater the diversity of chromosome combinations generated by meiosis.

## I. Meiotic Errors: Source of Chromosomal Disorders

- In nondisjunction, one member of a homologous pair of chromosomes fails to separate from the other, and both go to the same pole. This event leads to one gamete with an extra chromosome and another other lacking that chromosome.
- Fertilization with a normal haploid gamete results in aneuploidy and genetic abnormalities that are invariably harmful or lethal to the organism.



← Nondisjunction in gamete

← Aneuploidy in zygote

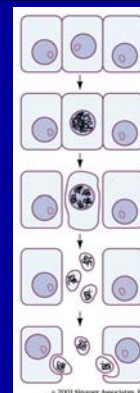
Figure 9.18

## J. Cell Death

- Cells may die by necrosis or may self-destruct by apoptosis, a genetically programmed series of events that includes the detachment of the cell from its neighbors and the fragmentation of its nuclear DNA.

### 9.2 Two Different Ways for Cells to Die

|                    | NECROSIS   | APOPTOSIS  |
|--------------------|--|--|
| Stimuli            | Low O <sub>2</sub> , toxins, ATP depletion, damage | Specific, genetically programmed physiological signals       |
| ATP required       | No   | Yes  |
| Cellular pattern   | Swelling, organelle disruption, tissue death       | Chromatin condensation, membrane blebbing, single-cell death |
| DNA breakdown      | Random fragments                                   | Nucleosome-sized fragments                                   |
| Plasma membrane    | Burst  | Blebbled   |
| Fate of dead cells | Ingested by phagocytes                             | Ingested by neighboring cells                                |
| Reaction in tissue | Inflammation                                       | No inflammation  |



Membrane "Blebbing" by a WBC via apoptosis.

Figure 9.19