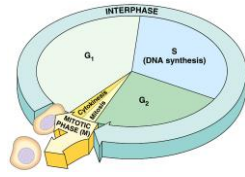
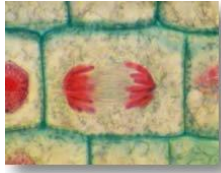


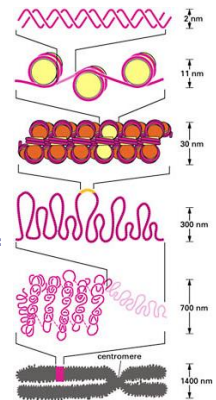
Chapter 11.3 Cell Division



A bit about DNA

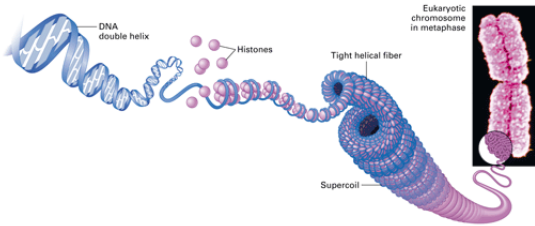
- DNA is organized in chromosomes

- ◆ double helix DNA molecule
- ◆ associated proteins = histone proteins
- ◆ DNA-protein complex = chromatin
 - organized into long thin fiber



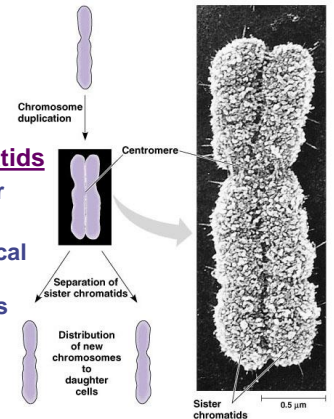
Copying DNA with care...

- After DNA duplication chromatin condenses
 - ◆ coiling & folding to make a smaller package
 - ◆ from DNA to chromatin to highly condensed mitotic chromosome



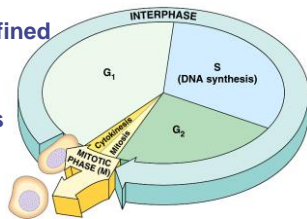
Chromosome

- Duplicated chromosome consists of 2 sister chromatids
 - ◆ narrow at their centromeres
 - ◆ contain identical copies of the chromosome's DNA



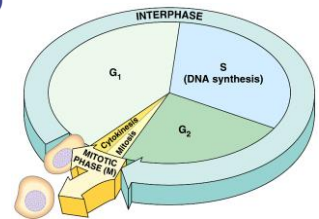
Interphase

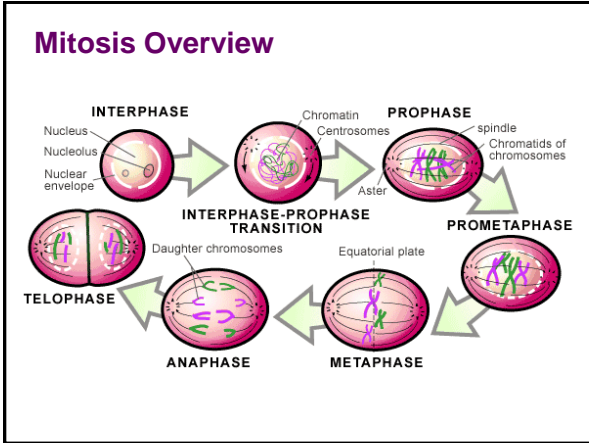
- 90% of cell life cycle
 - ◆ cell doing its "everyday job"
 - produce RNA, synthesize proteins
 - ◆ prepares for duplication if triggered
- Characteristics
 - ◆ nucleus well-defined
 - ◆ DNA loosely packed in long chromatin fibers



Mitosis

- copying cell's DNA & dividing it between 2 daughter nuclei
- Mitosis is divided into 4 (5) phases
 - ◆ prophase
 - ◆ (prometaphase)
 - ◆ metaphase
 - ◆ anaphase
 - ◆ telophase





Prophase

- Chromatin (DNA) condenses
 - visible as chromosomes
 - chromatids
 - fibers extend from the centromeres
- Centrioles move to opposite poles of cell
- Fibers (microtubules) cross cell to form mitotic spindle
 - actin, myosin
- Nucleolus disappears
- Nuclear membrane breaks down

Early mitotic spindle, Centromere, Chromosome, consisting of two sister chromatids

Prometaphase

- Proteins attach to centromeres
 - creating kinetochores
- Microtubules attach at kinetochores
 - connect centromeres to centrioles
- Chromosomes begin moving

PROMETAPHASE
Fragments of nuclear envelope, Kinetochore, Nonkinetochore microtubules, Spindle pole, Kinetochore microtubule

Kinetochores

- Each chromatid has own kinetochore proteins found at the centromere
 - microtubules attach to kinetochore proteins

Kinetochore, Centromere

Metaphase

- Spindle fibers align chromosomes along the middle of cell
 - meta = middle
 - metaphase plate
 - helps to ensure chromosomes separate properly
 - so each new nucleus receives only 1 copy of each chromosome

METAPHASE
Metaphase plate, Spindle

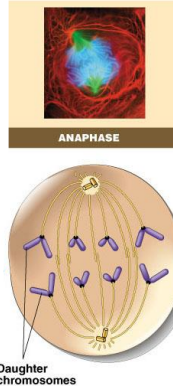
Centrosome (spindle pole), Centriole pair, Aster, Kinetochore, Sister chromatids, Metaphase plate, Overlapping nonkinetochore microtubules, Kinetochore microtubules

Microtubules, Chromosomes, Centromere, Kinetochores

(a) Diagram of two duplicated chromosomes arrayed at the metaphase plate
(b) Transmission electron micrographs

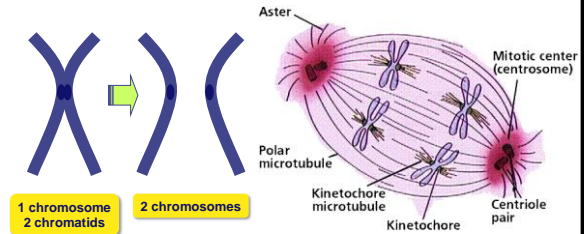
Anaphase

- Sister chromatids separate at kinetochores
 - ◆ move to opposite poles
 - ◆ pulled at centromeres
 - ◆ pulled by motor proteins “walking” along microtubules
 - increased production of ATP by mitochondria
- Poles move farther apart
 - ◆ polar microtubules lengthen



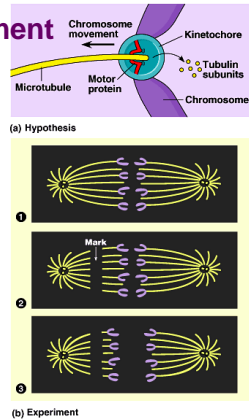
Separation of Chromatids

- In anaphase, proteins holding together sister chromatids are inactivated
 - ◆ separate to become individual chromosomes
 - ◆ **separase** and **securin**



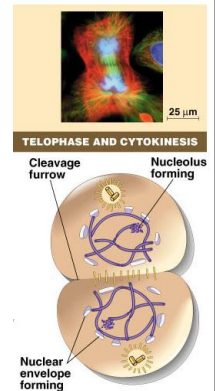
Chromosome Movement

- Kinetochores use motor proteins that “walk” chromosome along attached microtubule
 - ◆ microtubule shortens by dismantling at kinetochore (chromosome attachment) end



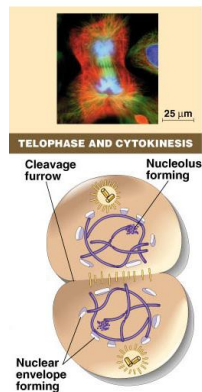
Telophase

- Chromosomes arrive at opposite poles
 - ◆ daughter nuclei form
 - ◆ nucleoli form
 - ◆ chromosomes disperse
 - no longer visible under light microscope
- Spindle fibers disperse
- **Cytokinesis** begins
 - ◆ cell division

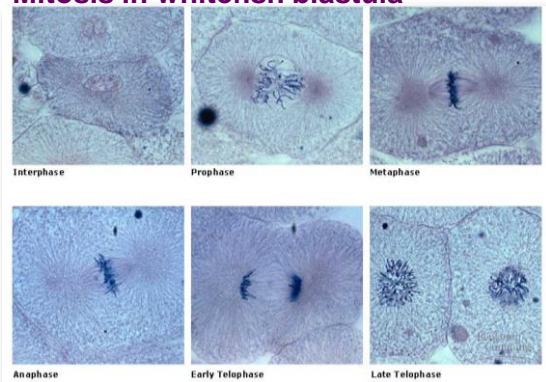


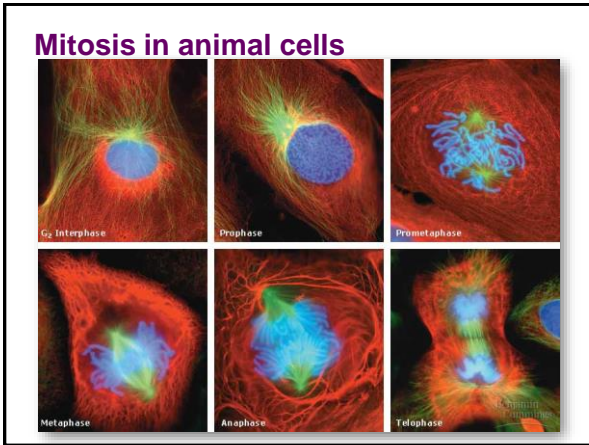
Cytokinesis

- Animals
 - ◆ **cleavage furrow** forms
 - ◆ ring of **actin** microfilaments forms around equator of cell
 - myosin proteins
 - ◆ tightens to form a cleavage furrow, which splits the cell in two
 - like tightening a draw string



Mitosis in whitefish blastula





Cytokinesis in Plants

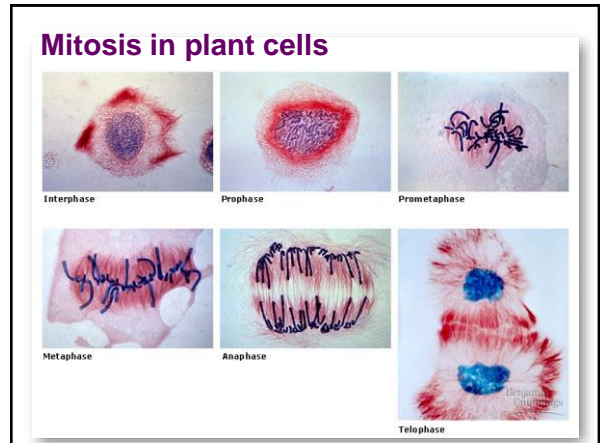
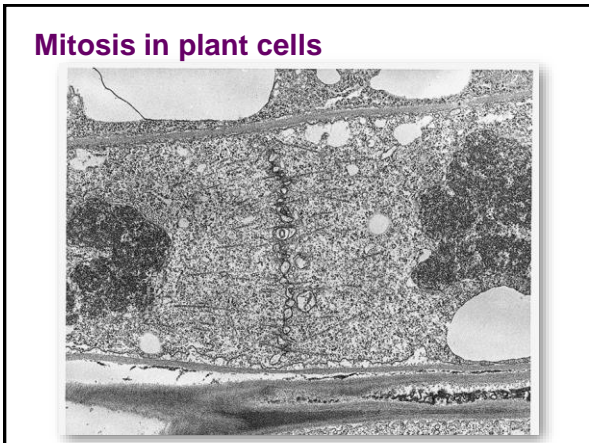
- Plants
 - vesicles move to equator line up & fuse to form 2 membranes = **cell plate**
 - derived from Golgi
 - new cell wall is laid down between membranes
 - new cell wall fuses with existing cell wall

Nucleus of daughter cell Wall of parent cell Vesicles forming daughter cell cell plate Nucleus of daughter cell

Cell wall New cell wall

Vesicles containing cell wall material Cell plate Daughter cells

(b) Cell plate formation in a plant cell



Evolution Link

- Mitosis in eukaryotes likely evolved from **binary fission in bacteria**
 - single circular chromosome
 - no membrane-bound organelles

E. coli cell Plasma membrane Cell wall Bacterial chromosome

- Chromosome replication begins. Soon thereafter, one copy of the origin begins to move toward the other end of the cell.
- Replication continues. One copy of the origin is now at each end of the cell.
- Replication finishes. The plasma membrane grows inward, and new cell wall is deposited.
- Two daughter cells result.

Evolution Link

- Mechanisms intermediate between binary fission & mitosis seen in modern organisms
 - protists

Hypothetical sequence Evidence from modern organisms

Bacterial chromosome (a) Prokaryotes

Chromosomes (b) Dinoflagellates

Microtubules Intact nuclear envelope

Kinetochore microtubules (c) Diatoms

Intact nuclear envelope

Kinetochore microtubules (d) Most eukaryotes

Centrosome Fragments of nuclear envelope