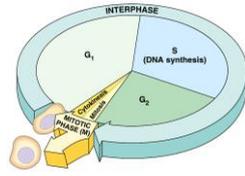
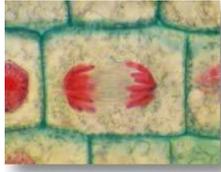


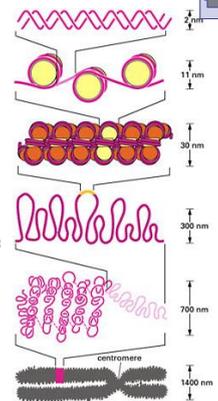
Chapter 11.3 Cell Division



A bit about DNA

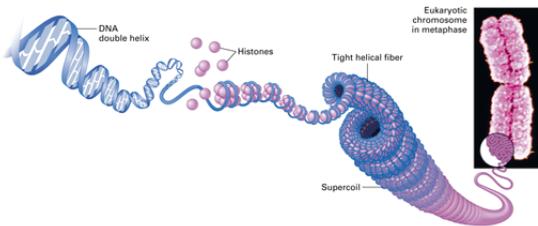
■ DNA is organized in chromosomes

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



Copying DNA with care...

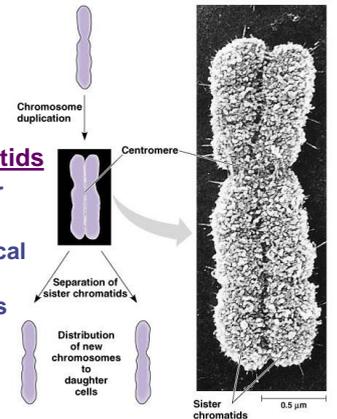
- After DNA duplication chromatin condenses
- ◆ coiling & folding to make a smaller package
 - ◆ from DNA to chromatin to highly condensed mitotic chromosome



Chromosome

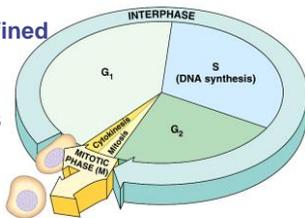
■ Duplicated chromosome consists of 2 sister chromatids

- ◆ 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

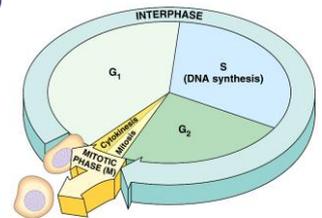


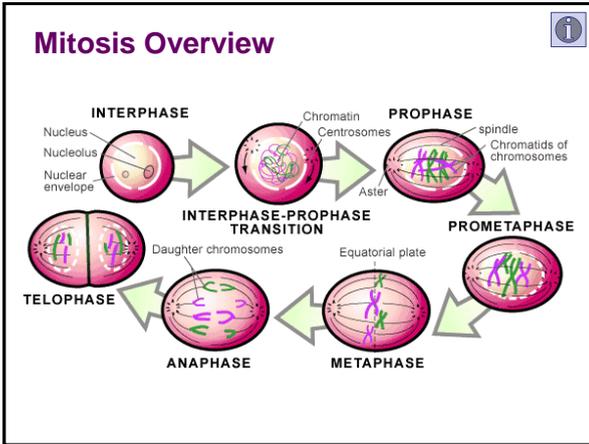
Mitosis

■ 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

PROPHASE
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, Kinetochores, Nonkinetochore microtubules, Spindle pole, Kinetochores microtubule

Kinetochores

- Each chromatid has own kinetochore proteins
 - 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

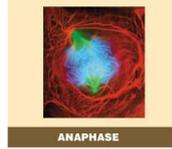
METAPHASE
Metaphase plate, Spindle

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

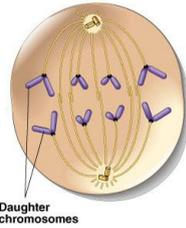
(a) Diagram of two duplicated chromosomes arrayed at the metaphase plate
(b) Transmission electron micrographs

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



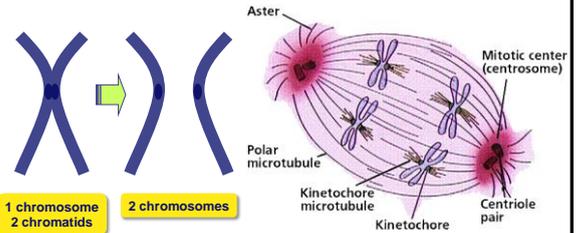
ANAPHASE



Daughter chromosomes

Separation of Chromatids

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

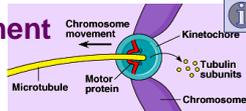


1 chromosome
2 chromatids

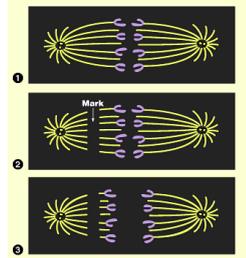
2 chromosomes

Chromosome Movement

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



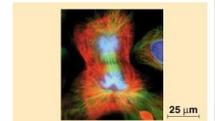
(a) Hypothesis



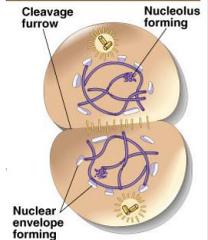
(b) Experiment

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

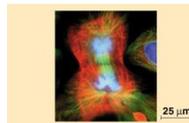


TELOPHASE AND CYTOKINESIS

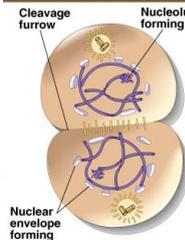


Cytokinesis

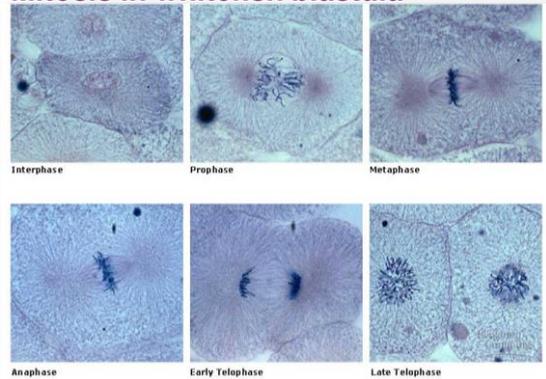
- Animals
 - ◆ **cleavage furrow** forms
 - ◆ ring of **actin** microfilaments forms around equator of cell
 - myosin proteins
 - ◆ tightens to form a cleavage furrow, which splits the cell in two
 - like tightening a draw string

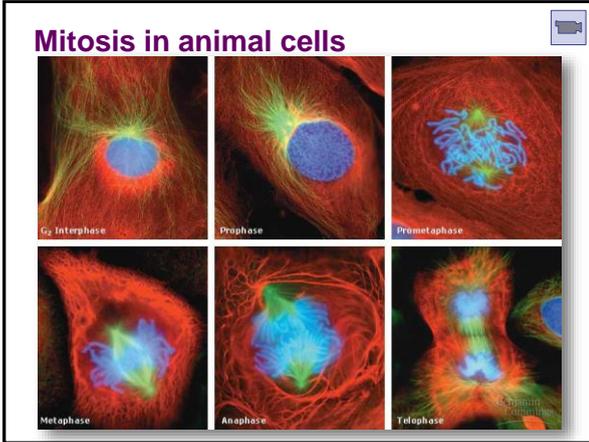


TELOPHASE AND CYTOKINESIS



Mitosis in whitefish blastula

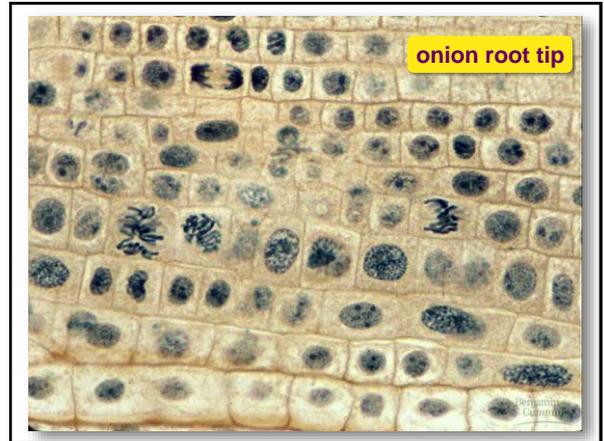
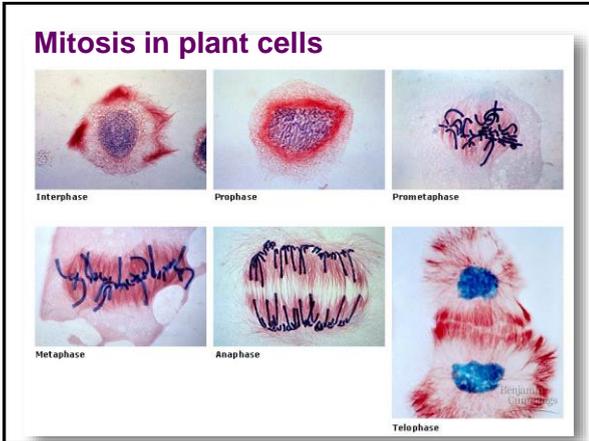




Cytokinesis in Plants

- 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

(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

Origin of replication Plasma membrane
 Cell wall
 E. coli cell Bacterial chromosome
 Two copies of origin
 Origin Origin
 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
 Centrioles
 Fragments of nuclear envelope