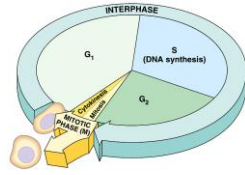
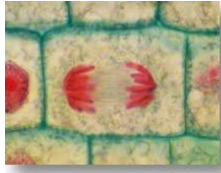
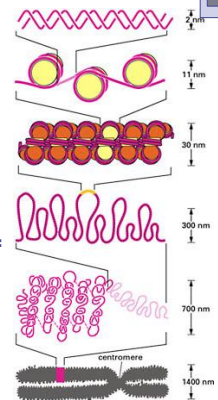


## Chapter 9 Cell Division



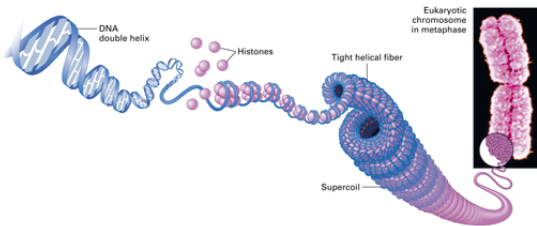
### A bit about DNA

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



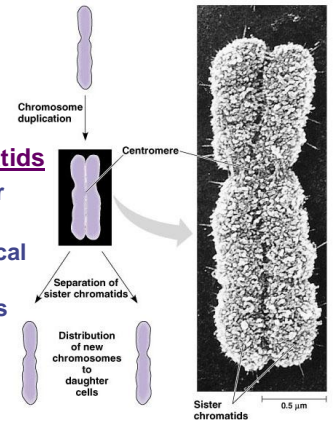
### Copying DNA with care...

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



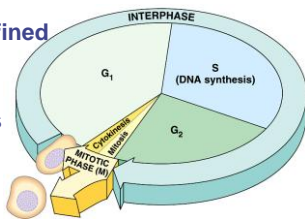
### Chromosome

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



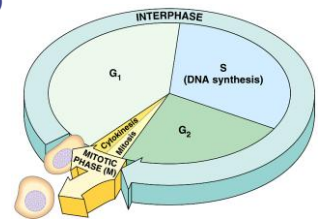
### Interphase

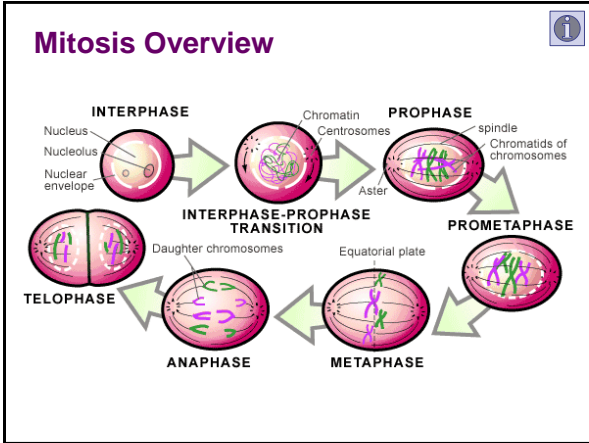
- 90% of cell life cycle
  - ◆ cell doing its "everyday job"
    - produce RNA, synthesize proteins
  - ◆ prepares for duplication if triggered
- Characteristics
  - ◆ nucleus well-defined
  - ◆ DNA loosely packed in long chromatin fibers



### 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, Kinetochores, Nonkinetochore microtubules, Spindle pole, Kinetochore 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, Kinetochores, Sister chromatids, Metaphase plate, Overlapping nonkinetochore microtubules, Kinetochore microtubules

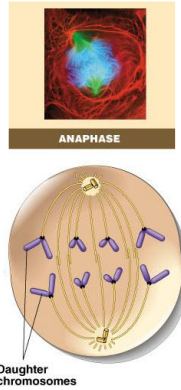
(a) Diagram of two duplicated chromosomes arrayed at the metaphase plate

(b) Transmission electron micrographs

Microtubules, Chromosomes, Centrosome, Kinetochores, 1 µm

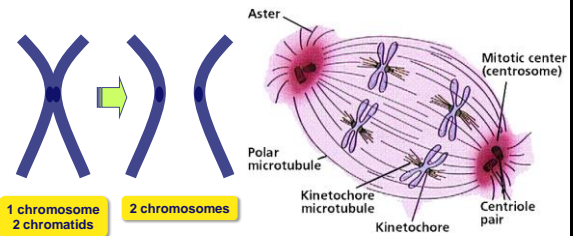
### Anaphase

- 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



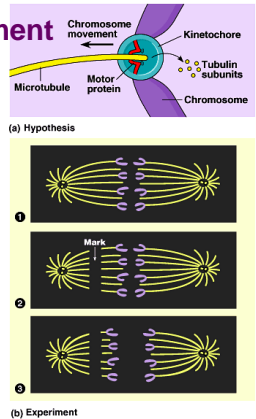
### Separation of Chromatids

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



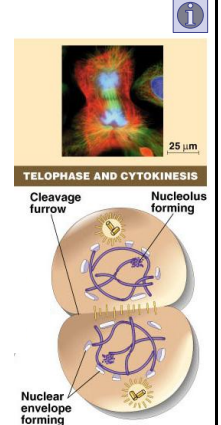
### Chromosome Movement

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



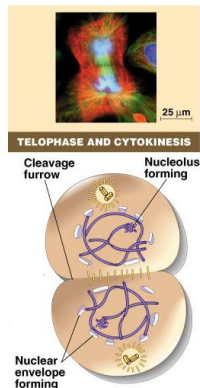
### Telophase

- 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

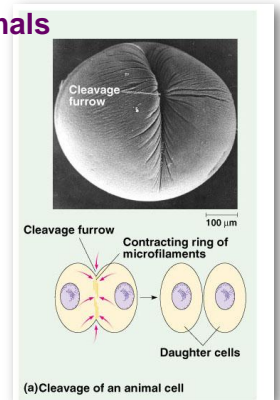


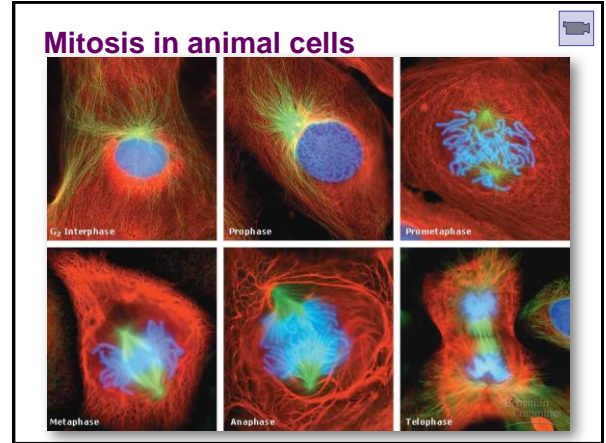
### Cytokinesis

- 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



### Cytokinesis in Animals

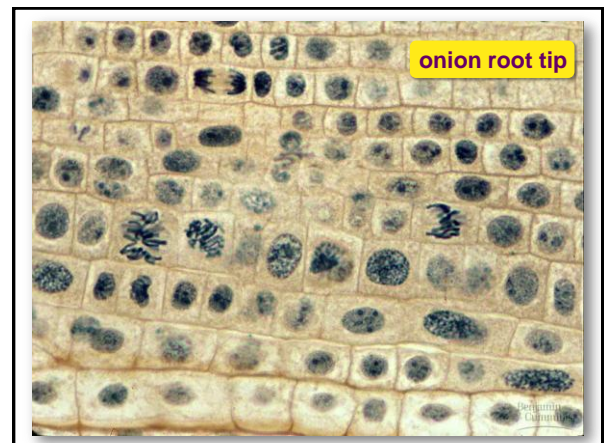
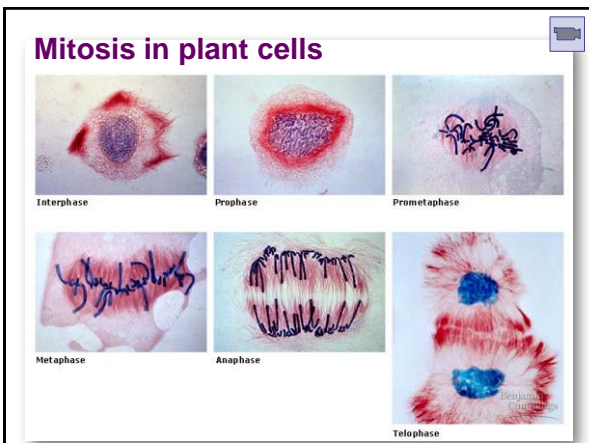
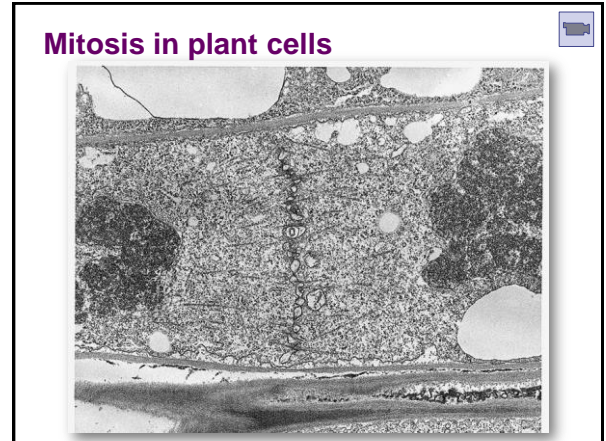




### Cytokinesis in Plants

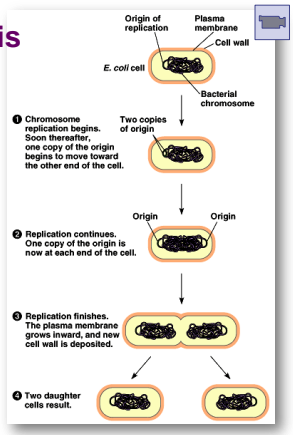
- Plants
  - ◆ vesicles move to equator line up & fuse to form 2 membranes = **cell plate**
    - derived from Golgi
  - ◆ new cell wall is laid down between membranes
    - new cell wall fuses with existing cell wall

(b) Cell plate formation in a plant cell



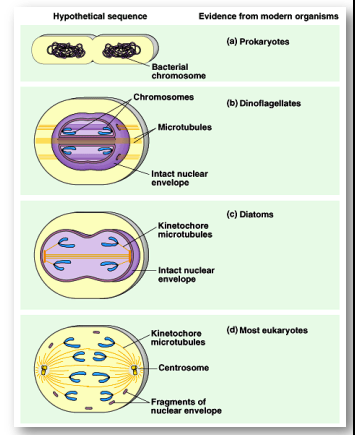
### Evolution of mitosis

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



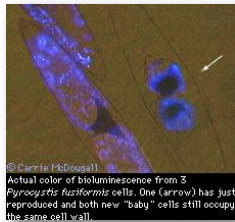
### Evolution Link

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



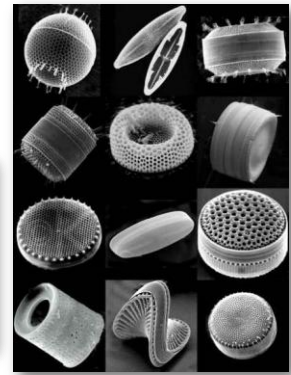
### Dinoflagellates

- algae
- ◆ "red tide"
- ◆ bioluminescence



### Diatoms

- microscopic algae
- ◆ marine
- ◆ freshwater



Any Questions??