The Cell Cycle

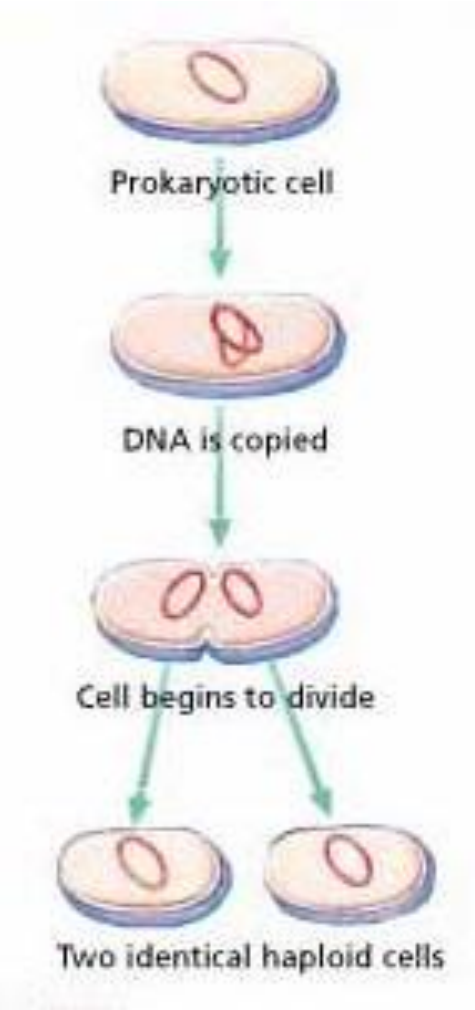
Chapter 12

Key Roles of Cell Division

1. Continuity of life is based on reproduction of cells, or cell division
2. Reproduction of an entire organism; ex: an amoeba is a one celled organism.
3. Production of progeny from multicellular organisms. Ex: plant cuttings
4. Sexually reproducing organisms from single cell (fertilized egg → fetus → infant)
5. Renewal & repair of damaged or worn out cells

Cell Division Roles

- Prokaryotic cells
  - Binary fission = reproduction
  - Origin of Replication = point where replication begins in bacteria DNA
- Eukaryotic cells
  - Development, growth, and repair



Cell Cycle

- Cell cycle – life of a cell from the time it is formed until its own division into two daughter cells
  - Passes identical genetic material to cellular offspring.

Cellular Organization
Genetic Material

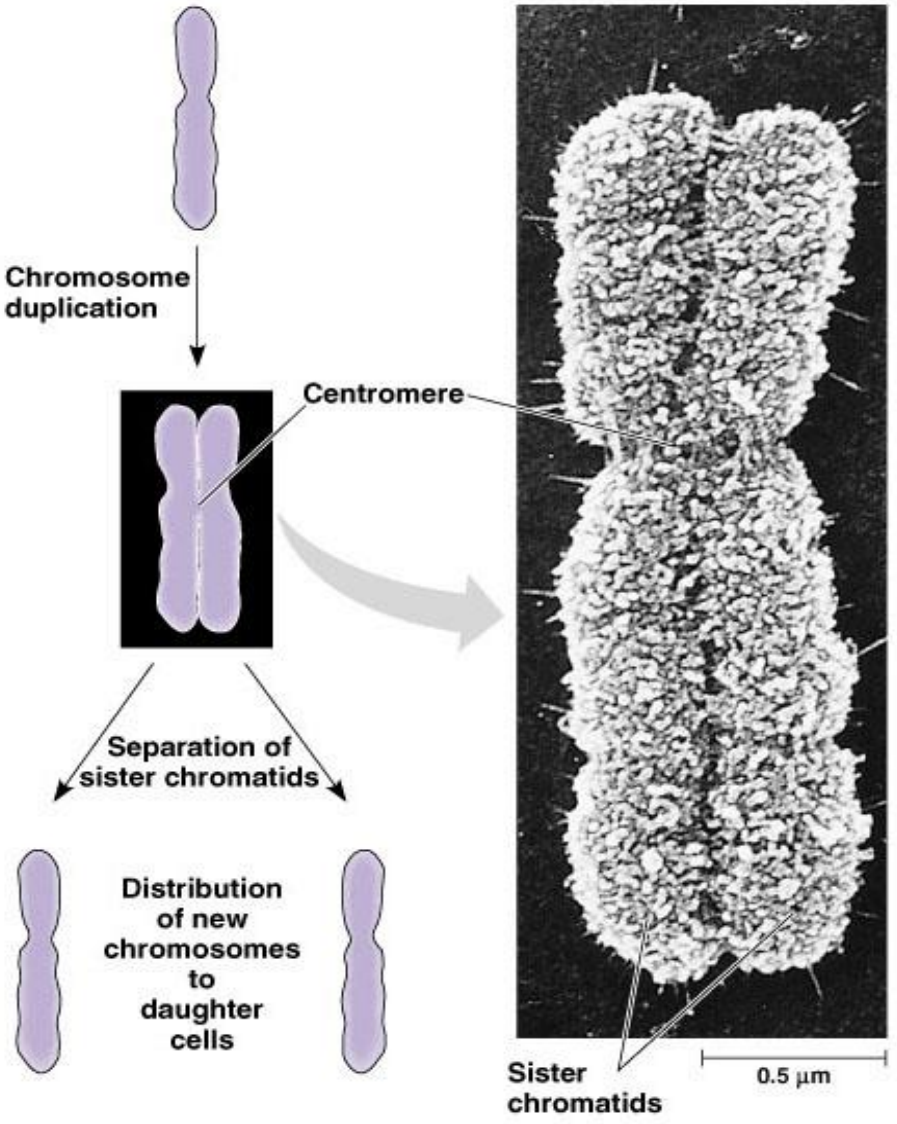
- **DNA** – cell's genome, genetic material
  - Typical human has ~ 2n of DNA
  - All new cells will have an EXACT copy of the DNA
- **Chromosomes** – coiled DNA
  - Structure that contains all the cell's packaged DNA
  - Eukaryotic chromosomes made of **chromatin** – complex of DNA and associated proteins that helps maintain the structure of the chromosome
  - Each chromosome carries 100s-1000s of genes

Chromosome Numbers

- Each organism has a characteristic number of chromosomes.
- Human somatic cells (body cells) have 46 chromosomes
- Gametes (reproductive cells – sperm / egg) have half the # of chromosomes (human eggs and sperm have 23 chromosomes).

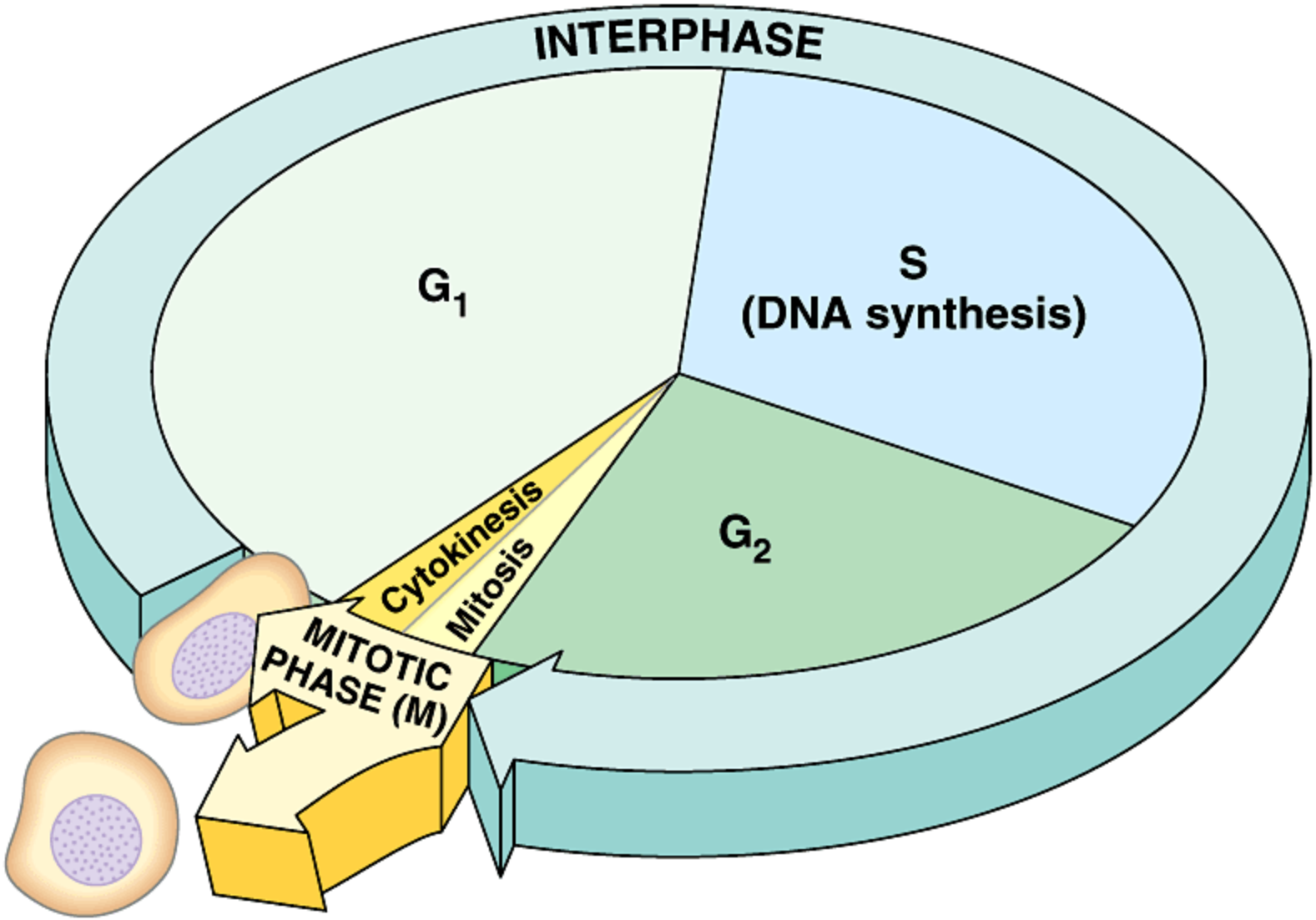
Chromosome Structure

- Non-dividing cells' chromosomes are in the form of **CHROMATIN**
- Following DNA replication chromosomes coil & condense
- Duplicated chromosomes have 2 halves = **SISTER CHROMATIDS**
- Chromatids are connected by a **CENTROMERE**



Phases of the cell cycle

- Interphase (90% of cell's life)
  1. G_1 Phase
  2. S Phase
  3. G_2 Phase
- M phase – mitotic phase (10% of cell's life)
  1. Prophase
  2. Metaphase
  3. Anaphase
  4. Telophase
- Cytokinesis



Interphase

- Accounts for ~ 90% of cell's cycle
- Cell grows and copies chromosomes
- Divided into 3 subphases:
  1. G_1 (first gap)
  2. S phase (synthesis)
  3. G_2 (second gap)
  - During all 3 subphases cell grows by producing proteins & cytoplasmic organelles

- Human cell takes ~ 24 hours to divide
  - Chromosomes duplicated during s-phase (10-12hrs)
  - Cell grows in G1 (5-6hrs)
  - Cell continues to grow in G2 (4-6hrs)
  - M phase (< 1 hr)

MITOSIS

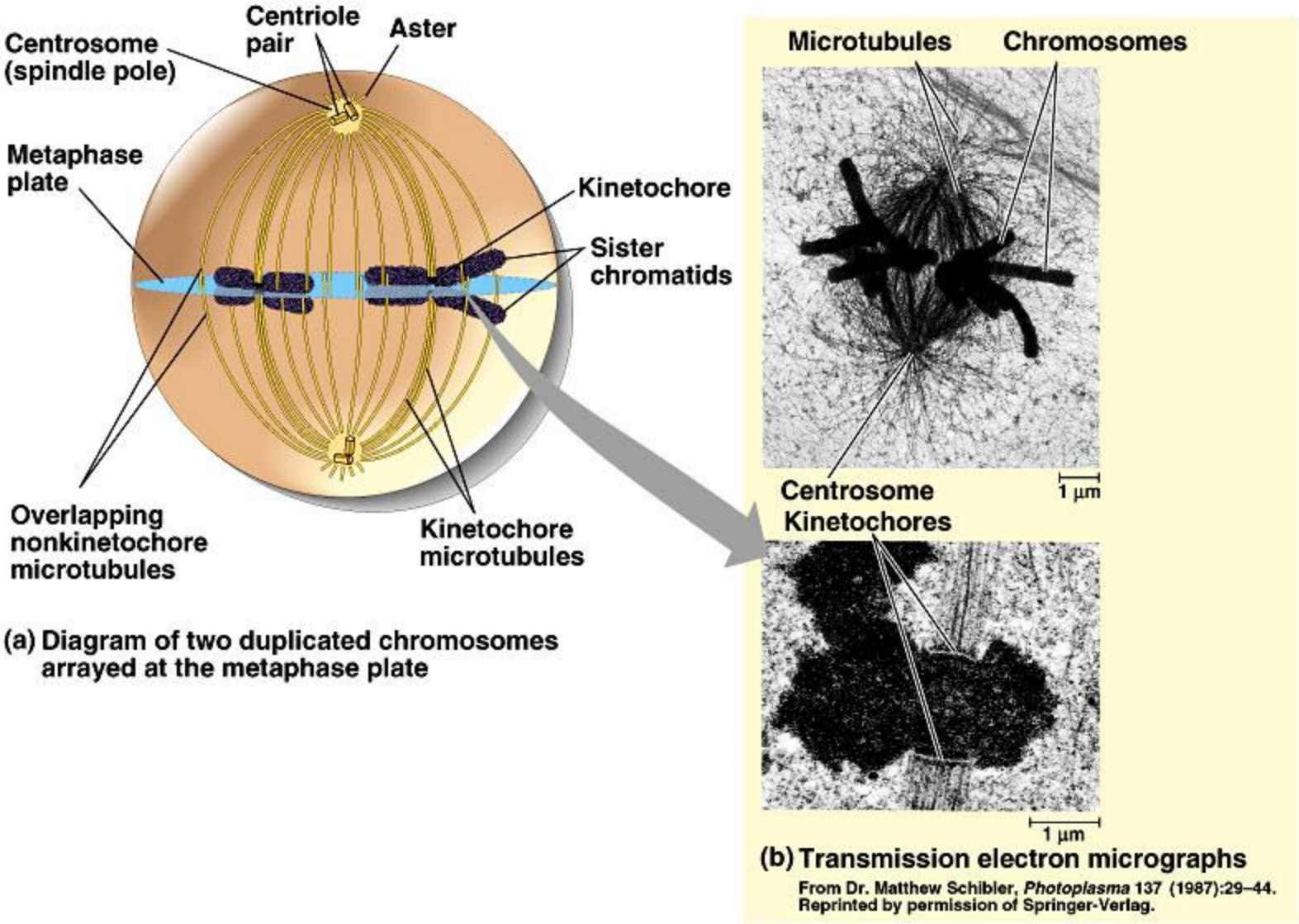
- **MITOSIS** - Division of the **NUCLEUS**
- **CYTOKINESIS** = division of the cytoplasm
  - Human body ~ 200 trillion somatic cells (we all started as one)
  - Mitosis **MAINTAINS** the chromosome number
    - If a cell begins w/ 46 chromosomes, the new cell will have 46 chromosomes.

Cytoskeleton – Role in Cell Cycle

- Microtubules
  - Hollow tubes that move chromosomes
  - Centrioles – 9 sets of triplet microtubules
  - Centrosome – microtubule-organizing center near the nucleus
- Microfilaments
  - Actin – 2 strands intertwined
  - Helps with cleavage furrow formation

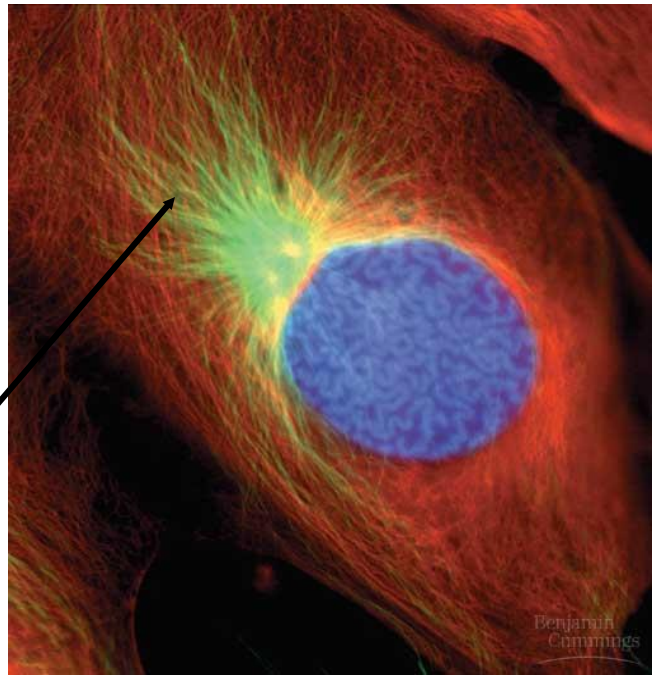
Structures involved in cell division

1. **Spindle fibers** (mitotic spindle) – fibers made of microtubules and associated proteins that move the chromosomes during division
2. **Centrosome** – nonmembranous organelle that organize and produce the spindle
   - Single centrosome replicates during interphase
   - **Asters** – radial arrays of microtubules forming from the centrosome
3. **Kinetochore** – group of proteins associated with sections of chromsomal DNA at the centromere
   - Place of microtubule attachment



M phase – Mitosis - **Prophase**

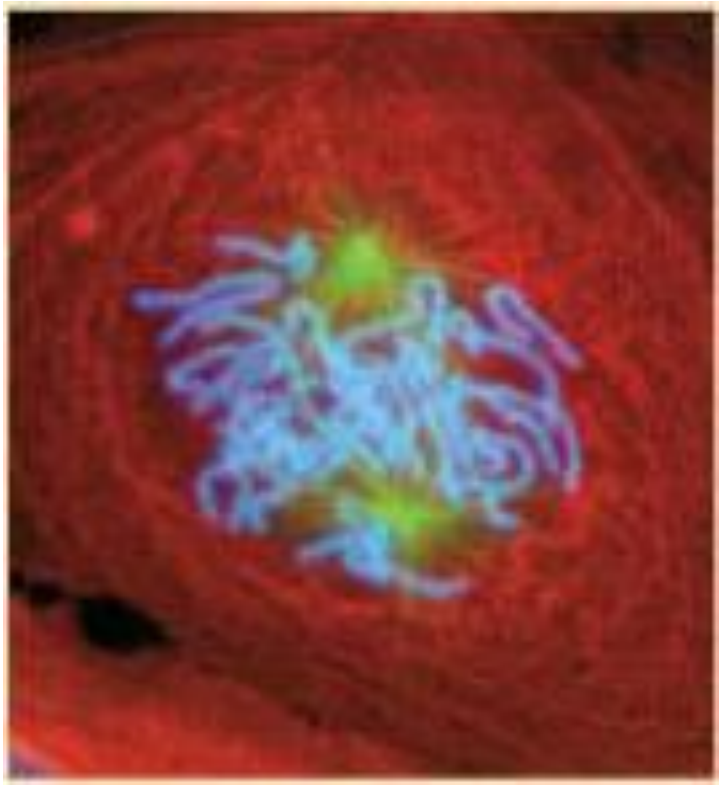
- Chromatin condenses into chromosomes becoming visible under light microscope
- Nucleoli disappear
- Duplicated chromosomes w/ 2 sister chromatids
- Mitotic spindles form
- Lengthening of spindles pushes centrosomes away from each other.



•**Lung cells from newt**
•22 chromosomes
•Chromosomes- blue
•Microtubules- green
•Intermediate filaments- red

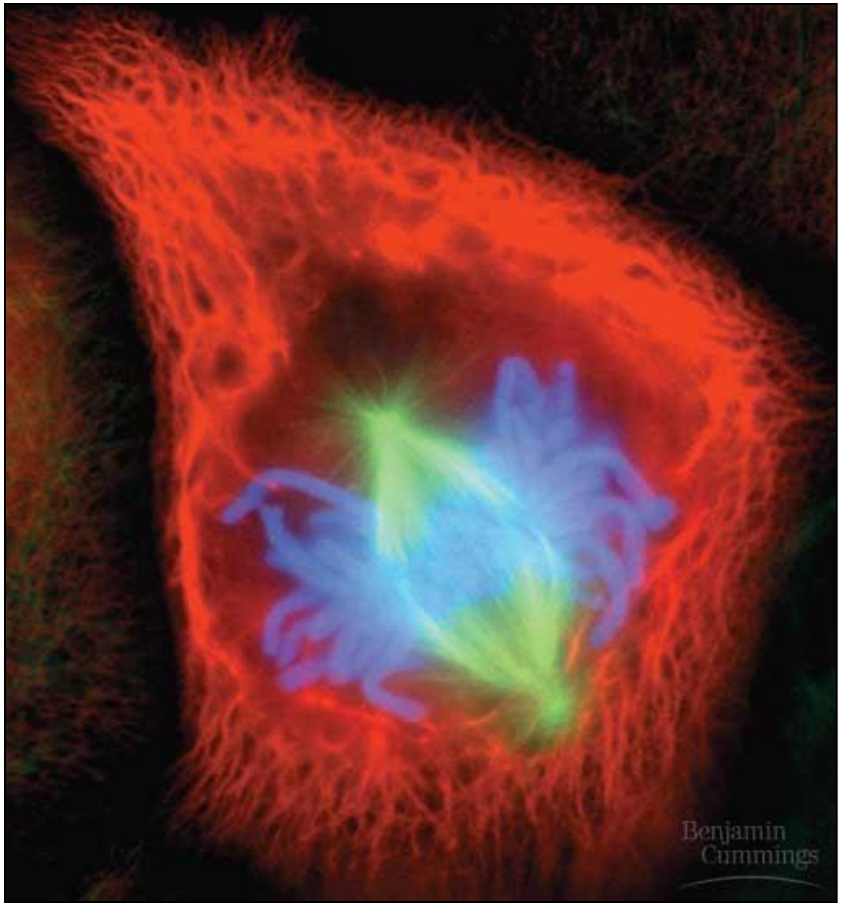
M phase – Mitosis - **Prometaphase**

- Nuclear envelop starts to breakup
- Microtubules can now interact with chromosomes and attach to centromere
- Each chromatid now has a kinetochore
- Nonkinetochore mircotubules interact with those on the opposite pole



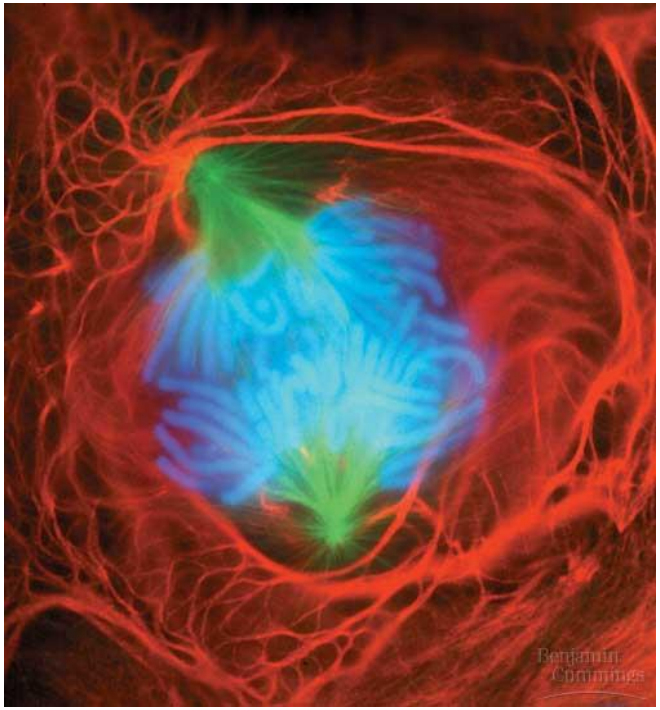
M phase – Mitosis – **Metaphase**

- Longest stage of mitosis ~ 20 minutes
- Centrosomes to opposite ends
- Chromosomes line up at equator = **metaphase plate**; middle of the cell because of tugging from kinetochore microtubules
- Microtubules that originate from the centrosomes are attached to each side of the sister chromatid's kinetochore
- Microtubule = spindle b/c of shape.



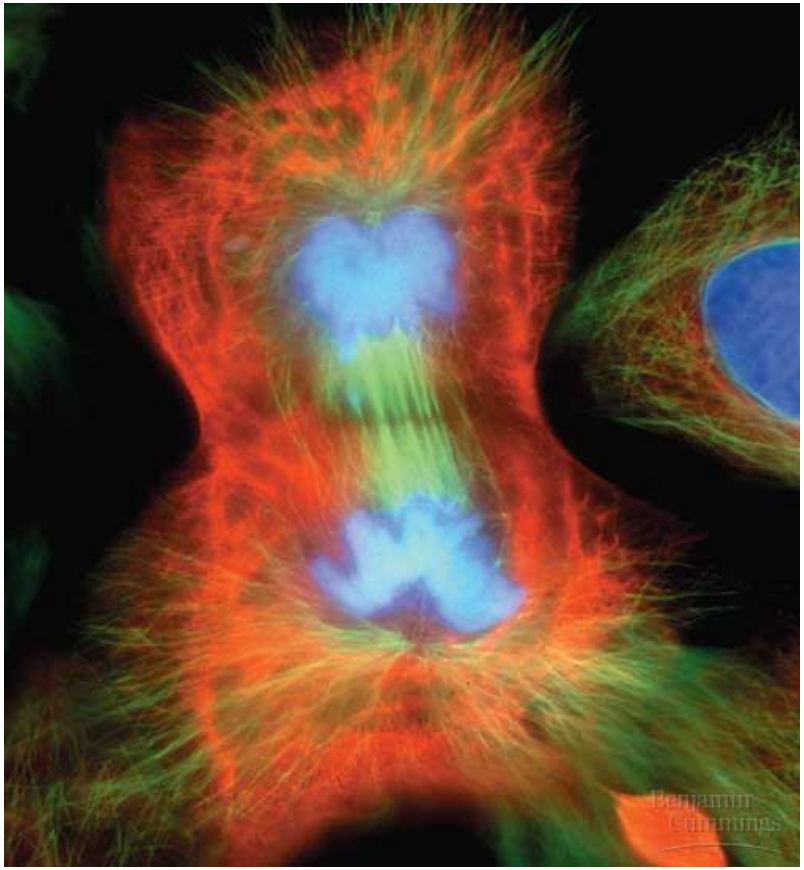
M phase – Mitosis – **Anaphase**

- Shortest stage
- Sister chromatids are pulled apart by microtubules (spindle fibers)
  - Caused by action of motor proteins as they depolymerize the kinetochore microtubules at the kinetochore end
  - This action shortens the fibers
- Chromosomes move toward opposite ends of cell
- Cell elongates – due to nonkinetochore microtubules moving past one another also using motor proteins
- End of anaphase, two ends of cell have EQUIVALENT & complete new set of chromosomes



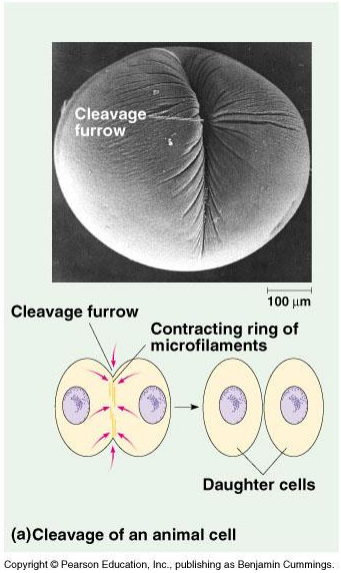
M phase – Mitosis – **Telophase**

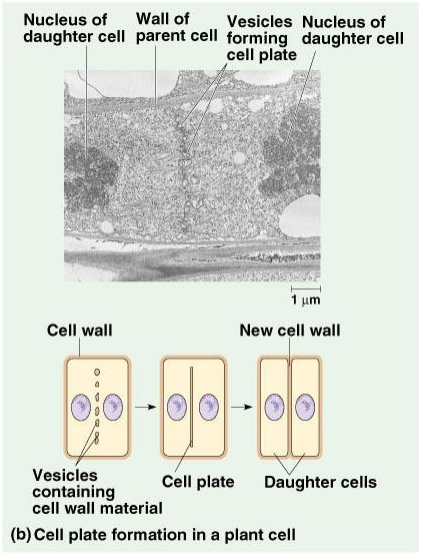
- Daughter cell nuclei and nucleoli begin to form
- Nuclear envelop forms around each set of chromosomes
- Chromosomes uncoil to chromatin state
- Nuclear division is complete



M phase – Mitosis – **Cytokinesis**

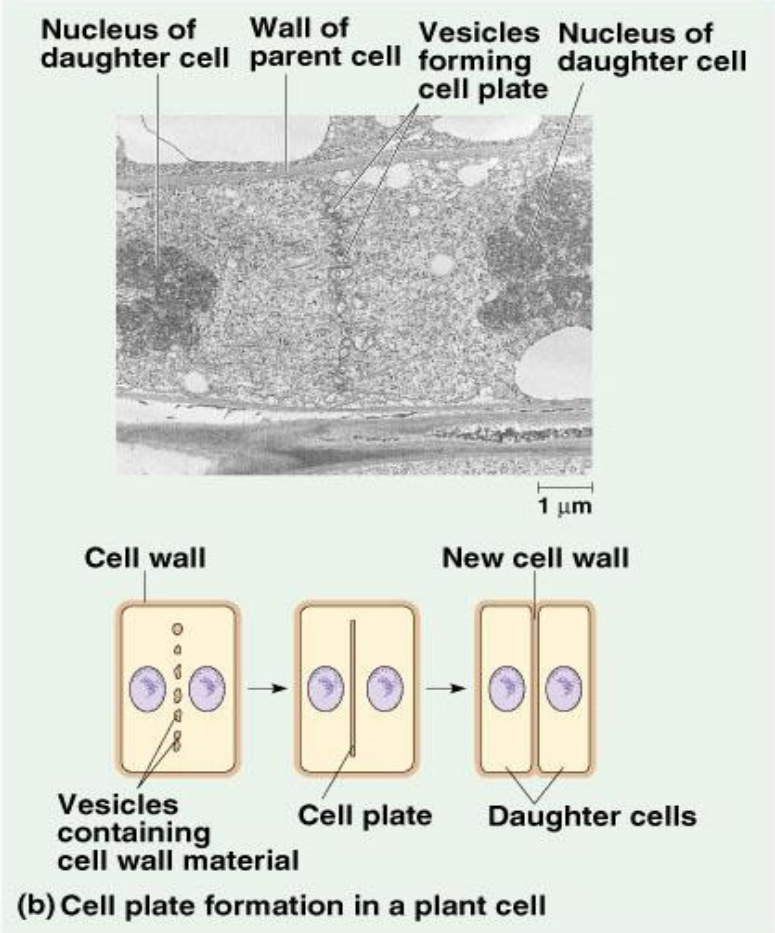
- Animal cells
  - Cleavage – process that separates the two daughter cells
  - Cleavage furrow – when a rin of actin forms on the cell surface and then interacts with myosin protein
    - It begins to contract until the cell is divided





M phase – Mitosis – **Cytokinesis**

- Plant Cells
  - Cell plate – forms from the fusion of membrane vesicles made from the golgi apparatus
  - Deposits of cell wall material are collected in cell plate
  - Plasma membrane forms followed by cell wall from cell plate contents.



Cell Cycle Control

- 3 checkpoints throughout the cell cycle
  - G1, G2, and M
- Cyclin dependent kinases
- Cyclin increases in number in the S phase and then breaks down after Mitosis

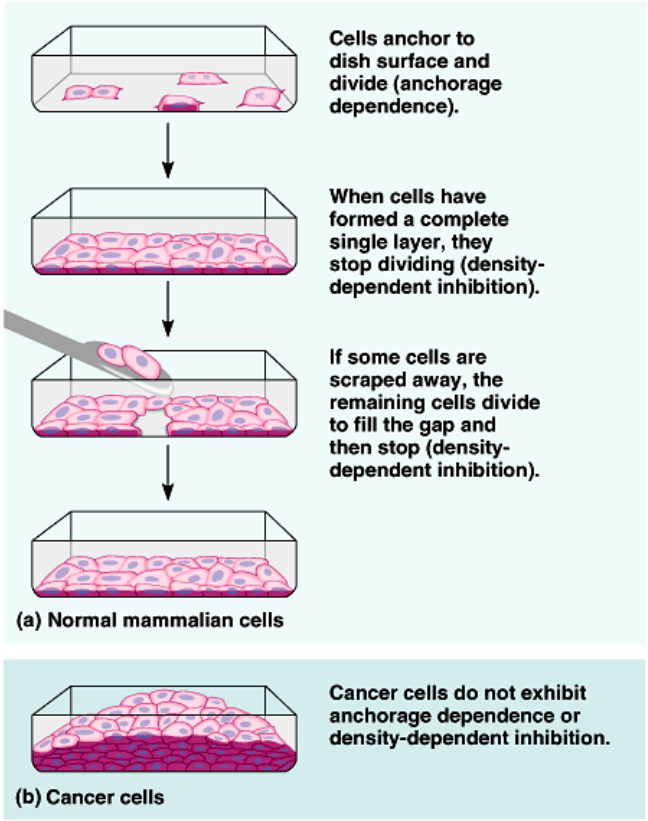
- Cyclin binds to Cdks to activate them
  - Becomes Mitosis promoting factor - MPF

Cell Cycle regulation

- Growth factors = proteins released by certain cells that stimulates other cells to divide
  - Platelet derived growth factor – PDGF
    - Released from platelets
    - Bind to tyrosine kinase receptors on cells called fibroblasts (cells that aid in wound healing)
    - Triggers the fibroblasts to move past the G1 checkpoint

Cell Cycle regulation

- Density-dependent inhibition = phenomenon where crowded cells stop dividing
  - In the lab, cells will fill a space. When some cells are removed, mitosis is triggered and the cells divide to fill the space again



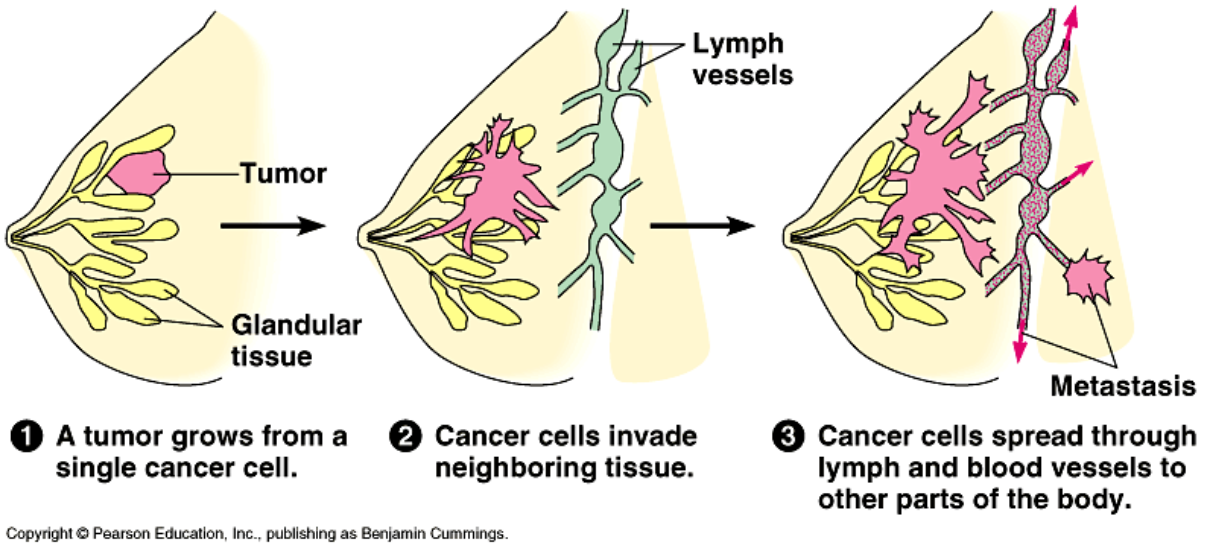
Cell Cycle regulation

- Anchorage dependence = to divide, cells must be attached to a substratum

- Cancer cells do not exhibit density-dependent inhibition or anchorage dependence
  - Normally cells undergo apoptosis when an irreparable mistake occurs in DNA replication, but cancer cells bypass that normal control

Cancer

- Transformation – normal cell to cancer cell
- Tumor: benign or malignant
- Metastasis



- HeLa Cell video