


Mitosis & the Cell Cycle

The Cell Cycle



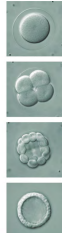
The Cell Theory "Cell Doctrine"

1. All organisms are constructed of one or more cells.
2. The cell is the basic unit of life.
3. All cells arise from previous cells.


"Omnis cellula e cellula!"

Cellula e Cellula


- * Growth & Development
 - New cells produced
 - Need the right number of cells in the right location
 - Either too few or too many is bad.
- * Cell Replacement
 - Lost or damaged cells replaced
- * Reproduction
 - New organism formed



Sea urchin embryo





Sea star regenerating



Budding Hydra

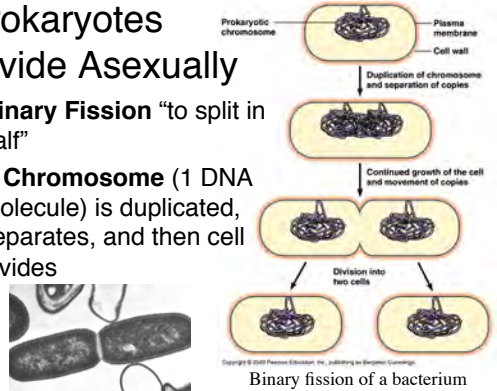
Cellula e Cellula

- * Cells divide to reproduce

- I. **Asexual Reproduction** offspring from single parent
 -  Sea star regenerating an arm
- II. **Sexual Reproduction** offspring from union of egg and sperm (DNA from both parents)
 -  Sperm cells and egg cell

Prokaryotes Divide Asexually

- * **Binary Fission** "to split in half"
- * A **Chromosome** (1 DNA molecule) is duplicated, separates, and then cell divides



Prokaryotic chromosome

Plasma membrane

Cell wall

Duplication of chromosome and separation of copies


Continued growth of the cell and movement of copies

Division into two cells

Binary fission of a bacterium

Eukaryotic Cells Have Multiple Chromosomes

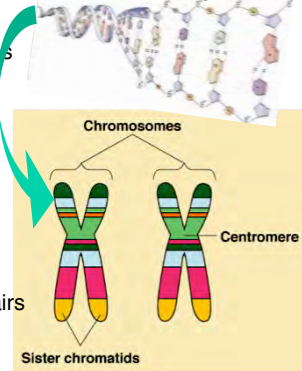
- * In division, each new cell needs the correct number and kind of chromosomes
 - Humans have 46 different chromosomes
- * Replicate and divide chromosomes in nucleus
- * Distribution of organelles



Cellular Division Vocabulary

Levels of Doubles —

- * Each chromatid contains double-stranded DNA
 - Two **complementary** strands
- * Each *uplicated* chromosome contains sister chromatids
 - Two **identical** sisters
- * In *diploid* organisms, chromosomes are in pairs
 - Two **homologous** chromosomes



Chromosomes

Sister chromatids

Centromere

Mitosis & the Cell Cycle

Chromosomes Must Duplicate Before Division

Human duplicated chromosome

Chromosome duplication and separation

The Cell Cycle

- * Ordered sequence of events in a cell's life
- * **Interphase ($G_1/S/G_2$):** 90% of cell cycle
 - Most cellular activity
- * **Mitotic phase (M)**
 - Mitosis = nucleus divides
 - Cytokinesis = cytoplasm & plasma membrane divides

The eukaryotic cell cycle

The Cell Cycle

Interphase:

1. **G_1 :** Growth stage, part 1
 - Cell is metabolically active and grows larger
2. **S:** Synthesis stage
 - DNA is replicated
3. **G_2 :** Growth stage, part 2
 - More metabolism & growth

The eukaryotic cell cycle

S Stage —

All cell reproduction requires DNA duplication

- * Each cell must have its own copy of genetic material
 - **DNA replication in S Stage of Interphase**
- * Then DNA must be separated (**segregation**) so that each cell has a complete copy
 - **Mitosis of Mitotic Phase**

Replication of chromosomes

- * Chromosomes are unduplicated at start of cell cycle (End of Mitotic Phase/ Start of G_1)
- * Chromosomes are duplicated before cell divides (End of G_2 / Start of Mitotic Phase)

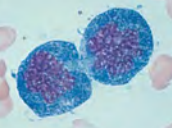
Duplicated chromosomes

- * Duplicated chromosome (**dyad**): two sister **chromatids**
- * Sister chromatids contain identical DNA
- * Sister chromatids are held together at their **centromeres** by **cohesin** proteins

Mitosis & the Cell Cycle

Variation in Rates of Cell Division

- * Divide Constantly and Rapidly
 - Skin
 - Epithelial (most)
 - Bone Marrow Cells
 - Spermatogonia (after puberty)
- * Divides under certain circumstances
 - Liver Cells
 - Epithelial Cells surrounding egg
- * Do Not Divide in Adulthood
 - Most Nerve Cells
 - Osteocytes
 - Most Muscle Cells

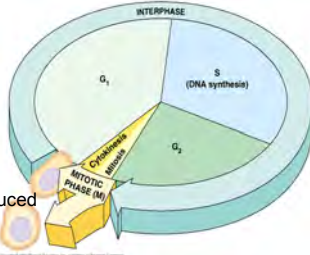


The Cell Cycle

Typical Human Cell Cycles:

1. **S Stage:** 10–12 hrs
2. **G₂ Stage:** 4–6 hrs
3. **M Phase:** <1 hr
4. **G₁ Stage:** variable
 - Many epithelial cells divide daily
 - G₁ = 5–6 hrs
 - Liver cells hold until induced
 - G₁ = many days*
 - Neurons stop dividing
 - G₁ = the rest of your life*

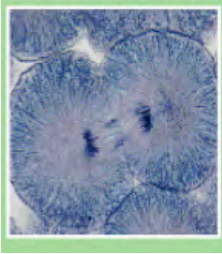
* [on hold in G₁ = "G₀"]



The eukaryotic cell cycle

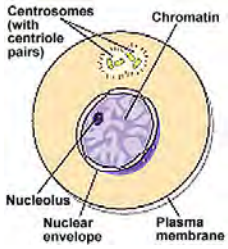
Mitotic Division

1. **Asexual (Mitotic) Reproduction**
 - a. **Mitosis:** production of two identical nuclei
 - b. **Cytokinesis:** physical division of the cell into two cells



Mitotic Division

- * Division of **Somatic** (body) cells
- * Mitosis does NOT include Interphase
 - But remember: Replication already occurred in Interphase S Stage
- * Mitosis is the division of one nucleus to form two new identical nuclei

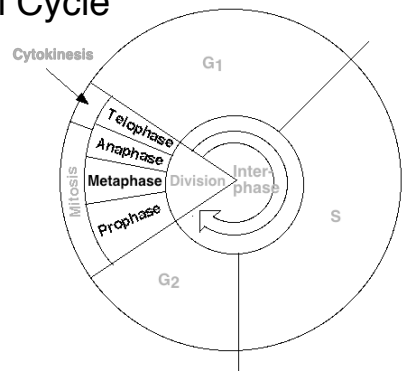


Interphase — before and after mitosis

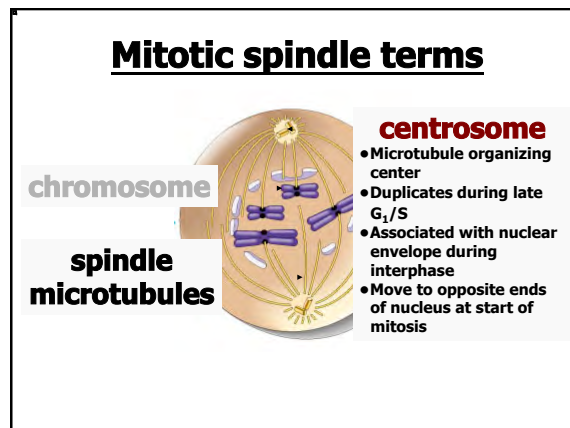
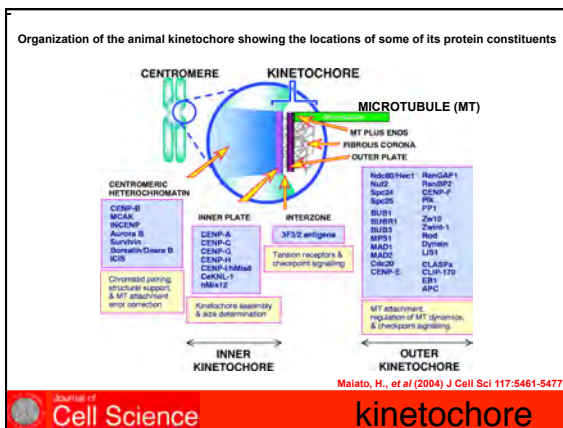
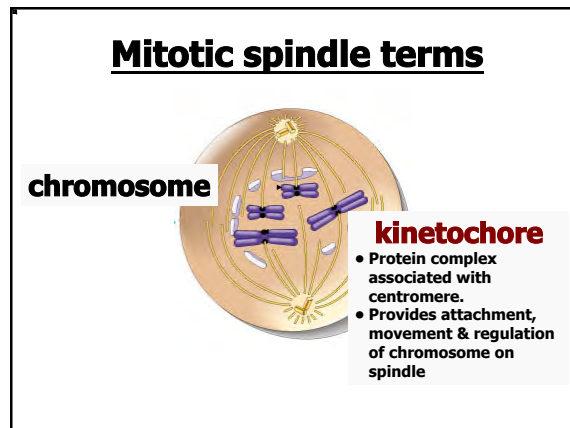
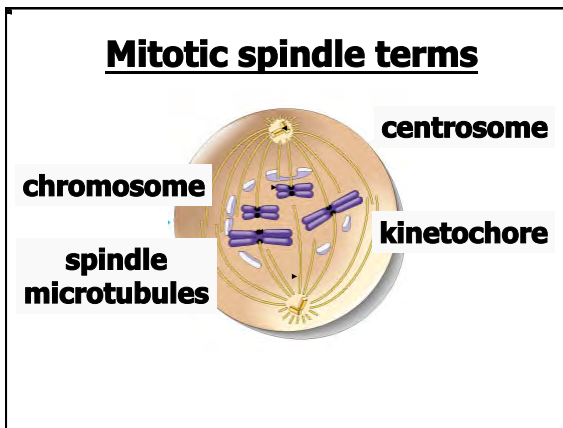
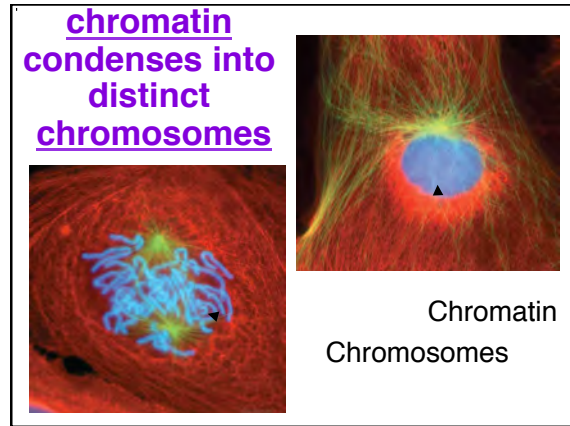
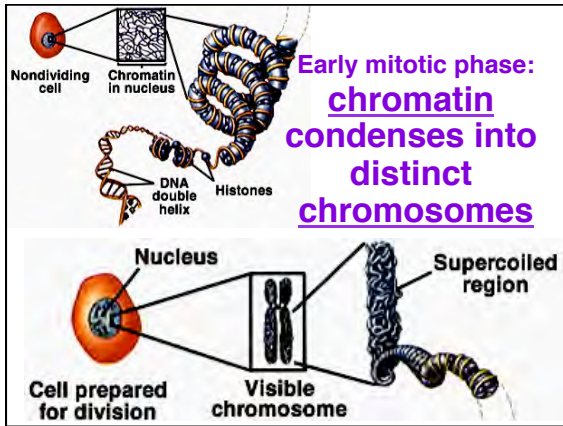
Stages of Mitosis

- * Beginning - 1 nucleus with 1 set of duplicate chromosomes (**two** chromatids/chromosome)
- * 4 stages:
 1. Prophase
 2. Metaphase
 3. Anaphase
 4. Telophase
- * End - 2 new nuclei, each with 1 set of unduplicate chromosomes (now **one** chromatid/chromosome)

Cell Cycle

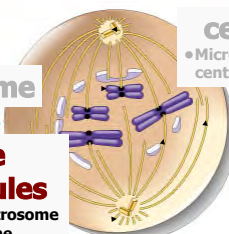


Mitosis & the Cell Cycle



Mitosis & the Cell Cycle

Mitotic spindle terms



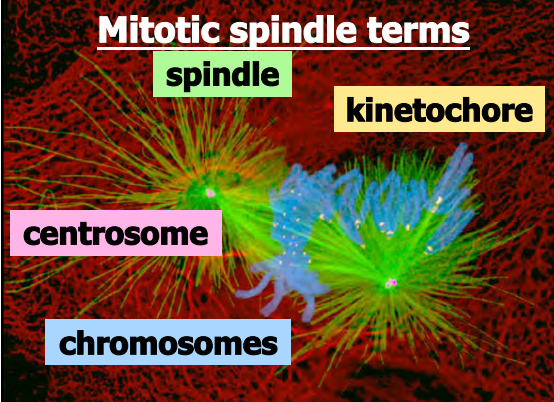
chromosome

spindle microtubules

- **Aster:** anchor centrosome to plasma membrane
- **Kinetochores MTs:** from centrosome to centromere
- **Polar MTs:** overlap MTs from opposite centrosome

centrosome
• Microtubule organizing center

Mitotic spindle terms



spindle

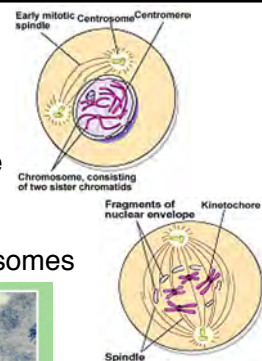
kinetochore

centrosome

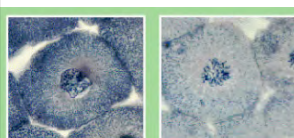
chromosomes

1. Prophase

- * Chromosomes condense
- * Nuclear envelope breaks down
- * Spindle forms & attaches chromosomes



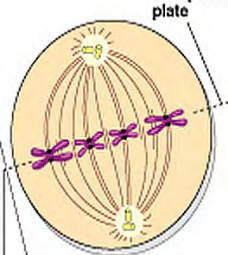
Early mitotic spindle, Centrosome, Centromere, Chromosome, consisting of two sister chromatids, Fragments of nuclear envelope, Kinetochore, Spindle microtubules



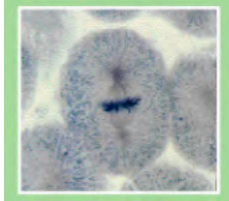
Prophase

2. Metaphase

- * Chromosome dyads align in one line on **Metaphase plate**

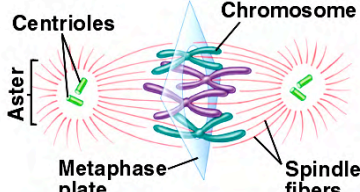


Metaphase plate, Spindle

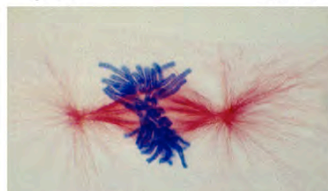


Metaphase

Metaphase

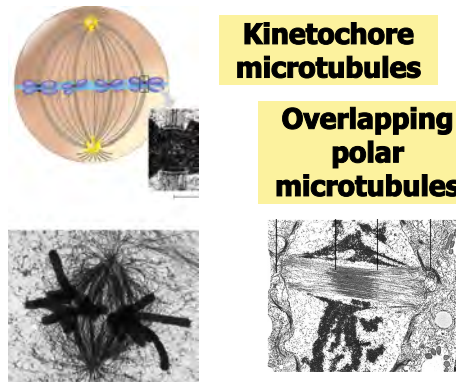


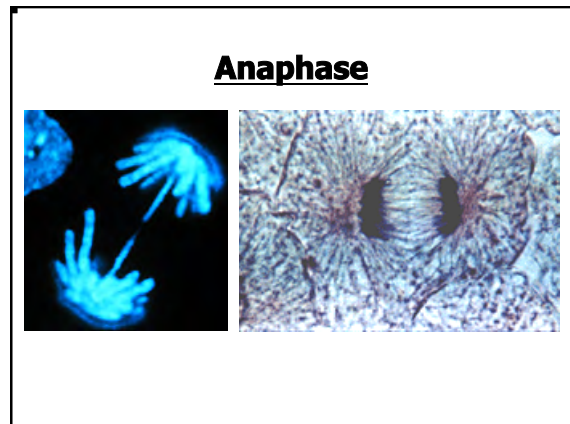
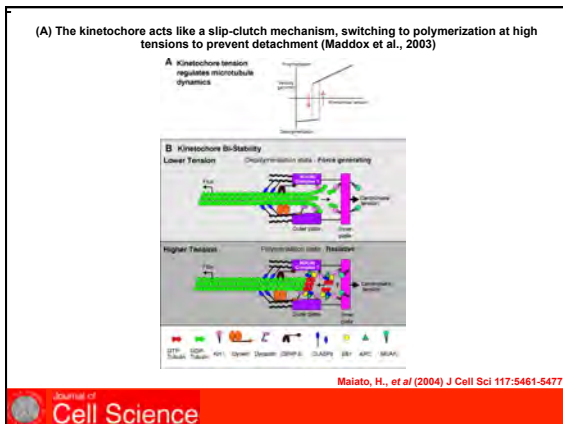
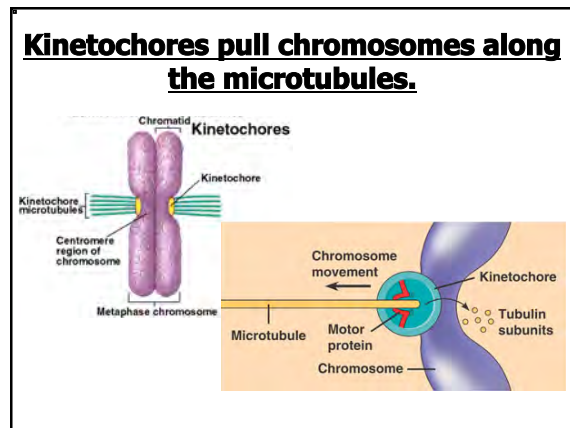
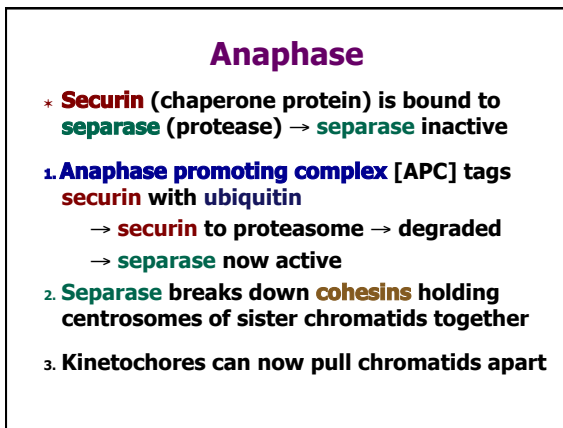
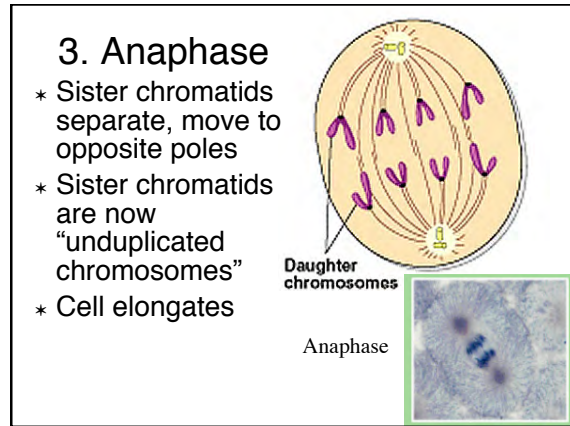
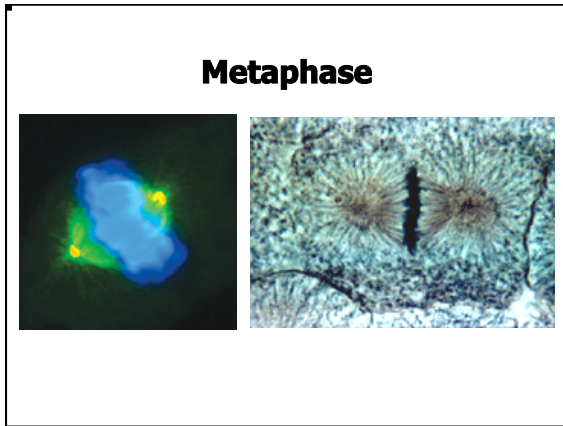
Centrioles, Aster, Chromosome, Metaphase plate, Spindle fibers



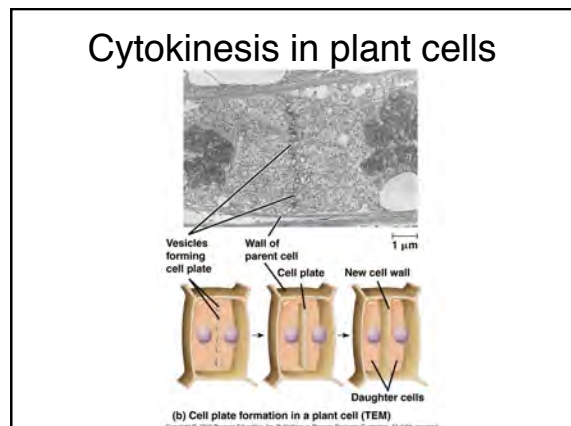
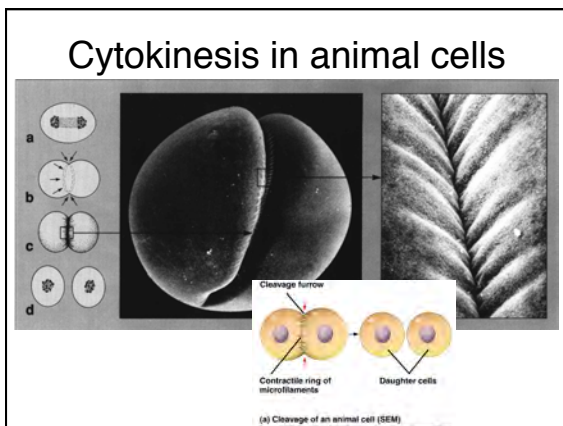
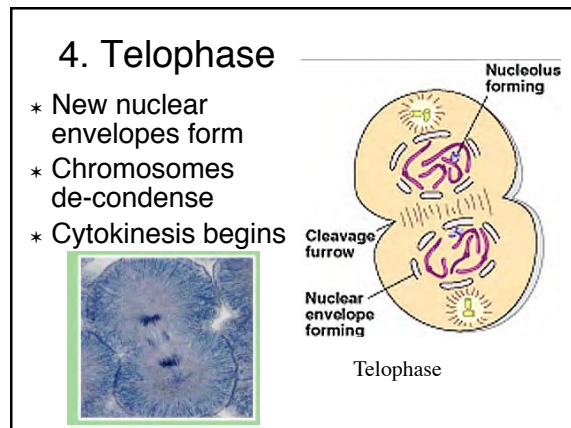
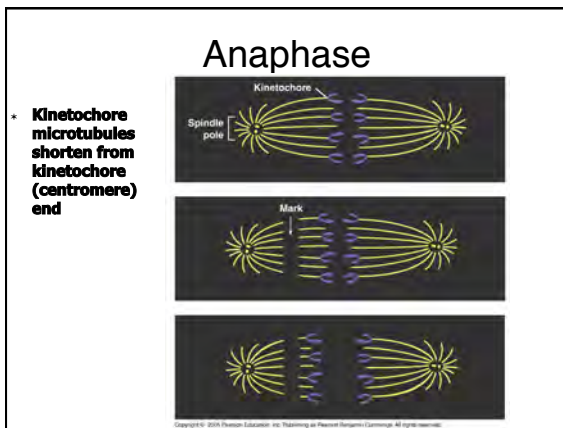
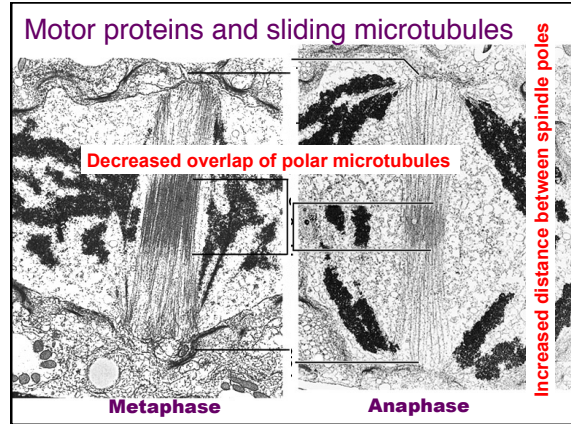
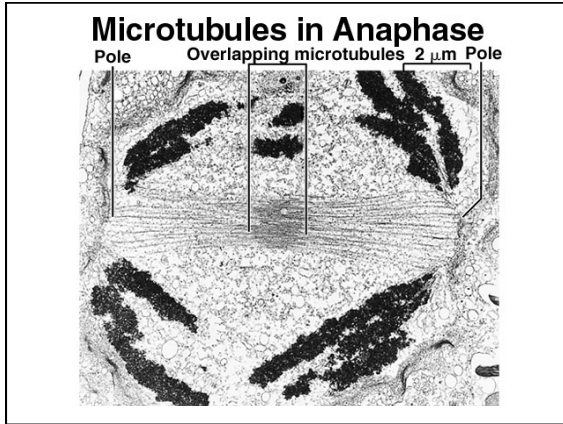
Kinetochores microtubules

Overlapping polar microtubules

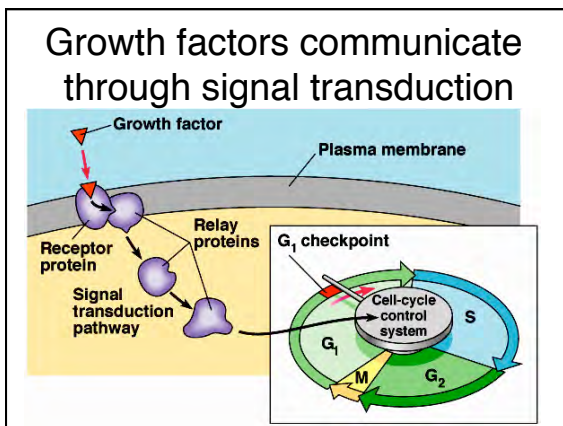
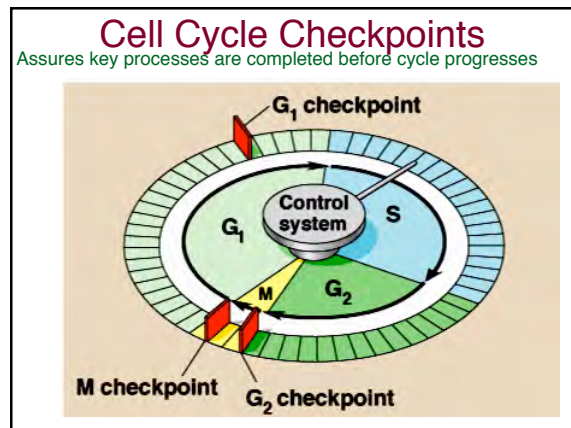
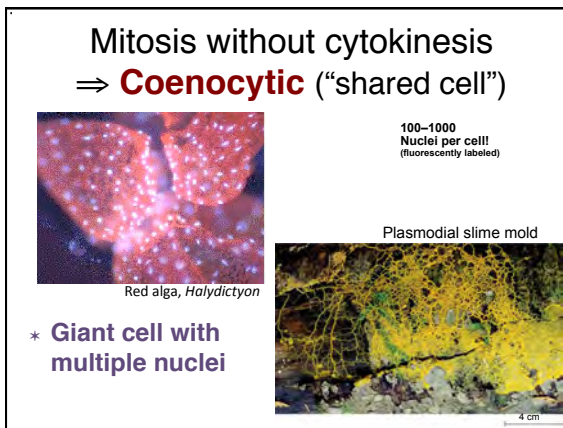
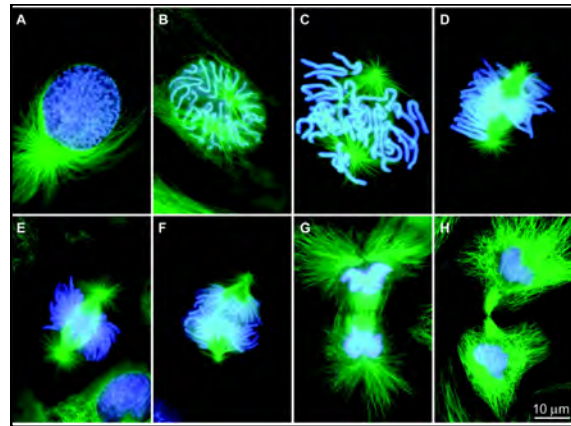
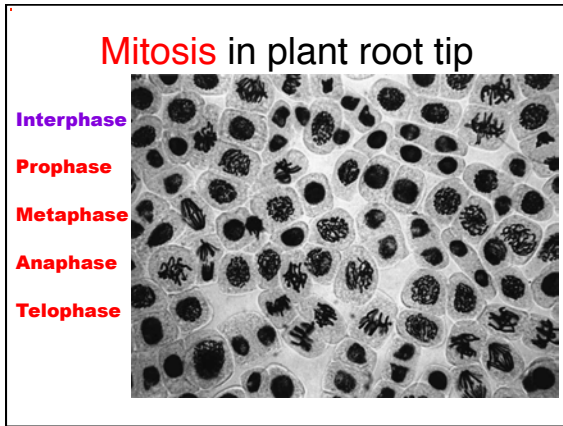




Mitosis & the Cell Cycle



Mitosis & the Cell Cycle



- ## Cell Cycle Checkpoints
- Assures key processes are completed before cycle progresses
- * **G₁ checkpoint:**
 - ✓ Sufficient growth & reserves to support replication
 - ✓ Pre-replication check for DNA damage
 - ✓ Internal clock
 - ✓ External growth factors and/or inhibitors
 - * **G₂ checkpoint:**
 - ✓ Sufficient growth & reserves to support mitosis & cytokinesis
 - ✓ Duplication of centrosomes
 - ✓ Replication of DNA
 - ✓ Pre-mitotic check for DNA damage
 - * **M checkpoint**
 - ✓ Spindle formed & functioning
 - ✓ Chromosome kinetochores correctly attached to spindle
 - ✓ Chromosomes properly aligned & untangled on metaphase plate
- 