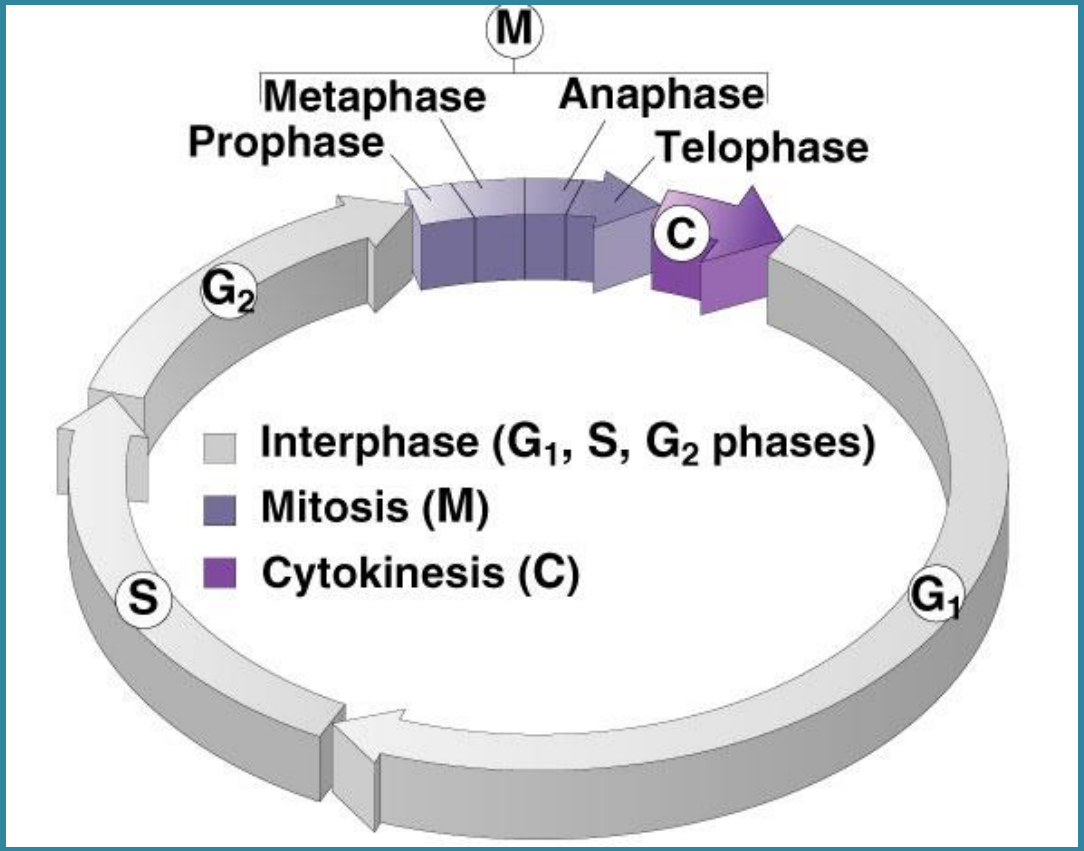
The Cell Cycle

Mitosis: the process by which cells reproduce themselves, resulting in daughter cells that contain the same amount of genetic material as the parent cell.

Phases of the Cell Cycle

- Interphase
  - G_1 - primary growth
  - S - genome replicated
  - G_2 - secondary growth
- M - mitosis
- C - cytokinesis

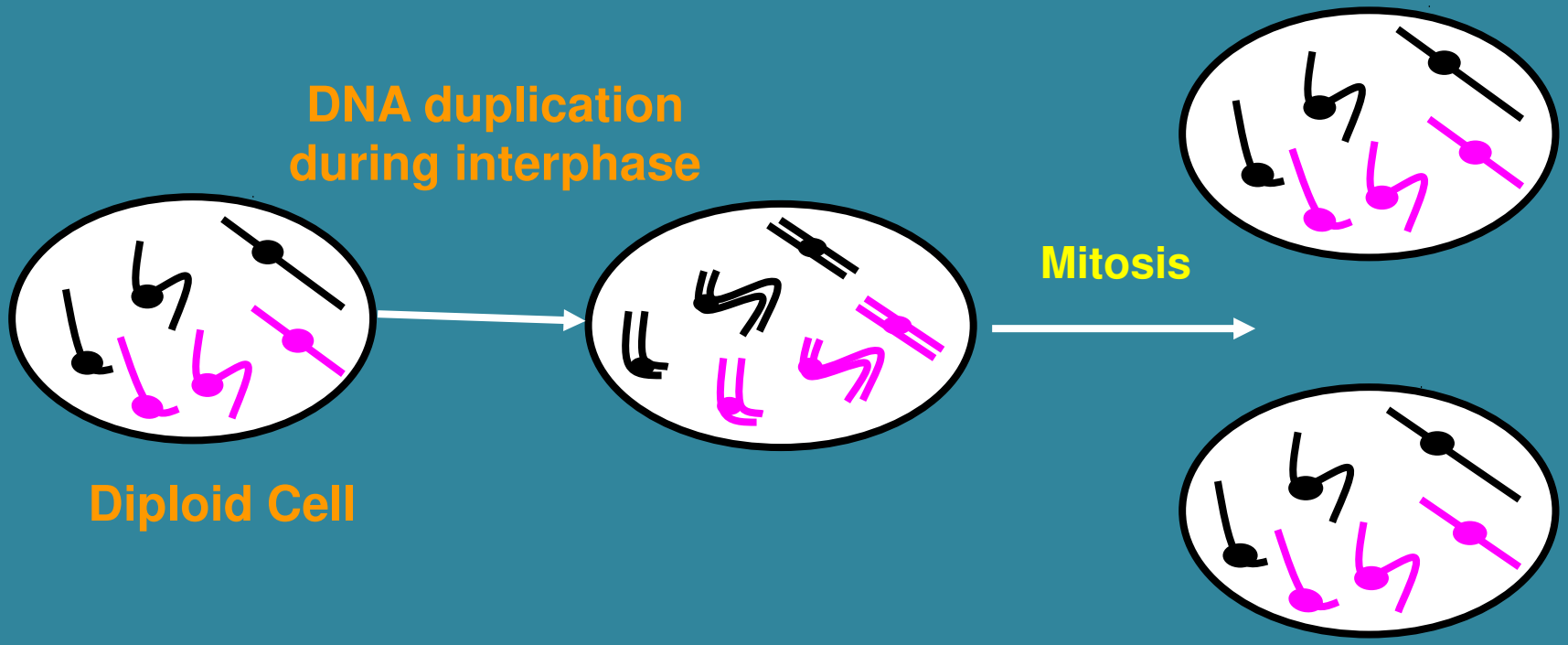


Interphase – G_2 Stage

- ✓ 2nd Growth Stage
- ✓ Occurs after DNA has been copied
- ✓ All cell structures needed for division are made (e.g. centrioles)
- ✓ Both organelles & proteins are synthesized

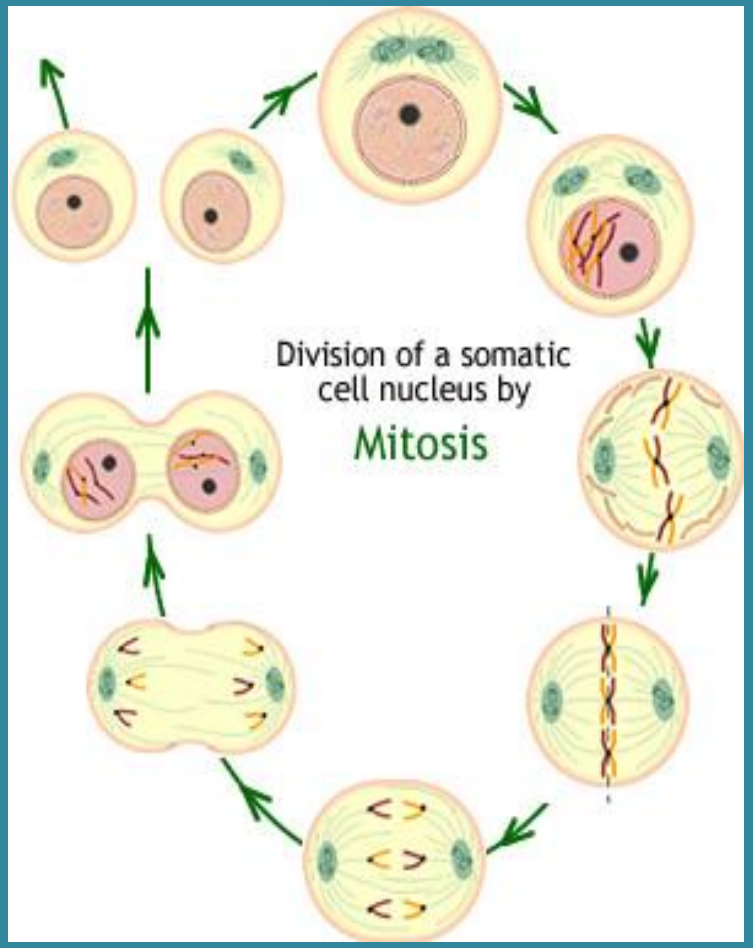
Mitosis

- Some haploid & diploid cells divide by mitosis.
- Each new cell receives one copy of every chromosome that was present in the original cell.
- Produces 2 new cells that are both genetically identical to the original cell.



Mitosis Cycle

- Interphase
- Prophase
- Metaphase
- Anaphase
- Telophase
- Cytokinesis



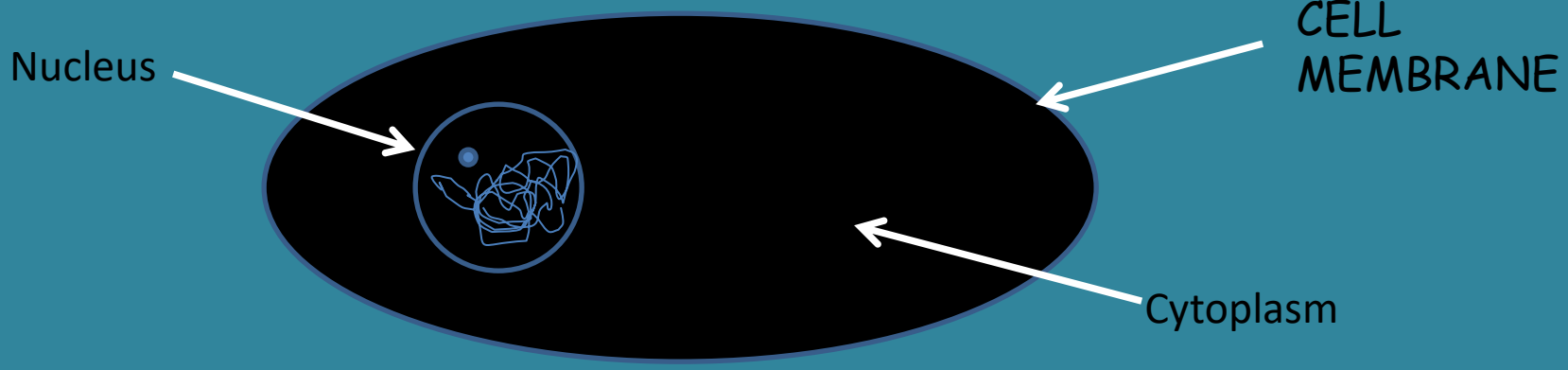
http://www.cellsalive.com/mitosis.htm

Cell Division Occurs in a series of stages of phases

Interphase

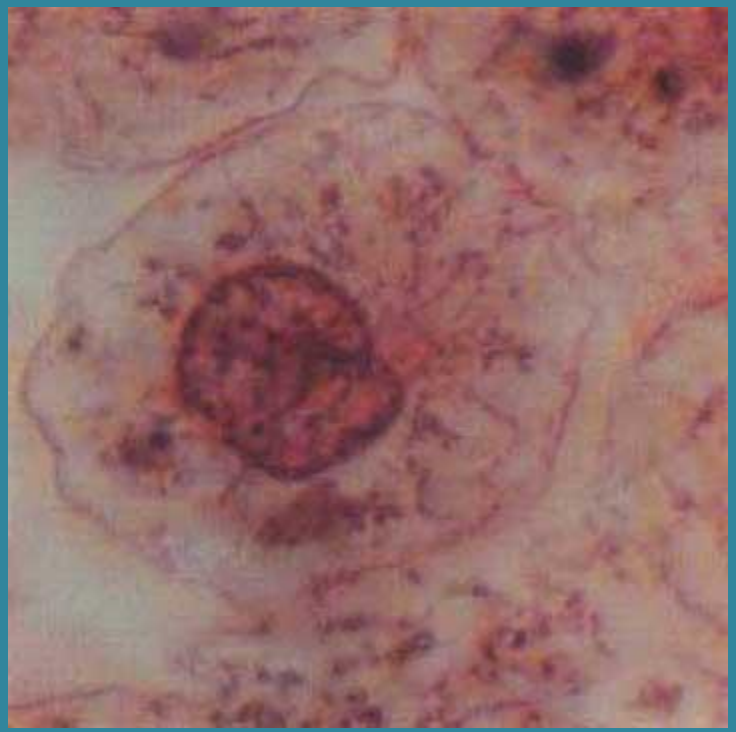
occurs before mitosis begins

- Chromosomes are **copied** (# doubles)
- Chromosomes appear as threadlike coils (**chromatin**) at the start, but each chromosome and its copy(**sister** chromosome) change to sister chromatids at end of this phase

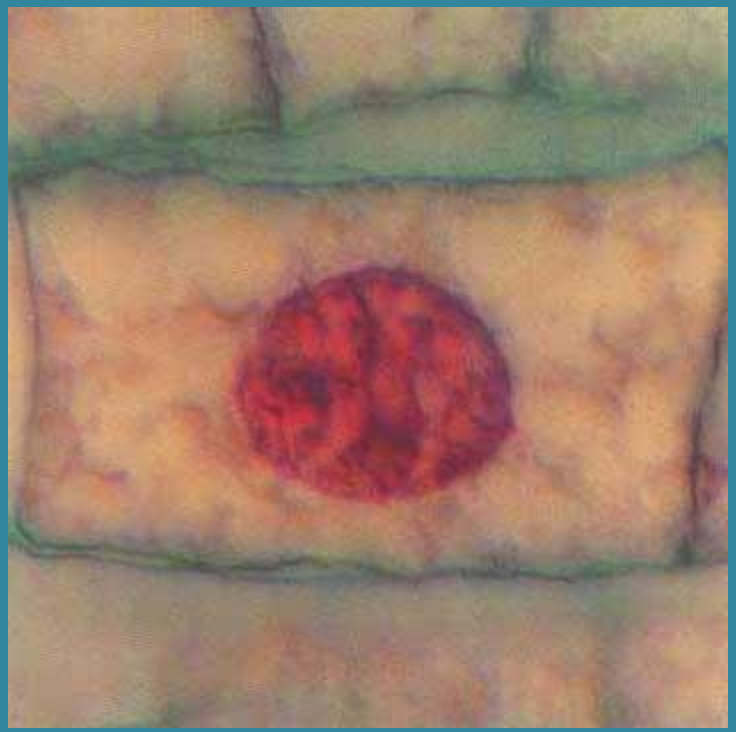


Interphase

Animal Cell



Plant Cell



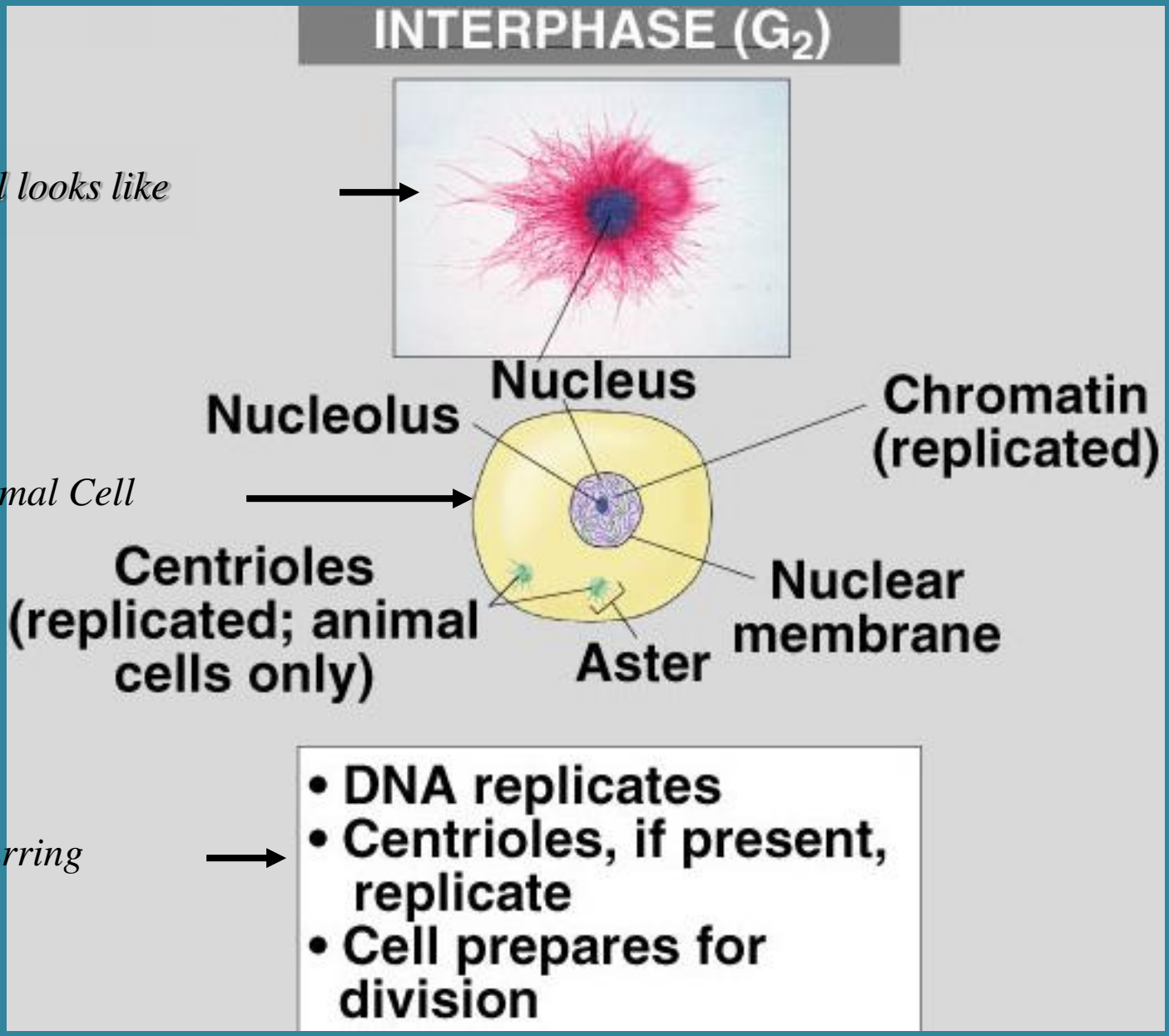
Photographs from: http://www.bioweb.uncc.edu/biol1110/Stages.htm

Interphase

- G_1 - Cells undergo majority of growth
- S - Each chromosome replicates (Synthesizes) to produce sister chromatids
  - Attached at centromere
  - Contains attachment site (kinetochore)
- G_2 - Chromosomes condense - Assemble machinery for division such as centrioles

What's Happening in Interphase?

What the cell looks like

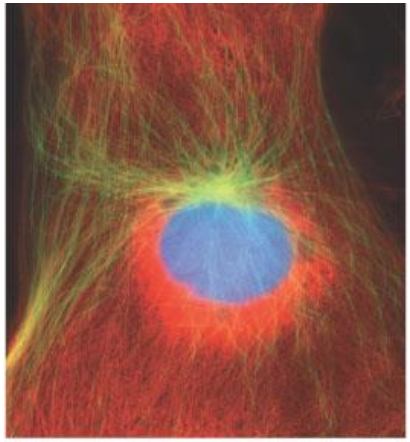


What's occurring

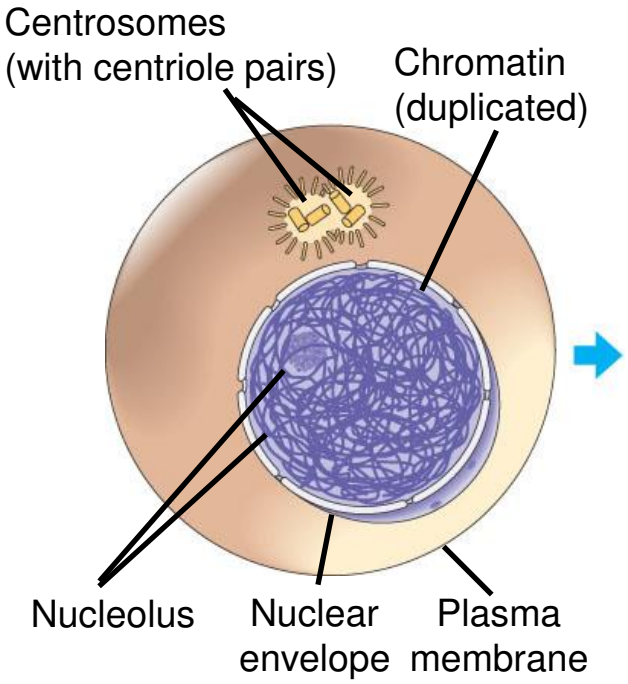
G_2 of Interphase

- A nuclear envelope bounds the nucleus.
- The nucleus contains one or more nucleoli (singular, nucleolus).
- Two centrosomes have formed by replication of a single centrosome.
- In animal cells, each centrosome features two centrioles.
- Chromosomes, duplicated during S phase, cannot be seen individually because they have not yet condensed.

The light micrographs show dividing lung cells from a newt, which has 22 chromosomes in its somatic cells (chromosomes appear blue, microtubules green, intermediate filaments red). For simplicity, the drawings show only four chromosomes.

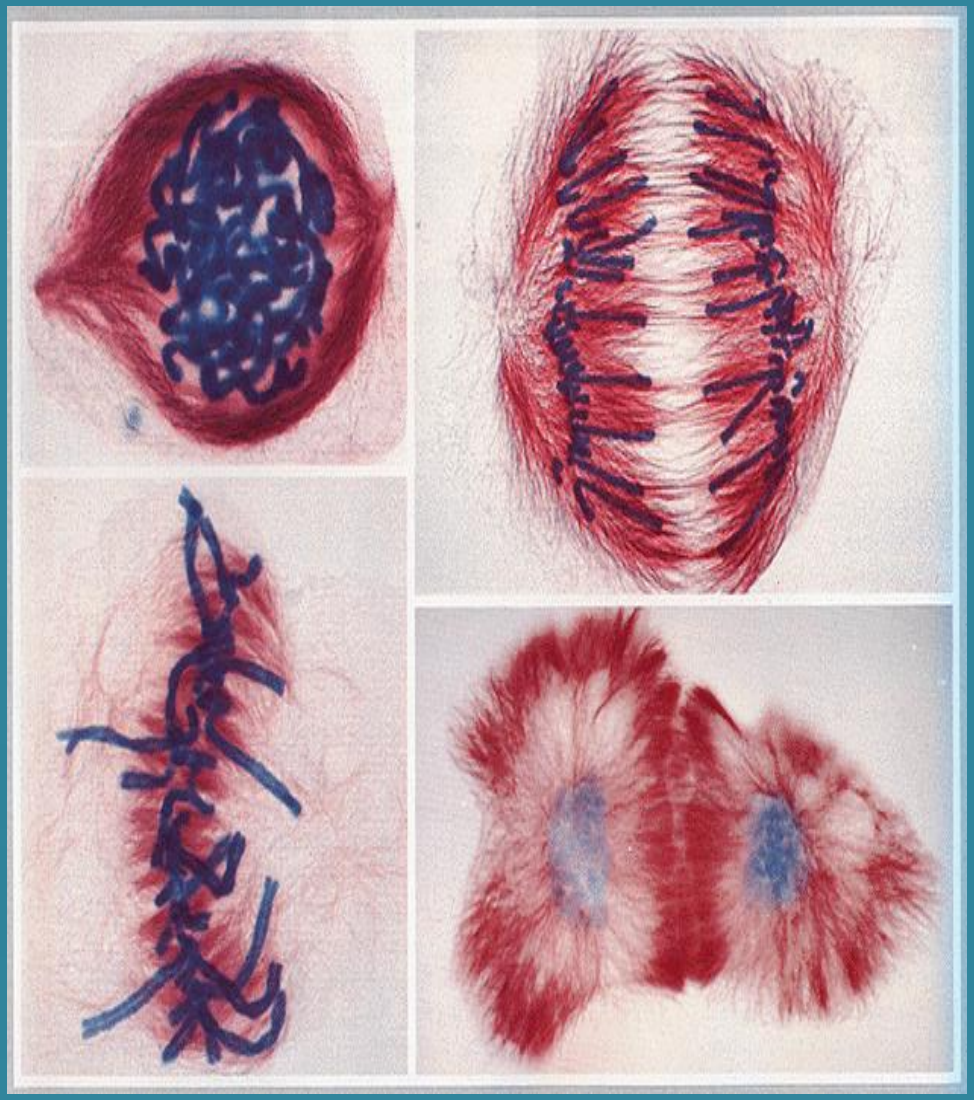


G_2 OF INTERPHASE



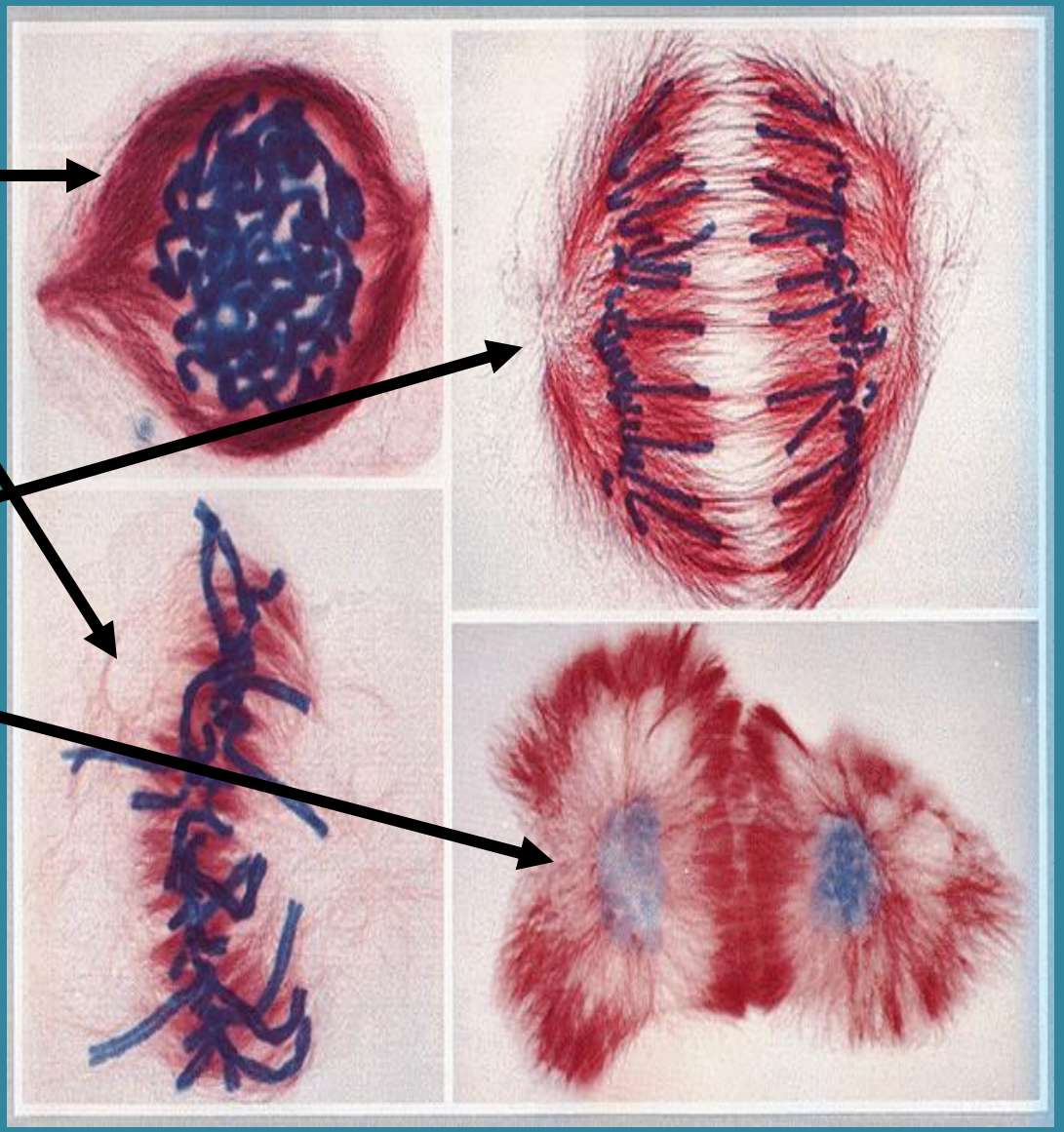
Mitosis

- ✓Division of the nucleus
- ✓Also called karyokinesis
- ✓Only occurs in eukaryotes
- ✓Has four stages
- ✓Doesn't occur in some cells such as brain cells



Four Mitotic Stages

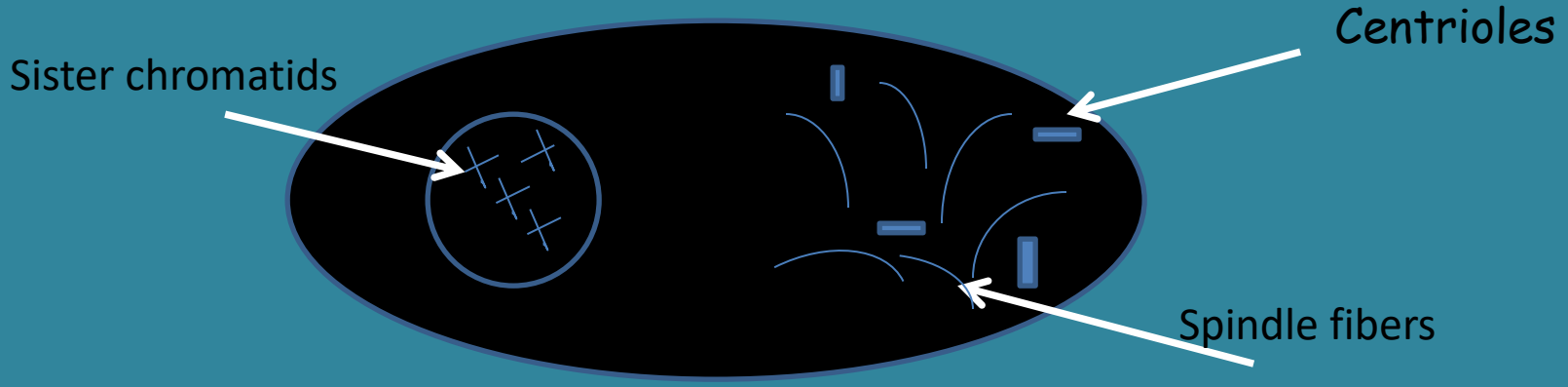
- ✓Prophase
- ✓Metaphase
- ✓Anaphase
- ✓Telophase



Prophase

1st step in Mitosis

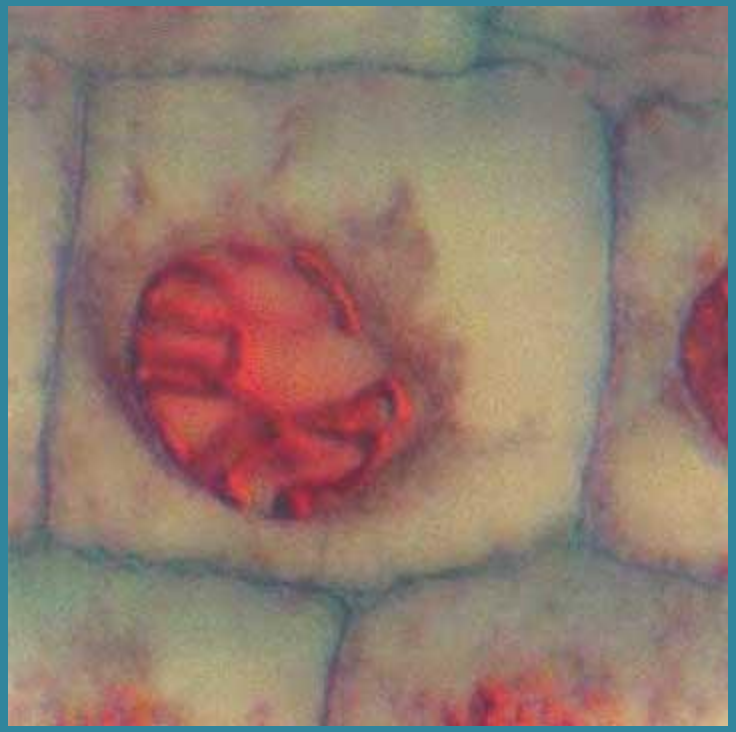
- **Mitosis** begins (cell begins to divide)
- **Centrioles** (or poles) appear and begin to move to opposite end of the cell.
- **Spindle fibers** form between the poles.



Prophase

Animal Cell

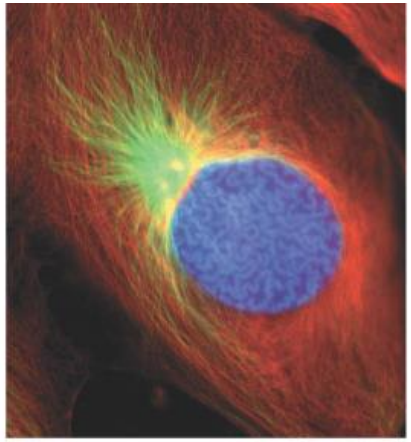
Plant Cell



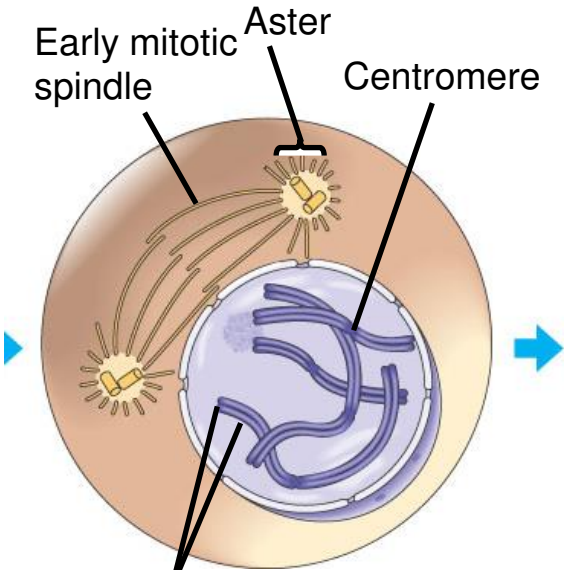
Photographs from: http://www.bioweb.uncc.edu/biol1110/Stages.htm

Prophase

- The chromatin fibers become more tightly coiled, condensing into discrete chromosomes observable with a light microscope.
- The nucleoli disappear.
- Each duplicated chromosome appears as two identical sister chromatids joined together.
- The mitotic spindle begins to form. It is composed of the centrosomes and the microtubules that extend from them. The radial arrays of shorter microtubules that extend from the centrosomes are called asters (“stars”).
- The centrosomes move away from each other, apparently propelled by the lengthening microtubules between them.

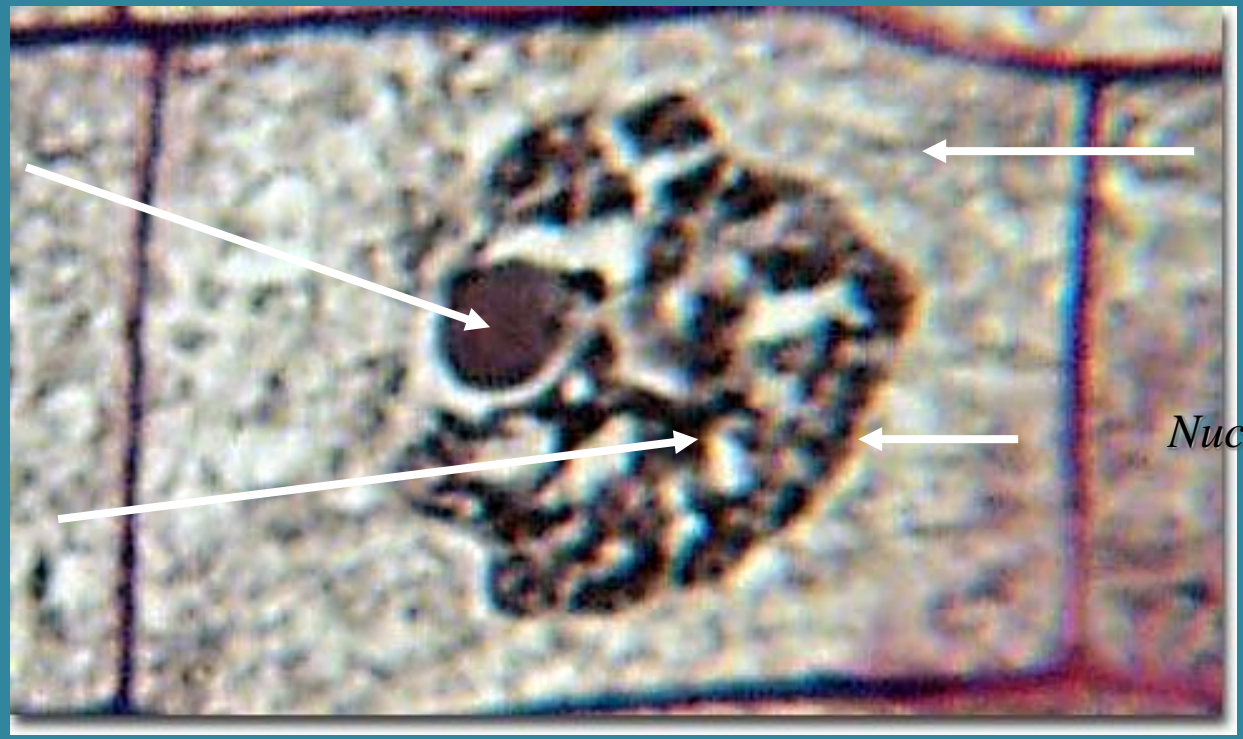


PROPHASE



Early Prophase

- ✓ Chromatin in nucleus condenses to form visible chromosomes
- ✓ Mitotic spindle forms from fibers in cytoskeleton or centrioles (animal)



Late Prophase

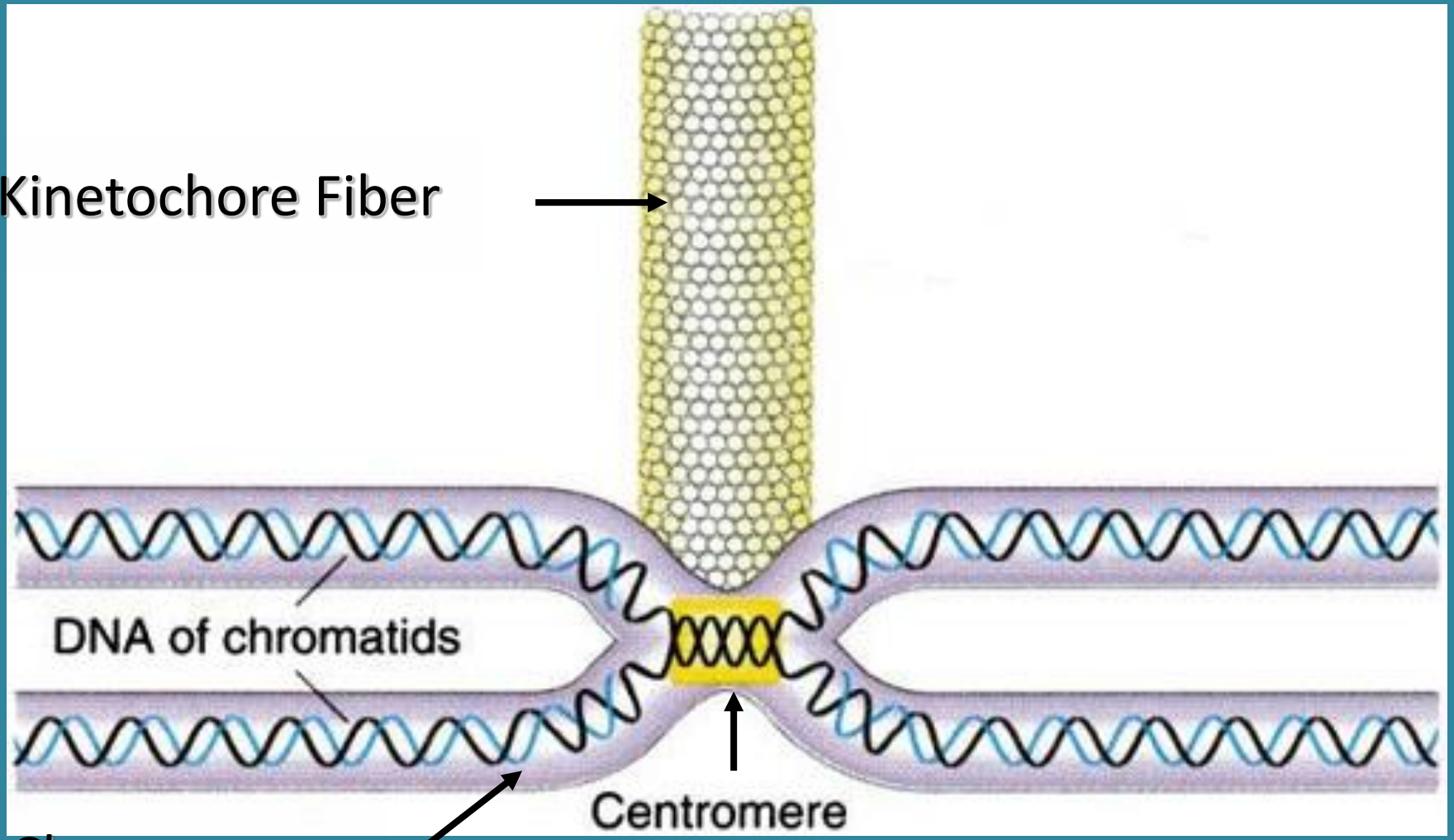
- ✓ Nuclear membrane & nucleolus are broken down
- ✓ Chromosomes continue condensing & are clearly visible
- ✓ Spindle fibers called kinetochores attach to the centromere of each chromosome
- ✓ Spindle finishes forming between the poles of the cell

Late Prophase

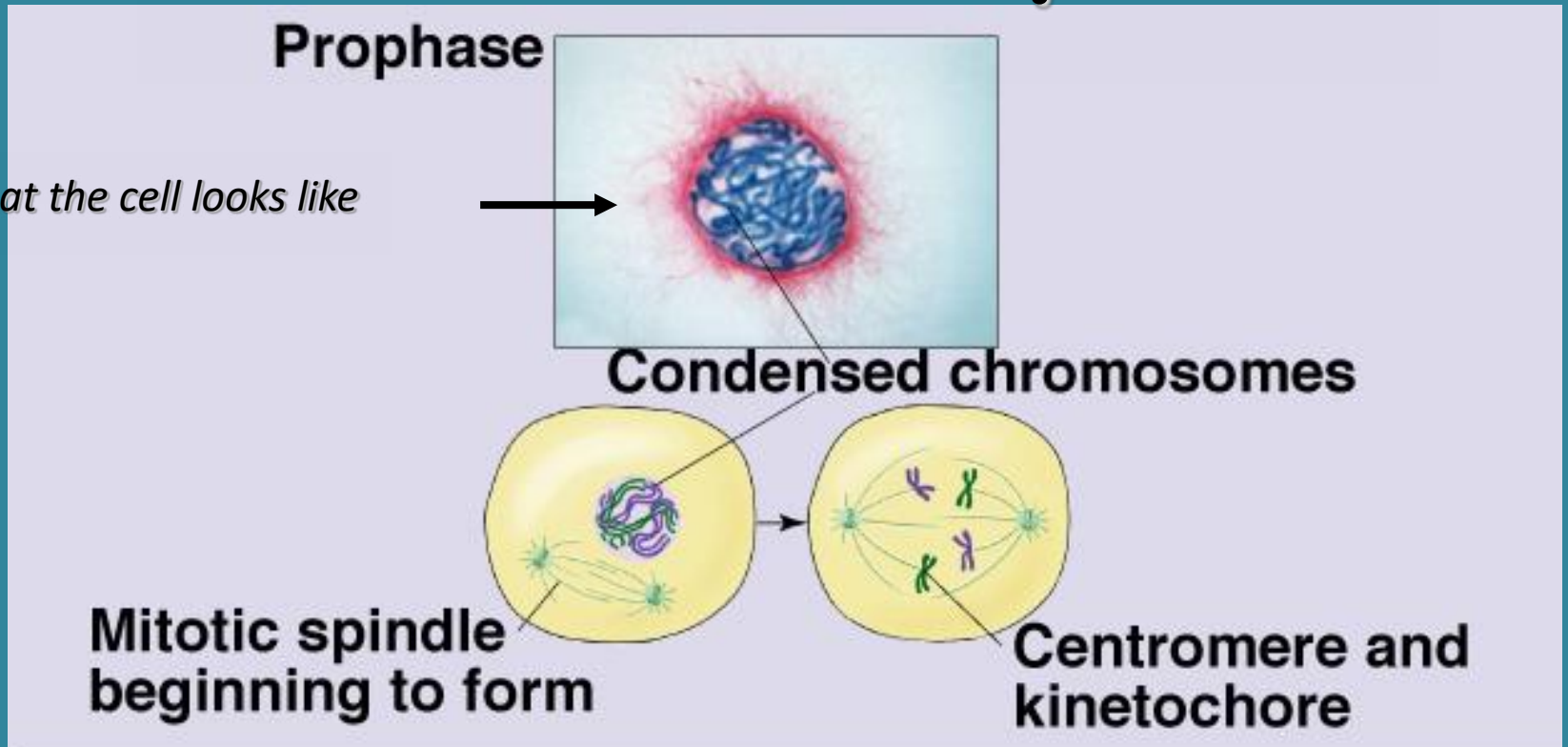
Chromosomes

Nucleus & Nucleolus have disintegrated

Spindle Fiber attached to Chromosome



Review of Prophase



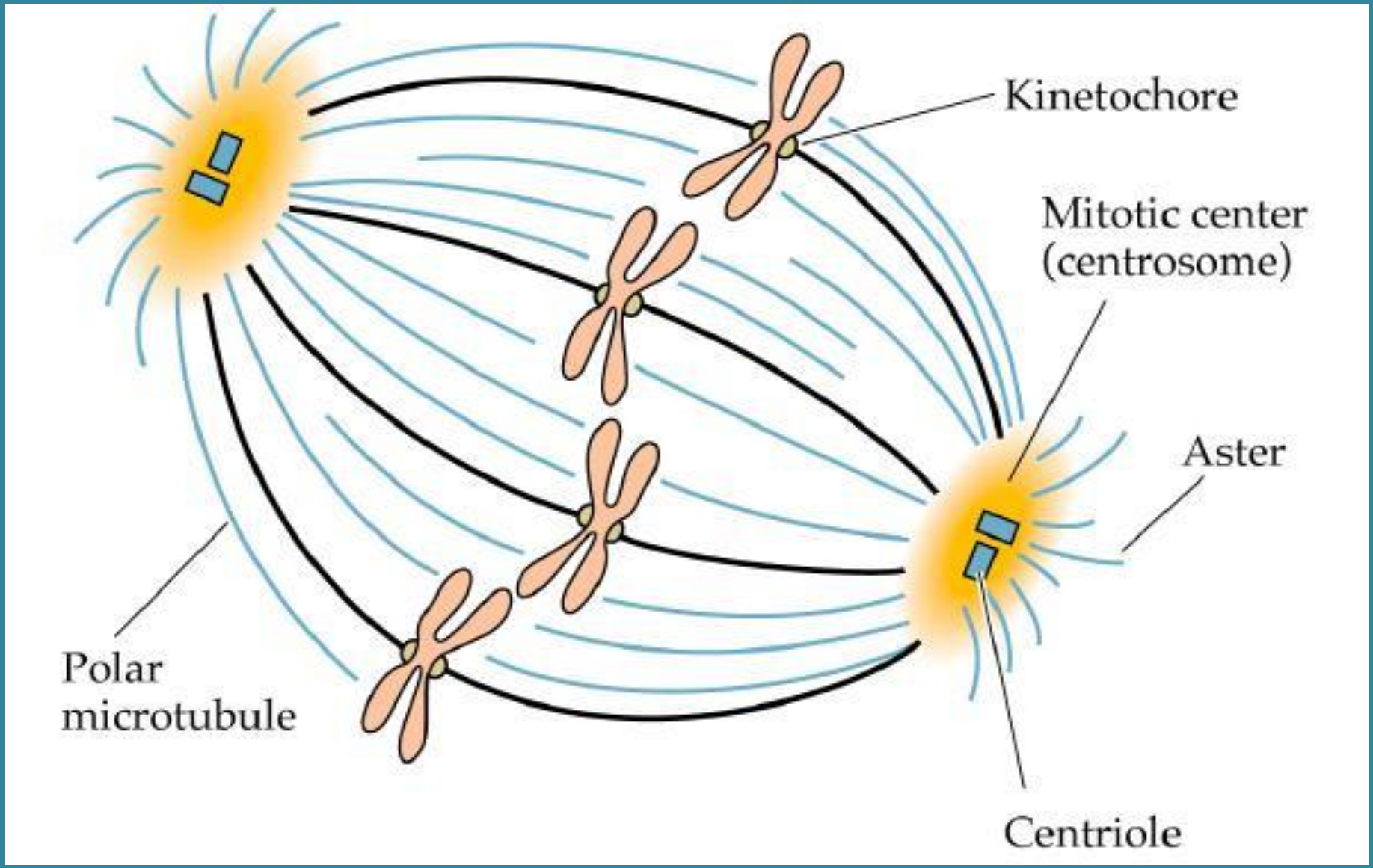
- Nuclear membrane disintegrates, and nucleolus disappears
- Chromosomes condense
- Mitotic spindle begins to form and is complete at the end of prophase
- Kinetochores begin to mature and attach to spindle

What's happening

Spindle Fibers

- ✓The mitotic spindle form from the microtubules in plants and centrioles in animal cells
- ✓Polar fibers extend from one pole of the cell to the opposite pole
- ✓Kinetochore fibers extend from the pole to the centromere of the chromosome to which they attach
- ✓Asters are short fibers radiating from centrioles

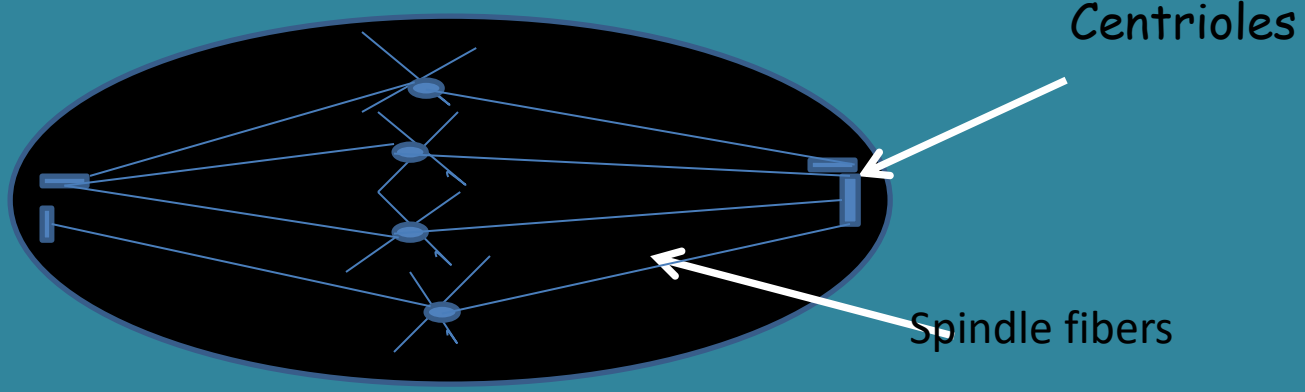
Sketch The Spindle



Metaphase

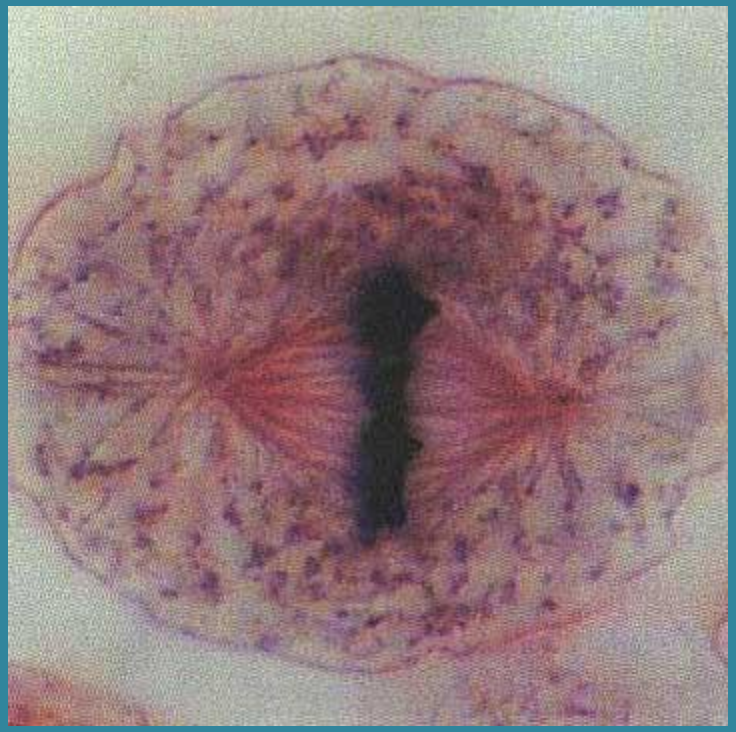
2nd step in Mitosis

- **Chromatids** (or pairs of chromosomes) attach to the spindle fibers.

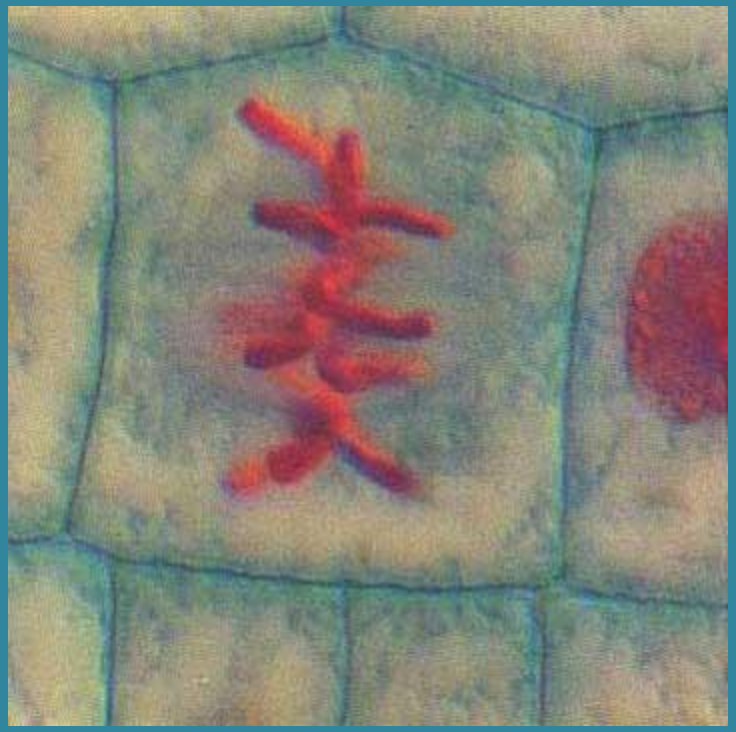


Metaphase

Animal Cell



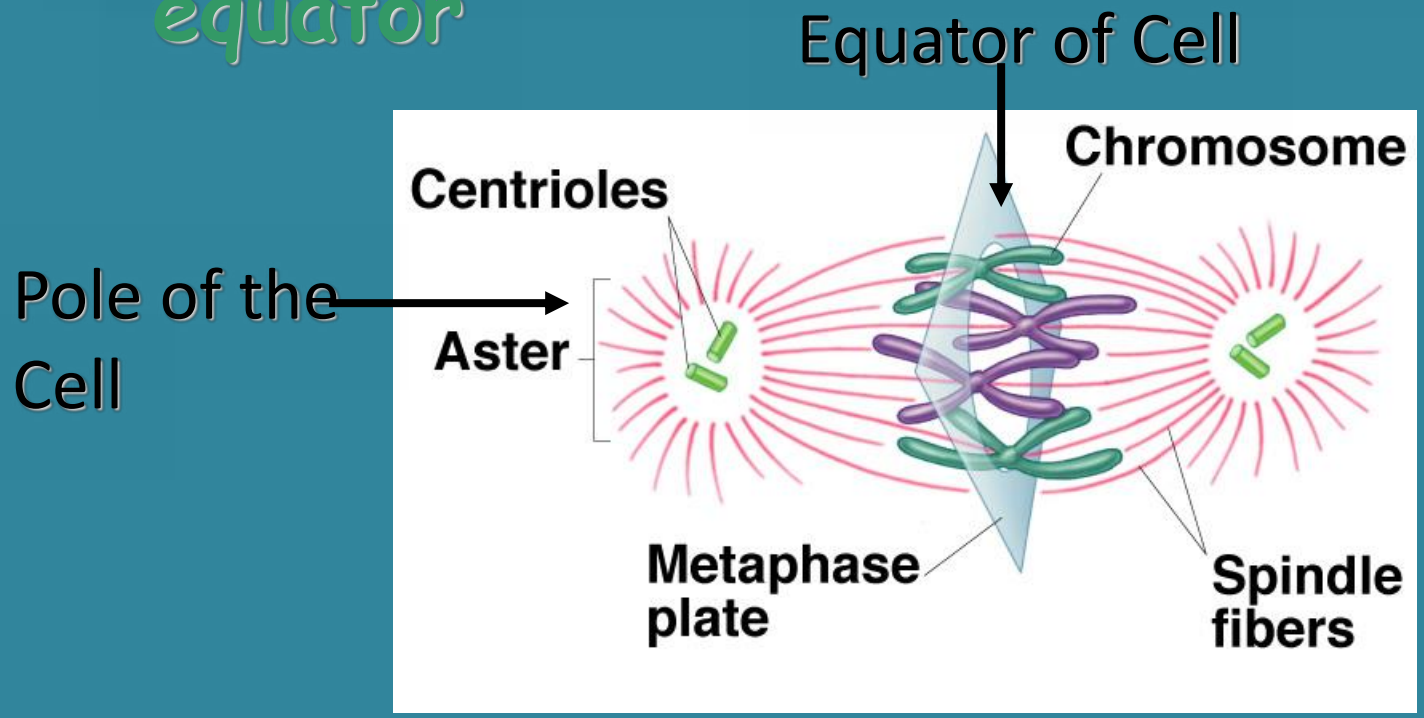
Plant Cell



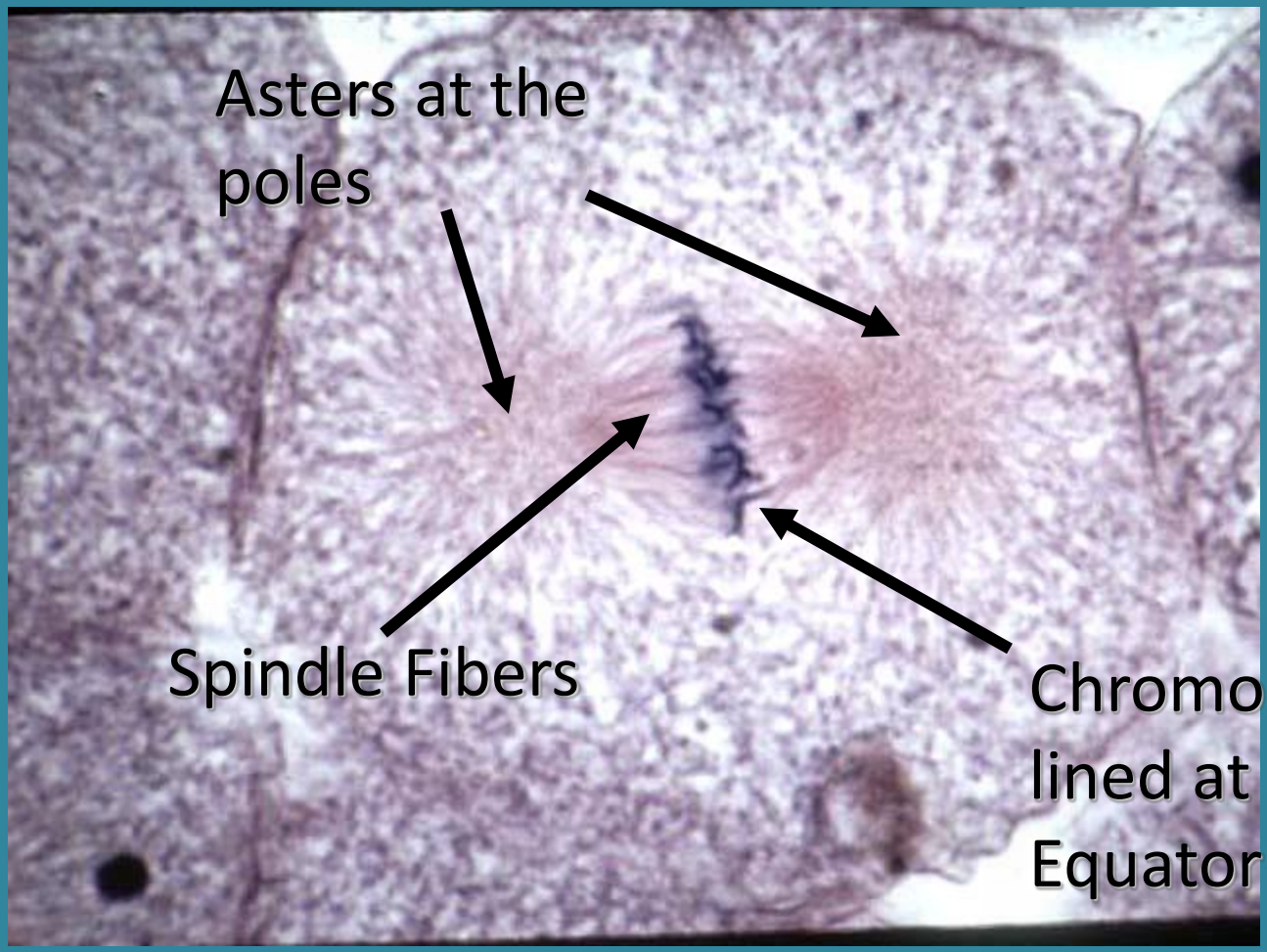
Photographs from: http://www.bioweb.uncc.edu/biol1110/Stages.htm

Metaphase

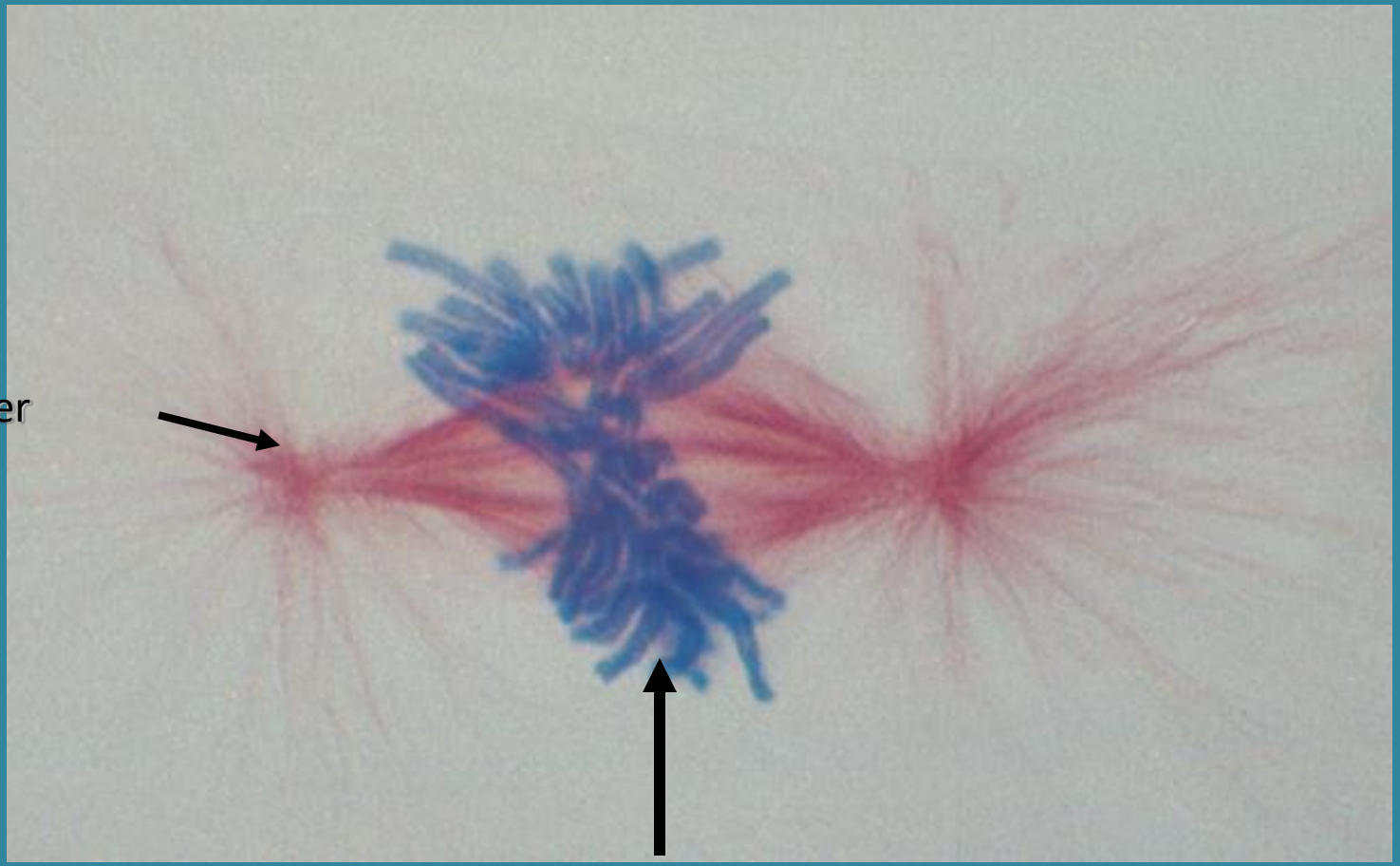
- ✓Chromosomes, attached to the kinetochore fibers, move to the center of the cell
- ✓Chromosomes are now lined up at the equator



Metaphase

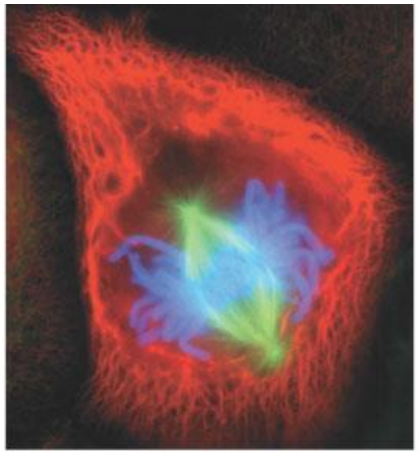

Asters at the poles
Spindle Fibers
Chromosomes lined at the Equator

Metaphase

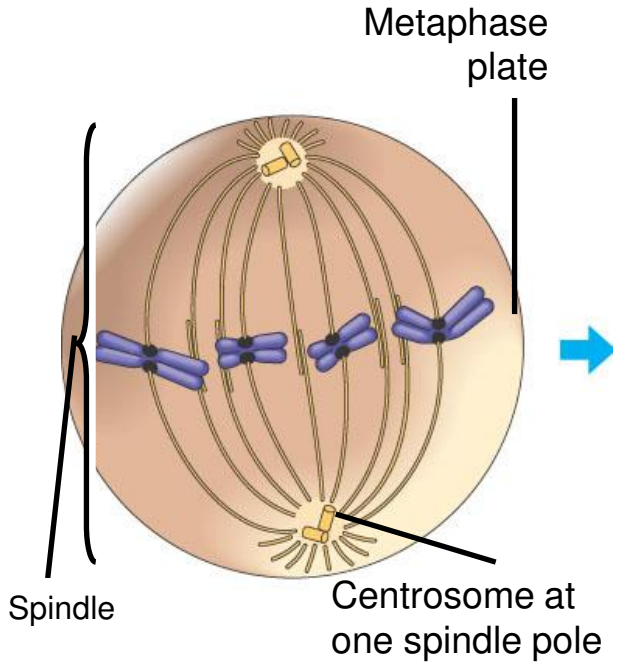


Metaphase

- Metaphase is the longest stage of mitosis, lasting about 20 minutes.
- The centrosomes are now at opposite ends of the cell.
- The chromosomes convene on the metaphase plate, an imaginary plane that is equidistant between the spindle's two poles. The chromosomes' centromeres lie on the metaphase plate.
- For each chromosome, the kinetochores of the sister chromatids are attached to kinetochore microtubules coming from opposite poles.
- The entire apparatus of microtubules is called the spindle because of its shape.

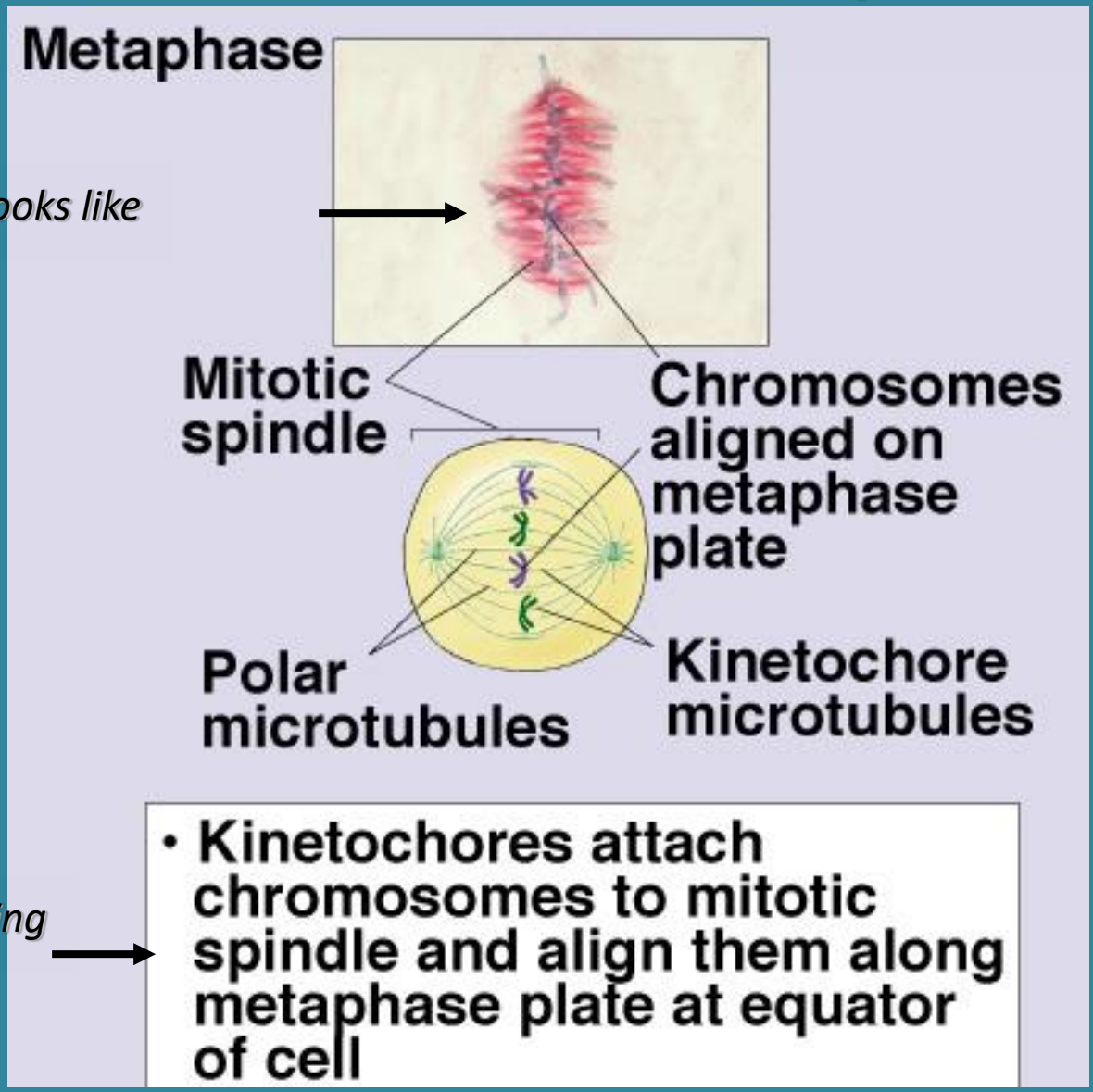


METAPHASE



Review of Metaphase

What the cell looks like



What's occurring

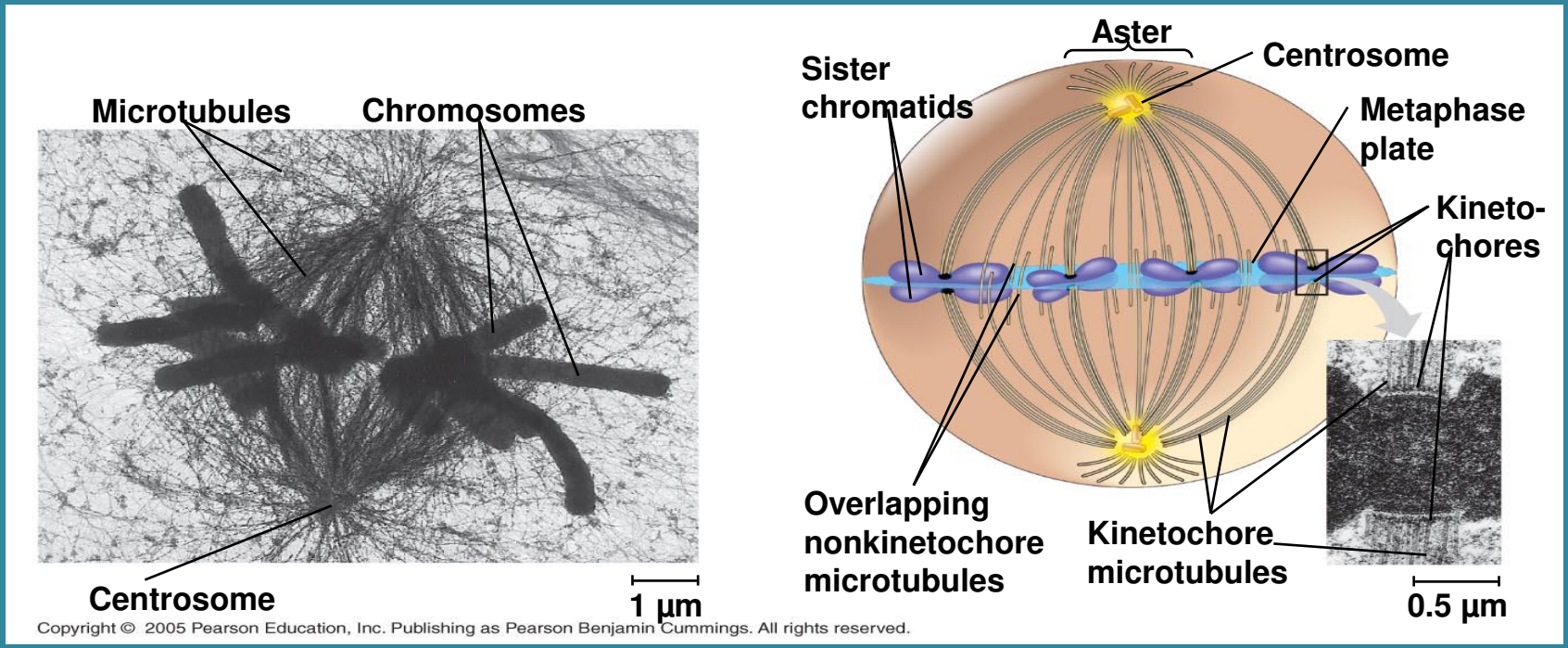
- Kinetochores attach chromosomes to mitotic spindle and align them along metaphase plate at equator of cell

The Mitotic Spindle

- The spindle includes the centrosomes, the spindle microtubules, and the asters
- The apparatus of microtubules controls chromosome movement during mitosis
- The centrosome replicates, forming two centrosomes that migrate to opposite ends of the cell
- Assembly of spindle microtubules begins in the centrosome, the microtubule organizing center
- An aster (a radial array of short microtubules) extends from each centrosome

The Mitotic Spindle

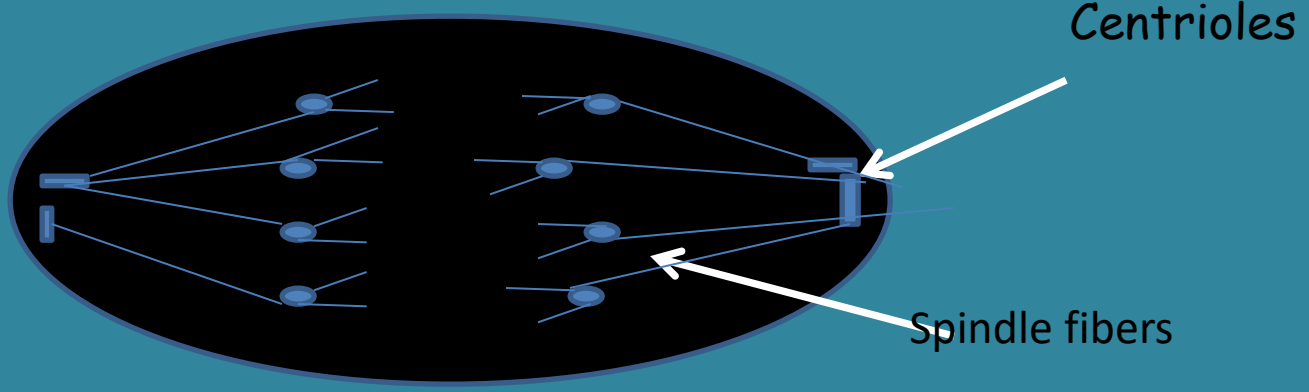
- Some spindle microtubules attach to the kinetochores of chromosomes and move the chromosomes to the metaphase plate
- In anaphase, sister chromatids separate and move along the kinetochore microtubules toward opposite ends of the cell



Anaphase

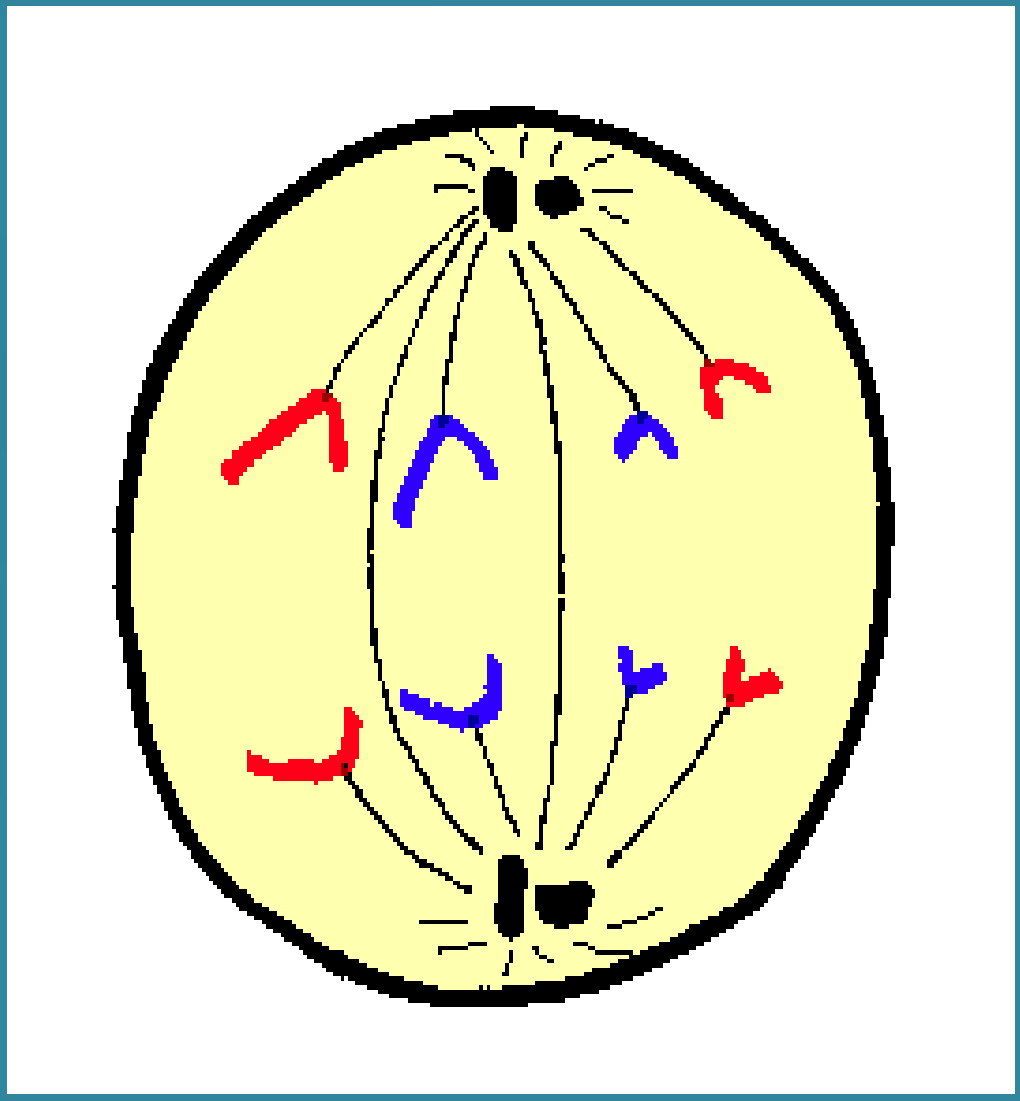
3rd step in Mitosis

- **Chromatids** (or pairs of chromosomes) separate and begin to move to opposite ends of the cell.



Anaphase

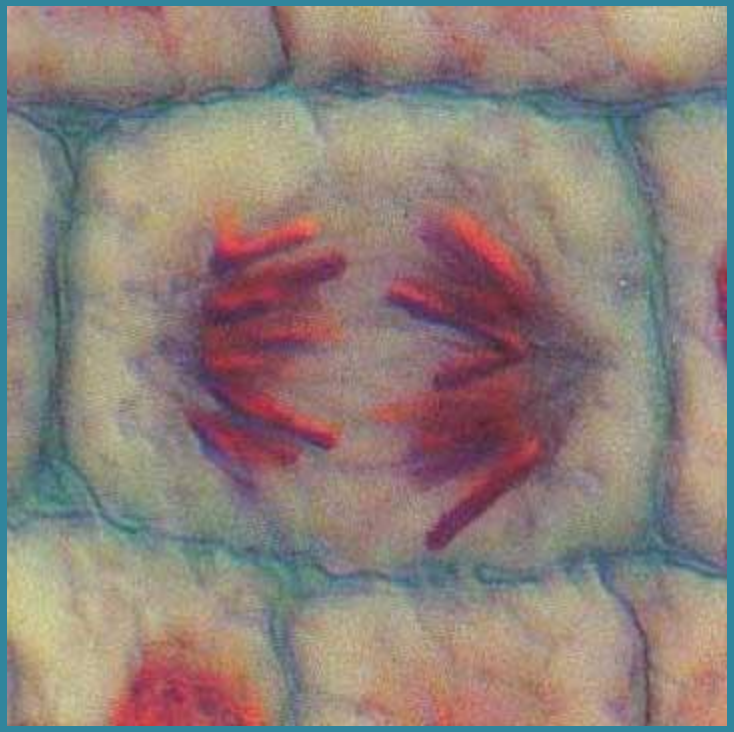
- ✓Occurs rapidly
- ✓Sister chromatids are pulled apart to opposite poles of the cell by kinetochore fibers



Anaphase

Animal Cell

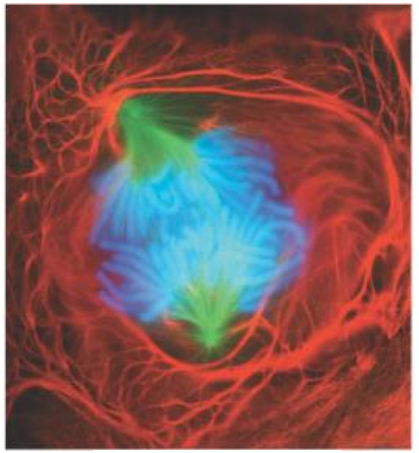
Plant Cell



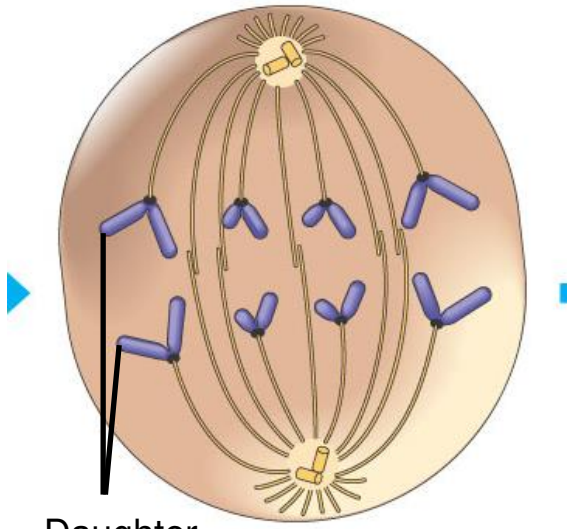
Photographs from: http://www.bioweb.uncc.edu/biol1110/Stages.htm

Anaphase

- Anaphase is the shortest stage of mitosis, lasting only a few minutes.
- Anaphase begins when the two sister chromatids of each pair suddenly part. Each chromatid thus becomes a full-fledged chromosome.
- The two liberated chromosomes begin moving toward opposite ends of the cell, as their kinetochore microtubules shorten. Because these microtubules are attached at the centromere region, the chromosomes move centromere first (at about 1 µm/min).
- The cell elongates as the nonkinetochore microtubules lengthen.
- By the end of anaphase, the two ends of the cell have equivalent—and complete—collections of chromosomes.

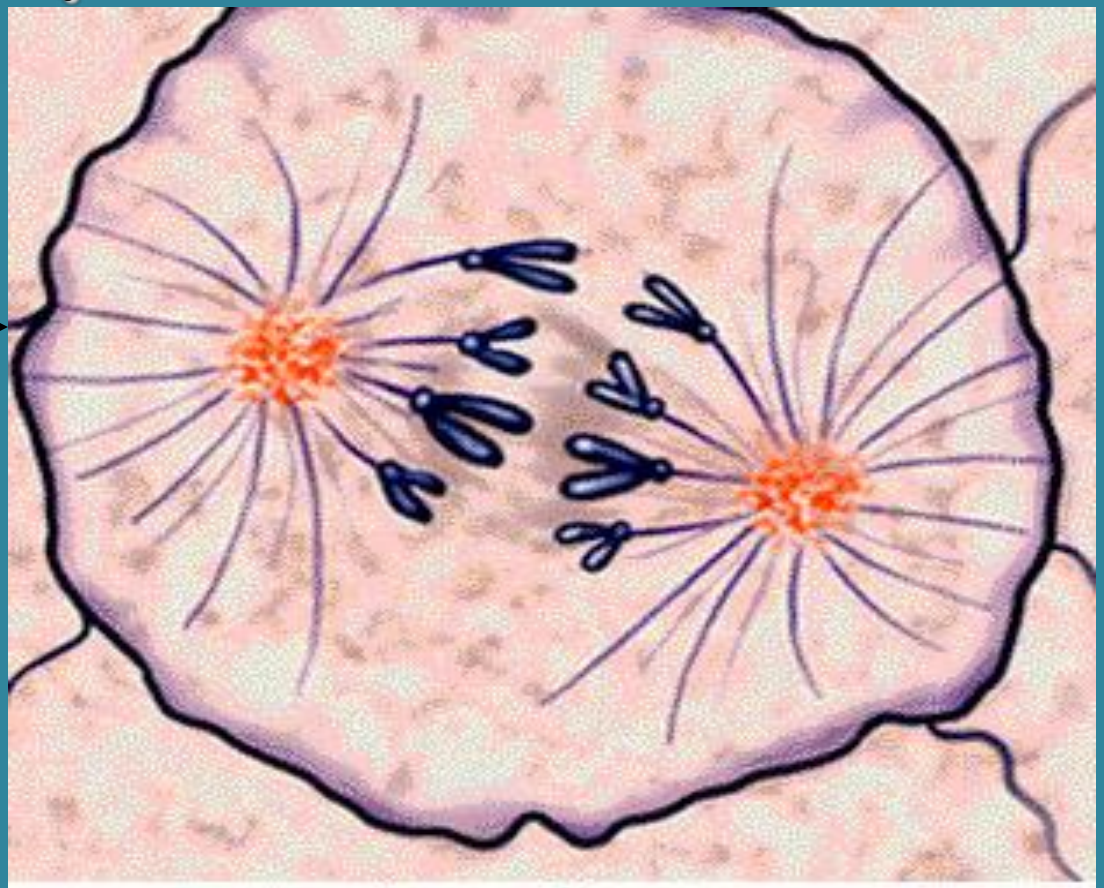


ANAPHASE



Anaphase Review

What the cell looks like



What's occurring

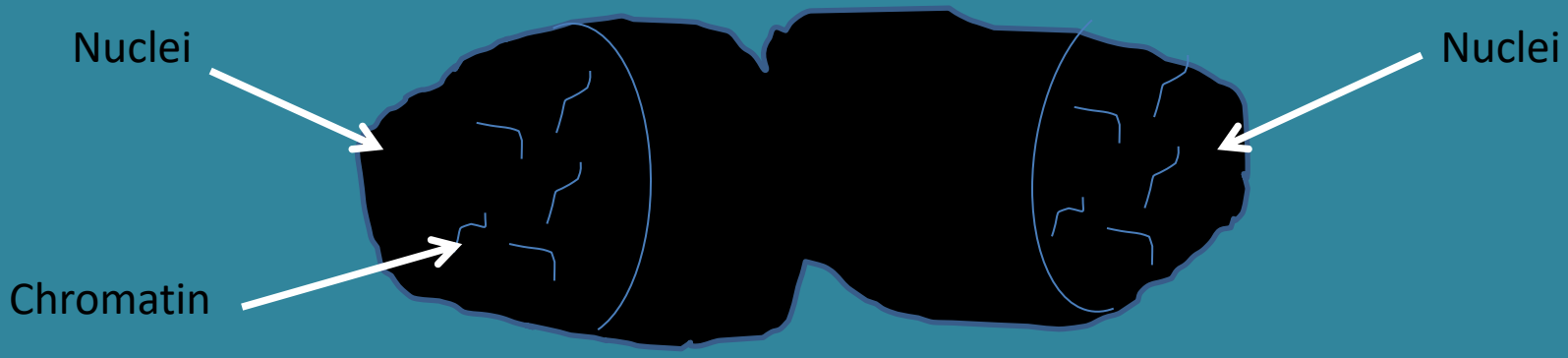
Anaphase

Centromeres divide in two.
Spindle fibers pull sister chromatids to opposite poles of cell.
Each pole (future daughter cell) now has an identical set of genes.

Telophase

4th step in Mitosis

- Two new **nuclei** form.
- Chromosomes appear as chromatin **(threads** rather than **rods).**
- **Mitosis** ends.



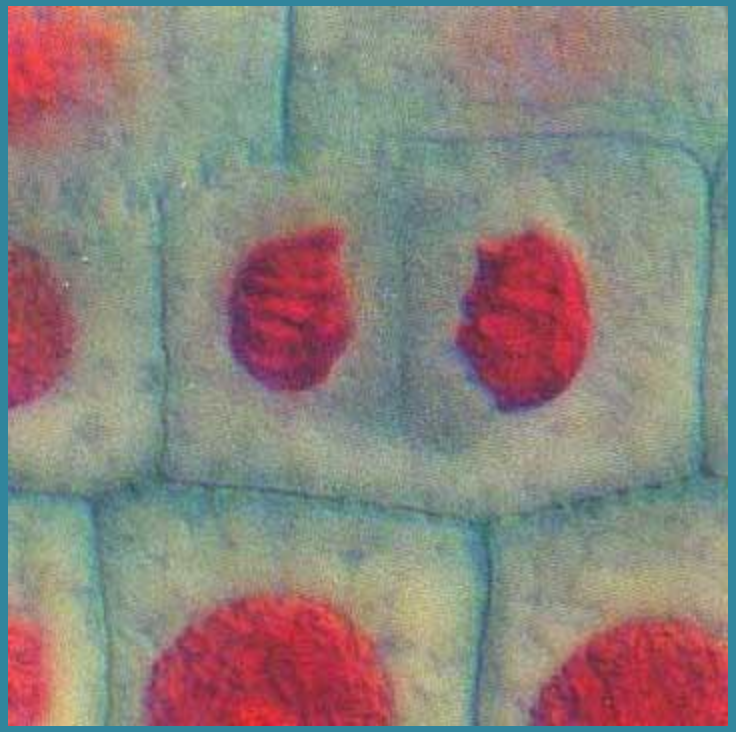
Telophase

- ✓Sister chromatids at opposite poles
- ✓Spindle disassembles
- ✓Nuclear envelope forms around each set of sister chromatids
- ✓Nucleolus reappears
- ✓CYTOKINESIS occurs
- ✓Chromosomes reappear as chromatin

Telophase

Animal Cell

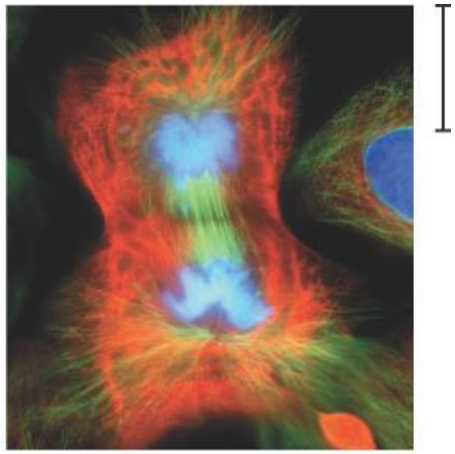
Plant Cell



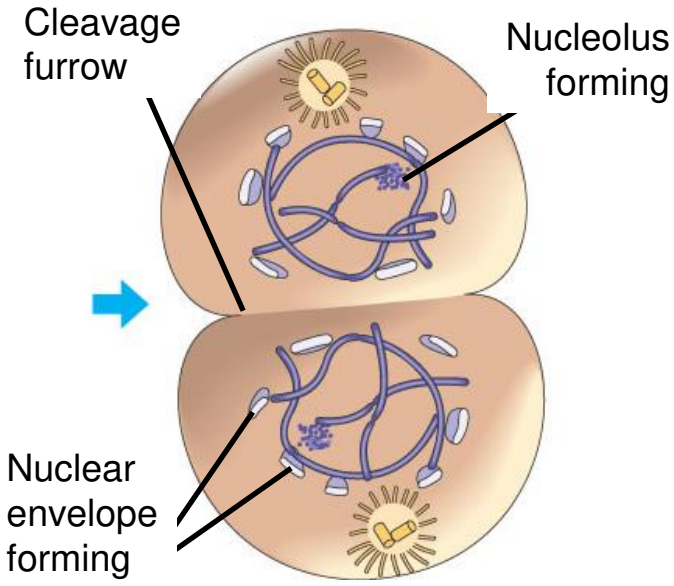
Photographs from: http://www.bioweb.uncc.edu/biol1110/Stages.htm

Telophase

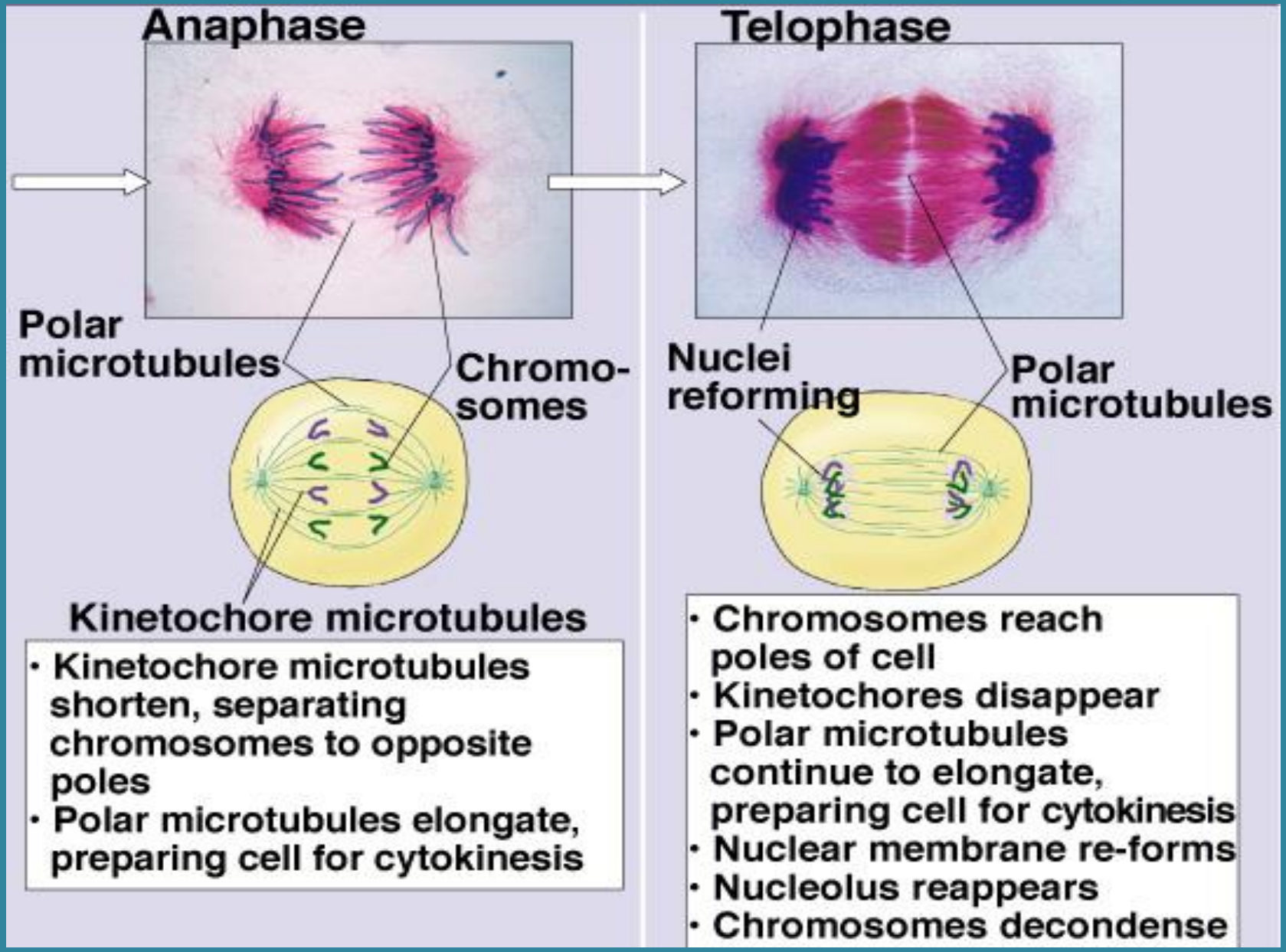
- Two daughter nuclei begin to form in the cell.
- Nuclear envelopes arise from the fragments of the parent cell's nuclear envelope and other portions of the endomembrane system.
- The chromosomes become less condensed.
- Mitosis, the division of one nucleus into two genetically identical nuclei, is now complete.



TELOPHASE AND CYTOKINESIS



Comparison of Anaphase & Telophase



Cytokinesis

occurs after mitosis

- Cell membrane moves inward to create two **daughter** cells – each with its own **nucleus** with identical **chromosomes.**

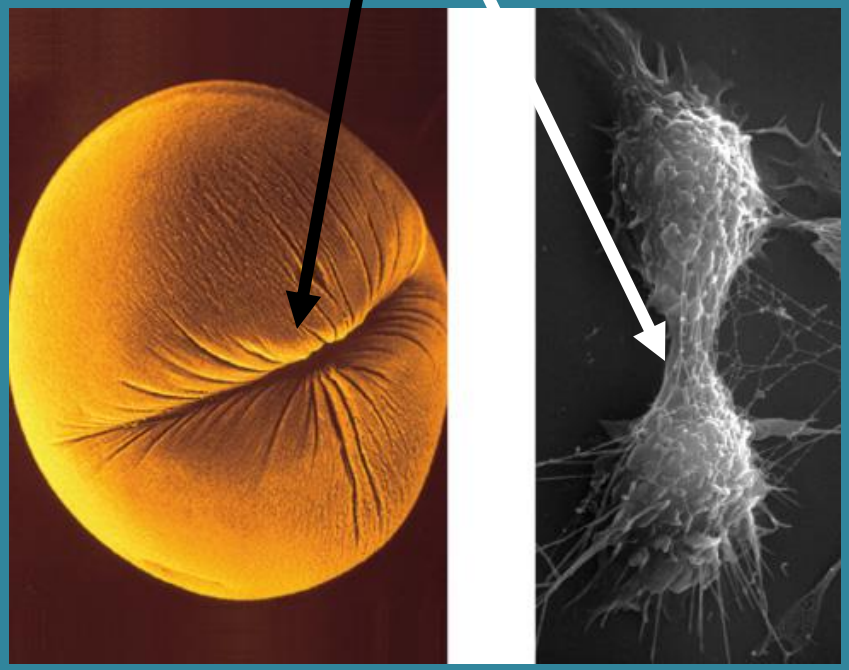
Cytokinesis

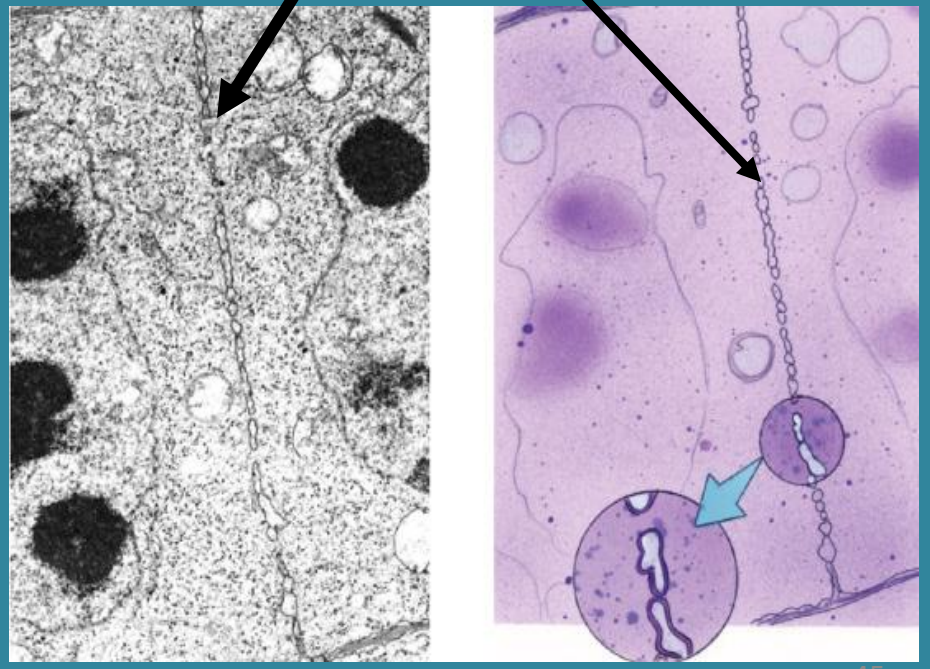
- ✓ Means division of the cytoplasm
- ✓ Division of cell into two, identical halves called daughter cells
- ✓ In plant cells, cell plate forms at the equator to divide cell
- ✓ In animal cells, cleavage furrow forms to split cell

Cytokinesis

Cleavage furrow in animal cell

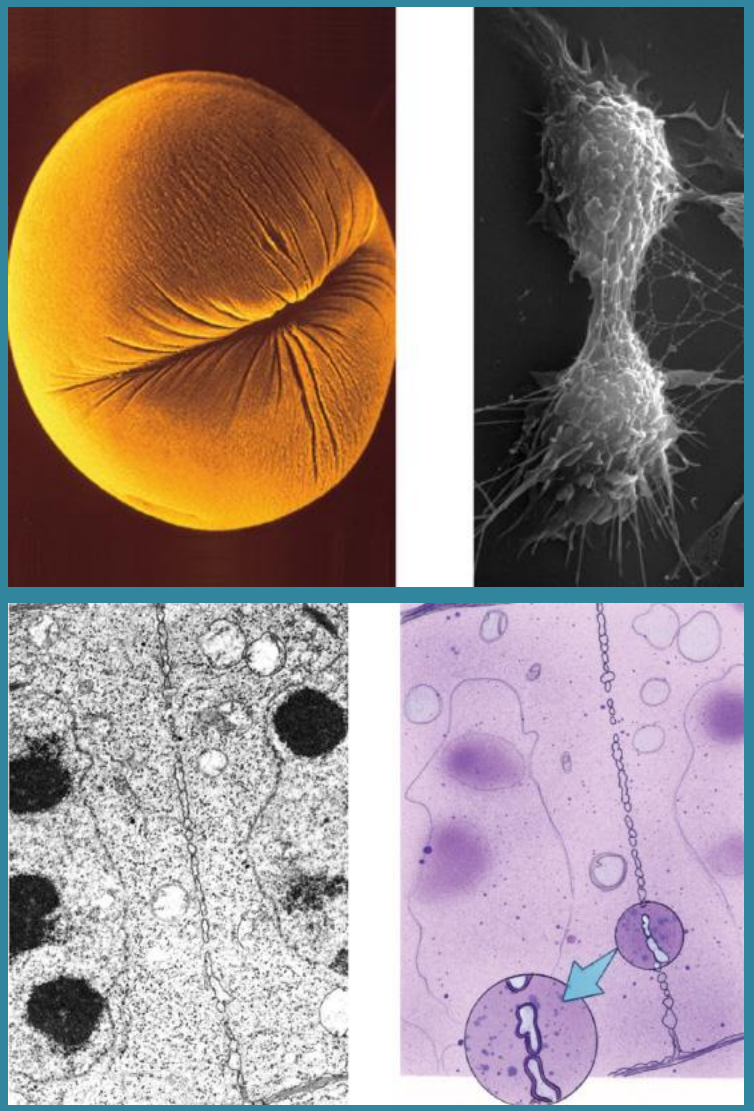
Cell plate in plant cell



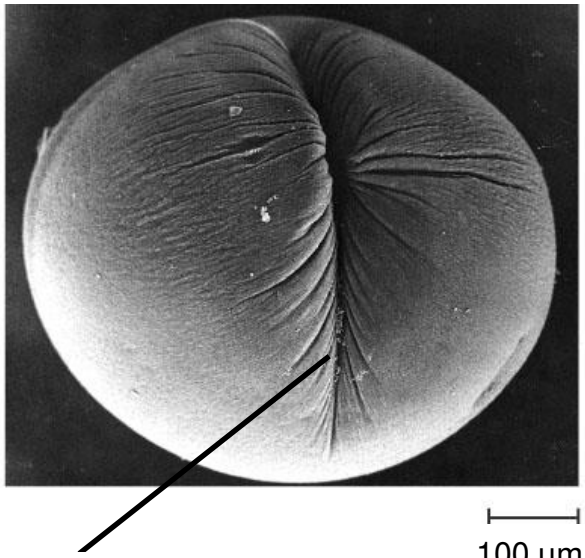


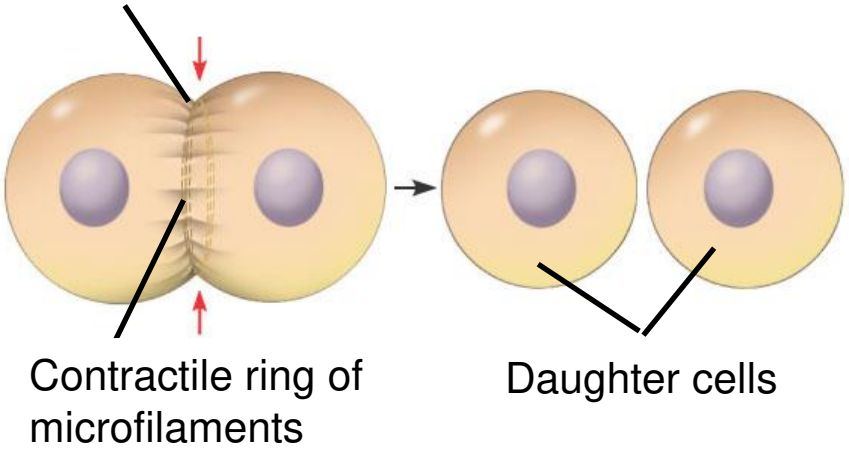
Cytokinesis

- Cleavage of cell into two halves
  - Animal cells
    - Constriction belt of actin filaments
  - Plant cells
    - Cell plate
  - Fungi and protists
    - Mitosis occurs within the nucleus

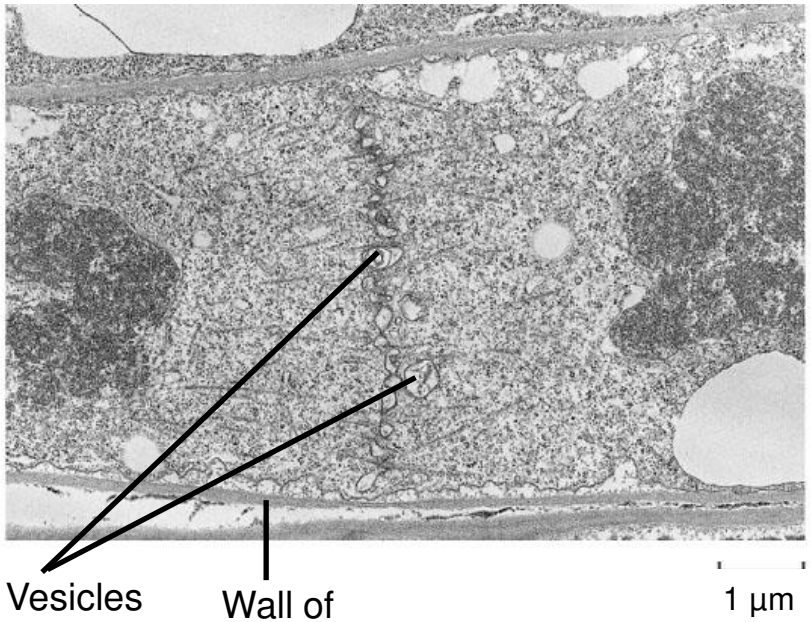


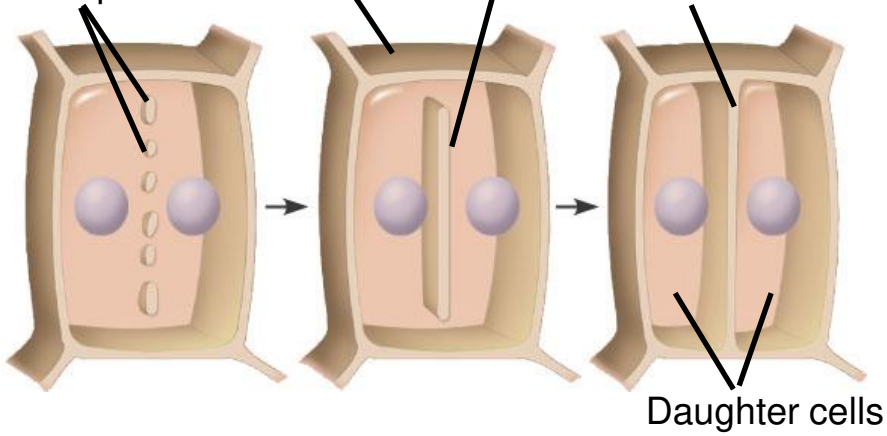
Cytokinesis In Animal And Plant Cells



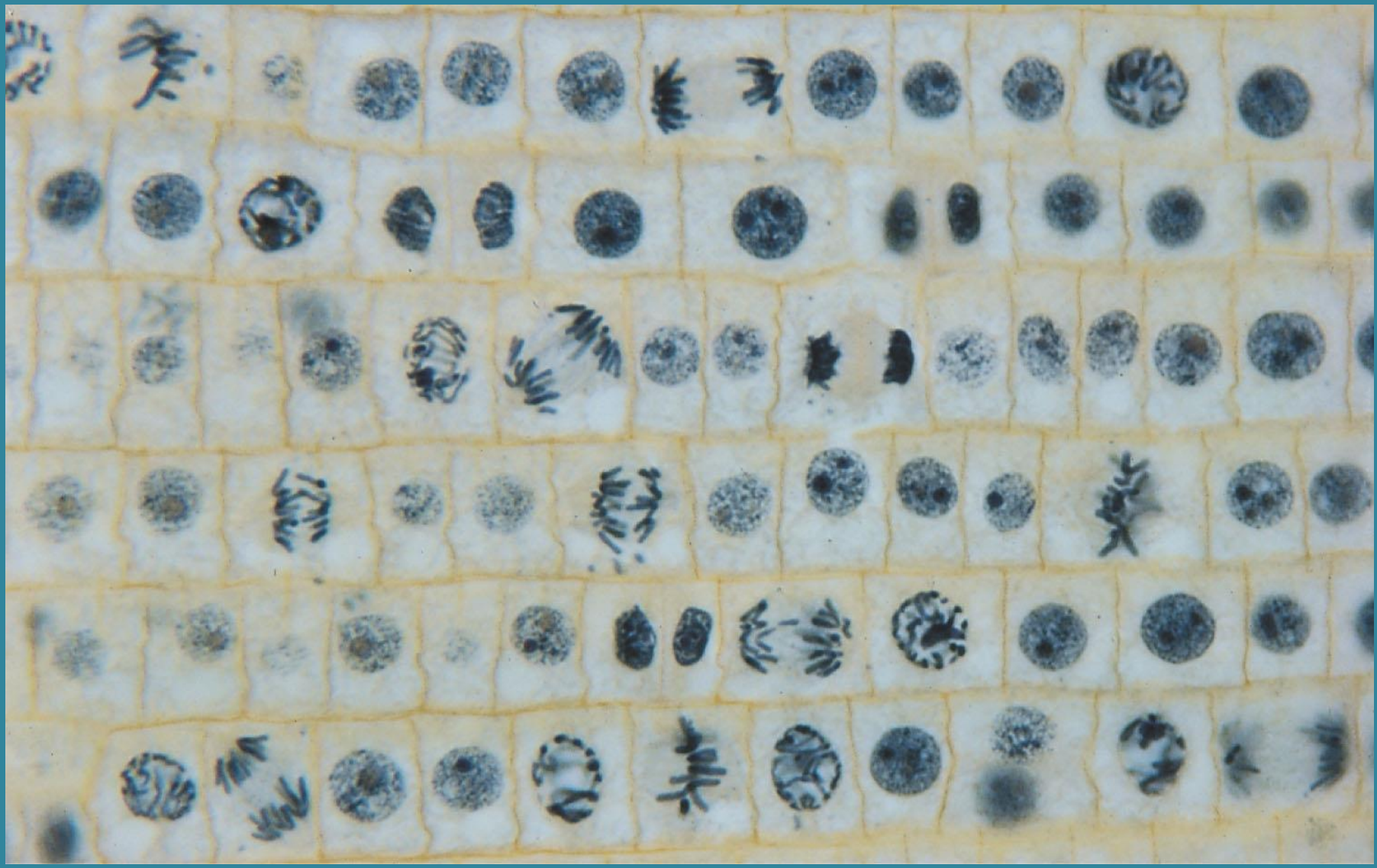


(a) Cleavage of an animal cell (SEM)

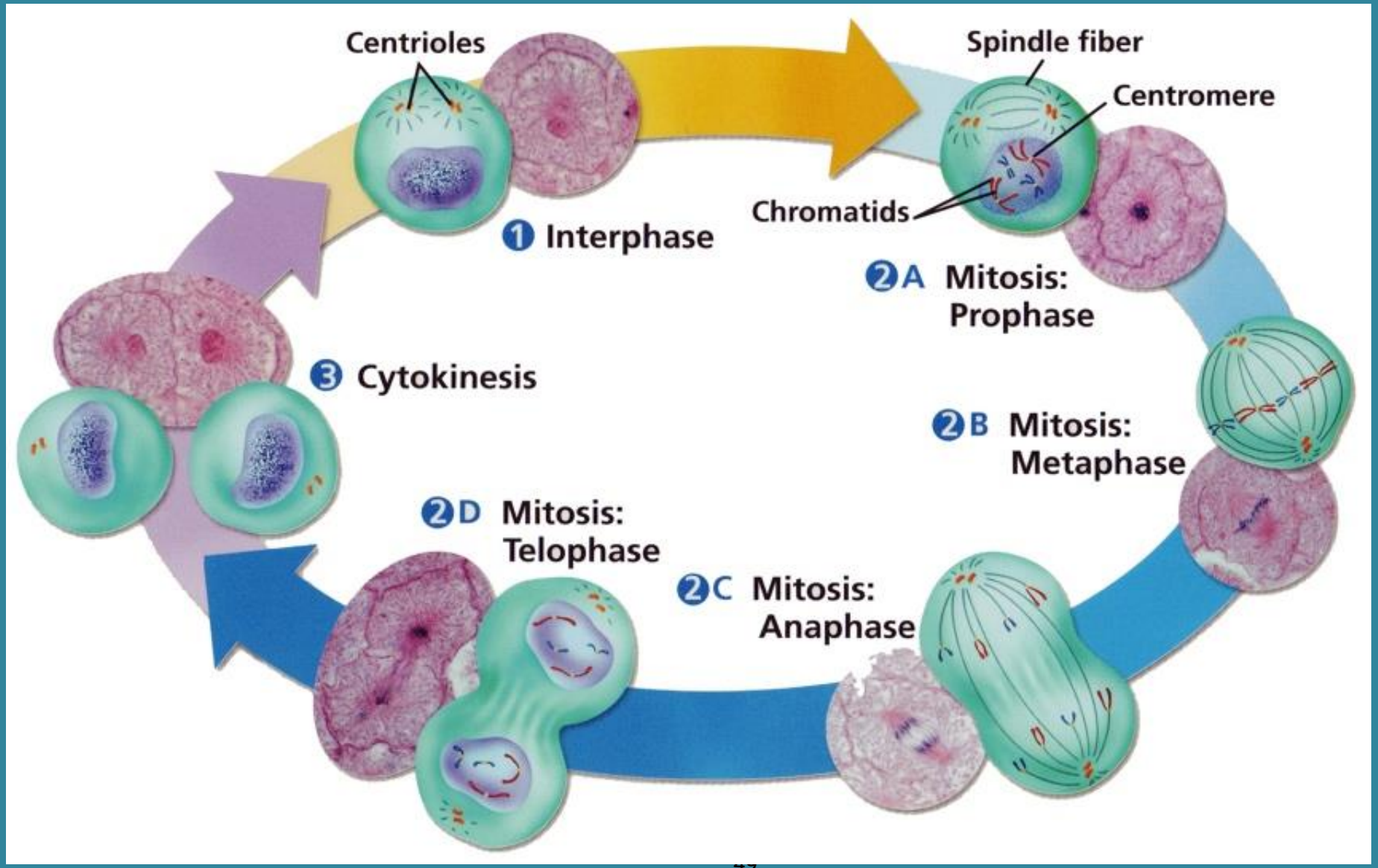




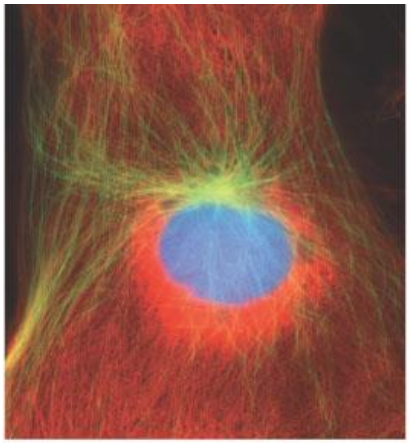
(b) Cell plate formation in a plant cell (SEM)



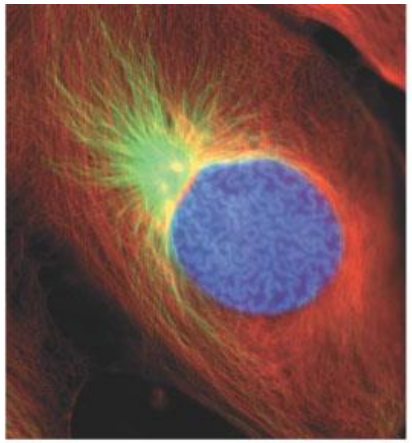
Cell Cycle


Centrioles
Spindle fiber
Centromere
Chromatids
1 Interphase
2A Mitosis: Prophase
2B Mitosis: Metaphase
2C Mitosis: Anaphase
2D Mitosis: Telophase
3 Cytokinesis

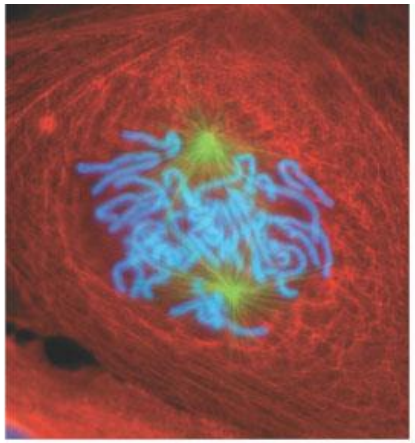
Mitotic Division of an Animal Cell



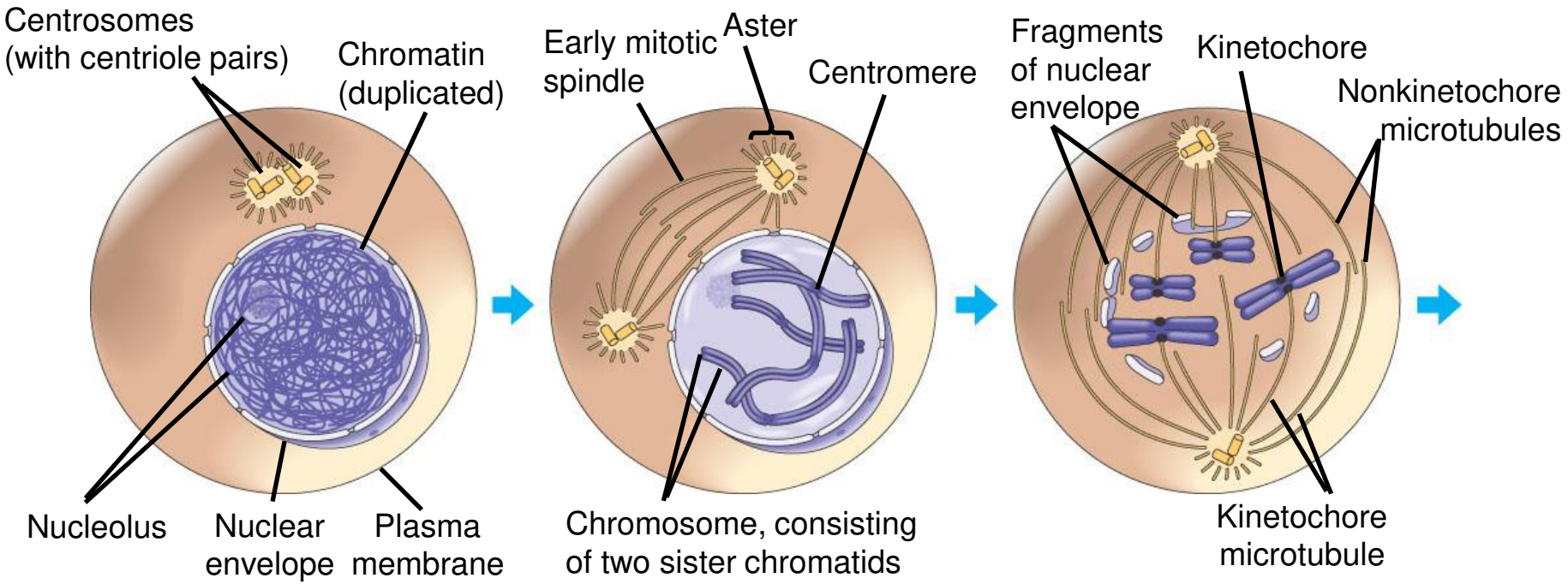
G_2 OF INTERPHASE



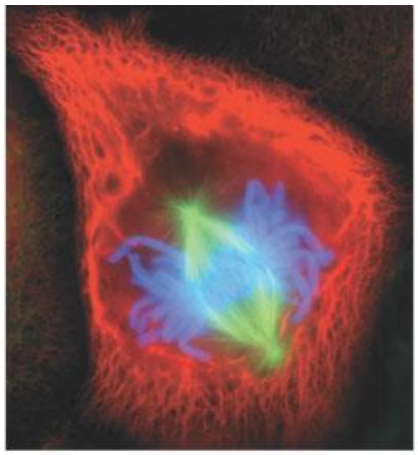
PROPHASE



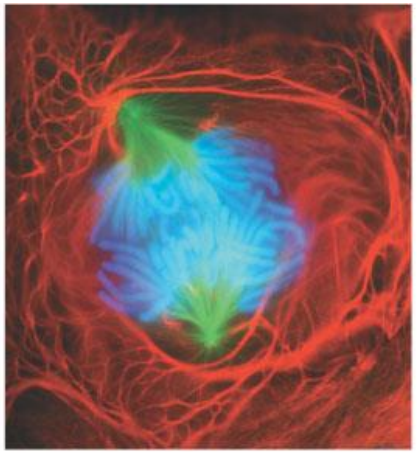
PROMETAPHASE



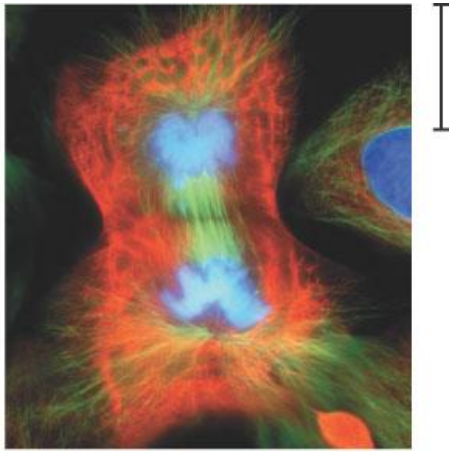
Mitotic Division of an Animal Cell



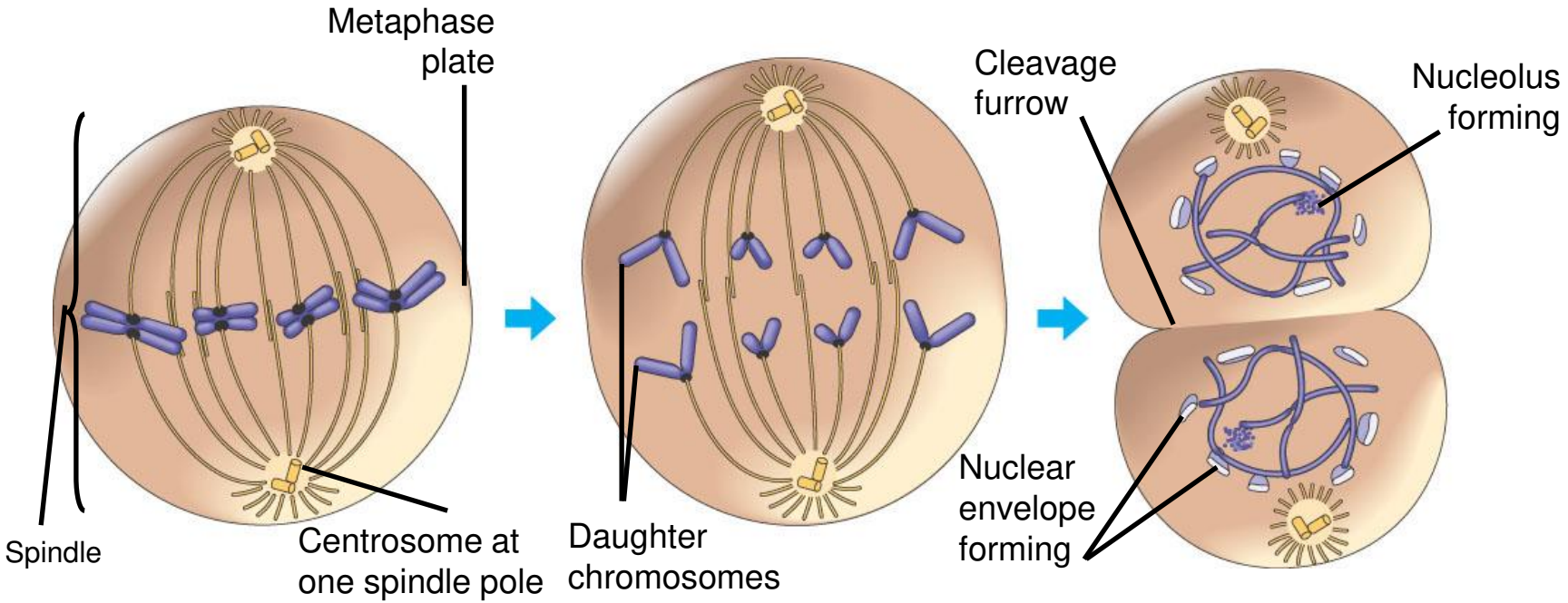
METAPHASE



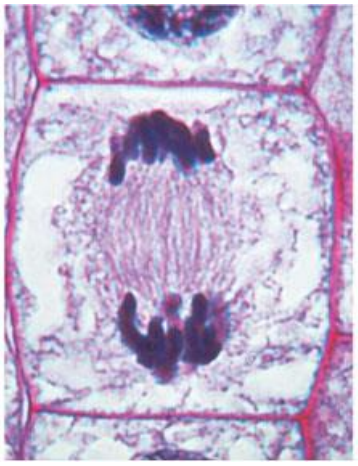
ANAPHASE

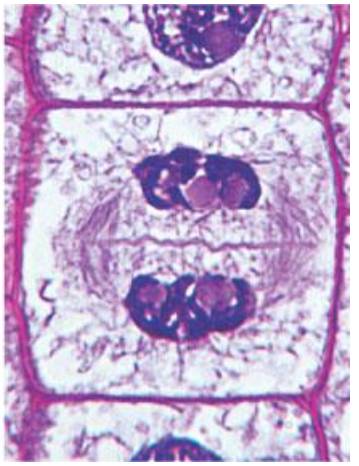


TELOPHASE AND CYTOKINESIS



Mitosis in a plant cell





Prophase. The chromatin is condensing. The nucleolus is beginning to disappear. Although not yet visible in the micrograph, the mitotic spindle is staring to from.

Prometaphase. We now see discrete chromosomes; each consists of two identical sister chromatids. Later in prometaphase, the nuclear envelop will fragment.

Metaphase. The spindle is complete, and the chromosomes, attached to microtubules at their kinetochores, are all at the metaphase plate.

Anaphase. The chromatids of each chromosome have separated, and the daughter chromosomes are moving to the ends of cell as their kinetochore microtubles shorten.

Telophase. Daughter nuclei are forming. Meanwhile, cytokinesis has started: The cell plate, which will divided the cytoplasm in two, is growing toward the perimeter of the parent cell.

Sketch the Cell Cycle