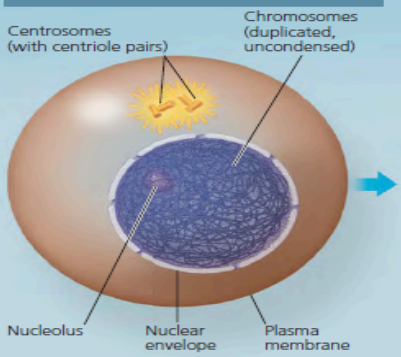
Cheat Sheet

G_2 of Interphase

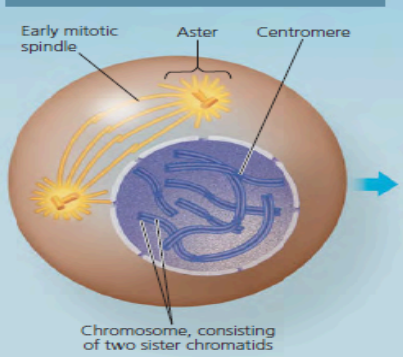


G_2 of Interphase

- A nuclear envelope encloses the nucleus.
- The nucleus contains one or more nucleoli (singular, *nucleolus*).
- Two centrosomes have formed by duplication of a single centrosome. Centrosomes are regions in animal cells that organize the microtubules of the spindle. Each centrosome contains 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, and intermediate filaments red. For simplicity, the drawings show only 6 chromosomes.

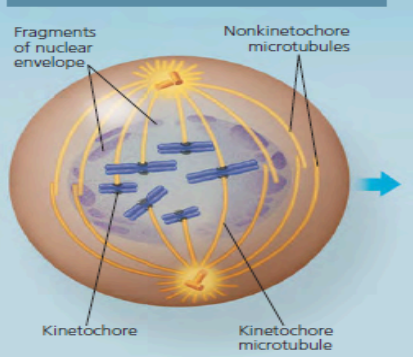
Prophase



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 at their centromeres and, in some species, all along their arms by cohesins (sister chromatid cohesion).
- The mitotic spindle (named for its shape) 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, propelled partly by the lengthening microtubules between them.

Prometaphase

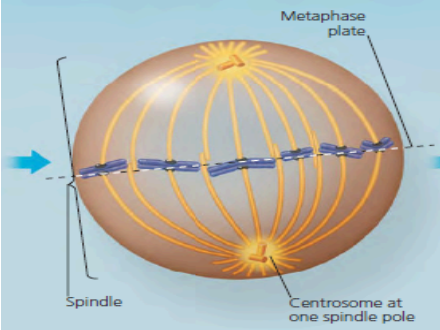


Prometaphase

- The nuclear envelope fragments.
- The microtubules extending from each centrosome can now invade the nuclear area.
- The chromosomes have become even more condensed.
- Each of the two chromatids of each chromosome now has a kinetochore, a specialized protein structure at the centromere.
- Some of the microtubules attach to the kinetochores, becoming "kinetochore microtubules," which jerk the chromosomes back and forth.
- Nonkinetochore microtubules interact with those from the opposite pole of the spindle.

? *How many molecules of DNA are in the prometaphase drawing? How many molecules per chromosome? How many double he-*

Metaphase



Metaphase

- The centrosomes are now at opposite poles of the cell.
- The chromosomes convene at the *metaphase plate*, a plane that is equidistant between the spindle's two poles. The chromosomes' centromeres lie at the metaphase plate.
- For each chromosome, the kinetochores of the sister chromatids are attached to kinetochore microtubules coming from opposite poles.

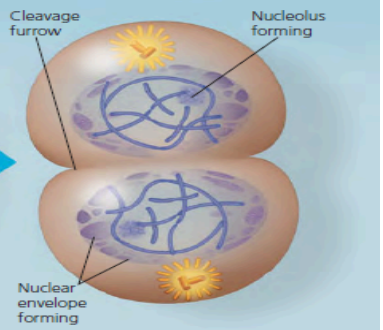
ANIMATION **BioFlix** Visit the Study Area at **www.masteringbiology.com** for the BioFlix® 3-D Animation on Mitosis.

Anaphase

Anaphase

- Anaphase is the shortest stage of mitosis, often lasting only a few minutes.
- Anaphase begins when the cohesin proteins are cleaved. This allows the two sister chromatids of each pair to part suddenly. Each chromatid thus becomes a full-fledged chromosome.
- The two liberated daughter 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.

Telophase and Cytokinesis



Telophase

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

Cytokinesis

- The division of the cytoplasm is usually well under way by late telophase, so the two daughter cells appear shortly after the end of mitosis.
- In animal cells, cytokinesis involves the formation of a cleavage furrow, which pinches the cell in two.

Chapter 12 Questions

1. **What is a cell's DNA, or genetic information called?**
2. How much DNA does a typical human cell have?
3. **What are human body cells that are not reproductive called? How many chromosomes do these cells have in humans**
4. **What are reproductive cells called?**
5. How many chromosomes do cabbage plant, chimpanzee, elephant, and hedgehog non-reproductive cells have?
6. **What form does chromatin take when a cell is not dividing? When it is?**
7. **What is the structure of a duplicated chromosome?**
8. **What are the phases of the cell cycle?**
9. **How long do the phases last?**
10. **What are the phases of mitosis? Explain them in detail.**
11. **What is the mitotic spindle?**
12. **What is a centrosome?**
13. **What is a kinetochore?**
14. **What is the metaphase plate?**
15. **What cleaves the cohesins holding the sister chromatids together?**
16. **How does the cell extend horizontal?**
17. **What occurs during cytokinesis in animal cells?**
18. **What occurs during cytokinesis in plant cells?**
19. **What is difference between binary fission in prokaryotes and eukaryotes?**
20. **What are two special types of cell division used by some eukaryotes?**
21. **What triggers and coordinates key events in the cell cycle?**
22. **What are checkpoints and where are they found?**
23. **What are the kinases that drive the cell cycle called and what activates them?**
24. **What is MPF?**
25. **When does the cyclin level rise and fall?**
26. **What is the most important checkpoint?**
27. **What occurs at the M checkpoint?**
28. **What is the S phase checkpoint?**
29. **What is PDGF?**
30. **What is density-dependent inhibition?**
31. **What is anchorage dependence?**
32. **What are HeLa cells?**
33. **What is transformation?**
34. **What is metastasis?**

Chapter 12 Answers

1. Genome
2. 2 m (250,000 times greater than cell's diameter)
3. Somatic cells
4. Gametes, half chromosomes of somatics
5. 18, 48, 56, 90
6. Long thin fiber when not dividing, condense during cell division (densely coiled and folded, much shorter and thicker)
7. Two identical sister chromatids attached by protein complexes called cohesins (called sister chromatid cohesion) all along length, each chromatid with centromere (region with repetitive sequences in DNA where chromatid is attached mostly closely attached to sister (attachment mediated by proteins that recognize and bind to centromeric DNA, other bound proteins condense the DNA). Portions of chromatid on either side of centromere called arms
8. Mitotic (M) phase (includes mitosis and cytokinesis) and interphase (90% of cycle with G1 phase ("first gap"), S phase ("synthesis"), G2 phase ("second gap)"). Cell grows by producing proteins and cytoplasmic organelles during all three interphase phases. Duplication of chromosomes occurs entirely during S phase.
9. G2 generally lasts 4-6 hours, others are variable (S takes about half of cycle)
10. Prophase, prometaphase, metaphase, anaphase, telophase
11. Structure that begins to form in cytoplasm during prophase, consists of fibers of microtubules and associated proteins, other microtubules of cytoskeleton partially disassembled to form spindle
12. Subcellular region containing material that functions to organize cell's microtubules (type of microtubule-organizing center), duplicates in interphase
13. Structure made of protein that assemble on specific sections of DNA at each centromere, chromosome's pair face in opposite directions, some spindle microtubules attach to kinetochores (kinetochore microtubule, one in yeast cells, 40 or so in some mammalian cells)
14. Imaginary plane midway between poles where centromeres are located during metaphase
15. Separase during anaphase
16. Nonkinetochore microtubules (overlap extensively in metaphase) push centrosomes apart when motor proteins start walking away from each other using ATP during anaphase
17. Process called cleavage. Shallow groove in cell surface near metaphase plate called cleavage furrow appears. Cytoplasmic side of furrow is contractile ring of actin microfilaments, which interacts with myosin molecules to contract
18. Vesicles from Golgi apparatus move along microtubules to middle of cell, where they coalesce to produce a cell plate, contents of vesicles form cell wall between daughters

19. In eukaryotes involves mitosis, does not in prokaryotes. In bacteria, replication begins at the origin of replication, two origins are produced. One origin moves rapidly to other end of cell using an actin-like protein. Cell elongates and pinches
20. In unicellular protists called dinoflagellates, nuclear envelope remains intact and microtubules pass through nucleus inside cytoplasmic tunnels.
    In unicellular eukaryotes called diatoms and some yeasts, nuclear envelope remains intact and microtubules form spindle within nucleus
21. Cell cycle control system (cyclically operating set of molecules in the cell)
22. Control point where stop and go-ahead signals can regulate cycle, found in G_1, G_2, and M phases
23. Cyclin-dependent kinases (Cdks). Kinases at constant concentration, but usually inactive. To be active, kinase must be attached to a cyclin (protein that has cyclically fluctuating concentration)
24. cyclin-Cdk complex that was discovered first (maturation-promoting factor), triggers cell's passage into M phase, past G_2 checkpoint. Phosphorylates many proteins to trigger mitosis. Causes phosphorylation of proteins of nuclear lamina, promoting fragmentation of envelope during prometaphase. Synthesis of cyclin begins in late S phase, continues through G_2, cyclin protected from degradation during this stage. Cyclin combines with Cdk to produce MPF, when enough MPF accumulate cell passes G_2 checkpoint. MPF activity peaks during metaphase, phosphorylates proteins, initiates cyclin degration during anaphase to terminate M phase. Degradation continues during G_1
25. Rises during S and G_2 phases, falls abruptly during M phase
26. G_1 checkpoint. If cell receives go ahead signal, will complete phases and divide. If not, may exit cycle and switch to G_0 phase (nondividing state), most human cells at G_0 phase (mature nerve and muscle cells never divide, liver cells can be called back from G_0 phase by external cues)
27. Anaphase does not occur until all chromosomes are properly attached. Regulatory protein complex becomes activated only when kinetochores are properly attached to spindle (not cyclin-Cdk complex), sets off events that activate separase
28. Stops cells with DNA damage from proceeding in the cell cycle
29. Platelet-derived growth factor, made by platelets, causes fibroblasts (connective tissue cell) to divide. Fibroblasts have PDGF receptors, binding triggers STP that allows cells to pass G_1 checkpoint and divide
30. Phenomenon in which crowded cells stop dividing
31. Animal cells must be attached to substratum to divide
32. Cancer cells from Henrietta Lacks that have been reproducing in culture since 1951
33. Process that causes cells to behave like cancer cells
34. Spread of cancer cells to locations distant from their original site