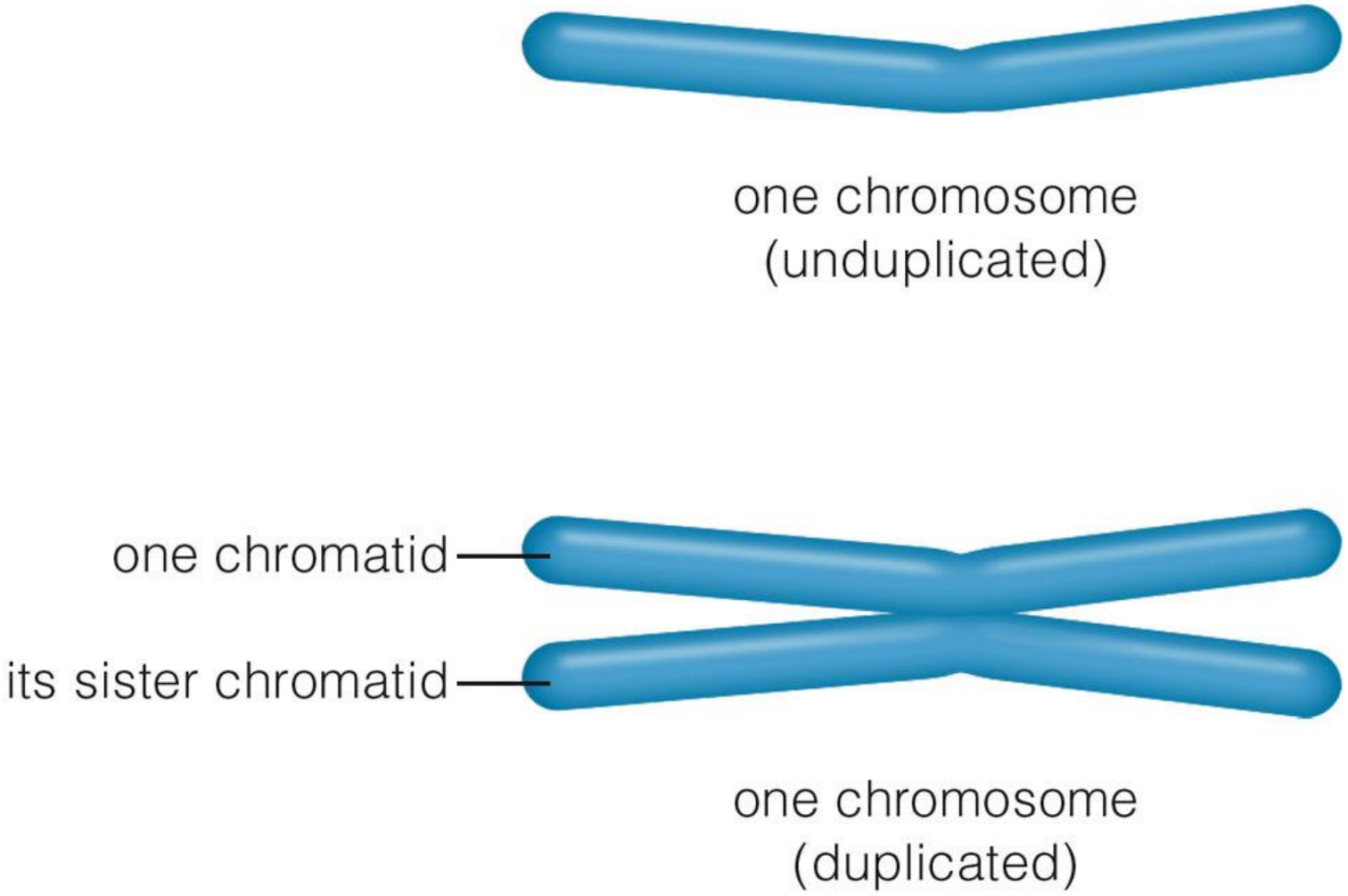
Cell Division – Mitosis and the Cell Cycle

A Chromosome and Sister Chromatids

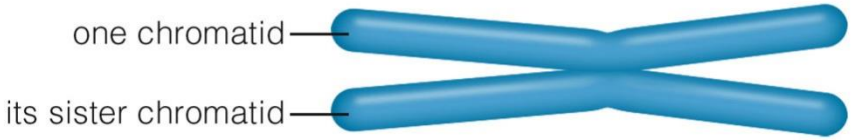


Key Points About Chromosome Structure

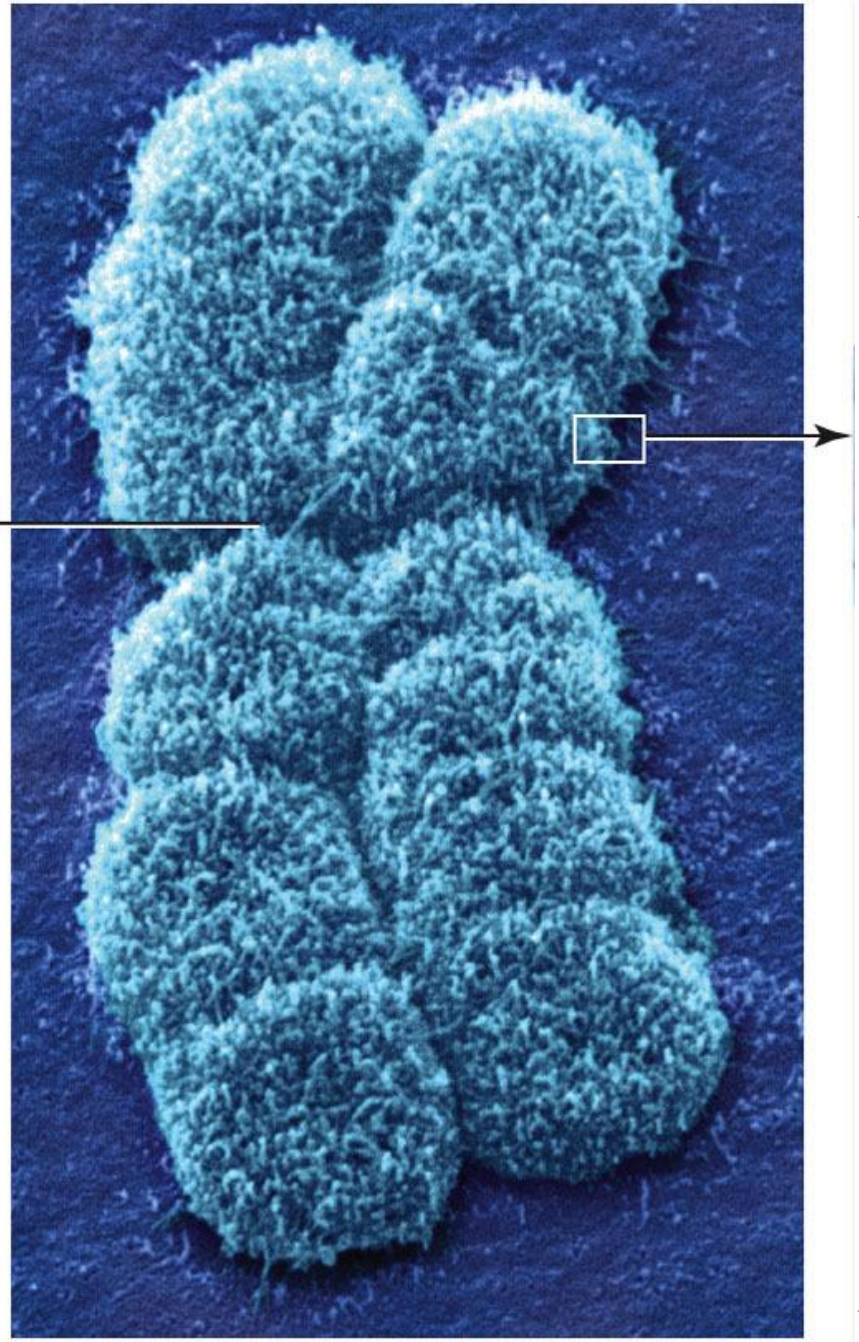
- A chromosome consists of DNA that is wrapped around proteins (**histones**) and condensed

- Each histone and the DNA wrapped around it make up a **nucleosome**, the smallest unit of structural organization in chromosomes

one chromosome
(unduplicated)



one chromosome
(duplicated)



A Duplicated human chromosome in its most condensed form. If this chromosome were actually the size shown in the micrograph, its two DNA strands would stretch out about 800 meters (0.5 miles).

Fig. 9-3a, p. 143

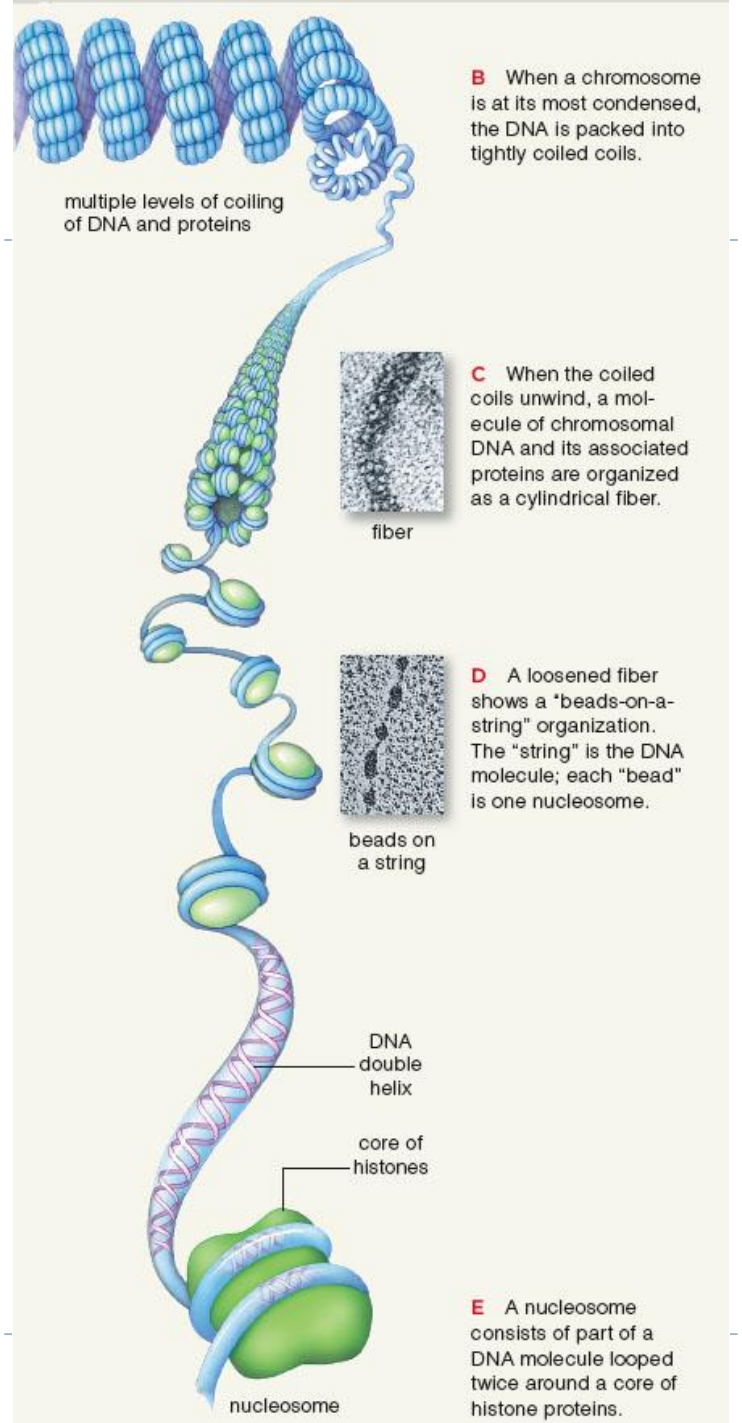
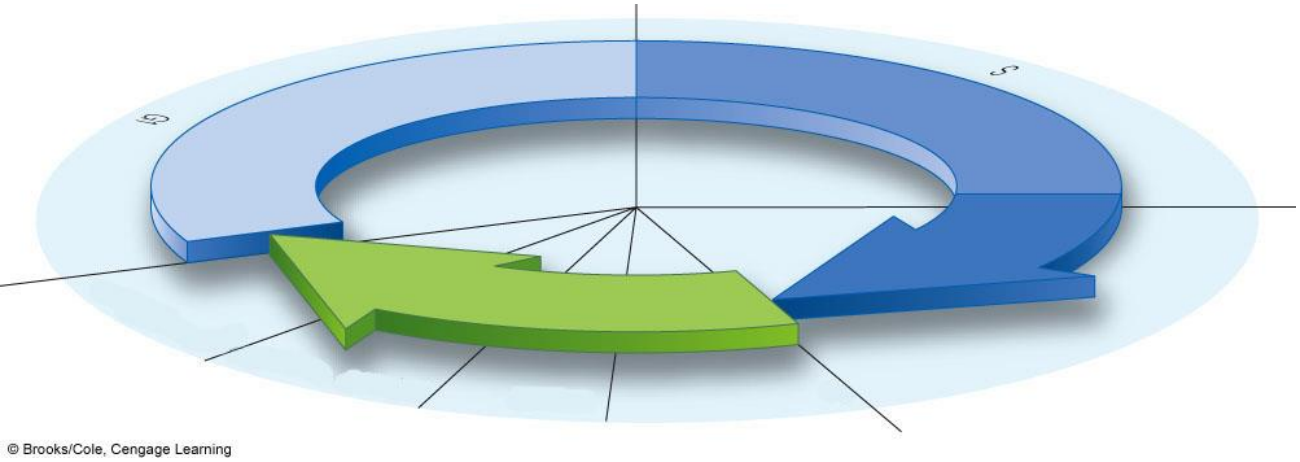
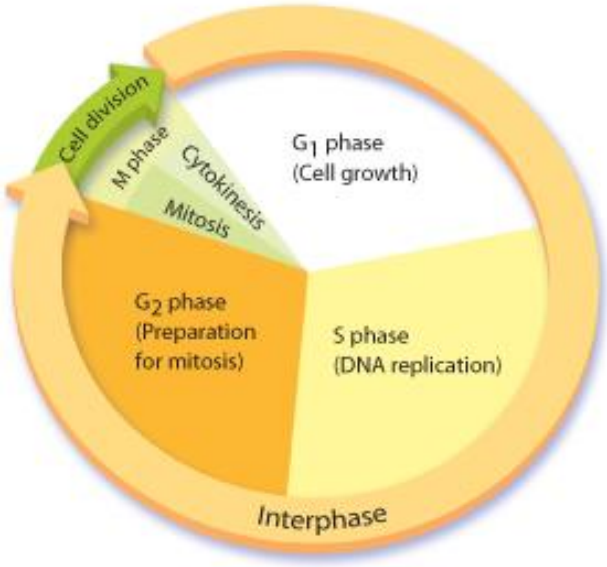


Fig. 9-3 (b-e), p. 143

9.2 Introducing the Cell Cycle

- **Cell cycle**
  - A sequence of three stages (interphase, mitosis, and cytoplasmic division) through which a cell passes between one cell division and the next



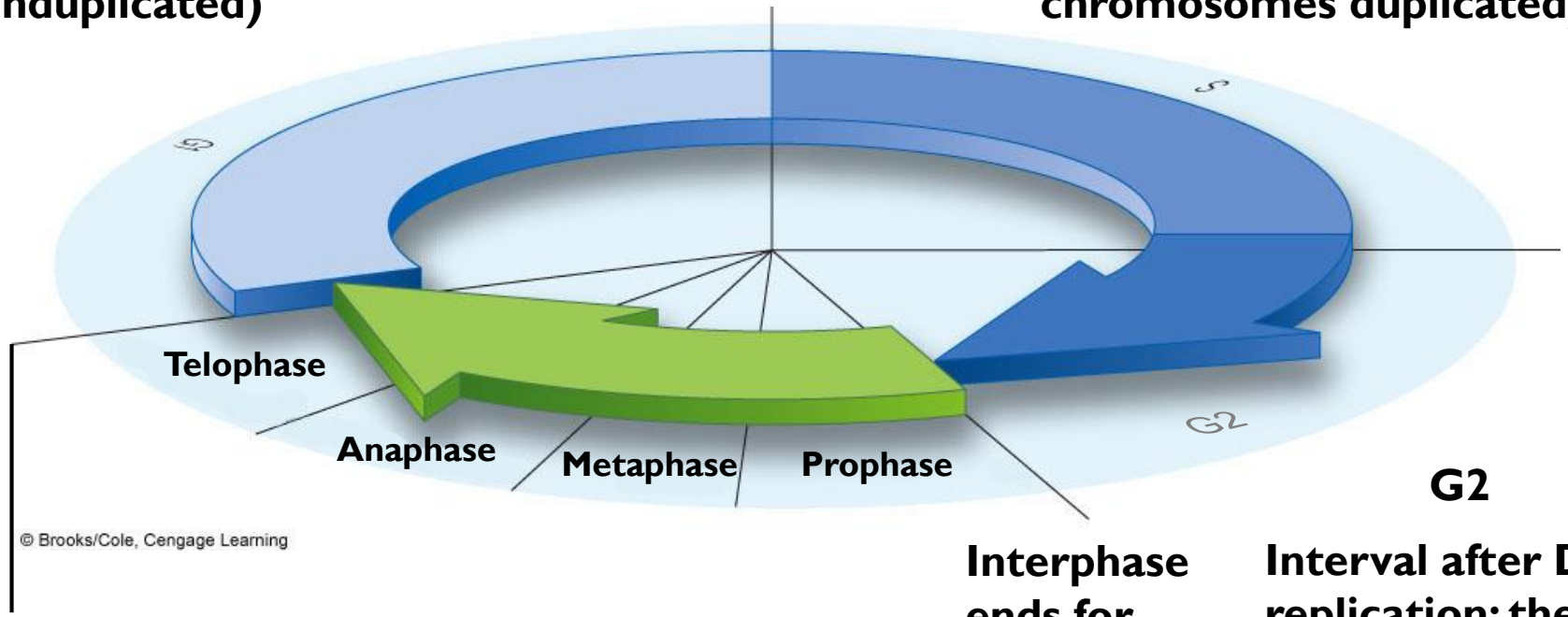


G1

Interval of cell growth before DNA replication (chromosomes unduplicated)

S

Interval of cell growth when the DNA is replicated (all chromosomes duplicated)



cytoplasmic division; each descendant cell enters interphase

Interphase ends for parent cell

G2

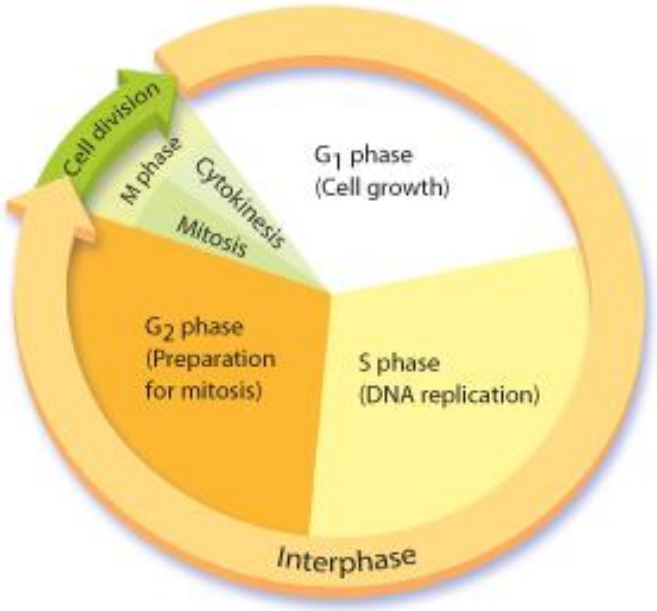
Interval after DNA replication; the cell prepares to divide

Stepped Art

Fig. 9-4, p. 144

Interphase

- **Interphase** consists of three stages, during which a cell increases in size, doubles the number of cytoplasmic components, and duplicates its DNA
  - G1: Interval of cell growth and activity (most of cells activity)
  - S: Interval of DNA replication (synthesis)
  - G2: Interval when the cell prepares for division



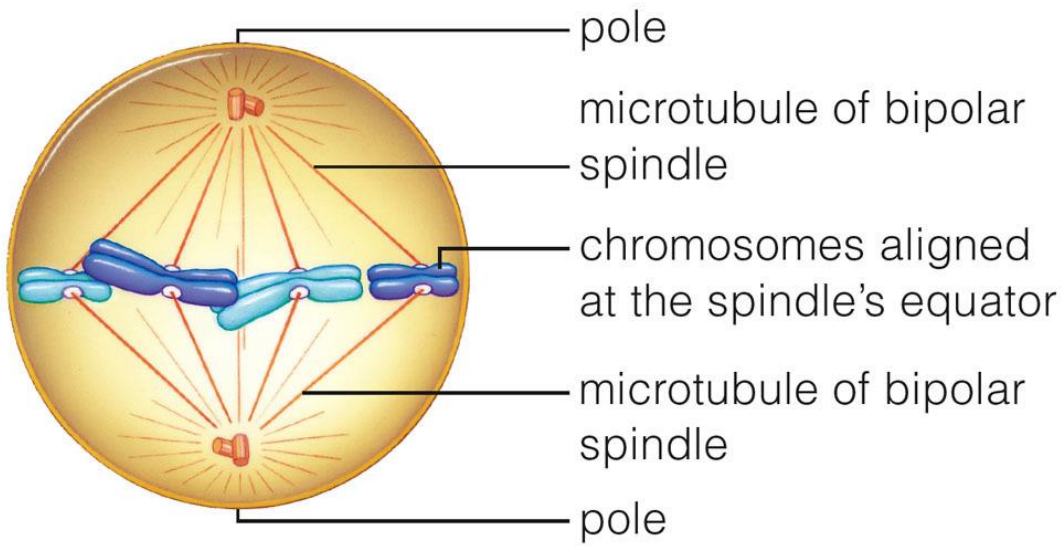
Mitosis and the Chromosome Number

- Mitosis produces two diploid nuclei with the same number and kind of chromosomes as the parent

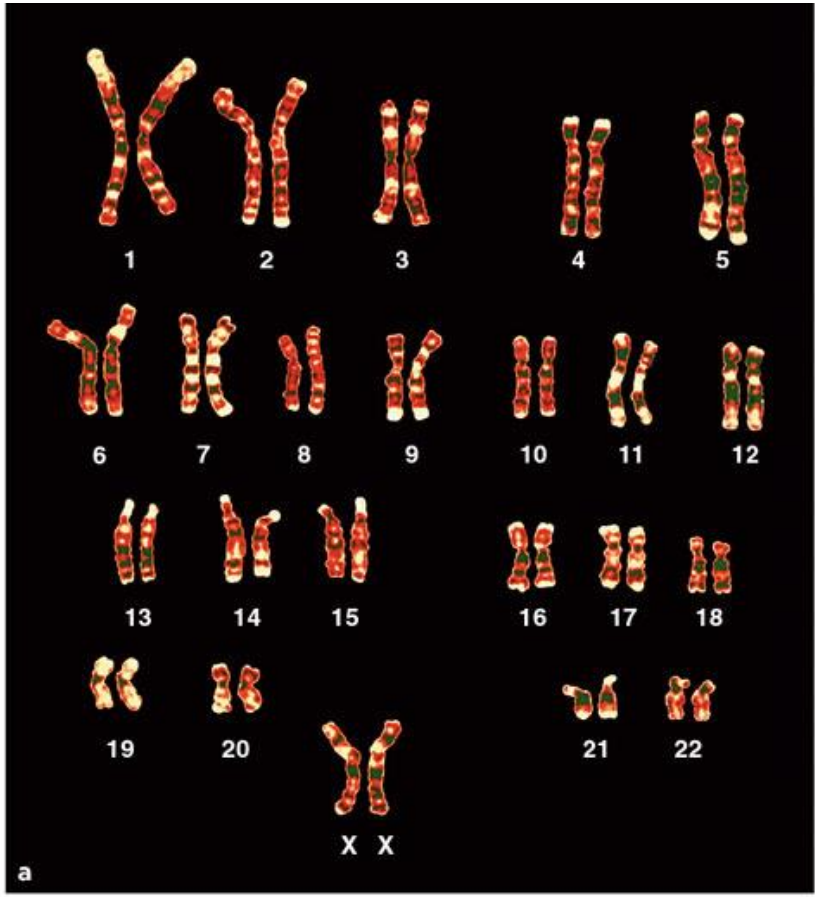
- **Chromosome number**
  - The sum of all chromosomes in a type of cell
  - Human cells have 46 chromosomes paired in 23 sets (**diploid** number)
  - Pairs have the same shape and information about the same traits (except sex chromosomes XY)

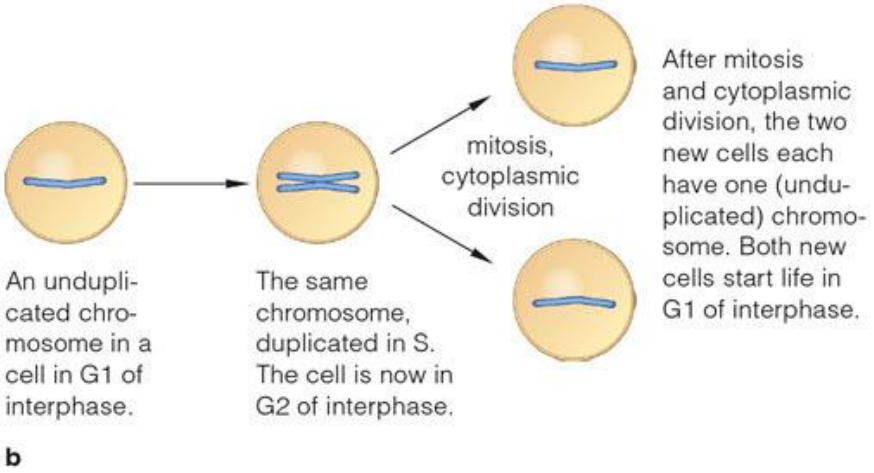
Mitosis and the Chromosome Number

- **Bipolar spindle**
  - A dynamic network of microtubules that forms during nuclear division
  - Grows into the cytoplasm from opposite poles of the cell and attaches to duplicated chromosomes
  - Microtubules from opposite poles attach to different sister chromatids and separate them



Mitosis Maintains Chromosome Number





9.3 A Closer Look at Mitosis

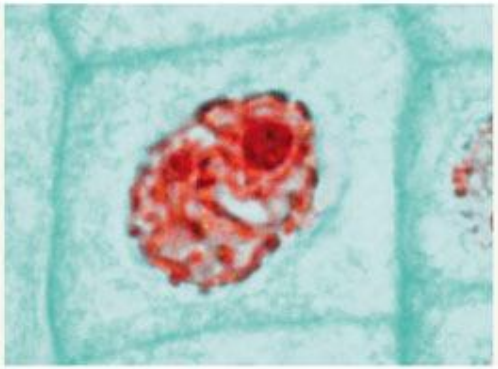
- When a nucleus divides by mitosis, each new nucleus has the same chromosome number as the parent cell

- There are four main stages of mitosis:

1) prophase
2) metaphase
3) anaphase
4) telophase

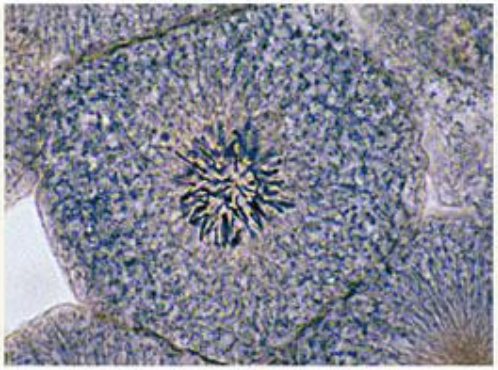
Prophase

- **Prophase**
  - Chromosomes condense
  - Microtubules form a bipolar spindle
  - Nuclear envelope breaks up
  - Microtubules attach to the chromosomes
- **Centrosome**
  - A region near the nucleus that organizes spindle microtubules; usually includes two centrioles



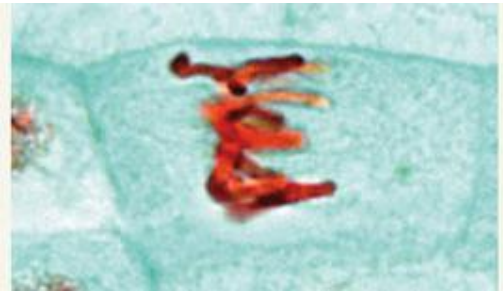
B Prophase

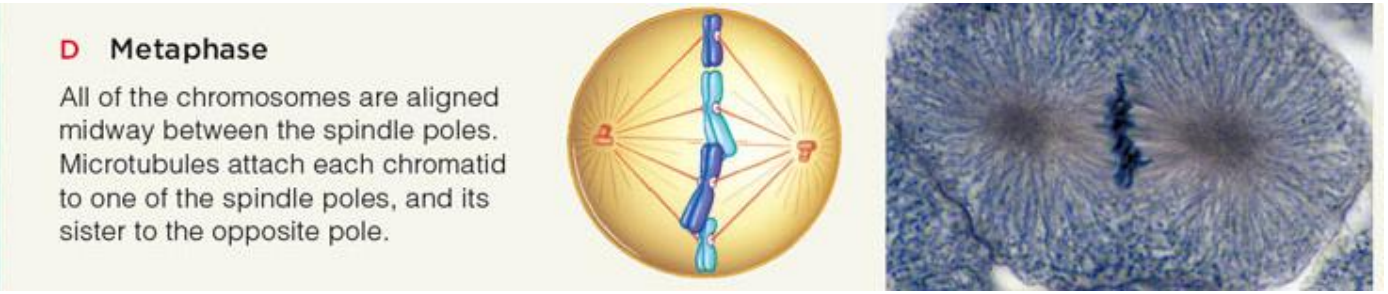
The chromosomes become visible as discrete structures as they condense further. Microtubules assemble and move one of the two centrosomes to the opposite side of the nucleus, and the nuclear envelope breaks up.



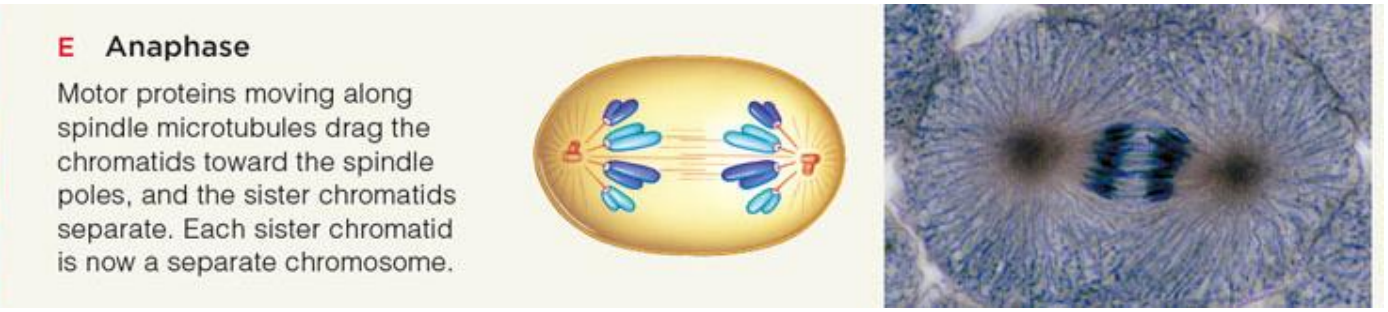
Metaphase and Anaphase

- **Metaphase**
  - All duplicated chromosomes line up midway between the spindle poles





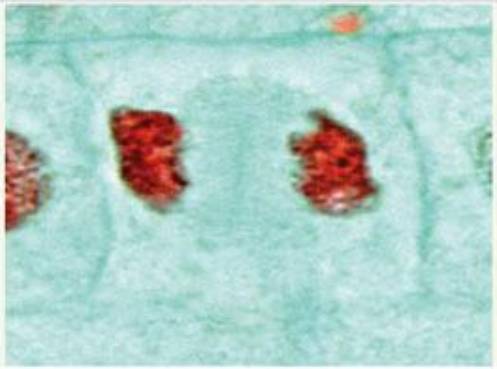
- **Anaphase**
  - Microtubules separate the sister chromatids of each chromosome and pull them to opposite spindle poles



Telophase

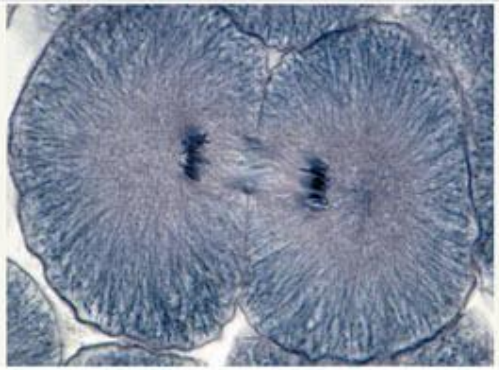
- **Telophase**
  - Two clusters of chromosomes reach the spindle poles
  - A new nuclear envelope forms around each cluster

- Two new nuclei are formed, each with the same chromosome number as the parent cell



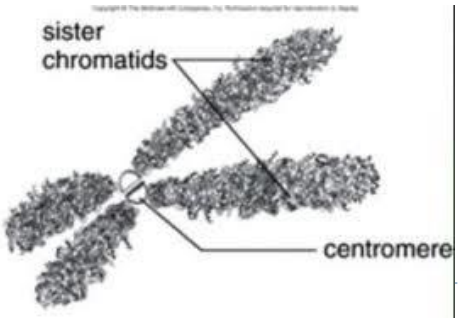
F Telophase

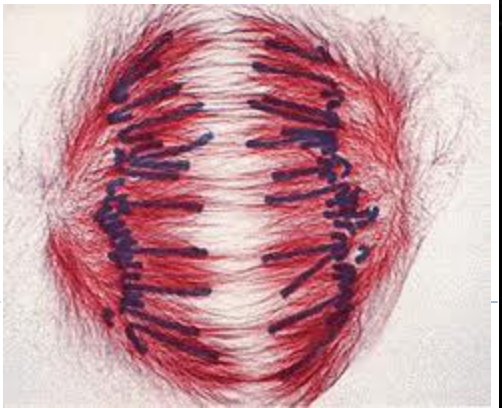
The chromosomes reach the spindle poles and decondense. A nuclear envelope begins to form around each cluster; new plasma membrane may assemble between them. Mitosis is over.

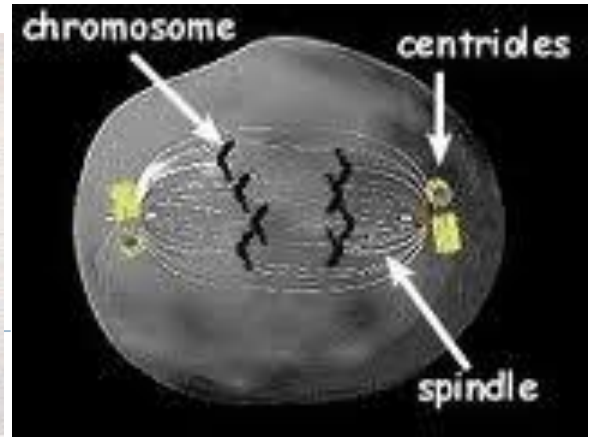


Important Cell Structures Involved in Mitosis

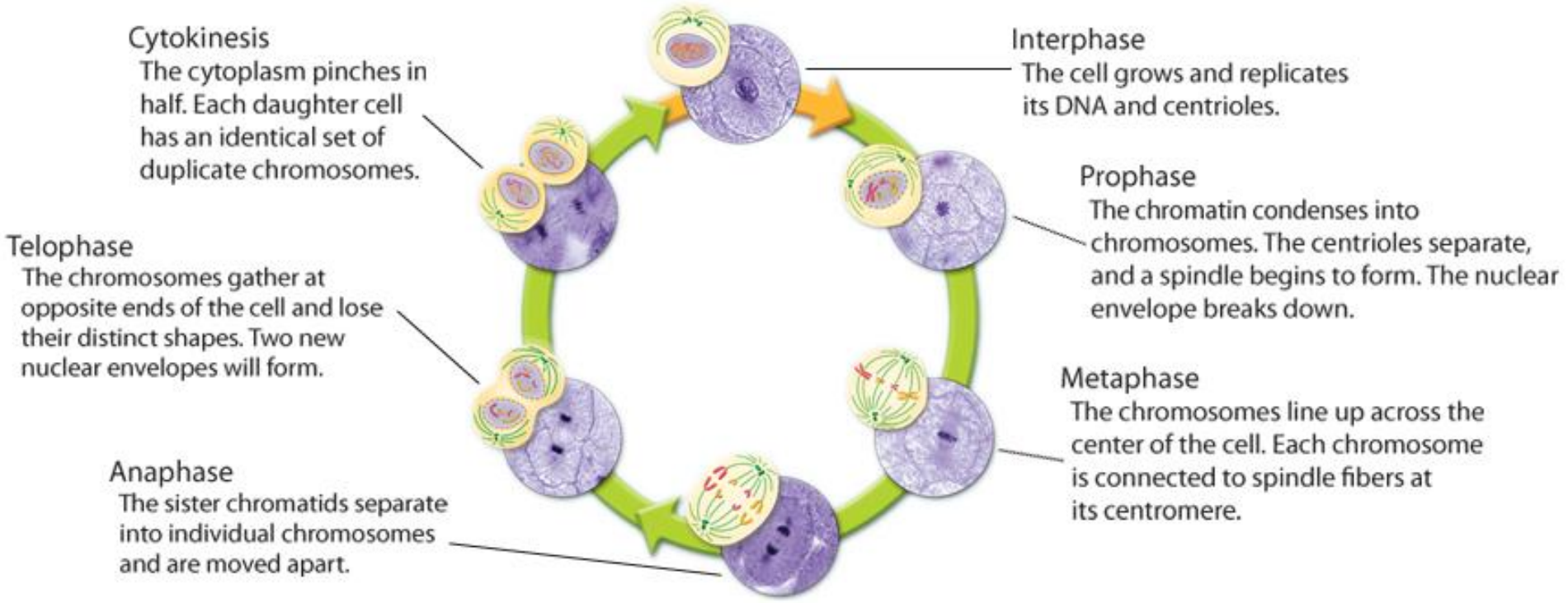
- **Chromatid** – each strand of a **duplicated** chromosome
- **Centromere** – the area where each pair of chromatids is joined
- **Centrioles** – tiny structures located in the cytoplasm of animal cells that help organize the spindle
- **Spindle** – a fanlike microtubule structure that helps separate the chromatids



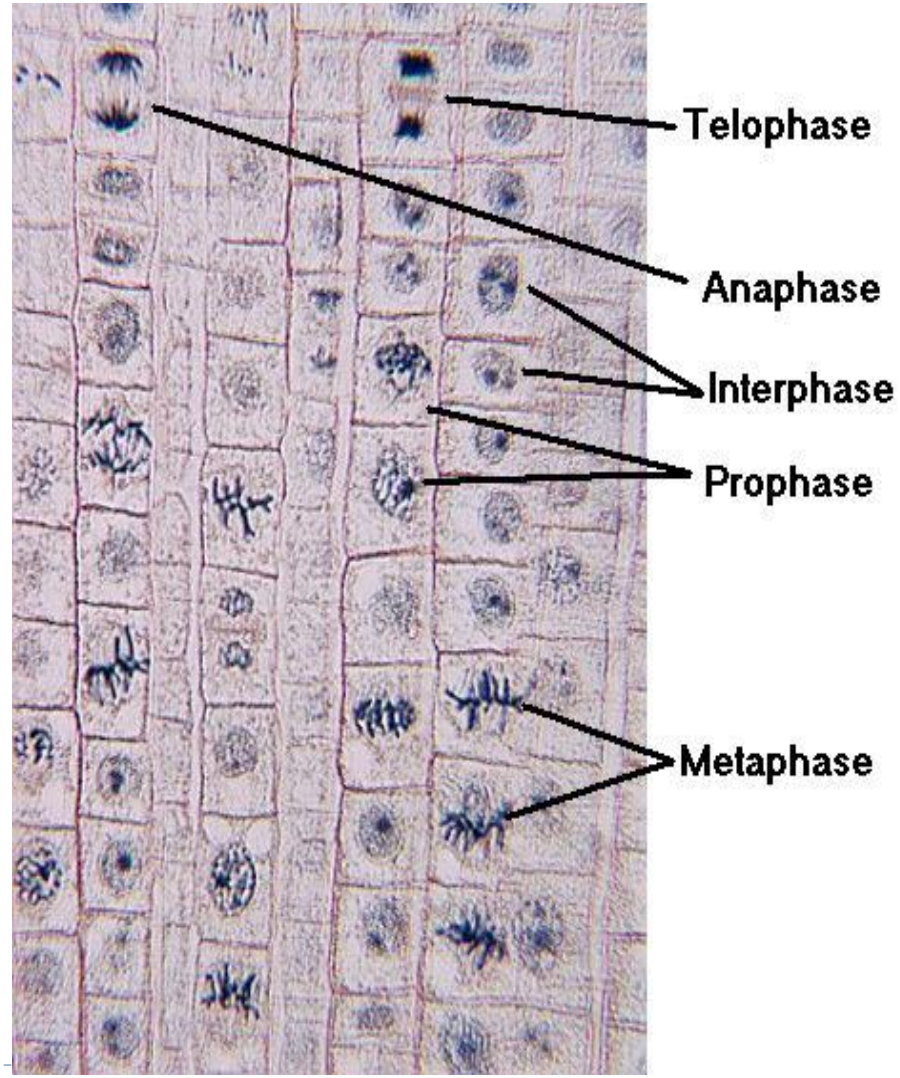




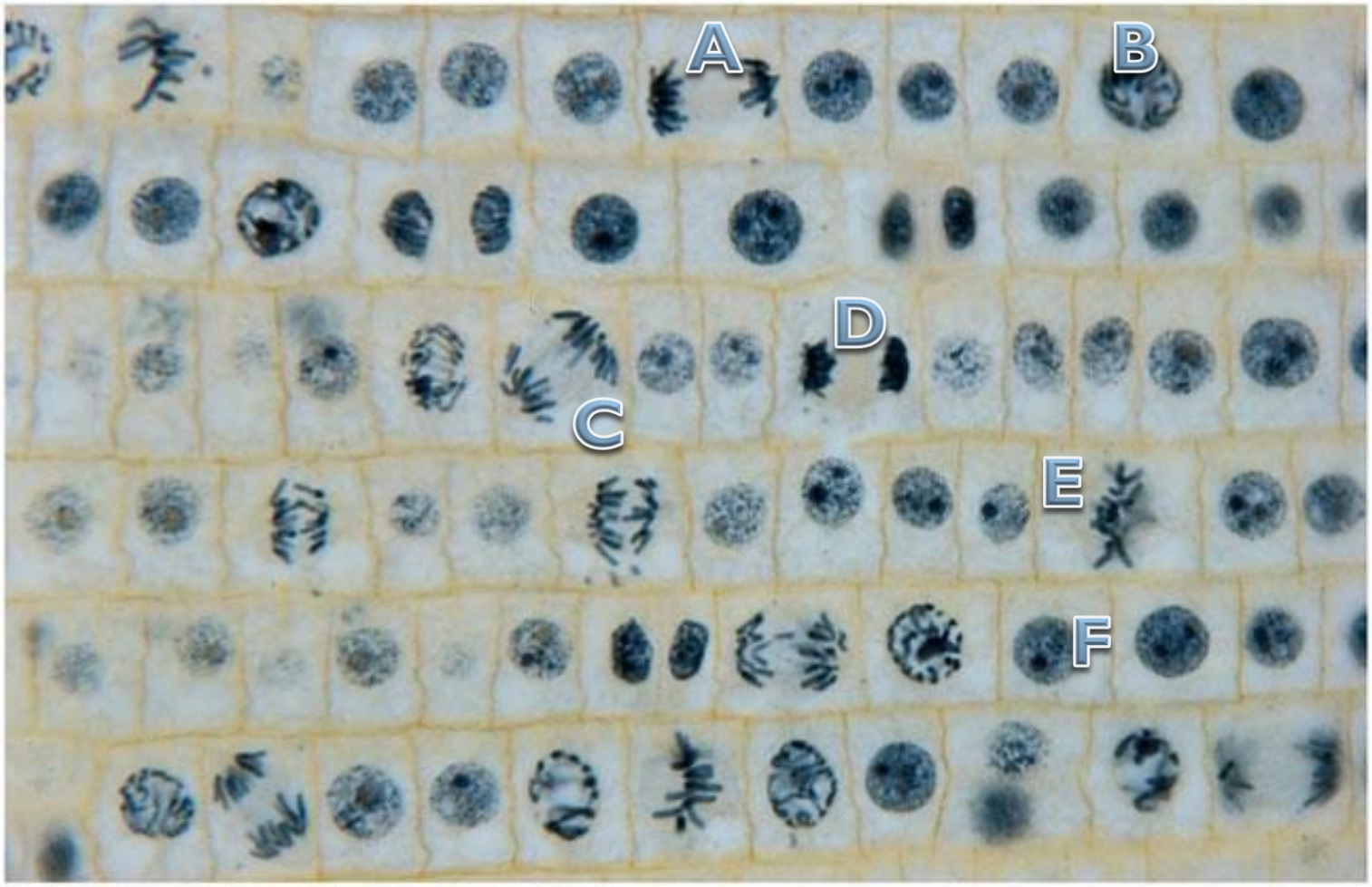
The Cell Cycle



Onion Cell Mitosis



Test yourself!!!



Onion root tip and fish mitosis lab

- Find an label a cell in each of the following phases in both the onion root tip and fish blastodisc.
- You may choose to draw the pictures or take a picture with a camera and label it on the computer. Label all the structures listed IF THEY ARE VISIBLE – if they are not visible, note it!
  - Interphase – nucleus, cell membrane, nuclear membrane, chromatin cell wall
  - Prophase –nuclear membrane, chromosomes
  - Metaphase – spindle, chromosomes, poles, equator
  - Anaphase – spindle, chromosomes,
  - Telophase – nuclear membrane, cell plate (onion), nucleus, cytokenesis
- Use your book to describe the major steps that occur in each of the phases of mitosis. (Section 9.3)

Cell Cycle Diagram

Label the sections with the following terms

- Interphase
- Prophase
- Telophase
- G1
- G2
- Metaphase
- S
- Cytokinesis
- Cell Division
- Anaphase
- Mitosis

Then add this information in the correct place!

- Chromosomes condense
- Cytoplasm divides
- Chromosomes align at the "equator"
- Microtubules assemble into a spindle
- Nuclear membrane breaks up
- Sister chromatids move toward opposite poles
- Centrosomes (with centrioles in animal cells) move to opposite poles
- New nuclear membranes form
- DNA replication occurs/chromosomes duplicate
- Cells undergo normal metabolic processes
- Spindle/microtubules attach to sister chromatids
- Chromosomes reach the poles
- Cell makes proteins for mitosis

Cell Cycle Diagram

Label the sections with the following terms

- Interphase
- Prophase
- Telophase
- G1
- G2
- Metaphase
- S
- Cytokinesis
- Cell Division
- Anaphase
- Mitosis

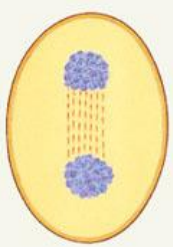
Then add this information in the correct place!

- Chromosomes condense
- Cytoplasm divides
- Chromosomes align at the "equator"
- Microtubules assemble into a spindle
- Nuclear membrane breaks up
- Sister chromatids move toward opposite poles
- Centrosomes (with centrioles in animal cells) move to opposite poles
- New nuclear membranes form
- DNA replication occurs/chromosomes duplicate
- Cells undergo normal metabolic processes
- Spindle/microtubules attach to sister chromatids
- Chromosomes reach the poles
- Cell makes proteins for mitosis

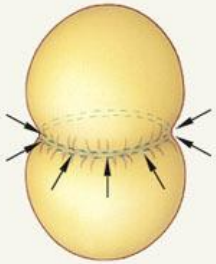
9.4 Cytoplasmic Division Mechanisms

- In most eukaryotes, the cytoplasm divides between anaphase and the end of telophase
- **Cytokinesis**
  - The process of cytoplasmic division
- Animal cells
  - A **contractile ring** partitions the cytoplasm
  - A band of actin filaments rings the cell midsection, contracts, and pinches the cytoplasm in two
- Plant cells
  - A **cell plate** forms midway between the spindle poles; it partitions the cytoplasm when it reaches and connects to the parent cell wall

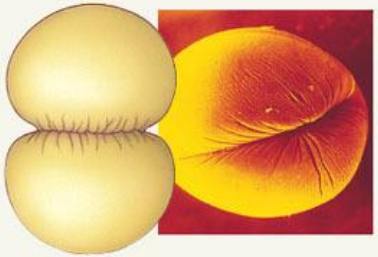
Cytoplasmic Division in Animal and Plant Cells



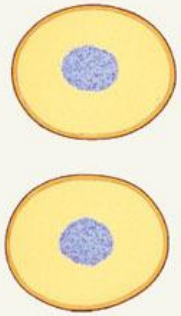
1 Mitosis is completed, and the bipolar spindle is starting to disassemble.



2 At the former spindle equator, a ring of actin filaments attached to the plasma membrane contracts.

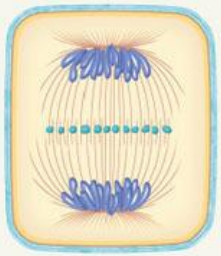


3 This contractile ring pulls the cell surface inward as it continues to contract.

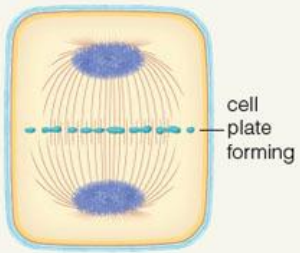


4 The contractile ring contracts until the cytoplasm is partitioned and the cell pinches in two.

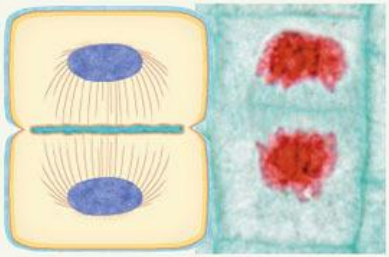
A Contractile Ring Formation



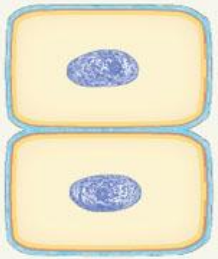
1 The plane of division (and of the future cross-wall) was established by microtubules and actin filaments that formed and broke up before mitosis began. Vesicles cluster here when mitosis ends.



2 The vesicles fuse with each other and with endocytic vesicles bringing cell wall components and plasma membrane proteins from the cell surface. The fused materials form a cell plate along the plane of division.



3 The cell plate expands outward along the plane of division until it reaches the plasma membrane. When the cell plate attaches to the plasma membrane, it partitions the cytoplasm.

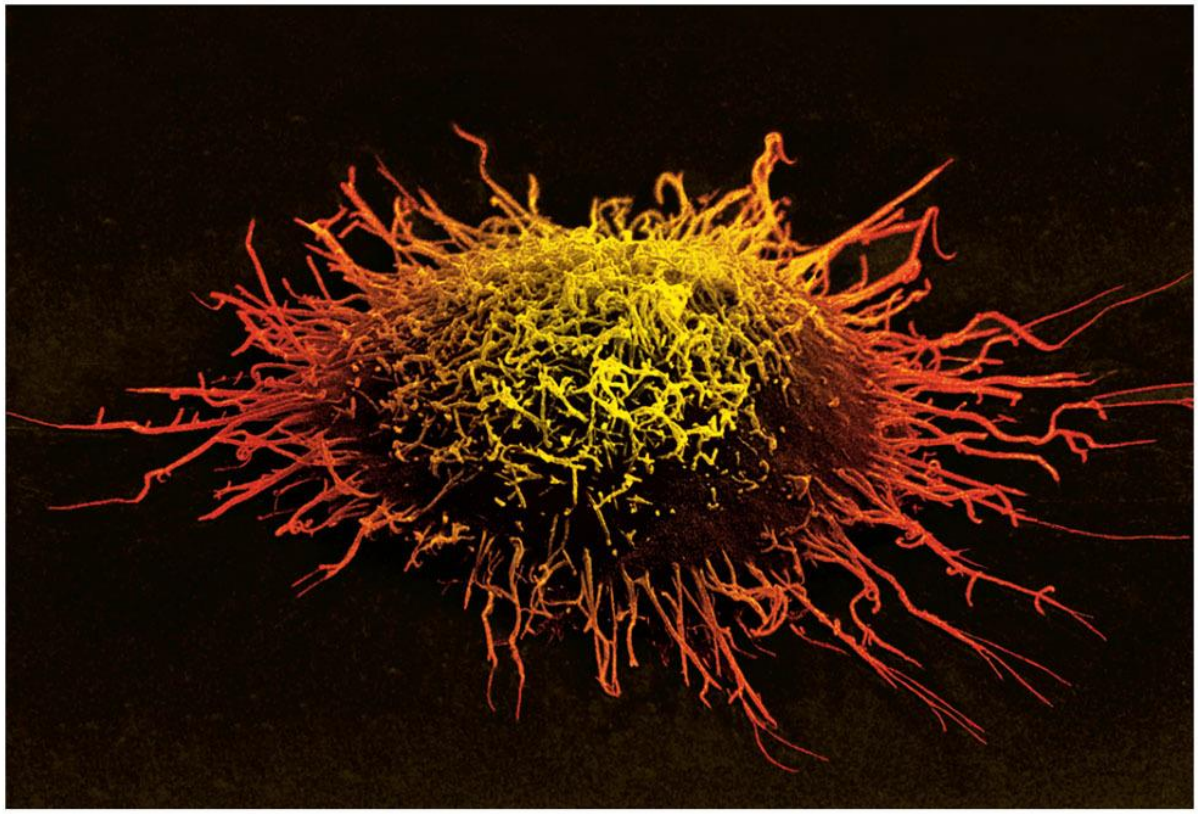


4 The cell plate matures as two new primary cell walls surrounding middle lamella material. The new walls join with the parent cell wall, so each daughter cell becomes enclosed by its own wall.

B Cell Plate Formation

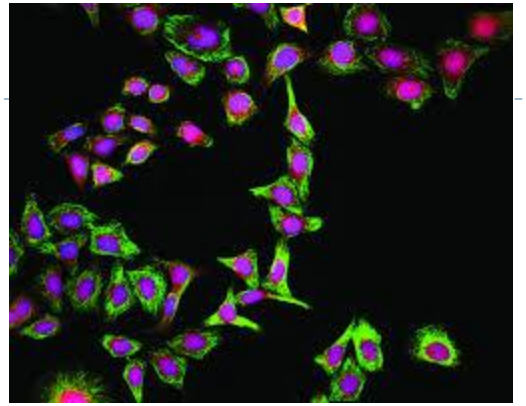
9.5 When Control is Lost

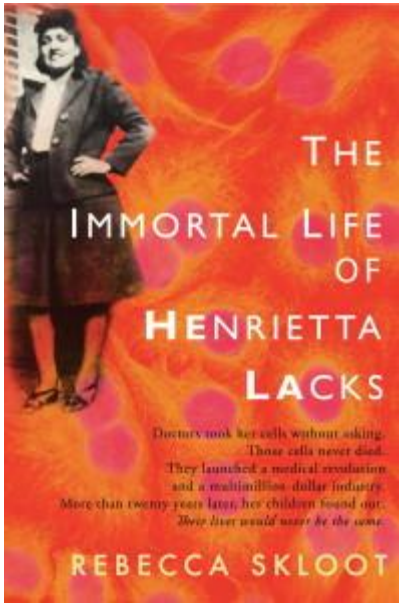
- Sometimes, controls over cell division are lost
  - Cancer may be the outcome



HeLa cells

- Video on HeLa cells





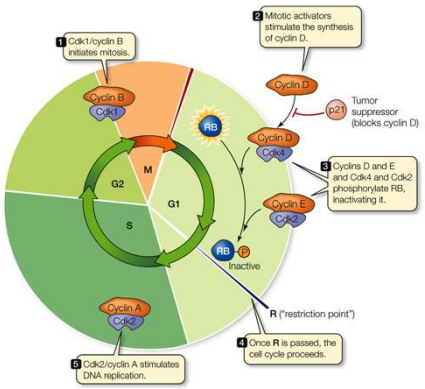
Cell Cycle Controls

- Checkpoints in the cell cycle allow problems to be corrected before the cycle advances

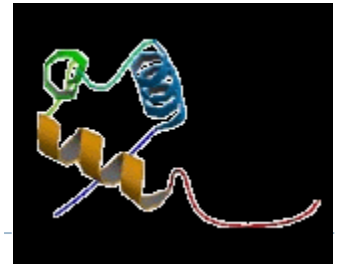
- Proteins produced by checkpoint genes interact to advance, delay, or stop the cell cycle
  - **Kinases** can activate other molecules to stop the cell cycle or cause cells to die
  - **Growth factors** can activate kinases to start mitosis

How do cells know when to divide?

- Regulatory proteins instruct the cells when to divide
  - Internal regulatory proteins make sure that steps in the cell cycle are completed before the next step occurs
  - External regulatory proteins direct the cell to speed up or slow down the cycle
    - Ex. Growth factors – stimulate the division of the cell (embryonic development and wound healing)

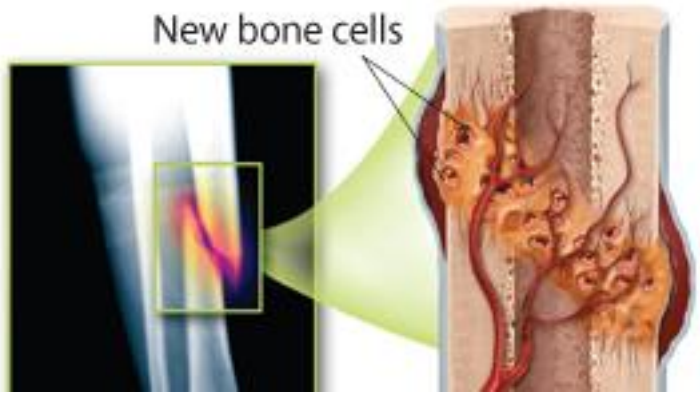


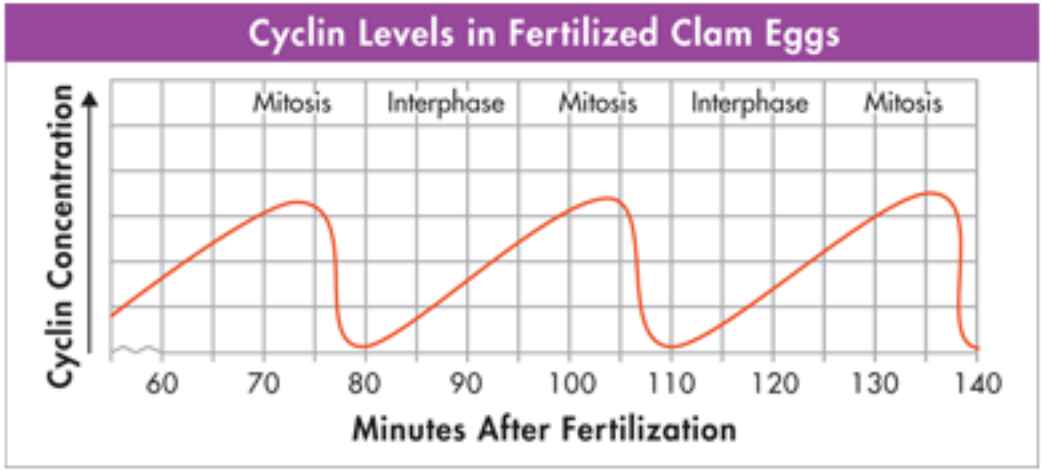
LIFE 8e, Figure 9.6



Regulating the cell cycle

- How do cells know when to divide?????
  - Some cells don't divide once they are formed (muscle and nerve)
  - Cells in the bone marrow that make blood cells and digestive tract divide as fast as every few hours
- Cyclins = a family of proteins that regulates the cell cycle in eukaryotes





Checkpoint Failure and Tumors

- When all checkpoint mechanisms fail, a cell loses control over its cell cycle and may form a **tumor** (abnormal mass) in surrounding tissue

- Usually one or more checkpoint gene products are missing in tumor cells
  - Tumor suppressor gene products inhibit mitosis
  - Protooncogene products stimulate mitosis

Cancer

- Cancer = occurs when some of the body's cells lose the ability to control growth
  - Cancer cells do not respond to the signals that regulate growth and divide uncontrollably
  - Cancer cells absorb nutrients needed by other cells, block nerve connections, and prevent organs from functioning.

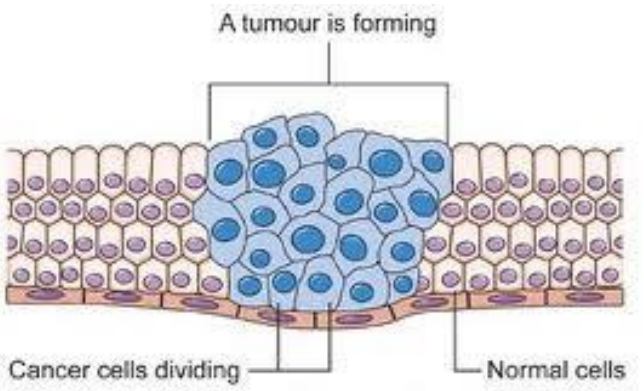
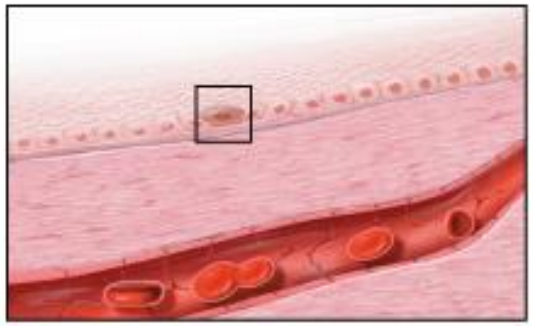


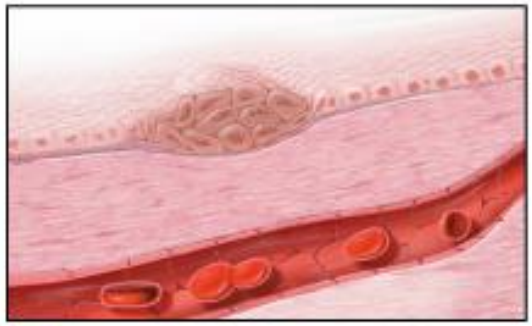
Diagram showing how cancer cells keep on reproducing to form a tumour

Cancer Cont.

- **Tumor** = a mass of cancer cells
  - **Benign tumors** = noncancerous tumors that do not spread to other tissue
  - **Malignant tumor** = cancerous tumor that invade and destroy surrounding tissue
  - **Metastasis** = the spread of cancer cells
  - Mayo Clinic Metastasis



1 A cell begins to divide abnormally.



2 The cancer cells produce a tumor, which begins to displace normal cells and tissues.

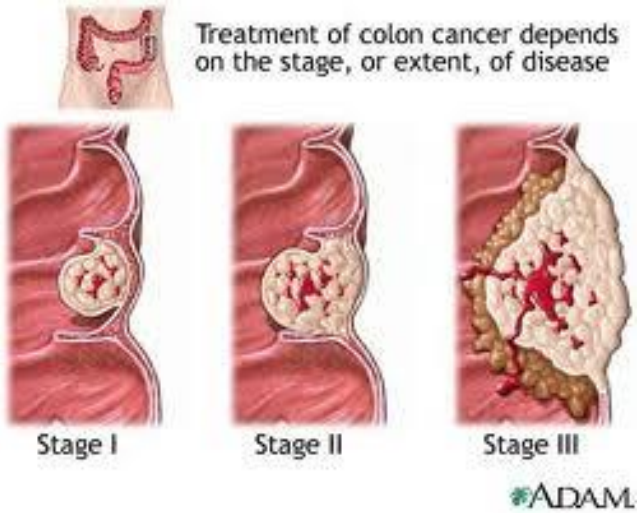
3 Cancer cells are particularly dangerous because of their tendency to spread once they enter the bloodstream or lymph vessels. The cancer then moves into other parts of the body and forms secondary tumors, a process called metastasis.

Causes of cancer

- Caused by defects in the genes that regulate cell growth and development
  - Sources of gene defects include
    - tobacco
    - radiation exposure
    - defective genes
    - viral infection
  - Many cancers have a defective p53 gene which halts the cell cycle until chromosomes have been replicated

Treatment of cancer

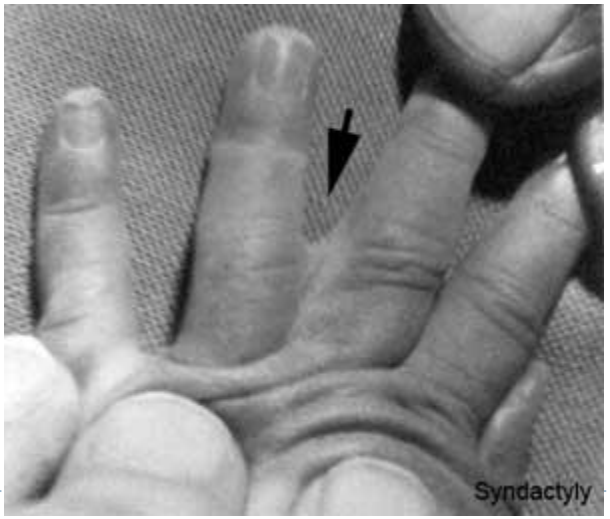
- Surgery
- Radiation
- Chemotherapy – chemical compounds that kill cancer
  - Targets rapidly dividing cells and also interferes with cell division in normal cells (side effects)



Skin Cancers

Apoptosis

- Apoptosis = programmed cell death
  - Cells either are damaged and die or they have programmed cell death
  - In apoptosis the cell and chromatin shrink, cell membrane breaks and other cells recycle it
  - Ex – mouse foot, human hand

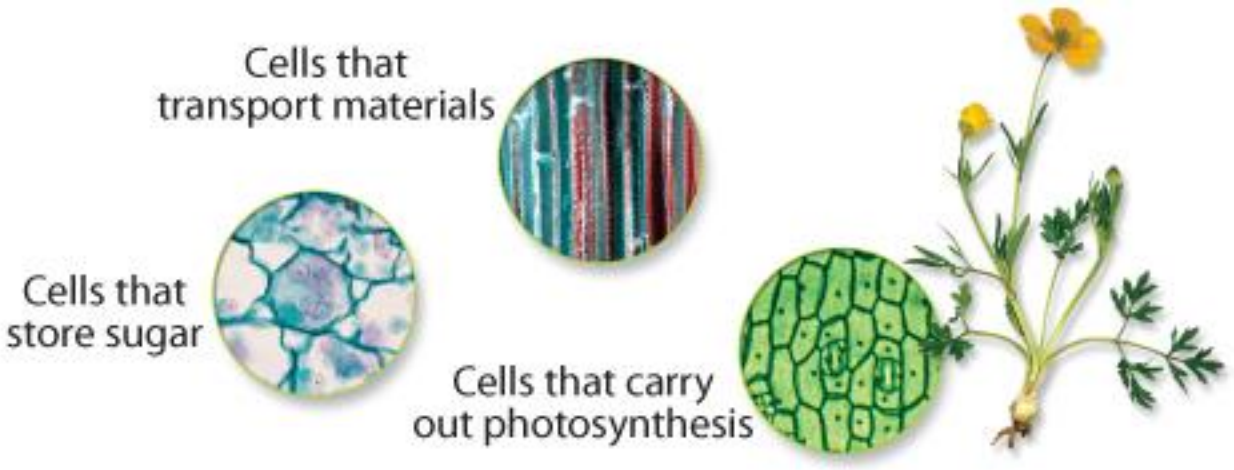


10.4 Cell Differentiation

- The human body contains hundreds of different cell types, and every one of them develops from the single cell that starts the process. How do the cells get to be so different from each other?

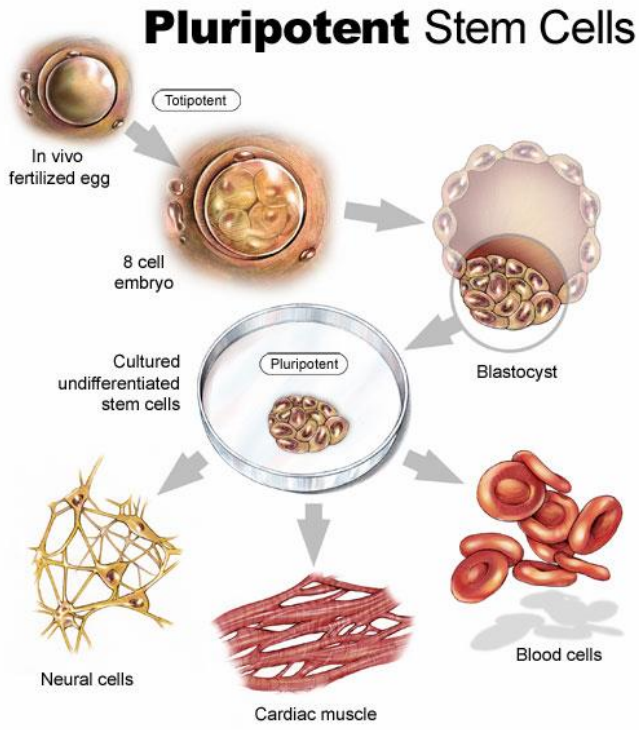
Differentiation

- During the development of an organism, cells differentiate into many types of cells.



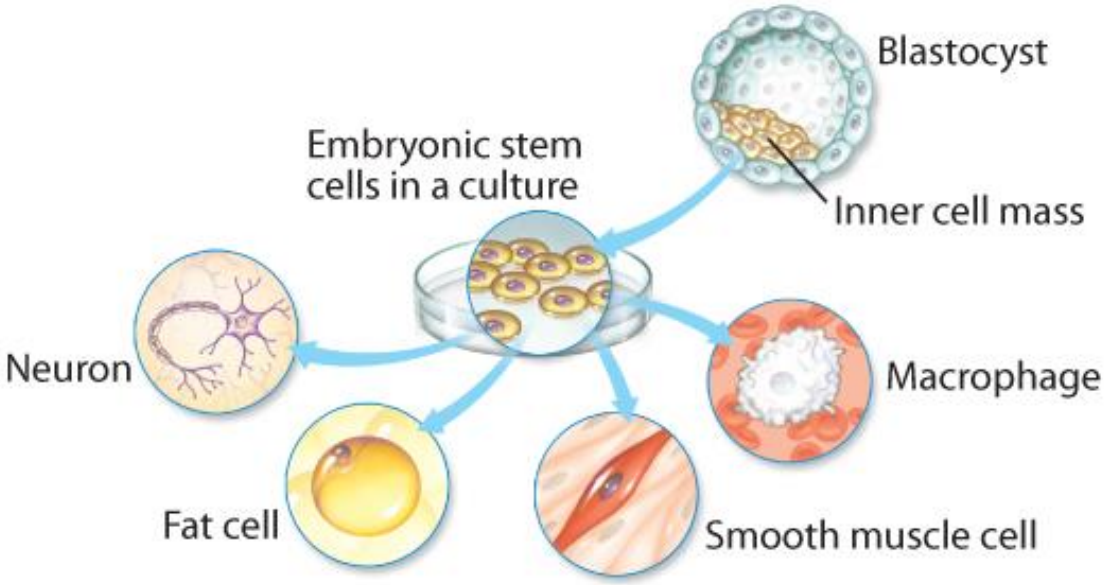
Stem Cells

- Stem cells = the unspecialized cells from which differentiated cells develop
- Totipotent cells= can develop into any type of cell in the body
- Pluripotent = can develop into most (but not all) of the body's cell types
  - Inner cells in the early embryo
  - (a hollow ball called a blastocyst)



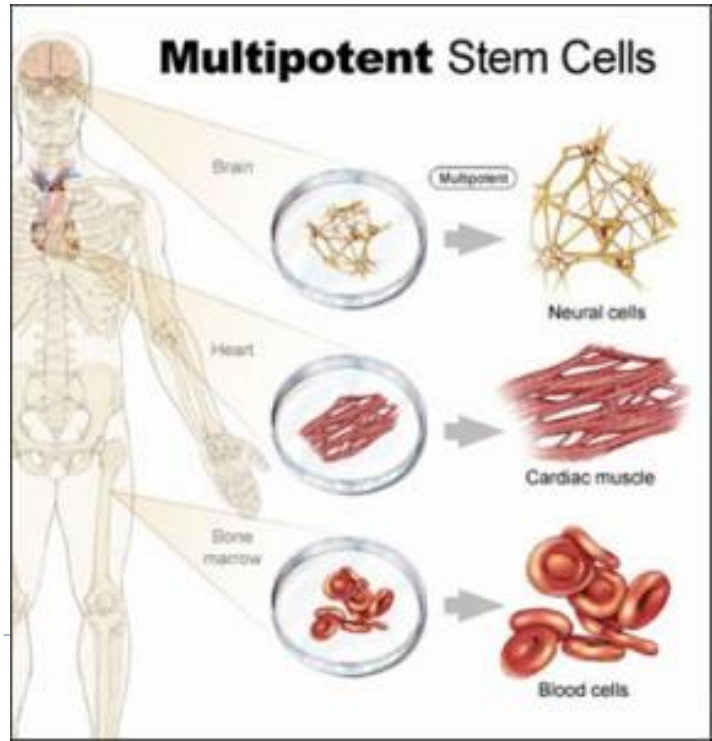
Embryonic Stem Cells

- Found in the inner cells mass of the early embryo.
- Embryonic stem cells are pluripotent. (cells have the capacity to produce most cell types in the human body)



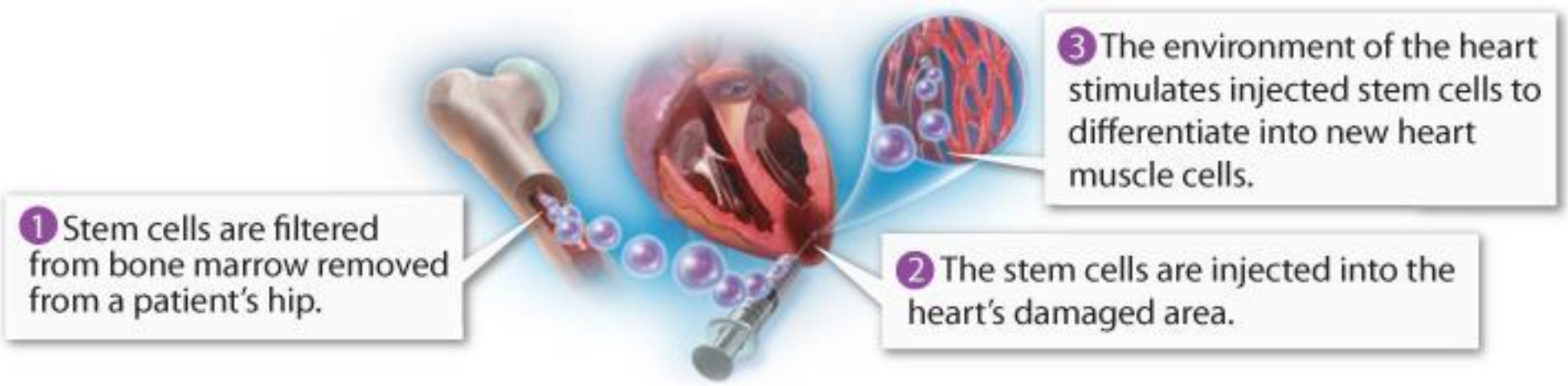
Adult Stem Cells

- Adult stem cells are **multipotent.** They can produce many types of differentiated cells
- Adult stem cells of a given organ or tissue typically produce only the types of cells that are unique to that tissue.
- Peyton Manning Stem Cells?????
- Skin Cell Spray
- Research is being done to clone adult cells and make embryonic stem cells



Stem Cell Research

- Repair or replace badly damaged cells and tissues.
  - heart attack
  - stroke
  - spinal cord injuries.



Stem Cells – the ethical concerns

- Embryonic stem cells are harvested from early embryos
  - Most methods destroy the embryo
  - In the past, US limited funding for the embryonic cell lines used for research - NIH has136 embryonic stem lines in the US that are currently being used for research
  - Research is being done to
    - harvest embryonic stem cells without destroying the embryo
    - turning adult stem cells into pluripotent cells
    - Embryonic stem cells out of umbilical cord blood
      - Cord Blood Banking News Clips
      - Cord Blood Registry Video