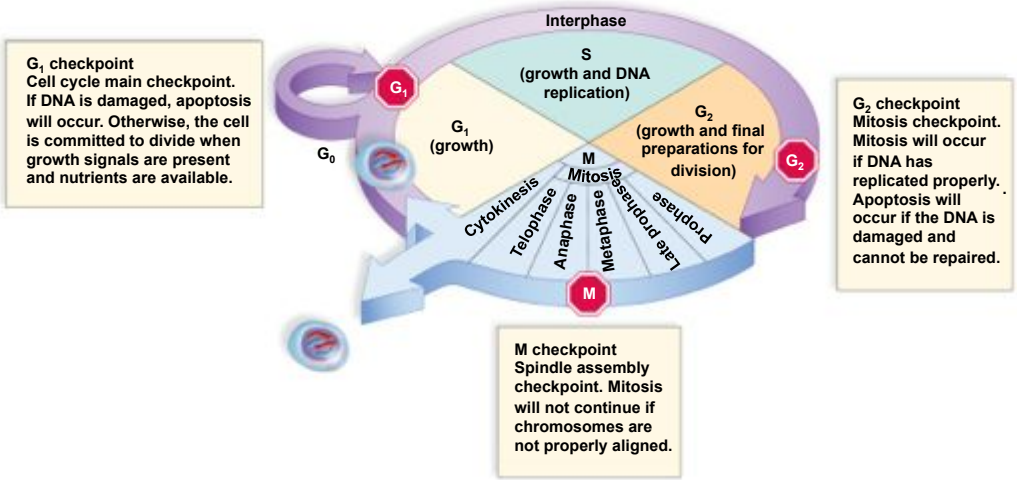
BIOLOGY

10th Edition

Sylvia S. Mader

Chapter 9: pp. 150 - 168

The Cell Cycle and Cellular Reproduction



PowerPoint® Lecture Slides are prepared by Dr. Isaac Barjis, Biology Instructor

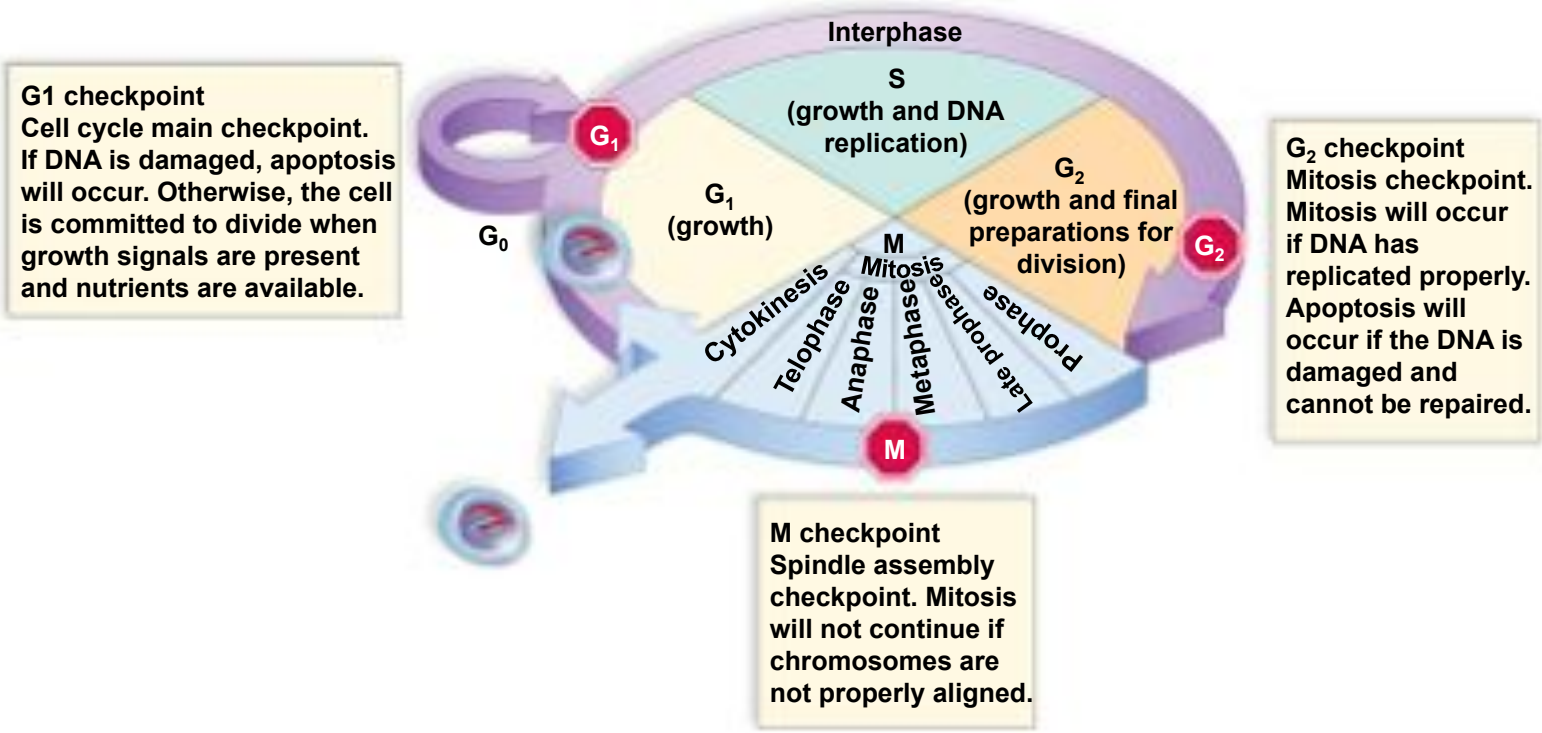
Outline

- The Cell Cycle
  - Interphase
  - Mitotic Stage
  - Cell Cycle Control
  - Apoptosis
- Mitosis & Cytokinesis
- Mitosis in Animal Cells
- The Cell Cycle & Cancer
- Prokaryotic Cell Division

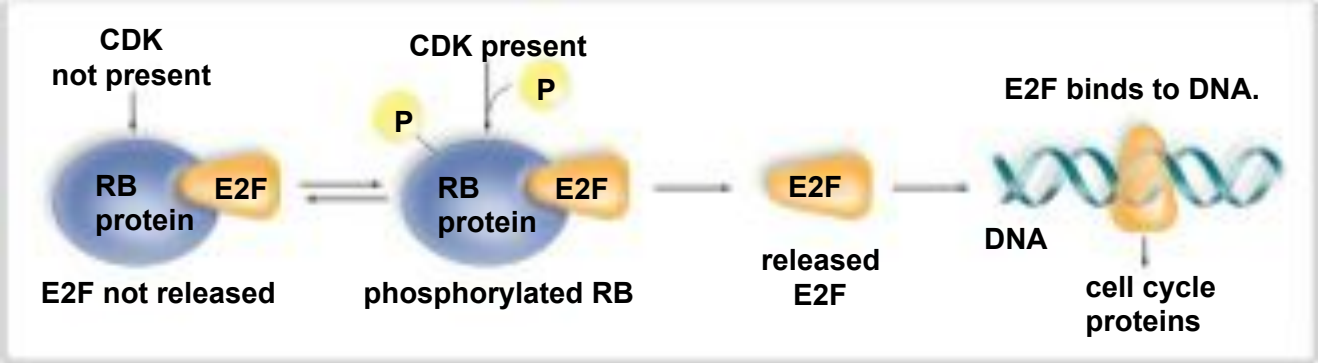
The Cell Cycle

- An orderly set of stages from the first division to the time the *daughter cells* divide
- Just prior to next division:
  - The cell grows larger
  - The number of organelles doubles
  - The DNA is replicated
- The two major stages of the cell cycle:
  - Interphase
  - Mitosis

The Cell Cycle



Regulation at the G1 Checkpoint



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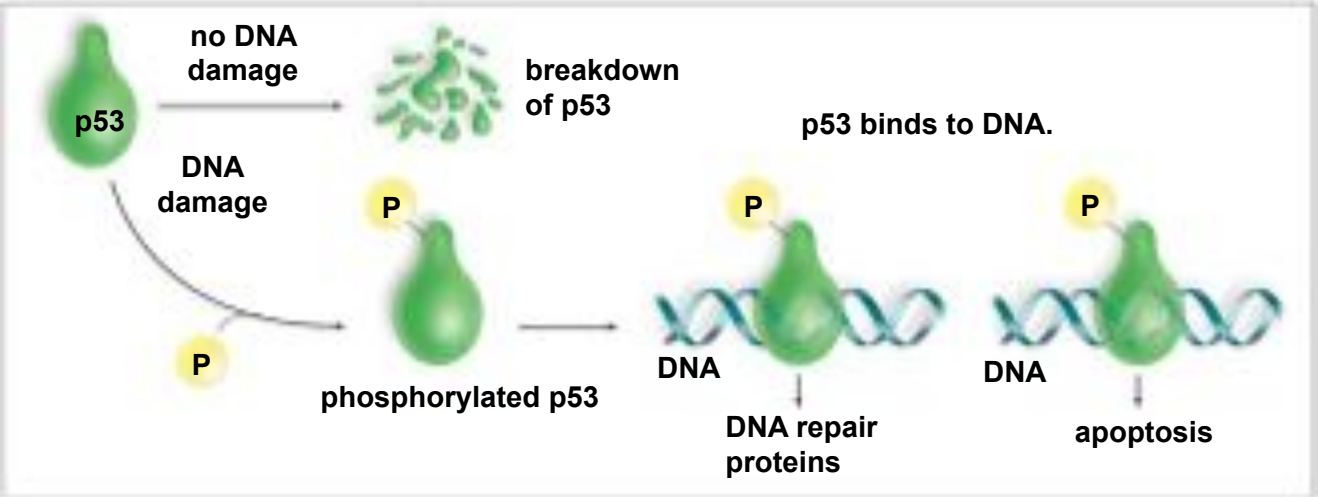


b.

Interphase

- Most of the cell cycle is spent in interphase
- Cell performs its usual functions
- Time spent in interphase varies by cell type
- Nerve and muscle cells do not complete the cell cycle (remain in the **G0** stage)

Interphase

- Interphase consists of: G1, S and G2 phases
  - G_1 Phase:
    - Recovery from previous division
    - Cell doubles its organelles
    - Cell grows in size
    - Accumulates raw materials for DNA synthesis (DNA replication)
  - S Phase:
    - DNA replication
    - Proteins associated with DNA are synthesized
    - Chromosomes enter with 1 chromatid each
    - Chromosomes leave with 2 identical chromatids each
  - G_2 Phase:
    - Between DNA replication and onset of mitosis
    - Cell synthesizes proteins necessary for division

Mitotic (M) Stage

- Includes:
  - Mitosis (karyokinesis)
    - Nuclear division
    - Daughter chromosomes distributed to two daughter nuclei
  - Cytokinesis
    - Cytoplasm division
    - Results in two genetically identical daughter cells

Cell Cycle Control

- Cell cycle controlled by internal and external signals
- A *signal* is a molecule that either stimulates or inhibits a metabolic event.
  - External signals
    - Growth factors
      - Received at the plasma membrane
      - Cause completion of cell cycle
  - Internal signals
    - Family of proteins called cyclins
    - Increase and decrease as cell cycle continues
    - Without them cycle stops at G_1, M or G_2 (checkpoints)
    - Allows time for any damage to be repaired

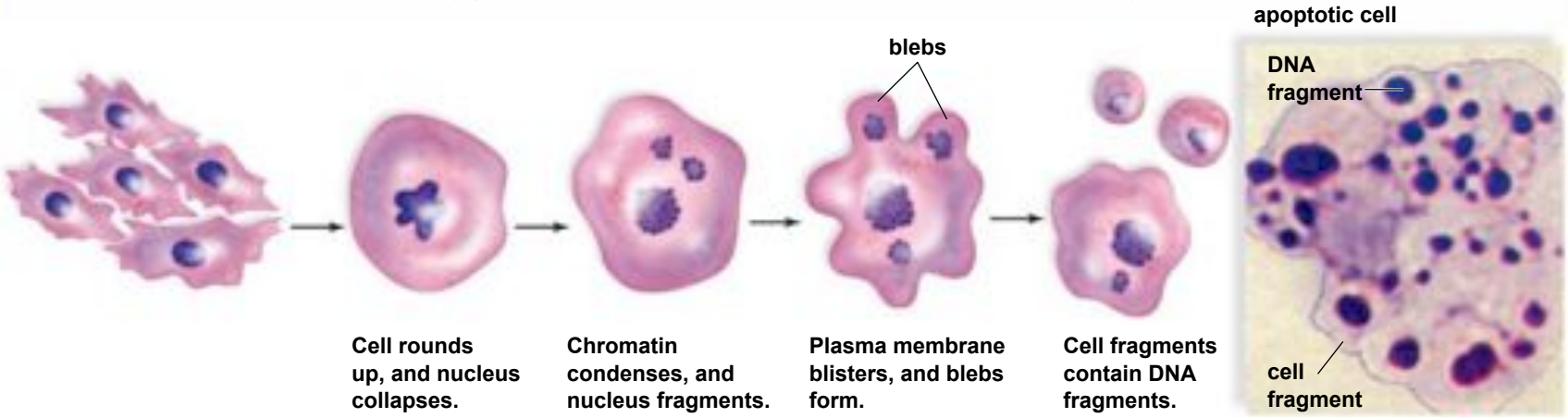
Apoptosis

- Apoptosis is programmed cell death
- It involves a sequence of cellular events:
  - fragmenting of the nucleus,
  - blistering of the plasma membrane
  - engulfing of cell fragments.
- Apoptosis is caused by enzymes called caspases.
- Mitosis and apoptosis are opposing forces
  - Mitosis increases cell number
  - Apoptosis decreases cell number

Apoptosis

- Cells harbor caspases in check by inhibitors
  - Can be unleashed by internal or external signals
- Signal protein P53
  - Stops cycle at G_1 when DNA damaged
  - Initiates DNA attempt at repair
    - If successful, cycle continues to mitosis
    - If not, apoptosis is initiated

Apoptosis



Courtesy Douglas R. Green/LaJolla Institute for Allergy and Immunology

Mitosis: Preparation

- DNA is in very long threads
  - Chromosomes
  - Stretched out and intertangled between divisions
  - DNA is associated with histone proteins
  - Collectively called chromatin
- Before mitosis begins:
  - Chromatin condenses (coils) into distinctly visible chromosomes
  - Each species has a characteristic chromosome number
    - Humans 46
    - Corn 20
    - Goldfish 94

Chromosome Number

- The **diploid (2n) number** includes two sets of chromosomes of each type
  - Humans have 23 different types of chromosomes
    - Each type is represented twice in each body cell (Diploid)
    - Only sperm and eggs have one of each type (haploid)
  - The number for humans is=23
    - Two representatives of each type
    - Makes a total of 2=46 in each nucleus
      - One set of 23 from individual's father (paternal)
      - Other set of 23 from individual's mother (maternal)

Chromosome Numbers of Some Eukaryotes

TABLE 9.1

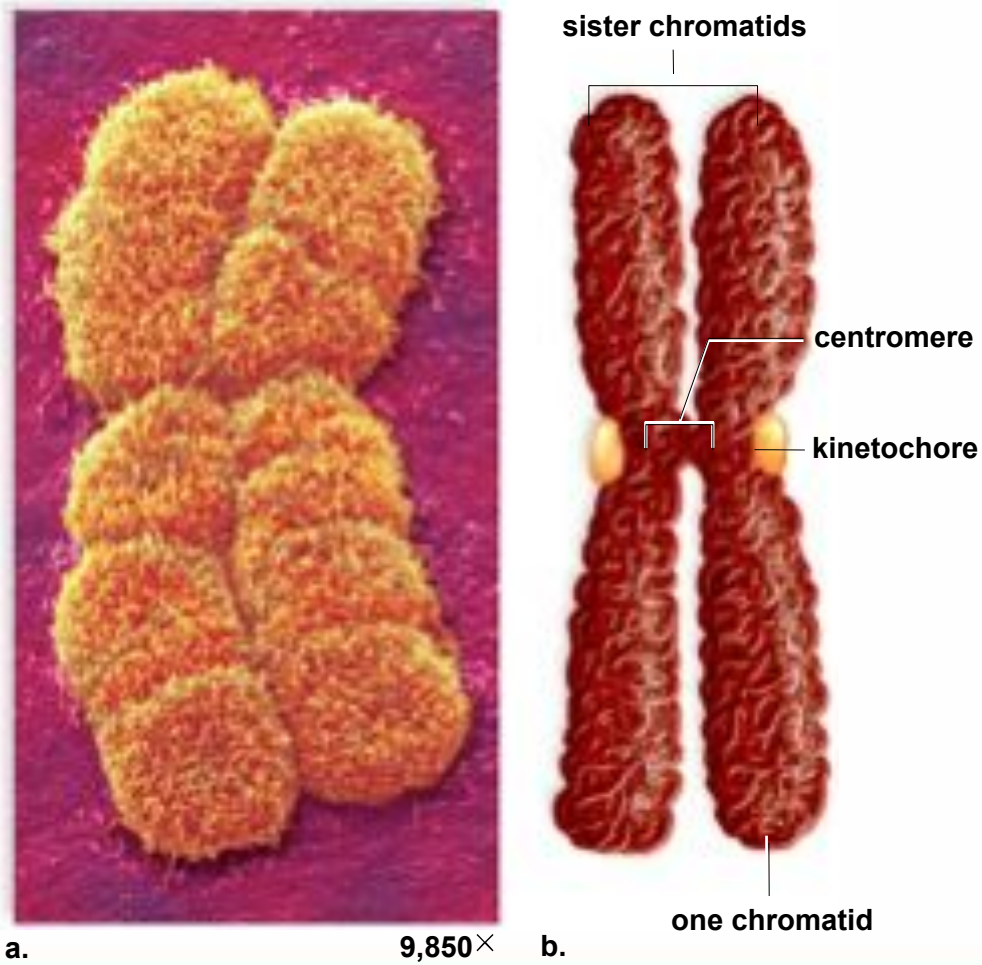
Diploid Chromosome Numbers of Some Eukaryotes

Type of Organism	*Name of Chromosome*	*Chromosome Number*
Fungi	*Saccharomyces cerevisiae* (yeast)	32
Plants	*Pisum sativum* (garden pea)	14
	Solanum tuberosum (potato)	48
	Ophioglossum vulgatum (Southern adder's tongue fern)	1,320
Animals	*Drosophila melanogaster* (fruit fly)	8
	Homo sapiens (human)	46
	Carassius auratus (goldfish)	94

Chromosome Structure

- At end of S phase:
  - Each chromosome internally duplicated
  - Consists of two identical DNA chains
    - Sister chromatids (two strands of genetically identical chromosomes)
    - Attached together at a single point (called centromere)
- During mitosis:
  - Centromeres holding sister chromatids together simultaneously break
  - Sister chromatids separate
  - Each becomes a daughter chromosome
  - Sisters of each type distributed to opposite daughter nuclei

Duplicated Chromosome



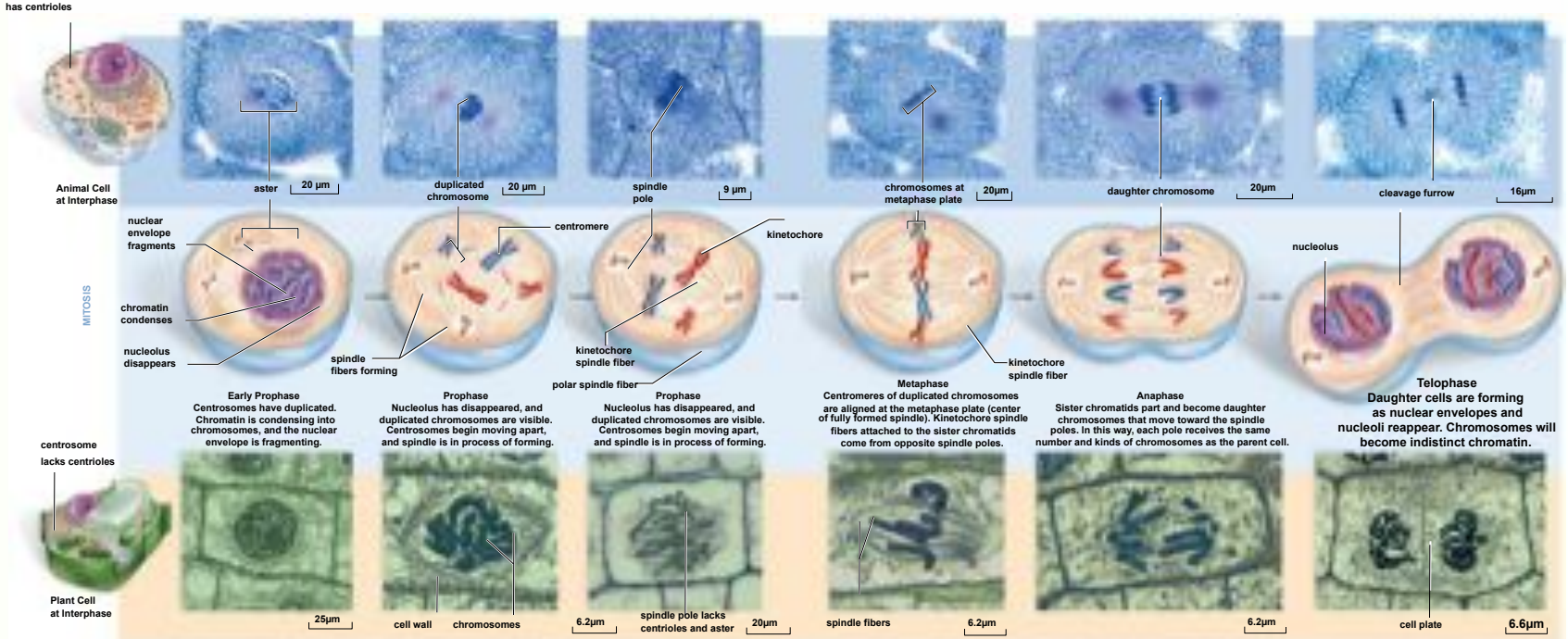
Mitosis in Animal Cells

- Just outside nucleus is the centrosome
  - This is the microtubule organizing center
  - Organizes the mitotic spindle
    - Contains many fibers
    - Each composed of a bundle of microtubules
  - In animals, contains two barrel-shaped centrioles
    - Oriented at right angles to each other within centrosome
    - Each with 9 triplets of microtubules arranged in a cylinder
- Centrosome was also replicated in S-phase, so now two centrosomes

Mitosis in Animal Cells: Prophase

- Prophase
  - Chromatin has condensed
    - Chromosomes distinguishable with microscope
    - Visible double (two sister chromatids attached at centromere)
  - Nucleolus disappears
  - Nuclear envelope disintegrates
  - Spindle begins to take shape
  - Two centrosomes move away from each other
  - Form microtubules in star-like arrays – asters

Mitosis in Animals



Animal cell(Early prophase, Prophase, Metaphase, Anaphase, Telophase): © Ed Reschke; Animal cell(Prometaphase): © Michael Abbey/Photo Researchers, Inc.; Plant cell(Early prophase, Prometaphse): © Ed Reschke; Plant cell(Prophase, Metaphase, Anaphase): © R. Calentine/Visuals Unlimited; Plant cell(Telophase): © Jack M. Bostrack/Visuals Unlimited;

Mitosis in Animal Cells: Prometaphase

- Prometaphase
  - Centromere of each chromosome develops two kinetochores
    - Specialized protein complex
    - One over each sister chromatid
      - Physically hook sister chromatids up with specialized microtubules (kinetochore fibers)
      - These connect sisters to opposite poles of mother cell

Mitosis in Animal Cells: Metaphase & Anaphase

- Metaphase
  - Chromosomes are pulled around by kinetochore fibers
  - Forced to align across equatorial plane of cell
    - Appear to be spread out on a piece of glass
    - Metaphase plate
    - Represents plane through which mother cell will be divided
- Anaphase
  - Centromere dissolves, releasing sister chromatids
  - Sister chromatids separate
    - Now called daughter chromosomes
    - Pulled to opposite poles along kinetochore fibers

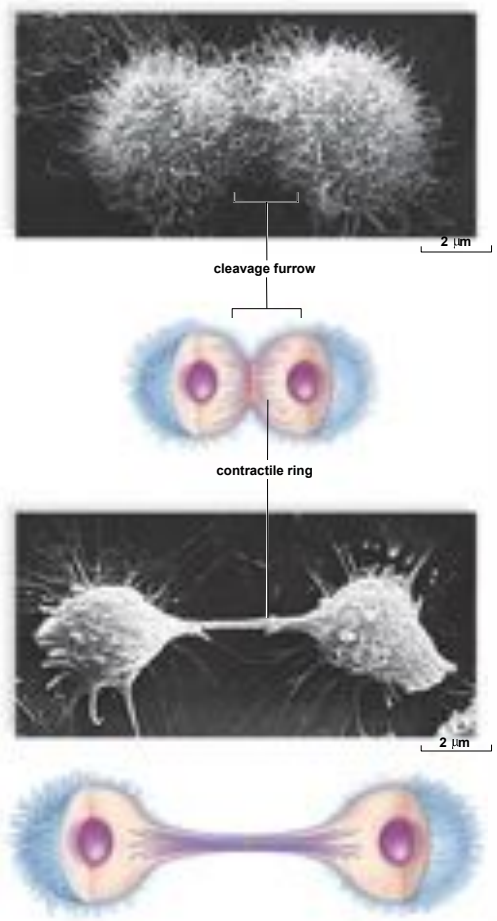
Mitosis in Animal Cells: Telophase

- Telophase
  - Spindle disappears
  - Now two clusters of daughter chromosomes
    - Still two of each type with all types represented
    - Clusters are incipient daughter nuclei
  - Nuclear envelopes form around the two incipient daughter nuclei
    - Chromosomes uncoil and become diffuse chromatin again
    - Nucleolus reappears in each daughter nucleus

Cytokinesis: Animal Cells

- Division of cytoplasm
- Allocates mother cell's cytoplasm equally to daughter nucleus
- Encloses each in it's own plasma membrane
- Often begins in anaphase
- Animal cytokinesis:
  - A cleavage furrow appears between daughter nuclei
  - Formed by a contractile ring of actin filaments
  - Like pulling on a draw string
  - Eventually pinches mother cell in two

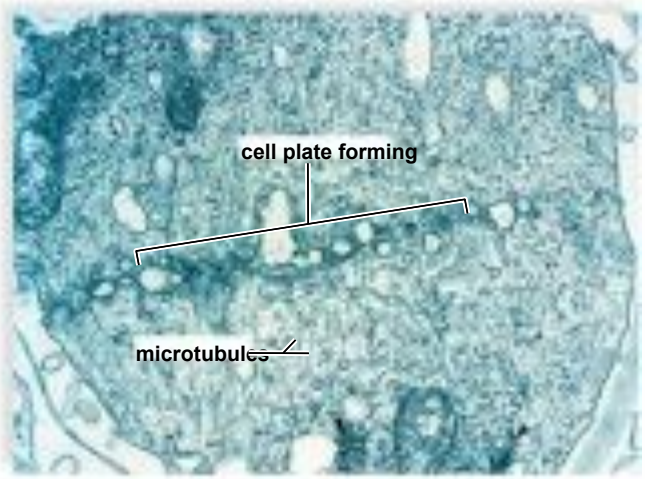
Cytokinesis in Animal Cells



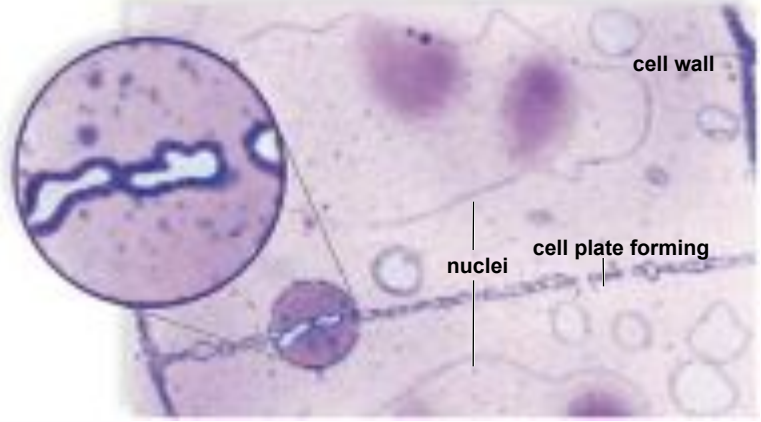
Cytokinesis: Plant Cells

- Rigid cell walls outside plasma membrane do not permit furrowing
- Begins with formation of a cell plate
  - Many small membrane-bounded vesicles
  - Eventually fuse into one thin vesicle extending across the mother cell
  - The membranes of the cell plate become the plasma membrane between the daughter cells
    - Contents of vesicles become the middle lamella between the two daughter cells
    - Daughter cells later secrete primary cell walls on opposite sides of middle lamella

Cytokinesis in Plant Cells



Vesicles containing cell wall components fusing to form cell plate



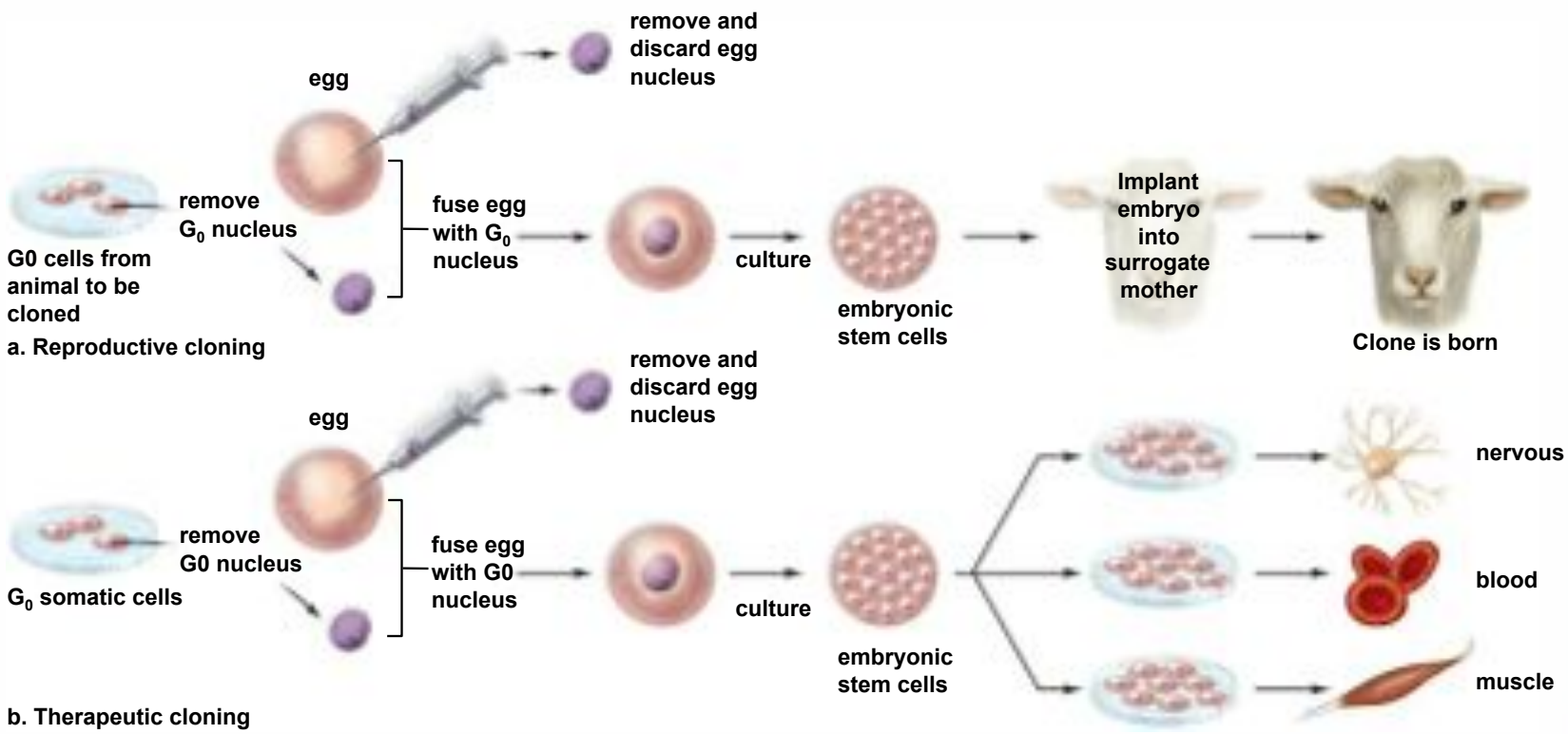
Function of Mitosis

- Permits growth and repair.
  - In plants it retains the ability to divide throughout the life of the plant
  - In mammals, mitosis is necessary:
    - Fertilized egg becomes an embryo
    - Embryo becomes a fetus
    - Allows a cut to heal or a broken bone to mend

Stem Cells

- Many mammalian organs contain *stem cells*
  - Retain the ability to divide
  - Red bone marrow stem cells divide to produce various types of blood cells
- **Therapeutic cloning** to produce human tissues can begin with either adult stem cells or embryonic stem cells
- Embryonic stem cells can be used for **reproductive cloning**, the production of a new individual

Two Types of Cloning



The Cell Cycle and Cancer

- Abnormal growth of cells is called a neoplasm
  - Benign neoplasms are not cancerous
    - Encapsulated
    - Do not invade neighboring tissue or spread
  - Malignant neoplasms are cancerous
    - Not encapsulated
    - Readily invade neighboring tissues
    - May also detach and lodge in distant places – metastasis
    - Results from mutation of genes regulating the cell cycle
- Carcinogenesis – development of cancer
  - Tends to be gradual
  - May be years before cell is obviously cancerous

Characteristics of Cancer Cells

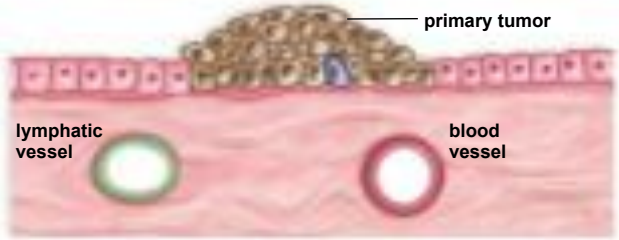
- Lack differentiation
  - Are nonspecialized
  - Are immortal (can enter cell cycle repeatedly)
- Have abnormal nuclei
  - May be enlarged
  - May have abnormal number of chromosomes
  - Extra copies of genes
- Form tumors
  - Mitosis controlled by contact with neighboring cells – contact inhibition
  - Cancer cells have lost contact inhibition

Characteristics of Cancer Cells

- Undergo metastasis
  - Original tumor easily fragments
  - New tumors appear in other organs
- Undergo angiogenesis
  - Formation of new blood vessels
    - Brings nutrient and oxygen to tumor

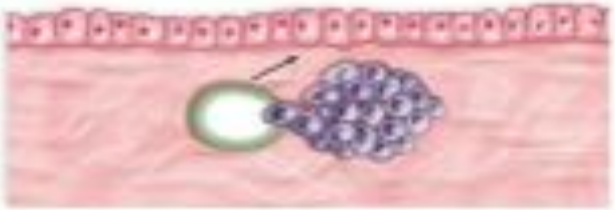
Progression of Cancer

New mutations arise, and one cell (brown) has the ability to start a tumor.



Cancer in situ. The tumor is at its place of origin. One cell (purple) mutates further.

Cancer cells now have the ability to invade lymphatic and blood vessels and travel throughout the body.



New metastatic tumors are found some distance from the primary tumor.

Cancer Cells vs. Normal Cells

Cancer Cells Versus Normal Cells

Cancer Cells	*Normal Cells*
Nondifferentiated cells	Differentiated cells
Abnormal nuclei	Normal nuclei
Do not undergo apoptosis	Undergo apoptosis
No contact inhibition	Contact inhibition
Disorganized, multilayered	One organized layer
Undergo metastasis and angiogenesis	

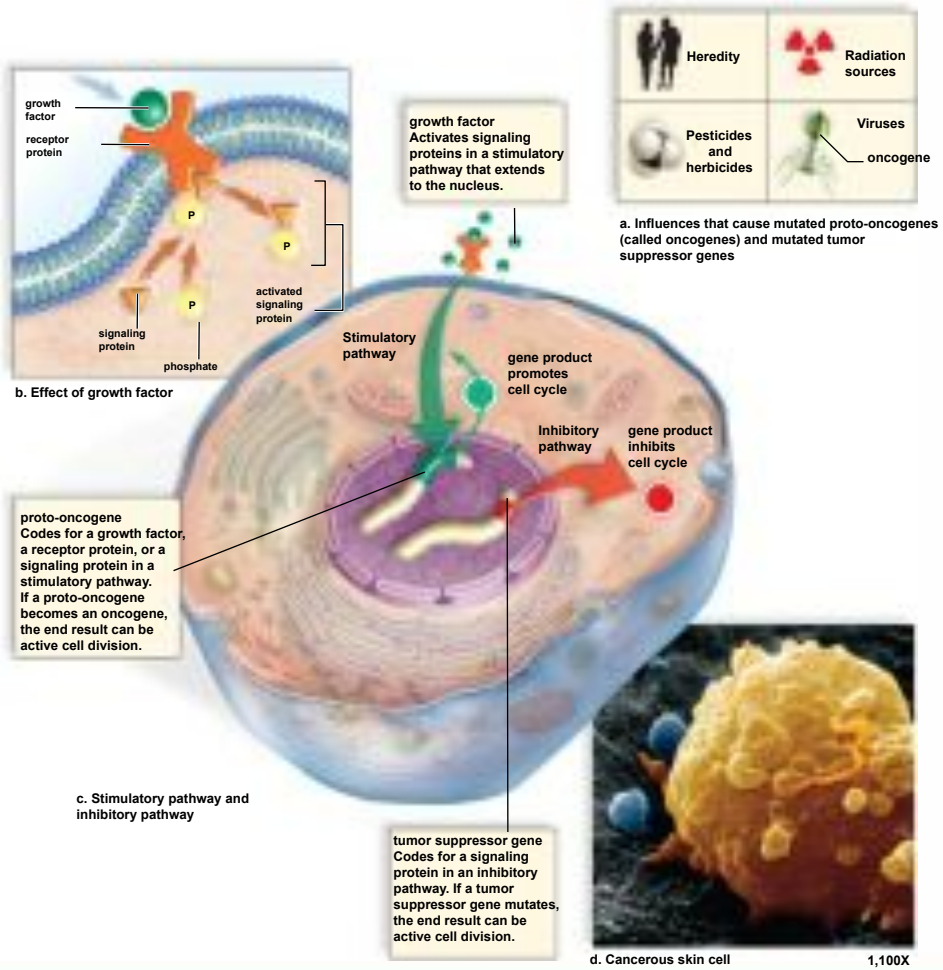
Origins of Cancer: Oncogenes

- Mutations in DNA repair mechanisms
- Oncogenes
  - Proto-oncogenes promote the cell cycle in various ways
  - Tumor suppressor genes inhibit the cell cycle in various ways
  - Both normally regulated in coordination with organism's growth plan
  - If either mutates, may lose control and become oncogene

Origins of Cancer: Telomerase

- Chromosomes normally have special material at each end called telomeres (end parts)
- These get shorter each cell division
- When they get very short
  - The cell will no longer divide
  - Almost like running out of division tickets
- Telomerase is an enzyme that adds telomeres
- Mutations in telomerase gene:
  - Keeps adding new telomeres
  - Allow cancer cells to continually divide
  - Like counterfeit tickets

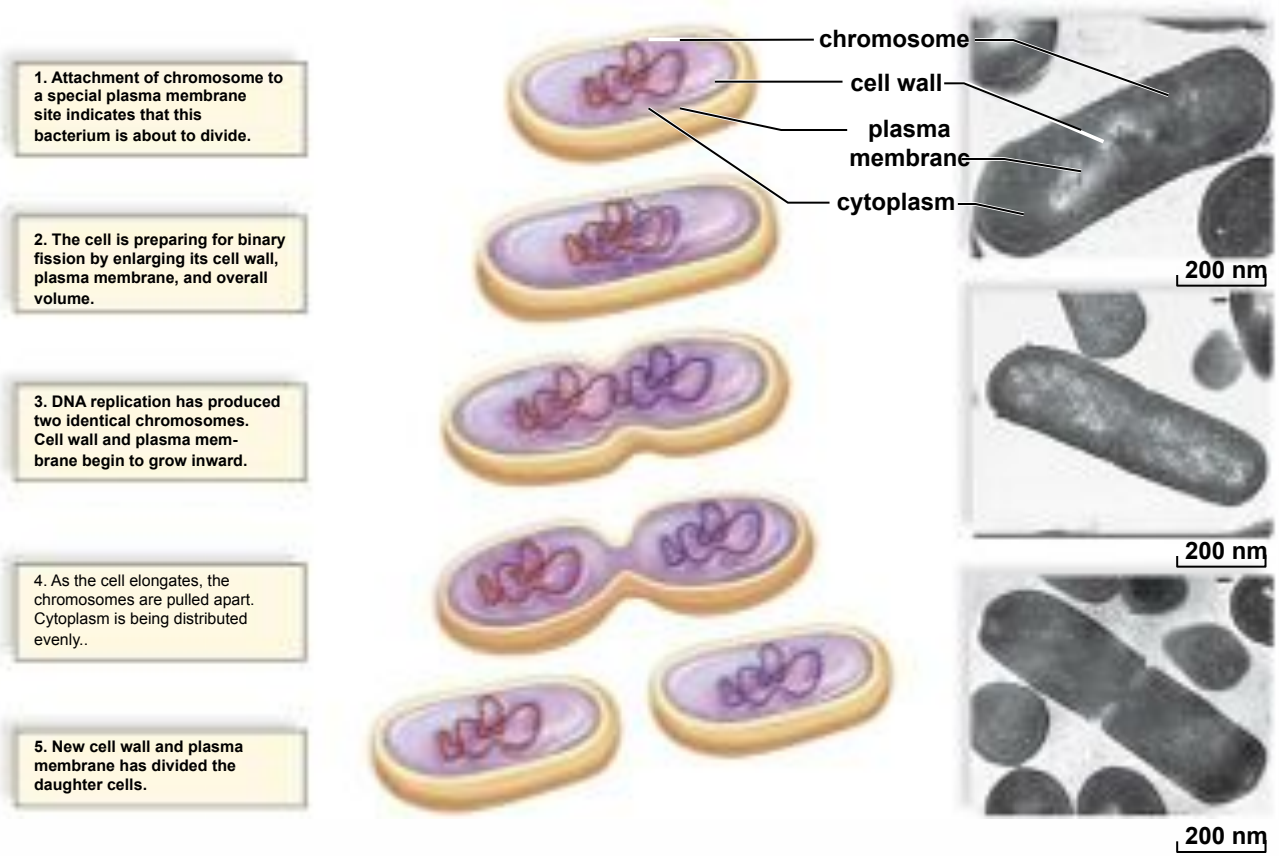
Causes of Cancer



Prokaryotic Cell Division

- Prokaryotic chromosome a ring of DNA
  - Folded up in an area called the nucleoid
  - 1,000 X length of cell
  - Replicated into two rings prior to division
  - Replicate rings attach to plasma membrane
- Binary fission
  - Splitting in two between the two replicate chromosomes
  - Produces two daughter cells identical to original cell – Asexual Reproduction

Binary Fission of Prokaryotes



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Functions of Cell Division

Functions of Cell Division

Type of Organism	*Cell Division*	*Function*
Prokaryotes Bacteria and archaea	Binary fission	Asexual reproduction
Eukaryotes		
Protists, and some fungi (yeast)	Mitosis and cytokinesis	Asexual reproduction
Other fungi, plants, and animals	Mitosis and cytokinesis	Development, growth, and repair

Review

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