Ivan's Chapter 5 Study Guide
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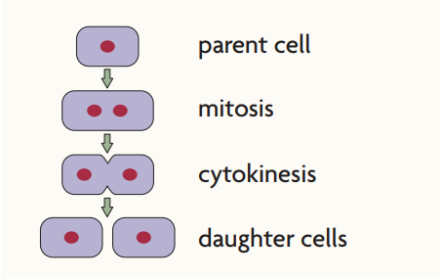
When you have completed the exam and no longer have any use for this study guide, give it to somebody who does not have one.

The Cell Cycle

- The Cell Cycle = Pattern of growth, DNA duplication, and cell division
  - Occurs in all eukaryotes
- Occurs in four stages
  - Gap 1
  - Synthesis
  - Gap 2
  - Mitosis
- Gap 1, synthesis, and gap 2 make up interphase
- Cycle was originally divided into interphase and mitosis
- Cells carry out normal functions and grow to prepare for division during interphase

Gap 1 (G1)

- First stage of cell cycle
- Organisms carry out normal functions
- Cells increase in size during this stage
- Cells spend most of their time in the G1 stage
  - Length varies by cell type
- Organisms must reach certain requirements to continue further
  - Nutrition, size, viability of DNA, signals to divide



The Result of Cellular Division

Synthesis (S)

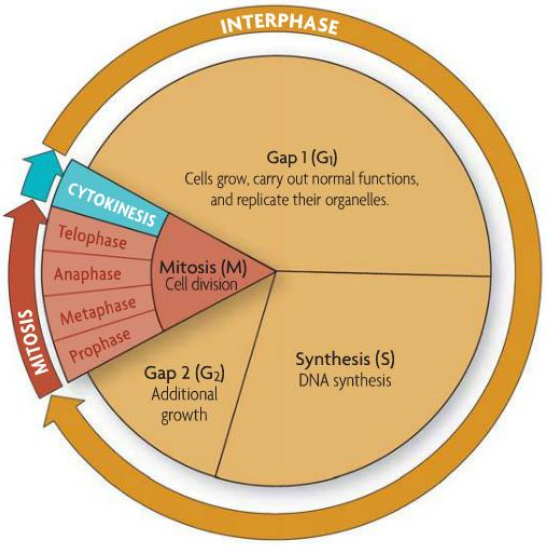
- Second stage of cell cycle
- Synthesis = The combining of parts to make a whole
- Cell copies its DNA
  - DNA is located in the nucleus of a eukaryote

Synthesis Cont.

- By the end, the cell contains two full sets of DNA
- During interphase, DNA is loose and disorganized

Gap 2 (G2)

- Third stage of cell cycle
- Cells continue normal functions
  - Continue to grow
- Cell must fit specific specification to continue onwards
  - Size, DNA viability



The Cell Cycle

Mitosis (M)

- Fourth stage of cell cycle
- Includes mitosis and cytokinesis
  - Mitosis = Division of cell nucleus and its contents
  - Cytokinesis = Process which divides the cytoplasm
    - Results in two genetically identical cells
- During mitosis…
  - The nuclear membrane dissolves
  - Duplicated DNA condenses around proteins
    - Separates and two new nuclei form
- Similarities with cell cycle in all eukaryotes suggests common ancestry

Cell Type	Life Span
Skin cell	2 weeks
Red blood cell	4 months
Liver cell	300-500 days
Intestinal lining	4-5 days
Intestinal muscles and other tissues	16 years

Rate of Cell Division

- Rate of division is linked to need for cells
- In humans, synthesis, G2 and mitosis take a total of 12 hours
- The G1 stage varies between cell types
- The rate of cell division is highest in embryos and children
- Cells divide based on wear and tear
- Cells that rarely/never divide enter the G0 stage
  - Cells in this stage carry out regular functions, but do not prepare to divide
  - Neurons are permanently in this stage
  - Lymphocytes remain in this stage for years until they sense an invader

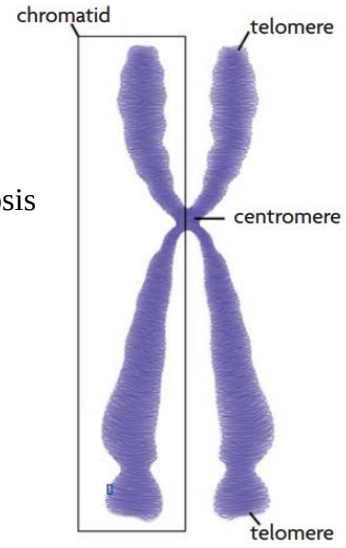
Finite Cell Size

- Cells have upper and lower size limits
  - Lower limit is due to intercellular space concerns
  - Upper limit is due to ratio of surface area to volume
    - Could result in surface area too small for exchange of materials
- Not all cells are shaped like a cube or sphere
  - Some are very long and thin
- Growth and division must be coordinated to maintain suitable size
  - If cell more than doubled size before dividing, the result would be too large
  - If a cell less than doubled size before dividing, the result would be too small

Chromosomes and Mitosis

- Deoxyribonucleic Acid (DNA) is a double-stranded molecule
  - Made of 4 nucleotides
    - Cytosine
    - Thymine
    - Adenine
    - Guanine
- Chromosome = one long continuous thread of DNA
  - Contains genes and regulatory information
- Your body cells contain 46 chromosomes
  - If stretched out, the DNA in each of your cells would be 10 feet long
- To fit into your cells, DNA wraps around proteins which organize and condense it
  - Allows cell to carry out division during mitosis
    - DNA must be divided between two nuclei
  - If they weren't condensed, the DNA could become entangled
- When a cell isn't dividing, DNA is a loose and unorganized spaghetti
- During interphase, proteins need to access specific genes for the cell to make proteins or copy the DNA sequence
- Each chromosome is associated with proteins called histones
  - DNA is wrapped around these histones at regular intervals
  - Histones interact with each other
    - This further compacts the DNA
  - At this stage, the DNA is called chromatin
    - DNA strand folds back on itself
- The chromatin further condenses as the cell further progresses into mitosis
  - Continues to coil more tightly around the proteins
- Chromosomes look like Xs
  - One half of the duplicated chromosome is called a chromatid
    - Two identical chromatids are called sister chromatids
  - Chromatids are held together at the centromere
    - Region of the chromosome which looks pinched
- Ends of DNA molecules form telomeres
  - Made of repeating nucleotides
    - Do not form genes
  - Prevent ends of chromosomes from attaching to each other

DNA

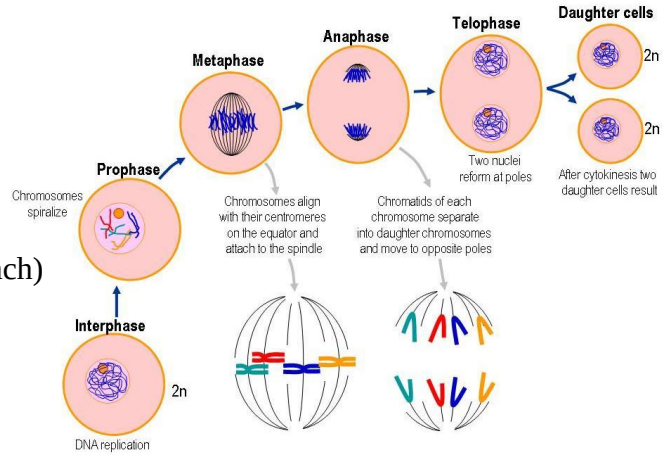


A chromosome

        - Prevent loss of genes
    - A short section of the telomere is lost each time that DNA is copied
- By the end of interphase, the cell has two full sets of chromosomes and is large enough to divide

Mitosis

- Divides a cell's nucleus into two genetically identical nuclei
    - Each has its own full set of DNA
- Occurs in all cells except for reproductive cells
- Prepares the cell for cytokinesis
- Four phases are prophase, metaphase, anaphase, and telophase
- 1: Prophase
    - Chromatin condenses into tightly coiled chromosomes
        - Each consists of two identical sister chromatids
    - Nuclear envelope breaks down and the nucleolus vanishes
    - Centrosomes and centrioles migrate to opposite sides of the cell
    - Spindle fibers grow from centrioles and extend towards the center
- 2: Metaphase
    - Spindles attach to protein structures on each centromere
        - Align chromosomes along the cell's equator
- 3: Anaphase
    - Sister chromatids separate from each other
    - Spindle fibers shorten
        - Pulls sister chromatids towards the opposite sides of the cell
- 4: Telophase
    - Identical chromosomes are positioned at each pole (end) of the cell
    - The nuclear membrane begins to form
    - Chromosomes begin to uncoil
    - Spindle fibers fall apart



*The 4 Processes of Mitosis (Note that Interphase and cytokinesis are **NOT** part of mitosis)*

Cytokinesis

- Divides the cytoplasm into two cells
- Completes the cell cycle
- In animal cells, the membrane forms a furrow (trench)
    - Is pulled inward by filaments
    - Gradually pinches shut
- In plant cells, a plate forms between the two nuclei
    - Made by the Golgi apparatus
        - Supplies new plasma membrane
    - A new cell wall is made as cellulose is built up
- The cytoplasm is divided evenly in both plants and animals
- Unicellular organisms form new cells to reproduce
- Multicellular organisms form new cells to grow and repair
    - There are some exceptions, such as hydra, which reproduce asexually
- Cytokinesis is not part of mitosis

External Factors in Regulation of Cell Division

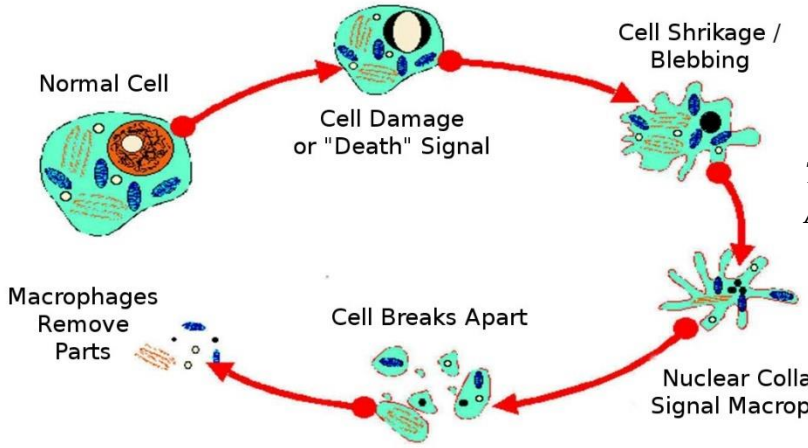
- Include physical and chemical signals
- Physical signal: cell-to-cell contact
  - Cells stop growing as they touch each other
- Cells release chemical signals which tell other cells to grow
- Growth factors are proteins that stimulate cell division
  - Bind to receptors that activate genes to trigger cell growth
- Platelets help to form clots which stop bleeding
  - Made from sticky fragments of bone marrow cells
  - Store a type of growth factor which triggers the growth of many cell types
    - Helps to repair wounds
- Erythropoietin stimulates the production of red blood cells
  - A decrease in oxygen would cause your body to produce more erythropoietin
- Human growth hormone results in bone growth

Internal Factors in Regulation of Cell Division

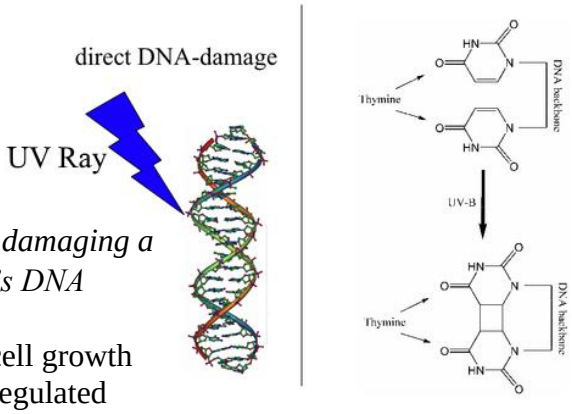
- External factors binding to cell receptors can trigger internal factors which affect the cell cycle
  - Two well studied factors are kinases and cyclins
    - Help a cell advance into each stage of the cell cycle
- Kinase enzymes transfer phosphate groups between molecules
  - Increases the target molecule's energy or shape
  - Kinases which control the cell cycle are activated by cyclins
- Cyclins are proteins which are rapidly created and destroyed at various points of the cell cycle

Apoptosis

- Apoptosis is programmed (intentional) cell death
- Occurs when cells receive signals to activate genes which produce self-destructive enzymes
- During apoptosis, the nucleus shrinks and breaks up
  - The cell is flagged for destruction by immune cells
    - Cell chemicals are recycled



The Process of Apoptosis



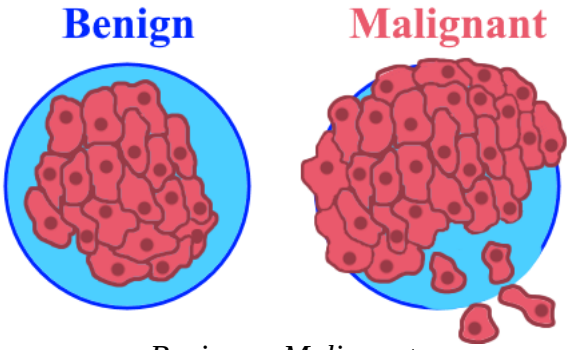
UV Light damaging a cell's DNA

How Cancer Forms

- Linear growth increases by a constant
  - Normal cellular reproduction
- Exponential growth increases by a ratio
  - Cancer cells
- Cancers are a class of diseases caused by uncontrolled cell growth
  - Occurs when the cell cycle is allowed to run unregulated
- Cancer cells keep diving, paying no attention to physical or chemical constraints
  - They pay no attention to cell cycle checkpoints
- A clump of cancer cells is called a tumor
- Cells in benign tumors cluster together, and do not invade neighboring cells
  - Benign tumors can often be cured by removing them
- Cancer cells in malignant tumors spread and invade healthy cells
- Cancer cells metastasize when they break away from the tumor and travel to another part of the body through the bloodstream or lymph system
- Tumors are harmful because cancer cells take up space and resources while not performing any useful functions
  - Tumors can also put pressure on nearby organs and damage them
- An example of a type of cancer would be a melanoma, which is a cancer of the skin
- Cancer can be caused by internal factors
  - Mutations in oncogenes which accelerate the cell cycle or genes which stop the cell cycle
    - These genetic errors can be inherited
- Cancer can also be caused by external factors
  - Radiation can damage DNA and create cancerous cells
  - Carcinogens are molecules which promote the development of cancers
    - Tobacco smoke, as an example
  - Some viruses can spread mutated oncogenes
    - The HPV virus (human papillomavirus) can insert these genes into healthy cells and cause cervical cancer
- Cancer clusters are areas or groups with a high incidence of cancer

A, B, C, Ds of cancer

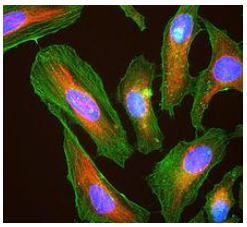
- Asymmetry - irregular shape
- Border - irregular border
- Color - change and/or uneven distribution of color
- Dimension - anything larger than 6mm (1/4in)
- New growth or changes in growth



Benign vs Malignant Tumors

Cancer Treatment and Research

- Somebody who studies cancer is called an Oncologist
  - *Onco* = Cancer
- A standard anti-cancer routine involves radiation therapy and chemotherapy
  - Radiation therapy uses fine beams of targeted radioactive particles to destroy cancer cells



Stained HeLa Cells

- The beam of radiation damages cancer cell DNA to the point where it cannot divide anymore
- The radioactive particles are accelerated through the use of a Linear particle accelerator
- Radiation is localized to a specific region of the body since it also harms healthy cells

  - Chemotherapy uses a combination of drugs to either kill cancerous cells or prevent them from multiplying
    - Similar to radiation, chemotherapy also harms healthy cells. However, due to its nature chemotherapy is systemic, meaning that it travels across the entire body

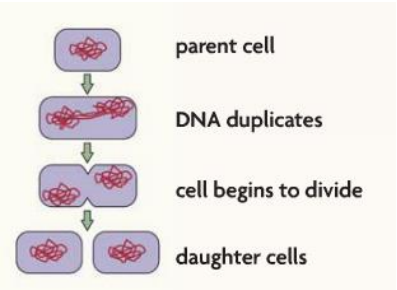
- The most widely used cancer cells are from the HeLa cell line
  - HeLa cells are widely used since they're an immortal cell line
    - Cells from an immortal cell line are mutated in a way that allows them to divide indefinitely
  - HeLa cells were sourced from Henrietta Lacks on February 8th, 1951 without her consent
    - The cells were taken by biologist George O. Gey from the John Hopkins hospital during a biopsy of her cervical tumor
    - Henrietta lacks died on October 4th, 1951
  - HeLa cells are still the most widely used culture, since they reproduce so Rapidly

<u>Sexual vs Asexual Reproduction</u>

- Sexual reproduction is used to create offspring from two parents
  - involves the joining of two gametes (sex cells) in order to produce an offspring
  - The offspring's genetic material is a blend of those from both parents
- Asexual reproduction is used to create offspring from a single parent
  - Does not involve the joining of two gametes
  - Except for mutations, offspring are genetically identical to their parents

<u>Binary Fission</u>

- Binary fission is asexual reproduction by division of an organism into two parts
  - Used by prokaryotes in place of mitosis
  - Both mitosis and binary fission are asexual processes which form two genetically identical daughter cells
- Prokaryotes have no nuclei or spindle fibers and feature circular chromosomes
- Binary fission starts with the chromosome being copied
  - Both chromosomes are attached to the cell membrane
- As the cell increases in length, the chromosomes move away from each other
- When the cell is twice its original size, it performs cytokinesis
  - The membrane pinches inward and a new cell wall is put into place



Binary Fission

Pros and Cons of Asexual Reproduction

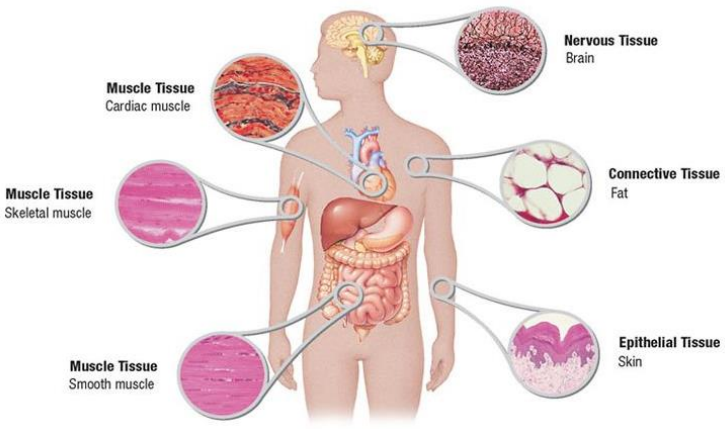
- Asexual reproduction is very efficient compared to sexual reproduction
  - Is useful for stable environments without much change
- However, asexual reproduction is unfavorable in changing conditions
  - Beneficial genes would not be spread to other cell lines
- Still, sexual reproduction is more costly and requires more time than asexual reproduction

Asexual Reproduction in Multicellular and Unicellular Eukaryotes

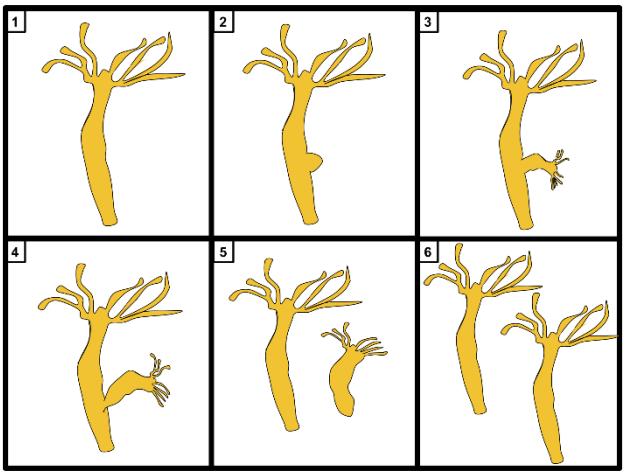
- Multicellular eukaryotic organisms such as starfish can reproduce asexually
- Includes budding, fragmentation, and vegetative reproduction
- In budding, a small projection forms on the parent
  - This projection eventually grows into a separate offspring
  - Hydras and Yeast reproduce through budding
- In fragmentation the parent splits into multiple pieces, each of which can grow into a whole organism
  - Used by flatworms and starfish
- Plants such as potatoes and strawberries produce through vegetative reproduction
  - Offspring grow out of underground roots and are often connected to the parent through structures known as runners
- Organisms such as sea anemones can produce through both sexual and asexual reproduction

Organ Systems in Multicellular Organisms

- Cells within multicellular organisms communicate and work together
  - Form larger and more complex structures
- Tissues are groups of cells which work together to perform similar functions
- Groups of tissues which perform similar functions form organs
- Groups of organs which work together form organ systems
  - Organ systems help to maintain homeostasis



The many organ systems in the human body



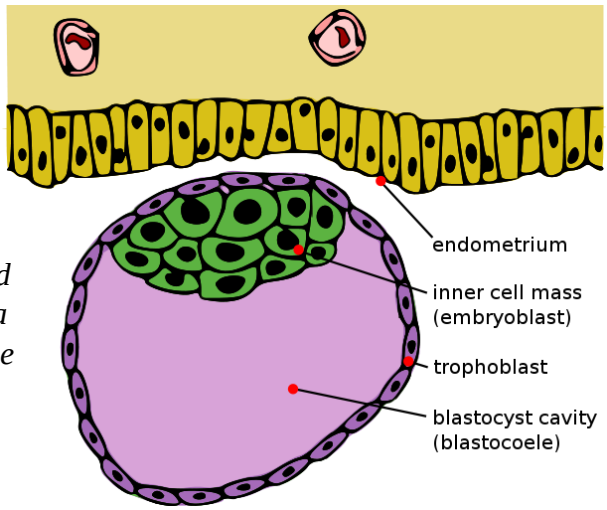
How Budding Works (In Hydra)

Specialized Cells

- In order to form systems that perform specific functions, cells must specialize
- Cell differentiation is the process by which unspecialized cells develop into specialized cells
- Specialized cells only use the genes that they need to function
    - Cells differentiate which gene is which any only use specific ones
- DNA is like a cookbook for cell function
- Cell locations also helps to determine how it will differentiate
- Animal eggs undergo rapid divisions after being fertilized
    - The produced cells move to specific areas and begin to differentiate
    - The early animal embryo is shaped like a hollow ball
        - Later, the ball folds inwards and forms an inner cell layer
        - An opening is also created in the outer layer
    - In vertebrates, the outer cell layer differentiates to form skin and neural tissue
    - The middle layer forms internal organs

The Magic of Stem Cell

- Stem cells can divide and renew themselves for long periods of time, remain undifferentiated, and differentiate into a variety of specialized cells
- Examples of cells types that come from stem cells are neurons and muscle cells
- Stem cells are categorized for their potential to develop into different specialized cells
    - Totipotent stem cells can differentiate into any type of cell
        - Only found in fertilized eggs and the first few cells produced afterwards
    - Pluripotent stem cells can grow into almost any cell except for totipotent cells
        - Found inside of embryos
    - Multipotent (*somatic*) stem cells are limited to a closely related cell family
- Although multipotent stem cells have been studied for decades, scientist were unable to grow embryonic stem cells until 1998
- Adult stem cells are partially undifferentiated cells
    - They are found in all of the body's systems, as well as in adults, children, and umbilical blood
    - Can be taken from a living patient, grown outside the body, and put back in
        - Low risk of transplantation rejection
    - Fewer in numbers and contain more DNA abnormalities than embryonic stem cells
    - If treated with the right molecules, adult stem cells can turn differentiate into a completely different type of tissue
        - Called Transdifferentiation



An approximately 5-day old human embryo, known as a blastocyst in this early stage

- Embryonic stem cells are undifferentiated cells
    - Are sourced from 3-5 embryos
        - Taken from a cluster of undifferentiated cells
            - Known as the inner mass
    - Pluripotent, meaning that they can become any of the 200 types of body cells
    - Can be used in the future to treat traumatic brain injury, strokes, and more
    - However, these cells can be rejected as foreign material
        - The stem cells could also grow into a tumor
- Today, stem cells are used to treat leukemia and lymphoma
- In the future, stem cells could be used to treat many more diseases
- Stem cells could also be used for drug testing, making it less costly.

Key Terms	Definitions
The Cell Cycle	A pattern of growth, DNA duplication, and cell division
Synthesis	The combining of parts to make a whole
Mitosis	Division of a cell nucleus and its contents
Cytokinesis	Process which divides the cytoplasm
Chromosome	One long continuous thread of DNA
Histones	Proteins which the chromosomes wrap around
Chromatin	Loosely wrapped chromosomes
Chromatid	One half of a duplicated chromosome
Centromere	Pinched region in the chromosome where the two chromatids are held together
Telomere	Repeating nucleotides at the end of a chromosome to protect the genes
Prophase	See the Mitosis section
Metaphase	See the Mitosis section
Anaphase	See the Mitosis section
Telophase	See the Mitosis section
Growth factors	Proteins that stimulate cell division
Cancers	Diseases caused by uncontrolled cell growth
Benign Tumor	Contains cells which cluster together and do not invade healthy cells
Malignant Tumor	Contains cancerous cells which spread and invade healthy cells
Metastasize	When cancer cells break away from a tumor and travel to another part of the body
Asexual reproduction	Reproduction with only one parent
Binary reproduction	Asexual reproduction used by prokaryotes
Tissues	Groups of cells which work together to perform similar function
Organs	Groups of tissues which perform similar functions
Organ systems	Groups of organs which work together
Cell differentiation	The process by which unspecialized cells develop into specialized cells
Stem cells	Cells which can remain unspecialized and later develop into a specialized cell

Amoeba Sisters: Cell Cycle

- Multicellular organism grows by making more cells
- Mitosis and cytokinesis make new cells
- Cancer is caused by unregulated cell reproduction
    - Can divert blood cells to grow towards them
- Toxins, radiation and UV light can cause cells to become cancerous
- Tumors are a mass of cancer cells
- Cells are either in interphase
    - Growing
    - Replication
- Or M-phase
    - Mitosis, cytokinesis
- Hair cells frequently undergo mitosis
- Checkpoints are along cell cycle to check if a cell is performing properly
    - G1, G2, M
- Apoptosis = self-destruction of a damaged cell
    - Makes sure that it doesn't go on to divide
- Positive regulators allow the cell cycle to move forward
    - Cdk
    - Cyclin
        - Types rise and fall throughout cell cycle
        - Each phase tends to have a different type of cyclin binding with Cdk
- Negative regulators hamper the cell cycle from moving forward
    - p53 initiates apoptosis
- G0 phase
    - Resting phase
    - Cells perform functions, but do not prepare to divide
    - Neurons are permanently in this phase
        - Therefore, neurons do not replicate
- Mitosis is useful for repairing cells
    - Done to make new cells
        - Reproductive cells do not go through mitosis, but instead undergo meiosis
- DNA can be condensed into chromosomes
    - Made of DNA and protein

Bozeman: Phases of Mitosis

- Mitosis is the division of the nuclei
    - Making two identical daughter cells
- How humans grow, repair cells
- Gap 1 - Growing
- Synthesis - Duplicating DNA
- Gap 2 - Continues to grow
- Mitosis - Mitosis
- You get two cells at the end of the cell cycle
- Cells spend most time in interphase
- Mitosis is composed of multiple phases

- Centrosome is made of microtubules and a centriole
    - Centriole organizes microtubules
        - Only in animal cells
- DNA is condensed into chromosomes
    - Each site is called a sister chromatid
        - Both are exactly the same
- Kinetochore is found in the center of each chromatid
    - Attaches to microtubules of spindle
- Interphase
    - Not part of mitosis
    - DNA is duplicated
    - Centrosomes replicate
    - Can't see chromosomes
- Prophase
    - DNA begins to condense
        - Can start to see chromosomes
    - Mitotic spindle forms
- Prometaphase
    - Nuclear envelope breaks apart
    - Some microtubules attach to the kinetochore
- Metaphase
    - All chromosomes line up in the middle
        - Metaphase plate
- Anaphase
    - Chromatids separate
        - Equal amounts of DNA in each daughter cell
- Telophase
    - Cleavage furrow forms
    - Daughter nuclei form
        - Forms around each daughter chromosome set
    - Microtubules elongate cell
- Cytokinesis
    - The daughter cells begin to split apart
- Cells go back to interphase
- Remember IPPMATC
- The longest phase of all is interphase
    - The longest part of interphase is G1
- Spindle fibers are made of microtubules