Mitosis

- An Introduction to Genetics
- An Introduction to Cell Division
- DNA is Packaged in Chromosomes
- Cell Cycle
- Mitosis and Cytokinesis
- Variations in Cell Division
- Cell Division and Cancer

An Introduction to Genetics

- Genes influence virtually every aspect of an organism
- Genes, and the traits they influence, are transmitted from one generation to the next
  - A key feature of living things
- Genetics studies the nature of genes, how they function, the traits they govern, and how they are transmitted

- Proteins have many functions in cells and in organisms
  - e.g., Structural proteins, signaling proteins, hormones, transport proteins, enzymes, etc.
- A gene is a piece of DNA that directs the production of a protein

- Mutated genes can encode proteins with altered function or with no function
  - Belgian blue cattle posses a mutated gene that does not function
    - The protein myostatin is not produced
    - Myostatin normally inhibits muscle growth
    - Without myostatin, muscle growth is more pronounced

Questions we can ask

- How does a gene encode a protein?
  - How does DNA factor into it all?
- How does a mutated gene affect this protein?
- How are genes passed from one cell to new cells when the cells divide
  - How are traits of any kind passed from generation to generation?

An Introduction to Cell Division

- The library of genes within a living thing is large
  - 20,000 – 25,000 genes in the human genome
- This information has been amassed and edited over 3.8 billion years of evolution

- Most cells within an organism contain a complete copy of that organism's genome
  - Humans have trillions of cells
  - We possess trillions of copies of our genome within us
- A given type of cell uses only a subset of these genes
  - Different cell types use different subsets of genes
  - Different genes are active in different cells
- When cells duplicate, they must accurately copy the entire genome
  - Even genes not used by that particular type of cell must be duplicated

- Today, we will study DNA as it is packaged in units called chromosomes
- We will also investigate how DNA is passed to new cells by mitosis and meiosis
- Later, we will discuss:
  - How genes are expressed
  - How gene expression affects traits
  - How our understanding of this process is used in biotechnology

<u>Cell Theory Review</u>

- All living things are built of cells
- All cells come from preexisting cells
  - The process of making new cells is termed "cell division"

- Cell division is involved in many diverse processes
  - Growth of a baby
  - Development of a plant
  - Healing of a wound
- In your body, up to 25 million cell divisions are completed each second

- All of the different types of cells in your body divide at some time
- Some retain the ability to divide indefinitely
  - e.g., Cells in bone marrow produce 180 million new red blood cells each minute
- Some cells stop dividing
  - e.g., Most human brain cells are formed in the first trimester *in utero*, with relatively few cell divisions for the rest of your life

- When a cell divides, the new cells produced are called "daughter cells"
- Each daughter cell must receive a complete genome
- Prior to cell division, a cell's DNA is duplicated
  - "DNA replication"
- During cell division, this DNA is segregated equally into the two daughter cells

- Each cell receives a complete genome

- Cell division consists of two parts
- Mitosis
  - The equal division of the cell's genome
- Cytokinesis
  - The division of the cytoplasm, membranes, and other organelles

Chromosomes

- Each DNA molecule is a long double helix
- DNA is wrapped around many histone protein "spools"
  - DNA + spools = "chromatin"
- A single unit of chromatin is a chromosome
  - Comprised of a long DNA molecule and its proteins

DNA replication

- DNA double helix of a chromosome unwinds
- Both existing strands serve as templates for the synthesis of new DNA strands
- Replicated DNA double helices are produced
- Each possesses one old strand and one new strand
- The replicated DNA remains connected at one point
  - Centromere

- Before DNA replication
  - One chromosome = one chromatid
- After DNA replication
  - One chromosome = two chromatids

- Different species have different numbers of chromosomes
  - e.g., Humans have 46
  - e.g., Fruit flies have 8
- Eukaryotic chromosomes tend to come in pairs
  - The two chromosomes in a pair are similar, but not identical, in structure and content
  - "Homologous chromosomes"

- Humans have 46 chromosomes
  - 23 pairs of homologous chromosomes
  - Two full sets of 23 chromosomes
    - One full set from each parent

- Two copies each of 23 different chromosomes
  - One copy of each from each parent
- Diploid, or 2n
  - 2 = the number of sets of chromosomes
  - n = the number of chromosomes in a set

- Humans possess 23 pairs of chromosomes
  - 22 pairs are autosomes
    - "Non–sex chromosomes"
  - The 23rd pair constitute the sex chromosomes
    - X and Y chromosomes
      - XX in females
      - XY in males

- A karyotype is a pictorial arrangement of an organism's full complement of chromosomes

- DNA is generally uncondensed
- DNA can be condensed
- DNA condenses before cell division
  - Cell division involves the movement of chromosomes
  - Chromosomes are much more easily moved when they are "packed up" in their condensed forms
    - You "pack up" your belongings into boxes before you move

Cell Cycle

Cell cycle

- Repeating pattern of growth, genetic duplication, and division
- Two main phases
  - Interphase
  - Mitotic phase
- Ends with cytokinesis

Interphase

- Three subphases
  - G_1 (gap-one)
    - Normal cell operations and cell growth
  - S (synthesis)
    - Duplication of chromosomes

- G_2 (gap-two)
  - Cytoplasmic growth and preparation for division

Mitotic phase (M phase)

- Two processes take place
  - Mitosis
    - Division of the nucleus
  - Cytokinesis
    - The end of the cell cycle
    - Division of the cytoplasm and its contents

Mitosis and Cytokinesis

- Mitosis is the separation of a cell's duplicated chromosomes
- Four phases
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase

IPMAT
I Propose Marriage to Anna/Andrew by Telephone

Prophase

- Replicated DNA condenses
- Mitotic spindle begins to form
- Centrioles begin migrating in animal cells
- Nuclear membrane is disassembled

Metaphase

- Chromosomes line up on equatorial plate
- Mitotic spindle is complete
  - Centromeres attached to centrioles

Anaphase

- Sister chromatids separate
  - Once sisters, the separate chromatids can now be considered individual chromosomes

Telophase

- Chromosomes arrive at poles

- Chromosomes unwind (decondense)
- Nuclear membranes are assembled
- Result is one cell containing two nuclei

Cytokinesis

- Begins as early as anaphase
- Protein filaments form a ring around the cellular equator
  - Ring contracts, forming a "cleavage furrow"
  - Membrane fusion pinches cell into two cells
    - Cytoplasm and contents are divided roughly in half

Variations in Cell Division

- Plants possess a rigid cell wall, and cannot perform cytokinesis in the same manner as animal cells
  - New cell wall and plasma membrane are grown down the middle of parent cell
  - Formed by fusion of vesicles
    - "Cell plate" is formed
    - Material inside vesicles forms cell wall

The Cell Cycle Runs Amok: Cancer

- The cell cycle controls the division of cells
  - Some cells divide at certain times, while others do not
- Cancer involves the unrestrained division of cells
  - The cell cycle fails to properly regulate these cells

- Two requirements for a cell to become cancerous
  - Accelerator must get stuck
    - Division inducing genes always on
  - Brakes must fail
    - Division suppression genes disabled

- Checkpoint proteins monitor the cell cycle
  - Can advance cycle with growth factors
  - Can inhibit cycle when DNA is damaged
  - Can induce cell death if cycle cannot be completed
- Mutated checkpoint genes cause these genes to act like stuck accelerators or failed brakes

- Moles and most tumors are neoplasms
  - Benign and kept +/- in check
- Cancers are malignant neoplasms
  - Can move to new locations in the body through metastasis

- Cancers have four characteristics
  - Growth and division is abnormal, resulting in co-opting of additional nutrients
  - Structural elements are abnormal, resulting in changes in cell form and function
  - Adhesion abilities are reduced or lost, resulting in cells that move easily
  - Lethal effects will occur if the cells are not killed or controlled