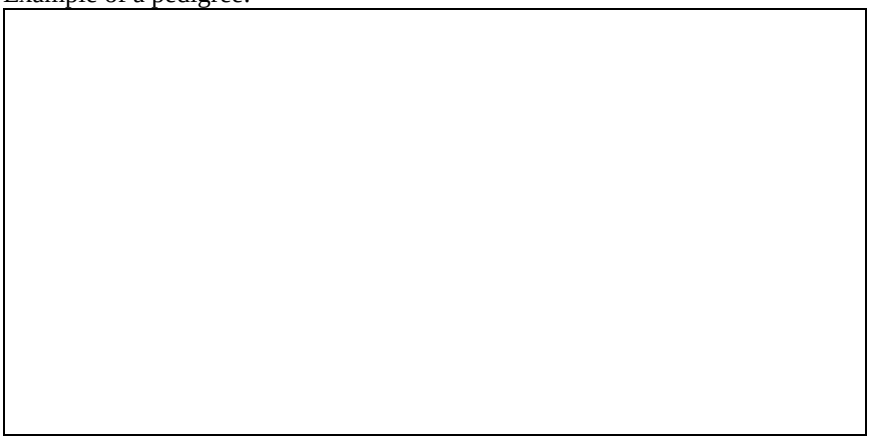
CHAPTER 12 – *HUMAN GENETICS*

- **Genome =** complete set of genetic material in any organism
  - An organism's genome fits into the nucleus of a single cell because it is tightly wound around proteins called **histones** and then coiled up more.
  - Human Genome Project: study that allowed for sequencing of human DNA (determine order of bases in all genes)
    - Functions of the resulting proteins have not all been determined
    - Allows us to identify disease-causing mutations, etc.

- **Genetic Mistakes/Mutations:**
  - 1) **Nondisjunction**: either homologous chromosomes or chromatids do not separate properly in meiosis I or II; end up with gametes that have too few or too many chromosomes.
    - Example of nondisjunction: Down Syndrome – also known as trisomy 21, because children with Down Syndrome have a third (extra) 21st chromosome.
    - Patients with Down Syndrome are MRDD (mentally retarded and developmentally delayed).
    - The chance of nondisjunction increases with increasing age of mother
  - 2) **Duplication:** Part of a chromosome is repeated
  - 3) **Deletion**: Part of a chromosome is lost
  - 4) **Inversion:** The order of two chromosomal fragments on the same chromosome is reversed.
  - 5) **Translocation:** Fragment of one chromosome attaches to a different, non-homologous chromosome.
    - *Note: For a review of duplication, deletion, inversion, and translocation, see page 252.*
    - *Note: Any time a duplication, deletion, inversion, or translocation occurs, the intended DNA sequence is altered, which can result in production of a "wrong" protein (a protein that is functionless or a protein that performs a task it shouldn't).*
  - 6) **"Jumping Genes" (also known as transposons):** A single specific gene (NOT a chromosome fragment that may contain several genes, like in translocation) leaves its original location and jumps into the middle of other genes, resulting in a disruption of genetic function.

- How do Mendel's principles apply to human genetics?
  - You can study the occurrence of traits in a family by creating a pedigree showing several generations of a family.
  - Example of a pedigree:



CHAPTER 12, continued.

- **Recessive Human Disorders:**
  - Most human genetic disorders are recessive.
  - If a person is heterozygous for the recessive disease, he or she is called a **carrier**, meaning he/she has the recessive allele for the disease, but also has the dominant, normal allele, and so does not have the disease.
  - Only people who are homozygous recessive for the disease-causing allele will have the disease. (Homozygous dominant and heterozygous people are disease-free.)
  - You can use a punnett square to determine the probability that a child of two carriers (or the child of one carrier and one homozygous recessive parent) will have the disorder.
  - Example of recessive genetic disease: cystic fibrosis

- **Dominant Human Disorders:**
  - If a person is heterozygous or homozygous dominant, he/she will have the disease.
  - Only homozygous recessive people are disease-free.
  - Ex: dwarfism, Huntington's Disease (Huntington's is a progressive disease of the nervous system that affects mental status and muscle coordination.)

- **Sex-linked Human Disorders:**
  - Most sex-linked characteristics are carried on the X chromosome.
  - Recall: males are XY, females are XX.
  - For a male, the X-linked characteristics are always passed from the mother.
  - For X-linked disorders, a male only needs one copy (from mom) to have a disease, while a female will need two copies (one from mom, one from dad).
  - Example: color blindness

- **Genetics and Cancer:**
  - Simply defined, **cancer** is the uncontrolled growth of abnormal cells in the body.
  - Normally one class of genes produces proteins called growth factors that start cell division.
  - There is a second class of genes called **tumor suppressor genes** that produce proteins that can stop cell division if necessary. (Cell division is stopped if there is a mistake in DNA replication, when DNA is damaged, etc.)
  - Usually, cancer develops when several (not just one) genetic mutations occur.
    - Examples of mutations that can lead to cancer:
      - Mutation causing increased production of growth factor
        - Such a mutated gene is sometimes called an **oncogene** (a cancer causing gene).
      - Mutation that shuts down production of proteins from tumor suppressor genes.

- **Inherited Cancer:**
  - If cancer-causing mutations occur in cells that ultimately produce gametes, these mutations are passed on to offspring and there is an increased risk that the offspring will develop cancer.
  - Example: BRCA genes = inherited mutated tumor suppressor genes that increase the risk of developing breast cancer.

CHAPTER 13 – *SCIENTIFIC STUDY OF DNA*

- **Biotechnology:** use of organisms to perform jobs for humans (using yeast to make bread, for example)
- **Recombinant DNA Technology:** combining genes from different sources (even different species) into a single DNA molecule.
- **Bacteria are considered the "workhorses" of modern biotechnology.**
    - Biologists can use bacteria to produce many genes and proteins; these genes and proteins can then be placed into other organisms.
    - **Plasmid** = small circular DNA molecule found in bacteria that is separate from the larger bacterial chromosome.
        - A plasmid contains many genes and can make copies of itself.
        - Plasmids can pass from one bacterial cell to another (gene sharing)
            - Sharing of genetic material between bacteria can allow for increased survival of bacteria (if bacteria pass on genes for antibiotic-resistance to other bacteria, for example).

- Plasmids can be used for human's benefit in recombinant DNA technology.
    - We can use plasmids to insert genes for useful products.
    - The plasmid is taken out of a bacterial cell and the desired gene from any kind of cell is inserted into the plasmid. The plasmid is now a combination of this new DNA and its original DNA; the plasmid is "recombinant".
    - The recombinant plasmid is put back into the bacterial cell; DNA replication occurs; many copies of the desired gene are made. This is called *gene cloning.*
    - We are able to cut a desired gene out of one DNA molecule and stick it into the plasmid by using **restriction enzymes**:
        - Restriction enzymes recognize short DNA sequences and then cut DNA at specific points within those sequences.
        - DNA ligase is used to stick the new, cut DNA into the plasmid DNA.

- Useful products that come from recombinant DNA technology (using plasmids):
    - Recombinant bacteria can break down chemicals and clean up toxic waste sites.
    - Recombinant bacteria can be used to mass produce pesticides, drugs, etc.
    - Recombinant bacteria can be used to mass produce insulin for diabetics.
    - Recombinant yeast can be used to develop effective vaccines against disease-causing organisms:
        - Genes for proteins from the hepatitis B virus have been cloned in yeast cells.
        - The yeast cells mass produce these hepatitis B proteins.
        - The hepatitis B proteins are then used to make vaccines for humans to fight hepatitis B infection.

- **Genetic Engineering of Plants and Animals:**
    - **GMO = genetically modified organism** (an organism that has acquired one or more genes by artificial/laboratory means).
    - **Transgenic GMO:** an organism whose new genetic material comes from a different species.
    - **GM plants:** have "better" characteristics (increased resistance to disease, for example).
    - **GM animals**: have "better" characteristics (sheep with better quality wool, pigs with leaner meat, for example).
    - **Animal cloning**: allows for mass production of an animal with a desirable set of traits.

- DNA Lab Techniques:
    - **PCR = polymerase chain reaction**
        - Mass produces DNA in a test tube by using DNA polymerase and primers specific for a region of interest.

Chapter 13, continued.

PCR, continued.

- Allows for one specific DNA segment to be copied.
- Can produce billions of identical DNA segments in a few hours.

- **Gel Electrophoresis:**
  - Sorts DNA fragments by size
  - Large fragments stay on the top of the gel while small fragments fall to the bottom of the gel.
  - The gel can be stained with a dye and is then visible under UV light.
  - A series of DNA "bands" (fragments) is seen under UV light. This is known as a "banding pattern".
    - Each individual's banding pattern is unique and is therefore known as a "DNA fingerprint".
    - By combining PCR and Gel Electrophoresis, DNA from a blood sample can be used to obtain a banding pattern.

- How are genes controlled?

- **Regulation of genes in prokaryotes:**
  - **Operon** = a cluster of genes specific for one certain function.
  - **Lac operon =** contains genes that code for lactose-digesting enzymes.
    - **Promoter** = control sequence of DNA (where RNA polymerase attaches during transcription)
    - **Operator =** acts like a switch and determines whether or not RNA polymerase can attach to the protein.
    - **Repressor protein** = can bind to the operator and therefore block attachment of RNA polymerase to the promoter.
    - **If NO lactose is present in the cell,** the repressor protein is active and the lactose-digesting genes cannot be transcribed.
    - **If lactose is present in the cell,** lactose binds to the repressor protein and deactivates the repressor protein. Now RNA polymerase can bind to the promoter and the lactose-digesting proteins are produces. The lactose can be digested.
- **Regulation of genes in eukaryotes:**
  - Same general idea as operons in prokaryotes
  - Transcription factors = proteins that regulate transcription by binding to promoters or to RNA polymerases
    - Transcription factors can be activated or deactivated by chemical signals (hormones, for example)
  - **Gene expression**: the transcription and translation of genes into proteins.
  - **Cellular differentiation:** as an embryo continues to develop, individual cells become more specialized in structure and function.
    - Specific cells only express genes that code for proteins <u>with functions in that cell!</u> (For example, the insulin gene is only active/expressed in pancreas cells.)
  - **Stem Cells:** certain cells that remain undifferentiated.
    - **Stem cells are said to be pluripotent,** meaning they have multiple potentials (that is, they can become any type of cell).
    - Stem cells are found in bone marrow, but the most pluripotent type of stem cell is found in an embryo.
  - **Homeotic genes**: master control genes that control the development of body parts *and* make sure that each body part ends up in the right location (a mutation to a homeotic gene in a fruit fly may produce a mutant fly with eyes on its antennae, for example).

CHAPTER 14 – *EVOLUTION*

- **Evolution:** all of the changes that have transformed life over time; also, the change of a species over time.
- **Adaptation:** an inherited characteristic that improves an organism's ability to survive and reproduce in a particular environment.
- **Darwin**: theorized that Earth was ancient and that species can change over time.
- **Darwin's *Origin of the Species* proposed two major theories:**
    - **1)** Species living on earth today descended from ancestral species.
        - Descendants of the earliest organisms spread into various habitats over millions of years.
        - In these varied habitats, organisms accumulated different adaptations for diverse ways of life – Darwin called this phenomenon *descent with modification.*
    - 2) **Natural Selection:**
        - Individuals with inherited characteristics that are well-suited to their environment will survive and reproduce more successfully than others and will therefore produce more offspring than other individuals. (Survival of the fittest)

- **Evidence of Evolution (of species descending from a common ancestor):**
    - FOSSIL RECORD:
        - Fossil = preserved remains or markings left by an organism.
        - Fossil record = collection of life's remains in rock layers (the oldest fossils are in the bottom layers and the youngest fossils are found in the top layers).
    - HOMOLOGOUS STRUCTURES:
        - Similar structures found in different species who share a common ancestor (bones in human arm are similar in appearance to those found in cat foreleg, whale flipper, and bat wing).
            - Note: Homologous structures do NOT have the same function in all species.
        - (Vestigial structures – remnants of structures that may have had important functions in an ancestral species but have no clear purpose in modern descendants; example: tailbone in humans)
    - SIMILARITIES IN DEVELOPMENT:
        - Embryos of multiple different species look very similar.
    - MOLECULAR BIOLOGY:
        - Similarities in DNA sequences of genes of different species indicates a common ancestor.
        - The more similar the DNA, the more closely related the species and the more likely that they share a close common ancestor.
        - Example: there is a 99% similarity between the DNA sequences for the hemoglobin gene in humans and chimps.

- More evolution terms:
    - **Population:** a group of individuals *of the same species* living in the same area at the same time.
    - **Artificial selection:** selective breeding of domesticated plants and animals to produce offspring with genetic traits that humans value (example: dog breeding).
    - **Microevolution:** change in a population's gene pool; a generation-to-generation change in the frequencies of alleles in a population.
    - **Gene pool:** <u>all</u> the alleles in <u>all</u> the individuals within one population (the gene pool is the reservoir from which the next generation draws its genes).
    - **Hardy- Weinberg Equilibrium:** Occurs when populations are <u>not</u> undergoing change to their gene pools; therefore, these populations are <u>not</u> presently evolving.
        - At equilibrium, the frequencies of alleles in the population's gene pool are constant over time.

CHAPTER 14, continued.

- Even though populations rarely remain in equilibrium for long, the concept is useful because it provides a "no-change" baseline number that makes it possible to recognize when a gene pool is changing.

- **Several factors that can change a population's gene pool:**
  - **GENETIC DRIFT** = change in the gene pool of a population due to chance.
    - **Bottleneck effect**: disasters (earthquakes, etc.) can drastically decrease the size of a population which therefore decreases the size of the gene pool.
      - This can alter which alleles are represented most frequently among the survivors.
      - Some alleles may even be eliminated from the gene pool.
      - The bottleneck effect results in a decrease in genetic variation.
    - **Founder effect:** when a few individuals leave a large population and colonize an isolated area
      - The smaller the new colony, the less its genes will resemble the gene pool of the original population.
      - Change in the gene pool here is determined by the genetic makeup of the colony founders
  - **GENE FLOW:** exchange of genes with another population (interbreeding)
  - **MUTATION:** change in an organism's DNA
    - *A mutation is the original source of the genetic variation that is the raw material for natural selection!*
  - **NATURAL SELECTION** – see page 5 of this study guide.
  - **FITNESS –** contribution that an individual makes to the gene pool of the next generation compared to the contributions of other individuals in that population.

- **Natural Selection and Sickle Cell Anemia:**
  - Why are sickle cell anemia and sickle trait so common in African countries?
  - **Sickle Cell Anemia: caused by abnormal hemoglobin.**
    - AA – normal hemoglobin, normal rbcs ("rbc" = red blood cell)
    - AA' – have both normal rbc and "sickle shaped" rbc
      - These individuals have sickle trait.
    - A'A' – all rbcs are sickle shaped and the individuals have full-blown sickle cell anemia
      - Individuals who are A'A' (with all sickle cells) have severe anemia.
        - Basically, the odd shape of these rbcs prevents them from flowing easily through capillaries. Instead, these sickle cells clump together and clog capillaries.
          - Sickle cell anemia affects mostly Africans and African-Americans.
          - In Africa, individuals who carry the A' allele (either heterozygously or homozygously) do have an unusual survival advantage.
          - Malaria is very common in African nations. African individuals who carried the A' allele (sickle trait) were able to resist malarial infection. Thus, those individuals with sickle trait or sickle cell anemia had a favorable adaptation against malaria and survived. Basically, the unusual shape of the "sickled" red blood cells prevented malarial infection.