Chapter 1-DNA

- ***DNA***, the blueprint of all of life, is made up of ***deoxyribose***, a five-sugar molecule, a ***phosphate group***, hence the ACID part of the name, and nucleotide bases
    - Together the sugar, phosphate group, and bases come together to make an individual ***Nucleotide***, the repeated monomers of a nucleic acid, four types…
        1. ***Adenine***, a purine, is a double-ringed nitrogenous base
        2. ***Guanine***, a purine, is a double-ringed nitrogenous base
        3. ***Cytosine***, a pyrimidine, is a single-ringed nitrogenous base
        4. ***Thymine***, a pyrimidine, is a single-ringed nitrogenous base
        5. ***Uracil***, a pyrimidine, is a single-ringed nitrogenous base
    - An individual strand of a nucleic acid is riddled with many different nucleotides and there is no cap limit on how many can make up a single strand
        - The nucleotides can link up in a long chain to form a SINGLE strand of DNA and are linked together through ***phosphodiester bonds***
        - The phosphodiester bond is created through the combination of the phosphate group of one nucleotide and the sugar of another nucleotide - thus each individual strand is called the sugar-phosphate backbone of DNA/RNA
    - However, TWO strands make up a DNA molecule — the two strands are wrapped around each other to form a ***double helix***, a twisted ladder shape
        - To bond the two strands together, a hydrogen bond is formed between the two strands - meaning the strands are WEAKLY connected to one another
        - It is important to note that guanine pairs with cytosine and adenine pairs with thymine (DNA) and uracil (RNA) - this is called ***base pairing***
        - The two strands are said to be ***complementary***, meaning if one strand is A—T—C then the other strand is T—A—G
    - The two strands run in different directions, meaning they are ***antiparallel*** to each other, with one side of a strand being called ***5'*** and the other ***3'***

DNA	RNA
Double-Stranded	Single-Stranded
Thymine	Uracil
Deoxyribose	Ribose
Stores and Transfers Genetic Information	Carry out Instruction Given out Encoded in DNA
Found Mostly in Nucleus - but also in mitochondria and chloroplasts	RNA is formed in the nucleolus and is then transferred into the cytoplasm to do its "job"
Fairly Stable	More Reactive
Self-Replicable	Synthesized by Transcription

Chapter 2-RNA

- ***RNA***, the "construction workers" of life, is made up of ***ribose***, a five-sugar molecule, a ***phosphate group***, hence the ACID part of the name, and nucleotide bases (excluding thymine)
    - ***Messenger RNA (mRNA)*** is a temporary RNA version of a DNA recipe that is built through transcription and used to send genetic information to a ribosome so that translation can occur to get the primary structure of a protein
    - ***Ribosomal RNA (rRNA)***, an RNA molecule that is produced in the nucleolus and makes up part of the ribosomes, is responsible for assisting the ribosome during translation by catalyzing the reaction and ensuring the mRNA is properly aligned with the ribosome
    - ***Transfer RNA (tRNA)*** is an RNA molecule that shuttles amino acids to the ribosome so that the translation can take place, it does its job by reading the mRNA and "picking out" the appropriate amino acid to be paired with that section of the code
    - ***Interfering RNA (RNAi)***, small "snippets" of RNA that are made naturally or artificially, are used to bind to specific sequences of RNA and mark them for destruction - two types ***siRNA*** and ***miRNA***

Chapter 3-History

- The history of the discovery of DNA is not written by a single person, rather it was written by many different minds who, in all, helped us finally understand the fundamentals of DNA
    - In 1869, ***Friederich Miescher*** would famously be the first person to witness DNA when he discovered a microscopic substance in pus he took off a bandage, he called it "***nuclein***" since he realized it was from the nucleus of the cell and then ***Albrecht Kossel*** would perform "surgery" on the substance and separate the non-protein portion from the protein portion - in doing so, he discovered the nucleobases of DNA
    - ***Phoebus Levene*** identified the base, sugar, and phosphate portions of RNA and then theorized the backbone was "glued" together by the phosphate groups
    - After years of believing that RNA (then called yeast nucleic acid) was found exclusively in plants and DNA (then called thymine nucleic acid) was found exclusively in animals - ***Jean Brachet*** found RNA and DNA in a sea urchin proving they are both in animals
    - In 1943, ***Oswald Avery*** and two other coworkers underwent an experiment that proved that DNA, not proteins, are responsible for hereditary information being passed down to the next generation and ***Alfred Hershey*** and ***Martha Chase*** would prove Avery correct
    - ***Erwin Chargaff*** would develop what is now called "***Chargaff's Rule***" which stated that the number of guanine is always equal to the number of cytosine and the number of adenine is always equal to the number of thymine in DNA
    - ***Raymond Gosling***, a graduate student who was supervised by ***Rosalind Franklin***, took an X-Ray Dissfraction image of DNA, and the image was then given by ***Maurice Wilkens*** to ***Watson Crick*** and ***James Watson*** who would make a 3D model of DNA - thus discovering that DNA was an antiparallel structure in the form of a "twisted ladder"
    - Watson, Crick, and Wilkens would win a Nobel prize for "discovering DNA" when in fact it was Franklin and Gosling (Franklin died and Gosling was "too young") however, to his credit, Crick would not stop there and would theorize the ***Central Dogma of DNA*** and later discovered the "codons" (thus becoming the father of molecular biology)

Chapter 4-Genome

- The "order" of the nucleotides in a DNA strand will determine the genetic code for an organism, in other words, it's a special alphabet in our cells that "spell out" our recipes (i.e. genes)
    - The ***Human Genome Project*** discovered 20,000 to 25,000 different genes in our ***genome***, the total number of genes in a cell/organism
    - In eukaryotic cells, DNA is wrapped around proteins called ***histones***, and then these histones are bunched into groups called ***nucleosomes***
    - To keep the DNA wrapped around the histone and still be able to allow for transcription to occur, some of the genes become fully condensed into coils, the ***heterochromatin*** (genetically inactive), while the other half is loosely wrapped around the histone, the ***euchromatin*** (genetically active) or the half that will undergo transcription

Chapter 5-Replication

- For DNA to be passed on to the next generation it must first go through the process of DNA ***Replication***, the copying of a segment of DNA, and the process is actually quite simple…
    1. First, since the DNA molecule's natural form is a "twisted ladder," it must first be "untwined" by breaking the hydrogen bonds - this is done by ***helicase***, an enzyme, and this creates a "y-shaped fork" thus called a ***replication fork***
    2. To hold the DNA "in place" and stop it from "re-twisting" itself, ***topoisomerases***, an enzyme, cut and rejoins the helix to prevent it from tangling thus relaxing the molecule in place and allowing for replication to occur
    3. ***DNA Polymerase*** then, starting at the ***origin of replication*** (the first nucleotide involved), adds the corresponding nucleotide to the separated strands - however, it must be initiated by an enzyme called ***primase*** which adds a short strand of RNA nucleotides called a ***primer*** - the primer is then degraded by enzymes and replaced with DNA
    4. Remember that one of the strands, called the ***leading strand***, is added to with nucleotides continuously (meaning DNA polymerase steadily adds SINGLE nucleotides to the strand) and the other strand, called the ***lagging strand***, is added to discontinuously
        a. Meaning DNA polymerase adds GROUPS of nucleotides, called ***Okazaki Fragments***, to the lagging strand — the reason is that the lagging strand is placed in the direction of 3' to 5' instead of the usual 5' to 3' (the direction of the leading strand) and polymerase prefers the 5' to 3' direction
        b. So the polymerase on the leading strand can move fast, but the polymerase on the lagging strand is slow, so to make it quicker the polymerase prepares the nucleotides prior to adding them (thus making groupings of nucleotides
    5. ***Ligase*** then "re-glues" the DNA back together to reform the "twisted ladder" formation and the hydrogen bonds eventually reform between the nucleotides and two IDENTICAL DNA molecules are produced (remember this occurs during the S phase)
- The DNA molecule is said to be semiconservative since it conserves half of the original molecule in each of the two new ones
    - However, it's important to note that the last few nucleotides cannot be replicated since the overall process would be ruined, so this portion, called telomeres, is lost and the chromosome gets shorter and shorter over time

Chapter 6-Central Dogma

- DNA is only the "cookbook" of our everyday lives, RNA is the "chef" and proteins is the final product or the "meal"
    - DNA is transcribed into mRNA, which is then translated into a chain of amino acids to produce proteins in the end
    - Transcription occurs in the nucleus and the translation occurs in the cytoplasm with the help of ribosomes in eukaryotic cells and in prokaryotic cells, the process always occurs only in the cytoplasm

Lesson 1-Transcription

- ***Transcription***, the process by which an RNA molecule copies the DNA and produces a corresponding DNA molecule, occurs in the nucleus of the cell
    - Remember transcription does not copy the entire "cookbook" but rather it copies a single recipe within the book (i.e. gene)
    - However, in prokaryotes a process called ***polycistronic transcript*** can take place - meaning one recipe can be copied to produce several proteins, while eukaryotes undergo ***monocistronic transcript***, meaning one recipe can be copied to produce a single protein
- The process is quite similar to replication, the only difference is that the ending product of the process is an RNA molecule
    1. The DNA molecule is "untwisted" and "unzipped" by the helicase separating the ***coding strand***, the strand not being copied into an mRNA, from the ***template strand***, the strand being copied into an mRNA (meaning it is complementary to the template strand and identical to the coding strand)
    2. Transcription always occurs in the 5' to 3' direction (i.e. making the template strand the leading strand) and the process always begins at the ***promoter***, the "docking site" for the "cargo ship (i.e. the mRNA strand)
        a. The promoter is the docking site, meaning that it is not copied in the process, rather it just tells the polymerase where to begin
        b. The true start of the code is called the ***start site***, you can think of it as the first piece of cargo being added to the cargo ship
    3. Starting at the start site, ***RNA Polymerase*** will add the corresponding RNA nucleotides to the template strand and will add until it reaches the ***terminator***, the "master" of the "docking site" who tells the "cargo ship" that the cargo process is over
        a. You can think of the polymerase as the "captain of the ship," it takes the nucleotides at the docking station and adds them to its ship
        b. The "captain" will rename the cargo into his preferred language (i.e. instead of using DNA nucleotides, he will use RNA nucleotides
    4. The ligase "retwists" the DNA strand and the mRNA is sent off to translation in prokaryotes and ready for processing in eukaryotes

Lesson 2-RNA Processing

- In eukaryotes, not all of the transcribed nucleotides will "make it" to the translation stage, as those that are non-coding regions will be removed in the process of ***splicing***
    - In the ***heterogeneous nuclear RNA (hnRNA)***, the introns, the non-coding regions, will be separated from the exons, the coding regions, to form the mRNA
    - Spliceosome, the enzyme involved in splicing, will remove the introns from the hnRNA and leave only the exons of the molecule
    - The hnRNA thus becomes mRNA and, once the ***poly(A) tail*** is added to the 3' end and the ***5' GTP cap*** is added to the 5' end, the mRNA is ready for translation in the cytoplasm

Lesson 3-Translation

- ***Translation***, the process by which mRNA is "translated" into an amino acid chain, is the last major "gear" of the Central Dogma that Crick famously spoke of
    - After processing, the now mature mRNA will make its way to a ribosome in the cytoplasm or one that is attached to the *RER*, the ***ribosome*** is just there to hold everything in place as translation occurs
        - Ribosomes contain three binding sites - ***A site***, ***P site,*** and ***E site*** - and the mRNA will be sent through each site in the order of A to P to E - as the mRNA is being read, a corresponding polypeptide is being built
    - Remember that an amino acid corresponds to a particular ***codon***, a sequence of three nucleotides
        - This is how DNA is a blueprint for life because without it the codons will not exist and the proteins that carry out all of life's processes will never be built
        - It is important to note that in ALL organisms, the ***start codon***, the initiation of protein synthesis, is ***A—U—G*** (which codes for ***methionine***) and there are three different types of ***stop codon***, the termination of protein synthesis
    - A tRNA, which is in the shape of a three-dimensional four-leaf-clover, will then be sent out to find an amino acid that corresponds with its anticodon; it will attach and then "shuttle" the amino acid to the ribosome (this all requires ATP)
        - One end of it is called the ***anticodon***, which holds its own set of nucleotides, if a codon is located that is complementary to this anticodon, then this specific tRNA will make its way to the codon and attach to the codon
        - On the other side of the tRNA is an amino acid, so when the anticodon attaches to the codon it is indirectly bonding an amino acid to the mRNA
        - However, its important to note that evolution has allowed the third nucleotide in the anticodon to experience "***wobble pairing***" which is like a second layer of defense against a possible genetic defect - ex:/ guanine pairing with adenine
    - The process of translation is actually quite simple…
        1. ***Initiation*** is when A—U—G is read on the mRNA, and a tRNA with the corresponding anticodon (U—A—C) is sent out to look for methionine (Met)
        2. ***Elongation*** is when the "middle" amino acids are added to methionine and, in all, it builds a polypeptide chain or rather the primary structure of the protein
        3. ***Termination*** is when translation is ended by the reading of a stop codon

Chapter 4-Gene Regulation

- Most of what we know about ***gene regulation***, the regulation of genes so that only certain genes are expressed at a certain moment, comes from our studies on ***E. Coli*** since they are cheap, abundant, and naturally exist in humans (i.e. in our large intestines)

Lesson 1-Pre-Transcriptional Regulation

- Gene regulation mostly occurs pre-transcriptional - which is called ***pre-transcriptional regulation***
    - For transcription to occur, DNA must be unwound and RNA polymerase must bind at the promoter, however, molecules called ***transcription factors*** are used to either encourage or inhibit this process from happening - these factors usually do this by making it more difficult for the polymerase to reach or bind to the start site
    - Sometimes ***epigenetic changes***, changes to the packaging of DNA, usually occur through the modification to a histone by making the DNA wrap tighter - making that section of the DNA "untouchable," or making it looser - making that section easier to reach
- An ***operon***, "clusters" of genes that are under the control of a single promoter, is most famously exemplified through the ***lac operon***, which controls the expression of the enzymes that break down lactose (they have four major parts…)
    - ***Regulatory Gene*** is the operons that code for the proteins that will become the "***repressors***," which are capable of attaching to the operator and blocking transcription - to turn off the repressor, an ***inducer*** must bind to it and cause it to "fall off" the operator
        - To control transcription, an operon can control either the ***promoter gene***, the region where the RNA polymerase binds to begin transcription, or the ***operator***, the region that controls whether transcription will occur
        - ex:/ in the lac operon, to turn off transcription, a repressor is produced by the regulatory gene and it is then attached to the operator - to turn it off an inducer, lactose in this example, will bind to the repressor and make it fall off the operator
    - ***Structural Genes***, which code enzymes needed in a chemical reaction, will be transcribed at the same time to produce a particular enzyme - ex:/ the lac operon codes for three enzymes in the process of digesting lactose

Lesson 2-Post-Transcriptional Regulation

- Gene regulation can also occur post-transcriptionally or even post-translational…
    - ***Post-Transcriptional Regulation*** occurs when the cell realized that an RNA it just built is unneeded and so they demand for it to be destroyed
        - To stop the RNA from entering the translation stage, RNAi binds to the RNA (by having the complementary nucleotides) making a DOUBLE-stranded RNA
        - Remember that RNA prefers to be single-stranded, so when RNAi turns the RNA into a double-strand, the cell will give out orders to have the RNA be destroyed
    - ***Post-Translational Regulation*** is when the cell realizes the protein it made is not yet required and so they undergo mechanisms to keep the enzyme "quiet"
        - They can bind other proteins, use phosphorylation, pH changes, cleavages…
        - This usually occurs with enzymes

Lesson 3-Embryonic Development

- After conception, the two haploid cells (sperm and ovum) combine to form a diploid called a ***zygote***, however, to produce an organism, this zygote will have to continuously multiply through a process called ***morphogenesis***, a process in which a cell changes shape and organization many times by a series of stages and through many cellular divisions
    - Fertilization triggers the zygote to go through a series of cell divisions, as this occurs, the embryo will develop more and more cells and each of these cells will become specialized
    - All cells start off at a "blank slate" in which a cell must then choose a "task" it wishes to undergo for the rest of the organism's life
    - ex:/ one cell may choose to join the nervous system and become a neuron to help out with the eye for example
- For this to occur, certain genes in a cell must be "turned off" and others must make stronger - to do this, cells called ***organizers*** will release signals that let each cell know what "part" to play
    - Once the organizer tells a cell what part to play, the cell cannot leave that part - in other words, a cell does not typically differentiate itself (however, the phenomenon can occur)
    - ex:/ an organizer may tell a cell to become a muscle cell, to do this, certain genes such as their durability will be turned off and the gene for flexibility will be increased - however, a phenomenon can switch and increase durability and decrease flexibility to become a bone - however, this is quite uncommon and frankly rare to occur
- The genes that turn certain cells in the early embryo into their "future jobs" are called ***homeotic genes*** and a subset of these genes are called ***hox genes***
    - These genes must work coordinately and must be modified at exactly the right time, if not, an embryo may develop a brain in the wrong region or a foot where a hand should be
    - Usually, this leads to the ending of development, and the embryo will die soon after
- Additionally, some cells were added to the organism with no actual role to play, these cells are usually put through apoptosis when development is almost complete - for example, we develop with the skin between our fingers, but these cells are killed at the end of development

Chapter 5-Mutations

- ***Mutation***, an error in the genetic code, can occur when DNA is damaged and cannot be repaired or if the damage is repaired incorrectly
    - Damage can be caused by chemicals in a thorough ***cross-linking***, when "inappropriate" chemical bonds are formed between the molecules of DNA and external chemicals - however, it can also be caused by radiation leading to breaks in the DNAs strand
    - However, a mutation is only an issue if it is expressed and causes a change in the gene product (RNA or protein) - the product of mutation can be negative/positive/neutral
- A mutation can also occur when DNA polymerase or RNA polymerase makes a mistake…
    - DNA polymerase has proofreading capabilities since DNA lasts forever through its many duplications and that is passed down from cell to cell and generation to generation - in other words, mistakes in DNA can last forever and so mistakes are more deadly
    - On the other hand, RNA polymerase does not have proofreading capability since RNA is a <u>temporary</u> molecule and an issue will not cause long-term issues

Lesson 1-Base Substitution

- There are two main types of mutations, one being a ***base substitution***, mutations that occur when a nucleotide is substituted for another base - three main types…
    - ***Nonsense Mutation*** is when the original codon becomes a stop codon leading to a "premature" termination of protein synthesis
    - ***Missense Mutation*** is when the original codon becomes a different codon leading to the wrong amino acid being added to the polypeptide chain
    - ***Silent Mutation*** is when a codon is replaced with itself leading to the correct amino acid being added - meaning this is a neutral mutation

Lesson 2-Gene Rearrangement

- Mutation can also occur through a ***gene rearrangement*** when a DNA sequence is deleted, duplicated, inversion, or translocated
    - ***Translocation*** - when two different chromosomes, or two different regions of one chromosome, break and rejoin in a way that causes a gene to be lost/repeated/interrupted
    - ***Insertion***, the incorrect addition of nucleotide(s) to a DNA sequence, and ***deletion***, the incorrect removal of nucleotide(s) from a DNA sequence, can lead to devastating consequences such as ***frameshift mutation***: a change in the sequence of codons used by the ribosome leading to an incorrect protein being produced
    - ***Inversion***, when changes occur in the orientation of chromosomal regions, can lead to harmful effects if the affected region is an important regulatory sequence
    - ***Duplication***, the addition of an extra copy of genes, is usually caused by an unequal cross-over during meiosis or chromosomal rearrangement - this may cause different traits to be expressed since one gene can maintain the original function while the other evolves
    - ***Transposons***, gene segments that can cut/paste themselves throughout the genome, which can interrupt a gene and cause errors in gene expression

Chapter 6-Pathogens

Lesson 1-Bacteria

- ***Bacteria***, a common pathogen, are prokaryotes that come in many shapes and sizes - they can infect many things and can sometimes cause harm, but not always
    - It is important to note that while bacteria do in fact divide through fission - meaning they have a low genetic diversity - they are able to perform conjugation with other bacteria and swap some of their DNA to support each other in fighting threats to their safety such as the antibiotics we use (meaning conjugation leads to increased antibiotic resistance)
    - ex:/ We have a mutualistic relationship with certain bacteria that live within our guts - while we provide them "shelter," they provide us help with our digestion

Lesson 2-Viruses

- A ***virus***, a nonliving agent that is capable of infecting cells, surprisingly needs to infect in order for them "survive" making them a nonliving "agent"
    - A virus has only two parts… a protein capsid and genetic material made of DNA or RNA these agents are very specific to their ***hosts***, the cells they infect
    - Their main goal is to replicate/spread itself, and so to do this, a virus will need to make more capsid and increase its genome - eventually, it will assemble into a larger particle
    - The virus will hold genes that regulate the building of capsid and any other functions that the host cannot provide - if two viruses infect the host, then the genetic material "mix" and the "offspring" will be a mix of the two viruses
- Unlike bacteria cells, animals do not have a protective layer so the virus does not have to break out of the cell when it has "served its purpose" rather the cell just exits the cell through exocytosis
    - When the virus does this, it will leave in a vesicle and will now be able to navigate the cellular world with a free protective layer of phospholipids
    - These types of viruses are called ***enveloped viruses***
- ***Retroviruses***, such as HIV, are RNA viruses that use enzymes called reverse transcriptase to convert their RNA genomes into DNA so that they can be inserted into a host genome
    - RNA viruses have a high rate of mutations since there is a lack of proofreading mechanisms when they replicate their genomes
    - They are difficult to treat since this will lead to genetic diversity in the virus, meaning the doctors will not have a single drug that will wipe all of the viruses at once
    - They evolve quickly, so new drugs have to be constantly made to combat these viruses
- Additionally, if two viruses infect the same cell, their genetic material will mix and a genetic variance will be created

Lesson 3-Bacteriophage

- The most commonly studied virus is a ***bacteriophage***, a virus that infects bacteria, undergoes either a lytic cycle or a lysogenic cycle in order to replicate itself
    - In the ***lytic cycle***, the virus will immediately start using the machinery of the cell to replicate its own genetic material and create more capsid - once complete, the virus will lyse the cell and a bunch of newly formed viruses will spread into the nearby regions
    - In the ***lysogenic cycle***, the virus will attach itself to a host and become dormant until a trigger occurs that makes the virus switch into a lytic cycle - this can be more deadly, as the virus can stay dormant for a very long time, meaning the virus will be duplicated through the many cellular divisions and when the lytic cycle begins, the virus will already be spread all over the cellular environment
- Sometimes a lysogenic cycle can lead to ***transduction***, the process by which DNA is transferred between cells through the use of a lysogenic virus
    - This can actually be beneficial to bacteria, for example, let's say a virus detaches itself from a host and accidentally takes a chunk of the host's DNA with it
    - That means that the next host can have a chunk of another cell's DNA, so what if the chunk of DNA was a gene that allowed for antibiotic resistance?

Chapter 7-Biotechnology

- ***Biotechnology***, the use of living organisms/cells to create new technologies, can be used in anything from agriculture to medicine to even industrial production
    - It has the potential to bring many benefits to society, such as new medical treatments, more efficient and sustainable agriculture, and new industrial processes
    - However, it also raises important ethical, legal, and social issues that need to be carefully considered…
- ***Recombinant DNA***, the creation of artificial DNA by combining genetic material from different sources, is done by splicing DNA molecules in organisms by using enzymes
    - The artificial DNA is then inserted into host cells in order to create a "desired" trait or to study the function of specific genes
    - This can be used to create new organisms, create new medical treatments, and improve our agriculture through newly made products
- ***Polymerase Chain Reaction (PCR)***, a laboratory technique used to make many copies of a DNA sequence, is used to make a large quantity of a DNA from a small quantity of DNA
    - ***Amplification***, the process by which many copies of genes are created, is the "backbone" of what a PCR is
    - The PCR uses a machine called a ***thermocycler*** to mimic the process of replication, thereby creating many copies of the gene in question
- ***Transformation***, the process by which bacteria are given foreign DNA, can be used to produce insulin for humans who cannot produce it naturally
    - This allows us to mass produce medicines that will produce proteins that a person is unable to produce on their own
    - The bacteria is added to a biological system and it then forms a mutualistic relationship with the human
    - ***Transfection*** is the process by which eukaryotic cells are given foreign DNA - however, this technique is not as widely used as transformation
- ***Gel Electrophoresis*** is a laboratory technique that is used to separate DNA, RNA, and proteins based on their size, weight, and charge
    - Since DNA and RNA are NEGATIVELY charged, they will navigate toward the positive pole, and to separate them further, the gel is specifically built so that the smaller fragments can move faster than the larger fragments
    - ex:/ the fingerprints of each person is different since some people have many small fragments, while others will have a few large fragments - the slight differences in everyone's DNA are called ***polymorphism***
    - ***Restriction Fragment Length Polymorphism (RELPs)***, the fragments, are used in forensics by comparing the RELPs left at a crime scene to the RELPs of a suspect
- ***DNA Sequencing*** is a technique that allows scientists to understand the order of nucleotides in a DNA molecule so that they can design their own DNA and study a specific gene they had in mind