Life University Class, Oct. 24, 2007
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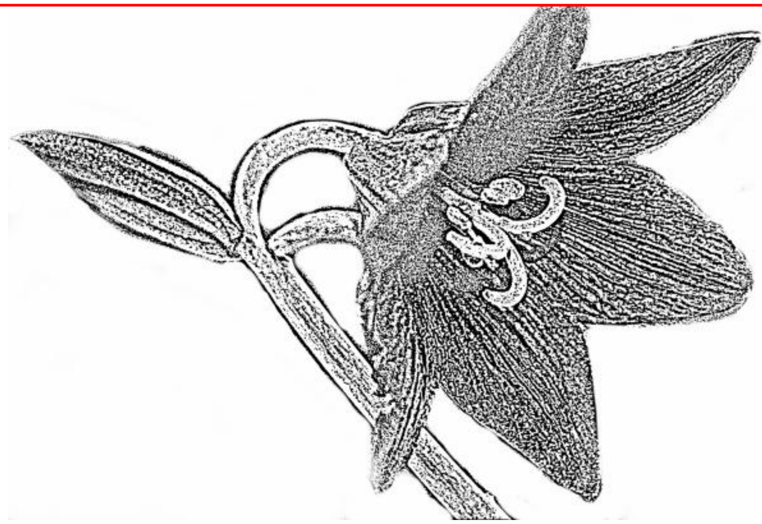
Before class, please read the following chapter from The Exchange of Truth. We will cover this chapter in greater detail during class, with emphasis on understanding DNA replication and using Punnett Squares.



3 MOLECULES AND MENDEL

Fundamentals of DNA and Genetics

In chapters 1 and 2 you learned some reasoning skills foundational to understanding science and the scientific method. For the next two chapters, apply your new skills to the study of life, or biology, for that is what *biology* means, "the study of life." In Chapter 3 you will learn about DNA and genetics, and in Chapter 4 you will study gene mutations and mathematical probability. Having a good understanding of these biological and mathematical basics will allow you to discern truth from fiction in biology and beyond.

As you read the next two chapters, you can avoid much confusion by memorizing the definitions listed at the beginning of the sections on DNA and genetics. First though, let's begin by reading a parable of Jesus. Reflect on this parable as you read the chapter, and we will discuss its relevance to our study at the end of the chapter. Luke 8: 4-15 says:

> *And when a great multitude had gathered, and they had come to Him from every city, He spoke by a parable: "A sower went out to sow his seed. And as he sowed, some fell by the wayside; and it was trampled down, and the birds of the air devoured it. Some fell on rock; and as soon as it sprang up, it withered away because it lacked moisture. And some fell among thorns, and the thorns sprang up with it and choked it. But others fell on good ground, sprang up, and yielded a crop a hundredfold." When he had said these things He cried, "He who has ears to hear, let him hear!" Then His disciples asked Him, saying, "What does this parable mean?" And he said, "To you it has been given to know the mysteries of the kingdom of God, but to the rest it is given in parables, that seeing they may not see, and hearing they may not understand (Isaiah 6:9).*
>
> *Now the parable is this: The seed is the word of God. Those by the wayside are the ones who hear; then the devil comes and takes away the word out of their hearts, lest they should believe and be saved. But the ones on the rock are those who, when they hear, receive the word with joy; and these have no root, who believe for a while and in time of temptation fall away. Now the ones that fell among thorns are those who, when they have heard, go out and are choked with cares, riches, and pleasures of life, and bring no fruit to maturity. But the ones that fell on the good ground are those who, having heard the word with a noble and good heart, keep it and bear fruit with patience.*

* *Unless noted otherwise, all discussions involving cells pertain to human cells.*

DNA

Terms to memorize

a. **DNA**—Deoxyribonucleic acid. Large molecule shaped like a twisted ladder. Each "step" of the ladder contains a pair of nucleotides, joined at the middle by a hydrogen bond. One side of the ladder, called a DNA strand, contains instructions to make enzymes and other proteins needed to build and maintain cells.

b. **Nucleotide base—**consists of a phosphate molecule, a deoxyribose sugar, and an amino acid (either adenine, thymine, guanine, or cytosine).

c. **Base pair—**A pair of nucleotide bases, joined at the middle by a hydrogen bond. Makes a "step" on the DNA ladder. Adenine always pairs with thymine, and cytosine always pairs with guanine. The DNA in just one normal human cell contains 3.2 billion base pairs.

d. **RNA**—Ribonucleic acid. Similar to DNA (ribose sugar instead), and important in protein manufacture.

e. **Amino acids**—molecules that are the building blocks of proteins. Made primarily from nitrogen, carbon, oxygen, and hydrogen. There are 20 naturally occurring amino acids.

f. **Proteins**—chains of amino acids. Examples of proteins include enzymes, hair, the lens in your eye, and countless other things.

g. **Enzymes—**A protein that acts as a catalyst, which means it participates in chemical reactions and speeds them up, but it is not destroyed in the process. Some enzymes help manufacture new chemicals, while other enzymes help break down chemicals, as in digestion.

h. **Codon—**A set of three nucleotide bases on a strand of DNA that act as "code words." Since there are 4 bases in DNA and 3 "letters" in each code word, a total of $4^3 = 64$ code words exist in the DNA language. Most of the code words refer to a certain amino acid, but some signal the beginning or ending of protein manufacture.

What does DNA do?

At the moment of your conception, an egg cell, containing 23 of your mom's chromosomes, and a sperm cell containing 23 of your dad's chromosomes united and began duplicating. Incredibly, now your body contains billions of cells, all duplicated from that original cell, and inside the nucleus of every one exists a copy of the original 23 chromosome pairs.

Chromosomes are a single strand of DNA (Fig. 3.1). Perhaps you have seen a photo or picture of chromosomes where they looked like a little "x," but this shape only occurs for a short duration during cell division. When a cell is not dividing, the DNA is stretched out into long strands. When it is time for the cell to divide, one of the first actions is the DNA replicates. The DNA "unzips," and free nucleotides in the surrounding fluids come in and attach on the unzipped portion. Since adenine only pairs with thymine and cytosine only pairs with guanine, two identical copies of DNA form, one for each new cell.

Genes contain the instructions for making you, and since half of these instructions came from mom and half from dad, you look a little bit like mom and a little bit like dad, but not exactly like either one.

Between periods of cell division, or *mitosis*, the DNA actively participates in the manufacture of proteins (Fig. 3.2). *Every* protein is synthesized in accordance with instructions in DNA[1]. During protein manufacture, only portions of DNA, called *genes,* unzip. The sequence of nucleotide bases on some genes varies little from person to person. However, enough different genetic information exists so no two people (except identical twins) have the same DNA. Genes contain the instructions for making you, and since half of these instructions came from mom and half from dad, you look a little bit like mom and a little bit like dad, but not exactly like either one.

Protein manufacture, or synthesis, requires two steps, *transcription* and *translation*. Transcription begins at a *promoter*, a DNA base sequence signaling the start of a gene. An enzyme assists in unzipping and combining nucleotides to form a strand of messenger RNA (mRNA). The nucleotide pairing is the same for RNA as for DNA, except when adenine is the base on DNA, uracil (not thymine) pairs with it on the RNA side.

After reaching a certain point on the gene, the mRNA molecule releases, carrying the transcribed message over to a cell organelle called a *ribosome,* and translation begins. At the ribosome, mRNA combines with transfer RNA (tRNA). Each tRNA molecule has an amino acid attached to a triplet of nucleotides known as an *anticodon*. The anticodons find their matching codon on the mRNA, and as they link up, the new protein forms. The amino acids link with peptide bonds, and when translation finishes, the protein releases into the cell.

Amazing facts about DNA

Scientists define *genomes* as the DNA contained in a haploid (half) number of chromosomes for a given species. The genome of a human contains about 30,000 genes made up of 3.2 billion base pairs! Let's look at some numerical facts about just one chromosome, chromosome number 22[2].

- 48 million base pairs
- 700 genes
- Smallest gene is 1000 base pairs long
- Largest gene is 583,000 base pairs long
- Average gene is 19,000 base pairs

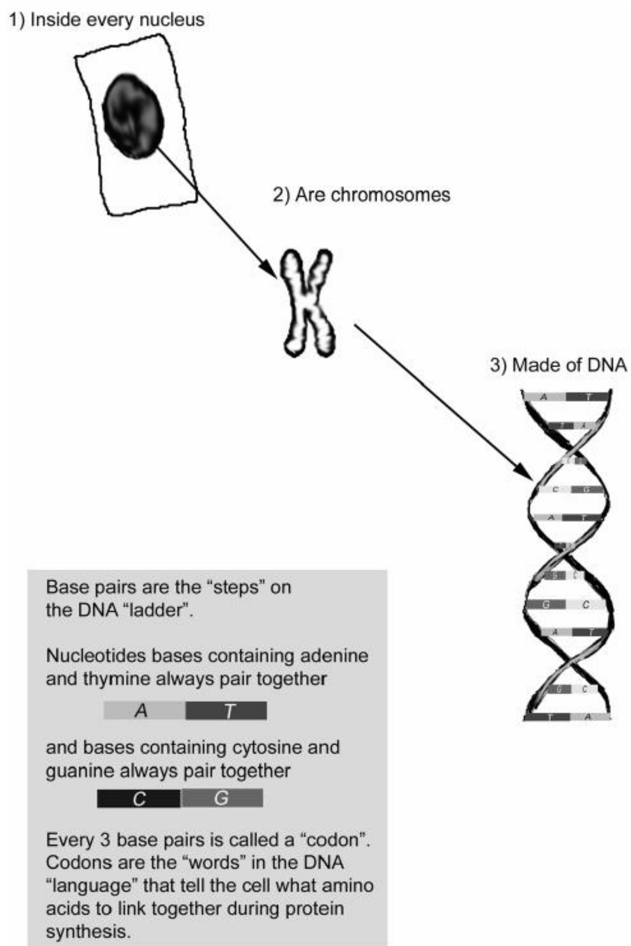


Figure 3.1 Location and structure of DNA.

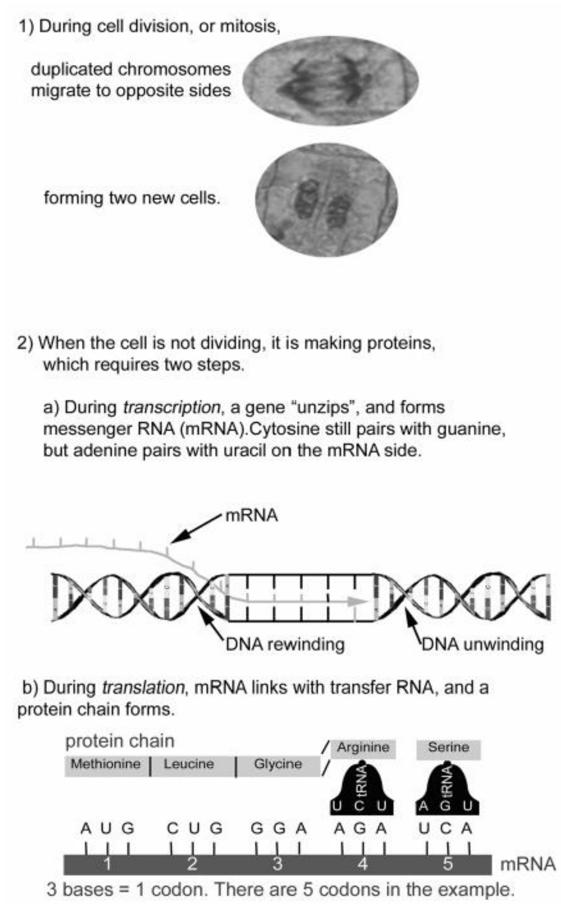


Figure 3.2 Cell processes during and after cell division

Since every three base pairs is a "code word" for a specific amino acid, chromosome 22 can make proteins ranging from about 333 to almost 200,000 amino acids long! Keep in mind we are just talking about one chromosome. Even a microscopic bacterium like E. coli has 4,279 genes in its genome. We will discuss the significance of these numerical facts when we cover mutations and probability in Chapter 4.

Why concern ourselves with DNA?

Every living organism contains the wonderfully complex DNA molecule, yet has so many different arrangements that each species has unique sequences of DNA base pairs. DNA is a fantastic example of unity amidst diversity. Starr and Taggart believe "*This molecular constancy and variation among species is the foundation for the unity and diversity of life*."[3]

DNA does nothing without help from other chemicals, none of which will ever make or do anything without a First cause organizing them to produce and reproduce life.

Chemically, this is correct, but Scripturally, it is not. DNA is a "second cause." DNA is super-special and super-important, but it does not work by itself. DNA requires the correct environment containing the proper chemicals to unwind it and start the protein synthesis process. DNA does nothing without help from other chemicals, none of which will ever make or do anything without a First cause organizing them to produce and reproduce life.

Genetics

More terms to memorize!

a. **Genetics:** Study of heredity.

b. **Heredity:** The total genetic endowment obtained from the parents.

c. **Gene:** A segment of DNA containing the information for a heritable trait, passed on from parent to offspring.

d. **Allele:** Multiple forms of the same gene. Examples include alleles for hair color, eye color, and skin color.

e. **Chromosome:** A DNA-containing body. Found in the nucleus of human cells.

f. **Locus:** The exact location of a gene on a chromosome

g. **Homologous pair of chromosomes:** Two chromosomes having the same alleles in the same order. Human cells have 23 homologous pairs of chromosomes.

h. **Diploid:** The condition of having two pairs of chromosomes.

i. **Haploid:** The condition of having only one member of each homologous pair of chromosomes. A characteristic of egg and sperm cells (gametes).

j. **Genotype:** A single gene pair.

k. **Phenotype:** The physical trait expressed by a gene pair, or genotype.

l. **Homozygous:** Having the same alleles at the same locus on homologous chromosomes; a "purebred."

m. **Heterozygous:** Having different alleles at the same locus on homologous chromosomes; a "hybrid."

Gregor Mendel (1822-1884)

Most scientists consider Gregor Mendel, a contemporary of Darwin, the "father of genetics." Although we know little of his personal beliefs, we do know he was a Franciscan monk, and we know he rejected Darwin's ideas about evolution. His pea experiments, carefully controlled and mathematically analyzed, provided the basis for our understanding of heredity[4]. Mendel worked with thousands, as opposed to tens or even hundreds of pea plants, because he understood how important mathematical probability was in experimentation.

What is *mathematical probability*? We'll talk about it more in Chapter 4, but for now, here's a simple example. If I flip a coin, the mathematical probability of it landing on heads is 1 in 2, or 50%. If I test this with an experiment and flip a coin 4 times, I may or may not get the coin to land on heads 2 of 4 times. However, the more times I flip the coin, the greater the chances are that I will come up with results closer to the mathematical probability of 50%.

Mendel understood mathematical probability, which is why he studied so many pea plants. For example, in a test with pea seed color, he had 8,023 seeds in his experiment[5]! In any science experiment, the more times the experiment is repeated with similar outcomes, the more believable it is. Mendel hypothesized that plants might inherit two "units" (what we now call genes) of information about a trait, one from each parent. To test his hypothesis, he studied pea plants through two generations.

We can better understand Mendel's genetic tests by drawing a *Punnett Square* (Fig. 3.3). The Punnett Square helps us visualize the transfer of genetic material from parent to offspring. To study pea color, Mendel obtained plants that were homozygous (purebred) for yellow and green peas. He knew crossfertilizing purebred green with purebred yellow plants would result in yellow pea plants, because the allele for yellow pea color dominates over the allele for green pea color. This is called *simple dominance*. Keep in mind not all alleles display simple dominance.

When using a Punnett Square, represent a dominant allele with a capital letter, and a recessive allele with a lowercase letter. For our discussion with peas, we will represent the dominant, yellow allele with a capital Y, and the recessive, green allele with a lowercase y. In a purebred yellow plant, all the cells in the plant have a pair of Y alleles. We say their genotype is YY, pronounced "big Y, big Y." When the plant forms gametes, or sex cells, which only contain one of each allele, the only possibility is for the gametes to have Y alleles. Likewise, a purebred green plant's genotype is yy or "little y, little y," and its gametes only contain recessive y alleles.

Using the Punnett square in Figure 3.3, it is easy to determine the genotype of offspring produced by crossing purebred green and yellow plants:

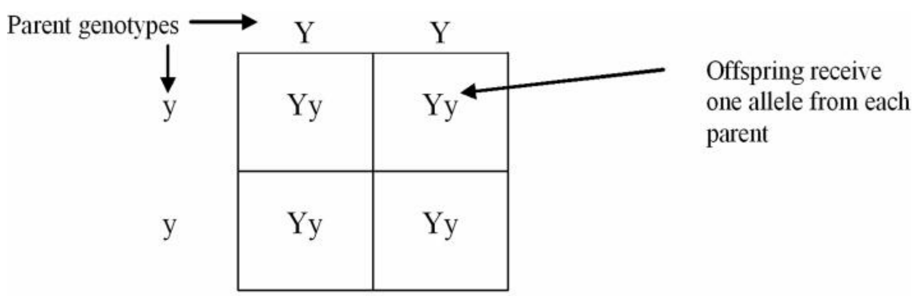


Figure 3.3. Punnett square for crossing of purebred green (yy) with purebred yellow (YY) peas.

The Punnett square gives the mathematical probability of the outcome of a crossing. In the cross shown in Fig. 3.3, there is a 100% probability the offspring will possess a Yy genotype, and therefore all peas would express the yellow phenotype. However, since Mendel couldn't see the genes, and since all the peas were yellow, he had no idea if they were YY or Yy genotypes. Therefore, he crossed the heterozygous Yy plants with each other, and studied this new generation, described in Figure 3.4.

	Y	y
Y	YY	Yy
y	Yy	yy

Figure 3.4. Punnett square for crossing of hybrid (Yy) pea plants.

3 out of 4, or 75% of the plants will have the yellow phenotype. A 50% probability exists for having offspring with a Yy genotype, and 25% probability for either YY or yy genotypes. In Mendel's actual experiment with pea color, he found 6,022 out of 8,023, or 75.06% of the plants were yellow, incredibly close to the predicted percentage.

The results of Mendel's pea experiments serve as the basis for the Theory of Segregation, stated as follows:

> *Diploid cells have pairs of genes, on pairs of homologous chromosomes. The two genes of each pair are segregated during the formation of gametes [reproductive cells], so they end up in different gametes.*[6]

Knowledge of mathematical probability is critical to understanding how traits pass from parents to offspring in sexually reproducing animals, and when experimental observations match up with theory, we gain confidence that what we are observing is really "the way it is."

The scientists of Mendel's day did not understand his experiments, and only later did others appreciate the significance of his work. Now, Mendel's experiments and theories serve as the foundation to any study of genetics.

Asexual reproduction

All the preceding genetics discussions referred to sexually reproducing organisms like birds, bees and bass. We have not discussed asexually reproducing organisms, like bacteria. These organisms only contain a haploid number of chromosomes, and when they divide, they make a copy of their DNA for the new cell. The two resulting cells are clones of each other. However, there are processes, such as *conjugation* in bacteria, where two bacteria exchange sections of DNA. Processes like conjugation ensure "unity amidst diversity" in asexually reproducing organisms. It is so important to look for unity amidst diversity in Creation, because it is an attribute that reflects the triune nature of God. He is the First cause, and DNA and reproduction are the second causes He employs to ensure His creation will always be a reflection of Him, leaving mankind without excuse for knowing about Him (Romans 1:20).

Chapter 3 Summary:

Your body is made from billions of cells, amazingly complex, tiny, self-replicating systems. Inside every single one of your cells is a nucleus, and inside that are 23 homologous pairs of chromosomes. The total number of chromosome pairs in a cell varies between organisms. Each chromosome is a continuous strand of DNA containing distinct sections called genes. DNA has the shape of a spiral staircase, and the steps are pairs of nucleotide bases linked in the middle by a hydrogen bond.

A gene's DNA contains a coded message for the manufacture of a specific protein. Proteins are just chains of amino acids, and every 3 bases on a DNA strand is a code word, or codon for one of the 20 known amino acids. Cells manufacture protein molecules via transcription and translation.

Inside each cell, there are about 1 billion code words. This equals about 1000 books of 500 pages each.

The sum of all of your genes, or your genome, contains an astounding 3.2 billion base pairs of DNA., which means that inside each cell, there are about 1 billion code words. This equals about 1000 books of 500 pages each, using the smallest print you can read, and your cells can duplicate this information in about 8 or 9 hours!

By applying the truths of the senses, truths of understanding, and truths of belief to the question "How did DNA get here?", the only logical answer is that *the God of the Bible created DNA*. This truth becomes clearer when we study further the parable of the sower, quoted at the beginning of this chapter. Remember that parables are analogies or abstract truths applied to a variety of situations.

Dr. A.E. Wilder-Smith (1915-1995), a Bible believing Christian with three doctorate degrees, applied the parable of the sower to explain that God, not evolution, created the genetic code[7]. Wilder-Smith said that when we think, we think in a concept, and we put that concept into a code, which is our language. For example, if someone gives me a gift, I think of the concept of thanksgiving, and I put that concept into a code (the phrase “thank you”), and that code is my language. Smith said there is no natural law for codes, that they are entirely arbitrary.

For example, “gracias” (Spanish) also means thank you, and so does “spaciba” (Russian). There is no natural law that says when the concept of thanksgiving comes to my mind, the organization of that thought has to be expressed as the English phrase “thank you.” The point here is that we can express the concept of thanksgiving by using a language, which is an organized code created by people. We use this code to organize and express our thoughts.

In the parable of the sower, Jesus told his disciples the seed represented the Word of God. Think about this now. From a material standpoint, what are seeds? Seeds are just “packets of genes,” and genes are code words, and just like languages are expressions of human thoughts, the 64 code words contained in genes are expressions of God’s thoughts! When we look at God’s word, we see that when planted in fertile soil (a good and noble heart), the seed bears much fruit, but when planted in poor soil (a hard heart), it withers away. The same thing happens to a physical seed, and is an incredible example of God revealing His attributes to us through a study of His works. God is the First cause who created the “letters” of the DNA “alphabet,” and used them to create assembly instructions for every living thing. The unity amidst diversity we see in Creation is an attribute of God, and the molecular constancy (every living thing has DNA) and variation (everything except clones have different arrangements of DNA) are because of Him, not in spite of Him.