Name_____ Date_____

TEKS 2.B.6.A Biology

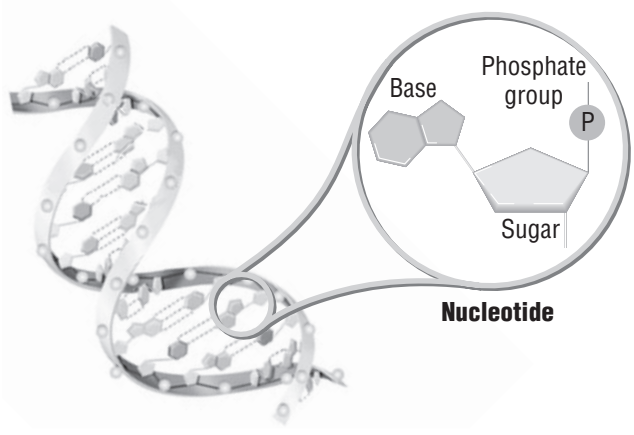
MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (A) identify components of DNA, and describe how information for specifying the traits of an organism is carried in the DNA;

STANDARD REVIEW

James Watson and Francis Crick were the first to piece together a model of the structure of DNA. The discovery of DNA's structure was important because it clarified how DNA could serve as genetic material. Watson and Crick determined that a DNA molecule is a double helix—two strands twisted around each other, like a winding staircase. As shown below, each strand is made of linked nucleotides. Nucleotides are the subunits that make up DNA. Each nucleotide is made of three parts: a phosphate group, a five-carbon sugar molecule, and a nitrogen-containing base. The five-carbon sugar in DNA nucleotides is called deoxyribose, from which DNA gets its full name, deoxyribonucleic acid.



While the sugar molecule and the phosphate group are the same for each nucleotide in a molecule of DNA, the nitrogen base may be any one of four different kinds: adenine (A), guanine (G), thymine (T), and cytosine (C). An adenine on one strand always pairs with a thymine on the opposite strand, and a guanine on one strand always pairs with a cytosine on the opposite strand.

Name_____ Date_____

TEKS 2.B.6.B Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (B) recognize that components that make up the genetic code are common to all organisms;

STANDARD REVIEW

Messenger RNA (mRNA) is the form of RNA that carries the instructions for making a protein from a gene and delivers it to the site of translation. The information is translated from the language of RNA—nucleotides—to the language of proteins—amino acids. The RNA instructions are written as a series of three-nucleotide sequences on the mRNA called codons. Each codon along the mRNA strand corresponds to an amino acid or signifies a start or stop signal for translation.

The chart below shows the genetic code—the amino acids and the "start" and "stop" signals—that are coded for by each of the possible 64 mRNA codons.

With few exceptions, the genetic code is the same in all organisms. For example, the codon GUC codes for the amino acid valine in bacteria, in eagles, in plants, and in your own cells. For this reason, the genetic code is often described as being nearly universal. Some exceptions include the ways cell organelles that contain DNA (such as mitochondria and chloroplasts) and a few microscopic protists read "stop" codons.

Name_____ Date_____

TEKS 2.B.6.B Biology

❶ Find the first base of the mRNA codon in this column of the table.

❷ Follow that row to the column that matches the second base of the codon.

❸ Move up or down in that box until you match the third base of the codon with this column of the chart.

Codons in mRNA

First base	Second base U	Second base C	Second base A	Second base G	Third base
U	UUU, UUC Phenylalanine UUA, UUG Leucine	UCU, UCC, UCA, UCG Serine	UAU, UAC Tyrosine UAA, UAG Stop	UGU, UGC Cysteine UGA–Stop UGG–Tryptophan	U C A G
C	CUU, CUC, CUA, CUG Leucine	CCU, CCC, CCA, CCG Proline	CAU, CAC Histidine CAA, CAG Glutamine	CGU, CGC, CGA, CGG Arginine	U C A G
A	AUU, AUC, AUA Isoleucine AUG–Start	ACU, ACC, ACA, ACG Threonine	AAU, AAC Asparagine AAA, AAG Lysine	AGU, AGC Serine AGA, AGG Arginine	U C A G
G	GUU, GUC, GUA, GUG Valine	GCU, GCC, GCA, GCG Alanine	GAU, GAC Aspartic acid GAA, GAG Glutamic acid	GGU, GGC, GGA, GGG Glycine	U C A G

Name_____ Date_____

TEKS 2.B.6.C Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

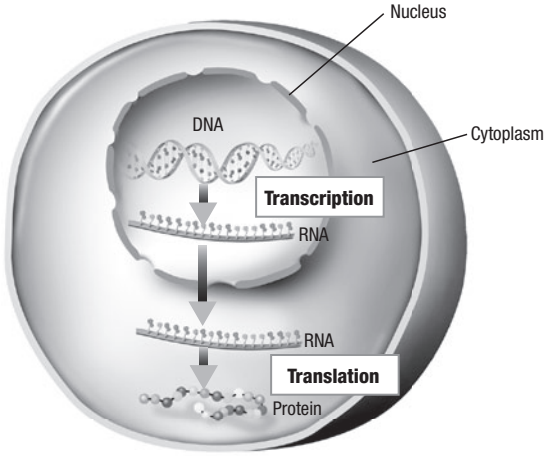
(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (C) explain the purpose and process of transcription and translation using models of DNA and RNA;

STANDARD REVIEW

Traits, such as eye color, are determined by proteins that are built according to instructions coded in DNA. Recall that proteins have many functions, including acting as enzymes and cell membrane channels. Proteins, however, are not built directly from DNA. Ribonucleic acid is also involved.

Like DNA, ribonucleic acid is a nucleic acid—a molecule made of nucleotides linked together. RNA differs from DNA in three ways. First, RNA consists of a single strand of nucleotides instead of the two strands found in DNA. Second, RNA nucleotides contain the five-carbon sugar ribose rather than the sugar deoxyribose, which is found in DNA nucleotides. Ribose contains one more oxygen atom than deoxyribose. And third, in addition to the A, G, and C nitrogen bases found in DNA, RNA nucleotides can have a nitrogen base called uracil—abbreviated as U. No thymine (T) bases are found in RNA. Like thymine, uracil is complementary to adenine whenever RNA base-pairs with another nucleic acid.

A gene's instructions for making a protein are coded in the sequence of nucleotides in the gene. The instructions for making a protein are transferred from a gene to an RNA molecule (called messenger RNA) in a process called transcription. In a process called translation, cells then use two different types of RNA (transfer RNA and ribosomal RNA) to read the instructions on the messenger RNA molecule and put together the amino acids that make up the protein. The entire process by which proteins are made based on the information encoded in DNA is called gene expression, or protein synthesis. This process is summarized in the figure below.



Name_____ Date_____

TEKS 2.B.6.D Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (D) recognize that gene expression is a regulated process;

STANDARD REVIEW

Gene expression is the entire process by which proteins are made based on the information encoded in an organism's DNA. The process of gene expression does not occur randomly in organisms. Instead, it is a carefully controlled or regulated process.

The ways in which gene expression is regulated differs in prokaryotic and eukaryotic cells. For example, in prokaryotes, cells control the expression of genes by controlling transcription. By contrast, the cells of eukaryotes can control gene expression at many different stages of the protein synthesis process.

Prokaryote genes are usually organized into operons, segments of DNA made up of a promoter, an operator, and one or more genes that code for all the proteins needed for a specific task. The promoter is a DNA segment that enables a gene to be transcribed and helps RNA polymerase locate the start of the gene. Operators are DNA segments that interact with proteins to control transcription by turning genes "on" or "off."

The *lac* operon can serve as an example for how gene expression occurs in prokaryotes. The *lac* operon is made up of several genes that act as a unit to control the production of the enzymes needed to break down lactose. When lactose is detected the *lac* operon is switched "on." This signals transcription to begin making the enzymes needed to break down lactose. When no lactose is detected, the *lac* operon switches "off," preventing transcription.

Eukaryotes can regulate gene expression at different stages of protein synthesis. Often, gene regulation occurs at the start of transcription, just as it does in prokaryotes. However, in eukaryotes, transcription is under the control of many elements, such as regulatory DNA sequences and transcription factors that work together, to start, speed up, or slow down the transcription process. Each gene in a eukaryotic cell has a specific combination of regulatory DNA sequences. These combinations help the cell function in a particular way by turning on only those genes that are needed to make proteins that carry out specific functions.

RNA processing also plays an important role in gene regulation in eukaryotes. RNA processing, which occurs in the nucleus, produces a molecule of mRNA through transcription. This mRNA then undergoes processing to remove some nucleotide segments (introns) and to add a cap and tail that will help it bind to a ribosome for transport out of the nucleus. The remaining nucleotide segments (exons) are then spliced together, and the mRNA segment moves into the cytoplasm. This processing of the mRNA removes nucleotide segments that are not needed in the making of the final protein.

Name_____ Date_____

TEKS 2.B.6.E Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (E) identify and illustrate changes in DNA and evaluate the significance of these changes;

STANDARD REVIEW

A change in an organism's DNA is called a mutation. Mutations in gametes can be passed on to offspring of the affected individual, but mutations in body cells affect only the individual in which they occur.

Most mutations affect a single gene. Two types of gene mutations are point mutations and frameshift mutations. A point mutation is a mutation in which one DNA nucleotide is replaced by another. A frameshift mutation involves the insertion or deletion of a nucleotide in the DNA sequence. Gene mutations can be modeled by errors in a sentence. Consider the statement below. Each letter represents a nucleotide, and each three-letter word represents a codon.

THE CAT ATE THE RAT.

In the case of a point mutation, one nucleotide is replaced by another.

THE CAT ATE THE **B**AT.

In some cases, the point mutation has little to no impact. In the example above, the effect of the mutation is minimal, as the statement still makes sense. In other cases, a point mutation can have a greater impact, causing diseases such as the blood disorder sickle-cell anemia. In the sentence below, the effect of the point mutation is greater, as the statement no longer makes sense. DNA polymerase often identifies and repairs point mutations.

THE CAT A**M**E THE RAT

Frameshift mutations usually have a greater impact on the polypeptide than point mutations. Consider the statement below, which shows the effect of a nucleotide deletion.

T_EC ATA TET HER AT

The first "H" has been deleted. This causes the entire DNA sequence's reading frame to shift and the statement no longer makes sense. Likewise is true if a nucleotide is added to the sequence. Huntington's Disease is a progressive brain disorder caused by an addition frameshift mutation.

Name_____ Date_____

TEKS 2.B.6.F Biology

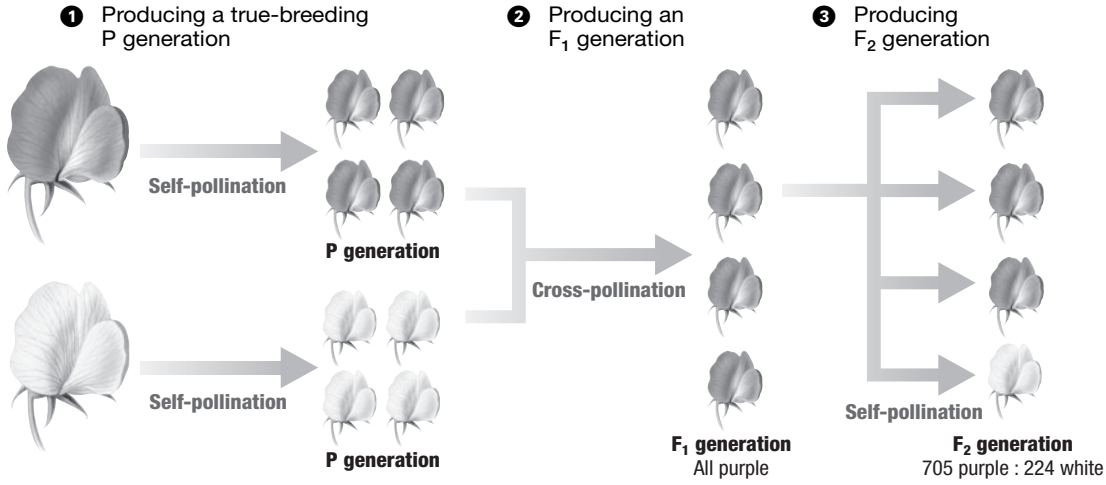
MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (F) predict possible outcomes of various genetic combinations such as monohybrid crosses, dihybrid crosses and non-Mendelian inheritance;

STANDARD REVIEW

Modern genetics is based on Gregor Johann Mendel's explanations for the patterns of heredity that he studied in garden pea plants. Mendel's first experiments used monohybrid crosses and were carried out in three steps, which are shown below.



For each of the seven characteristics that Mendel studied in this experiment, he found a similar 3-to-1 ratio of contrasting traits in the F2 generation. Mendel's experiments showed that offspring do not show a trait for every allele they receive. Instead, combinations of alleles determine traits. The set of alleles that an individual has for a characteristic is called the genotype. The trait that results from a set of alleles is the phenotype. In other words, genotype determines phenotype. Phenotype can also be affected by conditions in the environment, such as nutrients and temperature. If an individual has two of the same allele of a certain gene, the individual is homozygous for the related character. On the other hand, if an individual has two different alleles of a certain gene, the individual is heterozygous for the related character. In the heterozygous case, the dominant allele is expressed.

Name_____ Date_____

TEKS 2.B.6.F Biology

Although Mendel was correct about the inheritance of the traits he studied, most patterns of inheritance are more complex than those that Mendel identified. First, not all genes have only two alleles. There can be multiple alleles. Second, not all characteristics are controlled by one gene. Other patterns of inheritance include sex-linked genes (when alleles are located only on the X or Y chromosome), polygenic inheritance (when several genes affect one characteristic), incomplete dominance (when an offspring has a phenotype between that of its parents), and codominance (when both alleles of a gene are fully expressed).

Name_____ Date_____

TEKS 2.B.6.G Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (G) recognize the significance of meiosis to sexual reproduction;

STANDARD REVIEW

Some organisms reproduce by joining gametes to form the first cell of a new individual. The gametes are haploid—they contain one set of chromosomes. Meiosis is a form of cell division that halves the number of chromosomes when forming specialized reproductive cells, such as gametes or spores. Meiosis involves two divisions of the nucleus—meiosis I and meiosis II.

Steps of Meiosis

Before meiosis begins, the DNA in the original cell is replicated. Thus, meiosis starts with homologous chromosomes. Recall that homologous chromosomes are similar in size, shape, and genetic content. The stages of meiosis are summarized below:

Step 1: Prophase I The chromosomes condense, and the nuclear envelope breaks down. Homologous chromosomes pair along their length. Crossing-over occurs when portions of a chromatid on one homologous chromosome are broken and exchanged with the corresponding chromatid portions of the other homologous chromosome.

Step 2: Metaphase I The pairs of homologous chromosomes are moved by the spindle to the equator of the cell. The homologous chromosomes remain together.

Step 3: Anaphase I The homologous chromosomes separate. As in mitosis, the chromosomes of each pair are pulled to opposite poles of the cell by the spindle fibers. But the chromatids do not separate at their centromeres—each chromosome is still composed of two chromatids. The genetic material, however, has recombined.

Step 4: Telophase I Individual chromosomes gather at each of the poles. In most organisms, the cytoplasm divides (cytokinesis), forming two new cells. Both cells or poles contain one chromosome from each pair of homologous chromosomes. Chromosomes do not replicate between meiosis I and meiosis II.

Step 5: Prophase II A new spindle forms around the chromosomes.

Step 6: Metaphase II The chromosomes line up along the equator and are attached at their centromeres to spindle fibers.

Step 7: Anaphase II The centromeres divide, and the chromatids (now called chromosomes) move to opposite poles of the cell.

Step 8: Telophase II A nuclear envelope forms around each set of chromosomes. The spindle breaks down, and the cell undergoes cytokinesis. The result of meiosis is four haploid cells.

In humans, each gamete receives one chromosome from each of 23 pairs of homologous chromosomes. But, which of the two chromosomes that an offspring receives from each of the 23 pairs is a matter of chance. This random distribution of homologous chromosomes during meiosis is called independent assortment. Each of the 23 pairs of chromosomes segregates (separates) independently. Thus, 22^3 (about 8 million) gametes with different gene combinations can be produced from one original cell by this mechanism. Crossing-over adds even more recombination.

Name_____ Date_____

TEKS 2.B.6.H Biology

MECHANISMS OF GENETICS

The student will demonstrate an understanding of the mechanisms of genetics.

(B.6) **Science concepts.** The student knows the mechanisms of genetics, including the role of nucleic acids and the principles of Mendelian Genetics. The student is expected to (H) describe how techniques such as DNA fingerprinting, genetic modifications, and chromosomal analysis are used to study the genomes of organisms.

STANDARD REVIEW

A genome is all of an organism's genetic material. Other than identical twins, no two individuals have the same genetic material. Studying genomes enables scientists to learn about the function of genes and to identify genetic mutations, as well as analyze evolutionary relationships among organisms. Scientists use a variety of techniques to study organisms' genomes. Some of these techniques involve cutting long DNA molecules into smaller pieces with restriction enzymes, and then separating and reading the fragments using gel electrophoresis.

In 2003 the U.S., along with several other countries, completed the Human Genome Project. The goal of this project was to identify and sequence all human genes. The project relied on a technique called DNA, or gene, sequencing. Gene sequencing allows scientists to determine the order of DNA nucleotides in genes or in entire genomes. To do this, scientists mix an unknown strand of DNA with the enzyme DNA polymerase, and add samples of the four nucleotide bases: adenine, thymine, cytosine, and guanine. The nucleotide bases are tagged with trace amounts of dye. The unknown strand of DNA is used as a template to make multiple new strands of DNA. When a tagged nucleotide base is incorporated into a new DNA strand, DNA synthesis stops, producing strands of different lengths. The fragments then are separated using gel electrophoresis, and analyzed in DNA sequencing computers.

DNA fingerprinting is a second technique scientists use to study genomes. A DNA fingerprint is a pattern of dark bands on photographic film that is made when an individual's DNA restriction fragments are separated by gel electrophoresis, probed, and then exposed to an x-ray film. Each individual (other than identical twins) has a unique pattern of banding, or DNA fingerprint. The banding patterns from two individuals can be compared to establish whether they are related, such as in a paternity case. DNA fingerprinting also is valuable for identifying the genes that cause genetic disorders, such as Huntington's disease and sickle cell anemia.

Name_____ Date_____

TEKS 2.B.6.H Biology

Another technique used to study genomes is genetic modification. Genetic modification involves scientists identifying and isolating genes that code for specific traits, and then manipulating those factors that affect the genes' expression. In 1973, Stanley Cohen and Herbert Boyer conducted an experiment that revolutionized genetic studies in biology. They isolated the gene that codes for ribosomal RNA (rRNA) from the DNA of an African clawed frog and then inserted it into the DNA of *Escherichia coli* bacteria. During transcription, the bacteria produced frog rRNA, thereby becoming the first genetically altered organisms.

In some cases, scientists study an organism's chromosomes directly to learn about their genomes. A karyotype is a picture of all the chromosomes in a cell, grouped together in pairs and organized in order of decreasing size. The chromosomes are stained during metaphase, which produces a distinct pattern of banding on each chromosome. Karyotypes can be used to identify the possible location of a gene or a genetic abnormality on a chromosome. Karyotypes also can show how chromosomes change over time.