

# Genetics

## Module B, Anchor 3

### Key Concepts:

- An individual's characteristics are determined by factors that are passed from one parental generation to the next.
- During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene.
- Punnett squares use mathematical probability to help predict the genotype and phenotype combinations in genetic crosses.
- The principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes.
- Mendel's principles of heredity, observed through patterns of inheritance, form the basis of modern genetics.
- Some alleles are neither dominant nor recessive. Many genes exist in several different forms and are therefore said to have multiple alleles. Many traits are produced by the interaction of several genes.
- Environmental conditions can affect gene expression and influence genetically determined traits.
- The DNA that makes up genes must be capable of storing, copying, and transmitting the genetic information in a cell.
- DNA is a nucleic acid made up of nucleotides joined into long strands or chains by covalent bonds.
- DNA polymerase is an enzyme that joins individual nucleotides to produce a new strand of DNA.
- Replication in most prokaryotic cells starts from a single point and proceeds in both directions until the entire chromosome is copied.
- In eukaryotic cells, replication may begin at dozens or even hundreds of places on the DNA molecule, proceeding in both directions until each chromosome is completely copied.
- The main differences between DNA and RNA are that (1) the sugar in RNA is ribose instead of deoxyribose; (2) RNA is generally single-stranded, not double-stranded; and (3) RNA contains uracil in place of thymine.
- In transcription, segments of DNA serve as templates to produce complementary RNA molecules.
- The genetic code is read three "letters" at a time, so that each "word" is three bases long and corresponds to a single amino acid.
- Ribosomes use the sequences of RNA codons to assemble amino acids into polypeptide chains.
- The central dogma of molecular biology is that information is transferred from DNA to RNA to protein.
- Mutations are heritable changes in genetic information.
- The effects of mutations on genes vary widely. Some have little or no effect; some produce beneficial variations. Some negatively disrupt gene function.
- Mutations often produce proteins with new or altered functions that can be useful to organisms in different or changing environments.

- Human genes follow the same Mendelian patterns of inheritance as the genes of other organisms. Many human traits follow a pattern of simple dominance. The alleles of other human genes display codominant inheritance. Because the X and Y chromosomes determine sex, the genes located on them show a pattern of inheritance called sex-linkage.
- Changes in a gene's DNA sequence can change proteins by altering their amino acid sequences, which may directly affect one's phenotype.
- If nondisjunction occurs during meiosis, gametes with an abnormal number of chromosomes may result, leading to a disorder of chromosome numbers.
- Recombinant DNA technology – joining together DNA from 2 or more sources – makes it possible to change the genetic composition of living organisms.
- Transgenic organisms can be produced by the insertion of recombinant DNA into the genome of a host organism.
- Ideally, genetic modification could lead to better, less expensive, and more nutritious food as well as less harmful manufacturing processes.
- Recombinant DNA technology is advancing the prevention and treatment of disease.
- DNA fingerprinting analyzes sections of DNA that vary widely from one individual to another.

### **Vocabulary:**

Genetics	fertilization	allele	principle of dominance
Trait	segregation	hybrid	gene
Gamete	probability	genotype	phenotype
Homozygous	heterozygous	codominance	independent assortment
Multiple allele	polygenic trait	base pairing	Incomplete dominance
Replication	DNA polymerase	nucleotides	nucleic acid
RNA	messenger RNA	ribosomal RNA	RNA polymerase
Transfer RNA	transcription	polypeptide	genetic code
Codon	anticodon	translation	gene expression
Biotechnology	PCR	genetic marker	transgenic
Recombinant DNA	clone	plasmid	gene therapy
DNA fingerprinting	genome	autosome	sex-linked gene
Sex chromosome	nondisjunction		

### **Basic Mendelian Genetics:**

1. Different forms of a gene are called:
  - A. hybrids
  - B. dominant factors
  - C. alleles
  - D. recessive factors
2. Organisms that have two identical alleles for a particular trait are said to be:
  - A. hybrid
  - B. heterozygous
  - C. homozygous
  - D. dominant

3. What is the difference between a dominant and recessive allele?

4. State the principle of dominance. How does this explain the phenotype of heterozygous organisms?

According to this principle, under what conditions will an organism show a recessive phenotype?

5. State the principle of segregation. How does this explain how two heterozygous organisms can produce homozygous offspring?

6. State the principle of independent assortment.

7. What is a punnett square? How are punnett squares used in genetics?

8. Show the cross between two guinea pigs. One is heterozygous for black color, the other is white. Record the genotypic and phenotypic ratios of the offspring.

**Other Patterns of Inheritance:**

1. Compare and contrast codominance, incomplete dominance, and complete dominance.
2. Compare and contrast multiple alleles and polygenic traits.
3. Why do multiple alleles and polygenic traits produce many different phenotypes for a trait?
4. Can a trait show more than one inheritance pattern?
5. You would like to determine if a plant shows codominance or incomplete dominance. What type of cross would you perform and why? Explain how you would know whether the gene involved showed co- or incomplete dominance.
6. What is the relationship between genes and the environment?

**DNA Structure:**

1. Thoroughly describe the structure of a DNA molecule.
  
  
  
  
  
  
  
  
  
  
2. What are the base pairing rules? If the percentage of adenine in a sample goes up 5 %, what will happen to the percentage of thymine? What will happen to the percentage of guanine?
  
  
  
  
  
  
  
  
  
  
3. What are the three roles of DNA? Explain how the structure of DNA aids in each role.
  
  
  
  
  
  
  
  
  
  
4. What happens when a piece of DNA is missing?
  - A. Genetic information is stored
  - B. Genetic information is transmitted
  - C. Genetic information is lost
  - D. Genetic information is copied

**DNA Replication:**

1. Thoroughly describe the process of DNA replication.

2. Compare and contrast DNA replication in prokaryotes and eukaryotes.
3. What is base pairing and how is it involved in DNA replication?
4. When a DNA molecule is replicated, how do the new molecules compare to the original molecule? How does replication ensure that this occurs?

**Transcription:**

1. Thoroughly describe the process of transcription.
2. What is made during transcription?
3. Why is transcription necessary for protein synthesis?

4. Suppose you start with a DNA strand ACCGTCACG. Use the rules of base pairing to determine the complementary RNA strand.
5. Compare and contrast DNA and RNA structure. How does the different structure of RNA relate to its different function in cells?
6. Compare and contrast DNA replication and transcription.
7. Describe the process of RNA editing.

**Protein Synthesis:**

1. List the three types of RNA. Describe the role of each in protein synthesis.
2. What is made during protein synthesis?
3. What are codons and anticodons? How do they work together during protein synthesis?

4. Thoroughly describe the process of protein synthesis.
5. Explain why controlling the proteins in an organism controls the organism's characteristics.
6. What is the correct sequence of transfer of genetic information in most organisms?
  - A. RNA, DNA, protein
  - B. DNA, RNA protein
  - C. protein, DNA, RNA
  - D. RNA, protein, DNA
7. What are the roles of endoplasmic reticulum and ribosomes in protein synthesis?
8. Does protein synthesis occur in all organisms?

**Mutation:**

1. What is a mutation?
2. What are some causes of mutation?
3. List and describe the types of gene mutations.



4. What types of gene mutations are most severe? Why?
5. List and describe the types of chromosome mutations.
6. How does the repetitive nature of the genetic code help to reduce the damage done by mutations?
7. One difference between a gene mutation and a chromosomal mutation is
  - A. A gene mutation affects the DNA of more genes than a chromosomal mutation.
  - B. A gene mutation can involve as insertion or deletion, but cannot involve a frameshift
  - C. A chromosomal mutation can affect the number of chromosomes in a cell
  - D. A chromosomal mutation is more likely to be passed on to offspring or daughter cells
8. Most mutations
  - A. have no effect on the organism
  - B. are beneficial
  - C. are harmful
  - D. are fatal

**Human Heredity:**

1. A normal human zygote contains
  - A. 23 chromosomes
  - B. 46 chromosomes
  - C. 44 chromosomes
  - D. XYY chromosomes
2. What is a nondisjunction? How does a nondisjunction cause chromosome disorders?
3. What is the difference between autosomes and sex chromosomes?

4. What are sex-linked traits? How are they inherited differently between males and females?

5. Which of the following forms a Barr body:

- A. one of the Y chromosomes in a male cell
- B. one of the X chromosomes in a male cell
- C. one of the X chromosomes in a female cell
- D. both of the X chromosomes in a female cell

**Genetic Engineering:**

1. Organisms that contain genes from other organisms are called

- A. transgenic
- B. mutagenic
- C. donors
- D. clones

2. Describe what happens during a polymerase chain reaction. What is the use of PCR?

3. Explain what genetic markers are and describe how scientists use them.

4. What are transgenic organisms? What are the potential benefits of transgenic organisms? Concerns?

5. How can genetic engineering impact human health?

6. Describe the uses of DNA fingerprinting.

7. A gene that makes it possible to distinguish a bacterium that has been transformed from one that has not is:

- A. a resistance gene
- B. an antibiotic
- C. a genetic marker
- D. a clone

8. Explain what a DNA probe is and describe how it could be used to identify a person who has an allele for a genetic disorder.

# Genetics

## Module B, Anchor 2

### Basic Mendelian Genetics:

1. Different forms of a gene are called:

*C. alleles*

2. Organisms that have two identical alleles for a particular trait are said to be:

*C. homozygous*

3. What is the difference between a dominant and recessive allele?

*A dominant allele shows whenever it is present. A recessive allele shows only if no dominant alleles are present.*

4. State the principle of dominance. How does this explain the phenotype of heterozygous organisms?

*Some alleles are dominant, others are recessive. Heterozygous organisms have one dominant and one recessive allele. The dominant allele takes over and shows over the recessive allele.*

According to this principle, under what conditions will an organism show a recessive phenotype?  
*When no dominant alleles are present, as in  $tt$ .*

5. State the principle of segregation. How does this explain how two heterozygous organisms can produce homozygous offspring?

*Alleles segregate during the formation of gametes. Each organism contains two alleles for each trait. These alleles go into different gametes during meiosis. The heterozygous parent has  $Tt$  as the genotype. The  $T$  separates from the  $t$  when gametes are formed. This allows the  $T$  or  $t$  to pair up with another letter, giving homozygous phenotypes.*

6. State the principle of independent assortment.

*Alleles segregate independently during the formation of gametes.*

7. What is a Punnett square? How are Punnett squares used in genetics?

*Punnett squares show the possible offspring of a cross. They are used to predict outcomes of crosses.*

8. Show the cross between two guinea pigs. One is heterozygous for black color, the other is white. Record the genotypic and phenotypic ratios of the offspring.

Black – $Tt$		$T$	$t$
White $tt$	$t$	$Tt$	$tt$
	$t$	$Tt$	$tt$

*genotype ratio: 1:1 ratio of  $Tt$ ,  $tt$*

*phenotype ratio: 1:1 ratios or black to white*

### **Other Patterns of Inheritance:**

1. Compare and contrast codominance, incomplete dominance, and complete dominance.

*Codominance – both alleles are equally dominant, both show up in the heterozygous offspring*

*Incomplete dominance – one allele is dominant, but not completely; heterozygous offspring show a blend of parental traits*

*Complete dominance – one allele is completely dominant over the other, heterozygotes show Dominant trait*

2. Compare and contrast multiple alleles and polygenic traits.

*Multiple alleles – one gene controls the trait, more than two alleles exist for the trait*

*Polygenic traits – multiple genes control the trait*

*In both instances, more phenotypes are present than with a more simple inheritance pattern*

3. Why do multiple alleles and polygenic traits produce many different phenotypes for a trait?

*Multiple alleles have more options for alleles, producing more phenotypes. Polygenic traits show a continuum of traits as they are controlled by multiple genes. Any alteration of any allele for any gene results in a slight change in phenotype.*

4. Can a trait show more than one inheritance pattern?

*Yes. For example, blood type in humans shows multiple alleles, codominance, and complete dominance.*

5. You would like to determine if a plant shows codominance or incomplete dominance. What type of cross would you perform and why? Explain how you would know whether the gene involved showed co- or incomplete dominance.

*Breed the two homozygous plants to get a hybrid plant. If both traits show up, the plant shows codominance. If a blend shows the plants show incomplete dominance. For example, you breed a red plant and a white plant. If the hybrid offspring are red with white spots, they show codominance. If the offspring are pink, they show incomplete dominance.*

6. What is the relationship between genes and the environment?

*Gene expression is affected by the environment. For example, a set of identical twins may be predisposed genetically to heart disease. One twin exercises and eats well. They do not develop heart disease due to their lifestyle. The other twin smokes and eats poorly. They do develop heart disease.*

### **DNA Structure:**

1. Thoroughly describe the structure of a DNA molecule.

*DNA is composed of nucleotides; nucleotides are composed of sugar, phosphate, and nitrogenous base. DNA has a double helix shape. The sides of the helix are sugar-phosphate backbone. They are composed of deoxyribose and phosphate. The “rungs” of the helix are composed of base pairs. Adenine bonds with thymine and cytosine with guanine. The two sides of the molecule run antiparallel. The sides are held together with covalent bonds. The base pairs are held together with hydrogen bonds.*

2. What are the base pairing rules? If the percentage of adenine in a sample goes up 5 %, what will happen to the percentage of thymine? What will happen to the percentage of guanine?

*Adenine – thymine*

*Cytosine – guanine*

*Thymine will also go up 5%. Guanine will go down 5%.*

3. What are the three roles of DNA? Explain how the structure of DNA aids in each role.

*Store information – stores information in the sequence of the base pairs*

*Copy and transmit information – the hydrogen bonds between bases break easily, exposing the bases to be copied. The covalent bonds hold the two sides together during replication. This allows the molecule to be copied and passed on to offspring.*

4. What happens when a piece of DNA is missing?

*C. Genetic information is lost*

### **DNA Replication:**

1. Thoroughly describe the process of DNA replication.

*The DNA molecule is unwound. The hydrogen bonds between the bases are broken. Enzymes match up bases according to the base-pairing rules. The leading and lagging strands are assembled in opposite directions. Once the strands are fully replicated, the new DNA molecules are proof-read.*

2. Compare and contrast DNA replication in prokaryotes and eukaryotes.

*In prokaryotes, DNA replication starts at a single point and proceeds in both directions. In eukaryotes, replication starts in multiple locations.*

3. What is base pairing and how is it involved in DNA replication?

*A=T C=G This ensures that the two DNA strands are identical, as A must bond with T and C must bond with G.*

4. When a DNA molecule is replicated, how do the new molecules compare to the original molecule? How does replication ensure that this occurs?

*Each new molecule is comprised of one new strand and one original strand. The two molecules are identical to each other and to the template strand. Since the old molecule is used as a template and the base-pairing rules must be followed, the strands are identical.*

### **Transcription:**

1. Thoroughly describe the process of transcription.

*The DNA strand is unwound starting at the promoter region. RNA polymerase binds to the promoter region on one DNA strand and begins matching base pairs. This continues until the termination sequence is reached. The RNA strand breaks off the DNA and the DNA reforms. The RNA is then edited.*

2. What is made during transcription?

*RNA*

3. Why is transcription necessary for protein synthesis?

*Each DNA molecule contains many genes, each coding for a different protein. RNA contains only the gene for one protein. Also, DNA does not leave the nucleus. Protein synthesis occurs in the cytoplasm. RNA is capable of traveling to the cytoplasm for protein synthesis.*

4. Suppose you start with a DNA strand ACCGTCACG. Use the rules of base pairing to determine the complementary RNA strand.

*UGGCAGUGC*

5. Compare and contrast DNA and RNA structure. How does the different structure of RNA relate to its different function in cells?

*Both –made of nucleotides; contain phosphate, adenine, cytosine, guanine*

*RNA – contains ribose and uracil; single-stranded; only one gene*

*DNA – contains deoxyribose and thymine; double stranded, many genes*

6. Compare and contrast DNA replication and transcription.

*Both – DNA is unwound and bases are added*

*Replication – entire molecule is copied; template strand becomes part of new molecules*

*Transcription – only part of one strand is copied; template strand rejoins and is left as it was*

7. Describe the process of RNA editing.

*RNA is cut into introns and exons. Exons are used to create final RNA molecule. The same RNA strand can be cut and rejoined in multiple ways, producing different final RNA from the same original molecule.*

### **Protein Synthesis:**

1. List the three types of RNA. Describe the role of each in protein synthesis.

*Messenger RNA – carries the message from DNA to be used to create proteins*

*Ribosomal RNA – makes up ribosomes, the site of protein synthesis*

*Transfer RNA – reads the mRNA and matches up complementary amino acids*

2. What is made during protein synthesis?

*protein*

3. What are codons and anticodons? How do they work together during protein synthesis?

*Codons – sequences of three bases on mRNA*

*Anticodon – sequence of three bases on tRNA complementary to mRNA codon*

*The anticodons and codons are complementary to each other. The tRNA matches up with the mRNA. On the opposite end of the tRNA is an amino acid. This is how the tRNA translates the mRNA into an amino acid sequence.*

4. Thoroughly describe the process of protein synthesis.

*The mRNA is transcribed in the nucleus. It travels to the cytoplasm, where it binds to the ribosome. The mRNA moves through the A and P sites of the ribosome. The tRNA molecules*

*match up with the exposed codons on the mRNA. The amino acids on the other end of each tRNA bind together to form a polypeptide. When the stop codon is reached, the polypeptide is released.*

5. Explain why controlling the proteins in an organism controls the organism's characteristics. *Proteins determine all of our traits. The order of amino acids in a protein determine how it functions. Any alteration in a protein will result in a change of loss of function for the characteristic it controls in the organism.*

6. What is the correct sequence of transfer of genetic information in most organisms?  
*B. DNA, RNA protein*

7. What are the roles of endoplasmic reticulum and ribosomes in protein synthesis?  
*Rough ER houses ribosomes. Ribosomes are the site of protein synthesis. The rough ER also modifies proteins after translation.*

8. Does protein synthesis occur in all organisms?  
*Yes.*

### **Mutation:**

1. What is a mutation?  
*A heritable change in the genetic material of an organism.*

2. What are some causes of mutation?  
*Carcinogens, mistakes in replication, etc.*

3. List and describe the types of gene mutations.  
*Substitution – one base is switched for another*  
*Insertion – one base is added to the sequence*  
*Deletion – one base is removed from the sequence*  
*Insertion and deletion mutations fall into the category of frameshift mutations.*

4. What types of gene mutations are most severe? Why?  
*Frameshift mutations alter more codons, and thus have a more severe effect on the function of the protein. If substitution mutations result in a stop codon they are also severe.*

5. List and describe the types of chromosome mutations.  
*Deletion – gene deleted*  
*Duplication – extra copy of gene included*  
*Inversion – gene order is reversed*  
*Translocation – genes from nonhomologous chromosomes are switched*

6. How does the repetitive nature of the genetic code help to reduce the damage done by mutations?



*Multiple codons code for the same amino acid. Therefore, a mutation may change a base without changing the amino acid for which that codon codes. This would result in no change in the protein function.*

7. One difference between a gene mutation and a chromosomal mutation is  
*C. A chromosomal mutation can affect the number of chromosomes in a cell*
8. Most mutations  
*A. have no effect on the organism*

### **Human Heredity:**

1. A normal human zygote contains  
*B. 46 chromosomes*
2. What is a nondisjunction? How does a nondisjunction cause chromosome disorders?  
*Nondisjunction occurs when the chromosomes fail to separate properly during meiosis. This results in a gamete having too many or too few of a particular chromosome. If this gamete is fertilized, the resulting organism will have a chromosome disorder.*
3. What is the difference between autosomes and sex chromosomes?  
*Sex chromosomes determine gender. Autosomes are all the remaining chromosomes.*
4. What are sex-linked traits? How are they inherited differently between males and females?  
*Traits on the x chromosome. Males have one x chromosome, while females have two. This means that a male will show any trait on its X, even a recessive one. Females still require two copies of the recessive X to show such a trait. Therefore, x-linked traits are more common in males than in females.*
5. Which of the following forms a Barr body:  
*C. one of the X chromosomes in a female cell*

### **Genetic Engineering:**

1. Organisms that contain genes from other organisms are called  
*A. transgenic*
2. Describe what happens during a polymerase chain reaction. What is the use of PCR?  
*The first step in using the polymerase chain reaction method to copy a gene is to heat a piece of DNA, which separates its two strands. Then, as the DNA cools, primers bind to the single strands. Next, DNA polymerase starts copying the region between the primers. These copied can serve as templates to make still more copies.*
3. Explain what genetic markers are and describe how scientists use them.  
*A gene that makes it possible to distinguish bacteria that carry a plasmid from those that don't carry it. Scientists use genetic markers to determine if a transgenic attempt was successful.*

4. What are transgenic organisms? What are the potential benefits of transgenic organisms? Concerns?

*Organisms that contain genetic material from other species. Transgenic organisms may improve agricultural yields, reduce pesticide use, manufacture human proteins, etc. There is some fear over unintended side-effects. For example, crops may spread pesticide resistance to weed species. Allergic reactions or other illnesses may occur, transgenic organisms are patented which reduces the free nature of food supplies, etc.*

5. How can genetic engineering impact human health?

*Genetic engineering could help produce human proteins for use in medicine. There is also some concern over an increase in disease or allergies.*

6. Describe the uses of DNA fingerprinting.

*Establishing family relationships, crime scenes, etc.*

7. A gene that makes it possible to distinguish a bacterium that has been transformed from one that has not is:

*C. a genetic marker*

8. Explain what a DNA probe is and describe how it could be used to identify a person who has an allele for a genetic disorder.

*Small segments of DNA that help locate a particular gene in a long DNA sequence. They could be used to analyze the individual's DNA to determine the presence, or lack thereof, of a gene.*