Name _____ Class _____ Date _____

25 MENDELIAN GENETICS
Activity 1. Mendel's Principles of Heredity

Many of the basic concepts of heredity were worked out in the mid-1800s by the Austrian monk Gregor Mendel (1822–1884). Mendel cultivated garden peas, which he used to study plant inheritance. From these experiments, Mendel concluded that each hereditary trait is controlled by two separate factors, one from each parent, and that these factors are passed on unchanged from generation to generation. Mendel knew nothing of chromosomes or genes. However, what he called "factors" are now known to be genes, which are found on the chromosomes.

Mendel was very careful in his studies to use plants that "bred true"—that is, plants that showed the same traits generation after generation. Also, he studied only seven different traits, and there were two contrasting forms for each trait.

THE LAW OF DOMINANCE

When Mendel crossed two true-breeding pea plants that showed one pair of contrasting traits, only one of these traits was evident in the resulting offspring. For example, if he crossed a tall plant and a short plant, all offspring were tall. The trait that was expressed was described as *dominant*, while the trait that did not show in the offspring was *recessive*. Of the pairs of contrasting traits that Mendel studied, he found that in each case one trait proved dominant. Tall stems were dominant, short stems recessive; round seeds were dominant, wrinkled seeds recessive, etc. Mendel concluded that of every pair of contrasting traits, one is dominant and the other recessive.

The pure-breeding parent generation is called the P generation. The offspring of the crosses between members of the P generation are called the first filial, or F_1, generation. Crosses between members of the F_1 generation produce the second filial, or F_2, generation, and so on. In Mendel's experiments members of the F_1 generation were *hybrids*—they were the offspring of unlike parents.

1. In Mendel's experiments, he crossed pea plants that had green pods with plants that had yellow pods. He found that all the offspring had green pods.
   a. The plants used in the original cross made up the ___P___ generation.
   b. The offspring of the cross made up the ___First___ filial, or ___F2___, generation.
   c. The pod color that was dominant was ___Green___, while the pod color that was recessive was ___yellow___

2. What is a hybrid?
   offspring of unlike parents

THE PRINCIPLE OF SEGREGATION

In another experiment, Mendel allowed the hybrid members of the F_1 generation to undergo self-fertilization. The offspring of this cross were the F_2 generation. Of the F_2

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generation, three-fourths showed the dominant trait and one-fourth showed the recessive trait. This showed that although members of the F_1 generation all showed the dominant trait, these plants also carried the recessive factor (gene), and that this factor was passed on to the F_2 generation. These results led Mendel to the conclusion that each trait is controlled by a pair of factors, one from each parent. (The F_1 hybrids obviously carried the dominant factor of one parent and the recessive factor of the other parent.)

Since the gametes fuse in fertilization, each gamete must carry only one of the factors, and the zygote formed by the fusion of the two gametes then carries two, one from each parent. In the formation of gametes, the two factors must separate, or *segregate*. Each gamete receives one factor for each trait. This is Mendel's law of segregation. The dominant trait is expressed whenever the dominant factor (gene) for that trait is present. For example, in the experiments on stem length, all members of the F_1 hybrid generation were tall. Only an organism possessing two recessive factors for a given trait will show the recessive trait.

An individual with two dominant or two recessive genes is said to be *homozygous*, while the hybrid, with one dominant and one recessive gene, is *heterozygous*. The dominant trait is shown by two capital letters (TT for tallness, for example), and the recessive by two lower case letters (tt for shortness). The homozygous dominant is TT, the homozygous recessive is tt, and the hybrid is Tt.

Genes that govern the expression of a trait are found at the same position of each chromosome of a pair of chromosomes. Different forms of a gene controlling a particular trait are called *alleles*.

1. In the pea plants studied by Mendel, how many factors controlled a given trait?

   2 – one from each parent

2. What is Mendel's law of segregation?

   In the formation of gametes, the 2 factors for each trait (located on homologous chromosomes) must separate or segregate from one another.

   This law essentially describes meiosis

3. Different forms of a gene that controls a particular trait are called alleles.

4. Use G for green pods (dominant) and g for yellow pods (recessive).

   a. A pea plant that is homozygous dominant for green pods would be shown as GG.

   b. A pea plant that is heterozygous for green pods would be shown as Gg.

   c. A pea plant that is homozygous recessive for yellow pods would be shown as gg.

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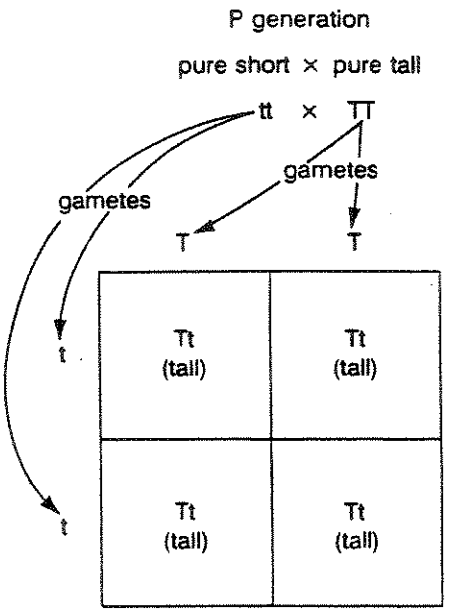
25 MENDELIAN GENETICS
Activity 2. Basic Concepts in Genetics

THE PUNNETT SQUARE

The Punnett square is a convenient method for visualizing genetic crosses. The boxes that make up the square show all possible zygotes resulting from a cross of gametes bearing a specific trait. The letters representing each possible type of sperm are placed along the top of the square, and those for each possible type of egg along the side. For example, in a pea plant that was heterozygous for stem length (Tt), half the gametes would receive the dominant factor for stem length (T) and half would receive the recessive (t). Thus, the plant would produce two types of gametes. A plant that was pure dominant (TT) or pure recessive (tt) would produce only one type of gamete—T or t respectively.

A cross between a homozygous tall plant (TT) and a homozygous short plant (tt) is shown in the Punnett square diagram. The resulting F_1 generation is all heterozygous tall. The physical appearance of an individual is called the *phenotype*. Thus, the phenotype of all members of the F_1 generation is tall. The *genotype*, on the other hand, is the genetic makeup of the individual. In this case all members of the F_1 generation have a heterozygous, or hybrid, genotype. The genotypes of the P generation were homozygous dominant and homozygous recessive.



F_1 offspring: 100% tall

1. The physical appearance of an individual is its phenotype, while the genetic makeup of an individual is its genotype.
2. Use a Punnett square to show the offspring of a cross between two pea plants that are heterozygous for stem length (Tt × Tt). Give the phenotypes and genotypes of the offspring.

	T	t
T	TT	Tt
t	Tt	tt

Phenotypes: 3 tall : 1 short

Genotypes: 1 TT
2 Tt
1 tt

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3. Use a Punnett square to show the offspring of a cross between a pea plant that is homozygous tall (TT) and one that is heterozygous (Tt). Give the phenotypes and genotypes of the offspring.

	T	t
T	TT	Tt
T	TT	Tt

Phenotypes: all tall

Genotypes: 2 TT
2 Tt

4. Use a Punnett square to show the offspring of a cross between a pea plant that is heterozygous tall (Tt) and one that is homozygous recessive for stem length (tt). Give the phenotypes and genotypes of the offspring.

	t	t
T	Tt	Tt
t	tt	tt

Phenotypes: 2 tall 2 short

Genotypes: 2 Tt
2 tt

INDEPENDENT ASSORTMENT

Following his crosses of plants with one pair of contrasting traits, Mendel did crosses of plants that showed two pairs of contrasting traits. Such a cross might involve a plant with long stems and round seeds (both dominant) and one with short stems and wrinkled seeds (both recessive). The first plant could be represented as TTRR, the second as ttrr. Each plant would produce only one type of gamete—one would be TR and the other tr. All offspring of the cross would be hybrids with long stems and round seeds (TtRr).

To find out whether there was any relationship between the two traits—for example, whether the dominant traits segregated together—Mendel allowed the hybrid plants to undergo self-fertilization. This is a *dihybrid cross*, a cross involving organisms that are hybrid for two traits. The results of such a cross showed that the factors (genes) for each trait were segregated independently of any others in the course of gamete formation. This is Mendel's law of independent assortment. It has since been found that there are exceptions to this law.

1. What is Mendel's law of independent assortment?

In the formation of gametes during meiosis the movement (migration) of 1 pair of homologous chromosomes to opposite poles does not influence the movement (migration) of other homologous pairs (all genetic recombinations are possible)

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CHAPTER 25 Activity 2. Basic Concepts in Genetics

2. Work out the following dihybrid cross. Round seeds are dominant over wrinkled seeds, and yellow seeds are dominant over green seeds. A plant that is hybrid for both traits (RrYy) is allowed to undergo self-fertilization (RrYy × RrYy).

   a. The four types of gametes formed are RY, Ry, rY, and ry.

   b. Fill in the Punnett square below. Give the phenotypes of the offspring of this cross and the percentage of each phenotype produced.

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RR	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

3. In the dihybrids that Mendel worked with, the genes for the individual traits were located on separate chromosomes. If the genes for two or more of these traits had been located on the same chromosome, would Mendel have developed his law of independent assortment?

No — the genes would not have shown independent movement (migration). They would be linked.

4. Using the Punnett squares below, work out the following crosses:

   a. TTYY × TtYy

	TY	Ty	tY	ty
TY	TTYY	TTYy	TtYY	TtYy
Ty	Same as above			
tY		"		"
ty		"		"

a.

   b. rrYy × RRyy

	Ry	Ry	Ry	Ry
rY	RrYy			
ry	Rryy			
rY	RrYy			
ry	Rryy			

b.

Same as left column

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TEST CROSS

A test cross is a method for determining whether an organism that shows a dominant trait is pure dominant for that trait or heterozygous. In a test cross, the organism in question is crossed with a pure recessive for the trait. If the test organism is heterozygous, some of the offspring of the cross will show the recessive trait. If the test organism is homozygous dominant, none of the offspring will show the recessive trait. Large numbers of offspring are necessary for valid results.

1. In guinea pigs, black coat color is dominant over white. How would you find out whether a black guinea pig is homozygous for coat color (BB) or heterozygous (Bb)?

make the Black guinea pig with a homozygous recessive

B_? x bb

2. Using the Punnett squares below, show how the results of a test cross would differ with a guinea pig that was homozygous dominant for coat color (BB) and one that was heterozygous for coat color (Bb).

	b	b
B	Bb	Bb
B	Bb	Bb

all black

	b	b
B	Bb	Bb
b	bb	bb

½ black : ½ white

INCOMPLETE DOMINANCE

Although all the traits that Mendel studied showed simple dominant or recessive forms, not all traits show this pattern of inheritance. In *blending inheritance*, or *incomplete dominance*, the heterozygous organism is different in appearance from either of the homozygous parents. The trait in question is intermediate in character between the two contrasting homozygous traits. For example, crossing pure red (RR) and pure white (WW) Japanese four-o'clocks results in an F_1 generation in which all the flowers are pink (RW).

1. As examples of blended inheritance, show a cross between a pure red snapdragon (RR) and a pure white snapdragon (WW). In the second square show a cross between two members of the F_1 generation (RW × RW). For each cross, give the phenotypes of the offspring.

	W	W
R	RW	RW
R	RW	RW

Phenotypes: all pink

	R	W
R	RR	RW
W	RW	WW

Phenotypes: 1 red, 2 pink, 1 white

CHAPTER 25 Activity 2. Basic Concepts in Genetics

CODOMINANCE

Codominance is a condition similar to incomplete dominance. In the heterozygous condition, one allele of a pair is not completely suppressed. An intermediate form, or blending, is expressed in the case of incomplete dominance. In *codominance,* both alleles are expressed. The roan coat in cattle is an example. If you cross an individual that is homozygous for white coat (C^WC^W) with one that is homozygous for red coat (C^RC^R), the offspring will have a roan-colored coat (C^RC^W). If the coat is viewed through a microscope, both red and white hairs are seen to be present, indicating that the alleles for red and white hair are expressed at the same time.

1. How is incomplete dominance expressed?
as a blended appearance

2. In a cross involving codominance, both dominant alleles are expressed.

MULTIPLE ALLELES

All traits discussed so far have been controlled by a single pair of alleles. However, there are some traits, such as blood type in humans, that involve more than two genes. Human blood type involved three genes—A, B, and O. Genes A and B are dominant, while O is recessive. The four homan blood types are A, B, AB, and O. Genotypes of multiple alleles are shown using the capital letter I for dominant and lowercase i for recessive. Thus, for example, type A blood is genotype I^AI^A or I^Ai, and type O blood is ii.

1. What are multiple alleles?
more than 2 alleles for a given gene locus

2. Name two traits in humans that are determined by multiple alleles.
Blood types

3. A man with type AB blood marries a woman with type O blood. Using the following Punnett square, show all possible genotypes of their offspring.

	O	O
A	AO	AO
B	BO	BO

4. Does any specific blood type illustrate the characteristics of codominance?
AB ⟷ A + B

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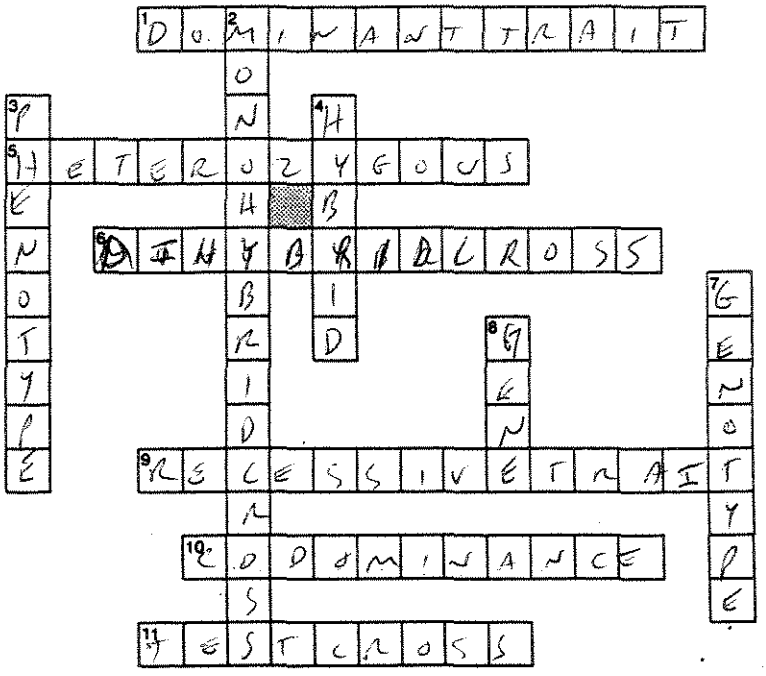
Chapter 25. Vocabulary Puzzle



Across

1. The trait that covers the expression of its contrasting allele.
5. Having two different alleles for a trait.
6. A cross involving two pairs of contrasting traits.
9. A trait that is masked in offspring with contrasting alleles.
10. Two dominant alleles are expressed at the same time without blending of the traits.
11. A test used to determine whether an organism is homozygous or heterozygous.

Down

2. A genetic cross involving one pair of contrasting traits.
3. The appearance of an individual as a result of its genetic makeup.
4. An individual that is heterozygous for a particular trait.
7. The genetic makeup of an individual.
8. A distinct unit of heredity.

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