LIFEPAC®

SCIENCE

STUDENT BOOK

10th Grade | Unit 7

Alpha Omega PUBLICATIONS

SCIENCE 1007

Genetics and Inheritance

LIFEPAC Test is located in the center of the booklet. Please remove before starting the unit.

Author:
A. Kenneth Moore, Ph.D.

Editor-in-Chief:
Richard W. Wheeler, M.A.Ed.

Editor:
Harold Wengert, Ed.D.

Consulting Editor:
Rudolph Moore, Ph.D.

Revision Editor:
Alan Christopherson, M.S.

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Alpha Omega
PUBLICATIONS

804 N. 2nd Ave. E.
Rock Rapids, IA 51246-1759

Genetics and Inheritance

In Genesis 1:1 we read, "In the beginning God created the heaven and the earth." Genesis 1:12 states, "And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind …" And again in Genesis 1:24 we read, "And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so."

How often have you seen a puppy or a kitten or a human baby that resembles its parents? Often we have made these observations without a second thought. As the Scripture indicates, offspring resemble their natural parents. A pig has never been known to give birth to a sheep or a snake to give birth to a pigeon. How beautiful and how significant are the laws of heredity that God provided at the Creation.

Up to the mid-nineteenth century heredity was thought to result from the flowing together of substances from all the parts of each parent's body and the blending of these substances to form a new individual. The new individual would not resemble either parent, but would have features of each. If this theory were true, however, how could two purple-flowered plants produce plants that bear white flowers? How could brown-eyed parents have a child with blue eyes? How could pure white and black goats produce spotted kids or white sheep have brown lambs or pure-colored cattle give birth to spotted calves? Read Genesis 30:30–31:12. We can conclude that some characteristics are common for a species, such as feathers, flying, and toothless beaks for grasping food, in birds; and yet other unique characteristics are found in the individual. The mechanism of heredity established by God at the Creation allows for change, and it provides for constancy from one generation to the next. Man was unaware of these principles until an Austrian monk, Gregor Mendel, discovered some of the pieces of the puzzle. Since that time, much progress has been made in completing the picture.

Objectives

Read the following objectives. The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC®. Each section will list according to the numbers below what objectives will be met in that section. When you have finished this LIFEPAC, you should be able to:

1. Describe how the principles of scientific investigation apply to the history of the study of heredity.
2. Explain the pattern by which single traits are transmitted from parents to offspring.
3. Describe the mechanism of probability and how inheritance of a trait is due to "chances."
4. Predict the types and frequency of traits in offspring.
5. Describe procedures to determine genotypes of individuals with dominant phenotypes.
6. Explain why gene expression may differ with different allelic combinations.
7. Compare chromosomes and genes.
8. Describe why genes and chromosomes are paired.
9. Describe how chromosomes control the inheritance of sex.

10. Explain the pattern by which a trait controlled by a sex-linked gene is inherited.
11. Outline the process of meiosis and explain why cells resulting from this process contain different combinations of genetic information.
12. Define nondisjunction and explain its significance in the appearance of chromosome disorders.
13. Describe how environmental factors may influence gene expression.
14. Explain how genetic information is encoded within the DNA molecule.
15. Describe how new hereditary factors arise.
16. Explain how the principles of genetics influence the development of an individual's characteristics.

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

1. GREGOR MENDEL'S EXPERIMENTS

Many historians have described Gregor Mendel as an obscure monk who stumbled onto the nature of hereditary mechanisms while tending his garden between morning and evening prayers. However, he was clearly an alert and practical scientist who entered the monastery as part of his academic training as well as in response to his religious convictions. During life prior to joining the monastery, Mendel exhibited an active interest in crop improvements as demonstrated by the many awards he received for developing new varieties of fruit and vegetables. Also, he established thirty-four "pure" strains of peas in his garden in preparation for **hybridization** experiments. In 1865 he published the results of his seven years of study on cross-breeding of his garden peas.

Why did Mendel select the garden pea? These plants were easy to grow and their pollen-producing stamen and egg-containing pistil were easy to reach. Normally, pea plants self-pollinate; but to selectively crossbreed his plants, Mendel would remove the stamen and cover the flower with a bag to prevent chance **pollination** from other pea plants in the garden. In his experiments Mendel would select flowers of plants with the desired **trait** and would dust the pollen from the stamen of one plant onto the pistil of the other plant. He observed the offspring of these plants for several generations.

Most of the plants studied were different only in a single trait or hereditary feature. For example, Mendel obtained tall plants that produced only tall plants when allowed to **self-fertilize**, and short plants that produced only short plants when self-fertilized. In total he studied seven traits:

seed shape: round versus wrinkled
internal seed color: yellow versus green plant pigmentation
seed coat color: pigmented versus unpigmented
height: tall (six to seven feet) versus short (nine to eighteen inches)
pod color: green versus yellow
pod shape: round and inflated versus constricted and wrinkled
flower position: flowers along stems (axial) versus flowers at the top only (terminal)

Hundreds of crosses between each of these pairs of traits were performed. Did the offspring resemble one or both of the parents, or did the characteristics blend?

Section Objectives

Review these objectives. When you have completed this section, you should be able to:

1. Describe how the principles of scientific investigation apply to the history of the study of heredity.
2. Explain the pattern by which single traits are transmitted from parents to offspring.
3. Describe the mechanisms of probability and how inheritance of a trait is due to "chances."
4. Predict the types and frequency of traits in offspring.
5. Describe procedures to determine genotypes of individuals with dominant phenotypes.
6. Explain why gene expression may differ with different allelic combinations.

Vocabulary

Study these following words to enhance your learning success in this section.

allele	**chromosome**	**deviation**
dihybrid cross	**dominant**	**F_1 generation**
F_2 generation	**gametes**	**gene**
genotype	**heterozygous**	**homozygous**
hybrid	**incomplete dominance**	**meiosis**
monohybrid cross	**multiple alleles**	**P_1 generation**
phenotype	**pollination**	
principle of independent assortment		**principle of segregation**
probability	**Punnett square**	**recessive**
self-fertilization	**test cross**	**trait**
true-breeding		

THE MONOHYBRID CROSS

When crossing a pair of "pure-breeding" plants that differed only in a single **trait**, Mendel dusted pollen from one strain on to the pistil of the opposite trait flower. In this and subsequent experiments in which he reversed the plant that provided stamen and pistil, he found that the results did not depend upon which was the male or female plant. From these observations he concluded that the male and female parents equally contribute hereditary material. In this section we will study Mendel's experiments, results, and conclusions. You will apply the results of Mendel's work to activities of your own to test your understanding of the Mendelian principles of heredity.

Mendel's results. The results observed when tall plants were crossed with short plants showed all the offspring to be tall. When yellow-seed plants were crossed with green-seed plants, only yellow seeds were produced. Furthermore, when the round-seeded variety were bred to the wrinkled-seeded variety, only round seeds were grown. Mendel found that for each of the seven pairs of traits, one of the characteristics present in the parent plants was apparently lost in the next generation. This observation led to the question, what would happen if these offspring were allowed to self-pollinate?

Since Mendel's experiments specific terms have been adopted to designate the original parental generation as the **P_1 generation**; the offspring of the P_1, **F_1 generation** (first filial generation); the offspring of the F_1, the **F_2 generation**; and so on.

The seeds produced by the cross-fertilization of the P_1 generation were collected and planted. The plants that grew are the F_1 or **hybrid**. The F_2 plants were grown from seeds collected from **self-fertilized** F_1 plants. A cross between plants that differs only in one characteristic is called a **monohybrid cross**.

Since traits of P_1 plants did not blend in producing the F_1 plants, Mendel called the trait that was apparent in the F_1 generation the **dominant** trait. He called the trait that disappeared the **recessive** trait. For example, when a plant with green pods was crossed with a plant with yellow pods, all of the F_1 plants produced green pods. Green pods were dominant and yellow pods were recessive.

Following self-fertilization, the F_1 generation plants gave rise to F_2 plants in which the recessive trait reappeared. Traits that had disappeared now resurfaced. Being trained in statistics, Mendel went a step further. He counted the individuals produced from several hundred F_1 crosses and tabulated the total number of plants with dominant traits and those with recessive traits. In the cross between plants with round and wrinkled seeds, he counted 7,324 peas in the F_2 generation. Of those peas, 5,474 were round-seeded and 1,850 were wrinkled. Mendel's mathematical mind did not miss the fact that these figures represent three round-seed plants being produced for every one wrinkled-seed plant (5,474 to 1,850), or a 3 to 1 ratio. When other monohybrid crosses were examined, all gave ratios of approximately 3:1 between dominant and recessive traits. (See Figure 1.)

P_1 Cross Dominant		Recessive	Frequency in F_2 Generation	Actual Ratio
1. round	x	wrinkled seeds	5474 round 1850 wrinkled 7324 total	2.96 : 1
2. yellow	x	green seeds	6022 yellow 2001 green 8023 total	3.01 : 1
3. colored	x	white seed coat	705 colored 224 white 929 total	3.15 : 1
4. inflated	x	constricted pods	882 inflated 299 constricted 1181 total	2.95 : 1
5. green	x	yellow pods	428 green 152 yellow 580 total	2.82 : 1
6. axial	x	terminal flowers	651 axial 207 terminal 858 total	3.14 : 1
7. long	x	short stems	787 long 277 short 1064 total	2.84 : 1

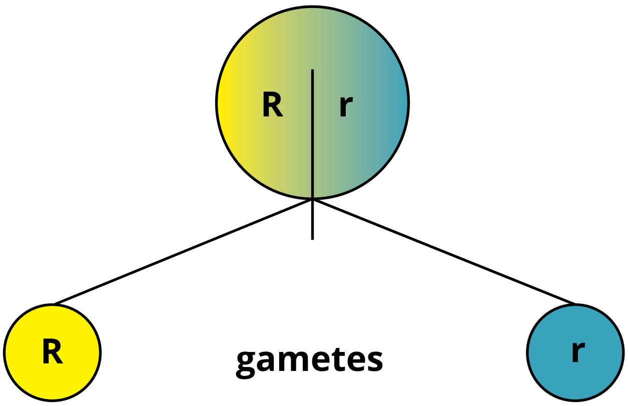
| Figure 1: Monohybrid-Cross Ratios

Mendel's conclusions. Having observed that traits which disappeared in the F_1 generation reappeared in the F_2 generation, Mendel reasoned that something must be present within the plant to control the characteristic. He called these unknown controls, *factors*. Today we call these unknown controls, **genes**. In addition, he reasoned that a given trait in peas is controlled by a pair of factors. What makes this conclusion impressive is that **chromosomes** and genes had not been discovered.

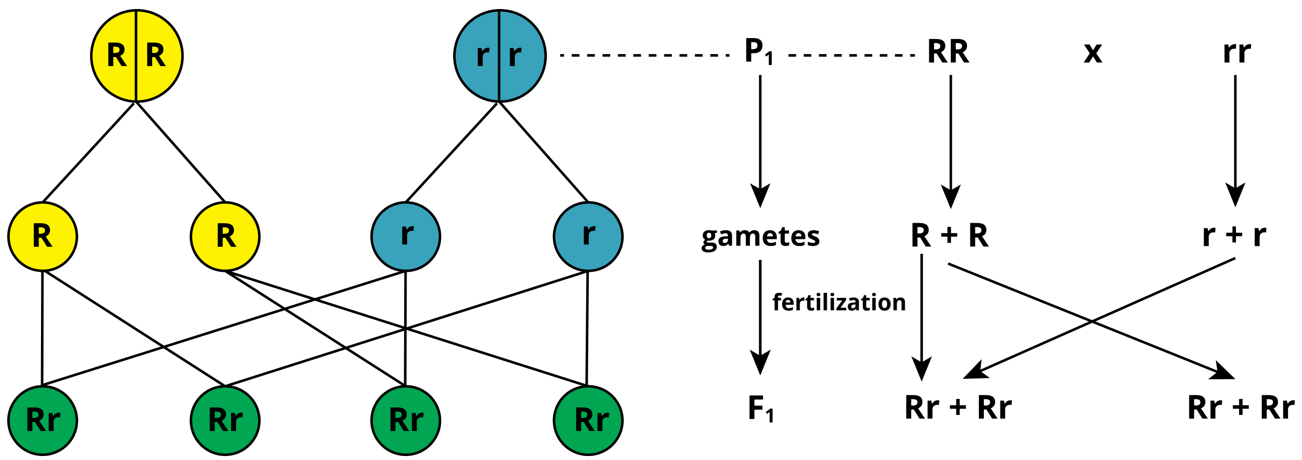
Mendel hypothesized that during gamete formation the pair of factors (genes) controlling a trait separated into single, individual gametes. Therefore, each gamete carried only one gene for the trait from each pair. This process of separation and gamete formation is referred to as Mendel's first principle, the **principle of segregation**.

A second conclusion Mendel developed is the *principle of dominance* and *recessiveness*. In explaining this principle he introduced the use of symbols such as Y and y to represent dominant and recessive traits, respectively. He suggested that each plant inherits two distinct hereditary factors for each trait, one from each parent. During **pollination** the plant passes one of the two factors in each reproductive cell (pollen grain or ovule).

Together Mendel's two conclusions can be used to explain how a trait can disappear in the F_1 generation and reappear later. Assign the letter Y for yellow seeds. A pure yellow-seeded plant would be written YY, which indicates that both factors (genes) for this trait are for yellowness. The dominant trait is assigned the capital letter. Similarly, the small letter y stands for the recessive trait, green seeds. Thus the pure green-seed producing plant would be represented as yy. When the genes of an organism are represented by pairs of symbols for a trait being studied, this pairing indicates the organism's **genotype**. By assigning the genotype in this manner, Mendel was able to make predictions as to the kinds and proportions of **gametes** or sex cells each parent could produce. Genes are located on chromosomes. During your study of cells in Science LIFEPAC 1003, you learned that chromosomes exist in pairs and that when gametes are produced, one member of each pair of chromosomes is found in a gamete and the other member of the chromosome pair is found in another gamete. That is, genes are passed to the offspring from the parents, one from each parent so that in the offspring a pair of chromosomes also exists. If one of the chromosomes has the dominant gene for a given trait and the other chromosome has the recessive gene for that trait, the dominant gene masks or hides the recessive trait. A recessive trait does not alter the outward appearance (**phenotype**) of the organism controlled by that dominant gene. Using Mendel's symbols, a cross between **true-breeding** round-seeded pea plants (RR) with wrinkled-seeded pea plants (rr) produced only round-seeded pea plants (Rr). This plant, having received a factor from each parent, possesses a dominant gene for round seeds and a recessive gene for wrinkled seeds. Since the two factors are different (Rr) the plant is said to be **heterozygous**. Each parent (RR and rr) having both genes alike is called **homozygous**. The different forms of genes associated with the same trait, but giving different effects (R and r), are called **alleles**. An allele is an alternative form of a gene.



| Figure 2: Gamete Formation



| Figure 3: Cross of Homozygous Dominant and Homozygous Recessive

Complete the following sentences.

1.1 The Austrian monk, a. ____________________ , stated that unknown structures called b. ____________________ were responsible for controlling hereditary traits.

1.2 The name later given to these structures was ____________________ .

1.3 Mendel claimed that these structures could be a. ____________________ or b. ____________________ with respect to one another.

1.4 A a. ____________________ trait completely hides or masks the presence of its counterpart, the b. ____________________ trait.

1.5 Mendel's first principle, the principle of a. ____________________ states that in the process of forming b. ____________________ , the two inheritance factors for any trait always c. ____________________ and are distributed to different d. ____________________ .

1.6 The difference between appearance and genetic makeup has led to the development of two terms to distinguish the two conditions. The appearance of the organism for the trait is called a. ________________ ; the actual genetic makeup is called b. ____________________ .

1.7 Consider the following cell information.

a. The cells of a pea plant are all derived from a single cell formed by the fusion of two ____________________ , one from each parent.

b. Each sex cell contains ____________________ the normal number of chromosomes.

c. The process that restores the normal chromosome number in the offspring is ____________ .

d. Any gene can occur in two or more different forms called ____________________ .

Match the following items.

1.8	________	heterozygous, dominant cell	a.	Rr
1.9	________	homozygous, recessive cell	b.	RR
1.10	________	homozygous definition	c.	rr
1.11	________	heterozygous definition	d.	identical alleles
1.12	________	homozygous, dominant cell	e.	unlike alleles
			f.	RY

Answer the following questions.

1.13 Using height in pea plants, what is meant by each of the following terms?

a. allele ____

b. homozygous ____

c. heterozygous ____

1.14 Why will a cross involving true-breeding tall pea plants and true-breeding small pea plants produce offspring that are all tall? In your answer give a definition of dominance. ___________

____

____

____

PROBABILITIES

The field of mathematics that deals with "chances" that a certain event may happen is the field of **probabilities**. This mathematical tool is useful only in chance or random occurring events. In this section you will study how the occurrence of specific events can be predicted.

Random events. Games of chance are excellent examples of probabilities of an event occurring. When flipping a coin or a marked disc, how often will the coin fall tails? What is the probability of it landing heads? Note that chance events ask the question, "How often will, or should, the event occur?"

The answer to these questions is usually expressed as a fraction or a percentage. If heads will appear 500 out of 1,000 times the coin is flipped, the chance for a head is 500/1000 or one-half. The alternative to a head is a tail. Therefore, the rest of the coin flips will result in tails, also a 50 percent chance.

Suppose that you have a group of color cards divided equally into four colors (red, black, yellow, and green) and that each color has fourteen cards, numbered from 1 to 14. The chance or probability of drawing a red card from the group is 14/56 or 1/4. The chance for drawing a 5 of any color from the group is 4/56 or 1/14.

Complete the following activities.

1.15 Calculate this probability.

a. What is the probability of drawing a red five from the group of cards described in the reading? ____________________

b. Explain. ____________________

1.16 Determine this probability.

a. What is the probability of a yellow-seed plant (YY) forming a Y gamete? ____________________

b. Explain. ____________________

1.17 Determine this probability.

a. What is the chance of a green-seed plant (yy) forming a y gamete? ____________________

b. Explain. ____________________

1.18 Make the following prediction.

a. If you have a heterozygous yellow-seed plant (Yy) what is the probability of forming a Y gamete? ____________________

b. A y gamete? ____________________

c. Explain. ____________________

____

Independent events. An important principle in probabilities is that the occurrence of a chance event during one trial does not influence the results of later trials. If you flip a coin and it comes up a head, what is the chance that the next flip will be a head? The chance for a head to occur on *any* flip is 1/2. A preceding event does not alter the probability of the next flip also being a head. If you toss the coin fifty times and all fifty turn up heads, the next toss still has a 50 percent chance of being a head.

This fact leads to the second important principle of probabilities; that is, if two trials are performed at the same time, the chance that the two independent events will occur together is the product of the chance for each occurring separately. For example, if you flip two coins at the same time, what is the chance for both coins turning up heads? The probability that a single coin will be heads is 1/2; therefore, the chance of having both heads is 1/2 x 1/2 or 1/4.

What is the chance of having both coins turn up tails? The answer is 1/2 x 1/2 = 1/4. This answer is due to the fact that the probability of two events occurring together is the product of each of their probabilities.

What is the chance of having the combination of one head and one tail? It is not 1/4, because two different ways exist to obtain this occurrence. You could have coin #1 turn up heads and coin #2 turn up tails (a probability of 1/2 x 1/2 = 1/4), or you could have coin #1 turn up tails and coin #2 turn up heads (a probability of 1/2 x 1/2 = 1/4). Each of these events follows the second principle; however, since this combination can occur in two ways, you add the probability of the two ways: 1/4 = 1/4 = 1/2.

Suppose you have a cube with each side numbered, from one to six. What is the chance of rolling that cube and having the side numbered 5 appear on top? Since the cube has six sides, the chance for any given side to appear on top is one out of six. If two cubes are rolled, what is the chance for both cubes to have the number 5 face up? The answer is 1/6 x 1/6 = 1/ 36, the product of the probability for each of the events.

Do the following investigation.

The following supplies are needed.

- 2 coins
- box (cardboard shoebox is good)

Follow the following directions and complete the activities.
Place a check in the box when each step is completed.

☐ 1. Do the following activity with another student. One person should toss a penny and the other serve as the recorder. The tosser should flip the penny in a cardboard box (shoebox) to prevent it from rolling away.

1.19 What are your chances for tossing a. a head? _______________ b. a tail? _______________

☐ 2. Toss the penny 10 times and record the number of times a head appears and the number of times a tail occurs.

Deviation Experiment

(Continued on next page)

1.20 Results obtained: a. heads ___________ b. tails ___________

How many times did you expect to get c. heads? ___________ d. tails? ___________

☐ 3. Calculate the **deviation** observed from the expected, using the following formula:

Difference between expected heads and observed heads ___________
+
Difference between expected tails and observed tails ___________
=
Deviation ___________
total number of tosses

The more the experimental results deviate from the expected results, the more the deviation value will approach the value of 1.0. As your results get closer to the expected results, the deviation is smaller and nears the value of 0.0.

1.21 The deviation for your 10 tosses is ____ .

1.22 Interpret the meaning of the deviation value you obtained. __________________________

____

☐ 4. Now continue tossing the coin and record your results until you have tossed the coin 100 times.

1.23 Results obtained:

heads obtained a. ______________ tails obtained b. ______________

heads expected c. ______________ tails expected d. ______________

1.24 What is the deviation for the 100 tosses? ____

____

☐ 5. Record the total number of heads and tails you obtained on the chalkboard. After the whole class has completed the coin tossing and recorded their results on the board, total the results for the class. If the class is small you may repeat the 100-toss trial several times and total the results.

1.25 Total tosses for the class ______________

1.26 Results of tosses:

heads obtained a. ______________ tails obtained b. ______________

Deviation Experiment

(Continued on next page)

1.27 Calculate the deviation.

Class deviation = ______________________________

1.28 How does increasing the total number of coin tosses from 10 to 100 affect the deviation?

____

____

1.29 How does increasing the total number of tosses from 100 to the total for the class (or added tosses) affect the deviation? ______________________________

____

1.30 What two important probability principles were established in this exercise?

a. ______________________________

b. ______________________________

☐ 6. Now obtain two pennies.

☐ 7. Toss the coins 100 times and record your results.

1.31 How many times did two heads occur, two tails occur, and one head and one tail occur?

HH obtained a. ______________________________

TT obtained b. ______________________________

HT obtained c. ______________________________

1.32 The percent of occurrence is the obtained results divided by the total tosses and multiplied by 100. Calculate the percent occurrence for each combination.

percent HH occurrence a. ______________________________

percent TT occurrence b. ______________________________

percent HT occurrence c. ______________________________

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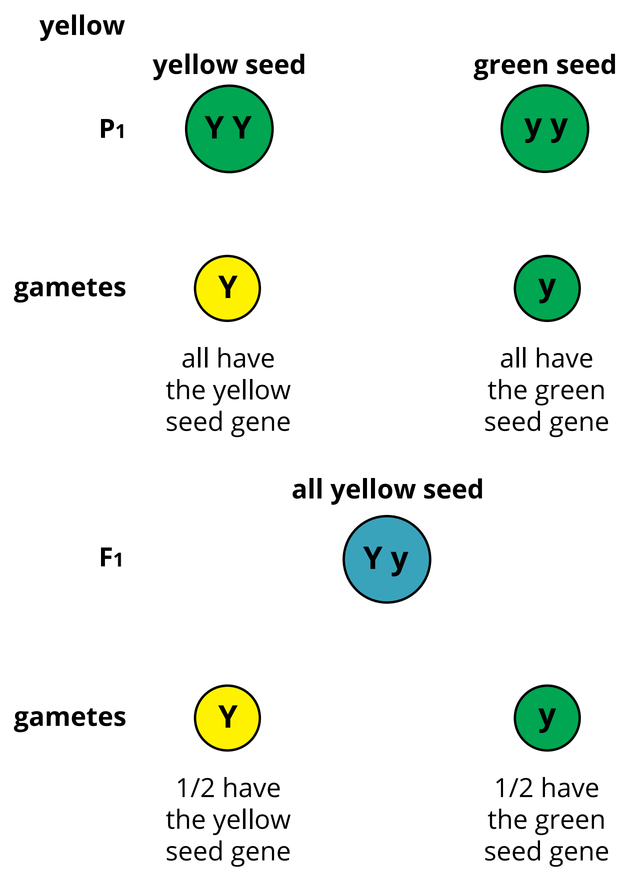
Deviation Experiment



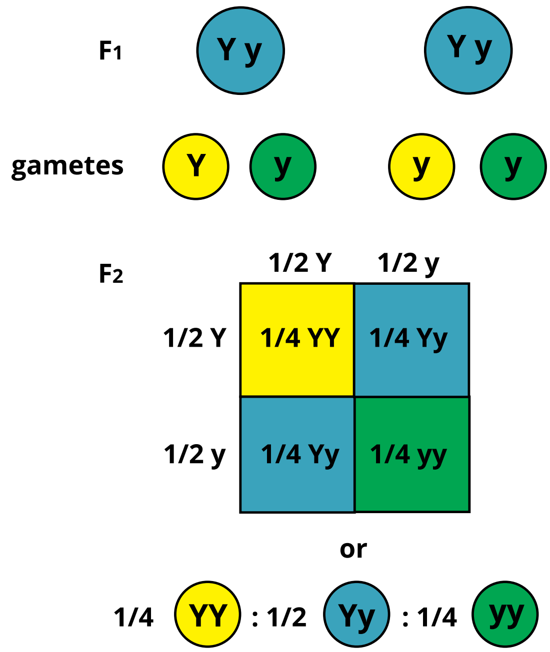
| Figure 4: Dominant-Recessive Cross

Since pairs of genes separated during the production of gametes and recombined during fertilization, Mendel was able to predict outcomes for specific crosses. True-breeding, yellow-seeded (YY) plants produce gametes all of which have the gene for yellow seeds (Y). True-breeding, green-seeded (yy) plants produce gametes all of which have the gene for green seeds (y). When a true-breeding, yellow-seeded plant is crossed with a true-breeding, green-seeded plant, the F_1 will receive a gene for yellow seed (Y) from one parent and a gene for green seed (y) from the other parent. All of the F_1 from this cross will have the same genotype (Yy) and the same phenotype (yellow seeds). Only one dominant gene from yellow is needed to instruct the plant to produce yellow seeds.

Since one of the two genes for seed-color in the F_1 plant is for yellow (Y) and the other for green (y), the gametes formed by the plant will contain different information. Half of the gametes will contain the heredity instructions for yellow seeds; and the other half, for green seeds. If both types of seeds are produced in equal numbers, the chance for an F_1 gamete to carry the yellow-seed trait is 1 out of 2 or 1/2, and the chance that it is carrying the green-seed trait is 1 out of 2 or 1/2. During cross-pollination an equal chance exists that any gamete will unite with any other gamete to form the F_2 plant. The chance, or probability, of two gametes pollinating is the product of the frequency of occurrence of each gamete. For example, the probability of a gamete with the Y gene uniting with another Y gene gamete is 1/2 x 1/2 = 1/4. The same result is true for two y gametes. That is, 1/4 of all F_2 plants should have two Y genes (YY) and have yellow seeds and 1/4 of all F_2 plants should have two y genes (yy) and have green seeds. What about the union of a Y gamete with a y gamete? The probability of the pollen carrying the Y trait is 1/2 , and the probability of the ovule having the y trait is 1/2, or the chances for a Y and y to be brought together at pollination is 1/2 x 1/2 = 1/4. However, the pollen could have been y (1/2) and the ovule could have been Y (1/2). In either case the fertilization would have produced a heterozygous plant Yy. Since the probability of producing a heterozygous F_2 plant is the sum of both probabilities, the probability is 1/4 + 1/4 = 2/4 = 1/2. These numbers represent a genotypic ratio of 1:2:1.

Because the yellow-seed gene is dominant, all of the heterozygous plants will produce seeds that are phenotypically yellow. Now examine the phenotypes of all of the F_2 plants: The yellow-seed producing plants are the 1/4 YY and the 1/2 Yy. When these figures are added together, you find that 3/4 of the plants produce yellow seeds and 1/4 produce green seeds (yy). This ratio is a 3 to 1 phenotypic ratio. Remember what Gregor Mendel observed in his cross-pollination studies, a 3 to 1 ratio.

Mendel's first principle is the *principle of segregation*. Offspring possess inheritance factors from each parent, and the factors are not fused, but they are passed separately to the next generation. This powerful tool provides the opportunity to understand the basis of heredity. It allows us to make predictions regarding hybridization in agriculture.



| Figure 5: F_2 Generation

Complete the following statements.

1.33 Genetics experiments on the breeding of plants or animals are based on the laws of

________________________ .

1.34 Consider the following events.

a. When flipping a penny, what is the chance that it will come up a head? ________________

b. If you flip the penny a second time, what is the chance that it will come up a head?

____

c. You have had 25 heads come up in 25 consecutive flips. If you flip the coin one more time,what is the chance of coming up with a head? ______________

d. The previous events are examples of the principle of ________________________ .

1.35 If you have two pennies, what is the probability of both coming up heads? ________________

1.36 What is the probability of having the combination of one head and one tail? ______________

1.37 The probability of two independent events occurring together is the ____________________ of the probability of each event occurring separately.

1.38 All probabilities are expressed as a. ____________________ between the range of b. ____________________ to c. ____________________ . (See Activity 1.20.)

Review the results of activities 1.31 and 1.32.

1.39 How do your results compare to what you predicted? ____________________

____

1.40 What can you do to have results closer to the predicted ones? ____________________

____

1.41 What major probability principle is demonstrated in this exercise? (Hint: It is a relationship between the probability of separate events and the probability of a combination of events).

____

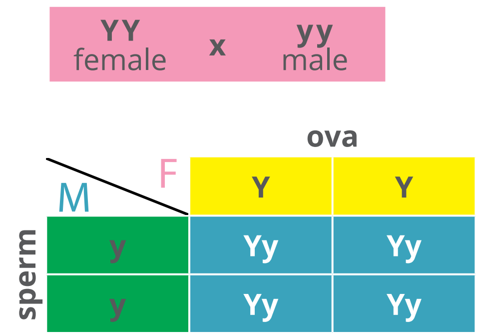
____

TEACHER CHECK __________ initials __________ date

CROSS PREDICTIONS

Mendel's work formed the basis of the genetic knowledge of today's geneticist. One of the activities of a geneticist is to predict the phenotype and genotype distribution of an experimental population resulting from different types of crosses. In this section you will learn how to predict population distributions from different types of crosses.

Punnett square. Studying genetics, we can use a checkerboard-like chart to diagram all of the possible combinations of gametes, the resulting fertilizations, and the types of offspring produced. The grid system used is called the **Punnett square** and is named after R. C. Punnett, the man who developed it. Across the top line of the grid the alleles present in the gametes of the female are indicated. Along the side of the grid the alleles found in the male gamete are shown. In the squares of the grid, the two gametes are joined together predicting the offspring and the two alleles of such a fertilization. For example, the P_1 cross between a true-breeding, yellow-seeded female and a green-seeded male is represented in Figure 6.



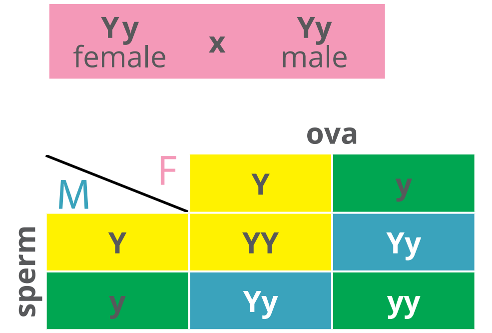
genotypic ratio: all Yy

phenotypic ratio: all yellow

| Figure 6:
Homozygous Dominant-Recessive Cross

Note that all of the offspring of the cross are geno-typically (Yy) and phenotypically (yellow seeds) alike.

The F_1 plants are allowed to self-fertilize forming a cross between two heterozygous plants, Yy and Yy. This cross is shown in Figure 7. In this cross the genotypes of the offspring are 1/4 YY, 1/2 Yy and 1/4 yy; the phenotypes are 3/4 yellow seed and 1/4 green seed.



genotypic ratio: 1YY: 2Yy: 1yy

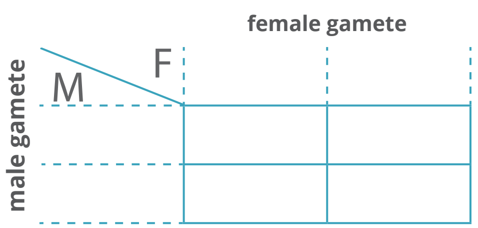
phenotypic ratio: 3 yellow: 1 green

| Figure 7: Heterozygous Cross

Complete the following activity.

1.42 Complete the Punnett square for each of the following cross-pollinations and give the genotypic and phenotypic ratios.

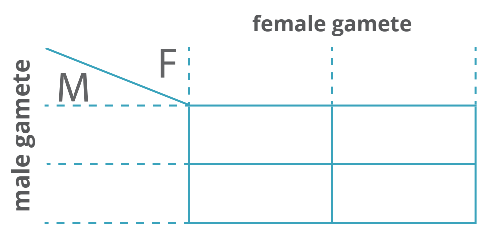
a. **YY x Yy**



genotypic ratio: ______________

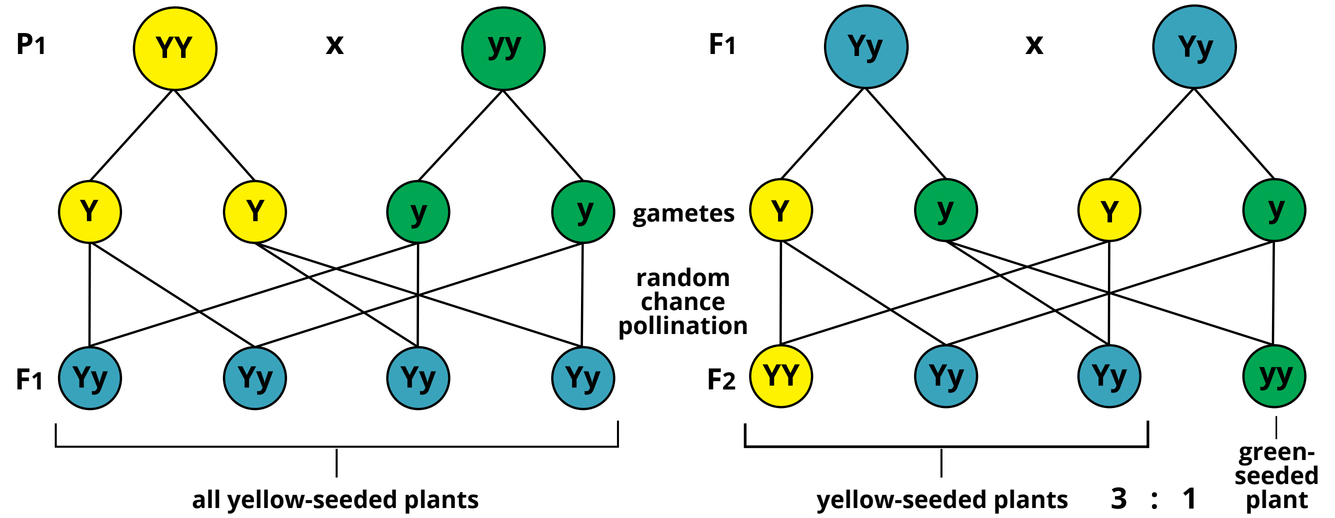
phenotypic ratio: ______________

b. **Yy x yy**



genotypic ratio: ______________

phenotypic ratio: ______________

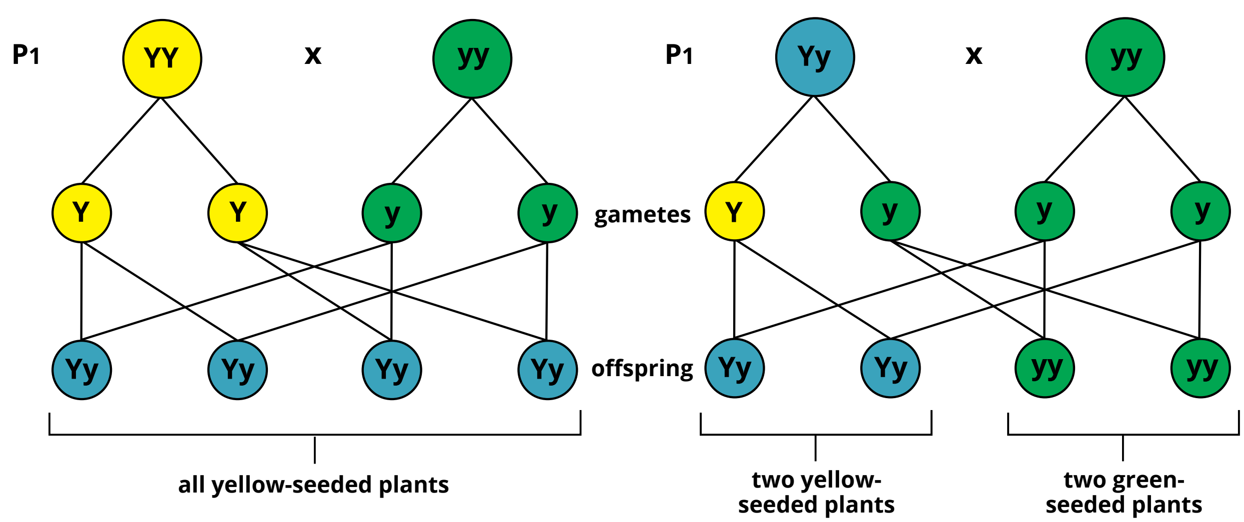


| Figure 8: F_1 and F_2 Generations

Crosses can be diagrammed another way. Study the above examples. These are the same cross-pollinations shown prior to Activities 1.42 and 1.43.

Test cross. When the organism being studied shows the dominant phenotype, such as yellow seeds or round seeds, how can you determine the geno-type? The genotype could be either YY or Yy. The method by which Mendel was able to determine the genotype of his peas is called the **test cross**.

To do a test cross, Mendel cross-pollinated the plant in question with a known true-breeding, recessive plant. In the case of the yellow-seeded plants, he crossed them with green-seeded plants (yy). If his yellow-seeded plant in question had a homozygous genotype (YY), all offspring from this cross would be yellow (Yy). However, if the plant in question happened to be heterozygous for yellow seeds, then half of the offspring would produce yellow seeds (Yy) and half would produce green seeds (yy).



| Figure 9: Test Cross Results

Note that by using a homozygous recessive to test cross, the homozygous recessive parent always provides a recessive gene in the gamete of the known plant. If the organism in question is heterozygous, the unknown parent will produce half of its gametes with the dominant trait and half with the recessive trait. By random chance in fertilization, one gamete has the same potential for fertilization as the other. Therefore, the two recessive genes should come together 50 percent of the time, indicating that the genotype in question is carrying a hidden recessive.

Complete the following activities.

1.43 Suppose you have pea plants in your garden and find that some produce round seeds and others produce wrinkled seeds. You collect the seeds and count them, finding that 10,793 seeds are round and 3,542 are wrinkled. These two phenotypes are alleles to each other.

a. Which allele is dominant? ______________________

b. Which allele is recessive? ______________________

c. Using symbols, write the possible genotypes for the round seeds. ______________________

d. Using symbols, write the possible genotypes for wrinkled seeds. ______________________

e. Describe what you would do to determine if a particular plant is homozygous or heterozygous. ____

____

____

f. Diagram the cross with symbols to illustrate the test results you could expect from the cross you predicted in e.

1.44 In your own words state Mendel's first principle and explain how it relates to genes and the formation of gametes. ____

____

1.45 What is a test cross? ____

____

1.46 Create a Punnett square that shows a test cross for a tall pea plant.

1.47 With the following crosses of pea plants, give the flower color of offspring and the ratio expected (red is dominant).

a. red x red (both homozygous) ______________________________

b. red x white (both homozygous) ______________________________

c. red (heterozygous) x white ______________________________

d. red (heterozygous) x red (homozygous) ______________________________

e. red x red (both heterozygous) ______________________________

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Dihybrid cross. To determine how two characters interact in inheritance, Mendel next crossed strains that differed in two traits. A two trait cross is called a dihybrid cross. For example, Mendel crossed plants having yellow (YY), round (RR) seeds with a strain that produced green (yy), wrinkled (rr) seeds. All the F_1 generation plants had the expected traits, because the yellow, round plants, which produced yellow, round seeds were dominant. This P_1 dihybrid cross can be diagrammed as shown in Figure 10.

P_1	**YYRR**	**x**	**yyrr**
gametes	**YR (all)**		**yr (all)**
F_1		**YyRr (all)**	

| Figure 10: Dihybrid Cross

The F_1 plants were then allowed to cross-pollinate. Note that each hybrid plant produces four kinds of gametes.

F_1 self-pollination **YyRr** **x** **YyRr**

gametes **YR** **Yr** **yR** **yr** **YR** **Yr** **yR** **yr**

| Figure 11: F_1 Dihybrid Cross

This separation of gametes indicates that the traits being studied appear on different pairs of chromosomes and that, when the pairs of chromosomes divide during **meiosis** (gamete production), one chromosome pair exerts no influence on any other chromosome pair. The cross-fertilization is random with chance ruling which types of gametes unite to produce F_2 plants. A Punnett square for the self-pollination of F_1 plants is shown in Figure 12.

female gametes

M (male gametes) \ F	YR	Yr	yR	YR
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

| Figure 12: Punnett Square for a Dihybrid Cross

The F_2 generation exhibits four different phenotypes, as follows:

- yellow, round seeds
  (both dominant traits) – 9/16
- yellow, wrinkled seeds
  (one dominant and one recessive trait) – 3/16
- green, round seeds
  (one recessive and one dominant trait) – 3/16
- green, wrinkled seeds
  (both recessive traits) – 1/16

This cross produces a 9:3:3:1 phenotypic ratio. In examining the genotypes you find some are homozy gous for yellow or round and others are heterozygous. All green or wrinkled seeds are homozygous for the recessive trait.

This data represent the second major principle that Mendel described, the **principle of independent assortment**. According to this principle, the separation of genes on a given pair of chromosomes into gametes is completely independent of the distribution of any other chromosome pair. Note that this principle applies only when the two traits being studied are on different chromosome pairs since the chromosomes, and not the genes, assort independently.

Complete the following activities.

1.48 A student analyzed ears of corn that demonstrated two traits in the F_2 kernels, purple and white colors and smooth and wrinkled shape. A tabulation of 135 individual kernels gave the following results.

purple smooth = 75 white smooth = 28
purple wrinkled = 24 white wrinkled = 8

a. How many phenotypes are present? ______________________________

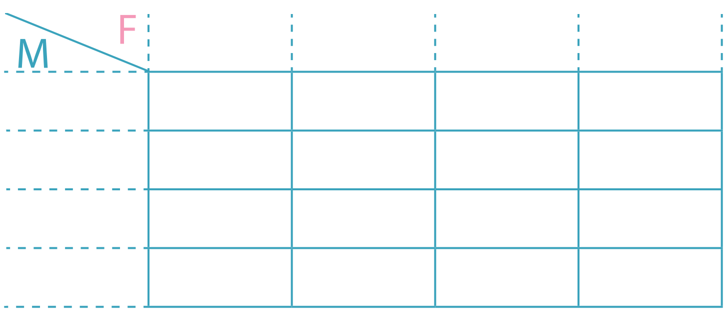
b. What are the phenotypes present? ______________________________

c. Estimate the best whole number ratio from your tabulations. ______________

d. Which alleles are dominant? ______________________________

e. Which alleles are recessive? ______________________________

f. Using symbols, diagram a cross that would give these results. Do a Punnett square making predictions for the outcome of this cross.



g. How do the corn kernel embryos compare in number to the predicted number? __________

____

h. Account for the difference between the expected and experimental values. ____________

____

1.49 Which of Mendel's main principles of inheritance is illustrated with these activities (1.48 a–h)?

____

1.50 Mendel's second principle, the principle of a. ______________________________ , states that the b. ______________________ of two or more pairs of factors occurs c. ________________________ or randomly.

1.51 Do genes from one parent congregate in one gamete and those from the other parent in other gamete? ____

____

1.52 In a dihybrid cross, why in the F_2 can we get nine genotypes, but only four phenotypes? _____

____

1.53 What will the phenotypic ratio be for the F_2 generation in a dihybrid cross?

____

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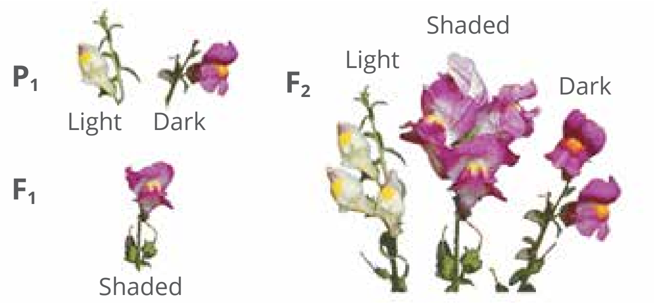
APPLICATION OF MENDELIAN GENETICS

Mendel's principles governing heredity have been shown to operate in many different species of plants and animals. His experiments have been repeated and have demonstrated that these principles apply to inheritance of traits in general. This section will help you explore some important applications of Mendelian genetics.



| Figure 13: Incomplete Dominance in Snapdragons

Applied genetics. In cattle the horned condition is a dominant trait while hornlessness is the recessive allele. Animals with horns can injure themselves or other cattle. To have greater efficiency in raising cattle and producing more beef for the table, the rancher wants to eliminate the horned condition from his herd. How can he establish a pure strain of hornless cattle that breeds true?

Similar types of breeding and pollination experiments are being performed in attempts to improve agricultural products. New breeds of hybrid corn, wheat, rice, and other crops are now available to give greater yields per acre as well as better nutritional value. One of the major nutritional problems in the world is the unavailability of adequate protein in the diet. In general, plant protein is low quality protein because they are short some of the amino acids essential for human growth and development. New corn varieties being developed by geneticists offer great promise in reducing the world protein deficiency problem.

Incomplete dominance. The traits and mechanisms of inheritance observed by Mendel describe dominant and recessive genes, but dominance does not occur in every trait. With some traits both alleles are expressed in the offspring. The occurrence of **incomplete dominance** or the blending of traits is not an uncommon event. The four-o'clock flower and the snapdragon illustrate this principle. When pure red (RR) are crossed with pure white (rr) varieties, all of the F_1 are pink. Neither red nor white is dominant; therefore, both colors are expressed in the heterozygous F_1. When two pink F_1 flowers are crossed, the F_2 ratio of plants approximates 1/4 red (RR), 1/4 white (rr), and 1/2 pink (Rr), or a 1:2:1 ratio.

Other examples of incomplete dominance include the roan color (red and white hairs intermingled) in cattle and the palomino color in horses. A roan calf is the heterozygous (Rr) F_1 produced by breeding red (RR) and white (rr) cattle. The F_2 generation is 1/2 roan, 1/4 red, and 1/4 white.

Complete the following activities.

1.54 Using symbols, diagram the cross between roan and white cattle.

1.55 Red-flowered snapdragons are crossed with white-flowered, producing all pink snapdragons in the F_1. What would you expect if you crossed

a. white with white? ______________________

b. red with red? ______________________

c. red with pink? ______________________

d. pink with pink? ______________________

e. pink with white? ______________________

f. pink with red? ______________________

1.56 Explain why a cross involving true-breeding, red snapdragons and true-breeding,white snapdragons produce all pink offspring. ______________________________

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Do the following Bible study.

1.57 Read Genesis 30:30–31:12 again. On the basis of what you have learned about inheritance, dominance, and recessive traits, explain the results of Jacob's increase in herd population.

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Multiple alleles. In your study thus far, the fact that a particular gene has either of two alleles has been assumed. Many instances are now known to have any one of a series of several alleles; therefore, an individual with a pair of genes may have any two alleles of this series. When three or more alleles may give the expression for a particular gene, they are said to be a series of **multiple alleles**.

One example to be described here is the color of a rabbit's coat. The normal wild-type rabbit has banded hairs. Nearest the skin it is gray, then a band of yellow, and finally a black or brown tip. This banded coloring is called *agouti*. Rabbits with albino hair, hair lacking pigmentation, are also known. Crosses between a true-breeding (homozygous) agouti and homozygous albino individuals produce an F_1, all being agouti. The F_2 from a breeding of F_1 rabbits yields a 3:1 ratio of agouti to white with agouti dominant over white. Clearly this breeding is the typical Mendelian monohybrid cross.

Other rabbits have been found to lack the yellow coat pigment and appear as a silvery-gray color. This silvery-gray color is known as *chinchilla*. A cross between a chinchilla rabbit and an agouti rabbit gives an F_1 of all agouti and the F_2 shows 3 agouti to 1 chinchilla. Thus, genes determining chinchilla and agouti appear to be alleles with agouti again dominant. If a cross is made between the chinchilla and albino, the F_1 are all chinchilla; and the F_2 shows 3 chinchilla to 1 albino. The chinchilla allele is dominant to the albino. Therefore, rabbits appear to have three different alleles for coat color: agouti, chinchilla, and albino.

Multiple-allele genes interact to produce a trait when neither dominant gene can produce its effect in the presence of the other.

Complete the following activities.

1.58 Indicate the coat color and the proportion of offspring with that color for each of the following crosses of rabbits. Assume all are homozygous.

a. agouti x agouti ______________________________

b. chinchilla x chinchilla ______________________________

c. agouti x albino ______________________________

d. chinchilla x albino ______________________________

e. albino x albino ______________________________

f. agouti x chinchilla ______________________________

1.59 Indicate the phenotypic ratio of the following crosses.

a. crossing the offspring from 1.58 c. (agouti x albino) ______________________________

b. crossing the offspring from 1.58 d. (chinchilla x albino) ______________________________

c. crossing the offspring from 1.58 f. (agouti x chinchilla) ______________________________

1.60 Interpret the results from 1.58 and 1.59. ______________________________

____

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Review the material in this section in preparation for the Self Test. The Self Test will check your mastery of this particular section. The items missed on this Self Test will indicate specific areas where restudy is needed for mastery.

SELF TEST 1

Write the letter for the correct answer (each answer, 2 points).

1.01 Gene individuals that carry contrasting inheritance factors are called ________ .
a. heterozygotes b. homozygotes c. alleles

1.02 In the cross BB x bb the percent of offspring in the F_1 generation that will have the same genotype as their parents is ________ .
a. 100% b. 50% c. 25% d. 0%

1.03 The total of all genes carried by an organism is referred to as the ________ .
a. genotype b. phenotype c. prototype

1.04 Mendel's principle of segregation implies that the two members of an allelic pair of genes ________ .
a. are distributed to separate gametes
b. may contaminate one another
c. are associated dependently depending on all other genes
d. are segregated pairwise

1.05 A (TT) genotype is said to be ________ .
a. homozygous b. heterozygous c. dihybrid

1.06 If the parent genotypes are Aa and Aa, the offspring are expected to be ________ .
a. 1/2 AA and 1/2 aa b all Aa
c. 1/4 AA, 1/2 Aa, 1/4 aa d. 3/4 AA and 1/4 aa

1.07 A family has seven sons. The chance that their eighth child will be a daughter is ________ .
a. one chance in seven b. one chance in eight
c. one chance in two d. practically none

1.08 The probability that both of two tossed coins will come down heads (or tails) is ________ .
a. 1/2 x 1/2 or 1/4 b. 1/4 x 1/4 or 1/2 c. 1/4 x 1/4 or 1/8

1.09 This cross will yield four phenotypes in the 1:1:1:1 ratio: ________ .
a. rryy x rryy b. RrYy x rryy c. RrYy x RrYy d. RRYY x rryy

1.010 Different forms of a given gene are known as ________ .
a. alleles b. chromosomes c. recessives d. dominants

1.011 For a recessive gene to appear in an individual, he must inherit ________ .
a. two genes for that trait b. one gene for that trait
c. three genes for that trait d. no genes for that trait

1.012 When neither of the genes of a pair is dominant or recessive, the genes are said to be

________ .

a. multiple alleles
b. incomplete dominant alleles
c. incomplete alleles

Define the following terms (each answer, 3 points).

1.013 allele ____________________

1.014 heterozygous ____________________

1.015 monohybrid cross ____________________

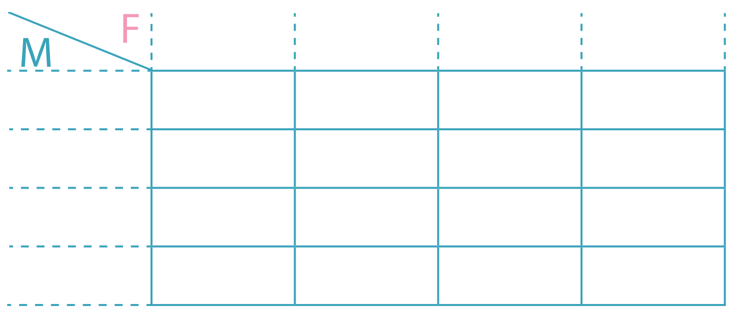
1.016 phenotype ____________________

1.017 multiple alleles ____________________

1.018 test cross ____________________

Complete these items (each answer, 5 points).

1.019 Complete the Punnett square for a cross between YyRr and YyRr showing number and genotype of the gametes, genotype and phenotype ratios of the F_2 generation, and the ratio of traits.



1.020 How can knowledge of genetics be used to improve the agricultural production of food?

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____

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42/52 **SCORE** ________ **TEACHER** ________ ________
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