## Review the Concepts

Work through the following exercises to review the concepts in this chapter. For additional review, check out the activities at www.mybiology.com. The website offers a pre-test that will help you plan your studies.

### Exercise 1 (Modules 9.1 – 9.4)

These modules discuss the basic principles of heredity and introduce the vocabulary of genetics. Read the modules carefully, and then practice using the vocabulary by matching each phrase on the left with a word or phrase on the right. (This is just a start; you will remember these terms better as you use them.)

_____ 1. A unit that determines heritable characteristics
_____ 2. Varieties that always produce offspring identical to parents
_____ 3. The offspring of two different varieties
_____ 4. When two alleles of a pair differ, the one that is hidden
_____ 5. A feature that varies among individuals, such as flower color
_____ 6. Parent organisms that are mated
_____ 7. A diagram that shows possible combinations of gametes
_____ 8. A breeding experiment that uses parents different in one character
_____ 9. One of the alternative versions of a gene for a character
_____ 10. Relative numbers of organisms with various traits
_____ 11. An organism that has two different alleles for a gene
_____ 12. Each variant of a character, such as purple and white flower color
_____ 13. An organism's genetic makeup
_____ 14. Separation of allele pairs that occurs during gamete formation
_____ 15. Fertilization of a plant by pollen from a different plant
_____ 16. An organism that has two identical alleles for a gene
_____ 17. The science of heredity
_____ 18. The location of a gene on a chromosome
_____ 19. What an organism looks like; its expressed traits
_____ 20. Offspring of the $F_1$ generation
_____ 21. When pollen fertilizes eggs from the same flower
_____ 22. Separation of allele pairs during gamete production
_____ 23. When two alleles of a pair differ, the one that determines appearance
_____ 24. Where the two alleles for a certain character are located
_____ 25. Offspring of the P generation
_____ 26. A hybridization

A. Allele
B. Homozygous
C. Hybrid
D. Genotype
E. Segregation
F. $F_2$ generation
G. True-breeding
H. Heterozygous
I. Self-fertilization
J. Dominant
K. P generation
L. Monohybrid cross
M. Locus
N. Phenotype
O. Cross
P. $F_1$ generation
Q. Recessive
R. Homologous chromosomes
S. Gene
T. Phenotypic ratio
U. Trait
V. Cross-fertilization
W. Punnett square
X. Character
Y. Genetics
Z. Segregation

## Exercise 2 (Modules 9.3–9.4)

Test your knowledge of Mendel's principles by answering the following questions. You may want to test your ideas on scratch paper.

1. A pea plant with green pods is crossed with a plant with yellow pods. (Note: We're talking about the *pods* here, not the peas inside!) All their offspring have green pods.
   a. Which allele is dominant? Which allele is recessive?

   b. Using letters, what is the genotype of the green parent? The yellow parent?

   c. What are the genotypes of the offspring?

2. $F_1$ pea plants from the above cross are crossed. Use a Punnett square to figure out the genotypic and phenotypic ratios in the $F_2$ generation.
   a. Genotypic ratios:

   b. Phenotypic ratios:

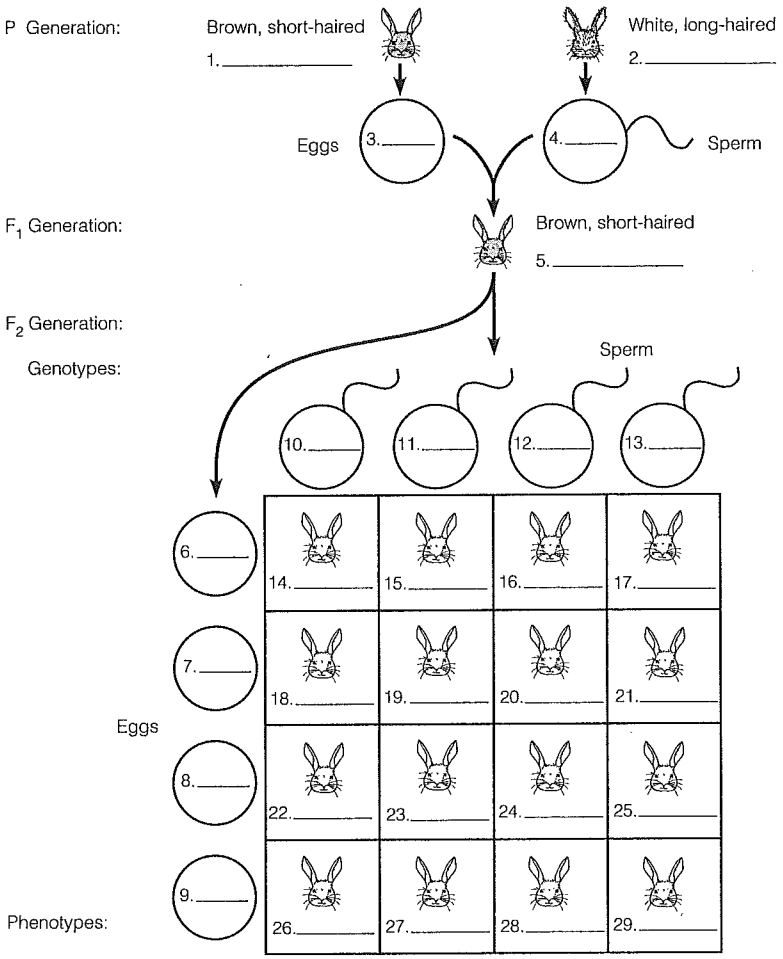
3. Two black mice mate. Six of their offspring are black and two are white.
   a. What are the genotypes of the parents?

   b. For which offspring are you sure of the genotypes?

## Exercise 3 (Module 9.5)

Gregor Mendel studied the inheritance of two characteristics at once and found that each pair of alleles segregates independently during the formation of gametes. In other words, if a tall pea plant with purple flowers is crossed with a short plant with white flowers, some of their descendants can be tall with white flowers. The tall and purple alleles do not have to stick together—they are independent.

So far, the textbook has discussed inheritance in peas and dogs. Just to be different, let's look at a genetic cross involving rabbits. In rabbits, the allele for brown coat is dominant, the allele for white coat recessive. The allele for short fur is dominant, the allele for long fur recessive. Imagine mating a true-breeding brown, short-haired rabbit with a white, long-haired rabbit. Using Module 9.5 as a model, write the genotypes of rabbits and gametes in the P, $F_1$, and $F_2$ generations in the blanks in the Punnett square. You may want to modify the drawings (add some hair and color) to show the phenotypes of the rabbits in the $F_2$ generation. Then use the Punnett square to figure out the phenotypic ratios in the $F_2$ generation—the proportion of rabbits that you can expect to be brown and short-haired, brown and long-haired, white and short-haired, and white and long-haired. Write their phenotype and their proportions in the blanks at the bottom.




30. _____ 31. _____

32. _____ 33. _____

34. _____ 35. _____

36. _____ 37. _____

## Exercise 4 (Module 9.6)

After reading this module on testcrosses, test your understanding by answering the following questions.

1. Recall that brown coat color in rabbits is dominant and white color is recessive. Suppose you have a group of rabbits—some brown and some white.
   a. For which phenotype(s) do you know the genotype(s)?

   b. For which phenotype(s) are you unsure of the genotype(s)?

2. Using *B* and *b* to symbolize the brown and white alleles:
   a. What are the possible genotypes of a white rabbit in your group?

   b. What are the possible genotypes of a brown rabbit?

3. Suppose you wanted to find out the genotype of a brown rabbit. What color rabbit would you mate it with?

4. A brown buck (male) is mated with a white doe (female). In their litter of 11 young, six are white and five are brown. Using a Punnett square to check your answer, what is the genotype of the buck?

5. Use a Punnett square to figure out the ratio of brown and white offspring that would have been produced by the above mating if the brown buck had been homozygous.

6. If half the offspring from a testcross are of the dominant phenotype and half are of the recessive phenotype, is the parent of the dominant phenotype (but unknown genotype) homozygous or heterozygous?

7. If all the offspring from a testcross are of the dominant phenotype, is the parent with the dominant phenotype (but unknown genotype) homozygous or heterozygous?

## Exercise 5 (Module 9.7)

The rules of probability can be used to predict the flip of a coin, the drawing of a card from a deck, or the roll of a pair of dice. They also govern segregation and recombination of genes. Read Module 9.7 carefully, and then fill in the blanks below.

The probability scale ranges from [1]_____ (an event that is certain not to occur) to [2]_____ (an event that is certain to occur). The probabilities of all possible outcomes for an event must add up to [3]_____. Imagine rolling a pair of dice, one die at a time. Each of the six faces of a die has a different number of dots, from one to six. If you roll a die, the probability of rolling a one is [4]_____. The probability of rolling any number other than one is [5]_____. The outcome of a given roll is unaffected by what has happened on previous rolls. In other words, each roll is a(n) [6]_____ event.

If you roll two dice simultaneously, what is the probability of "snake eyes" (both ones)? The roll of each die is an independent event. The probability of such a

compound event (both dice coming up ones) is the [7]_____ of the separate probabilities of the independent events. Therefore, the probability of rolling two ones is [8]_____ × [9]_____ = [10]_____. This is called the rule of [11]_____.

This rule also governs the combination of genes in genetic crosses. The probability that a heterozygous *(Pp)* individual will produce an egg containing a *p* allele is [12]_____. The probability of producing a *P* egg is also [13]_____. If two heterozygous individuals are mated, what is the probability of a particular offspring being [14]_____ recessive *(pp)*? The probability of producing a *p* egg is 1/2. The probability of producing a *p* sperm is also 1/2. The production of egg and sperm are independent events, so to calculate their combined probability we use the rule of [15]_____. Thus the chance that two *p* alleles will come together at fertilization to produce a *pp* offspring is [16]_____ × [17]_____ = [18]_____.

Back to the dice for a moment. What is the probability that a roll of two dice will produce a three and a four? There are two different ways this can occur. The first die can come up a three and the second a four, or the first can come up a four and the second a three. The probability of the first combination is $1/6 \times 1/6 = 1/36$. The probability of the second is also $1/6 \times 1/6 = 1/36$. According to the rule of [19]_____, the probability of an event that can occur in two or more alternative ways is the [20]_____ of the separate probabilities of the different ways. The probability of rolling a three and a four is therefore [21]_____ + [22]_____ = [23]_____.

Similarly, what is the probability that a particular offspring of two heterozygous parents will itself be heterozygous? The probability of the mother producing a *P* egg is [24]_____. The probability of the father producing a *p* sperm is also [25]_____. Therefore, the probability of a *P* egg and a *p* sperm joining at fertilization is [26]_____ × [27]_____ = [28]_____. Or a *p* egg and a *P* sperm could join. The probability of this occurring is also [29]_____. According to the rule of addition, the probability of an event that can occur in two alternative ways is the sum of the separate probabilities. Therefore, the probability of heterozygous parents producing a heterozygous offspring is [30]_____ + [31]_____ = [32]_____.

## Exercise 6 (Module 9.8)

After you read this module, use the information in the illustration to solve the following problems. You will probably want to work out Punnett squares on scratch paper.

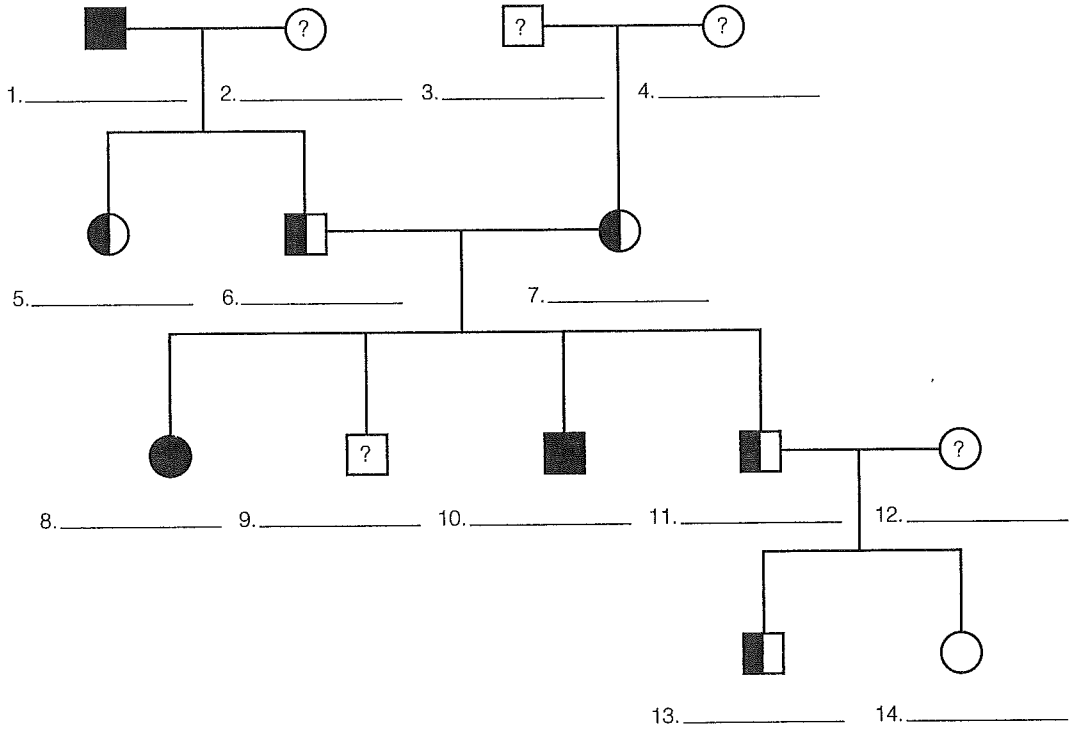
1. A man and woman, both without freckles, have four children. How many of the children would you expect to have freckles?

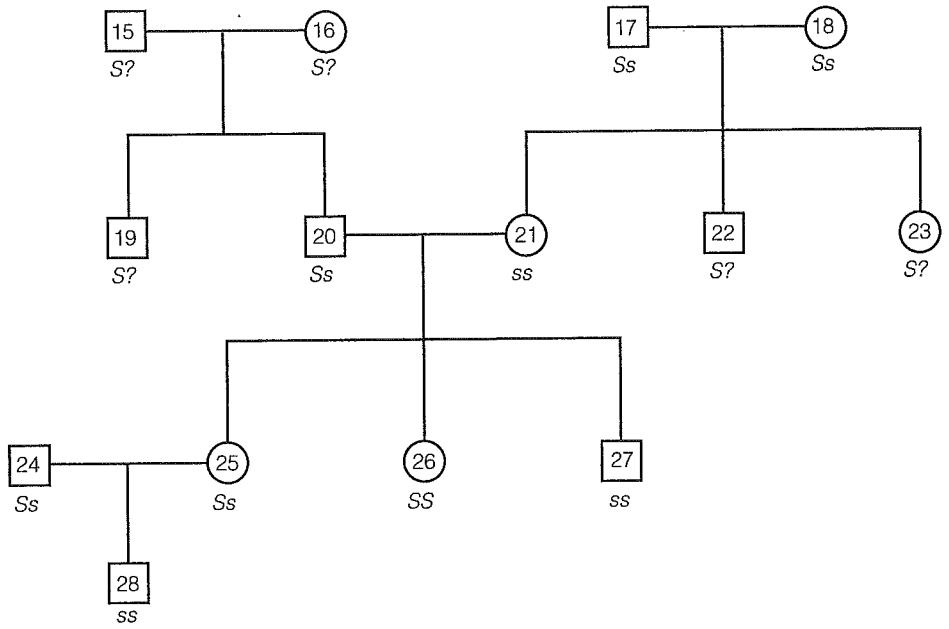
2. Both Fred and Wilma have widow's peaks. Their daughter Shirley has a straight hairline. What are Fred and Wilma's genotypes?

3. A man and woman both have free earlobes, but their daughter has attached earlobes. What is the probability that their next child will have attached earlobes?

## Exercise 7 (Module 9.8)

Family trees called pedigrees are used to trace the inheritance of human genes. The two pedigrees below show the inheritance of sickle-cell disease (described in Modules 9.9 and 9.13), which is caused by an autosomal recessive allele. In the first pedigree, the square and circle symbols are colored, as far as genotypes are known. Fill in the genotypes—*SS*, *Ss*, or *ss*—below the symbols. Use question marks to denote unknown genotypes. Complete the second pedigree by coloring in the symbols, following the rules described in Module 9.8. Again denote unknowns with question marks.



## Exercise 13 (Module 9.20)

What determines an individual's sex? Sex is generally determined by genes and chromosomes, but the process of sex determination works differently in different species. Match each group of organisms below with their system of sex determination.

_____ 1. Most plants, including peas, and corn (earthworms and land snails too)
_____ 2. Humans and fruit flies
_____ 3. Date palms and marijuana
_____ 4. Some butterflies, birds, and fishes
_____ 5. Grasshoppers and roaches
_____ 6. Ants, bees
_____ 7. Wild strawberries

A. Females are ZW, males ZZ.
B. Females are diploid, males haploid.
C. Females are XX, males XO (one X).
D. Females are XX, males XY.
E. Sexes not separate; all individuals produce both eggs and sperm.

## Exercise 12 (Modules 9.20–9.23)

Genes located on the sex chromosomes—called sex-linked genes—determine many traits unrelated to maleness or femaleness. Due to the X-Y sex-determination system of humans, sex-linked traits show a peculiar pattern of inheritance. Red-green color blindness is a recessive sex-linked trait in humans. After reading these modules, see if you can describe the inheritance of color blindness by filling in the blanks below.

The genes for normal color vision and red-green color blindness, like most human sex-linked traits, are carried on the [1]_____ chromosome. A capital letter *C* represents the [2]_____ allele for normal vision; a small *c* represents the color-blindness allele. A male with normal color vision has the genotype [3]_____. (Because these genes are carried on the X chromosome, their symbols are shown as superscripts on the letter X.) A color-blind male has the genotype [4]_____.

A color-blind male will transmit the allele for color blindness to all his [5]_____ but none of his [6]_____. This is because only his daughters inherit his [7]_____ chromosome, and only his [8]_____ chromosome is passed to all his sons. All the children of a color-blind male and a homozygous dominant female will have normal color vision. Their sons will inherit only the normal vision allele, but their daughters will be [9]_____ of the color-blindness allele, thus possessing the genotype [10]_____.

A heterozygous female carrier transmits the color-blindness allele to [11]_____ of her offspring. If she and a male with normal vision have children, [12]_____of their sons will be normal and [13]_____ will be color blind. [14]_____ of their daughters will be normal, because they inherit at least one dominant allele from their [15]_____. But half these daughters will be [16]_____ of the color-blindness trait, because they inherit the color-blindness allele from their mother.

Color blindness is much more common in men than in women. If a man inherits a single color-blindness allele from his [17]_____, the gene will be expressed

and he will be color blind. Because a man has only one [18]_____chromosome, whatever genes it carries are seen in the man's phenotype. If a woman inherits just one color-blindness allele, she has relatively normal vision, because the dominant normal allele on her other X chromosome masks most of the effects of the color-blindness allele. For a woman to be color blind, she would have to inherit [19]_____ alleles from both her mother and her father, which is much less likely.

Because the Y chromosome is so much smaller than the X, it carries many fewer genes. One important gene on the Y chromosome is called the [20]_____ gene. It seems to code for proteins that control other genes on the Y related to "maleness." The Y chromosome is special—it is the only chromosome unique to one sex. (Both men and women, after all, possess [21]_____ chromosomes.) Because the Y is passed essentially unchanged from father to son, it is useful for tracing human [22]_____. But lest men become smug about this unique genetic endowment, it is perhaps relevant to note that the Y chromosome is the only chromosome that an individual can live without. (Think about it!)

## Test Your Knowledge

### Multiple Choice

1. How did Mendel's studies in genetics differ from earlier studies of breeding and inheritance?
   **a.** Mendel worked with plants; earlier studies used animals.
   **b.** Mendel was able to explain the "blending" hypothesis.
   **c.** Mendel's work was more quantitative.
   **d.** Mendel worked with wild species, not domesticated ones.
   **e.** Mendel found that offspring inherit characteristics from both parents.

2. A true-breeding fruit fly would be _____ for a certain characteristic.
   **a.** homozygous dominant
   **b.** homozygous recessive
   **c.** heterozygous
   **d.** Any of the above can be true-breeding.
   **e.** a or b

3. When looking at the inheritance of a single characteristic, Mendel found that a cross between two true-breeding peas (between purple and white, for example) always yielded a _____ in the $F_2$ generation.
   **a.** 1:1 phenotypic ratio
   **b.** 3:1 genotypic ratio
   **c.** 1:2:1 phenotypic ratio
   **d.** 3:1 phenotypic ratio
   **e.** 1:1 genotypic ratio

4. Alternative forms of genes for a particular character are called
   **a.** traits.
   **b.** alleles.
   **c.** linked genes.
   **d.** genotypes.
   **e.** phenotypes.

5. A fruit fly has two genes for eye color, but each of its sperm cells has only one. This illustrates
   **a.** independent assortment.
   **b.** linked genes.
   **c.** pleiotropy.
   **d.** polygenic inheritance.
   **e.** segregation.

6. Mendel made some crosses where he looked at two characteristics at once—round yellow peas crossed with wrinkled green peas, for example. He did this because he wanted to find out
   **a.** how new characteristics originated.
   **b.** whether different characteristics were inherited together or separately.
   **c.** how plants and animals adapt to their environments.
   **d.** whether the characteristics influence each other—whether color affects degree of roundness, for example.
   **e.** Actually, Mendel never had a clear purpose in mind.

7. A pea plant with purple flowers is heterozygous for flower color. Its genotype is *Pp*. The *P* and *p* alleles in the pea plant's cells are located
   a. next to each other on the same chromosome.
   b. at corresponding locations on homologous chromosomes.
   c. on the X and Y chromosomes.
   d. at different locations on the same chromosome.
   e. at different locations on homologous chromosomes.

8. When an individual has both $I^A$ and $I^B$ blood group alleles, both genes are expressed and the individual has group AB blood. This is an example of
   a. codominance.
   b. a dihybrid.
   c. pleiotropy.
   d. incomplete dominance.
   e. linked genes.

9. How many genes are there on one chromosome?
   a. one
   b. two
   c. hundreds
   d. thousands
   e. millions

10. Which of the following is *not* true of linked genes?
    a. They tend to be inherited together.
    b. They violate Mendel's principle of independent assortment.
    c. They are on the same chromosome.
    d. They can form new combinations via crossing over.
    e. They are relatively rare; most genes are unlinked.

11. T. H. Morgan and his students were able to map the relative positions of genes on fruit fly chromosomes by
    a. coloring chromosomes with dyes and observing them under a microscope.
    b. scrambling the chromosomes and observing how the flies changed.
    c. crossing various flies and looking at the proportions of offspring.
    d. transplanting chromosomes from one fly to another.
    e. looking at crosses that showed independent assortment.

12. The sex chromosomes of a human female are ____. The sex chromosomes of a human male are ____.
    a. XX . . . XY
    b. YY . . . XX
    c. XX . . . YY
    d. XY . . . XX
    e. YY . . . XY

13. Most sex-linked traits in humans are carried on the ____ chromosome, and the recessive phenotypes are seen most often in ____.
    a. X . . . women
    b. X . . . men
    c. Y . . . women
    d. Y . . . men

14. The most common fatal genetic disease in the United States is
    a. sickle-cell disease.
    b. cystic fibrosis.
    c. Huntington's disease.
    d. hemophilia.
    e. PKU.

15. The Y chromosome is useful for tracing ancestry because
    a. every human has one.
    b. it carries a large number of genes.
    c. it carries a small number of genes.
    d. it is the location of most sex-linked genes.
    e. it is passed on virtually unchanged.

16. Which of the following human genetic disorders is sex linked?
    a. hemophilia
    b. PKU
    c. cystic fibrosis
    d. sickle-cell disease
    e. all of the above

17. There are various procedures that can be used to detect genetic disorders before birth. Among the tests discussed in this chapter, _____ is the least invasive, while _____carries the highest risk.
    a. chorionic villus sampling . . . amniocentesis
    b. ultrasound imaging . . . genetic screening
    c. ultrasound imaging . . . chorionic villus sampling
    d. chorionic villus sampling . . . ultrasound imaging
    e. amniocentesis . . . ultrasound imaging

### Essay

1. Explain why Gregor Mendel was able to figure out the principles of heredity, while many other investigators before (and some after) Mendel failed to do so.
2. If you flip two coins, the probability that you will get two heads is 1/4, but the probability that you will get one head and one tail is 1/2. Explain why.
3. Why are organisms such as peas and fruit flies better subjects for genetics studies than human beings?
4. What determines a human's sex? Describe two other systems of sex determination in different organisms.
5. What are some of the ethical questions posed by genetic testing?

## Apply the Concepts

### Multiple Choice

1. A brown mouse is mated with a white mouse. All of their offspring are brown. If two of these brown offspring are mated, what fraction of their offspring will be white?
   a. all
   b. none
   c. 1/4
   d. 1/2
   e. 3/4
2. Suppose you wanted to know the genotype of one of the brown $F_2$ mice in question 1. The easiest way to do it would be to
   a. keep careful records of the parent mice.
   b. mate it with a brown mouse.
   c. mate it with a mouse of its own genotype.
   d. mate it with a white mouse.
   e. It can't be done.
3. Some dogs bark while trailing; others are silent. The barker gene is dominant, the silent gene recessive. The gene for normal tail is dominant over the gene for screw (curly) tail. A barker dog with a normal tail who is heterozygous for both characteristics is mated to another dog of the same genotype. What fraction of their offspring will be barkers with screw tails?
   a. 3/4
   b. 9/16
   c. 3/16
   d. 1/4
   e. 1/16
4. Two heterozygous tall pea plants with purple flowers are crossed. The probability that one of their offspring will have white flowers is 1/4. The probability that one of their offspring will be short is 1/4. What is the probability that one of their offspring will be short with white flowers?
   a. 0
   b. 1/16
   c. 1/8
   d. 1/4
   e. 1/2
5. A young woman had a baby. Her blood group is AB. The baby's blood group is A. There are two possible fathers: Jim is group A, and Michael is group O. Which man could be the father?
   a. either
   b. Jim
   c. Michael
   d. neither
   e. impossible to tell given this evidence
6. Which of the following illustrates pleiotropy?
   a. In fruit flies, the genes for scarlet eyes and hairy body are located on the same chromosome.
   b. Matings between earless sheep and long-eared sheep always result in short-eared offspring.
   c. Wheat kernels can range from white to red in color, a trait controlled by several genes.
   d. The human cystic fibrosis gene causes many symptoms, from respiratory distress to digestive problems.
   e. An individual with both $I^A$ and $I^B$ alleles has blood group AB.
7. When two gray-bodied fruit flies are mated, their offspring total 86 gray-bodied males, 81 yellow-bodied males, and 165 gray-bodied females. The allele for yellow body is
   a. sex-linked and dominant.
   b. not sex-linked and dominant.
   c. sex-linked and recessive.
   d. not sex-linked and recessive.
   e. impossible to say on the basis of this information.