

# Finding Phenotypes And Genotypes For Two Traits

In genetics, a Punnett square is used to show the chances that certain traits will appear in offspring. If only one trait is involved, a Punnett square with four boxes is used. If two traits are involved, then a sixteen box Punnett square is needed. A Punnett square always gives you the expected results. Offspring, however, are produced by chance and may not agree exactly with expected results.

In this investigation, you will

- substitute properly marked coins for gamete cells and toss the coins to represent offspring.
- determine the expected offspring and compare it to observed offspring obtained through coin tossing.
- write a report based on your data explaining the similarity or dissimilarity of expected and observed results and how sample size affects results.

## Materials



adhesive tape  
scissors  
pencil  
pennies—2  
nickels—2

## Procedure

### Part A. Cross Between Genotypes

#### *AaMm* and *Aamm*

#### Expected Results

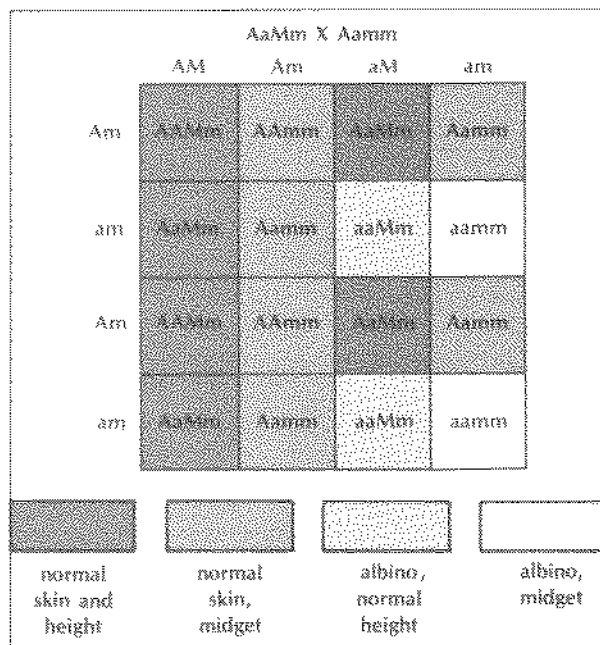
The Punnett square in Figure 19-1 represents a cross involving two characteristics, skin pigment and body height. The parents' genotypes are *AaMm* and *Aamm*. The gene *A* is for normal skin pigment. The gene *a* is for albinism (no pigment). The gene *M* is for normal body height. The gene *m* is for short height (midget).

The Punnett square shows the possible gametes of each parent and the possible offspring. The squares are shaded according to phenotype.

• Determine the four phenotypes and how many offspring of each there are.

• Record these numbers in the "Number expected for 16 offspring" column of Table 19-1. To calculate the number expected for 96 offspring,

FIGURE 19-1



multiply each number just recorded by 6. Record these new numbers in the "Number expected for 96 offspring" column of Table 19-1.

### Observed Results

● Cover both sides of two pennies and two nickels with adhesive tape. **CAUTION:** Always be careful with scissors.

● Mark the four coins as shown in Figure 19-2.

● Toss the four coins (two pennies in one hand, two nickels in the other) onto your desk a total of 96 times.

● Read the genotypes that appear and record the phenotypes in Table 19-1. (Use the Punnett square as a guide if necessary.) Make a slash (/) in the

proper row to indicate the phenotype represented by the coins.

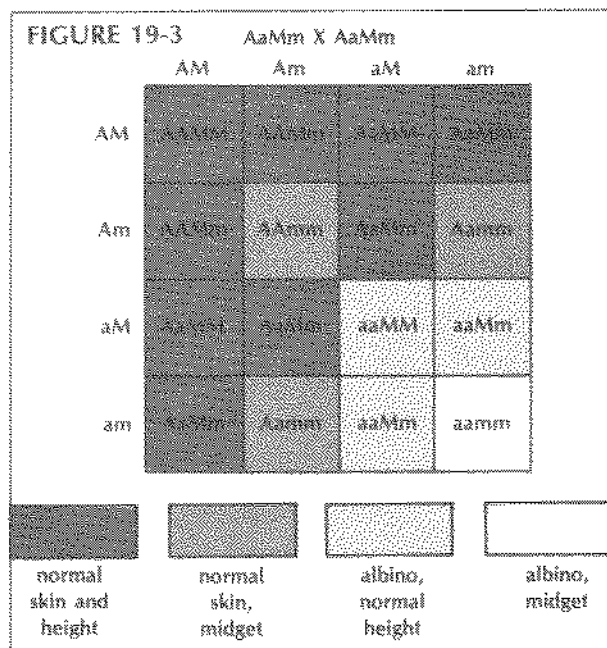
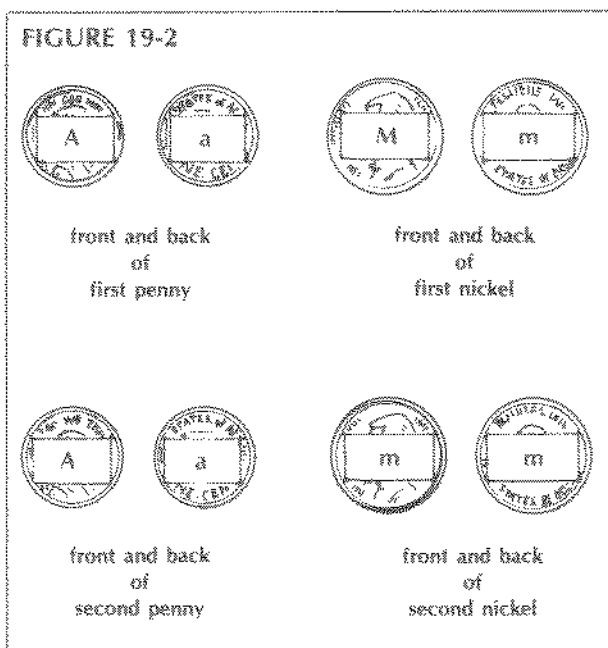
● Place the totals for each phenotype in the proper column of Table 19-1.

### Part B. Cross Between Genotypes *AaMm* and *AaMm*

#### Expected Results

The Punnett square in Figure 19-3 represents a cross between parents which are heterozygous for skin pigment and body height. As in Part A, the Punnett square shows gametes and possible offspring. Also, the squares are shaded according to phenotype.

● Determine the four phenotypes and how many offspring of each there are.



**TABLE 19-1. RESULTS OF CROSS BETWEEN *AaMm* and *Aamm***

PHENOTYPE COMBINATIONS	GENOTYPES	NUMBER EXPECTED FOR 16 OFFSPRING	NUMBER EXPECTED FOR 96 OFFSPRING	TOSS RESULTS	TOTAL NUMBER OBSERVED
Normal skin and normal height	<i>AAMm</i> <i>AaMm</i>				
Normal skin but midget	<i>AAMm</i> <i>Aamm</i>				
Albino but normal height	<i>aaMm</i>				
Albino and midget	<i>aamm</i>				

● Record these numbers in the "Number expected for 16 offspring" column of Table 19-2. To calculate the next column, multiply each number just recorded by 6. Record these new numbers in the "Number expected for 96 offspring" column of Table 19-2.

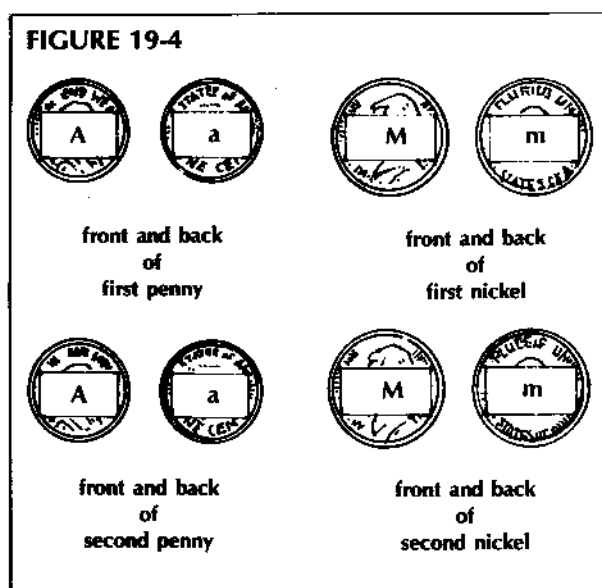
### Observed Results

● Use the four coins from the first cross but change the nickel with *m* on both sides so that it has an *M* on one side. The coins should match Figure 19-4.

● Toss the four coins a total of 96 times.

● Read the genotypes that appear and record the phenotypes in Table 19-2.

● Place the totals for each phenotype in the proper column of Table 19-2.



PHENOTYPE COMBINATIONS	GENOTYPES	NUMBER EXPECTED FOR 16 OFFSPRING	NUMBER EXPECTED FOR 96 OFFSPRING	TOSS RESULTS	TOTAL NUMBER OBSERVED
Normal skin and normal height	<i>AAMM</i> <i>AAMm</i> <i>AaMM</i> <i>AaMm</i>				
Normal skin but midget	<i>AAmm</i> <i>Aamm</i>				
Albino but normal height	<i>aaMM</i> <i>aaMm</i>				
Albino and midget	<i>aamm</i>				

## Analysis

Summarize this investigation by writing a report on separate paper that includes

- the purpose of the investigation.
- (a) how the number of expected offspring in a genetic cross can be determined.  
(b) the exactness of expected results.  
(c) how the number of observed offspring in a genetic cross can be determined.  
(d) the exactness of observed results.
- (a) how the number of expected offspring for Part A compares to the observed offspring for Part A. (Use specific data for your comparison.)  
(b) why the numbers in these two columns may not be equal.
- how Part A supports our understanding of genetics. (Reread introduction if necessary.)

5. why the total of observed and expected offspring in Part A differ from the totals of observed and expected offspring in Part B.
6. (a) how the observed and expected offspring might have compared if only 16 coin tosses were used instead of 96.  
(b) the need for using large numbers of observed offspring when attempting to prove that genetic totals of expected results do agree with observed results.
7. how Part B supports our understanding of genetics.
8. (a) the advantage of tossing and reading properly marked coins over using living organisms.  
(b) whether the comparison between coins and living organisms is correct and why.

## Extending Your Investigation

- Properly predict through the Punnett square in Figure 19-5 the expected phenotype combinations and number of each in a family with 16 offspring if one parent is *Aamm* and the other is *AAMm*.
- Properly mark four coins to agree with the parents' genotypes of *Aamm* and *AAMm*.
- Toss the four coins a total of 96 times, recording your observed results in Table 19-3.

FIGURE 19-5

		Aamm X AAMm			
		Am	Am	am	am
AM					
Am					
aM					
am					

TABLE 19-3. RESULTS OF CROSS BETWEEN *Aamm* and *AAMm*

PHENOTYPE COMBINATIONS	GENOTYPES	NUMBER EXPECTED FOR 16 OFFSPRING	NUMBER EXPECTED FOR 96 OFFSPRING	TOSS RESULTS	TOTAL NUMBER OBSERVED
Normal skin and normal height	<i>AAMm</i> <i>AaMm</i>				
Normal skin but midget	<i>Aamm</i> <i>Aamm</i>				
Albino but normal height	<i>aaMM</i> <i>aaMm</i>				
Albino and midget	<i>aamm</i>				

## Analysis, Extension

1. Explain why the results in Table 19-3 are not the same as in Part A or B of this experiment.

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Pedigrees are not reserved for show dogs and race horses. All living things, including humans, have pedigrees. A pedigree is a diagram that shows the occurrence and appearance, or phenotype, of a particular genetic trait from one generation to the next in a family. Genotypes for individuals in a pedigree usually can be determined with an understanding of inheritance and probability.

In this investigation, you will

- (a) learn the meaning of all symbols and lines that are used in a pedigree.
- (b) calculate expected genotypes for all individuals shown in pedigrees.

## Procedure

### Part A. Background Information

The pedigree in Figure 20-1 shows the pattern of inheritance in a family for a specific trait. The trait being shown is earlobe shape. Geneticists recognize two general earlobe shapes, free lobes and attached lobes (Figure 20-2). The gene responsible for free lobes (*E*) is dominant over the gene for attached lobes (*e*).

In a pedigree, each generation is represented by a Roman numeral. Each person in a generation is numbered. Thus each person can be identified by a generation numeral and individual number. Males are represented by squares whereas females are represented by circles.

### Part B. Reading a Pedigree

In Figure 20-1, persons I-1 and I-2 are the parents. The line which connects them is called a marriage line. Persons II-1, 2, and 3 are their children. The line which extends down from the marriage line is the children line. The children are placed left to right in order of their births. That is, the oldest child is always on the left.

1. What sex is the oldest child? \_\_\_\_\_
2. What sex is the youngest child? \_\_\_\_\_

FIGURE 20-1

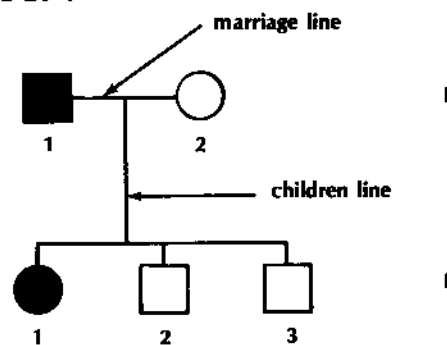
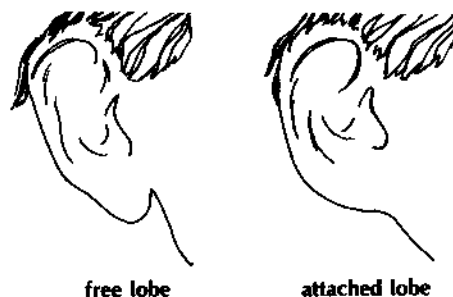


FIGURE 20-2



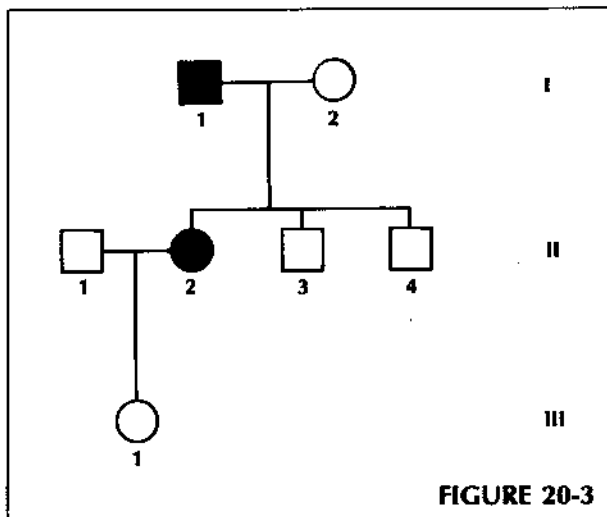


FIGURE 20-3

Using a different pedigree of the same family at a later time shows three generations. Figure 20-3 shows a son-in-law as well as a grandchild. Generation I may now be called grandparents.

3. Which person is the son-in-law? \_\_\_\_\_
4. To whom is he married? \_\_\_\_\_
5. What sex is their child? \_\_\_\_\_

### Part C. Determining Genotypes from a Pedigree

The value of a pedigree is that it can help predict the genes (genotype) of each person for a certain trait.

All shaded symbols on a pedigree represent individuals who are homozygous recessive for the trait being studied. Therefore, persons I-1 and II-2 have  $ee$  genotypes. They are the only two individuals who are homozygous recessive and show the recessive trait. They have attached earlobes.

All unshaded symbols represent individuals who have at least one dominant gene. These persons show the dominant trait.

To predict the genotypes for each person in a pedigree, there are two rules you must follow.

**Rule 1.** Assign two recessive genes to any person on a pedigree whose symbol is shaded. (These persons show the recessive trait being studied.) Small letters are written below the person's symbol.

**Rule 2.** Assign one dominant gene to any person on a pedigree whose symbol is unshaded. (These persons show the dominant trait being studied.) A capital letter is written below the person's symbol.

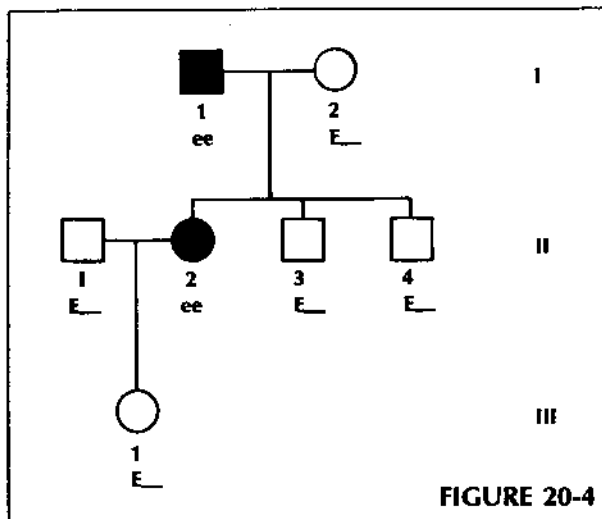


FIGURE 20-4

These two rules allow one to predict some of the genes for the persons in a pedigree. Figure 20-4 shows the genes predicted by using these two rules.

To determine the second gene for persons who show the dominant trait, a Punnett square is used. In Figure 20-4, we already know that the grandfather (I-1) is  $ee$ . If the grandmother (I-2) were  $EE$ , could any  $ee$  children (like II-2) be produced? A Punnett square shows this combination to be impossible. Thus, the grandmother must be heterozygous or  $Ee$ .

6. (a) Can an  $Ee$  parent and an  $ee$  parent have the results shown in generation II? \_\_\_\_\_
- (b) Prove your answer by showing the results in the below left Punnett square.

	e	e
E		
e		

	E	E
e		
e		

- (c) Can an  $EE$  parent and an  $ee$  parent have the results shown in Generation II? \_\_\_\_\_
- (d) Prove your answer to the above question by showing the results in the above right Punnett Square.

7. (a) Predict the second gene for person II-3.  
(Read it from the Punnett square.) \_\_\_\_\_

- (b) Predict the second gene for person II-4.  
\_\_\_\_\_

(c) Could child II-3 or II-4 be *EE*? \_\_\_\_\_

Explain. \_\_\_\_\_

To predict the second gene for person II-1, a different method must be used, since he could be either *EE* or *Ee*.

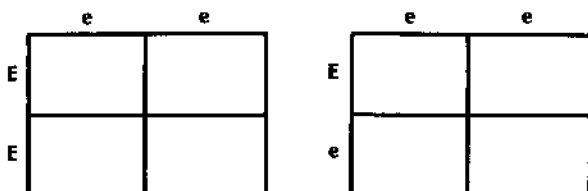
8. (a) Can an *EE* person married to an *ee* person (II-2) have children with free earlobes?

\_\_\_\_\_

(b) Can an *Ee* person married to an *ee* person

have children with free earlobes? \_\_\_\_\_

(c) Prove your answers by showing the results of these crosses in the Punnett squares below.



In this case, the second gene from person II-1 cannot be predicted using Punnett squares. Either genotype *Ee* or *EE* may be correct. When this situation occurs, both genotypes are written under the symbol (Figure 20-5).

Predicting the second gene for III-1 results in her being heterozygous. Although her mother must provide her with one recessive gene, she has free lobes, so the second gene must be dominant (Figure 20-5).

At some time in the future, if II-1 and II-2 have many more children, one might be able to predict the father's second gene. For example, if they have ten children and all show the dominant free lobes, one could safely conclude that he is *EE*. If, however, they have some children with attached earlobes (*ee*), then he must be *Ee*.

## Analysis

- Draw a pedigree for a family showing two parents and four children.
  - include a marriage line and label it.
  - include a children's line and label it.
  - make the oldest two children boys and the youngest two girls.

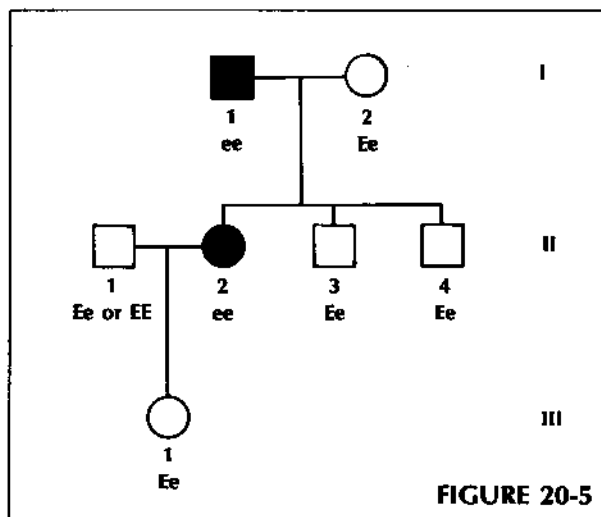
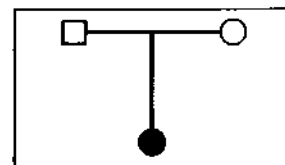


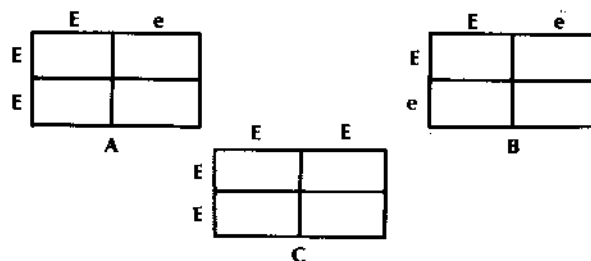
FIGURE 20-5

When both parents show a dominant trait and their child or children all show a dominant trait, one cannot predict the second gene for anyone if only a small family is available.

Examine this pedigree:

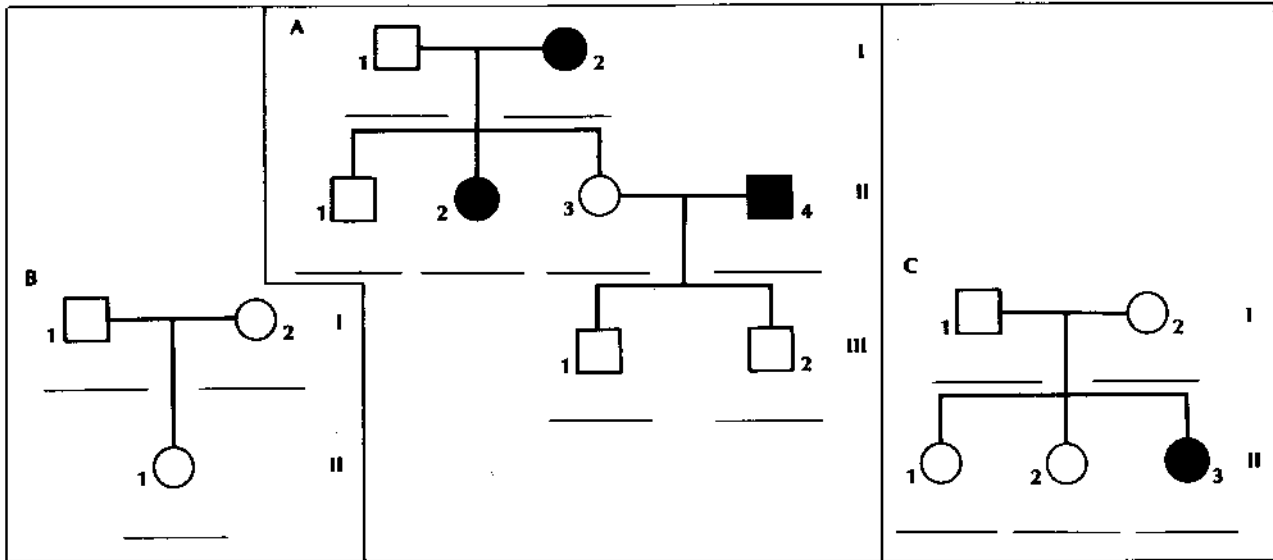


9. (a) Which Punnett square, A, B, or C, would best fit this family? \_\_\_\_\_

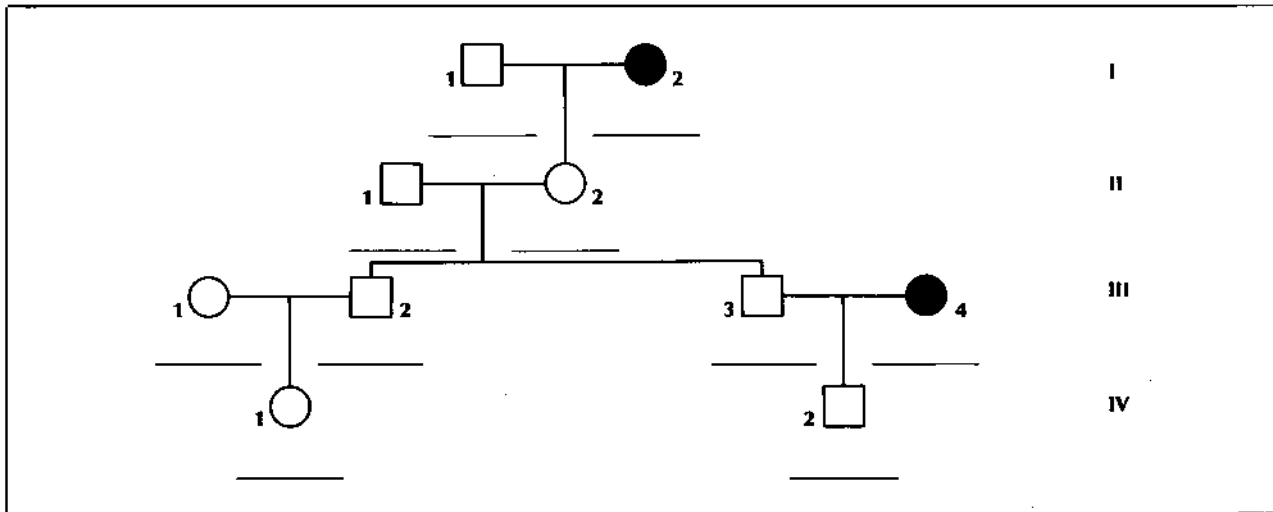


(b) Explain. \_\_\_\_\_

- Using the pedigree from question 1, indicate that person II-2 has attached earlobes.
- Using the pedigrees below, predict the genotypes for these families. (Remember the two rules—first give all shaded symbols two recessive genes and give unshaded symbols one dominant gene.) Write the letters on the lines provided.



- Examine the pedigree below.



- How many generations are shown? \_\_\_\_\_
- How many persons have free earlobes? \_\_\_\_\_
- How many persons have attached earlobes? \_\_\_\_\_
- Identify by generation and number those persons with attached earlobes. \_\_\_\_\_  
\_\_\_\_\_
- Give the genotype for all persons having attached earlobes. \_\_\_\_\_
- How many children did the original generation have? \_\_\_\_\_

- Predict the genotypes for all persons in question 4 using the lines below each person's symbol.

An examination of the chromosomes of a cell under high magnification can give much information about an organism. If the cells are from an unborn human, its sex can be determined before it is born. It can also be determined if the unborn may have certain birth defects or problems caused by improper chromosome numbers in its cells.

The pages given to you by your teacher show chromosomes from a normal and abnormal unborn human. These are from body (somatic) cells and have been enlarged about 5000 times natural size.

In this investigation, you will

- (a) learn what a karyotype is.
- (b) prepare a karyotype of a normal human's chromosomes.
- (c) prepare a karyotype of an abnormal human's chromosomes.

## Materials



- scissors
- tape
- 1 page of normal chromosomes
- 1 page of abnormal chromosomes
- 2 charts for mounting of chromosomes

## Procedure

### Part A. Normal Human Karyotype

● Examine the page marked "Normal Human Chromosomes" supplied by your teacher. These chromosomes are actually an enlarged drawing of what is seen through a microscope. The chromosomes have also been stained to show their "banded" appearance. Note that two chromosomes are unshaded. They have been marked this way to aid you in preparing the karyotype. Cut out each chromosome with scissors. **CAUTION:** *Always be careful with scissors.* To make the task easier and faster, leave margins of paper along each chromosome. Cut them out as rectangles or squares as shown here:



● Prepare a karyotype of these chromosomes. A karyotype is a pattern of chromosomes from one cell grouped into pairs and then organized by size.

● Match all chromosomes into pairs. To help determine pairs, use the banding patterns seen on the chromosomes. Temporarily put the two "unshaded" chromosomes aside. Mount each chromosome pair onto the numbered chart provided by your teacher.

● Position the longest pair on the upper left-hand corner. Consider them as pair number 1. Tape them into place. The next longest pair should follow until all pairs are taped on the sheet in decreasing order of size.

● The two unshaded chromosomes left over should be mounted in the lower right-hand corner above the words "sex chromosomes." Sex chromosomes determine the sex of an organism. In humans, a female results if both sex chromosomes match. These chromosomes are called XX sex chromosomes. In males, sex chromosomes do not match. They are called XY. The Y sex chromosome is much smaller than the X chromosome.

1. How many chromosomes are present in this karyotype? \_\_\_\_\_

2. How many chromosomes are present in each cell of this human? \_\_\_\_\_

Body cells are called somatic cells. Somatic cells are skin, liver, muscle, stomach, or kidney cells. The karyotype you just prepared is from a somatic human cell. The term "diploid chromosome number" or " $2n$  number" refers to the total number of chromosomes in any somatic cell of an organism. The diploid number varies from species to species. However, it does not differ from somatic cell to somatic cell of an organism.

3. What is the diploid chromosome number for your karyotype? \_\_\_\_\_

4. What is the  $2n$  chromosome number for your karyotype? \_\_\_\_\_

5. How many chromosomes would you expect to find in cells taken from the intestine of the person whose karyotype you just prepared?  
\_\_\_\_\_

6. Which sex chromosomes are present in the karyotype you prepared? \_\_\_\_\_

### Analysis

1. Define
  - (a) somatic cell \_\_\_\_\_
  - (b) karyotype \_\_\_\_\_
  - (c) diploid or  $2n$  chromosome number \_\_\_\_\_
  - (d) sex chromosomes \_\_\_\_\_

2. When karyotyping, what two major pieces of information can be gained about a child before it is born?  
\_\_\_\_\_

7. What is the sex of the person in the karyotype you prepared? \_\_\_\_\_

### Part B. Abnormal Human Karyotype

Examine the page marked "Abnormal Human Chromosomes" supplied to you by your teacher. Again, the sex chromosomes are unshaded to make identification easier.

● Prepare a second karyotype as you did the first one. Use a new numbered chart to tape the chromosomes in place.

Finding the incorrect chromosome number in human somatic cells of an unborn alerts a doctor and parents to the fact that their unborn is abnormal and will be born with birth defects. If the unborn has an extra number 8 chromosome, it is born with trisomy 8 syndrome. If the unborn has an extra number 13 chromosome, it is born with Patau syndrome. An extra number 18 chromosome results in Edward syndrome. An extra number 21 syndrome results in Down syndrome. (A syndrome is a series of defects or problems.)

8. How many chromosomes are present in this karyotype? \_\_\_\_\_

9. What is the diploid chromosome number for this karyotype? \_\_\_\_\_

10. (a) Which chromosome pair is abnormal?  
\_\_\_\_\_

(b) How is it abnormal? \_\_\_\_\_

11. What syndrome does this unborn have? \_\_\_\_\_  
\_\_\_\_\_

12. What sex will this unborn child be? \_\_\_\_\_  
\_\_\_\_\_

An inherited form of muscular dystrophy results in death due to a wasting away of skeletal muscles. The dominant normal gene is represented by the letter  $M$ . The recessive gene is represented by  $m$ . How is the trait inherited? Is it a sex-linked genetic disease or not? If it is sex-linked, the gene is located on the X chromosomes. If it is not sex-linked, the gene is located on a chromosomal pair other than the sex chromosomes.

In this investigation, you will

- mark coins to represent genes and chromosomes in gamete cells of human males and females.
- toss two coins together to simulate the offspring observed if muscular dystrophy is sex-linked.
- toss four coins together to simulate the offspring observed if muscular dystrophy is not sex-linked.
- determine whether or not muscular dystrophy is sex-linked through the analysis of your data and statements supplied by a hospital.

## Materials

adhesive tape  
pennies—2  
nickels—2  
pencil

## Procedure

### Part A. Observed Results If Sex-Linked

If a trait is sex-linked, the genes are located on the X chromosome. A heterozygous female ( $X^M X^m$ ) has a 50/50 chance that her egg cells will receive either an  $X^M$  or an  $X^m$  during meiosis. Normal males have genotype  $X^M Y$ . The chances that their sperm cells will receive either  $X^M$  or Y during meiosis are 50/50. You can determine the offspring of the cross  $X^M X^m \times X^M Y$  by coin tossing.

- Put adhesive tape on two pennies.
- Mark one penny to represent the possible egg cells. Mark one side  $X^M$  and the other side  $X^m$ .
- Mark the second penny to represent the possible sperm cells. Mark one side  $X^M$  and the other side Y.

- Toss both pennies together 48 times. Use slashes (/) to indicate in Table 23-1 the combination that results after each toss.

- Total the results of each genotype and record them in the table.

### Part B. Observed Results If Not Sex-Linked

If the trait is not sex-linked, the genes for muscular dystrophy are not attached to the sex chromosomes. Therefore, two pairs of chromosomes are involved in determining sex and the presence or absence of muscular dystrophy. In obtaining observed results by tossing coins, four coins are needed to represent the two chromosome pairs involved in the cross  $XXMm \times XYMm$ .

● Add tape to a penny and a nickel. NOTE: You may use the pennies from Part A, but they must be re-marked.

● Mark both sides of the penny with an X. Mark one side of the nickel *M* and the other side *m*. These coins represent possible gametes of a heterozygous female.

● Add tape to a second penny and nickel.

● Mark one side of the penny X and the other side Y. Mark one side of the nickel *M* and the other side *m*. These coins represent possible gametes of a heterozygous male.

● Toss the pennies and nickels together onto your desk 48 times. Use slash marks (/) to indicate in Table 23-2 the combination that results after each toss.

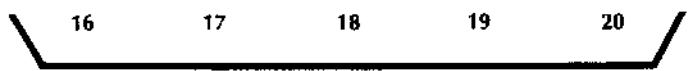
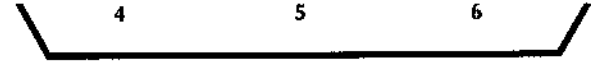
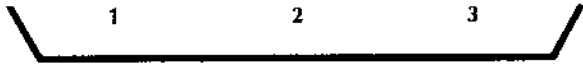
● Total the results of each genotype and record them in the table.

TABLE 23-1. RESULTS IF THE TRAIT IS SEX-LINKED			
OFFSPRING PHENOTYPE	OFFSPRING GENOTYPE	RESULT OF EACH TOSS	TOTALS OBSERVED
Normal female	$X^M X^M$ or $X^M X^m$		
Female with muscular dystrophy	$X^m X^m$		
Normal male	$X^M Y$		
Male with muscular dystrophy	$X^m Y$		

TABLE 23-2. RESULTS IF THE TRAIT IS NOT SEX-LINKED			
OFFSPRING PHENOTYPE	OFFSPRING GENOTYPE	RESULTS OF EACH TOSS	TOTALS OBSERVED
Normal female	$XM XM$ or $XM Xm$		
Female with muscular dystrophy	$Xm Xm$		
Normal male	$XYM$ or $XYm$		
Male with muscular dystrophy	$Xm Ym$		

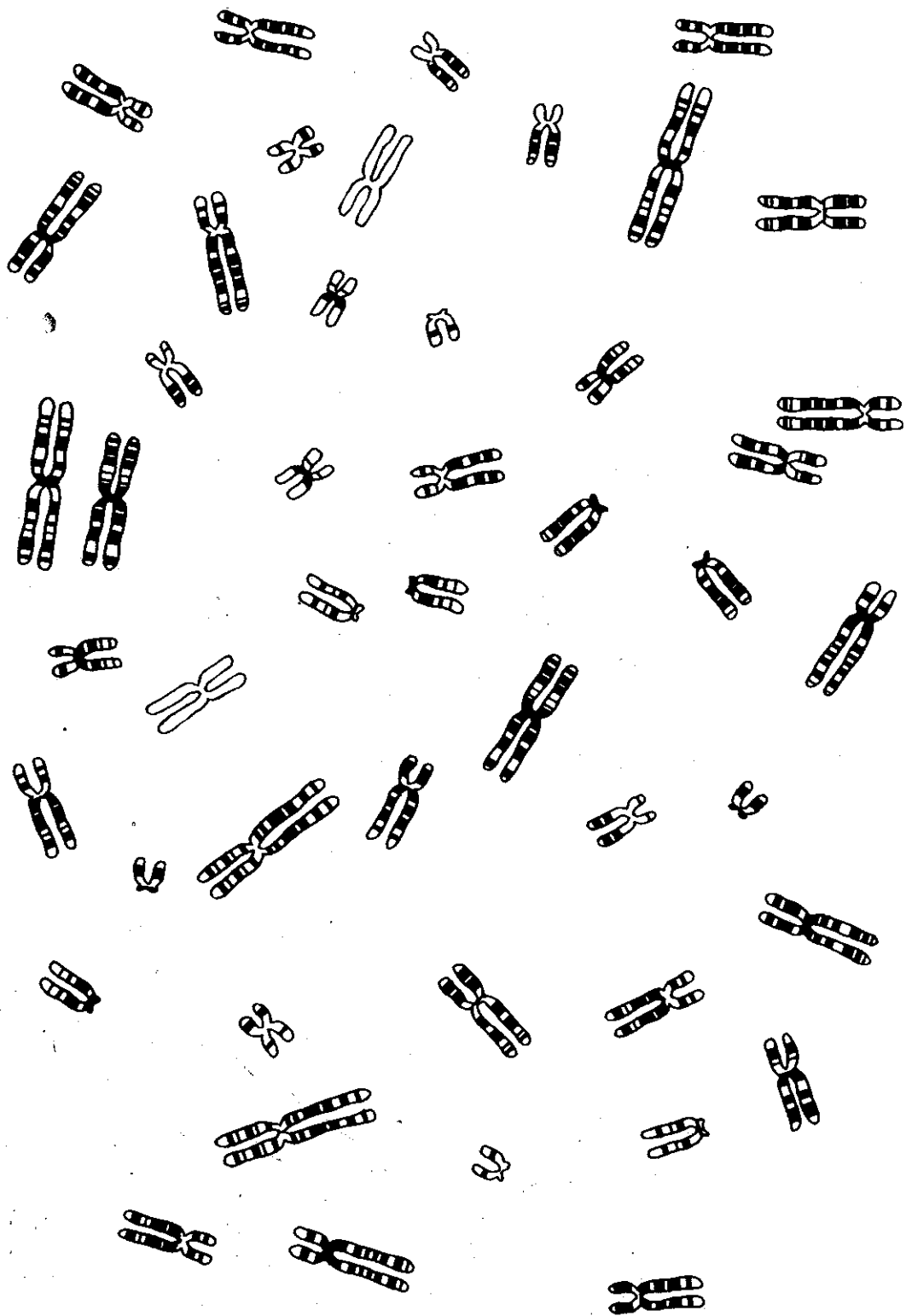
## Analysis

- If a trait is sex-linked, how many genes for muscular dystrophy must a female inherit to have the disease? \_\_\_\_\_
  - If a trait is sex-linked, how many genes for muscular dystrophy must a male inherit to have the disease? \_\_\_\_\_



sex chromosomes

Abnormal



Normal

