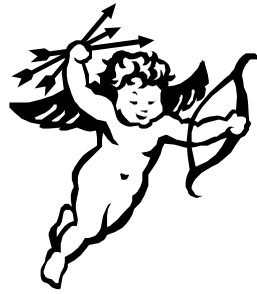


Genetics Problem Sets



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Introduction:

How do organisms come to look and act the way they do? How are characteristics passed from generation to generation? Genetics, the study of inheritance, attempts to answer these and other questions. Through the genetics problems presented in this packet we will investigate several simple forms of inheritance. While completing genetics problems, you will be asked to carry out step-by-step method which will include reading the problem, interpreting the information given, setting up a "Key", "working the crosses", and finally presenting and interpreting the results of the crosses.

In order to readily converse in the language of heredity you will first need to know and understand the follow terms. **Please define the words below in the space provided.** Refer to your notes or your *Biology Textbook (Chapter 10)* for help.

BASIC GENETICS VOCABULARY

P₁:

F₁:

F₂:

Allele:

Genotype:

Phenotype:

Homozygous:

Heterozygous:

Dominant:

Recessive:

True-breeding:

What must its genotype be if something is true-breeding? (hint: there are 2 answers)

Every Time You Work a Problem

1. **Set up a Key** (which indicates the dominant and recessive alleles; *even if you are unsure of which allele is dominant or recessive you should still set up a key to begin*)
2. **Show your Work**
 - a. Show the **cross** (who is being "crossed" with whom) when appropriate
 - b. Work the cross and **show the results**, (using "FOIL" or Punnett square method)
3. **Summarize your results** by giving:
 - a. fraction or percent of each genotype of offspring.
 - b. fraction or percent of each phenotype of offspring.

Genetics Problems Set #1

MONOHYBRID CROSS (Simple dominance)

Because we are examining the inheritance of only a **single** trait (i.e. height), we call this type of cross a **monohybrid** cross. When we work a cross we are determining the **possible combinations of alleles that could be present in the offspring** (children) of the parents. Since meiosis creates gametes with the haploid number of chromosomes- only **one allele for each trait can be present in a gamete**-- for example "D" or "d".

1. In peas, green pod color is dominant to yellow pod color. Show a cross between true-breeding green and true-breeding yellow plants (P₁ generation). Carry out the cross through the F₁ and F₂ generations. Show phenotypes, genotypes, and the percentages of the different phenotypes and genotypes for all generations.

2. Consider blue eyes in humans to be recessive to brown eyes. Show the expected children of a blue-eyed woman with a brown-eyed man whose mother had blue eyes. Include all genotypes and phenotypes and their percentages. State what you know (and don't know) about the brown-eyed man's father based on the information given here. What can you predict about the brown-eyed man's brothers and sisters?

3. In poultry, rose comb is dominant to single comb.
 - a. Cross a true-breeding rose-combed rooster with a single-combed hen. Then cross the F₁'s to produce an F₂ generation. Show the fractions or percents of all genotypes and phenotypes.
 - b. Explain how it is possible for a rose-combed rooster and a rose-combed hen to produce single-combed offspring. What percentage of the offspring is expected to have single combs in this cross?

4. In humans the ability to roll one's tongue is dominant to the inability to do so.
 - a. Show the expected offspring of a cross between a heterozygous roller and a homozygous roller. Include genotypes, phenotypes, and their percentages.
 - b. What would the genotypes of the parents have to be if a roller man and a non-roller woman have two roller and one non-roller children? What is the probability that the next child is a non-roller?

5. In domestic swine there is a dominant allele which produces a **white belt** around the body. The recessive allele produces uniform body color. One farmer wants to produce only belted hogs, and another wants only uniformly colored animals. Which farmer would have an easier time producing a true-breeding herd? Explain why. Tell how each farmer would proceed.
6. In cattle, the **polled** (hornless) condition is caused by a dominant allele, while the recessive allele causes horns to grow. A polled cow and a polled bull produce a calf that grows horns as it matures. Show the genotypes of all three. What is the probability that the pair's next calf will also grow horns?
7. **Albinism** (as in an "albino") in corn is caused by a recessive allele, and is normally lethal because the plant cannot manufacture food without chlorophyll, so dies after it has exhausted the food in the seed. It is possible experimentally to keep albino plants alive with special feeding techniques in which sugar is supplied to the plant through the leaves. Show the expected offspring from a cross between an albino plant and a normal plant that is heterozygous for albinism.
8. In Holstein cattle, spotting of the coat is caused by a recessive allele and solid coat color by a dominant allele. What types of offspring can occur in a cross between two spotted animals?
9. A woman has a rare eyelid abnormality called **ptosis**, which makes it impossible for her to open her eyes all the way. The condition is caused by a dominant allele. The woman's father had ptosis but her mother was normal. Her father's mother also had normal eyelids.
 - a. What are the genotypes of each of the people mentioned above?
 - b. What proportion of her children would be expected to have ptosis if she marries a man with normal eyelids?
10. In humans there is a gene called **sickle-cell anemia** that produces severe anemia when homozygous. The name of the disease comes from the fact that many of the red blood cells take on an abnormal sickle shape. People homozygous for this trait usually die before adulthood. Heterozygous people appear normal, **but** a medical test (holding a sample of the blood under abnormally low oxygen concentration) can reveal a hidden sickle-cell allele (cells in the blood sample will take on a sickle shape). A young woman about to be married is concerned about her future children because her brother died of sickle-cell anemia. A sample of her blood sickles under low oxygen concentration, but that of her prospective husband remains normal. What can you say about the man and the woman, and about their future children?

Genetics Problems Set #2

CODOMINANCE / INCOMPLETE DOMINANCE

For some traits when the alleles are **heterozygous the phenotype expressed is a combination** of both of the alleles. The expression of the heterozygous alleles is different from those of the parents, producing distinguishable hybrids. This type of inheritance is called codominance or incomplete dominance depending on the phenotype of the heterozygote. We treat these inheritance patterns differently because they are not inherited in a traditional Mendelian pattern.

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1. The Four O'clock plant has three genotypes for flower color expressed as three different phenotypes: **red** flowered plants, **white** flowered plants, and **pink** flowered plants.
  - a. Show the expected offspring of a cross between two pink-flowered plants. Include genotypes, phenotypes and percents or fractions.
  - b. Show the expected offspring of a cross between a red-flowered Four O'clock plant and a pink-flowered plant.
  
2. In shorthorn cattle the **R** allele, when homozygous, produces animals with red hair and the **R'** (this is called the "**R prime**") allele, when homozygous, produces cattle with white hair. An animal with a heterozygous genotype is **roan** in color, meaning its coat contains *both* red hairs and white hairs.
  - a. Describe the expected offspring when a breeder mates cows and bulls of the following phenotypes:
    1. red x red
    2. white x white
    3. red x roan
  - b. Which kind of true-breeding herd would be easier to establish: red or roan? Explain your answer.
  - c. What is the probability of a pair of roan cattle producing (1) a red calf? (2) a roan calf? (3) a white calf?

3. In humans there is a disease called **sickle-cell disease** that can cause severe anemia. The name of the disease comes from the fact that many of the red blood cells take on an abnormal sickle shape. People who are homozygous for the sickle-cell allele often die before adulthood. Heterozygous people appear normal, **but** when a sample of the blood is held under low oxygen concentration, the red cells take on the sickle shape.
- a. A young woman about to be married is concerned about her future children because her brother died of sickle-cell anemia. A sample of her blood sickles under low oxygen concentration, but that of her prospective husband remains normal. What can you say about the genotypes of the man and the woman?
- b. What are the chances that they will have a child who
- i. has sickle-cell disease?
  - ii. has blood that sickles under low oxygen?
  - iii. is normal?

## Genetics Problems Set #3

### MULTIPLE (MORE THAN TWO) ALLELES

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The traits we have studied so far have had only two different alleles to express their genotypes. Some traits have more than two alleles to express their genotype, these are referred to as multiple allele traits. Human blood type (ABO factor) is an example.

In humans there are **three alleles that influence blood type** (ABO factor):

$I_A$  represents the "A" allele

$I_B$  represents the "B" allele

$i$  represents the "O" allele

#### **Human blood types:**

The symbols  $I_A$ ,  $I_B$ ,  $i$ , represent the three alleles that control the human ABO blood group. The alleles  $I_A$  and  $I_B$  are codominant, and are both dominant to the  $i$ , allele. The phenotypes are stated as blood types **A**, **B**, **AB**, and **O**.

Additional information (regarding a different protein one can identify in blood):

A **separate gene** causes the MN blood groups. The **M** and **N** alleles are codominant (each causes its own antigen to be present in the blood). The genotypic expression of this separate gene is as follows: **M** blood is **MM**, **N** blood is **NN**, and **MN** blood is **MN**.

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1. List all possible genotypes for the human ABO blood groups, and indicate the phenotype for each.
  
2. A man with blood type A marries a woman with blood type AB.
  - a. The couple has a son with blood type B. Show the genotypes of the parents and the son.
  
  - b. Another couple with the same blood types has eleven children, but none of the children has blood type B. What is the most likely explanation for this?
  
  - c. Could either of these couples have a child with blood type **O**? Explain your answer.
  
3. Two newborn babies were accidentally mixed up in the hospital. Use the information given to answer the questions that follow.

Baby 1: Type O

Mrs. Brown: Type B

Mrs. Smith: Type B

Baby 2: Type A

Mr. Brown: Type AB

Mr. Smith: Type B

- a. Which child belongs to the Browns?  
Which child belongs to the Smiths?
  
- b. Give the genotype of everybody involved.



4. A man with blood type A is suing his wife for divorce on the grounds of infidelity. Their first and second children, whom they both claim, have blood types O and AB respectively. The third child, whom the man disclaims, has blood type B.
  - a. Can this information be used to support his case (*i.e.* – does the fact that the child has blood type B prove or disprove his case)?
  - b. The third child's blood was tested for the M-N blood group system. The child's blood was group M. The man is group N. Can this be used to support his case? **Refer to the information on previous page in the human blood type section.**
  
5. A man with blood type B is being sued for paternity (to determine if he is the father) by a woman with blood type A. The child the woman claims he fathered has blood type O.
  - a. Respond to the question "Is the man the father of the child?"
  - b. If this man is the father of the child, what are the genotypes of the parents?
  - c. If this man's blood type were AB, could he be the child's father? Explain.
  
6. What do the  $I_A$ ,  $I_B$ , and  $i_o$  alleles produce (*i.e.* – when the gene is transcribed and translated, what is produced)?

## Genetics Problems Set #4

### SEX-LINKED TRAITS

Humans have 23 pairs of chromosomes. Twenty-two (22) pairs are called **autosomes**. The chromosomes in the 23rd pair are called "**sex chromosomes**" because some of the genes on these chromosomes determine if the individual is female or male. Under normal conditions a human female has the genotype XX (meaning that she has two "X" chromosomes with a combination of genes on these chromosomes that determine that she is female.) Under normal conditions the human male has the genotype XY with a combination of genes on these chromosomes which determines that he is a male.

Female = XX  
Male = XY

Just like autosomes, the sex chromosomes carry genes for various traits. Some traits other than the sex of the individual are carried on the X and Y chromosomes. If you look at the "Y" chromosome you can see that it is physically smaller than the "X" chromosome. A current hypothesis suggests that there are some traits for which the "X" chromosome carries an allele, but for which the Y-chromosome carries **NO CORRESPONDING ALLELE**. These combinations result in the same phenotype being expressed by different genotypes in males and in females. Let's look at an example.

Humans can suffer from a disorder that inhibits the blood from clotting properly. This disorder, known as hemophilia, is due to a recessive allele (h). Normal blood clotting is dominant (H). Most people are normal. The allele for this blood clotting trait is found on the X-chromosome and there is **no CORRESPONDING allele for this trait found on the Y-chromosome**. Therefore women and men have different genotypes for blood clotting phenotypes.

Because the sex chromosomes are different from each other, and to remind ourselves that this is a sex-linked trait, we write the names of the alleles a little differently. In this case, we indicate which chromosomes the individual has and then using superscript indicate which allele is carried on that chromosome. Because the Y-chromosome does not carry a corresponding allele, we use a dash rather than an allele.

| Women (XX) |                                               | Men (XY) |                 |
|------------|-----------------------------------------------|----------|-----------------|
| Genotype   | Phenotype                                     | Genotype | Phenotype       |
| $X^H X^H$  | normal clotting                               | $X^H Y$  | normal clotting |
| $X^H X^h$  | normal clotting<br>considered a<br>"carrier") | $X^h Y$  | hemophilia      |
| $X^h X^h$  | hemophilia                                    |          |                 |

\*Notice that the genotypes for "normal" in males and females are different yet they express the same phenotype. Similarly, the genotypes for "hemophilia" are different in males and females yet they express the same phenotype.

## Sex-Linked Trait Problems

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### 1. HEMOPHILIA

Most people's blood clots normally. Hemophilia is a blood disorder that causes blood not to clot properly. The allele for **hemophilia is recessive** to the allele for normal blood clotting. These alleles are located on the human X chromosome. The Y chromosome is a genetic "blank" for this trait; it contains no allele for the blood-clotting gene.

(A number of cases of hemophilia have occurred among male descendants in the family of England's Queen Victoria. She, however, did not have hemophilia. Queen Victoria lived during the time of Charles Darwin.)

- a. Show the genotypes of parents that would produce a male descendant with hemophilia (when the mother does not have hemophilia).
- b. Show the genotype required of parents to produce a hemophiliac daughter.
- c. Explain what's wrong with the statement "That hemophiliac man's father was also a hemophiliac, so he must have inherited the disease from his father."

### 2. RED-GREEN COLOR BLINDNESS

Red / green color-blindness in humans is recessive and X-linked (same inheritance pattern as hemophilia).

- a. A woman has normal vision, but her father is color-blind. Is she necessarily a carrier (heterozygous)? Explain.
- b. A woman has normal vision with no family history of color blindness and a man is color-blind. Diagram all genotypes and phenotypes of parents and expected children in a family where the woman has normal vision and no family history of color blindness, and the man is color-blind.
- c. In a large family, all nine sons were color-blind and all four daughters had normal vision. Give the likeliest genotypes and phenotypes of all concerned.

### 3. BOBBED HAIRS

The trait called "bobbed hairs" in the fruit fly (*Drosophila*) is recessive and is located on the X chromosome only. Assume all flies are true-breeding. We would like to figure out if this gene is carried on an autosome or a sex-chromosome.

- a. Carry out a cross (on paper) **to the F<sub>2</sub> generation** between a bobbed male and a true-breeding, wild type (normal) female. Show all genotypes, phenotypes, and their percentages. At what point in the cross (at which generation) would the results show you whether this trait is a sex-linked or a normal (autosomal) trait? (*Hint: To answer this, you'll need to carry out this problem, to the F<sub>2</sub> generation, as if it is normal (autosomal) AND as if it were sex-linked. Then you should compare your F<sub>1</sub> and F<sub>2</sub> results. So the question is asking, at which generation, F<sub>1</sub> or F<sub>2</sub>, do the results come out differently if autosomal or if sex-linked?*)
- b. Carry out to the F<sub>2</sub> generation the **reciprocal** cross to the above. (Start with a bobbed female and a normal male in the P<sub>1</sub>.) Show all genotypes, phenotypes, and expected fractions or percents. At what point in the cross would the results show you whether this trait is a sex-linked or a normal (autosomal) trait?

### 4. BAR EYES

A rare mutation in fruit flies produces eyes with an unusual shape called "bar eyes." In order to understand the inheritance pattern of this trait scientists crossed a normal (wild type) female and a bar-eyed male (both true-breeding). The results of the cross are seen below.

|                |                     |     |                   |                      |
|----------------|---------------------|-----|-------------------|----------------------|
| P <sub>1</sub> | NORMAL FEMALE       | X   | BAR-EYED MALE     | (both true-breeding) |
| F <sub>1</sub> | 32 BAR-EYED FEMALES | and | 35 NORMAL MALES   |                      |
| F <sub>2</sub> | 28 BAR-EYED FEMALES |     | 31 NORMAL FEMALES |                      |
|                |                     |     | 29 BAR-EYED MALES |                      |
|                |                     |     | 30 NORMAL MALES   |                      |

- a. Using these data, explain the inheritance pattern of this trait (*i.e.* – is the bar-eye allele dominant or recessive? sex-linked or autosomal?) (*Hint: There are four possible inheritance patterns. To help you, you can do crosses on paper for all the possibilities, and then compare the actual results to your results on paper. Whichever one it matches, should be the inheritance pattern*)
- b. What are the genotypes of all the flies involved?

## Genetics Problems Set #5

### PEDIGREE CHARTS

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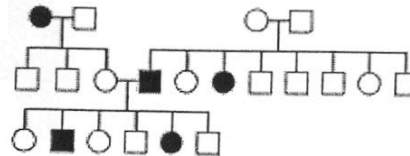
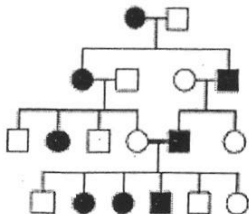
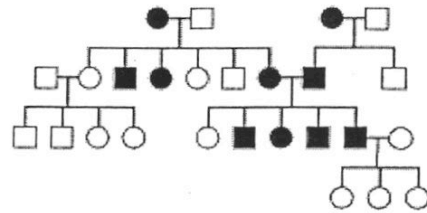
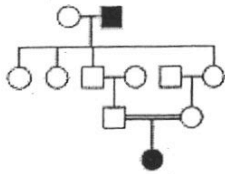
Pedigrees are a way of tracking genetic traits within family trees.

- Squares represent men, while circles represent women.
- Shaded symbols mean the person has whatever condition is being tracked.

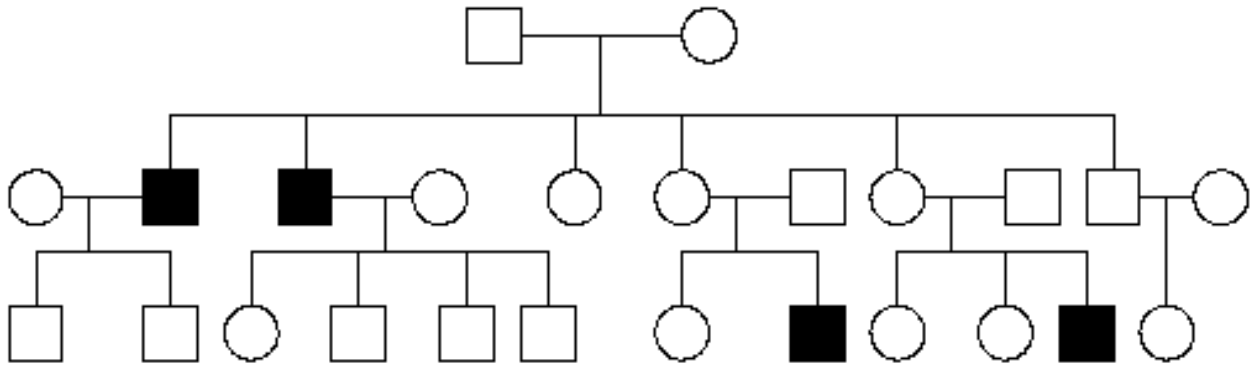
We will work through these first four pedigrees as a class. We want to figure out 1) whether the gene for the trait is carried on an autosome or sex chromosome, 2) whether the allele for that trait is dominant or recessive, and 3) the genotypes of as many of the people as we can.

Some hints that we can use or patterns that we can look for that will help us answer these questions:

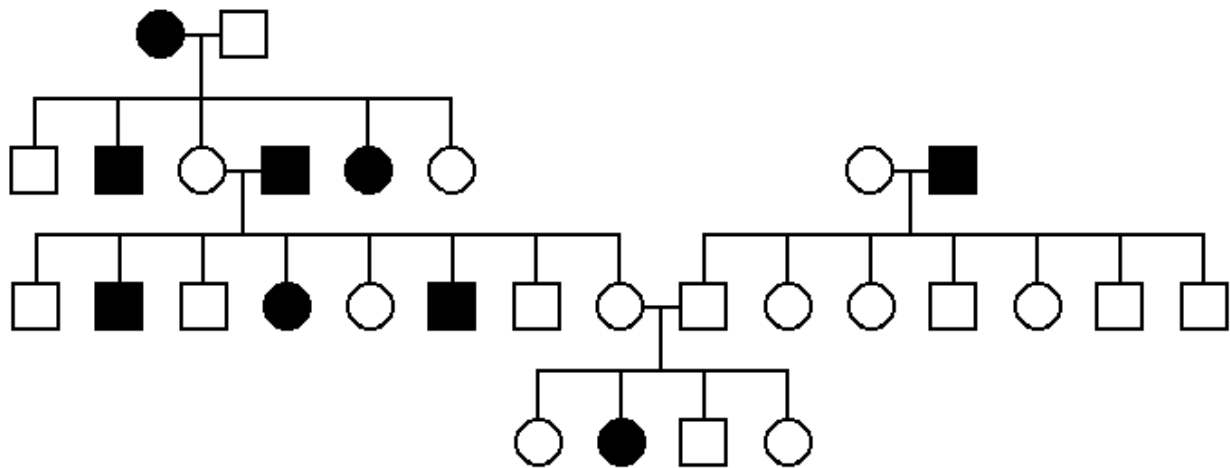
- Do both sexes possess the trait?
- Are there examples where neither parent has the trait, but kids do (*i.e.* – where the trait skips a generation)?
- Generally, when pedigrees follow a trait through a family tree, individuals from outside that family can generally be assumed to not possess that trait.



1. Below is a pedigree of the Buffanblue family. Shaded family members are afflicted with a condition that turns their skin blue and their hair yellow. This is caused by a recessive allele located on the X-chromosome. Write in the genotypes of as many of the people as you can. Use question marks in places where you're unsure.

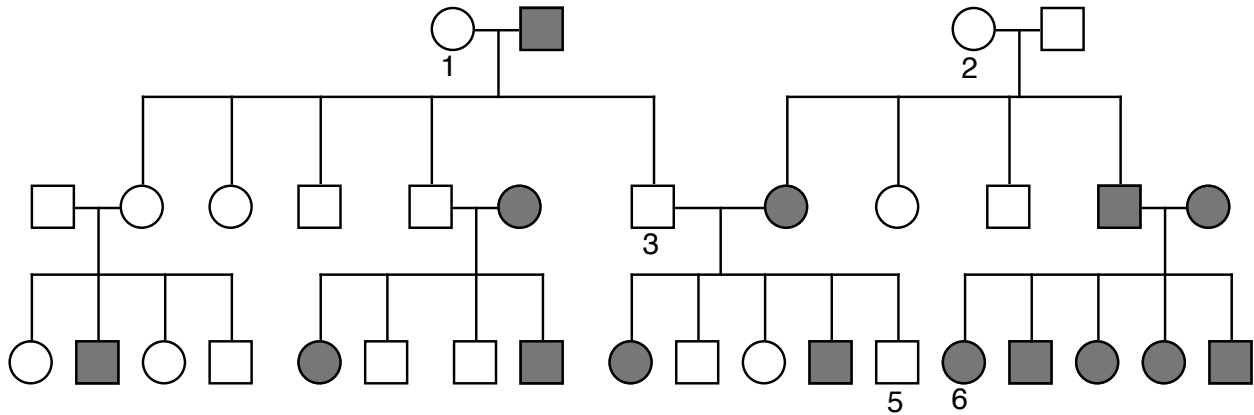


2. Below is a pedigree of the Ivory family. Shaded family members have albinism. Describe how this trait is inherited in this family. Is the gene for albinism found on an autosome or sex chromosome? Is the allele for albinism recessive or dominant? Also describe the genotypes of as many of the people as you can.



3. Use the pedigree below to answer the following questions. Remember squares are males and circles are females, and shaded individuals have whatever trait is being considered.

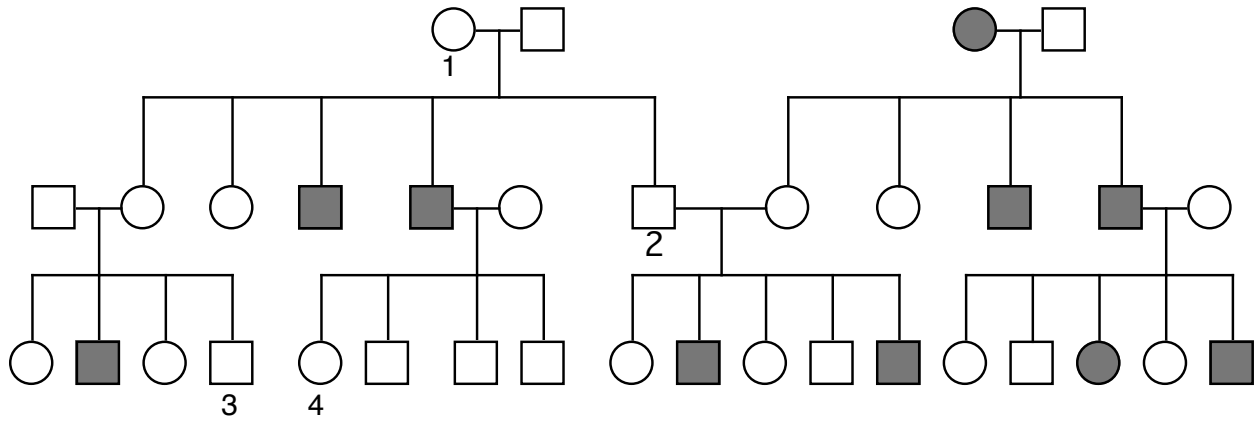
**Pedigree: Albinism (an autosomal recessive)**



- What is the most likely genotype of individual #1? What other genotypes might this person have?
- What is the most likely genotype of individual #2? What other genotypes might this person have?
- What is the most likely genotype of individual #3? What other genotypes might this person have?
- If individual #5 and individual #6 have children, what percent of their children would you expect to be albino?
- How could you tell just by looking at this pedigree whether albinism is dominant or recessive?

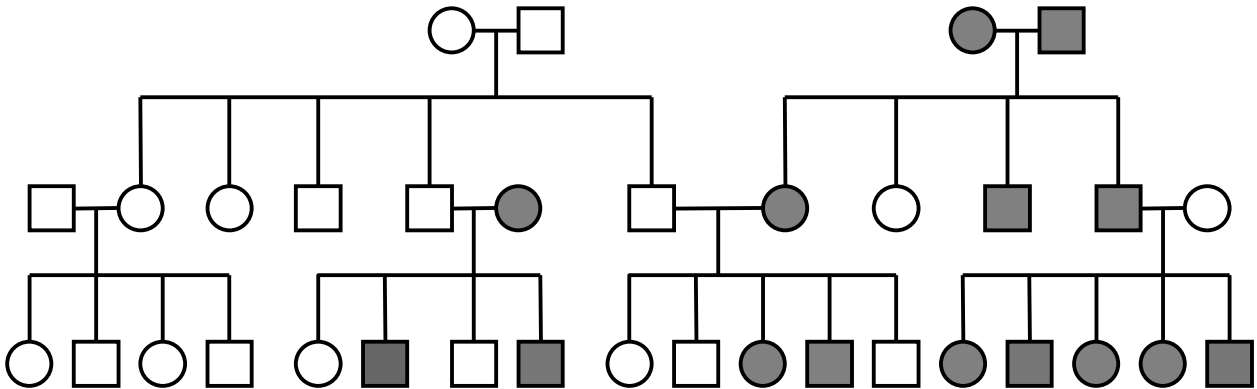
4. Use the pedigree below to answer the following questions.

**Pedigree: Hemophilia (x-linked recessive)**



- What is the genotype of individual #1?
- What is the genotype of individual #2?
- If individual #3 and individual #4 had children, what would be the expected phenotypes for their kids?

5. Consider the following pedigree for Mystery Trait Z.



- Is Mystery Trait Z autosomal or x-linked?
- Is the allele dominant or recessive?
- What makes you think so?