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Tracking Traits with Pedigree Charts

Genetics Demonstration Kit

Introduction

A pedigree chart is a tool used in genetics to determine a family's pattern of inheritance for a given trait. By studying a family's pedigree, the genotype associated with the represented trait may be determined for many family members. When students help construct and then analyze a large-scale magnetic pedigree chart of England's Queen Victoria (1819–1901), they learn about sex-linked traits and the genetic patterns associated with sex-linked inheritance.

Concepts

- Pedigree analysis
- Genetic probability
- Sex-linked trait

Background

Human sex chromosomes are identified as X and Y with males having one of each and females having two X chromosomes. Hemophilia is a sex-linked recessive trait in which one or more of the proteins required to clot blood is absent. The gene for hemophilia is located on the X chromosome, with no corresponding gene on the Y chromosome. Therefore males that inherit the hemophilia gene will exhibit the trait. Heterozygous females, however, are *carriers*, and do not exhibit the trait. Only homozygous recessive females will have hemophilia. In the past, hemophiliacs often died at an early age due to excessive bleeding from an injury or uncontrolled internal hemorrhaging from a bump or fall. Today treatment is available by infusion of the blood clotting factor that is low or missing in people stricken with hemophilia.

A pedigree chart is used to show the pattern of inheritance for a specific trait in a family. Each generation is on one line and is represented by a Roman numeral. Unions that produce offspring are indicated by a short horizontal line between the parents. A vertical line descends from this horizontal line to the next generation. Siblings are connected by a longer horizontal line from which short vertical lines descend to each offspring. Offspring are usually depicted by birth order with the oldest on the left and the youngest on the right. Males are represented by squares and females by circles. The symbols of those who exhibit the trait are shaded. In the case of sex-linked traits where the female is a carrier but does not exhibit the trait, half of the circle is shaded.

Materials

Classroom magnetic chalkboard or dry erase board

Magnetic circles, 2" diameter*

Red, 5

White, 30

Magnetic squares, 2"*

Red, 10

White 35

**Materials included in kit.*

Magnetic strip, 1/2" x 12.5'*

Marker, dry erase

Red colored pencils, one per student

Scissors

Preparation

1. Using scissors, cut four of the red magnetic circles in half.
2. Using the blank Queen Victoria Pedigree Chart as a guide, place white magnetic squares (representing males) and white circles (representing females) on the magnetic board to represent Queen Victoria, her husband, Prince Albert, and four generations of the queen's descendants. *Note:* Do not place any red squares or half-circles on the board at this time.

3. Cut pieces from the magnetic strip for the horizontal lines that connect siblings in a generation. The horizontal strips will vary from several inches to a few feet, depending on the number of offspring.
4. Draw in the vertical lines to each offspring and the horizontal lines connecting spouses.
5. Photocopy enough of the blank Queen Victoria Pedigree Charts, Narration sheets, and Tracking Traits Worksheets for each student.

Procedure

1. Read the narration describing the genealogy of the royal family of Queen Victoria and the incidence of hemophilia among her descendants.
2. As the narration is read, place red half-circles on top of the representative white circles to indicate females who are carriers of the hemophilia trait (see Answer Key). Instruct students to shade in the corresponding half-circles on their blank pedigree charts with a red colored pencil. *Note:* You may wish to have students volunteer to read the narration and place the red magnets in the correct positions on the board.
3. Place red squares on top of the representative white squares (or replace white squares with red) to indicate males who have hemophilia that are mentioned in the narration (see Answer Key). Instruct students to shade in the corresponding squares on their blank pedigree charts with a red colored pencil.
4. When it is uncertain whether or not a male descendant of Queen Victoria had hemophilia, use a dry erase marker to draw a question mark on top of the representative white square. Have students do the same on their charts.
5. Write the names of Queen Victoria, Prince Albert, and descendants mentioned in the narration on the board next to their respective symbols. Instruct students to do the same on their charts.
6. Write the age at death in parentheses next to the names of the males who had hemophilia. Instruct students to do the same on their charts.
7. Have students complete the Tracking Traits with Pedigree Charts Worksheet, using their completed charts as a reference.

Tips

- This kit contains enough reusable materials to perform the demonstration an unlimited number of times: magnetic circles—5 red and 30 white, magnetic squares—10 red and 35 white, and a ½" magnetic strip, 12.5 feet.
- Students should have a basic understanding of pedigree charts—how parents, offspring, and siblings are represented—as well as how to determine genetic probability using Punnett squares.
- Variations of Queen Victoria's pedigree chart may be found in other references. The general rule of representing offspring in birth order from left to right is sometimes ignored for better spacing or to show other relationships such as marriage of first, second or third cousins. The purpose of this activity is to track the trait of hemophilia; therefore such relationships are not indicated and all offspring are represented in birth order from left to right.
- Royalty often changed names upon marriage or when particular titles were conferred upon them; therefore some names of Victoria's offspring and their spouses may differ in other accounts. For example, prior to succeeding his uncle as Grand Duke of Hesse, Ludwig (Alice's husband) was known as Louis IV.
- Both Edward VII and George V had more children than shown on the chart, noted by a double backslash (\). Since the hemophilia trait was not passed on to Edward or his descendants, only the offspring that were in line to assume the throne of England are represented.
- Be very sensitive when asking students to make their own pedigree charts. Students who are adopted, for example, may not know traits of their biological parents or grandparents. Drawing a chart for a family of a close friend may be an option.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12

Evidence, models, and explanation

Content Standards: Grades 5–8

Content Standard C: Life Science, reproduction and heredity

Content Standards: Grades 9–12

Content Standard C: Life Science, molecular basis of heredity

Answers to Worksheet Questions

Use the completed Queen Victoria Pedigree Chart to answer questions 1–5.

- In addition to Alice and Beatrice, Queen Victoria had three other daughters—Victoria (Vicky), Helena, and Louise. Complete the Punnett square below to indicate the possible genotypes of these daughters. What is the probability that any of the queen's daughters would be carriers of hemophilia?

	X^H	Y	
X^H	$X^H X^H$	$X^H Y$	H = normal h = hemophilia
X^h	$X^H X^h$	$X^h Y$	

The probability of any of the queen's daughters being a carrier of hemophilia is 1/2 or 1:1.

- The genotype of many of Queen Victoria's female offspring is unknown with respect to hemophilia. Why is this so?

Since hemophilia is a sex-linked trait, females may be carriers of the disease without exhibiting the trait; therefore, one cannot be certain of the genotype of a female offspring of a carrier. If such an offspring married a man with normal blood and had children with hemophilia, then the genotype would be known.

- Vicky and her sister Helena (question 1) had eight and five children, respectively, with a total of seven male offspring. None of these grandchildren of Queen Victoria had any symptoms of hemophilia. How does this information help infer what Vicky's and Helena's genotypes might be?

Since both women had several male offspring and none of them had hemophilia, the likelihood that either Vicky or Helena was a carrier of hemophilia is small. One still cannot be certain, however.

- Queen Victoria's son Leopold married a woman with normal blood. Complete the Punnett square below to indicate the possible genotypes of their offspring. What is the probability of Leopold having a son with hemophilia?

	X^h	Y	
X^H	$X^H X^h$	$X^H Y$	H = normal h = hemophilia
X^H	$X^H X^h$	$X^H Y$	

The probability of Leopold having a son with hemophilia is zero.

- England's reigning monarch is Queen Elizabeth II, a great-granddaughter of Queen Victoria's oldest son, Edward VII. Elizabeth's oldest son, Charles, is next in line for the throne. What is the possibility that Charles inherited hemophilia? Explain your answer.

It is extremely unlikely that Prince Charles inherited hemophilia. Since Charles' ancestor Edward VII did not inherit the trait from his mother, Queen Victoria, no incidence of hemophilia is found in that branch of the royal family.

- Choose a genetic trait that some, but not all, members of your immediate family exhibit. Draw a pedigree chart on a separate sheet of paper showing at least two generations, your parents and yourself along with any siblings you may have. If information is available, you may include grandparents as well. Be sure to include a key indicating the trait represented.

Student charts will vary. Note to teacher: See the Tips section regarding students' personal pedigree charts.

References

Van Hoeck, K. *Genetics: Laboratory and Classroom Activities*, 2nd ed.; Flinn Scientific: Batavia, IL; 2010, pp 24–25.

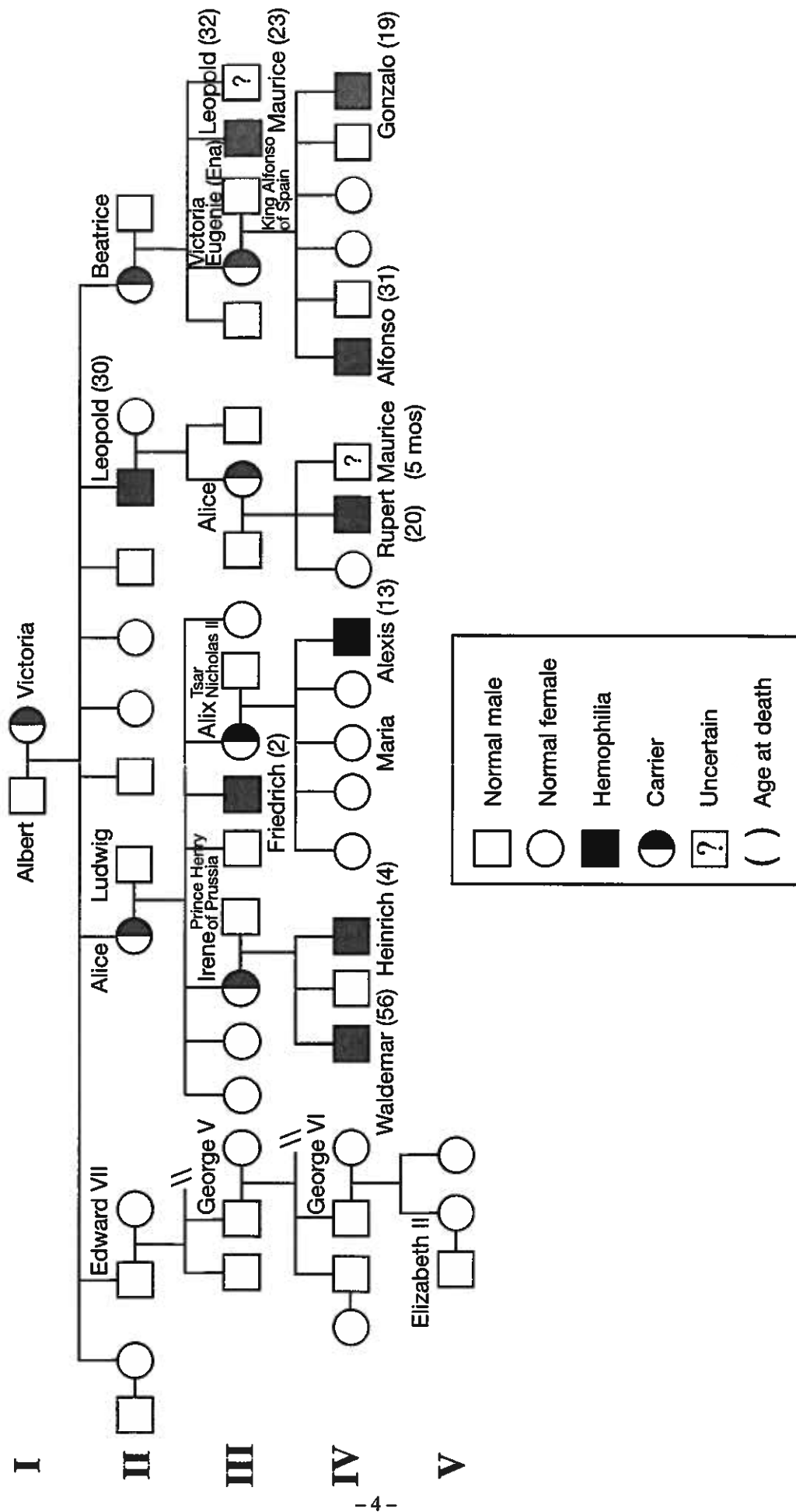
Materials for Tracking Traits with Pedigree Charts—Genetics Demonstration Kit are available from Flinn Scientific, Inc.

Catalog No.	Description
FB1965	Tracking Traits with Pedigree Charts— Genetics Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Queen Victoria's Pedigree Chart

Answer Key



Tracking Traits with Pedigree Charts

Narration:

Queen Victoria (Generation I) was the Queen of Great Britain from 1837 to 1901. She was married to Prince Albert and had nine children. Queen Victoria was a carrier of *hemophilia*, which is a sex-linked recessive trait in which one or more of the proteins required to clot blood is absent.

Victoria's second daughter Alice (G II) was also a carrier of the disease. She married Prince Ludwig of Hesse (part of modern-day Germany) and had seven children. Alice's second son Friedrich (G III) had hemophilia and died after a fall at two years of age. Irene (G III), Alice's third daughter, was a carrier. Irene married Prince Henry of Prussia and had three sons. Only Irene's middle son was spared from the disease. Her youngest, Heinrich (G IV), died at age four after a fall. Even though Irene's eldest son Waldemar (G IV) lived to the age of 56, his death was directly caused by hemophilia when he was not able to receive a needed blood transfusion during World War II.

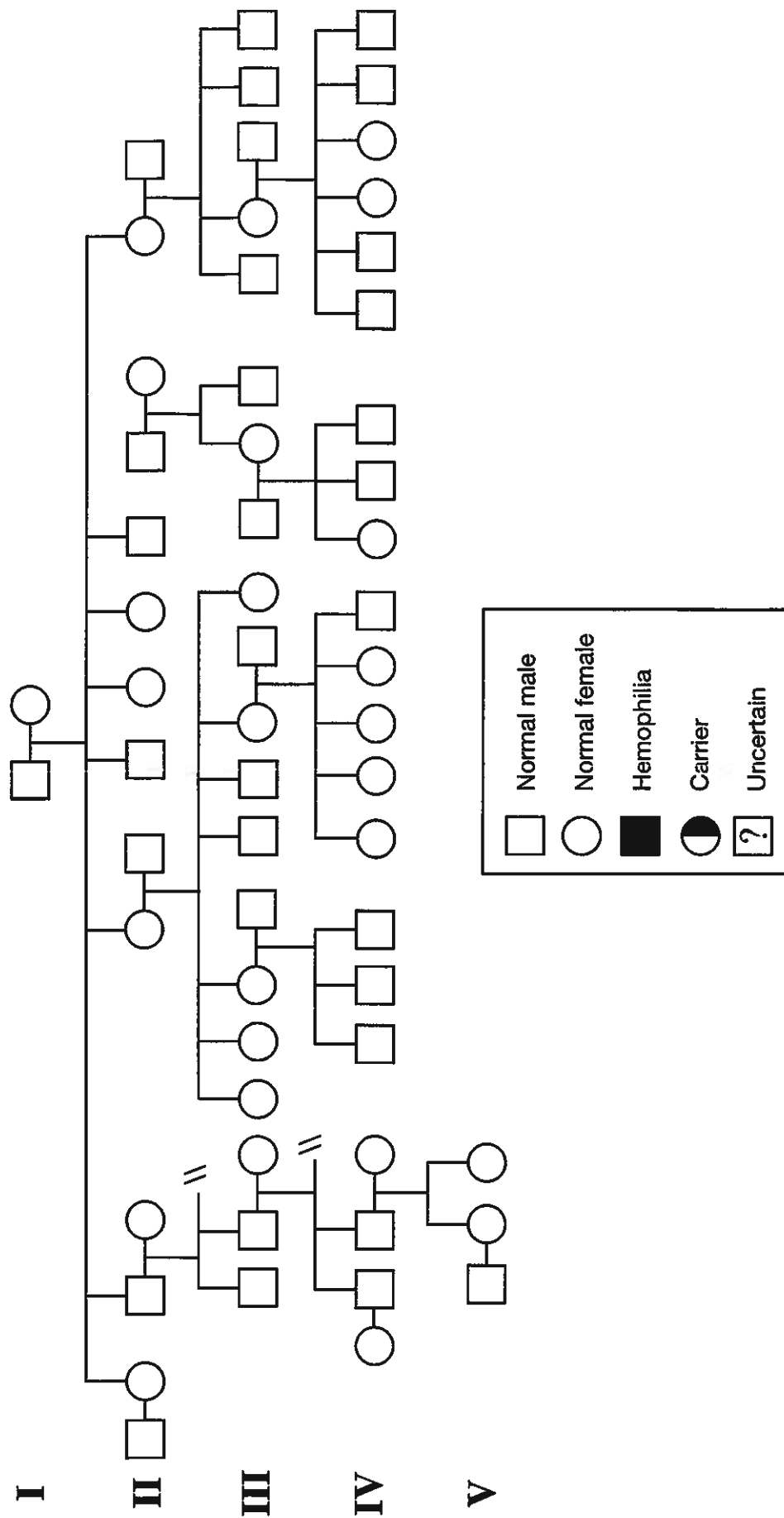
Alice's fourth daughter Alix (G III) was a carrier. She married Tsar Nicholas II of Russia. They had four girls and one son, Alexis (G IV). Alexis had hemophilia. Whether or not the daughters were carriers is unknown because the entire family was executed in 1918 during the Russian Revolution. The third daughter, Maria, may have been a *symptomatic carrier* (one who exhibits some blood clotting impairment without the diagnosis of hemophilia) because she experienced severe bleeding during a tonsillectomy.

Queen Victoria's youngest son Leopold (G II) was the queen's only son with hemophilia. He married and had two children before he died at age 30 due to internal bleeding after a fall. His only daughter Alice (G III) was a carrier. Alice had three children. Her youngest son Maurice (G IV) died at 5 months of age, so it is unknown if he had hemophilia. Alice's oldest son Rupert (G IV) did have hemophilia and died at age 20 from injuries sustained in a car accident.

The youngest offspring of Queen Victoria, daughter Beatrice (G II), was a carrier. She had four children. Her second son Leopold (G III) died at age 32 from complications due to hemophilia during a knee operation. Beatrice's youngest, Maurice (G III), was killed in action during World War I at age 23. Whether or not Maurice had hemophilia is in question. Some believe he would not have been allowed to go into combat if he had the disease.

Beatrice's only daughter Victoria Eugenie (called Ena) married King Alfonso XIII of Spain. Ena (G III) was a carrier and passed the trait to her oldest son Alfonso (G IV) and to her youngest son Gonzalo. They died in separate car accidents at the ages of 31 and 19, respectively, due to severe internal bleeding.

Queen Victoria's Pedigree Chart



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Name: _____

Tracking Traits with Pedigree Charts Worksheet

Discussion Questions

Use the completed Queen Victoria Pedigree Chart to answer Questions 1–5.

1. In addition to Alice and Beatrice, Queen Victoria had three other daughters—Victoria (Vicky), Helena, and Louise. Complete the Punnett square below to indicate the possible genotypes of these daughters. What is the probability that any of the queen's daughters would be carriers of hemophilia?

	X^H	Y	
X^H			$H = \text{normal}$ $h = \text{hemophilia}$
X^h			

2. The genotype of many of Queen Victoria's female offspring is unknown with respect to hemophilia. Why is this so?
3. Vicky and her sister Helena (question 1) had eight and five children, respectively, with a total of seven male offspring. None of these grandchildren of Queen Victoria had any symptoms of hemophilia. How does this information help infer what Vicky's and Helena's genotypes might be?
4. Queen Victoria's son Leopold married a woman with normal blood. Complete the Punnett square below to indicate the possible genotypes of their offspring. What is the probability of Leopold having a son with hemophilia?

	X^h	Y	
X^H			$H = \text{normal}$ $h = \text{hemophilia}$
X^H			

5. England's reigning monarch is Queen Elizabeth II, a great-granddaughter of Queen Victoria's oldest son, Edward VII. Elizabeth's oldest son, Charles, is next in line for the throne. What is the possibility that Charles inherited hemophilia? Explain your answer.
6. Choose a trait that some, but not all, members of your immediate family exhibit. Draw a pedigree chart on a separate sheet of paper showing at least two generations, your parents and yourself along with any siblings you may have. If information is available, you may include grandparents as well. Be sure to include a key indicating the trait represented.