

Pick the Risk: The Polygenic Pedigree Challenge

Abstract

Students are challenged to track and record the passage of colored pom poms (representing genes) through generations of a family using a pedigree. Students learn that common chronic diseases (such as heart disease) run in families and are caused by the combined action of multiple genes.

Logistics

Time Required

▶ **Class Time:**
30 - 45 minutes

▶ **Prep Time:**
30 minutes

Materials

Copies of student pages, colored pencils or crayons, disposable cups, colored pom poms.

Prior Knowledge Needed

Genes are passed from parents to offspring and contribute to observable physical characteristics. Pedigrees are used to track genetic information.

Appropriate For:

Ages: 12 - 18
USA grades: 7 - 12

Learning Objectives

- ▶ An inherited trait can be determined by one or by many genes.
- ▶ All humans have the same genes, but each inherits slightly different forms or “flavors” of each gene.
- ▶ Many common diseases (such as heart disease) run in families and have a genetic component.
- ▶ Most common diseases are caused by the combined action of multiple genes and environmental factors.
- ▶ An individual's risk of developing a common disease is estimated by looking at siblings, parents and grandparents in a family medical history.

Pick the Risk: The Polygenic Pedigree Challenge

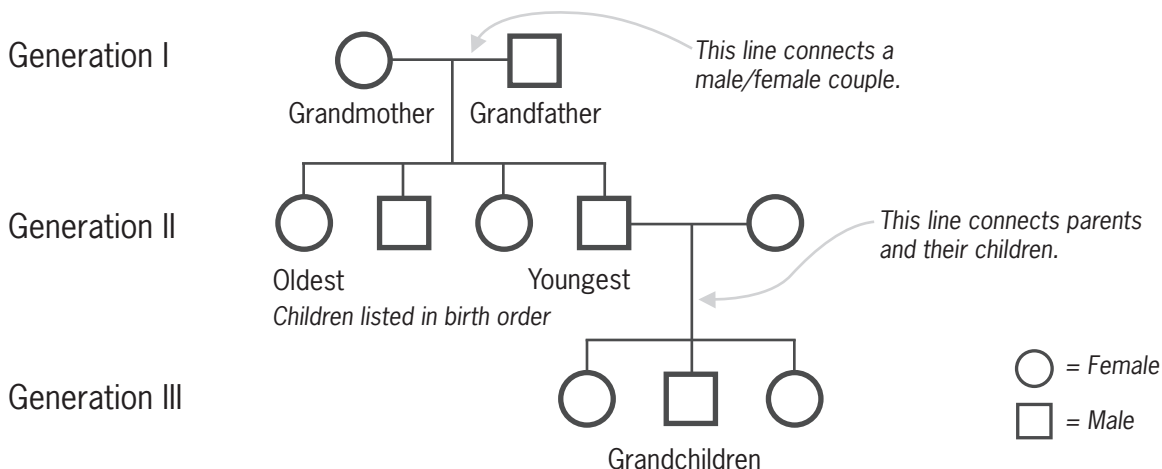
Classroom Implementation

To engage students in this topic:

- Compare the prevalence of rare genetic disorders caused by a single gene such as cystic fibrosis (1 in 10,000) with the prevalence of more common diseases such as heart disease (1 in 3).
- Ask the students: Do common diseases like heart disease, diabetes, or colon cancer have a genetic component?
- Explain that most common diseases do have a genetic component and tend to run in families. However, common diseases differ from rare genetic disorders in that they are usually not caused by defects in a single gene. Rather, they result from the combined effects of multiple genes and environmental factors. Thus, they are called multifactorial diseases.
- Explain that because more than one gene is involved in most common diseases, the inheritance of a common disease is not predictable.
- Information found in a family health history and recorded on a pedigree is used to estimate an individual's genetic risk (low, medium, or high) of developing a common disease.

Activity instructions:

- Explain that the following activity will explore how common “polygenic” diseases (in this case, heart disease) are inherited.
- Invite students to find a partner with whom they will work to complete the activity; pass out the student pages and other materials.
- Review the symbols and structure used for a pedigree:



Quantities

Per Group of 2

- ▶ One copy of participant pages
- ▶ 2 - 3 disposable cups
- ▶ Colored pencils or crayons
- ▶ Colored pom poms (5 different colors: at least 10 red, 2 yellow, 1 each of orange, green, blue)

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- Invite students to begin by following the instructions found on the student pages; each pair of students should complete the pedigree analysis and answer the questions that follow.

Class Discussion:

- Point out that this activity differs from reality in the following ways:
 - » The number of genes contributing to a polygenic disease is usually not known.
 - » The number of genes carried by parents or offspring that can increase heart disease risk is not known.
 - » Environmental factors can also vary an individual's risk of developing multifactorial diseases.
- Emphasize that these are a few of the reasons why heart disease and other common diseases are so complex, and why the inheritance patterns for such diseases are difficult to predict.
- Therefore, individuals are placed in general categories (high, medium, or low risk groups) based on features from their family health history that correlate with a certain probability of developing a disease.
 - » For example, it is said that an individual who has a parent (or possibly a grandparent) with heart disease may be "at risk" and should take steps to protect themselves.
- Describe the important features to identify in a family health history (see chart at <http://learn.genetics.utah.edu/units/health>), including what is meant by a "close" relative.
 - » Siblings, parents, and possibly grandparents, are informative when assessing an individual's risk of developing a common disease and need be included in a family health history. It is unlikely that all of the same risk factors (genes) will be present in less closely related family members.
- Discuss why each feature in the chart indicates an individual may be at *increased* risk for developing heart disease.
 - » Each feature indicates that the family has accumulated more risk factors (genetic or environmental). Therefore, an individual in this family is more likely to develop disease.
- Discuss behaviors and choices that can *reduce* an individual's risk of developing heart disease.
- Conclude the class discussion by reminding students that genetic susceptibility does not mean an individual will inevitably inherit a disease. Positive lifestyle changes and healthy living can reduce genetic risk dramatically. That is why it is so important to know your family health history. If you know you are "at risk" you can take steps to protect yourself.

Common Misconception

Students may think that all heritable traits (and genetic disorders) are caused by a single gene and exhibit dominant or recessive patterns of inheritance. But more commonly, traits result from the combined action of many genes and environmental factors. Such multifactorial traits can exhibit varied and complex patterns of inheritance that are not easy to predict.

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Extension:

- Illustrate that multifactorial traits vary within a population along a continuum:
 - » Combine class results from Grandma and Grandpa's children (not grandchildren) to generate a population of people who inherited a low, medium, or high risk of developing heart disease.
 - » Calculate the total number of individuals in the population (4 X # of student pairs).
 - » Calculate the number of individuals that inherited a low, medium or high risk of developing heart disease.
 - » Graph the results with the low, medium and high risk categories along the x axis, and the number of individuals along the y axis.
 - » Draw a curved line over the histogram to show that this trait follows a bell-shaped distribution in the population, with most people at medium (or average) risk of developing heart disease.
 - » Emphasize that in reality heart disease risk varies within a population along a continuum, and an individual's location along this risk continuum is determined by his or her genes and environment.

Additional Resources

Visit the [Learn.Genetics](http://learn.genetics.utah.edu) website to get more great resources like this one!

Standards

U.S. National Science Education Standards

Grades 5-8:

Content Standard C: Life Science - Reproduction and Heredity

- » A new individual receives genetic information from its mother and its father.
- » Hereditary information is contained in genes. An inherited trait of an individual can be determined by one or by many genes.
- » Some traits are inherited and others result from interactions with the environment.

Content Standard F: Science in Personal and Social Perspectives - Risks and Benefits

- » Risk analysis considers the type of hazard and estimates the number of people that might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.

Grades 9-12:

Content Standard C: Life Science - Molecular Basis of Heredity

- » The genetic information that underlies heredity is encoded in genes.

Content Standard F: Science in Personal and Social Perspectives - Personal and Community Health

- » Many diseases can be prevented, controlled or cured.
- » Personal choice concerning fitness and health involves multiple factors. Understanding of biological consequences can influence decisions about health practices.

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U.S. National Health Education Standards

Grades 5-8:

Standard 1: Students will comprehend concepts related to health promotion and disease prevention to enhance health.

- » Describe how family history can impact personal health.

Grades 9-12:

Standard 1: Students will comprehend concepts related to health promotion and disease prevention to enhance health.

- » Analyze how genetics and family history can impact personal health.

AAAS Benchmarks for Science Literacy

Grades 6-8:

The Living Environment: Heredity - Begin the study of genetic traits-what offspring get from parents.

- » In organisms that have sexes, typically half of the genes come from each parent.

Grades 9-12:

The Living Environment: Heredity - Understanding DNA makes possible an explanation of such phenomena as the similarities and differences between parents and offspring and hereditary diseases.

- » Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious.



Credits

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Answer Key

1. The grandfather in this family was a “high risk” individual. How many of his children were either medium or high risk individuals? How many of his grandchildren were either medium or high risk individuals?

Answers will vary.

2. Did the number of “medium risk” and “high risk” individuals decrease or increase over subsequent generations? Why do you think that happened?

Decrease. Risk of inheriting heart disease from an affected individual (such as a grandparent) decreases throughout the generations because it is unlikely that all of the necessary risk factors (genes) will be passed down to less closely related family members.

3. In this activity you were able to label family members as having a low, medium or high risk of developing heart disease. In reality, do you think it might be difficult to predict an individual's risk of developing heart disease? Why?

An individual's risk of developing heart disease IS difficult to predict because:

Heart disease is polygenic; the number of genes contributing to heart disease is not known.

The number of genes carried by parents or offspring that can increase heart disease risk is not known.

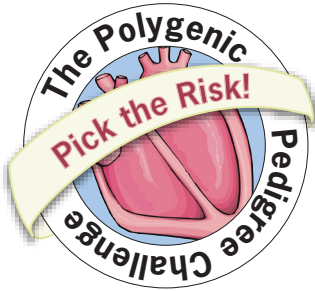
Environmental factors also vary an individual's risk of developing heart disease.

4. If a parent is diagnosed with heart disease, does that mean the children will have it also? Defend your answer. (Your brief answer should include the key word “risk”.)

Not necessarily. But because heart disease does have a genetic component, children of an affected parent have an increased risk of developing heart disease (relative to the population at large).

Name _____

Date _____



You are a researcher investigating heart disease. You know there are 6 genes in humans that can contribute to heart disease risk. All humans have these 6 genes, but we can inherit slightly different forms or “flavors” of these genes. Your challenge is to track and record the passage of these 6 genes (signified by colored pom poms) through generations of a family using a pedigree. Then, predict which members of this family are most likely to develop heart disease.

Follow the steps below to complete this challenge.

Part 1:

1. Obtain a blank pedigree, colored pencils or crayons, 2 disposable cups, and an assortment of colored pom poms from your teacher.
2. Choose one cup that will represent a grandmother. Place inside the cup 5 red pom poms (5 “normal” genes that do NOT contribute to heart disease) and 1 blue pom pom (1 gene that increases heart disease risk).
3. Choose one cup that will represent a grandfather. Place inside the cup 3 red pom poms (3 “normal” genes that do NOT contribute to heart disease), as well as 1 orange, 1 green, and 1 yellow pom pom (3 genes that increase heart disease risk).
4. On the pedigree, record the colors of pom poms present in both the grandmother and grandfather by filling in the blank circles using crayons or colored pencils.
5. With closed eyes, mix and randomly draw out 3 pom poms from each grandparent (6 pom poms total). This will represent the genetic information inherited by their first child.

Remember: No peeking! This needs to be random.

6. On the Pedigree, color in the combination of pom poms that were passed on to the child.
7. Return the pom poms to the appropriate grandparent. (Give grandma’s genes back to grandma, and give grandpa’s genes back to grandpa.)
8. Repeat steps 5-7 for each son or daughter in the second row of the pedigree. Do not do the son’s partner.

Name _____

Date _____

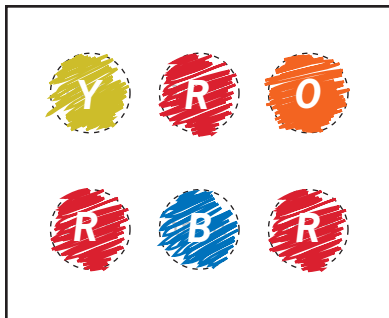
9. Diagnosis:

Look at each individual's 6 heart disease susceptibility genes (their combination of colored pom poms). Remember: The forms or "flavors" of a gene that increase heart disease risk are

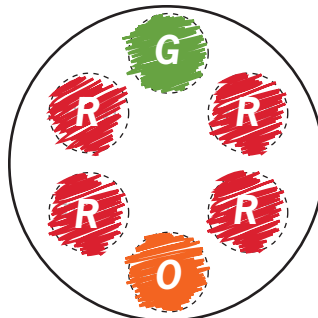


Label each individual in your pedigree as low, medium or high risk according to the chart below.

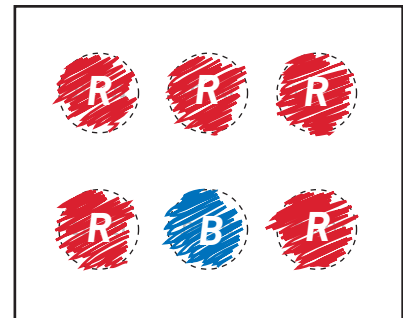
High Risk



Medium Risk



Low Risk



Part 2:

10. Place in a cup 6 pom poms that are the colors you drew for the second son in row 2.
11. The partner of the second son is a "low risk" woman. Place inside a cup 5 red pom poms and 1 yellow pom pom to represent her 6 heart disease susceptibility genes.
12. On the pedigree, color in the combination of pom poms (or genes) carried by the partner of the second son.
13. The couple has children. With closed eyes, mix and randomly draw out 3 pom poms from each parent (6 pom poms total). This will represent the genetic information inherited by their first child.
14. On the pedigree, color in the combination of pom poms that were passed on to the child.
15. Return the pom poms to the appropriate parent.
16. Repeat steps 12-14 to determine the genetic make-up of the other two children represented in the pedigree.
17. Label each individual that has been added to your pedigree as low, medium or high risk.

Name _____

Date _____

Student Pedigree

grandmother

grandfather

