Title: Unraveling the Sickle Cell Puzzle

Brief Overview:

This learning unit is intended to make students more familiar with genetic diseases and their transmission from parent to offspring. This unit also exercises the student's skills in predicting, estimating, collecting and reporting statistical data, expressing data in graphs and tables, answering questions using algebraic equations, and analyzing final results.

Links to NCTM 2000 Standards:

- **Mathematics as Problem Solving**
  Students will collect data and determine the percent frequency of specific genes in a given population.

- **Mathematics as Reasoning and Proof**
  Students will focus on learning to reason and construct proof by estimating and comparing with a real world model the frequency of sickle cell anemia in a population.

- **Mathematics as Communication**
  Students will communicate the mathematical data collected in their cooperative learning groups by sharing that data to formulate a class average and by using that information to support a debate on genetics.

- **Mathematics as Connections**
  Students will recognize the use of probability and percentages to analyze problems in real world situations.

- **Mathematics as Representation**
  Students will develop mathematical skills such as averaging, using tables and using formulas that represent populations to solve problems.

- **Number and Operation**
  Students will use computational tools and strategies such as prediction, basic mathematical skills and algebraic formulas to analyze collected data.

- **Patterns, Functions, and Algebra**
  Students will use genetic patterns and algebraic formulas to further their understanding of sickle cell anemia.

- **Geometry and Spatial Sense**
  Students will create a statistical graph of the class data and explore spatially through hands-on activities and demonstrations.

- **Data Analysis, Statistics, and Probability**
  Students will collect, predict, organize, and represent data to answer questions based on genetics. Students will discuss and support their opinions on the current topic of genetic testing of children in a classroom debate.

Links to Maryland High School Mathematics Core Learning Goals:

Functions and Algebra

- **1.1**
  Students will analyze a wide variety of patterns and functional relationships using the language of mathematics and appropriate technology. (l.l.l, l.l.2, l.l.3)

- **1.2**
  Students will model and interpret real-world situations, using the language of mathematics and appropriate technology. (l.2.5)

Geometry, Measurement, and Reasoning

- **2.2**
  Students will apply geometric properties and relationships to solve problems using tools and technology when appropriate. (2.2.3)

Data Analysis and Probability

- **3.1**
  Students will collect, organize, analyze, and present data. (3.l.l, 3.l.3)

- **3.2**
  Students will apply the basic concepts of statistics and probability to predict possible outcomes of real world situations. (3.2.l)

Links to National Science Education Standards:

- **Unifying Concepts and Processes**
  Students will collect evidence, model that evidence in a game, and explain their results in a debate.

- **Science as Inquiry**
  Students will demonstrate their understanding and strengthen their abilities to do scientific inquiry through collecting and processing data.

- **Life Science**
  Students will strengthen their understanding of heredity through classroom activities.

- **Science and Technology**
  Students will broaden their understanding of the use of technology in genetic testing.

- **Science in Personal and Social Perspectives**
  Students will acquire an appreciation of personal health and socio-ethnic health problems in the real world.

Grade/Level:

Middle school students, Grades 7-9

Duration/Length:

Four, fifty-minute class periods

Prerequisite Knowledge:

Students will need to have a basic knowledge of how genetic traits are passed from parents to offspring and knowledge of Punnet Squares. They will need to be familiar with genetic vocabulary, such as: gene mutation, carrier, and other related terms. Students also will need to have basic algebraic, estimating, and predicting math skills.

Student Outcomes:

Students will be able to:

- estimate and predict an outcome prior to data collection.
- collect and report statistical data.
- analyze their collected data and express it in tables and graphs.
- answer questions using algebraic equations and analyze the resulting data.
- form a personal opinion on genetic testing and support their opinion with facts in a classroom debate.

Materials/Resources/Printed Materials:

- Bulletin board materials
- Beans and containers
- Construction paper and yarn
- Data worksheets
- Copies of assessment for all students

Development/Procedures:

Day 1

- The class will be introduced to the topic of genetic diseases in a classroom discussion led by a knowledgeable Health Professional or the classroom teacher. In this discussion the teacher and students will share what they know about genetic diseases and how they relate to the information already covered in class on the topic of genetics. (Please see prerequisite knowledge listed above.) The discussion should cover genetic testing, how genetic diseases are transmitted, who can get these diseases, and should list several example diseases.
  Duration: approximately 20 minutes

- All students in the class will participate in an activity which demonstrates how sickle cell anemia is transferred from generation to generation in families. Using cards placed around their necks for identification, two students (the parent generation) will pass their genes onto their two "children". One parent will be a carrier of the sickle cell gene and the other parent will not be a carrier of the gene. Therefore one "child" will receive the sickle cell gene. The teacher will have enough cards for the entire class to each have two genes to pass on to several generations. Students will randomly be assigned genes and will enter the family tree as either parents, through marriage or as offspring. The teacher can predetermine the roles or assign roles as needed. Any "child" who receives two sickle cell genes will "develop" the disease and will not go on to reproduce. The carriers of the gene however will continue to pass the genes down in a family tree. A chart should be developed from the information as each team member receives or passes on genes. The teacher should stress the difference between carrying the gene for the disease and developing the disease and the random distribution of genes.
  Duration: 30 minutes

Day 2

- In a hands-on laboratory activity, students will determine the changes in the frequencies of the hemoglobin A and S genes in two experimental generations. The activity will involve students determining the frequencies of the A and S genes by randomly selecting two genes from a parent population of 75% hemoglobin A and 25% hemoglobin S genes. The "genes" will be red and black beans that are easily distinguishable from each other.

A student will select two beans at a time without looking and these beans will be categorized as either AA(two red) and placed in a container labeled AA, SS(two black) and placed in a container labeled SS, or one S and one A (one red and one black). The students will keep track of how many times SS, AA, and AS combinations were picked and will tally this on a provided chart. The students also will determine the total number of genes in the population, the percent of the A gene in the population, and the percent of the S gene in the population. This will be compared to the U.S and world percentages believed for these genes.

- The students will set aside all the beans in the SS jar and continue the activity using the beans in the AS jar and AA jar as the parents. The SS beans are removed because these represent people who are ill and not likely to reproduce. The activity is repeated the same as above and the new percentages are compared. (For a more detailed step by step listing of this activity, please see the included student worksheet.) The worksheet includes a precise procedure list, calculations, and discussion questions.
  Duration: 50 minutes

Day 3

- The students will take their data from the previous lesson's results and share it with the class to reach a class average. Since the "genes" were randomly picked, the student's data should be averaged to allow for more trials to be considered and to make the data more accurate. The students should obtain a class average for the frequency of gene A in the second generation and the frequency of gene S in the second generation. The same should be determined for the third generation, along with total population of genes in the third generation. The students should then graph these results in their lab groups to compare the changes in the gene population of the two generations. Reasons for the changes should be discussed as a class and the data should be compared to the real-world percentage of the sickle cell gene frequency of 4 - 16%. Students will then answer and review discussion questions at the end of the activity worksheet. See the worksheet for exact calculations and questions.
  Duration: 30 minutes

- The students will use the information from the activity and discussion on the frequency of the sickle cell gene, and prior discussed information on genetic testing to have a classroom debate. The debate will include the topics of, whether or not babies should be tested for sickle cell anemia at birth, and whether or not couples who plan to get married should be tested. The teacher will assign a panel to be "for" genetic testing and a panel to be "against" genetic testing. The remaining students in the class will have to ask questions of the panels and at the end will vote on whether they support genetic testing or not based on the information presented by the panels. The teacher should lead the debate in the direction of the pros and cons of genetic testing, the effects of the disease of sickle cell anemia, and encourage discussion of other genetic diseases.
  Duration: 20 minutes

Day 4

- Students will complete a summative evaluation on genetic testing. See included assessment.
  Duration: 25 minutes

Assessment:

- The activities presented over the previous three days allow for various forms of assessment throughout the activities. In the first day's activities the teacher can evaluate students on their class participation in the creation of a family genealogy of the passing of the sickle cell gene.

Also, the teacher can informally assess the knowledge of the topic by questions and answers during the class discussion on genetic diseases.

- During the hands-on activities, the teacher can check for understanding the procedure of the activity by involving himself or herself with each lab group to check progress and ask or answer questions. The summative evaluation for this activity will be collected on the third day and will include the graph of the class data, calculations, and completed discussion questions. This can be considered the hard copy of the lab work and be evaluated by the facilitating teacher as he or she sees fit or with the provided rubric.

- The final evaluation will be given in the form of a summative assessment on the fourth day and will consist of producing a Punnet Square of how the sickle cell gene is distributed by giving the genotype of two parents, calculations, and essay questions.

Extension/Follow Up:

- Activities for extension of the lesson may include having groups of students research other genetic diseases on the Internet. For example, students could research albinoism, cystic fibrosis, or color blindness and present the information they find to the class.

- Students also could research possible carriers that involve the use of genetics and DNA testing, such as, genetic counselors or forensic researchers.

- For further science inquiry, students may take the information gathered during the Internet research and use it to alter the Sickle Cell Anemia lab to express the frequency of a different genetic disease in a population.

Authors:

Sharon McCormley
Visitation Academy (Frederick)
Frederick County, MD

Julianna K. Shaw
Seaford High School
Sussex County, DE

Genetics Lab Activity- Sickle Cell Anemia

Teacher Background Information-

The passing of traits from a parent to offspring is known as heredity. In some cases a parent can pass a mutated gene on to their offspring which may result in a genetic disease. Sickle Cell Anemia is an example of a genetic disease that can be passed from the parent to the offspring. Sickle Cell Anemia results from a mutation in the gene for hemoglobin. Hemoglobin is responsible for carrying oxygen in red blood cells.

There are two know alleles for the production of hemoglobin. Individuals with normal red blood cells carry two hemoglobin A genes (AA). Individuals with Sickle Cell Anemia carry two hemoglobin S genes (SS) and have the disease. An individual may also be heterogeneous and carry both genes (AS). A heterogeneous individual will carry the sickle cell gene but will not suffer from the disease.

In the United States the allelic frequency for the S allele in the population is 4%. People carrying the SS genotype develop Sickle Cell Anemia and do not usually reproduce in the population. This keeps the frequency of the S allele low in the general population.

In Africa the S allele has a higher frequency in the population (16%). This is due to the fact that the AS heterogeneous genotype gives that individual a better chance of surviving malaria. Malaria is a common disease in Africa and will easily kill people with the genotype AA, leaving more heterogeneous AS individuals in the population to reproduce. This raises the frequency of the S gene in the population to 16%.

Reference

Basic Background Information Obtained From:

Biology- The Dynamics of Life, 1995, Mcgraw-Hill, Westerville, OH

Discussion Questions
TEACHER ANSWER KEY

1. What was the frequency of the A gene and S gene in the original population?

   A gene **Depends on Results** S gene **Depends on Results**

2. In the second generation, what was the frequency of both genes?

   A gene **Depends on Results** S gene **Depends on Results**

3. In the third generation, what was the frequency of both genes?

   A gene **Depends on Results** S gene **Depends on Results**

4. What are your conclusions?

   The frequency of the S hemoglobin gene decreases in each generation.

5. Do you see a pattern?

   Depends on student results

6. Since people with sickle cell do not usually live to have children of their own, why hasn't this disease died out?

   It is a genetic mutation of the hemoglobin gene and therefore can be created during DNA replication. It is not a virus nor is it curable.

7. Why is the frequency of sickle cell more prevalent in Africa than the U.S.?

   In Africa, the sickle cell allele protects heterogeneous individuals from malaria and thus balances the tendency of selection to eliminate the sickle cell gene.

8. Does a carrier for the sickle cell anemia show the trait? Explain.

   No. Because a carrier does not have a physical manifestation of the disease.

Summative Assessment
ANSWER KEY

Write a short essay answer to each of the following questions:

1. What is sickle cell anemia?

   Sickle cell anemia results from a mutant gene for hemoglobin and is potentially fatal.

2. Can I catch sickle cell anemia, like a cold? Why or why not?

   No. Because sickle cell anemia is not a virus. You cannot catch it from another person.

3. What are my chances of getting sickle cell anemia if both of my parents carry the genetic trait for it?

   Your chances would be 25%.

4. What does the word mutation mean in relation to genetics?

   The gene changes form during DNA replication.

5. What is a carrier in genetics?

   A carrier is a person who has a recessive gene for a trait but does not show the trait.

6. After listening to our discussion panel, would you want genetic testing of your child if you knew you and your spouse both carried a genetic trait for a potentially fatal disease? Why or why not?

   This is strictly the opinion of the student.

Circle the letter of the answer that best completes each statement.

7. A person with sickle cell anemia

   a. inherits 1 sickle cell gene from his or her mother;
   b. inherits 1 sickle cell gene from his or her father;
   c. inherits 2 sickle cell genes, 1 from each parent;
   d. none of these

8. Sickle cell anemia results from an error in the

   a. hemoglobin molecule
   b. white blood cells
   c. plasma
   d. blood vessels

Rubric for Sickle Cell Learning Unit

3
* accurate charting of class and world data
* showing algebraic formula computation
* thoughtful answers to discussion questions
* correct Punnet Square, calculations, and accurate essay questions

2
* inaccurate charting of class and world data
* getting algebraic formula answers correctly but not showing computation
* inaccurate answering of most discussion questions
* incorrect answers on Punnet Square, calculations, or essay questions

1
* incomplete charting of class and world data
* incomplete algebraic formula answers
* little effort in answering discussion questions
* most of information on Punnet Square, calculations, or essay unanswered

0
* not charting of class and world data
* no algebra answers
* no answers to discussion questions
* no answers to Punnet Square, calculations, or essay questions

Unraveling The Sickle Cell Puzzle

Objectives

1) Students will determine the change in the frequency of both the A hemoglobin allele and the S hemoglobin allele in two consecutive generations.

2) Students will graph the data obtained in the activity to compare the change in the data over the two generations.

Materials - Per Lab. Group

-75 red beans and 25 black beans
-5 large jars
- graphing paper
- a wax marking pencil

Procedure

1) Use the wax marking pencil to label each of the five jars. Label one “Parents”, one “AA Hemoglobin”, one “AS Hemoglobin”, one “SS Hemoglobin” and the last one “ Non-surviving Genes”.

2) Place the 75 red beans and the 25 black beans in the jar labeled “Parents”. This represents the parent generation in which red beans stand for the A hemoglobin allele and the black beans represent the S hemoglobin allele.

3) Place a cover on the “Parent” jar and shake gently to mix the beans.

4) On the Data sheet record your estimation and/or hypothesis of what you think will happen to the frequency (percent) of the Sickle Cell Gene in the next two generations of offspring.

5) Closing their eyes, one team member will randomly select two beans from the “Parent” jar. This will represent the two genes the offspring receives from the parents. Another team member will place the two beans in the appropriate labeled jar (AA Jar= two red beans, AS Jar= a red and a black bean, SS Jar= two black beans). A third team member will record the genotype of the offspring in Table 1- Second generation.

6) Repeat steps in number 4 until the “Parent” jar is empty.

7) Calculate the total population and the frequency of the S hemoglobin gene and A hemoglobin gene as directed in the Data and discussion section. The black beans that are in the “SS- jar” will then be placed in the “Non-surviving Genes” jar. These individuals will not grow to adulthood to reproduce and their genotypes will be removed from the population.

8) All the beans in the jars labeled “AA” and “AS” will then be placed back in the “Parent” jar and steps 3-6 will be repeated again to calculate the data for the third generation (Table 2).

9) Complete the graph and discussion questions described on the worksheet.

NAME ______________________________

Data and Observation Discussion Questions

What do you predict or estimate will happen to the frequency of the S Hemoglobin gene in the second and third generation?

____

____

Table 1

Second Generation

AA Genotypes	**AS Genotype**	**SS Genotype**

(Show **All** Your Work)

a. What is the total number of genes in the population?
A genes (Red Beans) + S genes(Black Beans) = _________

b. What is the percent frequency of the A gene?
(A / A + S)* 100 = ____________

c. What is the percent frequency of the S gene?
(S / A + S)* 100 = ____________

Third Generation

AA Genotypes **AS Genotype** **SS Genotype**

(Show **All** Your Work)

a. What is the total number of genes in the population?
A genes(Red Beans) + S genes(Black Beans) = ________

b. What is the percent frequency of the A gene?
(A / A + S)* 100 = ___________

c. What is the percent frequency of the S gene?
(S / A + S)* 100 = ___________

****GRAPH****

As a class calculate the average class frequencies for the A gene and S gene in the second generation.
A gene = ______ S gene = ______

As a class calculate the average class frequencies for the A gene and S gene in the third generation.
A gene = ______ S gene = ______

Using this information create a bar graph on a separate sheet of graph paper to represent the class data obtained. Include in your graph the United States average S gene frequency of 4%, a title, and a key to differentiate the second and third generations.

Discussion Questions

1. What was the frequency of the A gene and S gene in the original population?
   A gene _____________ S gene____________

2. In the second generation, what was the frequency of both genes?
   A gene _____________ S gene ___________

3. In the third generation, what was the frequency of both genes?
   A gene ______________ S gene ___________

4. What are your conclusions?

5. Do you see a pattern?

6. Since people with sickle cell do not usually live to have children of their own, why hasn't this disease died out?

7. Why is the frequency of sickle cell more prevalent in Africa than the U.S.?

8. Does a carrier for the sickle cell anemia show the trait? Explain.

NAME ________________________________

Summative Assessment

Write a short essay answer to each of the following questions:

1. What is sickle cell anemia?

____
____
____
____
____

2. Can I catch sickle cell anemia, like a cold? Why or why not?

____
____
____
____
____

3. What are my chances of getting sickle cell anemia if both of my parents carry the genetic trait for it?

____
____
____
____
____

4. What does the word mutation mean in relation to genetics?

____
____

5. What is a carrier in genetics?

____
____
____

6. After listening to our discussion panel, would you want genetic testing of your child if you knew you and your spouse both carried a genetic trait for a potentially fatal disease? Why or why not?

____
____
____
____
____
____

Circle the letter of the answer that best completes each statement.

7. A person with sickle cell anemia

   a. inherits 1 sickle cell gene from his or her mother;
   b. inherits 1 sickle cell gene from his or her father;
   c. inherits 2 sickle cell genes, 1 from each parent;
   d. none of these

8. Sickle cell anemia results from an error in the

   a. hemoglobin molecule
   b. white blood cells
   c. plasma
   d. blood vessels