Activity 4
Probability, Genetics, and Inheritance

Objectives
After completing this activity students will understand basic probability and single-gene inheritance. Students will be able to predict expected results for a coin tossing exercise and also for a simulated monohybrid genetic cross. Basic terms from genetics and inheritance will be introduced and students will understand the importance of DNA in regulating inheritance and cellular function.

Terminology
Adaptation, albino, asexual reproduction, cell, chance, characteristic, chromosomes, clone, code, classification, comparison, daughter cell, double helix, DNA, dominant trait, expected results, gamete, gene, genetic cross, genetic trait, genetics, genome, Human Genome Project, inheritance, inherited trait, meiosis, mitosis, molecules, mutation, nucleus, offspring, parent cell, probability, proteins, Punnett square, recessive trait, sexual reproduction, single-gene traits, variation, zygote

Grade Level: 4th-6th Grade

Ideal Class Size: 24 students divided into six groups of four

Subject Areas: Life science, inquiry skills, Alg-S1

Time
1-hour introduction and presentation
1-hour hands-on activity/experiment

Materials
- PowerPoint presentation or slide projector w/slides
- Flip chart or writing board and eraseable colored markers
- Equipment:
  - Pennies (40)
  - Mouse genetics puppets
  - Bags of male & female checker "gametes" (1 set of each/pair)
- Posters:
  - Genetics & Inheritance: Just what is DNA, and where is it found?
  - Genetics & Inheritance: How Does Inheritance Work?
  - Single Gene Traits in Humans
- Handouts:
  - Student Probability & Genetics Introduction (1/student)
  - Student Data Sheets for Probability & Genetics (1/student)
  - Genetics word search and DNA code puzzle

Advanced Preparation
1) Label checker gamete bags with either male or female mouse pictures. Fill each bag with eight black checkers and eight red checkers. Each student pair should receive a male gamete bag and a female gamete bag. (a class of 24 students should have 12 male bags and 12 female bags.)

2) Construct models or puppets of mice with black and red eyes to help explain dominant and recessive traits and the use of the Punnett square.

3) Copy the "Workshop Outline" onto a writing board or flip chart. This will help you complete all the steps in the scheduled amount of time.

Activity 4: Genetics & Inheritance
Workshop Outline

LECTURE AND DEMONSTRATIONS (30 minutes)

1. Introduction (15 minutes)
- A. Today's topic – Genetics & Inheritance
- B. Today's task list/workshop outline
- C. Review SAFE Rules
- D. Review the Methods of Science

II. Power Point Presentation (15 minutes)

TITLE ACTIVITY/EXPERIMENT (1 hour 30 minutes)

I. Conduct a probability activity (20 minutes)

II. Conduct a simulated genetic cross (50 minutes)

III. Science seminar (10 minutes)
- A. Sharing the Results
- B. Interpreting the Data

IV. Close-out (10 minutes)
- A. Wrap-up Questions
  - a. Single gene trait poster

Background Information (supplements information in PowerPoint presentation)

INTRODUCTION TO DNA

All animals and plants on Earth share something in common. They all use the same **code** to grow and function. This code can be found in bacteria, elephants, oak trees, and humans. It's the "master plan" for all organisms, like the source code for a computer program. It's the reason your toes are on the ends of your feet (where they belong) instead of on your hands or hanging off the edges of your ears. The code is called **DNA**, which is shorthand for **Deoxyribose Nucleic Acid**. DNA exists as long **molecules** within the **nucleus** of almost every **cell** in an organism.

The DNA is in the form of a twisted ladder that scientists call a **double helix.**

The rungs of the ladder make up the four-letter **DNA code** or alphabet: **A**, **T**, **C**, and **G**. These alphabet pieces are called **bases** and they bond together according to special rules: A always pairs with T, and C always pairs with G. [A–T C–G]

When the DNA code is read by the cell, only one strand of the code is used. The string of letters (or bases) make 3-letter long "words" and the words make "sentences," just like the letters, words, and sentences in your science textbook. In DNA, the "sentences" are called **genes**. One strand of DNA may contain many genes.

ATGCTCGAATAAATGTGAATTTGA

ATG CTC GAA TAA ATG TGA ATT TGA

<ATG CTC GAA TAA ATG TGA ATT TGA AAA TGG>

Genes tell the cells how to make other complex molecules called **proteins**. Cells produce thousands of different **proteins** that work together to allow organisms to do all the functions necessary for life.

Fun Fact #1:
Each cell in our body contains a lot of DNA (about 1.7 meters). If our cells were enlarged to the size of an aspirin pill, the DNA in that cell would be 10,000 meters long. That's as long as 109 football fields.

Fun Fact #2:
If you opened up all your cells and laid out the DNA end to end, the strands would stretch from the Earth to the Moon about 6,000 times.

CHROMOSOMES AND MITOSIS

The DNA in each cell is coiled up tightly and packed into compact units called **chromosomes**.

Each body cell of an organism has the same number of chromosomes. The number of chromosomes in each cell is different for different species of organisms. In **humans**, every cell contains **46** chromosomes. **Dogs** have **78** chromosomes in every cell. **Cats** have **38** chromosomes, **horses** have **64,** and **fruit flies** have **8**.

Within the nucleus of each cell, the chromosomes are found in pairs, with half coming from each parent. So for humans, **23**, or half of the **46** chromosomes in each of your cells came from your father and half (**23**) came from your mother.

> Fun Fact #3:
> The least number of chromosomes is found in a species of ant that has only 2 chromosomes. The record for the most chromosomes goes to a species of fern, which has 1,260 chromosomes in each cell.

Remember that within the **nucleus** of every **cell** in the body, the **chromosomes** contain the **DNA**, which carries the genetic code that directs how every cell functions. When the body makes new cells as part of growth, or to repair damaged tissues, the cells divide in a process called **mitosis**. During mitosis, each **parent cell** divides to form two **daughter cells**. The chromosomes in each parent cell also divide, so that each daughter cell has an exact copy of the chromosomes found in the parent cell. This way skin cells, for example, will all have the same genetic information so they will all function alike.

Asexual and Sexual Reproduction

Some organisms can produce "offspring" by making exact copies of the parent. This is called **asexual reproduction**, and is found in single-celled organisms like the *Paramecium* and *Amoeba*, and also in simple organisms like sponges. Many plants can also reproduce asexually. The offspring produced by asexual reproduction are always exact copies of their parents—in effect they are all **clones** of the parent organism. **Asexual reproduction** allows an organism to make lots of copies of itself, but all the copies are identical. So, how do we get so much **variation** in nature? Why don't we all look just like our brothers and sisters and parents?

When most organisms produce offspring, they use a different method, called **sexual reproduction**. In sexual reproduction, offspring are not exact copies of their parents. Instead, they receive half their genes from their mothers and half from their fathers, so offspring may have characteristics in common with both parents, but they also have many **unique traits**—characteristics that may not be seen in either parent.

During sexual reproduction, special cells called **gametes** are produced by each parent. Because these cells undergo a special type of cell division called **meiosis**, each gamete contains only half the number of chromosome found in the parent's body cells. So for humans, each body cell has 46 chromosomes (or 23 pairs–half from mom and half from dad), but each gamete only has **23** chromosomes, or one chromosome from each pair. During sexual reproduction, the male and female gametes unite to form a **zygote**, which then has the **46** chromosomes characteristic of human body cells. Zygotes undergo cell division and grow and eventually develop into adults. However, offspring produced by sexual reproduction are not identical to their parents or to their brothers and sisters, because they each received different combinations of the chromosomes from each parent. This is one way that **variation** is introduced into each generation.

Another way that **variation** can be achieved is through **mutation**. Sometimes when chromosomes are making copies of themselves, a mistake in the DNA code can occur. Also, there are factors in the environment that can cause errors or changes in the DNA code, such as UV radiation from sunlight, ionizing radiation from natural or man-made radioactive substances, and harsh chemicals

introduced into the environment. All of these can damage DNA and may result in a **mutation** in a gene.

INHERITANCE AND PROBABILITY

Now that you know how genetic traits are passed from parent to offspring, let's see if we can predict how a simple **inherited trait** will be passed from parents to their offspring. Many traits can be very complicated, and often more than one gene plays a part in how a trait will be expressed in an organism. For example, eye color, height, and weight in humans are all traits that are affected by more than one gene. But there are some traits in humans and other organisms that are determined by a single gene, and these are the kind of traits we will examine today.

But first, we need to look at the math behind inheritance. In **genetics**, when we are trying to figure out how traits may be passed from parents to offspring, **probability** is an important consideration. If we know a little bit about the trait we are studying, we can use **probability** to **predict** how the gene in question will be transferred from parents to offspring. As an example, let's toss a coin:

If you examine a **coin**, you'll see that it has 2 sides—heads and tails—and so there are 2 possible outcomes when the coin is tossed: it will land with the "heads" side up, or with the "tails" side up. When you toss the coin, the **probability** of getting a "heads" is ½, or 50%. This represents the number of desired outcomes (heads = 1) divided by the number of possible outcomes (heads + tails = 2). There is also a probability of ½ that we will get a "tails" if we toss the coin. If we toss our coin only two times, we might get 2 "heads", 2 "tails", or 1 "heads" and 1 "tails." But the more times we toss our coin, the more likely we are to get closer and closer to our **expected probability** of 50% "heads" and 50% "tails." Based upon what we know about coins, we form an **hypothesis** that the probability of getting a "heads" when we toss the coin is ½ or 50%. Then we **test** our hypothesis by tossing the coin and recording the results. *[a probability exercise will be conducted during class to demonstrate these concepts.]*

EYE COLOR IN MICE

Now that we've explored how probability is important in genetics, let's investigate the inheritance of a simulated genetic trait in mice that is determined by a **single gene**. Mice may have either black eyes or red eyes, and from the work of other mouse researchers we know that pure black-eyed mice bred to pure red-eyed mice always produce offspring with black eyes. Thus, we say that the gene for black eyes is **dominant** and the gene for red eyes is **recessive**, because the gene for black eyes "dominates" the gene for red eyes.

In genetics, it is often useful to represent genetic crosses like the one described above using a **Punnett square**:

We'll represent the mouse eye color gene by the letter **B**. The dominant gene for black eyes will be designated by "**B**"; the recessive gene for red eyes by "**b**". In the cross described above, because Dad is a "pure" black-eyed mouse, he's designated as **BB**. Mom is a "pure" red-eyed mouse, designated by **bb**.

Dad's genes
pure black eyes (**BB**)

Mom's genes
pure red eyes (**bb**)

	B	**B**
b	**Bb**	**Bb**
b	**Bb**	**Bb**

Offspring: all black eyes (**Bb**)

BB x **bb**
Dad can produce gametes that have only "**B**" genes. Mom can produce gametes that have only "**b**" genes. All offspring will be **Bb** and have black eyes.

What happens if we now breed together the offspring from the cross above? Using another **Punnett square** will help us figure out what outcome we expect from this cross.

Dad's genes
black eyes (**Bb**)

Mom's genes
black eyes (**Bb**)

	B	**b**
B	**BB**	**Bb**
b	**Bb**	**bb**

Offspring: ¾ have black eyes (**BB** or **Bb**) ¼ have red eyes (**bb**)

Bb x **Bb**
Dad now produces ½ of his gametes with the dominant "**B**" gene and ½ with the recessive "**b**" gene. So does Mom. The offspring have both black and red eyes: ¾ carry the dominant **B** gene and have black eyes; ¼ carry 2 recessive **b** genes and have red eyes.

So, from this genetic cross, we **expect** to produce:
- **1** "pure" black-eyed mouse (**BB**)
- **2** black-eyed mice that each carry 1 **B** and 1 **b** gene (**Bb**)
- **1** "pure" red-eyed mouse (**bb**)

The Punnett square helps us form an **hypothesis** about the outcome we expect when we breed together 2 mice that each have **Bb** genes. Let's test that **prediction**. *[a simulated mouse genetic cross will be conducted during class to demonstrate these concepts.]*

OTHER TOPICS THAT COULD BE COVERED

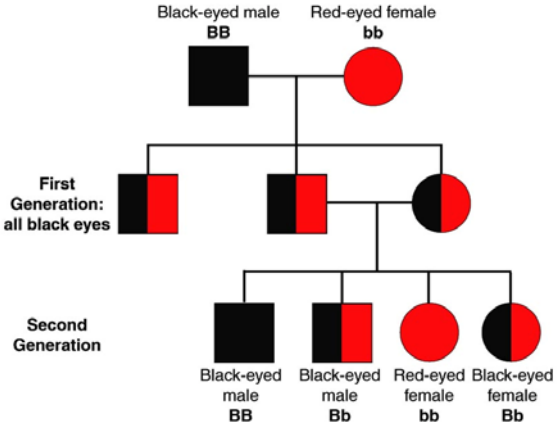
1. As an example of how a single-gene mutation may greatly affect an organism, you could use an **albino** and **normal rat snake** or corn snake as a demo. Albinism is usually a single-gene mutation. Talk about the impacts to a snake that needs to be camouflaged to avoid predators and to hunt for prey efficiently.

2. Survey the class for **single-gene traits** that are easy to detect in **humans**. Those in the chart below are easy to determine:

DOMINANT TRAIT	RECESSIVE TRAIT
tongue **roller**	non tongue roller
crossed hands—**left** thumb on top	right thumb on top
widow's peak present	no widow's peak
able to **wiggle ears**	can't wiggle ears
no hitchhiker's thumb	**hitchhiker's thumb**
bent pinky (end of little finger bends toward 4th finger when little fingers are held side-by-side)	straight little finger
free ear lobes	attached ear lobes
hair present on the middle segment of any or all fingers	no hair on middle segments of fingers
Dimples present on face	no dimples

3. Talk about **pedigrees**. Pedigrees basically are family trees that trace genetically inherited traits of interest. Geneticists use pedigrees to study human and animal diseases. Breeders use pedigrees to track traits that they are interested in promoting in their animals or plants.

Sample pedigree from our mouse eye-color experiment:



4. Talk about the **Human Genome Project**. The entire human **genome** has now been mapped. (A genome includes all the genes of an organism) Show chromosome maps that indicate the genetic disorders/traits that have been mapped to specific areas of specific chromosomes. Other genomes that either have already been mapped or will be mapped in the near future include:
   - **rice**
   - **yeast**
   - ***Arabidopsis*** (a small plant in the mustard family)
   - **fruit fly** (*Drosophila*)
   - **round worm** *(C. elegans)*
   - **mouse** (*Mus*)
   - **Japanese pufferfish**
   - ***Plasmodium*** (the parasite that causes malaria)
   - **mosquito**
   - ***E. coli* and 46 other bacteria and 16 prokaryotes**
   - **Dog**

Fun Fact #4
The human genome contains 3 billion base pairs of DNA, about the same amount as frogs and sharks. But other genomes are much larger. A newt genome has about 15 billion base pairs of DNA, and a lily genome has almost 100 billion.

Fun Fact #5
The human genome codes for about 35,000 genes.

LECTURE AND DEMONSTRATIONS (30 minutes)

1. Introduction (15 minutes)

A. Today's topic
Today's topic is "Probability, Genetics, and Inheritance." We're going to meet an SREL researcher named Travis Glenn who uses DNA to figure out which male and female alligators are the parents of which baby gators. Then you'll get to do a probability exercise with coin tosses and conduct your own simulated genetic cross.

B. Today's task list / workshop outline

C. Review SAFE Rules

D. Review the Methods of Science

II. PowerPoint Presentation (15 minutes)

III. Demonstrations (5 minutes)

A. Cracking the Code
[Suggestion: Lead the students through the first line of their "DNA Code Puzzle" to illustrate how a genetic code is translated]

EXPERIMENT (1 hour 30 minutes)

I. Conduct a probability exercise (20 minutes)

[Pass out a Probability Data Sheet and a penny to each student. Lead them through the coin toss exercise and collect their data on the front board. Explain the math involved as outlined in the introductory material and segue into probability, genetic crosses, and the use of Punnett squares.]

II. Conduct a simulated genetic cross (50 minutes)
[Review the concepts of dominant and recessive (Bb) traits and illustrate the use of the Punnett square using the following crosses for eye color in mice: BB X bb and Bb X Bb where BB = black eyes, Bb = black eye dominance/red eye recessive, and bb = red eyes. Discuss probability and how a hypothesis, or prediction, can be made using the Punnett square. Then conduct an experiment using the checker" gametes" to see how well the actual results of the cross support

the expected results. Students will then conduct their own experiments using the instructions on the student data sheets.]

III. Science Seminar (10 minutes)

A. Sharing the results

B. Graphing and interpreting the data

IV. Close-out (10 minutes)

A. Wrap-Up Questions

[Take a minute to answer questions the students may have come up with during the activity, and to assess their comprehension of the material covered. Share the large Single Gene Trait poster with the class.]