

Color Vision Genetics Evolution Simulation

GRADE LEVEL 7 - 12th

SUBJECTS Life Sciences; Analyzing and Interpreting Data; Stability and Change

DURATION Prep: 45 minutes; Activity: 60 minutes

SETTING Classroom

OBJECTIVES

In this lesson, students will:

1. Model natural selection by participating in a simulation using probability and selective pressure
2. Learn about color vision and its genetic history in humans and other primates.
3. Understand the difference between dichromatic and trichromatic vision
4. Understand how sex-linked traits can affect males and females in different proportions

OVERVIEW

In this lesson, students will participate in a natural selection simulation, flipping pennies to mimic the probability of passing on certain traits. The traits are the three genes for color-vision, found on the X chromosome. In the simulation, students will simulate 6 generations of primates, and track how the gene pool changes over time. The activity loosely mimics some of the mechanisms that led to the evolution of our own improved color vision.

MATERIALS

- 6 different colors of post-it notes. Each color needs as many post-its as students in your class (note: red and goldenrod are the first two colors used in the example PowerPoint; it is not strictly necessary to match, but helpful.)
- 6 giant stickies or a lot of blackboard/dry-erase board real estate
- pennies, 1 for each student
- power point presentation and projector
- pens or pencils, 1 for each student
- additional tape (if post-its are not sticking by themselves)

SCIENTIFIC TERMS FOR STUDENTS

- » **chromosome:** a coiled thread of DNA packaged into a rod shaped structure that contains hereditary information
- » **gene:** a segment of DNA, at a specific location on a chromosome, that is the basic unit of heredity
- » **gene pool:** all the possible traits that can be handed down from one generation to the next in a population
- » **sex-linked gene:** a gene that is located on the same chromosome that determines gender
- » **gamete:** a type of cell that fuses with another cell to form a zygote, which can give rise to a new, genetically distinct individual.
- » **dichromatic:** refers to vision that can detect two wavelengths of light
- » **trichromatic:** refers to vision that can detect three wavelengths of light
- » **selective pressure:** an environmental condition in which individuals that are better adapted to their environment are more likely to survive and reproduce than others of the same species
- » **population:** all members of one species in a particular area
- » **species:** a group of organisms that share their most recent common ancestor and can produce viable offspring
- » **primate:** any of various mammals of the order Primates, having a highly developed brain, eyes facing forward, a shortened nose and muzzle, and opposable thumbs. Lemurs, monkeys, apes, and humans are examples of primates.
- » **colorblindness:** the inability to perceive certain color differences
- » **deuteranopia:** a form of color blindness where distinguishing between red and green are the main problem colors. In deuteranopia, the third color sensitive gene is either missing or malfunctioning, rather than simply not working well.

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BACKGROUND FOR EDUCATORS

Many of us might take our color vision for granted, but human vision has changed dramatically over the course of evolutionary time. In fact, many species have gone through shifts in the range of their color perception, and many of them see the world very differently than humans. Whales and many other marine mammals don't see 'color' the way the human eye does. They are effectively monochromatic, much like black and white television. Honeybees don't perceive red/green the way humans do, but they can detect UV light. Most placental mammals, including many of our pets, are dichromatic, or what we would refer to as colorblind. Not so long ago, so were we.

Where does color vision 'live' in our DNA? How is it passed along? There are three genes for human trichromatic vision, and they code for Red/Green/Blue or RGB. are physically located on the same chromosomes that determine sex in humans. Specifically, they are on the 'X' chromosome, not the 'Y' chromosome. They are dominant, although there is no corresponding recessive allele, meaning that the gene for seeing a particular color doesn't have a recessive counterpart. If you have a functional copy of a gene and express it, you will be sensitive to that wavelength of light and 'see' that color. If the gene is missing or damaged, you will not 'see' that color of light. Since females (XX) have two X chromosomes, there are two chances to get a working copy of a gene. Males (XY) have only one and so only have one chance for a working copy. Males therefore have a much higher incidence of color blindness than females.

In this simulation, we will simulate how these genes and chromosomes are passed from generation to generation in a small population. At a certain point, we will introduce selective pressures (in the form of attributes of the physical environment) that will selectively kill off certain members of the population. They will be replaced by the offspring of surviving members of the population, and gradually we should see the make-up and proportions of the gene pool change. However, like in the real world, some of this is due to chance—anything could happen!

TEACHER PREP

1. It is **highly suggested** that you go through the power point first- much of the simulation will make more sense.
2. Make a set of 'Generations' posters (or make space on a white-board or chalk board- you will need a lot of room.) You will need six posters total, From Generation 0 to Generation 6.
3. Make the "Generation 0" primates, one for each student in your class. You will need a minimum of 20 primates/ students to do the activity. The initial primates should be 50/50 male and female. Of those, 15-20% of them should have '3-color vision'. EXAMPLES:

EXAMPLE #1: Class of 30

3 X***X***

2 X***Y

12 X**X**

13 X** Y

EXAMPLE #2: Class of 22

2 X***X***

2 X*** Y

9 X**X**

9 X** Y

4. Set up the first Generation poster- 'Generation 0' with the post-its in 'bar graph' position, like so (excepting the one



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primate 'post-it' which has fallen out of the 'M-2' bar and is sticking to the bottom- have some extra tape handy!):

5. Place all subsequent posters (generations 1-5) in a row after generation 0. Only Generation 0 should have post-its on it- all others should be blank.
6. Make sure you have a penny for every student.

ACTIVITY

Go through the steps outlined in the power point presentation. Make any changes you like ahead of time, or use as is. Notes are included for the teacher in the slides that have instructions, details, and formative assessments. It is presented much more clearly in the power point presentation- however, here is a basic overview of the steps:

1. Each student takes a primate post-it of generation 0 (red) from the poster and labels one of their chromosomes 'heads,' and the other 'tails.'
2. Each student finds a partner that has a primate post-it of the opposite sex, and in pairs they flip their pennies (four times total) to determine which of their chromosomes they give to their two 'offspring.'
3. The resulting chromosome combinations from step 2 are written on the next color/generation of post-its (goldenrod for generation 1).
4. Students then replace the red post-its on the generation 0 poster.
5. Repeat steps 1-4 for generation 2, except that they will use their generation 1 primate (goldenrod). *Students may need to start mixing matings, especially if there aren't enough of one gender.*
6. After generation 2 some of their primates will expire due to 'selective pressures,' This means that some primates

will die before producing generation 3! Lead students through this process with the slides in the presentation.

7. Students whose primates expired put their post-its on the generation 2 poster - those genes can't be used to make generation 3!
8. Create generation 3! Students whose primates expired should get back in the game by finding two new 'parents' whose primates are still alive to make them a replacement primate.
9. Repeat steps 6-8 for the next generations, using a different selective pressure (see slides) each time. After three rounds of selective pressure, we should start to see some shifts in the proportions of 2 and 3-color vision primates.

When you have completed the simulation, your collected data might look something like the photo at the bottom of this page.

EXTENSIONS

Visit the Color of Life exhibit at the Academy! Plan a field trip for your school and take advantage of the Color of Life Educator Guide, online soon! For field trip information and reservations, visit <http://www.calacademy.org/educators/plan-a-trip>

RESOURCES

Academic article on primate color evolution:
<http://http-server.carleton.ca/~btansley/psyc3702/notes/Evolution%20of%20colour%20vision.pdf>

Researcher Jay Neitz and his fascinating work with primates at the Univ. of Washington:
<https://www.youtube.com/watch?v=1zw2RE-PavQ>



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Next Generation Science Standards

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Developing and using models</p> <p>6-8: Use and/or develop a model of simple systems with uncertain and less predictable factors</p> <p>6-8: Develop and/or use a model to predict and/or describe phenomena</p> <p>9-12: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems</p>	<p>Middle school:</p> <p>LS1.B: Growth and Development of Organisms: Animals engage in characteristic behaviors that increase the odds of reproduction.</p> <p>LS2.A: Interdependent Relationships in Ecosystems: Organisms, and populations of organisms, are dependent on their environmental interactions with living things and non-living factors.</p> <p>LS3.A: Inheritance of Traits: Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits</p> <p>High school:</p> <p>LS2.A: Interdependent Relationships in Ecosystems: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and non-living resources and from such challenges as predation, competition, and disease.</p> <p>LS4.B: Natural Selection: Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.</p>	<p>Cause and effect</p> <p>6-8: Cause and effect relationships may be used to predict phenomena in natural or designed systems.</p> <p>6 - 8: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.</p> <p>9-12: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.</p>