ESI Environmental Science Institute
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Color Vision in Primates and Other Mammals

Lesson plan for grades K-12

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RESOURCES:

- Color Vision Deficiencies, Stuart Grais, DePaul University – Discussion on colorblindness in humans with many great pictures of how objects appear to trichromatic and dichromatic humans. http://facweb.cs.depaul.edu/sgrais/colorvisiondefi.htm
- Color Blindness Simulator, will change any uploaded image into how it appears under different color vision types. http://www.colblindor.com/coblis-color-blindness-simulator/
- NG Caine & NI Mundy (2000). Demonstration of a foraging advantage for trichromatic marmosets (*Callithrix geoffroyi*) dependent on food color. *Proceedings of the Royal Society of London B* (2000) 267, 439-444. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1690559/pdf/10737399.pdf
- Color Vision: Almost Reason Enough for Having Eyes. By Neitz, Carroll and Neitz. http://www.neitzvision.com/images/CV-ReasonForEyes.pdf
- Neitz Lab Website, color vision and molecular genetics: http://www.neitzvision.com/content/home.html
- Test for Color Vision http://colorvisiontesting.com/what%20colorblind%20people%20see.htm

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

§112.11. Science, Kindergarten: 5A, 10A
§112.12. Science, Grade 1: 10A
§112.13. Science, Grade 2: 10A
§112.14. Science, Grade 3: 9C, 10A, 10B
§112.15. Science, Grade 4: 10A, 10B
§112.16. Science, Grade 5: 10A, 10B
§112.18. Science, Grade 6: 12D, 12E
§112.19. Science, Grade 7: 11A, 11B, 11C, 12A, 12B, 12E
§112.34. High School Biology: 5B, 6F, 8B, 12B

PERFORMANCE OBJECTIVES (in order of increasing difficulty to permit tailoring to different age groups)**:**

Students will apply the scientific method and will be able to:

- Compare the advantages of dichromacy and trichromacy and the vision abilities of different animals
- Discuss natural selection for trichromatic color vision as a means of increasing foraging efficiency
- Identify the electromagnetic spectrum; visible light
- Discuss the genetics of color vision; opsin genes
    - Inheritance of opsin genes; why red-green colorblindness is more prevalent in males

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MATERIALS (Per testing station – adjust the number of stations needed by the number of students)**:**

- 20 ¼ inch lime green pompoms (sold in bags of 48)
- 20 ¼ inch red pompoms (sold in bags of 48)
- 2 lime green feather boas
- 2 9-inch aluminum pie pans (or other flat container)
- 2 plastic cups (or other receptacle in which the students can place the pompoms)
- Stop watch
- Worksheet (attached)
- Powerpoint Presentation (for the whole class)

CONCEPTS:

While many people believe that mammals, such as dogs and cats, are colorblind, this is not actually true! Most mammals have what is known as **dichromatic color vision**. This means that they have two types of color-detecting cells in the retina of their eyes: blue cones and green cones. Because they have these two types of cones, they are actually able to discriminate blue and violet colors from yellow and green colors. However, most mammals cannot discriminate green colors from red colors.

Unlike almost all other mammals, many primates (lemurs, monkeys, apes, and humans) can discriminate green and red colors because they have what is known as **trichromatic color vision**. In other words, they have three types of color-detecting cells in their retinas: blue cones, green cones, and red cones. Therefore, not only can trichromats discriminate blues/violets from yellows/greens, they can additionally discriminate greens from reds. Interestingly, almost all birds, lizards, and fish have what is known as **tetrachromatic color vision**, meaning that they have four types of color-detecting cells (ultraviolet cones, blue cones, green cones, and red cones). Therefore, a goldfish has even *better* color vision than a person!

Teachers can utilize the Powerpoint Presentation included with this lesson plan to reinforce the concepts discussed above, and the material in the BACKGROUND section in preparation for the Search Activity described in the EXPLORE section

BACKGROUND:

Why might it have been beneficial for primates to have evolved a red color-detecting cell on their retina, giving them trichromatic color vision? In other words, why would it be helpful for a primate to be able to discriminate green colors from red colors?

The major hypothesis for why many primates have evolved trichromatic color vision is that it allows primates to detect red food objects (e.g. ripe fruit or young leaves) against green leaf backgrounds. Many fruits turn orange or red as they ripen but are green when unripe (such as apples or strawberries). Also, young leaves in many tree species are red, only turning green as they mature. Young, red leaves are richer in protein and have fewer chemical defenses than mature, green leaves and are thus preferred by many primates.

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This activity is based on an experiment conducted by Nancy Caine and Nick Mundy (see Resources above) on trichromatic and dichromatic marmoset monkeys. In the original experiment, the monkeys foraged for orange or green Kix cereal in green-dyed wood shavings. We have adapted the exercise to include items you can get from most craft stores, but feel free to change it to your own needs/resources!

IMPORTANT: ~5-10% of men are red-green colorblind, so you are likely to encounter colorblindness among your students.

PREPARATION:

- Coil the boas into separate pie pans
- In one pan, sprinkle the lime green pompoms evenly over the boa; in the other pan, sprinkle the red pompoms
- Place a cup next to each pie pan

EXPLORE:

Begin with the pie pan that has the green pompoms. Each student will “forage” for (i.e. pick out) pompoms over a 10 second period.

1. Student stands in front of pie pan with one hand behind their back (they can only use one hand to forage); another student will keep time (stop watch or wall clock with a second hand).
2. When the time begins, pick the pompoms out of the pan and place them in the cup; continue to pick out pompoms until 10 seconds have passed and time is “up”.
3. Repeat for the pie pan with the red pompoms.
4. Compare the number of lime green pompoms to red pompoms that were picked out of the pans. (Most students should pick out a greater number of red pompoms than lime green pompoms.)

EXPLAIN:

Discussion questions

- Based on your pompom exercise, do you think all humans see the same colors equally?
- Which animals can see blues? Greens? Reds?
- When shown an image (e.g. a bowl of green and red apples – see Powerpoint Presentation), what would this picture look like to a dog? A monkey? A bird?
- Why might it be important for a monkey to be able to see red colors?
- Why might it be important for a bird to see red colors?
- What kinds of problems might people with red-green colorblindness have navigating the world? *e.g.: Traffic lights, determining how well meat is cooked, determining fruit ripeness, etc.**
- What types of advantages would people with red-green colorblindness have compared to people with trichromatic color vision?

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*If you have students in your class that are red-green colorblind, perhaps they would feel comfortable offering some perspective on how they learned that they were colorblind and strategies they use to discriminate reds from greens.

ELABORATE:

Activity Add-Ons (listed in order of increasing difficulty to permit tailoring to different age groups):

- Counting – students count the number of pompoms
- Comparing quantities – students compare the number of red pompoms to green pompoms (e.g. which quantity is greater?)
- Addition – If students work in groups, they could sum the number of red/green pompoms collected by their group members (and compare to other groups)
- Fractions – e.g. there were 12 red pompoms, and I picked up 8 in 5 seconds; therefore, I picked up 2/3 of the red pompoms.
- Percents – (per above) I picked up 66.6% of the red pompoms
- Data collection – organize results into a table
- Graph – graph the results of the class members
- Scientific method – prior to the activity, ask students to develop a hypothesis about the benefit of having trichromatic (or dichromatic) color vision; outline predictions based on this hypothesis; organize their results into a data table/graph
- Generate hypotheses about color vision capabilities in different vertebrate groups
    - Brainstorm/develop methods for testing their hypotheses in the field
- Punnett square activity to investigate opsin gene inheritance
- Diagram inheritance of opsin genes for their own family

Additional Activity (for younger children)**:**

Children could color images as seen through the eyes of a given animal. For example, children could color a picture of a forest as seen through the eyes of a raccoon (monochromat; only see black and white); a fox (dichromat; blues/violets and greens/yellows); and their own eyes (trichromat; blues/violets, greens/yellows, reds).

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Name________________________ Date: ______________

Monkey Foraging and Color Vision

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1. According to the color vision types, I am a (circle one)

trichromat **dichromat**

2. My foraging success:

	# of targets collected	# of targets available	% success
Lime green pompoms			
Red pompoms			

To calculate foraging success for each target type, divide the number of targets collected by the number of targets available, and multiply this result by 100. (# of targets collected ÷ #of targets available) x 100.

3. What is the average foraging success of my group? Discuss your results.