COLORS OF NATURE / KIT 3
BIOLOGY AND ART

HOW DOES COLOR HELP US UNDERSTAND THE LIVING WORLD AROUND US?

The **Colors of Nature Kits** are designed to help students explore the question: *how do art and science help us understand the world around us?* Through a series of investigations students become familiar with core practices of art and science, developing scientific and artistic habits of mind that empower them to engage in self-directed inquiry through the generation and evaluation of ideas. Kit 3 explores this question through the lens of art and biology: the study of life and living organisms.

A STEAM APPROACH TO EDUCATION (Science, Technology, Engineering, Art, Math)

STEAM is an educational philosophy that seeks to balance the development of divergent and convergent thinking by integrating the arts with traditional STEM fields (Science, Technology, Engineering, Math). In the STEAM approach to learning, students engage in projects and experiments that reflect the transdisciplinary nature of real-world problem solving. Rather than focusing on the delivery and memorization of content as isolated facts or repetition of rote procedures, STEAM seeks to develop scientific and artistic habits of mind and the confidence to engage in self-directed inquiry by familiarizing students with the core practices of art and science in an open and exploratory environment. The STEAM investigations in this kit are designed to foster creative engagement by promoting individual agency and establishing meaningful connections to students' own lives.

For additional teaching resources visit www.colorsofnature.org

INTRODUCTION / FOSTERING ENGAGEMENT IN ART AND SCIENCE

ART / SCIENCE OVERLAP

Both science and art seek to broaden our understanding of the world around us. Although art and science are often thought of as separate ways of knowing, they are similar in many important ways in principles and practice. Driven by curiosity, creativity and technique, both disciplines contribute new experiences, ideas, and technologies to society and create the foundation of knowledge from which future innovations emerge. The core practices of art and science reveal significant overlap as well: observing, questioning, experimenting, analyzing, and communicating are the means by which both disciplines generate and distribute new ideas and technologies.

CORE PRACTICES of ART and SCIENCE

Observing
Experimenting
Questioning
Analyzing
Describing
Communicating

ENGAGEMENT IN SCIENCE PRACTICE

Young children engage naturally in core science practices. They make observations and test and revise their predictions as they seek to understand how the world around them works (how high can I stack these blocks before they tumble?). But when science is presented in the classroom as isolated facts to be memorized, or procedural steps to copy, students can lose sight of their own capacity to question the world around them, test their ideas, and share their discoveries. Many students, especially girls and people from non-dominant groups, start to view science as rote, passionless, and uncreative. Students who have difficulty memorizing and repeating facts, or making connections to complex systems that don't feel relevant to their daily lives begin to disengage from science. Again, these STEAM investigations should emphasize developing familiarity with the practice and tools of scientific inquiry, rather than on memorizing content or achieving specific results.

ENGAGEMENT IN ART PRACTICE

Similarly, young children almost universally engage in art making. As they learn to handle and control their mark-making tools, the progress from simple scribbles to the development of symbols that represent their understanding of the world. As the complexity of the symbols increase, children begin to aim for realism (of proportion, form, lighting) in their representation.

Around age 9, as social awareness increases, children begin to shift their focus from the expressive pleasure of making art to the results of their work, especially in comparison to the work of their peers. Between age 10 and 13, children decide whether or not they are good at art (as opposed to whether or not they enjoy making art), and it is in this stage of development that many children cease to engage in art-making, believing they do not have the talent to produce "good" (realistic) results. These beliefs are often reinforced by peers and adults who similarly value conventions of realism in western art. When an adult claims "they can't draw," we automatically understand them to mean that they can't draw realistically, not that they can't move a pen across a piece of paper. With continued practice and instruction, nearly everyone can develop skills of realistic representation. Nevertheless, the following STEAM investigations should remain focused on the act of art making itself: an awareness of the opportunities that present themselves and the creative choices that are made in the course of artistic practice. The results of each activity are useful as a record of the process, but emphasis should be placed on the importance of observing, experimenting, and reflecting throughout the process of making.

INSTRUCTIONAL METHOD

We advocate for a STEAM approach that quiets the inner negative voice, focuses on open outcomes, and values student ideas and expression. Foundational to our approach are practices that promote identification with science and art, including the use of real science and art tools; connect science and art to everyday life; and offer students the chance to participate in authentic science and art practice.

Give students choices when possible. A sense of agency can increase identification with science.

Accept student responses as value-neutral.

Ask questions and encourage discussion and reflection.

Connect activities to everyday practices and student-relevant ideas.

GUIDING DISCUSSION AND REFLECTION

It is important to establish an environment that encourages imaginative speculation, or thinking outside the box. If students are conditioned to "take things seriously" during classtime, they might not be comfortable offering the creative or humorous answers that are often generated by divergent thinking.

The instructor should continue asking questions to lead the discussion beyond the point where students offer answers that they believe are "correct" or what they think the instructor expects to hear. This can be facilitated by the instructor's willingness to contribute their own playful ideas and follow up with questions that solicit deeper analysis:

What do this fly's eyes remind you of?

They remind me of a discoball!

What about them is like a discoball?

What does a discoball do to light?

What do you think the fly's eyes do to light?

How might this be useful for the fly?

ASKING QUESTIONS TO DEEPEN ENGAGEMENT

Each investigation in this kit provides:

A central question to focus the investigation, repeated in the header of each page.

Specific questions integrated with the procedural steps of the activity to prompt the discussion, *shown in italics for quick reference.*

Throughout the activity, the instructor should use open questions to guide observation, encourage experimentation, and prompt reflection.

Questions should aim to:

Expand upon an idea:
What else could you do with this? What else could this be for? What else could this mean?

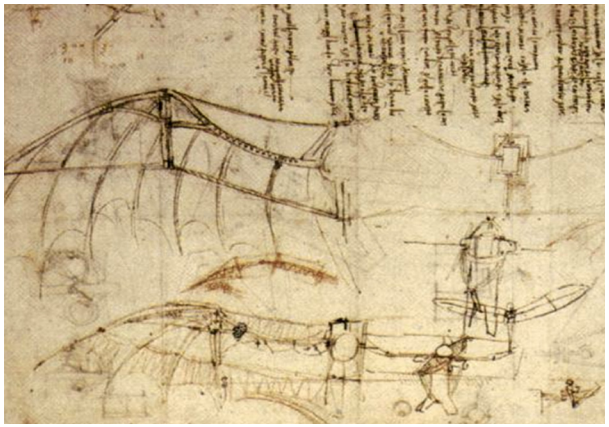
Draw attention to specific details:
What do you see? What texture? Color? Pattern?
What is different/similar between this and that?

Encourage synthesis with existing knowledge:
What does this remind you of?
Where have you seen something like this before?
What about this is different than where you saw something similar before?

NOTEBOOK EXTENSION *30 minutes*

Keeping a notebook is a common practice in both art and science. The notebook is a place to keep track of ideas, observations, measurements, sketches and other information relevant to the ideas the practitioner is exploring. It is a space that allows for informal musings and reflections alongside notes and data recorded for later reference. Each investigation in the Colors of Nature Kits includes suggestions on how to incorporate the notebook into the lesson.

Notebooks can be incorporated into numerous other classroom activities beyond these investigations, providing a private space for students to reflect on what they are learning and develop their ideas outside of the normal constraints of classroom assignments.



Part of a page from one of Leonardo Da Vinci's notebooks, showing a study of the bone structure of a wing, and ideas for the design of a flying machine.

MATERIALS

- Blank student notebooks
- Writing/ drawing tools (pens, pencils, etc.)
- Glue stick

INTRODUCTION

Discuss with students the various reasons why artists and scientists might keep notebooks and how it helps them study the world around them.

Why do artists and scientists keep notebooks?

Some examples include, but are not limited to:

- observe a subject more closely
- record observations when other methods of recording not possible or available at the time
- capture additional information such as measurements, notes, other observations
- keep a record of what was done, how data was collected
- think through and work out ideas and designs on paper before trying in real life

PREPARE NOTEBOOKS FOR USE

Discuss with students what information might be useful to include in their notebook, to assist with identification and use as a reference of their observations. At the very least, have students write their name on the inside cover, so missplaced notebooks can be returned to their owner when found.

What information might be important to include in the notebook?

Some examples include, but are not limited to:

- name
- contact information
- page numbers
- page titles
- table of contents
- dates of entries or observations
- measurements
- photos or other materials that can be glued in

GRADES:
4-6

TIME REQUIREMENT
60 minutes

SCIENCE STANDARDS (NGSS)

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

4LS1.1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

NATIONAL CORE ART STANDARDS (NCAS)

VA.CR.1.4: Brainstorm multiple approaches to a creative art or design problem.

VA.RE.8.4: Interpret art by referring to contextual information and analyzing relevant subject matter, characteristics of form, and use of media.

COLORS OF NATURE / KIT 3

HOW DOES COLOR HELP US UNDERSTAND THE LIVING WORLD AROUND US?

INVESTIGATION 1 / ADAPTIVE COLORATION: CAMOUFLAGE

HOW DOES COLOR HELP ANIMALS SURVIVE AND REPRODUCE?

OVERVIEW

In this activity, students explore why animals have the colors they do and consider how different coloration strategies help them survive and reproduce. Students then analyze the formal elements (shape, color, pattern and value) of animal camouflage and use their observations as a guide to design an effective camouflage pattern for a specific habitat.

1. Students review animal cards in groups to explore adaptive coloration.
2. Students analyze examples of animal camouflage.
3. Students pick a habitat for which they will design a camouflage pattern.
4. Using colored paper, scissors and glue, students design and create swatches of camouflage patterns for their chosen environment.
5. In groups, students evaluate each other's design solutions to determine what components are (and are not) effective for blending in with their habitat.

LEARNING OBJECTIVES

- *Students will be able to discuss and give examples of how various coloration strategies enhance a species' ability to survive and reproduce successfully.*
- *Students will analyze the formal elements of effective animal camouflage and apply their knowledge to create solutions to a design problem.*
- *Students will identify criteria for evaluating effective camouflage, and apply these criteria to the design of a camouflage pattern for a specific environment.*
- *Students will communicate about their design solutions.*

Photo by P. Teal Sullivan

INSTRUCTIONAL APPROACH

This investigation is designed to introduce students to the biological **function of color** in animal **survival and reproduction**. To foster engagement and identity, we advocate for the sharing and discussion of students' own relevant experiences with animal coloration and human uses of color, and for providing students with opportunities to make choices based on individual preference throughout the activity, so that they are active agents of their own inquiry. The instructor should facilitate student exploration through questions and prompts that encourage:

- *analysis of forms, colors, and patterns in animal coloration*
- *consideration of the costs and benefits of coloration strategies*
- *identification of formal elements that contribute to effective camouflage*
- *application of these formal criteria to the design and evaluation of a camouflage textile pattern for a specific habitat of students own choosing*

The instructor should accept all student answers as value neutral.

SCIENCE BACKGROUND

Why does the bee have stripes and the leopard have spots? Why is one frog brown, but another bright blue? Coloration is one example of the traits that influence animals' survival and reproduction. The remarkable array of colors and patterns we see are adaptations to the unique environments and specific conditions, such as food sources and threats, under which different species survive and reproduce. These **adaptive coloration** strategies range from colors and patterns that are hard to detect, to colors and patterns that are hard to miss. Conspicuous colors and patterns send obvious signals between species, such as warning predators of toxicity, or within species, such as advertising reproductive fitness to attract potential mates.

Coloration that resembles the surrounding environment, called **camouflage**, helps an animal avoid detection. This strategy enhances the survival of prey by concealing them from predators. It also helps predators avoid detection when hunting prey. A common misconception among students is that animals "choose" their colors in order to gain a selective advantage. Instead, camouflaged individuals are more likely to survive and reproduce, passing on these traits to their offspring (i.e., natural selection). Similarly, animals that are best able to attract mates also are more likely to reproduce successfully. Over time, selection pressure on individuals results in the colors we see today across different species.

ART BACKGROUND

Professional artists who had observed the variety of camouflage as a survival strategy in nature were some of the first advocates for the use of camouflage for military purposes, where avoiding detection is a tactical advantage. Today, camouflage patterns find applications far beyond the military: biologists use camouflage to observe wild animals at close range without disrupting behavior; hunters use camouflage to avoid detection by prey; and artists and designers continue to explore the changing meaning of concealment in an era of ubiquitous surveillance and big data. A recent experiment involved designing camouflage to confuse face-recognition technologies by creating a pattern of face-like features that can prevent the software from detecting a "real" face.

A formal analysis of camouflage involves discussing some of the basic elements of art and design: **shape**, **color** and **pattern.** **Shape** refers to the form of a space enclosed by a boundary, such as a line or a contrasting color. Shapes can be geometric (square, triangle, circle, ellipse, hexagon, etc.) or organic (these shapes are irregular, complex, and often asymmetrical). **Color** refers to the wavelengths of light we see reflected off of a surface. Color can be described both in terms of hue (the name of the spectrum color, such as red, orange, yellow, green, blue, violet) and value (lightness or darkness, such as light blue or dark blue, with white being the lightest value and black the darkest). **Pattern** refers to the repetition of similar shapes.

KIT MATERIALS

- **Animal coloration cards**
- **Habitat background cards**
- **6 x 6" colored origami squares. The pack should contain a wide variety of solid colors.** *(4 sheets per student will be used, but have enough on hand that students can choose a color scheme, e.g. about 8 squares available per student)*
- **Scissors** *(1 per student)*
- **Glue sticks** *(1 per student)*
- **Tracing paper** *(1 pad 9x12", or roll)*
- **Camouflage fabric swatches** *(3 different patterns)*

ADDITIONAL SUPPLIES

- **Scrap paper** *(newspaper or copy paper, to protect tables from glue)*
- **Pencils** *(1 per student)*
- **Notebooks** *(if applicable)*

SETUP *5 minutes*

Assemble materials.

INVESTIGATION: *55 minutes*

WHY DO ANIMALS HAVE THE COLORS THEY DO?
15 min

1. Engage the students by asking them to share what their favorite animal is.

What are its colors?
Why might it be colored the way it is?

Accept all answers as value neutral. Consider using think-pair-share to encourage all students to think about the question and have a chance to participate.

2. Divide students into groups of 4 or 5. Divide and distribute the Animal coloration cards to each group. Have students review the cards and come up with ideas for why each animal might be colored the way it is. Circulate among the groups, facilitating thinking by asking questions:

What do you notice about the color of the habitat?
What advantage might that color give an animal

3. As students discuss coloration, ask students to group animals that they think have similar reasons for being colored the way they are.

4. Ask students to share their ideas with the group. Students can choose a representative from the group to share group ideas with the whole class, if desired.

5. As students share, collect ideas on the board and ask students for suggestions for grouping similar color functions.

Many students are familiar with some categories of adaptive coloration but may need to be prompted with further questions to come up with others. While there are numerous strategies and types of adaptive color, the main categories of adaptive color are as follows. Some animals employ more than one color strategy.

Camouflage (colors and shapes that blend into the environment). Ask:

How does blending in with its environment help an animal survive? Reproduce?

Warning (conspicuous colors and patterns such as red, white, yellow, black, that warn predators of toxicity). Ask:

How might bright, high-contrast (light next to dark) warning colors help an animal survive? Reproduce?

Mimicry (warning colors on non-poisonous animals that send a false signal and "trick" predators). Ask:

How do bright warning colors help a non-poisonous animal survive? Reproduce?

Display (conspicuous colors and patterns that attract a mate). Ask:

How do bright display colors help an animal survive? Reproduce?

WHAT MAKES A CAMOUFLAGE PATTERN EFFECTIVE?

5 minutes

1. Now, ask students to select the animal coloration cards that represent camouflage and from them choose one example they particularly like.

2. Have students carefully examine their chosen animal's coloration and its habitat, and write down what they notice about the animal's coloration that helps it blend with its environment.

3. Prompt students to think about the formal elements of camouflage: shape, pattern and color.

a. **Shape:** Have students offer a list of shapes and draw them on the board (triangle, circle, square, oval, star, etc.). What are some examples of shapes you see in your animal camouflage (if they can't be named, they can be described or drawn)?
b. **Pattern:** What is a pattern (repeating shapes)? What are some examples of pattern in animal camouflage?
c. **Color:** What are some examples of colors that animals use for camouflage? How do the colors relate to their habitat?

4. Now, based on their analysis of the animal cards, ask the whole group to create a list of criteria for effective camouflage. Accept all ideas and write them on the board. Students can revise this list if necessary after they create and evaluate their own camouflage patterns.

HOW DO HUMANS USE CAMOUFLAGE?

5 minutes

1. Ask students to consider that humans are animals too, but we are able to adjust our "coloration" by changing the way we dress. Ask students to share the reason they picked the colors of the clothes they are wearing today.

Note: in order to avoid introducing or confirming the misconception that animals also choose their colors, engage in a short discussion about how human camouflage differs from the examples of animal coloration they just explored. Ask:

Do these animals choose their color?
Why are the animals colored this way?
How is human camouflage different from animal camouflage?

2. Now that students have examined various coloration strategies, prompt students to consider how humans have used their observations of camouflage in nature to create fabrics they can wear to blend in with a variety of environments. Prompt students to consider:

How is camouflage useful to people? In what situations might we want to use camouflage?

3. Show students the camouflage fabric swatches and ask them what environment they might use each pattern in.

4. Now, show examples of camouflage patterns in their intended environments. We have provided these examples as a resource at: http://www.colorsofnature.org/camouflage/. As a group, analyze the formal elements (shape, pattern and color) of the camouflage designs:

What part of the environment does THIS specific color blend with?
What part of the environment does THIS color blend with?
What shapes do you see? What shapes repeat?
How do the shapes and pattern relate to the environment?
Why does it matter to use a range of colors? shapes?

CAMOUFLAGE DESIGN *20 minutes*

1. Let students know that they will now use their analysis of effective camouflage in nature to design their own camouflage fabric to be worn in a specific environment of their choosing. Students will make a "swatch" (a small example of the fabric pattern) out of colored origami paper by picking a background color and 3 additional colors from which they will cut out shapes to apply to their background.

2. Have students choose an environment they like from the habitat background cards. They will be designing a camouflage fabric to be worn in this environment.

> *Note: If desired, habitats can also be pulled from other sources, such as books, magazines, or online. Students could also select a real environment adjacent to the classroom on which to base a camouflage pattern.*

3. Ask students to formally analyze their chosen habitat:

> *What shapes do you see?*
> *What patterns do you see?*
> *What colors do you see?*

The design below was inspired by the habitat above.
Photo by P. Teal Sullivan

4. In their notebooks or on a piece of paper, have students list the dominant colors and draw the main shapes they observe in their habitat.

5. To facilitate analysis of shapes in their environment, pass out tracing paper. Students can overlay their habitat card with the tracing paper and trace the main shapes they see. Suggest that students focus on the shapes that stand out to them, or that they see repeating in the environment (as opposed to tracing the whole image).

6. When students are finished, have them choose 4 colors of paper based on their analysis of the habitat. Students will use one color as a background, and cut out shapes from the three other colors to paste to the background in order to make their camouflage pattern "swatch".

7. Distribute scissors and glue sticks to each student, along with a sheet of scrap paper (newspaper, used printer paper, etc.) to be used as a protective backing while they apply glue to their shapes.

8. Have students use their habitat analysis drawings as a formal reference and cut out shapes from three of the colored papers they chose, saving one sheet for the background.

9. Then, have students arrange and glue their shapes to the background paper, cutting out and adding more shapes as needed in order to achieve a pattern that "blends" with their habitat. Students can use scissors to trim shapes that hang over the edge of the background paper.

DESIGN REVIEW *10 minutes*

1. When students have finished creating their camouflage designs, divide into small groups (or table groups) of 4 or 5.

2. Have students present their camouflage design to their group, explaining their reasoning for the shapes and colors they used and how those help the design blend with their habitat. You can write guiding questions on the board to facilitate small group discussion:

What shapes did you see in your habitat?
What shapes did you use for your camouflage?
What colors did you see in your habitat? Which colors worked the best for the camouflage?
What would change if you designed another camouflage pattern for this environment?

To foster STEAM thinking, encourage students to reflect on their choices in a non-judgmental way. Guide students away from evaluating their design solutions as good/bad or right/wrong; instead, prompt students to notice that there are multiple possible design solutions to a given problem and that the process of design is one of trying out solutions, evaluating them, and then refining them. Asking the following questions can help students think about how to optimize their design solutions:

What works? Why?
What could be improved or changed?

3. When each student has had a chance to present their work, ask the groups to reconsider the list of criteria for effective camouflage that they made as a class earlier. Now that they have had experience designing a camouflage pattern, ask each group to offer any revisions or additions to the list based on their observations of what was and was not effective.

NOTEBOOKS

Students can paste their camouflage design into their notebooks and reflect on their design experience. Prompt them to write about:

Why is camouflage useful? To animals? To humans?
What are the criteria for effective camouflage?

Students come up with a wide variety of camouflage designs. Photo by P. Teal Sullivan

EXTENSION: DESIGN AND REFINE *30-60 minutes*

This extension gives students the opportunity to explore design as an iterative process of evaluating and refining solutions to a problem. In this activity, students will create variations on their camouflage patterns for a single habitat in order to optimize their design.

NGSS
3-5-ETS1-2. *Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.*

NCCAS
VA.CR.1.4: *Brainstorm multiple approaches to a creative art or design problem.*
VA.CR.3.4: *Revise artwork in progress on the basis of insights gained through peer discussion.*

1. After evaluating their first camouflage patterns, have students make a note of what worked and what could be improved to create a more effective camouflage with their habitat.

2. Now, let students know they will be creating a new design based on their analysis of their first camouflage pattern (what worked well and what could be improved).

More examples of designs inspired by specific habitats.
Photo by P. Teal Sullivan

3. Have students pick 4 new (or the same) colors of paper, and create another camouflage pattern for their habitat.

4. When finished, have students present their two design swatches in small groups. Have the groups respond to the camouflage options:

Does one pattern blend into the habitat more effectively than the other?
What specifically (shape, color, pattern, value) makes it more effective?
Based on what works, how could this pattern be further improved?

5. If time allows, students can create another iteration of their camouflage pattern, incorporating ideas from their peers and their own reflection to further improve their design.

6. As a whole group, have students share what they discovered in the process of refining their camouflage designs.

What changed about your design from the first swatch to the second or third?
What did you discover in this design process that could be applied to designing a camouflage for a different habitat?

OTHER RESOURCES

ELEMENTS OF ART:
Understanding Formal Analysis: The Elements of Art
2011. The J. Paul Getty Museum, Los Angeles
https://www.getty.edu/education/teachers/building_lessons/elements_art.pdf
(1 page PDF handout)

CAMOUFLAGE:
Camouflage pattern examples:
http://www.colorsofnature.org/camouflage

Adaptive Coloration in Animals
Cott, Hugh B. 1940. Methuen, Oxford University.
https://archive.org/details/adaptivecolorati00cott
(Public domain, available free in multiple digital formats)

Warpaint: the Story of Camouflage
BBC broadcast, 30 minutes audio
http://www.bbc.co.uk/programmes/b00768wm

HyperFace Camo
https://ahprojects.com/projects/hyperface/

Camouflage is a ubiquitous strategy in nature. This parrot blends in seamlessly to its background.

GRADES:
4-6

TIME REQUIREMENT
60 minutes, Investigation 2
55-90 minutes, Investigation 3

SCIENCE STANDARDS (NGSS)

4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

NATIONAL CORE ART STANDARDS (NCAS)

VA:Re7.2.4 Analyze components in visual imagery that convey messages.

VA:Re7.1.5 Compare one's own interpretation of a work of art with the interpretation of others.

MA:Cr1.1.1.4 Conceive of original artistic goals for media artworks using a variety of creative methods, such as brainstorming and modeling.

MA:Cr2.1.1.5 Develop, present, and test ideas, plans, models, and proposals for media arts productions, considering the artistic goals and audience.

COLORS OF NATURE / KIT 3

HOW DOES COLOR HELP US UNDERSTAND THE LIVING WORLD AROUND US?

INVESTIGATION 2 / ADAPTIVE COLORATION: UV SIGNALS

HOW DOES UV COLORATION HELP SOME PLANTS AND ANIMALS SURVIVE AND REPRODUCE?

INVESTIGATION 3 / COMMUNICATING THE INVISIBLE: STOP MOTION ANIMATION

HOW CAN WE DESIGN EFFECTIVE MODELS TO COMMUNICATE THE ROLE OF UV SIGNALS IN SOME PLANTS' AND ANIMALS' SURVIVAL AND REPRODUCTION?

OVERVIEW

This two-part investigation introduces students to an adaptive coloration strategy that is common in plants and animals: ultraviolet (UV) signals that are seen only by animals with eyes that can detect UV. Humans and many other animals cannot see these patterns because UV light falls outside the visible spectrum our own eyes detect.

In the first part of the investigation, students explore examples of animals that see different colors than we do, including in the ultraviolet (UV) part of the electromagnetic spectrum. Using UV flashlights, students examine how the world might appear differently to animals that can see UV, as well as discover UV "secret signals" that communicate information.

In the second part of the investigation, students explore how to communicate a phenomenon that is normally invisible to us through the design of a stop motion animation that models the function of UV "secret signals" in the survival and reproduction of certain plants and animals.

LEARNING OBJECTIVES

- *Students will be able to discuss and give examples of how various coloration strategies enhance an individual's ability to survive and reproduce successfully.*
- *Students will explore how some plants and animals use UV coloration to send information to other animals that are capable of visually detecting UV signals.*
- *Students will design an animated model to communicate how a plant or animal uses UV coloration to send visual signals to other animals as part of its survival strategy.*
- *Students will communicate about their design solutions.*

INVESTIGATION 2 / ADAPTIVE COLORATION: UV SIGNALS

How does color help animals survive and reproduce?

INVESTIGATION 3 / ANIMATION DESIGN

How can we design effective models to communicate the role of uv signals in some plants' and animals' survival and reproduction?

INSTRUCTIONAL APPROACH

This two-part investigation is designed to further elaborate the **function of color** in plant and animal **survival and reproduction** by exploring **ultraviolet coloration** in plants and animals. To foster engagement and identity, we advocate for the sharing and discussion of students' own relevant experiences with animal coloration and animal vision that differs from our own, and for providing students with opportunities to make choices based on individual preference throughout the activity, so that they are active agents of their own learning.

In the second part of the investigation, students are challenged to **communicate** the role of **UV "secret signals"** in the survival and reproduction of a plant or animal of their choice by designing a stop motion animation. The instructor should facilitate student exploration and idea development through questions and prompts that encourage:

- *consideration of the costs and benefits of different coloration strategies*
- *consideration of how animals might see differently than humans*
- *experimentation with materials and techniques for communicating through visual means a phenomenon that is normally invisible to humans*

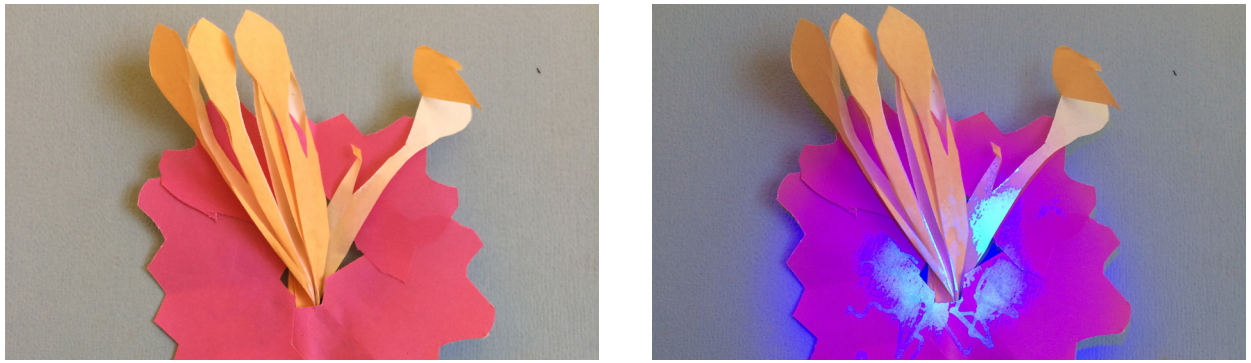
The instructor should accept all student answers as value neutral.

SCIENCE and ART OVERLAP

Communication is a **core practice** of both science and art. Communication allows ideas and results to be shared, evaluated, and ultimately extended to produce new knowledge. There are many ways to communicate information: through discussions, writing, equations, graphs, charts, models and drawings, and more. Scientists and artists alike rely on effective communication, and the ability to interpret and derive meaning from the communications of others, in order to advance and innovate.

Developing and using models is also a **core practice** of both art and science. A model is a representation (often simplified) of a system that aids in understanding the system (often complex or unavailable for direct observation). For example, an astrophysicist might make a computer model that simulates the surface of the sun in order to examine and evaluate ideas about the motion of distant, super-hot particles, whereas a painter might make a sketch to understand and evaluate their compositional ideas before applying them to a large canvas. An architect might make a scale model of a house to work out issues before construction, and a meteorologist might use a model of today's weather to predict sun or rain tomorrow.

In this investigation, students will use stop motion animation to model the behavior of an animal in response to information that is normally invisible to us: UV signals. To evaluate the effectiveness of their communication, students will present and respond to each other's' animated models, providing feedback to the creators for potential refinements.



In this paper model, the flower looks different under normal incandescent light (left) than under UV light (right). Photo by P. Teal Sullivan

SCIENCE BACKGROUND

Adaptive coloration is an example of the various traits that influence plant and animal survival and reproduction. Some coloration strategies, such as camouflage, function by making an animal difficult to detect, while other coloration strategies are meant to be easily seen. These strategies, using bright and high-contrast colors that stand out from the surrounding environment, are meant to send a **signal**. In the case of **warning colors**, the signal tells potential predators "I'm dangerous," whereas **mating display colors** function to attract potential mates. Humans can see the black and yellow warning stripes of a stinging bee, and the brilliant display colors of a male peacock, but many plants and animals have color signals that are invisible to us, sometimes in conjunction with colors visible to humans.

The human eye is capable of detecting only a small range of wavelengths in the electromagnetic spectrum. We call this the **visible spectrum:** the colors of the rainbow from red through violet. Other animals have eye structures that detect different parts of the electromagnetic spectrum and therefore see the colors of the world quite differently than we do. Just beyond visible violet is **ultraviolet light (UV)**, which humans cannot see, but many other species can. Because of this, the adaptive coloration strategies of many plants and animals include UV markings, providing colorful signals that are visible only to species that can see UV.

UV signals communicate a variety of information between a sender and receiver. Plants that are pollinated by insects with UV vision often have UV **nectar guides**, or patterns that help direct their pollinators towards the center of the flower. Some fish are known to have distinct UV facial markings that help them with **species recognition**, allowing them to distinguish their own species from other non-competitive reef fish when defending their territory. **Mate selection** by females in some species of butterflies and birds has been shown to be influenced by the qualities of the UV markings on males.

Although humans cannot see UV light, there are other ways we can detect its presence in plant and animal coloration. Specialized camera equipment can detect UV light, showing us the shape and location of the UV coloration in photographs. Another method of detection is the **spectrometer**, a tool used to measure wavelengths of light. By measuring a surface with a spectrometer, it is possible to determine whether or not that surface reflects UV light and at what intensity.

INSTRUCTORS NOTE:
If we can't actually see UV, why do "blacklights" (UV-emitting light sources) make some things glow? An important distinction here is UV reflectance versus UV fluorescence. When UV light reflects off a surface, animals that detect UV see it as a distinct color, the way that we see the color red when red wavelengths of light reflect off a surface. When we use a "blacklight" (usually a combination of UV wavelengths and visible violet wavelengths that help us detect that it is "on") in low ambient lighting, certain colors will appear to glow. This is not actually UV reflectance, but UV fluorescence, a phenomenon whereby a pigment absorbs UV light and re-emits that light as a slightly longer wavelength in the visible spectrum. Fluorescent pigments are common in plants and animal coloration, but not all UV signals are fluorescent: some pigments simply reflect UV light.

While "blacklight" is useful to demonstrate how shapes and patterns normally invisible to us can be detected using special tools, it does not actually show us how the world looks to an animal that can see reflected UV.

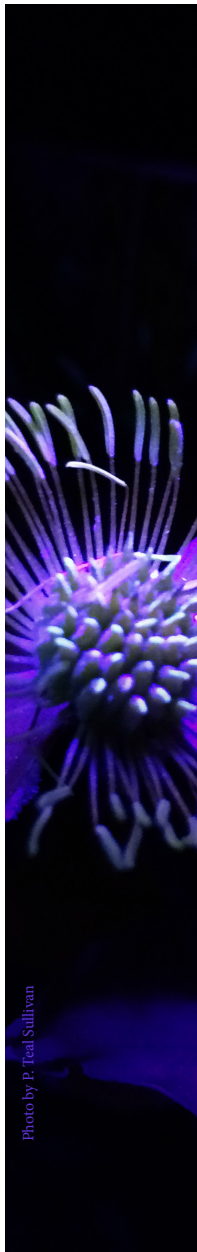


Photo by: Teal Sullivan

INVESTIGATION 2 / ADAPTIVE COLORATION: UV SIGNALS

How does color help animals survive and reproduce?

INVESTIGATION 3 / ANIMATION DESIGN

How can we design effective models to communicate the role of uv signals in some plants' and animals' survival and reproduction?

ART BACKGROUND

Humans have long employed the arts to address the particular challenge of communicating knowledge of the invisible. Artists do this by using visual symbols, such as lines, shapes, and colors, to represent larger ideas. The meanings communicated by visual symbols are not fixed, and ultimately depend on the interpretation of the receiver who is influenced by personal, historical, and cultural factors.

How do we know if we are **communicating** effectively if there is no fixed meaning to the symbols we use? In art and design this issue is addressed through a system of audience or user feedback. By **presenting** work to an audience and collecting their **responses** and interpretations, artists and designers can determine whether their intended meaning has been adequately conveyed or whether refinements must be made.

Stop motion animation is a technique that has been in use since the invention of moving pictures in the late 1800s. It involves creating a series of photographs in which objects are moved slightly between each shot so that, when the pictures are viewed in rapid succession, the objects appear to move on their own. Today, we can use specialty software programs to facilitate the production of stop motion animations as a one form of visual communication.

In this stop-motion scene, the artist uses a blacklight and UV ink to make the image on the left appear differently (UV image on right). Photo by P. Teal Sullivan

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How can we design effective models to communicate the role of uv signals in some plants' and animals' survival and reproduction?

KIT MATERIALS

- **UV secret signals cards**
- **UV flower photos**
- **Multi-colored construction paper** *(10-color pack, 240 sheets)*
- **Blank index cards 5x8"** *(1 per group of 2 students, with extras available)*
- **Multicolor felt tipped markers** *(1 pack per 2 students)*
- **UV "invisible" ink** *(1 two-oz jar)*
- **Small cups or jars to distribute ink** *(1 per 2 students)*
- **UV flashlights** *(1 per 2 students)*
- **Variety pack small round paintbrushes** *(1 per 2 students)*
- **Scissors** *(1 per student)*
- **Glue sticks** *(1 per student)*
- **Craft feather bundle** *(1 per 2 students)*
- **UV reflective butterfly wings** *(1 per 3-4 students)*

ADDITIONAL MATERIALS

- **Pencils** *(1 per student)*
- **Scrap paper** *(newspaper or copy paper, for protecting tables from glue)*
- **Fresh flowers** *if available/ other UV fluorescent items around classroom (determine with UV flashlight)*
- **Tablet or other iOS/ Android device with camera and Stop Motion Studio App** *(free for iOS or Android) (1 per group of 3-4)*
- **Notebooks** *(if applicable)*

SETUP *5 minutes*

Assemble materials. Check batteries for charge in blacklights and cameras. Pull shades, or cover windows if possible using cloth or black garbage bags (some ambient light is ok, but the blacklights work best in a dark environment).

INVESTIGATION 2
UV SECRET SIGNALS: *55 minutes*

DOES THE WORLD LOOK THE SAME TO OTHER ANIMALS? *15 min*

1. Engage students by asking them to share their knowledge or ideas about how the world looks to other animals.

Does the world look the same to other animals as it does to us?

What are some examples of animals that see differently than we do?

What is different about their vision that allows them to see this way?

Collect student ideas about variations in animal vision on the board. Many students are familiar with the idea that snakes can detect their prey using infrared sensors, or that dogs can't see all colors we do (they only have two color cones in their eyes, while we have three). Some students might be familiar with the idea that some animals can see ultraviolet light.

2. Now, have students gather in small groups (3-4 students) and hand out the UV flashlights, feathers and butterfly wings (and flowers if available) to each group.

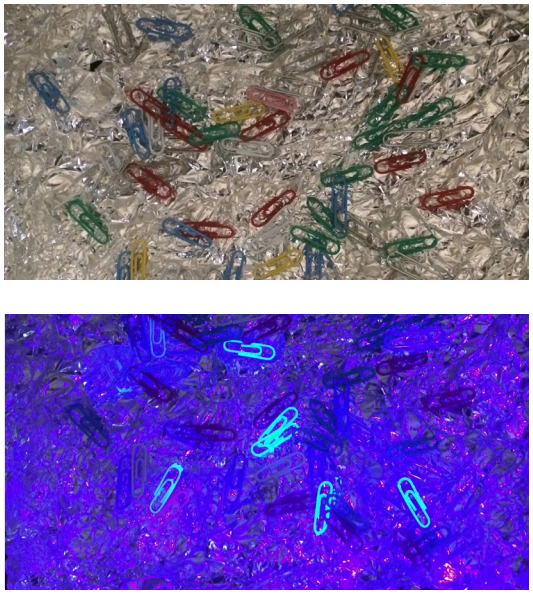
SAFETY NOTE: Let students know that UV can be harmful and they should not aim the flashlight at anyone's eyes or look directly at it.

3. Turn off the overhead lights and ask students to examine the feathers and flowers and other things around them.

What do you notice?
What stands out, or attracts your attention?

4. After a few minutes of exploration, turn the overhead lights back on and ask students to notice how the visual environment changes.

Do the same things attract your attention under white light as UV?
Or do different things stand out?



(above) Everyday objects in the classroom sometimes "glow" under a blacklight (below). Photo by P. Teal Sullivan

FUNCTIONS OF COLOR AND SECRET SIGNALS

15 minutes

1. Distribute the animal coloration and UV flower photos to the small groups.

2. Have each group brainstorm the functions of color for each card. How does the habitat relate to the colors of the organism? If the students have already reviewed the coloration cards in the previous investigation in this kit (Adaptive Coloration: Camouflage), this can be a brief review and they can skip to step 4.

3. Have the whole group share ideas about functions of color and create categories:

a. ***Camouflage*** *(colors and shapes that blend into the environment)*
b. ***Warning*** *(conspicuous and often contrasting colors such as red, white, yellow, black, that warn predators of toxicity)*
c. ***Mimicry*** *(warning colors on non-poisonous animals that send a false signal and "trick" predators)*
d. ***Display*** *(conspicuous colors and patterns that attract a mate)*

4. Ask students to select the cards that represent display coloration and set aside the rest. Prompt students to consider how display coloration helps this plant or animal survive and reproduce. Prompt students to discuss both the costs (more conspicuous to predators/ prey) and benefits (more attractive to mates) of display coloration.

5. Now, show students a graphic of the electromagnetic spectrum, and have them identify the part of the spectrum that is visible to humans. Googling the electromagnetic spectrum will provide a number of pictures that show the visible spectrum vs. the parts of the spectrum that are not visible to humans, such as UV and infrared.

6. Let students know that some species of animals can see UV light, including many birds, insects, spiders, reptiles and fish. Ask students to think about their exploration with the UV flashlights.

How might the world look differently to animals that can see UV?

7. Considering what they know about functional colors, ask students how UV coloration might help a plant or animal survive or reproduce? Collect student ideas on the board. (For example: UV markings enhance display pattern, and only some animals can see these markings). The connection between what animals see and how animals and plants look (e.g., their colors) can sometimes be a difficult one for students to make. Consider facilitating small group discussions around this idea, using questioning prompts, to make sure that students grasp this core idea.

8. Show students UV secret signals cards.

9. Let students know that it was only in the past century that people discovered some animals could see UV. Tell students that scientists are still finding new examples of UV signals using special tools like a spectrometer or special filters and sensors on cameras that detect UV reflectance and can capture an image of it.

INVESTIGATION 2 / ADAPTIVE COLORATION: UV SIGNALS

How does color help animals survive and reproduce?

INVESTIGATION 3 / ANIMATION DESIGN

How can we design effective models to communicate the role of uv signals in some plants' and animals' survival and reproduction?

COMMUNICATING THE INVISIBLE

15 minutes

1. Let students know that they will be designing a stop motion animation to communicate how UV signals enhance the survival or reproduction of a plant or animal. Students will get to choose from several scenarios. It is important to let students select a scenario that they like in order to facilitate ownership and learner control over the task.

2. Divide students into groups of 2-3 (two will facilitate more engagement in the task). Distribute the UV signals cards and ask students to spend a few minutes reviewing the organisms and the role of UV signals in their survival or reproduction.

3. Ask students to consider how a scientist who studies UV signals might communicate their findings to other people who can't actually see UV themselves (for example with writing, diagrams, UV photographs, etc.). Collect student ideas.

4. Prompt students to think about how they could represent the change in behavior of an animal in response to seeing a UV signal? And how could they best represent how this signal benefits the survival and reproduction of the plant or animal that is sending the UV signal?

5. Show example of stop motion animation to give students an idea of the outcome (Visit colorsofnature.org and look for the link to the stop motion animation example).

6. With the remainder of the period, have the groups brainstorm a scenario to animate that communicates how their organism uses UV signals to help it survive or reproduce.

INVESTIGATION 3

ANIMATION DESIGN: *55 minutes minimum,but allow up to 1.5 hours if possible*

1. Divide students into their working groups from investigation 2 (they will already have chosen a UV signal card and brainstormed a scenario to animate).

2. Distribute index cards and instruct each group to make a storyboard for their animation. A storyboard is a visual outline of key moments in the animation. Have students divide the index card into a grid of 10 squares and quickly sketch out the action that will occur in each scene, like a cartoon. These do not need to be elaborate drawings, just reference points to guide the production. The final animation will be around 10 seconds long, so it's best to keep the story simple!

STORYBOARD EXAMPLE

3. Using the construction paper, scissors and glue, have students create backgrounds for their scenes and the characters that will appear in the story. Students should use their storyboard as a guide to the components and characters that will be needed for each scene.

4. Using a brush and the invisible UV ink, students can add the UV signals to their construction paper characters as needed. These can be made visible using the UV flashlight when filming.

5. To animate the scene, have students move the characters across the background, taking a picture each time.

6. Use tablets or other iOS/Andriod devices with cameras and the Stop Motion Studio app (or digital cameras and iMovie) to capture each image and create the animation. (While students are often able to complete this task easily, we have provided further step-by-step instructions are in the resources section of colorsofnature.org).

INSTRUCTORS NOTE:
If cameras and animation software are unavailable, students can still explore designing a graphic representation of their organisms' UV signal by using their story board as the basis for creating a finished comic strip. UV ink could be added to the appropriate panels and the comic strip could be presented with a blacklight flashlight for viewing.

FILM FESTIVAL

Allow 5 minutes per group, if possible

At the end of the period, have students present their animations and tell the class about their creative choices in representing the function of their chosen organisms UV signal as a coloration strategy. One possibility would be to upload all animations onto the teacher's computer and have students present as they are shown on a projector. If a projector is not available, another option would be to divide the class in half and have one half of the class circulate to view presentations on the iPads. The class would switch roles after the first group is finished.

Have students describe their animation and answer:

How does your organism use UV signals as part of their coloration strategy?

How does this UV signal help your organism survive or reproduce?

Ask the class to give constructive feedback to the creators, considering:

In what ways does the animation effectively communicate the organisms' UV signal and how it enhances survival or reproduction?

How did the creators' choices of materials or animation techniques show the UV signal?

What could be changed about this animation to better communicate the function of the UV signal and how it helps the organism survive or reproduce?

Many insects can see UV light because of cone cells in their eyes that differ from those of humans.