Animal Coloration

Activities on the Evolution of Concealment

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by Robert Stebbins, David Ipsen, and Gretchen Gillfillan. New edition revised by Judy Diamond and Judy Scotchmoor

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We dedicate this book to science teachers and parents who inspire in their children a sense of wonderment and awe about evolution and the natural world.

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Preface to Revised Edition

by Judy Diamond and Judy Scotchmoor

In the 1960s, Robert Stebbins created a team to develop one of the most popular and enduring guides to teaching natural selection. They chose to help students understand evolution through a feature of the environment that every child could directly experience: the coloration of animals and the ways that coloration aids in the defense against predators.

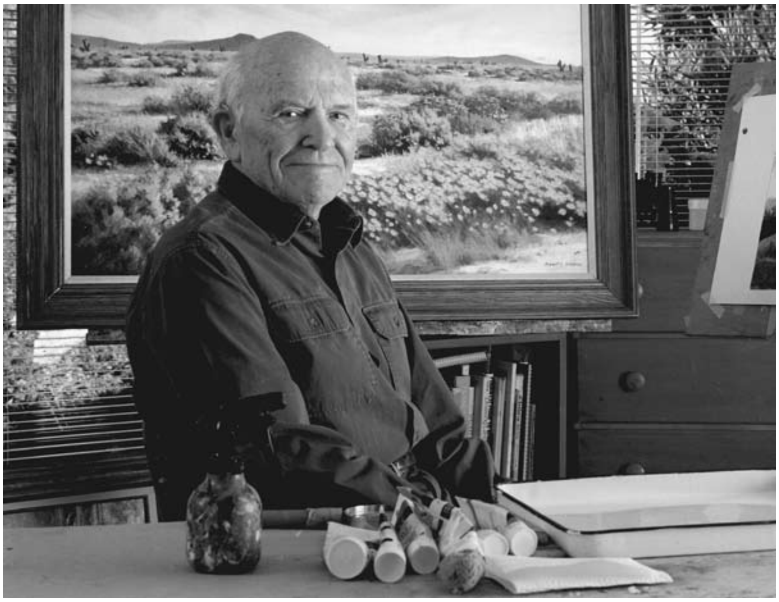
Robert and his team strived for an active and inquiry-based approach to science education in which students were encouraged to observe, make models, experiment, and test their ideas. They believed that by direct investigation, children would better construct a mental framework for deep understanding of biological processes. This approach to teaching biology through active learning was highly innovative, and today it is widely accepted as the foundation for the effective teaching of science, as advocated by the National Academy of Science's National Science Education Standards (NRC 2000).

Robert Stebbins inspects a salamander on the University of California at Berkeley campus in 1951. Photo by Oliver Pearson. Used with permission of the Museum of Vertebrate Zoology, University of California, Berkeley.

Robert Stebbins pioneered a collaborative approach to the development of science education activities. He is an internationally acclaimed scientist and the author of one of the most widely used books on herpetology, *A Field Guide to Western Reptiles and Amphibians*. As a professor of zoology at the University of California at Berkeley and Curator of Herpetology at the Museum of Vertebrate Zoology, Stebbins was deeply committed to a "whole-organism" approach to teaching biology. He influenced several generations of scientists to become actively involved in communicating science to youth and the public. Although a university professor, he chose to devote some of his time to create activities that would help children better understand the natural world. Stebbins recognized the kind of teamwork and expertise that would be required to create activities that would inspire lasting change in young students and yet be easy to use in a classroom or outdoor setting. To this end, he formed a partnership with an experienced elementary teacher, Gretchen Gillfillan, and an innovative engineer, David Ipsen. Together, Stebbins, Ipsen, and Gillfillan developed a set of activities that are as timely and relevant today as they were 40 years ago, and that rank among the best examples of how to teach natural selection to youth.

The activity book, *Animal Coloration, An Introduction to Natural Selection*, was first published in 1966 by the Regents of the University of California. It was the result of over five years of field testing and experimentation as part of the Elementary School Science Project at UC Berkeley funded by the National Science Foundation. This book also served as the basis for a study conducted by Larry Lowery on how students develop attitudes toward science (see Lowery 1965 and 1967 in Appendix D). A revision of *Animal Coloration* was produced by Robert Stebbins in 1971 for the Adelaide school district in Australia.

The National Science Teachers Association (NSTA) Press has made this timely book accessible once again to educators. This new edition was revised by Judy Diamond and Judy Scotchmoor. Diamond is Professor and Curator at the University of Nebraska State Museum and author of the 2005 NSTA Press book, *Virus and the Whale: Exploring Evolution in Creatures Small and Large.* Scotchmoor is Assistant Director of the University of California Museum of Paleontology and director of the website, *Understanding Evolution* (*http://evolution.berkeley.edu*). Diamond and Scotchmoor were



Robert Stebbins in 2004 by Charles Brown. Used with permission of the Museum of Vertebrate Zoology, University of California, Berkeley.

aided in their revisions by Robert Stebbins, his wife, Anna-rose, and his daughter, Mary Stebbins. Alan B. Bond graciously helped us with updating the chapter on animal vision as well as many other aspects of the revision. Support and encouragement was also provided by Linda Allison, the children's science author, and by the U.C. Davis science educator, Richard Ponzio. We also thank Daniel G. Mulcahy and Meredith J. Mahoney for their excellent biography of Robert Stebbins (2006).

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Mulcahy, D. G., and M. J. Mahoney. 2006. Robert Cyril Stebbins. *Copeia* 2006(3): 563–572.

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Introduction

by Robert C. Stebbins

This science book aims to increase students' awareness of the ways that wild organisms are adapted to their environments. Since the coloration of animals is easily observed, that attribute was selected for particular attention.

This book is intended primarily for students in the upper elementary school grades 4 through 6. It can be used in its entirety or specific activities can be used as a replacement resource to augment the science curriculum. If taught in full, "Animal Coloration" will require most of the time available for science for an entire term. This book focuses on the investigation of a few important concepts thoroughly, while stressing the methods of science. The activities within this book can also contribute to achievement in art, language, writing, and mathematics.

Even though the activities suggest a specific teaching procedure, it should be remembered that each activity is intended to be an investigation by the students. Although procedures are offered within each chapter, encourage the students to devise their own solutions to problems.

When the function of the colors of animals is considered, concealment often comes first to mind, and it is this aspect of coloration that is stressed within this book. It is important, however, not to overlook other interpretations, as the study proceeds. Some discussion of the role of color and pattern in advertisement and in mimicry is desirable to avoid a one-sided approach. The chief objective of this book is to suggest to students that features of animal coloration observed by them may serve one or more functions. Rather than accept them as simply the way things are, students may find through study and observation that particular features of coloration serve animals in important and often surprising ways. Also given attention is the question of how such features may have evolved. Thus the idea of natural selection is introduced.

The book seeks to develop a scientific attitude: The approach is inductive and experimental, and students are told little, so they can discover much. Students make hypotheses based on their observations and then attempt to test them through experimentation. It is hoped that through such experiences, students will begin to appreciate how scientific knowledge and understanding are attained.

Through the understanding of nature that the students gain from these activities, it is hoped that they will develop a greater regard for the natural environment, which is so rapidly being altered by the activities of humans. As a result of their study of other living things, students may better see themselves in perspective in the living world as part of the process of evolution and as guardians, as well as users, of the living things that share the Earth with them.

Suggestions for Teachers

Principles of concealing coloration are explored using models of animals. Most activities can be conducted in a natural or semi-natural outdoor setting. However, since many schools do not have such environments nearby, all activities can be performed indoors or in the schoolyard. Models are used because of the difficulty in experimenting with living animals.

The reader may wonder why more stress has not been placed on the study of living animals in their natural habitats. The reason lies in growing urbanization. How can one instill in students an appreciation of wild animals and the natural environments in which they dwell when so many of our young people are growing up in urban environments where there is no wild nature nearby? One is often forced to improvise. It is especially important that city dwellers have an appreciation of nature if the integrity of the Earth's living system is to be preserved. In Western societies urban populations predominate and are largely responsible for decisions that effect the total environment. The fate of all living things, including ourselves, is to a large extent now in the hands of urban people.

We hope that our approach to the study of animal coloration will cause all students to look with greater appreciation and understanding at the wild animals that they encounter around their homes or on trips in the field. In using this book, outdoor studies should be stressed whenever possible, because the survival value of an animal's colors is best understood in its natural habitat.

General Organization of the Book

The book is composed of eight chapters, each of which focuses on a single aspect of animal coloration. Each chapter begins with a discussion of the scientific principles involved, and we recommended that the background information be read before beginning the activities.

Following the background information are an overview of the activities and the materials that are required. Whenever possible, field trips should be encouraged so that students can observe animals in their natural habitats. Some suggestions regarding field trips can be found in Appendix A.

Each chapter is composed of one or more activities that focus on the scientific principles involved. Each activity is intended for a 50- to 60-minute class session. You will probably find, however, that some material goes faster and some slower than indicated, depending on both the interest of the students and their skill in developing or carrying out any experiment involved.

Each activity contains a list of materials needed and suggested teaching procedures. The proposed activities have been field-tested and used successfully by classroom teachers in several elementary schools. Arranging for the props for some of the activities must be done several days to several weeks in advance.

Keeping records in notebook form helps the students to structure their learning. Specific suggestions for notebook and sample notebook forms are included in these activities. Entries need not be restricted to the forms suggested. The classroom notebook may also be used for keeping records of observations in the field.

Along with the activity instructions are five appendices:

- Appendix A gives instructions for field trips.
- Appendix B is a glossary of terms that may be unfamiliar to students.
- Appendix C gives the scientific and common names of the animal species mentioned in the book.
- Appendix D lists references and resources on animal coloration and evolution that may be useful in preparing for and teaching the activities.
- Appendix E includes acknowledgments for earlier editions of this book.

National Science Education Standards

Animal Coloration and National Science Education Standards

by Judy Scotchmoor

Each of the activities within this book provides an opportunity to incorporate concepts from the National Science Education Content Standards A: Science as Inquiry, C: Life Science, and G: History and Nature of Science, for grades 5–8. The following table summarizes each activity with the learning outcomes and relevant content standard.

Activity Number	Lesson title	Summary of activity and learning outcomes	National Science Education Content Standards A, C, and G for Grades 5–8
Chapter 1	**Evolution and the Functions of Color**		
Activity 1-1	Observing Colors in Animals	Students understand that color patterns may serve several functions.	Living systems at all levels of organization demonstrate the complementary nature of structure and function.
Chapter 2	**About Fish**		
Activity 2-1	The Fish and Its Problems	Students hypothesize that coloration may function to conceal an animal.	Living systems at all levels of organization demonstrate the complementary nature of structure and function. The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.
Chapter 3	**The Vision of Animals**		
Activity 3-1	An Experiment on Vision	Students test the assumption that all animals "see" as humans do.	Living systems at all levels of organization demonstrate the complementary nature of structure and function. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

Activity Number	Lesson title	Summary of activity and learning outcomes	National Science Education Content Standards A, C, and G for Grades 5–8
Chapter 4	**Matching Background Color**		
Activity 4-1 Activity 4-2 Activity 4-3	Highlight and Shadow Countershading Under Varied Lighting Experimenting With Colors in Concealment	Students test assumption that objects that are the same color as their background are concealed. Students predict what shading patterns will reduce highlights and shadows. Students experiment with countershading. Students gather data to test their hypotheses. Students are introduced to natural selection.	Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment. Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations. It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.

Activity Number	Lesson title	Summary of activity and learning outcomes	National Science Education Content Standards A, C, and G for Grades 5–8
Chapter 5	**Disruptive Coloration**		
Activity 5-1	The Influence of Color on Disruption	Students investigate how natural selection can change the character of a fish population when the habitat changes.	All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment. A population consists of all individuals of a species that occur together at a given place and time. Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations. It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.
Activity 5-2	The Tiger Hunt	Students test their hypotheses about disruptive patterns.	
Activity 5-3	Camouflaging the Mud-Fish	Students apply their understanding of disruptive patterns to predict what pattern will be most advantageous in a changing environment.	
Activity 5-4	Catch the Fish	Students use models to test their hypotheses.	

Activity Number	Lesson title	Summary of activity and learning outcomes	National Science Education Content Standards A, C, and G for Grades 5–8
Chapter 6	**Concealment of Giveaway Parts**		
Activity 6-1	Eye Concealment	Students design an experiment to test color patterns that may be effective in concealing the eye.	Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment. Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations. It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.
Activity 6-2	An Experiment With Eye Stripes	Students test hypotheses about the effectiveness of eye stripes in fish.	
Activity 6-3	Coincident Disruptive Coloration	Using models, students examine disruptive coloration to conceal the legs of a frog.	

Activity Number	Lesson title	Summary of activity and learning outcomes	National Science Education Content Standards A, C, and G for Grades 5–8
Chapter 7	**Concealing Behavior**		
Activity 7-1	Concealing Behavior	Students examine aspects of behavior that influence the effectiveness of an animal's concealing coloration. Students discover various ways in which a moth might minimize its shadow.	Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment. An organism's behavior evolves through adaptation to its environment.
Activity 7-2	The Lizard Game	Students demonstrate understanding of the influence of behavior on concealment.	Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.
Chapter 8	**Observing Nature**		
Activity 8-1	Observing Nature	Students apply their understandings to animals in their natural habitats.	Living systems at all levels of organization demonstrate the complementary nature of structure and function. The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment. All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment. An organism's behavior evolves through adaptation to its environment.

3 The Vision of Animals

In studying animal coloration, it is easy to forget that the colors we see may not be the same as the colors that other animals see. Seeing depends not just on the nature of the light that reaches one's eyes, but also on the way that one's eyes and brain respond to the light.

The Sense of Sight

The light that makes seeing possible is a form of radiant energy, similar to the waves that carry radio and TV signals. It differs only in the length of the waves and therefore the frequency with which they strike or pass an object in their path. The length and frequency of the waves are simply related: The shorter the waves, the more frequently they will pass.

The frequencies for light waves are much higher than for radio waves. A typical frequency for radio waves is a million waves per second (the one thousand kilocycle setting on an AM radio). A typical light frequency is 500 trillion waves per second (a trillion being a million million). Sunlight contains both infrared (lower frequencies) and ultraviolet (higher frequencies) radiation. Surfaces illuminated by sunlight will reflect differing amounts of red or green or blue. The presence of infared or ultraviolet radiation in sunlight can be detected by certain photographic film. Just as various chemicals respond to the light we can see, others respond to the light we cannot see.

The human eye is sensitive to only a limited range of frequencies. Expressed in trillions of waves per second, the approximate range of the eye is from 400 to 800. The lowest frequency corresponds to red light, the highest to violet light. Intermediate frequencies give colors ranging from orange to yellow, green, and blue. If our eyes were able to respond to even lower frequencies (infrared light) or higher frequencies (ultraviolet light), we would see many things differently.

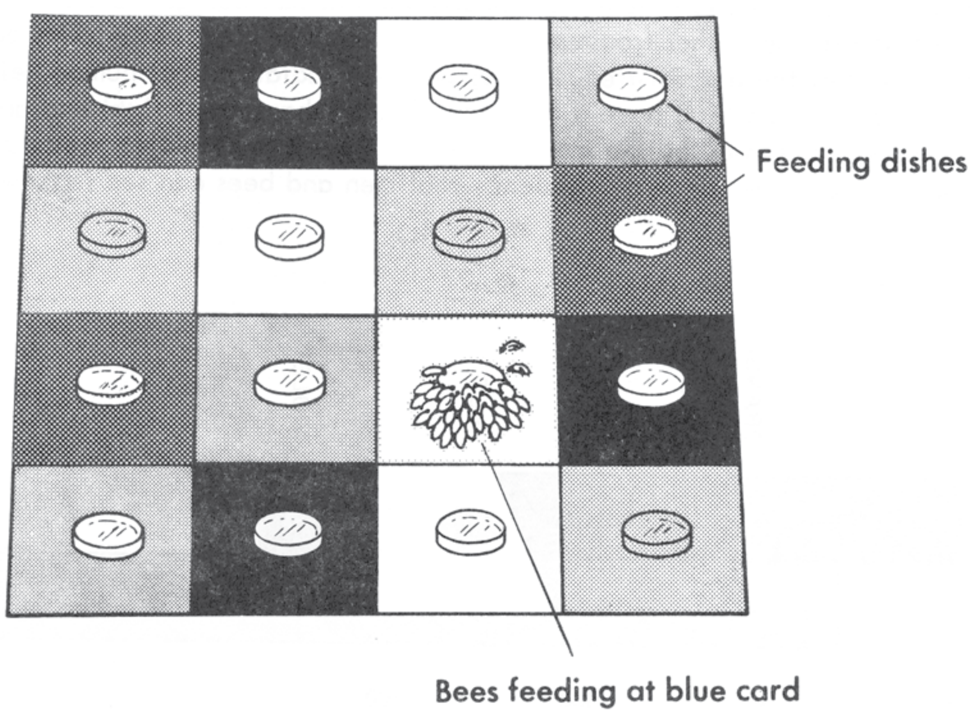
The ability of the eyes to detect light depends on the presence of sensory cells in the retina. The retina is the light-sensitive layer of cells at the back of the eye, and it determines which light frequencies will be detected. The human retina contains two basic types of cells, rods and cones. The rods are more sensitive and respond better in dim light. They do not discriminate between colors, however, giving only a perception of shades of grey. The cones respond if the light intensity is high enough and allow us to perceive colors.

Some other animals have a different light-sensing apparatus. A different system of cones can give a different range of color sensations, without some of the colors that we see or including light frequencies that humans don't see, such as ultraviolet or infrared. Many animals have no cones, which gives them only black-and-white vision.

The Vision of Bees

Karl von Frisch, an Austrian zoologist, investigated the visual range and color discrimination of honeybees. In a typical experiment, von Frisch arranged a checkerboard of 16 squares of cardboard on a table (see Figure 3a). One square was colored (e.g., blue), and the remainder were various shades of grey, ranging from white to black. On each card was placed a shallow glass dish of water. The water on the blue square was sweetened with sugar.

Figure 3a. Checkerboard Experiment to Test the Vision of Honey Bees



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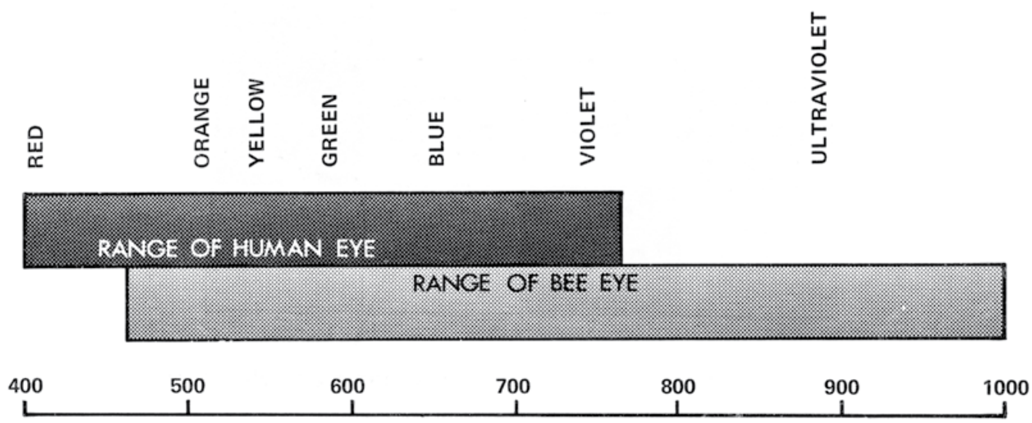
After the bees learned the location of the sugar, they would continue to go to it even though the position of the blue square with the sweetened water was changed frequently. After several hours, clean squares and dishes were set out, this time without sweetened water on the blue card. The bees continued to alight on the blue square, however, confirming that they identified the food location by color.

A similar experiment using a red card gave quite different results. To the bees' eyes, the red card and the dark grey or black cards apparently looked much the same. In searching for the food, they would go to some of the grey or black cards as well as to the red.

Von Frisch conducted a number of experiments of this sort, including some in which different colors were used together. From them, he concluded that not only were bees red-blind, but also they failed to distinguish between many of the colors that we recognize as different. He found that they confused yellow with green or orange, and blue with violet.

Since von Frisch's early experiments on the color vision of honeybees, many more experiments have been conducted, and it has been well confirmed that bees do not see red. But their ability to distinguish other colors is better than von Frisch's experiments seemed to show. Later experimenters found that bees are able to distinguish many colors, just as human beings do, though not always the same ones. Besides their inability to see red, they seem to distinguish oranges and yellows and greens more poorly than human beings. But it also appears that they may distinguish the higher frequency radiations such as blues and violets better than human beings. And at the highest frequencies, bees see radiation that human beings are blind to. Ultraviolet waves, which have a frequency higher than violet light and are not sensed by human eyes, are sensed by the eyes of bees. To bees, ultraviolet is as much a color as yellow or blue. The range of light frequency that humans and bees can see is shown in Figure 3b.

Figure 3b. Comparison of Vision in Man and Honey Bee



The experiments on the color vision of honeybees show that bees must see a different world than we do. The most obvious difference is that the many red flowers in nature cannot look red to bees. Von Frisch's experiments suggest that red flowers would look dark grey or black, not the conspicuous color that humans see. If the attraction of bees alone had influenced the evolution of flower coloration, one would not expect red flowers to survive.

Two explanations are possible. One is that many red flowers may reflect ultraviolet light and therefore appear colorful to bees. This has been found to be true of some red varieties of poppy. The other possibility is that red flowers have evolved to attract other kinds of pollinators. Nectar-feeding birds, such as hummingbirds, have eyes that are more sensitive to red wavelengths than those of bees, and hummingbirds feed more often from flowers that reflect only red light.

The Vision of Other Animals

Experiments have also been performed with other animals. Although results are far from complete, a few rough generalizations can be made. In general, apes and many monkeys have color vision much like ours, although some nocturnal monkeys are nearly color-blind. Like many other animals that are active only at night, nocturnal monkeys have an increase in the number of light sensitive rods and fewer cones and therefore probably little color vision.

Insects often discriminate between colors, though often not quite as humans. Most are able to detect ultraviolet, as does the honey bee. Some also resemble the honey bee in not seeing red. But many can see well into the red part of the spectrum.

Fish, birds, and reptiles that have color vision have more kinds of cones than humans do and presumably see a richer range of colors. They also often see further into the range of infrared and ultraviolet than humans can. Birds usually have color vision, though nocturnal birds such as owls often lack it. The same contrast is often seen in reptiles. Diurnal lizards (lizards active during the day) usually have color vision, but nocturnal lizards usually do not.

Most mammals have at best a weak color sense. Horses, rats, elephants, and many other familiar mammals probably see only a black-and-white world, or close to it. Dogs and cats have only a very limited ability to discriminate colors.

Because of the wide variation in visual perception in other animals, the human viewer must be careful in judging what function an animal's colors may serve. Some colors that appear to be concealing from a human perspective might not have that effect on a predatory bird or fish. And perhaps more importantly, colors that look conspicuous to a human being may not to another animal. Does a black-and-white zebra look conspicuous to a lion that perhaps may see everything in black and white?

Activity 3-1 An Experiment on Vision

Introduction

In their study of animal coloration, the students will be "hiding" animals from themselves. If the students cannot easily spot a fish, they may assume that the fish will be overlooked by another fish or by a preying bird or mammal. If a moth escapes the students' attention, they may assume that the moth will be likely to escape the attention of its real predators.

This activity questions such assumptions. Perhaps the eyes of some fish perceive different colors than our eyes. Possibly some foraging birds do not detect the same colors that we see in the moths they prey on.

In this activity, students learn what it would be like to have greatly limited color vision. Viewing the world through red cellophane, they see the world in one color and discover that objects that once stood out conspicuously now fade into the background. The paper animal that is easy prey to the student with ordinary vision becomes well camouflaged to the student who sees only red.

The function of the red cellophane is to absorb any color of light passing through it except red. Thus, all objects appear to be different shades of red, the particular shade depending on how much red light is contained in the total light reflected from them. If an object reflects no red light at all, it appears black when viewed through the cellophane. For example, a white object, since it reflects all colors well, appears bright red; but a blue object (provided it is pure blue) appears black. Since few colors are pure, however, most objects appear somewhat red, whatever their color.

Wearing the red mask, therefore, a student may fail to notice a red paper bird on a green bush. Both the bird and the bush will appear red (perhaps even the same shade of red if the paper color was carefully selected) and will therefore tend to blend together.

ACTIVITY 3-1 NOTES

Procedures	Props and Supplies
1. Discussion of animal vision	
2. Planning the hunt	
3. Preparing the props	Copied patterns for students, construction paper in selected colors, red and clear cellophane (approximately 10 sq. feet of each), 1" masking tape (approximately 80 feet), scissors 1 per student
4. Conducting the hunt	
5. Notebook entry: Experiment report	Notebook forms
6. Discussion of results	
7. Discussion of bee vision	

Preparation for Activities

Selection of habitat: If reasonably well planted with shrubs, the schoolyard may serve as an adequate habitat. The area should be restricted to a particular section of the schoolyard or to the vicinity of a particular walkway. If available, a wilder habitat is preferred; however, areas in which the footing might be uncertain should be avoided since the colored masks are likely to distort the students' vision of the ground at their feet.

Selection of color for animals: The paper animals should be made of colors that blend well with the surroundings when viewed through the red cellophane masks but are conspicuous when viewed without them. Take a sheaf of the available construction papers to surroundings similar to the selected habitat and view them through red cellophane. Discard those that do not blend well with the surroundings when viewed through the cellophane. From among those that remain, select the one that is most conspicuous when viewed without the cellophane.

Preparation of patterns: Patterns for a rabbit, bird, turtle, snake, frog, butterfly, and duck are presented in Figures 3c and 3d. Duplicate enough of each pattern to supply one seventh of the class.

Suggested Teaching Procedure

1. **Discussion of animal vision:** Ask the students whether they think that other animals see the same as we do. Presumably they will be aware that certain animals have better vision at a distance than we and that others have better night vision, etc. They may not, however, have considered the possibility that some animals might have a different color sensitivity.

   Discuss the problems of an animal that must hide from other animals whose eyes are sensitive only to black and white. Presumably its coloration would not be nearly so critical as if its predators' eyes were sensitive to color. Various colors having the same brilliance might all appear the same shade of grey to a black-and-white visioned animal. A red caterpillar crawling over a green leaf might be as hard to see as one that matched the leaf color exactly.

2. **Planning the hunt:** Ask the students what an animal would see if its eyes were sensitive only to red light. Would it help or hinder its detec-

Figure 3c. Animal Shapes 1

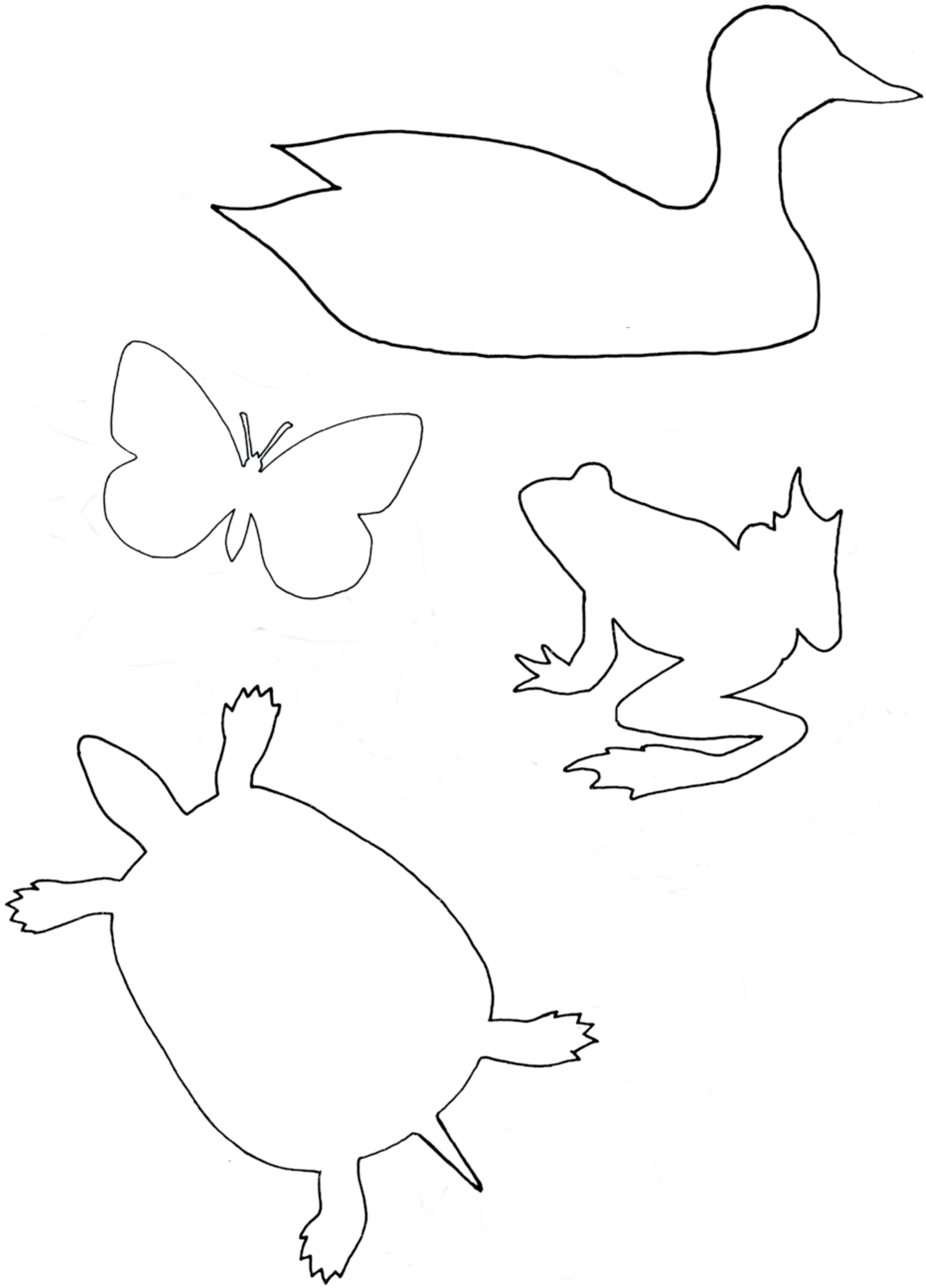
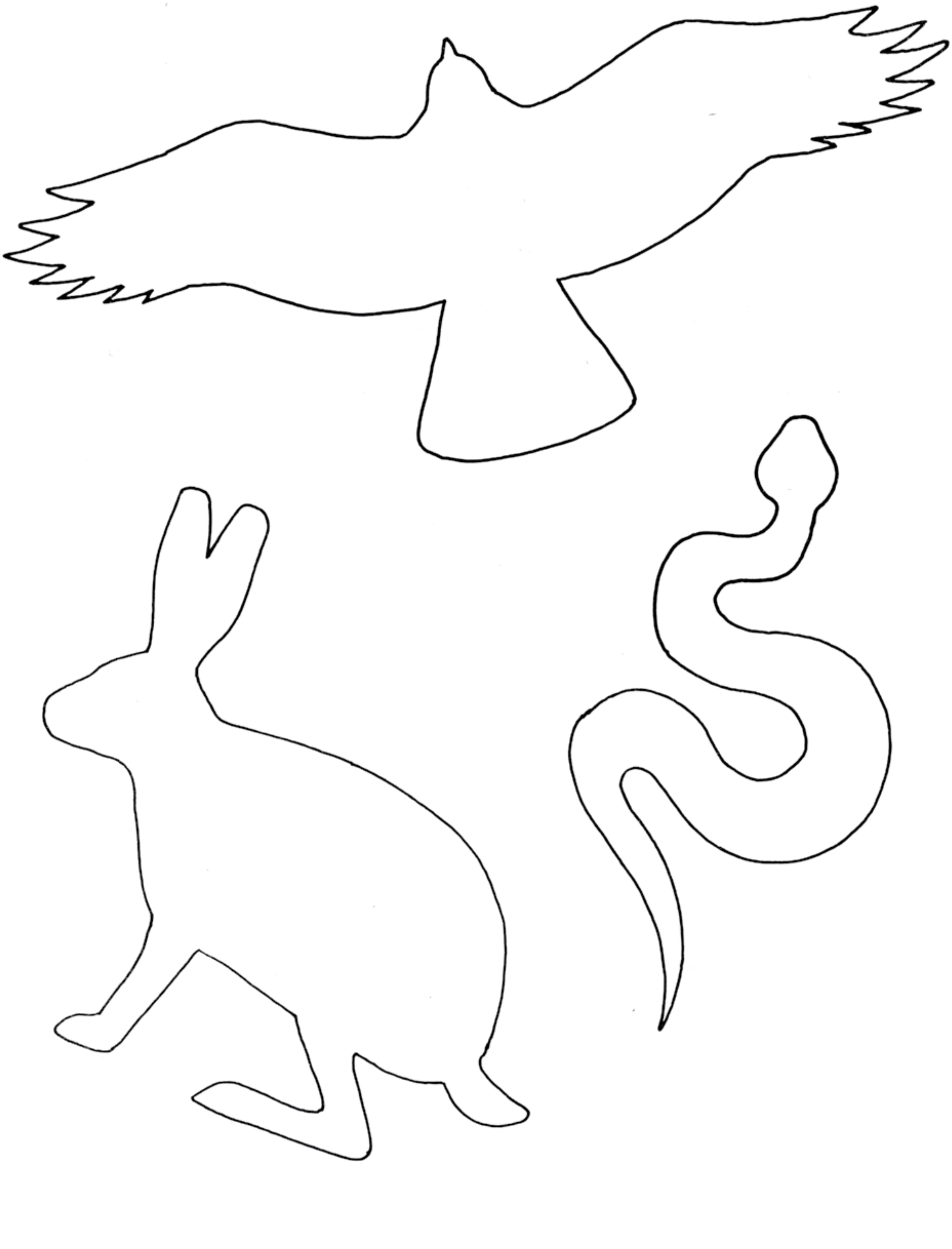


Figure 3d. Animal Shapes 2

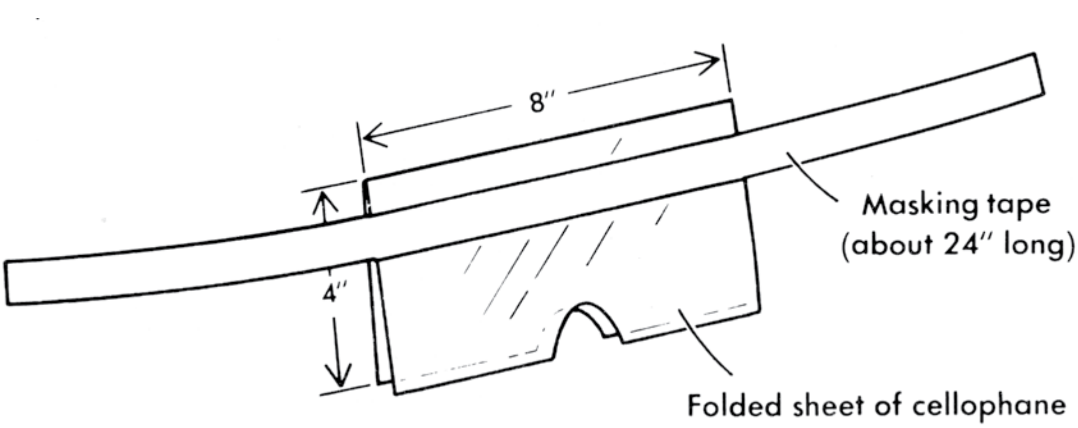


tion of camouflaged animals? Discuss ways in which students might answer these questions, leading them into the planned experiment. Prior to beginning the experiment, ask students to predict what they think will happen. This will be their working hypothesis. Not all students will have the same hypothesis and it will be helpful to list all of the ideas presented. The experiment will serve to test their hypotheses.

3. **Preparing the props:** Distribute one pattern to each student. Have the students cut out two paper animals apiece.

   After the animals are prepared, have half the students make red cellophane masks and the other half make clear cellophane masks. The masks are made by folding an 8" × 8" sheet of cellophane in half and attaching a 24" length of masking tape (see Figure 3e). A cutout for the nose may be necessary to give a good fit. A single thickness of cellophane may be used if preferred.

Figure 3e. Cellophane Mask



   The function of the clear masks is to ensure that the chief difference between the vision of the "normal-sighted" hunters and the "red-sighted" hunters is the color perceived. If the red mask restricts or distorts the vision, so also will the clear mask.

4. **Conducting the Hunt:** Divide the class into two groups. Have the first group position all the paper animals in the selected area out of sight of the second group. The animals should be placed in view in more-or-less natural poses.

After the animals are hidden, have the second group don red masks and see how many animals they can capture in ten minutes. Have the students record the number of each type of animal found. Then have the groups reverse roles. Record the results as before.

Finally, repeat the whole procedure but with the foragers wearing the clear masks. These hunts may be stopped after 5 minutes if it becomes obvious that many more animals are being found than before.

5. **Notebook entry:** Upon returning to the classroom, have the students work cooperatively to make entries in their notebooks or create a data table that can be photocopied for each student.

6. **Discussion of results:** Unless the hunting time was so long that all the animals could be located in the time allowed (even by the red-masked predators) the results should show that the prey were much less easily perceived by the predators with single-color vision; that is, by the red-masked students. Ask students if the experiment supported or refuted their hypotheses. Emphasize that if their prediction turned out to be incorrect, they did not "fail." That is the way scientists work—they test multiple hypotheses and they eliminate those that are not supported by the results of their experiments. In the discussion, relate these findings to von Frisch's experiment to determine the nature of bee vision from the introduction to this chapter.

ACTIVITY 3-1 AN EXPERIMENT ON VISION

Name:

Date:

Title of Experiment:

My Hypothesis:

Description of Experiment:

Results:

Conclusions:

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*Page numbers in **boldface** type refer to figures.*