

color of life



Educator Guide

Grade 3–Grade 5

What's Inside:

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- B. EXHIBIT MAP**
- C. KEY CONCEPTS**
- D. VOCABULARY**
- E. MUSEUM CONNECTIONS**
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CALIFORNIA
ACADEMY OF
SCIENCES

What stories does color tell?

Welcome to the *Color of Life* exhibit, which uses color as a tool to help audiences better understand the world. In the exhibit students explore how color communicates, connects, evolves, and provides insight into plant and animal diversity.

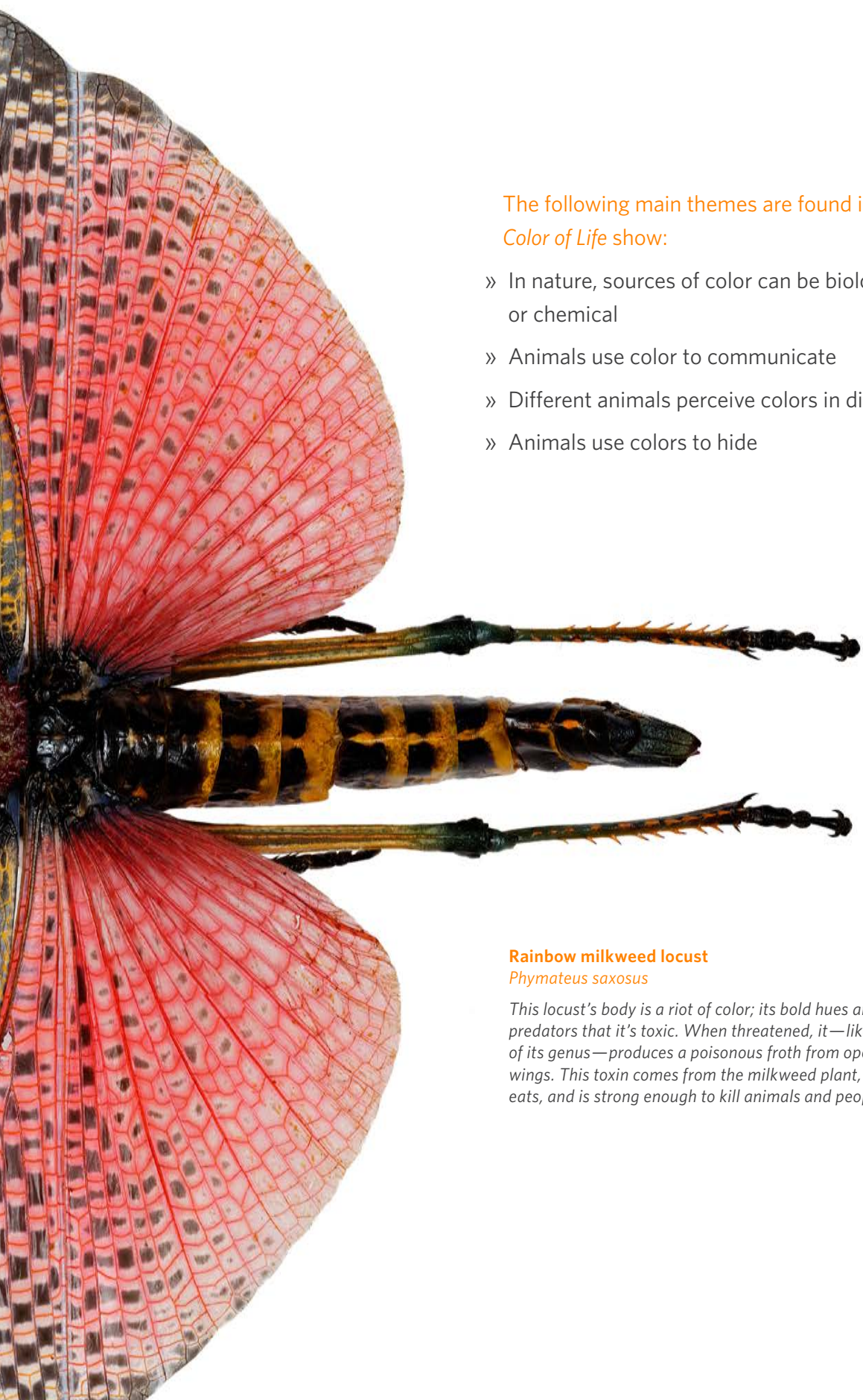
This exhibit includes opportunities for students to engage with and experience the importance of color in the natural world. From the different sources of color, to the ways that animals use color to communicate and hide, *Color of Life* is filled with interactive experiences. Through hands-on exhibits and striking visuals, students can learn about a wide range of color stories. They can get a feel for what it might be like to attract a mate with color and dance, and observe first-hand the ability of some animals to hide using camouflage. Students also have the opportunity to explore the science of how animals see, and how light and eye structure affect color perception.

The *Color of Life* exhibit is home to a range of plants and animals that exemplify some important uses of color in the natural world. Live animals in the exhibit include colorful Gouldian finches, color-changing green tree pythons, and cephalopods (octopuses and cuttlefish), who are masters of hiding in plain sight. Students will also have opportunities throughout the exhibit to learn about how scientists and communities are taking action to protect the organisms displayed and described in the exhibit.

The *Color of Life* exhibit provides a lens for understanding and preserving biodiversity in our own backyards and around the globe.



A. EXHIBIT OVERVIEW



The following main themes are found in the *Color of Life* show:

- » In nature, sources of color can be biological, structural, or chemical
- » Animals use color to communicate
- » Different animals perceive colors in different ways
- » Animals use colors to hide

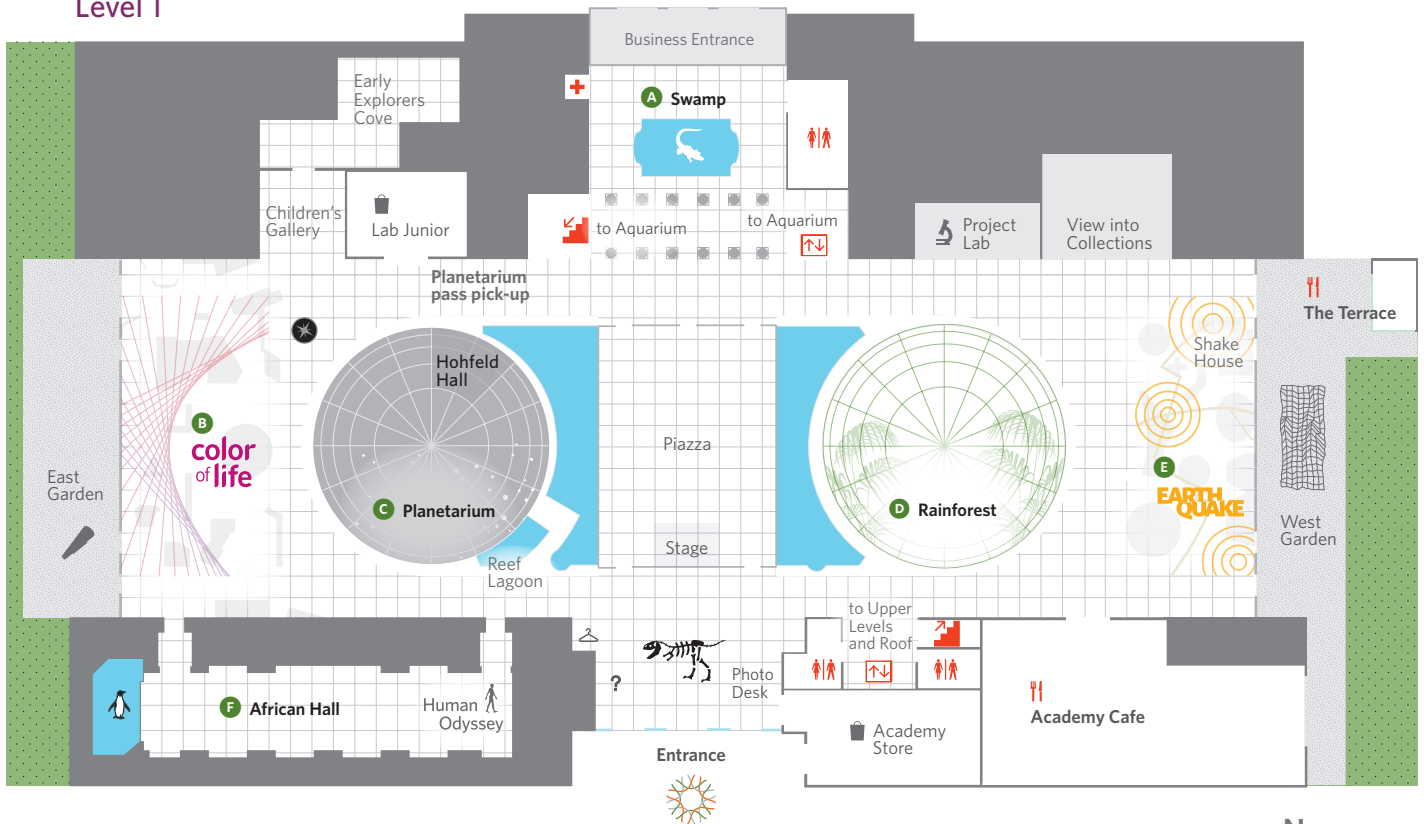
Rainbow milkweed locust

Phymateus saxosus

This locust's body is a riot of color; its bold hues are a warning to predators that it's toxic. When threatened, it—like other members of its genus—produces a poisonous froth from openings beneath its wings. This toxin comes from the milkweed plant, which the locust eats, and is strong enough to kill animals and people.

California Academy of Sciences Map

Level 1



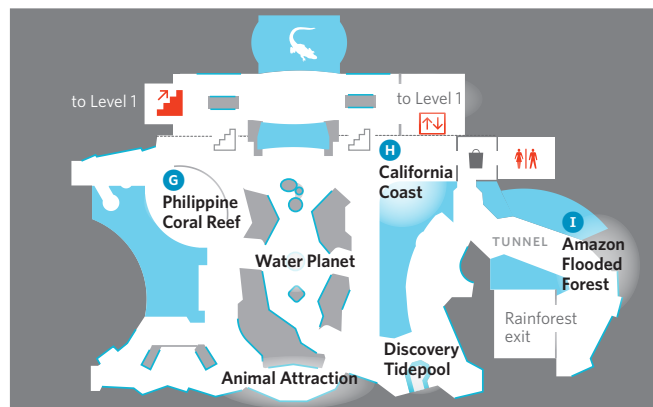
Art

The Academy is home to two permanent sculptures by renowned artist Maya Lin.

- What is Missing?**
in the East Garden (Level 1)
- Where the Land Meets the Sea**
in the West Garden (Level 1)

Architecture

Designed by acclaimed architect Renzo Piano, the Academy is the world's greenest museum. View 2.5 acres of native California plants from the Living Roof's **Observation Deck**.



Lower Level | Aquarium

Dining

Academy Cafe
The Terrace

Shopping

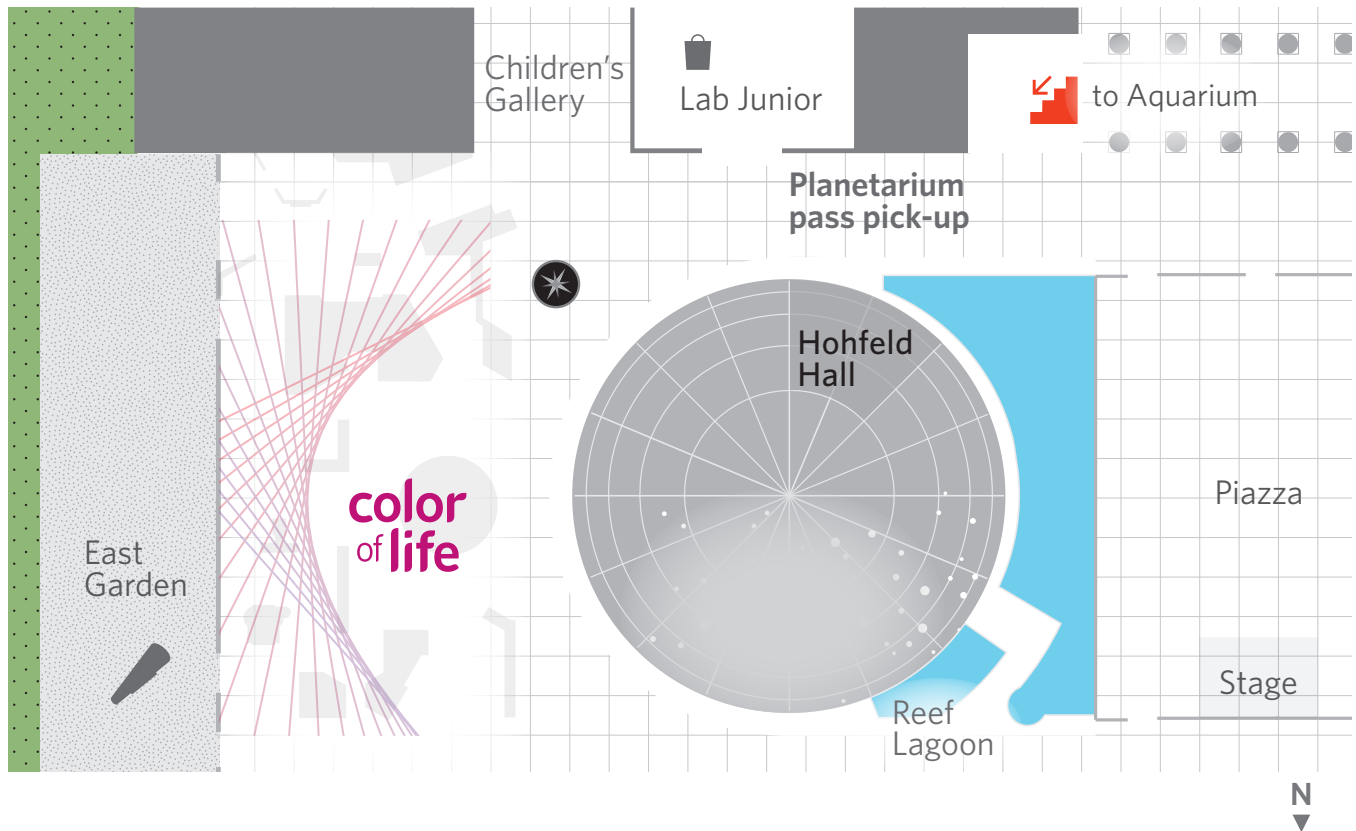
Academy Store (Level 1)
Lab Junior Store (Level 1)
Aquarium Store (Lower Level)

Play

Early Explorers Cove is a learn, play, and activity area for children ages 5 and under.



Color of Life Map



Enter the world of color. Live animals and stunning interactive environments take you over the rainbow and reveal the significant roles color plays across a spectrum of species.

Located on Level 1



Illuminating Color: Color Sources

When it comes to color, light holds the key.

Main ideas:

- » Pigments are molecules that give an object a certain color by only reflecting light of that color.
- » Animals like squid, octopuses, and cuttlefish have dynamic organs called chromatophores in their skin, which control overlapping layers of color and allow the animals to make quick color changes.
- » Iridescent butterfly wings change color when they move or when you look at them from a different angle because of tiny structures that interact with light.
- » Some animals glow, either by absorbing and releasing light (fluorescence), or making their own chemical light (bioluminescence).

Take a closer look!



Blue morpho

Morpho menelaus

The blue hues of these butterflies' iridescent wings aren't due only to a pigment, but appear when light scatters off the microscopic (nano-scale) ridges of the wings' scales. Below the tiny light-scrambling structures is a layer of pigment that absorbs some colors and allows others to scatter about. Change the angle of the light and new colors emerge.

Diet: Tree sap, fruit juices, decomposing animals

Distribution: Central and South America

Learn about some specimens in the exhibit and where their color comes from!

Hairy scorpion

Hadrurus arizonensis

Scientists find these glowing scorpions in the dark using high-energy ultraviolet (uv) light that collides with fluorescent molecules in the adult scorpion's exoskeleton. The molecules then release lower-energy light that humans can see. This adaptation for reflecting uv light could be a method of sunblock leftover from a time when these animals were more active during the day.

Diet: Insects, spiders and small vertebrates

Distribution: Southwestern United States and Northwestern Mexico



Seeing in Color: Animal Vision

Evolution has built a range of eyes, from simple to complex.

Main ideas:

- » Human eyes have evolved to have three types of light-receptors, called cones, which help us to see millions of colors. Eyes with two cones detect only thousands.
- » Some of the simplest eyes don't detect color at all, only the presence of light and where it's coming from.
- » Some animal brains are able to combine information from other senses with visual information to help them "see" more than just visible light.
- » Some organisms communicate with uv light, which humans cannot detect.

Take a closer look!

Learn about some of the live animals in the exhibit that see in interesting ways.



Green tree python

Morelia viridis

After hatching from their eggs, young green tree pythons are yellow or red, which helps them blend in as they feed along the edge of the forest. As they get older and move deeper into the forest canopy, their scales turn green. Pythons have special pit-like organs in their faces that detect infrared light as heat. Their brains process heat and visual information together to create one infrared-enhanced image. Small rodents give off body heat, allowing snakes to spot them, even at night.

Diet: Reptiles, birds, and rodents

Distribution: New Guinea, Indonesia, Australia

Carpenter bee

Xylocopa sp.

Many plants sport yellow, white, or blue flowers to grab bees' attention. That's because bees can't see red. Flower petals may also have patterns visible only in ultraviolet light—which bees can see. They follow the patterns like arrows pointing the way toward nectar. In return for this sugary treat, these pollinators spread the flowers' pollen.

Diet: Pollen and nectar

Distribution:
Worldwide



The Language of Color: Color Communicates

Color communicates within and between species, sending messages that can attract or repel.

Main ideas:

- » Males and females of a species often have different coloration, with males often exhibiting bright colors and attention-getting movements to attract a mate.
- » Color gives plants a voice by attracting animals to pollen and ripe fruit to help the plant reproduce and distribute seeds.
- » Bright colors displayed by a plant or animal can also mean “keep away,” warning others that they are poisonous, or ready for a fight.

Take a closer look!

Learn about some of the organisms discussed in the exhibit that use color to communicate.



Sweet cherry

Prunus avium

Green cherries turn red when ripe. The color transformation shouts, “Eat me!” But most seeds can’t survive the journey through the guts of just any animal. To hitch the right ride, many fruits are color-coded to attract a specific herbivore, from birds to bats to rodents. Birds and squirrels readily eat these cherries, and have helped to spread the nonnative species throughout North America.

Native range: Europe and Asia

Coastal peacock spider

Maratus speciosus

Each species of these Australian jumping spiders has a unique dance, which helps the females find the right mate. A male coastal peacock spider reveals the bright orange hairs bordering its abdomen during its high-energy dance. Although only one-fifth of an inch long, peacock spiders can jump up to 40 times their body length!

Diet: Juvenile crickets and other insects

Distribution: Western Australia



© Jürgen Otto



Hide and Sneak: Color Conceals

Living creatures use color, pattern, texture, and behavior as strategies to hide.

Main ideas:

- » Prey have evolved colors and patterns to hide from predators, while predators evolved similar camouflage to ambush unsuspecting prey
- » Not all animals camouflage by matching their surrounding perfectly; some blend in with bold patterns that trick the eye
- » Some animals change color to blend in—some within seconds, others from season to season, and others as they mature and move to new habitats
- » Aquatic animals often have two-toned coloration, which hides them from predators above and below the water.

Take a closer look!

Learn about some animals discussed in the exhibit that use camouflage.



African penguin

Spheniscus demersus

These flightless birds adapted for water and warm weather use a form of camouflage called countershading to hide from predators in open expanses of water that may not seem to offer many hiding places. Underwater predators have a hard time seeing their white bellies against the bright sky, and their black backs hide them from predators looking down into the water.

Diet: Fish and marine invertebrates

Distribution: Southern Africa

Giant Malaysian leaf insect

Phyllium giganteum

Flora or fauna? It's hard to tell when an animal is as well camouflaged as this insect. These master mimics even waver as they walk, like leaves blowing in the wind. Males of this species are even more rare and difficult to find. Females usually reproduce without mating and lay unfertilized eggs that grow into more females.

Diet: Plant leaves, including oak and bramble

Distribution: Southeast Asia to Australia



Exhibit Highlights



Color Visualizer

Experience color in new ways.

Sky blue. Blood red. Bright yellow. Which colors calm you? Which scare you? Which grab your attention? Inside of the Visualizer, pluck a string to discover nature's vibrant language. Each time you do, a new story about color will appear. You can even pluck multiple strings at the same time to blend colors and explore more stories. Take a stroll around the outside of the Visualizer to learn more about the physics of light and color.



Colors of Love

Ready to dance?

During mating season, a male tries to look his best. His colorful feathers or lively displays showcase his worth to nearby females. But this showy behavior comes at a cost; attracting attention can increase the risk of a predator's attack. Only the healthiest males can hope to compete. In this interactive exhibit, visitors are challenged to move to the music and match the mating dance moves of the coastal peacock spider, lesser bird-of-paradise, and golden-headed manakin.



C. KEY CONCEPTS



Bee Vision

What does the bee see?

Explore a meadow of wild flowers first with your own vision, then from a bee's perspective. Bees have eyes that have evolved to detect colors of light that are undetectable to human eyes. What a bee sees might surprise you!



Magnificent Magnification

What can you discover by looking closer?

Lean in and take a good look. You'll uncover new features... and mysteries. Up close, even organisms that appear simple can be surprisingly complex. Use an interactive touch screen to zoom in and explore organisms at micro scale!



Related to *Color of Life*

adaptation	a behavior or physical characteristic that allows an organism to survive or reproduce in its environment
biodiversity	the variety of plants, animals and other organisms in a system or area
camouflage	colors or patterns that help animals blend in with their surroundings, making it harder for predators (or prey) to see them
cephalopod	a class of marine mollusks that have a prominent head and a set of at least 8 arms and/or tentacles; members include octopuses, squid, cuttlefish, and nautiloids
compound eye	eyes made up of many tiny units that gather light from slightly different directions, which the brain pieces together into a single image
ecosystem	a community of living organisms and the physical environment with which they interact
habitat	the place or type of place where an organism naturally lives and grows
invertebrate	an animal that does not have a backbone, such as a jellyfish or a sea star



D. VOCABULARY

iridescence	an optical phenomenon where certain surfaces appear to change color as the viewer's angle of observation changes
melanin	the main pigment that colors mammal fur and human skin
pigment	material that causes color in plants and animals
pollination	in plants, the process by which pollen is transferred from the male reproductive organs to the female reproductive organs to form seeds
predator	an animal that hunts other animals
prey	an animal hunted or caught for food
reflection (of light)	when light bounces off of a surface
refraction (of light)	the bending of light that happens when it travels from one medium to another, for example from air to water



Science Behind the Scenes

Caring for cephalopods

» What is it like to work with an octopus?

“Taking care of cephalopods is a little bit more complicated than just feeding... because they are very smart,” says **Aquarium Biologist Marisa Avila**. Part of Avila’s job is to provide enrichment to keep them from getting bored in captivity. The group of animals called cephalopods includes species of octopuses, cuttlefish, and squid, among others. For species of cuttlefish, enrichment might mean simply providing them with live food, a varied diet, and a naturalistic habitat. For animals like the day octopus (*Octopus cyanea*), biologists challenge them in more creative ways, including giving them their food in closed jars or other containers that the animal needs to open. To help them get used to people and provide enrichment, Avila stays with the octopus while they open the jar and eat. “They like to play,” says Avila. How does an octopus play? According to Avila, “You just let them touch your arm.” Octopuses are tactile and explore with touch. Says Avila, “They are tasting you with their suckers as they’re touching you. They also like splashing water over their arms, but it’s really about them exploring you.”

In addition to being playful and curious, other evidence of cephalopods’ complicated brains is their ability to camouflage and communicate with color. “They are capable of being extremely cryptic,” says **Assistant Curator Charles Delbeek**.

By cryptic, Delbeek means that these animals are very good at concealing themselves. This is because many cephalopods have specialized cells in their skin called chromatophores. These cells contain a sac of pigments, and the sac can expand so that the pigment is more visible, or contract to hide the pigment. Says Delbeek, “they can control all of these cells all over their body, so they can create patterns that help them mimic their background.” Many cephalopods can also change the texture of their skin to further change their appearance. Some appear to mimic other animals, or even algae-covered rocks.

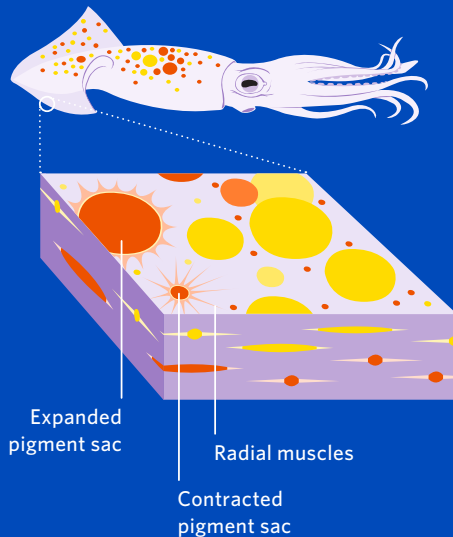
Cephalopods use color and pattern for communicating as well as hiding. They are capable of very fine control over their appearance, allowing them to pulsate patterns across their bodies, and even display different colors and patterns across the two halves of their bodies. “That’s another reason why we know that their brains are so complex,” says Avila.

In addition to keeping cephalopods from getting bored, a challenge for aquarium scientists keeping octopuses and cuttlefish on display is cephalopods’ short natural lifespan, which ranges from just a few months to a few years for some octopus species. Academy biologists have successfully bred dwarf cuttlefish (*Sepia bandensis*), but many of the cephalopods are extremely difficult to breed, and



E. MUSEUM CONNECTIONS

Each chromatophore is made up of a sac of colored pigment attached to muscles and nerves. Muscles tug on the elastic pigment sac, and the spot of color grows as the sac stretches into a thin disc. When the muscles relax, the pigment sac retracts and the spot of color shrinks.

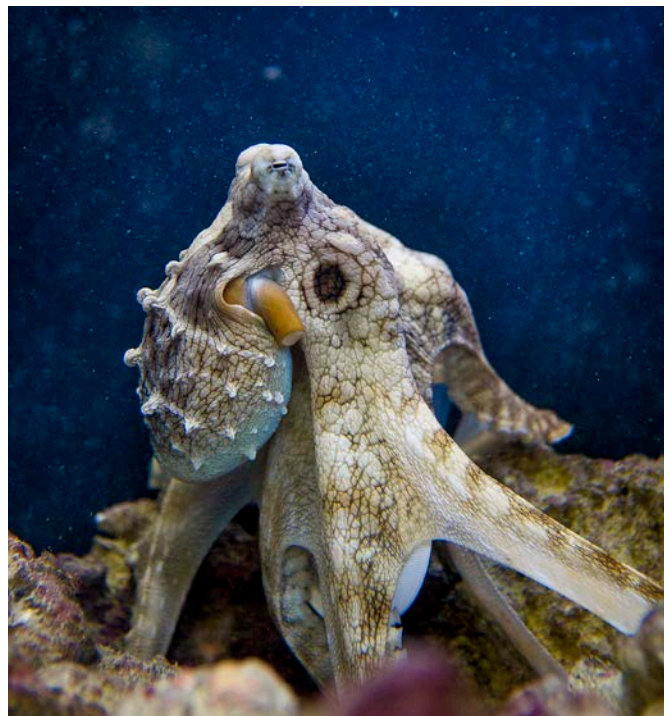


Color-changing skin helps squid, octopuses, and cuttlefish express themselves to potential mates or rivals—and, when necessary, disappear in a flash.



Dynamic organs in their skin, called chromatophores, control overlapping layers of color: reds, yellows, oranges, blacks, and browns. And iridescent cells, located deeper in the skin, add even more variation, helping these animals communicate using their whole bodies.

animals on display are often captured in the wild and brought to the Academy. A current research focus of the aquarium staff is to successfully breed other cephalopod species with the goal of having more sustainable aquarium populations. “One of the AZA’s (Association of Zoos and Aquariums) main goals is sustainability, so it’s about sustaining our collections,” says Delbeek. “Our long term goal is that institutions are breeding their own animals so that we’re not taking from the wild.”



Specimen Spotlight

Gouldian finch

Erythrura gouldiae

You might notice that Gouldian finches seem to show a lot of variety in their color combinations. Yes, these birds are all the same species. These distinct colorations, called color polymorphisms, or “morphs,” happen naturally. The most obvious variations are the birds’ head colors, which can be yellow/orange, red, or black. Combined with their color-blocked bodies that include green, purple, yellow, and white, these finches are strikingly colorful. But there is more to these colors than meets the eye.

For Gouldian finches, different head colors are linked to different behavioral and hormonal traits, and these traits seem to influence how common each morph is in the population. In the wild Australian population, the most common color of head plumage is black. Red-headed morphs seem to be less common because they are so aggressive. Red males spend most of their time fighting other males over nesting territory. This high-stress behavior and relatively high testosterone levels have an impact on red morphs, decreasing their



David Liittschwager © California Academy of Sciences





overall numbers in the wild. Black morphs generally lead lower-stress lives, resulting in a longer lifespan. These less aggressive morphs share nesting and parenting duties across sexes, which may also contribute to their prominence in the population, despite losing nesting sites to fighting red morphs. Yellow morphs are the most rare in the wild and are the most peaceful, avoiding all aggressive interaction with red and black.

Female Gouldian finches choose to breed with males with matching head plumage. These pairings are a better genetic match and result in a lower mortality rate. Although the females have corresponding head plumage (black, red, and yellow), their overall colors are paler than their male counterparts.

And that's not the last of the Gouldian Finches' interesting color stories. These birds also exhibit ontogenic color change, or colors that change over the lifespan of the animal. In the case of these finches, young birds are gray and olive green, and it's not until the birds are mature that they exhibit the striking, color-block pattern.

Unfortunately, the population of these birds in the savannahs of Australia has dwindled to just 2500 individuals, due to threats from invasive species, disease, and destruction of their natural habitat. In addition to conservation efforts in their natural habitat, captive breeding efforts are designed to preserve this species by maintaining a population and educating the public. What role do you think exhibiting low-population animals like the Gouldian finch has in preservation and conservation?



Related Exhibits

Visit our other exhibits for more examples of the role color plays in biodiversity.



African Hall

Explore the wilds of Africa from its hot and dry deserts to high elevation rainforests and discover the adaptations plants and animals have for surviving in harsh conditions when water is scarce. African Hall offers an in-depth look into Africa's diverse and changing ecosystems showcasing iconic animals including lions and zebras. Five living dioramas include pancake tortoises, chameleons and the watery world of an entire colony of African penguins.



Rainforests of the World

Expand your exploration of unique ecosystems in Rainforests of the World. Your journey begins on the forest floor and takes you through the different layers of the rainforest. Explore the diversity of plants and animals found in tropical rainforests around the world. Life in the rainforest has adapted to the presence of abundant water, long daylight hours, and seasonal flooding.





Philippine Coral Reef

Explore a tropical coral reef without getting wet in the stunning Philippine Coral Reef exhibit which focuses on one of the world's most diverse marine ecosystems. The 25-foot deep, 212,000 gallon tank offers spectacular underwater views of reef algae and animals and focuses on their unique adaptations and ecological interactions.



Water Planet

Learn how aquatic animals are adapted to survive in their environment as students explore the essential connections between life and water. Learn about a variety of animals that live in and without water. Learn how each animal has unique adaptations for reproducing, moving, feeding, sensing, and defending themselves in their environments. Through interactive stations in the exhibit, students can also explore the different properties of water found on Earth—fresh water, salt water, hot and cold water, surface and subsurface water, frozen, liquid, and vapor forms, and how organisms are adapted to each.



Suggested Activities to Download

Download these activities from our website to enrich your field trip experience.

- » **At-Academy Activity:** Light in Air and Water Scavenger Hunt
(suggested grades 3–8)

www.calacademy.org/educators/lesson-plans/light-in-air-and-water

- » **Anytime Activity:** Flowers Seeking Pollinators
(suggested grades 3–7)

www.calacademy.org/educators/lesson-plans/flowers-seeking-pollinators

- » **Anytime Activity:** Habitat Adaptation Matchup
(suggested grades 1–3)

www.calacademy.org/educators/lesson-plans/habitat-adaptation-matchup

**Be sure to review our
teacher resources online!**

[www.calacademy.org/
educators/teaching-resources](http://www.calacademy.org/educators/teaching-resources)

- » **Pre-, during-, and post
visit activities:** short, lively
activities to focus your
class trip.
- » **Anytime lesson plans:** Full-
period lessons to integrate
into your yearly curriculum.



Next Generation Science Standards

Crosscutting Concepts

Patterns

Cause and effect

Stability and change

Structure and function

Disciplinary Core Ideas

GRADE 3

» Life Science

LS1.B: Growth and Development of Organisms

Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.

LS3.A: Inheritance of Traits

Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment.

LS3.B: Variation of Traits

Different organisms vary in how they look and function because they have different inherited information. The environment also affects the traits that an organism develops.

LS4.B: Natural Selection

Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing.

LS4.C: Adaptation

For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

LS4.D: Biodiversity and Humans

Populations live in a variety of habitats, and change in those habitats affects the organisms living there.

GRADE 4

» Life Science

LS1.A: Structure and Function

Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

LS1.D: Information Processing

Different sense receptors are specialized for particular kinds of information, which may be then processed by the animal's brain.

» Physical Science

PS4.B: Electromagnetic Radiation

An object can be seen when light reflected from its surface enters the eyes.

GRADE 5

» Life Science

LS1.C: Organization for Matter and Energy Flow in Organisms

Plants acquire their material for growth chiefly from air and water.

» Earth and Space Science

ESS3.C: Human Impacts on Earth Systems

Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, and air. But individuals and communities are doing things to help protect Earth's resources and environments.

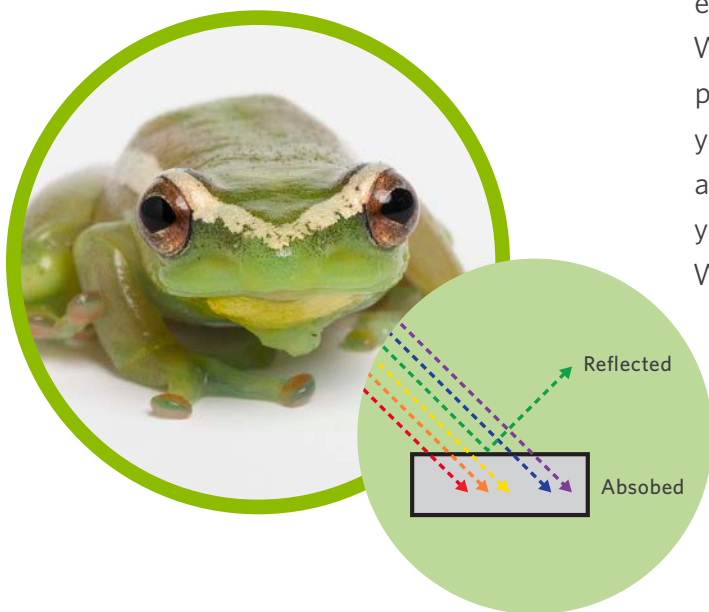


Guiding Questions and Answers

Use these questions to get students thinking about the *Color of Life* exhibit.

» How is light related to sight?

Look around the room. Any object you see is visible to you because light is bouncing off of that object and into your eye. At that point, your brain and eyes work together to understand what you're seeing. If an object doesn't give off its own light, it can only be seen if there is a source of light that then bounces off of the object. If there is no light source (that could be the sun, lamps, overhead lights, a flashlight, a candle) then you would not be able to see these objects, because there would be no light bouncing off of them. What light sources do you observe right now? What are some objects (or animals!) that you can think of that give off their own light?



» What are the different ways that animals use color to communicate? How do humans use color to communicate?

Many animals use color to attract a mate. Often males of a species have adapted to have flashy coloring meant to communicate to the female that they would make a good mate. And once they have found a mate, some animals use color to warn other males to stay away! Color may be used as a warning to protect animals from predators—some brightly-colored animals are sending the message “I taste bad!” so that they won’t get eaten! Humans use color to communicate as well, but sometimes colors mean different things in different parts of the world. There are some important color messages many of us have agreed on, for example red means stop and green means go. We use cosmetics to color our hair and other parts of our bodies to look more attractive, younger or more healthy. Color is also used in advertisements to attract our attention. Can you think of other ways that we use color? What colors have meaning to you?

Guiding Questions and Answers

- » **What do you think might happen if an animal that is highly camouflaged is moved to a new environment? What if this were a prey animal? What if it were a predator?**

Some animal species have adapted over very long periods of time (millions of years) to blend into their environment. This ability to camouflage allows prey animals to survive by hiding from predators. If an animal adapted to blend with the lush green of the tropical forest was suddenly moved to drier environment with fewer plants and lighter colors, the animal would stand out—a bright green against a light background. Not being able to hide from predators would mean that it would be more likely to be eaten and less likely to survive. Camouflage also allows some predators to sneak up on their prey. If they find themselves in an environment where they are easy to spot, they would have a hard time catching the food that they need to survive.

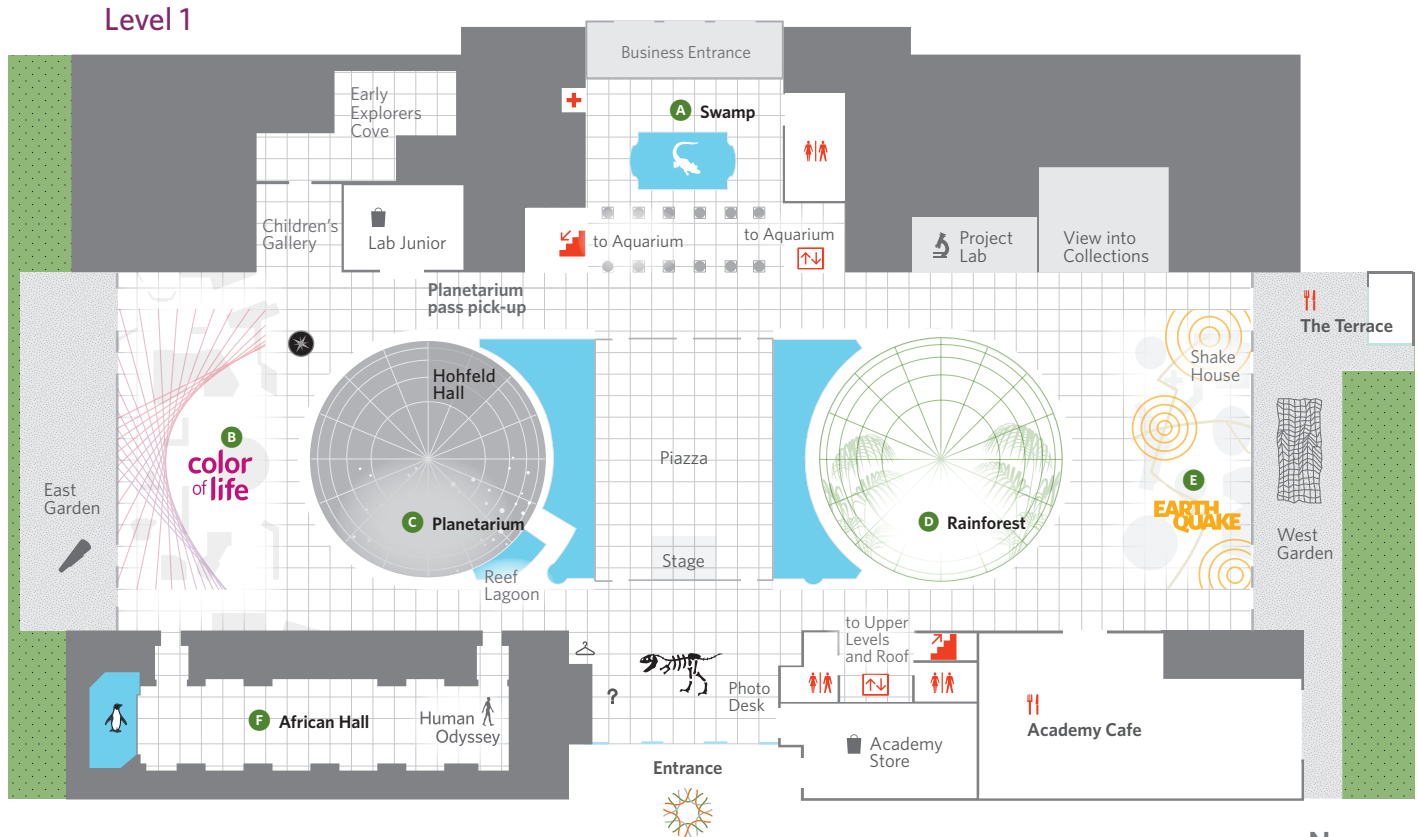
- » **How do plants communicate with color?**

Since plants are pretty much stuck in one place, they have evolved various ways of sending signals to other organisms. The color of some plants attracts pollinators. Other plants even mimic the colors of pollinator females to attract males. Plants have also evolved to advertise ripe fruits to animals that will eat them and scatter the seeds, spreading the plant to new locations. Sometimes a plant's colors tell animals to stay away, such as brightly colored foliage to advertise that they are toxic and not good to eat!

Prey have evolved colors and patterns to hide from predators, while predators evolved similar camouflage to ambush unsuspecting prey.



California Academy of Sciences Map



Art

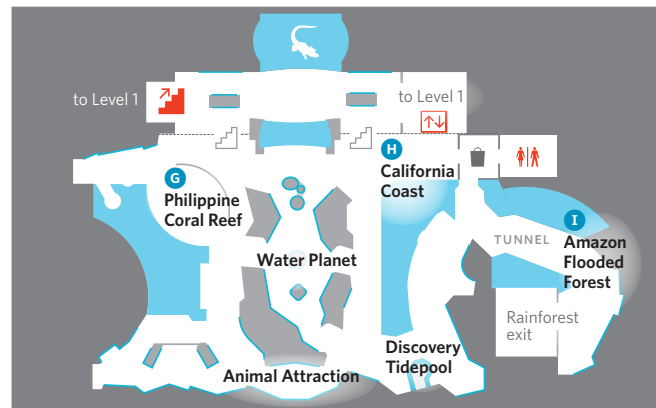
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