frontiers | Frontiers for Young Minds

BIODIVERSITY
Published: 12 March 2024
doi: 10.3389/frym.2024.1270515

BRIGHT COLORS: EAT ME AT YOUR OWN RISK

Retna Arun*, Hannah Gurholt*, Udita Bansal and Swanne P. Gordon

Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY, United States

YOUNG REVIEWERS:

SIA
AGE: 10

VINCI
AGE: 11

WOO
AGE: 11

Some poisonous animals use bright coloration to protect themselves from other animals that want to eat them. These bright colors are also called warning colors. Frogs, snakes, butterflies, skunks, and more all use warning coloration. But how do the animals get their bright colors and toxic poisons? Warning colors can be passed down to certain animals from their parents, and other animals get them from the foods they eat. Just because some animals have bright colors does not always mean they are toxic. Some animals, also known as mimics, copy the colors of toxic animals so they can protect themselves from being eaten. We will explore how poisonous animals show their true colors, and how non-poisonous animals that display the same signals can also be protected from predators. You may notice similar connections between color and warning signals all around you!

HOW DO ANIMALS PROTECT THEMSELVES FROM PREDATORS?

Have you ever wondered how animals protect themselves from being eaten by other animals? There are a couple of ways that animals can protect themselves from predators. Some animals hide from predators

by blending in with plants, tree bark, and leaves around them, like the forest-dwelling rocket frogs and leaf-tailed geckos. Arctic foxes also blend in with the white snow of their arctic tundra habitats (Figure 1A). We call this **cryptic coloration**, or camouflage.

CRYPTIC COLORATION

A way that some animals hide from predators by blending in with their surroundings. Also known as camouflage.

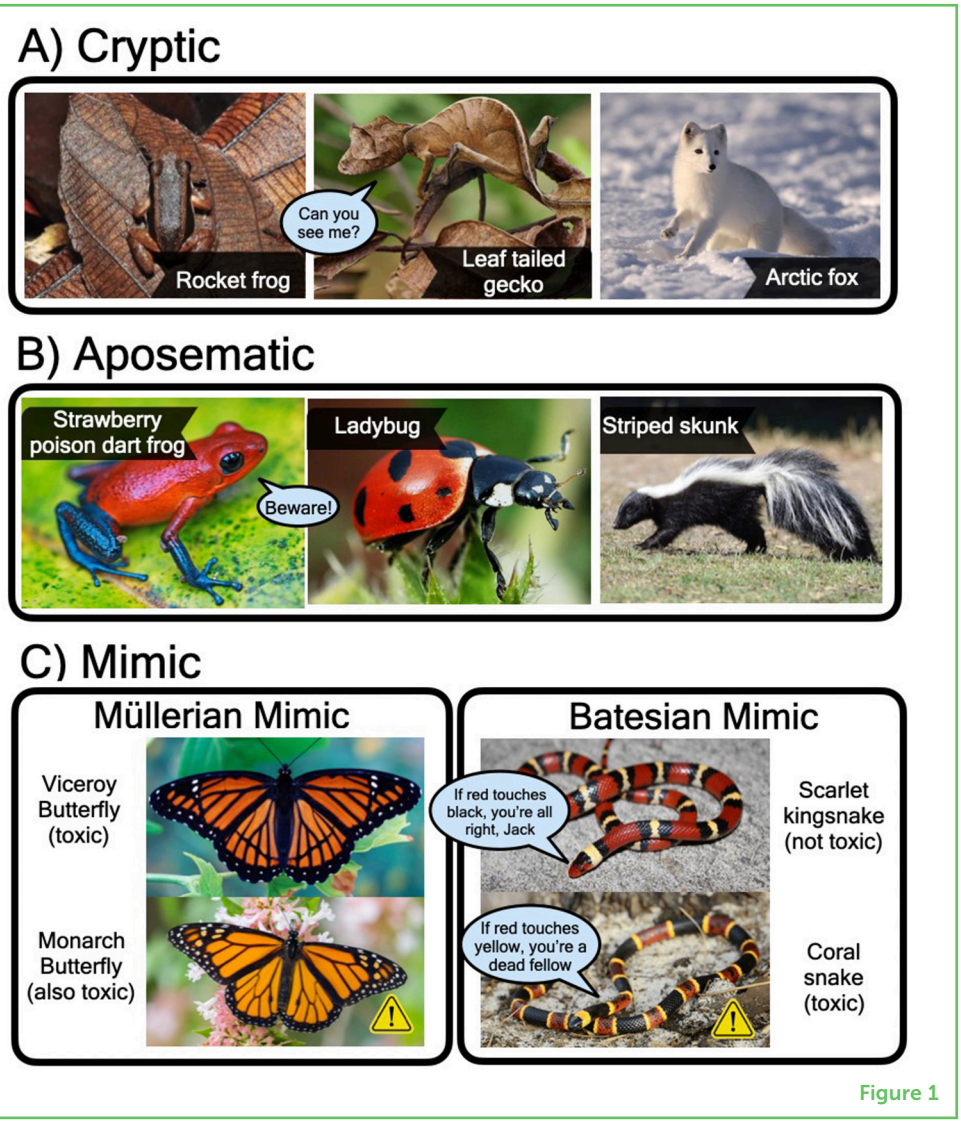

Figure 1

(A) Cryptic animals that camouflage themselves in their environments include the rocket frog, leaf-tailed gecko, and the arctic fox. **(B)** Aposematic animals that show warning signals include the strawberry poison dart frog, ladybug, and striped skunk. **(C)** The viceroy butterfly and monarch butterfly both are toxic to predators, so they are examples of Müllerian mimics. The coral snake is toxic but its mimic, the scarlet kingsnake, is not. This is an example of a Batesian mimic (Copyright © 2023 Google Images).

Other animals are bright and colorful. These animals are often red, yellow, or orange, which helps them stand out from their green or brown surroundings and makes them easy for predators to spot. That seems to make no sense, right? Why would animals want to stand out and risk being eaten? One reason for bright colors is to show predators that they are dangerous to eat! This strategy is called **aposematism** [1] (Figure 1B).

APOSEMATISM

A defense strategy used against predators, in which a warning signal is paired with a defense mechanism.

WARNING! I AM DANGEROUS!

There are several ways that animals can show predators that they are dangerous to eat. First, the animals must have a primary warning signal

that predators can either *see* (think of the bright colors on a monarch butterfly's wings), *smell* (think of a skunk's spray), or *hear* (think of a rattlesnake's rattle). Next, the animals will have a secondary defense to signal their distastefulness to predators, usually poisonous chemicals called **toxins**.

TOXIN

A substance that is poisonous and can make animals that eat it feel sick or die.

This article will focus on aposematic coloration in animals, which means that color is used as the warning signal. The bright warning colors act as a sign telling predators that the animals have a secondary defense, such as being toxic. This means that these colorful animals can make predators feel sick or die if they are eaten. If a predator survives, it learns to avoid these brightly colored animals in the future. How do animals get their warning colors? As we describe below, they can get their colors from their parents and/or they can get their colors from the foods they eat.

APOSEMATISM FROM PARENTS

Just like humans inherit characteristics like the color of our eyes, skin, and hair from our parents, animals can inherit colors from *their* parents. Some aposematic animals are brightly colored because their parents passed down their bright colors to them. Coral snakes have red, black, and yellow stripes on their bodies, which they inherit from their parents (Figure 1C). They have venom and their bites can be deadly to predators and to humans. Some mammals, like the skunk, also get their warning coloration from their parents. Predators know to avoid skunks and their smelly spray because of their black-and-white striped coloration [2].

YOU ARE WHAT YOU EAT: APOSEMATISM FROM FOOD (AND PARENTS)

Some animals also have warning colors because of what they eat (in combination with what they inherit from their parents). Their foods can give them a bright warning color *and* provide toxins that make them poisonous to predators. For example, many animals get their bright colors from **carotenoids** in their foods. Carotenoids are non-toxic yellow, orange, or red colors found in many of the foods that you eat, like carrots, bell peppers, and beetroots. The brightly colored tropical poison dart frog (Figure 1B) gets its color from its parents *and* from its diet of ants, beetles, and millipedes—which contain carotenoids. In addition to carotenoids, ants and other animals in the poison dart frog's diet contain toxins that the frog can use to make itself toxic. Ever heard your parents say you will turn into a donut if you eat too many donuts? That is kind of what happens with the poison dart frog's color and toxicity. If these animals eat more carotenoids or toxins, they become more brightly colored and more toxic.

CAROTENOID

Yellow, orange, or red colors found in vegetables, monarch butterflies, aphids, and ladybugs. They are non-toxic.

Carotenoids are also found in weedy plants called milkweeds, which are eaten by the beautiful monarch butterfly. Carotenoids help give monarch butterflies their bright orange wings [3]. Monarch butterflies also eat and store a poisonous chemical called a **cardenolide** from milkweed. While cardenolides are poisonous to the monarch's predators, monarchs are protected by a gene they inherit from their parents, which helps them reduce the negative effects of cardenolides. Cardenolides are not delivered in spray, like a skunk, or by a bite, like a snake. Instead, monarch butterflies store toxic cardenolides throughout their bodies, so when they are eaten, the predator also eats these toxins.

CARDENOLIDE

Poisonous chemical in the milkweed plant that monarch butterflies store to protect themselves from predators.

Another animal that gets its warning color from carotenoids in its food is the bright aphid. Aphids are yellow or orange sap-sucking bugs that also eat milkweed. They get their color from the milkweed and from their parents. Like monarchs, they can also store cardenolides from the milkweed to make themselves toxic. One predator of the aphid has grown to use the toxins from its prey: the beautiful ladybug. Ladybugs are beetles known for their red wings with black spots. They get their color from their parents and their carotenoid-containing diet of aphids. They get their toxicity from the cardenolides stored in the aphids they eat. Eating more aphids during their larval (immature) stage increases the toxins in their bodies and makes their bodies more red.

WHAT HAPPENS WHEN A PREDATOR EATS A TOXIC ANIMAL?

If a bird eats a monarch butterfly, the toxic cardenolides will cause the bird to throw up (Figure 2), since birds do not have protection from these toxins [4]. After the bad experience, the bird learns to avoid eating things that look like the monarch butterfly, including other orange insects. This is an example of an experience called **taste aversion**. Humans can experience taste aversion, too! Just like birds, after we get sick from eating a certain food, we typically stay away from that food for a while, out of fear that it might make us sick again.

TASTE AVERSION

When a predator has a bad experience eating an animal and learns to avoid eating that animal in the future.

ARE BRIGHT ANIMALS ALWAYS TOXIC?

If an animal shows a warning color and is toxic, that means the animal is honestly signaling its toxicity to predators. Sometimes toxic species will copy each other and present the same warning signal, so that predators learn to avoid both species. For example, in Figure 1C, you may have noticed how similar the viceroy butterfly and monarch butterfly look. These two poisonous species have grown to resemble one another. This is known as **Müllerian mimicry**.

MÜLLERIAN MIMIC

A poisonous animal that copies another's warning signal, so that predators learn to avoid both animals.

Figure 2

If a blue jay gets sick after eating a monarch butterfly, it will learn to associate the colors of the monarch with feeling sick, and will not try to eat monarchs (or their mimics) again in the future. This is called taste aversion (Image was drawn by Weixin Du; Original image captured by Lincoln Brower and published in Scientific American in 1969).

Figure 2

BATESIAN MIMIC

A non-poisonous that animal copies a poisonous animal's warning signal, so that predators will avoid it, too.

Not every animal that shows a warning color is toxic, though—some animals have a warning color but are not toxic. Certain non-toxic animals mimic the warning colorations of other animals that *are* toxic. You may call that cheating! These are called **Batesian mimics**. Unlike Müllerian mimics, which are *honest* about their toxicity, Batesian mimics are *dishonest*. These animals take advantage of predators that avoid the bright colors they have learned to mean danger. Batesian mimics are protected because they look like true aposematic animals. One example is the scarlet kingsnake, which is a mimic of the coral snake in the United States (Figure 1C). These snakes look so similar that Americans have created a rhyme to help people tell the difference between them: "If red touches yellow, you are a dead fellow; if red touches black, you are all right, Jack". This means that snakes with red and yellow stripes touching are dangerous! [5] Be careful though, because this pattern does not hold for all coral snakes outside of the United States.

APOSEMATISM IS ALL AROUND YOU

In summary, aposematism is a way that dangerous prey draw attention to themselves to warn predators not to eat them. If you look outside, you may recognize examples of aposematism all around you, such as ladybugs, bees, and wasps. There are also examples in your own life! Warning road signs are often neon yellow or red, to make the danger clear to drivers. Or think about spicy chips, which are often more boldly colored, along with their packaging (Figure 3). What other examples can you think of? Think deeply about the colors you see all around you and what they are telling you. Be honest, and do not be afraid to be bold and show a little color!

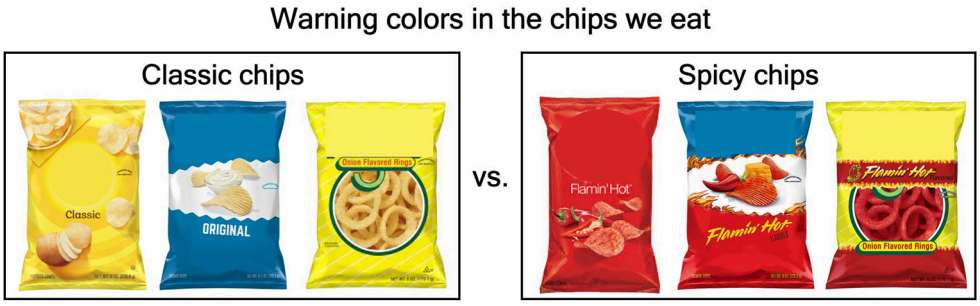

Figure 3

Colors can serve as warning signs in our daily lives, too. There are even aposematic colors in the foods we eat. For example, spicy chips usually have more bright red colors (both in the chips and the packaging) than classic chips do (Copyright © 2023 Google Images).

ACKNOWLEDGMENTS

We would like to thank Weixin Du for drawing Figure 2. Thank you to Amaya López Gordon and Monique Pipkin for providing feedback on each of the drafts.

REFERENCES

1. Rojas, B., Valkonen, J., and Nokelainen, O. 2015. Aposematism. *Curr. Biol.* 25:R350–R351. doi: 10.1016/j.cub.2015.02.015
2. Stankowich, T., Caro, T., and Cox, M. 2011. Bold coloration and the evolution of aposematism in terrestrial carnivores. *Evolution* 65:3090–3099. doi: 10.1111/j.1558-5646.2011.01334.x
3. Davis, A. K., Cope, N., Smith, A., and Solensky, M. J. 2007. Wing color predicts future mating success in male monarch butterflies. *Ann. Entomol. Soc. Am.* 100:339–344. doi: 10.1603/0013-8746(2007)100339:WCPFMS2.0.CO;2
4. Brower, L. P. 1969. Ecological chemistry. *Sci. Am.* 220:22–29. doi: 10.1038/scientificamerican0269-22
5. Callaway, E. 2014. Snakes mimic extinct species to avoid predators. *Nature.* doi: 10.1038/nature.2014.15397

SUBMITTED: 31 July 2023; **ACCEPTED:** 28 February 2024;
PUBLISHED ONLINE: 12 March 2024.

EDITOR: Didone Frigerio, University of Vienna, Austria

SCIENCE MENTORS: Manjusha Verma and Maria Olivia Casanueva

CITATION: Arun R, Gurholt H, Bansal U and Gordon SP (2024) Bright Colors: Eat Me at Your Own Risk. Front. Young Minds 12:1270515. doi: 10.3389/frym.2024.1270515

YOUNG REVIEWERS

SIA, AGE: 10
Sia is a bubbly, active girl, has won Olympiad medals in English and Science, and is a creative painter. She is very talkative and a very keen observer of her surroundings. She enjoys learning swimming and listening to music. Sia reads a lot of books and some of her favorite authors are Roald Dahl and Sudha Murthy. She also enjoys paying online games with her school friends.

VINCI, AGE: 11
Vinci is attending a private school in Cambridge, UK. He is very interested in science, especially in paleontology.

WOO, AGE: 11
Woo is attending a private school in Cambridge, UK. He is very interested in science, especially in chemistry.

AUTHORS

RETNA ARUN
My name is Retna Arun. I am an undergraduate student studying biological sciences at Cornell University. In my position as a research assistant, I help study the effects of artificial light at night on monarch butterflies. I am interested in how animals evolve different patterns, structures, and colors. *rsa95@cornell.edu

HANNAH GURHOLT
My name is Hannah Gurholt. I am a Ph.D. student in the Department of Ecology & Evolutionary Biology at Cornell University. I study how artificial light at night impacts how butterflies develop, move, and behave. *hg459@cornell.edu

UDITA BANSAL
I am from India. I am a Ph.D. student at Cornell University and a National Geographic Explorer. I am interested in everything to do with color! The ways animals use color to communicate with each other, whether it is anger, attraction, or avoiding being

eaten by predators is fascinating to me. I have studied a variety of animals including tigers, but my favorites are reptiles!

SWANNE P. GORDON

Swanne Gordon is an assistant professor of ecology and evolutionary biology at Cornell University. Her research surrounds important questions such as: why is there diversity in nature and how is it maintained? When not at work, she likes to read, go on long walks, and spend time with her two amazing children Amaya and Kai.