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BIODIVERSITY
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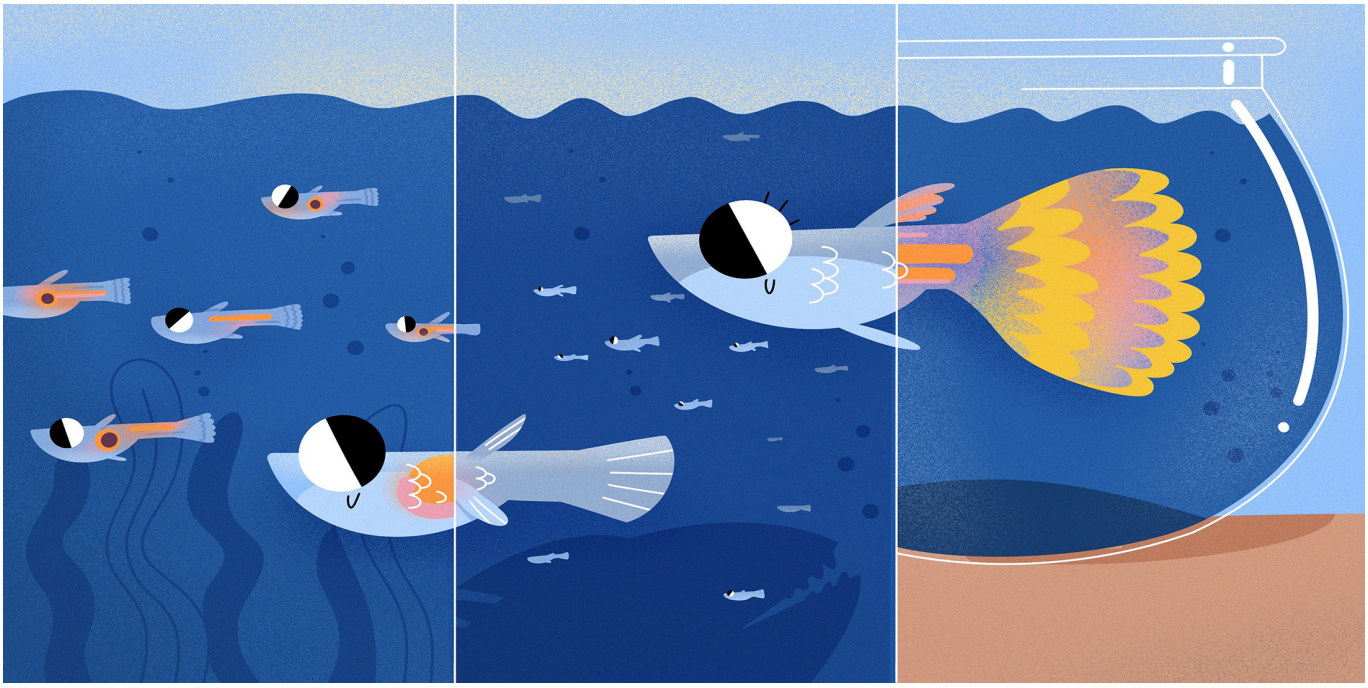

GUPPIES: SMALL FISH TO ANSWER BIG QUESTIONS IN ECOLOGY AND EVOLUTION

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YOUNG REVIEWERS:

BRYSON
AGE: 10

FROYLÁN
AGE: 15

NICOLÁS
AGE: 12

If you have ever been to a pet store and stopped at the aquariums, you have most likely seen a guppy. Guppies come in diverse shapes and sizes. Some have large, beautiful fins, while others have bright-colored bodies. It turns out that guppies are not only popular with pet owners. Scientists find guppies to be fascinating because these fish are perfect for studying how species rapidly adapt to new environments. Next time you stop at a pet store, be sure to admire these small but interesting fish.

WHAT IS A GUPPY?

If you have ever been to a pet store, you have probably seen a Trinidadian guppy, usually just called guppies! These cute fish are popular in the pet trade but look different from their wild populations. This is because they have been bred in captivity to have desirable traits,

such as beautiful colors and fin shapes (Figure 1). In the wild, guppies are small freshwater fish that are <2 inches long. Although most fish lay eggs, guppies give birth to fully formed babies. Guppies are native to rivers and lakes in northeastern South America. However, guppies now live on every continent except for Antarctica. Guppies have been introduced around the world to feed on and reduce mosquito larvae, which is a form of biocontrol—using helpful organisms to get rid of pests or other problems in nature. Guppies also spread through the pet trade because many pet owners release unwanted guppies into ponds or streams. However, these guppies can create problems in these new areas because they can harm native species and the ecosystem.

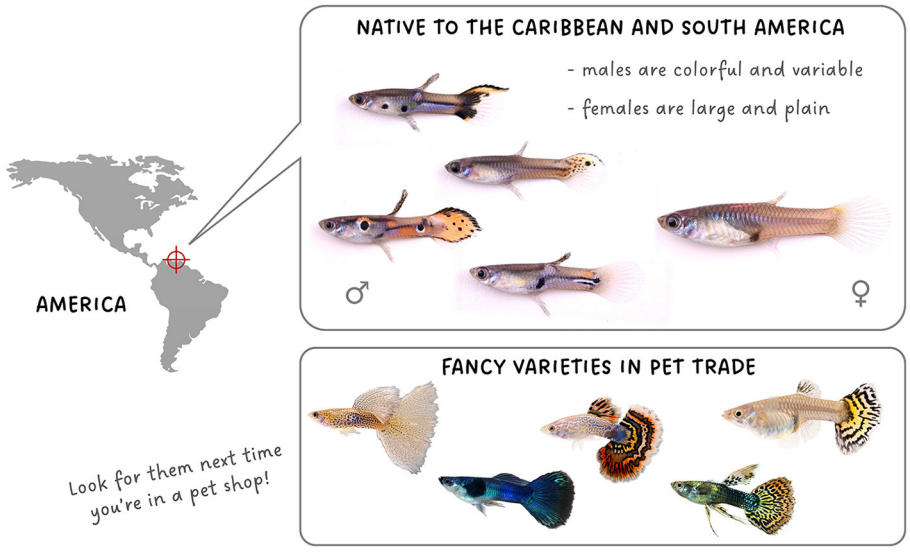

Figure 1

Guppies are small fish native to northeast South America. However, they have been specially bred to have traits like beautiful colors and fin shapes, which are admired by pet owners [photo credits: Y. Yang (top box), Shutterstock/J. Kornelius (bottom box left second), Shutterstock/P. Paipa (bottom box except left second)].

MODEL ORGANISM

An organism that is studied to understand how biological processes occur. What we learn from model organisms can be applied to other organisms.

EVOLUTION

Any changes to the genes in a population of organisms over generations. Over time, these small changes can lead to bigger consequences like adaptation to the environment or emergence of new species.

BIODIVERSITY

The variety of species found on Earth, or in a particular area on Earth.

GUPPIES AS A MODEL ORGANISM

Biocontrol companies and pet stores are not the only ones interested in guppies. Scientists love to study guppies because they are a **model organism** for studying **evolution**. Evolution is any change to the genetic code of populations over generations, and it is why we see so much amazing **biodiversity** on Earth. Scientists are particularly interested in guppies found in Trinidad, an island in the Caribbean off the coast of Venezuela. Guppies in Trinidad often live in freshwater streams that have several large and beautiful waterfalls. Guppies can sometimes move upstream of the waterfalls, but the bigger fish that eat them cannot. This has led to two different forms of guppies: those that live with predators (high-predation habitats) and those that do not (low-predation habitats). Scientists use these habitats to test how environmental differences lead to biodiversity in guppies. Guppies that live with predators are smaller, have more babies, and are less colorful. Guppies that do not live with predators are the opposite: they are larger, have fewer babies, and have bright colors (Figure 2). Tracking these and other guppy characteristics is a perfect way for scientists

to understand how guppies evolve to become so different in many locations [1].

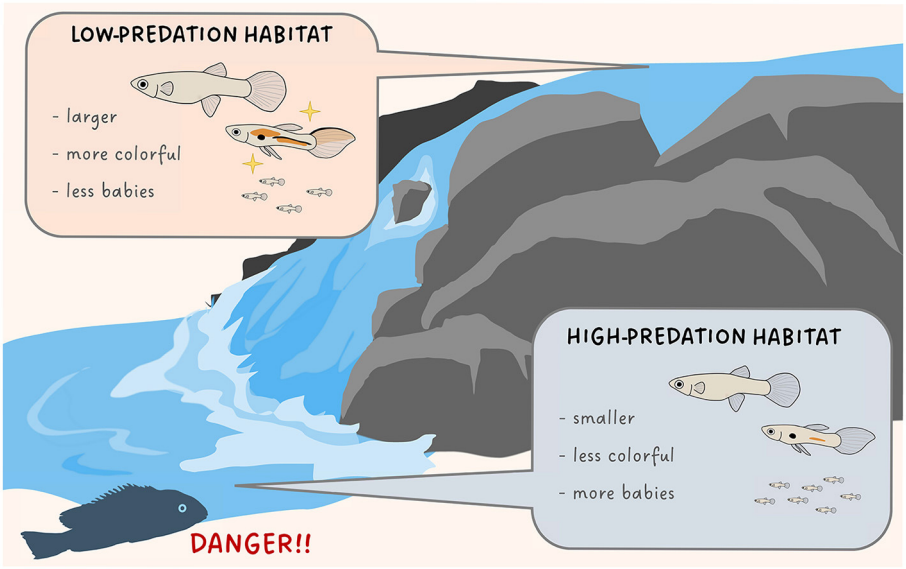

Figure 2

Figure 2

Guppies in Trinidad live in two types of habitats that are separated by waterfall barriers: high predation, where guppies live with larger fish predators; and low predation, where guppies live without predators. This separation between habitats has happened independently in many different streams in Trinidad. This is important because it allows scientists to test how predators, and other factors in the habitat, can cause evolutionary changes to guppy populations. Guppies in these two habitats differ in many characteristics, including body size, color, and behavior.

NATURAL SELECTION

A process by which populations adapt to their environments. Natural selection leads to organisms that are better at surviving and reproducing in their particular environments.

ADAPTATION

The process by which species' traits change over generations to better suit their environment, usually through natural selection.

LEARNING FROM GUPPIES—NATURAL SELECTION

Guppies help us understand how species evolve through **natural selection**. Natural selection is a process that leads to changes in populations so that they can survive better in their environments. Any group of organisms has small variations, or differences, among group members. Guppies do too! This variation is important for populations to survive because some traits are better for certain environments. When the environment changes, some guppies will have better chances of survival than others because of their traits. Guppies that survive can reproduce and pass these traits to their babies. After a few generations, the population of guppies will have changed to show more of these useful traits. These evolutionary changes caused by natural selection make the population better suited to life in the new environment. This process is called **adaptation**. Together, changes in the environment and adaptation give rise to a diversity of traits, and with time, can give rise to entirely new species.

When guppies live with big predatory fishes, they need to avoid being eaten. One way they do this is by speeding up their life cycles. These guppies reproduce fast, so they have a good chance of having babies before they are eaten. These guppies also have many babies, so that even if some babies are eaten, others will survive. High-predation guppies have many other behaviors that help them avoid predators, such as staying in bigger groups and being more alert. Guppies who live without predators have different problems. Because they are not being eaten by predators, there tends to be more guppies. More

guppies means more competition for food. These guppies become adults later and produce fewer, but larger, babies. This is because bigger fish are better at outcompeting other fish for food (Figure 2).

What is super interesting is that these unique traits can evolve rapidly in guppies. Scientists used to think that big evolutionary changes took thousands or even millions of years. Now we know this is not always true—evolution can happen much faster than we ever realized [2]. One way we know this is by manipulating guppies in streams in Trinidad. Scientists moved guppies from high-predation environments to low-predation environments above waterfalls that did not have guppies. These introduced guppies developed the same traits seen in other low-predation guppy populations in just 11 years (20–40 generations; see [2] for this example and many more)!

LEARNING FROM GUPPIES—SEXUAL SELECTION

SEXUAL SELECTION

The process by which evolution favors characteristics that help individuals find mates.

Guppies also help us understand how species evolve through **sexual selection**. Sexual selection is the process that changes organisms because of differences in their ability to find a mate. Individuals that mate and reproduce more have more babies that inherit their traits. So, traits that help individuals to get mates are favored over time. Sometimes these traits help an individual attract a mate, while other traits allow an individual to outcompete a rival for mates. In guppies, females usually choose which male they want to mate with. Often, they are more attracted to bright, colorful males, especially those that have more orange. Biologists do not know why female guppies prefer these colors. One idea is that they are attracted to bright colors because it looks like their food [3], or it is possible that brighter males tend to have more babies. They are also usually healthier and have genes that are better suited to their environments. To show off his colors, a male will "dance" around a female. If the female likes what she sees, she will mate with the male. So why do wild guppies not evolve to become super colorful, like the pet guppies? Here is the catch: in environments with a lot of predators, bright colors and dancing are dangerous. Colorful, dancing males are more likely to attract a predator. So, males in high-predation environments are less colorful (Figure 2), and they typically skip their dance and try to mate with the female immediately.

GUPPIES HAVE BECOME AN INVASIVE SPECIES

INVASIVE SPECIES

A species that is outside its typical native range, spreads, and causes problems for native species or humans.

Remember how we said that guppies have spread all over the world? They are now found in ponds, lakes, and even hot springs! While it is fascinating that guppies can adapt quickly to new environments, they also create many problems because they become **invasive species** outside their native range. Invasive species can harm the

ecosystem and the native species that live there. Ecosystems result from complex interactions between species and their environment. Introducing a fish that acts differently than the native species can impact how the whole ecosystem functions. By eating native species or competing with them, guppies threaten local biodiversity. Take, for example, native fish called gobies found in Hawai'i, also called O'opu. O'opu are freshwater fish that live in streams and can climb waterfalls as tall as 330 feet! Sadly, gobies are doing poorly because guppies eat their eggs and babies, compete with them for food, and change the amount of nutrients in their environment. Some species of gobies are now at risk of going extinct. Understanding how guppies interact with other species and impact ecosystems will help us protect native biodiversity.

ECO-EVOLUTIONARY FEEDBACK

The fascinating thing about guppies evolving so quickly is that we can watch the process in real time! When organisms evolve, they also change the way they interact with their environments. And here is the most interesting part: when they change, the environment can change, too. For example, imagine an organism that is better at eating a particular kind of food. As more organisms evolve this trait, the amount of that food in the ecosystem will decrease. This change in food availability can change the whole ecosystem. Sometimes the environment can change so much that organisms in that environment then must adapt to these *new* conditions—including the organisms that caused the change in the first place! This back-and-forth between evolutionary change in the organisms (caused by the environment), and environmental change in the ecosystem (caused by evolution), is called **eco-evolutionary feedback** [1].

ECO-EVOLUTIONARY FEEDBACK

A process in which organisms adapt to their environment, change their environment, and subsequently adapt to the *new* environment that they have created.

Let us take guppies as an example. When guppies adapt from high- to low-predation environments, they feed on different diets. High-predation guppies prefer to eat small invertebrate animals, which are more nutritious than algae. When they move to a low-predation site, they start out by feeding on invertebrates more than algae. Soon, the guppies reach high population numbers, while the number of invertebrates decreases. Invertebrates eat algae, so with fewer invertebrates, more algae can grow. With their environment now changed, these guppies must adapt once more, by feeding on the abundance of algae.

CONCLUSION

The next time you stop at a pet store, take the time to admire the diversity of traits in guppies. Thanks to guppies, we have learned a lot about how species interact with their environments and how they can evolve rapidly. We still have much to learn from guppies.

Understanding their evolutionary processes can help us understand how the diversity we see in nature came about. Oh, and one last thing: if all that you have learned about guppies makes you want one for a pet, just be sure to not release it into the wild!

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

BRYSON, AGE: 10

Bryson loves science and biology, and is very good at math. He loves martial arts and practices grappling and MMA. Finally, he loves animals.

FROYLÁN, AGE: 15

Hi, my name is Froylán, I am 15 years old and I live in Mexico. Athletics training is one of my hobbies, and I also enjoy studying topics related to human and animal biology. It is been great participating in this activity as it aligns with my aspirations to become a doctor in the future. Understanding and enjoying this manuscript has been easy for me, thanks to my passion for biology.

NICOLÁS, AGE: 12

Hello, my name is Nicolás. I am 12 years old and I enjoy playing the bass and practicing archery. I believe I am quite intelligent, although I can be forgetful at times. I am particularly interested in the study of human anatomy and medicine. I am a big fan of Green Day, Guns N' Roses, Hombres G, AC/DC, and Bon Jovi.

AUTHORS

PETER C. SEARLE

Peter Searle is a Ph.D. student in the Department Ecology and Evolutionary Biology at Cornell University. He is interested in anything and everything that has to do with fish! He is interested in why fish are so diverse (did you know there are more than 30,000 fish species?) and he enjoys asking questions like "Why are there green fish and yellow fish?" He likes studying guppies because it turns out the fish can evolve rapidly when introduced into new environments. *pcs222@cornell.edu

JEFERSON RIBEIRO AMARAL

As an enthusiast of the interactions between invasive and native species and their ecosystem effects, Jeferson has been working with invasion biology since he was an undergraduate at the State University of Rio de Janeiro, Brazil. Now, as a Ph.D. student at Cornell University, his goal is to analyze the effects of urbanization on non-native species' invasiveness and the evolutionary mechanisms behind this process. His connection with guppies (and many similar species) became real after working in the aquarium trade with ornamental fish.

CALEB J. AXELROD

Caleb Axelrod is a postdoctoral researcher at Cornell University. He got his Ph.D. at the University of Guelph in Canada. Caleb loves brains! He wants to find out why some animals have bigger brains than others. Does a bigger brain make you smarter? When is it important to be smart? He studies these questions in fish. He studies fish because there are so many different species of fish and they live in hugely diverse habitats, and also because he loves fishing. :)

UDITA BANSAL

Udita Bansal is from India, and currently a Ph.D. student at Cornell University. She is interested in everything color! How animals use color to communicate with each other, whether it is anger or attraction, or to avoid being eaten by predators are some questions that fascinate her. She has studied a variety of animals including tigers, but her favorites are reptiles! Of course, she likes guppies with the variety of colors and patterns they display to attract females!

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.

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. I like studying about guppies in my free time because they utilize their coloration in a variety of ways.

AMINA MOHAMED

Amina Mohamed is from Kerala, a state in India, and she is a Ph.D. student at Cornell University. She is interested in what guppies eat, and how that affects their pee and poo! It blows her mind that guppies can evolve their traits rapidly in response to their environments. She used to be a chemist, but her love and curiosity for things in nature made her switch to ecology.

ANDRÉS LÓPEZ-SEPULCRE

Andrés is interested in eco-evolutionary feedback and rapid evolution, so he loves guppies. He is originally from a coastal town in Spain, where he grew to love ecology on beaches, in tidepools, and in marshes. He has traveled the world following his dream to become a scientist and is now an assistant professor at Cornell University. He loves to cook, travel, birdwatch, and spend time with his kids Amaya and Kai.

KATHRYN A. TALBERT

Kathryn is a lab tech in the Department of Ecology and Evolutionary Biology at Cornell University. She helps take care of the guppies in the lab, and she is interested in studying what all affects guppies' behavior. She started studying guppies because she loves the water and loves to fish and wanted to learn more about those ecosystems.

STEPHANIE M. TRAN

Stephanie Tran is a Ph.D. student at Cornell University. She is interested in the role of social behavior in eco-evolutionary feedback and has worked with a variety of freshwater organisms. In her free time, she loves to go on hikes and take photos of cool wildlife that she comes across.

YUSAN YANG

Yusan Yang is from Taiwan, and currently an assistant professor at the University of South Florida. She got her Ph.D. at the University of Pittsburgh. She is interested in why animals do what they do, and why they have so many different colors. She studies poison frogs and guppies because they have all kinds of cool colors and interesting behaviors! Do you know that male guppies dance desperately to attract females, and that a poison frog male will get super angry if you play another male's call in his territory?