# How the Guppy Got Its Spots

Introduction

Why Do Male Guppies Look Different in Different Streams?

With his theory of evolution by natural selection, Darwin proposed a mechanism for descent with modification. If a population of organisms has variation, inheritance, and differential reproductive success, then the composition of the population changes from one generation to the next.

Just because a theory works on paper, however, doesn't mean that it works in the real world. This lab will challenge you to design a study that would allow you to document evolution by natural selection in nature. The EvoBeaker simulations you will use are based on a classic study by John Endler (1980) of natural selection in guppies. After you have designed and run your own experiments, you will have a chance to analyze some of Endler's experiments and results.
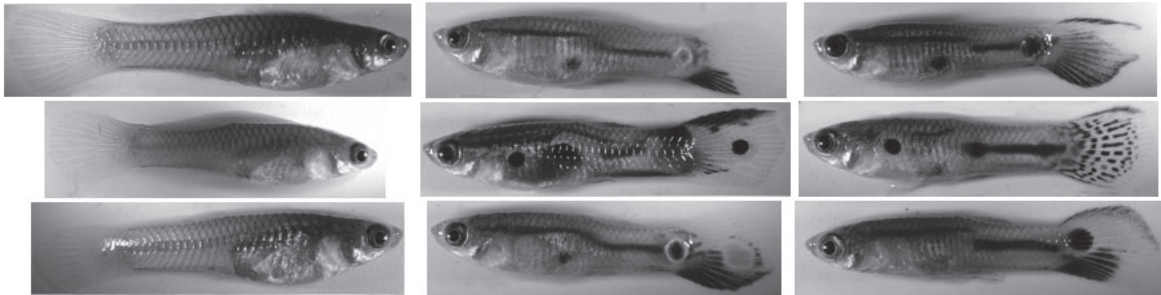
Color Variation in Guppies

Most of us know guppies only as dramatically patterned aquarium fish (right). But the domesticated guppies we see in fish tanks are descended from wild ancestors. Wild guppies, *Poecilia reticulata*, live in mountain streams in the tropical forests of northeastern Venezuela, Margarita Island, Trinidad, and Tobago (below).
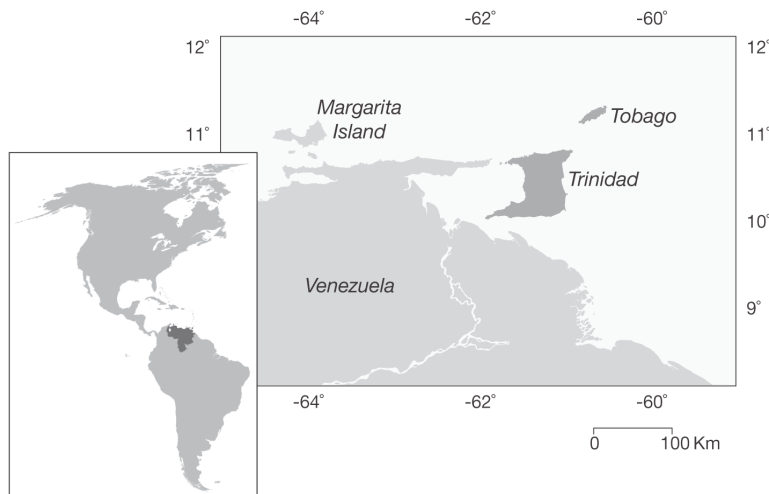
Wild female guppies, like their domesticated cousins, are silvery gray and inconspicuous (below, left). Wild males, while not so extravagantly ornamented as the males on this page, are nonetheless impressively showy (below, right). They wear stripes, spots, and splashes of color that can be orange, yellow, black, blue, or iridescent. No two males are exactly alike.

In this lab, your first task in conducting field research on wild guppies will be to assess the variation among males in several populations.


Color diversity in wild guppies Females in wild populations are silvery gray (left). Males are brightly colored and highly variable (center and right). (Photos: Cara Gibson and Katie McGhee; provided by Helen Rodd.)

Exercise 1: Assessing Color Variation Among Males in Guppy Populations

[1]   Launch **SimBio Virtual Labs**. Select **How The Guppy Got Its Spots** from the **Evobeaker Labs** options.

[2]   On the right you should see a map of your field site. You will be studying guppy populations in two streams, West Stream and East Stream. Both streams have waterfalls that guppies cannot cross, dividing each stream into upper and lower sections. East Stream also has a tributary, Meir Creek. Thus there are five places to look for guppies. In addition, you have three fish tanks set up in a field station near the streams, where you will conduct your experiments.
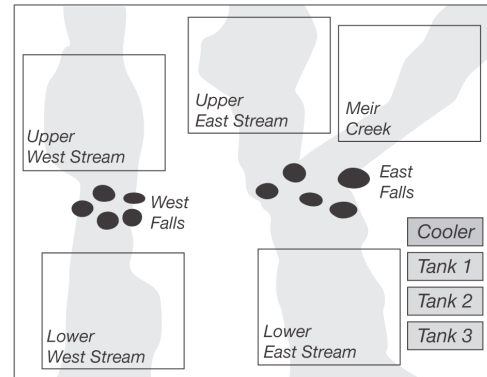
[3]   When the lab starts you are looking at the Upper West Stream in the Fish Pool view on the left-hand side of the screen. (Note that the Upper West Stream is highlighted on the map.) Click on different areas of the map to see the different pools appear in the Fish Pool view.

When viewing different zones in the Fish Pool view, you will be able to see several species of fish. Some of the guppies may look different from the others, but you won't be able to clearly see differences in their coloring until you catch them. You will also see some larger fish. These are predatory species known to eat guppies. The small blue rectangles you will see represent the various things that guppies eat, such as plant matter and detritus.

The guppies at your field site have a maximum life span of around 120 days. The predatory fish have much longer life spans.

[4]   The first thing you need to do is examine how colorful the guppies are in each pool. Click again on **Upper West Stream** in the map to make that zone appear in the Fish Pool.

To catch a guppy, double-click or CTRL-click (⌘ click on a Mac) on it. This will open a window containing a picture of the guppy, and also includes data telling you (among other things) whether the guppy is male or female and the guppy's **Spot Brightness**. Spot brightness is a measure of how many spots a guppy has and how colorful the guppy is.

[5]   If your first guppy is female, throw it back into the stream by closing the pop up window. Keep catching guppies until you get a male. Count your male guppy's spots.

[6]   Examine several males and see if you can confirm that males with more spots tend to have higher spot brightness scores.

[6.1]   **Now catch 15-20 male guppies and record their spot brightness on the table below.**

MALE #	SPOT BRIGHTNESS	MALE #	SPOT BRIGHTNESS
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

[6.2]   **In the space below, record any other observations you think might be important, such as what other species you find living in the pool along with the guppies:**

   NOTES ON UPPER WEST STREAM:

[6.3]   **On the grid below, plot a histogram showing the variation in spot brightness among the male guppies in Upper West Stream:**

Upper West Stream:

Number of males

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Spot brightness
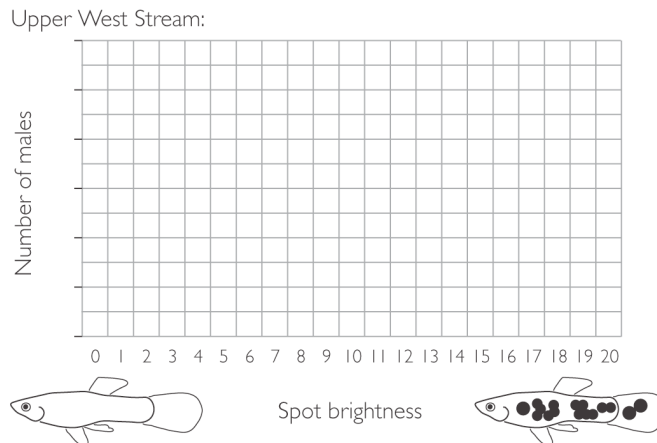
[7]   Now that you know how much variation there is among the males in Upper West Stream, you need to characterize the variation among the males in each of the other pools. You will have already noticed that sampling guppies can get tedious after a while, so you can 'hire' an assistant to do it for you. To do so, go to the **EXPERIMENT** menu and select **HIRE ASSISTANT**. You will see the same view as before, but on the lower right is something new: a histogram showing the variation in spot brightness among the male guppies in the currently selected research site.

[8]   You can copy or print your assistant's histogram for your records. To copy the histogram, mouse over the center of your histogram and right-click (Windows) or Control-Click (OSX). Choose "Copy View to Clipboard." Then open a document in a word processing program where you can paste the picture and use the **PASTE** command to place the screen shot in the document. Be sure to indicate what the histogram is (i.e., "Histogram of Upper West Stream before any manipulations") and include important notes on that pool as in step 6.2.

[8.1]   **How does your assistant's graph (which includes all the males in the pool) compare to yours from page 3 (which includes a smaller sample of males from the pool)?**

[8.2]   **Visit Lower West Stream, Upper East Stream, and Lower East Stream by clicking on each pool on the Map. For each stream, COPY or PRINT your assistant's histogram. Write the stream name and take notes on features of the stream and the other species that live there. Finally, visit Meir Creek to see what lives there.**

[8.3]   **Before moving on to the next section, write a short description of the natural history information you've found so far in your studies, including any differences between the pools. This should include your observations, but NOT hypotheses for what you saw—don't try to explain anything yet, just summarize the facts:**

Exercise 2: Why Are Males From Different Locations Different?

You have discovered that male guppies from some locations are showier than the males from other locations. The question you must answer now is: Why? You will answer this question in two steps.

Exercise 2a: Generating Hypotheses and Designing Experiments

[1]   The first step in determining why the male guppies from some locations are showier than the males from other locations is to brainstorm several hypotheses.

[1.1]   **Write down at least two hypotheses for what might be causing the differences in male showiness between the pools. Think about things other than the guppies themselves that were different between the pools:**

[1.2]   **Now you must design an experiment (or a series of experiments) that will distinguish between your hypotheses or that will eliminate one of them as an explanation. In planning your experiment(s), be aware that you have three fish tanks at your disposal for conducting your research (Tank 1, Tank 2, and Tank 3 on the map). Click on the tanks to see that the background in each tank is a different color.**

In conducting your experiments, EvoBeaker will allow you to do the following (instructions for doing each are given below):

–   You can move a guppy, or other fish, from place to place within a pool or tank.

–   You can move guppies from one pool to another.

–   You can move guppies to a tank.

–   You can move individuals of other species between pools or into one of the tanks.

–   You can remove guppies or other species from a pool or tank.

–   You can rear guppies (with or without other species) in a tank for as many generations as you choose.

–   You can allow time to pass in a pool for as long as you choose. Recall that the maximum guppy life span is around 120 days.

[1.3]   Describe the logic of your experiment(s) in the space below. What species will you use? What will you do with them? How long will your experiment(s) have to run before you can collect data? What data will you collect? What graphs will you draw to analyze the data? Sketch what your graphs will look like if each hypothesis is correct, and also what they will look like if each hypothesis is wrong.

Describe your experiment(s) here:

Exercise 2b: Conducting Experiments

[1]   The next step is to design and conduct experiments to test your hypotheses. Use **EVOBEAKER** to carry out your experiments. Be sure to record data and take notes as you go. As time permits, continue refining your hypotheses—or generating new ones—and testing them until you feel confident that you know the reason why the male guppies look different in different pools.

The following are instructions you may find useful while conducting your experiments:

How To Add Fish or Fish Food

If you want to add a fish or some fish food directly to a tank or pool, do the following:

- –   On the map, click on any tank or pool.

- –   Click on the **ADD CRITTER** tool. (It will look like a female guppy at first.)

- –   Select the icon of what you would like to add to your tank or pool from the menu.

- –   Either click one time in the Fish Pool to add one critter or click and drag to draw a box to add many critters at once.

How to Transplant Fish

If you want to transplant guppies or individuals of other species from a pool to a tank or from one pool to another, do the following:

- –   Click on the **SELECT** tool (the arrow button).

- –   Select a single fish by clicking on it. You can select multiple individuals by dragging a rectangle around them, or by holding down the shift key and clicking separately on each individual you want to select.

- –   Move your selected fish by clicking on it (or by clicking on one of your group of selected fish). While holding the mouse button down, drag the cursor to the place you want the fish to go (this can include dragging them to another pool or to one of the tanks), then release the mouse button.

How to Remove Fish

- –   To temporarily remove a fish from a pool or tank, you can transplant the fish to the Cooler. The cooler is a holding tank. Fish stored in the cooler will not move around or interact with each other.

- –   To permanently remove a fish, select the **DELETE** tool (the trash-can button). Click on the individual you want to remove, or drag a rectangle around a group of fish you want to remove. Be careful with the **DELETE** tool; fish of species other than guppies do not reproduce in our simulation.

★   NOTE: *Don't forget to switch back to the* **SELECT** *tool (the arrow button) when you are done to avoid accidentally killing innocent bystanders.*

How to Run Experiments

Each pool or tank can run independently of the others, so you can do an experiment in one without worrying about what's happening in others. To allow time to advance in one of the pools or tanks:

–   On the map, click on the pool or tank (for example, 'Tank 2').

–   Before you start, write down the time denoted on the **DAYS** clock shown at the bottom of the window. Writing down the start time will help you keep track of how long the experiment has been running. Recall that guppies live for about 120 days.

–   To run the simulation, click the **GO** button. You will see the fish swim around, and you will see the Days advance on the clock. Remember: Guppies live for around 120 days— you will want to run your experiments for long enough to have several generations of guppies live and die before recording your results. Be patient, evolution is a slow process!

–   To stop the simulation, click the **STOP** button.

–   If, instead, you wish time to advance one day at a time, use the **STEP** button.

–   If you want to clear a tank, you can do so by moving all its inhabitants to the Cooler (see instructions above for transplanting fish). You can also simply kill all of the tank's inhabitants.

–   Use the **RESET** button only if you want to restore **all** sites (all tanks and streams) to their original states—as they were when you first loaded the guppy lab.

A Friendly Warning Before You Continue:

The control panel at the bottom of the screen includes a **RESET** button. Clicking the **RESET** button will restore the entire simulation to starting conditions, including all five streams, all three tanks, and the cooler. Remember, do not press the **RESET** button unless you really want to start over.

[1.1]   **When you have a hypothesis that you feel is supported by your experimental results, summarize these results in a short paper (~2 pages).** Use graphs and statistical analyses that allow you to demonstrate and support your conclusions.

Record your notes, observations, and data from your experiments below and on the following pages:

Notes, observations, and data from your experiments (continued):

Notes, observations, and data from your experiments (continued):

John Endler's Experiments

In 1980 John Endler published the results of two experiments on guppies that are now considered classics. Endler had examined numerous guppies from each of several natural streams. He found that the males in some locations had many more spots, on average, than the males in other populations.

Endler's hypothesis was that predators are responsible for much of this variation among populations. He had noticed that guppies sharing their stream with predatory cichlids had fewer spots than guppies living with Rivulus. Cichlids are ravenous predators of adult guppies. Rivulus eat only juvenile guppies.

In his first experiment, Endler collected guppies from 18 locations in 11 different streams. He moved these fish into artificial ponds in a greenhouse, and let them grow for about 6 months—long enough for several generations of fish to grow up, reproduce, and die.

Endler then divided his guppy population among 10 greenhouse ponds. To four ponds he added a single cichlid. To four other ponds he added half a dozen Rivulus. The remaining two ponds he left without predators as controls. Five months later, and again 14 months later, Endler sampled male guppies from his ten populations and counted their spots.

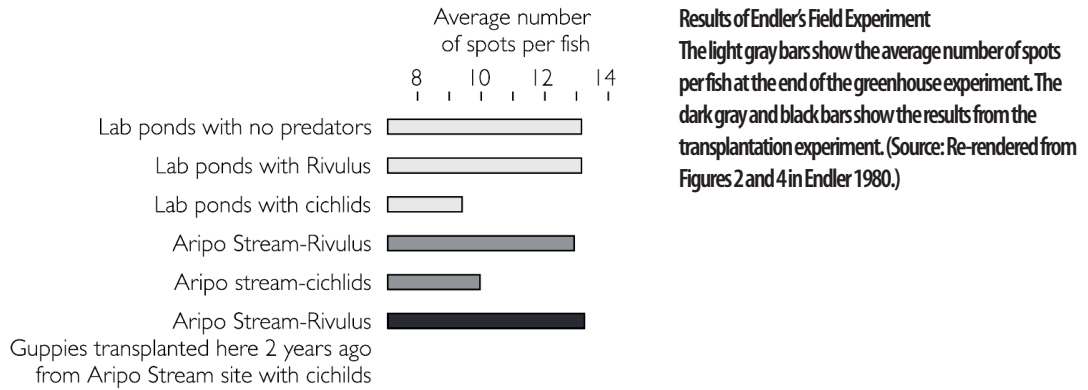[1]   Endler's actual results appear below. Examine Endler's graph.
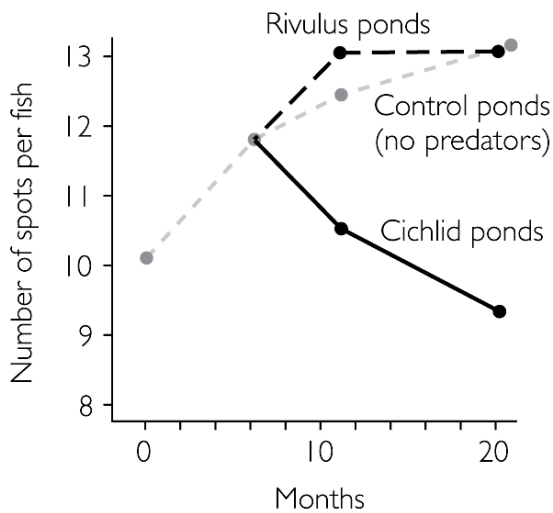
Results from Endlers' greenhouse experiment
Endler established his guppy population at month zero. At month six, he divided his guppies among ten ponds with different predators. The graph shows the average number of spots per male in the founding population, the Rivulus ponds, the Cichlid ponds, and the predator-free ponds at 0, 6, 10 and 20 months. (Source: Re-rendered from Figure 1 in Endler 1980.)

[1.1]   **How do Endler's results compare with your EvoBeaker results? Was Endler's hypothesis correct?**

In his second experiment, Endler sought to replicate his greenhouse results in the wild. Among the tributaries of the Aripo River in Trinidad, Endler found a guppy population living with cichlids, a guppy population living with Rivulus, and a stream that contained Rivulus, but no cichlids or guppies. Endler caught about 200 guppies from the population living with cichlids and moved them to the stream with Rivulus, but no guppies. He returned two years later to sample males from all three locations.

[2]   Examine Endler's actual results below.

Average number
of spots per fish

8   10   12   14

Lab ponds with no predators

Lab ponds with Rivulus

Lab ponds with cichlids

Aripo Stream-Rivulus

Aripo stream-cichlids

Aripo Stream-Rivulus
Guppies transplanted here 2 years ago
from Aripo Stream site with cichilds

Results of Endler's Field Experiment
The light gray bars show the average number of spots per fish at the end of the greenhouse experiment. The dark gray and black bars show the results from the transplantation experiment. (Source: Re-rendered from Figures 2 and 4 in Endler 1980.)

[2.1]   **How do Endler's results compare with your EVOBEAKER results? Are the results from his field experiment consistent with the results from his greenhouse experiment? [If you have time and your results were different than Endler's, go back and repeat Endler's experiments in EvoBeaker. Try moving guppies from either lower stream to Meir Creek, which you will already have discovered has Rivulus, but no guppies.]**

Literature Cited

Endler, John A. 1980. Natural selection on color patterns in *Poecilia reticulata*. Evolution 34: 76-91.

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