Published in final edited form as:
Sci Teach. 2012 July ; 79(5): 32–37.

The Guppy Game:

Understanding the big ideas of natural and sexual selection

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Keywords

Natural Selection

Adaptation, interactions between species and their environments, and change over time are fundamental principles in biology (NRC 1996). They represent aspects of two of the big ideas in science: evolution and natural selection (NRC 2011). To help students understand these ideas, we developed the “Guppy Game.” In this article, we describe the game and how we used it in an AP biology classroom to model the dynamic processes of population genetics and environmental influence on behaviors.

About the Guppy Game

The Guppy Game allows students to learn science content in an interactive, student-driven manner. They are exposed to the idea of fitness (how traits might be advantageous or disadvantageous) as they explore how different varieties of fish adapt to environments and make hypotheses about which habitats will favor which traits. The game teaches how sensory biases help fish survive by finding different colors of food or camouflaging themselves from lurking predators. As the game progresses, students learn how these biases can interact with demands of sexual selection. By simulating different populations of guppies in various environments, students collect data and examine how genetic drift occurs in populations over time. In essence, the Guppy Game models the balance between the pressures of natural selection and sexual selection.

Playing the game

The Guppy Game has six rounds—one for each habitat. Each round consists of three seasons, and each season has a Survival Phase and a Reproduction Phase. Students play in groups of four, and at the beginning of the game, each player receives a different guppy card. Four guppy cards exist: one fancy and one wild male (different strains of the same

On the web
Project NEURON: http://neuron.illinois.edu

species) and one fancy and one wild female (Figure 1, page 34). (**Note:** All Guppy Game materials are available online [see “On the web”].)

The Survival Phase considers the pressures of natural selection and the ability to find food and avoid predation. Students take turns rolling the die and determining if their guppies survive (Figure 2, page 35). Male guppies must roll equal to or over their brightness value, which is listed on the guppy card; this brightness value reflects the ability to avoid predation (i.e., predators can more easily see brightly colored males, reducing their chance of survival). Females must roll equal to or under their sensory bias to successfully find enough food to survive. A strong bias (i.e., attraction to bright colors) makes her more likely to find food. In this phase, it is best to be drably colored (low male brightness value) and have a strong sensory bias (high female value) to hide or find food, respectively.

The Reproduction Phase considers traits beneficial for sexual selection (e.g., bright coloration). Students roll the die to determine if their guppies reproduce (Figure 2). Males must roll equal to or under their brightness value to mate (the higher the brightness value, the more likely to mate) and females must roll equal to or over their bias to find a mate (the lower the bias, the less picky and easier to find a mate).

Because of the opposing pressures between survival and reproduction, students learn that certain brightness and sensory bias values are not inherently good or bad but may increase the likelihood of survival, depending on environment and contextual considerations. For example, a male guppy wants to be bright when trying to impress a potential mate (i.e., the Reproduction Phase) but not when hiding from predators in drab environments (i.e., the Survival Phase). This is why many animals such as birds are brightly colored during their mating season but more drably colored the rest of the year. Similarly, a female guppy might want to have a strong preference for bright colors (and high sensory bias) when searching for food, but it may not be as helpful when choosing a mate (she is overly picky and may pass on an opportunity to mate with drably colored males).

Students record their survival and reproduction points on score cards (Figure 3, page 36). Points are awarded for survival (+1) and reproduction (+2). Since one needs to survive to reproduce, every round it’s possible to earn 0, 1, or 3 points. Points reflect the “fitness” of that guppy in that particular environment. The Guppy Game is played over the course of three seasons to illustrate that genetic change over time is neither purely random nor completely deterministic. Over seasons (i.e., generations), guppies better adapted to the environmental pressures are more likely to survive and reproduce. Students keep the same guppy card throughout the game.

Because the environment can influence the effect of brightness or sensory bias on fitness, different habitat cards exist: murky pond, fish tank, clear stream, Amazon River, practice pond, and quiet brook (Figure 4, page 36). These cards help students understand the relationship between species and environment and the external influences on population genetics.

All student groups begin the Guppy Game in the practice pond environment so they can acquaint themselves with the game’s basic rules. They then proceed to the different habitats in no particular order. Habitats’ different external pressures influence the selective processes in each environment, and habitat cards adjust scoring accordingly. For example, in the fish tank, all guppies’ probability of survival increases because of ample food and no predation. Conversely, in the Amazon River, predators challenge survival, and the habitat card prompts students to adjust their guppies’ sensory bias or brightness values to reflect a decreased probability of survival.

After students play through multiple seasons in each of the habitats, they notice trends in their data. Teachers can pool classroom data to highlight the relationship between behavior and environmental fitness. Students should notice that predation and the ability to find food have a greater influence in some environments than in others and draw conclusions about which guppies are best adapted for which environments. Students may also notice exceptions to some of the rules (e.g., some guppies may have survived in environments with slim odds). Using examples from the Guppy Game, teachers can assess students' understanding of core science concepts and their ability to make a claim and support it with evidence.

Discussion and assessment

The Guppy Game can frame discussion about the dynamic process of natural and sexual selection. To introduce the relationship between traits and environment, we ask students why males and females of some species are different colors. Students discuss how color impacts guppies' survival in terms of predation and attraction to potential mates. Their analysis can also include characteristics of habitats. For example, different environments, such as murky water, can alter the significance of bright coloration. Students can make predictions about the viability of color traits in different environments and then test these predictions with the Guppy Game.

Through the discussion, students begin to connect the concept of selection to the evolutionary or adaptive process that takes place in genes. Based on the observations from the score cards about the fitness of certain traits, students can see that certain traits are selected for and passed on to future generations; others become less likely to be transmitted to offspring.

Student discussions may also include environmental adaptations. For example, the introduction of a new predator might influence the survival of a certain guppy. Human influences, such as increased sedimentation in ponds, can also change the balance of natural and sexual selection for guppy populations. Students can begin to think about the forces that influence natural selection and how the balance of sexual and natural selection may be altered.

To assess student learning, teachers may ask students to develop a scientific explanation based on the data they collected from the Guppy Game. This explanation should include claim, evidence, and reasoning, as described by McNeill and Martin (2011) (Figure 5, p. 37).

Conclusion and teacher feedback

Teachers have successfully used the Guppy Game to engage high school biology students in discussion about the impact of environment on species diversity, reporting that students catch on quickly to the principles of the game and manipulate the environments to see which guppies have an advantage. Students can observe general trends through pooled classroom data and anomalies in individual guppies or seasons. The Guppy Game illustrates why species diversity is maintained; as the environment changes, the relative desirability of different traits can depend on external pressures.

Teachers reported that after using the Guppy Game class discussions seemed more logical because students supported their claims with concrete examples of data from the game and the reasoning that linked the claim and data. Students' written explanations also included stronger links among the three elements of a scientific explanation: claim, evidence, and reasoning (Novak, McNeill, and Krajcik 2009). One teacher commented that students who

normally struggled with science found the Guppy Game engaging and demonstrated their knowledge about key ideas through their predictions, discussions, and scientific explanations.

The Guppy Game is a dynamic model of the balance of natural and sexual selection. These concepts are part of the "disciplinary core ideas" identified in *Framework for K–12 Science Education* (Biological Evolution) (NRC 2011). The game highlights how variation in species' characteristics and habitat together influence their survival. Students playing the Guppy Game collect and use data illustrating these big ideas of science—and begin to appreciate the complexity of change over time.

Acknowledgments

This project was supported by the National Center for Research Resources and the Division of Program Coordination, Planning, and Strategic Initiatives of the National Institutes of Health through Grant Number R25 RR024251-03. The opinions expressed are the authors' and not the funding agency's.

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About Project NEURON

The Guppy Game is part of a unit created for a National Institutes of Health Science Education Partnership Award–funded program, Project NEURON, that brings together education and neuroscience faculty and graduate students to develop high school neuroscience curriculum.

These lessons address crosscutting concepts of stability and change (NRC 2011). Students participate in inquiry-based experiments and discussions as they develop an answer to the driving question, “Do you see what I see?”

Other activities explore the connections between visual and behavioral neuroscience in humans and guppies. For example, in the “What Color Do You See?” activity, students test how environment influences their own vision by sorting colored candies in different light conditions. In the “Do Fish Have a Favorite Color?” activity, they test guppy “penny pecking” behavior to assess guppy color preference and practice data collection, hypothesis testing, and experimental design. All curriculum materials are available on the Project NEURON website (see “On the web”).

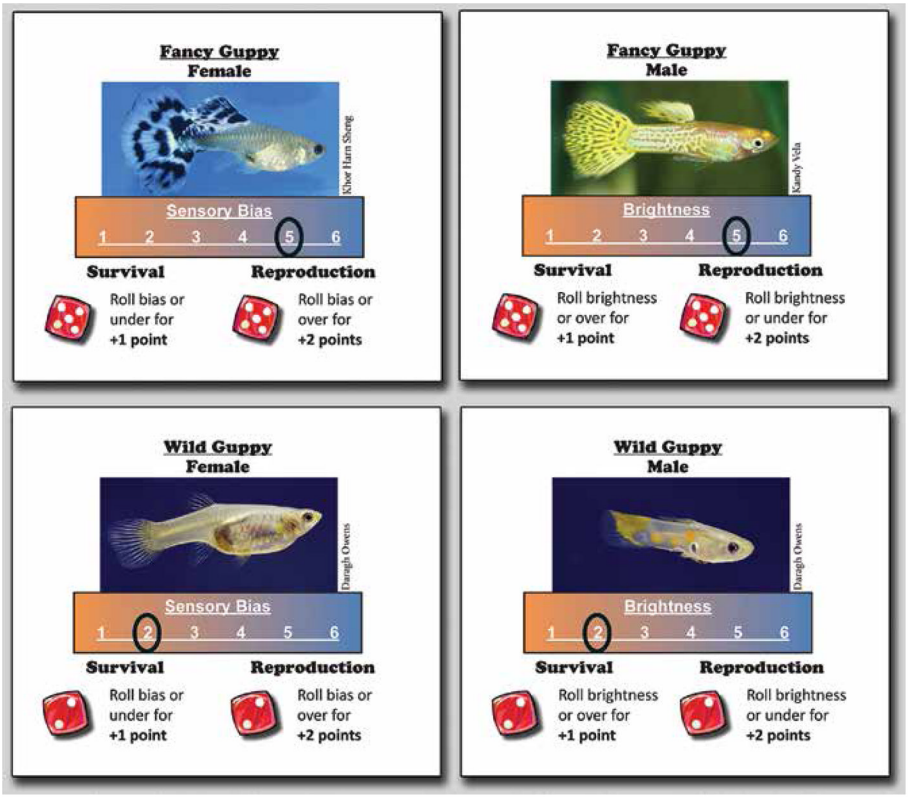


FIGURE 1. Guppy cards

The four guppy cards include information about the sensory bias for females and brightness for males. The fancy male guppy has a greater brightness value than the wild male guppy. The cards also indicate scoring for the Survival and Reproduction Phases.

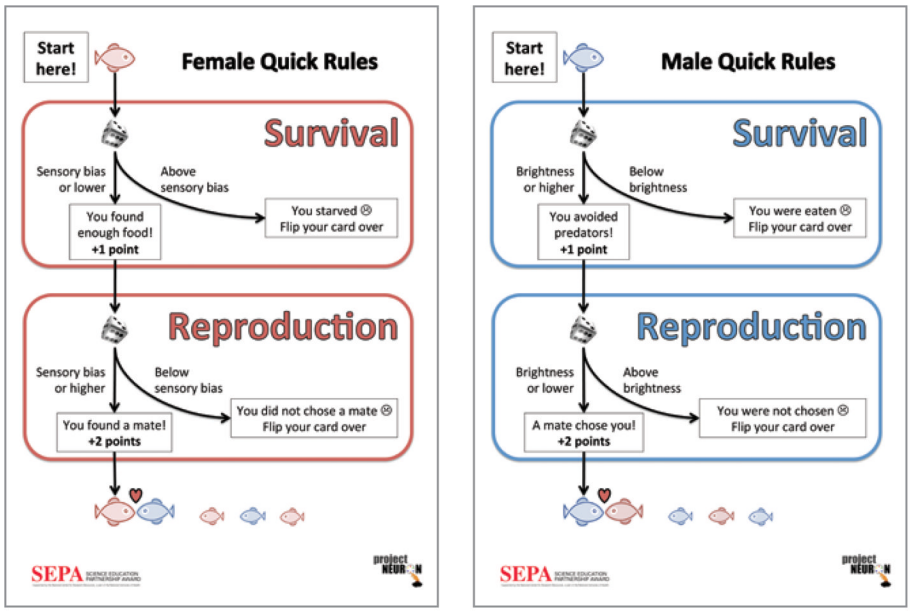
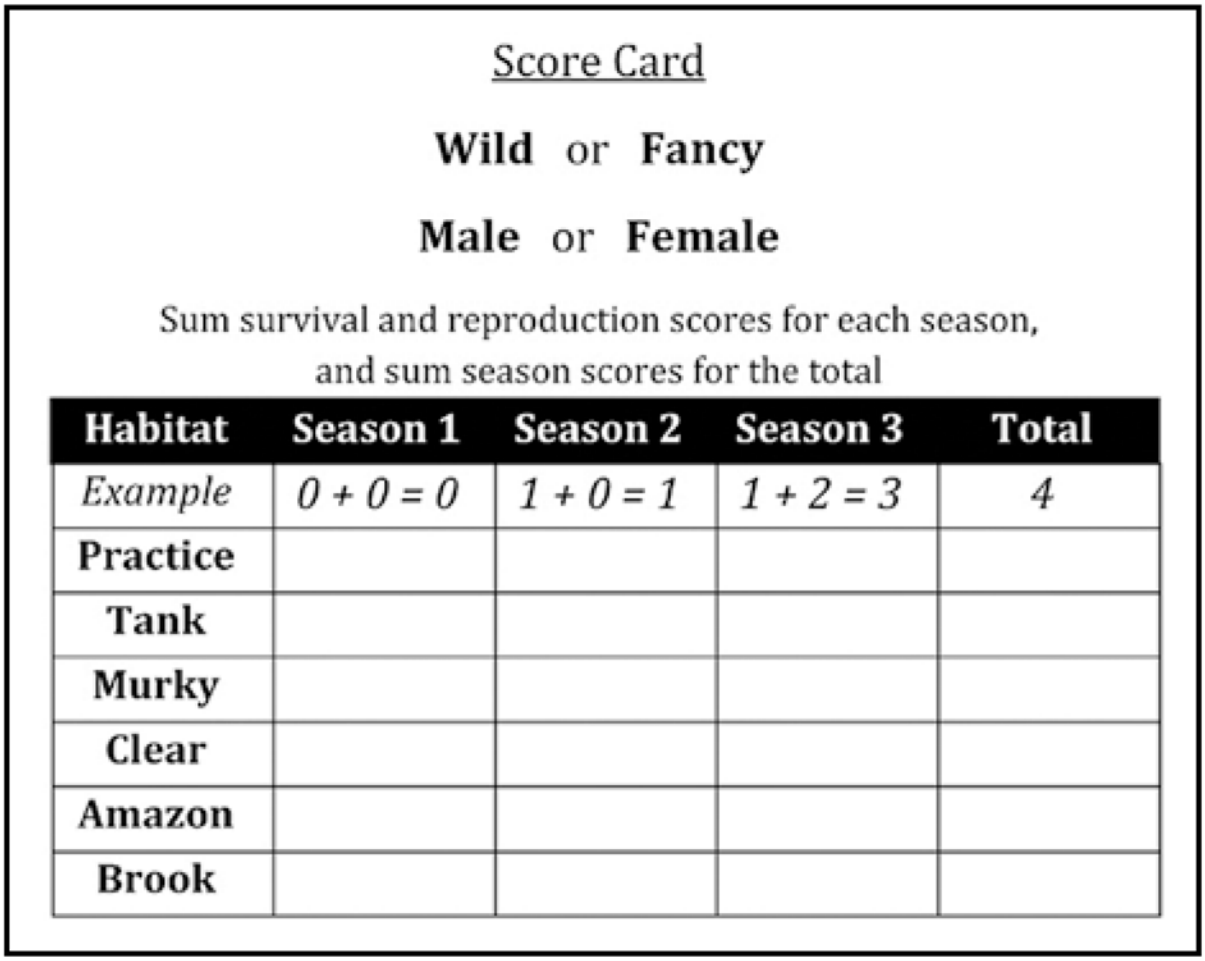


FIGURE 2. Guppy Game rules of survival and reproduction

The Guppy Game Quick Rules outline the flow and scoring of the game. There are slightly different scoring rules for the males and females in the Survival and Reproduction Phases.



Score Card

Wild or **Fancy**

Male or **Female**

Sum survival and reproduction scores for each season, and sum season scores for the total

Habitat	Season 1	Season 2	Season 3	Total
Example	*0 + 0 = 0*	*1 + 0 = 1*	*1 + 2 = 3*	*4*
Practice				
Tank				
Murky				
Clear				
Amazon				
Brook				

FIGURE 3. Guppy Game score card

The score card is designed for collecting the data from each fish over multiple seasons. Playing the game over multiple rounds allows students to see how trends in the data emerge.

FIGURE 4. Habitat cards

The habitat cards outline how to modify the scoring based on environmental considerations. Each card defines an environmental factor that will impact the role of sensory bias or brightness and instructs how to modify the scoring.

Claim	Statement connects the principles of natural selection or sexual selection to multiple environments.
Evidence	Students make specific reference to supporting data gathered during the Guppy Game. Students describe guppy reproduction and survival in multiple environments.
Reasoning	Students highlight key content: ◆ the interconnection between environment and animal traits, ◆ the influence of both natural and sexual selection on species behavior and traits, and ◆ certain traits can be either beneficial or deleterious, depending on the environment.

FIGURE 5.
Scientific explanation.