NABT BioClub RECOMMENDATION

Spork & Beans: Addressing Evolutionary Misconceptions

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They are found at picnics and family outings, apparently attracted by the food provided at these events. Large populations in fast food establishments further support their association with food. Yet little is known about the biology of *Utensilus plastica* (common name: plastic eating utensil). We have conducted an in-depth study of this easily overlooked species and discovered that it possesses a number of characteristics which make it an excellent model organism for exploring natural selection and evolution in the classroom.

○ *Utensilus plastica:* A Model Organism

Central to this determination was our finding that the spoon, spork, and fork are sexually reproducing variations, or phenotypes, of the species. We have repeatedly observed the prolific nature of these utensils, capable of producing multiple generations in a matter of minutes. This makes possible the collection of population data for the species within one class period. Although similar in shape and often associated with *U. plastica*, the knife is a different species, its resemblance apparently the result of convergent evolution. We do believe there is a mutualistic relationship between the knife and at least one variant of *U. plastica* (the fork), but have not investigated it thoroughly.

In addition to distinguishable traits and a short generation time (both characteristics exhibited by *U. plastica*), genetic variability is prerequisite for exploring evolutionary concepts. Natural selection acts on this heritable variation among a population to adapt it to changing environmental conditions. After conducting extensive genetic research, we found that a single gene controls the anterior morphology of *U. plastica*, resulting in a spoon-like or fork-like appearance. This gene for utensil shape comes in two different versions, or alleles (U^S and U^F). These two alleles exhibit incomplete dominance, with both traits expressed, but neither completely displayed in the heterozygous condition (U^SU^F, the spork). You may have already anticipated that the genotypes of the spoon and fork are U^SU^S and U^FU^F, respectively.

A final requirement in any model for investigating natural selection is that the traits associated with genetic variability influence the reproductive success of the organism. As you are no doubt already aware, the homozygous condition in *U. plastica* (U^SU^S or U^FU^F) impacts feeding behavior and the type of prey an individual can successfully obtain. For instance, forks are somewhat limited in their ability to acquire prey items by scooping, but excel at the quick stab and grab. In contrast, spoons are unquestionably the superior predator when it comes to liquid prey. With attributes of both the spoon and fork, sporks may represent the "best of both worlds" in their ability to alter feeding behavior and prey selection in different environments. In environments where a particular feeding behavior is favored, we expect differential reproductive success among the various phenotypes to change allele frequencies in the utensil population over several generations (evolution through natural selection).

This lesson requires students to reconcile their explanations of concepts with actual observations testing their developing understanding and preconceptions of evolution.

Figure 1. *Utensilus plastica* with potential prey items.

Our examination of *U. plastica* in the wild has confirmed that the species occupies a variety of culinary environments. An abundance of evidence supports the assertion that the spoon- or fork-like trait is more successful depending on environmental conditions. For instance, the lack of genetic variability at coffee stands (all spoons) indicates that the U^S allele is fixed in these populations, while the U^F allele increases significantly among utensils in salad bars. Traditional restaurants that offer a variety of food items appear to maintain the U^S and U^F alleles in relatively equal numbers, although the spork is rarely found. In contrast, certain chicken and taco chains support utensil populations consisting entirely of sporks, which we find intriguing.

Finally, access to these organisms easily facilitates the establishment of artificial populations for classroom study. The species is readily maintained with minimal space and nutrient requirements. These organisms survive with no difficulty in drawers, shoeboxes, or even freezer bags.

We have maintained a thriving population for years with prey items (uncooked beans and mini-marshmallows) purchased from local grocery stores.

Granted, our report on the life history traits of *U. plastica* is a spoof. However, we regularly use these plastic utensils to help our students gain a deeper understanding of natural selection and evolution (Table 1). In addition, we address a number of documented misconceptions regarding evolution with a fun and easy inquiry-based activity. Below we briefly describe a basic lesson that follows the 5E, a format that adopts a constructivist model of learning (Trowbridge & Bybee, 1990).

Table 1. Objectives for the lesson.

Upon completion of the lesson, students will be able to:
1. describe how particular traits increase the success of an organism in its environment.
2. explain how the process of natural selection operates.
3. define adaptation.
4. describe the role that variation in traits, caused by genetic mutation and sexual recombination, plays in natural selection.
5. define and recognize microevolution in a population.
6. explain how natural selection can cause microevolution.
7. contrast the effect that natural selection has on individuals and populations.
8. explain how evolution is the result of organisms interacting with their environments, but is not goal-oriented.

○ The Lesson

Engage

The lesson begins with a humorous discussion about the advantages and disadvantages of sporks. We announce our discovery that sporks and spoons are the same species, omitting any reference to forks. Our students then predict whether the spoon or spork is better adapted for a marshmallow environment and explain their reasoning. Most students choose the spork, but there are always a few that advocate for the spoon.

Explore

Before the spoon vs. spork debate wanes, we remind students that scientists reach conclusions based on evidence. We highlight the need for results from experimental research to determine the better competitor in a marshmallow environment. Data collection can be conducted in a number of ways, with more or less teacher guidance. What follows is the procedure we use in a 50-minute class period.

Figure 2. Students competing with utensils.

Students gather around a large table on which we scatter a bag or two of mini-marshmallows. Maximum group size can vary. We have conducted the activity with groups up to 36, amplifying the fun and intensity of competition. Small populations are prone to the random effects of genetic drift; a population size of 12 utensils (students) may be the minimum required to clearly demonstrate natural selection.

We supply them with a spoon or spork before explaining the objective: Capture as many prey items as possible in 20-30 seconds. Students simulate predation by competing to capture marshmallows. Individuals who capture the most are declared winners because they acquired enough resources to reproduce and pass on their genes. The need to replace the population for a second round of predation serves as an excellent opportunity for students to review simple Mendelian genetics. They use Punnett squares to determine the possible outcomes of various crosses. Actual offspring are determined by flipping a coin to see which allele each individual passes to its offspring (heads = U^S).

Students record the number of each phenotype in the population following several rounds of predation. With marshmallow prey, the number of spoons quickly decreases, while sporks and forks multiply over successive generations. A substantial change in the population requires only three or four rounds to demonstrate (Table 2).

Table 2. Actual population data for *U. plastica* over six generations. The marshmallow environment of Generations 1-4 was replaced with beans for Generations 5-6.

Generation	# Spoons	# Sporks	# Forks	# S alleles	# F alleles
1	11	11	0	33	11
2	7	14	1	28	16
3	4	16	2	24	20
4	3	13	6	19	25
5*	6	14	2	26	18
6*	8	13	1	29	15

Explain

Students easily grasp the role of natural selection as a mechanism for evolution, using population data on the board. They see allele frequencies change from one generation to the next (microevolution) because the U^F allele is more adaptive in marshmallow environments (Table 2). Students also clarify the idea that populations evolve, not individuals; they see that an organism's genotype does not change, the frequencies of alleles among a population do.

Through questions and discussion, we challenge students to confront their preconceptions about natural selection and evolution. This facilitates the integration of newly-acquired knowledge into a deeper understanding, rather than allow students to rely on rote memorization and potentially maintain misconceptions (Bransford et al., 2000).

Elaborate

We replace the marshmallows with uncooked lima beans, explaining that global climate change, or an invasive species, has altered the environment. Within two or three generations, the frequency of the U^S allele increases noticeably (Table 2), as the forks succumb to natural selection (beans cannot be stabbed). As long as two sporks remain, more fork offspring may be produced, but usually cannot survive the round.

Evaluate

We assess student understanding throughout the lesson, evaluating the reasoning behind student predictions and whether conclusions are based on evidence. A quiz, the questions we ask, and other assessment techniques are available in our detailed lesson plan available on the GVSU Integrated Science Web site (www.gvsu.edu/isci), through the "5E Lesson Plans" menu option.

○ Addressing Evolutionary Misconceptions

Natural selection and evolution are among the most commonly misunderstood biological concepts that we teach our students. The theoretical nature of these concepts challenges students who struggle with abstract thinking. Unfortunately, students can correctly make a set of logical choices that maintain or form new evolutionary misconceptions (Greene, 1990). We believe the concrete approach of our lesson reduces the likelihood of this occurring. This lesson requires students to reconcile their explanations of concepts with actual observations, testing their developing understanding and preconceptions of evolution (Jensen & Finley, 1996; Crow, 2004). In particular, we use *Spork & Beans* to address the following misconceptions identified in the literature.

1. Mutations are detrimental to fitness (Alters & Nelson, 2002). This activity illustrates that a mutation (U^S to U^F) may result in a more adaptive trait under certain environmental conditions.
2. Changes in traits are a result of need/use/disuse (Mayr, 1982; Brumby, 1984; Bishop & Anderson, 1990). Students can see that the spoon is capable of capturing prey and that the U^F allele is unnecessary.
3. Acquired characteristics are heritable (Mayr, 1982; Alters & Nelson, 2002). We point out to students that individuals who become adept at a particular feeding behavior do not pass on this skill to offspring.
4. Students do not recognize the importance of genetic variation (Mayr, 1982; Rutledge & Warden, 2000). We confront this misconception by suggesting that students simulate a round of predation with an all-spoon population!
5. Environmental conditions are not considered important in causing selective pressures (Rutledge & Warden, 2000). This activity clearly demonstrates how the environment (marshmallow or bean prey) can drive the evolution of a population.
6. Students do not recognize the role of reproductive success in evolution (Rutledge & Warden, 2000). A few rounds of predation emphasize that survival is not enough; they must pass on their genes to offspring to affect change in the population.
7. Evolutionary change is based on gradual modifications in traits, not the changing proportion of individuals with particular alleles (Mayr, 1982; Bishop & Anderson, 1990; Rutledge & Warden, 2000). By counting the number of individuals in the population, students see that the proportion of three distinct phenotypes varies from generation to generation. In the marshmallow environment, this lesson illustrates an increase in the frequency of the U^F allele as more individuals with that allele survive and reproduce.
8. Evolution is deterministic (Lord & Marino, 1993; Bishop & Anderson, 1990; Alters & Nelson, 2002). By altering the environment (replacing marshmallow prey with beans), we help students to evaluate the idea that evolution is working toward some predetermined endpoint. Students come to realize that evolution is the result of organisms interacting with current environmental conditions, and is not goal-oriented. •

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