Pancake Evolution: A Novel & Engaging Illustration of Natural Selection

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Abstract

Understanding the theory of natural selection is crucial for any student of biology, but many secondary and postsecondary students struggle with the concepts. We present a novel, engaging exercise to illustrate natural selection through making pancakes. After students make pancakes (representing offspring) with various ingredients (illustrating genetic diversity and allelic variation), other students (representing the environment) judge the pancakes on the basis of taste. Only the highest-ranking pancakes are made in a second generation (illustrating population change over time), and new ingredients are added. After several generations of pancakes, with each generation exposed to ever-changing "environments," students understand the fundamental concepts associated with the theory of natural selection.

Key Words: *Evolution; natural selection; pancakes.*

○ Introduction

Despite the primacy of evolutionary theory in the field of biology, a minority of individuals in the United States accept this fundamental concept (Miller et al., 2006). Educators have developed numerous methods to teach the concept of natural selection (e.g., Heim, 2002; Kalinowski et al., 2013; Hildebrand et al., 2014; Hongsermeier et al., 2017), but misconceptions among high school and college students are rampant (Gregory, 2009; Yates & Marek, 2015).

While no pedagogical technique is universal in its ability to promote scientific literacy, analogies are particularly helpful in explaining abstract scientific concepts because they promote higher-level thinking and the understanding of the new concepts (Gardner, 2016). One example of this is the use of familiar foods to illustrate complex scientific concepts. The use of food to illustrate scientific concepts has been shown to be more effective than standard science curricula for primary school students (Duffrin et al., 2010; Hovland et al., 2013), but few secondary and postsecondary science curricula utilize food. Here, we present a novel method to teach fundamental tenets of evolution through natural selection using pancakes and familiar food ingredients (see Table 1). These biology core ideas are requirements for meeting High School Next Generation Science Standards LS4B/LS4C and for all introductory college biology courses. All analogies have the potential for fostering misconceptions, so Table 1 also shows potential misconceptions.

Briefly, pancake batter is used to represent a shared genotypic background, to which variations (i.e., novel alleles or phenotypic traits) are introduced in the form of added ingredients. These novel "food alleles" – ingredients like chocolate, paprika, pickles, and bacon bits – represent variation at a food "gene." Students first make pancakes with a single random ingredient, representing acquisition of the first novel "food allele." The pancakes are then eaten, judged, and scored on the basis of their palatability, using the students' taste preferences as environmental selective pressures. Particularly delicious pancakes persist, representing an adaptive benefit of the novel allele, while unpalatable pancakes, given low scores, are abandoned (representing death without reproduction). Thus, the most delicious alleles in the first generation are perpetuated to the next generation, where new food genes similarly acquire novel alleles. This represents subsequent acquisition of new diversity at different genes. And by perpetuating this process of adding novel ingredients, tasting, and judging palatability across multiple rounds (i.e., generations), students illustrate the process of selection for adaptive combinations of alleles in a given environment and selection against maladaptive combinations.

○ Materials & Procedure

After preparation of pancake batter and ingredients, this laboratory can be completed in 60–90 minutes, making it conducive to both class and laboratory time periods. For each student group, materials needed include a portable electric hot-plate burner, small frying pan, spatula, pancake batter, and various ingredients (student food allergies and dietary restrictions influence selection of ingredients).

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Table 1. Representation of major components of natural selection, corresponding components in the laboratory exercise, and potential for misconceptions from the analogy.

Component of Selection & Evolution	Lab Component	Potential for Misconceptions
Shared genotypic background	Pancake batter	The origin of variation appears to be in the addition of elements (genes) to the organism, rather than in mutation and genetic recombination of existing genes.
Trait variation, de novo genetic diversity, alleles	Added ingredients	
Selective environmental pressure	Taste preferences, scoring	In nature, genotypes and phenotypes that are more likely to be eaten are less likely to increase in frequency in the population. The opposite is true in this activity.
Traits positively affecting survival are reproduced and thus are more common in the population	Ingredient perpetuation after generation 1	One common misconception is that individuals, rather than populations, evolve. With only two or three pancake generations, this misconception may be reinforced.
Distribution of traits in a population can change when conditions change	Generation 2 results from scoring	
Species and trait extinction/ elimination	Low scoring results in not using the ingredient in subsequent generations	

Table 2. Example ingredients used to illustrate how alleles can create different phenotypes.

"Gene"	"Allele 1"	"Allele 2"
Spice	Cumin	Paprika
Dairy	Cheddar cheese	Blue cheese
Vegetable	Kale	Pickles
Candy	Chocolate chip	Caramel
Condiment	Hot sauce	Mustard
Candy bar	Reese's Cup	Milky Way
Meat	Bacon bits	Vienna sausage

Table 3. Instructions for "Pancake Producers" (i.e., reproductive pairs).

Step 1	Prepare your batter with the assigned ingredient.
Step 2	Cook a single, large pancake (your offspring) in the provided pan on the burner with a setting of medium low.
Step 3	Cut your pancake into enough pieces for each Judge and distribute.
Step 4	Clean your pan and cooking area.
Step 5	You will now become a "Pancake Judge" for the next generation of pancakes.

A food-safe space is needed; we have used a physics laboratory and an outdoor classroom, but numerous other campus options are available.

First, students are divided into two large groups: "Pancake Producers" (with each pancake produced representing an offspring) and "Pancake Judges" (representing the environment in which offspring are born and, therefore, the selective pressure shaping population traits).

Pancake Producers are divided into groups of two or three students. Identical pancake batter is provided for all groups, representing similar genetic composition, and each group is then given a unique ingredient (for examples, see Table 2). Clear instructions are given to each Pancake Producer group and each Judge (see Tables 3 and 4). Once a single large pancake with the novel ingredient is made, the pancake is sliced into small pieces and distributed to the Judges for a "blind" rating on a scale from 1 (completely inedible) to 10 (delicious); instructors can create their own taste scale. A high score represents successful reproductions of the recipe (or the offspring, following the analogy; for an example, see Table 5, generation 1).

After tabulating the results of generation 1, the previous Judges become the new Pancake Producers, and the two top-ranking pancake ingredients are used in the next batch. Half of the newly assigned Pancake Producers will use winning ingredient 1 from generation 1, and the other half winning ingredient 2. Each producer group is also assigned a new ingredient at random (via coin flip or use of a random number generator; see Table 5, generation 2). Thus, during the second generation, each pancake will have two ingredients, and the

Table 4. Instructions for "Pancake Judges" (i.e., the environment).

Step 1	With a blindfold on, taste each pancake piece and, without input from others, rate it from 1 to 10 (think about a "9" being a pancake you would definitely make again, a "6" being one you might make again, and a "3" being one you would not make).
Step 2	Input your data on the provided worksheet for each pancake.
Step 3	You will now become a "Pancake Producer" for the next generation of pancakes.

Table 5. Example results from "Pancake Judges" after generation 1 and generation 2. After generation 1, Reese's Cups and cheddar cheese pancakes were remade in generation 2, each with another additional ingredient. Unexpected results often occur after generation 2 (such as cheese + oregano, which students said tasted like pizza), illustrating that evolution often results in unpredictable results based on the environment.

Generation 1	Reese's Cup	Cheddar Cheese	Vienna Sausage	Kale	Pickle	Mustard
Student 1	8	9	4	3	4	2
Student 2	9	7	5	1	3	1
Student 3	7	8	3	2	3	4
Student 4	7	9	4	1	3	3
Student 5	9	9	4	3	4	3
Student 6	9	8	4	5	6	2
Student 7	9	7	8	5	6	3
Student 8	8.5	7	5	2	2	2
Student 9	8.5	6	5	2	2	1
Student 10	8	7	4	3	2	2
Gen. 1 Average	**8.3**	**7.7**	**4.6**	**2.7**	**3.5**	**2.3**
Generation 2	**Reese's + Curry**	**Reese's + Oregano**	**Reese's + Hot Sauce**	**Cheese + Curry**	**Cheese + Oregano**	**Cheese + Hot Sauce**
Student 1	9	9	8	9	9	8
Student 2	10	5	4	8	8	1
Student 3	8	8	9	1	9	1
Student 4	8	8	6	8	9	1
Student 5	9	6	4	5	6	1
Student 6	8	7	8	9	9	2
Student 7	9	7	9	9	9	5
Student 8	5	5	7	4	9	4
Student 9	6	5	8	5	4	8
Student 10	4	4	3	4	7	1
Student 11	7	3	8	4	7	1
Student 12	6	5	3	5	5	1
Gen. 2 Average	**7.4**	**6**	**6.4**	**5.9**	**7.6**	**2.8**

environment has changed. If time allows, a third generation of pancakes can be produced using the same method.

For advanced learners, modifications to this laboratory can easily be made to illustrate more complex evolutionary concepts. Table 6 presents alterations to the protocol that can be used as analogies for genetic drift, neutral theory, evidence for evolution, and cladistics, and instructors are encouraged to develop other modifications.

○ Assessment of the Pancake Demonstration

Two methods were used to assess the ability of this laboratory to improve student understanding of natural selection: (1) evaluation of scores on natural selection questions on examinations, compared to scores on other topics on the same examinations; and (2) evaluation of student lab reports in which students were asked to write a

Table 6. Example modifications of the standard lab protocol to teach advanced evolutionary concepts.

Advanced Concept	Modification of Standard Procedure
Genetic drift after bottleneck	During the second generation of pancake production, a "surprise" power loss is applied to all but one burner. As a result, the only pancake produced and, thus, reproduced will be the one from the functional burner.
Neutral theory	Neutral theory of molecular evolution suggests that for some alleles there is no selective advantage in variants; this can be illustrated by shifting from one form of a food to another, very similar, one. For instance, the change from a Reese's Cup to a Reese's Egg or Tree in a blindfolded taste test shows no difference. Students are then challenged to think about this in the context of human traits with questions such as "Are there traits that vary from person to person or population to population that do not have any impact on fitness?" This is a springboard for considerations of how these traits might change over time without the constraints of fitness on frequencies.
Evidence for evolution	After several generations of creating and judging pancakes, students are asked to imagine that the pancakes they made are preserved in an anaerobic environment for millions of years. Students are then asked what could be analyzed to reconstruct the evolutionary history of the pancakes. Appearance of ingredients (phenotype of fossils), chemical analysis of the ingredients (genotype of fossils), and ingredient geographic distribution through geological time (biogeography) are examples of answers.
Clades and monophyletic groups	After two rounds of making and judging pancakes, introduce the concept of cladistics and guide the students in constructing clades based on similarities in ingredients.

Table 7. Representative quiz and examination questions, showing the percentage of students answering the question correctly (n = 78).

Question	% Students Correct
During the pancake lab, you illustrated natural selection. Match the following components with the correct natural selection term in questions 1–4: a. ingredients, b. Pancake Judges, c. pancake batter, d. winning pancakes.	
1. Allele variation	94
2. Environment	86
3. Ancestral organism	85
4. Surviving population	100
5. All of the following are correct descriptions of the way that natural selection occurs, except that a. populations are composed of individuals that have variation in traits b. individuals change traits during their lifetime, passing on these traits to offspring c. populations have more offspring than can survive in the environment d. individuals more suited to the environment survive, passing on their traits to offspring	78
6. *Evolution* is a term that is often misinterpreted. Which of the following is the unit that evolves, or changes, over time? a. An element b. An atom c. An individual d. A population	90

paragraph describing how the activity illustrated the theory of natural selection using the following terms: *adaptation*, *selection*, *genetic variation*, *trait variation*, *environment*, and *population*.

Table 7 shows that, depending on the question, between 78% and 100% of students correctly answered natural selection questions. The total quiz and exam averages (covering topics other than evolution) were 58% and 73%, respectively, showing greater understanding of natural selection. A paired t-test (alpha level 0.05) indicated that students answered more natural selection questions correctly (M = 88.4, SD = 16.2) than non–natural selection questions (M = 71.4, SD = 13.7) on the same examination ($t_{68} = 2.0$, $p < 0.001$). In addition, 100% of students attempting the lab report assignment at the conclusion of the activity correctly explained how the lab illustrated natural selection (n = 75).

○ Conclusions

We have found this short laboratory exercise to be an engaging method to teach fundamental principles of natural selection. This interactive activity uses an analogy to assist student learning by building on students' own relevant knowledge, a pedagogically supported technique (Glynn, 1994).

Such noncontroversial activities are particularly needed in regions where lack of acceptance of evolution is founded in identity-protective cognition. In such areas, simply providing scientific information fails to foster acceptance of scientific conclusions, and other means of teaching the concepts are necessary (Walker et al., 2017). Our students truly enjoy the pancake-making exercise, and evidence shows that they learn much from this demonstration. Many common misconceptions, such as "survival of the fittest" and "individual evolution," are easily identified and articulated by students after completing this lab.

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