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ABSTRACT

Considerable anecdotal evidence indicates that some of the most difficult concepts that both high school and undergraduate elementary-education students struggle with are those surrounding evolutionary principles, especially speciation. It's no wonder that entry-level biology students are confused, when biologists have multiple definitions of "species." We developed this speciation activity to provide clarity and allow students a hands-on experience with a speciation model.

Key Words: Speciation; phenotype; genotype; evolution.

○ Teacher Background

A "species" is commonly defined as a group of individuals that actually or potentially reproduce in nature, but this definition clearly has limits. Although many separate species *could* breed with one another, they may avoid doing so because of differences in reproductive timing, reproductive behaviors, reproductive physiology, or anatomy. Another possibility is that separate species breed but produce sterile offspring. For example, a horse and donkey are different species (in fact, they have different numbers of chromosomes), but when a female horse and a male donkey reproduce, they deliver a mule. Mules are usually sterile but have, on rare occasions, produced offspring (Lofholm, 2007). Still, we consider horses and donkeys separate species. Therefore, the concept of speciation (how new species are formed) is a complicated one and is often confusing for students to grasp. Speciation is further complicated by the number of different definitions biologists have proposed for identifying an individual species. Some of these definitions include species recognition, phenetic, phylogenetic, and biological species concepts (Wilkins, 2006).

Our activity strives to explain one example of speciation, the biological species concept. This concept, a long-standing and commonly used definition of "species" in textbooks, states that animals capable of interbreeding

and producing fertile offspring are considered the same species. Speciation occurs when separate populations become so genetically different that they can no longer mate successfully with each other. This can occur in different ways for different species, but most commonly geographic isolation (e.g., by mountains, oceans, or rivers) is an important part of the process.

We explained what could happen after geographic isolation prevented interbreeding between two portions of a population. As time passed, these populations become more distinct through genetic drift. We further discussed how, in some cases, the two new populations are considered "subspecies" if they are able to produce fertile offspring when the two populations have subsequent contact. However, if they are unable to produce fertile offspring after reintroduction because they either cannot or will not breed, they are considered different biological species. We used this "geographic isolation" concept to portray a potential speciation scenario in birds for the activity.

Materials (for a class size of ~28)

- 300 paper clips (6 colors × 50 of each color)
- 28 tag-board Tropical Bird discs (Figure 1)
- 12 small plastic cups for the paper clips to refill alleles (not required but helps with organization)

Lesson Plan

To create geographic isolation, we organized our room so that there was an initial starting location and two separate future locations ("islands") to which the birds would be displaced (three locations total). We had long lab tables on either side of the room, which were our islands, and a central instructor's lab table, which served as our "Mainland population area."

We started by distributing the tag-board discs and allowed students to examine them, while asking students to explain the phenotypes and genotypes we were tracking. We asked for

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eight volunteers, who became our Mainland population of tropical birds. Each volunteer selected his or her alleles (color of paper clips), and each allele (paper clip) was clipped onto the appropriate section of the disc. The information for homozygous and heterozygous combinations are shown in Figure 1. We recorded the phenotypes and genotypes in data table A (Figure 2). Our goal was for students to understand how speciation could occur without needing to understand the details of Hardy-Weinberg.

These eight students formed mating pairs and selected classmates to become their offspring. Each mating pair created only one offspring per round. The parental generation selected one of their alleles for each trait to donate to their offspring, who attached them to their disc. The parental group then had to replace the paper clips they passed on to their offspring. Again, total genotypes and phenotypes were recorded. Now the Mainland population was 12.

We explained that the Mainland population was hit by a hurricane and half of the population was thrown north to a tropical island and half south to a separate tropical island. We randomized the divisions by having the students count off to twelve and rolled

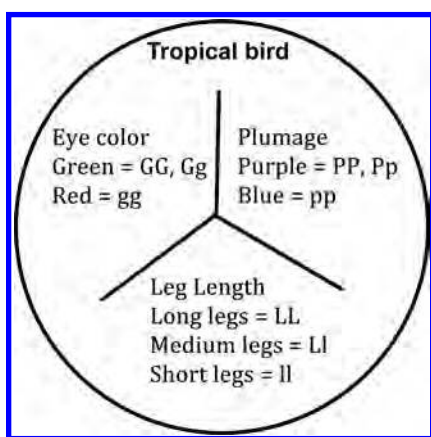


Figure 1. Game-piece example.

Population	Gene and Trait Distribution Over Time ^A										Sample data- no selective pressures given						
	Numbers of Individuals of Each Genotype										Number of Individuals of Each Different Phenotype						
	Green Green GG	Green Red Gg	Red Red gg	Purple Purple PP	Purple Blue Pp	Blue Blue pp	Orange Orange LL	Orange Yellow Ll	Yellow Yellow ll	Green	Red	Purple	Blue	Long	Med	Short	
Initial	1	6	1	2	5	1	2	5	1	7	1	7	1	3	4	1	
1 st breeding	1	9	2	3	8	1	3	2	2	10	2	11	1	3	7	2	
2 nd breeding South	2	5	2	2	5	2	3	3	4	7	2	7	2	3	2	4	
3 rd breeding South	1	5	2	1	5	2	1	2	5	6	2	6	2	1	2	5	
4 th breeding South	1	4	1	1	3	2	1	2	3	5	1	4	2	1	2	3	
5 th - 2 nd breeding S	0	5	1	0	5	1	0	2	4	5	1	5	1	0	2	4	
2 nd breeding North	1	6	2	2	6	3	3	6	0	7	2	8	1	3	6	0	
3 rd Breeding North	1	3	2	1	4	1	3	3	0	4	2	5	1	3	3	0	
4 th breeding North	3	2	0	0	4	1	5	0	0	5	0	4	1	5	0	0	
5 th - 2 nd breeding N	0	2	2	0	4	0	1	2	1	2	2	4	0	1	2	1	

Figure 2. Example data table: no selective pressure.

two dice to select six members to go north. Students continued to mate within their own island, adding individuals. Once birds had mated for three generations, they died and those students returned to the class group as possible offspring selections. Each group tracked the genotypes and phenotypes for each round of mating. If there was an odd number, one student mated twice. (This second mating did not count against his or her three-generation mating limit.)

At the end of 8–10 generations, the model was stopped and the students separated into one of the following groupings: (1) according to leg length, (2) plumage, or (3) eye color. This allowed the class to see the comparisons between the islands for each phenotype.

○ Teaching Strategies

If you want students to use the gene pools to practice allele selection, genotypes and phenotypes, or the Hardy-Weinberg equation, use the student instructions and data table A (Figure 2). If your goal is for students to acknowledge that speciation can occur in populations separated (e.g., geographically) with different selective pressures, then use student instructions and data table B (Figure 3) or no table. If you do not use a table, you can have each pair of populations (North Island vs. South Island) separate into phenotypes along a room length, and then have students compare the populations.

Examples of selective pressures are given below. The easiest way for students to discuss the specific selective pressure is to go through a round of the activity, utilizing only one selective pressure at a time. By using the separate rounds, students can look at the influences of each selective pressure alone.

○ Founder Effect

A “founder effect” occurs when a new population is started by a few members of the original population. The new population has less genetic variation than the original one. By completing the activity as stated above, you will always see a founder effect. To demonstrate the activity without a founder effect, you must start out with identical genotypes on each of the two “islands.” We suggest that you not implement any other selective pressures on either North Island or South Island populations. In this way, students can compare how movements of specific gene pools can radically change the final populations’ gene pools.

Selective Pressure: Avoiding Predation

Add the selective pressure of different leg lengths being an advantage on different islands. On North Island, birds with short legs (ll) survive because they are able to hide from avian predators in short scrub bush. South Island birds need

Changes in Traits When Populations Are Isolated ^B							
Sample data							
Population	Number of Individuals with Each Phenotype						
	Eye Color		Plumage		Leg Length		
	Green (GG, Gg)	Red (gg)	Purple (PP, Pp)	Blue (pp)	Long (LL)	Medium (L)	Short (ll)
Mainland	7	1	7	1	3	4	1
Final South	4	4	6	2	3	3	2
Final North	3	5	4	4	4	3	3

Isolation type = geographic
 Selection pressure = Sexual selection for Plumage color (Blue was selected for on the North Island and the South Island had no selection pressure.)

Figure 3. Example data table: sexual selection pressure.

long legs (LL) because they are better able to flee their reptilian predators. If a bird (student) has long legs on North Island, he or she will not survive to reproduce. If a bird (student) has short legs on South Island, he or she will not survive to reproduce. On either island, if a bird (student) has medium legs, he or she will reproduce.

Selective Pressure: Sexual Preference

The plumage on the male birds is often bright, usually as a result of selective pressures exerted by females for bright plumage in males. South Island has a selective preference for blue plumage, with no selective pressure on North Island. If South Island has an odd number, then the student who mates twice must be blue (if available).

We conducted this activity with eight separate sections of an entry-level biology class designed for elementary education majors. We found, through discussion and exam answers, that these students had a clearer understanding of speciation's role in the larger cross-cutting concept of evolution after this activity. We plan to conduct research on the impact of this activity on students' understanding of speciation in the future. Anecdotally, students report a clearer understanding of the tie between genetic drift and speciation. When students were asked at the end of the semester to identify one significant biology concept they had learned, one student said:

One thing I learned this semester is that plants and animals adapt according to their environment and resources. I've never really

understood evolution or believed in it, but the studies this semester taught me that species have adapted and changed throughout time based upon the resources they had to survive. For example, learning about birds and doing the activity of the birds that lived on different islands and how they adapted differently because they had different resources to survive. (J. Benda, personal communication, May 5, 2014)

Supplemental Online Resources

<https://drive.google.com/folderview?id=0BxgTK9pSNg0ycV85NjNVdlRyRGM&usp=sharing>

Additional Resources

- McComas, W.F. (Ed.) (2006). *Investigating Evolutionary Biology in the Laboratory*. Dubuque, IA: Kendall/Hunt.
- Shubin, N. (2009). *Your Inner Fish*. New York, NY: Vintage.
- Weiner, J. (1994). *The Beak of the Finch*. New York, NY: Vintage.
- Howard Hughes Medical Institute (2013). *The origin of species*. [Online.] Available at <http://www.hhmi.org/biointeractive/origin-species>.

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