HOW-TO-DO-IT

A Student Activity that Simulates Evolution

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Abstract

We describe an activity that uses cards to simulate evolution. The mechanism of the evolutionary pressure in the simulation is clearly indicated for the students. This simulation is useful for allowing student experimentation by varying conditions.

Key Words: *Evolution; phenotype; genotype; evolutionary pressure; complete dominance; incomplete dominance.*

Evolution is a sensitive subject. The assault on the teaching of this central theory of biology by one state school board or another is an almost annual event. Many students are resistant to the idea of evolution on the basis of religious beliefs. Confronting these students directly is often unproductive (Moore, 2009).

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This activity provides a way to make the fundamental concepts of evolution more understandable and potentially more acceptable to students by allowing them to simulate the validity of a simplified model. Students can use this activity to explore many effects on the genetic change in a population using a hands-on, active-learning approach. The small population used in the model may help overcome the issue of large numbers suggested by Leonard (2009).

This activity is a card-based simulation of evolution based on the "Dropping Your Genes" activity (Atkins & Roderick, 1991). Cards simulate simple genotypes for plant size and plant taste. Each side of each card represents a single allele; thus, a plant is represented by two cards, one for taste and one for size. Each side of the taste card represents an allele for taste; each side of the size card represents a size allele. For example, a short bitter plant might be represented by one card with lowercase t's on each side and another with lowercase s's on each side (referred to as "ttss"). A tall and sweet plant (TTSS) has one card with capital T's on both sides and another with capital S's on both sides. Reproduction is simulated by pairing the cards from reproducing plants (determined by rules, which can be varied) and then dropping the cards; the allele that is face-up is the allele that is passed on to the next generation. In the case of the two examples provided, the face-up cards must be T, t, S, and s. The combination of the alleles from all cards represents the genome of the next-generation plant (TtSs in this case).

Predator pressure (dinosaurs eating the plants), simulated by a set of "eating rules" based on a preference for certain phenotypes, is then used to remove the most desirable plants from the model population (including the parent plants and the daughter plants). In the example below, the dinosaurs prefer tall and sweet plants. After a number of the most desirable plants are consumed, the remaining plants reproduce again. Ultimately, this leads to the reduction or elimination of the most desirable (to the dinosaurs) plant phenotypes. The model is set so that a steady-state population is maintained; the dinosaurs eat exactly the number of plants that are produced by reproduction. The simulation thus provides examples of fixation (Figure 1).

If the predator pressure is designed in certain ways (for example, if either tall, bitter plants, or short, sweet plants are undesirable to the dinosaurs), fixation into two groups may occur in the simulation. It can be explained to students that this might give rise to speciation due to decreased crossbreeding between the two groups, or other predators in other geographic regions.

This activity presumes that students have received basic instruction in constructing Punnett squares and predicting offspring genotypes. The model allows for development of students' graphing and data-analysis skills. It could promote a discussion of the role and utility of modeling in science. A suggested strategy is to assign half of the class to do the incomplete dominance approach and half to do the complete dominance approach.

The American Biology Teacher, Vol. 74, No. 2, pages 117–120. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2012.74.2.11

The effects of population sizes, genetically different initial populations, incomplete dominance versus complete dominance, and varied predator pressure (how picky they are about what they eat) can be easily explored using this simulation. The student handout for this activity follows.

○ Student Handout: Genetics & Evolution Activity

To illustrate the effects of a predator on a population, we will consider a hypothetical plant from the Jurassic period and a dinosaur species that eats the plant. The dinosaurs prefer the plants to be tall and sweet. What will happen over several generations as the dinosaurs preferentially eat the tallest and sweetest plants?

To model the genetics of the plant, we'll use the method developed by Atkins and Roderick (1991). The plant will be considered to have one gene for each trait (taste and height). Note that this is a big simplification, but it will make our job easier and still allow us to explore the effects of the predator pressure.

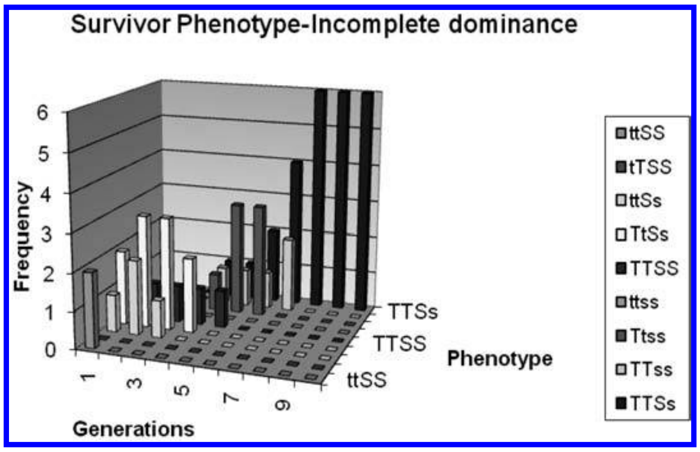

Figure 1. These student-generated data illustrate a case in which the diverse initial population (2 ttSS, 1 ttSs, 2 TtSs, 1 TTSS), when subject to the pressure of a predator that prefers tall (TT) and sweet (SS) under conditions in which incomplete dominance is assumed, resulted in a uniform population of TTSs plants in 8 generations.

Table 1. Combined genotypes and phenotypes for incomplete dominance model.

Incomplete Dominance	SS	Ss	ss
TT	TTSS Tall & sweet	TTSs Tall & semisweet	TTss Tall & bitter
Tt	TtSS Medium & sweet	TtSs Medium & semisweet	Ttss Medium & bitter
Tt	ttSS Short & sweet	ttSs Short & semisweet	ttss Short & bitter

The taste gene can thus have either a sweet "S" or bitter "s" allele. Each plant will have two alleles; thus, the possible genotype combinations are SS, Ss, or ss. Similarly for height, the genotype possibilities will be TT, Tt, or tt. Depending on whether we use incomplete dominance or complete dominance, the phenotypes are given below in Tables 1 and 2.

The dinosaurs' eating behavior will be modeled by a set of eating rules that follows the preference for tall and sweet plants (Table 3). To keep our model simple, we are going to consider a grid of six plants (Table 4). In Table 14, tabulate the gene pools and genotypes present for each generation's survivors (after the dinosaur eats).

To greatly simplify the plant reproduction, we will mate them in pairs, using each one once, by arranging them in alphabetical order and mating the first one in the top half to the first one in the bottom half. Each new plant is named using the next available letter. Thus, A and D mate to produce G; B and E mate to produce H; and C and F mate to produce I. To determine the genotype of the daughter plants, make cards with each allele of the genotype written on either side (thus, A is represented by two cards, one with T & T on both sides

Table 2. Combined genotypes and phenotypes for complete dominance model.

Complete Dominance	SS	Ss	ss
TT	TTSS Tall & sweet	TTSs Tall & sweet	TTss Tall & bitter
Tt	TtSS Tall & sweet	TtSs Tall & sweet	Ttss Tall & bitter
Tt	ttSS Short & sweet	ttSs Short & sweet	ttss Short & bitter

Table 3. Dinosaur eating rules.

Phenotype, in Decreasing Preference	Genotype–Incomplete Dominance	Genotype–Complete Dominance
Tall & sweet	TTSS	TTSS, TTSs, TtSS, TtSs
Medium & sweet	TtSS	–
Short & sweet	ttSS	ttSS, ttSs
Tall & semisweet	TTSs	–
Medium & semisweet	TtSs	–
Short & semisweet	ttSs	–
Tall & bitter	TTss	TTss, Ttss
Medium & bitter	Ttss	–
Short & bitter	ttss	ttss

Table 4. First generation.

(A) TTSS	(D) TtSs
(B) ttSS	(E) TtSs
(C) ttSS	(F) ttSs

and one with S & S on both sides; E has two cards with T & t on opposite sides of one card and S & s on opposite sides of the other). Drop the four cards for the two parent plants, and the genotypes facing up are the ones of the daughter plant.

Complete Table 5 to show your results for G, H, I.

Now apply the eating rules in Table 3 (your instructor will tell you whether to use incomplete or complete dominance; be sure to indicate this in Table 14). Start with the beginning of the alphabet and go toward the end. The dinosaur will eat the first three plants that are its top priority. If enough top-priority plants are not available, start again and use the next-lower priority. Mark a single line through the eaten plants. Tabulate the results for that generation in Table 14 and place the surviving plants in alphabetical order in Table 6. Use the same mating procedure as before to determine plants J, K, and L.

Repeat the eating, rewriting, and mating procedure to complete 10 generations of data in Tables 7–13, recording survivor data after each eating cycle in Table 14.

Table 5. Second generation.

(A) TTSS	(D) TtSs	(G)
(B) ttSS	(E) TtSs	(H)
(C) ttSS	(F) ttSs	(I)

Table 6. Third generation.

		(J)
		(K)
		(L)

Table 7. Fourth generation.

		(M)
		(N)
		(O)

Table 8. Fifth generation.

		(P)
		(Q)
		(R)

Table 9. Sixth generation.

		(S)
		(T)
		(U)

Table 10. Seventh generation.

		(V)
		(W)
		(X)

Table 11. Eight generation.

		(Y)
		(Z)
		(AA)

Table 12. Ninth generation.

		(AB)
		(AC)
		(AD)

Table 13. Tenth generation.

		(AE)
		(AF)
		(AG)

Table 14. Data summary for ________________ dominance.

Generation	Allelle Frequency				Genotypes								
	T	t	S	s	TTSS	TtSS	ttSS	TTSs	TtSs	ttSs	TTss	Ttss	ttss
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

○ Data Analysis & Conclusions

1. Use Punnett squares to predict the percentage chance of each possible genotype offspring of B and E.
2. Make graphs of allele frequency vs. generation. Summarize the effects of the predator pressure in your model on the allele frequency.
3. Make graphs of genotype vs. generation. Summarize the effects of the predator pressure in your model on the genotype.
4. Make graphs of phenotype vs. generation. Summarize the effects of the predator pressure in your model on the phenotype.
5. Compare your results with those of other students using the same and different dominance models. How consistent were the results if the dominance model was the same? What patterns, if any, are observed between the two dominance models?

Suggested further exploration:

1. Modify the experiment to make the reproduction random.
2. Modify the experiment to increase the sample size.
3. Modify the experiment to make the dinosaur eating preference operable only 67% of the time (1–4 on a six-sided die).

References

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