A Simulation of COEVOLUTION Using Playing Cards

ROBERT TATINA

Because of its ability to unite so many disparate facts and concepts, the theory of descent with modification is considered the linchpin of biology (Dobzhansky, 1973). One of the more important explanations of how descent with modification occurs is the theory of natural selection (Darwin, 1890). In spite of the importance of these theories, students may be leaving biology classrooms at all levels without a proper understanding of them (See Brumby, 1979; Demastes et al., 1995; Fahrenwald, 1999; Ferrari & Chi, 1998; Tatina, 1989; Zimmerman, 1987).

Responding to the importance of teaching about evolution, a plethora of authors have published articles that provide activities designed to help students understand evolution. McComas (1991) listed 18 such activities published in the non-textbook/laboratory manual literature. I found an additional 16 articles in a search of the ERIC database using "natural selection" as the keyword and three more in very recent literature. Citations for these are listed in the Appendix. Several of these articles describe activities that use simulations to elucidate concepts associated with natural selection. None, however, examine the reciprocal effects of two species as they interact.

Darwin (1890) described the consequences of the interactions of two species in these words: "... if any one species does not become modified and improved in a corresponding degree with its competitors, it will be exterminated." Van Valen (1973), in examining rates of extinctions, mathematically explained the coevolution of two species as a "zero sum game," dubbing it the Red Queen's Hypothesis. Later Dawkins (1996) described coevolution using the analogy of an "arms race," in which two superpowers keep improving their weaponry only to find that neither has gained an increased advantage relative to the other. A similar absence of relative gain holds for coexisting species that interact competitively or as predator/prey or parasite/host.

In this article, I describe a simulation of a coevolutionary "arms race" and introduce a way of teaching it that lets students use the theory of natural selection to explain the outcomes of the simulation. The simulation uses the numerical cards from an UNO® playing card deck (marketed by International Games Inc., 1551 Plainfield Road, Joliet, IL 60435; available at most large department stores) to represent the speeds of individuals in populations of predators and their prey. (Alternatively, numbered index cards or regular playing cards may be substituted.) Simple descriptive statistics are then used to illustrate changes in the two populations.

ROBERT TATINA is Professor of Biology, Dakota Wesleyan University, Mitchell, SD 57301; e-mail: rotatina@dwu.edu.

Materials

- Two UNO® card games or four decks of regular playing cards for three pairs of teams, 16 cards per team. See Table 1 for card distribution to each team.
- 12 envelopes, each marked with a "Predator" or "Prey" designation and a code letter to show predator/prey pairs (e.g., Predator A with Prey A, Predator B with Prey B, etc).

Table 1. Card distribution for each team.

TEAM	CARDS									
	#0	#1	#2	#3	#4	#5	#6	#7	#8	#9
Predator A	1	2	10	2	1					
Prey A		1	2	10	2	1				
Predator B			1	2	10	2	1			
Prey B				1	2	10	2	1		
Predator C					1	2	10	2	1	
Prey C						1	2	10	2	1

The Simulation

In my mixed majors introductory biology classes, I have teams of several individuals who operate as a unit. To initiate the simulation, each of these teams receives an envelope containing 16 numbered UNO® cards and a label indicating whether they represent a prey or predator population and with which species they have a predator or prey relationship. Each card in the envelope represents an individual and its running speed. In the predator/prey pair envelopes, the cards form frequency distributions of running speeds such that the prey population on average is slightly faster than the predator population.

To put the game in the context of a real coevolutionary relationship, I introduce the behaviors of predators and prey either by verbal description or by showing a video. My most used example is developed about cheetahs and gazelles, in which a cheetah stalks gazelles until it gets close enough to one to initiate a chase. From then it becomes a foot race for both the gazelle and the cheetah, the winner outrunning (and usually outmaneuvering) the loser. I then instruct the class that its envelopes contain a set of numbered cards that represent either a population of gazelles or cheetahs and that the students are to follow these rules in playing the game:

Rules of Play

1. Each team is a population of predators or prey and gets 16 character cards, each with a running speed on it. Thus, each card represents a different individual in the population. See the Materials section for the numerical values of the cards.
2. Each team secretly calculates the average running speed of its population from the numbers on its cards, shuffles the cards, and then places the cards in a pile face down between its team members and its opponent's team members.
3. Play begins as each team simultaneously turns one card face up to represent the interaction of a predator and its prey.
4. The outcome of the interaction depends upon the speeds of the predator and the prey. If the predator is faster than the prey (all other things being equal), the predator will capture the prey and consume it; otherwise the prey outruns the predator and escapes, while the predator starves. (In nature predator/prey interactions are not this simple since the predator may not starve because it failed to capture a particular prey.) In the event of a tie, a coin toss will be used to determine the outcome.
5. At the end of the encounter, the victor (the team with the higher point value on the card showing) keeps its winning card face-up in a new pile; the loser turns its card face down in a separate new pile.
6. The game continues with each team revealing one card at a time, with the winner of the predator-prey interaction placing its winning card in a face-up pile and the loser placing its card in a face-down pile, until all 16 interactions have been decided.
7. Each team then calculates the average speed of the survivors (face-up cards).
8. Additional rounds of the simulation may be played after forming new populations based on the average speed of the survivors of the previous round. To do this, each team multiplies the average speed of its survivors by 16 and then selects 16 cards whose values total 16 times the average speed of the survivors. These 16 cards become the next generation and the game continues as described in Steps #3 to #7.

Post-Game Discussion

When the game is over, I ask the groups for the before-and-after average speeds of their population, which I display for all to see. Table 2 shows an example of the outcomes of 12 simulations produced by two of my classes. It should be noted that the average speed of most of the populations increased and that overall the predator populations and their prey changed little relative to one another. Then I ask the groups to discuss the following:

1. What happened to the average speed of the predator and prey population in your game? In all games? (Because of the randomness of encounters in the game, not all populations will show an increase; however the majority will because of the "stacked" decks. If some do not, I ask for an explanation, expecting to hear about the effects of chance.)
2. Using the postulates of the Theory of Natural Selection, explain your outcome if the cards represented real populations that behaved as the cards do in the game. Here I am looking for them to apply the postulates that:
   - within a population, individuals vary (in the simulation they vary in speed, i.e., different speeds are different phenotypes)
   - there is a struggle for survival among different phenotypes leading to
   - differential survival (and reproduction) of those phenotypes.
3. If the population at the end of the game represents the reproducers, how will the next generation compare to the generation at the start of the game? Why? (They should indicate that, if speed is inherited, the average speed of the population should increase because the

Table 2. Average speeds of predator and prey populations before and after a one-round simulation. See Materials section for descriptions of predator/prey deck composition.

		PREDATOR			PREY		
Trial Number	Predator/Prey	Before	After	Ave. Gain	Before	After	Ave. Gain
1	A/A	2.00	3.00	1.00	3.00	3.20	0.20
2	A/A	2.00	2.60	0.60	3.00	3.20	0.20
3	A/A	2.00	2.67	0.67	3.00	3.23	0.23
4	A/A	2.00	3.00	1.00	3.00	3.15	0.15
5	B/B	4.00	5.00	1.00	5.00	5.07	0.07
6	B/B	4.00	5.00	1.00	5.00	5.15	0.15
7	B/B	4.00	4.70	0.70	5.00	5.25	0.25
8	B/B	4.00	5.00	1.00	5.00	5.00	0.00
9	C/C	6.00	7.00	1.00	7.00	7.20	0.20
10	C/C	6.00	7.30	1.30	7.00	7.00	0.00
11	C/C	6.00	6.75	0.75	7.00	7.25	0.25
12	C/C	6.00	6.25	0.25	7.00	7.25	0.25

survivors are generally faster individuals and will be the reproducers.)

4. To reinforce the premise that it is the average speed of the population that is changing, I ask the groups to consider whether the speed of the individual increases. If they think within the context of the simulation alone, they should realize that the number on a card, which represents the speed of an individual, cannot change. However, as individuals of slower speed are lost from the population, its average speed increases. The same is true of the action of natural selection. As a consequence of the unequal survival and reproduction of different genotypes, a population changes over generations. If they think about physical training increasing the speed of an organism, they might say speed increases. This leads to discussing whether that kind of gain is heritable and a consideration of the inheritance of acquired characteristics.

If more than one round is played, have the students plot the average speed of the predator and of the prey as a function of generation number. Then ask the class to describe what the graph portrays. They should see a somewhat parallel increase in speed for both populations, which is what the Red Queen's Hypothesis (Van Valen, 1973) would predict for real interacting populations.

One round of the simulation followed by discussion can be completed in a 50-minute class period. If done in grades 9-12, the activity would meet the following content standards of the National Research Council (1996): "A. understanding about scientific inquiry" (specifically, using theory to explain observations) and "C. an understanding of biological evolution."

Acknowledgment

Two reviewers suggested changes that significantly improved this paper. Special thanks go to the reviewer who suggested additional rounds of the game.

References

Brumby, M. (1979). Problems learning the concept of natural selection. *Journal of Biological Education, 13*(2), 119-122.

Darwin, C. (1890). *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life, 6th Edition.* New York, NY: D. Appleton and Company.

Dawkins, R. (1996). *The Blind Watchmaker.* New York, NY: W.W. Norton & Company.

Demastes, S.S., Settlage, Jr., J. & Good, R. (1995). Students' conception of natural selection and its role in evolution: Cases of replication and comparison. *Journal of Research in Science Teaching, 32*(5), 535-550.

Dobzhansky, T. (1973). Nothing in biology makes sense except in light of evolution. *The American Biology Teacher, 35*(3), 125-129.

Fahrenwald, C.R. (1999). Biology teachers' acceptance and understanding of evolution and the nature of science. Ph. D. Dissertation, University of South Dakota.

Ferrari, M. & Chi, M.T.H. (1998). The nature of naive explanations of natural selection. *International Journal of Science Education, 20*(10), 1231-1256.

McComas, W.F. (1991). Resources for teaching evolutionary biology labs: An analysis. *The American Biology Teacher, 53*(4), 205-209.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

Stebbins, R.C. & Allen, B. (1975). Simulating evolution. *The American Biology Teacher, 37*(4), 206-211.

Tatina, R. (1989). South Dakota high school biology teachers and the teaching of evolution & creationism. *The American Biology Teacher, 51*(5), 275-280.

Van Valen, L. (1973). A new evolutionary law. *Evolutionary Theory, 1,* 1-30.

Zimmerman, M. (1987). The evolution-creation controversy: Opinions of Ohio high school biology teachers. *Ohio Journal of Science, 87*(4), 115-125.

Appendix. Articles that provide activities designed to help students understand evolution.

Easton, C.M. (1997). Card lab: A population genetics simulation exercise. *The American Biology Teacher, 59*(8), 518-521.

Fifield, S. & Fall, B. (1992). A hands-on simulation of natural selection in an imaginary organism, *Platysoma apoda. The American Biology Teacher, 54*(4), 230-235.

Fiero, B. & Mackie, S. (1997). A natural selection lab for environmental biology. *The American Biology Teacher, 59*(6), 354-359.

Goff, C. (1995). Survival of the fittest. *The Science Teacher, 62*(6), 24-25.

Hazard, E.B. (1998). Teaching about intermediate forms. *The American Biology Teacher, 60*(5), 359-361.

Heim, W.G. (2002). Natural selection among playing cards. *The American Biology Teacher, 64*(4), 276-278.

Hinds, D.S. & Amundson, J.C. (1975). Demonstrating natural selection. *The American Biology Teacher, 37*(1), 47-48.

Knapp, P.A. & Thompson, J.M. (1994). Lessons in biogeography: Simulating evolution using playing cards. *Journal of Geography, 93*(2), 96-100.

Kuhn, D.J. (1969). A simulation game on natural selection. *The Science Teacher, 36*(1), 68.

Lauer, T.E. (2000). Jelly Belly® jelly beans & evolutionary principles in the classroom: Appealing to the student's stomachs. *The American Biology Teacher, 62*(1), 42-45.

Leonard, W.H. & Edmondson, E. (2003). Teaching evolution through the founder effect: A standards-based activity. *The American Biology Teacher, 65*(7), 538-541.

McCarty, R.V. & Marek, E.A. (1997). Natural selection in a Petri dish. *The Science Teacher, 64*(8), 36-39.

Maret, T.J. & Rissing, S.W. (1998). Exploring genetic drift and natural selection through a simulation activity. *The American Biology Teacher, 60*(9), 681-683.

Nolan, M.J. & Ostrovsky, D.S. (1996). A gambler's model of natural selection. *The American Biology Teacher, 58*(5), 300-301.

Silverman, J. (1998). Studying the genetics of behavior & evolution by adaptation & natural selection. *The American Biology Teacher, 60*(5), 356-358.

Tashiro, M.E. (1984). A natural selection game. *The American Biology Teacher, 46*(1), 52-53.

Vogt, K.D. (2002). An exercise to demonstrate the concept of an adaptive landscape & a simulation of complex systems. *The American Biology Teacher, 64*(8), 605-607.

Welch, L.A. (1993). A model of microevolution in action. *The American Biology Teacher, 55*(6), 362-365.

Young, H.J. & Young, T.P. (2003). A hands-on exercise to demonstrate evolution by natural selection & genetic drift. *The American Biology Teacher, 65*(6), 444-448.