ENSI Mini-Lesson

Natural Selection.... a Cumulative Process

or

Natural Selection Among Playing Cards

by Werner G. Heim

Adapted from an article in *The American Biology Teacher*, April 2002

SYNOPSIS:

A common criticism of natural selection is "how can it produce novel complex useful structures by pure random chance?" Darwin's answer to this "difficulty", (which he actually raised himself), was that selection is NOT a random process, and furthermore, it is cumulative, which he ably explained. Unfortunately, these facts are seldom included in typical classwork on evolution. It should be a required part for every presentation of natural selection.

This lesson provides an elegant, easy way for students to actually compare Darwin's cumulative non-random selection with the non-cumulative version so often erroneously implied. Students working in pairs attempt to produce a full sequence of 13 cards of one suit (ace - to king). This must be done by shuffling the suit of cards for each round, then checking the cards. Half the teams must look for the full sequence each time, and repeat the process until this is accomplished. The other teams start to "build" their sequence by pulling the ace when it first appears as the top card, then adding to the stack whenever the "next" card for the sequence is shuffled to the top. Discussion clearly reveals how the second method mimics Darwinian natural selection, while the first does not.

CONCEPTS:

Natural selection is a non-random process.
Evolution by natural selection is a cumulative process.
Cumulative selection can produce novel useful complex structures in relatively short periods of time.

MATERIALS:

Ideally (for teams of 2): 1 deck of cards for every 8 students (4 decks for a class of 32)
Acceptable (for teams of 4): 1 deck of cards for every 16 students (2 decks per class of 32)
scratch paper
envelopes (numbered: 1-16 for class of 32)
printed Background & Instructions (optional, could be handled orally)
printed Discussion Questions (optional; this could be handled orally)
Article on which this lesson is based (pdf)
Copy of this lesson (pdf)

TIME:

One teaching period (40-50 minutes)

TEACHING PREPARATION & STRATEGY:

1. This is best done in conjunction with your introduction to natural selection. It could probably work as well before students study it, or after. Vary with different classes to see which works best. Let us know your conclusions.
2. Separate the cards into their 4 suits (all 13 cards for each suit), and place each set of 13 cards into a separate numbered envelope. Be sure you have enough sets for each team (of 2- 4). These sets can be re-used in subsequent periods.
3. Run off copies of instructions and discussion questions if desired (one set per team is fine).
4. Have scratch paper handy.

PROCEDURE:

1. Divide the class into teams (of 2-4 each)
2. Each team has at least a "recorder" and a "player".
3. The Recorder records the number of rounds played (tally mark for each)
4. Player(s): serve as shuffler, card handler, and/or observer.
5. You may introduce the "game" in various ways, depending on their background and experience.
    a. Simply as "an interesting game" .. to be discussed as to its significance afterwards.

b. Announce that this is a "Natural Selection" simulation.
c. Point out that there is often confusion about natural selection being a random process, and many wonder how such a random process could produce useful complex structures in a reasonable time period.
d. Let them read the Background and Instructions, do the activity, then be prepared to discuss the questions in class.

6. Point out that Odd-Numbered teams will follow procedure A, and Even-Numbered teams must do procedure B. When a team achieves the goal (full sequence ace-to-king), the recorder reports the number of rounds taken to do it. One of the players thoroughly shuffles the cards, returns them to the envelope, and hands it in to the teacher. That team goes to work on the questions, preparing for class discussion.

7. About 5-10 minutes after the last B team has turned in its number of rounds played, call a halt to all remaining team activity. Each remaining set of cards is thoroughly shuffled, returned to its envelope, and this is handed in to the teacher. Display the number of rounds taken by each team, and begin to **discuss** the questions.

8. Above all, it is **critical** that students come away with a clear understanding that cumulative natural selection (as Darwin postulated) is a primary source for all new characteristics which have arisen since life began. The cumulative aspect of this is critical partly to show how it increases probabilities for increasingly complex or new combinations in relatively short time spans.

The other function of the cumulative feature is that it builds upon already-successful structures. This has also been called "successive selection of adaptive combinations." It's this cumulative feature which is key to its creative potential. Natural selection is often assumed (incorrectly) to be simply an elimination process, removing all the ill-adapted mutations as they appear. However, especially with details of molecular structures and processes being revealed and understood in diverse species, we have a growing body of observations most easily explained by descent with modification: evolution, occurring as a result of cumulative natural selection.

EPILOG AND COMMENTS:

1. It is important that no religious group (or even "creationists", and certainly no students) be ridiculed for their beliefs which maintain that evolution is wrong. Simply make the general true statement that there are many who misunderstand and may misrepresent evolution, and the point of this exercise is to clearly demonstrate what natural selection IS, and what it is NOT, primarily to clear up the widely held misconceptions. If asked where the misconceptions came from, explain that lots of new ideas can be misunderstood, and if someone writes articles presenting a misconception, many people accept it without questioning, and innocently repeat the ideas to others. This is especially true if the misconception seems to strengthen one's deeply held beliefs.

2. For example, you can mention that some may have heard that an organ such as an eye or an enzyme system could not have arisen by pure chance within a reasonable length of time, therefore evolution could not produce such complex structures or processes, much less complete organisms. The premise is correct, but the conclusion is wrong, because the basic assumption is wrong: evolutionary biology does NOT make this claim. Rather, it claims that such structures and processes arose largely by the accumulation of favorable mutations through the process of cumulative natural selection. Mutation is a chance process (within limits); selection is an anti-chance process. As the card game simulation showed, evolution by cumulative selection of favorable mutations (those that contribute to survival) is a relatively rapid process.

3. If you want to take an even closer look at the evolution of the eye, explore the following web sites. Note that there are also many web sites which attempt to discredit these evolutionary explanations for eye evolution, but an element common to all is their total disregard for **cumulative** selection and how this alone increases probabilities profoundly.
For a general overview of eye evolution: <http://www.cs.colorado.edu/~lindsay/creation/eye.html>
For a slide in a series by Richard Dawkins (from which you can navigate to other slides):
<http://tecn.rutgers.edu/genbio102/genbio102/4Evoeyes/sld014.htm>
For a computer graphic modeling a plausible sequence of eye evolution:
<http://www.biol.lu.se/funkmorf/vision/dan/model.html>
For a nice, brief explanation useful for answering classroom questions (along with similar questions):
<<http://www.nsta.org/pbsevolution4> (scroll down about 75% for eye evolution question)

EXTENSIONS & VARIATIONS:

1. Further evidence that species are the product of long term accumulated modifications can be found in the existence of **pseudogenes**. An excellent series of lessons available on this site enables students to experience the existence of pseudogenes by exploring the production of vitamin C in selected organisms and how this points to common ancestry. Take a look at the **Pseudogenes Suite** <http://www.indiana.edu/~ensiweb/lessons/psa.ball.html>. The existence of pseudogenes also suggests that natural selection provides a more parsimonious explanation for the origin of species than does "intelligent design", a fairly recent version of what is essentially "scientific creationism", both of which are pseudoscience.

2. In conjunction with this lesson, provide your students with a natural selection simulation experience which takes them through at least a few generations of selection, e.g. "**The Chips Are Down**" natural selection lesson, at <http://www.indiana.edu/~ensiweb/lessons/ns.chips.html>, or "**Natural Selection of Bean Hunters**" at <http://www.indiana.edu/~ensiweb/lessons/ns.beans.html>.

REFERENCES: In addition to those listed in the article by Dr. Heim:

Dawkins, Richard. 1996. *Climbing Mount Improbable.* New York: Norton & Co.

A Critical Review of Behe's Darwin's Black Box and the flaws in the author's "irreducible complexity" ideas. Includes examples of complex structures and molecular processes whose probable evolutionary sequence by cumulative selection have been figured out. <http://www.indiana.edu/~ensiweb/behe.rev.html>

ATTRIBUTIONS:

Original article: "Natural Selection Among Playing Cards" by Werner G. Heim, in the April 2002 issue of *The American Biology Teacher*, vol. 64, no. 4, pages 276-278. Dr. Heim is Professor Emeritus of Biology, Department of Biology, The Colorado College, 14 East Cache La Poudre, Colorado Springs, Colorado 80903-3294; E-mail: wheim@coloradocollege.edu

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