CUMULATIVE NATURAL SELECTION

BACKGROUND: When studying natural selection, the question often arises "how can pure chance create new complex structures or processes, much less new species?" Implied here is that natural selection is a process of pure chance, which is a common misconception; selection is not a matter of chance. Furthermore, natural selection does not say that all parts of a complex system must come together all at once. Natural selection is a stepwise constructive process which selectively builds new functional complex systems piece by piece, often just modifying previous systems to perform new functions. This truly creative ability of natural selection is often unappreciated or even misunderstood. The purpose of this lesson is for you to experience the effectiveness of cumulative natural selection, both in its creative potential, and in its increased efficiency, as reflected in how it increases the probability of complex systems to form.

PROCEDURE: Working in teams of 2-4 (as directed by your teacher), you will work with one suit of 13 cards (ace to king), shuffling the suit thoroughly for each round, and attempting to produce a particular sequence, following the rules assigned to your team, as follows:

FOR THE "A" TEAM, Odd-numbered sets:

1. Shuffle the cards thoroughly.

2. The recorder keeps track of the number of rounds played, increasing the count by one each time after the shuffling is completed.

3. Examine the cards. Are they in the order ace, 2, 3 ... jack, queen, king?
   - A. If so, inform the instructor of the recorder's count, i. e. of how many rounds have been played. Then stop as the goal has been reached.
   - B. If not, play another round, i. e. repeat steps 1., 2. and 3.

FOR THE "B" TEAM, Even-numbered sets:

1. Shuffle the cards thoroughly.

2. The recorder keeps track of the number of rounds played, increasing the count by one each time after the shuffling is completed.

3. Examine the cards. Is the top card an ace? If so, use it to start an "organism" stack. After this stack has been started ask whether the top card is the next one needed to construct the "organism." If, for example, the top (and only) card in the "organism" stack is the ace, then the next card needed is the two. Or if the top card in the "organism" stack is a seven, the next card needed is the eight, etc.
   - A. If the top card is the next card needed for the construction of the "organism," place it face up on the "organism" stack. Then repeat steps 1., 2. and 3.
   - B. If the top card is not the next card needed for the construction of the "organism," do not place any card on the "organism" stack. Instead repeat steps 1., 2., and 3.

4. When all the cards are in the organism stack (with the king on top), inform the instructor of the recorder's count, i. e. of how many rounds have been played. Then stop as the goal has been reached.

DISCUSSION: When you have achieved the target sequence (or when your teacher says to stop trying), return the cards to their envelope, and work on answering the discussion questions on a separate sheet:

Name_____ Date_____ Per.____

CUMULATIVE NATURAL SELECTION
DISCUSSION

When you have achieved the target sequence (or when your teacher says to stop trying), return the cards to their envelope, and work on answering the following questions. Be prepared to participate in class discussion of these questions.

1. In what ways is shuffling the equivalent of genetic mutations?

   In what ways is it not?

   Does the model (card "game") distinguish between phenotype and genotype?

2. What is the one, critical respect in which the actions of the odd- and even-numbered teams differed?

   What is the biological equivalent of this difference?

3. What, in the game, represented selection?

4. Why, in the game, was selection cumulative?

5. What was the average number of observed generations needed to evolve the organism by the **even-numbered** teams?

   How does this figure compare to the **calculated** average number of generations? (Hint: On the average, in each round, the ace has a 1:13 chance of coming up, the "2" has a 1:12 chance, etc. The sum of the numbers from 1 to 13 is 91)

6. What was the average number of observed generations needed to evolve the organism by the **odd-numbered** teams?

   Do we have the data to answer this question?

   What would be the **calculated** number of generations? (Hint: We need to have the ace show up first, with a probability of 1/13, then the "2," with a probability of 1/12 ... to the king with a probability of 1/1. 1/13 X 1/12 X 1/11 ... 1/1 is approximately $1.6X10^{-10}$. $1/1.6X10^{-10}$ is about $6.2X10^{9}$. Shortcut: 13! = 6,227,020,800.)

7. How many times faster is the evolution of our model organism **with** *versus* **without** cumulative selection among the mutations?

8. What new understanding has this lesson taught you?