Cumulative Change and Natural Selection
Student Material

Directions

Diamonds and Heart Teams:
Goal: Build a complete sequence of the cards from the ace through the king through a random process.

Procedure: Shuffle the deck of 13 cards so that the cards randomly arrange in order
from the ace through the king. Overall, your team is in an "all or nothing" situation as you are successful only if the complete sequence is present after a given shuffle.

After shuffling the deck of 13 cards, turn the deck over. Observe the order (ace, 2, 3 ... jack, queen, king) of the cards in the deck. If the cards are in order (ace through the king) your experiment can end. If the cards do not appear in this order, repeat the process until the cards appear in order or you are asked to stop.

If the ace or any other consecutive sequence of cards starting with the ace is present at the top of the stack, record this information and the number of the trial. Also, keep a record of any other sequence with consecutive numbered cards(7, 8, & 9, etc.) that appear anywhere in the deck.

Clubs and Spades Teams:
Goal: Build a complete sequence of the cards ace through the king using a process of cumulative selection.

Procedure: Shuffle the deck of 13 cards. Turn the deck over. If the top card is an ace, separate it from the deck to start the sequence. If the ace is not the top card, reshuffle the deck and repeat the process. After finding the ace as the top card, if the next card in the deck is the 2, stack it with the ace. Otherwise, continue to reshuffle the deck until the 2 appears. Continue the process until the ace-king sequence is complete or you are asked to stop. Record the number of trials completed and the results for each trial.

<u>Questions</u>
After comparing your results with other teams as directed by the teacher, answer the following questions.

1. Identify the key variable that made the process used by the Hearts/Diamonds teams different from that of the Clubs/Spades teams. Explain how the rate that the ace-king sequence was built was influenced by this variable?

2. If the Hearts/Diamonds team had been able to pull out the partial sequences of cards (such as a 5,6, & 7) to use to make a longer and more complete sequence of cards as other cards (such as the ace, 1, 2, 3, &4) appeared after a shuffle, do you think it would have been possible for the Hearts/Diamonds teams to complete their sequences with fewer shuffles than needed by the Clubs/Spades teams? Why?

3. Mutations are changes in the genetic structure of organisms and, within limits, occur randomly. What represented the process of mutation in this model? Defend your answer.

3. In thinking about how a domesticated species such as dogs, horses, cattle, and chicken have changed biologically through time, how does this model represent the change in one or more of these species?

4. Adaptive radiation occurs as one species evolves into 2 or more species. For example, mammals with hoofs have evolved into different species (horses, camels, goats, sheep, pigs, giraffes, etc.). How did the process used by Clubs/Spades team model this evolutionary process?

5. Factors such as temperature, food supply, space, coloration, availability of water, and the presence of other organisms act as selective forces that sort out, or select, mutations that enhance the probability of an individual to survive and reproduce. What was the selective force or factor in the model used in this activity?

6. In which teams was the selection process cumulative? Explain.

7. How did the cumulative selection process used in this activity model the cumulative selection that occurs in nature?

8. Based on our model using the cards, critique the assertion that “mutation is a chance process (within limits) and that selection is an anti-chance process.”

9. Using this model as a basis for your explanation, how would you explain to someone that the human eye or some other structure in the human body did not result from one, or even a few, dramatic or major mutations? Cumulative Change and Natural Selection.

Cumulative Change and Natural Selection
Teacher Material

Overview
This activity is designed to model and develop the two following and major concepts:

- Natural selection is a stepwise constructive process, which selectively builds new functional and complex systems piece by piece, often just modifying previous systems to perform new functions.

- Mutation is a chance or random process within limits. Evolution occurs through the cumulative selection of mutations that contribute to the survival of the species. As our card game model shows, the cumulative selection of mutations can be a relatively rapid process.

Objective
After completing this activity, students should know that even though mutations tend to be random, natural selection is cumulative.

TEKS
7 knows the theory of evolution
7A identify evidence of change in species using fossils, DNA sequences, anatomical similarities, & embryology
7B illustrate the results of natural selection in speciation, diversity, phylogeny, adaptation, behavior & extinction.
C3E evaluate models according to their adequacy in representing biological objects or events

Materials
Playing cards divided up by suit. One packet of 13 cards of one suit should be available for each pair or team of students.

Engagement
How has a common item such as an automobile, radio, telephone, television, grocery store, refrigerator, bicycle, a soft drink, basketball shoes, baseball gloves, cell phones, airplanes, computers, toothpaste, etc. changed over time?

When a new model of an automobile or a basketball shoe is introduced, is it entirely different than earlier models?

Exploration
Form teams of two or more students on the basis the suits in a deck of cards.

Diamonds and Heart Teams:
Goal: Build a complete sequence of the cards from the ace through the king through a random process.

Procedure: Shuffle the deck of 13 cards so that the cards randomly arrange in order
from the ace through the king. Overall, your team is in an “all or nothing” situation as you are successful only if the complete sequence is present after a given shuffle.

After shuffling the deck of 13 cards, turn the deck over. Observe the order (ace, 2, 3 ... jack, queen, king) of the cards in the deck. If the cards are in order (ace through the king) your experiment can end. If the cards do not appear in this order, repeat the process until the cards appear in order or you are asked to stop.

If the ace or any other consecutive sequence of cards starting with the ace is present at the top of the stack, record this information and the number of the trial. Also, keep a record of any other sequence with consecutive numbered cards(7, 8, & 9, etc.) that appear anywhere in the deck.

Clubs and Spades Teams:
Goal: Build a complete sequence of the cards ace through the king using a process of cumulative selection.

Procedure: Shuffle the deck of 13 cards. Turn the deck over. If the top card is an ace, separate it from the deck to start the sequence. If the ace is not the top card, reshuffle the deck and repeat the process. After finding the ace as the top card, if the next card in the deck is the 2, stack it with the ace. Otherwise, continue to reshuffle the deck until the 2 appears. Continue the process until the ace-king sequence is complete or you are asked to stop. Record the number of trials completed and the results for each trial.

Concept formation and Evaluation
Discuss the following questions as a class or within teams after a comparison of the results of the different teams.

1. Identify the key variable that made the process used by the Hearts/Diamonds teams different from that of the Clubs/Spades teams. Explain how the rate that the ace-king sequence was built influenced by this variable? *Variable: The method used by the team. A complete sequence of the cards from ace through kings had to form randomly during one shuffle of the cards for The Hearts/Diamond teams. A complete sequence of cards from ace through king could be formed as the cards that fit into the sequence being formed could be pulled out of the deck and added to the sequence. As the sequence became longer and the deck smaller, the probability of getting the needed card increased (the probability of finding an ace at the top of the complete deck of hearts or another suit is 1/13. However, the probability of getting a 10, is 1/4 when the sequence ace through 9 has already been formed.*

2. If the Hearts/Diamonds team had been able to pull out the partial sequences of cards (such as a 5,6, & 7) to use to make a longer and more complete sequence of cards as other cards (such as the ace, 1, 2, 3, &4) appeared after a shuffle, do you think it would have been possible for the Hearts/Diamonds teams to complete their sequences with fewer shuffles than needed by the Clubs/Spades teams? Why? *It is probable that the process would be more rapid as cards needed in the sequence appeared and saved.*

3. Mutations are changes in the genetic structure of organisms and, within limits, occur randomly. What represented the process of mutation in this model? Defend your answer. *A random process (the shuffling) determined the card that appeared on the top of the deck after each shuffle. If the card fit into the sequence, it was selected. If it did not fit into the sequence it was not selected. Mutations occur randomly and are selected through either natural or artificial selection.*

3. In thinking about how domesticated species such as dogs, horses, cattle, and chicken have changed biologically through time, how does this model represent the change in one or more of these species? *Horses have a long evolutionary history. Today, horses are quite diverse as certain characteristics have been selected by both natural and artificial selection.*

4. Adaptive radiation occurs as one species evolves into 2 or more species. For example, mammals with hoofs have evolved into different species (horses, camels, goats, sheep, pigs, giraffes, etc.). How did the process used by Clubs/Spades team model this evolutionary process? *Mutations that increased the probability of an individual and population to survive and reproduced occurred and accumulated in an isolated population. As a result, the population gradually changed and became different than the population that it had become isolated from. Each of the Clubs/Spades teams was likely to have different sequences built after a given number of shuffles of the deck.*

5. Factors such as temperature, food supply, space, coloration, availability of water, and the presence of other organisms act as selective forces that sort out, or select, mutations that enhance the probability of an individual to survive and reproduce. What was the selective force or factor in the model used in this activity?
6. In which teams was the selection process cumulative? Explain. *The criterion for selection was the rule followed for forming a complete sequence.*

7. How did the cumulative selection process used in this activity model the cumulative selection that occurs in nature? *Cards that appeared that fit into or made the sequence were retained. Those that did not fit into or form the sequence were rejected.*

8. Based on our model using the cards, critique the assertion that “mutation is a

chance process (within limits) and that selection is an anti-chance process." *The card that appeared on the top of the deck and mutations that appear are the result of a random process. The card or mutation selected "fit in."*

9. Using this model as a basis for your explanation, how would you explain to someone that the human eye or some other structure in the human body did not result from one, or even a few, dramatic or major mutations? *Mutations are cumulative as they build on earlier and different mutations. Dramatic or major mutations often result in the death of an organism.*

Background Information

Students often view evolutionary transition as *x* to *y* to *z* where the transition from one major group makes the change to another in one "mighty" change. Other students might assert that cumulative selection can result in changes among species (dogs, horses, etc.), but not in the evolution of new species and that no transitional forms that bridge or connect one species to another have been found. Such thinking is riddled with misconceptions and this model lesson was designed to help dispel such misconceptions.

The National Academy of Science publication *Science and Creationism* responds to questions about the existence of intermediate or transitional forms in lines of evolutionary descent as follows:

> So many intermediate forms have been discovered between fish and amphibians, between amphibians and reptiles, between reptiles and mammals, and along the primate lines of descent that it often is difficult to identify categorically when the transition occurs from one to another particular species. Actually, nearly all fossils can be regarded as intermediates in some sense; they are life forms that come between the forms that preceded them and those that followed.

The recent discovery of the fossil remains of a four-legged, 50 million-year-old whale strengthened the evidence of the close relationship between whales and herbivores and provided an additional example of an intermediate form in the line of evolutionary descent for vertebrates. The presence of formations in the ear cavities of these fossil whales links them to artiodactyls (hoofed mammals such as cows and hippos). These fossils also have legs and distinctive ankle structure similar to those of artiodactyls as described in this excerpt from *Science*:

> In the last decade, mounting evidence that whales are highly specialized ungulates (hoofed mammals) has been bolstered by the discovery of an impressive array of previously unknown fossil whales in Pakistan, India, and Egypt, which largely fill the morphological gulf between land mammals and ocean-dwelling cetaceans (whales, dolphins, and porpoises)... The move to the ocean required many

> adaptations to living in water, but the earliest whales still closely resembled land animals. One of the most spectacular transitional forms is the "walking whale" *Ambulocetus* from the middle Eocene (about 47 to 48 million years ago). This species had relatively well-developed limbs, paraxonic feet (where the plane of symmetry passes between the third and fourth digits), and hoof like terminal toe bones... The most important evidence comes from the shape and orientation of joint surfaces of several anklebones in the new fossils.
>
> These specialized features, typically associated with adaptation to running, have only been observed in artiodactyls and are widely considered diagnostic of the order. Their presence in an animal that was probably better adapted for aquatic than terrestrial locomotion strongly suggests common heritage rather than convergent evolution... The existing evidence suggests that cetaceans branched very early from artiodactyls, emerging from an unknown basal artiodactyl that had a slightly more primitive ankle than any known artiodactyl, including *Diacodexis* (the oldest artiodactyl) and anthracotherioids. The latter may be ancestral to hippopotami. (*Science*, Vol. 293, Issue 5538, 2216-2217, September 21, 2001).

Overall, there is a growing number of fossils finds that illustrate the pathway of the evolution of specific species. In addition genomic studies are providing data that provide evidence of relationships of species to one another.

Reference

This activity was adapted from the following:

Hein, Werner G. (2002). Natural Selection Among Playing Cards, *The American Biology Teacher*. 64: (4) 276-278.

Lammer, Larry. Natural Selection…A Cumulative Process…It's in the Cards. ENSI web lesson at http://www.indiana.edu/~ensiweb/lessons/ns.cum.l.html

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