

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

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National Science Education Standard—Life Science

Biological Evolution

Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

Teacher Materials

Learning Sequence Item:

1002

Genetic Variability

May 1996

Adapted by: Diane Schranck

The Processes of Evolution: Mutation, Recombination, and Natural Selection. Students should observe the phenotypic expressions of mutations and determine their evolutionary significance in terms of “fitness.” [They should examine the processes of genetic variability, including mutations, crossing over, and sexual recombinations.] They can study the genetic basis of evolution by examining artificial breeding experiments. (*Biology, A Framework for High School Science Education*, p. 114.)

Contents

Matrix

Suggested Sequence of Events

Lab Activities

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2. That Pesky Gene
3. To Mutate or Not to Mutate

Assessments

1. Changes in Gene Frequency, I
2. Changes in Gene Frequency, II
3. Genetic Variation, I
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5. Genetic Variation, III

1002

The Processes of Evolution: Mutation, Recombination, and Natural Selection. Students should observe the phenotypic expressions of mutations and determine their evolutionary significance in terms of “fitness.” [They should examine the processes of genetic variability, including mutations, crossing over, and sexual recombinations.] They can study the genetic basis of evolution by examining artificial breeding experiments. (*Biology, A Framework for High School Science Education, p. 114.*)

Learning Sequence

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>That Pesky Gene Activity 2</p> <p>To Mutate or Not to Mutate Activity 3</p> <p>Changes in Gene Frequency, I Assessment 1</p> <p>Changes in Gene Frequency, II Assessment 2</p> <p>Genetic Variation, I Assessment 3</p> <p>Genetic Variation, II Assessment 4</p> <p>Genetic Variation, III Assessment 5</p>			<p>The Peppered Moth Activity 1</p>

Suggested Sequence of Events

Event #1

Lab Activity and Reading

1. The Peppered Moth (90 minutes)

Alternative or Additional Activities

2. That Pesky Gene (55 minutes)
3. To Mutate or Not to Mutate (90 minutes or two 45 minute class periods)

Event #2

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

- Barnes, Deborah M., “‘Fragile X’ Syndrome and Its Puzzling Effects,” [Research News, Current Literature 15], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, p. 151–152.
- Lewin, Roger, “Why is the World Full of Large Females?” [Research News, Current Literature 13], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, p. 148.
- Marx, Jean L., “The AIDS Virus Can Take On Many Guises,” [Research News, Current Literature 12], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, p. 145–147.
- Marx, Jean L., “Detecting Mutations in Human Genes,” [Research News, Current Literature 16], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, p. 153–154.
- Marx, Jean L., “Gene Transfer is Coming on Target,” [Research News, Current Literature 17], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, p. 155–156.
- Marx, Jean L., “Evolution’s Link to Development Explored,” [Research News, Current Literature 19], *Biological Science: A Molecular Approach*, BSCS Blue Version, Sixth Ed., Toby King, Ed., 1990, pp. 161–163.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

History and Nature of Science

The Peppered Moth**Is this an example of industrial melanism?****Overview:**

Students will simulate the forces of predation and pollution on black and light moths to see how this form of natural selection as a result of a mutant dominant gene can cause a population change. After completing this activity, have students read “Evolution’s Link to Development Explored” (Reading 1).

Materials:**Per lab group (2–4 students):**

construction paper, 1 large sheet any color except black or white, 11 x 17

construction paper, black, 8½ x 11, 2 sheets

construction paper, white, 8½ x 11, 2 sheets

paper cups, 5-oz or larger, 2

hole puncher, hand-held

scissors

Procedure:

As a time saver, teachers prepare materials for the “rounds,” otherwise, students prepare materials for the rounds. These rounds represent fluctuations in the peppered moth population of pre- and post-industrial revolution in England. Students cut four strips of black construction paper and four strips of white construction paper, 1½ x 11 inches per strip. These strips represent trees. With the remaining white and black construction paper, students punch out a minimum of 100 white dots and 100 black dots. These dots represent the moth population. White dots represent peppered moths while black dots represent melanin moths. One cup is the pouring pot, which holds the moths (or genes) to be used in the current round. The second cup, is the reserve pot, which holds the moths that do not survive the current round(s).

Before the students begin the actual experiment, explain the parameters in this manner:

The moths are represented by dots. If a white dot falls on a black tree, that moth will be visible to birds and will be eaten. If a black dot falls on a white tree, that moth likewise, will be visible to birds and be eaten. These moths, obviously, do not survive and are placed in the reserve pot.

If a moth survives by landing completely on a tree that is the same color as the moth (camouflaged), the moth is successful and reproduces. When this happens, students add two moths of that same color (successful reproduction) to the pouring pot for the next round. Again, moths that do not land on any trees also survive—they just do not reproduce this time—and are returned (no additional dots) to the pouring pot for the next round.

If any round, all of the populations of either color of moths get eaten, students may import three of that color—due to migration—for the next round.

Now, begin the experiment by telling the story of the Industrial Revolution in England (read the italicized text immediately after the words, “Round 1,” etc., in the instructions that follow). As you

proceed through the rounds, elicit responses from the students as to what condition they believe their trees are in—and how many strips/black trees they should place on their background paper.

Round 1. Pre-Industrial Revolution.

In this pristine world, there was little smoky pollution. The trees were unaffected by wood smoke and by the little coal that was burned in some homes for heating.

The students place four white strips of paper on the background sheet in a random manner—but not overlapping. They place 20 white dots and 5 black dots into their pouring pot. They then sprinkle these randomly (so that the dots are fairly evenly distributed) onto the background sheet from a height of about 30 cm (about a foot). Students pick up any dots/moths that miss the paper completely, and re-sprinkle these dots until all the moths have landed either on the “ground” or on a tree. They then remove any visible moths from the trees—those that land against a different colored tree, i.e., easily seen—and place these in the reserve pot.

Students count the total number of remaining moths (by color) and record on their chart for round one. They then add these moths to the pouring pot. Be sure to indicate to the students that the moths (from the “ground” area) do survive—they just did not reproduce in this instance and are therefore candidates for the next round.

Round 2. Early Industrial Revolution

In the early stages of industrialization, England experienced an increase in coal smoke pollution. The cool ashes stuck everywhere, choking out the lichen and turning everything dark.

The students place three white strips and one black strip in a random order and fashion on the background paper and sprinkle the moths from the pouring pot onto the paper as before. They repeat the procedure, removing the visible moths from the trees and placing them in the reserve pot. They count the moths as record as before. However, this time, before picking up the remaining moths, students put two moths (of the same color as the parent moth) for each moth that successfully reproduced (camouflaged) into the pouring pot. (Note: moths added to the pouring pot due to successful reproduction will be counted in the next round.) They then pick up all the moths for the next round.

Round 3. Mid-Industrial Revolution

As pollution continues, the number of dark trees and rocks increases.

The students repeat the above procedure—only this time they use two white strips and two black strips placed in random order and fashion.

Round 4. Late Industrial Revolution

Now things are really getting bad. Coal smoke hangs in the air. Water from clothes being washed has a definite coal color tinge and the smell is in the air.

The students now use only one white strip [there is a little hope] and three black strips, again placing the strips in random order and fashion, and repeating the procedure as before.

Round 5. England at Its Worst

The eyes burn from the pollution. Mucus from the nose is darkened. Tree bark—and trees—darken and die. Factories burn hundreds of tons of coal everyday in manufacturing. The lichens have all died.

Students repeat the above procedures using only four black strips and no white strips (the lichen is dead and the bark is dark.) They are to repeat the removal and reproductive instructions and record the final set of data.

After a post-lab discussion, students should read “Evolution’s Link to Development Explored” (Reading 1).

Background:

Peppered moths (*Biston betularia*) were known to British naturalists who noted that they were found on light colored lichen-covered trees and rocks. Against this background, the light mottled coloring of these moths made them almost invisible to predatory birds. Until 1845, all reported specimens of peppered moths had been light-colored. As the Industrial Revolution developed in England, excessive smoke was produced in the industrial areas. This smoke killed the lichens and left the trees and rocks black. In 1845, a black specimen of the peppered moth was found. This black form of moth (*Biston betularai carbonaria*) was able to reproduce and spread because it became invisible against the new dark background. Though this moth carried a dominant mutant gene, B, soon the dark form accounted for 98% of the peppered moth population at the height of England’s pollution in about 1890. It was thought that this mutant gene was responsible for creating a form of moth that was less readily visible to birds. Thus natural selection against the light form of moth was greater during the years of heavy pollution than against the dark form.

Years later, several experiments were conducted by H. B. D. Kettlewell to prove his hypothesis that the color of the moths protected them from predators. By filming the actual episodes, he was able to demonstrate that when equal numbers of black and white peppered moths were available on black trees, the birds ate 43 white moths and only 14 black moths. On light trees, in a less industrialized area, the birds ate 164 black moths but only 26 of the light form.

In recent years, controls on pollution have increased and the levels of smoke have decreased. Many of the trees have returned to their original normal colors and the numbers of the light form of *Biston* have significantly increased.

Natural Selection is practical and picks traits (favors them) that increase survival in the current situation. The successful individual today may not be the successful individual of tomorrow.

Variations:

Similar scenarios can be created using other organisms. Varying colors of lizards and butterflies may provide similar results.

Adapted from:

Original material by Diane Schranck (Yates H. S.) and Tom Ivy (Lee H. S.), Houston, Texas. *Biological Science: A Molecular Approach*, 6th Ed., BSCS, Lexington, Mass.: D. C. Heath and Co., 1990. Eberhard, Carolyn, *Biology*, 2nd Ed., Philadelphia, Penn.: Cornell Univ., Saunders College Publishing, 1982.

Kaskel, Hummer, Kennedy and Oram, *Laboratory Biology: Investigating Living Systems*, Columbus, Ohio: Charles E. Merrill Publishing Co., 1983.

Miller, and Levine, *Biology*, Englewood Cliffs, N. J.: Prentice Hall, 1991.

Towle, *Modern Biology Laboratories*, Austin, Texas: Holt, Rinehart and Winston Publisher, 1989.

an additional activity for Event 1

Teacher Sheet

Science as Inquiry

That Pesky Gene

Can we ever get rid of the undesirable gene?

Overview:

In this simulation, students will try to “select” for a favorable characteristic by trying to eliminate the unfavorable. While they will be able to cause an increase in the frequency of the favorable gene, they should also discover that it is nearly impossible to eliminate the unfavorable gene. After completing this activity, have students read “Evolution’s Link to Development Explored” (Reading 1).

Materials:

Per lab group (2–4 students):

beans, red, 150*

beans, white, 150*

paper cups, three 5-oz.

pencil

map pencils, 2 different colors

calculator (optional)

*One 1-lb vat of each color beans is more than adequate for a class of 28.

Procedure:

Round 1. Students create a chart listing the possible bean color combinations of red/red, red/white and white/white. They then count out 50 white and 50 red beans and determine the gene frequency of each ($50 / 100 = 0.5$), and record the beginning gene frequencies. The students put 25 white and 25 red beans into two cups (representing parents) and gently mix the beans.

Without looking, students draw one bean from each cup and record the resulting combinations on their chart for Round One. Once all the beans have been paired and counted, students remove all of the w/w bean combinations and place them in the third cup.

Round 2. The students calculate the new gene frequencies for the remaining beans. They first count the new number of white beans and record the number. They then count the total number of beans (red and white) and divide this total into the new number of white beans. This is the white bean frequency.

For the red bean frequency, students subtract the new white bean frequency from 1.0.

Example:

White bean frequency. After Round 1, one student group had the following numbers: 15 w/w, 20 r/w, 15 r/r. After removing the w/w combinations there were 20 r/w and 15 r/r color combinations, with a total of 20 white beans and 50 red beans. They then divided the number of white beans, 20, by the total number of beans, 70, to get 0.285, which rounds to 0.29—or 29—the frequency of the white bean.

Red bean frequency. Subtracting 0.29 from 1.00 equals 0.71—or 71—the frequency for the red bean.

Continuing the procedure, students gather enough beans of each color to equal the new gene frequencies. They divide these equally into the two cups—odd numbers could go into either cup as long as the

total in each cup is equal. For example, cup 1 might have 14 white beans and 36 red, while cup 2 holds 15 white beans and 35 red. The total for each cup still equals 50 beans per cup. Students must record the new gene frequencies before they begin to pull beans from their cups.

Rounds 3–5. Students repeat the entire process to get an accurate understanding of the developing pattern. They should determine that while the frequency for the white gene decreases, it is never totally eliminated. It is possible that the frequency may become stable at some point. Have the students graph their results with a line graph—one line for the white beans and one line for the red beans.

Note. Students will have trouble at the end of the first round in determining the number of beans that they will need for the second round. You will have to walk them through the mathematics of the entire first round. Once they have been totally through the first round, the rest of the rounds become easier. It is helpful to remind the students that they will begin each round with a total of 100 beans (50 in each cup). It is also possible to get valid results with fewer than five rounds. Discussions of the activity might include topics such as why genetic manipulation has been important to developing new and improved food crops.

After a post-lab discussion, students should read the suggested reading “Evolution’s Link to Development Explored.”

Background:

Most of the food items that modern humans consume in this country have been genetically engineered through selective breeding. We can have square tomatoes, yellow peppers, designer eggplants, meatier chickens, leaner beef and all sorts of other things because the genetic makeup of these items has been altered.

Modern plants and animals that we use do not resemble their original wild ancestors. Broccoli, cauliflower, kale, brussel sprouts, and cabbage (red and white) all have a common ancestor—wild mustard. None of these plants closely resemble their “parent” or each other, but through selective breeding, certain desirable characteristics were selected. Certainly the unique breeds of dogs and cats provide evidence of this same selective process.

Variations:

Other objects such as beads and buttons can be substituted for the beans. Just be sure there is a visible trait that varies.

Application of human gene mutations like sickle cell anemia could be presented—this would tie into Micro-unit 1004, Activity 4.

Adapted from:
Campbell, Neil A., *Biology*, Benjamin Cummings, 1990.

an alternative activity for Event 1

Teacher Sheet

Science as Inquiry

To Mutate or Not to Mutate

Why aren't we all alike?

Overview:

In this investigation, students will be asked to measure variations within a species and to describe what advantages a species would have maintaining this variation. After this activity, students should read “Why is the World Full of Large Females?” (Reading 2).

Materials:

Per lab group (3–4 students):

petri dish

seeds, germinated (mung beans, radishes, tomatoes, lentils), 20–30

metric rulers, 4

graph paper

Procedure:

Part 1. Have the students measure the germinated seeds to the nearest millimeter and organize their numbers in a chart. Students use this data to determine the range of measurements, mode and the median. Have students plot their data on the graph paper.

Part 2. Create a data table on the chalkboard, or overhead, for students to record measurements for the entire class. Have the students take the following measurements on their lab partners and record the measurements on the board: 1) length of earlobe from the lowest point of the inside of the ear to the lowest point of the earlobe, 2) from tip of thumb to tip of little finger with hand fully extended and, 3) from center of right eye pupil to center of left eye pupil. The students must determine which unit of measurement is most practical.

After students have recorded the measurements for each person in the class, they determine the mode and the median for each characteristic, and create graphs for each characteristic. The graphs and questions can be done for homework.

After a post-lab discussion, students should read “Why is the World Full of Large Females?” (Reading 2).

Background:

Germinate the seeds by placing a folded moist paper towel in the bottom on a petri dish and sprinkling the needed number of seeds on the towel. Place the seeds in a warm, dark area for a couple of days.

Many variations can be observed within a population. Most of these variations are harmless mutations and have no apparent survival advantage or disadvantage. It is possible that a mutation which occurs infrequently might prove to be beneficial, such as in the case of the Peppered Moth. In such cases, the beneficial mutation may become the new characteristic for a population and thus increase the likelihood of species survival. Such changes are called adaptations.

The mode is simply the number that appears more frequently in a set of data. The median is a simple

average. For example, in the set of data [4, 4, 6, 6, 6, 8, 9, 10, 10], six is the mode and the median is 7. Sometimes the mode can be equal to the median.

Variations:

Ask the students if they can think of some other variation in humans which can be measured (height, weight, etc.). Have the students to investigate variations within species of animals such as dogs, cats, chickens and cattle. Have them to try to discover why these animals were bred for certain characteristics.

Adapted from:

Biological Science: A Molecular Approach, 6th Ed., BSCS, Lexington, Mass.: D. C. Heath and Co., 1990.

Eberhard, Carolyn, Biology, 2nd Ed., Philadelphia, Penn.: Cornell Univ., Saunders College Publishing, 1982.

Kaskel, Hummer, Kennedy and Oram, Laboratory Biology: Investigating Living Systems, Columbus, Ohio: Charles E. Merrill Publishing Co., 1983.

Miller, and Levine, Biology, Englewood Cliffs, N. J.: Prentice Hall, 1991.

Towle, Modern Biology Laboratories, Austin, Texas: Holt, Rinehart and Winston Publisher, 1989.

Science as Inquiry

Changes in Gene Frequency, I**Item:**

Explain why a change in the environment might influence the frequency of the genetics for a particular organism. Can you give an example?

Answer:

A change in the environment might cause a particular variety of an organism to be selected against for survival, thereby allowing a different variation to become more dominant in number. This more dominant variation would have a better chance of passing its genes to future offspring of the species. The peppered moth would be an example of a change in a population due to selection.

Science as Inquiry

Changes in Gene Frequency, II**Item:**

The darker moths became numerous over the lighter variation in England because of which of the following?

- A. The smog killed the lichen.
- B. The smog killed the lighter variety.
- C. The birds ate the lighter variety which landed on the darker lichen.
- D. A genetic shift in the lighter variety occurred because of the smog.

Justification:

Explain your answer to the above question.

Answer:

C. As the pollution became worse, the light lichen died and the tree bark became darker. The lighter variety of moths were able to be seen to be eaten. This allowed the darker variety to be better camouflaged. Because the darker variety had a better chance at survival and to produce offspring, the dark gene was passed on at a higher frequency.

Science as Inquiry

Genetic Variation, I**Item:**

What advantage do you think that a tall variety of seedling would have over a smaller variety?

Answer:

The taller seedling might be better able to compete for sunlight, therefore would be able to carry on photosynthesis sooner than a seedling which must rely longer on its cotyledon for food.

Science as Inquiry

Genetic Variation, II**Item:**

Explain why you believe there is so much variety in human characteristics

Answer:

Sexual reproduction leads to the recombination of genetic traits. As the genes are traded, new combinations are created for each new individual. Therefore, except for identical twins, each individual's genes, and characteristics, are different from every other individual.

Science as Inquiry

Genetic Variation, III**Item:**

Explain how a farmer or rancher might go about selecting favorable characteristics for animals or plants.

Answer:

Pollen from plants with desirable characteristics is used to fertilize female flowers of plants with desirable characteristics. The resulting seeds are cultivated and the process is repeated until the desired characteristic becomes dominant.

Similarly with animals, sperm from an animal with the desired characteristics is used to fertilize the eggs from a female animal also with the desired characteristic. Through successive generational breeding, the desired characteristics become dominant.

Consumables		
Item	Quantity (per lab group)	Activity
beans, red	150	2*
beans, white	150	2*
construction paper, 11 x 18: any color except black or white	1 sheet 1	
construction paper, black, 8½ x 11	2 sheets	1
construction paper, white, 8½ x 11	2 sheets	1
graph paper	—	3*
map pencil, 2 different colors	1 each color	2*
paper cups, 5 oz or larger	5	1, 2*
pencil, #2	1	1
seeds, germinated: mung beans, radishes, tomatoes, lentils	20–30	3*

Nonconsumables		
Item	Quantity (per lab group)	Activity
calculator (optional)	1	2*
hole puncher, hand-held	1	1
metric ruler	4	3*
petri dish	1	3*
scissors	1 pr	1

*indicates alternative or additional activity

Key to activities:

1. The Peppered Moth
2. That Pesky Gene
3. To Mutate or Not to Mutate

Activity Sources

- Biological Science: *A Molecular Approach*, 6th Ed., BSCS, Lexington, Mass.: D. C. Heath and Co., 1990.
- Campbell, Neil A., *Biology*, Benjamin Cummings, 1990.
- Eberhard, Carolyn, *Biology*, 2nd Ed., Philadelphia, Penn.: Cornell Univ., Saunders College Publishing, 1982.
- Kaskel, Hummer, Kennedy and Oram, *Laboratory Biology: Investigating Living Systems*, Columbus, Ohio: Charles E. Merrill Publishing Co., 1983.
- Miller, and Levine, *Biology*, Englewood Cliffs, N. J.: Prentice Hall, 1991.
- Towle, *Modern Biology Laboratories*, Austin, Texas: Holt, Rinehart and Winston Publisher, 1989.