REPRODUCTION AND HEREDITY

By Jamika Lasker, B.S., and Erin S. Kelleher, Ph.D.

OVERVIEW

Students will perform crosses between fruit fly strain with different physical characteristics, and observe 1) the transmission of traits from parents to offspring and 2) that offspring produced by sexual reproduction exhibit diverse combinations of parental traits.

OBJECTIVES AND STANDARDS

Conceptual Learning

- Heredity is the passage of genetic instructions from one generation to the next, through chromosomes contained in gametes.
- Sexual reproduction results in more diverse offspring and involves the fertilization of an egg cell from one parent with the sperm cell of the other.
- Sexual reproduction can produce diverse offspring because each sperm and egg cell contains a unique combination of parental genes.

Science, Math and Health Skills

- Observation
- Data Collection
- Hypothesis Testing

TEXAS ESSENTIAL KNOWLEDGE AND SKILLS

7.14A: Define heredity as the passage of genetic instructions from one generation to the next generation.

7.14B: Compare the results of uniform or diverse offspring from sexual reproduction or asexual reproduction.

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NEXT GENERATION SCIENCE STANDARDS

MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

TIME

3 class periods (15 minutes setup, 45 minutes for activity); allow 2 weeks between Class Periods 2 and 3. See SETUP for options.

MATERIALS

Items which can be purchased at Carolina Biological Supply Company (CBS) are marked with their specific product names and stock numbers, beginning with "CBS#" (https://www.carolina.com/)

- Computer access to the Drosophila Web site. (See "SETUP.")
- Drosophila media (CBS# 173210)
- Drosophila vials with enclosures (CBS# 173076, 2 per group)
- Vials containing *Drosophila melanogaster* (fruit flies), living, wild type, vial of 25–30. Each adult fly is capable of producing 1–2 offspring (approximately 50 offspring per vial) over a span of 2 weeks, given proper care and environmental conditions. (CBS# 172100, standard red)
- Vials containing *D. melanogaster*: White-eyed, curly-winged, stubble-bristled fruit flies. Flies with curly alleles and stubble alleles must be maintained as heterozygotes. These flies often are available from research labs, but they can be purchased from the Bloomington Drosophila Stock Center. Search for items 36364 or 39631. (https://bdsc.indiana.edu/)
- FlyNap® Anesthetic Kit (CBS# 173010). Each kit contains a 10 mL vial of FlyNap® (100 doses) and 12 anesthetic wands. Flies remain "napping" for 50 minutes to several hours without being killed or sterilized.
- Coins for flipping
- Microscopes
- Paint brushes
- Photocopies of each student page, 1 set per student or student team or group

Option: Make sure you maintain vials of live fruit flies for students to use for their experiments. However, if you also wish for students to examine dead flies, place vials of flies in a freezer for 20 minutes. Be certain to freeze the vials upside down (cotton-side down), so that the flies fall drop to the cotton as they die and do not get stuck in food.

SETUP

Order fruit flies, media and appropriate supplies from Carolina Biological Supply and Bloomington Drosophila Stock Center as indicated under "Materials," and according to classroom size. In order for your students to perform their crosses, you will need to rear your wild-type females in isolation for 5 days. This will clear most of the sperm from any previous matings out of their reproductive tracts so that they will use sperm from the males you provide to fertilize their eggs.

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Anesthetize the fruit flies using FlyNap®. (Refer to "Procedure" for each class period's requirements.) Dip the provided wand into the bottle of FlyNap®. Turn the culture vial of flies upside down, then slide wand in between the cotton and side of the vial. Continue to hold the vial upside down while the flies fall asleep and drop onto the cotton (see demonstration videos URLs listed below). For more information about Flynap® kits and the anesthetic process, view the following CBS videos.

Flynap
(https://www.youtube.com/watch?v=DkiCFkB9cSo)
Observing Phenotypes and Crossing *Drosophila melanogaster*
(https://www.youtube.com/watch?v=DkiCFkB9cSo)

Set the power on all microscopes to 20X. Allow students to change the magnification setting.

In order for your students to perform the crosses, you will need to rear your wild-type females in isolation for 5 days. This will clear most of the sperm from any previous matings out of the females' reproductive tracts, so that they will use sperm from the males you provide to fertilize their eggs.

Photocopy or print student sheets for (1 set per student or student group or team). Students will complete it in sections. Collect the sheets at the end of each class period.

For Class Period 1: Load and open the activity's classroom PowerPoint® slide set. You will be using Slides 1–4.)

For Class Period 2: Computers must be able to run Adobe Flash software. You may need the assistance of IT personnel to install the software and make sure it functions properly prior to class. Load the program on student computers. Also load and open the activity's PowerPoint® slide set. You will begin with Slide 5.

Adobe Flash Software (Scroll down to "Free tools." Click "Download and Install Flash Player" followed by "Enable Flash Player in browser.")
https://helpx.adobe.com/download-install.html?promoid=2K4PCJ2R&mv=other
Drosophila Web Page
http://sciencecourseware.org/vcise/drosophila/)

For Class Period 3: Completed student sheets from previous portions of this activity.

Have students work in groups of 4, or make pair groups depending on availability of microscopes and other materials.

PROCEDURE

Class Period 1. Computer Simulation of Reproduction in Fruit Flies (Student sheet:

1. Project Slide 2 containing photographs of males and female fruit flies (*Drosophila melanogaster*). The male of the species appears at the bottom of the left photo, and to the right of the female on the composite image on the right. Ask students to identify and record as many differences in physical characteristics and they can. Key differences are body size (females are larger), abdomen shape (females have pointed bottoms, males rounded), and abdomen pigmentation (females have stripes all the way down their abdomens, males have solid black bottoms).

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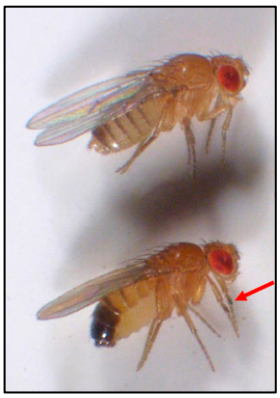

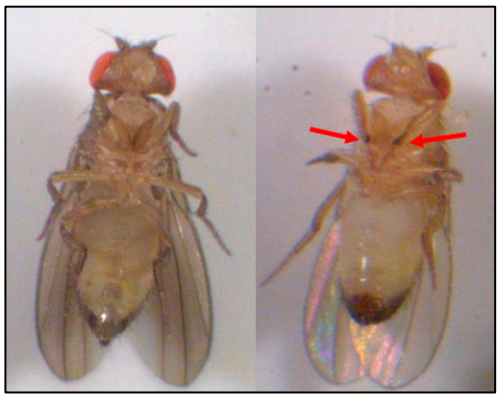

2. Explain to students that the red arrows in both images points to the male fruit fly's sex comb bristles. Males and females appear different because they have different roles in sexual reproduction. Male fruit flies have elaborate genitalia for passing sperm to the female. Loss of the sex combs reduces the abilities of males to reproduce. Female fruit flies have larger bodies in order to produce large, yolk-filled eggs. The female flies also have a pointed abdomen that allows them to place the fertilized egg onto food, which will provide a nutrition source for the developing offspring.

3. Tell students that today they will be learning about how sexual reproduction between two different parents can produce diverse offspring.

4. Project the pictures of a family (Slide 3) showing the same family as they appear in different years. (Or you can use a famous family photo). Ask, *Do the children* (offspring) *look the same or different*? Prompt students to identify traits that were passed from specific parents to specific offspring. You also may ask students to think about traits they've inherited from their parents and/or how they differ from their siblings.

5. Direct students to perform fruit-fly mating simulator activity as described on their worksheet. The simulator software will allow them to perform matings between flies with different physical characteristics, and observe the diverse offspring produced.

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Class Period 2. Observation of Male and Female Parents, Production of Offspring and Establishment of Experimental Crosses

1. Tell the students that today they will be using live fruit flies (*D. melanogaster*) to learn about how physical traits are transmitted from parent to offspring. The flies will have three different physical traits. Project Slide 4 that show images of two different eye colors. Explain to students that different fruit flies also can be born with different eye colors.

2. Now project Slide 5, which shows fruit flies (in each photo, females on the left, males on the right) having different wing shapes. Ask students, *How do these flies differ?* Explain that we refer to the wing shape as either curly or straight.

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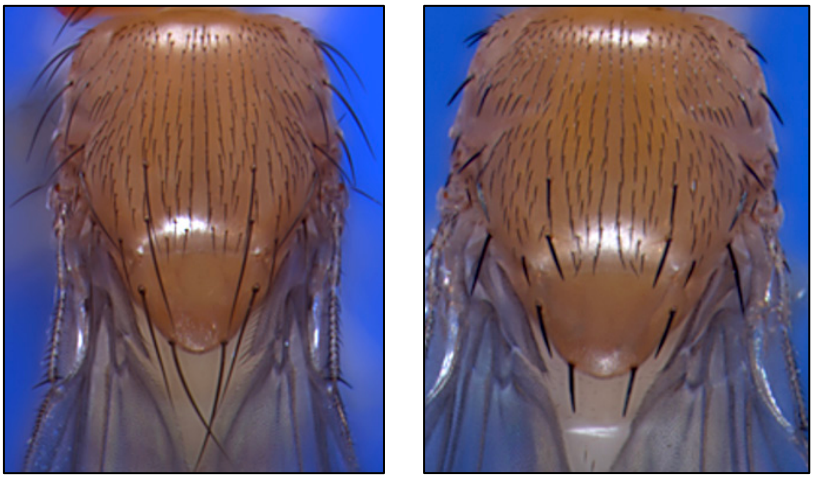
Follow with Slide 6, which depicts bristle length on two different fruit flies (long bristles shown in the left image). Repeat the question, *How do these flies differ?*



3. If you already have not done so, anesthetize the females from the wild-type strain and the males from the mutant strain with Flynap® (see "SETUP" for instructions and supplementary videos).

4. Place vials of sleeping flies by each microscope station. First have students look at and compare different flies at 20X. Keep in mind that students may want to increase the magnification to look at finer structures on the flies.

5. Instruct students to describe differences between the two parent flies. Ask, *What is the body color, eye color, wing and bristle phenotype of the male parent? What about the female parent?*

6. As a class you will predict possible offspring that can be produced by a cross between the two parents. First, each student will make their own pair of parental gametes (sperm and egg cells). To do this, they will flip a coin to determine which parental copy (1 or 2) will be placed in a sperm and egg cell. Heads means the offspring receives copy 1, tails means copy 2.

Male Genes	Copy 1	Copy 2
Gene E	e	e
Gene Y	y	Y
Gene B	b	B

Female Genes	Copy 1	Copy 2
Gene E	E	E
Gene Y	y	y
Gene B	b	b

Because the two copies of each gene carried by the mother (chart above right) are identical, all her eggs also will be identical, carrying a single copy of each of the three genes (E, y, b)

The genetic makeup of the father (chart above left assumes that you are working with a strains of the genotype w;Cyo/+;Sb/+.

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7. Have students fertilize their eggs with sperm to determine the genes that are inherited by their offspring. For example: if their sperm is e, Y, B, their offspring will be as follows.

Parents' Genes	Father Gene Copy 2	Mother Gene Copy 1 or 2
Gene E	e	E
Gene Y	Y	y
Gene B	B	b

Prompt students to use the table provided on their worksheet (shown below) to determine the physical traits of their offspring based on their genes. For example, the sample offspring from above will have red eyes, curly wings and short bristles.

Eye Color	Wing Shape	Bristle Length
EE = red	YY = curly	BB = short
Ee = red	Yy = curly	Bb = short
ee = white	yy = straight	bb = long

8. Survey your students about the physical traits that are exhibited by their offspring. You can keep track of the different types of offspring (i.e., different combinations of physical traits) and how many students produced an offspring with this group of traits. Your students should produce 1 of 4 of the following offspring genotypes.

    A. Red eyes, straight wings, long bristles
    B. Red eyes, curly wings, long bristles
    C. Red eyes, straight wings, short bristles
    D. Red eyes, curly wings, short bristles

9. Based on the data, ask your students to predict what fraction or proportion of offspring will correspond to each offspring class (A–D). Assuming everyone was "honest" in their coin flipping and your class is reasonably large, each of the four offspring types should be produced roughly 25% of the time.

10. Ask the students to place their parent fruit flies into a single vial. Explain that parent flies in the vial will mate and offspring produced in about 2 weeks.

11. Keep adult flies in the appropriate treatment vials for 5 days, then discard them. (You can anesthetize the flies with Flynap®, then dump them in a cup of soapy water, or alternatively, you can tap the parents directly into soapy water.) *You must retain the original vial, since this is where your offspring are developing.* In 2 weeks students will have plenty of offspring from the cross to observe.

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Class Period 3. Data Collection from Experimental Crosses

1. If you have not already done so, anesthetize the F1 offspring from the parental crosses with Flynap®. Place the fruit flies under the microscope for students to observe.

2. Ask students to look at the offspring, determine how they are different, and use the paint brush to sort them into groups according to the same characteristics (eye color, wing shape, bristle length).

3. Ask your students to record on their student sheets all of the combinations of eye color, wing shape, bristle length that they observe, as well as the number of offspring exhibiting that combination.

4. As a class, compare the proportion of different offspring types predicted from the activity and the production of theoretical gametes and offspring, to observed proportions from the live crosses.

5. Have students construct basic data analysis by graphing predicted and observed proportions.

6. After class, anesthetize the fruit flies with Flynap®, then dump the flies in a cup of soapy water to kill them. Discard.

IMAGE SOURCES

Page 1. Photo of a single *Drosophila melanogaster* fruit fly © Roblan. Licensed for use.
Page 4. Microscopic photos of male and female *Drosophila melanogaster* fruit flies courtesy of the Jean and Alexander Heard Library, Vanderbilt University Library. BSCI 1511L Statistics Manual: Drosophila phenotypes. http://researchguides.library.vanderbilt.edu/c.php?g=156859&p=1515661
Page 4. Photos of an interracial family and children © Frenk Kaufmann. Licensed for use.
Page 5. Macro photos of *D. melanogaster* eyes courtesy of FlyBase. http://flybase.org/
Page 5. Microscopic photos of curly-winged and straight-winged fruit flies © The Exploratorium, Microscope Imaging Station. http://annex.exploratorium.edu/imaging_station/.
Page 6. Microscopic photos of *D. melanogaster* bristles courtesy of FlyBase. http://flybase.org/

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FRUIT FLIES: COMPUTER SIMULATION

Name _____ Name _____

1. Look at the projected picture of the two fruit flies. *How are they the same? How are they different?*

_____

_____

2. Your teacher has loaded the following web page on your computer. Look for the "Enter as Guest" button to launch the software program, which is an interactive fruit fly crossing simulator.
   http://sciencecourseware.org/vcise/drosophila/

3. You will be prompted to "Order flies." For the female, choose "Wildtype," which indicates that the mother will have the most common physical characteristics exhibited by fruit flies in nature: red eyes, straight wings and long bristles. For the male select the following physical traits: white eyes, curly wings (CY), and stubble bristles (SB).

4. Follow directions to cross parent flies, and sort offspring flies under a microscope view.
   a. Click "Sort flies" to observe phenotypes of offspring.
   b. Click on each pile, and record the phenotype in the table below,
   c. Select "add to notebook."
   d. Send results to computer to "Analyze" the results. Be sure to click on "Ignore sex."

5. In the table below, describe the combinations of phenotypes you observed in your model offspring. If it is not indicated that an individual has the rare physical trait (white eyes, curly wings, stubble bristles) then you may assume that they have the common physical trait (red eyes, straight wings, long bristles). Individuals that have only common physical traits (red eyes, straight wings, long bristles) are described as "+". Curly winged individuals are described in the first row of the table as an example.

OFFSPRING FREQUENCY

Wing Shape	Eye Color	Bristle Length	Number of Offspring
Curly	Red	Long	

6. In the online "Analyze" results table, reflect on the traits offspring inherited from the parent flies. *Do all the offspring of sexual reproduction between male and female fruit flies exhibit the same physical characteristics, or do they display different combinations of physical characteristics?*

5.

_____

_____

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WORKING WITH LIVE FRUIT FLIES

Name _____ Name _____

1. Your teacher has provided male and female fruit flies for you to observe under the microscope. Describe physical traits of each in the table below.

SELECT PHYSICAL TRAITS OF MALE AND FEMALE FRUIT FLIES

Sex	Eye Color	Wing Shape	Bristle Length
Male			
Female			

2. Based on your observations using the fruit-fly mating simulator, predict the possible offspring that can be produced by a cross between the two parents.

_____

_____

3. The eye color of fruit flies (white or red) is determined by gene E. The wing shape of fruit flies (curly or straight) is determined by gene Y. The bristle length of fruit flies (long or stubble) is determined by gene B. Just like people, fruit flies have two copies of every gene, one they inherit from their mother and one they inherit from their father. Sometimes both copies of genes are the same, while at other times the copies are different.

4. Look at table below, which shows the physical traits that are produced by different combinations of gene copies for each of the three genes (E, Y and B). Specific traits in genes are identified using two letters in either upper or lower case.

Eye Color	Wing Shape	Bristle Length
EE = red	YY = curly	BB = short
Ee = red	Yy = curly	Bb = short
ee = white	yy = straight	bb = long

The genetic makeup of traits in the female and male fruit flies you have been provided with are listed in the table below.

PARENTAL GENES

Female Genes	Copy 1	Copy 2
Gene E	E	E
Gene Y	y	y
Gene B	b	b

Male Genes	Copy 1	Copy 2
Gene E	e	e
Gene Y	y	Y
Gene B	b	B

(Continued)

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5. You will make your own pair of parental gametes (1 egg and 1 sperm). To do so, you will need both charts from Step 4 (bottom of page 8).

   Flip a coin to determine what information you record in the chart "Coin Toss," below. Begin with either the male or female parent fly. If the coin lands on "heads," use information found under Copy 1; if tails, use information listed under Copy 2. Record your answers in the chart below. Repeat the procedure for the other parental fly.

COIN TOSS

Trait Type	Male Genes (sperm)	Female Genes (egg)
Eye Color		
Wing Shape		
Bristle Length		

6. Assuming your egg is fertilized by your sperm, use the table below to predict the physical traits that will be exhibited by the offspring that are produced.

PREDICT FIRST GENERATION (F1) GENETIC OUTCOMES

Trait Type	Offspring Traits
Eye Color	
Wing Shape	
Bristle Length	

7. Based on the traits of the offspring that were produced by yourself and your classmates in Steps 5 and 6, answer the following questions.

   a. Which combinations of traits do you expect to observe among the offspring of your fruit fly parents?

   _____

   _____

   b. What proportion or fraction of the offspring do you think will exhibit red eyes, curly wings, and long bristles?

   _____

   _____

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EXAMINING OFFSPRING

Name _____ Name _____

1. Record different combinations of physical traits you observe among your offspring and the number of offspring with each combination of traits in the data table provided.

Eye Color	Wing Shape	Bristle Length	Number of Offspring

2. Consider the different combinations of traits that are exhibited by your offspring. What traits are identical among all of the offspring? What traits differ among the offspring?

_____

_____

3. Why do you think that multiple offspring from the same parents have different combinations of physical traits?

_____

_____

CHALLENGE YOURSELF!

From the data in question 12, calculate and record the proportion of F1 generation offspring that inherited curly wings, red eyes, and long bristles.

_____

_____

Was your prediction from question 7 correct? If it was not, how did your observations differ from your prediction?

_____

_____

On the following page, construct a graph based on your data that best presents and compares inherited traits for each generation of fruit flies.

(Continued)

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REPRODUCTION AND HEREDITY: DATA COLLECTION

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