INHERITED TRAITS IN HUMANS AND FRUIT FLIES

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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. This updated version streamlines and simplifies the experiments to make them more accessible to 7th grade students.

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.

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

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

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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/).

- *Drosophila* media, university research labs may be able to provide a small amount of media in prepared vials with enclosures at no cost. However, you can also purchase this from Carolina Biological Supply (CBS# 173210).
- *Drosophila* vials with enclosures. If you are unable to obtain from a university research lab you may purchase them from Carolina Biological Supply (CBS# 173076, 2 per group).
- Vials containing living *Drosophila melanogaster* (fruit flies) are often available from university research labs at no cost. Wild-type flies, white eyed mutants and curly winged mutants are required for this activity. If you cannot locate a local lab, wild type flies with red eyes and straight wings (CBS# 172100), white-eyed mutants (CBS #172220), and curly-winged mutants (Item # 172750) are available in vials of 25–30 adults from Carolina Biological. Each adult fly is capable of producing 1-2 offspring over a span of 2 weeks, given proper care and environmental conditions. (CBS# 172100, standard red). Note that the curly-winged mutants also carry other mutations that your students may notice.
- 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.
- Vials Popsicle sticks or small scraps of paper, 2 per student.
- Microscopes.
- Paint brushes.
- Photocopies of each student page, 1 set per student or student team or group.

SETUP

These quick videos might provide helpful review before you teach this material. "Flynap" (https://www.youtube.com/watch?v=DkiCFkB9cSo); "Observing Phenotypes and Crossing *Drosophila melanogaster*" (https://www.youtube.com/watch?v=DkiCFkB9cSo); "TEDEd genetics video" (https://www.youtube.com/watch?v=Mehz7tCxjSE&t=124s).

1. **1-2 months in advance:** Order fruit flies, media and appropriate supplies from a local university research lab or from Carolina Biological Supply. If you have a lot of students and few flies, you can rear the flies yourself for 1 generation (~2 weeks) to ensure you have lots of flies to spread across multiple classes.

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2. **5 Days in Advance:** You need to separate wild-type straight winged females from the adult male flies. This will ensure they do not contain sperm from any previous matings, so that your students can control the "fathers" of their baby flies. To separate the females from the males, anesthetize the fruit flies using FlyNap®**.** 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. The flies will remain asleep for 50 minutes. Diagnostic differences in abdominal coloration and genitalia between male and female flies can be found on slides 3 and 6 of the slide show. Once you have separated the females based on their sexual characteristics, place them in a separate female only vial.

3. **Class period 1:** Load and open the activity's classroom PowerPoint® slide set. You will be using Slides 1–7; Anesthetize the fruit flies using FlyNap® all the adults you need for a given class period. The critical flies for your students are the wild-type females, and their white eyed and curly winged male mates. For each group we recommend 10-20 females and 5-10 of each type of male; Divide the wild-type flies among the available microscope stations, placing a mixture of wild-type, white-eyed, and curly-winged flies at each station; Set the magnification on all microscopes to 20X. Allow students to focus the microscopes to their personal preference: Photocopy or print student sheets for (1 set per student or student group or team). Students will complete it in sections; Throw away the parents from your students' crosses. This will ensure there are not too many fruit fly larvae in the vial. Overcrowding the developing flies can lead to poor health as well as soupy fly food that is difficult to work with.

4. **Class Period 2:** Anesthetize the offspring from both vials of each group in the class. Keep the offspring from each vial separate so that students may observe the independent groups of offspring produced from both sets of parents. Separate index cards or pieces of paper are good for maintaining the separate groups of offspring; Load and open the activity's classroom PowerPoint® slide set. You will be using Slides 8–12.

PROCEDURE

Class period 1. Trait Inventory in Humans and Fruit Flies

1. Working with a partner the students will observe 5 physical traits they exhibit, which are determined by genes they inherited from their parents. The pictures on this website might help you and your students determine which traits they have (https://askabiologist.asu.edu/mendelian-traits-humans). When they are done tell them the traits are genetic: transmitted from parent to offspring. In this lesson, they will be developing and testing hypotheses about how traits are transmitted from parents to offspring. Ask the students the following question: *What do they know about the transmission of traits from parents to offspring?*

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2. **Project Slide 1:** Tell students they will be learning about the transmission of traits from parents to offspring in humans (the Smith family) and fruit flies.

3. **Project slide 2:** Remind the students about the difference between attached and detached earlobes.

4. **Project slide 3.** Ask the students to consider whether the transmission of attached vs detached earlobes from parent (Will and Jada Pinkett Smith) to offspring (Jayden and Willow). Ask the students the following questions: *How can Jayden have attached earlobes if both parents have attached earlobes? Why do Jayden and Willow inherit different traits (attached vs detached earlobes) if they have the same parents?*

5. **Project Slide 4:** Ask your students to define a hypothesis as best they can. Discuss the given definition of a hypothesis and ask your students to develop a hypothesis about how traits are transmitted from parent to offspring, which accounts for their observations of the Smith's earlobes. They should write their hypothesis down on their worksheet.

6. **Project Slide 5:** Introduce fruit flies as an experimental tool used by many scientists to study the transmission of traits from parents to offspring. Ask your students the following question: *What traits do they observe that differ among the fruit flies on the slide?* They should observe many differences including in eye color, eye shape, wing color, wing shape, body shape and bristle appearance (body hair).

EXPLORE

1. Students will work in groups to explore different traits in fruit flies using microscopes, taking advantage of stations you set up before class. The students should work together to identify and record traits that differ among the flies. They should observe that the flies can have either red or white eyes, and that the flies can have either straight or curly wings. After about 5 minutes of observation, you lead them in a discussion of their observations. PowerPoint slides 6 and 7 include photographs of red vs white eyes, and curly vs straight wings. Some students may notice other traits that vary, in particular the darker abdominal pigmentation of male flies.

2. Ask students to brainstorm ideas together with their group of how they can use the fruit flies you have provided to study the transmission of eye color and wing-shape from parent to offspring. Hopefully they will independently come up with the idea that they can cross fruit flies with different eye colors and wing shapes and then observe these traits among offspring. If not, you might have to suggest this experimental approach to your students.

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3. **Project Slide 8:** Containing photographs of males and female fruit flies (Drosophila melanogaster). Tell your students that in order to set up matings between fruit flies, they will have to learn to tell male and female fruit flies apart. 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).

4. Explain to the students that flies appear different because they have different roles in sexual reproduction. Male fruit flies have elaborate genitalia for passing sperm to the female. Female fruit flies have larger bodies in order to produce large, yolk-filled eggs. The 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. At the end of the lesson students should be able to identify the males and female flies.

5. Tell your students that to ensure reproduction between male and female flies, they will place multiple males and females with the same mating vial. This way if a female doesn't like the look of a particular male or *vice versa*, she has other options. The students need to set up two types of matings: one which examines the inheritance of eye color, and the other which examines the inheritance of wing-shape.

    - Wild-type females mated white eyed males
    - Wild-type females mated with curly winged males

6. Ask that students verify with you when they have made piles of red eyed females and white eyed males, and straight winged females and curly winged males, that they will use in their crosses. After you've checked that they have selected the correct parents, the flies should be placed in vials together (two vials, 1 for each trait). Students must be careful to place flies on the side of the plastic vial, so they don't wake up in the food.

7. The flies will wake up in an hour or two, mate, and the females will lay eggs. Students will observe the offspring over a two-week period as they develop from embryos, to larvae, to pupae, and finally to adult flies.

8. At the end of the class period or as homework the students should make a prediction about what traits the offspring will display in each cross, which is based on the hypothesis they made about how traits are transmitted from parent to offspring. Predictions are recorded on the student's worksheet.

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9. For homework students should perform their genetic trait inventory on someone in their household. It need not be a genetic relative, since the focus of the exercise is revealing individual differences in genetic traits rather than the inheritance of those traits. When they have completed the homework portion, collect the assignment and keep their worksheets.

10. **2 Weeks Later:** Students should have abundant offspring in each of their two vials. They should record the number of offspring displaying red or white eyes, and curly or straight wings in data tables on their worksheets. Using the table below, you may tabulate the overall data from the class for each cross.

RED + WHITE EYES

Student Names or Group #	Red Eyes	White Eyes
	Total:	**Total:**

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STRAIGHT + CURLY WINGS

Student Names or Group #	Red Eyes	White Eyes
	Total:	**Total:**

EXPLAIN

11. Once you have tabulated the data from each cross you can discuss as a group what your students have observed. *Did all of the offspring inherit the trait of one parent for eye color? What about wing shape?* If you have implemented your crosses correctly, the students should observe that:

    - All offspring of red eyed females and white-eyed males have red eyes.
    - About half of the offspring of straight-winged females and curly winged males have curly wings, while the other half have straight wings.

12. Ask your students to consider their results. *Why do all of the offspring in the eye color cross inherit their mother's red eyes, while only half of the offspring in the wing shape cross inherit their mother's straight wings?* One thing your students might propose is that red eyes are dominant to white.

13. Explain to your students that differences in many physical traits, such as eye color or wing shape in fruit flies, are caused by differences in genes. Every fruit fly individual has a gene that determines eye color, however, some individuals have variants of this gene, called alleles, that cause their eyes to be red, while others have alleles that cause their eyes to be white. The offspring of the parents with different wing changes have different wing shapes (some curly, some straight) because they inherited different wing-shape alleles from their parents.

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14. **Project Slide 9:** Explain to your students that for the gene determining eye color, the *E* allele makes the fly have red eyes and the *e* allele makes the flies have white eyes. Each fly has two alleles of every gene, just like every human.

15. **Project Slide 10:** Explain to your students that when red eyed females and white eyed males produce offspring, a single *E* allele is transmitted to the offspring through the egg, while a single *e* allele is transmitted to the offspring through the sperm. All of the offspring display red eyes because a single *E* is enough to produce red eyes. *E* is dominant to *e.*

16. Explain to you students that when an individual has two copies of the same allele, either dominant or recessive that individual is referred to as homozygous. The parents in the eye color cross are homozygous, with the female being homozygous for dominant red-eye alleles and the male being homozygous for the recessive white eye allele. However, when an individual has two different allele, one dominant and one recessive, that individual is referred to as heterozygous. The offspring in the eye color cross is heterozygous.

17. **Project Slide 11:** Explain to your students that curly wings are established by big *Y* and straight wings are produced by little *y.* Similar to *E,* big *Y is* dominant to little y*,* such that *YY* and *Yy* individuals both have curly wings.

18. **Project Slide 12:** Explain to your students that when an individual is heterozygous, i.e., has two different alleles, only one allele is transmitted to any given offspring through sperm and eggs. For example, individual offspring of a *Yy* father inherit *Y* or *y* but not both.

19. Ask the students:

    - *Based on what they have just learned, do they hypothesize that their curly-winged fathers were* YY *or* Yy*?* Ask them to support their logic by referring to offspring wing shapes that they observed. They should record their hypothesis on their worksheet before proceeding.

EXTEND

1. Students will test their hypotheses about whether the curly winged males were homozygous or heterozygous through a simulation. Split your class into two roughly equal sized groups. If each group contains a similar number of male and female students, you can let the girls be the female flies and the boys be the male flies. Alternatively, you will have to assign half the students in each group to act as the male or female fly.

2. Give every student two popsicle sticks. Alternatively, if you don't have popsicle sticks, two small sheets of paper will also work fine. Each student should write a single letter on each of the two popsicle sticks/sheets of paper according to the table below. The popsicle sticks/sheets of paper correspond to their alleles.

Group #	Sex	Stick / Sheet 1	Stick / Sheet 2
Group 1	Male	*Y*	*Y*
Group 1	Female	*y*	*y*
Group 2	Male	*Y*	*Y*
Group 2	Female	*y*	*y*

3. Individuals in group 1 will simulate matings between *YY* males and *yy* females. Individuals in group 2 will simulate matings between *Yy* males and *yy* females. For each mating, students will randomly select 1 allele (on a popsicle stick or a sheet of paper), which will be transmitted in their gametes (sperm or egg) to form their offspring. Students will record the gene variants and determine wing-shape of each offspring produced.

4. After a few minutes have passed, or the students have run out of space on their data tables, ask them to total up their results. *How many curly-winged offspring did they produce? How many straight-winged offspring?* They should record their totals on their student worksheet, and you should discuss them as a class. Your students should observe that when the male fly is homozygous for curly-winged alleles (*YY*, group 1) all of the offspring have curly wings. However, when the curly winged father is heterozygous (*Yy*, group 2), both curly and straight winged offspring are produced. Given these observations, the father must have been *Yy*.

EVALUATE

The questions below are provided on your student's worksheet and will evaluate their understanding of the concepts learned in this exercise. You can adjust the questions or your grading to different class types.

1. In humans, detached earlobes are dominant to attached earlobes. Both Will Smith and Jada Pinkett Smith (mom and dad) have detached earlobes, while their son Jaden has attached earlobes. *How can a child inherit a trait that neither of his parents has?* [A good answer will explain that dominant alleles mask the trait conferred by the recessive allele. Therefore, although both Will and Jada have detached earlobes, they each carry an allele for attached earlobes, which they transmitted to their son Jaden.]

2. Specify whether Will, Jada, Jaden and Willow are homozygous, heterozygous or could be either for their ear lobe alleles. Circle the correct answer in the following table. (Correct answers in bold.)

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Will	**Homozygous / Heterozygous / Either**
Jada	Homozygous / **Heterozygous** / Either
Jaden	**Homozygous** / Heterozygous / Either
Willow	Homozygous / Heterozygous / **Either**

3. Write the two alleles of the red-eyed offspring of red-eyed females and white-eyed males: *Ee*

4. *Are the baby flies homozygotes or* **heterozygotes***?* Circle the correct answer.
   (Correct answer in bold.)

5. *If these flies were allowed to mate with their brothers and sisters, would the inbred grandbaby flies have red eyes, white eyes or both?* Explain your answer. [A good answer will explain that because the parents are heterozygotes (Ee) the offspring will be both red and white eyed.]

6. *In sexually reproducing organisms, why do the same pair of parents produce diverse offspring with different observable traits?* Draw on your observations of ear lobe shape in the Smith family, and fruit fly-wing shape to support your claim. [A good answer will explain that different offspring are produced in sexual reproduction because offspring inherit different combinations of alleles from their parents. An excellent answer would point out that this arises from the random selection of one allele in heterozygous parents, resulting in different alleles being transmitted to different offspring.]

GLOSSARY

Hypothesis — An idea about how a natural process works. A good hypothesis draws on real world observations and can be evaluated using scientific experiments.

Prediction — An expected outcome of an experiment given that a hypothesis is true.

Homozygous — Individuals have two copies of the same allele: both dominant or both recessive.

Heterozygous — Individuals have one copy of two different alleles: one dominant and one recessive.

Dominant Alleles — Determine an individual's trait in one or two copies. The trait specified by the dominant allele will be exhibited by both homozygous and heterozygous individuals.

Recessive Alleles — Require two copies to determine an individual's trait. The trait specified by the recessive allele will be exhibited only by individuals who are homozygous for the recessive allele.

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