Lesson Plan: Monster Mash

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Target Grade: 6th

Teacher Prep Time: 20 minutes

Lesson Time: 6 hours 20 minutes (We recommend doing this lesson over 7 days, 1 part per day.)

- Part 1: Multigenerational Observations - Shnorfs
    - 10 min – Beginning Thoughts
    - 15 min – Shnorf Observations
    - 15 min – Constructing Shnorf Model
    - 15 min – Sharing Shnorf Model
- Part 2: Multigenerational Observations - Dromos
    - 5 min – Introduction
    - 20 min – Dromo Observation
    - 15 min – Constructing Dromo Model
    - 15 min – Sharing Dromo Model
- Part 3: Shnorf Genetics
    - 5 min – Introduction
    - 5 min – Predicting Shnorf Families
    - 15 min – Where Shnorf Traits Come From
    - 20 min – Revising Shnorf Model
    - 15 min – Sharing Shnorf Model
- Part 4: Predicting the Frequency of Traits - Shnorfs
    - 5 min – Introduction
    - 20 min – Punnett Squares
    - 15 min – Revising Shnorf Model
    - 15 min – Sharing Shnorf Model
- Part 5: Predicting the Frequency of Traits - Dromos
    - 5 min – Introduction
    - 10 min – Where Dromo Traits Come From
    - 15 min – Types of Reproduction
    - 15 min – Revising Dromo Model
    - 15 min – Sharing Dromo Model
- Part 6: Applying the Model
    - 5 min – Introduction
    - 10 min – Relate to Humans
    - 20 min – Ploobs
- Part 7: Verifying the Model
    - 5 min – Introduction
    - 15 min – Reading
    - 10 min – Reading Analysis
    - 15 min – Final Revision of Heredity Model
    - 15 min – Sharing Final Heredity Model

Where This Lesson Fits in:

Before students do this lesson, they should know what a trait is and be able to list several traits that humans have. In addition, they should know that traits can either be inherited or acquired.

Students will also work with equivalent fractions in this activity.

Lesson Overview:

During this lesson students will create a model of heredity. Students will construct this model using observations of two different species of monsters. Each species reproduces differently, one by sexual reproduction, and one by asexual reproduction. Students will identify patterns in various sets of offspring and parents. This will allow them to make revisions to their model and include the two distinct types of reproduction (sexual and asexual) as well as develop a way to predict the fraction of offspring they would expect to have a given trait. Students will then use this model to explain the type of reproduction in humans. In addition, students' models will be challenged by giving them pictures of a parent and offspring from a monster that is capable of doing both types of reproduction. This will require students to revise their model. The lesson concludes with students checking their models against a grade-level appropriate scientific reading.

Learning Objectives:

- Students will be able develop a model to describe sexual and asexual reproduction.
- Students will know that organisms can reproduce by using sexual reproduction, asexual reproduction, or by using both types of reproduction.
- Given the genetic makeup of a single parent for asexual reproduction, or both parents for sexual reproduction, students will be able to predict the expected fraction of offspring that will show a trait.
- Students will be able to identify advantages of sexual and asexual reproduction.

NGSS:

- **Performance Expectation**
  - 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.

- **Science and Engineering Practice**
  - #2 Developing and Using Models
    - Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
      - Evaluate limitations of a model for a proposed object or tool.
      - Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable patterns.
      - Develop and/or use a model to predict and/or describe phenomena.
- **Disciplinary Core Idea**
  - LS3.B Variation of Traits
    - In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.
- **Cross Cutting Concept**
  - #1 Patterns
    - In grades 6-8, students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates

of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.

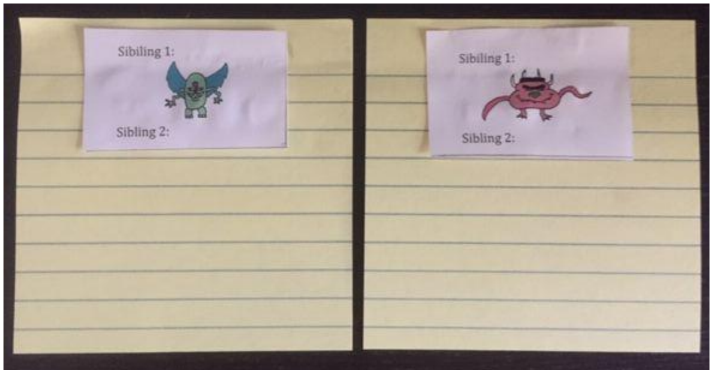
Materials Needed (see start of lessons sequence for suggested students per group)**:**

- 1 Worksheet (per student + one class worksheet)
- 1 How Species Reproduce Reading (per student)
- 1 Poster paper 2.2 ft x 2.8 ft (per group)
- Sticky notes multiple sizes. It is helpful to have lines on the sticky notes
    - 3x3
    - 4x4
    - 3x5
- 1 Sibling sticky note set (per group) - printed in color if possible
- 1 Family sticky note (per group) - printed in color if possible
- 1 Possible offspring sticky note (per group)
- Document camera

Teacher Prep:

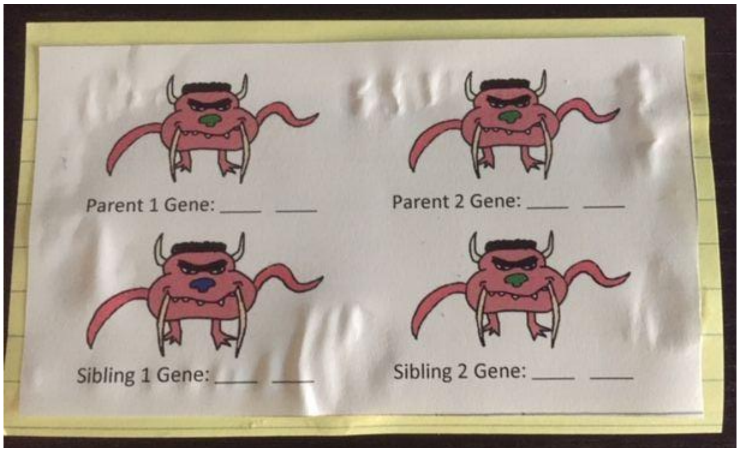
Part 1:

- Print out student worksheet
- Make sibling sticky note sets by printing the template which contains the two monsters seen below. Cut the monsters apart and glue them on the top of two separate 4x4 sticky notes leaving room for students to draw the second sibling underneath.



Part 2:

- Make family sticky notes by printing the template which contains the monster below. Cut the families apart and glue on a 3x5 sticky note.



- Make possible offspring sticky notes by printing the template which contains the text below. Cut the text apart and glue it on a 3x3 sticky note.

Lesson Sequence:

* For this activity we recommend students work in groups of 4. The groups can be of 3 but you want an even number of groups overall. It is important that the groups are made up of mixed level students.

Part 1: Multigenerational Observations - Shnorfs	
10 minutes	**Beginning Thoughts** ● Hand out worksheets to students. ● Keep one worksheet to be the class worksheet. This will be put under the document camera to record student answers as they complete the activity. ● Have students answer questions 1-3 on their own. ● Discuss student responses to the questions and fill in the class consensus answer on the class worksheet. By the end of the conversation make sure that students understand that traits are qualities or characteristics of a living thing. These can be visible such as eye color or not visible such as an outgoing personality. Traits are passed down from parent to offspring and can be influenced by the environment. Make sure that students understand that some traits like your personality are influenced by both the environment and your parents but other traits such as eye color are just determined by your parents. Tell students, “In this activity we will only focus on traits that are inheritable or passed down from parent to offspring.” ● Show students slide 2. ● Ask students, “What are some traits that you notice in the monster on the slide?” ○ ESR: Spots, feet, moon-shaped eyes, horns, claws.

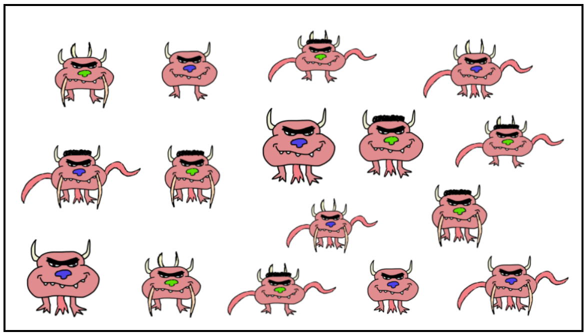
What traits does this monster have?

- Ask students, “Are there many correct answers to this question and do most species have a few or a lot of different traits?”
    - ESR: There are many correct answers and most species have many different traits.

15 minutes

Shnorf Observations

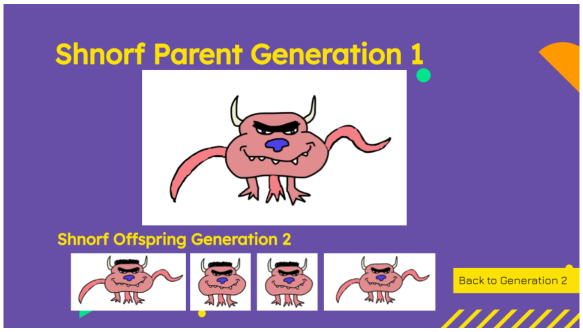
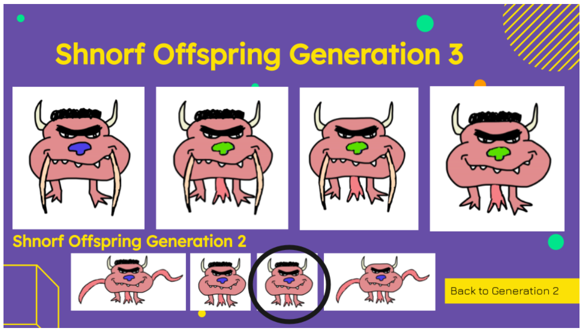
- Tell students, “We will now be exploring a species of monsters called shnorfs.”
- Show students slide 3 and have them write down the traits that can vary between shnorfs for question 4. Then, have students share their answers and record these in the class worksheet. Make sure students have all traits that can vary listed for question 4.



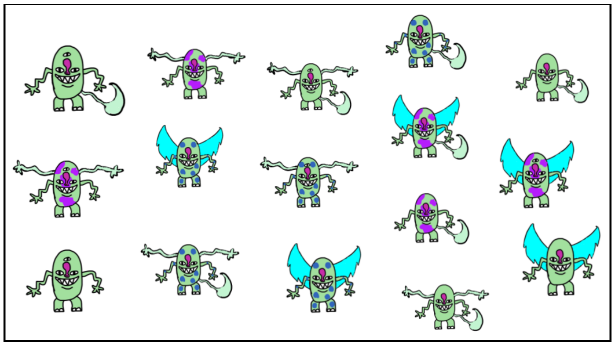
- Show students slide 4 and tell them, “The shnorfs you see here are all siblings.”

Shnorf Offspring Generation 2

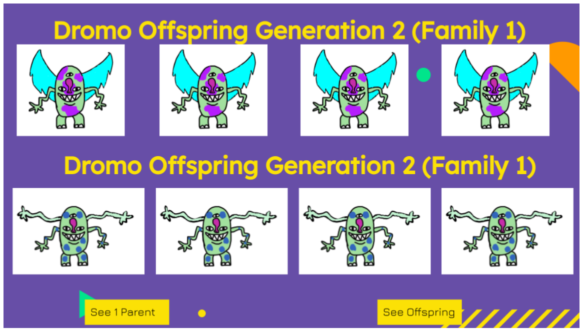
- Have students circle the traits that are the same for the siblings in question 4 and do this in on the class worksheet.
- Have students complete question 6 on their own. Then, discuss their answers as a class. By the end of the discussion, students should understand that siblings share some traits in common, but also have some unique traits.
- Have a discussion about what a scientific model is. “A model is a way to show our understanding of a phenomenon. One way to do this is to use drawings or words to represent the model of our understanding in our head. We should make sure to include information that would allow for predictions so that we are able to go

	out and further test our model." ● As a class, fill in the sentence frames in question 7 about the information that should be included in a model of heredity in the class worksheet while students fill these in on their worksheets. ● Tell students, "We now have the choice to either look at one parent of the shnorf siblings, or a set of offspring produced by one of the shnorf siblings." Have students vote on which they would prefer and record this for question 8. Click on the corresponding Parent or Offspring hyperlink in the slide to take you to the correct slide. **Be sure not to click through the slides as this would spoil later parts of the activity.**  Shnorf Parent Generation 1 Shnorf Offspring Generation 2 Back to Generation 2  Shnorf Offspring Generation 3 Shnorf Offspring Generation 2 Back to Generation 2 ● Have students individually answer questions 9 and 10. Then, have them share their answers and record the class consensus answer in the class worksheet. ○ If students chose to look at the parent (generation 1 shnorf), they should notice and record that the parent is similar but not exactly the same as its offspring for question 6. ○ If students chose to look at the offspring produced by one of the siblings (generation 3 shnorfs), they should notice and record that the generation 3 siblings look similar but not exactly the same as their generation 2 parent, AND that some traits begin to appear in generation 3 that did not show up in their parent (such as tusks).
15 minutes	**Constructing Shnorf Model** ● Put up slide 5 and explain the mechanics of making a poster to show their model or understanding of heredity. Make sure they understand that all writing and drawing should be on sticky notes so that it can be moved around and modified when needed.

	 Making a Poster of Your Model My thoughts about heredity. A drawing to help people understand my thinking. • Put all drawing and writing on sticky notes. • You can move around your sticky notes when needed • Do not fill up your entire poster, you will add more to it later. ● Tell students, “You will now get into groups of four and construct an initial model of heredity, use questions 7 and 10 to help.” ● Randomly assign students or create groups of four and give each group poster paper and sticky notes. Have students create an initial model by drawing/writing on sticky notes, then sticking them onto the poster paper where they see fit. ● While students are doing this, walk around and ask groups questions.
15 minutes	**Sharing Shnorf Model** ● Have groups explain their model to another group. ● Select two groups to share their models with the class. ● Have students fill out question 12 on their own and then share their thoughts with the class. Record the class consensus answer in the class worksheet.
Part 2: Multigeneration Observations - Dromos	
5 minutes	**Introduction** ● Ask students, “What is a trait?” ○ ESR: A quality or characteristic of a living thing. ● Ask students, “What species of monster did we learn about last session?” ○ ESR: Shnorfs. ● Ask students, “What patterns did we observe in these monsters' parents and siblings?” ○ We observed that shnorfs are similar to but not exactly like their parents and siblings.
20 minutes	**Dromo Observations** ● Tell students, “We will now be exploring a species of monsters called dromos.” ● Show students slide 6 and have them write down the traits that can vary between dromos for question 13. Then, have students share their answers and record these in the class worksheet. Make sure students have all traits that can vary listed for question 13.



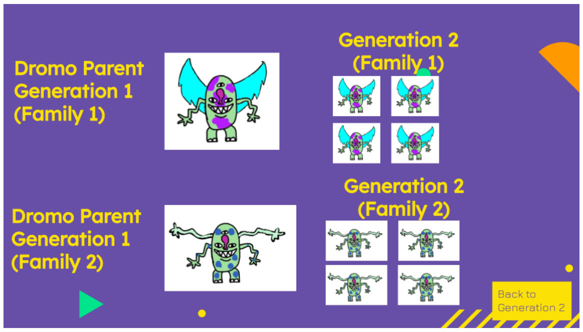
- Tell students, “We are going to look at a set of dromo offspring but before we do, let’s look back at question 12 and see what we predicted we would see in these offspring.” Let a few students share their answers.
- Show students slide 7 and tell them, “The dromos you see here are two different sets of siblings.”



Dromo Offspring Generation 2 (Family 1)

Dromo Offspring Generation 2 (Family 1)

- Discuss if their predictions from question 12 match what is shown and have them fill in question 14 on their worksheet. Based on the shnorfs, they should not have made the correct predictions.
- Have students complete questions 15-19 on their own. Then, discuss their answers as a class and record the class consensus answers on the class worksheet.
  - For question 18, most students will say that their parents must look just like them. Ask students, “How likely is it that within a species, two individuals find each other that are identical to each other and have an offspring?” Do not give them the answer to this question but make sure that they realize that it is probably not that often.
  - For question 19, make sure students say that offspring can be identical. Then ask students, “Do humans ever have offspring that are identical and if so how often does this happen?”
    - ESR: When humans have twins they are identical, but this is rare.
- Tell students, “We now have the choice to either look at one parent of the domo siblings, or the set of offspring produced by one of the dromo siblings.” Have students vote on which they would prefer and record this for question 20. Click on the corresponding hyperlink in the slide which will take you to the correct slide. Be sure not to click through the slides as this would spoil later parts of the activity.



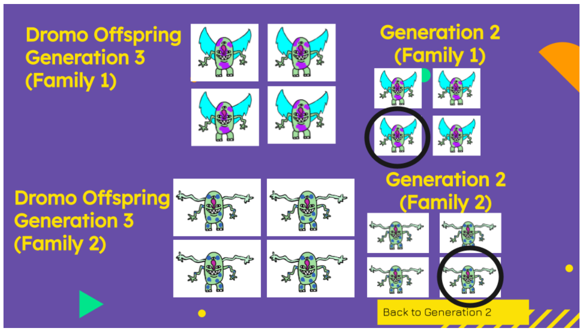
Dromo Parent Generation 1 (Family 1)

Generation 2 (Family 1)

Dromo Parent Generation 1 (Family 2)

Generation 2 (Family 2)

Back to Generation 2



Dromo Offspring Generation 3 (Family 1)

Generation 2 (Family 1)

Dromo Offspring Generation 3 (Family 2)

Generation 2 (Family 2)

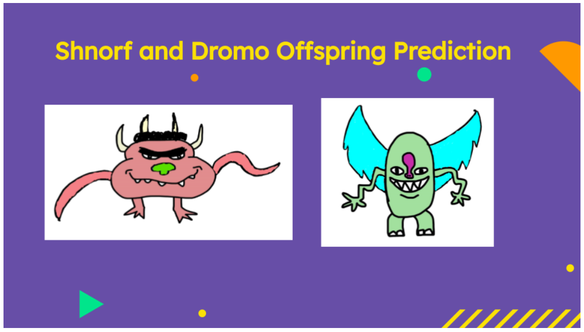
Back to Generation 2

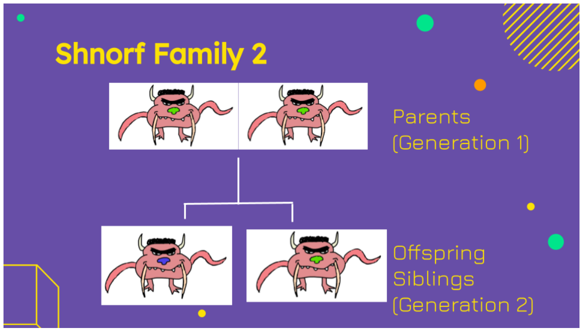
- Have students answer questions 21-22 on their own. Then discuss their answers as a class and record the class conscious answers in the class worksheet.
    - For question 21, in either scenario, students should see that the offspring are always identical to the parent.
    - For question 22, make sure students understand that dromo siblings are the same and shnorf siblings are similar but different. Ask students, “Does our current model of heredity predict that offspring would commonly look the same?”
        - ESR: No.
        - If student are struggling with this ask them, “Shnorf families are similar to human families. If we picked two human families at random, how likely would it be that all of the siblings in each family would look identical?” (ESR: Very unlikely.)
        - Tell students, “When we picked two dromo families at random, what did we notice?” (ESR: Each set of siblings were the same.)
        - Ask students, “Do you think that shnorfs and dromos have the same or different models of heredity?” Make sure that students realize that they might need more than one model of heredity to explain how traits are handed down in all species.
- Fill in question 23 in the class worksheet while students fill it in on their worksheet.

15 minutes

Constructing Dromo Model

- Tell students, “You will now get back into your groups and adapt your model of heredity, use questions 19 and 23 to help. In addition, you will need to draw a sibling of the shnorf and dromo that I give you. It will also be shown on the slide. Make sure that you include writing to explain why you drew them with the traits that you did. Use your model to help you with this.”
- Display slide 8 so students can see a colored picture of the shnorf and dromo

	and pass out the sibling sticky notes.  Shnorf and Dromo Offspring Prediction ● Have students adapt their models by drawing/writing on sticky notes, then sticking them onto the poster paper where they see fit. ● While students are adapting their model, walk around and ask groups questions.
15 minutes	**Sharing Dromo Model** ● Have groups explain their model to another group. Direct them to focus on the portions of their model they added to or changed in this most recent revision. ● Select two groups to share their models with the class. ○ Make sure that you select groups that have different drawings for the shnorf sibling. This will allow you to discuss that for the shnorfs there are multiple correct answers but for the dromos there is only one correct answer.
Part 3: Shnorf Genetics	
5 minute	**Introduction** ● Ask students, “What is a trait?” ○ ESR: A quality or characteristic of a living thing. ● Ask students, “What species of monster did we learn about last session?” ○ ESR: We were learning about dromos. ● Ask students, “What patterns did we observe in dromo parents and siblings?” ○ ESR: We learned that dromos are exactly the same as their parents and siblings. ● Ask students, “What patterns did we observe in shnorf parents and siblings the session before?” ○ ESR: We learned that shnorfs are similar to but not exactly like their parents and siblings. ● Tell students, “Today we will be exploring the shnorf families more in detail and see if we can figure out how traits are passed down from parent to offspring.”
5 minutes	**Predicting Shnorf Families** ● Display slide 9. ○ This slide comes up in parts. Students will only be able to see the siblings when the slide first comes up. ● Have students answer question 25 on their own, using the colored pictures on the slide to help. Students are expected to draw parents with oppositely colored noses, as they will likely assume that parents must show traits that are passed to their offspring. ● Advance slide 9 to show the parents and ask students, “Are you surprised by

	this?” Have them fill in whether their predictions were correct for question 26.  Shnorf Family 2 Parents (Generation 1) Offspring Siblings (Generation 2)
15 minutes	**Where Shnorf Traits Come From** ● Tell students, “We will have to work together to determine why the parents do not look like we thought they would.” Then, have students answer questions 27-30 on their own. After, have them share their responses with the class while you record the class consensus answer in the class worksheet. ○ Make sure for question 28, students understand that the parents must have carried the genetic information to encode for the blue nose, despite both showing the green nose trait. Record the class consensus answer in the class worksheet. ○ Make sure for question 30 students understand that if nose color were determined by just one piece of information, the parents would only have the information for green nose and not be able to pass down the information for blue nose. ● Have students fill out question 31 on their own. After, have them share their responses with the class while you record the class consensus answer in the class worksheet. ○ Make sure students understand that if nose color were determined by two pieces of information, the parents could carry the information for both green and blue noses even though they only show green noses. ○ Also, discuss that if a shnorf carries two different pieces of genetic information, one for blue nose and one for green nose, they will only show the green nose trait. ● As a class, go over question 32. You will need to give students most of the vocabulary words for the blanks in the sentence frame (We are exploring the trait of **nose color.** The genetic information for traits are stored in **genes**. Within a **gene**, there are two pieces of information, these are called **alleles. Alleles** code for the different versions of a trait; for example, **blue nose** and **geen nose**. Even though the **alleles** could be different in a **gene**, only one will be seen). Fill in the blanks in the class worksheet while students fill these in on their worksheets. ● Tell students, “Using the vocabulary words that we learned for question 32, try to fill out question 33.” After students have individually completed question 33, have them share their responses with the class while you record the class consensus answer in the class worksheet. Make sure students understand that each parent is passing down one allele to their offspring. ● Have students answer question 34 on their own and then share what they think goes in the blanks. Once a class consensus has been reached, fill in the answers in the class worksheet.

20 minutes	**Revising Shnorf Model** ● Tell students, “You will now get back into your groups and adapt your model of heredity, use question 34 to help. In addition, you will need to determine the alleles of the shnorf family we have been working with. You will use “B” for the blue nose allele and “G” for the green nose allele.” Have students fill this in for the blanks in the first bullet point of question 35. ● Show students the family sticky note, and show them the line, and explain that each line represents an allele in the gene. Tell students, “Make sure that you include writing to explain your assigned alleles. In addition, you are going to determine the possible allele combinations in offspring from these parents.” ● Show students the possible offspring sticky note. Show them where to record the alleles and whether a monster with that set of alleles would display a green or blue nose. Tell students, “Use the possible alleles to determine what fraction of offspring you expect to show a blue nose as opposed to a green nose.” ● Give each group a family and a predicting offspring sticky note. ● If slide 9 is not already displayed, be sure to display it so that students can see colored pictures of the shnorf family. ● Have students adapt their models by drawing/writing on sticky notes, then sticking them onto the poster paper where they see fit. ● While students are adapting their model, walk around and ask groups questions.
15 minutes	**Sharing Revised Shnorf Model** ● Have groups explain their model to another group. Direct them to focus on the portions of the model they added in this most recent revision. ● Select two groups to share their models with the class. ○ Make sure that you select groups that have different predictions about the alleles in the green nosed sibling. These alleles could either be GG or BG. It is impossible to tell from the data that is given. ● While the groups are sharing their models, make sure that the class agrees that the alleles that could be present in an offspring of these parents are: BB, GG, BG, and GB. Of these BG, GB, and GG all would show a green nose and BB would show a blue nose. Therefore, only ¼ of their offspring should have blue noses and ¾ of their offspring should have green noses.
Part 4: Predicting the Frequency of Traits - Shnorfs	
5 minutes	**Introduction** ● Ask students, “What did we learn last time about how traits are passed down?” ○ ESR: Organisms have at least two alleles per trait. Parents pass down one allele each to their offspring. ● Ask students, “Do we always show all of the alleles that we have?” ○ ESR: Organisms can carry an allele for a trait, but not exhibit the trait, like the parents of the blue-nosed shnorf. ● Ask students, “What alleles would make it so a shnorf shows a green nose?” ○ ESR: GG, BG, or GB. ● Ask students, “What were the possible alleles an offspring could be born with if their parents both had the alleles BG? ○ ESR: BB, BG, GB, and GG. ○ Write the allele combinations on the board, and write what color the offspring’s nose would be for each combination.

	● Ask students, “What fraction of these offspring would have a green nose?” ○ ESR: BG, GB, and GG all would give a green nose therefore ¾ of their offspring would be expected to show green noses.
20 minutes	**Punnett Squares** ● Tell students, “Geneticists do exactly what we just did to calculate the probability that an offspring will carry a certain trait, but they use a box to help with their calculations.” ● Tell students, “Geneticists call these boxes Punnett squares.” Fill this in for the blank in question 36 on the class worksheet while students fill it in on their worksheets. ● Show students how to make a Punnett square by putting the alleles of the parents on the outside of the box. Remind students that it does not matter if they write the traits as BG or GB because they are genetically equivalent. ● Then, show them how to fill in the center of the box. ● In each square of the box write a “blue” or “green” for the nose color that would be observed. ● Use the box to calculate the fraction of the offspring that are expected to show a blue or green nose, and verify that this matches their calculations from the previous day. ● Display slide 10 so students can see a colored picture of the shnorfs for question 37.  Shnorf Offspring Born March, 2021 ● Have students answer question 37 on their own. After, have students share their responses with the class. Make sure students realize that the expected and actual number can vary. Record the class consensus answer in the class worksheet. ● Discuss question 38 as a class and record the class consensus answer in the class worksheet while students record it in their worksheets. ○ To help students understand why having more data produces numbers that are closer to the predicted values, ask students the following questions while you fill in the table on the board. For this section to work, you need to have them use equivalent fractions out of 12. This allows you to talk about a scenario in which the parents produce 3 offspring. ○ Ask students, “What is the predicted fraction of shnorfs that will show a blue nose?” (ESR=1/4) Have students give you the equivalent fractions out of 8 (2/8) and 12 (3/12) as well. Record this in the table. ○ Ask students, “If the monsters’ first offspring has a blue nose, what is the fraction of their offspring that have blue noses?” (ESR: 1/1) Have students give you the equivalent fractions out of 4, 8, and 12 as well.

Record these in the table. Point out that this is far from the 3/12 predicted from the model.
    - Ask students, “If the monsters’ second offspring has a green nose, what is the fraction of their offspring that have blue noses?” (ESR: 1/2). Have students give you the equivalent fractions out of 4, 8, and 12 as well and record these in the table.
    - Tell students, “This is still far from the predicted number.” Ask students, “Is it closer to the predicted number?” (ESR: Yes) Record this on the table.
    - Ask students, “If the monsters’ third offspring has a green nose, what is the fraction of their offspring that have blue noses?” (ESR: 1/3) Have students give you the equivalent fractions out of 6 and 12 as well, and record these in the table.
    - Ask students, “Is this getting closer to the predicted value?” (ESR: Yes) Record this in the table.
    - Ask students, “What does this show us about sample size?”(ESR: The larger the sample, the closer it is to our predicted numbers.)

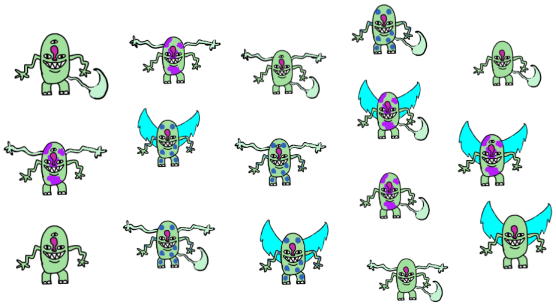
Offspring	Actual Fractions with Blue Nose	Match	Is it closer
Blue Nose	1/1=4/4=8/8=12/12	No	
Blue Nose and Green Nose	1/2=2/4=4/8=6/12	No	Yes
Blue Nose, Green Nose, and Green Nose	1/3=2/6= 4/12	No	Yes
Predicted Fractions with Blue Nose ¼=2/8=3/12			

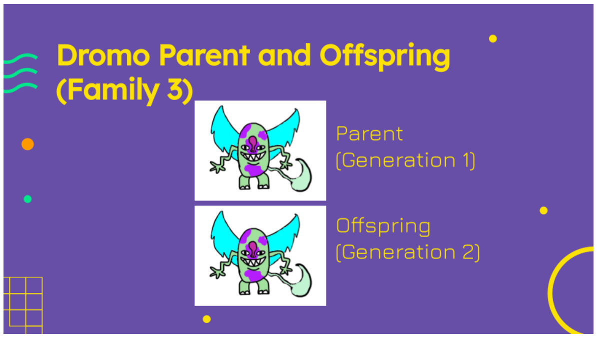
- Have students answer question 39 on their own and then discuss what the terms dominant and recessive mean. Then, record the class consensus answer on the class worksheet.
    - A dominant allele is an allele that is expressed as a trait when only one of that allele exists in an individual’s genome. A recessive allele is an allele that is not expressed as a trait when only one of that allele exists in an individual’s genome.
- Have students answer question 40 on their own and then share what they think goes in the blanks. Once a class consensus has been reached, fill in the answers in the class worksheet.

15 minutes

Revising Shorf Model

- Tell students, “You will now get back into your groups and adapt your model of heredity, use question 40 to help. In addition, you will need to add a Punnett square for two shnorf parents, one with tusks and one without tusks. You will use your Punnett square to predict the fraction of offspring that would have tusks. The tusk allele is known to be recessive. You can use “T” for the tusk allele and “N” for the no tusk allele.”
- Have students adapt their models by drawing/writing on sticky notes, then

	sticking them onto the poster paper where they see fit. ● While students are adapting their models, walk around and ask groups questions.
15 minutes	**Sharing Shorf Model** ● Have groups explain their model to another group. Direct them to focus on the portions of their models they added to or changed in this most recent revision. ● Select two groups to share their models with the class. ○ Make sure that you select groups that have different sets of alleles for the shnorf with no tusk. This shnorf could have the alleles TN or NN. If the parents are TT and NN then 0/4 or none of the offspring will have tusks, but they all will be carriers. If the parents are TT and TN, then ½ of them will have tasks, and ½ of them will not have tusks, but will be carriers. ● Make sure that you introduce the word carrier (an offspring that carries a recessive allele but does not show the trait).
Part 5: Predicting the Frequency of Traits - Dromos	
5 minute	**Introduction** ● Ask students, "What did we learn about genetic material last session?" ○ ESR: Genetic material is stored in genes. Genes contain two alleles. Genes determine our traits. Even if a monster has two different alleles they will only show one of the traits. The trait shown is the dominant trait. ● Ask students, "Can we make predictions about what traits will show up in offspring? If so, how?" ○ ESR: We can make predictions about the traits in offspring if we know the alleles of the parents. We can use the alleles of the parents to make a Punnett square which will give us the fraction of offspring we would expect to show a given trait. However, the fractions that we get are just probabilities and might be off from the actual number of offspring that are born with this trait.
10 minutes	**Where Dromo Traits Come From** ● Tell students, "Today, we will look at dromo families in more detail and see if what we learned from shnorfs can be applied to dromos." ● Display slide 11 for students.  ● Ask students, "Are all dromos identical?" Be sure that students understand that not all dromos look identical. Circle "no" on the class worksheet while students do this on their worksheet under question 42. ● Display slide 12 with a new dromo parent and offspring.

	 Dromo Parent and Offspring (Family 3) Parent (Generation 1) Offspring (Generation 2) ● Have students answer question 43 on their own and then share their ideas with the class and record the class consensus answer in the class worksheet. ● Have students answer question 44 on their own and then discuss. Students may be tempted to think each dromo has 2 identical parents. ● Ask students, “How likely is it for two identical dromos to find each other?” If students are struggling, show them slide 11 again to remind them how much variation exists within the species and ask the question again. By the end of the conversation make sure they understand that this is not likely to happen. Have students record this in their worksheet under question 45. ● Have students attempt to answer questions 46 and 47 by themselves. Then have a class discussion and make sure they understand that even if you have two parents with the exact same genetic information, they can have a child that has different genes than them if they carry a recessive allele. Fill in the answer for questions 46 and 47 in the class worksheet. If needed, have students correct their answers. ● Ask students, “How do you think that a parent could be identical to their offspring?” By the end of the discussion, make sure students realize that this can only happen if one parent hands down all of their genetic information, and that this would mean that there must only be one parent involved in the process. This means that dromo offspring only have one parent. Fill in questions 48 and 49 in the class worksheet while students copy this onto their worksheet.
15 minutes	**Types of Reproduction** ● Ask students, “Shnorfs undergo sexual reproduction to produce offspring. What was needed for shnorfs to reproduce?” Have a class discussion and make sure that students understand that to get a blue nosed offspring they have to have two parents. Fill this in for question 50 in the class worksheet while students fill it in on their worksheet. ● Have students fill in question 51 on their own and then share their answers. Write the class consensus answer in the class worksheet. ● Have students answer question 52 on their own and then discuss the answer. Make sure students understand that during asexual reproduction, one parent hands down all of their genetic information to their offspring. Record this in the class worksheet while students correct their answer if needed. ● Have students tell you what to fill into the two blanks for question 53. Fill these in on the class worksheet while students fill it in on their worksheet.

15 minutes	**Revising Dromo Model** ● Tell students, “You will now get back into your groups and adapt your model of heredity, use question 53 to help. Make sure that you include a definition of sexual and asexual reproduction in your model.”
15 minutes	**Sharing Dromo Model** ● Have groups explain their model to another group in the room. Direct them to focus on the portions of the model that they added in this most recent revision. ● Select two groups to share their models with the class.
Part 6: Applying the Model	
5 minutes	**Introduction** ● Ask students, “What are the ways that organisms can reproduce?” ○ ESR: Sexual and asexual reproduction. ● Ask students, “What is the difference between sexual and asexual reproduction? ○ ESR: Sexual reproduction needs two parents and each parent passes down half of their genetic information to their offspring. Asexual reproduction only has one parent and they pass down all of their genetic information to their offspring. ● Ask students, “What species of monster reproduces through sexual reproduction? What species of monster reproduces through asexual reproduction?” ○ ESR: Shnorfs reproduce through sexual reproduction, and dromos reproduce through asexual reproduction.
10 minutes	**Relating to Humans** ● Tell students, “We will now apply our models to humans.” Have students answer questions 55-58 on their own and then share their answers. Record the class consensus answers in the class worksheet. ● Have students answer question 59 on their own and then share their response. Make sure that students understand that because freckles are a dominant trait and neither parent had freckles, that neither parent could carry the allele for freckles to pass down to their child, therefore the child could not possibly have freckles.
20 minutes	**Ploobs** ● Tell students, “We will now explore a third type of monster called ploobs.” ● Display slide 13 and have students answer questions 60-61.  Ploob Offspring Born December, 2013 ● Discuss students' answers and record the class consensus answer in the class worksheet. At this point students should assume that ploobs reproduce sexually.

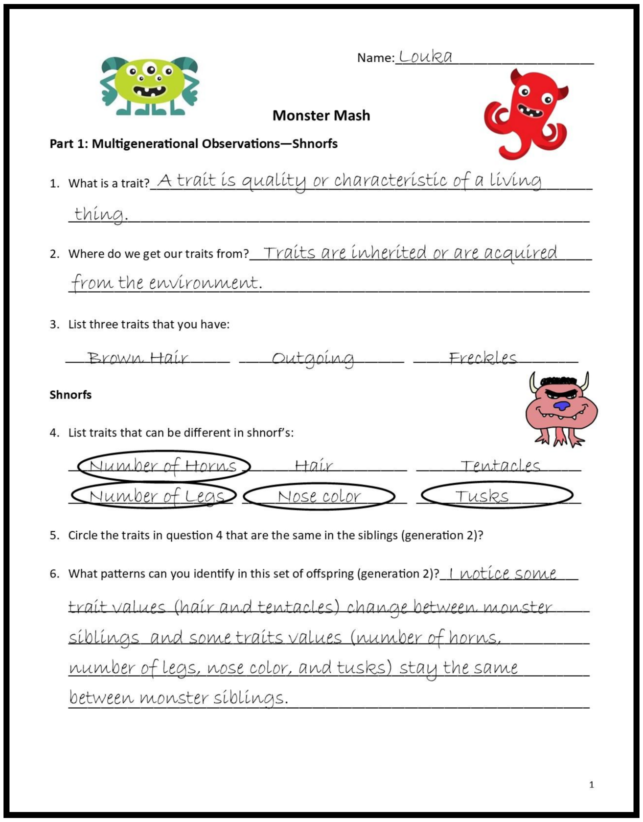
	● Display slide 14. Remind students that these offspring are siblings of the first set, just born at a different time. Then, have them fill in questions 62-65.  Ploob Offspring Born June, 2021 ● Discuss students' answers and record the class consensus answer in the class worksheet. Make sure that students understand that ploobs seem to be reproducing both sexually and asexually. ● Have students tell you what to fill into the blank for question 66. Fill this in on the class worksheet while students fill it in on their worksheet. ● Have students answer questions 67 and 68 on their own. Share responses as a class but do not discuss whether they are right or wrong.
Part 7: Verifying the Model	

5 minutes	**Introduction**
	● Ask students, “What are the ways that organisms can reproduce?”
	    ○ ESR: Sexual reproduction, asexual reproduction, and some species can do both.
	● Ask students, “What is the difference between sexual and asexual reproduction?”
	    ○ ESR: Sexual reproduction needs two parents and each parent passes down half of their genetic information to their offspring. Asexual reproduction only has one parent and they pass down all of their genetic information to their offspring.

15 minutes	**Reading** ● Pass out the “How Species Reproduce” reading to students. ● Have students take turns reading each paragraph. ● After the section on asexual reprodution, stop and discuss the differences and similaries between the reading and their models. ● Repeat this process after the sections on sexual reproduction, and both types of reproduction.
10 minutes	**Reading Analysis** ● Have students answer questions 69-71 on their own. Then, have them share their answers and record the class consensus answers for question 71 only in the class worksheet. ● Have students tell you what to fill into the blank for question 72. Fill this in on the class worksheet while students fill it in on their worksheet.

15 minutes	**Final Revision of Heredity Model** ● Tell students, “You will now get back into your groups and do the final revision of your model of heredity, use questions 66 and 72 to help with this. Make sure that each person in your group picks one type of asexual reproduction and makes a sticky note to include on your poster explaining that type of reproduction.”
15 minutes	**Sharing Final Heredity Model** ● Have groups explain their model to another group in the room. Direct them to focus on the portions of their model that they added to or changed in this most recent revision. ● Select two groups to share their models with the class. ● Tell students that they have helped you learn a lot about how living organisms reproduce and that you will hang their posters around the room to remind us of what we have learned.

Example Student Work:



Name: Louka

Monster Mash

Part 1: Multigenerational Observations—Shnorfs

1. What is a trit? A trait is quality or characteristic of a living thing.
2. Where do we get our traits from? Traits are inherited or are acquired from the environment.
3. List three traits that you have:

Brown Hair | Outgoing | Freckles

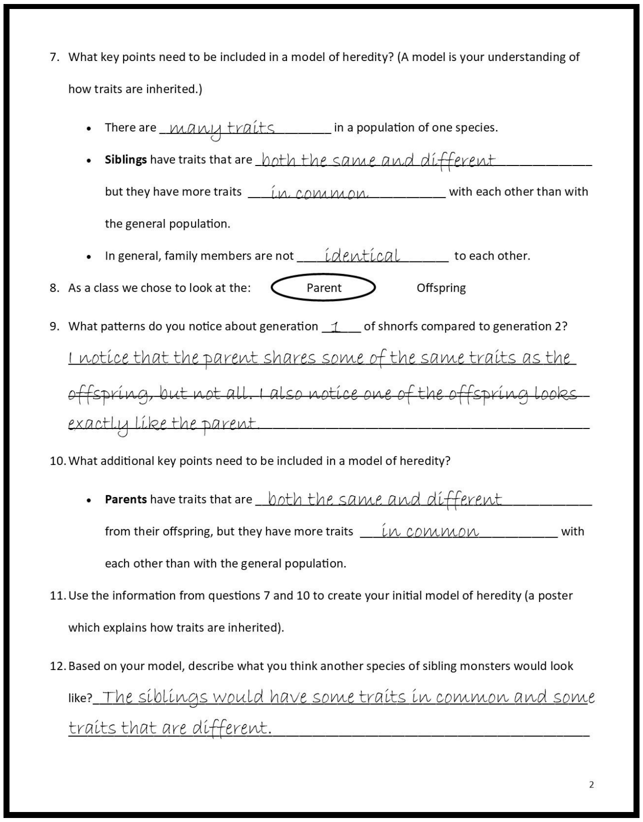
Shnorfs

4. List traits that can be different in shnorf's:

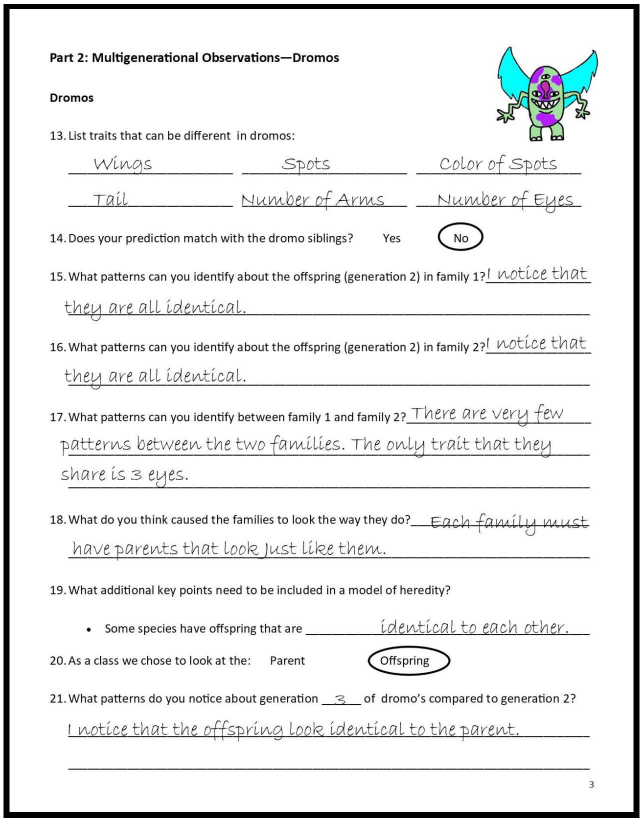
[✓ Number of Horns] | Hair | Tentacles

[✓ Number of Legs] | [✓ Nose color] | [✓ Tusks]

5. Circle the traits in question 4 that are the same in the siblings (generation 2)?
6. What patterns can you identify in this set of offspring (generation 2)? I notice some trait values (hair and tentacles) change between monster siblings and some traits values (number of horns, number of legs, nose color, and tusks) stay the same between monster siblings.



7. What key points need to be included in a model of heredity? (A model is your understanding of how traits are inherited.)
   - There are many traits in a population of one species.
   - **Siblings** have traits that are both the same and different but they have more traits in common with each other than with the general population.
   - In general, family members are not identical to each other.
8. As a class we chose to look at the: [✓ Parent] Offspring
9. What patterns do you notice about generation 1 of shnorfs compared to generation 2? I notice that the parent shares some of the same traits as the offspring, but not all. I also notice one of the offspring looks exactly like the parent.
10. What additional key points need to be included in a model of heredity?
    - **Parents** have traits that are both the same and different from their offspring, but they have more traits in common with each other than with the general population.
11. Use the information from questions 7 and 10 to create your initial model of heredity (a poster which explains how traits are inherited).
12. Based on your model, describe what you think another species of sibling monsters would look like? The siblings would have some traits in common and some traits that are different.



Part 2: Multigenerational Observations—Dromos

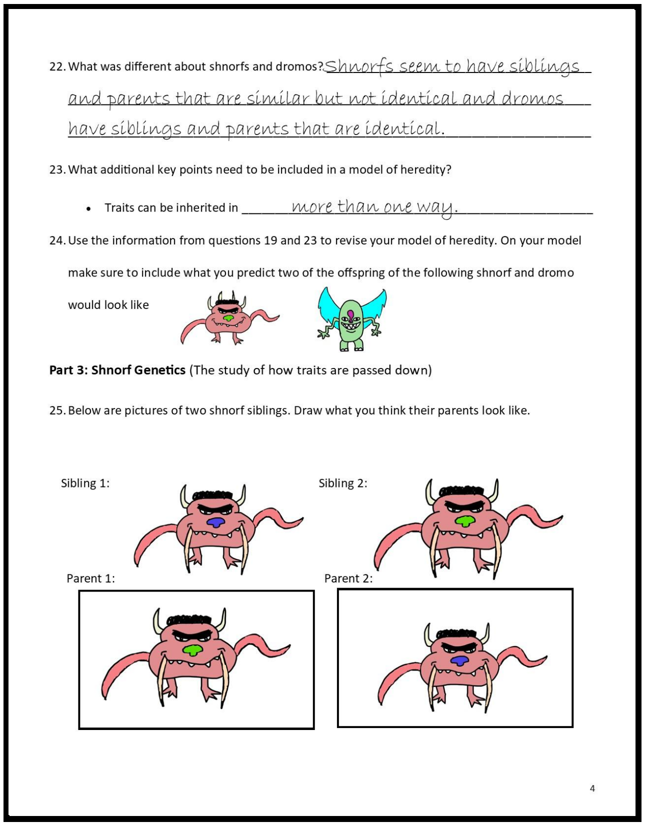
Dromos

13. List traits that can be different in dromos:

Wings | Spots | Color of Spots

Tail | Number of Arms | Number of Eyes

14. Does your prediction match with the dromo siblings? Yes [✓ No]
15. What patterns can you identify about the offspring (generation 2) in family 1? I notice that they are all identical.
16. What patterns can you identify about the offspring (generation 2) in family 2? I notice that they are all identical.
17. What patterns can you identify between family 1 and family 2? There are very few patterns between the two families. The only trait that they share is 3 eyes.
18. What do you think caused the families to look the way they do? Each family must have parents that look just like them.
19. What additional key points need to be included in a model of heredity?
    - Some species have offspring that are identical to each other.
20. As a class we chose to look at the: Parent [✓ Offspring]
21. What patterns do you notice about generation 3 of dromo's compared to generation 2? I notice that the offspring look identical to the parent.



22. What was different about shnorfs and dromos? Shnorfs seem to have siblings and parents that are similar but not identical and dromos have siblings and parents that are identical.
23. What additional key points need to be included in a model of heredity?
    - Traits can be inherited in more than one way.
24. Use the information from questions 19 and 23 to revise your model of heredity. On your model make sure to include what you predict two of the offspring of the following shnorf and dromo would look like

Part 3: Shnorf Genetics (The study of how traits are passed down)

25. Below are pictures of two shnorf siblings. Draw what you think their parents look like.

26. Were your predictions correct? Yes [✓ No]

27. Where did sibling 1's nose color come from? Their parents.

28. What does this mean about the parents' genes (genetic make up) ? Their parents must have carried this trait even though they did not show it.

29. If nose color is determined by one piece of genetic information, would it be possible for two green-nosed parents to have a blue-nosed offspring? Yes [✓ No]

30. Justify your answer to number 29. Nose color cannot be determined by one piece of genetic information because then the parents would not have had the information to pass down a blue nose.

31. Could nose color be determined by two pieces of genetic information? Why or why not?

Nose color could be determined by two pieces of genetic information because this would allow the parent to pass down the information for a blue nose and still have the information for a green nose which is seen.

32. We are exploring the trait of nose color. The genetic information for traits are stored in genes. Within a gene, there are two pieces of information, these are called alleles. Alleles code for the different versions of a trait; for example, blue nose and green nose. Even though the alleles could be different in a gene, only one will be seen.

33. What does this mean about how genetic information is passed down? Each parent must pass down only one allele to their offspring.

34. We will use B to represent the blue nose allele and G to represent the green nose allele.

35. What additional key points need to be included in a model of heredity?

- Genetic information is stored in genes which contain two alleles and determines what traits we have.
- Not all alleles that are carried are seen.
- Parents pass down one allele each to their offspring.

36. Use the information from question 35 to revise your model of heredity. In addition, make sure to include the following about the shnorf family consisting of two green-nosed parents, with blue-nosed AND green-nosed offspring:

- The alleles which are contained in each family member's genes.
- The possible allele combinations that the parents could pass down to their offspring.
- The fraction of offspring that are expected to show green noses, and the fraction of offspring that are expected to show blue noses.

Part 4: Predicting the Frequency of Traits - Shnorfs

37. Geneticists use Punnett squares to calculate the fraction of siblings that will inherit a certain trait from their parents. Confirm that your model matches the fractions from this method.

		Parent 2	
		B	G
Parent 1	B	BB blue	BG green
	G	GB green	GG green

Both methods predict that 3/4 of the offspring will have green noses and 1/4 of the offspring will have blue noses.

38. The following are eight siblings which are offspring from the parents we have been studying. Do these offspring match our predictions from question 36 and why?

	Green Nose	Blue Nose
Predicted Fraction (out of 8)	6/8	2/8
Actual Fraction (out of 8)	5/8	3/8

No, the actual fraction of offspring with blue noses is not equivalent to the predicted values. This is because our model just gives us probabilities these can be off from the actual numbers.

39. When is our model the most accurate? When the sample size is big.

40. The terms **dominant** and **recessive** are often used in discussing the inheritance of traits. What do you think these terms mean? The dominant trait is the trait that is seen when the monster has mixed alleles, and the recessive trait is only shown when the monster has two alleles for the recessive trait.

41. What additional key points need to be included in a model of heredity?

- If the allele is dominant only one allele for that trait is needed for the trait to be displayed.
- If the allele is recessive two alleles for that trait are needed for the trait to be displayed.
- Punnett squares give the fractions of offspring with a certain trait but these numbers are not guaranteed.

42. Use the information from question 41 to revise your model of heredity. On your model, include a Punnett square to show the probability that two shnorf parents, one with tusks (allele "T") and one with no tusks (allele "N"), would have offspring with tusks. Having tusks is known to be a recessive trait.

Part 5: Predicting the Frequency of Traits — Dromos

43. Are all dromos identical? Yes [✓ No]

44. What patterns did you notice about the dromo parent and their offspring that you saw?

The dromo parents and offspring look identical.

45. What does this mean about dromo parents? They may be identical to each other.

46. How likely is this to happen? Not very likely.

47. If you have identical parents, does this mean you will have identical offspring? Yes [✓ No]

48. Give an example to support your answer to question 47.

	Gene	Expressed Trait
Parent 1	BG	Green Nose
Parent 2	BG	Green Nose
Offspring	BB	Blue Nose

49. How could a parent produce identical offspring to them? This could only happen if a parent hands down all of their genetic information to their offspring.

50. What does this imply about dromos? Dromos only have one parent.

To reproduce, shnorfs undergo **sexual reproduction**.

51. How many parents are needed for sexual reproduction? Two parents are needed for sexual reproduction.

52. When an offspring is produced though sexual reproduction, what does this mean about where the offspring's genetic makeup comes from? Half of it comes from the offspring's mother and half of it comes from the offspring's father.

53. What do you think asexual reproduction is, and how many parents are needed? Asexual reproduction is when one parent gives all of their genetic information to their offspring, and only one parent is needed.

54. What additional key points need to be included in a model of heredity?

- Some species produce offspring through Sexual reproduction, others produce offspring through asexual reproduction.

55. Use the information from question 54 to revise your model of heredity. On your model, make sure to include a definition of sexual and asexual reproduction.

Part 6: Applying the Model

56. What patterns have you noticed in sets of human siblings? Human siblings are similar but not identical to one another.

57. What patterns have you noticed between parents and their children? Parents and children are similar, but not identical each other.

58. Use your model to make a claim about which type of reproduction humans undergo.

Humans undergo [✓ Sexual Reproduction] Asexual reproduction

because sexual reproduction needs two parents which humans have and leads to siblings that are similar but not identical to one another which is seen in humans.
evidence

59. According to your model, what does this mean about a human child's genes? A child's genes are composed of two alleles, one from their mother and one from their father.

60. In humans, the allele for freckles is known to be dominant. Use your model to calculate the probability that two parents without freckles will have a child with freckles.

	Gene	Expressed Trait
Parent 1	NN	No Freckles
Parent 2	NN	No Freckles
Child	NN	No Freckles

Since freckles are dominant, the parents can not carry the allele for freckles, and there is a 0/4 chance of their child being freckled.

Ploobs

61. What patterns did you notice in the ploob offspring born in December of 2013? The ploob siblings are similar but not identical to one another.

62. Use your model to make a claim about which type of reproduction ploobs undergo.

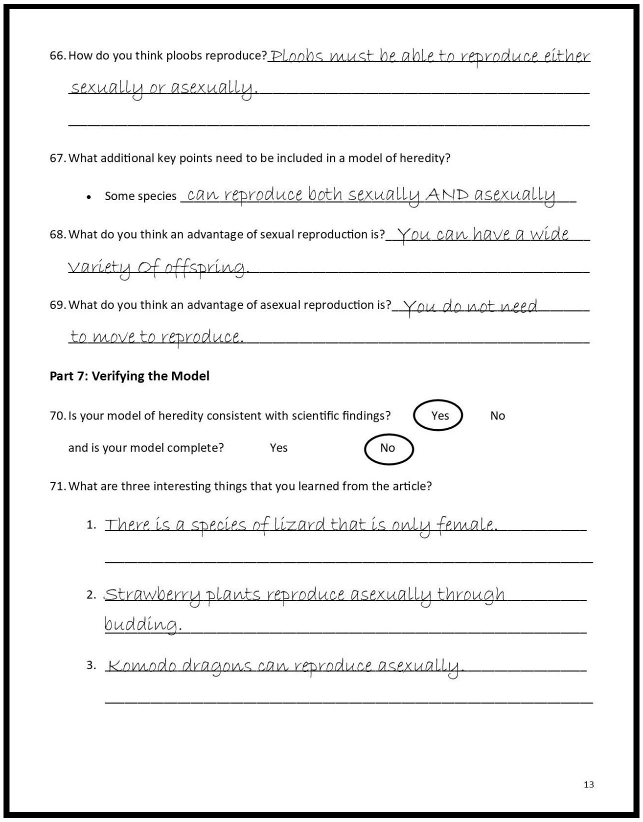
Ploobs undergo [✓ Sexual Reproduction] Asexual reproduction

because ploobs have offspring that are not identical and sexual reproduction is the only type of reproduction that leads to this.
evidence

63. What patterns did you notice in the ploob offspring born in June of 2021? The ploob siblings are identical to one another.

64. Was your prediction in question 62 correct? Yes [✓ No]

65. What evidence supports this? The second set of offspring are identical, so most likely reproduced asexually.



66. How do you think ploobs reproduce? Ploobs must be able to reproduce either sexually or asexually.

67. What additional key points need to be included in a model of heredity?

- Some species can reproduce both sexually AND asexually

68. What do you think an advantage of sexual reproduction is? You can have a wide variety of offspring.

69. What do you think an advantage of asexual reproduction is? You do not need to move to reproduce.

Part 7: Verifying the Model

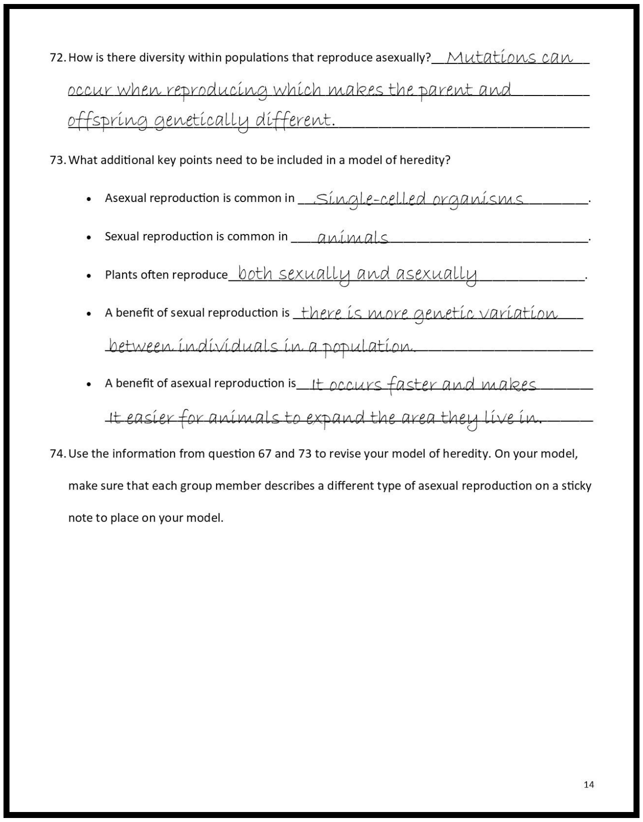
70. Is your model of heredity consistent with scientific findings? [✓ Yes] No

and is your model complete? Yes [✓ No]

71. What are three interesting things that you learned from the article?

1. There is a species of lizard that is only female.
2. Strawberry plants reproduce asexually through budding.
3. Komodo dragons can reproduce asexually.

13



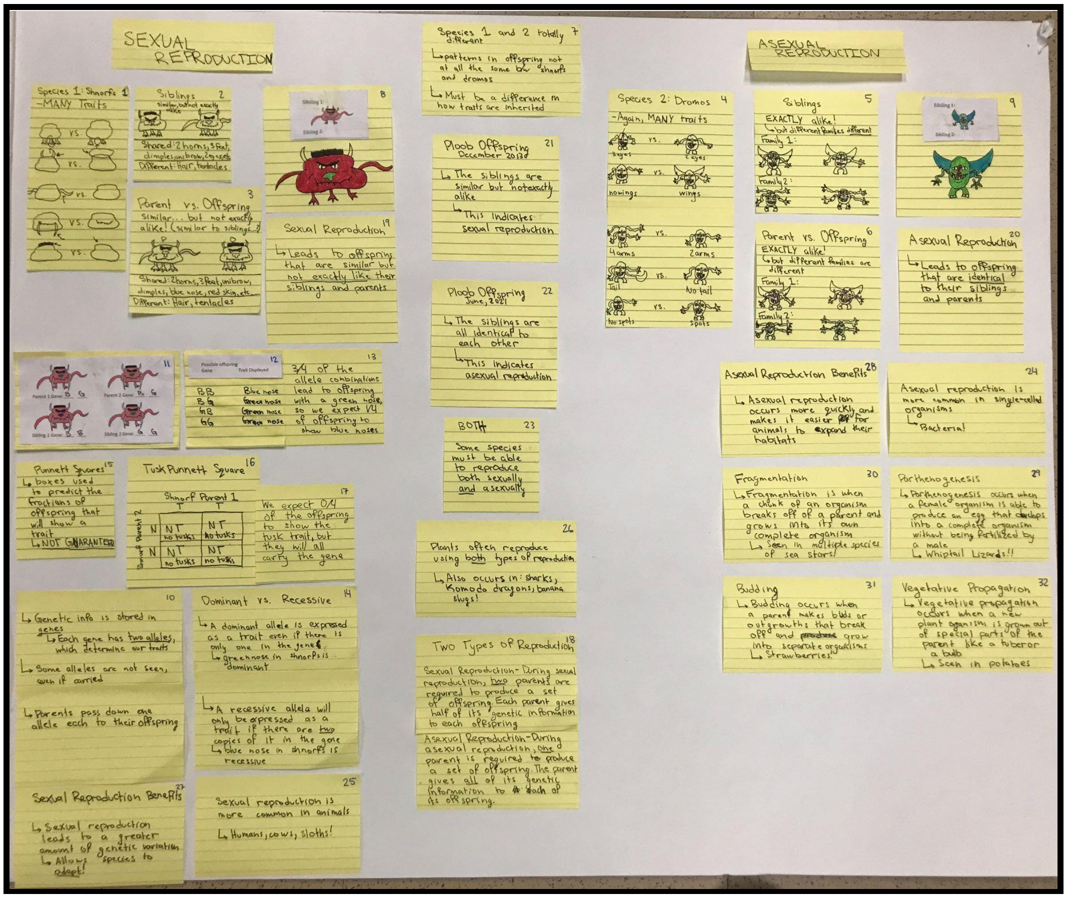
72. How is there diversity within populations that reproduce asexually? Mutations can occur when reproducing which makes the parent and offspring genetically different.

73. What additional key points need to be included in a model of heredity?

- Asexual reproduction is common in Single-celled organisms.
- Sexual reproduction is common in animals.
- Plants often reproduce both sexually and asexually.
- A benefit of sexual reproduction is there is more genetic variation between individuals in a population.
- A benefit of asexual reproduction is It occurs faster and makes it easier for animals to expand the area they live in.

74. Use the information from question 67 and 73 to revise your model of heredity. On your model, make sure that each group member describes a different type of asexual reproduction on a sticky note to place on your model.

14



SEXUAL REPRODUCTION

Species 1: Shnorfs 1
-MANY Traits

Siblings 2
similar, but not exactly alike
Shared: 2 horns, 3 feet, dimples, unibrow, 2 eyes, etc.
Different: Hair, tentacles

Parent vs. Offspring 3
similar... but not exactly alike! (similar to siblings...)
Shared: 2 horns, 3 feet, unibrow, dimples, blue nose, red skin, etc.
Different: Hair, tentacles

8

Sexual Reproduction 19
↳ Leads to offspring that are similar but not exactly like their siblings and parents

11

12

Possible offspring Gene	Trait Displayed
BB	Blue nose
BG	Green nose
GB	Green nose
GG	Green nose

13
3/4 of the allele combinations lead to offspring with a green nose, so we expect 1/4 of offspring to show blue noses

Punnett Squares! 15
↳ boxes used to predict the fractions of offspring that will show a trait
↳ NOT GUARANTEED

Tusk Punnett Square 16

Shnorf Parent 2 \ Shnorf Parent 1	T	T
N	NT no tusks	NT no tusks
N	NT no tusks	NT no tusks

17
We expect 0/4 of the offspring to show the tusk trait, but they will all carry the gene

10
↳ Genetic info is stored in genes
↳ Each gene has two alleles, which determine our traits
↳ Some alleles are not seen, even if carried
↳ Parents pass down one allele each to their offspring

Dominant vs. Recessive 14
↳ A dominant allele is expressed as a trait even if there is only one in the gene
↳ green nose in shnorfs is dominant
↳ A recessive allele will only be expressed as a trait if there are two copies of it in the gene
↳ blue nose in shnorfs is recessive

Sexual Reproduction Benefits 27
↳ Sexual reproduction leads to a greater amount of genetic variation
↳ Allows species to adapt!

25
Sexual reproduction is more common in animals
↳ Humans, cows, sloths!

Species 1 and 2 totally different 7
↳ patterns in offspring not at all the same b/w shnorfs and dromos
↳ Must be a difference in how traits are inherited

Ploob Offspring 21
December 2013
↳ The siblings are similar but not exactly alike
↳ This indicates sexual reproduction

Ploob Offspring 22
June, 2021
↳ The siblings are all identical to each other
↳ This indicates asexual reproduction

BOTH 23
Some species must be able to reproduce both sexually and asexually

26
Plants often reproduce using both types of reproduction
↳ Also occurs in: sharks, Komodo dragons, banana slugs!

Two Types of Reproduction 18
Sexual Reproduction - During sexual reproduction, two parents are required to produce a set of offspring. Each parent gives half of its genetic information to each offspring
Asexual Reproduction - During asexual reproduction, one parent is required to produce a set of offspring. The parent gives all of its genetic information to each of its offspring.

ASEXUAL REPRODUCTION

Species 2: Dromos 4
-Again, MANY traits

Siblings 5
EXACTLY alike!
↳ but different families different
Family 1:
Family 2:

9

Parent vs. Offspring 6
EXACTLY alike!
↳ but different families are different
Family 1:
Family 2:

Asexual Reproduction 20
↳ Leads to offspring that are identical to their siblings and parents

Asexual Reproduction Benefits 28
↳ Asexual reproduction occurs more quickly and makes it easier for animals to expand their habitats

24
Asexual reproduction is more common in single-celled organisms
↳ Bacteria!

Fragmentation 30
↳ Fragmentation is when a chunk of an organism breaks off of a parent and grows into its own complete organism
↳ Seen in multiple species of sea stars!

Parthenogenesis 29
↳ Parthenogenesis occurs when a female organism is able to produce an egg that develops into a complete organism without being fertilized by a male
↳ Whiptail Lizards!!

Budding 31
↳ Budding occurs when a parent makes buds or outgrowths that break off and ~~produce~~ grow into separate organisms
↳ Strawberries!

Vegetative Propagation 32
↳ Vegetative propagation occurs when a new plant organism is grown out of special parts of the parent like a tuber or a bulb
↳ Seen in potatoes

Content Notes for Teachers:

This lesson only deals with Mendelian traits. Mendelian traits are determined by two possible alleles, one dominant and one recessive, and are determined by a single genetic locus (gene) on a chromosome. In reality, the inheritance of traits can be much more complicated than this: many traits are controlled by a number of possible alleles, by a number of different genes, and do not have to be dominant or recessive (codominance or incomplete dominance). Grade-level appropriate content for 6th grade, however, dictates that students exclusively look at Mendelian traits. Students will learn of the more complex inheritance of traits when they reach high school, as per NGSS.