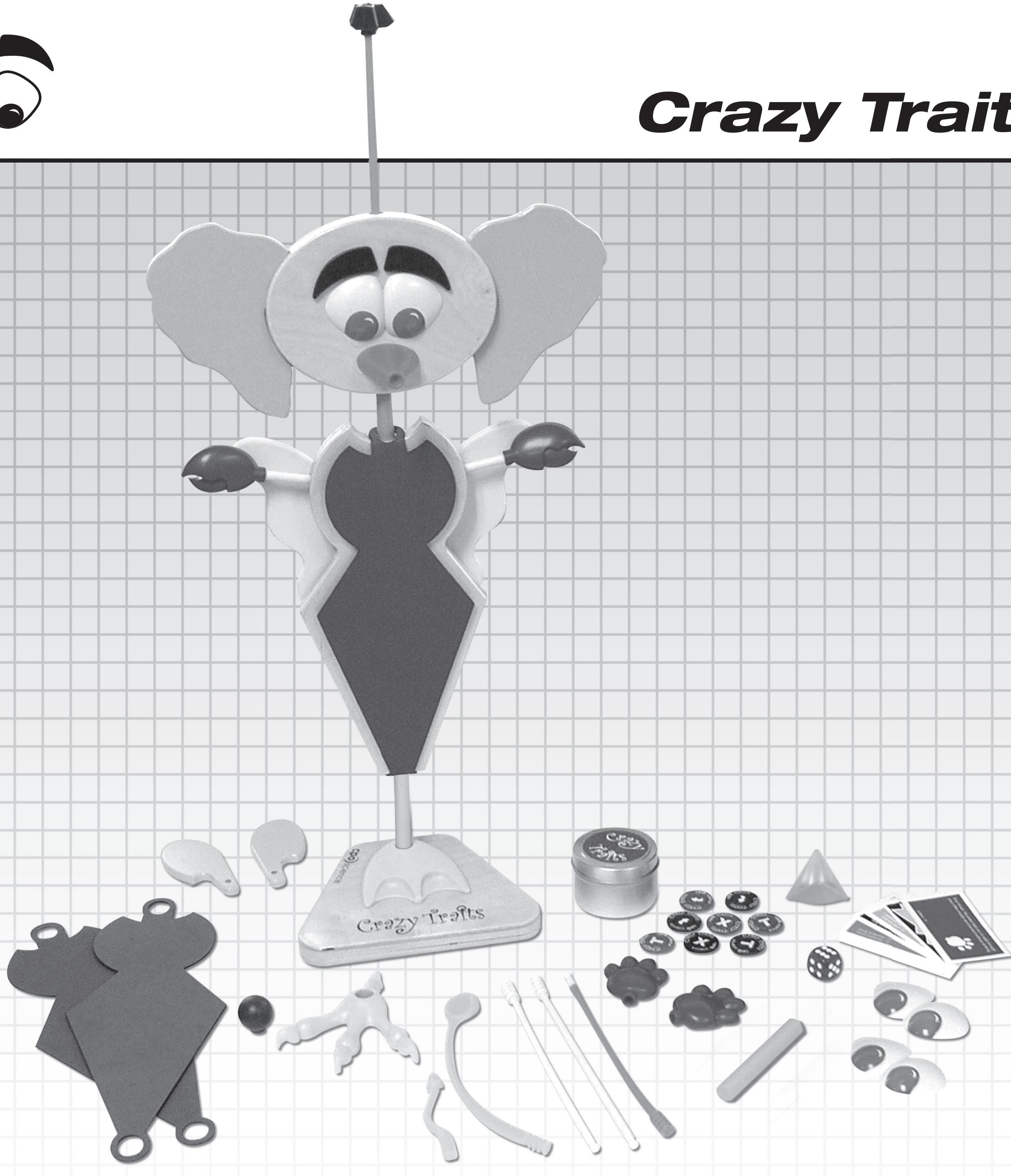
Crazy Traits



Investigations

HEREDITY AND EVOLUTION

- Investigations
- Blackline Masters
- Assessment Questions

cpo science

Curriculum Resource Guide: Crazy Traits

Credits

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Crazy Traits Investigations

Level A Investigations

A-1 Dominant and Recessive Traits

Key Question: What are dominant and recessive traits?

Students discover that most traits typically have two forms - a dominant form and a recessive form. The students look at a sample population of crazy creature faces and count how many individuals have each form of the facial traits. Students use this data to hypothesize which form of each trait is dominant and which is recessive. Students discover the concept that the dominant form of the trait is not necessarily the most common form.

A-2 Probability

Key Question: What role does chance play in an organisms's heredity?

Students learn how chance affects an organism's genetic makeup. Students flip coins to determine which alleles a crazy creature offspring will inherit from its parents. Students build the creature that they flip for and compare their creation to their classmates. This will show students how genetically diverse the organisms can be even with just fourteen traits.

A-3 Predicting Traits

Key Question: How can you predict probable traits?

Students learn how to use punnett squares to predict the most likely traits of the offspring of the creatures. Students look at punnett squares to determine the most probable phenotype for each trait of the offspring. Students then flip coins to see what genotypes and phenotypes the offspring will actually have. This shows students that even though punnett squares can be used to predict the outcome, chance still plays a huge role in genetics.

A-4 Other Patterns of Inheritance

Key Question: What are some exceptions to the basic pattern of inheritance?

Students look at some crazy creature data about traits that do not follow the basic rules for dominance. Students make predictions about skin and eye color from what they already understand about how traits are passed on. Then, students color data sheets for these traits and count the creatures with each form to learn about incomplete dominance and codominance.

A-5 Adaptations

Key Question: How do adaptations help an organism survive in its environment?

Students are challenged to think about how an organism is suited for its environment. The class rolls a die to determine their habitat. Then students choose crazy Creature traits that will be advantageous for survival. Students build the creature and compare their creation to the organisms designed by their classmates. Finally, students play a game of “Adaptation Survivor” in which points are awarded or deducted for having or not having a particular trait in a given scenario. The game continues until all the creatures are “extinct” except one - the winner!

A-6 Changing Environments

Key Question: How does the environment influence adaptations?

Students further explore the concept that an organisms' adaptations are specially designed for its particular habitat. Students use the crazy creature that they created in Investigation A-5. The class rolls for a new environment. Then, students describe how the changing environment will affect the creature the build in the last investigation.

Level B Investigations

B-1 Dominant and Recessive Traits

Key Question: How can you identify dominant and recessive forms of a trait?

Students discover that most traits typically have two forms - a dominant form and a recessive form. The students look at a sample population of crazy creature faces and count how many individuals have each form of the facial traits. Students learn to calculate the gene frequency by creating a ratio and use this data to hypothesize which form of each trait is dominant and which is recessive. Students are introduced to the concept that the dominant form of the trait is not necessarily the most common form.

B-2 Other Patterns of Inheritance

Key Question: What are some exceptions to the basic patterns of inheritance?

students look at some crazy creature data about traits that do not follow the basic rules for dominance. Students make predictions about skin and eye color from what they already understand about how traits are passed on. Then, students color data sheets for these traits and count the creatures with each form to learn about incomplete dominance and codominance.

B-3 Crazy Traits

Key Question: What role does chance play in heredity?

Students flip coins to determine which alleles a crazy creature offspring will inherit from its parents. They learn how an organism's genotype determines its phenotype. Students discover that organisms that receive one dominant and one recessive allele will show the dominant phenotype. They are also introduced to the concept of incomplete dominance and codominance. Students build the creature that they flip for and compare their creation to their classmates. This shows students how genetically diverse the organisms can be even with just fourteen traits.

B-4 Punnett Squares

Key Question: How are punnett squares used to make predictions about inheritance?

Students learn how to use punnett squares to predict the most likely traits of the offspring of the creatures they built. Two groups work together and "mate" the crazy creatures that they flipped for in the previous investigation. Students create punnett squares to determine the most probable phenotype for each trait of the offspring. Students then flip coins to see what genotypes and phenotypes the offspring will actually have. This shows students that even though punnett squares can be used to predict the outcome, chance still plays a huge role in genetics.

B-5 Pedigrees and Genetic Disorders

Key Question: How can a pedigree be used to trace a genetic disorder over generations?

Students learn about pedigrees by studying a sample. Then, students are challenged to create their own pedigree about a genetic disorder in crazy creatures called "night blindness." Students flip coins to determine what alleles are passed on from generation to generation. Students draw and color the pedigree as they flip for traits.

B-6 Sex-Linked Traits

Key Question: What are sex-linked traits and how are they passed on to offspring?

In this investigation, students learn about sex-linked traits. Students are given information about the parent generation in a family that suffers from night-blindness, a sex-linked disorder carried on the X chromosome in this population of crazy creatures. Students flip coins to see what possible genotypes and phenotypes their offspring could have. Finally, students use the information to create a pedigree about this family.

B-7 Crazy Adaptations

Key Question: How does the environment influence traits?

In this investigation, students are challenged to think about how an organism is adapted to its environment. The class rolls a die to determine their habitat. They also play a game of "Adaptation Survivor" in which points are awarded or deducted for having or not having a particular trait in a given scenario. The game continues until all the creatures are "extinct" except one - the winner!

Level C Investigations

C-1 Meiosis and Chromosomes

Key Question: How are gametes formed?

In this investigation, students model the process of meiosis. Using chromosome cutouts, students move the chromosomes through the phases and even model the process of crossing over. Finally, students randomly select two of the gametes that they produced to create an offspring. This will demonstrate to the students how an offspring receives half of its genetic information from the mother and half from the father.

C-2 Advanced Punnett Squares

Key Question: How are punnett squares used to make predictions?

Students learn how to use punnett squares to predict the most likely traits of the offspring of two creatures. Students create punnett squares to determine the most probable phenotype for each trait of the offspring. Some of the traits are linked so the students will need to pay attention to all the possible combinations of alleles. Students then flip coins to see what genotypes and phenotypes the offspring will actually have. This shows students that even though punnett squares can be used to predict the outcome, chance still plays a huge role in genetics.

C-3 Hardy-Weinberg Principle

Key Question: How can the frequency of alleles and genotypes in a population be calculated?

In this investigation, students learn about the Hardy-Weinberg Principle, which can be used to calculate allele and genotype frequency in a population. Students draw cards and simulate mating by trading cards with other students. Students calculate the gene frequency over five generations to see how the population shifts.

C-4 Speciation

Key Question: Where does a new species come from?

Students study ten ancestors of present day crazy creatures, looking for similarities and differences. Students will then be challenged to create a cladogram showing the evolutionary history of these organisms. Students will be asked to think about what environmental conditions may have led to the adaptations in the organisms over time. Students learn about the process of speciation as they think about the changes in these ancient organisms.

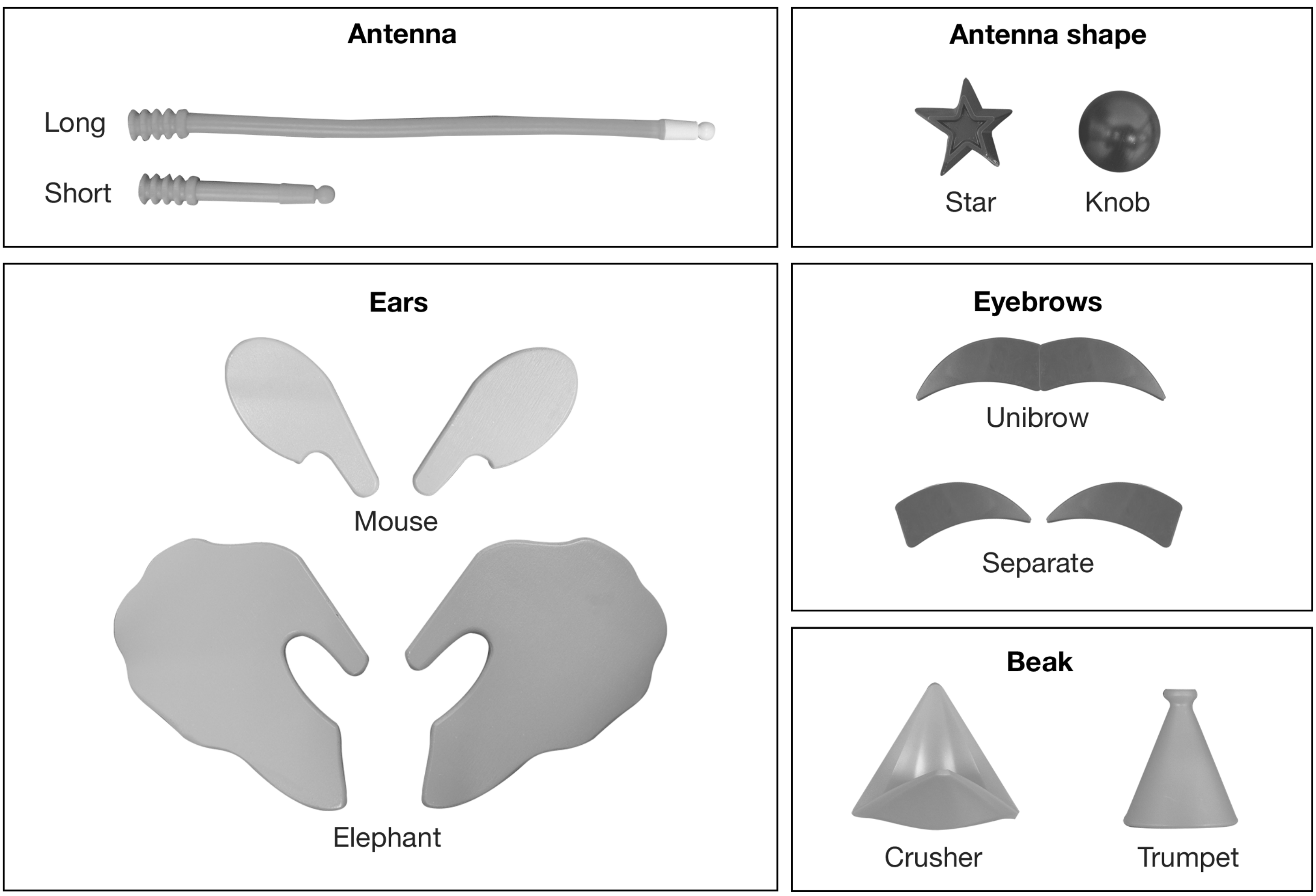
A1 Dominant and Recessive Traits

What are dominant and recessive traits?

Traits are characteristics that an organism can pass onto its offspring. NASA scientists have discovered living organisms on the planet Geneticus. They have asked you to research a species named *Creaturus crazarius*—commonly called crazy creatures. To begin your research, you will take an inventory of the facial traits of crazy creatures to determine their basic patterns of inheritance.

1 Getting ready

In this investigation, you examine the facial traits of the crazy creatures. Look at the graphic below to see the various forms that the traits can take.



1. Choose one form of each facial trait and build the face of a crazy creature.
2. Switch facial traits and see if you can determine how many different faces you can build with the pieces.

2 Stop and think

a. Think about the forms of the traits. What are the advantages, if any, to having either form of each trait? What are the disadvantages, if any, to having either form of each trait? Explain your answers.

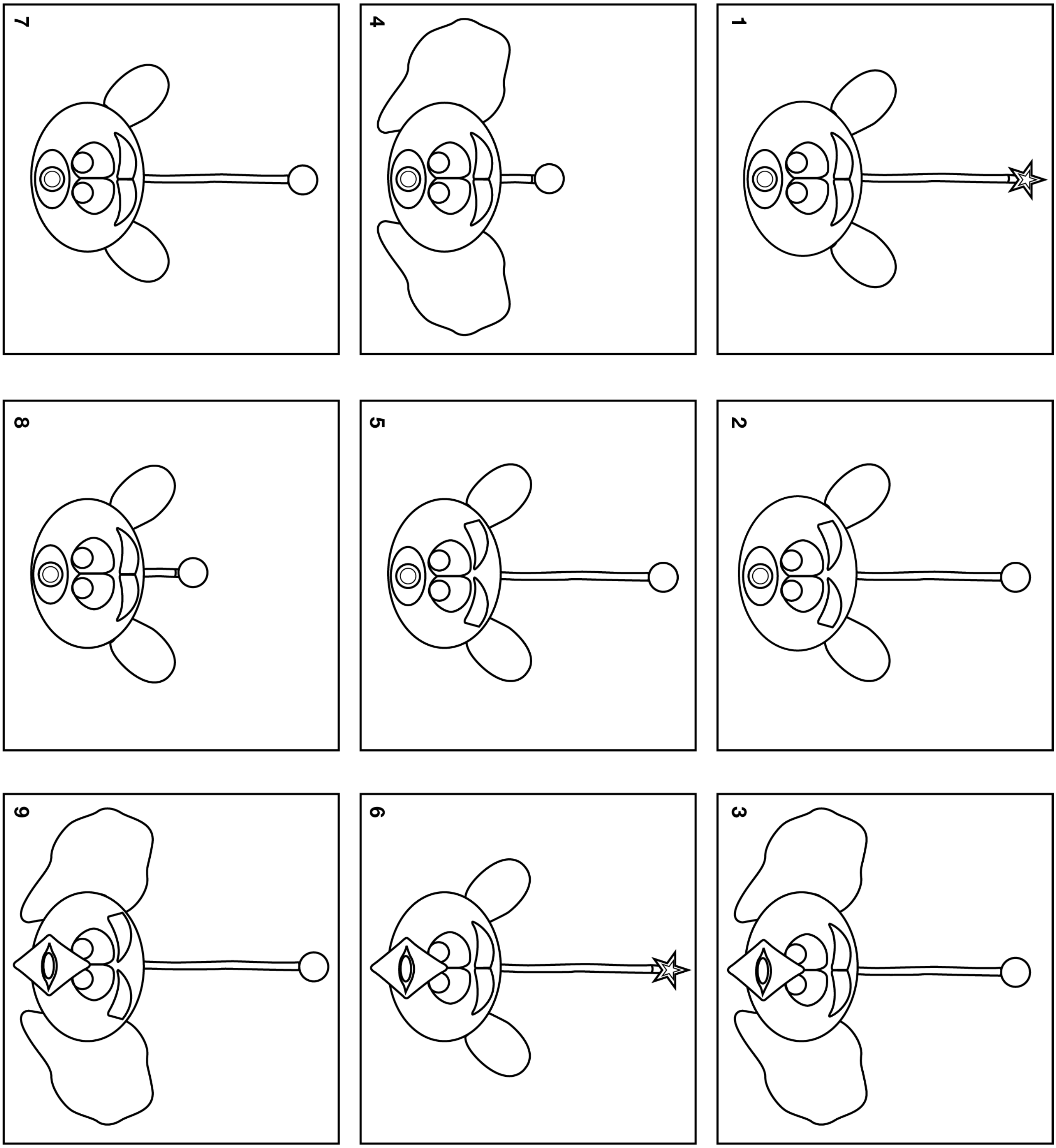
b. Why is there variation in the facial features of the crazy creatures? Explain your answer.

3 Collecting the data

Examine the sheets of creature faces on the next several pages. There are 50 faces in all. Count how many organisms you find with each form of the trait and record the totals into the appropriate columns of Table 1.

Table 1: Population data for facial traits

Trait	Number of organisms with Form 1	Number of organisms with Form 2
antenna	long:	short:
antenna shape	star:	knob:
ears	mouse:	elephant:
eyebrows	unibrow:	separate:
beak	crusher:	trumpet: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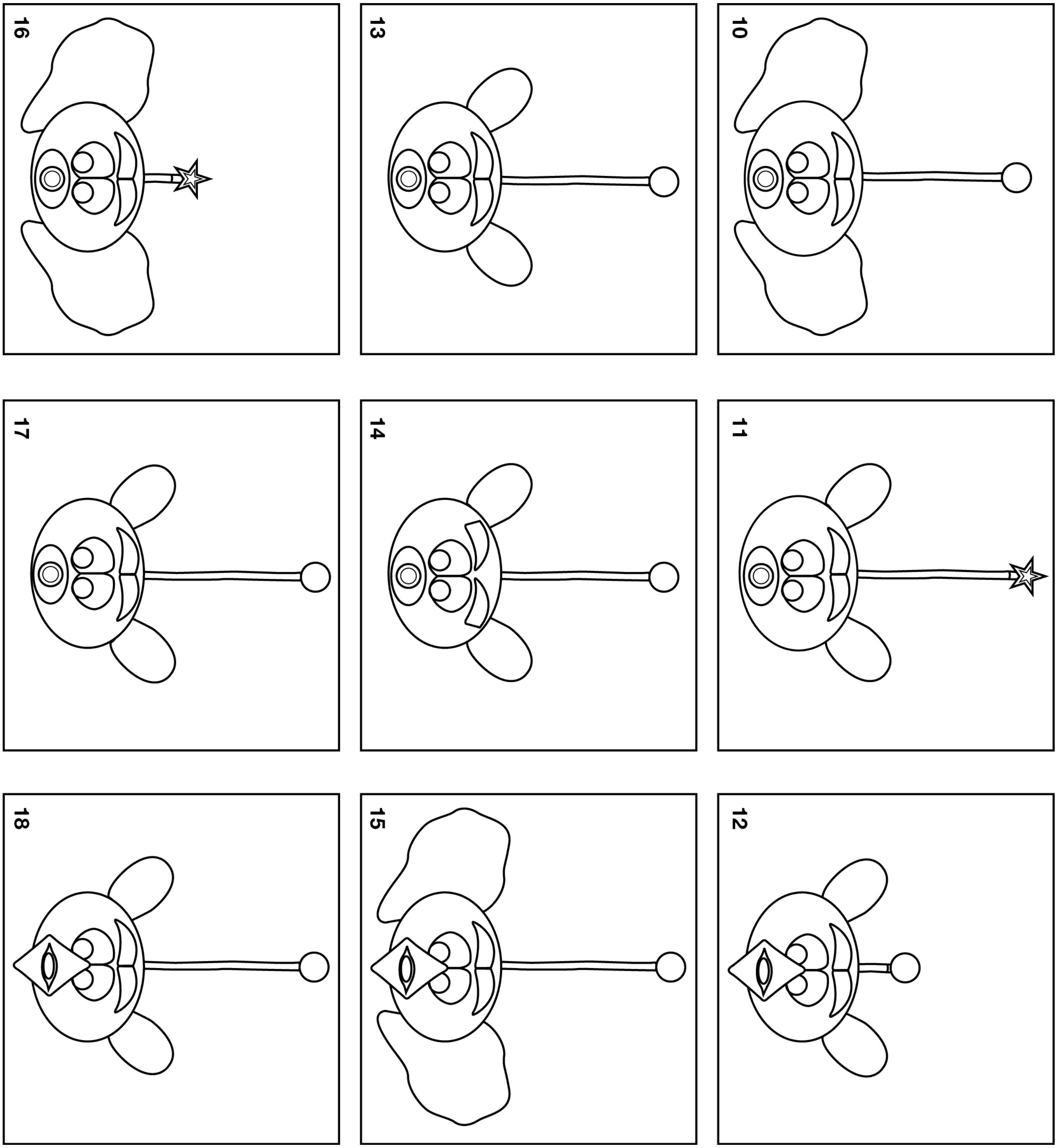

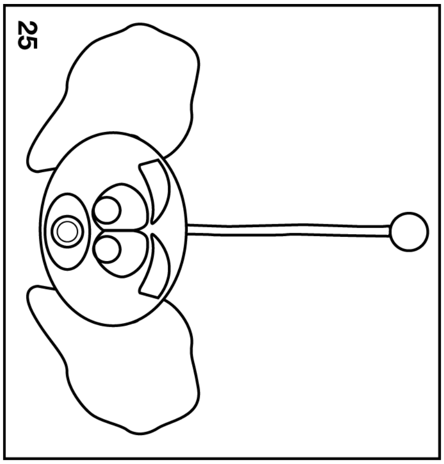
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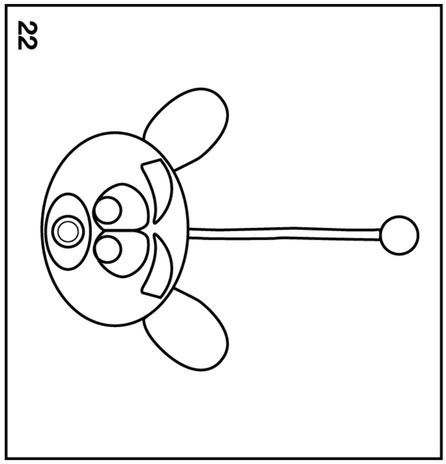
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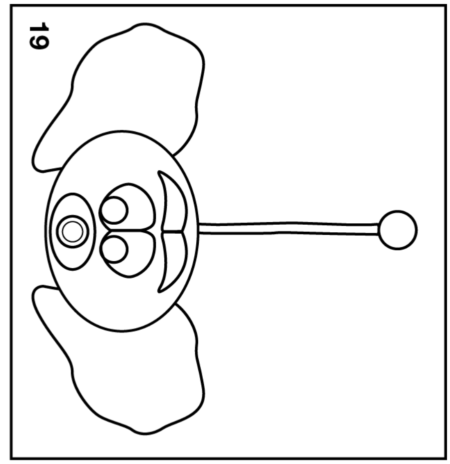
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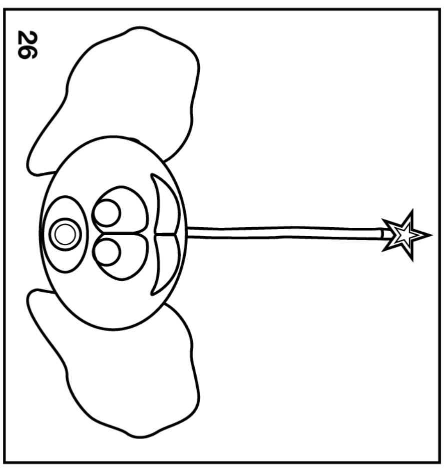
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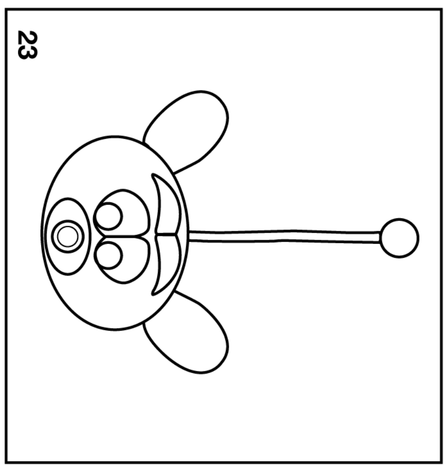
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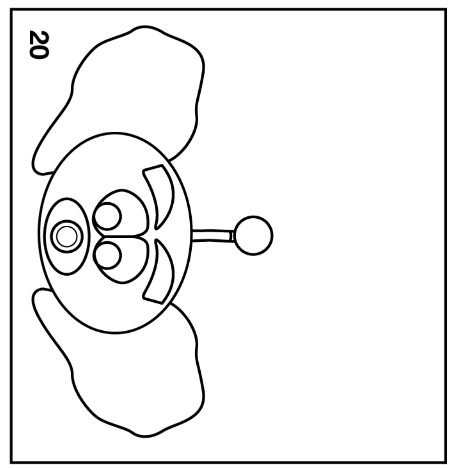
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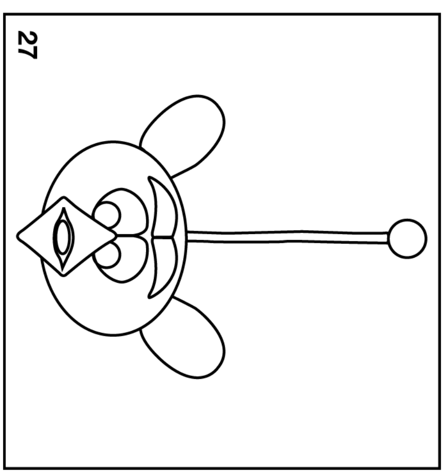
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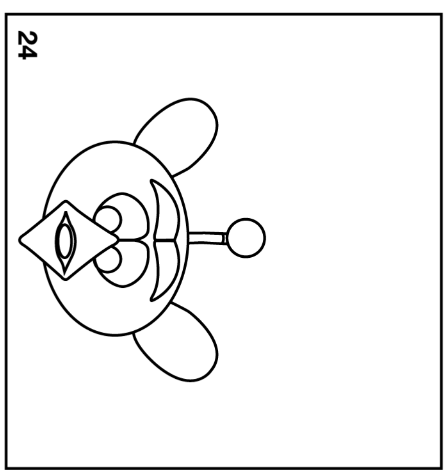
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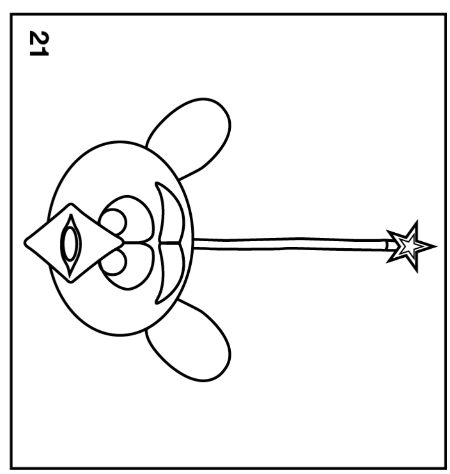
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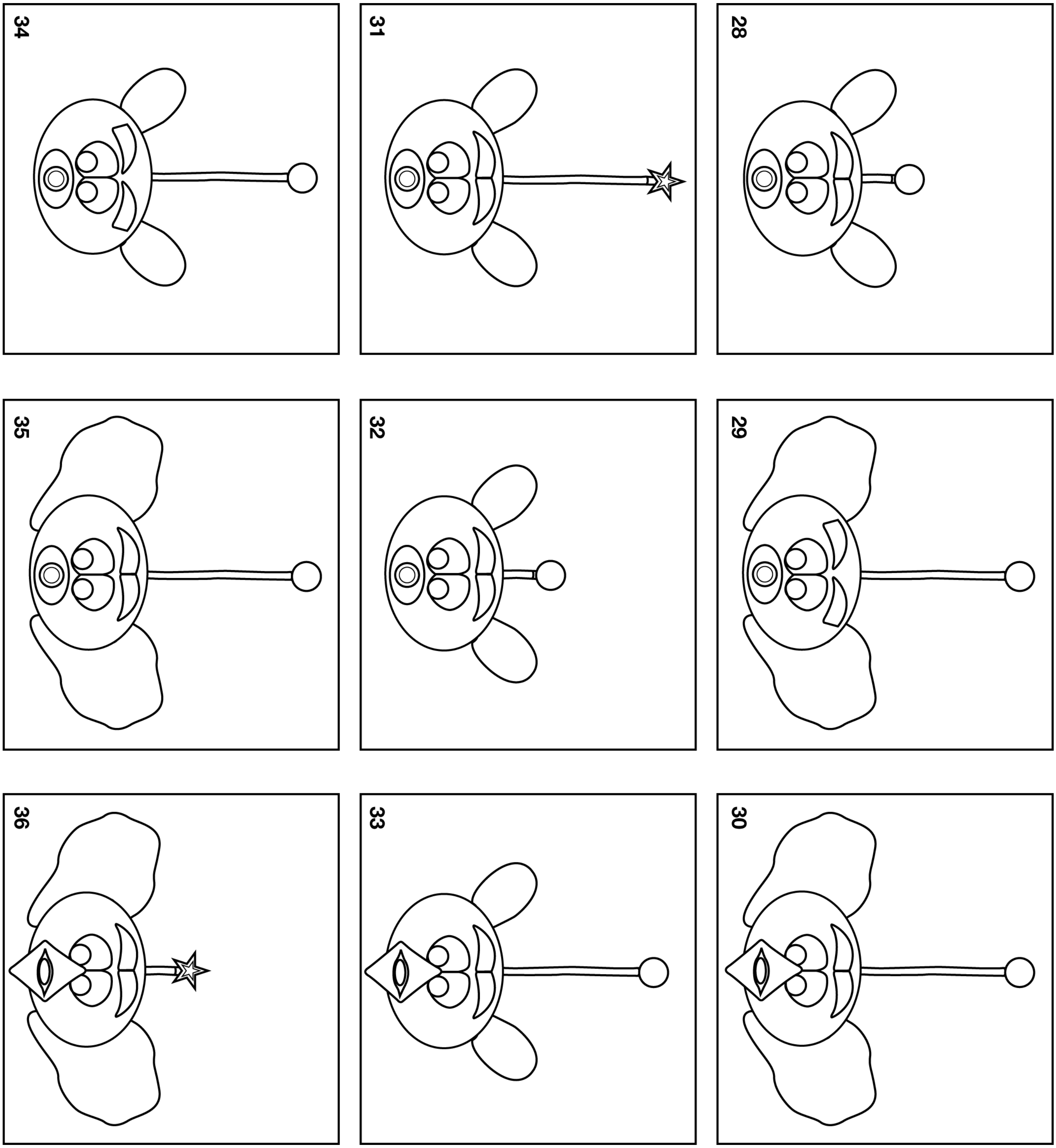
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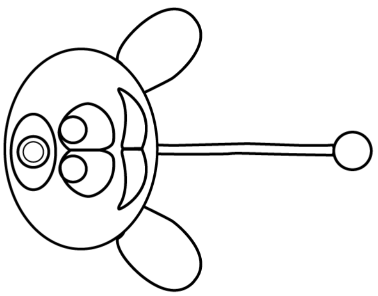

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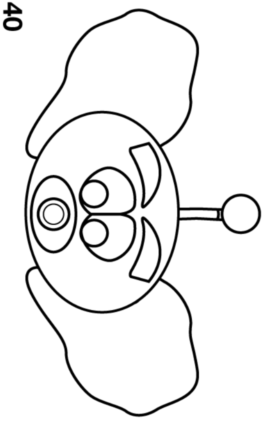

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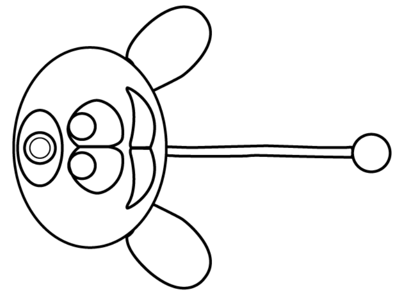

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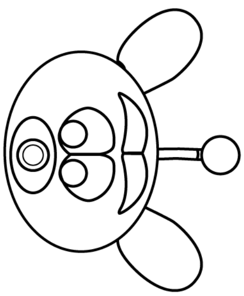

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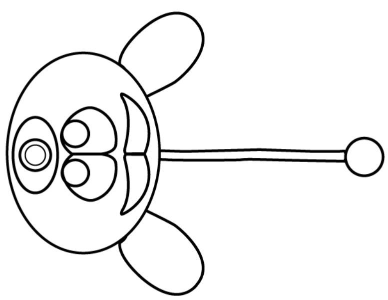

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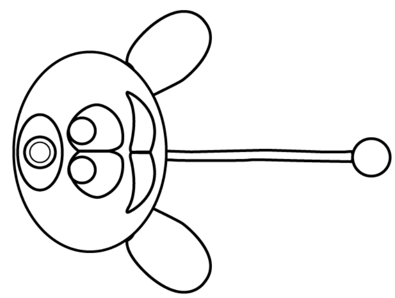

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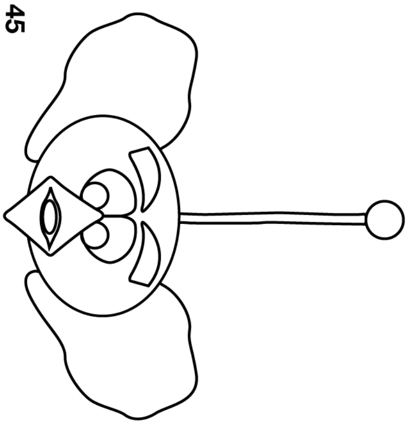

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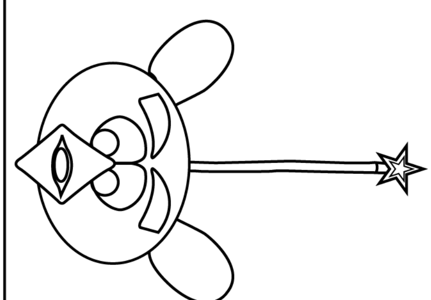

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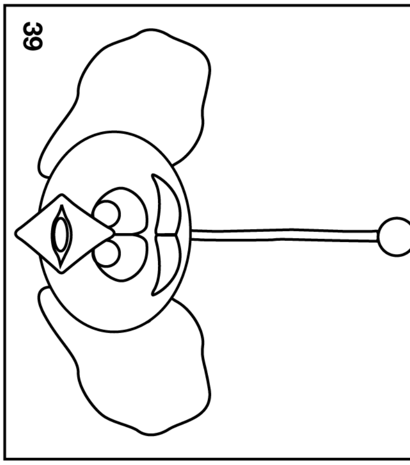

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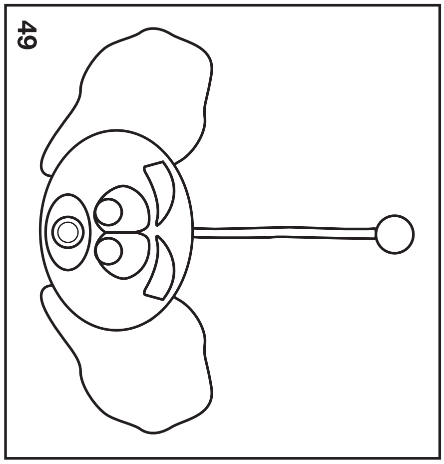

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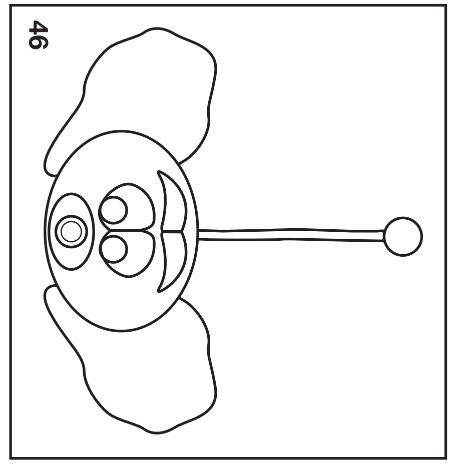

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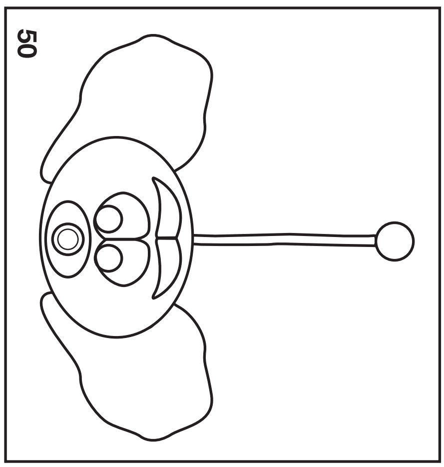

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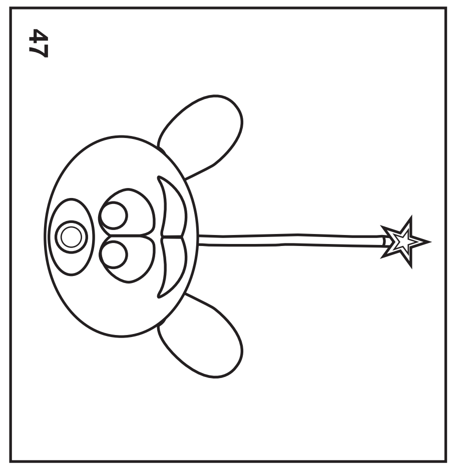

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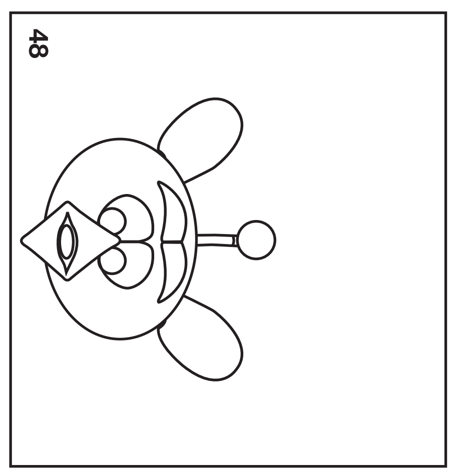


4 Thinking about what you observed

a. For each trait, which form was most common?

b. Why do you think one form is more common than the other?

c. Think about the sample size. How might the results have been different if you looked at a smaller sample? What about a larger sample? Describe how sample size might affect the results.

d. In organisms found on Earth, traits are determined by units called *genes*. For each trait, an organism gets one gene from its mother and one gene from its father. Different forms of the same gene are called *alleles*. For each trait, there is a *dominant allele* and a recessive allele. The dominant allele masks the effect of the *recessive allele* for the trait. Based on your population data, do you think the traits of crazy creatures have dominant and recessive alleles? Use your data to explain your results.

e. Based on your data, hypothesize which allele is dominant and which allele is recessive. Record your predictions in the chart below.

Trait	Predicted dominant allele	Predicted recessive allele
antenna		
antenna shape		
ears		
eyebrows		
beak		

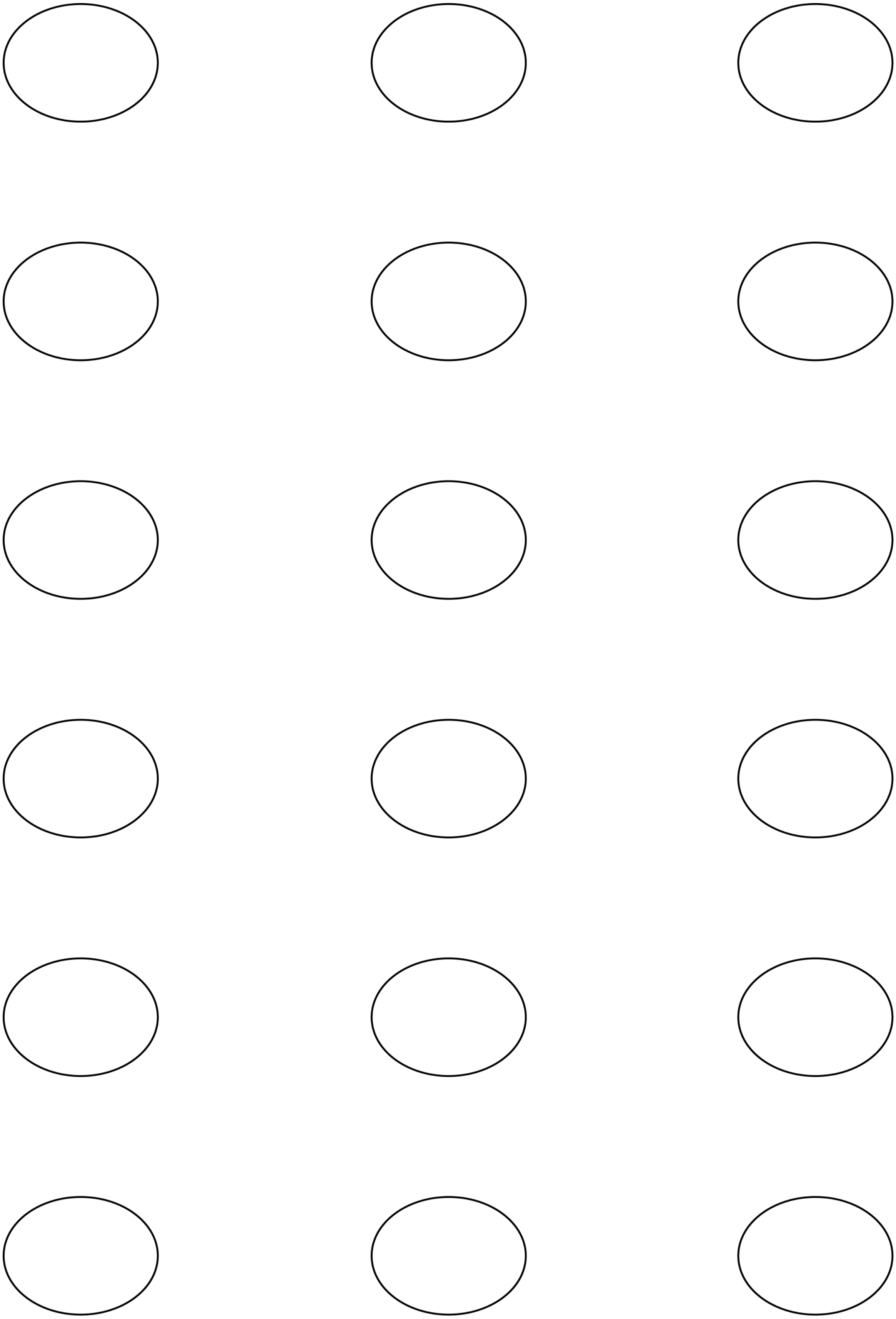
f. Ask your teacher which alleles are dominant and which are recessive, then fill in the chart below. Were your predictions correct? Why or why not?

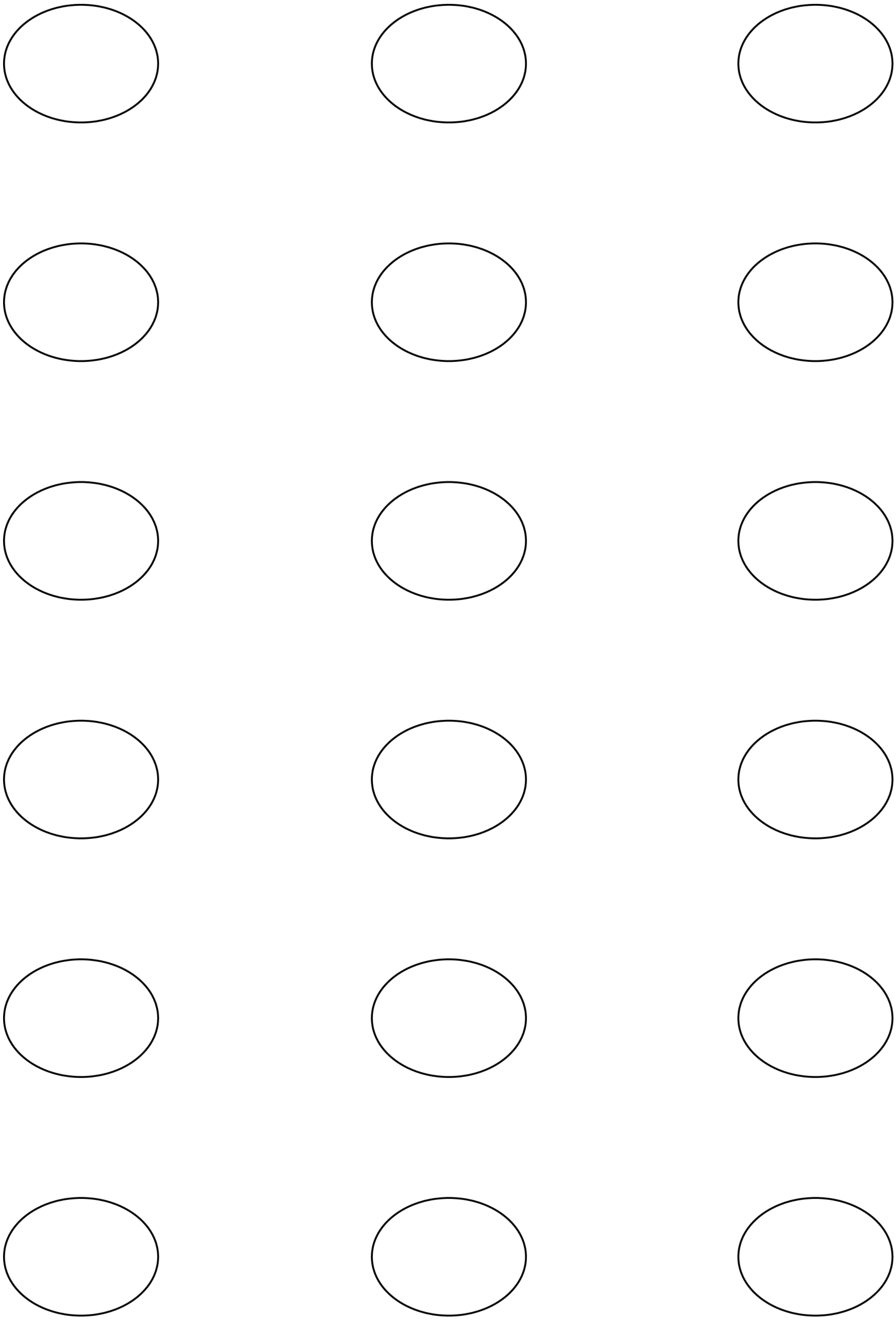
Trait	Actual dominant allele	Actual recessive allele
antenna		
antenna shape		
ears		
eyebrows		
beak		

g. Sometimes people incorrectly assume that the dominant alleles are always more common. Was this true? Use evidence to explain your answer.

5 Exploring on your own

Flip coins to determine the allele for the ear shape of a sample population of creatures. Use a capital **T** to represent the dominant allele and a lowercase **t** to represent the recessive allele. In this activity, we will assume that both parents have the same alleles for ear shape (**Tt**). You will need a blue (egg) coin with a capital **T** on one side and a lower case **t** on the other side. You will also need a green (sperm) coin with a capital **T** on one side and a lower case **t** on the other side. If you flip **TT** or **Tt**, the creature will have elephant ears. If you flip **tt**, the creature will have mouse ears. How many creatures do you think will have elephant ears? How many do you think will have mouse ears? Flip the coins to see if you are correct. Draw your results on the sheet of blank faces you are given.





Assessment

1. What is the term for a characteristic that an organism can pass on to its offspring?

2. What is a gene?

3. Explain how an organism receives two genes for each trait.

4. What is an allele? Name a crazy creature trait and the two alleles for that trait.

5. What is the difference between dominant and recessive alleles? Explain your answer.

6. Are dominant alleles always more common? Explain your answer.

A2 Probability

What role does chance play in an organism's heredity?

NASA has found an isolated population of crazy creatures on Geneticus that all have the same combination of alleles – one dominant allele and one recessive allele for all their traits. Since all the parents have the same alleles, many have incorrectly assumed that the future generations will look exactly the same as the parents. You know that this isn't the case! It is true that for each gene, you get at least one allele from your mother and one from your father. However, the alleles you actually end up with are determined by two factors: (1) the alleles that your parents have; and (2) the allele from each parent you inherit. The alleles you inherit from each parent are determined by chance. In this investigation, you will play a probability game that will show how their offspring might look.

1 Determining the genotype

1. The first trait you will flip for is gender. Choose the male sex chromosome coin (X on one side and Y on the other) and the female sex chromosome coin (X on both sides). Place both coins in the cup and shake. Toss the coins onto the table. Record the allele from each parent and genotype in columns 2, 3, and 4 of the first row of Table 1.
2. You will flip coins to see what allele for each of the other traits your creature inherits from each parent. This will determine the creature's genotype and phenotype. An organism's *genotype* is the alleles of a gene it contains. An organism's *phenotype* is the form of a trait that it displays. In this activity, both parents have the same genotype for all traits (**Tt**) since they are from that isolated population on Geneticus. You will need the blue (egg) coin with a capital **T** on one side and a lower case **t** on the other side. You will also need the green (sperm) coin with a capital **T** on one side and a lower case **t** on the other side.
3. Flip the coins for the next trait – skin color. Place the coins in the cup. Shake the cup and toss the two coins on the lab table. The side that lands up on each coin represents the sperm and egg that unite during fertilization. Record your results in Table 1.
4. Repeat this procedure for traits 3 through 14.

Table 1: Genotypes and phenotypes of offspring

Trait	Allele from mother	Allele from father	Genotype	Phenotype
1. Gender				
2. Skin color				
3. Leg				
4. Foot				
5. Arms				
6. Hands				
7. Eye color				
8. Eyebrows				
9. Beak				
10. Ears				
11. Antenna				
12. Antenna shape				
13. Tail				
14. Wings				

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** - blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** - green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2 Stop and think

a. What information do the letters on the sperm and egg coins indicate: alleles, genotype, or phenotype?

b. For the sperm coin, what are the chances of getting a **T** or getting a **t**? State your answer as a fraction and a percent.

c. For the egg coin, what are the chances of getting a **T** or getting a **t**? State your answer as a fraction and a percent.

d. When both coins are flipped at once, what are your chances of getting each of the following combinations: **TT**, **Tt**, or **tt**? State your answer for each as a fraction and a percent.

3 Building your creature

1. Once you have completed columns 2 through 4 of Table 1, use Table 2 to look up the phenotype for each trait. Record the phenotype for each trait in column 5 of Table 1.
2. Once you have completed Table 1, select the correct body parts to build your creature.
3. Orient the body for either male (round end down) or female (round end up).
4. Carefully assemble your creature.
5. Give your creature a name and make it a name tag.
6. Display your creature in the area designated by your teacher.

4 Thinking about what you observed

a. Examine the creatures. Do any of them look exactly alike? Do any of them look exactly like their parents? Why or why not?

b. How does this investigation explain why offspring may resemble their parents, but never look exactly like them?

c. How does this investigation explain why siblings may resemble each other, but never look exactly alike (unless they are identical twins)?

d. Count the number of males and number of females. Does the number of each match the chances of getting a male or female in the game? Why or why not?

e. Explain to the NASA scientists why the offspring of this isolated population of **Tt** crazy creatures may end up looking quite different from their parents.

5 Exploring on your own

Write about the life of your crazy creature. Pretend that it lives somewhere here on Earth. Think about the traits that it has. What type of habitat is it best suited for? What type of food might it eat? What predators would eat it? How would it protect itself? Even though you are pretending, describe real habitats, organisms, and conditions that exist on Earth.

Assessment

1. What two factors determine the alleles an organism ends up with?

2. What is the difference between genotype and phenotype?

3. List the possible genotypes for a crazy creature with elephant ears.

4. Both parents in this investigation were **Tt** for all traits. How would the results have differed if both parents were **TT**? Or what if both parents were **tt**? Explain.

5. What is the genotype for males? What is the genotype for females?

6. What is the process that flipping the coins represents? Why is this process important?

Extra space for notes:

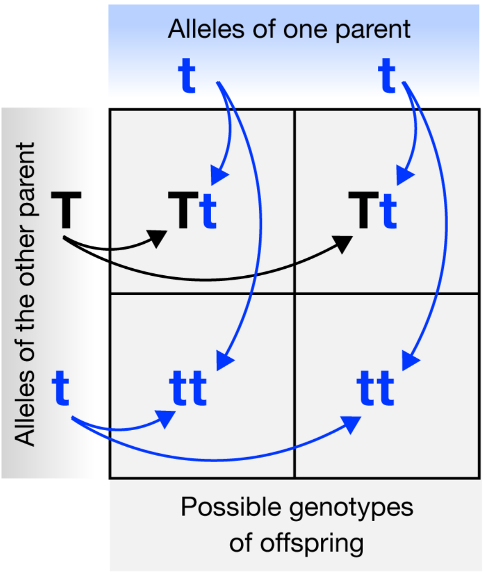
A3 Predicting Traits

How can you predict probable traits?

NASA is setting up an educational exhibit to teach people about crazy creatures and their planet, Geneticus. NASA has asked you to help them select the initial breeding pair to include in their exhibit. They want to be sure that the parents that they pick and their offspring will represent a variety of all the traits that crazy creatures can have. You know that you can predict the genotypes and phenotypes of offspring if you know the genotypes of the parents. A ***punnett square*** shows all the possible combinations of alleles from the parents. In this investigation, you will use punnett squares to help NASA select the best creatures for their new display.

1 Making the predictions

Look at this punnett square showing the parents from the investigation - **Tt** for all the traits. The two alleles for each of the parents are shown outside the squares – one parent across the top and one parent down the side. Since each parent gives at least one allele to their offspring, the squares represent the four possible combinations of alleles that the offspring could receive. If this parent gives this allele and this parent gives this allele, and so forth.



a. What are the possible genotypes of the offspring?

Probability plays an important part in heredity. Although we can use punnett squares to show the possible combinations, the actual chance of inheriting a certain genotype or phenotype is still random. ***Probability*** is the mathematical chance that an event will occur. Probability can be expressed as a fraction or a percentage. Since there are four possibilities in punnett squares, it is easy to make fractions: $^1/_4$, $^2/_4$ or $^1/_2$, $^3/_4$, or $^4/_4$ or 1. To convert these fractions to percentages, take the numerator of the fraction divided by the denominator and multiply by 100, as shown right.

	T	t
T	TT	Tt
t	Tt	tt

TT = $^1/_4$ = 25%

Tt = $^2/_4$ = 50%

tt = $^1/_4$ = 25%

b. What is the probability of the offspring showing the dominant phenotype?

1. You will predict the probable traits of the offspring of two crazy creatures to see if they are suitable candidates for the NASA education exhibit. You will work with another team and use the creatures you created in the last investigation. Your teacher will pair you up with another team that has a creature of the opposite gender.
2. The gender row of Table 1 has been partially filled in for you. Since there is a 50% chance of the offspring being male or female, you will guess what gender you think the offspring will be. Fill in your prediction in the predicted phenotype column of Table 1.
3. Now, fill in the genotypes for the mother and father for all the other traits in columns 2 and 3 in Table 1.
4. You will make predictions for the other traits by looking at example punnett squares shown here. Start by looking to find the matching punnett square that shows the cross of the two genotypes for skin color from the examples below.

A

	T	T
T	TT	TT
T	TT	TT

B

	T	T
T	TT	TT
t	Tt	Tt

C

	T	T
t	Tt	Tt
t	Tt	Tt

D

	T	t
T	TT	Tt
t	Tt	tt

E

	T	t
t	Tt	tt
t	Tt	tt

F

	t	t
t	tt	tt
t	tt	tt

5. Determine which phenotype is more probable by counting how many offspring would have each phenotype. Use Table 2 to determine which genotypes show which phenotypes. Fill in the most likely phenotype in column 4 of Table 1. In some cases like gender, you will find that there is an equal chance of having either phenotype – two would have one trait, while the other two would have the other trait. If this is true, you guess what phenotype you think that the offspring will most likely have.
6. Next, make a fraction to show how many of the offspring would most likely have the predicted phenotype. Create a fraction by using the number of offspring with the more common phenotype divided by four (the total number of squares). Use this fraction to find the percent in step 7.
7. Finally, find the percent of the offspring that would have most likely have the predicted phenotype. To calculate a percent, divide the numerator by the denominator and multiply by 100. Record the percent in column 5 of Table 1.
8. Repeat these steps for traits 3 through 14.

Table 1: Predicted phenotypes and probability

Trait	Genotype of mother	Genotype of father	Predicted phenotype	% probability	Actual genotype	Actual phenotype
1. Gender	XX	XY		50%		
2. Skin color						
3. Leg						
4. Foot						
5. Arms						
6. Hands						
7. Eye color						
8. Eyebrows						
9. Beak						
10. Ears						
11. Antenna						
12. Antenna shape						
13. Tail						
14. Wings						

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** – blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** – green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2 Stop and think

a. What is a punnett square? What information is needed to create a punnett square?

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b. What is probability? What does probability have to do with inheritance?

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3 Checking the predictions

1. Now, you will flip coins to see if your predictions are right. The first trait you will flip for is gender. Choose the male sex chromosome coin (**X** on one side and **Y** on the other) and the female sex chromosome coin (**X** on both sides). Place both coins in the cup and shake. Toss the coins onto the table and record your results in the actual genotype column of Table 1.
2. For the other traits, you'll need to use the correct egg and sperm coins for each parent. Use the data in Table 1 to find the parents' genotype for each trait. Then, select the egg and sperm coin that has the same alleles as the genotype. For example, if the father's genotype for skin color is **TT**, choose the sperm coin that has a capital **T** on both sides of the coin. If the mother's genotype for skin color is **tt**, find the egg coin that has a lower case **t** on both sides of the coin.

3. Place both coins in the cup, shake, and toss out onto the table. Record your results in column 6 of Table 1.
4. Use Table 2 to look up the phenotype. Record the phenotype of the offspring in the last column of Table 1.
5. Repeat this procedure for all the traits.
6. Build your creature and compare with other creatures in the class.

4 Thinking about what you observed

a. Why do you need to choose different egg and sperm coins for each trait and for each parent?

b. How many of the actual phenotypes matched your predicted phenotypes? Explain your results.

c. Which parent does your offspring share the most traits with, the mother, father, or both equally?

d. Are punnett squares unnecessary if both parents have the same genotype? Explain.

e. What are the possible percents for probability when using punnett squares? Explain why these are the only possibilities.

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f. From your investigation, what is your recommendation for NASA for the genotypes of the breeding pair? Explain your choices.

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5 Exploring on your own

Make an informational sign to display at the NASA educational exhibit explaining punnett squares and probability to the public. Your sign should show the genotypes and phenotypes of the parents. It should also explain why this pair was selected. Also, be sure to include the appropriate punnett squares to show the predictions for the possible offspring.

Assessment

1. What is the phenotype for a crazy creature with a genotype of **TT** for beak?

2. What is the genotype for a crazy creature with mouse ears?

3. If a **TT** parent mated with a **tt** parent, what is the probability of the offspring having the dominant phenotype?

4. If a **Tt** parent mated with a **tt** parent, what is the probability of the offspring having the **tt** genotype?

5. Why couldn't two crazy creatures with separate eyebrows ever produce an offspring with a unibrow? Explain your answer.

6. Can a **TT** parent and a **Tt** parent ever produce a **tt** offspring? Explain your answer.

7. Punnett squares only show the possible combinations of alleles. What is the role of chance in inheritance?

Extra space for notes:

A4 Other Patterns of Inheritance

What are some exceptions to the basic pattern of inheritance?

Congratulations! NASA is very pleased with your study of the traits of crazy creatures. Your study showed that many traits have a dominant form that masks the recessive form. However, NASA has contacted you about some unusual data that has been found regarding other traits of the crazy creatures. In this investigation, you will learn about traits that are more complicated than one form simply being dominant to another recessive form.

Additional materials

- crayons or colored pencils

1 Thinking about what you will do

Remember from your study of facial traits that different forms of the same gene are called alleles. You found that for each of the facial traits you studied there is a dominant allele and a recessive allele. By counting the traits of the crazy creatures in a certain population, you saw that the dominant allele masks the effect of the recessive allele for the trait. Now NASA has contacted you with some very interesting information. It seems that when a blue crazy creature mated with a red crazy creature, the offspring was purple - not blue or red! How can this be?

NASA scientists originally thought that there must be some mistake. To collect more data, they set up a breeding program to study the skin color of crazy creatures. The breeding program consisted of twenty-four red-skinned females and twenty-four blue-skinned males for the parent generation. Each mating pair produced one offspring for a total of twenty-four individuals in the first generation. The members of the first generation were mated with each other to produce twenty-four organisms of a second generation. They have asked you, as a geneticist, to look at the results to help explain these unusual findings.

2 Stop and think

a. What would you need to know in order to predict what color skin the offspring will have?

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b. Think about skin color in crazy creatures. How could a red-skinned organism crossed with a blue-skinned organism result in purple-skinned organisms?

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c. Predict how many of the twenty-four organisms will have each skin color in each generation.

3 Looking at the data

You will be given a data sheet of the twenty-four organisms produced in each generation of the breeding program to help you understand the results.

1. Color in the organisms to show what skin color the offspring have. Color the organisms marked P on the body purple. The organisms marked B on the body should be colored blue. Finally, the organisms marked on the body R should be colored red. Do not color the heads or the eyes. Only color the body for now.
2. Count how many organisms have each skin color in each generation. Use the numbers to answer the questions below.

4 Thinking about what you observed

a. How many organisms had each skin color in each generation?

b. Did your results match your predictions? Why or why not? Explain your answer.

c. After some additional research, you learn that skin color is an example of ***incomplete dominance***. In incomplete dominance, the two traits blend - just like mixing paints. Instead of the color blue being dominant to the color red or vice versa, the two colors are combined, which results in the color purple. You have just discovered that tail length in crazy creatures is also an example of incomplete dominance. One allele is for a long tail, while the other allele is for no tail. Predict what these two alleles blended would look like. Explain your prediction.

d. On Earth, flower color in snapdragons is an example of incomplete dominance. If a true-breeding, red-flowered snapdragon is crossed with a true-breeding, white-flowered snapdragon, what color flowers do you predict that the offspring will have? What color flowers would the second generation have if two members of the first generation were crossed? Explain your predictions.

5 Looking at another exception

The skin color breeding program has also produced some other interesting results with another trait—eye color. The twenty-four red-skinned females of the parent generation had green eyes. The twenty-four blue-skinned males of the parent generation had red eyes.

1. What color eyes do you think that the offspring in each generation will have? Write your prediction about eye color as a hypothesis.

2. Look back at your data sheets. Color the eyes marked R red and the eyes marked G green.
3. Count how many organisms have each color eyes. Use the numbers to answer the questions below.

6 Applying what you have learned

a. How many organisms had each eye color in each generation?

b. Did your results match your predictions? Why or why not? Explain your answer.

c. Use your results to explain why eye color is not an example of incomplete dominance.

d. Eye color in crazy creatures is an example of codominance. In ***codominance***, an organism that has both alleles of a gene displays both traits at the same time. How is this different than incomplete dominance?

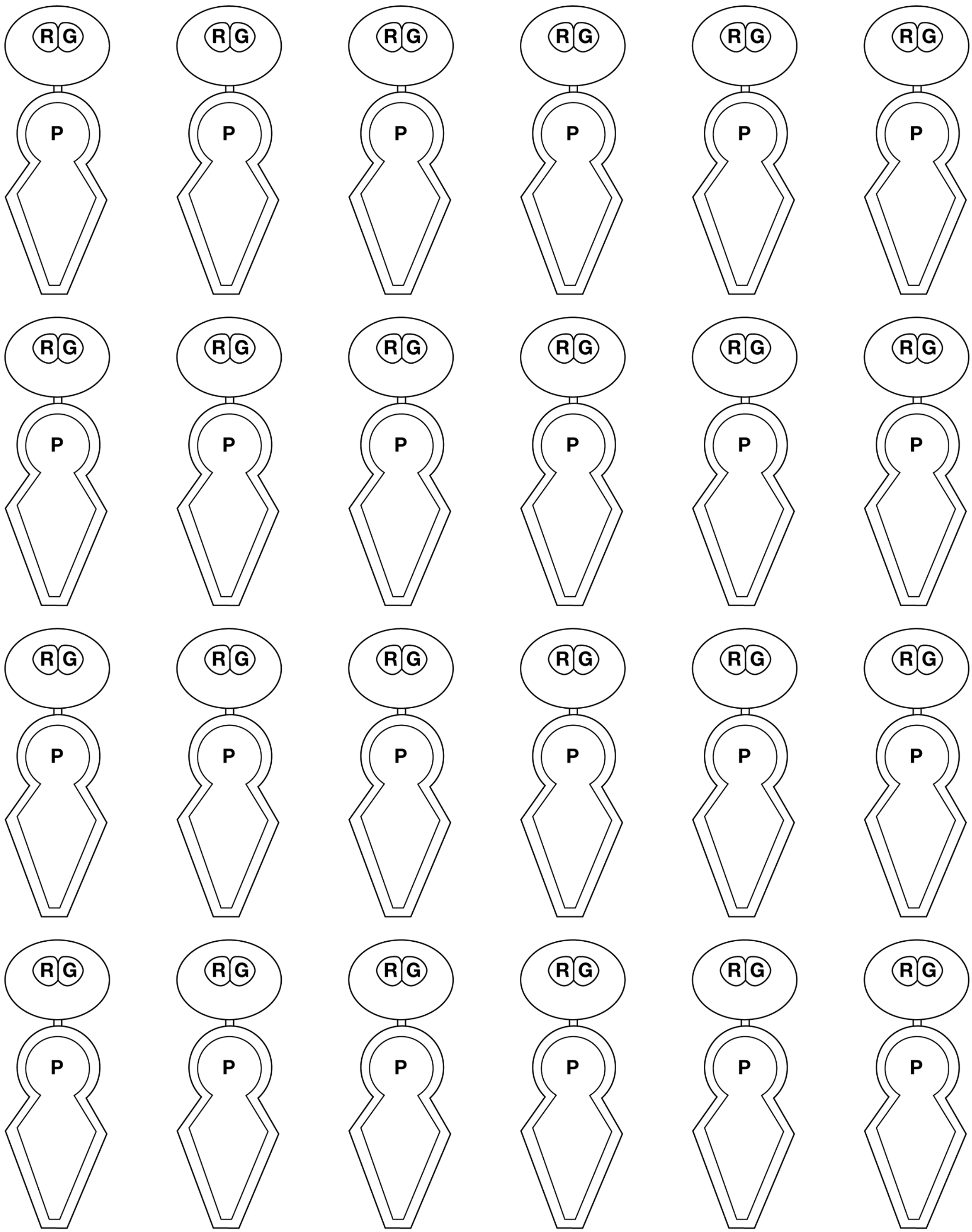
e. On Earth, a cross between a black cat and a tan cat results in a tabby cat (black and tan mixed together). What do you think the offspring of a tabby cat and a black cat would look like? Why?

7 Exploring on your own

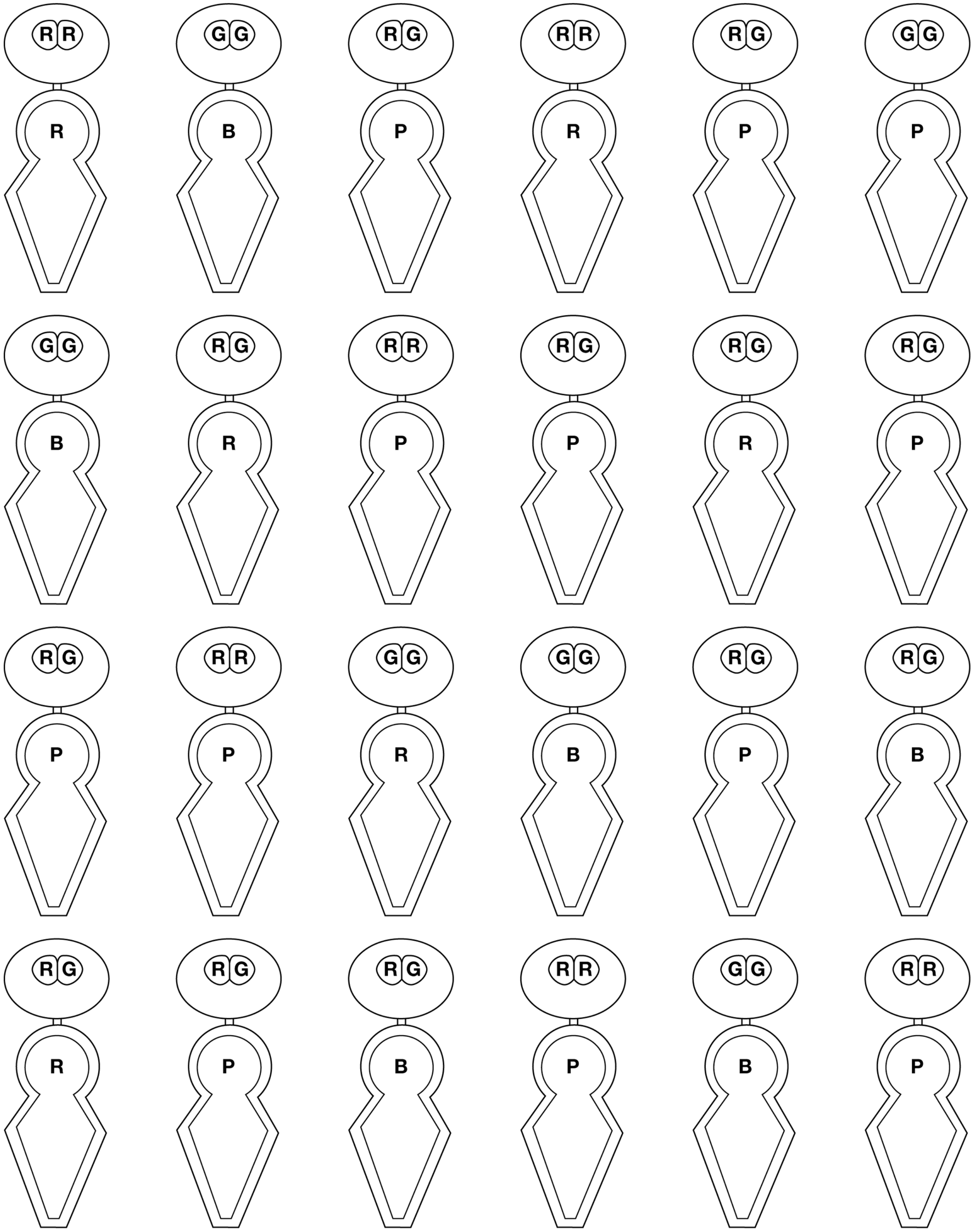
a. In these investigations, genes have just two alleles. Multiple alleles are also common in organisms. Research human blood type to find out more about this pattern of inheritance.

b. There are also inherited traits that are determined by more than one gene. These traits are called polygenic traits. Find out what human traits are polygenic.

First Generation



Second Generation



Assessment

1. What is the difference between incomplete dominance and codominance? Explain your answer.

2. If a black chicken is crossed with a white chicken in a certain species, the offspring are black and white chicken. These chicken are an example of which pattern of inheritance?

3. In another species of chickens, a cross between a black chicken and a white chicken produces blue chickens. These chickens are an example of which pattern of inheritance?

4. The diagram below shows a cross between a tabby cat and a tan cat. What is the probability of offspring with black fur? Tabby fur? Tan fur?

	T	T
B	BT	BT
T	TT	TT

A5 Adaptations

How do adaptations help an organism survive in its environment?

NASA noticed that one area of the planet Geneticus is undergoing rapid environmental change. Scientists have proposed that the population of crazy creatures in that changing area be relocated to another part of the planet with a different environment. You know that *adaptations*, or inherited traits that help an organism survive, are specially suited to their particular environment. Challenge the policy-making members of the administration to join you in playing this game of Adaptation Survivor to show how organisms are adapted to their environments.

1 Determining your environment

Your class will determine the environment in which your creature will live. Your class will roll the die for each environmental variable. Record the results in Table 1.

Table 1: Environmental data

Environmental variable	Possibilities with roll of the die	Outcome
Surface color	1, 2 = Blue soil 3, 4 = Purple soil 5,6 = Red soil	
Food source	1, 2 = chocolate candies 3, 4 = jumbo marshmallows 5, 6 = milkshakes	
Predator	1, 2 = *Hawkus giganticus* (flies over the land and snatches prey by their antennae) 3, 4 = *Frightus catus* (afraid of water but can run very fast) 5, 6 = *Microtus pesticus* (a blind army ant that crawls on the ground and attacks in large groups but cannot fly)	
Topography	1, 2 = flat 3, 4 = mountainous 5,6 = swampy	

2 Stop and think

a. What is an adaptation?

b. What kinds of adaptations would your creature need in order to survive in the environment in Table 1?

3 Choosing your traits

1. Think about adaptations that would help an organism survive in the environment your class determined in Part 1. Choose the traits from Table 2 below that would be adaptations for the environment.

Table 2: Possible genotypes and phenotypes of traits

Trait	Genotypes and phenotypes
1. Skin color	**TT** – red **Tt** – purple **tt** – blue
2. Eye color	**TT** – red **Tt** – one red and one green **tt** – green
3. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
4. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
5. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
6. Leg	**TT** – short **Tt** – short **tt** – long
7. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
8. Arms	**TT** – long **Tt** – long **tt** – short
9. Hands	**TT** – paws **Tt** – paws **tt** – claws
10. Antenna	**TT** – long **Tt** – long **tt** – short
11. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
12. Tail	**TT** – long **Tt** – short **tt** – none
13. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2. Complete Table 3 by filling in the genotype and phenotype for each trait you choose.
3. Tell whether each trait is an adaptation or not. If a trait is an adaptation, explain how it will help your creature survive in their environment. Record your answers in the last column of Table 3.
4. Build your creature and compare it with others in the class.

Table 3: Genotype and phenotype of your creature

Trait	Genotype	Phenotype	Adaptation? If yes, explain
1. Skin color			
2. Eye color			
3. Eyebrows			
4. Beak			
5. Ears			
6. Leg			
7. Foot			
8. Arms			
9. Hands			
10. Antenna			
11. Antenna shape			
12. Tail			
13. Wings			

4 Playing the Game of Adaptation Survivor

You will now see if your creature can survive the unpredictable conditions of a changing world. The object of the game is to be the last surviving creature in your environment. You earn or lose points based upon whether your creature's particular set of traits are adaptations for survival. **When your creature earns a minus-three total, it becomes extinct.**

1. Your teacher will choose someone to draw the first Environment Card and read it aloud. Each card describes two environmental conditions or events – read only the *one* condition that is facing you as you draw it. For each environmental condition, your creature can:
   a. thrive (+1);
   b. be pushed closer to extinction (-1);
   c. or, have no effect (+0).

   The scoring is based upon your creature's phenotype for a given trait. For example, if a very successful land predator finds its way onto your island, your only chance for survival may be the set of wings that your creature possesses. This would give you an advantage over a non-winged creature. For that Environment Card, you will earn a plus one (+1). If your creature does not possess wings, then you earn a minus one (-1).
2. There are some special cards in the deck, called Catastrophe Cards. If one of these cards is drawn, you might earn minus one, regardless of your characteristic makeup.
3. Your class will continue drawing Environment Cards.
4. Play until there is only one surviving creature. This is the winner of the game. NOTE: If a final card wipes out the last two or more creatures (complete extinction), then there is no winning survivor. Do you think that a complete extinction like this is likely to happen often? Why or why not?

5 Thinking about what you observed

a. What were some advantageous adaptations in this game? Which traits proved to be harmful? Explain.

b. If your class played this game again with all the same creatures and environments, do you think that the same creature would be the last survivor? Why or why not?

c. Create three of your own Environment Cards or Catastrophe Cards. Be sure to include the scenario, the adaptation in question, and the plus and minus values.

d. What does this game show about adaptations and changes in the environment? What do organisms need to do in order to be successful?

e. In this simulation, you were allowed to select traits that would be helpful for the environment that you rolled for. How might the game have turned out differently if you were directed to use the crazy creature that you created in the last investigation? What does this show about the relationship between organisms and their environment?

f. A team of scientists wants to relocate the population of crazy creatures. Explain why this would not be a good solution to the problem. Be sure to include the words adaptation and environment in your argument.

6 Exploring on your own

Organisms that are relocated into a new environment where they are not naturally found are called introduced species. Choose an introduced species to research using books and the internet. Find out about the adaptations of the organism and how successful it was in the new environment. Also, look to see what impact the introduced species had on its new environment and the organisms that are native to that area.

Assessment

1. What is an inherited trait that helps an organism survive called?

2. Adaptations can be physical or behavioral. A physical adaptation is a characteristic or structure that an organism actually has, like wings or coloring. A behavioral adaptation is an organism's actions, like hunting at night or freezing in the presence of predators. Label these adaptations as physical or behavioral adaptations.
   a. turtle's hard shell ____________________
   b. porcupine's quills ____________________
   c. opossum plays dead ____________________
   d. arctic hare's fur color ____________________

3. The adaptations in the Adaptation Survivor game were all physical adaptations. Invent three of your own behavioral adaptations for your crazy creature based on its environment. Describe how these actions help the creature survive.

4. Describe three changes in the environment that force an organism to adapt.

5. What happens to organisms that don't adapt to the changing environment? Give an example.

Extra space for notes:

A6 Changing Environments

How does the environment influence adaptations?

The game of Adaptation Survivor simulates how a changing environment can influence a population of organisms. In this investigation, you will use the same creature you built in the last investigation. What would happen if the creature's environment suddenly changed?

Materials

- Crazy Traits game
- Dice

1 Changing the environment

Use the same creature you built in the last investigation. Now, its environment has changed! Determine a new environment in which your creature will live. Roll the die for each environmental variable and record your results in Table 1.

Table 1:New environment for your creature

Environmental variable	Possibilities with roll of the die	Outcome
Surface color	1, 2 = Blue soil 3, 4 = Purple soil 5, 6 = Red soil	
Food source	1, 2 = chocolate candies 3, 4 = jumbo marshmallows 5, 6 = milkshakes	
Predator	1, 2 = *Hawkus giganticus* (flies over the land and snatches prey by their antennae) 3, 4 = *Frightus catus* (afraid of water but can run very fast) 5, 6 = *Microtus pesticus* (a blind army ant that crawls on the ground and attacks in large groups but cannot fly)	
Topography	1, 2 = flat 3, 4 = mountainous 5, 6 = swampy	

2 Analyzing your results

a. How is the new environment similar and different than the environment you rolled for in the last investigation?

b. List the traits of your creature that may help it survive in its environment. Describe how each trait could help it survive.

c. List the traits of your creature that would not help it survive in its new environment. Explain how each trait could affect the creature's survival in negative ways.

3 Applying your knowledge

a. In a population of organisms similar to your creature, which traits do you think would be passed onto offspring in this new environment? Which traits might disappear over time?

b. How similar is this new environment that you rolled for to the first environment that you created the creature for in the last investigation? What if the new environment was totally different? Or what if the new environment was only slightly different?

c. List some natural events that might cause an organism to move to a new environment.

4 Exploring on your own

Draw a picture of what your crazy creature might look like after many generations of living in the new environment. Write a paragraph to describe what adaptations it has developed to be successful in its new habitat.

Assessment

1. How are an organism's adaptations related to its environment?

2. Name three adaptations that a polar bear has for living in its environment.

3. Describe the adaptations of an organism from your local area and how it is suited to your environment.

4. Circle the most correct statement about adaptations:
   a. Individual organisms can quickly adapt to changes in their environment.
   b. Over many generations, a population of organisms may adapt to changes in the environment.
   c. Sudden changes in the environment cause a population of organisms to quickly acquire new adaptations.

5. Does environmental change always have a negative effect on organisms? Give an example to support your answer.

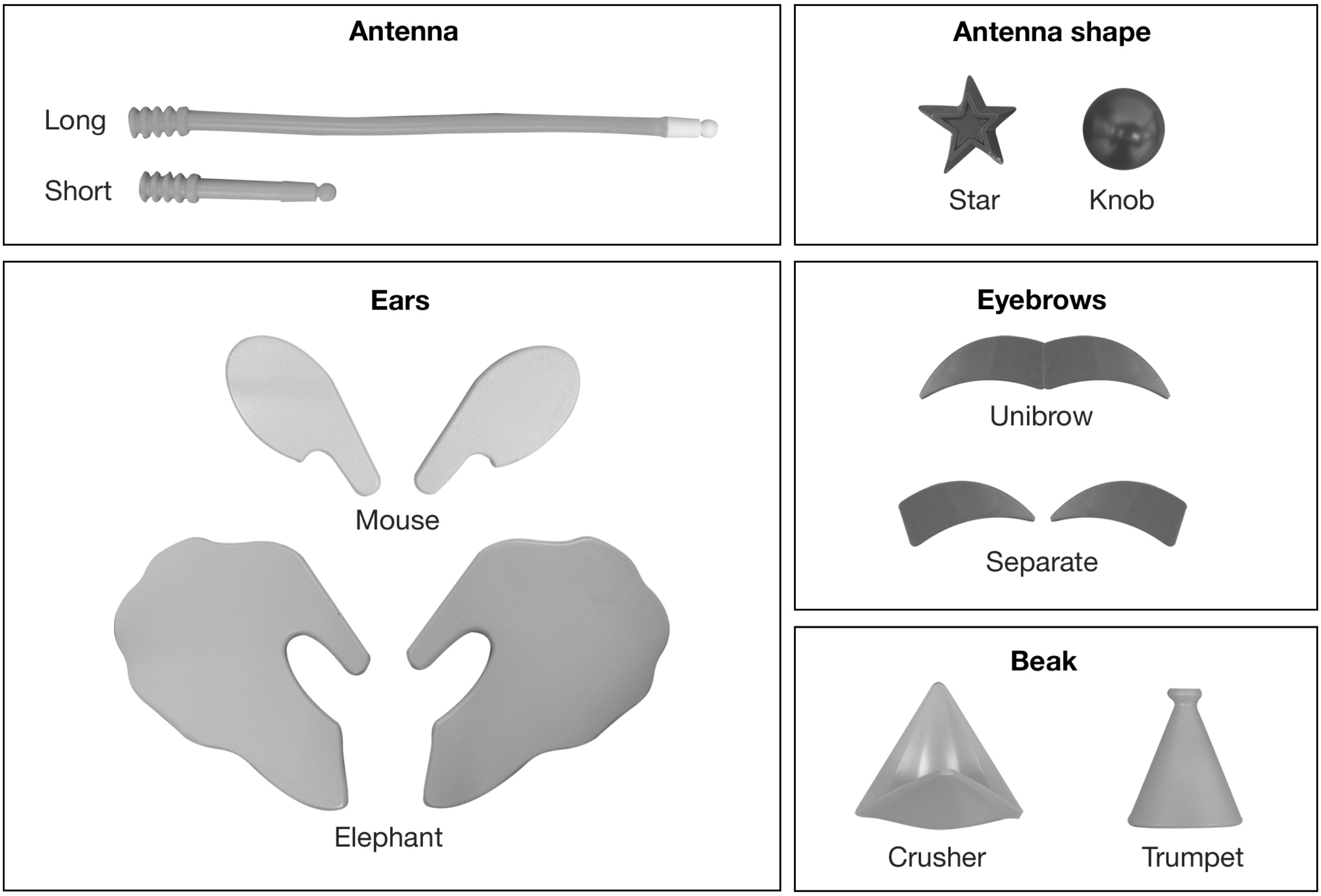
B1 Dominant and Recessive Traits

How can you identify dominant and recessive forms of a trait?

Traits are characteristics that an organism can pass on to its offspring. NASA scientists have discovered living organisms on the planet Geneticus. They have asked you to research a species named *Creaturus crazarius*—commonly called crazy creatures. To begin your research, you will take an inventory of the facial traits of crazy creatures to determine their basic patterns of inheritance.

1 Getting ready

In this investigation, you will study the faces of the crazy creatures. Look at the graphic below to see the various forms that the traits can take.



1. Choose one form of each facial trait and build the face of a crazy creature.
2. Switch facial traits and see if you can determine how many different faces you can build with the pieces.

2 Stop and think

a. Think about the forms of the traits. What are the advantages, if any, to having either form of each trait? What are the disadvantages, if any, to having either form of each trait? Explain your answers.

b. Why is there variation in the facial features of the crazy creatures? Explain your answer.

3 Collecting the data

1. Examine the sheets of creatures that follow this page. Count how many organisms you find with each form of the trait and record the totals into the appropriate columns of Table 1.

Table 1: Population data for facial traits

Trait	No. of organisms with Form 1	Freq. of organisms with Form 1	No. of organisms with Form 2	Freq. of organisms with Form 2
antenna	long:		short:	
antenna shape	star:		knob:	
ears	mouse:		elephant:	
eyebrows	unibrow:		separate:	
beak	crusher:		trumpet:	

2. Calculate the frequency of each form of the trait. Record the frequency in the correct columns of Table 1. Use this formula:

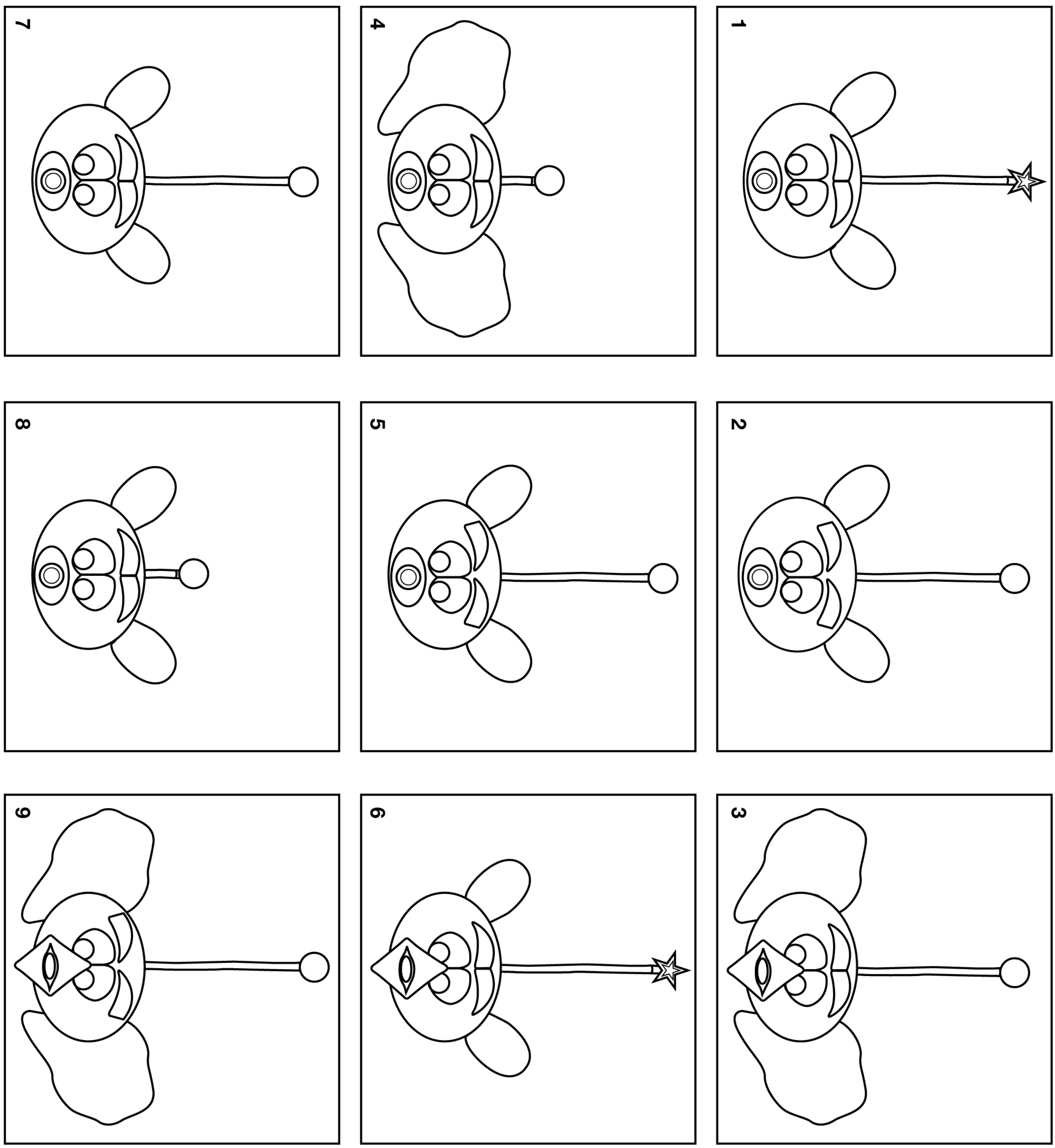
$$(\text{No. of organisms with form of trait} \div \text{No. of organisms in population}) \times 100$$

3. Now repeat the same process for the other traits.
4. Make a bar graph of the data. Your graph should compare frequencies for each form of the trait. Put traits on the *x*-axis and frequency on the *y*-axis.

Title ______________________________

y-axis: ______________________________

x-axis: ______________________________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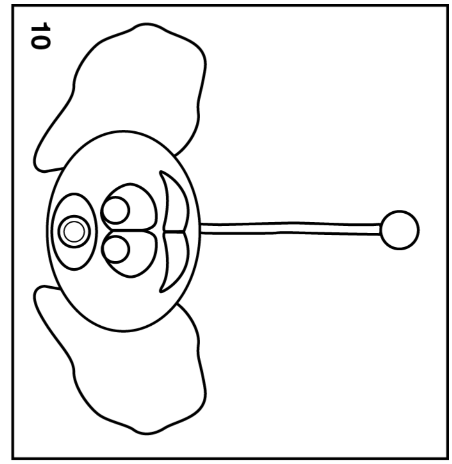
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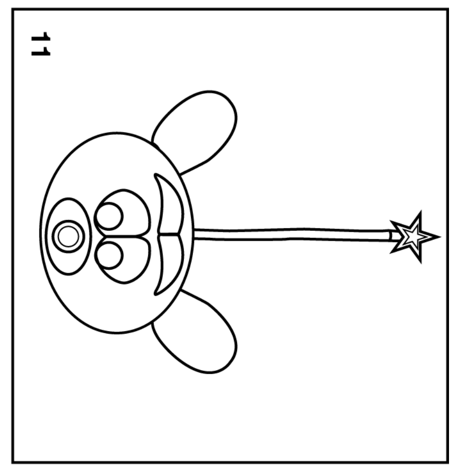
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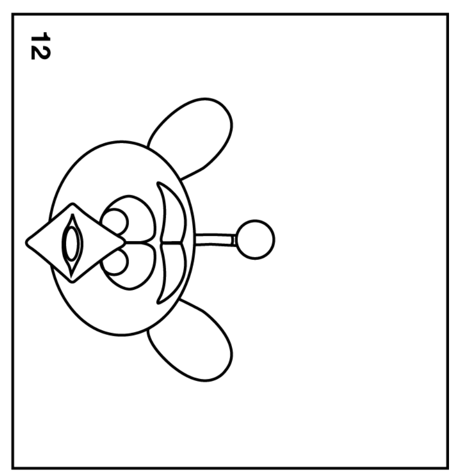
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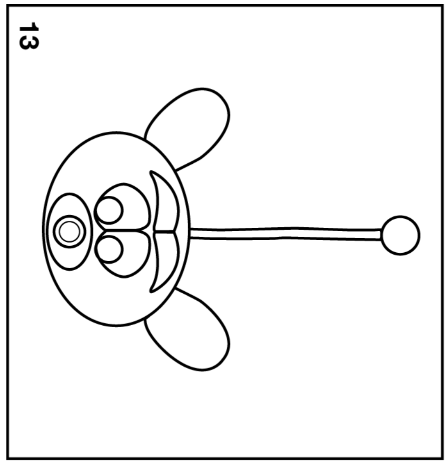
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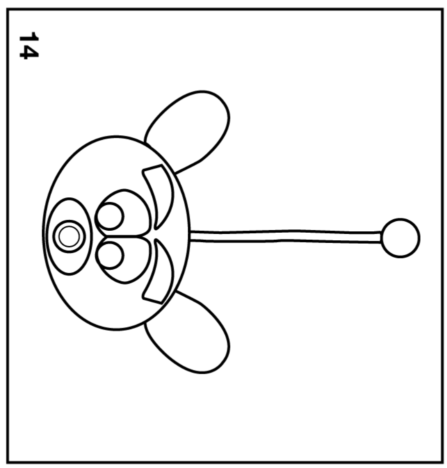
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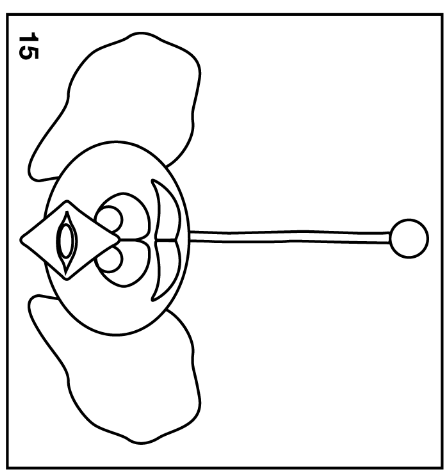
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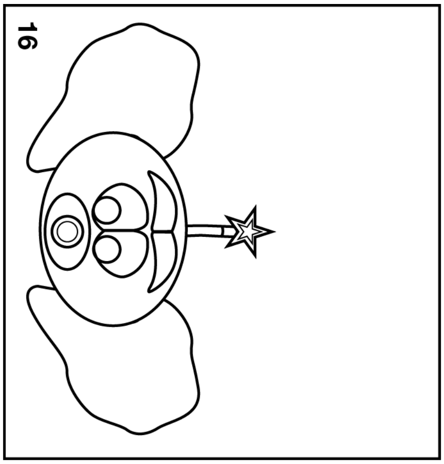
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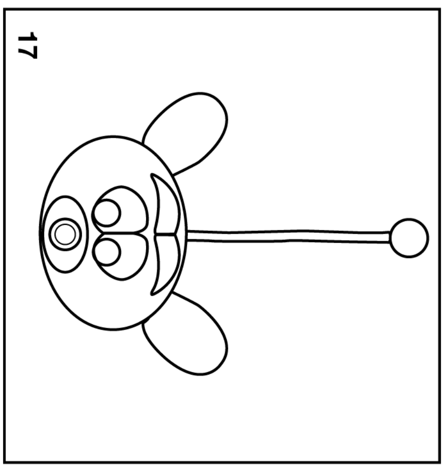
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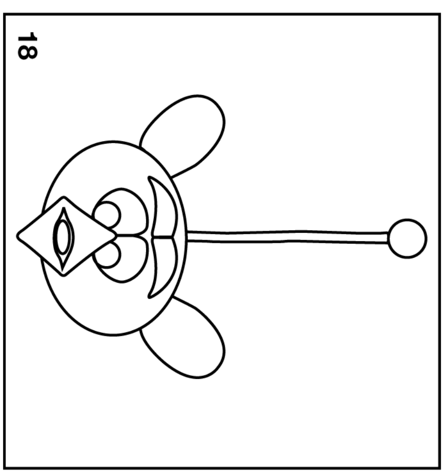
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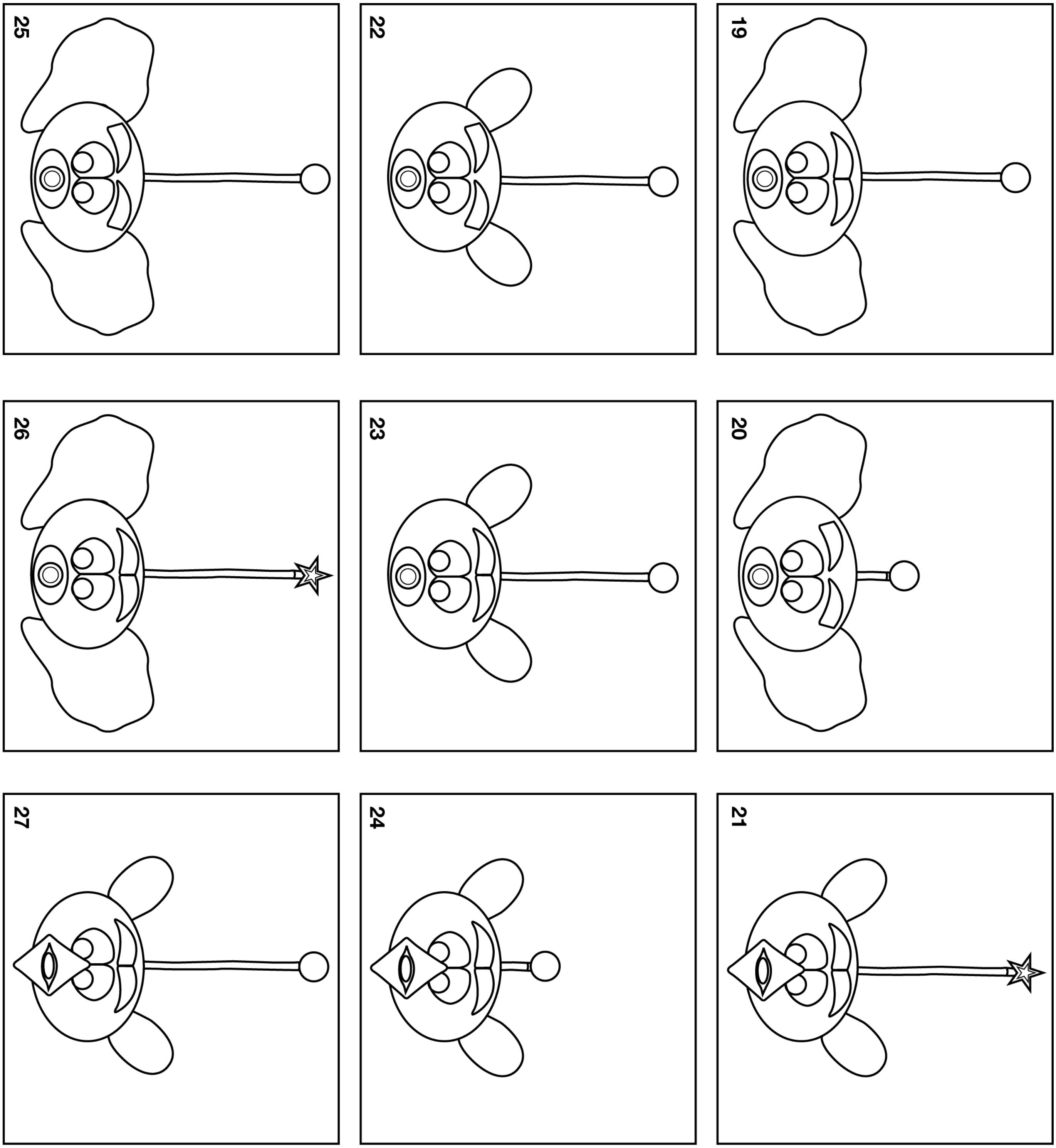
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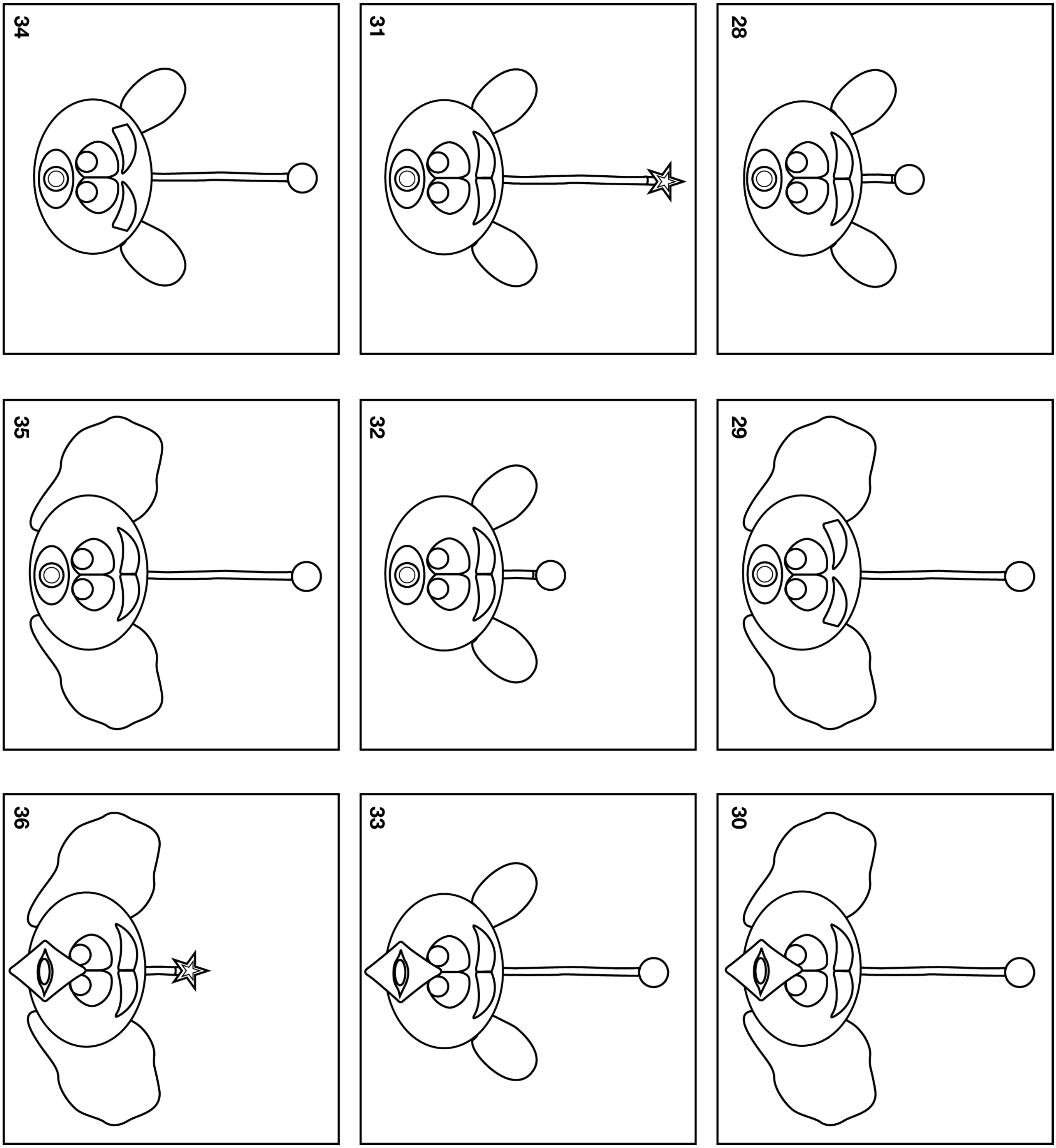
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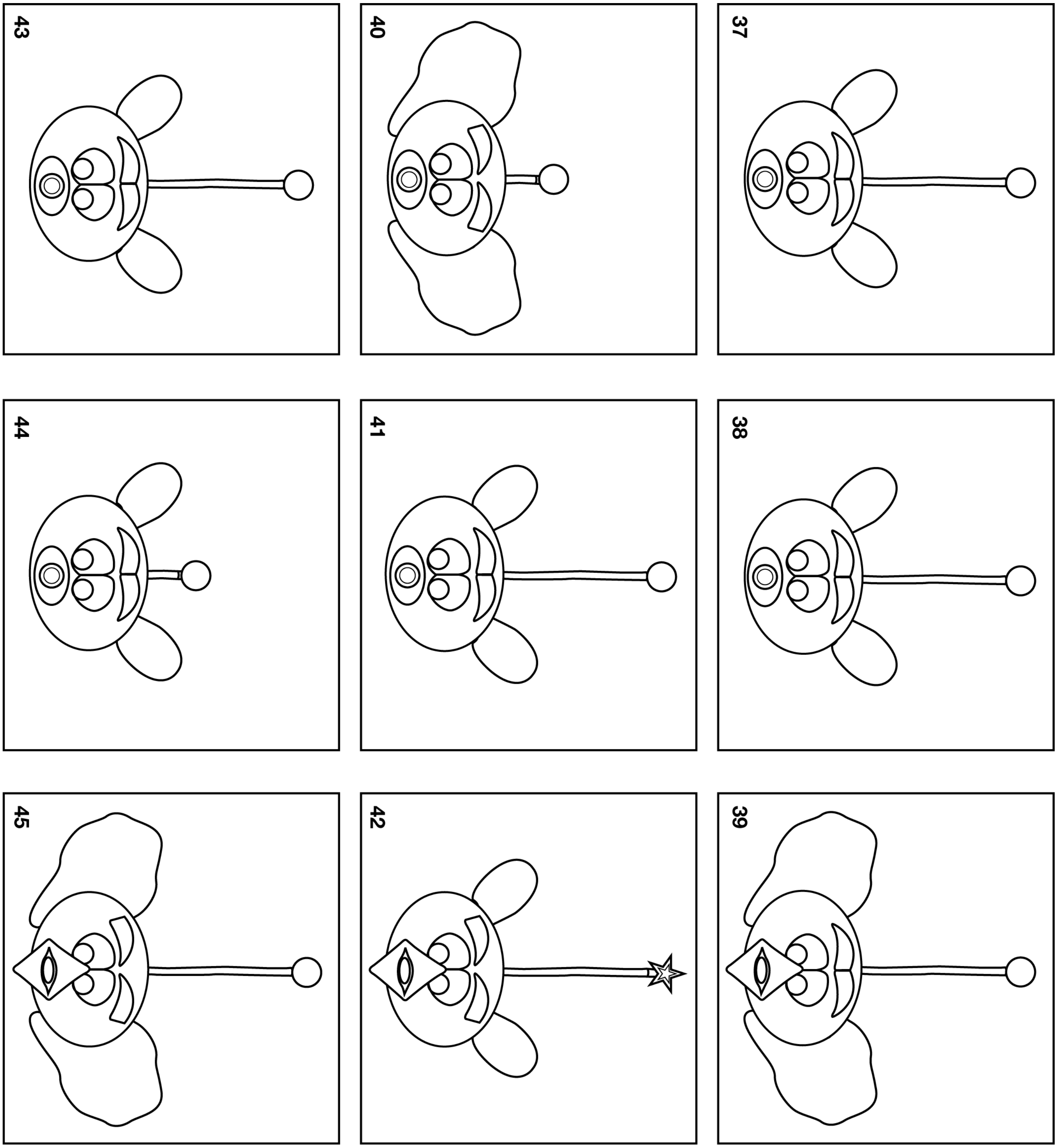
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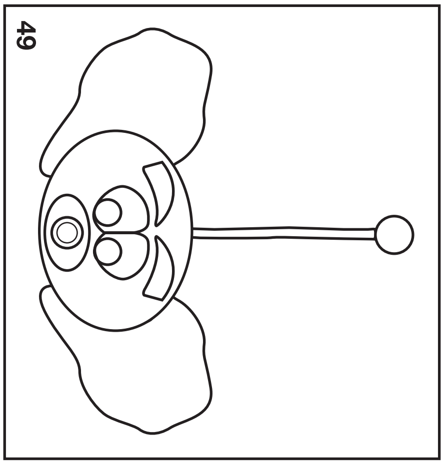
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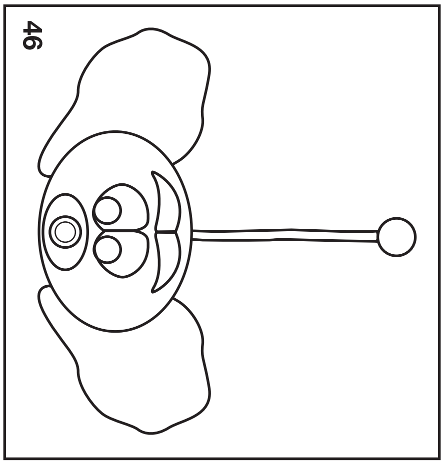
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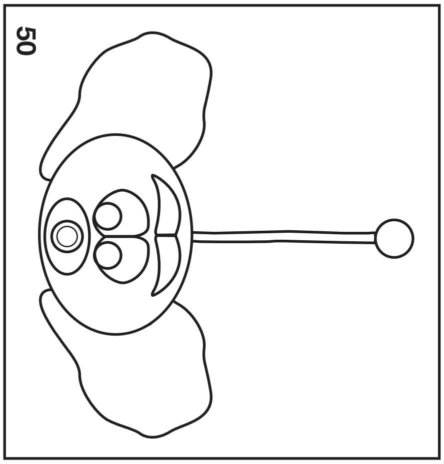
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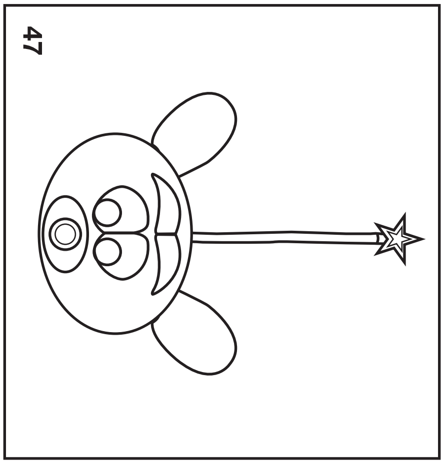
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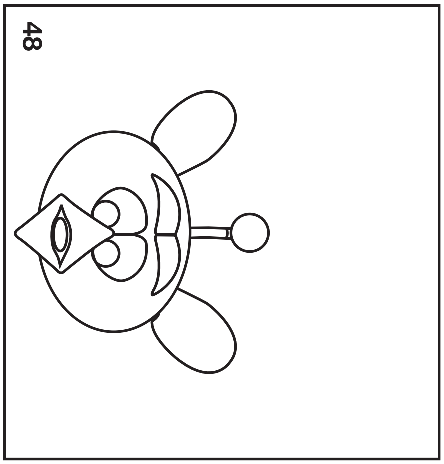
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4 Thinking about what you observed

a. For each trait, which form was most common?

b. Why do you think one form is more common than the other?

c. Think about the sample size. How might the results have been different if you looked at a smaller sample? What about a larger sample? Describe how sample size might affect the results.

d. In organisms found on Earth, traits are determined by units called *genes*. For each trait, an organism gets one gene from its mother and one gene from its father. Different forms of the same gene are called *alleles*. For each trait, there is a *dominant allele* and a *recessive allele*. The dominant allele masks the effect of the recessive allele for the trait. Based on your population data, do you think the traits of crazy creatures have dominant and recessive alleles? Use your data to explain your results.

e. Based on your data, hypothesize which are the dominant and recessive alleles for the traits in the chart below.

Trait	Predicted dominant allele	Predicted recessive allele
antenna		
antenna shape		
ears		
eyebrows		
beak		

f. Ask your teacher which alleles are dominant and which are recessive, then fill in the chart below.

Trait	Actual dominant allele	Actual recessive allele
antenna		
antenna shape		
ears		
eyebrows		
beak		

Were your predictions correct? Why or why not?

g. Sometimes people incorrectly assume that the dominant alleles are always more common. Was this true? Use evidence to explain your answer.

h. Remember that a ratio is a way to compare two numbers. To find a ratio, write the two numbers that you want to compare as a fraction. Divide both the top and bottom number of the fraction by the smallest number. Finally, write the answers as a ratio, rounded to the nearest whole number. What was the ratio of dominant to recessive genes for facial traits in the sample population of crazy creatures?

5 Exploring on your own

You will flip coins to determine the allele for the ear shape of a sample population of creatures. We will use a capital **T** to represent the dominant allele and a lowercase **t** to represent the recessive allele. In this activity, we will assume that both parents have the same alleles for ear shape (**Tt**). You will need a blue (egg) coin with a capital **T** on one side and a lower case **t** on the other side. You will also need a green (sperm) coin with a capital **T** on one side and a lower case **t** on the other side. If you flip **TT** or **Tt**, the creature will have elephant ears. If you flip **tt**, the creature will have mouse ears. How many creatures do you think will have elephant ears? Flip the coins to see if you are correct. Draw your results on the sheet of blank faces you are given.

Assessment

1. What is the term for a characteristic that an organism can pass on to its offspring?

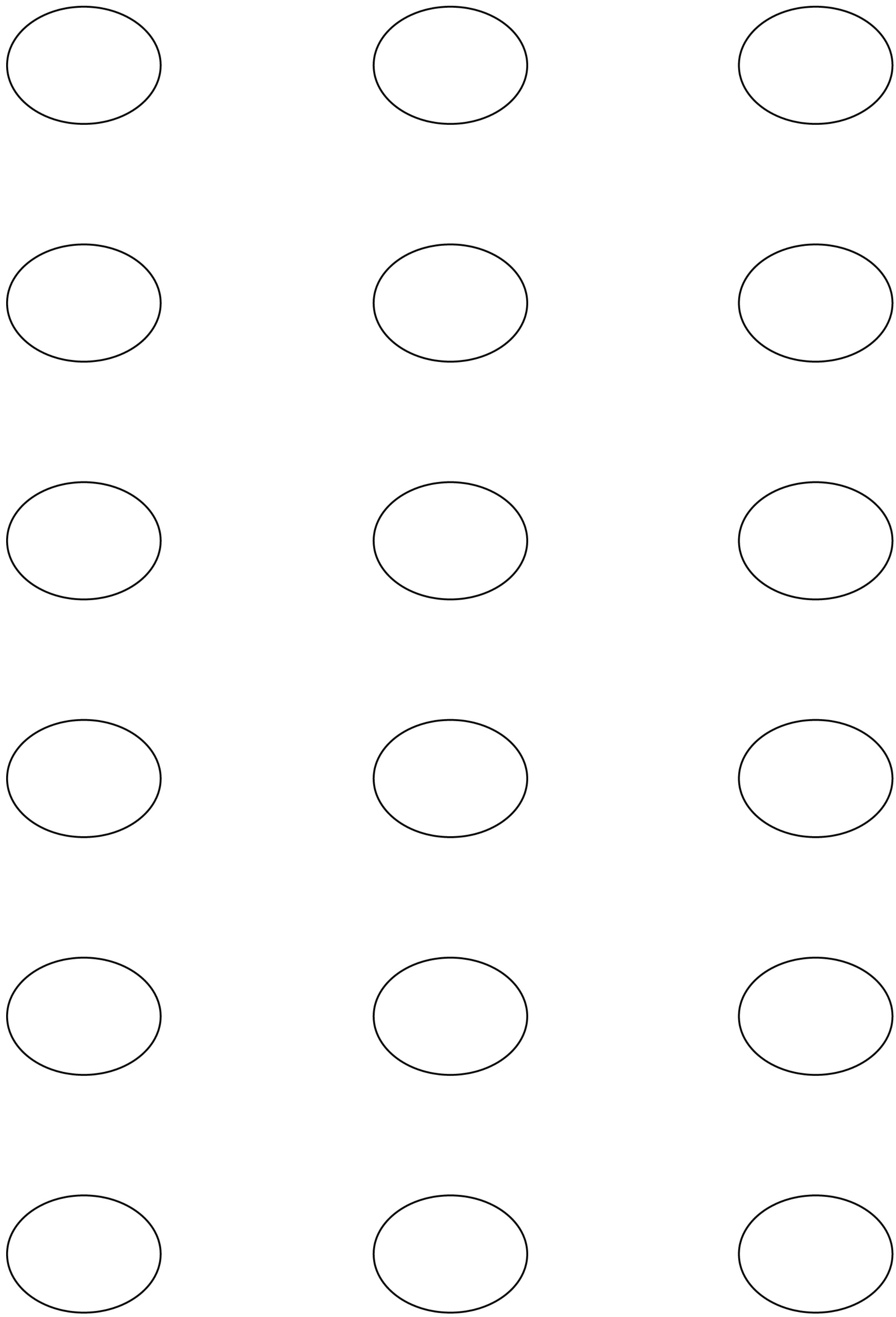
2. What is a gene?

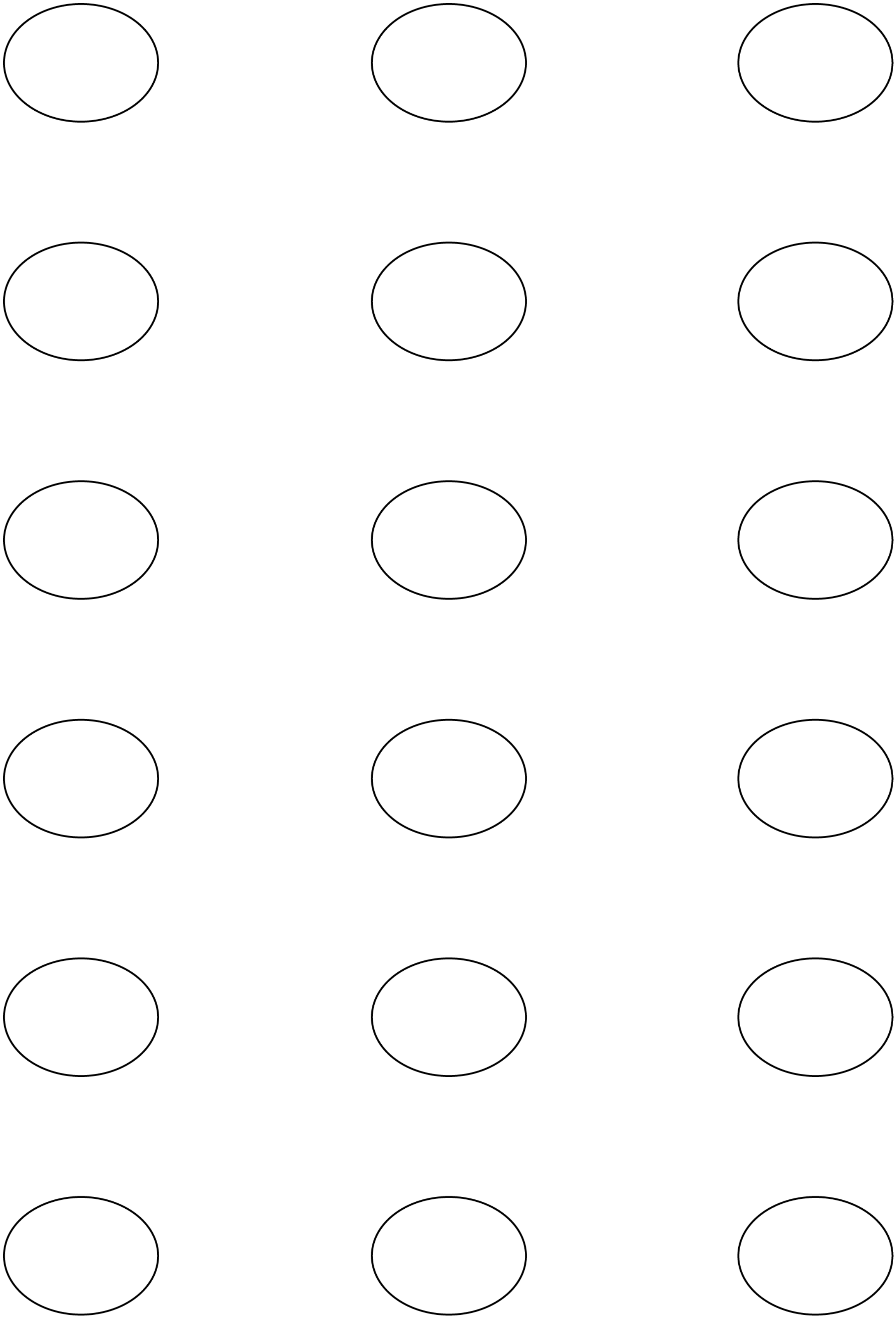
3. Explain how an organism receives two genes for each trait.

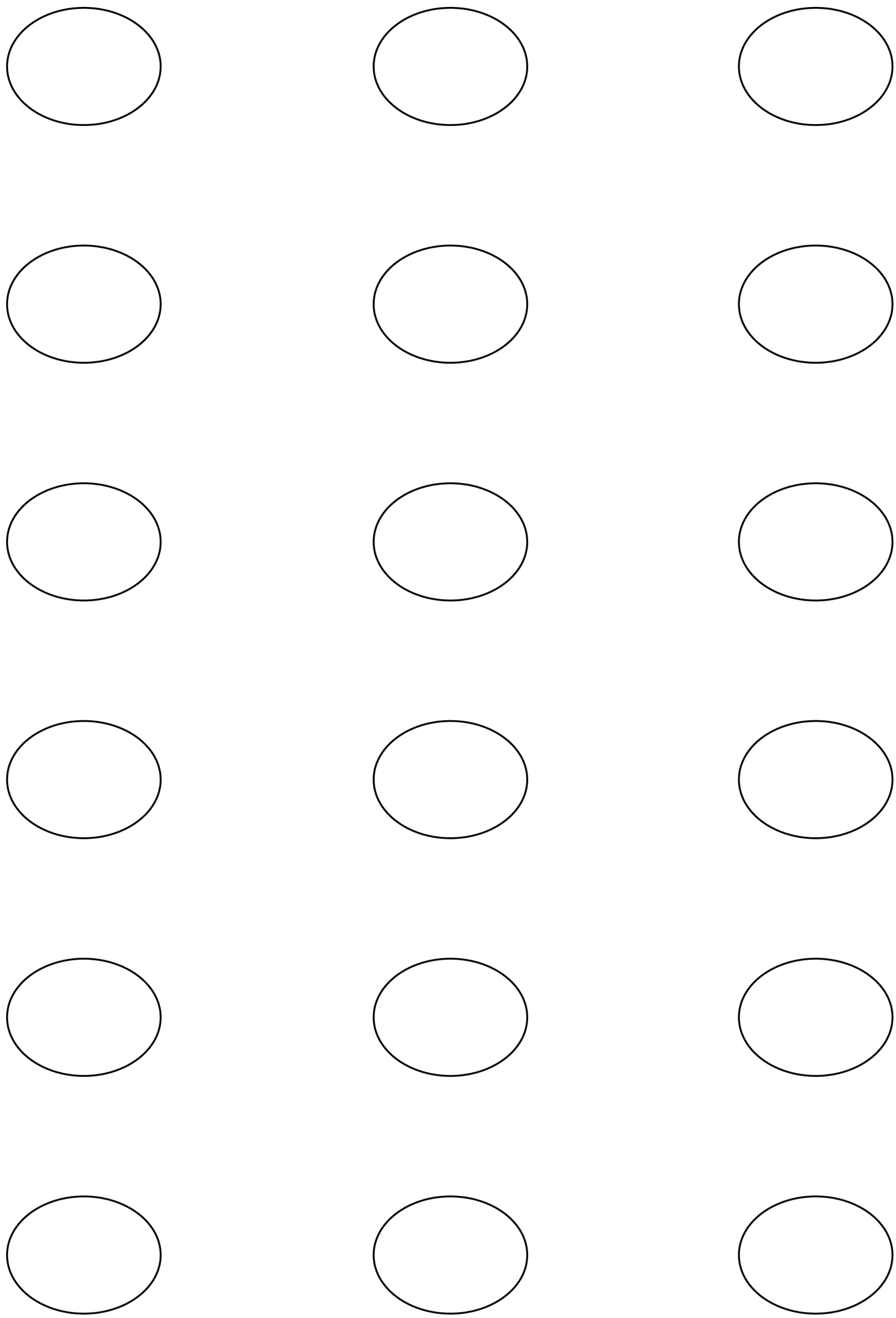
4. What is an allele? Name a crazy creature trait and the two alleles for that trait.

5. What is the difference between dominant and recessive alleles? Explain your answer.

6. Are dominant alleles always more common? Explain your answer.







B2 Other Patterns of Inheritance

What are some exceptions to the basic patterns of inheritance?

You have learned that many traits have a dominant form that masks the recessive form. In this investigation, you will learn about traits that are more complicated than one form simply being dominant to another recessive form.

Additional materials

- Crayons or colored pencils

1 Thinking about what you will do

Remember from your study of facial traits that different forms of the same gene are called *alleles*. You found that for each of the facial traits you studied there is a dominant allele and a recessive allele. By counting the traits of the crazy creatures in a certain population, you saw that the *dominant allele* masks the effect of the *recessive allele* for the trait. But skin color in the creatures does not fit this pattern. It seems that when a blue crazy creature mated with a red crazy creature, the offspring are purple! How can this be?

NASA scientists studying the crazy creatures originally thought that there must be some mistake. To collect more data, they set up a breeding program to study the skin color of crazy creatures. The breeding program consisted of twenty-four red-skinned females and twenty-four blue-skinned males for the parent generation. Each mating pair produced one offspring for a total of twenty-four individuals in the first generation. The members of the first generation were mated with each other to produce twenty-four organisms of a second generation. They have asked you to look at the results to help explain these unusual findings.

2 Stop and think

a. What would you need to know in order to predict what color skin the offspring will have?

b. Think about skin color in crazy creatures. How could a red-skinned organism crossed with a blue-skinned organism result in purple-skinned organisms?

c. Predict how many of the twenty-four organisms will have each skin color in each generation.

3 Looking at the data

You will be given a data sheet of the twenty-four organisms produced in each generation of the breeding program to help you understand the results.

1. Color in the organisms to show what skin color the offspring have. Color the organisms marked P on the body purple. The organisms marked B on the body should be colored blue. Finally, the organisms marked R on the body should be colored red. Do not color the heads or eyes.
2. Count how many organisms have each skin color in each generation. Use the numbers to answer the questions below.

4 Thinking about what you observed

a. How many organisms had each skin color in each generation? Calculate the percent of crazy creatures that had each skin color.

b. Did your results match your predictions? Why or why not? Explain your answer.

c. After some additional research, you learn that skin color is an example of incomplete dominance. In *incomplete dominance*, the two traits blend - just like mixing paints. Instead of the color blue being dominant to the color red or vice versa, the two colors are combined, which results in the color purple. You have just discovered that tail length in crazy creatures is also an example of incomplete dominance. One allele is for a long tail, while the other allele is for no tail. Predict what these two alleles blended would look like. Explain your prediction.

d. On Earth, flower color in snapdragons is an example of incomplete dominance. If a true-breeding, red-flowered snapdragon is crossed with a true-breeding, white-flowered snapdragon, what color flowers do you predict that the offspring will have? What color flowers would the second generation have if two members of the first generation were crossed? Explain your predictions.

5 Looking at another exception

The skin color breeding program has also produced some other interesting results in regards to eye color. The twenty-four red-skinned females of the parent generation had green eyes. The twenty-four blue-skinned males of the parent generation had red eyes.

1. What color eyes do you think that the offspring in each generation will have? Write your prediction about eye color as a hypothesis.

2. Look back at your data sheets. Color the eyes marked R red and the eyes marked G green.
3. Count how many organisms have each color eyes. Use the numbers to answer the questions below.

6 Applying what you have learned

a. How many organisms had each eye color in each generation? Calculate the percent of crazy creatures that had each eye color.

b. Did your results match your predictions? Why or why not? Explain your answer.

c. Use your results to explain why eye color is not an example of incomplete dominance.

d. Eye color in crazy creatures is an example of codominance. In *codominance*, an organism that has both alleles of a gene displays both traits at the same time. How is this different than incomplete dominance?

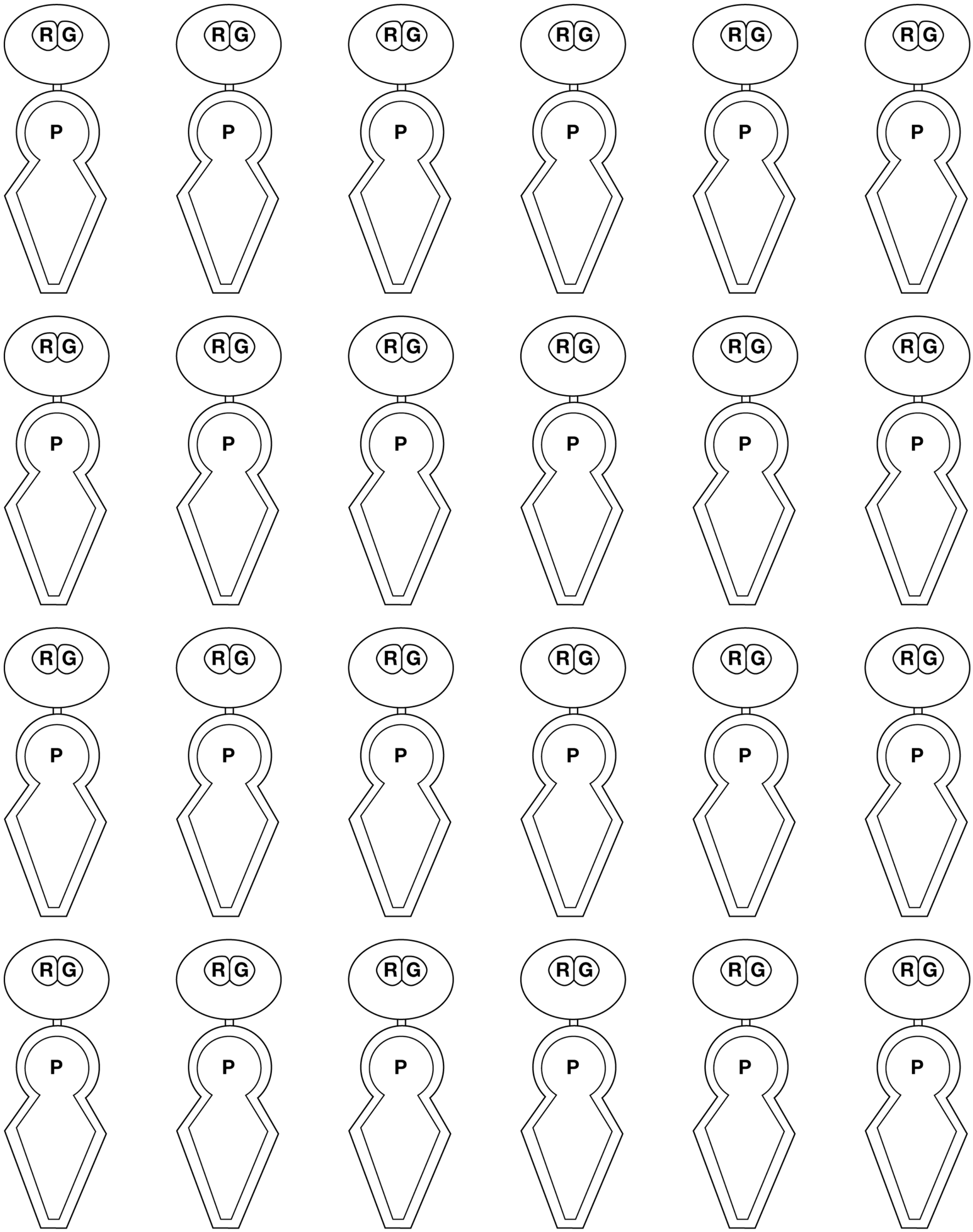
e. On Earth, a cross between a black cat and a tan cat results in a tabby cat (black and tan mixed together). What do you think the offspring of a tabby cat and a black cat would look like?

7 Exploring on your own

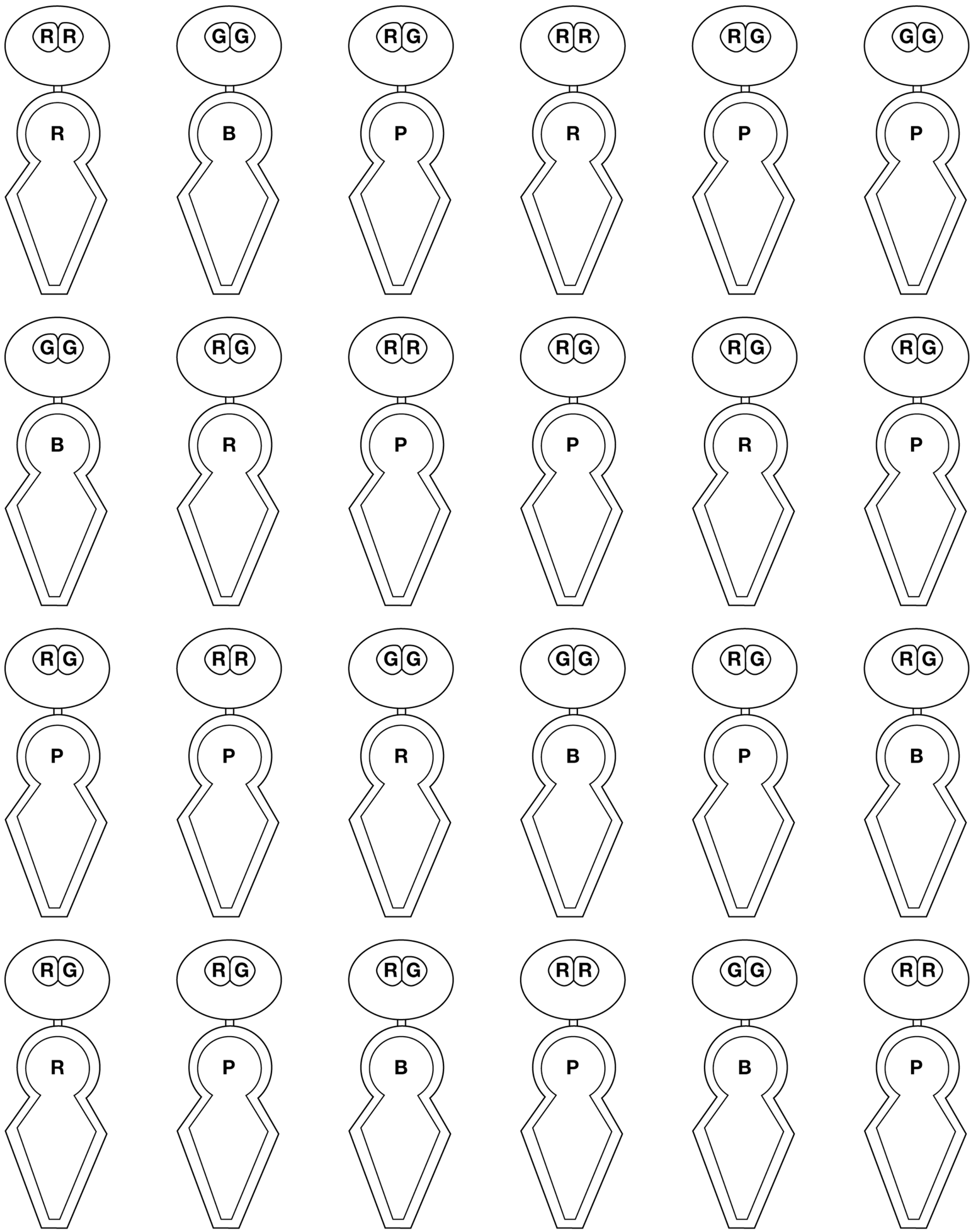
a. In these investigations, genes have just two alleles. Multiple alleles are also common in organisms. Research human blood type to find out more about this pattern of inheritance.

b. There are also inherited traits that are determined by more than one gene. These traits are called polygenic traits. Find out what human traits are polygenic.

First Generation



Second Generation



Assessment

1. What is the difference between incomplete dominance and codominance? Explain your answer.

2. If a black chicken is crossed with a white chicken in a certain species, the offspring are black and white chicken. These chicken are an example of which pattern of inheritance?

3. In another species of chickens, a cross between a black chicken and a white chicken produces blue chickens. These chickens are an example of which pattern of inheritance?

4. The diagram below shows a cross between a tabby cat and a tan cat. What is the probability of offspring with black fur? Tabby fur? Tan fur?

	T	T
B	BT	BT
T	TT	TT

Additional notes:

B3 Crazy Traits

What role does chance play in an organism's heredity?

NASA scientists have found an isolated population of crazy creatures on the planet Geneticus that all have the same combination of alleles – one dominant allele and one recessive allele for all their traits. Since all the parents have the same alleles, many have incorrectly assumed that the future generations will look exactly the same as the parents. You know that this isn't the case! It is true that for each gene, you get at least one allele from your mother and one from your father. However, the alleles you actually end up with are determined by two factors: (1) the alleles that your parents have; and (2) the alleles from each parent you inherit. The alleles you inherit from each parent are determined by chance. *Probability* is the mathematical chance that an event will occur. In this investigation, you will play a probability game that will show how the offspring of this unique population might look.

Additional materials

- Name tags
- Markers

1 Determining the genotype

1. The first trait you will flip for is gender. Choose the male sex chromosome coin (***X*** on one side and ***Y*** on the other) and the female sex chromosome coin (***X*** on both sides). Place both coins in the cup and shake. Toss the coins onto the table. Record the allele from each parent and genotype in columns 2, 3, and 4 of the first row of Table 1.
2. Next, flip coins to determine the allele for each of the other traits your creature inherits from each parent. This will decide the creature's genotype and phenotype. An organism's *genotype* is the alleles of a gene it contains. An organism's *phenotype* is the form of a trait that it displays. In this activity, both parents have the same genotype for all traits (**Tt**) since they are from that isolated population on Geneticus. You will need the blue (egg) coin with a capital **T** on one side and a lower case **t** on the other side. You will also need the green (sperm) coin with a capital **T** on one side and a lower case **t** on the other side.
3. Flip the coins for the next trait – skin color. Place the coins in the cup. Shake the cup and toss the two coins on the lab table. The side that lands up on each coin represents the sperm and egg that unite during fertilization. Record your results in Table 1.
4. Repeat this procedure for traits 3 through 14.

Table I: Genotypes and phenotypes of offspring for Part 1

Trait	Allele from mother	Allele from father	Genotype	Phenotype
1. Gender				
2. Skin color				
3. Leg				
4. Foot				
5. Arms				
6. Hands				
7. Eye color				
8. Eyebrows				
9. Beak				
10. Ears				
11. Antenna				
12. Antenna shape				
13. Tail				
14. Wings				

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** - blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** - green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2 Stop and think

a. What information do the letters on the sperm and egg coins indicate: alleles, genotype, or phenotype?

b. Since the parents all have **Tt** for a genotype, which phenotype do the parents show for all the traits – the dominant or the recessive phenotype?

c. For the sperm coin, what are the chances of getting a **T** or getting a **t**? State your answer as a fraction and a percent.

d. For the egg coin, what are the chances of getting a **T** or getting a **t**? State your answer as a fraction and a percent.

e. When both coins are flipped at once, what are your chances of getting each of the following combinations: **TT**, **Tt**, or **tt**? State your answer for each as a fraction and a percent.

3 Building your creature

1. Once you have completed columns 2 through 4 of Table 1, use Table 2 to look up the phenotype for each trait. Record the phenotype for each trait in column 5 of Table 1.
2. Once you have completed Table 1, select the correct body parts to build your creature.
3. Orient the body for a male (round end down) or female (round end up).
4. Carefully assemble your creature.
5. Give your creature a name and make it a name tag.
6. Display your creature in the area designated by your teacher.

4 Thinking about what you observed

a. Examine the creatures. Do any of them look exactly alike? Do any of them look exactly like their parents? Why or why not?

b. How does this investigation explain why offspring may resemble their parents, but never look exactly like them?

c. How does this investigation explain why siblings may resemble each other, but never look exactly alike (unless they are identical twins)?

d. Count the number of males and number of females. Does the number of each match the chances of getting a male or female in the game? Why or why not?

e. Which trait(s) are examples of codominance?

f. Which trait(s) are examples of incomplete dominance?

g. Which trait(s) are examples of complete dominance?

5 Exploring on your own

If time permits, work with another group whose creature is the opposite gender. Follow the steps below to create offspring of the couple:

1. Record the genotypes of each parent in the first column of Table 3.
2. First, toss for gender using the male and female sex chromosome coins.
3. For each trait, you'll need to use the correct egg and sperm coins for each parent. Use the data in Table 1 to find the parents' genotype for each trait. Then, select the egg and sperm coin that has the same alleles as the genotype. For example, if the father's genotype for skin color is **TT**, choose the sperm coin that has a capital **T** on both sides of the coin. If the mother's genotype for skin color is **tt**, place the egg coin that has a lower case **t** on both sides of the coin.
4. Place both coins in the plastic cup, shake, and toss out onto the table. Record your results in the fourth column of Table 3.
5. Use Table 2 to look up the phenotypes. Record the phenotypes of the offspring in the last column of Table 3.

Table 3: Offspring genotypes and phenotypes for Part 5

Trait	Genotype of mother for the trait	Genotype of father for the trait	Genotype of offspring (after mating)	Phenotype of offspring
1. Gender				
2. Skin color				
3. Leg				
4. Foot				
5. Arms				
6. Hands				
7. Eye color				
8. Eyebrows				
9. Beak				
10. Ears				
11. Antenna				
12. Antenna shape				
13. Tail				
14. Wings				

6 Applying what you learned

a. Which parent does your offspring share the most traits with, the mother, father, or both equally?

b. Why do you need to choose different egg and sperm coins for each trait and for each parent?

c. What is the process that flipping the coins represents? Why is this process important?

d. There is always a 50% chance of having a male offspring. Explain why this statement is true. You may use a diagram to help explain.

e. In part 1, you started off with both parents having identical genotypes for all traits. Use what you have learned in the investigation to explain why this is unrealistic in nature.

Assessment

1. What two factors determine what alleles an organism ends up with?

2. What is the difference between genotype and phenotype?

3. List the possible phenotypes for skin colors.

4. List the possible genotypes for a crazy creature with elephant ears.

5. Both parents in this investigation were **Tt** for all traits. How would the results have differed if both parents were **TT**? Or what if both parents were **tt**? Explain.

6. What is the genotype for males? What is the genotype for females?

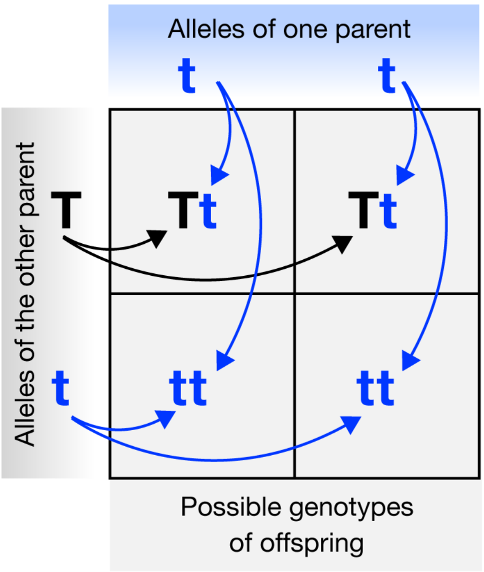
B4 Punnett Squares

How are punnett squares used to make predictions about inheritance?

NASA is setting up an educational exhibit to teach people about crazy creatures and their planet, Geneticus. NASA has asked you to help them select the initial breeding pair to include in their exhibit. They want to be sure that the parents that they pick and their offspring will represent a variety of all the traits that crazy creatures can have. You know that you can predict the genotypes and phenotypes of the offspring if you know the genotypes of the parents. A *punnett square* shows all the possible combinations of alleles from the parents. In this investigation, you will create punnett squares to help NASA select the best creatures for their new display.

1 Making the predictions

Look at this punnett square showing the parents from the B -3 investigation - **Tt** for all the traits. The two alleles for each of the parents are shown outside the squares – one parent across the top and one parent down the side. Since each parent gives at least one allele to their offspring, the squares represent the four possible combinations of alleles that the offspring could receive. If this parent gives this allele and this parent gives this allele, and so forth.



a. What are the possible genotypes of the offspring?

____

____

____

Probability plays an important part in heredity. Although we can use punnett squares to show the possible combinations, the actual chance of inheriting a certain genotype or phenotype is still random. Probability is the mathematical chance that an event will occur. Probability can be expressed as a fraction or a percentage. Since there are four possibilities in punnett squares, it is easy to make fractions: $^1/_4$, $^2/4$ or $^1/_2$, $^3/_4$, or $^4/_4$ or 1. To convert these fractions to percentages, take the numerator of the fraction divided by the denominator and multiply by 100.

	T	**t**
T	**TT**	**Tt**
t	**Tt**	**tt**

TT = $^1/_4$ = 25%

Tt = $^2/_4$ = 50%

tt = $^1/_4$ = 25%

b. What is the probability that the offspring will show the dominant phenotype?

____

1. You will predict the probable traits of the offspring of two crazy creatures to see if they are suitable candidates for the NASA education exhibit. You will work with another team and use the creatures you created in the last investigation. Your teacher will pair you up with another team that has a creature of the opposite gender.
2. The gender row of Table 1 has been partially filled in for you. Since there is a 50% chance of the offspring being male or female, you will guess what gender you think the offspring will be. Fill in your prediction in the predicted phenotype column.
3. Now, fill in the genotypes for the mother and father for all the other traits in columns 2 and 3 in Table 1.
4. For each trait, make a punnett square to show the possible combinations of alleles for the offspring.
5. Determine which phenotype is more probable by counting how many offspring would have each phenotype. Use Table 2 to determine what phenotypes the genotypes show. Fill in the most likely phenotype in column 4 of Table 1. In some cases as with gender, you will find that there is an equal chance of having either phenotype – two would have one trait, while the other two would have the other trait. If this is true, you guess what phenotype you think that the offspring will most likely have.
6. Next, make a fraction to show how many of the offspring would most likely have the predicted phenotype. Create a fraction by using the number of offspring with the more common phenotype divided by four (the total number of squares). Use this fraction to find the percent in step 7.
7. Finally, find the percent of the offspring that would most likely have the predicted phenotype. To calculate a percent, divide the numerator by the denominator and multiply by 100. Record the percent in column 5 of Table 1.
8. Repeat these steps for traits 3 through 14.

Table 1: Predicted phenotypes and probability

Trait	Genotype of mother	Genotype of father	Predicted phenotype	% probability	Actual genotype	Actual phenotype
1. Gender	XX	XY		50%		
2. Skin color						
3. Leg						
4. Foot						
5. Arms						
6. Hands						
7. Eye color						
8. Eyebrows						
9. Beak						
10. Ears						
11. Antenna						
12. Antenna shape						
13. Tail						
14. Wings						

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** - blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** - green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2 Stop and think

a. What is a punnett square? What information is needed to create a punnett square?

b. What is probability? What does probability have to do with inheritance?

3 Checking the predictions

1. Now, you will flip coins to see if your predictions are right. The first trait you will flip for is gender. Choose the male sex chromosome coin (***X*** on one side and ***Y*** on the other) and the female sex chromosome coin (***X*** on both sides). Place both coins in the cup and shake. Toss the coins onto the table and record your results in Table 1.
   For the other traits, you'll need to use the correct egg and sperm coins for each parent. Use the data in Table 1 to find the parents' genotype for each trait. Then, select the egg and sperm coin that has the same alleles as the genotype. For example, if the father's genotype for skin color is **TT**, choose the sperm coin that has a capital **T** on both sides of the coin. If the mother's genotype for skin color is **tt**, find the egg coin that has a lower case **t** on both sides of the coin.
2. Place both coins in the cup, shake, and toss out onto the table. Record your results in column 6 of Table 1.
3. Use Table 2 to look up the phenotype. Record the phenotype of the offspring in the last column of Table 1.
4. Repeat this procedure for all the traits.
5. Build your creature and compare with other creatures in the class.

4 Thinking about what you observed

a. Why do you need to choose different egg and sperm coins for each trait and for each parent?

b. How many of the actual phenotypes matched your predicted phenotypes? Explain your results.

c. Which parent does your offspring share the most traits with, the mother, father, or both equally?

d. Are punnett squares unnecessary if both parents have the same genotype? Explain.

e. What are the possible percents for probability when using punnett squares? Explain why these are the only possibilities.

f. From your investigation, what genotypes will you recommend to NASA for the initial breeding pair for their new exhibit? Explain your choices.

5 Exploring on your own

Make an informational sign to display at the NASA educational exhibit explaining punnett squares and probability to the public. Your sign should show the genotypes and phenotypes of the parents. It should also explain why this pair was selected. Also, be sure to include the appropriate punnett squares to show the predictions for the possible offspring.

Assessment

1. What is the phenotype for a crazy creature with a genotype of **TT** for beak?

2. What is the genotype for a crazy creature with mouse ears?

3. If a homozygous dominant (**TT**) parent mated with a homozygous recessive (**tt**) parent, what is the probability of the offspring having the dominant phenotype? Show the punnett square with your answer.

4. If a heterozygous (**Tt**) parent mated with a homozygous recessive (**tt**) parent, what is the probability of the offspring having the homozygous recessive (**tt**) genotype? Show the punnett square with your answer.

5. Why couldn't two crazy creatures with separate eyebrows ever produce an offspring with a unibrow? Explain your answer using a punnett square.

6. Can a pure dominant (**TT**) parent and a mixed-allele (**Tt**) parent ever produce a pure recessive (**tt**) offspring? Explain your answer using a punnett square.

7. In skin color, why isn't the phenotype for **Tt** red? Which other trait follows this pattern? Why?

8. In eye color, why isn't the phenotype for **Tt** red? Which other trait follows this pattern? Why?

9. Why can't you create a punnett square if you only know the phenotypes of the parents? Give an example with your explanation.

10. Punnett squares only show the possible combinations of alleles. What is the role of chance in inheritance?

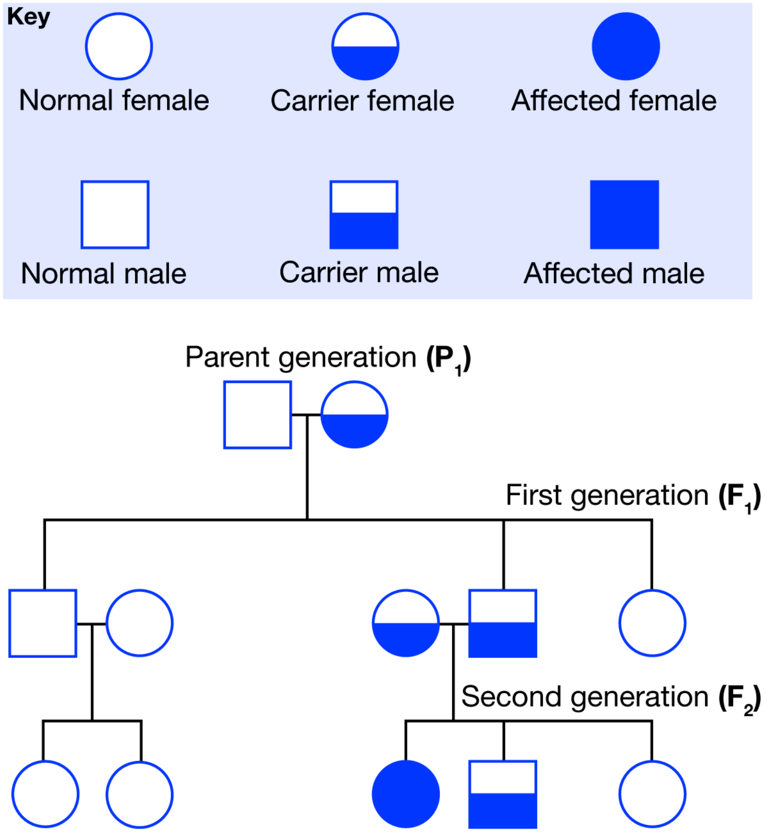
B5 Pedigrees and Genetic Disorders

How can a pedigree be used to trace a genetic disorder over generations?

A *pedigree* is a tool used by geneticists to study traits and genetic disorders in generations of families. A *genetic disorder* is an abnormal condition that an organism inherits from its parents. A pedigree traces a genetic disorder through generations and help predict the chances of future offspring having a genetic disorder. In this investigation, you will learn how to create a pedigree for a genetic disorder in crazy creatures called “night blindness.”

1 Reading pedigrees

The diagram (right) shows a pedigree of a family that carries a genetic disorder. Notice the different symbols for normal individuals, affected individuals, and carriers. Normal individuals do not even have one allele for the disorder. Affected individuals have two alleles for the disorder - one from each parent. These individuals actually have the disorder. A *carrier* is an individual that has one allele for the disorder, but does not have the disorder. Carriers can pass on the allele for the disorder to their offspring. Look at the pedigree and answer the questions. You will then use the pedigree as a model for this investigation.



a. How many carrier females are in the F_1 (first) generation?

____

b. Can you explain why only one of the individuals in this pedigree has the disorder? Which generation is it?

____

____

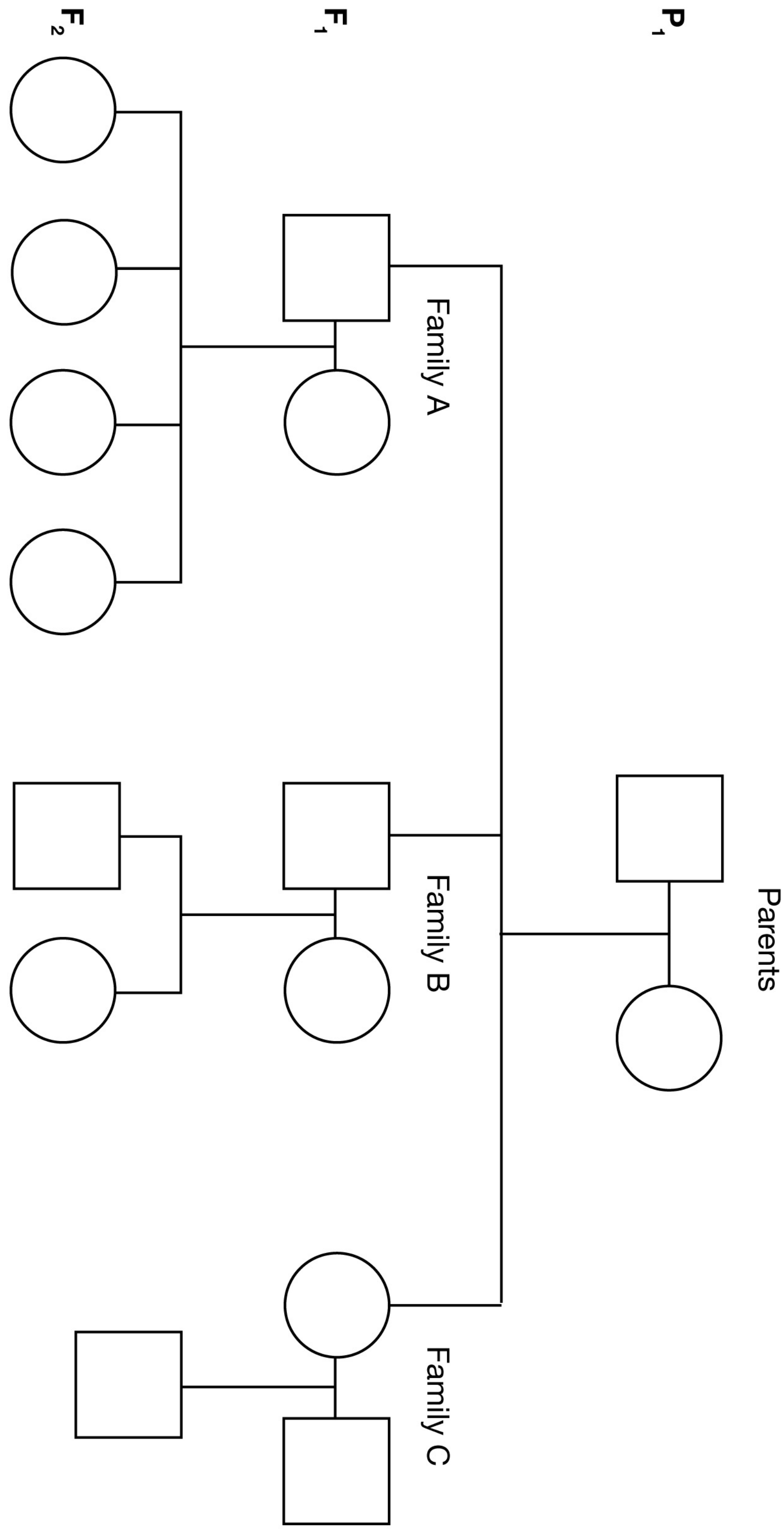
____

2 Drawing pedigrees

NASA scientists have discovered a nocturnal crazy creature. Red eyes are a beneficial trait for night time vision. Creatures born with one green eye have adequate vision at night, but those born with two green eyes are virtually blind at night—a condition NASA calls "night blindness." Create a pedigree that traces an eye color trait in a family produced by the breeding crazy creatures. During the activity, use the following key to record genotypes and phenotypes and to color the pedigree.

Genotype	Phenotype
TT	red eyed, normal
Tt	one red and one green eye, carrier of night blindness
tt	green eyed, has night blindness

1. Find the P_1 breeding pair (the parent generation) on the blank pedigree diagram. Shade the pedigree to show the parent female with one red and one green eye (**Tt**). The parent male has a green eyes (**tt**). Locate the correct eye models that represent each parent's eye color.
2. The breeding pair produces three offspring: two males and one female. These are the F_1 generation offspring. Choose the correct allele coins and flip them. This is the first generation offspring or F_1 generation. The circles and squares have been drawn for you. Color the templates after you determine their eye color. You will need to flip the same coins a total of three times - once for each offspring.
3. One of the first generation (F_1) male mates with a female that has red eyes (**TT**). They produce four female offspring. This is Family A on the pedigree. Flip the correct coins to determine the genotypes of each of their offspring. Color your results on the pedigree chart.
4. Another F_1 generation male mates with a female that has a green eyes (**tt**). They produce two offspring - one male and one female. This is Family B on the pedigree. Flip the correct coins to determine the genotypes of their offspring. Record your results on the pedigree.
5. The F_1 female mates with a male that has a one red and one green eye (**Tt**). They produce one male offspring. This is Family C on the pedigree. Flip the correct coins to determine the genotype of this offspring. Record your results on the pedigree.
6. For the F_2 (second) generation crosses, choose any of the individuals from the pedigree, determine the genotype of the mate and the number of each gender of offspring that the pair produces. Flip the correct coins and draw a new pedigree chart as you work. Label the generations. Create a key for the symbols.


P1
F1
F2
Parents
Family A
Family B
Family C

3 Thinking about what you observed

a. How many males are in the F_2 (second) generation offspring? How many females are in the F_2 generation?

b. Share your results with others. Is everyone's pedigree the same? Why or why not?

c. Why is an individual who has one dominant allele and one recessive allele called a carrier? Explain your answer.

d. Explain why it isn't really necessary to flip the coins if both parents have green eyes.

e. Explain why it IS necessary to flip coins if both parents are carriers.

4 Exploring on your own

Pedigrees are often used to predict the offspring having a genetic disorder. Choose a genetic disorder to research. Is it a recessive or dominant disorder? What are the symptoms? What are the treatments? How many people are affected with the disorder? Are there particular groups of people who are more or less likely to inherit this disorder? Present your findings to the class. Prepare at least one visual to support your presentation.

Assessment

1. What is a pedigree?

2. Why are pedigrees useful?

3. Draw these parts of a pedigree:
   a. normal male
   b. carrier female
   c. affected male

4. What is a carrier?

5. Could two normal organisms ever have a carrier offspring? Explain your answer.

B6 Sex-Linked Traits

What are sex-linked traits and how are they passed on to offspring?

Scientists identify some inherited traits as *sex-linked traits*. The alleles for sex-linked traits are carried on the sex chromosomes (X or Y). Sex-linked alleles do not have an equal probability of males and females inheriting the trait. For example, red-green color blindness in humans occurs more often in males than in females. Being color blind is less likely in females because the allele for the disorder is found only on an X chromosome of the 23rd pair. It is missing from the male Y chromosome. Therefore in order to be color blind, a female would have to inherit the allele from her mother and father.

NASA has discovered that almost all of the night-blind crazy creatures in a new population tend to be male. This most likely occurred due to a recent mutation on the sex chromosomes. Night-blindness is a sex-linked trait in this new population.

1 A sex-linked genetic disorder in crazy creatures

For this activity, use the X and Y gender coins, the correct sperm and egg coins and the chart below to create a pedigree explaining this phenomenon. When using both coin sets, combine the genotypes using superscripts shown below:

Genotype	Phenotype
$X^T X^T$	normal female (red-eyed)
$X^T X^t$	carrier female (red-eyed)
$X^t X^t$	night blind female (green-eyed)
$X^T Y$	normal male (red-eyed)
$X^t Y$	night blind male (green-eyed)

a. Which is dominant, red or green eyes? How can you tell?

b. Why can't a male crazy creature be a carrier of night-blindness?

2 Creating a pedigree

1. The P_1 breeding pair (the parent generation) consists of a night blind female and a normal male. This breeding pair has four offspring. Flip the gender coins first. Because this trait is sex-linked, if the offspring is a female, flip both sperm and egg coins. If the offspring is male, flip only the egg coin. Record the genotypes and phenotypes for each flip in Table 1 for Family A.
2. A second breeding pair consists of a carrier female and a normal male. Family B has three offspring. Flip the gender coins first. Remember, for offspring that are female, flip sperm and egg coins. Complete Table 1 as you flip.
3. Family C consists of a normal female and a night blind male. This pair only produces two female offspring. (No need to flip the gender coins!) Fill in Table 1.
4. The P_1 generation for Family D has a carrier female and a night blind male. They produce two offspring. Flip the correct coins and complete Table 1.

Table 1: Genotypes and phenotypes of the offspring

Family	F1 Genotype	F1 Phenotype
A		
A		
A		
A		
B		
B		
B		
C		
C		
D		
D		

3 Drawing your pedigrees

Now that you know the genotypes and phenotypes for the F_1 generations, draw pedigrees for each family using the space below. Use additional paper if you need it. Be sure to include a key and label each family and generation (P_1 and F_1).

4 Thinking about what you observed

a. Make a punnett square for Family A. Will any female offspring of this cross be night blind?

b. What is the percent chance that the offspring of family A will be carriers? What percentage of family A could be night blind?

c. For Family B, can any of the female offspring be night blind? Why or why not?

d. Explain why the male offspring in family B have a 50 percent chance of being night blind.

e. Explain why the male offspring in Family C will always be normal.

f. Will any of the male offspring be normal in Family D? If so, what is the percent chance?

g. Explain the 2 ways a female crazy creature can inherit night blindness.

Assessment

1. What are sex-linked traits? How are they different than the dominant/recessive pattern of inheritance you learned about earlier?

2. Explain, using your knowledge of sex-linkage, why night blindness is more common in male crazy creatures than in female crazy creatures.

3. In sex-linked traits that are carried on the X chromosome, can males ever be carriers of the trait? Explain your answer.

4. Color-blindness is a sex-linked trait in humans that is carried on the X chromosome. Suppose a color-blind male has children with a female that carries the allele for color blindness. Make a punnett square of the cross and list the possible genotypes and phenotypes of their offspring.

Extra space for notes and sketches:

B7 Crazy Adaptations

How does the environment influence traits?

NASA noticed that one area of the planet, Geneticus is undergoing rapid environmental change. The administration has proposed that the population of crazy creatures in that changing area be relocated to another part of the planet. You think that this is a disastrous idea! You know that *adaptations*, or inherited traits that help an organism survive, are specially suited to their particular environment. Challenge the policy-making members of the administration to join you in playing this game of Adaptation Survivor to see how organisms are built for their environments.

1 Determining your environment

Your class will roll the die for an environment for your creature. Record the results of the roll in Table 1..

Table 1: Environmental data

Environmental variable	Possibilities with roll of the die	Outcome
Surface color	1, 2 = Blue soil 3, 4 = Purple soil 5, 6 = Red soil	
Food source	1, 2 = chocolate candies 3, 4 = jumbo marshmallows 5, 6 = milkshakes	
Predator	1, 2 = *Hawkus giganticus* (flies over the land and snatches prey by their antennae) 3, 4 = *Frightus catus* (afraid of water but can run very fast) 5, 6 = *Microtus pesticus* (a blind army ant that crawls on the ground and attacks in large groups but cannot fly)	
Topography	1, 2 = flat 3, 4 = mountainous 5, 6 = swampy	

2 Stop and think

a. What is an adaptation? Where do adaptations come from?

b. How are adaptations suited to a particular environment? Give an example.

3 Getting ready to play

Build the crazy creature that you flipped for in Investigation B - 3.

a. Describe the adaptations your creature has for surviving in the environment your class rolled for. Be creative.

b. Compare your creature to the creatures of the other groups in your class. How do you think your creature will compete against these other creatures?

4 Playing the Game of Adaptation Survivor

You will now see if your creature can survive the unpredictable conditions of a changing world. The object of the game is to be the last surviving creature in your environment. You earn or lose points based upon whether your creature's particular set of traits are adaptations for survival. **When your creature earns a minus-three total, it becomes extinct.**

1. Your teacher will choose someone to draw the first Environment Card and read it aloud. Each card describes two environmental conditions or events – read only the *one* condition that is facing you as you draw it. For each environmental condition, your creature can:
   a. thrive (+1);
   b. be pushed closer to extinction (-1);
   c. or, have no effect (+0).

   The scoring is based upon your creature's phenotype for a given trait. For example, if a very successful land predator finds its way onto your island, your only chance for survival may be the set of wings that your creature possesses. This would give you an advantage over a non-winged creature. For that Environment Card, you will earn a plus one (+1). If your creature does not possess wings, then you earn a minus one (-1).
2. There are some special cards in the deck, called Catastrophe Cards. If one of these cards is drawn, you might earn minus one, regardless of your characteristic makeup.
3. Your class will continue drawing Environment Cards.
4. Play until there is only one surviving creature. This is the winner of the game. NOTE: If a final card wipes out the last two or more creatures (complete extinction), then there is no winning survivor. Do you think that a complete extinction like this is likely to happen often? Explain.

5 Choosing your traits

1. Now, you get to build a crazy creature specially suited to the environment your class rolled for in Part 1. Based on the environment, think about the adaptations your creature will need to survive. Choose the traits for your creature from Table 2 below.

Table 2: Possible genotypes and phenotypes of traits

Trait	Genotypes and phenotypes
1. Skin color	**TT** – red **Tt** – purple **tt** – blue
2. Eye color	**TT** – red **Tt** – one red and one green **tt** – green
3. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
4. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
5. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
6. Leg	**TT** – short **Tt** – short **tt** – long
7. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
8. Arms	**TT** – long **Tt** – long **tt** – short
9. Hands	**TT** – paws **Tt** – paws **tt** – claws
10. Antenna	**TT** – long **Tt** – long **tt** – short
11. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
12. Tail	**TT** – long **Tt** – short **tt** – none
13. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

2. Complete Table 3 by filling in the genotype and phenotype for each trait you choose for your new creature.
3. Tell whether each trait is an adaptation or not. If a trait is an adaptation, explain how it will help your creature survive in their environment. Record your answers in the last column of Table 3.

Table 3: Genotype and phenotype of your creature

Trait	Genotype	Phenotype	Adaptation? If yes, explain
1. Skin color			
2. Eye color			
3. Eyebrows			
4. Beak			
5. Ears			
6. Leg			
7. Foot			
8. Arms			
9. Hands			
10. Antenna			
11. Antenna shape			
12. Tail			
13. Wings			

4. Build your creature.

6 Playing the game of Adaptation Survivor

Now, play the game of Adaptation Survivor again with the creature that you built specifically for the environment.

7 Thinking about what you observed

a. How did your specially adapted crazy creature compete compared to your first creature that was not designed for the environment? Did it make a difference that you were able to select traits? Why or why not?

b. Describe how a favorable adaptation in one environment could be an unfavorable adaptation in another environment. Give an example in your explanation.

c. Create three of your own Environment Cards or Catastrophe Cards. Be sure to include the scenario, the adaptation in question, and the plus and minus values.

d. What would you tell the decision-making administrative team about the idea to relocate the threatened population of crazy creatures? What does this investigation show about adaptations and the environment?

8 Exploring on your own

Create a picture of your crazy creature in its environment. Draw what the environment looks like from the description you rolled. Draw the traits that your specially adapted crazy creature has. Be sure to include your creature's food source and predator in the scene. Share your drawing with your classmates.

Assessment

1. Adaptations can be physical or behavioral. Physical adaptations are characteristics or structures that an organism actually has, like wings or coloring. Behavioral adaptations are an organism's actions, like hunting at night or freezing in the presence of predators. Label these adaptations as physical or behavioral adaptations.
   a. turtle's hard shell ________________________
   b. porcupine's quills ________________________
   c. opossum plays dead ________________________
   d. arctic hare's fur color ________________________
2. The adaptations in the Adaptation Survivor game were all physical adaptations. Invent three of your own behavioral adaptations for your crazy creature based on its environment. Describe how these actions help the creature survive.

____

____

____

____

____

3. Most adaptations help an organism get food, move, stay safe, reproduce, or carry on other life processes like maintaining body temperature or getting oxygen. Label these adaptations with their primary purpose from the list.

   Nutrition   Locomotion   Defense   Reproduction   Other life processes

   a. Fennec foxes have huge ears to help regulate their body temperature in the hot desert where they live.

____

   b. Male cardinals have bright, beautiful feathers to attract females.

____

   c. Great blue herons have sharp, strong beaks for spearing fish.

____

   d. Skunks can spray a noxious gas up to fifteen feet when threatened.

____

   e. The hummingbird's wings allow them to migrate thousands of miles annually.

____

4. Explain why a polar bear is not adapted to live in the desert.

5. Describe the adaptations of an organism from your local area and how it is suited to your environment.

6. How do changes in an organism's environment affect it chances for survival? Explain.

C1 Meiosis and Chromosomes

How are gametes formed?

Like many Earth organisms, crazy creatures reproduce sexually. The forms of each trait that offspring inherit are a combination of those from the mother and father. How does this process work? In this investigation, you will model how traits are passed on from parents to offspring using paper chromosomes. A *chromosome* is a structure made of DNA and proteins found in the nucleus of a cell. Each chromosome consists of segments called genes. Each *gene* determines the phenotype for a trait.

Additional materials

- index cards
- crayons or colored pencils
- scissors
- newsprint
- markers

1 Thinking about what you will do

Crazy creatures reproduce sexually. Sexual reproduction is a type of reproduction that involves special types of cells called *gametes*. Gametes contain half the number of chromosomes as body cells (all the other cells in a multicellular organism). The body cells of crazy creatures have four chromosomes. The gametes of crazy creatures have two chromosomes. The male gametes are called *sperm*. The female gametes are called *eggs*. In body cells, the chromosomes occur in pairs. The chromosomes in each pair are called *homologous chromosomes* (equivalent) pairs. Each gamete has only one of the chromosomes from each homologous pair.

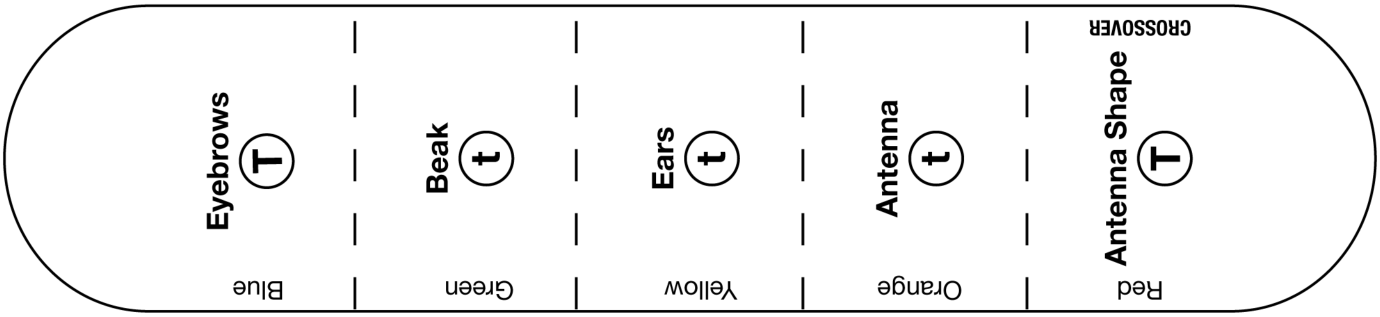
A body cell has the same number of chromosomes as its parent cell. Body cells are produced by mitosis. *Mitosis* is the process in cell division where the nucleus divides into two nuclei, each with an identical set of chromosomes. How do sex cells end up with only half the number of chromosomes? *Meiosis* is cell division that produces gametes with half the number of chromosomes. During meiosis, a cell undergoes two divisions to produce four gametes, each with half the number of chromosomes as the parent cell. This is so that when sperm and egg combine to form offspring, each gamete contributes half the normal number of chromosomes. The offspring has the normal number of chromosomes, half from the male parent and half from the female parent.

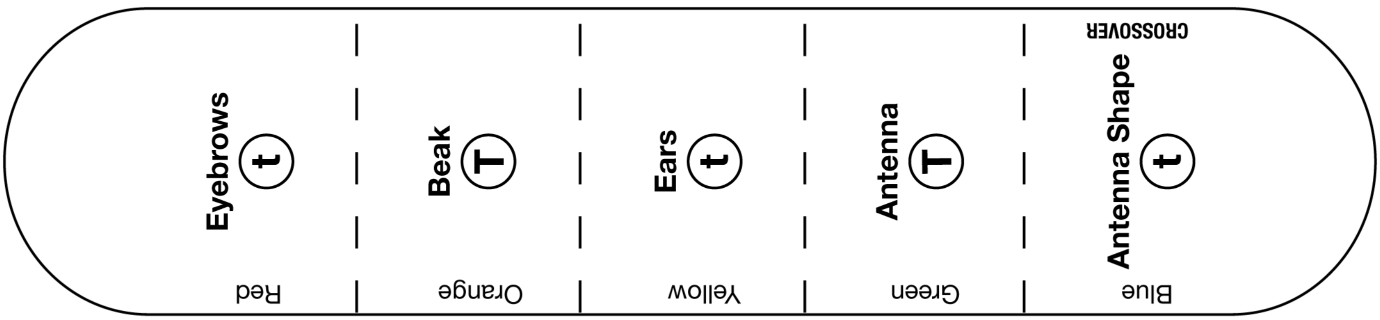
2 Getting ready

1. Crazy creatures have two homologous pairs of chromosomes in their body cells (4 chromosomes), excluding the sex chromosomes. We will ignore the sex chromosomes in this investigation and you will flip the sex chromosome coins to determine the gender of your creature. Start by cutting out 8 chromosomes for each of your crazy creature parents - a total of 16 chromosomes.
2. Color the chromosomes as directed on the cutouts.
3. The genotypes of the alleles are already filled in on the chromosome cut-outs. Notice that you will have two copies of each of the chromosomes - so two will be exactly the same!
4. Create a body cell “nucleus” for the mother and another for the father.

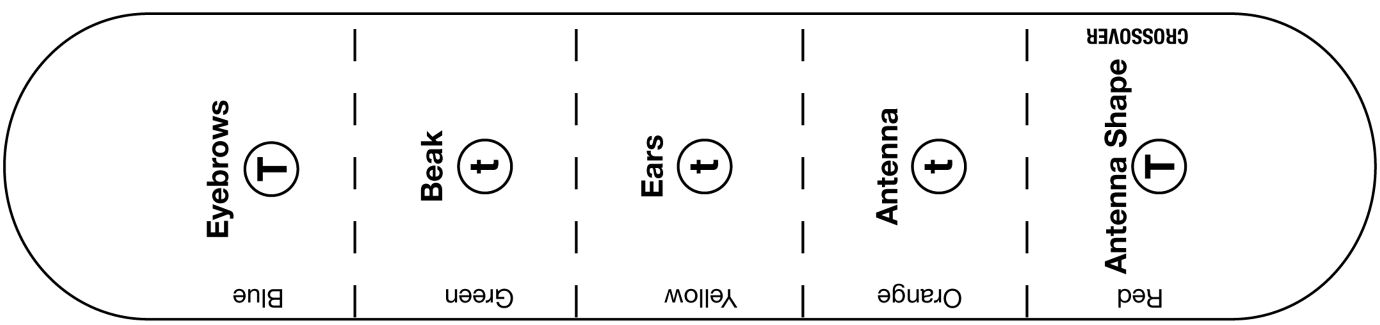
Father's Chromosome - 1st Pair

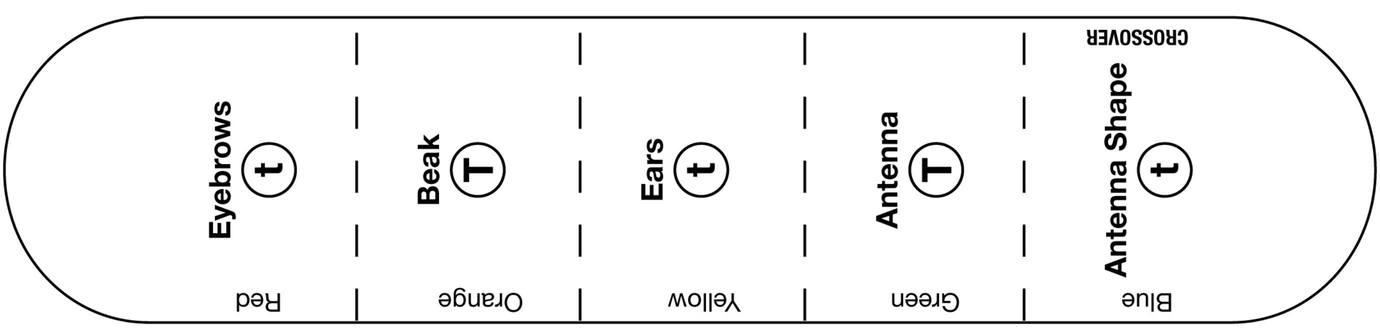
Copy A





Copy B





Father's Chromosome - 2nd Pair

Copy A

Skin color	T	Yellow	
Eye color	T	Green	
Tail	t	Orange	
Wings	T	Red	
Leg	t	Purple	
Foot	t	Blue	
Arms	T	Orange	CROSSOVER
Hands	T	Yellow	

Skin color	t	Yellow	
Eye color	T	Yellow	
Tail	T	Green	
Wings	t	Blue	
Leg	t	Purple	
Foot	T	Red	
Arms	t	Orange	CROSSOVER
Hands	T	Yellow	

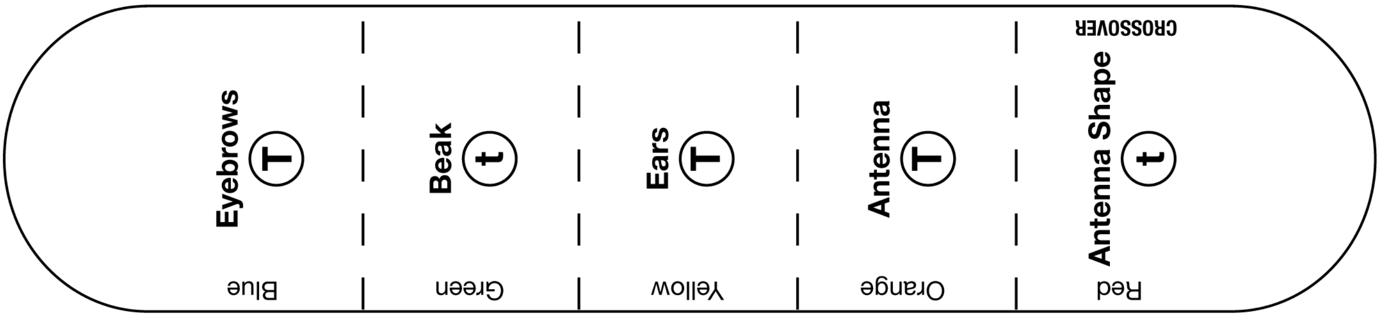
Copy B

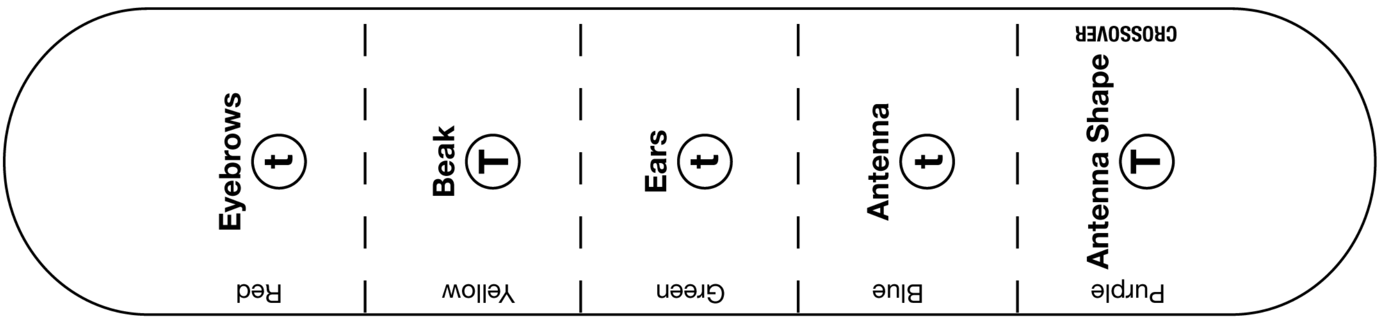
Skin color	T	Yellow	
Eye color	T	Green	
Tail	t	Orange	
Wings	T	Red	
Leg	t	Purple	
Foot	t	Blue	
Arms	T	Orange	CROSSOVER
Hands	T	Yellow	

Skin color	t	Yellow	
Eye color	T	Yellow	
Tail	T	Green	
Wings	t	Blue	
Leg	t	Purple	
Foot	T	Red	
Arms	t	Orange	CROSSOVER
Hands	T	Yellow	

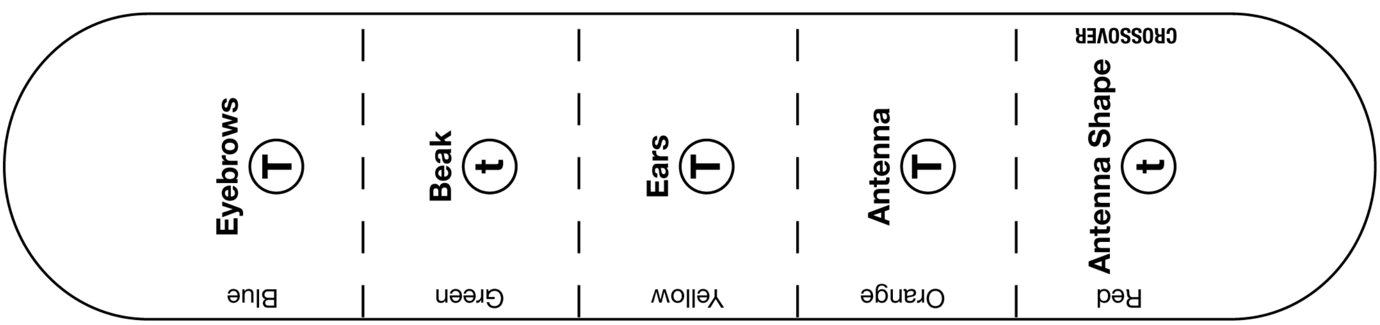
Mother's Chromosome - 1st Pair

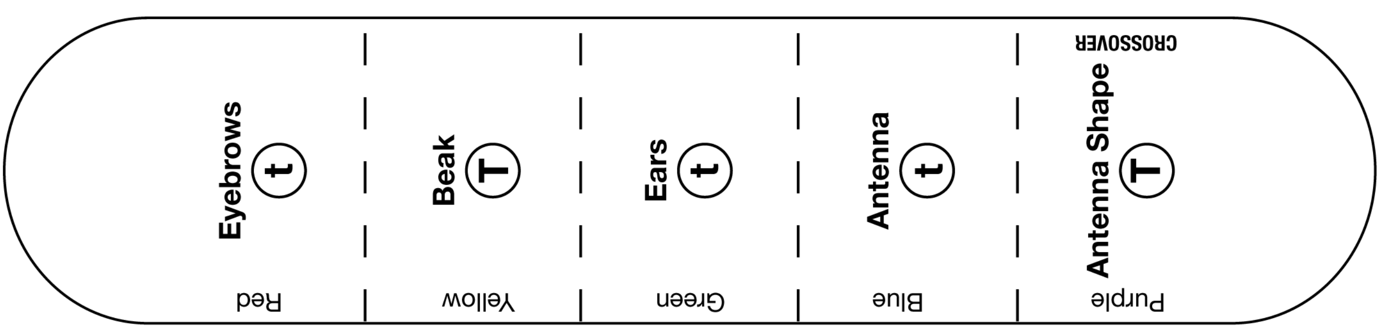
Copy A





Copy B





Mother's Chromosome - 2nd Pair

Copy A

Skin color	Eye color	Tail	Wings	Leg	Foot	Arms	Hands
					CROSSOVER		
T	t	t	t	T	t	t	T
Green	Blue	Purple	Red	Orange	Yellow	Green	Blue

Skin color	Eye color	Tail	Wings	Leg	Foot	Arms	Hands
					CROSSOVER		
t	T	T	T	t	T	T	t
Yellow	Green	Blue	Purple	Red	Orange	Yellow	Green

Copy B

Skin color	Eye color	Tail	Wings	Leg	Foot	Arms	Hands
					CROSSOVER		
T	t	t	t	T	t	t	T
Green	Blue	Purple	Red	Orange	Yellow	Green	Blue

Skin color	Eye color	Tail	Wings	Leg	Foot	Arms	Hands
					CROSSOVER		
t	T	T	T	t	T	T	t
Yellow	Green	Blue	Purple	Red	Orange	Yellow	Green

3 Stop and think

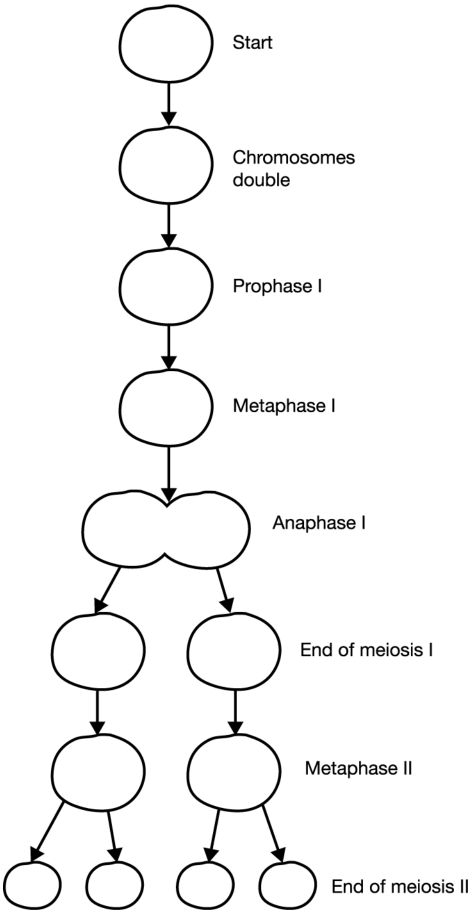
a. Why did you set up eight chromosomes for each parent?

b. In crazy creatures, how many chromosomes will each egg and sperm end up with?

c. Why is it important that gametes contain half the number of chromosomes as body cells?

4 Undergoing meiosis

Draw the diagram to the right on your sheet of newsprint. Move your chromosomes through the phases of meiosis in the diagram to produce gametes for each parent.



Prophase I

- Chromosomes form homologous pairs (same colors) to make tetrads. You have two tetrads - each with four sister chromatids.
- This is when *crossing over* can occur because the homologous chromosomes are close to each other. Crossing over is when the chromosome arms overlap to form a crossover between two non-sister chromatids. You will simulate crossing over by swapping the alleles for the bottom traits on each pair of chromosomes. For each trait that is labeled "crossover," cross out what is on one chromosome and fill it in on the other and so forth for all six traits.

Metaphase I

- The tetrads line up across the center of the cell.
- The spindle fibers attach.

Anaphase I

- Homologous pairs separate.
- The spindle fibers move the homologous chromosomes to opposite sides of the cell.

End of meiosis I

- Cytokinesis occurs to form two daughter cells. Each cell contains one doubled chromosome from each homologous pair. A complete set of chromosomes is called a *diploid* set.

Metaphase II

- Chromosomes line up along the center of the cell.
- The spindle fibers attach to the centromeres.

End of meiosis II

- The two sister chromatids separate at the center.
- The spindle fibers pull them to opposite sides of the cell.
- Cytokinesis happens again to create four new daughter cells.
- Each of the new cells contains half the original number of chromosomes as the original cell. A half set of chromosomes is called a *haploid* set.

5 Creating a creature

1. First, flip coins to determine the gender of your creature. Find the female sex chromosome coin (X on both sides) and the male sex chromosome coin (X on one side and Y on the other). Toss the coins and record the information in Table 1.
2. Close your eyes and randomly select one egg and one sperm. These will be the sperm and egg that unite during fertilization.
3. Fill in Table 1 below with the correct information. Use Table 2 to help determine what phenotypes your creature will have.

Table 1: Genotypes and phenotypes of offspring

Trait	Allele from mother	Allele from father	Genotype	Phenotype
1. Gender				
2. Skin color				
3. Leg				
4. Foot				
5. Arms				
6. Hands				
7. Eye color				
8. Eyebrows				
9. Beak				
10. Ears				
11. Antenna				
12. Antenna shape				
13. Tail				
14. Wings				

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** - blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** - green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

4. Build the creature.

6 Thinking about what you observed

a. When does DNA replication occur?

b. Why can crossing over only occur during prophase?

c. Why are there two divisions in meiosis and only one division in mitosis?

d. Explain how the gametes ended up being haploid.

e. Were the four gametes formed as a result of meiosis identical? Explain your answer.

f. Which parent does the offspring more closely resemble - the mother or the father?

7 Exploring on your own

Use index cards to create your own flipbook to show the phases of Meiosis. A flipbook is a series of at least twenty pages with individual drawings that change position slightly on each page. When you flip through the pages quickly, the individual drawings look like they are moving. It is a good idea to plan out your sketches using scrap paper first. It is easiest to limit your chromosomes count to two pairs. Color coding also works nicely. You may want to do some tracing to be sure that the pictures on each page line up correctly. Be sure to draw several pages for each phase to show a gradual change. Label important structures and events at least once in the booklet: cell membrane, nuclear membrane, homologous pair of chromosomes, tetrad, sister chromatids, centromere, centriole, spindle fibers, interphase, prophase I & II, metaphase I & II, anaphase I & II, telophase I & II, crossing over, daughter cells.

Assessment

1. What is meiosis? How does meiosis differ from mitosis?

2. Describe the steps of meiosis.

3. Complete this chart about mitosis and meiosis in crazy creatures.

Table 3: Genotypes and phenotypes of offspring

Trait	Mitosis	Meiosis
Type of cell produced		
Number of cell divisions		
Number of cells produced		
Number of chromosomes in each cell (haploid or diploid)		

4. Explain the process of crossing over. What is it and when does it occur during meiosis?

Extra space for notes:

C2 Advanced Punnett Squares

How are punnett squares used to make predictions?

NASA is setting up an educational exhibit to teach people about crazy creatures and their planet, Geneticus. NASA has asked you to help them select the initial breeding pair to include in their exhibit. They want to be sure that the parents that they pick and their offspring will represent a variety of all the traits that crazy creatures can have. You know that you can predict the genotypes and phenotypes of the offspring if you know the genotypes of the parents. A *punnett square* shows all the possible combinations of alleles from the parents. However, there are some special situations to consider like when two traits are linked. In this investigation, you create punnett squares to help NASA select the best creatures for their new display.

Additional materials

- nickels
- pennies
- masking tape
- marker

1 Punnett squares

An organism's *phenotype* is the form of a trait that it displays, like long arms. An organism's *genotype* is the alleles, or forms, of a gene it contains, like one dominant (**T**) allele and one recessive (**t**) allele. Remember that an organism receives one allele for each trait from each parent.

A simple punnett square

Look at this example punnett square (right). The two alleles for each of the parents are shown outside the squares – one parent across the top (**Tt**) and one parent (**Tt**) down the side. Since each parent gives at least one allele to their offspring, the squares represent the four possible combinations of alleles that the offspring could receive. If this parent gives this allele and this parent gives this allele, and so forth.

	T	t
T	TT	Tt
t	Tt	tt

Remember that probability plays an important part in heredity. Although we can use punnett squares to show the possible combinations, the actual chance of inheriting a certain genotype or phenotype is still random. *Probability* is the mathematical chance that an event will occur. Probability can be expressed as a fraction or a percentage. Since there are four possibilities in these single trait punnett squares, it is easy to make fractions: $^{1}/_{4}$, $^{2}/_{4}$ or $^{1}/_{2}$, $^{3}/_{4}$, or $^{4}/_{4}$ or 1. To convert these fractions to percentages, take the numerator of the fraction divided by the denominator and multiply by 100.

a. Look at the punnett square above. List the possible genotypes and the probability for each in fractions and percents.

A punnett square for two linked traits

Sometimes, two or more traits are linked. In crazy creatures, there are three sets of linked traits: leg with foot, arms with hands, and antenna with antenna shape. Because the four linked alleles can combine in more ways than just four possibilities, the punnett square will not look the same as the traditional one trait cross. Here is an example of a punnett square with two linked traits. The letter C is also used to avoid confusion. The diagram also shows how to determine the possible gametes produced during meiosis.

Mother | Father

CcTt x CcTt

Mother's possible gametes \ Father's possible gametes	CT	Ct	cT	ct
CT	CCTT	CCTt	CcTT	CcTt
Ct	CCTt	CCtt	CcTt	Cctt
cT	CcTT	CcTt	ccTT	ccTt
ct	CcTt	Cctt	ccTt	cctt

1 CCTT	2 CcTT	1 ccTT
2 CCTt	4 CcTt	2 ccTt
1 CCtt	2 Cctt	1 cctt

b. List the possible genotypes and the probability for each as a fraction and percent.

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2 Doing the experiment

1. Columns 2 and 3 of Table 1 show the genotypes of the parents for each trait.
2. For each trait or pair of traits, make a punnett square to show the possible combinations of alleles for the offspring. Use the examples to help you set up your punnett squares.
3. For each punnett square, list the possible genotypes and the probability for each as a fraction and percent.
4. Predict the phenotype of a single offspring for each trait. Use your calculations to help you make your predictions.
5. Repeat these steps for all the traits. Notice that there are three sets of traits that are linked – leg with foot, arms with hands, and antenna with antenna shape. Pay attention to the punnett squares for these to make sure you include all the possible combinations. Use the letter C for one trait and the letter T for the other to avoid confusion.

Table 1: Predicted phenotypes and probability

Trait	Genotype of mother	Genotype of father	Predicted phenotype	% probability	Actual genotype	Actual phenotype
1. Gender	XX	XY				
2. Skin color	Tt	Tt				
3. & 4. Leg/foot	CCTt	CcTT				
5. & 6. Arms/hands	ccTT	Cctt				
7. Eye color	TT	TT				
8. Eyebrows	Tt	Tt				
9. Beak	tt	Tt				
10. Ears	Tt	tt				
11. & 12. Antenna/ shape	CcTt	CcTT				
13. Tail	TT	tt				
14. Wings	TT	tt				

Table 2: Key to genotypes and phenotypes

Trait	Genotypes and phenotypes
1. Gender	**XX** – female **XY** – male
2. Skin color	**TT** - red **Tt** - purple **tt** - blue
3. Leg	**TT** – short **Tt** – short **tt** – long
4. Foot	**TT** – webbed **Tt** – webbed **tt** – talon
5. Arms	**TT** – long **Tt** – long **tt** – short
6. Hands	**TT** – paws **Tt** – paws **tt** – claws
7. Eye color	**TT** – red **Tt** – one red and one green **tt** - green
8. Eyebrows	**TT** – unibrow **Tt** – unibrow **tt** – separate
9. Beak	**TT** – trumpet **Tt** – trumpet **tt** – crusher
10. Ears	**TT** – elephant **Tt** – elephant **tt** – mouse
11. Antenna	**TT** – long **Tt** – long **tt** – short
12. Antenna shape	**TT** – knob **Tt** – knob **tt** – star
13. Tail	**TT** – long **Tt** – short **tt** – none
14. Wings	**TT** – no wings **Tt** – no wings **tt** – wings

3 Stop and think

a. What is a punnett square? What information is needed to create a punnett square?

b. What is probability? What does probability have to do with inheritance?

4 Checking the predictions

1. You will flip coins to see if your predictions are right. First, you'll need to make the correct egg and sperm coins for each possible combination of traits. Use masking tape and a marker to make the coins represent the genotypes of the parents. For instance, mark both sides of two nickels **T**. Mark two more nickels with **T** on one side and **t** on the other side. Finally, mark both sides of two nickels with **t**. Then create six coins with the letter C/c using the same steps.
2. Now, use the data in Table 1 to find the parents' genotype for each trait. Select the egg and sperm coin that has the same alleles as the genotype. For example, if the father's genotype for skin color is **TT**, choose the sperm coin that has a capital **T** on both sides of the coin. If the mother's genotype for skin color is **tt**, find the egg coin that has a lower case **t** on both sides of the coin.
3. Place both coins in the tin cup, shake, and toss out onto the table. Record your results in column 7 of Table 1.
4. Use Table 2 to look up the phenotype. Record the phenotype of the offspring in the last column of Table 1. Do this for all the traits.
5. You will need to use **T** and **C** coins for the traits that are linked.

5 Thinking about what you observed

a. Why do you need to choose different egg and sperm coins for each trait and for each parent?

b. How many of the actual phenotypes matched your predicted phenotypes? Explain your results.

c. Which parent does your offspring share the most traits with, the mother, father, or both equally?

d. Why are punnett squares unnecessary if both parents are TT or tt? Explain.

e. What are the possible percents for probability when using punnett squares for a single trait? What about when two traits are linked? Explain why these are the only possibilities.

f. From your investigation, what genotypes will you recommend to NASA for the initial breeding pair for their new exhibit? Explain your choices.

6 Exploring on your own

Make an informational sign to display at the NASA educational exhibit explaining punnett squares and probability to the public. Your sign should show the genotypes and phenotypes of the parents. It should also explain why this pair was selected. Also, be sure to include the appropriate punnett squares to show the predictions for the possible offspring.

Assessment

1. If a **CcTt** parent mated with a pure recessive **cctt** parent, what is the probability of the offspring having a **cctt** genotype?

2. Can a **TT** parent and a **Tt** parent ever produce a **tt** offspring? Explain your answer.

3. Why can't you create a punnett square if you only know the phenotypes of the parents? Give an example with your explanation.

4. If two **CcTt** parents for leg and foot mated, what would the phenotypic ratio for their offspring be?

5. In humans, *three* alleles determine blood types. The diagram (right) shows the genotypes for each blood type. List the possible genotypes and phenotypes of the children produced by parents with the following genotypes:

   a. Mother: AO; Father: AB

   b. Mother: BB; Father: OO

   c. Mother: BO; Father: BO

Parent Alleles	A	B	O
A	AA (Type A)	AB (Type AB)	AO (Type A)
B	AB (Type AB)	BB (Type B)	BO (Type B)
O	AO (Type A)	BO (Type B)	OO (Type O)

Extra space to draw your punnett squares:

C3 Hardy-Weinberg Principle

How can the frequency of alleles and genotypes in a population be calculated?

There has been a change in the available food sources for crazy creatures on planet Geneticus. There is a huge decline in the number of chocolate candies and jumbo marshmallows, which are two of the crazy creatures' preferred foods. However, there is still an ample supply of milkshakes, another food that crazy creatures eat. NASA scientists believe that this change in environment will not present a problem for crazy creatures since the trumpet beak is the dominant form of the trait for beak shape. After all, the trumpet beak is better suited for eating milkshakes than the crusher beak, the recessive form of the trait. They think that the crusher beak would just disappear over time so that in the future all the crazy creatures will have trumpet beaks. In this investigation, you will complete a simulation that illustrates the *Hardy-Weinberg Principle*, which is a way to calculate the frequency of alleles and genotypes in a population.

Additional materials

- 60 **T** cards
- 240 **t** cards

1 Thinking about what you will do

G. H. Hardy, an English mathematician, and W. R. Weinberg, a German physician, determined the effects of random mating on the frequencies of alleles in a population over successive generations. Their work, called the Hardy-Weinberg Principle, is almost like a punnett square for populations instead of just individuals. Just like a punnett square can predict the probability of the genotypes of the offspring of two known parents, the Hardy-Weinberg Principle can be used calculate the frequency of particular alleles and genotypes in a given population.

For this investigation, you will assume that **T** and **t** are the only alleles in the population, which means that **TT**, **Tt**, and **tt** are the only possible genotypes. The Hardy-Weinberg Principle states that if you counted all the alleles for this trait, the fraction of **T** alleles plus the fraction of **t** alleles would add up to 1. This is the Hardy-Weinberg equation: $p^2 + 2pq + q^2 = 1$. In the equation, p represents the number of **T** alleles and q represents the number of **t** alleles. This means that the number of **TT** (p^2) organisms plus the number of **Tt** (pq) organisms plus the number of **tt** (q^2) organisms equals 1. The pq (**Tt**) is multiplied by two since there are two ways to inherit that combination: **T** from the male and **t** from the female or **T** from the female and **t** from the male. When the population settles at these genotypic frequencies, it is said to be in equilibrium. In order to reach Hardy-Weinberg equilibrium, these conditions must be met:

1. There must be a large population.
2. Mating must be random.
3. There can be no selection for a particular allele.
4. There are no mutations.
5. There is no migration or isolation.

In this simulation, you will see how a population with all the right conditions reaches Hardy-Weinberg equilibrium. The alleles will be represented by cards with either **T** or **t** printed on them. You will start by picking alleles for your population from the gene pool. You will simulate mating by trading cards with other students. You will complete five rounds of trading to create five generations of your population. You will calculate gene frequency to see how the population changes over time.

2 Stop and think

a. Give an example of a situation when it would be helpful to be able to calculate the frequency of alleles or genotypes in a population.

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b. What conditions need to be met in order for a population to reach Hardy-Weinberg equilibrium?

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3 Doing the experiment

1. Select 10 cards from the gene pool. Count how many **T** cards you have and how many **t** cards you have. After your teacher finishes adding up the totals for your class, record the results in Table 1. Calculate the frequencies of **T** and **t** in your class and record your results in Table 1.
2. Flip the cards over so you can't see the letters. Randomly pair your cards so you have five sets. Flip the sets back over and count how many **TT**, **Tt**, and **tt** combinations you have. Calculate the frequencies. Record this data in Table 2. After your teacher finishes adding up the totals for your class, record the class counts and calculate the class frequencies. Record this information in Table 3.
3. Now, you will simulate random mating. Hold your ten cards like you are playing cards - so that you are the only one that can see them. Find another student to trade with. Let that student take one of your cards without looking. You take one of their cards without looking. Put aside the new card that you traded for so that it won't be traded again in this round. Trade four more cards with four different students - only trade one with each person. Remember, no looking!
4. You should have five of your original cards in your hand and five new cards that you traded for. Randomly pair up your ten cards so that you have five new pairs. Count how many **TT**, **Tt**, and **tt** combinations you have. Calculate the frequencies. Record this data in Table 2. After your teacher finishes adding up the totals for your class, record the class counts and calculate the class frequencies. Record this information in Table 3.
5. Complete four more rounds of random mating as described in step 3. Record your results and the class results as described in step 4.
6. Calculate your final frequencies. Record this information in Table 4. Compare your final frequencies to the ideal values in Table 4.

Table 1: Class allele frequencies

	T	t	Total
Count			
Frequency			1

Table 2: Individual genotype frequencies

	TT	Tt	tt	Total	TT	Tt	tt	Total
Generation 1								1
Generation 2								1
Generation 3								1
Generation 4								1
Generation 5								1

Table 3: Class genotype frequencies

	TT	Tt	tt	Total	TT	Tt	tt	Total
Generation 1								1
Generation 2								1
Generation 3								1
Generation 4								1
Generation 5								1

Table 4: End results

Individual Values	Class Values	Ideal Frequencies
Final frequency for **TT**	Final frequency for **TT**	Value of p^2 (**TT**): 0.36
Final frequency for **Tt**	Final frequency for **Tt**	Value of 2 pq (**Tt**): 0.48
Final frequency for **tt**	Final frequency for **tt**	Value of q^2 (**tt**): 0.16

4 Analyzing the data

a. Genetically speaking, what do the following parts of the simulation represent?

- the initial pool

- **T** or **t** cards

- pairing up two cards

- trading cards with other students

b. Prepare a graph of your data and the class results. Put generations 1 through 5 on the *x*-axis and the frequency on the *y*-axis. Plot the data for both your individual results and the class results. What does your data show? How do your results compare to the class results?

c. How close were your final **TT**, **Tt**, and **tt** frequencies to the ideal values? Explain any differences.

d. Why was it important to collect class data?

e. What process is occurring when there is a change in genotypic frequencies over a long period of time?

f. What would happen if it were more advantageous to be heterozygous (**Tt**)? Would there still be homozygous organisms? Explain.

g. What happens to the recessive genes over successive generations? Why?

h. How would emigration and immigration affect the gene frequency of **T** and **t** in this population?

5 Exploring on your own

Design an experiment to show how one of the following affects allele frequencies over several generations: migration, isolation, no selection, no random mating, very small population, or mutations.

Title ____________________

y-axis: ____________________

x-axis: ____________________

Assessment

1. What is the Hardy-Weinberg Principle?

2. What conditions need to exist to reach Hardy-Weinberg equilibrium?

3. Why is the Hardy-Weinberg Principle useful to scientists?

4. Why doesn't the recessive gene eventually disappear from the population?

Extra space for notes:

C4 Speciation

Where does a new species come from?

NASA has discovered fossils on planet Geneticus! *Fossils* are the preserved remains of once-living things. Scientists used these fossils to create pictures of what the ancestors of crazy creatures looked like. *Ancestors* are the organisms from which others have descended. In this investigation, you will use the pictures to create a *cladogram* that shows the evolutionary relationships among these organisms. You will be challenged to think about how species evolve and become extinct as a result of changes in the environment.

Additonal materials

- Large sheet of paper
- Colored pencils or markers

1 Thinking about evolution and extinction

A scientific theory states that newer species come from older species through a process called *evolution*. A *species* is an isolated population of similar organisms that interbreed and produce fertile offspring. One way for a new species to evolve happens in three steps: *isolation, adaptation*, and *species formation*. *Isolation* happens when a population becomes divided by an event like a flood, volcanic eruption, or earthquake. The original population becomes divided into smaller populations that are physically and reproductively isolated from the others. *Adaptation* happens through natural selection. The event that causes isolation may also change the environment. As the environment changes, the population that lives there undergoes natural selection. If the environments are different, each population will have different adaptations. *Species formation* happens when the isolated population becomes so different that they can no longer interbreed even if they were united again. Over generations, the isolated populations become genetically different from each other resulting in the formation of one or more new species.

Extinction occurs when the environment changes and the adaptations of a species are no longer sufficient for its survival. Changes may include increased competition with other species, newly introduced predators, loss of habitat, and catastrophes. One reason that species may become extinct is lack of genetic variation. Genetic variation is the variety of alleles in a population. Genetic variation is necessary for natural selection and ensures that a population has a better chance of survival should the environment change. As a species' population gets smaller, its genetic variation may decrease. Therefore, a small population may be more susceptible to extinction than a large population if their environment changes. If genetic variation is not present, the population may not have enough favorable adaptations to survive changes in the environment.

2 Getting ready

1. Examine the sheets of ancient organisms from planet Geneticus. Compare and contrast the major characteristics of the creatures.
2. Make a list in Table 1 of the different characteristics of the creatures that may be used to show evolutionary relationships.

Table 1: Ancestral creature characteristics

Creature Number	Characteristics
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

3 Stop and think

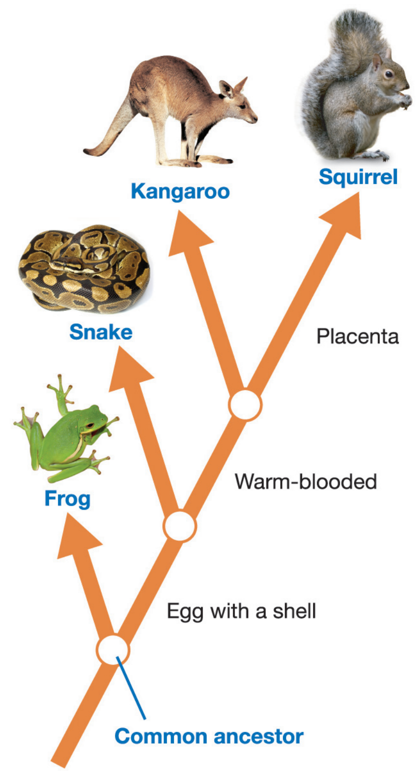
a. Which creature would you identify as the most advanced creature? Explain your choice.

b. Which creature is the most unlike the present day crazy creature? Explain your choice.

c. What sort of environmental changes might have led to the adaptations that you observe in these creatures?

4 Creating the cladogram

Based on the information in Table 1, create a cladogram that shows the possible evolutionary relationships among these creatures. An example of a simple cladogram is shown to the right. Your cladogram will look much different than the one shown. It may resemble a tree with many branches. Be creative! Use separate paper to draw your cladogram.



Sample cladogram

5 Thinking about what you observed

a. Which creatures are most closely related? Why?

b. Which creatures are the most distantly related? Why?

c. Choose a point on your diagram where two creatures branch. Describe what their common ancestor may look like. Be creative!

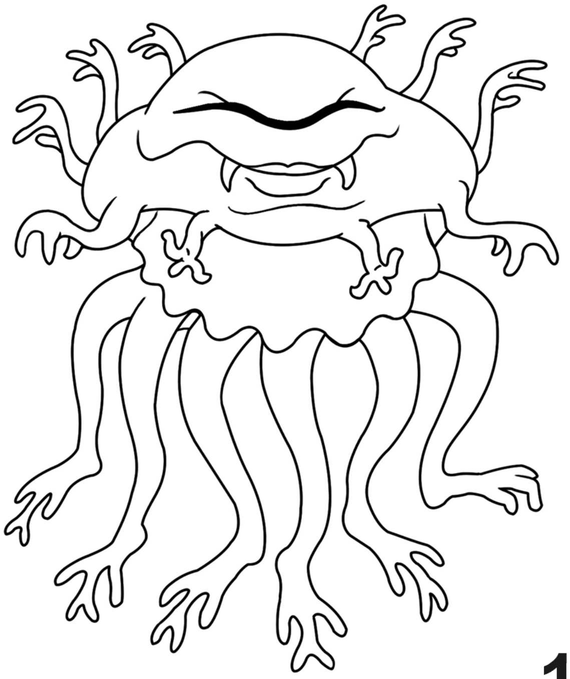
d. Creature 2 and 7 are clearly closely related. Create a scenario that might have led to the development of these two distinct species using the words: isolation, adaptation, and species formation.

e. Creature 10 is now extinct. State some possible reasons for the extinction of this creature.

f. Creature 3 is an endangered species. There seem to be fewer than 1,000 of these creatures left on planet Geneticus. Explain, using your knowledge of natural selection, why it might be difficult to stop the decline of this creature population.

6 Exploring on your own

Once you have completed the investigation, pick one creature and write a brief description of the creature's habitat, food source, and predators. Then describe the creature's adaptations to its habitat, food source, and predators.



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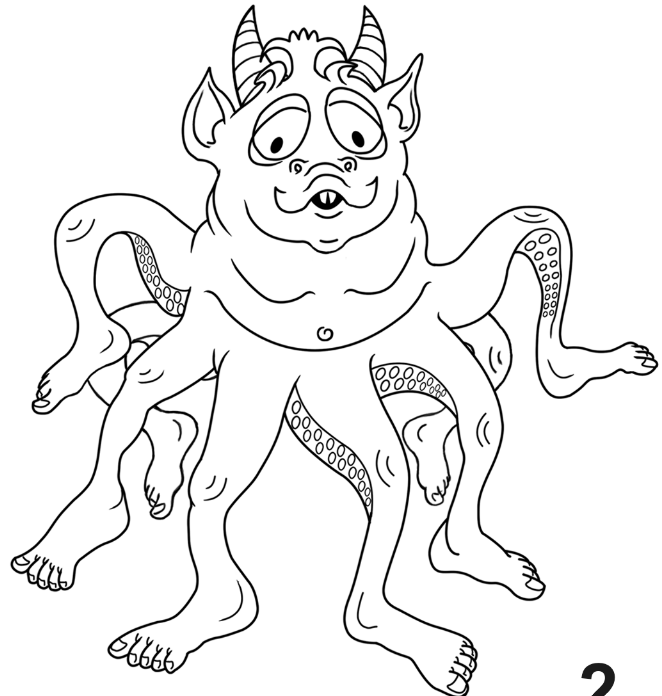

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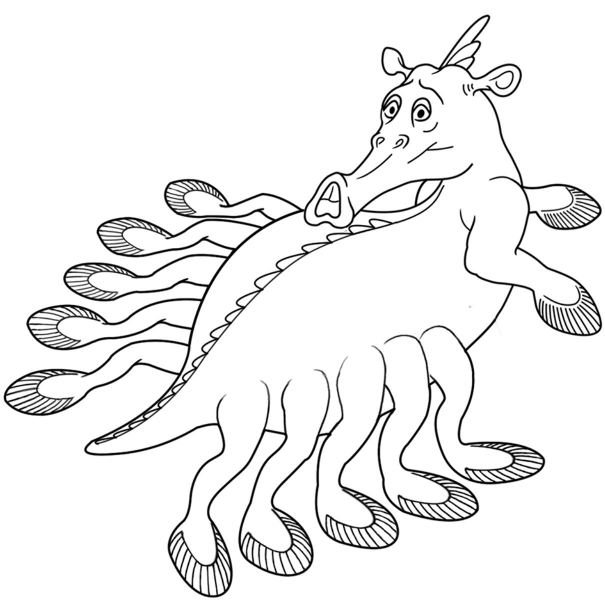

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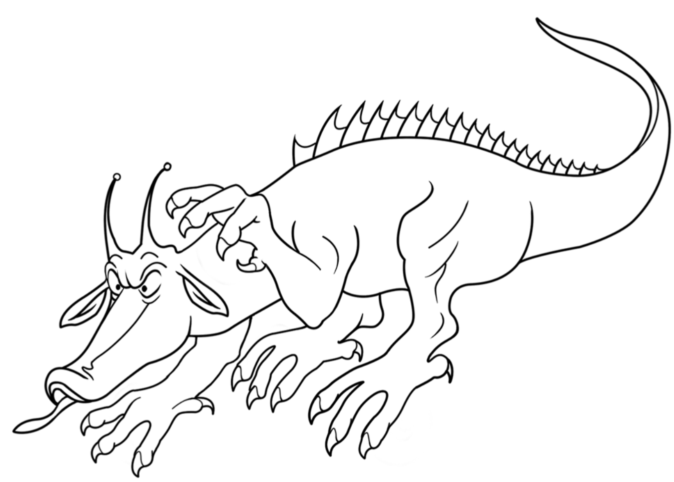

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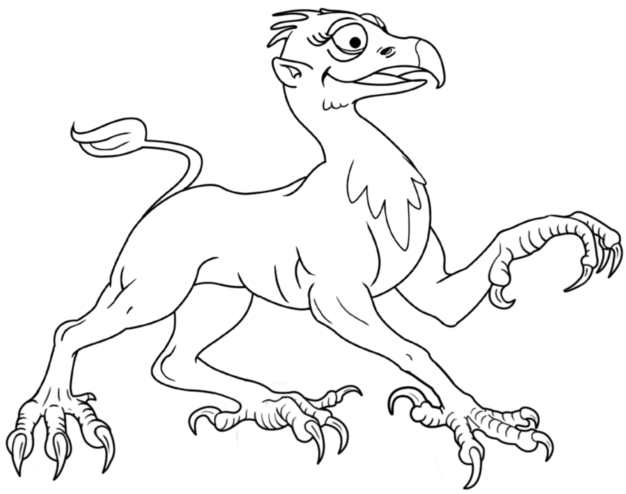

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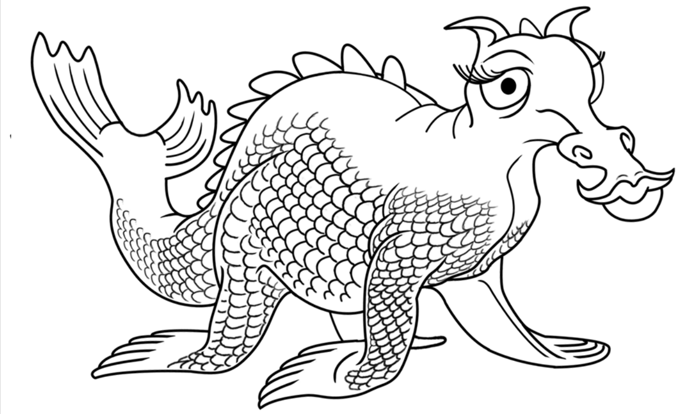

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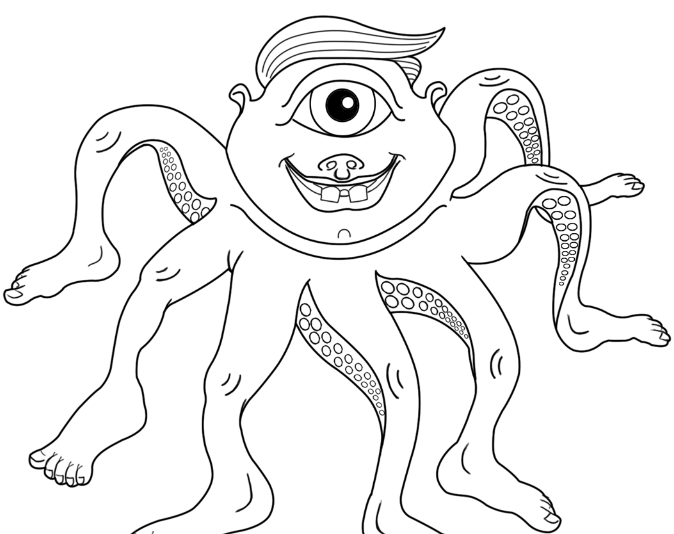

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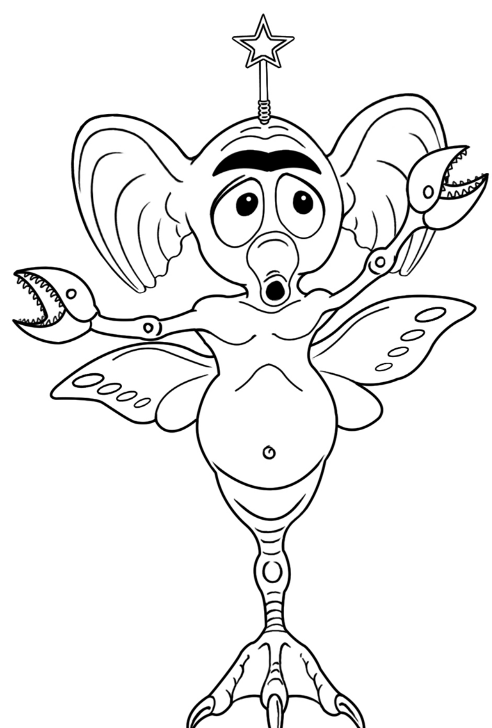

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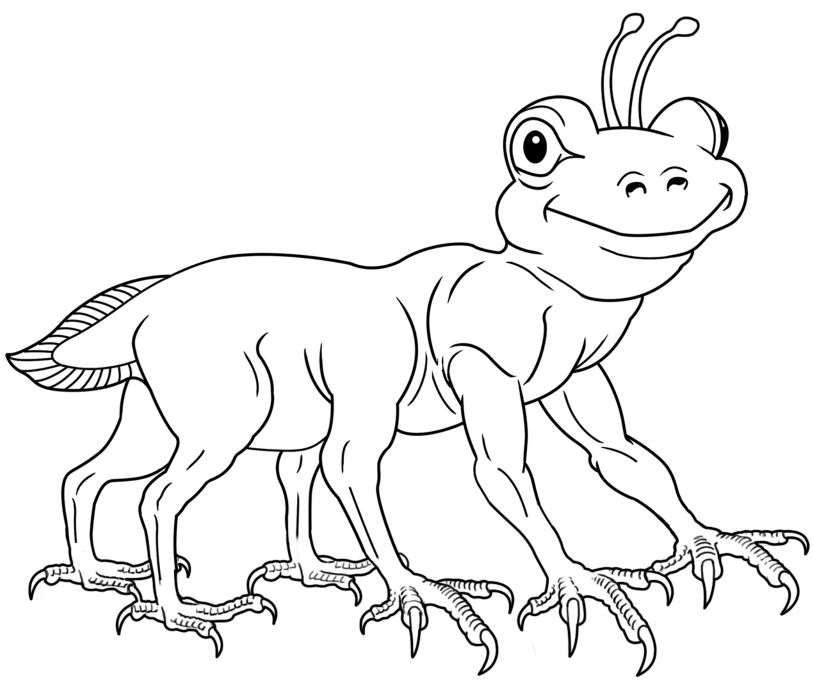

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Assessment

1. What is a cladogram and how is it used?

2. Describe how a new species evolves.

3. Match the terms to the correct description.

____________	isolation	a.	happens through natural selection
____________	species formation	b.	happens when the isolated populations become so different that they can no longer interbreed
____________	adaptation	c.	happens when a population becomes divided by an event

4. What is extinction? List three causes for extinction.

5. Why is a population with less genetic variation more likely to become extinct than a population with lots of genetic variation?