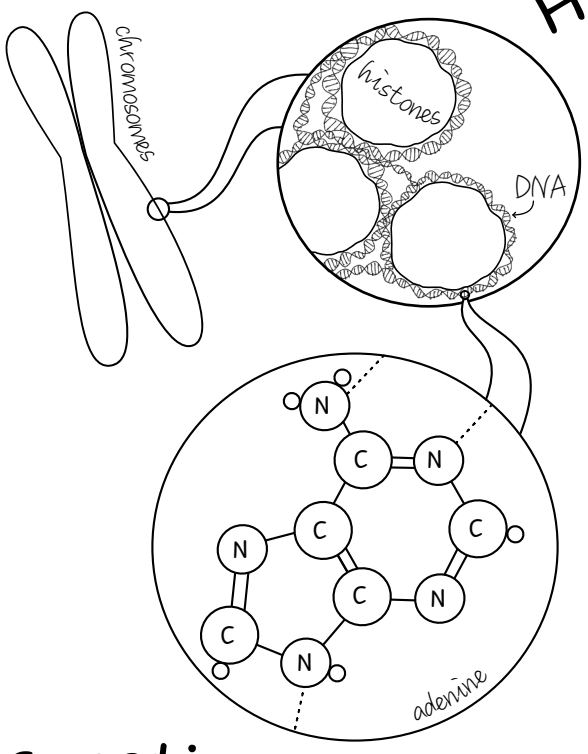
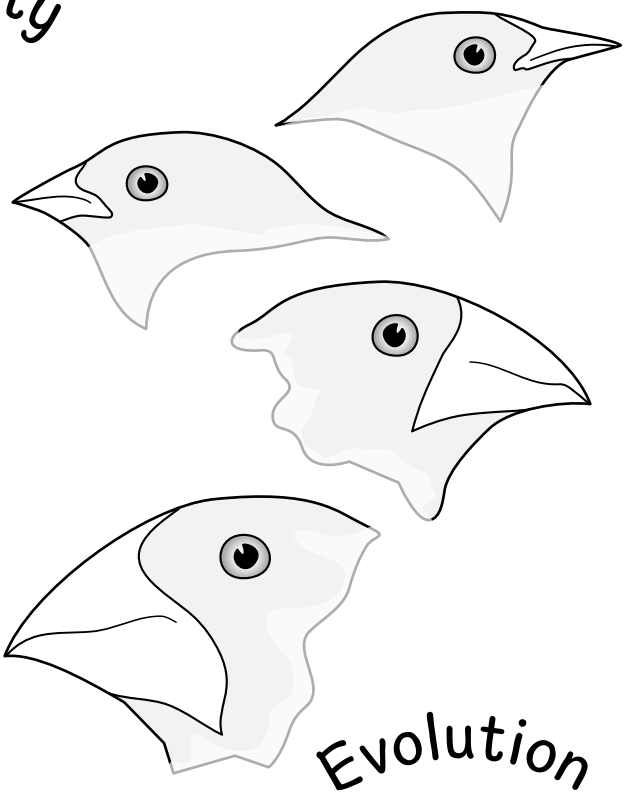
BIOLOGY

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Heredity



Genetics



Evolution

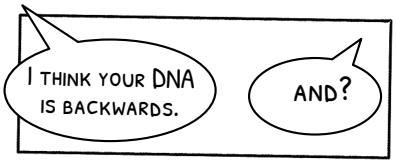
BIOLOGY

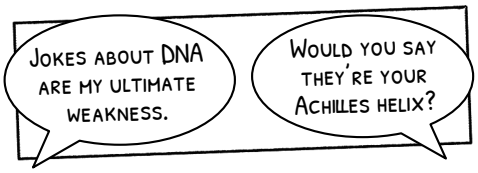
~ SPRING 2022 ~

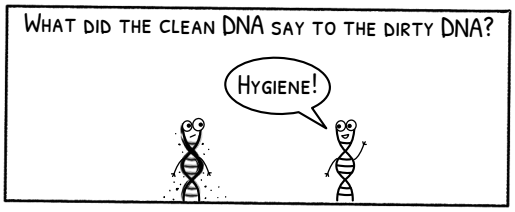
	Date	Topic	Page(s)
Week 1	Monday, Jan 24	What is a species?	-
	Wednesday, Jan 26	Life finds a way	-
	Friday, Jan 28	*Activity: Vegetative propagation with potato*	
Week 2	Monday, Jan 31	Mendel's famous experiment	
	Wednesday, Feb 2	The laws of heredity 1	
	Friday, Feb 4	*Deep dive: The Mendelian paradox.*	
Week 3	Monday, Feb 7	The laws of heredity 2	
	Wednesday, Feb 9	Pet pedigree puzzle	
	Friday, Feb 11	*Deep dive: Hemophilia and the royal families of Europe*	
Week 4	Monday, Feb 14	Punnett squares	
	Wednesday, Feb 16	**Heredity Quiz Show**	
	Friday, Feb 18		
Week 5	Monday, Feb 21	What is a gene?	
	Wednesday, Feb 23	Chromosomes and linked traits	
	Friday, Feb 25	*Activity: Gummy worm karyotypes*	
Week 6	Monday, Feb 28	Protein synthesis	
	Wednesday, Mar 2	Blood types explained	
	Friday, Mar 4	*Activity: What's the blood type?*	
Week 7	Monday, Mar 7	Meiosis and mistakes	
	Wednesday, Mar 9	Mutations	
	Friday, Mar 11	*Deep dive: Red-green colorblindness*	
Week 8	Monday, Mar 14	Nature and nurture	
	Wednesday, Mar 16	Calico cat puzzle	
	Friday, Mar 18	*Deep dive: Why Red Delicious are the least delicious apples*	
Week 9	Monday, Mar 21	Modifying genes & gene therapy	
	Wednesday, Mar 23	**Genetics Quiz Show**	
	Friday, Mar 25		
Week 10	March 28- April 1	SPRING BREAK	

Live classes are held each Monday and Wednesday. Activities and reading assignments listed on Fridays are completed independently. There are two sessions of each of the Monday/Wednesday classes. The first session starts at 11 am EST. The second session starts at 1:00 pm EST. Each live class lasts between 30 and 45 minutes.

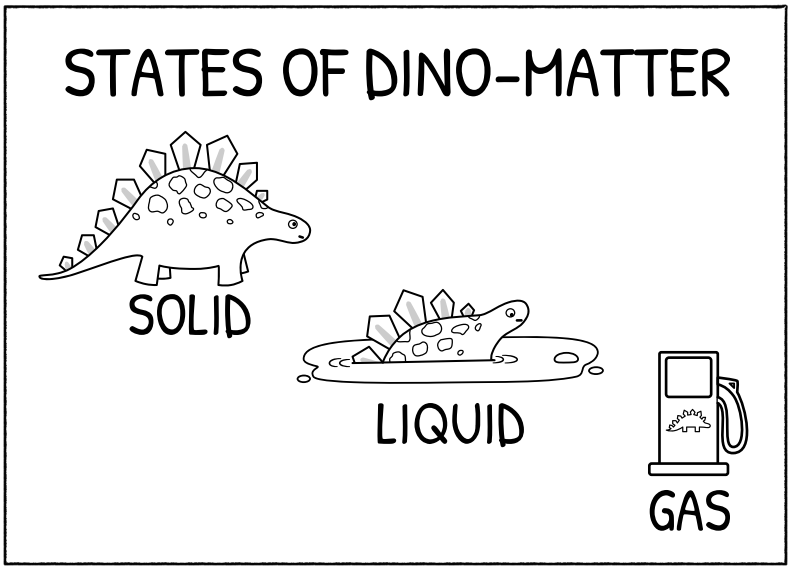
The classes are recorded and can be watched anytime after the recording date. Each week also has optional activities or reading assessments (deep dives). Students who complete and submit all activities and assignments will receive a bonus certificate of completion.







	Date	Topic	Page(s)
Week 11	Monday, Apr 4	Endangered vs invasive species	
	Wednesday, Apr 6	Darwin and the Galapagos	
	Friday, Apr 8	*Activity: Journey of the HMS Beagle*	
Week 12	Monday, Apr 11	Survival of the fittest	
	Wednesday, Apr 13	Color-changing moths	
	Friday, Apr 15	*Deep dive: When Sherpas climb Mt. Everest*	
Week 13	Monday, Apr 18	Genetic drift	
	Wednesday, Apr 20	Phylogenies and family trees	
	Friday, Apr 22	*Activity: Model a gene in a population*	
Week 14	Monday, Apr 25	What is a species really?	
	Wednesday, Apr 27	How are animals related?	
	Friday, Apr 29	*Deep dive: How DNA analysis rewrote phylogenetic trees*	
Week 15	Monday, May 2	Australia vs New Zealand	
	Wednesday, May 4	The fossil record	
	Friday, May 6	*Activity: Build your own phylogeny*	
Week 16	Monday, May 9	Timeline of life on Earth	
	Wednesday, May 11	**Evolution Quiz Show**	
	Friday, May 13	*Summary anchor diagram*	



How to use this course:

For younger students (2nd-5th grade) we recommend a "get the basics" approach that focused on the Mon/Wed classes. For older or more advanced students (6th-8th grade) we recommend completing each of the activities and assignments to reinforce the concepts covered.

Option One: Get the Basics

Ideal for younger students

Participate in Mon-Wed classes only. Skip the Friday activities. Participate in quiz show review days. Save the science activities, deep dive articles, and other assignments for a later date.

Option Two: The Full Course

Ideal for older students & advanced learners

Participate in Mon-Wed classes and do the Friday activities and reading assignments.

Complete all quizzes and assignment to receive a certificate of completion at the end of the course.

Tips for best learning:

- ☑ Read the pages that go with each lesson before watching the video. Take 10-15 minutes before class to see if you can fill in the blanks. If you can't fill in everything, that's okay! Listen during class to see if you can complete the page.
- ☑ If a lesson moved too fast, rewatch it later to help learn the concepts.
- ☑ Download the answer key for the notes, but don't look at the answers until after you give things a try yourself!

Project Supply List:

Jan 28 - Vegetative Propagation with Potato
- Potato or sweet potato (for quicker results, use one where the eyes have already begun to sprout)
- Knife
- 4 small pots or cups
- Potting soil

Jan 24-Feb 18 - Heredity Anchor Diagram
- Paper and art supplies

Feb 25 - Gummy Worm Karyotypes
- Enough gummy worms or other oblong-shaped colorful candy to create 23 pairs of chromosomes
- Pencil
- Paper
- Knife or Scissors

Mar 4 - What's the Blood Type?
- Home blood typing kit (optional)

Mar 18 - Apple Variety Taste Test
- Several varieties of apple including Red Delicious, Granny Smith, and three other types.
- Knife

Feb 21-Mar 25 - Genetics Anchor Diagram
- Paper and art supplies

April 8 - Journey of HMS Beagle
- Printable world map
- Paper and scissors
- Yarn or art supplies such as crayons, colored pencils, markers, or paint

April 22 - Model a Gene in a Population
- 20 black marbles and 20 white marbles (or some items that can be drawn randomly in a sample)

May 6 - Build your own phylogeny
- Paper and art supplies

Apr 4-May 13 - Evolution Anchor Diagram and Timeline
- Paper and art supplies

Which science standards are covered in this course?

The standards listed below are the national science standards for K-12 education in the United States. They are commonly referred to as Next Generation Science Standards or NGSS.

MS-LS1-4. *Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.* ***April 4, April 6, April 11, April 13***

MS-LS1-5. *Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.* ***Mar 14***

MS-LS3-1. *Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.* ***Feb 21, Feb 23, Feb 28, Mar 2, Mar 9, Apr 4***

MS-LS3-2. *Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.* ***Jan 26, Jan 31, Feb 2, Feb 7, Feb 14***

MS-LS4-1. *Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.* ***April 25, April 27, May 4, May 9***

MS-LS4-2. *Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.* ***April 20, April 27***

MS-LS4-3. *Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.* ***April 20***

MS-LS4-4. *Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.* ***April 11, April 13***

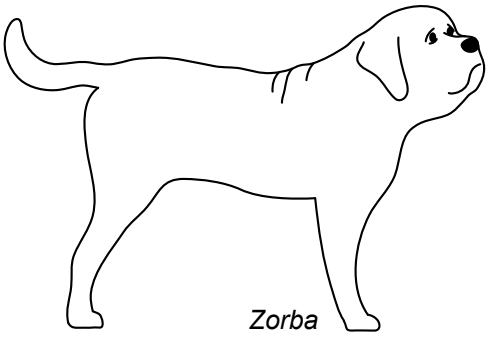
MS-LS4-5. *Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.* ***Mar 21***

MS-LS4-6. *Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.* ***April 18***

Date	Topic	NGSS	Page(s)
Wednesday, Jan 26	Life finds a way	MS-LS3-2	-
Monday, Jan 31	Mendel's Famous Experiment	MS-LS3-2	
Wednesday, Feb 2	The laws of heredity 1	MS-LS3-2	
Monday, Feb 7	The laws of heredity 2	MS-LS3-2	
Monday, Feb 14	Punnet squares	MS-LS3-2	
Monday, Feb 21	What is a gene?	MS-LS3-1	
Wednesday, Feb 23	Chromosomes and linked traits	MS-LS3-1	
Monday, Feb 28	Protein synthesis	MS-LS3-1	
Wednesday, Mar 2	Blood types explained	MS-LS3-1	
Wednesday, Mar 9	Mutations	MS-LS3-1	
Monday, Mar 14	Nature and nurture	MS-LS1-5,	
Monday, Mar 21	Modifying genes and gene therapy	MS-LS4-5	
Monday, Apr 4	Endangered vs invasive species	MS-LS1-4, MS-LS3-1	
Wednesday, Apr 6	Darwin and the Galapagos	MS-LS1-4	
Monday, Apr 11	Survival of the fittest	MS-LS1-4, MS-LS4-4	
Wednesday, Apr 13	Color-changing moths	MS-LS1-4, MS-LS4-4	
Monday, Apr 18	Genetic Drift	MS-LS4-6	
Wednesday, Apr 20	Phylogenies and family trees	MS-LS4-2, MS-LS4-3	
Monday, Apr 25	What is a species really?	MS-LS4-1	
Wednesday, Apr 27	How are animals related?	MS-LS4-1, MS-LS4-2	
Wednesday, May 4	The fossil record	MS-LS4-1	
Monday, May 9	Timeline of life on Earth	MS-LS4-1	

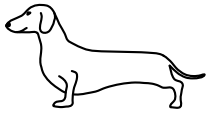
What makes a species?

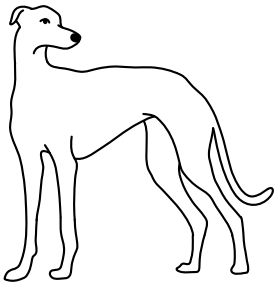
The domestic dog includes hundreds of different breeds with diverse personalities, shapes, and sizes. The biggest dog, an English Mastiff named Zorba, weighed more than 143 kg (315 pounds) and measured 94 cm (37 inches) tall from ground to shoulder. The smallest dog, a Chihuahua named Milly, is just under 10 cm (4 inches) tall and weighs just 0.5 kg (about 1 pound). Mastiffs, Chihuahuas, Dachshunds, and Greyhounds are all called dogs, but they are incredibly different animals!



Zorba

Milly





English Mastiff	Chihuahua	Dachshund	Greyhound
70-91 cm / 28-36 in 54-100 kg / 120-230 lbs	15-25 cm / 6-10 in 1.4-3 kg / 3.3-6.6 lbs	20-23 cm / 8-9 in 7-14 kg / 16-32 lbs	68-76 cm / 27-30 in 26-40 kg / 57-88 lbs

1. What makes a dog a dog? Share your opinion:

2. If the characteristics you described above were used as the official definition of a dog, would cats also be called dogs?

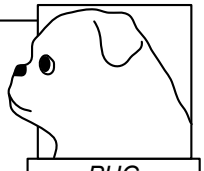
3. List three similarities and differences between cats (*Felis*) and dogs (*Canis*):

Similarities between cats and dogs:

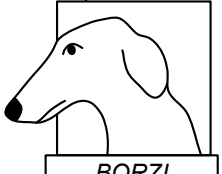
SPHYNX CAT

MAINE COON

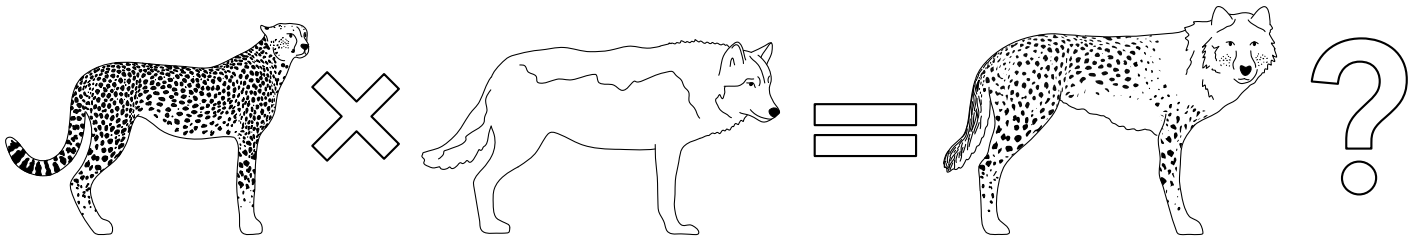
Differences between cats and dogs:



PUG

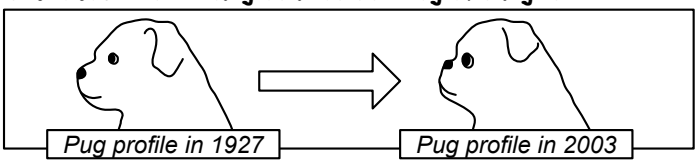


BORZI



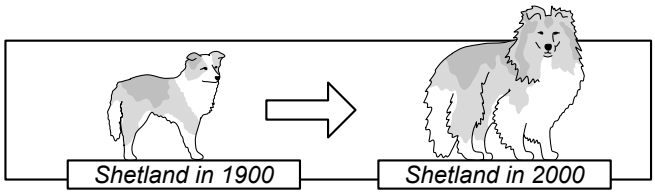
4. Coyotes, wolves, and dogs can all interbreed, creating hybrids like the wolfdog, coywolf, coydog or dogote. Lions and tigers can also be bred to create hybrids, which are called ligers or tigons. In your opinion, would it be possible to cross a cheetah with a wolf? If so, what would you call this hybrid? A woltah? A cheef?

Selective breeding can cause big changes



Pug profile in 1927 *Pug profile in 2003*

Breeders prized the "squished face" appearance of the Pug and chose dogs with shorter and shorter snouts. Because of their face shape, modern Pugs are susceptible to eye trouble and breathing problems.



Shetland in 1900 *Shetland in 2000*

In 1900, Shetland sheepdogs were reported to weigh between 7 and 10 pounds and have medium length fur. The modern Shetland Sheepdog has doubled in size and has much longer fur.

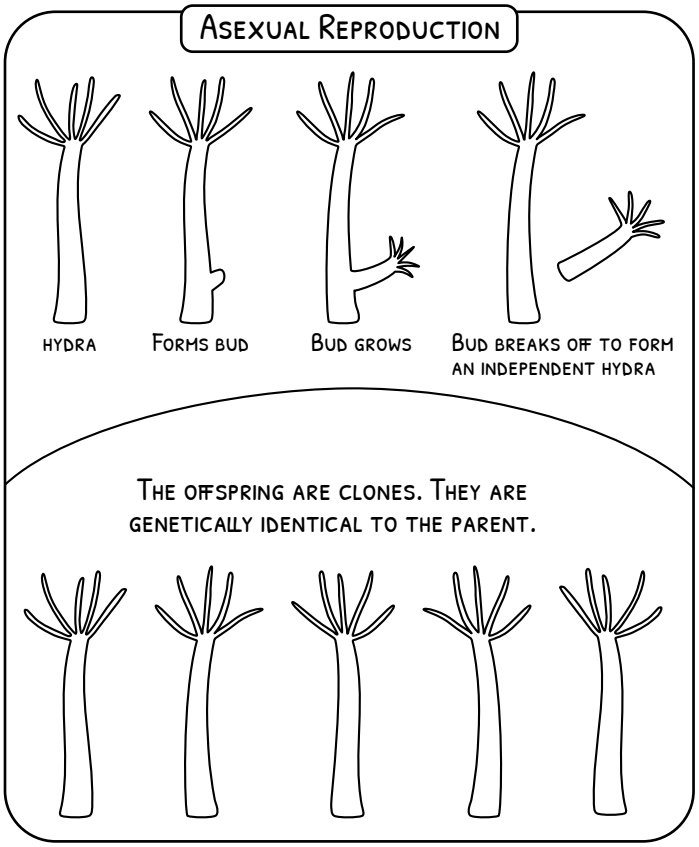
5. Suppose that a settlement on Mars uses Great Danes for pulling sleds while a different settlement uses Chihuahuas for hunting cockroaches that hide in small spaces. If the people in the first settlement selectively breed their Great Danes to be larger and stronger while the people in the second settlement breed their Chihuahuas to be smaller and faster, what would you expect Mars dogs to look like after approximately 1,000 years have passed? Would Great Danes and Chihuahuas be different species from each other then?

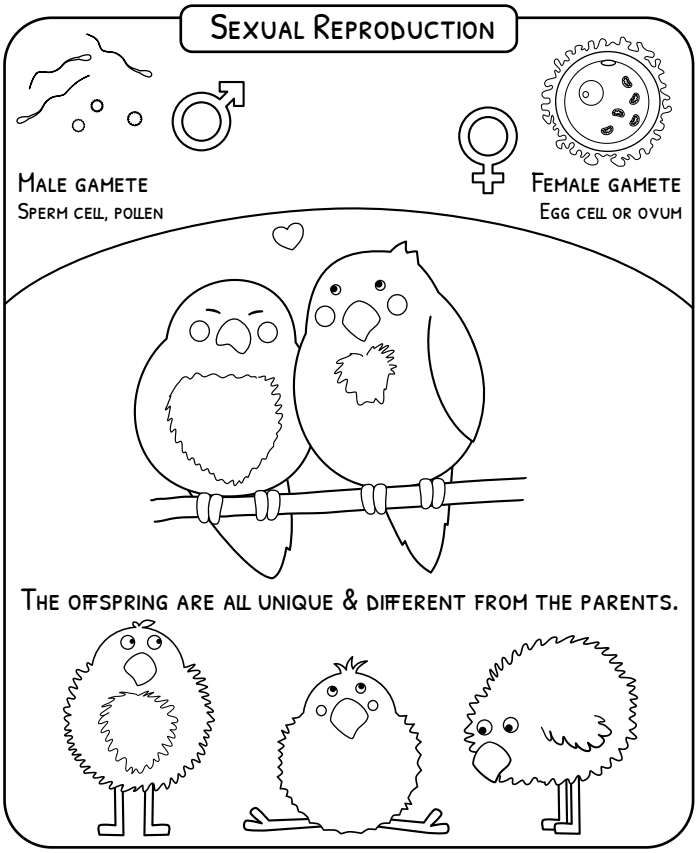
Martian Great Dane in 3020

Martian Chihuahua in 3020

Life finds a way

The **ability to reproduce** is one of the key characteristics in most definitions of life. There are two main strategies: asexual reproduction, which creates identical clones, and sexual reproduction which creates offspring that are different from each parent.





Record the primary advantages and disadvantages in each category below. Consider the following:

- Speed of reproduction: Is the next generation formed and independently growing within minutes or days? Does it take years to form an independent next generation?
- Genetic diversity: is the diversity high (which provides greater resistance to disease) or low (which makes a population more at risk from disease)?
- Does reproduction require a mate? Could one individual reproduce?

ASEXUAL REPRODUCTION

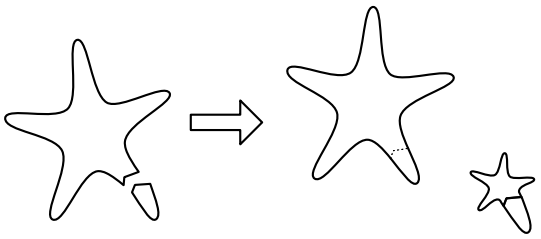
ADVANTAGES:	DISADVANTAGES:

SEXUAL REPRODUCTION

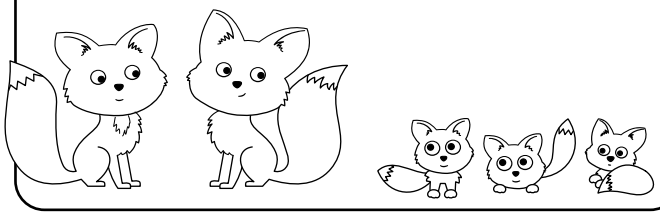
ADVANTAGES:	DISADVANTAGES:

Match each reproductive strategy with the correct definition:

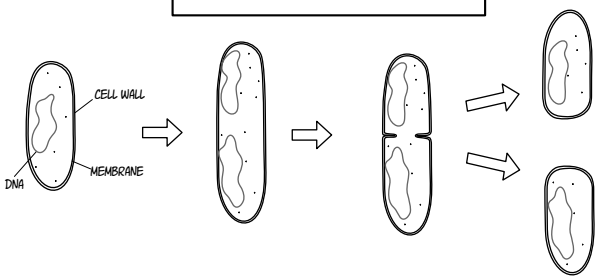
FRAGMENTATION



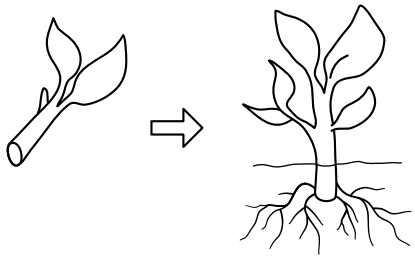
SEXUAL REPRODUCTION



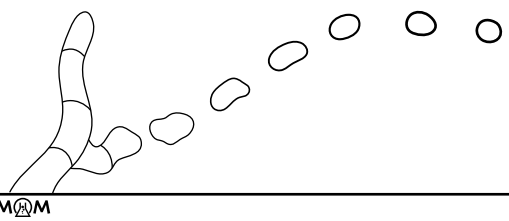
BINARY FISSION



VEGETATIVE PROPAGATION



SPORE FORMATION



Genetic information from two individuals is combined to create offspring that are different from both parents. This reproductive strategy is the most common among animals, fungi, and plants.

An organism is split into pieces. Each of those fragments then develops into adult individuals that are clones of the original organism. Molds, lichen, sponges, certain worms, and sea stars all use this reproductive strategy.

The division of a single cell into two identical cells. This reproductive strategy is used by bacteria and archaea.

A specialized cell forms that can withstand harsh environmental conditions such as drought or extreme heat. Once the conditions improve, the cell germinates and begins growing. This strategy can be either sexual or asexual. Commonly used by fungi.

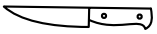
Asexual reproduction occurring in plants where a fragment or cutting is separated from the parent plant and grows as a separate individual. Commonly used with food crops such as bananas, sweet potato, sugarcane, and pineapple.

Hands-on Science Project

PROPAGATE A POTATO

MATERIALS:

Potato or sweet potato



Knife

Rubbing Alcohol

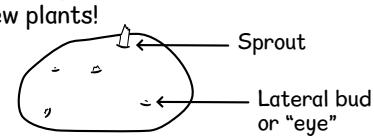
4 identically-sized pots or bags
Use a large pot or bucket with drainage holes, or a large burlap sack

Potting soil.
Enough to fill all 4 containers

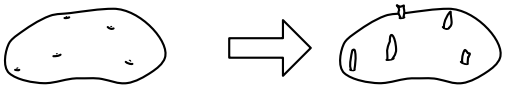
For best results, use older potatoes

Most commercially-available potatoes are treated with chlorpropham, a compound that prevents sprouting. For best results, select a tuber where you can see small sprouts or swelling in the "eyes" of the tuber. If you do not see any sprouts or signs of budding, let the potato sit for two weeks at room temperature.

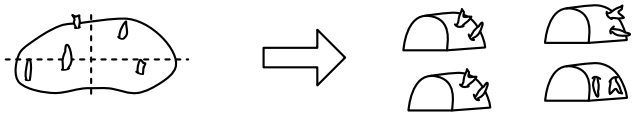
Potatoes are tubers, specialized root structures that store starch. Tubers contain buds that can grow into new plants!



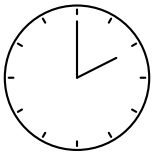
1. Place the potato in a dark and warm area (such as a kitchen cupboard) and let it sit there until sprouts have formed at the eyes. This may take between 1 to 3 weeks.



2. When the potato has sprouts, clean the knife with rubbing alcohol. Use the clean knife to cut the potato into 4 pieces that are roughly equal in size. Make sure that each piece of potato has at least one or two "eyes" with sprouts. If there are many sprouts on the piece of potato, break off all but the three best sprouts.



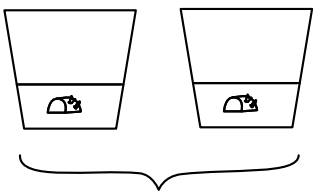
3. Let the cut pieces sit at room temperature for 24 hours. This drying process helps prevent mold from growing on the potatoes after they are planted.



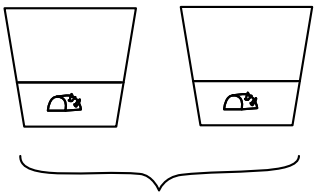
4. Fill the pots or burlap bags 1/3 full with potting soil. Place one potato piece in each container so that the potato is approximately 5 cm or 2 inches below the surface of the soil.

5. Water the soil in each pot so that it is moist. Place two of the pots in a very sunny location and the other two pots in a shady location.

6. Care for the plants by keeping the soil moist with regular watering. Do not let the soil become too wet or waterlogged and be careful that it doesn't dry out completely.



Place two pots in a bright location, either under lamps or next to a window that receives several hours of full sunlight.

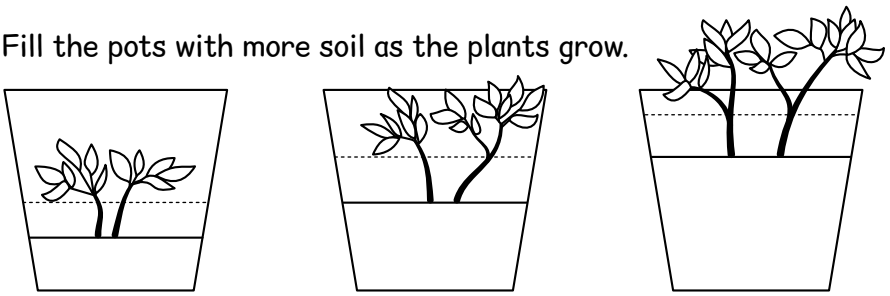


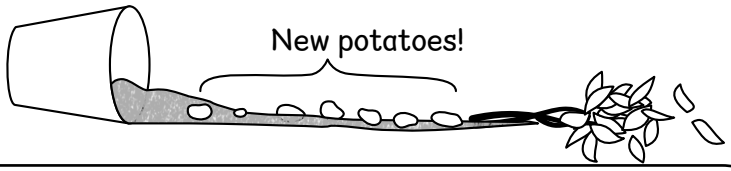
Place two pots in a location with less light (but not dark).

7. After sprouting, continue to add additional layers of potting soil until the pot is full. Record your observations about the size and appearance of the above-ground plants at regular intervals.

8. After 10 to 15 weeks or when the plants begin to die back, pour out the potting soil and sort through it to find the new potato tubers. How many tubers did you find? Which plants produced the most potatoes?

Fill the pots with more soil as the plants grow.

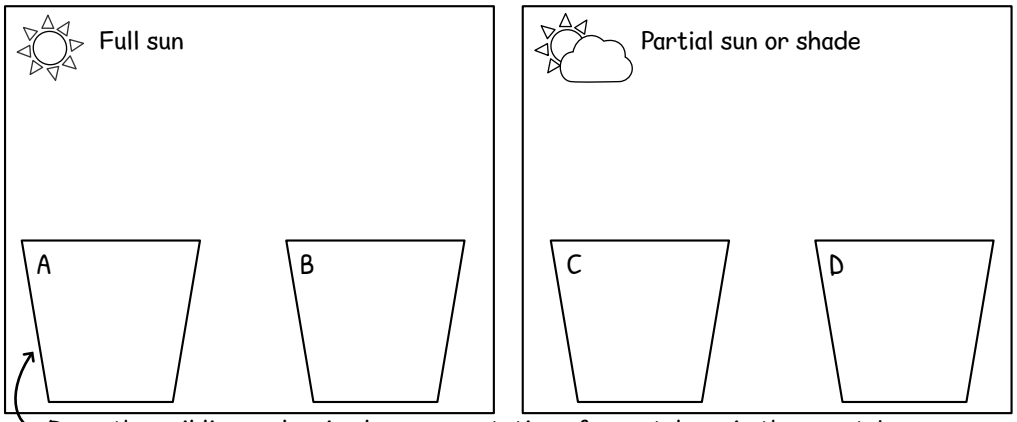




Observations just after the first sprouts emerge:

Noting the date is a vital part of recording

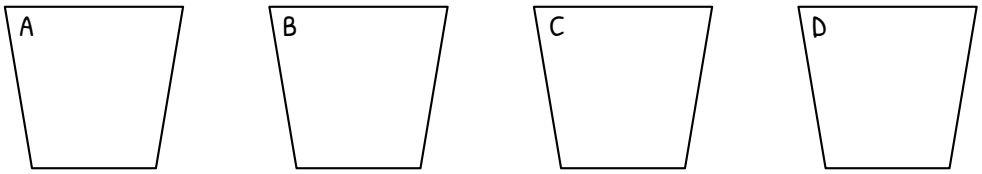
DATE:



Write a line or two about what you observe.

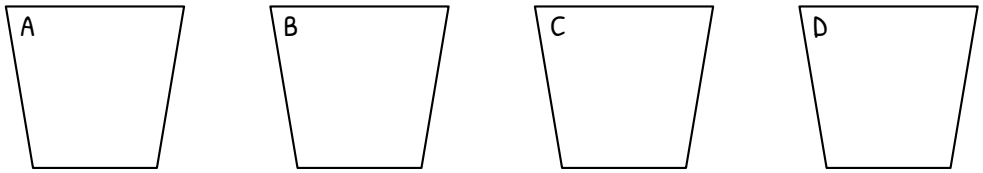
Observations 1 week after the first sprouts emerge. Draw the approximate size and shape of the potato plants growing in each container.

DATE:



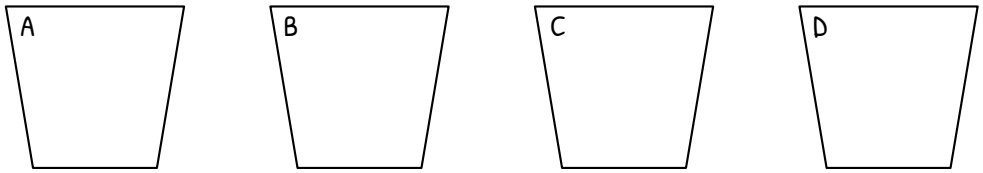
Observations 3 weeks after the first sprouts emerge:

DATE:



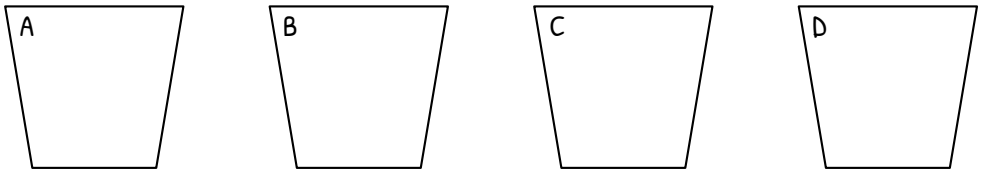
Observations 6 weeks after the first sprouts emerge:

DATE:



Observations 10 weeks after the first sprouts emerge:

DATE:



When to harvest potatoes?

Farmers usually wait until the tops of the potato plants have turned yellow and died back before harvesting. This allows the plant to store the most starch in the tubers.

With potatoes grown indoors, you can wait for the plants to go dormant or you can harvest them anytime after 10-12 weeks of growth. The choice is yours. Harvesting before 10 weeks will result in very small (pea and marble size) potatoes.

How to harvest potatoes.

You can either pour the entire bucket out and sift through all the dirt at once, or harvest one potato at a time by putting a fork into the soil at the outside edges of the plant and carefully lifting the plant up enough to remove a potato. You can then set the plant back in place and water thoroughly.

If the skins are thin and rub off easily or if the potatoes are damaged then they won't store well and should be eaten sooner rather than later. Enjoy!

A mound of clones! How potato farmers grow their crop.

While potatoes can be grown from seed, farmers typically produce exact genetic clones of the desired variety and grow them into "seed potatoes," small potatoes about the size of a ping pong ball. Those potatoes are planted in fields and fertilized three to four weeks after planting. The plants are carefully irrigated because potatoes don't grow well when overwatered. Potatoes are ready for harvesting between 80 and 115 days after planting. They are carefully dug up and stored between 10 and 14 days in cool temperatures (≈15°C) to allow the skins time to harden and minor injuries to seal. To prevent sprouting, potatoes can be stored for up to six months at a temperature of 3-4°C.

Dreaded pests: Potato Blight and the Irish Potato Famine

From 1845-1852, Ireland experienced a devastating famine when a fungus-like microorganism called Phytophthora infestans caused a serious disease known as potato blight. The blight caused the Irish to lose about ¾ of their most important food crop and resulted in over a million people dying of starvation and millions emigrating away from the island in the following years when the potato harvest was poor. Ireland is possibly the only country in the world that has a lower population today than in 1840.

Observations after digging up the potatoes. How many potatoes were in each container? What were the relative sizes?

DATE:

A	B	C	D

The question of inheritance

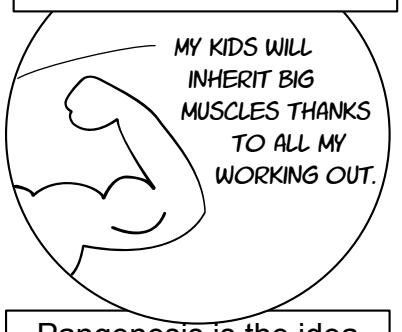
Throughout history, people have had different ideas about how traits are inherited. The three ideas described below were common when Mendel was alive. Which of these ideas best explains what you have observed about traits and how they are inherited? Rate them from one star (there are lots of counter examples for this idea) to four stars (this idea explains inheritance very well).

Lamarckism

Lamarckism is the belief that acquired traits can be inherited. Giraffes are able to lengthen their necks by constantly stretching, so their offspring will inherit a longer neck.

☆ ☆ ☆ ☆

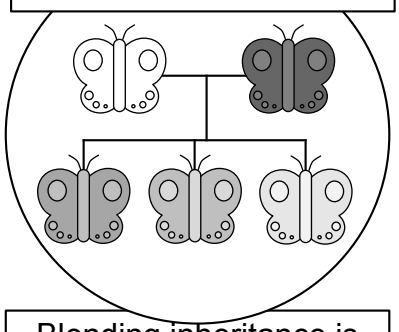
Pangenesis



Pangenesis is the idea that each part of the body produces small particles called gemmules that accumulate and are then passed on to offspring. It is the mechanism for Lamarckian inheritance.

☆ ☆ ☆ ☆

Blending



Blending inheritance is the idea that each trait will be inherited by the offspring at about the average level of each parent. For example, your hair color falls between your parents' hair colors.

☆ ☆ ☆ ☆

Gregor Mendel

mathematician, biologist, abbot, and founder of genetics.

FILL IN THE BLANKS USING THESE WORDS:

garden inheritance traits pea genetics

Gregor Mendel was a monk at St. Thomas Abbey. During Mendel's lifetime, the question of how _____ were passed from one generation to the next was one of the great mysteries of science. Popular ideas to explain _____ included Lamarckism, the idea that acquired traits could be inherited.

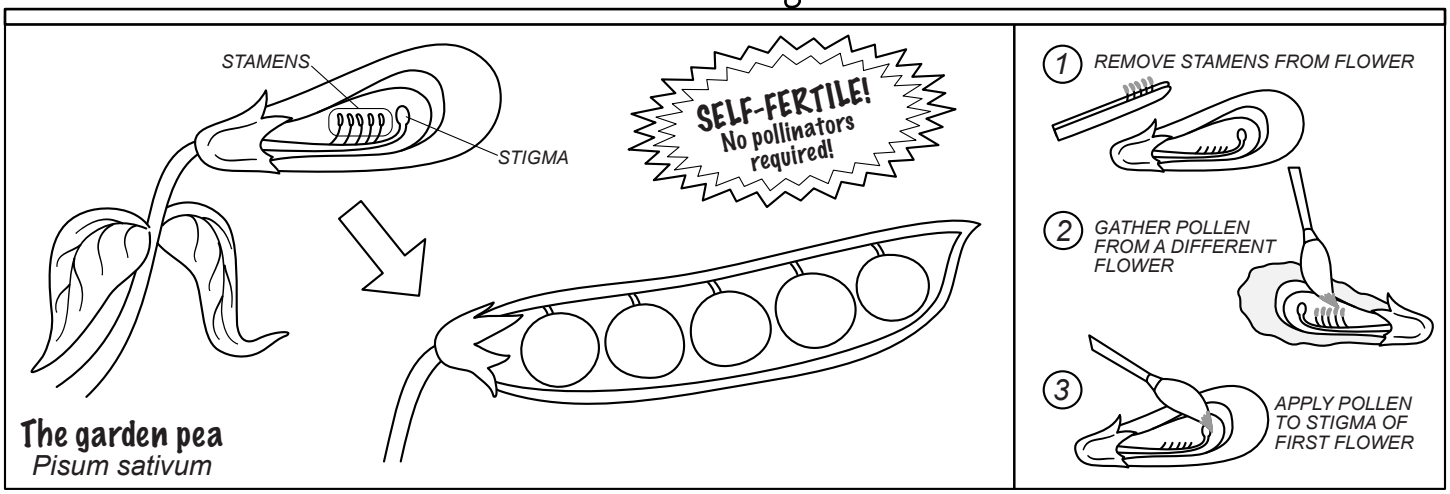
In the 1850s, Mendel conducted experiments to discover how inheritance worked. He studied the characteristics of _____ plants, such as green and yellow seeds. His experiments were conducted in a small _____ next to the abbey.

His conclusions were incredibly advanced for his time and he is widely considered to be the founder of modern _____.

THE LOCATION OF ST. THOMAS ABBEY

GREGOR MENDEL 1822-1884

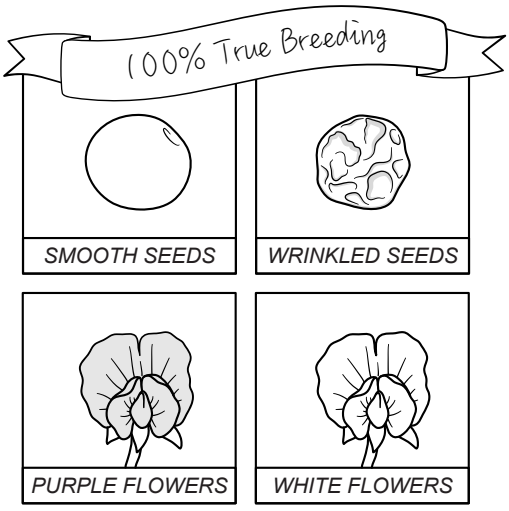
A famous experiment



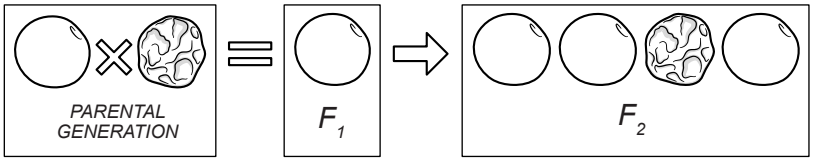
The garden pea
Pisum sativum

Peas are self-fertile. They do not need pollinators and unless a person intervenes, the pollen on the stamens will fertilize the stigma and produce a pea pod filled with seeds. To cross-pollinate two different pea plants, Mendel used tweezers to remove the stamens from one flower (1) and used a paintbrush to gather pollen from the flower of a different plant (2). The pollen was then applied to the stigma of the first plant to produce hybrid seeds (3).

MEET THE PARENT PEAS!



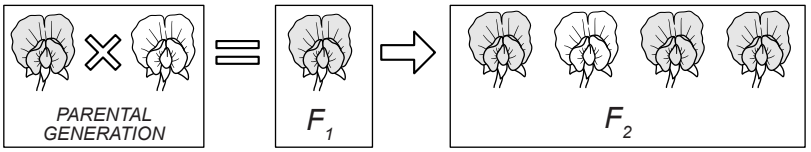
THE EXPERIMENT



A pea plant with smooth seeds is cross-fertilized with a plant that has wrinkled seeds.

ALL of the seeds in that first generation (called the F_1 generation) are smooth.

When those first generation seeds (F1) are self-fertilized, the next generation shows a 3 to 1 ratio of smooth to wrinkled seeds.



We see the same result with flower color.

If you were Mendel, how would you explain these results? Why is one trait disappearing in the F_1 generation and then coming back again in the next?

Disappearing and reappearing traits?

Mendel's results explained.

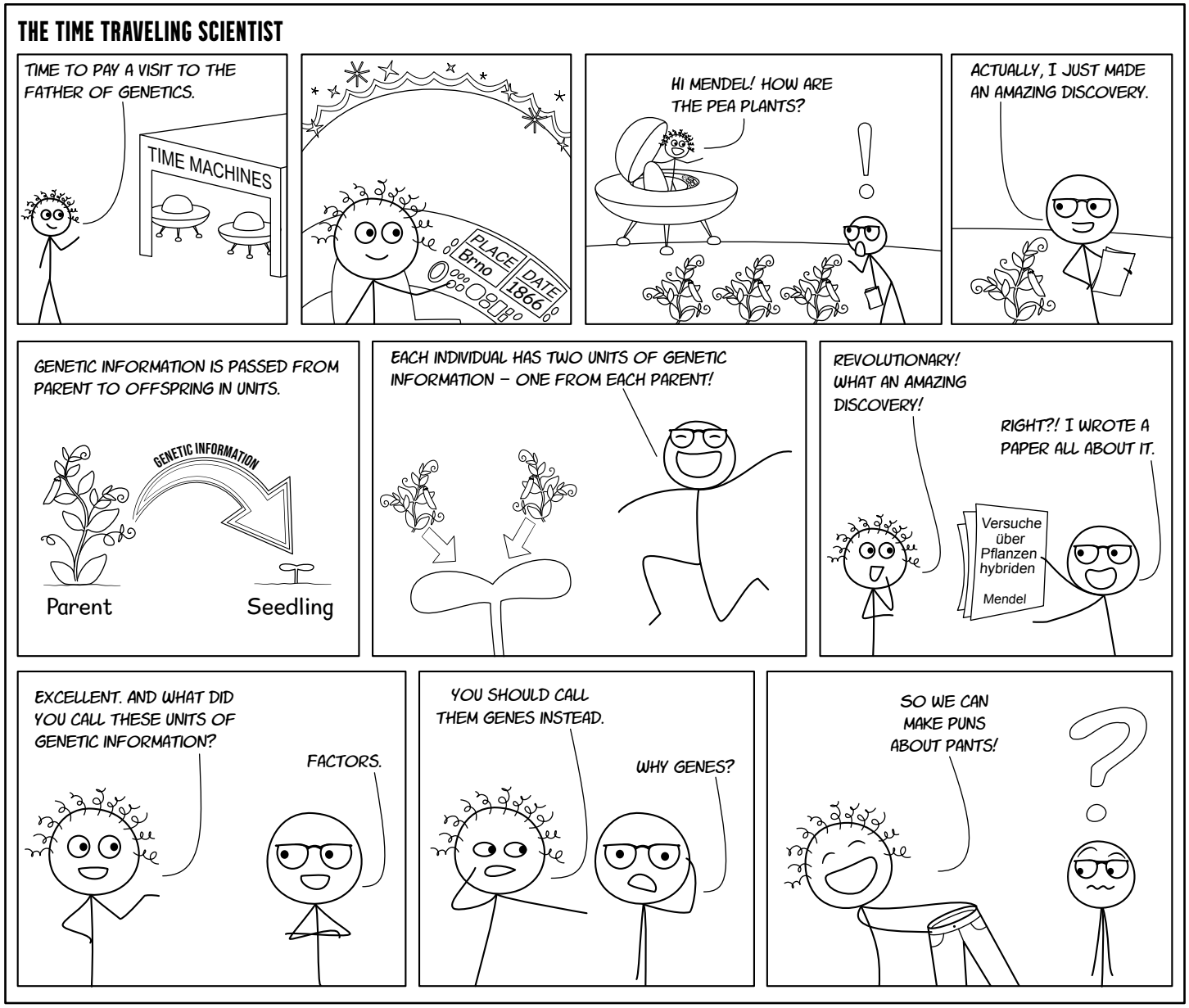
FILL IN THE BLANKS USING THESE WORDS:

inherited	generation	ignored	traits	dominant

When crossing two true-breeding pea plants with different traits, Mendel found that the F_1 or first _____ of plants looked identical to one of the parent plants. The trait from the other parent had "disappeared." But when these plants were self-pollinated, they were no longer true-breeding. Both of the _____ appeared with a consistent ratio: ¼ of the plants had the trait that had disappeared while ¾ of the plants had the other trait.

To explain this phenomenon, Mendel said that each plant _____ two factors, one from each parent. Some factors (now called genes) were _____ and others were recessive.

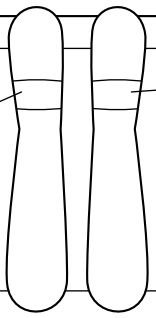
He published his research but it was _____ for more than thirty years. Mendel wasn't recognized for his work until other scientists discovered the same facts in the 1900s.



Genotype

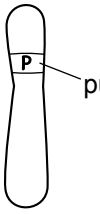
the genetic information

In this example, we use "**P**" to represent the _____ for purple flower color and "p" to represent the allele for white flower color.



The gene for flower color.*

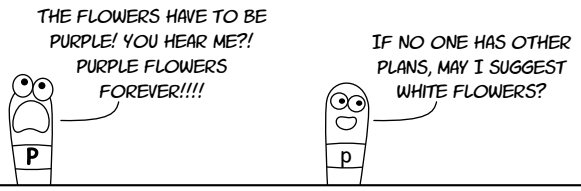
There isn't just one gene for flower color! There are different versions of this gene. One has instructions for purple flowers. Another version has instructions for white flowers. Different versions of the same gene are called **alleles**.



purple allele

white allele

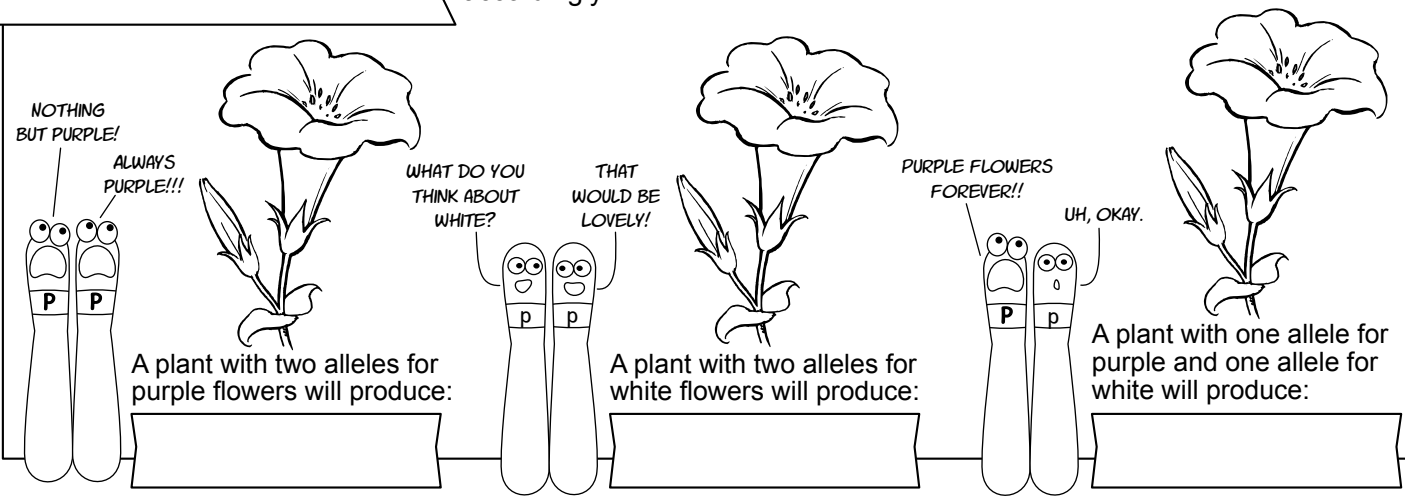
*We'll learn more about what genes are (segments of DNA) and where they are located (on chromosomes) in the next unit. For now, we can think of them as a little bosses telling the organism what to do.



Phenotype

the observed trait

In this example, there are two phenotypes: purple flowers and white flowers. Write the expected phenotype in each box below, then color the flowers accordingly:

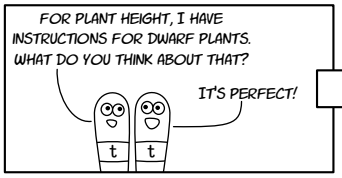


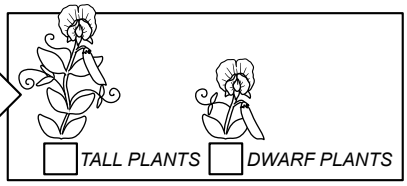
A plant with two alleles for purple flowers will produce:

A plant with two alleles for white flowers will produce:

A plant with one allele for purple and one allele for white will produce:

*In the example above, the purple allele is **dominant** and the white allele is **recessive.** The traits below also have a dominant allele (represented by a capital letter) and a recessive allele (lower case letter). Use this information to indicate the phenotype that will be produced from each pair of alleles:*

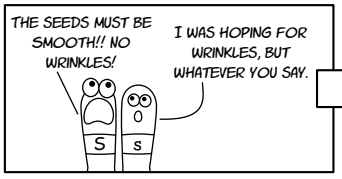


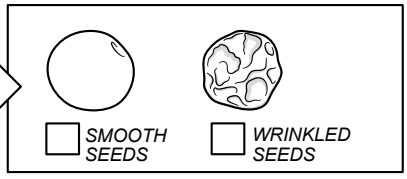


*For seed color (yellow or green), the **genotype** is:*

Yy

*The **phenotype** will be:*

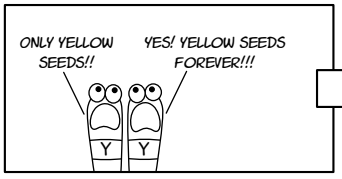


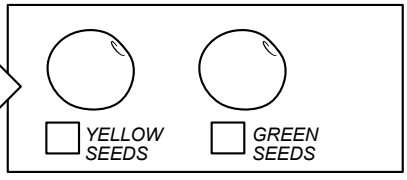


*For plant height (tall or dwarf), the **genotype** is:*

Tt

*The **phenotype** will be:*



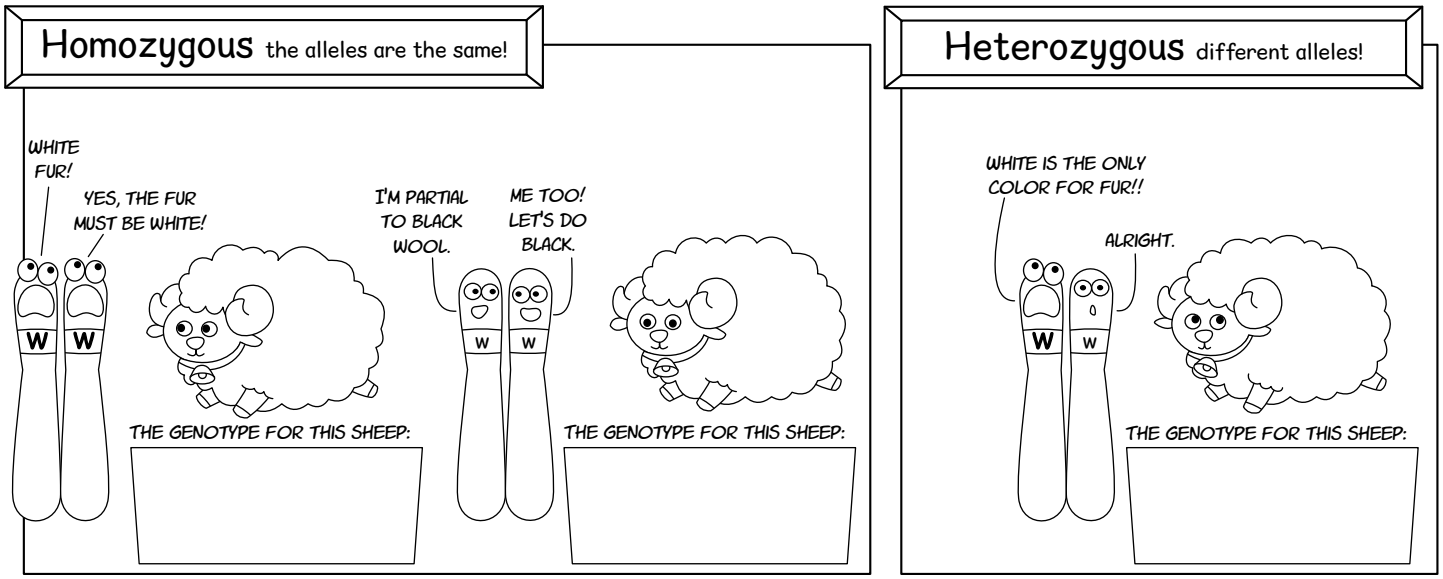


*For seed color (yellow or green), the **genotype** is:*

yy

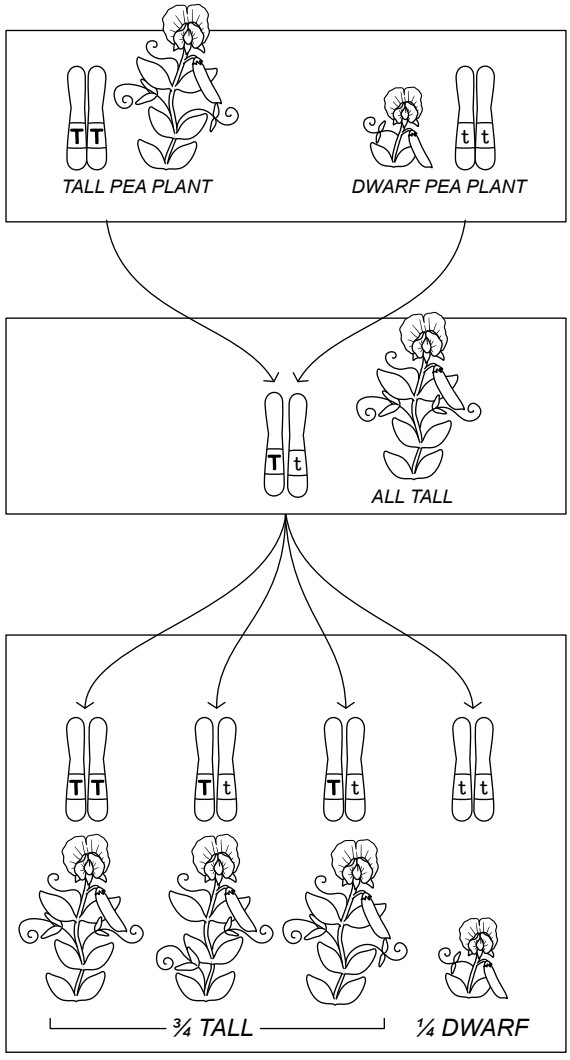
*The **phenotype** will be:*

The traits Mendel studied follow a **dominance / recessive** pattern. The trait of wool color in sheep does as well, which explains why black sheep are less common than white. Color in the sheep below with the correct phenotype and then label each block below as either "Homozygous dominant," "Homozygous recessive," or "Heterozygous."



Mendel's results explained (in more detail)

Write either "heterozygous" or "homozygous" in each of the labels below.

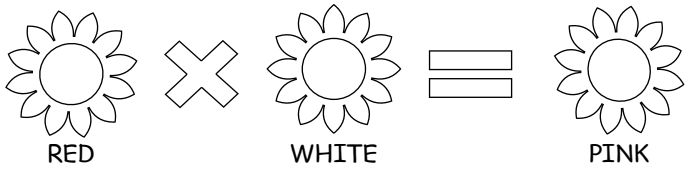


The plants in the parent generation are true-breeding or _____ for their trait, which is plant height. The tall plants always produce seeds that grow into tall plants. The dwarf plants always produce seeds that grow into dwarf plants.

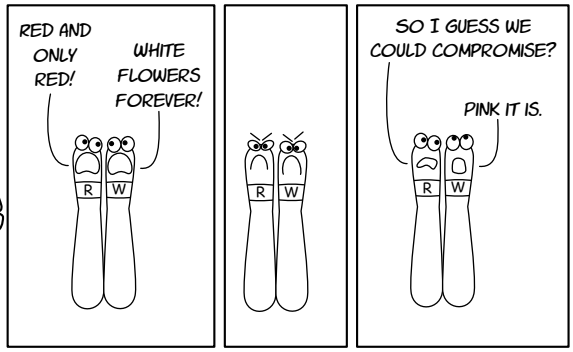
The F_1 generation received one allele from each parent plant and are _____ for plant height. All of the plants in this generation are tall. The plants will be self-fertilized to form the F_2 generation.

In the F_2 generation, a quarter of the plants show the phenotype of dwarfism. These plants are _____ recessive. Half of the plants are tall but are _____, which means they are no longer true-breeding.

In real life, things are often more complicated...

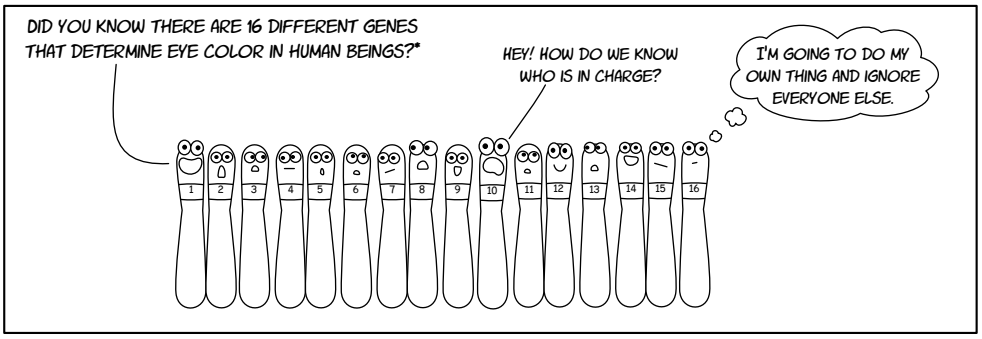


In cases of incomplete dominance, the heterozygous phenotype is different than either of the homozygous phenotypes!



Most human traits are controlled by multiple genes and have complicated inheritance patterns. We sometimes think of eye color as being a trait that follows Mendelian inheritance patterns with brown eyes being dominant and blue eyes being recessive.

But it's not that simple! With more than 16 different genes playing a role in the process, two blue-eyed parents can indeed have a brown-eyed child. The same is true with many other traits including hair color, earlobes, and more.



** For further reading, see Genotype-phenotype associations and human eye color by Desiree White in the Journal of Human Genetics. Published Oct 14, 2010.*

Draw lines to match each term with the correct description:

Recessive

Dominant

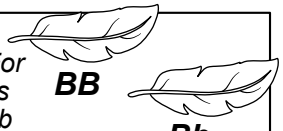
Homozygous

Heterozygous

Genotype

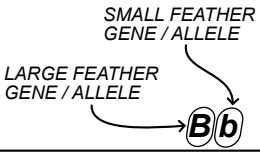
Phenotype

Only one copy (allele) of a gene is needed for the trait to be expressed. For example, if the trait for large feathers is represented by B, then both BB and Bb would result in big feathers.



The copies (alleles) of the gene are both the same. From the Greek word "homos," which means same, and "zugos," which means yoked.

The genetic information of an organism. The term can also refer to the genetic information of a specific trait.



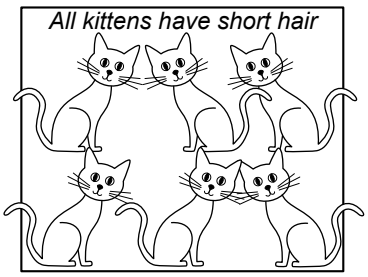
There are two different versions (alleles) of the gene. From the Greek words "heteros," which means different, and "zugos," which means yoked.

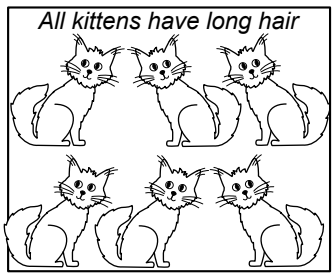
The trait will only be expressed if there are two identical copies (alleles) of the gene. For example, if small feathers are represented by b, then only the genotype of bb will produce small feathers.

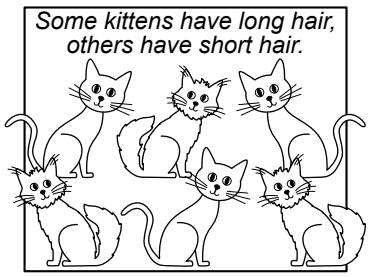
The observable characteristics or traits of an individual, for example, having either small or large feathers.

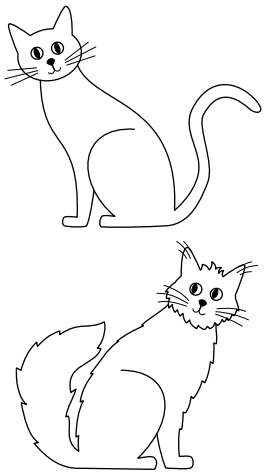
Laws of heredity

Yujun buys two pure-bred cats, each with a pedigree showing that all of their ancestors have the same trait for hair length. One cat is long haired. The other is short haired. Now the cats are going to have kittens. Yujun knows that hair length is a recessive/dominant trait in cats, but doesn't remember which trait is dominant. Match each of the possible outcomes with the correct conclusion:









LONG HAIR IS A DOMINANT TRAIT

SHORT HAIR IS A DOMINANT TRAIT

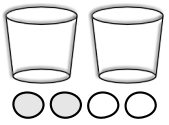
AT LEAST ONE OF THE CATS WAS NOT PURE-BRED.

1. SEGREGATION - the alleles are distributed randomly

Mendel's first law states that the chance of inheriting an allele (or genetic factor) is random. For example, in the case of yellow or green seeds in pea plants, if the parent is heterozygous (Yy) there is a 50% chance the offspring will receive the yellow (Y) allele and a 50% chance they will receive the green (y) allele. This is called the principle of segregation.

Try it yourself!

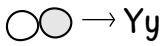
Supplies: *2 cups and 4 objects to represent yellow and green alleles. The objects should have the same shape and size but different colors. You could use dried peas, beans, marbles, dice, marshmallows or any items of the same size. Just make sure they are marked or colored so that you can tell tell them apart.*



STEP 1 Place 1 object of each color in each cup. Assign one of the colors to be dominant (Y) and the other to be recessive (y).

STEP 2 Without looking, draw one pea from each cup.

STEP 3 Record whether you got two yellows (**YY**), one of each (**Yy**), or two greens (**yy**) in the tables below. Go back to **STEP 1** and repeat until the table below is full.

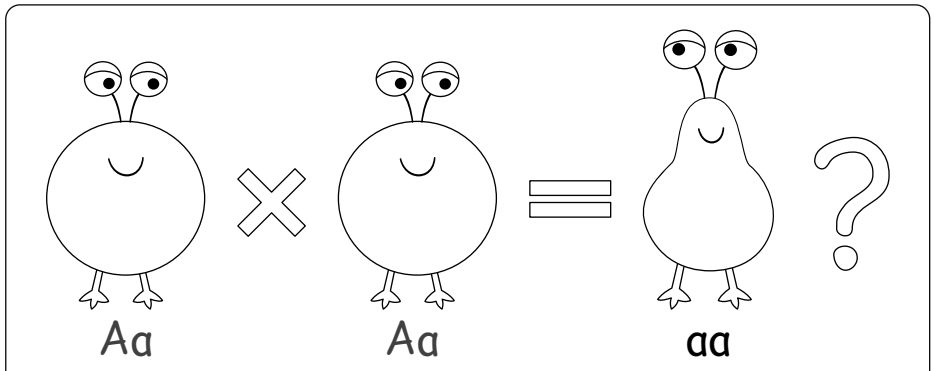


STEP 4 Color each cell green if it holds **yy** and yellow if it holds **YY** or **Yy**.

Count the number of yellow and green cells. Was your result close to a 3-to-1 ratio of yellow to green peas (30 yellow and 10 green)? If you repeated this activity 3 more times, would you expect the overall ratio to be closer to or further away from ¾ yellow and ¼ green?

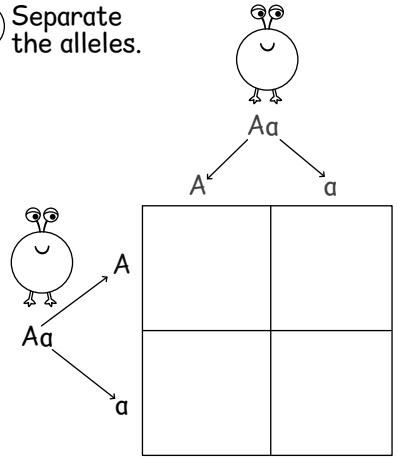
Punnett Squares

Since the probability of getting one allele or another is 50/50, we can use a tool called a Punnett square to see all of the possible combinations AND how likely they are to occur! For example, if a round shape is dominant and pear shape is recessive, a punnet square shows us how likely it is that two heterozygous aliens would produce a pear-shaped alien:

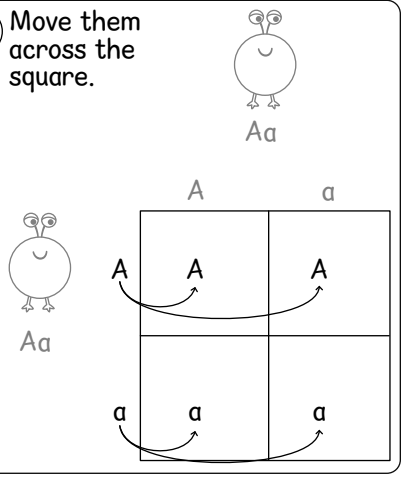


Round body shape (A) is dominant and pear body shape (a) is recessive. How many of the offspring will be pear-shaped (aa) from a heterozygous cross (Aa x Aa)? A Punnett square can tell us the answer!

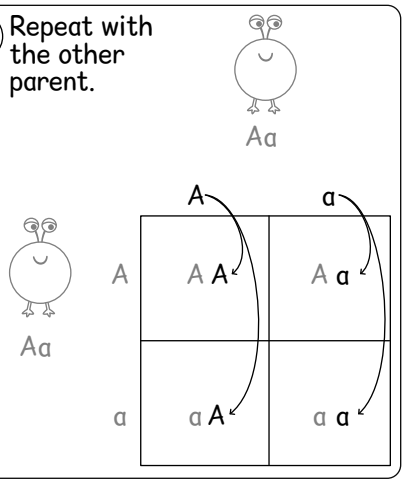
1 Separate the alleles.



2 Move them across the square.

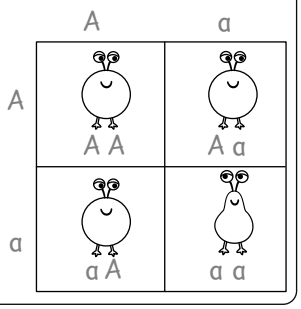


3 Repeat with the other parent.

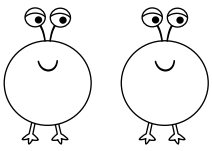


4 Evaluate your results!

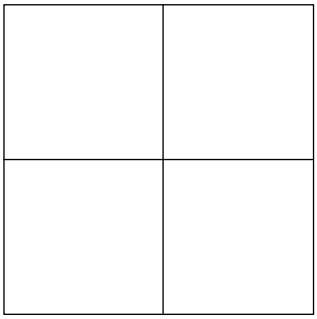
Round heterozygous aliens have a ¼ chance of producing a pear-shaped alien.

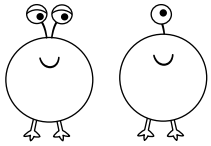


Fill in the Punnett squares for each of the following crosses. Two eyes (B) is a dominant trait. One eye (b) is recessive. Write down the chance of producing a one-eyed alien for each cross. If no squares are "bb," then a one-eyed alien can't be produced from that cross (0% chance). If one square is bb, the chance is 25%. If two squares are bb, the chance is 50%, etc.

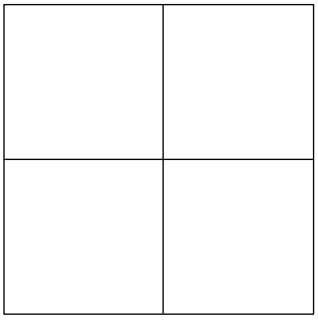


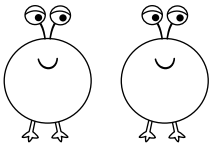
Bb x Bb



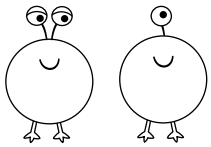


BB x bb



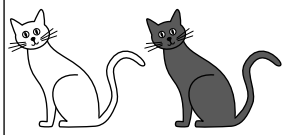


BB x Bb

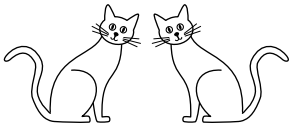


Bb x bb

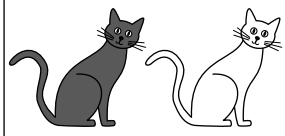
With cats, white fur is dominant (W) with dark hair (w) being recessive. Using that information, fill out the following Punnett squares, then outline the ww genotypes in a dark color. Which cross produced the most dark cats?



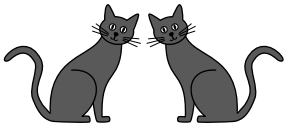
Ww x ww



Ww x Ww



ww x WW

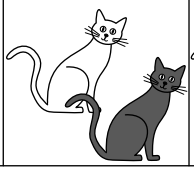
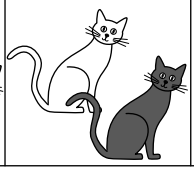
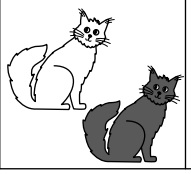
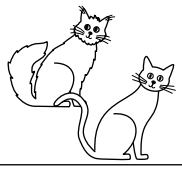
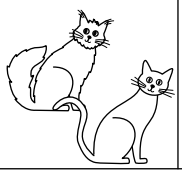
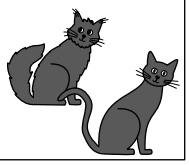


ww x ww

2. INDEPENDENT ASSORTMENT - traits are inherited independently

Mendel's second law of inheritance says that the inheritance of one trait (such as a cat having long hair or short) has no influence on the inheritance of another trait (such as the color of the cat fur). This is called the principle of independent assortment. It applies to a lot of traits, but not all of them! Some genes are inherited together because they are located close together on the same chromosome.

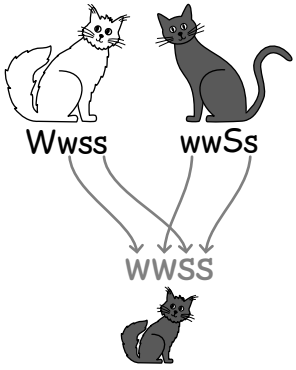
*It doesn't matter if the hair is long or short, cats with the **W** allele will be white, while cats with the **ww** genotype will be dark-haired.*

Genotype	SS	Ss	ss	WW	Ww	ww
Phenotype	*SHORT HAIR*	*SHORT HAIR*	*LONG HAIR*	*WHITE HAIR*	*WHITE HAIR*	*DARK HAIR*
						

*It doesn't matter what color the cat is, cats with the genotype of **SS** or **Ss** will have short hair. Long hair is only produced by the genotype **ss**.*

Could this pair of cats produce a black long-haired kitten? Check yes or no, then show why or why not.

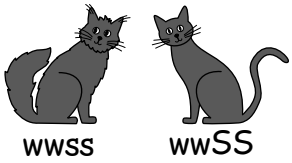
- [x] YES
- [ ] NO



Could this pair of cats produce a white long-haired kitten? Check yes or no, then show why or why not.

- [ ] YES
- [x] NO

The white allele (W) is needed for white fur and neither parent carries that allele. The genotype "ss" is needed for long hair, but the only genotype the kitten can have is Ss, which will produce short hair.

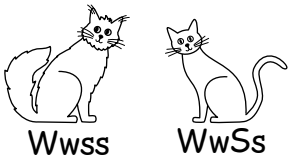


A white longhaired cat can be:

WWss or Wwss

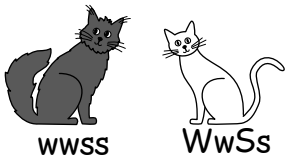
Could this pair of cats produce a black short-haired kitten? Check yes or no, then show why or why not.

- [ ] YES
- [ ] NO



Could this pair of cats produce a white longhaired kitten? Check yes or no, then show why or why not.

- [ ] YES
- [ ] NO

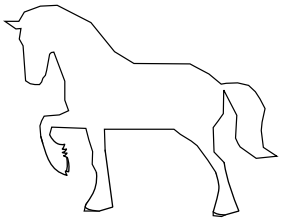


How to Read A Pedigree Chart

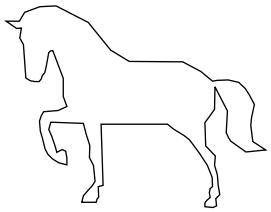
A pedigree chart is a family tree that tracks how a trait has been passed along. It typically follows the rules below:

- Males are represented by squares, and females are represented by circles.
- A filled shape means the individual exhibits the trait.
- Horizontal lines between two individuals exhibit mating pairs.
- Vertical lines descend from parents to a horizontal line that connects the offspring.

Profile of a breed with feathered feet



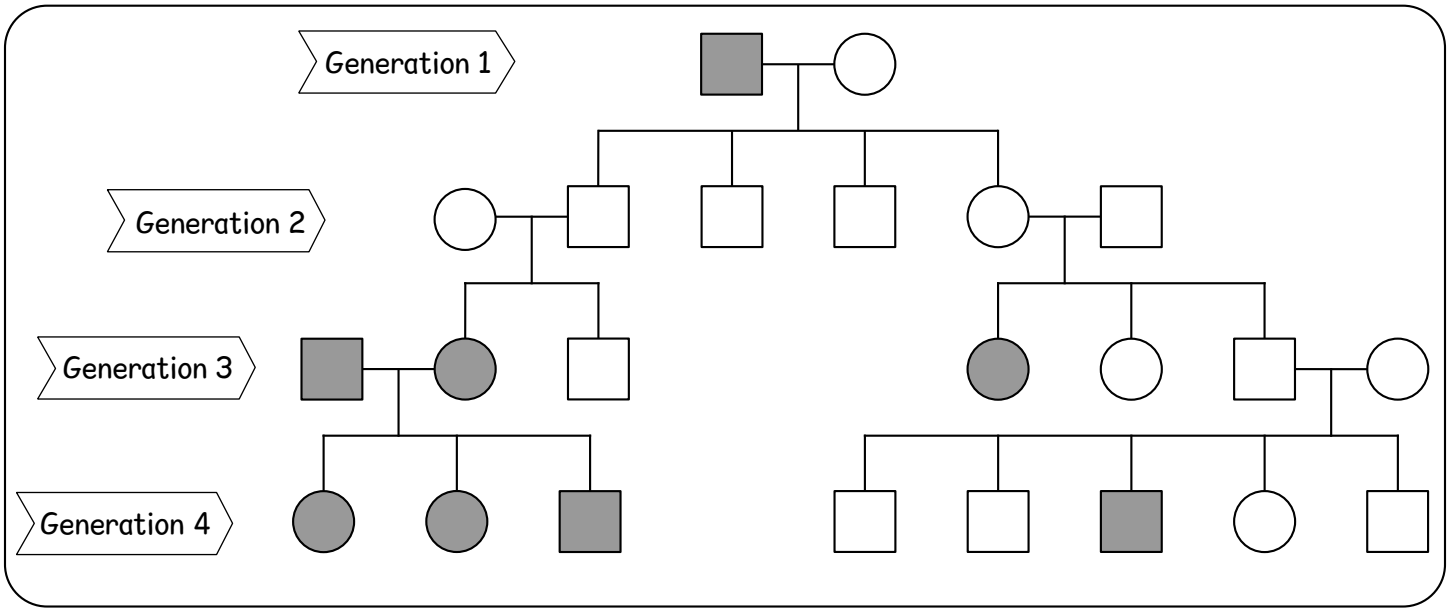
Profile of a breed without feathered feet



The "feathered" foot has long hair on the lower leg that covers the hoof.

A non-feathered foot has short hair.

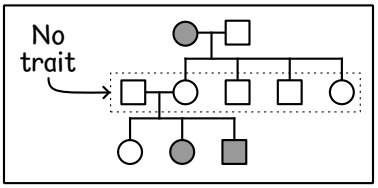
Below is a pedigree chart for the trait of "feathered feet," the long hair that cover the hooves of certain horse breeds like Clydesdales, Shires, Friesians, and Ardennes.* Each shaded shape represents a horse with feathered feet.



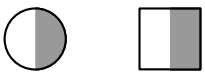
Is the trait mapped in this pedigree chart dominant or recessive? Explain how you know.

AA, Aa, or aa?

Can a dominant trait skip a generation? What about a recessive trait? Explain.



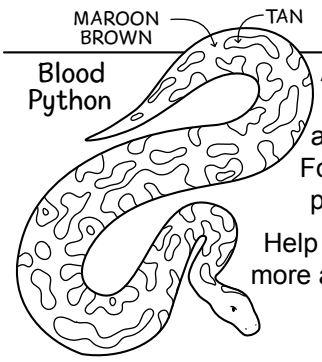
When tracking a recessive trait, a half-shaded shape is used to indicate a carrier. Can you identify a horse or horses in this pedigree that must be carriers of the trait? If yes, shade in their shapes!



A carrier of the trait!

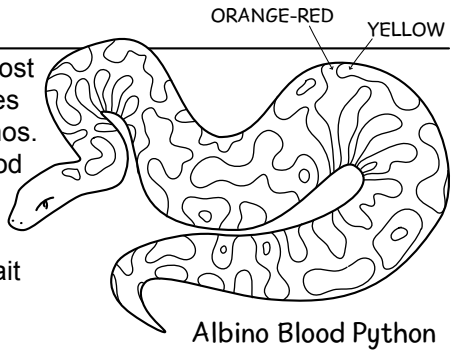
**While a cross between a fathered horse (such as a Clydesdale) and a non-feathered horse (such as a Thoroughbred) will result in a horse that is non-feathered, the genetics of feathering have not been studied in detail. It's likely to include more than one gene and be more complicated than the hypothetical example used here.*

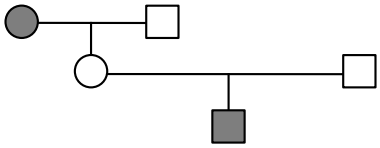
Pet Pedigree Puzzle #1



At Ella's pet store, albino blood pythons have been the most popular snake breed. Ella has space to breed two snakes and wants to choose a pairing that will produce more albinos. Fortunately, Ella has pedigree charts of the store's four blood pythons: Julius Squeezer, Basil, Medusa, and Naga.

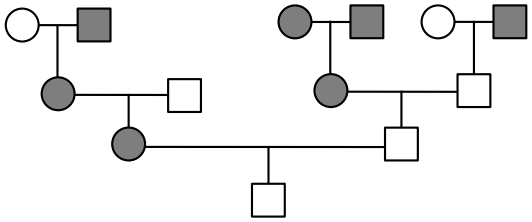
Help Ella make the choice that will give the highest chance of more albino pythons! Remember that albinism is a recessive trait and the pedigrees only show phenotype, not genotype.





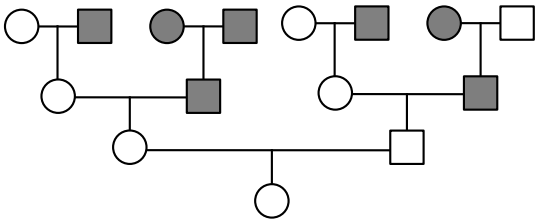
Julius Squeezer

Julius Squeezer is the an albino blood python with beautiful cream and orange coloring.



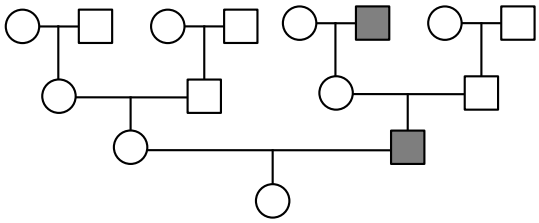
Basil

Basil has standard coloring and a very friendly temperament. He is easy to hold.



Naga

Naga has standard coloring and an aggressive temperament. Gloves are required for handling.



Medusa

Medusa has standard coloring and loves to swim. She takes a plunge anytime she's around water.

What genotype is Julius Squeezer? The dark color allele is represented by **A**. The albinism allele is represented by **a**.

☐ **AA** or **Aa** ☐ **Aa** ☐ **aa**

What genotype is Basil?

☐ **AA** or **Aa** ☐ **Aa** ☐ **aa**

What genotype is Naga?

☐ **AA** or **Aa** ☐ **Aa** ☐ **aa**

What genotype is Medusa?

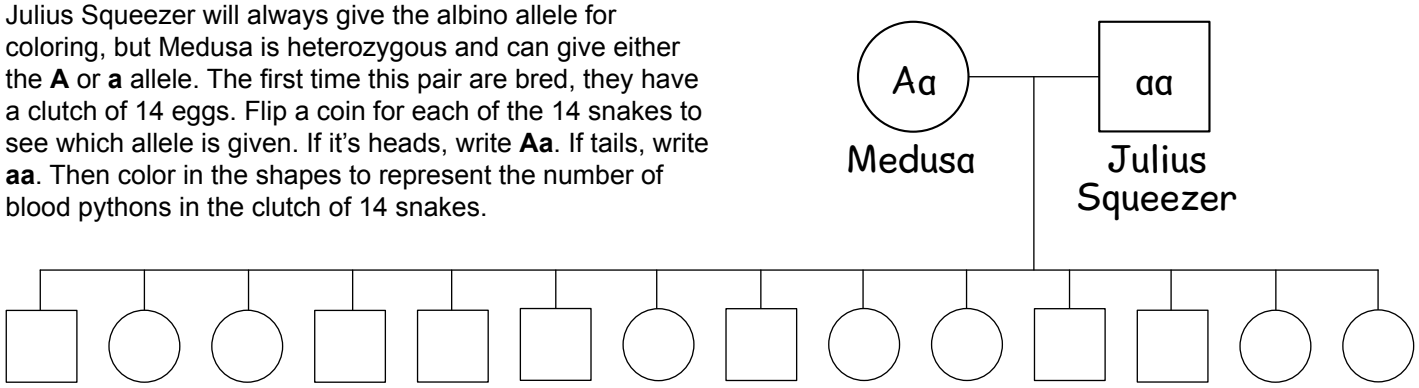
☐ **AA** or **Aa** ☐ **Aa** ☐ **aa**

Which snakes should Ella select for breeding and why?

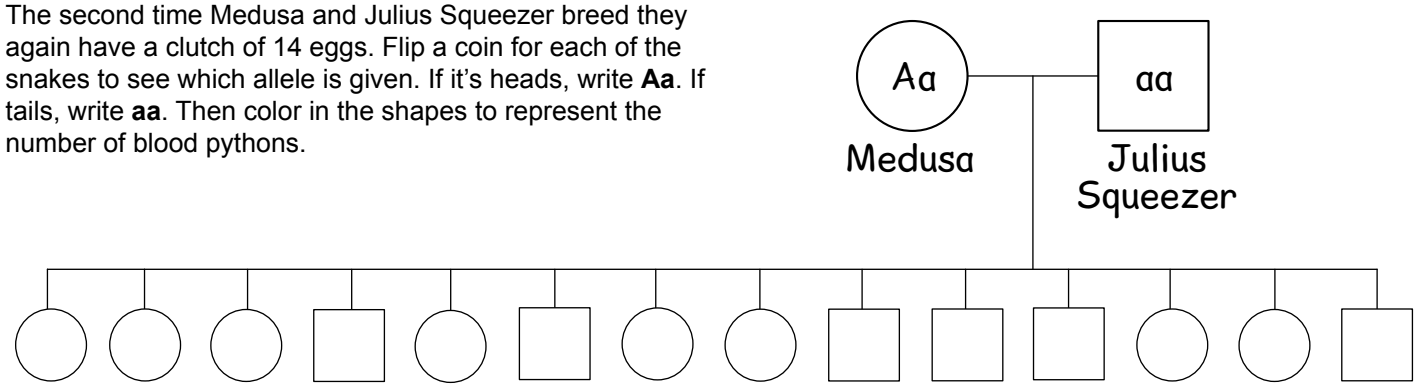
Mendel's First Law is like flipping a coin...

The probability of an aa x Aa cross giving albino snakes may be 50/50, but that doesn't mean you'll see that exact ratio in real life! Explore Mendel's first law by using a coin to determine whether these snakes produce albino blood pythons. Color the albinos (**aa**) orange. Use brown to mark the standard coloring (**AA** or **Aa**) which is also called **wildtype**.

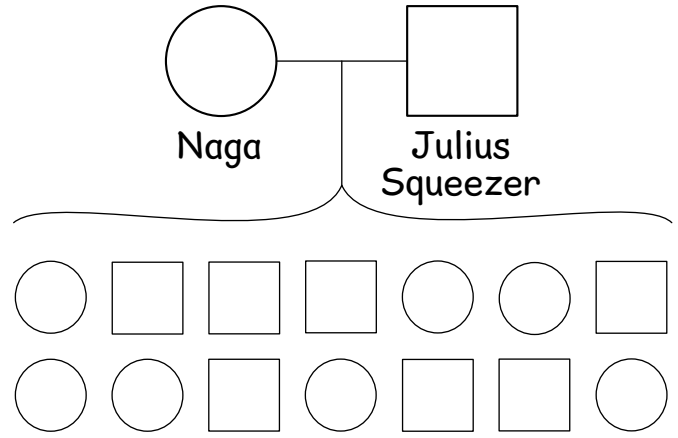
Julius Squeezer will always give the albino allele for coloring, but Medusa is heterozygous and can give either the **A** or **a** allele. The first time this pair are bred, they have a clutch of 14 eggs. Flip a coin for each of the 14 snakes to see which allele is given. If it's heads, write **Aa**. If tails, write **aa**. Then color in the shapes to represent the number of blood pythons in the clutch of 14 snakes.



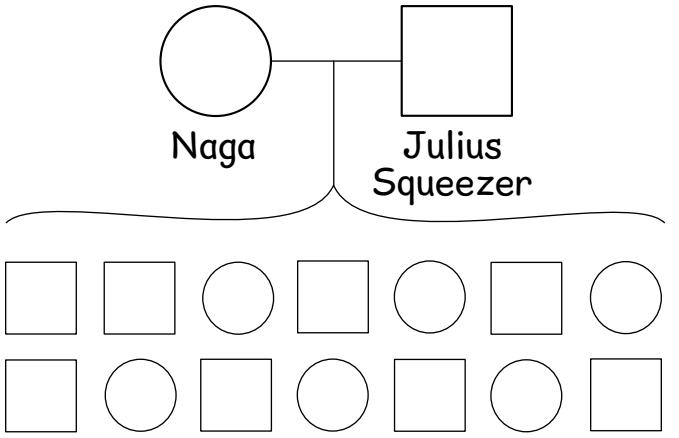
The second time Medusa and Julius Squeezer breed they again have a clutch of 14 eggs. Flip a coin for each of the snakes to see which allele is given. If it's heads, write **Aa**. If tails, write **aa**. Then color in the shapes to represent the number of blood pythons.



Assuming Naga is heterozygous (**Aa**), flip a coin to see what proportion of this clutch of eggs would be expected to be albinos. Then color in the results.



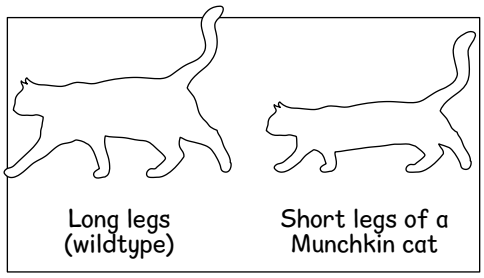
Assuming Naga is homozygous (**AA**), what proportion of this clutch of eggs would be albinos? Do you need to flip a coin here?



Pet Pedigree Puzzle #2

Riley is fostering a pregnant munchkin cat named Percy for their local animal shelter. The short legs of the munchkin are caused by a dominant mutation (**M**). The mutation is lethal if homozygous (the **MM** genotype fails to develop in utero). Heterozygous (**Mm**) gives the munchkin phenotype of short legs, and homozygous recessive (**mm**) results in long legs (**wildtype**).

The animal shelter has a waiting list of people ready to adopt Percy's kittens. They want to know what the probability is of the kittens being munchkins, but no one knows if Percy's mate was a munchkin (**Mm**) or not (**mm**). Calculate the probability of munchkin kittens from each possible cross.

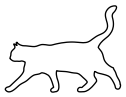


Possibility 1: Munchkin x Munchkin cross

Mm

Mm

Possibility 2: Munchkin x Wildtype cross



mm

Mm

What the probability of munchkin kittens if both parents are munchkins?

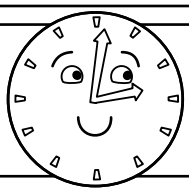
- ☐ 100% - every kitten will be a munchkin.
- ☐ Greater than 50% - approximately 2 out of every 3 kittens will be a munchkin.
- ☐ 50% - there's a 50/50 chance of the munchkin trait.
- ☐ 25% - there's a 1 in 4 chance of the munchkin trait.

What the probability of munchkin kittens if one parent is a munchkin and the other is wildtype (has long legs)?

- ☐ 100% - every kitten will be a munchkin.
- ☐ Greater than 50% - approximately 2 out of every 3 kittens will be a munchkin.
- ☐ 50% - there's a 50/50 chance of the munchkin trait.
- ☐ 25% - there's a 1 in 4 chance of the munchkin trait.

The Governing Council of the Cat Fancy* refuses to recognize munchkins as a breed because of health issues associated with the short legged trait. If you were a member of the GCCF, would you be in favor of recognizing munchkins as a breed, be neutral on the issue, or be in favor of prohibiting further breeding of munchkins?

An organization that registers pedigreed cats in the United Kingdom.



Quiz Time!

ANSWER THE QUESTIONS TO SEE WHAT YOU LEARNED ABOUT CELLULAR LIFE!

1 Which statement is true?

A. Members of the same species must be approximately the same size.
B. Members of the same species can breed with each other and produce offspring.
C. Scientists always agree on whether animals are in the same species.
D. Only animals have species.

2 Which type of reproduction will result in the most genetic diversity?

A. Fragmentation
B. Binary fission
C. Vegetative propagation
D. Spore formation
E. Sexual reproduction

3 Every trait is controlled by a single gene, and each gene is determined by two alleles.

A. True
B. False

4 Select each true statement below.

A. A dominant trait can skip a generation.
B. A recessive trait can skip a generation.
C. When two parents share the same genotype, their offspring will share the same genotype.
D. When two parents share the same phenotype, their offspring will share the same phenotype.

5 What does the notation BB mean to a geneticist?

A. Two dominant alleles
B. Two recessive alleles
C. At least one dominant allele
D. One dominant and one recessive allele

6 If a homozygous black guinea pig (BB) is crossed with a homozygous white guinea pig (bb), what is the probability that an offspring will have black fur?

A. 0%
B. 25%
C. 50%
D. 75%
E. 100%

7 If an organism has a homozygous genotype for a trait, which of the following must be true?

A. Its offspring will also have a homozygous genotype.
B. Its offspring will also have a heterozygous genotype.
C. It's offspring will exhibit the dominant phenotype for the trait.
D. The organism's parent(s) also had a homozygous genotype for the trait.
E. None of the above

8 Select each true statement below.

A. If you know an organisms genotype for a trait, then you also know its phenotype.
B. If you know an organisms phenotype for a trait, then you also know its genotype.
C. A parent always shares a genotype with its offspring.
D. A parent always shares a phenotype with its offspring.

9 An organism that has two different alleles for a single trait is said to be _____ for that trait.

10 An organism has a phenotype for a dominant trait while some of its offspring have the phenotype of for the recessive trait. What can we conclude about this organism?

A. Is heterozygous for the trait.
B. It is homozygous dominant for the trait.
C. It is homozygous recessive for the trait.
D. There is not enough information to tell.

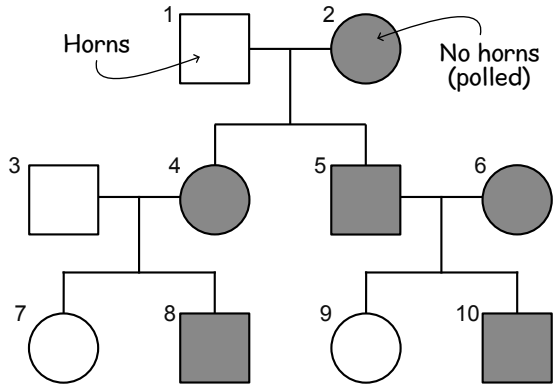
11 In this type of inheritance, one allele for a specific trait is not completely expressed over its paired allele.

A. Complete dominance
B. Incomplete dominance
C. Co-dominance
D. Trisomy

12 What is a Mendelian trait?

A. A trait that involves alleles
B. A trait that is passed down by dominant and recessive alleles of one gene
C. A trait resulting from an allele that is independently and equally expressed along with the other
D. A trait exhibited by pea plants

Below is a pedigree chart for cattle tracking when they have **no horns**, a Mendelian trait. (Cattle without horns are called *polled* cattle and are usually viewed as more desirable than cattle with horns.) Each of the cattle is numbered for reference.



13 Is having no horns a dominant or recessive trait in cattle? Explain how you know.

14 We can assign the alleles A and a to the trait "no horns" exhibited in the pedigree chart. In that case, what is the specific meaning of both A and a?

15 Label each member of the pedigree chart that can be fully identified. Are there any that you can't determine? Explain.

16 List the number of each of the cattle that has horns.

17 List the number of each of the cattle that is heterozygous in the pedigree above.

18 If we cross two cattle with horns, could the offspring have no horns? Explain.

19 If we cross two cattle with no horns, could the offspring have horns? Explain.