<u>Task 1: Introduction</u>

LT: I can use various resources in order to establish an initial claim describing what caused a newt population to become more poisonous.

Watch the video that will explain your role in this unit. In this role, you will solve a mystery about a specific population of rough-skinned newts.

https://sites.google.com/a/ps207tigers.org/207sci/newt

The Rough-Skinned Newt

Rough-skinned newts may not appear dangerous: they are no longer than 20 centimeters (8 inches), with stubby legs and teeth that look like tiny bumps. However, some of these newts are the most poisonous animals in the Pacific Northwest. One rough-skinned newt can have enough poison in its body to kill dozens of humans!

Rough-skinned newts have brown, bumpy skin on their backs, with bright orange skin on their bellies. When threatened by predators, newts curl their bodies to show the orange undersides of their necks and tails. The orange color warns predators to stay away, and most predators do. The only predators that regularly eat rough-skinned newts are common garter snakes.

Newts hatch in the water, but they spend most of their lives on land, often hiding under fallen leaves or bark. At night, they hunt for insects, tiny fish, and other small prey. When they are ready to mate, rough-skinned newts return to the water, where males and females swim together in pairs. The females lay poisonous eggs and attach them to underwater plants.

Meet a Scientist Who Studies Natural Selection

Dave Yuan spends his days surrounded by millions of yeast, the one-celled organisms used to make bread rise. However, Yuan isn't a baker—he's a geneticist who studies natural selection. Yeast are good organisms for studying natural selection, because they reproduce very quickly. Scientists can control the yeast organisms' environment and watch what happens to many generations of yeast in a short period of time as they pass genes down. "We use a special tool to bar code different lineages (family lines) of yeast—there are about half a million unique lineages," says Yuan. "We can watch natural selection under all kinds of conditions. For example, we can grow yeast until there's no more food or space for them, then transfer them to a fresh environment and see what happens." Yuan and his team do this type of experiment 50 to 100 times over a few months, then see how certain traits are distributed in the population of yeast. Lineages that developed adaptive traits should be more common in the population because they have lived long enough to pass on their genes, while lineages that developed non-adaptive traits should be less common in the population.

It's no surprise to Yuan that he grew up to be a scientist. He's always been interested in science, especially in understanding how there came to be so many different types of organisms on Earth. He majored in biology in college, then worked as a lab assistant for a few years—he wanted to try out scientific research as a job to see whether he liked it. After a few years, he decided to go to graduate school, and today he works as a researcher studying natural selection at the molecular level.

For Yuan, studying natural selection is exciting because he sometimes learns things that nobody has ever known before. "I like that whatever I work on, I'm working toward discovery of some kind," he says. "You're in the lab all day, but at a higher level, what you're doing is on the cutting edge of what we're learning. We're actually discovering things."

On the other hand, he says things don't always go as planned. "Failure is something that every lab scientist is very familiar with, but I think that's not well known outside of research," he says. Since he and his team are working with new information and technologies, they sometimes run into problems that nobody expected—and they have to solve them. "These are experimental systems," he says. "We make things up as we go and troubleshoot, look at what we have and try to deal with very complicated machines. A lot of times, things just don't work, and it can be frustrating."

When Yuan thinks about his path to working as a scientist, he wishes he could tell his younger self a few things—like the importance of learning as much math as he could. "I was pretty good at math in junior high and high school, but I didn't like it. I thought, 'you just have to get through this and then never use it again,' but that's not really true." Yuan says he uses math and statistics every day in his research. A background in computer coding would be helpful, too. Computer coding is "a very useful tool" for scientific research, according to Yuan.

Yuan plans to continue studying natural selection—but he hopes someday to do his work outside of the lab. Some biologists study natural selection in the field, taking trips to different environments to observe and gather information, and Yuan hopes to be one of them: "I've always wanted to do something where I get to go out into nature," he says. "It's rare, but there are people who do it!"

To: Student Biologists
From: Dr. Alex Young, Head Biologist
Subject: Claims About the Rough-Skinned Newts

Hello, student biologists! I'd like to ask for your help in investigating the following claims. These claims were brought to us by park visitors.

Claim 1: Some people think that some newts became more poisonous because they wanted to—newts do seem like smart creatures!

Claim 2: Others suggest something in the environment caused the newts to become more poisonous.

Please let us know what you find out about these claims!

A. ***Which claim do you agree with? Explain your reasoning.***
B. ***Why are yeast good organisms for studying natural selection?***

<u>Task 2: Observing Fur Traits and Temperature in the SIM</u>

LT: I can use a simulation to describe why the distribution of fur traits changes over time.

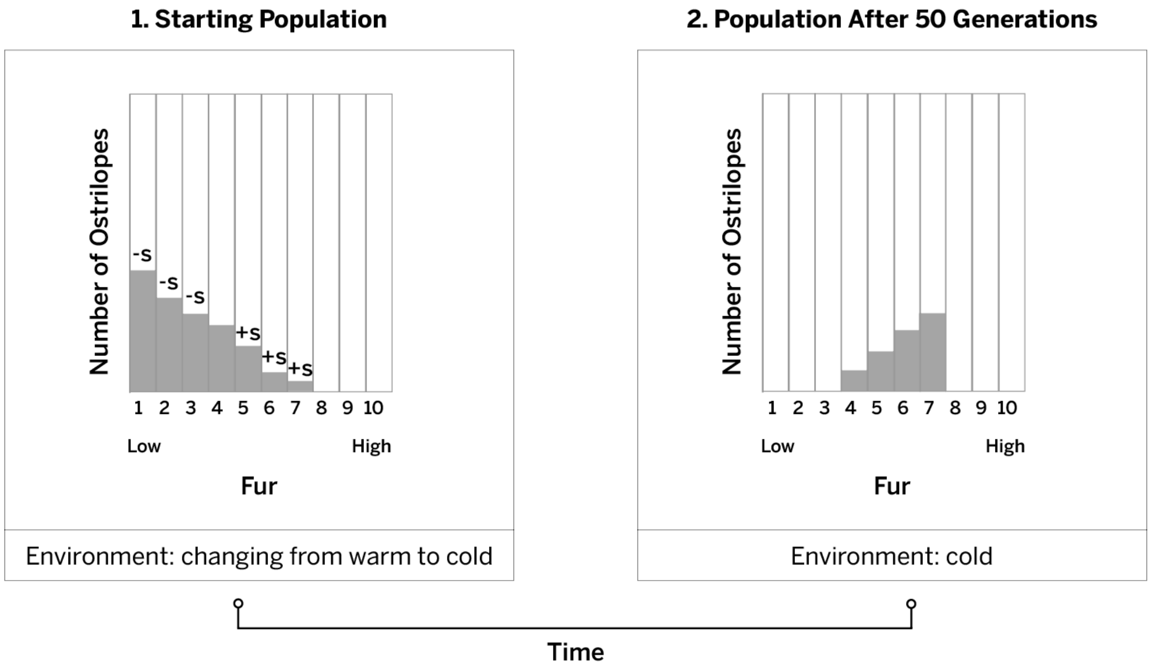
1. Open the Natural Selection Simulation https://apps.learning.amplify.com/naturalselection/naturalselection_74.html
2. Open the mode: Fur and Temperature A.
3. Change the temperature of the environment to cold (Level 1) by moving the Temperature slider.
4. Press RUN and observe the population for at least 50 generations.
5. Press ANALYZE and compare starting and ending histograms.

a. Why do you think the distribution of fur traits changed over time?

b. Which trait became more common over time? Why do you think this happened?

Fur and Temperature, Population A

Goal: Show how and why Population A changed after the environment changed from warm to cold.



Trait Labels

+s = **more** likely to survive **-s** = **less** likely to survive

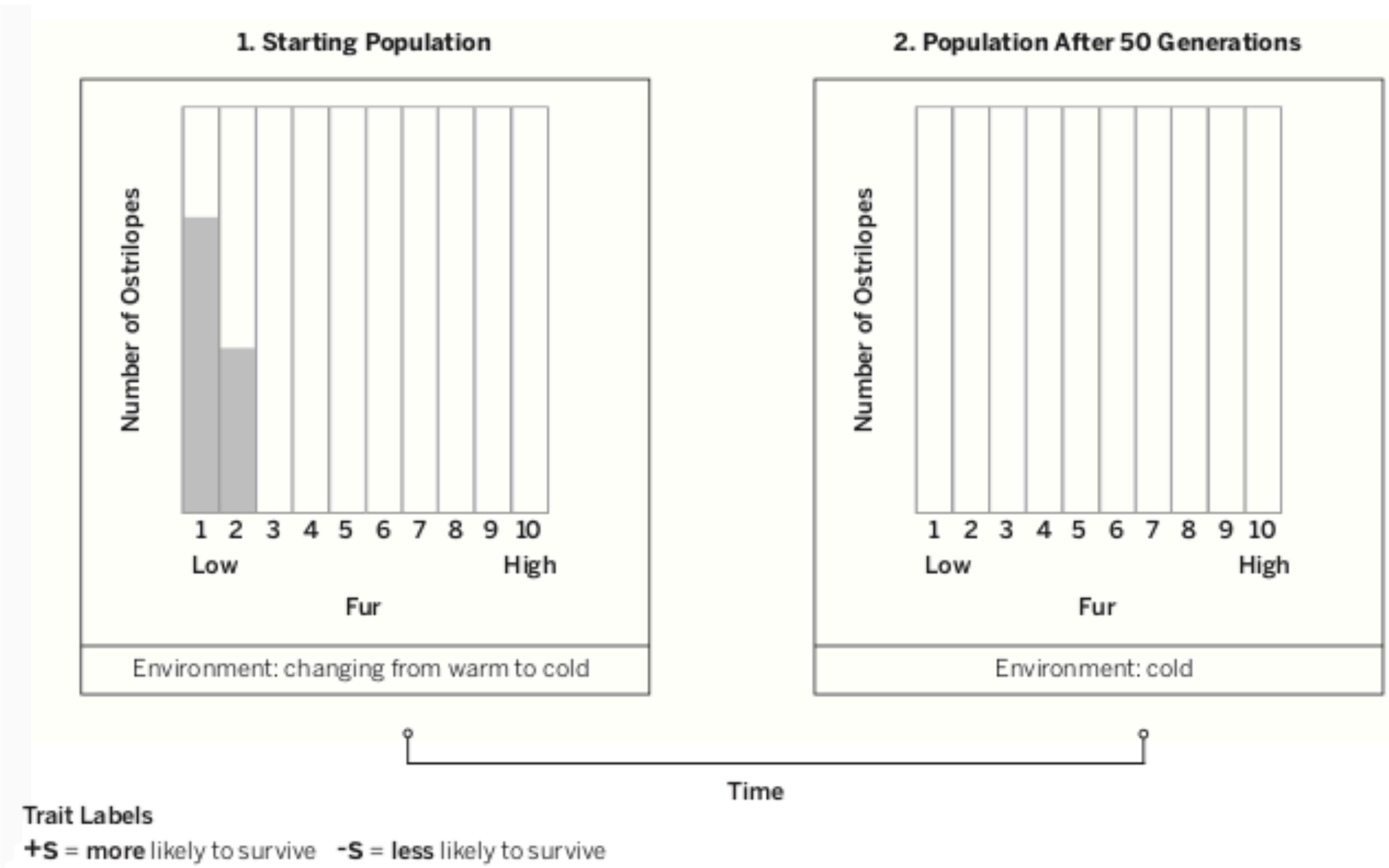
We just learned that traits for higher fur levels are adaptive traits in a cold environment because they help ostrilopes survive in cold environments. Lower fur-level traits make it difficult to survive in a cold environment. This means traits for lower fur levels are non-adaptive traits in cold environments. You will continue to investigate what causes the distribution of traits in a population to change as you create another model.

Predicting Fur Traits in a Cooling Environment

Show your prediction about how the distribution of traits in Population B will change as a result of the environment becoming cold.

Do: Analyze Histogram 1 and label that histogram with any Trait labels that apply.
Predict Histogram 2 by shading in the bars for the different trait levels.
TIP: You can use Trait labels more than once and you do not have to use all of them.

Fur and Temperature, Population B



For more information about histograms, watch the following video:
https://sites.google.com/a/ps207tigers.org/207sci/histograms

Testing Predictions in the Sim Simulating a Cooling Environment

Goal: Test your predictions about how the distribution of fur traits in Ostrilope Population B will change when the environment becomes colder over time.

Do:

1. Open the Natural Selection Simulation and open the mode: Fur and Temperature B.
2. Change the temperature of the environment to cold (Level 1) by moving the Temperature slider.
3. Press RUN and observe the population for at least 50 generations.
4. Zoom into the environment and observe several individuals with different traits.
5. Use the Traits Histogram Window to observe the distribution of traits in the population.
6. Press ANALYZE and compare starting and ending histograms.

a. Did Population B change in the way you predicted? Why or why not?

b. How did the fur-level trait compare in Population A and Population B? We saw in the second Sim activity that the distribution of traits in Population B could not shift like Population A did toward more individuals with high fur level. Why?

Task 3: Investigating Adaptive Traits in the Sim
LT: I can run a simulation in order to gather evidence to describe if color is an adaptive trait.

Is blending in with the environment always helpful for survival? Investigate this question in the Sim.
You will observe ostrilopes (yellow, green, and blue) in a yellow environment.

a. **MAKE A CLAIM: If blending in with the environment is always adaptive, which body-color trait do you predict to be adaptive?**

Investigating Environment A in the Simulation Do: 1. Open the Natural Selection Simulation and open the mode: Camouflage. 2. Under Biotic Factors: Carnithons, make sure Include Carnithons is selected. 3. Under Abiotic Factors, change the Surface-Color slider to Yellow Level 7. 4. Press RUN and observe ostrilopes with different color traits for 50 generations. You can also refer to the Traits Histogram Window while the Sim is running. 5. After 50 generations, press ANALYZE and compare the color traits in the starting ostrilope population to the population after 50 generations. Tip: Do not change the initial ostrilope distribution of traits.

b. Which ostrilopes were more likely to survive and become more common in the population? Which ostrilopes were less likely to survive and become less common in the population?

c. Explain what happened to the populations in both environments and why that supports or refutes the claim that yellow color is always an adaptive trait in a yellow environment.

Investigating Environment B in the Simulation
Do:

1. Open the Natural Selection Simulation and open the mode: Camouflage.

2. Under Biotic Factors: Carnithons, do not include Carnithons.

3. Under Abiotic Factors, change the Surface-Color slider to Yellow Level 7.

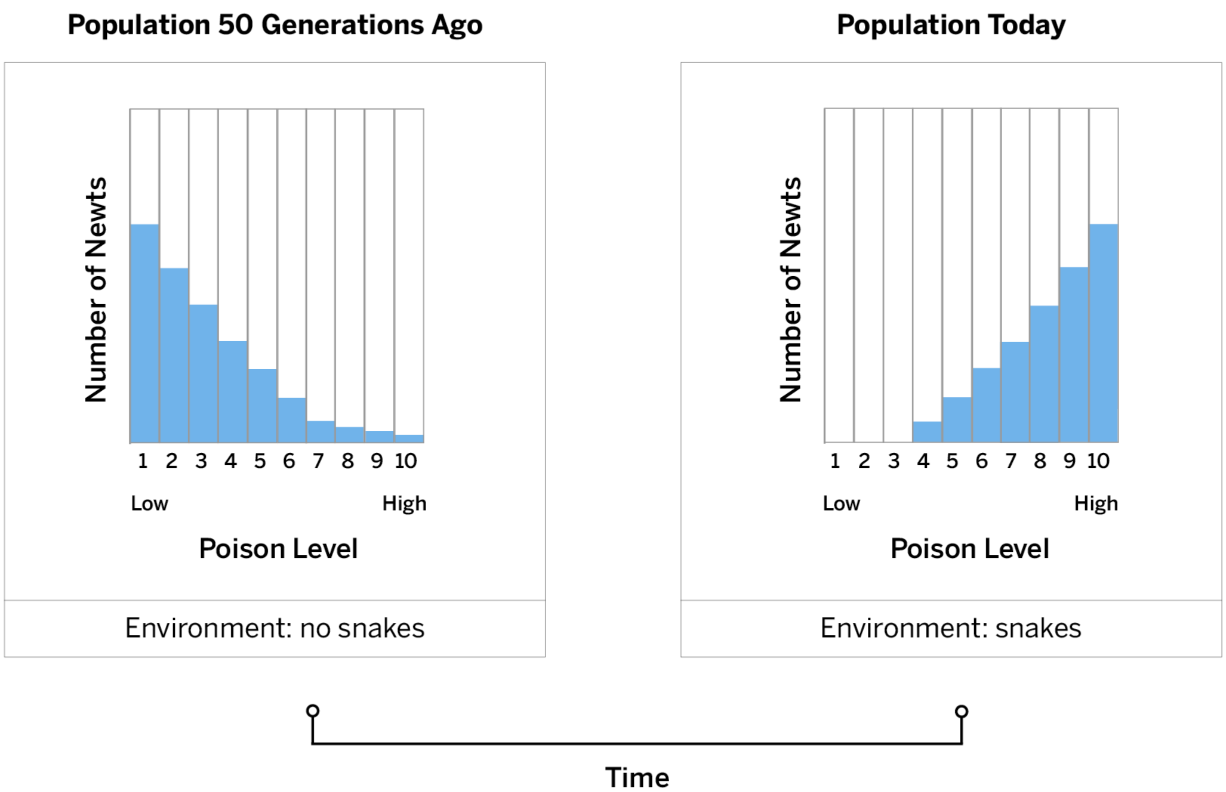
4. Press RUN and observe ostrilopes with different color traits for 50 generations. You can also refer to the Traits Histogram Window while the Sim is running.

5. After 50 generations, press ANALYZE and compare the color traits in the starting ostrilope population to the population after 50 generations.

d. Which ostrilopes were more likely to survive and become more common in the population? Which ostrilopes were less likely to survive and become less common in the population?

e. Explain what happened to the populations in both environments and why that supports or refutes the claim that yellow color is always an adaptive trait in a yellow environment.

Now, we will return to our population of newts. Let's consider what we know about the rough-skinned newts so far. We know the effect we're investigating is the changed distribution of traits in the newt population—there are more highly poisonous newts now than there were in the population 50 generations ago. Given everything we've learned about populations, variation, and trait distribution, let's review the evidence we have to think about the causes of this change.



How could these facts be related? Create a statement about how these facts might be related in a cause–and–effect relationship.

Task 4: Claims Revisited

LT: I can apply information gathered in a simulation to describe what caused a newt population to become more poisonous.

Dr. Alex Young would like to know about your progress in solving the mystery about the rough-skinned newts.
What caused this newt population to become more poisonous?
Use what you have learned so far to consider these claims:

Claim 1: Individual newts became more poisonous because they wanted to.

Claim 2: The newt population became more poisonous because of something in the environment.

Choose one or more claims to support with evidence and reasoning.
You may also want to explain why one or more of the claims is definitely not correct.
Be sure to use some of the vocabulary words you have learned so far:

- adaptive trait
- distribution
- environment
- non-adaptive trait
- population
- trait
- variation

To: Student Biologists
From: Dr. Alex Young, Head Biologist
Subject: Rough-Skinned Newts

I hope you are making progress in your investigation of the poisonous rough-skinned newts.

We're hoping to share an explanation with park visitors as soon as possible. Can you explain what you know so far about the newt population? We would really appreciate if you could send over a scientific argument that connects your evidence to your claim with reasoning. That will really help our visitors understand more about the newts.

Task 5: Investigating Reproduction

LT: I can run a simulation in order to gather evidence to describe if sexual reproduction results in offspring with adaptive traits.

Goal: Gather evidence to support or refute the claim that reproduction always creates individuals with adaptive traits.

Do:
1. Open the Natural Selection Simulation and open the mode: Reproduction Claims.
2. Press RUN to complete the data tables below.

Tips:
- Slow down and pause the Sim to carefully observe traits after reproduction.
- Reset the Sim between trials.
- If the ostrilope you are following gets eaten before it reproduces, select and follow a similar ostrilope.

Ostrilopes with adaptive traits (Yellow Color 7)
1. Select and follow an ostrilope that blends into its environment (one that has an adaptive color trait).
2. Follow the ostrilope until it reproduces. Pause the Sim.
3. Observe and record the color-trait level of both parents and the offspring in the data table below.
4. Reset the Sim. Repeat the above steps for Trial 2.

	Parent color-trait level	Parent color-trait level	Offspring color-trait level
Trial 1			
Trial 2			

Ostrilopes with non-adaptive traits
1. Select and follow an ostrilope that does not blend into its environment (one that has a non-adaptive color trait).
2. Follow the ostrilope until it reproduces. Pause the Sim.
3. Observe and record the color-trait levels of both parents and the offspring in a data table.
4. Reset the Sim. Repeat the above steps for Trial 2.

	Parent color-trait level	Parent color-trait level	Offspring color-trait level
Trial 1			
Trial 2			

a. Does reproduction always create individuals with adaptive traits? Explain.

Task 6: Population Traits Text Resources

LT: I can use text evidence to describe how traits vary within a population

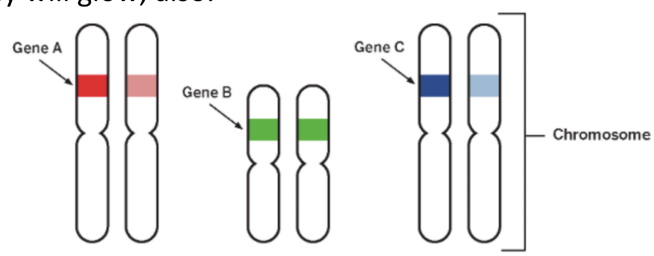
Glowing Jellies

Imagine splashing in a calm ocean cove at night. As you splash, you notice green flashes in the water: glowing jellies! These are called crystal jellies. They can't sting humans, so you can swim and watch them glow green as you bump into them.

Where does this trait of being able to glow come from? In 1992, some scientists decided to find out. They examined the cells of crystal jellies and discovered that the glow comes from a protein. They gave the protein the name Green Fluorescent Protein, or GFP for short. To find out how these jellies make GFP, scientists investigated the jellies' genes. A gene is instructions for an organism's cells to make a particular protein. Scientists were able to find the gene that gave the jellies' cells instructions to make the GFP protein.

If a jelly has the GFP gene, its cells can make green fluorescent protein. If its cells make green fluorescent protein, the jelly can glow. The gene leads to the protein, which leads to the trait.

How does a jelly get the gene for glowing? When a pair of adult jellies reproduce, each one passes down genes to the offspring. Genes are found on chromosomes and chromosomes come in pairs. An organism has two copies of any given gene because there is one copy on each chromosome in a pair. However, the two copies of any particular gene can be the same version or different versions. These different versions of a gene are called alleles. When jellies reproduce sexually, each parent passes down one of each of their chromosomes (with all their genes on it) to the offspring. If at least one of the adult jellies has the version of the gene that is instructions for GFP, then that gene could be passed down to the offspring. Offspring with that gene will have cells that produce GFP, so they will glow, also.



This diagram shows three pairs of chromosomes. Chromosomes have many genes, but in this diagram only shows one for each chromosome. There are two copies of each gene, one on each chromosome of the pair. When an organism reproduces sexually, it gives the offspring one of each of its chromosomes and therefore one copy of each gene.

Scientists think that jellies glow as a defense against predators. The bright glow might startle or confuse predators, or it might attract bigger predators that could scare away or eat the jelly's attacker! Glowing is an adaptive trait for jellies because it helps them survive in their environment.

1. Where do the genes that determine an individual's traits come from?

2. How do genes determine an individual's traits?

3. How can an individual be born with an adaptive trait?

The Deadly Dare

Rough-Skinned Newt Defenses

Rough-skinned newts may look harmless, but they are extremely poisonous.

In 1979, friends dared a 29-year-old man in Oregon to swallow a living rough-skinned newt. The man didn't realize how poisonous rough-skinned newts are. A lethal, fast-acting poison called tetrodotoxin (TTX) oozes from their skin. The man swallowed the newt whole and started feeling weak a few minutes later. He described a numb feeling all over his body. His friends tried to take him to a hospital, but he refused. Just 20 minutes later, the man was dead.

Of course, the newt the man swallowed died, too. In that particular case, being poisonous didn't help that individual newt survive. If newts have to be eaten in order to defend themselves, being poisonous doesn't sound like a very good defense! How is being poisonous—having a high level of TTX poison—an adaptive trait for a rough-skinned newt?

Why Poison Is Adaptive

One reason TTX is adaptive is that it acts quickly. A predator that tries to eat a poisonous newt may become sick before it's able to kill the newt, allowing the newt to escape. In fact, TTX acts so quickly that sometimes predators die before finishing their meals. Scientists have observed rough-skinned newts crawling out of dead or paralyzed predators.

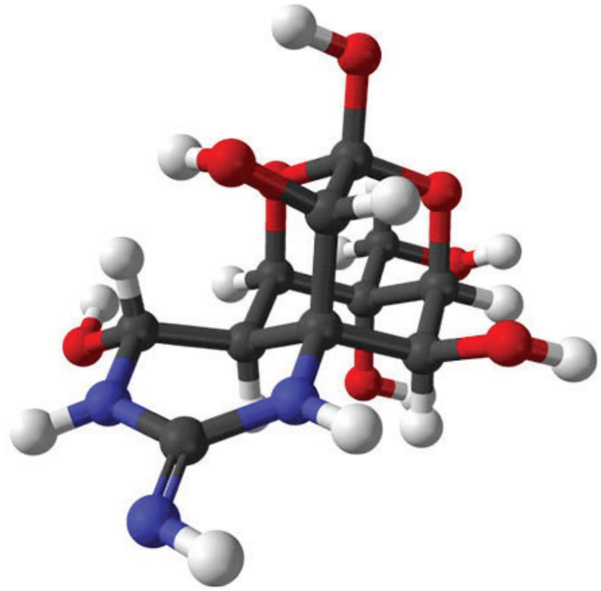
Even more important, predators can smell and taste TTX poison. The main predator of rough-skinned newts is the garter snake. Scientists have found evidence that garter snakes use their senses of smell and taste to tell whether a rough-skinned newt is too poisonous to eat. They have even observed garter snakes doing quick "taste tests"—licking rough-skinned newts before deciding whether to eat them.

Scientists have studied whether garter snakes are able to detect TTX poison in newts. Biologists have placed one newt and one garter snake together in a cage to see whether the snake would eat the newt. They have tried this test over and over again, using different snakes and different newts. Even though the newts are placed directly in front of the snakes, not every newt gets eaten! Biologists are able to consider the cause-and-effect relationship between high poison levels and survival in newts by examining a population of newts with high variation. The newts in the test range from having no poison to having very high levels of TTX in their bodies. In these tests, the snakes consistently eat the newts with the lowest levels of TTX, and do not eat the newts with high levels of TTX. These results are evidence that garter snakes can detect TTX and that they prefer to eat rough-skinned newts with lower levels of TTX. The more poisonous a rough-skinned newt is, the less likely it is to be eaten by a garter snake. That means high levels of TTX are an adaptive trait in rough-skinned newts that live near garter snakes.

The common garter snake is one predator that eats rough-skinned newts.

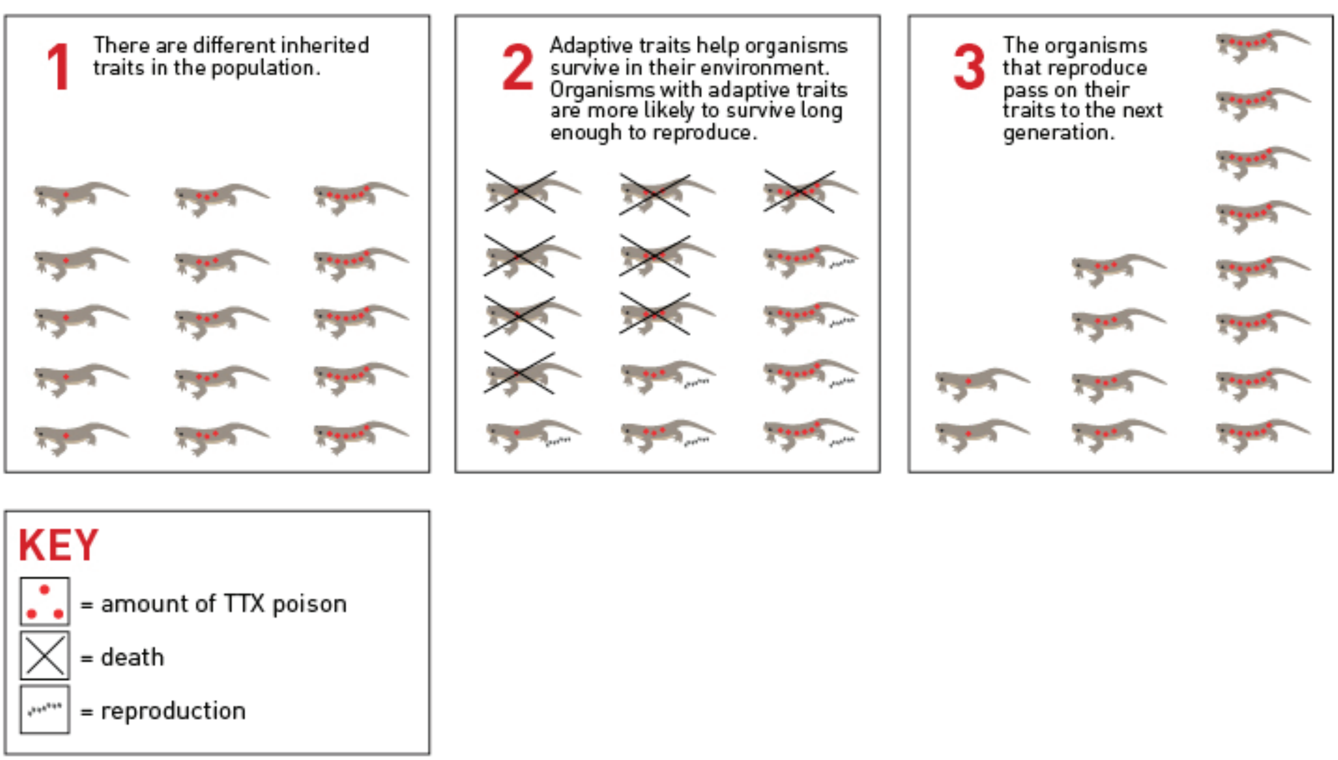
How Adaptive Traits Spread

If snakes are in its environment, a poisonous newt is less likely to die from being eaten than a newt that isn't poisonous. The newts that don't get eaten have a better chance of living longer, and that's important because it means more chances to reproduce. Organisms have to reproduce in order to pass on their genes, which are the instructions for making the protein molecules that determine traits: if they don't reproduce, their traits die with them. In the newt population, more poisonous newts are more likely to survive long enough to reproduce and pass down their genes, and therefore the trait of being poisonous, to the next generation. As a result, there will be more and more highly poisonous rough-skinned newts in each generation. This will cause the distribution of traits in the population to change over many generations. Scientists call this process natural selection. This process does not only happen in rough-skinned newts. It has been observed in populations of different species all over the world.



A rough-skinned newt's poison is a type called tetrodotoxin, or TTX for short. This is a model of a molecule of TTX.

How Natural Selection Works



Other Poisonous Organisms

Being poisonous is an adaptive trait for many different organisms, not just rough-skinned newts. There are many poisonous plants, such as deadly nightshade, hemlock, and mint. You might be surprised to see mint on this list, since you've probably eaten mint yourself! The poisons in mint are harmless to humans, but deadly to some plant-eating insects. These poisons are what give mint its minty taste and smell—they are warning signals telling insects to stay away.

Like rough-skinned newts, poisonous plants are poisonous as a defense against being eaten. Plants can't run away from animals that want to eat them, so they have to defend themselves in other ways—with adaptive traits like tough bark, sharp thorns, and being poisonous.

Deadly nightshade (left) is an extremely poisonous plant; eating just a few berries can kill a human. Mint (right) is harmless to humans, but deadly to some insects.

Besides poison, plant defenses include sharp thorns and thick bark.

1. Which individuals are most likely to die before reproducing, those with adaptive traits or non-adaptive traits? Why? (Hint: You may use the newt population as an example in your explanation.)

2. When many individuals with the same trait die before reproducing, what happens to the distribution of that trait in the population? Why?

3. Why are there more newts with a high-poison level in the population in Diagram 3 than in the population in Diagram 1?

4. Are the newts with high poison in Diagram 3 simply the oldest newts? How do you know?

Task 7: <u>**Mutations (Text)**</u>

LT: I can use text evidence to describe if traits created through mutations are adaptive.

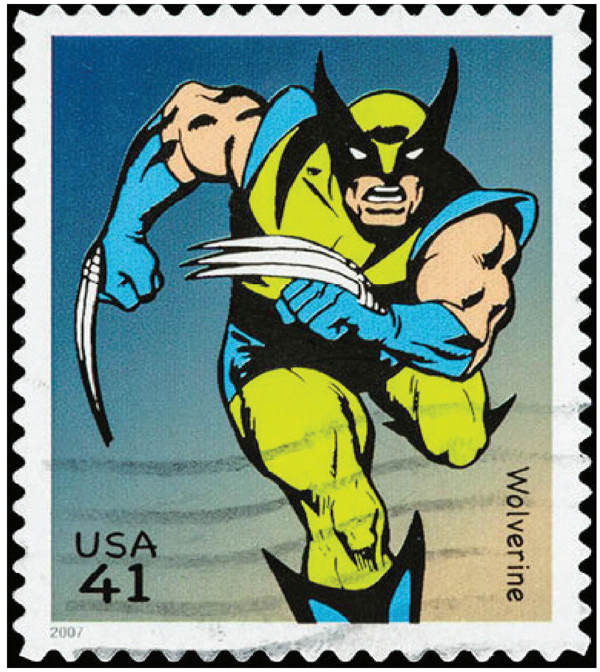
Mutations: Not Just for Superheroes

Chapter 1: Movie Mutations

In movies, mutations are always exciting: they might give someone special powers or extra limbs. However, real mutations can be very boring: they might not have any noticeable effect at all. What is a mutation, anyway? The answer has to do with genes and the way they are passed down when organisms reproduce.

Genes are instructions for making protein molecules, and those protein molecules determine an organism's traits. When organisms reproduce, they pass down copies of their genes to their offspring. However, the copies aren't always perfect: as genes are duplicated, changes can occur. These changes are called mutations, and they can be passed from parent to offspring when organisms reproduce. Most of the changes are minor and don't affect traits at all, but every once in a while, mutated genes give instructions to make a new protein molecule that leads to a new trait in the offspring.

The new traits that arise from mutations may be adaptive or non-adaptive, or they may have no effect on survival and reproduction. It all depends on the organisms' environment. If a new trait makes organisms less likely to survive and reproduce in their environment, the trait is non-adaptive. Organisms born with that trait don't have a very good chance of surviving long enough to reproduce and pass their mutated genes down to the next generation. If they don't pass the mutated genes down, they don't pass the new trait down either. Mutated traits that are non-adaptive usually remain uncommon in the population.



In movies and comic books, mutations make people into superheroes. In the real world, mutations often have no visible effect at all.

On the other hand, mutated genes sometimes result in a new trait that turns out to be adaptive. Adaptive traits help organisms survive and reproduce in their environments. If a mutation results in an adaptive trait, organisms with that trait are more likely to reproduce and pass on their mutated genes to the next generation.

Through natural selection, adaptive traits become more and more common in the population over time. A trait that is adaptive in one environment may be non-adaptive in another, and that's what makes mutations so important. Environments don't stay the same forever. Mutations can introduce new traits, increasing the chance that one of those traits might help make a population better able to adapt to a changing environment. To learn more about mutations, you can explore one or more of the following chapters.

Chapter 2: Revenge of the Bed Bugs

They creep into your bed at night and suck your blood, then crawl back to hide in their lairs... Bed bugs are seriously creepy! These tiny insects live in walls and furniture, and they survive by feeding on the blood of humans. Bed bugs have been a problem for humans for thousands of years. In the past, people didn't have any good way of attacking bed bugs—these insects hide during the day, only coming out at night when people are sleeping. People couldn't kill bed bugs by leaving poison for them to eat, because they won't eat anything but blood.

Then, in the 1940s, the situation changed: people invented new insecticides that were very effective at killing bed bugs. Like all insects, bed bugs have hard exoskeletons covering their bodies like suits of armor. However, the new insecticides penetrated the bed bugs' exoskeletons, killing bed bugs even if they just touched the insecticide. People sprayed these new insecticides wherever bed bugs were found, and killed huge numbers of bed bugs.

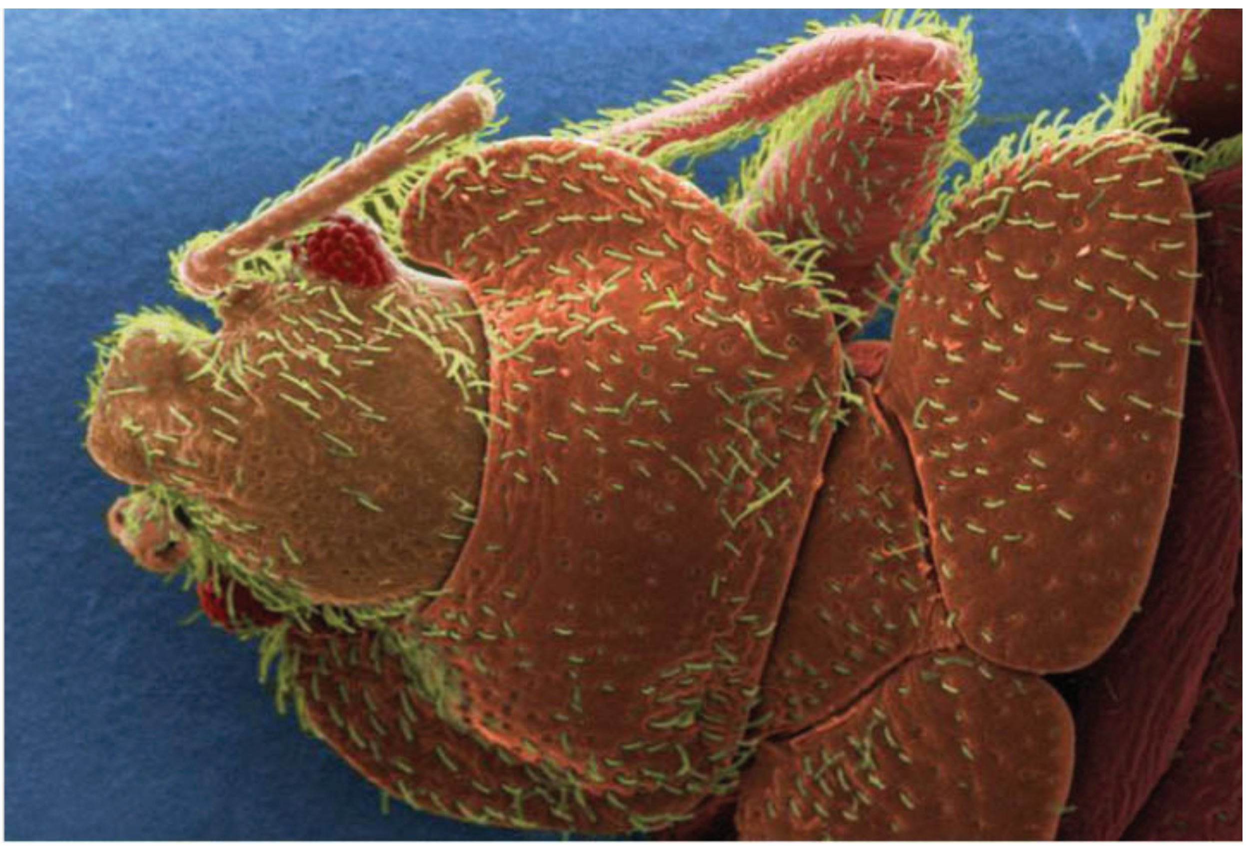
The insecticides didn't kill all of the bed bugs, however. In fact, they caused some effects that people hadn't predicted. Some bed bugs survived—mostly the individuals lucky enough to have extra-tough exoskeletons that were harder for insecticides to penetrate. These tough-skinned bed bugs began reproducing. Today, bed bugs with extra-tough exoskeletons are becoming more and more common in the bed bug population.

Scientists have studied the genes of tough-skinned bed bugs and compared them to the genes of ordinary bed bugs. They discovered mutations to several genes in the tough-skinned bed bugs. The mutations give the cells instructions to make protein molecules different from the protein molecules that other bed bugs can make. These new

Bed bugs live inside walls and furniture and survive by feeding on the blood of humans.

protein molecules all affect the exoskeleton in different ways, strengthening the bed bugs' armor. Before these mutations appeared in the bed bug population, there weren't any bed bugs with the trait of armor strong enough to resist insecticides.

The bed bugs' environment changed when people started using the new insecticides. However, a mutated trait in the bed bug population turned out to be adaptive in the bed bugs' new environment, so it helped the bed bugs with that trait survive. In the bed bugs' new insecticide-filled environment, stronger armor is an adaptive trait that helps them survive. Organisms with stronger armor are more likely to survive and reproduce, so they are more likely to pass on their mutated genes—and their adaptive traits. Through the process of natural selection, tough-skinned bed bugs are becoming more common with each new generation. Ironically, people's use of insecticide has produced a stronger bed bug population!



All bed bugs have exoskeletons, but some exoskeletons are thicker than others due to mutations.

Chapter 3: Cane Toad Invaders

Huge poisonous toads have invaded Australia! Humans brought cane toads from Asia to Australia in the 1930s, hoping the toads would eat beetles that were destroying crops. Unfortunately, the toads didn't eat many beetles. They ate almost anything else that could fit into their mouths, however. These big toads grow up to 22 centimeters (9 inches) long and weigh up to 1.8 kilograms (4 pounds). Cane toads are extremely poisonous, and no Australian predators can survive eating them. Without predators in their new environment, the cane toad population began growing and spreading. Today, cane toads are common in areas more than 1,500 kilometers (932 miles) from the place where they were first introduced to Australia.

Because there are so many cane toads in Australia, they compete with each other for food. The cane toads are eating everything in sight, so food becomes scarce in any area where they live. To survive, cane toads have to keep moving into new areas with more food sources. The first toads to reach new territory get to eat all the food they want. Slower toads are stuck with whatever is left.

Recently, Australian scientists have been finding cane toads with bigger, more muscular legs. These bigger legs can be traced back to mutations that changed the toads' genes. Scientists compared the big-legged toads to ordinary cane toads. They identified several gene mutations that gave the cells instructions to make protein molecules that were different from the protein molecules that other toads could make. These new protein molecules affected the cane toads' legs, increasing the leg size and strength. Having bigger legs is an adaptive trait that helps cane toads survive in an environment where there isn't much food to go around. Bigger, stronger legs help these toads outrun other cane toads and be the first ones to get to the food in new areas. With better chances of getting food, big-legged toads are more likely to survive and reproduce. Because of this, they are also

Cane toads like this one can grow up to 22 cm (9 in) long and weigh up to 1.8 kg (4 lbs).

more likely to pass on their mutated genes to their offspring. Along with these mutated genes, they pass on their adaptive traits.

When humans introduced cane toads to Australia, the cane toads' environment changed. With no predators hunting them in their new environment, there were more cane toads and therefore much less food was available. However, mutations led to a new trait in the population that turned out to be adaptive in the new environment. The mutated trait for bigger legs was adaptive for cane toads in an environment with scarce food because it helped them get more food and survive. Through the process of natural selection, big-legged cane toads are becoming more and more common in the cane toad population. These stronger, faster toads are spreading across Australia, invading new areas all the time.

Through the process of natural selection, cane toads with big, strong legs are becoming more and more common in the cane toad population.

Chapter 4: Red Lobster, Blue Lobster

What color are lobsters? In pictures, they're usually red. However, that's only after they've been caught and cooked. When they're alive and living in the ocean, lobsters are usually a greenish brown that blends into the ocean floor—except when a genetic mutation causes them to be bright blue! About one in every two million wild lobsters is blue in color. Why? A genetic mutation caused the lobster's body to produce more of a certain protein molecule than usual, which turned its shell blue instead of the normal brownish green. This mutation introduced a new trait into the lobster population: bright blue shells.

Most lobsters are greenish-brown.

Having a blue shell may sound like the kind of trait that might make a lobster less likely to survive in its environment. After all, blue lobsters don't blend into their environment as well as greenish-brown ones do. However, research shows that being blue doesn't seem to make the blue lobsters any more or less likely to survive in their environments. In the 1990s, scientists studied blue lobsters: they mated a female blue lobster with a male blue lobster, producing all blue offspring. They released the offspring into the wild and studied them to see whether they survived at the same rates as lobsters with normal greenish-brown coloring. The scientists found no difference in the blue lobsters' survival rates compared with normal lobsters. The genetic mutation that results in blue shells appears to be a neutral mutation—that is, the trait is not adaptive in the environment, but it's not non-adaptive either. Blue shells seem to have no effect on survival and reproduction.

About one in every two million lobsters has a mutation that causes its shell to be bright blue.

The trait for blue shells has not caused a big change in the lobster population. The mutated trait still passes from one lobster generation to the next, just like the traits for greenish-brown shells. Lobsters with blue shells are just as likely to survive as lobsters with greenish-brown shells, so lobsters with these two color traits are likely to have about the same number of offspring. That means that the mutated trait has become neither more common nor less common in the population.

Lobsters also come in other colors: occasionally, people catch lobsters that are yellow, orange, red, or white! All of those other colors are also caused by genetic mutations. These rare lobsters' colors make them stand out in a crowd of living lobsters, but once cooked, colorful lobsters look just like their brownish-green relatives: like nearly all other lobsters, they turn bright red when boiled. (The only lobsters that don't turn color when they're cooked are extremely rare albino lobsters, which have no coloring at all.)

For each organism (bed bug, Cane Toad and lobster) answer the questions below:

1. How did the population change?

2. What was the cause?

3. What was the effect?

<u>Task 8: Mutations (SIM)</u>
LT: I can collect SIM evidence to describe if traits created through mutations are adaptive.

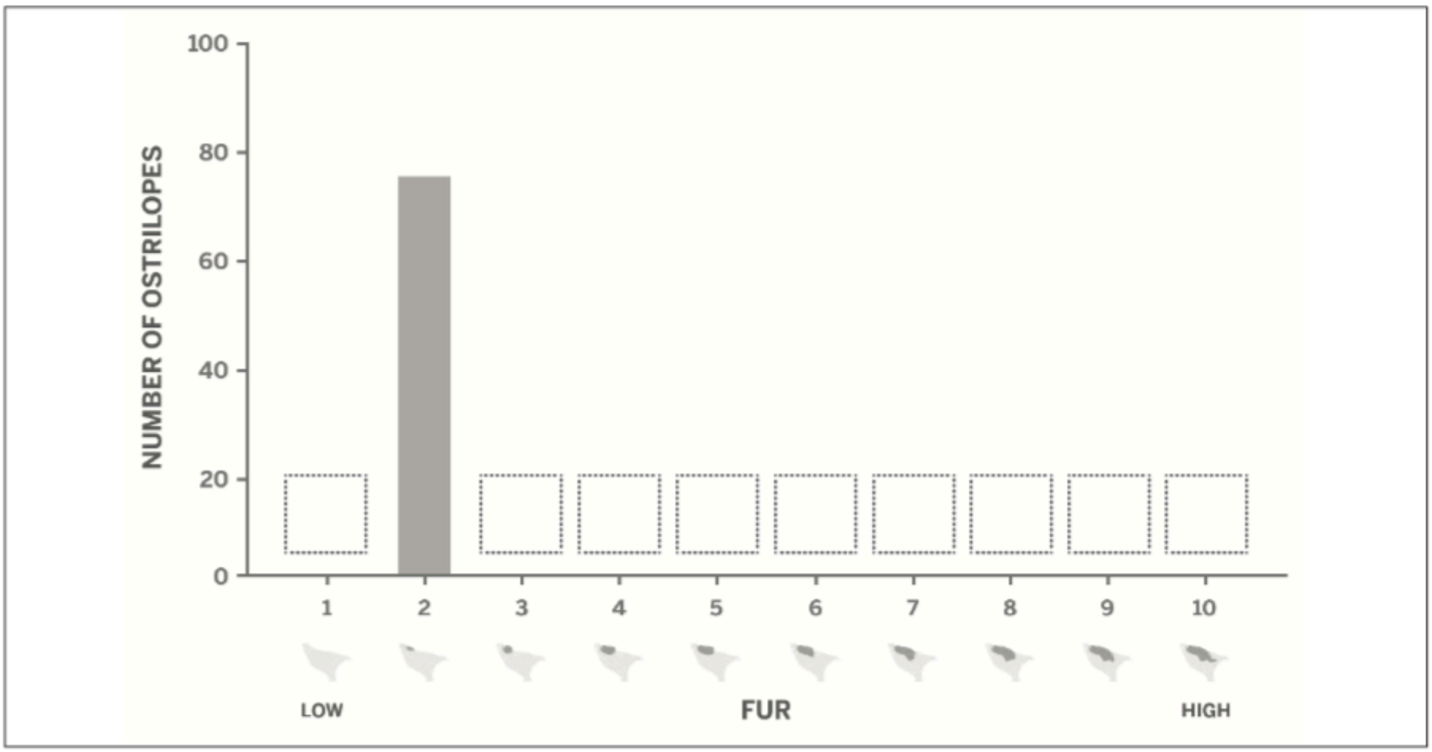
Investigating Mutant Fur Traits in the Sim Observing Mutations in the *Natural Selection* Simulation

In the Sim activity that follows, you will investigate a low-fur population of ostrilopes with the trait distribution shown in the histogram below.

- In the Sim, you will be able to turn on mutations for fur traits.
- You will make the environment for this population cold.

Before you do this, study the histogram below and answer the question that follows.

Part 1: Making a Prediction
Think about which new traits would be adaptive and non-adaptive in a cold environment. Label any traits that would be adaptive with an A. Label any traits that would be non-adaptive with an NA.



1. Are all traits that are introduced by mutations adaptive? Do you think non-adaptive traits can be introduced into a population through mutations? Why or why not?

Part 2: Testing Predictions in the *Natural Selection* Simulation

Goal: Perform tests in the Sim to see if mutations can introduce both adaptive and non-adaptive traits into the population.

Do:

1. Open the *Natural Selection* Simulation and open the mode: Mutations and Traits.
2. Change the temperature of the environment to cold (Level 1) by moving the Temperature slider.
3. Turn ostrilope fur-trait mutations on by pressing the Ostrilope icon and pressing the Mutations toggle.
4. Press RUN and observe the population for at least 50 generations.
5. Press ANALYZE and use the Generations slider to carefully observe new traits in the population.

Tips:
Press the Histogram icon in the lower-left corner of Run to observe the introduction of traits into the population.

Look for the red indicator above the heads of ostrilopes that are born with mutant traits.

Look at an ostrilope fur-trait histogram from Generation 50 or above and determine if there are any adaptive traits that were introduced through mutations.

a. How do you know the traits you identified in the histogram were adaptive?

b. Look at an ostrilope fur-trait histogram from Generation 5 and determine if there are any non- adaptive traits that were introduced through mutations. How do you know the traits you identified in the histogram were non-adaptive?

c. Are all traits that are introduced by mutations adaptive? Do you think non-adaptive traits can be introduced into a population through mutations? Why or why not?

Task 9: Reasoning About the Rough-Skinned Newts

LT: I can make connections between evidence sources and claims in order to explain how a population of newts became more poisonous.

Evidence

A. Sometime between 50 generations ago and today, ___________________ became part of this newt population's environment.

This matters because . . .

> The newts that are the ____________________ common are the ones that have ____________________ traits to help them avoid being eaten by snakes.

Evidence

B. 50 generations ago, most newts had the trait for Poison Level __________________. Today, most newts have the trait for Poison Level __________________.

This matters because . . .

> The distribution of traits changing in a population is an effect caused by natural selection. This evidence suggests that Poison Level _______________ is the adaptive trait for today's environment.

Evidence

C. 50 generations ago, some newts had each of the poison-level traits. Today, no newts have the trait for Poison Level ________________.

This matters because . . .

> A trait disappearing from a population is an effect caused by that trait being ____________________. This evidence suggests that newts with Poison Level 1 do not live long enough to _________________ and pass their genes to their __________________________.

Evidence

D. From "The Deadly Dare": "Even more important, predators can smell and taste TTX poison. The main predator of rough- skinned newts is the ____________________. Scientists have found evidence that garter snakes use their senses of smell and taste to tell ____."

This matters because . . .

> This evidence suggests that Poison Level 10 is the most _______________ trait for this environment, meaning newts with Poison Level 10 tend to have the longest lives and are able to ________________ the most, which means they pass their _______________ to the most offspring in the next generation.

Therefore, . . .

> The newt population became more poisonous because the ___________________ in this environment caused poison to be a(n) ______________________ trait, and Poison Level 10 is the most common because the newts with this trait were able to live longer and reproduce more than other newts.

<u>Task 10:</u>
LT: I can analyze and describe evidence that supports a claim explaining the causes for a population change, an event of natural selection.

The Stickleback Fish in Its Environment

Sticklebacks are small fish with sharp spines that stick up from their backs.

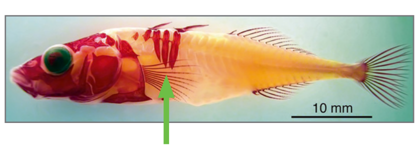
Sticklebacks are small fish—a full-grown stickleback is usually only about 5 centimeters (2 inches) long. These little fish live in two very different environments: the quiet lakes and ponds of Oregon and the huge Pacific Ocean. As you might guess from their name, stickleback fish have sharp spines sticking up from their backs. Unlike many other fish, sticklebacks don't have scales: instead, they have bony plates of armor protecting their bodies. Sticklebacks can have just a few plates of armor for protection, or they can have many—and the less armor a stickleback has, the faster it swims.

This is what three-spined sticklebacks look like.

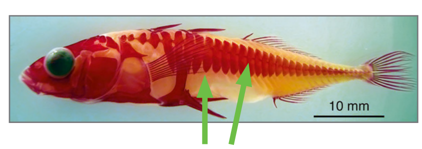
less armor, faster

more armor, slower

These are three-spined sticklebacks that have been stained to show their plates of armor.



plates of armor



plates of armor

These sticklebacks look identical from the outside, but take a closer look: the fish skeletons on the bottom have been stained to show their plates of armor.

What Do Sticklebacks Eat?

Stickleback fish may be small, but they are fierce predators. Sticklebacks catch and eat small animals such as worms, small shrimp, insect larvae, fish eggs, and young fish—including young sticklebacks.

Sticklebacks eat tiny water animals like these.

What Eats Sticklebacks?

Predators that eat sticklebacks include other fish, birds, and a predator you might not expect: dragonflies! As adults, green darner dragonflies have thin green bodies, large eyes, and four transparent wings. However, these insects actually spend most of their lives underwater! They first hatch as wingless nymphs, with gills for breathing underwater. Green darner dragonfly nymphs often catch and eat sticklebacks.

How can an insect eat a fish? Green darners are large—the nymphs can grow to 5 cm (2 in) long, which is bigger than some fish. They are fast, too—green darner nymphs shoot jets of water out of their bodies to move quickly underwater. They also have big jaws, which they use to catch young fish, insects, and tadpoles. Sticklebacks are so small that dragonfly nymphs are one of their main predators in lakes and ponds.

Green darner dragonfly nymphs have big jaws that allow them to eat fish.

Another important predator of sticklebacks is the Chinook salmon. Chinook salmon hatch in rivers, but they swim out to the ocean and live most of their lives there. When they are ready to reproduce, the salmon travel back to the rivers where they first hatched. Because they live in both rivers and the ocean, Chinook salmon are comfortable in both salt water and freshwater—just like sticklebacks.

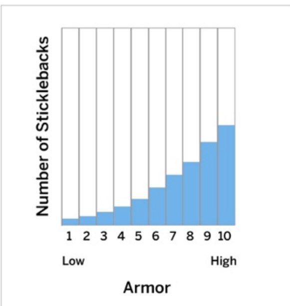
Chinook salmon are big, strong fish. They are the largest species of salmon in the western United States, weighing up to 55 kilograms (120 pounds)! These big fish eat mostly smaller fish, including little sticklebacks.

Chinook salmon are big fish that can live in both salt water and freshwater.

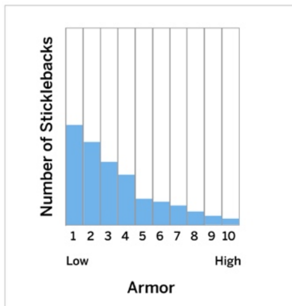
Stickleback Armor

Armor Traits Distribution Over Time

Stickleback Population When They Arrived 13 Generations Ago



Stickleback Population Now



Sticklebacks with Armor, Stained Red

Very high amount of armor: 30 plates

High amount of armor: 20 plates

Low amount of armor: 5 plates

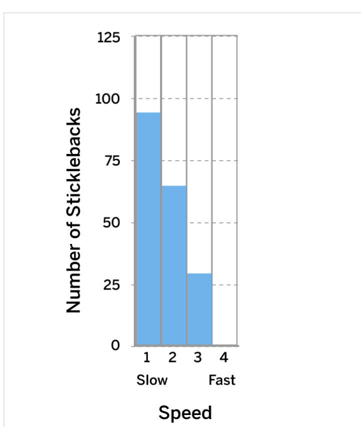
Very low amount of armor: 4 plates

Scientists can clearly see and count the plates of armor of a stickleback fish by using a special stain that colors the armor. In this photo, you can see the armor plates in red.

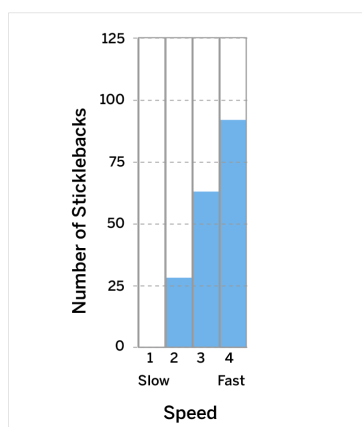
The individuals in the stickleback population 13 generations ago had many plates of armor; they were considered to have high levels of armor. Over time, the individuals have developed less armor.

As you can see, most of the individuals now have only four plates of armor. They are considered to have low levels of armor. Scientists found that sticklebacks with low levels of armor are faster swimmers than sticklebacks with high levels of armor.

Population 13 Generations Ago



Population Now



As you can see in this histogram, most of the sticklebacks in the population were slow swimmers 13 generations ago. Now, most of the sticklebacks are fast swimmers.

Scientists do not know why this drastic change occurred. However, they do know that when sticklebacks have less armor, they are able to swim faster. There are a few reasons why swimming faster could be helpful for sticklebacks.

Some biologists think the change in sticklebacks has more to do with their ability to escape predators. Others think it is so they can catch prey.

What caused the stickleback population to have less armor and become faster?
Use the evidence cards to support either claim:
Claim 1: The sticklebacks have less armor so that they can escape predators.
Claim 2: The sticklebacks have less armor so that they can catch prey.

Evidence Card A: Average Life Span of Sticklebacks in Current Environment

Armor level	Speed	Average life span
low armor	fast	4 years
medium armor	medium	2 years
high armor	slow	1 year

Reproduction: Most sticklebacks reproduce about once a year.

Evidence Card B: Stickleback Predators

Previous Environment
Stickleback predator: salmon

The sticklebacks' main predators used to be salmon. Salmon catch their prey by trapping them in their large, strong jaws. They do not need to be as fast as dragonfly nymphs to catch sticklebacks.

Current Environment
Stickleback predator: dragonfly nymph

The sticklebacks' main predator is now the dragonfly nymph. Dragonfly nymphs use a burst of speed to attack their food.

Evidence Card C: Prey Speed

Previous Environment

Stickleback prey:
In their previous environment, sticklebacks used to eat fish eggs, seed shrimp, and copepods (a type of very small crustacean).

fish eggs | **seed shrimp** | **copepods**

Speed:

very slow	fast	very fast

Current Environment

Stickleback prey:
In their current environment, sticklebacks eat fish eggs, snails, and water fleas.

fish eggs | **snails** | **water fleas**

Speed:

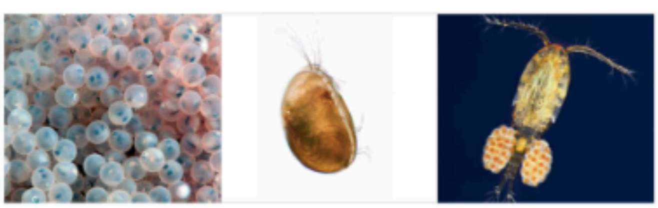
very slow	slow	medium

Evidence Card D: Prey Population Size

Previous Environment

Stickleback prey:
In their previous environment, sticklebacks used to eat fish eggs, seed shrimp, and copepods (a type of very small crustacean).

fish eggs | **seed shrimp** | **copepods**



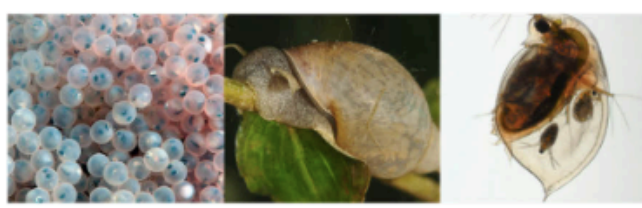
Population Size:

very large	small	very small

Current Environment

Stickleback prey:
In their current environment, sticklebacks eat fish eggs, snails, and water fleas.

fish eggs | **snails** | **water fleas**

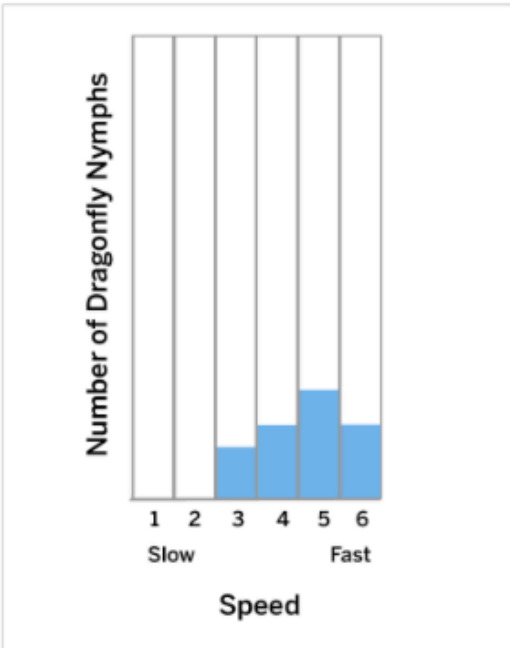


Population Size:

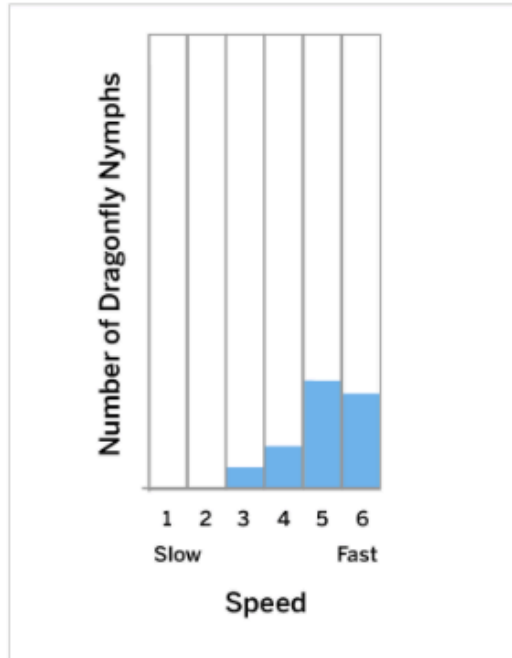
very small	small	very large

Evidence Card E: Speed of Dragonfly Nymphs

Before Sticklebacks Arrived

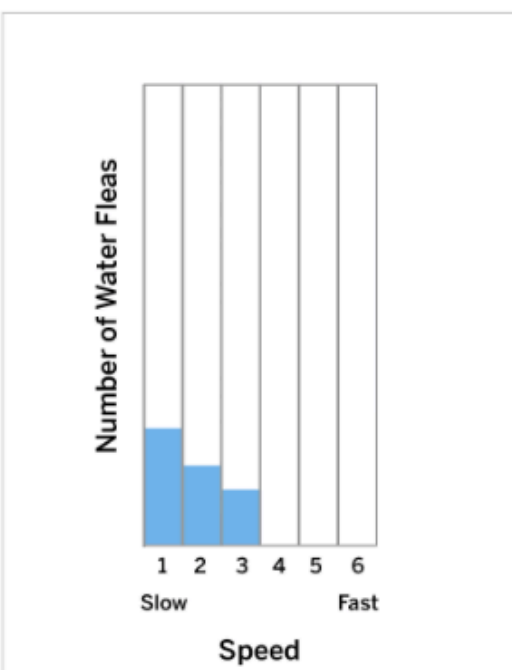


After 13 Generations of Sticklebacks in the Lake

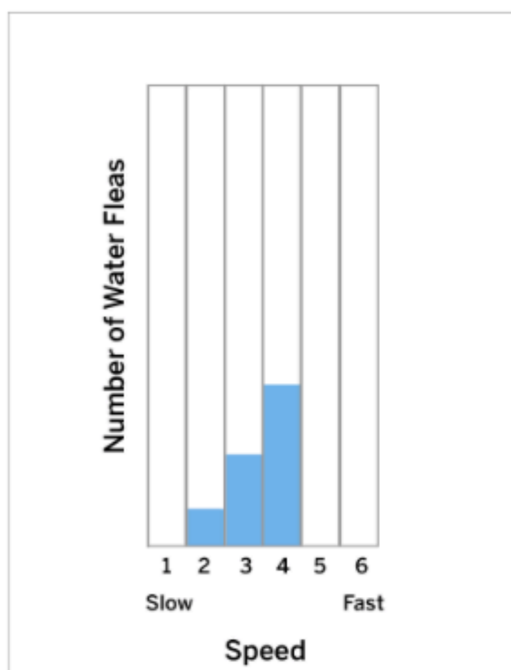


Evidence Card F: Speed of Water Fleas

Before Sticklebacks Arrived



After 13 Generations of Sticklebacks in the Lake



Write a scientific argument that addresses the question:
What caused the stickleback population to have less armor and become faster?
-State your claim and show how it could explain the change in the population.
-Then, use evidence to support your claim.
-To make your argument more convincing, be sure to consider the following questions:

- Does your argument clearly explain why the distribution of traits have shifted so much in the stickleback population?
- Do you describe your supporting evidence?
- Do you thoroughly explain how the evidence supports your claim?