High School Science Enrichment

1 of 3

Wayne-Westland
COMMUNITY SCHOOLS

Science Enrichment Contents

Science Enrichment

Section 1

Nuggets and CER

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DATA Nugget

The ground has gas!

Featured scientist: Iurii Shcherbak from Michigan State University

Research Background:

If you dig through soil, you'll notice that soil is not hard like a rock, but contains many air pockets between soil grains. These spaces in the soil contain gases, which together are called the **soil atmosphere**. The soil atmosphere contains the same gases as the atmosphere that surrounds us above ground, but in different concentrations. It has the same amount of nitrogen, slightly less oxygen (O_2), 3-100 times more carbon dioxide (CO_2), and 5-30 times more nitrous oxide (N_2O, which is laughing gas!).

Nitrous oxide and carbon dioxide are two greenhouse gasses responsible for much of the warming of global average temperatures. Sometimes soils give off, or emit, these **greenhouse gases** into the earth's atmosphere, adding to climate change. Currently scientists are working to figure out why soils emit different amounts of these greenhouse gasses.

During the summer of 2010, Iurii and his fellow researchers at Michigan State University studied nitrous oxide (N_2O) emissions from farm soils. They measured three things: (1) the concentration of nitrous oxide 25 centimeters below the soil's surface (2) the amount of nitrous oxide leaving the soil (3) and the average temperature on the days that nitrous oxide was measured. The scientists reasoned that the amount of nitrous oxide entering the atmosphere is positively associated with how much nitrous oxide is in the soil and on the soil temperature.

Measuring nitrogen (N_2O) *gas escaping from the soil in a variety of conditions, like varying temperatures throughout the year. Photo credits: J.E. Doll MSU*

Name____________________

Fill in the table below with the names and abbreviations of the **three gases** mentioned in the Research Background and whether it is a greenhouse gas.

Full Gas Name	Chemical Abbreviation	Is it a greenhouse gas?

Scientific Question: What relationship is there, if any, between soil N_2O concentrations and soil temperature and soil N_2O emissions?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data below to answer the scientific question:

Day	N_2O Concentration in the Soil (ppm)	N_2O Emissions (g/ha*day)	Temperature (°C)
180	4.5	9.3	16.1
186	3.8	11.9	27.3
194	4.8	19.5	23.7
201	4.5	27.7	22.7
205	7.9	24.3	24.8
212	4.1	11	22.7
217	3.4	8.8	23.8
221	3.5	18.4	25.3
236	2.4	11.9	21.1
243	1.9	3.4	26.9
257	1.6	4.2	16

- **N_2O emissions** are the amount of nitrous oxide gas leaving the soil, in units of grams per hectare per day. A hectare is about the size of a football field. An N_2O emission rate of 10 g/ha*day means that in one day, 10 grams of nitrous oxide over a hectare of soil moves from the soil into the air.
- **N_2O concentration in the soil** is the amount of nitrous oxide gas in the soil atmosphere. It is measured in units of parts per million (ppm), which is the number of atoms of a specific gas for every million atoms of all gasses. For example, 4.0 ppm N_2O means that for every million atoms of gas in the air, there are 4 atoms of nitrous oxide.

What data will you graph to answer the question?

Independent variables: ______________________________

Dependent variable: ______________________________

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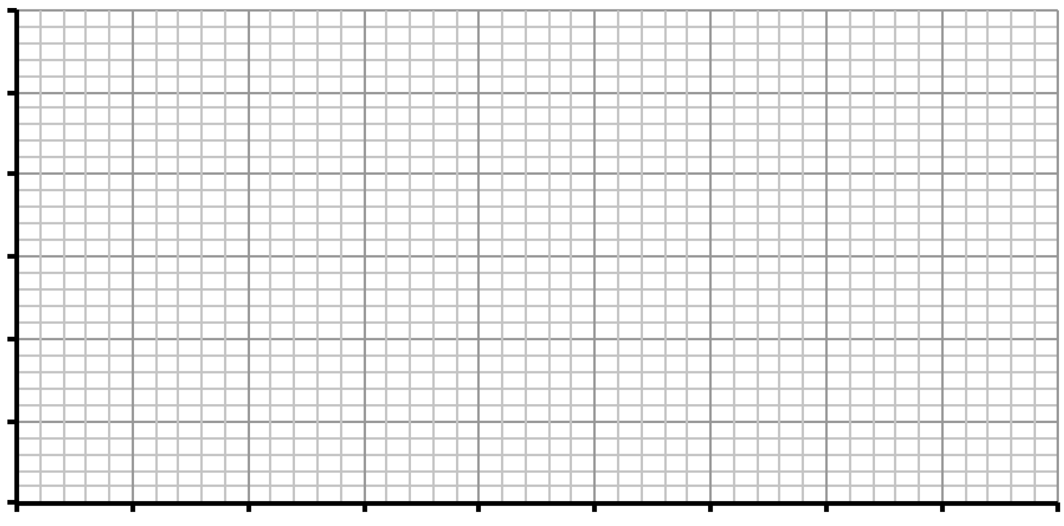
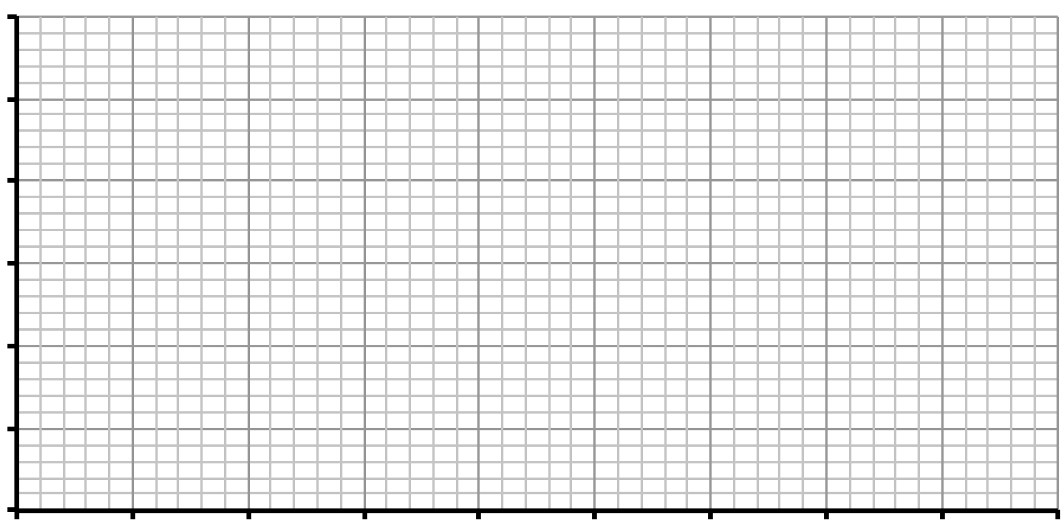
Draw your graphs below: Identify any changes, trends, or differences you see in your graphs. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.





Name____________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graphs.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about N_2O and how it influences climate change when released into the atmosphere from the soil.

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Did the data support Iurii’s hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Iurii’s research? What future data should be collected to answer your question(s)?s

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DATA Nugget

Lizards, Iguanas, and Snakes! Oh My!

Featured scientists: Heather Bateman & Mélanie Banville from Arizona State University

Research Background:

Scientist Mélanie searching for reptiles in the Central Arizona-Phoenix LTER.

Throughout history people have settled mainly along rivers and streams. Easy access to water provides resources to support many people living in one area. In the United States today, people have settled along 70% of rivers.

Today, rivers are very different from what they were like before people settled near them. The land surrounding these rivers, called **riparian habitats**, has been transformed into land for farming, businesses, or housing for people. This **urbanization** has caused the loss of green spaces that provide valuable services, such as water filtration, species diversity, and a connection to nature for people living in cities. Today, people are trying to restore green spaces along the river to bring back these services. Restoration of disturbed riparian habitats will hopefully bring back native species and all the other benefits these habitats provide.

Scientists Heather and Mélanie are researchers with the Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER) project. They want to know how restoration will affect animals living near rivers. They are particularly interested in reptiles, such as lizards. Reptiles play important roles in riparian habitats. Reptiles help energy flow and nutrient cycling. This means that if reptiles live in restored riparian habitats, they could increase the long-term health of those habitats. Reptiles can also offer clues about the condition of an ecosystem. Areas where reptiles are found are usually in better condition than areas where reptiles do not live.

Heather and Mélanie wanted to look at how disturbances in riparian habitats affected reptiles. They wanted to know if reptile **abundance** (number of individuals) and **diversity** (number of species) would be different in areas that were more developed. Some reptile species may be sensitive to urbanization, but if these habitats are restored their diversity and abundance might increase or return to pre-urbanization levels. The scientists collected data along the Salt River in Arizona. They had three sites: 1) a non-urban site, 2) an urban disturbed site, and 3) an urban rehabilitated site. They counted reptiles that they saw during a survey. At each site, they

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searched 21 plots that were 10 meters wide and 20 meters long. The sites were located along 7 transects, or paths measured out to collect data. Transects were laid out along the riparian habitat of the stream and there were 3 plots per transect. Each plot was surveyed 5 times. They searched for animals on the ground, under rocks, and in trees and shrubs.

Scientific Question: How do urbanization and riparian rehabilitation impact reptile diversity and abundance?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

What do you predict? Given the hypothesis, what are your predictions for lizard abundance and diversity at the three sites?

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Scientific Data:

Use the data below to answer the scientific question:

Reptiles	Non-Urban	Urban Rehabilitated	Urban
Tiger Whiptail Lizard	9	12	0
Common Side-blotched Lizard	8	15	4
Zebra-tailed Lizard	4	2	2
Desert Spiny Lizard	10	0	0
Ornate Tree Lizard	5	7	0
Desert Iguana	2	0	0
Long-tailed Brush Lizard	3	0	0
Western Diamond-backed Rattlesnake	1	0	0
Reptile Diversity			
Reptile Abundance			

Name____________________

What data will you graph to answer the question?

Independent variable: ________________

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Dependent variables: ________________

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The Common Side-blotched Lizard

Graph the data below:

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Interpret the data:

Make a claim that answers the scientific question.

Support your claim using data as evidence. Describe the relationship between the dependent and independent variables. Refer to specific parts of the table or graph.

Describe your scientific reasoning and explain how the evidence supports your claim.

What do the data from this study tell us about the scientist's hypothesis?

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer this question?

Name____________________

DATA Nugget

Crunchy or squishy? How El Niño events change zooplankton

Featured scientist: Laura Lilly from Scripps Institution of Oceanography, UC San Diego

Research Background:

El Niño events happen every 5 to 10 years and take place in the Pacific Ocean. El Niño occurs when the winds that blow west over the equator temporarily weaken, and even switch direction. This allows warm surface waters that typically pile up on the western side of the Pacific Ocean to flow to the east. In South America, El Niño brings heavy rains and floods because the warm water moves toward that continent. On the other hand, the warm water moves away from the continent of Australia, causing drought. In the U.S., warm waters travel up to California during El Niño years, causing the ocean to be much warmer than usual. El Niño's effects are so strong that it even changes the marine animals that live off the California coast in those years!

Laura identifies and counts zooplankton from a net tow using a microscope. Laura conducted these identifications while on a research ship at sea.

Laura's first experience with El Niño came when she was growing up in California. A strong El Niño event hit in 1997-98, and many cities in California flooded because of heavy rainstorms. The event even made the national news on TV! Laura's second El Niño experience came in 2015, the year she started training to become a scientist. These events had such a big impact on her that she decided to study how zooplankton in the ocean are affected by El Niño. **Zooplankton** are tiny drifting ocean animals ("zoo" = animal + "plankton" = drifter) that eat **phytoplankton** ("plant drifters"). Zooplankton are important for the ocean's food web because they are food for fish, whales, and seabirds.

Zooplankton come in many shapes, sizes, and species. The two main groups are **crustaceans** and **gelatinous animals**. Crustaceans look like small shrimp and crabs, with hard, crunchy shells and segmented legs like insects. In contrast, gelatinous animals are watery and squishy, like jellyfish. Laura wanted to know how El Niño events might affect which group of zooplankton are found off the coast of California.

Name____________________

Warm ocean waters during El Niño events have lower nutrient levels, so fewer phytoplankton grow leading to less food available for zooplankton. Gelatinous animals can survive in areas of the ocean where there is less food available. They are also able to live in warmer water than crustaceans. For these two reasons, Laura though that gelatinous animals may be able to live in the warmer water off California during El Niño events. Laura predicted that during the El Niño events of 1992-93, 1997-98, and 2015-16, the balance would shift in favor of gelatinous animals over crustaceans

Top image - Doliolids are a type of gelatinous zooplankton, meaning they have soft, watery bodies and not a lot of nutrition for other animals to eat. They can form large groups in the ocean called 'blooms'. *Bottom image* - Krill is a type of crustacean zooplankton, meaning that it is related to shrimp and crabs. It has a hard, segmented shell (exoskeleton). It is the main food source for blue whales and other whales and birds.

To test her idea, Laura used a long-term dataset that documents zooplankton collected offshore of southern California since 1951. Every spring, a ship goes out on the ocean and tows plankton nets for 30 minutes at 40 different locations. The ship brings back jars full of zooplankton. Scientists look at samples from those jars and identify the species and measure the lengths of each individual zooplankton in the sample. They then add up all the lengths of individual plankton to get the total biomass of each group. **Biomass** is similar to weight and shows us how big each animal is and how much space their group takes up. Scientists also measure water temperature and how much phytoplankton is found. The amount of phytoplankton is measured by detecting **chlorophyll** in the water. Chlorophyll from phytoplankton is a measure of how much food is available to zooplankton.

Scientific Question: Do the two main groups of zooplankton (crustaceans and gelatinous animals) increase or decrease in response to changes in their phytoplankton food during El Niño events?

Name____________________

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data below to answer the scientific question:

Year	Zooplankton biomass (mg C m-2)	Crustacean biomass (mg C m-2)	Gelatinous biomass (mg C m-2)	Temperature (Celcius)	Nitrate (uM)	Chlorophyll (ug/L)
1990	766.3	439.7	49.5	11.7	7.1	11.1
1991	1333.4	74.3	882.6	13.4	1.3	0.9
1992	461.1	211.0	19.1	13.2	2.6	2.5
1993	440.0	276.1	40.5	11.4	13.0	2.9
1994	490.0	343.1	19.1	12.5	5.1	2.4
1995	452.4	515.6	42.5	13.9	0.0	0.7
1996	1216.9	758.4	56.0	11.9	8.4	5.2
1997	527.9	242.7	94.4	12.3	8.2	0.6
1998	429.2	274.0	35.0	13.7	0.0	2.1
1999	909.8	379.7	196.1	11.8	9.8	2.7
2000	1359.7	734.1	162.1	13.8	1.6	1.4
2001	1053.3	561.3	53.1	10.8	9.4	13.0
2002	1320.6	719.0	166.1	12.3	3.7	8.8
2003	2829.9	925.3	284.0	12.7	1.3	4.3
2004	633.9	351.1	47.8	11.5	13.5	5.5
2005	1201.1	579.4	143.0	12.5	4.5	3.0
2006	973.3	850.7	138.9	14.2	0.5	0.9
2007	893.9	783.7	68.0	11.4	17.7	0.8
2008	1208.5	1007.2	234.4	10.6	18.0	2.5
2009	439.0	392.7	46.2	12.7	3.1	1.8
2010	943.2	495.7	161.2	10.5	18.2	2.5
2011	1351.3	1267.7	178.7	11.1	13.6	7.5
2012	408.8	694.3	98.3	10.4	19.1	1.8
2013	1616.0	957.0	243.7	12.0	7.9	1.1
2014	956.0	638.5	160.8	12.5	9.7	2.2
2015	478.4	209.0	127.2	13.6	2.1	1.3
2016	1058.0	902.9	125.1	12.4	7.0	2.8

**Units are: 'micrograms carbon per meter^2' for crustaceans and gelatinous organisms; degrees C for temperature; micromolar concentration (μM) for nitrate; and micrograms per liter (μg L^{-1})] for chlorophyll. All measurements were taken at 10 m depth.*
***El Niño years are marked with grey cells in the table.*

Name____________________

What data will you graph to answer the question?

Independent variables: ____

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Dependent variables: ____

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Draw your graph(s) below: Identify any changes, trends, or differences you see in your graph(s). Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

Name____________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graph(s).

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how different groups of zooplankton change during El Niño events.

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Did the data support Laura's hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?

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DATA Nugget

Working to reduce the plastics problem

Featured scientist: Nick Robertson from Northland College

Written by: Theresa Paulsen from Ashland High School, Wisconsin

Research Background:

Plastics are materials that can be shaped easily and are used for many functions. This has made them extremely popular across the world. Thousands of products are made using plastic, including parts of cell phones, food wrappers from your lunch, and even the stitches you may need after an injury. In fact, if you look around right now, you can probably spot at least ten items made of plastic!

Nick (right) and one of his students (left) stretching the raw, preformed polymers.

Once a plastic is made, it tends to stick around. **Synthetic plastics**, made by humans from petroleum, cannot be broken down by nature's decomposers – bacteria and fungi. This means they impact the environment for many, many years. Some types can take *thousands* of years or longer to break down!

Nick is a chemist concerned with the negative impacts caused by plastics. He knows that in order to reduce the amount of synthetic plastics in the environment, we need an alternative. And, this alternative needs to be just as good as the synthetic plastic it is replacing. Nick and his undergraduate students at Northland College are testing new ways to make plastics that are **biodegradable**, meaning they can be decomposed naturally and won't last as long in the environment. His research focuses on stretchy plastics, called **elastomers.** Elastomers are what make up rubber bands, tires, hoses, non-latex gloves, and many more items we use every day.

To try to solve the problem of making a biodegradable elastomer that has all the qualities of a synthetic one, Nick and his students got to work. First, they had to consider the chemical structure of plastics. Plastics are made of **polymers**. "Poly" means "many" and "mer" means "parts". This means that plastics are made of long chain molecules with many repeating parts. These repeating parts are called **monomers**. Different monomers can be used to make different types of plastic.

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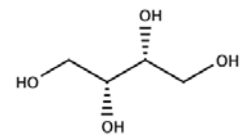
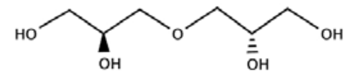
Nick chose to test two biodegradable monomers – diglycerol and meso-erythritol. Diglycerol is cheap and easy to buy. However, it might be too soft when used on its own. Meso-erythritol is more expensive, but more rigid. They wanted to use diglycerol and meso-erythritol because the chemical structures have the potential to create something that is not too rigid and not too flexible.

Substance	Chemical Structure
Meso-erythritol (ME)	
Diglycerol (D)	

Nick and his students designed an experiment in which they tested elastomers made from each of the monomers (diglycerol and meso-erythritol) alone, as well as elastomers made using both types of monomers. They made elastomers with the following percentage ratios of diglycerol over meso-erythritol: 100/0, 75/25, 50/50, 25/75, 0/100. The team was hoping to find the “sweet spot” between a product that is too stiff, and one that is not stiff enough to be useful in elastic materials. Once they finished making their elastomers, they prepared the stretch tests.

To start a stretch test, the team had to stamp out a piece of material from each elastomer, creating samples with the same size, shape, and thickness. They also cut pieces from rubber bands made of synthetic plastics to compare as a control. Next, they tested the elastomers using a machine that measures how much force is applied (**stress**) as a material is stretched (**strain**), both important measures of elasticity. The stress, or force per unit of area, is measured in megapascals (MPa) while the strain, or amount of stretch, is measured as a percent of the original length.

The sample on the right is made from 100% diglycerol and the left from 100% meso-erythritol.

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Scientific Question: What ratio of diglycerol and meso-erythritol results in a biodegradable elastomer that has similar properties to a rubber band?

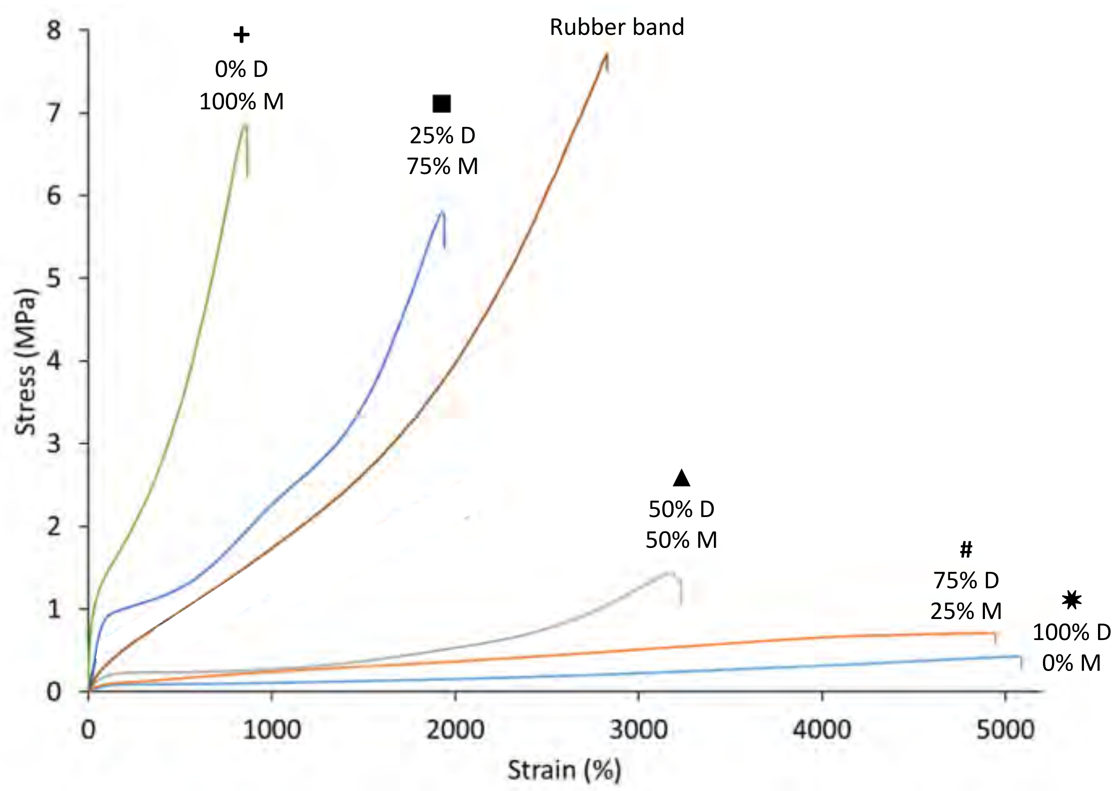
What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data and Graph:

Use the data and graph below to answer the scientific question:

The graph was produced by the Instron machine as it tested the various elastomers. The graph shows each elastomer's reaction to being stretched. The x-axis represents the percentage of stretch (strain), while the y-axis represents the force the elastomer exerts in resistance to stretching (stress). A strain of 1000% is equal to 10 times the original length of the material.

Each line represents an elastomer that Nick and his students were testing. They are labeled by what percent of diglycerol (D) and meso-erythritol (ME) are in the elastomer being tested. For example, the green line (labeled with +) has no diglycerol and is 100% meso-erythritol, so it represents a test of meso-erythritol alone. On the other hand, the orange line (labeled with #) is an elastomer with 75% diglycerol and 25% meso-erythritol.



Name___________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the graph, like the points at which each elastomer product snapped.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the two polymers and the process of engineering plastics.

Name__________________

Did the data support Nick's hypothesis? Use evidence to explain why or why not. If you feel the data are inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?

Name___________________

Alien life on Mars - caught in crystals?

Featured scientists: Charles Cockell, UK Centre for Astrobiology, University of Edinburgh, & Nikki Chambers, Astrobiology Teacher, West High School, Torrance, CA

Research Background:

Is there life on other planets besides Earth? This question is not just for science fiction. Scientists are actively exploring the possibility of life beyond Earth. The field of **astrobiology** seeks to understand how life in the universe began and evolved, and whether life exists elsewhere. Our own solar system contains a variety of planets and moons. In recent years scientists have also discovered thousands of planets around stars other than our Sun. So far, none of these places are exactly like Earth. Many planets have environments that would be very difficult for life as we know it to survive. However, there are life forms that exist in extreme environments that we can learn from. On Earth there are extremely hot or acidic environments like volcanic hot springs. Organisms also live in extremely cold places like Antarctic glacier ice. Environments with extremely high pressure, like hydrothermal vents on the ocean floor, also support life. If life can inhabit these extreme environments here on Earth, might extreme life forms exist elsewhere in the universe as well?

A view of the astrobiology lab.

Charles is an astrobiologist from Great Britain who is interested in finding life on other planets. The list of places that we might look for life grows longer every day. Charles thinks that a good place to start is right next door, on our neighboring planet, Mars. We know that Mars currently is cold, dry, and has a very thin atmosphere. Charles is curious to know whether there might still be places on Mars where life could exist, despite its extreme conditions. While there is no liquid water on the surface of Mars anymore, Mars once had a saltwater ocean covering much of its surface. The conditions on Mars used to be much more like Earth. Liquid water is essential for life as we know it. If there are places on Mars that still hold water, these could be great places to look for evidence of life. Charles thought that perhaps salt crystals, formed when these Martian oceans were evaporating, could trap pockets of liquid water.

Charles and his fellow researcher Nikki knew that there are a number of kinds of salts found in Martian soils, including chlorides, sulfates, perchlorates and others. They wanted to test their idea that water could get trapped when saltwater with these salts evaporate. They decided to compare the rate of evaporation for solutions with **magnesium sulfate** ($MgSO_4$) with another common salt solution: **sodium chloride**, or table salt (NaCl). They chose to investigate these two salts because they are less toxic to life as we know it than many of the other chloride, perchlorate, or sulfate salts. Also, from reading the work of other scientists, Charles knows the Martian surface is particularly rich in magnesium sulfate.

Charles and Nikki measured precise quantities of saturated solutions of magnesium sulfate and sodium chloride and placed them into small containers. Plain water was used as a control. There were three replicate containers for each treatment – nine containers in total. They left the containers open to evaporate and recorded their mass daily. They kept collecting data until the mass stopped changing. At this point all of the liquid had evaporated or a salt crust had formed that was impermeable to evaporation. They then compared the final mass of the control containers to the other solutions. They also checked the resulting crusts for the presence or absence of permanent **water-containing pockets**. Charles and Nikki used these data to determine if either salt makes crystals that can trap water in pockets when it evaporates.

Scientific Question: Do pockets of liquid water form when a salt solution evaporates?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the images and data table below to answer the scientific question:

LEFT: Sodium chloride crystals, Day 14; little mass change due to evaporation observed. No liquid water is visible.
RIGHT: Magnesium sulfate crystals, Day 14; no further mass change due to evaporation observed. Liquid water is visible in pockets throughout the crystals.

Name____________________

		Control	NaCl	MgSO4
Date	Day	Average mass of container + water (g)	Average mass of container + NaCl (g)	Average mass of container + MgSO4 (g)
7/14/2017	1	26.27	29.96	31.45
7/15/2017	2	23.31	28.50	29.00
7/16/2017	3	21.74	27.79	27.72
7/17/2017	4	19.37	26.51	25.90
7/18/2017	5	17.51	25.62	24.73
7/19/2017	6	15.90	24.91	24.45
7/20/2017	7	14.37	24.32	23.75
7/21/2017	8	12.29	23.10	23.54
7/22/2017	9	10.32	22.18	23.40
7/23/2017	10	8.99	21.62	23.42
7/24/2017	11	7.64	20.99	23.37
7/25/2017	12	6.45	20.03	23.36
7/26/2017	13	6.45	19.18	23.36
7/27/2017	14	6.45	18.45	23.36
7/28/2017	15	6.45	18.37	23.36
7/29/2017	16	6.45	18.36	23.36
**the mass of the containers used = 6.45g*				

What data will you graph to answer the question?

Independent variable(s): ____

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Dependent variable(s): ____

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Name___________________

<u>Draw your graph(s) below</u>: Identify any changes, trends, or differences you see in your graph(s). Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

<u>Interpret the data:</u>

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table, images, or graph(s).

Name__________________

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the conditions on Mars and whether these results indicate that life on Mars may be possible.

Did the data support Charles and Nikki's hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?

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DATA Nugget

All washed up? The effect of floods on cutthroat trout

Featured scientists: Ivan Arismendi and Stan Gregory from Oregon State University
Written by: Leilagh Boyle

<u>Research Background</u>:


Mack Creek, a healthy stream located within the old growth forests in Oregon. It has a diversity of habitats because of various rocks and logs. This creates diverse habitats for juvenile and adult trout.

Streams are tough places to live. Fish living in streams have to survive droughts, floods, debris flows, falling trees, and cold and warm temperatures. In Oregon, cutthroat trout make streams their home. Cutthroat trout are sensitive to disturbances in the stream, such as pollution and sediment. This means that when trout are present it is a good sign that the stream is healthy.

Floods are very common disturbances in streams. During floods, water in the stream flows very fast. This extra movement picks up sediment from the bottom of the stream and suspends it in the water. When sediment is floating in the water it makes it harder for fish to see and breathe, limiting how much food they can find. Floods may also affect fish reproduction. If floods happen right after fish breed and eggs hatch, young fish that cannot swim strongly may not survive. Although floods can be dangerous for fish, they are also very important for creating new habitat. Floods expand the stream, making it wider and adding more space. Moving water also adds large boulders, small rocks, and logs into the stream. These items add to the different types of habitat available.

Ivan and Stan are two scientists who are interested in whether floods have a large impact on the survival of young cutthroat trout. They were worried because cutthroat trout reproduce during the spring, towards the end of the winter flood season. During this time **juvenile trout,** less than one year old, are not good swimmers. The fast water from floods makes it harder for them to survive. After a year, juvenile trout become mature **adults.** These two age groups live in different habitats. Adult trout live in pools near the center of streams. Juvenile trout prefer habitats at the edges of streams that

Name____________________

have things like rocks and logs where they can hide from predators. Also, water at the edges moves more slowly, making it easier to swim. In addition, by staying near the stream edge they can avoid getting eaten by the adults in stream pools.

Ivan and Stan work at the H.J. Andrews Long Term Ecological Research site. They wanted to know what happens to cutthroat trout after winter floods. Major floods occur every 35-50 years, meaning that Ivan and Stan would need a lot of data. Fortunately for their research they were able to find what they needed since scientists have been collecting data at the site since 1987!

To study how floods affect trout populations, Ivan and Stan used data from Mack Creek, one of the streams within their site. They decided to look at the population size of both juvenile and adult trout since they occupy such different parts of the stream. For each year of data they had, Ivan and Stan compared the juvenile and adult **trout population data**, measured as the number of trout, with **stream discharge**, or a measure of how fast water is flowing in the stream. Stream discharge is higher after flooding events. Stream discharge data for Mack Creek is collected during the winter when floods are most likely to occur. Fish population size is measured during the following summer each year. Since flooding can make life difficult for trout, they expected trout populations to decrease after major flooding events.

Scientific Question: What is the effect of major flooding events on adult and juvenile trout populations in Mack Creek?

A cutthroat trout. It is momentarily unhappy, because it is not in its natural, cold Pacific Northwest stream habitat.

Scientists Ivan and Stan preparing to catch cutthroat trout in the stream.

Name____________________

Scientific Data:

Use the data below to answer the scientific question:

Year	Number of juvenile trout	Number of adult trout	Stream discharge (L/s)*
1987	26	53	2373.2
1988	18	35	3920.0
1989	18	35	3832.5
1990	22	59	6685.4
1991	44	47	3894.1
1992	33	53	3940.7
1993	44	58	4324.4
1994	31	67	2864.5
1995	38	52	4767.5
1996	81	52	9793.2
1997	81	60	7200.0
1998	73	80	5240.1
1999	41	61	5942.3
2000	43	56	9557.2
2001	26	70	1525.6
2002	36	48	5858.4
2003	66	42	4784.8
2004	44	55	4517.9
2005	30	68	4704.4
2006	48	64	6950.7
2007	68	58	6943.7
2008	37	80	4226.7
2009	83	70	6398.7

**The scientists measured stream discharge in liters per second (L/s). You can think about discharge as the number of cubes (one foot on each side) filled with water that pass by a point every second. A higher value means that more water is moving in the stream. This measurement is taken in the winter each year when discharge is at its maximum.*

What data will you graph to answer the question?

Independent variable(s): ____________________________________

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Dependent variable(s): ____________________________________

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Name____________________

<u>Draw your graph(s) below</u>: Identify any changes, trends, or differences you see in your graph(s). Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

Name____________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graph(s).

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the effects of flood disturbances on stream habitats.

Your next steps as a scientist:

Science is an ongoing process. What new question do you think should be investigated?

Name____________________

What future data should be collected to answer your question?

Independent variable(s): ___________________________________

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Dependent variable(s): _____________________________________

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For each variable, explain why you included it and how it could be measured.

What hypothesis are you testing in your experiment? A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Name____________________

DATA Nugget

Can a salt marsh recover after restoration?

Featured scientists: Liz Duff from Mass Audubon, Eric Hutchins from NOAA, & Rockport Middle School science club. Written by: Bob Allia, Cindy Richmond, & Dave Young.

Research Background:

In the 1990s, it was clear that the Saratoga Creek salt marsh was in trouble. The invasive plant, *Phragmites australis,* covered large areas of the marsh. Thick patches of *Phragmites* crowded out native plants. There were very few animals, especially migrating birds, because the plants grew too densely for them to move around.

Students collecting salinity data at a point along the transect. The tall, tan grass is invasive *Phragmites*.

Salt marshes are wetland habitats near oceans where water-tolerant salt-loving plants grow. Usually native grasses dominate the marsh, but where humans cause disturbance *Phragmites* can start to take over. Human disturbance was having a huge effect on the health of Saratoga Creek by changing the water coming into the marsh. Storm drains, built to keep rain water off the roads, were adding more water to the marsh. This **runoff**, or freshwater and sediments from the surrounding land, made the marsh less salty. The extra sediment made the problem even worse because it raised soil levels along the road. Raised soil means less salty ocean comes into the marsh during high tide.

In 1998, scientists, including members of the Rockport Conservation Commission and students from the Rockport Middle School science club, began to look at the problem. *Phragmites* grows best when salt levels are low. When salt levels are high, native grasses do better. The scientists thought that the extra fresh water and sediments added by the storm drains into the marsh was the reason *Phragmites* was taking over.

The scientists wanted to see if a restoration could reverse the *Phragmites* invasion. In 1999, a ditch was dug along the side the road to catch runoff before it entered the marsh. A layer of sediment was also removed from the marsh, allowing ocean water to reach the marsh during high tide once again. Students set up sampling areas, chosen to observe and record data, called **transects**. Transects were 25 meters long and students collected data every meter. The transects made it possible to return to the same points in the marsh year after year. Along the transects, students counted the number of *Phragmites* plants and calculated abundance as the percent of points along the transect where they found *Phragmites*. They also measured the height of *Phragmites* as a way to figure out how well it was growing.

Students in *Phragmites* portion of marsh.

The students compared *Phragmites* data from before 1999 and after 1999 to see if the restoration made a difference. They predicted that the abundance and height of *Phragmites* would go down after runoff was reduced by the restoration.

Scientific Question: Is there evidence that the Saratoga Creek restoration in 1999 was successful at reducing the *Phragmites* invasion?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

View of the Saratoga Creek salt marsh several years after restoration, showing location of one of the transects. Native grasses are growing in the foreground.

Name____________________

Scientific Data:

Use the data below to answer the scientific question:

Year	Average Phragmites Height (cm)	Frequency of Phragmites (%)*	
1998	(no data)	36%	
1999	280.3	36%	
2000	196	32%	*(After Ditch)*
2001	183	(no data)	
2002	177.5	32%	
2003	200.5	40%	
2004	173.2	44%	
2005	165.8	44%	
2006	193	40%	
2007	155.7	44%	
2008	183	60%	
2009	186.1	48%	
2010	127.8	32%	
2011	128.6	44%	
2012	115.7	32%	
2013	97.5	8%	
2014	116.5	8%	
2015	0	0%	

**Frequency of* Phragmites *is calculated as the percent of locations where* Phragmites *plants were present along the 25 meter transect. 0% indicates* Phragmites *was not found at any points along the transect, where 100% indicates* Phragmites *was found at all points along the transect.*

What data will you graph to answer the question?

Predictor variable: ______________________________

Response variables: ______________________________

____

Name____________________

Draw your graphs below: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

Name____________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graphs.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the effect of the storm drains and how this disturbance affected the marsh.

Name____________________

Did the data support the scientists' hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on the scientists' research? How do your questions build on the research that has already been done?

Name____________________

DATA Nugget

Invasive reeds in the salt marsh

Featured scientists: Lori LaFrance from Ipswich High School, Massachusetts and Liz Duff from Mass Audubon

Research Background:

Phragmites australis is an invasive **reed**, a type of grass that grows in water. *Phragmites* is taking over saltwater **marshes** in New England, or wetland habitats near the Atlantic Ocean coast. *Phragmites* does so well it crowds out native plants that once served as food and homes for marsh animals. Once *Phragmites* has invaded, it is sometimes the only plant species left! *Phragmites* does best where humans have disturbed a marsh, and scientists were curious why that might be. They thought that perhaps when a marsh is disturbed, the **salinity**, or amount of salt in the water, changes. *Phragmites* might be able to survive after disturbances that cause the amount of salt in the water to drop, but becomes stressed when salinity is high.

Culverts run under roads and allow water from the ocean to enter a marsh. *Phragmites* can be seen growing in the background.

Fresh water in a marsh flows from the upstream source to downstream. Saltwater marshes end at the ocean, where freshwater mixes with salty ocean water. One type of disturbance is when a road is cut through a marsh. Upstream of the road, the marsh is cut off from the salt waters from the ocean, so only fresh water will enter and salinity will drop. Downstream of the road, the marsh is still connected to the ocean and salinity should be unaffected by the disturbance. Often, a **culvert** (a pipe that runs under the road) is placed to allow salt water to pass from the ocean into the marsh. The amount of ocean water flowing into the marsh is dependent on the diameter of the culvert.

Students at Ipswich High School worked with scientists from the Mass Audubon, a conservation organization, to look at the *Phragmites* in the marsh. They looked at an area where the salinity in the marsh changed after a road was built. They wanted to know if this change would affect the amount of *Phragmites* in that marsh. In 1996, permanent posts were placed 25 meters apart in the marsh. That way, scientists could collect data from the same points each year. At these posts, students used **transects,** a straight line measured from a point to mark where data is collected. Then they collected

Name____________________

data on all the plants that were found every meter along the transects. Data has been collected at these same points since 1996. In 2005, an old 30cm diameter culvert was replaced with two 122cm culverts. These wider culverts allow much more salty ocean water to flow under the road and into the marsh. Students predicted that after the culverts were widened, more ocean water would enter the marsh. This would make salinity go up, making it harder for *Phragmites* to grow, and it would decline in numbers. Students continued to survey the plants found along transects at each permanent post and documented their findings.

Students collecting data on the plant species present in the marsh using transects. Every 1m along the tape, students observe which plants are present. *Phragmites* is the tall grass that can be seen growing behind the students.

Scientific Question: How did replacing the narrow culverts with wider culverts change the growth of *Phragmites* in the marsh?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data below to answer the scientific question:

Location	**Average percent of *Phragmites* in each transect before the culvert was widened (1996-2005)**	**Average percent of *Phragmites* in each transect after the culvert was widened (2005-2014)**
Transect 1(marsh side of culvert – upstream)	27%	17%
Transect 2 (marsh side of culvert – upstream)	60%	56%
Transect 3 (marsh side of culvert – upstream)	40%	0%
Transect 0 (ocean side of culvert – downstream)	52%	52%

Name____________________

Average percent of upstream transects (3) before restoration ____________

Average percent of upstream transects (3) after restoration ____________

Percent of downstream transect before restoration ____________

Percent of downstream transect after restoration ____________

What data will you graph to answer the question?

Independent variables: ______________________________

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Dependent variable: ______________________________

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<u>Graph the data below</u>:

Name____________________

Interpret the data: Make a claim based on the evidence that helps answer the original research question. Connect the pattern in the data to a pattern in the natural world. Justify your reasoning using data.

Your next steps as a scientist: Science is an ongoing process. What new question do you think should be investigated? What future data should be collected to answer your question?

Name____________________

Finding a Foothold

Featured scientists: Darrel Nash & Sarah Hall from Kentridge High School, Washington

Research Background:

Have you ever noticed that the ground at a beach has rocks of many different sizes? These rocks, sand, and dirt are all called **substrates**. The types of substrate we see are described by the size of the particles that cover the ground. These can range from large boulders down to fine grains of sand and dirt, with many sizes in between. No matter what type of substrate you see at the beach, you can find organisms that will live in or on it. Just like there are different types of substrates, there are different types of organisms that can live there. How can we determine which types of organisms prefer which types of substrates? That is the job of field researchers!

Students and teachers at Kentridge High School have made many field trips to the beach and have seen lots of organisms. Normally, they just noticed what they could see easily in front of them. Students became interested to know how the type of substrate influences which organisms will live there. They noticed that the snails in the aquarium at school like to stick to the glass walls of the tank. Do snails and other shelled mollusks found near the ocean, like chitons, periwinkles, whelks and limpets, also like to live on large, stable substrates? The students went to beach to find out!

Students collecting mollusk data on different beach substrates

Mollusks have a "foot" which may be able to attach more securely to larger substrates, such as boulders, and allow them more room to move. So, the students expected to find more mollusks on boulders than on other types of substrates. To gather the data needed to answer this question, the students went to a local beach. They looked at sections of the beach with substrates of all types. On these different substrates, they kept track of all the different types of organisms that were present. They measured the frequency that they observed four types of mollusks (chitons, limpets, whelks, and periwinkles) on the following substrates: boulder, gravel, pebble, logs, sand, and shell debris. Frequency was measured as the proportion of times that a particular organism was present on a substrate type, out of the total number of observations. For example, if they observed 2 boulders and saw limpets on 1, the frequency would = ½ or 0.5.

Scientific Question: What types of substrates are most commonly inhabited by mollusks?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data below to answer the scientific question:

Substrate	Chiton	Limpet	Whelk	Periwinkle Snail
boulder	0.00	0.26	0.00	0.13
cobble	0.02	0.41	0.17	0.21
gravel	0.02	0.32	0.06	0.07
logs	0.00	0.14	0.00	0.07
sand	0.01	0.19	0.07	0.10
shells	0.00	0.12	0.02	0.04

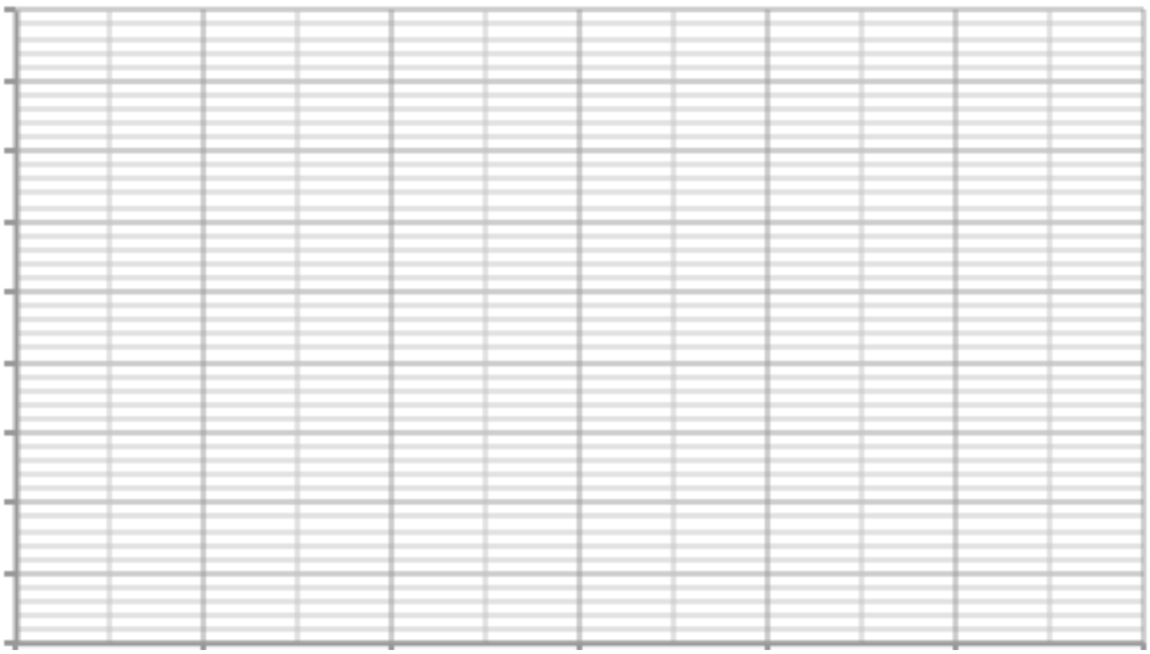
What data will you graph to answer the question?

Predictor variable: ________________________________

Response variable: ________________________________

Name____________________

Graph the data below:



Interpret the data: Make a claim based on the evidence that helps answer the original research question. Connect the pattern in the data to a pattern in the natural world. Justify your reasoning using data.

Name____________________

Your next step as a scientist: Science is an ongoing process. Did this study fully answer your original question? What new questions do you think should be investigated? What future data should be collected to answer them?

Name____________________

DATA Nugget

Which would a woodlouse prefer?
Featured scientist: Nora Straquadine from Michigan State University

Research Background:


Woodlice, small terrestrial crustaceans.

Woodlice are small crustaceans that live on land. They look like bugs, but are actually more closely related to crabs and lobsters. To escape predators they hide in dark places. They spend most of their time underground and have very poor eyesight.

One day, when digging around in the dark dirt of her compost pile, Nora noticed that there were many, many woodlice hiding together. This made her wonder how woodlice decide where to live. Because woodlice have very simple eyesight, Nora thought that maybe they use dark and light colors to decide where to go. They might choose to move towards darker colors and away from lighter colors to prevent ending up above ground where predators can easily find them.

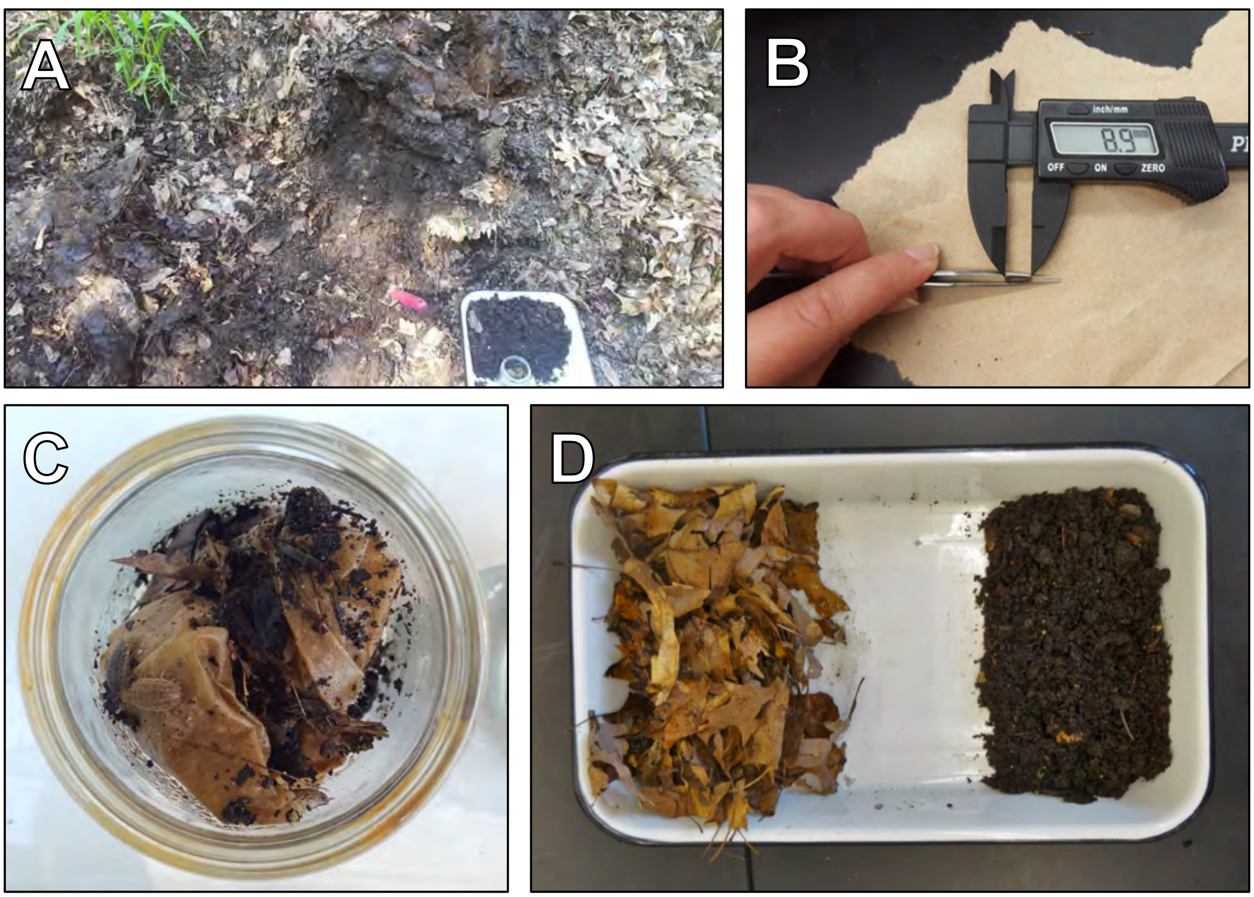
Nora, along with classmates in her ecology class at Michigan State University, decided to run an experiment to study woodlice behavior. She collected 10 woodlice from her compost pile and placed them in a jar. She brought the jar into the lab. Then she chose a set of trays to work with from what she had in the lab – white, with tall sides. The sides of the tray were tall and smooth so the woodlice were not able to climb out. On one end of the tray Nora put some dark soil, and on the other side she put lighter leaves. If her hypothesis was correct, Nora predicted that woodlice would more often choose to move towards the dark soil habitat, compared to the lighter leaves habitat.

For each trial, Nora gently picked up a single woodlouse with forceps. She then placed it in the center of the tray. All the woodlice were positioned so they started facing the top of the tray, not at either habitat type. The woodlice then chose to move towards one end of the tray or the other. When they reached one of the piles the students recorded which habitat they chose. It was then picked up with forceps. Nora and her classmates recorded its length and placed it in a new jar so it could be released back into the compost pile once the experiment was done.

Name____________________

After running this experiment and looking at the data, Nora realized it did not work. The small sample size of only 10 individuals was not enough to see a pattern. Also, she realized that after one woodlouse went a certain way, all the others would follow it, maybe because they were following a scent trail. She decided she had to do the experiment again, this time with more woodlice and in a way that would prevent them following each other's scent trails.

For her second try, Nora increased her sample size and collected 51 woodlice from a different compost pile. Just like the first experiment, Nora placed lighter leaves on one end of a white tray and dark soil on the other. All the methods were the same, except for a few important changes. To get rid of scent trails, this time Nora wiped down the middle of the tray with a clean wet paper towel between trials. She also realized that she had forgotten to control for humidity on both sides of the tray, so she added equal amounts of water to both habitats to control for humidity. This ensured that if woodlice did show a preference for either habitat it would be due to habitat color, not humidity. Nora also used a stopwatch and recorded how long it took for an individual to choose one of the two habitats.



A. Nora collecting woodlice from the compost pile for her experiment, B. Nora measuring a woodlouse with calipers, C. Woodlice in a jar with a moist paper towel for humidity, D. The white tray with light leaves and dark soil habitats.

Name____________________

Scientific Question: Do woodlice have a preference for the dark soil or the light leaves, or neither?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data from Nora's second experiment to answer the scientific question:

Table 1: Individual number, time it took to choose (seconds), individual length (millimeters), and habitat choice (dark soil, light leaves).

#	Time (s)	Length (mm)	Habitat Choice
1	10.06	12.6	Soil
2	19.16	9.3	Soil
3	9.19	8.2	Soil
4	3.91	10.4	Leaves
5	1.53	12.5	Soil
6	19.47	10.8	Soil
7	7.9	6.7	Leaves
8	12.85	9.9	Leaves
9	15.19	7.7	Leaves
10	2.44	10	Soil
11	2.56	7.4	Soil
12	2	7.7	Soil
13	3.09	9	Soil
14	4.44	13	Soil
15	9.81	9.2	Soil
16	2.69	9.1	Soil
17	4.5	7.2	Leaves
18	4.81	12.1	Leaves
19	4.37	9.3	Leaves
20	33.91	7.3	Leaves
21	35.22	9	Soil
22	17.12	6.3	Leaves
23	27.63	7.6	Leaves
24	2.07	8.1	Leaves
25	27.09	6.5	Leaves
26	5.81	11	Soil

#	Time (s)	Length (mm)	Habitat Choice
27	47.25	8.7	Leaves
28	11.97	8.8	Leaves
29	4.06	8.1	Leaves
30	9.72	10.9	Leaves
31	7.09	7.3	Soil
32	3.84	8.9	Leaves
33	4	7.1	Leaves
34	6.78	11.3	Leaves
35	2.75	8.8	Soil
36	15.03	6.1	Soil
37	2.28	5.3	Soil
38	1.28	8.5	Leaves
39	6.87	8.1	Leaves
40	4.29	6.5	Leaves
41	8.78	7.6	Leaves
42	3	8.1	Soil
43	8.22	6.7	Leaves
44	2.09	8.1	Soil
45	6.44	10.3	Soil
46	4.63	12.4	Soil
47	4.87	7.5	Leaves
48	3.16	10.6	Leaves
49	7.54	8.9	Soil
50	1.41	11.5	Leaves
51	4.1	8.9	Leaves

Number of individuals that chose soil	
Number of individuals that chose leaves	

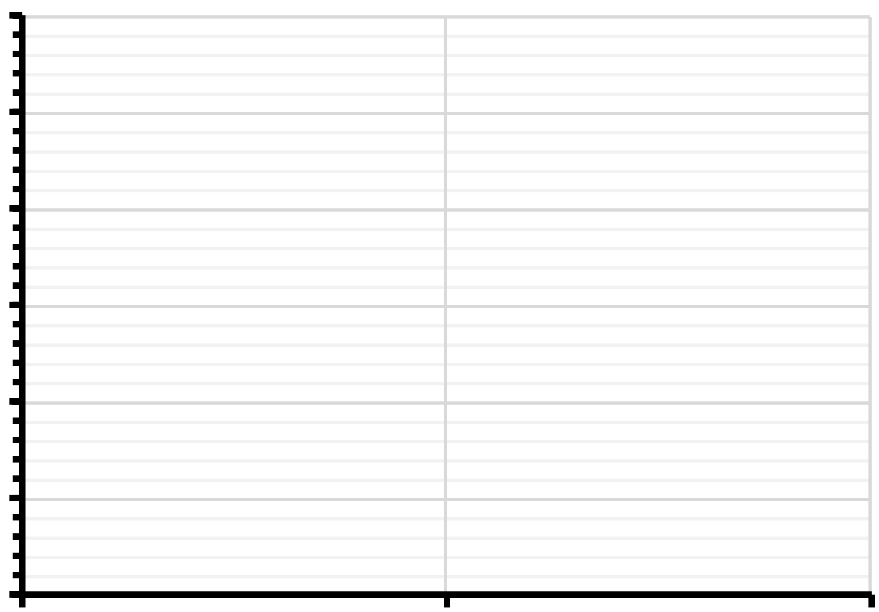
Name____________________

What data will you graph to answer the question?

Independent variable: ____

Dependent variable: ____

Draw your graph below: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



Interpret the data:

Make a claim that answers the scientific question.

Name____________________

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about woodlice and their poor eyesight.

Did the data support Nora's hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Nora's research? What future data should be collected to answer your question(s)?

Name____________________

How do brain chemicals influence who wins a fight?

Featured scientists: Andrew Bubak and John Swallow from the University of Colorado at Denver, and Kenneth Renner from the University of South Dakota

Research Background:

In nature, animals compete for resources. These resources include space, food, and mates. Animals use aggression as a way to capture or defend these resources, which can improve their chances of survival and mating. **Aggression** is a forceful behavior meant to overpower opponents that are competing for the same resource. The outcome (victory or defeat) depends on several factors. In insects, the bigger individuals often win. However, if two opponents are the same size, other factors can influence outcomes. For example, an individual with more experience may defeat an individual with less experience. Also individuals that are fighting to gain something necessary for their survival have a strong drive, or motivation, to defeat other individuals.

Researchers Andrew, Ken, and John study what role an animal's brain plays in regulating behavior when motivation is present. They wanted to know if specific chemicals in the brain influenced the outcome of a physically aggressive competition. Andrew, Ken, and John read a lot papers written by other scientists and learned that there is a brain chemical that plays an important role in regulating aggressive behavior. This chemical is called **serotonin** and is found in the brains of all animals, including humans. Even a small amount of this chemical can make a big impact on aggressive behavior, and perhaps the outcome of competition.

Picture 1. Two stalk-eyed flies rearing/extending forearms in battle. Photo credit: Sam Cotton.

Name____________________

The researchers decided to do an experiment to test what happens to aggression during competition as serotonin levels in the brain increase. They used stalk-eyed flies in their experiment. Stalk-eyed flies have eyes on the ends of stalks that stick out from the sides of their heads (Pictures 1 & 2). They reasoned that brain serotonin levels in stalk-eyed flies influence their aggressive behaviors in battle and therefore impact the outcome of competition. If their hypothesis is true, they predicted that increasing the brain serotonin in a stalk-eyed fly would make it more likely to use aggressive behaviors, and flies that used more aggressive behaviors would be more likely to win. Battling flies use high-intensity aggressive attacks like jumping on or striking an opponent. They also use less aggressive behaviors like flexing their front legs or rearing up on their hind legs.

Picture 2. A male stalk-eyed fly compared to the size of a dime. Photo credit: Andrew Bubak, June 2016.

To test their hypothesis, the researchers set up a fair test. A **fair test** is a way to control an experiment by only changing one piece of the experiment at a time. By changing only one variable, scientists can determine if that change caused the differences they see. Since larger flies tend to win fights, the flies were all matched up with another fly that was the same size. This acted as an experimental control for size, and made it possible to look at only the impact of serotonin levels on aggression. The scientists also controlled for the age of the flies and made sure they had a similar environment since the time they were born. The experiment had 20 trials with a different pair of flies in each. In each trial, one fly received corn mixed with a dose of serotonin, while another fly received plain corn as a control. That way, both flies received corn to eat, but only one received serotonin.

Each pair of flies was placed in a fighting arena and starved for 12 hours to increase their motivation to fight over food. Next, food was placed in the center of the arena, but only enough for one fly! The researchers observed the flies, recording three types of behaviors for each opponent. High intensity behaviors were when the fighting flies touched one another. Low-intensity behaviors were when the flies did not touch each other, for example jump attacks, swipes, and lunges. The last behavior type was retreating from the fight. Flies that retreated fewer times than their opponent were declared the winners. After the battles, the researchers collected the brains of the flies and measured the concentration of serotonin in each fly's brain.

Scientific Question: How does serotonin level affect aggressive behavior and, therefore, the probability of winning against an opponent of similar size?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

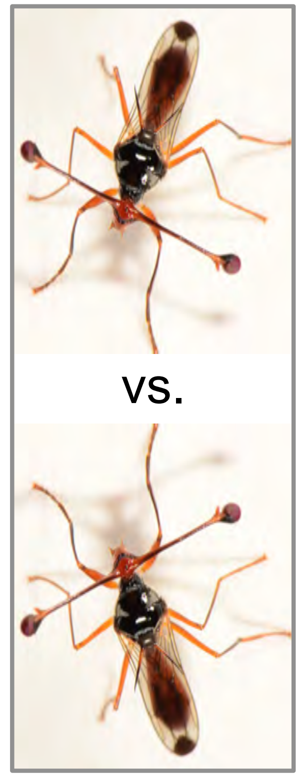
Name____________________

Scientific Data:

Use the data in the following two tables to answer the scientific question:

Table 1. Serotonin Levels vs. Outcomes of Stalk-Eyed Flies

Battle Number	Serotonin Levels (concentration measured in picograms of serotonin per microgram of brain matter [pg/μg]) Winner (pg/μg)	Loser (pg/μg)
Battle 1	62	45
Battle 2	190	38
Battle 3	34	113
Battle 4	57	24
Battle 5	99	59
Battle 6	23	32
Battle 7	139	21
Battle 8	67	16
Battle 9	80	26
Battle 10	121	26
Battle 11	42	15
Battle 12	49	22
Battle 13	19	16
Battle 14	69	29
Battle 15	75	24
Battle 16	89	21
Battle 17	46	38
Battle 18	97	36
Battle 19	151	24
Battle 20	21	106
Average serotonin level (pg/ug)		



The units used by the researchers are picograms (pg) and micrograms (μg). A picogram is one-trillionth ($1/10^{12}$) of a gram and a microgram is one-millionth ($1/10^6$) of a gram. The level of serotonin found in the brain is given using the ratio of serotonin measured in picograms to brain matter in micrograms.

Name____________________

Table 2. Stalk-Eyed Fly Behaviors vs. Outcomes In Battle

Observed Behaviors In Battle	How many winners did this?	How many losers did this?
High-Intensity	16	5
Swipe/lunge	11	4
Jump Attack	11	2
Retreats	2	20

High-intensity behaviors include any behavior where the flies came in contact with each other. Low-intensity behaviors included swipe/lunge and jump attacks.

Data for serotonin levels of the winners and losers are listed in Table 1. As mentioned before, the researchers fed one of the two stalk-eyed flies serotonin-rich food before each trial. They did this to make sure the difference in serotonin between the two flies was high enough to be measured and have an effect on behavior. However, there were times where the natural level of serotonin in the control fly was higher than that of the treated fly. Therefore, the data in Table 1 compares serotonin levels for winners and losers, but does NOT identify whether a fly was treated or not. Table 2 shows frequencies of behaviors compared to outcome.

What data will you graph to answer the question?

Table 1:

Independent variable: ____________________

Dependent variable: ____________________

Table 2:

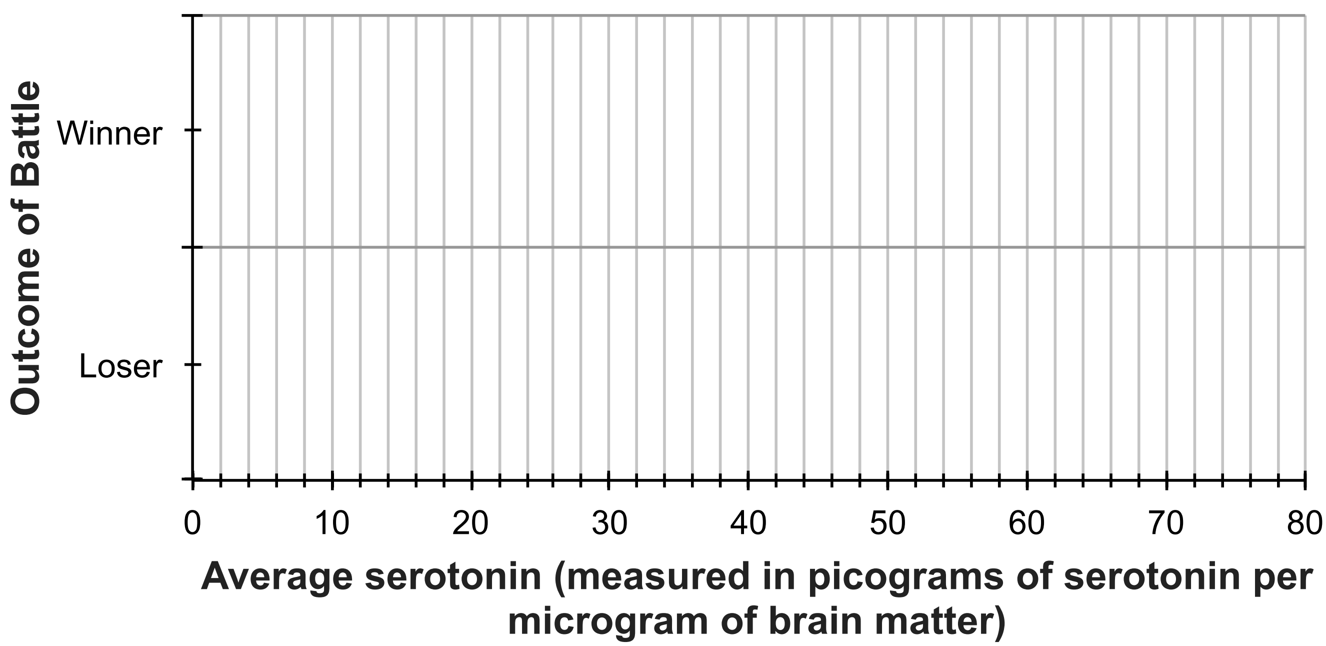
Independent variable: ____________________

Dependent variable: ____________________

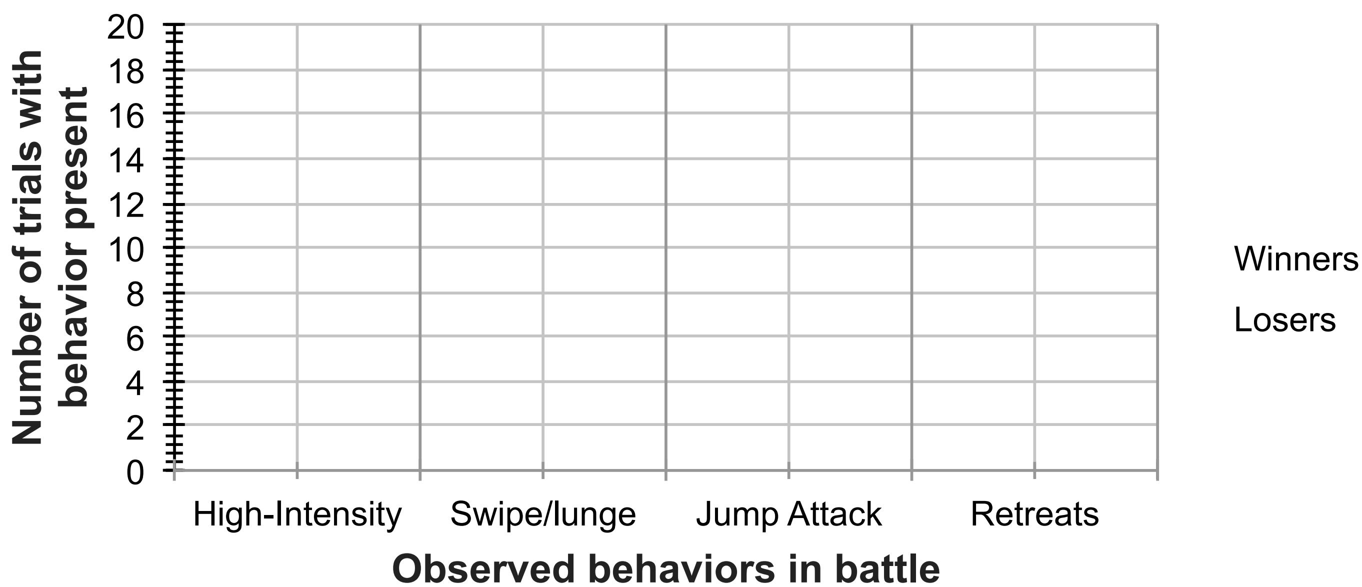
Name____________________

Draw your graphs below: Identify any changes, trends, or differences you see in your graphs. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

Graph 1



Graph 2



Name____________________

Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the tables or graphs.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how brain chemicals influence animal behavior.

Name____________________

Did the data support Andrew, Ken, and John's hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Andrew, Ken, and John's research? What future data should be collected to answer your question(s)?

Name____________________

DATA Nugget

Fish fights

Featured scientist: Alycia R. Lackey from Michigan State University

Research Background:

In many animals, males fight for territories. Getting a good territory and making sure other males don't steal it is very important! Males use these territories to attract females for mating. The males that get the best territories are more likely to mate with females and have more babies. Only the males that have babies will pass on their genes to the next generation.

Stickleback fish use the shallow bottom areas of lakes to mate. Male stickleback fish fight each other to gain the best territories in this habitat. In their territories, males build a nest out of sand, aquatic plants, and glue they produce from their kidneys. The better the nest, the more females a male can attract. Males then use courtship dances to attract females to their nests. If a female likes a male, she will deposit her eggs in his nest. Then the male will care for those eggs and protect the offspring that hatch.

A male stickleback in his territory *(front)* and an intruding male *(back)*

Alycia is a scientist who is interested in understanding what makes a male stickleback a good fighter and defender of his territory. Perhaps more aggressive males are better at defending their territory and nests because they are better at fighting off other males. She used sticklebacks she collected from British Columbia to test her hypothesis.

In her experiment, 24 males were kept in 6 large tanks, with 4 males in each tank. Alycia watched each of the 24 males every day for 10 days. She recorded the behaviors of each fish when they were competing for territories, defending their territory, and building their nests. She also recorded the size of the males' territories and whether they had a nest each day.

As Alycia observed the fish, she measured three things:

1. Average Male Net Aggression: A number that indicates how many times the fish performed an aggressive behavior, like charging or nipping, minus the number of aggressive behaviors performed by another fish directed at that fish.
2. Average Territory Size: Each fish either had no territory (given the number 0), a small territory (1), or a large territory (2). Their territories changed during the experiment from one day to the next, so scientists averaged the values over the 10 days.
3. Days With Nest: The number of days over the course of the experiment that a fish had a nest.

Name____________________

Scientific Question: How does aggressiveness in male sticklebacks affect their ability to defend their territories?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data:

Use the data below to answer the scientific question:

	Average Male Net Aggression	**Average Territory Size**	**Days With Nest**
Fish #	*(aggression performed minus aggression received per minute)*	*(0: none, 1: small, 2: large)*	*(number of days with nest)*
1	-1.28	0.14	0
2	0.20	0.07	0
3	-0.11	0.29	0
4	-0.47	0.50	0
5	-1.02	0.54	0
6	-1.32	0.00	0
7	0.94	1.14	0
8	-1.18	0.00	0
9	-2.18	0.00	0
10	-0.12	0.36	0
11	1.58	1.00	0
12	-0.24	1.00	0
13	-0.46	0.00	0
14	0.49	1.64	1
15	0.66	2.00	3
16	0.45	1.07	2
17	0.49	1.71	3
18	0.38	1.71	1
19	-0.77	0.44	1
20	1.18	1.93	4
21	-0.11	0.29	1
22	0.85	2.00	3
23	1.35	1.93	3
24	1.09	1.00	3

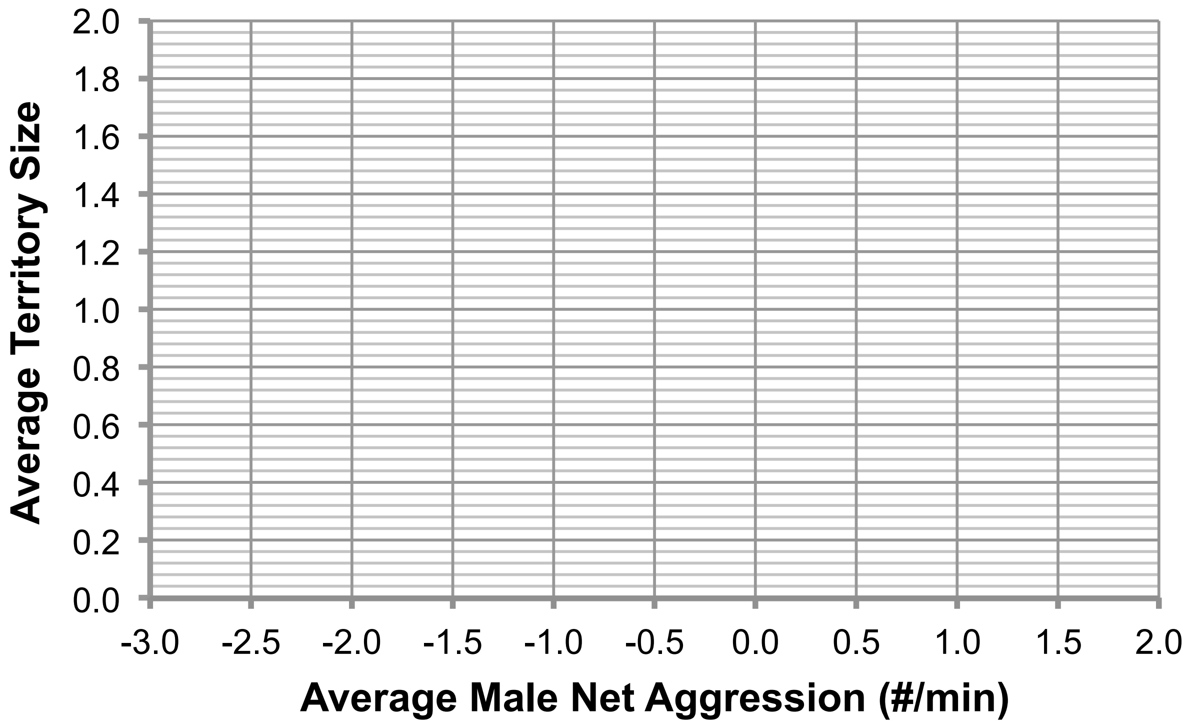
What data will you graph to answer the question?

Independent variable: ________________________________

Dependent variable: ________________________________

Name____________________

Draw your graph below: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



Interpret the data:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graph.

Name____________________

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the importance of territories for male sticklebacks.

Did the data support Alycia's hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

Your next step as a scientist: Science is an ongoing process. What new questions do you think should be investigated? What future data should be collected to answer them?

Name____________________

DATA Nugget

Green crabs: invaders in the Great Marsh

Featured scientist: Alyssa Novak from the Center for Coastal Studies/Boston University

Research Background:

Marshes are areas along the coast that flood with each tide. They are incredibly important habitats. Marshes act as homes to a large number of species. They also protect the coast from erosion during storms and act as a filter for nutrients and pollution. Many species are unique to these habitats and provide crucial support to the marsh. For example, native eelgrass is a type of plant that reduces erosion by holding sediments in place with their roots.

Alyssa holding an invasive green crab, introduced from Europe to the American Atlantic Coast. This crab causes many problems in its new range, including the loss of native eelgrass.

In an effort to help protect and restore marshes, we must understand current-day issues that are affecting their health. The introduction of species that are not originally from the marsh may disrupt the ecosystem and threaten the survival of native species. One species that has recently caused a lot of trouble is the European green crab. This crab species was accidentally carried to the Atlantic coast back in the early 1800s from Europe. Since then, they have become extremely invasive and their numbers have exploded! Compared to native crabs, the green crab digs a lot when it searches for food and shelter. This digging uproots eelgrass and causes its population numbers to fall. In many spots where green crabs have been introduced, marshes are now bare and no more grass can grow.

Invasive Green Crabs caught in trap that has been underwater for 25 hours

Native eelgrass growing in Essex Bay, an area within the Great Marsh

Name____________________

The Great Marsh is one of the coastal habitats affected by invasive green crabs. Located on the North Shore of Massachusetts, the Great Marsh is known for being the longest continuous stretch of salt marsh in all of New England. Alyssa is a restoration ecologist who is very concerned with the conservation of the Great Marsh and other important coastal ecosystems. She and other scientists are trying to reduce the effects of non-native species in the Great Marsh.

A major goal for Alyssa is to restore populations of a native eelgrass. Eelgrass does more than just prevent erosion. It also improves water quality, provides food and habitat for native animals, and acts as an indicator of marsh health. Scientists like Alyssa want to know whether planting eelgrass back into the marsh would be successful. If green crabs are responsible for the loss of eelgrass from the marsh, then restorations where green crab numbers are low should be more successful. Alyssa has been measuring green crab populations in different areas by laying out traps for 24 hours. Alyssa has set these traps all around Essex Bay, an area within the Great Marsh. She recorded the total number of green crabs caught at each location (as well as their body size and sex).

Scientific Question: What locations in Essex Bay are most promising for eelgrass restoration, based on the number of invasive green crabs?

Scientific Data:

Use the data below to answer the scientific question:

Location in Essex Bay	Total Catch of Female Crabs*	Total Catch of Male Crabs	Total Number of Green Crabs	Suitability Score**
16	175	39		
17	132	47		
18	535	37		
19	150	10		
20	103	7		
21	98	7		
22	29	5		
23	351	95		
24	186	46		
25	220	77		
26	149	13		
27	160	69		
28	97	42		

**Total Catch was measured by counting how many crabs were found in a single trap after being set in a location for 25 hours (Data collected July 10, 2014)*

***Suitability Score is a measure of how suitable a site is for eelgrass restoration, and is calculated based on the number of invasive Green Crabs found at a site. The more green crabs present, the less suitable the site for eelgrass restoration.*

Name____________________

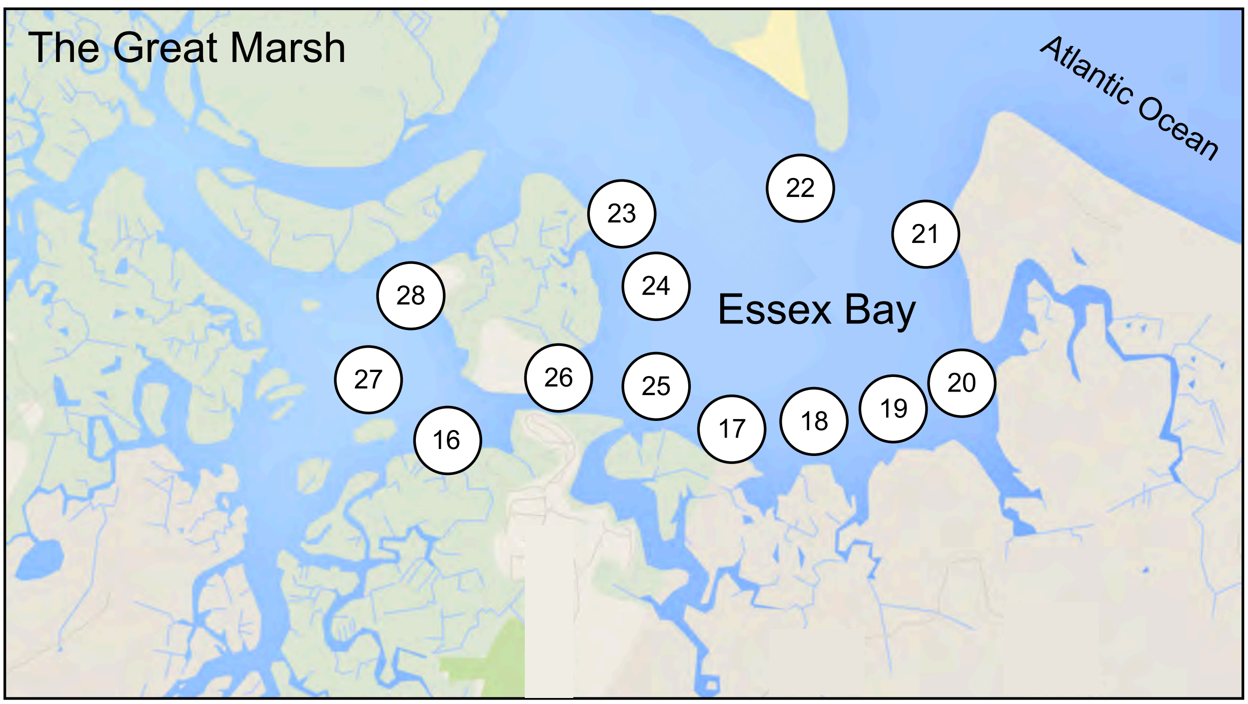
<u>Calculating the Suitability Score</u>: Complete the table and assign a suitability score to each location based on the total number of crabs per trap (Total Catch). A score of 1 indicates that there are many crabs and the site is not very suitable for restoration, while a score of 4 is the best and indicates the site is very suitable for restoration.

Total Catch > 175 crabs = score of 1
100 < Total Catch < 175 crabs = score of 2
50 < Total Catch < 100 crabs = score of 3
Total Catch < 50 crabs = score of 4

<u>Fill in the map below</u>: Identify any trends or differences you notice in the suitability scores on the map. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.

Choose a color for each Suitability Score (1-4) and fill out the key & map

1 = ◯ 2 = ◯ 3 = ◯ 4 = ◯



Name____________________

<u>Interpret the data</u>:

Make a claim that answers the scientific question.

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the presence of invasive green crabs and how that affects eelgrass.

Name____________________

Your next steps as a scientist:

Science is an ongoing process. What new questions do you think should be investigated?

What hypothesis would you like to test? A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

What future data should be collected to test your hypothesis?

Independent variable(s): ____

Dependent variable(s): ____

For each variable, explain why you included it and how it could be measured.

Name____________________

DATA Nugget

Is chocolate for the birds?
Featured scientist: Skye Greenler from Colorado College

Research Background:

About 9,000 years ago humans invented agriculture as a way to grow enough food for people to eat. Today, agriculture happens all over the globe and takes up 40% of Earth's land surface. To make space for our food, humans must clear large areas of land, creating a **disturbance**, or drastic change, to the habitat. This disturbance removes the native plants already there, including trees, small flowering plants, and grasses. Many types of animals including mammals, birds, and insects need these native plants for food or shelter and will now find it difficult to live in the area. For example, a woodpecker bird cannot live somewhere that has no trees because they live and find their food in the trees.

However, some agriculture might help some animals because they can use the crops being grown for the food and shelter they need to survive. One example is the cacao tree, which grows in the rainforests of South America. Humans use the seeds of this plant to make chocolate, so it is a very important crop! Cacao trees need very little light. They grow best in a unique habitat called the forest understory, which is composed of the shorter trees and bushes under the large trees found in rainforests. To get a lot of cacao seeds for chocolate, farmers need to have large rainforest trees above their cacao trees for shade. In many ways, cacao farms resemble a native rainforest. Many native plant species grow there and there are still taller tree species. However, these farms are different in important ways from a native rainforest. For example, there are

Skye out in the field counting birds along one of her four transects.

Name____________________

many more short understory trees in the farm than there are in native rainforests. Also, there are fewer small flowering plants on the ground because humans that work on cacao farms trample them as they walk around the farm.

Skye is a biologist who wanted to know whether rainforest birds use the forest when they are disturbed by adding cacao farms. Skye predicted she would see many fewer birds in the cacao farms, compared to the rainforest. To measure bird **abundance**, she simply counted birds in each habitat. To do this she chose one rainforest and one cacao farm and set up two transects in each. Transects are parallel lines along which the measurements are taken. She spent four days counting birds along each transect, for a total of eight days in each habitat. She had to get up really early and count birds between 6:00 and 9:00 in the morning because that's when they are most active.

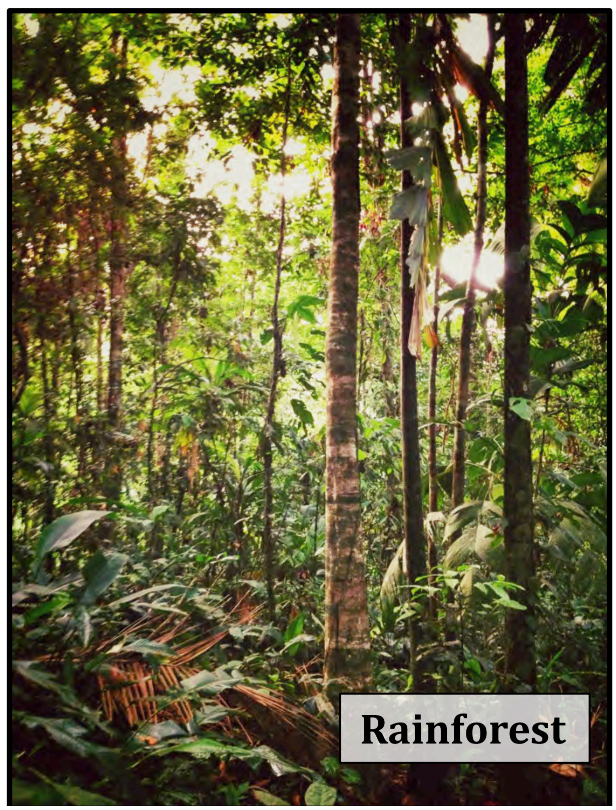
Scientific Question 1**:** What is the effect of cacao farms on bird abundance?

Scientific Data 1:

Use the data from Table 1 to answer scientific question 1:

Table 1: Bird Observation Data

	Total Bird Count
Cacao	106
Rainforest	116



The image on the left shows a typical cacao farm with some taller trees remaining to provide shade for the cacao. The image on the right shows an undisturbed rainforest. In the rainforest, all the taller trees and small flowering plants remain.

Name____________________

What data will you use to answer question 1?

Independent variable: ____

Dependent variable: ____

Interpret the data:

Make a claim that answers scientific question 1 – What is the effect of cacao farms on bird abundance?

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how agriculture may act as a disturbance.

Skye's next steps: Skye was shocked to see so many birds in cacao farms! She decided to take a closer look at her data. Skye wanted to know how the types of birds she saw in the cacao farms compared to the types of birds she saw in the rainforest. She predicted that cacao farms would have different types of birds than the undisturbed rainforest. She thought the bird types would differ because each habitat has different types of food available for birds to eat and different types of plants for birds to live in.

Skye broke her abundance data down to look more closely at four groupings of birds:

1. Toucans (Eat: large insects and fruit from large trees, Live: holes in large trees)
2. Hummingbirds (Eat: nectar from flowers, Live: tree branches and leaves)
3. Wrens (Eat: small insects, Live: small shrubs on the forest floor)
4. Flycatchers (Eat: small insects, Live: tree branches and leaves)

Name____________________

Scientific Question 2: What is the effect of cacao farms on the abundance of different bird types?

What is the hypothesis? Find the hypothesis in *Skye's next steps* (above) and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation.

Scientific Data 2:

Use the data from Table 2 to answer scientific question 2:

Table 2. Bird Observation Data by Bird Type

Date	Habitat	Toucans	Hummingbirds	Wrens	Flycatchers
3/16/13	Cacao	**0**	**0**	**0**	**11**
3/22/13	Cacao	**1**	**2**	**0**	**7**
3/25/13	Cacao	**0**	**3**	**0**	**10**
4/4/13	Cacao	**0**	**7**	**1**	**5**
4/8/13	Cacao	**0**	**7**	**0**	**9**
4/12/13	Cacao	**0**	**6**	**0**	**9**
4/18/13	Cacao	**0**	**6**	**0**	**6**
4/25/13	Cacao	**0**	**7**	**2**	**7**
3/14/13	Rainforest	**1**	**3**	**2**	**2**
3/14/13	Rainforest	**2**	**4**	**10**	**8**
3/21/13	Rainforest	**2**	**2**	**9**	**3**
3/26/13	Rainforest	**2**	**4**	**7**	**4**
4/6/13	Rainforest	**2**	**1**	**8**	**3**
4/9/13	Rainforest	**2**	**3**	**8**	**6**
4/20/13	Rainforest	**3**	**2**	**8**	**5**
4/22/13	Rainforest	**0**	**0**	**0**	**0**

Total Count (abundance)	Toucans	Hummingbirds	Wrens	Flycatchers
Cacao				
Rainforest				

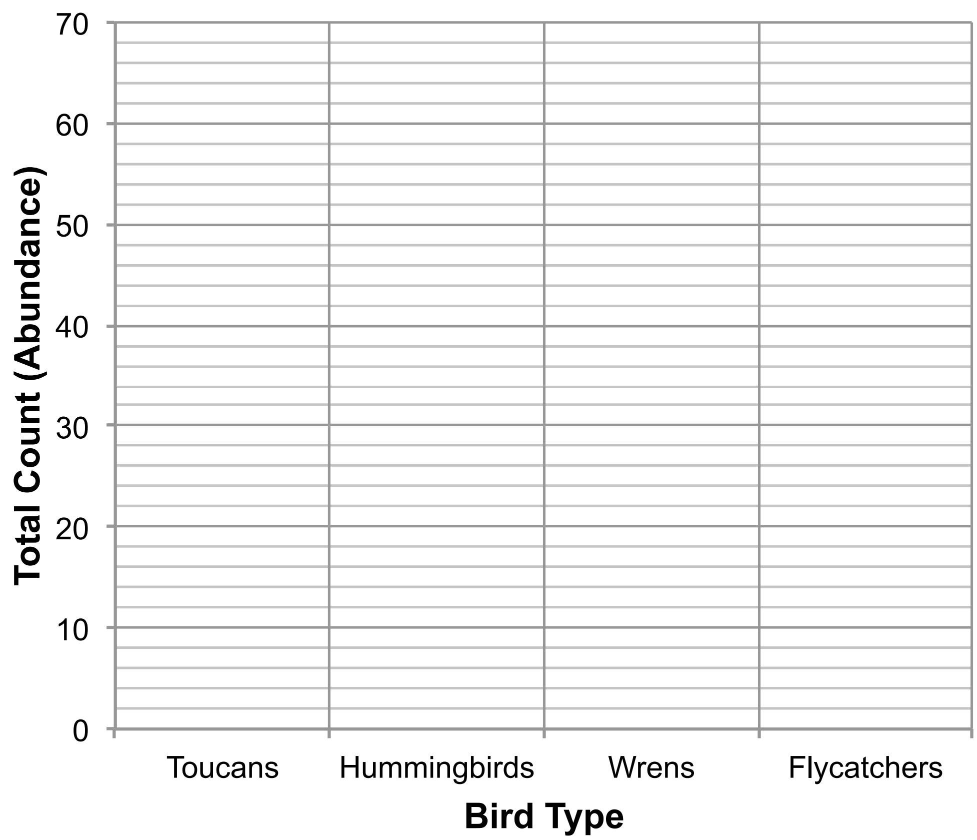
Name____________________

What data will you graph to answer question 2?

Independent variable: ____

Dependent variable: ____

<u>Draw your graph below</u>: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



<u>Interpret the data</u>:

Make a claim that answers scientific question 2 – What is the effect of cacao farms on the abundance of different bird types?

Name____________________

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about diet and living preferences of the different types of birds.

Did the data support Skye's hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Skye's research? What future data should be collected to answer your question(s)?

Name____________________

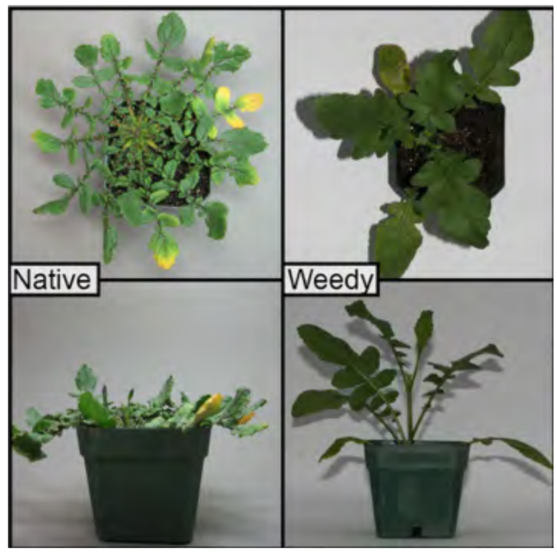
DATA Nugget

Fast weeds in farmer's fields

Featured scientists: Ashley Carroll from Gull Lake Middle School and Jeff Conner from the Kellogg Biological Station at Michigan State University

Research Background:

Weeds in agricultural fields cost farmers $28 billion per year in just the United States alone. When fields are full of weeds the crops do not grow as well. Sometimes weeds even grow better than the crops in the same field. This may make you wonder, how do weeds grow so well compared to other types of plants? Scientists think that weeds may have evolved certain traits that allow them do well in agricultural fields. These **adaptations** could allow them to grow better and pass on more of their genes to the next generation.



Native and weedy radish plants.

Weedy radish is considered one of the world's worst agricultural weeds. This plant has spread around the world and can now be found on every continent except Antarctica. Weedy radish commonly invades wheat and oat fields. It grows better than crops and lowers the amount of food produced in these fields. Weedy radish evolved from native radish only after humans started growing crops. Native radish only grows in natural habitats in the Mediterranean region.

Because weedy radish evolved from native radish recently, they are still very closely related. They are so closely related they are actually listed as the same species. However, some traits have evolved rapidly in weedy radish. For example, native radish grow much slower and take a few months to make flowers. However, weedy radish can make flowers only three weeks after sprouting! In a farmer's field, the crop might be harvested before a native radish would be able to make any seeds, while weedy radish had plenty of time to make seeds.

The differences between native versus weedy radish interested Ashley, a teacher in Michigan. To learn more she sought out a scientist studying this species. She found Jeff, a plant biologist at the Kellogg Biological Station and she joined his lab for a summer to work with him. That summer, Ashley ran an experiment where she tested

Name____________________

Ashley collecting data on the traits of weedy and native radish.

whether the rapid flowering and seed production of weedy radish was an adaptation to life in agricultural fields.

Ashley planted four populations of native radish and three populations of weedy radish into fields growing oat crops. Ashley made sure to plant multiple populations of radish to add replication to her experiment. Multiple populations allowed her to see if patterns were the same across populations or if each population grew differently. For each of these populations she measured **flowering frequency**. This trait is the total number of plants that produced flowers within the limited time between tilling and harvesting. Ashley also measured **fitness**, by counting the total number of seeds each plant produced over its lifetime. Whichever plant type produced a greater number of seeds had higher fitness. Oats only grow for 12 weeks so if radish plants were going to flower and make seeds they would have to do it fast. Ashley predicted the weedy radish population would produce more flowers and seeds than native radish during the study. Ashley expected few native radish plants would flower before harvest.

Scientific Question: How does flower production differ between native and weedy radish? How does this affect fitness in an agricultural setting?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies

Name____________________

Scientific Data:

Use the data below to answer the scientific question:

Type of Radish	Radish population	Number of plants	Percent (%) plants flowering	Fitness (number of seeds per plant)
Native	DAES	46	13%	0
	GHIL	33	64%	1
	MAES	44	9%	0
	ZYIL	45	60%	8.7
Average Native				
Weedy	AFFR	42	69%	17.4
	BINY	17	82%	10.5
	NAAU	30	87%	4.2
Average Weedy				

What data will you graph to answer the question?

Independent variable(s): ____

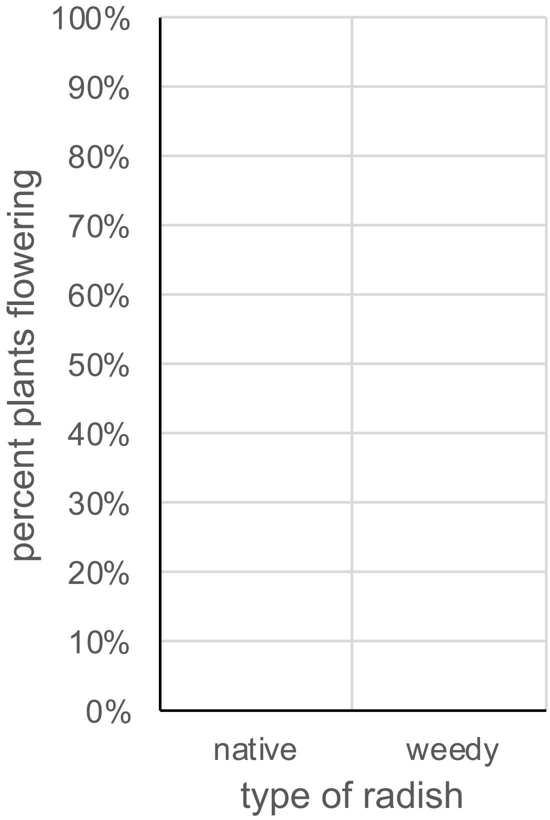
____

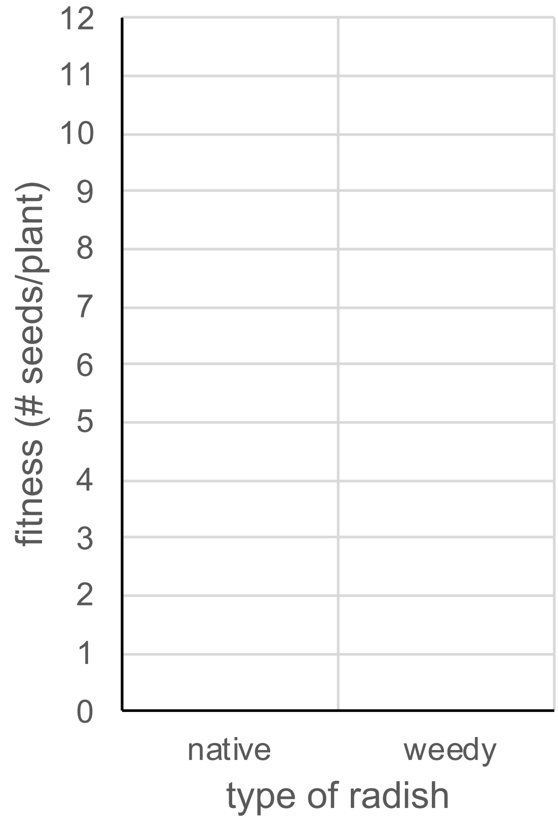
Dependent variable(s): ____

____

Name____________________

Draw your graphs below: Identify any changes, trends, or differences you see in your graphs. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.





Interpret the data:

Make a claim that answers the scientific question.

Name____________________

What evidence was used to write your claim? Reference specific parts of the table or graphs.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how weedy adaptations affect radish fitness in agricultural fields.

Did the data support Ashley's hypothesis? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Name____________________

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Ashley's research? How do your questions build on the research that has already been done?

Name________________________

DATA Nugget

The carbon stored in mangrove soils
Featured scientist: Sean Charles from Florida International University

Research Background:

In the tropics and subtropics, **mangroves** dominate the coast. There are many different species of mangroves, but they are all share a unique characteristic compared to other trees – they can tolerate having their roots submerged in salt water.

Mangroves are globally important for many reasons. They form dense forested wetlands that protect the coast from erosion and provide critical habitat for many animals. Mangrove forests also help in the fight against climate change. Carbon dioxide is a greenhouse gas that is a main driver of climate change. During photosynthesis, carbon dioxide is absorbed from the atmosphere by the plants in a mangrove forest. When plants die in mangrove forests, decomposition is very slow. The soils are saturated with saltwater and have very little oxygen, which decomposers need to break down plants. Because of this, carbon is stored in the soils for a long time, keeping it out of the atmosphere.


Sean Charles taking soil samples amongst inland short mangroves.

Sean is a scientist studying coastal mangroves in the Florida Everglades. Doing research in the Everglades was a dream opportunity for Sean. He had long been fascinated by the unique plant and animal life in the largest subtropical wetland ecosystem in North America. Mangroves are especially exciting to Sean because they combine marine biology and trees, two of his favorite things! Sean had previously studied freshwater forested wetlands in Virginia, but had always wanted to spend time studying the salty mangrove forests that exist in the Everglades.

Sean arrived in the Everglades with the goal to learn more about the factors important for mangrove forests' ability to hold carbon in their soils. Upon his arrival, he noticed a very interesting pattern – the trees were much taller along the coast compared to inland. This is because mangroves that grow close to the coast have access to important nutrients found in ocean waters, like phosphorus. These nutrients allow the trees to grow large and fast. However, living closer to the coast also puts trees at a higher risk of damage from storms, and can lead to soils and dead plants being swept out to sea.

Tall mangroves growing close to the coast.

Sean thought that the combination of these two conditions would influence how much carbon is stored in mangrove soils along the coast and inland. Larger trees are generally more productive than smaller ones, meaning they might contribute more plant material to soils. This led Sean to two possible predictions. The first was that there might be more carbon in soils along the coast because taller mangroves would add more carbon to the soil compared to shorter inland mangroves. However, Sean thought he might also find the opposite pattern because the mangroves along the coast have more disturbance from storms that could release carbon from the soils.

To test these competing hypothesis, Sean and a team of scientists set out into the Everglades in the Biscayne National Park in Homestead, Florida. Their mission was to collect surface soils and measure mangrove tree height. To collect soils, they used soil cores, which are modified cylinders that can be hammered into the soil and then removed with the soil stuck in the tube. Tree height was measured using a clinometer, which is a tool that uses geometry to estimate tree height. They took these measurements along three transects. The first transect was along the coast where trees had an average height of 20 meters. The second transect between the coast and inland wetlands where trees were 10 meters tall, on average. The final transect was inland, with average tree height of only 1 meter tall. With this experimental design Sean could compare transects at three distances from the coast to look for trends.

Once Sean was back in the lab, he quantified how much carbon was in the soil samples from each transect by heating the soil in a furnace at 500 degrees Celsius. Heating soils to this temperature causes all organic matter, which has carbon, to combust. Sean measured the weight of the samples before and after the combustion. The difference in weight can be used to calculate how much organic material combusted during the process, which can be used as an estimate of the carbon that was stored in the soil.

Name________________________

Scientific Question: How does the amount of soil carbon change with decreasing mangrove height from the coast to inland wetlands?

What is the hypothesis? Find the two hypotheses in the Research Background and underline them. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies. Having two alternative hypotheses means that more than one mechanism may explain a given observation. Experimentation can determine if one, both, or neither hypotheses are supported.

Scientific Data:

Use the data below to answer the scientific question:

Habitat type	Distance from coast	Mangrove tree height	Sample along transect	Proportion soil organic carbon
coastal fringe	closest	tallest	1	0.258
coastal fringe	closest	tallest	2	0.354
coastal fringe	closest	tallest	3	0.333
coastal fringe	closest	tallest	4	0.298
coastal fringe	closest	tallest	5	0.337
intermediate	intermediate	intermediate	1	0.274
intermediate	intermediate	intermediate	2	0.369
intermediate	intermediate	intermediate	3	0.384
intermediate	intermediate	intermediate	4	0.379
intermediate	intermediate	intermediate	5	0.370
inland	furthest	shortest	1	0.158
inland	furthest	shortest	2	0.185
inland	furthest	shortest	3	0.179
inland	furthest	shortest	4	0.212
inland	furthest	shortest	5	0.084

**Distance from the coast was measured in meters (m), and then broken up into 3 categories. These categories are closest (10-20 m from coast), intermediate (100-120 m from coast), and furthest (275-300 m from coast).*
***Mangrove tree height was measured in meters (m), and then broken up into 3 categories. These categories are shortest (<1.5 m), intermediate (2-6 m), and tallest (10-20 m).*
****Proportion soil organic carbon is calculated after measuring the difference in soil sample weights before and after combustion.*

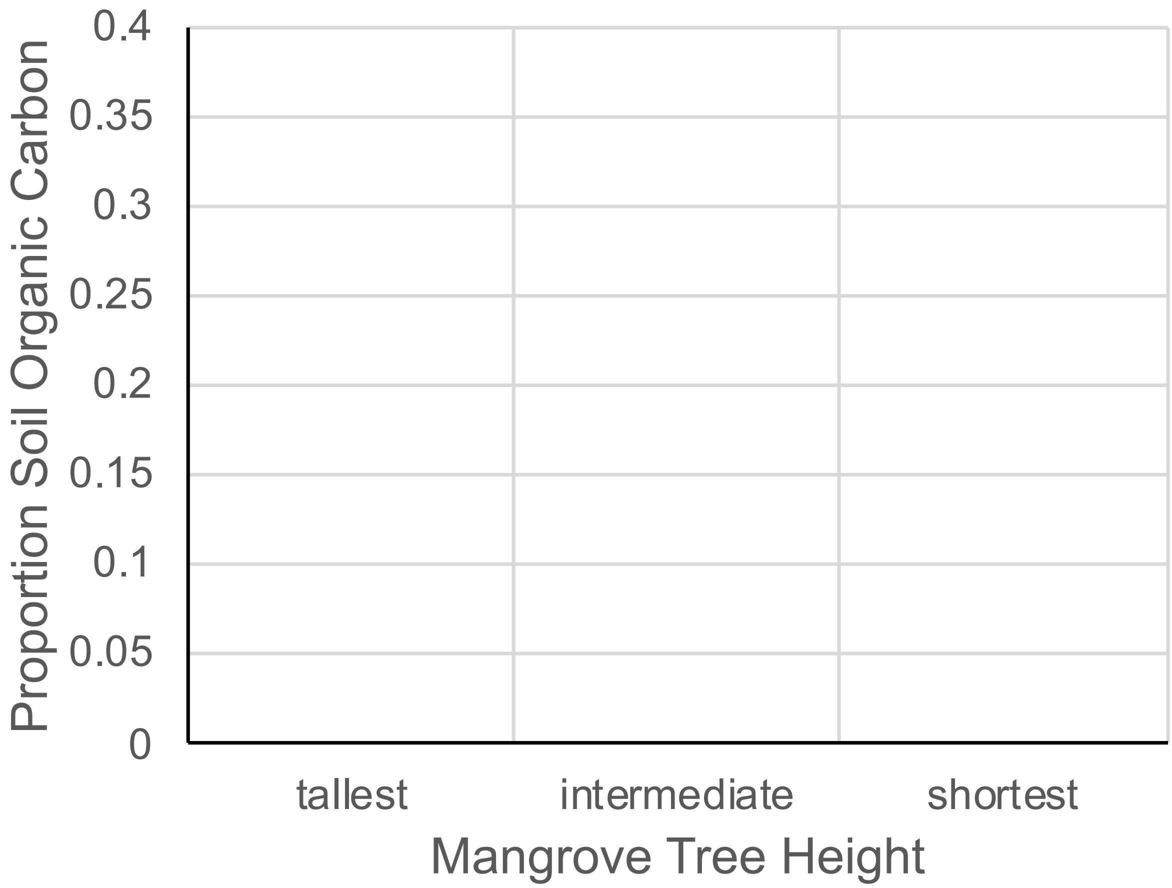
What data will you graph to answer the question?

Independent variables: ________________________________

Dependent variable: ________________________________

Name________________________

Draw your graph(s) below: Identify any changes, trends, or differences you see in your graph(s). Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



Interpret the data:

Make a claim that answers the scientific question.

Name________________________

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about how carbon gets into the soil, and why taller trees contribute more carbon to soils.

Did the data support one, both, or neither of Sean's two hypotheses? Use evidence to explain why or why not. If you feel the data were inconclusive, explain why.

Name________________________

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on Sean's research? What future data should be collected to answer your question(s)?

Name____________________

DATA Nugget

Beetle, it's cold outside!

Featured scientists: Caroline Williams & Andre Szejner Sigal, University of California, Berkeley, & Nikki Chambers, Biology Teacher, West High School, Torrance, CA

Research Background:

Walking across a snowy field or mountain, you might not notice many living things. But if you dig into the snow, you'll find a lot of life!

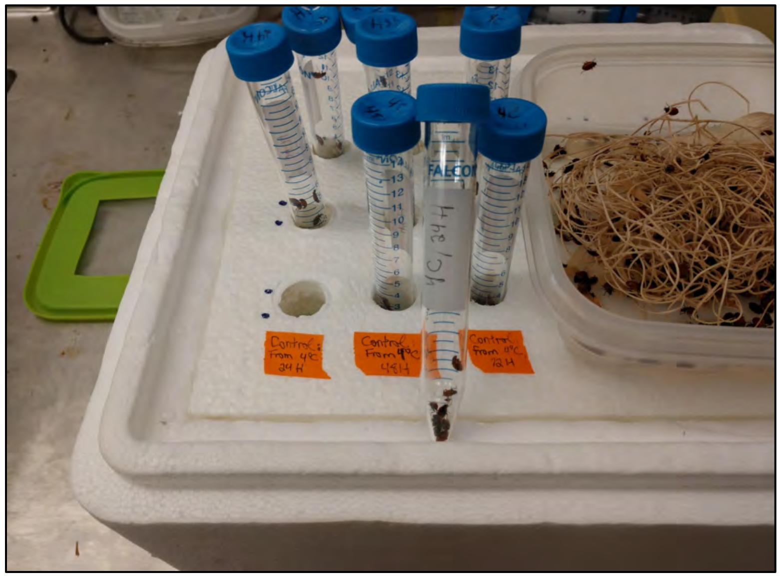
Until recently, climate change scientists thought warming in winter would be good for most species. Warmer winters would mean that species could avoid the cold and would not need to deal with freezing temperatures as often or for as long. Caroline is a scientist who is thinking about winter climate change in a whole new way. Snow covers the soil, acting like an insulating blanket. Many species rely on the snow for protection from the winter's cold. When temperatures climb in the winter, snow melts and leaves the soil uncovered for longer periods of time. This leads to the shocking pattern that warmer temperatures actually means the soil gets colder!

Caroline is interested in how species that rely on the snow will respond to climate change. She studies a species of insect called lady beetles. Lady beetles are **ectotherms**, meaning their body temperature matches that of their environment. Because climate change is reducing the amount of snow in the lady beetle habitat, Caroline wanted to know how they would respond to these changes.

Caroline and her team, Andre and Nikki, decided to investigate what happens to lady beetles when they are exposed to longer periods of time in cold temperatures. When soil temperatures drop below freezing (0°C), lady beetles go into a **chill coma**, or a temporary, reversible paralysis. When temperatures are below freezing, it is so cold that they are unable to move. When temperatures rise back above freezing, they wake from their chill comas. When lady beetles are in chill comas, they are easier for predators to catch because they can't escape. They are also unable to find food or mates. Scientists can measure how fast it takes lady beetles to recover from chill coma, called **chill coma recovery time**, and use this as a measure of their performance.

They designed an experiment to test whether the amount of time lady beetles spend in freezing temperatures affects how long it takes them to wake up from a chill coma. Caroline thought that lady beetles exposed to lengthy freezing temperatures would be harmed because freezing causes tissue damage and the insect must use more energy to survive. She predicted that the longer the lady beetles had been exposed to the cold, the longer it would take them to wake up from their chill comas.

To begin the experiment, Andre and Nikki placed groups of lady beetles in tubes. They then placed the tubes in an ice bath, bringing the temperature down to 0°C, the point when lady beetles enter chill coma. They varied the amount of time each tube was in the ice baths and tested chill coma recovery times after 3, 24, 48, 72, or 96 hours. After removing the tubes from the ice baths, they put the lady beetles on their backs with their legs in the air and left them at room temperature, 20°C. Andre and Nikki timed how long it took each beetle to wake up and turn itself over.



Beetles in their pre-testing habitat are on the right; tubes with beetles about to be immersed in a cooler filled with crushed ice are on the left.

In the experiment, they used two different populations of lady beetles. Population 1 had been living in the lab for several weeks before the experiment began. They were not in great health and some had started to die. In order to make sure they had enough beetles for the experiment, Caroline purchased more lady beetles, which she called Population 2. Population 2 only spent a few days living in the lab before testing and were in much better health. Caroline noted the differences in these populations and thought their age, health, and background might affect how they respond to the experiment. She decided to track which population the lady beetles were from so she could analyze the data separately and see if the health differences between Population 1 and 2 changed the results.

<u>Scientific Question:</u> Does the amount of time lady beetles spend at freezing temperatures affect how long it takes for them to wake up from a chill coma?

<u>What is the hypothesis?</u> Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Name____________________

Draw a model demonstrating the impact of climate change on lady beetles:

1. Include the terms **climate change**, **air temperature**, **snow cover**, **soil temperature**, **ectotherms**, **and chill coma** in your model. Write out the name of each variable and put a box around it. If necessary, you may use other terms in your model as well.
2. Add arrows to connect the boxes. Arrows represent the interactions between the variables in the system. For example, you can use arrows to show positive or negative effects of one variable on another. Use the direction of the arrow to show the direction of the relationships.
3. Once you have drawn your arrows, label them with the type of interaction. For example, label an arrow with the words "negatively affects" if the arrow connects a variable that has a negative impact on another.

Scientific Data:

Use the data below to answer the scientific question:

Beetle Population 1		
Time exposed to freezing temperature (hours)	**Mean chill coma recovery time (seconds)**	**Standard error (SE) chill coma recovery time**
3	212	44.3
24	136	25.0
48	100	15.5
72	63	6.4
96	119	25.0

Beetle Population 2		
Time exposed to freezing temperature (hours)	**Mean chill coma recovery time (seconds)**	**Standard error (SE) chill coma recovery time**
3	41	2.6
24	47	2.2
48	48	2.1
72	53	3.7
96	50	4.6

**Standard error (SE) tells us how confident we are in our estimate of the mean, and depends on the number of replicates in an experiment and the amount of variation around the mean. A large SE means we are not very confident, while a small SE means we are more confident.*

Name____________________

What data will you graph to answer the question?

Independent variable(s): ____

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Dependent variable(s): ____

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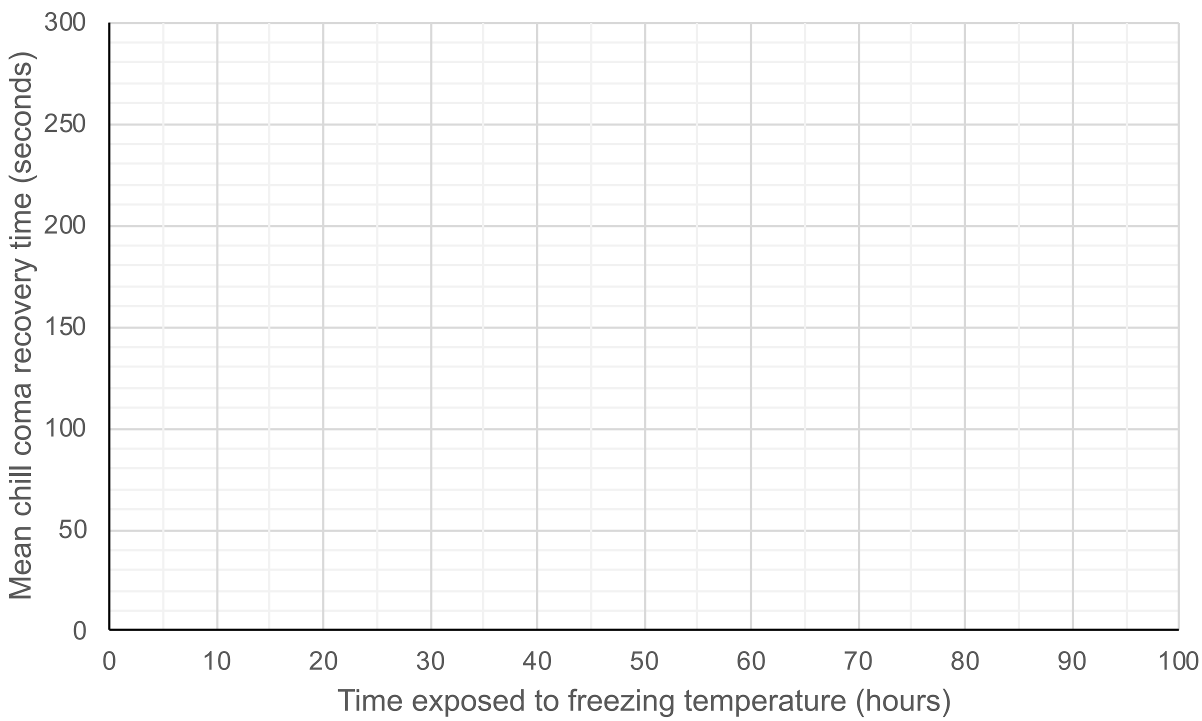
Draw your graph below: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



Interpret the data:

Make a claim that answers the scientific question.

Name____________________

What evidence was used to write your claim? Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the effects of cold temperatures on lady beetles and how this relates to their health and recovery time.

Did the data support Caroline, Andre, and Nikki's hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

<u>Your next steps as a scientist:</u> Science is an ongoing process. What new question(s) should be investigated to build on Caroline, Andre, and Nikki's research? How do your questions build on the research that has already been done?