9th/10th Grade Biology
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Inquiry Based Evolution Unit Plan

Day	Lesson Title	Description
Day One ★△☄↔=	Natural Selection	Students will explore how natural selection can impact allele frequencies of a population.
Day Two ☀★△=	Darwin's Theory of Evolution	Students will understand how the theory of evolution evolved.
Day Three ★△☀♢	Darwin's Theory of Evolution	Students will explore varying views on the theory of evolution.
Day Four ★△↔☀	Hardy-Weinberg Equation	Students will be able to calculate the Hardy-Weinberg Equation
Day Five ☀ ★☄⧖△↔	Genetic Variation and Natural Selection	Day One of Origami Birds Lab
Day Six ☀ ★☄△↔	Speciation and Selection Pressure	Day Two of Origami Birds Lab
Day Seven ☀★☄△ ↔	Founder Effect and Genetic Drift	Day Three of Origami Birds Lab
Day Eight ☀ ★☄⧖△↔♢	Wrap Up and Concept Mapping	Wrap Up - Concept Mapping of Evolutionary Topics
Day Nine ★☀↔=	Micro/Macro/Assisted Evolution and Evolution Research	Students will learn about micro/macro evolution, as well as current research in evolution around the related concept of assisted evolution.
Day Ten = ☀★♢△↔	Socratic Seminar on Assisted Evolution	Students will discuss their opinions on assisted evolution through the format of a Socratic Seminar.

Symbols Key:

☄ = Inquiry ★ = Differentiation ☀ = Real World Competency

= Assessment △ = NGSS Practices ♢ = Argumentation

↔ = NGSS Cross-Cutting Themes

First Day of Unit: Natural Selection (★△☄↔=)

Standard	BIO.B.3.1.1: Explain how natural selection can impact allele frequencies of a population.
	BIO.B.3.1.2: Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).

Objective	**Essential Question**
To understand natural selection. To understand evolution occurs between populations not individuals To understand how factors can contribute to the development of a new species	How does a theory evolve over time? How does structure affect function?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
51 minute period		**Teacher will…**	**Students will …**
6 min	**Engage (Quick Start/ Review)**	Show students an newspaper cartoon image: Man is but a Worm and ask them what do they see, what do they think, and what do they wonder about the image △ - 1. Asking questions and defining problems	Respond to the cartoon prompt. Practice their skills of observation and inference.
37 min	**Explore**	Split students into a group of 4 and give each group a fork, spoon, knife, pincher, beans, and paper plate. Ask students to complete the bird investigation. ☄ inquiry lab ↔ - 2. Cause and Effect: Mechanism and Explanation	Explore how natural selection in birds leads to evolution.

		↔ - 1. Structure and Function	
5 min	**Explain**	Ask students based off their observations what do they think is natural selection?	Formulate a definition for natural selection from what they observed in the bird investigation.
	Extend		
3 min	**Evaluate (Assessment/ Closure)**	Ask students to write on an index card one question they have about evolution. (diagnostic =) This will give me an idea of what students would like to learn about evolution.	Write a question they have about evolution.
Homework	Ask students to watch The Making of a Theory: Darwin, Wallace, and Natural Selection (https://www.youtube.com/watch?v=XOiUZ3ycZwU) and write a 5 sentence summary.		
Core Vocabulary	Population, variation, natural selection, allele frequency		
Notes/Lesson Differentiation	If students finish activity early they can begin watching The Making of a Theory video (★)		

Materials for Day 1 Lesson:

Engage image:

See-Think-Wonder

1. What do you see? (Just the facts)
2. What do you think? (What does it make you think?)
3. What do you wonder? (What questions do you have?)

Bird Investigation

Materials: beans, fork, spoon, knife, clothespin, and paper plate

Name:_____

LAB INVESTIGATIONS:
The Strange Birds of (insert name of school here)

Introduction
On the Island of (insert name of school here), there exists a strange **population** of birds. Within this population there is a great amount of **variation** in the shape of the beak. Some birds have a beak that is sharp and narrow like a knife. Other birds have a beak that is forked. A third variation has a beak that dips like a scoop. Lastly, there are birds that have a beak that can pinch. Recently, food has become scarce on the island causing competition within the population of birds. The only resource left for the birds to eat is dried beans. Investigate how natural selection will affect this species.

Hypothesis
Which bird beak shape is best adapted for gathering dried beans?

Materials
Dried beans, plastic spoon, plastic fork, plastic knife, clothespin, plates, cups

Procedure
1. You will work in groups of four. Each member will be given a different item (spoon, fork, clothespin, or knife). Each item represents a different type of bird beak.
2. With your free hand behind your back you will have 30 seconds to collect dried beans using your tool. The instructor will be the timekeeper for the entire class.
3. After this first round, you will record your data into the data chart below. The bird that obtains the least amount of food will become extinct.
4. Repeat this procedure until there is only one left standing.

Data

Beak Type	Round 1 (# of beans)	Round 2 (# of beans)	Round 3 (# of beans)
Fork Beak			
Knife Beak			
Pincher Beak			
Spoon Beak			

Describe each beak structure in terms of advantages and disadvantages:
- Spoon:
- Fork:
- Knife:
- Pincher:

Analysis Questions:
1. Explain how the data supported or rejected your hypothesis.

2. From your observations, what do you think are the principles of natural selection?

3. If you returned to the Island of (insert name of school) in the future, hundreds of years from now, what would you expect to see in the population of finches? Why?

4. On the nearby Isle of (Insert last name here), the primary food source is worms instead of dried beans. Do you think that selection would be different on this island? How?

5. What do you think is the difference between natural and artificial selection?

Second Day of Unit: Darwin's Theory of Evolution (☀★△=)

Standard	BIO.B.3.1.1: Explain how natural selection can impact allele frequencies of a population.
	BIO.B.3.1.2: Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).
	BIO.B.3.2.1: Interpret evidence supporting the theory of evolution (i.e., fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).
	BIO.B.3.3.1: Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.

Objective	**Essential Question**
To understand how the theory of evolution developed. To determine how scientific terms relate to the development of a theory. To understand evolution occurs between populations not individuals To understand Lamarck, Linnaeus, Cuvier, Wallace, and Darwin's theories of evolution.	How does a theory evolve over time? How does structure affect function?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
51 minute period		**Teacher will…**	**Students will …**
6 min	**Engage (Quick Start/ Review)**	Ask students to write down two interesting facts they learned about Darwin and Wallace in last night's video? (fromative =) This will allow me to assess how well the students grasped the video and a way for me to keep them accountable for their work.	Use their summaries from homework to write down two interesting facts about Darwin and Wallace.
	Explore		
42 min	**Explain**	Discuss the scientists involved in the history and/or development of the Theory of Evolution.	Connect terms such as hypothesis and inference to the development of scientific theories.
	Extend	Ask students to create a tweet for each of the following scientists: Lamarck, Linnaeus, Cuvier, Wallace, Darwin.	Use the internet and class notes to come up with a tweet for each scientist.

		The tweet activity will require students to summarize in their own words what the most important contributions of each scientist are. △ - 8. Obtaining, Evaluating, and Communicating Information	
3 min	**Evaluate (Assessment/ Closure)**	Ask students to write down on an index card one thing they've heard about the theory of evolution that they're not sure is fact or myth? (diagnostic =) This will allow me to have time before the next class to read through the myths so that I can best address the students needs.	Think about what they have heard about evolution from friends, relatives, or the media.
Homework	Students will finish completing the tweet activity for homework (due day 4) and read the following article for day 3: *Does evolutionary theory need a rethink?* (☀): http://www.nature.com/news/does-evolutionary-theory-need-a-rethink-1.16080		
Core Vocabulary	Hypothesis, inference, law, theory, principle, fact, and observation		
Notes/Lesson Differentiation	If students finish tweet activity they can begin reading the Nature article for homework (★) Depending on students ability to read scientific literature, an article comparing views on evolution should be selected that is appropriate for their level (★)		

Materials for Day 2 Lesson:
Tweet Activity Format

Name:_____

Scientist Tweets

Write one tweet as each of the following scientists (Lamarck, Linnaeus, Cuvier, Wallace, Darwin) about their theory of evolution:

Each tweet should include a picture of the scientist, a 140 max character count, and at least two hashtags.

Third Day of Unit: Darwin's Theory of Evolution (★△☀♢)

Standard	BIO.B.3.2.1: Interpret evidence supporting the theory of evolution (i.e., fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).
	BIO.B.3.3.1: Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.

Objective	**Essential Question**
To develop skills to address societal preconceptions about evolution using evidence. To understand how the theory of evolution evolves. To develop scientific argumentation skills. To understand whether or not the structure of the theory of evolution supports how we believe evolution occurs.	How does a theory evolve over time? How does structure affect function?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
51 minute period		**Teacher will…**	**Students will …**
15 min	**Engage (Quick Start/ Review)**	1. (10min) Post myths (anonymously) about evolution that students wrote down and ask them to write down how the previous days lesson on the theory of evolution and the reading last night addressed the myth. 2. (5min) Discuss with students, evidence they used to address specific myths about evolution.	Explore how to use evidence to address societal preconceptions about scientific theories. (☀)
15 min	**Explore**	Ask students to create a list of evidence for why we should re-evaluating the theory of evolution and one for why we	Be able to distinguish what is good evidence for each side of the argument.

		should not re-evaluate the theory.	
21 min	**Explain (10 min)**	Discuss with students the reading from last night and answer any clarifying questions the students may have.	Ask for clarifications on confusing topics or vocabulary discussed in the article. The article from Nature will allow students to understand what are good online sources for scientific information.
	Extend (11 min)	1. (8min) Ask students to partner up. One student will be Partner A and other Partner B. Partner A will be for revaluating the theory of evolution and Partner B will be for not re-evaluating the theory of evolution. Each student will have 4 minutes to try change their partner's mind using their lists of evidence from the reading. 2. (3min) Debrief with the students by asking them if their partner convinced them to change their assigned view and if so what evidence convinced you to reconsider your side? (◇Argumentation) △ -7. Engaging In Argument From Evidence	Develop scientific argumentation skills by using evidence to back up their claim.
	Evaluate (Assessment/ Closure)		
Homework	Tweet activity from the previous day will be due the fourth day.		
Core Vocabulary			

Notes/Lesson Differentiation	Depending on the class and students' abilities, a different article may need to be selected that is at the student's reading ability. (★) The Pro/Con list can actually be created as a class rather than individually if students are struggling to find the evidence for pros and cons on their own.(★)

Fourth Day of Unit: Hardy Weinberg Equation (★△↔☀)

Standard	BIO.B.3.1.1: Explain how natural selection can impact allele frequencies of a population.
	BIO.B.3.1.2: Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).
	BIO.B.3.3.1: Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.

Objective	**Essential Question**
To understand the conditions necessary for a population to be at equilibrium. To understand that the Hardy-Weinberg equation can not be used for a population undergoing natural selection. To be able to calculate genotypic frequencies using the Hardy-Weinberg equation of a population at equilibrium.	How does structure affect function?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
51 minute period		**Teacher will…**	**Students will …**
8 min	**Engage (Quick Start/ Review)**	1. Project a map of the prevalence in the world of lactose intolerance. 2. Give students the phenotypes of a family with lactose intolerance and ask them to label the homozygous dominant trait, the heterozygous dominant trait, and the homozygous recessive trait.	1. Review terms from the genetic units that will be necessary to understanding and calculating Hardy Weinberg frequencies. 2. Be engaged through the use of a human genetic example they most likely have heard of.

		3. (3min) Review with students what the following terms are: genotype, phenotype, homozygous, heterozygous, dominant, recessive. (☀ Real World Competency) △ - 4. Analysing and Interpreting Data	
30 min	**Explore**	Ask the class to complete the goldfish activity, which models the Hardy-Weinberg equation in a population at equilibrium and how natural selection does not fit the conditions necessary for Hardy Weinberg. ↔ 4. - Systems and System Models ↔ 7. Stability and Change △ - 4. Using mathematics, information, computer technology, and computational thinking	Practice calculating p, q, p^2, 2pq, q^2 for a population at equilibrium using the Hardy Weinberg equation. Students will then try calculate the Hardy Weinberg frequencies in a population affected by natural selection (a factor that does not meet the Hardy Weinberg conditions).
13 min	**Explain**	1. Explain to students the conditions necessary for Hardy Weinberg. 2. Show how the formula ($p^2 + 2pq + q^2 = 1$) is derived from $p + q = 1$ using the quadratic formula. 3. Using lactose intolerance as an example, show students how to calculate Hardy Weinberg frequencies using the equation. △ - 4. Using mathematics, information, computer technology, and computational thinking	Begin to understand how the condition necessary for Hardy Weinberg, where the equation comes from, and how they can use it calculate genotypic frequencies in a population at equilibrium.
	Extend		
	Evaluate (Assessment/ Closure)		

Homework	Students will complete for homework three Hardy-Weinberg problems online at http://www.phschool.com/science/biology_place/labbench/lab8/hardwein.html
Core Vocabulary	
Notes/Lesson Differentiation	Students should have used the quadratic formula in math, however if not, students may struggle to understand the mathematical derivation of the equation. (★) Depending on the student population, not all students may have access to computers at home. For those who don't, provide a hand out of the questions for homework so they can complete the assignment by hand. (★)

Engage Activity

Hardy Weinberg Lactose Intolerance Example:

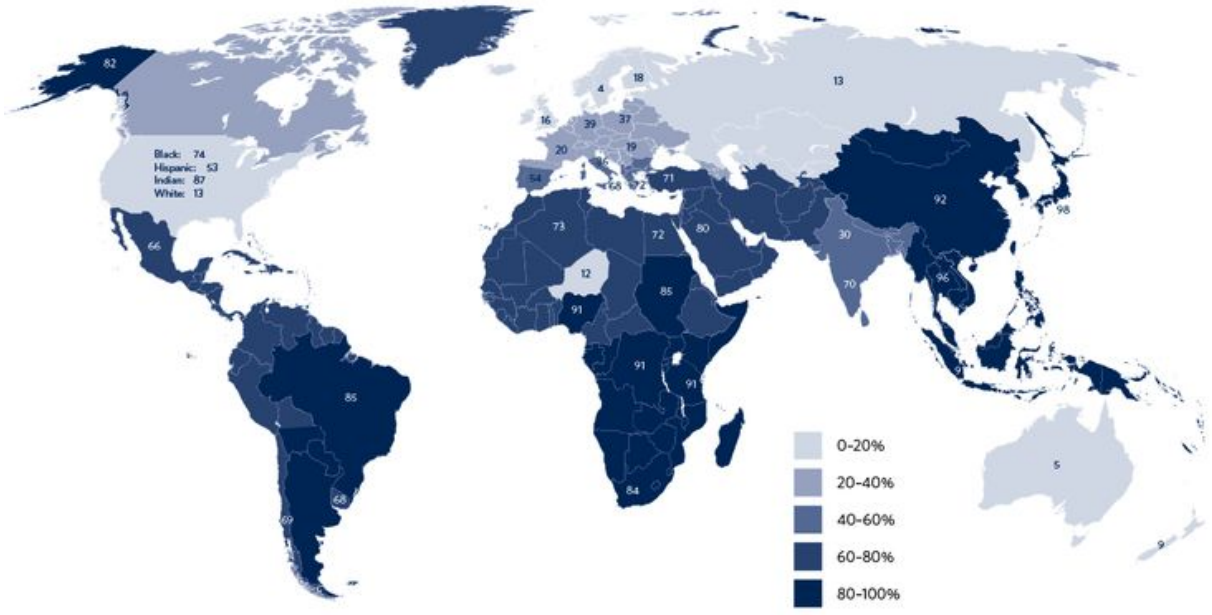


Image from http://www.foodbeast.com/news/map-of-milk-consumption-lactose-intolerance-around-the-world/

Lactose is a sugar found in milk. The enzyme lactase breaks down lactose. Lactose intolerance is the inability to digest milk due to a mutation in the enzyme lactase.

In a family of four children, one sibling of the four has lactose intolerance, while the other three siblings are able to digest milk. Based on these given phenotypes find the genotypes for the mom, the dad, and each of the four children. Then based on your knowledge list which are homozygous dominant, homozygous recessive, or heterozygous.

Materials for Day 4 Lesson:

(Explanation and activity from http://www.carolina.com/teacher-resources/Interactive/teaching-hardy-weinberg-in-the-classroom/tr10630.tr)

Explain

"The Hardy-Weinberg principle states that allele and genotype frequencies remain stable in a population over generations if certain conditions are met:

1. The population is very large.
2. Mating is random.
3. There is no immigration or emigration.
4. There are no mutations.
5. Natural selection is not occurring.

When all of these conditions are met, the population is said to be in Hardy-Weinberg equilibrium. If the allele or genotype frequencies do change over time, then scientists assume that 1 or more of the conditions is not being met and the population may be evolving.

The Hardy-Weinberg equation allows scientists to estimate the allele and genotype frequencies in a population. The frequencies can be compared across generations to determine whether evolution may be occurring. Assuming that a population includes only 2 alleles for a given trait, the proportion of dominant alleles (p) plus the proportion of recessive alleles (q) is equal to 1 (i.e., 100% of the population). Squaring both sides of the equation $p + q = 1$ produces the equation $p^2 + 2pq + q^2 = 1$. Here p^2 is the number of individuals with a homozygous dominant genotype, $2pq$ is the number of individuals with a heterozygous genotype, and q^2 is the number of individuals with a homozygous recessive genotype."

Gold Fish Activity

Materials: 2 Bags of Cheese Goldfish® Crackers, 2 Bags of Pretzel Goldfish® Crackers, Plates or Napkins, Student Data Sheet

Preparation:

1. Pour the contents of all 4 bags of Goldfish® snacks into a large bowl—the lake.
2. Depending on class size, you may wish to divide your class into pairs or allow them to work individually.
3. Give each student or pair a copy of the Student Data Sheet and a plate or napkin; have them wash their hands before beginning.

4. Explain that brown (pretzel) Goldfish® are homozygous recessive individuals (gg) and that orange (cheese) Goldfish® display the dominant phenotype and therefore may be either homozygous dominant (GG) or heterozygous (Gg).

Activity:

Name:_____

Hardy-Weinberg Equilibrium

"The Hardy-Weinberg equation allows scientists to estimate the allele and genotype frequencies in a population. The frequencies can be compared across generations to determine whether evolution may be occurring" (Berkeley 2015)

Procedure:

Activity 1: Hardy-Weinberg Equilibrium

1. Each student or pair will remove 10 Goldfish® from the lake and place them on the plate or napkin. In order to ensure random choice, close your eyes while selecting.
2. Record the number of orange and brown Goldfish® in Table 1 as Generation 1.
3. Close your eyes and select 3 of their 10 Goldfish® at random. Place these 3 goldfish to the side.
4. Return to the lake, close your eyes, and randomly select 3 new Goldfish® to replace those that were removed.
5. Record your new count of orange and brown Goldfish® in Table 1 as Generation 2.
6. Repeat steps 3–5 until you have data for 5 generations.
7. After data have been collected, use the Hardy-Weinberg equation to calculate p, q, $p2$, $q2$, and $2pq$ for each generation.

Table 1. Hardy-Weinberg Equilibrium

Generation	Number of Orange Goldfish®	Number of Brown Goldfish®	p	q	$p2$	$2pq$	$q2$
1							
2							
3							
4							
5							

Activity 2: Hardy-Weinberg and Natural Selection

1. Each student or pair will remove 10 Goldfish® from the lake and place them on the plate or napkin. In order to ensure random choice, close your eyes while selecting.
2. Record the number of orange and brown Goldfish® in Table 2 as Generation 1.
3. Select and remove 3 of your brown Goldfish®. (If you do not have 3 brown ones on, substitute an orange one for brown)
4. Return to the lake, close your eyes, and randomly select 3 new Goldfish® to replace those that were removed. It is important that this step be random.
5. Record your new count of orange and brown Goldfish® in Table 2 as Generation

2, and then, as before, select 3 brown ones to remove.

6 Repeat steps 3–5 until you have data for 5 generations.

7 After data have been collected, use the Hardy-Weinberg equation to calculate p, q, p^2, q^2, and $2pq$.

Table 2. Hardy-Weinberg and Natural Selection

Generation	Number of Orange Goldfish®	Number of Brown Goldfish®	p	q	p^2	$2pq$	q^2
1							
2							
3							
4							
5							

Activity Conclusion:

"Once class data is collected, have students compare the genotype frequencies in both simulations. The class data from the first activity should result in fairly constant frequencies over the 5 generations. When selection is introduced in the second activity, the genotype frequencies should vary over the 5 generations. Discuss what conditions must exist for frequencies to remain stable over multiple generations. What do changing frequencies indicate in a population? Have students discuss whether Hardy-Weinberg equilibrium is possible in nature."

Day Five: Genetic Variation and Natural Selection (☀ ★ ☄ ⧖ △ ↔)

Standard	**3.1.B.C1** Describe species as reproductively distinct groups of organisms. Analyze the role that geographic isolation can play in speciation. Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity within a population. Describe how the degree of kinship between species can be inferred from the similarity in their DNA sequences.
	BIO.B.3.1.3 Explain how genetic mutations may result in genotypic and phenotypic variations within a population.
	BIO.B.3.1.1 Explain how natural selection can impact allele frequencies of a population.

Objective	**Essential Question**
• Students will understand that due to genetic mutations in a population, variability can occur in offspring. • Students will understand that due to limited resources, individuals will have to compete for resources such as food/water/space. • Students will understand that due to genetic variability, some offspring will be better suited to the environment than offers, and be able to outcompete other individuals for these resources (natural selection.)	How do differences between organisms of the same species occur? How do those differences contribute to the organism's survival? How do these trends shape a species over time? How does evolution produce an ideally adapted species if genetic variation is random?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
5 minutes	**Engage (Quick Start/ Review)**	Do Now: A cartoon of 3 siblings will be shown on the board, along with this question: Think of your own siblings (or cousins, or siblings that you know). Your genetics were passed down to you from your mother and	Write down answer to Do Now, then share out responses.

		father, and the same process happened for your siblings. If this is true, how can we account for the differences between siblings? How are you and your siblings different? ☀ Responses will be shared out in class and teacher will ask guided questions such as - "How do you think this difference occurred if you both have DNA from the exact same people?" For this Do Now, I wanted students to think back to the genetics and recall how genetic material is passed down from parents to offspring. I also wanted to introduce the idea behind genetic variability - that the random mixing of the genes leads to slight phenotypic and genotypic differences even in highly related individuals.	
5 minutes	**Explain**	Show definitions of genetic variability/natural selection and ask students to copy them down on the lab sheet. Tell students that we will be doing an activity for the next few days that will demonstrate how small changes in genetic variability and natural selection can lead to large changes over many generations. I wanted to start students off with the definitions of these difficult topics to ground their understanding of the lab we are about to do, and put them	Copy down definition, get into lab groups.

		in the right frame of mind to approach the lab as an evolution exercise instead of just an excuse to throw things around the room.	
25 minutes	**Explore**	Students will go through the procedure of Day One of the Origami Bird Experiment. The teacher will move from group making sure students are focused, on task, and understanding the greater meaning behind the experiment. This can be accomplished by asking selective questions such as, "Do you understand how this parent bird can produce offspring that look different?" "If this bird has to fly long distances, which of these offspring would be best at that?" "What do you think would happen to the other birds (that don't fly as well?" I chose this particular activity because I thought it was a good way to for students to explore natural selection via genetic variation in a hands-on, tangible way. As they make birds, they will discover that some "designs" are better than others, but they will not be able to just "create" the best bird out of nothing - they will have to rely on random (via dice and coins) mutations to slowly shift towards a better Origami Bird. This mimics the random yet directed nature of evolution in the "real world", a concept I am especially	Work in groups of four to follow the procedure of Day One of the Origami Bird experiment. Create birds, create a data table, and analyze results in the lens of variation and selection.

10 minutes		anxious for them to understand. This lab also involves elements of inquiry, as they will have to construct a data table that best suits their results and determine the most efficient way to construct their new birds. ✌ However, I will have a data table premade for those students who would be unable to construct a data table on their own in the time frame required. ★ △ -4. Analysing and Interpreting Data	
	Extend	Create data table on board for class data. When students appear to be finished, call their attention to a large class "map" that details the habitats of the Origami Birds. On this day, only the center of the map should be filled out, as a desert with oases between. The original Origami Bird will be taped to the center, with a circle around it. Ask each group to tape their "winning" origami birds on the desert part of the map, surrounding the original Origami Bird. Explain that we will see how the map changes as we continue with the lab. Real World Connection: I will introduce the students the to Turkey Vulture, a bird they may be familiar with already. It also lives in the desert, and has evolved several abilities that help it survive there,	As students finish, they will turn their attention to the discussion questions. They will enter their class data on the board for their "best" birds, and will copy down the class data to aid them in answering the discussion questions.

		including an ability to glide very long distances with a large wingspan and the ability to go days without meals. I will remind students that these traits evolved over countless years of random variation in the turkey vulture's evolution. ☀ I wanted to introduce the idea of this big map to tie together the three days of the lab. It will be an excellent visual representation of how we can take one parent - the original Origami Bird, which I will tape to the very center of the map. Over the next few days, students will see how different populations and even species the evolved the Origami bird "spread" over the map. The map will also serve as a visual model of our experiment. I also wanted to include a real life example of the theories we were studying after every day of the lab. △ - 2. Developing and Using Models ↔ 4. - Systems and System Models ↔ 7. Stability and Change	
5 minutes	**Evaluate (Assessment/ Closure)**	Ask students to answer the following question on a small piece of paper. How did genetic variation contribute to our experiment today? What role did genetic variation have in shaping your winning origami bird? ⧗ Since we had explicitly defined genetic variation earlier in the lesson, I want to	Write down answer to exit ticket.

		see if the students could connect the idea of random genetic mutations leading to differences in fitness to the lab we had just done. If students struggle with this exit ticket, I know we will need to address the mechanisms of the lab more explicitly on Day Two.	
Homework	Students will answer rest of discussion questions for homework and come to class prepared to share their answers out.		
Core Vocabulary	Genetic Variability, Natural Selection, Survival of the Fittest		
Notes/Lesson Differentiation ★	-Students who struggle with experimental inquiry will be provided with a data table for the lab instead of being asked to create one -Students will be deliberately placed in lab groups of differentiated ability to allow students to share knowledge/technique -Since students are working individually, teachers will be available to provide support/prompting for groups that are struggling		
Materials	Paper, tape, straws, ruler, scissors, coin, six-sided die , large map, "Fly Zone" with tape line and metersticks on side set up in classroom.		

Day One of Origami Birds Lab:

Origami Bird Experiment

Name:
Date:

Vocab: Define the following terms:
Genetic Variation:

Natural Selection:

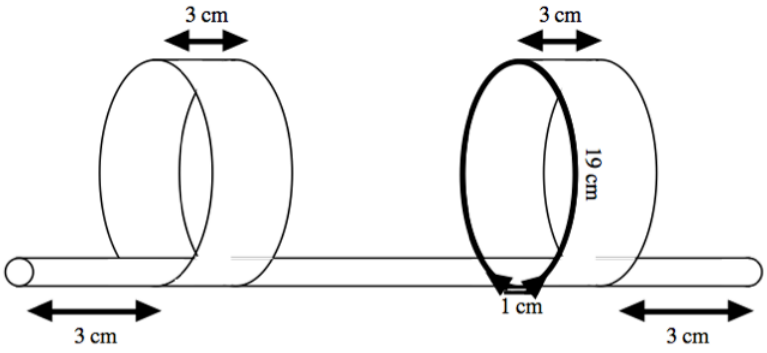
DAY ONE:

INTRODUCTION: The Origami Bird lives in a great desert where water and food are scarce. However, there are oases (patches of water and food) in this desert, although they are far apart. The Origami Bird depends on finding these oases to survive the harsh conditions of the desert. However, it can't stay in one oasis too long or all the food and water will be depleted. Therefore, the survival of the Origami Bird depends on its ability to fly long distances every few days.

In this lab you will breed several generations of Origami Birds and observe the effect of various genotypes on the evolutionary success of these animals.

MATERIALS:
Paper, tape, straws, ruler, scissors, coin, six-sided die

PROCEDURES:
1. Prepare your parent bird.
Cut two strips of paper, each 3 cm x 20 cm.
Loop one strip of paper with a 1 cm overlap and tape. Repeat for the other strip. Tape each loop 3 cm from the end of the straw, like the diagram below.



PROCEDURE:

1. Take your parent bird to the area in the room designated as the "Flight Zone." Stand on the line and release your bird with a gentle, overhand throw. Record the distance flow. Repeat the flight and record the average ((Flight 1+ Flight 2) / 2 = Average) in a data table you create below.

3. Time to breed your next generation – the F1 generation! Each time the parent bird breeds, it will lay 3 eggs. The first egg will be a clone of the parent (you can just use the parent again.) The second two eggs will have slight mutations from the parent. To determine the mutations, follow this procedure.

a) Flip the coin. The coin determines whether the mutation will occur at the bird's head or tail. Heads = head. Tail = tail.

b) Roll the dice. The Dice will determine the specific mutation.

1 = The wing moves 1 cm *toward* the end of the straw.

2 = The wing moves 1 cm *away* from the end of the straw.

3 = The circumference of the wing *increases* 2 cm.

4 = The circumference of the wing *decreases* 2 cm.

5 = The width of the wing *increases* 1 cm.

6 = The width of the wing *decreases* 1 cm.

4) In the Flight Zone, test all three birds of the new generation twice. The most successful bird is the one that can fly the farthest. Mark which chick was the most successful on your data table.

5) Use the most successful bird as the "parent" of the next generation. Repeat the process above started with step 3 for the new generation, F2. For each new bird produced, record its measurements and flight in the data table.

6) Stop when you have determined the best bird in generation F2. Enter your data in the class data table on the board.

Data Table:

Create a data table to record your results. Make sure your data table includes the bird's generation (P, F1, F2), the bird's number, its measurements, the distance flown, and whether it was the winner of its generation.

DISCUSSION:
Answer the questions. Use complete sentences.

1. Did your experiment result in better flying birds?

2. Evolution is the result of two processes: **genetic variation** and **natural selection.**

a. How did your experiment produce variation among the offspring?

b. How did your experiment select offspring to breed the next generation?

3. Compare your "winning" bird with your neighbor's youngest bird. Explain why some aspects of the birds are similar, and explain why some aspects of the birds are different.

4. Predict the appearance of your youngest bird's descendants if. . .

a. the selection conditions remain the same and the longest flying bird survives to produce the most offspring.

b. the selection conditions change the worst flying bird survives to produce the most offspring.

5. Darwin coined the term **"survival of the fittest**," which means that the organisms that are best adapted to survive in their environments live long enough to produce offspring and pass on their genes. Which birds were the "fittest" in this experiment? Why would they be more likely to survive and have offspring?

Day Six: Speciation and Selection Pressure (☀ ★ ☄ △ ↔)

Standard	**3.1.B.C1** Describe species as reproductively distinct groups of organisms. Analyze the role that geographic isolation can play in speciation. Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity within a population. Describe how the degree of kinship between species can be inferred from the similarity in their DNA sequences.
	BIO.B.3.1.2 Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).

Objective	Essential Question
• Students will understand how populations can become so distinct that new species are created • Students will grasp that factors such as geography, resources, or competition can drive speciation, and we call them selection pressure.	How does one species "change" into another species? What external forces might create new species?

Lesson Agenda			
Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
10 minutes	**Engage (Quick Start/ Review)**	Ask students to pair-share with a partner about the discussion questions they were supposed to do for homework. Warn students that the teacher will be cold-calling pairs to answer discussion questions, so agree on your answers and be prepared. Allow about 5 minutes of discussion and 5 minutes to share out to the class. Before moving on, address any misconceptions that arose from discussion or exit ticket. I wanted to start off by making sure students had drawn the correct conclusions about yesterday's lab, and I have found that allowing students to pair-share allows them to prepare and sort out their answers before participating in group discussions. The pair-share will also help students that need extra support have the chance to verbalize/refine their ideas with a partner. ★	Pair-share discussion questions from last night, then share out to class.

3 minutes	**Explain**	Explain that we will be continuing the lab today by splitting up the lab groups into three different scenarios. Provide each group with their original Origami Bird from the previous class (parent.) and all necessary materials. Before getting started, define the term "population" and ask students to write it down on their lab sheet, since that is the concept we will be exploring today. Knowing the biological definition for population is essential to the students comprehension of speciation, so it should be defined before the lesson.	Prepare for lab, fill in definition of population.
30 minutes	**Explore**	Hand groups handouts with one of three scenarios. Students will come up with procedure, but teacher should circulate and help students who are stuck. I chose to continue this lab so that students could get an idea of how different selection pressures could continue the variation/selection to a point where new species arise. I chose to have students design more the lab procedure this time to have them scaffold into inquiry, although they can use many of their techniques from the previous day. I also chose to make one of the scenarios very similar to the scenario from yesterday. I would make sure that students who I noticed struggling with yesterday's experiment or	Each groups will design an experiment to test at least 2 generations of birds in their new habitat. ☄ The lab sheet provides some scaffolding to help them set up this experiment. It also requires that a teacher check their progress before they experiment. △ - 1. Asking questions and defining problems. △ - 2. Analysing and Interpreting Data △ - 3. Planning and Carrying Out Investigations △ - 7. Obtaining, Evaluating, and Communicating Information ↔ 4.System and System Models ↔ 6.Structure and Function ↔ 7. Stability and Change

		who I thought needed more structure would end up getting that scenario- since their experiment would be virtually identical to yesterday's, it would require much less experimental design and be more suitable for students who needed a level of differentiation. ★	
	Extend	-	
10 minutes	**Evaluate (Assessment/ Closure)**	Students would come back together and again create a class data table, and visually compare the shapes of birds for different scenarios. The map will be extended to include an island, a forest at the end of the desert, and large, wide stretch in the desert, where students will pin their birds. Most important, I will tell the students that if an Origami Bird ever differs in any dimension more than 3cm from the universal parent, it can be considered a new species. I will ask the students to consider which "new species" were created, and place colored star stickers on the "wings" to ID our new species. Real World Connection: I will introduce the students the to African Cichlid Fishes in Lake Victoria. One founder fish species was introduced to the lake approx 200,000 years ago, and now there are over 200 unique species of these fish with different habitats, behaviors, morphology, etc. A	ID new species, pin birds on map, and compare species visually and mathematically to groups with different or similar scenarios.

		real life example of rapid speciation. ☀ I wanted to keep the map going so the class can continue seeing the spread of traits and differences from an original species, both geographically and visually. I wanted to wait until the end to introduce the idea of speciation because I wanted students to focus on the selection pressures when conducting the lab, and then eventually have that lead into speciation, as it does in the real world. △ ☀	
Homework	On the lab sheet, there will be a few new discussion questions and also some new vocab: speciation, selection pressure, and population. The vocab will be defined, and I will ask the students to tell me how each term appeared in the lab and how it was related to the Origami Birds. **Warn students that labs will be collected at the end of the day tomorrow, so to fill in any blank parts from Day One and Day Two that night.** I thought this would be a great way to practice the inquiry technique of "experiment first, explain later" to see if students can correctly connect these vocab terms to the activities that they had just performed.		
Core Vocabulary	Speciation, Selection Pressure, Population		
Notes/Lesson Differentiation ★	-students who struggle with experimental design will be placed in group with design most similar to previous experiment -Students will be deliberately placed in lab groups of differentiated ability to allow students to share knowledge/technique -Since students are working individually, teachers will be available to provide support/prompting for groups that are struggling		
Materials	Paper, tape, straws, ruler, scissors, coin, six-sided die , large map, "Fly Zone" with tape line and metersticks on side set up in classroom.		

Three Scenarios for students:

1) A population of Origami Birds is caught in a hurricane and blown out of the desert and onto a small island. There are no natural predators on the ground, but the winds are so strong that birds can be blown out to sea and die if they spend any time in the air.

2) A population of Origami birds flies to the very edge of the jungle, where they find a huge forest with lots of food and water. However, there are predatory hawks in this new habitat who will try to prey on the Origami Birds. However, the hawks can **only** fly in a straight line.
3) There is a great drought in the desert, and a population of Origami Birds is caught on the edge where oases are even farther apart. The birds will need to fly very far to get resources.

Day Two:

Vocab- Define the following terms:
Population:

1) Take the original parent bird handed to you by the teacher and the scenario you are assigned. With your lab group, consider how you will design an experiment to test the performance of your Origami Bird population in this particular situation. Your experiment must take the following into account:

· You must produce offspring with genetic variability in the same way as Day One (with the heads/tails and dice).
· There must be 3 offspring in each generation, and they must be tested against each other. Just like the first day, one of the offspring must be a "clone" of the parent (can keep using paren).
· The most "successful" offspring will be the only parent of the next generation
· You must test at least two generations. P-> F1 -> F2

Think of the following questions to design your experiment:

a) Given your scenario, how should your Origami Birds fly to survive in their new environment?

b) What will be considered a "good" flight? What will be considered a "bad" flight? How can you measure this?

c) Write down the procedural steps you will use to test the flight of your birds.

d) Draw a data table to record flight data and bird measurements.

e) Have a teacher check your work before moving on!

Discussion Questions:

1) Did your experiment produce birds that were better suited for your environment?

2) How did your birds compare to other birds in the same scenario?

3) How did your birds compare to other birds in a different scenario?

4) Why do you think the birds ended up looking different in different scenarios?

Speciation is the term used when a population of organisms is so different from the original population that they can be considered a new species.
For the purposes of this experiment, any Origami Bird that differs by 3cm or more in any measurement from the parent bird is a "new species."

5) In total, how many "new species" did the class create?

Homework:

The following terms are defined for you. For each one, explain how the lab you did today relates to the term. For example, on Day One we learned the term Genetic Variation. Genetic Variation relates to our lab because the dice rolls simulate the random genetic variability that offspring have that make them different from the parent bird.

Speciation: The formation of new and distinct species in the course of evolution.

Population: A group of organisms of the same species that live in the same area.

Selection Pressure: Any factor which alters the behavior and/or survival of living organisms within a given environment.

Day Seven: Founder Effect and Genetic Drift (☀★☄△↔)

Standard	**BIO.B.3.1.2** Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).

Objective	**Essential Question**
Students will understand the mechanisms behind genetic drift and the founder effect. Students can explain why founder effect limits genetic diversity. Students can explain that genetic drift disproportionately affects small populations, and limits genetic diversity.	How can the genetic diversity of a population be suddenly limited? What are the results of limited genetic diversity? What random events can influence evolution?

Lesson Agenda			
Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
5 minutes	**Engage (Quick Start/ Review)**	Put up Do Now: Tell student to consider the following scenario: If someone was to randomly drawn the names of 20 students at the high school, would they get a representative sample of the high school in terms of age,	Answer Do Now.

		race, gender, and grade? Why or why not? ☀ I wanted to do this Do Now to introduce students to the idea that random sampling is not going to perfectly reproduce the original population, and any random event that isolates a few individuals is going to result in an incomplete picture.	
5 minutes	**Explain**	Discuss Do Now. Answer should be no, that they would not get a totally representative sample. To get a totally representative sample, they would have to have perfect sampling methods or sample the whole school. Explain to students we are going to see the effect of random sampling on evolution today.	Participate in class discussion.
25 minutes	**Explore**	Perform exercises in lab groups designed to simulate genetic drift and founder effect. Walk around and make sure students are on right track. I wanted to illustrate two other evolutionary mechanisms, genetic drift and founder effect. I thought students might be bored by making and throwing straw "birds" at this point, so I focused the lab today on a familiar scenario (Origami Birds) but it was more of a thought experiment as opposed to a physical one. I wanted students to primarily understand that random sampling of a small group in Founder effect could lead to	Students will first simulate founder effect and genetic drift in Day 3 of the lab. △ - 4. Analyzing and Interpreting Data △ - 4. Using mathematics, information, computer technology, and computational thinking. ↔ 7. Stability and Change

		drastically different population makeups, which is why it is essential for them to compare their "island" to their neighbors to see differences. For genetic drift, I wanted them to see that genetic drift was more extreme in a small pop than a large one, which is why I included a question about a larger population. To differentiate, students who I know are struggling with math will be provided with handouts that explain how to solve problems with percents in a more exhaustive way. This can be provided for all students if math literacy is low throughout the class. ★	
15 minutes	**Extend**	Once again, pin surviving birds on extended map, and create class data table. Real World Connection: I will tell the students about this study, which traced the high prevalence of Huntington's Disease in a lake community in Venezuela back to its source, an woman who was one of the original founders of the community. Since the community was founded by such a small number of people and she had 10 children, there is a much higher rate of Huntington's in the region now than would be expected. ☀ I wanted to finish out the class map so we can see all the different ways our Origami Birds changed phenotypes,	Compare results to others in class data table, copy down results, and finish work on discussion questions. △ - 2. Developing and Using Models ↔ 4. - Systems and System Models

		species, and/or locations from the "original population." I like the example because it is a great real world example of the founder effect and also shows how these mechanisms affect humans.	
1 minute	**Evaluate (Assessment/ Closure)**	Collect lab sheets (students were warned yesterday that they would be collected at the end of day 3). These sheets will be used as a formative assessment to design instructional wrap up of these concepts tomorrow. I realize that this lab covers a lot of important material in 3 days, so I wanted to collect their lab sheets and make sure that the information I meant to impart actually got through. Obviously it will be hard to grade all the lab sheets that night, but a quick skim through should show patterns where students excelled/struggled. ⧗ Since Day Four of the lab is designated as a wrap-up/discussion, this will allow me to tailor the topics the students seem to be struggling with for revision.	Hand in lab sheets.
Homework	Students will be given a separate sheet which contains the definitions of all the concepts we covered with the Origami Birds Lab - Natural Selection, Genetic Variation, Speciation, Selection Pressure, Population, Genetic Drift, and Founder Effect. Students will be asked. to match the definition with the scenario from the Origami Birds lab that illustrated that principle. Since the students will be asked to draw a concept map tomorrow linking all of these principles together, I wanted to make sure they they got additional practice in linking the definitions to examples, especially since I took their lab sheets away from them. My hope is that they will come to class having reviewed the concepts from the last three days, ready to work with them all together.		

Core Vocabulary	Founder Effect, Genetic Drift, Decreased Genetic Variability
Notes/Lesson Differentiation ★	Students will continue to work in diverse groups For students struggling with the math involved in this lab, the teacher will prepare a sheet listing example problems and how to solve them (concepts of percents, etc.)

Day Three:

For the following scenarios, consider the following **population** of Origami Birds. They all live in the same area, and are of the same species, but there are 5 different phenotypes. Each phenotype represents exactly 1/5 (or 20%) of the total population.

Phenotype A Birds: have the same dimensions as the Parent Origami Bird
Phenotype B Birds: have a longer back wing than the Parent Origami Bird
Phenotype C Birds: have a longer front wing than the Parent Origami Bird
Phenotype D Birds: have a shorter front wing than the Parent Origami Bird
Phenotype E Birds: have a shorter back wing than the Parent Origami Bird

Scenario One:
Some vacationing humans have come to visit the desert where the Origami birds live. They decide that the birds are so beautiful they want to bring them home to their private island, which currently has no Origami Birds living on it. They decide to capture 5 birds to bring back with them.
Roll the dice 5 times to determine the phenotype of the bird captured. Rolling a 1 means that a bird of phenotype A is captured. Rolling a 2 means that a bird of phenotype B is captured…etc. If you roll a six, choose a phenotype of your choice.

Number Rolled	Phenotype of Bird Captured

The 5 birds are removed to the island and become a new population. Calculate the new percent makeup of the population based on phenotype.

For example, if you have two birds of Phenotype A out of 5 birds total, your population is 40% birds of Phenotype A.

Phenotype of Bird	Percent of New Population
Phenotype A	
Phenotype B	
Phenotype C	
Phenotype D	
Phenotype E	

This scenario illustrates a phenomenon called Founder Effect.
Founder Effect is when **genetic diversity** is reduced because a very small number of individuals are taken at random from a larger population.
1) How the definition of Founder Effect relate to the scenario you just explored?

2) Compare your population to the populations on other islands (other groups). Are the populations the same? Why or why not?

3) Over time, what do you think the population of the island would look like as the birds breed and reproduce? How will it be similar/different from the population left behind in the desert?

4) Do you think this made the overall population more genetically diverse or less genetically diverse? Why?

Scenario Two:
The same population of Origami Birds happens to live in a part of the desert where sandstorms are common. Every time a sandstorm comes along, some Origami Birds are killed randomly – **this is not a survival of the fittest scenario**, as all birds have an equal chance of being randomly killed by the sandstorm. Your population contains 25 individual birds, with 5 birds of each phenotype. To calculate which survive and which die, roll the dice once for each phenotype.
If you roll a 1, 100% of birds with that phenotype die.
If you roll a 2, 80% of birds with that phenotype die.
If you roll a 3, 60% of birds with that phenotype die.
If you roll a 4, 40% of birds with that phenotype die.
If you roll a 5, 20% of birds with that phenotype die.
If you roll a 6, 0% of birds with that phenotype die.

For example, if your first roll is a 4, then 40% of birds with phenotype A die. That is 2/5 birds, leaving you with 3 birds of phenotype A.

Phenotype	Roll	# of Individuals Before Sandstorm	# of Individuals after Sandstorm
A		5	
B		5	
C		5	
D		5	
E		5	
		Total Number of Birds Left ->	

Calculate the total number of individuals left by adding up the total of the far right column. Then, calculate the new percent of the population for each phenotype by dividing the new # of individuals / total individuals, and multiplying by 100.

Phenotype	# of Individuals after sandstorm	Total Number of All Birds	% of Total Birds Before Sandstorm	% of Total Birds After Sandstorm
A			20%	
B			20%	
C			20%	
D			20%	
E			20%	

This scenario illustrates a phenomenon called Genetic Drift
Genetic Drift is when random events such as natural disasters randomly remove some genes from the population and change the overall genetic makeup of the group.

1) How does the scenario you just performed illustrate genetic drift?

2) Before the sandstorm, each phenotype was exactly 20% of the population. How did this change after the sandstorm?

3) How did your population look different/similar from other groups? Why do you think there are differences?

4) Did any phenotypes totally disappear? What about in other groups?

5) Do you that phenotypes would have disappeared if the population of birds was 1000? 100,000? Think about natural disasters in real life before answering.

6) Do you think this made the overall population more genetically diverse or less genetically diverse? Why?

Homework:

Origami Birds Wrap-Up Homework

Name/Date:

Match the following definitions with the scenarios from the Origami Birds lab that illustrate them.

Population: A group of organisms of the same species that live in the same area.	A) You had to flip a coin and roll dice to determine how offspring were going to chance in appearance from the parent bird
Founder Effect is when genetic diversity is reduced because a very small number of individuals are taken at random from a larger population.	B) If a Origami Bird changed more than 3cm from the original Parent Bird, it was considered a new species
Speciation: The formation of new and distinct species in the course of evolution.	C) A sandstorm came along and changed the frequency of different phenotypes of a population of Origami Birds
Selection Pressure: Any new factor which alters the behavior and/or survival of living organisms within a given environment.	D) A group of Origami Birds who live in the same area and have only small differences in genotype and phenotype from each other
Genetic Drift is when random events such as natural disasters randomly remove some genes from the population and change the overall genetic makeup of the group.	E) The Origami birds that flew “best” were selected to be the only “parent” for the next generation.

Genetic Variation: the random mutations that allow offspring to have small differences in phenotype or genotype from their parents.	F) The original Origami Bird population needed to fly between distant oases to survive, and only the Origami Birds that could fly well survived.
Natural Selection: Some individuals survive better than other individuals because of small differences in phenotype.	G) A population of Origami Birds were suddenly blown onto an island where flying would cause them to be blown out to sea, killing them. Therefore, the organisms that were worse at flying survived and reproduced.
Survival of the Fittest: the organisms that are best adapted to survive in their environments live long enough to produce offspring and pass on their genes	H) Rich tourists came and randomly selected only 5 Origami Birds to populate their islands with

Sample Class Map:
Black: Day One
Pink: Day Two
Red: Day Three

Day Eight: Wrap Up and Concept Mapping (☀ ★ ☄ ⧖ △ ↔ ♢)

Standard	**3.1.B.C1** Describe species as reproductively distinct groups of organisms. Analyze the role that geographic isolation can play in speciation. Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity within a population. Describe how the degree of kinship between species can be inferred from the similarity in their DNA sequences.
	BIO.B.3.1.3 Explain how genetic mutations may result in genotypic and phenotypic variations within a population.
	BIO.B.3.1.1 Explain how natural selection can impact allele frequencies of a population.
	BIO.B.3.1.2 Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).

Objective	**Essential Question**
SWBAT connect the different evolutionary concepts we have explored together into a concept map. SWBAT demonstrate their knowledge of the interconnectedness of evolutionary mechanisms.	How do all the factors that drive evolution work together?

Lesson Agenda			
Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
5 minutes	**Engage (Quick Start/ Review)**	Teacher will have reviewed the lab reports handed in by the students and determined the topics students understood well and those that they were still struggling with. The Do Now should reflect a topic that was less understood. For instance, if the lab sheets indicated that the students struggled to differentiate founder effect and genetic drift, the Do Now could take	Answer Do Now.

		the form of three scenarios which the students had to ID as either founder effect or genetic drift. Obviously, the topic should be revisited and discussed with the class as students respond to the Do Now. Teacher should also circulate and note if students have done the matching homework from last night. **Teacher should hand back lab sheets, as students will need to use them for their concept maps.** Since the labs were being used as formative assessments, this will be a powerful tool to assess which of the topics the students had the greatest difficulty with and readress it before the concept mapping assessment.	
15 minutes	**Explain**	As a class, review the homework matching sheet. It is important that students understand which topics go along with with definitions before starting the concept map, so checking for understanding is useful here. Explain to students that the Origami Birds lab showed us some of the mechanisms of evolution, but that the lab was a bit untrue to life because it treated the events as separate and happening over a short period of time, where in fact they could be happening all at once, usually over much longer time periods. Give an example: In the lab, every single offspring had a	

		mutation from the parents that caused them to fly farther or shorter (genetic variation). In real life, those variations would be so small that they wouldn't produce those big changes in phenotypes for many, many generations. At the same time as that process is going on, the desert ecosystem could be changing slowly over time to make the oases far between. Emphasize the length of time and interconnectedness of factors for students. I will then re-introduce the idea of Darwin's Finches as a real life example of founder effect/selection pressure/genetic variation working together to create many different species of the same bird. ☀ I want students to understand that while the activities we did in lab are useful, they do not mimic real life scenarios in some ways, and get a chance to critique the lab activities for their scientific soundness. Explain to students that we will be summing up the lab by creating individual concept maps that link these terms together. If students are unfamiliar with concept maps, show a sample concept map for an unrelated topic. See example concept map handout and drawing below. If students were unfamiliar with the idea of concept maps, I wanted to give them some	

		examples and practice to ease into the idea. I wanted to let students work individually first, to get them thinking about the lab and how they personally view the concepts working together. Then, I wanted to give them a chance to revise, revisit, and collaborate with their peers to make a stronger, more unified concept map. This is the map I want to assess, since it is the more refined product.	
10 minutes	**Explore**	Monitor individual progress, give suggestions. If several students will struggle with the association and concept linking associated with this assessment, bring them into a small group session with in the corner of the class and help guide their thinking. ★ Working individually to think creatively can be a struggle for some students, and I wanted to give them a differentiated option that would provide support without just making the assignment easier or giving them the answers. △ - 2. Developing and Using Models △ - 4. Analysing and Interpreting Data △ - 6. Constructing Explanations and Designing Solutions △ - 8. Obtaining, Evaluating, and Communicating Information	Work individually on their concept maps.

20 minutes		↔ 4. - Systems and System Models ↔ 7. - Stability and Change	
	Extend	Group students back into lab groups. Monitor student work by circulating throughout the class. Make sure students are on track, give time warnings, help settle arguments, and ask students to back up assertions with evidence - promote scientific thinking. ⧗ △ - 2. Developing and Using Models △ - 4. Analysing and Interpreting Data △ - 6. Constructing Explanations and Designing Solutions △ - 8. Obtaining, Evaluating, and Communicating Information ↔ 4. - Systems and System Models ↔ 7. - Stability and Change	Work with lab groups to create one large, unified concept map. Use their individual rough drafts and lab experiences to collaborate, argue, and ultimately decide on one unified concept map.♢ Put it on large poster paper using markers.
	Evaluate (Assessment/ Closure)	Collect concept maps at end of period.	
Homework	No homework.		
Core Vocabulary	-		
Notes/Lesson Differentiation ★	-Groupwork. -Students who need it will receive help from teacher during individual concept mapping.		
Materials	Large poster paper, markers.		

Origami Birds Concept Map Assessment:

Name:
Date:

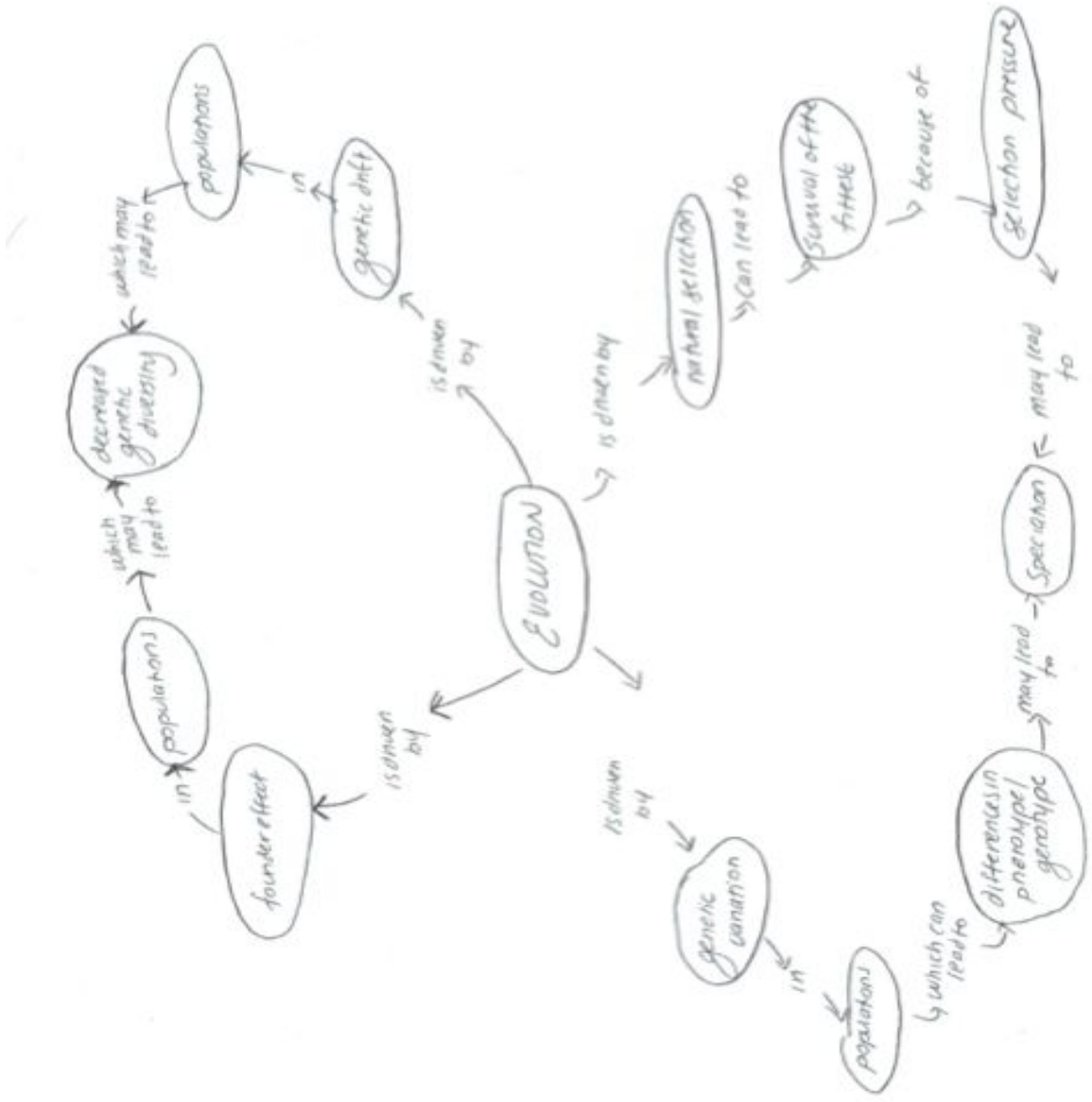
Instructions: You will create a concept map about evolution using vocab words from the lab. The concept map should connect these concepts with linking words in a way that is scientifically accurate and allows the viewer to easily see connections between the topics. You will first make a rough draft individually, and then work as a lab group to come up with a large, unified concept map that will be graded.

- You must use **all** the words in the word bank on your map.
- You can add **as many additional words/phrases as you need**. You can also use words from the word bank more than once.
- You do not have to use all the "suggested linkers", but can use that list as a guide to help you start linking concepts together. You may use linking words that are not part of the suggested list.
- Your word bank words must be circled
- Your connecting lines must have arrows indicating the thought process. However, you can also draw lines with arrows at both ends.
- **You may use your labs, homework, and notes to help you with this assessment.**

Word Bank	**Suggested Linkers**
Natural Selection	Is driven by
Genetic Variation	Is caused by
Population	Results in
Founder Effect	Can Lead to
Speciation	Because of
Selection Pressure	Which can cause
Survival of the Fittest	Which affects
Differences in Genotype/Phenotype	In
Decreased Genetic Variation	By
	And
	As a result of
	Which produces

Draw your rough draft concept map here. (evolution would be circled in the middle as a starting point.)

Sample Concept Map:



Day Nine: Macro/Micro/Assisted Evolution & Evolution Research (★☀↔=)

Standard	**BIO.B.3.1:** Explain the mechanisms of evolution.
	BIO.B.3.3: Apply scientific thinking, processes, tools, and technologies in the study of evolution.

Objective	**Essential Questions**
SWBAT differentiate between the concepts of macro and micro evolution and relate these concepts to assisted evolution. SWBAT analyze scientific research regarding evidence and formulate an educated stance regarding the ethics of assisted evolution..	Does micro-evolution influence macro-evolution? In what ways does the process of scientific research relate to and affect knowledge regarding evolution?

Lesson Agenda

Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
5 minutes	**Engage (Quick Start/ Review)**	Prompt students to engage with the following Do Now through discussion with their classmates. Students will then share out to the class. Do Now: If evolution only occurs at a population level, at what point do individuals show different traits? This will prime students for the following direct instruction on micro and macro evolution.	Answer Do Now.
10 minutes	**Explain**	Through direct instruction, teacher will define and explain the concepts of macro and micro evolution, and further apply those concepts to the mechanism of assisted evolution. ↔ - 2. Cause and Effect: Mechanism and Explanation	Take notes on micro/macro/assisted evolution.

10 minutes	**Explore**	Transition students to the scientific research segment of the lesson. Teacher will prompt students to talk about scientific research that they have heard of in any field of science. Teacher will then discuss briefly how scientific research is generally conducted, specifically touching on current research on assisted evolution. This will naturally transition into discussing the articles on evolution for the next day's Socratic Seminar.	Share out to the class about scientific research that they have heard of through their experiences, media, etc. (☀) This will require students to draw on their real-world experiences and connect their experiences back to the academic setting.
15 minutes	**Extend**	Introduce and hand out the two articles for the following day's Socratic Seminar. Teacher will also briefly discuss the purpose of and format of the Socratic Seminar. Teacher will prompt students to read the article together in small groups. While students are reading, teacher will go around to each group periodically to address any questions that they may not have been able to answer themselves.	Read the provided articles together in groups, helping each other work through the articles and any content questions that arise. This will allow students to become familiar with the ideas presented in the articles, while allowing for peer support if any reading difficulties arise. Additionally, the presence of the teacher while these articles are being read will allow for students to ask clarifying questions if need be, allowing them to more coherently develop their position for the next day's Socratic Seminar.
	Evaluate (Assessment / Closure)	Provide students with the following exit ticket: Relate the scientific research process back to the articles given in class. (=) As students leave, teacher will provide them with the rubric that they will be	Students will complete the exit ticket. The exit ticket will be used as an ungraded formative assessment. Based on the students' responses to the exit ticket, the teacher can choose to devote some time to clarify

		assessed on for the following day's Socratic Seminar.	facets of the scientific research process as needed in the next day's class period.
Homework	Students will have to formulate a stance on assisted evolution with concrete points of evidence surrounding it, to be discussed in the following day's Socratic Seminar. Students will have to fill in at least 5 sentences on the Socratic Seminar Guiding Questions handout, to help prime them for the Seminar. Students will also be highly encouraged to read the Partner Evaluation rubric to understand what they will be assessed on, as well as what they will be assessing their partners on.		
Core Vocabulary	Micro evolution, Macro evolution, Assisted evolution		
Notes/Lesson Differentiation	-Differentiation in the form of presenting the same concept through direct instruction and groupwork. (★) -Students who need it will receive help from teacher during the group readings of the articles.		
Materials	Copies of the two articles for the Socratic Seminar		

Article 1:
http://www.nytimes.com/2015/11/10/opinion/the-risks-of-assisting-evolution.html?_r=2

Article 2:
https://www.washingtonpost.com/news/energy-environment/wp/2015/02/03/coral-reefs-are-in-such-bad-shape-that-scientists-may-have-to-take-control-of-their-evolution/

Socratic Seminar Guiding Questions Handout:

The following materials are from Ms. Nabeehah Parker, Biology Teacher at Julia R. Masterman Laboratory and Demonstration School.

Student Handout

NAME_____ Date_____ Period_____

Open-Ended Questions for a Socratic Seminar

When preparing for a Socratic Seminar, write questions using these sentence frames to stimulate your thinking about the article(s) you read. Choose and complete 5 of the following:

- What puzzles me is...
- I'd like to talk with people about...
- I'm confused about...
- Don't you think this is similar to...
- Do you agree that the big ideas seem to be...

Student Handout

I have questions about...

Another point of view is...

I think it means...

Do you think...

What does it mean when the author says...

Do you agree that...

Socratic Seminar Partner Evaluation Rubric:

Student Handout

NAME_____ Date_____ Period_____

Socratic Seminar
Discussion Partner Evaluation

Name of person you are observing _____

Your name _____

Seminar Topic _____ Date _____

1) Record a check for each time your partner contributed in a meaningful way: ____ ____ ____ ____ ____

2) On a scale of 1-5, with 5 being the highest, how well did your partner do at the following?

_____ Analysis and Reasoning
Did your partner....
Cite reasons and evidence for his/her statements with support from the text?
Demonstrate that they had given thoughtful consideration to the topic?
Provide relevant and insightful comments?
Demonstrate organized thinking?
Move the discussion to a deeper level?
Notes/Comments:

_____ Discussion Skills
Did your partner...
Speak loudly and clearly?
Stay on topic?
Talk directly to other students rather than the teacher?
Stay focused on the discussion?
Invite other people into the discussion?
Share air time equally with others (didn't talk more than was fair to others)?
Notes/Comments:

_____ Civility
Did your partner...
Listen to others respectfully?
Enter the discussion in a polite manner?
Avoid inappropriate language (slang, swearing)?
Avoid hostile exchanges?
Question others in a civil manner?
Notes/Comments:

Day Ten: Socratic Seminar on Assisted Evolution (= ☀★♢△↔)

Standard	**BIO.B.3.3:** Apply scientific thinking, processes, tools, and technologies in the study of evolution.

Objective	**Essential Questions**
SWBAT articulate their educated opinions regarding assisted evolution, and will be able to use concrete evidence to support these stances. (☀, ♢) ↔ - 7. Stability and Change as that is a key component in the debate around assisted evolution. SWBAT discuss their opinions with other students in a reasonable, rational, and respectful manner. (☀, ♢) Both of these objectives are necessary real-world competency skills. Regardless of the academic area, one needs to be able to articulate and argue their stance clearly, provide relevant support, and be able to consider other's opinions rationally as well.	What are the pros and cons of assisted evolution, and why? △: Asking Questions and Defining Problems, as students will be posing questions regarding assisted evolution and defining/debating the benefits and problems of assisted evolution.

Lesson Agenda			
Agenda/Time	**5 E's**	**Learning Activities**	
		Teacher will…	**Students will …**
5 minutes	**Engage (Quick Start/ Review)**	Remind students of the guidelines and format for the Socratic Seminar and solicit any questions from students regarding any logistical issues regarding the Socratic Seminar. The seminar will take place in two different rounds in a fishbowl seating conformation. Students will be partnered together, with one partner participating in the discussion and the other	Listen to the instructions for the Socratic Seminar.

		partner assessing his/her contribution from the outside of the fishbowl. This will help promote student engagement even among those students that are observing and not discussing. After the first round of discussion ends, students that were observing will now participate in the discussion, and vice versa.	
10 minutes	**Explain**	Facilitate the Socratic seminar. Teacher will prompt the discussion to be between students, as opposed to students direct their comments at the teacher. This can be a tough habit to break, but it is important that students learn to communicate their ideas to their peers and respond directly to their peers' ideas as well, with the teacher ideally only serving as a loose guiding force for the seminar.	The 1st group of students will discuss their stances on assisted evolution through the medium of the Socratic seminar. The 2nd group of students will observe and assess the 1st group using the provided rubric.
10 minutes	**Explore**	Teacher will facilitate the second round of the Socratic Seminar in the same manner as the first round.	2nd group of students discusses while 1st group observes and assesses.
	Extend	Leads debrief with the whole class to discuss salient points that emerged out of the Socratic Seminar. Students will be prompted to raise key points that strongly resonated with them. This will help students be aware of the key points that had arisen from the	Participate in the debrief of the Socratic Seminar as led by the teacher.

15 minutes		discussion and provide an impetus for further reflection upon the same.	
	Evaluate (Assessment / Closure)	Explain the summative assessment paper assignment and provide students with the rubric for both options. Teacher will also field any questions on this assignment that may arise.	Listen to teacher's explanation of final summative assessment and ask any relevant questions that may arise.
Homework	Summative assessment paper with two options: 1. Write a claim-evidence-reasoning opinion paper on any topic in evolution that you have a strong opinion about, using evidence and reasoning to strengthen your claim. Students will already explicitly have been exposed to the CER framework through previous assignments in previous units. 2. Present a brief literature review of any contemporary evolution research that you find interesting. The assessment would be due a week from this lesson. (=, ★)		
Core Vocabulary	Assisted evolution		
Notes/Lesson Differentiation	-The Socratic Seminar is a differentiated method of discussing assisted evolution, as in the previous day we would have had students discussing differentiated evolution in small groups, whereas the Socratic Seminar is a larger discussion which allows every student to both participate and observe in the discussion of the concept. (★) -The summative assessment is differentiated to allow students to pick the assignment that they feel would be most interesting and meaningful for them. (★)		
Materials	Socratic Seminar handouts (given on Day 9), rubrics for the summative assessment		

Summative Paper Assessment Rubrics:

Option 1, CER Rubric:

	Document Formatting	**Claim** *A statement or conclusion that answers the original question/problem.*	**Evidence** *Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	**Reasoning** *A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
1	Document is less than two pages In length and does not follow requested formatting.	No claim made and no areas of support stated.	No data is provided to support the claim.	No reasoning is provided to link the evidence and the claim. AND/OR No conclusion is provided to summarize the overall argument.
2	Document is… 1.) Two or more pages in length 2.) Double spaced 3.) 12pt Times New Roman font 4.) 1 inch margins	A claim is stated without areas of support. AND/OR An idea is articulated without being presented as an explicit claim.	The data and/or examples used as evidence do not adequately support the claim. AND/OR Evidence may be sufficiently related to the claim, but not be thoroughly explained. AND/OR Evidence may not be provided from two different, credible sources.	Reasoning is provided to link the evidence and the claim, but no conclusion is provided to summarize the overall argument.
3		A reasonable or probable claim is established at the beginning of the paper, and reasons for support of claim are stated in a succinct and well-articulated manner.	The data and/or examples used as evidence do not strongly supports the claim. AND/OR Evidence is thoroughly explained. AND/OR	Reasoning is provided that describes well the relationship between the claim and evidence, AND a conclusion is provided to summarize the overall argument and shows proof of deep thought regarding the argument.

			Evidence is provided from two different, credible sources.	

Option 2, Contemporary Research Rubric:

CATEGORY	3	2	1
Format		Document is… 1.) Two or more pages in length 2.) Double spaced 3.) 12pt Times New Roman font 4.) 1 inch margin	Document is less than two pages In length and does not follow requested formatting.
Main Topic	Main topic is a relevant and contemporary topic in the field of education research, and is clearly defined and well articulated. The greater implications of this topic is also clearly articulated throughout the paper.	Main topic Main topic is a relevant and contemporary topic in the field of education research and is clearly defined, but greater implications of this topic is not detailed.	Main topic is not clearly defined and/or is not a contemporary topic in the field of evolution research.
Quality of Information	Information clearly relates to the main topic. It includes several supporting details and/or examples from credible sources.	Information clearly relates to the main topic. It provides 1-2 supporting details and/or examples from credible sources..	Information has little or nothing to do with the main topic, and/or no examples are given.
Conclusion	Information is very organized with well-constructed paragraphs. There is a clear introduction, body, and conclusion to the essay.	Information is organized with well-constructed paragraphs. However, the essay lacks a clear introduction, body, and/or conclusion.	Information is not organized with well-constructed paragraphs. There is no clear introduction, body, or conclusion to the essay.