Name: _____ Period: _____ Date: _____

Lesson 1: How Did This Little Girl Get So Sick?

Prior Experiences: Describe a time when you or a family member got really sick, and you went to the doctor and the doctor wrote you a prescription for a medicine to take for several days. Did the medicine help you get better?

_____

_____

_____

_____

Procedure:

1. You will watch a video clip (13 min. long) that will introduce you to the case of a little girl who also got sick and went to the doctor to get medicine to help her get better.

2. Make a record of any important events that occurred in this little girl's case, that might help us understand what happened to her and why it happened in the space below.

Observations

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Making Sense: Record some questions you now have about Addie's case or other cases you are thinking of related to bacteria or antibiotics.

_____

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Conclusions: What conclusions did your class draw about the types and kinds of bacteria involved in Addie's case? Summarize your conclusions in the space below.

Next Steps: What ideas did your class come up with for what we should investigate in our next lesson?

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Lesson 3a: Student Activity Sheets

Warm up: Answer the following questions below

1. What do we know about who can get infected by antibiotic resistant bacteria?
2. What do we know about where you can get Community-associated MRSA and Hospital-acquired MRSA?
3. Where exactly can we pick up bacteria from things in our everyday world?

Individually:

1. Write down two places in the school where you think there might be a lot of bacteria, and write down two places in the school where you think there will be very little bacteria. Explain why you chose these places.
2. We know Addie was exposed to bacteria on the playground, but how do you think it got into her body?

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Day 2: Student Activity Sheet 3a.1

Warm up: Answer the following question below

Our main three questions that we were wondering about last class were: Where can we pick up bacteria? How does bacteria get on me from the environment? How can we get the bacteria off of us?

1. Pick at least one of the three main questions and refine your investigation questions to align with that main question. For example: I'm picking main questions number 1 and 2: "Where can we pick up bacteria? And "How does bacteria get on me from the environment?" So I want to see how much bacteria is found on the light switch? And if I touch the light switch and then swab my finger, will I see the same bacteria transfer to my finger?

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Lesson 3a: Student Investigation Sheet

A. Question your group decided to investigate: Be sure it is testable and specific.

_____

_____

_____

_____

Share your question with your teacher before moving on to the next step. Teacher's initials: _____

C. How will you investigate your question? Think about: How could you plan an experiment to test your question? What two (or more) different groups could you compare to answer your question? How are your going to measure which one of your experimental groups changes more? What you should measure, depends on what question you are asking. Be specific in your detailing out your plan. Start by listing your experimental groups.

The groups we are comparing to test our question are:

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B. A prediction to your question: What do you think will happen and why.

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D. Observations related to your investigation

(you will collect data here with tables or charts in a few days).

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E. An Explanation of Your Findings: Provide a scientific explanation that includes a claim that answers your question, supported with evidence. Include reasoning as to why the interpretation of the observations counts as evidence for this claim, as well as any relevant scientific principles that help account for why you got the results you did.

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Lesson 4: How Do (Did) Antibiotics and Antiseptics Work?

Connecting to the previous lesson: What did your friends and relatives report about their use of and experience with antibiotics?

Brainstorm:

1. What are some sources of information about how to control and prevent the transmission of diseases? What would qualify as a reliable source?

2. What source of information will your class use to gather information? Why is it considered a reliable source?

Procedure:

3. Use the symbols in the table below to annotate the text in preparation for a class discussion about the recommendations for antibiotic use.

?	!	∞
This part is confusing OR I have a question	*This part is interesting OR This part is important*	*I have a personal connection to this part OR I can connect this to my prior knowledge or experience*

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Jigsaw Summary: How do antibiotics work?

Summarize what you learned from your classmates in your Jigsaw group about how different types of antibiotics work to kill bacteria.

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Constructing a mathematical model:

Construct a graph of the data in the table you made as a class of # of bacteria vs. # of doses bacteria. Label your axis, and make sure to choose equal intervals for each axis.

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Construct an Explanation: How do antibiotics work?

Write an explanation that tells how the mathematical model you co-constructed in class helps us understand why it is necessary to take all of the prescribed doses of antibiotics, even when we are already feeling better in advance of finishing them.

Gallery Walk: What should we include in our Consensus Model?

As you observe your classmates' initial models of how antibiotics worked in Addie's system, keep track of the elements or ideas you feel are important to represent in the class Consensus Model. You may sketch ideas or jot down notes in the box below.

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Making Sense:

Record some questions you now have about bacterial growth, antibiotics, or Addie's case.

_____

_____

_____

_____

_____

_____

_____

Conclusions:

What conclusions did your class draw about the interaction between antibiotics and bacteria?

Next Steps: What ideas did your class come up with for what we should investigate in our next lesson?

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Lesson 3b: How do our Petri dish samples (swabs) compare?

Predictions: Based on what you figured out so far about antibiotics work, would you change any of your predictions from lesson 3a (section B)? Explain.

_____

_____

_____

_____

Next Steps: In section C and section D of lesson 3a, you outlined a plan of the observations you wanted to make today that will help you answer your group's research question. In addition to these observations, what other observations would you like to be able to make today, in order to answer the questions the class came up with, such as:

a) Where can we pick up bacteria
b) How does it get transferred to us?
c) How effective are different cleaning methods for get the bacteria off of us?

_____

_____

L3b: Investigation 1

Safety Guidelines for Investigation 1

- Keep the Petri dishes in the sealed ziplock bags during the entire investigation.
- Dispose of the sealed ziplock bags with Petri dishes inside in an appropriate biohazard recepticle.

Any additional procedure notes regarding Investigation 1

_____

_____

_____

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Observations for Investigation 1

Petri dish sample	Observations

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Making Sense for Investigation 1

1. **Where can we pick up bacteria?:** Which places had the most/least amounts of bacteria?

2. **How can bacteria get on us from things in the environment?:** What patterns did you notice between the way the bacteria was transferred onto the petri dishes and the kind of growth observed?

3. **How can we get the bacteria off of us?:**
    a. Were the methods you used to remove bacteria from a surface effective in getting rid of the bacteria?

    b. To what degree were they effective? Did they remove all, some, or none of the bacteria? How do you know if bacteria was removed?

    c. Which method was the most/least effective?

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Conclusions for Investigation 1:

4. Write a scientific explanation for one of the questions below. Remember to include a **claim** that answer the questions, **evidence** that support claim, and **reasoning** that references how the possible mechanisms behind your explanation work.
    d) Where can we pick up bacteria
    e) How does it get transferred to us?
    f) How effective are different cleaning methods for get the bacteria off of us?

Next Steps:

7. How is it possible that when we first swabbed the Petri dishes, we saw no bacteria on them, but now, a few days later, they we see bacteria colonies on them?

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L3b: Investigation 2

Purpose (of Investigation 2): What question(s) did your class have at end of the last investigation?

_____

_____

_____

Predictions: If you could zoom in really close to see what was happening during this process, what do you think you would see?

_____

_____

_____

Procedure for Investigation 2

- Watch the time-lapse video of the bacteria in agar.
- Draw and/or summarize your observations to describe what you see a single bacteria doing that would cause the colony to increase in size over time.
- According to the video, how long does it take for one bacteria to reproduce? Record this in your observations to the right.

Observations

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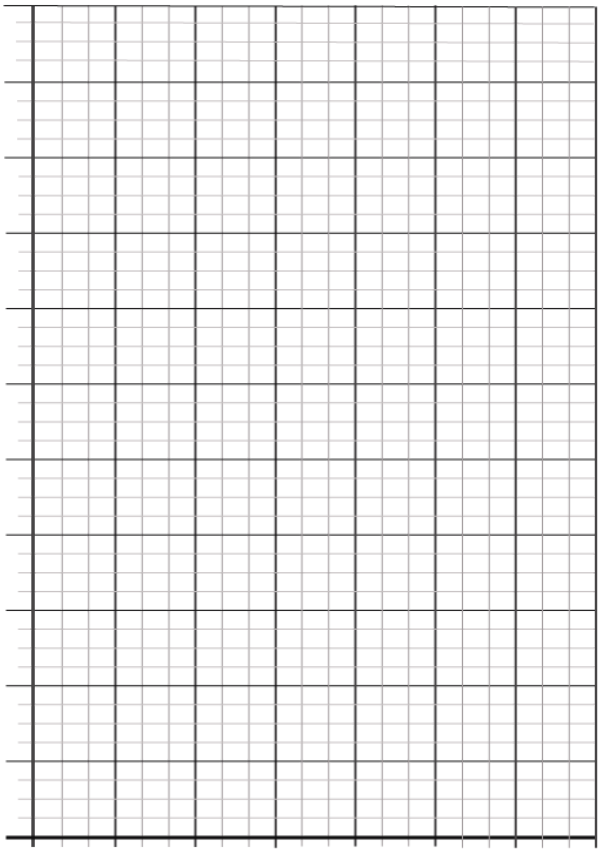
Making Sense of Investigation 2:

7. Use the time it takes a single bacteria to reproduce into two bacteria to do a quick calculation. How long would it take to end up with 8 bacteria, if you started with 1 bacteria in this environment? _____

8. First complete the table showing the growth of the bacteria population over 400 minutes. Then construct a graph of # bacteria vs. time in hours. Label the axis % major intervals on both axis.

Time (in min.)	Time (in hrs.)	# of bacteria
0	0	1
400	6 ⅔	



9. Describe in words, the pattern of change of population growth in the table and graph.

Conclusions:

10. What are some discoveries your class made with regard to the question, *"Why did some of the petri dishes appear to have no bacteria present and then days later they had visible bacteria?"*

11. How is what we discovered helpful for explaining what might have happened in Addie?

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Next steps: How would both reproduction and repeated doses of antibiotics affect the size of a bacteria population?

Let's figure this out by building a new mathematical model to predict what would happen to the population every hour if:

- we started out with an initial infection of 1,000,000 bacteria
- took our first dose of antibiotic immediately (at hour zero)
- the antibiotics was 99.99% effective
- any surviving bacteria continue to double every 20 minutes.
- we took another dose every 4 hours for 24 hours.

Time (in hrs.)	# of bacteria before dose	Antibiotic dose given?	# of bacteria after the dose reaches them
0		----yes --->	
1		no	
2		no	
3		no	
4		---yes --->	
5		no	
6		no	
7		no	
8		---yes --->	
9		no	
10		no	
11		no	
12		---yes --->	
13		no	
14		no	
15		no	
16		---yes --->	
17		no	
18		no	
19		no	
20		---yes --->	
21		no	
22		no	
23		no	
24		---yes --->	

12. Complete the table.

13. Was the bacteria population eliminated 24 hours later? Explain

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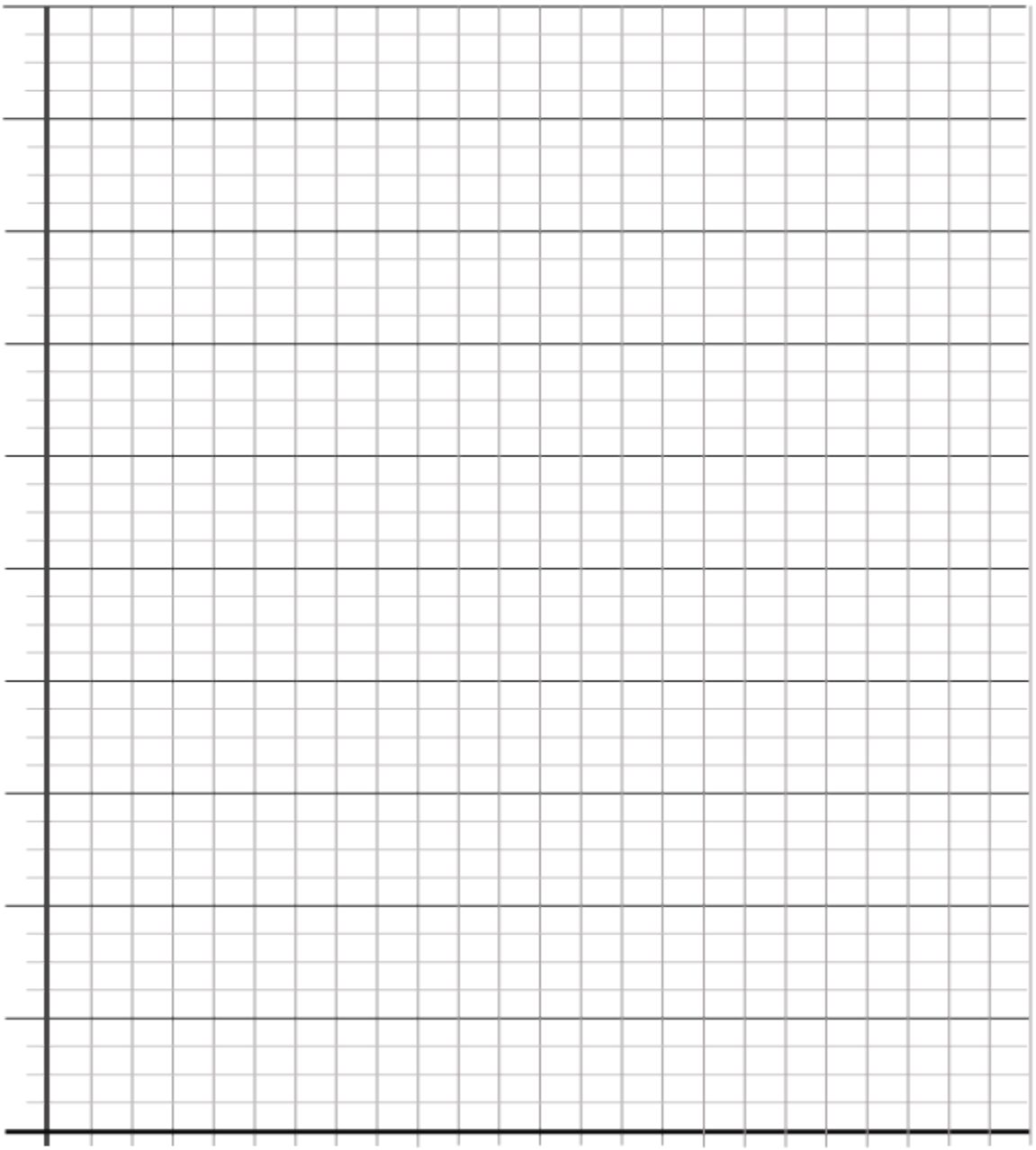
14. Construct a graph of # bacteria vs. time in hours. Label the axis and the major intervals on both axis.



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15. How is what we discovered through this lesson relevant for explaining what might have happened in Addie?

16. How is what we discovered relevant to the CDC recommendations that you take all of your antibiotics doses when you have a bacterial infection?

17. Your tables and graphs predict some pretty complex changes in the population size over time. *But would we see these sorts of population changes happening a real bacteria population over multiple doses of antibiotics?* How might design a new investigation using the petri dishes again to investigate this question? Draw or describe your ideas for that investigation below:

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Lesson 5a: Bacteria vs. Antibiotics - What happens when they are put together?

What do we already know?

In the previous lesson we learned several things about antibiotics and how they work, we also started a draft of our consensus model about the interactions between antibiotics and bacteria in Addie's case. We also came up with some ideas of what we need to investigate next. Please review packet 4 about what the class decided we need to investigate next.

What do we need to do next?

In your small groups brainstorm some ideas that could test the idea you came up with at the end of class yesterday. That the strength of Addie's antibiotic might not be strong enough. Remember to base your thoughts on what we have learned about bacteria and antibiotics so far. We will eventually be working with live samples and will need to follow specific guidelines, because of this your experiment must be limited to using one bacteria and one antibiotic. You will work as a group but please remember to keep your own record.

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Making Predictions:

Now that we have designed our experiment, we need to make some predictions about what we think we might see in the Petri dishes when we look at them in a few days. When drawing your models make sure to consider the differences in antibiotic strength and address the differences you might notice within the different dishes. Make sure you label your drawings and include your reasoning (why do you think you will get these results?) on the lines below.

Reasoning

_____

_____

_____

_____

_____

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Organizing your Data:

In the space below design a data table in order to keep track of the results of your investigation.

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Self Reflection and Possible Next Steps: Think about what we have learned so far about Addie's case and consider the following prompts. Please have these completed and ready to share at the beginning of the next class.

1) Now that we have set up an investigation and made some predictions about what we might see, how does this help us in understanding Addie's case? Relate your predictions to Addie's condition.

_____

_____

_____

_____

_____

_____

_____

2) When we check our investigations in a few days we will be able to collect some data that will help us determine what is happening to Addie, however do you think this one data point will be enough to see a pattern in the bacteria growth? Consider some possible next step we might need to take in order to figure out how antibiotic resistance occurs over time.

_____

_____

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3) We also want to consider the difference in our two investigations with bacteria. If you were a doctor how would you treat the bacteria(s) in the first investigation verse the bacteria in this investigation? Why? Make sure you explain your reason in treating these the same or different.

_____

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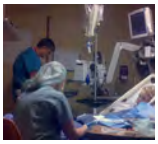
Name: _____ Period: _____ Date: _____

L6: Why did antibiotics stop working for Addie?

Warm-up: What is your current thinking about why the antibiotics seemed to stop working for Addie?

Write down all of the evidence that supports your thinking that we've gathered since learning about Addie, antibiotics, and bacteria. You may want to refer back to your notes for this task. A chart has been provided to help you organize your thoughts.

Question	Data source	What we figured out
L1: How did Addie get so sick?	 Frontline video and our own experiences	
L2 Can this happen to me? How common is this sort of problem?	 Historical data and information about MRSA	
L3a Where can we pick up bacteria in our world?	 Placing sanitized hands on agar plates	

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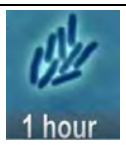
L4 How do (did) antibiotics and antiseptics work?	 CDC recommendations and video of antibiotics at work	
L3b Why are there things growing in the dish?	 Bacteria colonies emerge in our agar dishes  Bacteria reproduce under microscope (time lapse v ideo)	
L5a. How much bacteria grow and how much die off when antibiotics and bacteria are put together in the same environment?	 Antibiotic-soaked disks in dish	

Sharing Initial Ideas: How could we take everything we know and try to make it work together to see if it helps us figure out why antibiotics stopped working for Addie?

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Modeling:

1. Develop a model that answers the question, "Why did antibiotics stop working for Addie?"

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Asking Questions: A lot of questions have come came from making our models of "Why did antibiotics stop working for Addie?" Think of the few that are the most compelling for you (or are bothering you the most) and write each one on a Post-It note.

Day 2 Warm-up: Take a look at the questions you were thinking about from last class or any new questions you came up with for homework. Swap questions with a person next to you.

1. What new ideas did your neighbor's questions make you think about? Were your questions similar or different? How were they similar or different?
2. Is there another question you are now thinking about? Write that question down on a Post-it note.

Next Steps:
Given our unit question, sub-questions, and other driving questions, what should we make sure to do in our next class? Brainstorm some ideas in the space below.

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Lesson 5b: What is happening with our antibiotic experiments?

Warm-up: Record what you notice about your experiments in the space below.

1. Sketch your dish, as well as one other group's dish:

My dish	Another group's dish

2. Where do you see bacterial growth on the plate? Where is bacteria not growing?

3. What else do you notice looking at the plates?

Sharing Initial Ideas:

1. How specifically could we test our idea that bacteria near and away from the ring are different?

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2. Do you expect any differences between the two plates when we look at them again? How might they turn out differently, if at all? Explain your answer.

Setting up the investigation:
Plate your bacteria much as in 5a, except your bacteria will come from the agar plates.

Prepare two plates. For the first, swab around the edge of the zone of inhibition. Mix this with 50 mL of water and plate.

For the second plate, take a similar amount of bacteria from an area of the plate farther away from the zone of inhibition and mix with 50 mL of water.

Label both plates.

Sharing Initial Ideas: What could we do while we wait for our bacteria to be ready?

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Simulations:

Components we want in our simulation	Reason for the component

Next Steps:

1. What did we identify as a likely reason for why no bacteria were growing in the zone of inhibition?

2. Why did we decide to replate bacteria from the edge of and away from the zone of inhibition?

3. What should we do next class?

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Name: _____ Period: _____ Date: _____

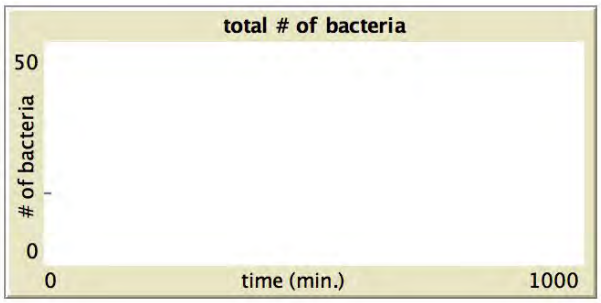
Lesson 7: How do different doses of antibiotics affect a bacteria population in a simulated infection?

Purpose: Use a computational model to conduct an investigation to determine how do different doses of antibiotics affect a population of bacteria in an infection?

Investigation 1 : What do bacteria do when they infect a person?

Predict. If 16 individual bacteria infected a patient's blood stream, and that person did not take any antibiotics AND that person's immune system did not respond to fight the infection, make a prediction showing what you think would happen to the total number of bacteria in that patient over time in the space below.

1a) Sketch a graph showing your prediction:



1b) Why would this happen?

_____

_____

_____

_____

Procedure: In this this next investigation you will start the model with an equal number of individuals of each of these 4 types of bacteria:

Notice that each bacteria is slightly different in the structure of its cell membrane:

- The purple one shown on the left has 3 holes (pores) in its cell membrane
- The green to the right of the purple one has 4 holes (pores)in its cell membrane
- The brown one to the right of the green one has 5 holes (pores)in its cell membrane
- The red one to the right of the brown one has 6 holes (pores) in its cell membrane.

1. Go to http://inquiryhub.dls.ucar.edu/bio/BacterialInfection.html on your computer to launch the *Bacterial Infection* simulation.

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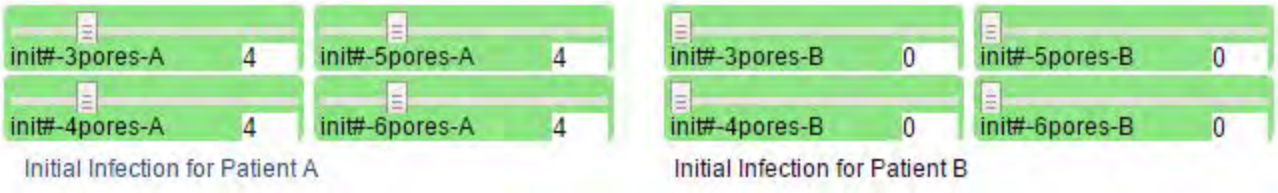
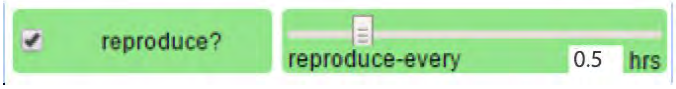
2. Set these sliders to the values shown so that Patient A will start with some bacteria, but Patient B will have none:



3. Set these values for the medicine that patient A and patient B will automatically be given (this will set it to none):

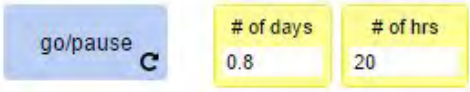
4. Set this switch and slider to these values so that the bacteria will reproduce every 0.5 hours:



5. Press the ***SETUP*** to initialize the model

6. Then press ***GO/PAUSE*** to run the model.

7. Pause the model by pressing ***GO/PAUSE*** when the simulation reaches 20 hours of simulation time. Notice the ***GO/PAUSE*** button no longer is darkened when the mode is paused.



8. Record you observations in the space below

Observations - Investigation 1:

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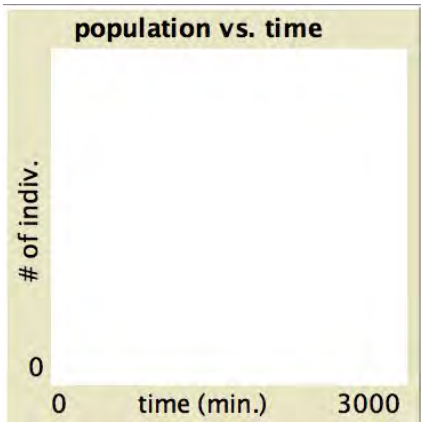
Observations (from Investigation 1 continued)

9. Pick one of the lines from one of your population vs. time graphs from one of the patients. Sketch the shape of that line to the right.



10. Record the current # of bacteria in the population in each patient in the table below. (You can get a count of each variation by hovering your cursor over the point in the bar graph)

Variation		in patient A		in patient B	
# of pores in the cell membrane	Color visualization for this variation	# of bacteria that I started with	# of bacteria that I ended with	# of bacteria that I started with	# of bacteria that I ended with
3	purple	4		4	
4	green	4		4	
5	brown	4		4	
6	red	4		4	

11. Run the model another time (follow all steps on the previous page) or compare your results to someone sitting next to you (a partner's), and make note of any similarities and differences between the results in this model run and the previous run in the space below.

Similarities between model runs	**Differences between model runs:**

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Making Sense (of Investigation 1)

1. You observed bacteria reproduce (divide) in the simulation, forming two separate new bacteria from one old bacteria.

Old bacteria: Circle the bacteria cell on the right with 5 holes (pores) in its cell membrane. If the cell reproduced once how many cells would it form? _____

New bacteria: Draw the cells that would be produced when the cell you circled reproduces. Show what the cell membrane structures look like in the space below:

2. If in every simulation you did, you always started with the same number of each type of bacteria. They each have enough food so that they each can reproduce every 2 hours. Why then, do you end with more of some type of bacteria vs. others, each time you run the model?

_____

_____

_____

Conclusions

3. What part of the population vs. time graphs, provide evidence to support the claim that, "Bacteria are unintentionally competing for space in these environments"?

_____

_____

_____

4. Would you expect the bacteria that are growing in the petri dishes in your classroom to follow a similar pattern of growth? Explain.

_____

_____

_____

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Investigation 2: How does the antibiotic interact with the bacteria?

Predict. Will the antibiotic kill the bacteria that have fewer pores in their cell membrane as often as it kills bacteria that have more pores in their cell membrane? Explain.

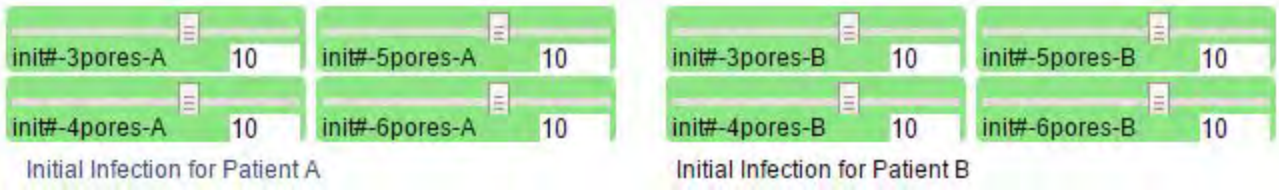
_____

_____

_____

Procedure: In this next investigation you will start the model with a population of bacteria in the body and administer only one small dose of antibiotic & record your observations.

1. Set these sliders so that both patients start with 40 total bacteria (10 of each kind):



2. Set these sliders so that both patients will get 50 mg of antibiotic with a single dose:

3. Turn off bacteria reproduction for now:

4. Press the ***SETUP*** to initialize the model

5. Then press ***GO/PAUSE*** to run the model.

6. When you are ready press the ***MANUAL DOSE A*** button. You should see antibiotic molecules at the top of the screen and see them start flowing downward. Then press ***MANUAL DOSE B*** button.

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7. Pause the model by pressing **GO/STOP** again, after the antibiotics that reached the bottom of the screen recirculated back up to the top again.

8. Rerun the model a 2nd time, but this time record the total # of bacteria of each variation that you end with after pausing the model in the previous step and calculate what % of the population is now made up of that variation of bacteria.

9. Repeat the model run (steps 1-7) a few more times to compare what is similar and different between the results in each model run.

Observations (from Investigation 1)

Variation		in patient A				in patient B			
# of pores in the cell membrane	Color visualization for this variation	# of bacteria that you started with	% of the population for this variation (at the start)	# of bacteria that you ended with	calculate what % of the population is made up of that variation	# of bacteria that you started with	% of the population for this variation (at the start)	# of bacteria that you ended with	calculate what % of the population is made up of that variation
3	purple	10	25%			10	25%		
4	green	10	25%			10	25%		
5	brown	10	25%			10	25%		
6	red	10	25%			10	25%		

Making Sense (of Investigation 2)

1) What similarities did you notice in how the bar graphs changed across all your model runs?

_____

_____

_____

2) What differences did you notice in how the bar graphs changed across all your model runs?

_____

_____

_____

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Conclusions (for Investigation 2)

3) Based on the results from this investigation, which trait variations of bacteria tend to have a higher chance of surviving exposure to antibiotics from their surrounding environment? Why?

_____

_____

_____

_____

4) In the space below draw a model that helps show why bacteria in this simulation with certain trait variations tend to have a better chance of surviving a single dose of antibiotic compared to other bacteria. Label and annotate your model.

Include the following in your model (and include labels):

- Antibiotic particles
- Structural differences in the cell membrane for the different types of bacteria
- The different ways that antibiotic particles can interact with the cell membrane of bacteria: what happens when an antibiotic particle reaches a part of a bacteria cell membrane that has a pore in it vs. a spot that does not.
- What happens to the bacteria if an antibiotic particle gets inside of the cell.

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5) All the bacteria shown in the models to the right are the same variation (green bacteria each with 4 holes in their membranes). The same amount of antibiotic has just been added into the bloodstream of both patients.

The arrow points to a single bacterium located at the same location in both environments. Is that bacterium in the left environment (patient) as likely, more likely, or less likely to die as the bacterium in the right environment (patient)? Why or why not?

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Investigation 3: How will the combination of both reproduction and antibiotic application affect the bacteria population?

In this investigation you will add in some of what you did in investigation 1:

- Bacteria will reproduce every 2 hrs
- You will start with 16 total bacteria in the infection (4 of each variation)

You will apply antibiotic like you did in investigation 2, but you will apply much more of it:

- You will increase the amount of medicine in a single dose (from 50 mg to 200 mg).
- You will automatically apply repeated doses of the medicine every 4 hours until the bacterial infection is gone.

Predict. Will it take the same number of doses to wipe out the bacteria population in every run of the simulation? Explain.

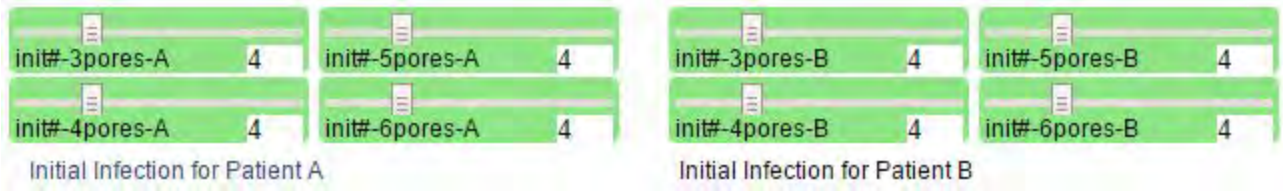
_____

_____

_____

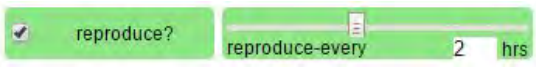
Procedure

1. Set these sliders to the values shown so that both patient A and patient B start with the same number of each kind of bacteria (4 of each):



2. Set these values for the medicine that both patients will always be given 100 mg every 4 hours:

3. Set bacteria reproduction for every two hours:



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4. Press the ***SETUP*** to initialize the model

5. Then press ***GO/PAUSE*** to run the model.

6. Pause the model by pressing **GO/PAUSE** again, after the infection has been eliminated from both patients.

7. Record your observations below.

8. Either rerun the simulation multiple times on your own, or combine the observations from all the people in your group.

Observations **(from Investigation 3)**

Trial	Results for this student	
1	# doses given to A	# doses given to B
2	# doses given to A	# doses given to B
3	# doses given to A	# doses given to B
4	# doses given to A	# doses given to B
5	# doses given to A	# doses given to B
6	# doses given to A	# doses given to B
7	# doses given to A	# doses given to B
8	# doses given to A	# doses given to B

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Making Sense **(of Investigation 3)**

1) What was the range of doses given to all the patients to eliminate their infections?

2) What was the most frequent amount of doses (mode) that were given to a patient in order to eliminate the infection?

3) What was the median number of doses that were given to a patient in order to eliminate the infection?

4) What was the average # of doses (mean) given to all the patients to eliminate their infections?

Conclusions **(for Investigation 3)**

5) Which statistical measure (range, mode, median, mean) would most useful for determining an answer to the question, "What is typical number of doses that a person needs to take in order to wipe out their bacterial infection?"

_____

_____

_____

6) The results of computer simulations are often used as evidence in claims that scientists and engineers make. Why might it be necessary to report more than one of these statistical measures in order to not mislead people who use and prescribe antibiotics (like patients and doctors)?

_____

_____

_____

_____

_____

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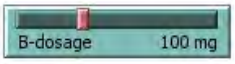
Investigation 4: Investigation 4: How does changing the conditions in the environment affect the population?

Predict. How will decreasing the amount of antibiotic given or increasing the reproduction rate affect the number of doses of bacteria that a person typically needs to take in order to wipe out their bacterial infection?" Why?

In your research team you will help the entire class explore this question, by (1) selecting a sub-question to investigate, (2) dividing up the research investigation tasks amongst group members, (3) analyzing and interpreting your results and (4) presenting your results to the class.

A. How will decreasing the amount of medicine per dose affect the population?

The value used in investigation 3 was **100 mg.**

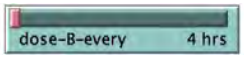


Other options on these sliders include:

50 mg
150 mg
200 mg

B. How will taking doses less often affect the population?

The value used in investigation 3 was every **4 hrs**

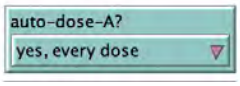


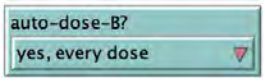
Other options on these sliders include:

6 hrs 8 hrs 10 hrs
12 hrs 14 hrs 16 hrs
18 hrs 20 hrs 22 hrs 24 hrs

C. How will skipping a regular dose affect the population?

The value used in the investigation 1 was "no" and the value used in investigation 3 was "yes, skip no doses".





Other options on these choosers include:

"yes, but skip dose 2"
"yes, but skip dose 3"
"yes, but skip dose 4"

D. How will increasing the rate of bacteria reproduction affect the population

The value used in investigation 3 was every **2 hours.**

Other options on this slider include:

reproduce-every 0.5 hrs *reproduce-every 1.0 hrs*
reproduce-every 1.5 hrs *reproduce-every 2.5 hrs*
reproduce-every 3.0 hrs *reproduce-every 3.5 hrs*
reproduce-every 4.0 hrs

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Design your investigation as a group

- What variables are you controlling between simulation runs between group members?

- What type of data will you intend to collect and how will you record it (e.g. written record, table of results, saving images of your graphs to the desktop, putting results into a google document, etc...)? Who will record it?

- What, if any, statistical measure(s) are you planning to calculate when your data collection is completed?

- How are you coordinating or dividing up the research work?

Making Sense (of Investigation 4)

What discoveries did you make? What was the most interesting result you uncovered in your investigations?

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Conclusions (for Investigation 4)

1. Many groups discovered that under certain environmental condition bacteria with one kind of variation tended to become more common in the population over time. Which kind(s) of bacteria was this?_____

2. If a patient was infected by a population made up of 16 of these kind bacteria, would they be as easy, as hard, or harder to eliminate with antibiotics as a population of the 16 bacteria you started with?_____

3. Individual Stop and Jot: How is it possible that applying antibiotics can lead to a population of bacteria developing over time that is more resistant to antibiotics then they were initially?

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4. Why did one kind of bacteria tend to become the most prevalent variation (or only variation) in the population under certain environmental conditions? On a separate piece of paper, draw a model with explanatory text to explain why this SOMETIMES occurred. In your models make sure to include:

Sketches of five histograms:

- A bar graph of the initial population having an equal distribution of individuals with each trait variation in the population (25% of the population of each type of bacteria).
- Four more bar graphs showing the gradual shift in the distribution of trait variations in between one dose and the next (after 1 dose, 2 doses, 3 doses, and 4 doses) .

Additional representations showing the result of these mechanisms:

- Which variations in the population were killed with each dose.
- Which variations in the population reproduced after each dose and what variations their offspring were.

Annotations to link it all together.

- Annotations explaining the different steps in the model that account for what is causing one kind of bacteria to tend to take over (dominate the population) in certain environmental conditions.

5. Imagine you want to add a single, antibiotic-resistant bacterium to our simulation that was even more resistant to antibiotics than any of the variations that were in population to start with. Draw a picture of what its cell membrane would look like. Why would this structure give it a competitive advantage for survival over the other variations of bacteria from the simulation?

6. Sketch a graph showing how the introduction of a single bacterium of that type into the environment might affect the proportions of different kinds of bacteria in the population over time:

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Next Steps….

7. How might what you figured out:
    a) help us answer our driving question?
    b) help us predict what might happen in our petri dishes ?
    c) help us develop and produce a more effective infographic?

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Lesson 8: What is in Addie's world that is or isn't in our simulation?

8.1 - Connecting to the Previous Lesson

Think back to the 4 investigations from the NetLogo simulations you did in the last lesson.

What was the ***most significant outcome(s)*** of investigation 4 compared to the outcomes at the end of investigations 1-3.

_____

_____

_____

What was ***different about the conditions*** between investigation 4 and investigations 1-3 that seemed to have contributed to the significant outcome(s) you described above?

_____

_____

_____

What was ***similar about the conditions*** between investigation 4 and investigations 1-3 that seemed to also have contributed to the significant outcome(s) of investigation 4?

_____

_____

_____

8.2 - Our Simulation vs. Addie

You have observed 2 different systems *(A simulated environment and Addie's world)* in attempts to answer questions you had about why the antibiotics weren't working to kill the bacteria inside of Addie.

As a class, let's make a summary chart of key conditions and outcomes that we know were important parts of both the bacteria simulation and Addie's World.

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Systems Comparison Chart:

	A. NetLogo Simulation - Investigation 4 *(System #1)*	*B.* Addie's World *(System #2)*	C. Conditions or Outcome Common to both Systems
What "Types" (trait variations) were in the initial population	1. There was one initial population that represented a single infection. There were four different types variations of bacteria present in that initial population.	1. There were....	1….
What type of changes are occurring in the environment?	2. The amount of antibiotics in the environment changed over time. The amount of space available in the environment changed over time.	2. …..	2….
Which type of bacteria died the most/least? Why?	3. Some variations of bacteria died off more frequently than others because...	3. Some of the bacteria died off at first (Addie got better for a bit) because...	3. …

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Which type of bacteria reproduced more? Why?	4. The bacteria that reproduced more were the ones that….	4. Some bacteria reproduced more (after the initial antibiotics treatment). We know this because ...	4….
What is happening to the bacteria population over time?	**5.** The bacteria population seems like it is changing by...	**5….**	**5….**

8.3 - What Else Do We Need to Figure Out About Addie and Antibiotic Resistance?

Comparing the simulation to Addie's environment helped us to identify elements common to both systems. Though this helped us see similarities, let's now identify some limitations in the model that may be leading us to oversimplify what might have happened in Addie. And let's keep track of new questions we have related to each of these.

1. **Other differences between bacteria:**

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2. **Differences in the environment, besides antibiotics (or antiseptics), that might affect the survival of bacteria:**

3. **Other resources, besides space, that bacteria need:**

4. **Other things that might affect the rate of reproduction or the results of reproduction:**

8.4 - Petri dish connections.

- **Which of these questions does it seem our Petri dish experiments will help us answer? Put a star near those questions.**
- **Which of these questions does it seem really unlikely that our Petri dish experiments will help us answer? Circle those.**

8.5 - Next Steps:

Bacteria population changes are tricky to study up close for many reasons:

- The organism is microscopic.
- In an infection, the population is interacting with the surroundings in a place where it is very hard see what is happening to those bacteria first hand (e.g. a patient's body)

To help us address these constraints, we investigated an analogous system: our computer simulation and we are continuing to investigate another analogous system (our petri dish experiments). But now we've identified some possible limitations in sticking with only those systems to answer to our remaining questions.

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When scientists encounter these sorts of limitations, they often select a different system to investigate where they hope to see certain interactions within the system more easily.

Comparison Study Criteria Poster

If we select a different system to study that would help us answer our new questions, what criteria would it need to meet? We would need a system with another population where we can see what sorts of things:

Take a moment to think about these criteria. Brainstorm a list of other possible organisms that could be candidates for us to study further. List them in the space below and argue for why they would be worthy candidates, in light of the criteria above.

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Lesson 9: Can studying some other creatures help us figure out what we think is missing from our explanation for why bacteria change over time?

Evaluating possible candidates for our comparison study

Q1: After comparing possible candidates for a comparison study, talk as a group about what kind of sources of data we would need about each of these, in order to determine if its meets our criteria list. Write some of your ideas for possible sources of data in the space below:

_____

_____

_____

_____

_____

Q2: Record some noticings and wonderings from what you observe and learn about the candidate case presented in the video. We will use these noticings and wondering to evaluate whether this case might meet the criteria we had for a possible comparison study.

Noticings	Wonderings

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Looking at our criteria for our comparison study

Q3: Which of the criteria for our comparison study does this case appear to meet so far and why?

_____

_____

_____

_____

_____

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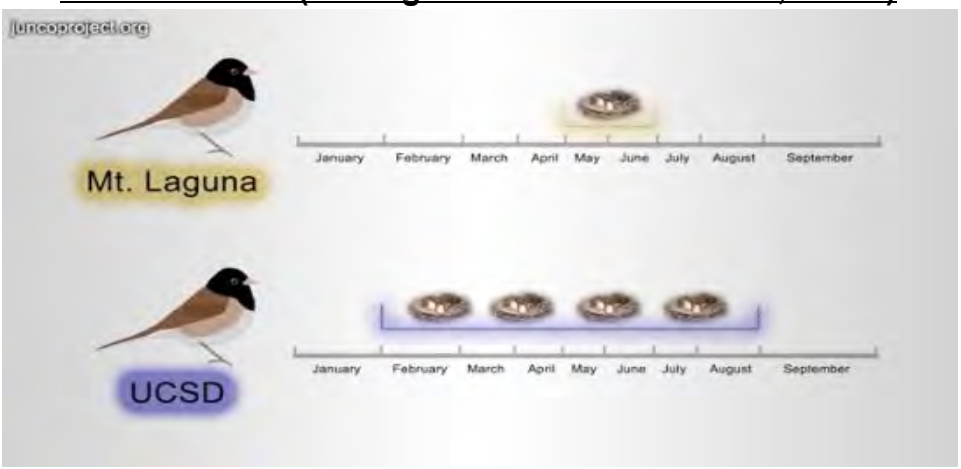
Home-learning Extension for Lesson 9: How does this additional data help inform whether these juncos would be a useful comparison study?

Analyze the data below about the juncos, and determine if it meets some of the criteria for the case we wanted to investigate.

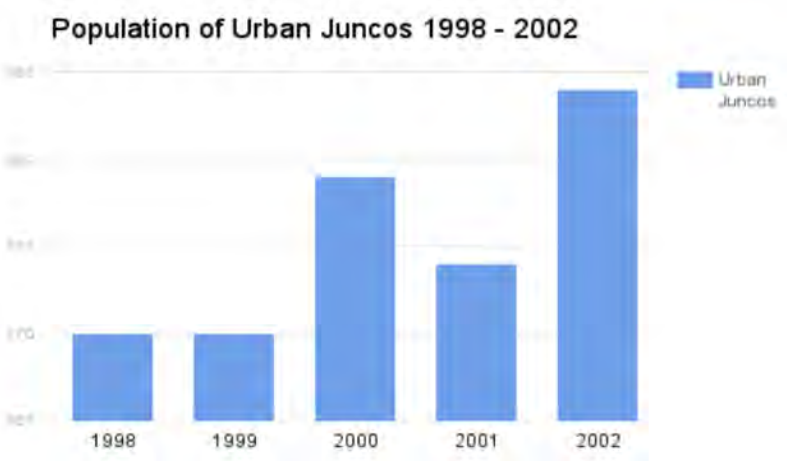
Data Source A:

According to the 'Alternative Nesting Article' juncos breed nowhere else in the city of San Diego and the adult survival rate averaged for two years (2000 - 2001 and 2001 - 2002), and was 62% for male and 61% for females. The percentages of chicks surviving to the next breeding season ranged from 12 - 21% per year and this helped the population remain stable with approximately 70 breeding pairs. (Yeh and Price 2004)

Data Source B: (Mt. Laguna = Mountain Juncos, UCSD)



Data Source C: (Urban Juncos = UCSD)



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Q1: What information can we pull from the two previous illustrations from Data Source B & C? Will this information be helpful in figuring out how the different populations are interacting with their respective environments? Why or why not?

Q2: Does the information in Source A reflect (or conflict with) what we are seeing in data Source B and C? Use evidence from all three sources to back up your claim.

Q3: What might be the cause for some of the **patterns in reproduction** you saw between the two populations of juncos?

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Q4: Based on what you noticed from the junco video, make an argument either for or against using this organism for a comparison study. Be sure to relate your reasoning to the criteria we needed for any case we might select.

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Lesson 5c: What's happening with our antibiotic experiment?

Purpose & Predictions

1. Why did we decide to replate the bacteria during the last investigation?

_____

_____

_____

_____

_____

2. What are we looking for in our plates, and what do we think we will see? Draw & explain your predictions.

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Making Sense After you have recorded your data in your data table on the student handout 5a.1, discuss and answer the following questions in small groups:

3. Now that you have two sets of data from two replatings, what, if any patterns in the data are you noticing?

4. What ideas do you have about why you are seeing these patterns?

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Home-learning Lesson 5c: What patterns do you think you will see in the data next time and how is this connected to Addie's case?

Next Steps:
If we do another round of replating, what patterns do you think you will see in the data next time?

Connecting to Our Driving Question:
How might the patterns we are noticing in the data in your group, or in other groups, help us understand what might have been happening in Addie's case ?
'

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Lesson 10: What is different about living in the city vs. the mountains from a bird's perspective?

What are some other possible explanations your group members came up with for the patterns in reproduction you saw in the two populations of juncos?

- the mountain juncos
- the juncos that stay year-round on the University of California at San Diego

_____

_____

_____

_____

_____

How are these possible explanations, related to other questions we had from lesson 9 about the mountain juncos and those that stay year-round on the University of California at San Diego (UCSD juncos)?

_____

_____

_____

_____

What new questions do you have about these two different environments the juncos are in?

_____

_____

_____

_____

These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Investigating the juncos' two environments:

Use the boxes below to represent what you found including patterns in climate data in whatever form is most useful for you (e.g. in a list, written, diagram, model, etc.).

	What is the environment like where the juncos are in the mountains?	**What is the environment like where the juncos are at the UCSD campus?**
Climate data		
Google Street View		

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Making Sense:

Record any ideas or questions you have about how similarities or differences between these two different environments, related to the resources that might be good for juncos:

Next Steps: What ideas did your class come up with for what we should investigate in our next lesson?

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Name: _____ Period: _____ Date: _____

Lesson 11a: What exactly makes these juncos "city birds"?

Connecting to the previous lesson:
Q1: What about the environment on the UCSD campus might make it easier for juncos to survive and reproduce there rather than in the mountains and what might make it harder?

_____

_____

_____

_____

Procedure:

1. You will see another video segment about the juncos.

2. During and after the video, fill in the following chart, be as clear and descriptive as possible.

Q2: How are city juncos different from mountain juncos?	**Q3:** How might this difference impact the juncos' interactions with the environment?

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Predictions:

Q4: Use **Figure 11a.1** to make a similar diagram for **both** a mountain junco and city junco. This diagram should depict your expectation for how these distances would differ between both types of birds.

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Graph Analysis:

Q5: What differences do you notice between mountain and city juncos from **Figure 11a.2**?

Q6: How does the information in this graph graph compare to the predictions you made above?

Q7: What patterns do you notice in **Figure 11a.3**?

Q8: Remember, this graph shows data about many different kinds of birds from around the world. Based on this, do you think it is useful to our questions about mountain and UCSD juncos? Explain your reasoning.

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Q9: Taking into account all the information presented so far, what questions do you still have about the differences between mountain and city juncos?

_____

_____

_____

_____

Design an Investigation: Is the bold behavior of the city juncos learned or instinct?

Q10: Use a written explanation, a model, or both to show how we could investigate whether the juncos' behavior is instinctual (inherited) or learned behavior.

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Next Steps:
Q11: What ideas did your class come up with for what we should investigate in our next lesson?

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Lesson 11b: How Do Scientists Determine if a Behavioral Trait is an Instinct (Born with it) or Not (Learned)?

Connecting to the previous lesson: What were we wondering about the juncos in the last lesson? What were we wondering about how to design an investigation to answer our questions?

_____

_____

_____

_____

Procedure:

1. You will read the study titled, "Molecular Determinants of Scouting Behavior in Honey Bees."

2. During and after reading, answer the following questions, citing the text where appropriate.

Comprehension Questions: Molecular Determinants of Scouting Behavior in Honey Bees

How does this study relate to our discussion about juncos in our last class?

_____

_____

_____

_____

_____

_____

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Summarize the steps (methodology) scientists took to determine whether the behavior of the honey bees was learned or inherited.

_____

_____

_____

_____

Draw a Model: How did scientists conduct their investigation in the honey bees study?

Draw a model that represents the steps/methods taken by scientists to determine whether honey bees' "novelty-seeking" behavior was inherited or learned.

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Design an Investigation: Is the bold behavior of the city juncos learned or instinctual?

Provide a written explanation, a model, or both to show how we could design and conduct an investigation to determine whether the juncos' behavior is instinctual (inherited) or learned behavior.

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Making Sense:

Record any questions you have about designing investigations or junco behavior.

_____

_____

_____

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Next Steps: What ideas did your class come up with for what we should investigate in our next lesson?

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Name: _____ Period: _____ Date: _____

Lesson 12: Do the juncos just learn to be bolder or is their behavior something they inherited?

Connecting to the previous lesson: What behavioral differences did we notice between the mountain and city juncos?

_____

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Predict: Are these differences in behavior between the populations inherited or learned? Explain.

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Part 1

Part 1 - Procedure:

1. Read excerpts 1 and 2 from the original research on the next page to see how the scientists investigated this question. As you read, evaluate the methodology the scientists used.

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Excerpt 1 from the original publication

Common garden, general methods

During June and July 2007, we captured 40 juveniles from both San Diego and Mt Laguna, using mist nets and walk-in traps. We targeted juveniles that had recently become nutritionally independent. The age of juveniles was confirmed through field observations of families and/or measurements of wing and tail length (Nolan et al. 2002). In some cases (n = 12 at Mt Laguna; n = 19 at San Diego), we knew the exact age of the captured juveniles because they were banded as nestlings (mean ± standard error of the mean; San Diego: 40.9 ± 4.3 days; Mt Laguna: 38.2 ± 1.7 days; t_{29} = 0.59, P = 0.56). Because junco nestlings fledge at ≈12 days posthatch and remain with and dependent on their parents until ≈25–30 days posthatch (Nolan et al. 2002), the juveniles that we captured had limited early exposure to their natal habitats (on average <15–20 days of life outside the nest).

Capture locations were distributed spatially throughout the study areas to avoid capturing closely related individuals (i.e., siblings), with juveniles captured from more than 13 different locations and on 15 different capture days within each study population across a period of 30 days. Of the subset of captured juveniles that were banded in the nest and thus had known parents (n = 31; see above), we only had 2 siblings from each population that were sampled for this study (San Diego: n = 2 of 31; Mt Laguna: n = 2 of 23).
Juveniles were housed in flocks in temporary outdoor aviaries (2.4 m L × 1.8 m W × 2.4 m H) in a fenced lawn in suburban San Diego, CA until 15 July 2007, when they were shipped via air cargo to the Kent Farm Bird Observatory indoor aviaries at Indiana University. From July 2007 onwards, birds from each population were housed in mixed sex flocks (≈50:50 male:female) in both large (6.4 m L × 3.2 m W × 2.4 m H) and small (2.5 m L × 2.1 m W × 2.4 m H) aviary rooms (henceforth "home aviaries") with equivalent densities (≈1 bird/m^2) and identical housing conditions. Birds were segregated by population, and all aviary rooms had identical exposure to human researchers and animal care staff.

n = number in the sample (Juncos)

Description of the average ages of the juncos collected from both locations.

= after hatching

= brothers and sisters

Identifies how many siblings were captured.

= large enclosures that house birds

= sorted into groups by their original population (criteria)

Excerpt 2 from the original publication

Early exploratory behavior (common garden)

From 25 March to 13 April 2008, we measured how rapidly and how extensively the birds from the common garden explored a novel aviary room, following methods adapted from Verbeek et al. (1994). The test room (2.5 m L × 2.1 m W × 2.4 m H) had not previously been inhabited by any of the birds in this study. There was a small (10 cm × 10 cm) cardboard loading door that allowed us to introduce the bird into the test room with minimal disturbance, and behaviors were observed through a one-way glass window.

= experimental setup where groups of organisms are moved to one environment to another; in this case they use identical aviaries.

= new or different

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Making Sense of Part 1

How does this experiment intend to compare the two populations of juncos?

What steps in the methods provide for a fair comparison of the two junco populations in the common garden experiment?

Part 2

On the next page are the results from the common garden study set next to the results of the field study you saw before. Carefully consider what each shows us about junco behaviors.

Procedure:

1. Examine the data gathered by the researchers in each study.

2. Consider what Flight Initiation Distance and Exploratory behavior actually mean for the birds in the two populations.

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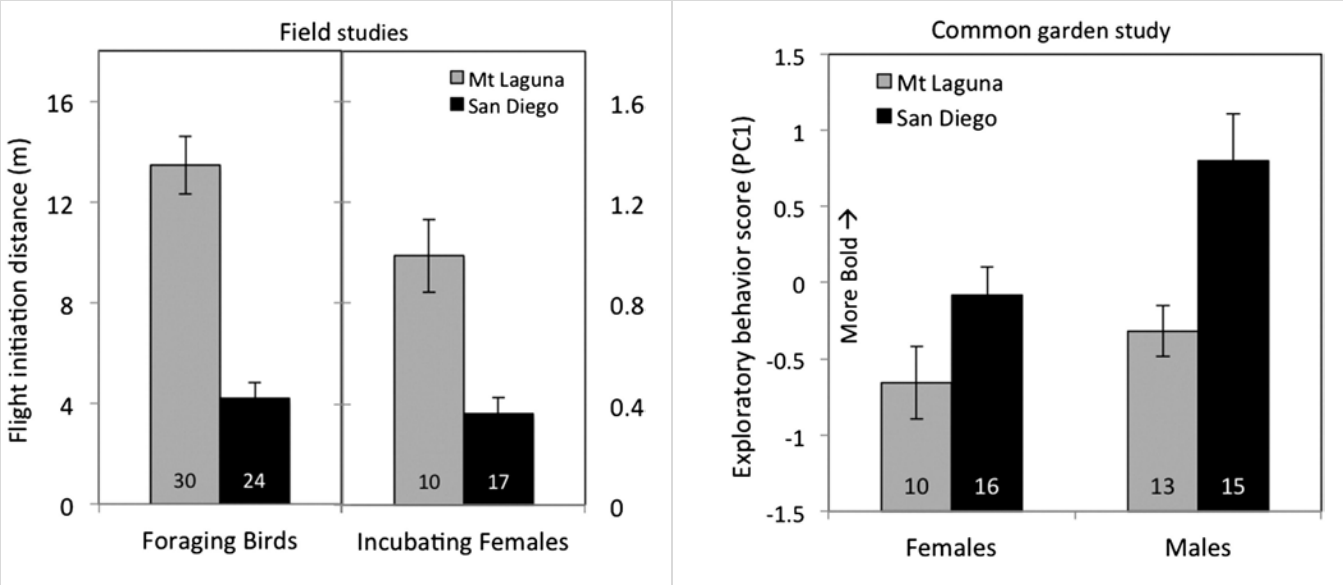

Making Sense of Part 2:

Analyze the graphs comparing mountain juncos and city juncos in field studies and the common garden experiments. What patterns do you notice between the two populations in these two experiments?

_____

_____

_____

What is the relationship between how close a bird will let a person get to them before flying away and their exploratory behavior?

_____

_____

_____

What do the results tell us about whether boldness in Juncos is inherited or learned?

_____

_____

_____

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Next Steps:

What new question(s) did your class raise related to how differences in alleles might be connected to differences in behavior?

What kind of things might we want to try to detect or measure inside of these birds (or other organisms) to investigate this question further?

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Name: _____ Period: _____ Date: _____

Lesson 5d: What's happening with our antibiotic experiment?

Purpose & Predictions

1. Why did we decide to replate the bacteria during the last investigation?

_____

_____

_____

_____

_____

2. What are we looking for in our plates, and what do we think we will see? Draw & explain your predictions.

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Making Sense After you have recorded your data in your data table on the student handout 5a.1, discuss and answer the following questions in small groups:

3. What, patterns in the data are you noticing in your plates (or other group's plates) across time?

4. What ideas do you have about why you are seeing these patterns?

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Home-learning Lesson 5c: What patterns do you think you will see in the data next time and how is this connected to Addie's case?

Next Steps:
If we do another round of replating, what patterns do you think you will see in the data next time?

Connecting to Our Driving Question:
How might the patterns we are noticing in the data in your group, or in other groups, help us understand what might have been happening in Addie's case ?
'

_____

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_____

_____

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_____

How might the patterns we are noticing in the data helping us understand why the frequency of antibiotic resistant bacteria infections has been increasing in the population over time?

_____

_____

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Name: _____ Period: _____ Date: _____

Lesson 13: Are there differences inside the birds that would help explain why they behave differently in response to things happening around them?

Connecting to the previous lesson: What did we figure out last class about what is causing the differences in boldness between the UCSD Juncos (city birds) and the mountain birds?

_____

_____

_____

Next Steps: What question did we still have about what is causing these different behaviors in the two populations of Juncos?

_____

_____

_____

Part A

You are going to read text from a published scientific study that collected some data that might help us with the questions we still have.

Procedure: Read the abstract from a study titled ***"Boldness behavior and stress physiology in a novel urban environment suggest rapid correlated evolutionary adaptation"*** led by Jonathan Atwell. This is from an article published in the peer-reviewed journal Behavioral Ecology in 2012. Feel free to mark up the text to try to uncover the important ideas. Look for the following:

- *What was this study asking?*
- *What were they trying to figure out?*
- *What kinds of data were they collecting?*
- *Can we tell just based on this what the scientists were actually DOING in their experiment(s)?*

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Abstract from the original publication

Novel or changing environments expose animals to diverse stressors that likely require coordinated hormonal and behavioral adaptations. Predicted adaptations to urban environments include attenuated physiological responses to stressors and bolder exploratory behaviors, but few studies to date have evaluated the impact of urban life on codivergence of these hormonal and behavioral traits in natural systems. Here, we demonstrate rapid adaptive shifts in both stress physiology and correlated boldness behaviors in a songbird, the dark-eyed junco, following its colonization of a novel urban environment. We compared elevation in corticosterone (CORT) in response to handling and flight initiation distances in birds from a recently established urban population in San Diego, California to birds from a nearby wildland population in the species' ancestral montane breeding range. We also measured CORT and exploratory behavior in birds raised from early life in a captive common garden study. We found persistent population differences for both reduced CORT responses and bolder exploratory behavior in birds from the colonist population, as well as significant negative covariation between maximum CORT and exploratory behavior. Although early developmental effects cannot be ruled out, these results suggest contemporary adaptive evolution of correlated hormonal and behavioral traits associated with colonization of an urban habitat.

Key words

- = A corticosteroid, $C_{21}H_{30}O_4$, that is secreted into the bloodstream by the adrenal cortex.
- = is a population shift from rural to urban areas, "the gradual increase in the proportion of people living in urban areas", and the ways in which each society adapts to the change.
- = a mutual relationship or connection between.

Summarize your responses to some of the following:

- *What was this study trying to figure out?*
- *What kinds of measurements were they collecting?*
- *Can we tell just based on this what the scientists were actually DOING in their experiment(s)?*
- *What did you learn that was new or unexpected?*
- *What new questions did you come away with?*

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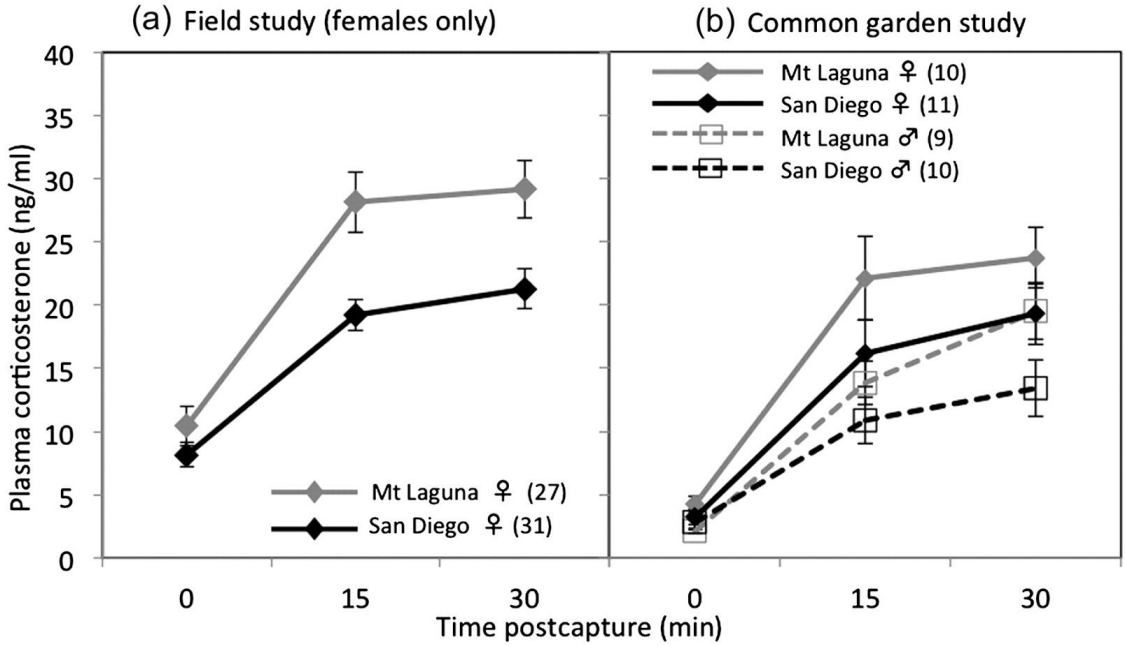
Part B

B. The graph below shows data for CORT (A substance that is secreted into the bloodstream by the adrenal cortex) in birds at the time of capture (before stress) and then 15 and 30 minutes after capture. The black lines in both graphs are juncos from San Diego and the gray lines are Juncos from the mountains where they previously lived (Mt. Laguna).

- Side (a) is data collected from the field (natural environment)
- Side (b) is data collected from a common garden experiment where the mountain juncos and the San Diego juncos were raised in the same environment[1].



What patterns do you notice in the (a) field study data? _____

_____

_____

What patterns do you notice in the (b) common garden study? _____

_____

_____

[1] **Footnote from paper:** The graph below includes initial (baseline) and stress-induced plasma corticosterone (CORT in colonist (San Diego) and ancestral range populations are shown from (a) field study of freeliving nesting females and (b) a captive common garden study of birds raised from early life under identical aviary conditions. We found significant population differences in both maximum CORT and CORT responsiveness (area) in both field and common garden studies, and there were also sex differences in the common garden.

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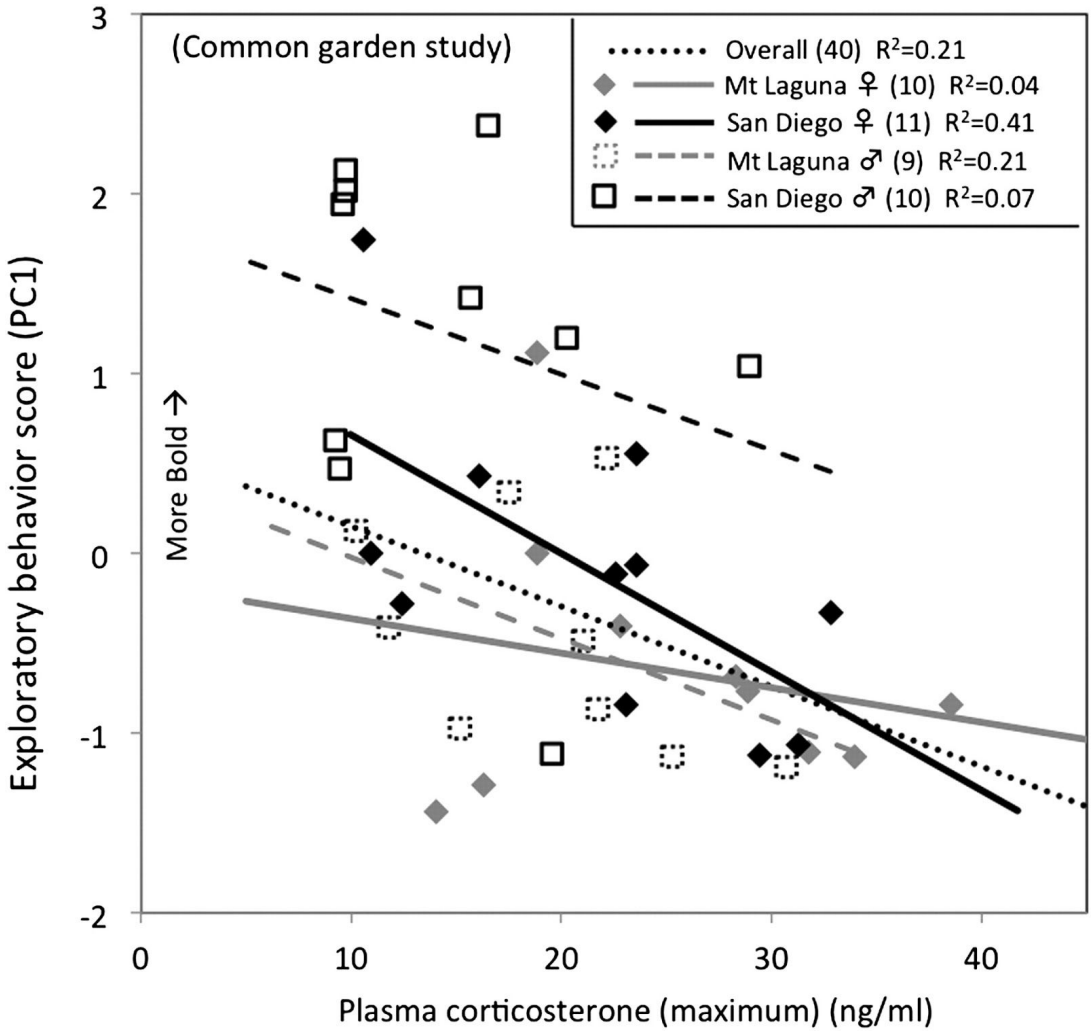
CORT (corticosterone) is a substance that is secreted into the bloodstream by the adrenal cortex. What do you think the effect of elevated levels of CORT in the bloodstream is?

Part C

Now look at the boldness data: Boldness is on the y-axis and CORT on the x-axis[2]:



2 **Text from paper:** Individual variation for maximum CORT and exploratory behavior from the common garden study. Max CORT predicted individual exploratory behavior scores (P = 0.021) in a GLM model the also included significant effects of population (P = 0.015) and sex (P = 0.049).

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What is the relationship between boldness and CORT levels? How is this relationship different for San Diego juncos (black lines) and for Mt Laguna juncos (gray lines)?

In humans, the adrenal cortex secretes hormones like adrenaline and testosterone (and other substances) into the bloodstream. If different Juncos were born with differences in how the cells in their adrenal cortex function related to the production and/or release of CORT, how could that help explain why they behave differently in response to things happening around them?

Making Sense: How does this data help us explain the connection between differences in the alleles that Juncos inherit from their parents and the behaviors they exhibit in response to things happening around them as adults? Draw and label and/or explain a model that explains this connection.

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Next Steps and New Questions:

What does this new data add to your thinking about how populations change over time?

What questions do you now have?

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Lesson 14: How do the changes that happened to the juncos populations compare to our bacteria populations?

14.1 - Connecting to the Previous Lesson

We have determined that both organisms we have been studied (bacteria in our Petri dishes and juncos) pass traits on from generation to generation. Summarize how the juncos' traits we observed being passed on are **different** than the trait(s) we considered in the bacteria.

_____

_____

_____

Summarize how the bacterial traits we observed being passed on are **similar** to the trait(s) we observed in juncos.

_____

_____

_____

Even though the type of traits being passed on is different in both populations, how do differences in trait variations between individuals within both populations contribute to how these populations changed over time?

_____

_____

_____

How do changes in the environment contribute to how these populations changed over time?

_____

_____

_____

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14.2 - Comparing the Bacteria in our Petri Dishes and Juncos

We have observed four different populations changing over time: (1) bacteria in Addie's world, (2) our NetLogo simulation, (3)Juncos, and (4) our bacteria in the Petri dish investigations. And that we have compared the NetLogo simulation to Addie's world already in Lesson 8. Let's use what we figured out in lesson 8, to compare it the other things we have learned since then from the juncos and the Petri dish investigations. This comparison across systems, will help us refine our model of why antibiotics weren't working to kill the bacteria inside of Addie and prepare our infographic.

In groups, make a summary chart of columns A and B regarding the key conditions and outcomes that we know were important parts of both the bacteria and juncos. Wait to fill out column C as a class.

Bacteria in Our Petri Dish Experiments vs. Juncos Comparison Chart

	Petri Dish Bacteria (System #1)	*Juncos (System #2)*	C. Conditions or Outcome Common to both Systems
What "Types" (trait variations) were in the initial population?	1. There was one initial ancestor population that had trait variations in it for antibiotic resistance, that we swabbed onto the first Petri dish with.	1. There was one *initial ancestor population that….*	1….
What type of changes are occurring in the environment?	2. The environment conditions of the Petri dish were different based on where in the dish and based on the concentration used in the drop from the bottle.	2. …..	2….
How did the environmental change affect which individuals tended to survive?	3. Some of the bacteria died near the antibiotic, we also observed that….	3.	3. ...

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Which type of individual reproduced more? Why?	4. The bacteria that reproduced more often near the antibiotic were the ones that….	4. The juncos that reproduced more were ... because….	4….
What is happening to the population over time?	**5.** ..The population that is replated from near the antibiotic disk is….	**5.** ….	**5….**

14.3 - Generalizing Our Model

What, if anything, would we need to change in the wording of column C, in order to make it a general model for explaining and predicting the mechanisms and outcomes we would expect to see at work **in all populations of all organisms over time**?

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Home-learning 14 - part 1 - What evidence might be useful to repurpose in our infographics?

You have lots of potential sources of evidence to use in your infographic. If you use it all of it, it be an overwhelming amount of information for a reader to make sense of. For home-learning, consider the sources of evidence we have and how they might be useful for helping other people understand what they need to know in the infographic we are making by filling out the table below. In the next lesson we will use your evaluation in the table below to make choices about what, if any evidence, you want to actually reuse or repurpose for use in your infographic.

System	*The evidence says….*	*It could be useful for helping other people understand what they need to know because:*
Addie's World		
Our "school" bacteria investigation		
NetLogo computer Simulation		

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System	*The evidence says….*	*It could be useful for helping other people understand what they need to know because:*
Juncos		
Petri Dish bacteria		

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Home-learning 14 - part 2 - What limitations or gaps might there be in our model still that we want to investigate further?

14.3 - Limitations to Our Model

What, limitations are there in our model right now that don't account for all the important differences between bacteria and juncos, that we might need to explore further in order to understand how it might be explain and predict the type of changes we would expect to see in **all populations of all organisms over time**? In order to identify possible limitations, we need to raise more questions about the things that are different between the systems.

What questions do you now have about how moving/transferring/migrating organisms back and forth between different environments might be affecting affecting the population over time (either in the juncos and bacteria or in other populations)?

_____

_____

_____

_____

What questions do you now have about how differences in reproduction and mating between bacteria and juncos might be affecting population changes over time (either in the juncos and bacteria or in other populations)?

_____

_____

_____

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What questions do you now have about the type of population changes you might see over a longer period of time (either in the juncos and bacteria or in other populations)?

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Lesson 15: How Can We Share What We've Learned with our Community?

Warm-up: Think back to all you've done to learn about the evolution of bacteria and the spread of antibiotic-resistant bacteria in this unit. From what you've learned, what are your biggest takeaways?

_____

_____

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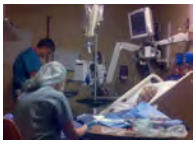
_____

There is so much we've learned about antibiotic-resistant bacteria, how it forms, and how people are responsible for its formation. It's time, now, to share this information with the larger community in an effort to put an end to the spread of antibiotic-resistant bacteria.

You filled out a version of the table below back in Lesson 6. Now that you've conducted more research and more investigations, add any additional or updated information to this table in the fourth column. Use the empty rows at the bottom of the table to add any additional relevant investigations, comparison chart from lesson 14, or research you've completed that will be helpful in explaining what behaviors people must engage in to prevent the spread of antibiotic-resistant bacteria.

Question	Data source	What we figured out	Updated/Revised Information
L1: How did Addie get so sick?	 Frontline video and our own experiences		

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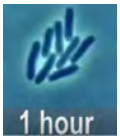
L2 Can this happen to me? How common is this sort of problem?	Historical data and information about MRSA 		
L3a Where can we pick up bacteria in our world?	 Placing sanitized hands on agar plates		
L4 How do (did) antibiotics and antiseptics work?	 CDC recommendations and video of antibiotics at work		
L3b Why are there things growing in the dish?	 Bacteria colonies emerge in our agar dishes  Bacteria reproduce under microscope (time lapse video)		

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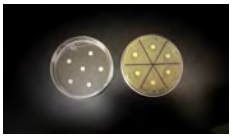
L5a. How much bacteria grow and how much die off when antibiotics and bacteria are put together in the same environment?	 Antibiotic-soaked disks in dish		

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Sharing Initial Ideas: How could we take everything we know about how antibiotic-resistant bacteria develop and spread and use it to send a strong, clear message to our community about how to prevent it? What will make our message stronger and more compelling than the current message being put out by the CDC?

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Jigsaw Activity: Designing Criteria for our Infographic

Note Taking: As you read your assigned article about a particular aspect of strong infographics, take notes here that you will share when you join your Jigsaw group (one person from each letter group).

_____

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_____

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Name: _____ Period: _____ Date: _____

Lesson 17a: Home-learning

Research Procedure

1. Read through Data Packets A, B, and C on the last pages of these Activity Sheets.
2. Summarize your discoveries from these data packets and complete the Making Sense sections on this page and the next.
3. Have this ready to share out by: _____

Making Sense

Data Source	**Summary of Discoveries:** **Q1:** How did each data packet help answer the question: "Can a child end up with some DNA that isn't 100% identical to the DNA found in mom and dad (50% from each)?"
Data packet A	
Data packet B	
Data packet C	

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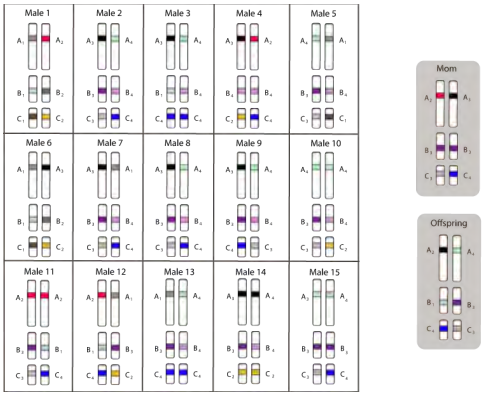
Q2: Think back to the method we considered for comparing all the alleles found in the mountain junco populations to all the alleles found in the UCSD population help us determine if a baby bird had a dad that was from the mountain population or a dad that was from the UCSD population. How much would the three sources of variation, summarized, above impact the reliability of that method?



a) They would have no impact on it.
b) They would have a negligible impact on it.
c) They would have a small, but noticeable impact on it.
d) They would have a very noticeable impact on it.

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Data Packet A: Mutation Rate

Scientists have investigated how often mutations occur in many organisms. How often a mutation appears in the DNA of the organism or in the gene pool of a larger population of that organism is referred to as the **mutation rate**. They have also identified all the possible number of locations that could undergo a mutation in the DNA. The smallest sub-unit of genetic information in the structure of the DNA is referred to as a base pair **(bp)**. And they have identified the number of genes that each of these organisms has in its entire set of DNA in its cells (its **genome**). Some of the DNA contains genes, while other parts of it do not.

The mutation rate of an organism, can be determined by comparing the DNA between lots of individuals, often across generations. They have found that the mutation rate is approximately constant per year and largely similar among genes. And they have also found that there is a great deal of similarity of mutation rates among mammals.

Q1: Compare using the estimated mutation rates of these organisms to humans to complete the calculations in the table below.

Organisms	A. Fruit Flies *(D. melanogaster)*	B. Mice *(M. musculus)*	C. Humans *(H. sapiens)*	D. Bacteria *(E. coli)*
1. Approximate # of genes in its genome	13600	20210	32,000	4288
2. Estimated mutation rate	~1 in every 10,000 genes	~1 in every 10,000 genes	~1 in every 10,000 genes	~1 in every 100,000,000 genes
3. Estimated # of mutations that would be found in the genes of each offspring	(1.36 on average) ↓ **= between 1 and 2**			
4. % of offspring's genes that are new ones not found in the parents (due to mutations)	% = part ÷ whole * 100 ↓ part ÷ whole * 100 ↓ 1.36 ÷ 13600 * 100 ↓ .001%			
5. % of offspring's genes that are found in the parent(s) (non-mutated)	= 100% - % from above ↓ = 100% - .001% ↓ = 99.999%			

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Q2: So does a child really inherit 50% of all its DNA from mom and 50% from dad? Explain.

Q3: What effect do you think these relatively small number of mutations per generation might have on a line of descendants after dozens of generations? Explain.

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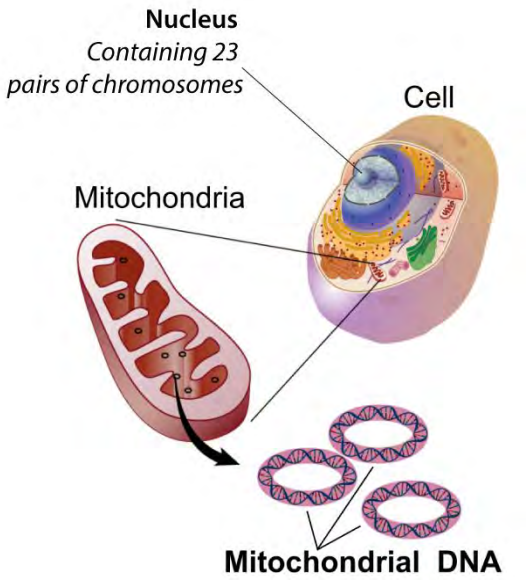
Data Packet B: Mitochondrial DNA

Images and text adapted from https://en.wikipedia.org/wiki/Mitochondrial_DNA

Scientists have investigated where all the DNA is found in humans and other mammals.The entire set of genes on all that DNA is found inside each of the cells of these animals.This is referred to as its **genome**. The entire genome in all body cells in people contain approximately 32,000 genes.

Although most of these genes are found on DNA that is packaged in chromosomes within the **nucleus** (in the form of 23 pairs of chromosomes), some DNA is found in a different part of the cell.



That additional DNA is found in a structure inside our cells called the **mitochondria**.

Mitochondria are structures within cells that convert the energy from food into a form that cells can use.

The genetic material found in mitochondria is known as **mitochondrial DNA** or mtDNA. The structure of this mtDNA forms a closed loop.

Mitochondrial DNA contains 37 genes, all of which are essential for normal mitochondrial function. But there are also part mitochondrial DNA that contain no genes.

Q1: Out of 32,000 genes in an entire human cell, what percentage are in the mitochondria?___

Q2: Is this a relatively large percent or relatively low percent? _____

In sexual reproduction, mitochondria are normally inherited exclusively from the mother; the mitochondria in mammalian sperm are usually destroyed by the egg cell after fertilization. Also, most mitochondria are present at the base of the sperm's tail, which is used for propelling the sperm cells; sometimes the tail is lost during fertilization.

Q3: So does a child really inherit 50% of all their DNA from mom and 50% from dad? Explain:

_____

_____

_____

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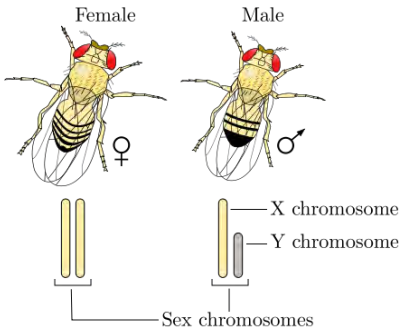
Data Packet C: Y chromosomes

Images and text adapted from https://en.wikipedia.org/wiki/Mitochondrial_DNA and https://en.wikipedia.org/wiki/XY_sex-determination_system

All animals have DNA that codes for genes present on their chromosomes. The genes that each of these organisms has in its entire set of DNA is referred to as its **genome.** The entire genome in all body cells in people contain approximately 32,000 genes.

In humans, most mammals, and some other insect species, such as the fruit fly, two of the chromosomes, called the X chromosome and Y chromosome, code for sex.



In these species, one or more genes are present on their Y-chromosome that determine maleness. In this process, an X chromosome and a Y chromosome act to determine the sex of offspring, often due to genes located on the Y chromosome that code for maleness. Offspring have two sex chromosomes: an offspring with two X chromosomes will develop female characteristics, and an offspring with an X and a Y chromosome will develop male characteristics.

Q1: Which chromosome appears shorter in the fruit fly diagram above, the X or the Y?_____

The two chromosomes that make up each of the 22 out of 23 pairs in a human karyotype, are the same length. In other words, both #2 chromosomes are the same length. Both #8 chromosomes are the same length (but #2 chromosomes are not the same length as #8 chromosomes). If the person is female, both #23 chromosomes will be the same length. But if the person is male, then the 23rd pair of chromosomes will be of different lengths.

Q2: The karyotype shown to the right is the one your class looked at in the last lesson. The pair of chromosomes in the bottom right corner are the 23rd pair. Was this person born male or female ?_____

Q3: The chromosome that carries the fewest number of genes in humans is the Y chromosome. The Y chromosome carries only about 344 genes. Some of the DNA in the Y chromosome has no genes in it. Out of all the genes within a cell, what percentage of them are on the Y chromosome?_____

Q4: Human females can pass on either one of the their two X chromosomes to an offspring, but a dad can pass on either an X chromosome or a Y chromosome. So does a child really inherit 50% of all their DNA from mom and 50% from dad? Explain:

_____

_____

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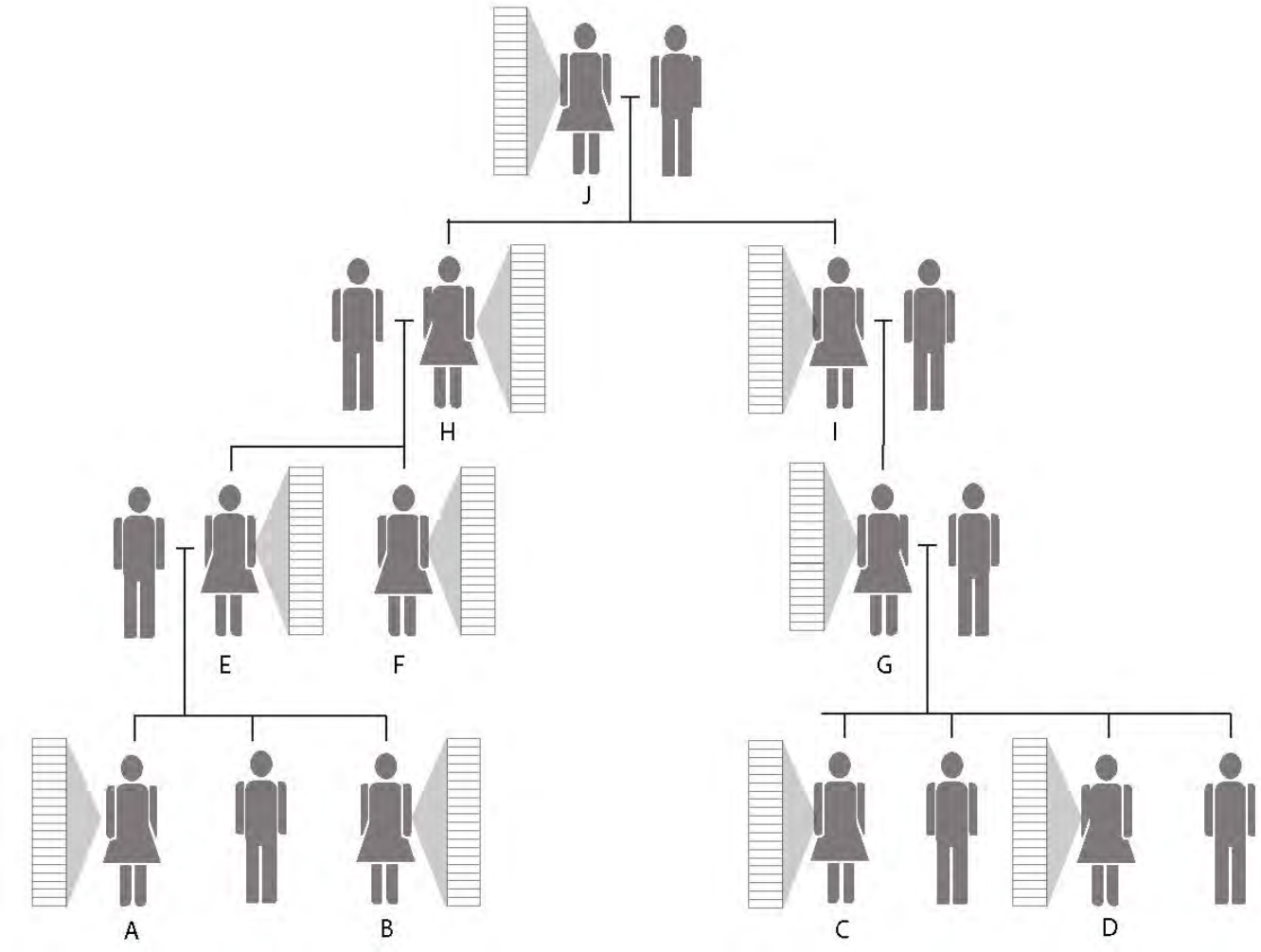
Name: _____ Period: _____ Date: _____

Lesson 17b: How can our new discoveries about how DNA is inherited help us figure out which populations an individual junco belongs to?

Part 1 - Class model: Construct a model showing accumulation of differences in the mitochondrial DNA (mtDNA) due to accumulation of mutations across three generations.



Q1: Could we build a similar model for predicting accumulation of mutations in Y-chromosomes in males from one generation to the next? Explain.

_____

_____

_____

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Part 2 - Using Mathematical and Computational thinking

Q2: Use your model on the previous page to determine the following:

Individuals we are comparing	What percentage of mtDNA do they share in common?	What percentage of mtDNA is different between them?
Any mom and daughter compared to one another		
Any two siblings compared to one another		
Any grandchild compared to their grandma		
Any great-grandchild compared to their great-grandma		

Individuals we are comparing	When did they last have a common ancestor?	What percentage of mtDNA do they share in common?	What percentage of mtDNA is different between them?
C and D	1 generation ago		
F and G	2 generations ago		
B and C	3 generations ago		

Q3: Why does individual C have more DNA in common with individual D, than they do with individual B?

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Part 3 - Using Mathematical and Computational thinking

Q4: Our model used a simpler mutation rate (1 out of 20 genes mutated) as opposed to the much lower mutation rate that scientists have measured (1 out of 10,000 genes mutated) that humans and other mammals incur across a generation. How could we use the actual mutation rates to scale the patterns in our model to more accurately reflect what we would see in humans and other mammals?

_____

_____

_____

Q5: Scale the predictions from our model to complete the table below:

Most recent common ancestor	Differences in mtDNA predicted in our model.	Similarities in mtDNA predicted in our model.	Differences in actual mtDNA predicted in humans and other mammals.	Similarities predicted in actual mtDNA predicted in humans and other mammals.
	1 out of 20 = 5%	19 out of 20 = 95%	1 out 10,000 = 0.01%	9,999 out of 10,000 = 99.99%
1 generations ago	2 out of 20 = 10%			
2 generations ago	4 out of 20 = 20%			
3 generations ago				
4 generations ago				
5 generations ago				

Q6: Using actual mutation rates in humans and other mammals, what % of mtDNA do you predict would be **different** between two individuals that shared a common female ancestor 8 generations ago?

Q7: Using actual mutation rates in humans and other mammals, what % of DNA in the Y-chromosome would be **similar** between any two males that shared a common male ancestor 10 generations ago?

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Part 4 - Conclusions and Next Steps

Q8: How might comparing mutations in mitochondrial DNA between two different juncos help us determine how many generations ago they last shared a common ancestor?

Q9: How might comparing mutations in mitochondrial DNA across other types of organisms (besides birds or humans) help us determine how long ago their ancestors started to diverge into separate species from a common ancestor?

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Name: _____ Period: _____ Date: _____

Lesson 18: What alleles are found in both populations?

18.1 - Connecting to the Previous Lesson

Q1: What did we decide we could figure out by comparing the relationship between the alleles found in the mountain population males, and the alleles in the UCSD offspring?

_____

_____

_____

Q2: What would researchers have to do to compare **all** the alleles found in the entire population of mountain juncos to all the alleles found in the entire population of UCSD juncos?

_____

_____

_____

Q3: Do you think it would be necessary to sample all of the birds in the population or could scientists compare DNA from a smaller sample of birds from both areas and still draw reliable conclusions? Explain.

_____

_____

_____

_____

_____

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18.2 - Reading Summary

Q4: How do patterns in allele 208 (at locus Gf05) found in samples of the UCSD population vs. the Laguna mountain population (LG), provide evidence that something is preventing most male UCSD juncos from migrating back to the mountains and interbreeding with females in that population?

Q5: How does the continued absence of certain alleles in the UCSD population help support the claim that there have been very little (or no) cross-breeding between males from the mountains and UCSD females since the founding event?

Q6: How might differences in wing length and tail length between the UCSD juncos and mountain juncos be contributing to keeping these two populations from interbreeding with one another?

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Next Steps:

Q7: What new questions or new ideas did this raise for your class?

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Name: _____ Period: _____ Date: _____

Lesson 19: Are there other trait differences that could lead a junco to mate with someone from their own population rather than an outsider?

19.1 - Connecting to the Previous Lesson

As a class summarize the two major trait differences we have seen in the juncos.

Trait	Mountain Junco evidence	UCSD Junco evidence	Do we have evidence that this is an inherited trait difference?
A. Boldness and exploratory behavior			
B. Wing & tail length			

Q1: Explain why a UCSD junco that mates with another UCSD junco is more likely to have offspring with trait variations that grant them a better competitive advantage for survival at UCSD, than if they had an offspring from mating with a mountain junco.

_____

_____

_____

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19.2 - Summarize other trait differences

Summarize the other traits differences observed in these juncos.

Trait	*Mountain Junco evidence*	*UCSD Junco evidence*
C. Other physical differences		
D. Other behavioral differences		
E. Other physiological differences		

Q2: Which of these trait differences might lead a UCSD junco to a mate with a bird from their own population rather than an outsider? Why?

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Next Steps:

Q3: What kind of investigation could be conducted to determine whether or not birds really can identify and/or prefer potential mates based on these trait differences? How would you design an experiment to test one of these possibilities? Draw and label your idea for such an experiment below:

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Name: _____ Period: _____ Date: _____

Lesson 20: Can birds really tell who they want to breed with by the feather color and song of their mate?

Q1: After reading your assigned article jot down some of the important ideas you want to present to class.

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Name: _____ Period: _____ Date: _____

Lesson 21: Are there other trait differences that could lead a junco to mate with someone from their own population rather than an outsider?

Part 1

Procedure: Analyze the photos of some of the juncos found in North America. Record your observations of how they appear to vary in appearance from one row to another below:

Photographs of juncos from different locations across N. America

Observed variation in their physical characteristics

:

Q1: Do you think there is a relationship between what these juncos look like, and the environments they live in? Explain.

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Part 2 **Procedure:** Summarize what you learned from the video about where juncos are found in the U.S and Canada.

Q2: What is similar about the environments where they tend to mate?

_____

_____

_____

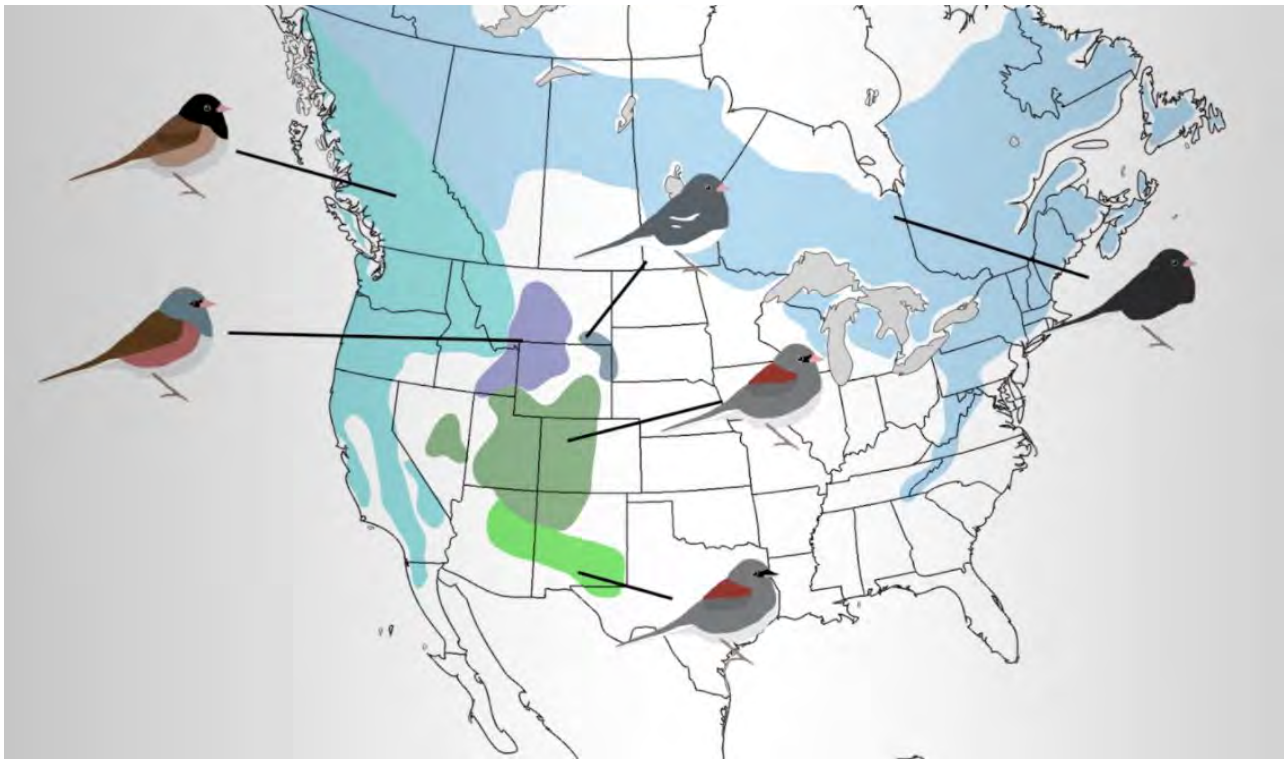
Q3: What is different about the environments where they tend to mate?

_____

_____

_____

Part 3 **Procedure** The map below shows the typical breeding ranges for six different populations of juncos. The UCSD juncos are not shown on this map. If you wanted to look for evidence of whether juncos from one these six populations ever interbred with juncos from another of the six populations, in what parts of the map do you think it would be more likely to observe such behavior? Mark those locations on the map with small stars.



These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Part 4 **Q4:** Look back at the first page of Lesson 17b. How could comparing the differences in mitochondrial DNA (mtDNA) between these birds help us determine how closely related these birds are to one another?

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Name: _____ Period: _____ Date: _____

Lesson 22: How closely related are the different populations of juncos found in North America?

The map below shows the breeding ranges of the juncos you looked at in the last lesson, as well as the breeding ranges of some other populations of juncos found in Mexico and other regions further south on the North American continent. The name of each population is referred to by four initials (e.g. PSJU).

Predict: Q1: Do you think the bird populations shown in Central America are as likely to interbreed with the ones you looked at in the United States and Canada in the last lesson? Explain your reasoning.

_____

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_____

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_____

Predict: Q2: Which birds do you think are less closely related? Why?

_____

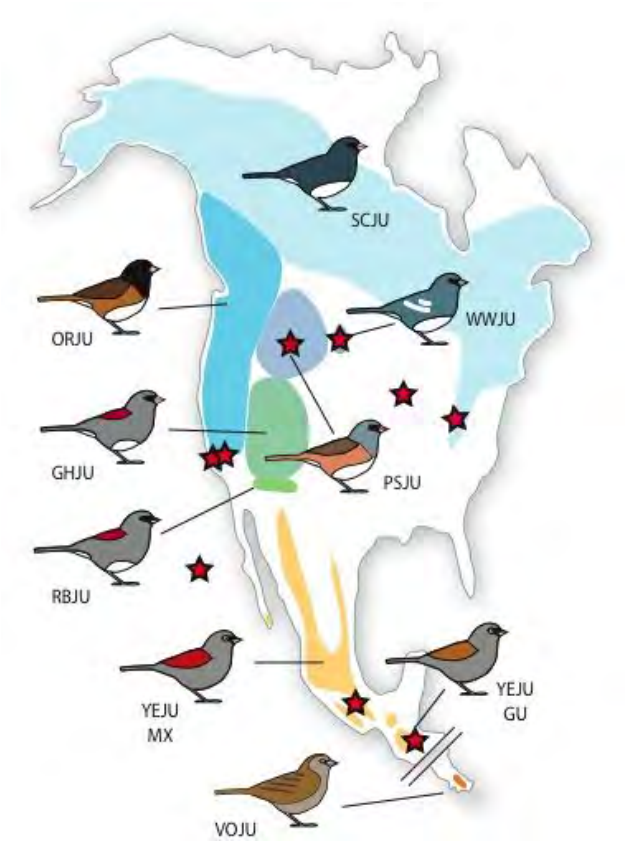

image above from http://www.indiana.edu/~kettlab/fieldsites.html

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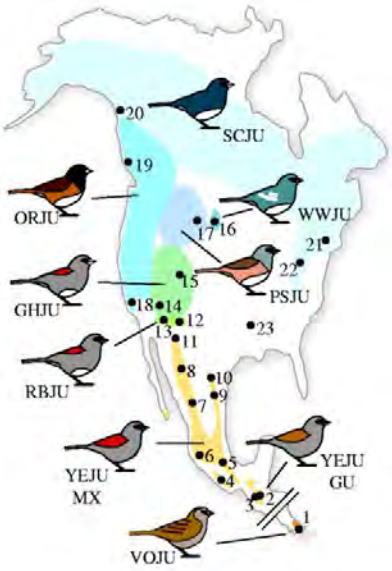
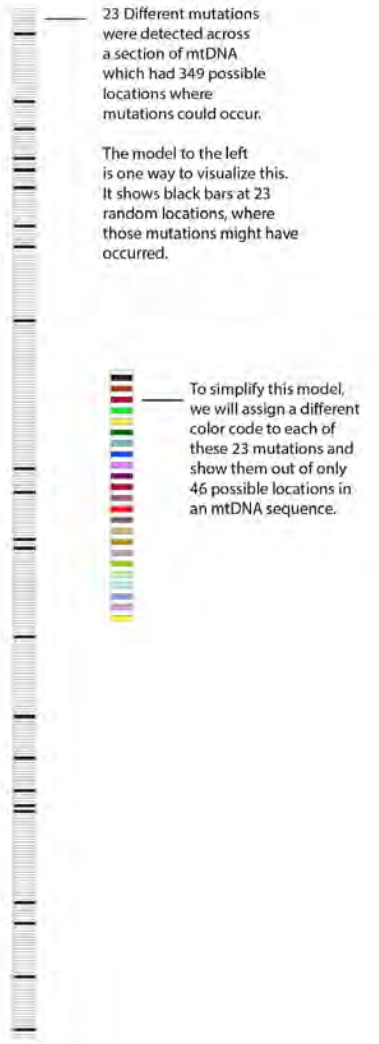
Part 2 The data and methodology below and the map shown below of sites sampled across North America is from the article *Recent postglacial range expansion drives the rapid diversification of a songbird lineage in the genus Junco*, authored by Roja Mila, John El. McCormack, Gabriela, Castañeda, Robert K. Wayne, and Thomas B. Smith, published in the Proceedings of the Royal Society. Published online on August 28, 2007. (http://rspb.royalsocietypublishing.org/content/274/1626/2653)

Sampling and mtDNA sequencing.

Individuals were captured in the field using mist nets, and blood and/or feather samples were collected for genetic analysis. Individual juncos were sampled from sites 2 through 10, 12, and 15 through 21 in this manner. Juncos from site 1 were sampled from toe-pad tissue of specimens nos. 37891 and 37853 in the Dickey Bird and Mammal Collection at UCLA. No individuals from site 11, 13, 14, and 22 were taken using this method of comparing DNA outlines below.



Sequencing of two different coding regions of the mtDNA (one which included 610 locations (610 bp[1]) and the other which included 327 locations (327 bp) where a mutation could occur yielded no variation across all individual juncos. A different region of the mtDNA, however showed 23 differences in the genetic code across 349 locations (349 bp), across juncos from different sample sites.



Q3: How does this representation shown in the mtDNA model above compare to what you drew on the first page of your **Lesson 17b Student Activity Sheets**?

[1] **bp** is an abbreviation for base pair. A **base pair** is the smallest subunit of genetic code within a strand of DNA. You can think of at base pair as a as the smallest section of DNA and as the smallest unique location you can identify in the genetic code. Alleles are sections of DNA composed of many base pairs.

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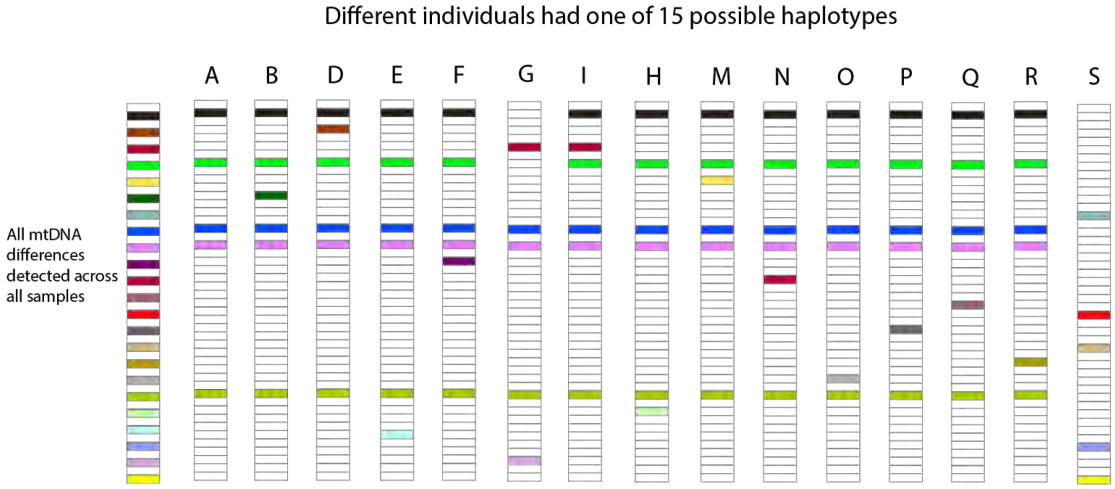
Results

15 different unique combinations of these 23 mutations in this section of mtDNA were detected across all the samples measured for this last region of mtDNA. Each unique combination is called a **haplotype**. A simplified representation of these 15 different haplotypes are shown here:



	The haplotypes found in the mtDNA from individuals sampled at this site															
Site sampled	A	B	D	E	F	G	H	I	M	N	O	P	Q	R	S	Number of birds sampled from this site
1															▮	2
2						▮										11
3						▮										8
4		▮														14
5	▮															28
6	▮	▮	▮													35
7	▮	▮					▮									33
8	▮						▮									19
9	▮				▮											4
10	▮							▮								8
12	▮															6
15	▮															7
16	▮															5
18	▮	▮								▮		▮				19
19	▮	▮					▮		▮	▮						15
20	▮						▮		▮							16
21	▮													▮		4

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Part 3

Q4: Identify two haplotypes that appear to be from individuals that are not very closely related (they share a common female ancestor longer ago).

Q5: Identify three haplotypes that appear to be from individuals that appear to be very closely related (they share a common female ancestor in the relatively recent past).

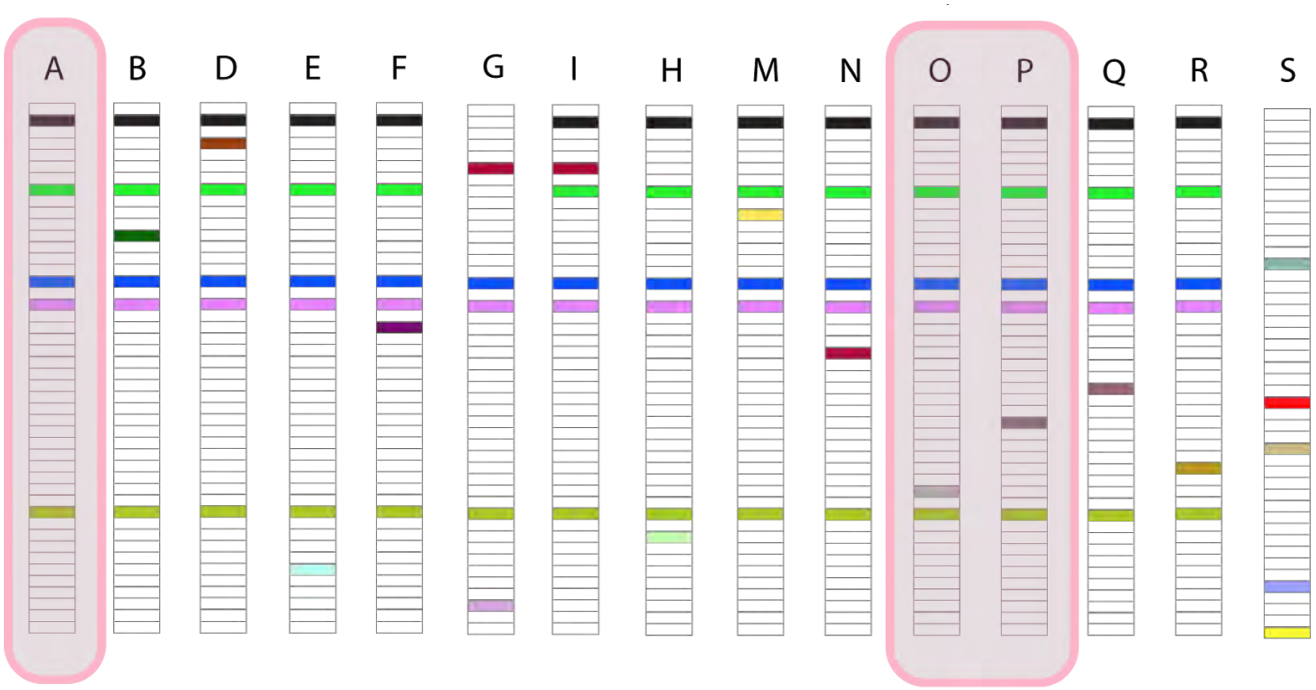
Q6: Based on your predictions you made on the first page, what are some other sites you'd like to compare? Identify 6 to 8 sites you are interested in comparing the mtDNA data from:

Site: _____ Site: _____ Site: _____ Site: _____

Site: _____ Site: _____ Site: _____ Site: _____

For each site you will use the chart on the previous page to identified which haplotypes were found there. Then on the next page you will circle haplotypes found in the mtDNA sampled from the birds at that site. For example, if the chart showed that haplotypes A, O and P were found at site 23, then you would circle the mtDNA models for those haplotypes shown below.

Site: **23**



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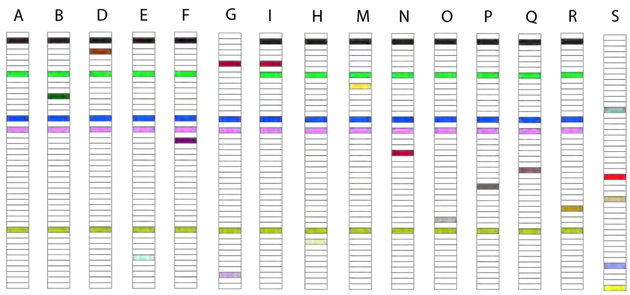
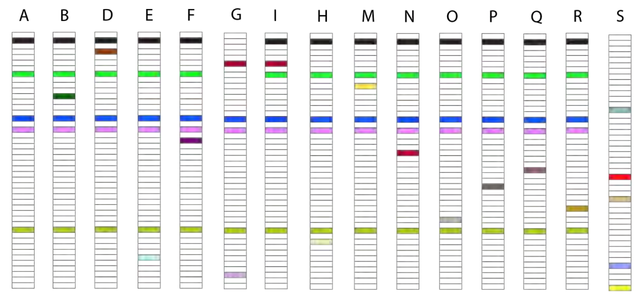
Q7: In the spaces below circle the haplotypes found for the sites you identified in **Q6**:

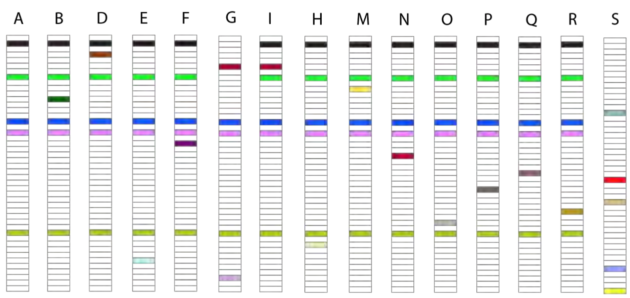
Site: ________



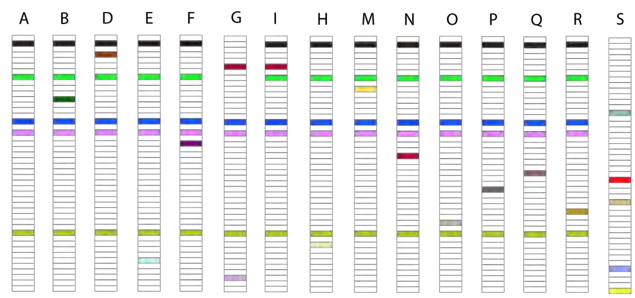
Site: ________



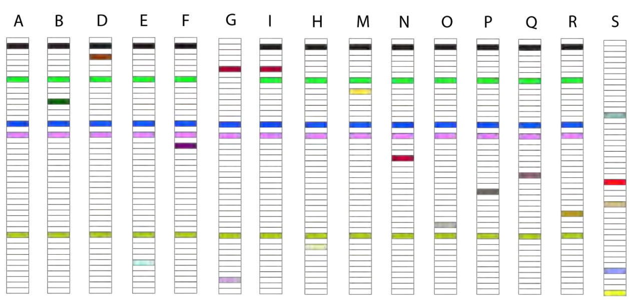
Site: ________



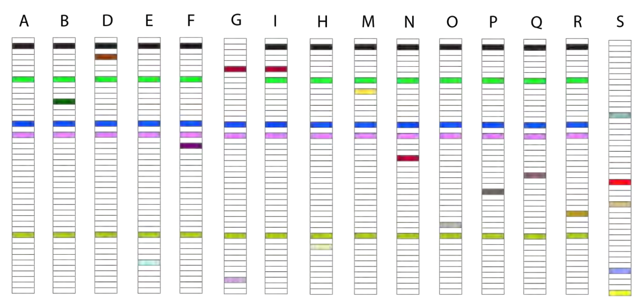
Site: ________



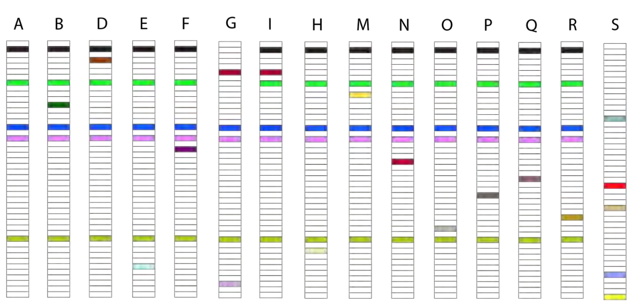
Site: ________



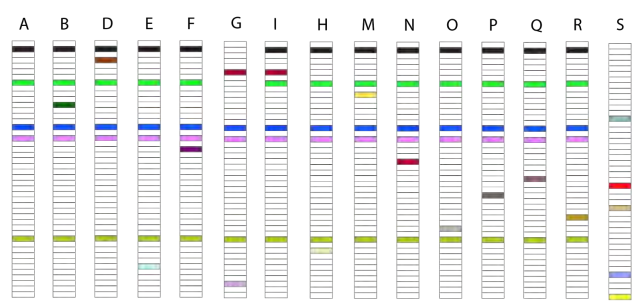
Site: ________



Site: ________



Site: ________



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Q8: Which of these sites appeared to have populations of birds that shared a common ancestor more recently than others?

Q9: Which of these sites appeared to have populations of birds that shared a common ancestor longer ago than others?

Q10: Were your predictions from the first page correct? Explain.

Part 4

Q11: How does the sort of analysis that the scientists did in the video compare to the analysis that we did?

Q12: What claims did the scientists in the video make based on their analysis?

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Part 5 **Conclusions Q13:** Construct a summary chart as a class for this phenomena:

	Phenomenon #1	Phenomenon #2
What phenomena are we trying to explain?		
What question can we now answer?		
What model do we think can apply to our explanation?		
Mechanisms that contributed to this phenomena	**What evidence do we have for this mechanism contributing to this outcome?**	
A. Physical, behavioral, and physiological trait variations due to genetic information inherited from parent(s)		
B. Environmental changes over time and/or between different places		
C. Migration (or movement of populations from one environment to another)		

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Mechanisms that contributed to this phenomena	What evidence do we have for this mechanism contributing to this outcome?
D. Sexual reproduction	
E. Mutation	
F. Isolation (geographic or reproductive)	
G. Natural selection	

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Next Steps

Q14: Compare the mechanisms (A through G) from question 13 to the ones you used in your explanation about what happened to Addie in earlier lessons and the larger question: "Why don't antibiotics work like they used to?"

Some of those mechanisms are ones that we have used to explain these two phenomena:

- Many antibiotics that used to help wipe out bacteria infections don't work on them anymore.
- There are lots of different kinds of pan-resistant bacteria in the world now, but weren't as many in the past.

But some of those mechanisms are ones that we did not include in previous explanations because we didn't have evidence about how they contribute to the evolution of populations over time.

Now we know these mechanisms (A through G) play a role if the evolution of birds. Which of these mechanisms are ones we didn't use in our previous explanation of Addie and our driving question?

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Name: _____ Period: _____ Date: _____

Lesson 23: How would these mechanisms affect the evolution of other organisms (including bacteria) over time?

Part 1 Data Source 1 -- Posted by the Kishony Lab at Harvard Medical School
Images from https://www.youtube.com/watch?v=plVk4NVIUh8

Q1: What is similar about this experimental setup and the experiments you conducted with *E. coli* in the Petri dishes in this unit?

Q2: What is different about this experimental setup and the experiments you conducted with *E. coli* in the Petri dishes in this unit?

Q3: Predict Bacteria with no variation in the starting population (identical DNA) were added to the right and left edge of the agar plate and allowed to grow as far as it could in 2 weeks. What do you predict you will see happen on the plate?

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Making Sense of the Results

Q4: What patterns do you notice in how the bacteria grew over the two weeks?

Q5: What are the different branches of lines that are drawn in helping us visualize, what is happening to the descendants of the bacteria that the investigators started with?

Q6: Why do some branches end before reaching the middle of the plate?

Conclusions

Q7: How is what we see happening here similar to our explanations of juncos in North America?

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Part 2 In the previous experiment the narrator says that mutants appear at various points in time across the two weeks of growth on the plate.

Q8: How would the DNA of the offspring of the mutant compare to its ancestors (the bacteria that was originally started on the edge of the plate)?

Q9: In an earlier lesson you learned that an individual *E. coli* bacterium has 4288 genes. When bacteria reproduce, all those genes in the DNA are duplicated and a copy of the DNA is passed on to each offspring (through binary fission). You also know that certain bacteria can reproduce every 20 minutes. If mutations in bacteria only occur at a rate about 1 in every 100,000,000 genes duplicated, how is it possible that so many mutations are showing up in the two weeks of this experiment?

Q10: What additional data would you need in order to figure out how mutations are causing some lines of descendants to be able to survive and reproduce into the parts of the plate with more and more antibiotic?

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Fast-Reproducing Microbes Provide a Window on Natural Selection
By CARL ZIMMER JUNE 26, 2007
http://www.nytimes.com/2007/06/26/science/26lab.html?ex=1184299200&en=72de3b507cf9d4c6&ei=5070
http://tinyurl.com/yt886v

Q11: What are some of the discoveries made by this group related to mutations in bacteria and how they can affect the outcomes of natural selection?

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Part 3 Revenge of the hopeful monster by Tanguy Chouard in NATURE|Vol 463|February 18th, 2010 http://www.nature.com/news/2010/100217/pdf/463864a.pdf

Q12: Read the first four paragraphs of the article. What question(s) about mutations will the rest of this article address?

Circle the section(s) of the rest of the article you will be reading and sharing:

1) Marine gladiators
2) Catching evolution red-handed
3) The rise of *Escherichia erlenmeyeri*
4) Of form, function and fitness

Q13: For your section(s), highlighting and annotating it to help you figure out:

- What did this group of scientists investigate?
- What evidence did they collect?
- What new claims or discoveries did they make about mutations based on this research?

Summarize these 3 things here:

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Q14: Summarize all claims we can now make about the role of mutations in the evolution of different organism from each of these sections of this article.

Marine gladiators	
Catching evolution red-handed	
The rise of *Escherichia erlenmeyeri*	
Of form, function and fitness	

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Part 4

Q15: What summary chart did your class make for this phenomena?

	Phenomenon #1	**Phenomenon #2**
What phenomena are we trying to explain?	Many antibiotics that used to help wipe out bacteria infections don't work on them anymore.	There are lots of different kinds of pan-resistant bacteria in the world now, but weren't as many in the past.
What question can we now answer?		
What model do we think can apply to our explanation?		
Mechanisms that contributed to this phenomena	**What evidence do we have for this mechanism contributing to this outcome?**	
A. Physical, behavioral, and physiological trait variations due to genetic information inherited from parent(s)		
B.Environmental changes over time **and** **Different environments in different locations**		

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Mechanisms that contributed to this phenomena	What evidence do we have for this mechanism contributing to this outcome
C. Migration (or movement of populations from one environment to another)	
D. Sexual reproduction	.
E. Mutation	
F. Isolation (geographic or reproductive)	
G. Natural selection	

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Name: _____ Period: _____ Date: _____

Lesson 24: How do we share everything we've figured out to prevent (or slow) the emergence of even more resistant bacteria in the future?

Part 1 - Connecting to the Previous Lesson

Q1: Over the course of this unit, you've worked to identify several mechanisms that drive evolution. List those below.

_____

_____

_____

_____

Q2: Which of these mechanisms are also important in helping explain why antibiotics couldn't help cure Addie of her bacterial infections?

_____

_____

_____

_____

_____

Q3: Do you feel differently about what the public should know about pan-resistant bacteria now compared to earlier in the unit? Share your thoughts/feelings.

_____

_____

_____

_____

_____

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Part 2 - Revisiting the Infographic

At the beginning of this unit, you were introduced to Addie's case and the growing frequency of pan-resistant bacterial infections in our world.

Through the study of different organisms you've learned:

- the mechanisms of evolution; and
- how these mechanisms could lead to the emergence of bacteria in the future that may be even harder to destroy than they are today.

Look back at the infographic you and your team created in Lesson 15. Knowing what you know now about evolution consider the following questions:

1. What is the audience for this infographic?
2. What is the goal of the infographic? Does it need to be adjusted in light of what you have learned?
3. What additional scientific understandings are necessary and appropriate to include for this particular audience and your particular goal?
4. What ideas will be too complex to add?
5. To what other audiences might this information be relevant?
6. How would you adjust the information you communicate to be readily understandable by all of these other audiences?

Use the guiding questions to revise your infographic or to replicate it for different audiences. Be prepared to defend your revisions to the class.

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