Cooperation & Survival 5E

Unit 2 Humans vs. Bacteria	Biology
Student Name:	

Biofilm See-Think-Wonder

As you watch the video, use the graphic organizer below to note down your ideas and questions.

See	Think	Wonder

Cooperation vs Cheating Investigation

When organisms live close together, they have to choose how to interact. Are they friends? Are they foes? Should they help their neighbors? All across the kingdoms of life, from bacteria to plants to humans, we face these same questions.

Procedure Part 1

Your task is to create the most nutritious meal possible. At the front of the room are food items to buy, each with a nutrition score. You have been given $10. You may spend them however you like on the options available. You may not buy part of an item. In calculating your nutrition score, you can count up to two servings of the same item; beyond that, you cannot earn more points. For example, if you buy a whole pizza, you will get 6 nutrition points (3 points per serving, two servings), even if the other 6 servings remain on your plate.

After assembling your meal, answer the following questions:

1. How much of your money did you spend?

   ____

2. What food(s) did you have in the end?

____

____

3. Calculate your nutrition score. Remember, only two servings of the same food item can count.

____

____

4. Describe your strategy for getting the most nutritious meal with your limited budget

____

____

____

Class data:

Strategy	Number of Students Using that Strategy	Average Nutrition Score Achieved through that Strategy

1. Based on the meals everyone created, which strategy or strategies are most successful? Why?

2. Are there any weaknesses of those strategies? If so, what are they, and why are they weaknesses?

Long Term Strategies
Introduction

In Part 1, did you work in a group? Have you ever worked in a group before? Did everyone contribute equally? What are the benefits and potential costs of working in a group?

Bacteria also collaborate in groups, with some individuals doing the majority of the 'work' while others may sit back and 'cheat' a little by exploiting the work of others. In this investigation, we will explore the conditions under which organisms may cooperate or cheat, and the impacts of these different strategies. First, you will interact with a simulation about collaboration and cheating, and then analyze data collected on a population of bacteria in cystic fibrosis patients.

Experimental Question

Procedure Part 2

1. Open up, The Evolution of Trust Simulation and click "...let's play a game." Note that you can turn the music off by clicking the sound button on the lower left hand side of the screen.

2. On the next screen, choose to cheat or cooperate in the each scenario, then answer the questions:

According to the first set of interactions, are you more successful when you always cheat, always cooperate, or sometimes cheat and sometimes cooperate? Explain why.

Do you think that strategy would be effective long term? Why or why not?

Imagine that you had to encounter the same person every day for this coin interaction. Would you be more successful if you both cheated every day or if you both cooperated?

If you began cheating, how do you think the other player would respond? How would that affect your success overall?

Using this information and the first part of the activity, explain why cooperation is a valuable evolutionary strategy, even if cheating might be more successful at times.

Natural variation results in individuals that respond differently to the same scenario. Even though we know that everyone is the most successful if everyone cooperates all the time, that may not happen.

3. Click "...more than once?" to move to the next screen

4. If you have time, play the first game, making any decisions that you want. Note your general observations below.

What strategy or strategies seemed successful against your varied opponents, and why?

5. If you played the first game, follow the arrows to move on to the tournament game. If you are skipping the first game, click on the fourth circle at the bottom to navigate directly to "one tournament." In this part, different characters (strategies) are pitted against each other.

6. Hover over the character names to see their strategies, and choose the strategy that you think will win the tournament. Note your choice, the winner, and observations in the table below (Data Table 1, Tournament)

7. Click on multiple tournaments, then use the data table (Data Table 2, Multiple Tournaments) to record the numbers of each type of player after each round. Then answer the question beneath it.

8. If you have time, replay the tournaments with all five characters.

9. Navigate to the next section, the evolution of distrust. You can either get there by clicking through the steps on the last screen, or click directly on the sixth circle at the bottom. We said before that everyone always cooperating results in the best outcomes for everyone, but that natural variation can add other behavior types. In this scenario, we see a group of cooperators where two variations have emerged: one copycat, and one cheater. Play the game with 10 rounds per match, 7 rounds per match, 5 rounds per match, and 2 rounds per match, and record your responses and observations (Data Table 3, The Evolution of Distrust).

10. If you have time and your teacher says to, you can play the rest of the game.

Data Tables

Data Table 1. Tournament Round
Predicted winner:

Winner of the Tournament	Observations
Who won in the short term? Who won at the end of the tournament?	

Data Table 2. Multiple Tournaments

Which strategy do you predict will win?

Round	Cooperate	Cheat	Copycat
0			
1			
2			
3			
4			
5			
6			
7			

Summarize: How did the proportions of each player type change throughout the game?

Why was the winning strategy so successful?

Data Table 3. Evolution of Distrust

Winner of the Tournament	How did the proportion of players of each type change over the course of the game?
1. Who won with 10 rounds per match, and what were their scores?	
2. Who won with 7 rounds per match, and what were their scores?	
3. Who won with 5 rounds per match, and what were their scores?	
4. Who won with 3 rounds per match, and what were their scores?	

Summarize:
Under what conditions is cooperation the best strategy, and why?

Under what conditions is copycatting the best strategy, and why?

Under what conditions is cheating the best strategy, and why?

Even if cheating is the best strategy under some conditions, it has shortcomings. How could a population of cheaters taking over a group make the whole group less successful?

Procedure Part 3

Cystic fibrosis (CF) is a genetic disease, in which a thick mucus builds up in the lungs of patients. Pathogenic bacteria often thrive in this mucus, causing frequent infections. Bacteria living in lungs of CF patients need to acquire iron from their environment (the human host). Cooperative bacteria living in these patients can generate biofilms. Here the bacteria produce molecules that help acquire iron, which can be shared amongst the bacteria living in the biofilm. Mutations may arise in a population of cooperating bacteria that turn the individual into a non-cooperator or 'cheat' that does not produce the beneficial molecule, even though they can still acquire iron from the other cooperative bacteria in their environment.

The data below represents samples of this bacteria population from a CF patient over time. The samples are sequential (sample 1 was taken first, followed by sample 2, and so forth). Analyze the data, and note your observations in the See-Think-Wonder graphic organizer.

Sample	Number of Cooperative Bacteria (in millions)	Number of Non-cooperative Bacteria (in millions)
1	100	5
2	90	8
3	85	15
4	75	25
5	62	40
6	50	45

7	25	30
8	5	25

Use the space below to complete your analysis.

See-Think-Wonder

See	Think	Wonder

Cooperation vs Cheating Investigation

When organisms live close together, they have to choose how to interact. Are they friends? Are they foes? Should they help their neighbors? All across the kingdoms of life, from bacteria to plants to humans, we face these same questions.

Procedure Part 1

Your task is to create the most nutritious meal possible. At the front of the room are food items to buy, each with a nutrition score. You have been given $10. You may spend them however you like on the options available. You may not buy part of an item. In calculating your nutrition score, you can count up to two servings of the same item; beyond that, you cannot earn more points. For example, if you buy a whole pizza, you will get 6 nutrition points (3 points per serving, two servings), even if the other 6 servings remain on your plate.

After assembling your meal, answer the following questions:

1. How much of your money did you spend?

____

2. What food(s) did you have in the end?

____

____

3. Calculate your nutrition score. Remember, only two servings of the same food item can count.

____

____

4. Describe your strategy for getting the most nutritious meal with your limited budget

____

____

____

Class data:

Strategy	Number of Students Using that Strategy	Average Nutrition Score Achieved through that Strategy

1. Based on the meals everyone created, which strategy or strategies are most successful? Why?

2. Are there any weaknesses of those strategies? If so, what are they, and why are they weaknesses?

Long Term Strategies
Introduction

In Part 1, did you work in a group? Have you ever worked in a group before? Did everyone contribute equally? What are the benefits and potential costs of working in a group?

Bacteria also collaborate in groups, with some individuals doing the majority of the 'work' while others may sit back and 'cheat' a little by exploiting the work of others. In this investigation, we will explore the conditions under which organisms may cooperate or cheat, and the impacts of these different strategies. First, you will interact with a simulation about collaboration and cheating, and then analyze data collected on a population of bacteria in cystic fibrosis patients.

Experimental Question

Procedure Part 2

1. Open up, The Evolution of Trust Simulation and click "...let's play a game." Note that you can turn the music off by clicking the sound button on the lower left hand side of the screen.

2. On the next screen, choose to cheat or cooperate in the each scenario, then answer the questions:

According to the first set of interactions, are you more successful when you always cheat, always cooperate, or sometimes cheat and sometimes cooperate? Explain why.

Do you think that strategy would be effective long term? Why or why not?

Imagine that you had to encounter the same person every day for this coin interaction. Would you be more successful if you both cheated every day or if you both cooperated?

If you began cheating, how do you think the other player would respond? How would that affect your success overall?

Using this information and the first part of the activity, explain why cooperation is a valuable evolutionary strategy, even if cheating might be more successful at times.

Natural variation results in individuals that respond differently to the same scenario. Even though we know that everyone is the most successful if everyone cooperates all the time, that may not happen.

3. Click "...more than once?" to move to the next screen

4. If you have time, play the first game, making any decisions that you want. Note your general observations below.

What strategy or strategies seemed successful against your varied opponents, and why?

5. If you played the first game, follow the arrows to move on to the tournament game. If you are skipping the first game, click on the fourth circle at the bottom to navigate directly to "one tournament." In this part, different characters (strategies) are pitted against each other.

6. Hover over the character names to see their strategies, and choose the strategy that you think will win the tournament. Note your choice, the winner, and observations in the table below (Data Table 1, Tournament)

7. Click on multiple tournaments, and use the simulation to record your responses and observations (Data Table 2, Multiple Tournaments), and answer the question beneath it.

8. If you have time, replay the tournaments with all five characters.

9. Navigate to the next section, the evolution of distrust. You can either get there by clicking through the steps on the last screen, or click directly on the sixth circle at the bottom. We said before that everyone always cooperating results in the best outcomes for everyone, but that natural variation can add other behavior types. In this scenario, we see a group of cooperators where two variations have emerged: one copycat, and one cheater. Play the game with 10 rounds per match, 7 rounds per match, 5 rounds per match, and 2 rounds per match, and record your responses and observations (Data Table 3, The Evolution of Distrust).

10. If you have time and your teacher says to, you can play the rest of the game.

Data Tables

Data Table 1. Tournament Round

Predicted winner:

Winner of the Tournament	Observations
Who won in the short term? Who won at the end of the tournament?	

Data Table 2. Multiple Tournaments

Which strategy do you predict will win?

Winner of the Tournament	Observations

Summarize: how does a world of copycats evolve from a mixed population? Why is this such a successful strategy?

Data Table 3. Evolution of Distrust

Winner of the Tournament	Observations
1. Who won with 10 rounds per match, and what were their scores?	

2. Who won with 7 rounds per match, and what were their scores?	
3. Who won with 5 rounds per match, and what were their scores?	
4. Who won with 3 rounds per match, and what were their scores?	

Summarize:
Under what conditions is cooperation the best strategy, and why?

Under what conditions is copycatting the best strategy, and why?

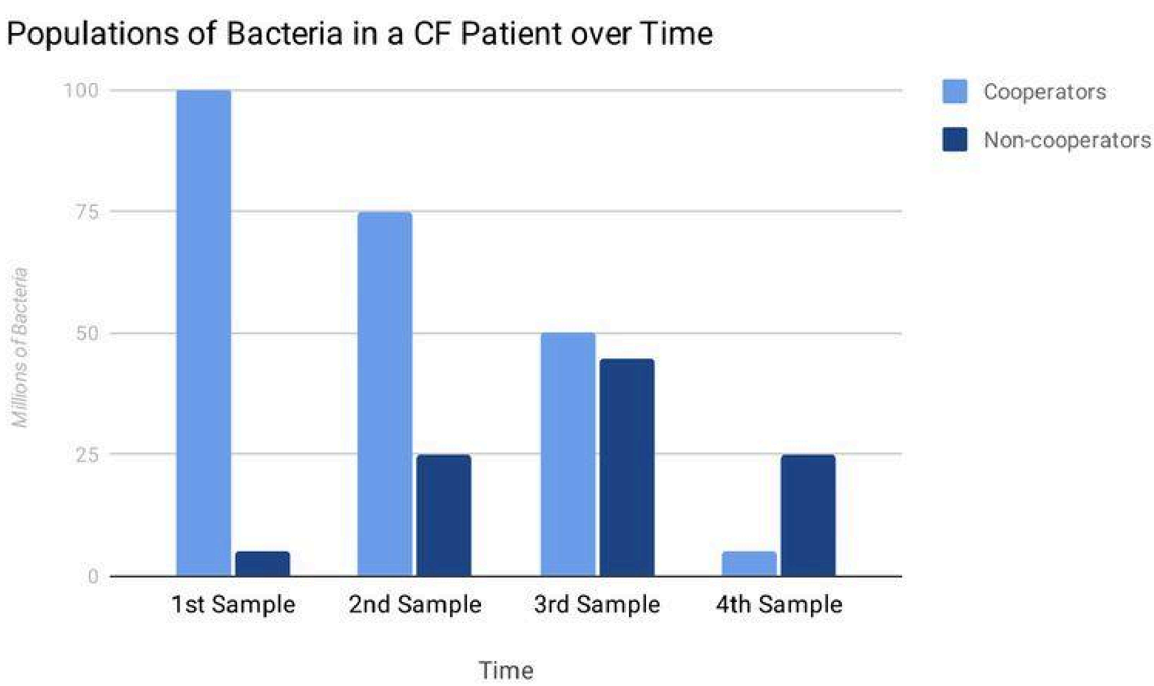
Under what conditions is cheating the best strategy, and why?

Even if cheating is the best strategy under some conditions, it has shortcomings. How could a population of cheaters taking over a group make the whole group less successful?

Procedure Part 3

Cystic fibrosis (CF) is a genetic disease, in which a thick mucus builds up in the lungs of patients. Pathogenic bacteria often thrive in this mucus, causing frequent infections. Bacteria living in lungs of CF patients need to acquire iron from their environment (the human host). Cooperative bacteria living in these patients can generate biofilms. Here the bacteria produce molecules that help acquire iron, which can be shared amongst the bacteria living in the biofilm. Mutations may arise in a population of cooperating bacteria that turn the individual into a non-cooperator or 'cheat' that does not produce the beneficial molecule, even though they can still acquire iron from the other cooperative bacteria in their environment.

The data below represents samples of this bacteria population from a CF patient over time. Analyze the data from the graph, and note your observations in the See-Think-Wonder graphic organizer.



See-Think-Wonder

See	Think	Wonder

Making Sense of the Cooperation vs. Cheating Investigation

Investigation Summary

1. What patterns did you notice in the proportions of individuals with specific traits within the data you collected? How are these patterns helping you make sense of how and why bacteria may have cooperative behaviors?

2. Explain how different conditions change the probability that cooperative behavior is beneficial to the individual, as observed in the investigation.

3. Under what circumstances is cooperative behavior beneficial for a population, as observed in the investigation? Not beneficial?

4. In a population of bacteria, why do you think non-cooperators (cheaters) could appear in a population of cooperators? Where did we see a similar example in the simulation?

5. How are cooperative behaviors in humans similar to cooperative behaviors in bacteria? How are they different?

6. What else do we need to know to better understand the phenomenon of bacteria cooperating to generate biofilms?

Cooperation vs. Cheating Investigation Rubric

Student Rubric - Cooperation vs. Cheating Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and respond to the Investigation Summary questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Cooperation vs. Cheating Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	**Pretty Good**	**Excellent**
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion

Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Evolution of Cooperation Notetaker

Guiding Prompt:

How did cooperation between bacteria evolve?

Directions:

1. Use your assigned video or text to complete the graphic organizer about your behavior
2. Share your ideas with your partners
3. Listen to the ideas of your partners and write down your notes in the space provided
4. Discuss how and why cooperative behavior may evolve over time in a population and write your ideas in the space provided below.

<u>My cooperative behavior:</u>

What I found interesting or surprising about this behavior:

Why is this behavior beneficial for a population or individual?

Some questions I still have about this behavior are:

Partner 1 cooperative behavior:

Notes on what I heard partner 1 say about the behavior:

Partner 2 cooperative behavior

Notes on what I heard my partner say about the behavior:

Group Ideas:

How do cooperative behaviors evolve over time through natural selection? Remember to discuss the following concepts in your response; variation, adaptation, competition, differential survival & reproduction, cause and effect

Cooperative Behavior of Bacteria in CF Patients Text

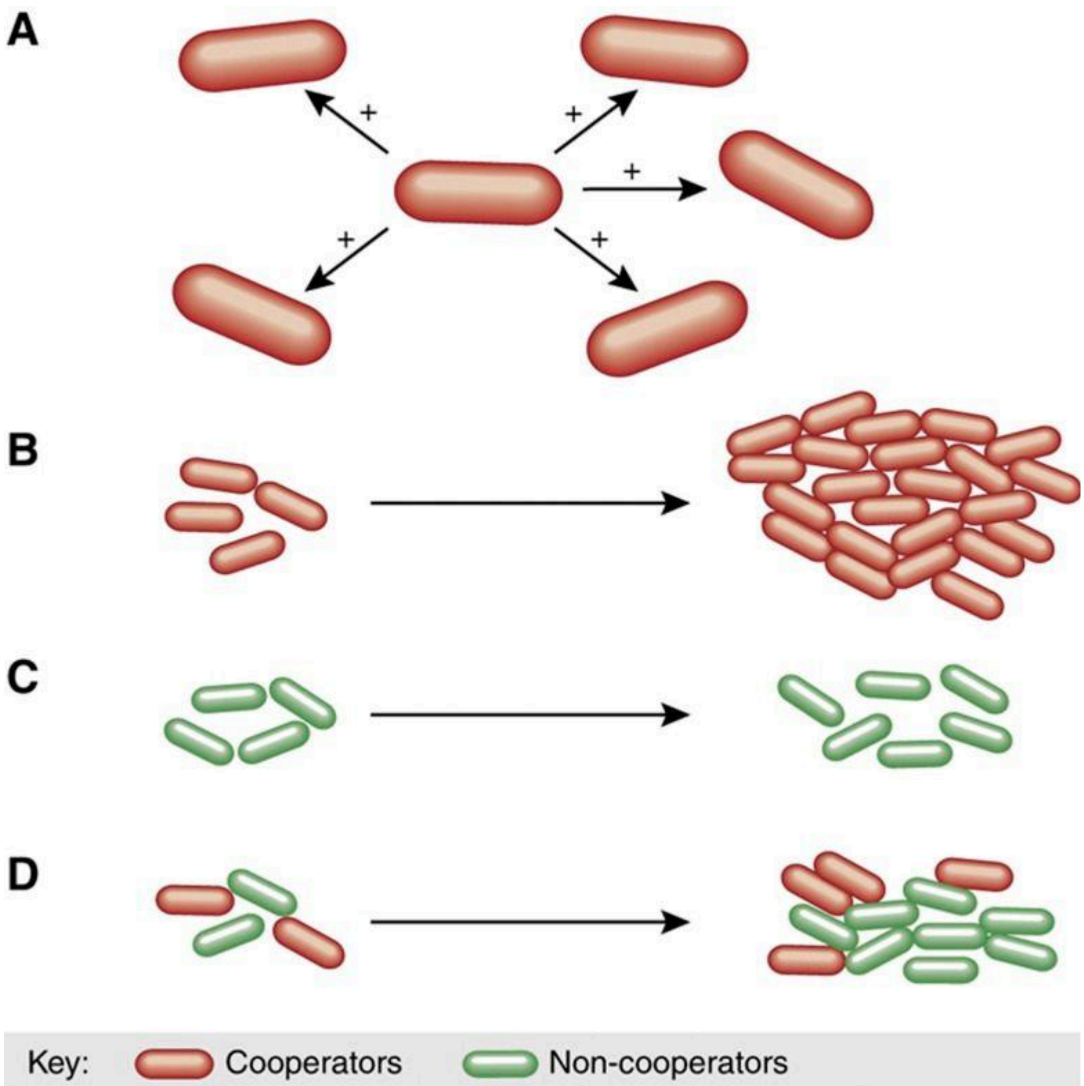
Cooperating and Cheating in Bacteria
By: Dr. Sandra Breum Andersen

Cooperation is defined as working together to the same end. We can think of many examples of when people do this, to achieve something greater than one could have done alone. Perhaps more surprising is that seemingly simple microbes can do this as well, of course without making a conscious effort to do so. The examples here focus on cooperation within a species, but there may also be cooperation between species.

One way that bacteria can cooperate is by excreting something into the environment that can benefit not only themselves, but also their neighboring cells that are often genetically related to them (Fig.1A). This could be an enzyme that breaks down antibiotics, a protective slimy layer to encapsulate the bacteria in a so-called biofilm (like you may find under the plug in the sink, or on teeth that haven't been brushed recently), toxins that kill off competitors, or compounds that assist in acquiring nutrients.

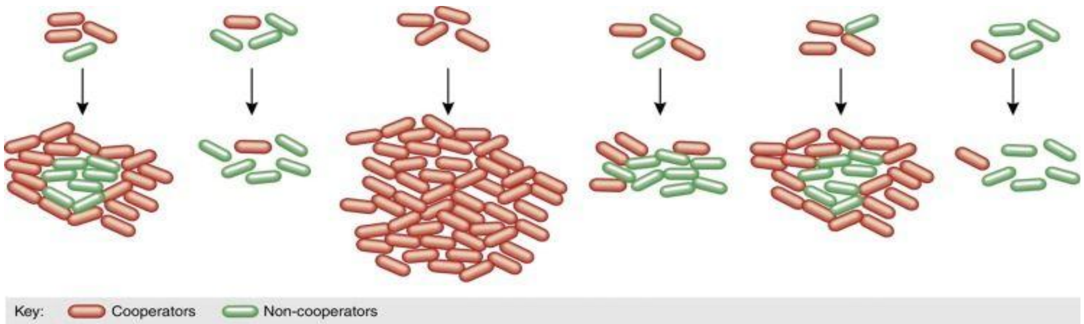
An example is the production of siderophores, which are compounds that help bacteria take up metals. Iron is required for bacterial growth, but limited in many environments. In the human body, iron is bound to a protein called transferrin to starve potential invading pathogens. Some bacteria can circumvent this by producing siderophores that have a higher affinity for iron than transferrin, effectively stealing the iron from the host carrier. The bacteria excrete siderophores, which bind to iron, and the iron-loaded siderophore can be taken up, by the producer or a neighbor.

A population of cooperating bacteria will do better than one of non-cooperators (Fig.1B+C). However, as we know from our own experiences with cooperation, this ideal outcome does not always reflect reality. A non-cooperating "cheat" will do well surrounded by cooperators, exploiting their costly behaviors. This way, a cheat may drive cooperators extinct even if this is to the detriment of the fitness of the entire population in the long run.



Cooperative social interactions that provide a population-level benefit often come at a cost to individual's cells. (A) A cooperative interaction provides a fitness benefit to recipients. (B) A population of cooperators has a higher productivity than (C) a population of non-cooperators. (D) Non-cooperators can exploit cooperators in mixed populations by benefiting from cooperation without contributing.

How does cooperation persist over time if cheats can invade? Cooperation is most frequently directed towards close genetic relatives, who are more likely to also be cooperative. This can be through spatial structure: if a bacterium is growing on a grain of dirt, or on a catheter, its neighbor is most likely a clone. Further, there may be population-level benefits to cooperation (Fig. 2).



Multilevel selection is essential for the evolution of cooperation among microbes. Cooperative strategies can have an evolutionary advantage in the global population, even though the same strategy is disadvantageous in local sub-populations. This happens because groups with a higher proportion of cooperators are more productive and therefore contribute more to the global gene pool.

From the beginning, it has been posed that microbial social behaviors are not just a quirk of interest to a particular scientific community, but also of great relevance to human health and disease. This is clear when we consider that the social behaviors affect bacterial traits such as antibiotic resistance, ability to colonize, and build biofilms. Often, the changes in bacteria we observe during infection are assumed to be adaptations to the host, i.e. changes that will increase a pathogen's fitness. A clear example is antibiotic resistance arising when a patient is receiving treatment. However, not all changes driven by social interactions will increase pathogen fitness in the long run – e.g. the loss of cooperation by cheat invasion. To manage our beneficial and harmful microbes it is crucial to understand the factors that drive evolution. We are now finally at a point where we are starting to show the role of social interactions in our microbial associates.

I have studied the evolution of iron acquisition in bacteria that infect cystic fibrosis (CF) patients. CF is a genetic disease that cause the build-up of thick mucus that bacteria can colonize. It is such infection that CF patients eventually die from. The bacterium Pseudomonas aeruginosa is found ubiquitously in the environment, and is a major CF pathogen due to its resilience to antibiotic treatment. At colonization, the bacteria produce siderophores to acquire iron, but frequently lose the ability to do so over the course of infection. This has been assumed to be because other mechanisms to acquire iron are more efficient in the deteriorating lung. With a large collection of bacterial isolates from Danish patients, we showed that it is actually the invasion of cheaters that cause the breakdown of cooperation.

The production of siderophores is frequently upregulated in the initial phase of infection, as this is a highly efficient way of acquiring iron. If this happens, non-producing cheats are highly likely to be sampled shortly after. That is, the more some cooperate, the easier it is for the cheats to invade. The cheats are relatives to the cooperators but have lost the production of siderophores from genetic mutations. They can, however, still take up the siderophores with iron produced by others, i.e. cheat. They lose this ability when there are no more cooperators to cheat on, likely because the siderophore receptor is also the entryway for lethal phages and toxins. So what happens with iron uptake when there is no one to cheat on? Iron uptake is "privatized" by upregulating a system that can take up iron from heme. This only happens when cooperation has been lost. With this we have shown that social interactions matter in clinical bacteria and should be taken into account when designing new treatment strategies.

C-E-R Graphic Organizer

1. Prewriting:
What is your question?

Support for your explanation

Claim based on the evidence (What is the answer to your question based on your evidence?)	Evidence (Observations/data that answers your question)	Scientific Reasoning (Why you think this happened based on background research)

2. Peer Review
Have a peer read your work and provide comments on what you plan to write.

3. Drafting

Write your explanation in paragraph form.

Scientific Explanation = Claim + Evidence + Science Reasoning

My claim is <u>(fill in with above claim)</u> because <u>(evidence and science reasoning)</u>

Leveraging Cooperative Behaviors Brainstorm

Directions:

1. Look back at your notes from the cooperative behavior.
2. For your originally assigned behavior, brainstorm how scientists could use what we know about that behavior to prevent infectious diseases, such as cholera.
3. After discussing your ideas with your group, using Think-Talk-Open Exchange, write down new ideas you have about using cooperative behaviors to prevent bacterial infections.

My Cooperative Behavior:

How could scientists use what we know about this behavior to prevent infectious diseases such as cholera?

After discussing possibilities from each type of behavior with my group mates, I now think …..

Summary Task

Summary Task

We recently completed a class consensus discussion. How did it go?

1. One thing that went well in the discussion:

One thing we can improve the next time we have a discussion:

One person who helped me learn today:

What did you learn from this person?

One idea that I contributed to my group or my class:

1. Explain what you know about the following questions, based on what we discussed today.

Explain how a cooperative behavior can evolve through natural selection.

2. How does a change in the environment, for example the introduction of cheaters in a cooperative environment, cause a change in a population? What evidence would you need to identify the causality?

3. How can scientists leverage cooperative behaviors in bacteria to prevent infections such as cholera? Give a specific example.

C-E-R Rubric

Component	Not Evident	Level 1: Beginning	Level 2: Developing	Level 3: Advancing	Level 4: Proficient
Claim	Does not make a claim	Claim does not answer the question (i.e., describe the relationship between the 2 variables)	Claim does answer the question but it is inaccurate.	Claim answers the question, and is accurate, but is incomplete	Claim answers the question, is accurate, and is complete. Completely describes the trend in the relationship between the IV and DV where appropriate.
Evidence	Does not provide evidence	Only provides inappropriate evidence (evidence does not support the claim)	Provides appropriate, but insufficient evidence to support the claim. May include some inappropriate evidence	Provides appropriate and sufficient evidence to support the claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support the claim
Reasoning: Science Concepts	Does not include reasoning	Restates evidence and does not include explanation of science concepts	Includes explanation of science concepts but all are inappropriate concepts that do not link evidence to claim	Includes explanation of some science concepts that link evidence to the claim, but are insufficient (one or more concepts that should have been included are not included) or some are inappropriate	Includes explanation of science concepts that link evidence to the claim (concepts are appropriate), and they are sufficient (no omission of key science concepts) and are clearly stated and accurate.
Reasoning: Logic	Does not include reasoning	Restates evidence or claim and does not include a logic statement that links the evidence to the claim	Attempts to include a logic statement that links the evidence to the claim but does not adequately link the evidence to the claim.	Includes a logic statement that attempts to link the evidence with the claim but needs to be more clearly stated to demonstrate logical reasoning	Includes a logic statement that links the evidence to the claim (including words such as *because* and *therefore*) that clearly demonstrates logical reasoning

Bubble net Feeding in Whales Text

Bubble-net feeding is a unique and complex cooperative feeding behavior engaged in by groups of humpback whales. Humpback whales are often solitary creatures that feed by themselves. In this method, they work together as a group. The group size can range from a minimum of two or three whales participating and up to sixty at one time. Whales can also perform a similar method of surface feeding called lunge feeding but this is done by individuals on their own.

Bubble-net feeding is a cooperative feeding method used by groups of humpback whales. This behavior is not instinctual, it is learned. Not every population of humpbacks know how to bubble net feed according to some studies. To be successful, they must learn the method. Humpback whales use vocalizations to communicate to one another and effectively and efficiently execute the bubble net so they all can feed. As the group circles a school of small fish such as salmon, krill, or herring they use a team effort to disorient and corral the fish into a net of bubbles.
One whale will typically begin to exhale out of their blowhole beneath the surface at the school of fish to begin the process. More whales will also start to blow bubbles while continuing to circle their prey. They corral the fish into a tight circle while creating a net of bubbles to surround the fish and keep them from escaping. The size of the bubble net created can range from three to thirty meters in diameter. One whale will sound a feeding call, at which point all whales simultaneously swim upwards with mouths open to feed on the trapped fish.

This method of feeding, which is uncommon and unique to humpback whales, has sparked plenty of interest. There has been some speculation behind the net of bubbles and how fish are trapped within. One study suggests that it is the acoustics from the exhalations from the whales that traps the fish. It is thought that within the circle it is silent but outside the sounds have such high intensity that it is nearly impossible for fish to escape. The energy from these calls have measured up to 4000 Hz.

There are also a multitude of theories behind why humpback whales use bubble netting as a feeding method. The earliest documentation of this feeding behavior was recorded in 1929 from the Norwegian Sea. They speculated that it was playful behavior between the whales and a form of socializing. Change in environmental factors over the years has also been discussed as a possibility behind why this feeding method was started. The most popular theory behind bubble net feeding is one of survival. After being hunted to near extinction it is believed that humpback whales developed this method of feeding so many whales as possible can feed in a short amount of time.

Read Generate Sort Solve Organizer

Prompt: Why do these whales cooperate in this way? How can we understand the cause or causes behind the evolution of this cooperative behavior? How could evidence about the proportion of cooperative whales over time help demonstrate that this behavior is beneficial to the survival and reproduction of the whales?

Generate Ideas:

Name:	**Name:**
Name:	**Name:**

Sort - Discuss each solution or idea and ☆star☆ the ideas that seem the most useful

Solve - Individually write your response to the prompt incorporating the most useful ideas from the sorting process!

How can we disrupt bacterial cooperation in cholera infections?

During the Second World War, Alan Turing was an English computer scientist that created a machine able to crack and decipher secret messaging between the Nazis. Thanks to Alan's work, the Allies were able to defeat the Nazis and win the war.

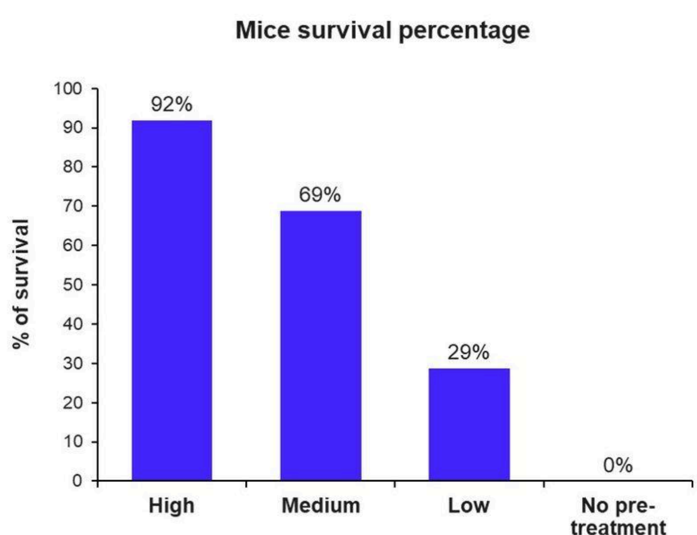
Cholera bacteria, like the Nazis, are able to communicate and help each other survive by creating colonies (biofilms) that protect them from harsh conditions and external attacks. We might need another brilliant mind like Alan Turing to help us decipher the bacterial communication and defeat them for good!

How can we interrupt cholera communication?

How do bacteria communicate with each other? Since bacteria have not invented their version of the iPhone yet, they use molecules to send messages to each other. *Quorum sensing* is the scientific name for bacterial communication. Bacteria can use this communication system to chat about the density of their population and adjust their replication, biofilm formation, and virulence level. The quorum sensing is a signaling system based on molecules that are produced and received from other bacteria. When there are a lot of cholera bacteria in a specific location in the body, the amount of molecules produced also increases (goes up) and this signals to other cholera bacteria to stop reproducing. When the number of cholera bacteria is low, the amount of molecules decreases (goes down) and this sends a signal to increase cholera replication (similar to what you learned about feedback mechanisms with blood glucose level).

Scientists have discovered that, if this communication is intercepted, it can be disrupted. For example, Cholera quorum sensing can be disrupted by other healthy bacteria. Our microbiome can produce molecules that mimic (imitate) cholerae molecules and alter biofilms production and reduce the production of cholera toxin.

Scientists have also created a genetically modified strain of healthy bacteria (called Nissle-cqsA) that can send fake messages (molecules) to cholera to stop its replication. Mice pre-treated with the highest concentration (amount) of Nissel-cqsA and then infected with cholera had a 92% survival rate, while all those that were not not pre-treated and then infected with cholera died (see the graph below). Think about this like a scam message. If the mice receive Nissel-cqsA bacteria before, when cholera arrives after, Nissel-cqsA sends a message to tell cholera to stop reproducing, saving the mice from cholera infection. The more the fake messages, the lower is the number of cholera replicating and the higher chances of survival.



However, since quorum sensing is also used by other bacteria (good ones included), some scientists are skeptical since the disruption of quorum sensing could also affect the communication of healthy bacteria and have a negative impact on the human microbiome.

A Special Case of Cheating

Another really interesting strategy that bacteria use to thrive is cheating. In this unit you figured out what happens when bacteria do not cooperate (when they cheat). The non cooperator (cheaters) will take resources from the bacteria that cooperate and this can reduce the overall number of bacteria in a population. If in a population there are more non-cooperators than cooperators, then the colony will not have enough resources for all bacteria and many might die. In this case, having too many cheaters is not a good thing.

However, bacteria have also learned how to make cheating an advantageous trait. Scientists call this social cheating, something specifically linked to the disruption of quorum sensing. What would be the advantage of cheating by not responding to quorum sensing? Since quorum sensing regulates the biofilm production, scientists believe that social cheaters can better adapt in an environment that is different from their natural environment. For instance, while cholera bacteria's natural environment is the aquatic habitat, when these bacteria infect humans, they have to adapt to the stomach's harsh acidic environment and then move into the intestine. Scientists have discovered that social cheaters show increased production of biofilms helping them survive in harsh environments (high pH, high salt, high temperature, and food scarcity). This is an example of how one size fits all does not work in the evolutionary process. Cheating can be a bad or a good thing. Indeed, as you discovered in the pocket mice investigation, traits are beneficial only based on the environment and the conditions the organism lives in.

Cooperation & Survival Mini-Rubric

Claim: Focus on disrupting bacterial cooperation - We can prevent infections/outbreaks by disrupting bacterial cooperation

Component	Developing	Proficient
Evidence	Effectively and clearly provides evidence that includes **some** of the elements below: • At least 2 examples of evidence are provided • Provided evidence is **data** from an investigation completed in the learning cycle • Evidence supports the claim(s) • If appropriate, evidence that refutes the claim is included and clearly indicated	Effectively and clearly provides evidence that includes **all** of the elements below: • At least 2 examples of evidence are provided • Provided evidence is **data** from an investigation completed in the learning cycle • Evidence supports the claim(s) • If appropriate, evidence that refutes the claim is included and clearly indicated

Scientific Reasoning & Logic	Effectively and clearly provides scientific reasoning and logic that includes **some** of the elements below:
	• An accurate explanation of the concept of the evolution of group behavior through natural selection is used to link the evidence to the claim including:
	  ◦ Variations in behavior
	  ◦ Behaviors as traits that may be advantageous in certain environments
	  ◦ Differential survival & reproduction for individuals and their genetic relatives in the group
	  ◦ Changes in behavior on the population level based on the environment
	• Includes a logic statement that links the evidence to the claim (including words such as because and therefore)
	• If appropriate, an idea or concept is used to refute or question the claim
		Effectively and clearly provides scientific reasoning and logic that includes **all** of the elements below:
		• An accurate explanation of the concept of the evolution of group behavior through natural selection is used to link the evidence to the claim including:
		  ◦ Variations in behavior
		  ◦ Behaviors as traits that may be advantageous in certain environments
		  ◦ Differential survival & reproduction for individuals and their genetic relatives in the group
		  ◦ Changes in behavior on the population level based on the environment
		• Includes a logic statement that links the evidence to the claim (including words such as because and therefore)
		• If appropriate, an idea or concept is used to refute or question the claim

Evaluation of claims, evidence, and reasoning	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **some** of the following components: • Cause and Effect or Patterns is checked off • An explanation of how cause and effect and/or patterns is used to defend the strength of the claim, evidence, or how the scientific	A lens is used to understand and/or evaluate the scientific concept and how it relates to the evidence and/or claim with **all** of the following components: • Cause and Effect or Patterns is checked off • An explanation of how cause and effect and/or patterns is used to defend the strength of the claim, evidence, or how the scientific

	concept links the claim and the evidence.	concept links the claim and the evidence.

Student Self-Evaluation Circle one			**Teacher/Peer Evaluation** Circle one		
Evidence	Developing	Proficient	**Evidence**	Developing	Proficient
Reasoning	Developing	Proficient	**Reasoning**	Developing	Proficient
Evaluation	Developing	Proficient	**Evaluation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		