CSET center to support excellence in teaching
Stanford University

INVESTIGATING ANT COLONY SEARCHING: A LINK TO A CITIZEN SCIENCE PROJECT

THE CENTER TO SUPPORT EXCELLENCE IN TEACHING
STANFORD UNIVERSITY

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Investigating Ant Behavior: A Link to Science in the Real World

Overview

The Center to Support Excellence in Teaching (CSET) has developed a lesson for teachers to use in science classes that build on the work of Dr. Deborah M. Gordon at Stanford University. The lesson is designed to engage students by providing opportunities for them to explore ants and their behavior, ask scientific questions, collect and analyze data and develop explanations about ant colonies and how ants work together. The lesson engages students in scientific inquiry and promotes curiosity about the natural world.

Synopsis of Lesson

Students begin the investigation by thinking about what they already know about ants. Next students investigate how ants work together to search a new environment.

Most species of ants cannot see, and operate mostly by smell. They smell with their antennae. To find anything new in their environment including food, or threats, an ant must get close enough to smell it. They also detect each other's presence by smell, touching each other with their antennae. All ant species live in colonies. Nestmates cooperate to monitor the colony's environment.

This experiment asks how ant colonies work together to monitor the environment. Any group of searchers, for example ants or robots, must manage a tradeoff between searching thoroughly and covering all the area. If there are many ants searching an area, each ant can spend a long time in one place, moving around in a very winding path to cover the ground thoroughly. When the area to search grows larger, ants need to move differently to cover more ground. When ants are exploring a new area, they may adjust the shape of their paths according to how large the area is, and how many ants are searching it.

In this investigation, students observe how ants search in a given area, and how they adjust the way they are searching when that area is doubled in size. During this time, students record observations and take photographs and videos of ant behavior. They will use this evidence to analyze how ants work together to search a novel area. Students share their thinking and develop explanations about ant search behavior in a novel area. Students also discuss additional questions they have about ant colony search behavior and design further experiments.

The questions students investigate are:
1) Do ants adjust their searching behavior when the area to be searched grows larger?
2) How many ants search the novel area?
3) How thoroughly do the ants search a novel area?
4) How do the ants change the shape of their paths when the area to be searched is larger?
5) Do the ants detect how many other ants are nearby by how often ants touch antennae?

Students will have the opportunity to join a larger research project. This project investigates how ants work together to search in different environments around the world.

The following website maintained by Professor Gordon's lab https://web.stanford.edu/~dmgordon/acs.html will allow students to enter and compare their data with others on different ant species around the world.

A student-friendly animated video introduces the question of collective search and how ants (or robots) work together without a plan: http://ed.ted.com/lessons/inside-the-ant-colony-deborah-m-gordon

A short video showing how to do the experiment is also available: https://web.stanford.edu/~dmgordon/acs.html

There are multiple opportunities in this lesson for students to engage in Next Generation Science Standards, Science and Engineering Practices. See the following link for more details about NGSS Science and Engineering practices: http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Other links are listed in Appendix B.

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Investigating Ant Behavior: A Link to Science in the Real World

Materials for each Group of 3 Students

1 - Ant arena for each team of 3 students (see Appendix A.)
30 - Minimum number of ants per group
1- Camera for taking still photos (or cell phone that has camera)
1- Video Camera (or cell phone that has video capability)
1- Calculator
1- Stopwatch (can be on a phone or other device)
3 - Notebooks (can be student's regular science journal or notebook)
3 - Hand lenses
3 - Student Data Collection Sheets
1 - Computer or tablet for viewing photos during Data Analysis
3 - Large binder clips

Materials for Teacher

Sugar solution
Cotton balls
Access to a refrigerator or cooler with ice

Preparation

Ant Arena Assembly

- Directions for making the arena are shown in Appendix A. Make one ant arena per group of 3 students.

Collection of Ants

- Organize students into teams of 3 to collect ants and conduct the experiment.
- Students need to collect their own ants either the day before the investigation or right before the investigation. Each group of 3 students will need to collect a minimum of 30 ants.
- Distribute the following equipment for ant collection (one set per group of 3 students).
    - Aspirator
    - Vial with lid
    - Cotton ball
    - Small watercolor paint brush
    - Cup of water
    - Tape
    - Pen or pencil
- Student directions for collecting ants:
    - If collecting ants the day before the investigation, place a cotton ball moistened with water at the bottom of the vial.

- Insert the aspirator onto the top of the vial.
- Find ants and record details about where the ants were found (example: nearest intersection and specific location such as under a log or on the sidewalk). Record this information on a piece of tape and put on the vial.
- Using the aspirator, suck the ant into the vial.
- Check to see that the ant has safely been collected into the vial.
- The paintbrush (with moistened bristles) can also be used to help pick up or move ants.
- Repeat until 30 ants have been collected. Note: do not mix ants from different locations. Start a new vial for each location. Try to collect all 30 ants from the same location. Ants from different nests will not work together and may fight with each other.
- When finished, cap the vial and cover the whole vial with paper or foil or place inside a bag so it is protected from light.

- The ants probably don't need food, only water. The cotton ball soaked in water should be sufficient if collecting the ants the day before the investigation. However, if you would like to feed the ants, you can place a small piece of apple into the vial.
- When the experiment is completed, return ants to their original location. (If they cannot be returned, freeze them and discard in the trash or compost.)

Optional Advance Preparation (to be done by the teacher)
If the ants fail to explore the arena in a trial run, the bottom of the arena can be wiped with sugar water to attract the ants. To do this, the bottom surface of the arena has to be covered with something transparent and waterproof, like a sheet of Mylar, that leaves the grid on the bottom still visible. This step may not be necessary, so try it without first.

One hour before the student investigation begins, use a cotton ball soaked in sugar water to wipe over the entire floor of the arena, except for the nest area. (The barriers should be removed for this step). Then wipe the chamber areas dry with a dry cotton ball. Do not place food into the arena. The residue of the sugar should be enough to attract the ants to the arena once the arena has been opened to them. In this experiment, the ants are not foraging or collecting food. They are searching a novel area to monitor whatever may be there. Be sure the barriers are back in place before giving the arenas to the students.

Helpful Links
There are several links listed in Appendix B that could be used as extensions to the lesson. They include talks by Dr. Gordon as well as a student-friendly animation about ant colonies. (see video at http://ed.ted.com/lessons/inside-the-ant-colony-deborah-m-gordon)

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Investigation- Teacher Guide

1. Place each of the vials containing the ants into an ice bucket or refrigerator for approximately 5-10 minutes before the experiment. This immobilizes the ants. If the ants are left in the refrigerator too long, they will die.

2. As the ants are being "cooled down," engage students by asking them to do a quick-write in response to the following question: What do you know about ants? What do you know about their physiology? What do you know about ant colony structure and how ants cooperate? Have students share their knowledge with their groups as well as with the class.

3. Tell students that they will be conducting an investigation with ants and will be observing their search behavior in a novel area.

4. Show students the ant arena and give a brief description of the different parts of the arena. Briefly describe how they will be using the arena during the investigation (see Procedure for Students as a guide).

5. Assign student roles:
    a. Timer and recorder: will call out times and record observations in writing for the group
    b. Arena manager: responsible for removing barriers, handling arena, and handling the ants.
    c. Videographer and photographer: will make a continuous record of the ant activity as well as take pictures at timed intervals

6. Orient students to the ant arena. Make sure they know what each section of the arena is named and where it is – nest area, area 1, area 2.

7. Distribute materials to each group, briefly orient students to the instructions, then instruct student groups to follow the investigation procedures.

8. After students have finished conducting the investigation, ask students to work in their groups to complete the analysis questions.

9. Conduct a class discussion of ant search behavior by having students share their responses to the analysis questions and discussing the implications. Make sure that you ask students to use evidence from the investigation to help explain their thinking.

10. Elaborate on student understanding of ant search behavior by asking students what additional questions they might have about ants after conducing this initial

investigation. Optional: Consider charting these questions in a public space in your classroom and providing an opportunity for students to design another investigation based on the additional questions.

11. Complete the lesson by asking students to respond to the following question individually in writing in their science notebooks:
    a. What do you now understand about ant colony searching behavior? Use evidence from the investigation as well as from your class discussion to support your statements.

Note for teachers: This activity involves calculating averages, graphing, and making plots. If your students do not already have these skills, you will need time to teach the skills or adjust the questions.

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Investigation- Procedure for Students

1. Check the materials that you received from your teacher, including the vial of ants. Be sure your group has all of the correct materials before beginning your investigation.

2. Make sure the cover on the arena is firmly in place using the large binder clips. Remove the nest insert from the ant arena and gently place the ants into the nest area, pouring the ants into a funnel made from paper with one end inside the nest (see video at https://web.stanford.edu/~dmgordon/acs.html)

3. You may need to use a small paintbrush (with the bristles moistened with water) to help transfer the ants. Try not to transfer any dirt or debris that may have been collected into the vial with the ants.

4. Do not shake or jostle ants in the arena at any time. This includes tapping on the cover of the arena and banging or jostling the lab table.

5. Slide the first barrier out so the ants can enter Area 1. Allow the ants to walk freely into the arena. (If the ants are alarmed they will not search.) All of the ants might not come out, or they might not come out all at once.

6. Start the timer when you see that some of the ants have moved out of the nest area into Area 1.

7. Observe the ants for at least 5 minutes. During this time, take photographs every 15 seconds and record video from the beginning to the end of the observation period to record the ants' searching behavior. Try to take the photographs and video from a fixed location, and make sure the entire search area is included in the photos. It may help to mount the camera and video recorder on a stand or tripod.

8. Write down your individual observations of what the ants seem to be doing and record notes on the Student Data Collection Sheet.

9. When the number of ants searching Area 1 seems to be more or less constant for at least 5 minutes, slide out the barrier between Area 1 and Area 2. Record the time when the barrier is removed. The ants are now free to explore Area 2, a space that is twice the size of Area 1.

10. Observe the ants for at least 5 minutes after you remove the second barrier. During this time, take a series of photographs every 15 seconds, and take a video of the

ants' searching behavior. At the end of your observation period, stop your timer and record the time.

11. Record your observations of what the ants are doing on the Student Data Collection Sheet.

12. Complete the Analysis Questions on your Student Data Collection Sheet.

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Student Data Collection Sheet

Analysis Part One:

Answer the following questions:

1. When ants are placed in the ant arena, what do you notice about their search behavior?

2. Describe how the ants explore their new environment.

3. What did you notice about the way they interact with each other?

4. Compare the way they searched Area 1 to how they searched Area 2.

Analysis Part Two: How many ants searched the novel area?

5. In Area 1, count the number of ants in Area 1 over time by counting the number of ants in each of the photos at 15 seconds, 30 seconds, 45 seconds, etc. Record your data in the table below.

Area 1

Time																				
# of ants in arena																				

6. After barrier 2 is open, count the number of ants in Area 1 + 2 over time. Record your data in the table below.

Area 1 + 2

Time																				
# of ants in arena																				

Area 2

Time																				
# of ants in arena																				

Graph the data:

Answer the following questions:

7. Based on your plotted data, describe three characteristics about ant search behavior.

8. What patterns do you notice about the ants' search behavior and the shape of the paths that they use?

Analysis Part Three: How thoroughly do the ants cover the area? How much of the area was covered?

9. For Area 1, count how many ants are in each grid square in each photo. (These are the data that can be contributed to the citizen science project to compare the colony searching behavior of different ant species. The data can be entered in the forms shown on the following website: https://web.stanford.edu/~dmgordon/acs.html)

10. For Area 1 and 2, count how many ants are in each grid square in each photo. (These are the data to be entered in the forms shown on the following website: https://web.stanford.edu/~dmgordon/acs.html)

11. Using the data from 10 and 11, count how many grid squares are occupied in Area 1 before the barrier is open. Make a count for each time of observation. You can then add these up over all times.

Area 1- Before barrier 2 is opened

Time																				
# of grid squares with ants																				

Area 1- After barrier 2 is opened

Time																				
# of grid squares with ants																				

Area 2- After barrier 2 is opened

Time																				
# of grid squares with ants																				

12. Plot the proportion of grid squares that are occupied by ants over time.

13. Make three plots of the frequency distribution of ants per grid square in:
    a. Area 1 before barrier 2 is opened,
    b. Area 1 after barrier 2 is opened, and
    c. Area 2 after barrier 2 is opened.

Plots:

Answer the following questions:

14. How thoroughly did the ants search in Area 1? Did searching ants cover the entire Area 1?

15. How thoroughly did the ants search when they were exposed to the larger Area 1 + 2? Did searching ants cover the entire Area 1 + 2?

16. Comparing the frequency distributions for Area 1 and for Areas 1 + 2. How did the spread of ants around the arena change when the barrier was opened and the ants had access to Areas 1 + 2? Was there a trend for more or fewer ants searching each square?

Analysis Part Four: Do the ants change their paths when the area to be searched gets larger? Do ants search more thoroughly, spending more time in a square, when there are more ants nearby?

17. Watch your video of the ants closely so you become familiar with the paths that the ants walk. Draw a picture of how ants searched in Area 1 before the 2nd barrier was opened, and in Area 1 + Area 2 after the 2nd barrier was opened.

Search path of ants in Area 1:	Search path of Ants in Area 1 + 2:

18. Use your drawings to compare the paths in Area 1 and Area 1+ 2. Describe the differences in how ants searched in Area 1 versus how they searched Area 1 + 2.

19. At fixed intervals, stop the video and find all of the ants. Restart the video and measure how long each ant you can see stays in the larger grid square (group of 4 grid squares) where you found it.

Area 1	**Time spent in larger grid squares (group of 4 squares)**
Ant 1	
Ant 2	
Ant 3	
Ant 4	
Etc.	
Area 1 + 2	**Time spent in larger grid squares (group of 4 squares)**
Ant 1	
Ant 2	
Ant 3	
Ant 4	
Etc.	

20. For Area 1, use the data from all the ants whose times in square you measured, to find the average time an ant spent in one of the larger grid squares.

21. For Area 1+ 2 after barrier 2 was opened, use the data from all ants whose times in square you measured to find the average time an ant spent in one of the larger grid squares.

22. Did the ants search more or less thoroughly when they had access to Areas 1 + 2? What is your evidence for your claim?

23. In Area 1, was the density of the ants high or low compared to when the 2nd barrier was open and they had access to Area 1 + Area 2? Explain.

24. What do you notice about the relationship between how long ants tended to spend searching in a square and the search paths of the ants?

Analysis Part Five: Do the ants detect how many other ants are nearby by how often ants touch antennae?

25. Use the photos taken over time for Area 1. Count the number of times an ant is touching another ant with its antennae, in each photo. Each antennal contact is an interaction. Count the number of ants in each photo and record these numbers in the chart below.

Area 1

Time																				
# of interactions																				
# of ants																				

26. After the second barrier is opened, use the photos taken over time for Area 1 + 2. Count the number of interactions, in antennal contacts, of ants in each photo. Count the number of ants in each photo and record these numbers in the chart below.

Area 1

Time																				
# of interactions																				
# of ants																				

Area 2

Time																				
# of interactions																				
# of ants																				

27. Describe any patterns you see in the data about number of interactions and number of ants.

28. Could the ants use the rate of interactions to assess how crowded they were? Did the ants change their search paths as a response to interactions? Explain and use evidence to support your claim.

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APPENDIX A

Directions for Making Ant Arena

Materials:

1. Foam sheets
2. Plexiglass to cover the arena
3. Grid with square cells, drawn on paper (you will make this)
4. Glue
5. Scissors
6. Ruler
7. Mylar, or other transparent , waterproof sheet material (optional)

Directions:

STEP 1

- Cut out **two** large pieces of foam, measurement: 5 inches (13 cm) x 5.0 inches (13 cm). This size is appropriate for small ants, less than 5 mm. Ant arena size depends on the size of the ants being used. A grid square (see p *) should be about 10% larger than an ant.

STEP 2

- Measure the length of one of the ants that you will use in this experiment. Using that measurement, draw on a piece of paper a grid with squares that measure about 10% longer than the length of your ant, and group those squares into sets of 4 (see example). Glue grid onto one of the foam pieces. Set aside.
- Take the other piece of foam and cut using dimensions shown. There will be 3 separate pieces.
- Glue the 3 pieces onto the first foam board on top of the grid according to the picture.

STEP 3

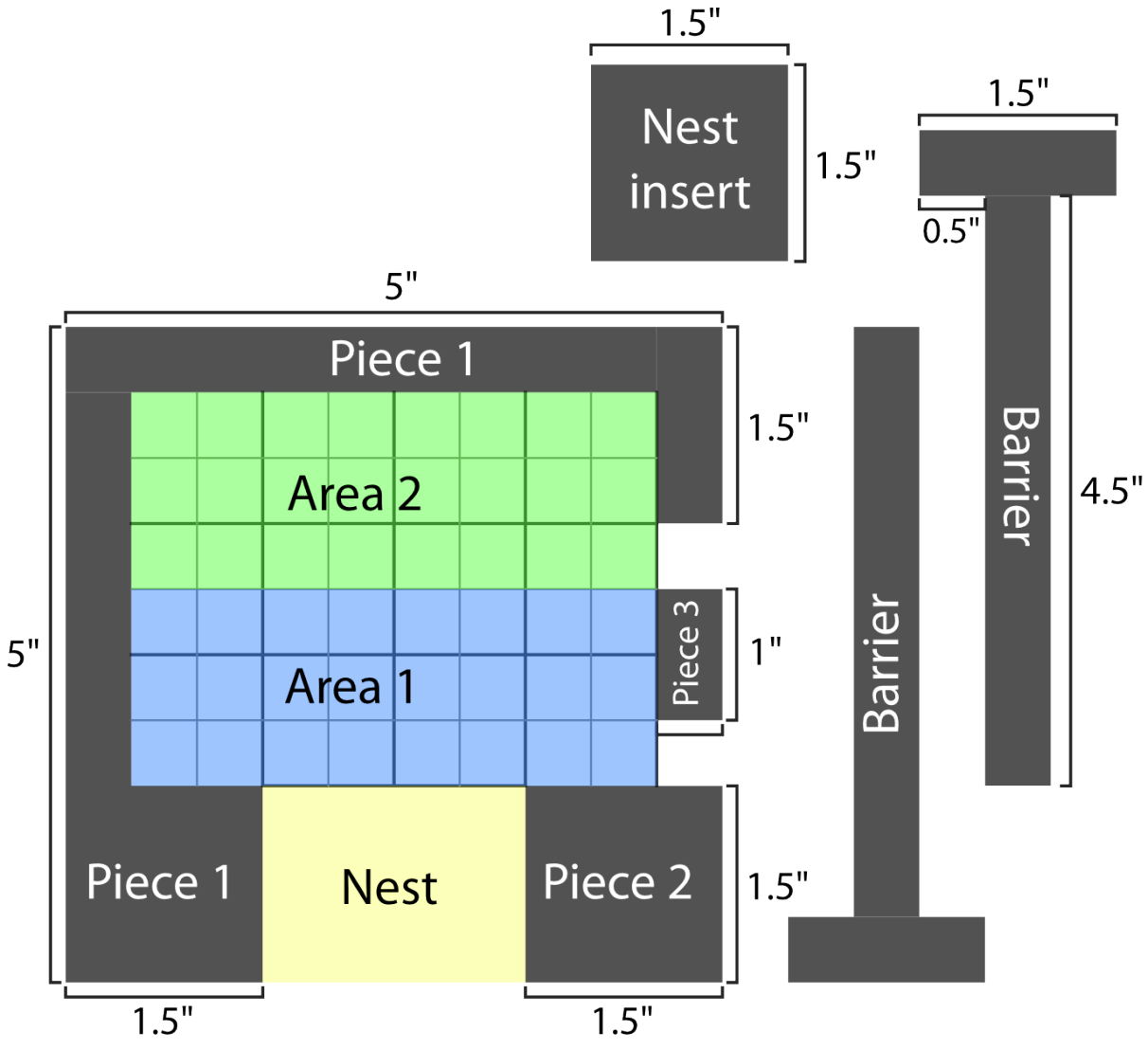
- Make 2 chamber separators out of foam (use scraps from the first sheet; see dimensions shown).
- Make an appropriately sized square nest insert from the foam.
- Cut a piece of plexiglass that fits over the top of the entire ant arena, measurement (for small ants): 5 inches (13 cm) x 5.0 inches (13 cm).

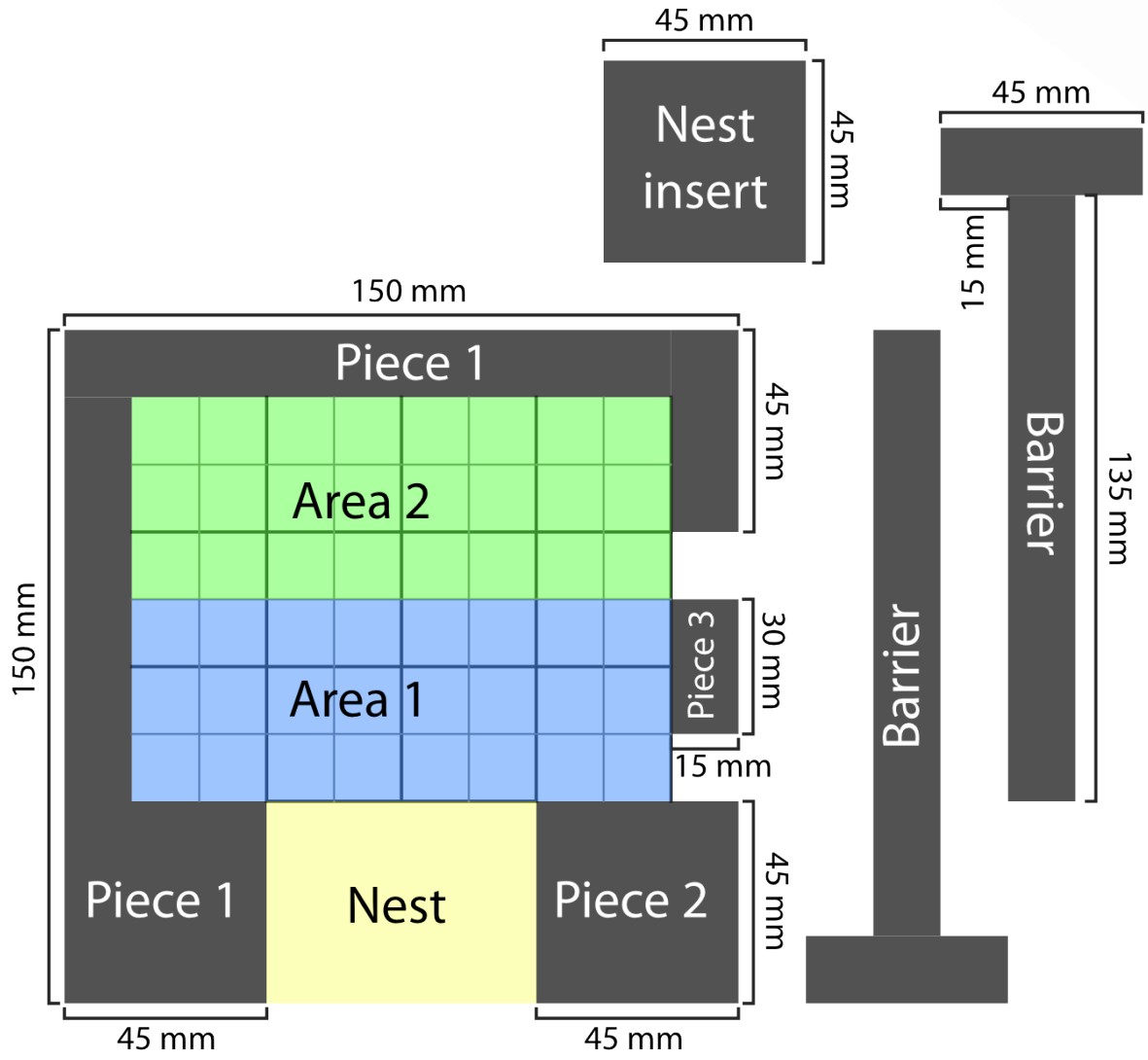
STEP 4

- Assemble the Ant Arena, making sure that the barriers can be opened and closed, and that the parts fit closely enough to prevent ants from escaping. If the arena is not clipped together securely, ants can escape over the barriers and edges as well as through the barriers.

Note: If the floor of the arena will be wiped with sugar water, there should be a waterproof layer, e.g. of clear plastic, over the grid on the bottom surface.

Ant Arena - Schematic (shown first in inches, then in millimeters)



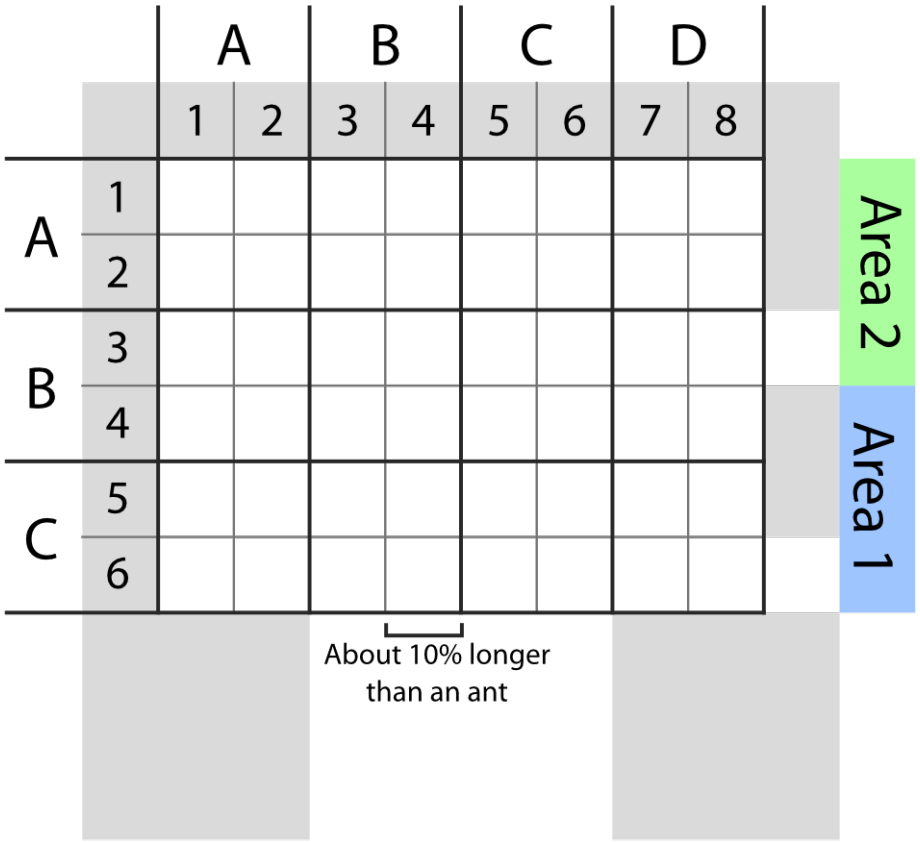


Example grid for the bottom of the arena

The size of the squares will vary with ant size. A square should be about 10% longer than an ant.

This is the suggested numbering for grid squares.
This numbering system can be used to enter the data for the citizen science project (see https://web.stanford.edu/~dmgordon/acs.html).

Example grid for the bottom of the ant arena
Size of squares and overall size of arena will vary with ant size.



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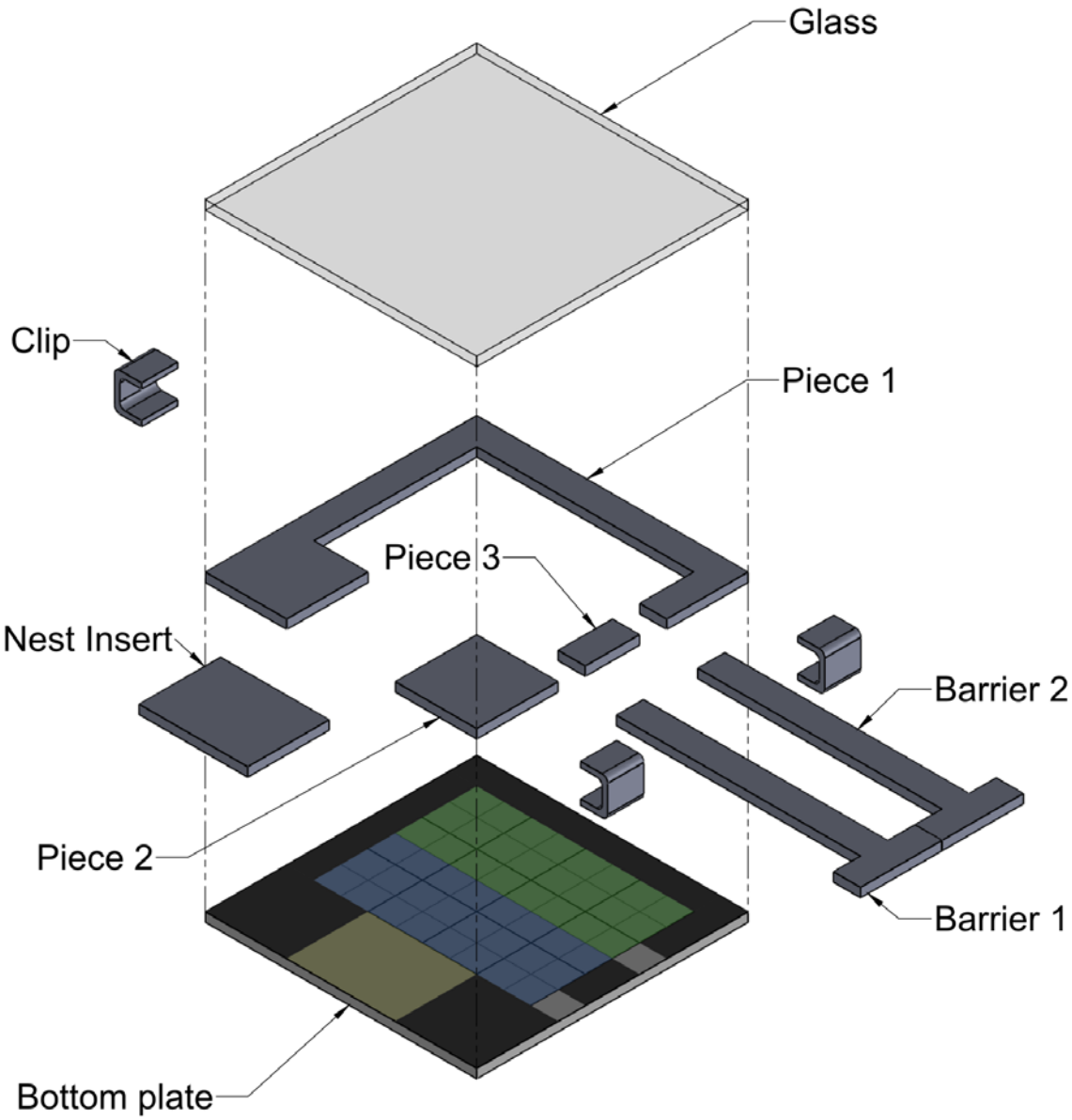
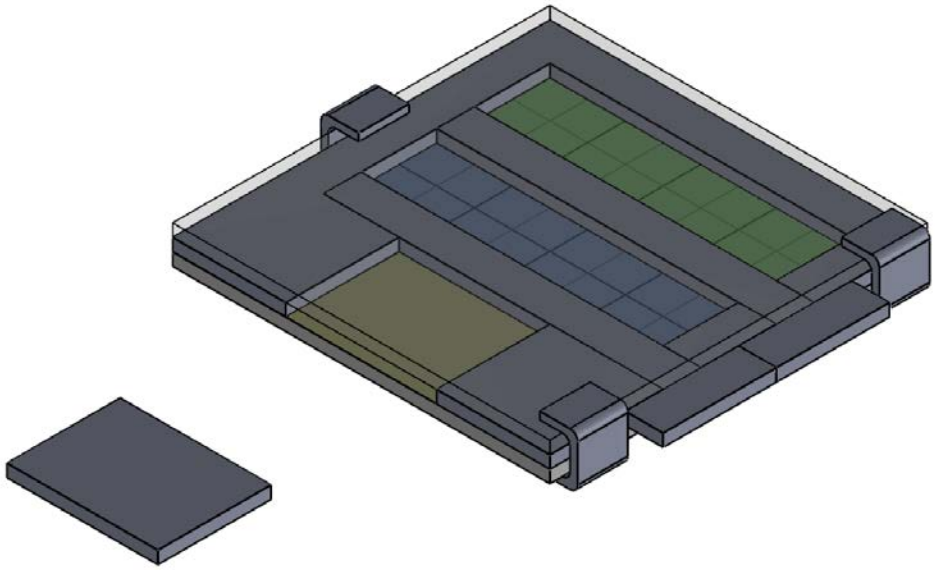
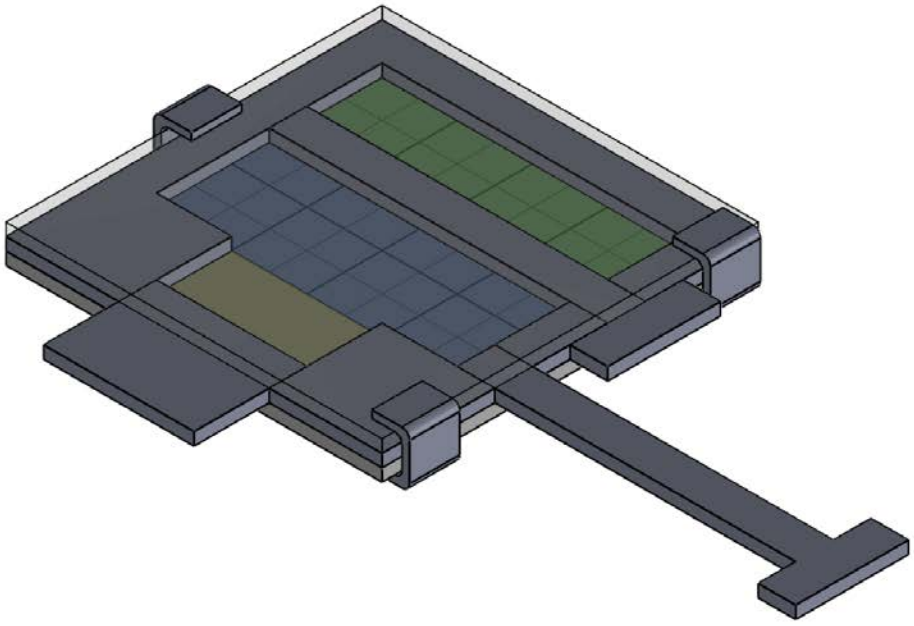
Arena components



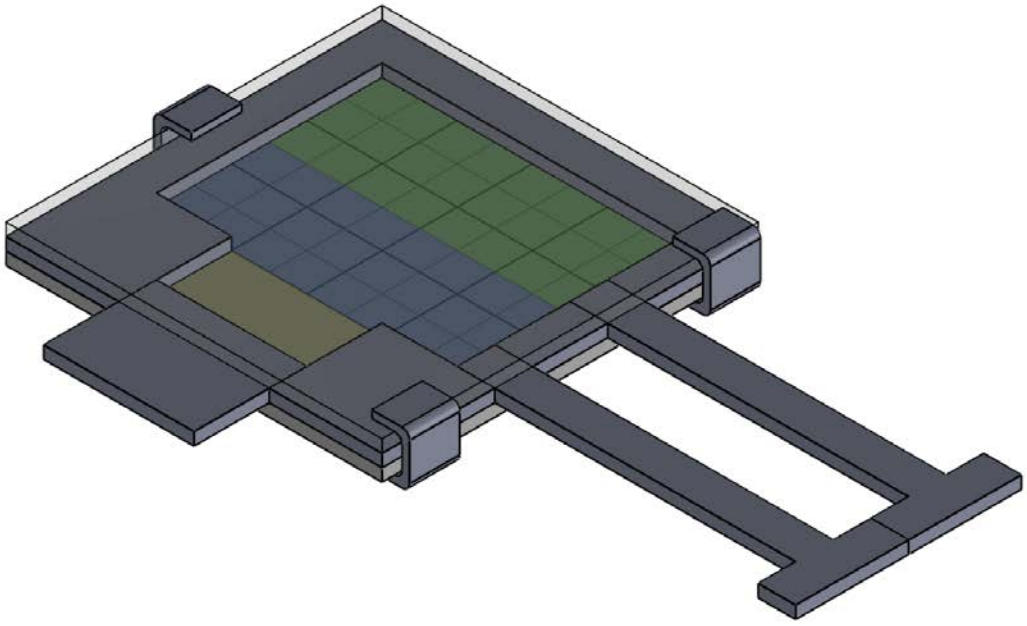
Remove nest insert to load ants



To begin the experiment, open barrier 1.



After the ants have searched area 1, open barrier 2.



Appendix B

Helpful Links about Ant Search Behavior

The following links could be used as an extension to the lesson. They include several talks by Dr. Gordon as well as a student friendly animation about ant colonies.

Video showing how to load the ants into the arena:
https://web.stanford.edu/~dmgordon/acs.html

Website for contributing data to citizen science project:
https://web.stanford.edu/~dmgordon/acs.html

About the experiment:

TED Ed animation:
http://ed.ted.com/lessons/inside-the-ant-colony-deborah-m-gordon

This experiment was performed in microgravity in the International Space Station:
http://journal.frontiersin.org/article/10.3389/fevo.2015.00025/full

Talks by D M Gordon about ant behavior

TED 2014 (includes this experiment)
http://www.ted.com/talks/deborah_gordon_what_ants_teach_us_about_the_brain_cancer_and_the_internet

TED 2003 on ant colony behavior
http://www.ted.com/talks/deborah_gordon_digs_ants

iBio talk on research on collective behavior in ants:
http://www.ibiology.org/ibioseminars/evolution-ecology/deborah-m-gordon-part-1.html