Lab 2: R2D2 and Probability

I'll bet, at some point in your life, you flipped a coin to decide something. Maybe neither you nor your roommate wanted to take out the trash, so you used a coin to decide who would do it.

Please open the spreadsheet for today: Lab 2 R2D2 and Probability (Emily and Yashar ex.) (https://bit.ly/EmilyAndYasharMTH098). You'll need to click the "Make a Copy" button. In this sheet, you'll see the results of two friends, Emily and Yashar, flipping coins to decide who takes out the trash each week, for a full year (about 52 weeks). Here's what you should see when you open it:

	week 1	week 2	week 3	week 4	week 5			
January	Emily	Yashar	Yashar	Emily	Yashar		Coin Type?	Flip! ☑
February	Yashar	Emily	Emily	Yashar			Fair	
March	Emily	Yashar	Yashar	Emily	Emily		☑	
April	Emily	Emily	Yashar	Yashar				
May	Yashar	Emily	Yashar	Emily	Yashar			
June	Emily	Emily	Emily	Emily				
July	Yashar	Emily	Emily	Yashar				
August	Yashar	Yashar	Emily	Emily				
September	Emily	Yashar	Emily	Emily				
October	Yashar	Yashar	Emily	Yashar				
November	Yashar	Emily	Yashar	Yashar	Emily			
December	Emily	Emily	Yashar	Emily				

Some notes:

- Heads, Emily takes out the trash. Tails, it's Yashar (I made Emily's name green to make it easier to differentiate between the two names).
- Your "Emily" and "Yashar" names will be in different places than the one above; that's because I'm using random numbers in the spreadsheet to "flip" a "coin" (*there are ways to make "dice" in spreadsheets – we'll talk more as we go through class about those).*
- See the little checkbox next to "Flip!"? If you toggle between that box being checked and unchecked, the "coins" will keep "flipping"! (or, to stop using quotes, the randomizer keeps generating new random numbers)

Go ahead and toggle that "Flip!" checkbox a few times. Each time, count how many times Emily's name shows up and how many times Yashar's name shows up.

1. **(1 point)** Generally, about what fraction of the time does Emily take out the trash?

2. **(1 point)** And about what fraction of the time does Yashar take out the trash?

3. **(2 points)** Suppose that Emily and Yashar are using a US quarter to flip to make their weekly decision. Please explain how you could have arrived at your answers for #1 and #2 without using the Google Sheet!

4. **(2 points)** Take a look at the results in the screenshot on the first page of this lab. Considering your answers to the previous questions, does it bother you at all that Emily had to take out the weekly trash ***every single week*** in June? Why or why not?

Now, suppose Emily decides to pull a fast one on Yashar, and rigs a coin so it flips more often in her favor. Answer the following questions ***without using the Google sheet***.

5. **(2 points)** Suppose that Emily and Yashar are using Emily's rigged coin to flip to make their weekly decision. What fraction of the time will Emily take out the trash? **Hint:** We know it's going to be "less than half"; she's rigged the coin in her favor. But what ***fraction*** would it equal, approximately? Either answer, or explain why you can't.

6. **(2 points)** I'm pretty sure I know how you answered that last one! What makes it different from #3?

See the little box that says "Fair" under "Coin Type" in the Google sheet? Uncheck that. Now Emily and Yashar are flipping the ***rigged*** coin! Go ahead a "flip" the rigged "coin" several times, until you have a good sense of how often Emily's name comes up. Then answer the next question!

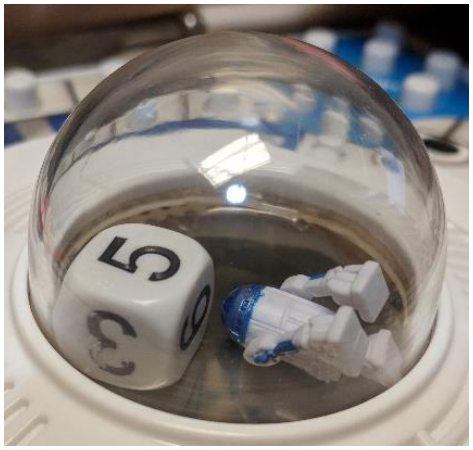
7. **(1 point)** About what fraction of the time is Emily taking out the trash? **Hint:** Use a denominator of 10.

Even before signing up for MTH 098, you likely could have answered questions 1 through 3…based on experience you already had in life. But then we twist the situation a little tiny bit, and the same question becomes impossible to answer without looking at data!

There are many occurrences in the world that have just two possible outcomes, like a heads/tails coin flip. But like with Emily's rigged coin, the two outcomes often aren't equally likely, and so researchers need to "flip coins" (repeatedly perform their experiment) to figure out what fraction of the time each outcome happens.

Some examples: fraction of high schoolers with ADHD (*they either have it or they don't*), fraction of bicycle commuting deaths attributed to inattentive motorists (*they either are or aren't caused by that*), fraction of the time a certain side effect from a drug occurs in someone taking the drug (*the side effect either happens or it doesn't*), and much more!

Today, we're going to be our own researchers, and we'll experiment with the Star Wars version of the game "Trouble". If you've never played it before, don't worry—you don't need to know the rules to do this lab. Here's the gist: each time a player plays their round, they push a little Plexiglas dome down and then let it pop back up. When it does, two things happen: a die rolls (we can ignore that for this lab) and a little R2D2 figure bounces around. Sometimes, he lands on his side (like the picture on the left). Other times, he lands on his "feet" (like the picture at right).[1]



Now, our son, Max, ***loves*** to play this game. After playing the game for years, Max asked one night, "I wonder how often R2 lands on his feet?" Today, in this lab, we're going to attempt to answer that!

8. **(2 points)** How do you think our experiment will be similar to the "rigged coin" version of Emily and Yashar's coin flip "experiment"? Write one or two sentences to explain.

Ideally, each of you would use the actual game board and "pop" the little dome to see what happens with R2D2. Since we can't do that, I've recorded number of short videos for you; in each video, you'll see him popping the dome 20 times (slowly enough so that you can observe what's happening with R2D2 on each push of the dome). You'll watch one of these videos, and count the number of times R2D2 lands on his feet.

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[1] Sometimes, he leans against the side. I just ignore those trials and do them again.

Use the instructions below to decide which video you'll watch!

- If your first name starts with the letters A through E, write down "**1**"; if it starts with F through L, write down "**2**". Otherwise, write down "**3**".
- If your ***last*** name starts with the letters A through M, write down "**1**"; otherwise, write down "**2".**
- If the month of your birthday is January through April, write down "**1**"; if it's May through August, write down "**2**". Otherwise, write down "**3**".

You should now have a 3-digit number, which will tell you which video to watch. Click on your number to watch it!

111	112	113	121	122	123
211	212	213	221	222	223
311	312	313	321	322	323

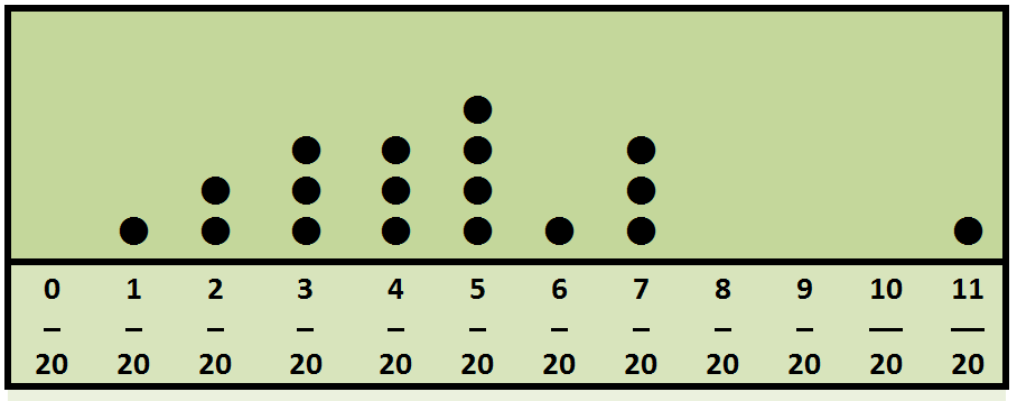
9. **(1 point)** Write a fraction that represents the rate at which R2 landed on his feet in your video (remember there were 20 trials!).

10. **(1 point)** Write an equivalent ***percentage*** to the fraction in #10. In case you need a little review with proportions and percentages, check out this video!

Now we'll take a look at what happened with ***all*** the videos (not just the one you watched). The results are below collected into a table. (Note: R2D2 didn't end up landing on his feet more than 11 times in any video.)

Fraction of "standing R2D2's per 20 flips"…	How many times did that happen?
$\frac{0}{20}$	0
$\frac{1}{20}$	1
$\frac{2}{20}$	2
$\frac{3}{20}$	3
$\frac{4}{20}$	3
$\frac{5}{20}$	4
$\frac{6}{20}$	1
$\frac{7}{20}$	3
$\frac{8}{20}$	0
$\frac{9}{20}$	0
$\frac{10}{20}$	0
$\frac{11}{20}$	1

Let's take a look at this data in a **dot plot.**



11. **(1 point)** How many different videos were there?

12. **(1 point)** What fraction of the videos saw ***exactly*** 5 standing R2D2's out of 20 rolls?

13. **(1 point)** What fraction of the videos saw ***more*** than 5 standing R2D2's out of 20 rolls?

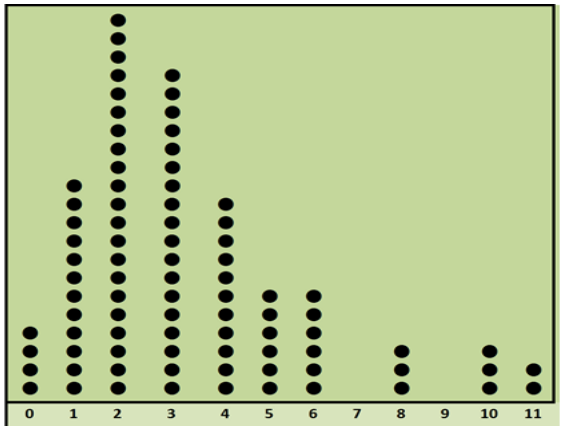
Now watch this video about why visualizing the data with a dot plot can be helpful (if you get stuck with the last few questions, it might also help you with them!).

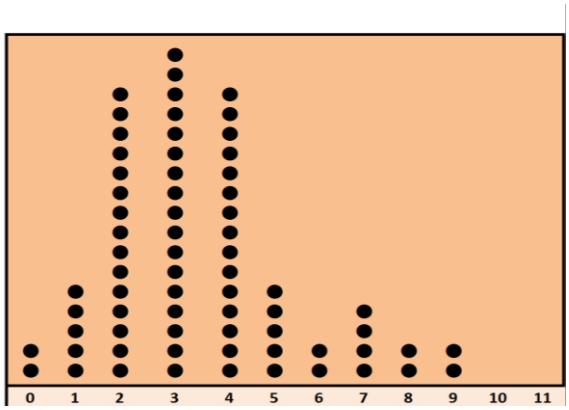
After watching that video, it appears that on **average** R2D2 lands on his feet just a little less than 5 out of 20 rolls[2], or just under 25% of the time. You can also "see" the average: in the video, I mentioned the "shape" of the data as it rises and then falls again; the average represents the balance point where the data stops rising and starts falling.

As you can see, it's often not good enough to look at a small, isolated sample of data (like the single video you watched) to draw a sweeping conclusion. You need to run an experiment many, many times in order to see the patterns that underlie the behavior. Just like Emily's rigged coin: even though we couldn't tell at ***first*** how often it came up heads, after watching the coin behave for a while, we saw that it was 10% (check your answer to #7!).

But now let's add another little wrinkle to this situation. Max came up with a theory after playing this game for a while: he claimed that if he "bounces" the dome, he'll get R2 to land on his feet more often than if he slowly presses the dome (in the "20 trials" video you watched, I was very careful to push down, listen for the click, then release. Max did away with the pause and simply "tapped" or "bounced" the dome).

When we're able to do this experiment in class, we can collect the real data that students generate. Here are the dot plots for both methods. The "standard method" (what you saw in the videos) is the green graph, and the "bounce method" is the orange one. As before, the numbers along the bottom are "Standing R2D2's out of 20 rolls".





[2] You can also see this by calculating the average the way many of you have probably done in the past: $\frac{1+2+2+3+3+3+4+4+4+5+5+5+5+6+7+7+7+11}{18}$, which, if you work it out, is about equal to 4.72 standing R2D2's per 20 rolls (or about 23% of the time). But, after watching the video, you now know ***what*** an average is actually ***calculating***.

Note: Each dot in those dot plots represents the results of one person "rolling" 20 times, just like in the last dot plot.

14. **(2 points)** Using these dot plots, give one reason that Max's "bounce" method appears to give a ***slight*** advantage over the traditional method. Be sure to comment on both dot plots when you answer. You don't need to use the "share/average" technique from the second video you watched (unless you really want to), but looking at where the average ***was*** in the video might be helpful.

15. **(2 points)** After looking at these two dot plots, a student once said, "No! Max's bounce method ***isn't*** better! Look…using the standard way, you were able to see some 10 out of 20's and 11 out of 20's. The best you did with the "bounce" method was 9 out of 20!" Write a sentence or two to respond to this claim. **Hint:** Your answer to #4 might help here.

16. **(3 points) You** may have also noticed that Sean's results for the "standard method" (the first green dot plot at the top of page 4) aren't quite in line with the historical student results for that method (the second green dot plot at the bottom of page 4). Gi9ve at least one difference! Can you think of any reason why this might be the case? Write a sentence or two to explain.