

4. In the “Difference” column, enter a function (aka an equation or formula) to tell Excel to subtract the before values from the after values.
 - a. Always start a formula with a “=” symbol, then select the cell from column B, then type a “-” symbol, then select the cell from column A, then hit enter.
 - b. The result will be displayed when you hit the enter key (see “-2” and “-4” shown in cells C2 and C3 below). The formula is shown in cell C4.
 - c. Once you type in the formula, you can copy and paste that formula into the remaining cells of column C.
 - d. If you want to calculate a paired t-test by hand, you will need these difference values. Otherwise, you will not use them to make your graphs or analyses.

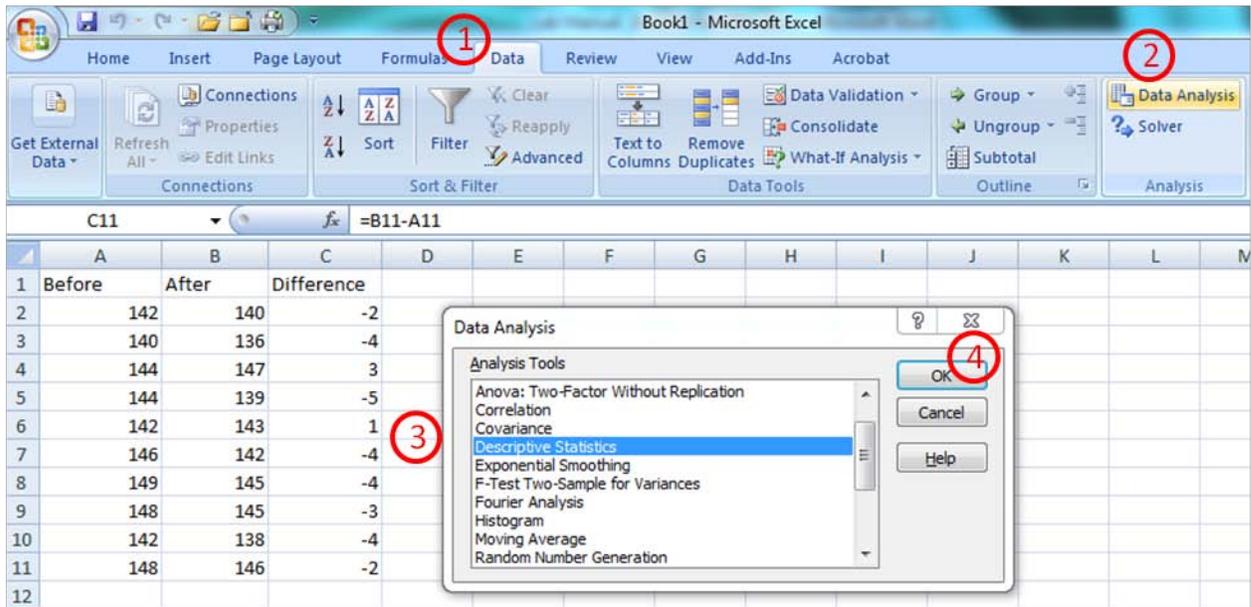
The screenshot shows the Microsoft Excel interface with the following data in the spreadsheet:

	A	B	C	D	E	F	G	H
1	Before	After	Difference					
2	142	140	-2					
3	140	136	-4					
4	144	147	=B4-A4					
5	144	139						
6	142	143						
7	146	142						
8	149	145						
9	148	145						
10	142	138						
11	148	146						

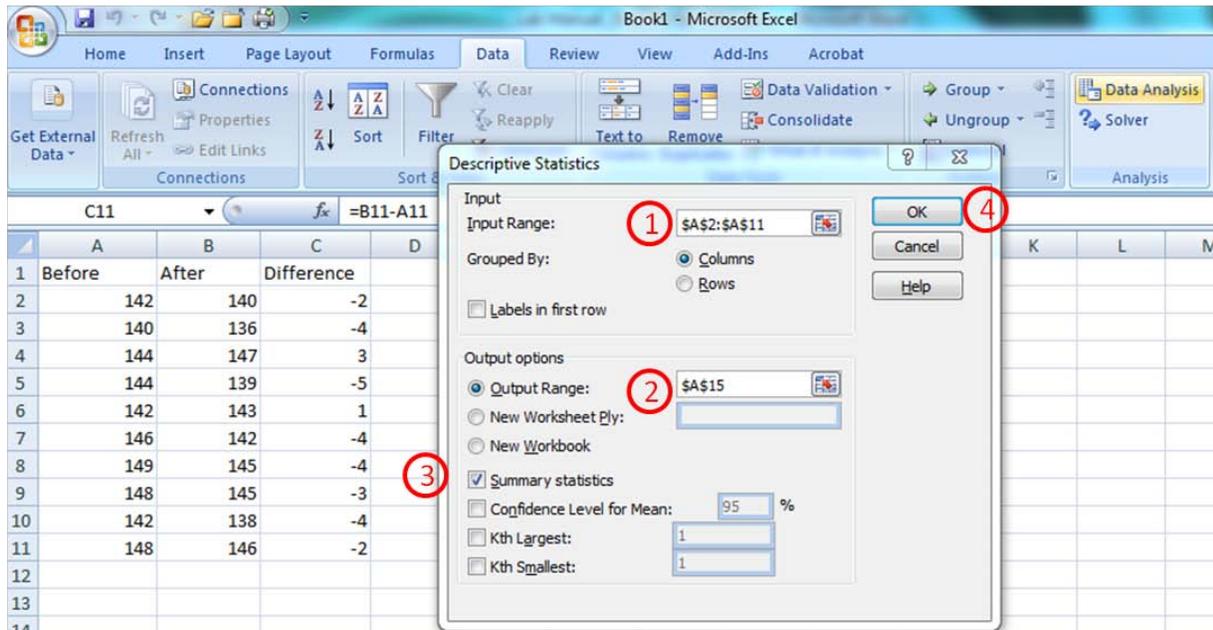
How to Calculate Summary Statistics in Excel: Two Methods

1. Use the data analysis tools.

- a. Open the worksheet with your data. Select the “Data” tab **1**, then “Data Analysis” **2**, then from the list choose “Descriptive Statistics” **3** and select “OK” **4**.



- b. From here, with your cursor in the Input Range **1**, select your data in column A. Then put your cursor in the Output Range block **2** and select an empty cell in your work sheet. Click the box labeled “Summary Statistics” **3** so a check mark appears, then select “OK” **4**.



- c. Excel will now show you the summary statistics. I have added highlights to show the mean, standard deviation, standard error, and sample size which are the summary statistics that you will most commonly use for your write-ups in our labs.

	A	B	C
1	Before	After	Difference
2	142	140	-2
3	140	136	-4
4	144	147	3
5	144	139	-5
6	142	143	1
7	146	142	-4
8	149	145	-4
9	148	145	-3
10	142	138	-4
11	148	146	-2
12			
13			
14			
15	<i>Column1</i>		
16			
17	Mean	144.5	
18	Standard Error	0.9803627	
19	Median	144	
20	Mode	142	
21	Standard Deviation	3.1001792	
22	Sample Variance	9.6111111	
23	Kurtosis	-1.4032926	
24	Skewness	0.1957746	
25	Range	9	
26	Minimum	140	
27	Maximum	149	
28	Sum	1445	
29	Count	10	
30			

OR

2. Type in the formulas. For any formula, you can then copy/paste into cells for adjacent columns (be sure to check that excel is using the correct cells to calculate the values)

- Mean: the formula to tell Excel to calculate a mean is “=average(select cells here)” ①. Type this formula into the appropriate cell and then hit enter.
- Standard Deviation: the formula to tell Excel to calculate a standard deviation is “=stdev(select cells here)” ②. Type this formula into the appropriate cell and then hit enter.
- Sample size: the formula to tell Excel to calculate your sample size is “=count(select cells here)” ③. Type this formula into the appropriate cell and then hit enter.
- Standard Error: The standard error is the standard deviation divided by the square root of the sample size. Therefore, the formula to tell Excel to calculate a standard error is “=[select the cell for standard deviation]/sqrt([cell for sample size])” ④. Type this formula into the appropriate cell and then hit enter.

	A	B	C	D	
1		Before	After	Difference	
2			142	140	-2
3			140	136	-4
4			144	147	3
5			144	139	-5
6			142	143	1
7			146	142	-4
8			149	145	-4
9			148	145	-3
10			142	138	-4
11	Descriptive Statistic	148	146	-2	
12					
13	Mean	144.5	=AVERAGE(C2:C11)	=AVERAGE(D2:D11)	①
14					
15	Standard Deviation	3.100179206	=STDEV(C2:C11)	=STDEV(D2:D11)	②
16					
17	Sample Size	10	=COUNT(C2:C11)	=COUNT(D2:D11)	③
18					
19	Standard Error	0.980362745	=C15/SQRT(C17)	=D15/SQRT(D17)	④
20					

- c. Notice that the output from Excel includes a lot of information (note that the mean is shown again here). For our purposes, you only need to include three pieces of information when you report your paired t-test results.

	A	B	C	D	E	F
1	Before	After		t-Test: Paired Two Sample for Means		
2	142	140				
3	140	136			Variable 1	Variable 2
4	144	147		Mean	144.5	142.1
5	144	139		Variance	9.611111	13.87778
6	142	143		Observations	10	10
7	146	142		Pearson Correlation	0.73599	
8	149	145		Hypothesized Mean Difference	0	
9	148	145	①	df	9	
10	142	138	②	t Stat	2.9794	
11	148	146		P(T<=t) one-tail	0.007733	
12				t Critical one-tail	1.833113	
13			③	P(T<=t) two-tail	0.0155	
14				t Critical two-tail	2.262157	
15						

- i. You should include your degrees of freedom (for a paired T-test, this is the sample size minus one) ①.
 - ii. You should include your t statistic ②.
 - iii. You should include your two-tailed P-value ③. NOTE: If a P-value is less than 0.05, then you know that your two groups that you compared are significantly different from each other. If the P-value is greater than or equal to 0.05, then the two groups are not different from each other.
 - iv. **Example of a sentence to be written in your results section:**
 “Average heart rate decreased after frog hearts were exposed to pilocarpine (t = 2.98, df = 9, P = 0.016; Figure 1)”, where Figure one would show your descriptive statistics (mean and error bars that are some measure of dispersion).
- d. **Hint: there is some information that you should NOT include in your papers:**
- i. NO RAW DATA should be in your paper as either a table or graph.
 - ii. **DO NOT** copy and paste the output shown above from Excel into your lab write-up.

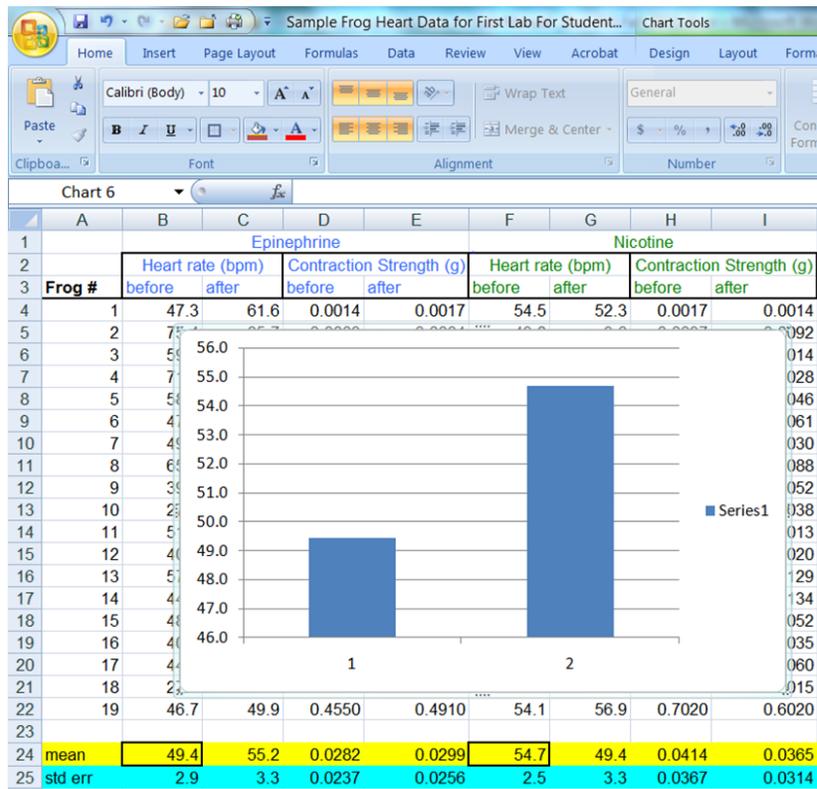
How to Create Graphs in Excel

1. Plot the means.

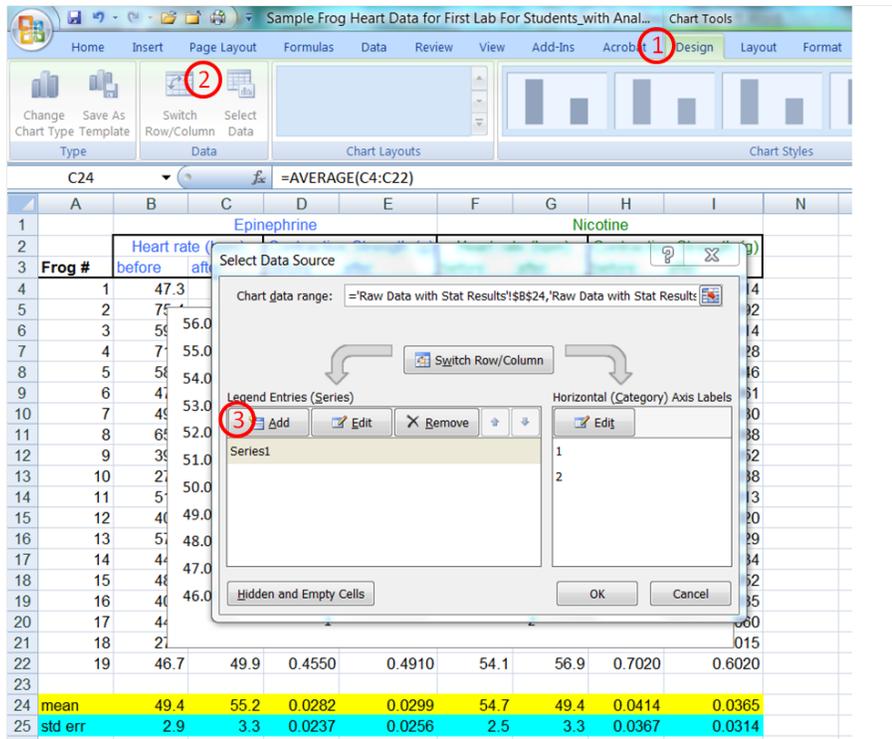
- In this example, you will plot frog heart rate before and after treatment with two drugs (epinephrine, nicotine). First, calculate your descriptive statistics by one of the methods shown above and organize your results below the columns of data as shown **1**.
- Holding the CTRL button on your keyboard, select the "Before" value for epinephrine **2** and then for nicotine **3**.
- Select the "Insert" tab **4**, then Column **5**, then Under 2D columns, select the first option. When you click this option, **1** you will see the image below.

		Epinephrine				Nicotine			
		Heart rate (bpm)		Contraction Strength (g)		Heart rate (bpm)		Contraction Strength (g)	
Frog #		before	after	before	after	before	after	before	after
1	1	47.3	61.6	0.0014	0.0017	54.5	52.3	0.0017	0.0014
2	2	75.4	85.7	0.0083	0.0084	49.2	9.8	0.0097	0.0092
3	3	59.0	60.0	0.0013	0.0015	59.0	55.0	0.0014	0.0014
4	4	71.0	72.2	0.0027	0.0026	67.0	70.0	0.0031	0.0028
5	5	58.6	59.0	0.0040	0.0040	56.2	56.6	0.0047	0.0046
6	6	47.7	55.3	0.0047	0.0070	61.1	52.2	0.0069	0.0061
7	7	49.4	45.8	0.0036	0.0041	63.5	37.7	0.0047	0.0030
8	8	65.1	71.3	0.0100	0.0092	79.7	67.8	0.0073	0.0088
9	9	39.5	42.0	0.0062	0.0058	49.0	40.5	0.0053	0.0052
10	10	27.0	47.4	0.0052	0.0022	30.0	28.8	0.0046	0.0038
11	11	51.2	59.1	0.0018	0.0020	58.1	59.1	0.0018	0.0013
12	12	40.1	50.5	0.0036	0.0034	48.0	44.6	0.0010	0.0020
13	13	57.0	56.0	0.0068	0.0065	58.0	53.0	0.0129	0.0129
14	14	44.4	44.3	0.0026	0.0030	54.0	55.0	0.0029	0.0134
15	15	48.0	76.0	0.0067	0.0049	53.0	64.0	0.0050	0.0052
16	16	40.0	42.0	0.0029	0.0017	60.0	54.0	0.0035	0.0035
17	17	44.4	48.0	0.0076	0.0070	50.4	49.8	0.0058	0.0060
18	18	27.3	22.6	0.0016	0.0017	34.3	31.6	0.0015	0.0015
19	19	46.7	49.9	0.4550	0.4910	54.1	56.9	0.7020	0.6020
24	mean	49.4	55.2	0.0282	0.0299	54.7	49.4	0.0414	0.0365
25	std err	2.9	3.3	0.0237	0.0256	2.5	3.3	0.0367	0.0314

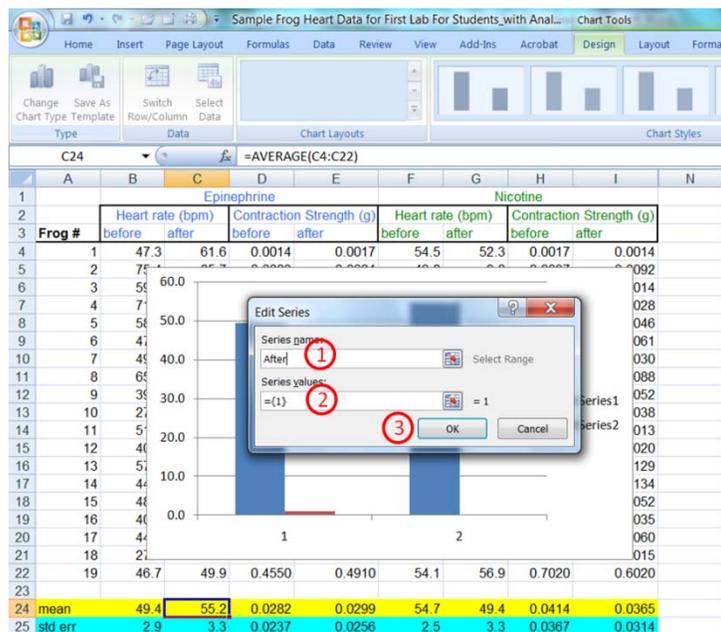
- Note that "Series 1" is your "Before" values (we'll re-name this in a minute).



- e. Now we need to add the “After” values in a second “series”. To do this, be sure to click the chart which will activate the “Chart Tools” area. In this area, select the “Design” ① tab, then “Select Data” ②, then “Add” ③.



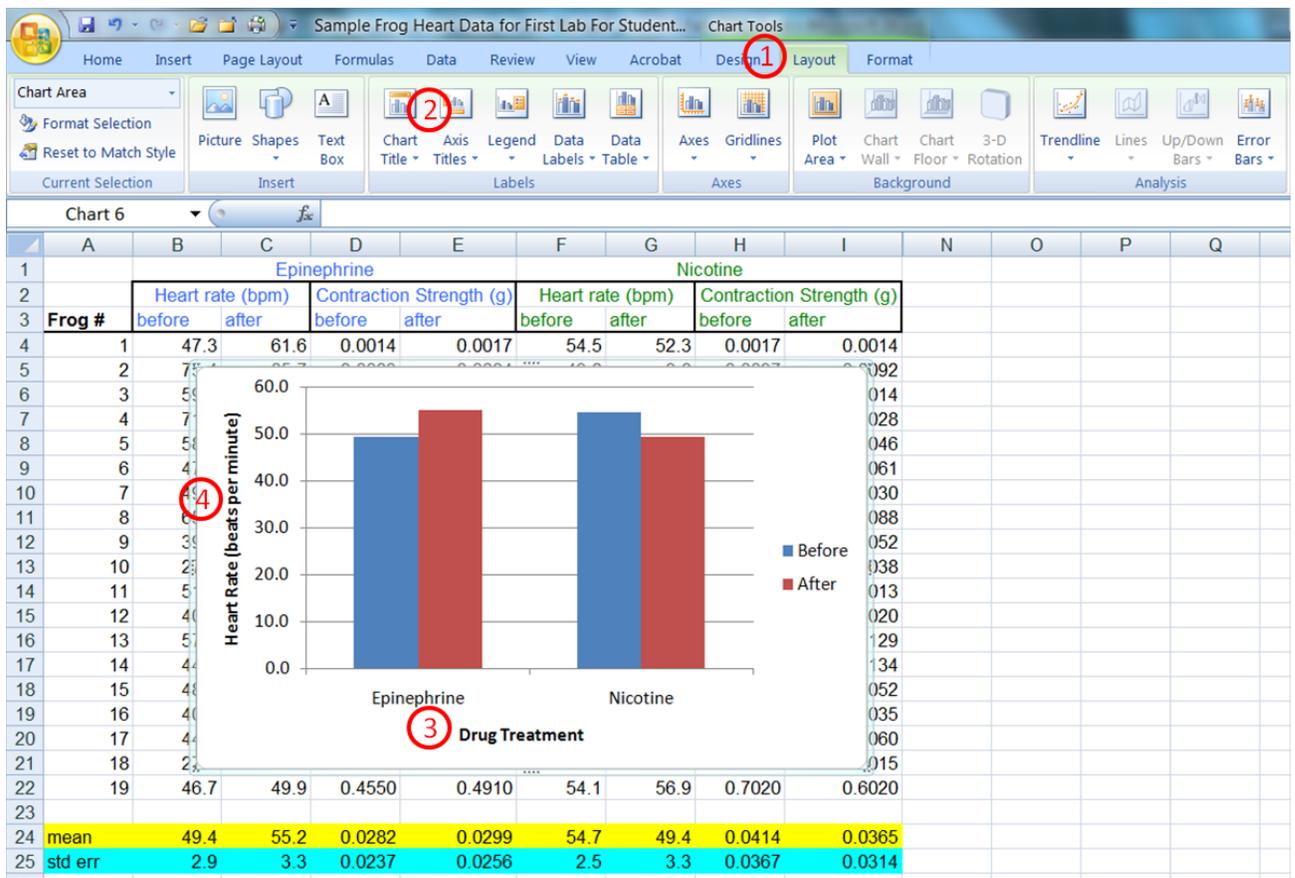
- f. For series name, type “After” ①. Note that a nonsense character automatically occurs for the Series values ②. Delete this. With your cursor in this box, hold the CTRL key and then select the after values for Heart Rate for Epinephrine (cell C24) and Nicotine (cell G24). Click “OK” ③ here and on the next screen.



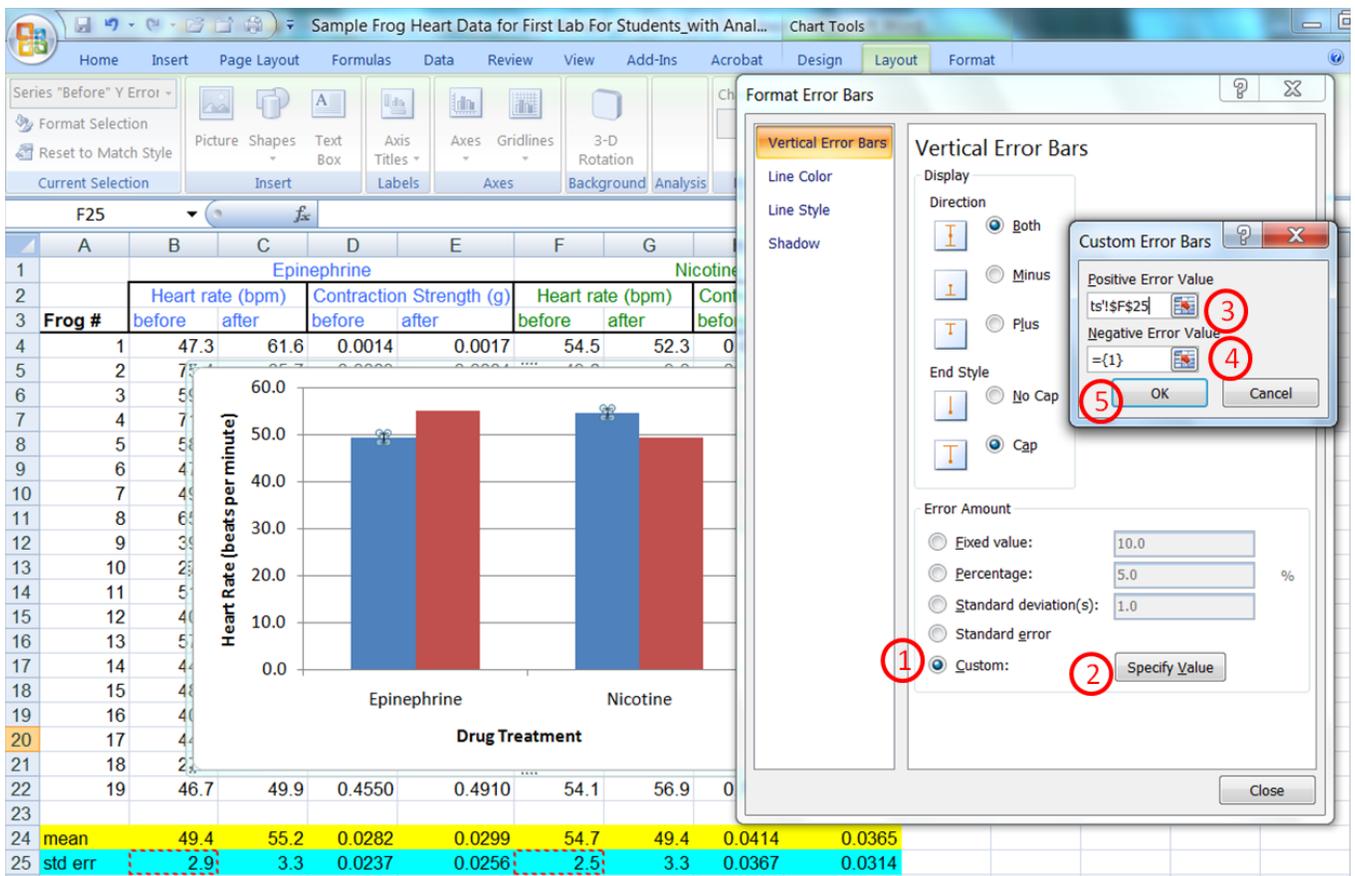
- g. We usually want the y-axis to go to zero when presenting data. To do this, right click on your y-axis and select “Format Axis”. Select “Axis Options”>“Minimum”>“Fixed” and then enter a “0”. Click “Close”.
- h. Now you will see the basic graph (image not shown). Next, you can fix the labeling.

2. Label the graph

- a. First, let’s fix the series 1 name and the names of the components of the series.
- b. Click on the graph to bring up the Chart Tools tab. Select Design>Select Data>Series 1>Edit (on the Legend Entries side of the box). Then type in “Before” for the series name and click “OK”.
- c. Click on the graph to bring up the Chart Tools tab. Select Design>Select Data>Series 1>Edit (on the Horizontal Axes Legend side of the box). Then type in “Epinephrine,Nicotine”, with the labels separated by a comma and no space after the comma (otherwise your label will be moved over a space when placed on your axis). Click “OK”, then click “OK” again. Now your graph has the data labeled correctly and you need only to add labels to your axes.
- d. To label the x-axis, click on the graph to bring up the Chart Tools tab. Select Layout ^①>Axis Titles ^②>Primary Horizontal Axis>Title Below Axis. Now a title will appear at the x-axis on your graph; click in the text box and type your title (e.g. Drug Treatment ^③). Do the same for the y-axis, except choose “Primary Vertical Axis”>“Rotated Title” to orient the text as shown below (be sure to include units of measure in parentheses) ^④.



3. Add the error bars. **Do not use any of the default settings for error bars** in Excel as they are incorrect. You must calculate either standard error or standard deviation and use these values to plot error bars on your graph. For this example, you will plot ± 1 standard error for each error bar.
 - a. Click on the graph to bring up the Chart Tools tab. Select Layout>Error Bars>More Error Bars options (the last choice on the drop down menu). To place error bars for the before values, click on “Before” and then “OK”.
 - b. From this menu, choose “Custom” ① and “Specify Value” ②. For the Positive Error Value ③, delete the nonsense characters. Hold the CTRL key and then select the “Before” standard error value of heart rate for Epinephrine and then for Nicotine. Repeat this process for the Negative Error Value ④. Select “OK” ⑤, then “Close”. Now the error bars are plotted for the Before values. Repeat this process for the After values.



4. Your graph is complete. Now that you know the basics, you can click on various options and change colors, remove the grid lines, change font size, line thickness graph style etc.