Learning Objectives

- Learn how to use the Paste Function menu in Excel 2013 to carry out a set of mathematical operations.
- Practice using a variety of common functions in Excel 2013.
- Learn how to record a macro.

Introduction

Mathematical functions describe natural phenomena in the form of an equation, relating 1 variable to another. In Lab Exercise #1: Mathematical Functions and Graphs, you learned about linear, exponential, and power mathematical functions. In this exercise, the “function” under discussion is quite different. Spreadsheet functions are formulae that have been written by a computer programmer to perform mathematical and other operations. Excel 2013 has >100 functions available for use. They make modeling faster and easier with fewer errors.

Standard Functions

As an introduction to spreadsheet functions, let’s suppose that there are 8 people in an elevator. The names of the 8 individuals and their weights are given in Figure 1.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Individual</td>
</tr>
<tr>
<td>2</td>
<td>Jared</td>
</tr>
<tr>
<td>3</td>
<td>Joseph</td>
</tr>
<tr>
<td>4</td>
<td>Benjamin</td>
</tr>
<tr>
<td>5</td>
<td>Anthony</td>
</tr>
<tr>
<td>6</td>
<td>Hunter</td>
</tr>
<tr>
<td>7</td>
<td>Alan</td>
</tr>
<tr>
<td>8</td>
<td>Charles</td>
</tr>
<tr>
<td>9</td>
<td>Kennedy</td>
</tr>
</tbody>
</table>

Figure 1
Imagine that the elevator can hold a maximum of 1,500 pounds, and that a 9th person would like to get on. Would the addition of a 9th person exceed the 1,500-pound safety limit? To answer this question, we need to know how much the 8 people in the elevator collectively weigh, and the weight of the 9th person. We could add cells B2–B9 to determine how much the 8 people on the elevator weigh. If we entered a mathematical formula in cell B10 to compute this, the formula reads \(=B2+B3+B4+B5+B6+B7+B8+B9\). The result is 1,300 pounds. The more complicated a formula becomes, however, the more likely it is that you will make a mistake in entering it. This is where spreadsheet functions come into play. Instead of entering \(=B2+B3+B4+B5+B6+B7+B8+B9\) into cell B10, we can use the SUM spreadsheet function and have the spreadsheet do the math for us.

To enter a spreadsheet function, first select the cell in which you want the function to be computed (in this case, cell B10, as in Figure 2). Then you can do 1 of 2 things. You can either use the Paste Function button, \(\text{fx}\), on your toolbar (indicated in Figure 2), or you can open the Formulas tab and click Insert Function (Figure 3). Either way, the Insert Function dialog box appears (Figure 4).
Look at the second white box in the Insert Function dialog box in Figure 4. It asks you to “Select a category.” You could choose to look at the most recently used functions, all the available functions, or you can check out the functions in a specific category, such as the financial functions, statistical functions, etc. If you choose “All” as a function category, you’ll see every function available in your spreadsheet package, listed in alphabetical order.

In Figure 4, we selected the “Most Recently Used” function category, so a list of the most recently used functions appears in the large white box. Note that the function “SQRT” is selected, and the program displays a brief description of the function at the bottom of the box: “Returns the square root of a number.” Select SUM and then click OK. Another dialog box will then appear, called “Function Arguments” (Figure 5).
You are asked to enter the addresses of the cells you wish to sum. Either select cells B2 through B9 or type in the range B2:B9. When you are finished, click OK.

There is a useful feature in the Function Arguments box that you should be aware of: the “Help on this function” information, accessed by clicking on the blue link located at the bottom-left corner of the window (Figure 5). If you don’t know how a function works, clicking on this link will provide additional information.

Once you have entered all the necessary data and clicked OK, the spreadsheet will return the answer in cell B10 (Figure 6). Although the spreadsheet displays the answer (1300) in cell B10, the formula bar (indicated by red arrow) shows that the cell really contains the function =SUM(B2:B9). Note that the spreadsheet automatically inserted an equal sign before the function name, alerting the spreadsheet that a function is being used.
Nested Functions

In some cases, you may need to perform >1 function at a time. “Nesting” 1 function inside another can give you the result you want. Returning to our elevator example, suppose that a 9th person, Peter, would like to board the elevator. He weighs 200 pounds. We want to enter a formula in cell B13 to determine whether he can safely board or not. If the total weight is ≤1,500 pounds, he can safely board. If the total weight is >1,500 pounds, he cannot safely board. We can use an IF function in cell B13 to carry out the operation and return the word “yes” if he can board or “no” if he cannot board (Figure 7).
As with the SUM function, first select the cell in which you want the function to be computed (in this case, cell B13). Click fx on your toolbar. Search for and select the IF function (Figure 8) from the Insert Function dialog box. You will notice at the bottom of the dialog box the words IF(logical_test,value_if_true,value_if_false). This is the syntax for the IF formula, and it provides the “rules” for entering an IF function. You should also see a brief description of the function that tells you the function “Checks whether a condition is met, and returns one value if TRUE, and another value if FALSE.”

![Figure 8](image)

In our exercise, we want to determine whether the total weight is ≤ or > 1,500 pounds. This is the logical test. If the logical test is TRUE, we want the word YES to be returned (he can safely board) in cell B13. If the logical test is FALSE, we want the word NO to be returned (he should not board) in cell B13. The Functional Arguments for the IF function is shown in Figure 9.
The logical test requires that we sum the weights of the original 8 individuals in cells B2–B9 and the weight of the 9th individual (cell B12) and determine whether the sum is ≤1,500. Because the logical test (IF function) contains the SUM function, it is called a nested function. To nest the SUM function within the IF function, place your cursor within the Logical test box and type SUM. Enter the cell range you want to SUM (B2:B9,B12). Also notice “<1500” in the Logical Test box (Figure 9). Type YES in the Value_if_true box. Type NO in the Value_if_false box. Click OK and the answer YES should appear in cell B13 as in Figure 10.
The final function in cell B13 reads \(=\text{IF(SUM(B2:B9,B12)<1500,"YES","NO")}\). When functions are nested within other functions, the spreadsheet will compute the answer to the “nested” functions (in this case, SUM) first and then will complete the outer functions.

**Array Formulae**

Functions such as SUM perform a calculation and generate a result in a single cell. An array formula, on the other hand, can perform multiple calculations, returning either a single result or multiple results. Array formulae act on ≥2 sets of values known as “array arguments.”

You create array formulae in the same way you create other formulae, with a few major exceptions. First, instead of selecting a single cell to enter a formula, you need to select a *series* of cells, then enter an array formula. Second, instead of clicking OK after you have completed the entries in the function palette, you press <Control>+<Shift>+<Enter> to enter the formula for all of the cells you have selected.

Let’s consider a new example. Suppose you want to construct a frequency distribution of the body masses of 44 elk. You have chosen 11 body mass (lb) categories: 250-299, 300-349, 350-399, 400-449, 500-549, 550-599, 600-649, 650-699, 700-749, 750-799, 800-850. To construct your frequency distribution you have decided to use the FREQUENCY function, which is an array formula, to generate the frequency data quickly.

Column E, labeled “Bins” in Figure 11, tells Excel how you want your data grouped. You can think of a bin as a bucket within which to place numbers. The task you are faced with now is to have the spreadsheet count the number of elk in each bin and return the answers in cells F2–F13. Because the frequency function is an array function, you will need to select cells F2–F13 (rather than a single cell) *before* using the *fx* button to summon the FREQUENCY formula (this step is illustrated in Figure 11).
So, to construct a frequency distribution of the body masses from the 44 elk, first select cells F2–F13 then select the $f_x$ button. An Insert Function dialog box will appear. Select Frequency and then click OK. A Function Arguments box will appear (Figure 12) and will guide you through the entries.
The Data_array is simply the data you want to summarize, given in cells B2:B45. The Bins_array is cells E2:E13. Instead of clicking OK in the Functions Arguments dialog box, press <Control>+<Shift>+<Enter> and the spreadsheet will return your frequencies (Figure 13). If we examine the formulae in cells F2–F13, every cell will have the formula \{=FREQUENCY(B2:B45,E2:E13)\}. The \{ \} symbols indicate that the formula is part of an array.
Figure 13

Typically, frequency data are depicted graphically as shown in Figure 14. If you change the data set in some way, the spreadsheet will automatically update the frequencies. If for some reason you get “stuck” in an array formula, just hit the Escape key and start again.
Macros

Constructing population models in Excel can involve repetitive, multi-step processes. Typing and mouse-clicking your way through a long series of commands over and over is time-consuming and error-prone. To automate a repetitive, multi-step task so you can repeat the task with a single click, you will need to record a macro. A macro is a small program that you construct yourself in order to run a sequence of repetitive spreadsheet actions. A macro allows you to achieve the same results with a single specific command.

You record a macro using Excel’s built-in macro recorder. Start the recorder by selecting Developer | Macro. If the Developer ribbon is not shown on the main ribbon panel you will need to load it. Load Developer by selecting File |
Options | Customize Ribbons. Within the second large box from the left, check the small box next to the word “Developer.“

Using the Elevator example data we used when we discussed standard functions above, we start the recorder by selecting Developer | Macro. The Macro dialog box will appear (Figure 15).

![Figure 15](image1.png)

The program will prompt you to name the macro and create a keyboard shortcut. Once you have entered the name and shortcut, click OK. Notice the Record Macro command button becomes the Stop Recording command button once you click OK (Figure 16).

![Figure 16](image2.png)
The spreadsheet will now record every action you take. Carry out the entire sequence of operations you want the macro to do, and then press the **Stop Recording button**. From this point on, Excel will mimic that entire sequence of actions you recorded whenever you press the keyboard shortcut or issue the macro command.

Notice the **Use Relative References** button is directly below the **Record Macro** (or the **Stop Recording** button) command button (Figure 16). By default this option is not selected so that your macro recorder assumes that the cell references you make in the course of developing your macro are absolute. In other words, if you select cell A1 as part of a macro, Excel will interpret your keystroke as cell $A$1. There are cases (for example, the Survival Analysis exercise) in which you will want to select the **Relative Reference** button as you record your macro.

Now that you have been introduced to simple functions, nested functions, arrays, and macros, it’s time to put them into practice. The following instructions will introduce you to some 20 commonly used spreadsheet functions.

Again, general directions followed by a step-by-step breakdown of these directions, as well as other explanatory comments, are given. As always, save your work frequently.

**Procedures**

A. Set up the spreadsheet.

1. Open a new spreadsheet and enter headings as shown in Figure 17.

2. Set up a linear series from 1 to 19 in cells A4–A22. We will consider a sample of 19 grizzly bears and their body masses. Enter 1 in cell A4. Enter $=1+A4$ in cell A5. Select cell A5 and copy it down to cell A22.

3. Enter the body masses for the 19 bears in cells B4–B22 as shown. These are the actual data, so just type in the numbers as shown in Figure 17.
B. Compute simple functions.

In this section, you will learn to use 11 standard spreadsheet functions to compute various things, like the mean (average) body mass of the 19 bears. For all functions, use the **Insert Function** menu (fx) on the formula bar to locate the appropriate function, review the Function Arguments, and complete the entries. You can double-check your results with mine at the end of this section.

1. Set up new headings in cells E3-E15 as shown in Figure 18.

![Figure 17](image)

![Figure 18](image)
2. In cell F5, use the **COUNT** spreadsheet function to count the total number of individuals in the sample.

The **COUNT** function counts the number of cells that contain numbers. In this case, you want to count the number of times that a number is contained in cells C4–C22. Select the **COUNT** function from the Insert Function menu and compute this result. After you are finished, cell F5 should display the number 19, and its formula should be `=COUNT(C4:C22)`.

3. In cells F6–F12, use the spreadsheet functions **SUM**, **AVERAGE**, **MEDIAN**, **MODE**, **MIN**, **MAX**, and **STDEV** to compute basic descriptive statistics for the population.

For each formula, use the Insert Function menu and read through the information in the Formula Arguments dialog box carefully. If you are unsure of the kind of information a statistic provides, click on the question mark on the bottom-left corner of the box. For each descriptive statistic your formulas should look like the following:

- **Count** =COUNT(B4:B23)
- **Sum** =SUM(B4:B23)
- **Average** =AVERAGE(B4:B23)
- **Median** =MEDIAN(B4:B23)
- **Mode** =MODE(B4:B23)
- **Min** =MIN(B4:B23)
- **Max** =MAX(B4:B23)
- **Stdev** =STDEV(B4:B23)

After you have finished, your spreadsheet should look like Figure 19, with the answers to each formula in cells F5–F12.
4. In cell F13, use the LARGE function to compute the 4th largest body mass. The LARGE function returns the \( k \)th largest value in a range of cells. In this case, the range of cells is C4–C22, and \( k = 4 \). Your formula should read \( =LARGE(C4:C22,4) \), and the answer should be 465.

5. In cell F14, use the RAND formula to generate a random number between 0 and 1. You will use the RAND function in many of the exercises in this course. This function has the form \( =RAND() \). The \( ( \) and \( ) \) are open and closed parentheses; you do not need to put anything inside them.

6. In cell F15, use the RANDBETWEEN function to generate a random number between 1 and 19. The RANDBETWEEN function generates a random integer between 2 specified values. The bottom value is the lowermost integer that can be randomly selected (1), and the top value is the uppermost integer that can be randomly selected (19). This function could be used to randomly select an individual from the population. The formula in cell F15 should read \( =RANDBETWEEN(C4,C22) \) or \( =RANDBETWEEN(1,20) \).

7. Press F9, the Calculate key, to generate new random numbers in cells F14 and F15. The F9 key is located at the top of your keyboard. When this button is pushed, the spreadsheet will recalculate all of the formulae in the spreadsheet. For random numbers, such as those generated by the RAND or RANDBETWEEN functions, a new random...
number will be generated when the spreadsheet is calculated. Verify this by examining the results in cells F14–F15 each time you press F9.

8. Save your work.

C. Compute multistep and nested functions.

Now we will turn to nested functions and multi-step functions. Multi-step functions are actually standard functions like **SUM**, **MIN**, and **MAX**, but there are more entries involved in the Formula Arguments. A function is nested if it uses >1 function to complete the calculations.

1. Set up new headings in cells G3-G13 as shown in Figure 20.

![Figure 20](image)

2. In cell H5, use the **COUNTIF** formula to count the number of times the modal value (201, given in cell F9) occurs. We will use the **COUNTIF** formula extensively. It counts the number of times a specific value occurs within a range of cells. Your formula should read

   \[
   =\text{COUNTIF(C4:C22,F9)}
   \]

   in cell H5, and your result should be 2, indicating that 2 bears of the 19 in our data set, weigh 201 lb.

3. In cell H6, use the **AND** function to determine if the value in cell C4 = 201 and the value in cell C5 = 93. The **AND** function returns the word TRUE or FALSE. It returns the word TRUE if all of the arguments in the formula are true (cell C4 = 201 and cell C5 = 93). If either condition is
not true, the spreadsheet returns the word FALSE. Your formula should read \( =\text{AND}(C4=201, C5=93) \). Your result should be TRUE.

4. In cell H7, use the OR function to determine if the value in cell C5 is either 90 or 95. The OR function is similar to the AND function in that it returns the word TRUE or FALSE. It returns the word TRUE if any of the arguments in the formula are true (cell C5 = 90 or cell C5 = 95). Your result should be FALSE.

5. In cell H8, use the CONCATENATE function to join the text in cell G6 with the text in cell G7. The CONCATENATE function joins several text strings into a single text string. The formula \( =\text{CONCATENATE}(G6, G7) \) should return the word “AndOr.” This does not mean anything, but serves to illustrate the function. We will use this function in some of the exercises. By the way, the formula \( =G6\&G7 \) would generate the same result.

6. In cell H9, use the VLOOKUP function to return the body mass of, say, bear 10. The VLOOKUP function searches in the column you specify for a value you specify and returns the value of the corresponding cell in a different column.

The VLOOKUP function needs 3 pieces of information:

- the value you want to find in the 1st column;
- the cells that define the table (the upper-left and lower-right cells of the table); and
- the number of the column in the table that holds the information you want the formula to return.

For example, the formula \( =\text{VLOOKUP}(10, A1:C22, 3) \) looks for the number 10 in the 1st column of the table defined by cells A1–C22, and it returns the value of the cell from the same row in the 3rd column. In our spreadsheet, this formula returns the body mass of bear 10.

7. In cell H10, use the NORMINV function to draw a random data point from a distribution whose mean \( (\bar{x}) \) is given in cell F7, and whose standard deviation (SD) is given in cell F12. Since here you will use the RAND function within the NORMINV function, this is a nested formula.
Generally speaking, for a set of normally distributed data, the function will generate a data value if you specify a probability associated with a normal curve. The function in cell H10 should read  
=\text{NORMINV}(\text{RAND()},\text{F7},\text{F12}).

In this case, we will first generate a random probability between 0 and 1. This probability will be applied to a normal distribution whose \( \bar{x} \) is given in cell F7 and whose SD is given in cell F12. The spreadsheet will then return the data value associated with that probability. Note when you press F9, the Calculate key, a new random number is computed, and thus a new random data point from the normal distribution is drawn.

8. In cell H11, use the \texttt{ROUND} function to round cell H10 to 0 decimal places. Your formula should read  \texttt{=ROUND(H10,0)}. Once you are familiar with this function, you may find yourself typing it in by hand.

9. In cell H12, use an \texttt{IF} function to return the number 0 if cell H11 is a negative number. Your formula should read,  \texttt{=IF(H11<0,0,H11)}. This tells the spreadsheet to evaluate the value in cell H11; if the number is < 0, return a 0; otherwise, return the number given in cell H11. This formula will prevent the spreadsheet from generating negative numbers.

10. In cell H13, use the \texttt{VLOOKUP} function to look up the body mass of the randomly selected individual listed in cell F15. Your formula should read  \texttt{=VLOOKUP(F15,A1:C22,3)}.

11. Save your work.

D. Utilize an array function.

1. Set up new headings in columns I and J as shown in Figure 21.
2. Select cells J6–J11. Use the **FREQUENCY** function to generate frequency data of the grizzly bear body masses in our data set. Use the bins in cells I6–I11. Remember that the **FREQUENCY** function is an array function.

In our example, each bin may “hold” several numbers. The bin labeled 100 holds the number of bear body masses that are \( \leq 100 \) lb. The bin labeled 200 holds the number of body masses that are 101-199 lb.

Don’t forget that to enter an array function such as the **FREQUENCY** function, you must press `<Control>+<Shift>+<Enter>` to generate a proper result. Cells J6–J11 should have the formula `{=FREQUENCY(C4:C22,I6:I11)}`.

3. Create a frequency histogram of the data in cells J6–J11. Label your axes appropriately (Figure 22).

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<table>
<thead>
<tr>
<th>Bear No.</th>
<th>Age (yr)</th>
<th>BM (lb)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
<td>209</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.5</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>209</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3.5</td>
<td>465</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>4.5</td>
<td>256</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4.5</td>
<td>395</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>5.5</td>
<td>258</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>5.5</td>
<td>311</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>7.5</td>
<td>375</td>
<td></td>
</tr>
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<td>7.5</td>
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<td>560</td>
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</tr>
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<td>16</td>
<td>7.5</td>
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<td>1</td>
</tr>
<tr>
<td>17</td>
<td>12.5</td>
<td>434</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>14.9</td>
<td>621</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>22.5</td>
<td>556</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 21*
4. Double-check your results. Your spreadsheet should now look as shown in Figure 22. Note that you will likely have different values in cells F14–F15, H10–H11, and H13 because random numbers are used to generate the results shown.

5. Save your work.

E. Write a macro to randomly select individuals from the population.

Now we will write a macro to randomly select an individual from the population, and we will record its body mass in column N. We will do this for 19 samples. Remember that you generated a random number between 1 and 20 in cell F15. You also looked up this randomly selected individual’s body mass with the \texttt{VLOOKUP} function in cell H13. In the macro you are going to write now, we will press F9 to generate a new randomly selected individual, then we will copy the value in cell H13 into cell N6. We will repeat the process for the second sample, but we will record the body mass of the randomly selected individual in cell N7 (and so on through cell N24).

1. Set up new headings in columns M and N as shown in Figure 23.
2. Write a macro to record the body masses of 19 randomly sampled bears from the population. There are many ways you can construct a macro to complete this task; here is 1 suggestion:

3. Select **Developer | Record Macro**. A dialog box will appear (Figure 24). Enter in a macro name (such as **Bear**) and a shortcut key (such as `<Control>+<b>`). Click **OK**.

4. Press **F9**, the calculate key, to generate a new randomly selected body mass. Select cell **H13**, the body mass of the randomly selected bear. Right click, then **Copy**.

5. Select cell **N5**, the top row of the body mass column.
6. Open **Home | Find and Select | Find**. A **Find and Replace** dialog box will appear (Figure 25).

![Find and Replace dialog box](image)

*Figure 25*

7. Leave the **Find what** box empty. Click the **Options >>** button in the lower right corner of the box to see more search options.

8. Select the **Search By Columns** option. Select **Find next**, then **Close**. Your cursor should have moved down to the next empty cell on your spreadsheet (N6).

9. Right click on cell **N6**. Select **Paste Special | Paste Values | Values**.

10. Click on **Developer | Stop Recording**.

11. That’s all there is to it. Now when you press the shortcut keys, `<Control>+<b>`, the spreadsheet will repeat the steps in the macro automatically. Run your macro until you have obtained the body masses of 19 randomly sampled bears in row N (Figure 26). Note that with this process, some bears in our population may be sampled more than once.
Now You Do It!

On your own, complete the steps below as indicated. Your laboratory report should include the following: (1) a paragraph explaining the objectives of this exercise, and (2) your graphs and answers to the 2 discussion questions below. Email me (whited@uamont.edu) your spreadsheet (but not your lab report). Turn in your lab report during lab next week.

1. Explore the formulae used in the exercise by changing some of the bear body masses. For example, change the body masses of bears 2 and 5 to 300 and 350 lb, respectively. How does this change affect the outcome of the AND and OR functions? Change other values in the data set as well. How do your changes affect the frequency distribution of the data?

2. Click on the $fx$ and select the function category ALL. A list of all functions is displayed. Click on a function that looks interesting, and notice the description of the function that appears in the lower portion of the dialog box. Select 3 functions that were not used in this exercise and explore how each function works. Choose functions that are likely to be relevant to the data set in the exercise.

3. You hypothesize that there is a relationship between grizzly bear age and body mass. How would you test your hypothesis? Do it.
Acknowledgement