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CHAPTER 1

Introduction to Spreadsheets

For many real-world problems, spreadsheets are the perfect tool. In this chapter, you will be introduced to how to use a spreadsheet. There are numerous spreadsheet programs: Google Sheets, Microsoft Excel, Apple Numbers, OpenOffice Calc, etc. All of them are very similar. This instruction will use Google Sheets, but if you are using one of the others, you should be able to follow along.

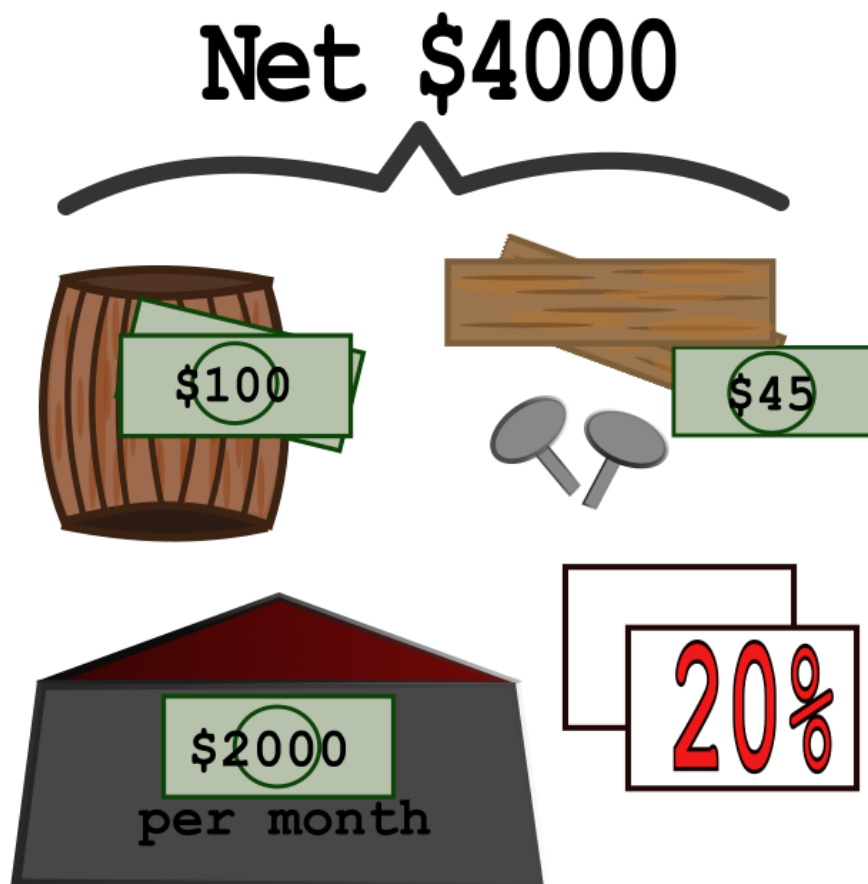
The first spreadsheet program (VisiCalc) was introduced in 1979 as a tool for finance people to play “what if” games. For example, a company might make a spreadsheet that told them how much more profit they would make if they changed from using an expensive metal to using a cheaper alloy.

In honor of its history, let’s start by studying a business question: I have a friend who dreams of quitting her job to become a cooper. (A cooper makes barrels that are used for aging wine and whiskey.) She says:

- It costs \$45 dollars in materials to build one barrel.
- A barrel sells for \$100 dollars.

- The workshop/warehouse she wants to rent costs \$2000 per month.
- Taxes take 20% of her profits.
- She needs to make \$4000 monthly after taxes.

She has asked you, “How many barrels do I need to make each month?”



1.1 Solving It Symbolically

Many problems can be solved two ways: symbolically or numerically. To solve this problem symbolically, you would write out the facts as equations or inequalities and then do symbol manipulations until you ended up with an answer. In this case, you would let b be the number of barrels and create the following inequality:

$$(1.0 - 0.2)(b(100 - 45) - 2000) \geq 4000$$

You would simplify it:

$$(0.8)(55b - 2000) \geq 4000$$

And simplify it more:

$$44b - 1600 \geq 4000$$

If that is true, then:

$$44b \geq 5600$$

And if that is true, then:

$$b \geq \frac{1400}{11}$$

1400/11 is about 127.27, so she needs to make and sell 128 barrels each month.

That is a perfect answer, and we didn't need a spreadsheet at all. Two things:

- As problems get larger and more realistic, it gets much more difficult to solve them symbolically.
- As soon as you say "Yes, you need to make and sell 128 barrels each month." Your friend will ask "What if I make and sell 200 barrels? How much money will I make then?"

So we use a spreadsheets to solve the problem numerically.

1.2 Solving It Numerically (with a spreadsheet)

Let's get back to our example. Put labels in the A column:

- Barrels produced (per month)

- Materials cost (per barrel)
- Sale price (per barrel)
- Pre-tax earnings (per month)
- Taxes (per month)
- Take home pay (per month)

Format them any way you like. It should look something like this:

	A
1	Barrels Produced (per month)
2	Materials cost (per barrel)
3	Sale price (per barrel)
4	Rent (per month)
5	Pretax Earnings (per month)
6	Taxes (per month)
7	Take home pay (per month)
8	

In the B column, the first four cells are values (not formulas):

- 115 formatted as a number with no decimal point
- 45 formatted as currency
- 100 formatted as currency
- 2000 formatted as currency

It should look something like this:

	A	B
1	Barrels Produced (per month)	115
2	Materials cost (per barrel)	\$45.00
3	Sale price (per barrel)	\$100.00
4	Rent (per month)	\$2,000.00

The next three cells in the B column will have formulas:

- $B1 * (B3 - B2) - B4$
- $0.2 * B5$
- $B5 - B6$

It should look something like this:

	A	B
1	Barrels Produced (per month)	115
2	Materials cost (per barrel)	\$45.00
3	Sale price (per barrel)	\$100.00
4	Rent (per month)	\$2,000.00
5	Pretax Earnings (per month)	\$4,325.00
6	Taxes (per month)	\$865.00
7	Take home pay (per month)	\$3,460.00
8		

Now you can share this spreadsheet with your friend and she can put different values into the cells for what-if games. Like “If I can get my materials cost down to \$42 per barrel, what happens to my take home pay?”

Sometimes it is nice to show a range of values for a variable or two. In this case, it might be nice to show your friend what the numbers look like if she produces 115, 120, 125, 130, 135, or 140 barrels per month.

We have one column, and now we need six. How do we duplicate cells?

1. Click B1 to select it and then shift-click on B7 to select all seven cells.
2. Copy them. (There is probably a menu item for this.)
3. Click C1 to select it
4. Paste them.

	A	B	C
1	Barrels Produced (per month)	115	115
2	Materials cost (per barrel)	\$45.00	\$45.00
3	Sale price (per barrel)	\$100.00	\$100.00
4	Rent (per month)	\$2,000.00	\$2,000.00
5	Pretax Earnings (per month)	\$4,325.00	\$4,325.00
6	Taxes (per month)	\$865.00	\$865.00
7	Take home pay (per month)	\$3,460.00	\$3,460.00
8			

We want the first cell in the new column to be 120. You could just type in 120, but let's do something more clever. Put a formula into that cell: $= B1 + 5$. Now the cell should show 120.

Why did we put in a formula? When we duplicate this column, this cell will always have 5 more barrels than the cell to its left.

Now let's duplicate the second column a few times. The easy way to do this is to select the cells as you did before and drag the lower-right corner to the right until column G is in the selection. When you end the drag, the copies will appear:

	A	B	C	D	E	F	G
1	Barrels Produced (per month)	115	120	125	130	135	140
2	Materials cost (per barrel)	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00
3	Sale price (per barrel)	\$100.00	\$100.00	\$100.00	\$100.00	\$100.00	\$100.00
4	Rent (per month)	\$2,000.00	\$2,000.00	\$2,000.00	\$2,000.00	\$2,000.00	\$2,000.00
5	Pretax Earnings (per month)	\$4,325.00	\$4,600.00	\$4,875.00	\$5,150.00	\$5,425.00	\$5,700.00
6	Taxes (per month)	\$865.00	\$920.00	\$975.00	\$1,030.00	\$1,085.00	\$1,140.00
7	Take home pay (per month)	\$3,460.00	\$3,680.00	\$3,900.00	\$4,120.00	\$4,340.00	\$4,560.00

Nice, right? Now your friend can easily see how many barrels correspond to how much take-home pay. Do you know what would be really helpful? A graph.

1.3 Graphing

Graphing is a little different on every different platform. Here is what you want the graph to look like.

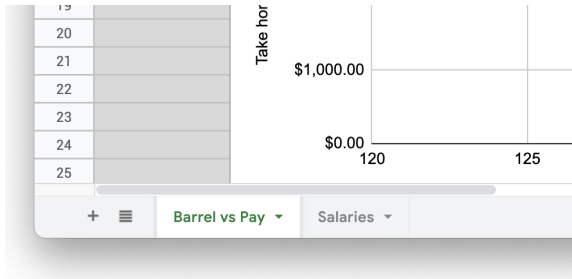


On Google Sheets:

1. Select cells B7 through G7.
2. Choose the menu item Insert -> Chart.
3. Choose the chart type (Line)
4. Add the X-axis to be B1 through G1.
5. Under the Customize tab, Set the label for the X-axis to be "Barrels Made and Sold".
6. Delete the chart title (which is the same as the Y-axis label).

1.4 Other Things You Should Know About Spreadsheets

Your spreadsheet document can have several “Sheets”. Each has its own grid of cells. The sheet has a name; usually, you call it something like “Salaries”. When you need to use a value from the “Salaries” sheet in another sheet, you can specify “Salaries!A2” – that is, cell A2 on sheet “Salaries”. To flip between the sheets there is usually a tab for each at the bottom of the document.



By default, the cell references are relative. That is when you write a formula in cell H5 that references the value in cell G4, the cell remembers “The cell that is one up and one to the left of me.” Thus, if you copy that formula into B9, now that formula reads the value from A8.

If you want an absolute reference, you use \$. If H5 references \$G\$4, G4 will be used no matter where on the sheet the formula is copied to.

You can use the \$ on the row or column. In \$A4, the column is absolute and the row is relative. In A\$4, the row is absolute and the column is relative.

1.5 Challenge: Make a spreadsheet

You have a company that bids on painting jobs. Make a spreadsheet to help you do bids. Here are the parameters:

- The client will tell you how many square meters of wall needs to be painted.
- Paint costs \$0.02 per square meter of wall
- On average, a square meter of wall takes 0.02 hours to paint.
- You can hire painters at \$15 per hour.
- You add 20% to your estimated costs for a margin of error and profit.

Make a spreadsheet such that when you type in the square meters to be painted, the spreadsheet tells you how much you will spend on paint and labor. It also tells you what your bid should be.



CHAPTER 2

Compound Interest

When you loan money to someone, you typically charge them some sort of interest. The most common loan of this sort is what the bank calls a “savings account”. Any money you put in the account is loaned to the bank. The bank then lends it to someone else, who pays interest to the bank. And the bank gives some of that interest to you. However, what if you leave the interest in your account? And you start making *interest on the interest*? This is known as *compound interest*.

2.1 An example with annual interest payments

Let’s say that you put \$1000 in a savings account that pays 6% interest every year. How much money would you have after 12 years? Let’s make a spreadsheet.

	A	B	C
1	Interest Rate	6.00%	
2			
3	After year:	Interest	Balance
4	0	\$0.00	1000
5	1	\$60.00	\$1,060.00

Create a new spreadsheet and edit the cells to look like this. All the cells in rows 1 - 4 are just values: just type in what you see.

The fifth row is all formulas:

After year	Interest	Balance
= A4 + 1	= B\$1 * C4	= C4 + B5

The interest rate field should be formatted as a percentage. One thing to know when dealing with percentages in the spreadsheet: if the field says “600%”, its value is 6.

The cells in the Interest and Balance column should be formatted as currency.

You are about to make a bunch of copies of the cells in the fifth row, so make sure they look right.

Click on A5 and shift-click on C5 to select all three cells. Drag the lower-right corner down to fill the rows 6 - 15.

A5:C16	fx	= A4 + 1		
	A	B	C	
1	Interest Rate	6.00%		
2				
3	After year	Interest	Balance	
4	0	\$0.00	1000	
5	1	\$60.00	\$1,060.00	
6	2	\$63.60	\$1,123.60	
7	3	\$67.42	\$1,191.02	
8	4	\$71.46	\$1,262.48	
9	5	\$75.75	\$1,338.23	
10	6	\$80.29	\$1,418.52	
11	7	\$85.11	\$1,503.63	
12	8	\$90.22	\$1,593.85	
13	9	\$95.63	\$1,689.48	
14	10	\$101.37	\$1,790.85	
15	11	\$107.45	\$1,898.30	
16	12	\$113.90	\$2,012.20	
17				

Look at the numbers. The first interest payment is \$60, but the last is \$113.90. Your balance has more than doubled!

2.2 Exponential Growth

We figured this out numerically by repeatedly multiplying the balance by the interest rate. What if you wanted to know what the balance would be n years after investing P_0 dollars

with an annual interest rate of r ? (Note that r in our example would be 0.06, not 6.0.)

Each year, the balance is multiplied by $1+r$, so after one year, P_0 would become $P_0 \times (1+r)$. The next year you would multiply this number by $(1+r)$ again: $P_0 \times (1+r) \times (1+r)$. The next year? $P_0 \times (1+r) \times (1+r) \times (1+r)$ See the pattern? P_n is this balance after n years, then

$$P_n = P_0(1+r)^n$$

Because n is an exponent, we call this *exponential growth*. And there are few things as terrifying to a scientist as the phrase “The population is undergoing exponential growth”.

2.3 Sensitivity to interest rate

For most people, the first surprising thing about compound interest is how quickly your money grows after a few years. The second thing that is surprising is how much difference a small change in the percentage rate makes.

Let’s add another set of columns that shows what happens to your money if you convince the bank to pay you 8% instead of 6%.

Copy everything from columns B and C:

	A	B	C	D	E
1	Interest Rate	6.00%		6.00%	
2					
3	After year	Interest	Balance	Interest	Balance
4	0	\$0.00	1000	\$0.00	1000
5	1	\$60.00	\$1,060.00	\$60.00	\$1,060.00
6	2	\$63.60	\$1,123.60	\$63.60	\$1,123.60
7	3	\$67.42	\$1,191.02	\$67.42	\$1,191.02
8	4	\$71.46	\$1,262.48	\$71.46	\$1,262.48
9	5	\$75.75	\$1,338.23	\$75.75	\$1,338.23
10	6	\$80.29	\$1,418.52	\$80.29	\$1,418.52
11	7	\$85.11	\$1,503.63	\$85.11	\$1,503.63
12	8	\$90.22	\$1,593.85	\$90.22	\$1,593.85
13	9	\$95.63	\$1,689.48	\$95.63	\$1,689.48
14	10	\$101.37	\$1,790.85	\$101.37	\$1,790.85
15	11	\$107.45	\$1,898.30	\$107.45	\$1,898.30
16	12	\$113.90	\$2,012.20	\$113.90	\$2,012.20
17					

Now edit the second interest rate to be 8%:

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	A	B	C	D	E
1	Interest Rate	6.00%		8.00%	
2					
3	After year	Interest	Balance	Interest	Balance
4	0	\$0.00	1000	\$0.00	1000
5	1	\$60.00	\$1,060.00	\$80.00	\$1,080.00
6	2	\$63.60	\$1,123.60	\$86.40	\$1,166.40
7	3	\$67.42	\$1,191.02	\$93.31	\$1,259.71
8	4	\$71.46	\$1,262.48	\$100.78	\$1,360.49
9	5	\$75.75	\$1,338.23	\$108.84	\$1,469.33
10	6	\$80.29	\$1,418.52	\$117.55	\$1,586.87
11	7	\$85.11	\$1,503.63	\$126.95	\$1,713.82
12	8	\$90.22	\$1,593.85	\$137.11	\$1,850.93
13	9	\$95.63	\$1,689.48	\$148.07	\$1,999.00
14	10	\$101.37	\$1,790.85	\$159.92	\$2,158.92
15	11	\$107.45	\$1,898.30	\$172.71	\$2,331.64
16	12	\$113.90	\$2,012.20	\$186.53	\$2,518.17
17					



CHAPTER 3

Introduction to Data Visualization

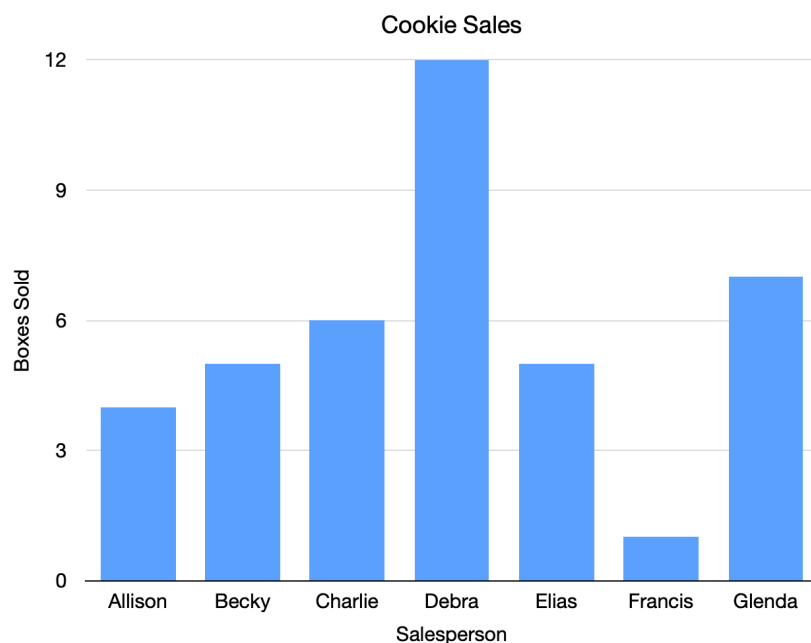
It is difficult for the human mind to look at a list of numbers and identify the patterns in them, so we often make pictures with the numbers. These pictures are called *graphs*, *charts*, or *plots*. Often the right picture can make the meaning in the data obvious. *Data visualization* is the process of making pictures from numbers.

3.1 Common Types of Data Visualizations

Depending on the type of data and what you are trying to demonstrate about it, you will use different types of data visualizations. How many types of data visualizations are there? Hundreds, but we will concentrate on just four: The bar chart, the line graph, the pie chart, and the scatter plot.

3.1.1 Bar Chart

Here is an example of a bar chart.



Each bar represents the cookie sales of one person. For example, Charlie has sold 6 boxes of cookies, so the bar goes over Charlie's name and reaches to the number 6.

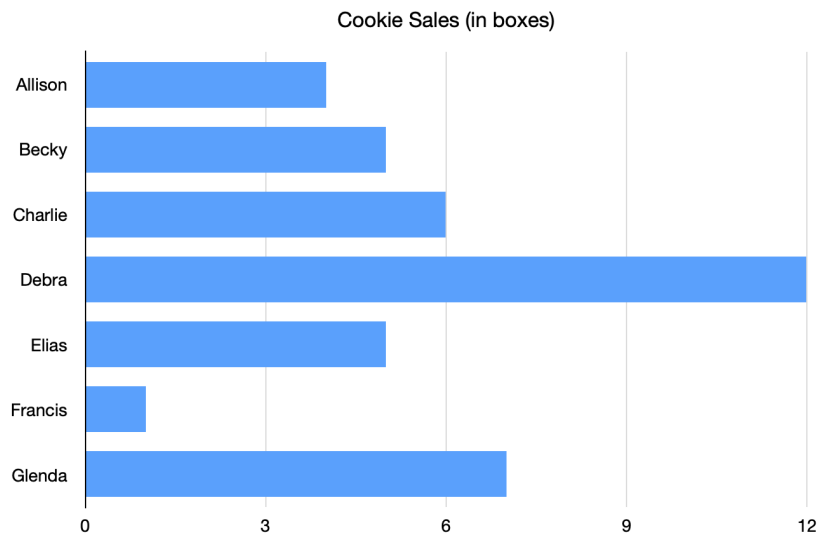
Looking at this chart, you probably think, "Wow, Debra has sold a lot more cookies than anyone else, and Francis has sold a lot fewer."

The same data could be in a table like this:

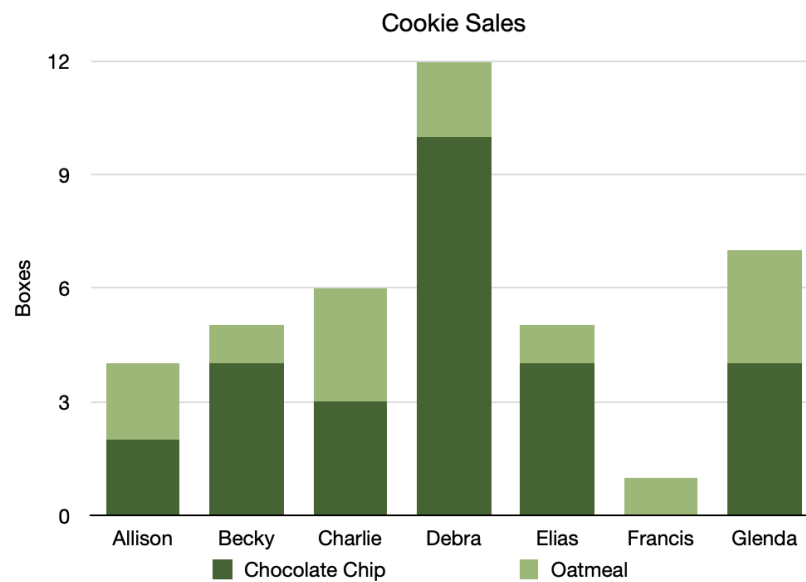
Salesperson	Boxes Sold
Allison	4
Becky	5
Charlie	6
Debra	12
Elias	5
Francis	1
Glenda	7

The table (especially a large table) is often just a bunch of numbers. A chart helps our brains understand what the numbers mean.

Bar charts can also go horizontally.



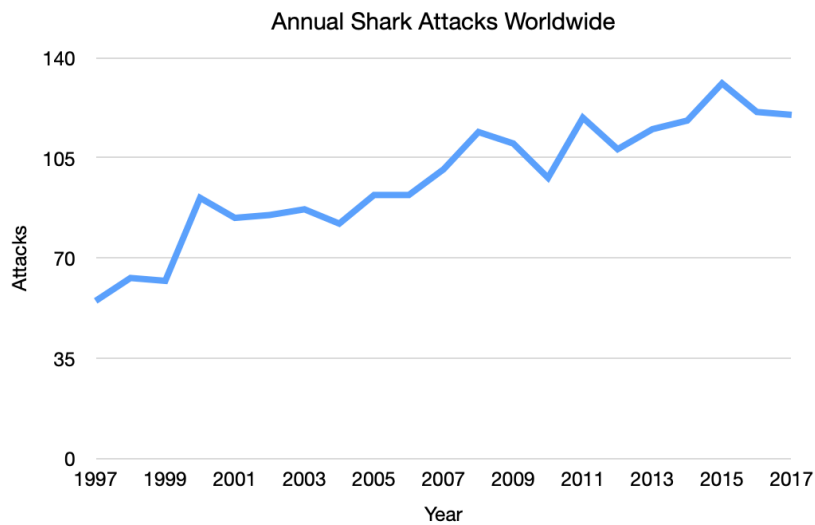
Sometimes we use colors to explain what contributed to the number.



This tells us that Becky sold more boxes of chocolate chip cookies than boxes of oatmeal cookies.

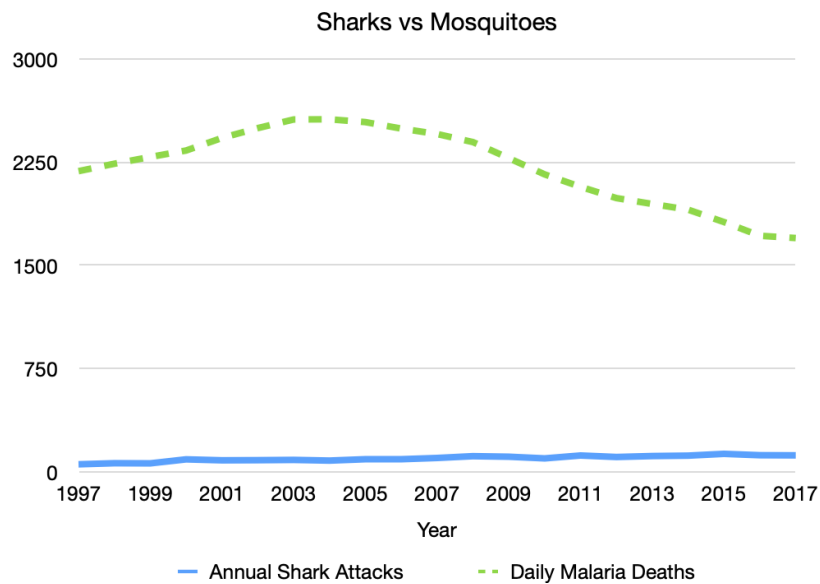
3.1.2 Line Graph

Here is a line graph.



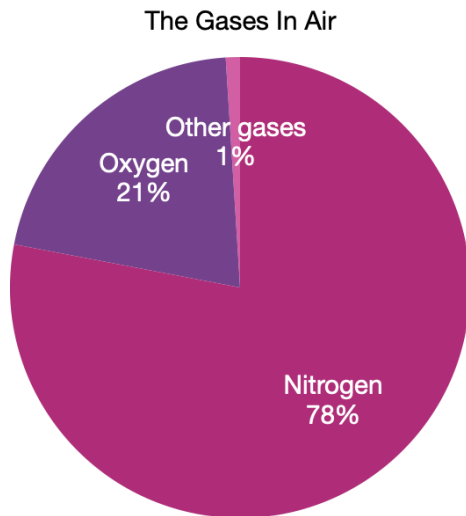
These are often used to show trends over time. Here, for example, you can see that the number of shark attacks has been increasing over time.

You can have more than one line on a graph.



3.1.3 Pie Chart

You use a pie chart when you are looking at the comparative size of numbers.



3.1.4 Scatter Plot

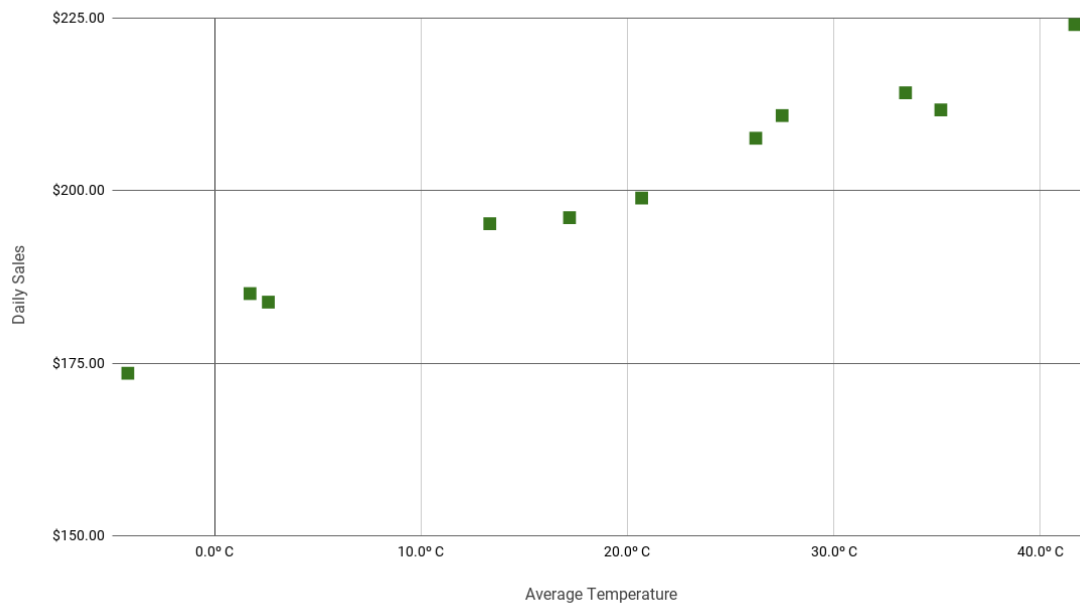
Sometimes you have a bunch of data points with two values and you are looking for a relationship between them. For example, maybe you write down the average temperature and the total sales for your lemonade stand on the 15th of every month:

Date	Avg. Temp.	Total Sales
15 January 2022	2.6° C	\$183.85
15 February 2022	-4.2° C	\$173.56
15 March 2022	13.3° C	\$195.22
15 April 2022	26.2° C	\$207.61
15 May 2022	27.5° C	\$210.88
15 June 2022	31.3° C	\$214.18
15 July 2022	33.5° C	\$215.23
15 Aug 2022	41.7° C	\$224.07
15 September 2022	20.7° C	\$198.94
15 October 2022	17.2° C	\$196.10
15 November 2022	1.7° C	\$185.10
15 December 2022	0.2° C	\$188.70

And you think “I wonder if I sell more lemonade on hotter days?”

You might create a scatter plot. For each day, you put a mark that represents that temperature and the sales that day:

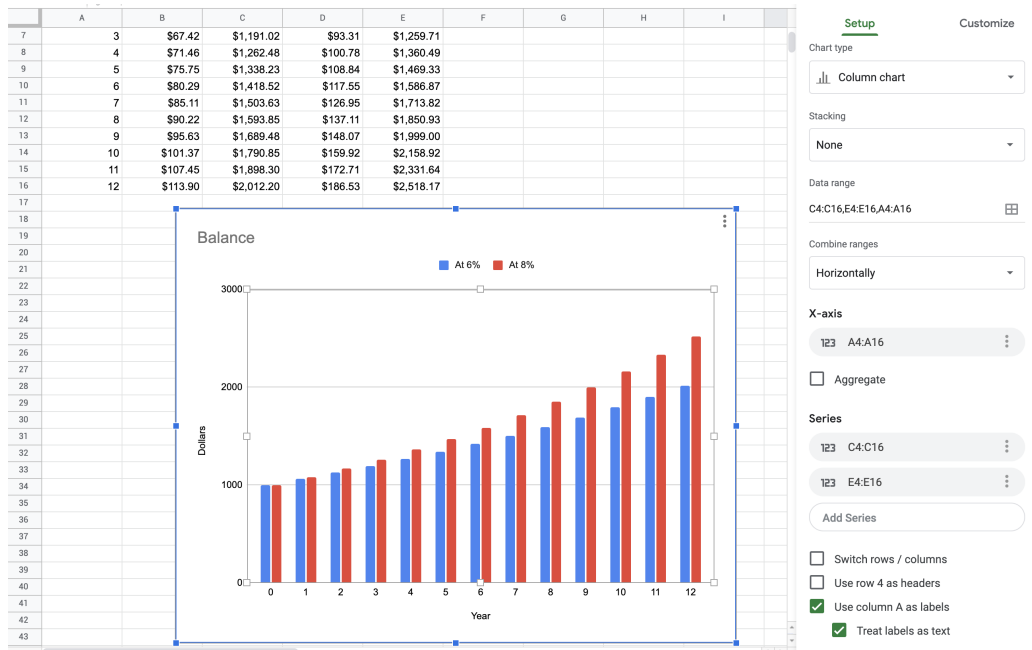
Temperature vs Lemonade Sales



From this scatter plot, you can easily see that you do sell more lemonade as the temperature goes up.

3.2 Make Bar Graph

Go back to your compound interest spreadsheet and make a bar graph that shows both balances over time:



The year column should be used as the x-axis. There are two series of data that come from C4:C16 and E4:E16. Tidy up the titles and legend as much as you like.

Looking at the graph, you can see the balances start the same, but balance of the account with the larger interest rate quickly pulls away from the account with the smaller interest rate.



APPENDIX A

Answers to Exercises



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