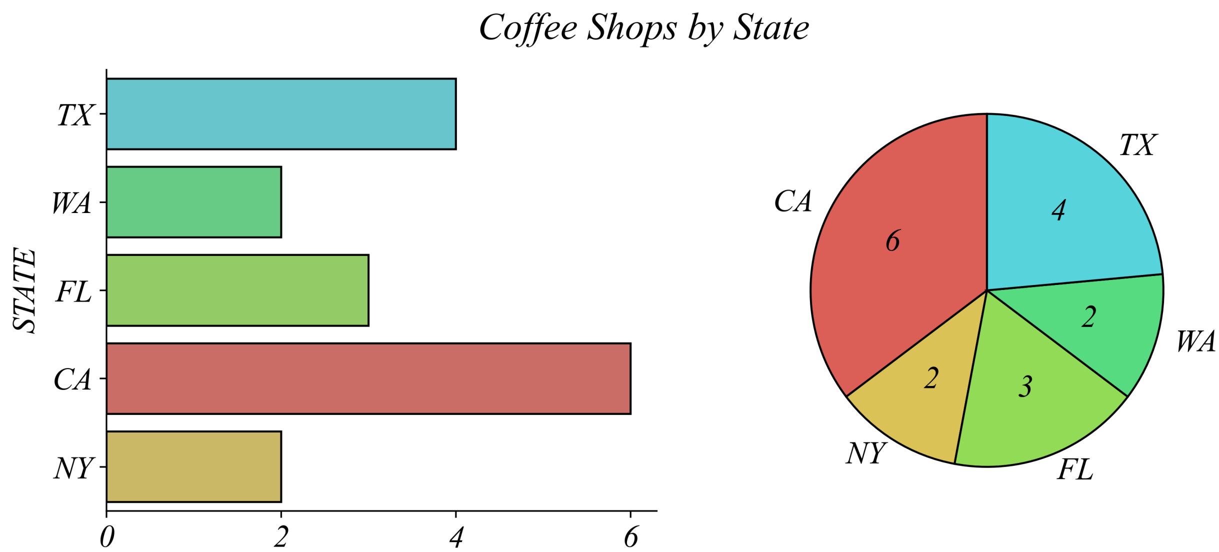
Notes 1.1 | Day 3 | Cross-Sectional (Categorical) Data

Choosing the right visualization is key for understanding and communicating data effectively. Let's say you are a data analyst advising a small coffee chain on where to start selling a new product. You can find the dataset: Coffee_Shops.csv. This dataset contains a **categorical variable** which indicates the state the shop operates in. Here are two visualizations of the number of chain locations across a few states: **bar chart** and a **pie chart**.

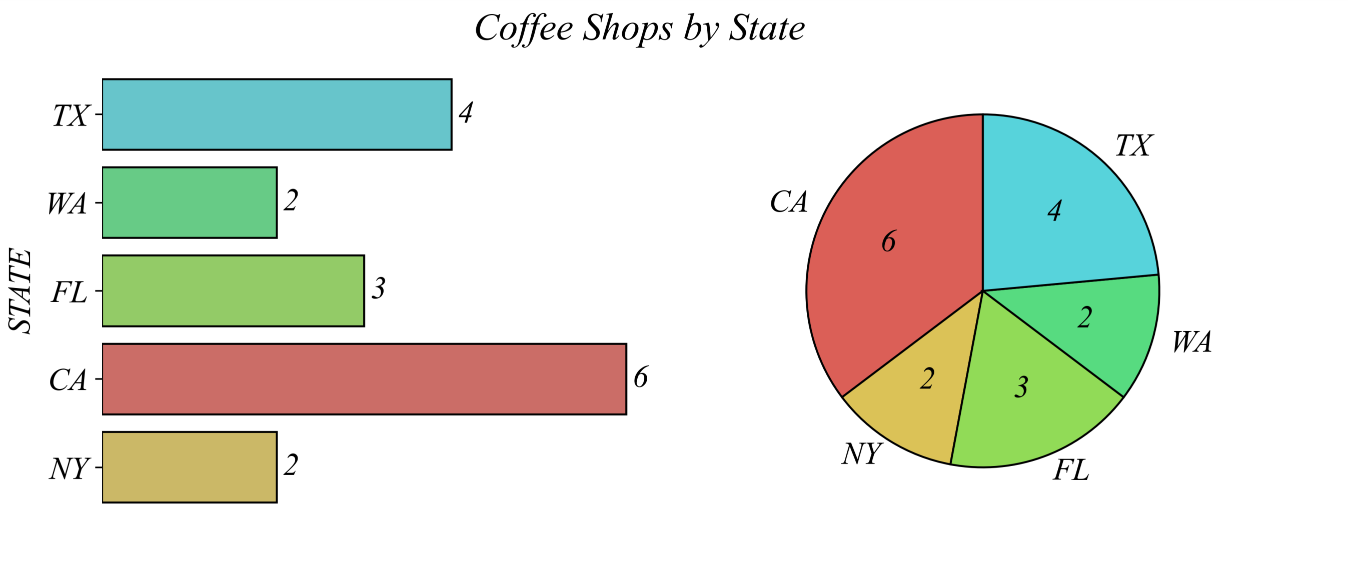


Does FL or WA have more shops?

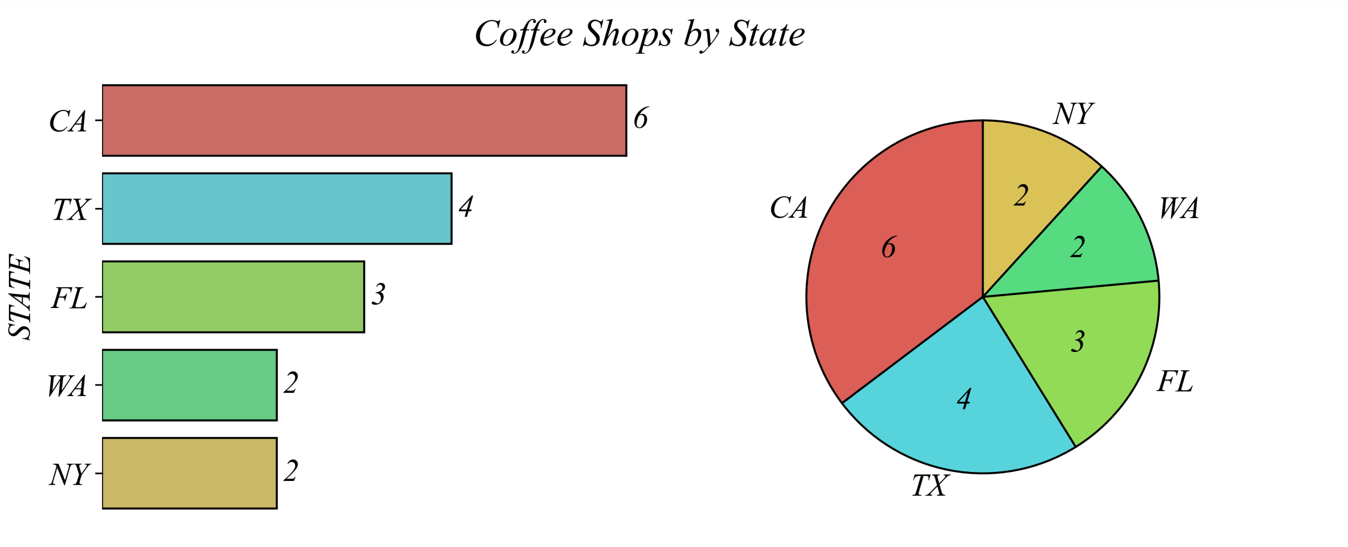
Which state has the most shops? It's easy to see from either chart that California (CA) has the most cafes, but not every comparison is this straightforward. For example, we might want to know whether Florida (FL) or Washington (WA) has more shops. In this case, the bar chart makes it much easier to see that FL has more shops than WA.

But we can make the figure better. When you look at the bar graph, you can easily see which of the two states has more shops, but it takes a second to read the exact numbers from the bar graph. We can make the bar graph easier to read by placing the number near the bar.

When asking "How many shops are in the state with the second most locations?", removing clutter guides your eye to the important information. Unnecessary elements like excessive grid lines or decorative features can distract from the key data.

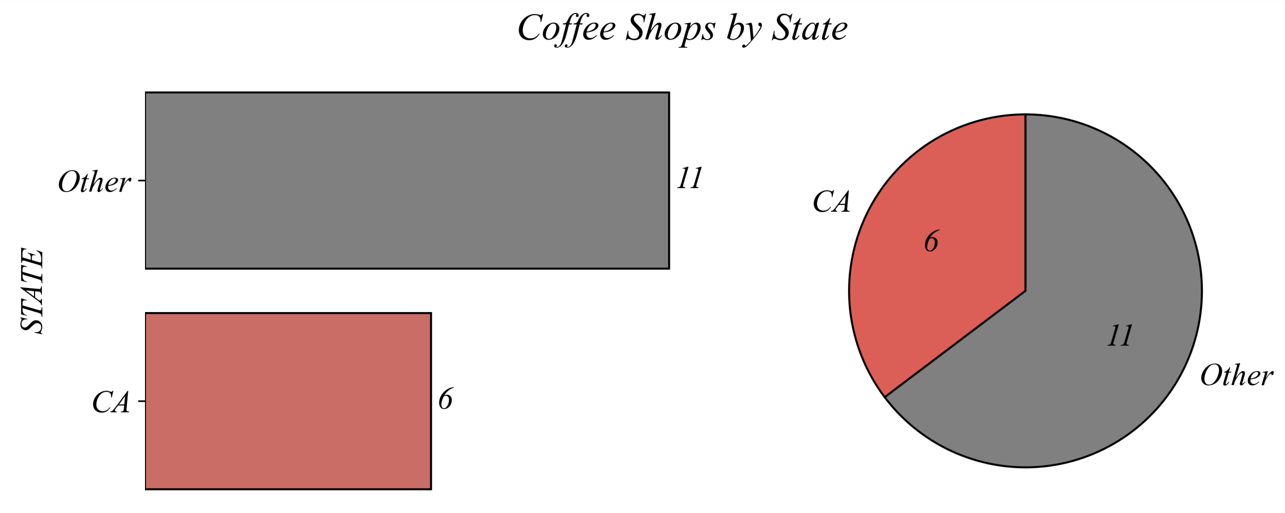


States have no inherent order, but sorting can make comparisons easier. We can arrange the bars from largest to smallest helps viewers quickly identify rankings and make comparisons. This helps us see relative sizes a bit more easily.

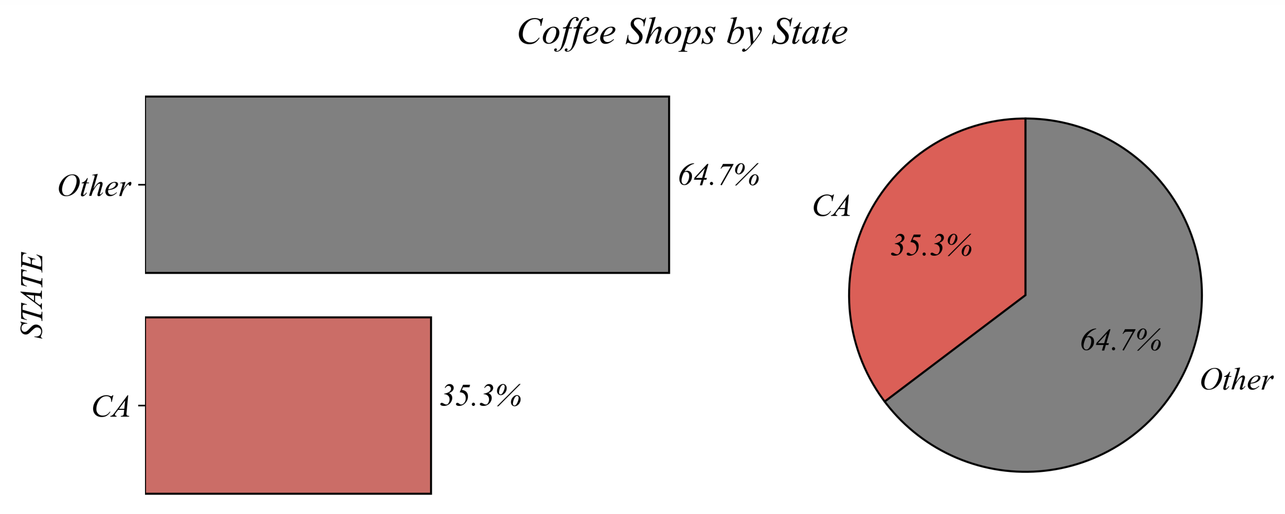


How does CA compare to the whole?

Sometimes we may want to ask a different kind of question. Instead of looking at all individual states, we might want to compare "CA vs Other". Instead of a nominal categorical variable with many categories, this creates a binary categorical variable (CA / Other). We can answer this question with the original figures, but this question is much easier to see when visualizing just the two categories. Here both a pie chart and a bar chart can communicate the data effectively.



But if we're trying to compare the share of shops that are in CA, a pie chart might work best. If the question is about percentages, a pie chart may work best because it naturally shows parts of a whole.



When presenting data, the best choice of chart depends on the comparison you want your audience to make.

Summary

- Binary Categorical Variables: use a **pie chart** or **bar graph**
- Nominal Categorical Variables: use a **bar graph**; maybe order by value
- Ordinal Categorical Variables: use an **ordered bar graph**

- Remove clutter; keep it simple

- Place information near the object it describes

Exercise 1.1 | Using Excel

Lets make some similar visualizations of the Coffee_Shops.csv dataset in Excel. The .csv file-type is a universal format which stands for "comma-separated values" and is one of the most used data formats. Open the file in Excel. Excel will likely show you a suggestion to convert the file to an Excel-specific format, xlsx. When working with Excel, it's often helpful to keep the csv file as your starting file and create a second file in the xlsx format. You can do this either by clicking on the notification bar or by going to Home and save as. You'll be propted to select the file format xlsx. Save as Coffee_Shops.xlsx.

The data is a single column with the title STATE and entries representing the state where the coffee shop is located. Since the data is categorical, before we can do either a bar chart or a pie chart, we need to summarize the frequencies of shops by state. We'll start by getting a list of all states in the sample using Excel's UNIQUE command. Pick a cell (eg. C5) to start a summary table with the column header "STATES". Then we can enter the following code into the cell below (eg. C6).

```
=UNIQUE(A2:A18)
```

This tells Excel to list out all the unique values contained in the data range between cell A2 and A18. Because we've entered this below the column header "STATES", this will create a nice column of all the unique states with coffee shop locations.

Next, we're going to count the number of coffee shops in each state. We'll do this with Excel's COUNTIF command. Start a new column next to "STATES" (eg. D5) and label it something like "SHOPS". Then in the cell below, use the COUNTIF command, using the data range and the state contained in the neighboring cell. With the example cell labels so far, enter the following in the cell below "SHOPS" (eg. D6):

```
=COUNTIF(A2:A18,C6)
```

This tells Excel to look at all the entries in the data range A2 to A18 and count the number of times the value in the cell C6 appears. In this example, earlier we constructed the cell C6 to contain one of the unique entries in the data range. Specifically, in this example it will contain "TX". This means the cell we just made (eg. D6) will tell us the number of coffee shops located in Texas (TX).

Finally, we want to use this command for all of the states in the list. We can do this in two ways. We should go through and write out each command for each row in the list of states. For example, the next cell could look like the following:

```
=COUNTIF(A2:A18,C7)
```

With a short list like this, it would be easy to do it manually like this. But sometimes lists are long and we might want to copy and paste the commands. The way the command is written, however, if we copy and past, it will move both the data range and the target text down the spreadsheet by one cell, giving the following incorrect command:

```
=COUNTIF(A3:A19,C7)
```

This misses the first entry in our data range. While in this case doesn't turn out to impact our numbers, it easily could. We can fix this problem by adding the "$" symbol to cell letters numbers we do not wish Excel to change when we copy and paste. So in the first cell in the "SHOPS" column (eg. D6), enter the following command:

```
=COUNTIF($A$2:$A$18,C6)
```

First, we'll make a bar chart with this frequency data. There are a couple ways to go about doing this. One way is to highlight the frequency data (including the column titles), go into the Insert tab, click on the bar chart button, and select a 2-d chart. This should produce a bar chart with the title "SHOPS" and bars with labels that correspond to their states. This is nice, but I think the figure looks nicer by reducing the clutter of horizontal grid lines. Simply click on the thing you'd like to remove and then hit delete. You can even rename the figure something like "Coffee Shop Locations" if you wish.

Second, we'll create a pie chart to highlight the share of coffee shops located in CA. To do this, we'll create another table with two rows right below our first frequency table. The first row will contain "CA" in a "STATE" column and a reference to the number of shops in the "SHOPS" column. Then in the second row, we'll count the number of total shops and subtract off the number of shops located in CA using the row above (eg. D13).

```
=COUNTIF(A2:A18,"*") - D13
```

The "*" in the COUNTIF command simply tells Excel to count all the text entries in the data range. Then we subtract off the number of shops located in CA, which is held in cell D13 in this example.

Then we can plot this data in a pie chart. Highlight the new frequency table and the column headers, go to the Insert tab, and click on 2-d pie chart. This produces a reasonable pie chart, but you can click on any element to modify it as you'd like.

Exercise 1.1 | Getting Started with Python

Now lets do this with Python. The steps are fundamentally the same as Excel. Except instead of clicking a bunch of things each time, we have code that does it for us in exactly the same way every time.

If you've never written code before, this might feel intimidating. It's not. Code is just a way of giving instructions to a computer. Instead of clicking buttons, you type out what you want to happen. That's it.

If you're like me, you may forget what you did with your data last time. When I work in Excel, I need to write down the steps I take so that if I need to go back, I can remember what I did. That's actually just what code does for us. It's a set of instructions we tell the computer. But instead of needing to follow those instructions ourselves, we just have the computer do them for us. And this allows us to easily communicate to others what we have done. We care about what we call 'Reproducible Science', and code is a big part of making sure others understand what we're doing and can easily copy our steps.

This is a set of powerful ideas that runs our modern world and runs modern science. And you will find it very useful in your projects not just this semester. There's a very good reason why we're spending time learning to think this way. It's not just for the nerds.

Notebooks

We use something called a notebook. You can find the Exercise 1.1 notebook on the course page — click on that link and it will open in Google Colab, running right in your browser. You can install Python on your computer, but for this class, there's really no need.

A notebook is a document with cells. Each cell is a little box. Some cells contain code. Some cells contain text. You run cells one at a time by clicking the play button or pressing Shift+Enter. When you run a code cell, the computer reads your instructions and does what you asked. The output appears right below the cell.

Here's the first thing that confuses people: cells run in the order you run them, not the order they appear on the page. If you skip a cell, the computer doesn't know about it. If you run cell 5 before cell 2, and cell 5 depends on something defined in cell 2, you'll get an error. The fix is simple: run cells from top to bottom, in order.

Variables

A variable is just a name that stores a value. When you write `x = 5`, you're telling the computer: remember the value 5 and call it x. The equals sign doesn't mean "equals" like in math. It means "assign." You're assigning the value 5 to the name x. Later, when you write `x`, the computer knows you mean 5.

You can store different types of things. Numbers are just numbers: `x = 5` or `y = 3.14`. Text needs quotes around it: `name = 'Taylor'` or `greeting = "Hello"`. The quotes tell the computer this is text, not a variable name. Without quotes, the computer would think Taylor is the name of some other variable and get confused.

You can do things with variables. With numbers, you can do math: `x + y` gives you 8 if x is 5 and y is 3. With text, you can combine them: `greeting + ' ' + name` gives you 'Hello Taylor'.

Here's another thing that confuses people: if you change a variable, you need to re-run the cells that use it. If you defined `x = 5` and then wrote `x + 10` which gave you 15, but then go back and change the first cell to `x = 100` without re-running it, the computer still thinks x is 5. You changed the text on the page, but you didn't tell the computer about it. Always re-run cells after making changes.

Functions

A function is something that does work for you. It has a name followed by parentheses. You put inputs inside the parentheses, and it gives you back an output. For example, `len('hello')` tells you how long the text is: the function is `len`, the input is `'hello'`, and the output is 5.

Some functions belong to objects. You'll see this written with a dot. When you write `df.head()`, you're saying: take the thing called df and run the head function on it. Think of it like "df's head" or "the head of df." This is how we work with data in Python.

Packages

Python on its own doesn't have everything you'd want. If it did, it would be a huge piece of software. So instead, we import external packages when we need them.

The data package we use is called `pandas`. It gives Python the ability to work with spreadsheets. At the top of the notebook, you'll see `import pandas as pd`. This loads pandas and gives it the nickname pd — just like my name is Taylor but some friends in college called me Little Tay. From then on, we use pd to access pandas functions.

The main thing pandas gives us is called a DataFrame. A DataFrame is just like a spreadsheet: rows and columns. To load data from a file, we write:

```
df = pd.read_csv('filename.csv')
```

This reads the file and stores the data in a variable called df. Now we can explore it:

- `df.head()` — shows the first few rows
- `df.shape` — tells you how many rows and columns
- `df.columns` — lists the column names
- `df['column_name']` — selects just one column
- `df['column_name'].unique()` — shows unique values in that column
- `df['column_name'].value_counts()` — counts how many of each value

Errors

Errors will happen. That's normal. When you see red text, read it. The last line usually tells you what went wrong:

- **NameError** — you're using a variable that doesn't exist yet, probably because you forgot to run an earlier cell
- **KeyError** — you're trying to access a column that doesn't exist, probably a typo
- **SyntaxError** — you wrote something the computer can't understand, probably a missing quote or parenthesis

The best way to learn is to experiment. Change things and see what happens. Break things on purpose. The notebook won't bite. If something stops working, you can always re-run all cells from the top and start fresh.

Exercise 1.1 | Python

As will be the case over and over again, doing these kinds of things is much simpler in python. Once we import the main packages and load the data, we can create a summary table and a nice figure very easily.

Lets start by creating a summary table using:

```
shops.value_counts()
```

This should print out a table of the counts by state. But it's easier to see this with a figure, so lets create a horizontal bar chart. We'll use the visualization package called Seaborn. We've nicknamed it sns. We have a bunch of data we want to count up by category, so we'll use the countplot.

```
sns.countplot(data=shops, y='STATE')
```

This tells python to use the dataset `shops`, count the categories in the column `STATE`, and then create bars coming off the y axis. This is really nice. But maybe we want to use colors to make it easier to visually separate the bars. We can just add a parameter into the function called 'hue' to tell python which column values to base the colors on.

```
sns.countplot(data=shops, y='STATE', hue='STATE')
```

There are lots of other things we can do to make this nicer. We have AI built into Google Colab, which can make figures look nicer that the basic figures.

Now lets make a figure of the binary categorical variable. Again in python this is very simple. Instead of doing a bunch of work in Excel, all we have to do is create a new column in `shops` called ['CA'], and have python enter a 'CA' if that row's 'STATE' value is equal 'CA' and 'Other' if its not equal. We can do this with a numpy function called 'where':

```
shops['CA'] = np.where(shops['STATE'] == 'CA', 'CA', 'Other')
```

So here we're defining the column `shops['CA']`. The function np.where() goes through every row, asking whether in that row, `shops['STATE'] == 'CA'`. If true, then it sets the value to `CA`. If False, it sets it to `Other`. We can see that this worked by printing out the dataset.

This gives us the binary categorical variable we wanted. You can get the counts using:

```
shops['CA'].value_counts()
```

If you like Pie Charts, you're out of luck with seaborn. In practice, we never really use them. If you do absolutely wish to, you can use the other plotting package called matplotlib. We can do this by just adding a `.plot(kind='pie')` to the end of value counts.

```
shops['CA'].value_counts().plot(kind='pie', autopct='%1.1f%%')
```

There's more you can do to make the figure look good. This is how I made the nice figures in the slides. But these are the basics, which is good enough for now.