Visualizing Data

Grinnell College

September 5, 2025

Goals for Class Today

We are going to learn how to do the following today:

1. Go over common graphics and when to use which
2. Give critique of graphic pitfalls
3. Describe the **distribution** of a variable
4. Make graphs that describe the relationship between 2 or more variables

Motivation: Tips Data

First 20 observations of the tips given to a waiter over the course of several months in a restaurant. Do more customers come to the restaurant on certain days?

Total Bill	Tip	Sex	Smoker	Day	Time	Size
13.42	1.58	Male	Yes	Fri	Lunch	2
16.27	2.50	Female	Yes	Fri	Lunch	2
10.09	2.00	Female	Yes	Fri	Lunch	2
20.45	3.00	Male	No	Sat	Dinner	4
13.28	2.72	Male	No	Sat	Dinner	2
22.12	2.88	Female	Yes	Sat	Dinner	2
24.01	2.00	Male	Yes	Sat	Dinner	4
15.69	3.00	Male	Yes	Sat	Dinner	3
11.61	3.39	Male	No	Sat	Dinner	2
10.77	1.47	Male	No	Sat	Dinner	2
15.53	3.00	Male	Yes	Sat	Dinner	2
10.07	1.25	Male	No	Sat	Dinner	2
12.60	1.00	Male	Yes	Sat	Dinner	2
32.83	1.17	Male	Yes	Sat	Dinner	2
35.83	4.67	Female	No	Sat	Dinner	3
29.03	5.92	Male	No	Sat	Dinner	3
27.18	2.00	Female	Yes	Sat	Dinner	2
22.67	2.00	Male	Yes	Sat	Dinner	2
17.82	1.75	Male	No	Sat	Dinner	2
18.78	3.00	Female	No	Thur	Dinner	2

We need something more than a data file to answer that

Claim

Most statistical analysis can be done graphically; the math is high-end filler

- If there is a relationship, it's usually visual
- If there isn't a relationship, it's usually visual
- Trick is finding the right graphics
- If I don't see the data somewhere in the paper I'm suspicious
  - And yes, it's easy to lie with graphics
- I'm basing this off of my time doing consulting work during grad school

Data Visualization

Why do we graph data?

- It (hopefully) allows us to interpret data...
  - quickly and
  - easily

What graph we use is dictated by

- the type of data
- the number of variables and
- what we are trying to convey (context)

Context

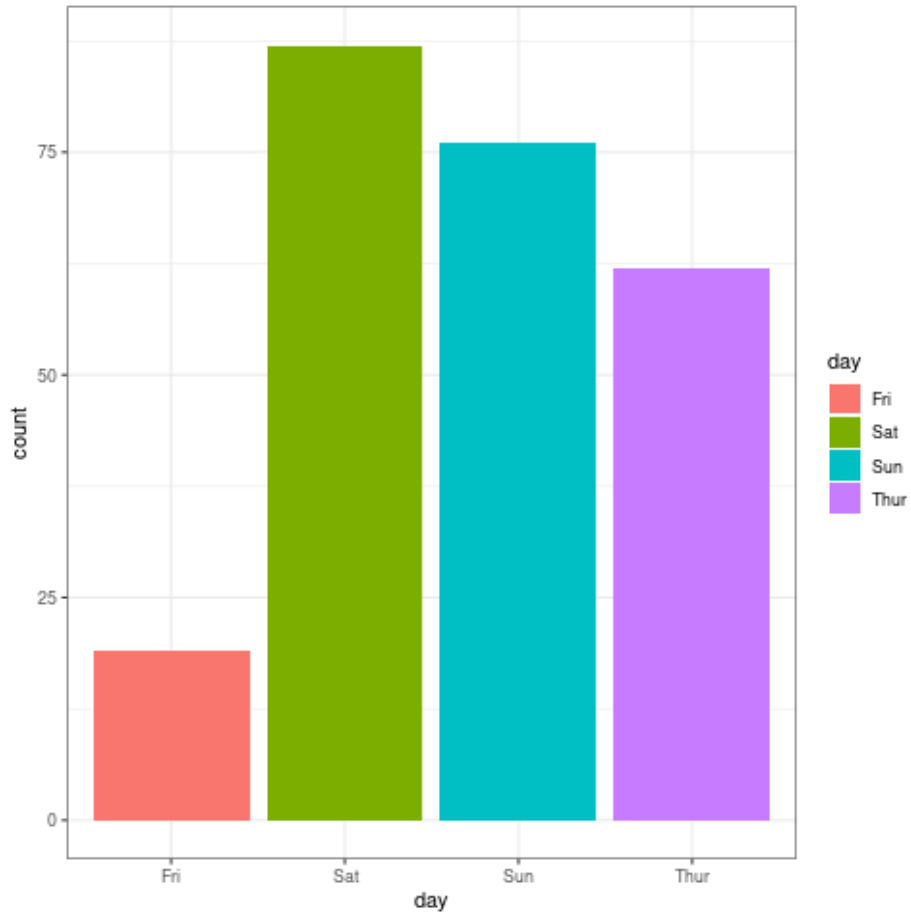
Context gives us the goal of what we want to convey from our data

- Eg If we are interested in the fastest 100m dashes in the Olympics over time we could plot the shortest time for each year
  - three numeric variables (all run times, shortest run times, and years)
  - The context lets us ignore "all run times"
  - More parsimonious

- Often, for a single variable, we are interested in the **distribution**
  - The distribution of a variable is the frequency certain values occur
  - Heavily tied to probability

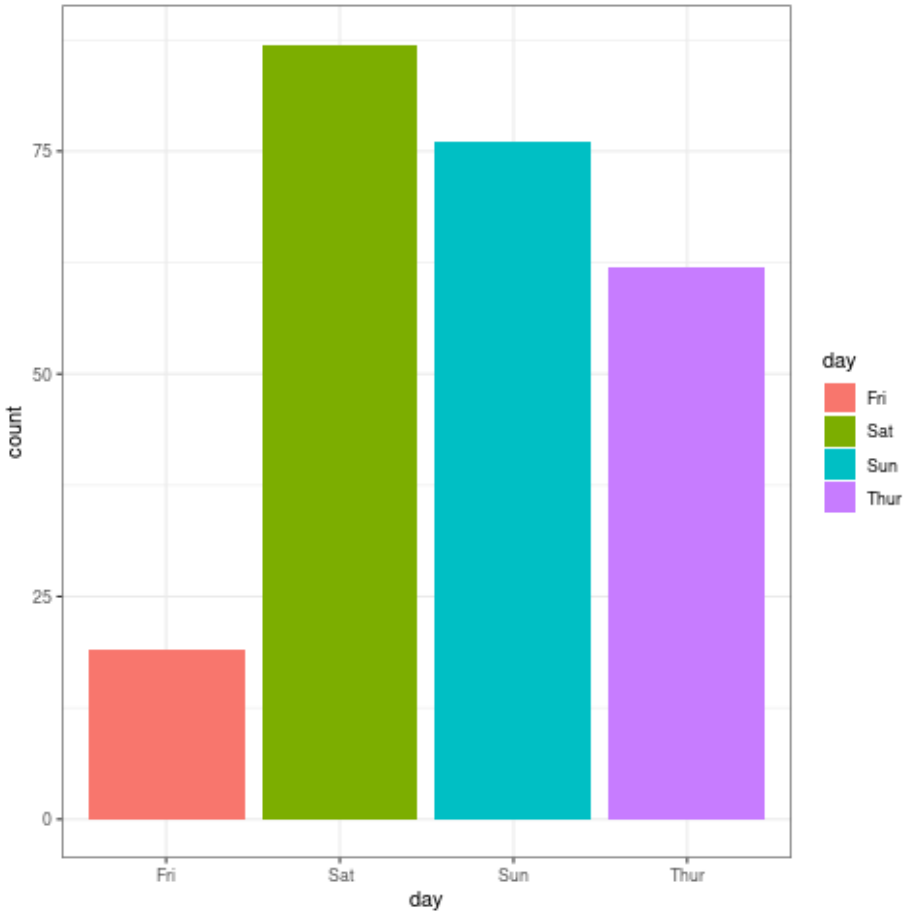
One Categorical Variable: Graph

When we have one categorical variable, a *barchart* is often used to tally the frequencies (counts) of that categorical variable



One Categorical Variable: Distribution

To describe the distribution of a categorical variable we need to talk about....



- how likely each category is
- the most and least likely category
- numbers help

When should we use pie charts?

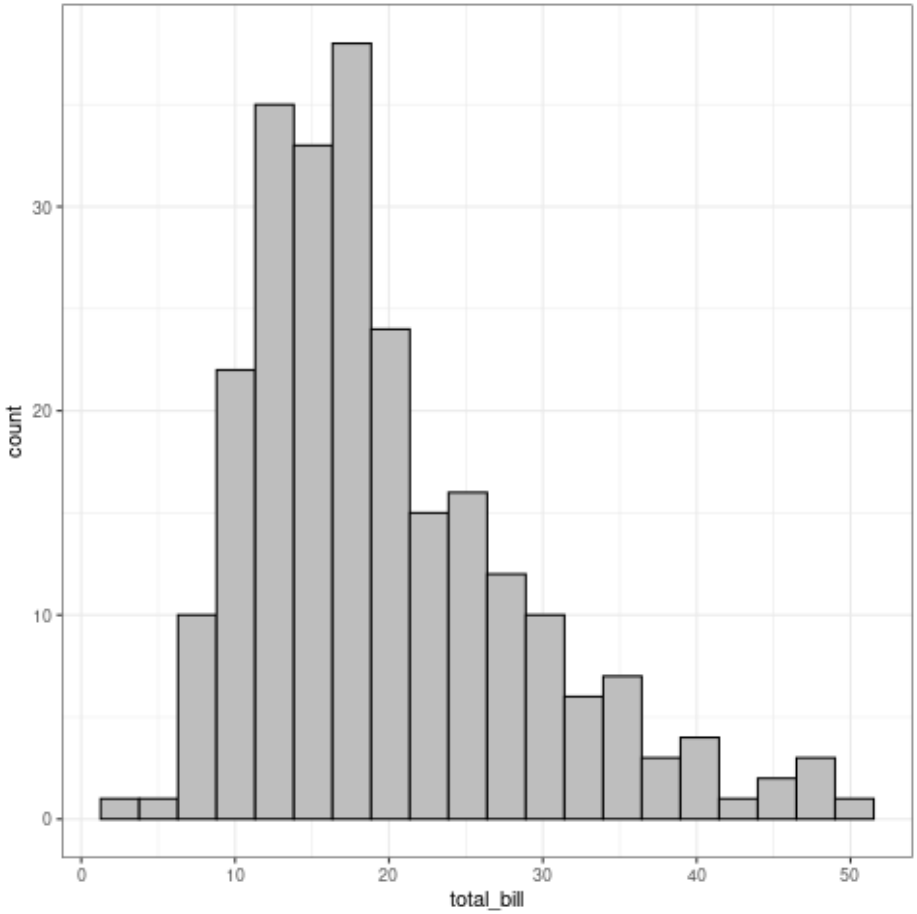
When do we use pie charts?

.....never?

- Humans are bad are reading angles/pie slices
- Bar charts can convey the same info, easier
- Dimensions of the graph are weird (bar chart with polar coordinates?)
- No strong advantage to pie charts

One Quantitative Variable: Graph

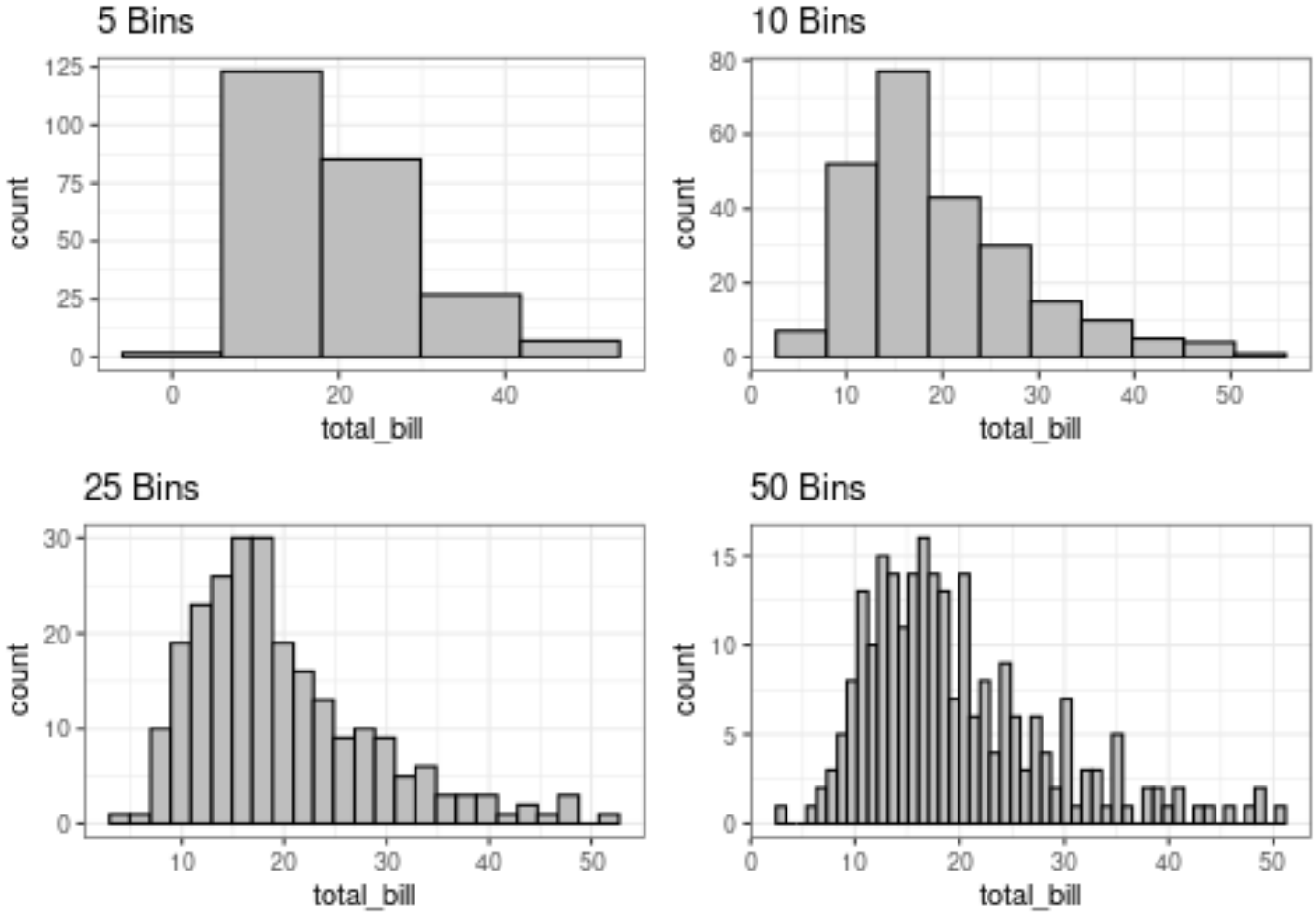
For quantitative variables, we use **histogram** to show the distribution.



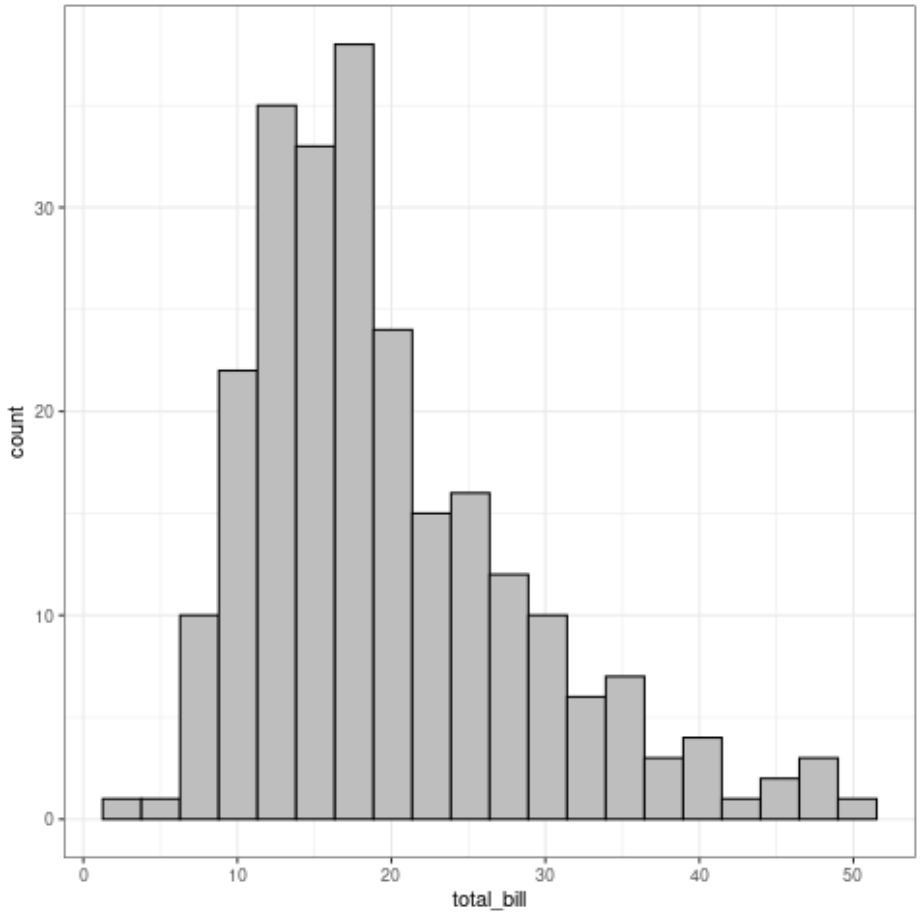
- Groups data into equally sp intervals/bins
- Each bin has either the count/frequence displayed c the proportion/percent disp
- Why favor one over the oth

Histogram Bin Width

Using wider/narrower bin width can drastically change the histogram
- too wide: can't tell exactly where data points are
- too narrow: overly detailed and hard to read



One Quantitative Variable: Distribution



Here, there is quite a bit more we can examine:

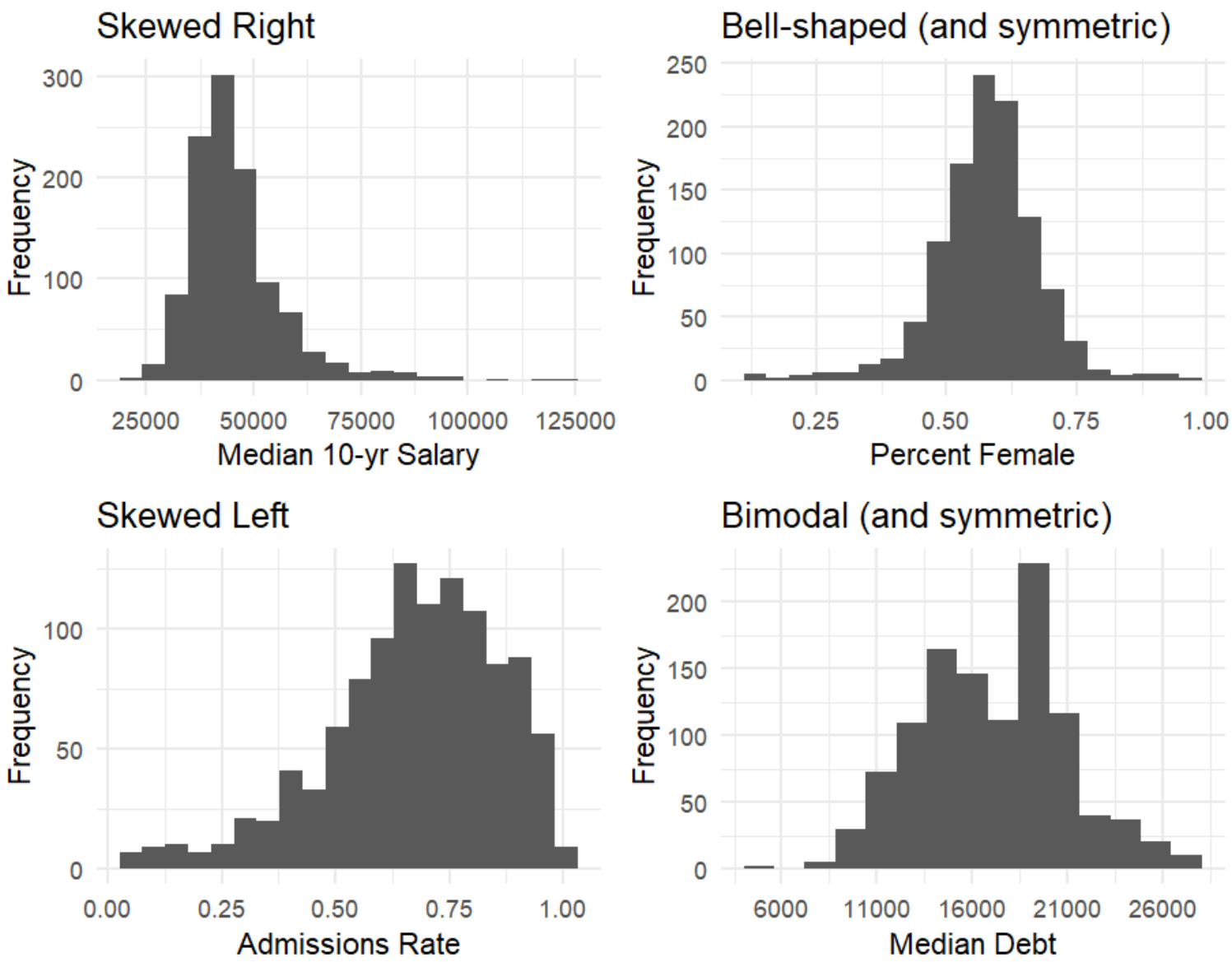
- Where does the "center" appear to be?
- How spread out is this data?
- What about the range of this data?
- Does it appear skewed (more data on one side?)

One Quantitative Variable - Distribution

We need to mention ALL of the following things:

- **Shape** - is the distribution symmetric, skewed, bell-shaped, bimodal?
- **Center** - where does the data bunch up (approx. mean or median)
- **Spread** - how spread out is the data (ie: range of values)
- **Outliers** - are there values that are much smaller/larger than the rest?
    - Even when there isn't outliers, we mention there isn't outliers

Distribution - Shape



Distribution - Center and Spread

- **Center**: typically we use means or medians
- **Spread**: typically we use standard deviation, range, or IQR

We will talk more about how to decide which thing to use for both center and spread in a few days (and how to calculate each)

Outliers

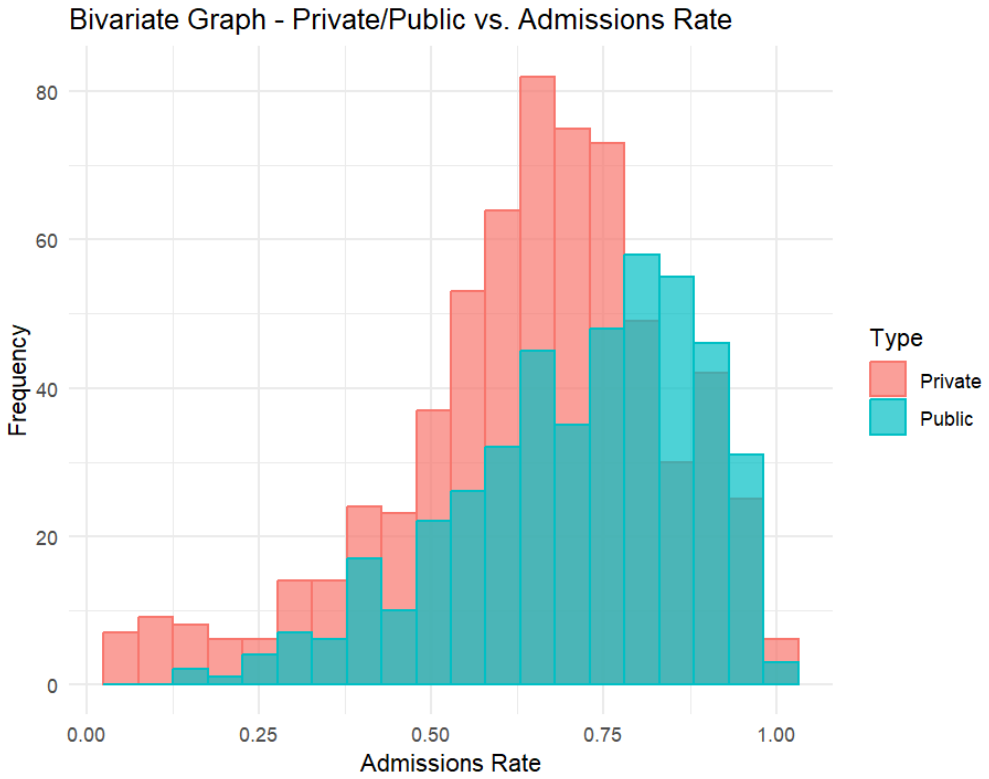
Outliers are data points that look *unusual* in that they either don't follow a pattern that we see in the data or are far away from other points

- If everything is an outlier, nothing is an outlier
- Using histograms, we look for gaps in the bins to identify outliers
  - How does this tie into the note on bin sizes?
- A group of outliers can indicate a *subpopulation*
- A fuzzy point is if the point is far away from other data points but follows the pattern
  - This will come up during linear regression

Bivariate Graphs

Bivariate graphs show the relationship between two variables and which one we use is still dictated by

- type of variables
- context



The Onion

News

Thousands Of Students Forced To Attend Iowa State After University Sets Acceptance Rate To 140%

Published: March 18, 2019

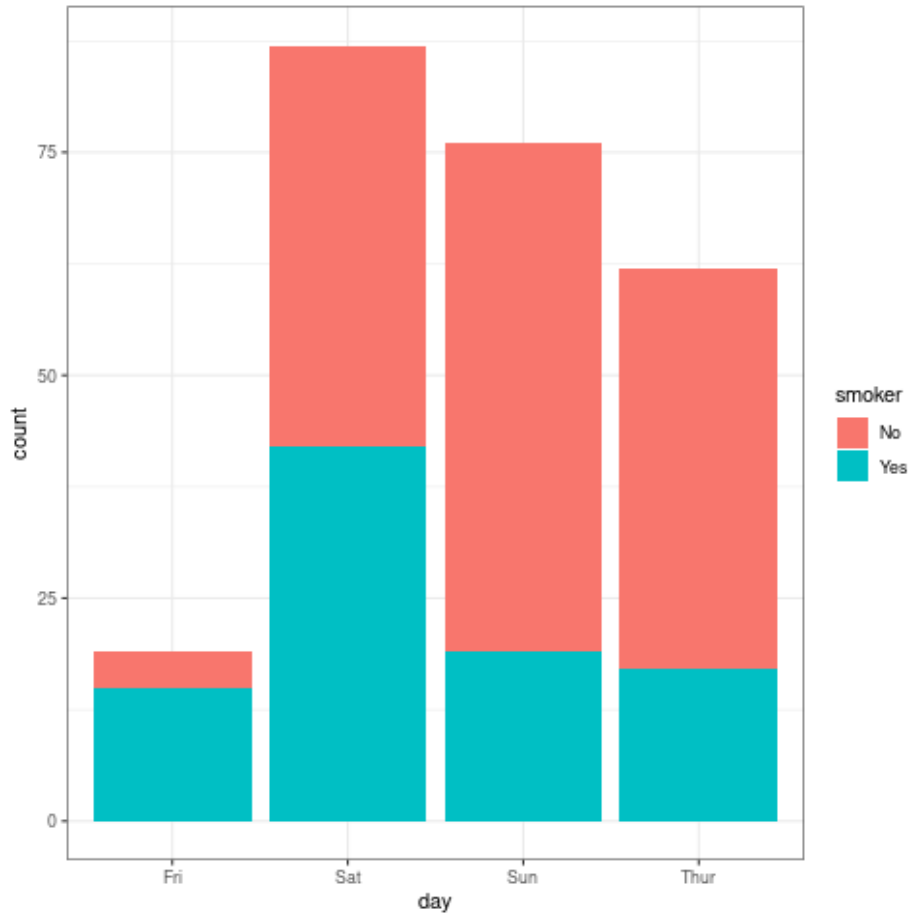
Association

It is very common for us to try to find a relationship between two (or more) variables

- When there seems to be some connection between two variables (knowing about one variable tells us about the other), we say they are **associated**.
- If there does not seem to be a relationship between the variables, we say they are **independent**.
- Occasionally talk about explanatory variables and response variables (misleading terms!!)

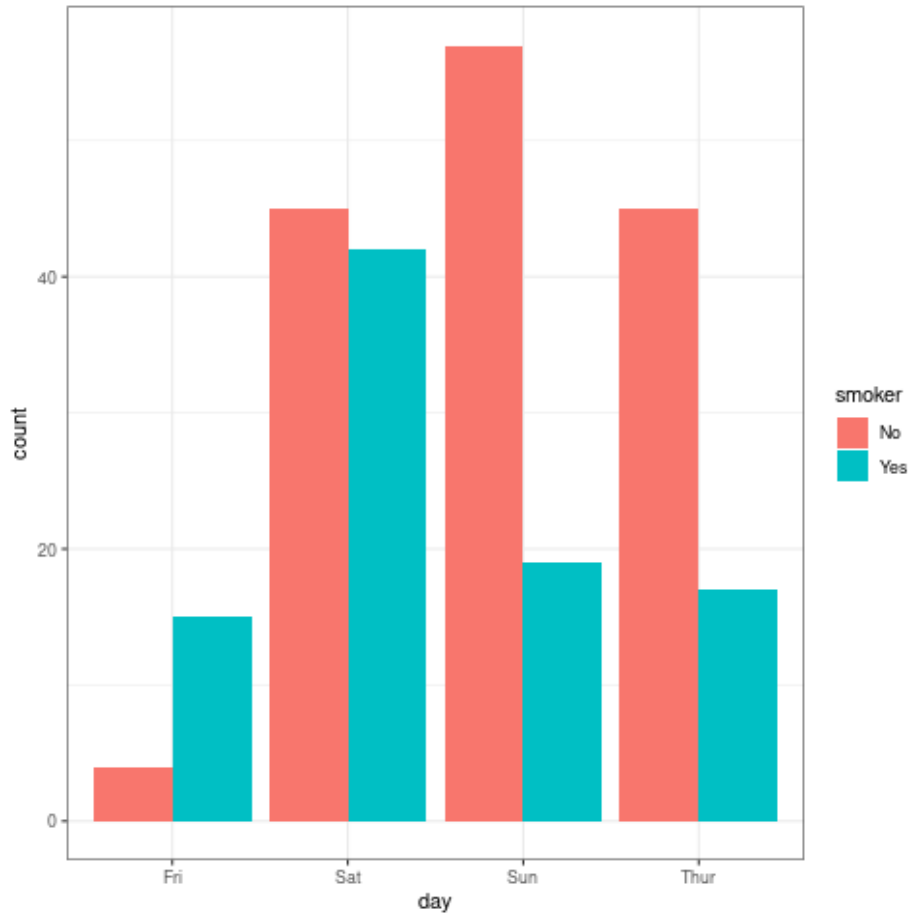
Categorical + Categorical → Stacked Bar

The first type of bivariate bar chart is known as a **stacked bar chart**, which allows us to break down one variable in terms of another. Here, we consider if any smokers were included in the party



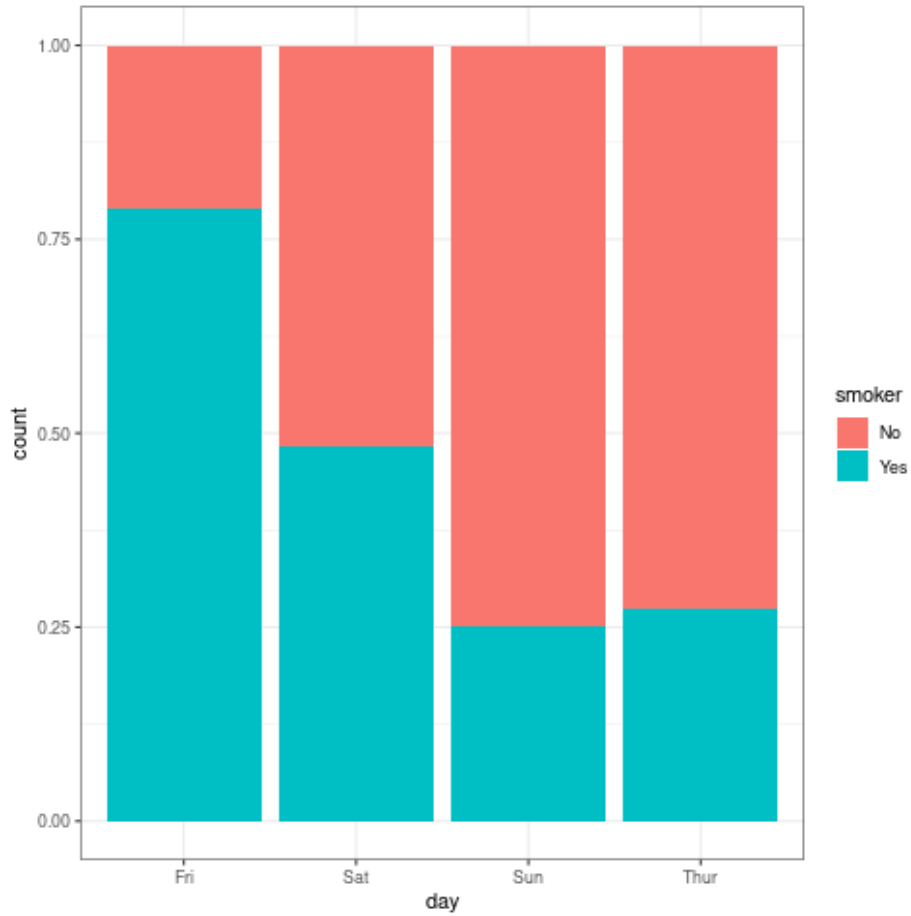
Categorical + Categorical → Dodge Bar

The second type of bivariate bar chart is known as a **dodged bar chart**, which presents both variables alongside one another. This makes comparing within groups much simpler



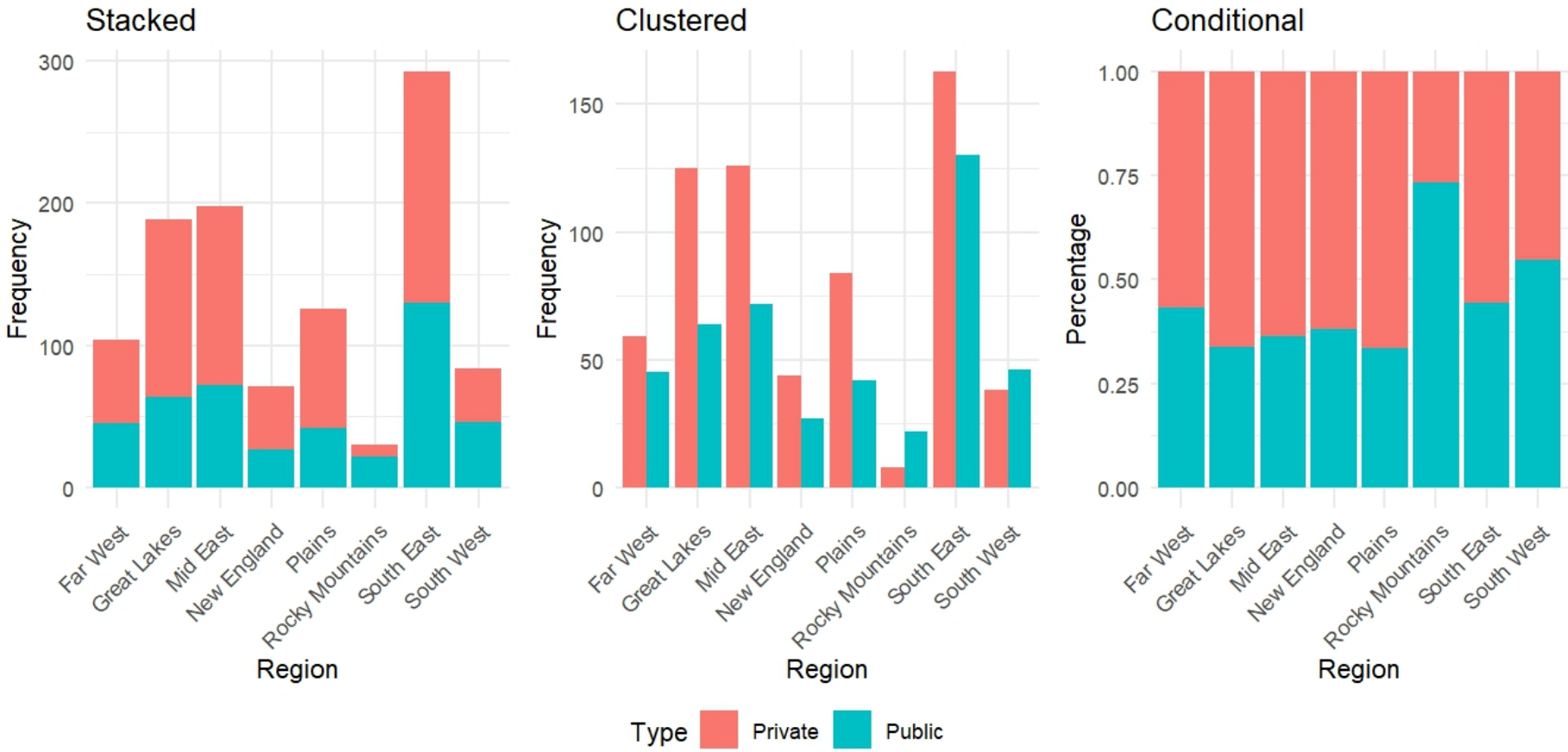
Categorical + Categorical → Filled Bar

The last type of bivariate bar chart is known as a **filled bar chart**, offering proportions. Although we lose absolute counts, we can now see relative frequencies within each group



Bivariate Bar Charts

Back to the college data. Are the variables "Region" and "Type" associated? Which bar chart is most helpful?



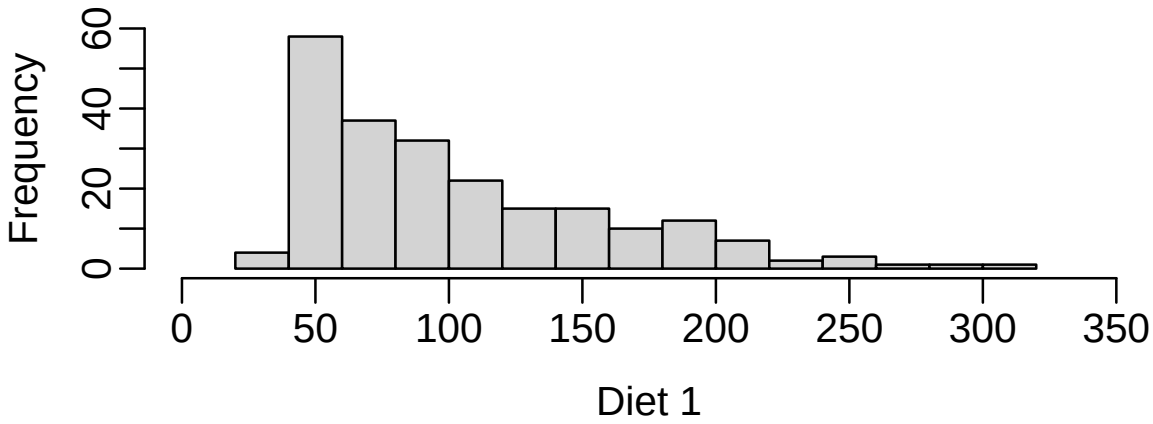
Quick Summary

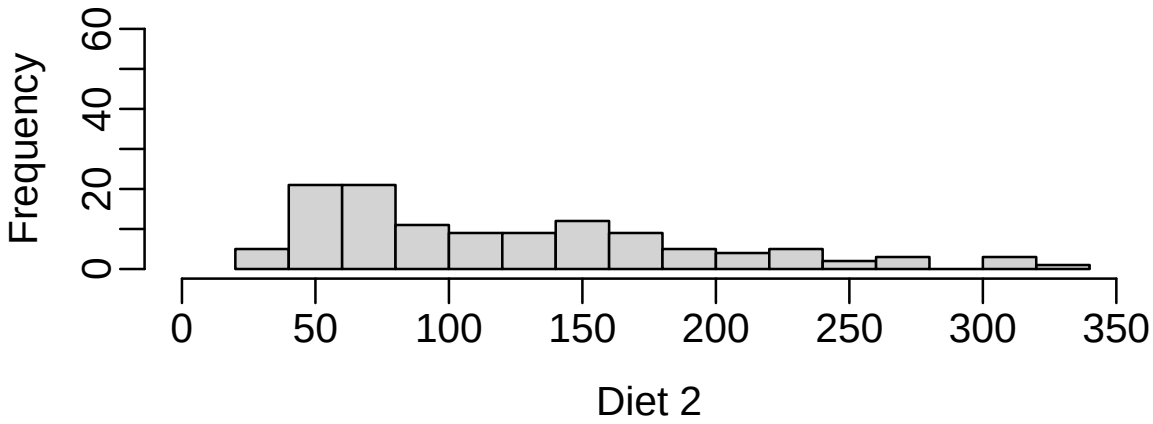
Advantages and Disadvantages to all three

- Stacked bar charts
  - Show the original variable's distribution easily
  - Hard to compare groups within a stack
  - Hard see the distribution for subpopulations
- Dodged (clustered) bar charts
  - Hard to see original distribution
  - Easy to compare groups (via counts)
  - Easy to see distributions for subpopulations
- Filled bar chart (conditional)
  - Impossible to see the original distribution
  - Easy to compare groups (via proportions)
  - Impossible to know subpopulations distributions

Alternative

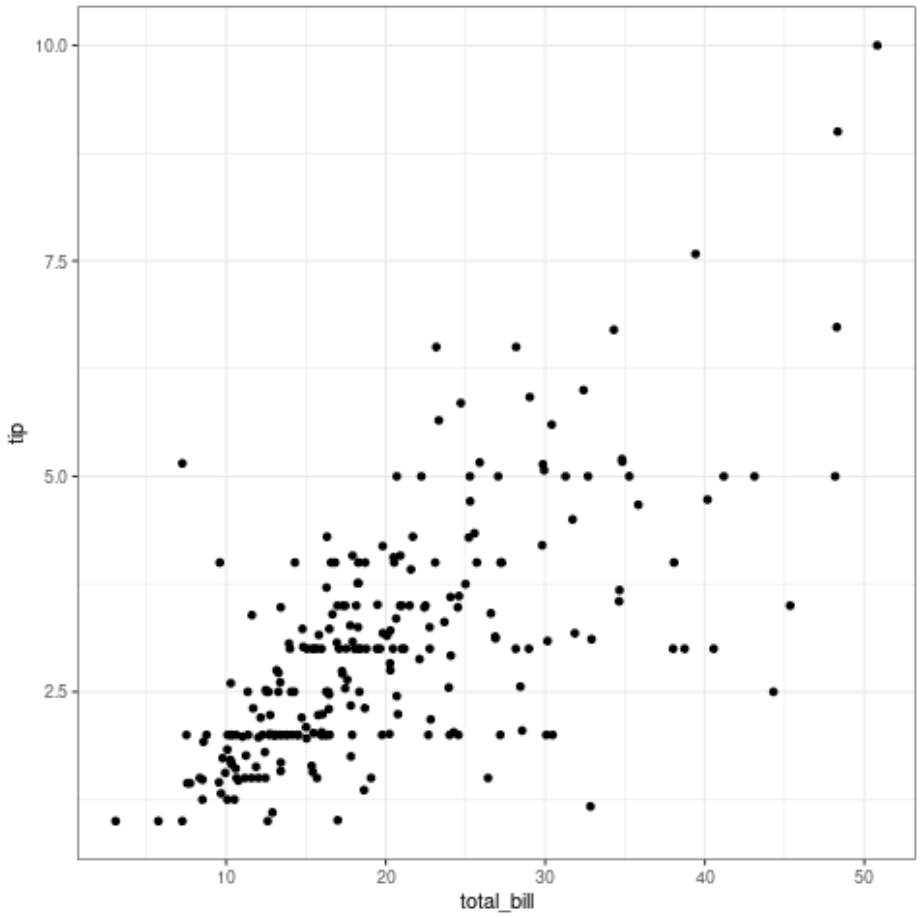
Can also produce two different histograms (KEEP AXIS THE SAME!!)





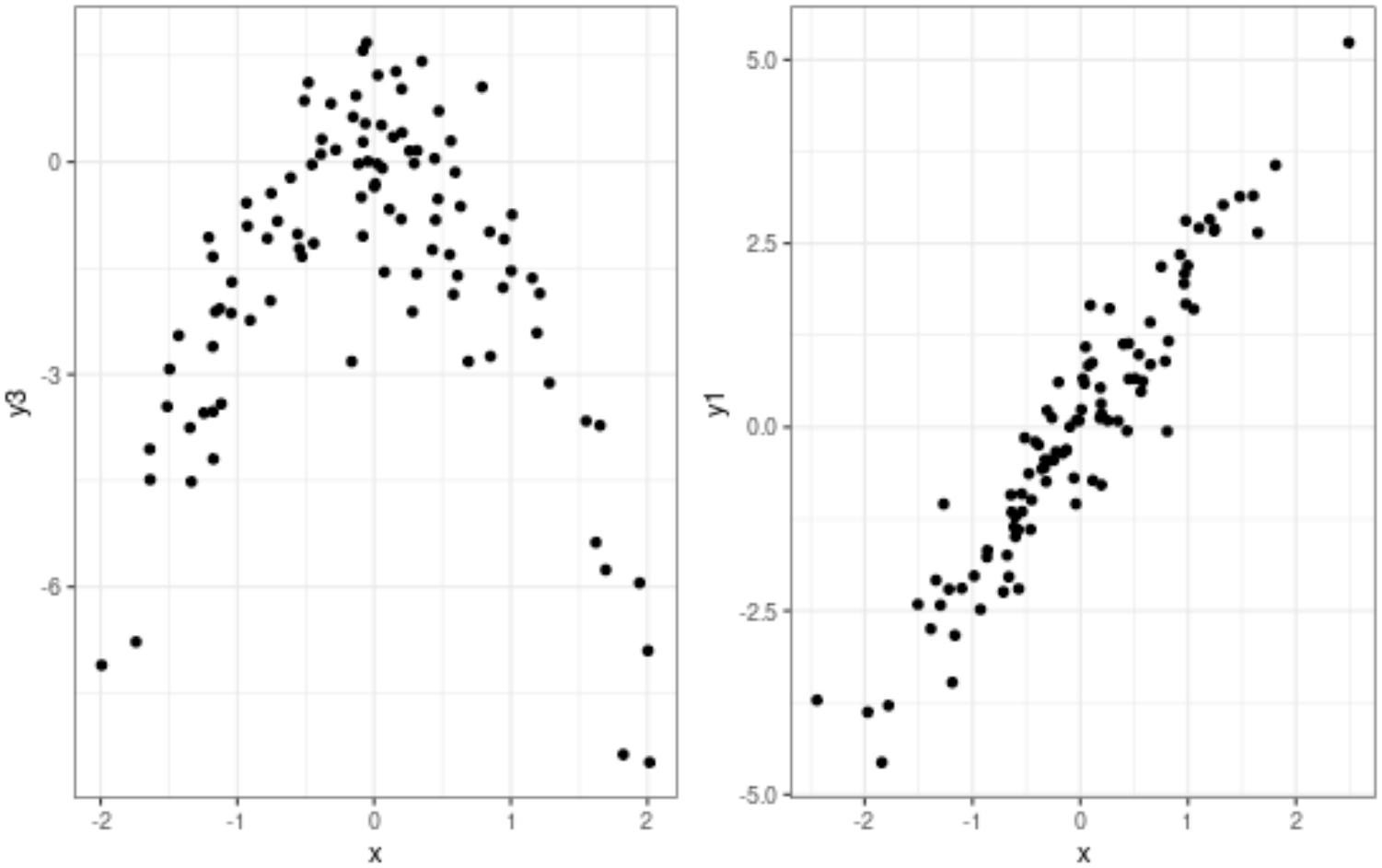
Quantitative + Quantitative → Scatterplots

Visual summaries investigating the relationship between two quantitative variables are often presented with a **scatterplot**



What kind of relationship do we see between the total bill and the tip amount?

Types of Quantitative Relationships



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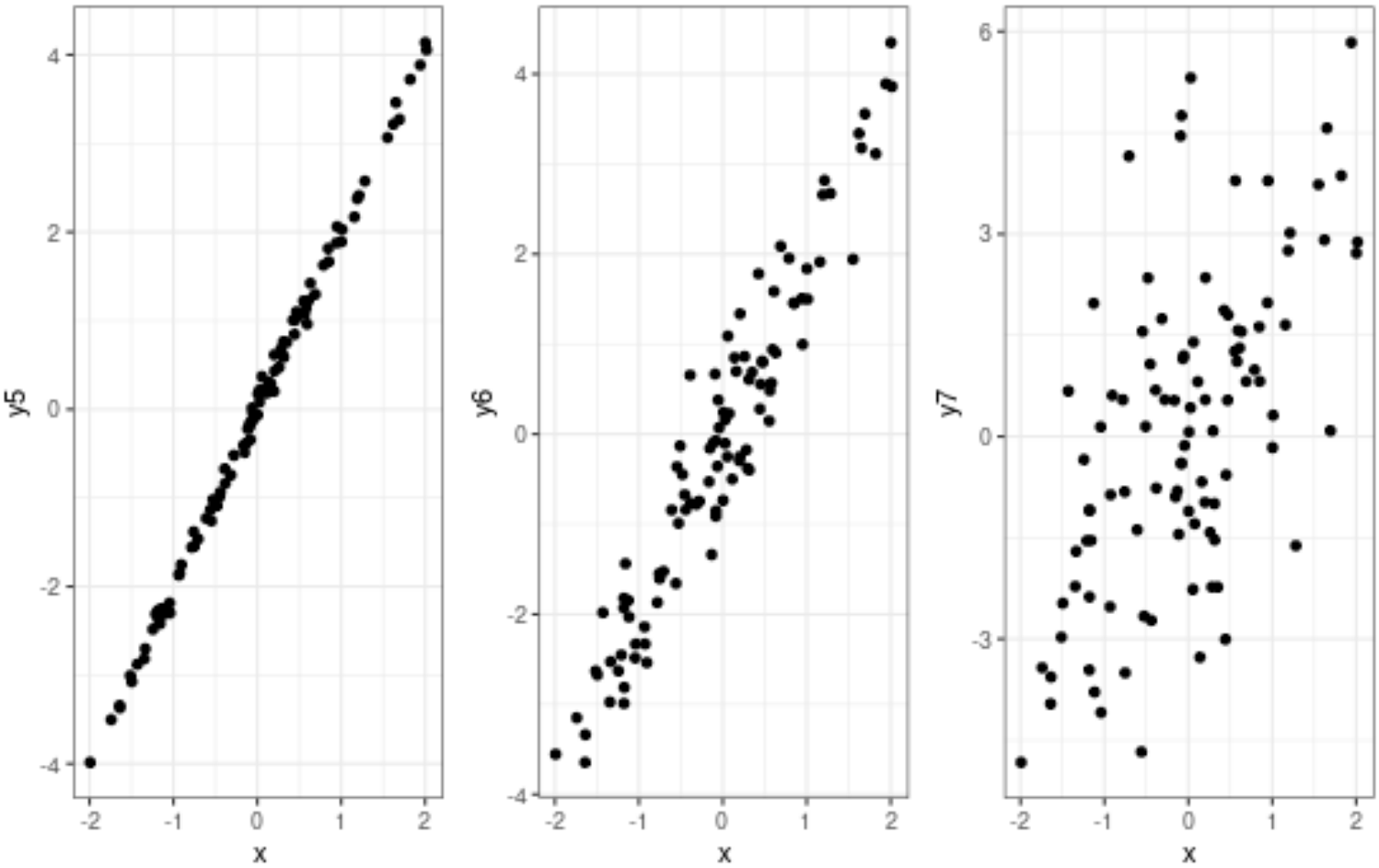
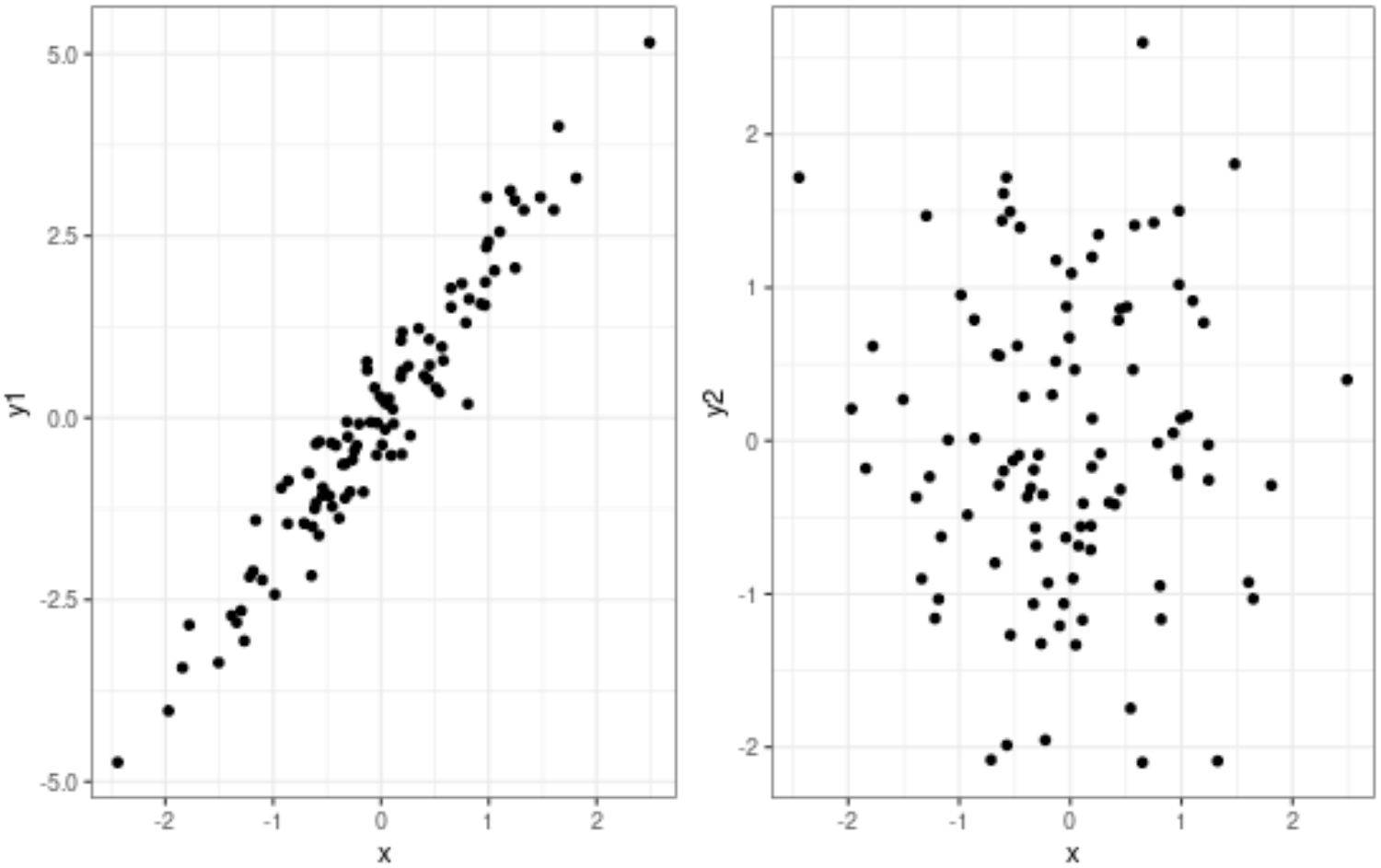


Types of Quantitative Relationships



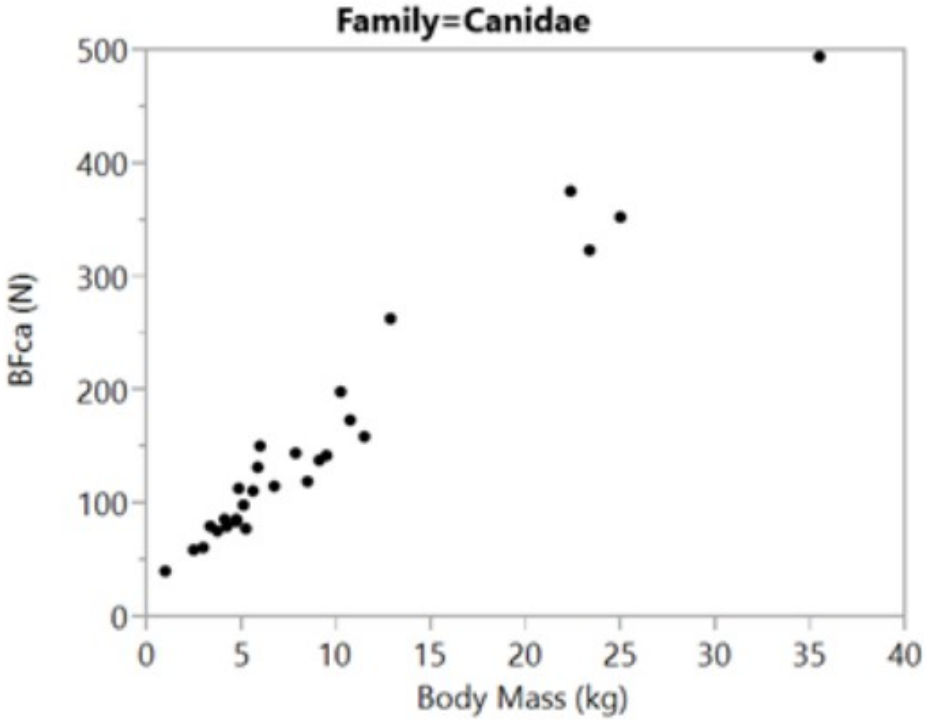
Describing a Scatterplot

To describe the relationship between variables in a scatterplot we need to mention all of the following:

- **Form**: what type of pattern exists (linear / non-linear / curved)
- **Strength**: how close are the points? (weak / moderate / strong)
- **Direction**: how the values of one variable relate to the values of the other variable (positive / negative)
- **Outliers**

Describing Scatterplots – Example

Canidae is the biological family that contains dogs, wolves, foxes, and similar mammals.
Two variables are bite force (N) and body mass (kg). Which would be the explanatory variable and which would be the response variable?



How do we describe the scatterplot?

source: "Bite Forces and Evolutionary Adaptations to Feeding Ecology in Carnivores," by P. Christiansen and S. Wade, Ecology, 88(2), 2007, pp. 347 – 358

Reflection

We'll take a few minutes to reflect on what we learned. Talk with those around you to come up with answers to the following questions:

- Why do we make graphics to display data?
- What is the **distribution** of a variable?
- Why do we care about whether a variable is categorical or quantitative?

Next Time

- One other graph to display quantitative data (boxplot)
- What to do when we have Quantitative + Categorical variables
- Lab for putting this all into practice