

Another set of solutions and notes to ‘R for Data Science’

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Chapter 1

Purpose of this book

This book contains my solutions and notes to Garrett Grolemund and Hadley Wickham's book, *R for Data Science* (R4DS). First and foremost my book is set-up as a resource and refresher for myself.

If you are looking for a place to check your solutions for R4DS I would recommend using ?'s solutions _____ as a source. ? has done a great job of getting community feedback and well vetted solutions. Though feel free to use this book as another point of reference (if you're curious to see a potentially alternative solution to a problem).

I am not actively seeking feedback, but if you find a major issue, or want to comment on one of my notes, feel free to open a github issue ?.

Chapter 2

Features of this book

Each chapter may contain the following:

- * list of functions and notes from the chapter¹.
- * Solutions to exercises
- * Appendix containing notes, or alternative solutions to problems

¹When functions show up in multiple locations I typically only note them the first time they appear.

Chapter 3

Origin of this book

‘R for Data Science’ is my go to resource I recommend for people interested in getting started in “data science”, R programming, or the “tidyverse”. I’ve gone through the book front to back three times and regularly come back to it as a reference.

I first read and completed the exercises to R4DS in early 2017 on the tail-end of completing a Master’s in Analytics program. My second time going through R4DS came in early 2018 when myself and a colleague, ?, organized an internal study group for our colleagues.

You can see my part of an internal talk I gave plugging “tidy” data science workflows (and implicitly the R4DS study group) here: [____](#)

The study group provided me a chance to clean-up my solutions, organize my notes, and pursue a vague ambition to publish my solutions and notes online into a book. After stumbling into ? online R4DS solutions this ambition no longer felt useful... but, roughly a year later, I got around to publishing it – and went through R4DS a third time.

Chapter 4

Plug for R4DS

Although reading a book three times in three years may seem excessive, R4DS is excellent on repeat engagements. After the first read, I felt comfortable doing most common types of data manipulation. On the second, functional programming methods and elegant iteration methods like those demonstrated in Chapter 25: many models felt easy and intuitive.

See a lightning talk I gave on “managing many models” [_____](#)

On the third R4DS reading, various functions or options I’d forgotten, or not invited the utility of suddenly popped-out to me as useful things I needed to add to my tool belt to replace less effective methods I’d been using (e.g. `tidyverse::enframe()`, `cache.extra` chunk option, ...).

4.1 Plug for R4DS

R4DS is very much a nuts and bolts book. It focuses more on data “tidying” and visualization than on some of the sexy topics

My Master’s program had provided me with a broad overview and strong foundation of knowledge on a wide range of analytic methods. However, having bounced between python, R, SQL, and SAS on different projects, the nuts and bolts of my coding skills had yet to mature.

Job interviews were coming-up and I was nervous my lack of fluency in coding would come through either in code submissions or reviews.

4.2 Acknowledgements

Of course Hadley Wickham and Garrett Grolemund for their amazing book, but also the entire team at RStudio producing superb materials. Stephen Kimel and my colleagues at NetApp for going through our study group together. The `(? community)[]` and `? communities` for creating such welcoming and inspiring environments for learning R programming.

Make sure the following packages are installed:

Chapter 5

Chapter 3

- `geom_point`: Add points to plot, `x`, `y`, `size`, `stroke`, `colour`, `alpha`, `shape`
- `geom_smooth`: Add line and confidence intervals to x-y plot, can use `se` to turn off standard errors, can use `method` to change algorithm to make line.
- `geom_bar`: Stack values on top of each to make bars.
- `geom_count`: Make bar charts out of discrete row values in dataframe.
- `geom_jitter`: like `geom_point()` but with randomness added
- `geom_boxplot`:
- `geom_polygon`:
- `geom_abline`:
- `facet_wrap`: `scales`, `space`
- `facet_grid`:
- `stat_count`:
- `stat_summary`:
- `stat_bin`:
- `stat_smooth`:
- position adjustments:
 - `identity`; `dodge`; `fill`;
 - `position_dodge`; `position_fill`; `position_identity`; `position_jitter`; `position_stack`;
- 3 ways to override default mapping
 -
- `coord_flip`:
- `coord_quickmap`:
- `coord_polar`:
- `coord_fixed`:

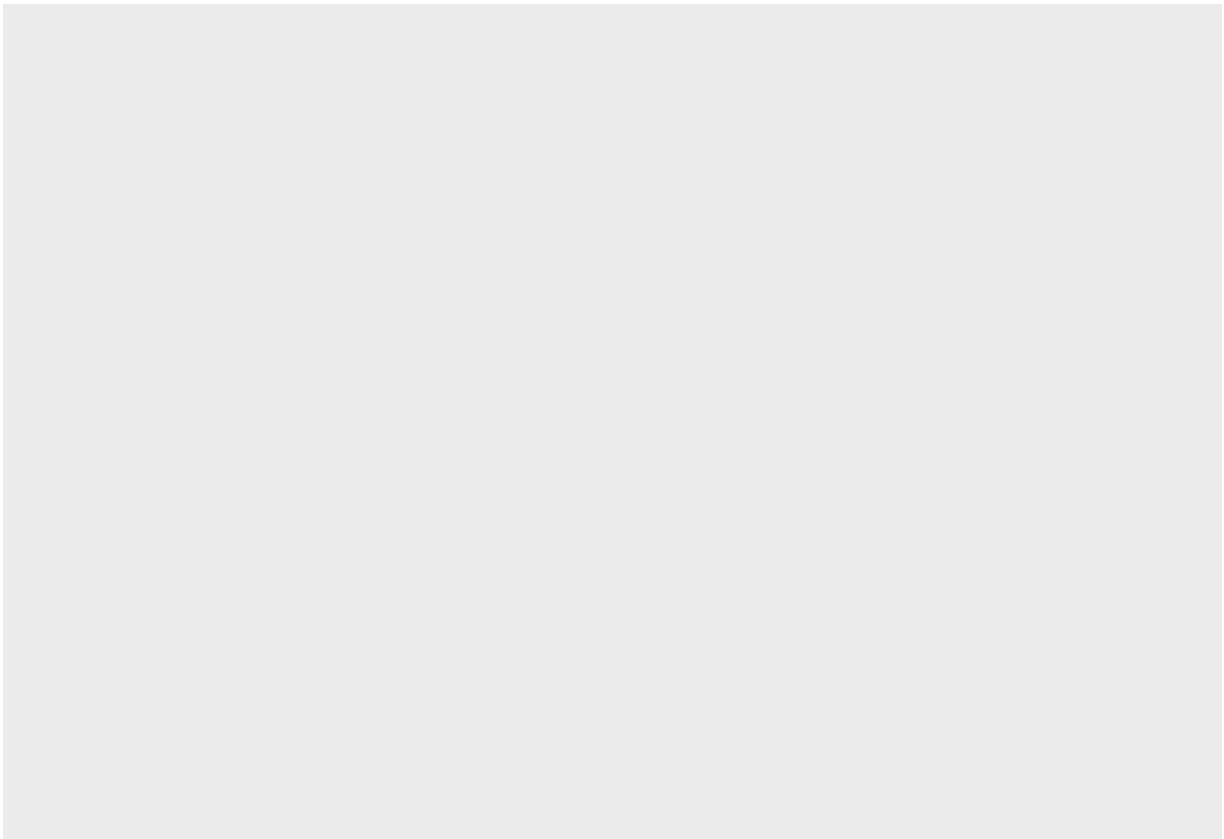
```
ggplot(data = <DATA>) +      <GEOM_FUNCTION>(  
    mapping = aes(<MAPPINGS>),  
    stat =  
<STAT>,  
    position = <POSITION>    ) +      <COORDINATE_FUNCTION> +      <FACET_FUNCTION>
```

5.1 3.2: First steps

5.1.1 3.2.4

1. Run `ggplot(data = mpg)`. What do you see?

```
ggplot(data = mpg)
```



Just a blank grey space.

2. How many rows are in mpg? How many columns?

```
ncol(mtcars)
```

```
## [1] 11  
nrow(mtcars)
```

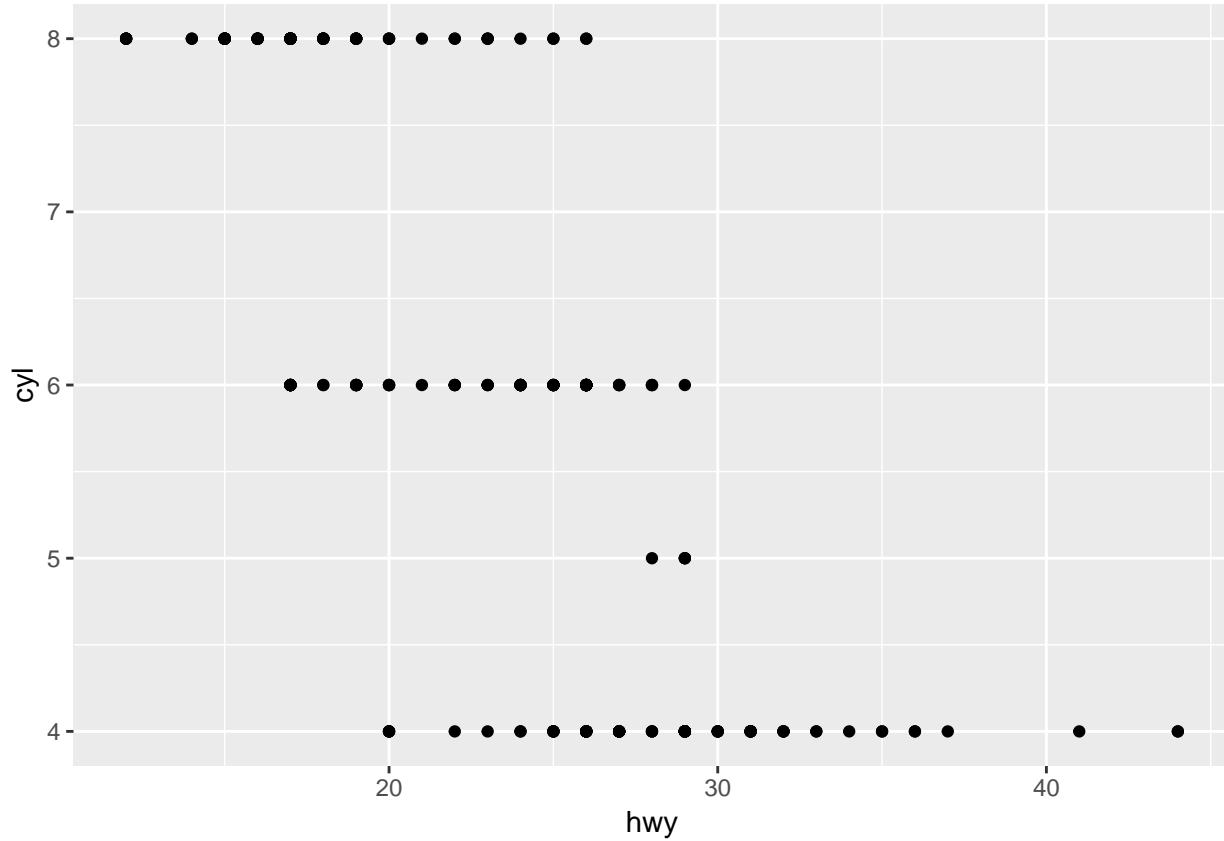
```
## [1] 32
```

3. What does the drv variable describe? Read the help for ?mpg to find out.

Front wheel, rear wheel or 4 wheel drive.

4. Make a scatterplot of hwy vs cyl.

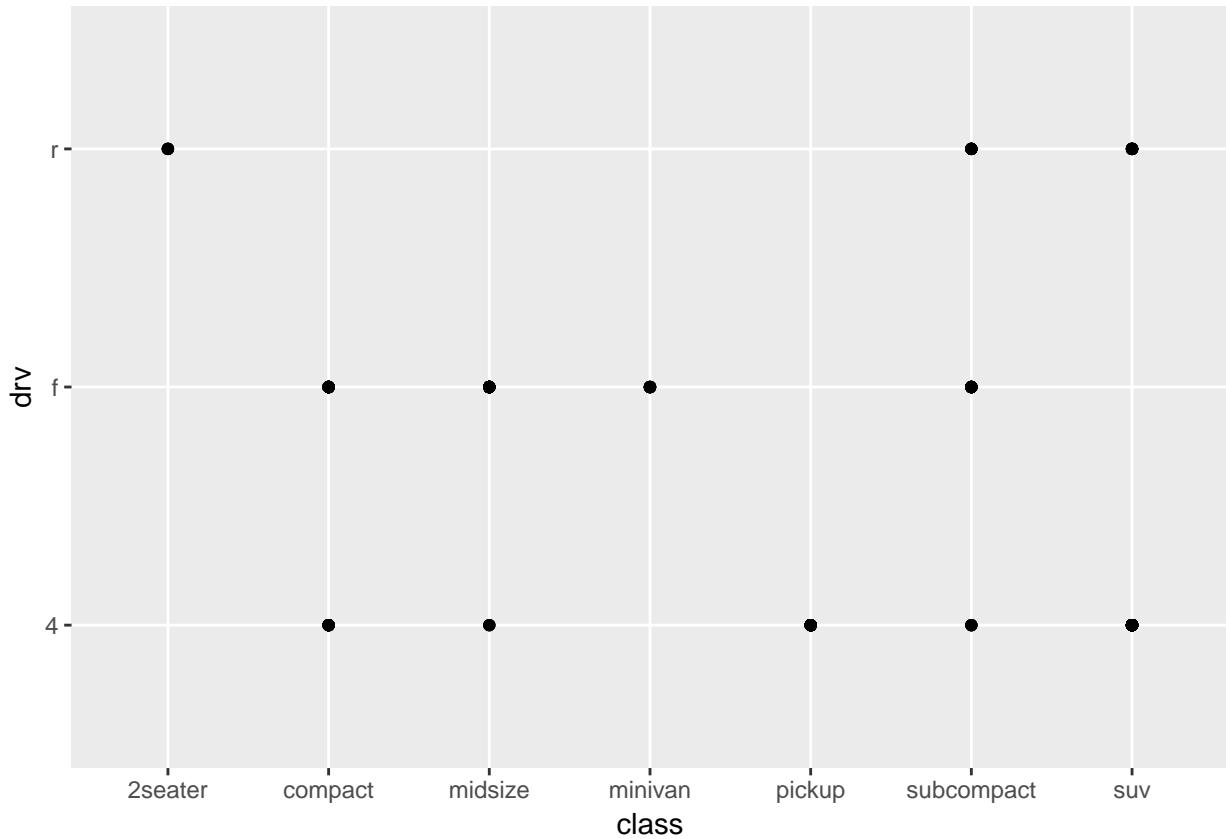
```
ggplot(mpg)+  
  geom_point(aes(x = hwy, y = cyl))
```



Inverse relationship.

5. What happens if you make a scatterplot of class vs drv? Why is the plot not useful?
(key question)

```
ggplot(mpg)+  
  geom_point(aes(x = class, y = drv))
```



The points stack-up on top of one another so you don't get a sense of how many are on each point.

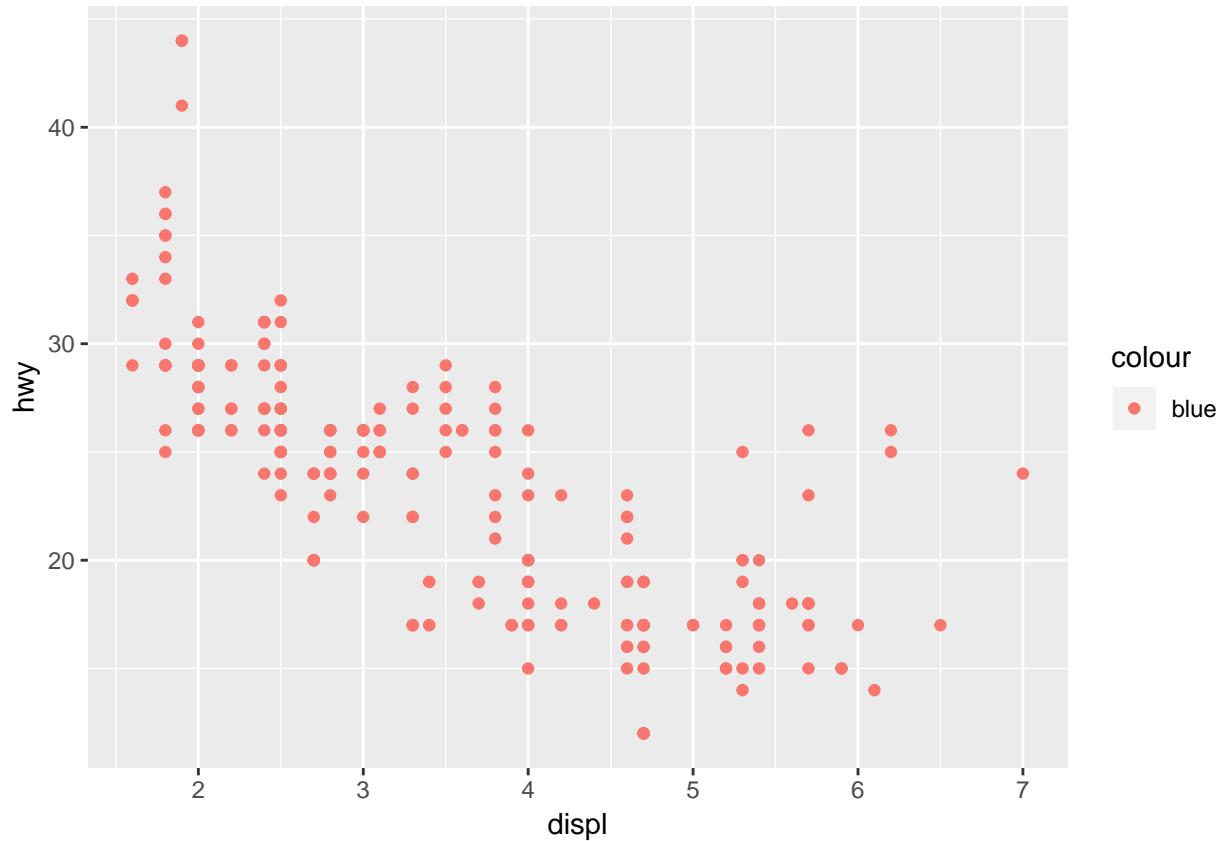
Any ideas for what methods could you use to improve the view of this data?

5.2 3.3: Aesthetic mappings

5.2.1 3.3.1.

- What's gone wrong with this code? Why are the points not blue?

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy, color = "blue"))
```



The `color` field is in the `aes` function so it is expecting a character or factor variable. By inputting “blue” here, ggplot reads this as a character field with the value “blue” that it then supplies its default color schemes to (1st: salmon, 2nd: teal)

2. Which variables in mpg are categorical? Which variables are continuous? (Hint: type ?mpg to read the documentation for the dataset). How can you see this information when you run mpg?

```
mpg
```

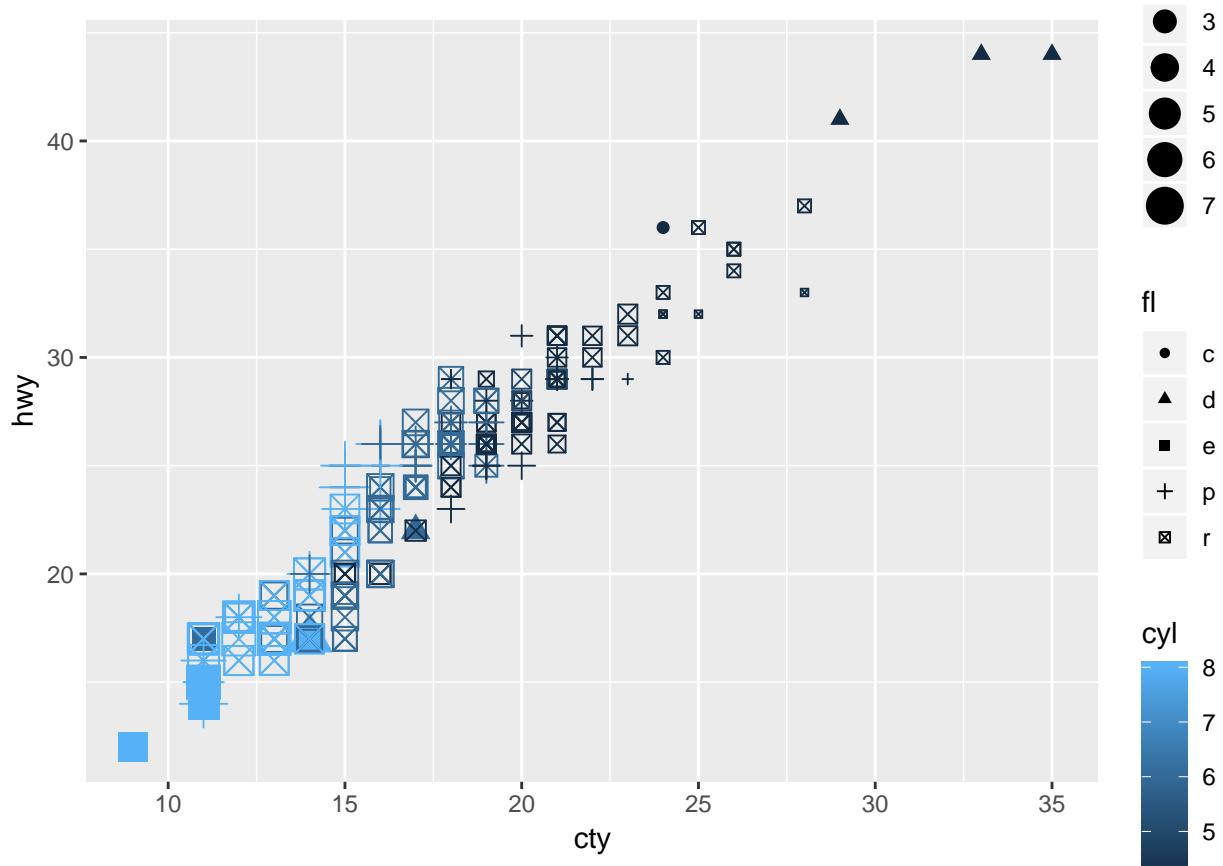
```
## # A tibble: 234 x 11
##   manufacturer model displ year cyl trans drv cty hwy fl class
##   <chr>        <chr>  <dbl> <int> <int> <chr> <chr> <int> <int> <chr> <chr>
## 1 audi         a4      1.8  1999     4 auto~ f      18    29 p   comp~
## 2 audi         a4      1.8  1999     4 manu~ f      21    29 p   comp~
## 3 audi         a4      2    2008     4 manu~ f      20    31 p   comp~
## 4 audi         a4      2    2008     4 auto~ f      21    30 p   comp~
## 5 audi         a4      2.8  1999     6 auto~ f      16    26 p   comp~
## 6 audi         a4      2.8  1999     6 manu~ f      18    26 p   comp~
## 7 audi         a4      3.1  2008     6 auto~ f      18    27 p   comp~
## 8 audi         a4 q~   1.8  1999     4 manu~ 4     18    26 p   comp~
## 9 audi         a4 q~   1.8  1999     4 auto~ 4     16    25 p   comp~
## 10 audi        a4 q~   2    2008     4 manu~ 4     20    28 p   comp~
## # ... with 224 more rows
```

The data is in tibble form already so just printing it shows the type, but could also use the `glimpse` and `str` functions.

3. Map a continuous variable to color, size, and shape. How do these aesthetics behave

differently for categorical vs. continuous variables?

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = cty, y = hwy, color = cyl, size = displ, shape = fl))
```



color: For continuous applies a gradient, for categorical it applies distinct colors based on the number of categories.

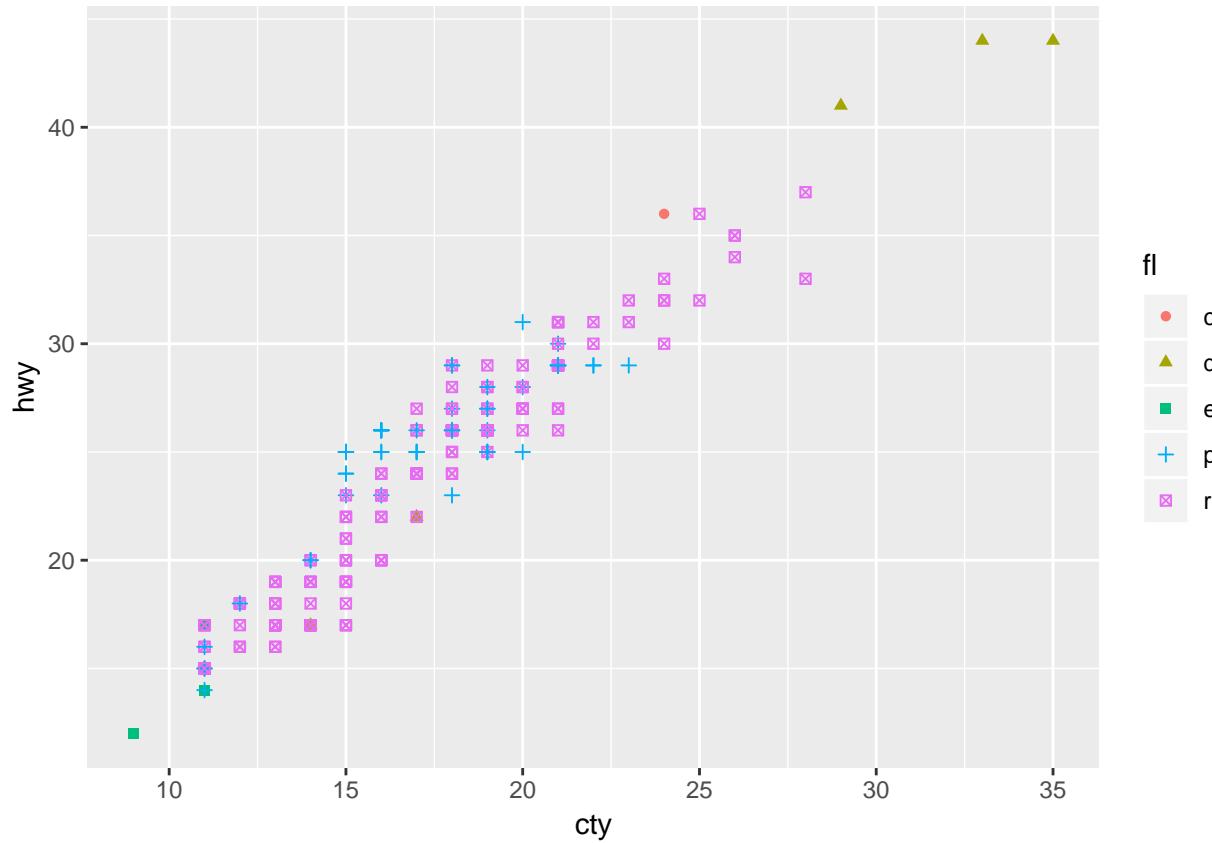
size: For continuous, applies in order, for categorical will apply in an order that may be arbitrary if there is not an order provided.

shape: Will not allow you to input a continuous variable.

4. What happens if you map the same variable to multiple aesthetics?

Will map onto both fields. Can be redundant in some cases, in others it can be valuable for clarity.

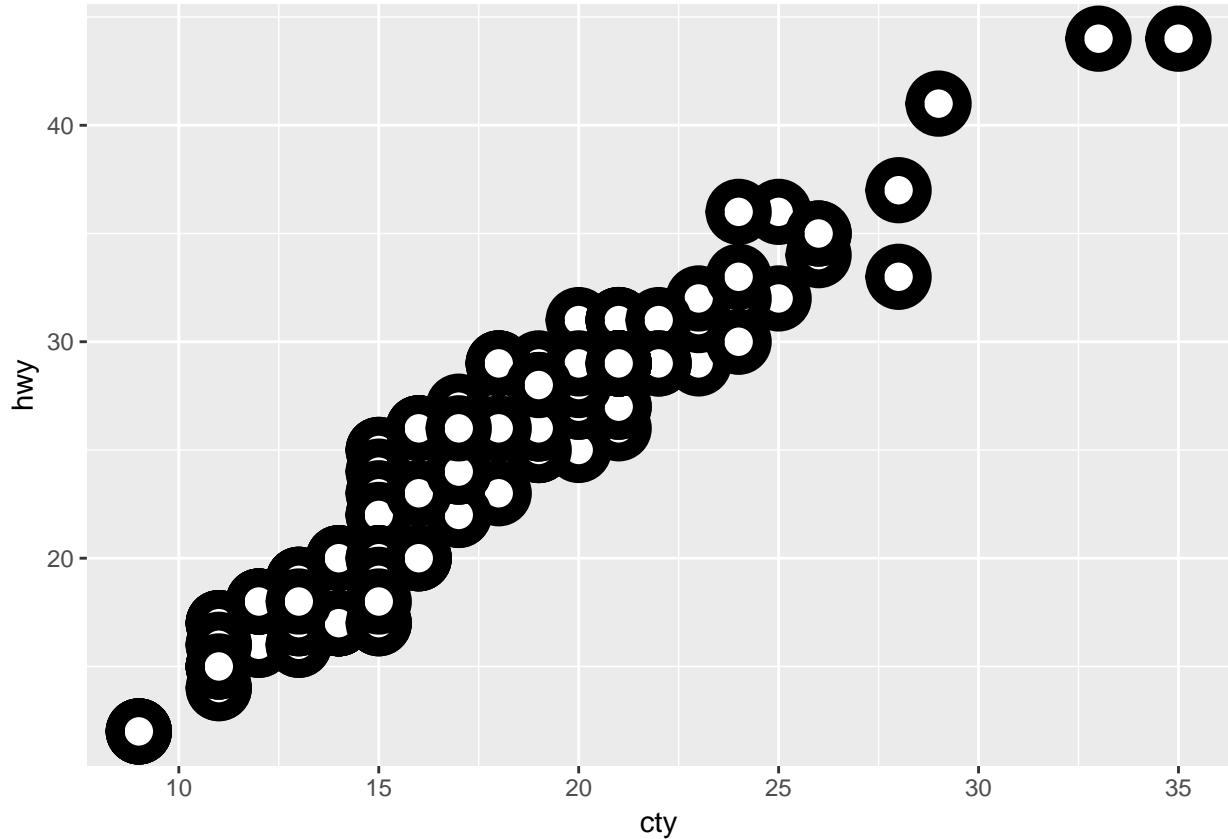
```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = cty, y = hwy, color = fl, shape = fl))
```



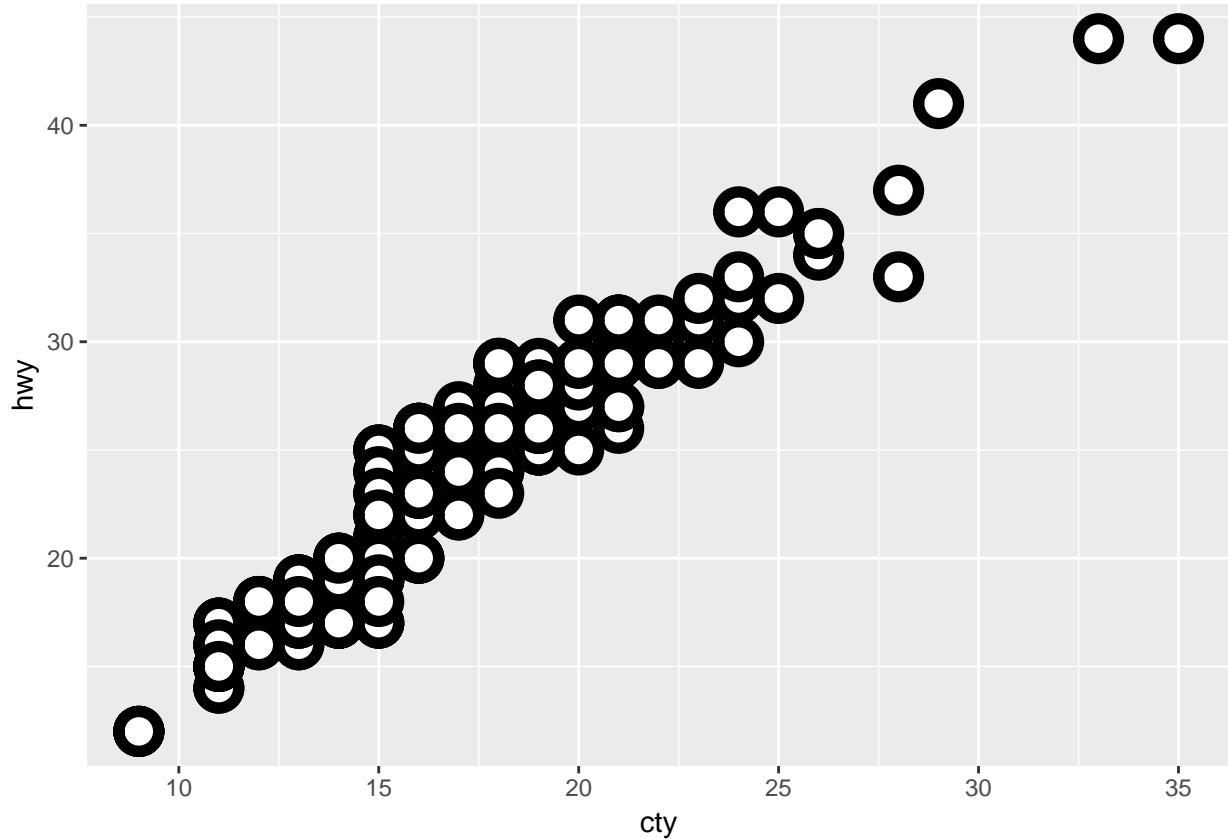
5. What does the stroke aesthetic do? What shapes does it work with? (Hint: use `?geom_point`)

```
?geom_point
```

```
## starting httpd help server ... done
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +
  geom_point(shape = 21, colour = "black", fill = "white", size = 5, stroke = 5)
```



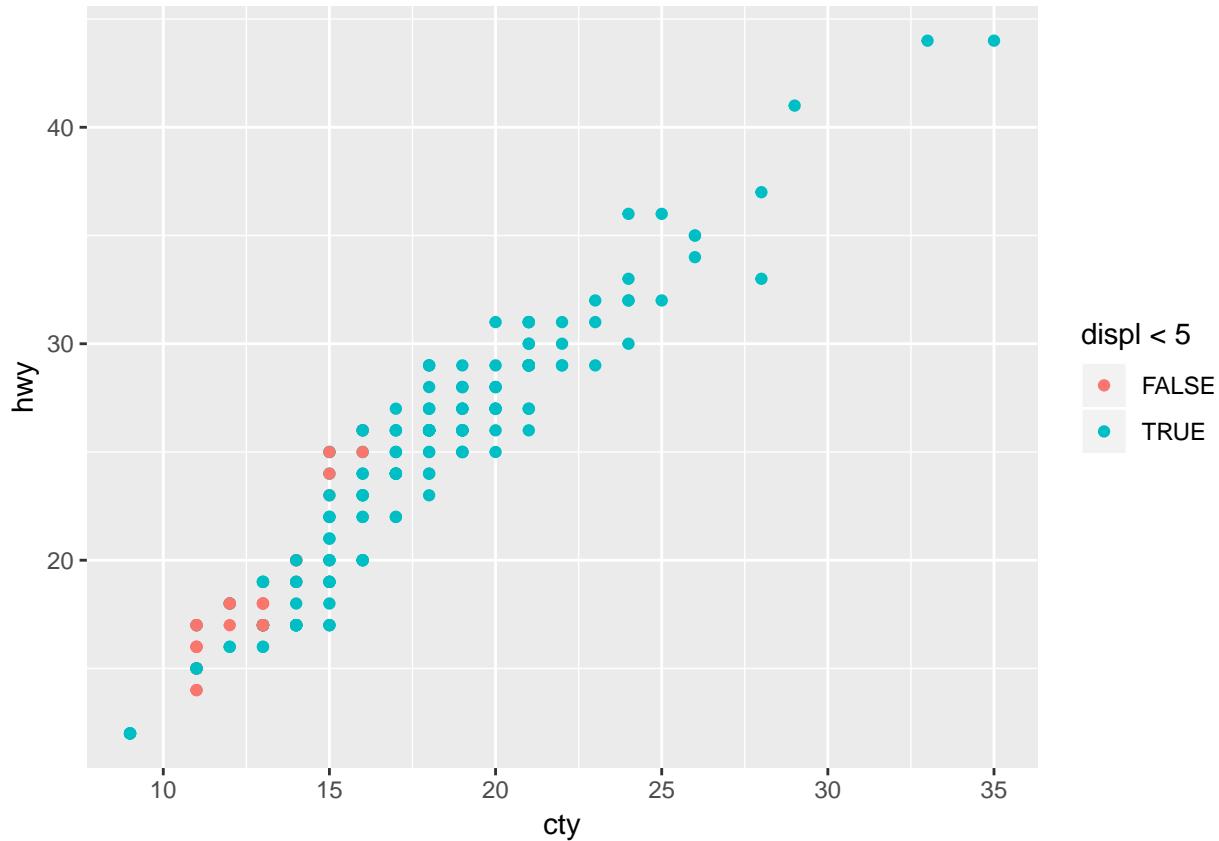
```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +  
  geom_point(shape = 21, colour = "black", fill = "white", size = 5, stroke = 3)
```



For shapes that have a border (like 21), you can colour the inside and outside separately. Use the stroke aesthetic to modify the width of the border.

6. What happens if you map an aesthetic to something other than a variable name, like `aes(colour = displ < 5)`?

```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy, colour = displ < 5)) +  
  geom_point()
```

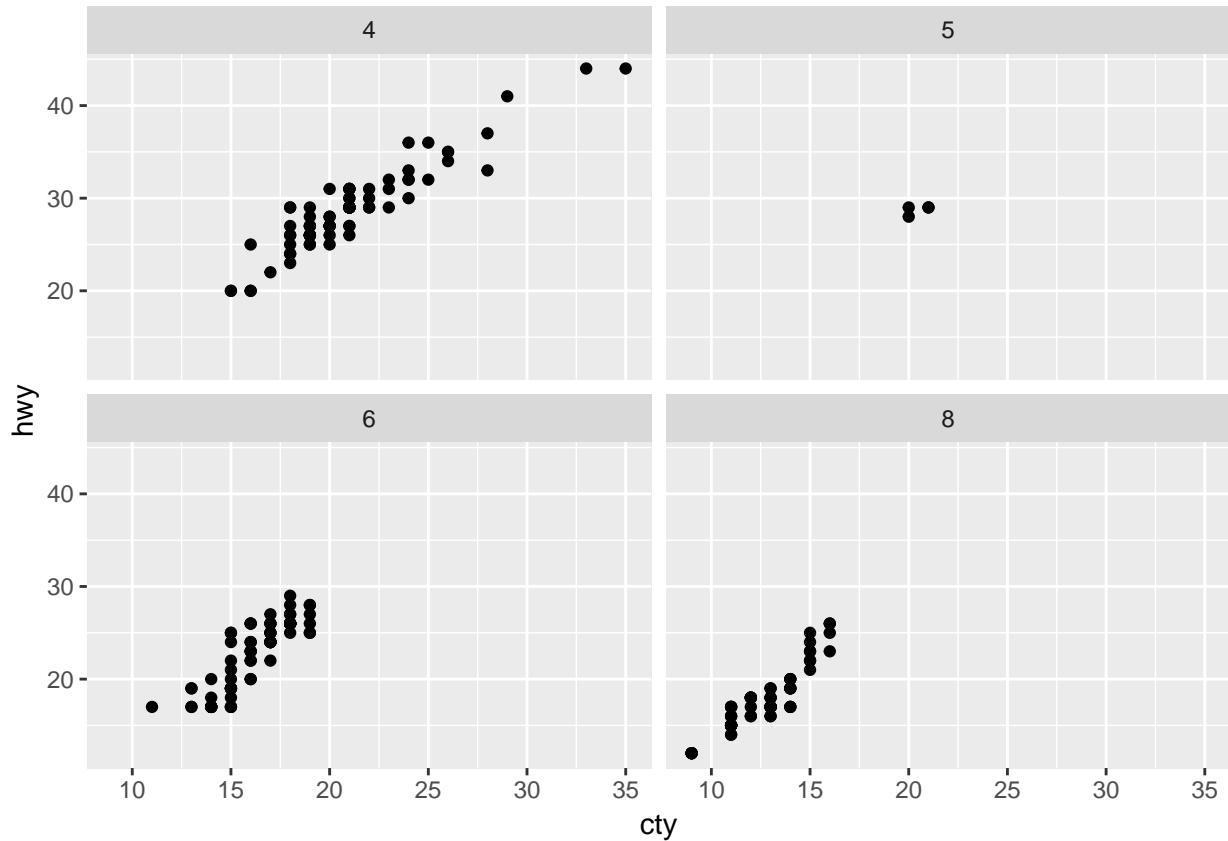


5.3 3.5: Facets

5.3.1 3.5.1.

- What happens if you facet on a continuous variable?

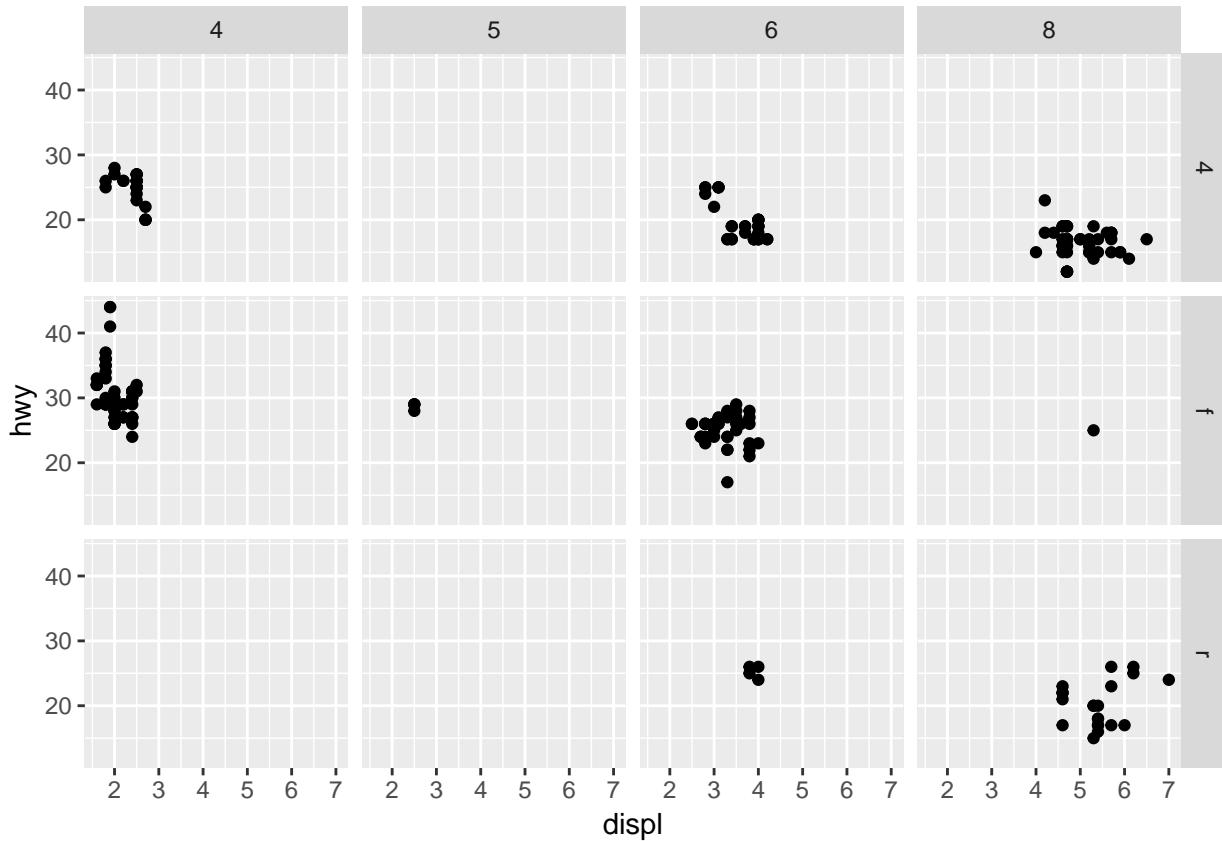
```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +
  geom_point() +
  facet_wrap(~cyl)
```



It will facet along all of the possible values.

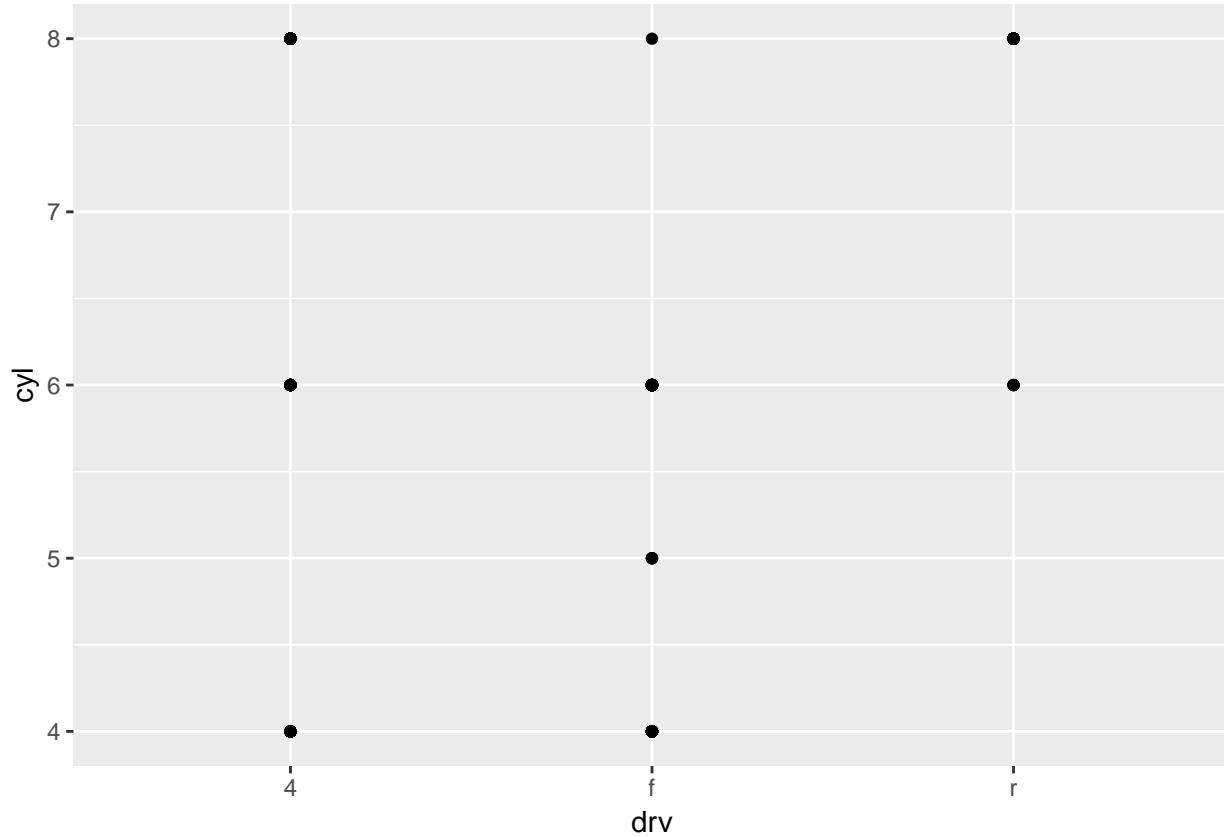
2. What do the empty cells in plot with `facet_grid(drv ~ cyl)` mean?

```
ggplot(data = mpg) +  
  geom_point(mapping = aes(x = displ, y = hwy)) +  
  facet_grid(drv ~ cyl)
```



How do they relate to this plot?

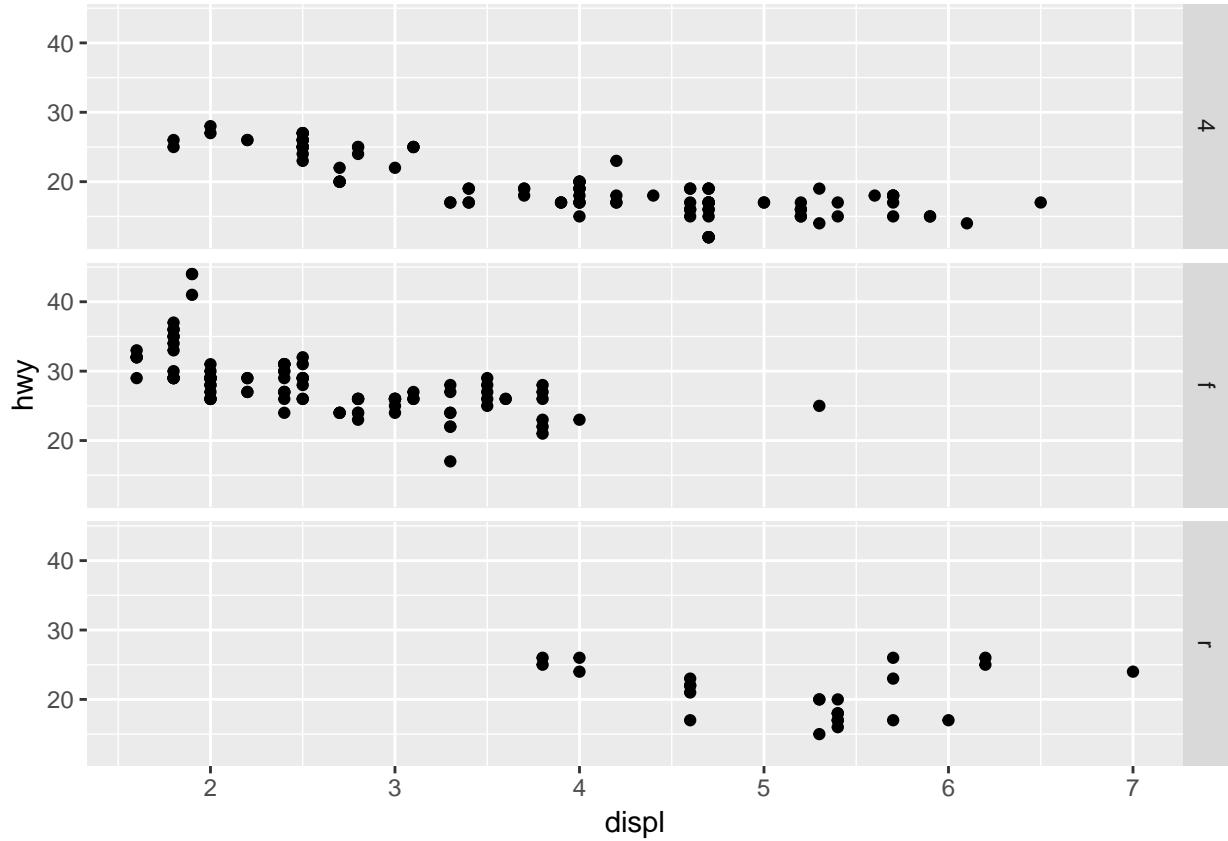
```
ggplot(data = mpg) +  
  geom_point(mapping = aes(x = disp, y = cyl))
```



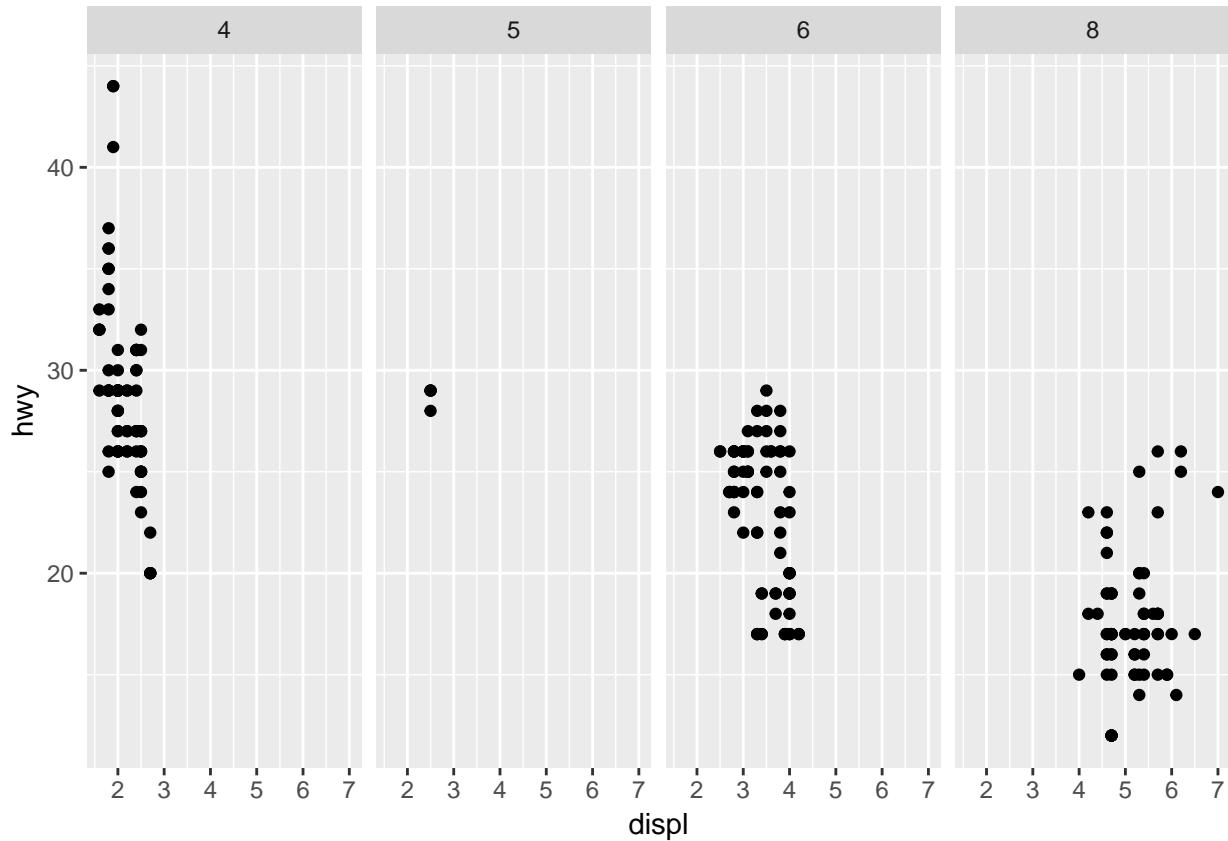
They represent the locations where there is no point on the above graph (could be made more clear by giving consistent order to axes).

3. What plots does the following code make? What does . do?

```
ggplot(data = mpg) +  
  geom_point(mapping = aes(x = displ, y = hwy)) +  
  facet_grid(drv ~ .)
```



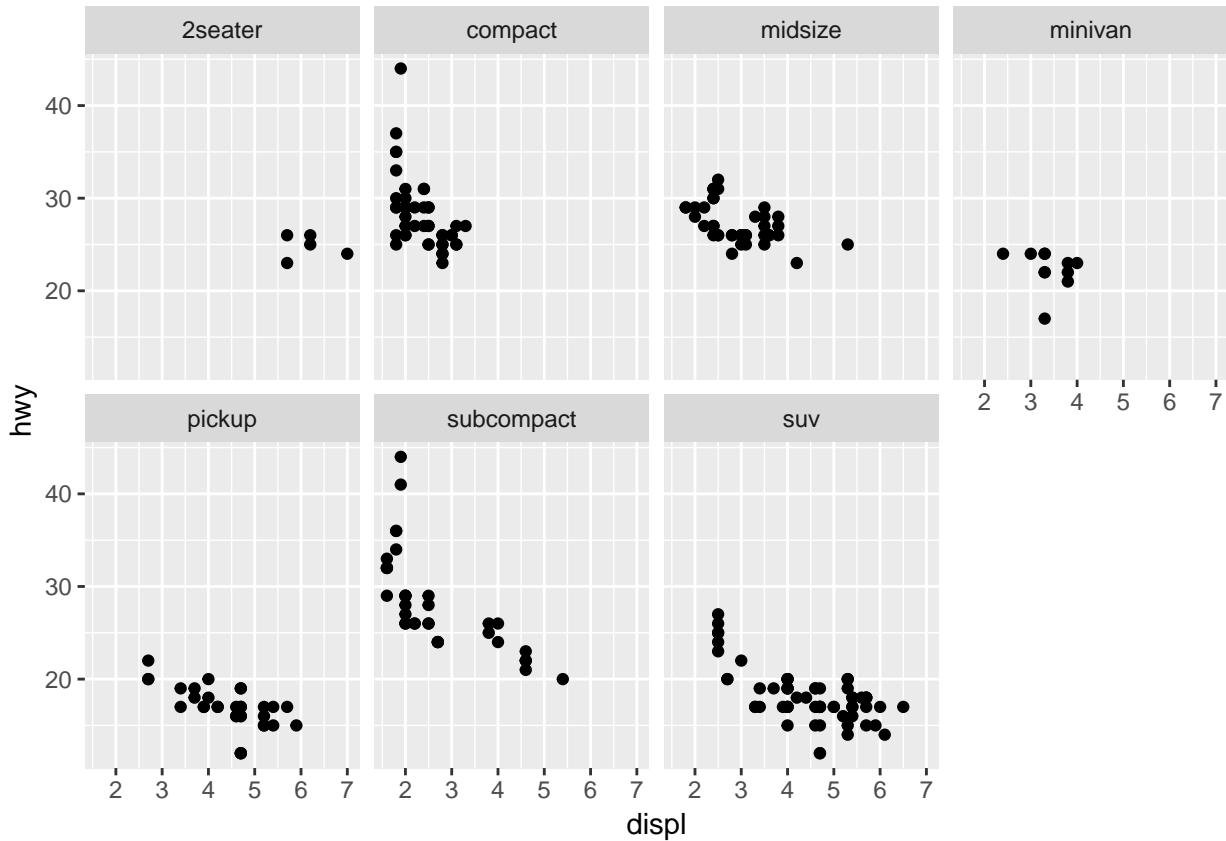
```
ggplot(data = mpg) +  
  geom_point(mapping = aes(x = displ, y = hwy)) +  
  facet_grid(. ~ cyl)
```



Can use to specify if to facet by rows or columns.

4. Take the first faceted plot in this section:

```
ggplot(data = mpg) +  
  geom_point(mapping = aes(x = displ, y = hwy)) +  
  facet_wrap(~ class, nrow = 2)
```



What are the advantages to using faceting instead of the colour aesthetic? What are the disadvantages? How might the balance change if you had a larger dataset?

Faceting prevents overlapping points in the data. A disadvantage is that you have to move your eye to look at different graphs. Some groups you don't have much data on as well so those don't present much information. If there is more data, you may be more comfortable using faceting as each group should have points that you can view.

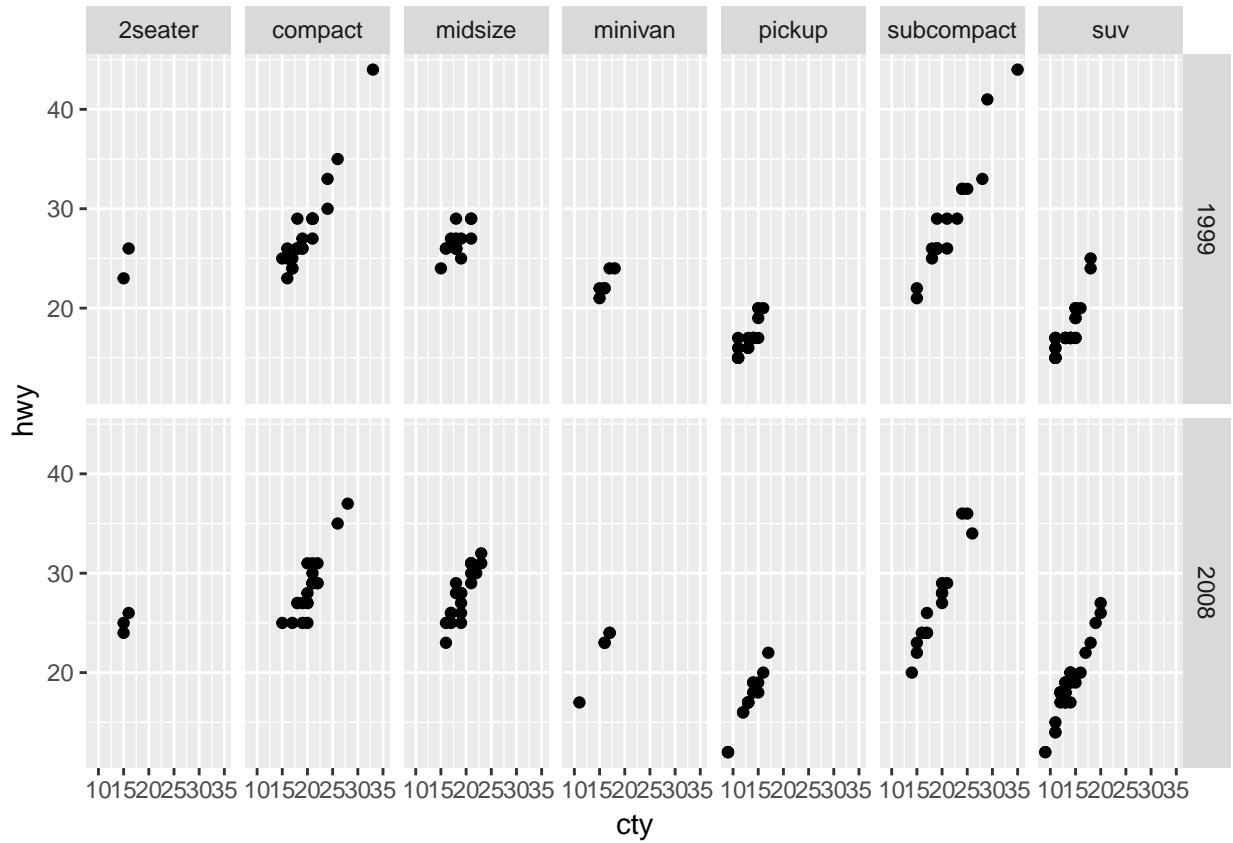
5. Read ?facet_wrap. What does nrow do? What does ncol do? What other options control the layout of the individual panels? Why doesn't facet_grid() have nrow and ncol argument?

nrow and ncol specify the number of columns or rows to facet by, facet_grid does not have this option because the splits are defined by the number of unique values in each variable. Other important options are scales which let you define if the scales are able to change between each plot.

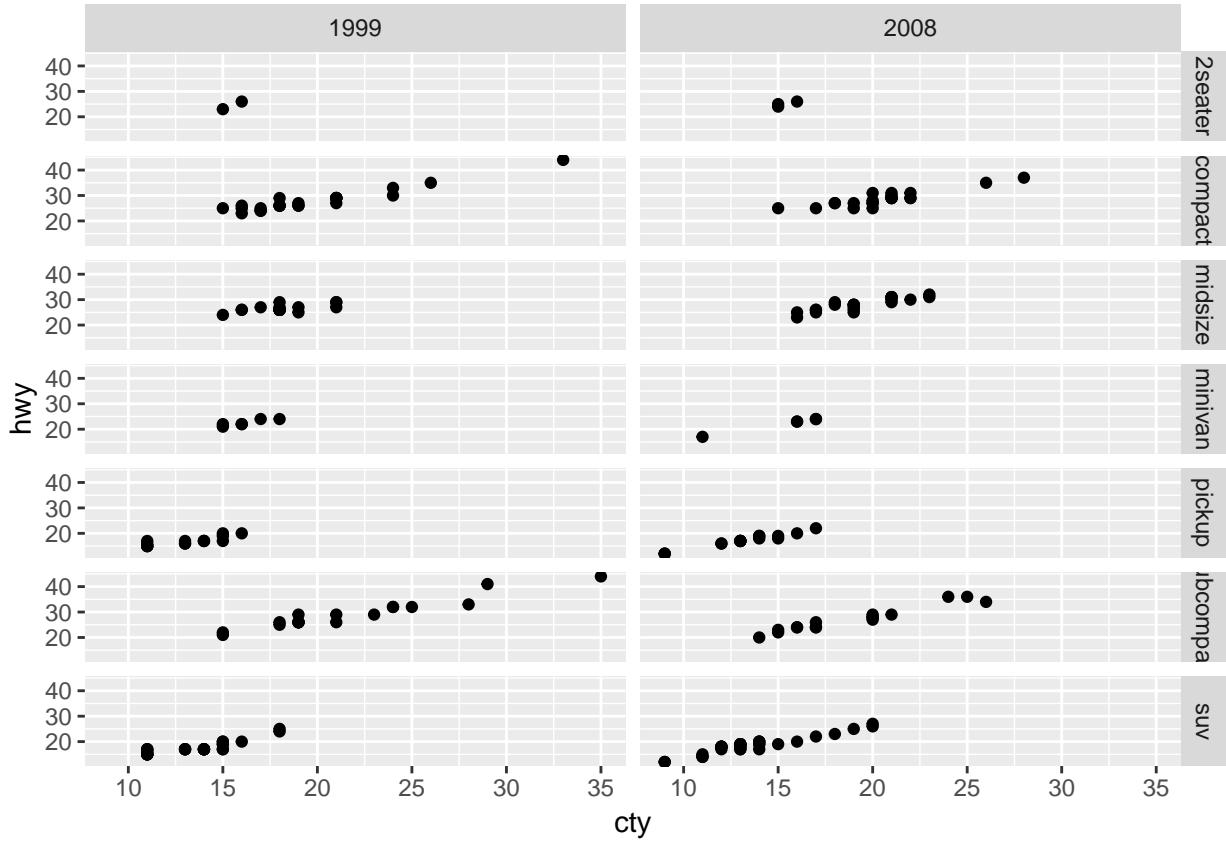
6. When using facet_grid() you should usually put the variable with more unique levels in the columns. Why?

I'm not sure why exactly, if I compare these, it's not completely unclear.

```
#more unique levels on columns
ggplot(data = mpg) +
  geom_point(mapping = aes(x = cty, y = hwy)) +
  facet_grid(year ~ class)
```



```
#more unique levels on rows
ggplot(data = mpg) +
  geom_point(mapping = aes(x = cty, y = hwy)) +
  facet_grid(class ~ year)
```



My guess though would be that it's because our computer screens are generally wider than they are tall. Hence there will be more space for viewing a higher number of attributes going across columns than by rows.

5.4 3.6: Geometric Objects

5.4.1 3.6.1

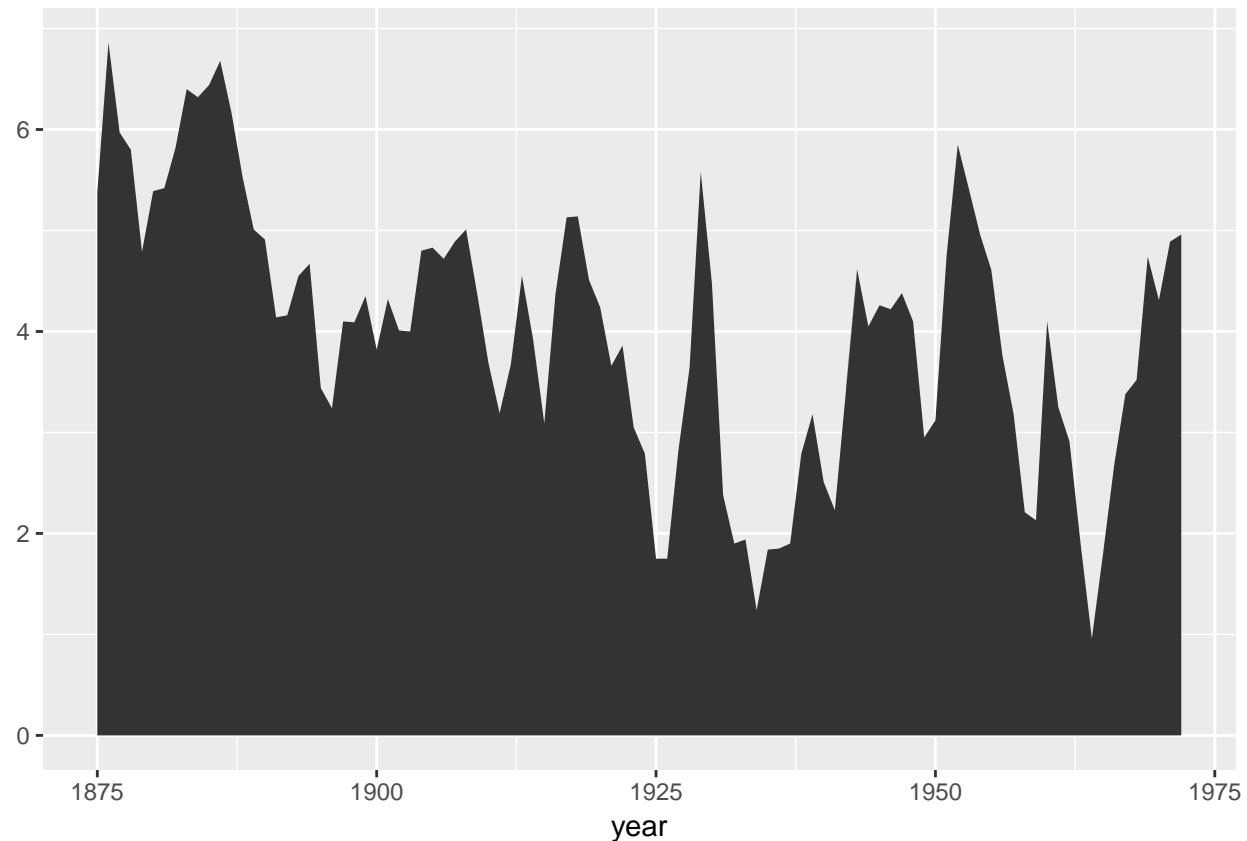
1. What geom would you use to draw a line chart? A boxplot? A histogram? An area chart?

- * geom_line
- * geom_boxplot
- * geom_histogram
- * geom_area + Notice that geom_area is just a special case of geom_ribbon

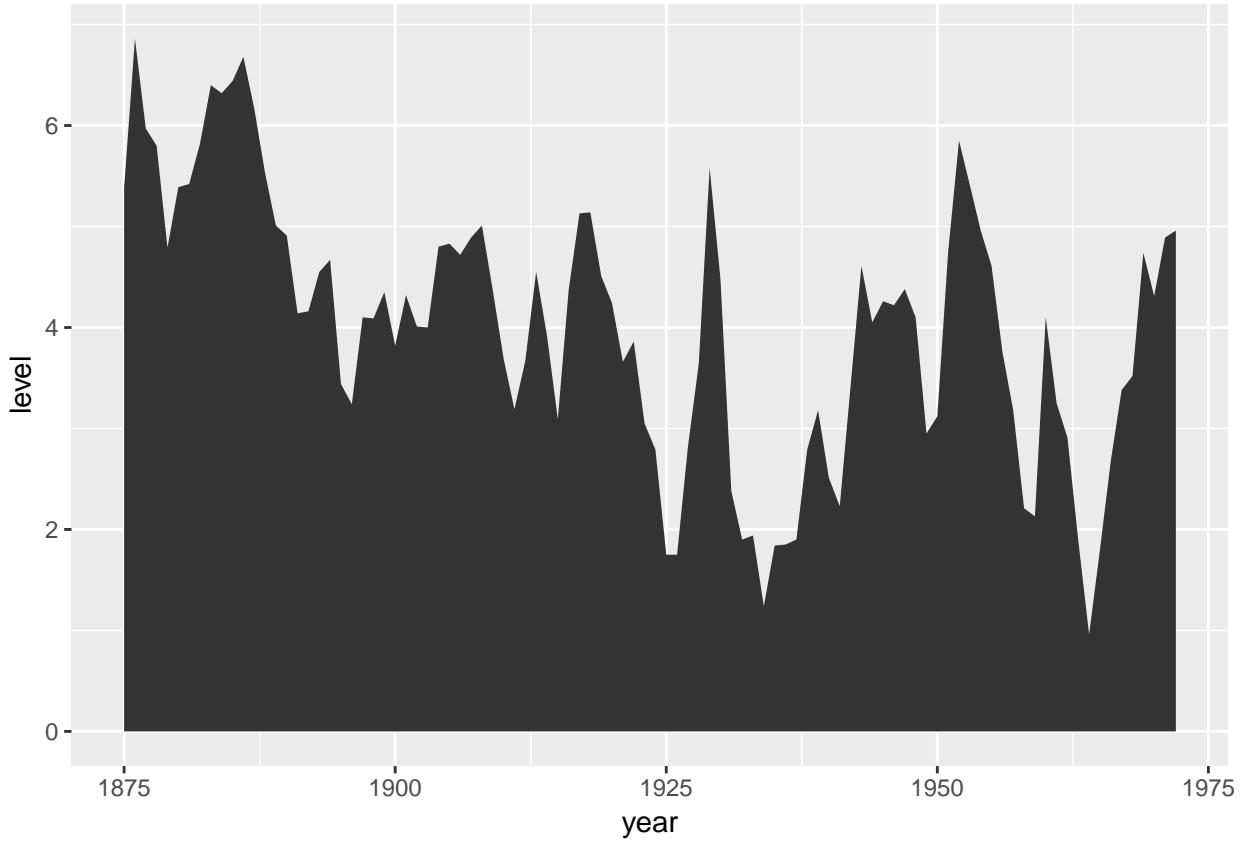
Example of geom_area:

```
huron <- data.frame(year = 1875:1972, level = as.vector(LakeHuron) - 575)
h <- ggplot(huron, aes(year))

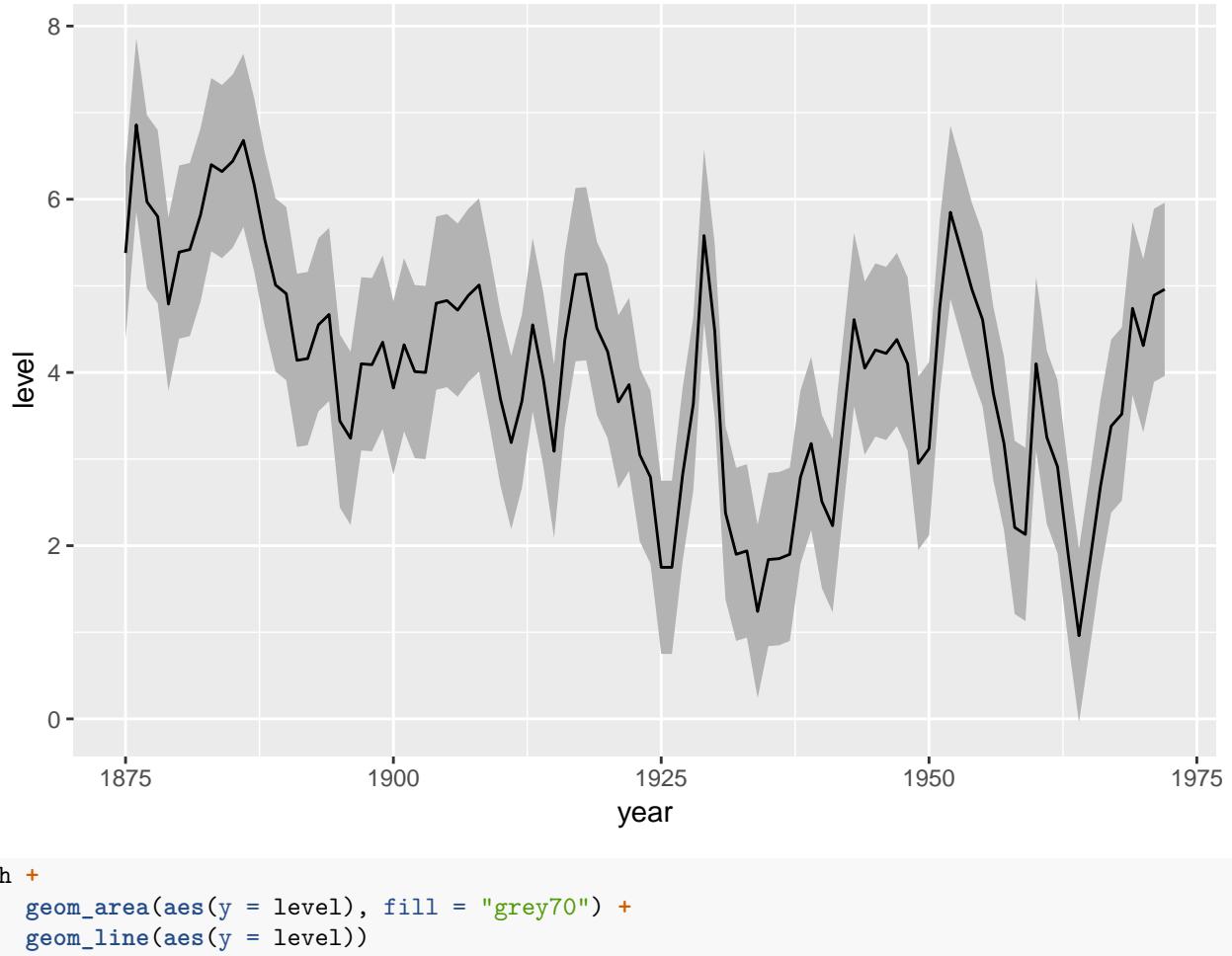
h + geom_ribbon(aes(ymin = 0, ymax = level))
```

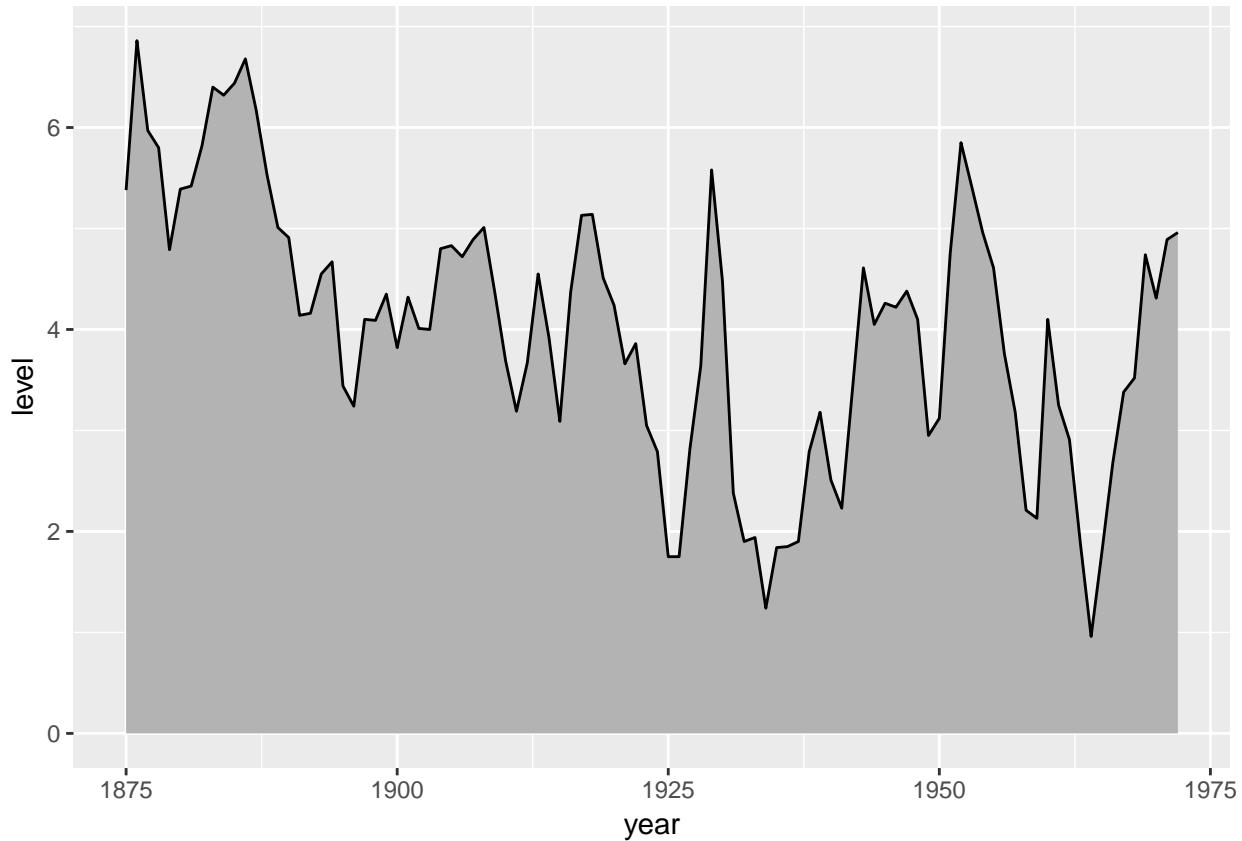


```
h + geom_area(aes(y = level))
```



```
# Add aesthetic mappings
h +
  geom_ribbon(aes(ymin = level - 1, ymax = level + 1), fill = "grey70") +
  geom_line(aes(y = level))
```

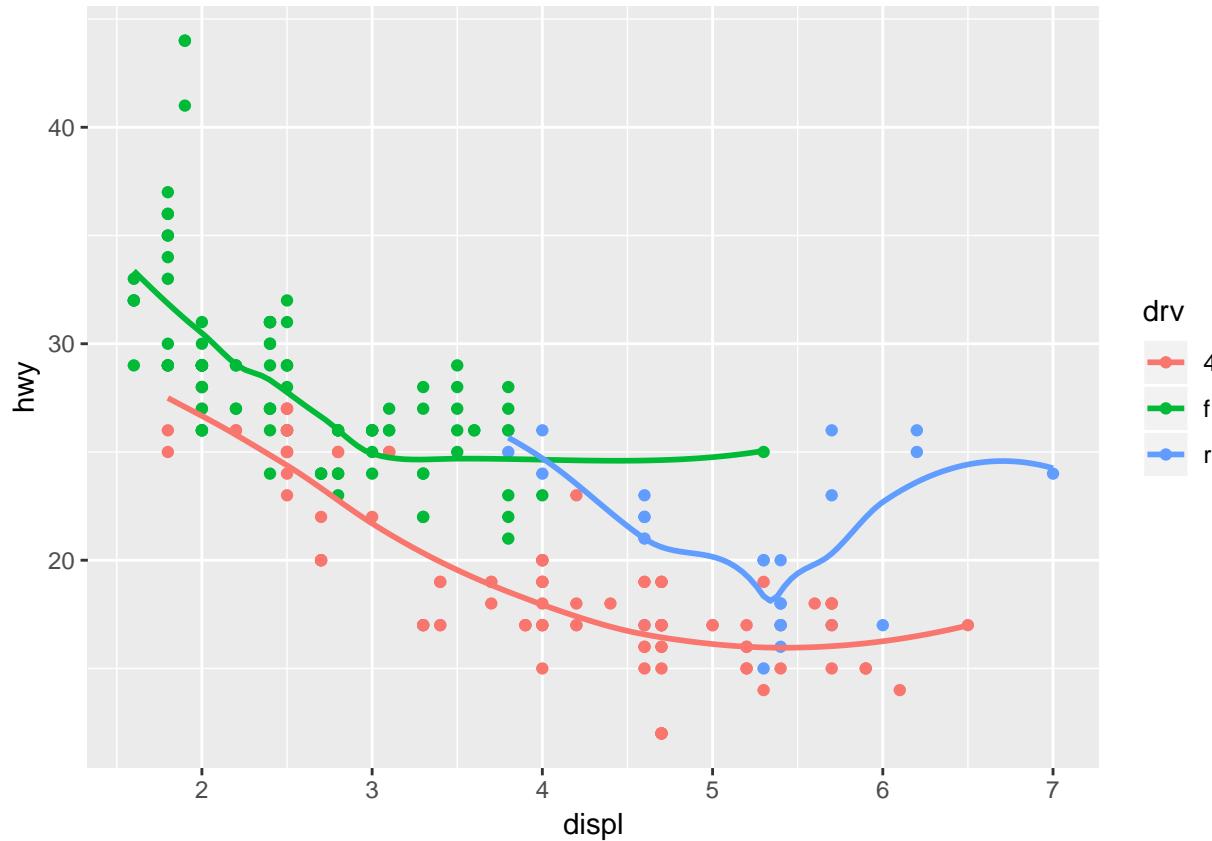




2. Run this code in your head and predict what the output will look like. Then, run the code in R and check your predictions.

```
ggplot(data = mpg, mapping = aes(x = displ, y = hwy, color = drv)) +
  geom_point() +
  geom_smooth(se = FALSE)
```

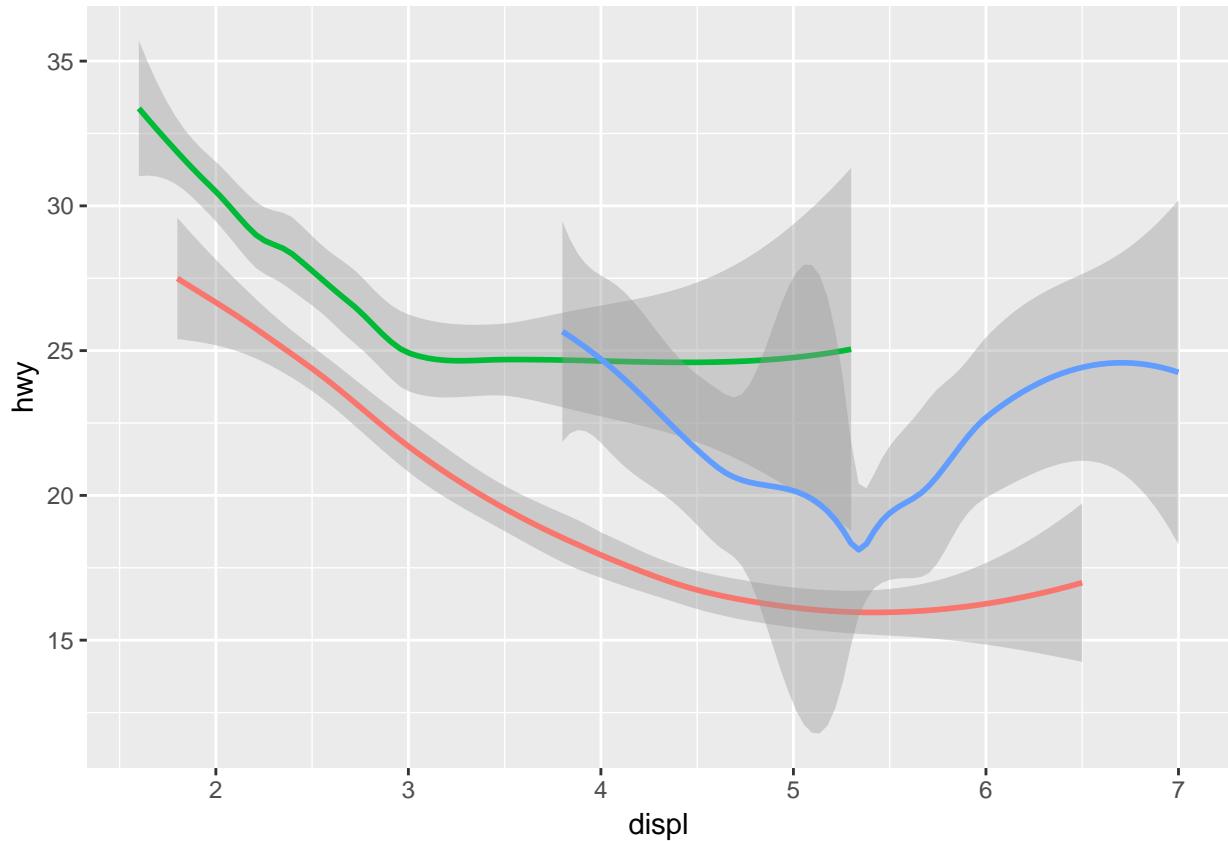
```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



3. What does `show.legend = FALSE` do? What happens if you remove it? Why do you think I used it earlier in the chapter?

```
ggplot(data = mpg) +
  geom_smooth(
    mapping = aes(x = displ, y = hwy, color = drv),
    show.legend = FALSE
  )
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



It gets rid of the legend that would be associated with this geom. You removed it previously to keep it consistent with your other graphs that did not include them to specify the `drv`.

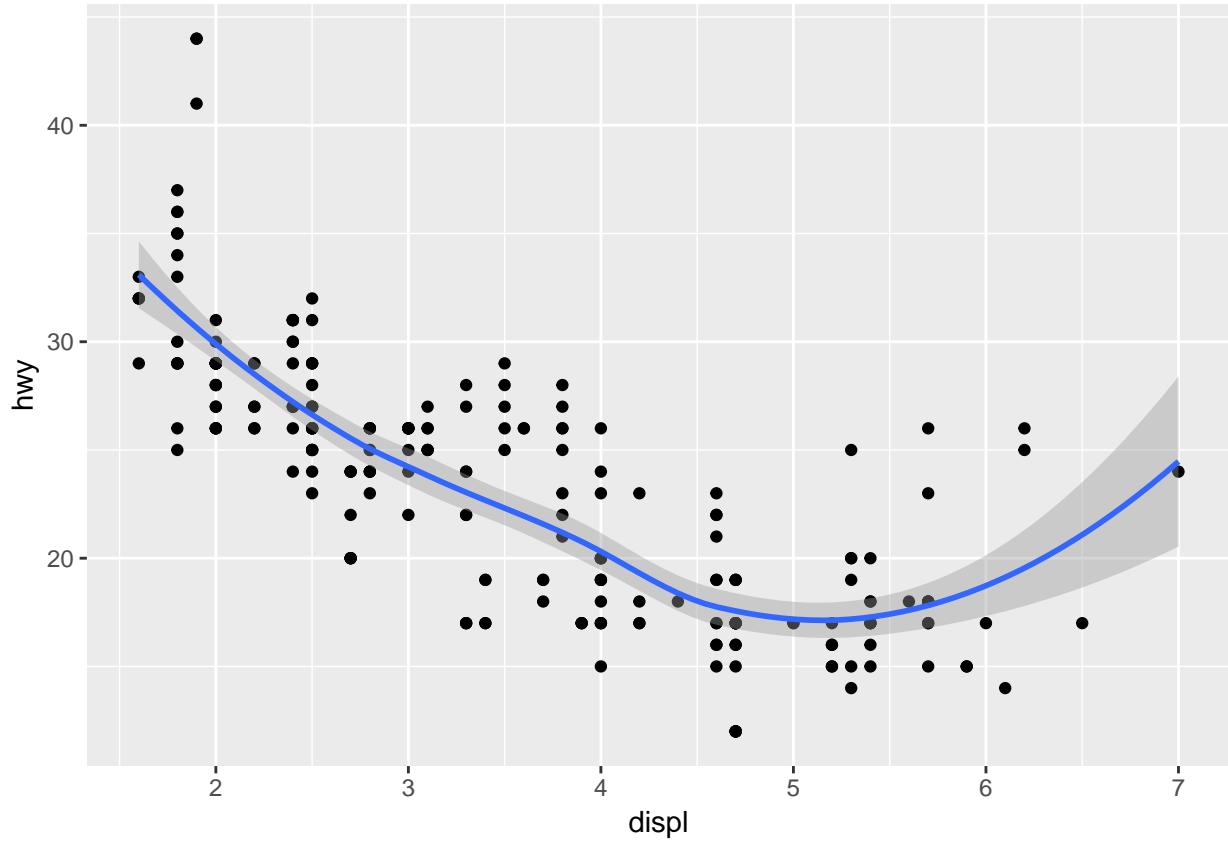
4. What does the `se` argument to `geom_smooth()` do?

`se` here stands for standard error, so if we specify it as `FALSE` we are saying we do not want to show the standard errors for the plot.

5. Will these two graphs look different? Why/why not?

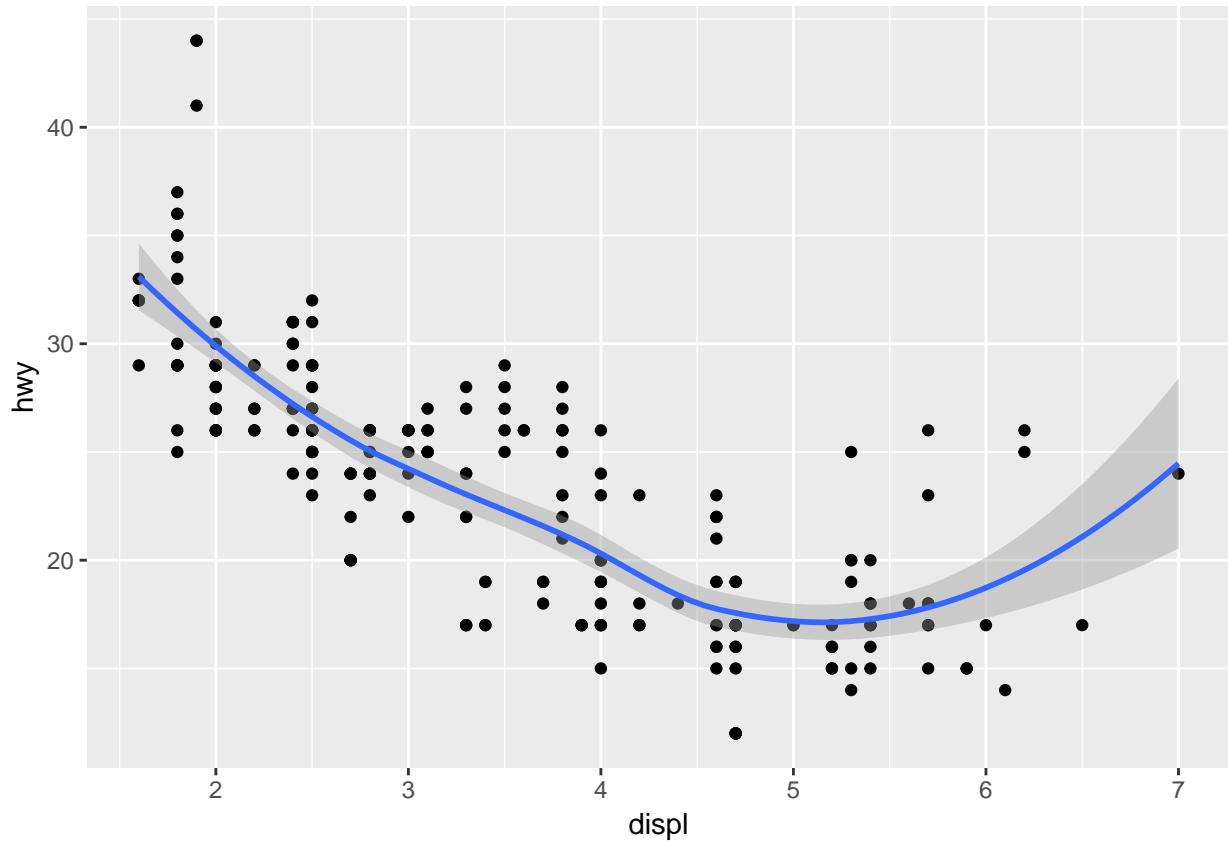
```
ggplot(data = mpg, mapping = aes(x = displ, y = hwy)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



```
ggplot() +
  geom_point(data = mpg, mapping = aes(x = displ, y = hwy)) +
  geom_smooth(data = mpg, mapping = aes(x = displ, y = hwy))
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

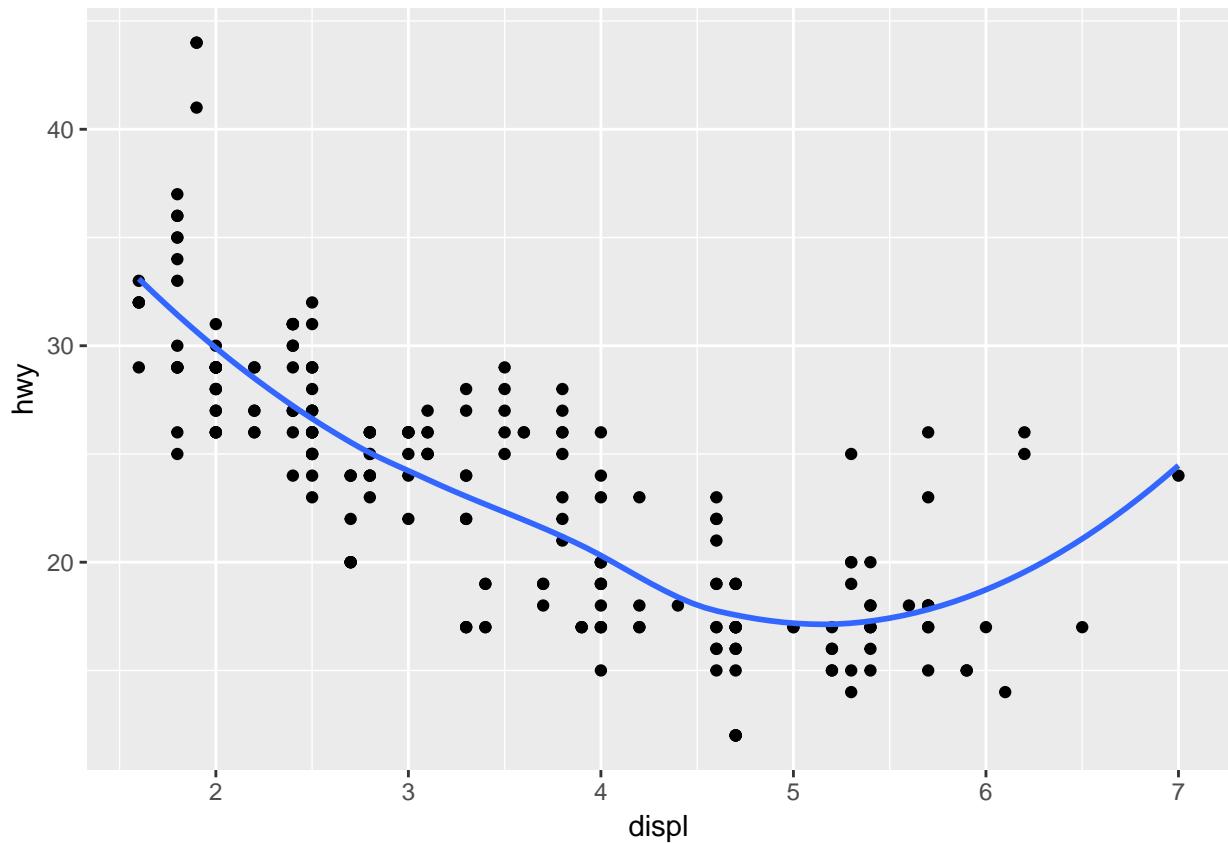


No, because local mappings for each geom are the same as the global mappings in the other.

6. Recreate the R code necessary to generate the following graphs.

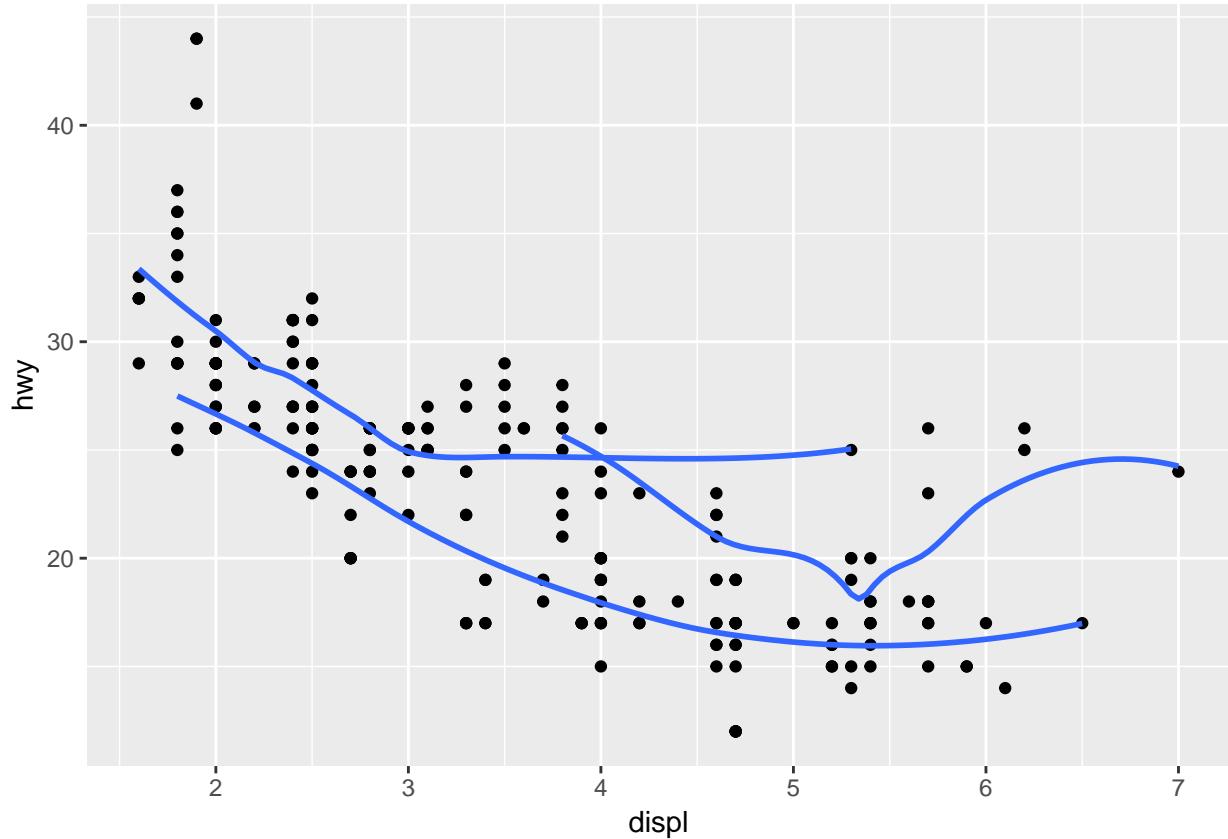
```
ggplot(mpg, aes(displ, hwy))+
  geom_point() +
  geom_smooth(se = FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



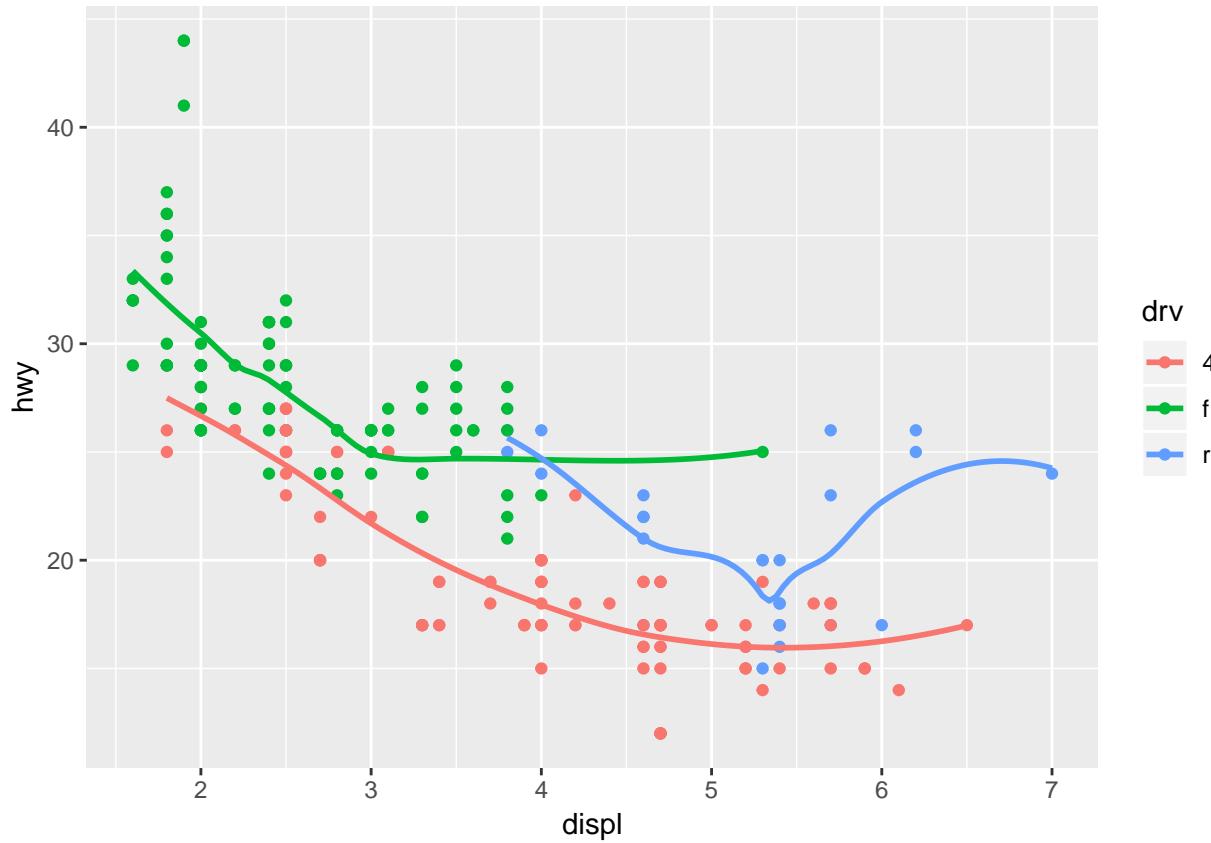
```
ggplot(mpg, aes(displ, hwy, group = drv)) +  
  geom_point() +  
  geom_smooth(se = FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



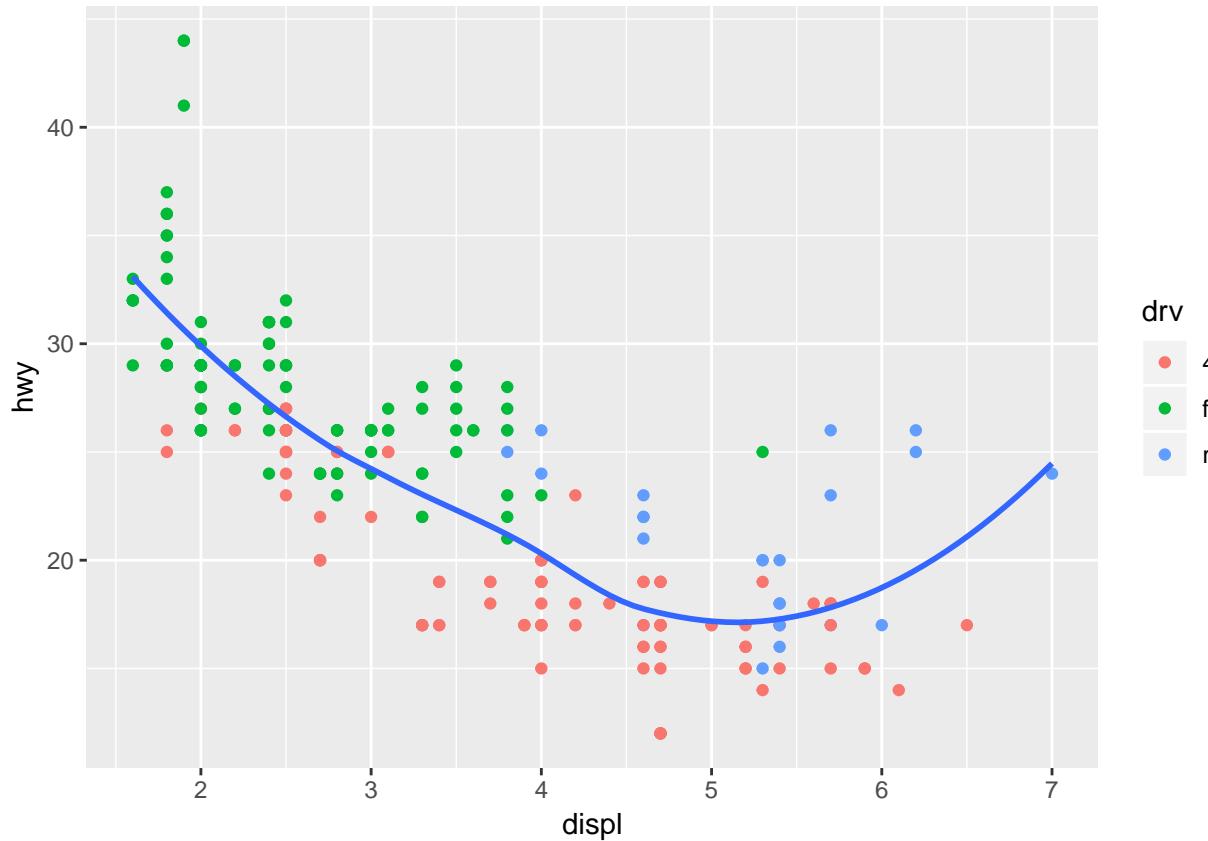
```
ggplot(mpg, aes(displ, hwy, colour = drv)) +  
  geom_point() +  
  geom_smooth(se = FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



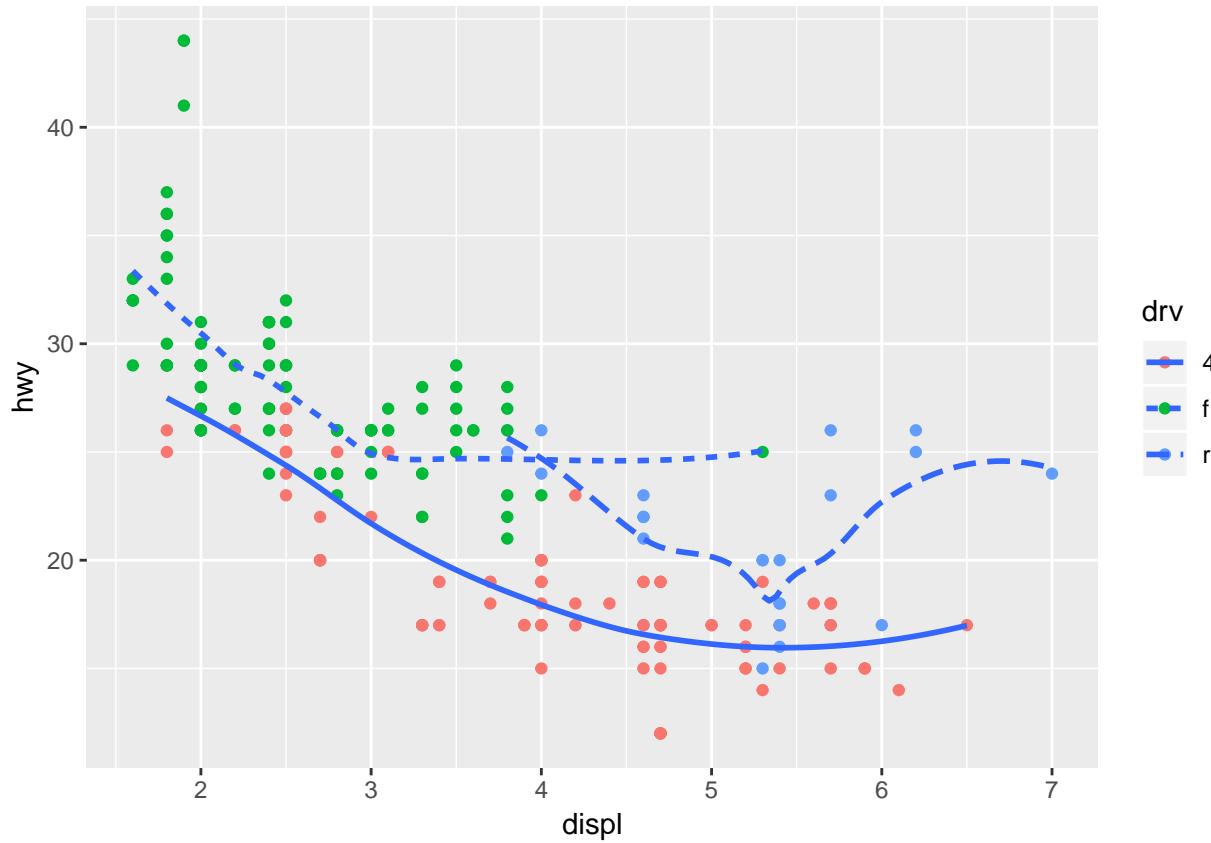
```
ggplot(mpg, aes(displ, hwy))+
  geom_point(aes(colour = drv)) +
  geom_smooth(se = FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

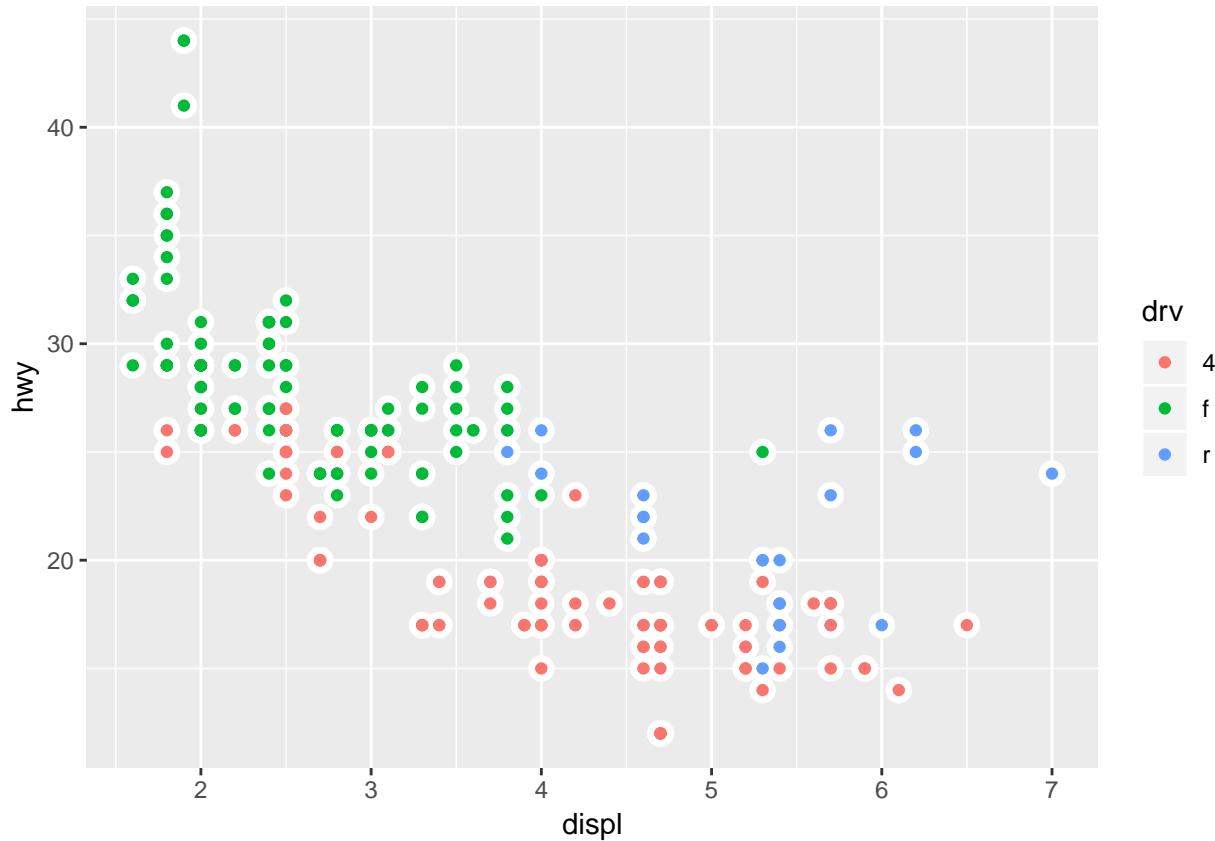


```
ggplot(mpg, aes(displ, hwy))+
  geom_point(aes(color = drv)) +
  geom_smooth(aes(linetype = drv), se = FALSE)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



```
ggplot(mpg, aes(displ, hwy)) +  
  geom_point(colour = "white", size = 4) +  
  geom_point(aes(colour = drv))
```



5.5 3.7: statistical transformations

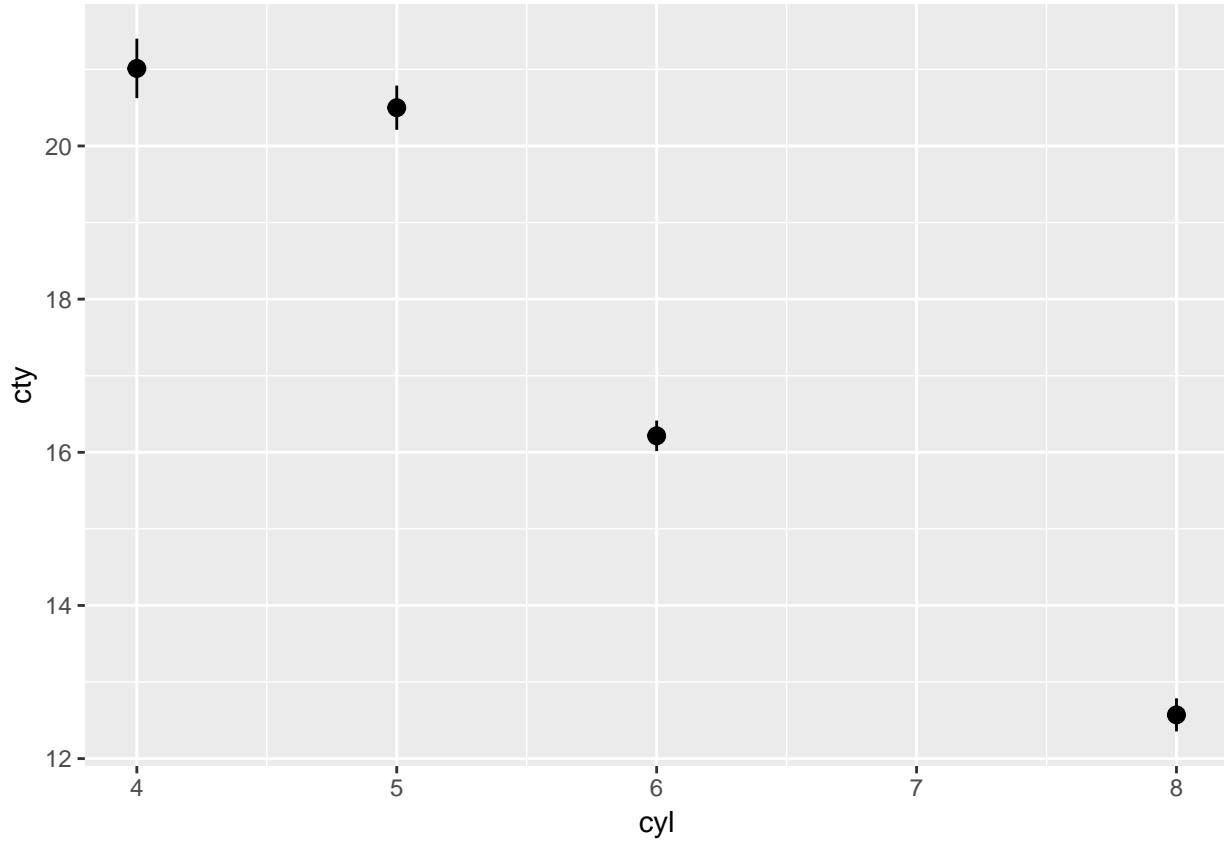
5.5.1 3.7.1.

- What is the default `geom` associated with `stat_summary()`? How could you rewrite the previous plot to use that `geom` function instead of the `stat` function?

The default is `geom_pointrange`, the point being the mean, and the lines being the standard error on the y value (i.e. the deviation of the mean of the value).

```
ggplot(mpg) +
  stat_summary(aes(cyl, cty))
```

```
## No summary function supplied, defaulting to `mean_se()`
```

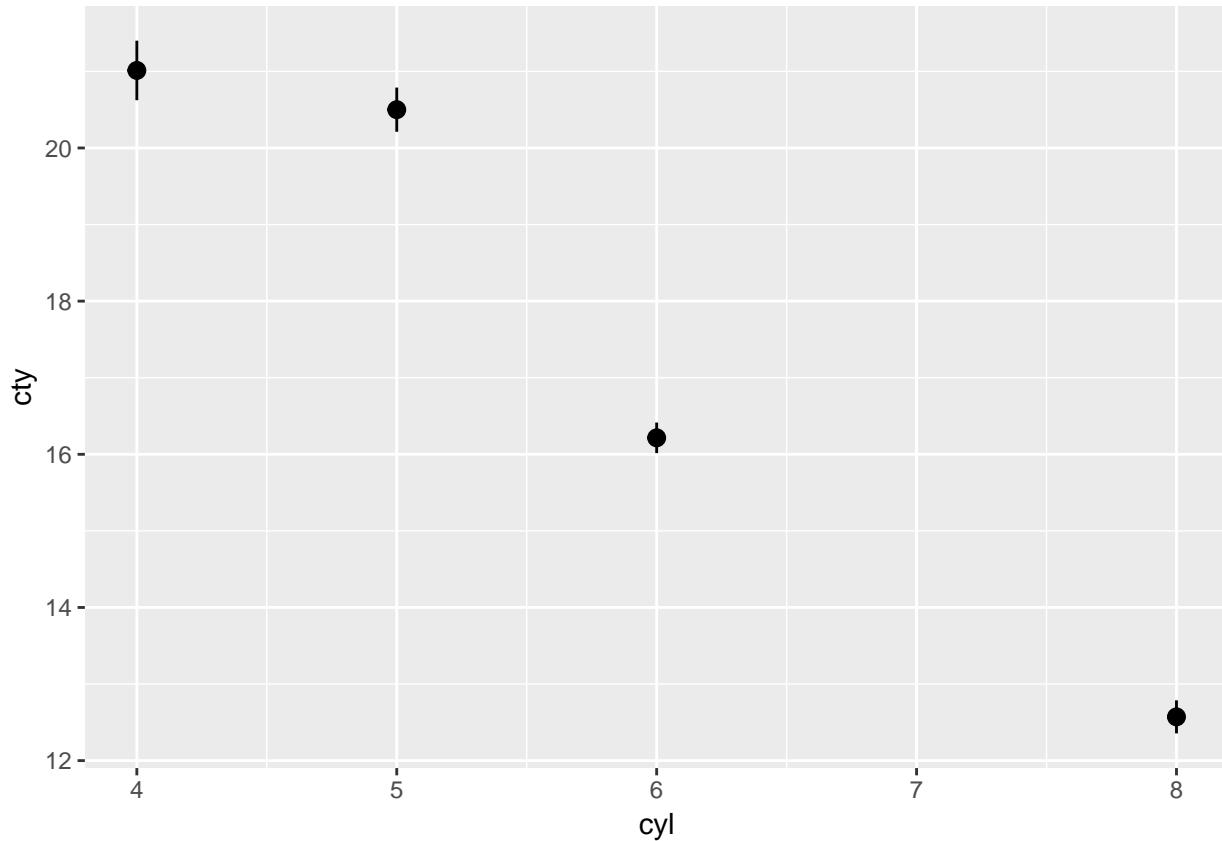


Rewritten with `geom1`:

```
ggplot(mpg) +  
  geom_pointrange(aes(x = cyl, y = cty), stat = "summary")
```

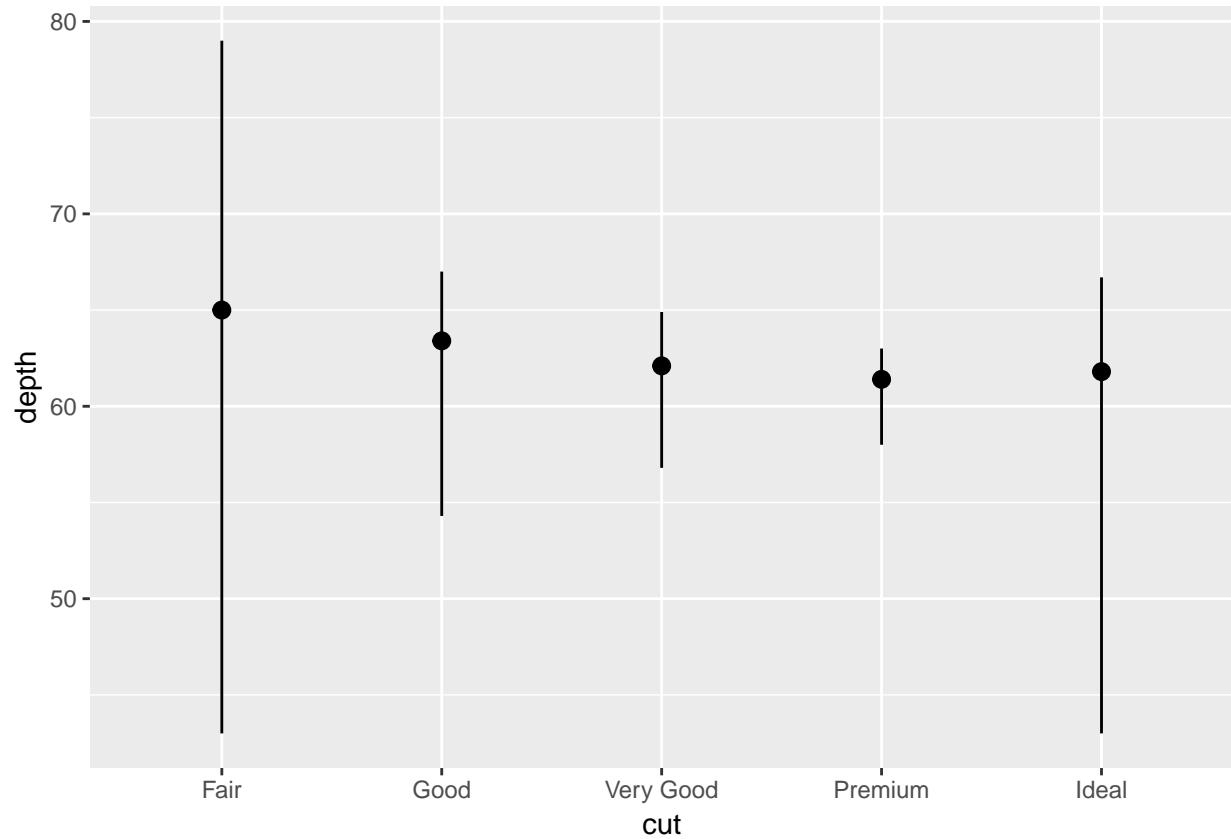
```
## No summary function supplied, defaulting to `mean_se()`
```

¹See 3.7.1.1 extension for notes on how to relate this to dplyr code.



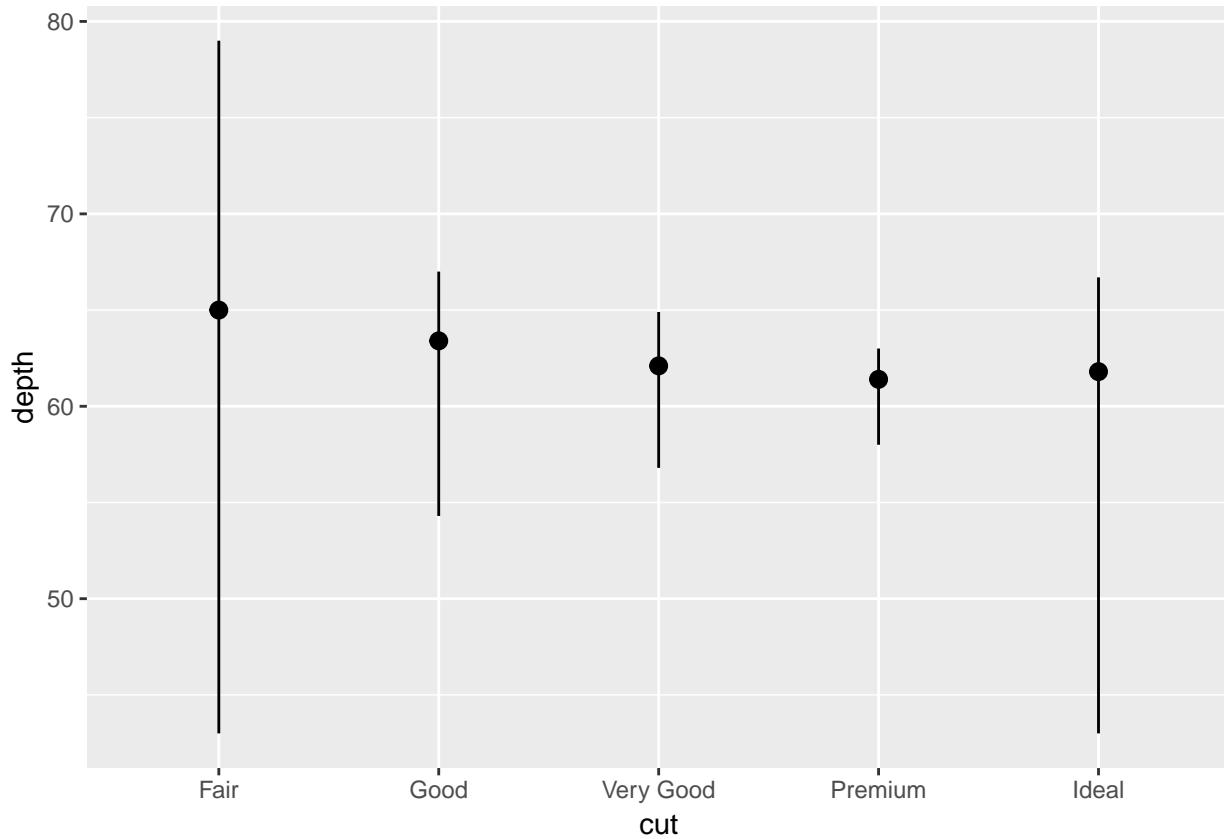
The specific example though is actually not the default:

```
ggplot(data = diamonds) +
  stat_summary(
    mapping = aes(x = cut, y = depth),
    fun.ymin = min,
    fun.ymax = max,
    fun.y = median
  )
```



Rewritten with geom:

```
ggplot(data = diamonds) +  
  geom_pointrange(aes(x = cut, y = depth),  
                  stat = "summary",  
                  fun.ymin = "min",  
                  fun.ymax = "max",  
                  fun.y = "median")
```



2. What does geom_col() do? How is it different to geom_bar()?

geom_col has "identity" as the defaultstat, so it expects to receive a variable that already has the value aggregated² [I often use this over geom_bar and do the aggregation with dplyr rather than ggplot2]

3. Most geoms and stats come in pairs that are almost always used in concert. Read through the documentation and make a list of all the pairs. What do they have in common?

?ggplot2

4. What variables does stat_smooth() compute? What parameters control its behaviour?

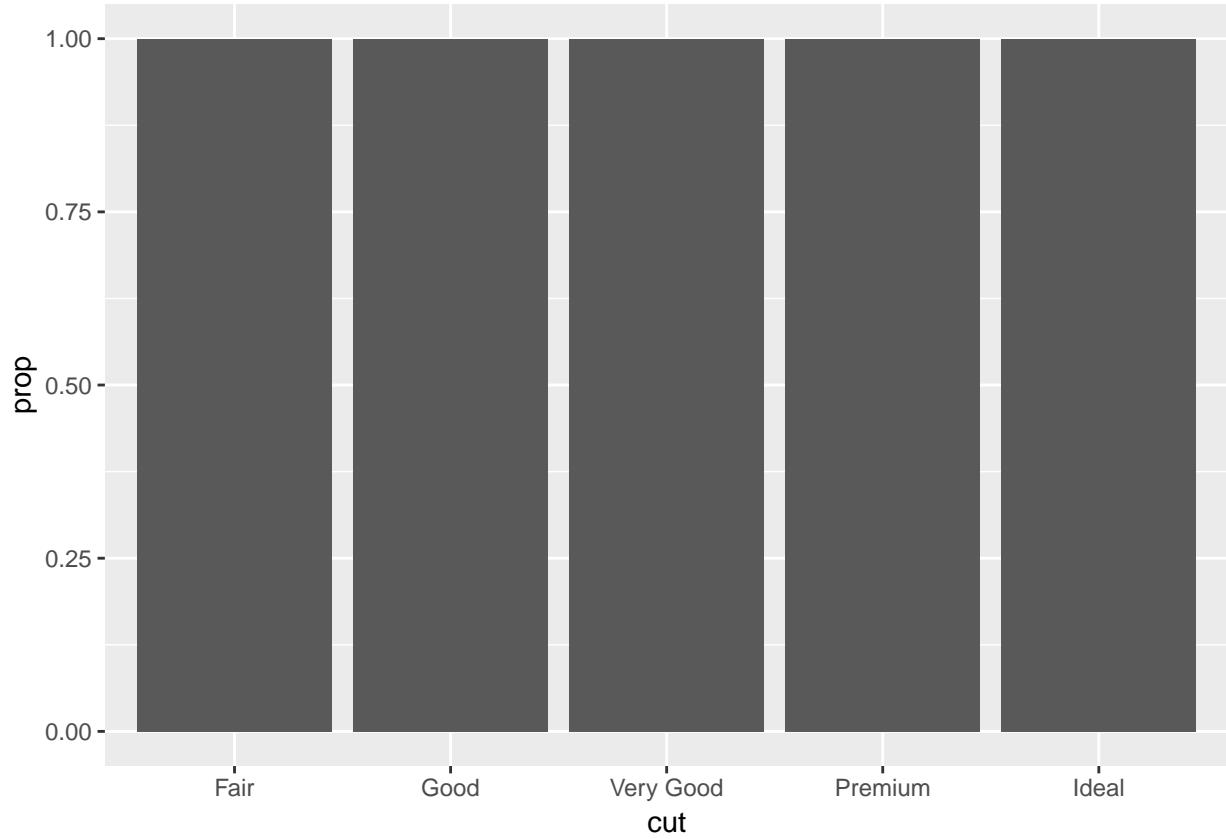
See here: <http://ggplot2.tidyverse.org/reference/#section-layer-stats> for a helpful resource. Also, someone who aggregated some online: <http://sape.inf.usi.ch/quick-reference/ggplot2/geom>²

5. In our proportion bar chart, we need to set group = 1. Why? In other words what is the problem with these two graphs?

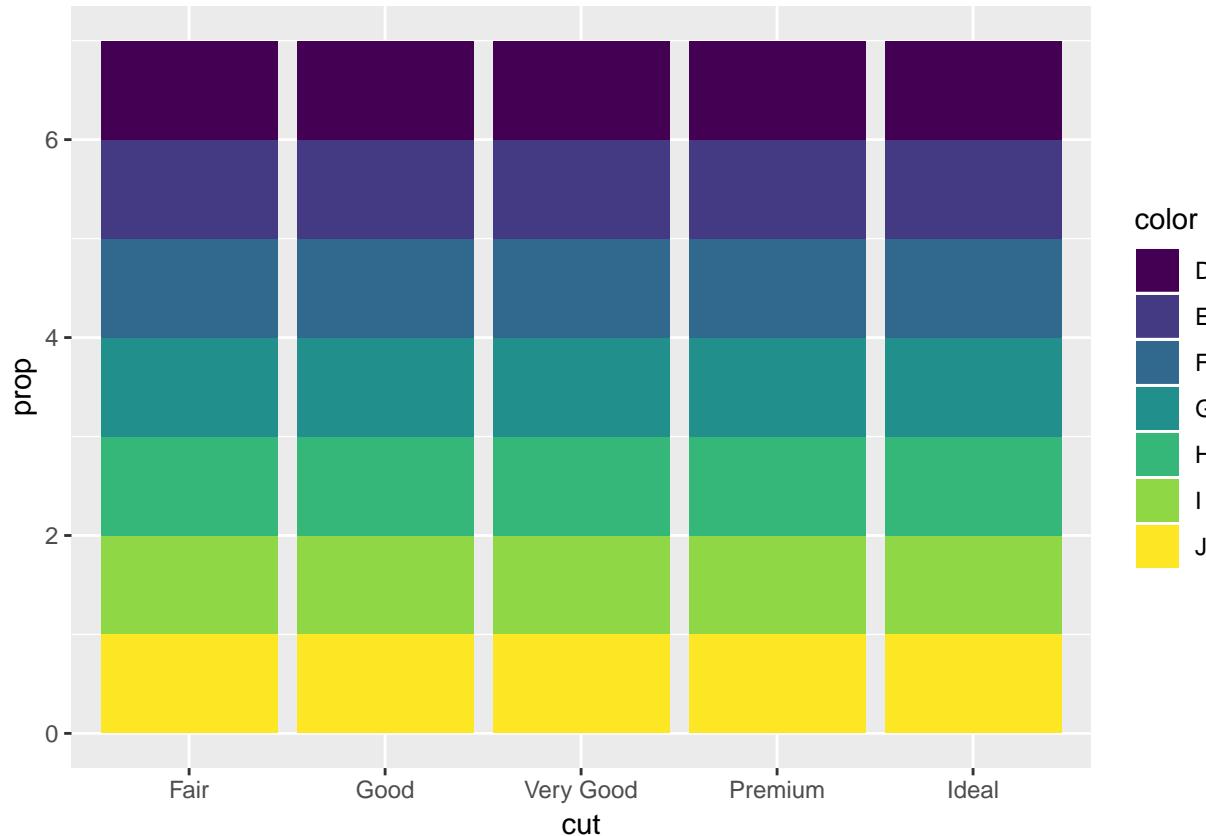
(key question)

```
ggplot(data = diamonds) +
  geom_bar(mapping = aes(x = cut, y = ..prop..))
```

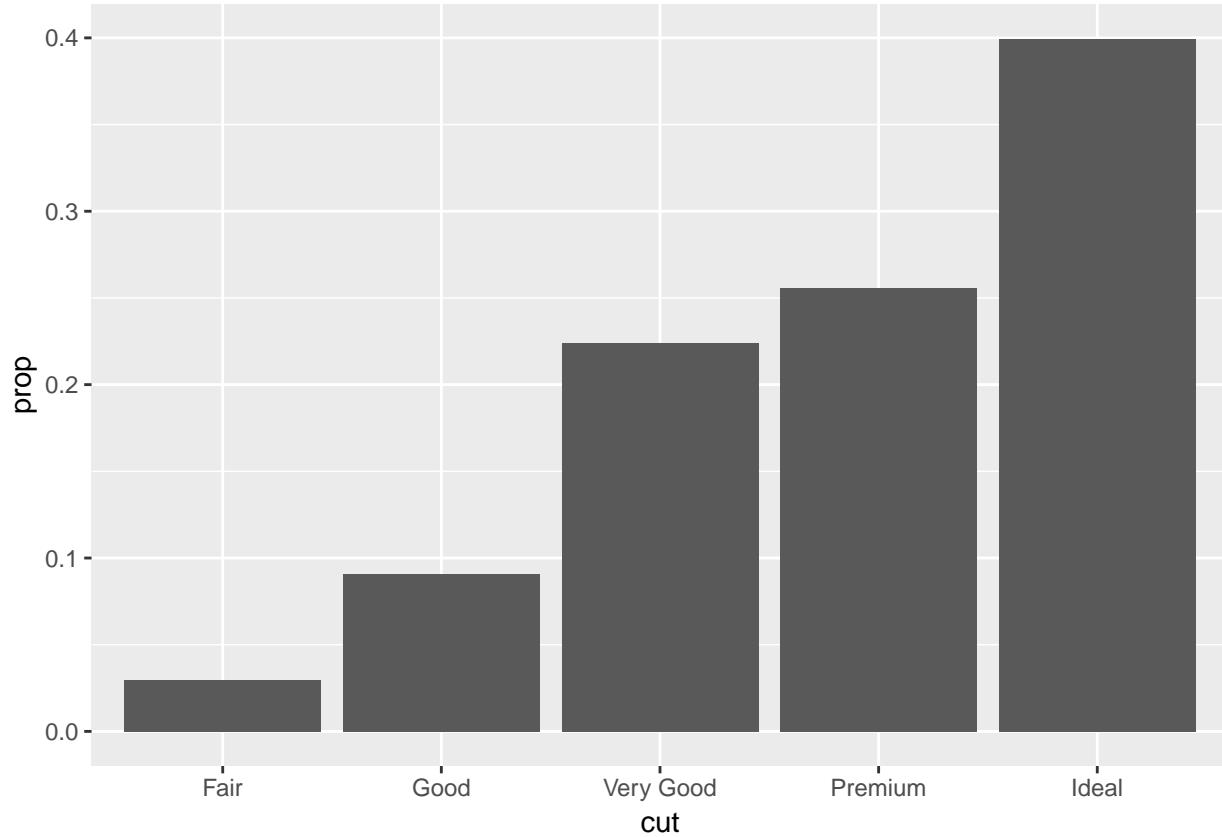
²Though it's missing some very common ones like geom_col and geom_bar.



```
ggplot(data = diamonds) +  
  geom_bar(mapping = aes(x = cut, fill = color, y = ..prop..))
```

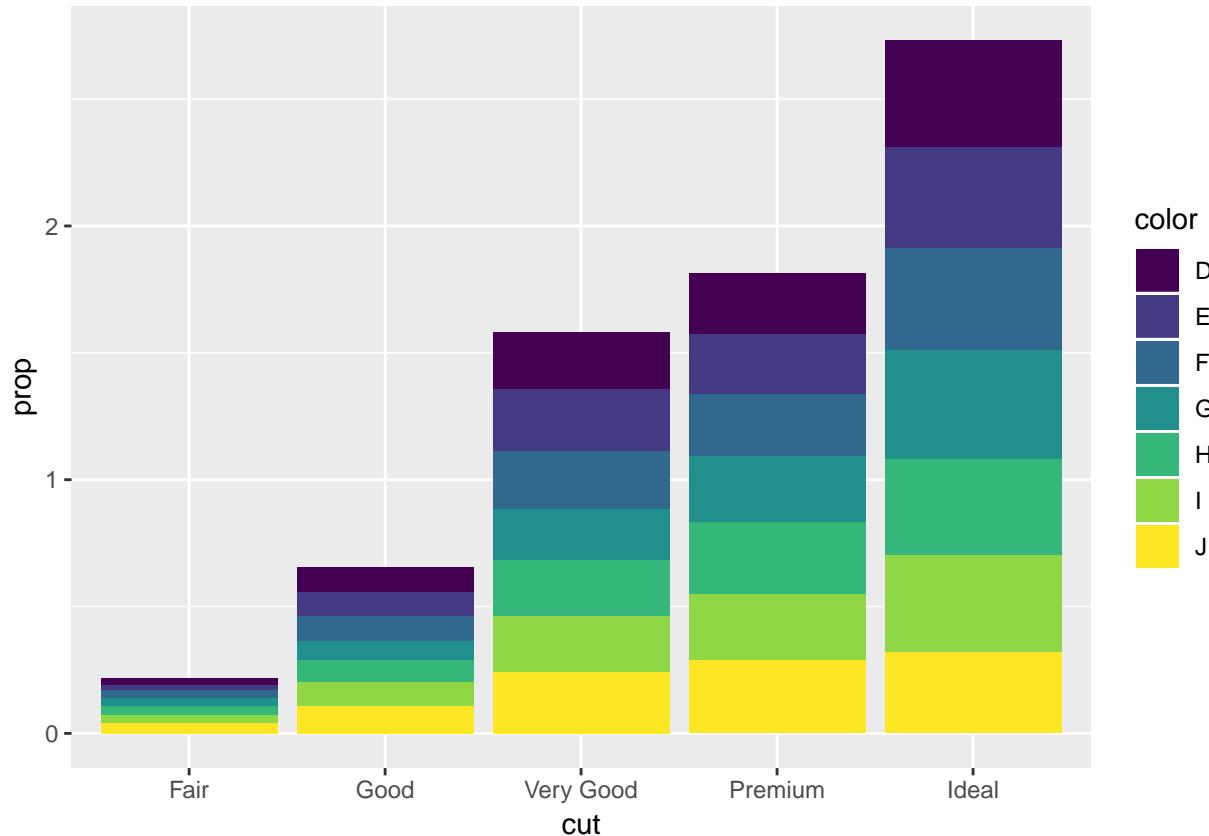


```
ggplot(data = diamonds) +  
  geom_bar(mapping = aes(x = cut, y = ..prop.., group = 1))
```



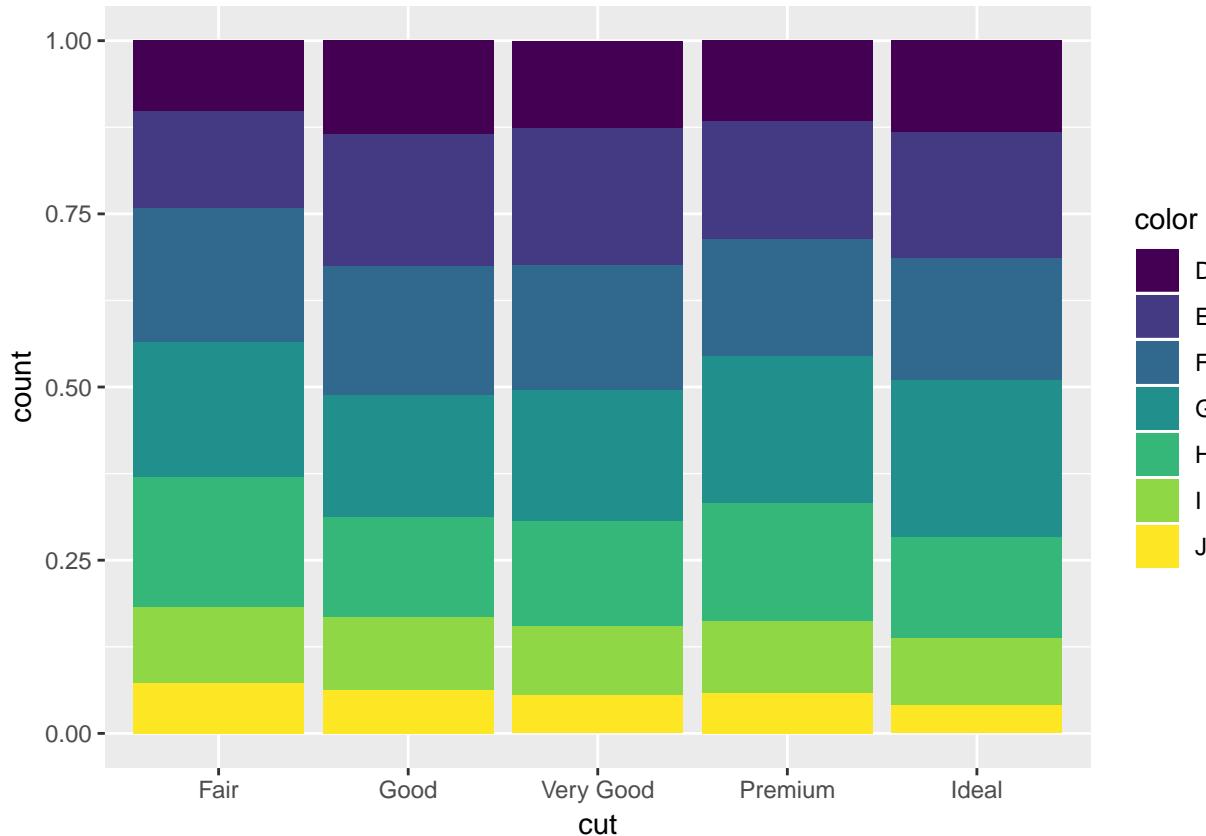
This is a solution, but still seems off as prop becomes out of a value greater than 1

```
ggplot(data = diamonds) +  
  geom_bar(mapping = aes(x = cut, fill = color, y = ..prop.., group = color))
```



For this second graph though, I would think you would want something more like the following:

```
ggplot(data = diamonds) +
  geom_bar(mapping = aes(x = cut, fill = color), position = "fill")
```



Which could be generated by this code as well

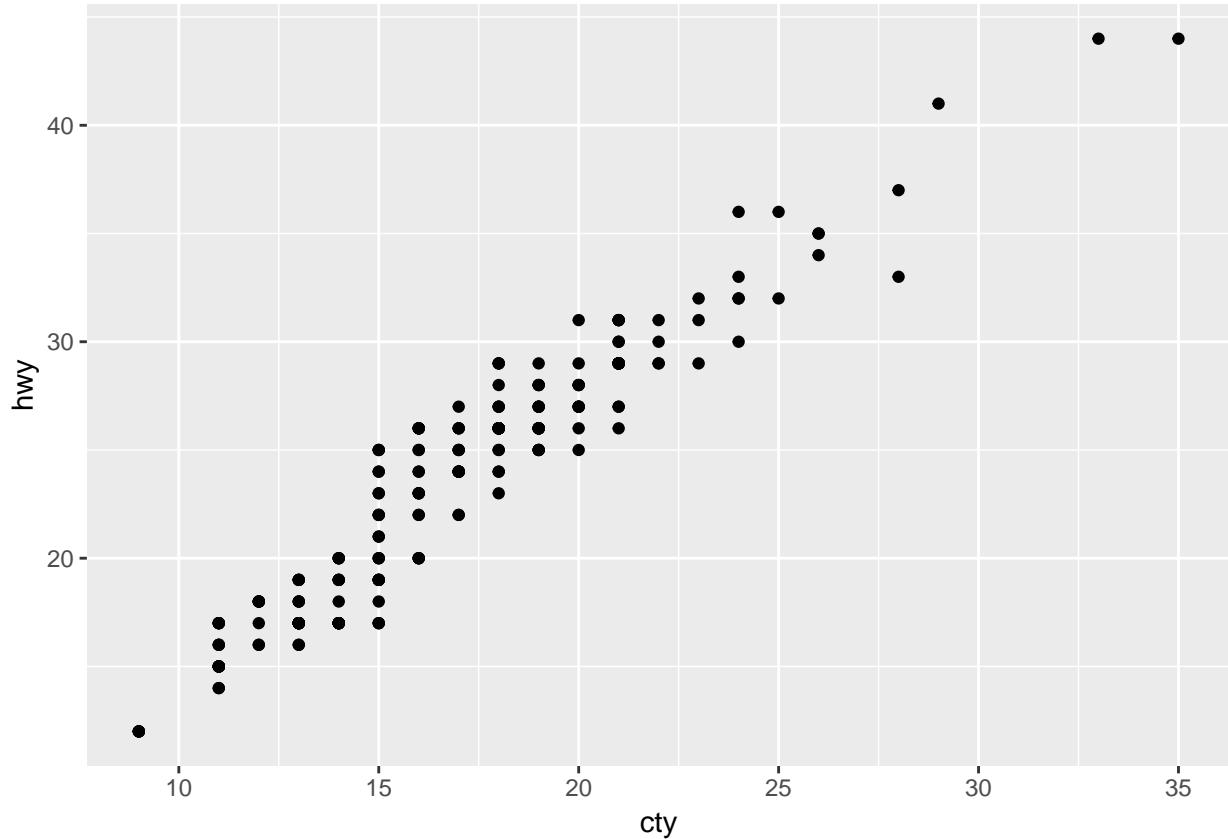
```
diamonds %>%
  count(cut, color) %>%
  group_by(cut) %>%
  mutate(prop = n / sum(n)) %>%
  ggplot(aes(x = cut, y = prop, fill = color)) +
  geom_col()
```

5.6 3.8: Position Adjustment

5.6.1 3.8.1.

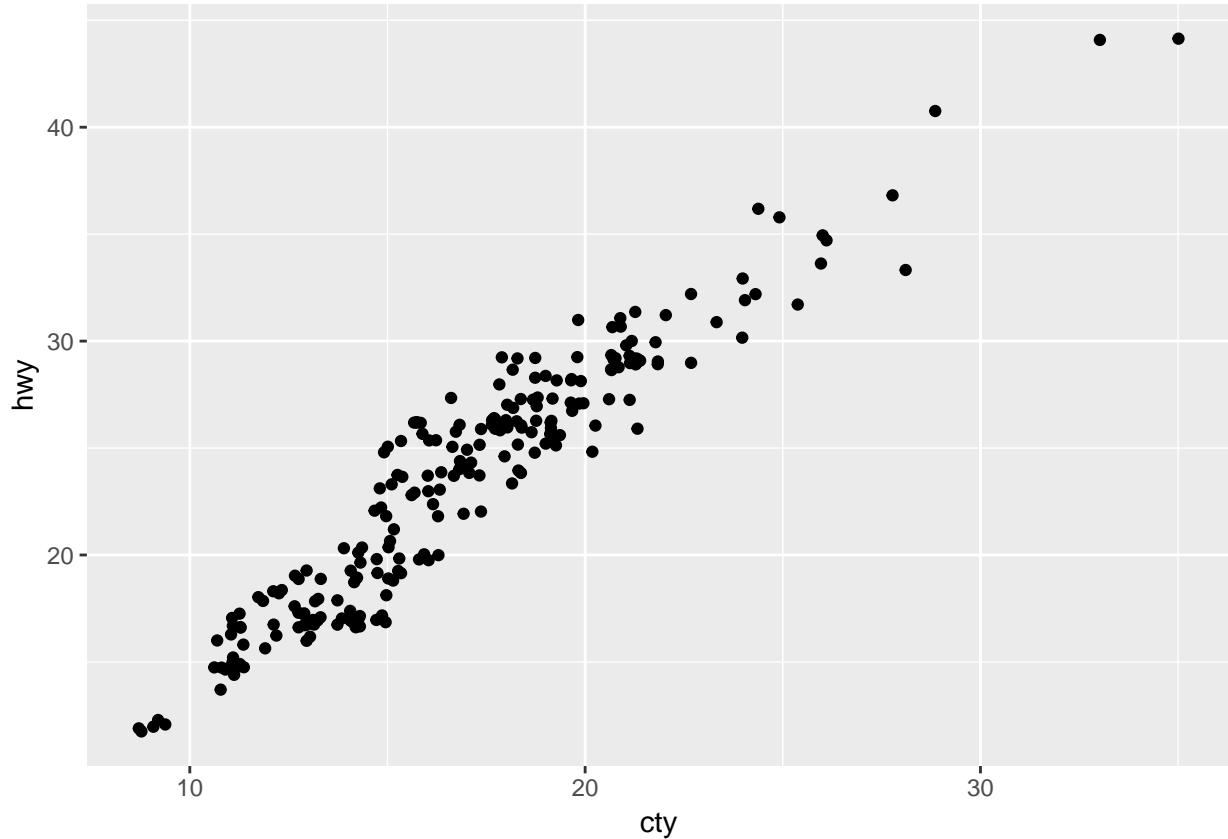
1.What is the problem with this plot? How could you improve it? (key question)

```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +
  geom_point()
```



The points overlap, could use `geom_jitter` instead

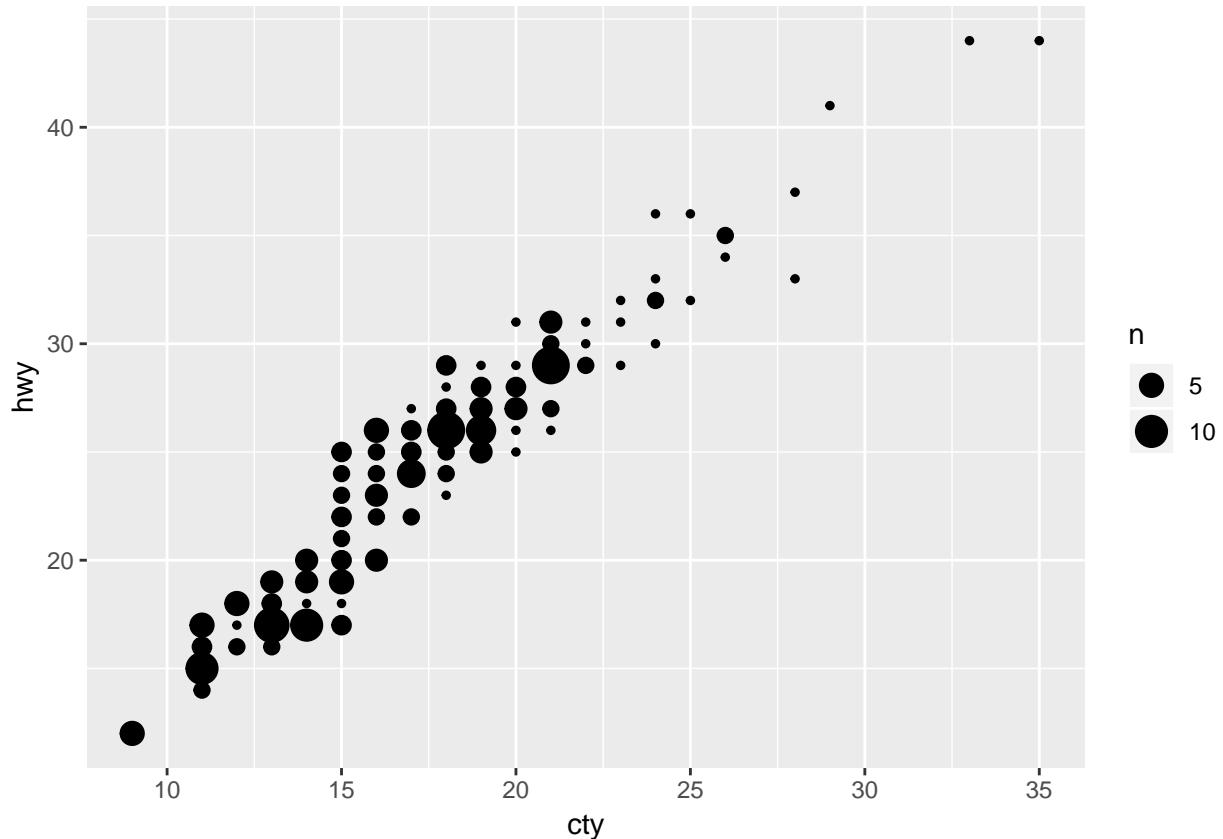
```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +  
  geom_jitter()
```



2. What parameters to `geom_jitter()` control the amount of jittering?
height and width

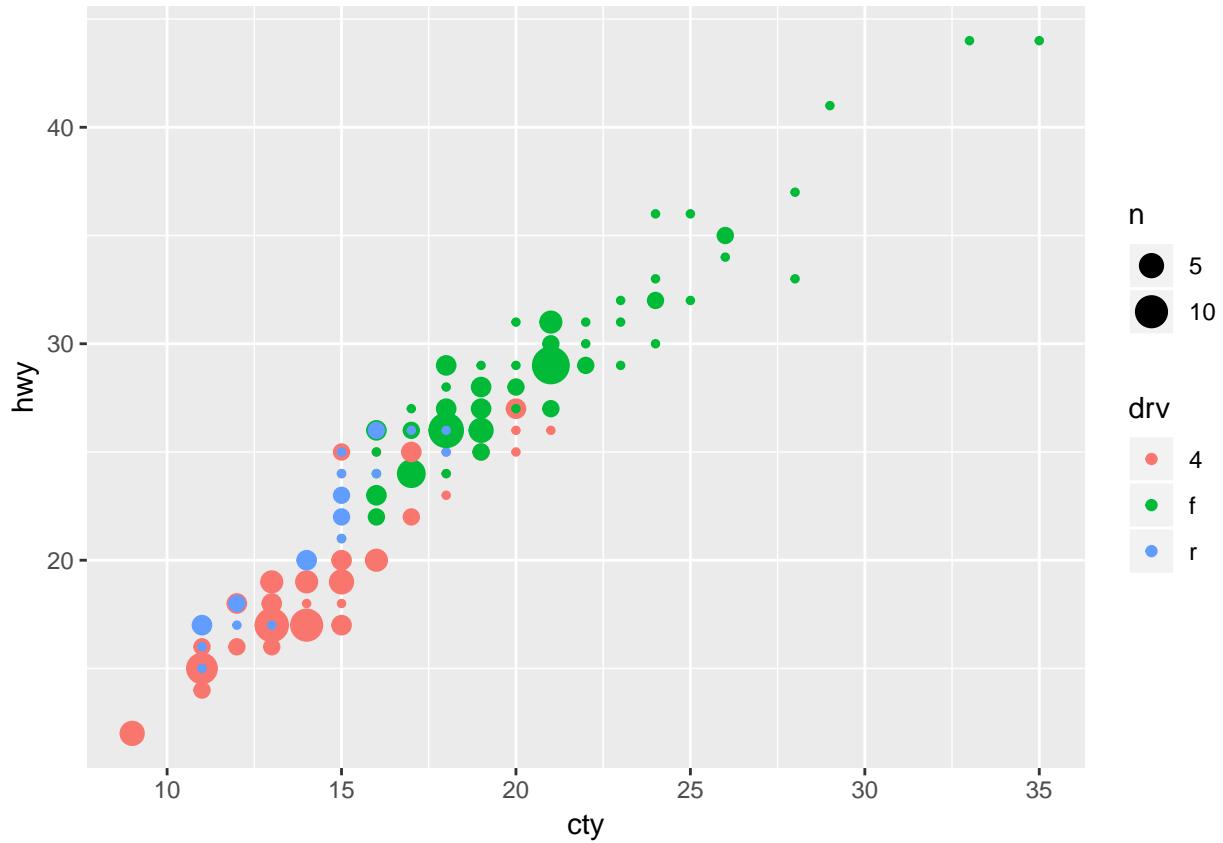
3. Compare and contrast `geom_jitter()` with `geom_count()`.
(key question) Take the above chart and instead use `geom_count()`

```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +  
  geom_count()
```

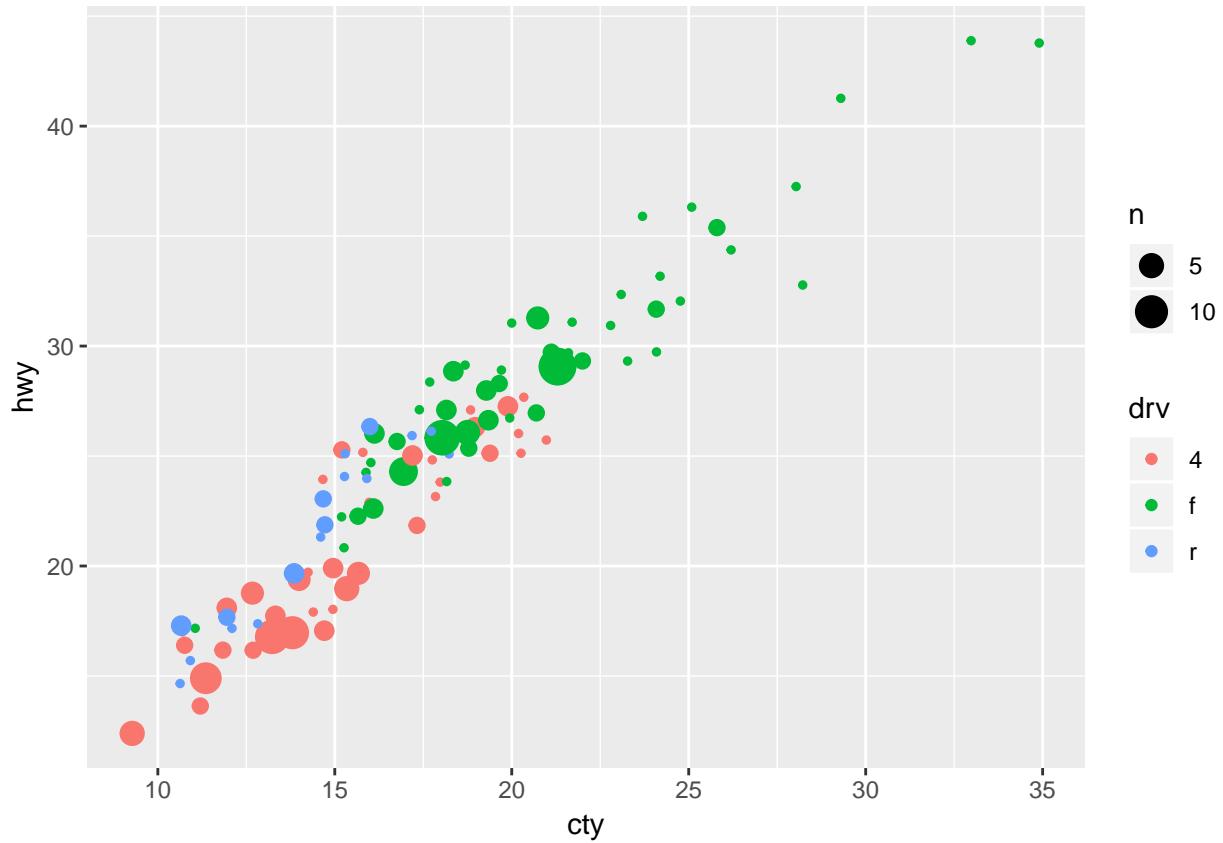


Can also use `geom_count` with `color`, and can use “jitter” in `position` arg.

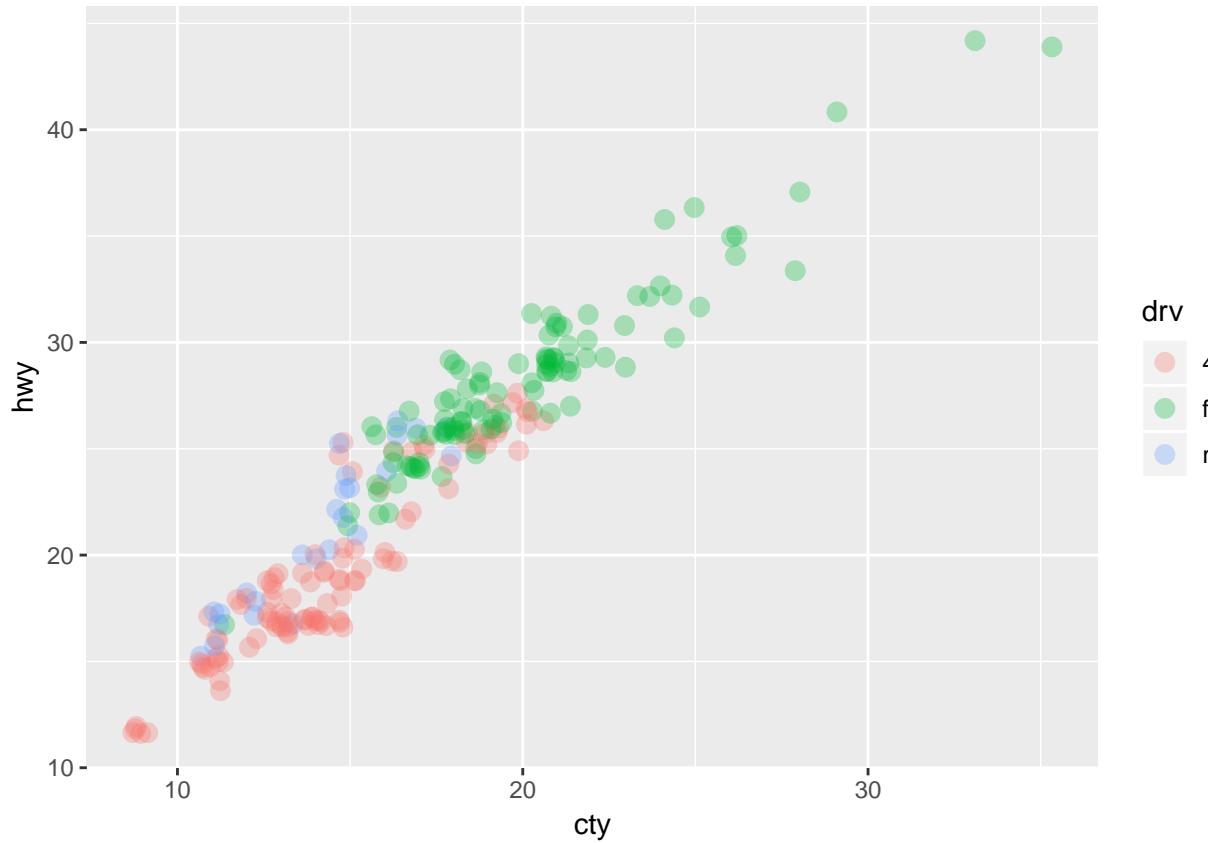
```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy, colour = drv)) +  
  geom_count()
```



```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy, colour = drv)) +  
  geom_count(position = "jitter")
```



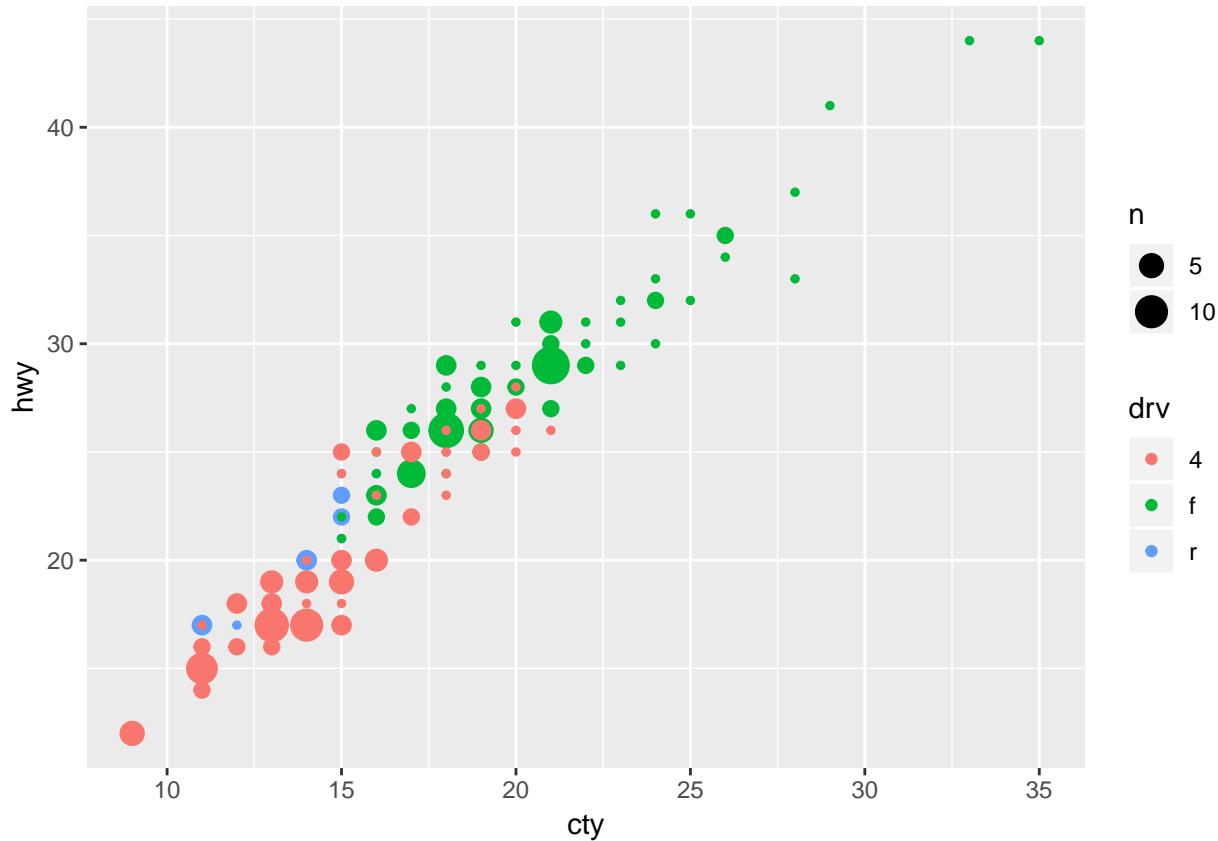
```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy, colour = drv)) +  
  geom_jitter(size = 3, alpha = 0.3)
```



One problem with `geom_count` is that the shapes can still block-out other shapes at that same point of different colors. You can flip the order of the stacking order of the colors with `position = "dodge"`. Still this seems limited.

```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy, colour = drv)) +
  geom_count(position = "dodge")
```

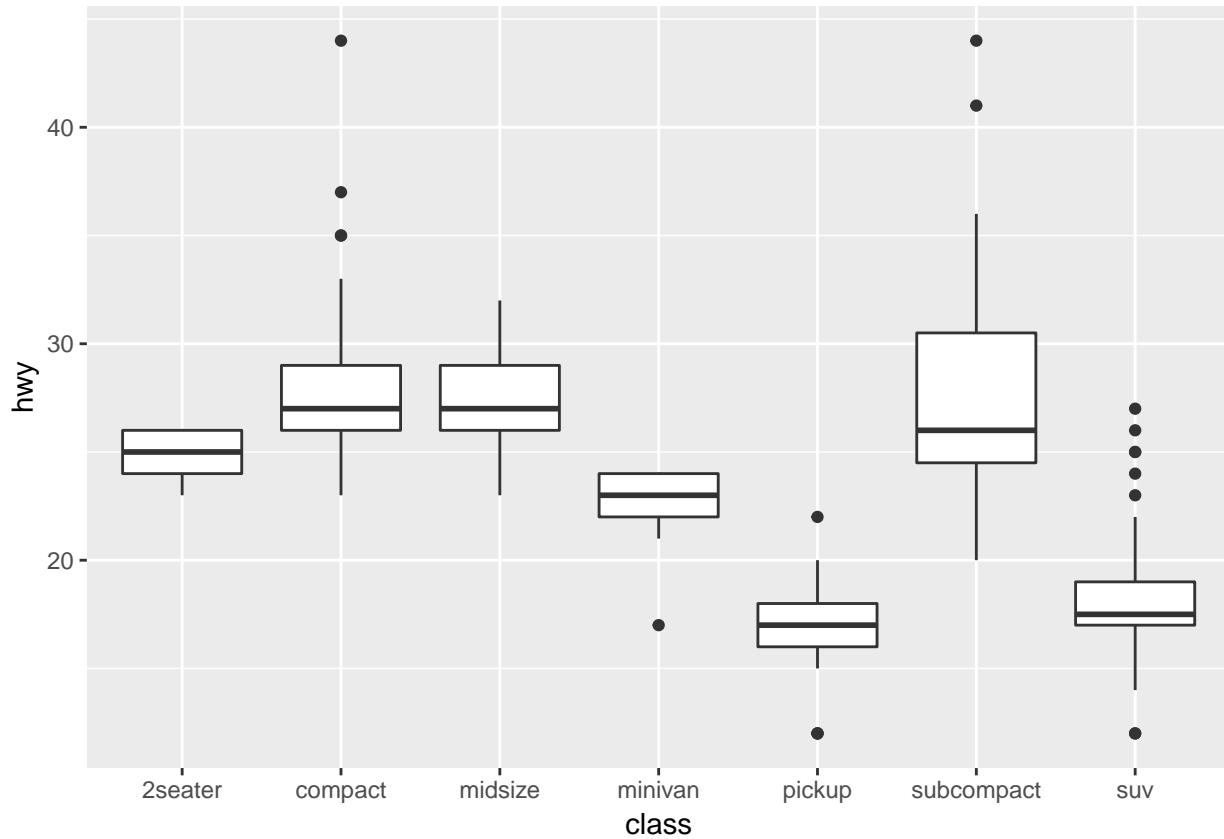
```
## Warning: Width not defined. Set with `position_dodge(width = ?)`
```



4. What's the default position adjustment for `geom_boxplot()`? Create a visualisation of the mpg dataset that demonstrates it.

`dodge`, but seems like `identity` is the same

```
ggplot(data=mpg, mapping=aes(x=class, y=hwy))+
  geom_boxplot()
```



5.7 3.9: Coordinate systems

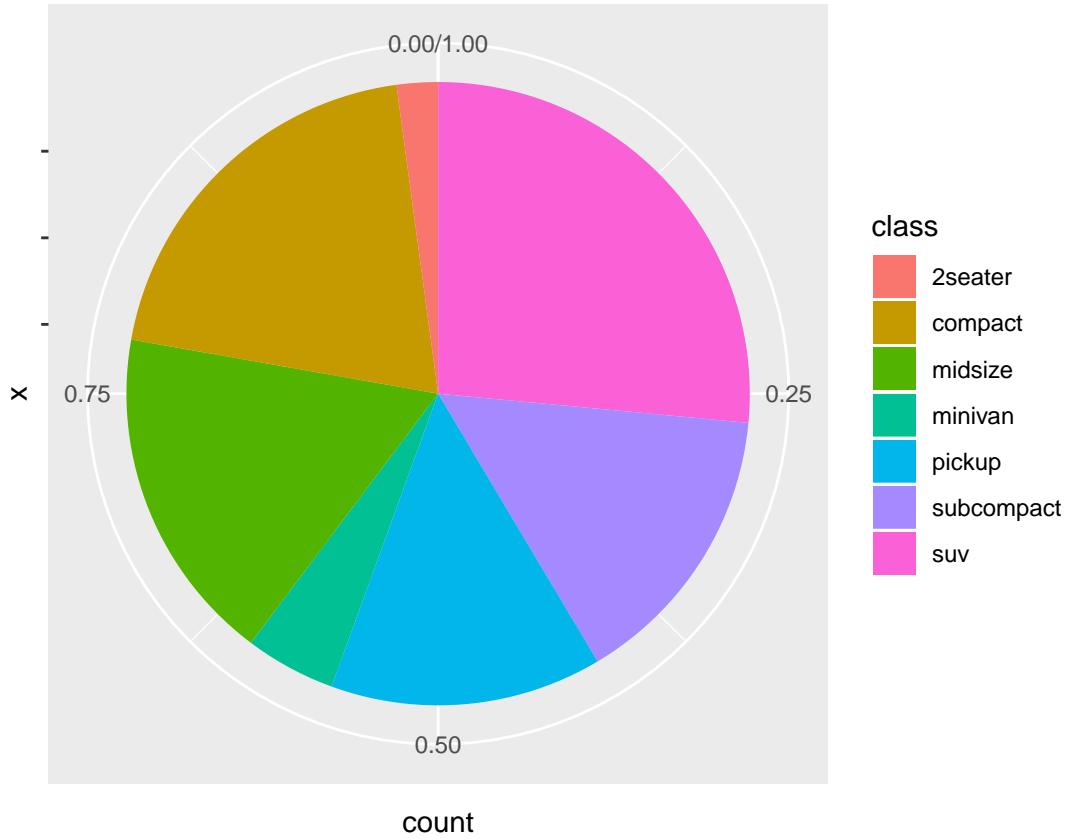
5.7.1 3.9.1.

1. Turn a stacked bar chart into a pie chart using `coord_polar()`.

These are more illustrative than anything, here is a note from the documentation:

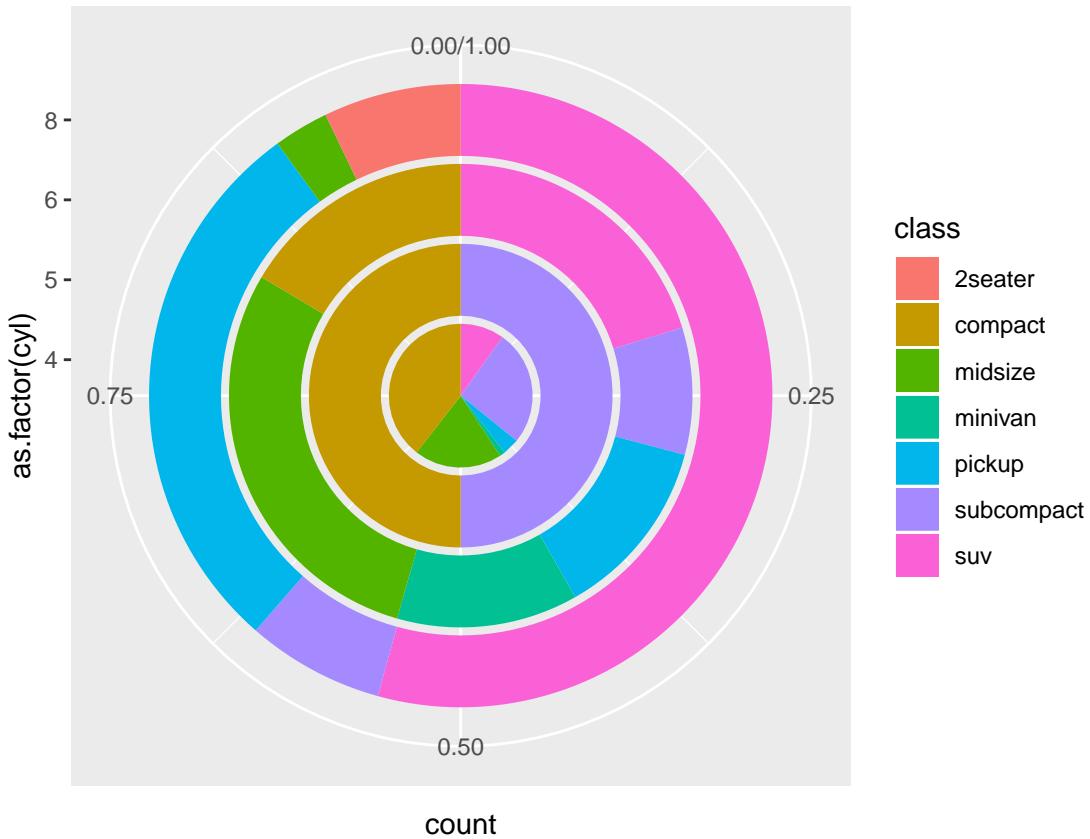
NOTE: Use these plots with caution - polar coordinates has major perceptual problems. The main point of these examples is to demonstrate how these common plots can be described in the grammar. Use with EXTREME caution.

```
ggplot(mpg, aes(x = 1, fill = class)) +
  geom_bar(position = "fill") +
  coord_polar(theta = "y") +
  scale_x_continuous(labels = NULL)
```



If I want to make multiple levels:

```
ggplot(mpg, aes(x = as.factor(cyl), fill = class)) +  
  geom_bar(position = "fill") +  
  coord_polar(theta = "y")
```



2. What does labs() do? Read the documentation.

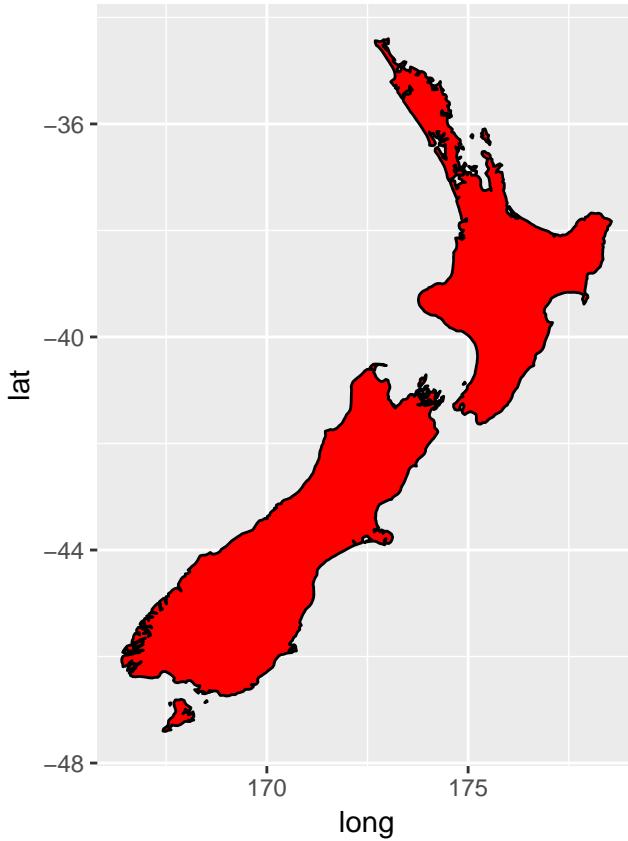
Used for giving labels.

```
?labs
```

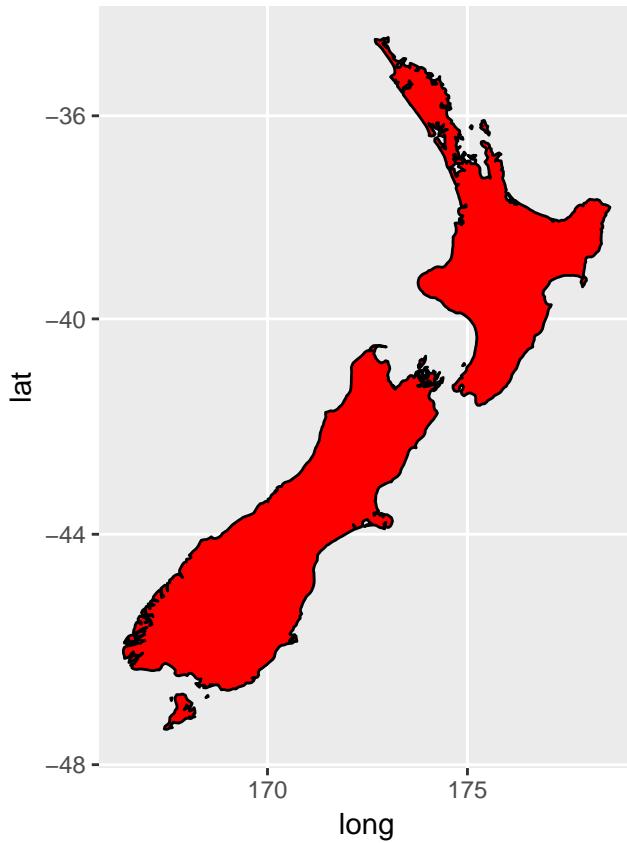
3. What's the difference between coord_quickmap() and coord_map()?

The first is an approximation, useful for smaller regions to be projected. For this example, do not see substantial differences.

```
nz <- map_data("nz")  
  
ggplot(nz,aes(long,lat,group=group))+  
  geom_polygon(fill="red",colour="black")+  
  coord_quickmap()
```



```
ggplot(nz,aes(long,lat,group=group))+  
  geom_polygon(fill="red",colour="black") +  
  coord_map()
```

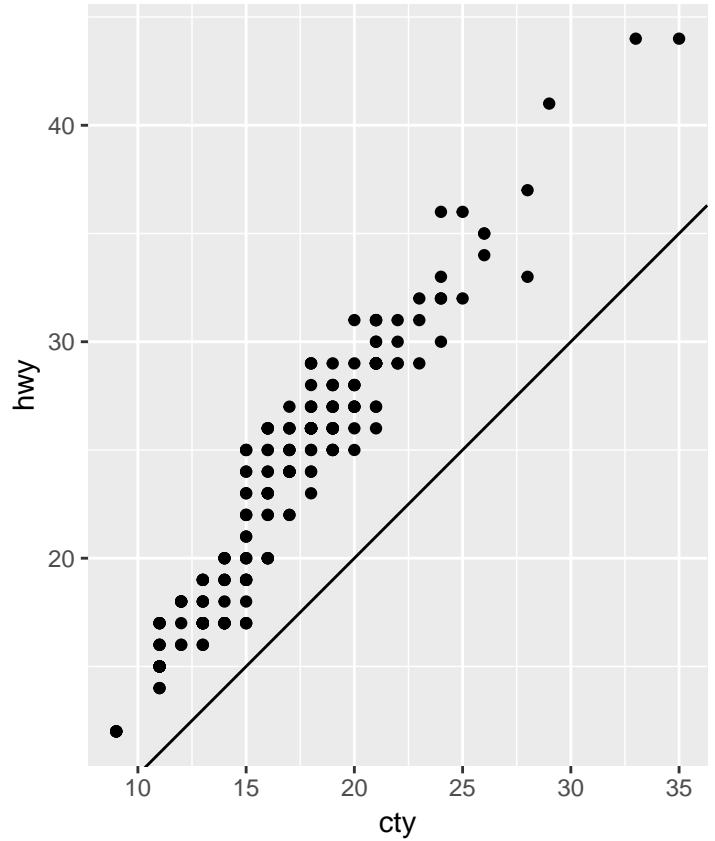


4. What does the plot below tell you about the relationship between city and highway mpg? Why is `coord_fixed()` important? What does `geom_abline()` do?

`geom_abline()` adds a line with a given intercept and slope (either given by `aes` or by `intercept` and `slope` args)

`coord_fixed` ensures that the ratios between the x and y axis stay at a specified relationship (default = 1). This is important for easily seeing the magnitude of the relationship between variables.

```
ggplot(data = mpg, mapping = aes(x = cty, y = hwy)) +  
  geom_point() +  
  geom_abline() +  
  coord_fixed()
```

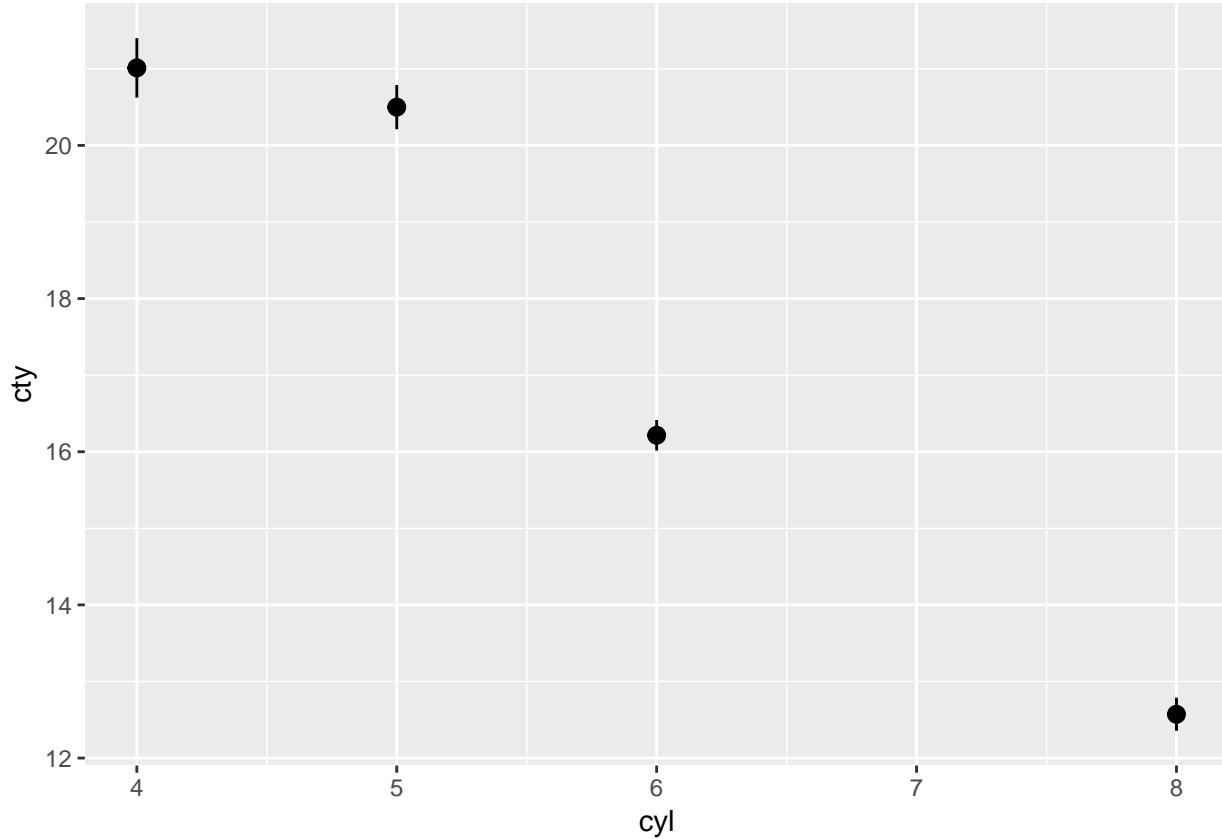


Chapter 6

Appendix

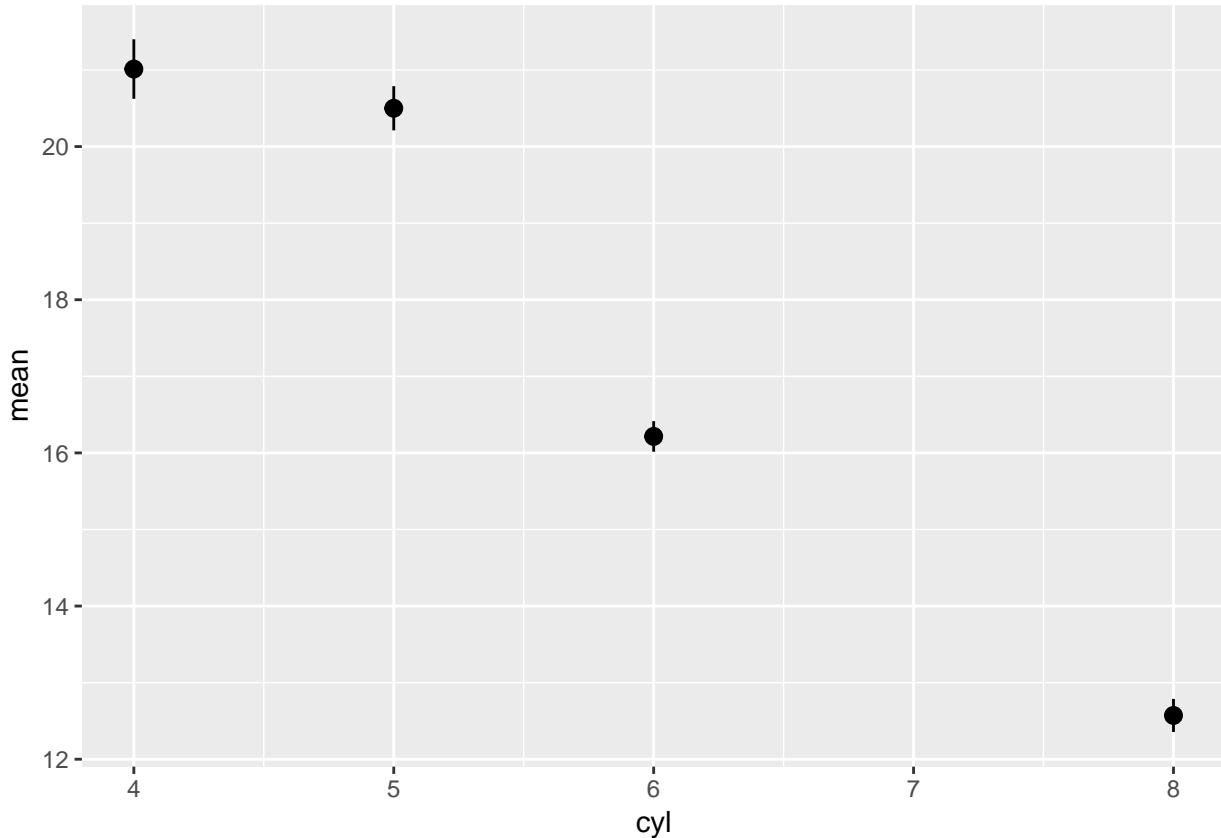
6.1 3.7.1.1 extension

```
ggplot(mpg, aes(x = cyl, y = cty, group = cyl)) +  
  geom_pointrange(stat = "summary")  
  
## No summary function supplied, defaulting to `mean_se()`
```



This seems to be the same as what you would get by doing the following with dplyr:

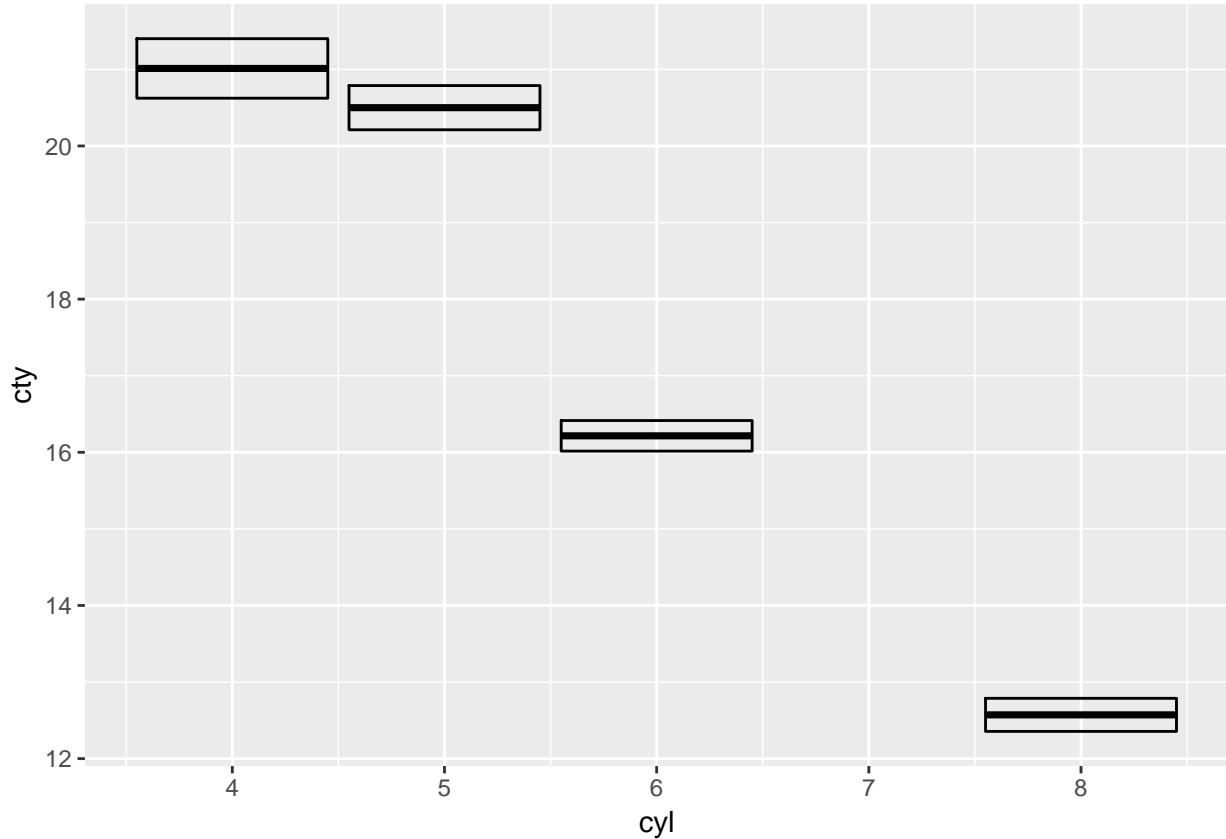
```
mpg %>%
  group_by(cyl) %>%
  dplyr::summarise(mean = mean(cty),
    sd = (sum((cty - mean(cty))^2) / (n() - 1))^(1/2),
    n = n(),
    se = sd / n^(1/2),
    lower = mean - se,
    upper = mean + se) %>%
  ggplot(aes(x = cyl, y = mean, group = cyl)) +
  geom_pointrange(aes(ymin = lower, ymax = upper))
```



Other geoms you could have set stat_summary to:

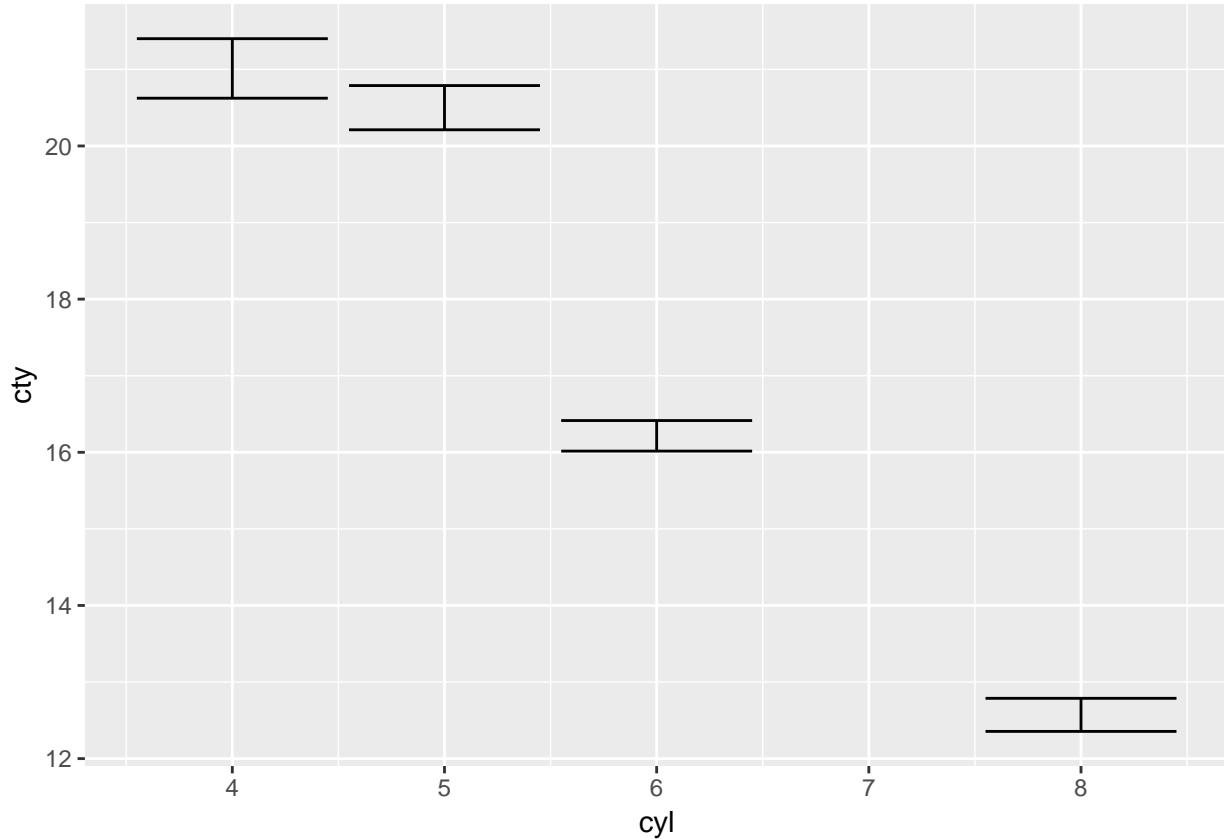
```
crossbar:
ggplot(mpg) +
  stat_summary(aes(cyl, cty), geom = "crossbar")
```

```
## No summary function supplied, defaulting to `mean_se()`
```



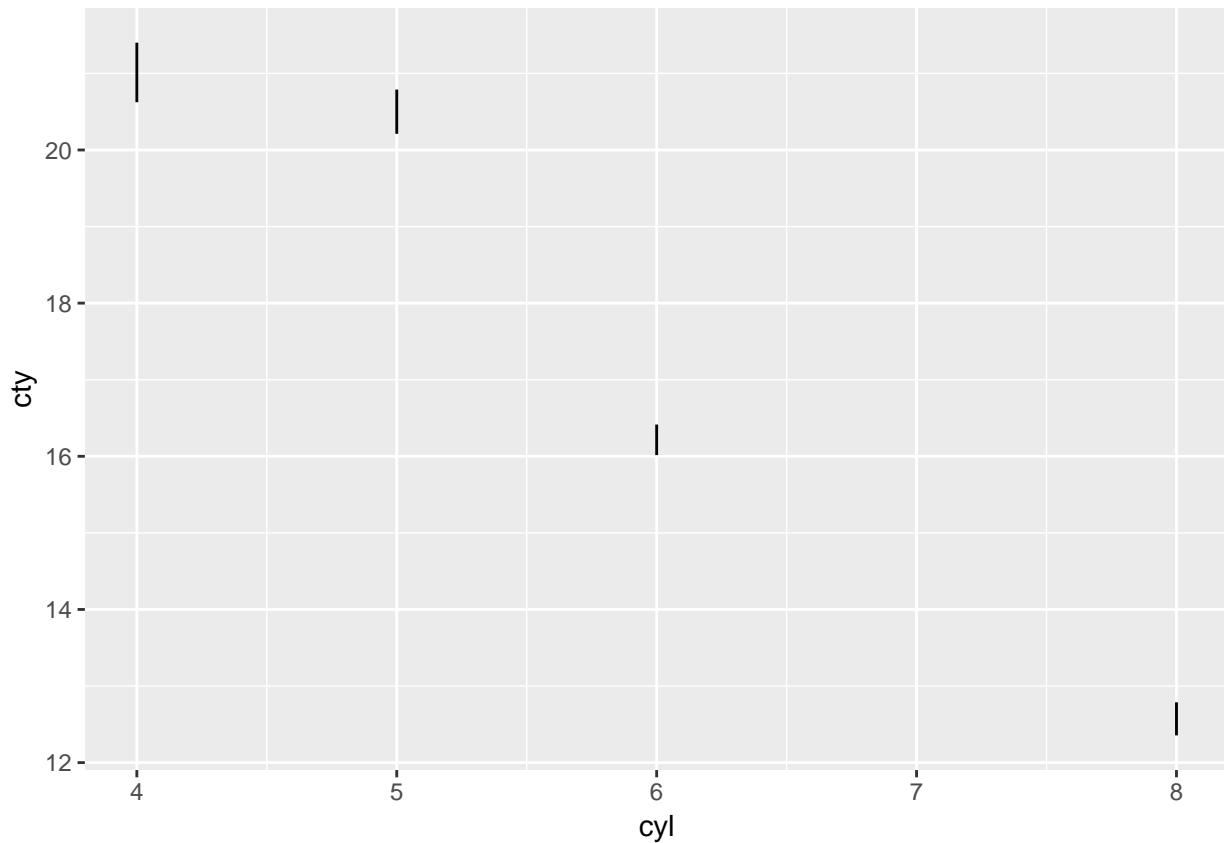
```
errorbar:  
ggplot(mpg) +  
  stat_summary(aes(cyl, cty), geom = "errorbar")
```

```
## No summary function supplied, defaulting to `mean_se()`
```



```
linerange:  
ggplot(mpg) +  
  stat_summary(aes(cyl, cty), geom = "linerange")
```

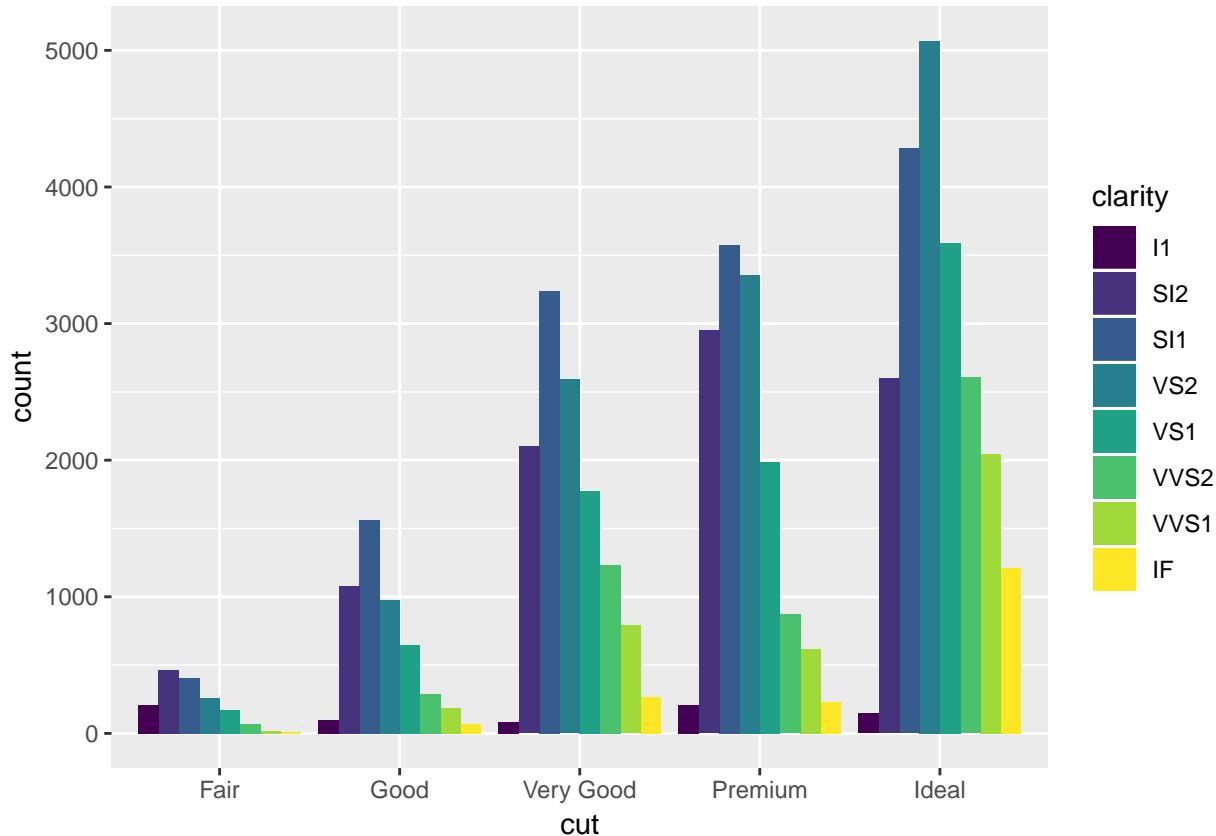
```
## No summary function supplied, defaulting to `mean_se()`
```



6.2 3.8: Position adustments

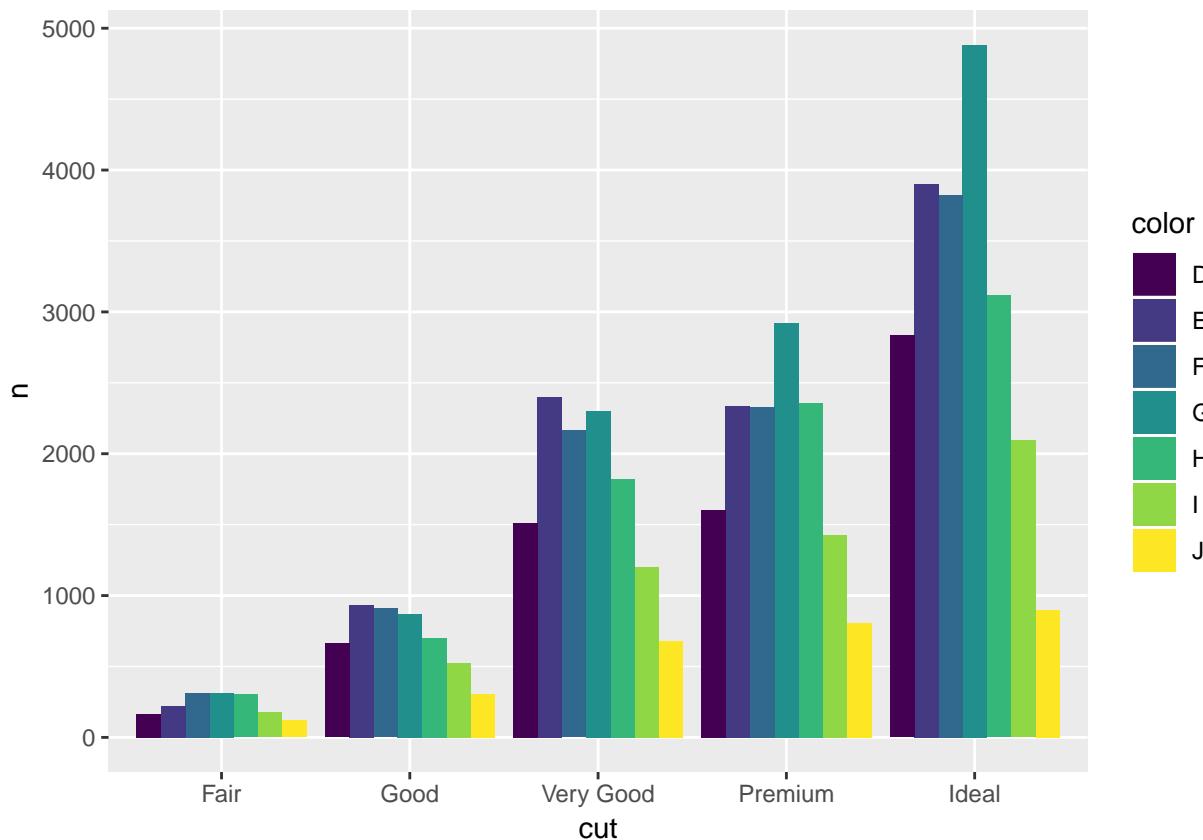
Some “dodge” examples

```
ggplot(data = diamonds) +  
  geom_bar(mapping = aes(x = cut, fill = clarity), position = "dodge")
```



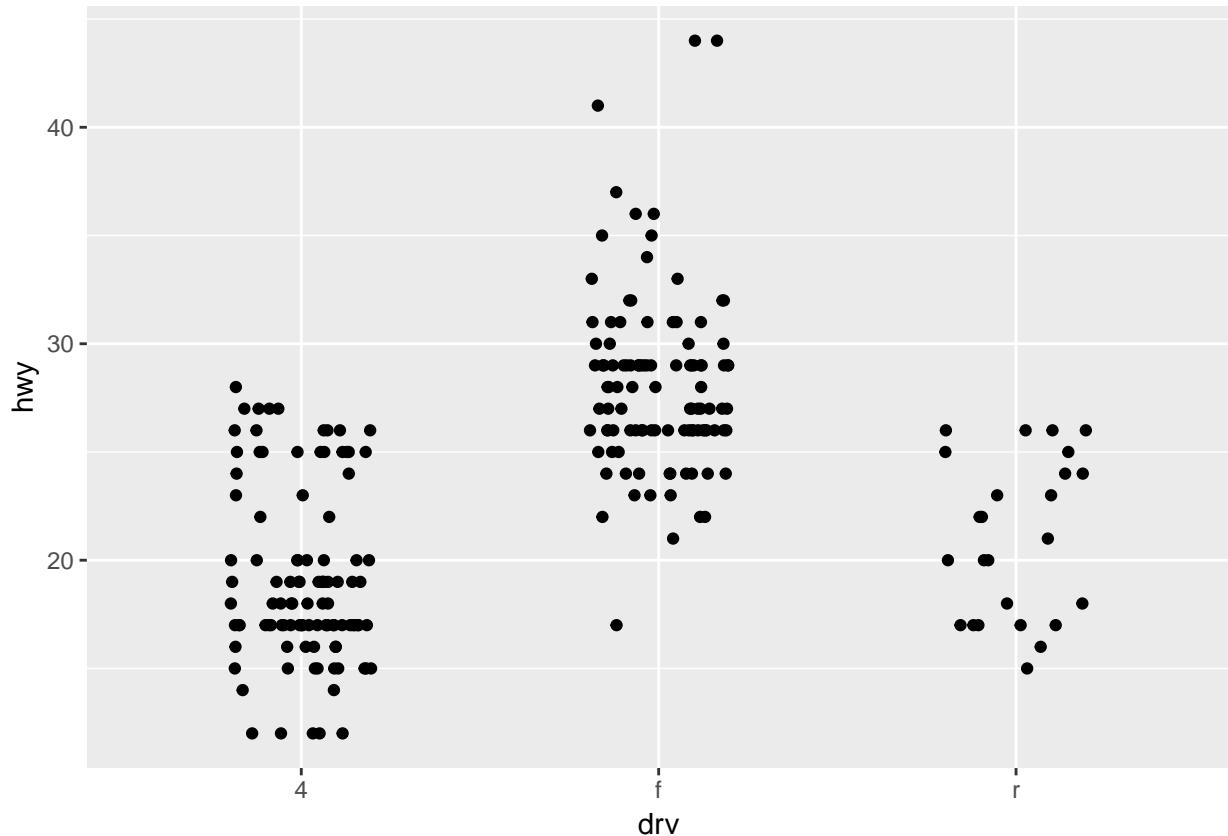
```

diamonds %>%
  count(cut, color) %>%
  ggplot(aes(x = cut, y = n, fill = color)) +
  geom_col(position = "dodge")
  
```



Looking at `geom_jitter` and only changing width.

```
ggplot(data = mpg, mapping = aes(x = drv, y = hwy))+
  geom_jitter(height = 0, width = .2)
```



6.3 3.9: Coordinate systems

`coord_flip` is helpful, especially for quickly tackling issues with axis labels `coord_quickmap` is important to remember if plotting spatial data. `coord_polar` is important to remember if plotting spatial coordinates. `map_data` for extracting data on maps of locations

6.4 add in table of contents and other details...

Make sure the following packages are installed:

```
knitr::opts_chunk$set(echo = TRUE, cache = TRUE)

library(ggplot2)
library(dplyr)
library(nycflights13)
library(Lahman)
library(gapminder)
library(tidyr)
library(plotly)
```

Chapter 7

ch. 5

Key functions from chapter:

- `filter()`: for filtering rows by some condition(s)
- `arrange()`: for ordering rows by some condition(s)
 - `desc`: order by descending instead (often use within `arrange` or with ranking functions)
- `select()`: for selecting columns by name, position, or criteria
 - helper functions: `everything`, `starts_with`, `ends_with`, `contains`, `matches`: selects variables that match a regular expression, `num_range("x", 1:3)`: matches `x1`, `x2` and `x3`
- `rename()`: rename variables w/o dropping variables not indicated
- `mutate()`: for changing columns and adding new columns * `group_by()`: for performing operations grouped by the values of some fields
- `summarise()`: for collapsing dataframes into individual rows or aggregates – typically used in conjunction with `group_by()`, typically used to aggregate
- `%>%`: pass the previous output into the first position of the next argument, think of as saying, “then you do...”
- `count`: shortcut for `<group_by([var])> -> <summarise(n = n())>`
- `near`: Are two values essentially equal (use to test equivalence and deals with oddities in floats)
- `is.na`: TRUE output if NA (and related values) else FALSE
- `between`: `between(Sepal.Length, 1, 3)` is equivalent to `Sepal.Length >=1 & Sepal.Length <=3`
- `transmute`: mutate but only keep the outputted column(s)
- `lead`, `lag`: take value n positions in lead or lag position
- `log`, `log2`, `log10`: log functions of base e, 2, 10
- `cumsum`, `cumprod`, `cummin`, `cummax`, `cummean`: Common cumulative functions
- `<`, `<=`, `>`, `>=`, `!=`: Logical operators
- `min_rank`, `row_number`, `dense_rank`, `percent_rank`, `cume_dist`, `ntile`: common ranking functions
- Location: `mean`; `median`
- Spread: `sd`: standard deviation; `IQR()`: Interquartile range; `mad()`: median absolute deviation

```
x <- c(1, 2, 3, 4, 6, 7, 8, 8, 10, 100)
IQR(x)
mad(x)
sd(x)
```

- Rank: `min`; `quantile`; `max`
- Position: `first(x)`, `nth(x, 2)`, `last(x)`. These work similarly to `x[1]`, `x[2]`, and `x[length(x)]` but let you set a default value if that position does not exist

```
first(x)
nth(x, 5)
last(x)
```

- measures of rank: `min`, `max`, `rank`, `quantile(x, 0.25)` is just 0.25 value (generalization of median, but allows you to specify)
- counts: `n()` for rows, `sum(!is.na(x))` for non-missing rows, for distinct count, use `n_distinct(x)`
- Counts and proportions of logical values: `sum(x > 10)`, `mean(y == 0)`
- `range()` returns vector containing min and max of values in a vector (so returns two values).
- `vignette`: function to open vignettes
 – e.g. `vignette("window-functions")`

7.1 5.2: Filter rows

7.2 5.2.4.

1. Find all flights that...

(key question)

1.1. Find flights that had an arrival delay of 2 + hrs

```
filter(flights, arr_delay >= 120) %>%
  glimpse()
```

```
## Observations: 10,200
## Variables: 19
## $ year              <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month             <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ day               <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ dep_time          <int> 811, 848, 957, 1114, 1505, 1525, 1549, 1558, 17...
## $ sched_dep_time   <int> 630, 1835, 733, 900, 1310, 1340, 1445, 1359, 16...
## $ dep_delay         <dbl> 101, 853, 144, 134, 115, 105, 64, 119, 62, 103, ...
## $ arr_time          <int> 1047, 1001, 1056, 1447, 1638, 1831, 1912, 1718, ...
## $ sched_arr_time   <int> 830, 1950, 853, 1222, 1431, 1626, 1656, 1515, 1...
## $ arr_delay         <dbl> 137, 851, 123, 145, 127, 125, 136, 123, 123, 13...
## $ carrier           <chr> "MQ", "MQ", "UA", "UA", "EV", "B6", "EV", "EV", ...
## $ flight             <int> 4576, 3944, 856, 1086, 4497, 525, 4181, 5712, 4...
## $ tailnum            <chr> "N531MQ", "N942MQ", "N534UA", "N76502", "N17984...
## $ origin             <chr> "LGA", "JFK", "EWR", "LGA", "EWR", "EWR", "EWR", ...
## $ dest               <chr> "CLT", "BWI", "BOS", "IAH", "RIC", "MCO", "MCI", ...
## $ air_time           <dbl> 118, 41, 37, 248, 63, 152, 234, 53, 119, 154, 2...
## $ distance           <dbl> 544, 184, 200, 1416, 277, 937, 1092, 228, 533, ...
## $ hour               <dbl> 6, 18, 7, 9, 13, 13, 14, 13, 16, 16, 13, 14, 16...
## $ minute              <dbl> 30, 35, 33, 0, 10, 40, 45, 59, 30, 20, 25, 22, ...
## $ time_hour          <dttm> 2013-01-01 06:00:00, 2013-01-01 18:00:00, 2013...
```

1.2. flew to Houston IAH or HOU

```
filter(flights, dest %in% c("IAH", "HOU"))
```

```
## # A tibble: 9,313 x 19
##       year month   day dep_time sched_dep_time dep_delay arr_time
```

```

##   <int> <int> <int>   <int>      <int>    <dbl>   <int>
## 1 2013     1     1    517       515      2     830
## 2 2013     1     1    533       529      4     850
## 3 2013     1     1    623       627     -4     933
## 4 2013     1     1    728       732     -4    1041
## 5 2013     1     1    739       739      0    1104
## 6 2013     1     1    908       908      0    1228
## 7 2013     1     1   1028      1026      2    1350
## 8 2013     1     1   1044      1045     -1    1352
## 9 2013     1     1   1114       900     134    1447
## 10 2013    1     1   1205      1200      5    1503
## # ... with 9,303 more rows, and 12 more variables: sched_arr_time <int>,
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>

```

1.3. flew through American, United or Delta

```
filter(flights, carrier %in% c("UA", "AA", "DL"))
```

```

## # A tibble: 139,504 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>   <int>      <int>    <dbl>   <int>
## 1 2013     1     1    517       515      2     830
## 2 2013     1     1    533       529      4     850
## 3 2013     1     1    542       540      2     923
## 4 2013     1     1    554       600     -6     812
## 5 2013     1     1    554       558     -4     740
## 6 2013     1     1    558       600     -2     753
## 7 2013     1     1    558       600     -2     924
## 8 2013     1     1    558       600     -2     923
## 9 2013     1     1    559       600     -1     941
## 10 2013    1     1    559       600     -1     854
## # ... with 139,494 more rows, and 12 more variables: sched_arr_time <int>,
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>

```

1.4. Departed in Summer

```
filter(flights, month <= 8 & month >= 6)
```

```

## # A tibble: 86,995 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>   <int>      <int>    <dbl>   <int>
## 1 2013     6     1     2       2359      3     341
## 2 2013     6     1    451       500     -9     624
## 3 2013     6     1    506       515     -9     715
## 4 2013     6     1    534       545    -11     800
## 5 2013     6     1    538       545     -7     925
## 6 2013     6     1    539       540     -1     832
## 7 2013     6     1    546       600    -14     850
## 8 2013     6     1    551       600     -9     828
## 9 2013     6     1    552       600     -8     647
## 10 2013    6     1    553       600     -7     700
## # ... with 86,985 more rows, and 12 more variables: sched_arr_time <int>,

```

```
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>
```

1.5. Arrived more than 2 hours late, but didn't leave late

```
filter(flights, arr_delay > 120, dep_delay >= 0)
```

```
## # A tibble: 10,008 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>
## 1 2013     1     1      811        630       101    1047
## 2 2013     1     1      848       1835       853    1001
## 3 2013     1     1      957        733       144    1056
## 4 2013     1     1     1114       900       134    1447
## 5 2013     1     1     1505      1310       115    1638
## 6 2013     1     1     1525      1340       105    1831
## 7 2013     1     1     1549      1445        64    1912
## 8 2013     1     1     1558      1359       119    1718
## 9 2013     1     1     1732      1630        62    2028
## 10 2013    1     1     1803      1620       103    2008
## # ... with 9,998 more rows, and 12 more variables: sched_arr_time <int>,
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>
```

1.6. were delayed at least an hour, but made up over 30 mins in flight

```
filter(flights, (arr_delay - dep_delay) <=-30, dep_delay >= 60)
```

```
## # A tibble: 2,074 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>
## 1 2013     1     1     1716        1545       91    2140
## 2 2013     1     1     2205        1720       285      46
## 3 2013     1     1     2326        2130       116    131
## 4 2013     1     3     1503        1221       162    1803
## 5 2013     1     3     1821        1530       171    2131
## 6 2013     1     3     1839        1700        99    2056
## 7 2013     1     3     1850        1745        65    2148
## 8 2013     1     3     1923        1815        68    2036
## 9 2013     1     3     1941        1759       102    2246
## 10 2013    1     3     1950        1845        65    2228
## # ... with 2,064 more rows, and 12 more variables: sched_arr_time <int>,
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>
```

Equivalent solution:

```
filter(flights, (arr_delay - dep_delay) <= -30 & dep_delay >= 60)
```

1.7. departed between midnight and 6am (inclusive)

```
filter(flights, dep_time >= 0 & dep_time <= 600)
```

```
## # A tibble: 9,344 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>
```

```

## 1 2013 1 1 517 515 2 830
## 2 2013 1 1 533 529 4 850
## 3 2013 1 1 542 540 2 923
## 4 2013 1 1 544 545 -1 1004
## 5 2013 1 1 554 600 -6 812
## 6 2013 1 1 554 558 -4 740
## 7 2013 1 1 555 600 -5 913
## 8 2013 1 1 557 600 -3 709
## 9 2013 1 1 557 600 -3 838
## 10 2013 1 1 558 600 -2 753
## # ... with 9,334 more rows, and 12 more variables: sched_arr_time <int>,
## # arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## # origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## # minute <dbl>, time_hour <dttm>
filter(flights, dep_time>=0, dep_time<=600)

## # A tibble: 9,344 x 19
##   year month day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>     <int>        <int>     <dbl>     <int>
## 1 2013    1     1      517        515       2.00    830
## 2 2013    1     1      533        529       4.00    850
## 3 2013    1     1      542        540       2.00    923
## 4 2013    1     1      544        545      -1.00   1004
## 5 2013    1     1      554        600      -6.00    812
## 6 2013    1     1      554        558      -4.00    740
## 7 2013    1     1      555        600      -5.00    913
## 8 2013    1     1      557        600      -3.00    709
## 9 2013    1     1      557        600      -3.00    838
## 10 2013   1     1      558        600      -2.00    753
## # ... with 9,334 more rows, and 12 more variables: sched_arr_time <int>,
## # arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## # origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## # minute <dbl>, time_hour <dttm>
```

2. Another useful dplyr filtering helper is `between()`. What does it do? Can you use it to simplify the code needed to answer the previous challenges?

This is a shortcut for `x >= left & x <= right`

solving 1.7. using `between`:

```
filter(flights, between(dep_time, 0, 600))
```

3. How many flights have a missing `dep_time`? What other variables are missing? What might these rows represent?

(key question)

```
filter(flights, is.na(dep_time))
```

```

## # A tibble: 8,255 x 19
##   year month day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>     <int>        <int>     <dbl>     <int>
## 1 2013    1     1       NA        1630       NA       NA
## 2 2013    1     1       NA        1935       NA       NA
## 3 2013    1     1       NA        1500       NA       NA
## 4 2013    1     1       NA         600       NA       NA
## 5 2013    1     2       NA        1540       NA       NA
```

```
## 6 2013 1 2 NA 1620 NA NA
## 7 2013 1 2 NA 1355 NA NA
## 8 2013 1 2 NA 1420 NA NA
## 9 2013 1 2 NA 1321 NA NA
## 10 2013 1 2 NA 1545 NA NA
## # ... with 8,245 more rows, and 12 more variables: sched_arr_time <int>,
## # arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## # origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## # minute <dbl>, time_hour <dttm>
```

8255, perhaps these are canceled flights.

4. Why is `NA ^ 0` not missing? Why is `NA | TRUE` not missing? Why is `FALSE & NA` not missing? Can you figure out the general rule? (`NA * 0` is a tricky counterexample!)

`NA^0`

```
## [1] 1
```

Anything raised to the 0 is 1.

`FALSE & NA`

```
## [1] FALSE
```

For the “AND” operator `&` for it to be TRUE both values would need to be TRUE so if one is FALSE the entire statement must be.

`TRUE | NA`

```
## [1] TRUE
```

The “OR” operator `|` specifies that if at least one of the values is TRUE the whole statement is, so because one is already TRUE the whole statement must be.

`NA*0`

```
## [1] NA
```

This does not come-out to 0 as expected because the laws of addition and multiplication here only hold for natural numbers, but it is possible that `NA` could represent `Inf` or `-Inf` in which case the output is `NaN` rather than 0.

`Inf*0`

```
## [1] NaN
```

See this article for more details: <https://math.stackexchange.com/questions/28940/why-is-infinity-multiplied-by-zero-not-a>

`##5.3: Arrange rows`

7.2.1 5.3.1.

1. Sort out all missing values to start

```
arrange(flights, desc(is.na(dep_time)))
```

```
## # A tibble: 336,776 x 19
##   year month   day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>
## 1 2013     1     1      NA           1630        NA        NA
```

```

## 2 2013 1 1 NA 1935 NA NA
## 3 2013 1 1 NA 1500 NA NA
## 4 2013 1 1 NA 600 NA NA
## 5 2013 1 2 NA 1540 NA NA
## 6 2013 1 2 NA 1620 NA NA
## 7 2013 1 2 NA 1355 NA NA
## 8 2013 1 2 NA 1420 NA NA
## 9 2013 1 2 NA 1321 NA NA
## 10 2013 1 2 NA 1545 NA NA
## # ... with 336,766 more rows, and 12 more variables: sched_arr_time <int>,
## # arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## # origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## # minute <dbl>, time_hour <dttm>
arrange(flights, desc(is.na(arr_delay)))

## # A tibble: 336,776 x 19
##   year month day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>     <int>        <int>     <dbl>    <int>
## 1 2013    1    1      1525       1530      -5    1934
## 2 2013    1    1      1528       1459      29    2002
## 3 2013    1    1      1740       1745      -5    2158
## 4 2013    1    1      1807       1738      29    2251
## 5 2013    1    1      1939       1840      59     29
## 6 2013    1    1      1952       1930      22    2358
## 7 2013    1    1      2016       1930      46     NA
## 8 2013    1    1       NA       1630      NA     NA
## 9 2013    1    1       NA       1935      NA     NA
## 10 2013   1    1       NA       1500      NA     NA
## # ... with 336,766 more rows, and 12 more variables: sched_arr_time <int>,
## # arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## # origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## # minute <dbl>, time_hour <dttm>
count(flights, is.na(arr_delay))

## # A tibble: 2 x 2
##   `is.na(arr_delay)` n
##   <lgl>           <int>
## 1 FALSE            327346
## 2 TRUE             9430
count(flights, is.na(dep_delay), is.na(arr_delay))

## # A tibble: 3 x 3
##   `is.na(dep_delay)` `is.na(arr_delay)` n
##   <lgl>           <lgl>           <int>
## 1 FALSE           FALSE          327346
## 2 FALSE           TRUE           1175
## 3 TRUE            TRUE           8255

```

2. Find most delayed departures

```

arrange(flights, desc(dep_delay)) %>%
  select(dep_delay)

```

```
## # A tibble: 336,776 x 1
```

```
##      dep_delay
##      <dbl>
## 1     1301
## 2     1137
## 3     1126
## 4     1014
## 5     1005
## 6      960
## 7      911
## 8      899
## 9      898
## 10     896
## # ... with 336,766 more rows
```

3. Find the fastest flights

```
arrange(flights, air_time) %>%
  glimpse()
```

```
## Observations: 336,776
## Variables: 19
## $ year           <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month          <int> 1, 4, 12, 2, 2, 2, 3, 3, 3, 3, 5, 5, 6, 8, 9, 9...
## $ day            <int> 16, 13, 6, 3, 5, 12, 2, 8, 18, 19, 8, 19, 12, 1...
## $ dep_time        <int> 1355, 537, 922, 2153, 1303, 2123, 1450, 2026, 1...
## $ sched_dep_time <int> 1315, 527, 851, 2129, 1315, 2130, 1500, 1935, 1...
## $ dep_delay       <dbl> 40, 10, 31, 24, -12, -7, -10, 51, 87, 41, 137, ...
## $ arr_time        <int> 1442, 622, 1021, 2247, 1342, 2211, 1547, 2131, ...
## $ sched_arr_time  <int> 1411, 628, 954, 2224, 1411, 2225, 1608, 2056, 1...
## $ arr_delay       <dbl> 31, -6, 27, 23, -29, -14, -21, 35, 67, 19, 109, ...
## $ carrier         <chr> "EV", "EV", "EV", "EV", "EV", "US", "9E", ...
## $ flight          <int> 4368, 4631, 4276, 4619, 4368, 4619, 2132, 3650, ...
## $ tailnum         <chr> "N16911", "N12167", "N27200", "N13913", "N13955...
## $ origin          <chr> "EWR", "EWR", "EWR", "EWR", "EWR", "LGA"...
## $ dest            <chr> "BDL", "BDL", "BDL", "PHL", "BDL", "PHL", "BOS"...
## $ air_time        <dbl> 20, 20, 21, 21, 21, 21, 21, 21, 21, 21, 21, ...
## $ distance         <dbl> 116, 116, 116, 80, 116, 80, 184, 94, 116, 116, ...
## $ hour             <dbl> 13, 5, 8, 21, 13, 21, 15, 19, 13, 21, 21, 21, 2...
## $ minute           <dbl> 15, 27, 51, 29, 15, 30, 0, 35, 29, 45, 59, 59, ...
## $ time_hour        <dttm> 2013-01-16 13:00:00, 2013-04-13 05:00:00, 2013...
```

4. Flights traveling the longest distance

```
arrange(flights, desc(distance)) %>%
  glimpse()
```

```
## Observations: 336,776
## Variables: 19
## $ year           <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ day            <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, ...
## $ dep_time        <int> 857, 909, 914, 900, 858, 1019, 1042, 901, 641, ...
## $ sched_dep_time <int> 900, 900, 900, 900, 900, 900, 900, 900, 90...
## $ dep_delay       <dbl> -3, 9, 14, 0, -2, 79, 102, 1, 1301, -1, -5, 1, ...
## $ arr_time        <int> 1516, 1525, 1504, 1516, 1519, 1558, 1620, 1504, ...
## $ sched_arr_time  <int> 1530, 1530, 1530, 1530, 1530, 1530, 1530, 1530, ...
```

```

## $ arr_delay      <dbl> -14, -5, -26, -14, -11, 28, 50, -26, 1272, -41, ...
## $ carrier        <chr> "HA", "HA", "HA", "HA", "HA", "HA", ...
## $ flight         <int> 51, 51, 51, 51, 51, 51, 51, 51, 51, 51, ...
## $ tailnum        <chr> "N380HA", "N380HA", "N380HA", "N384HA", "N381HA...
## $ origin         <chr> "JFK", "JFK", "JFK", "JFK", "JFK", "JFK"...
## $ dest           <chr> "HNL", "HNL", "HNL", "HNL", "HNL", "HNL"...
## $ air_time       <dbl> 659, 638, 616, 639, 635, 611, 612, 645, 640, 63...
## $ distance       <dbl> 4983, 4983, 4983, 4983, 4983, 4983, 4983, 4983, ...
## $ hour           <dbl> 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, ...
## $ minute          <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ...
## $ time_hour      <dttm> 2013-01-01 09:00:00, 2013-01-02 09:00:00, 2013...

```

and the shortest distance.

```

arrange(flights, distance) %>%
  glimpse()

```

```

## Observations: 336,776
## Variables: 19
## $ year          <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month         <int> 7, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ day           <int> 27, 3, 4, 4, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, ...
## $ dep_time      <int> NA, 2127, 1240, 1829, 2128, 1155, 2125, 2124, 2...
## $ sched_dep_time <int> 106, 2129, 1200, 1615, 2129, 1200, 2129, 2129, ...
## $ dep_delay     <dbl> NA, -2, 40, 134, -1, -5, -4, -5, -3, -3, 4, 6, ...
## $ arr_time      <int> NA, 2222, 1333, 1937, 2218, 1241, 2224, 2212, 2...
## $ sched_arr_time <int> 245, 2224, 1306, 1721, 2224, 1306, 2224, 2224, ...
## $ arr_delay     <dbl> NA, -2, 27, 136, -6, -25, 0, -12, 39, -7, -1, 9...
## $ carrier        <chr> "US", "EV", "EV", "EV", "EV", "EV", ...
## $ flight         <int> 1632, 3833, 4193, 4502, 4645, 4193, 4619, 4619, ...
## $ tailnum        <chr> NA, "N13989", "N14972", "N15983", "N27962", "N1...
## $ origin         <chr> "EWR", "EWR", "EWR", "EWR", "EWR", "EWR"...
## $ dest           <chr> "LGA", "PHL", "PHL", "PHL", "PHL", "PHL"...
## $ air_time       <dbl> NA, 30, 30, 28, 32, 29, 22, 25, 30, 27, 30, 30, ...
## $ distance       <dbl> 17, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, ...
## $ hour           <dbl> 1, 21, 12, 16, 21, 12, 21, 21, 21, 21, 21, ...
## $ minute          <dbl> 6, 29, 0, 15, 29, 0, 29, 29, 30, 29, 29, 29, 17...
## $ time_hour      <dttm> 2013-07-27 01:00:00, 2013-01-03 21:00:00, 2013...

```

#5.4: Select columns

#5.4.1. 1. Brainstorm as many ways as possible to select `dep_time`, `dep_delay`, `arr_time`, and `arr_delay` from `flights`.

```

vars <- c("dep_time", "dep_delay", "arr_time", "arr_delay")

#method 1
select(flights, vars)

#method 2, probably
indexes <- which(names(flights) %in% vars)
select(flights, indexes)

#method 3
select(flights, contains("_time"), contains("_delay"), -contains("sched"), -contains("air"))

```

```
#method 4
select(flights, starts_with("dep"), starts_with("arr")) %>%
  select(ends_with("time"), ends_with("delay"))

## # A tibble: 336,776 x 4
##   dep_time arr_time dep_delay arr_delay
##   <int>     <int>     <dbl>     <dbl>
## 1      517      830       2       11
## 2      533      850       4       20
## 3      542      923       2       33
## 4      544     1004      -1      -18
## 5      554      812      -6      -25
## 6      554      740      -4       12
## 7      555      913      -5       19
## 8      557      709      -3      -14
## 9      557      838      -3       -8
## 10     558      753      -2        8
## # ... with 336,766 more rows
```

2. What happens if you include the name of a variable multiple times in a `select()` call?

It only shows-up once.

3. What does the `one_of()` function do? Why might it be helpful in conjunction with this vector?

```
vars <- c("year", "month", "day", "dep_delay", "arr_delay")
```

Can be used to select multiple variables with a character vector or to negate selecting certain variables.

4. Does the result of running the following code surprise you? How do the select helpers deal with case by default? How can you change that default?

```
select(flights, contains("TIME"))
```

```
## # A tibble: 336,776 x 6
##   dep_time sched_dep_time arr_time sched_arr_time air_time
##   <int>     <int>     <int>     <int>     <dbl>
## 1      517      515      830      819      227
## 2      533      529      850      830      227
## 3      542      540      923      850      160
## 4      544      545     1004     1022      183
## 5      554      600      812      837      116
## 6      554      558      740      728      150
## 7      555      600      913      854      158
## 8      557      600      709      723       53
## 9      557      600      838      846      140
## 10     558      600      753      745      138
## # ... with 336,766 more rows, and 1 more variable: time_hour <dttm>
```

Default is case insensitive, to change this specify `ignore.case = FALSE`

```
select(flights, contains("TIME", ignore.case = FALSE))
```

```
## # A tibble: 336,776 x 0
```

##5.5: Add new vars

##5.5.2.

1. Currently `dep_time` and `sched_dep_time` are convenient to look at, but hard to compute with because they're not really continuous numbers. Convert them to a more convenient representation of number of minutes since midnight.

```
time_to_mins <- function(x) (60*(x %/% 100) + (x %% 100))

flights_new <- mutate(flights,
  DepTime_MinsToMid = time_to_mins(dep_time),
  #same thing as above, but without calling custom function
  DepTime_MinsToMid_copy = (60*(dep_time %/% 100) + (dep_time %% 100)),
  SchedDepTime_MinsToMid = time_to_mins(sched_dep_time))
```

2. Compare `air_time` with `arr_time - dep_time`. What do you expect to see? What do you see? What do you need to do to fix it?

You would expect that: $air_time = dep_time - arr_time$

However this does not seem to be the case when you look at `air_time` generally...

Let's create this variable. I'll name it `air_calc`.

First method:

```
flights_new2 <- mutate(flights,
  # This air_time_clac step is necessary because you need to take into account red-eye flights in
  air_time_calc = ifelse(dep_time > arr_time, arr_time + 2400, arr_time),
  air_calc = time_to_mins(air_time_calc) - time_to_mins(dep_time))
```

The above method is the simple approach, though it doesn't take into account the timezone of the arrivals locations. To hanle this, I do a `left_join` on the airports dataframe and change `arr_time` to take into account the timezone and output the value in EST (as opposed to locatl time). We have not learned about 'joins' yet, so don't worry if this loses you.

```
flights_new2 <- flights %>%
  left_join(select(nycflights13::airports, dest = faa, tz)) %>%
  mutate(arr_time_old = arr_time) %>%
  mutate(arr_time = arr_time - 100*(tz+5)) %>%
  mutate(
  # This arr_time_calc step is a helper variable I created to take into account the red-eye flights in ca
    arr_time_calc = ifelse(dep_time > arr_time, arr_time + 2400, arr_time),
    air_calc = time_to_mins(arr_time_calc) - time_to_mins(dep_time)) %>%
  select(-arr_time_calc)
```

Joining, by = "dest"

Curious if anyone explored the `air_time` variable and figured out the details of how exactly it was off if there was something systematic? I checked this briefly in the appendix, but did not go deep.

3. Compare `dep_time`, `sched_dep_time`, and `dep_delay`. How would you expect those three numbers to be related?

You would expect that: $dep_delay = dep_time - sched_dep_time$.

Let's see if this is the case by creating a var `dep_delay2` that uses this definition, then see if it is equal to the original `dep_delay`

```
##maybe a couple off, but for the most part seems consistent
mutate(flights,
  dep_delay2 = time_to_mins(dep_time) - time_to_mins(sched_dep_time),
  dep_same = dep_delay == dep_delay2) %>%
  count(dep_same)
```

```
## # A tibble: 3 x 2
##   dep_same     n
##   <lgl>     <int>
## 1 FALSE      1207
## 2 TRUE       327314
## 3 NA         8255
```

Seems generally to align (with `dep_delay`). Those that are inconsistent are when the delay bleeds into the next day, indicating a problem with my equation, not the `dep_delay` value as you can see below.

```
mutate(flights,
       dep_delay2 = time_to_mins(dep_time) - time_to_mins(sched_dep_time),
       dep_same = dep_delay == dep_delay2) %>%
filter(!dep_same) %>%
glimpse()

## Observations: 1,207
## Variables: 21
## $ year           <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ day            <int> 1, 2, 2, 3, 3, 3, 4, 4, 5, 5, 6, 7, 9, 9, 9, 10...
## $ dep_time        <int> 848, 42, 126, 32, 50, 235, 25, 106, 14, 37, 16, ...
## $ sched_dep_time <int> 1835, 2359, 2250, 2359, 2145, 2359, 2359, 2245, ...
## $ dep_delay       <dbl> 853, 43, 156, 33, 185, 156, 26, 141, 15, 127, 1...
## $ arr_time        <int> 1001, 518, 233, 504, 203, 700, 505, 201, 503, 3...
## $ sched_arr_time <int> 1950, 442, 2359, 442, 2311, 437, 442, 2356, 445...
## $ arr_delay       <dbl> 851, 36, 154, 22, 172, 143, 23, 125, 18, 130, 9...
## $ carrier         <chr> "MQ", "B6", "B6", "B6", "B6", "B6", ...
## $ flight          <int> 3944, 707, 22, 707, 104, 727, 707, 608, 739, 11...
## $ tailnum         <chr> "N942MQ", "N580JB", "N636JB", "N763JB", "N329JB...
## $ origin          <chr> "JFK", "JFK", "JFK", "JFK", "JFK", "JFK"...
## $ dest            <chr> "BWI", "SJU", "SYR", "SJU", "BUF", "BQN", "SJU"...
## $ air_time        <dbl> 41, 189, 49, 193, 58, 186, 194, 44, 201, 163, 1...
## $ distance        <dbl> 184, 1598, 209, 1598, 301, 1576, 1598, 273, 161...
## $ hour            <dbl> 18, 23, 22, 23, 21, 23, 23, 22, 23, 22, 23, 23, ...
## $ minute          <dbl> 35, 59, 50, 59, 45, 59, 59, 45, 59, 30, 59, 59, ...
## $ time_hour       <dttm> 2013-01-01 18:00:00, 2013-01-02 23:00:00, 2013...
## $ dep_delay2      <dbl> -587, -1397, -1284, -1407, -1255, -1284, -1414, ...
## $ dep_same        <lgl> FALSE, FALSE, FALSE, FALSE, FALSE, FALSE...
```

4. Find the 10 most delayed flights using a ranking function. How do you want to handle ties? Carefully read the documentation for `min_rank()`.

(key question)

```
mutate(flights,
       rank_delay = min_rank(-dep_delay)) %>%
arrange(rank_delay) %>%
head(10) %>%
select(flight, sched_dep_time, dep_time, dep_delay, rank_delay)
```

```
## # A tibble: 10 x 5
##   flight sched_dep_time dep_time dep_delay rank_delay
##   <int>     <int>     <int>     <dbl>     <int>
## 1 51        900       641      1301      1
## 2 3535      1935      1432      1137      2
## 3 3695      1635      1121      1126      3
```

```
##  4    177      1845     1139     1014      4
##  5   3075      1600      845     1005      5
##  6   2391      1900     1100      960      6
##  7   2119       810     2321     911      7
##  8   2007      1900      959     899      8
##  9   2047       759     2257     898      9
## 10    172      1700      756     896     10
```

Check-out different rank functions

```
x <- c(1, 2, 3, 4, 4, 6, 7, 8, 8, 10)

min_rank(x)

## [1] 1 2 3 4 4 6 7 8 8 10

dense_rank(x)

## [1] 1 2 3 4 4 5 6 7 7 8

percent_rank(x)

## [1] 0.0000000 0.1111111 0.2222222 0.3333333 0.3333333 0.5555556 0.6666667
## [8] 0.7777778 0.7777778 1.0000000

cume_dist(x)

## [1] 0.1 0.2 0.3 0.5 0.5 0.6 0.7 0.9 0.9 1.0
```

5. What does `1:3 + 1:10` return? Why?

(key question)

```
1:3 + 1:10
```

```
## Warning in 1:3 + 1:10: longer object length is not a multiple of shorter
## object length
```

```
## [1] 2 4 6 5 7 9 8 10 12 11
```

This is returned because `1:3` is being recycled as each element is added to an element in `1:10`.

6. What trigonometric functions does R provide?

```
?sin
```

7.3 5.6: Grouped summaries

```
not_cancelled %>%
  select(year, month, day, dep_time) %>%
  group_by(year, month, day) %>%
  mutate(r = min_rank(desc(dep_time))) %>%
  # ungroup %>%
  mutate( range_min = range(r)[1],
         range_max = range(r)[2]) %>%
  filter(r %in% range(r))
```

7.3.1 5.6.7.

1. Brainstorm at least 5 different ways to assess the typical delay characteristics of a group of flights. (key question)

90th percentile for delays for flights by destination

```
flights %>%
  group_by(dest) %>%
  summarise(delay.90 = quantile(arr_delay, 0.90, na.rm = TRUE)) %>%
  arrange(desc(delay.90))
```

```
## # A tibble: 105 x 2
##   dest   delay.90
##   <chr>    <dbl>
## 1 TUL      126
## 2 TYS      109.
## 3 CAE      107
## 4 DSM      103
## 5 OKC      99.6
## 6 BHM      99.2
## 7 RIC      90
## 8 PVD      81.3
## 9 CRW      80.8
## 10 CVG     80
## # ... with 95 more rows
```

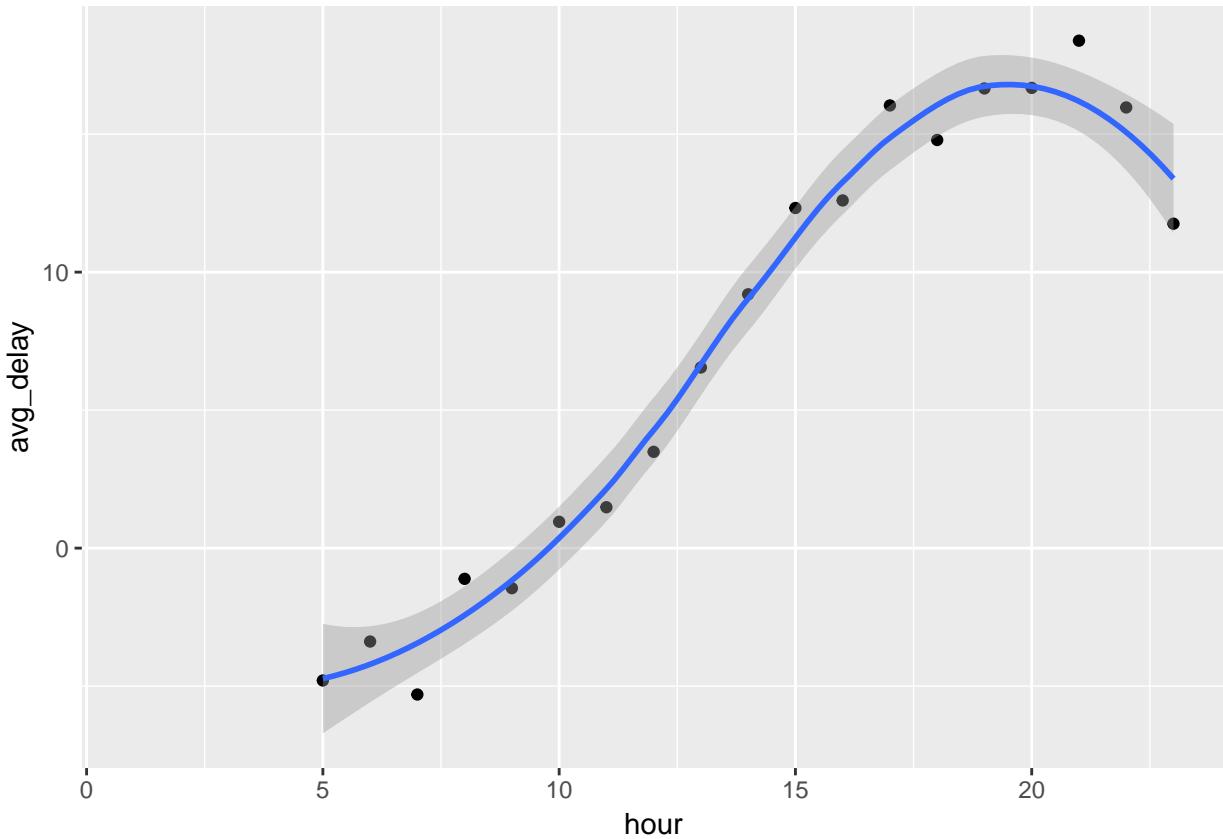
average dep_delay by hour of day

```
flights %>%
  group_by(hour) %>%
  summarise(avg_delay = mean(arr_delay, na.rm = TRUE)) %>%
  ggplot(aes(x = hour, y = avg_delay)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

```
## Warning: Removed 1 rows containing non-finite values (stat_smooth).
```

```
## Warning: Removed 1 rows containing missing values (geom_point).
```



Percentage of flights delayed or canceled by origin

```
flights %>%
  group_by(origin) %>%
  summarise(num_delayed = sum(arr_delay > 0, na.rm = TRUE)/n())
```

```
## # A tibble: 3 x 2
##   origin num_delayed
##   <chr>     <dbl>
## 1 EWR      0.415
## 2 JFK      0.385
## 3 LGA      0.382
```

Percentage of flights canceled by airline
(technically not delays...)

```
flights %>%
  group_by(carrier) %>%
  summarise(perc_canceled = sum(is.na(arr_delay))/n(),
            n = n()) %>%
  ungroup() %>%
  filter(n >= 1000) %>%
  mutate(most_rank = min_rank(-perc_canceled)) %>%
  arrange(most_rank)
```

```
## # A tibble: 11 x 4
##   carrier perc_canceled     n most_rank
##   <chr>     <dbl> <int>     <int>
```

```

## 1 9E          0.0632 18460      1
## 2 EV          0.0566 54173      2
## 3 MQ          0.0515 26397      3
## 4 US          0.0343 20536      4
## 5 FL          0.0261 3260       5
## 6 AA          0.0239 32729      6
## 7 WN          0.0188 12275      7
## 8 UA          0.0151 58665      8
## 9 B6          0.0107 54635      9
## 10 DL         0.00940 48110     10
## 11 VX         0.00891 5162       11

```

Percentage of flights delayed by airline

```

flights %>%
  group_by(carrier) %>%
  summarise(perc_delayed = sum(arr_delay > 0, na.rm = TRUE)/sum(!is.na(arr_delay)),
            n = n()) %>%
  ungroup() %>%
  filter(n >= 1000) %>%
  mutate(most_rank = min_rank(-perc_delayed)) %>%
  arrange(most_rank)

```

```

## # A tibble: 11 x 4
##   carrier perc_delayed     n most_rank
##   <chr>        <dbl> <int>     <int>
## 1 FL           0.597  3260      1
## 2 EV           0.479  54173     2
## 3 MQ           0.467  26397     3
## 4 WN           0.440  12275     4
## 5 B6           0.437  54635     5
## 6 UA           0.385  58665     6
## 7 9E           0.384  18460     7
## 8 US           0.371  20536     8
## 9 DL           0.344  48110     9
## 10 VX          0.341  5162      10
## 11 AA          0.335  32729     11

```

Consider the following scenarios:

1.1 A flight is 15 minutes early 50% of the time, and 15 minutes late 50% of the time.

```

flights %>%
  group_by(flight) %>%
  # filter(!is.na(arr_delay)) %>% ##Keeping this in would exclude the possibility of canceled
  summarise(early.15 = sum(arr_delay <= -15, na.rm = TRUE)/n(),
            late.15 = sum(arr_delay >= 15, na.rm = TRUE)/n(),
            n = n()) %>%
  ungroup() %>%
  filter(early.15 == .5, late.15 == .5)

```

```

## # A tibble: 18 x 4
##   flight early.15 late.15     n
##   <int>    <dbl>   <dbl> <int>
## 1 107      0.5     0.5     2
## 2 2072     0.5     0.5     2
## 3 2366     0.5     0.5     2

```

```

##  4   2500    0.5    0.5    2
##  5   2552    0.5    0.5    2
##  6   3495    0.5    0.5    2
##  7   3518    0.5    0.5    2
##  8   3544    0.5    0.5    2
##  9   3651    0.5    0.5    2
## 10  3705    0.5    0.5    2
## 11  3916    0.5    0.5    2
## 12  3951    0.5    0.5    2
## 13  4273    0.5    0.5    2
## 14  4313    0.5    0.5    2
## 15  5297    0.5    0.5    2
## 16  5322    0.5    0.5    2
## 17  5388    0.5    0.5    2
## 18  5505    0.5    0.5    4

```

1.2 A flight is always 10 minutes late.

```

flights %>%
  group_by(flight) %>%
  summarise(late.10 = sum(arr_delay >= 10)/n()) %>%
  ungroup() %>%
  filter(late.10 == 1)

```

```

## # A tibble: 93 x 2
##       flight late.10
##   <int>    <dbl>
## 1     94      1
## 2    730      1
## 3    974      1
## 4   1084      1
## 5   1226      1
## 6   1510      1
## 7   1514      1
## 8   1859      1
## 9   1868      1
## 10  2101      1
## # ... with 83 more rows

```

1.3 A flight is 30 minutes early 50% of the time, and 30 minutes late 50% of the time.

```

flights %>%
  group_by(flight) %>%
  # filter(!is.na(arr_delay)) %>% ##Keeping this in would exclude the possibility of canceled
  summarise(early.30 = sum(arr_delay <= -30, na.rm = TRUE)/n(),
            late.30 = sum(arr_delay >= 30, na.rm = TRUE)/n(),
            n = n()) %>%
  ungroup() %>%
  filter(early.30 == .5, late.30 == .5)

```

```

## # A tibble: 3 x 4
##       flight early.30 late.30      n
##   <int>    <dbl>    <dbl> <int>
## 1   3651     0.5     0.5    2
## 2   3916     0.5     0.5    2
## 3   3951     0.5     0.5    2

```

1.4 99% of the time a flight is on time. 1% of the time it's 2 hours late.

```
flights %>%
  group_by(flight) %>%
  # filter(!is.na(arr_delay)) %>% ##Keeping this in would exclude the possibility of canceled
  summarise(ontime = sum(arr_delay <= 0, na.rm = TRUE)/n(),
            late.120 = sum(arr_delay >= 120, na.rm = TRUE)/n(),
            n = n()) %>%
  ungroup() %>%
  filter(ontime == .99, late.120 == .01)

## # A tibble: 0 x 4
## # ... with 4 variables: flight <int>, ontime <dbl>, late.120 <dbl>,
## #   n <int>
```

Looks like this exact proportion doesn't happen. But let's look at those flights that have the greatest differences in proportion on-time vs. 2 hours late while still having values in both categories¹.

```
flights %>%
  group_by(flight) %>%
  summarise(ontime = sum(arr_delay <= 0, na.rm = TRUE)/n(),
            late.120 = sum(arr_delay >= 120, na.rm = TRUE)/n(),
            n = n()) %>%
  ungroup() %>%
  filter_at(c("ontime", "late.120"), all_vars(. != 0 & . != 1)) %>%
  mutate(max_dist = abs(ontime - late.120)) %>%
  arrange(desc(max_dist))
```

```
## # A tibble: 2,098 x 5
##   flight ontime late.120     n max_dist
##   <int>   <dbl>   <dbl> <int>    <dbl>
## 1 5288   0.927   0.0244    41    0.902
## 2 2085   0.901   0.00658   152    0.895
## 3 2174   0.914   0.0286    35    0.886
## 4 2243   0.9      0.0167   120    0.883
## 5 2180   0.889   0.0131   153    0.876
## 6 2118   0.867   0.00699   143    0.860
## 7 1167   0.864   0.00662   302    0.858
## 8 3613   0.886   0.0286    35    0.857
## 9 1772   0.891   0.0364    55    0.855
## 10 1157   0.847   0.00667   150    0.84
## # ... with 2,088 more rows
```

2. Which is more important: arrival delay or departure delay?

Arrival delay.

3. Come up with another approach that will give you the same output as `not_cancelled %>% count(dest)` and `not_cancelled %>% count(tailnum, wt = distance)` (without using `count()`). (key question)

```
not_cancelled <- flights %>%
  filter(!is.na(dep_delay), !is.na(arr_delay))

not_cancelled %>%
  group_by(dest) %>%
```

¹The output below is actually just maximizing difference in proportion 2 hrs late vs on time, it does not matter whether the higher proportion is on-time or late. It just happens in practice that the higher proportion is generally the on-time

```

  summarise(n = n())

## # A tibble: 104 x 2
##   dest      n
##   <chr>    <int>
## 1 ABQ      254
## 2 ACK      264
## 3 ALB      418
## 4 ANC       8
## 5 ATL     16837
## 6 AUS      2411
## 7 AVL      261
## 8 BDL      412
## 9 BGR      358
## 10 BHM     269
## # ... with 94 more rows

not_cancelled %>%
  group_by(tailnum) %>%
  summarise(n = sum(distance))

```

```

## # A tibble: 4,037 x 2
##   tailnum      n
##   <chr>    <dbl>
## 1 D942DN    3418
## 2 NOEGMQ   239143
## 3 N10156   109664
## 4 N102UW    25722
## 5 N103US    24619
## 6 N104UW    24616
## 7 N10575   139903
## 8 N105UW    23618
## 9 N107US    21677
## 10 N108UW   32070
## # ... with 4,027 more rows

```

4. Our definition of cancelled flights (`is.na(dep_delay) | is.na(arr_delay)`) is slightly suboptimal. Why? Which is the most important column?

You only need the `is.na(arr_delay)` column. By having both, it is doing more checks than is necessary.

While not precise, you can see that the number of rows with just `is.na(arr_delay)` would be the same in either case.

```

filter(flights, is.na(dep_delay) | is.na(arr_delay)) %>%
  count()

```

```

## # A tibble: 1 x 1
##       n
##   <int>
## 1  9430
filter(flights, is.na(arr_delay)) %>%
  count()

```

```

## # A tibble: 1 x 1
##       n
##   <int>
## 1  9430

```

```
## 1 9430
```

To be more precise, you could check these with the `identical` function.

```
check_1 <- filter(flights, is.na(dep_delay) | is.na(arr_delay))
```

```
check_2 <- filter(flights, is.na(arr_delay))
```

```
identical(check_1, check_2)
```

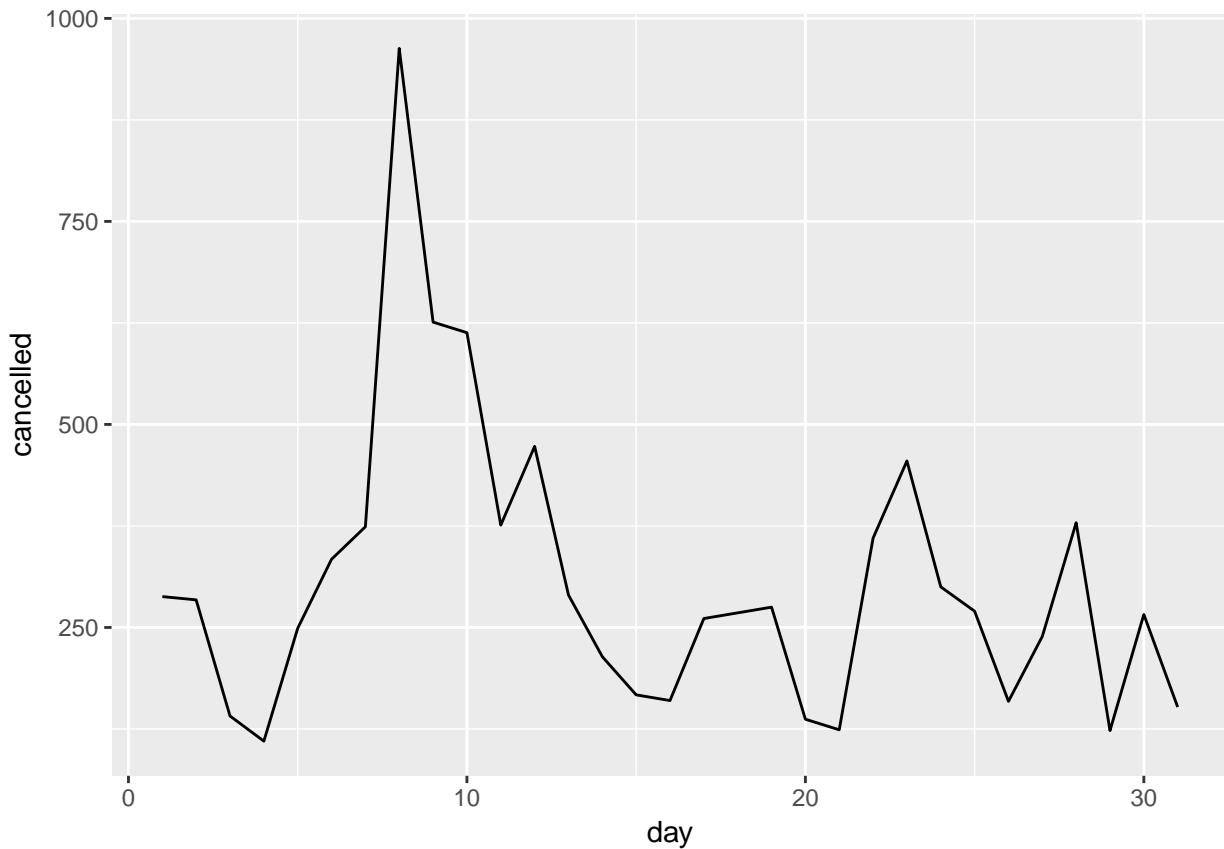
```
## [1] TRUE
```

5. Look at the number of cancelled flights per day. Is there a pattern?

(key question)

Number of canceled flights:

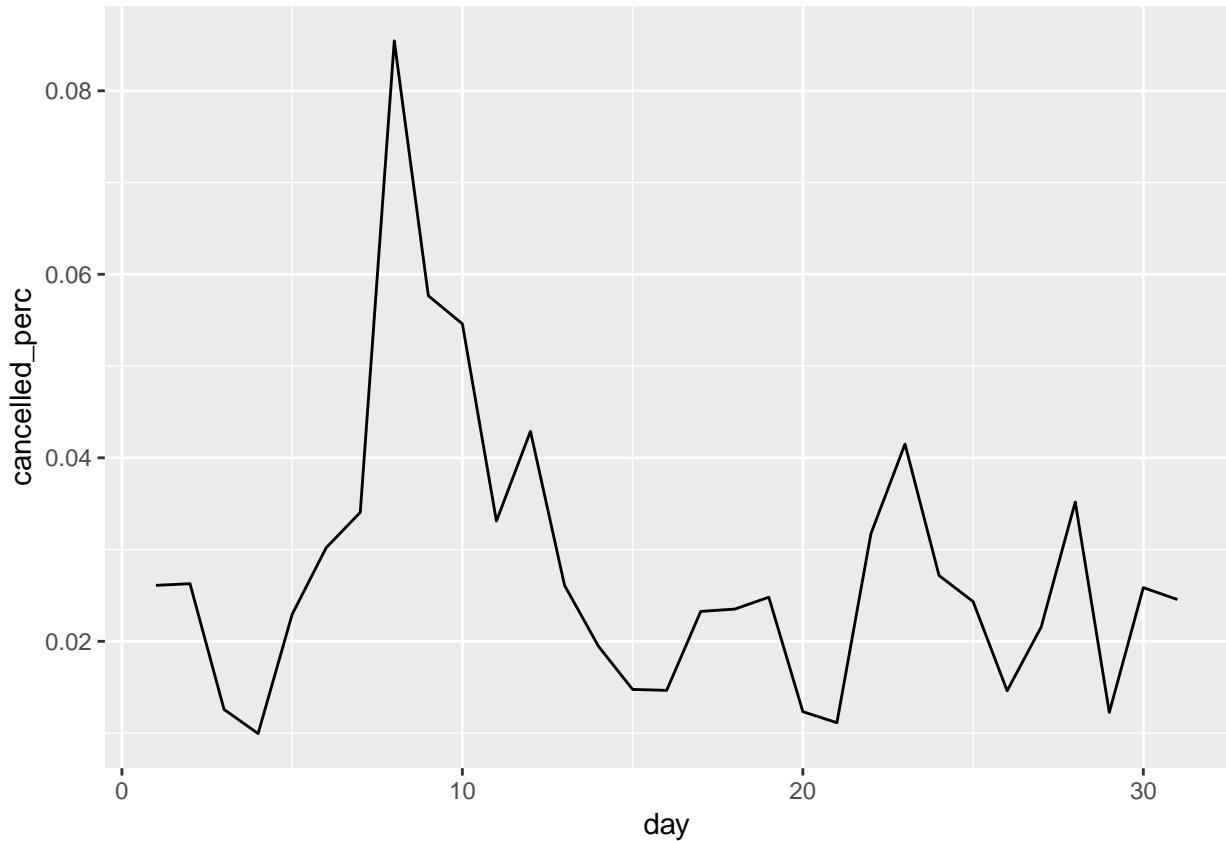
```
flights %>%
  group_by(day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  ggplot(aes(x = day, y = cancelled)) +
  geom_line()
```



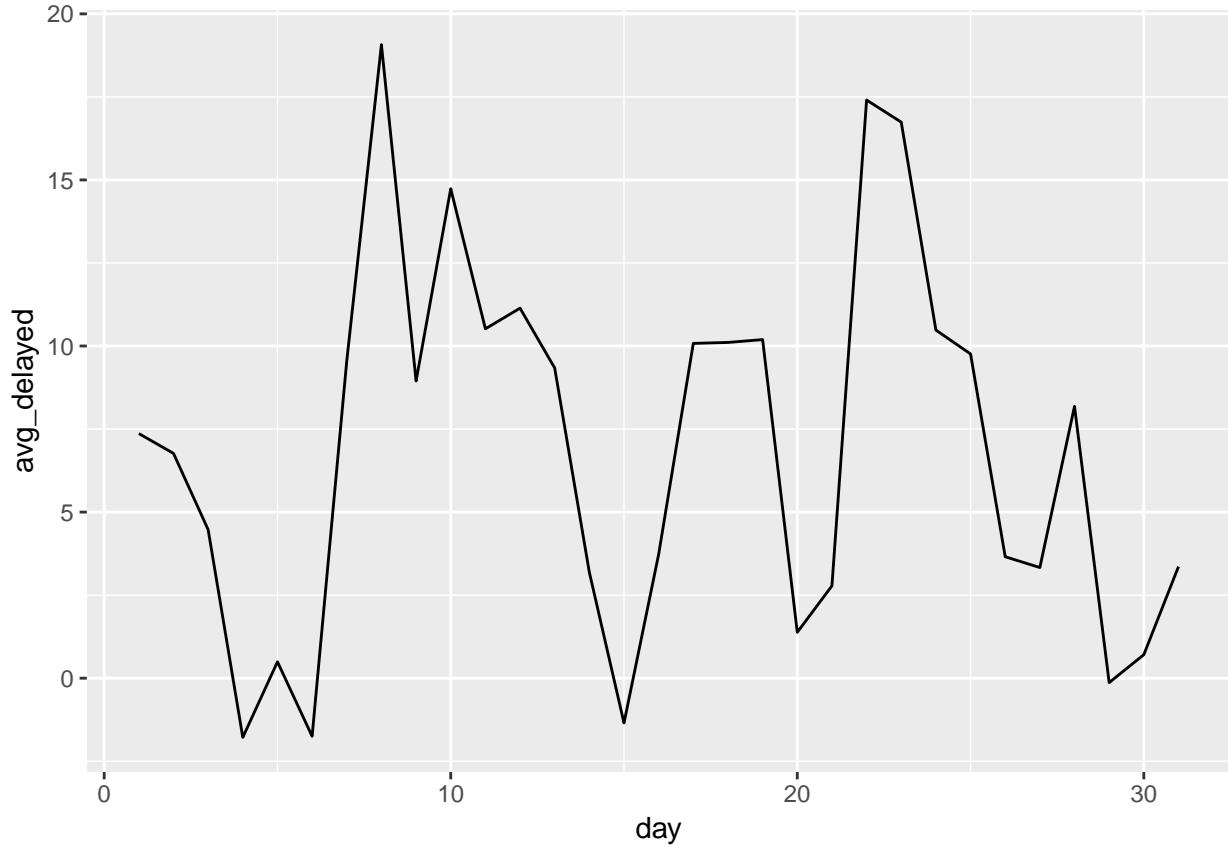
Is the proportion of cancelled flights related to the average delay?

Proportion of canceled flights and then average delay of flights by day:

```
flights %>%
  group_by(day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  ggplot(aes(x = day, y = cancelled_perc)) +
  geom_line()
```



```
flights %>%
  group_by(day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  ggplot(aes(x = day, y = avg_delayed)) +
  geom_line()
```



Looks roughly like there is some overlap.

I liked Vincent's approach to this problem better than my own and would recommend checking out his code.

6. Which carrier has the worst delays? Challenge: can you disentangle the effects of bad airports vs. bad carriers? Why/why not? (Hint: think about flights %>% group_by(carrier, dest) %>% summarise(n()))
 (key question)

```
flights %>%
  group_by(carrier) %>%
  summarise(avg_delay = mean(arr_delay, na.rm = TRUE),
            n = n()) %>%
  arrange(desc(avg_delay))
```

```
## # A tibble: 16 x 3
##   carrier avg_delay     n
##   <chr>      <dbl> <int>
## 1 F9        21.9    685
## 2 FL        20.1    3260
## 3 EV        15.8   54173
## 4 YV        15.6     601
## 5 OO        11.9      32
## 6 MQ        10.8   26397
## 7 WN         9.65   12275
## 8 B6         9.46   54635
## 9 9E         7.38   18460
## 10 UA        3.56   58665
```

```
## 11 US      2.13 20536
## 12 VX      1.76  5162
## 13 DL      1.64 48110
## 14 AA      0.364 32729
## 15 HA     -6.92   342
## 16 AS     -9.93    714
```

Difficult to untangle in the `origin` airports because carriers may predominantly go through one of the three. The code below produces the origin name that the carrier that flies from the most along with the proportion of associated flights.

```
flights %>%
  group_by(carrier, origin) %>%
  summarise(n = n()) %>%
  mutate(perc = n / sum(n)) %>%
  group_by(carrier) %>%
  mutate(rank = min_rank(-perc)) %>%
  arrange(carrier, rank) %>%
  filter(rank == 1) %>%
  select(carrier, highest_origin = origin, highest_prop = perc, n_total = n) %>%
  arrange(desc(n_total))
```

```
## # A tibble: 16 x 4
## # Groups:   carrier [16]
##   carrier highest_origin highest_prop n_total
##   <chr>    <chr>          <dbl>    <int>
## 1 UA        EWR            0.786   46087
## 2 EV        EWR            0.811   43939
## 3 B6        JFK            0.770   42076
## 4 DL        LGA            0.479   23067
## 5 MQ        LGA            0.641   16928
## 6 AA        LGA            0.472   15459
## 7 9E        JFK            0.794   14651
## 8 US        LGA            0.640   13136
## 9 WN        EWR            0.504   6188
## 10 VX       JFK            0.697   3596
## 11 FL       LGA            1        3260
## 12 AS       EWR            1        714
## 13 F9       LGA            1        685
## 14 YV       LGA            1        601
## 15 HA       JFK            1        342
## 16 OO       LGA            0.812   26
```

Below we look at destinations and the `carrier` that has the highest proportion of flights from one of the NYC destinations (ignoring for specific `origin` – JFK, LGA, etc. are not separated).

```
flights %>%
  group_by(dest, carrier) %>%
  summarise(n = n()) %>%
  mutate(perc = n / sum(n)) %>%
  group_by(dest) %>%
  mutate(rank = min_rank(-perc)) %>%
  arrange(carrier, rank) %>%
  filter(rank == 1) %>%
  select(dest, highest_carrier = carrier, highest_perc = perc, n_total = n) %>%
  arrange(desc(n_total))
```

```
## # A tibble: 105 x 4
## # Groups:   dest [105]
##   dest highest_carrier highest_perc n_total
##   <chr> <chr>           <dbl>    <int>
## 1 ATL   DL            0.614    10571
## 2 CLT   US            0.614     8632
## 3 DFW   AA            0.831     7257
## 4 MIA   AA            0.617     7234
## 5 ORD   UA            0.404     6984
## 6 IAH   UA            0.962     6924
## 7 SFO   UA            0.512     6819
## 8 FLL   B6            0.544     6563
## 9 MCO   B6            0.460     6472
## 10 LAX  UA            0.360     5823
## # ... with 95 more rows
```

To get at the question of ‘best carrier’, you may consider doing a grouped comparison of average delays or cancellations controlling for where they are flying to and from what origin...

7. What does the `sort` argument to `count()` do. When might you use it?

`sort` orders by `n`, you may want to use it when you

7.4 Grouped mutates (and filters)

7.4.1 5.7.1.

1. Refer back to the lists of useful `mutate` and filtering functions. Describe how each operation changes when you combine it with grouping.

2. Which plane (tailnum) has the worst on-time record?

```
flights %>%
  group_by(tailnum) %>%
  summarise(n = n(),
            num_not_delayed = sum(arr_delay <= 0, na.rm = TRUE),
            ontime_rate = num_not_delayed / n,
            sum_delayed_time_grt0 = sum(ifelse(arr_delay >= 0, arr_delay, 0), na.rm = TRUE)) %>%
  filter(n > 100, !is.na(tailnum)) %>%
  arrange(ontime_rate)

## # A tibble: 1,200 x 5
##   tailnum      n num_not_delayed ontime_rate sum_delayed_time_grt0
##   <chr>    <int>          <int>       <dbl>                <dbl>
## 1 N505MQ     242            83     0.343                5911
## 2 N15910     280           105     0.375                8737
## 3 N36915     228            86     0.377                6392
## 4 N16919     251            96     0.382                7955
## 5 N14998     230            88     0.383                7166
## 6 N14953     256           100     0.391                6550
## 7 N22971     230            90     0.391                6547
## 8 N503MQ     191            75     0.393                4420
## 9 N27152     109            43     0.394                2058
## 10 N31131    109            43     0.394               2740
## # ... with 1,190 more rows
```

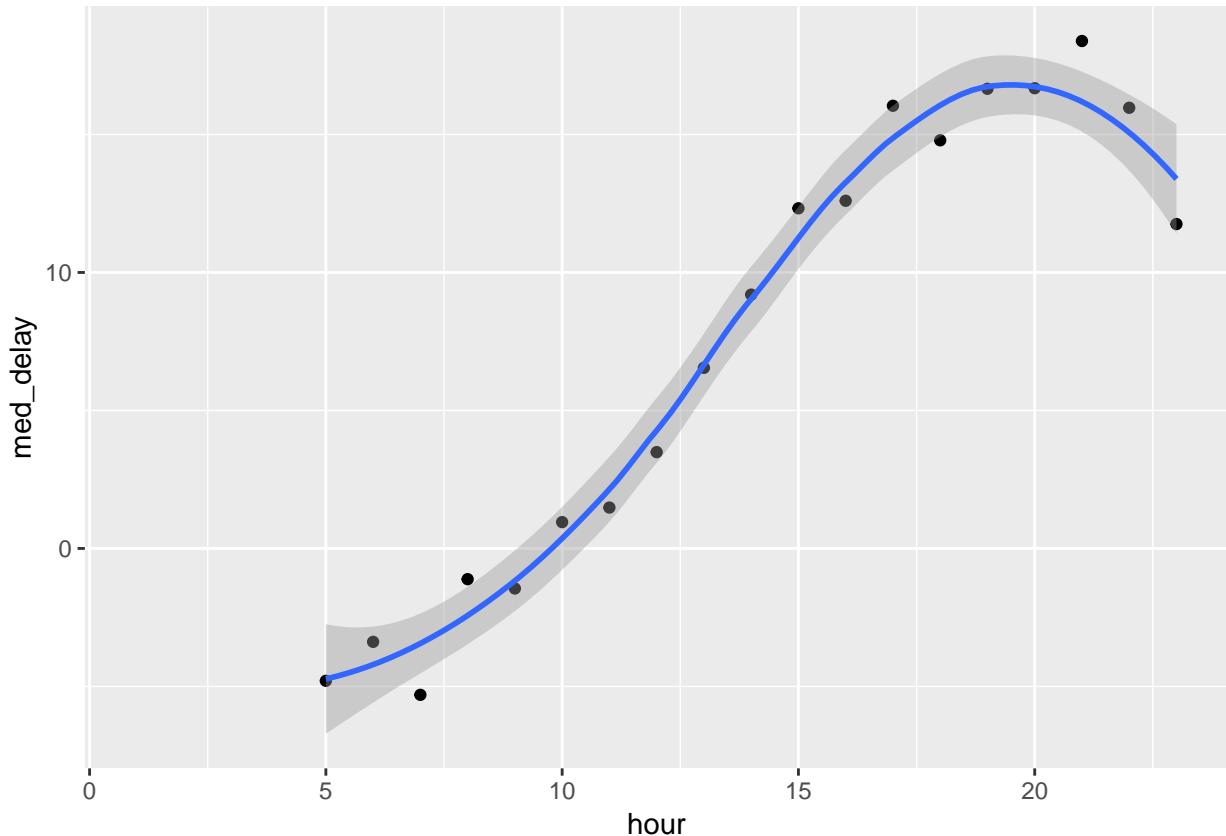
N505MQ

3. What time of day should you fly if you want to avoid delays as much as possible?

average `dep_delay` by hour of day

```
flights %>%
  group_by(hour) %>%
  summarise(med_delay = mean(arr_delay, na.rm = TRUE)) %>%
  ggplot(aes(x = hour, y = med_delay)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
## Warning: Removed 1 rows containing non-finite values (stat_smooth).
## Warning: Removed 1 rows containing missing values (geom_point).
```



Fly in the morning.

4. For each destination, compute the total minutes of delay. For each flight, compute the proportion of the total delay for its destination.

```
flights %>%
  group_by(dest, flight) %>%
  summarise(TotalDelay_DestFlight = sum(arr_delay, na.rm = TRUE)) %>%
  mutate(TotalDelay_Dest = sum(TotalDelay_DestFlight),
        PropOfDest = TotalDelay_DestFlight / TotalDelay_Dest)
```

```
## # A tibble: 11,467 x 5
## # Groups:   dest [105]
##   dest   flight TotalDelay_DestFlight TotalDelay_Dest PropOfDest
##   <chr>  <int>          <dbl>        <dbl>        <dbl>
## 1 ABQ      65           605         1113       0.544
## 2 ABQ     1505          508         1113       0.456
## 3 ACK     1191          652         1281       0.509
## 4 ACK     1195           20         1281       0.0156
## 5 ACK    1291          234         1281       0.183
## 6 ACK    1491          375         1281       0.293
## 7 ALB     3256          -12        6018      -0.00199
## 8 ALB     3260          111        6018       0.0184
## 9 ALB     3264          -47        6018      -0.00781
## 10 ALB    3811          570        6018       0.0947
## # ... with 11,457 more rows
```

I did this such that flights could have “negative” delays, this could have been approached differently though...

5. Delays are typically temporally correlated: even once the problem that caused the initial delay has been resolved, later flights are delayed to allow earlier flights to leave. Using `lag()` explore how the delay of a flight is related to the delay of the immediately preceding flight.

```
flights %>%
  group_by(origin) %>%
  mutate(delay_lag = lag(dep_delay, 1),
        diff_lag = abs(dep_delay - delay_lag)) %>%
  ungroup() %>%
  select(dep_delay, delay_lag) %>%
  na.omit() %>%
  cor()

##             dep_delay delay_lag
## dep_delay  1.0000000  0.3506866
## delay_lag  0.3506866  1.0000000
```

Correlation of

$$\text{dep_delay}_{t-1}$$

with

$$\text{dep_delay}_t$$

is 0.35 .

Below is a function to get the correlation out for any lag level.

```
cor_by_lag <- function(lag){
  flights %>%
    group_by(origin) %>%
    mutate(delay_lag = lag(dep_delay, lag),
          diff_lag = abs(dep_delay - delay_lag)) %>%
    ungroup() %>%
    select(dep_delay, delay_lag) %>%
    na.omit() %>%
    cor() %>%
    .[2,1] %>%
    as.vector()
}
```

Let's see the correlation pushing the lag time back.

```
cor_by_lag(1)
## [1] 0.3506866
cor_by_lag(10)
## [1] 0.2622796
cor_by_lag(100)
## [1] 0.04023232
cor_by_lag(1000)
## [1] 0.03191625
```

It makes sense that these values get smaller as flights that are further apart have delay lengths that are less correlated. See 5.7.1.8. for a sneak peak on iteration of this function.

6. Look at each destination. Can you find flights that are suspiciously fast? (i.e. flights that represent a potential data entry error). Compute the air time a flight relative to the shortest flight to that destination. Which flights were most delayed in the air?

```
flights %>%
  filter(!is.na(arr_delay)) %>%
  group_by(dest) %>%
  mutate(sd_air_time = sd(air_time),
        mean_air_time = mean(air_time)) %>%
  ungroup() %>%
  mutate(supect_fast_cutoff = mean_air_time - 4*sd_air_time,
        suspect_flag = air_time < suspect_fast_cutoff) %>%
  select(dest, flight, hour, day, month, air_time, sd_air_time, mean_air_time, suspect_fast_cutoff, suspect_flag)
## # A tibble: 4 x 10
##   dest  flight  hour  day month air_time sd_air_time mean_air_time
##   <chr> <int> <dbl> <int> <int>    <dbl>      <dbl>            <dbl>
## 1 BNA     3805    19    23     3      70     11.0         114.
## 2 GSP     4292    20    13     5      55      8.13        93.4
## 3 ATL     1499    17    25     5      65      9.81        113.
## 4 MSP     4667    15     2     7      93     11.8         151.
## # ... with 2 more variables: suspect_fast_cutoff <dbl>, suspect_flag <lgl>
```

7. Find all destinations that are flown by at least two carriers. Use that information to rank the carriers.

I found this question ambiguous in terms of what it wants when it says “rank” the carriers using this. What I did was to say filter to just those destinations that have at least two carriers and then count the number of destinations with multiple carriers that each airline travels to. So it’s almost which airlines have more routes to ‘crowded’ destinations.

```
flights %>%
  group_by(dest) %>%
  mutate(n_carrier = n_distinct(carrier)) %>%
  filter(n_carrier > 1) %>%
  group_by(carrier) %>%
  summarise(n_dest = n_distinct(dest)) %>%
  mutate(rank = min_rank(-n_dest)) %>%
  arrange(rank)
```

```
## # A tibble: 16 x 3
##   carrier n_dest rank
##   <chr>     <int> <int>
## 1 EV         51    1
## 2 9E         48    2
## 3 UA         42    3
## 4 DL         39    4
## 5 B6         35    5
## 6 AA         19    6
## 7 MQ         19    6
## 8 WN         10    8
## 9 OO          5    9
## 10 US         5    9
## 11 VX          4   11
## 12 YV          3   12
## 13 FL          2   13
## 14 AS          1   14
## 15 F9          1   14
## 16 HA          1   14
```

Another way to approach this may have been to say to evaluate the delays between carriers going to the same destination and used that as a way of comparing and ‘ranking’ the best carriers. This would have been a more ambitious problem to answer.

8. For each plane, count the number of flights before the first delay of greater than 1 hour.

```
tail_nums_counts <- flights %>%
  arrange(tailnum, month, day, dep_time) %>%
  group_by(tailnum) %>%
  mutate(cum_sum = cumsum(arr_delay <= 60),
        nrow = row_number(),
        nrow_equal = nrow == cum_sum,
        cum_sum_before = cum_sum * nrow_equal) %>%
  mutate(total_before_hour = max(cum_sum_before, na.rm = TRUE)) %>%
  select(year, month, day, dep_time, tailnum, arr_delay, cum_sum, nrow, nrow_equal, cum_sum_before, total_before_hour)
ungroup()

#let's change this to get rid of canceled flights, because those don't count as flights or delays.
tail_nums_counts <- flights %>%
  filter(!is.na(arr_delay)) %>%
  select(tailnum, month, day, dep_time, arr_delay) %>%
  arrange(tailnum, month, day, dep_time) %>%
  group_by(tailnum) %>%
  mutate(cum_sum = cumsum(arr_delay <= 60),
        nrow = row_number(),
        nrow_equal = nrow == cum_sum,
        cum_sum_before = cum_sum * nrow_equal) %>%
  mutate(total_before_hour = max(cum_sum_before, na.rm = TRUE)) %>%
  select(month, day, dep_time, tailnum, arr_delay, cum_sum, nrow, nrow_equal, cum_sum_before, total_before_hour)
ungroup()

tail_nums_counts %>%
  filter(!is.na(tailnum)) %>%
  arrange(desc(nrow), tailnum) %>%
  distinct(tailnum, .keep_all = TRUE) %>%
```

```
select(tailnum, total_before_hour) %>%
arrange(tailnum)

## # A tibble: 4,037 x 2
##   tailnum total_before_hour
##   <chr>          <dbl>
## 1 D942DN            0
## 2 NOEGMQ            0
## 3 N10156             9
## 4 N102UW            25
## 5 N103US            46
## 6 N104UW             3
## 7 N10575            0
## 8 N105UW            22
## 9 N107US            20
## 10 N108UW            36
## # ... with 4,027 more rows
```


Chapter 8

Appendix

The appendix is either extensions upon solutions. Solving the problems using functions we haven't learned yet, or other random notes / tidbits.

8.1 5.4.1.3.

You actually don't need `one_of` for selecting by character vector, more useful is when using it to negate fields by name.

```
select(flights, -one_of(vars))

## # A tibble: 336,776 x 15
##   year month   day sched_dep_time sched_arr_time carrier flight tailnum
##   <int> <int> <int>       <int>       <int> <chr>    <int> <chr>
## 1 2013     1     1        515        819  UA      1545 N14228
## 2 2013     1     1        529        830  UA      1714 N24211
## 3 2013     1     1        540        850  AA      1141 N619AA
## 4 2013     1     1        545       1022  B6      725  N804JB
## 5 2013     1     1        600        837  DL      461  N668DN
## 6 2013     1     1        558        728  UA      1696 N39463
## 7 2013     1     1        600        854  B6      507  N516JB
## 8 2013     1     1        600        723  EV      5708 N829AS
## 9 2013     1     1        600        846  B6       79  N593JB
## 10 2013    1     1        600        745  AA      301  N3ALAA
## # ... with 336,766 more rows, and 7 more variables: origin <chr>,
## #   dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
## #   time_hour <dttm>
```

8.2 5.5.2.1.

Other, more sophisticated method¹

```
mutate_at(.tbl = flights,
          .vars = c("dep_time", "sched_dep_time"),
          .funs = funs(new = time_to_mins))
```

¹This method is helpful for if you have more than just a couple variables you are applying a transformation to.

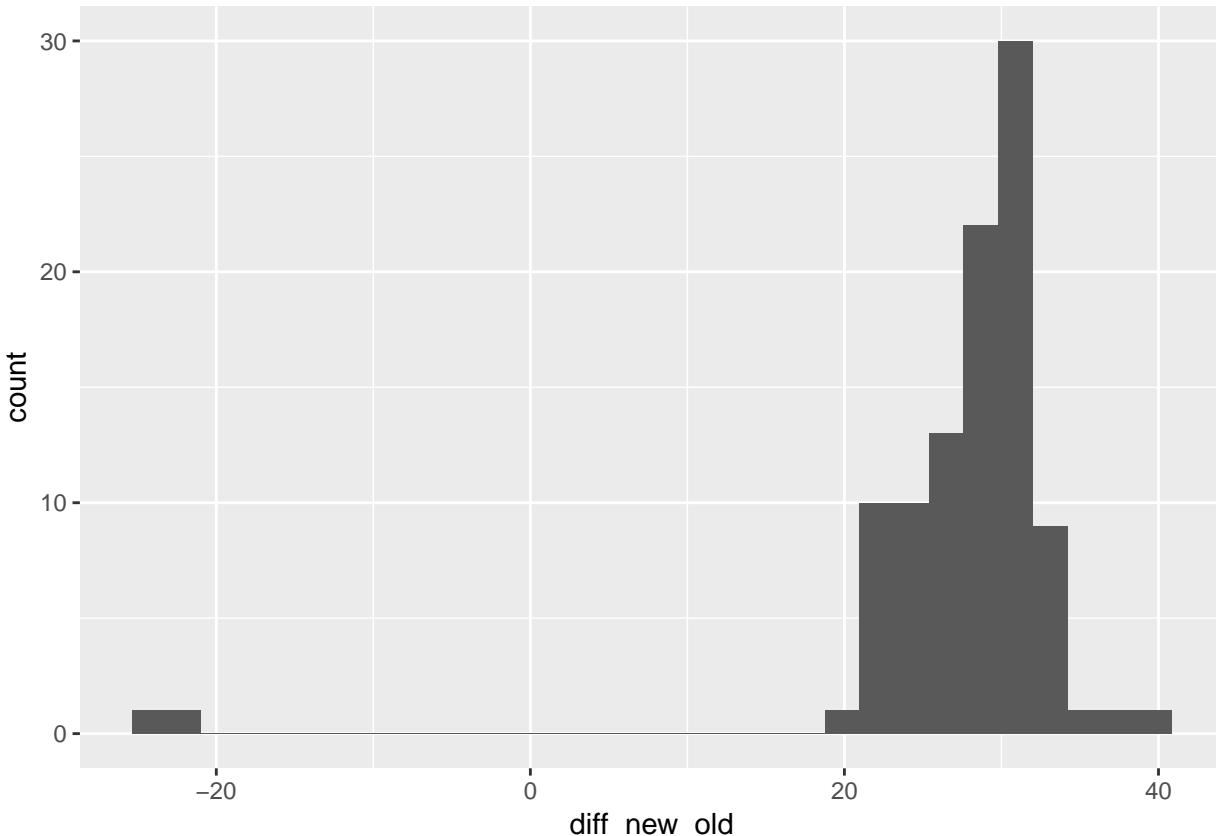
8.3 5.5.2.2

8.3.1 Closer look at `air_time`

Wanted to look at original `air_time` variable a little more. Histogram below shows that most differences are now between 20 - 40 minutes from the actual time.

```
flights_new2 %>%
  group_by(dest) %>%
  summarise(distance_med = median(distance, na.rm = TRUE),
            air_calc_med = median(air_calc, na.rm = TRUE),
            air_old_med = median(air_time, na.rm = TRUE),
            diff_new_old = air_calc_med - air_old_med,
            diff_hrs = as.factor(round(diff_new_old/60)),
            num = n()) %>%
  ggplot(aes(diff_new_old)) +
  geom_histogram()

## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
## Warning: Removed 5 rows containing non-finite values (stat_bin).
```



Regressing `diff` on `arr_delay` and `dep_delay` (remember `diff` is the difference between `air_time` and `air_calc`)

```
mod_air_time2 <- mutate(flights_new2, diff = (air_time - air_calc)) %>%
  select(-air_time, -air_calc, -flight, -tailnum, -dest) %>%
  na.omit() %>%
```

```

lm(diff ~ dep_delay + arr_delay, data = .)

summary(mod_air_time2)

##
## Call:
## lm(formula = diff ~ dep_delay + arr_delay, data = .)
##
## Residuals:
##      Min      1Q Median      3Q     Max
## -93.168 -6.684  0.688  6.878 101.169
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -33.511843   0.024118 -1389.5 <2e-16 ***
## dep_delay     0.533376   0.001355   393.5 <2e-16 ***
## arr_delay    -0.552852   0.001217  -454.2 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.43 on 319806 degrees of freedom
## Multiple R-squared:  0.3956, Adjusted R-squared:  0.3956
## F-statistic: 1.047e+05 on 2 and 319806 DF, p-value: < 2.2e-16

```

Doing such accounts for ~40% of the variation in the values.

The `dep_delay` and `arr_delay` variables are highly colinear which is part of the reason for the coefficients being opposite in the model.

```

flights_new2 %>%
  select(air_time, air_calc, arr_delay, dep_delay) %>%
  mutate(diff = air_time - air_calc) %>%
  select(-air_time, -air_calc) %>%
  na.omit() %>%
  cor()

##           arr_delay  dep_delay      diff
## arr_delay  1.0000000  0.91531953 -0.32086698
## dep_delay  0.9153195  1.00000000 -0.07582942
## diff      -0.3208670 -0.07582942  1.00000000

```

Typically, this suggests that you do not need to include both variables in the model as they will likely be providing the same information. Though here that is not the case as only including `arr_delay` associates with a steep decline in R^2 to just account for ~10% of the variation.

```

mod_air_time <- mutate(flights_new2, diff = (air_time - air_calc)) %>%
  select(-air_time, -air_calc, -flight, -tailnum, -dest) %>%
  na.omit() %>%
lm(diff ~ arr_delay, data = .)

summary(mod_air_time)

##
## Call:
## lm(formula = diff ~ arr_delay, data = .)
##
## Residuals:
##      Min      1Q Median      3Q     Max
## -93.168 -6.684  0.688  6.878 101.169
##
```

```

##      Min     1Q   Median     3Q     Max
## -182.960 -6.385    2.013   7.983 154.382
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.984e+01  2.710e-02 -1101.3 <2e-16 ***
## arr_delay   -1.144e-01  5.972e-04  -191.6 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 15.14 on 319807 degrees of freedom
## Multiple R-squared:  0.103, Adjusted R-squared:  0.103
## F-statistic: 3.67e+04 on 1 and 319807 DF, p-value: < 2.2e-16

```

Add predictions from models of `air_time` to dataframe and take sample of 500 from entire `flights` dataset to visualise.

```

flights_preds_mod <- flights_new2 %>%
  mutate(diff = (air_time - air_calc)) %>%
  na.omit() %>%
  modelr::spread_predictions(mod_air_time, mod_air_time2) %>%
  select(diff, dep_delay, arr_delay, air_calc, air_time, mod_air_time, mod_air_time2) %>%
  sample_n(500)

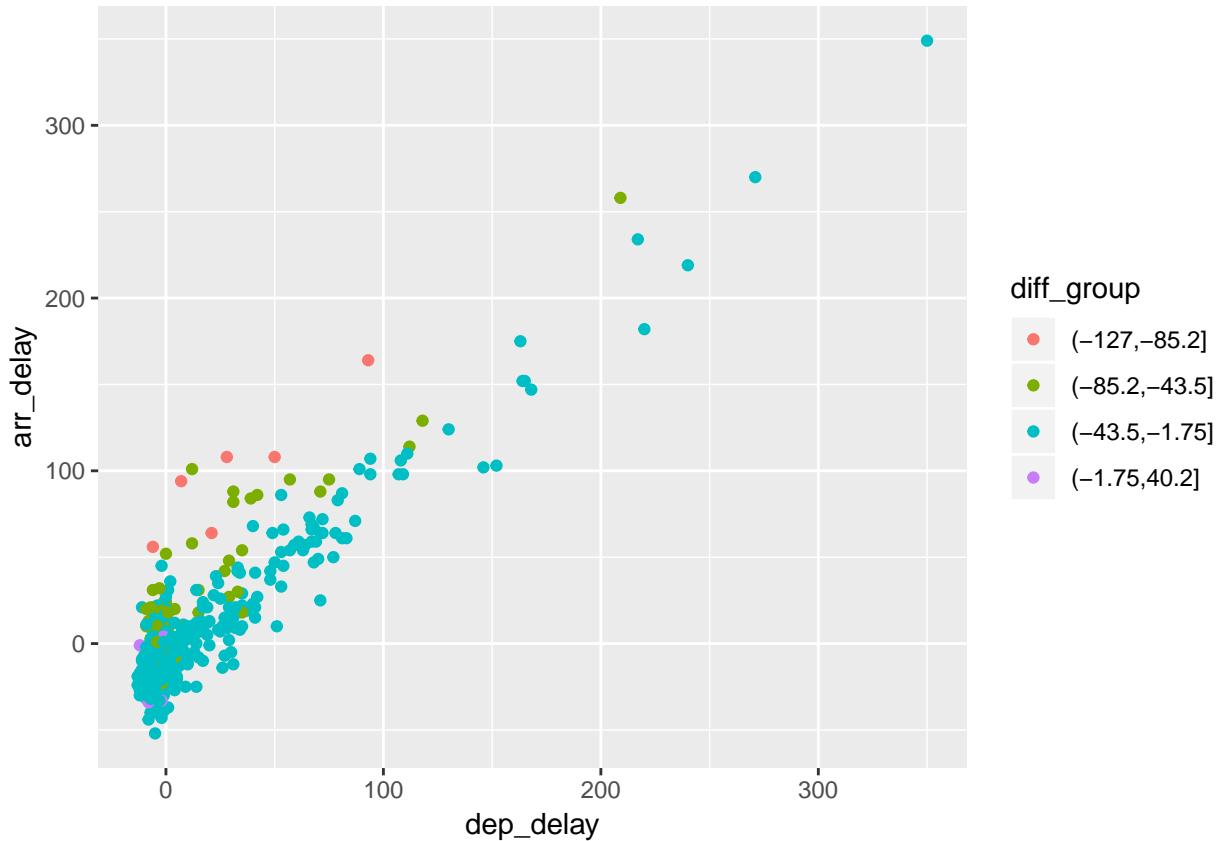
```

Looking at `dep_delay` on `arr_delay` with `diff` overlaid in colour.

```

flights_preds_mod %>%
  mutate(diff_group = cut(diff, 4)) %>%
  ggplot(aes(dep_delay, arr_delay)) +
  geom_point(aes(colour = diff_group))

```



I'm going to stop there though for now. Below are just some other plots I was messing around with.

8.3.2 Other plots with air_time

These are mostly just me messing around. This section will be very tough to follow.

Produce 3-d plot with actuals in black and predictions in red and green (not evaluated in html document).

```
a <- flights_preds_mod$arr_delay
b <- flights_preds_mod$dep_delay
c <- flights_preds_mod$diff
rgl::plot3d(a, b, c)

#one variable model
rgl::points3d(a, 0, flights_preds_mod$mod_air_time, color = "red")

#two variable model
rgl::points3d(a, b, flights_preds_mod$mod_air_time2, color = "green")
```

Plot of median air_time vs. median dist.

```
flights_new2 %>%
  select(dest, dep_time, arr_time, air_time, distance) %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  summarise(med_air = median(air_time, na.rm = TRUE),
```

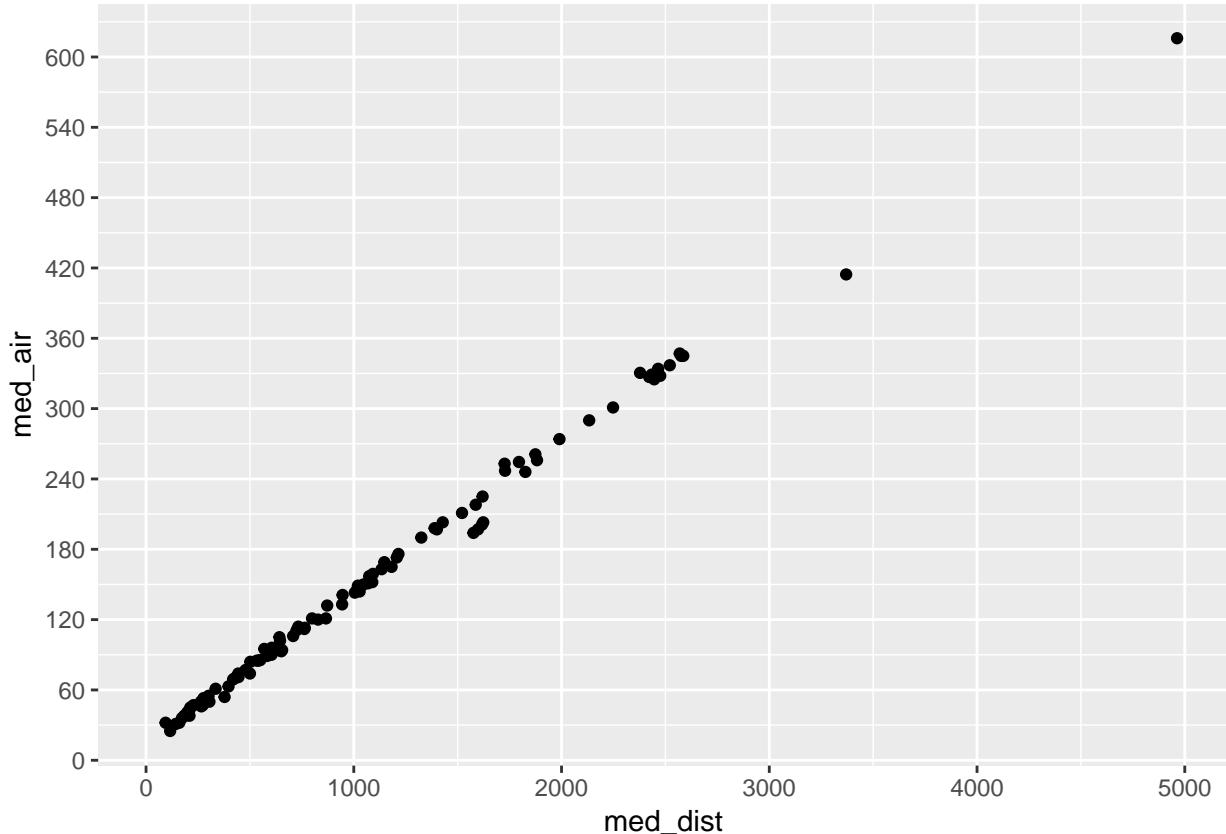
```

    med_dist = median(distance, na.rm = TRUE) %>%
ggplot(., aes(x = med_dist, y = med_air)) +
  geom_point() +
  scale_y_continuous(breaks = seq(0, 660, 60))

## Warning: funs() is soft deprecated as of dplyr 0.8.0
## please use list() instead
##
## # Before:
## funs(name = f(.))
##
## # After:
## list(name = ~f(.))
## This warning is displayed once per session.

## Warning: Removed 1 rows containing missing values (geom_point).

```



Use linear regression to identify those points that were off from the relationship between `air_time` and `distance`. +First build model +Add residuals onto dataframe +Arrange df so that largest residuals are at the top.

```

time_dist_mod <- lm(air_time ~ distance, data = flights)

flights %>%
  select(dest, dep_time, arr_time, air_time, distance) %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%

```

```

group_by(dest) %>%
  summarise(air_time = median(air_time, na.rm = TRUE),
            distance = median(distance, na.rm = TRUE)) %>%
  modelr::add_predictions(time_dist_mod) %>%
  modelr::add_residuals(time_dist_mod) %>%
  arrange(desc(abs(resid)))

```

A tibble: 105 x 5

| | dest | air_time | distance | pred | resid |
|----------------------------|-------|----------|----------|-------|-------|
| | <chr> | <dbl> | <dbl> | <dbl> | <dbl> |
| ## 1 | ANC | 414. | 3370 | 443. | -29.0 |
| ## 2 | HNL | 616 | 4963 | 644. | -28.4 |
| ## 3 | BQN | 194 | 1576 | 217. | -23.2 |
| ## 4 | SJU | 197 | 1598 | 220. | -23.0 |
| ## 5 | PSE | 201 | 1617 | 222. | -21.4 |
| ## 6 | STT | 203 | 1623 | 223. | -20.2 |
| ## 7 | EGE | 253 | 1726 | 236. | 16.9 |
| ## 8 | BGR | 54 | 378 | 66.1 | -12.1 |
| ## 9 | PSP | 330. | 2378 | 318. | 12.1 |
| ## 10 | HDN | 247 | 1728 | 236. | 10.6 |
| ## # ... with 95 more rows | | | | | |

Looks like BQN, SJU, PSE, and STT are the closer of dests with the greatest departures (in addition to the higher leverage points ANC and HNL). (note the columns here are median values despite the 'med' not being in the column names)

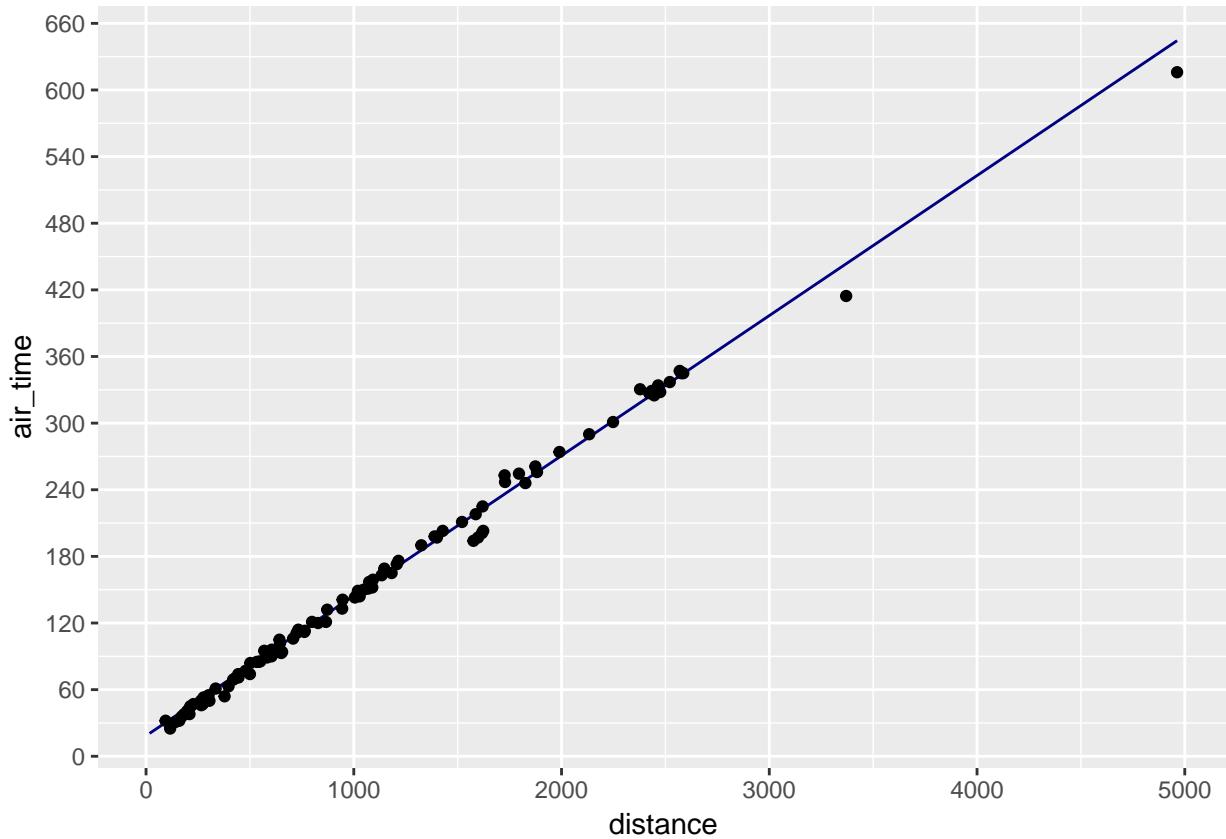
Let's do the samthing as above but just plot this output in a ggplot with our preds representing the line from our model. (are using our own specified model rather than just using `geom_smooth`.)

```

flights %>%
  select(dest, dep_time, arr_time, air_time, distance) %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  summarise(air_time = median(air_time, na.rm = TRUE),
            distance = median(distance, na.rm = TRUE)) %>%
  modelr::add_predictions(time_dist_mod) %>%
  modelr::add_residuals(time_dist_mod) %>%
  arrange(desc(abs(resid))) %>%
  ggplot(., aes(x = distance, y = air_time)) +
    geom_line(aes(y = pred), colour = "navy blue") +
    geom_point() +
    scale_y_continuous(breaks = seq(0, 660, 60))

```

Warning: Removed 1 rows containing missing values (geom_point).

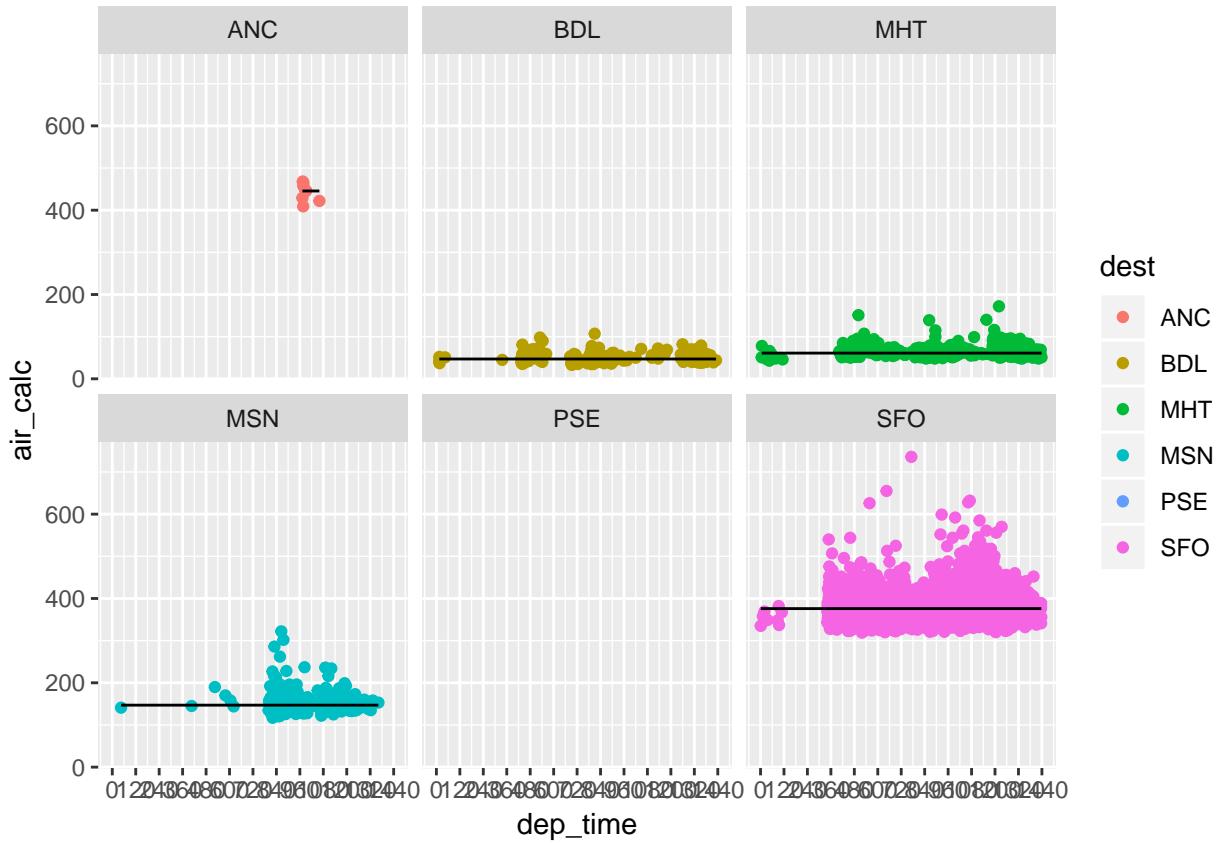


For fun, select 6 random dest and plot the dep_time vs air_calc (true air_time) with a median line cutting through the points.

```
set.seed(1234)
flights_new2 %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  mutate(med_calc = median(air_calc, na.rm = TRUE)) %>%
  nest() %>%
  sample_n(6) %>%
  unnest() %>%
  ggplot(aes(x = dep_time, y = air_calc)) +
  geom_point(aes(colour = dest)) +
  geom_line(aes(y = med_calc)) +
  scale_x_continuous(breaks = seq(0, 24*60, 120), limits = c(0, 24*60)) +
  facet_wrap(~dest)
```

Warning: Removed 604 rows containing missing values (geom_point).

Warning: Removed 101 rows containing missing values (geom_path).

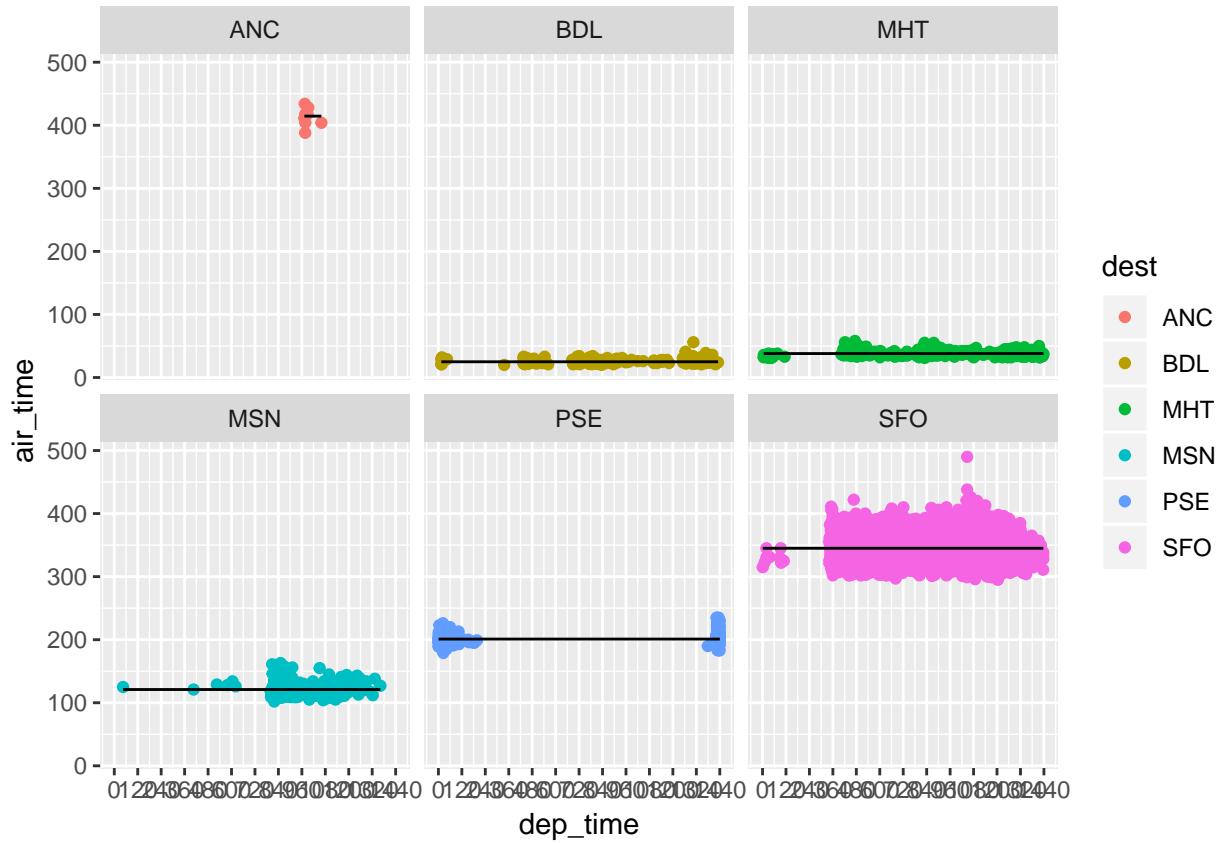


Do the same with the original air_calc values (would want to standardize access between these and above)

```
set.seed(1234)
flights %>%
  # select(dest, dep_time, arr_time, air_time, distance) %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  mutate(med_AirTime = median(air_time, na.rm = TRUE)) %>%
  nest() %>%
  sample_n(6) %>%
  unnest() %>%
  ggplot(aes(x = dep_time, y = air_time))+
  geom_point(aes(colour = dest))+
  geom_line(aes(y = med_AirTime))+
  scale_x_continuous(breaks = seq(0, 24*60, 120), limits = c(0, 24*60))+
  facet_wrap(~dest)
```

```
## Warning: Removed 289 rows containing missing values (geom_point).
```

```
## Warning: Removed 101 rows containing missing values (geom_path).
```



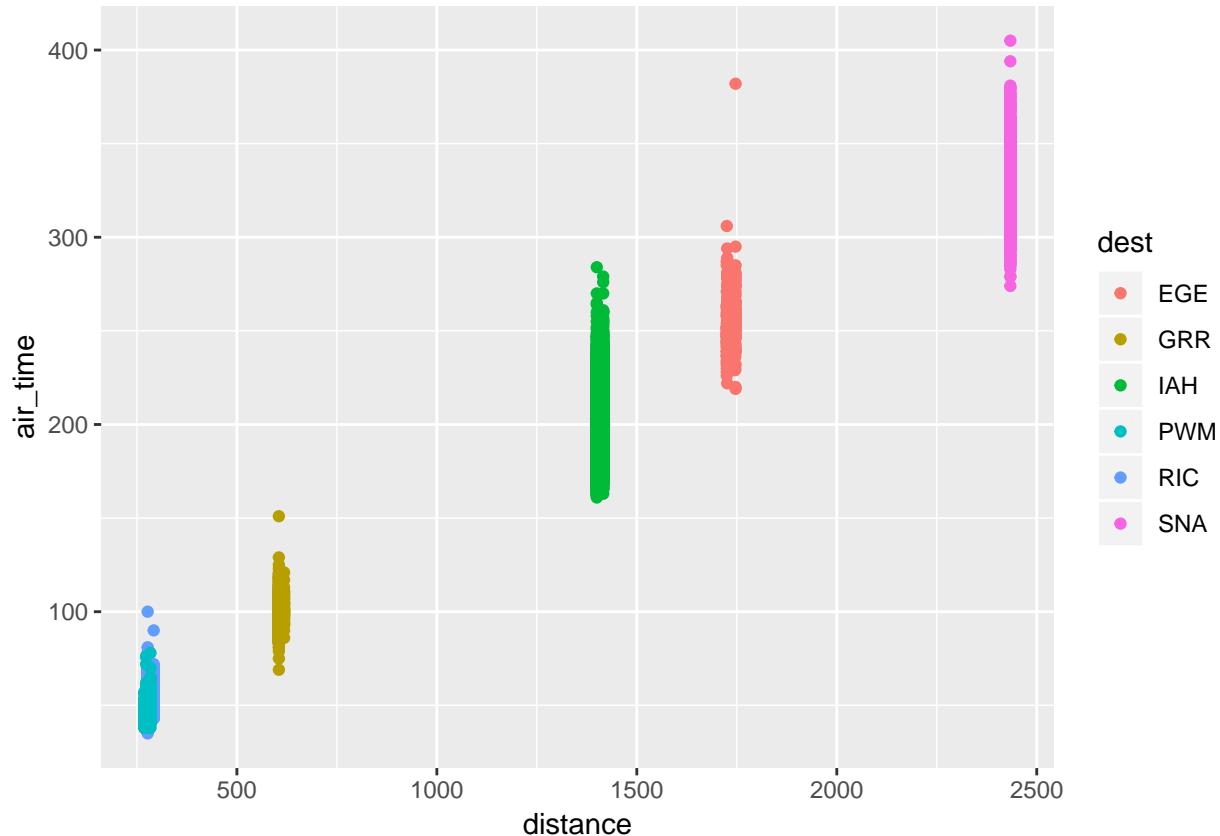
Explore the `air_time` var more. If you want to see how these may differ by different categories².

Select 6 random dests and plot all points for distance and `air_time`

```
flights %>%
  select(dest, dep_time, arr_time, air_time, distance) %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  nest() %>%
  sample_n(6) %>%
  unnest() %>%
  ggplot(aes(x = distance, y = air_time)) +
  geom_point(aes(colour = dest))
```

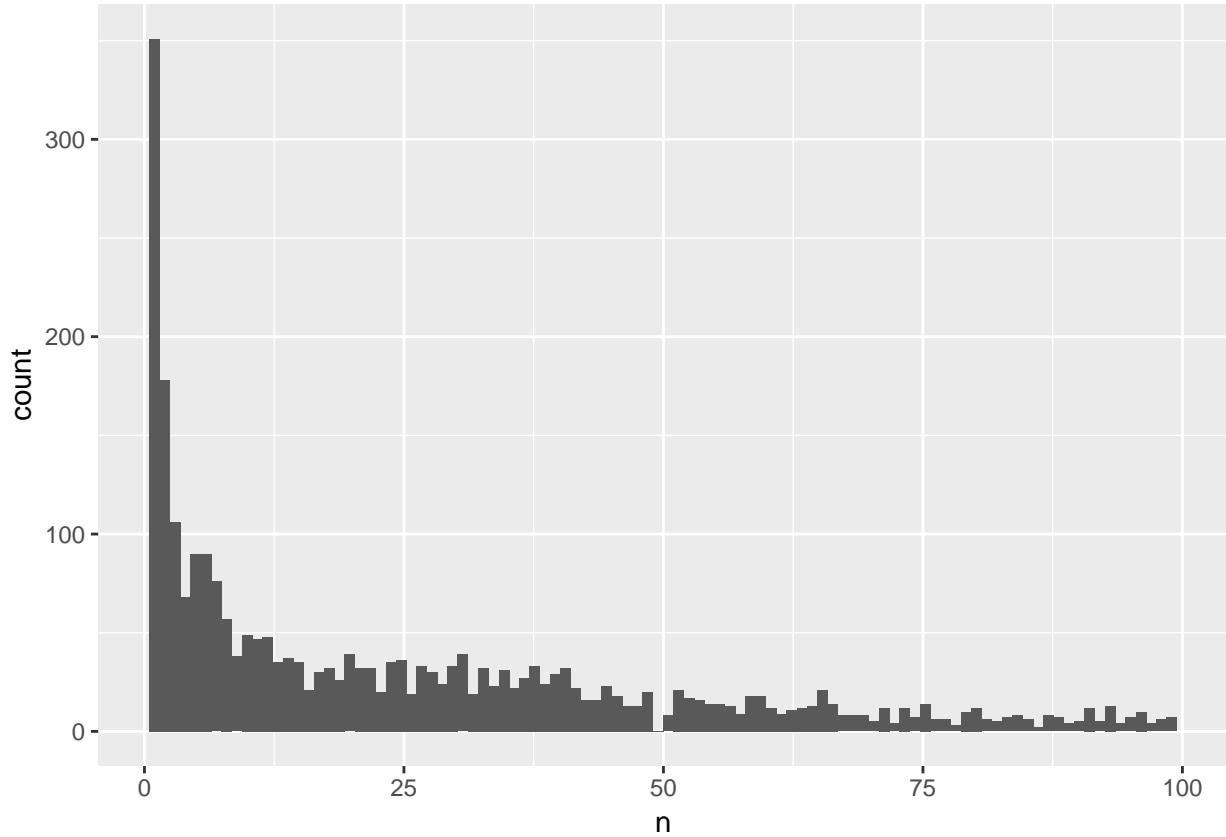
```
## Warning: Removed 341 rows containing missing values (geom_point).
```

²Linear regression is used here which aren't learned until later in the book though.



Distribution of times each flight number runs in window.

```
flights %>%
  group_by(flight) %>%
  summarise(n = n()) %>%
  ungroup() %>%
  filter(n < 100) %>%
  ggplot(aes(x = n)) +
  geom_histogram(bins = 100)
```



8.4 5.6.7.1.

Below is an extension on using the `quantile` method, but it is far beyond where we are right now.

For the question *90th percentile for delays for flights by destination* we used `quantile` to output only the 90th percentile of values for each destination. Here, I want to address what if you had wanted to output the delays at multiple values, say, arbitrarily the 25th, 50th, 75th percentiles. One option would be to create a new variable for each value and in each quantile function sepcify 0.25, 0.50, 0.75 respectively.

```
flights %>%
  group_by(dest) %>%
  summarise(delay.25 = quantile(arr_delay, 0.25, na.rm = TRUE),
            delay.50 = quantile(arr_delay, 0.50, na.rm = TRUE),
            delay.75 = quantile(arr_delay, 0.75, na.rm = TRUE))
```

```
## # A tibble: 105 x 4
##   dest   delay.25 delay.50 delay.75
##   <chr>    <dbl>    <dbl>    <dbl>
## 1 ABQ     -24     -5.5    22.8
## 2 ACK     -13      -3     10
## 3 ALB     -17      -4     28
## 4 ANC    -10.8     1.5    10
## 5 ATL     -12      -1     16
## 6 AUS     -19      -5     15
## 7 AVL     -11      -1     13
```

```
## 8 BDL      -18      -10      14
## 9 BGR     -21.8      -9    19.8
## 10 BHM     -20      -2      34
## # ... with 95 more rows
```

But there is a lot of replication here and the `quantile` function is also able to output more than one value by specifying the `probs` argument.

```
quantile(c(1:100), probs = c(0.25, .50, 0.75))
```

```
##   25%   50%   75%
## 25.75 50.50 75.25
```

So, in theory, rather than calling `quantile` multiple times, you could just call it once. However for any variable you create `summarise` is expecting only a single value output for each row, so just passing it in as-is will cause it to fail.

```
flights %>%
  group_by(dest) %>%
  summarise(delays = quantile(arr_delay, probs = c(0.25, .50, 0.75), na.rm = TRUE))
```

```
## Error: Column `delays` must be length 1 (a summary value), not 3
```

To make this work you need to make the value a list, so that it will output a single list in each row of the column [This style is covered at the end of the book in the section ‘list-columns’ in iteration.] [Also you need your dataframe to be in a tibble form rather than traditional dataframes for list-cols to work]. I am going to create another list-column field of the quantiles I specified.

```
prob_vals <- seq(from = 0.25, to = 0.75, by = 0.25)

flights_quantiles <- flights %>%
  group_by(dest) %>%
  summarise(delays_val = list(quantile(arr_delay, probs = prob_vals, na.rm = TRUE)),
            delays_q = list(c('25th', '50th', '75th')))

flights_quantiles
```

```
## # A tibble: 105 x 3
##       dest  delays_val  delays_q
##       <chr> <list>      <list>
## 1 ABQ    <dbl [3]>  <chr [3]>
## 2 ACK    <dbl [3]>  <chr [3]>
## 3 ALB    <dbl [3]>  <chr [3]>
## 4 ANC    <dbl [3]>  <chr [3]>
## 5 ATL    <dbl [3]>  <chr [3]>
## 6 AUS    <dbl [3]>  <chr [3]>
## 7 AVL    <dbl [3]>  <chr [3]>
## 8 BDL    <dbl [3]>  <chr [3]>
## 9 BGR    <dbl [3]>  <chr [3]>
## 10 BHM   <dbl [3]>  <chr [3]>
## # ... with 95 more rows
```

To convert these outputs out of the list-col format, I can use the function `unnest`.

```
flights_quantiles %>%
  unnest()
```

```
## # A tibble: 315 x 3
##       dest  delays_val  delays_q
```

```

##      <chr>      <dbl> <chr>
## 1 ABQ        -24    25th
## 2 ABQ        -5.5   50th
## 3 ABQ        22.8  75th
## 4 ACK        -13    25th
## 5 ACK         -3    50th
## 6 ACK          10   75th
## 7 ALB        -17    25th
## 8 ALB         -4    50th
## 9 ALB          28   75th
## 10 ANC       -10.8  25th
## # ... with 305 more rows

```

This will output the values as individual rows, repeating the `dest` value for the length of the list. If I want to spread the `delays_quantile` values into separate columns I can use the `spread` function that is in the tidy R chapter.

```

flights_quantiles %>%
  unnest() %>%
  spread(key = delays_q, value = delays_val, sep = "_")

```

```

## # A tibble: 105 x 4
##      dest  delays_q_25th delays_q_50th delays_q_75th
##      <chr>      <dbl>        <dbl>        <dbl>
## 1 ABQ        -24        -5.5        22.8
## 2 ACK        -13        -3          10
## 3 ALB        -17        -4          28
## 4 ANC       -10.8       1.5        10
## 5 ATL        -12        -1          16
## 6 AUS        -19        -5          15
## 7 AVL        -11        -1          13
## 8 BDL        -18        -10         14
## 9 BGR       -21.8       -9         19.8
## 10 BHM       -20        -2          34
## # ... with 95 more rows

```

Let's plot our unnested (but not unspread) data to see roughly the distribution of the delays for each destination at our quantiles of interest³.

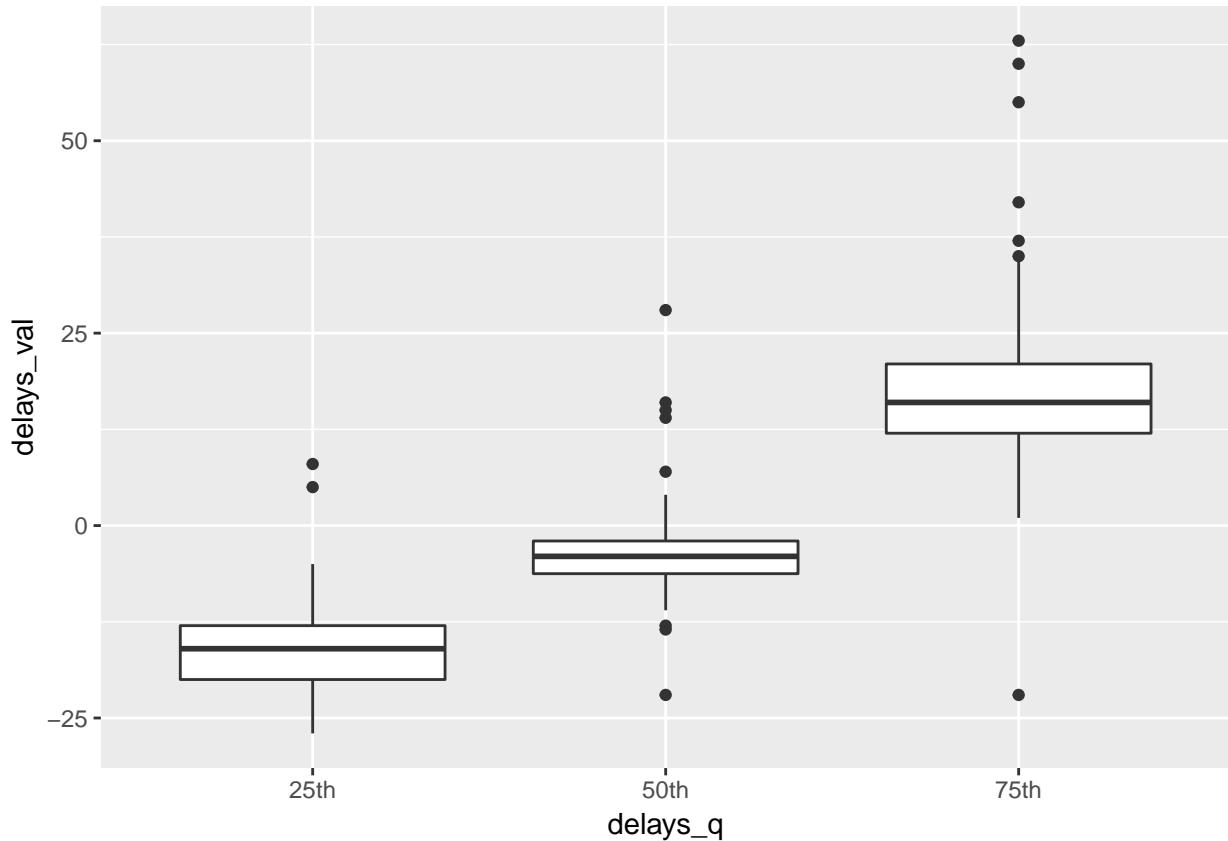
```

flights_quantiles %>%
  unnest() %>%
  # mutate(delays_q = forcats::fct_reorder(f = delays_q, x = delays_val, fun = mean, na.rm = TRUE)) %>%
  ggplot(aes(x = delays_q, y = delays_val)) +
  geom_boxplot()

## Warning: Removed 3 rows containing non-finite values (stat_boxplot).

```

³The mutate step that is commented-out would reorder the `delays_q` variable according to the mean value of the `delays_val`, but this is not necessary here so I commented it out. You will learn more about this in the factors chapter.lm



It can be a hassle naming the values explicitly. `quantile`'s default `probs` argument value is 0, 0.25, 0.5, 0.75, 1. Rather than needing to type the `delays_q` values `list(c('0%', '25%', '50%', '75%', '100%'))` you could have generated the values of these names dynamically using the `map` function in the `purrr` package (see chapter on iteration) to pass the `names` function over each value in `delays_val`.

```
flights_quantiles2 <- flights %>%
  group_by(dest) %>%
  summarise(delays_val = list(quantile(arr_delay, na.rm = TRUE)),
            delays_q = list(c('0th', '25th', '50th', '75th', '100th'))) %>%
  mutate(delays_q2 = purrr::map(delays_val, names))
```

`flights_quantiles2`

```
## # A tibble: 105 x 4
##   dest  delays_val delays_q  delays_q2
##   <chr> <list>     <list>    <list>
## 1 ABQ   <dbl [5]> <chr [5]> <chr [5]>
## 2 ACK   <dbl [5]> <chr [5]> <chr [5]>
## 3 ALB   <dbl [5]> <chr [5]> <chr [5]>
## 4 ANC   <dbl [5]> <chr [5]> <chr [5]>
## 5 ATL   <dbl [5]> <chr [5]> <chr [5]>
## 6 AUS   <dbl [5]> <chr [5]> <chr [5]>
## 7 AVL   <dbl [5]> <chr [5]> <chr [5]>
## 8 BDL   <dbl [5]> <chr [5]> <chr [5]>
## 9 BGR   <dbl [5]> <chr [5]> <chr [5]>
## 10 BHM  <dbl [5]> <chr [5]> <chr [5]>
## # ... with 95 more rows
```

And then let's unnest the data⁴.

```
flights_quantiles2 %>%
  unnest()

## # A tibble: 525 x 4
##   dest  delays_val delays_q  delays_q2
##   <chr>    <dbl> <chr>    <chr>
## 1 ABQ      -61    0th      0%
## 2 ABQ      -24    25th     25%
## 3 ABQ      -5.5   50th     50%
## 4 ABQ      22.8   75th     75%
## 5 ABQ      153    100th    100%
## 6 ACK      -25    0th      0%
## 7 ACK      -13    25th     25%
## 8 ACK      -3     50th     50%
## 9 ACK      10     75th     75%
## 10 ACK     221    100th    100%
## # ... with 515 more rows
```

8.5 5.6.7.4.

To measure the difference in speed you can use the `microbenchmark` function

```
microbenchmark::microbenchmark(sub_optimal = filter(flights, is.na(dep_delay) | is.na(arr_delay)),
                               optimal = filter(flights, is.na(arr_delay)),
                               times = 10)

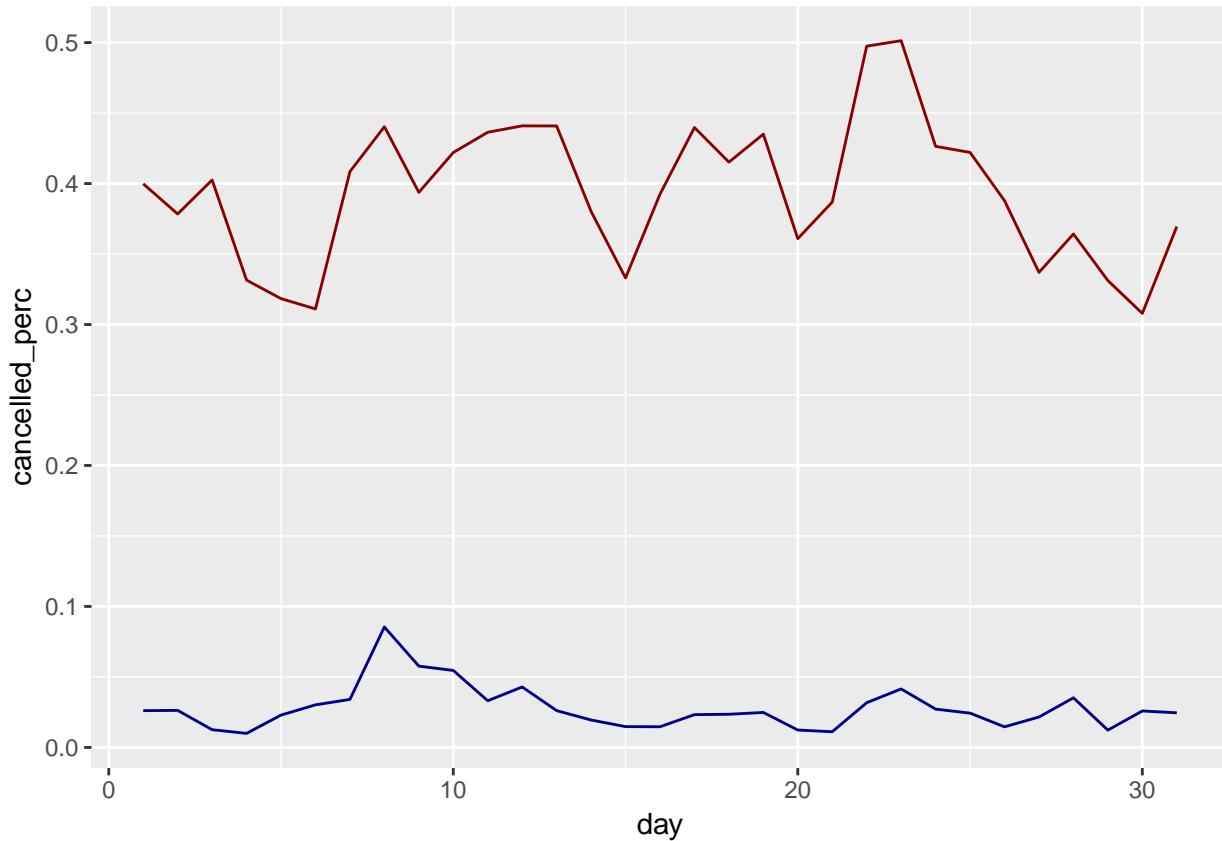
## Unit: milliseconds
##        expr      min       lq     mean   median      uq      max neval cld
##  sub_optimal 10.0161 11.2187 13.37128 12.7987 15.955 17.4132     10    b
##    optimal    7.6099  7.7573  8.73972  8.6421  9.655 10.6635     10    a
```

8.6 5.6.7.5.

Explore the percentage delayed vs. percentage cancelled.

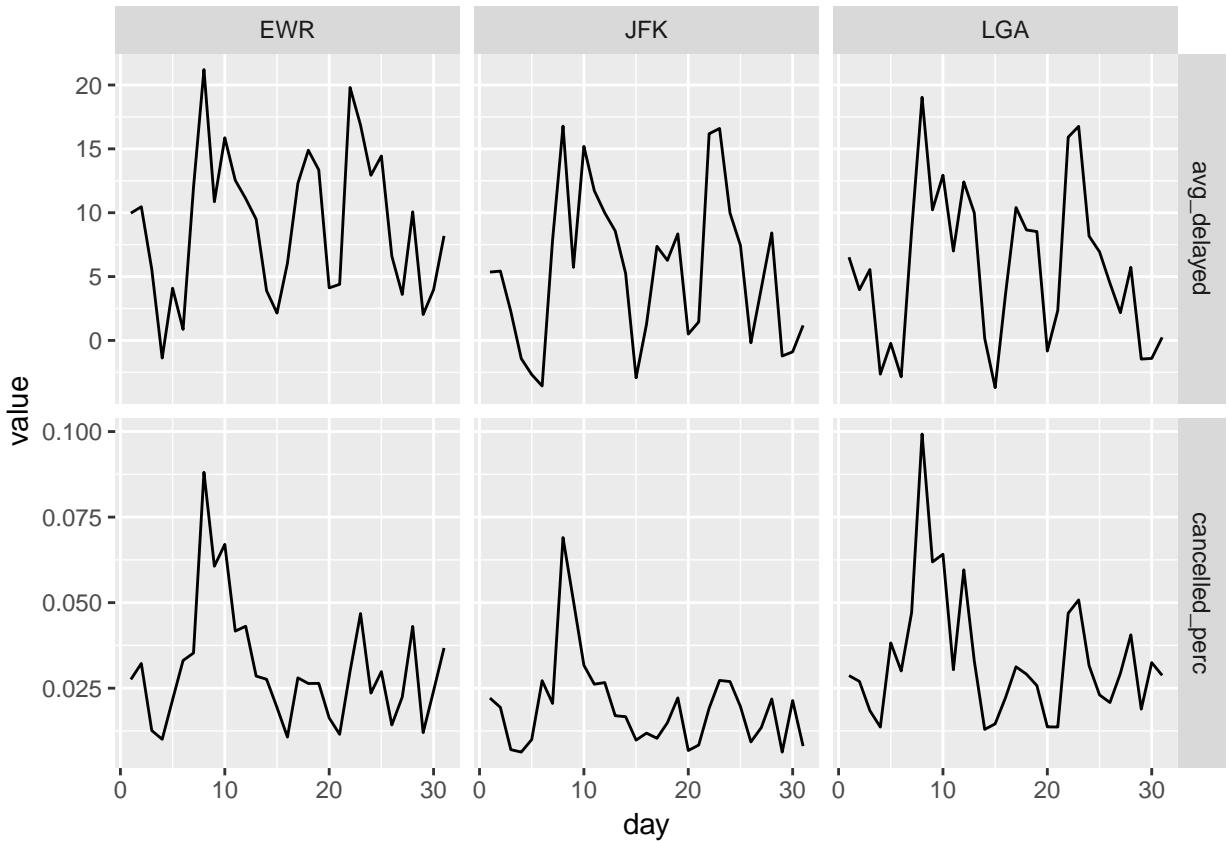
```
flights %>%
  group_by(day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            delayed = sum(arr_delay > 0, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num,
            delayed_perc = delayed / num) %>%
  ggplot(aes(x = day)) +
  geom_line(aes(y = cancelled_perc), colour = "dark blue") +
  geom_line(aes(y = delayed_perc), colour = "dark red")
```

⁴The names assigned by the `quantile` function are a little different from those I supplied.



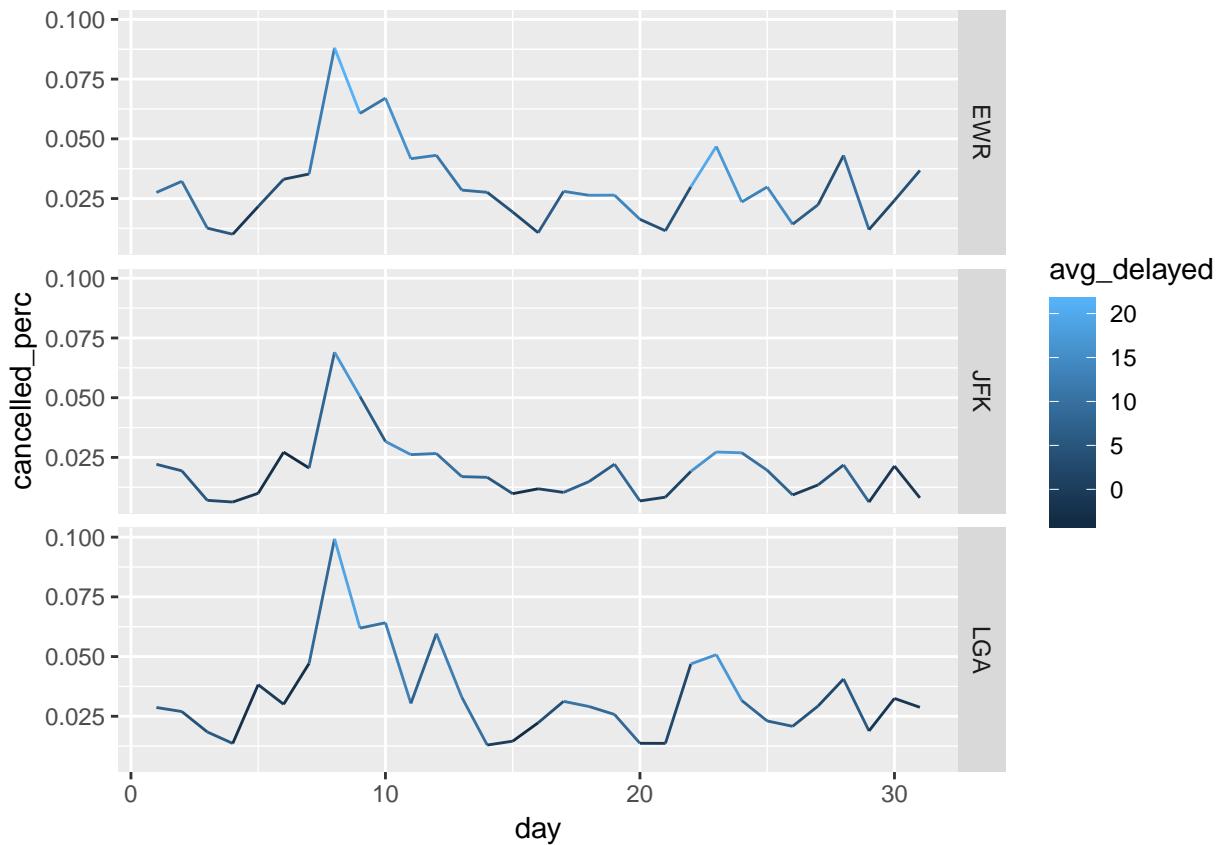
Let's try faceting by origin and looking at both values next to each other.

```
flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  gather(key = type, value = value, avg_delayed, cancelled_perc) %>%
  ggplot(aes(x = day, y = value)) +
  geom_line() +
  facet_grid(type ~ origin, scales = "free_y")
```



Look's like the relationship across origins with the delay overlaid with color (not actually crazy about how this look).

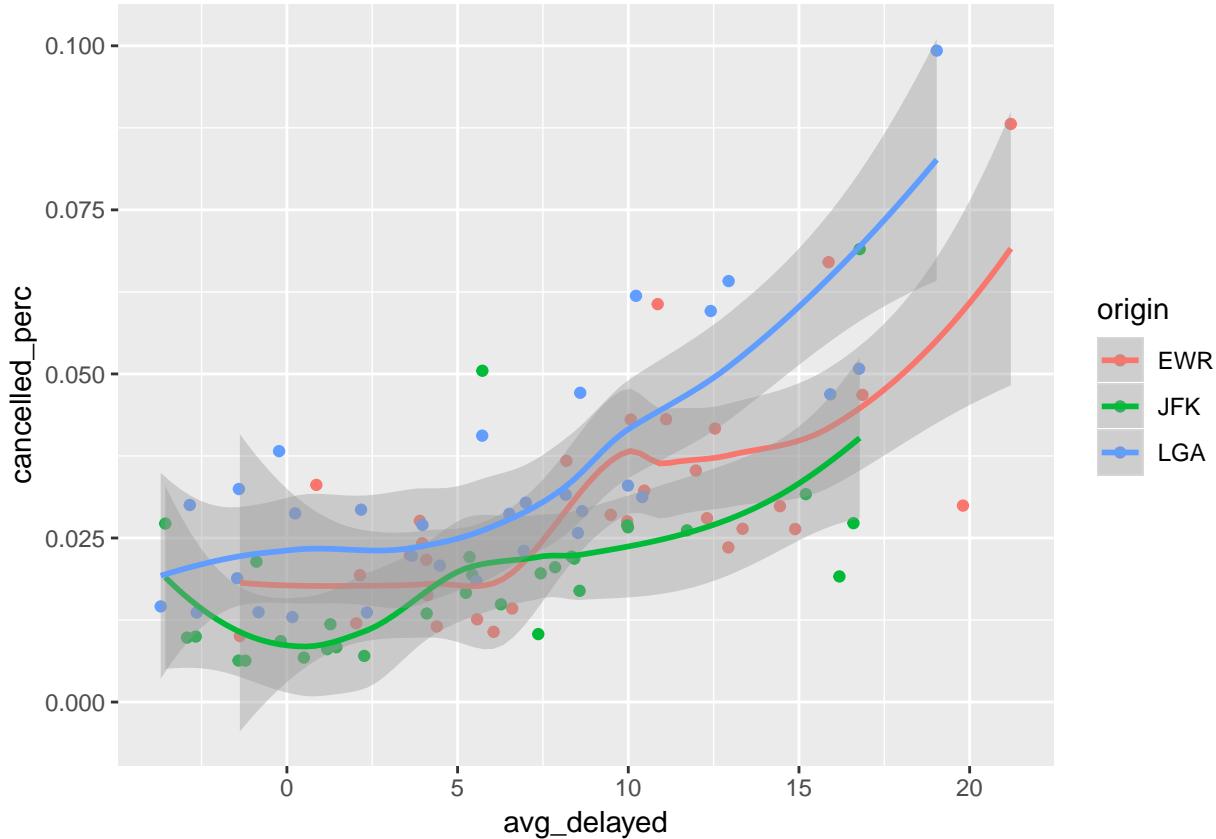
```
flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  ggplot(aes(x = day, y = cancelled_perc, colour = avg_delayed)) +
  geom_line() +
  facet_grid(origin ~ .)
```



Let's look at values as individual points and overlay a `geom_smooth`

```
flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  ggplot(aes(avg_delayed, cancelled_perc, colour = origin)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



8.6.1 Modeling approach

We also could approach this using a model and regressing the average proportion of cancelled flights on average delay.

```
cancelled_mod1 <- flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num) %>%
  lm(cancelled_perc ~ avg_delayed, data = .)

summary(cancelled_mod1)

##
## Call:
## lm(formula = cancelled_perc ~ avg_delayed, data = .)
##
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -0.026363 -0.009392 -0.002610  0.006196  0.048436 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 0.0152588  0.0020945   7.285 1.12e-10 ***
```

```

## avg_delayed 0.0018688  0.0002311   8.086 2.54e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.01342 on 91 degrees of freedom
## Multiple R-squared:  0.4181, Adjusted R-squared:  0.4117
## F-statistic: 65.39 on 1 and 91 DF,  p-value: 2.537e-12

# ggplot(aes(x = day, y = cancelled_perc))+
# geom_line()

```

If you were confused by the . in `lm(cancelled_perc ~ avg_delayed, data = .)`, the dot specifies where the output from the prior steps should be piped into. The default is for it to go into the first argument, but for the `lm` function, data is not the first argument, so I have to explicitly tell it that the prior steps output should be inputted into the data argument of the `lm` function. See On piping dots for more details.

The average delay accounts for 42% of the variation in the proportion of canceled flights.

Modeling the log-odds of the proportion of canceled flights might be more successful as it produces a variable not constrained by 0 to 1, better aligning with the assumptions of linear regression.

```

cancelled_mod2 <- flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num,
            cancelled_logodds = log(cancelled / (num - cancelled))) %>%
  lm(cancelled_logodds ~ avg_delayed, data = .)

```

To convert logodds back to percentage, I built the following equation.

```
convert_logodds <- function(log_odds) exp(log_odds) / (1 + exp(log_odds))
```

Let's calculate the MAE or mean absolute error on our percentages.

```

cancelled_preds2 <- flights %>%
  group_by(origin, day) %>%
  summarise(cancelled = sum(is.na(arr_delay)),
            avg_delayed = mean(arr_delay, na.rm = TRUE),
            num = n(),
            cancelled_perc = cancelled / num,
            cancelled_logodds = log(cancelled / (num - cancelled))) %>%
  ungroup() %>%
  modelr::spread_predictions(cancelled_mod1, cancelled_mod2) %>%
  mutate(cancelled_mod2 = convert_logodds(cancelled_mod2))

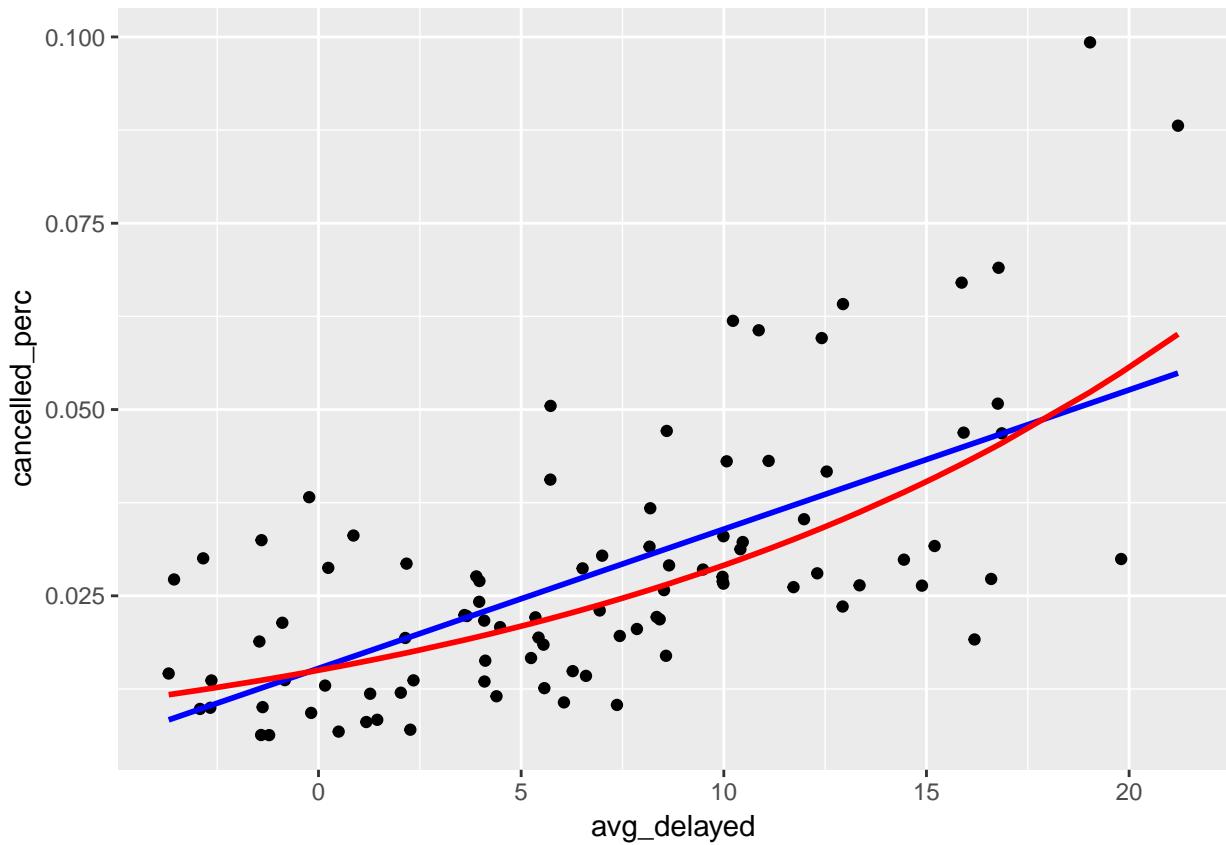
cancelled_preds2 %>%
  summarise(MAE1 = mean(abs(cancelled_perc - cancelled_mod1), na.rm = TRUE),
            MAE2 = mean(abs(cancelled_perc - cancelled_mod2), na.rm = TRUE),
            mean_value = mean(cancelled_perc, na.rm = TRUE))

## # A tibble: 1 x 3
##       MAE1     MAE2 mean_value
##   <dbl>    <dbl>      <dbl>
## 1 0.0101  0.00954     0.0279

```

Let's look at the differences in the outputs of the predictions from these models.

```
cancelled_preds2 %>%
  ggplot(aes(avg_delayed, cancelled_perc)) +
  geom_point() +
  scale_size_continuous(range = c(1, 2)) +
  geom_line(aes(y = cancelled_mod1), colour = "blue", size = 1) +
  geom_line(aes(y = cancelled_mod2), colour = "red", size = 1)
```



5

8.7 5.6.7.6.

As an example, let's look at just Atl flights from LGA and compare DL, FL, MQ.

```
flights %>%
  filter(dest == 'ATL', origin == 'LGA') %>%
  count(carrier)
```

```
## # A tibble: 5 x 2
##   carrier     n
##   <chr>    <int>
## 1 DL        5544
```

⁵Another approach may be to try and identify the individual risk of having a flight cancelled based on the average delay. If this is the case, you may want to use model evaluation techniques that separate models based on the assigned probabilities in which case MAE may actually not be the most appropriate evaluation technique. You could try using logistic regression for this. You may also consider taking into account the weight of each of the points. I had discussions on these, but decided they were too in the weeds so deleted them even from the appendix...

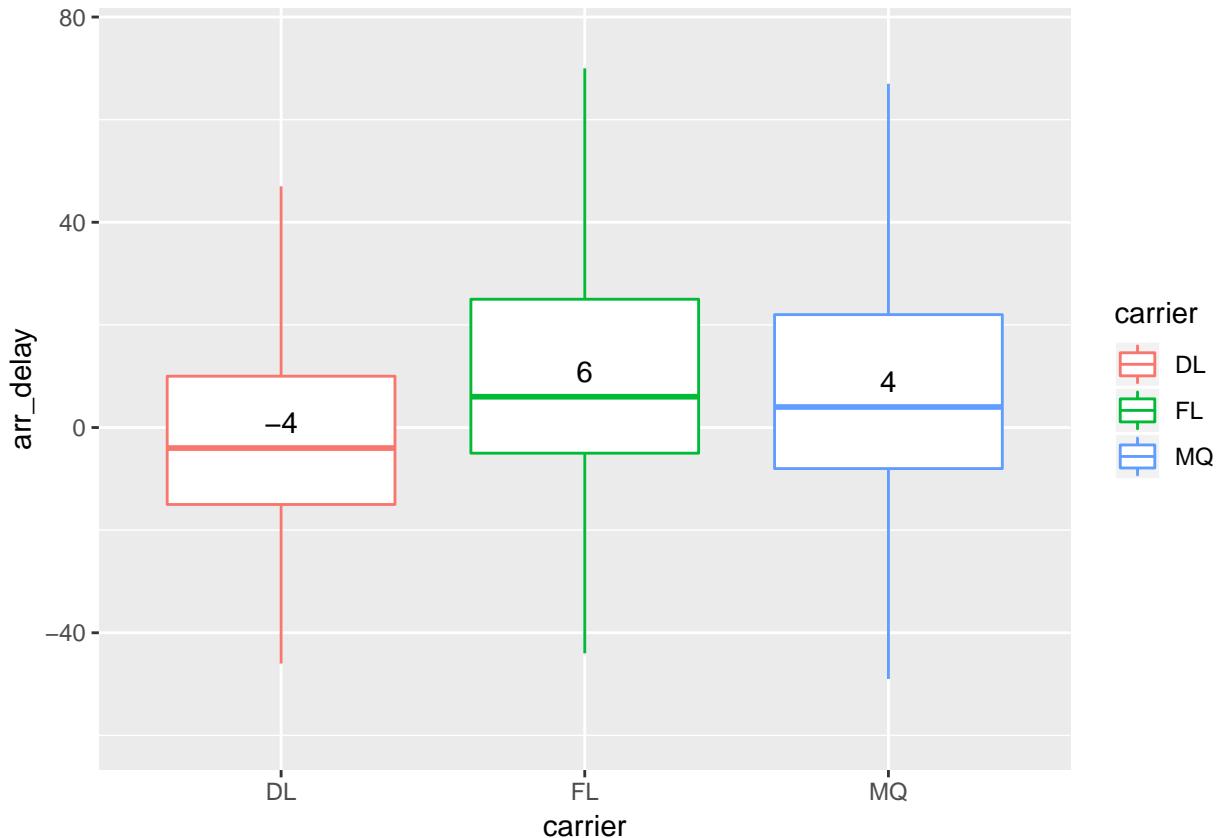
```
## 2 EV      1
## 3 FL     2337
## 4 MQ     2322
## 5 WN      59
```

And compare the median delays between the three primary carriers DL, FL, MQ.

```
carriers_lga_atl <- flights %>%
  filter(dest == 'ATL', origin == 'LGA') %>%
  group_by(carrier) %>%
  # filter out small samples
  mutate(n_tot = n()) %>%
  filter(n_tot > 100) %>%
  select(-n_tot) %>%
  ###
  filter(!is.na(arr_delay)) %>%
  ungroup()

label <- carriers_lga_atl %>%
  group_by(carrier) %>%
  summarise(arr_delay = median(arr_delay, na.rm = TRUE))

carriers_lga_atl %>%
  select(carrier, arr_delay) %>%
  ggplot() +
  geom_boxplot(aes(carrier, arr_delay, colour = carrier), outlier.shape = NA) +
  coord_cartesian(y = c(-60, 75)) +
  geom_text(mapping = aes(x = carrier, group = carrier, y = arr_delay + 5, label = arr_delay), data = 1)
```



Or perhaps you want to use a statistical method to compare if the differences in the grouped are significant...

```
carriers_lga_atl %>%
  lm(arr_delay ~ carrier, data = .) %>%
  summary()

##
## Call:
## lm(formula = arr_delay ~ carrier, data = .)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -64.74 -22.33 -11.33   4.67 888.67 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept)  6.3273    0.6149   10.29 < 2e-16 ***
## carrierFL    14.4172   1.1340   12.71 < 2e-16 ***
## carrierMQ     7.7067   1.1417    6.75 1.56e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 45.48 on 9979 degrees of freedom
## Multiple R-squared:  0.01692,    Adjusted R-squared:  0.01672 
## F-statistic: 85.86 on 2 and 9979 DF,  p-value: < 2.2e-16
```

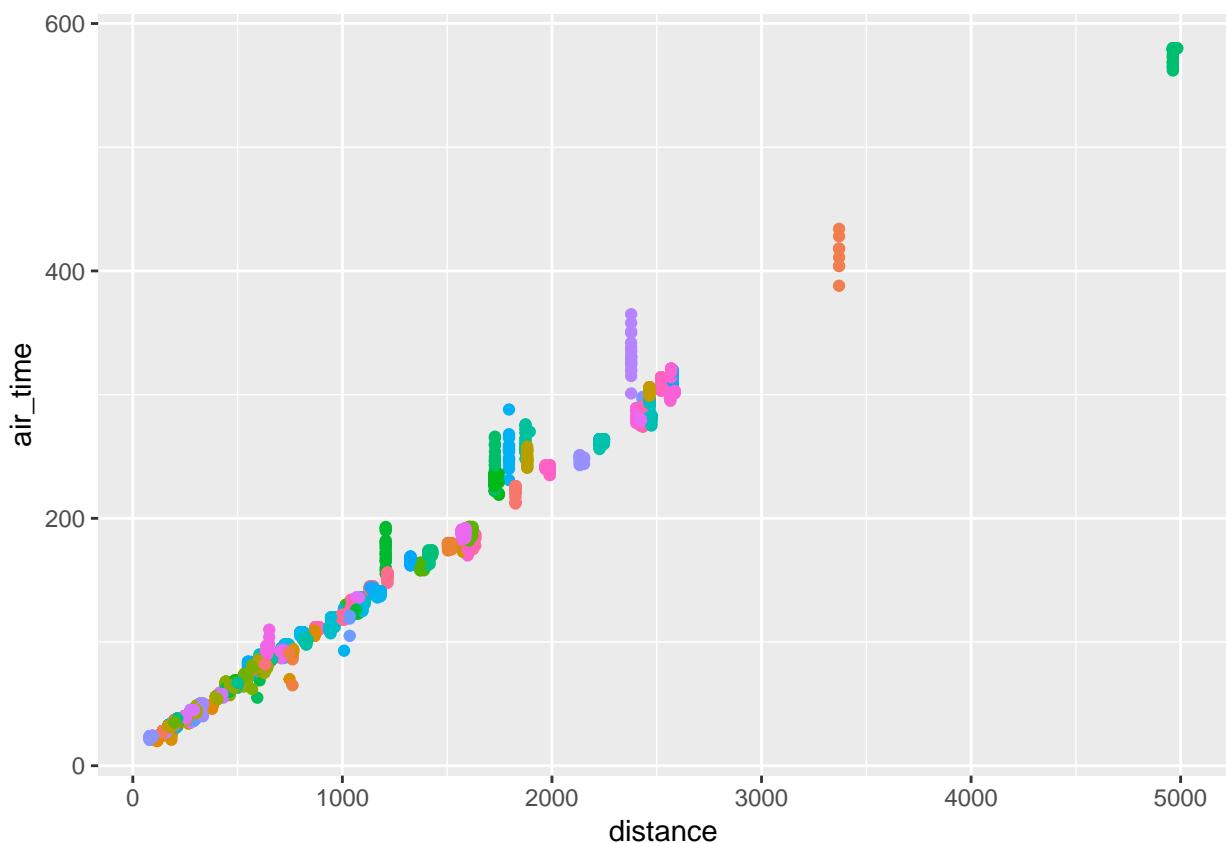
This shows the mean delay for DL is ~6.3, FL is ~20.7, MQ is ~14 and FL and MQ are significantly different

from DL (and DL is significantly different from 0)⁶. The carrier accouts for ~1.6% of the variation in arrival... etc....

8.8 5.7.1.6.

Let's look at the fastest 20 `air_times` for each destination.

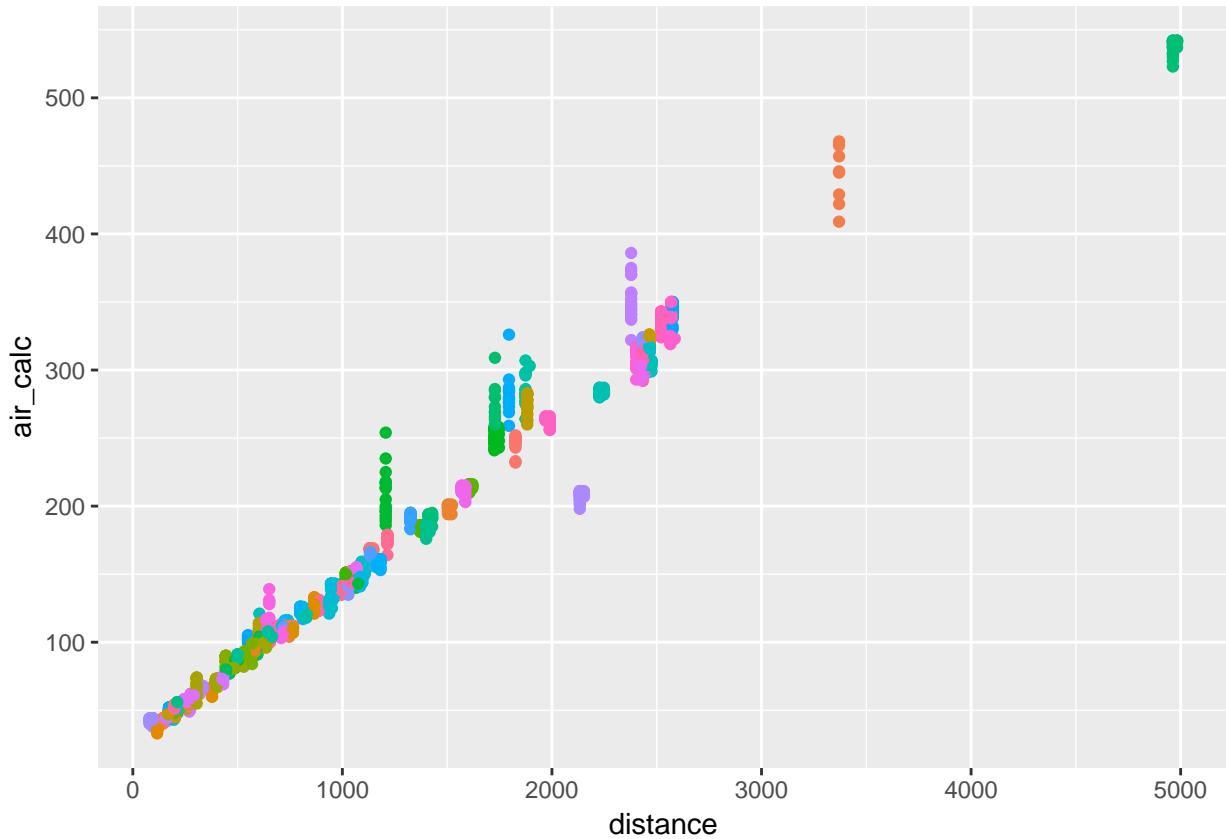
```
flights_new2 %>%
  group_by(dest) %>%
  mutate(min_rank = min_rank(air_time)) %>%
  filter(min_rank < 20) %>%
  ggplot(aes(distance, air_time, colour = dest)) +
  geom_point() +
  guides(colour = FALSE)
```



Let's do the same for my custom `air_time` calculation `air_calc`.

```
flights_new2 %>%
  group_by(dest) %>%
  mutate(min_rank = min_rank(air_calc)) %>%
  filter(min_rank < 20) %>%
  ggplot(aes(distance, air_calc, colour = dest)) +
  geom_point() +
  guides(colour = FALSE)
```

⁶Repeated t-test methods could be used for comparing MQ and FL, see function `pairwise.t.test`



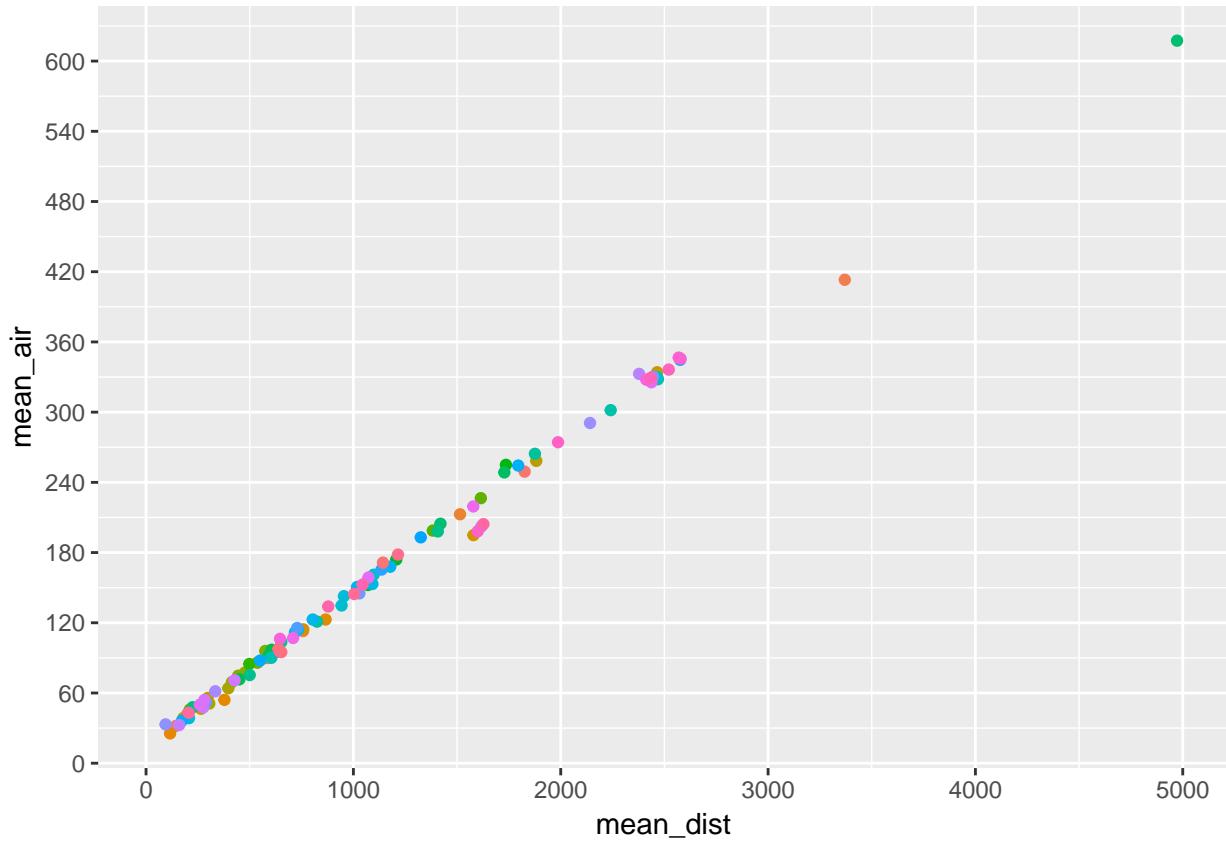
Rather than the fastest 20, let's look at the mean `dist` and `air_time` for each⁷.

First using the `air_time` value.

```
flights_new2 %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  summarise(mean_air = mean(air_time, na.rm = TRUE),
            mean_dist = mean(distance, na.rm = TRUE)) %>%
  ggplot(., aes(x = mean_dist, y = mean_air)) +
  geom_point(aes(colour = dest)) +
  scale_y_continuous(breaks = seq(0, 660, 60)) +
  guides(colour = FALSE)
```

```
## Warning: Removed 1 rows containing missing values (geom_point).
```

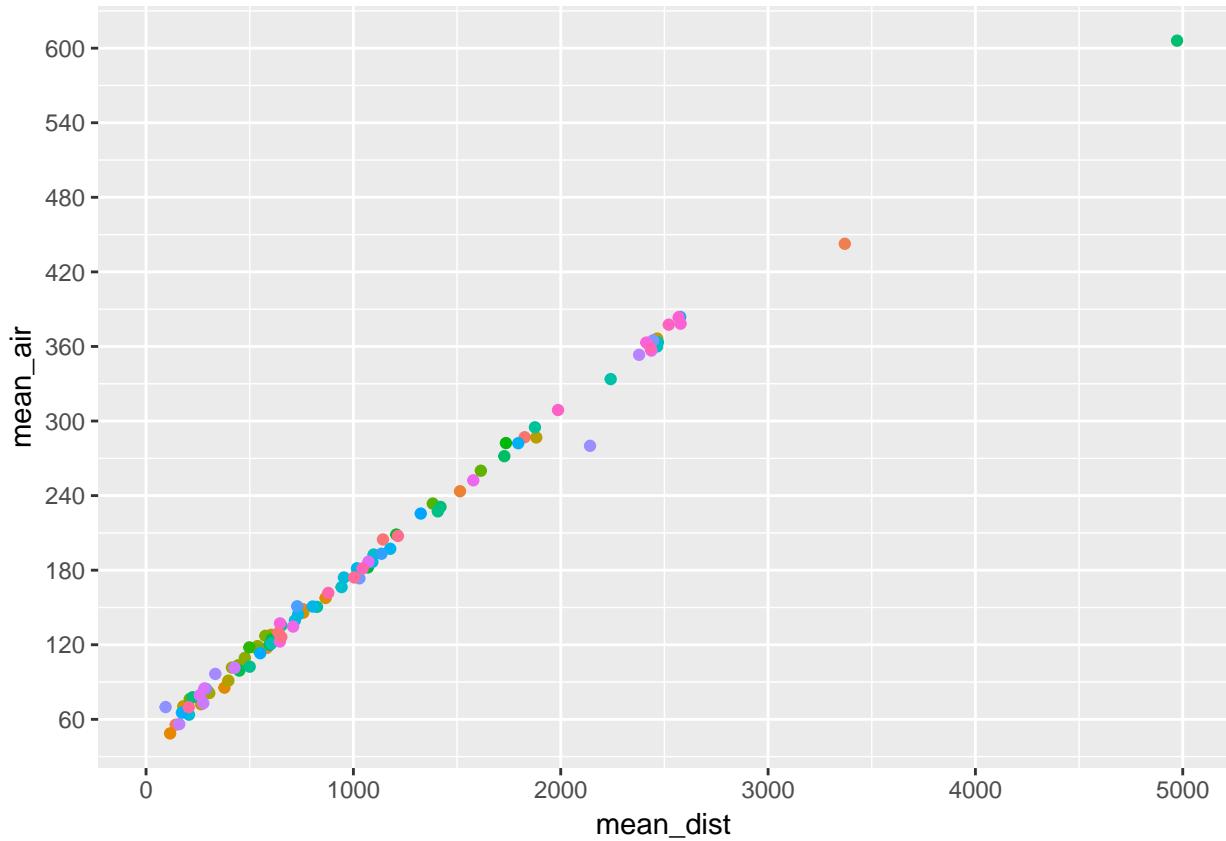
⁷Each colour corresponds with a `dest` though I excluded the legend.



Then with the custom air_calc.

```
flights_new2 %>%
  mutate_at(.vars = c("dep_time", "arr_time"),
            .funs = funs(time_to_mins)) %>%
  group_by(dest) %>%
  summarise(mean_air = mean(air_calc, na.rm = TRUE),
            mean_dist = mean(distance, na.rm = TRUE)) %>%
  ggplot(., aes(x = mean_dist, y = mean_air)) +
  geom_point(aes(colour = dest)) +
  scale_y_continuous(breaks = seq(0, 660, 60)) +
  guides(colour = FALSE)
```

Warning: Removed 5 rows containing missing values (geom_point).

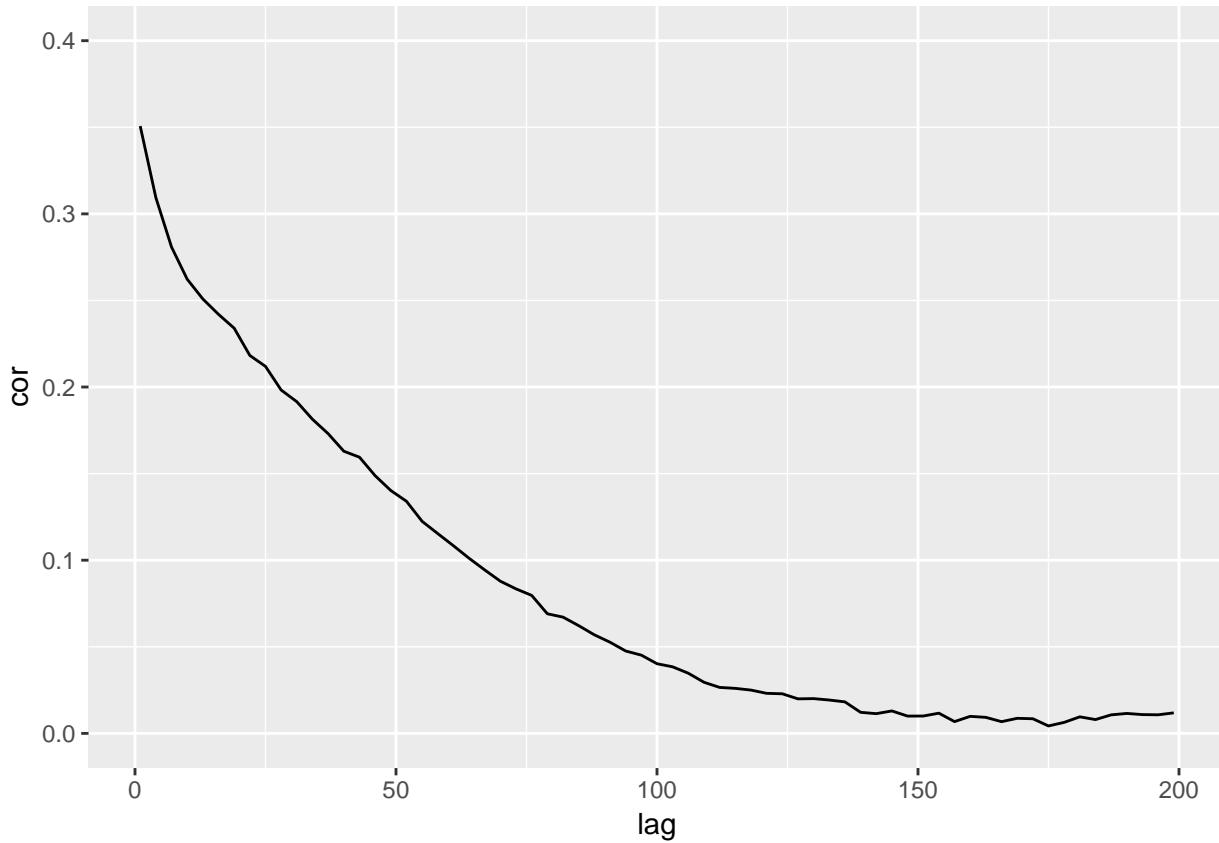


8.9 5.7.1.5

Let's run this for every 3 lags (1, 4, 7, ...) and plot.

```
lags_cors <- tibble(lag = seq(1,200, 3)) %>%
  mutate(cor = purrr::map_dbl(lag, cor_by_lag))

lags_cors %>%
  ggplot(aes(x = lag, cor)) +
  geom_line() +
  coord_cartesian(ylim = c(0, 0.40))
```



8.10 5.7.1.8.

```
tail_nums_counts %>%
  nest() %>%
  sample_n(10) %>%
  unnest() %>%
  View()
```

8.11 Other

8.11.1 On piping dots

The . let's you explicitly state where to pipe the output from the prior steps. The default is to have it go into the first argument of the function.

Let's look at an example:

```
flights %>%
  filter(!is.na(arr_delay)) %>%
  count(origin)
```

```
## # A tibble: 3 x 2
##   origin      n
```

```
## <chr> <int>
## 1 EWR    117127
## 2 JFK    109079
## 3 LGA    101140
```

This is the exact same thing as the code below, I just added the dots to be explicit about where in the function the output from the prior steps will go:

```
flights %>%
  filter(., !is.na(arr_delay)) %>%
  count(., origin)
```

```
## # A tibble: 3 x 2
##   origin     n
##   <chr>   <int>
## 1 EWR      117127
## 2 JFK      109079
## 3 LGA      101140
```

Functions in dplyr, etc. expect dataframes in the first argument, so the default piping behavior works fine you don't end-up using the dot in this way. However functions outside of the tidyverse are not always so consistent and may expect the dataframe (or w/e your output from the prior step is) in a different location of the function, hence the need to use the dot to specify where it should go.

The example below uses base R's `lm` (linear models) function to regress `arr_delay` on `dep_delay` and `distance`⁸. The first argument expects a function, the second argument the data, hence the need for the dot.

```
flights %>%
  filter(., !is.na(arr_delay)) %>%
  lm(arr_delay ~ dep_delay + distance, .)
```

```
##
## Call:
## lm(formula = arr_delay ~ dep_delay + distance, data = .)
##
## Coefficients:
## (Intercept)    dep_delay    distance
## -3.212779     1.018077    -0.002551
```

When using the `.` in piping, I will usually make the argument name I am piping into explicit. This makes it more clear and also means if I have the position order wrong it doesn't matter.

```
flights %>%
  filter(., !is.na(arr_delay)) %>%
  lm(arr_delay ~ dep_delay + distance, data = .)
```

You can also use the `.` in conjunction with R's subsetting to output vectors. In the example below I filter flights, then extract the `arr_delay` column as a vector and pipe it into the base R function `quantile`.

```
flights %>%
  filter(!is.na(arr_delay)) %>%
  .$arr_delay %>%
  quantile(probs = seq(from = 0, to = 1, by = 0.10))
```

```
##    0%   10%   20%   30%   40%   50%   60%   70%   80%   90%  100%
##  -86   -26   -19   -14   -10    -5     1     9    21    52  1272
```

⁸You may want to add a step to pipe this into `summary()` after the `lm` step as well.

`quantile` is expecting a numeric vector in it's first argument so the above works. If instead of `.$arr_delay`, you'd tried `select(arr_delay)` the function would have failed because the `select` statement outputs a dataframe rather than a vector (and `quantile` would have become very angry with you). One weakness with the above method is it only allows you to input a single vector into the base R function (while many functions can take in multiple vectors).

A better way of doing this is to use the `with` function. The `with` function allows you to pipe a dataframe into the first argument and then reference the column in that dataframe with just the field names. This makes using those base R functions easier and more similar in syntax to tidyverse functions. For example, the above example would look become.

```
flights %>%
  filter(!is.na(arr_delay)) %>%
  with(quantile(arr_delay, probs = seq(from = 0, to = 1, by = 0.10)))
```

| | 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| ## | -86 | -26 | -19 | -14 | -10 | -5 | 1 | 9 | 21 | 52 | 1272 |

This method also makes it easy to input multiple field names in this style. Let's look at this with the `table` function⁹

```
flights %>%
  filter(!is.na(arr_delay)) %>%
  with(table(origin, carrier))
```

| | | carrier | | | | | | | | | | | |
|----|-----|-----------|-------|------|-------|-------|-------|-----|------|-----|-------|----|----|
| | | ## origin | 9E | AA | AS | B6 | DL | EV | F9 | FL | HA | MQ | OO |
| ## | EWR | 1193 | 3363 | 709 | 6472 | 4295 | 41557 | 0 | 0 | 0 | 2097 | 6 | |
| ## | JFK | 13742 | 13600 | 0 | 41666 | 20559 | 1326 | 0 | 0 | 342 | 6838 | 0 | |
| ## | LGA | 2359 | 14984 | 0 | 5911 | 22804 | 8225 | 681 | 3175 | 0 | 16102 | 23 | |
| | | carrier | | | | | | | | | | | |
| | | ## origin | UA | US | VX | WN | YV | | | | | | |
| ## | EWR | 45501 | 4326 | 1552 | 6056 | 0 | | | | | | | |
| ## | JFK | 4478 | 2964 | 3564 | 0 | 0 | | | | | | | |
| ## | LGA | 7803 | 12541 | 0 | 5988 | 544 | | | | | | | |

8.12 plotly

the `plotly` package has a cool function `ggplotly` that allows you to add wrappers `ggplot` that turn it into html that allow you to do things like zoom-in and hover over points. It also has a `frame` argument that allows you to make animations or filter between points. Here is an example from the `flights` dataset.

Note that this will not render in a markdown format, but only in html.

```
p <- flights %>%
  group_by(hour, month) %>%
  summarise(avg_delay = mean(arr_delay, na.rm = TRUE)) %>%
  ggplot(aes(x = hour, y = avg_delay, group = month, frame = month)) +
  geom_point() +
  geom_smooth()

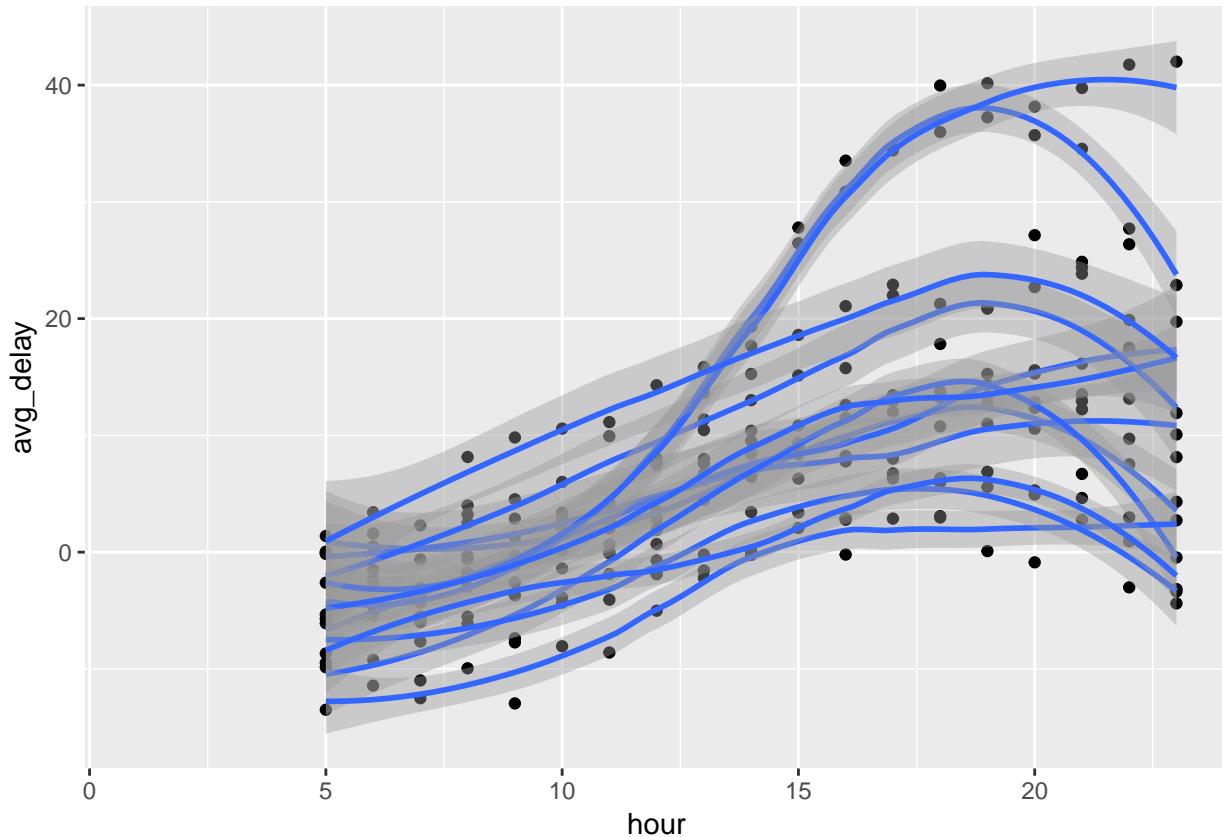
plotly::ggplotly(p)
```

This is the base from which this is built.

⁹`table` produces contingency tables.

```
flights %>%
  group_by(hour, month) %>%
  summarise(avg_delay = mean(arr_delay, na.rm = TRUE)) %>%
  ggplot(aes(x = hour, y = avg_delay, group = month)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
## Warning: Removed 1 rows containing non-finite values (stat_smooth).
## Warning: Removed 1 rows containing missing values (geom_point).
```



Make sure the following packages are installed:

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- `cut_width`: specify binsize of each cut (often use with `geom_boxplot`)
- `cut_number`: specify number of groups to make, allowing for variable binsize (often use with `geom_boxplot`)
- `geom_histogram`: ...
- `geom_freqpoly`: for if you want to have overlapping histograms (so outputs lines instead)
 - can set `y` as `..density..` to equalize scale of each (similar to how `geom_density` does).
- `geom_boxplot`: ...
- `geom_violin`: Creates double sided histograms for each factor of `x`
- `geom_bin2d`: scatter plot of `x` and `y` values, but use shading to determine count/density in each point
- `geom_hex`: same as `geom_bin2d` but hexagon instead of square shapes are shaded in
- `reorder`: `arg1` = variable to reorder, `arg2` = variable to reorder it by `arg3` = function to reorder by (e.g. median, mean, max...)
- `coord_cartesian`: adjust `x,y` window w/o filtering out values that are excluded from view
- `xlim`; `ylim`: adjust window and filter out values not within window (same method as `scale_x(/y)_continuous`)
 - these v. `coord_cartesian` is important for geoms like `geom_smooth` that aggregate as they visualize
- `ifelse`: vectorized if else (not to be confused with `if` and `else` functions)
 - `dplyr::if_else` is more strict alternative
- `case_when`: create new variable that relies on complex combination of existing variables
 - often use when you have complex or multiple `ifelse` statements accruing

9.1 7.3. Variation

9.1.1 7.3.4.

1. Explore the distribution of each of the `x`, `y`, and `z` variables in diamonds. What do you learn? Think about a diamond and how you might decide which dimension is the length, width, and depth.

`x` has some 0s which signifies a data collection error, `y` and `z` have extreme outliers (`z` more so).

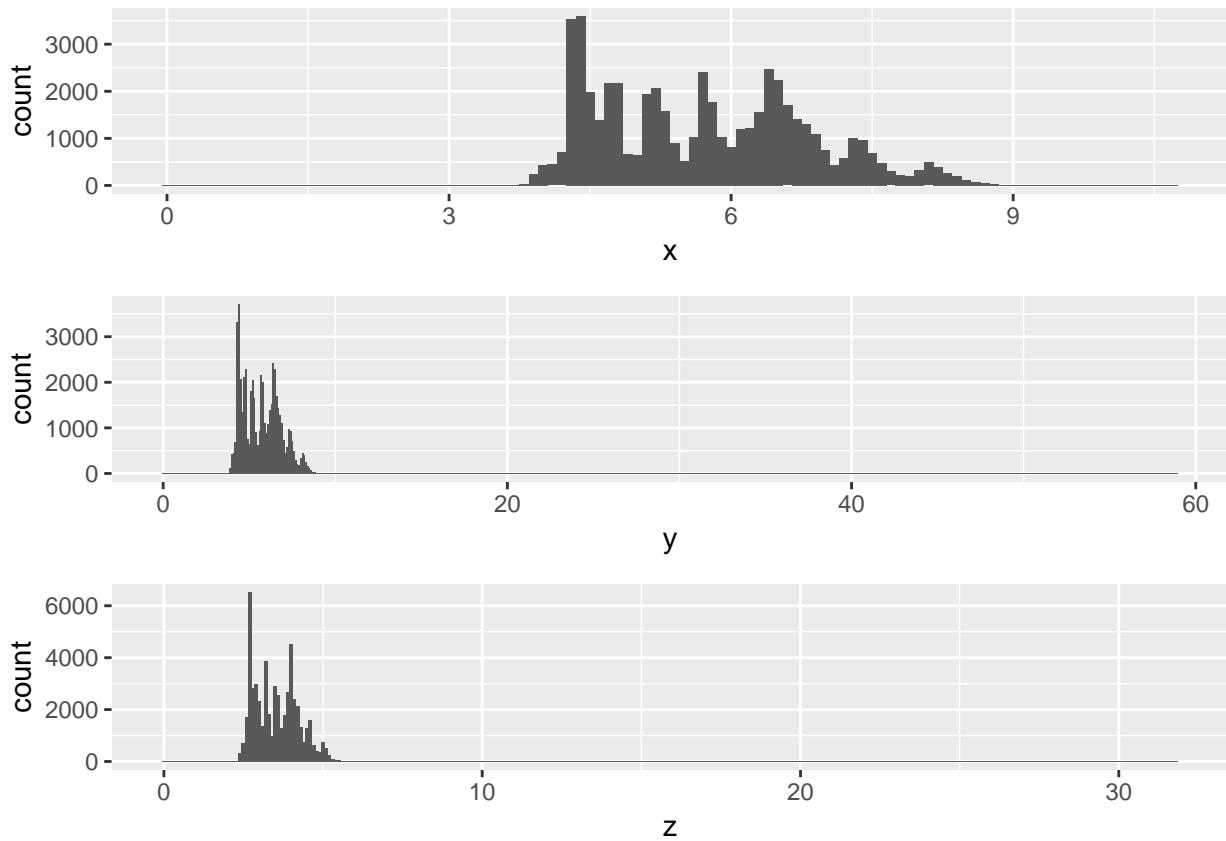
```
x_hist <- ggplot(diamonds) +
  geom_histogram(aes(x = x), binwidth = 0.1)

y_hist <- ggplot(diamonds) +
  geom_histogram(aes(x = y), binwidth = 0.1)

z_hist <- ggplot(diamonds) +
```

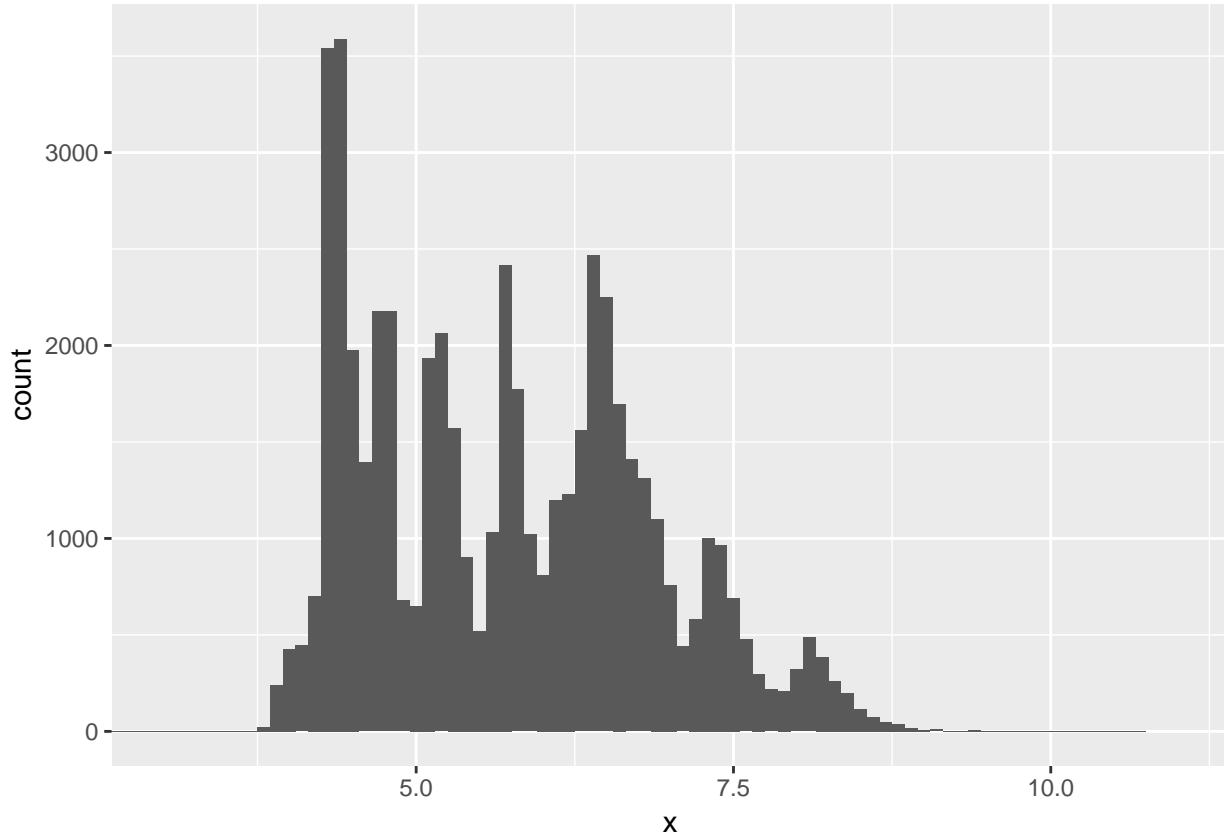
```
geom_histogram(aes(x = z), binwidth = 0.1)

gridExtra::grid.arrange(x_hist, y_hist, z_hist, ncol = 1)
```

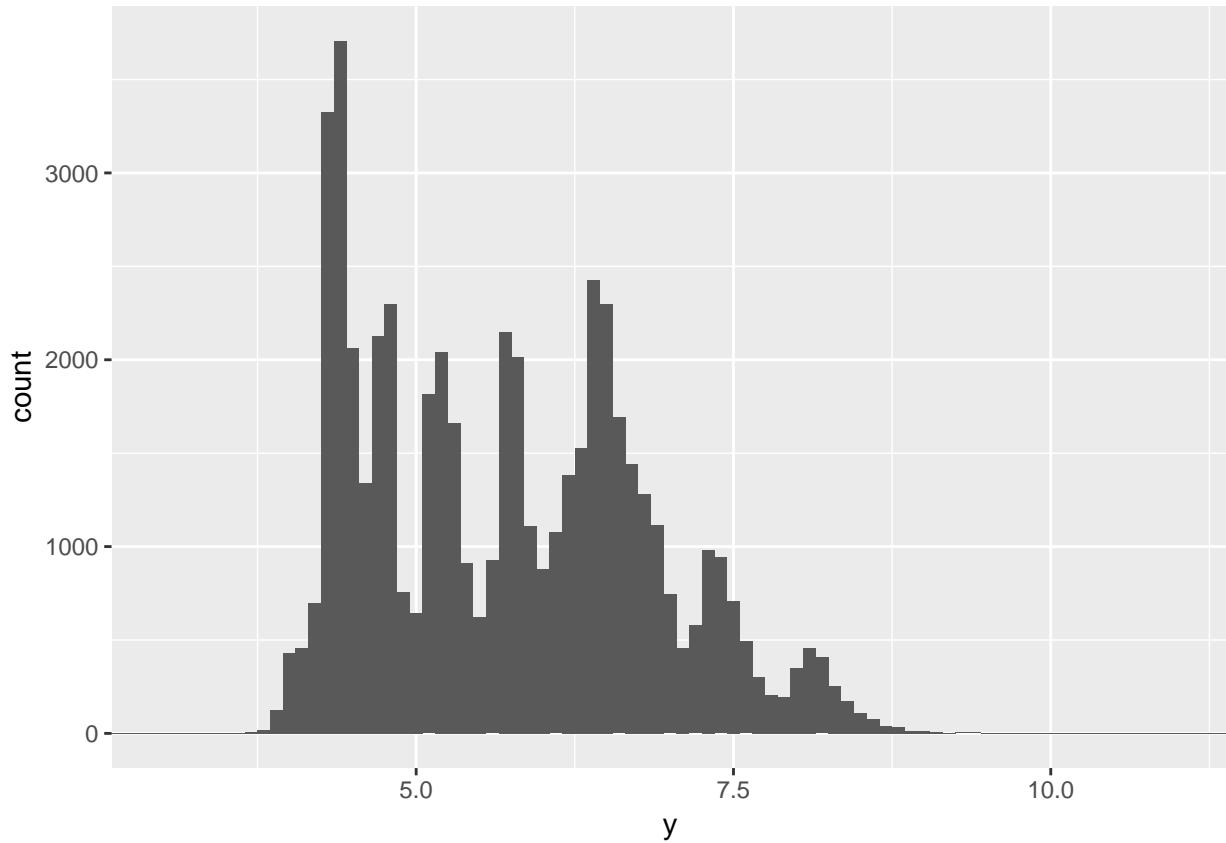


Below you see that all three have peaks and troughs on even points. X and y have more similar distributions than z.

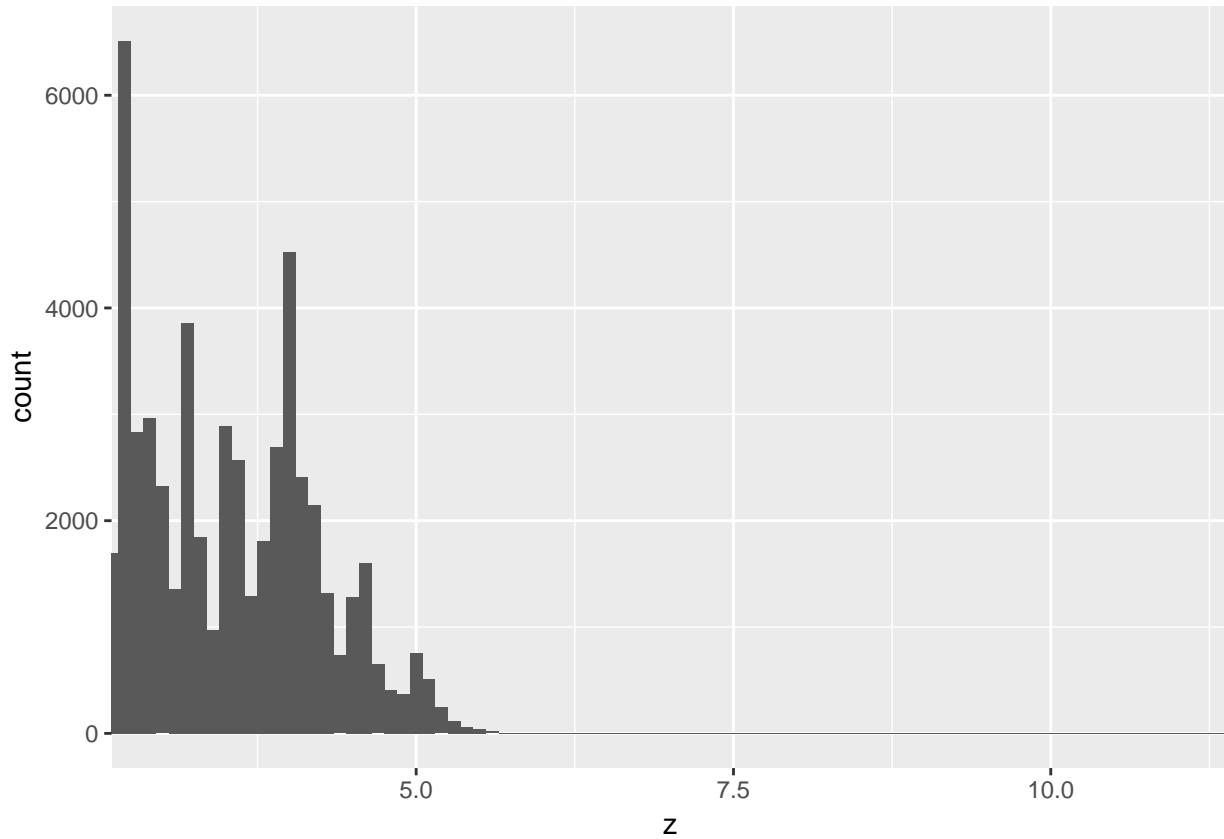
```
ggplot(diamonds) +
  geom_histogram(aes(x=x), binwidth=.1) +
  coord_cartesian(xlim = c(3,11))
```



```
ggplot(diamonds) +  
  geom_histogram(aes(x=y), binwidth=.1) +  
  coord_cartesian(xlim = c(3,11))
```

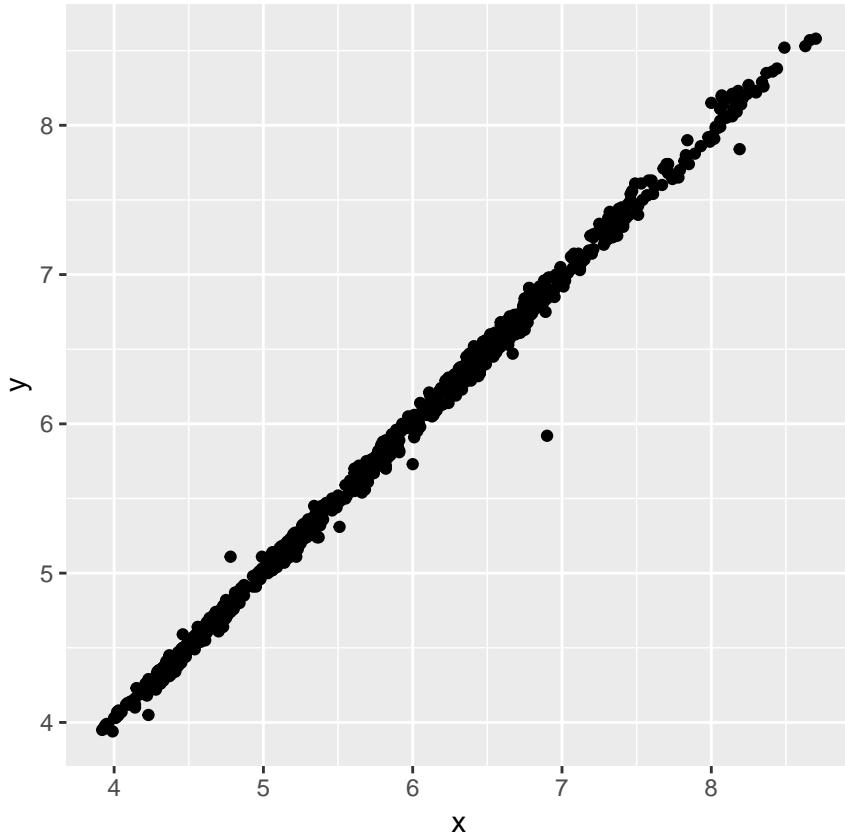


```
ggplot(diamonds)+  
  geom_histogram(aes(x=z), binwidth=.1)+  
  coord_cartesian(xlim = c(3,11))
```



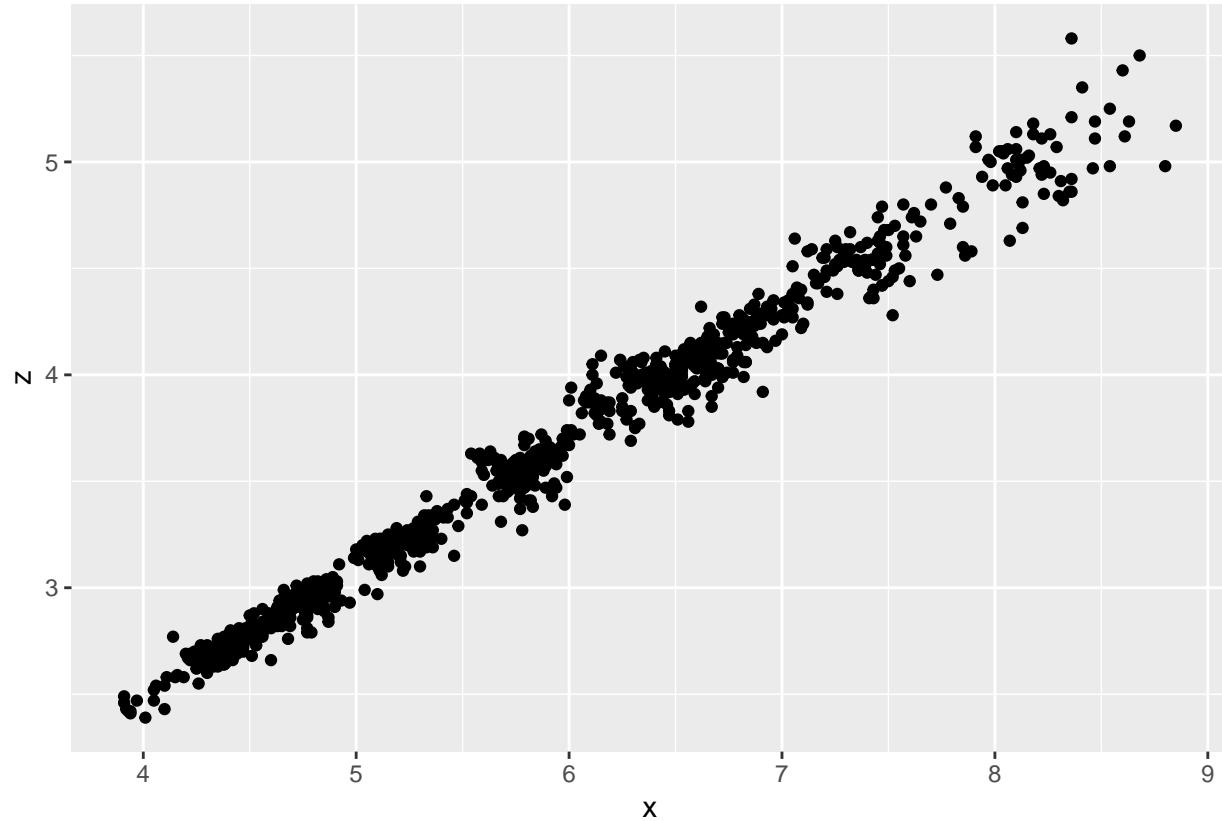
I would say that x and y are likely length and width and z depth because diamonds are typically circular on the face so will have the same ratio of length and width and we see this is the case for the x and y dimensions

```
diamonds %>%  
  sample_n(1000) %>%  
  ggplot() +  
  geom_point(aes(x, y)) +  
  coord_fixed()
```



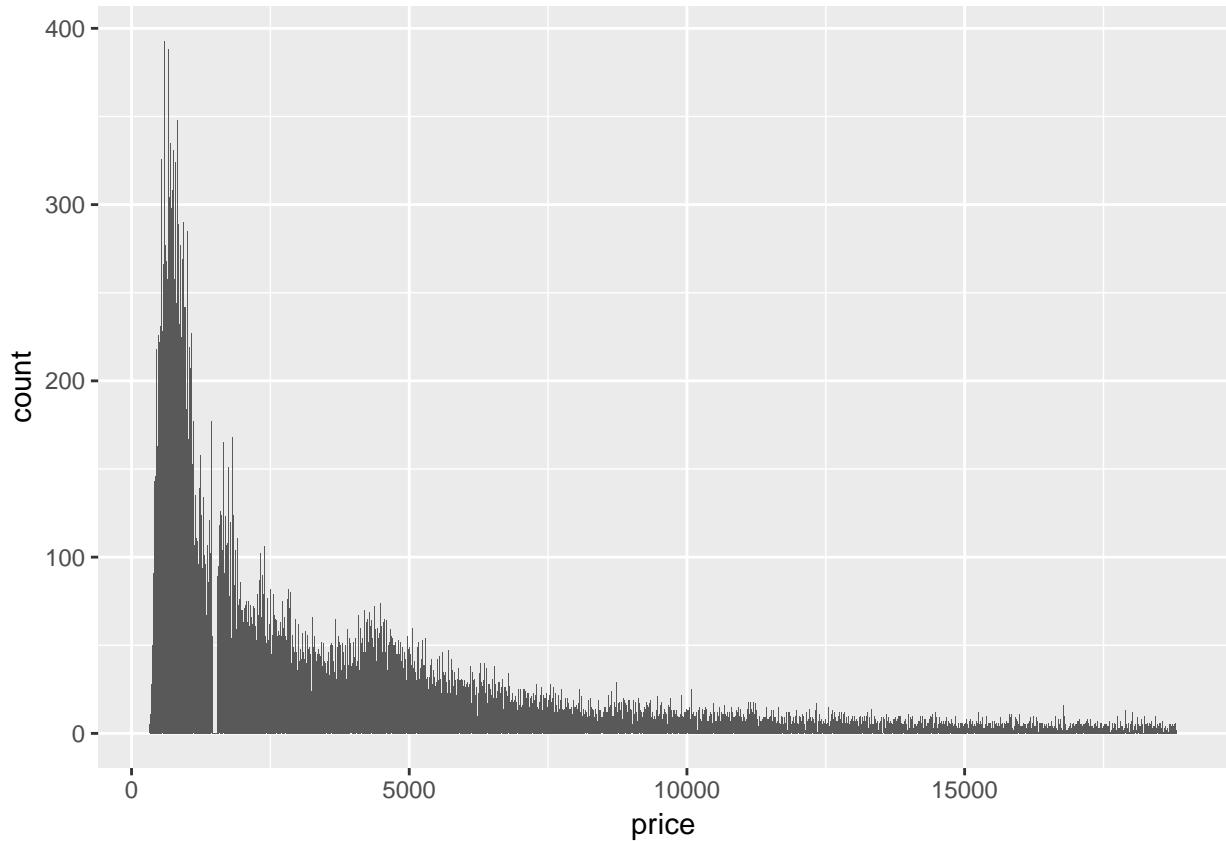
Whereas z tends to be more shallow.

```
diamonds %>%
  sample_n(1000) %>%
  ggplot() +
  geom_point(aes(x, z)) +
  coord_fixed()
```



2. Explore the distribution of price. Do you discover anything unusual or surprising? (Hint: Carefully think about the binwidth and make sure you try a wide range of values.)

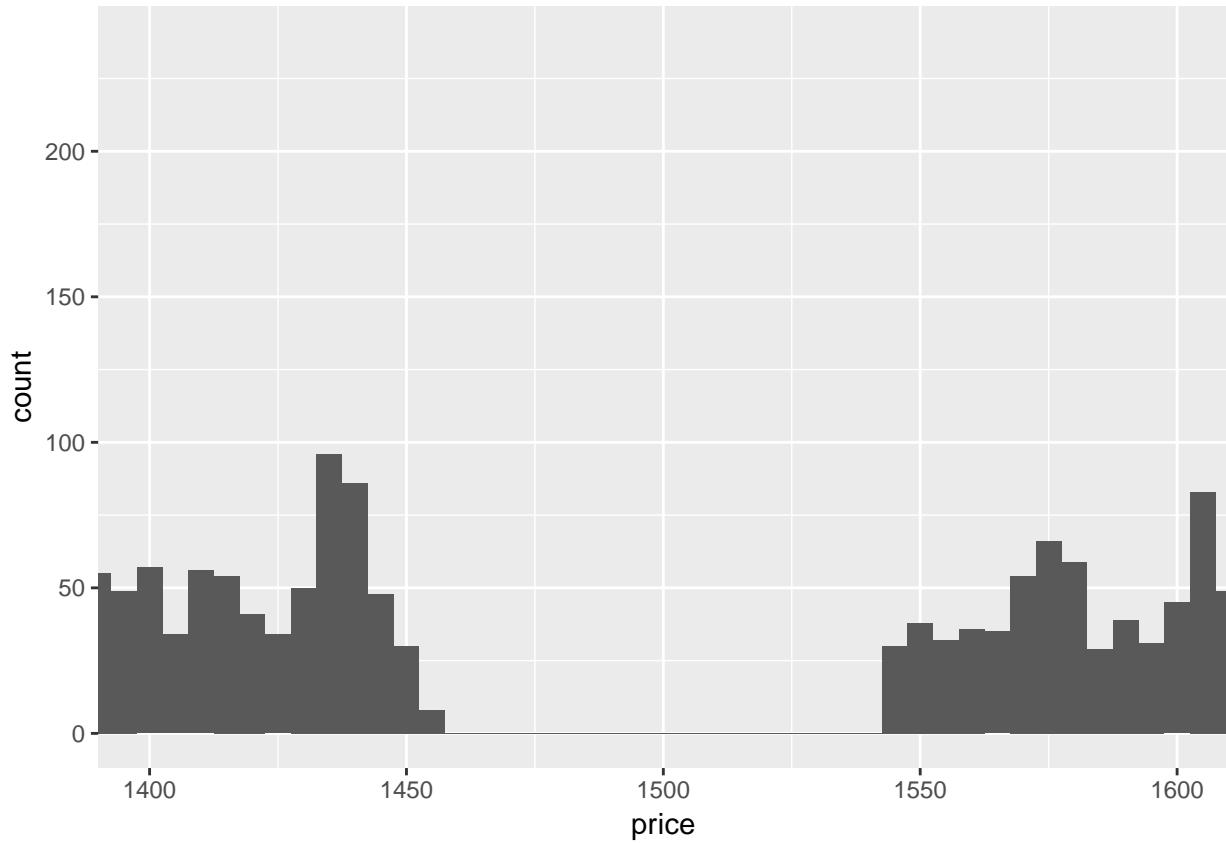
```
ggplot(diamonds) +  
  geom_histogram(aes(x = price), binwidth=10)
```



Price is right skewed.

Also notice that from 1400 to 1600 there are diamonds.

```
ggplot(diamonds)+  
  geom_histogram(aes(x = price), binwidth = 5)+coord_cartesian(xlim = c(1400,1600))
```



3. How many diamonds are 0.99 carat? How many are 1 carat? What do you think is the cause of the difference?

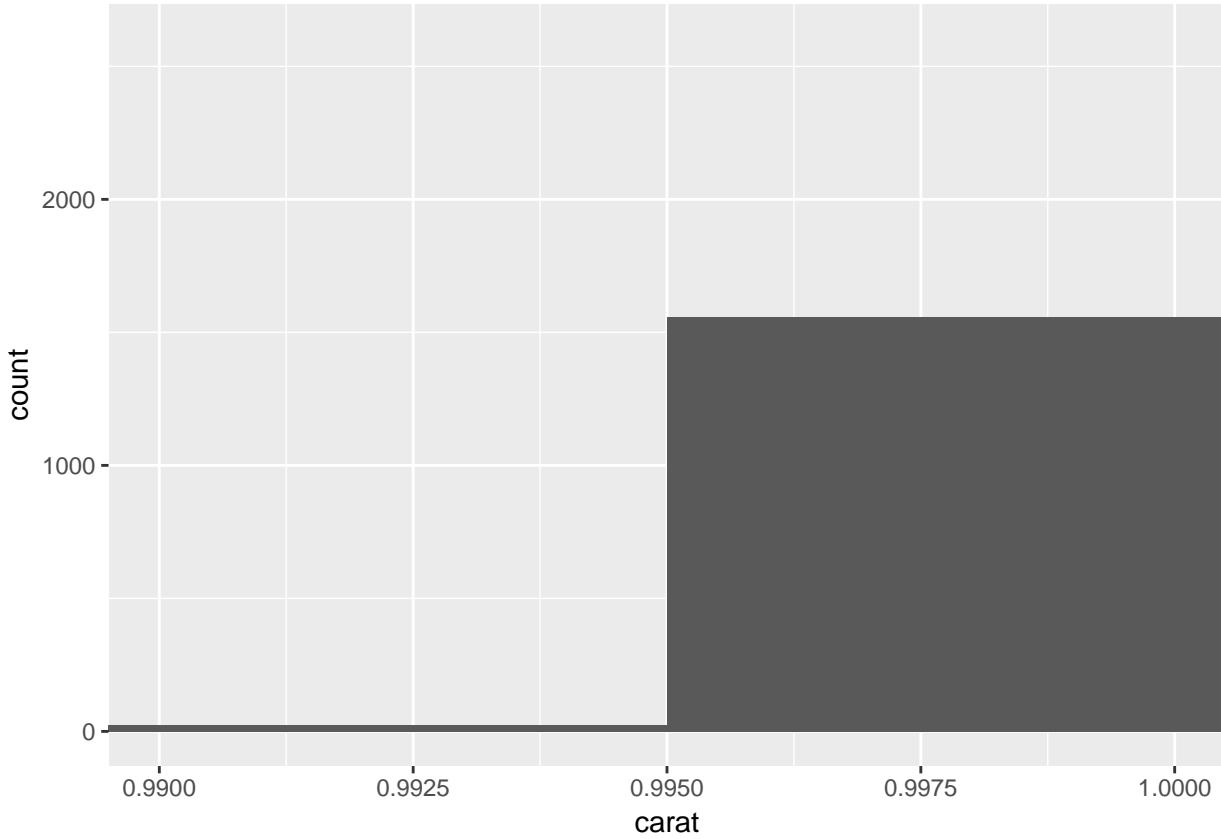
```
filter(diamonds, carat == 0.99) %>%
  count()
```

```
## # A tibble: 1 x 1
##       n
##   <int>
## 1     23
filter(diamonds, carat == 1) %>%
  count()
```

```
## # A tibble: 1 x 1
##       n
##   <int>
## 1    1558
```

For visual scale.

```
ggplot(diamonds) +
  geom_histogram(aes(x=carat), binwidth=.01) +
  coord_cartesian(xlim=c(.99,1))
```



The difference may be caused by jewelers rounding-up because people want to buy ‘1’ carat diamonds not 0.99 carat diamonds. It could also be that some listings are simply only in integers¹.

4. Compare and contrast `coord_cartesian()` vs `xlim()` or `ylim()` when zooming in on a histogram. What happens if you leave `binwidth` unset? What happens if you try and zoom so only half a bar shows?

`coord_cartesian` does not change data ust window view where as `xlim` and `ylim` will get rid of data outside of domain².

9.2 7.4. Missing values

9.2.1 7.4.1.

1. What happens to missing values in a histogram? What happens to missing values in a bar chart? Why is there a difference?

With numeric data they both filter out NAs, though for categorical / character variables the `barplot` will create a separate column with the category. This is because `NA` can just be thought of as another category though it is difficult to place it within a distribution of values.

Treats these the same.

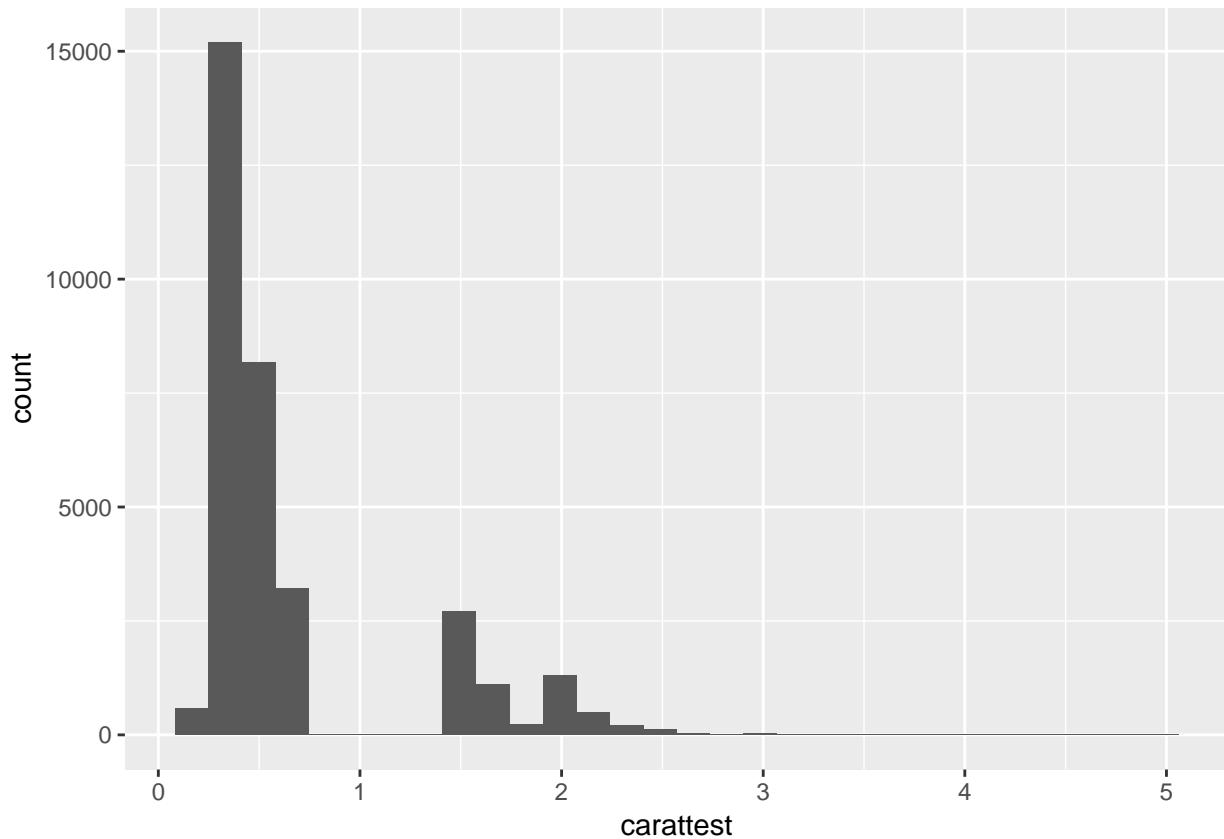
```
mutate(diamonds, carattest=ifelse(carat<1.5 & carat>.7, NA, carat)) %>%
  ggplot() +
  geom_histogram(aes(x=carattest))
```

¹not necessarily rounding one way or the other.

²This is especially important when building things like boxplots whose graphs depend on all points in the graph.

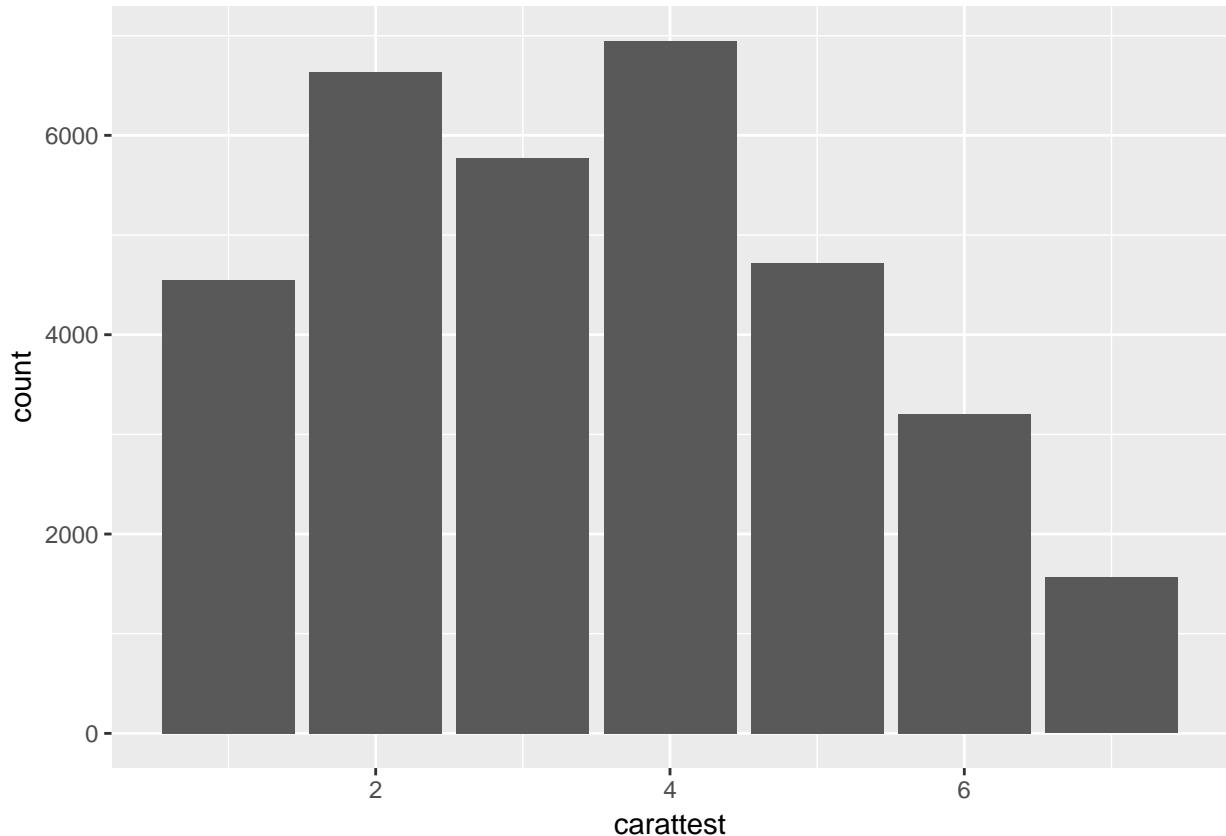
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
## Warning: Removed 20543 rows containing non-finite values (stat_bin).
```



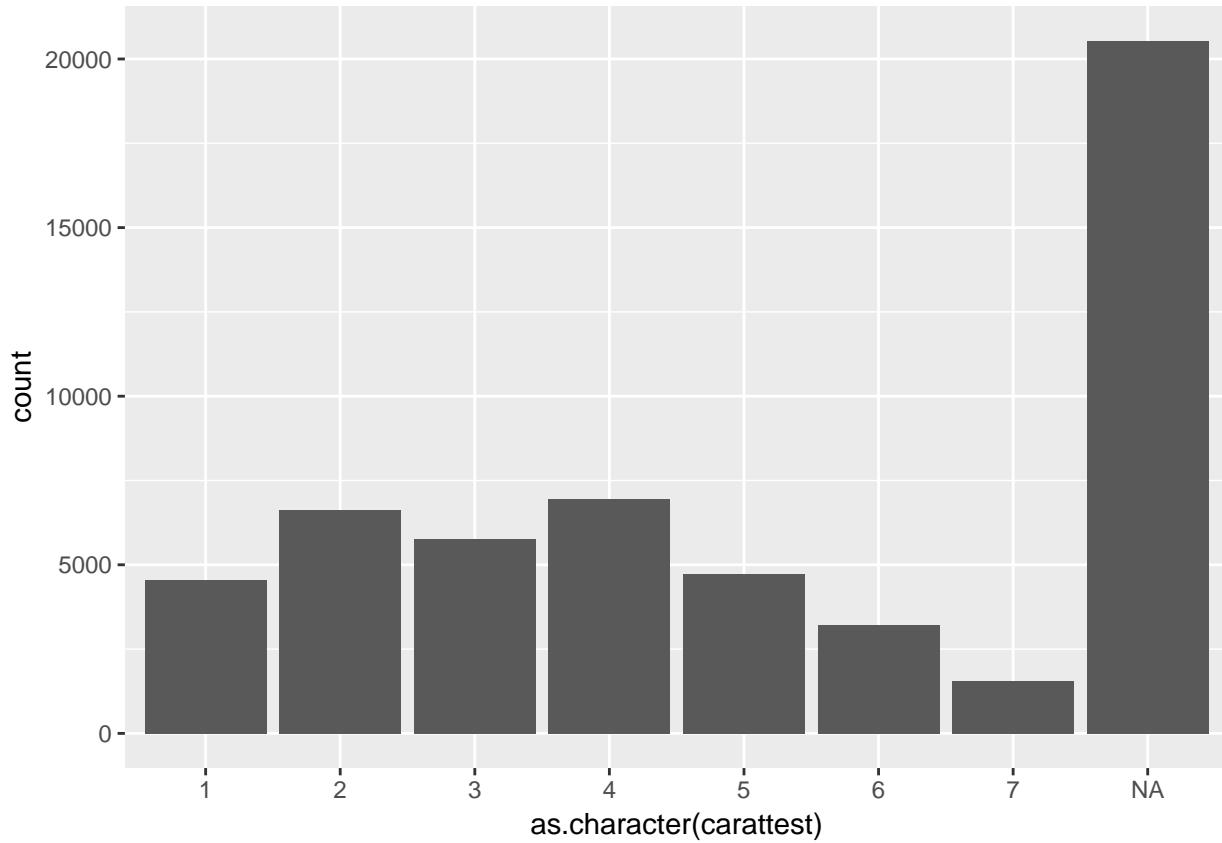
```
mutate(diamonds, carattest=ifelse(carat<1.5 & carat>.7, NA, color)) %>%
  ggplot() +
  geom_bar(aes(x=carattest))
```

```
## Warning: Removed 20543 rows containing non-finite values (stat_count).
```



For character than it creates a new bar for NAs

```
mutate(diamonds, carattest=ifelse(carat<1.5 & carat>.7, NA, color)) %>%
  ggplot() +
  geom_bar(aes(x = as.character(carattest)))
```



2. What does `na.rm = TRUE` do in `mean()` and `sum()`?

Filters it out of the vector of values.

9.3 7.5. Covariation

9.3.1 7.5.1.1.

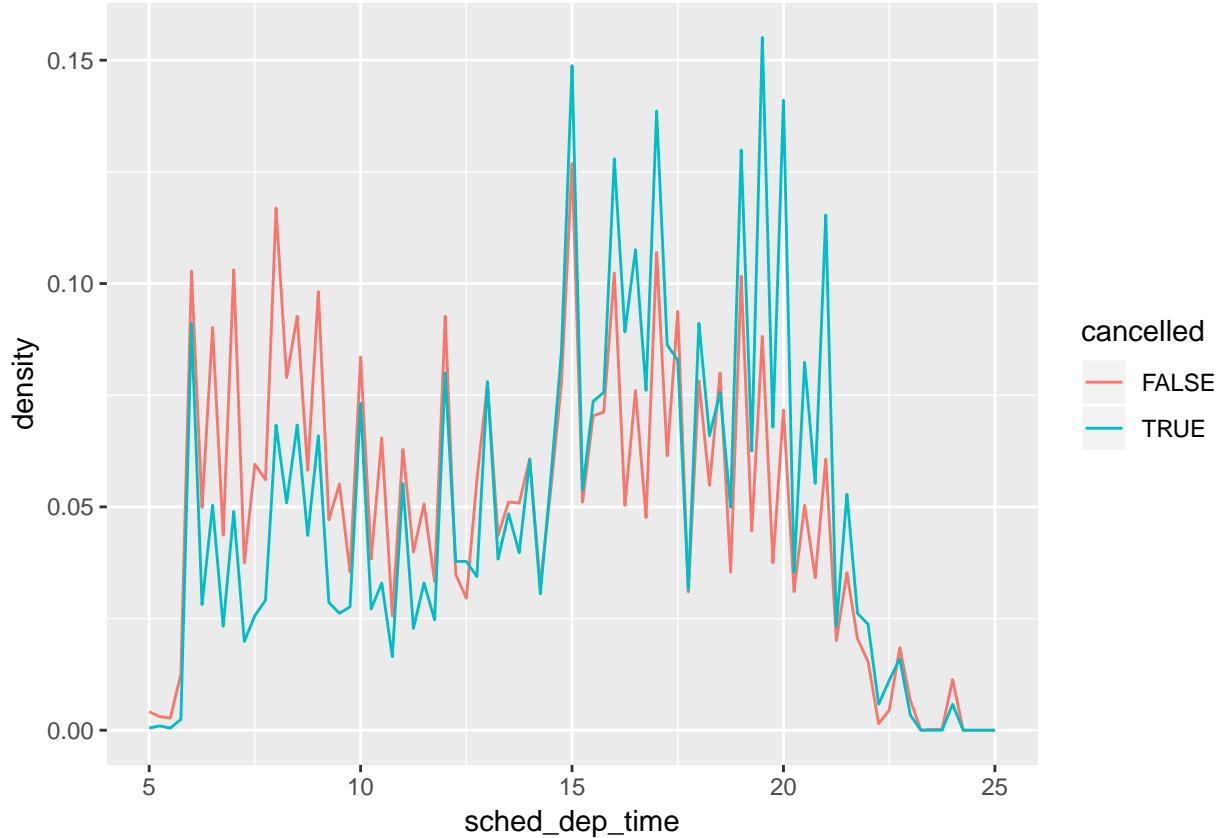
1. Use what you've learned to improve the visualisation of the departure times of cancelled vs. non-cancelled flights.

Looks like while non-cancelled flights happen at similar frequency in mornings and evenings, cancelled flights happen at a greater frequency in the evenings.

```
nycflights13::flights %>%
  mutate(
    cancelled = is.na(dep_time),
    sched_hour = sched_dep_time %/% 100,
    sched_min = sched_dep_time %% 100,
    sched_dep_time = sched_hour + sched_min / 60
  ) %>%
  ggplot(mapping = aes(x=sched_dep_time, y=..density...)) +
  geom_freqpoly(mapping = aes(colour = cancelled), binwidth = .25) +
  xlim(c(5,25))

## Warning: Removed 1 rows containing non-finite values (stat_bin).
```

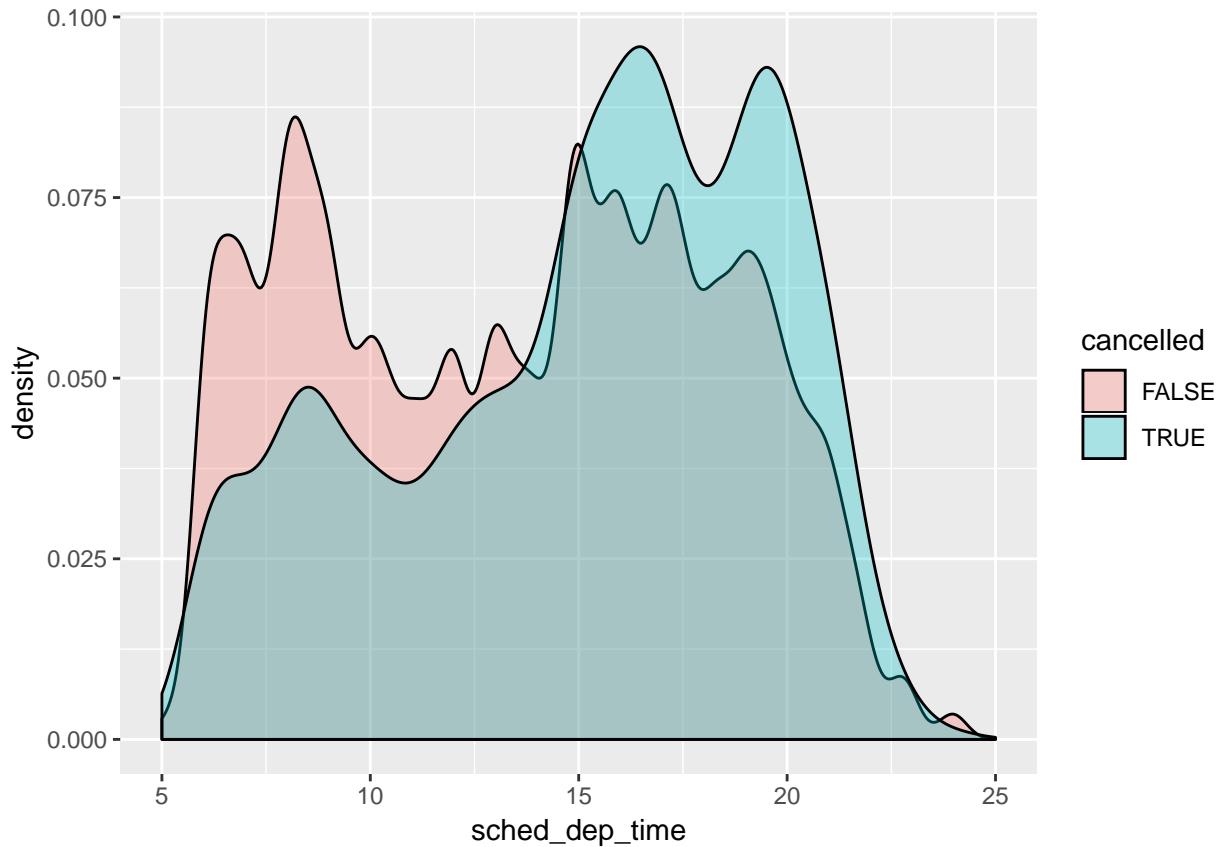
```
## Warning: Removed 4 rows containing missing values (geom_path).
```



Let's look at the same plot but smooth the distributions to make the pattern easier to see.

```
nycflights13::flights %>%
  mutate(
    cancelled = is.na(dep_time),
    sched_hour = sched_dep_time %% 100,
    sched_min = sched_dep_time %% 100,
    sched_dep_time = sched_hour + sched_min / 60
  ) %>%
  ggplot(mapping = aes(x=sched_dep_time)) +
  geom_density(mapping = aes(fill = cancelled), alpha = 0.30) +
  xlim(c(5,25))
```

```
## Warning: Removed 1 rows containing non-finite values (stat_density).
```



2. What variable in the diamonds dataset is most important for predicting the price of a diamond? How is that variable correlated with cut? Why does the combination of those two relationships lead to lower quality diamonds being more expensive?

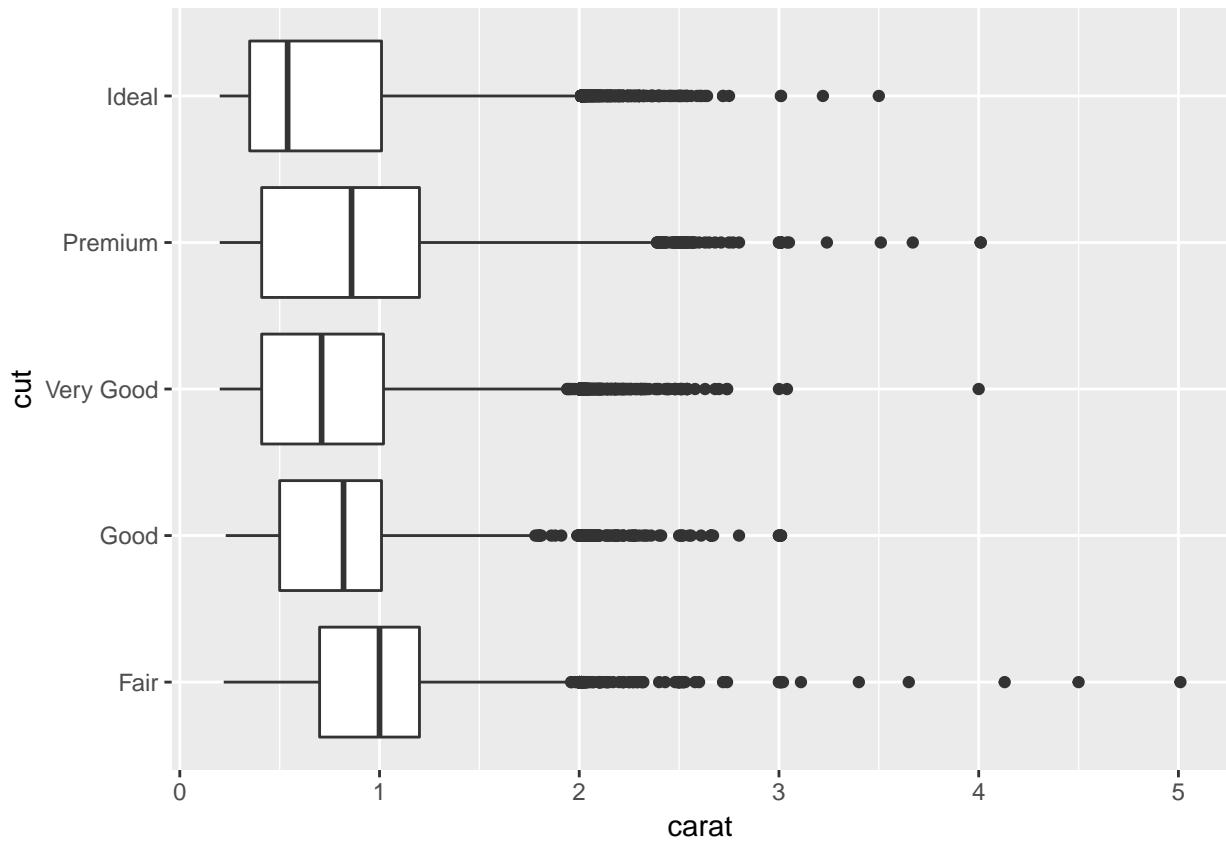
carat is the most important for predicting price.

```
cor(diamonds$price, select(diamonds, carat, depth, table, x, y, z))
```

```
##           carat      depth     table       x       y       z
## [1,] 0.9215913 -0.0106474 0.1271339 0.8844352 0.8654209 0.8612494
```

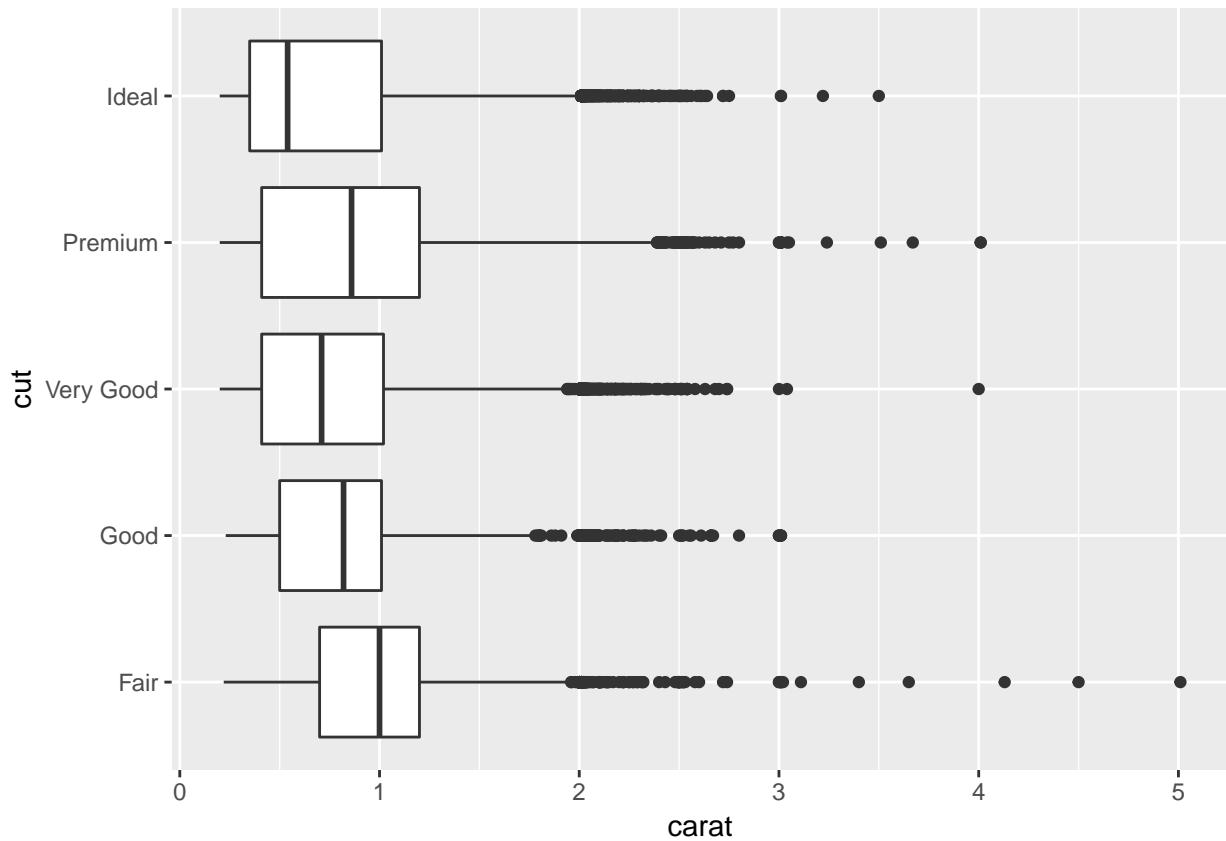
fair cuts seem to associate with a higher `carat` thus while lower quality diamonds may be selling for more that is being driven by the `carat` of the diamond (the most important factor in `price`) and the quality simply cannot offset this.

```
ggplot(data=diamonds, aes(x=cut, y=carat))+
  geom_boxplot()+
  coord_flip()
```



3. Install the `ggstance` package, and create a horizontal boxplot. How does this compare to using `coord_flip()`?

```
ggplot(diamonds) +  
  ggstance::geom_boxplot(aes(x = carat, y = cut))
```



Looks like it does the same thing.

4. One problem with boxplots is that they were developed in an era of much smaller datasets and tend to display a prohibitively large number of “outlying values”. One approach to remedy this problem is the letter value plot. Install the `lvplot` package, and try using `geom_lv()` to display the distribution of price vs cut. What do you learn? How do you interpret the plots?

I found this helpful: <https://stats.stackexchange.com/questions/301159/understanding-and-interpreting-letter-value-boxplot>

This produces a ‘letter-value’ boxplot which means that in the first box you have the middle ~1/2 of data, then in the adjoining boxes the next ~1/4, so within the middle 3 boxes you have the middle ~3/4 of data, next two boxes is ~7/8ths, then ~15/16ths etc.

```
set.seed(1234)
a <- diamonds %>%
  ggplot() +
  lvplot::geom_lv(aes(x = cut, y = price))

set.seed(1234)
b <- diamonds %>%
  ggplot() +
  geom_boxplot(aes(x = cut, y = price))
```

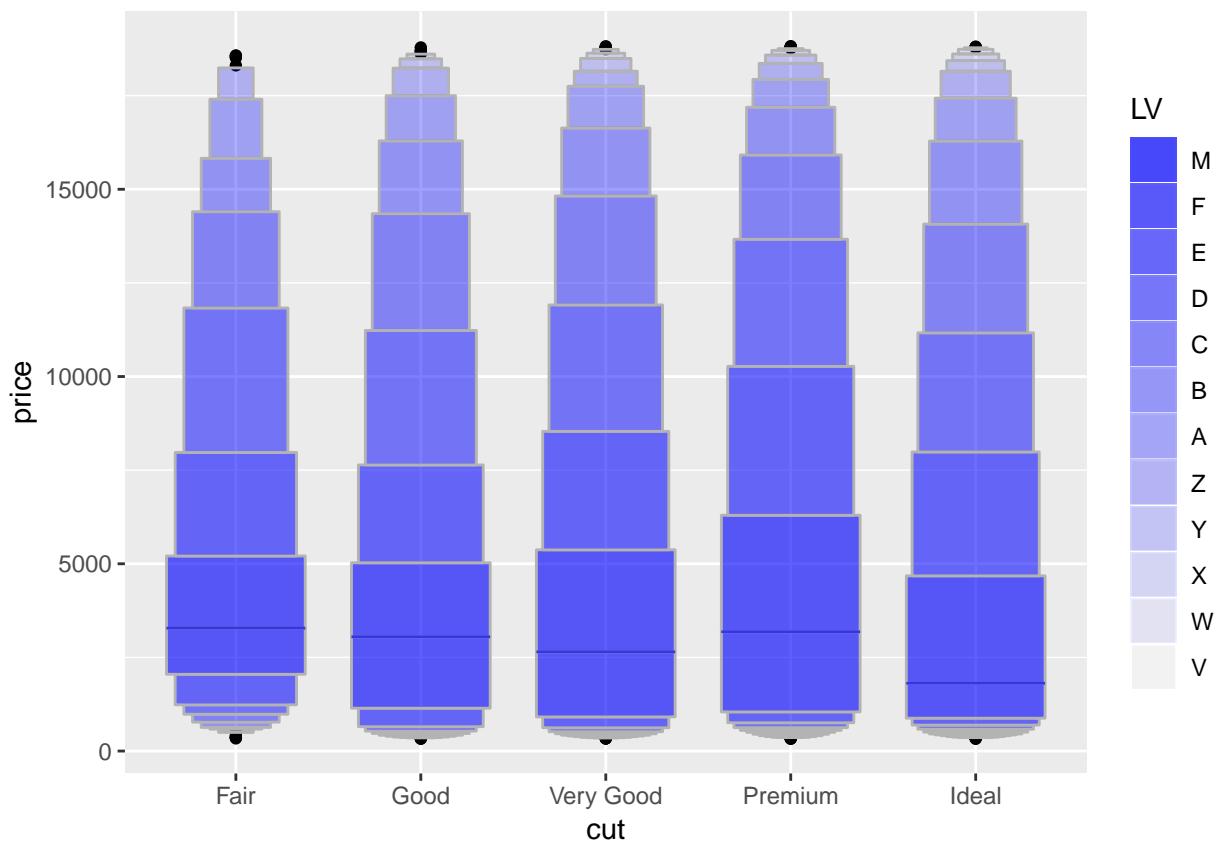
Perhaps a helpful way to understand this is to see what it looks like at different specified ‘k’ values (which)

You can see the letters when you add `fill = ..LV..` to the aesthetic.

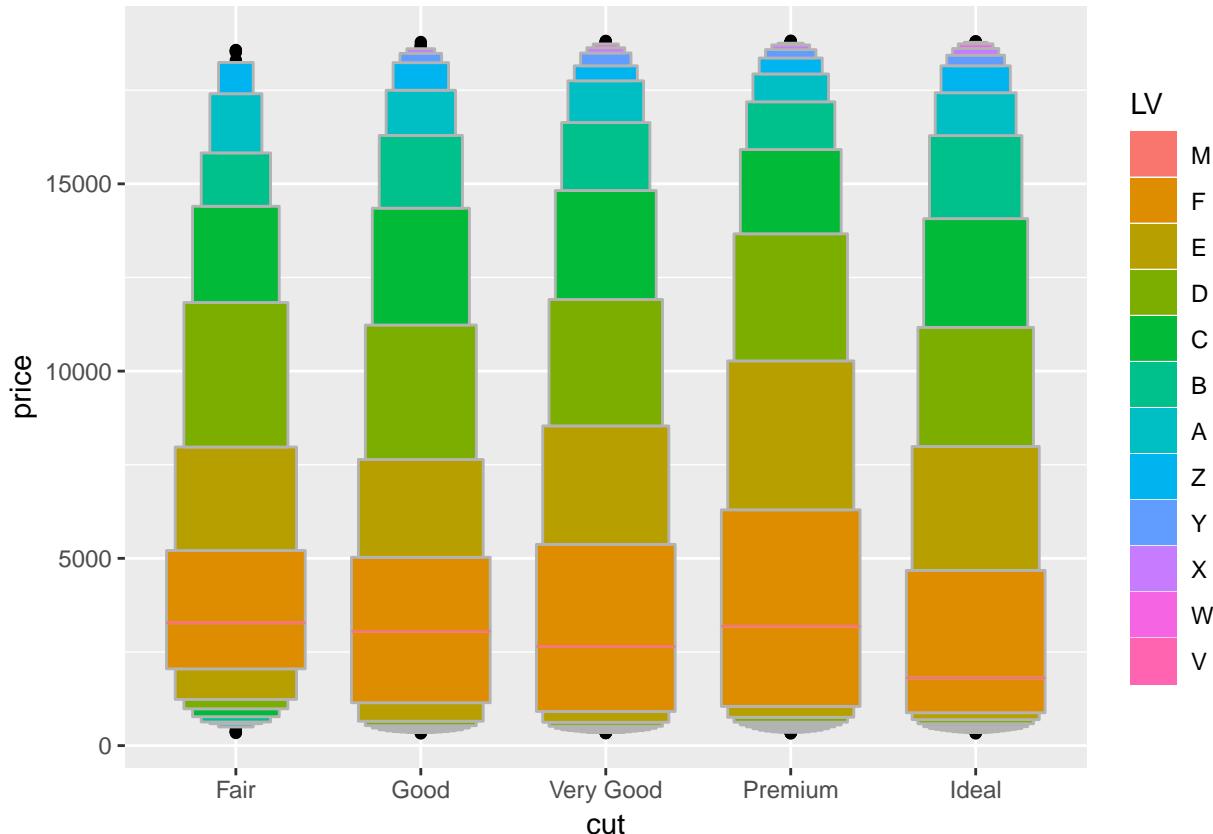
```
diamonds %>%
  ggplot() +
```

```
lvplot::geom_lv(aes(x = cut, y = price, alpha = ..LV..), fill = "blue")+
  scale_alpha_discrete(range = c(0.7, 0))
```

Warning: Using alpha for a discrete variable is not advised.



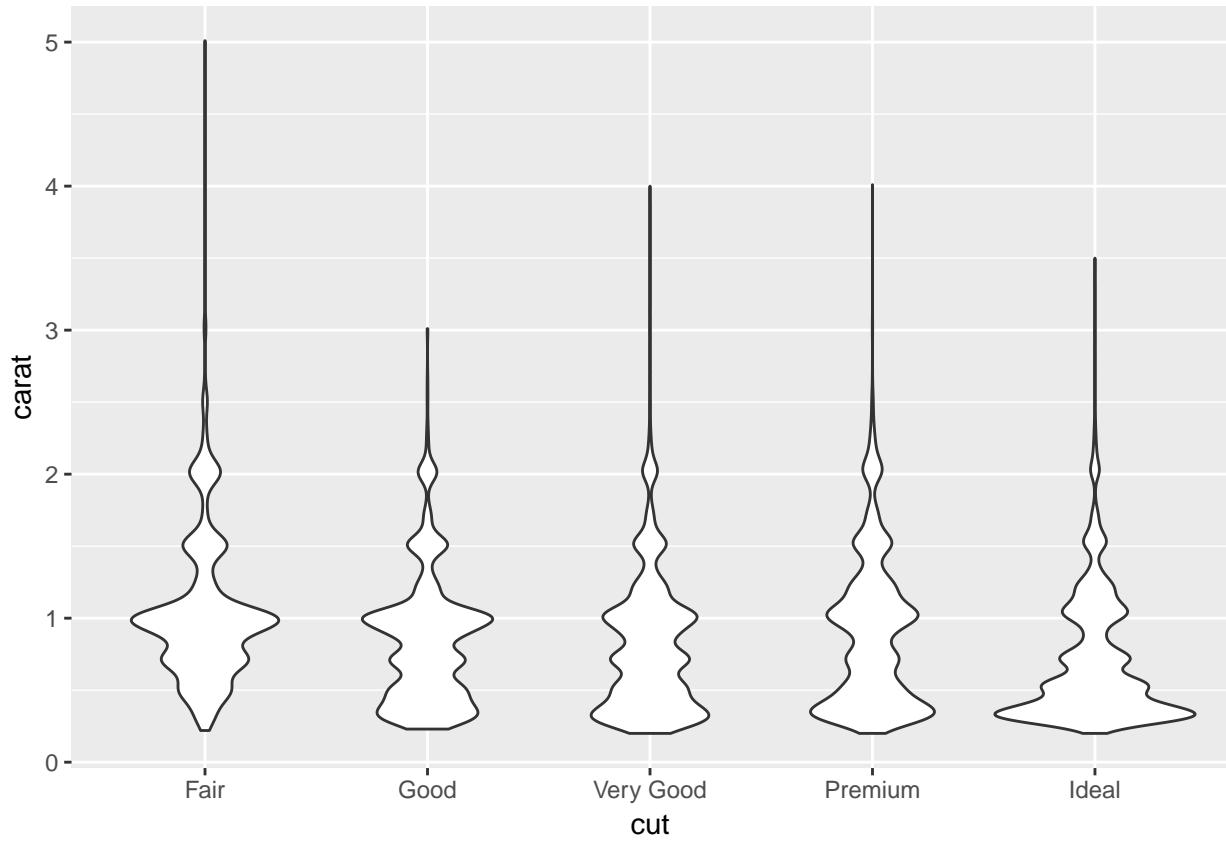
```
diamonds %>%
  ggplot()+
  lvplot::geom_lv(aes(x = cut, y = price, fill = ..LV..))
```



Letters represent ‘median’, ‘fourths’, ‘eights’...

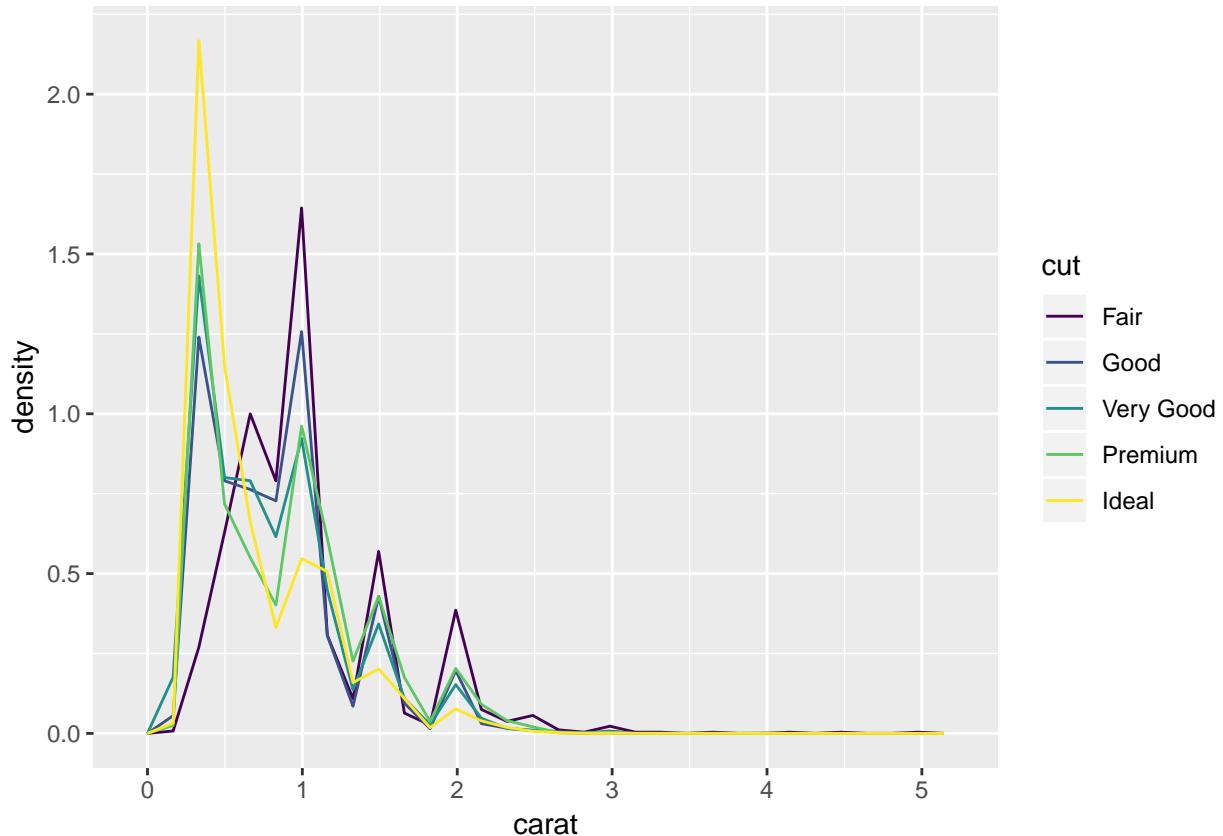
5. Compare and contrast `geom_violin()` with a faceted `geom_histogram()`, or a coloured `geom_freqpoly()`. What are the pros and cons of each method?

```
ggplot(diamonds, aes(x = cut, y = carat)) +
  geom_violin()
```



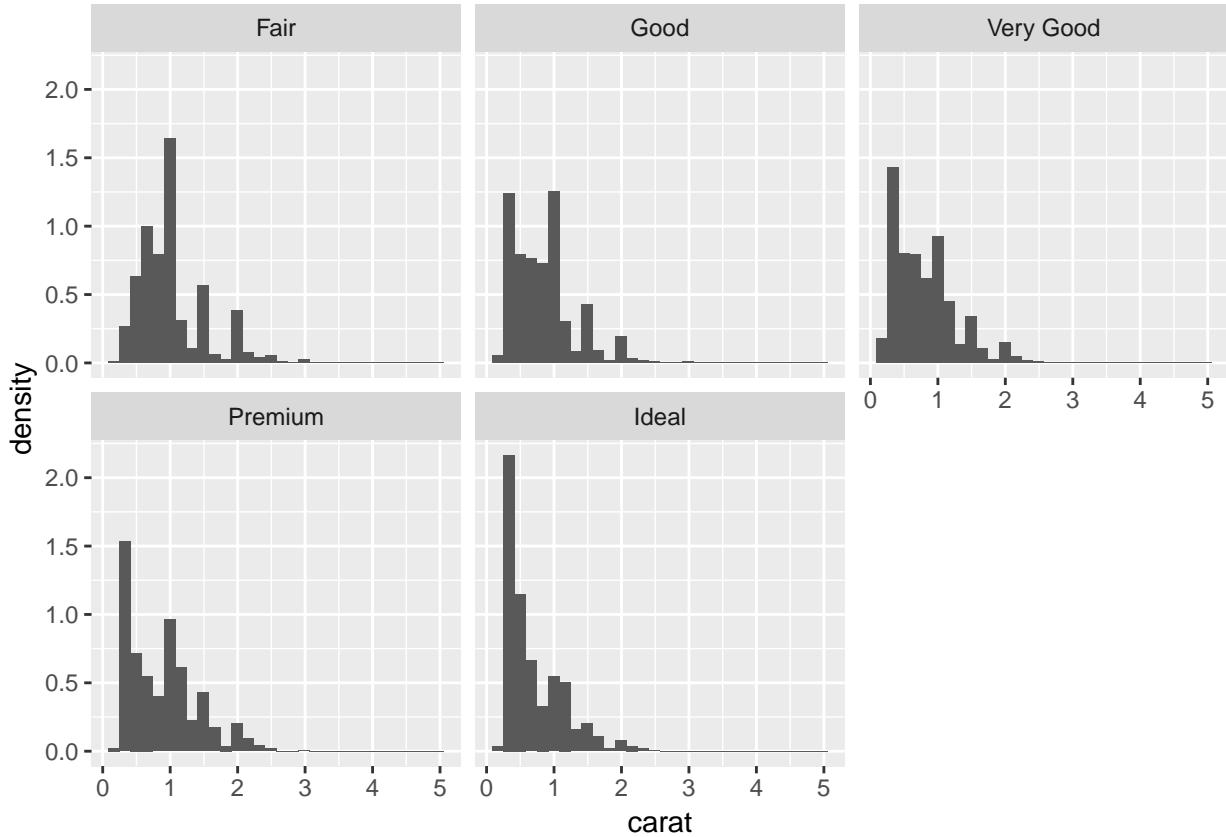
```
ggplot(diamonds,aes(colour = cut, x = carat, y = ..density..)) +  
  geom_freqpoly()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



```
ggplot(diamonds, aes(x = carat, y = ..density..)) +  
  geom_histogram() +  
  facet_wrap(~cut)
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

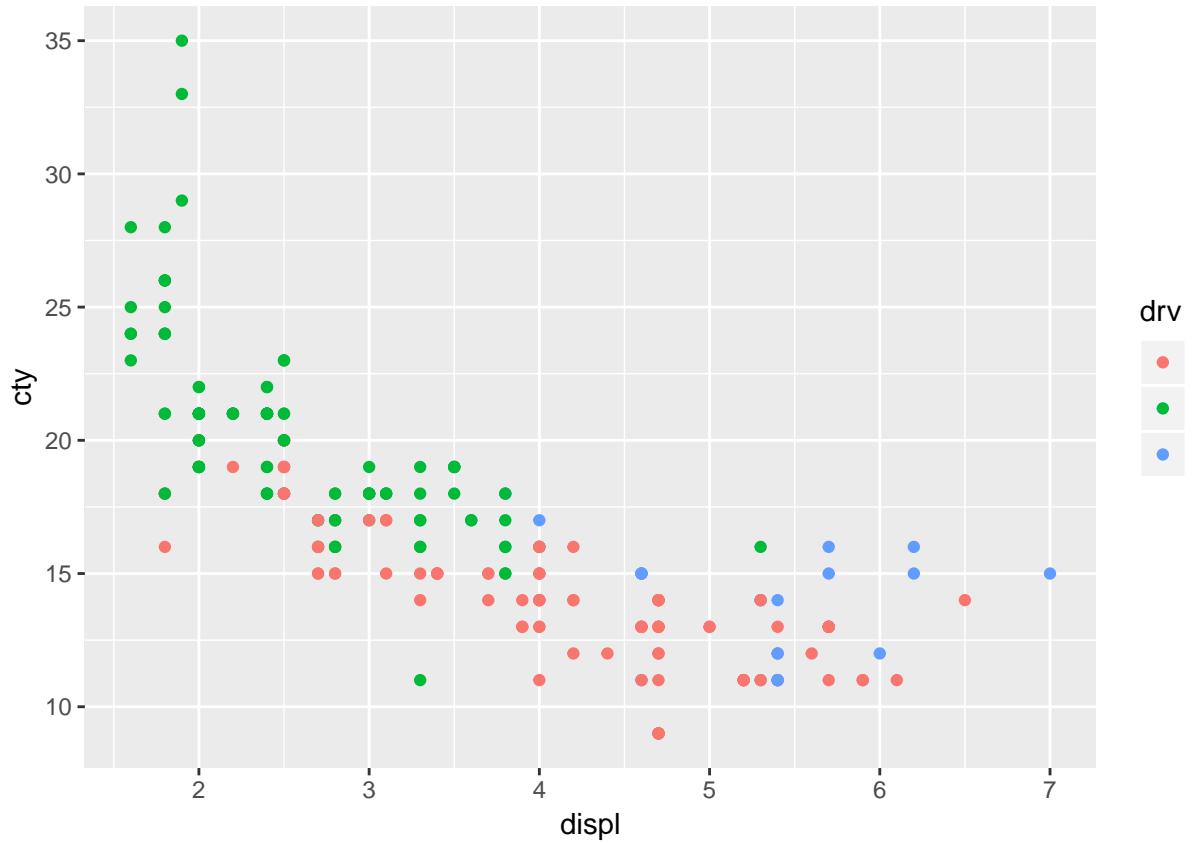


I like how `geom_freqpoly` has points directly overlaying but it can also be tough to read some, and the lines can overlap and be tough to tell apart, you also have to specify `density` for this and `geom_histogram` whereas for `geom_violin` it is the default. The tails in `geom_violin` can be easy to read but they also pull these for each of the values whereas by faceting `geom_histogram` and setting `scales = "free"` you can have independent scales. I think the biggest advantage of the histogram is that it is the most familiar so people will know what you're looking at.

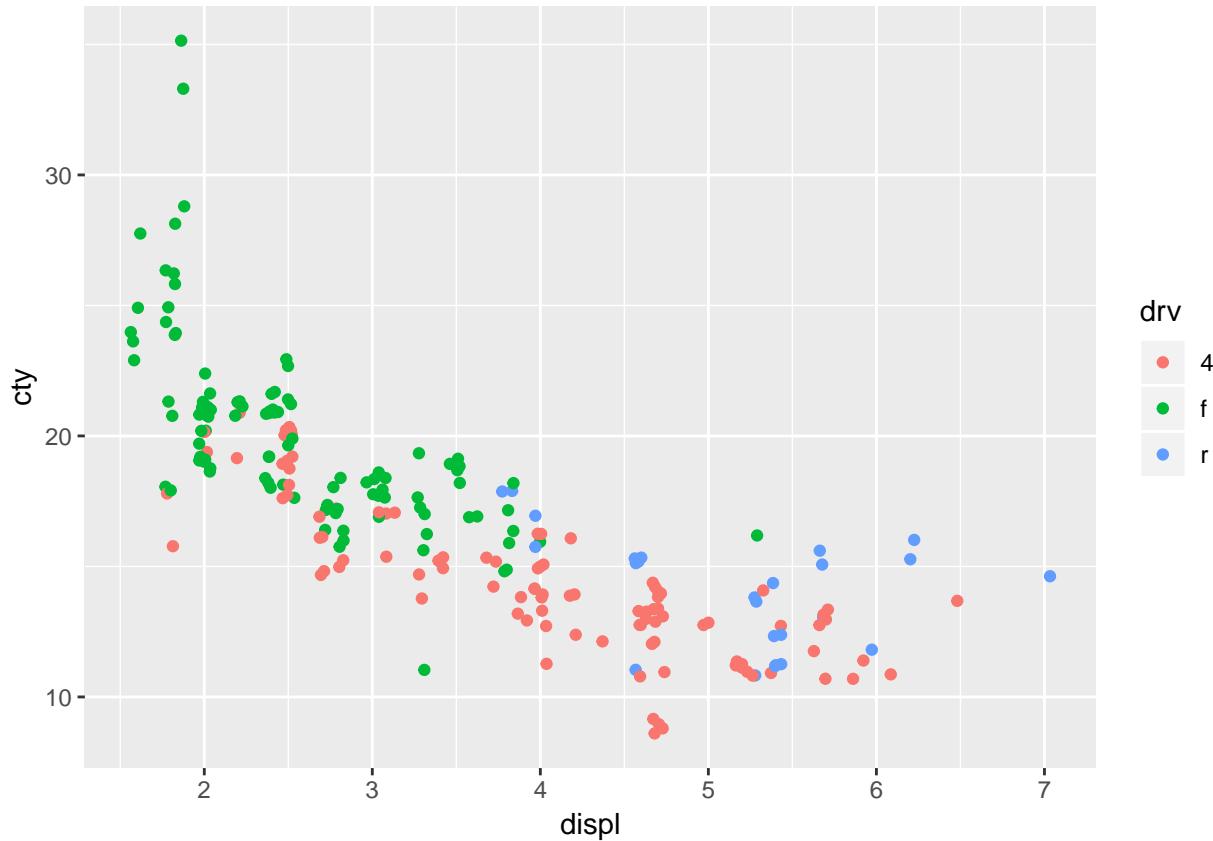
6. If you have a small dataset, it's sometimes useful to use `geom_jitter()` to see the relationship between a continuous and categorical variable. The `ggbeeswarm` package provides a number of methods similar to `geom_jitter()`. List them and briefly describe what each one does.

(Come back to)

```
ggplot(mpg, aes(x = displ, y = cty, color = drv)) +
  geom_point()
```

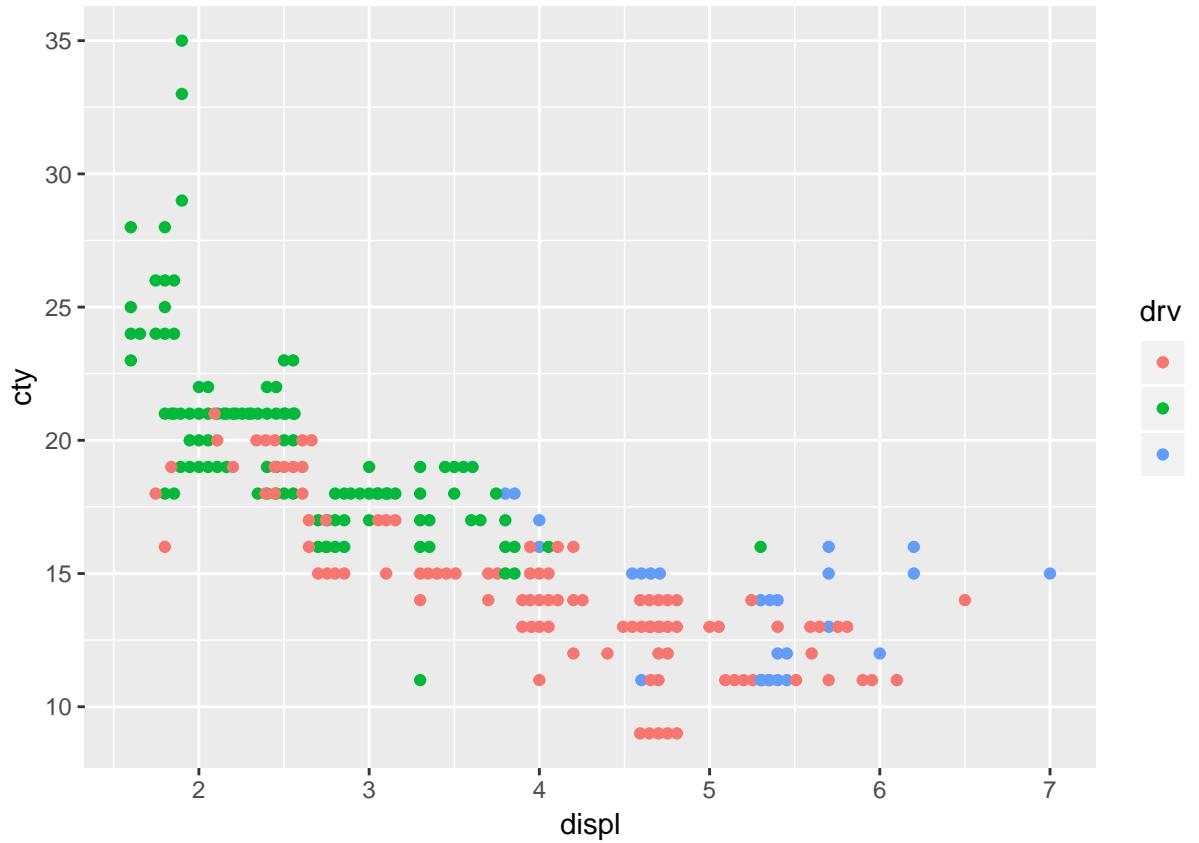


```
ggplot(mpg, aes(x = displ, y = cty, color = drv)) +  
  geom_jitter()
```



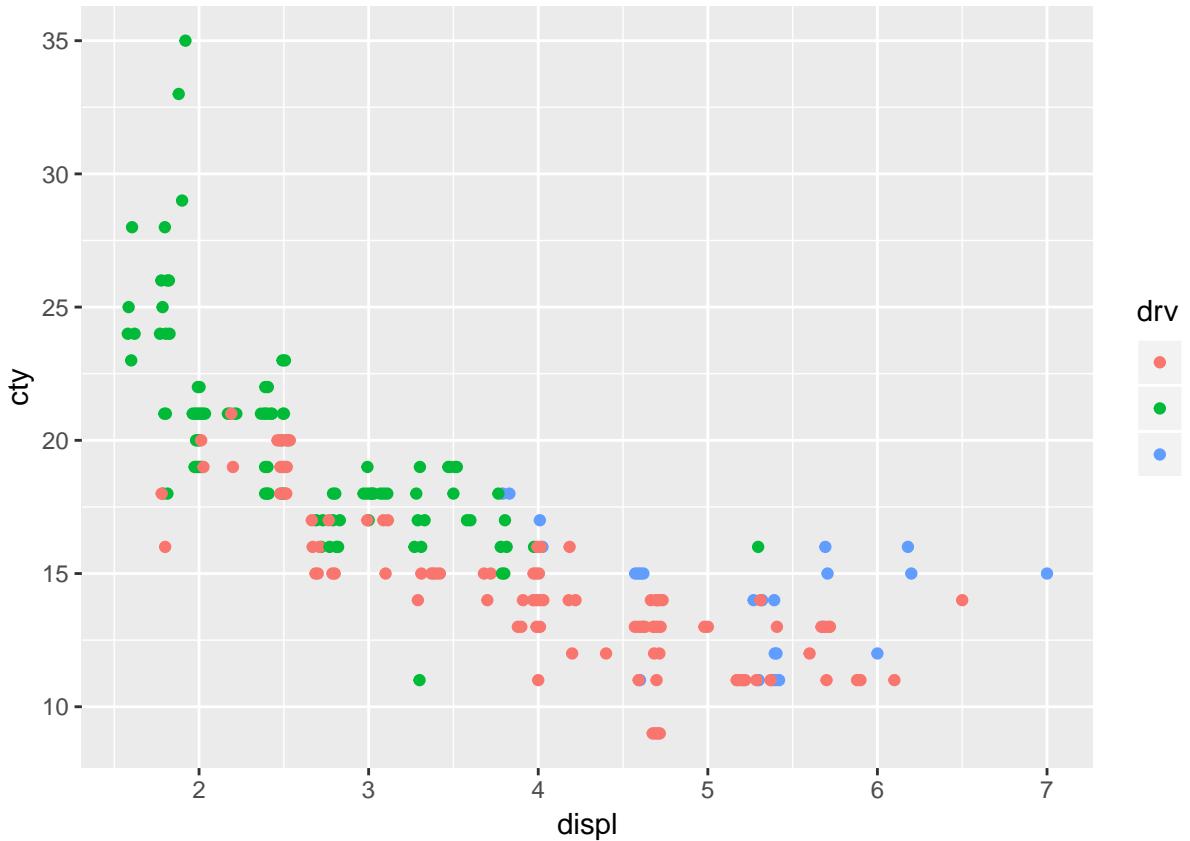
```
ggplot(mpg, aes(x = displ, y = cty, color = drv))+
  geom_beeswarm()
```

```
## Warning in f(...): The default behavior of beeswarm has changed in version
## 0.6.0. In versions <0.6.0, this plot would have been dodged on the y-
## axis. In versions >=0.6.0, groupOnX=FALSE must be explicitly set to group
## on y-axis. Please set groupOnX=TRUE/FALSE to avoid this warning and ensure
## proper axis choice.
```



```
ggplot(mpg, aes(x = displ, y = cty, color = drv))+
  geom_quasirandom()
```

```
## Warning in f(...): The default behavior of beeswarm has changed in version
## 0.6.0. In versions <0.6.0, this plot would have been dodged on the y-
## axis. In versions >=0.6.0, groupOnX=FALSE must be explicitly set to group
## on y-axis. Please set groupOnX=TRUE/FALSE to avoid this warning and ensure
## proper axis choice.
```



`geom_jitter` is similar to `geom_point` but it provides random noise to the points. You can control these with the `width` and `height` arguments. This is valuable as it allows you to better see points that may overlap one another. `geom_beeswarm` adds variation in a uniform pattern by default across only the x-axis. `geom_quasirandom` also defaults to distributing the points across the x-axis however it produces quasi-random variation, ‘quasi’ because it looks as though points follow some interrelationship³ and if you run the plot multiple times you will get the exact same plot whereas for `geom_jitter` you will get a slightly different plot each time. To see the differences between `geom_beeswarm` and `geom_quasirandom` it’s helpful to look at the plots above, but holding the y value constant at 1.

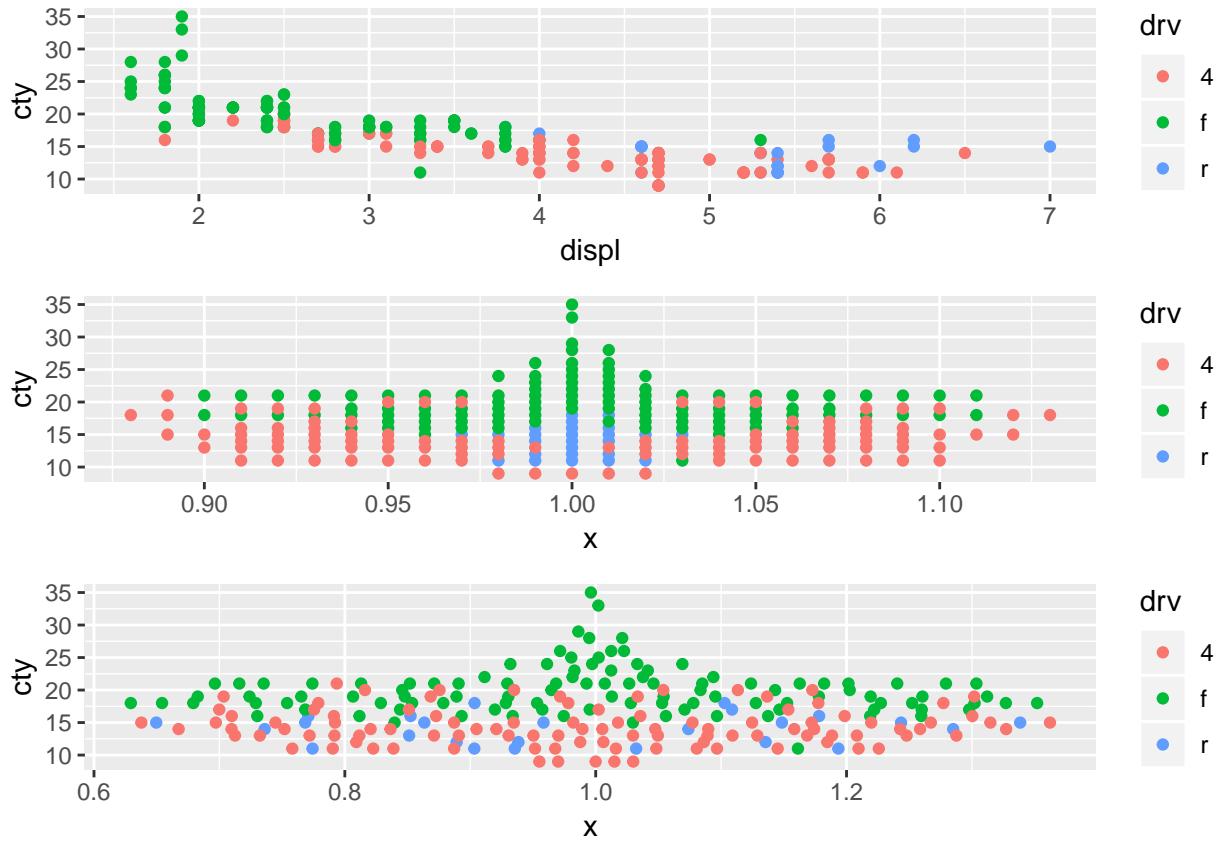
```
plot_orig <- ggplot(mpg, aes(x = displ, y = cty, color = drv))+
  geom_point()

plot_bees <- ggplot(mpg, aes(x = 1, y = cty, color = drv))+
  geom_beeswarm()

plot_quasi <- ggplot(mpg, aes(x = 1, y = cty, color = drv))+
  geom_quasirandom()

gridExtra::grid.arrange(plot_orig, plot_bees, plot_quasi, ncol = 1)
```

³Would need to read documentation for details.



9.3.2 7.5.2.1.

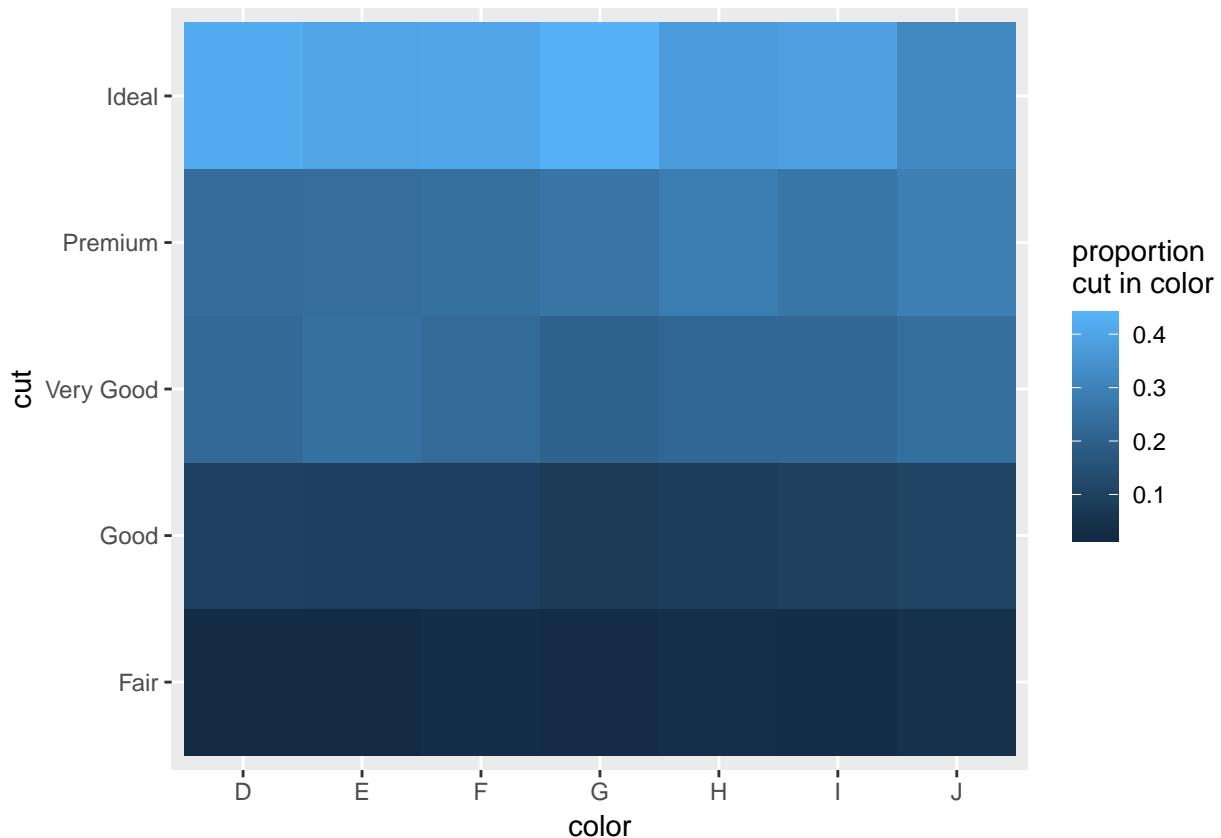
1. How could you rescale the count dataset above to more clearly show the distribution of cut within colour, or colour within cut?

Proportion cut in color:

(change `group_by` to `group_by(cut, color)` to set-up the converse)

```
cut_in_color_graph <- diamonds %>%
  group_by(color, cut) %>%
  summarise(n = n()) %>%
  mutate(proportion_cut_in_color = n/sum(n)) %>%
  ggplot(aes(x = color, y = cut)) +
  geom_tile(aes(fill = proportion_cut_in_color)) +
  labs(fill = "proportion\ncut in color")
```

`cut_in_color_graph`



This makes it clear that `ideal` cuts dominate the proportions of multiple colors, not just G. I thought am only so-so about this visualization with `geom_tile`... curious if someone had a better way of visualizing...?

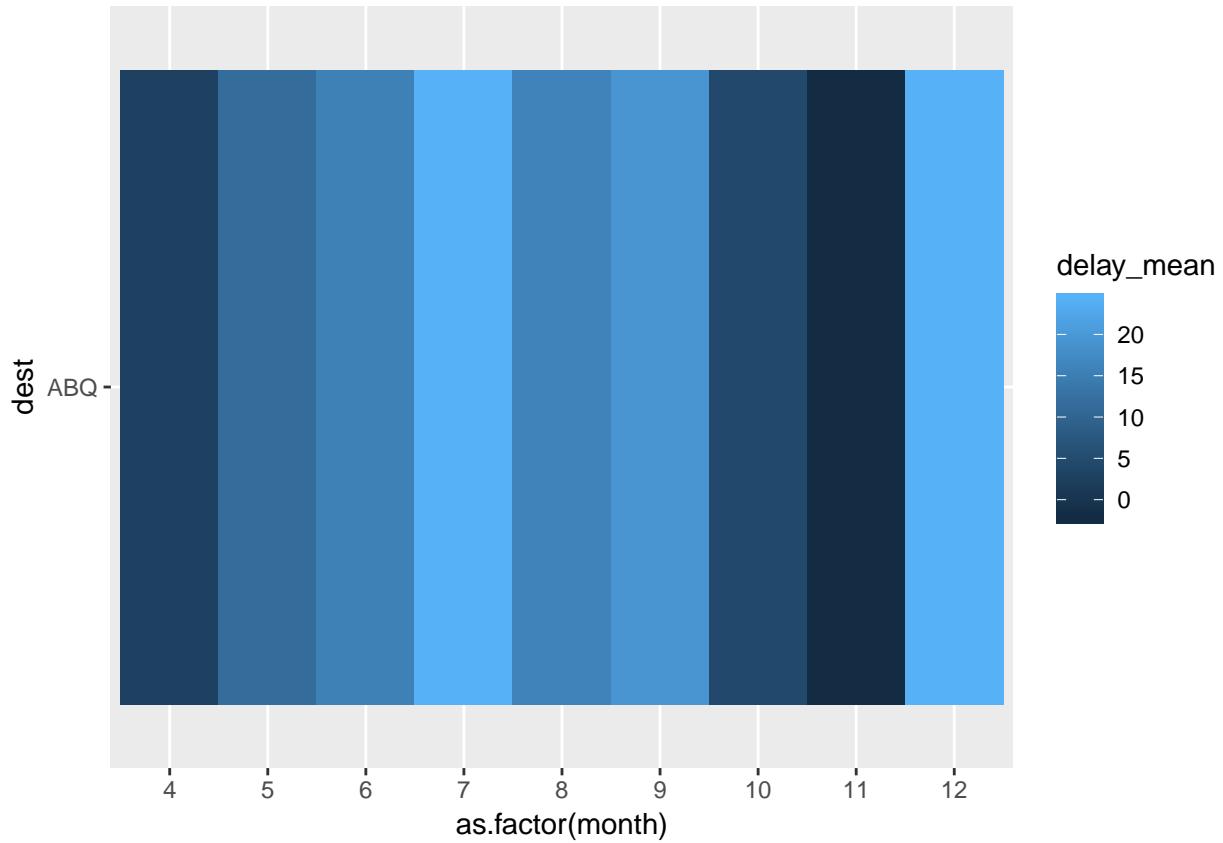
```
library(seriation)
library(d3heatmap)
library(heatmaply)
```

Did anyone explore these?

2. Use `geom_tile()` together with `dplyr` to explore how average flight delays vary by destination and month of year. What makes the plot difficult to read? How could you improve it?

I improved the original graph by adding in a filter so that only destinations that received over 10000 flights were included

```
flights %>%
  group_by(dest, month) %>%
  summarise(delay_mean = mean(dep_delay, na.rm=TRUE),
           n = n()) %>%
  mutate(sum_n = sum(n)) %>%
  select(dest, month, delay_mean, n, sum_n) %>%
  as.data.frame() %>%
  filter(dest == "ABQ") %>%
  #the sum on n will be at the dest level here
  filter(sum_n > 30) %>%
  ggplot(aes(x = as.factor(month), y = dest, fill = delay_mean))+
  geom_tile()
```

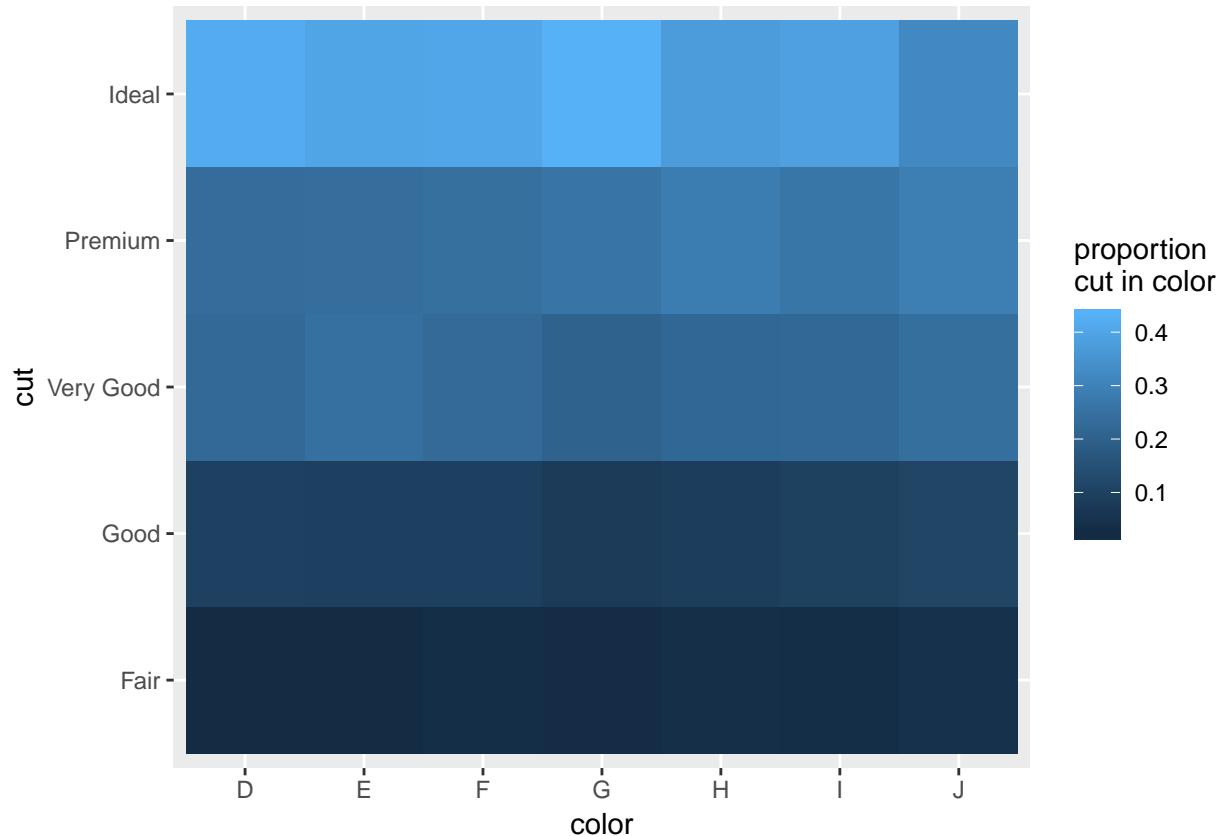


Another way to improve it may be to group the destinations into regions. This also will prevent you from filtering out data. We aren't given region information, but we do have lat and long points in the `airports` dataset. See appendix for notes.

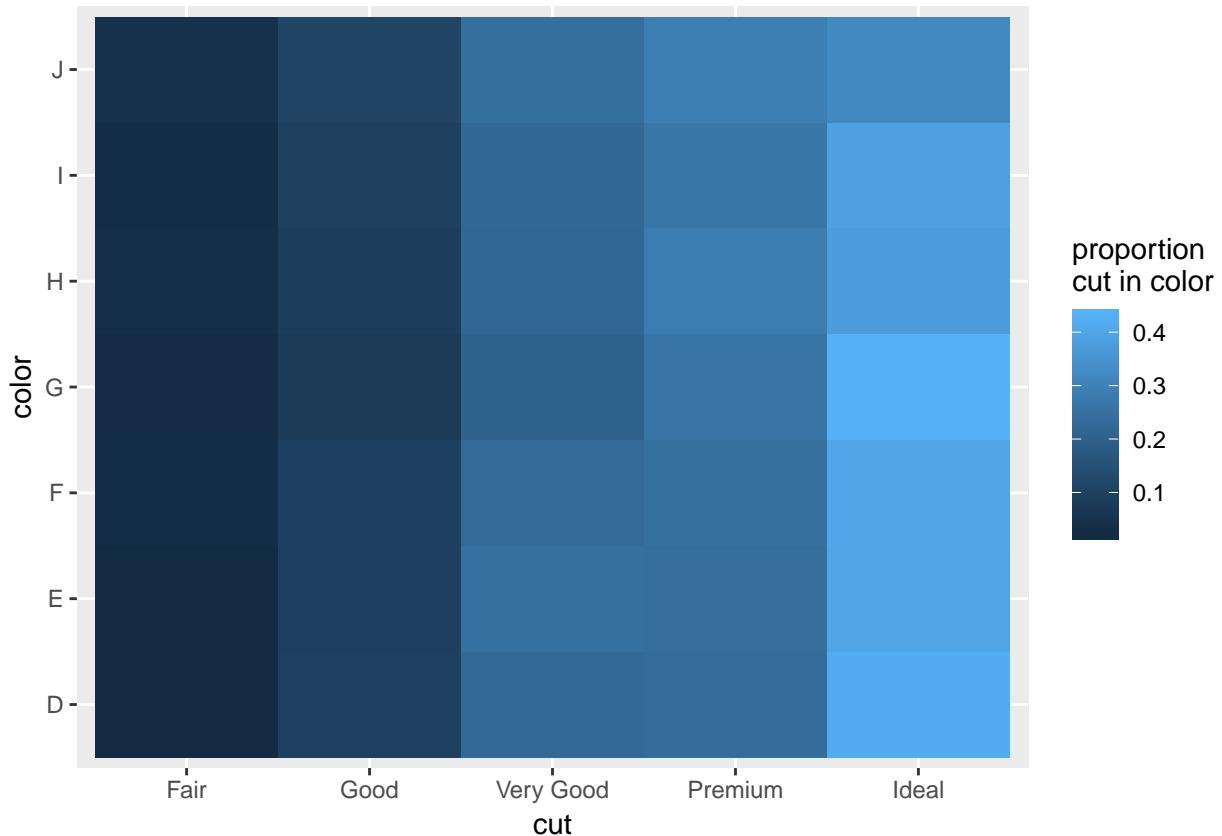
3. Why is it slightly better to use `aes(x = color, y = cut)` rather than `aes(x = cut, y = color)` in the example above?

If you're comparing the proportion of cut in color and want to be looking at how the specific cut proportion is changing, it may easier to view this while looking left to right vs. down to up. Compare the two plots below.

`cut_in_color_graph`



```
cut_in_color_graph+  
  coord_flip()
```

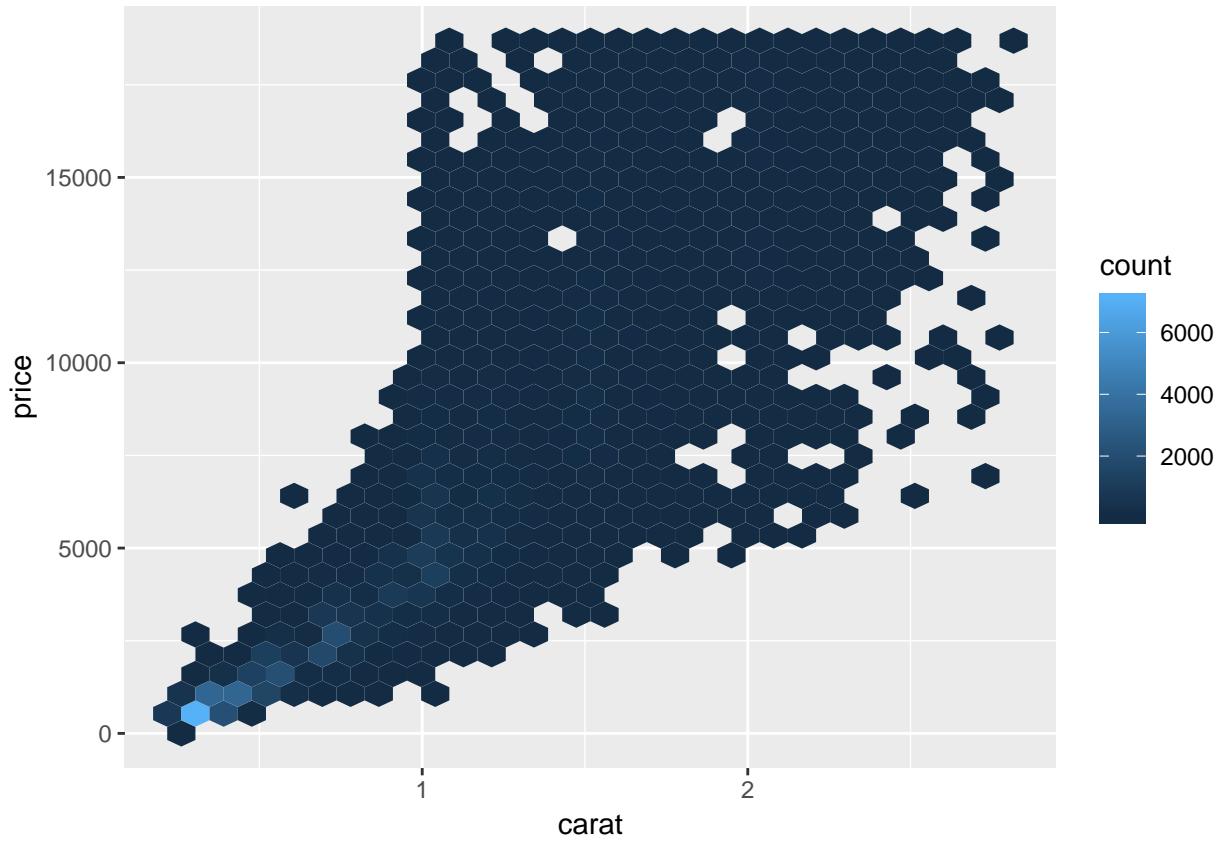


9.4 7.5.3 Two continuous variables

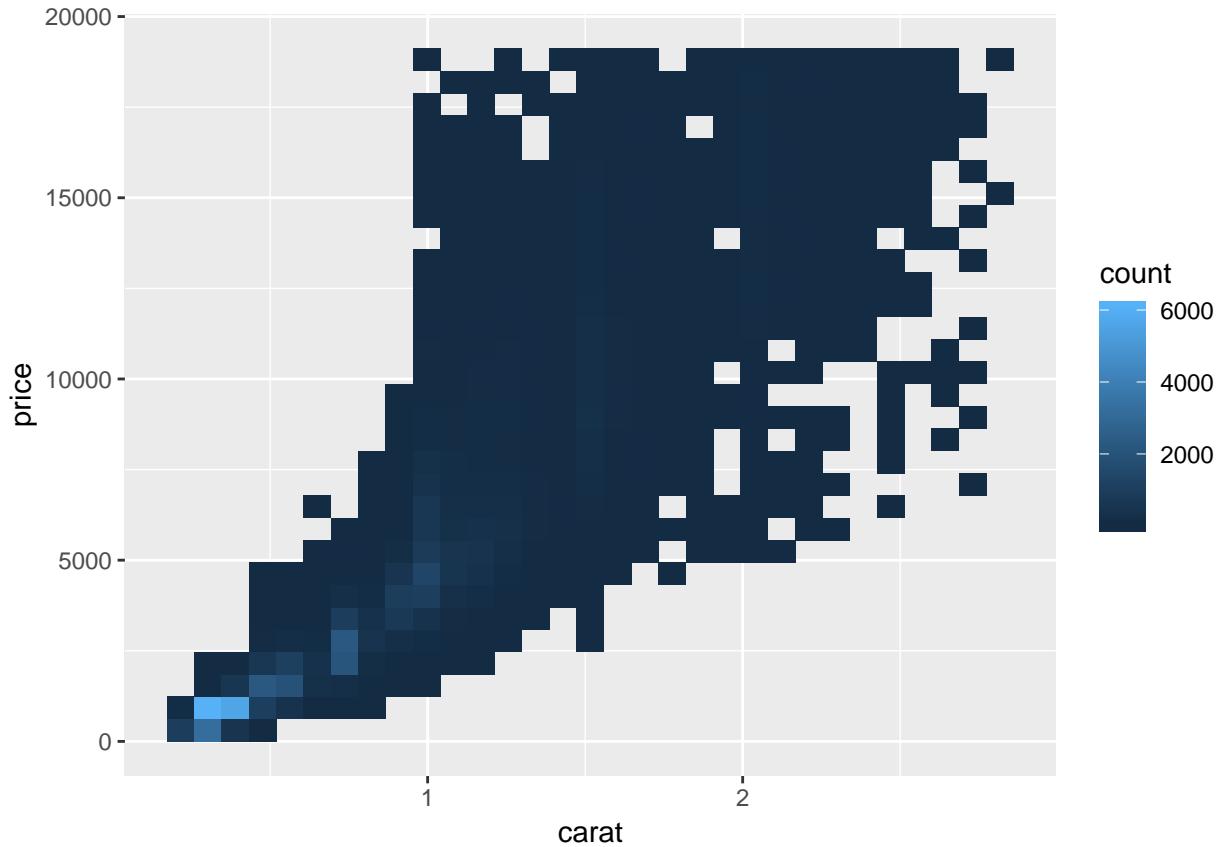
Two-d histograms

```
smaller <- diamonds %>%
  filter(carat < 3)

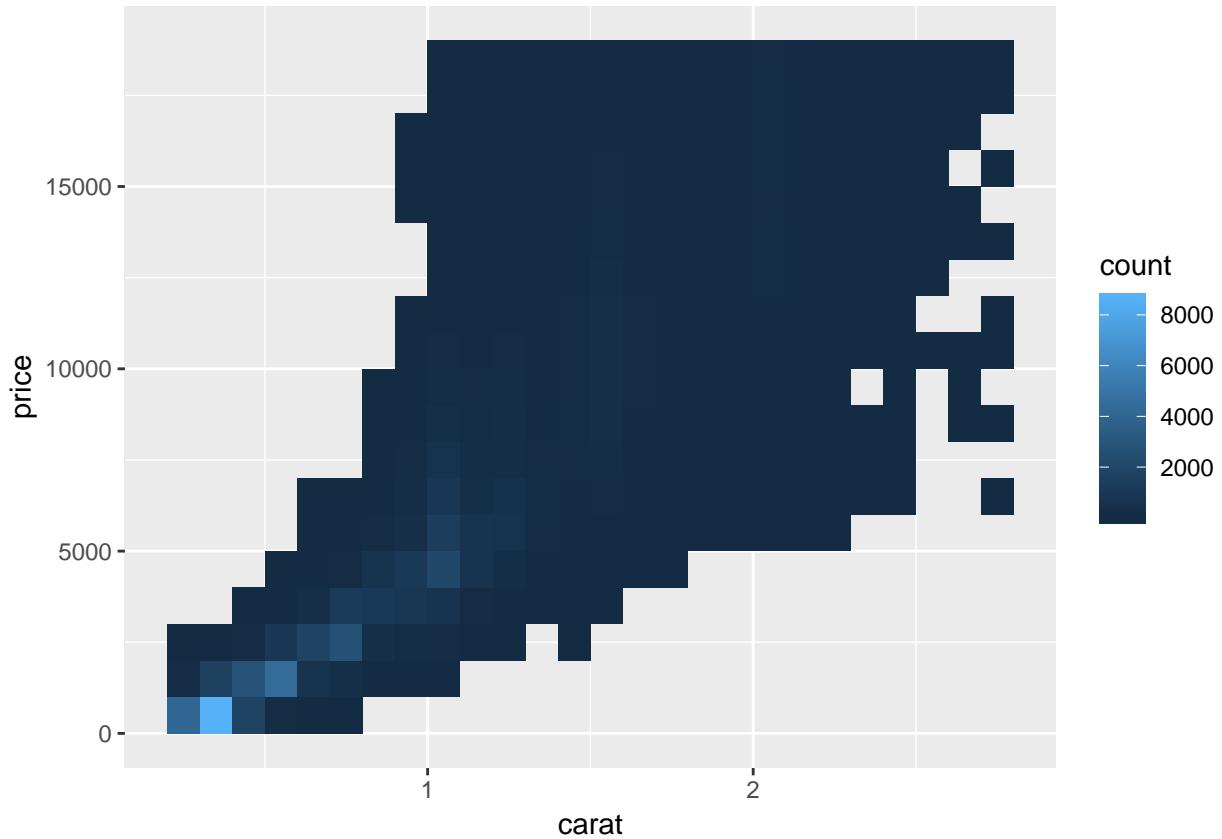
ggplot(data = smaller) +
  geom_hex(mapping = aes(x = carat, y = price))
```



```
#can change bin number
ggplot(data = smaller) +
  geom_hex(mapping = aes(x = carat, y = price), bins = c(30, 30))
```

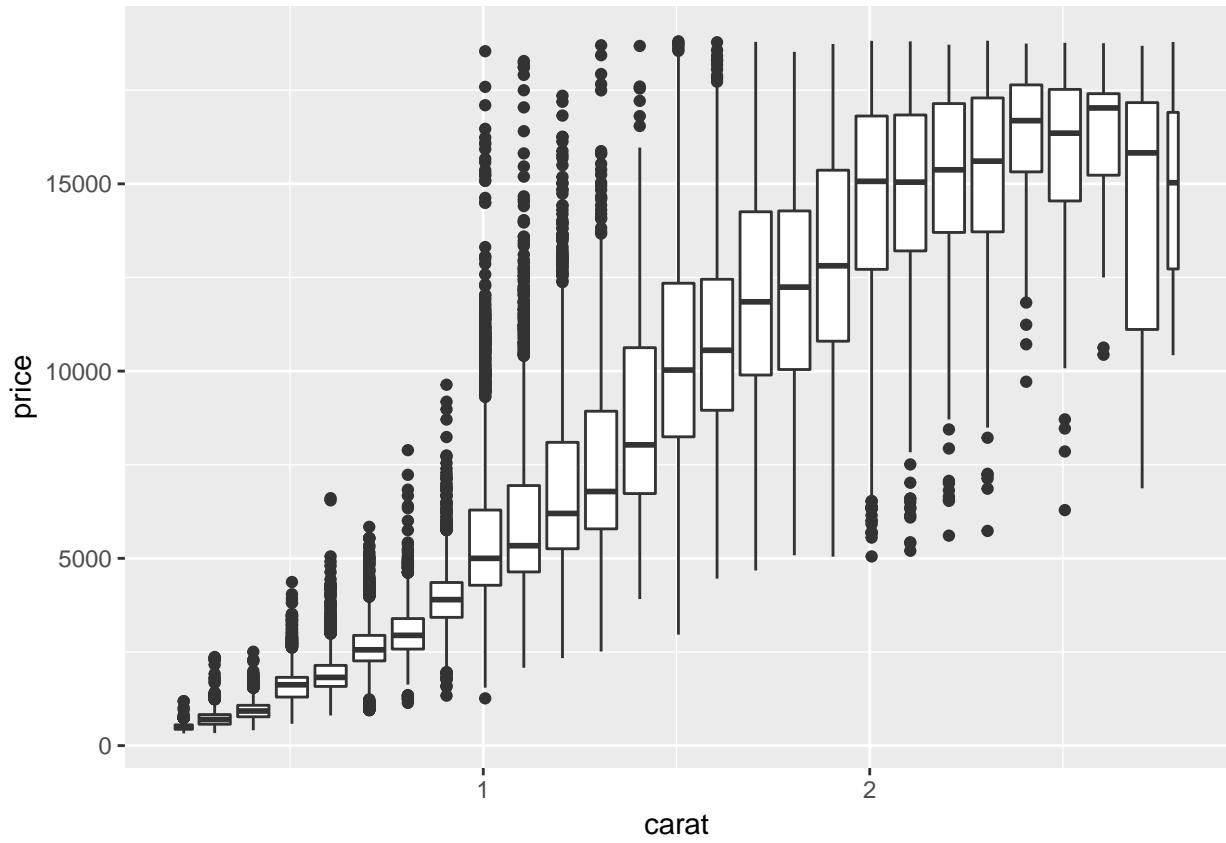


```
#or binwidth
ggplot(data = smaller) +
  geom_bin2d(mapping = aes(x = carat, y = price), binwidth = c(.1, 1000))
```

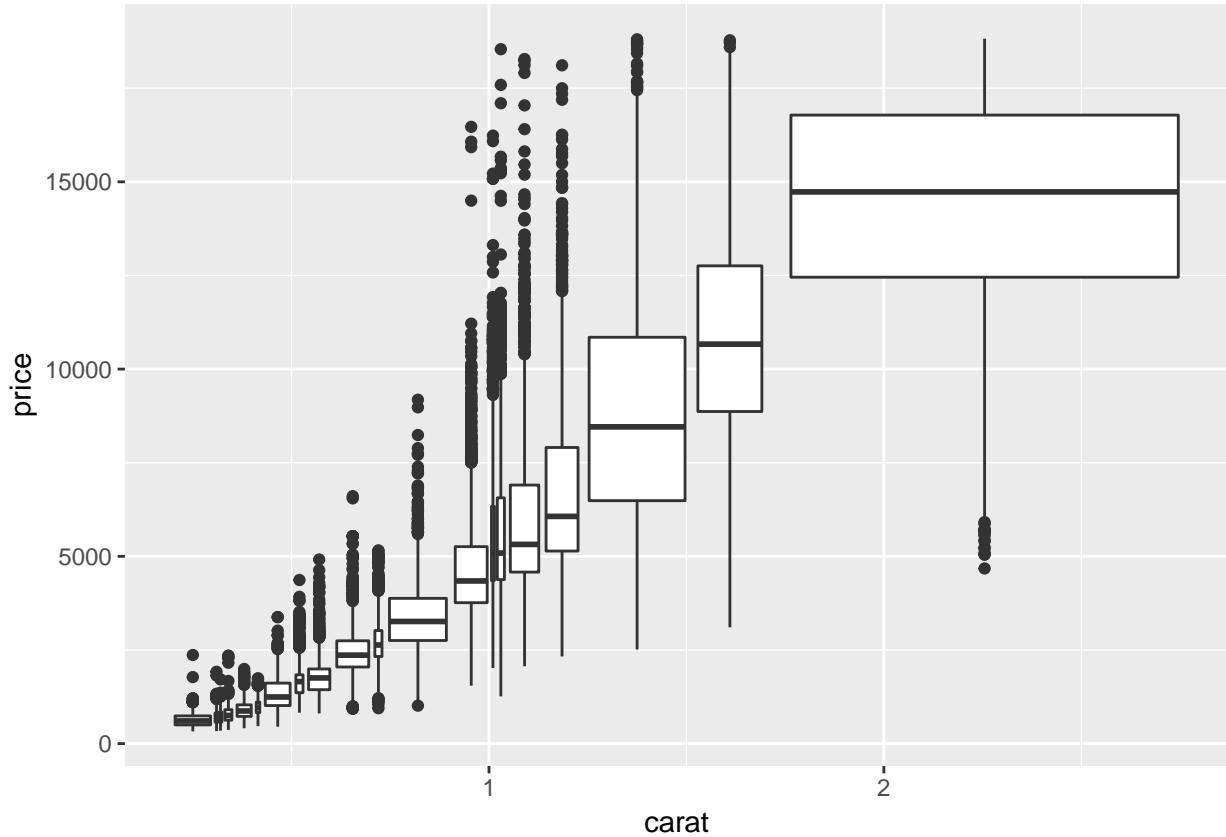


Binned boxplots, violins, and lvs

```
#split by width
ggplot(smaller, aes(x = carat, y = price))+
  geom_boxplot(aes(group = cut_width(carat, 0.1)))
```

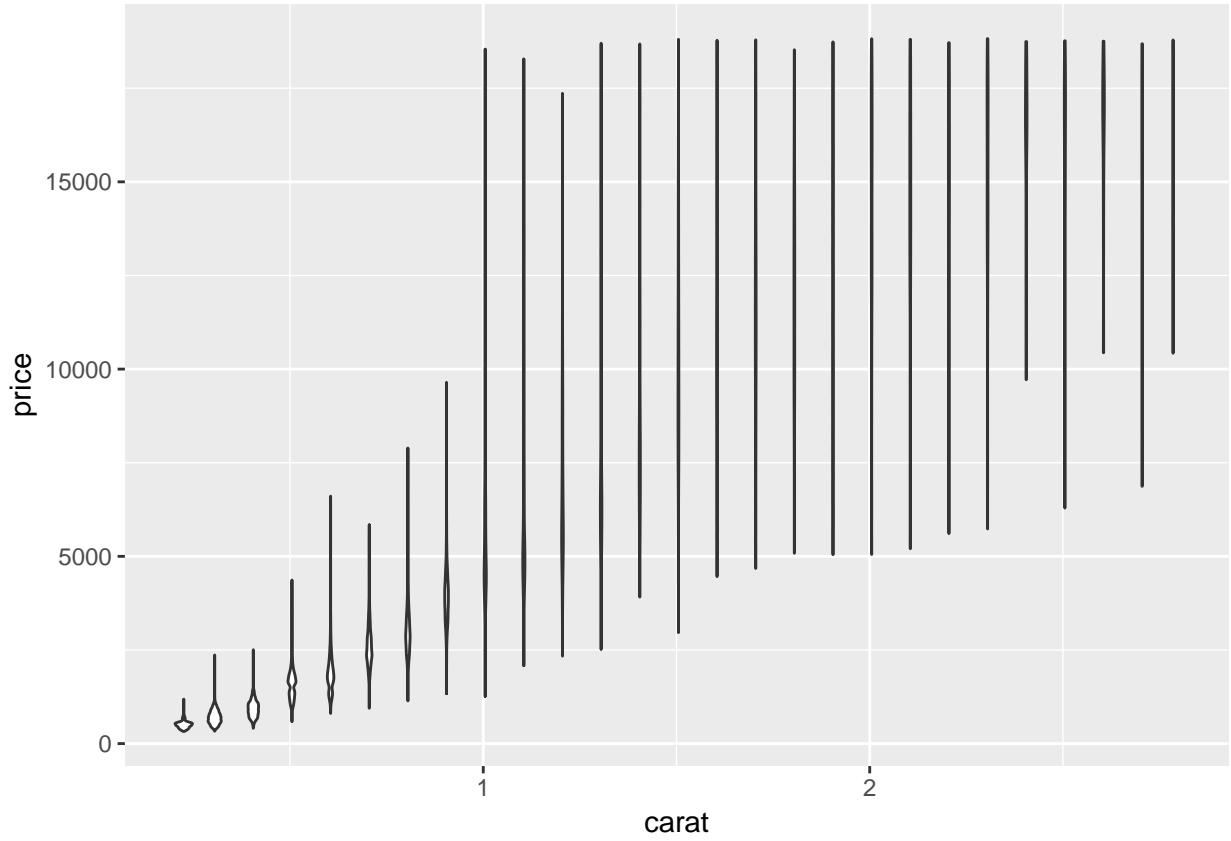


```
#split to get approximately same number in each box with cut_number()
ggplot(smaller, aes(x = carat, y = price))+
  geom_boxplot(aes(group = cut_number(carat, 20)))
```

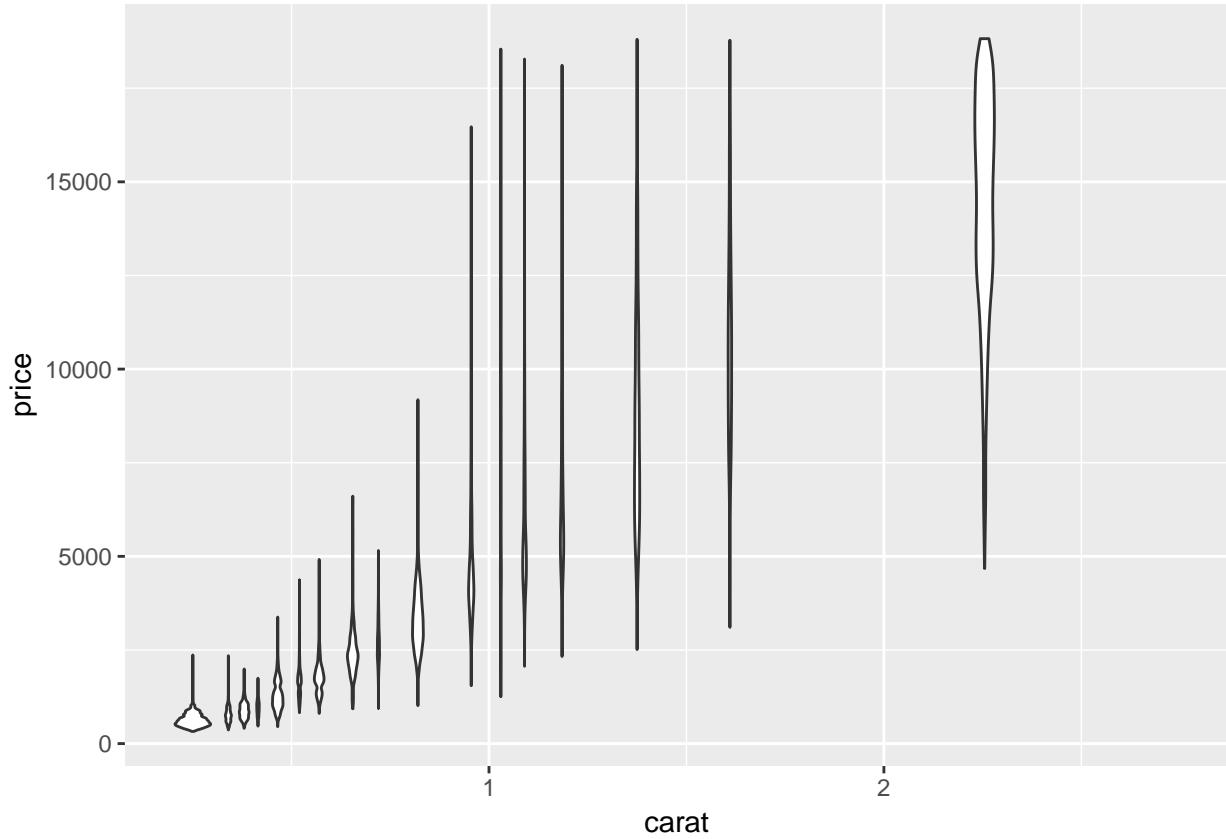


These methods don't seem to work quite as well with violin plots or letter value plots

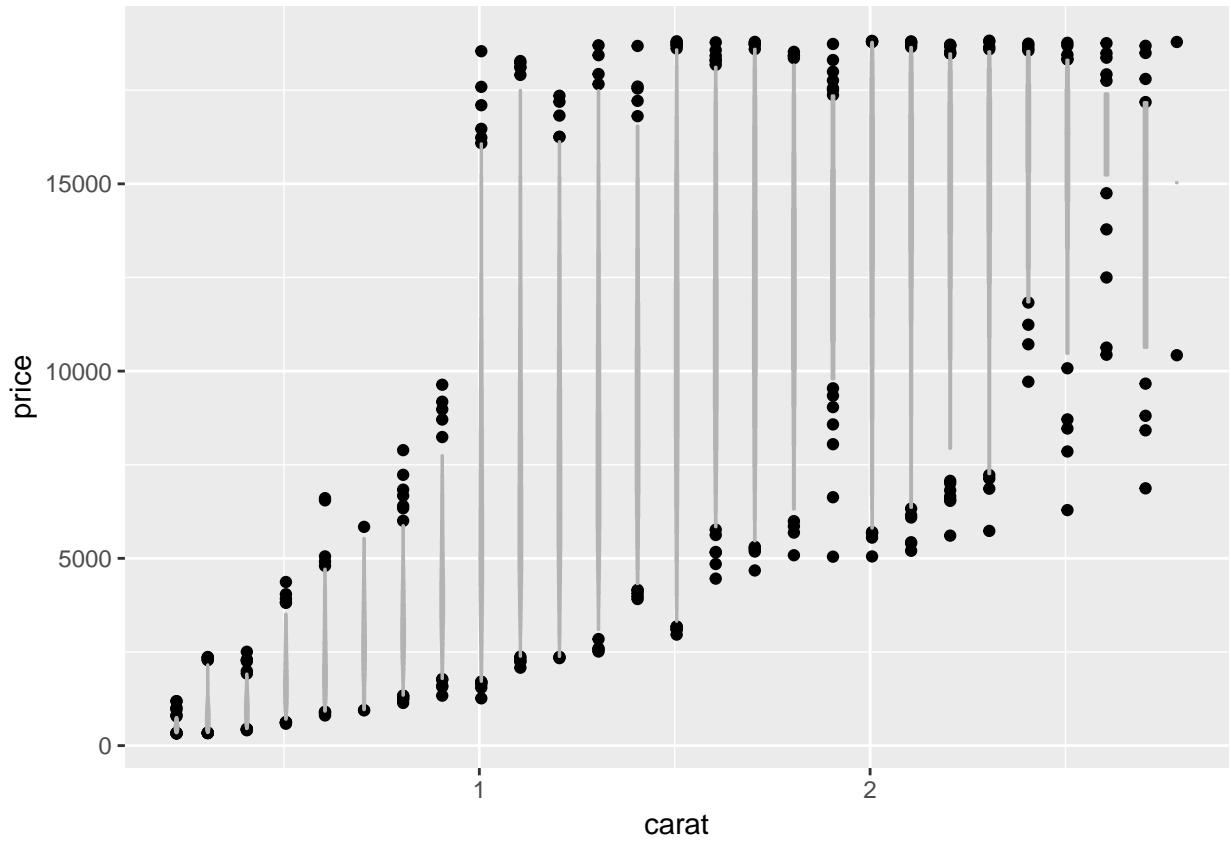
```
##violin
ggplot(smaller, aes(x = carat, y = price))+
  geom_violin(aes(group = cut_width(carat, 0.1)))
```



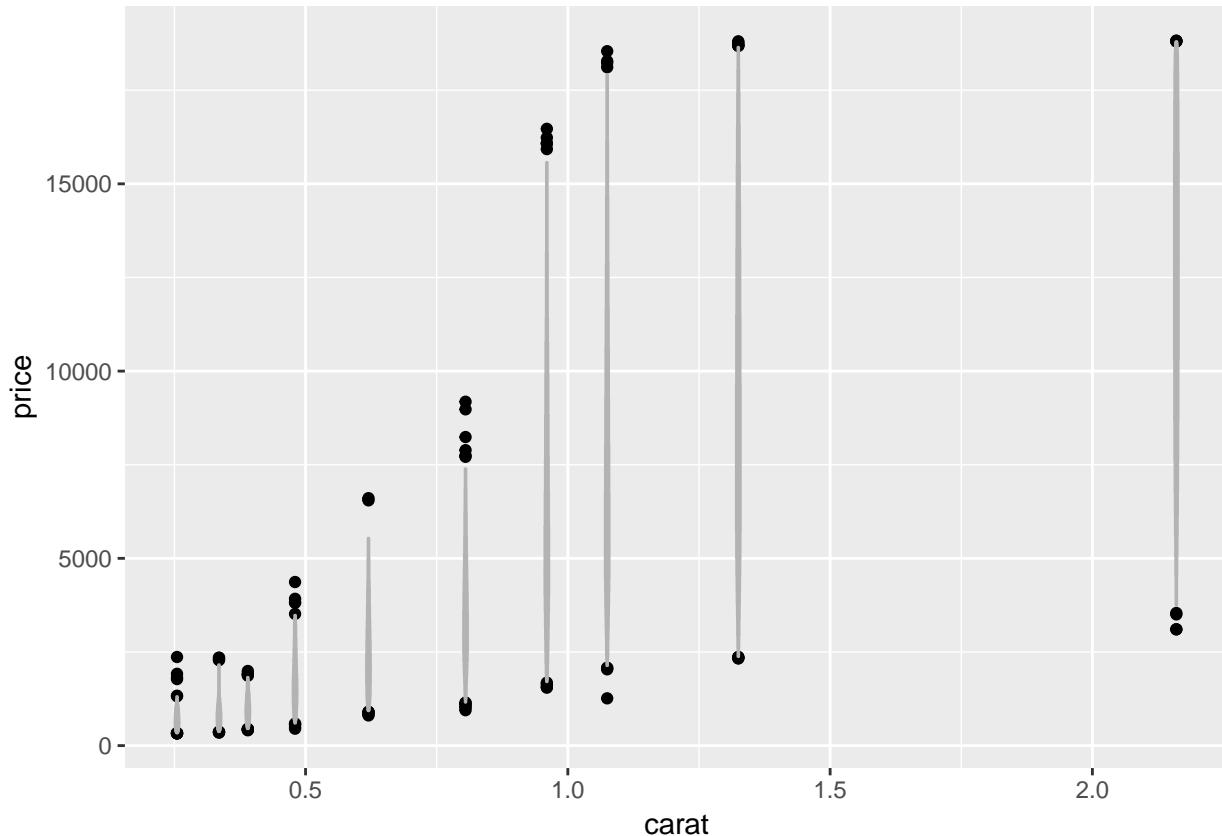
```
ggplot(smaller, aes(x = carat, y = price)) +  
  geom_violin(aes(group = cut_number(carat, 20)))
```



```
##letter value
ggplot(smaller, aes(x = carat, y = price))+
  lvplot::geom_lv(aes(group = cut_width(carat, 0.1)))
```

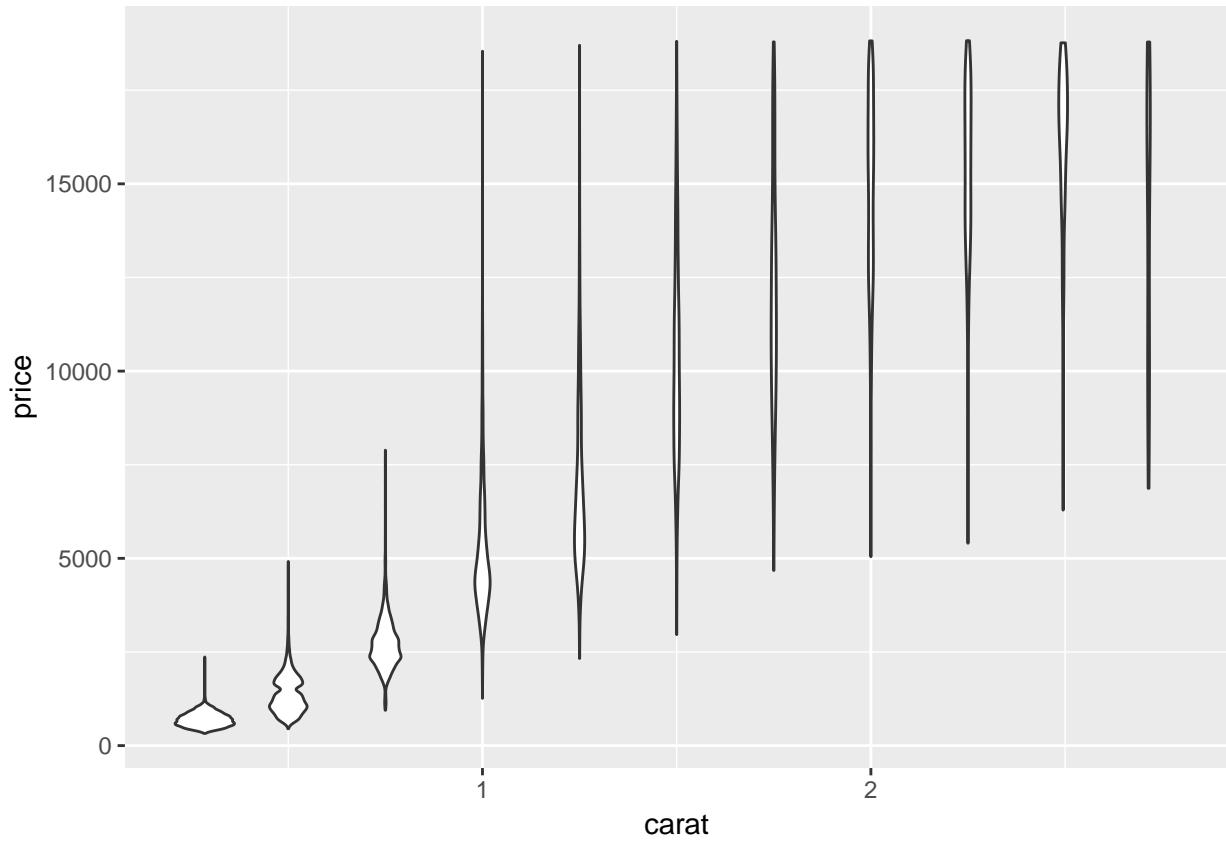


```
ggplot(smaller, aes(x = carat, y = price)) +  
  lvplot::geom_lv(aes(group = cut_number(carat, 10)))
```



But that may be because there is not enough information in each bin, they may be more effective with smaller bin sizes... Interested if anyone found more effective methods for using things other than boxplots with this binning style?

```
ggplot(smaller, aes(x = carat, y = price)) +  
  geom_violin(aes(group = cut_width(carat, .25)))
```



9.4.1 7.5.3.1.

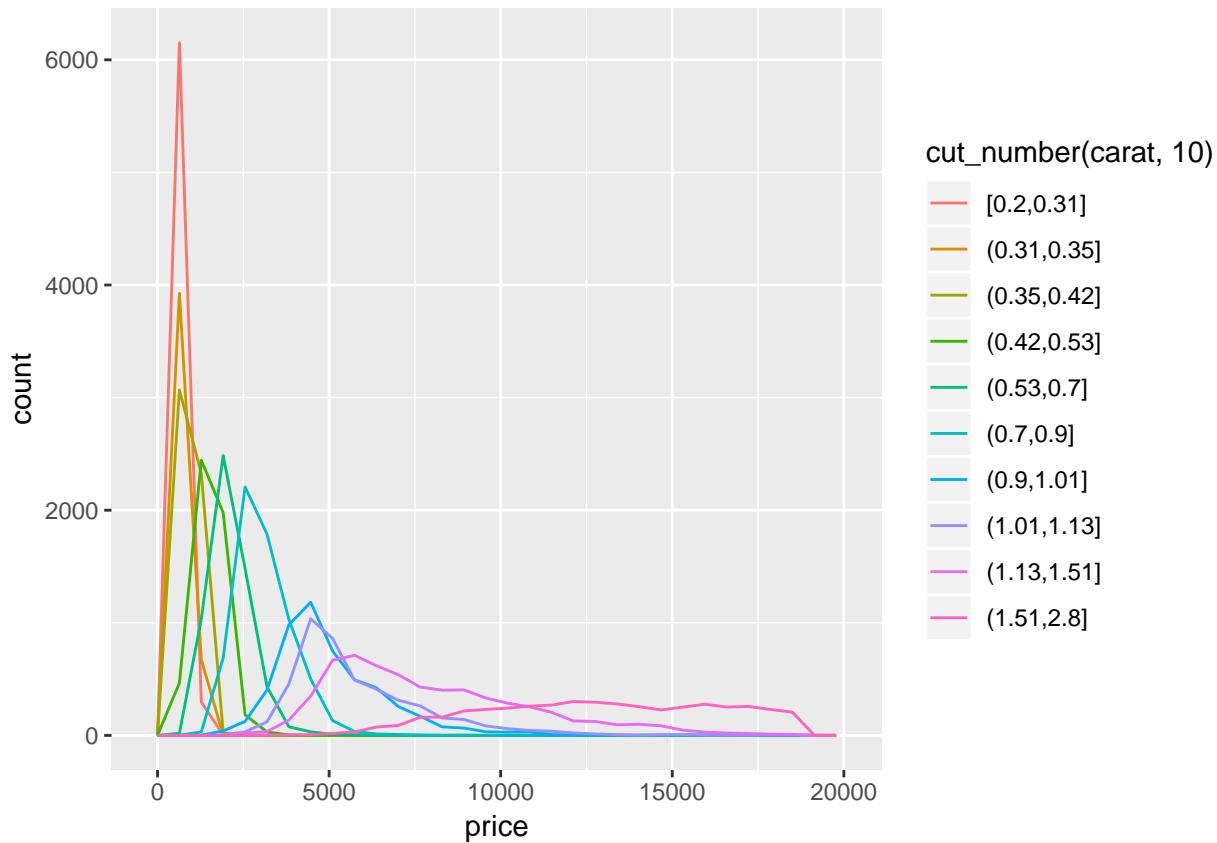
1. Instead of summarising the conditional distribution with a boxplot, you could use a frequency polygon. What do you need to consider when using `cut_width()` vs `cut_number()`? How does that impact a visualisation of the 2d distribution of carat and price?

You should keep in mind how many lines you are going to create, they may overlap each other and look busy if you're not careful.

For the visualization below I wrapped it in the function `ggplotly`. This function wraps your ggplot in html so that you can do things like hover over the points

```
ggplot(smaller, aes(x=price)) +
  geom_freqpoly(aes(colour = cut_number(carat, 10)))
```

`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.

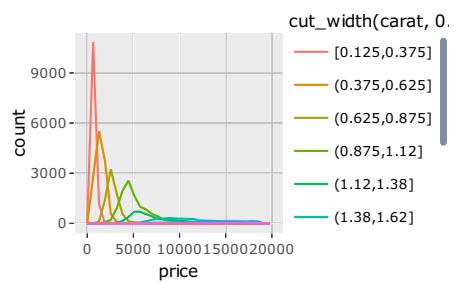


However, I set the code chunks such that it will only execute for html, not markdown docs.

```
p <- ggplot(smaller, aes(x=price)) +
  geom_freqpoly(aes(colour = cut_width(carat, 0.25)))

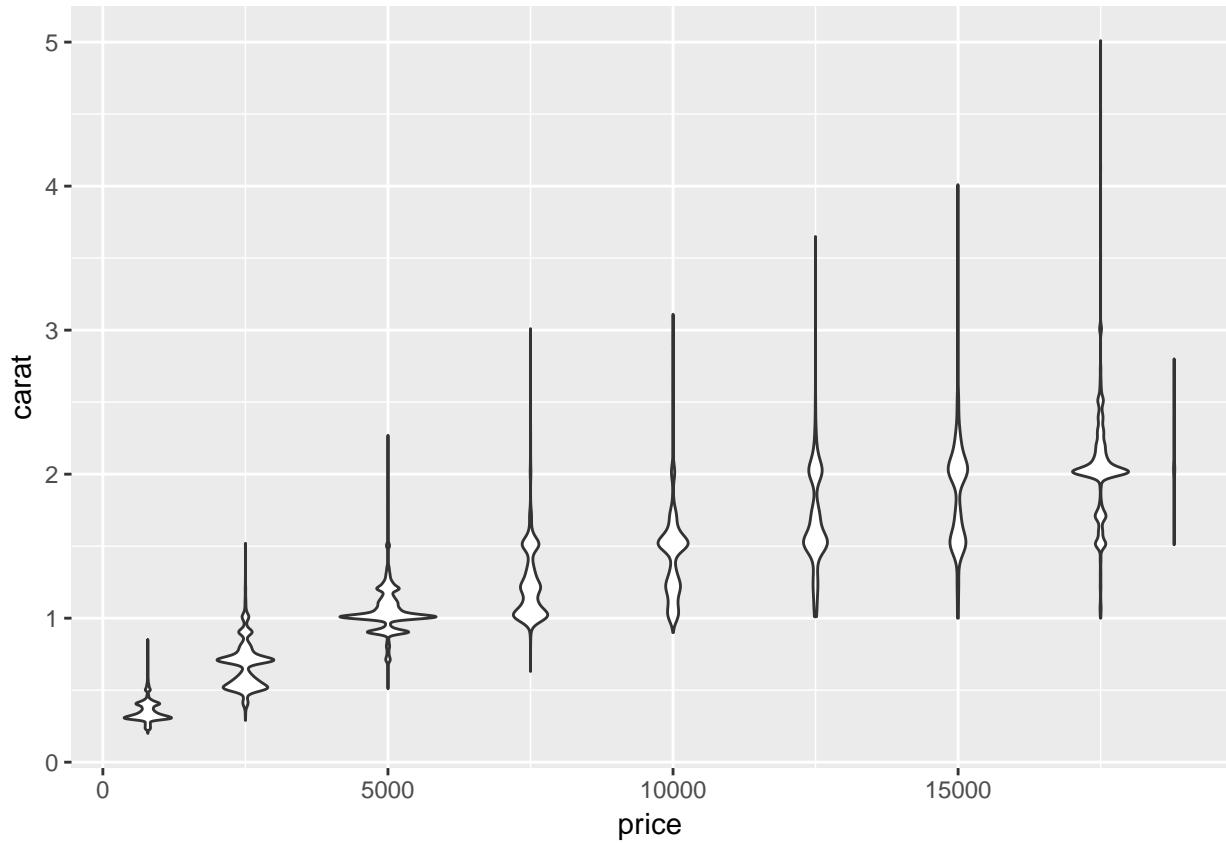
plotly::ggplotly(p)
```

`stat_bin()` using `bins = 30`. Pick better value with `binwidth`.



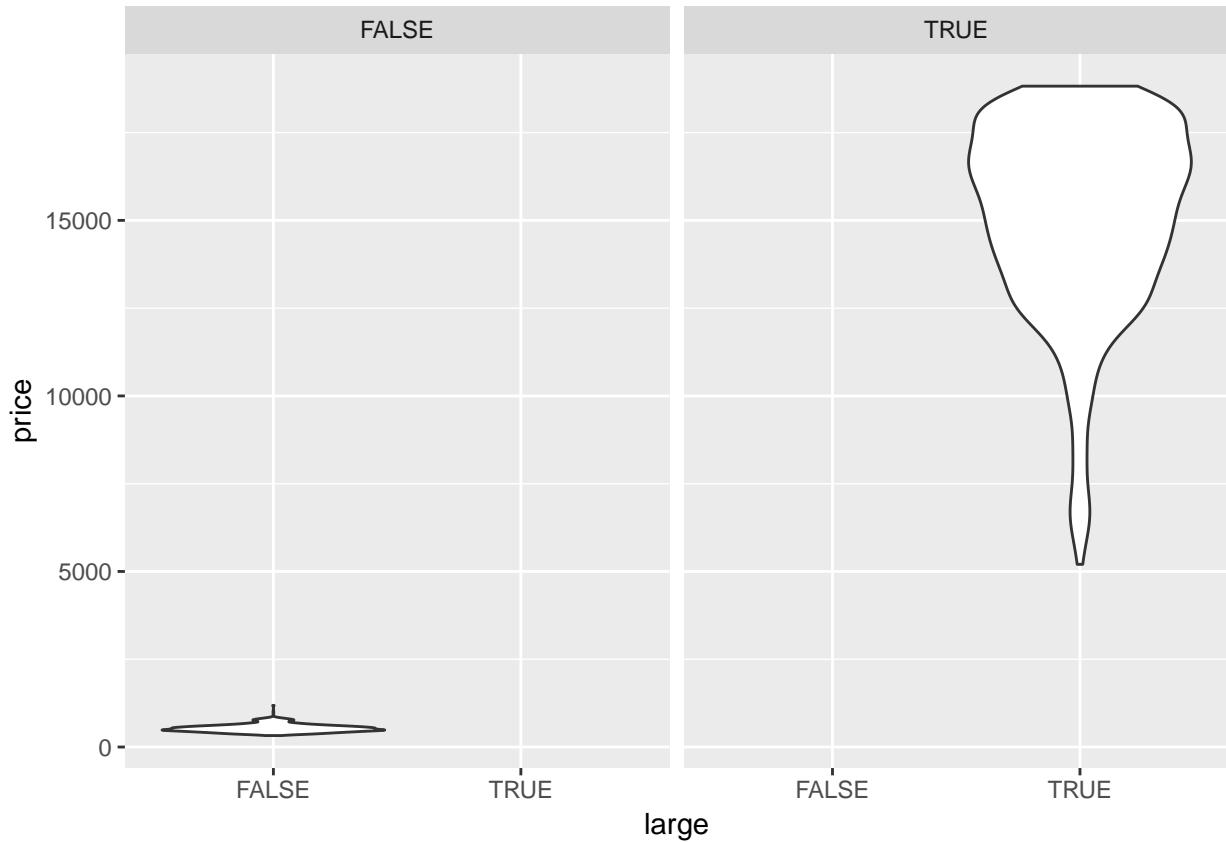
2. Visualise the distribution of carat, partitioned by price.

```
ggplot(diamonds, aes(x = price, y = carat)) +  
  geom_violin(aes(group = cut_width(price, 2500)))
```



3. How does the price distribution of very large diamonds compare to small diamonds. Is it as you expect, or does it surprise you?

```
diamonds %>%
  mutate(percent_rank = percent_rank(carat),
        small = percent_rank < 0.025,
        large = percent_rank > 0.975) %>%
  filter(small | large) %>%
  ggplot(aes(large, price)) +
  geom_violin() +
  facet_wrap(~large)
```

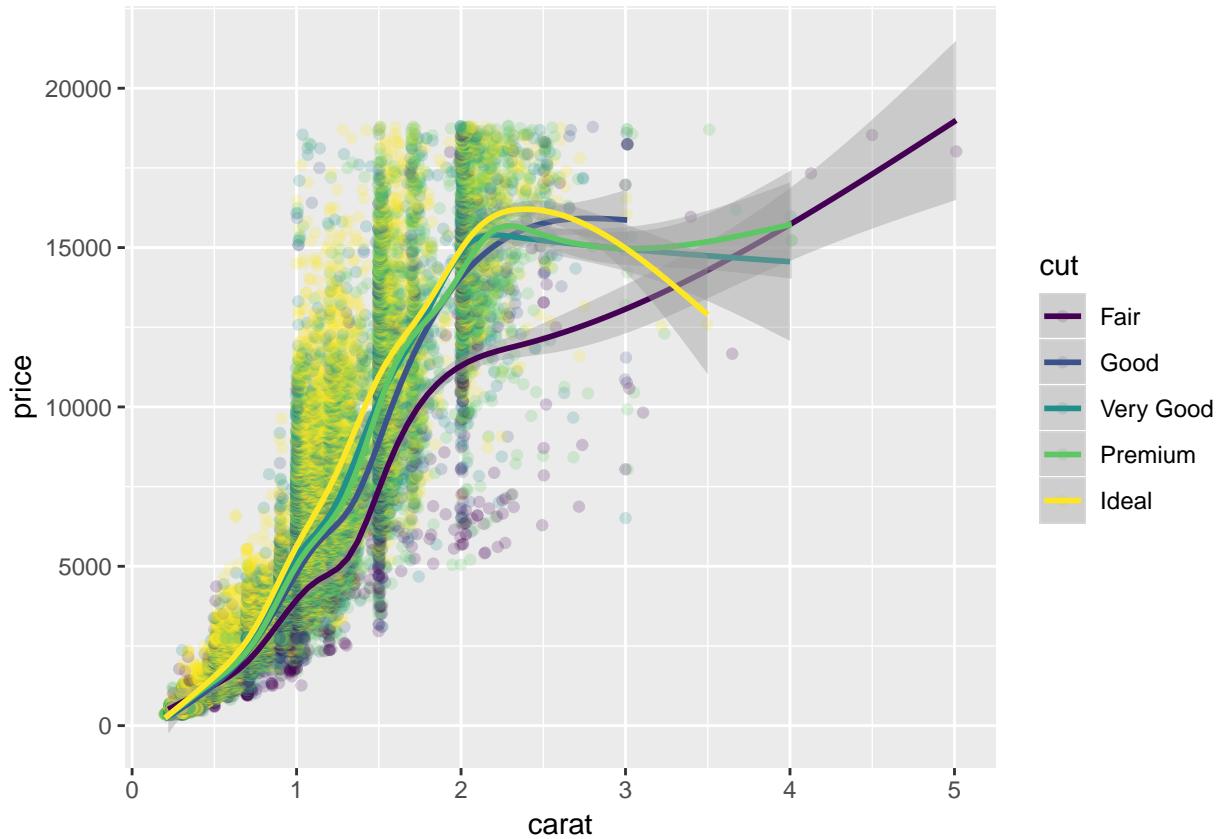


Small diamonds have a left-skewed distribution, whereas large diamonds have a right skewed distribution.

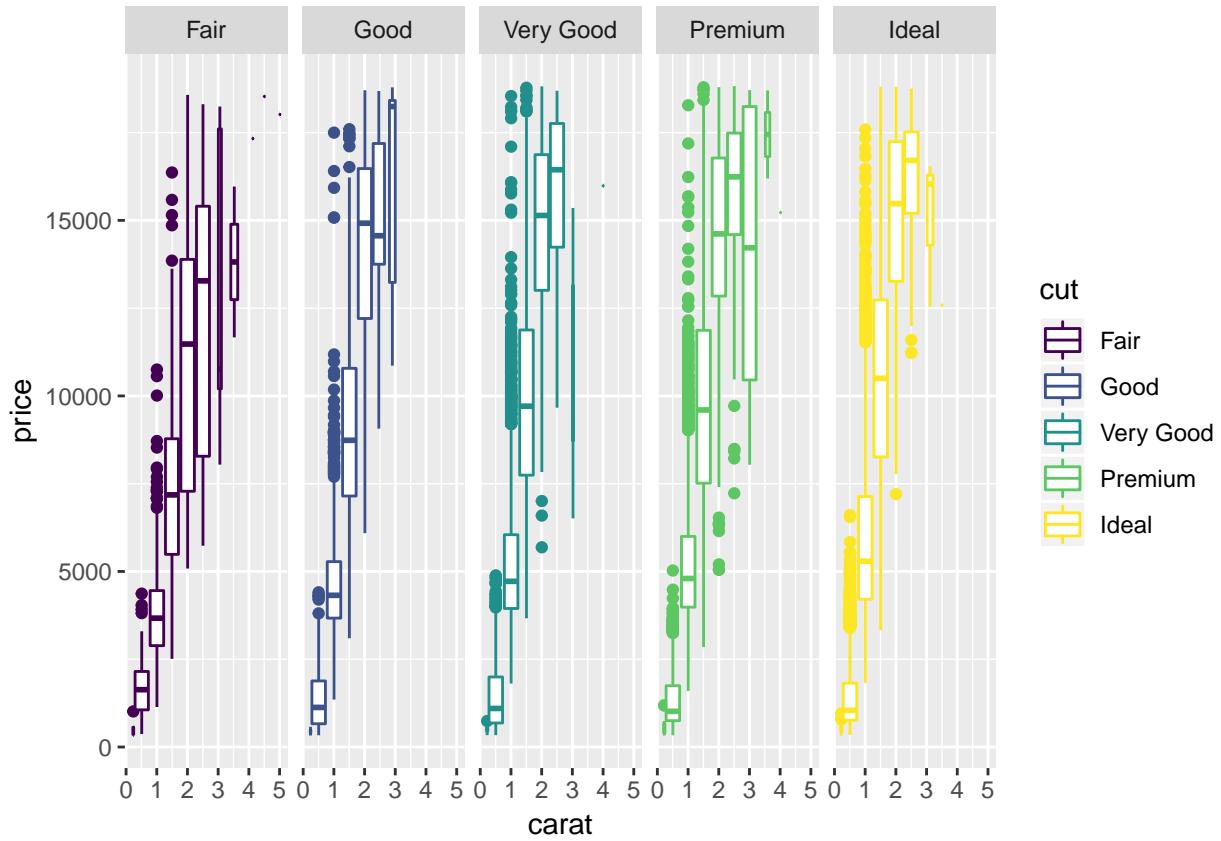
4. Combine two of the techniques you've learned to visualise the combined distribution of cut, carat, and price.

```
ggplot(diamonds, aes(x = carat, y = price))+
  geom_jitter(aes(colour = cut), alpha = 0.2)+
  geom_smooth(aes(colour = cut))
```

```
## `geom_smooth()` using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```

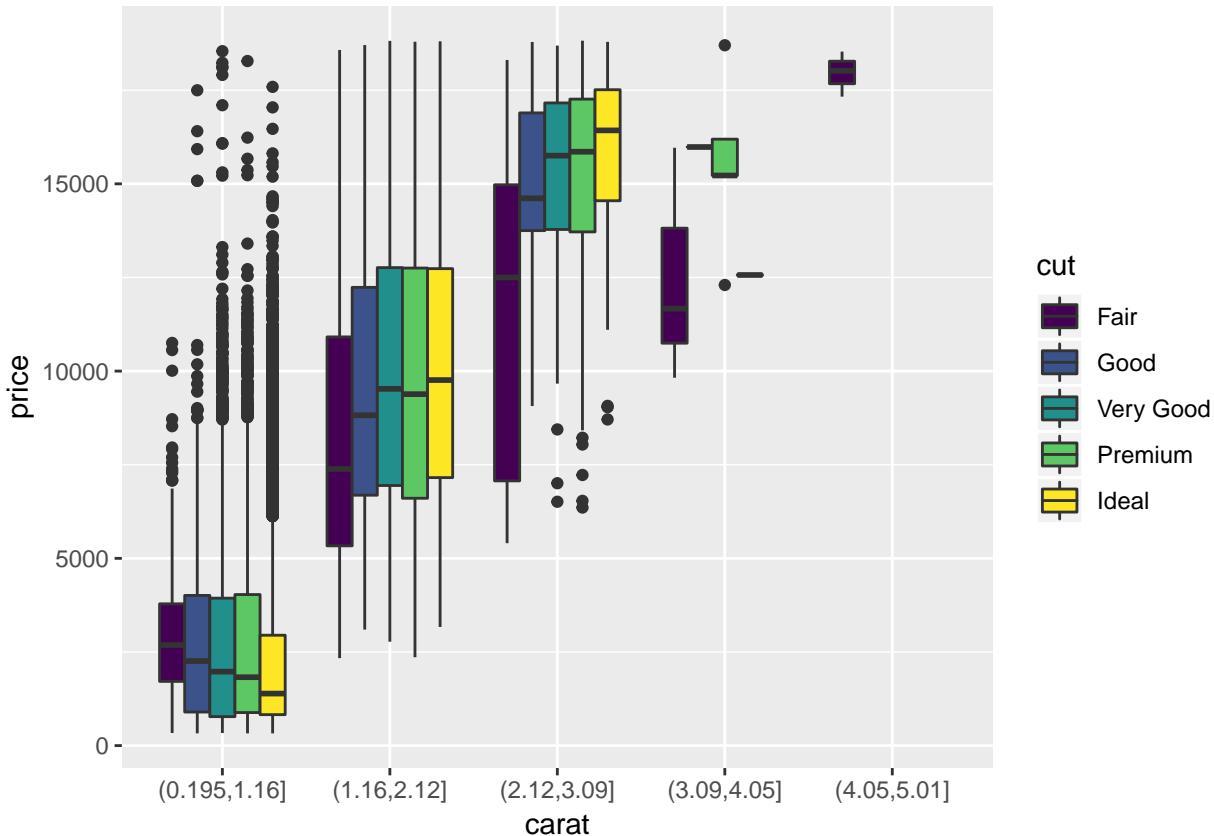


```
ggplot(diamonds, aes(x = carat, y = price)) +  
  geom_boxplot(aes(group = cut_width(carat, 0.5), colour = cut)) +  
  facet_grid(. ~ cut)
```



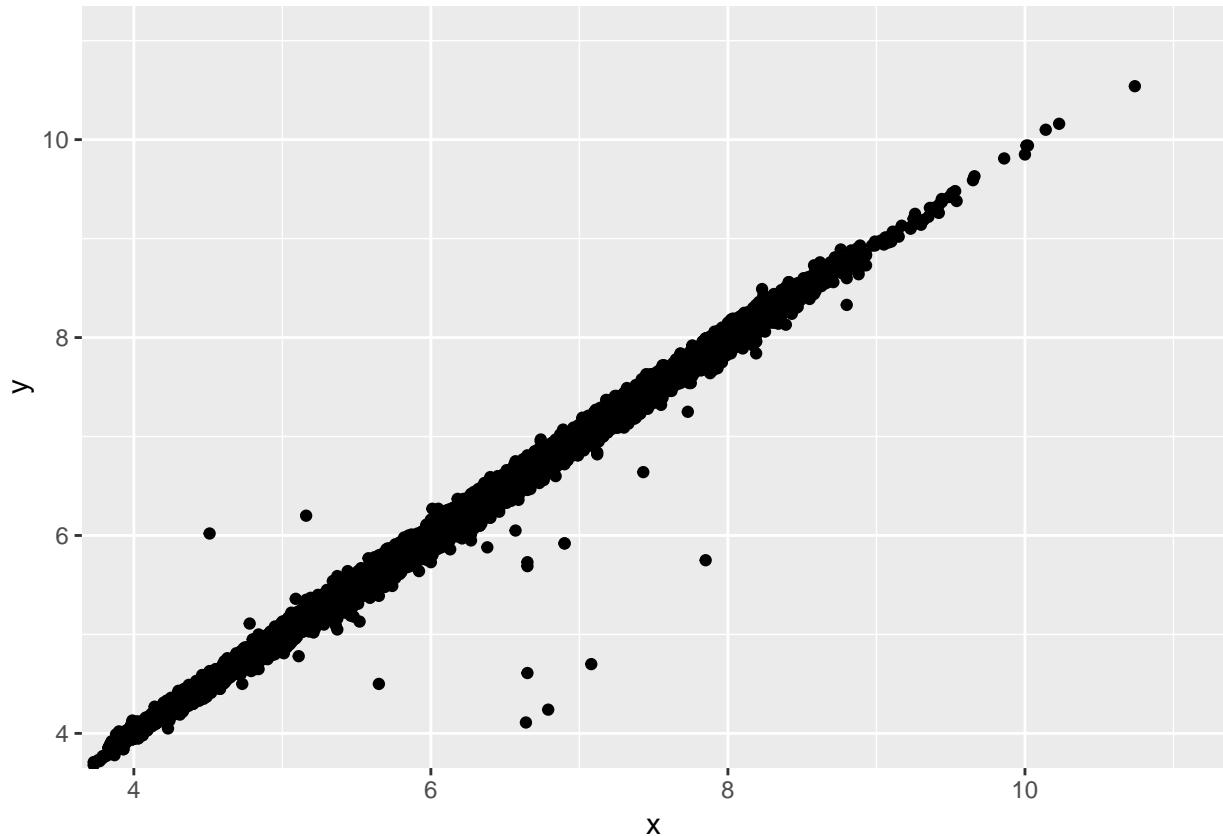
```
##I think this gives a better visualization, but is a little more complicated to produce, I also have to
diamonds %>%
  mutate(carat = cut(carat, 5)) %>%
  ggplot(aes(x = carat, y = price)) +
  geom_boxplot(aes(group = interaction(cut_width(carat, 0.5), cut), fill = cut), position = position_dodge(0.5))
```

```
mutate(carat = cut(carat, 5)) %>%
  ggplot(aes(x = carat, y = price)) +
  geom_boxplot(aes(group = interaction(cut_width(carat, 0.5), cut), fill = cut), position = position_dodge(0.5))
```



5. Two dimensional plots reveal outliers that are not visible in one dimensional plots. For example, some points in the plot below have an unusual combination of x and y values, which makes the points outliers even though their x and y values appear normal when examined separately.

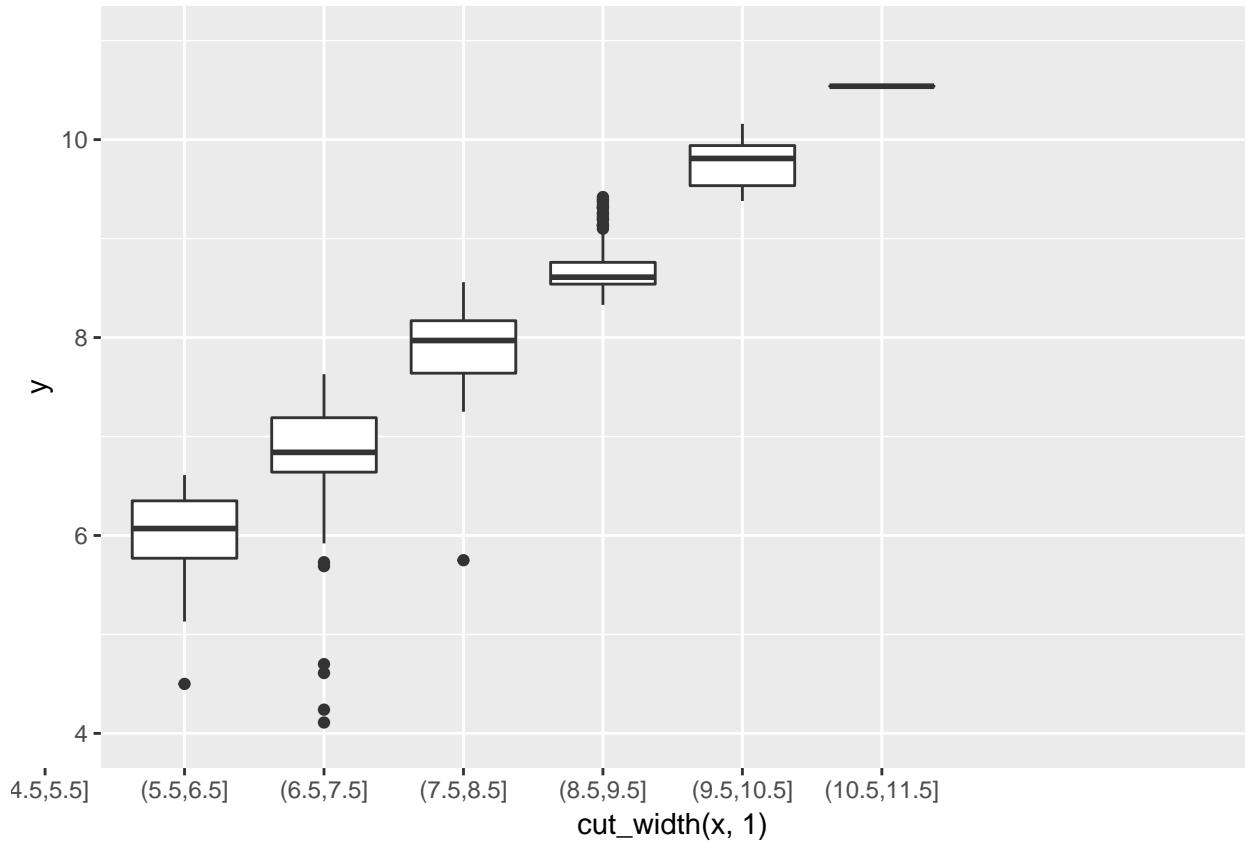
```
ggplot(data = diamonds) +
  geom_point(mapping = aes(x = x, y = y)) +
  coord_cartesian(xlim = c(4, 11), ylim = c(4, 11))
```



Why is a scatterplot a better display than a binned plot for this case?

Binned plots give less precise value estimates at each point (constrained by the granularity of the binning) so outliers do not show-up as clearly. They also show less precise relationships between the data. The level of variability (at least with boxplots) can also be tougher to intuit. For example, let's look at the plot below as a binned boxplot.

```
ggplot(data = diamonds) +
  geom_boxplot(mapping = aes(x = cut_width(x, 1), y = y)) +
  coord_cartesian(xlim = c(4, 11), ylim = c(4, 11))
```



Chapter 10

Appendix

10.1 7.5.2.1.2.

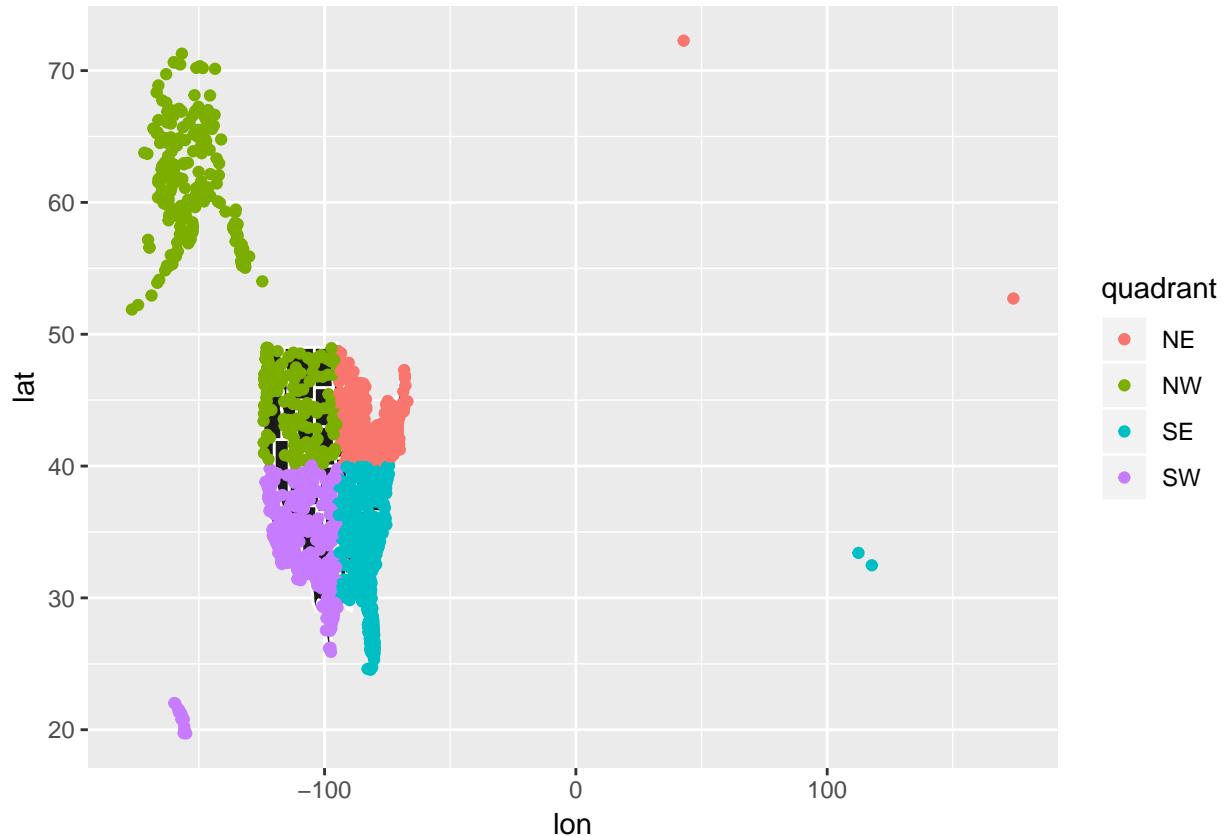
Plot below shows four regions I'll split the country into. Seems like for a few destinations the lat and long points were likely misentered (probably backwards).

```
all_states <- map_data("state")
p <- geom_polygon( data=all_states, aes(x=long, y=lat, group = group, label = NULL), colour="white", fill="white")

dest_regions <- nycflights13::airports %>%
  mutate(lat_cut = cut(percent_rank(lat), 2, labels = c("S", "N")),
        lon_cut = cut(percent_rank(lon), 2, labels = c("W", "E")),
        quadrant = paste0(lat_cut, lon_cut))

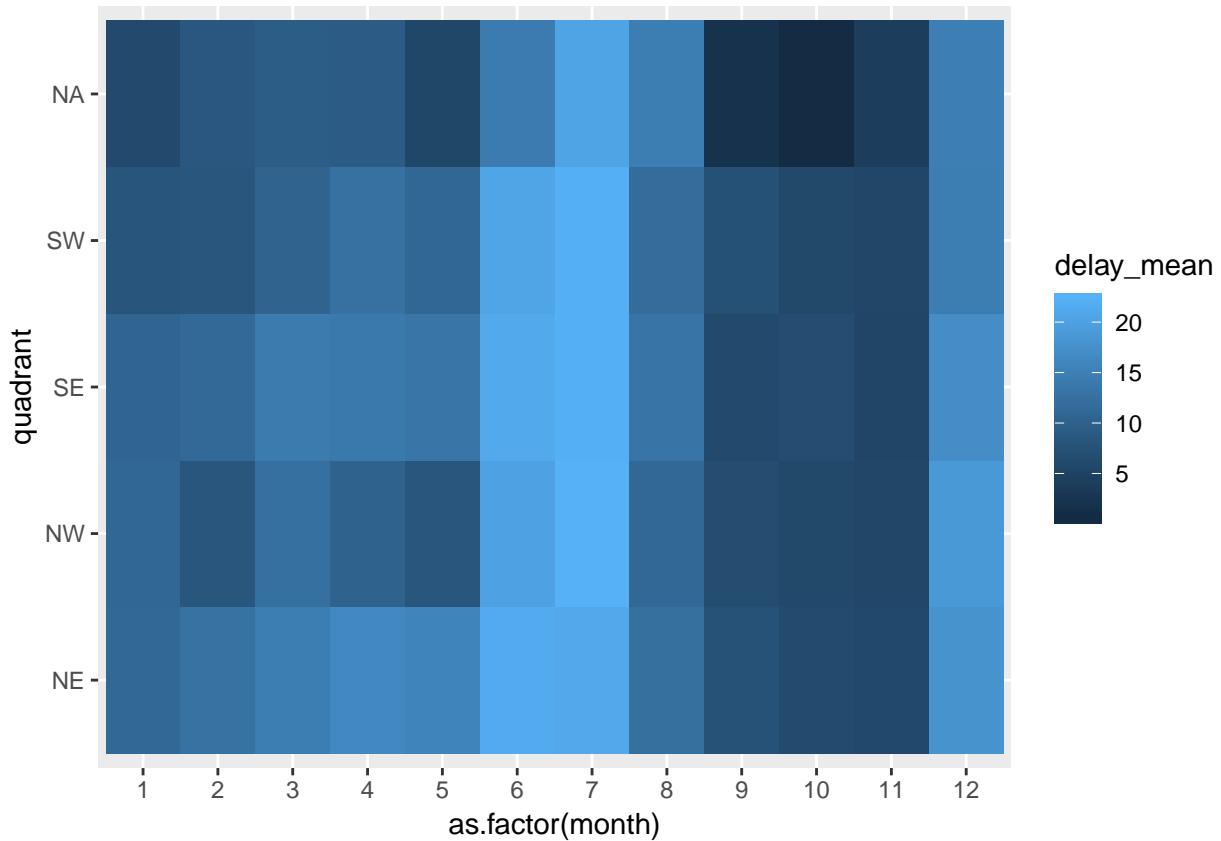
point_plot <- dest_regions %>%
  ggplot(aes(lon, lat, colour = quadrant)) +
  p +
  geom_point()

point_plot
```



Now let's join our region information with our flight data and do our calculations grouping by `quadrant` rather than `dest`. Note that those quadrants with NA (did not join with `flights`) looked to be Puerto Rico or other non-state locations.

```
flights %>%
  left_join(dest_regions, by = c("dest" = "faa")) %>%
  group_by(quadrant, month) %>%
  summarise(delay_mean = mean(dep_delay, na.rm=TRUE),
           n = n()) %>%
  mutate(sum_n = sum(n)) %>%
  #the sum on n will be at the dest level here
  # filter(sum_n > 10000) %>%
  ggplot(aes(x = as.factor(month), y = quadrant, fill = delay_mean))+
  geom_tile()
```



I think changing the color from light->dark to instead blue->red may make for a more effective visualization as well.

10.2 7.5.3.1.4.

To get the fill value to vary need to iterate through and make each graph separate, can't just use facet.

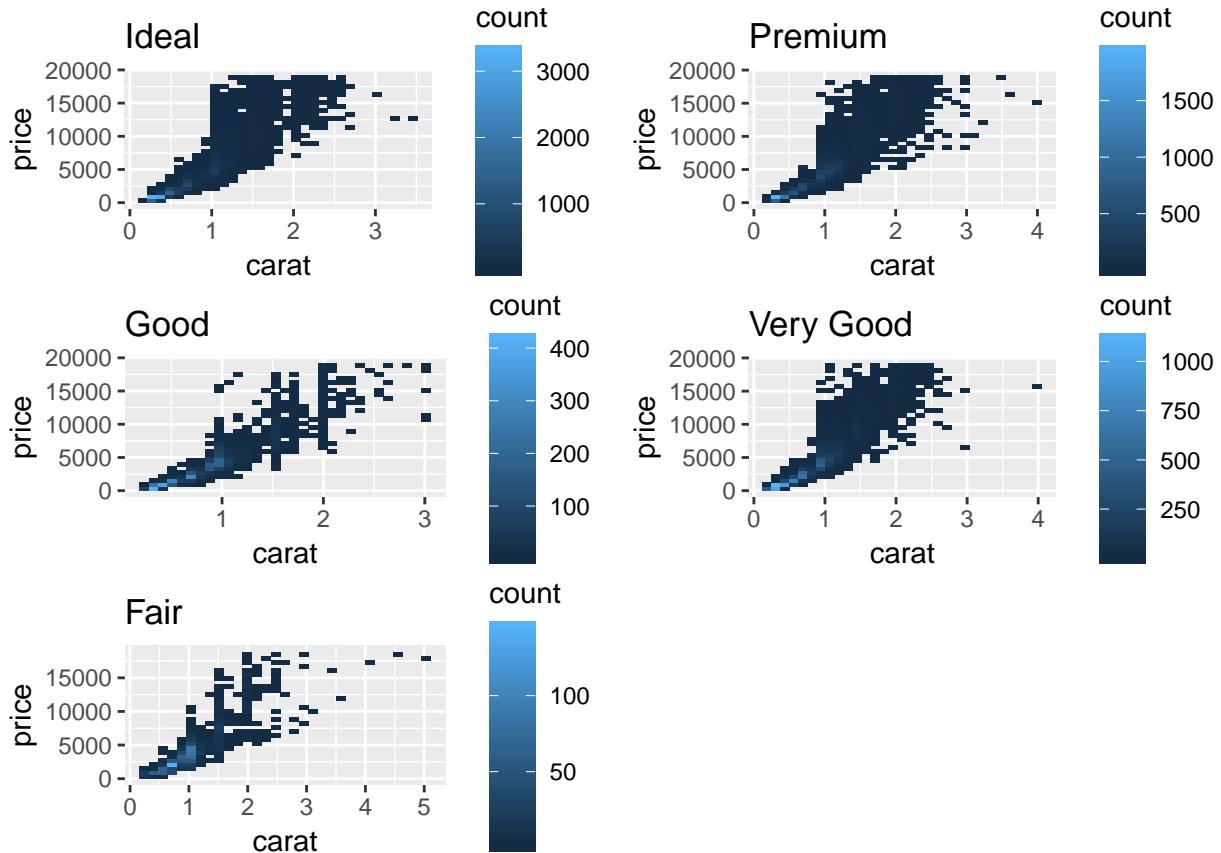
```

diamonds_nest <- diamonds %>%
  group_by(cut) %>%
  tidyr::nest()

plot_free <- function(df, name){
  ggplot(df) +
    geom_bin2d(aes(carat, price)) +
    ggtitle(name)
}

gridExtra::grid.arrange(grobs = mutate(diamonds_nest, out = purrr::map2(data, cut, plot_free))$out)

```



```
diamonds %>%
  mutate(cut =forcats::as_factor(as.character(cut), levels = c("Fair", "Good", "Very Good", "Premium",
  # with(contrasts(cut))
  lm(log(price) ~ log(carat) + cut, data = .) %>%
  summary()
```

```
##
## Call:
## lm(formula = log(price) ~ log(carat) + cut, data = .)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.52247 -0.16484 -0.00587  0.16087  1.38115
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 8.517337  0.001996 4267.70 <2e-16 ***
## log(carat)  1.695771  0.001910  887.68 <2e-16 ***
## cutPremium -0.078994  0.002810 -28.11 <2e-16 ***
## cutGood     -0.153967  0.004046 -38.06 <2e-16 ***
## cutVery Good -0.076458  0.002904 -26.32 <2e-16 ***
## cutFair     -0.317212  0.006632 -47.83 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2545 on 53934 degrees of freedom
```

```
## Multiple R-squared:  0.9371, Adjusted R-squared:  0.9371
## F-statistic: 1.607e+05 on 5 and 53934 DF,  p-value: < 2.2e-16
contrasts(diamonds$cut)

##          .L          .Q          .C          ^4
## [1,] -0.6324555  0.5345225 -3.162278e-01  0.1195229
## [2,] -0.3162278 -0.2672612  6.324555e-01 -0.4780914
## [3,]  0.0000000 -0.5345225 -4.095972e-16  0.7171372
## [4,]  0.3162278 -0.2672612 -6.324555e-01 -0.4780914
## [5,]  0.6324555  0.5345225  3.162278e-01  0.1195229

count(diamonds, cut)

## # A tibble: 5 x 2
##   cut      n
##   <ord>    <int>
## 1 Fair     1610
## 2 Good     4906
## 3 Very Good 12082
## 4 Premium   13791
## 5 Ideal    21551
```

Make sure the following packages are installed:

Chapter 11

ch. 10: Tibbles

```
vignette("tibble")
```

- **tibble**: produces a dataframe w/ some other helpful qualities that have advantages over `data.frame`
- **as_tibble**: convert to a tibble
- **tribble**: transposed tibble - set-up for data entry into a tibble in code
- **print**: can use print to set how the tibble will print

```
nycflights13::flights %>%  
  print(n = 2, width = Inf)
```

```
## # A tibble: 336,776 x 19  
##   year month   day dep_time sched_dep_time dep_delay arr_time  
##   <int> <int> <int>     <int>          <dbl>      <int>  
## 1  2013     1     1      517            515         2     830  
## 2  2013     1     1      533            529         4     850  
##   sched_arr_time arr_delay carrier flight tailnum origin dest air_time  
##   <int>          <dbl> <chr>    <int> <chr>   <chr> <dbl>  
## 1           819        11 UA       1545 N14228 EWR    IAH     227  
## 2           830        20 UA       1714 N24211 LGA    IAH     227  
##   distance hour minute time_hour  
##   <dbl> <dbl> <dbl> <dttm>  
## 1     1400     5     15 2013-01-01 05:00:00  
## 2     1416     5     29 2013-01-01 05:00:00  
## # ... with 3.368e+05 more rows
```

+ Also can convert with `as.data.frame` or use `options`, see 10.5.6 below

- **enframe**: let's you encode name and value, see 10.5.5 below
- **class**: for checking the class of the object
 - Though is not fully accurate, in that the actual object class of vectors is “base”, not double, etc., so kind of lies...

11.1 10.5

1. How can you tell if an object is a tibble? (Hint: try printing `mtcars`, which is a regular data frame).

Could look at printing, e.g. only prints first 15 rows and enough variables where you can see them all, or by

checking explicitly the `class` function¹

2. Compare and contrast the following operations on a `data.frame` and equivalent `tibble`. What is different? Why might the default data frame behaviours cause you frustration?

Dataframes can't do list-cols. Never changes type of input e.g. from strings to factors, never changes names of variables, never creates row names. Also, you can do list-cols with tibbles.

3. If you have the name of a variable stored in an object, e.g. `var <- "mpg"`, how can you extract the reference variable from a `tibble`?

```
var <- "var_name"

# Will extract the column as an atomic vector
df[[var]]
```

4. Practice referring to non-syntactic names in the following data frame by:

```
df <- tibble(`1` = 1:10, `2` = 11:20)
```

a. Extracting the variable called 1.

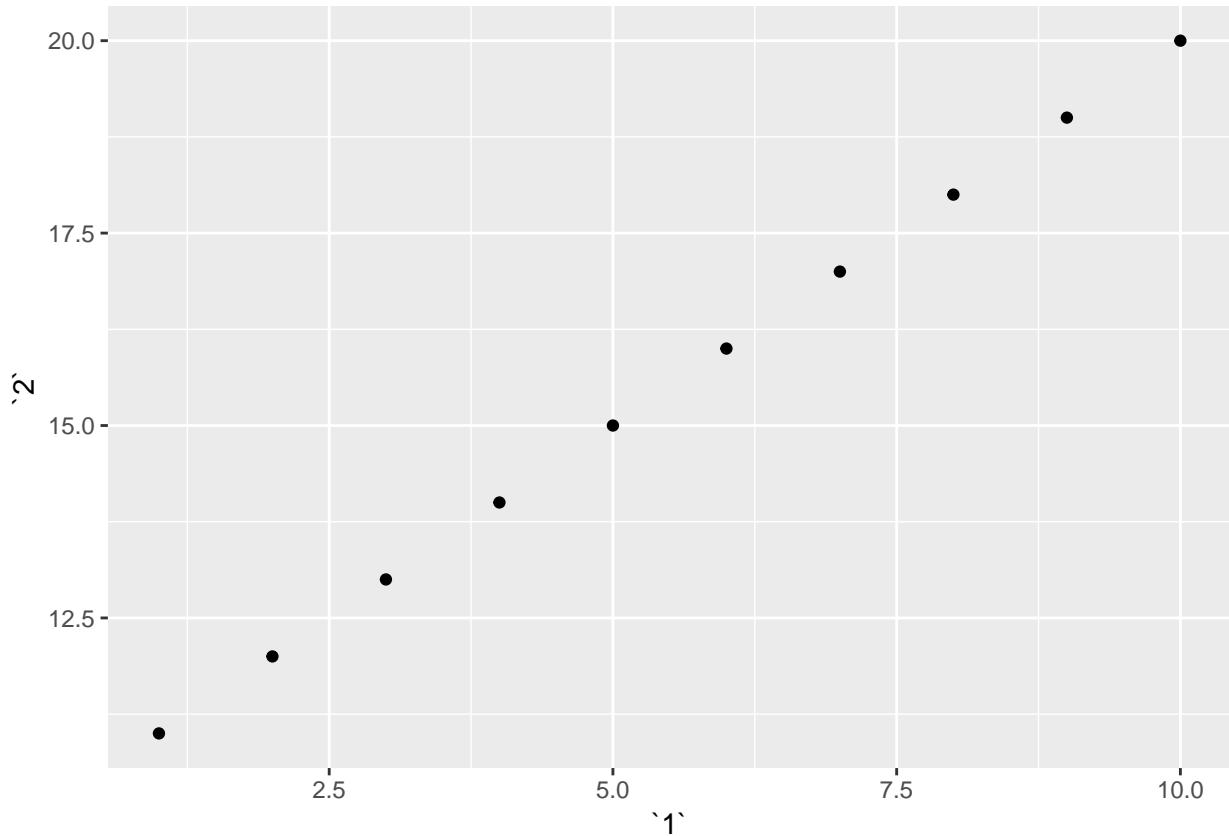
```
df %>%
  select(1)
```

```
## # A tibble: 10 x 1
##       `1`
##   <int>
## 1     1
## 2     2
## 3     3
## 4     4
## 5     5
## 6     6
## 7     7
## 8     8
## 9     9
## 10    10
```

b. Plotting a scatterplot of 1 vs 2.

```
df %>%
  ggplot(aes(x = `1`, y = `2`)) +
  geom_point()
```

¹Or could check a few other things such as if list-cols are supported



c. Creating a new column called 3 which is 2 divided by 1.

```
df %>%
  mutate(`3` = `1` / `2`)
```

```
## # A tibble: 10 x 3
##       `1`     `2`     `3`
##   <int> <int>  <dbl>
## 1     1      11  0.0909
## 2     2      12  0.167 
## 3     3      13  0.231 
## 4     4      14  0.286 
## 5     5      15  0.333 
## 6     6      16  0.375 
## 7     7      17  0.412 
## 8     8      18  0.444 
## 9     9      19  0.474 
## 10    10     20  0.5
```

d. Renaming the columns to one, two and three.

```
df %>%
  mutate(`3` = `1` / `2`) %>%
  rename(one = `1`,
         two = `2`,
         three = `3`)
```

```
## # A tibble: 10 x 3
```

```
##      one   two   three
##    <int> <int> <dbl>
## 1     1    11 0.0909
## 2     2    12 0.167
## 3     3    13 0.231
## 4     4    14 0.286
## 5     5    15 0.333
## 6     6    16 0.375
## 7     7    17 0.412
## 8     8    18 0.444
## 9     9    19 0.474
## 10    10   20 0.5
```

5. What does `tibble::enframe()` do? When might you use it?

Let's you encode "name" and "value"

```
tibble::enframe(1:3)
```

```
## # A tibble: 3 x 2
##   name value
##   <int> <int>
## 1     1     1
## 2     2     2
## 3     3     3
```

```
tibble::enframe(c(a = 5, b = 8))
```

```
## # A tibble: 2 x 2
##   name value
##   <chr> <dbl>
## 1 a      5
## 2 b      8
```

```
tibble::enframe(c(a = 5:8, b = 7:10))
```

```
## # A tibble: 8 x 2
##   name value
##   <chr> <int>
## 1 a1     5
## 2 a2     6
## 3 a3     7
## 4 a4     8
## 5 b1     7
## 6 b2     8
## 7 b3     9
## 8 b4    10
```

```
tibble::enframe(c(a = 5:8, b = 7:10, d = 9:12))
```

```
## # A tibble: 12 x 2
##   name value
##   <chr> <int>
## 1 a1     5
## 2 a2     6
## 3 a3     7
## 4 a4     8
## 5 b1     7
```

```
## 6 b2      8
## 7 b3      9
## 8 b4     10
## 9 d1      9
## 10 d2     10
## 11 d3     11
## 12 d4     12
```

6. What option controls how many additional column names are printed at the footer of a tibble?

- argument `tibble.width`

```
options(tibble.print_max = n, tibble.print_min = m)
options(tibble.width = Inf)
options(dplyr.print_min = Inf) #to always show all rows
```

Make sure the following packages are installed:

Chapter 12

ch. 11: Data import

- `read_csv()` reads comma delimited files, `read_csv2()` reads semicolon separated files (common in countries where , is used as the decimal place), `read_tsv()` reads tab delimited files, and `read_delim()` reads in files with any delimiter.
- `read_fwf()` reads fixed width files. You can specify fields either by their widths with `fwf_widths()` or their position with `fwf_positions()`. `read_table()` reads a common variation of fixed width files where columns are separated by white space.
- `data.table::fread`, good for raw speed
- `read_log()` reads Apache style log files. (But also check out `webreadr` which is built on top of `read_log()` and provides many more helpful tools.)

```
read_log(readr_example("example.log"))

## Parsed with column specification:
## cols(
##   X1 = col_character(),
##   X2 = col_character(),
##   X3 = col_character(),
##   X4 = col_character(),
##   X5 = col_character(),
##   X6 = col_integer(),
##   X7 = col_integer()
## )

## # A tibble: 2 x 7
##   X1      X2     X3      X4      X5           X6     X7
##   <chr>    <chr>  <chr>  <chr>  <chr>       <int>  <int>
## 1 172.21.~ <NA>  "Microsoft~ 08/Apr/2001~ GET /scripts/iisadmi~  200  3401
## 2 127.0.0~ <NA>  frank   10/Oct/2000~ GET /apache_pb.gif H~  200  2326
# readr_example finds the correct path associated with the package by doing the following:
## system.file("extdata", path, package = "readr", mustWork = TRUE)
```

- `parse_*`(): take character vector and return more specialized vector
 - `parse_logical`, `parse_integer`, `parse_double`, `parse_number`¹, `parse_character`, `parse_factor`(has `levels` as an argument), `parse_datetime`, `parse_date`, `parse_time` (these last three have an arg `oformat`)
- `locale` argument for use in parse functions to affect formatting and to pass into argument `locale = locale(<arg> = "<value>")`

¹can be helpful for dealing with parsing currencies or percentages for example...

- for double, e.g. `locale = locale(decimal_mark = ",")`
- for number, e.g. `locale = locale(grouping_mark = ".")`
- for character, e.g. `locale(encoding = "Latin1")`
- for dates, e.g. `locale(lang = "fr")` (to see built-in language options use `date_name_langs` and can create own with `date_names`)
- `problems`: returns problems on import
- `charToRaw` will show underlying representation of a character²
- `guess_encoding`: can guess encoding – generally would use this with `charToRaw` and helps avoid figuring out encoding by hand

```
x1 <- "El Ni\xf1o was particularly bad this year"
guess_encoding(charToRaw(x1))
```

```
## # A tibble: 2 x 2
##   encoding  confidence
##   <chr>        <dbl>
## 1 ISO-8859-1     0.46
## 2 ISO-8859-9     0.23
```

- If defaults don't work (primarily for dates, times, numbers) can use following to specify parsing: Year : `%Y` (4 digits). : `%y` (2 digits); 00-69 -> 2000-2069, 70-99 -> 1970-1999.

Month `%m` (2 digits).

`%b` (abbreviated name, like “Jan”).
 `%B` (full name, “January”).

Day `%d` (2 digits).

`%e` (optional leading space).

Time `%H` 0-23 hour.

`%I` 0-12, must be used with `%p`.

`%p` AM/PM indicator.

`%M` minutes.

`%S` integer seconds.

`%OS` real seconds.

`%Z` Time zone (as name, e.g. `America/Chicago`). Beware of abbreviations: if you're American, note that “EST” is a Canadian time zone that does not have daylight savings time. It is *not* Eastern Standard Time! We'll come back to this [time zones].

`%z` (as offset from UTC, e.g. `+0800`).

Non-digits `%.` skips one non-digit character.

`%*` skips any number of non-digits.

- `guess_parser`: returns what `readr` would think the character vector you provide it should be parsed into
- `parse_guess`: uses `readr`'s guess of the vector type to parse the column
- `col_*`: counterpoint to `parse_*` functions except for use when data is in a file rather than a string already loaded in R (as needed for `parse_*`)
 - `cols`: use this to pass in the `col_*` types,
 - `col_types = cols(x = col_double(), y = col_date())`
 - to read in all columns as character use `col_types = cols(.default = col_character())`
 - can set `n_max` to smallish number if reading in large file and still debugging parsing issues
- Recommend always input `cols`, if you want to be strict when loading in data set `stop_for_problems`
- `read_lines` read into character vector of lines (use when having major issues)
- `read_file` read in as character vector of length 1 (use when having major issues)
- `read_rds` reads in R's custom binary format³

²e.g. helpful for use w/ `parse_char`

³`readRDS` is base R version

- `feather::read_feather`: fast binary file format shared across languages⁴
- writing files⁵[`readr` functions will encode strings in UTF-8 and saves dates and date-times in ISO8601]:
 - `write_csv`, `write_tsv`, `write_excel_csv`, `write_rds`⁵, * `feather::read_feather`
- other packages for reading-in / writing data: `haven`, `readxl`, `DBI`, `odbc`, `jsonlite`, `xml2`, `rio`

12.1 11.2.2.

1. What function would you use to read a file where fields were separated with “|”?

`read_delim` for example:

```
read_delim("a|b|c\n1|2|3", delim = "|")
```

```
## # A tibble: 1 x 3
##       a     b     c
##   <int> <int> <int>
## 1     1     2     3
```

2. Apart from `file`, `skip`, and `comment`, what other arguments do `read_csv()` and `read_tsv()` have in common?⁶

`col_names`, `col_types`, `locale`, `na`, `quoted_na`, `quote`, `trim_ws`, `skip`, `n_max`, `guess_max`, `progress`

3. What are the most important arguments to `read_fwf()`?

`widths`

4. Sometimes strings in a CSV file contain commas. To prevent them from causing problems they need to be surrounded by a quoting character, like ” or ‘’. By convention, `read_csv()` assumes that the quoting character will be ”, and if you want to change it you’ll need to use `read_delim()` instead. What arguments do you need to specify to read the following text into a data frame?

```
"x,y\n1,'a,b'"
```

```
## [1] "x,y\n1,'a,b'"
read_delim("x,y\n1,'a,b'", delim = ",\"", quote = "'")
```

```
## # A tibble: 1 x 2
##       x     y
##   <int> <chr>
## 1     1 a,b
```

5. Identify what is wrong with each of the following inline CSV files. What happens when you run the code?

- `read_csv("a,b\n1,2,3\n4,5,6")`
 - needs 3rd column header, skips 3rd argument on each line, corrected: `read_csv("a,b\n1,2\n3,4,5,6")`
- `read_csv("a,b,c\n1,2\n1,2,3,4")`
 - missing 3rd value on 2nd line so currently makes NA, corrected: `read_csv("a,b,c\n1,2,1,2,3,4")`
- `read_csv("a,b\n1\"1")`
 - 2nd value missing and 2nd quote mark missing (though quotes are unnecessary), corrected: `read_csv("a,b\n\"1\", \"2\")`
- `read_csv("a,b\n1,2\na,b")`
 - Have character and numeric types,

⁴though does not support list-cols

⁵base R version is `saveRDS`

⁶* `skip = n`, `comment = #` any line that starts w/ input to comment will be skipped, `col_names = FALSE` or perhaps `c("x", "y", "z")`, `na = ". "`

- `read_csv("a;b\n1;3")`
 - need to make `read_csv2()` because is separated by semicolons, corrected: `read_csv2("a;b\n1;3")`

12.2 11.3.5.

1. What are the most important arguments to `locale()`?

- It depends on the `parse_*` type, e.g.
 - for double, e.g. `locale = locale(decimal_mark = ",")`
 - for number, e.g. `locale = locale(grouping_mark = ".")`
 - for character, e.g. `locale = locale(encoding = "Latin1")`
 - for dates, e.g. `locale = locale(lang = "fr")`
- Below are a few examples for double and number

```
parse_double("1.23")
## [1] 1.23
parse_double("1,23", locale = locale(decimal_mark=","))
## [1] 1.23
parse_number("the cost is $125.34, it's a good deal") #Slightly different than book, captures decimal
## [1] 125.34
parse_number("$123,456,789")
## [1] 123456789
parse_number("$123.456.789")
## [1] 123.456
parse_number("$123.456.789", locale = locale(grouping_mark = "."))#used in europe
## [1] 123456789
parse_number("$123'456'789", locale = locale(grouping_mark = "''))#used in Switzerland
## [1] 123456789
```

2. What happens if you try and set `decimal_mark` and `grouping_mark` to the same character? What happens to the default value of `grouping_mark` when you set `decimal_mark` to “,”? What happens to the default value of `decimal_mark` when you set the `grouping_mark` to “.”?

- can't set both to be same—if you change one, other automatically changes

```
parse_number("$135.435,45", locale = locale(grouping_mark = ".", decimal_mark = ","))
```

```
## [1] 135435.4
parse_number("$135.435,45", locale = locale(grouping_mark = "."))
## [1] 135435.4
```

3. I didn't discuss the `date_format` and `time_format` options to `locale()`. What do they do? Construct an example that shows when they might be useful.

- `date_format` and `time_format` in `locale()` let you set the default date and time formats

```
parse_date("31 january 2015", format = "%d %B %Y")
## [1] "2015-01-31"
parse_date("31 january 2015", locale = locale(date_format = "%d %B %Y"))
## [1] "2015-01-31"
#let's you change it in locale()
```

4. If you live outside the US, create a new locale object that encapsulates the settings for the types of file you read most commonly.

- I live in the US.
5. What's the difference between `read_csv()` and `read_csv2()`?
- Second expects semicolons
6. What are the most common encodings used in Europe? What are the most common encodings used in Asia? Do some googling to find out.
- Europe tends to use “%d-%m-%Y”
 - Asia tends to use “%d.%m.%Y”

7. Generate the correct format string to parse each of the following dates and times:

```
d1 <- "January 1, 2010"
d2 <- "2015-Mar-07"
d3 <- "06-Jun-2017"
d4 <- c("August 19 (2015)", "July 1 (2015)")
d5 <- "12/30/14" # Dec 30, 2014
t1 <- "1705"
t2 <- "11:15:10.12 PM"
t3 <- "11::15:10.12 PM"
```

Solutions:

```
parse_date(d1, "%B %d, %Y")
## [1] "2010-01-01"
parse_date(d2, "%Y-%b-%d")
## [1] "2015-03-07"
parse_date(d3, "%d-%b-%Y")
## [1] "2017-06-06"
parse_date(d3, "%d%.%b-%Y") #could use this alternatively
## [1] "2017-06-06"
parse_date(d4, "%B %d (%Y)")
## [1] "2015-08-19" "2015-07-01"
parse_date(d5, "%m/%d/%y")
## [1] "2014-12-30"
parse_time(t1, "%H%M")
```

```
## 17:05:00  
parse_time(t2, "%I:%M:%OS %p")  
  
## 23:15:10.12  
parse_time(t3, "%I%*%M:%OS %p")  
  
## 23:15:10.12
```

Make sure the following packages are installed:

Chapter 13

ch. 12: Tidy data

- spread: pivot, e.g. `spread(iris, Species)`
- gather: unpivot, e.g. `gather(mpg, drv, class, key = "drive_or_class", value = "value")`
- separate: one column into many, e.g. `separate(table3, rate, into = c("cases", "population"), sep = "/")`
 - default uses non-alphanumeric character as `sep`, can also use number to separate by width
- extract similar to separate but specify what to pull-out rather than what to split by
- unite inverse of separate

```
# example distinguishing separate, extract, unite
tibble(x = c("a,b,c", "d,e,f", "h,i,j", "k,l,m")) %>%
  tidyr::separate(x, c("one", "two", "three"), sep = ",", remove = FALSE) %>%
  tidyr::unite(one, two, three, col = "x2", sep = ",", remove = FALSE) %>%
  tidyr::extract(x2, into = c("a", "b", "c"), regex = "([a-z]+),([a-z]+),([a-z]+)", remove = FALSE)
```

```
## # A tibble: 4 x 8
##   x     x2    a     b     c     one    two    three
##   <chr> <chr> <chr> <chr> <chr> <chr> <chr>
## 1 a,b,c a,b,c a     b     c     a     b     c
## 2 d,e,f d,e,f d     e     f     d     e     f
## 3 h,i,j h,i,j h     i     j     h     i     j
## 4 k,l,m k,l,m k     l     m     k     l     m
```

- `complete()` takes a set of columns, and finds all unique combinations. It then ensures the original dataset contains all those values, filling in explicit NAs where necessary.
- `fill()` takes a set of columns where you want missing values to be replaced by the most recent non-missing value (sometimes called last observation carried forward).

```
# examples of complete and fill
treatment <- tribble(
  ~ person,           ~ treatment, ~ response,
  "Derrick Whitmore", 1,          7,
  NA,                 2,          10,
  NA,                 3,          9,
  "Katherine Burke",  1,          4
)

treatment %>%
  fill(person)
```

```
## # A tibble: 4 x 3
```

```

##   person      treatment response
##   <chr>       <dbl>    <dbl>
## 1 Derrick Whitmore     1        7
## 2 Derrick Whitmore     2       10
## 3 Derrick Whitmore     3        9
## 4 Katherine Burke     1        4

treatment %>%
  fill(person) %>%
  complete(person, treatment)

## # A tibble: 6 x 3
##   person      treatment response
##   <chr>       <dbl>    <dbl>
## 1 Derrick Whitmore     1        7
## 2 Derrick Whitmore     2       10
## 3 Derrick Whitmore     3        9
## 4 Katherine Burke     1        4
## 5 Katherine Burke     2       NA
## 6 Katherine Burke     3       NA

```

13.1 12.2: Tidy data

13.1.1 12.2.1.

1. Using prose, describe how the variables and observations are organised in each of the sample tables.

* `table1`: each country-year is a row with cases and pop as values * `table2`: each country-year-type is a row
 * `table3`: each country-year is a row with rate containing values for both `cases` and `population` * `table4a` and `table4b`: a represents cases, b population, each row is a country and then column are the year for the value

2. Compute the rate for `table2`, and `table4a + table4b`. You will need to perform four operations:

- Extract the number of TB cases per country per year.
- Extract the matching population per country per year.
- Divide cases by population, and multiply by 10000.
- Store back in the appropriate place.
- Which representation is easiest to work with? Which is hardest? Why?

with `table2`:

```

table2 %>%
  spread(type, count) %>%
  mutate(rate = 1000 * cases / population) %>%
  arrange(country, year)

```

```

## # A tibble: 6 x 5
##   country     year   cases population    rate
##   <chr>     <int>   <int>     <int>    <dbl>
## 1 Afghanistan 1999     745 19987071 0.0373
## 2 Afghanistan 2000    2666 20595360 0.129

```

```
## 3 Brazil      1999 37737 172006362 0.219
## 4 Brazil      2000 80488 174504898 0.461
## 5 China       1999 212258 1272915272 0.167
## 6 China       2000 213766 1280428583 0.167
```

with `table4` ‘a’ and ‘b’:

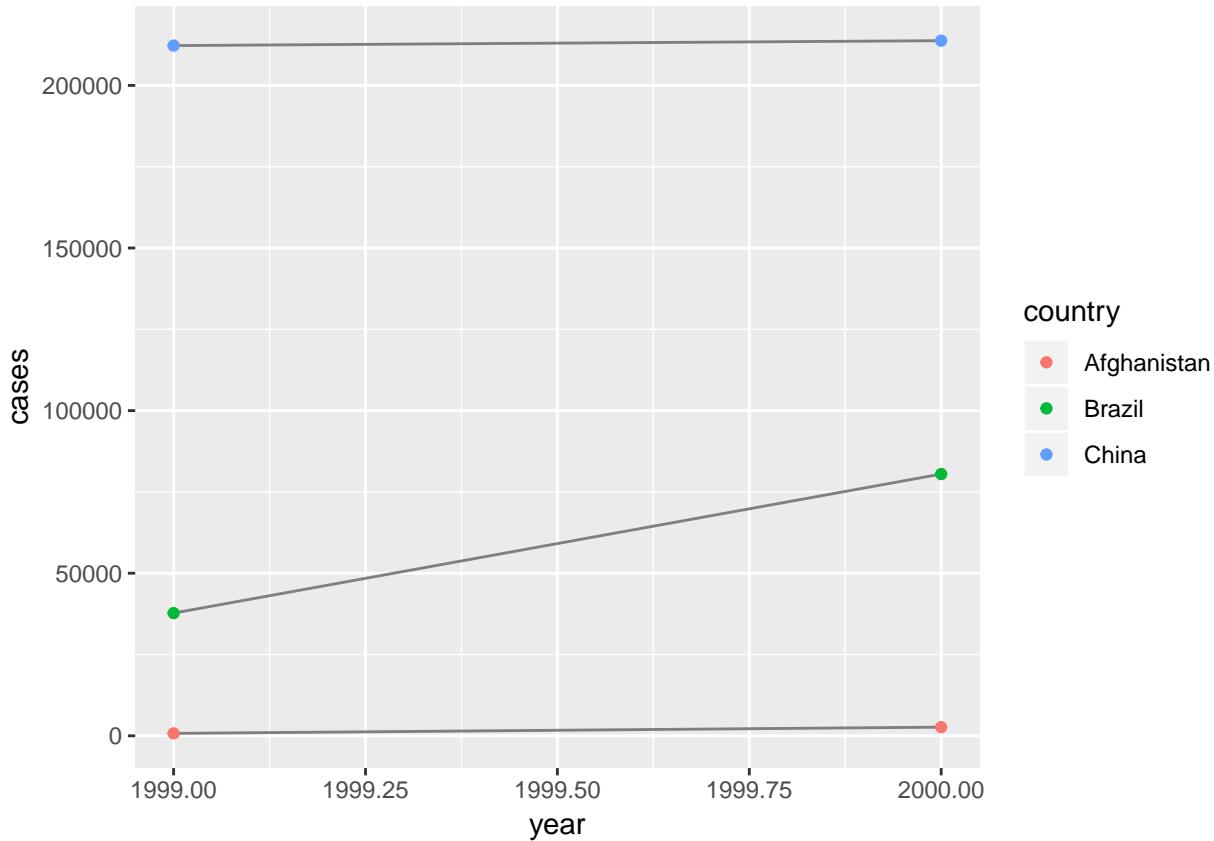
```
table4a %>%
  gather(2,3, key = "year", value = "cases") %>%
  inner_join(table4b %>%
    gather(c(2,3), key = "year", value = "population"),
    by = c("country", "year")) %>%
  mutate(rate = 1000 * cases / population)
```

```
## # A tibble: 6 x 5
##   country     year   cases population   rate
##   <chr>      <chr>   <int>      <int>   <dbl>
## 1 Afghanistan 1999     745    19987071 0.0373
## 2 Brazil       1999   37737   172006362 0.219
## 3 China        1999  212258  1272915272 0.167
## 4 Afghanistan 2000    2666   20595360 0.129
## 5 Brazil       2000   80488   174504898 0.461
## 6 China        2000  213766  1280428583 0.167
```

- between these, `table2` was easier, though `table1` would have been easiest – is fewer steps to get 1 row = 1 observation (if we define an observation as a country in a year with certain attributes)

3. Recreate the plot showing change in cases over time using `table2` instead of `table1`. What do you need to do first?

```
table2 %>%
  spread(type, count) %>%
  ggplot(aes(x = year, y = cases, group = country)) +
  geom_line(colour = "grey50") +
  geom_point(aes(colour = country))
```



- first had to spread data

13.2 12.3: Spreading and gathering

13.2.1 12.3.3.

1. Why are `gather()` and `spread()` not perfectly symmetrical?

Carefully consider the following example:

```
stocks <- tibble(
  year    = c(2015, 2015, 2016, 2016),
  half   = c( 1,      2,      1,      2),
  return = c(1.88, 0.59, 0.92, 0.17)
)

stocks %>%
  spread(year, return) %>%
  gather("year", "return", `2015`:`2016`)

## # A tibble: 4 x 3
##       half year  return
##   <dbl> <chr> <dbl>
## 1      1 2015    1.88
## 2      2 2015    0.59
## 3      1 2016    0.92
## 4      2 2016    0.17
```

```
## 4      2 2016    0.17
```

(Hint: look at the variable types and think about column names.)

- are not perfectly symmetrical, because type for key = changes to character when using gather – column type information is not transferred.
- position of columns change as well
- Both spread() and gather() have a convert argument. What does it do?*

Use this to automatically change key column type, otherwise will default in gather for example to become a character type.

2. Why does this code fail?

```
table4a %>%
  gather(1999, 2000, key = "year", value = "cases")
```

```
## Error in inds_combine(.vars, ind_list): Position must be between 0 and n
```

Need backticks on year column names

```
table4a %>%
  gather(`1999`, `2000`, key = "year", value = "cases")
```

```
## # A tibble: 6 x 3
##   country     year   cases
##   <chr>       <chr>  <int>
## 1 Afghanistan 1999    745
## 2 Brazil       1999  37737
## 3 China        1999 212258
## 4 Afghanistan 2000    2666
## 5 Brazil       2000  80488
## 6 China        2000 213766
```

3. Why does spreading this tibble fail? How could you add a new column to fix the problem?

```
people <- tribble(
  ~name,           ~key,     ~value,
  #----- / -----/
  "Phillip Woods", "age",    45,
  "Phillip Woods", "height", 186,
  "Phillip Woods", "age",    50,
  "Jessica Cordero", "age",   37,
  "Jessica Cordero", "height", 156
)
```

```
people %>%
  spread(key = "key", value = "value")
```

```
## Error: Each row of output must be identified by a unique combination of keys.
## Keys are shared for 2 rows:
## * 1, 3
## Do you need to create unique ID with tibble::rowid_to_column()?
```

Fails because you have more than one age for philip woods, could add a unique ID column and it will work.

```
people %>%
  mutate(id = 1:n()) %>%
  spread(key = "key", value = "value")

## # A tibble: 5 x 4
##   name           id   age height
##   <chr>      <int> <dbl>  <dbl>
## 1 Jessica Cordero     4    37    NA
## 2 Jessica Cordero     5    NA    156
## 3 Phillip Woods      1    45    NA
## 4 Phillip Woods      2    NA    186
## 5 Phillip Woods      3    50    NA
```

4. Tidy the simple tibble below. Do you need to spread or gather it? What are the variables?

```
preg <- tribble(
  ~pregnant, ~male, ~female,
  "yes",     NA,     10,
  "no",      20,     12
)
```

Need to gather gender

```
preg %>%
  gather(male, female, key="gender", value="Number")

## # A tibble: 4 x 3
##   pregnant gender Number
##   <chr>     <chr>   <dbl>
## 1 yes       male     NA
## 2 no        male     20
## 3 yes       female   10
## 4 no        female   12
```

13.3 12.4: Separating and uniting

13.3.1 12.4.3.

1. What do the extra and fill arguments do in separate()? Experiment with the various options for the following two toy datasets.

```
tibble(x = c("a,b,c", "d,e,f,g", "h,i,j")) %>%
  separate(x, c("one", "two", "three"))

## Warning: Expected 3 pieces. Additional pieces discarded in 1 rows [2].

## # A tibble: 3 x 3
##   one   two   three
##   <chr> <chr> <chr>
## 1 a     b     c
## 2 d     e     f
## 3 h     i     j

tibble(x = c("a,b,c", "d,e", "f,g,i")) %>%
  separate(x, c("one", "two", "three"))
```

```
## Warning: Expected 3 pieces. Missing pieces filled with `NA` in 1 rows [2].

## # A tibble: 3 x 3
##   one   two   three
##   <chr> <chr> <chr>
## 1 a     b     c
## 2 d     e     <NA>
## 3 f     g     i
```

`fill` determines what to do when there are too few arguments, default is to fill right arguments with NA can change this though.

```
tribble(~a, ~b,
       "so it goes", "hello, you, are") %>%
  separate(b, into=c("e", "f", "g", "h"), sep=",", fill = "left")
```

```
## # A tibble: 1 x 5
##   a         e     f     g     h
##   <chr>     <chr> <chr> <chr> <chr>
## 1 so it goes <NA> hello you are
```

`extra` determines what to do when you have more splits than you do `into` spaces. Default is to drop extra Can change to limit num of splits to length of `into` with value “merge”

```
tribble(~a, ~b,
       "so it goes", "hello, you, are") %>%
  separate(b, into=c("e", "f"), sep=",", extra="merge")
```

```
## # A tibble: 1 x 3
##   a         e     f
##   <chr>     <chr> <chr>
## 1 so it goes hello you,are
```

2. Both `unite()` and `separate()` have a `remove` argument. What does it do? Why would you set it to `FALSE`?

`remove = FALSE` allows you to specify to keep the input column(s)

```
tibble(x = c("a,b,c", "d,e,f", "h,i,j", "k,l,m")) %>%
  separate(x, c("one", "two", "three"), remove = FALSE) %>%
  unite(one, two, three, col = "x2", sep = ",", remove = FALSE)
```

```
## # A tibble: 4 x 5
##   x     x2   one   two   three
##   <chr> <chr> <chr> <chr> <chr>
## 1 a,b,c a,b,c a     b     c
## 2 d,e,f d,e,f d     e     f
## 3 h,i,j h,i,j h     i     j
## 4 k,l,m k,l,m k     l     m
```

3. Compare and contrast `separate()` and `extract()`. Why are there three variations of separation (by position, by separator, and with groups), but only one `unite`?

`extract` is like `separate` but provide what to capture rather than what to split by as in `regex` instead of `sep`.

```
df <- data.frame(x = c("a-b", "a-d", "b-c", "d&e", NA), y = 1)

df %>%
  extract(col = x, into = c("1st", "2nd"), regex = "([A-z]).([A-z])")
```

```

##      1st  2nd y
## 1     a    b 1
## 2     a    d 1
## 3     b    c 1
## 4     d    e 1
## 5 <NA> <NA> 1

df %>%
  separate(col = x, into = c("1st", "2nd"), sep = "[^A-z]")

```

```

##      1st  2nd y
## 1     a    b 1
## 2     a    d 1
## 3     b    c 1
## 4     d    e 1
## 5 <NA> <NA> 1

```

Because there are many ways to split something up, but only one way to bring multiple things together...

13.4 12.5: missing values

13.4.1 12.5.1.

1. Compare and contrast the `fill` arguments to `spread()` and `complete()`.

Both create open cells by filling out those that are not currently in the dataset, `complete` though does it by adding rows of iterations not included, whereas `spread` does it by the process of spreading out fields and naturally generating values that did not have row values previously. The `fill` in each specifies what value should go into these created cells.

```

treatment2 <- tribble(
  ~ person,           ~ treatment, ~ response,
  "Derrick Whitmore", 1,          7,
  "Derrick Whitmore", 2,         10,
  "Derrick Whitmore", 3,          9,
  "Katherine Burke",   1,          4
)

treatment2 %>%
  complete(person, treatment, fill = list(response = 0))

## # A tibble: 6 x 3
##   person       treatment response
##   <chr>        <dbl>     <dbl>
## 1 Derrick Whitmore     1        7
## 2 Derrick Whitmore     2       10
## 3 Derrick Whitmore     3        9
## 4 Katherine Burke     1        4
## 5 Katherine Burke     2        0
## 6 Katherine Burke     3        0

treatment2 %>%
  spread(key = treatment, value = response, fill = 0)

## # A tibble: 2 x 4

```

```
##   person      `1`      `2`      `3`
##   <chr>      <dbl>     <dbl>     <dbl>
## 1 Derrick Whitmore    7       10       9
## 2 Katherine Burke     4        0       0
```

2. What does the direction argument to `fill()` do?

Let's you fill either up or down. E.g. below is filling up example.

```
treatment <- tribble(
  ~ person,           ~ treatment, ~ response,
  "Derrick Whitmore", 1,            7,
  NA,                2,            10,
  NA,                3,            9,
  "Katherine Burke", 1,            4
)

treatment %>%
  fill(person, .direction = "up")

## # A tibble: 4 x 3
##   person      treatment response
##   <chr>      <dbl>     <dbl>
## 1 Derrick Whitmore    1       7
## 2 Katherine Burke     2      10
## 3 Katherine Burke     3       9
## 4 Katherine Burke     1       4
```

13.5 12.6 Case Study

13.5.1 12.6.1.

1. In this case study I set `na.rm = TRUE` just to make it easier to check that we had the correct values. Is this reasonable? Think about how missing values are represented in this dataset. Are there implicit missing values? What's the difference between an `NA` and zero?

In this case it's reasonable, an `NA` perhaps means the metric wasn't recorded in that year, whereas 0 means it was recorded but there were 0 cases.

Implicit missing values represented by say Afghanistan not having any reported cases for females.

2. What happens if you neglect the `mutate()` step? (`mutate(key = stringr::str_replace(key, "newrel", "new_rel")))`)

You would have had one less column, so 'newtype' would have been on column, rather than these splitting.

3. I claimed that `iso2` and `iso3` were redundant with `country`. Confirm this claim.

```
who %>%
  select(1:3) %>%
  distinct() %>%
  count()
```

```
## # A tibble: 1 x 1
##       n
##   <int>
## 1 219
```

```
who %>%
  select(1:3) %>%
  distinct() %>%
  unite(country, iso2, iso3, col = "country_combined") %>%
  count()
```

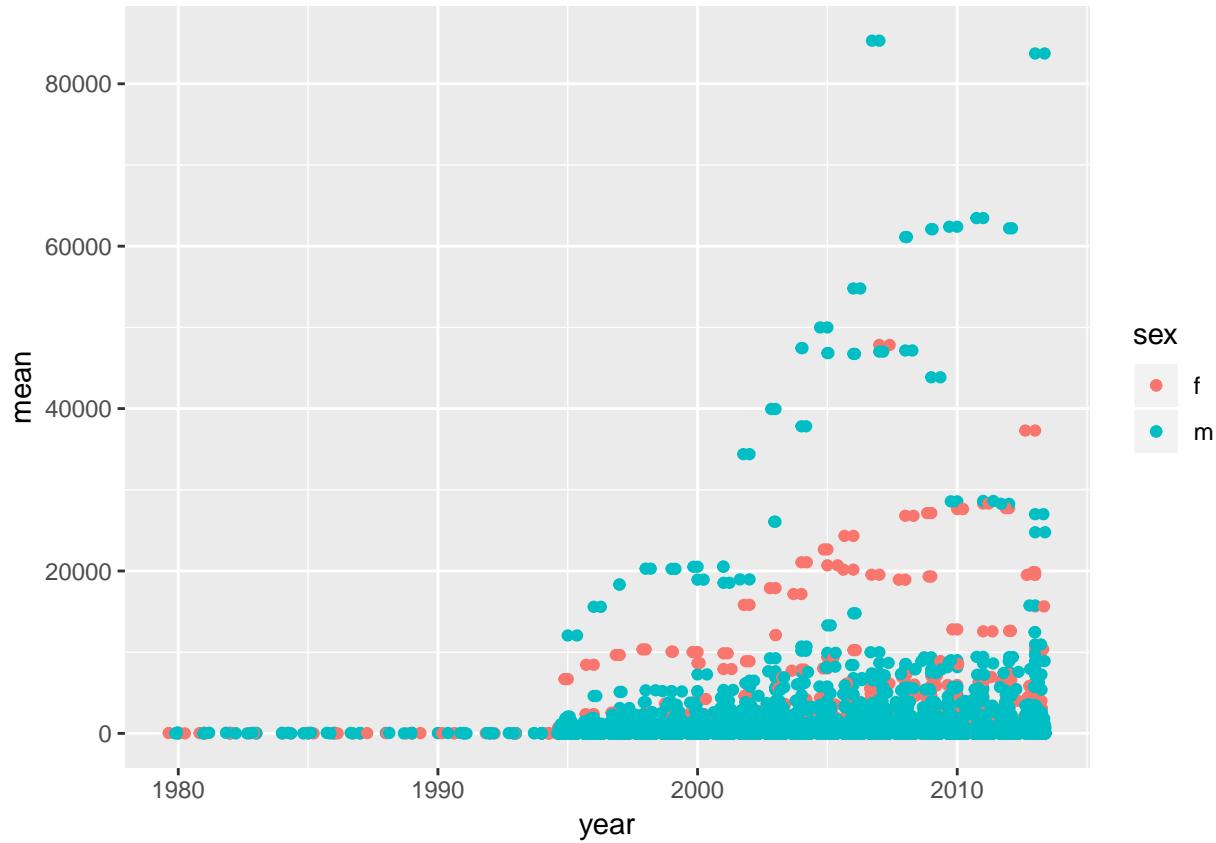
```
## # A tibble: 1 x 1
##       n
##   <int>
## 1    219
```

Both of the above are the same length.

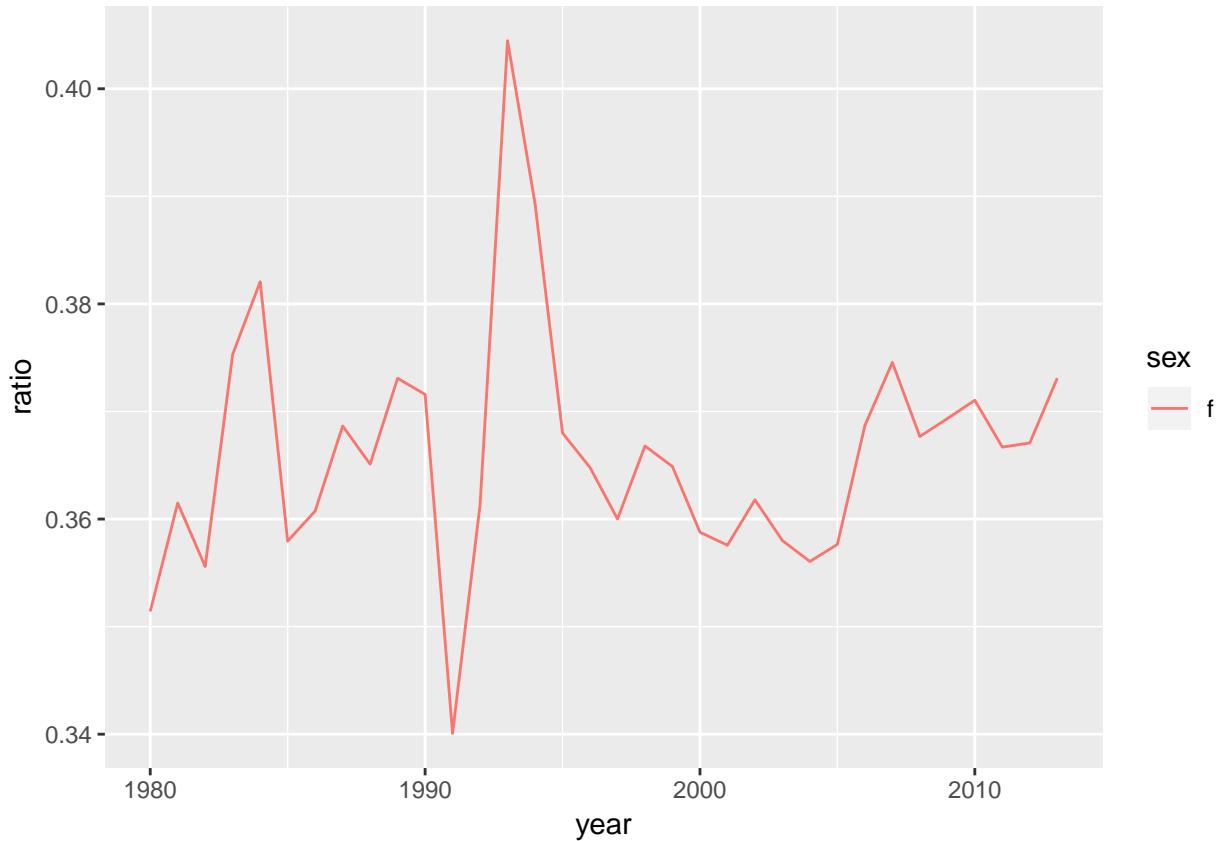
4. For each country, year, and sex compute the total number of cases of TB. Make an informative visualisation of the data.

```
who_present <- who %>%
  gather(code, value, new_sp_m014:newrel_f65, na.rm = TRUE) %>%
  mutate(code = stringr::str_replace(code, "newrel", "new_rel")) %>%
  separate(code, c("new", "var", "sexage")) %>%
  select(-new, -iso2, -iso3) %>%
  separate(sexage, c("sex", "age"), sep = 1)
```

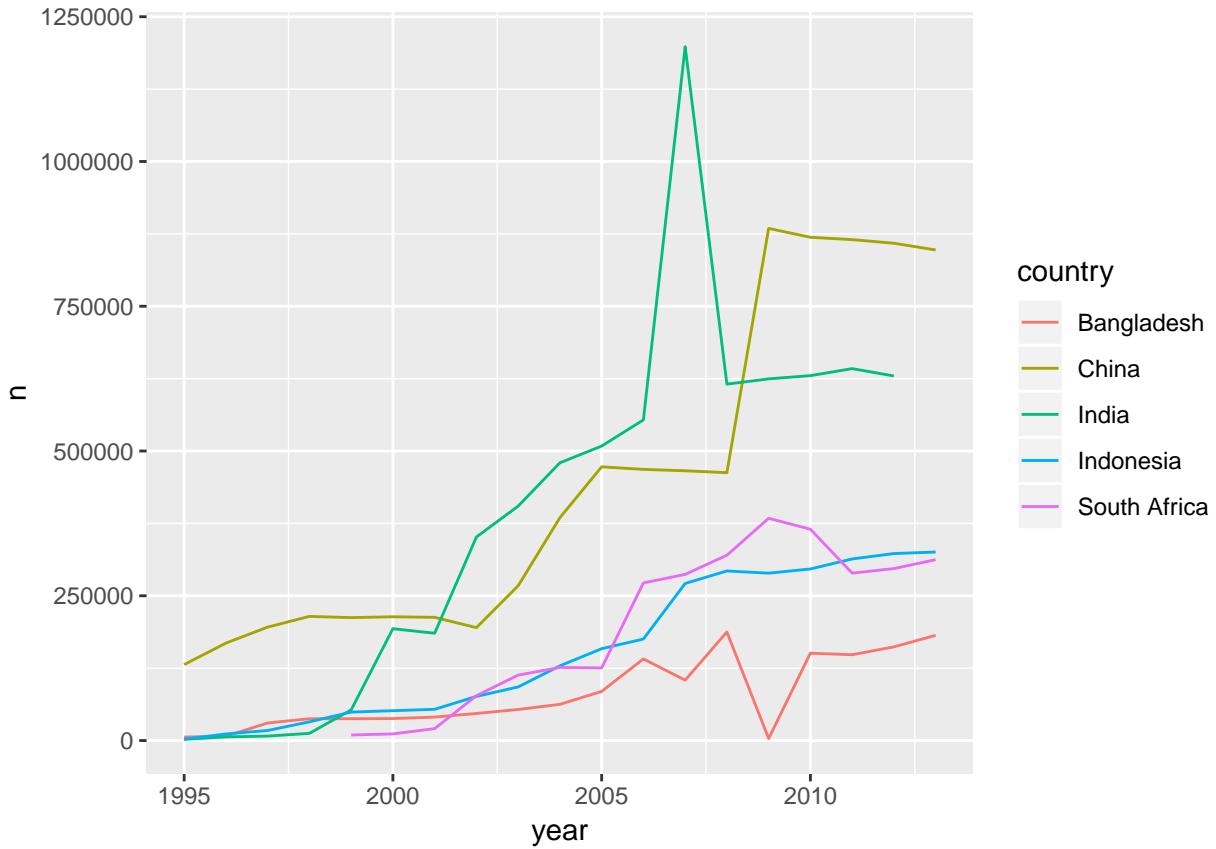
```
who_present %>%
  group_by(sex, year, country) %>%
  summarise(mean=mean(value)) %>%
  ggplot(aes(x=year, y=mean, colour=sex)) +
  geom_point() +
  geom_jitter()
```



```
#ratio of female tb cases over time
who_present %>%
  group_by(sex, year) %>%
  summarise(meansex=sum(value)) %>%
  ungroup() %>%
  group_by(year) %>%
  mutate(tot=sum(meansex)) %>%
  ungroup() %>%
  mutate(ratio=meansex/tot) %>%
  filter(sex=="f") %>%
  ggplot(aes(x=year, y=ratio, colour=sex))+
```

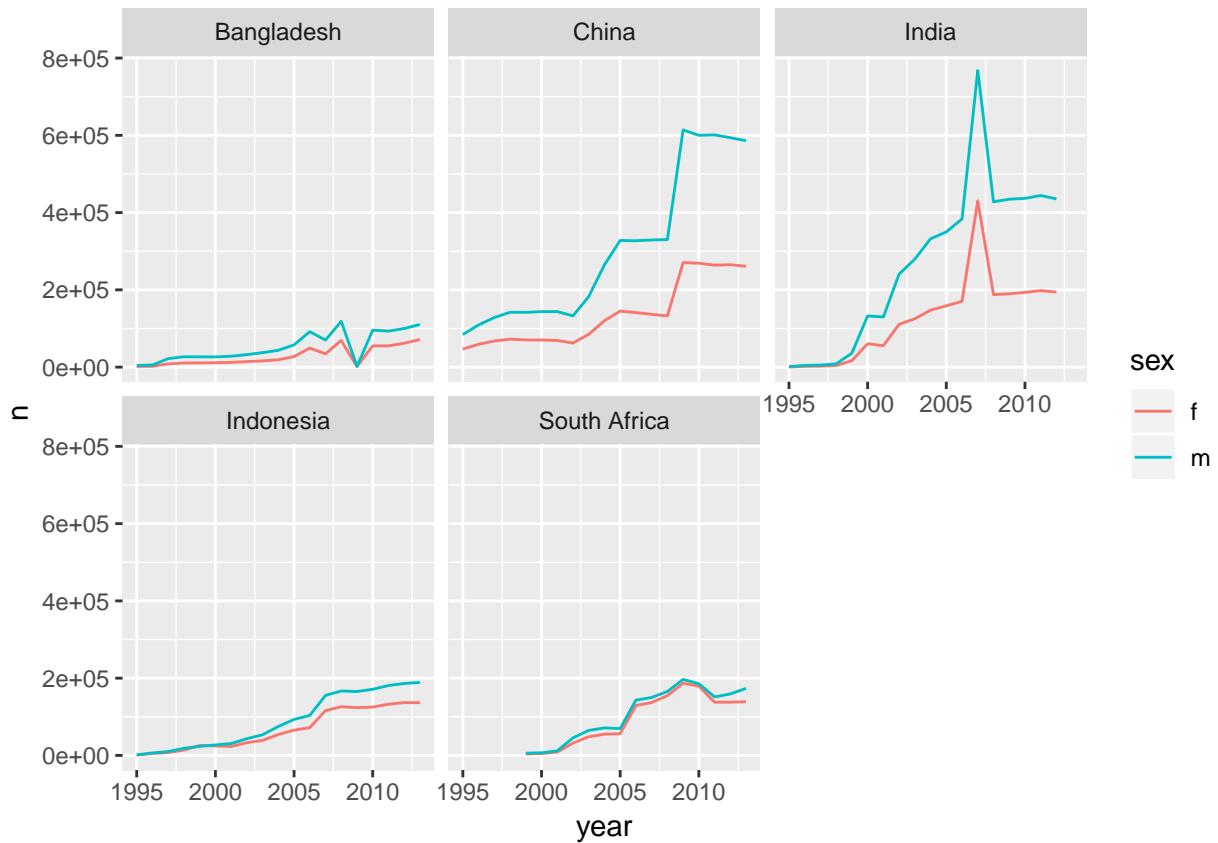


```
#countries with the most outbreaks
who_present %>%
  group_by(country, year) %>%
  summarise(n=sum(value)) %>%
  ungroup() %>%
  group_by(country) %>%
  mutate(total_country=sum(n)) %>%
  filter(total_country>1000000) %>%
  ggplot(aes(x=year,y=n,colour=country))+>
  geom_line()
```

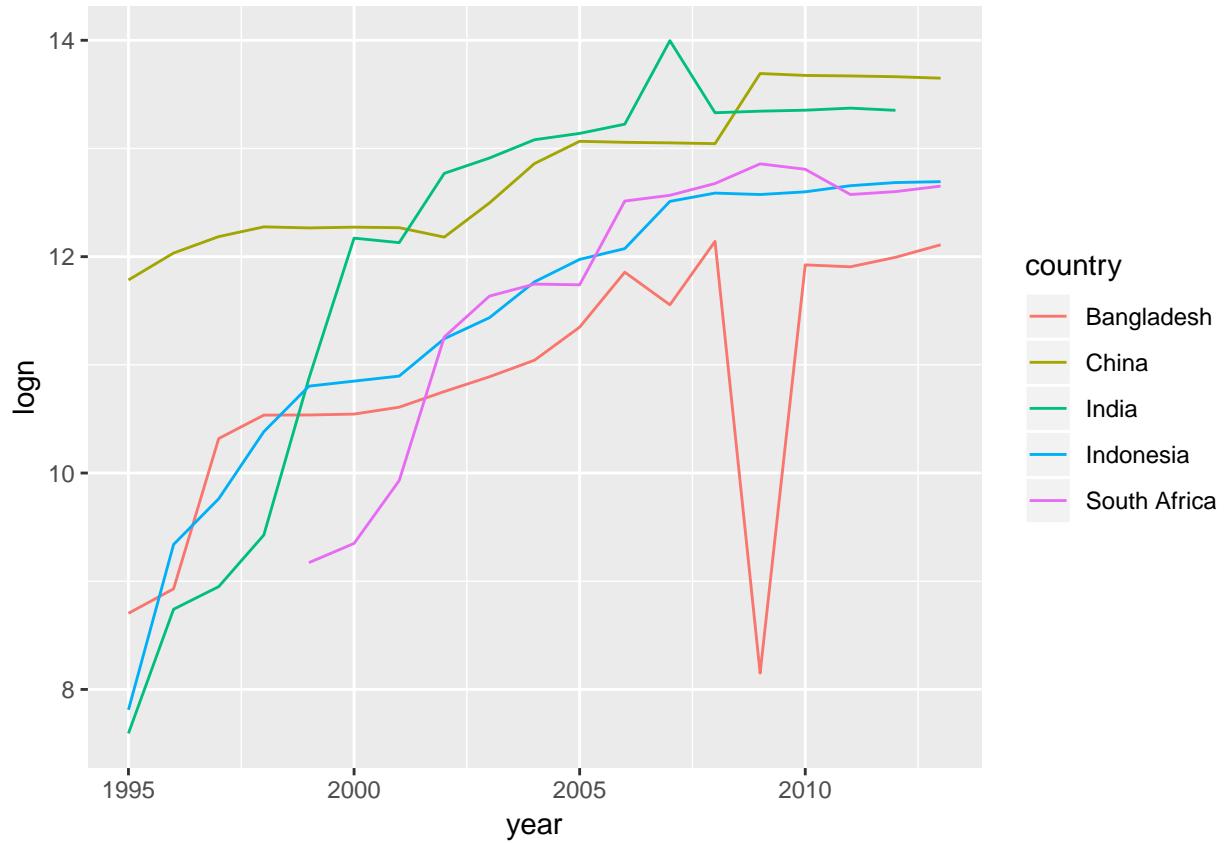


```
#countries with the most split by gender as well
who_present %>%
group_by(country, sex, year) %>%
summarise(n=sum(value)) %>%
ungroup() %>%
group_by(country) %>%
mutate(total_country=sum(n)) %>%
filter(total_country>1000000) %>%
ggplot(aes(x=year,y=n,colour=sex))+
```

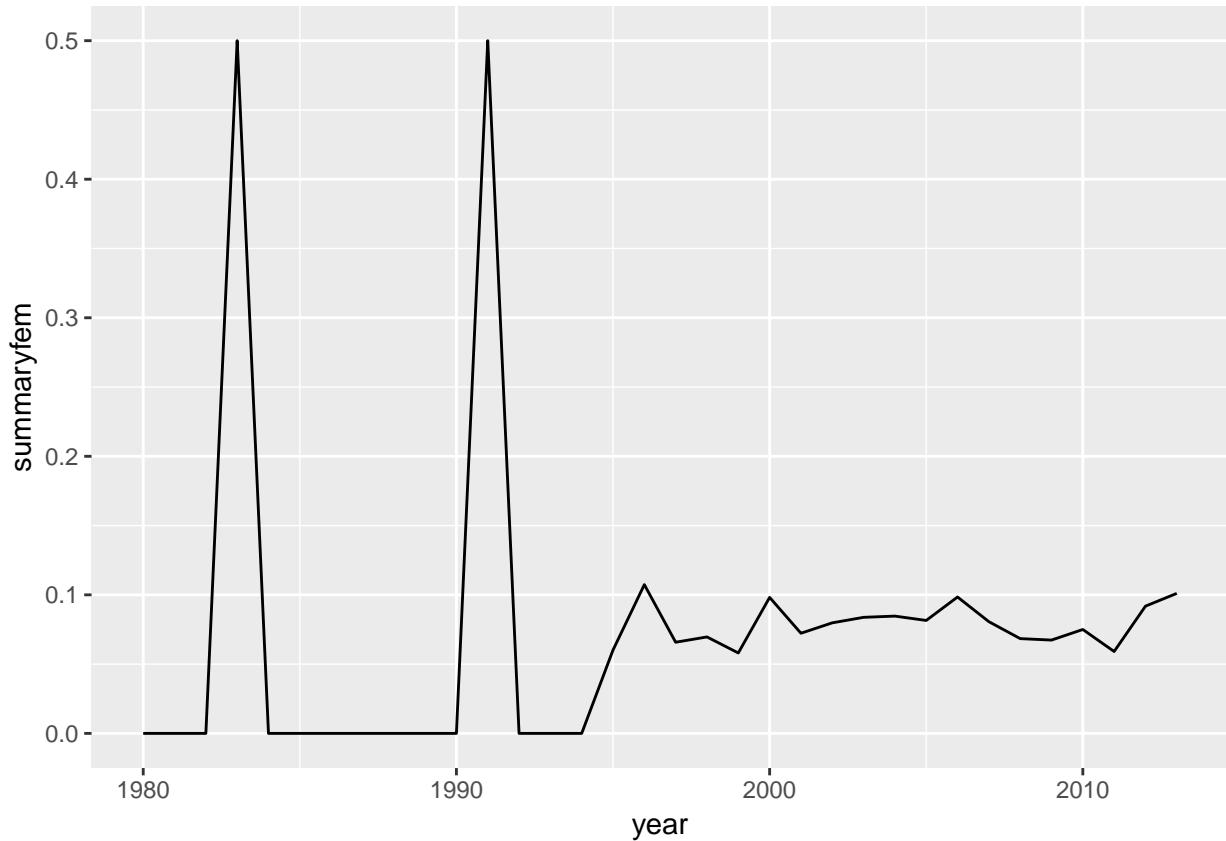
```
geom_line()+
facet_wrap(~country)
```



```
#take log and summarise
who_present %>%
  group_by(country, year) %>%
  summarise(n=sum(value), logn=log(n)) %>%
  ungroup() %>%
  group_by(country) %>%
  mutate(total_c=sum(n)) %>%
  filter(total_c>1000000) %>%
  ggplot(aes(x=year,y=logn, colour=country))+
  geom_line(show.legend=TRUE)
```



```
#average # of countries with more female TB cases
who_present %>%
  group_by(country, year, sex) %>%
  summarise(n=sum(value), logn=log(n)) %>%
  ungroup() %>%
  group_by(country, year) %>%
  mutate(total_c=sum(n)) %>%
  ungroup() %>%
  mutate(perc_gender=n/total_c, femalemore=ifelse(perc_gender>.5,1,0)) %>%
  filter(sex=="f") %>%
  group_by(year) %>%
  summarise(summaryfem=mean(femalemore,na.rm=TRUE )) %>%
  ggplot(aes(x=year,y=summaryfem))+ 
  geom_line()
```



Make sure the following packages are installed:

Chapter 14

ch. 13: Relational data

“The relations of three or more tables are always a property of the relations between each pairs.”

- Three families of verbs in relational data: *
- **Mutating joins**, which add new variables to one data frame from matching observations in another.
 - `inner_join`: match when equal
 - `left_join`: keep all observations in table in 1st arg
 - `right_join`: keep all observations in table in 2nd arg
 - `full_join`: keep all observations in table in 1st and 2nd arg
- **Filtering joins**, which filter observations from one data frame based on whether or not they match an observation in the other table.
 - `semi_join(x, y)` keeps all observations in `x` that have a match in `y`.
 - `anti_join(x, y)` drops all observations in `x` that have a match in `y`.
- **Set operations**, which treat observations as if they were set elements.
 - `intersect(x, y)`: return only observations in both `x` and `y` (when inputs are a df, is comparing across all values in a row).
 - `union(x, y)`: return unique observations in `x` and `y`.
 - `setdiff(x, y)`: return observations in `x`, but not in `y`.

`base::merge()` can perform all four types of mutating join:

| dplyr | merge |
|-------------------------------|--|
| <code>inner_join(x, y)</code> | <code>merge(x, y)</code> |
| <code>left_join(x, y)</code> | <code>merge(x, y, all.x = TRUE)</code> |
| <code>right_join(x, y)</code> | <code>merge(x, y, all.y = TRUE),</code> |
| <code>full_join(x, y)</code> | <code>merge(x, y, all.x = TRUE, all.y = TRUE)</code> |

SQL is the inspiration for dplyr’s conventions, so the translation is straightforward:

| dplyr | SQL |
|---|---|
| <code>inner_join(x, y, by = "z")</code> | <code>SELECT * FROM x INNER JOIN y USING (z)</code> |
| <code>left_join(x, y, by = "z")</code> | <code>SELECT * FROM x LEFT OUTER JOIN y USING (z)</code> |
| <code>right_join(x, y, by = "z")</code> | <code>SELECT * FROM x RIGHT OUTER JOIN y USING (z)</code> |
| <code>full_join(x, y, by = "z")</code> | <code>SELECT * FROM x FULL OUTER JOIN y USING (z)</code> |

14.1 13.2 nycflights13

```
flights
airlines
airports
planes
weather
```

14.1.1 13.2.1

- Imagine you wanted to draw (approximately) the route each plane flies from its origin to its destination. What variables would you need? What tables would you need to combine?

To draw a line from origin to destination, I need the lat lon points from airports as well as the dest and origin variables from flights.

- I forgot to draw the relationship between weather and airports. What is the relationship and how should it appear in the diagram?

origin from weather connects to aaf from airports' in a many to one relationship

- weather only contains information for the origin (NYC) airports. If it contained weather records for all airports in the USA, what additional relation would it define with flights?

It would connect to dest.

- We know that some days of the year are “special”, and fewer people than usual fly on them. How might you represent that data as a data frame? What would be the primary keys of that table? How would it connect to the existing tables?

Make a set of days that are less popular and have these dates connect by month and day

14.2 13.3 Keys

14.2.1 13.3.1

- Add a surrogate key to flights.

```
flights %>%
  mutate(surrogate_key = row_number()) %>%
  glimpse()
```

```
## Observations: 336,776
## Variables: 20
## $ year              <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, ...
## $ month             <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ day               <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ...
## $ dep_time          <int> 517, 533, 542, 544, 554, 554, 555, 557, 557, 55...
## $ sched_dep_time   <int> 515, 529, 540, 545, 600, 558, 600, 600, 600, 60...
## $ dep_delay         <dbl> 2, 4, 2, -1, -6, -4, -5, -3, -2, -2, -2, -2...
## $ arr_time          <int> 830, 850, 923, 1004, 812, 740, 913, 709, 838, 7...
## $ sched_arr_time   <int> 819, 830, 850, 1022, 837, 728, 854, 723, 846, 7...
## $ arr_delay         <dbl> 11, 20, 33, -18, -25, 12, 19, -14, -8, 8, -2, -...
## $ carrier           <chr> "UA", "UA", "AA", "B6", "DL", "UA", "B6", "EV", ...
## $ flight            <int> 1545, 1714, 1141, 725, 461, 1696, 507, 5708, 79...
```

```
## $ tailnum      <chr> "N14228", "N24211", "N619AA", "N804JB", "N668DN...
## $ origin       <chr> "EWR", "LGA", "JFK", "JFK", "LGA", "EWR", "EWR"...
## $ dest         <chr> "IAH", "IAH", "MIA", "BQN", "ATL", "ORD", "FLL"...
## $ air_time     <dbl> 227, 227, 160, 183, 116, 150, 158, 53, 140, 138...
## $ distance     <dbl> 1400, 1416, 1089, 1576, 762, 719, 1065, 229, 94...
## $ hour          <dbl> 5, 5, 5, 5, 6, 5, 6, 6, 6, 6, 6, 6, 6, 5, ...
## $ minute        <dbl> 15, 29, 40, 45, 0, 58, 0, 0, 0, 0, 0, 0, 0, ...
## $ time_hour    <dttm> 2013-01-01 05:00:00, 2013-01-01 05:00:00, 2013...
## $ surrogate_key <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, ...
```

2. Identify the keys in the following datasets

1. Lahman::Batting: player, year, stint

```
Lahman::Batting %>%
  count(playerID, yearID, stint) %>%
  filter(n > 1)
```

```
## # A tibble: 0 x 4
## # ... with 4 variables: playerID <chr>, yearID <int>, stint <int>, n <int>
```

1. babynames::babynames: name, sex, year

```
babynames::babynames %>%
  count(name, sex, year) %>%
  filter(n > 1)
```

```
## # A tibble: 0 x 4
```

```
## # ... with 4 variables: name <chr>, sex <chr>, year <dbl>, n <int>
```

1. nasaweather::atmos: lat, long, year, month

```
nasaweather::atmos %>%
  count(lat, long, year, month) %>%
  filter(n > 1)
```

```
## # A tibble: 0 x 5
```

```
## # ... with 5 variables: lat <dbl>, long <dbl>, year <int>, month <int>,
```

```
## #   n <int>
```

1. fueleconomy::vehicles: id

```
fueleconomy::vehicles %>%
  count(id) %>%
  filter(n > 1)
```

```
## # A tibble: 0 x 2
```

```
## # ... with 2 variables: id <int>, n <int>
```

1. ggplot2::diamonds: needs surrogate

```
diamonds %>%
  count(x, y, z, depth, table, carat, cut, color, price, clarity) %>%
  filter(n > 1)
```

```
## # A tibble: 143 x 11
```

| x | y | z | depth | table | carat | cut | color | price | clarity | n | |
|---|------|------|-------|-------|-------|------|-----------|-------|---------|-----|---|
| 1 | 0 | 0 | 64.1 | 60 | 0.71 | Good | F | 2130 | SI2 | 2 | |
| 2 | 4.23 | 4.26 | 2.69 | 63.4 | 57 | 0.3 | Good | J | 394 | VS1 | 2 |
| 3 | 4.26 | 4.23 | 2.69 | 63.4 | 57 | 0.3 | Very Good | J | 506 | VS1 | 2 |

```

## 4 4.26 4.29 2.66 62.2 57 0.3 Ideal H 450 SI1 2
## 5 4.27 4.28 2.66 62.2 57 0.3 Ideal H 450 SI1 2
## 6 4.29 4.31 2.71 63 55 0.3 Very Good G 526 VS2 2
## 7 4.29 4.31 2.73 63.5 56 0.31 Good D 571 SI1 2
## 8 4.31 4.28 2.67 62.2 58 0.3 Premium D 709 SI1 2
## 9 4.31 4.29 2.71 63 55 0.3 Ideal G 675 VS2 2
## 10 4.31 4.29 2.73 63.5 56 0.31 Very Good D 732 SI1 2
## # ... with 133 more rows
diamonds %>%
  mutate(surrogate_id = row_number())

```

```

## # A tibble: 53,940 x 11
##   carat cut color clarity depth table price     x     y     z
##   <dbl> <ord> <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
## 1 0.23  Ideal E    SI2     61.5    55  326  3.95  3.98  2.43
## 2 0.21  Prem~ E    SI1     59.8    61  326  3.89  3.84  2.31
## 3 0.23  Good  E    VS1     56.9    65  327  4.05  4.07  2.31
## 4 0.290 Prem~ I    VS2     62.4    58  334  4.2    4.23  2.63
## 5 0.31  Good  J    SI2     63.3    58  335  4.34  4.35  2.75
## 6 0.24  Very~ J    VVS2    62.8    57  336  3.94  3.96  2.48
## 7 0.24  Very~ I    VVS1    62.3    57  336  3.95  3.98  2.47
## 8 0.26  Very~ H    SI1     61.9    55  337  4.07  4.11  2.53
## 9 0.22  Fair   E    VS2     65.1    61  337  3.87  3.78  2.49
## 10 0.23 Very~ H    VS1     59.4    61  338  4     4.05  2.39
## # ... with 53,930 more rows, and 1 more variable: surrogate_id <int>

```

3. Draw a diagram illustrating the connections between the *Batting*, *Master*, and *Salaries* tables in the *Lahman* package. Draw another diagram that shows the relationship between *Master*, *Managers*, *AwardsManagers*.

For each dataset show just the `head(1)`

Combine by playerid

```

##   playerID yearID stint teamID lgID G AB R H X2B X3B HR RBI SB CS BB SO
## 1 abercda01 1871     1   TRO   NA 1  4 0 0   0  0 0 0 0 0 0 0 0 0 0 0
##   IBB HBP SH SF GIDP
## 1 NA NA NA NA   NA

##   playerID birthYear birthMonth birthDay birthCountry birthState
## 1 aardsda01      1981        12       27      USA       CO
##   birthCity deathYear deathMonth deathDay deathCountry deathState
## 1 Denver        NA        NA        NA      <NA>      <NA>
##   deathCity nameFirst nameLast  nameGiven weight height bats throws
## 1 <NA>        David   Allan David Allan   215    75    R    R
##   debut finalGame retroID bbrefID deathDate birthDate
## 1 2004-04-06 2015-08-23 aarッド001 aardsda01      <NA> 1981-12-27

```

Combine by playerID, yearID

```

##   playerID yearID stint teamID lgID G AB R H X2B X3B HR RBI SB CS BB SO
## 1 abercda01 1871     1   TRO   NA 1  4 0 0   0  0 0 0 0 0 0 0 0 0 0 0
##   IBB HBP SH SF GIDP
## 1 NA NA NA NA   NA

##   yearID teamID lgID playerID salary
## 1 1985    ATL    NL barkele01 870000

```

Combine by playerID

```
##   playerID birthYear birthMonth birthDay birthCountry birthState
## 1 aardsda01      1981        12       27        USA        CO
##   birthCity deathYear deathMonth deathDay deathCountry deathState
## 1   Denver        NA        NA        NA      <NA>      <NA>
##   deathCity nameFirst nameLast  nameGiven weight height bats throws
## 1     <NA>    David Aardsma David Allan     215     75     R     R
##       debut finalGame retroID bbrefID deathDate birthDate
## 1 2004-04-06 2015-08-23 aarッド001 aardsda01      <NA> 1981-12-27

##   yearID teamID lgID  playerID salary
## 1 1985    ATL    NL barkele01 870000
```

Connect by playerID

```
##   playerID birthYear birthMonth birthDay birthCountry birthState
## 1 aardsda01      1981        12       27        USA        CO
##   birthCity deathYear deathMonth deathDay deathCountry deathState
## 1   Denver        NA        NA        NA      <NA>      <NA>
##   deathCity nameFirst nameLast  nameGiven weight height bats throws
## 1     <NA>    David Aardsma David Allan     215     75     R     R
##       debut finalGame retroID bbrefID deathDate birthDate
## 1 2004-04-06 2015-08-23 aarՃ001 aardsda01      <NA> 1981-12-27

##   playerID yearID teamID lgID inseason G W L rank plyrMgr
## 1 wrighha01    1871     BS1     NA      1 31 20 10     3      Y
```

Connect by playerID

```
##   playerID birthYear birthMonth birthDay birthCountry birthState
## 1 aardsda01      1981        12       27        USA        CO
##   birthCity deathYear deathMonth deathDay deathCountry deathState
## 1   Denver        NA        NA        NA      <NA>      <NA>
##   deathCity nameFirst nameLast  nameGiven weight height bats throws
## 1     <NA>    David Aardsma David Allan     215     75     R     R
##       debut finalGame retroID bbrefID deathDate birthDate
## 1 2004-04-06 2015-08-23 aarՃ001 aardsda01      <NA> 1981-12-27

##   playerID           awardID yearID lgID tie notes
## 1 larusto01 BBWAA Manager of the Year  1983   AL <NA>     NA
```

How would you characterise the relationship between the Batting, Pitching, and Fielding tables?

All connect by playerID, yearID, stint

```
##   playerID yearID stint teamID lgID G AB R H X2B X3B HR RBI SB CS BB SO
## 1 abercda01    1871     1    TRO    NA 1 4 0 0    0 0 0 0 0 0 0 0 0 0
##       IBB HBP SH SF GIDP
## 1 NA NA NA NA     NA

##   playerID yearID stint teamID lgID W L G GS CG SHO SV IPouts H ER HR BB
## 1 bechtge01    1871     1    PH1    NA 1 2 3 3 2 0 0    78 43 23 0 11
##       SO BAOpp ERA IBB WP HBP BK BFP GF R SH SF GIDP
## 1 1 NA 7.96 NA NA NA O NA NA 42 NA NA     NA

##   playerID yearID stint teamID lgID POS G GS InnOuts PO A E DP PB WP SB
## 1 abercda01    1871     1    TRO    NA SS 1 NA      NA 1 3 2 0 NA NA NA
##       CS ZR
## 1 NA NA
```

14.3 13.4 Mutating joins

The most commonly used join is the left join: you use this whenever you look up additional data from another table, because it preserves the original observations even when there isn't a match.

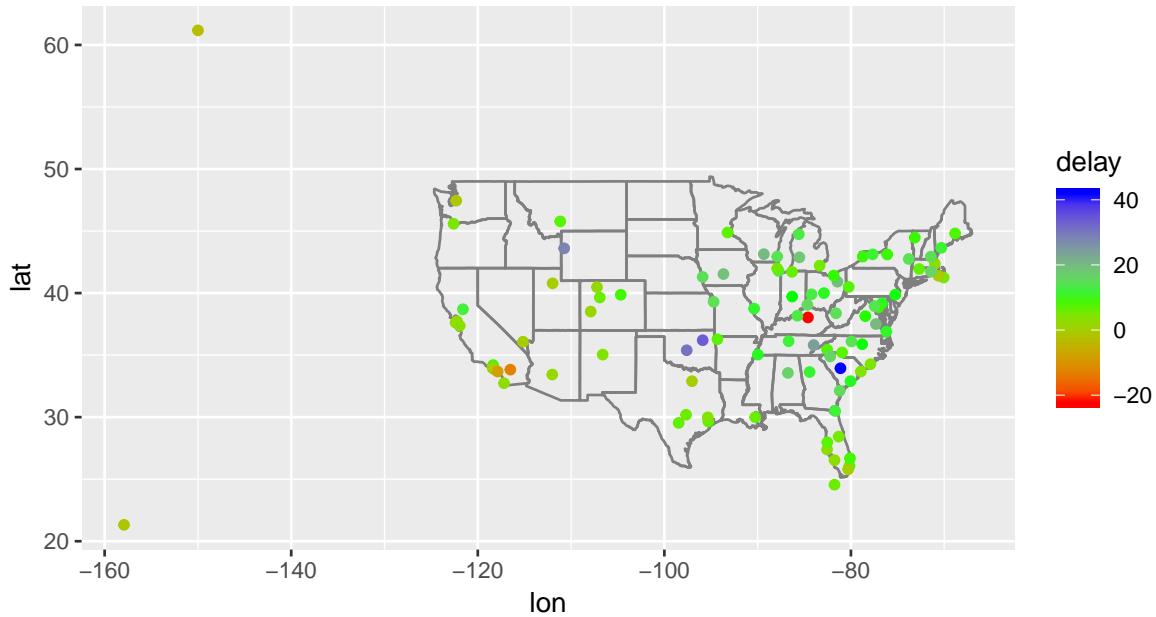
14.3.1 13.4.6

1. Compute the average delay by destination, then join on the `airports` data frame so you can show the spatial distribution of delays. Here's an easy way to draw a map of the United States:

```
airports %>%
  semi_join(flights, c("faa" = "dest")) %>%
  ggplot(aes(lon, lat)) +
  borders("state") +
  geom_point() +
  coord_quickmap()
```

Now adding in colour by average delay.

```
flights %>%
  semi_join(airports, c("dest" = "faa")) %>%
  group_by(dest) %>%
  summarise(delay = mean(arr_delay, na.rm=TRUE)) %>%
  left_join(airports, by = c("dest"="faa")) %>%
  ggplot(aes(lon, lat)) +
  borders("state") +
  geom_point(aes(colour = delay)) +
  coord_quickmap()+
  scale_color_gradientn(colours = rainbow(3))
```



2. Add the location of the origin and destination (i.e. the `lat` and `lon`) to `flights`.

```
flights %>%
  left_join(airports, by = c("dest" = "faa")) %>%
  left_join(airports, by = c("origin" = "faa"), suffix=c("_dest", "_origin")) %>%
  select(flight, carrier, dest, lat_dest, lon_dest, origin, lat_origin, lon_origin)

## # A tibble: 336,776 x 8
##   flight carrier dest  lat_dest lon_dest origin lat_origin lon_origin
##   <int> <chr>   <chr>    <dbl>    <dbl> <chr>      <dbl>    <dbl>
## 1 1545 UA     IAH      30.0    -95.3 EWR       40.7    -74.2
## 2 1714 UA     IAH      30.0    -95.3 LGA       40.8    -73.9
## 3 1141 AA     MIA      25.8    -80.3 JFK       40.6    -73.8
## 4 725 B6      BQN      NA       NA    JFK       40.6    -73.8
## 5 461 DL      ATL      33.6    -84.4 LGA       40.8    -73.9
## 6 1696 UA     ORD      42.0    -87.9 EWR       40.7    -74.2
## 7 507 B6      FLL      26.1    -80.2 EWR       40.7    -74.2
## 8 5708 EV      IAD      38.9    -77.5 LGA       40.8    -73.9
## 9 79 B6      MCO      28.4    -81.3 JFK       40.6    -73.8
## 10 301 AA     ORD      42.0    -87.9 LGA       40.8    -73.9
## # ... with 336,766 more rows
```

Note that the suffix allows you to tag names onto first and second table, hence why vector is length 2

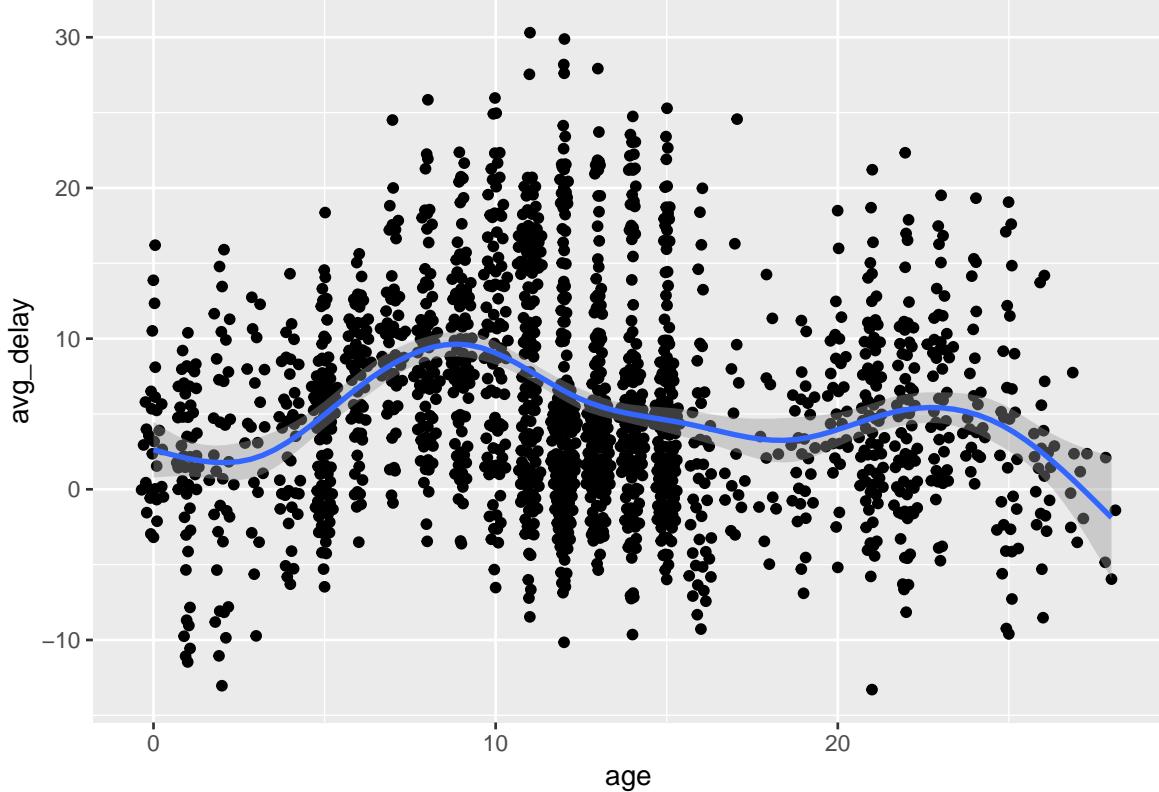
3. Is there a relationship between the age of a plane and its delays?

```
group_by(flights, tailnum) %>%
  summarise(avg_delay = mean(arr_delay, na.rm=TRUE),
            n = n()) %>%
  left_join(planes, by="tailnum") %>%
```

```

mutate(age = 2013 - year) %>%
filter(n > 50, age < 30) %>%
ggplot(aes(x = age, y = avg_delay)) +
ggbeeswarm::geom_quasirandom() +
geom_smooth()

```

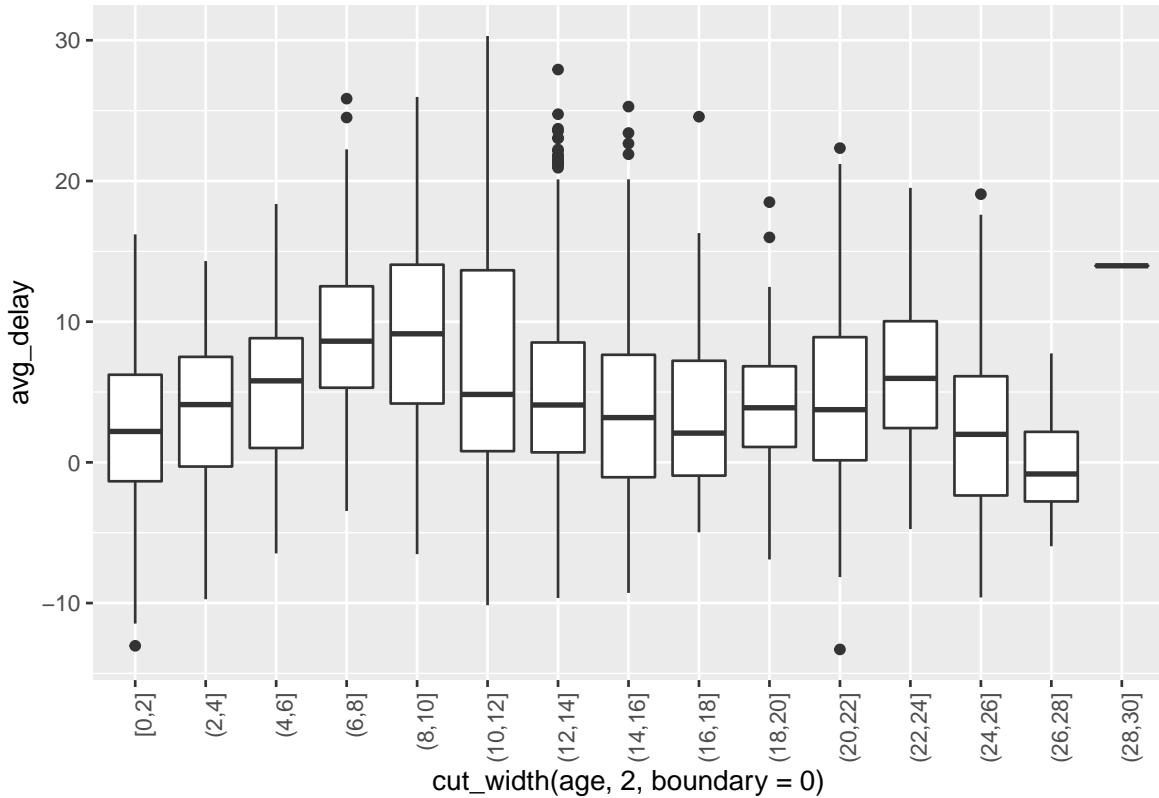


Looks as though planes that are roughly 5 to 10 years old have higher delays... Let's look at same thing using boxplots.

```

group_by(flights, tailnum) %>%
summarise(avg_delay = mean(arr_delay, na.rm=TRUE),
n = n()) %>%
left_join(planes, by="tailnum") %>%
mutate(age = 2013 - year) %>%
filter(n > 50, age <= 30, age >= 0) %>%
ggplot() +
geom_boxplot(aes(x = cut_width(age, 2, boundary = 0), y = avg_delay)) +
theme(axis.text.x = element_text(angle = 90, hjust = 1))

```



Perhaps there is not an overall trend association between age and delays, though it seems that the particular group of planes in that time range seem to have delays than either newer or older planes. On the other hand, there does almost look to be a seasonality pattern – though this may just be me seeing things... perhaps worth exploring more...

A simple way to test for a non-linear relationship would be to discretize age and then pass it through an anova

```
nycflights13::flights %>%
  select(arr_delay, tailnum) %>%
  left_join(planes, by="tailnum") %>%
  filter(!is.na(arr_delay)) %>%
  mutate(age = 2013 - year,
        age_round_5 = (5 * age %% 5) %>% as.factor()) %>%
  with(aov(arr_delay ~ age_round_5)) %>%
  summary()

##                               Df     Sum Sq Mean Sq F value Pr(>F)
## age_round_5      11 1062080  96553   47.92 <2e-16 ***
## Residuals    273841 551756442    2015
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 53493 observations deleted due to missingness
```

- There are weaknesses to using anova, but according to this test arrival delay does not appear to be randomly distributed across age
- The reason for such a difference may be trivial or may be confounded by a more interesting pattern... but these are deeper questions

4. *What weather conditions make it more likely to see a delay?*

There are a lot of ways you could have approached this problem. Below, I look at the average weather value for each of the groups FALSE, TRUE and Canceled – FALSE corresponding with non-delayed flights, TRUE with delayed flights and Canceled with flights that were canceled. If I were feeling fancy, I would have also added the standard errors on these...

```

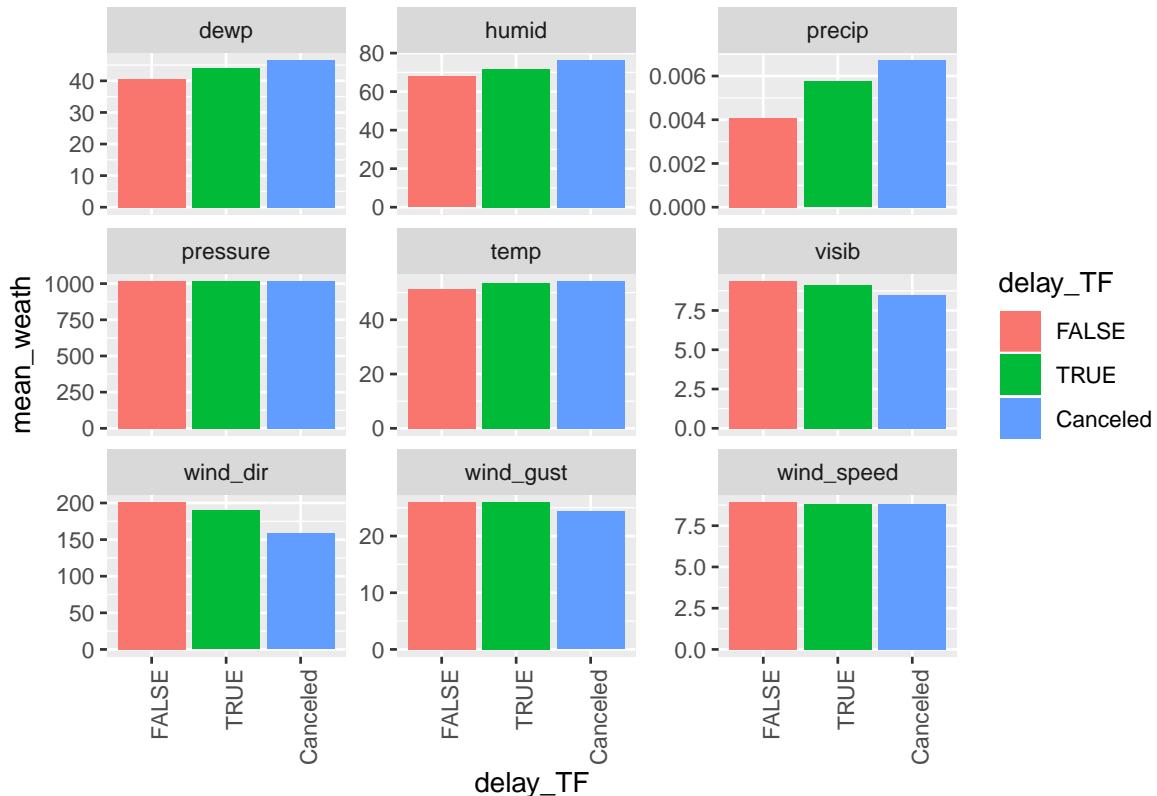
flights_weath <- mutate(flights, delay_TF = dep_delay > 0) %>%
  separate(sched_dep_time,
    into = c("hour_sched", "min_sched"),
    sep = -3,
    remove = FALSE,
    convert = TRUE) %>%
  left_join(weather, by = c("origin", "year", "month", "day", "hour_sched"="hour"))

flights_weath_gath <- flights_weath %>%
  select(sched_dep_time, delay_TF, sched_dep_time, temp:visib) %>%
  mutate(key = row_number()) %>%
  gather(temp, dewp, humid, wind_dir, wind_speed, wind_gust, precip, pressure, visib,
    key="weather", value="values")

flights_summarized <- flights_weath_gath %>%
  group_by(weather, delay_TF) %>%
  summarise(median_weath = median(values, na.rm = TRUE),
            mean_weath = mean(values, na.rm = TRUE),
            sum_n = sum(!is.na(values))) %>%
  ungroup() %>%
  mutate(delay_TF = ifelse(is.na(delay_TF), "Canceled", delay_TF),
        delay_TF =forcats::as_factor(delay_TF, c(FALSE, TRUE, "Canceled")))

flights_summarized %>%
  ggplot(aes(x = delay_TF, y = mean_weath, fill = delay_TF)) +
  geom_col() +
  facet_wrap(~weather, scales = "free_y") +
  theme(axis.text.x = element_text(angle = 90, hjust = 1))

```



While precipitation is the largest difference, my guess is that the standard error on this would be much greater day to day because as you can see the values are very low, so it could be that a few cases with a lot of rain may tick it up, but it may be tough to actually use this as a predictor...

5. *What happened on June 13 2013? Display the spatial pattern of delays, and then use Google to cross-reference with the weather.*

Looks like East coast is getting hammered and flights arriving from Atlanta and similar locations were very delayed. Guessing either weather issue, or problem in Atl or delta.

14.4 13.5 Filtering joins

14.4.1 13.5.1

1. *What does it mean for a flight to have a missing tailnum?*

All flights with a missing tailnum in the `flights` table were cancelled as you can see below.

```
flights %>%
  count(is.na(tailnum), is.na(arr_delay))
```

```
## # A tibble: 3 x 3
##   `is.na(tailnum)` `is.na(arr_delay)`     n
##   <lgl>              <lgl>             <int>
## 1 FALSE              FALSE            327346
## 2 FALSE              TRUE             6918
## 3 TRUE               TRUE             2512
```

What do the tail numbers that don't have a matching record in `planes` have in common? (Hint: one variable explains ~90% of the problems.)

```

flights %>%
  anti_join(planes, by="tailnum") %>%
  count(carrier, sort = TRUE)

## # A tibble: 10 x 2
##   carrier     n
##   <chr>    <int>
## 1 MQ        25397
## 2 AA        22558
## 3 UA        1693
## 4 9E        1044
## 5 B6         830
## 6 US         699
## 7 FL         187
## 8 DL         110
## 9 F9          50
## 10 WN         38

flights %>%
  mutate(in_planes = tailnum %in% planes$tailnum) %>%
  group_by(carrier) %>%
  summarise(flights_inPlanes = sum(in_planes),
            n = n(),
            perc_inPlanes = flights_inPlanes / n) %>%
  ungroup()

## # A tibble: 16 x 4
##   carrier flights_inPlanes     n perc_inPlanes
##   <chr>           <int> <int>        <dbl>
## 1 9E              17416 18460      0.943
## 2 AA              10171 32729      0.311
## 3 AS                714   714       1
## 4 B6              53805 54635      0.985
## 5 DL              48000 48110      0.998
## 6 EV              54173 54173       1
## 7 F9                635   685      0.927
## 8 FL              3073  3260      0.943
## 9 HA                342   342       1
## 10 MQ              1000 26397      0.0379
## 11 OO                 32    32       1
## 12 UA              56972 58665      0.971
## 13 US              19837 20536      0.966
## 14 VX                5162  5162       1
## 15 WN              12237 12275      0.997
## 16 YV                 601   601       1

```

Some carriers do not have many of their tailnums data in the `planes` table. Anyone have more insight here?

2. Filter flights to only show flights with planes that have flown at least 100 flights.

```

planes_many <- flights %>%
  count(tailnum, sort=TRUE) %>%
  filter(n > 100)

```

```
semi_join(flights, planes_many)

## # A tibble: 229,202 x 19
##   year month day dep_time sched_dep_time dep_delay arr_time
##   <int> <int> <int>    <int>           <int>     <dbl>    <int>
## 1 2013    1     1      517        515       2     830
## 2 2013    1     1      533        529       4     850
## 3 2013    1     1      544        545      -1    1004
## 4 2013    1     1      554        558      -4     740
## 5 2013    1     1      555        600      -5     913
## 6 2013    1     1      557        600      -3     709
## 7 2013    1     1      557        600      -3     838
## 8 2013    1     1      558        600      -2     849
## 9 2013    1     1      558        600      -2     853
## 10 2013   1     1      558        600     -2     923
## # ... with 229,192 more rows, and 12 more variables: sched_arr_time <int>,
## #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
## #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>,
## #   minute <dbl>, time_hour <dttm>
```

3. Combine `fueleconomy::vehicles` and `fueleconomy::common` to find only the records for the most common models.

```
fueleconomy::vehicles %>%
  semi_join(fueleconomy::common, by=c("make", "model"))
```

```
## # A tibble: 14,531 x 12
##   id make model year class trans drive cyl displ fuel hwy cty
##   <int> <chr> <chr> <int> <chr> <chr> <chr> <int> <dbl> <chr> <int> <int>
## 1 1833 Acura Integ~ 1986 Subc~ Auto~ Fron~ 4 1.6 Regu~ 28 22
## 2 1834 Acura Integ~ 1986 Subc~ Manu~ Fron~ 4 1.6 Regu~ 28 23
## 3 3037 Acura Integ~ 1987 Subc~ Auto~ Fron~ 4 1.6 Regu~ 28 22
## 4 3038 Acura Integ~ 1987 Subc~ Manu~ Fron~ 4 1.6 Regu~ 28 23
## 5 4183 Acura Integ~ 1988 Subc~ Auto~ Fron~ 4 1.6 Regu~ 27 22
## 6 4184 Acura Integ~ 1988 Subc~ Manu~ Fron~ 4 1.6 Regu~ 28 23
## 7 5303 Acura Integ~ 1989 Subc~ Auto~ Fron~ 4 1.6 Regu~ 27 22
## 8 5304 Acura Integ~ 1989 Subc~ Manu~ Fron~ 4 1.6 Regu~ 28 23
## 9 6442 Acura Integ~ 1990 Subc~ Auto~ Fron~ 4 1.8 Regu~ 24 20
## 10 6443 Acura Integ~ 1990 Subc~ Manu~ Fron~ 4 1.8 Regu~ 26 21
## # ... with 14,521 more rows
```

4. Find the 48 hours (over the course of the whole year) that have the worst delays. Cross-reference it with the `weather` data. Can you see any patterns?

First: Create two variables that together capture all 48 hour time windows across the year, at the day window of granularity (e.g. the time of day the flight takes off does not matter in establishing time windows for this example, only the day). Second: Gather these time windows into a single dataframe (note that this will increase the length of your data by ~364/365 * 100 %) Third: Group by `window_start_date` and calculate average `arr_delay` and related metrics.

```
delays_windows <- flights %>%
  #First
  mutate(date_flight = lubridate::as_date(time_hour)) %>%
  mutate(startdate_window1 = cut.Date(date_flight, "2 day")) %>%
  mutate(date_flight2 = ifelse(!(date_flight == min(date_flight, na.rm = TRUE)), date_flight, NA),
        date_flight2 = lubridate::as_date(date_flight2),
```

```

   startdate_window2 = cut.Date(date_flight2, "2 day")) %>%
select(-date_flight, -date_flight2) %>%
#Second
gather(startdate_window1, startdate_window2, key = "start_window", value = "window_start_date") %>%
filter(!is.na(window_start_date)) %>%
#Third
group_by(window_start_date) %>%
summarise(num = n(),
          perc_cancelled = sum(is.na(arr_delay)) / n(),
          mean_delay = mean(arr_delay, na.rm = TRUE),
          perc_delay = mean(arr_delay > 0, na.rm = TRUE),
          total_delay_mins = sum(arr_delay, na.rm = TRUE)) %>%
ungroup()

## Warning: attributes are not identical across measure variables;
## they will be dropped
#don't worry about warning of 'attributes are not identical...', that is
#because the cut function assigns attributes to the value, it's fine if
#these are dropped here.

```

Create tibble of worst 2-day period for mean arr_delay

```

WorstWindow <- delays_windows %>%
  mutate(mean_delay_rank = dplyr::min_rank(-mean_delay)) %>%
  filter(mean_delay_rank <= 1)

```

```

WorstDates <- tibble(dates = c(lubridate::as_date(WorstWindow$window_start_date), lubridate::as_date

```

Ammend weather data so that weather is an average across three NY locations rather than seperate for each¹

```

weather_ammended <- weather %>%
  mutate(time_hour = lubridate::make_datetime(year, month, day, hour)) %>%
  select(-one_of("origin", "year", "month", "day", "hour")) %>%
  group_by(time_hour) %>%
  summarise_all(mean, na.rm = TRUE) %>%
  ungroup()

```

Filtering join to just times weather for worst 2 days

```

weather_worst <- weather_ammended %>%
  mutate(dates = as_date(time_hour)) %>%
  semi_join(WorstDates)

```

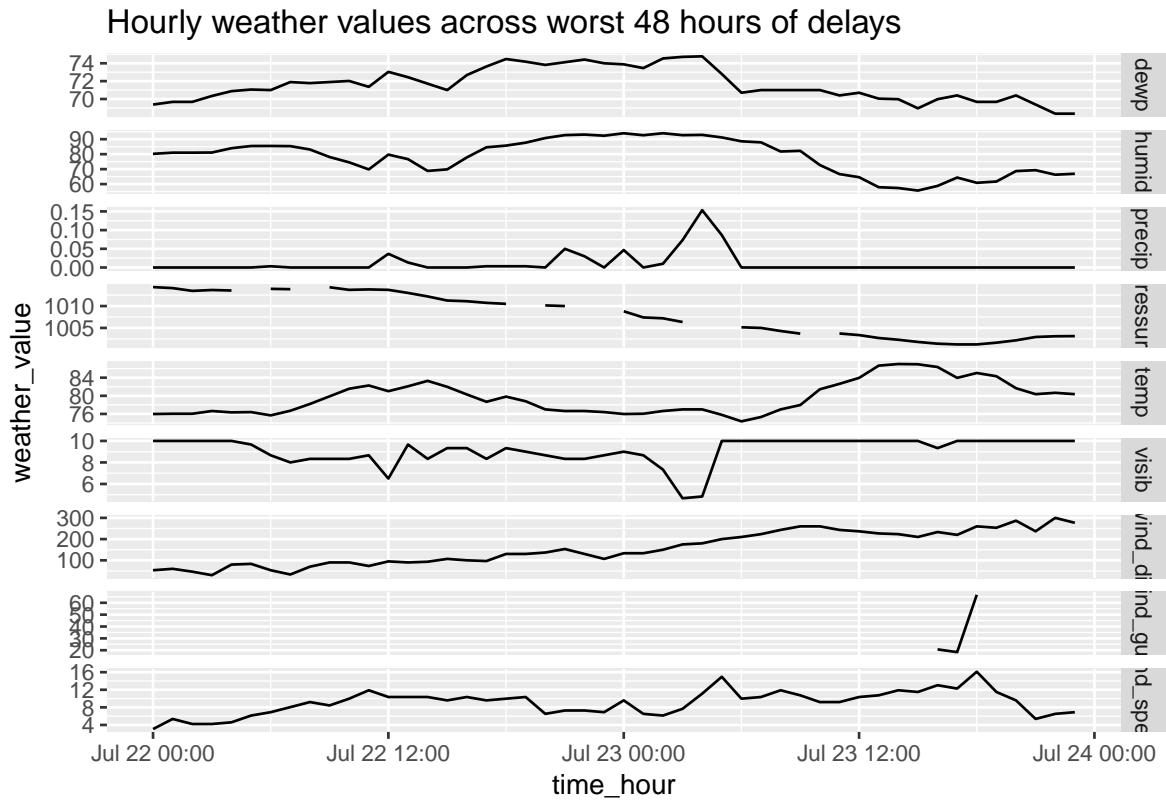
Plot of hourly weather values across 48 hour time windows.

```

weather_worst %>%
  select(-dates) %>%
  gather(temp:visib, key = "weather_type", value = "weather_value") %>%
  ggplot(aes(x = time_hour, y = weather_value)) +
  geom_line() +
  facet_grid(weather_type ~ ., scales = "free_y") +
  labs(title = 'Hourly weather values across worst 48 hours of delays')

```

¹note that a weighted average based on traffic would be more appropriate here because the mean_delay values will be weighted by number of flights going through each – hopefully lack of substantial difference between locatioins means this won't be too impactful...



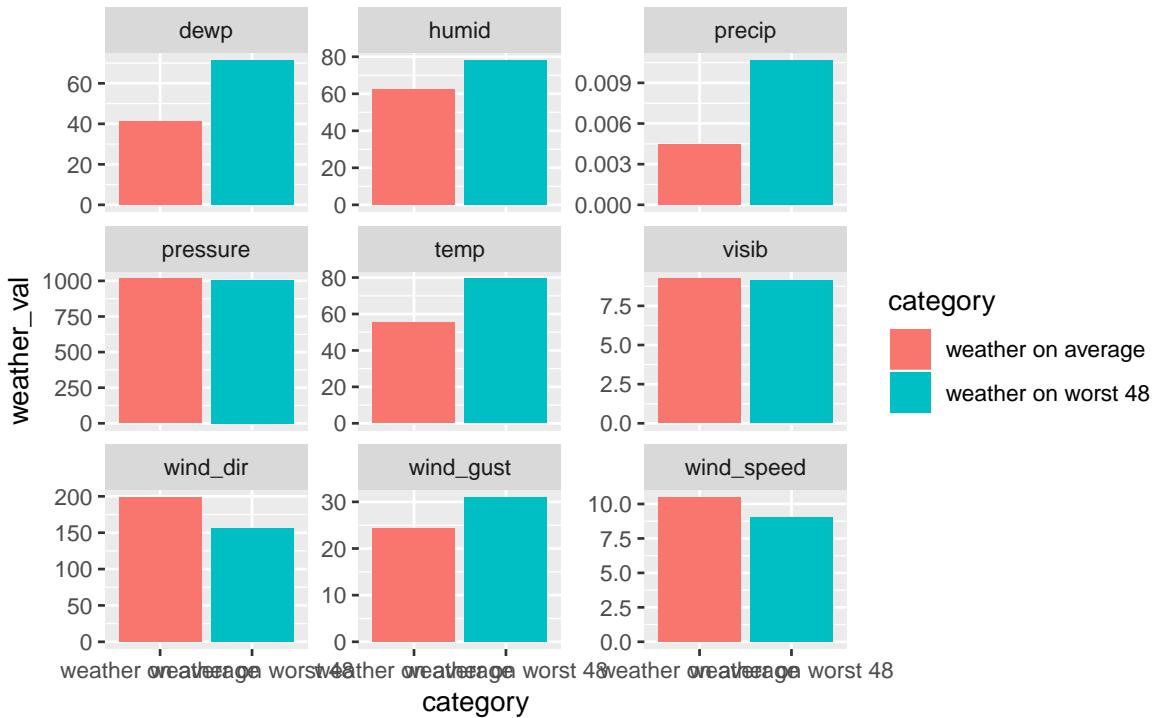
Patterns:

- `wind_gust` and `wind_speed` are the same.
- See high level of colinearity in spikes and changes, e.g. increase in `precip` corresponds with decrease in `visib` and perhaps uptick in `wind_spee`

Perhaps, we want to view how the average hourly weather values compare on the worst days to average weather days. Create summary of average hourly weather values for worst 48 hour period, for average period, and then append these and plot.

```
bind_rows(
  weather_worst %>%
    summarise_at(vars(temp:visib), mean, na.rm = TRUE) %>%
    mutate(category = "weather on worst 48") %>%
    gather(temp:visib, key = weather_type, value = weather_val)
  ,
  weather_ammended %>%
    summarise_at(vars(temp:visib), mean, na.rm = TRUE) %>%
    mutate(category = "weather on average") %>%
    gather(temp:visib, key = weather_type, value = weather_val)
) %>%
  ggplot(aes(x = category, y = weather_val, fill = category)) +
  geom_col() +
  facet_wrap(~weather_type, scales = "free_y") +
  labs(title = "Hourly average weather values on worst 48 hour window of delays vs. hourly average",
       caption = "Note that delays are based on mean(arr_delay, na.rm = TRUE)")
```

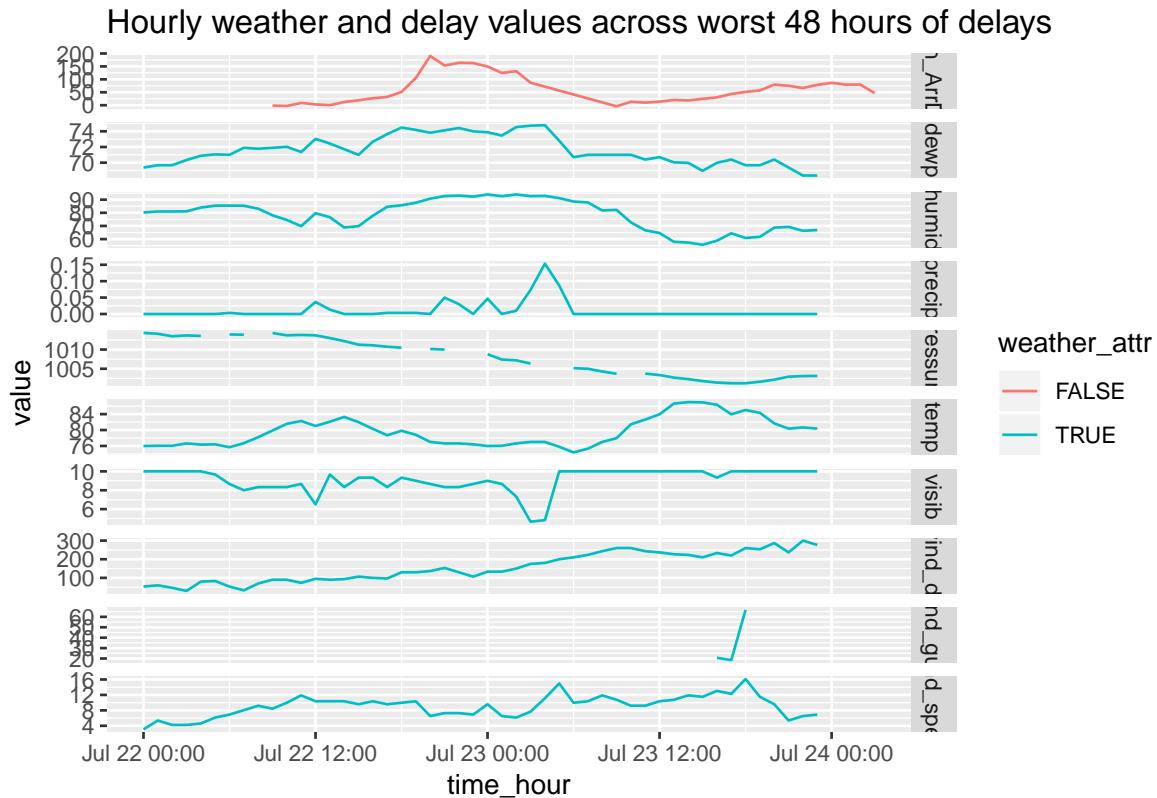
Hourly average weather values on worst 48 hour window of delays vs. hour



For this to be the worst 48 hour period, the weather doesn't actually seem to be as extreme as I would have guessed.

Let's add-in average `arr_delay` by planned departure time to this to see how the delay times throughout the day varied, to see if there was a surge or change in weather that led to the huge change in delays.

```
flights %>%
  mutate(dates = as_date(time_hour)) %>%
  semi_join(WorstDates) %>%
  group_by(time_hour) %>%
  summarise(value = mean(arr_delay, na.rm = TRUE)) %>%
  ungroup() %>%
  mutate(value_type = "Mean_ArrDelay") %>%
  bind_rows(
    weather_worst %>%
      select(-dates) %>%
      gather(temp:visib, key = "value_type", value = "value")
  ) %>%
  mutate(weather_attr = !(value_type == "Mean_ArrDelay"),
         value_type =forcats::fct_relevel(value_type, "Mean_ArrDelay")) %>%
  ggplot(aes(x = time_hour, value, colour = weather_attr)) +
  geom_line() +
  facet_grid(value_type ~ ., scales = "free_y") +
  labs(title = 'Hourly weather and delay values across worst 48 hours of delays')
```



Maybe that first uptick in precipitation corresponded with the increase in delay... but still, looks extreme like an incident caused this. I checked the news and it looks like a plane was crash landed onto the tarmac at one of the airports on this day https://en.wikipedia.org/wiki/Southwest_Airlines_Flight_345#cite_note-DMN_Aircraft_Totaled_20160808-4, I checked the incident time and it occurred at 17:45 Jul 22, looks like it overlaps with the time we see the uptick in delays.

I show plots and models of 48 hour time windows in a variety of other contexts and detail in Appendix

5. What does `anti_join(flights, airports, by = c("dest" = "faa"))` tell you? What does `anti_join(airports, flights, by = c("faa" = "dest"))` tell you?
`anti_join(flights, airports, by = c("dest" = "faa"))` – tells me the flight dests missing an airport
`anti_join(airports, flights, by = c("faa" = "dest"))` – tells me the airports with no flights coming to them
6. You might expect that there's an implicit relationship between plane and airline, because each plane is flown by a single airline. Confirm or reject this hypothesis using the tools you've learned above.

```
tail_carr <- flights %>%
  filter(!is.na(tailnum)) %>%
  distinct(carrier, tailnum) %>%
  count(tailnum, sort=TRUE)
```

```
tail_carr %>%
  filter(n > 1)
```

```
## # A tibble: 17 x 2
##   tailnum      n
##   <chr>     <int>
## 1 N146PQ      2
```

```

##  2 N153PQ      2
##  3 N176PQ      2
##  4 N181PQ      2
##  5 N197PQ      2
##  6 N200PQ      2
##  7 N228PQ      2
##  8 N232PQ      2
##  9 N933AT      2
## 10 N935AT      2
## 11 N977AT      2
## 12 N978AT      2
## 13 N979AT      2
## 14 N981AT      2
## 15 N989AT      2
## 16 N990AT      2
## 17 N994AT      2

```

You should reject that hypothesis, you can see that 17 tailnums are duplicated on multiple carriers.

Below is code to show those 17 tailnums

```

flights %>%
  distinct(carrier, tailnum) %>%
  filter(!is.na(tailnum)) %>%
  group_by(tailnum) %>%
  mutate(n_tail = n()) %>%
  ungroup() %>%
  filter(n_tail > 1) %>%
  arrange(desc(n_tail), tailnum)

```

```

## # A tibble: 34 x 3
##   carrier tailnum n_tail
##   <chr>    <chr>     <int>
## 1 9E       N146PQ      2
## 2 EV       N146PQ      2
## 3 9E       N153PQ      2
## 4 EV       N153PQ      2
## 5 9E       N176PQ      2
## 6 EV       N176PQ      2
## 7 9E       N181PQ      2
## 8 EV       N181PQ      2
## 9 9E       N197PQ      2
## 10 EV      N197PQ      2
## # ... with 24 more rows

```

#Appendix

##13.5.1.4

Graph all of these metrics at once using roughly the same method as used on 13.4.6 #4.

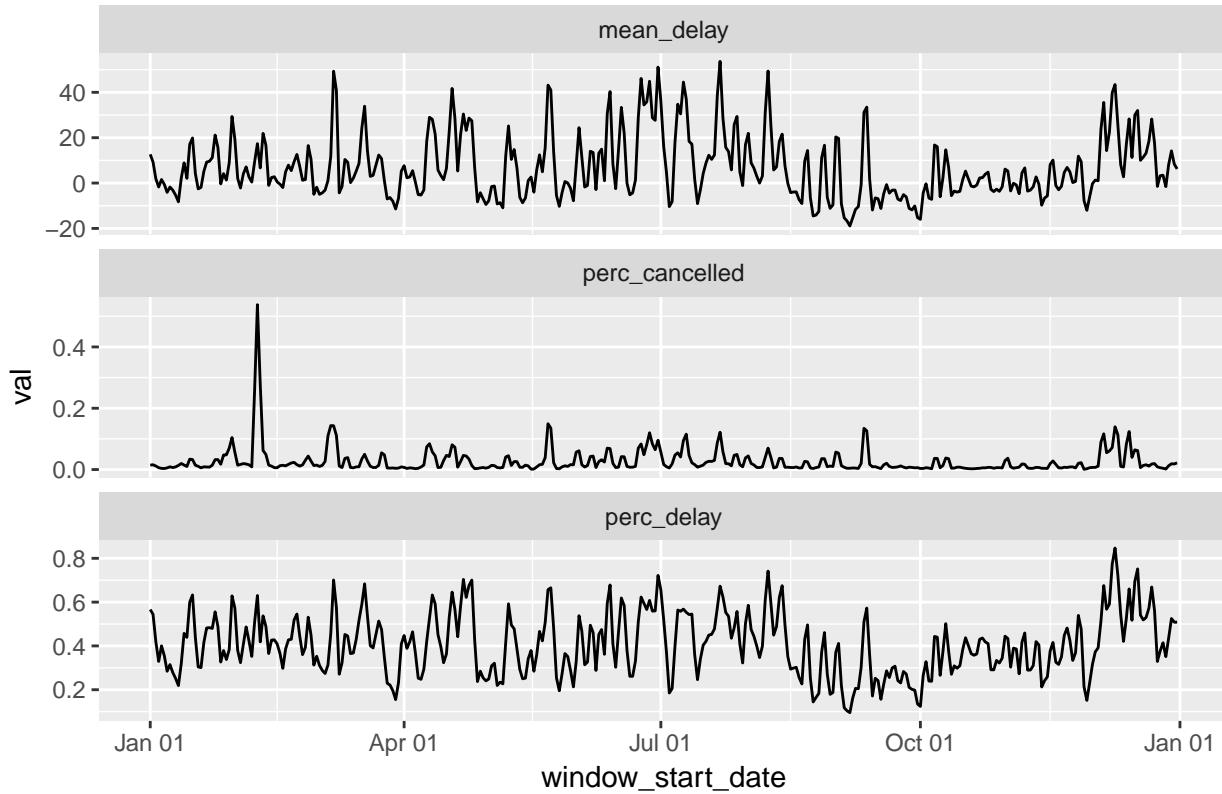
```

delays_windows %>%
  gather(perc_cancelled, mean_delay, perc_delay, key = value_type, value = val) %>%
  mutate(window_start_date = lubridate::as_date(window_start_date)) %>%
  ggplot(aes(window_start_date, val)) +
  geom_line() +
  facet_wrap(~value_type, scales = "free_y", ncol = 1) +

```

```
scale_x_date(date_labels = "%b %d")+
  labs(title = 'Measures of delay across 48 hour time windows')
```

Measures of delay across 48 hour time windows



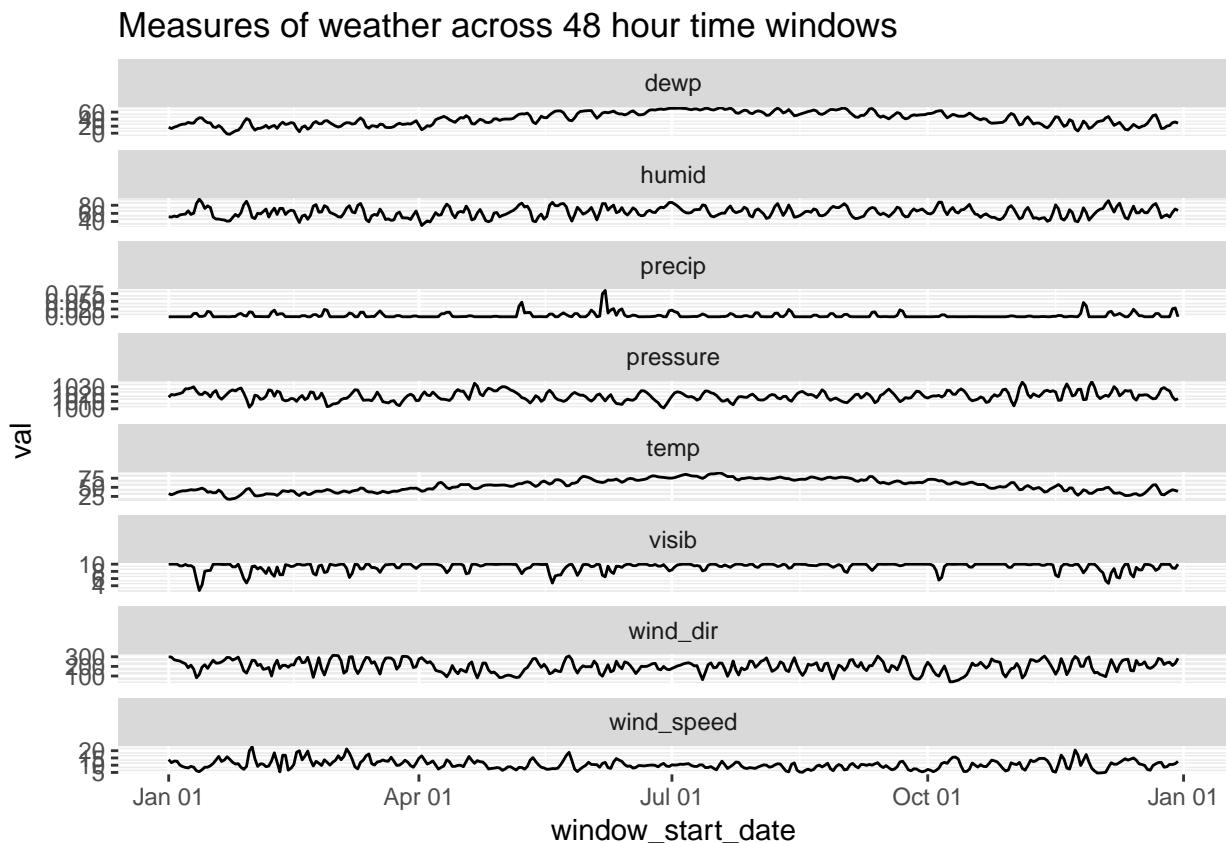
Create 48 hour windows for weather data. Follow exact same steps as above.

```
weather_windows <- weather_ammended %>%
  mutate(date_flight = lubridate::as_date(time_hour)) %>%
  mutate(startdate_window1 = cut.Date(date_flight, "2 day")) %>%
  mutate(date_flight2 = ifelse(!(date_flight == min(date_flight, na.rm = TRUE)), date_flight, NA),
         date_flight2 = lubridate::as_date(date_flight2),
         startdate_window2 = cut.Date(date_flight2, "2 day")) %>%
  select(-date_flight, -date_flight2) %>%
  #Second
  gather(startdate_window1, startdate_window2, key = "start_window", value = "window_start_date") %>%
  filter(!is.na(window_start_date)) %>%
  #Third
  group_by(window_start_date) %>%
  summarise_at(vars(temp:visib), mean, na.rm = TRUE) %>%
  ungroup() %>%
  select(-wind_gust)

## Warning: attributes are not identical across measure variables;
## they will be dropped
```

Graph using same method as above...

```
weather_windows %>%
  gather(temp:visib, key = weather_type, value = val) %>%
  mutate(window_start_date = lubridate::as_date(window_start_date)) %>%
  ggplot(aes(x = window_start_date, y = val)) +
  geom_line() +
  facet_wrap(~weather_type, ncol = 1, scales = "free_y") +
  scale_x_date(date_labels = "%b %d") +
  labs(title = 'Measures of weather across 48 hour time windows')
```

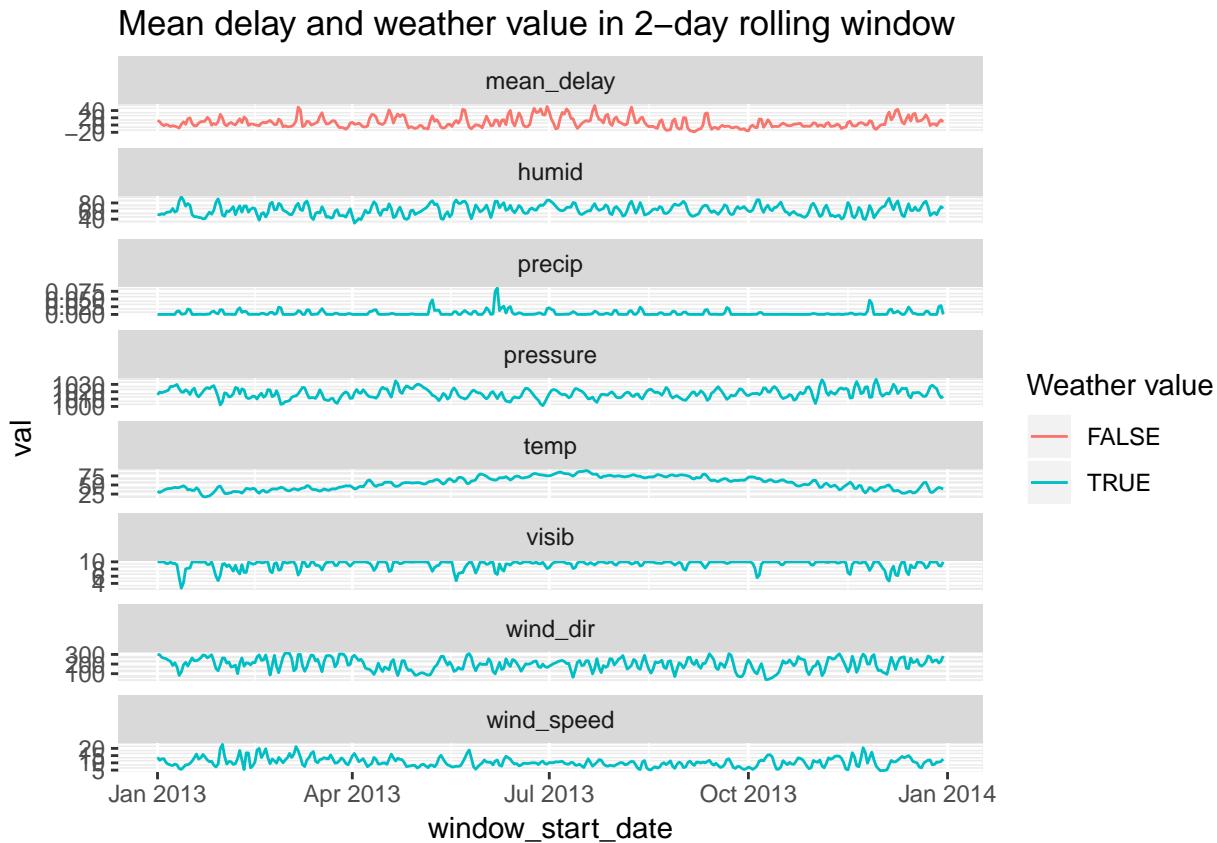


Connect delays and weather data

```
weather_delay_joined <- left_join(delays_windows, weather_windows, by = "window_start_date") %>%
  select(mean_delay, temp:visib, window_start_date) %>%
  select(-dewp) #is almost completely correlated with temp so removed one of them...
  na.omit()
```

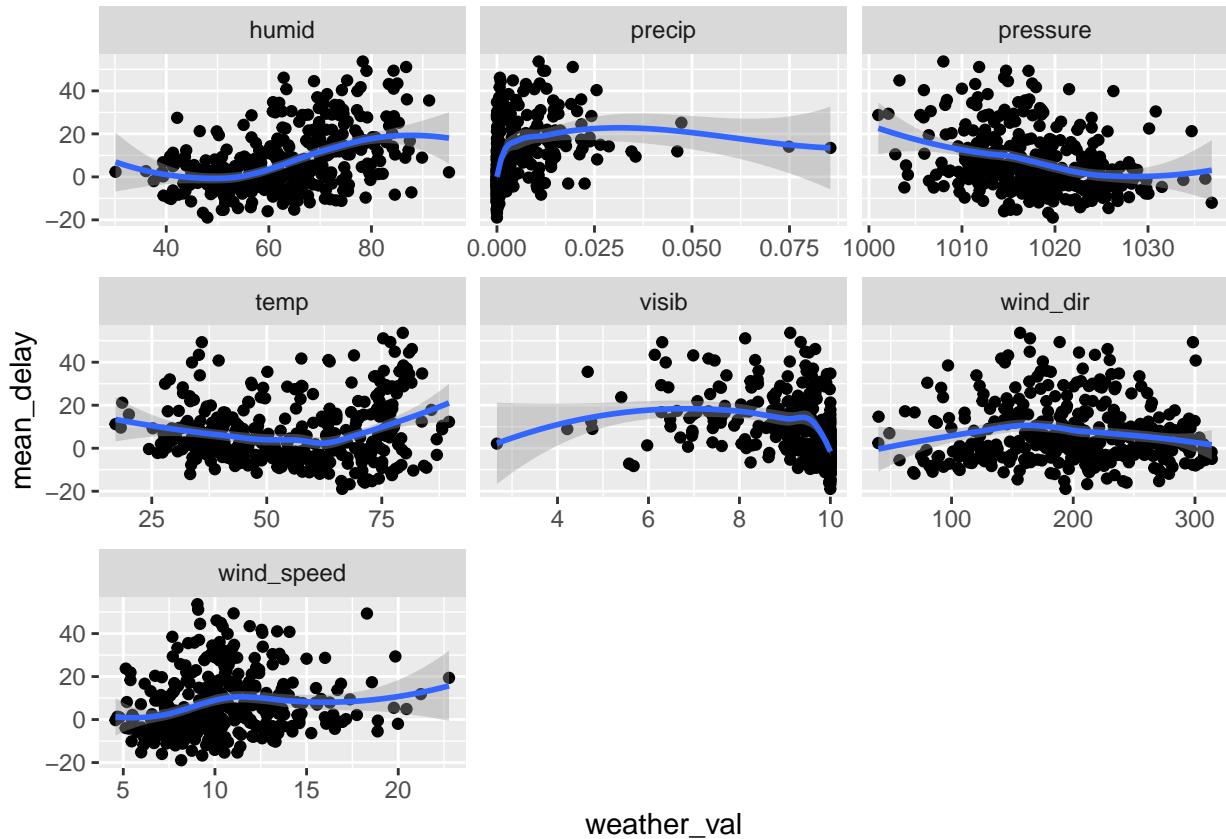
Plot of 48 hour window of weather scores against mean delay keeping intact order of observations

```
weather_delay_joined %>%
  gather(mean_delay, temp:visib, key = value_type, value = val) %>%
  mutate(window_start_date = lubridate::as_date(window_start_date),
        value_type = forcats::fct_relevel(value_type, "mean_delay")) %>%
  ggplot(aes(x = window_start_date, y = val, colour = !value_type == "mean_delay")) +
  geom_line() +
  facet_wrap(~value_type, scales = "free_y", ncol = 1) +
  labs(colour = "Weather value", title = "Mean delay and weather value in 2-day rolling window")
```



Plot of mean_delay against weather type, each point representing a different ‘window’

```
weather_delay_joined %>%
  gather(temp:visib, key = weather_type, value = weather_val) %>%
  ggplot(aes(x = weather_val, y = mean_delay)) +
  geom_point() +
  geom_smooth() +
  facet_wrap(~weather_type, scales = "free_x")
```



In a sense, these plots are not really valid as they obscure the fact that each point is not an independent observation (because there is a high level of association with w/e the value was on a single day with what it was in the previous day). E.g. `mean_delay` has a correlation of ~ 0.68 with prior days value as shown below... This is often ignored and we can also ignore it for now as it gets into time series and things we don't need to worry about for now... but something to be aware...

```
weather_delay_joined %>%
  mutate(mean_delay_lag = lag(mean_delay)) %>%
  select(mean_delay, mean_delay_lag) %>%
  na.omit() %>%
  cor()
```

```
##           mean_delay mean_delay_lag
## mean_delay      1.0000000      0.6795631
## mean_delay_lag  0.6795631      1.0000000
```

Data is not Independent (as mentioned above) and many problems associated with this... but let's ignore this for now and just look at a few statistics...

Can see below that raw correlation of `mean_delay` is highest with `humid`.

```
weather_delay_joined %>%
  select(-window_start_date) %>%
  cor()
```

```
##           mean_delay      temp      humid   wind_dir   wind_speed
## mean_delay      1.0000000  0.08515338  0.4549140 -0.05371522  0.16262585
## temp          0.08515338  1.00000000  0.3036520 -0.25906906 -0.40160692
## humid         0.45491403  0.30365205  1.0000000 -0.51010505 -0.30383181
```

```

## wind_dir -0.05371522 -0.25906906 -0.5101050 1.00000000 0.50039832
## wind_speed 0.16262585 -0.40160692 -0.3038318 0.50039832 1.00000000
## precip 0.36475598 0.02775525 0.4481898 -0.12853817 0.11176053
## pressure -0.31716918 -0.23873857 -0.2363718 -0.26627495 -0.25716938
## visib -0.38740156 0.12290097 -0.6647598 0.26307685 0.05275072
##           precip   pressure     visib
## mean_delay 0.36475598 -0.3171692 -0.38740156
## temp       0.02775525 -0.2387386 0.12290097
## humid      0.44818978 -0.2363718 -0.66475984
## wind_dir   -0.12853817 -0.2662749 0.26307685
## wind_speed 0.11176053 -0.2571694 0.05275072
## precip     1.00000000 -0.2265636 -0.44400337
## pressure   -0.22656357 1.0000000 0.12032520
## visib      -0.44400337 0.1203252 1.00000000

```

When accounting for other variables, see relationship with windspeed seems to emerge as important...

```
weather_delay_joined %>%
```

```

  select(-window_start_date) %>%
  lm(mean_delay ~ ., data = .) %>%
  summary()

```

```

##
## Call:
## lm(formula = mean_delay ~ ., data = .)
##
## Residuals:
##    Min      1Q  Median      3Q     Max
## -26.179  -7.581  -1.374   5.271  38.008
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 169.56872 132.07737  1.284  0.2000
## temp        0.05460   0.04702  1.161  0.2464
## humid       0.48158   0.09088  5.299 2.04e-07 ***
## wind_dir    0.01420   0.01376  1.032  0.3026
## wind_speed  1.15641   0.25561  4.524 8.28e-06 ***
## precip      140.84141  78.84192  1.786  0.0749 .
## pressure    -0.19722   0.12476 -1.581  0.1148
## visib      -1.15009   0.80567 -1.427  0.1543
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.64 on 356 degrees of freedom
## Multiple R-squared:  0.3332, Adjusted R-squared:  0.3201
## F-statistic: 25.42 on 7 and 356 DF, p-value: < 2.2e-16

```

For a variety of reasons, especially in cases where your observations are not independent, you may want to evaluate how the change in an attribute relates to the change in another attribute. In the cases below I plot the diffs for example:

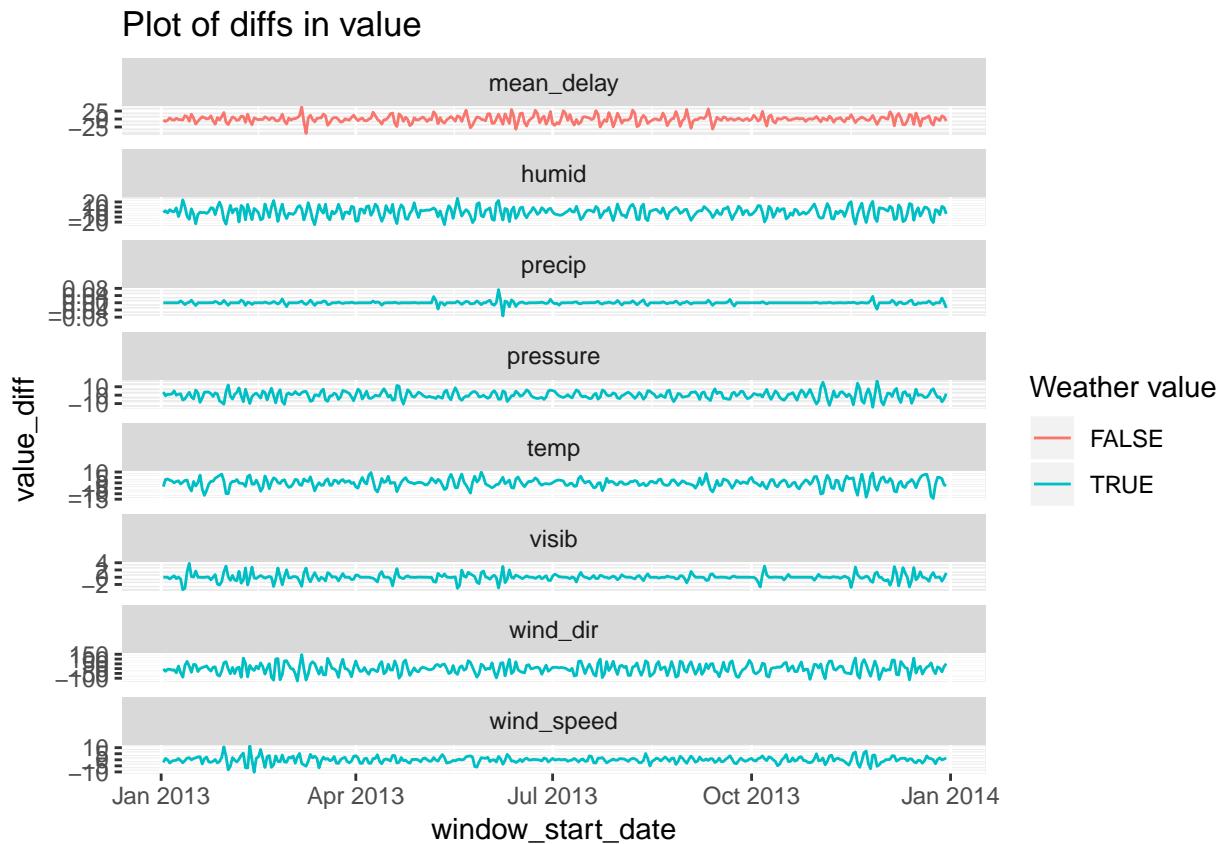
(average value on 2013-02-07 to 2013-02-08) - (average value on 2013-02-08 to 2013-02-09)

Note that the time windows are not distinct but overlap by 24 hours.

If doing a thorough account of time-series you would do a lot more than I show below...

```
weather_delay_joined %>%
  gather(mean_delay, temp:visib, key = value_type, value = val) %>%
  mutate(window_start_date = lubridate::as_date(window_start_date),
        value_type = forcats::fct_relevel(value_type, "mean_delay")) %>%
  group_by(value_type) %>%
  mutate(value_diff = val - lag(val)) %>%
  ggplot(aes(x = window_start_date, y = value_diff, colour = !value_type == "mean_delay")) +
  geom_line() +
  facet_wrap(~value_type, scales = "free_y", ncol = 1) +
  labs(colour = "Weather value", title = "Plot of diffs in value")
```

Warning: Removed 2 rows containing missing values (geom_path).

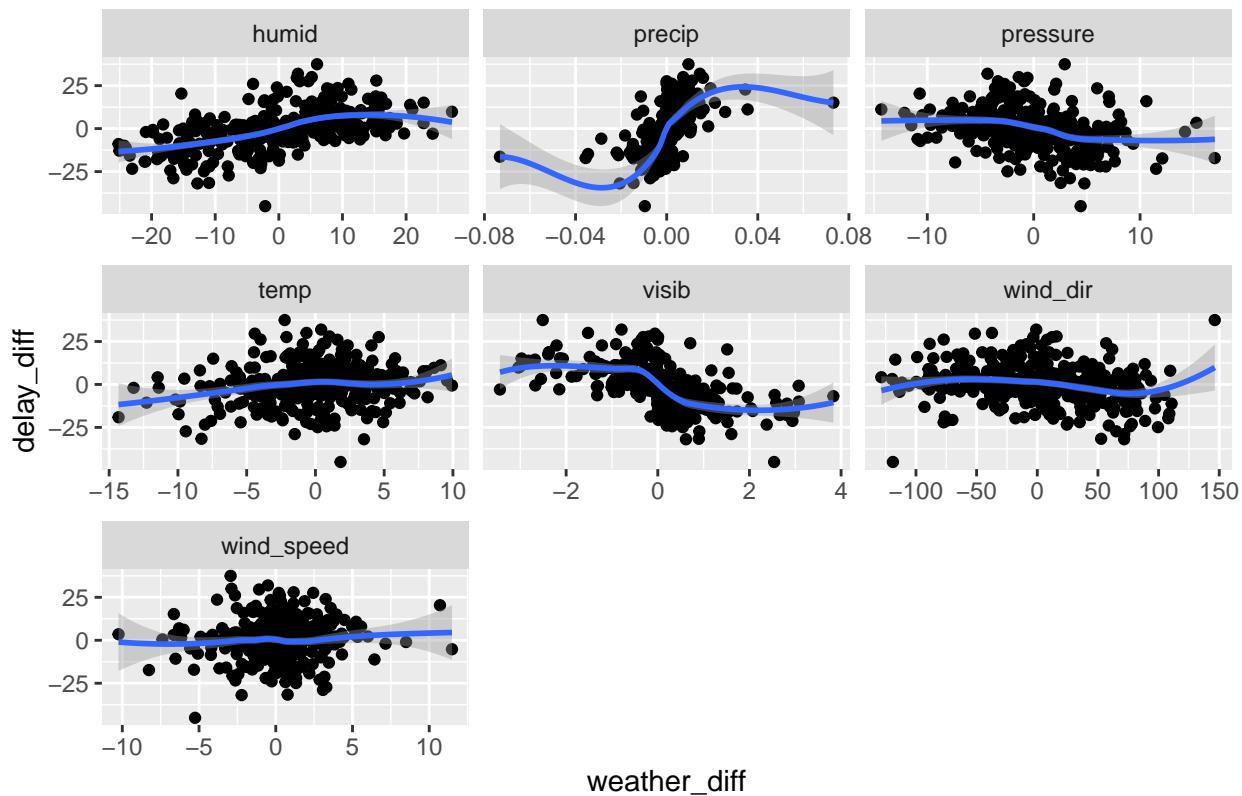


Let's plot these diffs as a scatter plot now (no longer looking at the order in which the observations emerged)

```
weather_delay_joined %>%
  gather(temp:visib, key = weather_type, value = val) %>%
  group_by(weather_type) %>%
  mutate(weather_diff = val - lag(val),
        delay_diff = mean_delay - lag(mean_delay)) %>%
  ungroup() %>%
  ggplot(aes(x = weather_diff, y = delay_diff)) +
  geom_point() +
  geom_smooth() +
  facet_wrap(~weather_type, scales = "free_x") +
  labs(title = "scatter plot of diffs in value")
```

```
## Warning: Removed 7 rows containing non-finite values (stat_smooth).
## Warning: Removed 7 rows containing missing values (geom_point).
```

scatter plot of diffs in value



Let's look at the correlation and regression against these diffs

```
diff_data <- weather_delay_joined %>%
  gather(mean_delay, temp:visib, key = value_type, value = val) %>%
  group_by(value_type) %>%
  mutate(diff = val - lag(val)) %>%
  ungroup() %>%
  select(-val) %>%
  spread(key = value_type, value = diff)

diff_data %>%
  select(-window_start_date) %>%
  na.omit() %>%
  cor()
```

| | humid | mean_delay | precip | pressure | temp |
|---------------|------------|-------------|-------------|------------|--------------|
| ## humid | 1.0000000 | 0.54331654 | 0.48014091 | -0.3427556 | 0.318534448 |
| ## mean_delay | 0.5433165 | 1.00000000 | 0.51510649 | -0.3247584 | 0.150601446 |
| ## precip | 0.4801409 | 0.51510649 | 1.00000000 | -0.3014413 | 0.074916969 |
| ## pressure | -0.3427556 | -0.32475840 | -0.30144131 | 1.0000000 | -0.488629288 |
| ## temp | 0.3185344 | 0.15060145 | 0.07491697 | -0.4886293 | 1.000000000 |
| ## visib | -0.7393902 | -0.53844191 | -0.49795469 | 0.2721685 | -0.206815887 |
| ## wind_dir | -0.4978895 | -0.20689204 | -0.20823801 | -0.2443716 | -0.003608694 |
| ## wind_speed | -0.1964910 | 0.05738881 | 0.15742776 | -0.3687487 | -0.085437521 |

```

##          visib    wind_dir  wind_speed
## humid      -0.73939024 -0.497889528 -0.19649100
## mean_delay -0.53844191 -0.206892045  0.05738881
## precip     -0.49795469 -0.208238012  0.15742776
## pressure    0.27216848 -0.244371617 -0.36874869
## temp       -0.20681589 -0.003608694 -0.08543752
## visib       1.00000000  0.378625695  0.06152223
## wind_dir     0.37862569  1.000000000  0.43970745
## wind_speed   0.06152223  0.439707451  1.00000000

diff_data %>%
  select(-window_start_date) %>%
  lm(mean_delay ~ ., data = .) %>%
  summary()

##
## Call:
## lm(formula = mean_delay ~ ., data = .)
##
## Residuals:
##    Min      1Q  Median      3Q     Max
## -32.843 -4.394 -0.189  3.749 27.177
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.022454  0.460301 -0.049 0.961121
## humid        0.281416  0.082305  3.419 0.000701 ***
## precip       324.087906 63.453719  5.107 5.34e-07 ***
## pressure     -0.275033  0.149084 -1.845 0.065895 .
## temp         -0.127570  0.143134 -0.891 0.373394
## visib        -2.420046  0.728749 -3.321 0.000991 ***
## wind_dir      0.002373  0.012316  0.193 0.847329
## wind_speed    0.128749  0.226138  0.569 0.569487
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.77 on 355 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.4111, Adjusted R-squared:  0.3995
## F-statistic: 35.4 on 7 and 355 DF,  p-value: < 2.2e-16

```

Make sure the following packages are installed:

Chapter 15

ch. 14: Strings

- `writeLines`: see raw contents of a string (prints each string in a vector on a new line)
- `str_length`: number of characters in a string
- `str_c`: combine two or more strings
 - use `collapse` arg to make vector of strings to single string
- `str_replace_na`: print NA as “NA”
- `str_sub`: start and end args to specify position to remove (or replace), can use negative numbers as well to represent from back
- `str_to_lower`, `str_to_upper`, `str_to_upper`: for changing string case
 - `locale` arg (to handle slight differences in characters)
- `str_order`, `str_sort`: more robust version of `order` and `sort` which take allow a `locale` argument
- `str_view`, `str_view_all`: shows how character and regular expression match
- `\d`: matches any digit.
- `\s`: matches any whitespace (e.g. space, tab, newline).
- `[abc]`: matches a, b, or c.
- `[^abc]`: matches anything except a, b, or c.
- `{n}`: exactly n
- `{n,}`: n or more
- `{,m}`: at most m
- `{n,m}`: between n and m
- `str_detect`: returns logical vector of TRUE/FALSE values
- `str_subset`: subset of TRUE values from `str_detect`
- `str_count`: number of matches in a string
- `str_extract`: extract actual text of a match
- `str_extract_all`: returns list with all matches
 - `simplify = TRUE` returns a matrix

- `str_match`: similar to `str_extract` but gives each individual component of match in a matrix, rather than a character vector (also have a `str_match_all`)
- `tidy::extract`: like `str_match` but name columns with matches which are moved into new columns
- `str_replace`, `str_replace_all`: replace matches with new strings
- `str_split` split a string into pieces – default is individual words (returns list)
 - `simplify = TRUE` again will return a matrix
- `boundary` use to specify level of split, e.g. `str_view_all(x, boundary("word"))`
- `str_locate`, `str_locate_all`: gives starting and ending positions of each match
- `regex` use in match to specify more options, e.g. `str_view(bananas, regex("banana", ignore_case = TRUE))`
 - `multiline = TRUE` allows ^ and \$ to match start and end of each line (rather than of string)
 - `comments = TRUE` allows you to add comments on a complex regular expression
 - `dotall = TRUE` allows . to match more than just letters e.g. \\n
- `fixed`, `coll` related alternatives to `regex`
- `apropos` searches all objects available from global environment (e.g. say you can't remember function name)
- `dir`: lists all files in a directory
 - `pattern` arg takes a regex
- `stringi` more comprehensive package than `stringr` (~5x as many funs)

15.1 14.2: String basics

Use `writeLines` to show what string 'This string has a \n new line' looks like printed.

```
string_exp <- 'This string has a \n new line'
print(string_exp)

## [1] "This string has a \n new line"
```

```
## This string has a
##   new line
```

To see full list of special characters:

```
? ``
```

Objects of length 0 are silently dropped. This is particularly useful in conjunction with `if`:

```
name <- "Bryan"
time_of_day <- "morning"
birthday <- FALSE

str_c(
  "Good ", time_of_day, " ", name,
  if (birthday) " and HAPPY BIRTHDAY",
  "."
)
```

```
## [1] "Good morning Bryan."
Collapse vectors into single string
str_c(c("x", "y", "z"), c("a", "b", "c"), collapse = ", ")
## [1] "xa, yb, zc"

Can use assignment form of str_sub()
x <- c("Apple", "Banana", "Pear")
str_sub(x, 1, 1) <- str_to_lower(str_sub(x, 1, 1))
x

## [1] "apple"  "banana" "pear"

str_pad looks interesting
str_pad("the dogs come for you.", width = 40, pad = "", side = "both") #must specify width =, side = d
## [1] ",,,,,,,,,the dogs come for you.,,,,,,,,,,"
```

15.1.1 14.2.5

1. In code that doesn't use stringr, you'll often see `paste()` and `paste0()`. What's the difference between the two functions?

`paste0` has no `sep` argument and just appends any value provided like another string vector. They differs from `str_c` in that they automatically convert NA values to character. Also, they do not return output

```
paste("a", "b", "c", c("x", "y"), sep = "-")
## [1] "a-b-c-x" "a-b-c-y"
paste0("a", "b", "c", c("x", "y"), sep = "-")
## [1] "abcx-" "abcy-"
```

What stringr function are they equivalent to?

`paste()` and `paste0()` are similar to `str_c()` though are different in how they handle NAs (see below). They also will return a warning when recycling vectors whose length do not have a common factor.

```
paste(c("a", "b", "x"), c("x", "y"), sep = "-")
## [1] "a-x" "b-y" "x-x"
str_c(c("a", "b", "x"), c("x", "y"), sep = "-")
## [1] "a-x" "b-y" "x-x"
```

```
## Warning in stri_c(..., sep = sep, collapse = collapse, ignore_null = TRUE):
## longer object length is not a multiple of shorter object length
```

```
## [1] "a-x" "b-y" "x-x"
```

How do the functions differ in their handling of NA?

```
paste(c("a", "b"), c(NA, "y"), sep = "-")
## [1] "a-NA" "b-y"
str_c(c("a", "b"), c(NA, "y"), sep = "-")
## [1] NA      "b-y"
```

2. In your own words, describe the difference between the `sep` and `collapse` arguments to `str_c()`.

`sep` puts characters between items within a vector, `collapse` puts a character between vectors being collapsed

3. Use `str_length()` and `str_sub()` to extract the middle character from a string.

```
x <- "world"
str_sub(x, start = ceiling(str_length(x) / 2), end = ceiling(str_length(x) / 2))
```

```
## [1] "r"
```

What will you do if the string has an even number of characters? In this circumstance the above solution would take the anterior middle value, below is a solution that would return both middle values.

```
x <- "worlds"
```

```
str_sub(x, ceiling(str_length(x) / 2 + 1), start = ceiling(str_length(x) / 2 + 1))
```

```
## [1] "l"
```

```
str_sub(x,
        start = ifelse(str_length(x) %% 2 == 0, floor(str_length(x) / 2), ceiling(str_length(x) / 2))
        end = floor(str_length(x) / 2) + 1)
```

```
## [1] "rl"
```

4. What does `str_wrap()` do? When might you want to use it? `indent = 0` for first line, `exdent = others`

- could use `str_wrap()` for editing of documents etc., setting `width=1` will give each word its own line

```
str_wrap("Tonight, we dine in Hell.", width = 10, indent = 0, exdent = 3) %>%
  writeLines()
```

```
## Tonight,
##   we dine in
##   Hell.
```

5. What does `str_trim()` do? What's the opposite of `str_trim()`? Removes whitespace from beginning and end of character, `side =` specifies which side

```
str_trim("  so much white space  ", side = "right") # (default is 'both')
```

```
## [1] "  so much white space"
```

6. Write a function that turns (e.g.) a vector `c("a", "b", "c")` into the string `a, b, and c`. Think carefully about what it should do if given a vector of length 0, 1, or 2.

```
vec_to_string <- function(x) {

  #If 1 or 0 length vector
  if (length(x) < 2)
    return(x)
  comma <- ifelse(length(x) > 2, ", ", " ")
  b <- str_c(x, collapse = comma)

  #replace ',' with 'and' in last
  str_sub(b, -(str_length(x)[length(x)] + 1), -(str_length(x)[length(x)] +
  1)) <- " and "
  return(b)
}
```

```
x <- c("a", "b", "c", "d")
vec_to_string(x)

## [1] "a, b, c, and d"
```

15.2 14.3: Matching patterns w/ regex

```
x <- c("apple", "banana", "pear")
str_view(x, "an")
```

```
apple
banana
pear
```

To match a literal \ need \\ because both string and regex will escape it.

```
x <- "a\b"
writeLines(x)

## a\b
str_view(x, "\\\\")
```

```
a\b
```

15.2.1 14.3.1.1

1. Explain why each of these strings don't match a \: "\\", "\\", "\\\\".

"\" -> leaves open quote string because escapes quote "\\", -> escapes second \ so left with blank
 "\\\" -> third \ escapes quote so left with open quote as well

2. How would you match the sequence "'\?

```
x <- "alfred\\'\\goes"
writeLines(x)

## alfred''\goes
str_view(x, "\\\\"'\\\\\\")
```

alfred''\goes

3. What patterns will the regular expression `\.\.\.\.\.` match?

Would match 6 character string of following form “(dot)(anychar)(dot)(anychar)(dot)(anychar)”

```
x <- c("alf.r.e.dd.ss..lsdf.d.kj")
str_view(x, pattern = "\\\\"'\\\\\\")
```

alf.r.e.dd.ss..lsdf.d.kj

How would you represent it as a string?

```
x_pattern <- "\\\\"'\\\\\\"
writeLines(x_pattern)

## \.\.\.\.
```

15.2.2 14.3.2.1

Using `\b` to set boundary between words (not used often)

```
apropos("\\\bsum\\b")

## [1] "contr.sum" "sum"

apropos("^(sum)$")

## [1] "sum"
```

1. How would you match the literal string "\$~\$"?

```
x <- "so it goes $~$ here"  
str_view(x, "\\$\\\\~\\\\\$")
```

```
so it goes $~$ here
```

2. Given the corpus of common words in `stringr::words`, create regular expressions that find all words that:

1. Start with "y".

```
str_view(stringr::words, "^\u03b9", match = TRUE)
```

```
\year  
\yes  
\yesterday  
\yet  
\you  
\young
```

2. End with "x"

```
str_view(stringr::words, "x$", match = TRUE)
```

```
\too[\u03b9]  
\so[\u03b9]  
\si[\u03b9]  
\ta[\u03b9]
```

3. Are exactly three letters long. (Don't cheat by using `str_length()`!)

```
str_view(stringr::words, "^...$", match = TRUE)
```

4. Have seven letters or more.

```
str_view(stringr::words, ".....", match = TRUE)
```

Since this list is long, you might want to use the `match` argument to `str_view()` to show only the matching or non-matching words.

15.2.3 14.3.3.1

Other special characters

* `\d`: matches any digit. * `\s`: matches any whitespace (e.g. space, tab, newline). * `[abc]`: matches a, b, or c. * `[^abc]`: matches anything except a, b, or c.

1. Create regular expressions to find all words that:

1. Start with a vowel.

```
str_view(stringr::words, "^[aeiou]", match = TRUE)
```

2. That only contain consonants. (Hint: thinking about matching “not”-vowels.)

```
str_view(stringr::words, "^[^aeiou]*[^aeiouy]$", match = TRUE)
```

3. End with `ed`, but not with `eed`.

```
str_view(stringr::words, "[^e]ed$", match = TRUE)
```

```
bed
hundred
red
```

4. End with `ing` or `ise`.

```
str_view(stringr::words, "(ing|ise)$", match = TRUE)
```

```
advertise
bring
during
evening
executee
king
meeting
morning
otherwiseee
practise
realise
ing
ise
ing
surpriseee
thing
```

2. Empirically verify the rule “i before e except after c”.

```
str_view(stringr::words, "(^ei)|cie|[^c]ei", match = TRUE)
```

```
slight
whether
science
society
weigh
```

3. Is “q” always followed by a “u”?

```
str_view(stringr::words, "q[^u]", match = TRUE)
```

of the words in list, yes.

4. Write a regular expression that matches a word if it's probably written in British English, not American English.

```
str_view(stringr::words, "(l|b)our|parat", match = TRUE)
```

```
colour  
labour  
separate
```

5. Create a regular expression that will match telephone numbers as commonly written in your country.

```
x <- c("dkl kls. klk. _", "(425) 591-6020", "her number is (581) 434-3242", "442", " dsi")  
str_view(x, "\\\(\d\d\d\\)\\\s\d\d\d-\d\d\d\\d\d\d")
```

```
dial 555-1234
      (423) 551-6520
her number is (583) 434-3242
442
dai
```

Aboves not a good way to solve this, will see better methods in next section.

15.2.4 14.3.4.1

Controlling number of times:

- ?: 0 or 1
- +: 1 or more
- *: 0 or more
- {n}: exactly n
- {n,}: n or more
- {,m}: at most m
- {n,m}: between n and m

By default these matches are “greedy”: they will match the longest string possible. You can make them “lazy”, matching the shortest string possible by putting a ? after them. This is an advanced feature of regular expressions, but it’s useful to know that it exists:

```
x <- "1888 is the longest year in Roman numerals: MDCCCLXXXVIII"
str_view(x, 'C{2,3}')
```

```
1888 is the longest year in Roman numerals: MDCCCLXXXVIII
```

```
str_view(x, 'C{2,3}?)')
```

```
1888 is the longest year in Roman numerals: MDCCCLXXXVIII
```

1. Describe the equivalents of ?, +, * in {m,n} form. ? : {0,1} + : {1, } * : {0, }
2. Describe in words what these regular expressions match: (read carefully to see if I'm using a regular expression or a string that defines a regular expression.)

1. ^.*\$: starts with anything, and ends with anything—matches whole thing

```
str_view(x, "^.*$")
```

```
1888 is the longest year in Roman numerals: MDCCCLXXXVIII
```

2. "\\\{.+\\\}" : match text in brackets greater than nothing

```
x <- c("test", "some in [brackets]", "just {} no match")
str_view(x, "\\\{.+\\\}")
```

```
test
some in [brackets]
just {} no match
```

3. \d{4}-\d{2}-\d{2} : 4 numbers - 2 numbers - 2 numbers

```
x <- c("4444-22-22", "test", "333-4444-22")
str_view(x, "\\\d{4}-\\\d{2}-\\\d{2}")
```

```
6444-22-22
test:
333-4444-22
```

4. "\\\\{{4}} : 4 brackets

```
x <- c("\\\\\\\\\\\\\\\\", "\\\\\\\\\\\\\\\\", "\\\\\\\\\\\\", "\\\\\\\\")  
writeLines(x)
```

```
## \\\\
## \\\\
## \\
## \  
str_view(x, "\\\\{{4}}")
```

```
XXXXX  
XXX  
XX  
X
```

```
x <- c("\\\\\\\\\\\\\\\\\\\\", "\\\\\\\\\\\\\\\\\\\\", "\\\\\\\\\\\\\\\\", "\\\\\\\\")  
str_view(x, "\\\\\\\\\\\\\\\\\\\\")
```

```
XXXXX  
XXX  
XX  
X
```

3. Create regular expressions to find all words that:

1. find all words that start with three consonants

```
str_view(stringr::words, "^[^aeoiu]{3}", match = TRUE)
```

```
christ
christmas
mrs
schlomo
school
straight
strategy
street
stlike
strong
structure
threw
through
throw
```

Include y because when it shows up otherwise, is in vowel form.

2. have three or more vowels in a row

```
str_view(stringr::words, "[aeiou]{3}", match = TRUE)
```

```
beauty
obvious
previous
quiet
serious
various
```

In this case, do not include the y.

3. have 2 or more vowel-consonant pairs in a row

```
str_view(stringr::words, "( [aeiou] [^aeiou]) {2,}", match = TRUE)
```

4. Solve the beginner regexp crosswords at <https://regexecrossword.com/challenges/beginner>.

15.2.5 14.3.5.1

1. Describe, in words, what these expressions will match:

*I change questions 1 and 3 to what I think they were meant to be written as `(.)\\1\\1` and `(.)\\1` respectively.

1. `(.)\\1\\1` : repeat the char in the first group, and then repeat that char again
2. `"(.)\\2\\1"` : 1st char, 2nd char followed by 2nd char, first char
3. `(..)\\1` : 2 chars repeated twice
4. `"(.)\\1\\1"` : chars shows-up 3 times with one character between each
5. `"(.)\\1\\3\\2\\1"` : 3 chars in one order with * chars between, then 3 chars with 3 letters in the reverse order of what it started

```
x <- c("steefddff", "ssdfsdfssdasdlkd", "DLKKJIOWdkl", "klnlsd", "t11", "(.)\\1\\1")
str_view_all(x, "(.)\\1\\1", match = TRUE) #xxx
```

ssdfsdf~~ffff~~sadasdkd

```
str_view_all(fruit, "(.)(.)\\2\\1", match = TRUE) #xyyx
```

ball p~~eppew~~
chill p~~eppew~~

```
str_view_all(fruit, "(..)\\1", match = TRUE) #xxyy
```

banana
coconut
cucumber
gujube
papaya
salal berry

```
str_view(stringr::words, "(.)\\.\\1\\.\\1", match = TRUE) #x.x.x
```

eleven

```
str_view(stringr::words, "(.)(..)(.).*\\"3\\"2\\"1", match = TRUE) #xyz.*zyx
```

paragraph

2. Construct regular expressions to match words that:

1. Start and end with the same character.

```
str_view(stringr::words, "^(..)*\\1$", match = TRUE)
```

2. Contain a repeated pair of letters (e.g. “church” contains “ch” repeated twice.)

```
str_view(stringr::words, "(..).*\\"1", match = TRUE)
```

3. Contain one letter repeated in at least three places (e.g. “eleven” contains three “e”s.)

```
str_view(stringr::words, "(.)++\\1.+\\1", match = TRUE)
```

15.3 14.4 Tools

Switch point with Stephen. Will take 30 minutes to go through the main points from exercises / solutions up to here.

15.3.1 14.4.2

1. For each of the following challenges, try solving it by using both a single regular expression, and a combination of multiple `str_detect()` calls.

1. Find all words that start or end with `x`.

```
str_subset(words, "^\u033|x$")
```

```
## [1] "box" "sex" "six" "tax"
```

2. Find all words that start with a vowel and end with a consonant.

```
str_subset(words, "^[aeiou].*[^aeiouy]$")
```

```
## [1] "about"      "accept"      "account"     "across"      "act"
## [6] "actual"     "add"        "address"     "admit"      "affect"
## [11] "afford"     "after"       "afternoon"   "again"      "against"
## [16] "agent"      "air"        "all"         "allow"      "almost"
## [21] "along"      "alright"    "although"    "always"     "amount"
## [26] "and"        "another"    "answer"      "apart"      "apparent"
## [31] "appear"     "appoint"    "approach"   "arm"        "around"
## [36] "art"         "as"         "ask"         "at"         "attend"
## [41] "awful"       "each"       "east"        "eat"        "effect"
## [46] "egg"         "eight"      "either"      "elect"      "electric"
## [51] "eleven"      "end"        "english"    "enough"     "enter"
## [56] "environment" "equal"      "especial"   "even"       "evening"
## [61] "ever"        "exact"      "except"     "exist"      "expect"
## [66] "explain"     "express"    "if"          "important" "in"
## [71] "indeed"      "individual" "inform"     "instead"    "interest"
## [76] "invest"      "it"         "item"        "obvious"   "occasion"
## [81] "odd"         "of"         "off"         "offer"     "often"
## [86] "old"         "on"         "open"        "or"         "order"
## [91] "original"    "other"      "ought"      "out"        "over"
## [96] "own"         "under"      "understand" "union"     "unit"
## [101] "unless"     "until"      "up"         "upon"      "usual"
```

Counted y as a vowel if ending with, but not to start. This does not work perfect. For example words like *ygritte* would still be included even though y is acting as a vowel there whereas words like *boy* would be excluded even though acting as a consonant there. From here on out I am going to always exclude y.

3. Are there any words that contain at least one of each different vowel?

```
vowels <- c("a", "e", "i", "o", "u")
words[str_detect(words, "a") &
      str_detect(words, "e") &
      str_detect(words, "i") &
      str_detect(words, "o") &
      str_detect(words, "u")]
```

```
## character(0)
```

No. More elegant way of doing this using iteration methods we'll learn later is below.

```
vowels <- c("a", "e", "i", "o", "u")

tibble(vowels = vowels, words = list(words)) %>%
  mutate(detect_vowels = purrr::map2(words, vowels, str_detect)) %>%
  spread(key = vowels, value = detect_vowels) %>%
  unnest() %>%
  mutate(unique_vowels = rowSums(.[2:6])) %>%
  arrange(desc(unique_vowels))
```

```
## # A tibble: 980 x 7
##   words      a      e      i      o      u  unique_vowels
##   <chr>    <lgl> <lgl> <lgl> <lgl> <lgl>      <dbl>
```

```

## 1 absolute    TRUE  TRUE  FALSE TRUE  TRUE      4
## 2 appropriate TRUE  TRUE  TRUE  TRUE  FALSE     4
## 3 associate   TRUE  TRUE  TRUE  TRUE  FALSE     4
## 4 authority   TRUE  FALSE TRUE  TRUE  TRUE      4
## 5 colleague   TRUE  TRUE  FALSE TRUE  TRUE      4
## 6 continue    FALSE TRUE  TRUE  TRUE  TRUE      4
## 7 encourage   TRUE  TRUE  FALSE TRUE  TRUE      4
## 8 introduce   FALSE TRUE  TRUE  TRUE  TRUE      4
## 9 organize    TRUE  TRUE  TRUE  TRUE  FALSE     4
## 10 previous   FALSE TRUE TRUE  TRUE  TRUE      4
## # ... with 970 more rows
#seems that nothing gets over 4

```

2. What word has the highest number of vowels? What word has the highest proportion of vowels? (Hint: what is the denominator?)

```

vowel_counts <- tibble(words = words,
                        n_string = str_length(words),
                        n_vowel = str_count(words, vowels),
                        prop_vowel = n_vowel / n_string)

```

'Experience' has the most vowels

```

vowel_counts %>%
  arrange(desc(n_vowel))

```

```

## # A tibble: 980 x 4
##   words      n_string n_vowel prop_vowel
##   <chr>        <int>    <int>      <dbl>
## 1 experience     10       4      0.4
## 2 individual     10       3      0.3
## 3 achieve        7       2      0.286
## 4 actual          6       2      0.333
## 5 afternoon       9       2      0.222
## 6 against         7       2      0.286
## 7 already         7       2      0.286
## 8 america          7       2      0.286
## 9 benefit          7       2      0.286
## 10 choose         6       2      0.333
## # ... with 970 more rows

```

'a' has the highest proportion

```

vowel_counts %>%
  arrange(desc(prop_vowel))

```

```

## # A tibble: 980 x 4
##   words n_string n_vowel prop_vowel
##   <chr>    <int>    <int>      <dbl>
## 1 a          1       1      1
## 2 too         3       2      0.667
## 3 wee         3       2      0.667
## 4 feed        4       2      0.5
## 5 in          2       1      0.5
## 6 look        4       2      0.5
## 7 need        4       2      0.5

```

```
## 8 room      4      2      0.5
## 9 so        2      1      0.5
## 10 soon     4      2      0.5
## # ... with 970 more rows
```

15.3.2 14.4.3.1

1. In the previous example, you might have noticed that the regular expression matched “flickered”, which is not a colour. Modify the regex to fix the problem.

2. From the Harvard sentences data, extract:

1. The first word from each sentence.

```
str_extract(sentences, "[A-z]*")
```

2. All words ending in *ing*.

```
#ends in "ing" or "ing."
sent_ing <- str_subset(sentences, ".*ing(\\.|\\s)")
str_extract_all(sent_ing, "[A-z]+ing", simplify=TRUE)
```

3. All plurals.

```
str_subset(sentences, "[A-z]*s(\\.|\\s)") %>% #take all sentences that have a word ending in s
  str_extract_all("[A-z]*s\\b", simplify = TRUE) %>%
  .[str_length(.) > 3] %>% #get rid of the short words
  str_subset(".*[^s]s\$") %>% #get rid of words ending in 'ss'
  str_subset(".*[^i]s\$") #get rid of 'this'
```

15.3.3 14.4.4.1

```
noun <- "(a|the) ([^ \\.]+)"

has_noun <- sentences %>%
  str_subset(noun) %>%
  head(10)

has_noun %>%
  str_extract_all(noun, simplify = TRUE)

#creates split into seperate pieces
has_noun %>%
  str_match_all(noun)

#Can make dataframe with, but need to name all
tibble(has_noun = has_noun) %>%
  extract(has_noun, into = c("article", "noun"), regex = noun)
```

1. Find all words that come after a “number” like “one”, “two”, “three” etc. Pull out both the number and the word.

```
#Create regex expression
nums <- c("one", "two", "three", "four", "five", "six", "seven", "eight", "nine")
nums <- str_c("\\b", nums)
```

```

nums_c <- str_c(nums, collapse = " | ")
re <- str_c("(,nums_c,)", " ", "[^ \\.]+)", sep = "")
re

sentences_with_nums <- sentences %>%
  str_subset(regex(re, ignore_case = TRUE))

#SAME THING, but in a DF
tibble(sentences_var = sentences_with_nums) %>%
  extract(sentences_var, into = c("num", "following"), regex = re, remove = FALSE)

```

2. Find all contractions. Separate out the pieces before and after the apostrophe.

```

contr <- "([^\ \\.]+)'([^\ \\.]*)" #note the () facilitate the split with functions
sentences %>%
  str_subset(contr) %>% #note the improvement this word definition is to the above [^ ]+
  str_match_all(contr)

```

15.3.4 14.4.5.1

1. Replace all forward slashes in a string with backslashes.

```

```r
x <- c("test/dklsk/")
str_replace_all(x, "/", "\\\\") %>%
 writeLines()
```

```
test\dklsk\
```

```

1. Implement a simple version of `str_to_lower()` using `replace_all()`.

```

```r
x <- c("BIdklsKOS")
str_replace_all(x, "[A-Z]", tolower)
```

```
[1] "bidklkos"
```

```

1. Switch the first and last letters in words. Which of those strings are still words?

```

```r
str_replace(words, "(^.)(.*)(.$)", "\\\3\\\2\\\1")
```

```

Any words that start and end with the same letter, e.g. 'treat', as well as a few other examples like,

15.3.5 14.4.6.1

When using `boundary()` with `str_split` can set to “character”, “line”, “sentence”, and “word” and gives alternative to splitting by pattern.

1. Split up a string like "apples, pears, and bananas" into individual components.

```
x <- "apples, pears, and bananas"
str_split(x, ",* ") #note that regular expression works to handle commas as well
```

```
## [[1]]
## [1] "apples"   "pears"    "and"      "bananas"
```

2. Why is it better to split up by boundary("word") than " "?

Handles commas and punctuation, I though still would prefer to use patterns where possible over boundary function. regex is more generally applicabale as well outside of R.

```
str_split(x, boundary("word"))
```

```
## [[1]]
## [1] "apples"   "pears"    "and"      "bananas"
```

3. What does splitting with an empty string ("") do? Experiment, and then read the documentation.
Splitting by an empty string splits up each character.

```
str_split(x, "")
```

```
## [[1]]
## [1] "a" "p" "p" "l" "e" "s" ","
## [18] "d" " " "b" "a" "n" "a" "n" "a" "s"
```

15.4 14.5: Other types of patterns

`regex` args to know:

- `ignore_case` = TRUE allows characters to match either their uppercase or lowercase forms. This always uses the current locale.
- `multiline` = TRUE allows ^ and \$ to match the start and end of each line rather than the start and end of the complete string.
- `comments` = TRUE allows you to use comments and white space to make complex regular expressions more understandable. Spaces are ignored, as is everything after #. To match a literal space, you'll need to escape it: "\ \".
- `dotall` = TRUE allows . to match everything, including \n.

Alternatives to `regex()`: * `fixed()`: matches exactly the specified sequence of bytes. It ignores all special regular expressions and operates at a very low level. This allows you to avoid complex escaping and can be much faster than regular expressions. * `coll()`: compare strings using standard `collation` rules. This is useful for doing case insensitive matching. Note that `coll()` takes a `locale` parameter that controls which rules are used for comparing characters.

15.4.1 14.5.1

1. How would you find all strings containing \ with `regex()` vs. with `fixed()`? would be \\ instead of \\\\"

```
str_view_all("so \\ the party is on\\ right?", fixed("\\\\"))
```

```
so [3] the party is on[4] eight?
```

2. What are the five most common words in sentences?

```
str_extract_all(sentences, boundary("word"), simplify = TRUE) %>%
  as_tibble() %>%
  gather(V1:V12, value = "words", key = "order") %>%
  mutate(words = str_to_lower(words)) %>%
  filter(!words == "") %>%
  count(words, sort = TRUE) %>%
  head(5)

## Warning: `as_tibble.matrix()` requires a matrix with column names or a ``.name_repair` argument.
## This warning is displayed once per session.

## # A tibble: 5 x 2
##   words      n
##   <chr> <int>
## 1 the     751
## 2 a       202
## 3 of      132
## 4 to      123
## 5 and     118
```

15.4.2 14.7.1

Other functions: `apropos` searches all objects available from the global environment—useful if you can't remember fun name. E.g. below checks those that start with `replace` and then those that start with `str`, but not `stri`

```
apropos("^replace")  
  
## [1] "replace"      "replace_na"  
  
apropos("^str[^i]")  
  
## [1] "str_c"          "str_conv"        "str_count"  
## [4] "str_detect"      "str_dup"         "str_extract"  
## [7] "str_extract_all" "str_flatten"    "str_glue"  
## [10] "str_glue_data"   "str_interp"     "str_length"  
## [13] "str_locate"      "str_locate_all" "str_match"  
## [16] "str_match_all"   "str_order"      "str_pad"  
## [19] "str_remove"      "str_remove_all" "str_replace"  
## [22] "str_replace_all" "str_replace_na" "str_sort"  
## [25] "str_split"       "str_split_fixed" "str_squish"
```

```
## [28] "str_sub"           "str_sub<-"      "str_subset"
## [31] "str_to_lower"        "str_to_title"   "str_to_upper"
## [34] "str_trim"            "str_trunc"     "str_view"
## [37] "str_view_all"         "str_which"     "str_wrap"
## [40] "strcapture"          "strftime"     "strheight"
## [43] "strOptions"           "strptime"     "strrep"
## [46] "strsplit"             "strtoi"       "strtrim"
## [49] "StructTS"             "structure"    "strwidth"
## [52] "strwrap"
```

1. *Find the stringi functions that:*

1. *Count the number of words.* – `stri_count`
2. *Find duplicated strings.* – `stri_duplicated`
3. *Generate random text.* – `str_rand_strings`

2. *How do you control the language that `stri_sort()` uses for sorting?*

`decreasing =`

Make sure the following packages are installed:

Chapter 16

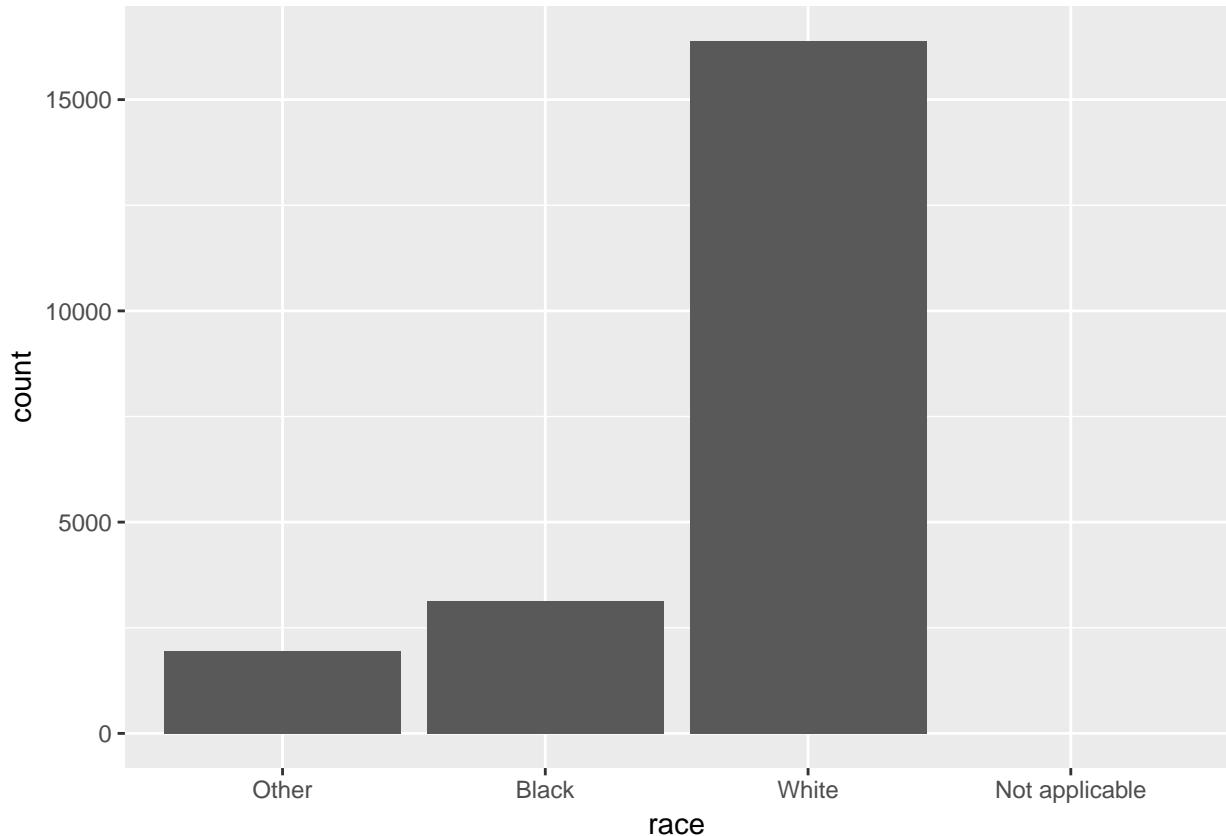
ch. 15: Factors

- `factor` make variable a factor based on `levels` provided
- `fct_rev` reverses order of factors
- `fct_infreq` orders levels in increasing frequency
- `fct_relevel` lets you move levels to front of order
- `fct_inorder` orders existing factor by order values show-up in in data
- `fct_reorder` orders input factors by other specified variables value (median by default), 3 inputs: `f`: factor to modify, `x`: input var to order by, `fun`: function to use on `x`, also have `desc` option
- `fct_reorder2` orders input factor by max of other specified variable (good for making legends align as expected)
- `fct_recode` lets you change value of each level
- `fct_collapse` is variant of `fct_recode` that allows you to provide multiple old levels as a vector
- `fct_lump` allows you to lump together small groups, use `n` to specify number of groups to end with

Create factors by order they come-in:

Avoiding dropping levels with `drop = FALSE`

```
gss_cat %>%
  ggplot(aes(race)) +
  geom_bar() +
  scale_x_discrete(drop = FALSE)
```



```
# Is there a similar way to do this with count?
```

16.1 15.4: Modifying factor order

Example with `fct_recode`

```
gss_cat %>%
  mutate(partyid = fct_recode(partyid,
    "Republican, strong"      = "Strong republican",
    "Republican, weak"        = "Not str republican",
    "Independent, near rep"  = "Ind,near rep",
    "Independent, near dem"  = "Ind,near dem",
    "Democrat, weak"          = "Not str democrat",
    "Democrat, strong"        = "Strong democrat"
  )) %>%
  count(partyid)

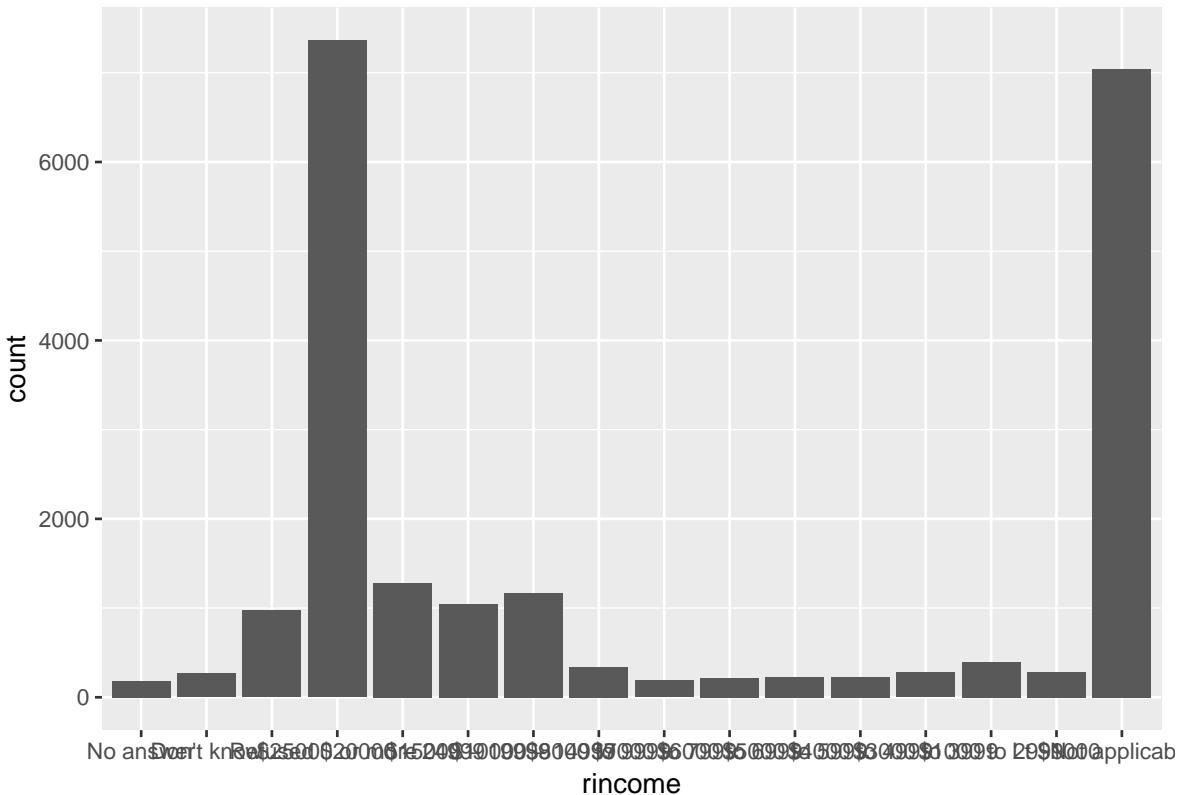
## # A tibble: 10 x 2
##   partyid             n
##   <fct>           <int>
## 1 No answer       154
## 2 Don't know      1
## 3 Other party     393
## 4 Republican, strong 2314
## 5 Republican, weak 3032
```

```
## 6 Independent, near rep 1791
## 7 Independent 4119
## 8 Independent, near dem 2499
## 9 Democrat, weak 3690
## 10 Democrat, strong 3490
```

16.1.1 15.3.1

1. Explore the distribution of `rincome` (reported income). What makes the default bar chart hard to understand? How could you improve the plot?

```
gss_cat %>%
  ggplot(aes(x = rincome)) +
  geom_bar()
```



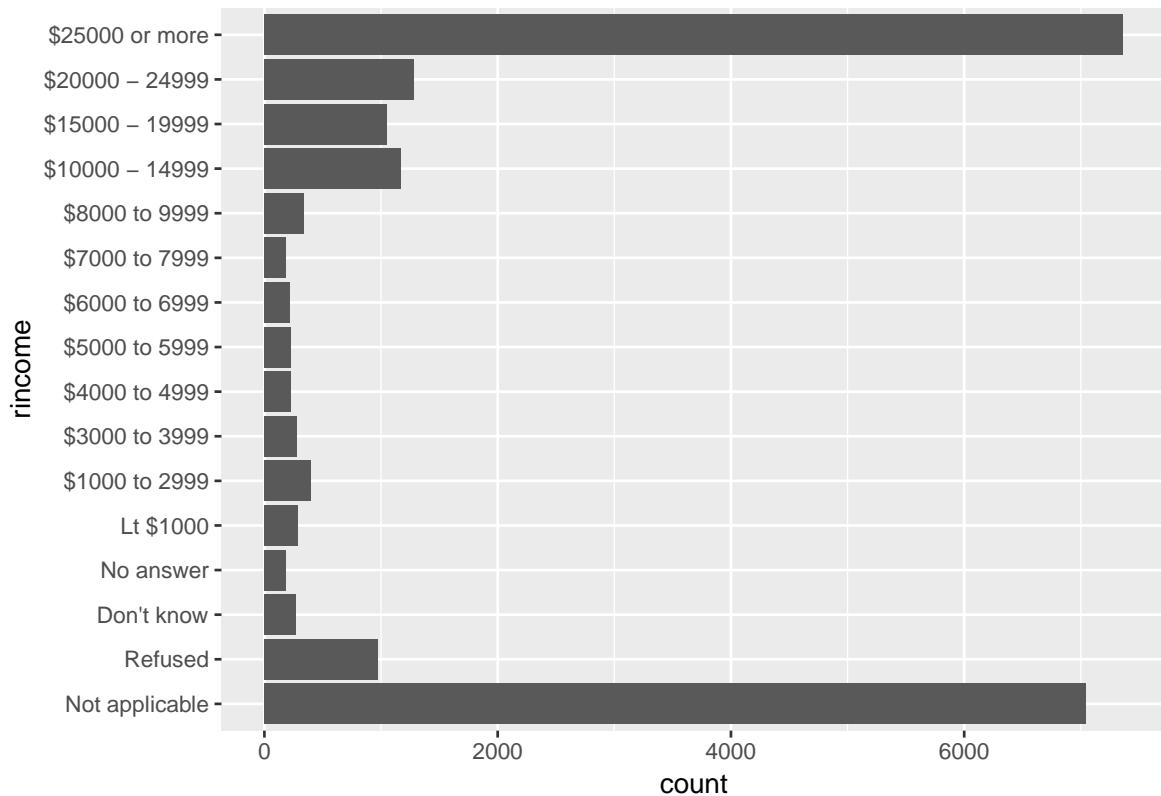
- Default bar chart has categories across the x-axis, I flipped these to be across the y-axis
- Also, have highest values at the bottom rather than at the top and have different version of NA showing-up at both top and bottom, all should be on one side
- In `bar_prep`, I used reg expressions to extract the numeric values, arrange by that, and then set factor levels according to the new order
 - Solution is probably unnecessarily complicated...¹

```
bar_prep <- gss_cat %>%
  tidyverse::extract(col = rincome, into = c("dollars1", "dollars2"), "[0-9]+[0-9]*([0-9]*)", remove)
  mutate_at(c("dollars1", "dollars2"), ~ifelse(is.na(.) | . == "", 0, as.numeric(.))) %>%
  arrange(dollars1, dollars2) %>%
```

¹Also had issue with not rendering for book.

```
mutate(rincome = fct_inorder(rincome))

bar_prep %>%
  ggplot(aes(x = rincome)) +
  geom_bar() +
  scale_x_discrete(drop = FALSE) +
  coord_flip()
```



2. What is the most common `relig` in this survey? What's the most common `partyid`?

```
gss_cat %>%
  count(relig, sort = TRUE)
```

```
## # A tibble: 15 x 2
##   relig          n
##   <fct>        <int>
## 1 Protestant    10846
## 2 Catholic      5124
## 3 None          3523
## 4 Christian     689
## 5 Jewish         388
## 6 Other          224
## 7 Buddhism       147
## 8 Inter-nondenominational 109
## 9 Moslem/islam  104
## 10 Orthodox-christian 95
## 11 No answer    93
## 12 Hinduism     71
```

```

## 13 Other eastern          32
## 14 Native american       23
## 15 Don't know             15
gss_cat %>%
  count(partyid, sort = TRUE)

```

```

## # A tibble: 10 x 2
##   partyid      n
##   <fct>     <int>
## 1 Independent    4119
## 2 Not str democrat  3690
## 3 Strong democrat  3490
## 4 Not str republican 3032
## 5 Ind,near dem    2499
## 6 Strong republican 2314
## 7 Ind,near rep     1791
## 8 Other party      393
## 9 No answer        154
## 10 Don't know      1

```

- `relig` most common – Protestant, 10846,
- `partyid` most common – Independent, 4119

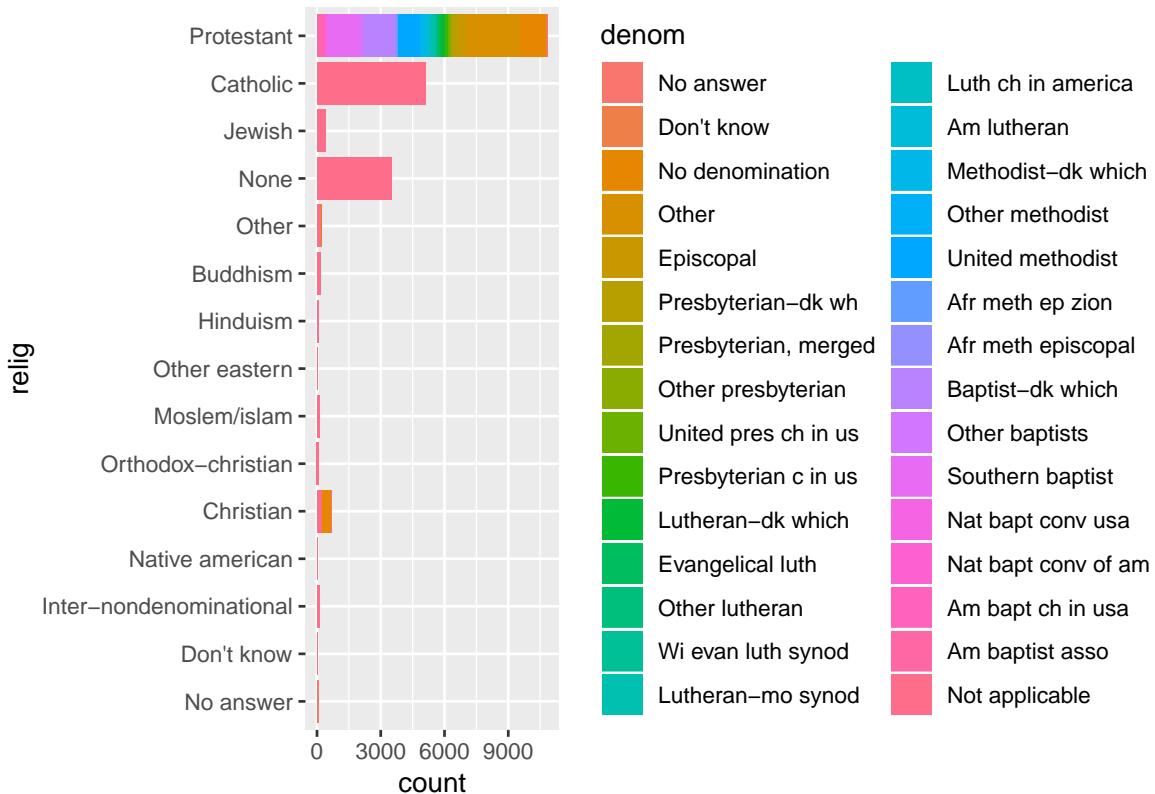
3. Which `relig` does `denom` (denomination) apply to? How can you find out with a table? How can you find out with a visualisation?

With visualization:

```

gss_cat %>%
  ggplot(aes(x=relig, fill=denom)) +
  geom_bar() +
  coord_flip()

```



- Notice which have the widest variety of colours – are protestant, and Christian slightly

With table:

```
gss_cat %>%  
  count(relig, denom) %>%  
  count(relig, sort = TRUE)
```

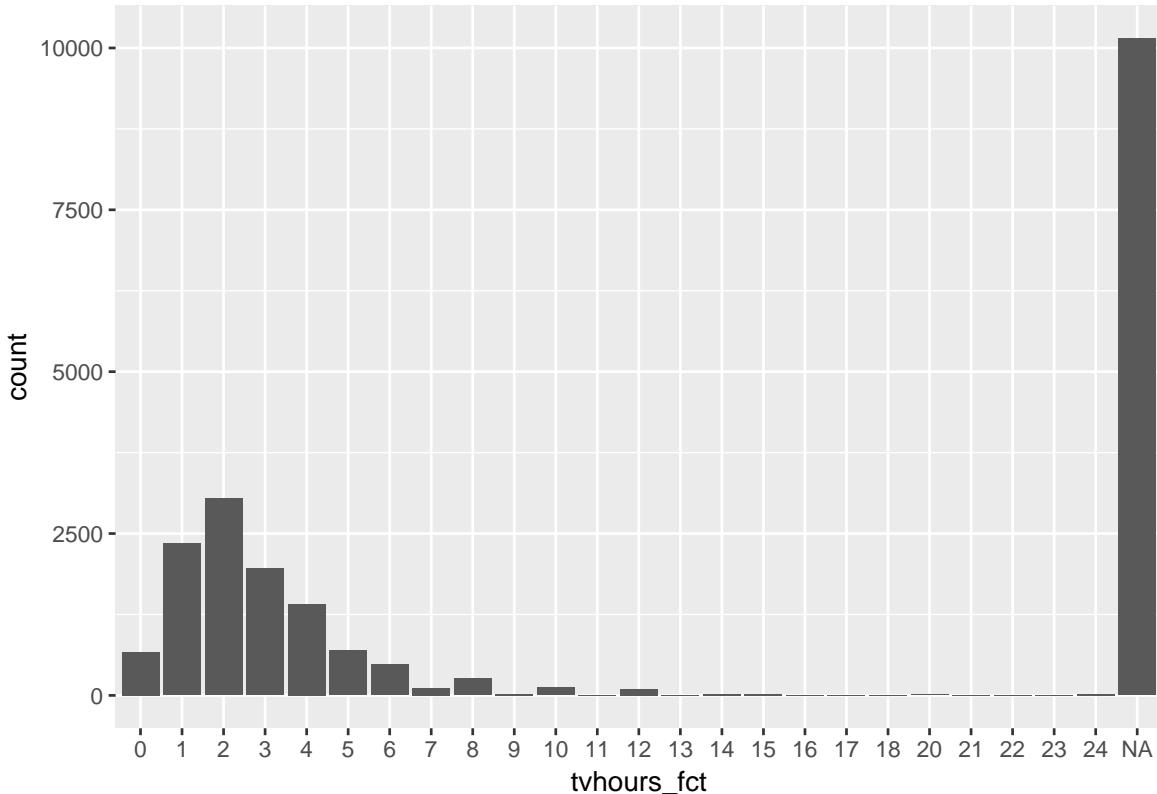
```
## # A tibble: 15 x 2
##   relig      <fct>    n <int>
## 1 Protestant   29
## 2 Christian    4
## 3 Other        2
## 4 No answer   1
## 5 Don't know  1
## 6 Inter-nondenominational 1
## 7 Native american 1
## 8 Orthodox-christian 1
## 9 Moslem/islam 1
## 10 Other eastern 1
## 11 Hinduism    1
## 12 Buddhism    1
## 13 None        1
## 14 Jewish      1
## 15 Catholic    1
```

16.2 15.4: Modifying factor order

16.2.1 15.4.1

- There are some suspiciously high numbers in `tvhours`. Is the mean a good summary?

```
gss_cat %>%
  mutate(tvhours_fct = factor(tvhours)) %>%
  ggplot(aes(x = tvhours_fct)) +
  geom_bar()
```



- Distribution is reasonably skewed with some values showing-up as 24 hours which seems impossible, in addition to this we have a lot of na values, this may skew results
- Given high number of missing values, `tvhours` may also just not be reliable, do NA's associate with other variables? – Perhaps could try and impute these NAs

- For each factor in `gss_cat` identify whether the order of the levels is arbitrary or principled.

```
gss_cat %>%
  purrr::keep(is.factor) %>%
  purrr::map(levels)
```

```
## $marital
## [1] "No answer"      "Never married"   "Separated"      "Divorced"
## [5] "Widowed"        "Married"
##
## $race
## [1] "Other"          "Black"           "White"          "Not applicable"
##
```

```

## $rincome
## [1] "No answer"      "Don't know"      "Refused"        "$25000 or more"
## [5] "$20000 - 24999"  "$15000 - 19999"  "$10000 - 14999"  "$8000 to 9999"
## [9] "$7000 to 7999"   "$6000 to 6999"   "$5000 to 5999"   "$4000 to 4999"
## [13] "$3000 to 3999"   "$1000 to 2999"   "Lt $1000"       "Not applicable"
##
## $partyid
## [1] "No answer"          "Don't know"        "Other party"
## [4] "Strong republican" "Not str republican" "Ind,near rep"
## [7] "Independent"       "Ind,near dem"     "Not str democrat"
## [10] "Strong democrat"
##
## $relig
## [1] "No answer"           "Don't know"
## [3] "Inter-nondenominational" "Native american"
## [5] "Christian"           "Orthodox-christian"
## [7] "Moslem/islam"        "Other eastern"
## [9] "Hinduism"            "Buddhism"
## [11] "Other"                "None"
## [13] "Jewish"               "Catholic"
## [15] "Protestant"          "Not applicable"
##
## $denom
## [1] "No answer"           "Don't know"        "No denomination"
## [4] "Other"                 "Episcopal"         "Presbyterian-dk wh"
## [7] "Presbyterian, merged" "Other presbyterian" "United pres ch in us"
## [10] "Presbyterian c in us" "Lutheran-dk which" "Evangelical luth"
## [13] "Other lutheran"      "Wi evan luth synod" "Lutheran-mo synod"
## [16] "Luth ch in america"  "Am lutheran"       "Methodist-dk which"
## [19] "Other methodist"     "United methodist"  "Afr meth ep zion"
## [22] "Afr meth episcopal"  "Baptist-dk which" "Other baptists"
## [25] "Southern baptist"    "Nat bapt conv usa" "Nat bapt conv of am"
## [28] "Am bapt ch in usa"   "Am baptist asso"  "Not applicable"

```

- `rincome` is principaled, rest are arbitrary

2. Why did moving “Not applicable” to the front of the levels move it to the bottom of the plot?
 - Becuase is moving this factor to be first in order

16.3 15.5: Modifying factor levels

16.3.1 15.5.1

1. How have the proportions of people identifying as Democrat, Republican, and Independent changed over time?

As a line plot:

```

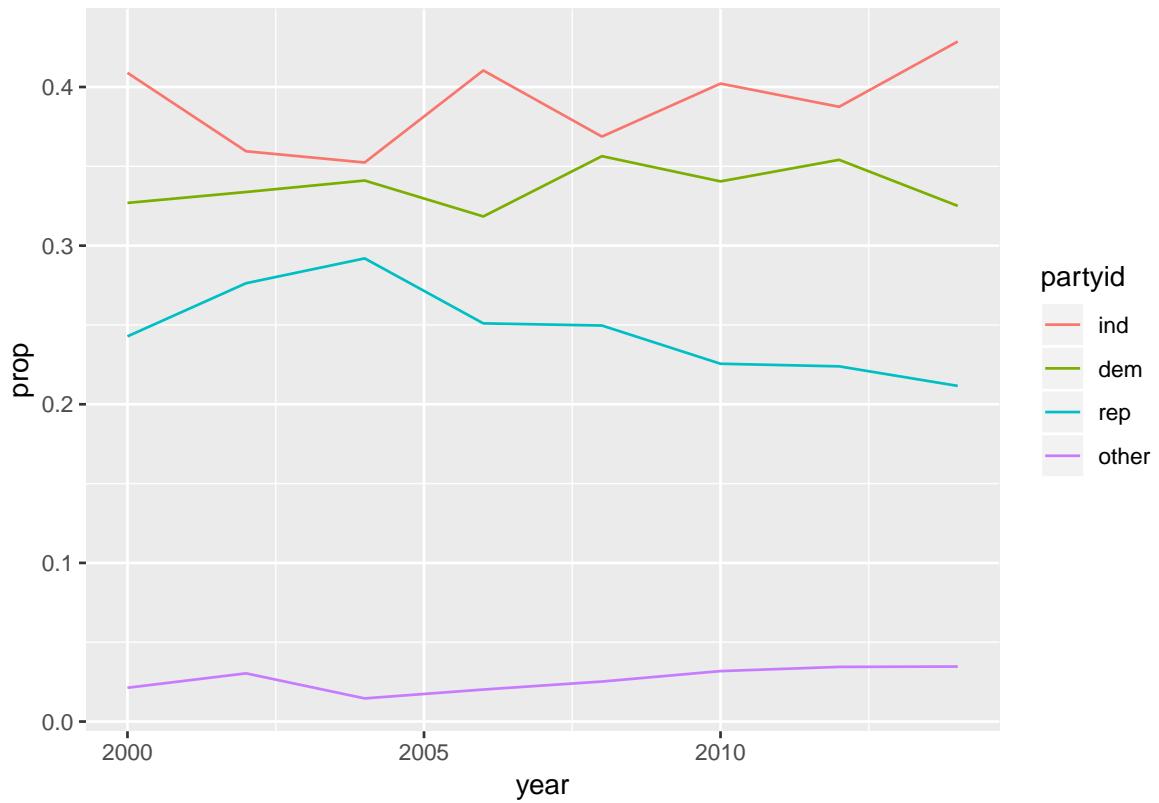
gss_cat %>%
  mutate(partyid = fct_collapse(
    partyid,
    other = c("No answer", "Don't know", "Other party"),
    rep = c("Strong republican", "Not str republican"),
    ind = c("Ind,near rep", "Independent", "Ind,near dem")),
    .by_group = TRUE)

```

```

dem = c("Not str democrat", "Strong democrat")
)) %>%
count(year, partyid) %>%
group_by(year) %>%
mutate(prop = n / sum(n)) %>%
ungroup() %>%
ggplot(aes(
  x = year,
  y = prop,
  colour = fct_reorder2(partyid, year, prop)
)) +
geom_line() +
labs(colour = "partyid")

```



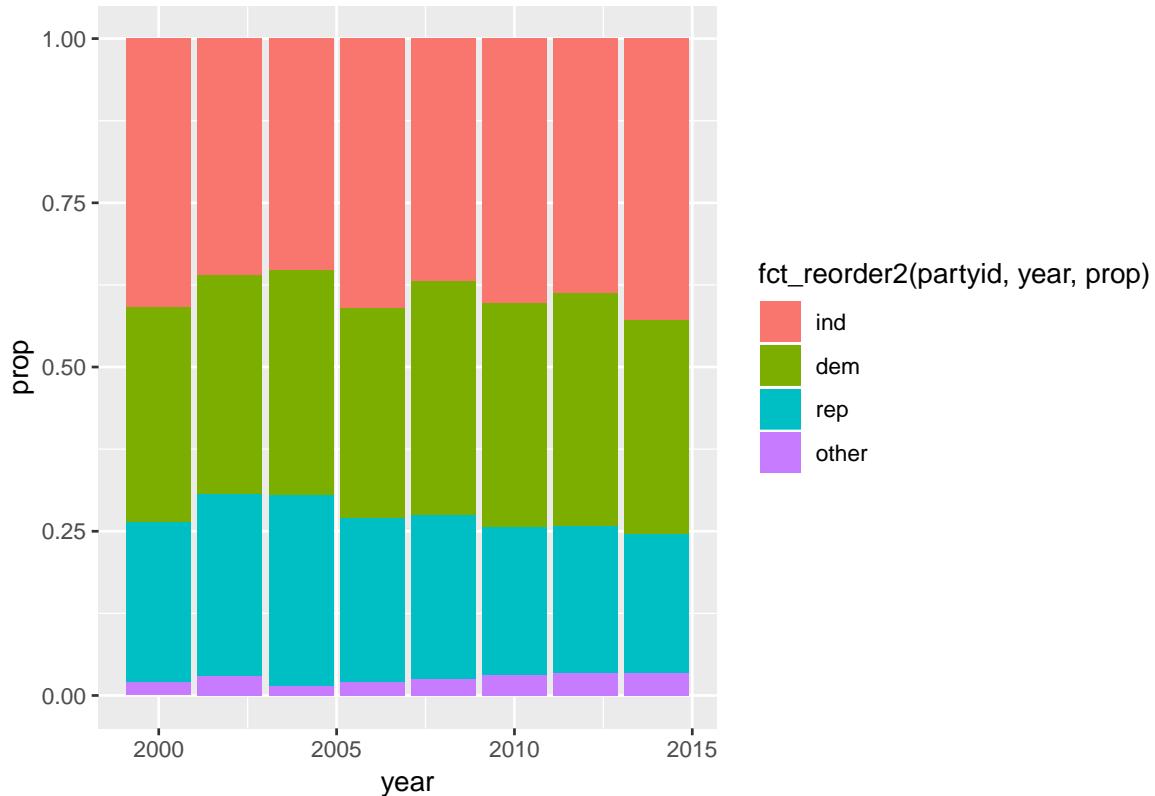
As a bar plot:

```

gss_cat %>%
  mutate(partyid = fct_collapse(
    partyid,
    other = c("No answer", "Don't know", "Other party"),
    rep = c("Strong republican", "Not str republican"),
    ind = c("Ind,near rep", "Independent", "Ind,near dem"),
    dem = c("Not str democrat", "Strong democrat")
)) %>%
count(year, partyid) %>%
group_by(year) %>%
mutate(prop = n / sum(n)) %>%
ungroup()

```

```
ggplot(aes(
  x = year,
  y = prop,
  fill = fct_reorder2(partyid, year, prop)
)) +
  geom_col() +
  labs(colour = "partyid")
```



- Suggests proportion of republicans has gone down with independents and other going up.
2. How could you collapse `rincome` into a small set of categories?

```
other = c("No answer", "Don't know", "Refused", "Not applicable")
high = c("$25000 or more", "$20000 - 24999", "$15000 - 19999", "$10000 - 14999")
med = c("$8000 to 9999", "$7000 to 7999", "$6000 to 6999", "$5000 to 5999")
low = c("$4000 to 4999", "$3000 to 3999", "$1000 to 2999", "Lt $1000")

mutate(gss_cat,
       rincome = fct_collapse(
         rincome,
         other = other,
         high = high,
         med = med,
         low = low
       )) %>%
       count(rincome)

## # A tibble: 4 x 2
##   rincome     n
##   <fct>    <int>
## 1 other      1000
## 2 high       1000
## 3 med        1000
## 4 low        1000
```

```
## <fct> <int>
## 1 other     8468
## 2 high      10862
## 3 med       970
## 4 low       1183
```


Chapter 17

Appendix

17.1 Viewing all levels

A few ways to get an initial look at the levels or counts across a dataset

```
gss_cat %>%
  purrr::map(unique)

## $year
## [1] 2000 2002 2004 2006 2008 2010 2012 2014
##
## $marital
## [1] Never married Divorced      Widowed      Married      Separated
## [6] No answer
## Levels: No answer Never married Separated Divorced Widowed Married
##
## $age
## [1] 26 48 67 39 25 36 44 47 53 52 51 40 77 45 49 19 54 82 83 89 88 72 34
## [24] 55 37 22 33 43 29 57 31 46 65 56 66 20 64 59 23 21 27 78 61 84 69 32
## [47] 76 41 70 75 80 24 50 30 62 60 28 35 38 73 87 58 63 42 85 NA 79 18 71
## [70] 68 74 81 86
##
## $race
## [1] White Black Other
## Levels: Other Black White Not applicable
##
## $rincome
## [1] $8000 to 9999  Not applicable $20000 - 24999 $25000 or more
## [5] $7000 to 7999  $10000 - 14999 Refused           $15000 - 19999
## [9] $3000 to 3999  $5000 to 5999  Don't know       $1000 to 2999
## [13] Lt $1000      No answer        $6000 to 6999  $4000 to 4999
## 16 Levels: No answer Don't know Refused $25000 or more ... Not applicable
##
## $partyid
## [1] Ind,near rep      Not str republican Independent
## [4] Not str democrat  Strong democrat    Ind,near dem
## [7] Strong republican Other party      No answer
## [10] Don't know
## 10 Levels: No answer Don't know Other party ... Strong democrat
```

```

## $relig
## [1] Protestant          Orthodox-christian
## [3] None                Christian
## [5] Jewish              Catholic
## [7] Other               Inter-nondenominational
## [9] Hinduism            Native american
## [11] No answer          Buddhism
## [13] Moslem/islam      Other eastern
## [15] Don't know

## 16 Levels: No answer Don't know ... Not applicable
## $denom
## [1] Southern baptist    Baptist-dk which    No denomination
## [4] Not applicable      Lutheran-mo synod   Other
## [7] United methodist    Episcopal           Other lutheran
## [10] Afr meth ep zion   Am bapt ch in usa  Other methodist
## [13] Presbyterian c in us Methodist-dk which Nat bapt conv usa
## [16] Am lutheran        Nat bapt conv of am Am baptist asso
## [19] Evangelical luth   Afr meth episcopal  Lutheran-dk which
## [22] Luth ch in america Presbyterian, merged No answer
## [25] Wi evan luth synod Other baptists      Other presbyterian
## [28] United pres ch in us Presbyterian-dk wh  Don't know

## 30 Levels: No answer Don't know No denomination Other ... Not applicable
## $tvhours
## [1] 12 NA  2  4  1  3  0  7  5  8 10  6 15 11 24 20 13 14 21  9 16 22 18
## [24] 17 23

gss_cat %>%
  purrr::map(table)

## $year
## 2000 2002 2004 2006 2008 2010 2012 2014
## 2817 2765 2812 4510 2023 2044 1974 2538
## $marital
## No answer Never married Separated Divorced Widowed
## 17 5416 743 3383 1807
## Married
## 10117
## $age
## 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
## 91 249 251 278 298 361 344 396 400 385 387 376 433 407 445 425 425 417
## 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53
## 428 438 426 415 452 434 405 448 432 404 422 435 424 417 430 390 400 396
## 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
## 387 365 384 321 326 323 338 307 310 292 253 259 231 271 205 201 213 206
## 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89
## 189 152 180 179 171 137 150 135 127 119 105 99 100 75 74 54 57 148
## 
```

```

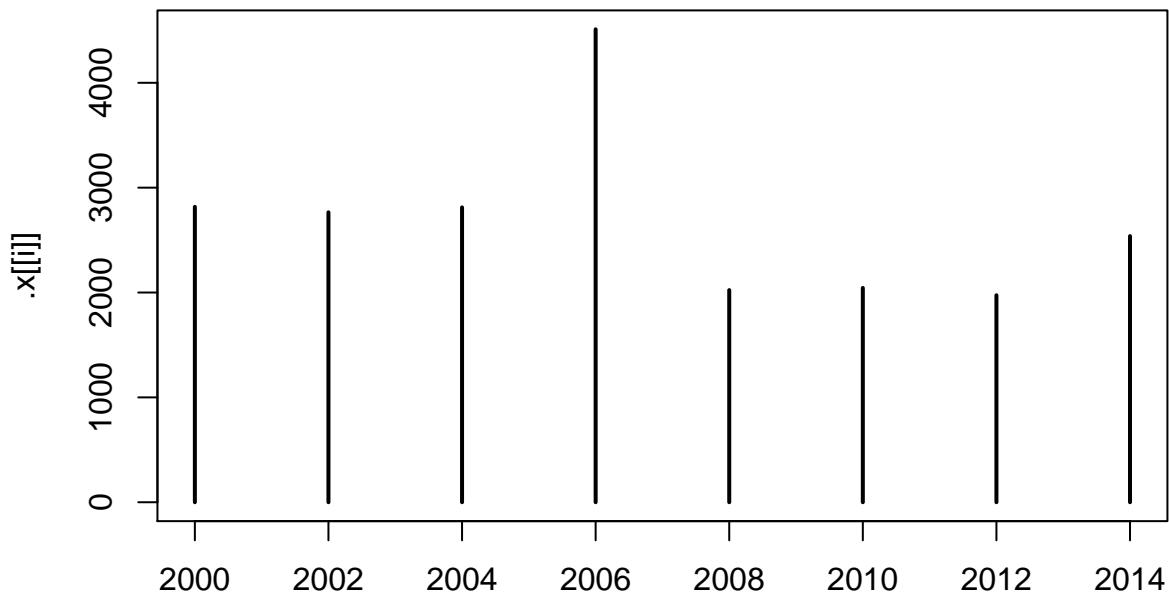
## $race
##
##          Other      Black      White Not applicable
##          1959       3129     16395           0
##
## $rincome
##
##          No answer   Don't know    Refused $25000 or more $20000 - 24999
##          183          267         975      7363        1283
## $15000 - 19999 $10000 - 14999 $8000 to 9999 $7000 to 7999 $6000 to 6999
##          1048         1168        340      188         215
## $5000 to 5999 $4000 to 4999 $3000 to 3999 $1000 to 2999 Lt $1000
##          227          226         276      395         286
## Not applicable
##          7043
##
## $partyid
##
##          No answer   Don't know    Other party
##          154            1          393
## Strong republican Not str republican Ind,near rep
##          2314          3032        1791
## Independent      Ind,near dem Not str democrat
##          4119          2499        3690
## Strong democrat
##          3490
##
## $relig
##
##          No answer   Don't know Inter-nondenominational
##          93             15          109
## Native american      Christian Orthodox-christian
##          23             689          95
## Moslem/islam        Other eastern Hinduism
##          104            32           71
## Buddhism            Other          None
##          147            224          3523
## Jewish              Catholic Protestant
##          388            5124        10846
## Not applicable
##          0
##
## $denom
##
##          No answer   Don't know No denomination
##          117            52          1683
## Other              Episcopal Presbyterian-dk wh
##          2534            397          244
## Presbyterian, merged Other presbyterian United pres ch in us
##          67              47          110
## Presbyterian c in us Lutheran-dk which Evangelical luth
##          104            267          122
## Other lutheran      Wi evan luth synod Lutheran-mo synod
##          30              71          212

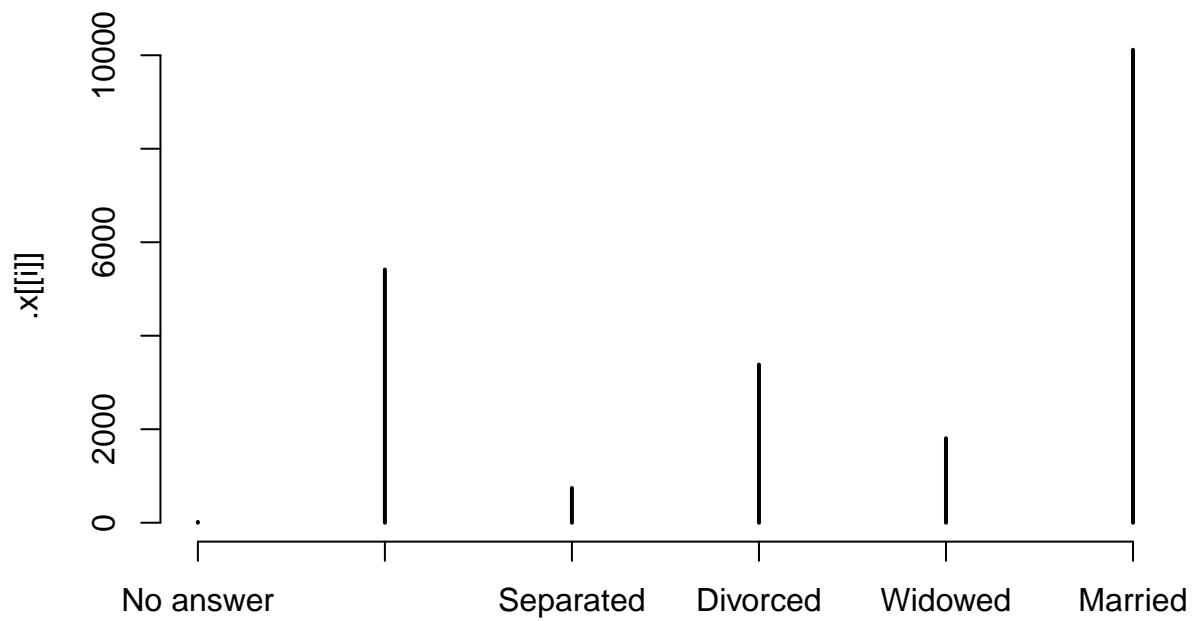
```

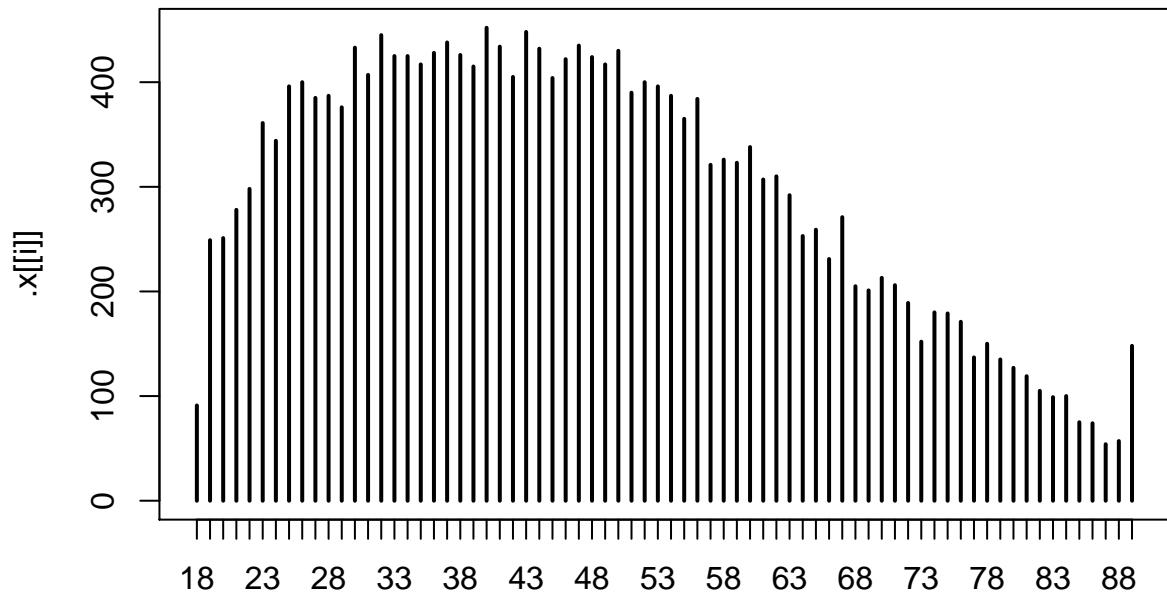
```

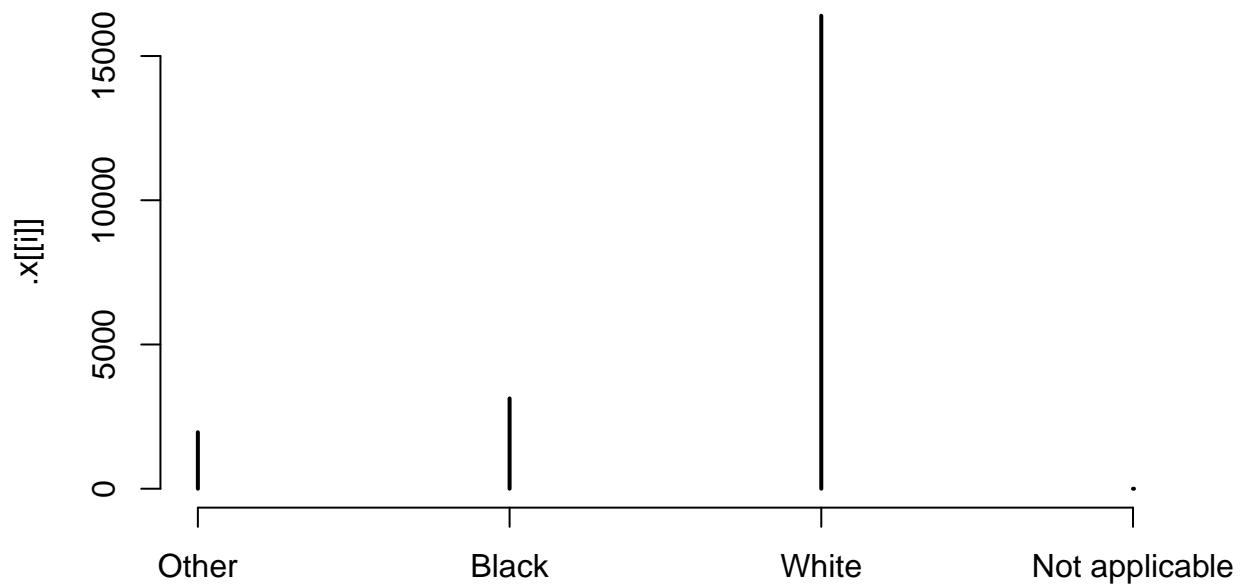
##   Luth ch in america          Am lutheran      Methodist-dk which
##                 71                  146                  239
##   Other methodist           United methodist    Afr meth ep zion
##                 33                  1067                  32
##   Afr meth episcopal        Baptist-dk which  Other baptists
##                 77                  1457                  213
##   Southern baptist          Nat bapt conv usa Nat bapt conv of am
##                 1536                  40                  76
##   Am bapt ch in usa         Am baptist asso Not applicable
##                 130                  237                  10072
##
## $tvhours
##
##   0   1   2   3   4   5   6   7   8   9   10  11  12  13  14
##  675 2345 3040 1959 1408 695 478 119 262 19 122 9 96 9 24
##   15   16   17   18   20   21   22   23   24
##   17   10    2    7   14    2    2    1   22
gss_cat %>%
  purrr::map(table) %>%
  purrr::map(plot)

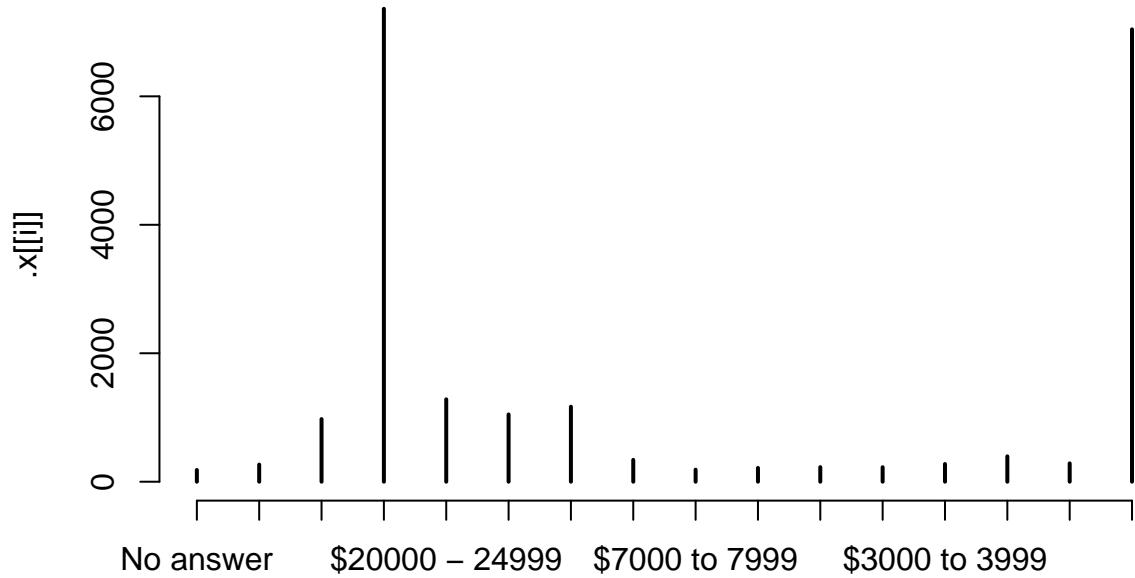
```

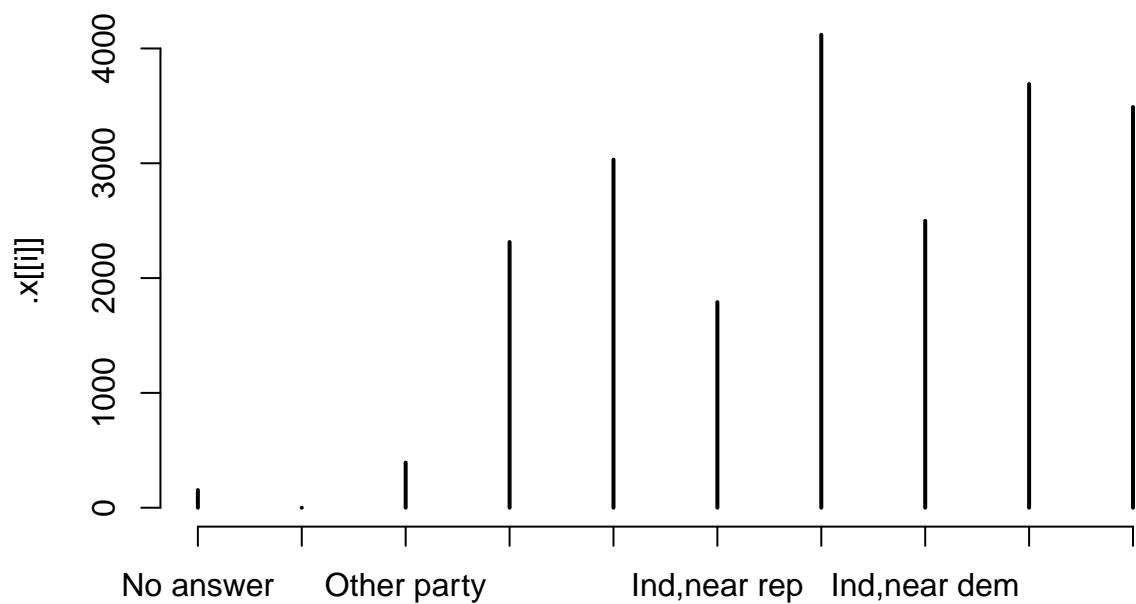


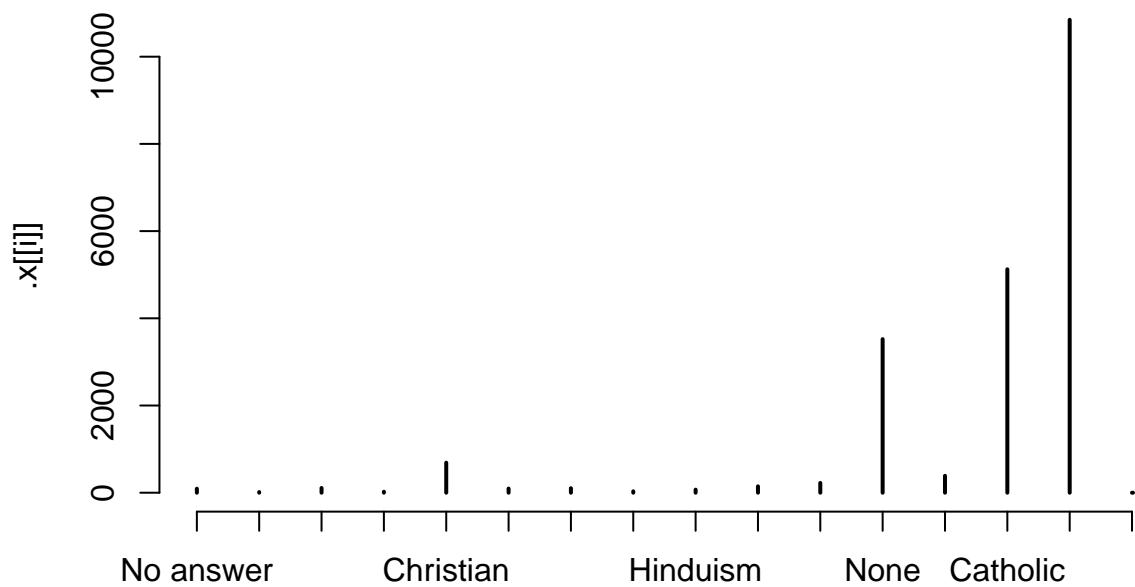


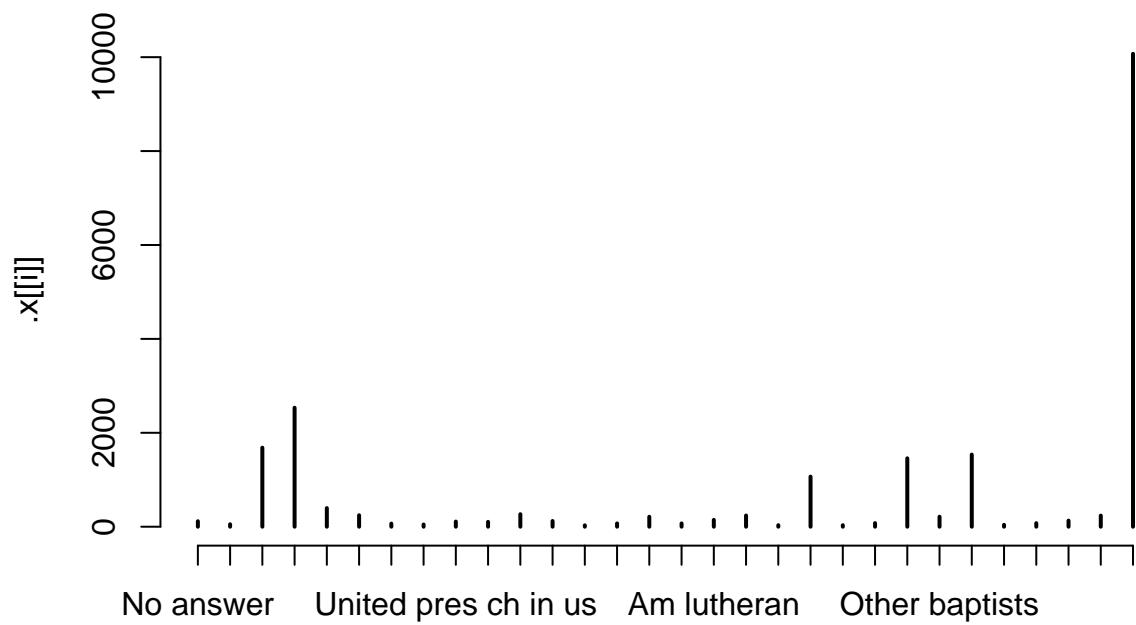


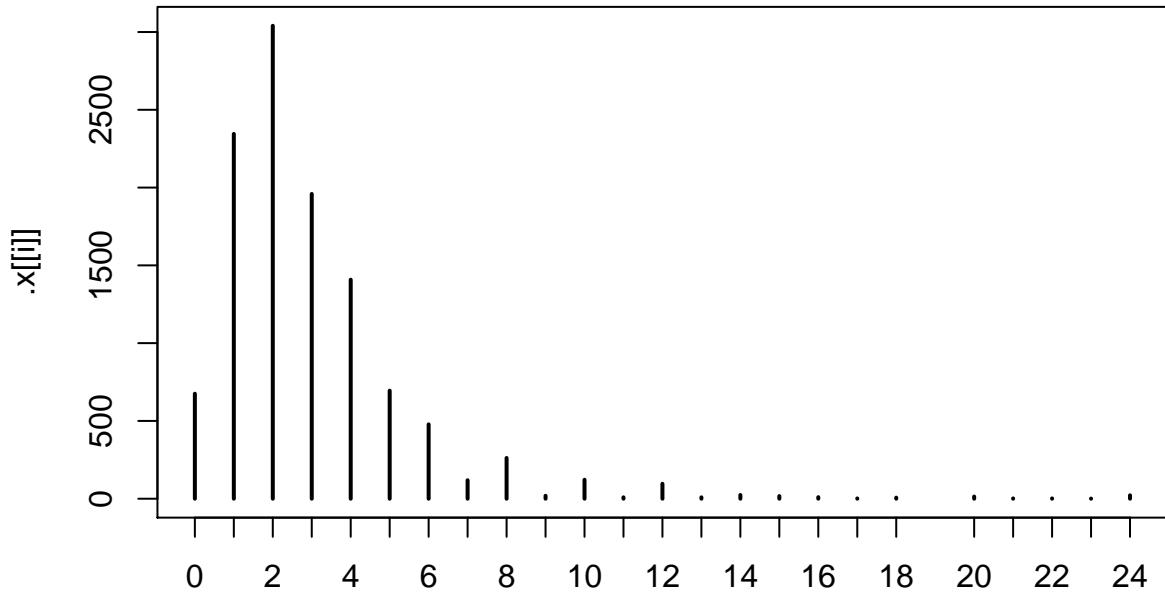












```

## $year
## [1] 2000 2002 2004 2006 2008 2010 2012 2014
##
## $marital
## [1] 1 2 3 4 5 6
##
## $age
##  [1] 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
## [24] 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
## [47] 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
## [70] 87 88 89
##
## $race
## [1] 1 2 3 4
##
## $rincome
##  [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
##
## $partyid
## [1] 1 2 3 4 5 6 7 8 9 10
##
## $relig
##  [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
##
## $denom
## [1] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

```

```
## [24] 24 25 26 27 28 29 30
##
## $tvhours
## [1] 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23
## [24] 24
```

17.2 Percentage NA each level

```
gss_cat %>%
  purrr::map(~(sum(is.na(.x)) / length(.x)))

## $year
## [1] 0
##
## $marital
## [1] 0
##
## $age
## [1] 0.003537681
##
## $race
## [1] 0
##
## $rincome
## [1] 0
##
## $partyid
## [1] 0
##
## $relig
## [1] 0
##
## $denom
## [1] 0
##
## $tvhours
## [1] 0.4722804
```

17.3 Print all levels of tibble

```
gss_cat %>%
  count(tvhours) %>%
  print(n = Inf)

## # A tibble: 25 x 2
##       tvhours     n
##       <int> <int>
##   1         0    675
##   2         1   2345
##   3         2   3040
```

```
## 4      3 1959
## 5      4 1408
## 6      5  695
## 7      6  478
## 8      7  119
## 9      8  262
## 10     9   19
## 11    10 122
## 12    11    9
## 13    12   96
## 14    13    9
## 15    14   24
## 16    15   17
## 17    16   10
## 18    17    2
## 19    18    7
## 20    20   14
## 21    21    2
## 22    22    2
## 23    23    1
## 24    24   22
## 25    NA 10146
```

Make sure the following packages are installed:

Chapter 18

ch. 16: Dates and times

- `today` get current date
- `now` get current date-time
- `ymd_hms` one example of straight-forward set-of functions that take either strings or unquoted numbers and output dates or date-times
- `make_datetime` create date-time from individual components, e.g. `make_datetime(year, month, day, hour, minute)`
- `as_date_time` and `as_date` let you switch between date-time and dates, e.g. `as_datetime(today())` or `as_date(now())`
- Accessor functions let you pull out components from an existing date-time:
 - `year, month, mday, yday, wday, hour, minute, second`
 - * `month` and `wday` have `label = TRUE` to pull the abbreviated name rather than the number, and pull full name with `abbr = FALSE`
 - You can also use these to set particular components `year(datetime) <- 2020`
- `update` allows you to specify multiple values at one time, e.g. `update(datetime, year = 2020, month = 2, mday = 2, hour = 2)`
 - When values are too big they roll-over e.g. `update(ymd("2015-02-01"), mday = 30)` will become ‘2015-03-02’
- Rounding functions to nearest unit of time
 - `floor_date, round_date, ceiling_date`
- `as.duration` convert diff-time to a duration
- Durations (can add and multiply):
 - `dseconds, dhours, ddays, dweeks, dyears`
- Periods (can add and multiply), more likely to do what you expect than duration:
 - `seconds, minutes, hours, days, weeks, months`
- Interval is a duration with a starting point, making it precise and possible to determine EXACT length
 - e.g. `(today() %--% next_year) / ddays(1)` to find exact duration
- `Sys.timezone` to see what R thinks your current time zone is
- `tz` = arg in `ymd_hms` let’s you change printing behavior (not underlying value, as assumes UTC unless changed)
- `with_tz` allows you to print an existing date-time object to a specific other timezone
- `force_tz` when have an object that’s been labeled with wrong time-zone and need to fix it

18.1 16.2: Creating date/times

Note that 1 in date-times is treated as 1 - second in numeric contexts, so example below sets `binwidth = 86400` to specify 1 day

```

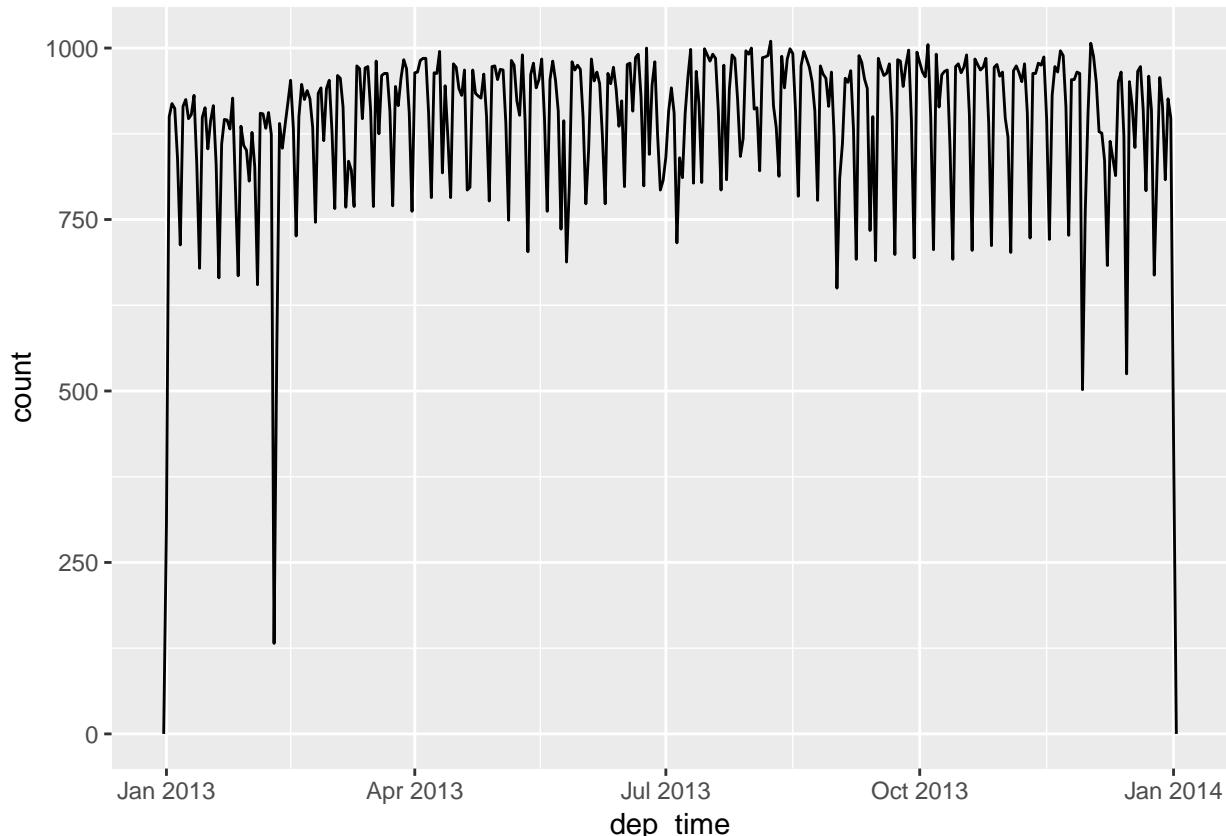
make_datetime_100 <- function(year, month, day, time) {
  make_datetime(year, month, day, time %/% 100, time %% 100)
}

flights_dt <- flights %>%
  filter(!is.na(dep_time), !is.na(arr_time)) %>%
  mutate_at(c("dep_time", "arr_time", "sched_dep_time", "sched_arr_time"), funs(make_datetime_100(year,
    select(origin, dest, ends_with("delay"), ends_with("time")))
  
```

Warning: funs() is soft deprecated as of dplyr 0.8.0
 ## please use list() instead
 ##
 ## # Before:
 ## funs(name = f(.))
 ##
 ## # After:
 ## list(name = ~f(.))
 ## This warning is displayed once per session.

```

flights_dt %>%
  ggplot(aes(dep_time)) +
  geom_freqpoly(binwidth = 86400)
  
```



18.1.1 16.2.4

- What happens if you parse a string that contains invalid dates?

```
ymd(c("2010-10-10", "bananas"))
```

```
## Warning: 1 failed to parse.
```

```
## [1] "2010-10-10" NA
```

- Outputs an NA and sends warning of number that failed to parse

- What does the `tzon` argument to `today()` do? Why is it important?

- Let's you specify timezones, may be different days depending on location

```
today(tzon = "MST")
```

```
## [1] "2019-05-22"
```

```
now(tzon = "MST")
```

```
## [1] "2019-05-22 19:30:52 MST"
```

- Use the appropriate lubridate function to parse each of the following dates:

```
d1 <- "January 1, 2010"
```

```
d2 <- "2015-Mar-07"
```

```
d3 <- "06-Jun-2017"
```

```
d4 <- c("August 19 (2015)", "July 1 (2015)")
```

```
d5 <- "12/30/14" # Dec 30, 2014
```

```
mdy(d1)
```

```
## [1] "2010-01-01"
```

```
ymd(d2)
```

```
## [1] "2015-03-07"
```

```
dmy(d3)
```

```
## [1] "2017-06-06"
```

```
mdy(d4)
```

```
## [1] "2015-08-19" "2015-07-01"
```

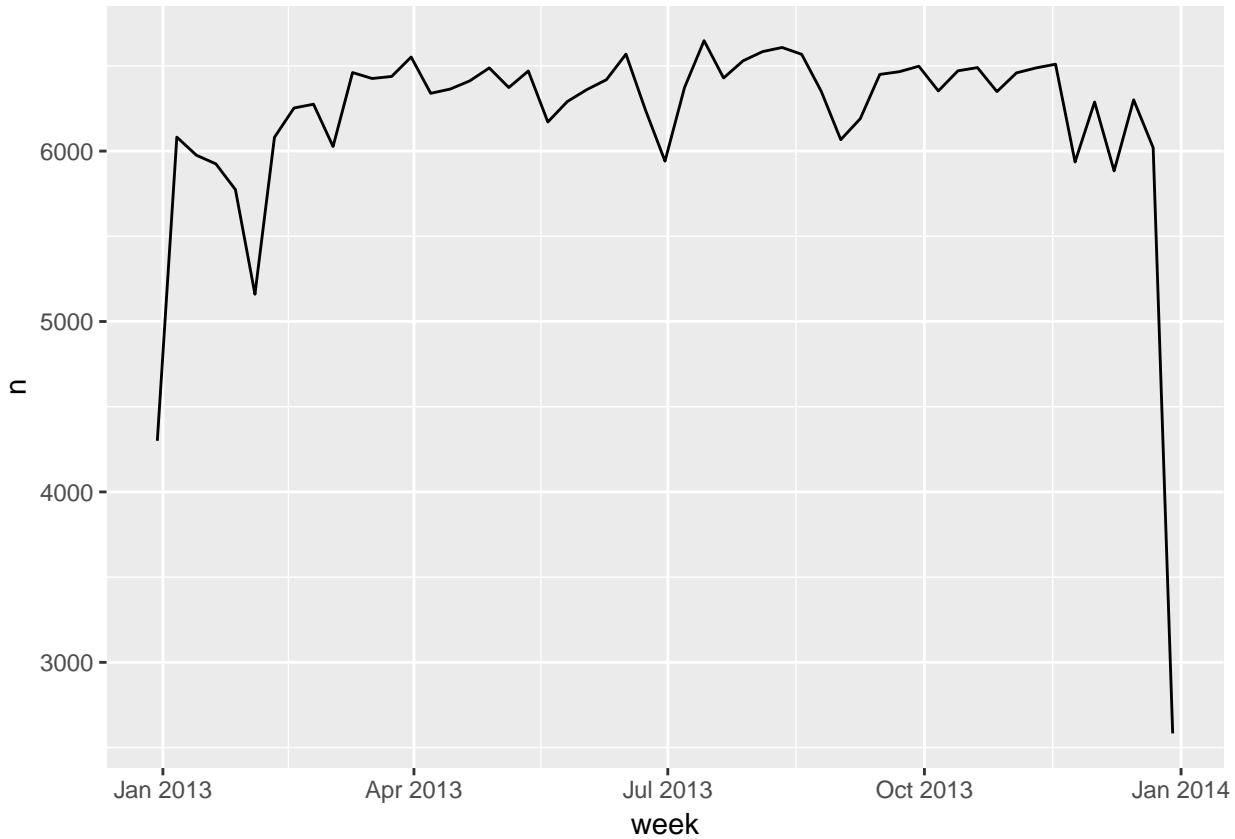
```
mdy(d5)
```

```
## [1] "2014-12-30"
```

18.2 16.3: Date-time components

This allows you to plot the number of flights per week

```
flights_dt %>%
  count(week = floor_date(dep_time, "week")) %>%
  ggplot(aes(week, n)) +
  geom_line()
```

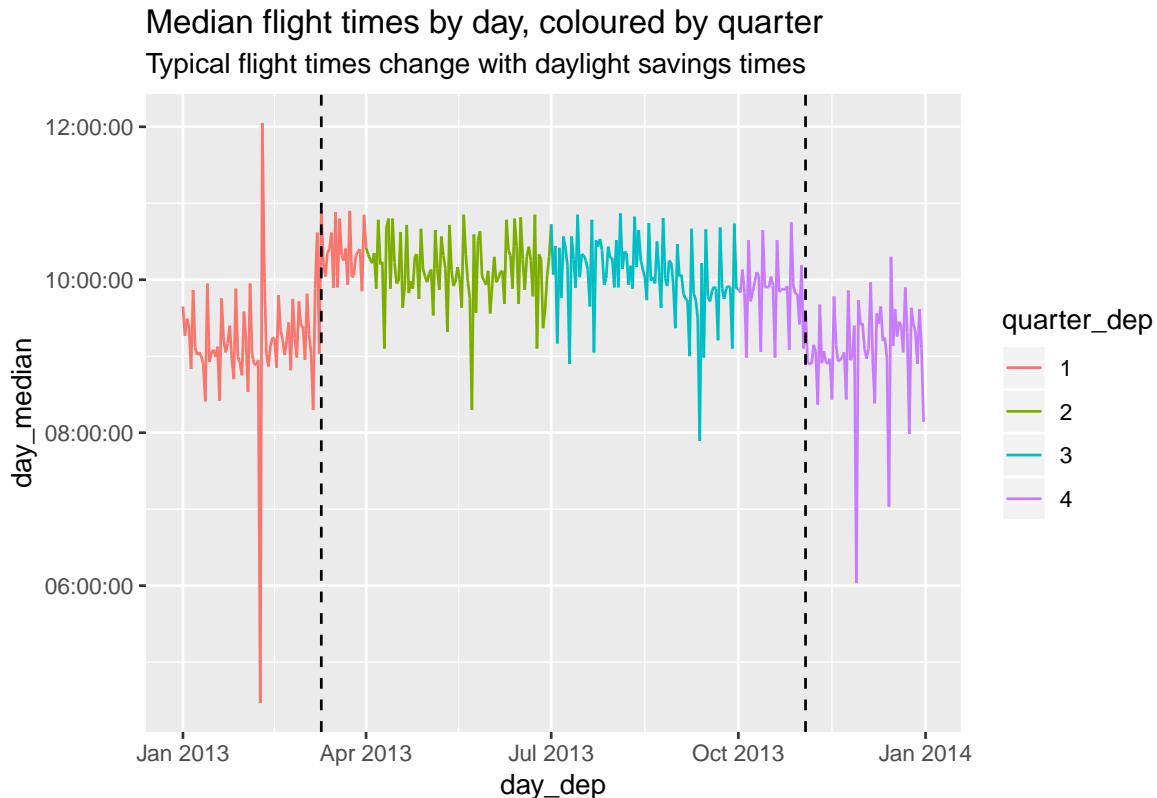


18.2.1 16.3.4

- How does the distribution of flight times within a day change over the course of the year?

Median flight time by day

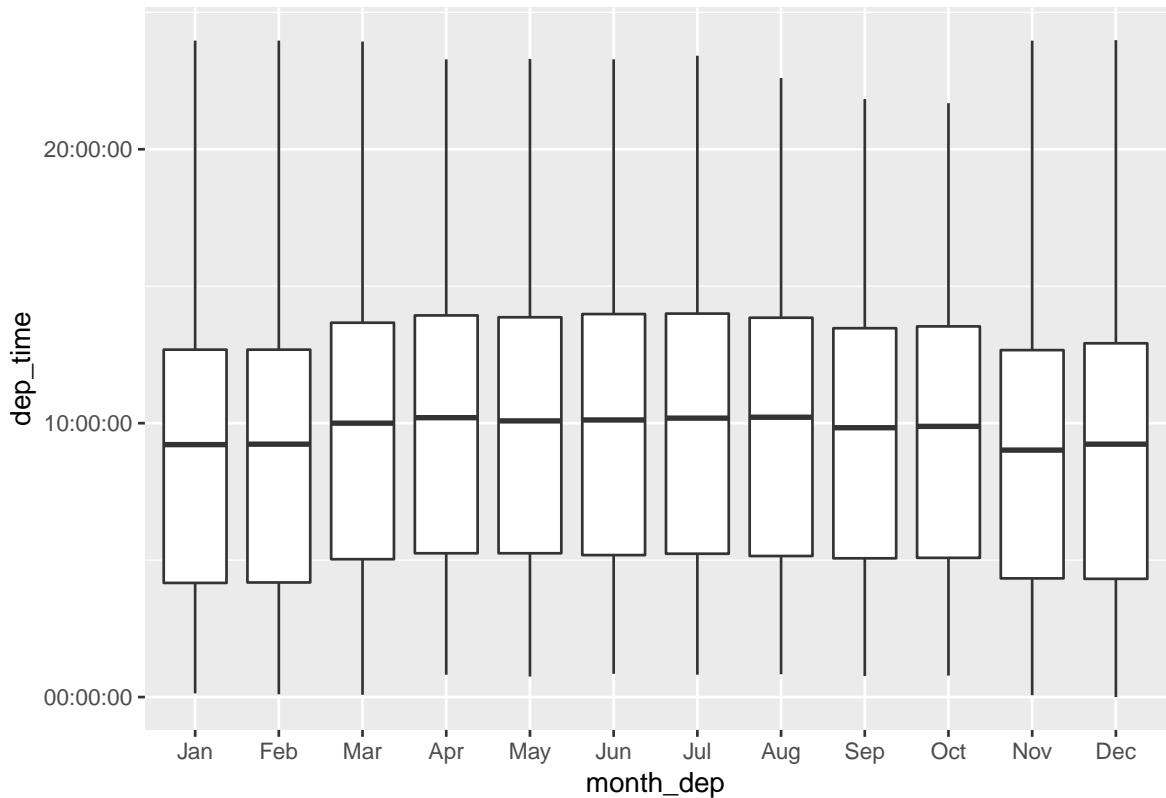
```
flights_dt %>%
  transmute(quarter_dep = quarter(dep_time) %>% factor(),
            day_dep = as_date(dep_time),
            dep_time = as.hms(dep_time)) %>%
  group_by(quarter_dep, day_dep) %>%
  summarise(day_median = median(dep_time)) %>%
  ungroup() %>%
  ggplot(aes(x = day_dep, y = day_median)) +
  geom_line(aes(colour = quarter_dep, group = 1)) +
  labs(title = "Median flight times by day, coloured by quarter", subtitle = "Typical flight times",
       geom_vline(xintercept = ymd("20130310"), linetype = 2) +
       geom_vline(xintercept = ymd("20131103"), linetype = 2)
```



- First couple and last couple months tend to have slightly earlier start times

Quantiles of flight times by month

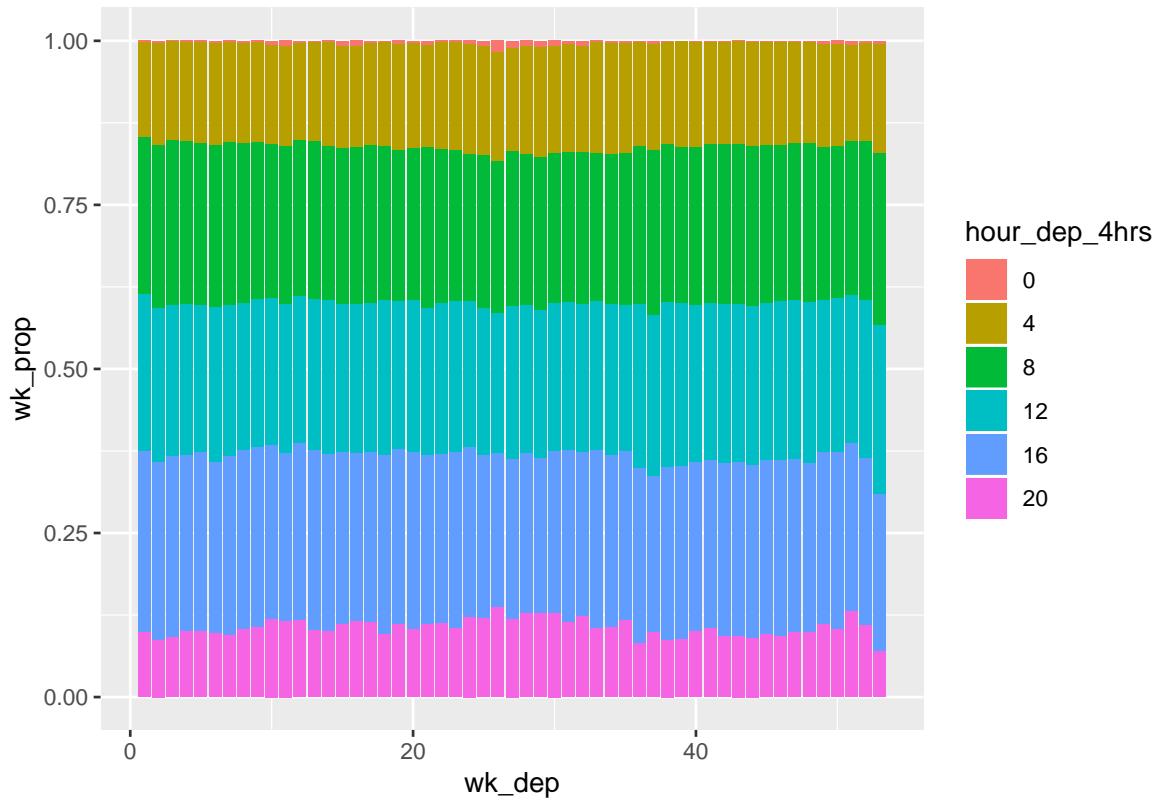
```
flights_dt %>%
  transmute(month_dep = month(dep_time, label = TRUE),
            quarter_dep = quarter(dep_time) %>% factor(),
            wk_dep = week(dep_time),
            dep_time = as.hms(dep_time)) %>%
  group_by(month_dep, wk_dep) %>%
  ungroup() %>%
  ggplot(aes(x = month_dep, y = dep_time, group = month_dep)) +
  geom_boxplot()
```



- Reinforces prior plot, shows that first couple and last couple months of year tend to have slightly higher proportion of flights earlier in day

Weekly flight proportions by 4 hour blocks

```
flights_dt %>%
  transmute(month_dep = month(dep_time, label = TRUE),
            wk_dep = week(dep_time),
            dep_time_4hrs = floor_date(dep_time, "4 hours"),
            hour_dep_4hrs = hour(dep_time_4hrs) %>% factor) %>%
  count(wk_dep, hour_dep_4hrs) %>%
  group_by(wk_dep) %>%
  mutate(wk_tot = sum(n),
        wk_prop = round(n / wk_tot, 3)) %>%
  ungroup() %>%
  ggplot(aes(x = wk_dep, y = wk_prop)) +
  geom_col(aes(fill = hour_dep_4hrs))
```



- Last week of the year have a lower proportion of late flights, and a higher proportion of morning flights

See 16.3.4.1 for a few other plots I looked at.

2. Compare `dep_time`, `sched_dep_time` and `dep_delay`. Are they consistent? Explain your findings.

```
flights_dt %>%
  mutate(dep_delay_check = (dep_time - sched_dep_time) / dminutes(1),
        same = dep_delay == dep_delay_check,
        difference = dep_delay_check - dep_delay) %>%
  filter(abs(difference) > 0)
```

```
## # A tibble: 1,205 x 12
##   origin dest  dep_delay arr_delay dep_time           sched_dep_time
##   <chr>  <chr>    <dbl>    <dbl> <dttm>             <dttm>
## 1 JFK    BWI      853     851 2013-01-01 08:48:00 2013-01-01 18:35:00
## 2 JFK    SJU      43      36 2013-01-02 00:42:00 2013-01-02 23:59:00
## 3 JFK    SYR      156     154 2013-01-02 01:26:00 2013-01-02 22:50:00
## 4 JFK    SJU      33      22 2013-01-03 00:32:00 2013-01-03 23:59:00
## 5 JFK    BUF      185     172 2013-01-03 00:50:00 2013-01-03 21:45:00
## 6 JFK    BQN      156     143 2013-01-03 02:35:00 2013-01-03 23:59:00
## 7 JFK    SJU      26      23 2013-01-04 00:25:00 2013-01-04 23:59:00
## 8 JFK    PWM      141     125 2013-01-04 01:06:00 2013-01-04 22:45:00
## 9 JFK    PSE      15      18 2013-01-05 00:14:00 2013-01-05 23:59:00
## 10 JFK   FLL     127     130 2013-01-05 00:37:00 2013-01-05 22:30:00
## # ... with 1,195 more rows, and 6 more variables: arr_time <dttm>,
## #   sched_arr_time <dttm>, air_time <dbl>, dep_delay_check <dbl>,
## #   same <lgl>, difference <dbl>
```

- They are except in the case when it goes over a day, the day is not pushed forward so it counts it as being 24 hours off
3. Compare `air_time` with the duration between the departure and arrival. Explain your findings. (Hint: consider the location of the airport.)

```
flights_dt %>%
  mutate(air_time_check = (arr_time - dep_time) / dminutes(1)) %>%
  select(air_time_check, air_time, dep_time, arr_time, everything())

## # A tibble: 328,063 x 10
##   air_time_check air_time dep_time           arr_time      origin
##       <dbl>     <dbl> <dttm>     <dttm>      <chr>
## 1         193     227 2013-01-01 05:17:00 2013-01-01 08:30:00 EWR
## 2         197     227 2013-01-01 05:33:00 2013-01-01 08:50:00 LGA
## 3         221     160 2013-01-01 05:42:00 2013-01-01 09:23:00 JFK
## 4         260     183 2013-01-01 05:44:00 2013-01-01 10:04:00 JFK
## 5         138     116 2013-01-01 05:54:00 2013-01-01 08:12:00 LGA
## 6         106     150 2013-01-01 05:54:00 2013-01-01 07:40:00 EWR
## 7         198     158 2013-01-01 05:55:00 2013-01-01 09:13:00 EWR
## 8          72      53 2013-01-01 05:57:00 2013-01-01 07:09:00 LGA
## 9         161     140 2013-01-01 05:57:00 2013-01-01 08:38:00 JFK
## 10        115     138 2013-01-01 05:58:00 2013-01-01 07:53:00 LGA
## # ... with 328,053 more rows, and 5 more variables: dest <chr>,
## #   dep_delay <dbl>, arr_delay <dbl>, sched_dep_time <dttm>,
## #   sched_arr_time <dttm>
```

- Initial check is off, so need to take into account the time-zone and difference from NYC, so join timezone document

```
flights_dt %>%
  left_join(select(nycflights13::airports, dest = faa, tz), by = "dest") %>%
  mutate(arr_time_new = arr_time - dhours(tz + 5)) %>%
  mutate(air_time_tz = (arr_time_new - dep_time) / dminutes(1),
        diff_Airtime = air_time_tz - air_time) %>%
  select( origin, dest, tz, contains("time"), -(contains("sched")))

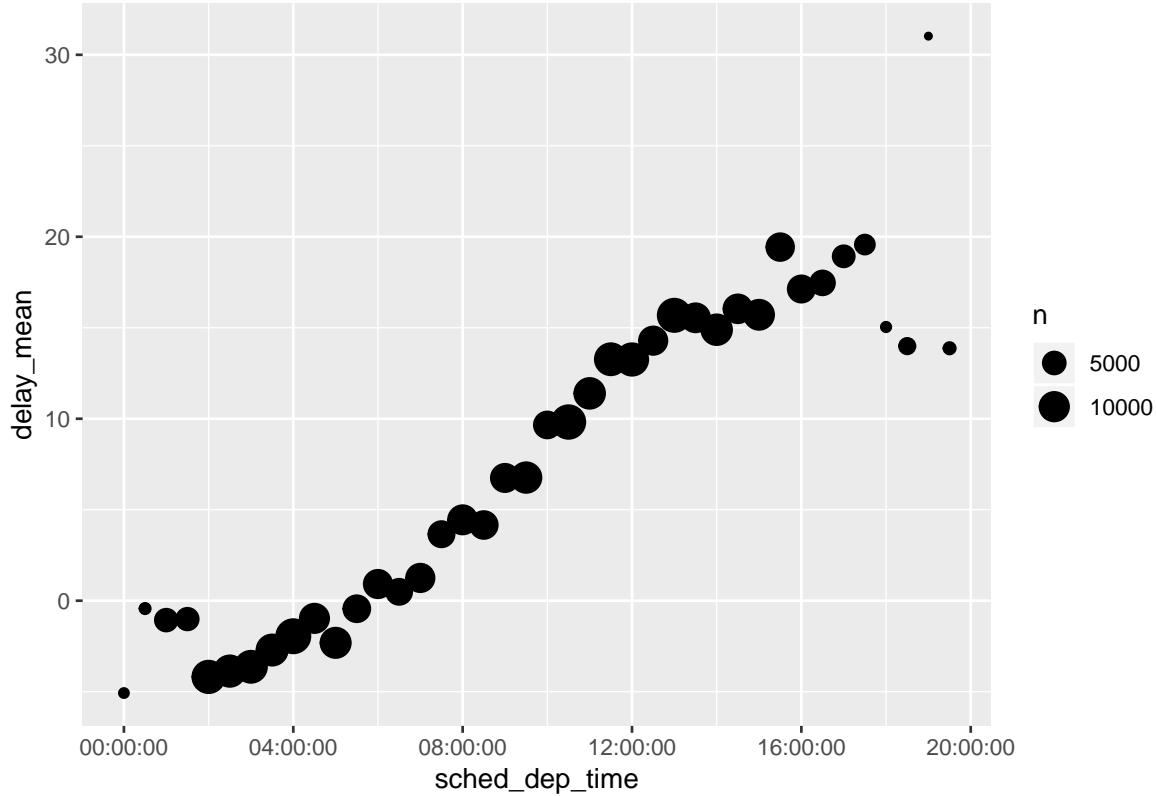
## # A tibble: 328,063 x 9
##   origin dest    tz dep_time           arr_time      air_time
##   <chr>  <chr> <dbl> <dttm>     <dttm>      <dbl>
## 1 EWR    IAH     -6 2013-01-01 05:17:00 2013-01-01 08:30:00     227
## 2 LGA    IAH     -6 2013-01-01 05:33:00 2013-01-01 08:50:00     227
## 3 JFK    MIA     -5 2013-01-01 05:42:00 2013-01-01 09:23:00     160
## 4 JFK    BQN     NA 2013-01-01 05:44:00 2013-01-01 10:04:00     183
## 5 LGA    ATL     -5 2013-01-01 05:54:00 2013-01-01 08:12:00     116
## 6 EWR    ORD     -6 2013-01-01 05:54:00 2013-01-01 07:40:00     150
## 7 EWR    FLL     -5 2013-01-01 05:55:00 2013-01-01 09:13:00     158
## 8 LGA    IAD     -5 2013-01-01 05:57:00 2013-01-01 07:09:00      53
## 9 JFK    MCO     -5 2013-01-01 05:57:00 2013-01-01 08:38:00     140
## 10 LGA   ORD     -6 2013-01-01 05:58:00 2013-01-01 07:53:00     138
## # ... with 328,053 more rows, and 3 more variables: arr_time_new <dttm>,
## #   air_time_tz <dbl>, diff_Airtime <dbl>
```

- Is closer but still off. In chapter 5, problem 5.5.2.1 I go further into this
- In Appendix section 16.3.4.3 filter to NAs

4. How does the average delay time change over the course of a day? Should you use `dep_time` or

`sched_dep_time`? Why?

```
flights_dt %>%
  mutate(sched_dep_time = as.hms(floor_date(sched_dep_time, "30 mins"))) %>%
  group_by(sched_dep_time) %>%
  summarise(delay_mean = mean(arr_delay, na.rm = TRUE),
            n = n(),
            n_na = sum(is.na(arr_delay)) / n,
            delay_median = median(arr_delay, na.rm = TRUE)) %>%
  ggplot(aes(x = sched_dep_time, y = delay_mean, size = n)) +
  geom_point()
```



- It goes-up throughout the day
- Use `sched_dep_time` because it has the correct day

5. On what day of the week should you leave if you want to minimise the chance of a delay?

```
flights_dt %>%
  mutate(weekday = wday(sched_dep_time, label = TRUE)) %>%
  group_by(weekday) %>%
  summarise(prop_delay = sum(dep_delay > 0) / n())

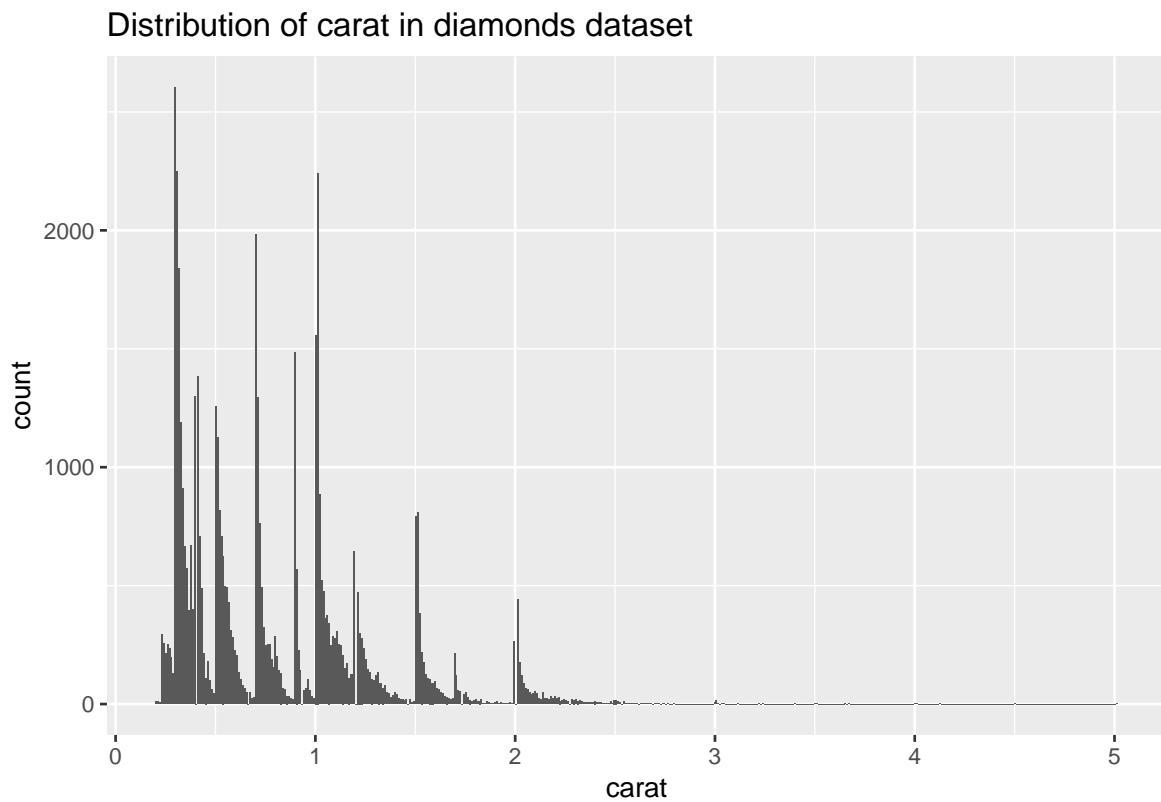
## # A tibble: 7 x 2
##   weekday prop_delay
##   <ord>     <dbl>
## 1 Sun       0.383
## 2 Mon       0.401
## 3 Tue       0.364
## 4 Wed       0.372
## 5 Thu       0.431
```

```
## 6 Fri      0.425
## 7 Sat      0.348
```

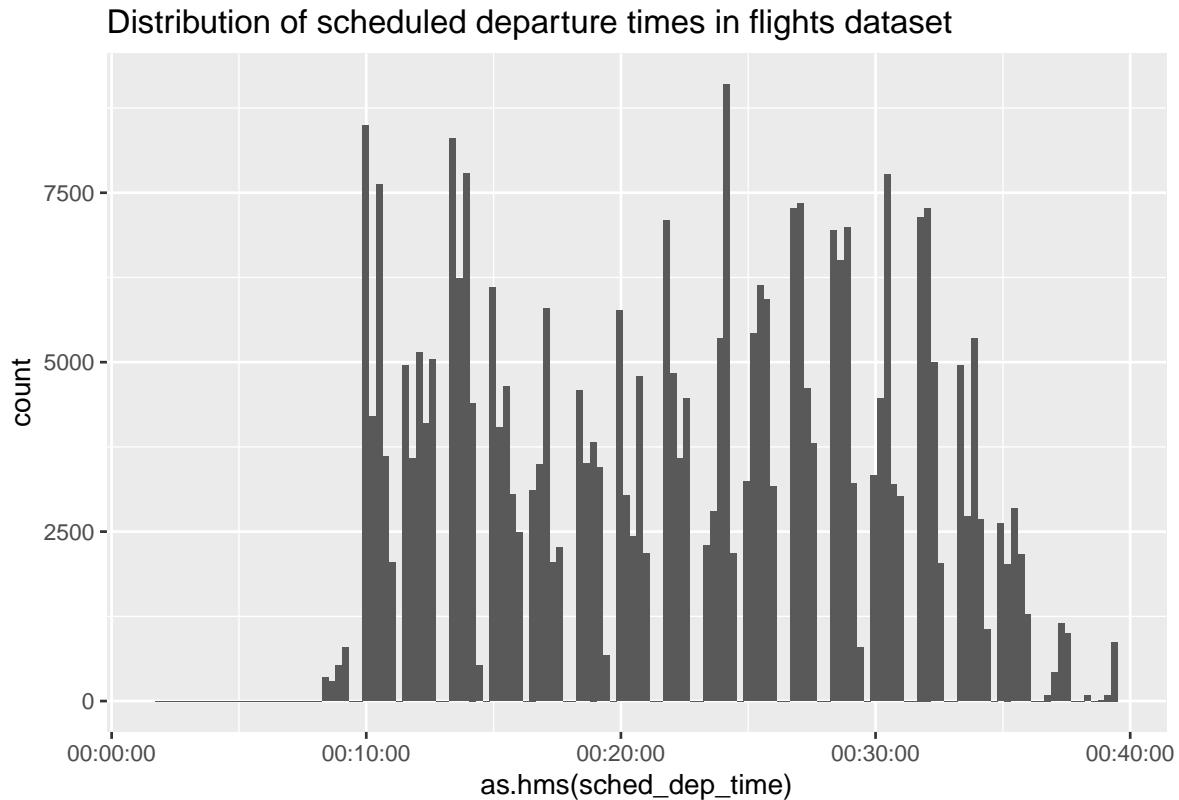
- wknd has a slightly lower proportion of flights delayed (Thursday has the worst)

6. What makes the distribution of diamonds\$carat and flights\$sched_dep_time similar?

```
ggplot(diamonds, aes(x = carat)) +
  geom_histogram(bins = 500) +
  labs(title = "Distribution of carat in diamonds dataset")
```



```
ggplot(flights, aes(x = as.hms(sched_dep_time))) +
  geom_histogram(bins = 24*6) +
  labs(title = "Distribution of scheduled departure times in flights dataset")
```



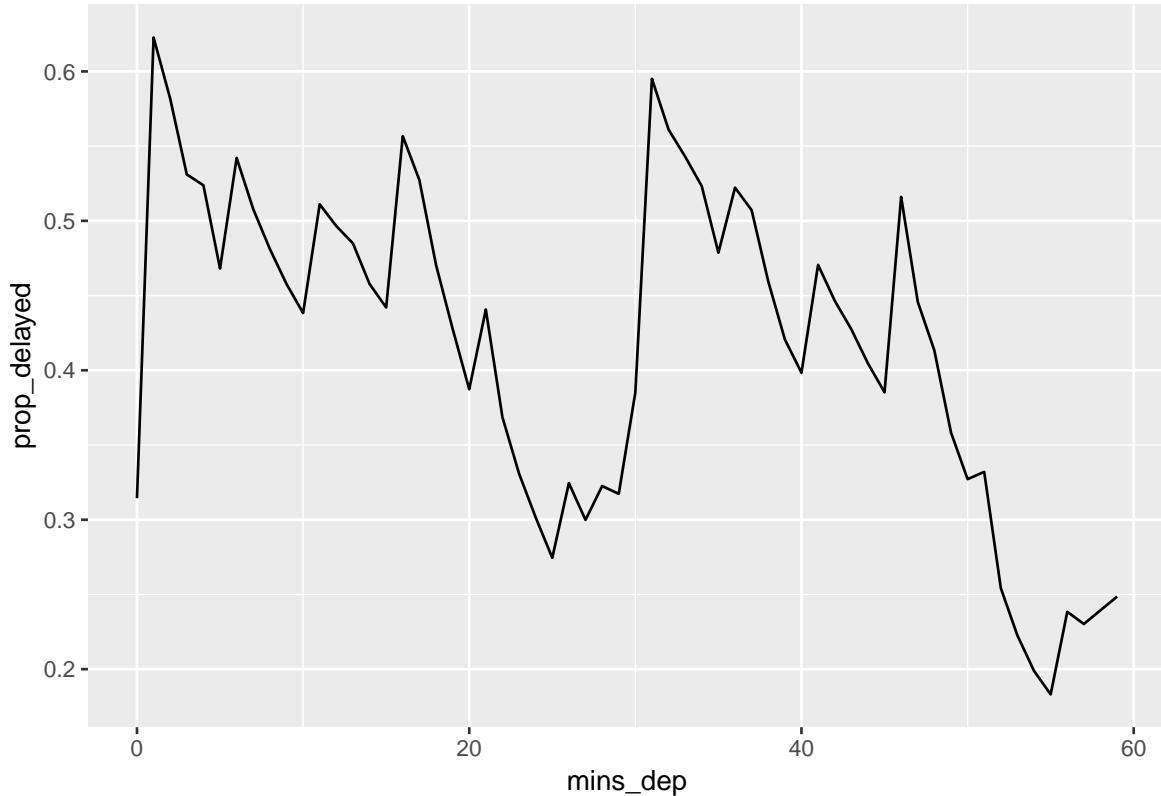
- Both have gaps and peaks at ‘attractive’ values

7. Confirm my hypothesis that the early departures of flights in minutes 20-30 and 50-60 are caused by scheduled flights that leave early. Hint: create a binary variable that tells you whether or not a flight was delayed.

```
mutate(flights_dt,
       mins_dep = minute(dep_time),
       mins_sched = minute(sched_dep_time),
       delayed = dep_delay > 0) %>%
group_by(mins_dep) %>%
summarise(prop_delayed = sum(delayed) / n()) %>%
ggplot(aes(x = mins_dep, y = prop_delayed)) +
geom_line()
```

| | date | date time | duration | period | interval | number | | |
|-----------|------|-----------|----------|--------|----------|--------|---------|--|
| date | - | | - + | - + | | - + | - + | |
| date time | | - | - + | - + | | | - + | |
| duration | - + | - + | - + | / | | | - + × / | |
| period | - + | - + | | - + | | | - + × / | |
| interval | | | / | | / | | | |
| number | - + | - + | - + × | - + × | - + × | - + × | - + × / | |

Figure 18.1: Permitted arithmetic operations between different data types



- Consistent with above hypothesis

18.3 16.4: Time spans

- **durations**, which represent an exact number of seconds.
- **periods**, which represent human units like weeks and months.
- **intervals**, which represent a starting and ending point.

Periods example, using durations to fix oddity of problem when flight arrives overnight

```
flights_dt <- flights_dt %>%
  mutate(
    overnight = arr_time < dep_time,
    arr_time = arr_time + days(overnight * 1),
    sched_arr_time = sched_arr_time + days(overnight * 1)
  )
```

Intervals example to get precise number of days dependent on specific time

```
next_year <- today() + years(1)
(today() %--% next_year) / ddays(1)
```

```
## [1] 366
```

To find out how many periods fall in an interval, need to use integer division

```
(today() %--% next_year) %/% days(1)
```

```
## [1] 366
```

18.3.1 16.4.5

1. Why is there `months()` but no `dmonths()`?

- the duration varies from month to month

2. Explain `days(overnight * 1)` to someone who has just started learning R. How does it work?

- this used in the example above makes it such that if `overnight` is TRUE, it will return the same time period but one day ahead, if false, does not change (as is adding 0 days)

3. a. Create a vector of dates giving the first day of every month in 2015.

```
x <- ymd("2015-01-01")
mons <- c(0:11)
(x + months(mons)) %>% wday(label = TRUE)
```

```
## [1] Thu Sun Sun Wed Fri Mon Wed Sat Tue Thu Sun Tue
## Levels: Sun < Mon < Tue < Wed < Thu < Fri < Sat
```

b. Create a vector of dates giving the first day of every month in the *current* year.

```
x <- today() %>% update(month = 1, mday = 1)
mons <- c(0:11)
(x + months(mons)) %>% wday(label=TRUE)
```

```
## [1] Tue Fri Fri Mon Wed Sat Mon Thu Sun Tue Fri Sun
## Levels: Sun < Mon < Tue < Wed < Thu < Fri < Sat
```

4. Write a function that given your birthday (as a date), returns how old you are in years.

```
birthday_age <- function(birthday) {
  (ymd(birthday) %--% today()) %/% years(1)
}
birthday_age("1989-09-07")
```

```
## [1] 29
```

5. Why can't `(today() %--% (today() + years(1)) / months(1))` work?

- Can't add and subtract intervals

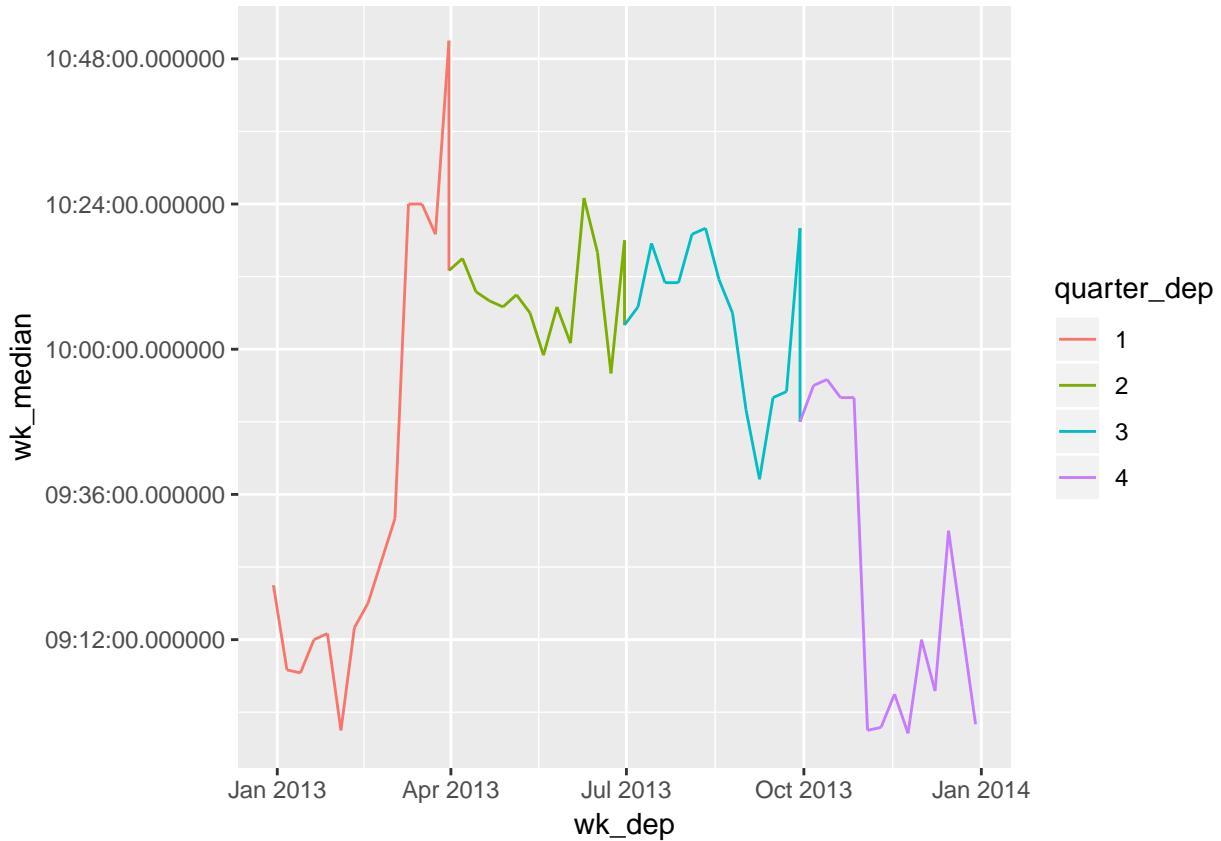
Chapter 19

Appendix

19.1 16.3.4.1

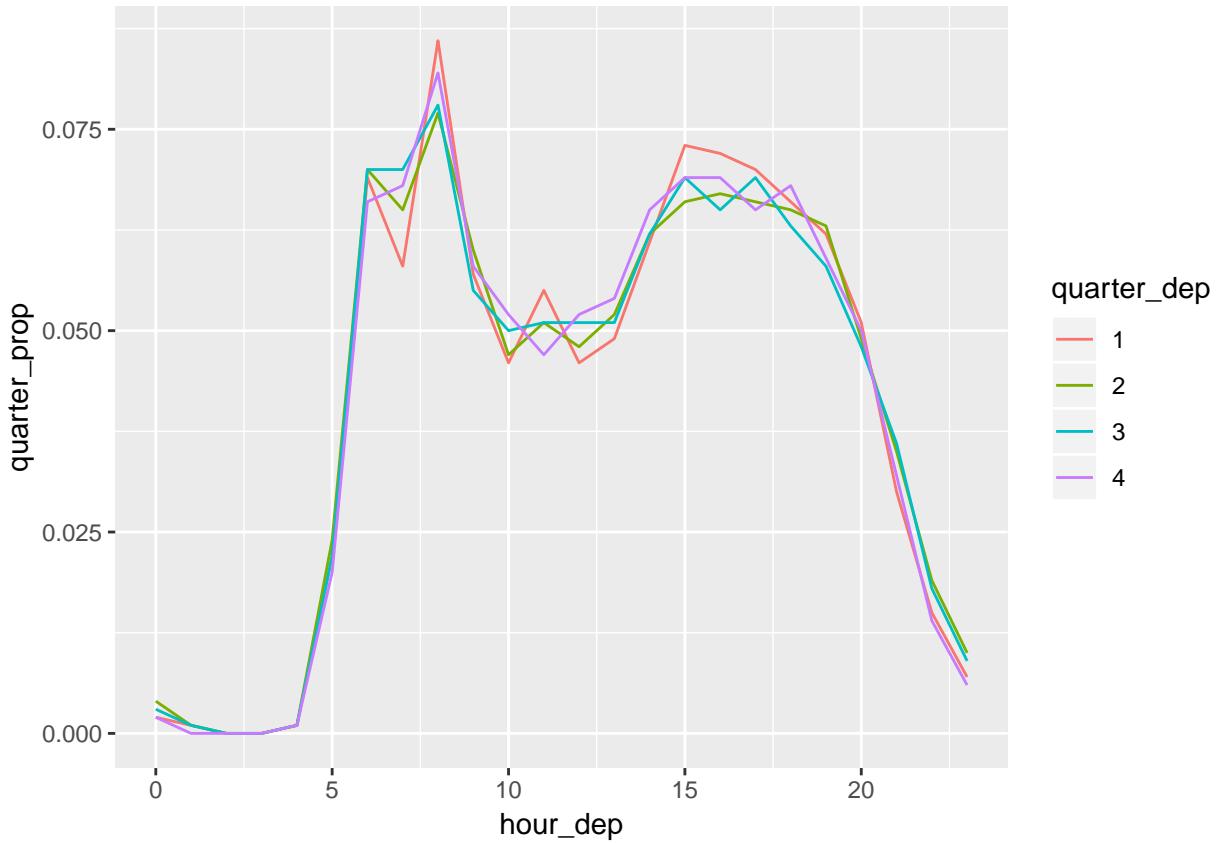
Weekly median flight time

```
flights_dt %>%
  transmute(quarter_dep = quarter(dep_time) %>% factor(),
            day_dep = as_date(dep_time),
            wk_dep = floor_date(dep_time, "1 week") %>% as_date,
            dep_time = as.hms(dep_time)) %>%
  group_by(quarter_dep, wk_dep) %>%
  summarise(wk_median = median(dep_time)) %>%
  ungroup() %>%
  mutate(wk_median = as.hms(wk_median)) %>%
  ggplot(aes(x = wk_dep, y = wk_median)) +
  geom_line(aes(colour = quarter_dep, group = 1))
```



Proportion of flights in each hour, by quarter

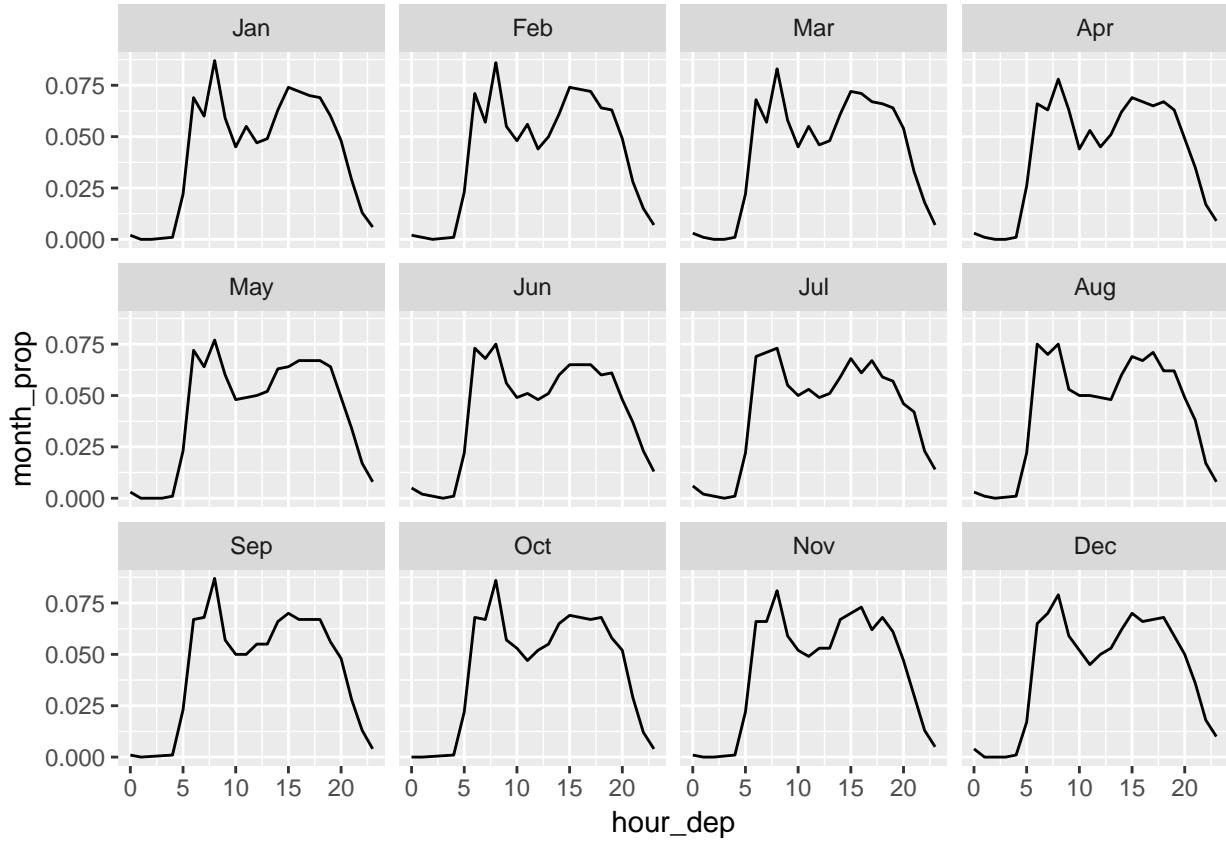
```
flights_dt %>%
  transmute(quarter_dep = quarter(dep_time) %>% factor(),
            hour_dep = hour(dep_time)) %>%
  count(quarter_dep, hour_dep) %>%
  group_by(quarter_dep) %>%
  mutate(quarter_tot = sum(n),
        quarter_prop = round(n / quarter_tot, 3)) %>%
  ungroup() %>%
  ggplot(aes(x = hour_dep, y = quarter_prop)) +
  geom_line(aes(colour = quarter_dep))
```



- Q1 seems to be a little more extreme at the local maxima

Look at proportion of flights by hour faceted by each month

```
flights_dt %>%
  transmute(month_dep = month(dep_time, label = TRUE),
            hour_dep = hour(dep_time)) %>%
  count(month_dep, hour_dep) %>%
  group_by(month_dep) %>%
  mutate(month_tot = sum(n),
        month_prop = round(n / month_tot, 3)) %>%
  ungroup() %>%
  ggplot(aes(x = hour_dep, y = month_prop)) +
  geom_line() +
  facet_wrap(~ month_dep)
```



19.2 16.3.4.3

- Perhaps these are flights where landed in different location...

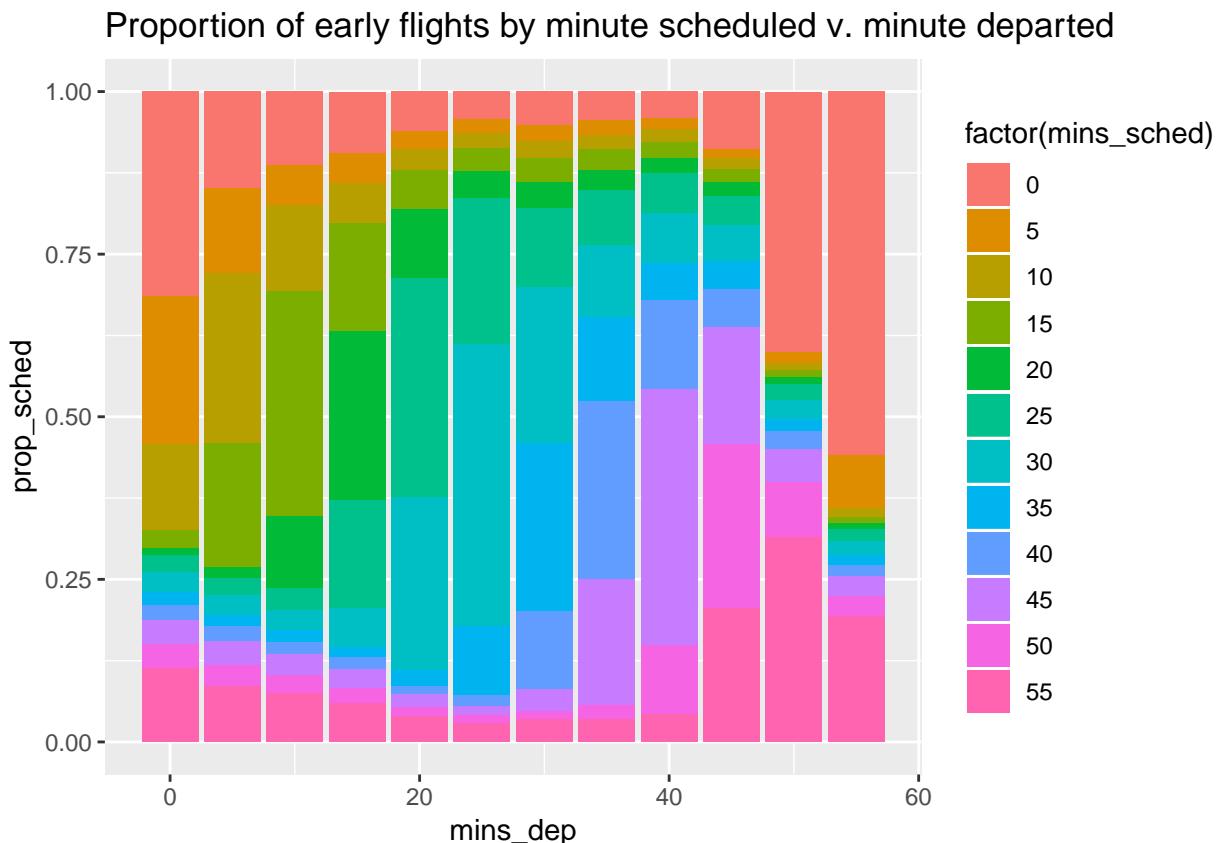
```
flights_dt %>%
  mutate(arr_delay_test = (arr_time - sched_arr_time) / dminutes(1)) %>%
  select( origin, dest, dep_delay, arr_delay, arr_delay_test, contains("time")) %>%
  filter(is.na(arr_delay))
```

```
## # A tibble: 717 x 10
##   origin dest  dep_delay arr_delay arr_delay_test dep_time
##   <chr>  <chr>     <dbl>     <dbl>           <dbl> <dttm>
## 1 LGA    XNA      -5        NA            89 2013-01-01 15:25:00
## 2 EWR    STL      29        NA           195 2013-01-01 15:28:00
## 3 LGA    XNA      -5        NA            98 2013-01-01 17:40:00
## 4 EWR    SAN      29        NA           108 2013-01-01 18:07:00
## 5 JFK    DFW      59        NA          -1282 2013-01-01 19:39:00
## 6 EWR    TUL      22        NA            111 2013-01-01 19:52:00
## 7 EWR    XNA      43        NA            148 2013-01-02 09:05:00
## 8 LGA    GRR     120        NA            179 2013-01-02 11:25:00
## 9 JFK    DFW      8         NA            102 2013-01-02 18:48:00
## 10 EWR   MCI     85        NA            177 2013-01-02 18:49:00
## # ... with 707 more rows, and 4 more variables: sched_dep_time <dttm>,
## #   arr_time <dttm>, sched_arr_time <dttm>, air_time <dbl>
```

19.3 16.3.4.4

*Below started looking at proportions...

```
mutate(flights_dt,
       dep_old = dep_time,
       sched_old = sched_dep_time,
       dep_time = floor_date(dep_time, "5 minutes"),
       sched_dep_time = floor_date(sched_dep_time, "5 minutes"),
       mins_dep = minute(dep_time),
       mins_scheduled = minute(sched_dep_time),
       delayed = dep_delay > 0) %>%
     group_by(mins_dep, mins_scheduled) %>%
     summarise(num_delayed = sum(delayed),
              num = n(),
              prop_delayed = num_delayed / num) %>%
     group_by(mins_dep) %>%
     mutate(num_tot = sum(num),
           prop_scheduled = num / num_tot,
           sched_dep_diff = mins_dep - mins_scheduled) %>%
     ungroup() %>%
ggplot(aes(x = mins_dep, y = prop_scheduled, fill = factor(mins_scheduled))) +
  geom_col() +
  labs(title = "Proportion of early flights by minute scheduled v. minute departed")
```

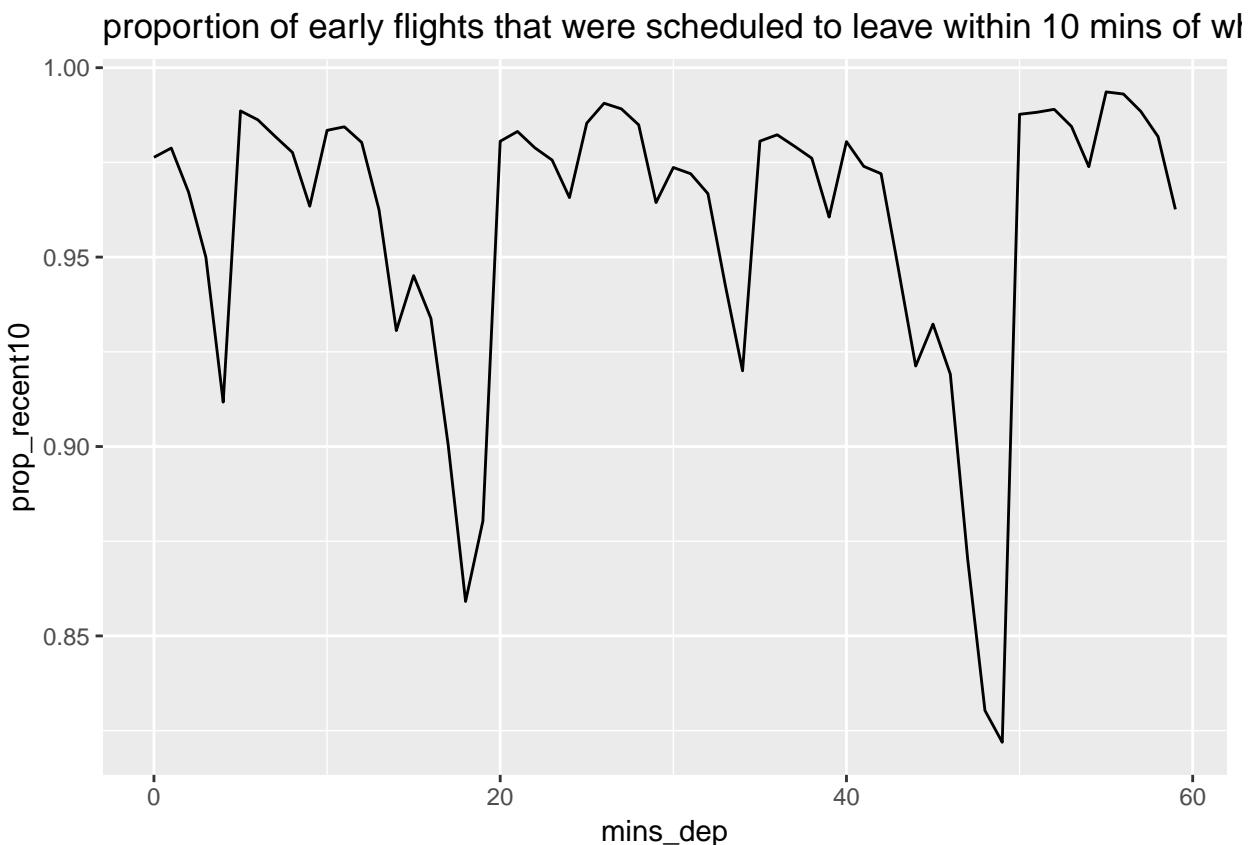


```
mutate(flights_dt,
       dep_old = dep_time,
```

```

sched_old = sched_dep_time,
# dep_time = floor_date(dep_time, "5 minutes"),
# sched_dep_time = floor_date(sched_dep_time, "5 minutes"),
mins_dep = minute(dep_time),
mins_sched = minute(sched_dep_time),
early_less10 = dep_delay >= -10) %>%
filter(dep_delay < 0) %>%
group_by(mins_dep) %>%
summarise(num = n(),
          sum_recent10 = sum(early_less10),
          prop_recent10 = sum_recent10 / num) %>%
ungroup() %>%
ggplot(aes(x = mins_dep, y = prop_recent10)) +
geom_line() +
labs(title = "proportion of early flights that were scheduled to leave within 10 mins of when they did")

```



```
knitr::opts_chunk$set(echo = TRUE, cache = TRUE, message = FALSE)
```

Make sure the following packages are installed:

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 3.5.2
```

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 3.5.3
```

```
library(forcats)
library(tidyr)

## Warning: package 'tidyr' was built under R version 3.5.3
library(lubridate)
library(stringr)
```


Chapter 20

ch. 18: Pipes (notes only)

- `pryr::object_size` gives the memory occupied by all of its arguments (note that built-in `object.size` does not allow measuring multiple objects so can't see shared space). This function is actually shown in chapter 18: Pipes
- Some functions do not work naturally with the pipe.
 - If you want to use `assign` with the pipe, you must be explicit about the environment

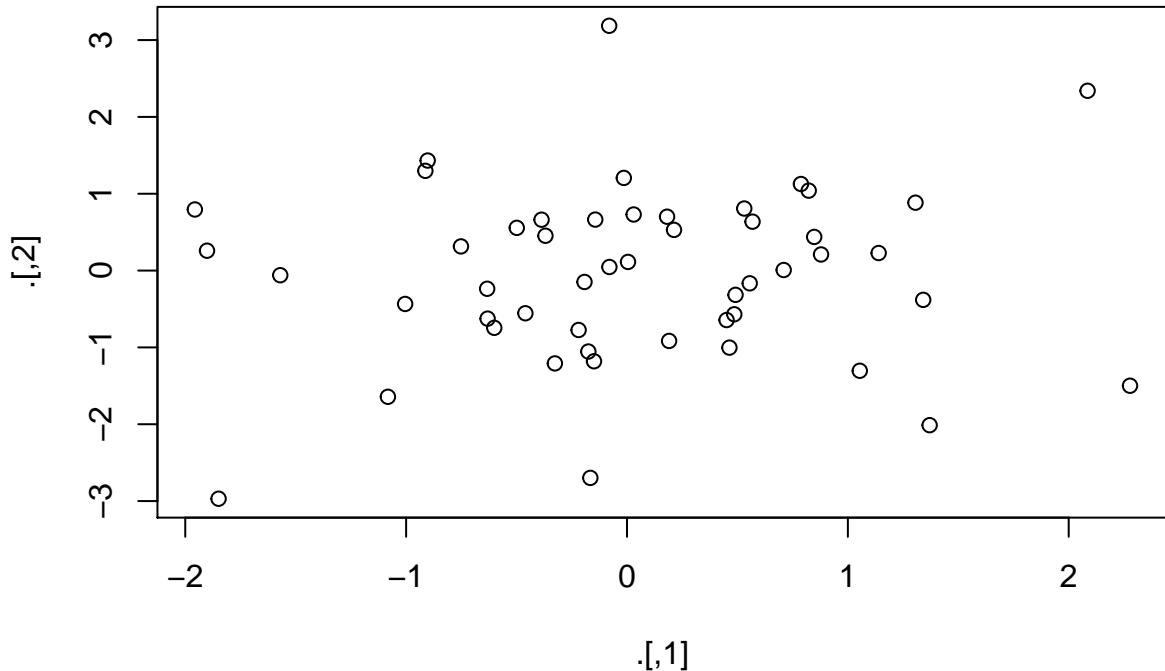
```
env <- environment()
"x" %>% assign(100, envir = env)
x
```

```
## [1] 100
```

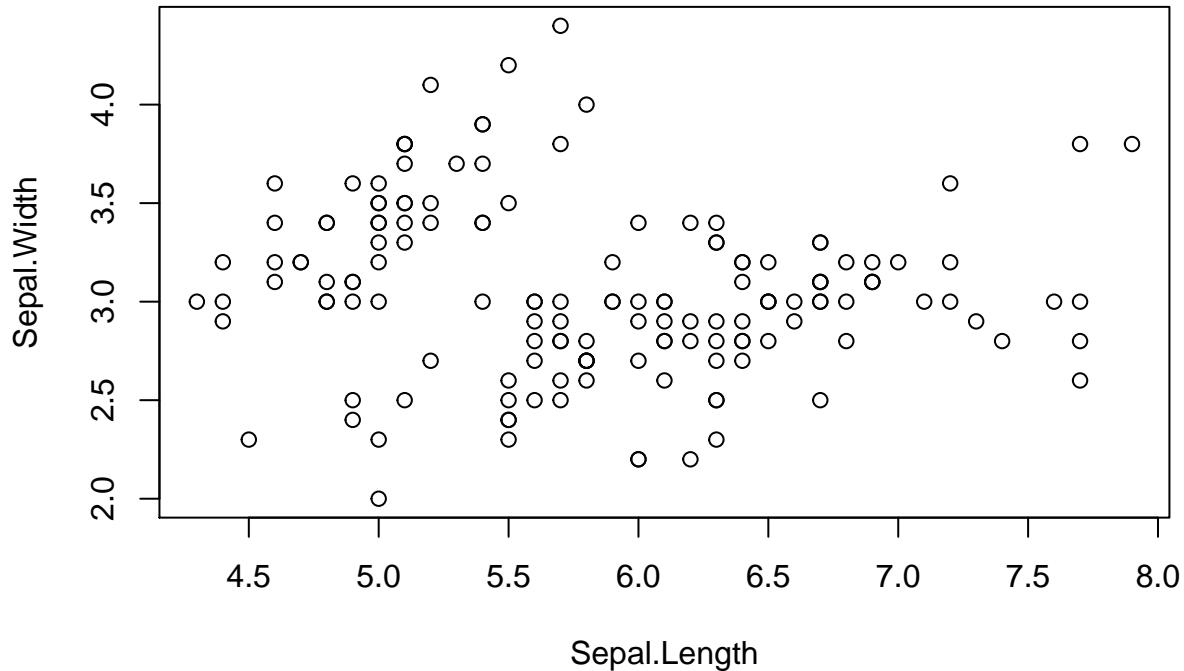
- `try`, `tryCatch`, `suppressMessages`, and `suppressWarnings` from base R all also do not work well

Other pipes = 'T pipe', `%T>%` that returns left-hand side rather than right. Will let the plot output, but then continues. Notice that this doesn't work for ggplot as ggplot does output something

```
library(magrittr)
rnorm(100) %>%
  matrix(ncol = 2) %T>%
  plot() %>%
  str()
```



```
##  num [1:50, 1:2] -1.08244 -1.84914 -0.08059 0.87865 0.00464 ...
iris %>%
  select(Sepal.Length, Sepal.Width) %T>%
  plot() %>%
  select(Sepal.Length) %>%
  head(10)
```



```
##      Sepal.Length
## 1          5.1
## 2          4.9
## 3          4.7
## 4          4.6
## 5          5.0
## 6          5.4
## 7          4.6
## 8          5.0
## 9          4.4
## 10         4.9
```

- `%$%` allows you to blow out the names of the arguments, I personally prefer using the `with` function for this instead as I find it to be a little more readable...
 - The two examples below are equivalent

```
mtcars %$%
  cor(disp, mpg)
```

```
## [1] -0.8475514
mtcars %>%
  with(cor(disp, mpg))

## [1] -0.8475514
knitr::opts_chunk$set(echo = TRUE, cache = TRUE, message = FALSE)
```

Make sure the following packages are installed:

```
library(nycflights13)
library(ggplot2)
library(dplyr)
library(forcats)
library(tidyr)
library(lubridate)
library(stringr)
library(e1071)
```

Chapter 21

ch. 19: Functions

- `function_name <- function(input1, input2) {}`
- `if () {}`
- `else if () {}`
- `else {}`
- `|| (or)`, `&& (and)` – used to combine multiple logical expressions
- `|` and `&` are vectorized operations not to be used with `if` statements
- `any` checks if any values in vector are TRUE
- `all` checks if all values in vector are TRUE
- `identical` strict check for if values are the same
- `dplyr::near` for more lenient comparison and typically better than `identical` as unaffected by floating point numbers and fine with different types
- `switch` evaluate selected code based on position or name (good for replacing long chain of `if` statements). e.g.

```
Operation_Times2 <- function(x, y, op){  
  first_op <- switch(op,  
    plus = x + y,  
    minus = x - y,  
    times = x * y,  
    divide = x / y,  
    stop("Unknown op!")  
  )  
  
  first_op * 2  
}
```



```
Operation_Times2(5, 7, "plus")
```

```
## [1] 24
```

- `stop` stops expression and executes error action, note that `.call` default is FALSE
- `warning` generates a warning that corresponds with arguments, `suppressWarnings` may also be useful to no
- `stopifnot` test multiple args and will produce error message if any are not true – compromise that prevents you from tedious work of putting multiple `if(){} else stop()` statements
- ... useful catch-all if your function primarily wraps another function (note that misspelled arguments will not raise an error), e.g.

```
commas <- function(...) stringr::str_c(..., collapse = ", ")
commas(letters[1:10])
```

```
## [1] "a, b, c, d, e, f, g, h, i, j"
```

- `cut` can be used to discretize continuous variables (also saves long `if` statements)
- `return` allows you to return the function early, typically reserve use for when the function can return early with a simpler function
- `cat` function to print label in output
- `invisible` input does not get printed out

21.1 19.2: When should you write a function?

21.1.1 19.2.1

1. Why is `TRUE` not a parameter to `rescale01()`? What would happen if `x` contained a single missing value, and `na.rm` was `FALSE`?
 - `TRUE` doesn't change between uses.
 - The output would be `NA`
2. In the second variant of `rescale01()`, infinite values are left unchanged. Rewrite `rescale01()` so that `-Inf` is mapped to 0, and `Inf` is mapped to 1.

```
rescale01_inf <- function(x){

  rng <- range(x, na.rm = TRUE, finite = TRUE)
  x_scaled <- (x - rng[1]) / (rng[2] - rng[1])
  is_inf <- is.infinite(x)
  is_less0 <- x < 0
  x_scaled[is_inf & is_less0] <- 0
  x_scaled[is_inf & (!is_less0)] <- 1
  x_scaled
}

x <- c(Inf, -Inf, 0, 3, -5)
rescale01_inf(x)
```

```
## [1] 1.000 0.000 0.625 1.000 0.000
```

3. Practice turning the following code snippets into functions. Think about what each function does. What would you call it? How many arguments does it need? Can you rewrite it to be more expressive or less duplicative?

```
mean(is.na(x))

x / sum(x, na.rm = TRUE)

sd(x, na.rm = TRUE) / mean(x, na.rm = TRUE)
```

- See solutions below:

```
x <- c(1, 4, 2, 0, NA, 3, NA)

#mean(is.na(x))
perc_na <- function(x) {
```

```

  is.na(x) %>% mean()
}

perc_na(x)

## [1] 0.2857143

#x / sum(x, na.rm = TRUE)
prop_weighted <- function(x) {
  x / sum(x, na.rm = TRUE)
}
prop_weighted(x)

## [1] 0.1 0.4 0.2 0.0 NA 0.3 NA

#sd(x, na.rm = TRUE) / mean(x, na.rm = TRUE)
CoefficientOfVariation <- function(x) {
  sd(x, na.rm = TRUE) / mean(x, na.rm = TRUE)
}

CoefficientOfVariation(x)

## [1] 0.7905694

```

4. Follow <http://nicercode.github.io/intro/writing-functions.html> to write your own functions to compute the variance and skew of a numeric vector.

- Re-do below to write measures for skew and variance (e.g. kurtosis, etc.)

```

var_bry <- function(x){
  sum((x - mean(x)) ^ 2) / (length(x) - 1)
}

skewness_bry <- function(x) {
  mean((x - mean(x)) ^ 3) / var_bry(x) ^ (3 / 2)
}

```

Let's create some samples of distributions – normal, t (with 7 degrees of freedom), unifrom, poisson (with lambda of 2).

Note that an example with a cauchy distribution and looking at difference in kurtosis between that and a normal distribution has been moved to the Appendix section 19.2.1.4.

```

nd <- rnorm(10000)
td_df7 <- rt(10000, df = 7)
ud <- runif(10000)
pd_12 <- rpois(10000, 2)

```

Verify that these functions match with established functions

```
dplyr::near(skewness_bry(pd_12), e1071::skewness(pd_12, type = 3))
```

```
## [1] TRUE
dplyr::near(var_bry(pd_12), var(pd_12))
```

```
## [1] TRUE
```

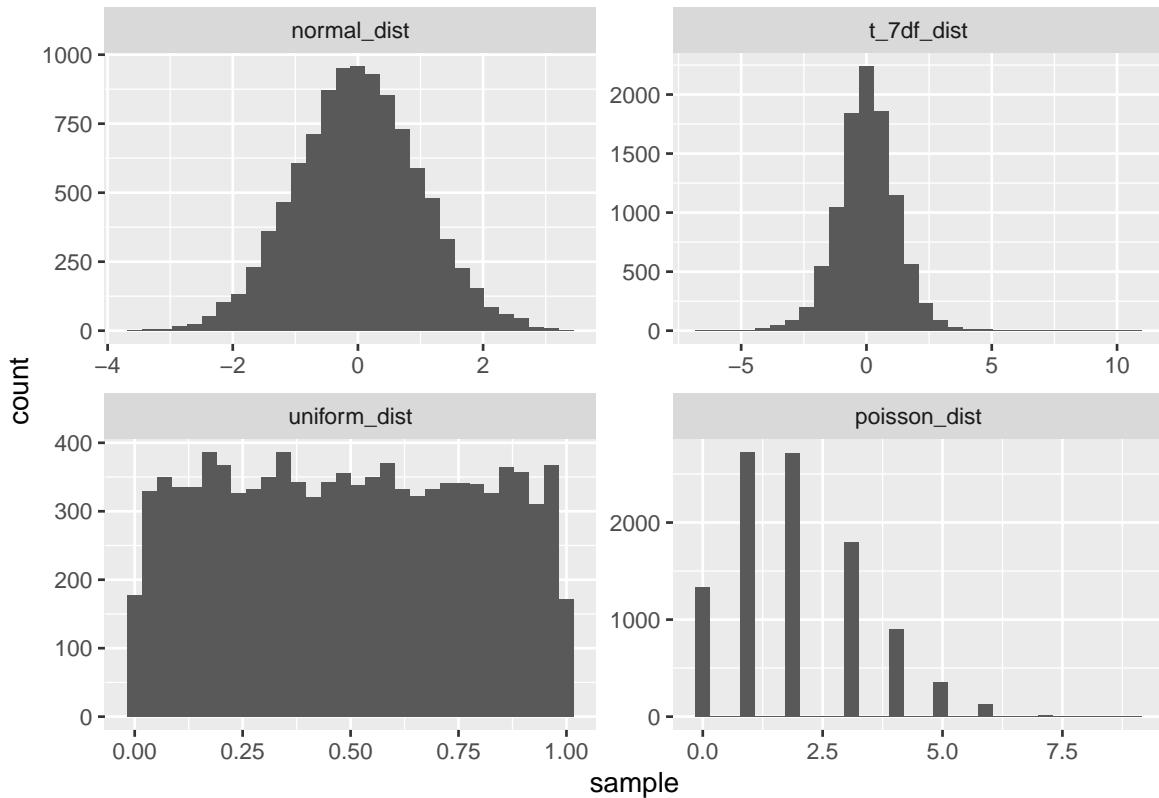
Let's look at the distributions as well as their variance an skewness

```

distributions_df <- tibble(normal_dist = nd,
                           t_7df_dist = td_df7,
                           uniform_dist = ud,
                           poisson_dist = pd_12)

distributions_df %>%
  gather(normal_dist:poisson_dist, value = "sample", key = "dist_type") %>%
  mutate(dist_type = factor(forcats::fct_inorder(dist_type))) %>%
  ggplot(aes(x = sample)) +
  geom_histogram() +
  facet_wrap(~ dist_type, scales = "free")

```



```

tibble(dist_type = names(distributions_df),
       skewness = purrr::map_dbl(distributions_df, skewness_bry),
       variance = purrr::map_dbl(distributions_df, var_bry))

```

```

## # A tibble: 4 x 3
##   dist_type      skewness  variance
##   <chr>          <dbl>     <dbl>
## 1 normal_dist   0.0203    0.977
## 2 t_7df_dist    0.143     1.42
## 3 uniform_dist  0.0152    0.0833
## 4 poisson_dist  0.664     1.96

```

- excellent video explaining intuition behind skewness: <https://www.youtube.com/watch?v=z3XaFUP1rAM>

5. Write `both_na()`, a function that takes two vectors of the same length and returns the number of positions that have an NA in both vectors.

```

both_na <- function(x, y) {
  if (length(x) == length(y)) {
    sum(is.na(x) & is.na(y))
  } else
    stop("Vectors are not equal length")
}

x <- c(4, NA, 7, NA, 3)
y <- c(NA, NA, 5, NA, 0)
z <- c(NA, 4)

both_na(x, y)

## [1] 2
both_na(x, z)

## Error in both_na(x, z): Vectors are not equal length

```

6. What do the following functions do? Why are they useful even though they are so short?

```

is_directory <- function(x) file.info(x)$isdir
is_readable <- function(x) file.access(x, 4) == 0

```

- first checks if what is being referred to is actually a directory
 - second checks if a specific file is readable
7. Read the complete lyrics to “Little Bunny Foo Foo”. There’s a lot of duplication in this song. Extend the initial piping example to recreate the complete song, and use functions to reduce the duplication.
- Do later...

21.2 19.3: Functions are for humans and computers

- Recommends snake_case over camelCase, but just choose one and be consistent
 - When functions have a link, common prefix over suffix (i.e. input_select, input_text over, select_input, text_input)
 - ctrl + shift + r creates section breaks in R scripts like below
- ```
test label -----
 - (though these cannot be made in markdown documents)
```

### 21.2.1 19.3.1

1. Read the source code for each of the following three functions, puzzle out what they do, and then brainstorm better names.

```

f1 <- function(string, prefix) {
 substr(string, 1, nchar(prefix)) == prefix
}
f2 <- function(x) {
 if (length(x) <= 1) return(NULL)
 x[-length(x)]
}
f3 <- function(x, y) {

```

```
 rep(y, length.out = length(x))
}
```

- f1: check\_prefix
- f2: return\_not\_last
- f3: repeat\_for\_length

2. Take a function that you've written recently and spend 5 minutes brainstorming a better name for it and its arguments.
  - Do later, consider doing for the airline fix time functions, or for the CaseAnalysis data
3. Compare and contrast `rnorm()` and `MASS::mvrnorm()`. How could you make them more consistent?
  - uses mu = and Sigma = instead of mean = and sd = , and has extra parameters like tol, empirical, EISPACK
  - Similar in that both are pulling samples from gaussian distribution
  - `mvrnorm` is multivariate though, could change name to `rnorm_mv`
4. Make a case for why `norm_r()`, `norm_d()` etc would be better than `rnorm()`, `dnorm()`. Make a case for the opposite.
  - `norm_*` would show the commonality of them being from the same distribution. One could argue the important commonality though may be more related to it being either a random sample or a density distribution, in which case the `r*` or `d*` coming first may make more sense. To me, the fact that the help pages has all of the ‘normal distribution’ functions on the same page suggests the former may make more sense. However, I actually like having it be set-up the way it is, because I am more likely to forget the name of the distribution type I want over the fact that I want a random sample, so it's easier to type `r` and then do ctrl + space and have autocomplete help me find the specific distribution I want, e.g. `rnorm`, `runif`, `rpois`, `rbinom`...

## 21.3 19.4: Conditional execution

- Function example that uses `if` statement. I thought this was a tricky function and added some notes below...

```
has_name <- function(x) {
 nms <- names(x)
 if (is.null(nms)) {
 rep(FALSE, length(x))
 } else {
 !is.na(nms) & nms != ""
 }
}
```

- note that if all names are blank, it returns the one-unit vector value NULL, hence the need for the `if` statement here...
- `is.null` is not vectorized in the way that `is.na` is – an example of base R not being perfectly consistent. E.g. its job is to return TRUE if given a NULL input, if you give it a list of NULL inputs it will return FALSE, e.g. `is.null(list(NULL, NULL))`

### 21.3.1 19.4.4

1. What's the difference between `if` and `ifelse()`? Carefully read the help and construct three examples that illustrate the key differences.

- `ifelse` is vectorized, `if` is not
  - Typically use `if` in functions when giving conditional options for how to evaluate
  - Typically use `ifelse` when changing specific values in a vector
- If you supply `if` with a vector of length > 1, it will use the first value

```
x <- c(3, 4, 6)
y <- c("5", "c", "9")

Use ifelse simple transformations of values like example below
ifelse(x < 5, 0, x)
```

```
[1] 0 0 6
cutoff_make0 <- function(x, cutoff = 0){
 if(is.numeric(x)){
 ifelse(x < cutoff, 0, x)
 } else stop("The input provided is not a numeric vector")
}

cutoff_make0(x, cutoff = 4)
```

```
[1] 0 4 6
cutoff_make0(y, cutoff = 4)
```

```
Error in cutoff_make0(y, cutoff = 4): The input provided is not a numeric vector
```

2. Write a greeting function that says “good morning”, “good afternoon”, or “good evening”, depending on the time of day. (Hint: use a time argument that defaults to `lubridate::now()`. That will make it easier to test your function.)

```
greeting <- function(when) {

 time <- hour(when)

 if (time < 12 && time > 4) {
 greeting <- "good morning"
 } else if (time < 17 && time >= 12) {
 greeting <- "good afternoon"
 } else greeting <- "good evening"

 when_char <- as.character(when)
 mid <- ", it is: "
 cat(greeting, mid, when_char, sep = "")

}
```

```
greeting(now())
```

```
good evening, it is: 2019-05-22 22:32:00
```

3. Implement a `fizzbuzz` function. It takes a single number as input. If the number is divisible by three, it returns “fizz”. If it’s divisible by five it returns “buzz”. If it’s divisible by three and five, it returns “fizzbuzz”. Otherwise, it returns the number. Make sure you first write working code before you create the function.

```
fizzbuzz <- function(x){
 if(is.numeric(x) && length(x) == 1){
 y <- ""
```

```

if (x %% 5 == 0) y <- str_c(y, "fizz")
if (x %% 3 == 0) y <- str_c(y, "buzz")
if (str_length(y) == 0) {
 print(x)
} else print(y)
} else stop("Input is not a numeric vector with length 1")
}

fizzbuzz(4)

[1] 4
fizzbuzz(10)

[1] "fizz"
fizzbuzz(6)

[1] "buzz"
fizzbuzz(30)

[1] "fizzbuzz"
fizzbuzz(c(34, 21))

Error in fizzbuzz(c(34, 21)): Input is not a numeric vector with length 1

```

4. How could you use `cut()` to simplify this set of nested if-else statements?

```

if (temp <= 0) {
 "freezing"
} else if (temp <= 10) {
 "cold"
} else if (temp <= 20) {
 "cool"
} else if (temp <= 30) {
 "warm"
} else {
 "hot"
}

```

- Below is example of fix

```

temp <- seq(-10, 50, 5)
cut(temp,
 breaks = c(-Inf, 0, 10, 20, 30, Inf), #need to include negative and positive infinity
 labels = c("freezing", "cold", "cool", "warm", "hot"),
 right = TRUE,
 ordered_result = TRUE)

[1] freezing freezing freezing cold cold cool cool
[8] warm warm hot hot hot hot
Levels: freezing cold cool warm hot

```

How would you change the call to `cut()` if I'd used `<` instead of `<=?` What is the other chief advantage of `cut()` for this problem? (Hint: what happens if you have many values in `temp`?)

- See below change to `right` argument

```

cut(temp,
 breaks = c(-Inf, 0, 10, 20, 30, Inf), #need to include negative and positive infinity
 labels = c("freezing", "cold", "cool", "warm", "hot"),
 right = FALSE,
 ordered_result = TRUE)

[1] freezing freezing cold cold cool cool warm
[8] warm hot hot hot hot hot
Levels: freezing cold cool warm hot

```

5. What happens if you use `switch()` with numeric values?

- It will return the index of the argument.
  - In example below, I input ‘3’ into `switch` value so it does the `times` argument

```

math_operation <- function(x, y, op){
 switch(op,
 plus = x + y,
 minus = x - y,
 times = x * y,
 divide = x / y,
 stop("Unknown op!")
)
}

math_operation(5, 4, 3)

```

```
[1] 20
```

6. What does this `switch()` call do? What happens if `x` is “e”?

```

x <- "e"

switch(x,
 a = ,
 b = "ab",
 c = ,
 d = "cd"
)

```

Experiment, then carefully read the documentation.

- If `x` is ‘e’ nothing will be outputted. If `x` is ‘c’ or ‘d’ then ‘cd’ is outputted. If ‘a’ or ‘b’ then ‘ab’ is outputted. If blank it will continue down list until reaching an argument to output.

## 21.4 19.5: Function arguments

*Common non-descriptive short argument names:*

- `x, y, z`: vectors.
- `w`: a vector of weights.
- `df`: a data frame.
- `i, j`: numeric indices (typically rows and columns).
- `n`: length, or number of rows.
- `p`: number of columns.

### 21.4.1 19.5.5

1. What does `commas(letters, collapse = "-")` do? Why?

- `commas` function is below

```
commas <- function(...) stringr::str_c(..., collapse = ", ")
commas(letters[1:10])

[1] "a, b, c, d, e, f, g, h, i, j"
commas(letters[1:10], collapse = "-")
```

`## Error in stringr::str_c(..., collapse = ", "): formal argument "collapse" matched by multiple arguments`

- The above fails because are essentially specifying two different values for the `collapse` argument
- Takes in vector of multiple strings and outputs one-unit character string with items concatenated together and separated by columns
- Is able to do this via use of ... that turns this into a wrapper on `stringr::str_c` with the `collapse` value specified

2. It'd be nice if you could supply multiple characters to the `pad` argument, e.g. `rule("Title", pad = "-+-")`. Why doesn't this currently work? How could you fix it?

- current `rule` function is below

```
rule <- function(..., pad = "-") {
 title <- paste0(...)
 width <- getOption("width") - nchar(title) - 5
 cat(title, " ", stringr::str_dup(pad, width), "\n", sep = "")
}

Note that `cat` is used instead of `paste` because paste would output it as a character vector, which is not what we want.
rule("Tis the season", " to be jolly")
```

`## Tis the season to be jolly -----`

- doesn't work because pad ends-up being too many characters in this situation

```
rule("Tis the season", " to be jolly", pad="+-")
```

`## Tis the season to be jolly ++++++-----`

- instead would need to make the number of times pad is duplicated dependent on its length, see below for fix

```
rule_pad_fix <- function(..., pad = "-") {
 title <- paste0(...)
 width <- getOption("width") - nchar(title) - 5
 width_fix <- width %/% stringr::str_length(pad)
 cat(title, " ", stringr::str_dup(pad, width_fix), "\n", sep = "")
}

rule_pad_fix("Tis the season", " to be jolly", pad="+-")
```

`## Tis the season to be jolly ++++++-----`

3. What does the `trim` argument to `mean()` do? When might you use it?

- `trim` specifies proportion of data to take off from both ends, good with outliers

```
mean(c(-1000, 1:100, 100000), trim = .025)
```

```
[1] 50.5
```

4. The default value for the `method` argument to `cor()` is `c("pearson", "kendall", "spearman")`. What does that mean? What value is used by default?

- is showing that you can choose from any of these, will default to use `pearson` (value in first position)

## 21.5 19.6: Return values

```
show_missings <- function(df) {
 n <- sum(is.na(df))
 cat("Missing values: ", n, "\n", sep = "")
 invisible(df)
}

x <- show_missings(mtcars)

Missing values: 0
str(x)

'data.frame': 32 obs. of 11 variables:
$ mpg : num 21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
$ cyl : num 6 6 4 6 8 6 8 4 4 6 ...
$ disp: num 160 160 108 258 360 ...
$ hp : num 110 110 93 110 175 105 245 62 95 123 ...
$ drat: num 3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
$ wt : num 2.62 2.88 2.32 3.21 3.44 ...
$ qsec: num 16.5 17 18.6 19.4 17 ...
$ vs : num 0 0 1 1 0 1 0 1 1 1 ...
$ am : num 1 1 1 0 0 0 0 0 0 0 ...
$ gear: num 4 4 4 3 3 3 3 4 4 4 ...
$ carb: num 4 4 1 1 2 1 4 2 2 4 ...
```

- can still use in pipes

```
mtcars %>%
 show_missings() %>%
 mutate(mpg = ifelse(mpg < 20, NA, mpg)) %>%
 show_missings()

Missing values: 0
Missing values: 18
```



# Chapter 22

## Appendix

### 22.1 19.2.1.4

*Function for Standard Error*

```
```r
x <- c(5, -2, 8, 6, 9)
sd(x, na.rm = TRUE) / sqrt(sum(!is.na(x)))
```

```
## [1] 1.933908
```

```r
sample_se <- function(x) {
  sd(x, na.rm = TRUE) / sqrt(sum(!is.na(x)) - 1)
}    #sqrt(var(x)/sum(!is.na(x)))

sample_se(x)
```

```
## [1] 2.162175
```

```

*Function for kurtosis*

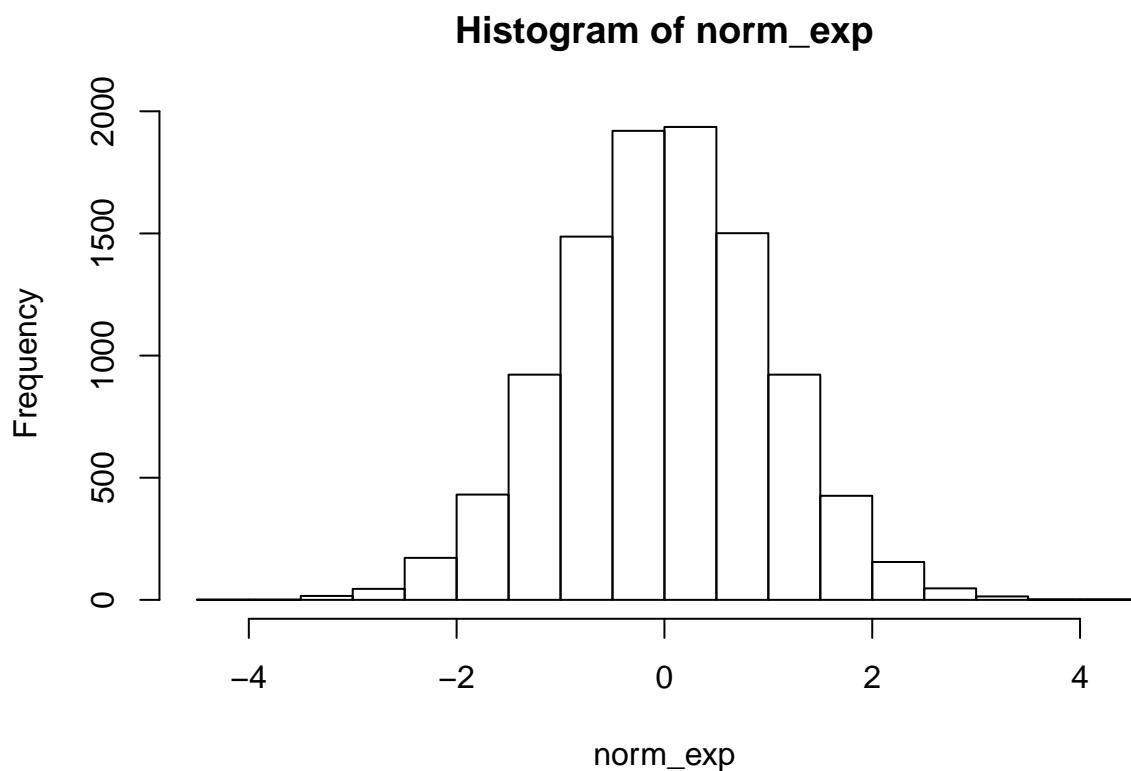
```
kurtosis_type3 <- function(x){
 sum((x - mean(x)) ^ 4) / length(x) / sd(x) ^ 4 - 3
}
```

Notice differences between cauchy and normal distribution

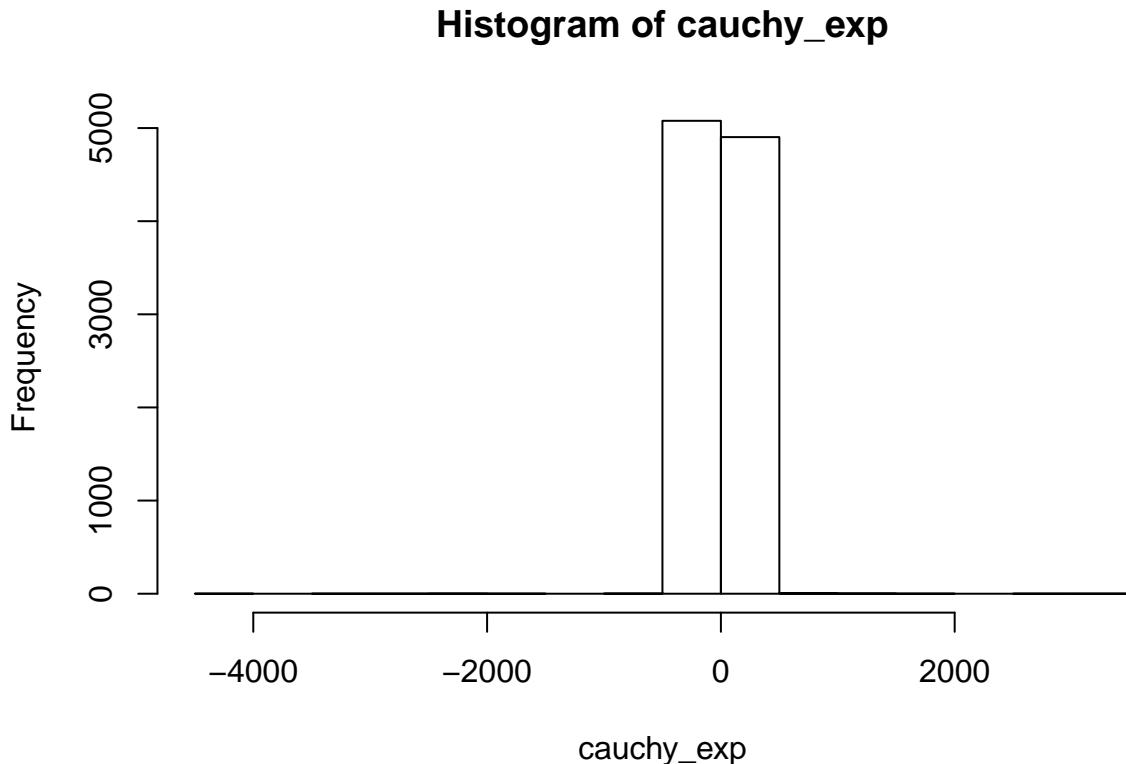
```
set.seed(1235)
norm_exp <- rnorm(10000)

set.seed(1235)
cauchy_exp <- rcauchy(10000)
```

```
hist(norm_exp)
```



```
hist(cauchy_exp)
```



```
kurtosis_type3(norm_exp)
```

```
[1] 0.06382172
```

```
kurtosis_type3(cauchy_exp)
```

```
[1] 1197.052
```

## 22.2 Changing values with indexes

\*In this section I use the word ‘indexes’ to refer to any base R method for specifying position<sup>1</sup>.

My solution to building the new function in 19.2.1.2 shows another way of replacing values over re-writing a new vector, namely by specifying indexes and then forcing those to be a new value.

For example, say we have a vector `c(1:20)` and we want to make all even values equal to 0. below is how you could do that by simply re-writing this to a new vector

```
x <- c(1:20)
```

```
x_0_even <- ifelse((x %% 2) == 0, 0, x)
```

```
x_0_even
```

<sup>1</sup>I am using the word loosely to mean both either the situation when you specify positions by a series of TRUE / FALSE values or a series of numeric indexes E.g. `x[c(TRUE, TRUE, FALSE, FALSE, TRUE)]` or `x[c(1, 2, 5)]`, ‘index’ obviously sounds more like the later, but I mean it generally to cover just ‘base R method of specifying positoin’.

```
[1] 1 0 3 0 5 0 7 0 9 0 11 0 13 0 15 0 17 0 19 0
```

Alternatively, you could do this by simply overwriting the values in a specified index with a value (like I did in question 19.2.1.2)

```
x <- c(1:20)
```

```
x[(x %% 2) == 0] <- 0
```

```
x
```

```
[1] 1 0 3 0 5 0 7 0 9 0 11 0 13 0 15 0 17 0 19 0
```

Both the indexing and the `ifelse` method give the same output. I have a slight preference for the `ifelse` method as I think it is a little easier to read. Also, it doesn't force you to overwrite your data – to save against this second problem I will often save a copy before applying the indexed approach (though if it's in a function don't need to worry about this as changes will default to occur within function not global environment). e.g.

```
x <- c(1:20)
```

```
x_0_even <- x
```

```
x_0_even[(x %% 2) == 0] <- 0
```

```
x_0_even
```

```
[1] 1 0 3 0 5 0 7 0 9 0 11 0 13 0 15 0 17 0 19 0
```

If you're curious about speed of each, you can see the index method tends to be faster on this dataset.

*Build functions (necessary for measuring speed):*

```
method_ifelse <- function(vector = c(1:20)){
 x <- vector
```

```
 x_0_even <- ifelse((x %% 2) == 0, 0, x)
```

```
 x_0_even
}
```

```
method_index <- function(vector = c(1:20)){
 x <- vector
 x[(x %% 2) == 0] <- 0
```

```
 x
}
```

*Measure time it takes to run:*

```
microbenchmark::microbenchmark(ifelse = method_ifelse(1:1000),
 index = method_index(1:1000),
 times = 500)
```

```
Unit: microseconds
expr min lq mean median uq max neval cld
ifelse 84.1 136.4 249.0698 176.10 231.5 9364.9 500 b
index 35.1 48.8 91.4872 57.25 78.1 9755.2 500 a
```

The index methods tends to be faster.

### 22.2.1 Applying indexing to dfs

I have a high preference for using tidyverse style approaches when applying transformations to dataframes, though there are instances when it's easier to use indexing methods. A common example of this is say we want to replace all of the NA values across multiple columns in a dataframe.

```
df <- tibble(x = c(NA, 3, 4),
 y = c(4, NA, NA))
```

The code below uses an indexing method to replace all NA values in the df with 0

```
df_cleanNA <- df
df_cleanNA[is.na(df)] <- 0

df_cleanNA
```

```
A tibble: 3 x 2
x y
<dbl> <dbl>
1 0 4
2 3 0
3 4 0
```

Below is the dplyr approach (requires knowledge of `mutate_all` and `fun`s)

```
mutate_all(df, funs(ifelse(is.na(.), 0, .)))

Warning: funs() is soft deprecated as of dplyr 0.8.0
please use list() instead
##
Before:
funs(name = f(.))
##
After:
list(name = ~f(.))
This warning is displayed once per session.

A tibble: 3 x 2
x y
<dbl> <dbl>
1 0 4
2 3 0
3 4 0
```

With a purrr function you could have done:

```
purrr::map_df(df, ~ifelse(is.na(.x), 0, .x))

A tibble: 3 x 2
x y
<dbl> <dbl>
1 0 4
2 3 0
3 4 0
```

If you're curious of speed of each, below is microbenchmark test

```
df_na0_index <- function(df){
 df[is.na(df)] <- 0
```

```

df
}

df_na0_dplyr <- function(df){
 mutate_all(df, funs(ifelse(is.na(.), 0, .)))
}

df_na0_purrr <- function(df){
 purrr::map_df(df, ~ifelse(is.na(.x), 0, .x))
}

```

*Measure time it takes to run:*

First on tiny dataset:

```

microbenchmark::microbenchmark(index = df_na0_index(flights),
 dplyr = df_na0_index(flights),
 purrr = df_na0_purrr(flights),
 times = 10)

```

```

Unit: milliseconds
expr min lq mean median uq max neval
index 145.9144 159.8083 243.9317 189.2320 330.7175 413.4093 10
dplyr 159.4655 193.9840 317.1806 344.1483 435.2011 467.4845 10
purrr 2298.6262 2364.6463 2806.8202 2527.1394 3334.5073 3903.0101 10
cld
a
a
b

```

Then on larger dataset:

```

microbenchmark::microbenchmark(index = df_na0_index(flights),
 dplyr = df_na0_index(flights),
 purrr = df_na0_purrr(flights),
 times = 10)

```

```

Unit: milliseconds
expr min lq mean median uq max neval
index 172.3755 195.8326 288.2473 219.0087 353.5119 619.1032 10
dplyr 130.6710 200.1751 305.5294 228.0457 317.2444 736.9749 10
purrr 2951.7207 3138.2734 3669.5680 3428.7996 3878.8450 5107.3379 10
cld
a
a
b

```

You should see that the index and dplyr method are pretty consistent on time, whereas the purrr method will be slower. For this example and some problems like this then indexing may be the best option (generally though I lean more towards using dplyr where possible).

I also wonder if there may be a better alternative to `ifelse` in this situation.

## 22.3 Better than `ifelse()`?

I end-up using `ifelse` a lot for basic transformations, I'm curious if there is a more efficient alternative for use with dplyr style...

- I learned about dplyr's functions `dplyr::recode` which is similar to `forcats::fct_recode` and can be used for replacing multiple character values.
- `dplyr::case_when` can be used for more complex criteria

## 22.4 Dplyr and functions

As was mentioned, dplyr uses non-standard evaluation. This means that when referring to column names from within a function, dplyr will require some slightly different syntax... I typically find ways around this by deploying tricks with the `*_verbs` or taking advantage of the `vars` functions and `*_at` or by messing with the names, though am interested to hear other methods...

Say you want to write a function that takes in a dataframe and a list of column names and you want to return a sum of these into a new column with the name corresponding with the name of the spliced together columns. What would be the most elegant way of doing this with tidyverse style?

## 22.5 19.2.3.5

```
```r
position_both_na <- function(x, y) {
  if (length(x) == length(y)) {
    (c(1:length(x)))[(is.na(x) & is.na(y))]
  } else
    stop("Vectors are not equal length")
}

x <- c(4, NA, 7, NA, 3)
y <- c(NA, NA, 5, NA, 0)
z <- c(NA, 4)
both_na(x, y)
```

```
## [1] 2
```

```r
both_na(x, z)
```

```
## Error in both_na(x, z): Vectors are not equal length
```

```

- specifies position where both are `NA`
- second example shows returning of 'stop' argument

*Make sure the following packages are installed:*

```
knitr::opts_chunk$set(echo = TRUE, cache = TRUE, message = FALSE)

library(tidyverse)
library(ggplot2)
library(dplyr)
library(tidyr)
library(nycflights13)
library(babynames)
library(nasaweather)
library(lubridate)
library(purrr)
library(readr)
```

# Chapter 23

## ch. 20: Vectors

Avoid using `==` to check for these other special values. Instead use the helper functions `is.finite()`, `is.infinite()`, and `is.nan()`:

|                            | 0 | Inf | NA | NaN |
|----------------------------|---|-----|----|-----|
| <code>is.finite()</code>   | x |     |    |     |
| <code>is.infinite()</code> |   | x   |    |     |
| <code>is.na()</code>       |   |     | x  | x   |
| <code>is.nan()</code>      |   |     |    | x   |

- `is.finite`, `is.infinite`, `is.na`, `is.nan`
- `typeof` returns type of vector
- `length` returns length of vector
- `pryr::object_size` view size of object stored
- specific NA values can be defined explicitly with `NA_integer_`, `NA_real_`, `NA_character_` (usually don't need to know)
- explicitly differentiate integers from doubles with `10L` v `10`
- explicit coercion functions: `as.logical`, `as.integer`, `as.double`, `as.character`, or use `col_[types]` when reading in so that coercion done at source
- test functions from `purrr` package that are more consistent than base R's
- `set_names` lets you set names after the fact, e.g. `set_names(1:3, c("a", "b", "c"))`
- For more details on subsetting: <http://adv-r.had.co.nz/Subsetting.html#applications>
- `str` checks structure (excellent for use with lists)
- `attr` and `attributes` get and set attributes
  - main types of attributes: **Names**, **Dimensions/dims**, **Class**. Class is important for object oriented programming which is covered in more detail here: <http://adv-r.had.co.nz/OO-essentials.html#s3>
- `useMethod` in function syntax indicates it is a generic function
- `methods` lists all methods within a generic
- `getS3method` to show specific implementation of a method
- Above are used together to investigate details of code for functions

## Vectors

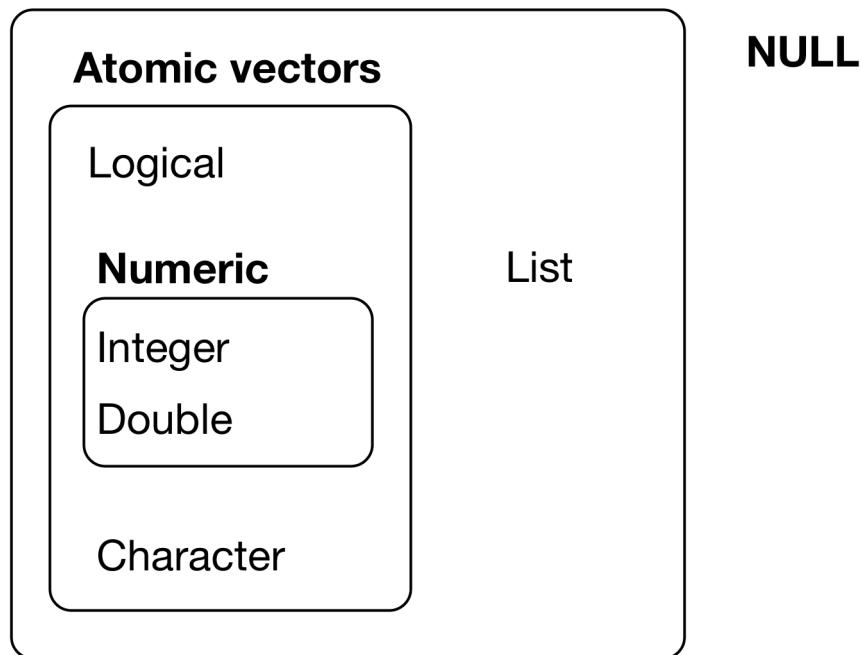


Figure 23.1: Types of vectors, not including augmented types

|                                             | lgL | int | dbl | chr | list |
|---------------------------------------------|-----|-----|-----|-----|------|
| is_logical()                                | x   |     |     |     |      |
| is_integer()                                |     | x   |     |     |      |
| is_double()                                 |     |     | x   |     |      |
| is_n <sup>umeric</sup> o <sup>de</sup> ic() |     | x   | x   |     |      |
| is_character()                              |     |     |     | x   |      |
| is_atomic()                                 | x   | x   | x   | x   |      |
| is_list()                                   |     |     |     |     | x    |
| is_vector()                                 | x   | x   | x   | x   | x    |

Figure 23.2: Purrr versions for testing types

```
as.Date

function (x, ...)
UseMethod("as.Date")
<bytecode: 0x000000001c61c828>
<environment: namespace:base>
methods("as.Date")

[1] as.Date.character as.Date.default as.Date.factor as.Date.numeric
[5] as.Date.POSIXct as.Date.POSIXlt
see '?methods' for accessing help and source code
getS3method("as.Date", "default")
```

```
function (x, ...)
{
if (inherits(x, "Date"))
x
else if (is.logical(x) && all(is.na(x)))
.Date(as.numeric(x))
else stop(gettextf("do not know how to convert '%s' to class %s",
deparse(substitute(x)), dQuote("Date")), domain = NA)
}
<bytecode: 0x000000001c7bfc48>
<environment: namespace:base>
```

- Unfortunately, tidyverse functions are not particularly easy to unpack/understand this way...

```
select

function (.data, ...)
{
UseMethod("select")
}
<bytecode: 0x0000000017fb7790>
<environment: namespace:dplyr>
methods("select")

[1] select.data.frame* select.default* select.grouped_df*
[4] select.list select.tbl_cube*
see '?methods' for accessing help and source code
getS3method("select", "default")
```

```
function (.data, ...)
{
select_.data, .dots = compat_as_lazy_dots(...))
}
<bytecode: 0x000000001962d8d8>
<environment: namespace:dplyr>
```

- **Augmented vectors:** vectors with additional attributes, e.g. factors (levels, class = factors), dates and datetimes (tzone, class = (POSIXct, POSIXt)), POSIXlt (names, class = (POSIXLt, POSIXt)), tibbles (names, class = (tbl\_df, tbl, data.frame), row.names) – in the integer, double and double, list, list types.

– data.frames only have class data.frame, whereas tibbles have tbl\_df, and tbl as well

```
a <- list(a = 1:3, b = "a string", c = pi, d = list(c(-1, -2), -5))

a[[4]][[1]]

[1] -1 -2
• class get or set class attribute
• unclass returns copy with ‘class’ attribute removed ## 20.3: Important types of atomic vector
```

### 23.0.1 20.3.5

1. Describe the difference between `is.finite(x)` and `!is.infinite(x)`.

- both `is.infinite` and `!is.infinite` return FALSE for NA or NaN values, therefore these values will become TRUE when negated, e.g. see example below:

```
is.finite(c(6,11,-Inf, NA, NaN))

[1] TRUE TRUE FALSE FALSE FALSE

!is.infinite(c(6,11,-Inf, NA, NaN))

[1] TRUE TRUE FALSE TRUE TRUE
```

2. Read the source code for `dplyr::near()` (Hint: to see the source code, drop the `()`). How does it work?
3. A logical vector can take 3 possible values. How many possible values can an integer vector take? How many possible values can a double take? Use google to do some research.
  - it checks if the difference between the value is within `tol` which by default is `.Machine$double.eps^0.5`
4. Brainstorm at least four functions that allow you to convert a double to an integer. How do they differ? Be precise.
  - `as.integer`, `as.factor` (technically is going to a factor), `round(, 0)`, `floor`, `ceiling`, these last 3 though do not change the type, which would remain an integer
5. What functions from the `readr` package allow you to turn a string into logical, integer, and double vector?
  - `parse_*` or `col_*`

### 23.1 20.4: Using atomic vectors

#### 23.1.1 20.4.6

1. What does `mean(is.na(x))` tell you about a vector `x`? What about `sum(!is.finite(x))`?
  - percentage that are NA or NaN
  - number that are either Inf, -Inf, NA or NaN
2. Carefully read the documentation of `is.vector()`. What does it actually test for? Why does `is.atomic()` not agree with the definition of atomic vectors above?
  - `is.vector` tests if it is a specific type of vector with no attributes other than names. This second requirement means that any augmented vectors such as factors, dates, tibbles all would return false.
  - `is.atomic` returns TRUE to `is.atomic(NULL)` despite this representing the empty set.

3. Compare and contrast `setNames()` with `purrr::set_names()`.

- both assign names after fact
- `purrr::set_names` is stricter and returns an error in situations like the following where as `setNames` does not

```
setNames(1:4, c("a"))

a <NA> <NA> <NA>
1 2 3 4

set_names(1:4, c("a"))

Error: `nm` must be `NULL` or a character vector the same length as `x`
```

4. Create functions that take a vector as input and returns:

```
x <- c(-3:14, NA, Inf, NaN)
```

1. The last value. Should you use `[` or `[[`?

```
return_last <- function(x) x[[length(x)]]
```

```
return_last(x)
```

```
[1] NaN
```

1. The elements at even numbered positions.

```
return_even <- function(x) x[((1:length(x)) %% 2 == 0)]
```

```
return_even(x)
```

```
[1] -2 0 2 4 6 8 10 12 14 Inf
```

1. Every element except the last value.

```
return_not_last <- function(x) x[-length(x)]
```

```
return_not_last(x)
```

```
[1] -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13
[18] 14 NA Inf
```

1. Only even numbers (and no missing values).

```
#only even and not na
```

```
return_even_no_na <- function(x) x[((1:length(x)) %% 2 == 0) & !is.na(x)]
```

```
return_even_no_na(x)
```

```
[1] -2 0 2 4 6 8 10 12 14 Inf
```

5. Why is `x[-which(x > 0)]` not the same as `x[x <= 0]`?

```
x[-which(x > 0)] #which only reports the indices of the matches, so specifies all to be removed
```

```
[1] -3 -2 -1 0 NA NaN
```

```
x[x <= 0] #This method reports T/F'sNaN is converted into NA
```

```
[1] -3 -2 -1 0 NA NA
```

- in the 2nd instance, NaNs will get converted to NA

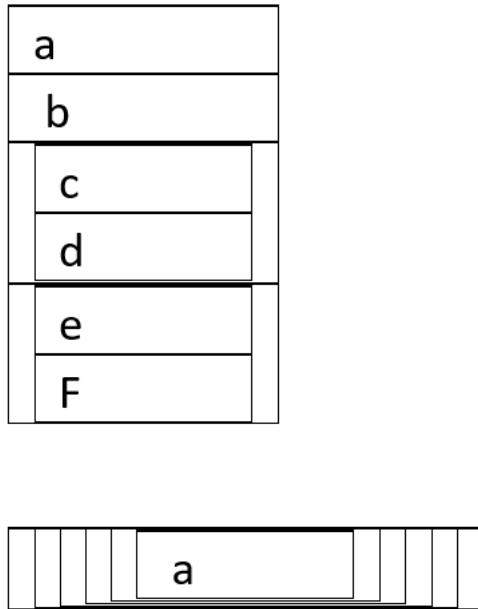


Figure 23.3: drawings 1 and 2 for 20.5.4.

6. What happens when you subset with a positive integer that's bigger than the length of the vector?  
What happens when you subset with a name that doesn't exist?
- you get back an NA though it seems to take longer in the case when subsetting by a name that doesn't exist.

## 23.2 20.5: Recursive vectors (lists)

- 3 ways of subsetting [], [[]], \$

### 23.2.1 20.5.4

```
a <- list(a = 1:3, b = "a string", c = pi, d = list(-1, -5))
```

1. Draw the following lists as nested sets:
  1. `list(a, b, list(c, d), list(e, f))`
  2. `list(list(list(list(list(a))))))`
  - I did not conform with Hadley's square v rounded syntax, but hopefully this gives a sense of what the above are:
2. What happens if you subset a tibble as if you're subsetting a list? What are the key differences between a list and a tibble?
  - dataframe is just a list of columns, so behaves similarly
  - dataframe has restriction that each column has the same number of elements whereas lists do not have this requirement

## 23.3 20.7: Augmented vectors

### 23.3.1 20.7.4

1. What does `hms::hms(3600)` return?

```
x <- hms::hms(3600)
```

How does it print?

```
print(x)
```

```
01:00:00
```

What primitive type is the augmented vector built on top of?

```
typeof(x)
```

```
[1] "double"
```

What attributes does it use?

```
attributes(x)
```

```
$class
[1] "hms" "difftime"
##
$units
[1] "secs"
```

2. Try and make a tibble that has columns with different lengths. What happens?

- if the column is length one it will repeat for the length of the other column(s), otherwise if it is not the same length it will return an error

```
tibble(x = 1:4, y = 5:6) #error
```

```
Error: Tibble columns must have consistent lengths, only values of length one are recycled:
* Length 2: Column `y`
* Length 4: Column `x`
```

```
tibble(x = 1:5, y = 6) #can have length 1 that repeats
```

```
A tibble: 5 x 2
x y
<int> <dbl>
1 1 6
2 2 6
3 3 6
4 4 6
5 5 6
```

3. Based on the definition above, is it ok to have a list as a column of a tibble?

- Yes, as long as the number of elements align with the other length of the other columns – this will come-up a lot in the modeling chapters.



# Chapter 24

## Appendix

### 24.1 subsetting nested lists

```
x <- list("a", list(list("c", "d"), "e2"), list("e", "f"))
x

[[1]]
[1] "a"
##
[[2]]
[[2]][[1]]
[[2]][[1]][[1]]
[1] "c"
##
[[2]][[1]][[2]]
[1] "d"
##

[[2]][[2]]
[1] "e2"
##

[[3]]
[[3]][[1]]
[1] "e"
##
[[3]][[2]]
[1] "f"
```

It can be confusing how to subset items in a nested list, lists output helps tell you the subsetting needed to extract particular items. For example, to output `list("c", "d")` requires `x[[2]][[1]]`, to output just `d` requires `x[[2]][[1]][[2]]`

*Make sure the following packages are installed:*

```
library(tidyverse)

Warning: package 'tidyverse' was built under R version 3.5.3
Warning: package 'ggplot2' was built under R version 3.5.2
```

```
> x <- list("a", list(list("c", "d"), "e2"), list("e", "f"))
> x
[[1]]
[1] "a"

[[2]]
[[2]][[1]]
[[2]][[1]][[1]]
[1] "c"

[[2]][[1]][[2]]
[1] "d"

[[2]][[2]]
[1] "e2"

[[3]]
[[3]][[1]]
[1] "e"

[[3]][[2]]
[1] "f"
```

Figure 24.1: subset nested lists

```
Warning: package 'tibble' was built under R version 3.5.2
Warning: package 'tidyr' was built under R version 3.5.3
Warning: package 'purrr' was built under R version 3.5.2
Warning: package 'dplyr' was built under R version 3.5.3

library(ggplot2)
library(dplyr)
library(tidyr)
library(nycflights13)
library(babynames)
library(nasaweather)
library(lubridate)
library(purrr)
library(readr)
library(stringr)
```



# Chapter 25

## ch. 21: Iteration

- Common `for` loop template:

```
output <- vector("double", ncol(df)) # common for loop style
for (i in seq_len(length(df))){
 output[[i]] <- fun(df[[i]])
}
```

- Common `while` loop template:

```
i <- 1
while (i <= length(x)){
 # body
 i <- i + 1
}
```

- `seq_along(df)` does essentially same as `seq_len(length(df))`
- `unlist` flatten list of vectors into single vector
  - `flatten_dbl` is stricter alternative
- `dplyr::bind_rows` save output in a list of dfs and then append all at end rather than sequential `rbinding`
- `sample(c("T", "H"), 1)`
- `sapply` is wrapper around `lapply` that automatically simplifies output – problematic in that never know what ouptut will be
- `vapply` is safe alternative to `sapply` e.g. for logical `vapply(df, is.numeric, logical(1))`, but `map_lgl(df, is.numeric)` is more simple
- `map()` makes a list.
  - `map_lgl()` makes a logical vector.
  - `map_int()` makes an integer vector.
  - `map_dbl()` makes a double vector.
  - `map_chr()` makes a character vector.
- shortcuts for applying functions in `map`:

```
models <- mtcars %>%
 split(. $cyl) %>%
 map(function(df) lm(mpg ~ wt, data = df))

models <- mtcars %>%
 split(. $cyl) %>%
 map(~lm(mpg ~ wt, data = .))
```

- extracting by named elements from `map`:

```
models %>%
 map(summary) %>%
 map_dbl("r.squared")

4 6 8
0.5086326 0.4645102 0.4229655
```

- extracting by positions from `map`

```
x <- list(list(1, 2, 3), list(4, 5, 6), list(7, 8, 9))
x %>%
 map_dbl(2)
```

```
[1] 2 5 8
```

- `map2` let's you iterate through two components at once
- `pmap` allows you to iterate over p components – works well to hold inputs in a dataframe
- `safely` takes funciton returns two parts, result and error object
  - similar to `try` but more consistent
- possibly similar to `safely`, but provide it a default value to return for errors
- `quietly` is similar to `safely` but captures all printed output messages and warnings
- `purrr::transpose` allows you to do things like get all 2nd elements in list, e.g. show later
- `invoke_map` let's you iterate over both the functions and the parameters, have an `f` and a `param` input, e.g.

```
f <- c("runif", "rnorm", "rpois")
param <- list(
 list(min = -1, max = 1),
 list(sd = 5),
 list(lambda = 10)
)

invoke_map(f, param, n = 5) %>% str()
```

```
List of 3
$: num [1:5] -0.428 -0.769 0.25 -0.192 -0.152
$: num [1:5] -0.984 6.574 2.184 7.456 4.675
$: int [1:5] 10 8 4 6 16
```

- `walk` is alternative to `map` that you call for side effects. Also have `walk2` and `pwalk` that are generally more useful
  - all invisibly return '`x` (the first argument) so can used in the middle of pipelines
- `keep` and `discard` keep or discard elements in the input based off if `TRUE` to predicate
- `some` and `every` determine if the predicte is true for any or for all of our elements
- `detect` finds the first element where the predicate is true, `detect_index` returns its position
- `head_while` and `tail_while` take elements from the start or end of a vector while a predicate is true
- `reduce` is good for applying two table rule repeatedly, e.g. joins
  - `accumulate` is similar but keeps all the interim results

## 25.1 21.2: For loops

### 25.1.1 21.2.1

1. Write for loops to (think about the output, sequence, and body **before** you start writing the loop):

1. Compute the mean of every column in `mtcars`.

```
output <- vector("double", length(mtcars))
for (i in seq_along(mtcars)){
 output[[i]] <- mean(mtcars[[i]])
}
output

[1] 20.090625 6.187500 230.721875 146.687500 3.596563 3.217250
[7] 17.848750 0.437500 0.406250 3.687500 2.812500
```

1. Determine the type of each column in `nycflights13::flights`.

```
output <- vector("character", length(flights))
for (i in seq_along(flights)){
 output[[i]] <- typeof(flights[[i]])
}
output

[1] "integer" "integer" "integer" "integer" "integer"
[6] "double" "integer" "integer" "double" "character"
[11] "integer" "character" "character" "character" "double"
[16] "double" "double" "double" "double"
```

1. Compute the number of unique values in each column of `iris`.

```
output <- vector("integer", length(iris))
for (i in seq_along(iris)){
 output[[i]] <- unique(iris[[i]]) %>% length()
}
output
```

```
[1] 35 23 43 22 3
```

1. Generate 10 random normals for each of  $\mu = -10, 0, 10$ , and  $100$ .

```
output <- vector("list", 4)
input_means <- c(-10, 0, 10, 100)
for (i in seq_along(output)){
 output[[i]] <- rnorm(10, mean = input_means[[i]])
}
output

[[1]]
[1] -8.843823 -10.040568 -11.007634 -9.882919 -9.620940 -8.124442
[7] -10.307687 -10.678167 -9.091309 -10.687259
##
[[2]]
[1] 0.31427242 -0.21250763 0.06659419 -1.25930491 1.07614657
[6] 0.52843455 0.46463658 2.06883157 -0.08848673 -1.09054395
##
[[3]]
[1] 9.430315 9.744143 9.083820 11.111326 8.863153 11.249675 10.695650
[8] 9.911813 10.047955 9.738796
##
[[4]]
[1] 100.80116 101.21818 99.18533 99.48762 99.83752 100.75819 100.10386
[8] 100.42267 99.43813 102.11514
```

2. Eliminate the for loop in each of the following examples by taking advantage of an existing function that works with vectors:

*example:*

```
out <- ""
for (x in letters) {
 out <- stringr::str_c(out, x)
}
out
```

- collapse letters into length-one character vector with all characters concatenated

```
str_c(letters, collapse = "")
```

```
[1] "abcdefghijklmnopqrstuvwxyz"
```

*example:*

```
x <- sample(100)
sd <- 0
for (i in seq_along(x)) {
 sd <- sd + (x[i] - mean(x))^2
}
sd <- sqrt(sd / (length(x) - 1))
sd
```

```
[1] 29.01149
```

- calculate standard deviation of x

```
sd(x)
```

```
[1] 29.01149
```

*example:*

```
x <- runif(100)
out <- vector("numeric", length(x))
out[1] <- x[1]
for (i in 2:length(x)) {
 out[i] <- out[i - 1] + x[i]
}
out
```

```
[1] 0.01405826 0.72474998 1.37576629 2.37279466 2.48855898
[6] 3.41041608 3.85955533 4.11948166 4.90929207 5.44512120
[11] 5.88420565 6.77483132 6.89207229 7.33167294 7.96794679
[16] 8.61985438 8.84413972 9.71099112 9.82239223 10.37191174
[21] 10.50869830 10.96367677 11.11503090 11.99593713 12.85421048
[26] 13.41957601 14.36501311 14.69567443 15.09995734 15.33024575
[31] 15.46485353 15.57988052 15.75140921 16.56088695 16.57063250
[36] 17.36853630 17.89651610 18.31080475 18.64202368 18.69922851
[41] 19.52558526 20.09898522 20.72053892 20.77788585 21.64180251
[46] 22.35095264 22.69652076 23.01528655 23.93626243 24.00241593
[51] 24.02771645 24.66623298 24.91832287 25.47645913 25.78888303
[56] 26.65207266 26.88364386 27.87863057 27.98844044 28.75665969
[61] 29.41738418 29.77209269 29.99132183 30.62947083 31.16863088
[66] 31.47227460 32.46135611 32.95027009 33.78690545 34.62108842
[71] 34.85529705 35.30529703 35.56589364 36.09810546 36.31399854
```

```
[76] 37.00522894 37.19061937 37.28726569 37.82858151 38.61261337
[81] 39.60344519 40.32174292 40.94582249 41.66943389 42.26802287
[86] 42.40609205 42.91161841 43.23227914 44.06238312 44.18112618
[91] 44.49852578 44.85614454 44.96929130 45.34966245 45.82163236
[96] 46.45231598 46.75246472 47.22741417 47.97262747 48.48227369
```

- calculate cumulative sum

```
cumsum(x)
```

```
[1] 0.01405826 0.72474998 1.37576629 2.37279466 2.48855898
[6] 3.41041608 3.85955533 4.11948166 4.90929207 5.44512120
[11] 5.88420565 6.77483132 6.89207229 7.33167294 7.96794679
[16] 8.61985438 8.84413972 9.71099112 9.82239223 10.37191174
[21] 10.50869830 10.96367677 11.11503090 11.99593713 12.85421048
[26] 13.41957601 14.36501311 14.69567443 15.09995734 15.33024575
[31] 15.46485353 15.57988052 15.75140921 16.56088695 16.57063250
[36] 17.36853630 17.89651610 18.31080475 18.64202368 18.69922851
[41] 19.52558526 20.09898522 20.72053892 20.77788585 21.64180251
[46] 22.35095264 22.69652076 23.01528655 23.93626243 24.00241593
[51] 24.02771645 24.66623298 24.91832287 25.47645913 25.78888303
[56] 26.65207266 26.88364386 27.87863057 27.98844044 28.75665969
[61] 29.41738418 29.77209269 29.99132183 30.62947083 31.16863088
[66] 31.47227460 32.46135611 32.95027009 33.78690545 34.62108842
[71] 34.85529705 35.30529703 35.56589364 36.09810546 36.31399854
[76] 37.00522894 37.19061937 37.28726569 37.82858151 38.61261337
[81] 39.60344519 40.32174292 40.94582249 41.66943389 42.26802287
[86] 42.40609205 42.91161841 43.23227914 44.06238312 44.18112618
[91] 44.49852578 44.85614454 44.96929130 45.34966245 45.82163236
[96] 46.45231598 46.75246472 47.22741417 47.97262747 48.48227369
```

### 3. Combine your function writing and for loop skills:

1. Write a for loop that prints() the lyrics to the children's song "Alice the camel".

```
num_humps <- c("five", "four", "three", "two", "one", "no")

for (i in seq_along(num_humps)){
 paste0("Alice the camel has ", num_humps[[i]], " humps.") %>%
 rep(3) %>%
 writeLines()

 writeLines("So go, Alice, go.\n")
}

Alice the camel has five humps.
Alice the camel has five humps.
Alice the camel has five humps.
So go, Alice, go.
##
Alice the camel has four humps.
Alice the camel has four humps.
Alice the camel has four humps.
So go, Alice, go.
##
```

```

Alice the camel has three humps.
Alice the camel has three humps.
Alice the camel has three humps.
So go, Alice, go.
##
Alice the camel has two humps.
Alice the camel has two humps.
Alice the camel has two humps.
So go, Alice, go.
##
Alice the camel has one humps.
Alice the camel has one humps.
Alice the camel has one humps.
So go, Alice, go.
##
Alice the camel has no humps.
Alice the camel has no humps.
Alice the camel has no humps.
So go, Alice, go.

```

1. Convert the nursery rhyme “ten in the bed” to a function. Generalise it to any number of people in any sleeping structure.

```

nursery_bed <- function(num, y) {
 output <- vector("character", num)
 for (i in seq_along(output)) {
 output[[i]] <- str_replace_all(
 'There were x in the _y\n And the little one said, \n"Roll over! Roll over!"\n So they all roll'
)
 str_c(output, collapse = "\n\n") %>%
 writeLines()
 }

 nursery_bed(3, "asteroid")

There were 3 in the asteroid
And the little one said,
"Roll over! Roll over!"
So they all rolled over and
one fell out.
##
There were 2 in the asteroid
And the little one said,
"Roll over! Roll over!"
So they all rolled over and
one fell out.
##
There were 1 in the asteroid
And the little one said,
"Roll over! Roll over!"
So they all rolled over and
one fell out.

```

1. Convert the song “99 bottles of beer on the wall” to a function. Generalise to any number of any vessel containing any liquid on any surface.

- This is a little bit of a lazy version...

```
beer_rhyme <- function(x, y, z){
 output <- vector("character", x)
 for (i in seq_along(output)){
 output[i] <-
 str_replace_all("x bottles of y on the z.\n One fell off...", c(
 "x" = (x - i + 1),
 "y" = y,
 "z" = z
))
 }
 output <- (str_c(output, collapse = "\n") %>%
 str_c("\nNo more bottles...", collapse = ""))
 writeLines(output)
}

beer_rhyme(4, "soda", "toilet")

4 bottles of soda on the toilet.
One fell off...
3 bottles of soda on the toilet.
One fell off...
2 bottles of soda on the toilet.
One fell off...
1 bottles of soda on the toilet.
One fell off...
No more bottles...
```

4. It's common to see for loops that don't preallocate the output and instead increase the length of a vector at each step. How does this affect performance? Design and execute an experiment.

```
preallocate <- function(){
 x <- vector("double", 100)
 for (i in seq_along(x)){
 x[i] <- rnorm(1)
 }
}

growing <- function(){
 x <- c(0)
 for (i in 1:100){
 x[i] <- rnorm(1)
 }
}

microbenchmark::microbenchmark(
 space = preallocate(),
 no_space = growing(),
 times = 20
)

Unit: microseconds
expr min lq mean median uq max neval cld
space 202.7 666.25 1207.845 751.15 917.25 8255.8 20 a
no_space 272.0 417.70 1128.010 776.65 1060.35 6634.3 20 a
```

- see roughly 35% better performance when creating ahead of time
- note: if you can do these operations with vectorized approach though – they're often much faster

```
microbenchmark::microbenchmark(
 space = preallocate(),
 no_space = growing(),
 vector = rnorm(100),
 times = 20
)

Unit: microseconds
expr min lq mean median uq max neval cld
space 392.9 423.50 508.805 479.4 566.75 761.1 20 b
no_space 540.1 566.65 685.740 650.5 736.65 1184.5 20 c
vector 17.3 20.15 22.580 22.3 24.95 30.0 20 a
• vectorized was > 10x faster
```

## 25.2 21.3 For loop variations

### 25.2.1 21.3.5

1. Imagine you have a directory full of CSV files that you want to read in. You have their paths in a vector, `files <- dir("data/", pattern = "\\.csv$", full.names = TRUE)`, and now want to read each one with `read_csv()`. Write the for loop that will load them into a single data frame.
- To start this problem, I first created a file directory, and then wrote in 26 csvs each with the most popular name from each year since 1880 for a particular letter<sup>1</sup>.
- Next I read these into a single dataframe with a for loop

```
append_csvs <- function(dir){
 #input vector of file paths name and output appended file

 out <- vector("list", length(dir))
 for (i in seq_along(out)){
 out[[i]] <- read_csv(dir[[i]], col_types = cols(.default = "c"))
 }
 out <- bind_rows(out) %>%
 type_convert()
 out
}
```

<sup>1</sup>Below is the code that accomplished this. I used `walk2` and methods we learn later in the chapter.

```
dir.create("ch21_csvs_example")

babynames %>%
 mutate(first_letter = str_sub(name, 1, 1)) %>%
 group_by(first_letter, year) %>%
 filter(dplyr::min_rank(~prop) == 1) %>%
 split(.by = first_letter) %>%
 # map(~select(.x, -first_letter)) %>%
 walk2(.x = ., .y = names(.),
 ~write_csv(.x,
 paste0("ch21_csvs_example/", "letter_", .y, ".csv"))
)
```

```
dir_examp <- dir("ch21_csvs_example",
 pattern = "csv$",
 full.names = TRUE)

names_appended <- append_csvs(dir_examp)
names_appended

A tibble: 3,514 x 6
year sex name n prop first_letter
<dbl> <chr> <chr> <int> <dbl> <chr>
1 1880 F Anna 2604 0.0267 A
2 1881 F Anna 2698 0.0273 A
3 1882 F Anna 3143 0.0272 A
4 1883 F Anna 3306 0.0275 A
5 1884 F Anna 3860 0.0281 A
6 1885 F Anna 3994 0.0281 A
7 1886 F Anna 4283 0.0279 A
8 1887 F Anna 4227 0.0272 A
9 1888 F Anna 4982 0.0263 A
10 1889 F Anna 5062 0.0268 A
... with 3,504 more rows
```

- See Using map for example of how this could be accomplished using `map` and `map(safely(read_csv))`.

2. *What happens if you use `for (nm in names(x))` and `x` has no names?*

```
x <- list(1:10, 11:18, 19:25)
for (nm in names(x)) {
 print(x[[nm]])
}
```

- each iteration produces an error, so nothing is written

*What if only some of the elements are named?*

```
x <- list(a = 1:10, 11:18, c = 19:25)
for (nm in names(x)) {
 print(x[[nm]])
}
```

```
[1] 1 2 3 4 5 6 7 8 9 10
NULL
[1] 19 20 21 22 23 24 25
```

- you have output for those with names and NULL for those without

*What if the names are not unique?*

```
x <- list(a = 1:10, a = 11:18, c = 19:25)
for (nm in names(x)) {
 print(x[[nm]])
}

[1] 1 2 3 4 5 6 7 8 9 10
[1] 1 2 3 4 5 6 7 8 9 10
[1] 19 20 21 22 23 24 25
```

- it prints the first position with the name

3. Write a function that prints the mean of each numeric column in a data frame, along with its name.  
 For example, `show_mean(iris)` would print:

```
show_mean(iris)
#> Sepal.Length: 5.84
#> Sepal.Width: 3.06
#> Petal.Length: 3.76
#> Petal.Width: 1.20
```

(Extra challenge: what function did I use to make sure that the numbers lined up nicely, even though the variable names had different lengths?)

```
show_mean <- function(df){
 # select just cols that are numeric
 out <- vector("logical", length(df))
 for (i in seq_along(df)) {
 out[[i]] <- is.numeric(df[[i]])
 }
 df_select <- df[out]
 # keep/discard funcs would have made this easy

 # make list of values w/ mean
 means <- vector("list", length(df_select))
 names(means) <- names(df_select)
 for (i in seq_along(df_select)){
 means[[i]] <- mean(df_select[[i]], na.rm = TRUE) %>%
 round(digits = 2)
 }

 # print out, use method to identify max chars for vars printed
 means_names <- names(means)
 chars_max <- (str_count(means_names) + str_count(as.character(means))) %>% max()
 chars_pad <- chars_max - (str_count(means_names) + str_count(as.character(means)))
 names(chars_pad) <- means_names

 str_c(means_names, ":", str_dup(" ", chars_pad), means) %>%
 writeLines()
}

show_mean(flights)

year: 2013
month: 6.55
day: 15.71
dep_time: 1349.11
sched_dep_time: 1344.25
dep_delay: 12.64
arr_time: 1502.05
sched_arr_time: 1536.38
arr_delay: 6.9
flight: 1971.92
air_time: 150.69
distance: 1039.91
hour: 13.18
minute: 26.23
```

4. What does this code do? How does it work?

```
trans <- list(
 disp = function(x) x * 0.0163871,
 am = function(x) {
 factor(x, labels = c("auto", "manual"))
 }
)
for (var in names(trans)) {
 mtcars[[var]] <- trans[[var]](mtcars[[var]])
}
mtcars
```

- first part builds list of functions, 2nd applies those to a dataset
- are storing the data transformations as a function and then applying this to a dataframe <sup>2</sup>

## 25.3 21.4: For loops vs. functionals

### 25.3.1 21.4.1

1. Read the documentation for `apply()`. In the 2d case, what two for loops does it generalise?
  - It allows you to input either 1 or 2 for the `MARGIN` argument, which corresponds with looping over either the rows or the columns.
2. Adapt `col_summary()` so that it only applies to numeric columns You might want to start with an `is_numeric()` function that returns a logical vector that has a TRUE corresponding to each numeric column.

```
col_summary_gen <- function(df, fun, ...) {
 #find cols that are numeric
 out <- vector("logical", length(df))
 for (i in seq_along(df)) {
 out[[i]] <- is.numeric(df[[i]])
 }
 #make list of values w/ mean
 df_select <- df[out]
 output <- vector("list", length(df_select))
 names(output) <- names(df_select)
 for (nm in names(output)) {
 output[[nm]] <- fun(df_select[[nm]], ...)
 %>%
 round(digits = 2)
 }

 as_tibble(output)
}

col_summary_gen(flights, fun = median, na.rm = TRUE) %>%
 gather() # trick to gather all easily

A tibble: 14 x 2
key value
```

---

<sup>2</sup>This is a very powerful practice because it allows you to save / keep track of your manipulations and apply them at other locations, while keeping the logic very well organized – go and use this for documenting your work / transformations

```

<chr> <dbl>
1 year 2013
2 month 7
3 day 16
4 dep_time 1401
5 sched_dep_time 1359
6 dep_delay -2
7 arr_time 1535
8 sched_arr_time 1556
9 arr_delay -5
10 flight 1496
11 air_time 129
12 distance 872
13 hour 13
14 minute 29

```

- the ... makes this so you can add arguments to the functions.

## 25.4 21.5: The map functions

### 25.4.1 21.5.3

1. Write code that uses one of the map functions to:

*Compute the mean of every column in mtcars.*

```
purrr::map_dbl(mtcars, mean)
```

```

mpg cyl disp hp drat wt
20.090625 6.187500 230.721875 146.687500 3.596563 3.217250
qsec vs am gear carb
17.848750 0.437500 0.406250 3.687500 2.812500

```

*Determine the type of each column in nycflights13::flights.*

```
purrr::map_chr(flights, typeof)
```

```

year month day dep_time sched_dep_time
"integer" "integer" "integer" "integer" "integer"
dep_delay arr_time sched_arr_time arr_delay carrier
"double" "integer" "integer" "double" "character"
flight tailnum origin dest air_time
"integer" "character" "character" "character" "double"
distance hour minute time_hour
"double" "double" "double" "double"

```

*Compute the number of unique values in each column of iris.*

```
purrr::map(iris, unique) %>%
 map_dbl(length)
```

```

Sepal.Length Sepal.Width Petal.Length Petal.Width Species
35 23 43 22 3

```

*Generate 10 random normals for each of  $\mu = -10, 0, 10$ , and 100.*

```

purrr::map_dbl(flights, ~mean(is.na(.x)))

year month day dep_time sched_dep_time
0.000000000 0.000000000 0.000000000 0.024511842 0.000000000
dep_delay arr_time sched_arr_time arr_delay carrier
0.024511842 0.025871796 0.000000000 0.028000808 0.000000000
flight tailnum origin dest air_time
0.000000000 0.007458964 0.000000000 0.000000000 0.028000808
distance hour minute time_hour
0.000000000 0.000000000 0.000000000 0.000000000

```

2. How can you create a single vector that for each column in a data frame indicates whether or not it's a factor?

```

purrr::map_lgl(iris, is.factor) %>%
 as_tibble() %>%
 mutate(column_names = row.names(.))

```

```

Warning: Calling `as_tibble()` on a vector is discouraged, because the behavior is likely to change.
This warning is displayed once per session.

```

```

A tibble: 5 x 2
value column_names
<lgl> <chr>
1 FALSE 1
2 FALSE 2
3 FALSE 3
4 FALSE 4
5 TRUE 5

```

- for this example, I added in a simple extra little trick to convert to a tibble and include original column names as a field

3. What happens when you use the map functions on vectors that aren't lists? What does `map(1:5, runif)` do? Why?

```

purrr::map(1:5, rnorm)

```

```

[[1]]
[1] -1.064424
##
[[2]]
[1] -0.3639783 2.2548781
##
[[3]]
[1] 0.1304770 0.5163387 0.6353970
##
[[4]]
[1] 1.65496321 0.47349442 -1.78736071 -0.07217471
##
[[5]]
[1] 0.07365547 -1.99156294 -0.62793851 -0.45125838 0.51591774

```

- it runs on each item in the vector. In this case then it is passing the values 1, 2, 3, 4, 5 into the first argument of `rnorm`, hence pattern above.

4. What does `map(-2:2, rnorm, n = 5)` do? Why?

```
map(-2:2, rnorm, n = 5)

[[1]]
[1] -0.6977255 -2.1261233 -1.7316471 -4.6001960 -1.1823920
##
[[2]]
[1] -2.4082034 -2.1048946 -1.5338096 -0.2212205 -1.2845211
##
[[3]]
[1] -0.19732827 0.53766974 -0.96960538 0.40444716 -0.02606404
##
[[4]]
[1] -0.18825386 2.05591129 -0.07400924 0.02438897 0.91307412
##
[[5]]
[1] 3.1330009 2.6605051 2.1530772 -0.2314711 1.4952553
```

- It makes 5 vectors each of length 5 with the values centered at the means of -2,-1, 0, 1, 2 respectively.
- The reason is that the default filling of the first argument is already named by the defined input of ‘n = 5’, therefore, the inputs are instead going to the 2nd argument, and hence become the mean of the different rnorm calls.

5. Rewrite `map(x, function(df) lm(mpg ~ wt, data = df))` to eliminate the anonymous function.

```
mtcars %>%
 purrr::map(~ lm(mpg ~ wt, data = .))
```

## 25.5 21.9 Other patterns of for loops

### 25.5.1 21.9.3

1. Implement your own version of `every()` using a for loop. Compare it with `purrr::every()`. What does purrr’s version do that your version doesn’t?

```
every_loop <- function(x, fun, ...) {
 output <- vector("list", length(x))
 for (i in seq_along(x)) {
 output[[i]] <- fun(x[[i]])
 }
 total <- flatten_lgl(output)
 sum(total) == length(x)
}
```

```
x <- list(flights, mtcars, iris)
every_loop(x, is.data.frame)
```

```
[1] TRUE
every(x, is.data.frame)
```

```
[1] TRUE
```

- mine can’t handle shortcut formulas or new functions

```

z <- sample(10)
z %>%
 every(~ . < 11)

[1] TRUE
e.g. below would fail
z %>%
every_loop(~ . < 11)

```

2. Create an enhanced `col_sum()` that applies a summary function to every numeric column in a data frame.

```

col_summary_enh <- function(x, fun){
 x %>%
 keep(is.numeric) %>%
 purrr::map_dbl(fun)
}
col_summary_enh(mtcars, median)

```

```

mpg cyl disp hp drat wt qsec vs am
19.200 6.000 196.300 123.000 3.695 3.325 17.710 0.000 0.000
gear carb
4.000 2.000

```

3. A possible base R equivalent of `col_sum()` is:

```

col_sum3 <- function(df, f) {
 is_num <- sapply(df, is.numeric)
 df_num <- df[, is_num]

 sapply(df_num, f)
}

```

But it has a number of bugs as illustrated with the following inputs:

```

df <- tibble(
 x = 1:3,
 y = 3:1,
 z = c("a", "b", "c")
)
OK
col_sum3(df, mean)
Has problems: don't always return numeric vector
col_sum3(df[1:2], mean)
col_sum3(df[1], mean)
col_sum3(df[0], mean)

```

What causes the bugs?

- The vector output is not always consistent in its output type. Also, returns error when inputting an empty list due to indexing issue.



# Chapter 26

## Appendix

### 26.1 21.3.5.1

#### 26.1.1 Using map

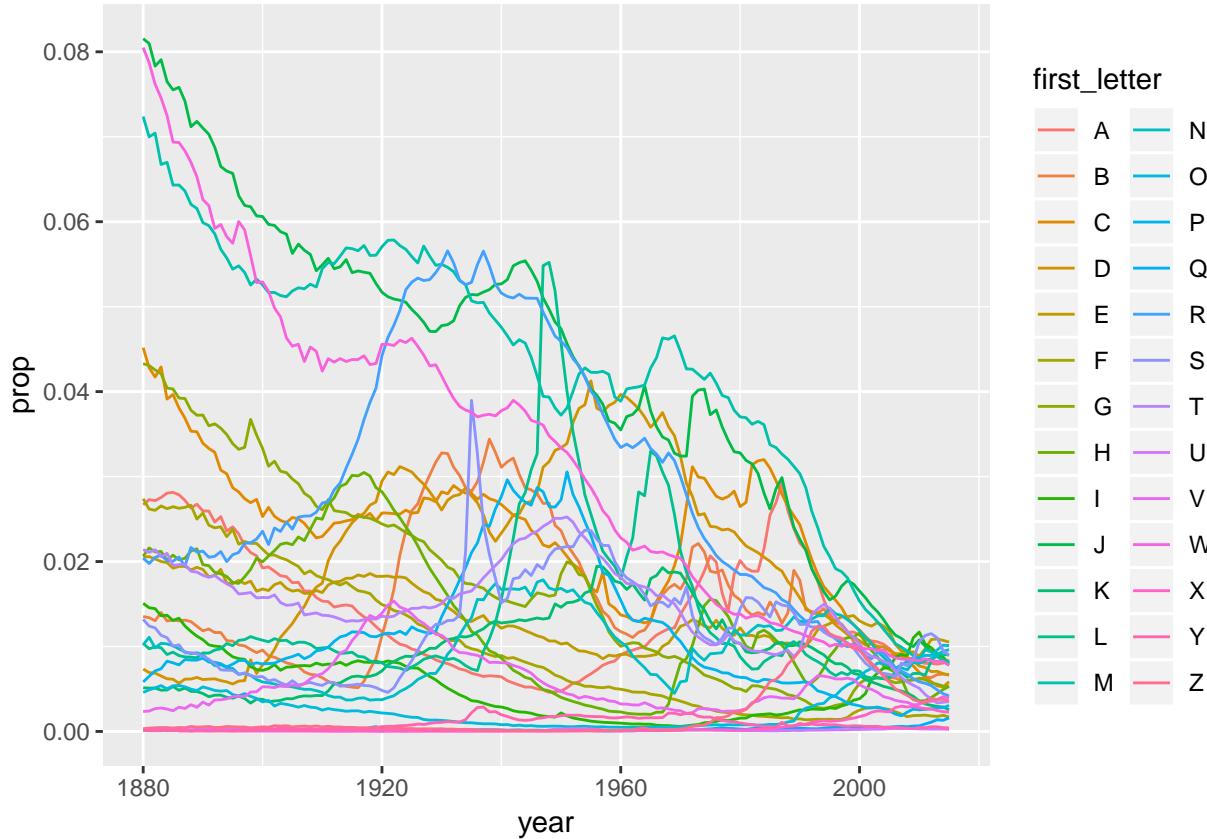
```
outputted_csv <- files_example %>%
 mutate(csv_data = map(file_paths, read_csv))

outputted_csv <- files_example %>%
 mutate(csv_data = map(file_paths, safely(read_csv)))
```

#### 26.1.2 Plot of names

- Below is a plot of the proportion of individuals named the most popular letter in each year. This suggests that the top names by letter do not have as large of a proportion of the population compared to historically.

```
names_appended %>%
 ggplot(aes(x = year, y = prop, colour = first_letter)) +
 geom_line()
```



### 26.1.3 csv other example

This is some code I used to read csvs from a shared drive. I added on the ‘file\_path\_pull’ and ‘files\_example’ components to add in information on the file paths and other details that were relevant... you might also add this data into a new column on the output...

```
files_path_pull <- dir("//companydomain.com/directory/",
 pattern = "csv$",
 full.names = TRUE)

files_example <- tibble(file_paths = files_path_pull[1:2]) %>%
 extract(file_paths, into = c("path", "name"), regex = "(.*)([0-9]{4}-[0-9]{2}-[0-9]{2})", remove = FALSE)

read_dir <- function(dir){
 #input vector of file paths name and output appended file
 out <- vector("list", length(dir))
 for (i in seq_along(out)){
 out[[i]] <- read_csv(dir[[i]])
 }
 out <- bind_rows(out)
 out
}

read_dir(files_example$file_paths)
```

## 26.2 21.3.5.2 with purrr

Slightly less attractive printing

```
show_mean2 <- function(df) {
 df %>%
 keep(is.numeric) %>%
 map_dbl(mean, na.rm = TRUE)
}

show_mean2(flights)

year month day dep_time sched_dep_time
2013.000000 6.548510 15.710787 1349.109947 1344.254840
dep_delay arr_time sched_arr_time arr_delay flight
12.639070 1502.054999 1536.380220 6.895377 1971.923620
air_time distance hour minute
150.686460 1039.912604 13.180247 26.230100
```

Maybe slightly better printing and in df

```
show_mean3 <- function(df){
 df %>%
 keep(is.numeric) %>%
 map_dbl(mean, na.rm = TRUE) %>%
 as_tibble() %>%
 mutate(names = row.names(.))
}

show_mean3(flights)

A tibble: 14 x 2
value names
<dbl> <chr>
1 2013 1
2 6.55 2
3 15.7 3
4 1349. 4
5 1344. 5
6 12.6 6
7 1502. 7
8 1536. 8
9 6.90 9
10 1972. 10
11 151. 11
12 1040. 12
13 13.2 13
14 26.2 14
```

Other method is to take advantage of the gather function

```
flights %>%
 keep(is.numeric) %>%
 map(mean, na.rm = TRUE) %>%
 as_tibble() %>%
 gather()
```

```
A tibble: 14 x 2
key value
<chr> <dbl>
1 year 2013
2 month 6.55
3 day 15.7
4 dep_time 1349.
5 sched_dep_time 1344.
6 dep_delay 12.6
7 arr_time 1502.
8 sched_arr_time 1536.
9 arr_delay 6.90
10 flight 1972.
11 air_time 151.
12 distance 1040.
13 hour 13.2
14 minute 26.2
```

## 26.3 21.9 mirroring keep

- below is one method for passing multiple, more complex arguments through `keep`, though you can also use function shortcuts (~) in `keep` and `discard`

```
how to pass multiple functions through keep?
can use map to subset columns by multiple criteria and then subset at end
flights %>%
 purrr::map(is.na) %>%
 purrr::map_dbl(sum) %>%
 purrr::map_lgl(~.>10) %>%
 flights[.]
```

```
A tibble: 336,776 x 6
dep_time dep_delay arr_time arr_delay tailnum air_time
<int> <dbl> <int> <dbl> <chr> <dbl>
1 517 2 830 11 N14228 227
2 533 4 850 20 N24211 227
3 542 2 923 33 N619AA 160
4 544 -1 1004 -18 N804JB 183
5 554 -6 812 -25 N668DN 116
6 554 -4 740 12 N39463 150
7 555 -5 913 19 N516JB 158
8 557 -3 709 -14 N829AS 53
9 557 -3 838 -8 N593JB 140
10 558 -2 753 8 N3ALAA 138
... with 336,766 more rows
```

## 26.4 invoke examples

Let's change the example to be with quantile...

```
invoke(runif, n = 10)
```

```

[1] 0.008568944 0.974083330 0.402514783 0.054610924 0.168163903
[6] 0.886665180 0.132476279 0.716397311 0.512501256 0.435942013

list("01a", "01b") %>%
 invoke(paste, ., sep = "-")

[1] "01a-01b"

set.seed(123)
invoke_map(list(runif, rnorm), list(list(n = 10), list(n = 5)))

[[1]]
[1] 0.2875775 0.7883051 0.4089769 0.8830174 0.9404673 0.0455565 0.5281055
[8] 0.8924190 0.5514350 0.4566147
##
[[2]]
[1] 1.7150650 0.4609162 -1.2650612 -0.6868529 -0.4456620

set.seed(123)
invoke_map(list(runif, rnorm), list(list(n = 10), list(5, 50)))

[[1]]
[1] 0.2875775 0.7883051 0.4089769 0.8830174 0.9404673 0.0455565 0.5281055
[8] 0.8924190 0.5514350 0.4566147
##
[[2]]
[1] 51.71506 50.46092 48.73494 49.31315 49.55434

list(m1 = mean, m2 = median) %>% invoke_map(x = rcauchy(100))

$m1
[1] 0.7316016
##
$m2
[1] 0.1690467

rcauchy(100)

[1] -1.99514216 1.57378677 1.44901985 0.82604308 2.30072052
[6] -0.04961749 0.52626840 0.29408692 0.47790231 -1.47138470
[11] -2.54305059 -0.35508248 -1.65511601 -1.08467708 -15.03813728
[16] -1.82118206 -0.62669137 -0.79456204 -0.06347636 5.19179251
[21] 1.48851593 3.42095041 0.03289526 0.65171559 -0.53864091
[26] 0.88812626 0.93375555 0.24570517 0.97348569 -1.11905466
[31] -0.51964526 128.72537963 2.72138263 0.97793363 0.36391811
[36] 2.77745450 -4.34935786 0.81096079 5.70518746 0.81669440
[41] -138.41947905 2.02359725 -1.96283674 2.40809060 2.04850398
[46] -9.41347275 -1.06265274 0.83312509 3.55625549 1.10375978
[51] -2.31140048 0.65162145 -0.45665528 -1.02179975 -1.71189590
[56] -2.57239721 2.35617831 -10.63750166 -0.41538322 -3.80770683
[61] -0.55070513 1.49607830 -1.30359005 1.09910916 -3.27457763
[66] 16.99304208 1.09921270 -4.86030197 -0.27969649 -0.31842181
[71] 1.16466121 1.59209243 -0.04514112 -2.52586678 -0.19951960
[76] 9.47599952 3.31841045 -1.82945785 0.51884667 -4.29179059
[81] 0.93155898 -0.11880720 -3.03333758 -21.16294537 3.16450655
[86] -0.39503234 2.19801293 1.27457150 0.59413768 0.60064481
[91] 17.70703023 1.01880490 0.80764382 -1.63905090 0.15086898
[96] -1.36865319 1.99173761 3.39988162 -0.63043489 -0.26058630

```

Let's store everything in a dataframe...

```

set.seed(123)
tibble(funns = list(rn = "rnorm", rp = "rpois", ru = "runif"),
 params = list(list(n = 20, mean = 10), list(n = 20, lambda = 3), list(n = 20, min = -1, max = 1)),
 with(invoke_map_df(funns, params))

A tibble: 20 x 3
rn rp ru
<dbl> <int> <dbl>
1 9.44 1 0.330
2 9.77 2 -0.810
3 11.6 2 -0.232
4 10.1 2 -0.451
5 10.1 1 0.629
6 11.7 1 -0.103
7 10.5 2 0.620
8 8.73 3 0.625
9 9.31 2 0.589
10 9.55 5 -0.120
11 11.2 0 0.509
12 10.4 3 0.258
13 10.4 4 0.420
14 10.1 1 -0.999
15 9.44 3 -0.0494
16 11.8 2 -0.560
17 10.5 1 -0.240
18 8.03 4 0.226
19 10.7 5 -0.296
20 9.53 2 -0.778

map_df(iris, ~ .x^2)

Warning in Ops.factor(.x, 2): '*' not meaningful for factors

A tibble: 150 x 5
Sepal.Length Sepal.Width Petal.Length Petal.Width Species
<dbl> <dbl> <dbl> <dbl> <lgl>
1 10.2 7 2.8 0.4 NA
2 9.8 6 2.8 0.4 NA
3 9.4 6.4 2.6 0.4 NA
4 9.2 6.2 3 0.4 NA
5 10 7.2 2.8 0.4 NA
6 10.8 7.8 3.4 0.8 NA
7 9.2 6.8 2.8 0.6 NA
8 10 6.8 3 0.4 NA
9 8.8 5.8 2.8 0.4 NA
10 9.8 6.2 3 0.2 NA
... with 140 more rows

select(iris, -Species) %>%
 flatten_dbl() %>%
 mean()

[1] 3.4645

```

```
mean.and.median <- function(x){
 list(mean = mean(x, na.rm = TRUE),
 median = median(x, na.rm = TRUE))
}
```

Difference between dfr and dfc, taken from here: <https://bio304-class.github.io/bio304-fall2017/control-flow-in-R.html>

```
iris %>%
 select(-Species) %>%
 map_dfr(mean.and.median) %>%
 bind_cols(tibble(names = names(select(iris, -Species))))
```

```
A tibble: 4 x 3
mean median names
<dbl> <dbl> <chr>
1 5.84 5.8 Sepal.Length
2 3.06 3 Sepal.Width
3 3.76 4.35 Petal.Length
4 1.20 1.3 Petal.Width
```

```
iris %>%
 select(-Species) %>%
 map_dfr(mean.and.median) %>%
 bind_cols(tibble(names = names(select(iris, -Species))))
```

```
A tibble: 4 x 3
mean median names
<dbl> <dbl> <chr>
1 5.84 5.8 Sepal.Length
2 3.06 3 Sepal.Width
3 3.76 4.35 Petal.Length
4 1.20 1.3 Petal.Width
```

```
iris %>%
 select(-Species) %>%
 map_dfc(mean.and.median)
```

```
A tibble: 1 x 8
mean median mean1 median1 mean2 median2 mean3 median3
<dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
1 5.84 5.8 3.06 3 3.76 4.35 1.20 1.3
```

## 26.5 indexing nms caution

When creating your empty list, use indexes rather than names if you are creating values, otherwise you are creating new values on the list. E.g. in the example below I the output ends up being length 6 because you have the 3 NULL values plus the 3 newly created named positions.

```
x <- list(a = 1:10, b = 11:18, c = 19:25)
output <- vector("list", length(x))
for (nm in names(x)) {
 output[[nm]] <- x[[nm]] * 3
}
output
```

```
[[1]]
NULL
##
[[2]]
NULL
##
[[3]]
NULL
##
$a
[1] 3 6 9 12 15 18 21 24 27 30
##
$b
[1] 33 36 39 42 45 48 51 54
##
$c
[1] 57 60 63 66 69 72 75
```

## 26.6 in class notes

the `map_*` functions are essentially like running a `flatten_*` after running `map`. E.g. the two things below are equivalent

```
map(flights, typeof) %>%
 flatten_chr()
```

```
[1] "integer" "integer" "integer" "integer" "integer"
[6] "double" "integer" "integer" "double" "character"
[11] "integer" "character" "character" "character" "double"
[16] "double" "double" "double" "double"
```

```
map_chr(flights, typeof)
```

```
year month day dep_time sched_dep_time
"integer" "integer" "integer" "integer" "integer"
dep_delay arr_time sched_arr_time arr_delay carrier
"double" "integer" "integer" "double" "character"
flight tailnum origin dest air_time
"integer" "character" "character" "character" "double"
distance hour minute time_hour
"double" "double" "double" "double"
```

Calculate the number of unique values for each level

```
iris %>%
 map(unique) %>%
 map_dbl(length)

map_int(iris, ~length(unique(.x)))
```

Iterate through different min and max values

```
min_params <- c(-1, 0, -10)
max_params <- c(11:13)
map2(.x = min_params, .y = max_params, ~runif(n = 10, min = .x, max = .y))
```

```

[[1]]
[1] 1.9234337 7.0166670 4.0117614 8.4583500 0.2343757 4.2187129
[7] 10.8194838 9.7166134 9.6376287 1.1006318
##
[[2]]
[1] 1.568348 7.837223 4.122198 7.881098 3.844479 2.252293 9.387532
[8] 1.123140 5.601348 6.138066
##
[[3]]
[1] 3.7997461 -2.3450586 1.2380998 11.9528980 1.1067551 10.4780551
[7] 11.0320783 4.0009046 -0.5541351 -6.6168221

```

When using pmap it's often best to keep the parameters in a dataframe

```

min_df_params <- tibble(n = c(10, 15, 20, 50),
 min = c(-1, 0, 1, 2),
 max = c(0, 1, 2, 3))

pmap(min_df_params, runif)

[[1]]
[1] -0.06470020 -0.69877110 -0.93927943 -0.05227306 -0.27940373
[6] -0.85770570 -0.45071534 -0.04590876 -0.41451665 -0.59548972
##
[[2]]
[1] 0.6478935 0.3198206 0.3077200 0.2197676 0.3694889 0.9842192 0.1542023
[8] 0.0910440 0.1419069 0.6900071 0.6192565 0.8913941 0.6729991 0.7370777
[15] 0.5211357
##
[[3]]
[1] 1.659838 1.821805 1.786282 1.979822 1.439432 1.311702 1.409475
[8] 1.010467 1.183850 1.842729 1.231162 1.239100 1.076691 1.245724
[15] 1.732135 1.847453 1.497527 1.387909 1.246449 1.111096
##
[[4]]
[1] 2.389994 2.571935 2.216893 2.444768 2.217991 2.502300 2.353905
[8] 2.649985 2.374714 2.355445 2.533688 2.740334 2.221103 2.412746
[15] 2.265687 2.629973 2.183828 2.863644 2.746568 2.668285 2.618018
[22] 2.372238 2.529836 2.874682 2.581750 2.839768 2.312448 2.708290
[29] 2.265018 2.594343 2.481290 2.265033 2.564590 2.913188 2.901874
[36] 2.274167 2.321483 2.985641 2.619993 2.937314 2.466533 2.406833
[43] 2.659230 2.152347 2.572867 2.238726 2.962359 2.601366 2.515030
[50] 2.402573

```

You can often use map a bunch of output that can then be stored in a tibble

```

tibble(type = map_chr(mtcars, typeof),
 means = map_dbl(mtcars, mean),
 median = map_dbl(mtcars, median),
 names = names(mtcars))

```

```

A tibble: 11 x 4
type means median names
<chr> <dbl> <dbl> <chr>
1 double 20.1 19.2 mpg
2 double 6.19 6 cyl

```

```
3 double 231. 196. disp
4 double 147. 123. hp
5 double 3.60 3.70 drat
6 double 3.22 3.32 wt
7 double 17.8 17.7 qsec
8 double 0.438 0 vs
9 double 0.406 0 am
10 double 3.69 4 gear
11 double 2.81 2 carb
```

*Provide the number of unique values for all columns excluding columns with numeric types or date types.*

```
num_unique <- function(df) {
 df %>%
 keep(~is_character(.x) | is.factor(.x)) %>%
 map(~length(unique(.x))) %>%
 as_tibble() %>%
 gather() %>%
 rename(field_name = key, num_unique = value)
}
```

```
num_unique(flights)
```

```
A tibble: 4 x 2
field_name num_unique
<chr> <int>
1 carrier 16
2 tailnum 4044
3 origin 3
4 dest 105
```

```
num_unique(iris)
```

```
A tibble: 1 x 2
field_name num_unique
<chr> <int>
1 Species 3
```

```
num_unique(mpg)
```

```
A tibble: 6 x 2
field_name num_unique
<chr> <int>
1 manufacturer 15
2 model 38
3 trans 10
4 drv 3
5 fl 5
6 class 7
```

*Make sure the following packages are installed:*

# Chapter 27

## ch. 23: Model basics

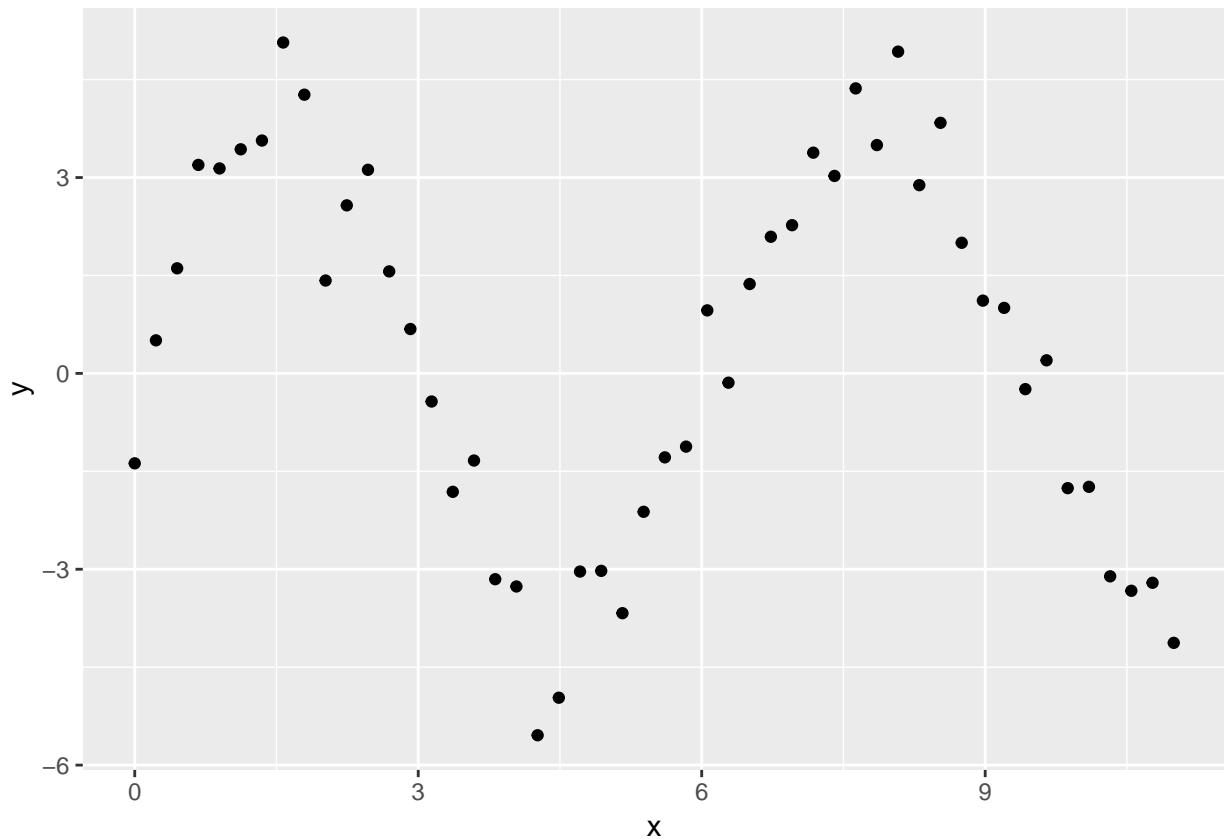
- `geom_abline` create line or lines given intercept and slopes, e.g. `geom_abline(aes(intercept = a1, slope = a2), data = models, alpha = 1/4)`
- `optim` general purpose function for optimization using Newton-Raphson search
- `coef` function for extracting coefficients from a linear model
- `modelr::data_grid`, can be used to generate an evenly spaced grid of values that covers region where data lies<sup>1</sup>
  - First arg is dataframe, next args are variable names to build grid from
  - when using with continuous data, `seq_range` or similar can be a good complement, see<sup>2</sup> for an example where this is used.
- `seq_range(x1, 5)` takes 5 values evenly spaced within this set. Two other useful args:
  - `pretty = TRUE` : will generate a “pretty sequence” ++ `seq_range(c(0.0123, 0.923423), n = 5, pretty = TRUE)` , 0, 0.2, 0.4, 0.6, 0.8, 1
  - `trim = 0.1` will trim off 10% of tail values (useful if vars have long tailed distribution and you want to focus on values near center) +‘expand = 0.1’ is kind of the opposite and expands the range by 10%
- `modelr::add_predictions` takes a data frame and modele an adds predictions from the model to a new column
- `modelr::add_residuals` is similar to above but requires actual value be in dataframe so that residuals can be calculated
- `modelr::spread_residuals` and `modelr::gather_residuals` allow you to do this for multiple models at once. equivalent are avaialble for `*_predictions` as well.
- use `model_matrix` to see what equation is being fitted
- To include all 2-way interactions can do something like this `model_matrix(sim3, y ~ (x1 + x2 + x3)^2)` or `model_matrix(sim3, y ~ (. )^2)`
- Use `I()` in `I(x2^2)` to incorporate squared term or any transformation that includes +, -, \*, or ^
- Use `poly` to include 1, 2, ... n order terms associated with a variable, e.g. `model_matrix(df, y ~ poly(x, 3))`
- `splines::ns()` represent safer alternative to `poly` that is less likely to become extreme, e.g. Interesting

<sup>1</sup>`expand.grid` is very similar to `data_grid`

<sup>2</sup>Below you can see the differences between splines and polynomials as we extrapolate outside of the immediate range of interest. Let's create another dataset with a slightly larger domain

```
sim5 <- tibble(
 x = seq(0, 3.5 * pi, length = 50),
 y = 4 * sin(x) + rnorm(length(x))
)

ggplot(sim5, aes(x, y)) +
 geom_point()
```



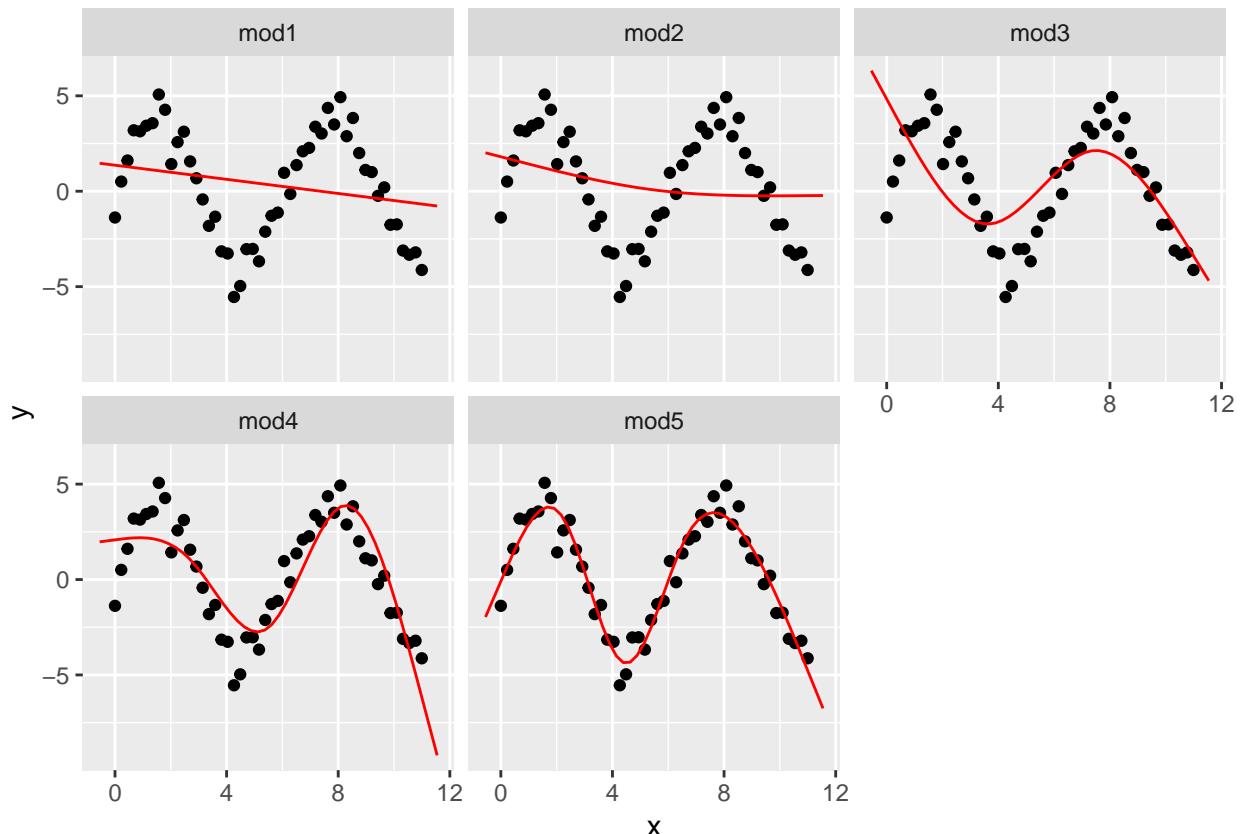
```

mod1 <- lm(y ~ splines::ns(x, 1), data = sim5)
mod2 <- lm(y ~ splines::ns(x, 2), data = sim5)
mod3 <- lm(y ~ splines::ns(x, 3), data = sim5)
mod4 <- lm(y ~ splines::ns(x, 4), data = sim5)
mod5 <- lm(y ~ splines::ns(x, 5), data = sim5)

grid <- sim5 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

ggplot(sim5, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)

```



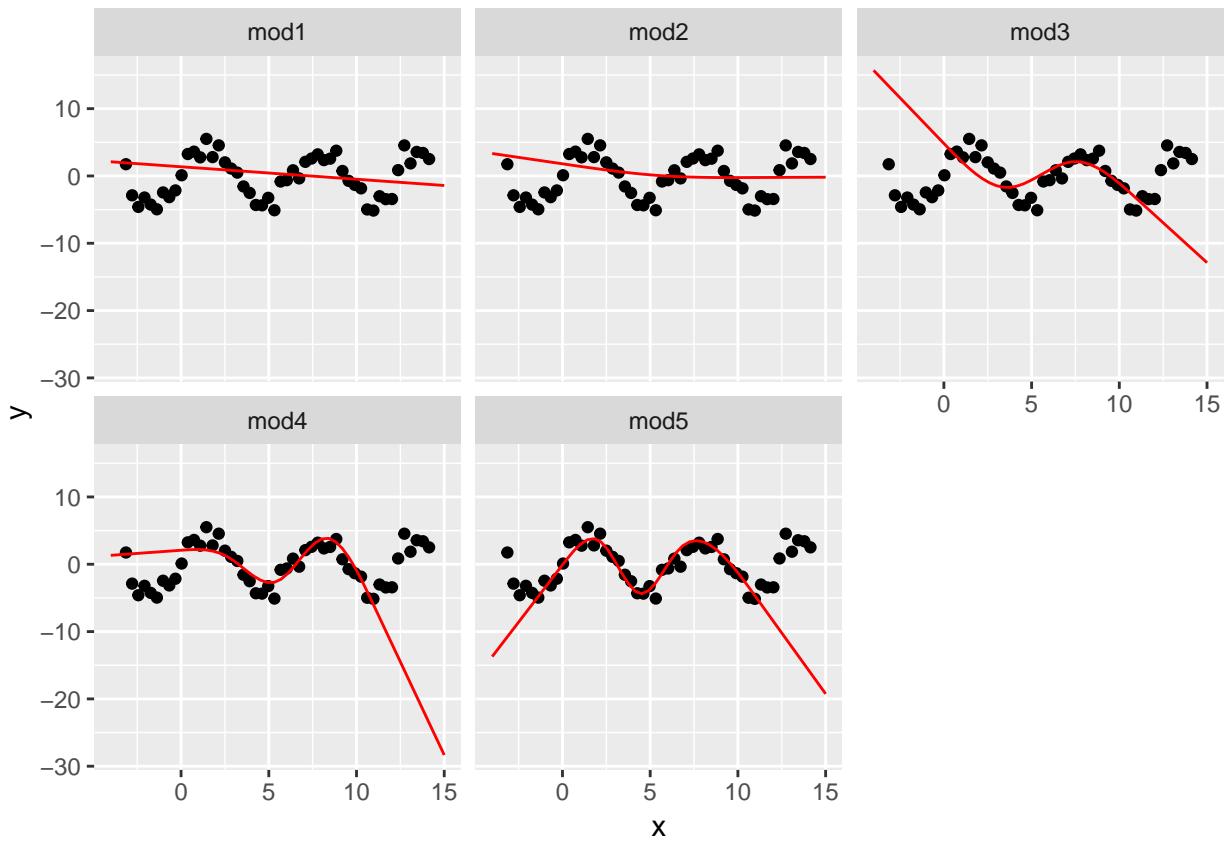
\*Notice that model with 5 degrees of freedom is able to now roughly approximate the model  
*Below are notes on performance of splines vs polynomials when extrapolating data*

```
sim5.1 <- tibble(
 x = seq(-pi, 4.5 * pi, length = 50),
 y = 4 * sin(x) + rnorm(length(x))
)
```

Plot the models that used ns for natural splines

```
grid <- sim5.1 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

ggplot(sim5.1, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)
```



\* Notice 5 degrees of freedom only allows it to mirror up-down-up-down, representing behavior of 5th degree polynomial, extrapolating outside of this performance is poor

*Build equivalent models using poly*

```
mod1 <- lm(y ~ poly(x, 1), data = sim5)
mod2 <- lm(y ~ poly(x, 2), data = sim5)
mod3 <- lm(y ~ poly(x, 3), data = sim5)
mod4 <- lm(y ~ poly(x, 4), data = sim5)
mod5 <- lm(y ~ poly(x, 5), data = sim5)

grid <- sim5.1 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

ggplot(sim5.1, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)
```

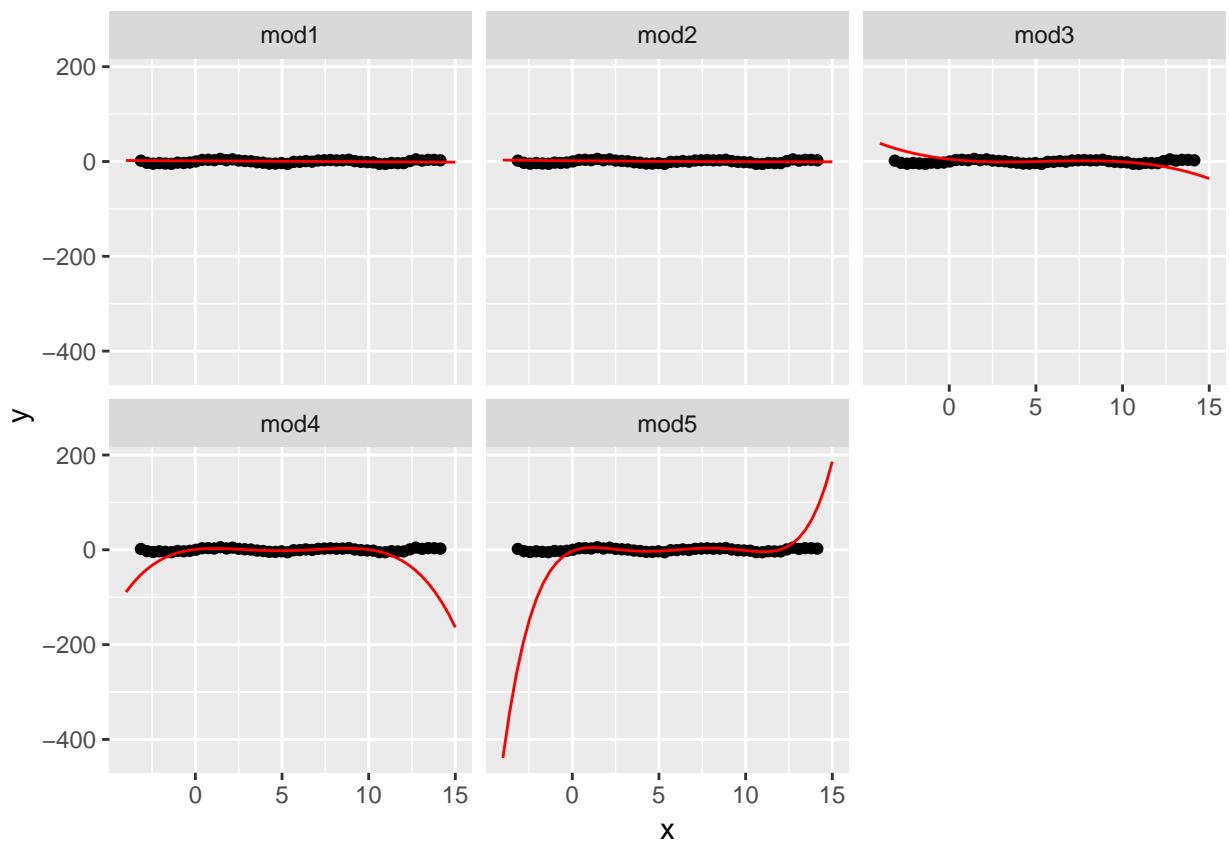
spline note<sup>3</sup>.

- `nobs(mod)` see how many observations were used in model building (assuming ‘mod’ represents a model)
- make dropping of missing values explicit with `options(na.action = na.warn)`
  - to make silent in specific models use e.g. `mod <- lm(y ~ x, data = df, na.action = na.exclude)`

## 27.1 23.2: A simple model

### 27.1.1 23.2.1

1. One downside of the linear model is that it is sensitive to unusual values because the distance incorporates a squared term. Fit a linear model to the simulated data below, and visualise the results. Rerun a few times to generate different simulated datasets. What do you notice about the model?



\* Performance on extrapolation becomes much worse for the polynomial though

\* Notice that the values cover a much larger codomain that is much farther from the actual data once extended.

<sup>3</sup>Below you can see the differences between splines and polynomials as we extrapolate outside of the immediate range of interest. Let's create another dataset with a slightly larger domain

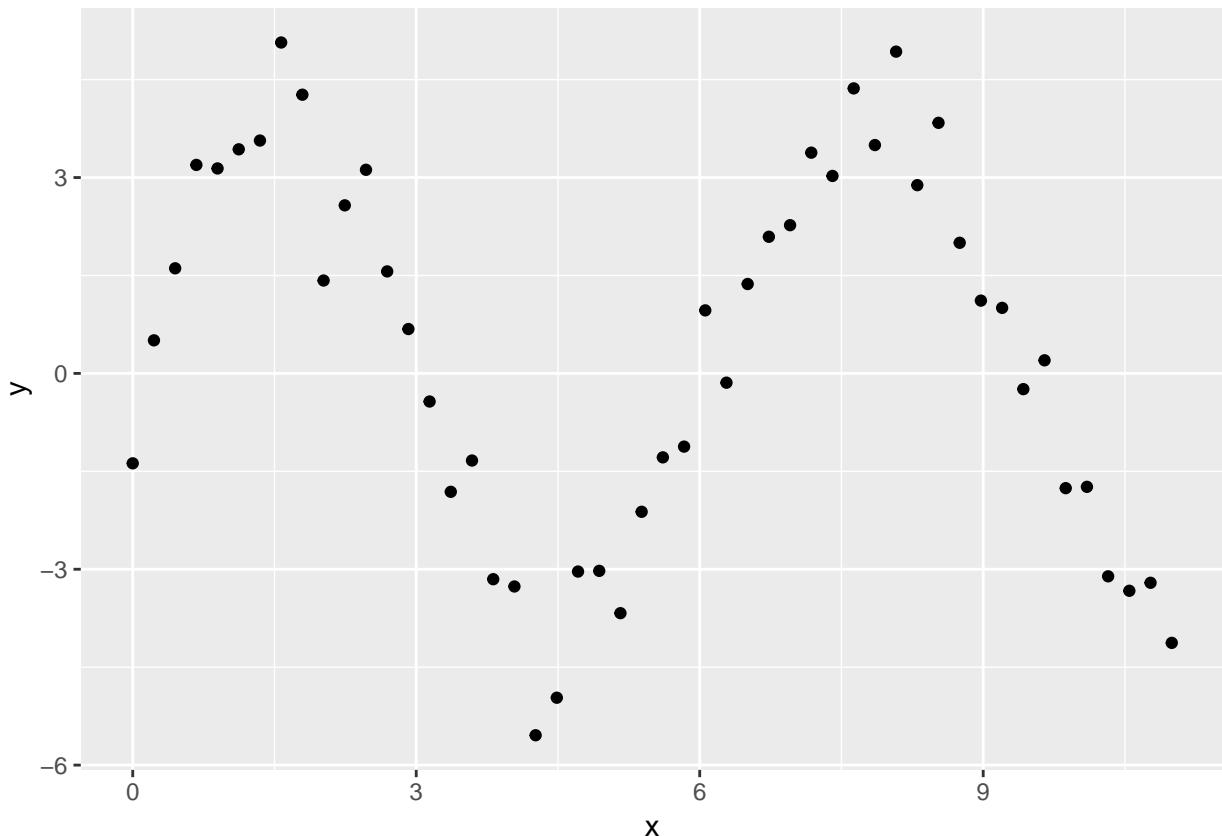
```
sim5 <- tibble(
 x = seq(0, 3.5 * pi, length = 50),
 y = 4 * sin(x) + rnorm(length(x))
)

ggplot(sim5, aes(x, y)) +
 geom_point()
```

```
sim1a <- tibble(
 x = rep(1:10, each = 3),
 y = x * 1.5 + 6 + rt(length(x), df = 2)
)
```

generate n number of datasets that fit characteristics of sim1a

```
sim1a_mult <- tibble(num = 1:500) %>%
 rowwise() %>%
 mutate(data = list(tibble(
 x = rep(1:10, each = 3),
 y = x * 1.5 + 6 + rt(length(x), df = 2)
))) %>%
#undoes rowwise (used to have much more of workflow with rowwise, but have
#changed to use more of map)
```



```
mod1 <- lm(y ~ splines::ns(x, 1), data = sim5)
mod2 <- lm(y ~ splines::ns(x, 2), data = sim5)
mod3 <- lm(y ~ splines::ns(x, 3), data = sim5)
mod4 <- lm(y ~ splines::ns(x, 4), data = sim5)
mod5 <- lm(y ~ splines::ns(x, 5), data = sim5)

grid <- sim5 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

ggplot(sim5, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)
```

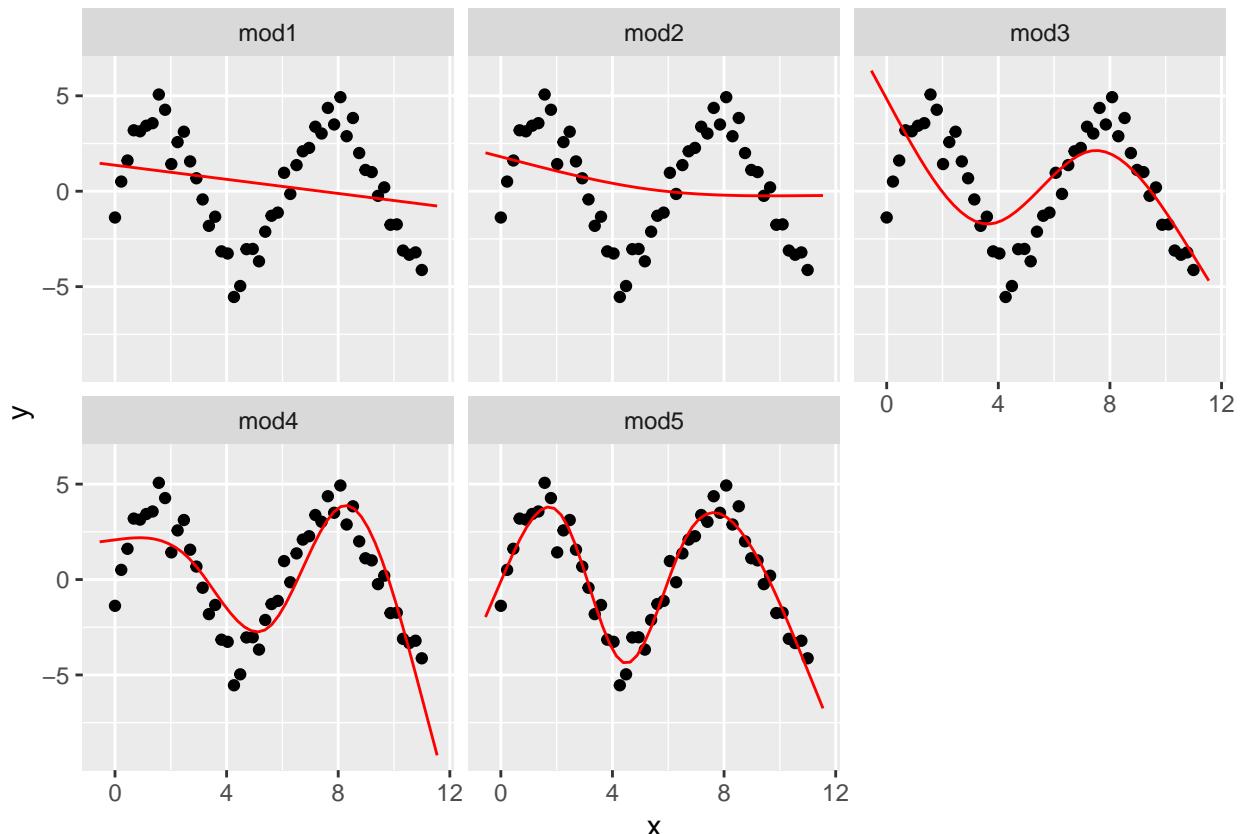
```

ungroup()

plots_prep <- sim1a_mult %>%
 mutate(mods = map(data, ~lm(y ~ x, data = .x))) %>%
 mutate(preds = map2(data, mods, modelr::add_predictions),
 rmse = map2_dbl(mods, data, modelr::rmse),
 mae = map2_dbl(mods, data, modelr::mae))

plots_prep %>%
 ggplot(aes(x = "rmse", y = rmse)) +
 geom_violin()

```



\*Notice that model with 5 degrees of freedom is able to now roughly approximate the model  
*Below are notes on performance of splines vs polynomials when extrapolating data*

```

sim5.1 <- tibble(
 x = seq(-pi, 4.5 * pi, length = 50),
 y = 4 * sin(x) + rnorm(length(x))
)

```

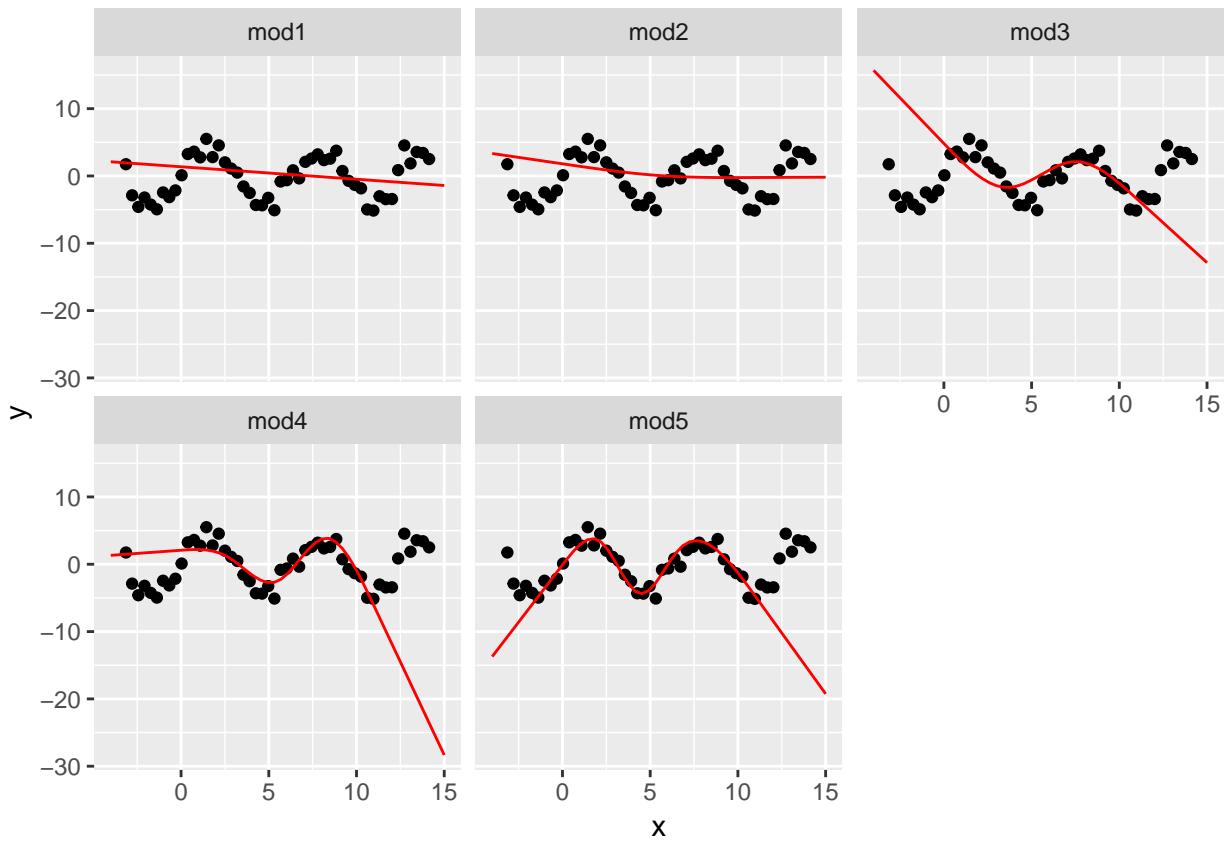
Plot the models that used ns for natural splines

```

grid <- sim5.1 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

ggplot(sim5.1, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)

```



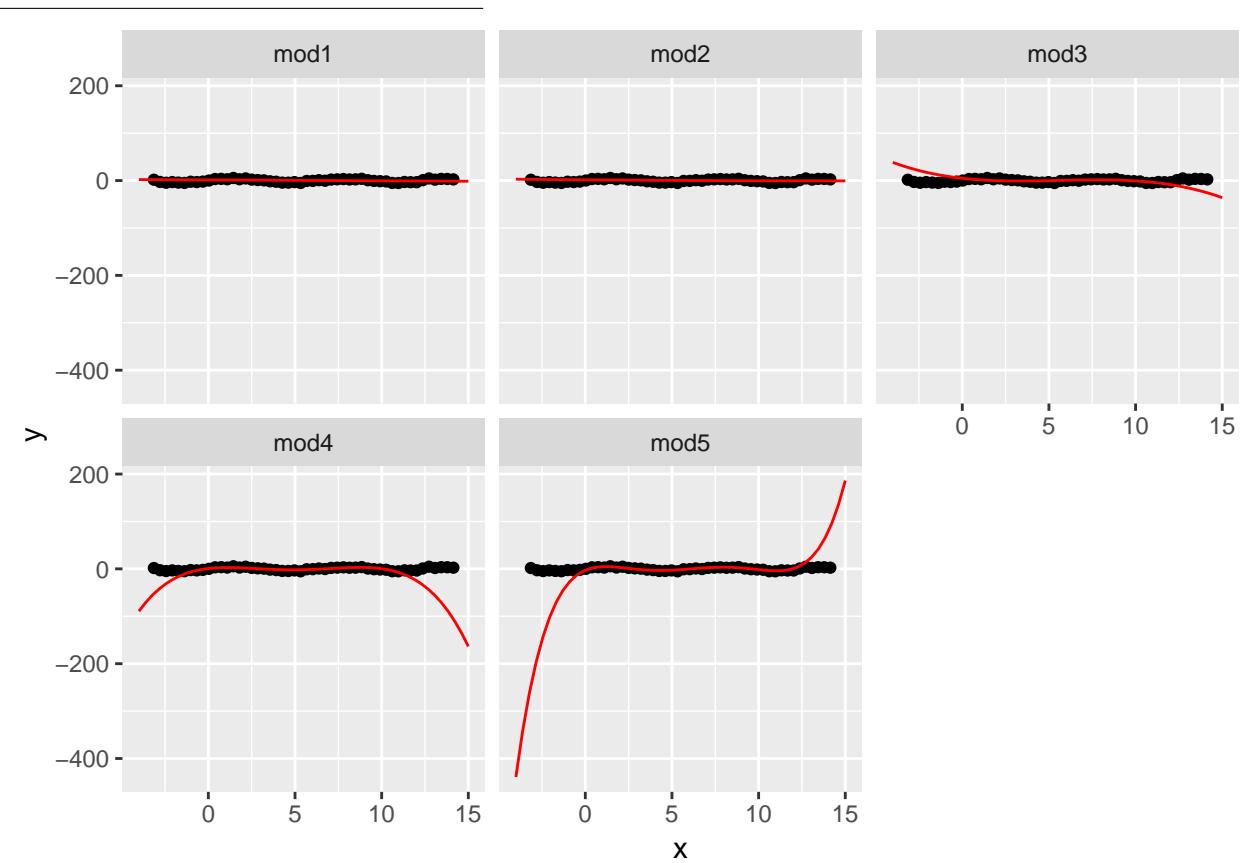
- Notice 5 degrees of freedom only allows it to mirror up-down-up-down, representing behavior of 5th degree polynomial, extrapolating outside of this performance is poor

*Build equivalent models using poly*

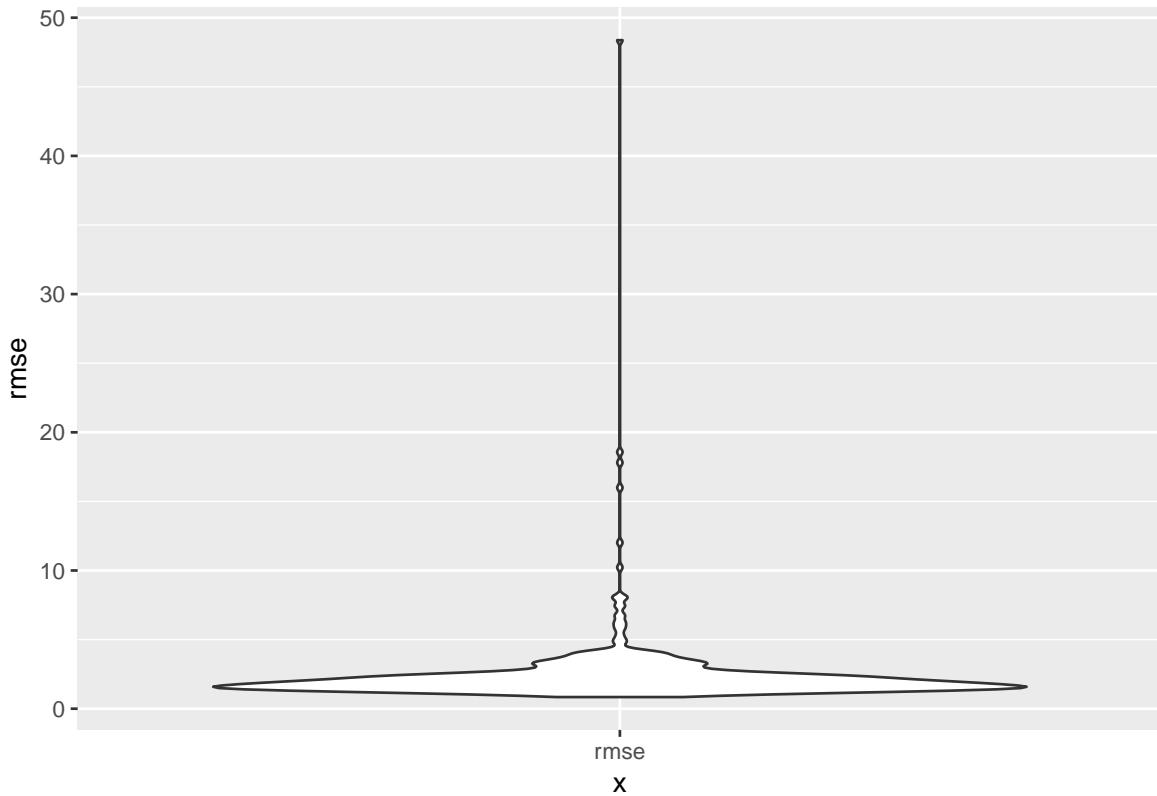
```
mod1 <- lm(y ~ poly(x, 1), data = sim5)
mod2 <- lm(y ~ poly(x, 2), data = sim5)
mod3 <- lm(y ~ poly(x, 3), data = sim5)
mod4 <- lm(y ~ poly(x, 4), data = sim5)
mod5 <- lm(y ~ poly(x, 5), data = sim5)

grid <- sim5.1 %>%
 data_grid(x = modelr::seq_range(x, n = 50, expand = 0.1)) %>%
 gather_predictions(mod1, mod2, mod3, mod4, mod5, .pred = "y")

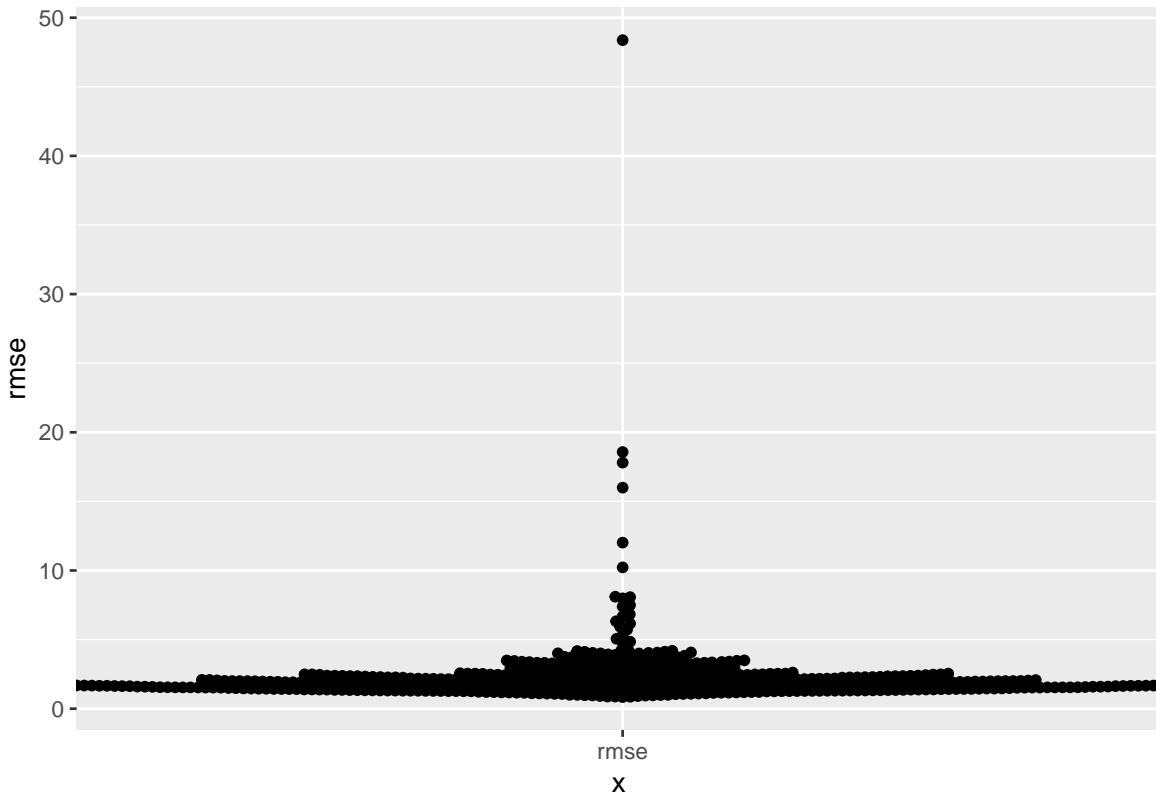
ggplot(sim5.1, aes(x, y)) +
 geom_point() +
 geom_line(data = grid, colour = "red") +
 facet_wrap(~ model)
```



- Performance on extrapolation becomes much worse for the polynomial though
- Notice that the values cover a much larger codomain that is much farther from the actual data once extended.



```
plots_prep %>%
 ggplot(aes(x = "rmse", y = rmse)) +
 ggbeeswarm::geom_beeswarm()
```



- as a metric it tends to be more susceptible to outliers, than say mae
2. One way to make linear models more robust is to use a different distance measure. For example, instead of root-mean-squared distance, you could use mean-absolute distance:

```
measure_distance <- function(mod, data) {
 diff <- data$y - make_prediction(mod, data)
 mean(abs(diff))
}
```

Use `optim()` to fit this model to the simulated data above and compare it to the linear model.

```
model_1df <- function(betas, x1 = sim1$x) {
 betas[1] + x1 * betas[2]
}

measure_mae <- function(mod, data) {
 diff <- data$y - model_1df(betas = mod, data$x)
 mean(abs(diff))
}

measure_rmse <- function(mod, data) {
 diff <- data$y - model_1df(betas = mod, data$x)
 sqrt(mean(diff^2))
}

best_mae_sims <- map(sim1a_mult$data, ~optim(c(0,0), measure_mae, data = .x))
best_rmse_sims <- map(sim1a_mult$data, ~optim(c(0,0), measure_rmse, data = .x))
```

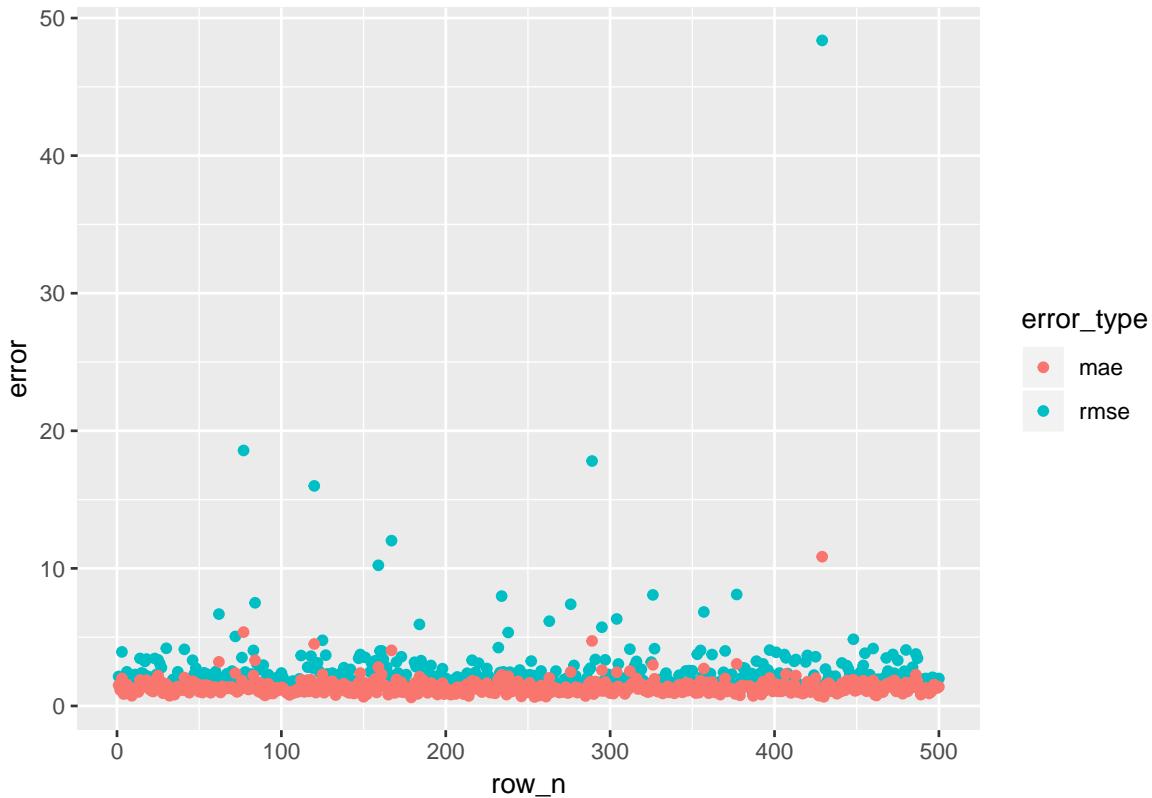
```

mae_df <- best_mae_sims %>%
 map("value") %>%
 transpose() %>%
 set_names(c("error")) %>%
 as_tibble() %>%
 unnest() %>%
 mutate(error_type = "mae",
 row_n = row_number())

rmse_df <- best_rmse_sims %>%
 map("value") %>%
 transpose() %>%
 set_names(c("error")) %>%
 as_tibble() %>%
 unnest() %>%
 mutate(error_type = "rmse",
 row_n = row_number())

bind_rows(rmse_df, mae_df) %>%
 ggplot(aes(x = row_n, colour = error_type)) +
 geom_point(aes(y = error))

```

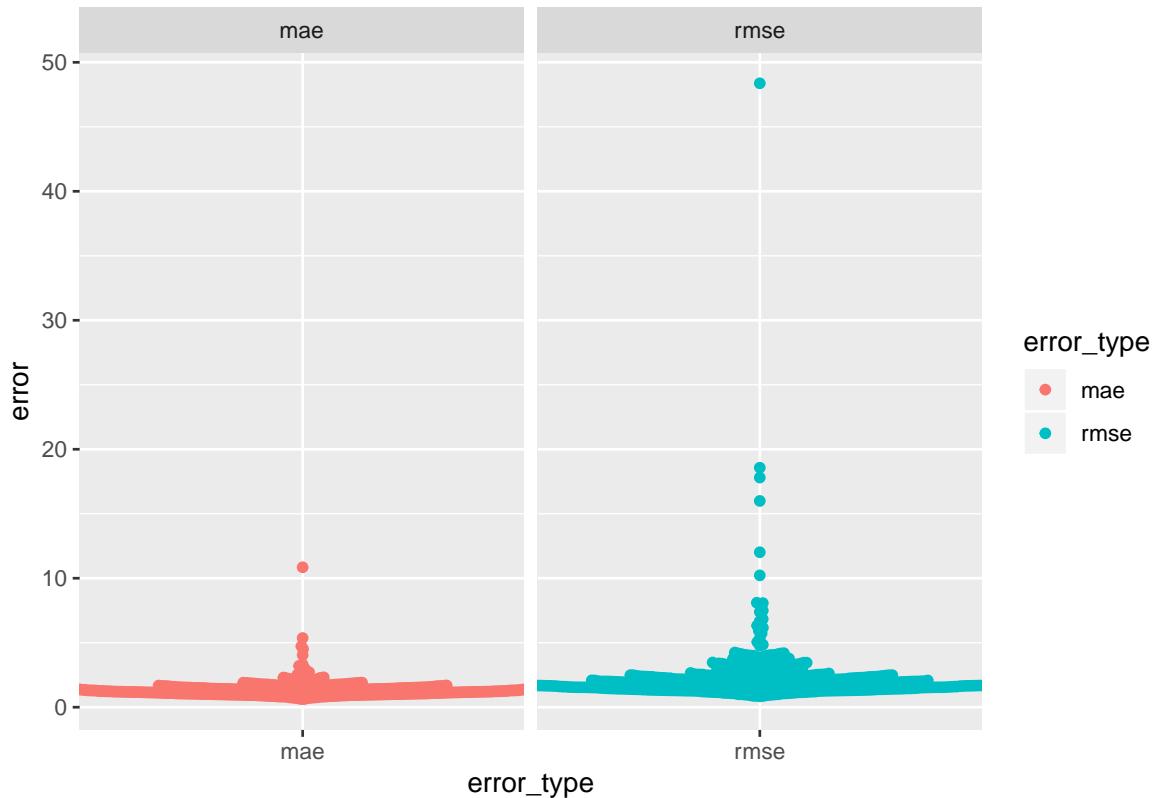


- you can see the error for rmse seems to have more extreme examples

```

bind_rows(rmse_df, mae_df) %>%
 ggplot(aes(x = error_type, colour = error_type)) +
 ggbeeswarm::geom_beeswarm(aes(y = error)) +
 facet_wrap(~error_type, scales = "free_x")

```

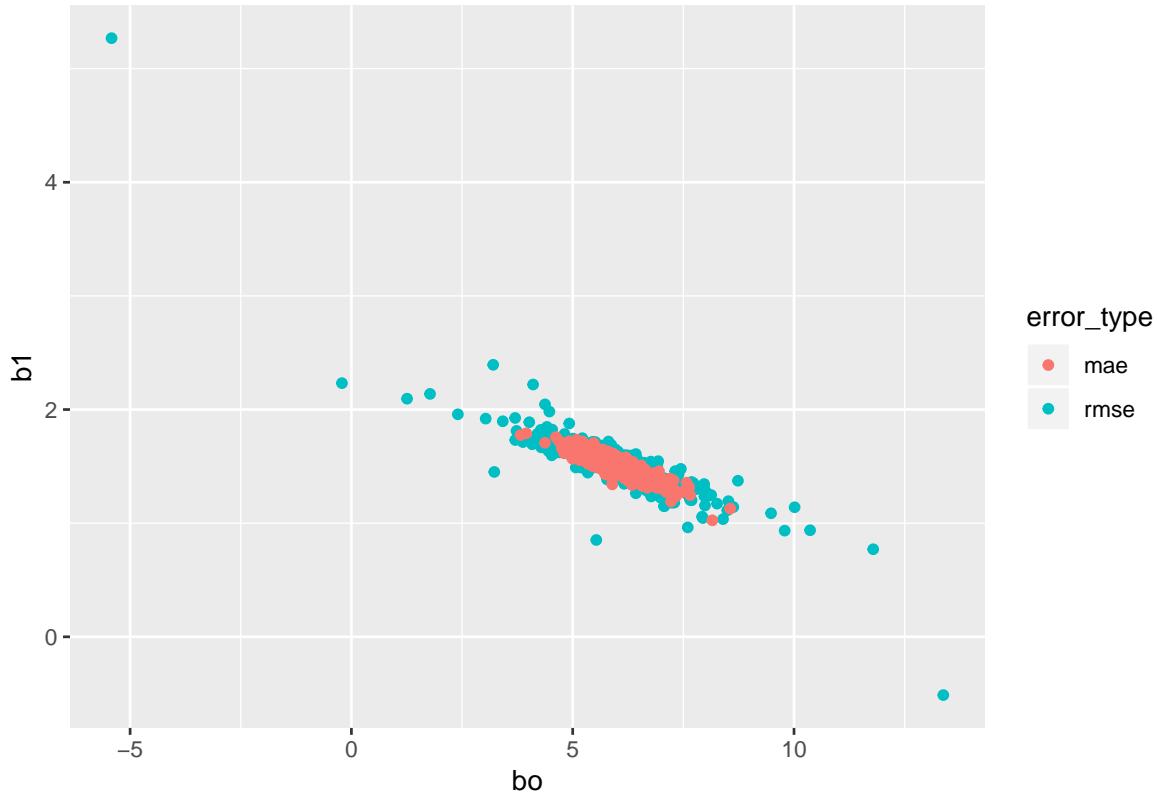


- let's look at differences in the coefficients produced

```
mae_df <- best_mae_sims %>%
 map("par") %>%
 transpose() %>%
 set_names(c("bo", "b1")) %>%
 as_tibble() %>%
 unnest() %>%
 mutate(error_type = "mae",
 row_n = row_number())

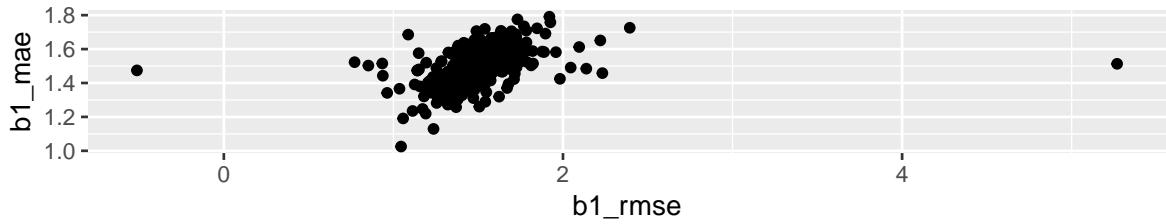
rmse_df <- best_rmse_sims %>%
 map("par") %>%
 transpose() %>%
 set_names(c("bo", "b1")) %>%
 as_tibble() %>%
 unnest() %>%
 mutate(error_type = "rmse",
 row_n = row_number())

bind_rows(rmse_df, mae_df) %>%
 ggplot(aes(x = bo, colour = error_type)) +
 geom_point(aes(y = b1))
```



- see more variability in the b1
- another way of visualizing the variability in coefficients is below

```
left_join(rmse_df, mae_df, by = "row_n", suffix = c("_rmse", "_mae")) %>%
 ggplot(aes(x = b1_rmse, y = b1_mae)) +
 geom_point() +
 coord_fixed()
```



3. One challenge with performing numerical optimisation is that it's only guaranteed to find one local optima. What's the problem with optimising a three parameter model like this?

```
model1 <- function(a, data) {
 a[1] + data$x * a[2] + a[3]
}
```

- the problem is that there are multiple “best” solutions in this example.  $a[1]$  and  $a[3]$  together represent the intercept here.

```
models_two <- vector("list", 2)

model1 <- function(a, data) {
 a[1] + data$x * a[2] + a[3]
}

models_two[[1]] <- optim(c(0, 0, 0), measure_rmse, data = sim1)
models_two[[1]]$par
```

```
[1] 4.219814 2.051678 -3.049197
model1 <- function(a, data) {
 a[1] + data$x * a[2]
}

models_two[[2]] <- optim(c(0, 0), measure_rmse, data = sim1)

models_two
```

```
[[1]]
```

```

[[1]]$par
[1] 4.219814 2.051678 -3.049197
##
[[1]]$value
[1] 2.128181
##
[[1]]$counts
function gradient
110 NA
##
[[1]]$convergence
[1] 0
##
[[1]]$message
NULL
##
##
[[2]]
[[2]]$par
[1] 4.222248 2.051204
##
[[2]]$value
[1] 2.128181
##
[[2]]$counts
function gradient
77 NA
##
[[2]]$convergence
[1] 0
##
[[2]]$message
NULL

```

- a1 and a3 are essentially equivalent, so optimizes somewhat arbitrarily, in this case can see the a1+a3 in the 1st (when there are 3 parameters) is equal to a1 in the 2nd (when there are only two parameters)...
- it would be nice if this spit out a warning of colinearity or something...

## 27.2 23.3: Visualising models

### 27.2.1 23.3.3

1. Instead of using `lm()` to fit a straight line, you can use `loess()` to fit a smooth curve. Repeat the process of model fitting, grid generation, predictions, and visualisation on `sim1` using `loess()` instead of `lm()`. How does the result compare to `geom_smooth()`?

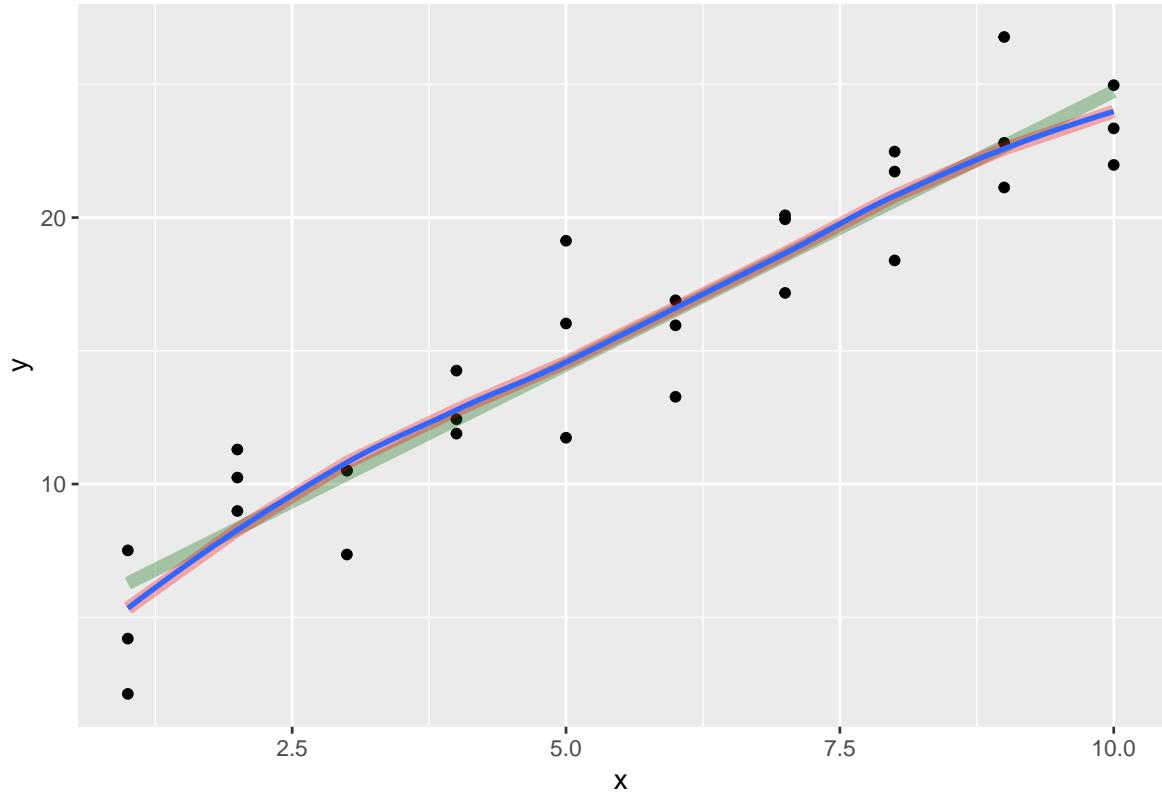
```

sim1_mod <- lm(y ~ x, data = sim1)
sim1_mod_loess <- loess(y ~ x, data = sim1)

#Look at plot of points
sim1 %>%
 add_predictions(sim1_mod, var = "pred_lin") %>%
 add_predictions(sim1_mod_loess) %>

```

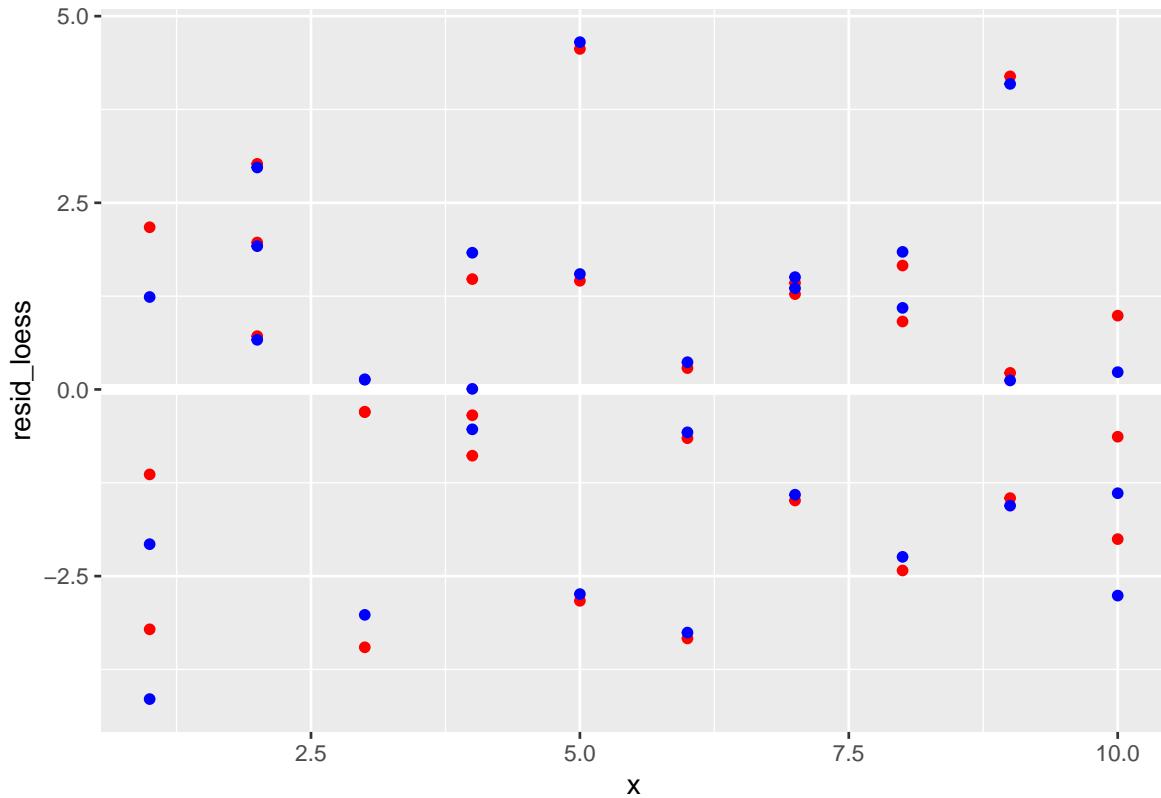
```
add_residuals(sim1_mod_loess) %>%
ggplot()+
 geom_point(aes(x = x, y = y))+
 geom_line(aes(x = x, y = pred_lin), colour = "dark green", alpha = 0.3, size = 2.5)+
 geom_line(aes(x = x, y = pred), colour = "red", alpha = 0.3, size = 2.5)+
 geom_smooth(aes(x = x, y = y), se = FALSE)
```



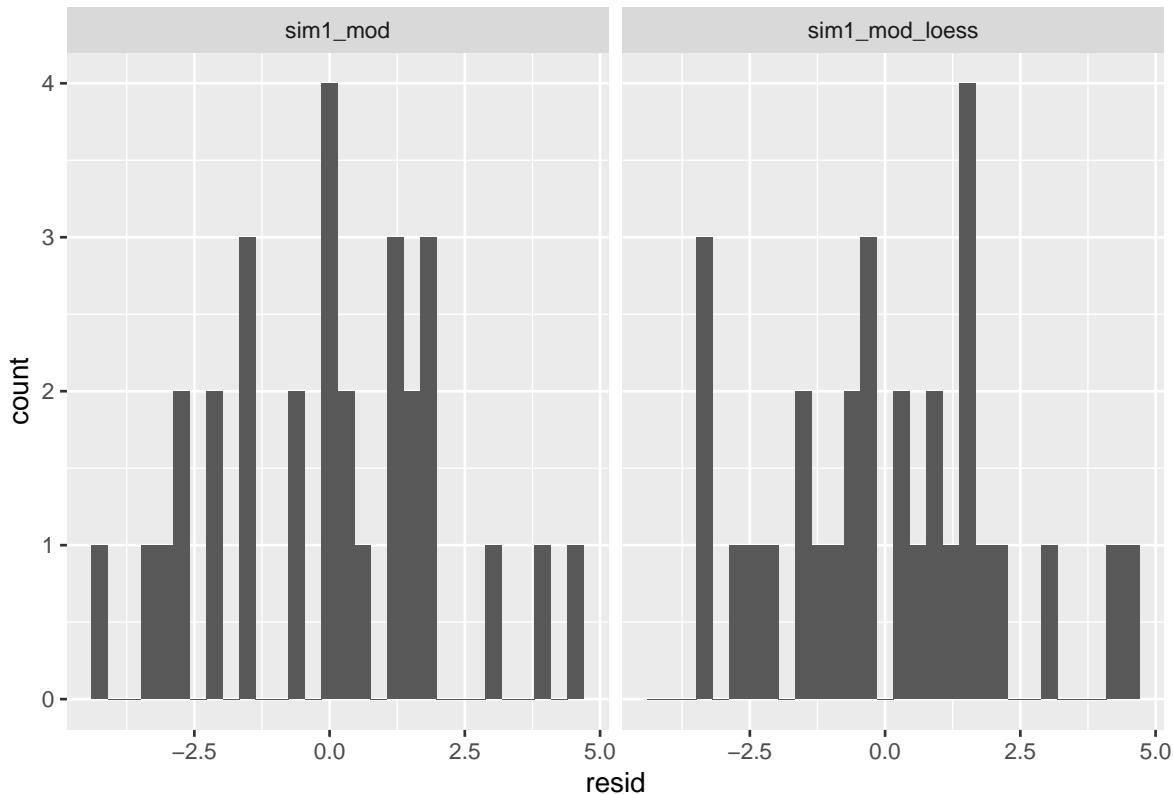
1-1.bb

- For sim1, the default value for `geom_smooth` is to use loess, os it is the exact same. `geom_smooth` will sometimes use gam or other methods depending on data, note that there is also a `weight` argument that can be useful
- this relationship looks pretty solidly linear
  - below are some plots of the resid, just for kicks

```
sim1 %>%
 add_predictions(sim1_mod_loess, var = "pred_loess") %>%
 add_residuals(sim1_mod_loess, var = "resid_loess") %>%
 add_predictions(sim1_mod, var = "pred_lin") %>%
 add_residuals(sim1_mod, var = "resid_lin") %>%
 # mutate(row_n = row_number) %>%
 ggplot()+
 geom_ref_line(h = 0)+
 geom_point(aes(x = x, y = resid_loess), colour = "red")+
 geom_point(aes(x = x, y = resid_lin), colour = "blue")
```



```
sim1 %>%
 gather_residuals(sim1_mod, sim1_mod_loess) %>%
 ggplot() +
 geom_histogram(aes(x = resid)) +
 facet_wrap(~model)
```



2. `add_predictions()` is paired with `gather_predictions()` and `spread_predictions()`. How do these three functions differ?

- `spread_predictions()` adds a new `pred` for each model included
- `gather_predictions()` adds 2 columns `model` and `pred` for each model and repeats the input rows for each model (seems like it would work well with facets)

```
sim1 %>%
 spread_predictions(sim1_mod, sim1_mod_loess)
```

```
A tibble: 30 x 4
x y sim1_mod sim1_mod_loess
<int> <dbl> <dbl> <dbl>
1 1 4.20 6.27 5.34
2 1 7.51 6.27 5.34
3 1 2.13 6.27 5.34
4 2 8.99 8.32 8.27
5 2 10.2 8.32 8.27
6 2 11.3 8.32 8.27
7 3 7.36 10.4 10.8
8 3 10.5 10.4 10.8
9 3 10.5 10.4 10.8
10 4 12.4 12.4 12.8
... with 20 more rows
```

*#How can I add a prefix when using spread\_predictions() ? -- could use the method below*

```
sim1 %>%
 gather_predictions(sim1_mod, sim1_mod_loess) %>%
 mutate(model = str_c(model, "_pred")) %>%
```

```

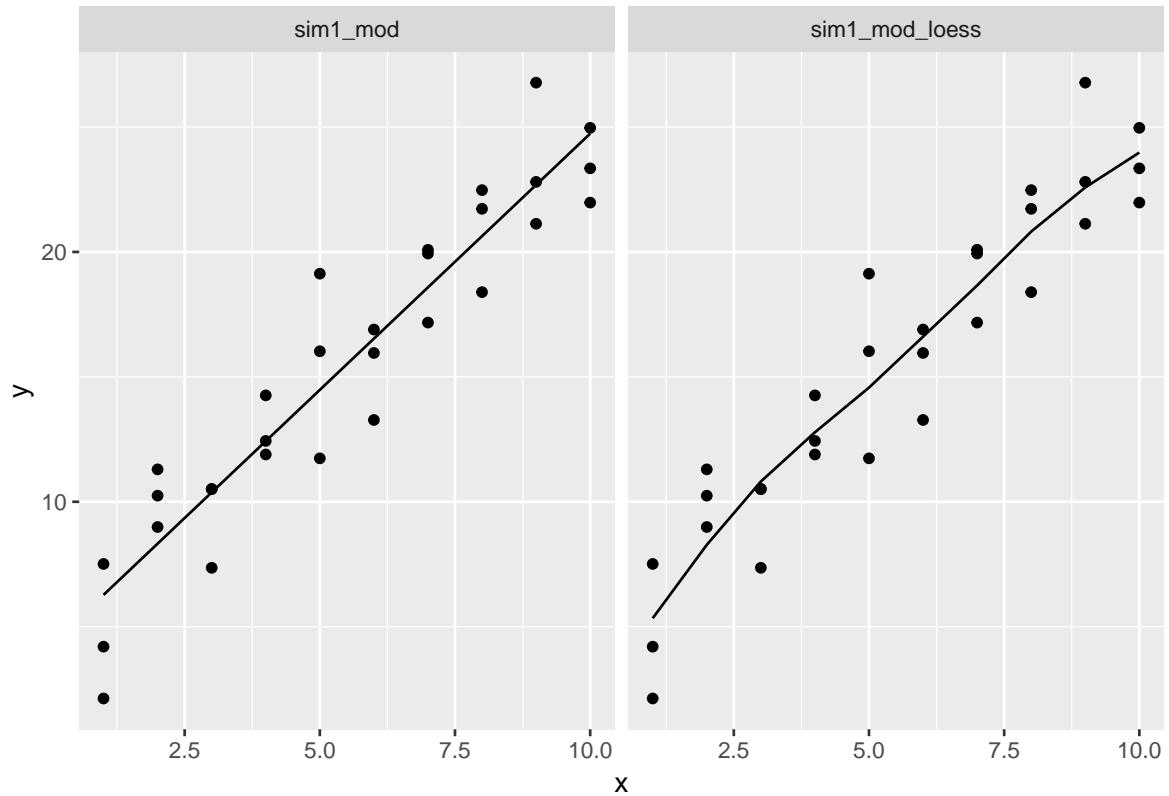
spread(key = model, value = pred)

A tibble: 30 x 4
x y sim1_mod_loess_pred sim1_mod_pred
<int> <dbl> <dbl> <dbl>
1 1 2.13 5.34 6.27
2 1 4.20 5.34 6.27
3 1 7.51 5.34 6.27
4 2 8.99 8.27 8.32
5 2 10.2 8.27 8.32
6 2 11.3 8.27 8.32
7 3 7.36 10.8 10.4
8 3 10.5 10.8 10.4
9 3 10.5 10.8 10.4
10 4 11.9 12.8 12.4
... with 20 more rows

#now could add a spread_residuals() without it breaking...

sim1 %>%
 gather_predictions(sim1_mod, sim1_mod_loess) %>%
 ggplot() +
 geom_point(aes(x = x, y = y)) +
 geom_line(aes(x = x, y = pred)) +
 facet_wrap(~model)

```



2-1.bb

3. What does `geom_ref_line()` do? What package does it come from? Why is displaying a reference line in plots showing residuals useful and important?

- It comes from ggplot2 and shows either a geom\_hline or a geom\_vline, depending on whether you specify h or v. `ggplot2::geom_ref_line`
4. Why might you want to look at a frequency polygon of absolute residuals? What are the pros and cons compared to looking at the raw residuals?
- may be good for situations when you have TONS of residuals, and is hard to look at?...
  - pros are it may be easier to get sense of count, cons are that you can't plot it against something like x so patterns associated with residuals will not be picked-up, e.g. heteroskedasticity, or more simply, signs that the model could be improved by incorporating other vars in the model

## 27.3 23.4: Formulas and model families

### 27.3.1 23.4.5

1. What happens if you repeat the analysis of `sim2` using a model without an intercept. What happens to the model equation? What happens to the predictions?

```
mod2 <- lm(y ~ x, data = sim2)
mod2_NoInt <- lm(y ~ x - 1, data = sim2)

mod2

##
Call:
lm(formula = y ~ x, data = sim2)
##
Coefficients:
(Intercept) xb xc xd
1.1522 6.9639 4.9750 0.7588

mod2_NoInt

##
Call:
lm(formula = y ~ x - 1, data = sim2)
##
Coefficients:
xa xb xc xd
1.152 8.116 6.127 1.911
```

- you have an ANOVA analysis, one of the variables takes on the value of the intercept, the others all have the value of the intercept added to them.
2. Use `model_matrix()` to explore the equations generated for the models I fit to `sim3` and `sim4`. Why is \* a good shorthand for interaction?

```
model_matrix(y ~ x1*x2, data = sim3)

A tibble: 120 x 8
`(Intercept)` x1 x2b x2c x2d `x1:x2b` `x1:x2c` `x1:x2d`
<dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
1 1 1 0 0 0 0 0 0
2 1 1 0 0 0 0 0 0
3 1 1 0 0 0 0 0 0
4 1 1 1 0 0 1 0 0
5 1 1 1 0 0 1 0 0
```

```

6 1 1 0 0 1 0 0
7 1 1 0 1 0 1 0
8 1 1 0 1 0 1 0
9 1 1 0 1 0 1 0
10 1 1 0 0 1 0 1
... with 110 more rows

model_matrix(y ~ x1*x2, data = sim4)

A tibble: 300 x 4
`(Intercept)` x1 x2 `x1:x2`
<dbl> <dbl> <dbl> <dbl>
1 1 -1 -1 1
2 1 -1 -1 1
3 1 -1 -1 1
4 1 -1 -0.778 0.778
5 1 -1 -0.778 0.778
6 1 -1 -0.778 0.778
7 1 -1 -0.556 0.556
8 1 -1 -0.556 0.556
9 1 -1 -0.556 0.556
10 1 -1 -0.333 0.333
... with 290 more rows

```

- because each of the levels are multiplied by one another (just don't have to write in the design variables)
3. Using the basic principles, convert the formulas in the following two models into functions. (Hint: start by converting the categorical variable into 0-1 variables.)

```

mod1 <- lm(y ~ x1 + x2, data = sim3)
mod2 <- lm(y ~ x1 * x2, data = sim3)

```

- do later
4. For `sim4`, which of `mod1` and `mod2` is better? I think `mod2` does a slightly better job at removing patterns, but it's pretty subtle. Can you come up with a plot to support my claim?

```

```r
mod1 <- lm(y ~ x1 + x2, data = sim4)
mod2 <- lm(y ~ x1 * x2, data = sim4)

grid <- modelr::seq_range(sim4$x1, n = 3, pretty = TRUE)

sim4 %>%
  gather_residuals(mod1, mod2) %>%
  mutate(resid_abs = (resid)^2) %>%
  group_by(model) %>%
  summarise(rmse = sqrt(mean(resid_abs)))
```

```
## # A tibble: 2 x 2
##   model   rmse
##   <chr> <dbl>
## 1 mod1   2.10
## 2 mod2   2.06

```

```
```
```

\* The aggregate `rmse` between the two models is nearly the same.

```
```r
sim4 %>%
  gather_residuals(mod1, mod2) %>%
  ggplot(aes(x = resid, fill = model, group = model)) +
  geom_density(alpha = 0.3)
```

```

```
! [] (23-model-basics_files/figure-latex/unnamed-chunk-19-1.pdf)<!-- -->
```

\* any difference in resids is pretty subtle...

\*Let's plot them though and see how their predictions differ\*

```
```r
sim4 %>%
  spread_residuals(mod1, mod2) %>%
  gather_predictions(mod1, mod2) %>%
  ggplot(aes(x1, pred, colour = x2, group = x2)) +
  geom_line() +
  geom_point(aes(y = y), alpha = 0.3) +
  facet_wrap(~model)
```

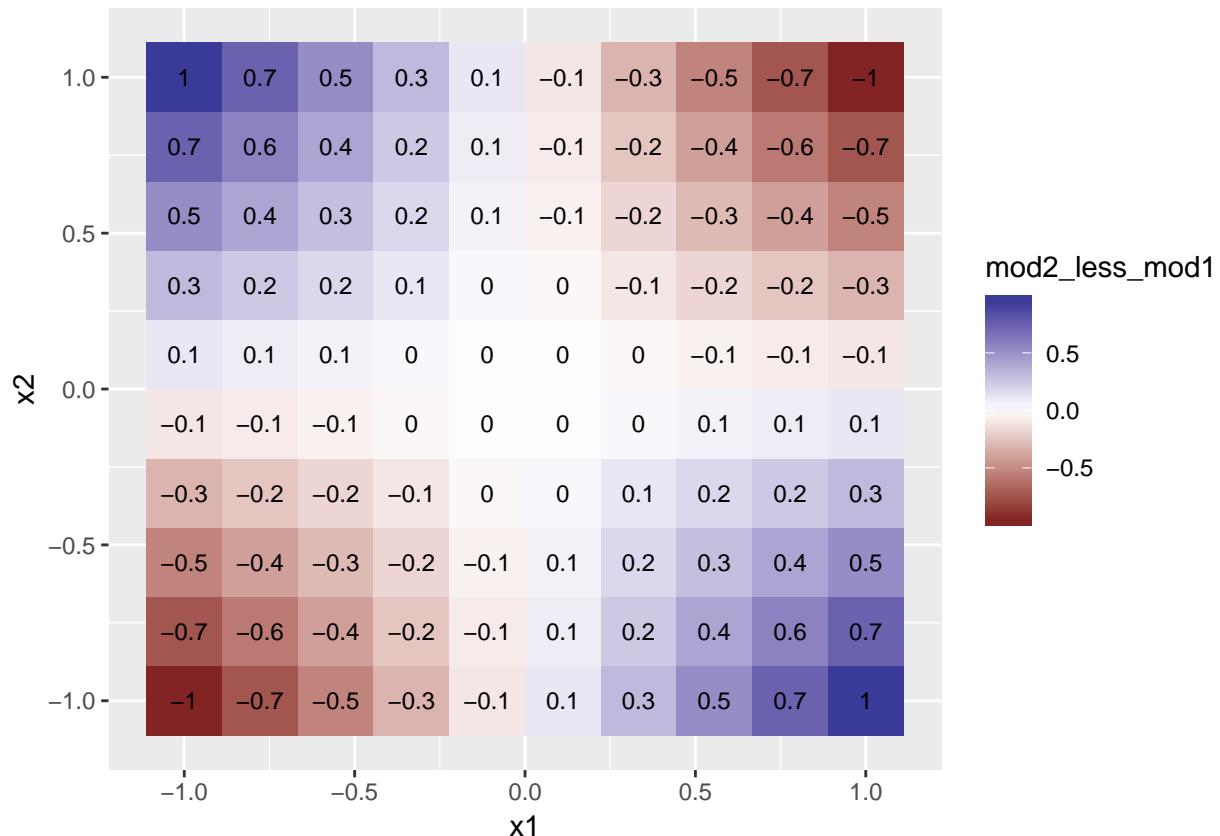
```

```
! [] (23-model-basics_files/figure-latex/unnamed-chunk-20-1.pdf)<!-- -->
```

\* notice subtle difference where for mod2 as x2 decreases, the predicted value for x1 also decreases, the values near where x2 and x1 are most near 0 should be where the residuals are most similar

\*Plot difference in residuals\*

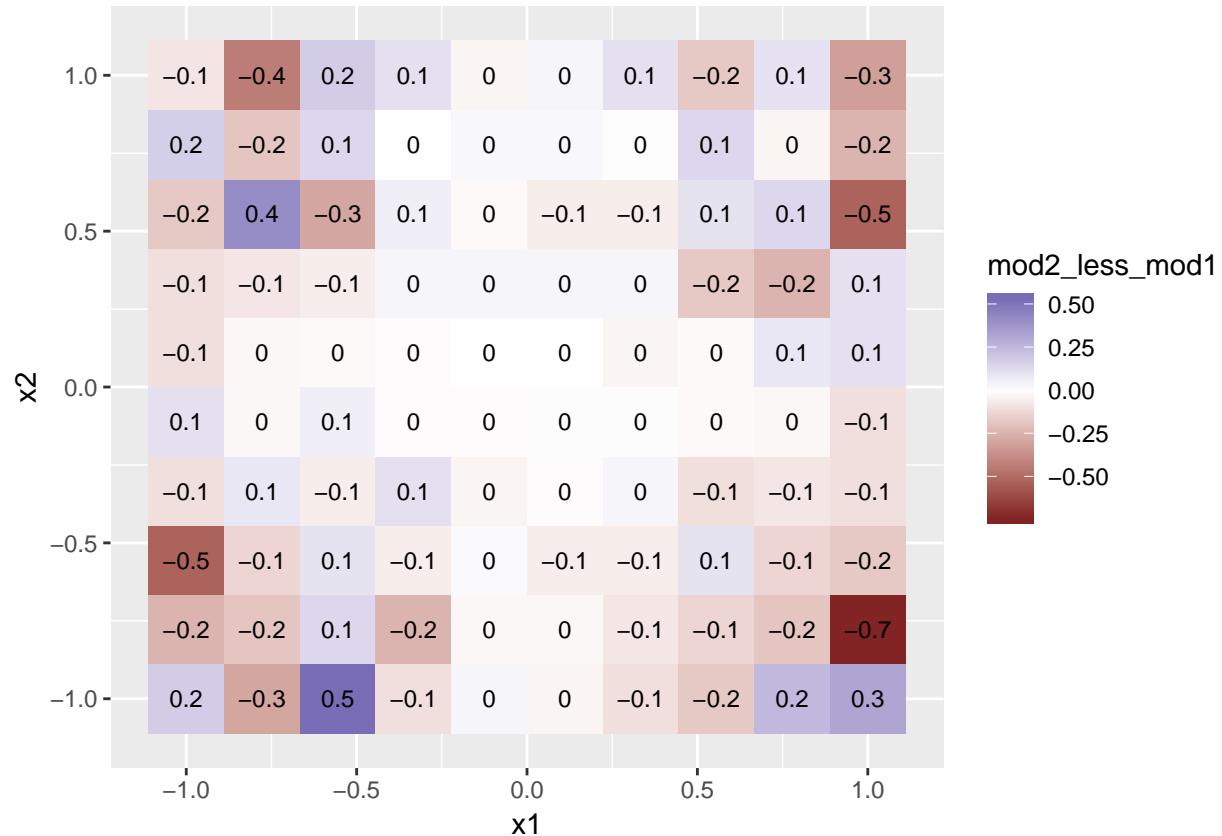
```
sim4 %>%
 spread_residuals(mod1, mod2) %>%
 mutate(mod2_less_mod1 = mod2 - mod1) %>%
 group_by(x1, x2) %>%
 summarise(mod2_less_mod1 = mean(mod2_less_mod1)) %>%
 ungroup() %>%
 ggplot(aes(x = x1, y = x2)) +
 geom_tile(aes(fill = mod2_less_mod1)) +
 geom_text(aes(label = round(mod2_less_mod1, 1)), size = 3) +
 scale_fill_gradient2()
```



- This shows how mod2 has higher valued predictions when x1 and x2 are opposite signs compared to the predictions from mod1

*Plot difference in distance from 0 between mod1 and mod1 resids*

```
sim4 %>%
 spread_residuals(mod1, mod2) %>%
 mutate_at(c("mod1", "mod2"), abs) %>%
 mutate(mod2_less_mod1 = mod2 - mod1) %>%
 group_by(x1, x2) %>%
 summarise(mod2_less_mod1 = mean(mod2_less_mod1)) %>%
 ungroup() %>%
 ggplot(aes(x = x1, y = x2))+
 geom_tile(aes(fill = mod2_less_mod1))+
 geom_text(aes(label = round(mod2_less_mod1, 1)), size = 3)+
 scale_fill_gradient2()
```



- see slightly more red than blue indicating that `mod2` may, in general, have slightly smaller residuals on a wider range of locations
  - however very little difference, and I might lean more towards `mod1` for simplicities sake



# Chapter 28

## Appendix

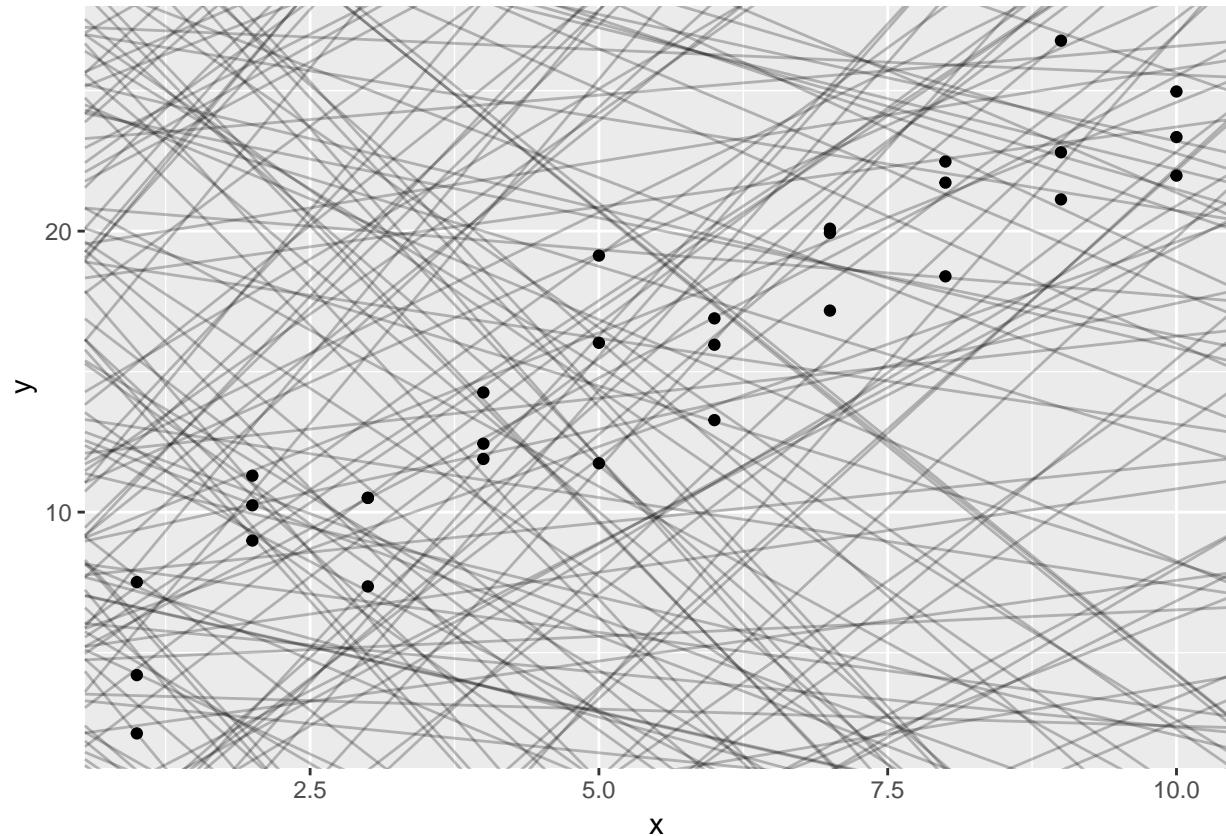
### 28.1 Other model families

- **Generalised linear models**, e.g. `stats::glm()`. Linear models assume that the response is continuous and the error has a normal distribution. Generalised linear models extend linear models to include non-continuous responses (e.g. binary data or counts). They work by defining a distance metric based on the statistical idea of likelihood.
- **Generalised additive models**, e.g. `mgcv::gam()`, extend generalised linear models to incorporate arbitrary smooth functions. That means you can write a formula like  $y \sim s(x)$  which becomes an equation like  $y = f(x)$  and let `gam()` estimate what that function is (subject to some smoothness constraints to make the problem tractable).
- **Penalised linear models**, e.g. `glmnet::glmnet()`, add a penalty term to the distance that penalises complex models (as defined by the distance between the parameter vector and the origin). This tends to make models that generalise better to new datasets from the same population.
- **Robust linear models**, e.g. `MASS:r1m()`, tweak the distance to downweight points that are very far away. This makes them less sensitive to the presence of outliers, at the cost of being not quite as good when there are no outliers.
- **Trees**, e.g. `rpart::rpart()`, attack the problem in a completely different way than linear models. They fit a piece-wise constant model, splitting the data into progressively smaller and smaller pieces. Trees aren't terribly effective by themselves, but they are very powerful when used in aggregate by models like **random forests** (e.g. `randomForest::randomForest()`) or **gradient boosting machines** (e.g. `xgboost::xgboost()`.)

### 28.2 23.2 book example

```
models <- tibble(
 a1 = runif(250, -20, 40),
 a2 = runif(250, -5, 5)
)

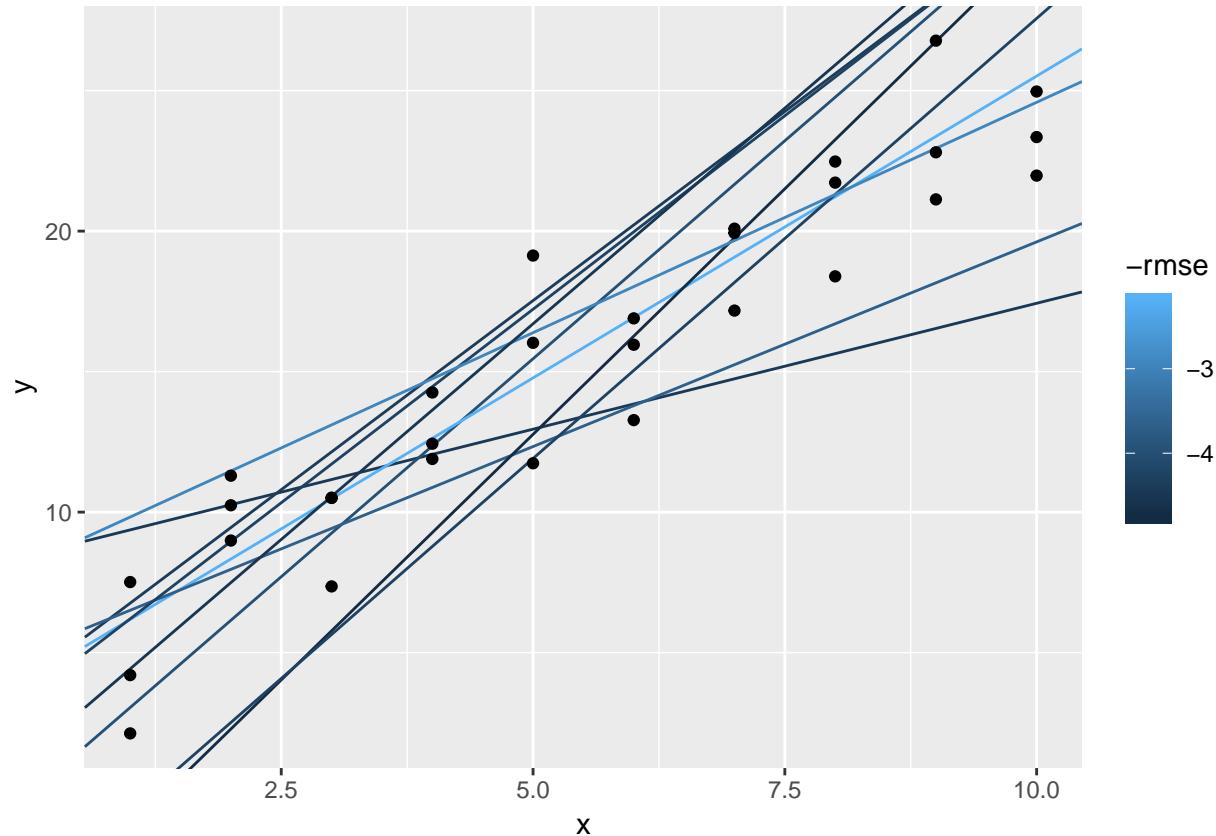
ggplot(sim1, aes(x,y)) +
 geom_abline(aes(intercept = a1, slope = a2), data = models, alpha = 0.25) +
 geom_point()
```



Next, let's set up a way to calculate the distance between predicted value and each point.

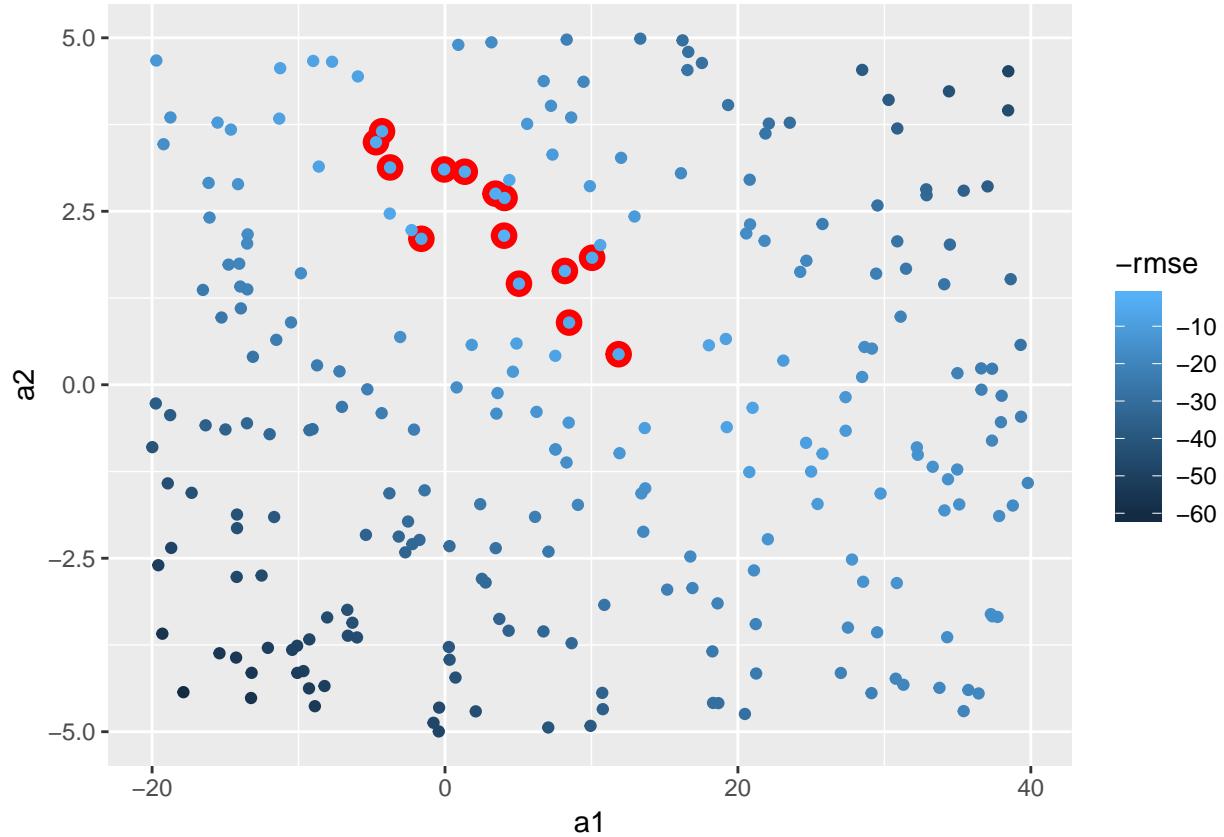
```
models_error <- models %>%
 mutate(preds = map2(.y = a1, .x = a2, ~mutate(sim1,
 pred = .x*x + .y,
 resid = y - pred,
 error_squared = (y - pred)^2,
 error_abs = abs(y - pred))),
 rmse = map_dbl(preds, ~with(.x, mean(error_squared)) %>% sqrt(.))),
 mae = map_dbl(preds, ~with(.x, mean(error_abs))),
 rank_rmse = min_rank(rmse))

ggplot(sim1, aes(x, y)) +
 geom_abline(aes(intercept = a1, slope = a2, colour = -rmse),
 data = filter(models_error, rank_rmse <= 10)) +
 geom_point()
```



Could instead plot this as a model of a1 vs a2 and whichever does the best

```
models_error %>%
 ggplot(aes(x = a1, y = a2)) +
 geom_point(colour = "red", size = 4, data = filter(models_error, rank_rmse < 15)) +
 geom_point(aes(colour = -rmse))
```



Could be more methodical and use Grid Search. Let's use the min and max points of the top 15 to set.

```
#need helper function because distance function expects the model as a numeric vector of length 2
sim1_rmse <- function(b0, b1, df = sim1, x = "x", y = "y"){
 ((b0 + b1*df[[x]]) - df[[y]])^2 %>% mean() %>% sqrt()
}

sim1_rmse(2,3)

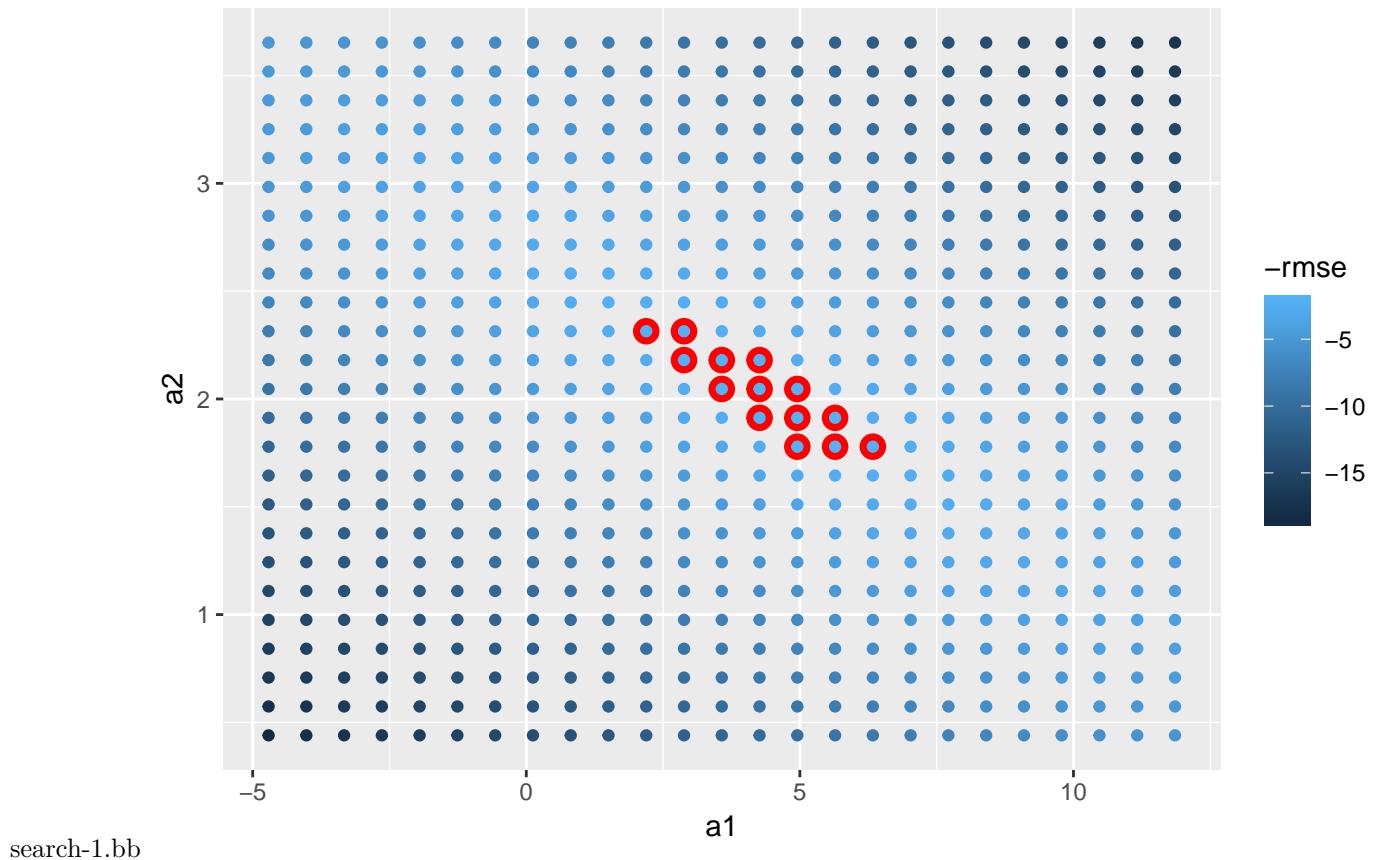
[1] 4.574414

grid_space <- models_error %>%
 filter(rank_rmse < 15) %>%
 summarise(min_x = min(a1),
 max_x = max(a1),
 min_y = min(a2),
 max_y = max(a2))

grid_models <- data_grid(grid_space,
 a1 = seq(min_x, max_x, length = 25),
 a2 = seq(min_y, max_y, length = 25)
) %>%
 mutate(rmse = map2_dbl(a1, a2, sim1_rmse, df = sim1))

grid_models %>%
 ggplot(aes(x = a1, y = a2))+
 geom_point(colour = "red", size = 4, data = filter(grid_models, min_rank(rmse) < 15))+
```

```
geom_point(aes(colour = -rmse))
```



In the future add-in a grid-search that would have used PCA to first rotate axes and then do min and max values.

Could instead use Newton-Raphson search with `optim`

```
model_1df <- function(betas, x1 = sim1$x) {
 betas[1] + x1 * betas[2]
}

measure_rmse <- function(mod, data) {
 diff <- data$y - model_1df(betas = mod, data$x)
 sqrt(mean(diff^2))
}

best_rmse <- optim(c(0,0), measure_rmse, data = sim1)

best_rmse$par

[1] 4.222248 2.051204
best_rmse$value

[1] 2.128181
```

Above is equivalent to R's `lm` function

```

sim1_mod <- lm(y ~ x, data = sim1)

sim1_mod %>% coef

(Intercept) x
4.220822 2.051533

rmse(sim1_mod, sim1)

[1] 2.128181

```

- Notice are *slightly* different, perhaps due to number of steps optim will take

E.g. could build a function for optimizing upon MAE instead and still works

```

measure_mae <- function(mod, data) {
 diff <- data$y - model_1df(betas = mod, data$x)
 mean(abs(diff))
}

best_mae <- optim(c(0,0), measure_mae, data = sim1)

best_mae$par

[1] 4.364852 2.048918

```

### 28.2.1 tidy grid\_space

Below is a pseudo-tidy way of creating the `grid_space` var from above, it actually took more effort to create this probably, so didn't use. However you could imagine if you had to do this across A LOT of values it could be worth doing it this way

```

fun_names <- tibble(fun = c(rep("min", 2), rep("max", 2)),
 coord = rep(c("x", "y"), 2),
 field_names = str_c(fun, "_", coord))

grid_space <- models_error %>%
 filter(rank_rmse < 15) %>%
 select(a1, a2) %>%
 rep(2) %>%
 invoke_map(.f = fun_names$fun,
 .x = .) %>%
 set_names(fun_names$field_names) %>%
 as_tibble()

grid_space

A tibble: 1 x 4
min_x min_y max_x max_y
<dbl> <dbl> <dbl> <dbl>
1 -4.71 0.440 11.9 3.65

```

## 28.3 23.4.5.4

Rather than `geom_density` or `geom_freqpoly` let's look at histogram with values overlaid rather than stacked.

```
```r
sim4 %>%
  gather_residuals(mod1, mod2) %>%
  ggplot(aes(x = resid, y = ..density.., fill = model))+
  geom_histogram(position = "identity", alpha = 0.3)
```

<!-- -->
```
knitr::opts_chunk$set(echo = TRUE, cache = TRUE, message = FALSE)
```

Make sure the following packages are installed:

Chapter 29

ch. 24: Model building

- `data_grid`, argument: `.model`: if the model needs variables that haven't been supplied explicitly, will auto-fill them with "typical" values; continuous → median; categorical → mode
- MASS::rlm robust linear model that uses "M estimation by default"
 - warning: MASS::select will clash with dplyr::select, so I usually won't load in MASS explicitly

29.1 24.2: Why are low quality diamonds more expensive?

```
# model for only small diamonds
diamonds2 <- diamonds %>%
  filter(carat <= 2.5) %>%
  mutate(lprice = log2(price),
        lcarat = log2(carat))

mod_diamond <- lm(lprice ~ lcarat, data = diamonds2)

mod_diamond2 <- lm(lprice ~ lcarat + color + cut + clarity, data = diamonds2)

diamonds2 <- diamonds2 %>%
  add_residuals(mod_diamond2, "resid_lg")
```

29.1.1 24.2.3

1. In the plot of `lcarat` vs. `lprice`, there are some bright vertical strips. What do they represent?

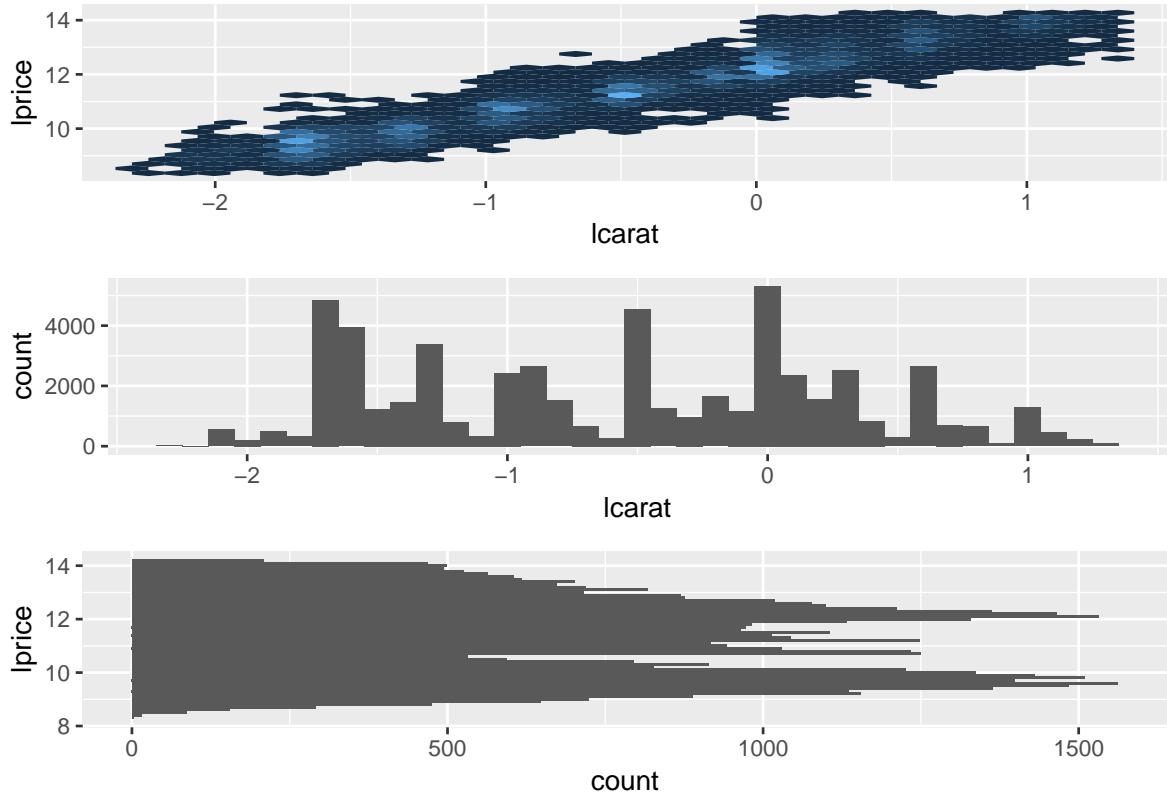
```
plot_lc_lp <- diamonds2 %>%
  ggplot(aes(lcarat, lprice)) +
  geom_hex(show.legend = FALSE)

plot_lp_lc <- diamonds2 %>%
  ggplot(aes(lprice, lcarat)) +
  geom_hex(show.legend = FALSE)

plot_lp <- diamonds2 %>%
  ggplot(aes(lprice)) +
  geom_histogram(binwidth = .1)
```

```
plot_lc <- diamonds2 %>%
  ggplot(aes(lcarat)) +
  geom_histogram(binwidth = 0.1)

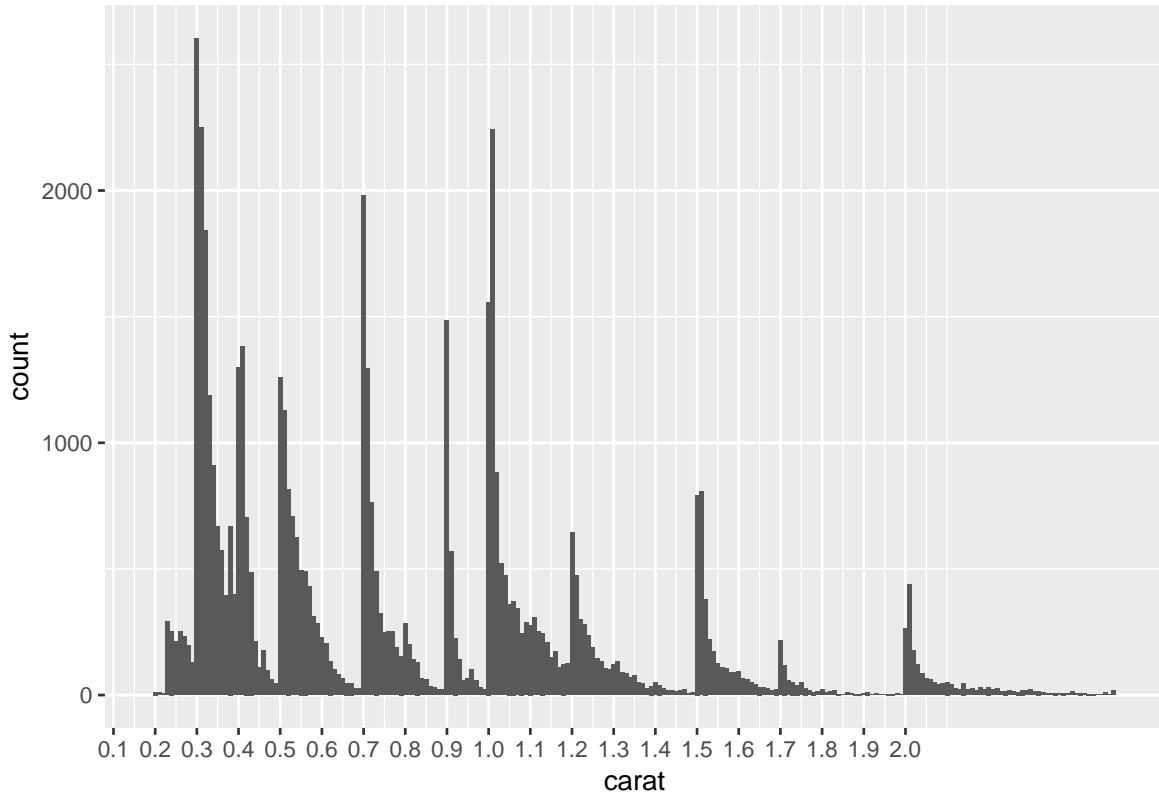
gridExtra::grid.arrange(plot_lc_lp, plot_lc, plot_lp + coord_flip())
```



- The vertical bands correspond with clumps of `carat_lg` values falling across a range of `price_lg` values

Histogram of `carat` values

```
diamonds2 %>%
  ggplot(aes(carat)) +
  geom_histogram(binwidth = 0.01) +
  scale_x_continuous(breaks = seq(0, 2, 0.1))
```



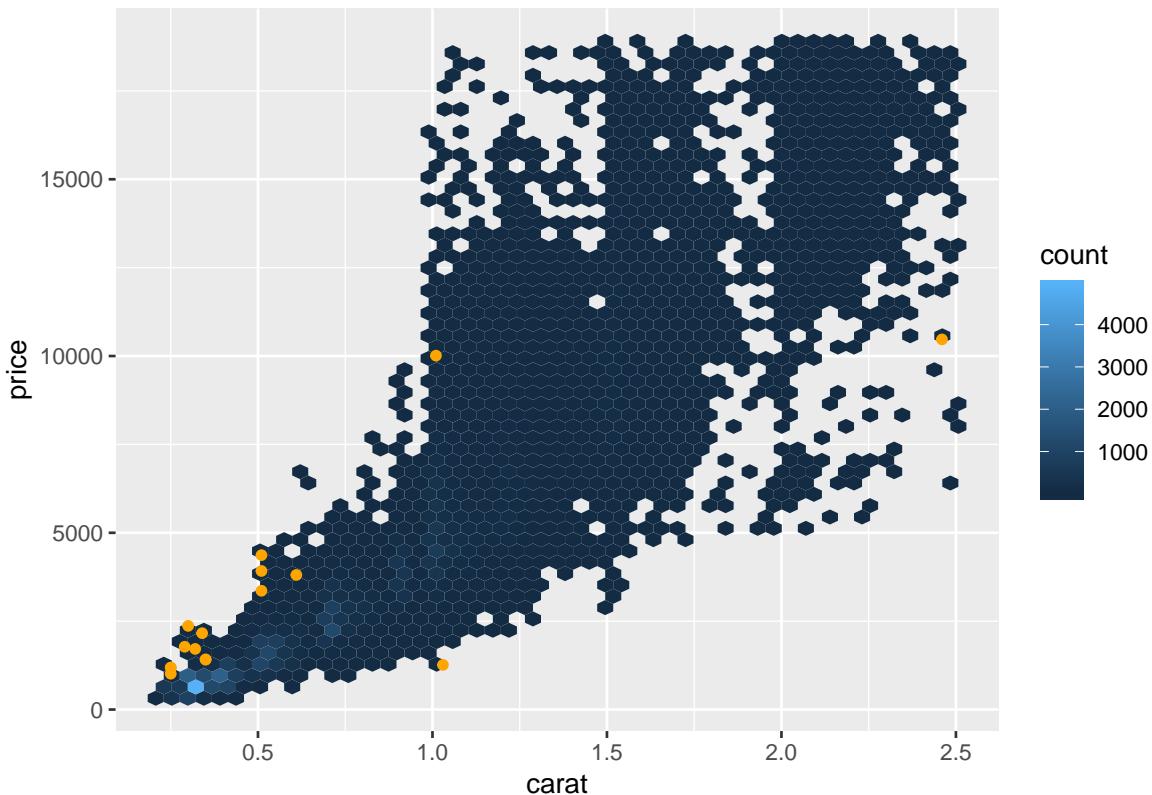
- The chart above shows spikes in carat values at 0.3, 0.4, 0.41, 0.5, 0.7, 0.9, 1.0, 1.01, 1.2, 1.5, 1.7 and 2.0, each distribution spikes at that value and then decreases until hitting the next spike
 - This suggests there is a preference for round numbers ending on tenths
 - It's curious why you don't see really see spikes at 0.6, 0.8, 0.9, 1.1, 1.3, 1.4, 1.6, 1.8, 1.9, it suggests either there is something special about those particular values – perhaps diamonds just tend to develop near those sizes so are more available in sizes of 0.7 than say 0.8
 - this article also found similar spikes: <https://www.diamdb.com/carat-weight-vs-face-up-size/> as did this: <https://www.pricescope.com/wiki/diamonds/diamond-carat-weight>, which use different data sets (though they do not explain the spike at 0.9 but no spike at 1.4)
2. If $\log(\text{price}) = a_0 + a_1 * \log(\text{carat})$, what does that say about the relationship between `price` and `carat`?
- because we're using a natural log it means that an a_1 percentage change in carat corresponds with an a_1 percentage increase in the price
 - if you had used a log base 2 it has a different interpretation that can be thought of in terms of relationship of doubling
3. Extract the diamonds that have very high and very low residuals. Is there anything unusual about these diamonds? Are they particularly bad or good, or do you think these are pricing errors?
- ```
extreme_vals <- diamonds2 %>%
 mutate(extreme_value = (abs(resid_lg) > 1)) %>%
 filter(extreme_value) %>%
 add_predictions(mod_diamond2, "pred_lg") %>%
 mutate(price_pred = 2^(pred_lg))

#graph extreme points as well as line of pred
diamonds2 %>%
```

```

add_predictions(mod_diamond2) %>%
mutate(extreme_value = (abs(resid_lg) > 1)) %>%
filter(!extreme_value) %>%
ggplot(aes(carat, price)) +
geom_hex(bins = 50) +
geom_point(aes(carat, price), data = extreme_vals, color = "orange")

```



- It's possible some of these were mislabeled or errors, e.g. an error in typing e.g. 200 miswritten as 2000, though given the wide range in pricing this does not seem like that extreme of a variation.

```

diamonds2 %>%
add_predictions(mod_diamond2) %>%
mutate(extreme_value = (abs(resid_lg) > 1),
 price_pred = 2^pred) %>%
filter(extreme_value) %>%
mutate(multiple = price / price_pred) %>%
arrange(desc(multiple)) %>%
select(price, price_pred, multiple)

```

```

A tibble: 16 x 3
price price_pred multiple
<int> <dbl> <dbl>
1 2160 314. 6.88
2 1776 412. 4.31
3 1186 284. 4.17
4 1186 284. 4.17
5 1013 264. 3.83

```

```

6 2366 774. 3.05
7 1715 576. 2.98
8 4368 1705. 2.56
9 10011 4048. 2.47
10 3807 1540. 2.47
11 3360 1373. 2.45
12 3920 1705. 2.30
13 1415 639. 2.21
14 1415 639. 2.21
15 1262 2644. 0.477
16 10470 23622. 0.443

```

- If the mislabeling were an issue of e.g. 200 to 2000, you would expect that some of the actual values were  $\sim 1/10$ th or 10x the value of the predicted value. Though none of them appear to have this issue, except for maybe the item that was priced at 2160 but has a price of 314, which is the closest error where the actual value was  $\sim 1/10$ th the value of the prediction
4. Does the final model, `mod_diamonds2`, do a good job of predicting diamond prices? Would you trust it to tell you how much to spend if you were buying a diamond?

```

perc_unexplained <- diamonds2 %>%
 add_predictions(mod_diamond2, "pred") %>%
 mutate(pred_2 = 2^pred,
 mean_price = mean(price),
 error_deviation = (price - pred_2)^2,
 reg_deviation = (pred_2 - mean_price)^2,
 tot_deviation = (price - mean_price)^2) %>%
 summarise(R_squared = sum(error_deviation) / sum(tot_deviation)) %>%
 flatten dbl()

1 - perc_unexplained

```

```
[1] 0.9653255
```

- $\sim 96.5\%$  of variance is explained by model which seems pretty solid, though is relative to each situation
- See 24.2.3.3 for other considerations, though even this is very incomplete. Would want to check a variety of other metrics to further evaluate trust.

## 29.2 24.3 What affects the number of daily flights?

These were some useful notes copied from this section of the chapter

```

daily <- flights %>%
 mutate(date = make_date(year, month, day)) %>%
 count(date)

daily <- daily %>%
 mutate(month = month(date, label = TRUE))

daily <- daily %>%
 mutate(wday = wday(date, label = TRUE))

term <- function(date) {

```

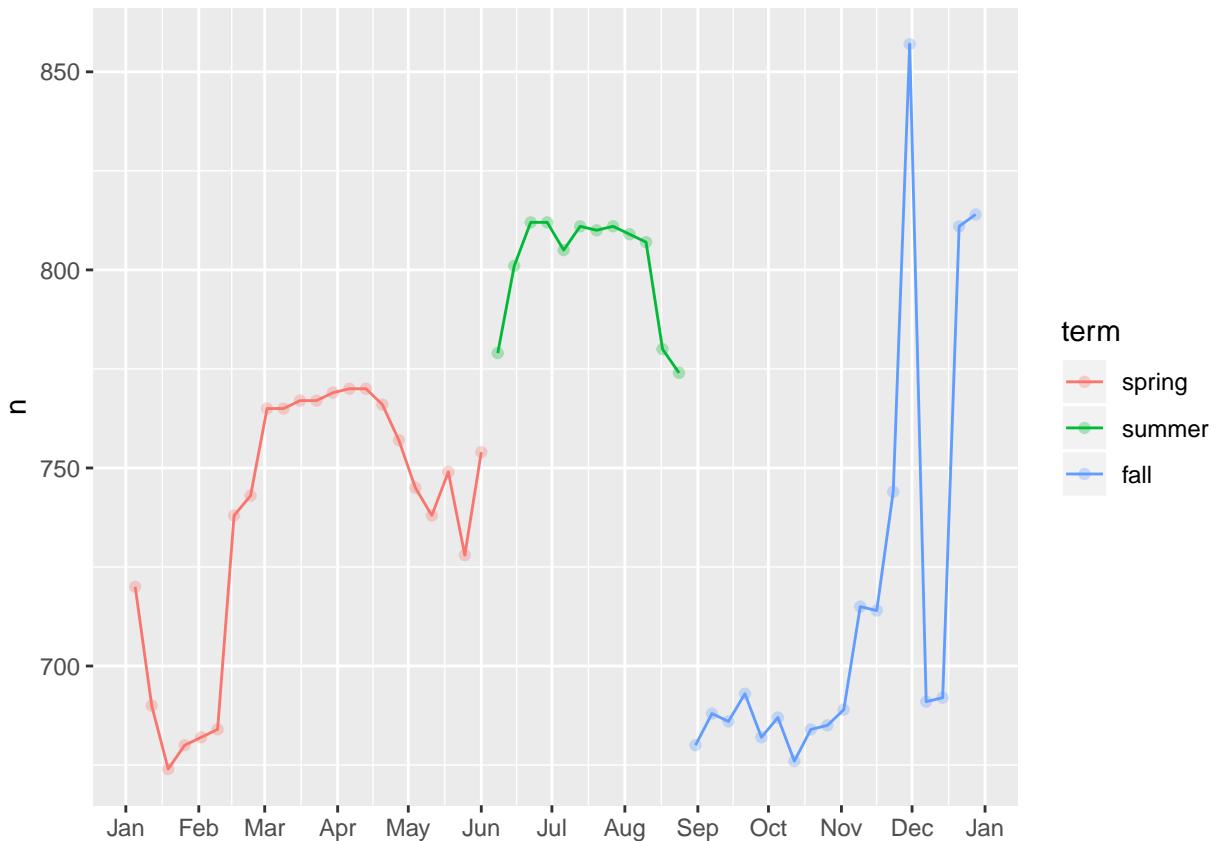
```

cut(date,
 breaks = ymd(20130101, 20130605, 20130825, 20140101),
 labels = c("spring", "summer", "fall")
)
}

daily <- daily %>%
 mutate(term = term(date))

daily %>%
 filter(wday == "Sat") %>%
 ggplot(aes(date, n, colour = term))+
 geom_point(alpha = .3)+
 geom_line()+
 scale_x_date(NULL, date_breaks = "1 month", date_labels = "%b")

```



### 29.2.1 24.3.5

1. Use your Google sleuthing skills to brainstorm why there were fewer than expected flights on Jan 20, May 26, and Sep 1. (Hint: they all have the same explanation.) How would these days generalise to another year?
  - January 20th was the day for MLK day<sup>1</sup>
  - May 26th was the day before Memorial Day weekend

<sup>1</sup>It was also the 2nd inauguration for Obama

- September 1st was the day before labor day

Based on the above, it seems a variable representing “holiday” or “holiday weekend” may be valuable.

- What do the three days with high positive residuals represent? How would these days generalise to another year?

```
daily <- flights %>%
 mutate(date = make_date(year, month, day)) %>%
 count(date)

daily <- daily %>%
 mutate(wday = wday(date, label = TRUE))

mod <- lm(n ~ wday, data = daily)

daily <- daily %>%
 add_residuals(mod)

daily %>%
 top_n(3, resid)

A tibble: 3 x 4
date n wday resid
<date> <int> <ord> <dbl>
1 2013-11-30 857 Sat 112.
2 2013-12-01 987 Sun 95.5
3 2013-12-28 814 Sat 69.4
```

- these days correspond with the Saturday and Sunday of Thanksgiving, as well as the Saturday after Christmas
- these days can fall on different days of the week each year so would vary from year to year depending on which day they fell on
  - ideally you would include some “holiday” variable to help capture the impact of these / better generalise between years

*Check the absolute values*

```
daily %>%
 top_n(3, abs(resid))

A tibble: 3 x 4
date n wday resid
<date> <int> <ord> <dbl>
1 2013-11-28 634 Thu -332.
2 2013-11-29 661 Fri -306.
3 2013-12-25 719 Wed -244.
```

- The days with the greatest magnitude for residuals were on Christmast Day, Thanksgiving Day, and the day after Thanksgiving
- Create a new variable that splits the `wday` variable into terms, but only for Saturdays, i.e. it should have `Thurs`, `Fri`, but `Sat-summer`, `Sat-spring`, `Sat-fall`. How does this model compare with the model with every combination of `wday` and `term`?

```
term <- function(date) {
 cut(date,
 breaks = ymd(20130101, 20130605, 20130825, 20140101),
 labels = c("spring", "summer", "fall")
```

```

)
}

daily <- daily %>%
 mutate(term = term(date))

example with wday_mod
Example_term_with_sat <- daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 lm(n ~ wday_mod, data = .)

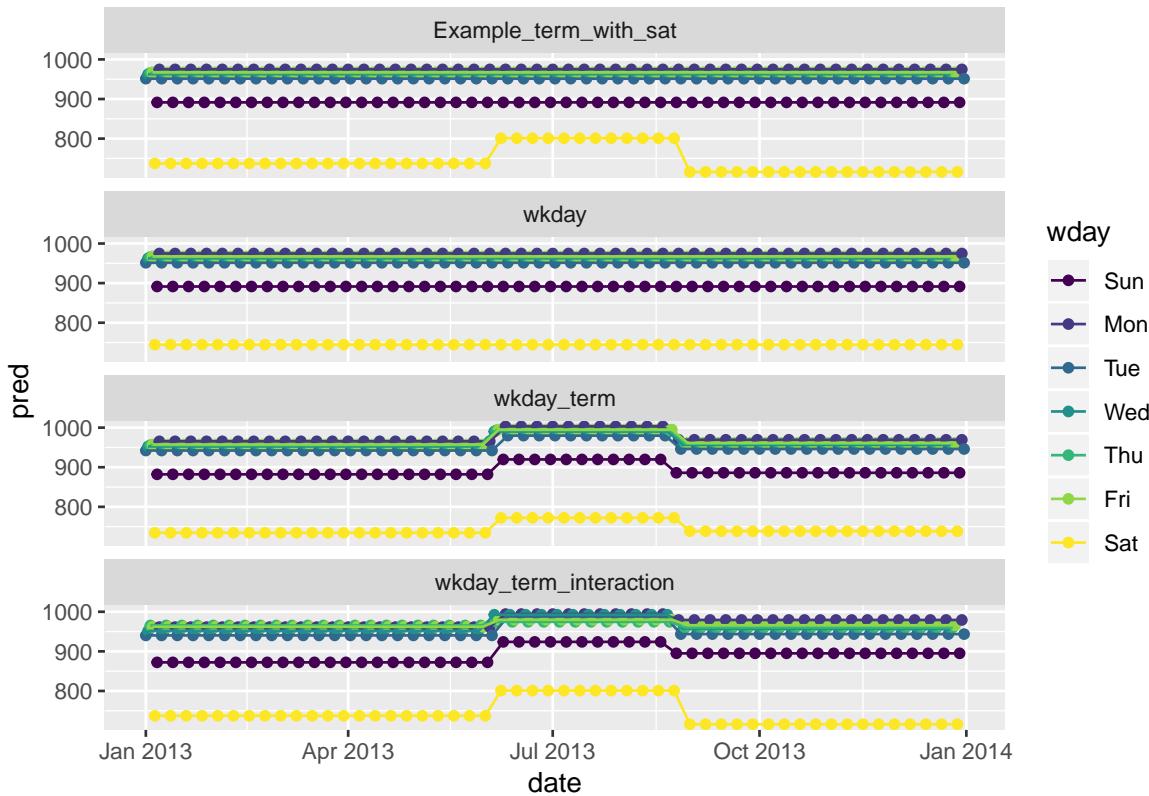
just wday
wkday <- daily %>%
 lm(n ~ wday, data = .)

wday and term, no interaction...
wkday_term <- daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 lm(n ~ wday + term, data = .)

wday and term, interaction
wkday_term_interaction <- daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 lm(n ~ wday*term, data = .)

daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 gather_predictions(Example_term_with_sat, wkday, wkday_term, wkday_term_interaction) %>%
 ggplot(aes(date, pred, colour = wday)) +
 geom_point() +
 geom_line() +
 facet_wrap(~model, ncol = 1)

```

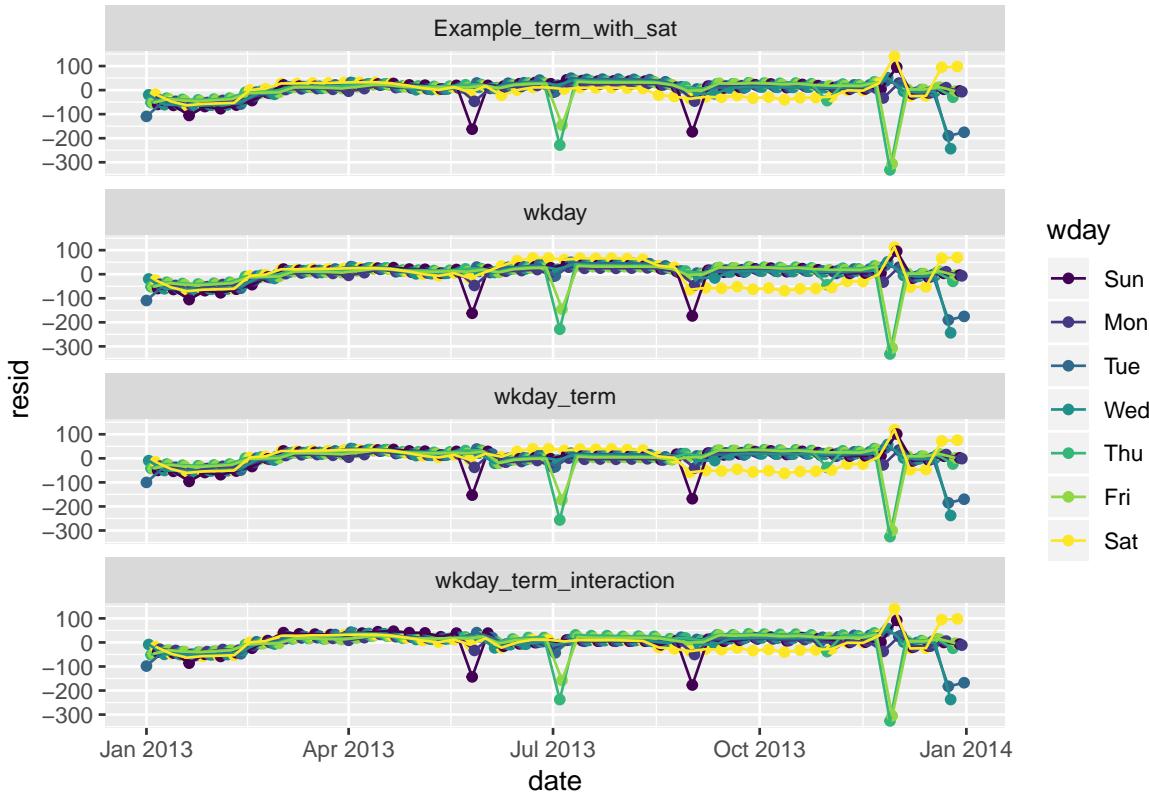


- In the example, saturday has different predicted number of flights in the summer
  - when just including `wkday` you don't see this differentiation
  - when including `wkday` and `term` you see differentiation in the summer, though this difference is the same across all `wdays`, hence the increased number for Saturday's is less than it shows up as compared to either the example (where the term is only interacted with for Saturday) or the `wkday_term_interaction` chart where the interaction is allowed for each day of the week
  - you see increases in flights across pretty much all `wdays` in summer, though you see the biggest difference in Saturday<sup>2</sup>

*Residuals of these models*

```
daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 gather_residuals(Example_term_with_sat, wkday, wkday_term, wkday_term_interaction) %>%
 ggplot(aes(date, resid, colour = wday)) +
 geom_point() +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```

<sup>2</sup>Interactions facilitate encoding these types of conditional relationships, i.e. the impact of summer depends on the day of the week (/ vice versa)



- The graphs with saturday term and interaction across terms do not show gross changes in residuals varying by season the way the models that included just weekday or weekday and term without an interaction do.
- note that you have a few days with large negative residuals<sup>3</sup>
  - these likely correspond with holidays

- Create a new `wday` variable that combines the day of week, term (for Saturdays), and public holidays. What do the residuals of that model look like?

*Create dataset of federal holidays*

```
holiday's that could have been added: Easter, black friday
consider adding a filter to remove Columbus day and perhaps Veteran's day
holidays <- tribble(
 ~HolidayName, ~HolidayDate,
 "New Year's", "2013-01-01",
 "MLK", "2013-01-21",
 "President's Day", "2013-02-18",
 "Memorial Day", "2013-05-27",
 "Independence Day", "2013-07-04",
 "Labor Day", "2013-09-02",
 "Columbus Day", "2013-10-14",
 "Veteran's Day", "2013-11-11",
 "Thanksgiving", "2013-11-28",
 "Christmas Day", "2013-12-25"
) %>%
 mutate(HolidayDate = ymd(HolidayDate))
```

<sup>3</sup>Remember this corresponds with days where the predictions are higher than the actuals.

Create model with Holiday variable

```
Example_term_with_sat_holiday <- daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 left_join(holidays, by = c("date" = "HolidayDate")) %>%
 mutate(Holiday = !is.na(HolidayName)) %>%
 lm(n ~ wday_mod + Holiday, data = .)
```

Look at residuals of model

```
daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 left_join(holidays, by = c("date" = "HolidayDate")) %>%
 mutate(Holiday = !is.na(HolidayName)) %>%
 gather_residuals(Example_term_with_sat_holiday, Example_term_with_sat) %>%
 ggplot(aes(date, resid, colour = wday)) +
 geom_point() +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```



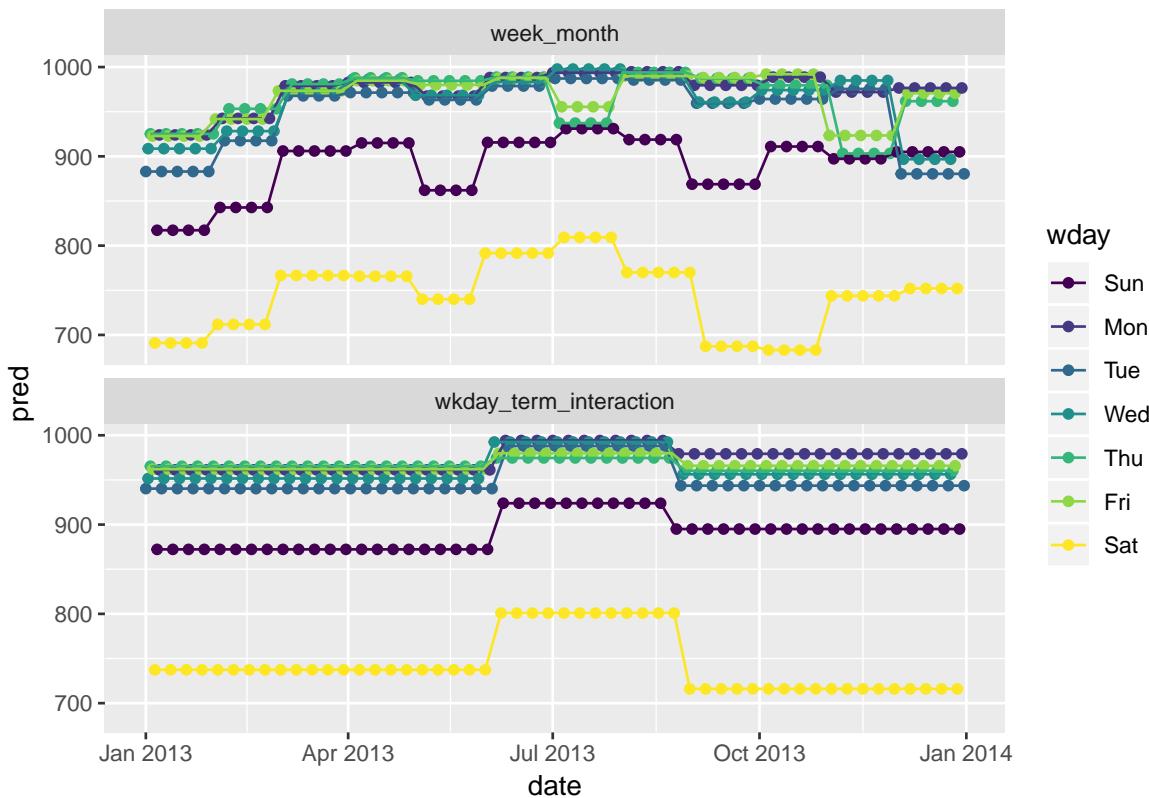
- Notice the residuals for day's like July 4th and Christas are closer to 0 now, though residuals for smaller holidays like MLK, President's, Columbus, and Veteran's Day are now positive when before they did not have such noticeable abberations
  - Suggests that just "holiday" is not enough to capture the relationship
    - In [24.3.5.4] I show how to create a "near holiday" variable (though I do not add any new analysis after creating this)
5. What happens if you fit a day of week effect that varies by month (i.e.  $n \sim wday * month$ )? Why is this not very helpful?

*Create model*

```
week_month <- daily %>%
 mutate(month = month(date) %>% as.factor()) %>%
 lm(n ~ wday * month, data = .)
```

*Graph predictions* (with  $n \sim wday * term$  as the comparison)

```
daily %>%
 mutate(month = month(date) %>% as.factor()) %>%
 gather_predictions(wkday_term_interaction, week_month) %>%
 ggplot(aes(date, pred, colour = wday)) +
 geom_point() +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```



- This model has the most flexibility / inputs, though this makes the pattern harder to follow / interpret
- Certain decreases in the month to month model are difficult to explain, for example the decrease in the month of May

*Graph residuals* (with  $n \sim wday * term$  as the comparison)

```
daily %>%
 mutate(month = month(date) %>% as.factor()) %>%
 gather_residuals(wkday_term_interaction, week_month) %>%
 ggplot(aes(date, resid, colour = wday)) +
 geom_point() +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```



The residuals seem to partially explain some of these inexplicable ups / downs:

- For the model that incorporates an interaction with month, you see the residuals in months with a holiday tend to cause the associated day of the week the holiday fell on to then have high residuals on the non-holiday days, an effect that is less pronounced on the models interacted with `term`
  - The reason for this is that for the monthly variables there are only 4-5 week days in each month, so a holiday on one of these can substantially impact the expected number of flights on the weekend in that month (i.e. the prediction is based just on 4-5 observations). For the term interaction you have more like 12 observations to get an expected value, so while there is still an aberration on that day, the other days predictions are less affected

Questions such as this fall into the general space of balancing “bias” vs. “variance”

6. What would you expect the model `n ~ wday + ns(date, 5)` to look like? Knowing what you know about the data, why would you expect it to be not particularly effective?

I would expect to see a similar overall pattern, but with more smoothed affects. Let’s check what these actually look like below.

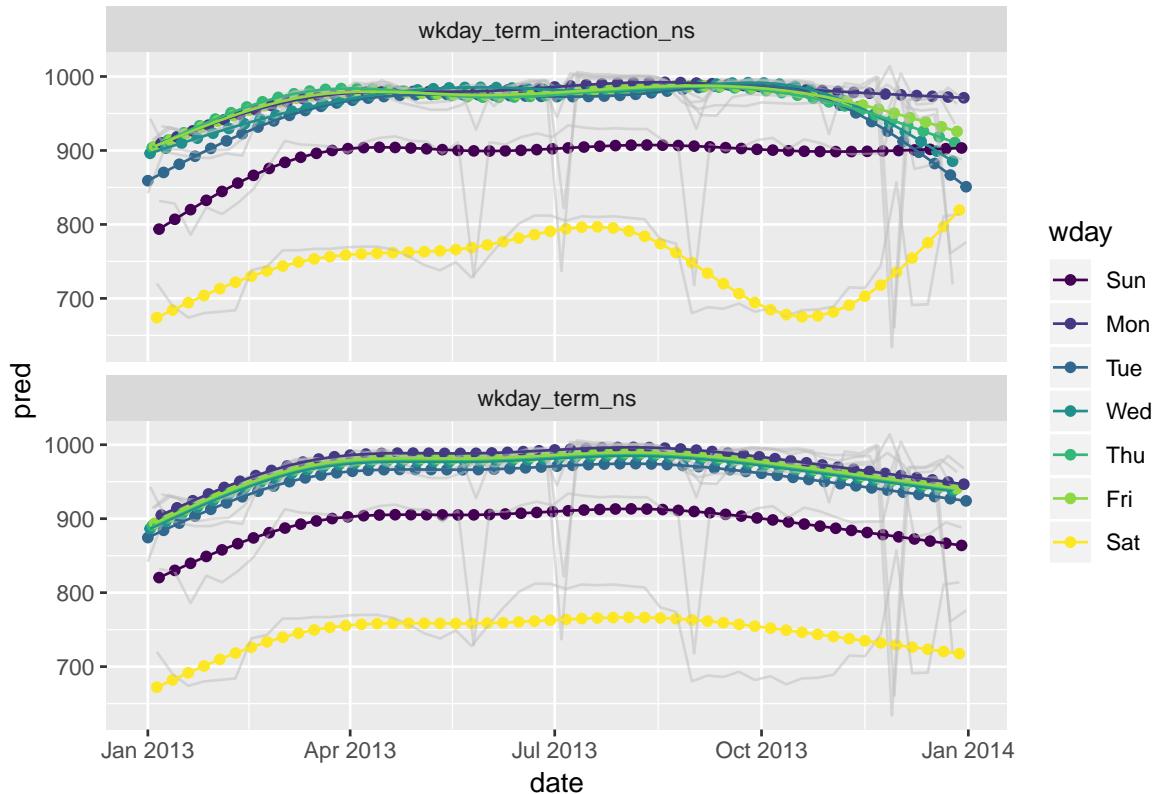
```
wkday_term_ns <- daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 lm(n ~ wday + splines::ns(date, 5), data = .)

wkday_term_interaction_ns <- lm(n ~ wday * splines::ns(date, 5), data = daily)
```

Look at predictions (light grey are actuals)

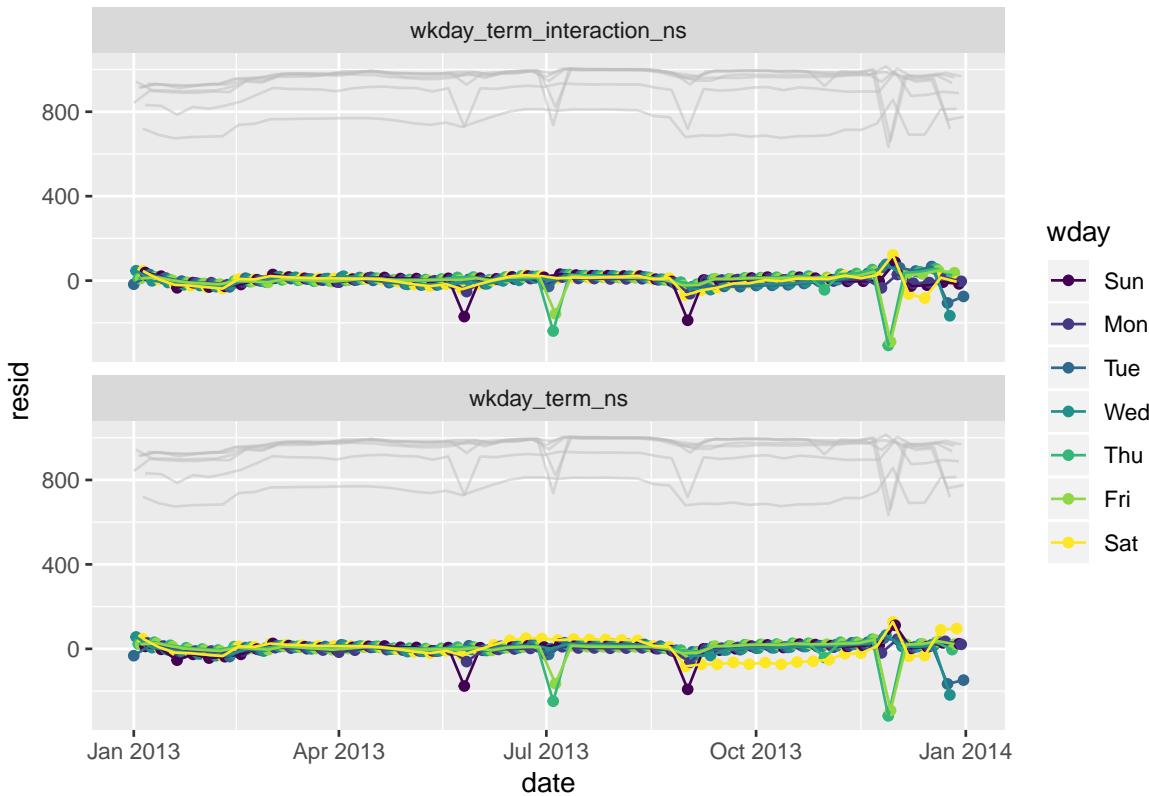
```
daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 gather_predictions(wkday_term_ns, wkday_term_interaction_ns) %>%
 ggplot(aes(date, pred, colour = wday)) +
```

```
geom_point()+
 geom_line(aes(x = date, y = n, group = wday), colour = "grey", alpha = 0.5) +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```



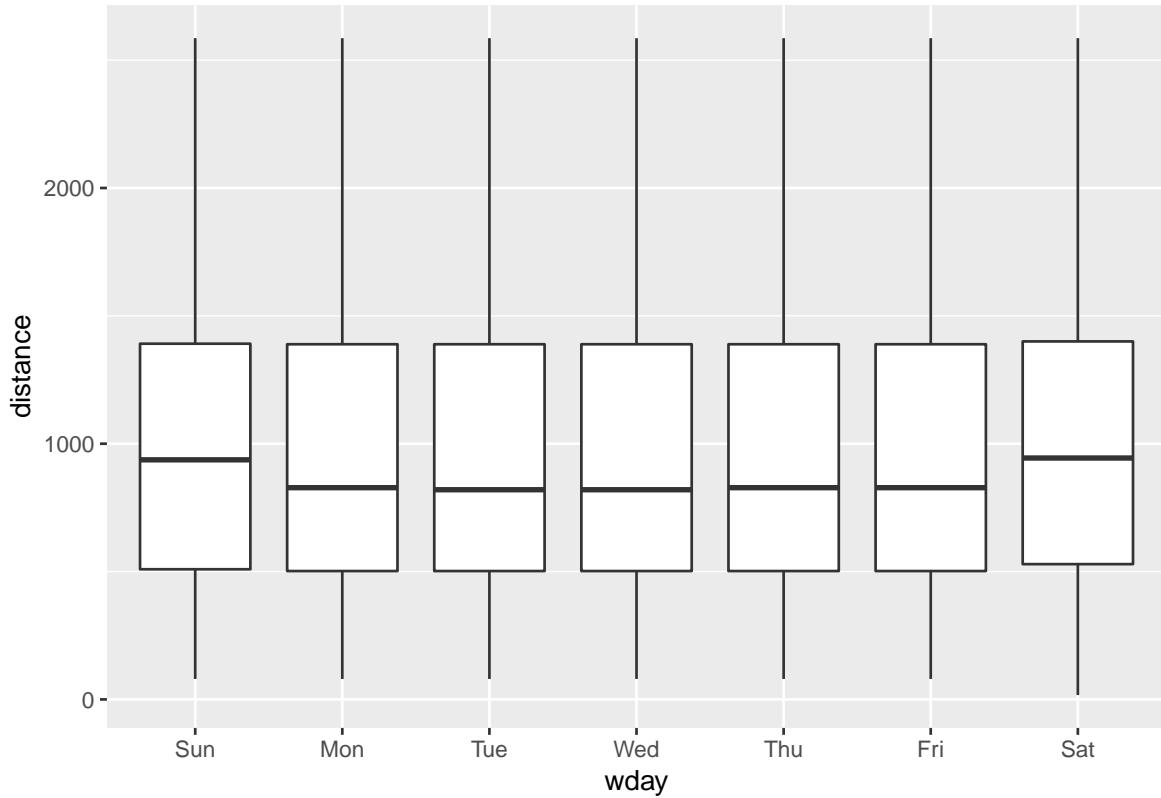
Look at residuals (in light grey are actuals)

```
daily %>%
 mutate(wday_mod = ifelse(wday == "Sat", paste(wday, "_", term), wday)) %>%
 gather_residuals(wkday_term_ns, wkday_term_interaction_ns) %>%
 ggplot(aes(date, resid, colour = wday)) +
 geom_point() +
 geom_line(aes(x = date, y = n, group = wday), colour = "grey", alpha = 0.5) +
 geom_line() +
 facet_wrap(~model, ncol = 1)
```



7. We hypothesised that people leaving on Sundays are more likely to be business travellers who need to be somewhere on Monday. Explore that hypothesis by seeing how it breaks down based on distance and time: if it's true, you'd expect to see more Sunday evening flights to places that are far away.

```
flights %>%
 mutate(date = lubridate::make_date(year, month, day),
 wday = wday(date, label = TRUE)) %>%
 select(date, wday, distance) %>%
 filter(distance < 3000) %>%
 ggplot(aes(wday, distance)) +
 geom_boxplot()
```

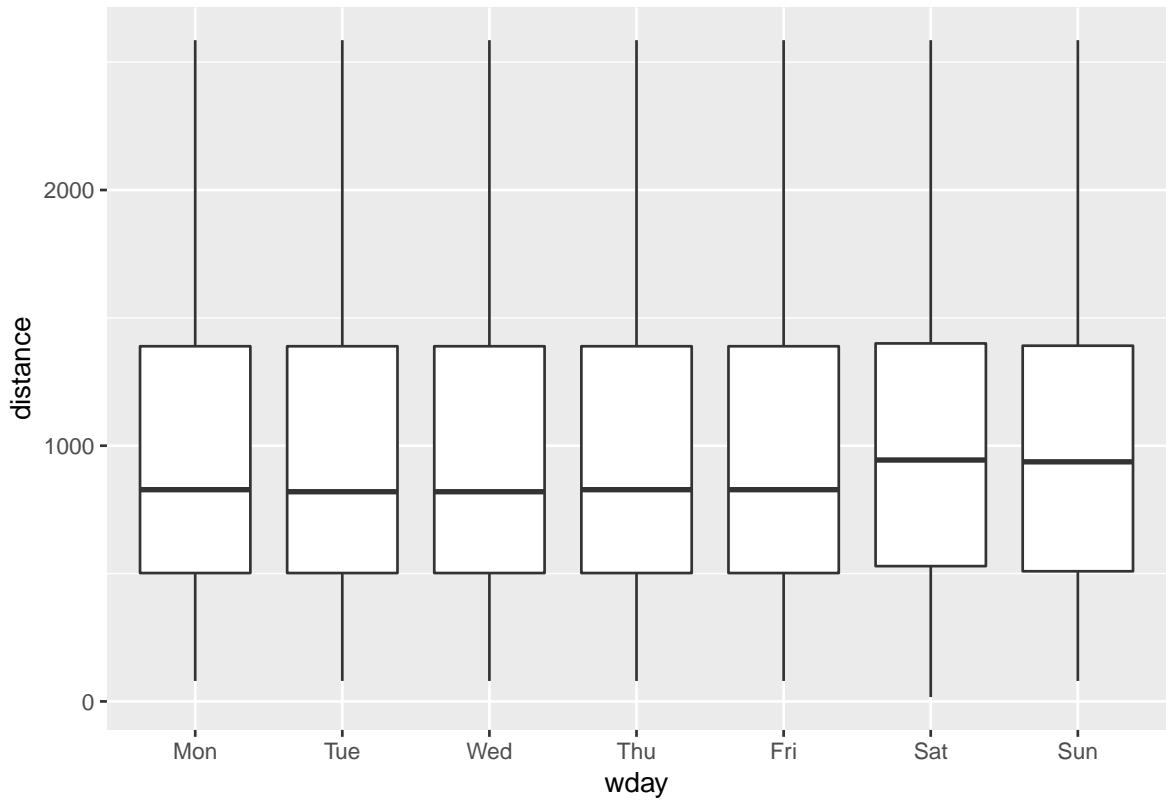


- 25th and 75th percentiles aren't different, but median is a little higher
- the same is the case for Saturday travel which does not seem to fit into this hypothesis as neatly. The effect seems more general to the weekend than just Saturday, and there seem like there may be other potential explanations than "business travel"

8. It's a little frustrating that Sunday and Saturday are on separate ends of the plot. Write a small function to set the levels of the factor so that the week starts on Monday.

```
wday_modified <- function(date){
 date_order <- (wday(date) + 5) %% 7
 date <- wday(date, label = TRUE) %>% fct_reorder(date_order)
 date
}

flights %>%
 mutate(date = lubridate::make_date(year, month, day),
 wday = wday_modified(date)) %>%
 select(date, wday, distance) %>%
 filter(distance < 3000) %>%
 ggplot(aes(wday, distance)) +
 geom_boxplot()
```





# Chapter 30

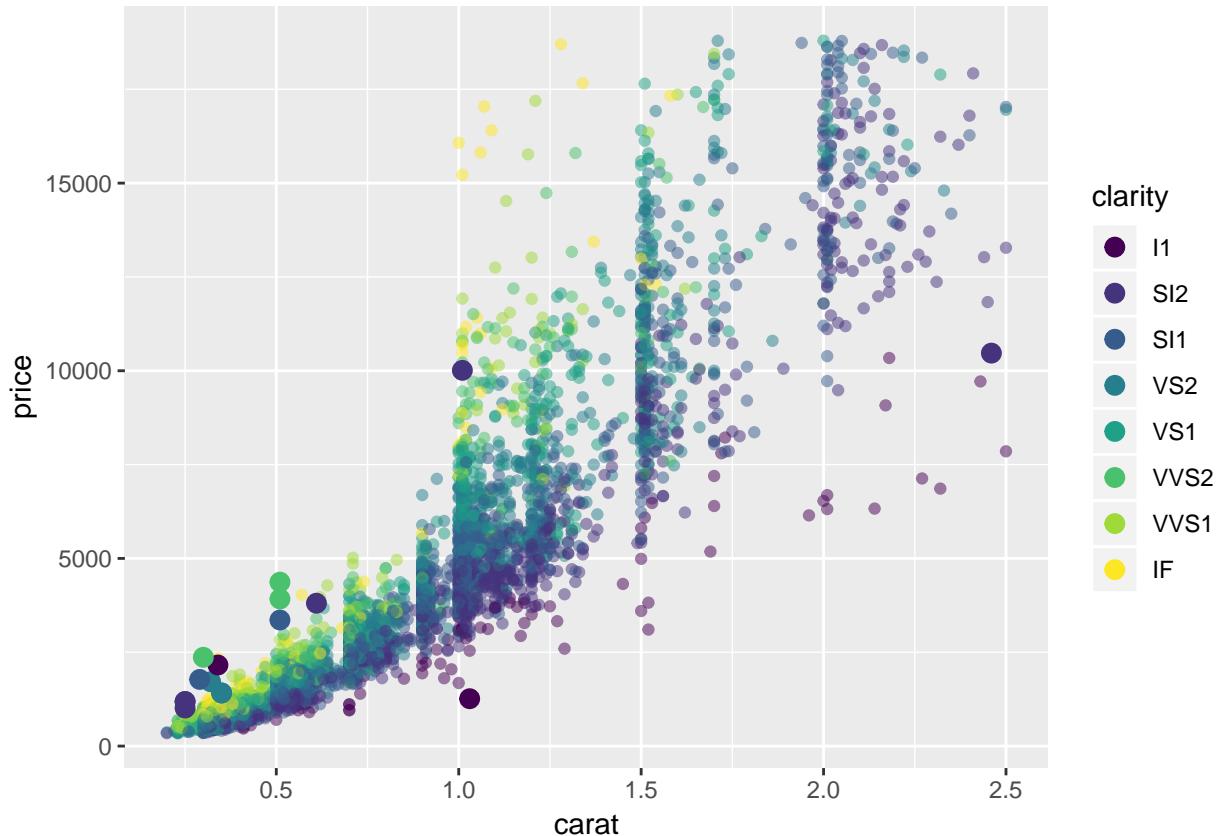
## Appendix

### 30.1 24.2.3.3

Plots of extreme values against a sample and colored by some of the key attributes

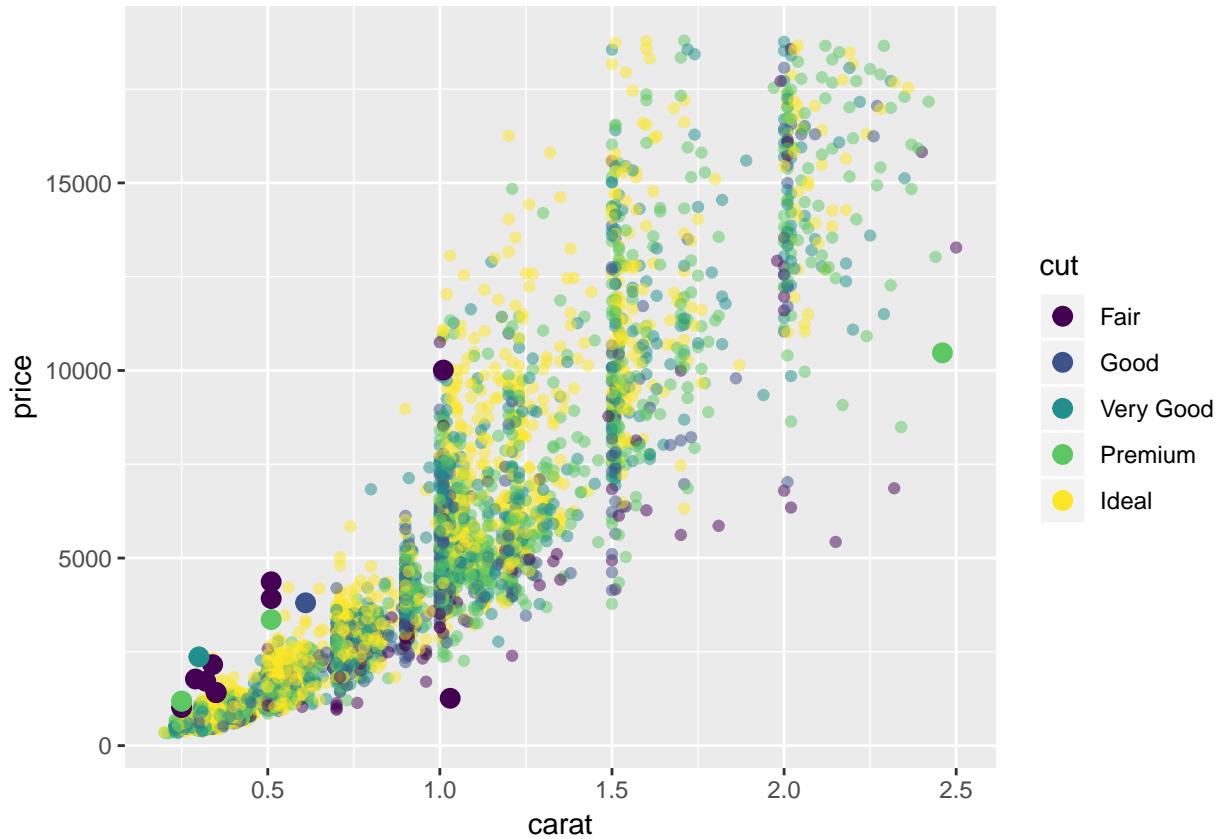
*Plots of extreme values against carat, price, clarity*

```
diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 sample_n(5000) %>%
 ggplot(aes(carat, price)) +
 geom_point(aes(carat, price, colour = clarity), alpha = 0.5) +
 geom_point(aes(carat, price, colour = clarity), data = extreme_vals, size = 3)
```



*Plots of extreme values against carat, price, cut*

```
diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 sample_n(5000) %>%
 ggplot(aes(carat, price)) +
 # geom_hex(bins = 50) +
 geom_point(aes(carat, price, colour = cut), alpha = 0.5) +
 geom_point(aes(carat, price, colour = cut), data = extreme_vals, size = 3)
```



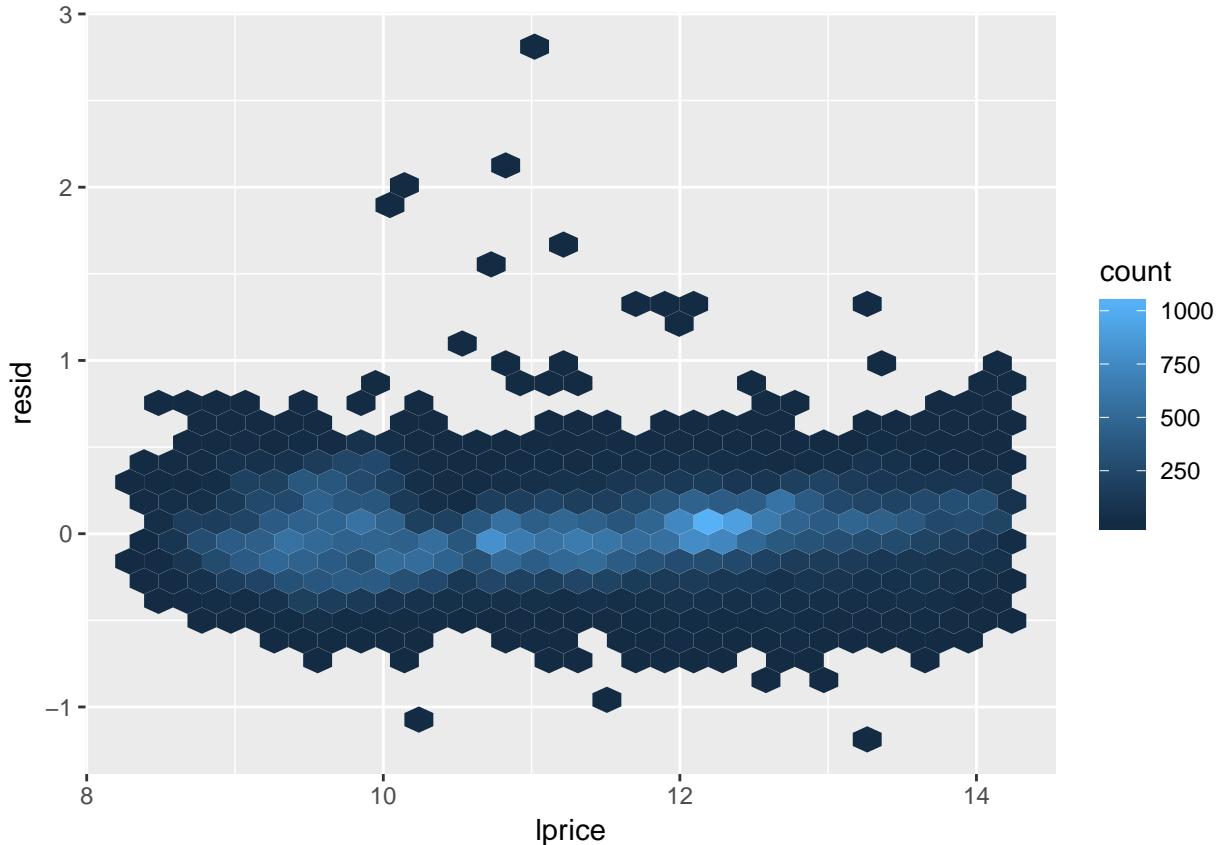
## 30.2 24.2.3.4

### 30.2.1 heteroskedasticity

Note that heteroskedasticity is one (of several other) important considerations that would be important when deciding how much you trust the model.

*residual vs lprice*

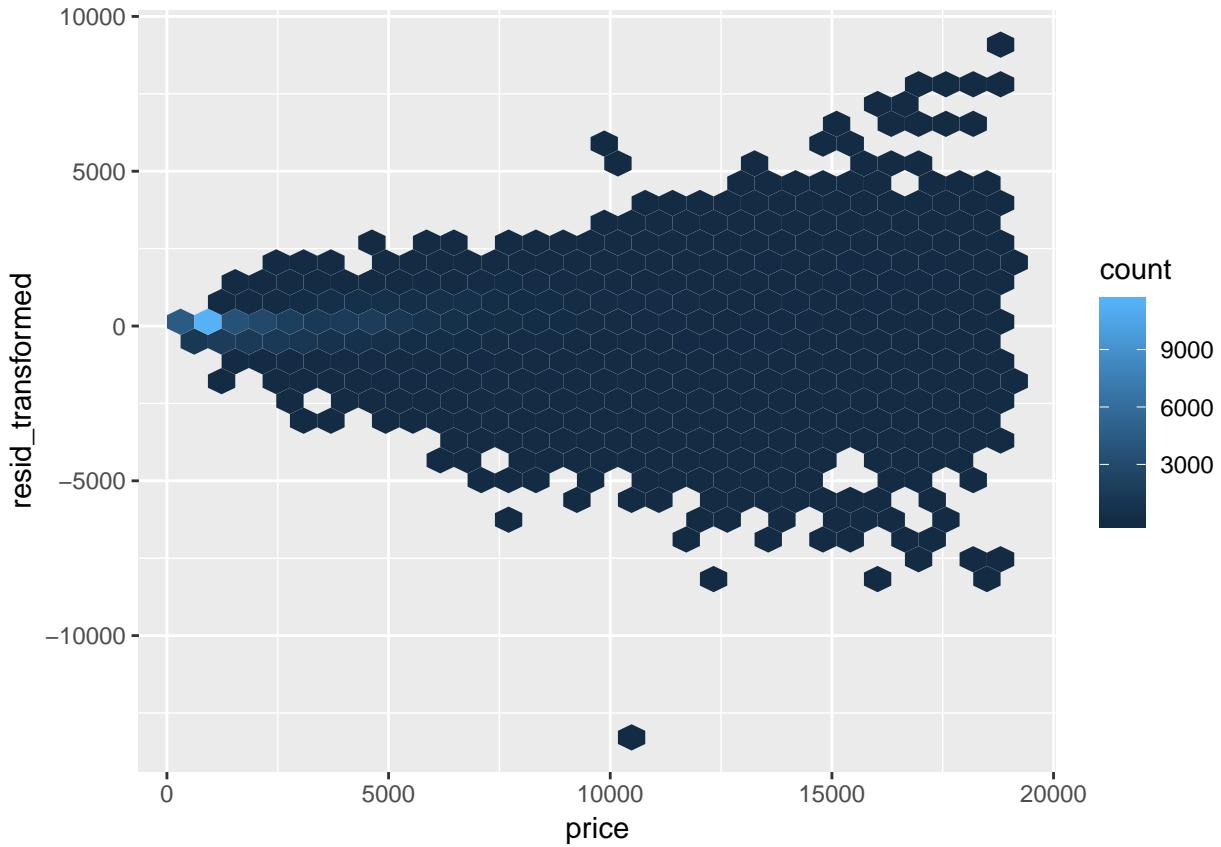
```
diamonds2 %>%
 add_residuals(mod_diamond2) %>%
 ggplot(aes(lprice, resid)) +
 geom_hex()
```



- the log transformation helped to ensure our residuals did not have heteroskedasticity against the predictor

*residual (transformed) vs price (resid\_transformed represents the residual against the residual after transforming it from a prediction for `log2(price)` to a prediction for `price`)*

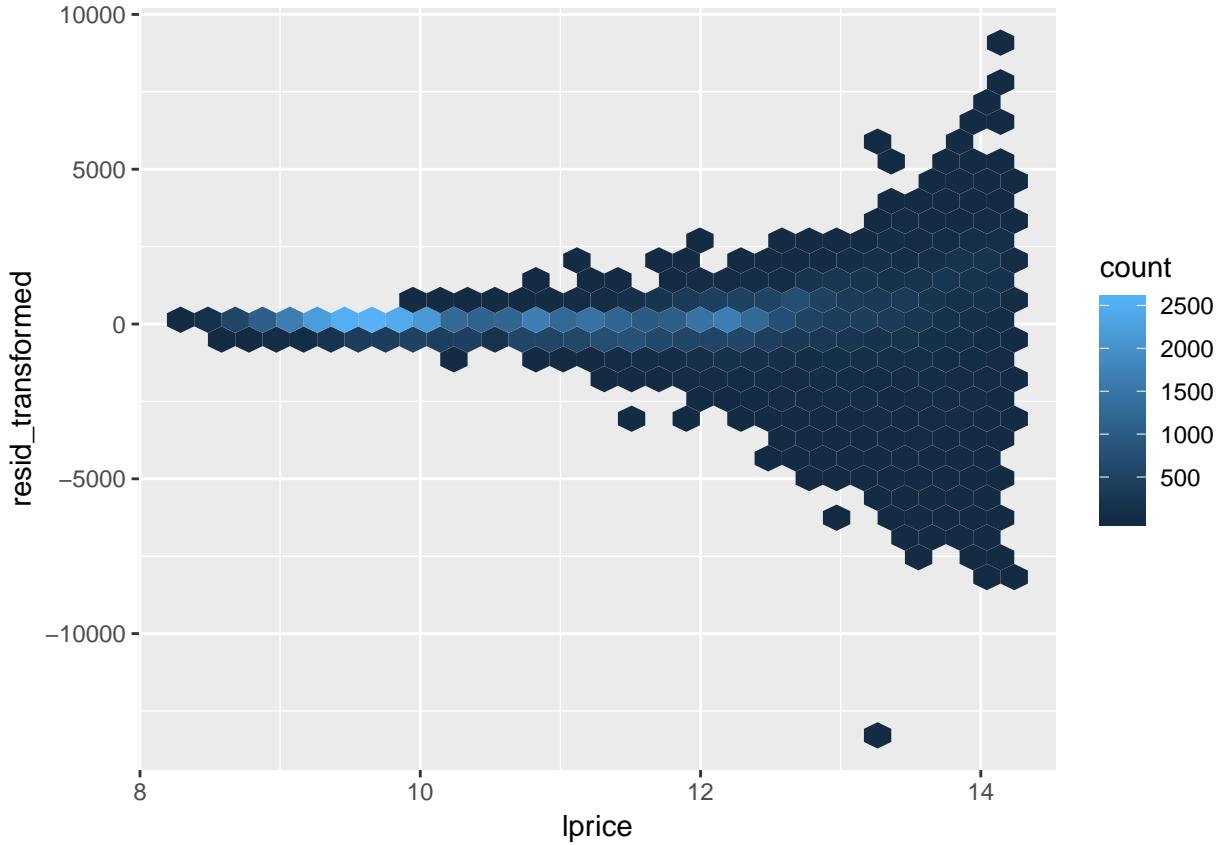
```
diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 mutate(resid_transformed = price - 2^(pred)) %>%
 ggplot(aes(price, resid_transformed)) +
 geom_hex()
```



- This is what heteroskedasticity looks like

*residual (transformed) vs log price* (`resid_transformed` represents the residual against the residual after transforming it from a prediction for `log2(price)` to a prediction for `price`)

```
resid v lprice (% change on x resid)
diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 mutate(resid_transformed = price - 2^(pred)) %>%
 ggplot(aes(lprice, resid_transformed)) +
 geom_hex()
```



### 30.2.2 rsquared on logged values

(incorrect) This is what I did initially. Below I calculate the  $R^2$  on the log values. Within the exercise solution I decided to report the  $R^2$  when calculated on  $2^{\hat{y}}$ . This has the more useful interpretation of representing the percentage of the variance on the actual price that the model captures, which seems more appropriate in some ways. This question about which is more appropriate to report may be worth revisiting in the future.

```
#to see if I'm doing it right let's calculate the R_squared of the model using this technique
ss_res <- diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 mutate(extreme_value = (abs(resid_lg) > 1),
 pred_exp = 2^(pred),
 squ_mod = (log2(price) - pred)^2,
 squ_error = (log2(price) - mean(log2(price)))^2) %>%
 .\$squ_mod %>% sum()

ss_tot <- diamonds2 %>%
 add_predictions(mod_diamond2) %>%
 mutate(extreme_value = (abs(resid_lg) > 1),
 pred_exp = 2^(pred),
 squ_mod = (log2(price) - pred)^2,
 squ_error = (log2(price) - mean(log2(price)))^2) %>%
 .\$squ_error %>% sum()
```

```
calculated by hand
1 - ss_res / ss_tot

[1] 0.9827876
built-in calculation
rsquare(mod_diamond2, diamonds2)

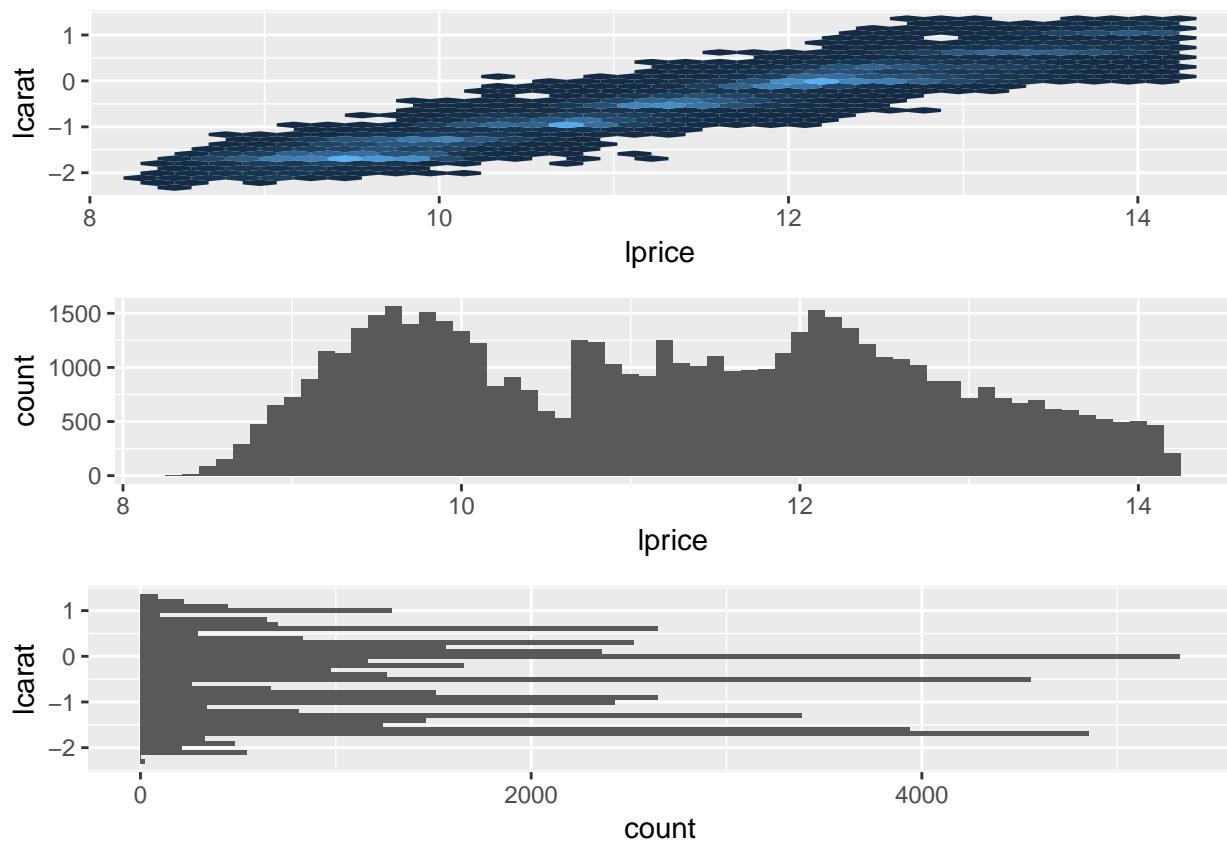
[1] 0.9827876
```

The R-squared is  $\sim 0.983$ , which means that the model accounts for 98.3% of the variance in price, which seems pretty solid.

### 30.3 24.2.3.1

Visualization with horizontal stripes and `lprice` as the focus

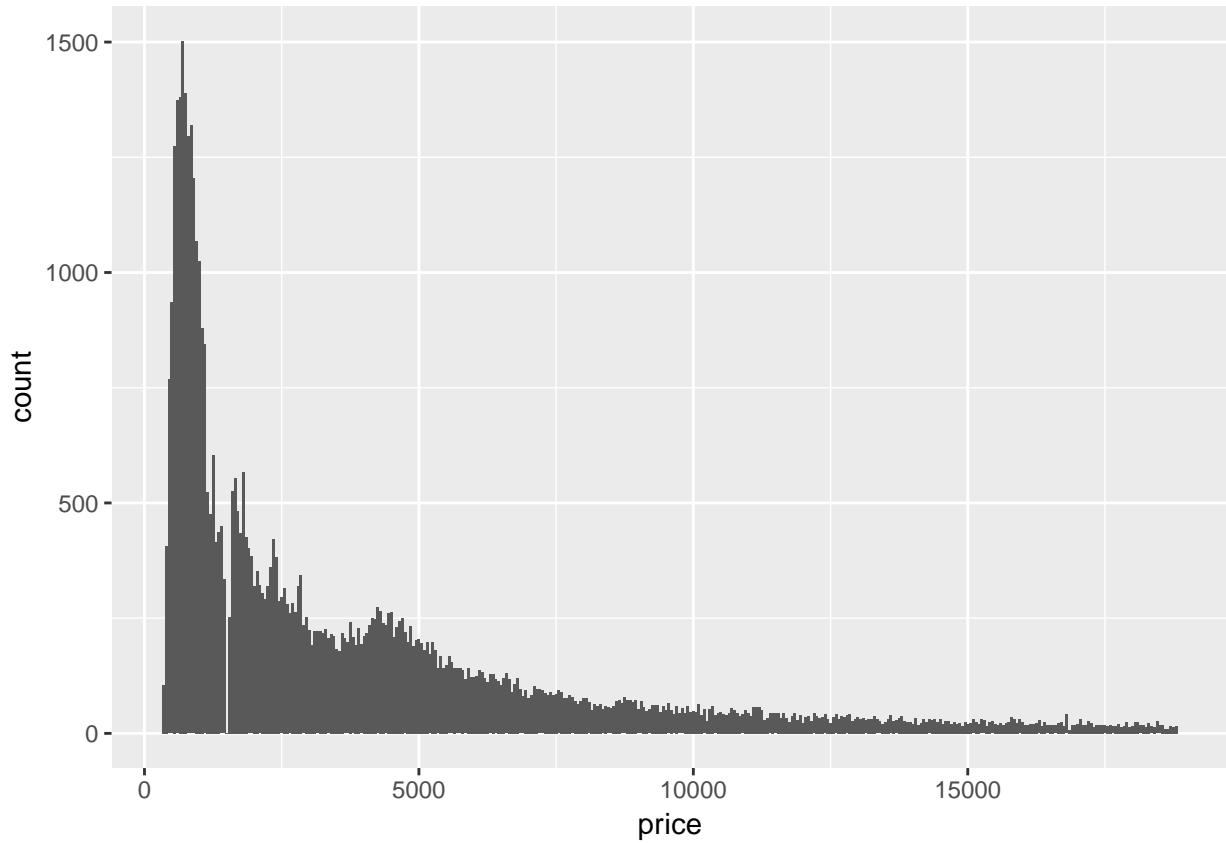
```
horizontal stripes
gridExtra::grid.arrange(plot_lp_lc, plot_lp, plot_lc + coord_flip())
```



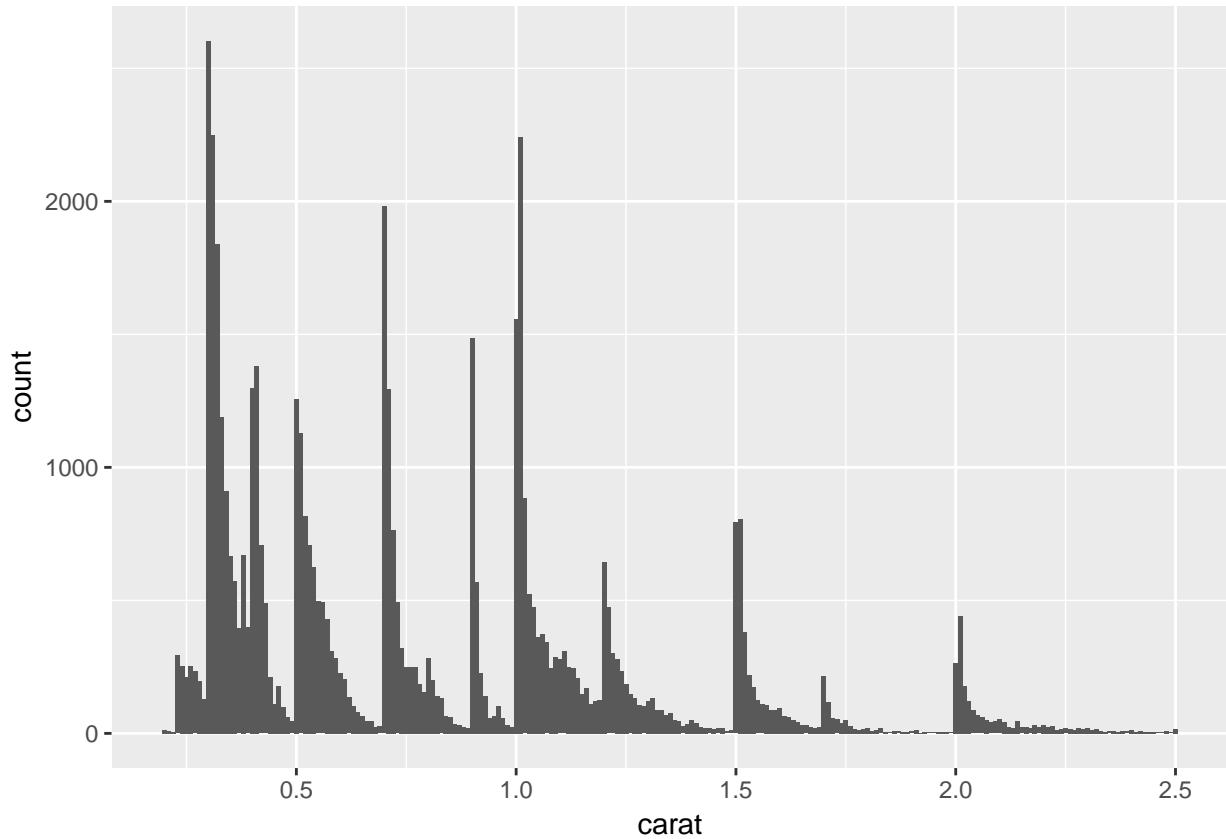
- same thing, just change orientation and highlight `lprice` with a histogram

*A few other graphs from this problem*

```
diamonds2 %>%
 ggplot(aes(price)) +
 geom_histogram(binwidth = 50)
```

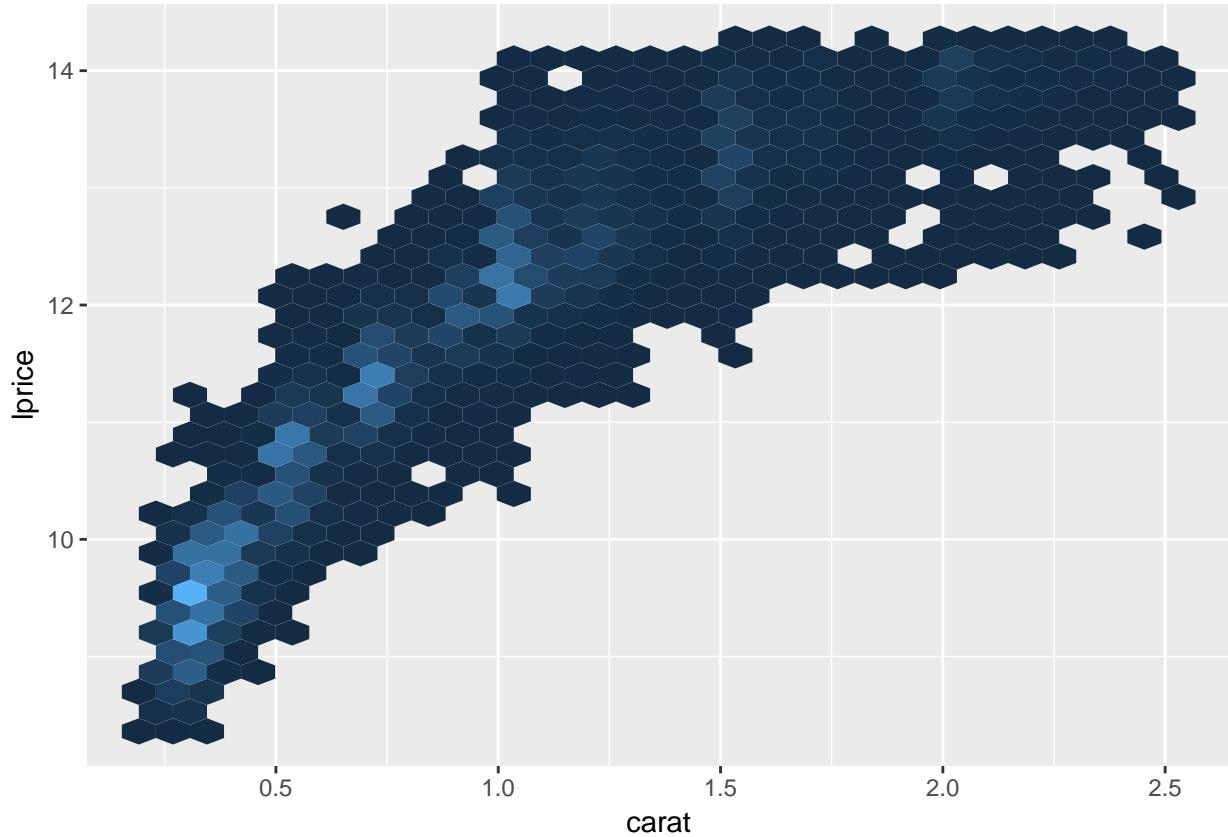


```
iamonds2 %>%
 ggplot(aes(carat)) +
 geom_histogram(binwidth = 0.01)
```

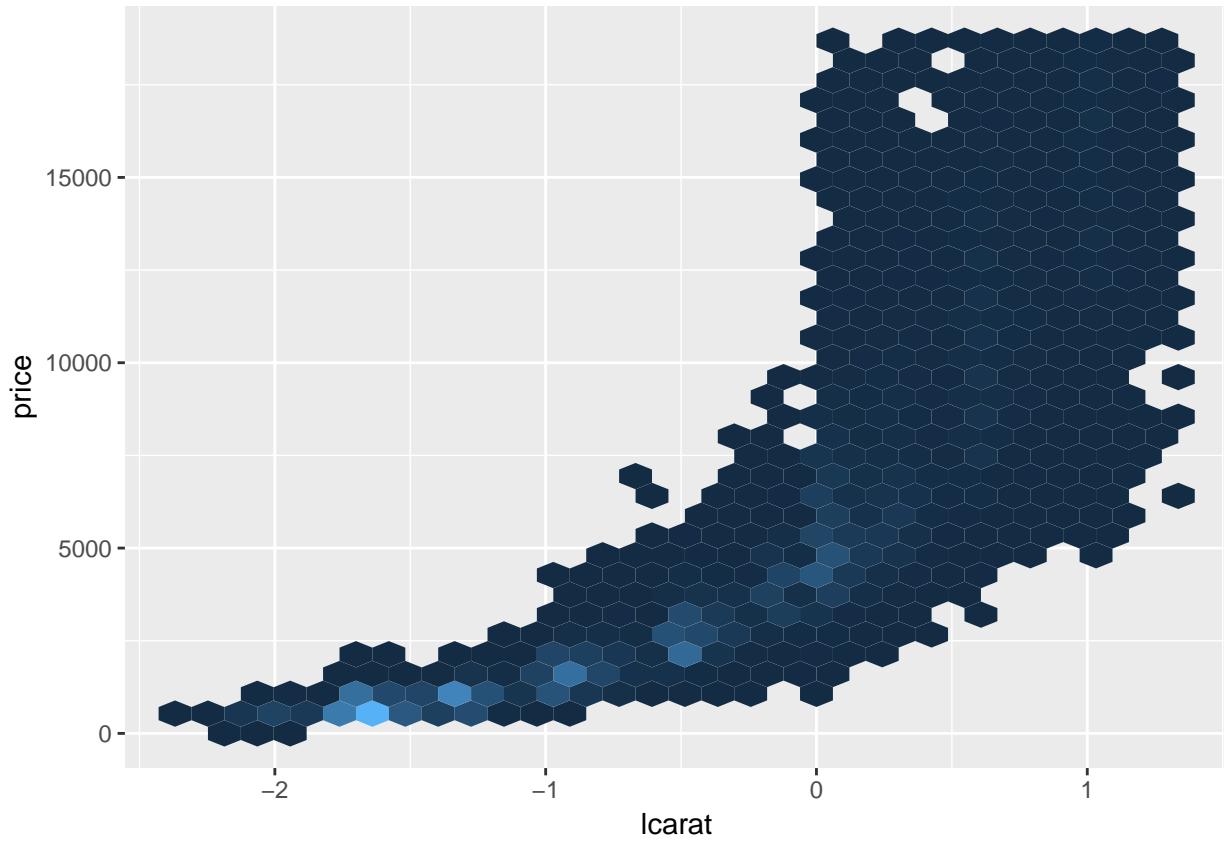


Taking the log of price seems to have a bigger impact on the shape of the geom\_hex graph

```
diamonds2 %>%
 ggplot(aes(carat, lprice)) +
 geom_hex(show.legend = FALSE)
```



```
diamonds2 %>%
 ggplot(aes(lcarat, price)) +
 geom_hex(show.legend = FALSE)
```



### 30.3.1 More notes on logs

While taking the log of both price and carat seems to help improve the ‘linearity’ of the model, perhaps taking the log of the price makes a bigger difference.

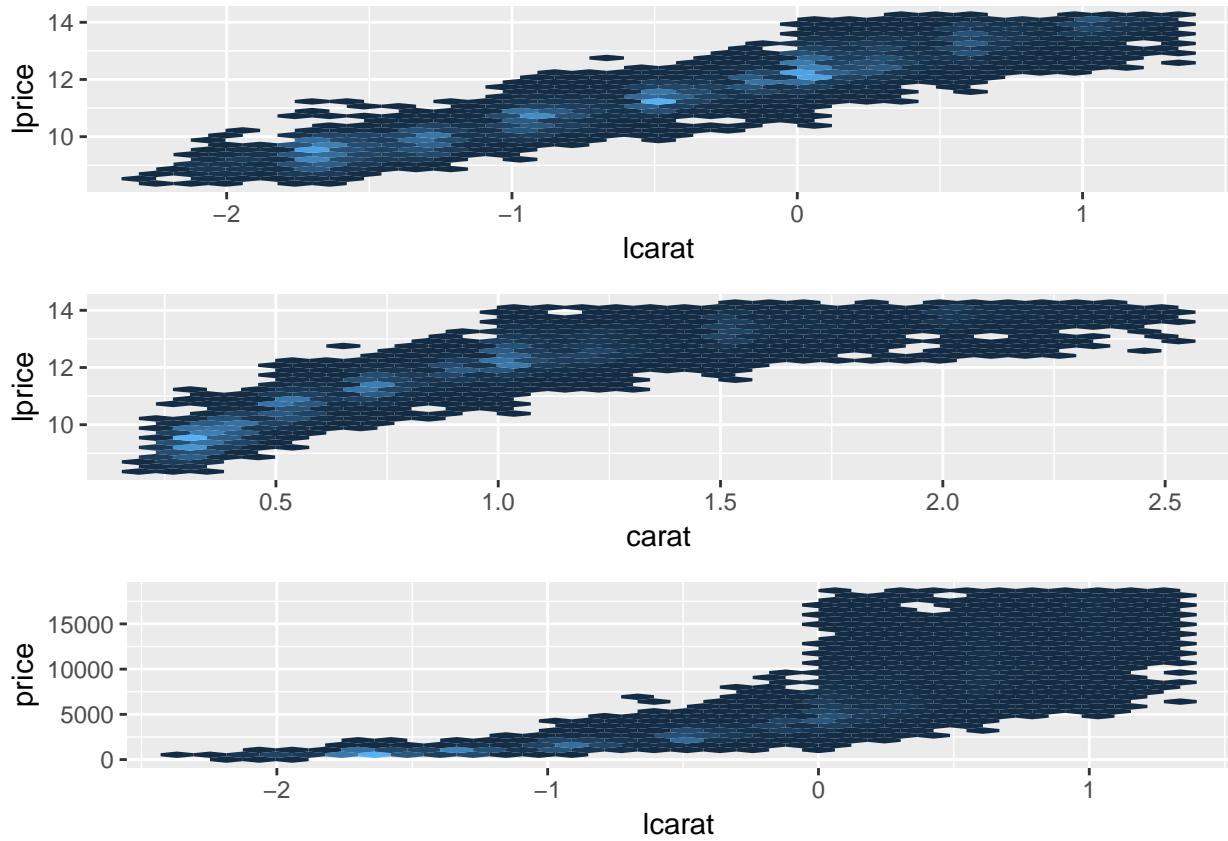
```
a few other plots
plot_c <- diamonds2 %>%
 ggplot(aes(carat)) +
 geom_histogram(binwidth = 0.1)

plot_p <- diamonds2 %>%
 ggplot(aes(price)) +
 geom_histogram(binwidth = 10)

plot_c_lp <- diamonds2 %>%
 ggplot(aes(carat, lprice)) +
 geom_hex(show.legend = FALSE)

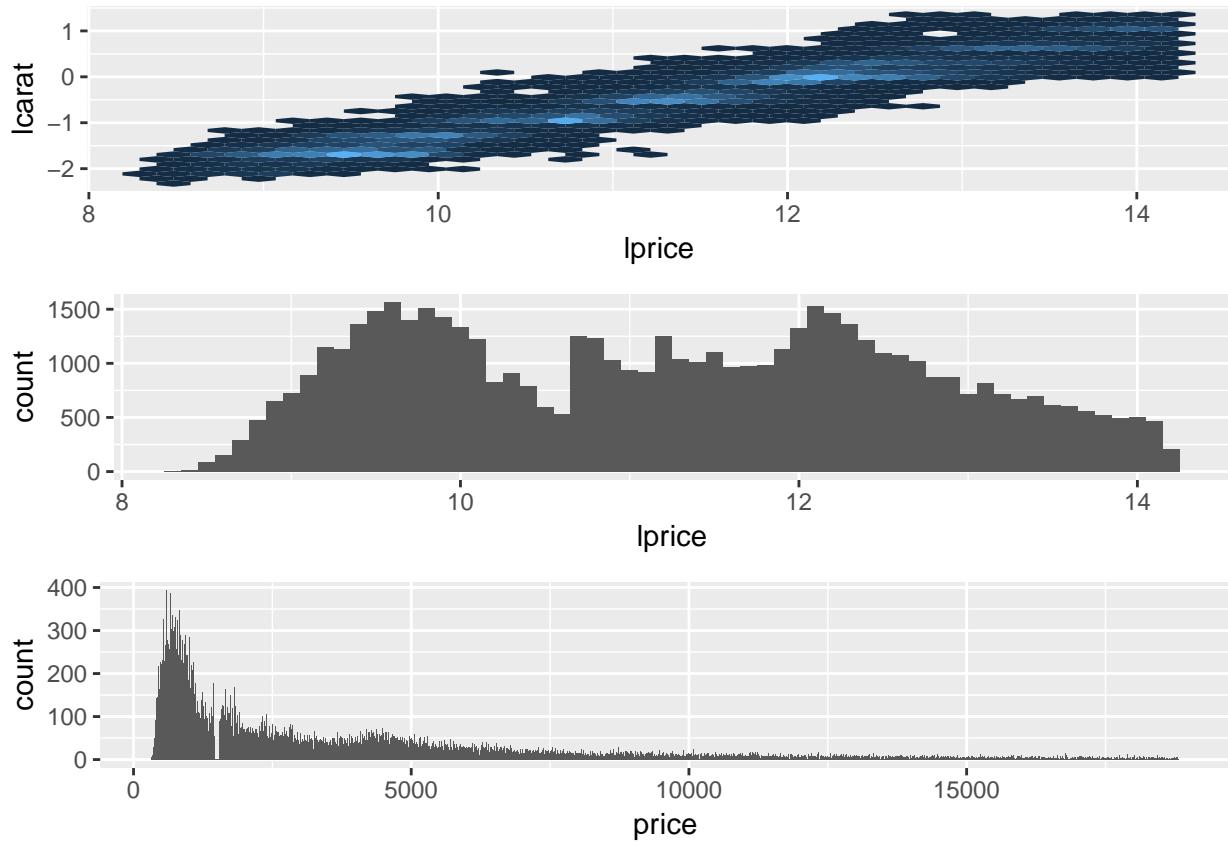
plot_lc_p <- diamonds2 %>%
 ggplot(aes(lcarat, price)) +
 geom_hex(show.legend = FALSE)

gridExtra::grid.arrange(plot_lc_p, plot_c_lp, plot_c_p)
```

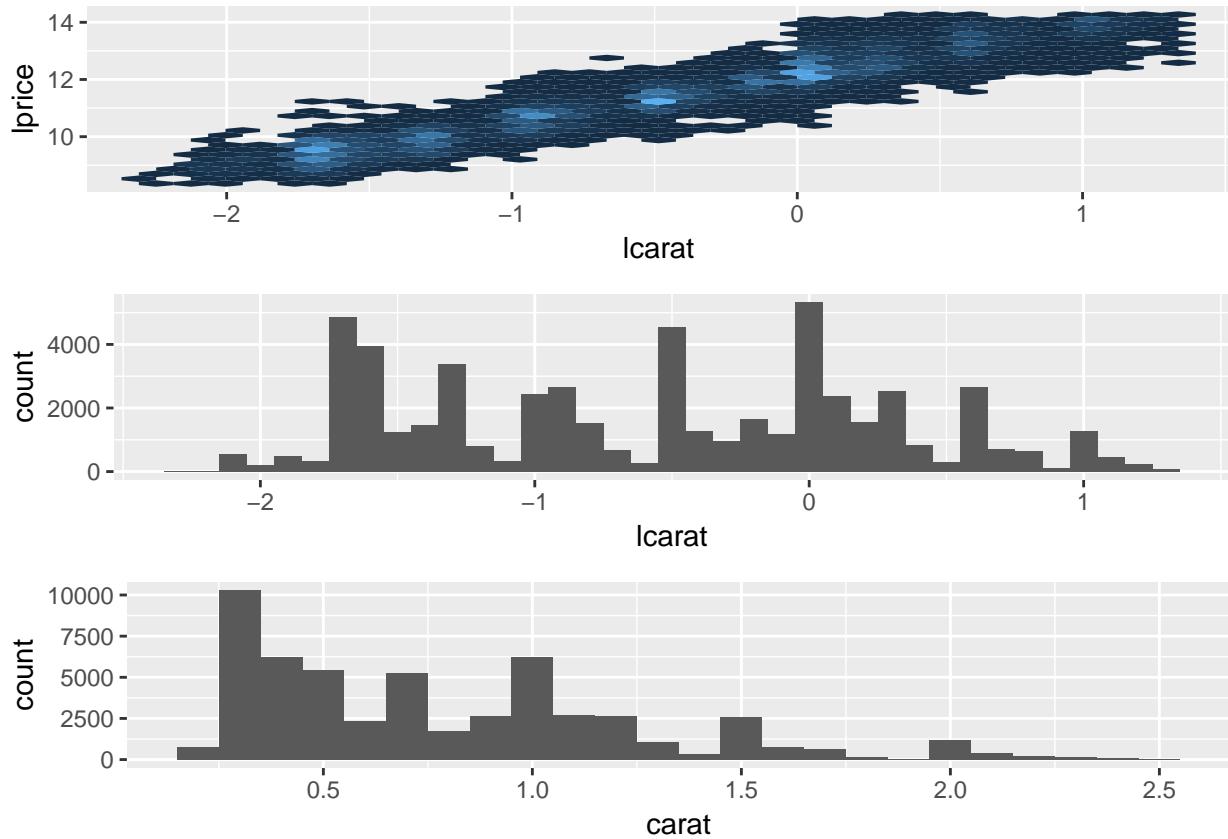


- The reason for this may be that the log of the price better resembles a normal distribution than the log of the carat, though taking the log of the carat does also help by, at the least, centering the distribution...

```
gridExtra::grid.arrange(plot_lp_lc, plot_lp, plot_p)
```



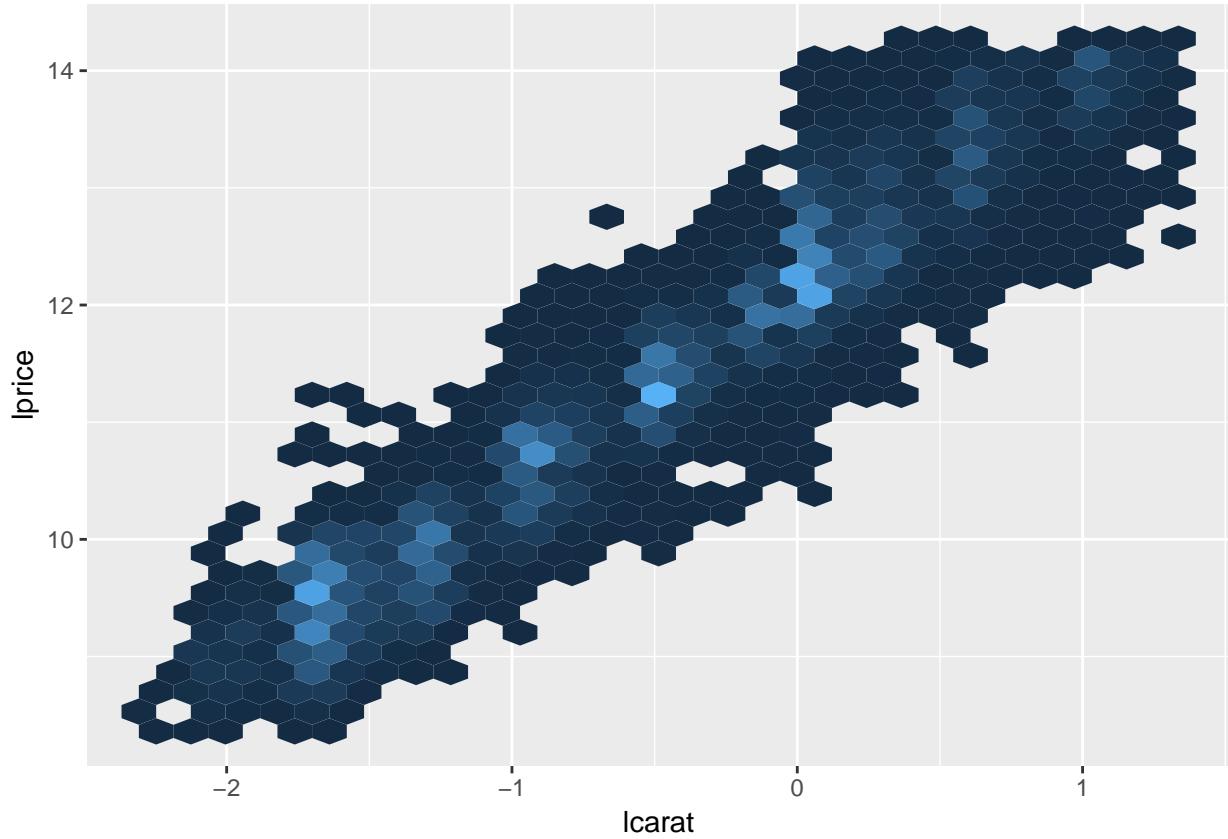
```
gridExtra::grid.arrange(plot_lc_lp, plot_lc, plot_c)
```



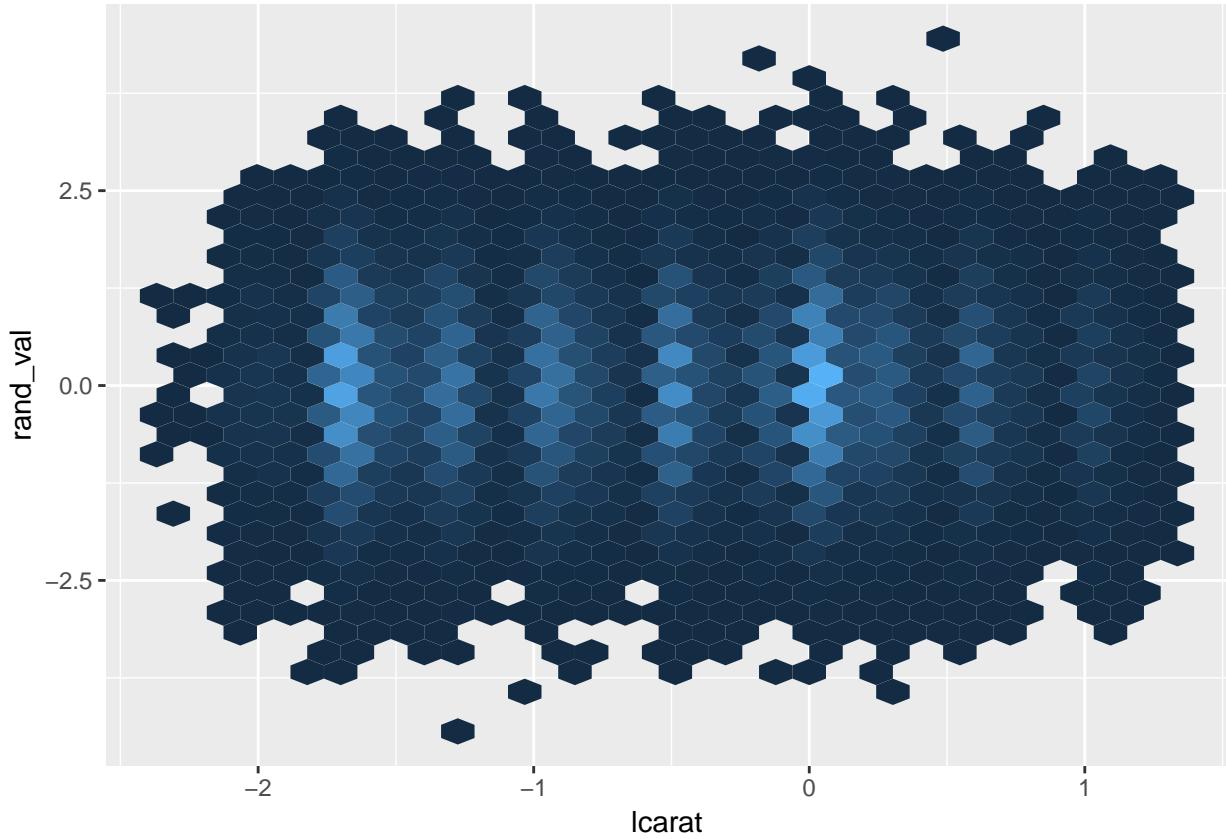
### 30.3.2 carat more clumped than price

(*Unnecessary*) \* let's see between price and carat, which causes the appearance of "bands" in the data \* to do this let's look at `geom_hex` when making the accompanying value random

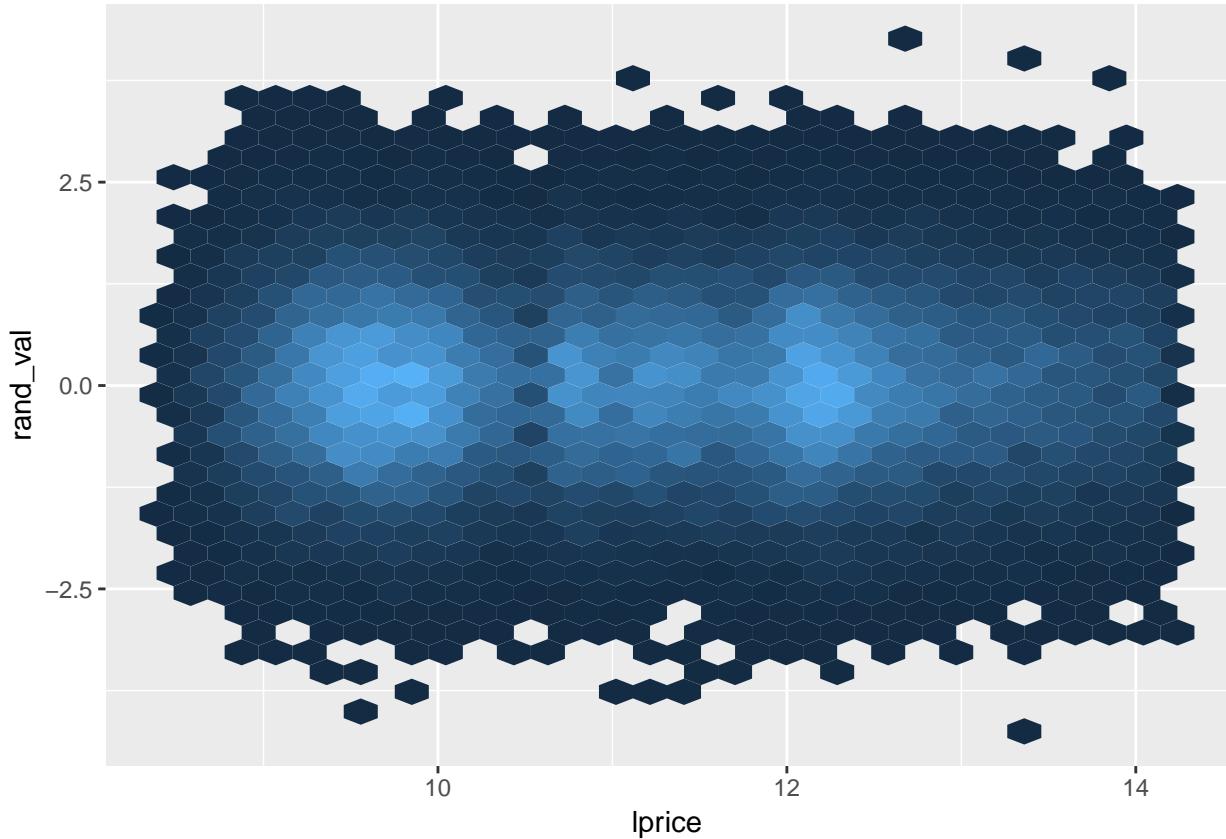
```
diamonds2 %>%
 mutate(rand_val = rnorm(n())) %>%
 ggplot(aes(lcarat, lprice)) +
 geom_hex(show.legend = FALSE)
```



```
diamonds2 %>%
 mutate(rand_val = rnorm(n())) %>%
 ggplot(aes(lcarat, rand_val)) +
 geom_hex(show.legend = FALSE)
```



```
diamonds2 %>%
 mutate(rand_val = rnorm(n())) %>%
 ggplot(aes(lprice, rand_val)) +
 geom_hex(show.legend = FALSE)
```



- clearly carat are much more clumped
- this check was unnecessary in this case, though the method felt worth saving

## 30.4 Logs (simulated examples)

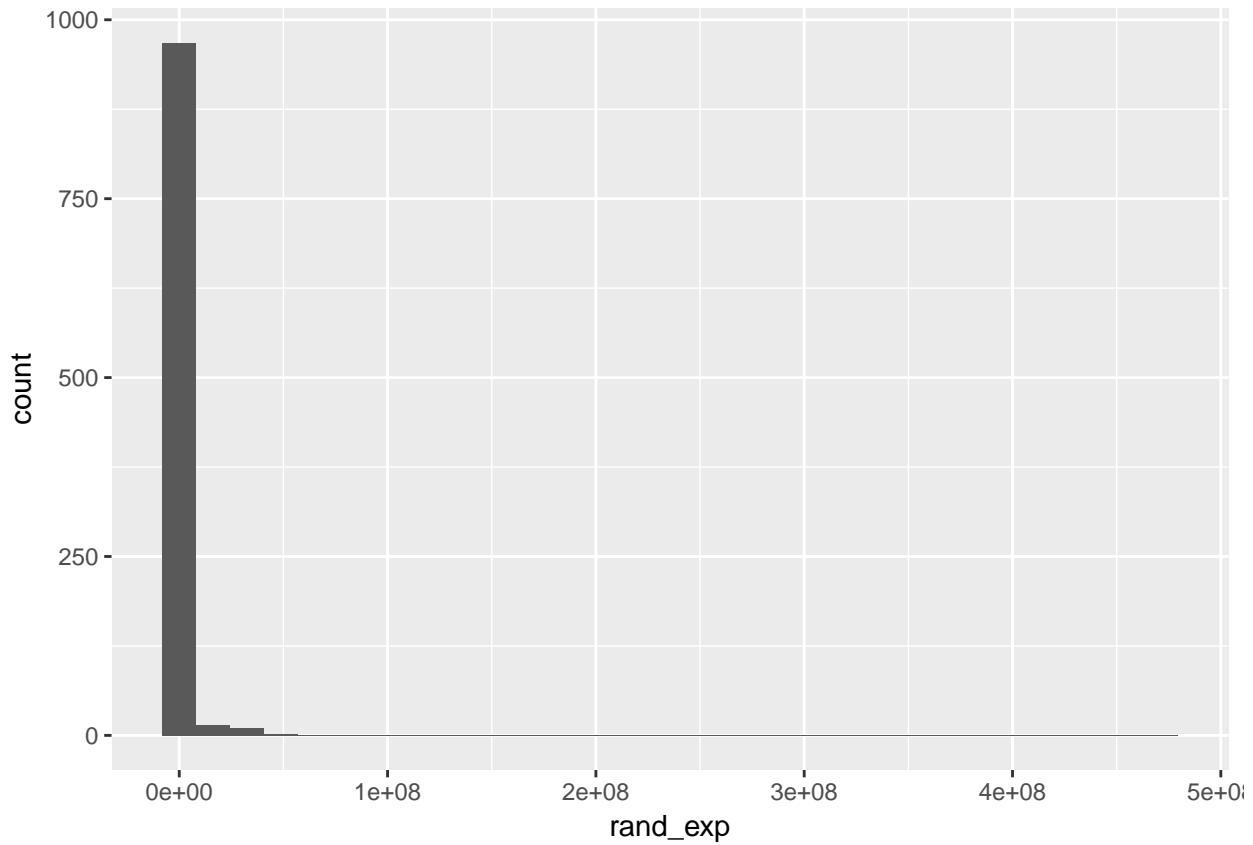
### 30.4.1 Exponential relationship

Taking the log of a value often centers the distribution which is helpful for getting more normal errors, it's actually not about making the relationship linear per se... but about making the errors normal (and linearizing the relationship has the effect of doing this). Let's generate some data.

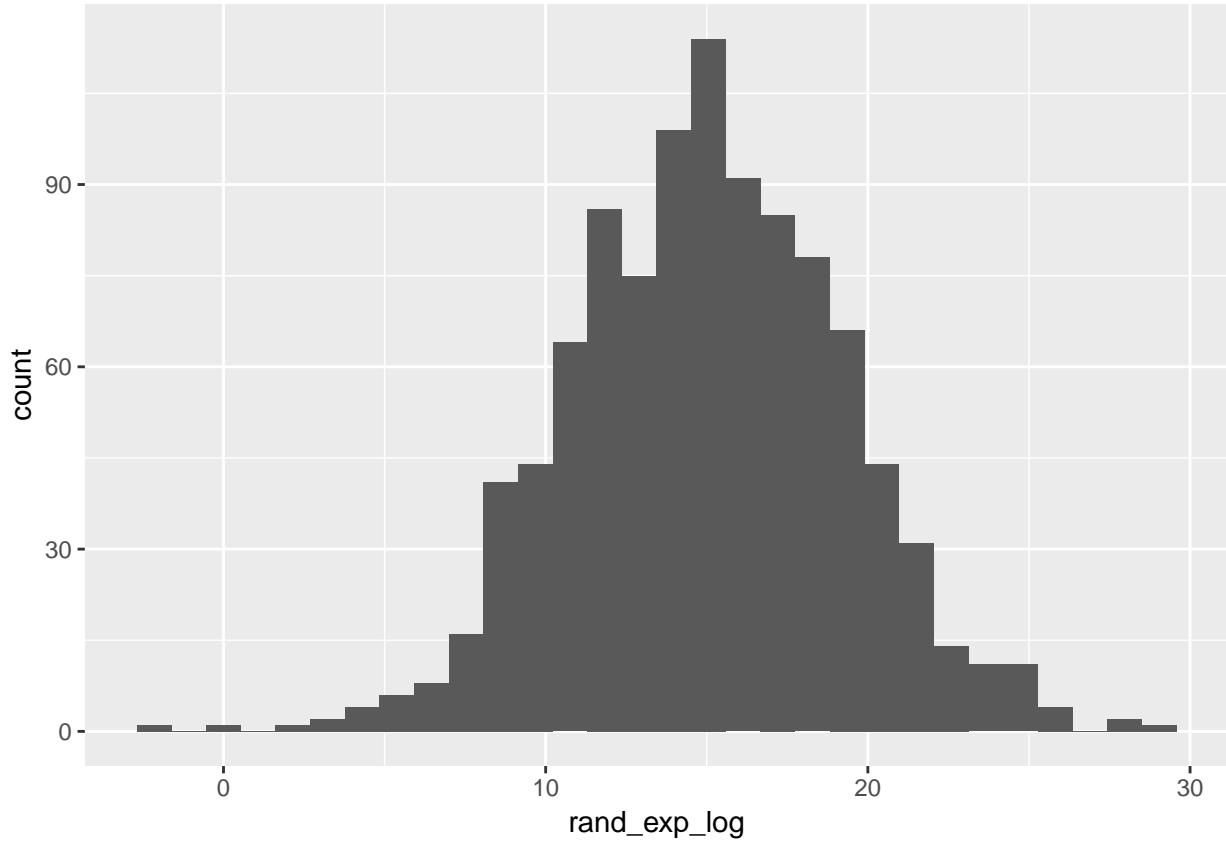
*Review logs on simulated dataset*

```
set.seed(12)
log_notes_df <- tibble(rand_origin = rnorm(1000, mean = 5),
 rand_noise = rand_origin + rnorm(1000, mean = 0, sd = 1),
 rand_exp = 8^rand_noise,
 rand_exp_log = log2(rand_exp))

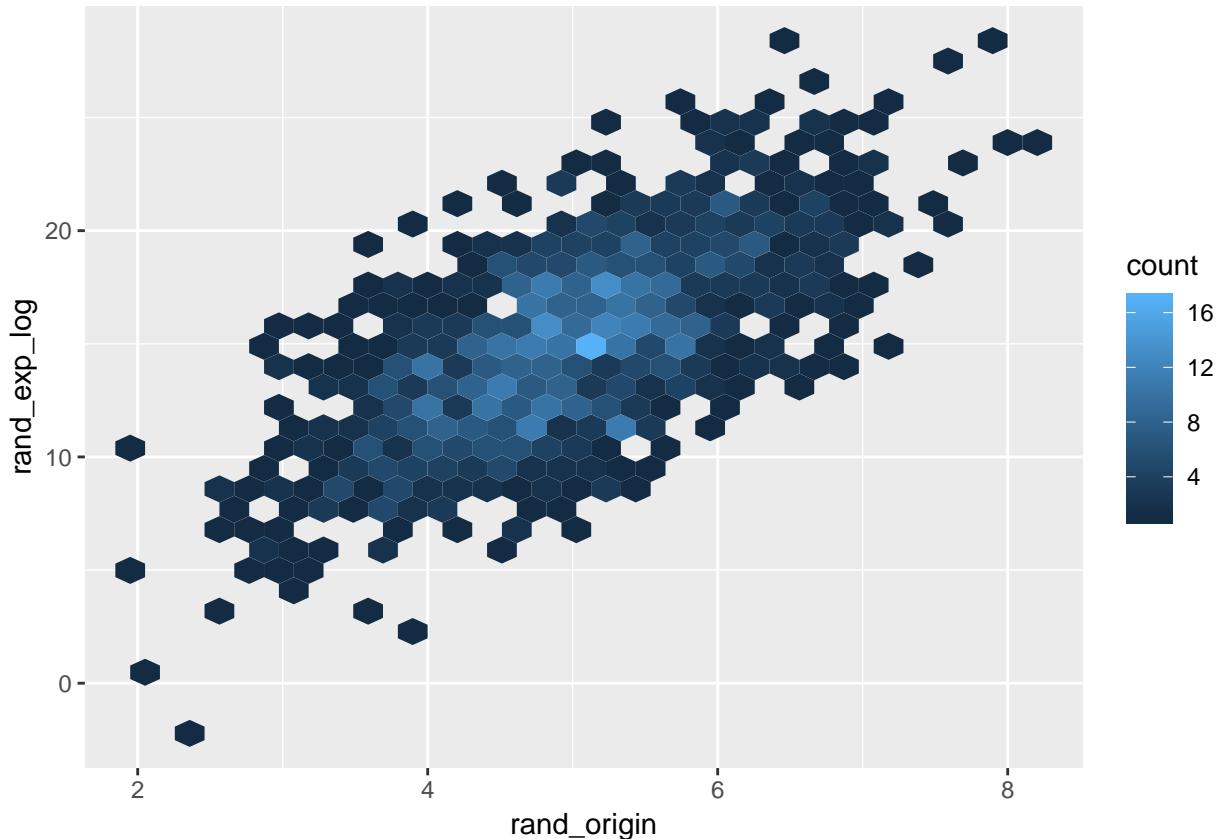
exponential distribution
log_notes_df %>%
 ggplot(aes(x = rand_exp)) +
 geom_histogram()
```



```
Then take log base 2 of
centered at 15 because 8 = 2^3 and it becomes 3*rnorm(mean = 5)
log_notes_df %>%
 ggplot(aes(x = rand_exp_log)) +
 geom_histogram()
```



```
The log helped us to uncover the relationship that existed between the original values and the values
log_notes_df %>%
 ggplot(aes(x = rand_origin, y = rand_exp_log)) +
 geom_hex()
```



```
coord_fixed()

for every one unit increase in 'rand_origin' we get a ~3 fold increase in the log of the output
this corresponds with the relationship being $2^{3 \cdot 1}$, i.e. 3 comes from 2^3 , and the 1 is because there
log_notes_df %>%
 lm(rand_exp_log ~ rand_origin, data = .)

Call:
lm(formula = rand_exp_log ~ rand_origin, data = .)

Coefficients:
(Intercept) rand_origin
0.246 2.972
• because of the properties of logs and exponents, taking the log transform is robust to linearizing any exponential relationship regardless of log
```

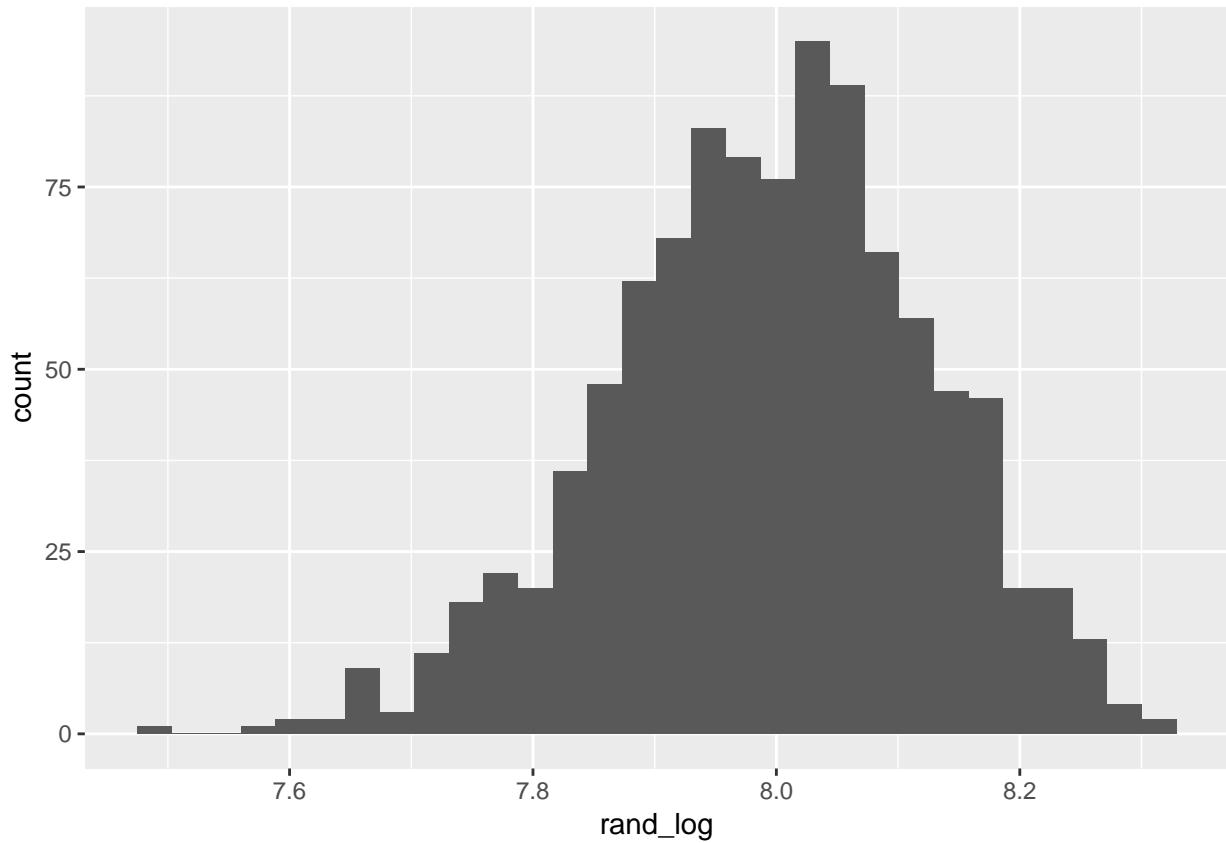
### 30.4.2 Log log relationship

What happens if you have a log relationship and you take the log of this leading to a log-log relationship? \* You would not need to take the log of a graph in this relationship, but let's look at what happens

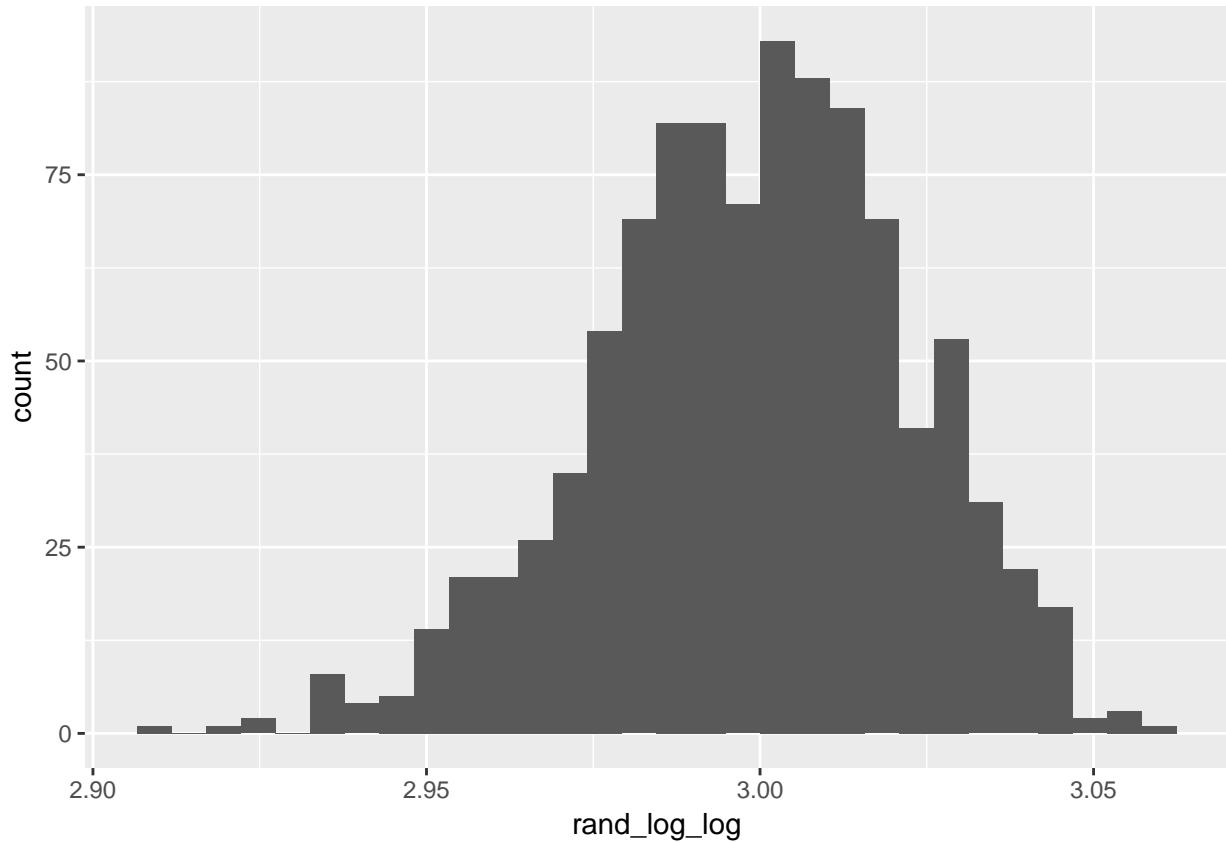
```
log_notes_df2 <- tibble(rand_origin = rnorm(1000, mean = 256, sd = 20),
 rand_noise = rand_origin + rnorm(1000, mean = 0, sd = 10),
```

```
rand_log = log2(rand_noise),
rand_log_log = log2(rand_log),
rand_exp = 2^rand_log)

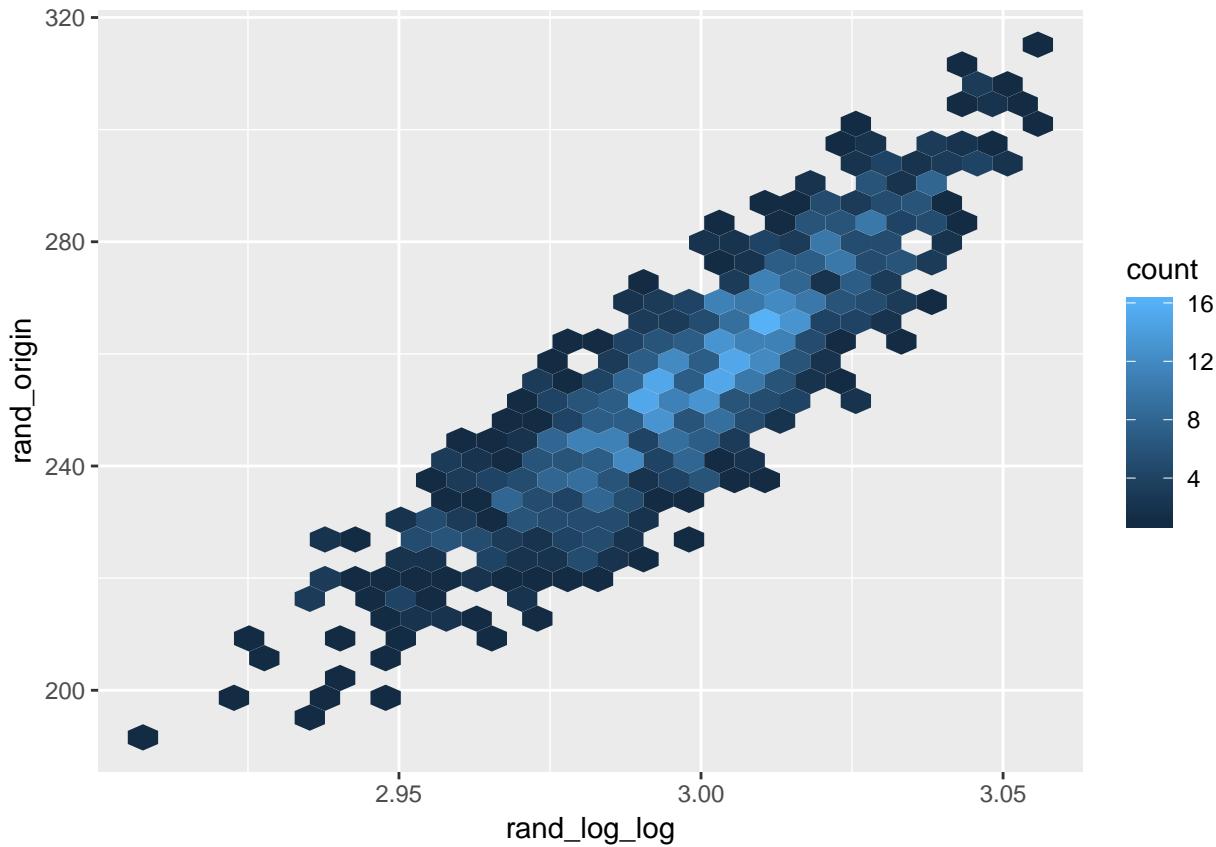
centered at 8 because 256 = 2^8
log_notes_df2 %>%
 ggplot(aes(x = rand_log))+
 geom_histogram()
```



```
centered at 3 because 2^3 = 8
log_notes_df2 %>%
 ggplot(aes(x = rand_log_log))+
 geom_histogram()
```



```
log_notes_df2 %>%
 ggplot(aes(x = rand_log_log, y = rand_origin)) +
 geom_hex()
```



- linear relationship still visually seems to exist

Conceptualizing Linear regression can actually get surprisingly complicated. I'll pull this into a separate blog post at some point.

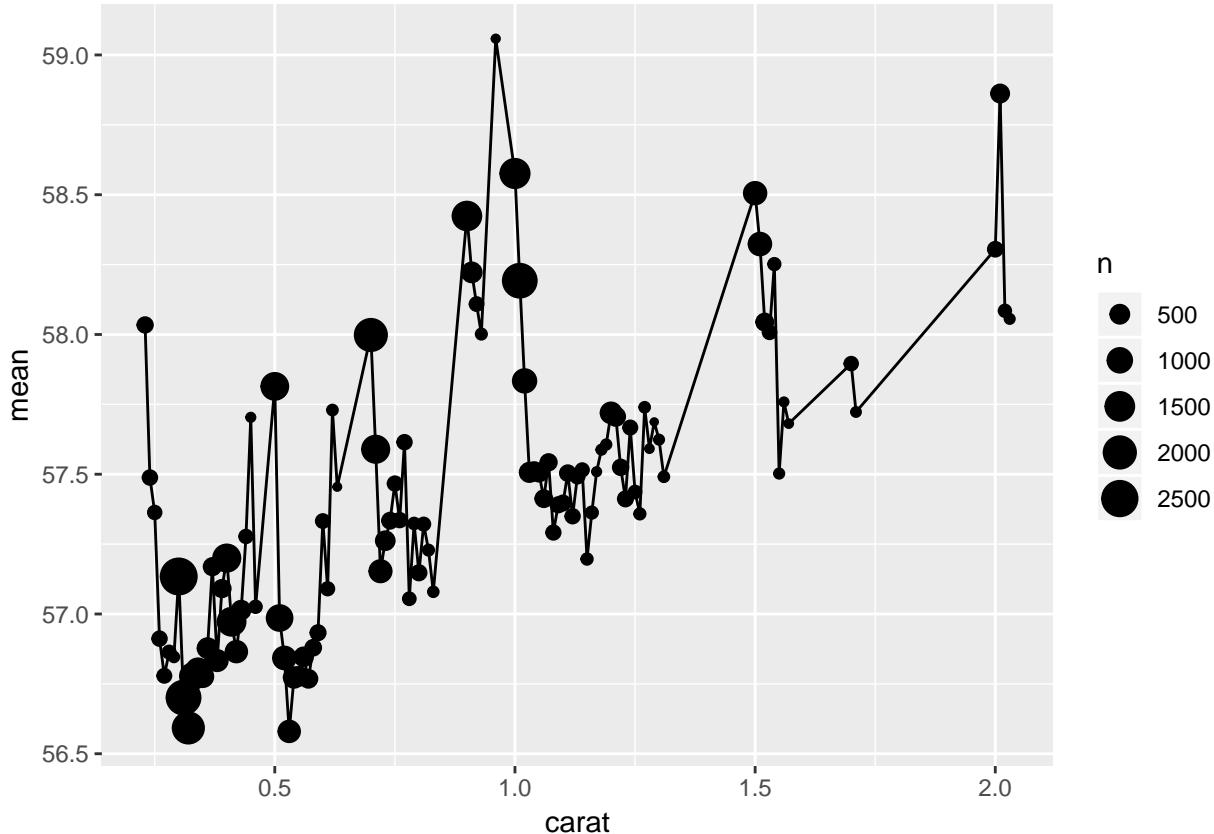
## 30.5 Diamonds data review

*(Section arguably unnecessary)*

### 30.5.1 carat by mean table value

table represents the percentage of the max area that is covered by the flat top part of the diamond

```
diamonds2 %>%
 group_by(carat) %>%
 summarise(n = n(),
 sd = sd(table),
 mean = mean(table)) %>%
 filter(n > 100) %>%
 ggplot(aes(x = carat, y = mean)) +
 geom_point(aes(size = n)) +
 geom_line()
```



### 30.5.2 Cutoff, Part 1

I get nervous that in the opening example that the diamonds dataset was biased because all values with price over 19000 or carat over 2.5 were removed. This seemed to have the affect of causing larger diamonds to have lower prices than expected. I was worried this might in some way impact the pattern described regarding the residuals across the other dimensions – so looked at the residuals when building the model on just diamonds with carats less than 0.90. None of the prices seemed to approach 19000 for carats this small so this seemed like a good place to validate the discussion on residuals.

The pattern did indeed hold for even just these small diamonds, so the example Hadley discusses seems appropriate.

*diamonds2 alternative... say that we only want to look at diamonds with carat less than 0.9*

```
diamonds_test <- diamonds %>%
 filter(carat <= 0.9) %>%
 mutate_at(vars(price, carat), funs(lg = log2))
```

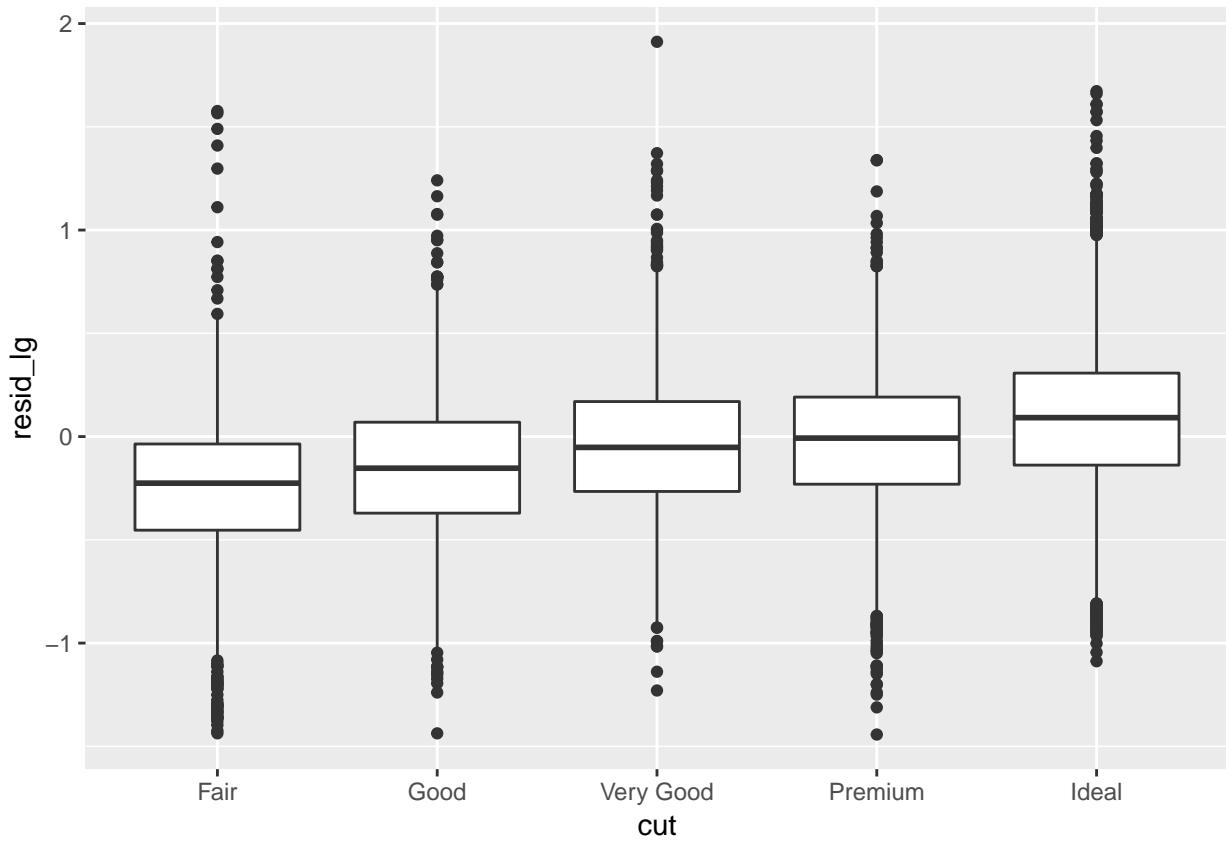
```
Warning: funs() is soft deprecated as of dplyr 0.8.0
please use list() instead
##
Before:
funs(name = f(.))
##
After:
list(name = ~f(..))
This warning is displayed once per session.
```

```
mod_diamond <- diamonds_test %>%
 lm(price_lg ~ carat_lg, data = .)

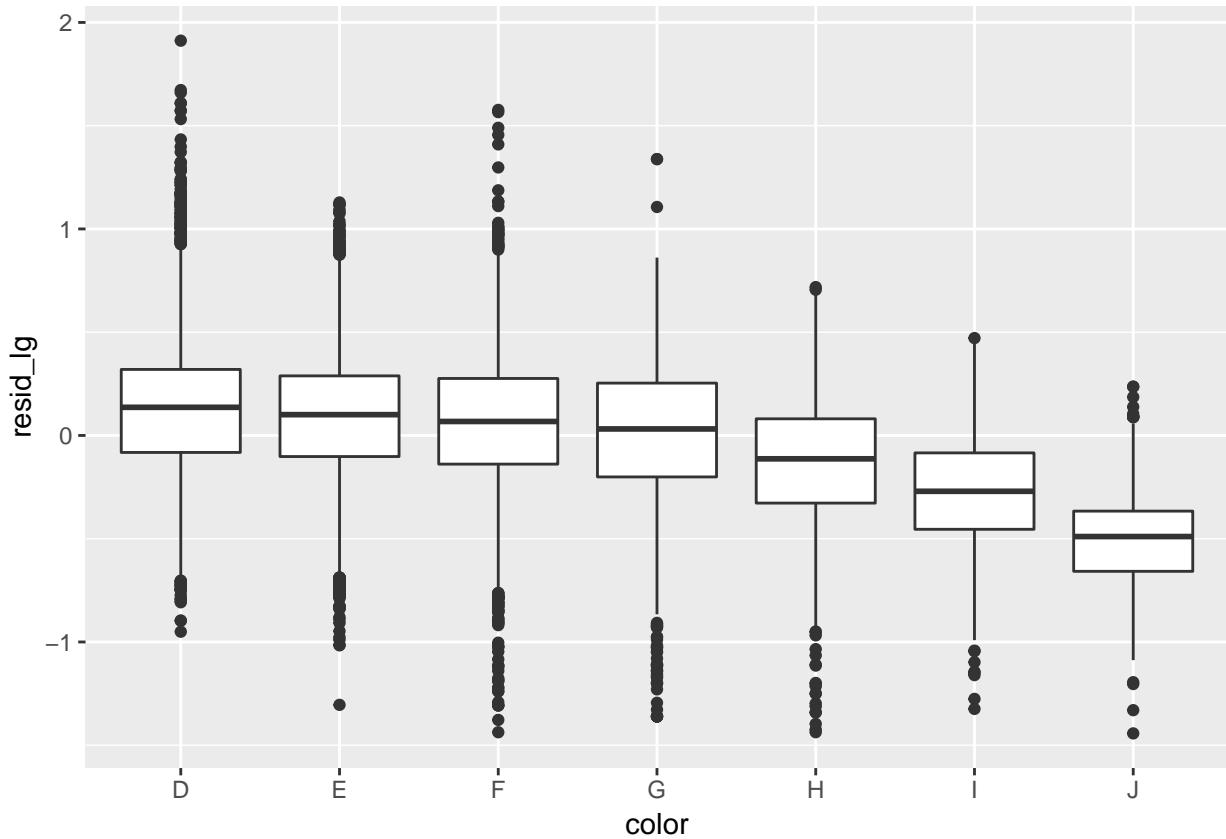
diamonds2_w_mod <- diamonds_test %>%
 add_residuals(mod_diamond, "resid_lg")
```

All the patterns Hadley pointed-out seem to hold on this slightly modified dataset

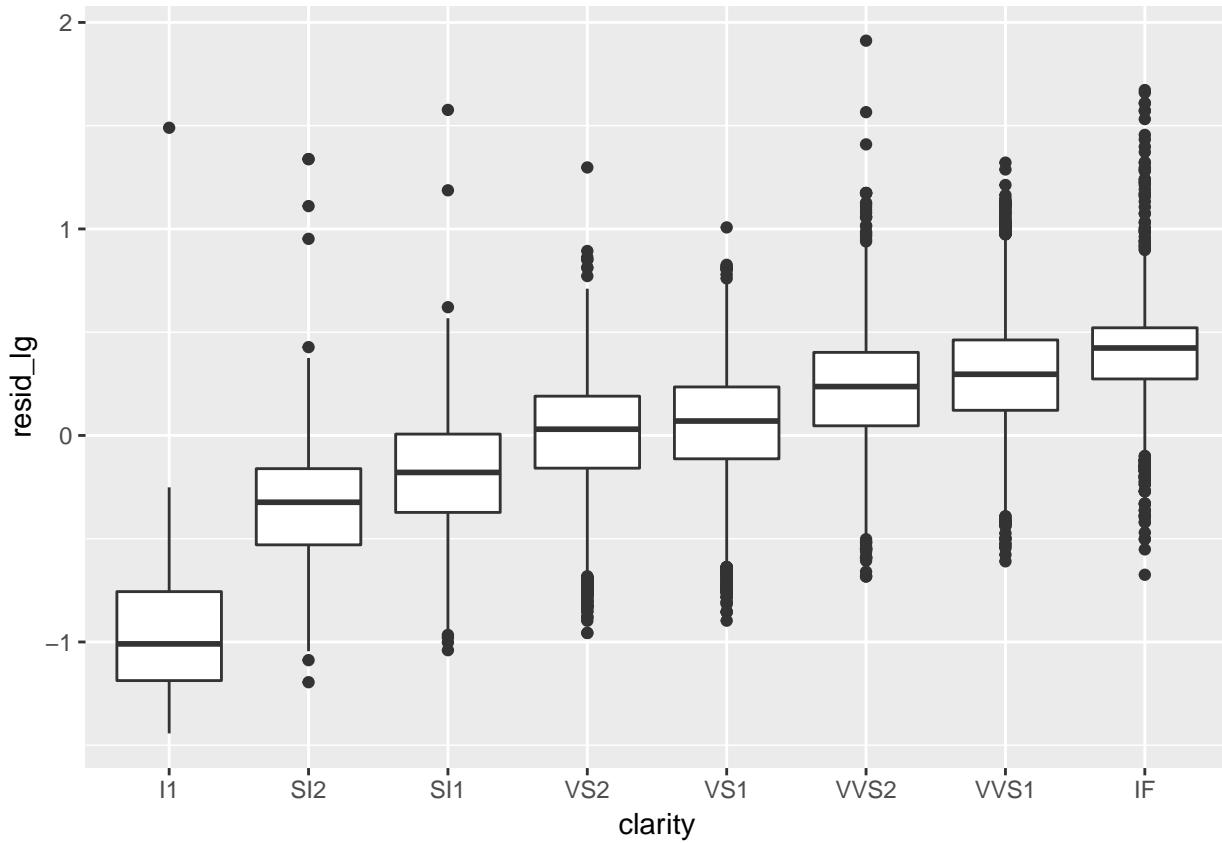
```
ggplot(diamonds2_w_mod, aes(cut, resid_lg)) + geom_boxplot()
```



```
ggplot(diamonds2_w_mod, aes(color, resid_lg)) + geom_boxplot()
```



```
ggplot(diamonds2_w_mod, aes(clarity, resid_lg)) + geom_boxplot()
```



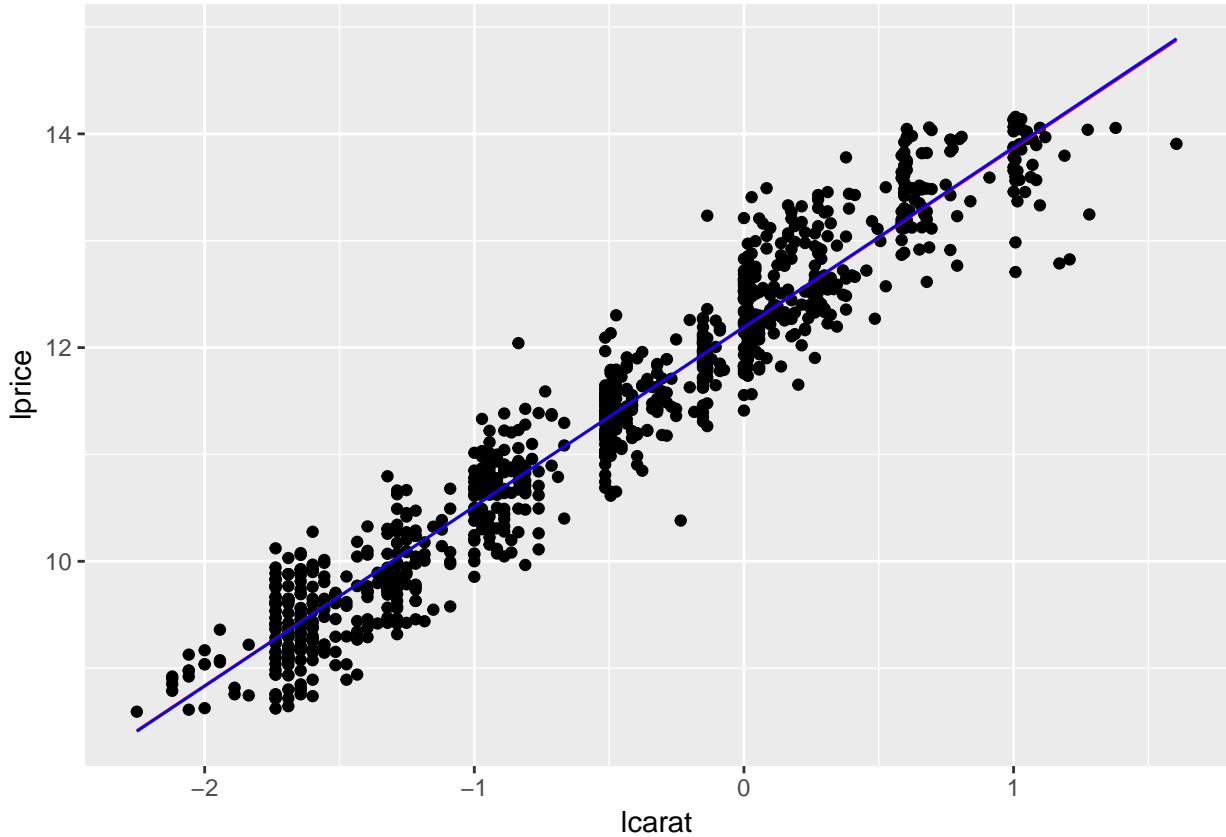
### 30.5.3 Cutoff, Part 2

Check if there are differences in coefficients when training on full diamonds data set v diamonds2 dataset

```
mod_diamonds <- diamonds %>%
 mutate(lprice = log2(price),
 lcarat = log2(carat)) %>%
 lm(lprice ~ lcarat, data = .)

mod_diamonds2 <- lm(lprice ~ lcarat, data = diamonds2)

diamonds %>%
 mutate(lprice = log2(price),
 lcarat = log2(carat)) %>%
 spread_predictions(mod_diamonds, mod_diamonds2) %>%
 sample_n(1000) %>%
ggplot(aes(x = lcarat, y = lprice)) +
 geom_point() +
 geom_line(aes(y = mod_diamonds), colour = "red") +
 geom_line(aes(y = mod_diamonds2), colour = "blue")
```



essentially no difference between the models that come-out when training on one v the other

### 30.6 25.3.5.4

In this section I create a marker for days that are “near a holiday”

```
near_holidays <- holidays %>%
 # This creates a series of helper variables to create the variable 'Holiday_IntervalDay' that represents
 mutate(HolidayWday = wday(HolidayDate, label = TRUE),
 HolidayWknd = lubridate::round_date(HolidayDate, unit = "week"),
 HolidayFloor = lubridate::floor_date(HolidayDate, unit = "week"),
 HolidayCeiling = lubridate::ceiling_date(HolidayDate, unit = "week"),
 Holiday_IntervalDay = case_when(HolidayWknd == HolidayFloor ~ (HolidayFloor - ddays(2)),
 TRUE ~ HolidayCeiling)) %>%
 mutate(Holiday_Period = interval(pmin(HolidayDate, Holiday_IntervalDay), pmax(HolidayDate, Holiday_IntervalDay)))

This returns each day and whether it occurred near a holiday
near_holiday <- map(near_holidays$Holiday_Period, ~(seq.Date(ymd("2013-01-01"), ymd("2013-12-31"), by =
 transpose() %>%
 map_lgl(any) %>%
 as_tibble() %>%
 rename(NearHoliday = value) %>%
 mutate(date = seq.Date(ymd("2013-01-01"), ymd("2013-12-31"), by = "day")))

near_holiday
```

```
A tibble: 365 x 2
NearHoliday date
<lgl> <date>
1 TRUE 2013-01-01
2 FALSE 2013-01-02
3 FALSE 2013-01-03
4 FALSE 2013-01-04
5 FALSE 2013-01-05
6 FALSE 2013-01-06
7 FALSE 2013-01-07
8 FALSE 2013-01-08
9 FALSE 2013-01-09
10 FALSE 2013-01-10
... with 355 more rows
```

- I ended-up not adding any additional analysis here, though the methodology for creating the “near holiday” seemed worth saving
- Could come back to add more in the future

*Make sure the following packages are installed:*



# Chapter 31

## ch. 25: Many models

- `nest` creates a list-column with default key value `data`. Each row value becomes a dataframe with all non-grouping columns and all rows corresponding with a particular group

```
iris %>%
 group_by(Species) %>%
 nest()
```

- `unnest` unnest any list-column in your dataframe.

Notes on `unnest` behavior: \* if there are multiple rows in the list-col being unnested, the existing row values will be duplicated

```
tibble(x = 1:100) %>%
 mutate(test1 = list(c(1,2))) %>%
 unnest(test1)

notice duplicated x values: 1,1,2,2,...100,100
Notice that in situations like the below one though, we get two new columns
however the row length does not change i.e. there are no duplicates created
(this is similar to the structure when using broom::glance)
tibble(x = 1:100) %>%
 mutate(test1 = list(tibble(a = 1, b = 2))) %>%
 unnest(test1)
```

- if there are multiple list-cols, specify the column to unnest or default behavior will be to unnest all (if not possible)
- when unnesting a single column but multiple list-cols exist, the default behavior is that if unnesting caused no change in row number than keep other list-cols, but if unnesting caused a change in row-number drop other columns. To override the former use `.drop = TRUE` to override the latter use `.drop = FALSE`.<sup>1</sup>

```
tibble(x = 1:100) %>%
 mutate(test1 = list(c(1,2)),
 test2 = list(c(3,4))) %>%
 unnest(test1) # use .drop = TRUE to drop test2 column

or to unnest both
tibble(x = 1:100) %>%
 mutate(test1 = list(c(1,2)),
```

<sup>1</sup>Note that if using `.drop = FALSE` in the latter case that you are creating replicated rows for list-col values

```
test2 = list(c(3,4)) %>%
unnest()
```

- when unnesting multiple columns, all must be the same length or you will get an error, e.g. below would fail:

```
tibble(x = 1:100) %>%
 mutate(test1 = list(c(1)),
 test2 = list(c(2,3))) %>%
unnest()
```

- To unnest multiple list-cols with different row-lengths, you should use multiple `unnest` statements, e.g. below would work:

```
tibble(x = 1:100) %>%
 mutate(test1 = list(c(1)),
 test2 = list(c(2,3))) %>%
unnest(test1) %>%
unnest(test2)
```

- Method for nesting individual vectors: `group_by %>% summarise`, e.g.:

```
iris %>%
 group_by(Species) %>%
 summarise_all(list)
```

```
A tibble: 3 x 5
Species Sepal.Length Sepal.Width Petal.Length Petal.Width
<fct> <list> <list> <list> <list>
1 setosa <dbl [50]> <dbl [50]> <dbl [50]> <dbl [50]>
2 versicolor <dbl [50]> <dbl [50]> <dbl [50]> <dbl [50]>
3 virginica <dbl [50]> <dbl [50]> <dbl [50]> <dbl [50]>
```

- the above has the advantage of producing atomic vectors rather than dataframes as the types inside of the lists
- `broom::glance` takes a model as input and outputs a one row tibble with columns for each of several model evalation statistics (note that these metrics are geared towards evaluating the training)
- `broom::tidy` creates a tibble with columns `term`, `estimate`, `std.error`, `statistic` (t-statistic) and `p.value`. A new row is created for each `term` type, e.g. intercept, x1, x2, etc.
- `ggtitle()`, alternative to `labs(title = "type title here")`
- see 25.4.5 number 3 for a useful way of wrapping certain functions in `list` functions to take advantage of the list-col format

## 31.1 25.2: gapminder

The set-up example Hadley goes through is important, below is a slightly altered copy of his example.

### Nested Data

```
by_country <- gapminder::gapminder %>%
 group_by(country, continent) %>%
 nest()
```

### List-columns

```
country_model <- function(df) {
 lm(lifeExp ~ year, data = df)
}
```

Want to apply this function over every data frame, the dataframes are in a list, so do this by:

```
by_country2 <- by_country %>%
 mutate(model = purrr::map(data, country_model))
```

Advantage with keeping things in the dataframe is that when you filter, or move things around, everything stays in sync, as do new summary values you might add.

```
by_country2 %>%
 arrange(continent, country)
```

```
A tibble: 142 x 4
country continent data model
<fct> <fct> <list> <list>
1 Algeria Africa <tibble [12 x 4]> <S3: lm>
2 Angola Africa <tibble [12 x 4]> <S3: lm>
3 Benin Africa <tibble [12 x 4]> <S3: lm>
4 Botswana Africa <tibble [12 x 4]> <S3: lm>
5 Burkina Faso Africa <tibble [12 x 4]> <S3: lm>
6 Burundi Africa <tibble [12 x 4]> <S3: lm>
7 Cameroon Africa <tibble [12 x 4]> <S3: lm>
8 Central African Republic Africa <tibble [12 x 4]> <S3: lm>
9 Chad Africa <tibble [12 x 4]> <S3: lm>
10 Comoros Africa <tibble [12 x 4]> <S3: lm>
... with 132 more rows
```

```
by_country2 %>%
 mutate(summaries = purrr::map(model, summary)) %>%
 mutate(r_squared = purrr::map2_dbl(model, data, rsquare))
```

```
A tibble: 142 x 6
country continent data model summaries r_squared
<fct> <fct> <list> <list> <list> <dbl>
1 Afghanistan Asia <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.948
2 Albania Europe <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.911
3 Algeria Africa <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.985
4 Angola Africa <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.888
5 Argentina Americas <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.996
6 Australia Oceania <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.980
7 Austria Europe <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.992
8 Bahrain Asia <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.967
9 Bangladesh Asia <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.989
10 Belgium Europe <tibble [12 x 4~ <S3: 1~ <S3: summary.l~ 0.995
... with 132 more rows
```

**unnesting**, dd another data frame with the residuals included and then unnest

```
by_country3 <- by_country2 %>%
 mutate(resids = purrr::map2(data, model, add_residuals))
```

```
resids <- by_country3 %>%
 unnest(resids)
```

```
resids
```

```
A tibble: 1,704 x 7
country continent year lifeExp pop gdpPercap resid
<fct> <fct> <int> <dbl> <int> <dbl> <dbl>
1 Afghanistan Asia 1952 28.8 8425333 779. -1.11
2 Afghanistan Asia 1957 30.3 9240934 821. -0.952
3 Afghanistan Asia 1962 32.0 10267083 853. -0.664
4 Afghanistan Asia 1967 34.0 11537966 836. -0.0172
5 Afghanistan Asia 1972 36.1 13079460 740. 0.674
6 Afghanistan Asia 1977 38.4 14880372 786. 1.65
7 Afghanistan Asia 1982 39.9 12881816 978. 1.69
8 Afghanistan Asia 1987 40.8 13867957 852. 1.28
9 Afghanistan Asia 1992 41.7 16317921 649. 0.754
10 Afghanistan Asia 1997 41.8 22227415 635. -0.534
... with 1,694 more rows
```

### 31.1.1 25.2.5

1. A linear trend seems to be slightly too simple for the overall trend. Can you do better with a quadratic polynomial? How can you interpret the coefficients of the quadratic? (Hint you might want to transform `year` so that it has mean zero.)

*Create functions*

```
function to center value
center_value <- function(df){
 df %>%
 mutate(year_cent = year - mean(year))
}

this function allows me to input any text to "var" to customize the inputs
to the model, default are a linear and quadratic term for year (centered)
lm_quad_2 <- function(df, var = "year_cent + I(year_cent^2")){
 lm(as.formula(paste("lifeExp ~ ", var)), data = df)
}
```

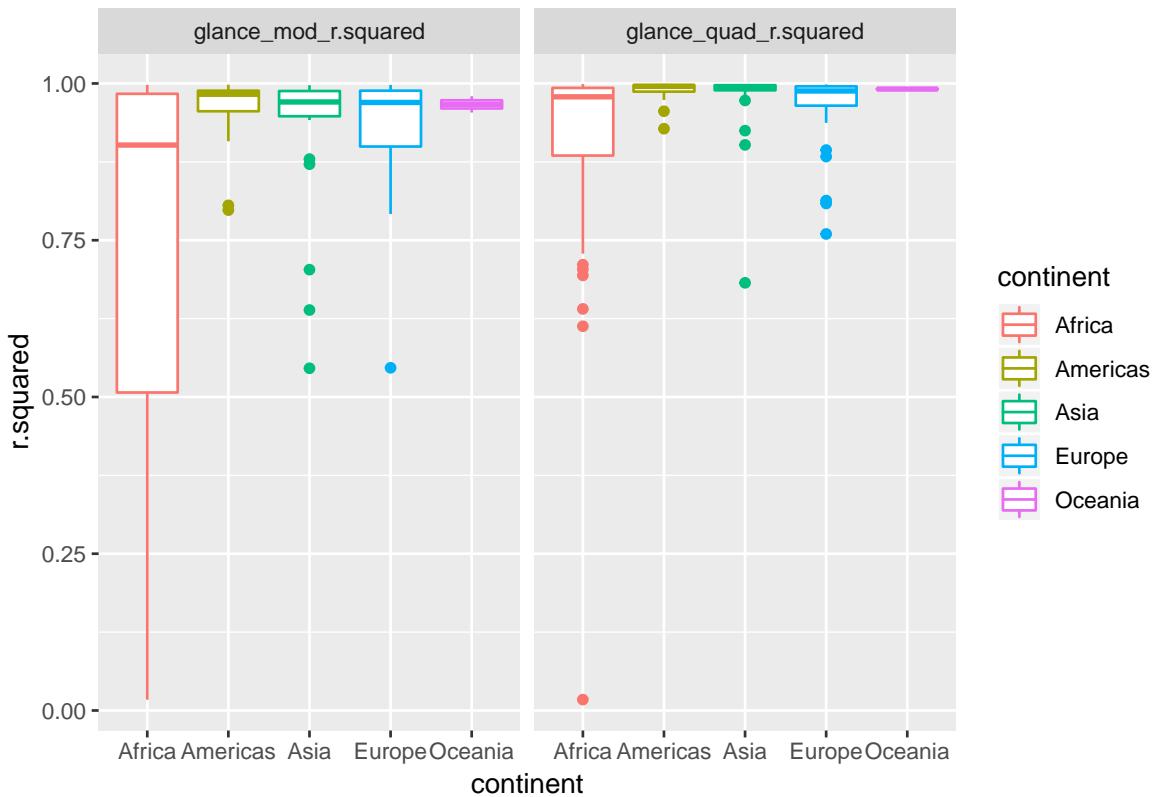
*Create dataframe with evaluation metrics*

```
by_country3_quad <- by_country3 %>%
 mutate(
 # create centered data
 data_cent = purrr::map(data, center_value),
 # create quadratic models
 mod_quad = purrr::map(data_cent, lm_quad_2),
 # get model evaluation stats from original model
 glance_mod = purrr::map(model, broom::glance),
 # get model evaluation stats from quadratic model
 glance_quad = purrr::map(mod_quad, broom::glance))
```

*Create plots*

```
by_country3_quad %>%
 unnest(glance_mod, glance_quad, .sep = "_", .drop = TRUE) %>%
 gather(glance_mod_r.squared, glance_quad_r.squared,
 key = "order", value = "r.squared") %>%
```

```
ggplot(aes(x = continent, y = r.squared, colour = continent)) +
 geom_boxplot() +
 facet_wrap(~order)
```

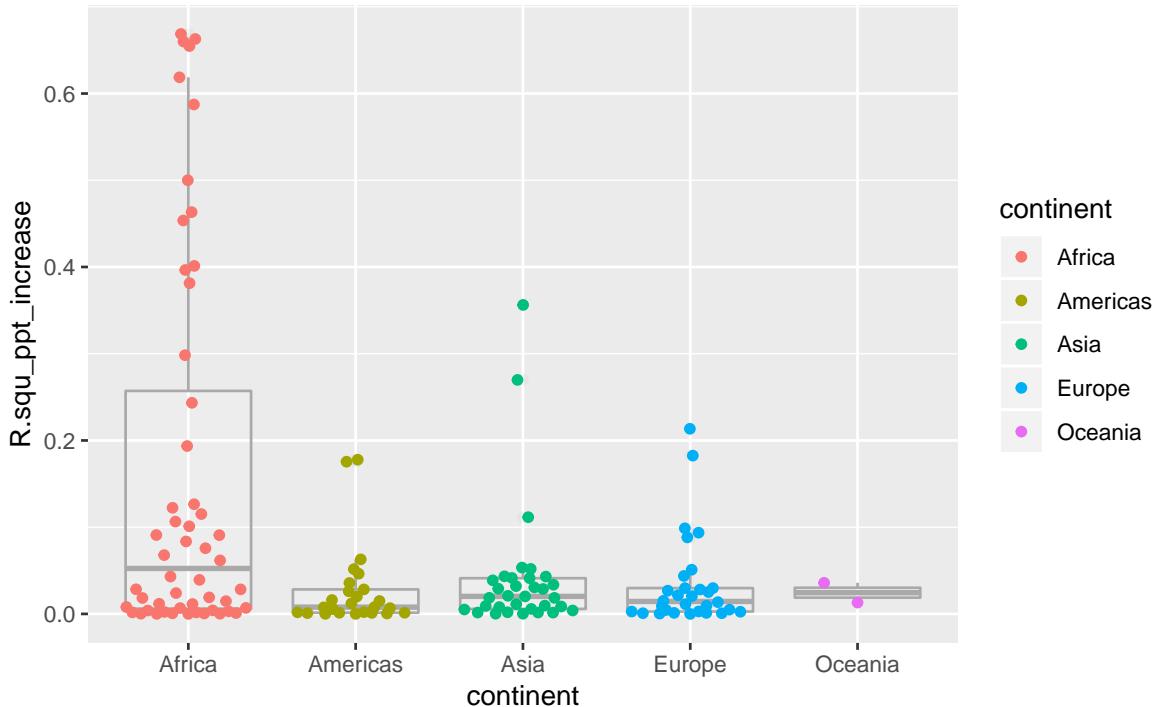


- The quadratic trend seems to do better → indicated by the distribution of the  $R^2$  values being closer to one. The level of improvement seems especially pronounced for African countries.

Let's check this for sure by looking at percentage point improvement in  $R^2$  in chart below

```
by_country3_quad %>%
 mutate(quad_coefs = map(mod_quad, broom::tidy)) %>%
 unnest(glance_mod, .sep = "_") %>%
 unnest(glance_quad) %>%
 mutate(bad_fit = glance_mod_r.squared < 0.25,
 R.squ_ppt_increase = r.squared - glance_mod_r.squared) %>%
 ggplot(aes(x = continent, y = R.squ_ppt_increase)) +
 # geom_quasirandom(aes(alpha = bad_fit), colour = "black") +
 geom_boxplot(alpha = 0.1, colour = "dark grey") +
 geom_quasirandom(aes(colour = continent)) +
 labs(title = "Percentage point (PPT) improvement in R squared value",
 subtitle = "(When adding a quadratic term to the linear regression model)")
```

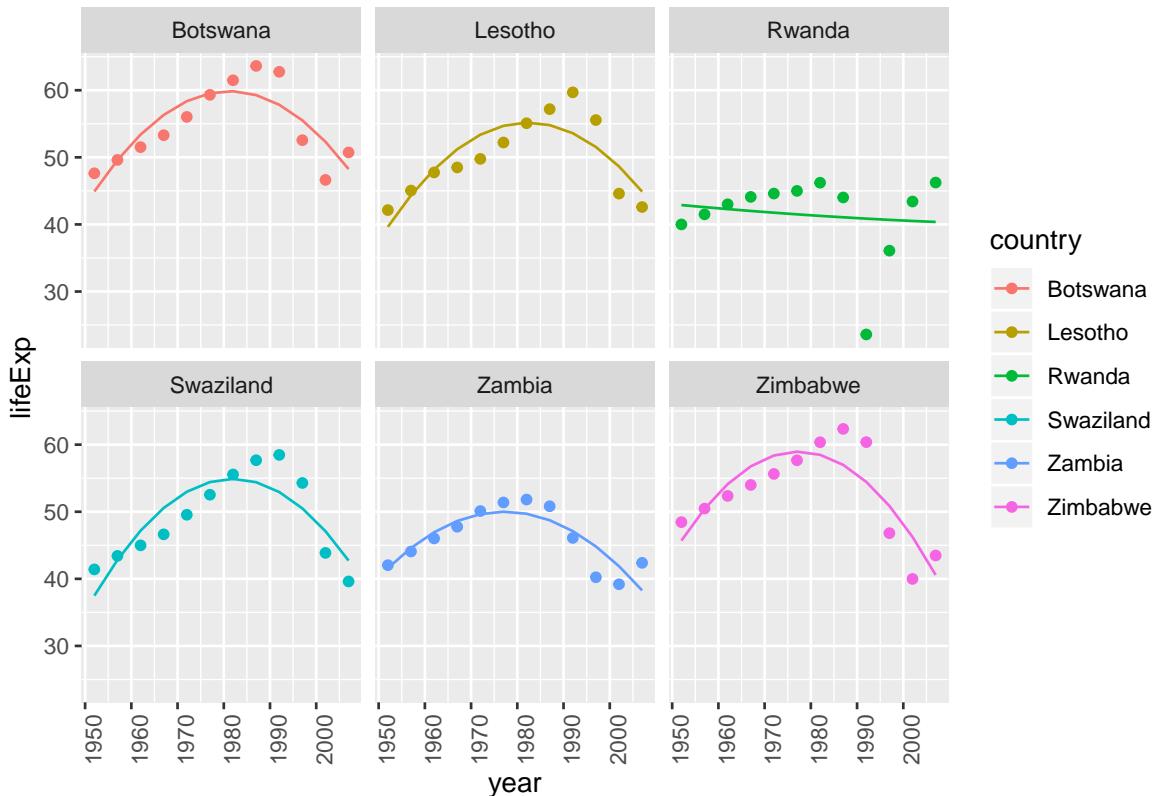
Percentage point (PPT) improvement in R squared value  
 (When adding a quadratic term to the linear regression model)



*View predictions from linear model with quadratic term (of countries where linear trend did not capture relationship)*

```
bad_fit <- by_country3 %>%
 mutate(glance = purrr::map(model, broom::glance)) %>%
 unnest(glance, .drop = TRUE) %>%
 filter(r.squared < 0.25)

#solve with join with bad_fit
by_country3_quad %>%
 semi_join(bad_fit, by = "country") %>%
 mutate(data_preds = purrr::map2(data_cent, mod_quad, add_predictions)) %>%
 unnest(data_preds) %>%
 ggplot(aes(x = year, group = country)) +
 geom_point(aes(y = lifeExp, colour = country)) +
 geom_line(aes(y = pred, colour = country)) +
 facet_wrap(~country) +
 theme(axis.text.x = element_text(angle = 90, hjust = 1))
```

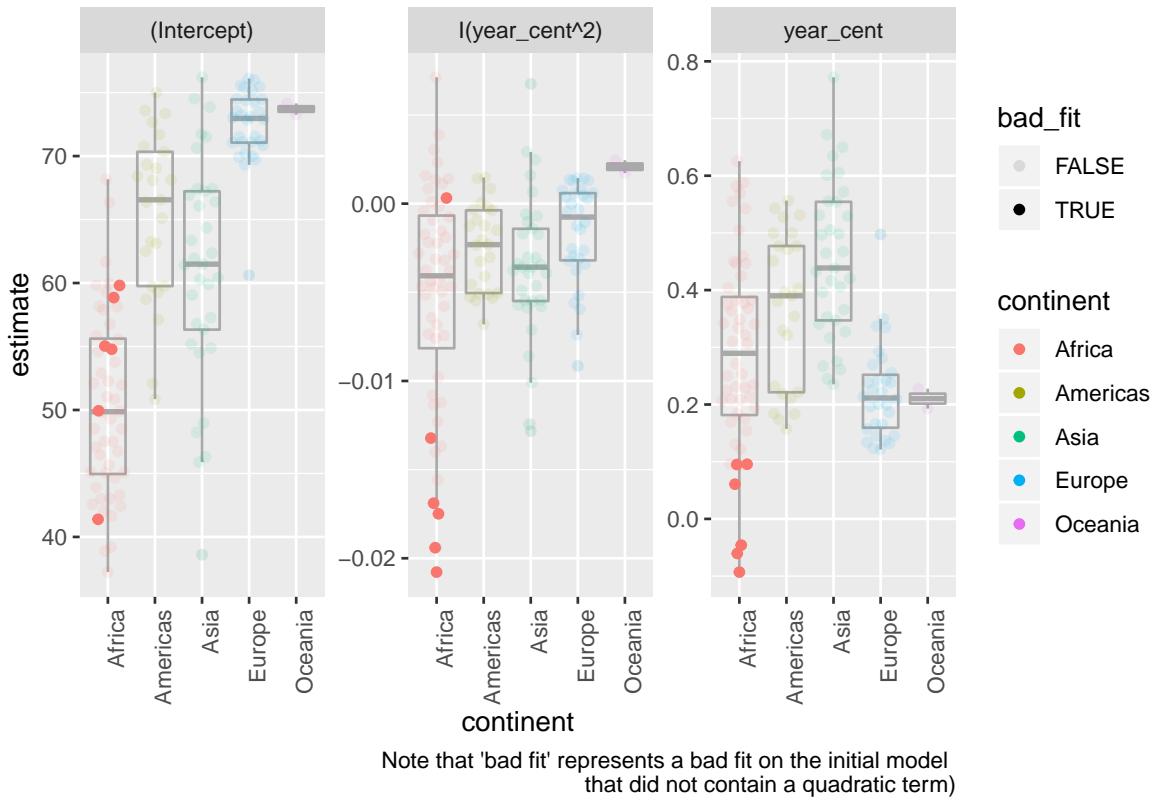


- while the quadratic model does a better job fitting the model than a linear term does, I wouldn't say it does a good job of fitting the model
- it looks like the trends are generally consistent rates of improvement and then there is a sudden drop-off associated with some event, hence an intervention variable may be a more appropriate method for modeling this pattern

#### Quadratic model parameters

```
by_country3_quad %>%
 mutate(quad_coefs = map(mod_quad, broom::tidy)) %>%
 unnest(glance_mod, .sep = "_") %>%
 unnest(glance_quad) %>%
 unnest(quad_coefs) %>%
 mutate(bad_fit = glance_mod_r.squared < 0.25) %>%
 ggplot(aes(x = continent, y = estimate, alpha = bad_fit)) +
 geom_boxplot(alpha = 0.1, colour = "dark grey") +
 geom_quasirandom(aes(colour = continent)) +
 facet_wrap(~term, scales = "free") +
 labs(caption = "Note that 'bad fit' represents a bad fit on the initial model \nthat did not contain the quadratic term")
 theme(axis.text.x = element_text(angle = 90, hjust = 1))
```

## Warning: Using alpha for a discrete variable is not advised.



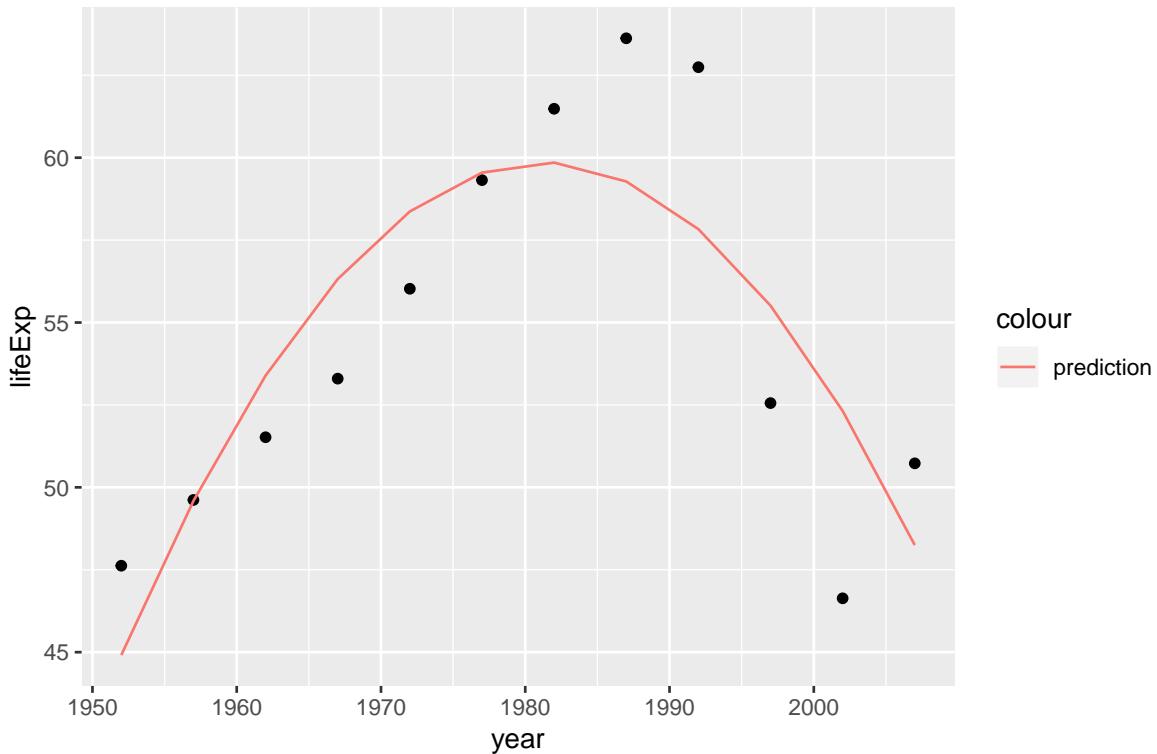
- The quadratic term (in a linear function, trained with the x-value centered at the mean, as in this dataset) has a few important notes related to interpretation
  - If the coefficient is positive the output will be convex, if it is negative it will be concave (i.e. smile vs. frown shape)
  - The value on the coefficient represents  $1/2$  the rate at which the relationship between `lifeExp` and `year` is changing for every one unit change from the mean / expected value of `lifeExp` in the dataset.
  - Hence if the coefficient is near 0, that means the relationship between `lifeExp` and `year` does not change (or at least does not change at a constant rate) when moving in either direction from `lifeExps` mean value.

To better understand this, let's look at a specific example. Excluding Rwanda, Botswana was the country that the linear model without the quadratic term performed the worst on. We'll use this as our example for interpreting the coefficients.

*Plots of predicted and actual values for Botswanan life expectancy by year*

```
by_country3_quad %>%
 filter(country == "Botswana") %>%
 mutate(data_preds = purrr::map2(data_cent, mod_quad, add_predictions)) %>%
 unnest(data_preds) %>%
 ggplot(aes(x = year, group = country)) +
 geom_point(aes(y = lifeExp)) +
 geom_line(aes(y = pred, colour = "prediction")) +
 labs(title = "Data and quadratic trend of predictions for Botswana")
```

### Data and quadratic trend of predictions for Botswana



(note that the centered value for year in the ‘centered’ dataset is 1979.5)

In the model for Botswana, coefficients are:

Intercept: ~ 59.81

year (centered): ~ 0.0607

year (centered)<sup>2</sup>: ~ -0.0175

Hence for every one year we move away from the central year (1979.5), the rate of change between year and price decreases by ~0.035.

Below I show this graphically by plotting the lines tangent to the models output.

```
botswana_coefs <- by_country3_quad %>%
 filter(country == "Botswana") %>%
 with(map(mod_quad, coef)) %>%
 flatten_dbl()
```

Helper functions to find tangent points

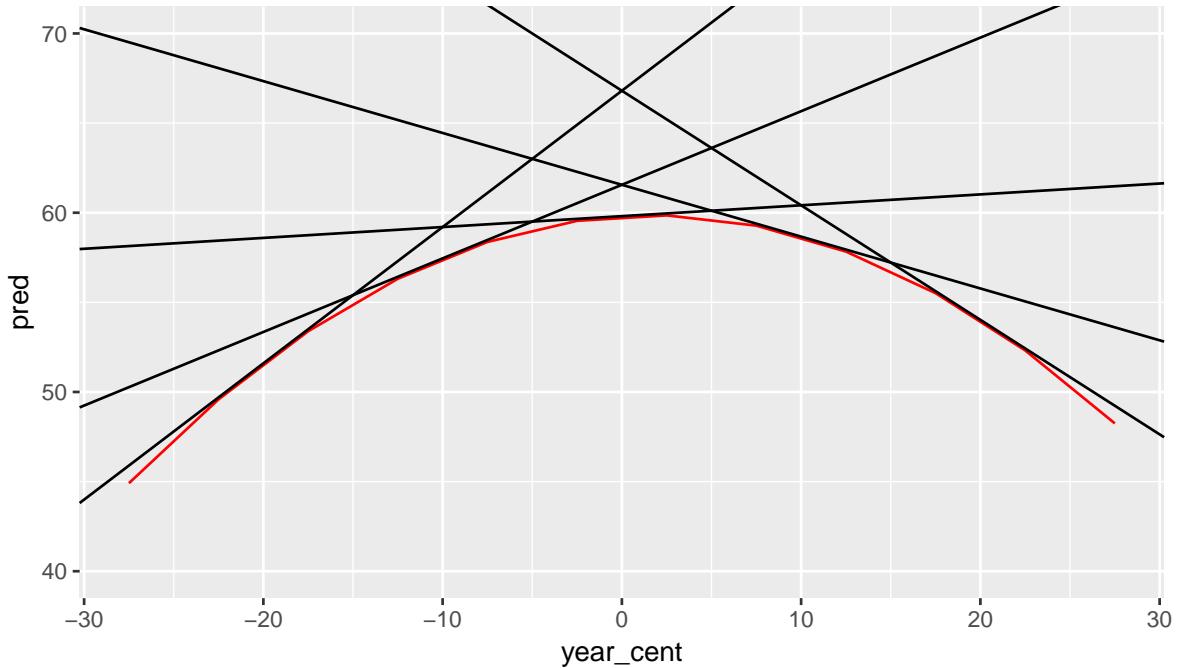
```
find_slope <- function(x){
 2*botswana_coefs[[3]]*x + botswana_coefs[[2]]
}

find_y1 <- function(x){
 botswana_coefs[[3]]*(x^2) + botswana_coefs[[2]]*x + botswana_coefs[[1]]
}

find_intercept <- function(x, y, m){
 y - x*m
}
```

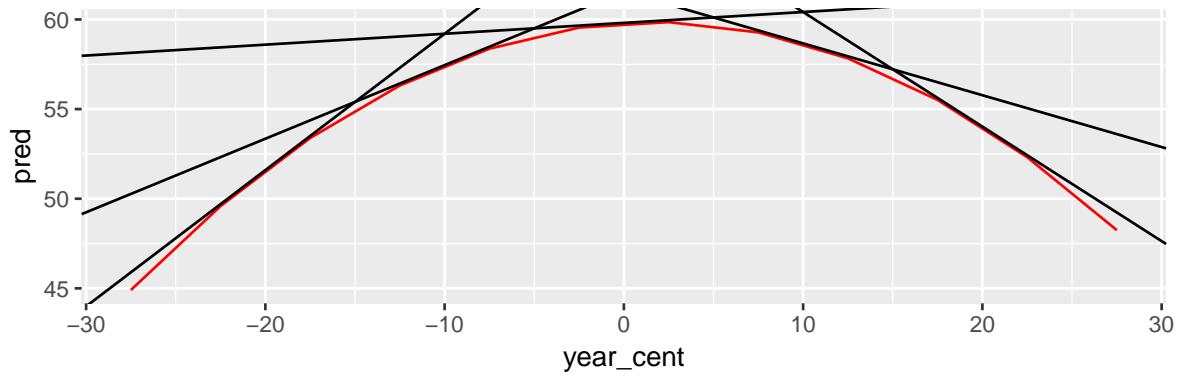
```
tangent_lines <- tibble(x1 = seq(-20, 20, 10)) %>%
 mutate(slope = find_slope(x1),
 y1 = find_y1(x1),
 intercept = find_intercept(x1, y1, slope),
 slope_change = x1*2*botswana_coefs[[3]]) %>%
 select(slope, intercept, everything())

by_country3_quad %>%
 filter(country == "Botswana") %>%
 mutate(data_preds = purrr::map2(data_cent, mod_quad, add_predictions)) %>%
 unnest(data_preds) %>%
 ggplot(aes(x = year_cent)) +
 geom_line(aes(x = year_cent, y = pred), colour = "red") +
 # geom_line(aes(y = pred, colour = "prediction")) +
 # labs(title = "Data and 2nd order model predictions for Botswana") +
 geom_abline(intercept = tangent_lines[[2]][[1]], slope = tangent_lines[[1]][[1]]) +
 geom_abline(intercept = tangent_lines[[2]][[2]], slope = tangent_lines[[1]][[2]]) +
 geom_abline(intercept = tangent_lines[[2]][[3]], slope = tangent_lines[[1]][[3]]) +
 geom_abline(intercept = tangent_lines[[2]][[4]], slope = tangent_lines[[1]][[4]]) +
 geom_abline(intercept = tangent_lines[[2]][[5]], slope = tangent_lines[[1]][[5]]) +
 ylim(c(40, 70)) +
 coord_fixed()
```



```
by_country3_quad %>%
 filter(country == "Botswana") %>%
 mutate(data_preds = purrr::map2(data_cent, mod_quad, add_predictions)) %>%
 unnest(data_preds) %>%
 ggplot(aes(x = year_cent)) +
```

```
geom_line(aes(x = year_cent, y = pred), colour = "red")+
 geom_abline(aes(intercept = intercept, slope = slope),
 data = tangent_lines)+
 coord_fixed()
```



Below is the relevant output in a table.

`x1`: represents the change in x value from 1979.5

`slope`: slope of the tangent line at particular `x1` value

`slope_diff_central`: the amount the slope is different from the slope of the tangent line at the central year

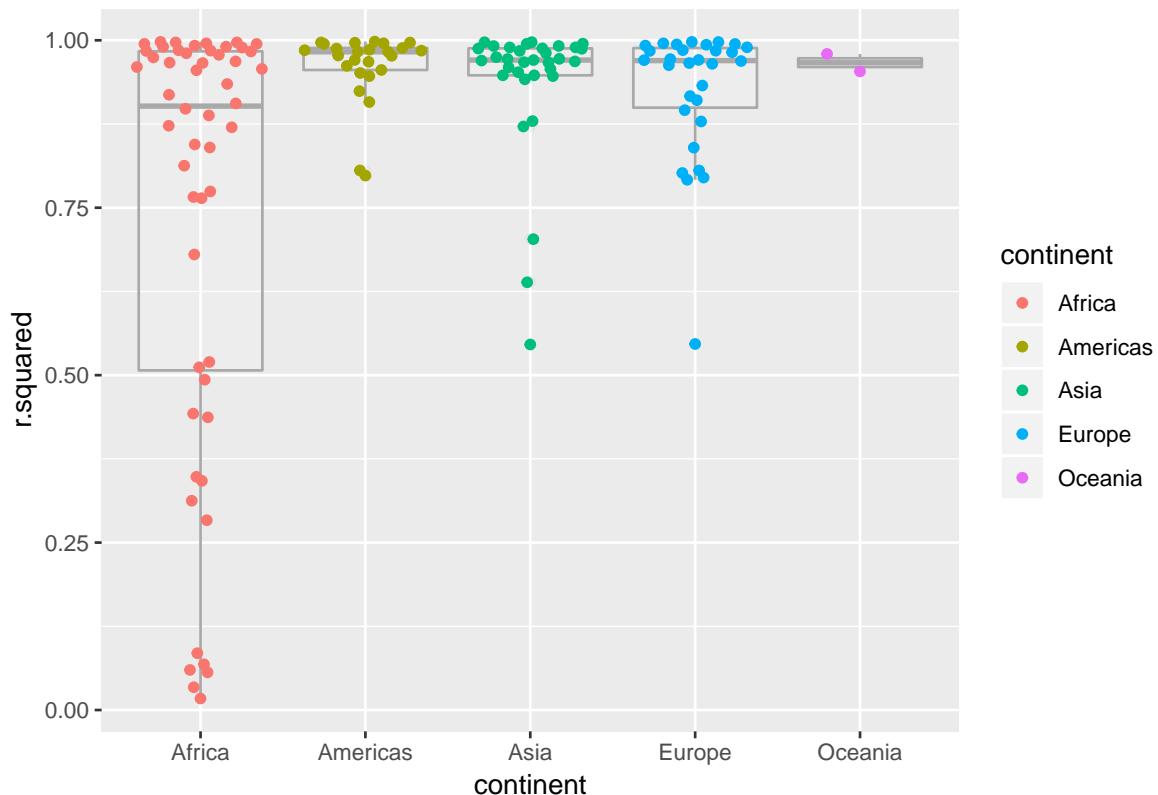
```
select(tangent_lines, x1, slope, slope_diff_central = slope_change)
```

```
A tibble: 5 x 3
x1 slope slope_diff_central
<dbl> <dbl> <dbl>
1 -20 0.760 0.700
2 -10 0.411 0.350
3 0 0.0607 0
4 10 -0.289 -0.350
5 20 -0.639 -0.700
```

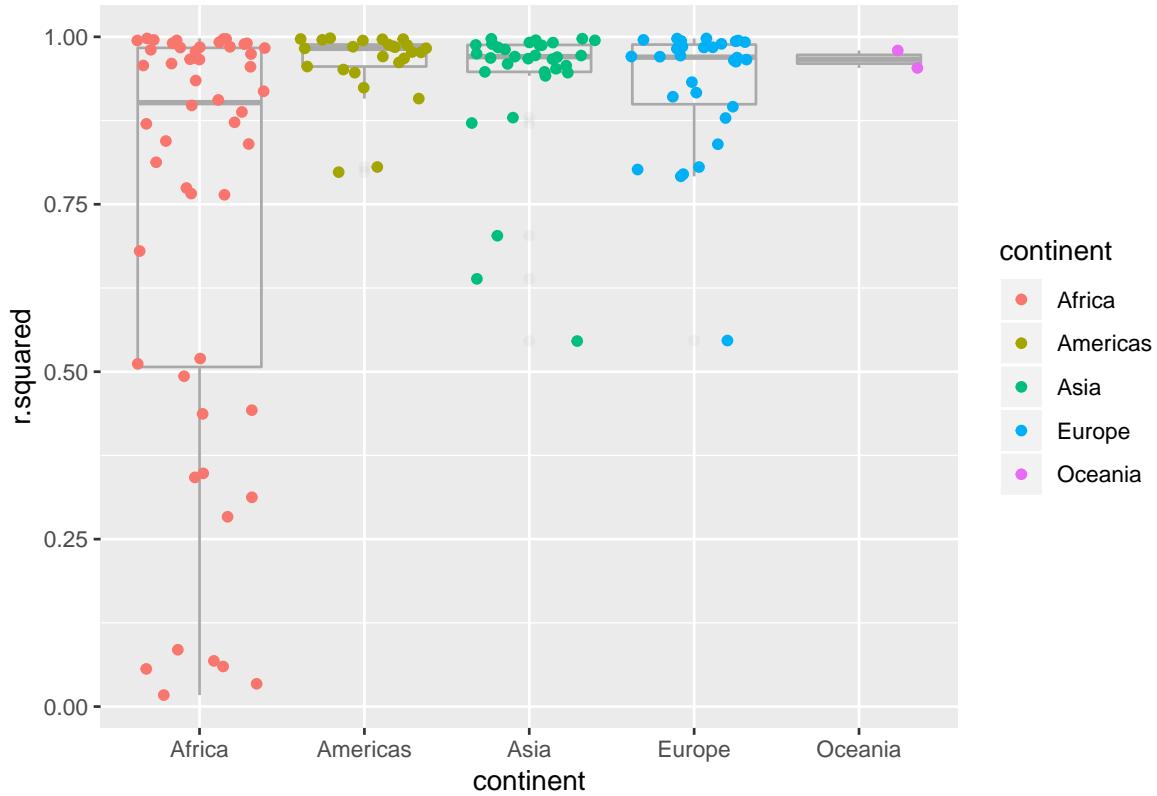
- notice that for every 10 year increase in `x1` we see the slope of the tangent line has decreased by 0.35. If we'd looked at just one year we would have seen the change was 0.035, this corresponding with 2 multiplied by the coefficient on the quadratic term of our model.
2. Explore other methods for visualising the distribution of  $R^2$  per continent. You might want to try the `ggbeeswarm` package, which provides similar methods for avoiding overlaps as jitter, but uses deterministic methods.

*visualisations of linear model*

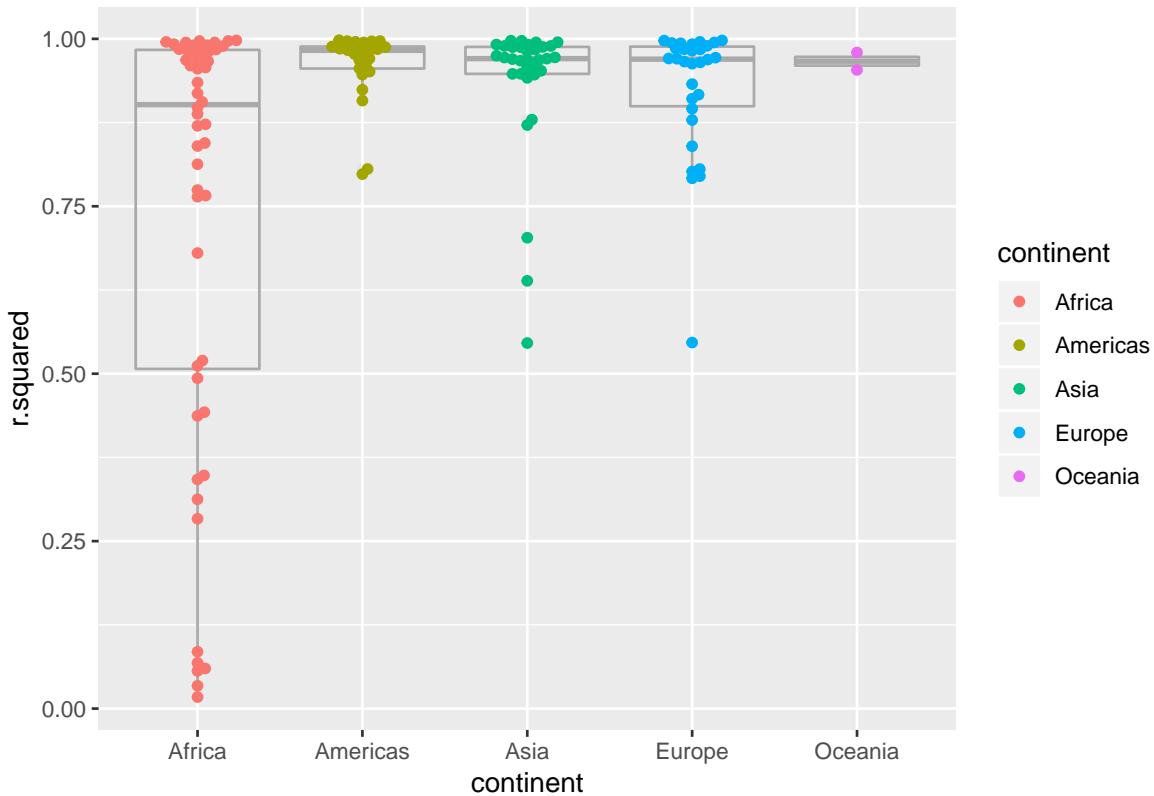
```
by_country3_quad %>%
 unnest(glance_mod) %>%
 ggplot(aes(x = continent, y = r.squared, colour = continent)) +
 geom_boxplot(alpha = 0.1, colour = "dark grey") +
 ggbeeswarm::geom_quasirandom()
```



```
by_country3_quad %>%
 unnest(glance_mod) %>%
 ggplot(aes(x = continent, y = r.squared, colour = continent)) +
 geom_boxplot(alpha = 0.1, colour = "dark grey") +
 geom_jitter()
```



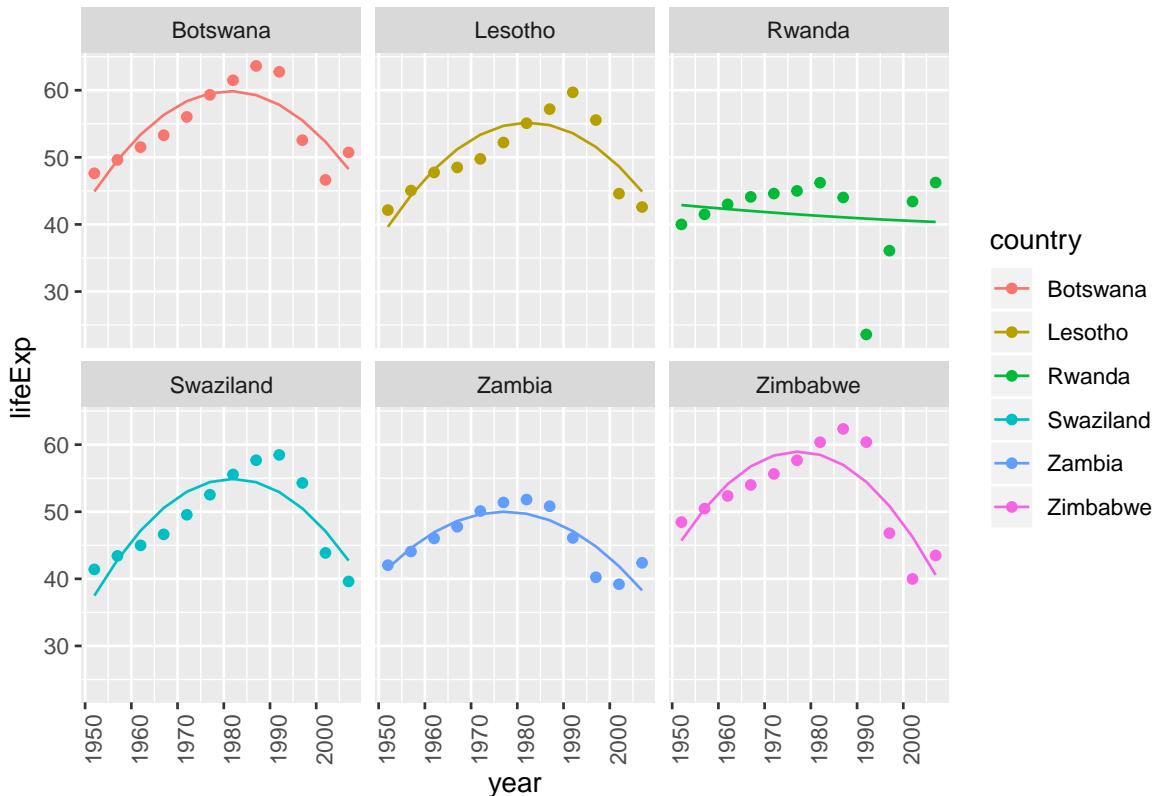
```
by_country3_quad %>%
 unnest(glance_mod) %>%
 ggplot(aes(x = continent, y = r.squared, colour = continent)) +
 geom_boxplot(alpha = 0.1, colour = "dark grey") +
 ggbeeswarm::geom_beeswarm()
```



- I like `geom_quasirandom` the best as an overlay on boxplot, it keeps things centered and doesn't have the gravitational pull effect that makes `geom_beeswarm` become a little misaligned

- To create the last plot (showing the data for the countries with the worst model fits), we needed two steps: we created a data frame with one row per country and then semi-joined it to the original dataset. It's possible to avoid this join if we use `unnest()` instead of `unnest(.drop = TRUE)`. How?

```
#first filter by r.squared and then unnest
by_country3_quad %>%
 mutate(data_preds = purrr::map2(data_cent, mod_quad, add_predictions)) %>%
 unnest(glance_mod) %>%
 mutate(bad_fit = r.squared < 0.25) %>%
 filter(bad_fit) %>%
 unnest(data_preds) %>%
 ggplot(aes(x = year, group = country)) +
 geom_point(aes(y = lifeExp, colour = country)) +
 geom_line(aes(y = pred, colour = country)) +
 facet_wrap(~country) +
 theme(axis.text.x = element_text(angle = 90, hjust = 1))
```



## 31.2 25.4: Creating list-columns

### 31.2.1 25.4.5

1. List all the functions that you can think of that take an atomic vector and return a list.

- `stringr::str_extract_all` + other `stringr` functions

(however the below can also take types that are not atomic and are probably not really what is being looked for) \* `list` \* `tibble` \* `map` / `lapply`

1. Brainstorm useful summary functions that, like `quantile()`, return multiple values.

- `summary`
- `range`
- ...

1. What's missing in the following data frame? How does `quantile()` return that missing piece? Why isn't that helpful here?

```
mtcars %>%
 group_by(cyl) %>%
 summarise(q = list(quantile(mpg))) %>%
 unnest()
```

```
A tibble: 15 x 2
cyl q
<dbl> <dbl>
1 4 21.4
```

```
2 4 22.8
3 4 26
4 4 30.4
5 4 33.9
6 6 17.8
7 6 18.6
8 6 19.7
9 6 21
10 6 21.4
11 8 10.4
12 8 14.4
13 8 15.2
14 8 16.2
15 8 19.2
```

- need to capture probabilities of quantiles to make useful...

```
probs <- c(0.01, 0.25, 0.5, 0.75, 0.99)

mtcars %>%
 group_by(cyl) %>%
 summarise(p = list(probs), q = list(quantile(mpg, probs))) %>%
 unnest()
```

```
A tibble: 15 x 3
cyl p q
<dbl> <dbl> <dbl>
1 4 0.01 21.4
2 4 0.25 22.8
3 4 0.5 26
4 4 0.75 30.4
5 4 0.99 33.8
6 6 0.01 17.8
7 6 0.25 18.6
8 6 0.5 19.7
9 6 0.75 21
10 6 0.99 21.4
11 8 0.01 10.4
12 8 0.25 14.4
13 8 0.5 15.2
14 8 0.75 16.2
15 8 0.99 19.1
```

- see [quantile example] for related method that captures names of quantiles (rather than requiring the user to manually input a vector of probabilities)

2. What does this code do? Why might it be useful?

```
mtcars %>%
 select(1:3) %>%
 group_by(cyl) %>%
 summarise_all(funs(list))
```

- It turns each row into an atomic vector grouped by the particular cyl value. It is different from nest in that each column creates a new list-column representing an atomic vector. If nest had been used, this would have created a single dataframe that all the values would have been in. Could be useful for running purr through particular columns...

- e.g. let's say we want to find the number of unique items in each column for each grouping, we could do that like so

```
mtcars %>%
 group_by(cyl) %>%
 select(1:5) %>%
 summarise_all(funs(list)) %>%
 mutate_all(funs(unique = map_int(., ~length(unique(.x)))))

Warning: funs() is soft deprecated as of dplyr 0.8.0
please use list() instead
##
Before:
funs(name = f(.))
##
After:
list(name = ~f(.))
This warning is displayed once per session.

A tibble: 3 x 10
cyl mpg disp hp drat cyl_unique mpg_unique disp_unique hp_unique
<dbl> <dbl> <dbl> <dbl> <dbl> <int> <int> <int> <int>
1 4 21 160 110 3.9 1 9 11 10
2 6 21 160 110 3.9 1 6 5 4
3 8 18.5 350 180 3.0 1 12 11 9
... with 1 more variable: drat_unique <int>

we could also simply overwrite the values (rather than make new columns)
mtcars %>%
 group_by(cyl) %>%
 select(1:5) %>%
 summarise_all(funs(list)) %>%
 mutate_all(funs(map_int(., ~length(unique(.x)))))

A tibble: 3 x 5
cyl mpg disp hp drat
<int> <dbl> <dbl> <dbl> <dbl>
1 1 21 160 110 3.9
2 2 21 160 110 3.9
3 3 18.5 350 180 3.0
```

## 31.3 25.5: Simplifying list-columns

### 31.3.1 25.5.3

- Why might the `lengths()` function be useful for creating atomic vector columns from list-columns?

If all you wanted were the length (not the number of unique items), you would still need a `map` function when using `length`:

```
mtcars %>%
 group_by(cyl) %>%
 select(1:5) %>%
 summarise_all(funs(list)) %>%
 mutate_all(funs(map_int(., length)))
```

```
A tibble: 3 x 5
cyl mpg disp hp drat
<int> <int> <int> <int> <int>
1 1 11 11 11 11
2 1 7 7 7 7
3 1 14 14 14 14
```

for this problem, using `lengths` prevents the need to use a `map` function

```
mtcars %>%
 group_by(cyl) %>%
 select(1:5) %>%
 summarise_all(funs(list)) %>%
 mutate_all(lengths)
```

```
A tibble: 3 x 5
cyl mpg disp hp drat
<int> <int> <int> <int> <int>
1 1 11 11 11 11
2 1 7 7 7 7
3 1 14 14 14 14
```

- is there a more helpful use case...?

2. List the most common types of vector found in a data frame. What makes lists different?
  - the atomic types: char, int, double, fact, date are all more common, they are atomic, whereas lists are not

# Chapter 32

## Appendix

### 32.1 models in lists

this is the more traditional way you might store models

```
models_countries <- purrr::map(by_country$data, country_model)

names(models_countries) <- by_country$country

models_countries[1:3]

$Afghanistan
##
Call:
lm(formula = lifeExp ~ year, data = df)
##
Coefficients:
(Intercept) year
-507.5343 0.2753
##
##
$Albania
##
Call:
lm(formula = lifeExp ~ year, data = df)
##
Coefficients:
(Intercept) year
-594.0725 0.3347
##
##
$Algeria
##
Call:
lm(formula = lifeExp ~ year, data = df)
##
Coefficients:
(Intercept) year
-1067.8590 0.5693
```

## 32.2 list-columns for sampling

say you want to sample all the flights on 50 days out of the year. List-cols can be helpful in generating a sample like this:

```
flights %>%
 mutate(create_date = make_date(year, month, day)) %>%
 select(create_date, 5:8) %>%
 group_by(create_date) %>%
 nest() %>%
 sample_n(50) %>%
 unnest()

A tibble: 46,565 x 5
create_date sched_dep_time dep_delay arr_time sched_arr_time
<date> <int> <dbl> <int> <int>
1 2013-03-07 2359 8 508 438
2 2013-03-07 2245 83 128 2356
3 2013-03-07 1905 307 212 2114
4 2013-03-07 2046 208 126 2214
5 2013-03-07 2129 169 130 2231
6 2013-03-07 2250 107 159 5
7 2013-03-07 2358 73 556 438
8 2013-03-07 2251 179 302 2357
9 2013-03-07 500 -4 628 648
10 2013-03-07 515 -5 738 814
... with 46,555 more rows
```

The alternative a join, e.g.

```
flights_samp <- flights %>%
 mutate(create_date = make_date(year, month, day)) %>%
 distinct(create_date) %>%
 sample_n(50)

flights %>%
 mutate(create_date = make_date(year, month, day)) %>%
 select(create_date, 5:8) %>%
 semi_join(flights_samp, by = "create_date")

A tibble: 46,109 x 5
create_date sched_dep_time dep_delay arr_time sched_arr_time
<date> <int> <dbl> <int> <int>
1 2013-01-07 2359 50 531 444
2 2013-01-07 500 -6 637 648
3 2013-01-07 525 -2 758 820
4 2013-01-07 540 -9 827 850
5 2013-01-07 540 -4 1020 1017
6 2013-01-07 530 14 822 829
7 2013-01-07 600 -15 646 709
8 2013-01-07 600 -8 843 904
9 2013-01-07 600 -6 708 715
10 2013-01-07 600 -5 741 801
... with 46,099 more rows
```

- I find the nest - unnest method more elegant

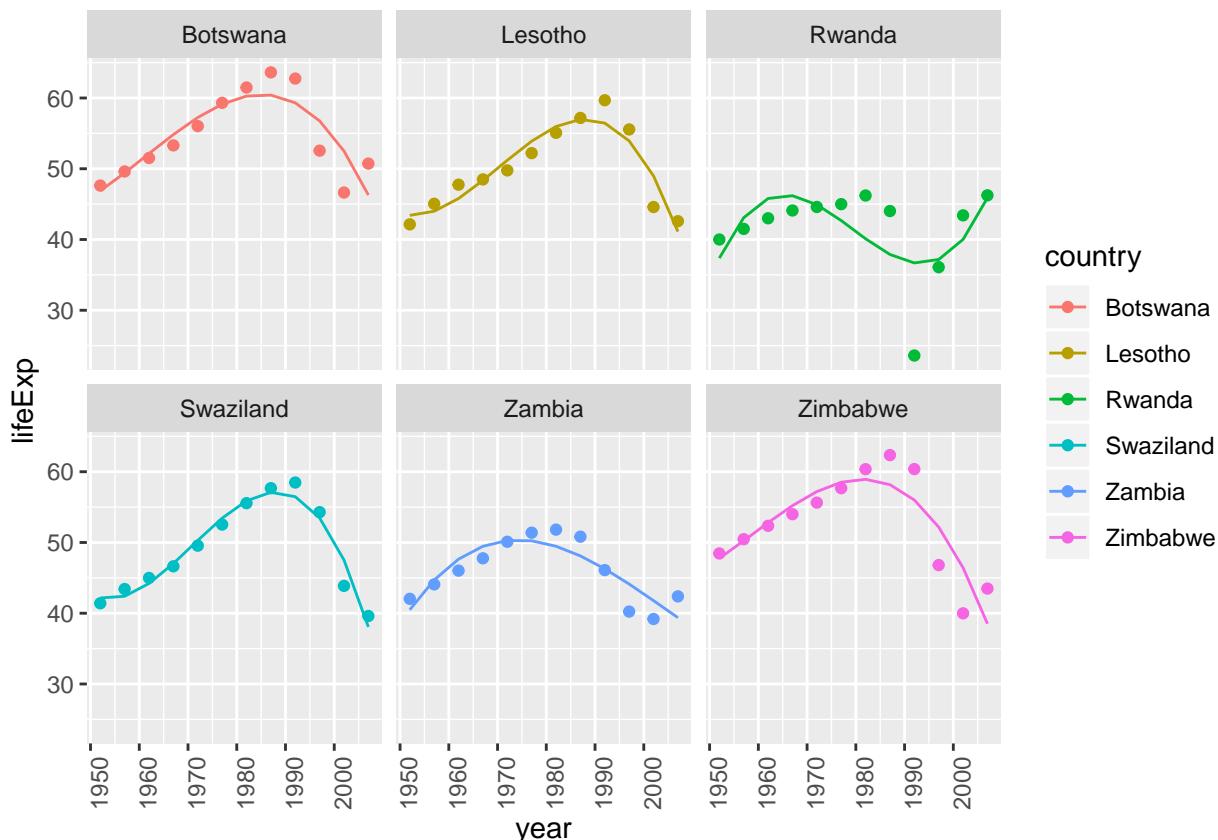
- I've found the `semi_join` method seems to run faster on large dataframes

## 32.3 25.2.5.1

### 32.3.1 Include cubic term

Let's look at this example if we had allowed year to be a 3rd order polynomial. We're really stretching our degrees of freedom in this case – these might be unlikely to generalize to other data well.

```
by_country3 %>%
 semi_join(bad_fit, by = "country") %>%
 mutate(
 # create centered data
 data_cent = purrr::map(data, center_value),
 # create cubic (3rd order) data
 mod_cubic = purrr::map(data_cent, lm_quad_2, var = "year_cent + I(year_cent^2) + I(year_cent^3)"),
 # get predictions for 3rd order model
 data_cubic = purrr::map2(data_cent, mod_cubic, add_predictions)) %>%
 unnest(data_cubic) %>%
 ggplot(aes(x = year, group = country)) +
 geom_point(aes(y = lifeExp, colour = country)) +
 geom_line(aes(y = pred, colour = country)) +
 facet_wrap(~country) +
 theme(axis.text.x = element_text(angle = 90, hjust = 1))
```



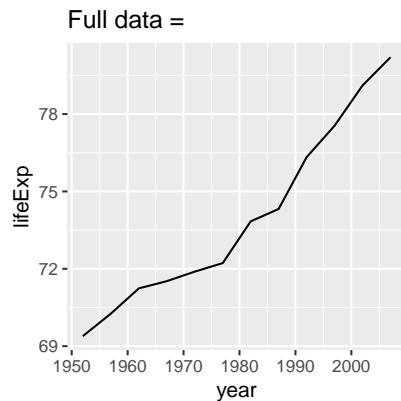
- interpretability of coefficients beyond quadratic term becomes less strait forward to explain

## 32.4 Multiple graphs in chunk

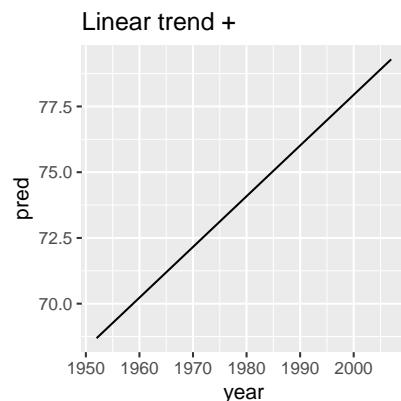
My work flow for pulling multiple graphs into a single input has typically been either to build the graphs seperately and then add each to the function `gridExtra::grid.arrange()` or to use faceting as much as possible.

In 25.2 Hadley showed an example where he put all the graphs within a chunk into a single outputted figure by setting the code chunk options for this. The chunk below is that example.

```
nz <- filter(gapminder, country == "New Zealand")
nz %>%
 ggplot(aes(year, lifeExp)) +
 geom_line() +
 ggtitle("Full data = ")
```

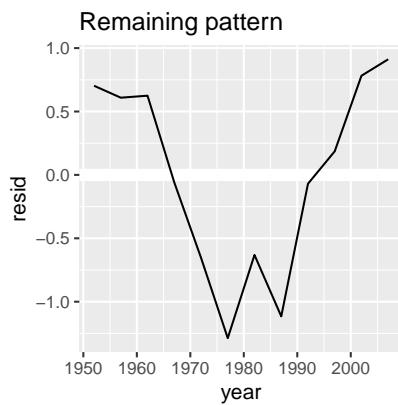


```
nz_mod <- lm(lifeExp ~ year, data = nz)
nz %>%
 add_predictions(nz_mod) %>%
 ggplot(aes(year, pred)) +
 geom_line() +
 ggtitle("Linear trend + ")
```



```
nz %>%
 add_residuals(nz_mod) %>%
 ggplot(aes(year, resid)) +
```

```
geom_hline(yintercept = 0, colour = "white", size = 3) +
geom_line() +
ggtitle("Remaining pattern")
```



- still printing as 3 individual plots, how to fix?

## 32.5 list(quantile()) examples

```
prob_vals <- c(0, .25, .5, .75, 1)
iris %>%
 group_by(Species) %>%
 summarise(Petal.Length_q = list(quantile(Petal.Length))) %>%
 mutate(probs = list(prob_vals)) %>%
 unnest()

A tibble: 15 x 3
Species Petal.Length_q probs
<fct> <dbl> <dbl>
1 setosa 1.0 0.25
2 setosa 1.4 0.5
3 setosa 1.5 0.75
4 setosa 1.58 1.0
5 setosa 1.9 0.25
6 versicolor 3.0 0.5
7 versicolor 4.0 0.75
8 versicolor 4.35 1.0
9 versicolor 4.6 0.25
10 versicolor 5.1 0.5
11 virginica 4.5 0.75
12 virginica 5.1 1.0
13 virginica 5.55 0.25
14 virginica 5.88 0.5
15 virginica 6.9 1.0
```

*Example for using quantile across range of columns  
Also notice dynamic method for extracting names*

```
iris %>%
 group_by(Species) %>%
```

```

summarise_all(funns(list(quantile(., probs = prob_vals)))) %>%
 mutate(probs = map(Petal.Length, names)) %>%
 unnest()

A tibble: 15 x 6
Species Sepal.Length Sepal.Width Petal.Length Petal.Width probs
<fct> <dbl> <dbl> <dbl> <dbl> <chr>
1 setosa 4.3 2.3 1 0.1 0%
2 setosa 4.8 3.2 1.4 0.2 25%
3 setosa 5 3.4 1.5 0.2 50%
4 setosa 5.2 3.68 1.58 0.3 75%
5 setosa 5.8 4.4 1.9 0.6 100%
6 versicolor 4.9 2 3 1 0%
7 versicolor 5.6 2.52 4 1.2 25%
8 versicolor 5.9 2.8 4.35 1.3 50%
9 versicolor 6.3 3 4.6 1.5 75%
10 versicolor 7 3.4 5.1 1.8 100%
11 virginica 4.9 2.2 4.5 1.4 0%
12 virginica 6.22 2.8 5.1 1.8 25%
13 virginica 6.5 3 5.55 2 50%
14 virginica 6.9 3.18 5.88 2.3 75%
15 virginica 7.9 3.8 6.9 2.5 100%

```

## 32.6 extracting row names

Don't know I'd do this...

```

quantile(1:100) %>%
 as_tibble() %>%
 rownames_to_column()

Warning: Calling `as_tibble()` on a vector is discouraged, because the behavior is likely to change ...
This warning is displayed once per session.

A tibble: 5 x 2
rowname value
<chr> <dbl>
1 1 1
2 2 25.8
3 3 50.5
4 4 75.2
5 5 100

```

## 32.7 invoke\_map example (book)

I liked Hadley's example with invoke\_map and wanted to save it

```

sim <- tribble(
 ~f, ~params,
 "runif", list(min = -1, max = -1),
 "rnorm", list(sd = 5),
 "rpois", list(lambda = 10)

```

```
)
sim %>%
 mutate(sims = invoke_map(f, params, n = 10))

A tibble: 3 x 3
f params sims
<chr> <list> <list>
1 runif <list [2]> <dbl [10]>
2 rnorm <list [1]> <dbl [10]>
3 rpois <list [1]> <int [10]>
```

## 32.8 named list example (book)

I liked Hadley's example where you have a list of named vectors that you need to iterate over both the values as well as the names and the use of enframe to facilitate this.

Below is the copied example and notes:

```
x <- list(
 a = 1:5,
 b = 3:4,
 c = 5:6
)

df <- enframe(x)
df

A tibble: 3 x 2
name value
<chr> <list>
1 a <int [5]>
2 b <int [2]>
3 c <int [2]>
```

The advantage of this structure is that it generalises in a straightforward way - names are useful if you have character vector of metadata, but don't help if you have other types of data, or multiple vectors.

Now if you want to iterate over names and values in parallel, you can use `map2()`:

```
df %>%
 mutate(
 smry = map2_chr(name, value, ~ stringr::str_c(.x, ": ", .y[1]))
)

A tibble: 3 x 3
name value smry
<chr> <list> <chr>
1 a <int [5]> a: 1
2 b <int [2]> b: 3
3 c <int [2]> c: 5
```

*Make sure the following packages are installed:*



# Chapter 33

## ch. 27: R Markdown

- shortcut for inserting code chunk is cmd/ctrl+alt+i
- shortcut for running entire code chunks: cmd/ctrl+shift+enter
- chunk options
  - chunk name is first part after type of code in chunk, e.g. code chunk by name: "```{r by-name}"
  - `eval = FALSE` show example output code, but don't evaluate
  - `include = FALSE` evaluate code but don't show code or output
  - `echo = FALSE` is for when you just want the output but not the code itself
  - `message = FALSE` or `warning = False` prevents messages or warnings appearing in the finished line
  - `error = TRUE` causes code to render even if there is an error
  - `results = 'hide'` hides printed output and `fig.show = 'hide'` hides plots

The following table summarises which types of output each option suppresses

| Option                         | Run code | Show code | Output | Plots |
|--------------------------------|----------|-----------|--------|-------|
| <code>eval = FALSE</code>      | -        | -         | -      | -     |
| <code>include = FALSE</code>   | -        | -         | -      | -     |
| <code>echo = FALSE</code>      | -        | -         | -      | -     |
| <code>results = "hide"</code>  | -        | -         | -      | -     |
| <code>fig.show = "hide"</code> | -        | -         | -      | -     |
| <code>message = FALSE</code>   | -        | -         | -      | -     |
| <code>warning = FALSE</code>   | -        | -         | -      | -     |

- \* allows you to hide particular bits of output
- `cache = TRUE` save output of chunk to separate folder (speeds-up rendering)
- `dependson = "chunk_name"` update chunk if dependency changes
- `cache.extra` if output from function changes, will re-render – useful for if you only want to update if for example a file changes, e.g.

```
rawdata <- readr::read_csv("a_very_large_file.csv")
```

- good idea to name code chunks after main object created
- `knitr::clean_cache` clear out your caches
- `knitr::opts_chunk` use to change knitting options
  - e.g.

```
when writing books and tutorials
knitr::opts_chunk$set(
 comment = "#>",
 collapse = TRUE
)

hiding code for report
knitr::opts_chunk$set(
 echo = FALSE
)
may also set `message = FALSE` and `warning = FALSE`
```

- `rmarkdown::render` programmatically knit documents
  - e.g. `rmarkdown::render("27-r-markdown.Rmd", output_format = "all")` to render all formats in YAML header
- `knitr::kable` to make dataframe more visible for printing when knitting
  - also see `xtable`, `stargazer`, `pander`, `tables`, and `ascii` packages
- `format` helpful when inserting numbers into texts, e.g.

```
comma <- function(x) format(x, digits = 2, big.mark = ",")
comma(3452345)

[1] "3,452,345"
comma(.12358124331)
```

```
[1] "0.12"
```

- Use `params:` in YAML header to add in specific values or create parameterized reports, e.g.

```
params:
 start: !r lubridate::ymd("2015-01-01")
 snapshot: !r lubridate::ymd_hms("2015-01-01 12:30:00")
 • Full chunk options here: https://yihui.name/knitr/options/
```

## 33.1 27.2 R Markdown basics

### 33.1.1 27.2.1

1. Create a new notebook using *File > New File > R Notebook*. Read the instructions. Practice running the chunks. Verify that you can modify the code, re-run it, and see modified output.

Done seperately.

2. Create a new R Markdown document with *File > New File > R Markdown...*. Knit it by clicking the appropriate button. Knit it by using the appropriate keyboard short cut. Verify that you can modify the input and see the output update.

Done seperately.

3. Compare and contrast the R notebook and R markdown files you created above. How are the outputs similar? How are they different? How are the inputs similar? How are they different? What happens if you copy the YAML header from one to the other?

- Both by default have code chunks display ‘in-line’ while working, though with RMD can force to not output in-line.

- When rendering, default of notebooks will be to render whichever chunks have been rendered during interactive session, whereas RMD document needs directions from code chunk options
    - I generally prefer .Rmd files to notebooks<sup>1</sup>.
4. Create one new R Markdown document for each of the three built-in formats: HTML, PDF and Word. Knit each of the three documents. How does the output differ? How does the input differ? (You may need to install LaTeX in order to build the PDF output — RStudio will prompt you if this is necessary.)

Done separately. HTML does not have page numbers. Plots or other outputs with interactive components will often only be viewable from html (e.g. flexdashboard, plotly, ...). Some input options will work across all formats, e.g. `toc: true`, however other options like code folding may be specific to a format, e.g. code folding will only work with html.

## 33.2 27.3: Text formatting with Markdown

*Print file from Hadley’s github page with common formatting:*

```
cat(readr::read_file("https://raw.githubusercontent.com/hadley/r4ds/master/rmarkdown/markdown.Rmd"))
```

*Other notes* The following will actually run in the console when knitted (and not in the knitted document):

```
summary(mpg)
```

### 33.2.1 27.3.1

1. Practice what you’ve learned by creating a brief CV. The title should be your name, and you should include headings for (at least) education or employment. Each of the sections should include a bulleted list of jobs/degrees. Highlight the year in bold.

*this is a weak example (see \_\_\_\_ for better examples):*

## 33.3 CV of Bryan Shalloway

```
####-####-####
```

## 33.4 Experience

---

|                        |              |
|------------------------|--------------|
| NetApp, Data Scientist | 2017-present |
| <b>Durham</b>          |              |

---



---

|                             |           |
|-----------------------------|-----------|
| Education Pioneers, Analyst | 2015-2016 |
| <b>Denver</b>               |           |

---



---

<sup>1</sup>I’ve found some of my company’s security software sometimes acts-up when working interactively if I have my chunk output in-line (just slows down). Hence, I ‘uncheck’ Show output inline for all Rmarkdown documents from Tools->Global Options ->Appearance.

---

Teach for America, High School Math 2013-2015

---

Durham

---

### 33.5 Education

---



---

IAA, MS 2017

---

+ Advanced Analytics

---



---

WashU in STL, AB 2012

---

+ Major: Cognitive Neuroscience

+ Minor: Political Science

+ Minor: American Culture Studies

2. Using the R Markdown quick reference, figure out how to:

1. Add a footnote.

Here is a foonote reference<sup>2</sup> and another <sup>3</sup> and a 3rd<sup>4</sup> and an in-line one<sup>5</sup>

---

A linked phrase.

---

pagebreaks above and below (AKA horizontal rules)

---

3. Add a block quote.

There is no spoon.

-Matrix

3. Copy and paste the contents of `diamond-sizes.Rmd` from <https://github.com/hadley/r4ds/tree/master/rmarkdown> in to a local R markdown document. Check that you can run it, then add text after the frequency polygon that describes its most striking features.

---

<sup>2</sup>Here is the foonote.

<sup>3</sup>here's one with multiple blocks.

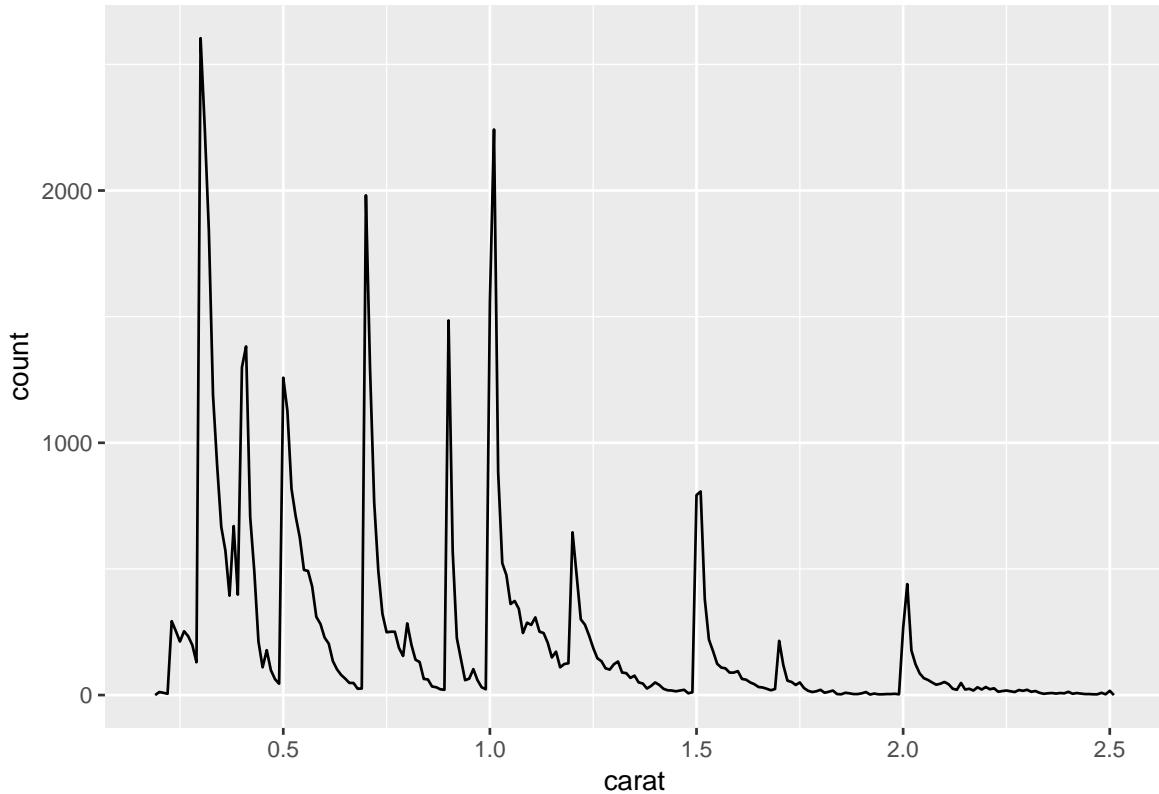
boo ya this is an awesome foonote.

don't you believe it!

<sup>4</sup>and the third

2. Add a horizontal rule.

<sup>5</sup>Superb fourth footnote.



- It's interesting that the count of number of diamonds spikes at whole numbers...

## 33.6 27.4: Code chunks

### 33.6.1 27.4.7

1. Add a section that explores how diamond sizes vary by cut, colour, and clarity. Assume you're writing a report for someone who doesn't know R, and instead of setting `echo = FALSE` on each chunk, set a global option.

- put this into a code chunk:

```
knitr::opts_chunk$set(echo = FALSE)
```

2. Download `diamond-sizes.Rmd` from <https://github.com/hadley/r4ds/tree/master/rmarkdown>. Add a section that describes the largest 20 diamonds, including a table that displays their most important attributes.

```
diamonds %>%
 filter(min_rank(-carat) <= 20) %>%
 select(starts_with("c")) %>%
 knitr::kable(caption = "The four C's of the 20 biggest diamonds")
```

3. Modify `diamonds-sizes.Rmd` to use `comma()` to produce nicely formatted output. Also include the percentage of diamonds that are larger than 2.5 carats.

```
diamonds %>%
 summarise(`proportion big` = (sum(carat > 2.5) / n()) %>%
```

Table 33.6: The four C's of the 20 biggest diamonds

| carat | cut       | color | clarity |
|-------|-----------|-------|---------|
| 3.01  | Premium   | I     | I1      |
| 3.11  | Fair      | J     | I1      |
| 3.01  | Premium   | F     | I1      |
| 3.05  | Premium   | E     | I1      |
| 3.02  | Fair      | I     | I1      |
| 3.01  | Fair      | H     | I1      |
| 3.65  | Fair      | H     | I1      |
| 3.24  | Premium   | H     | I1      |
| 3.22  | Ideal     | I     | I1      |
| 3.50  | Ideal     | H     | I1      |
| 3.01  | Premium   | G     | SI2     |
| 4.01  | Premium   | I     | I1      |
| 4.01  | Premium   | J     | I1      |
| 3.04  | Very Good | I     | SI2     |
| 3.40  | Fair      | D     | I1      |
| 4.00  | Very Good | I     | I1      |
| 3.01  | Ideal     | J     | SI2     |
| 3.67  | Premium   | I     | I1      |
| 3.01  | Ideal     | J     | I1      |
| 4.13  | Fair      | H     | I1      |
| 5.01  | Fair      | J     | I1      |
| 3.01  | Premium   | I     | SI2     |
| 3.01  | Fair      | I     | SI2     |
| 3.01  | Fair      | I     | SI2     |
| 3.01  | Good      | I     | SI2     |
| 3.01  | Good      | I     | SI2     |
| 4.50  | Fair      | J     | I1      |
| 3.04  | Premium   | I     | SI2     |
| 3.01  | Good      | H     | SI2     |
| 3.51  | Premium   | J     | VS2     |
| 3.01  | Premium   | J     | SI2     |
| 3.01  | Premium   | J     | SI2     |

```
 comma()) %>%
knitr::kable()
```

---

|            |        |
|------------|--------|
| proportion | big    |
|            | 0.0023 |

4. Set up a network of chunks where `d` depends on `c` and `b`, and both `b` and `c` depend on `a`. Have each chunk print `lubridate::now()`, set `cache = TRUE`, then verify your understanding of caching.

```
lubridate::now()
```

```
[1] "2019-05-22 22:38:04 EDT"
```

```
lubridate::now()
```

```
[1] "2019-05-22 22:38:04 EDT"
```

```
lubridate::now()
```

```
[1] "2019-05-22 22:38:05 EDT"
```

```
lubridate::now()
```

```
[1] "2019-05-22 22:38:05 EDT"
```

*Make sure the following packages are installed:*



# Chapter 34

## ch. 28: Graphics for communication

- `labs()` to add labels
  - common args: `title`, `subtitle`, `caption`, `x`, `y`, `colour`, ...
  - for mathematical equations use `quote` and see `?plotmath`
    - \* e.g. within `labs()` could do `y = quote(alpha + beta + frac(delta, theta))`
- `geom_text()` similar to `geom_point()` but with argument `label` that adds text where the point would be
  - use `nudge_x` and `nudge_y` to move position around
  - use `vjust` ('top', 'center', or 'bottom') and `hjust` ('left', 'center', or 'right') to control alignment of text
  - can use `+Inf` and `-Inf` to put text in exact corners
  - use `stringr::str_wrap()` to automatically add line breaks
  - `geom_label()` is like `geom_text()` but draws a box around the data that makes easier to see (can adjust `alpha` and `fill` of background box)
  - `ggrepel::geom_label_repel()` is like `geom_label()` but prevents overlap of labels
- `geom_hline()` and `geom_vline` for reference lines (often use `size = 2` and `colour = white`)
- `geom_rect()` to draw rectangle around points (controlled by `xmin`, `xmax`, `ymin`, `ymax`)
- `geom_segment()` to draw attention to a point with an arrow, (common args: `arrow`, `x`, `y`, `xend`, `yend`)
- `annotate` can add in labels by hand (not from values of dataframe)
- `scale_x_continuous()`, `scale_y_continuous()`, `scale_colour_discrete()`, ... `scale_{aes}_{scale_type}()`
  - `breaks` and `labels` are key args (can set `labels = NULL` to remove values)
  - `scale_colour_brewer(palette = "Set1")` for color blind people
  - `scale_colour_manual()` for defining colours with specific values, e.g. `scale_colour_manual(values = c(Republican = "red", Democratic = "blue"))`
  - for continuous scales try `scale_colour_gradient()`, `scale_fill_gradient()`, `scale_colour_gradient2()` (two colour gradient, e.g. + / - values), `viridis::scale_colour_viridis()`
  - date scales are a little different, e.g. `scale_x_date()` takes args `date_labels` (e.g. `date_labels = "%y"`) and `date_breaks` (e.g. `date_breaks = "2 days"`)
  - `scale_x_log10()`, `scale_y_log10...` to substitute values with a particular transformation
- `theme()` customize any non-data components of plots
  - e.g. remove legend with `theme(legend.position = "none")` (could also have inputted "left", "top", "bottom", or "right")
- `guides()` to control display of individual legends – use in conjunction with `guide_legend()` or `guide_colourbar()`
- `coord_cartesian()` to zoom using `xlim` and `ylim` args
- can customize your themes, e.g. `theme_bw()`, `theme_classic()...`, see `ggthemes` for a bunch of others
- `ggsave()` defaults to save most recent plot
  - key options: `fig.width`, `fig.height`, `fig.asp`, `out.width`, `out.height` (see chapter for details)

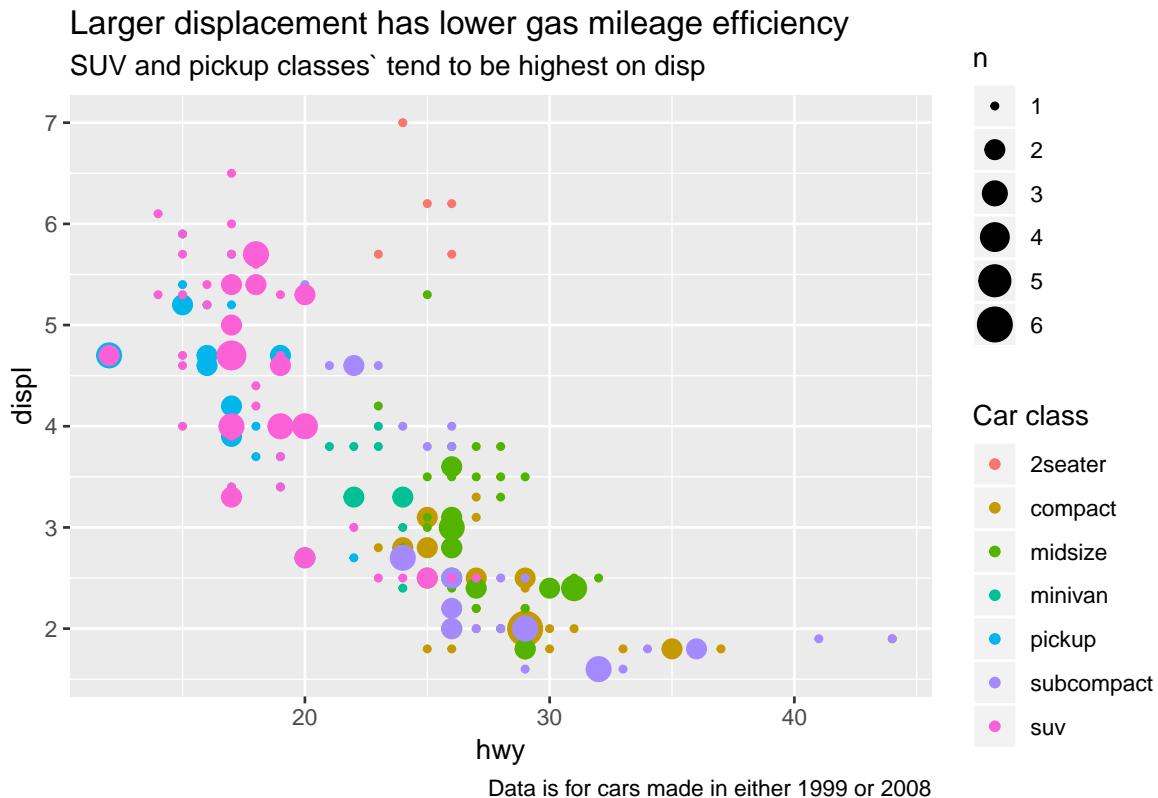
- other options: `fig.align`, `fig.cap`, `dev` (e.g. `dev = "png"`)

## 34.1 28.2: Label

### 34.1.1 28.2.1

1. Create one plot on the fuel economy data with customised `title`, `subtitle`, `caption`, `x`, `y`, and `colour` labels.

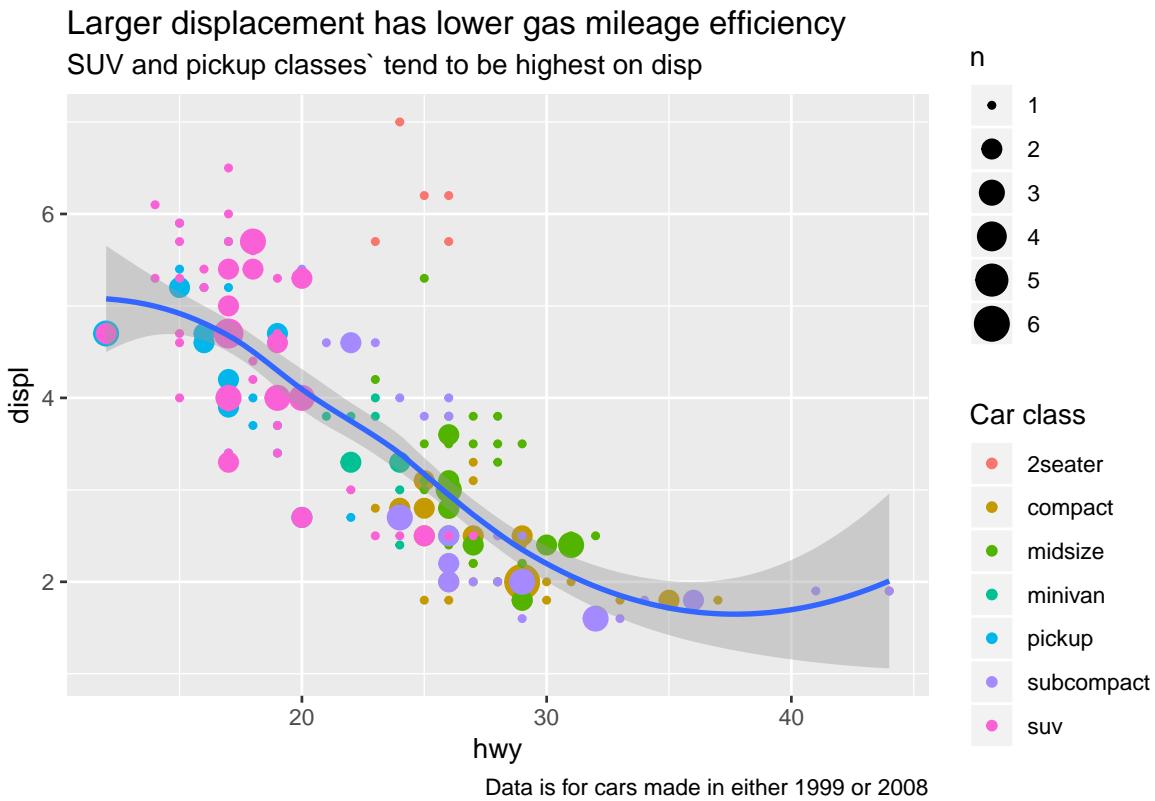
```
mpg %>%
 ggplot(aes(x = hwy, displ)) +
 geom_count(aes(colour = class)) +
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class")
```



2. The `geom_smooth()` is somewhat misleading because the `hwy` for large engines is skewed upwards due to the inclusion of lightweight sports cars with big engines. Use your modelling tools to fit and display a better model.

```
mpg %>%
 ggplot(aes(x = hwy, displ)) +
 geom_count(aes(colour = class)) +
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
```

```
 colour = "Car class")+
 geom_smooth()
```



You could take into account the class of the car

```
mpg %>%
 ggplot(aes(x = hwy, displ, colour = class))+
 geom_count()+
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class")+
 geom_smooth()
```

```
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : span too small. fewer data values than degrees of freedom.
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : pseudoinverse used at 22.985
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : neighborhood radius 2.015
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : reciprocal condition number 0
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : There are other near singularities as well. 1.0302
Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
```

```

as.matrix(model.frame(delete.response(terms(object))), : span too small.
fewer data values than degrees of freedom.

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : pseudoinverse used
at 22.985

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : neighborhood radius
2.015

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : reciprocal
condition number 0

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : There are other
near singularities as well. 1.0302

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : pseudoinverse used at 24.035

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : neighborhood radius 2.035

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : reciprocal condition number 7.8765e-017

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : There are other near singularities as well. 1

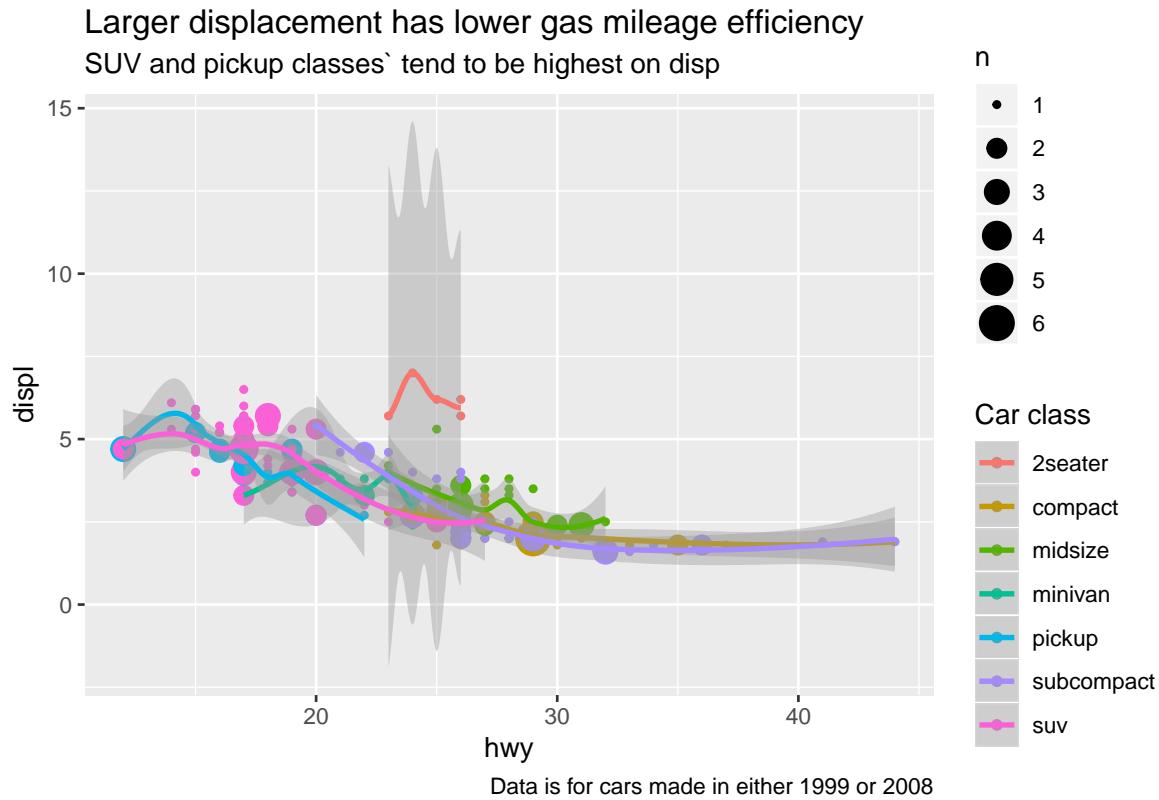
Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : pseudoinverse used
at 24.035

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : neighborhood radius
2.035

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : reciprocal
condition number 7.8765e-017

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : There are other
near singularities as well. 1

```



- Take an exploratory graphic that you've created in the last month, and add informative titles to make it easier for others to understand.

Done separately.

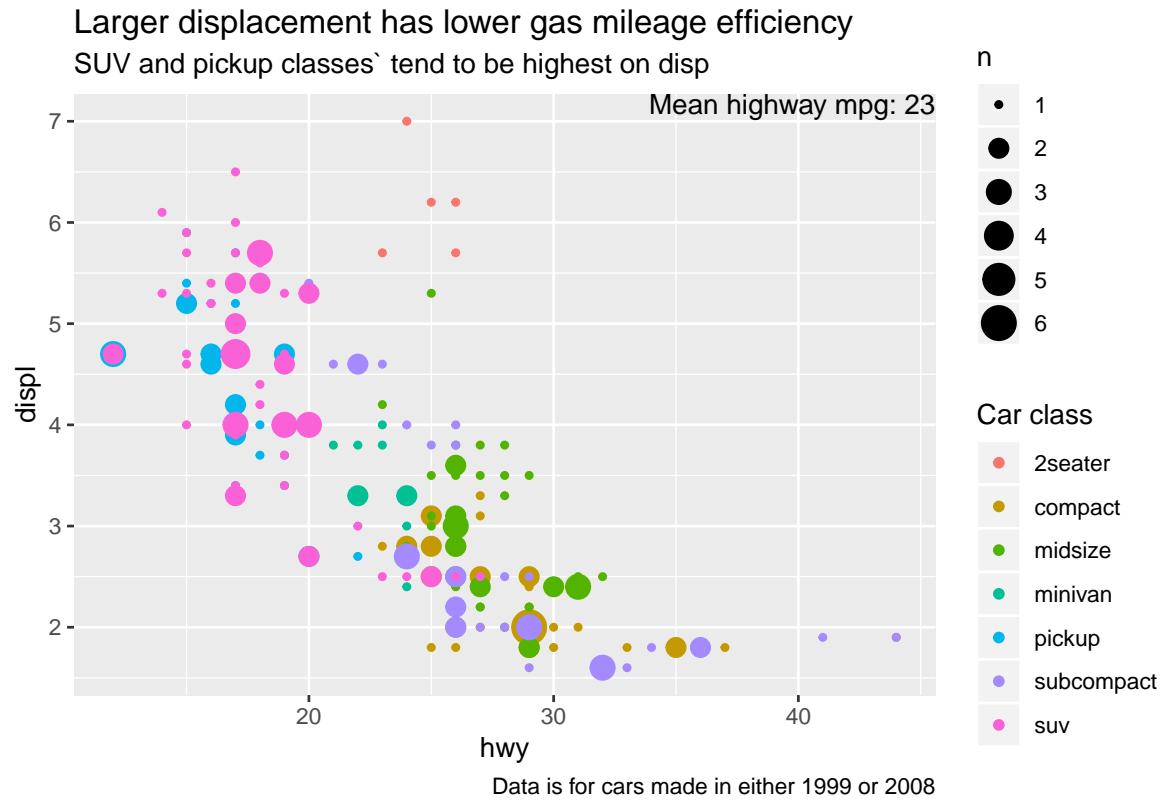
## 34.2 28.3: Annotations

### 34.2.1 28.3.1

- Use `geom_text()` with infinite positions to place text at the four corners of the plot.

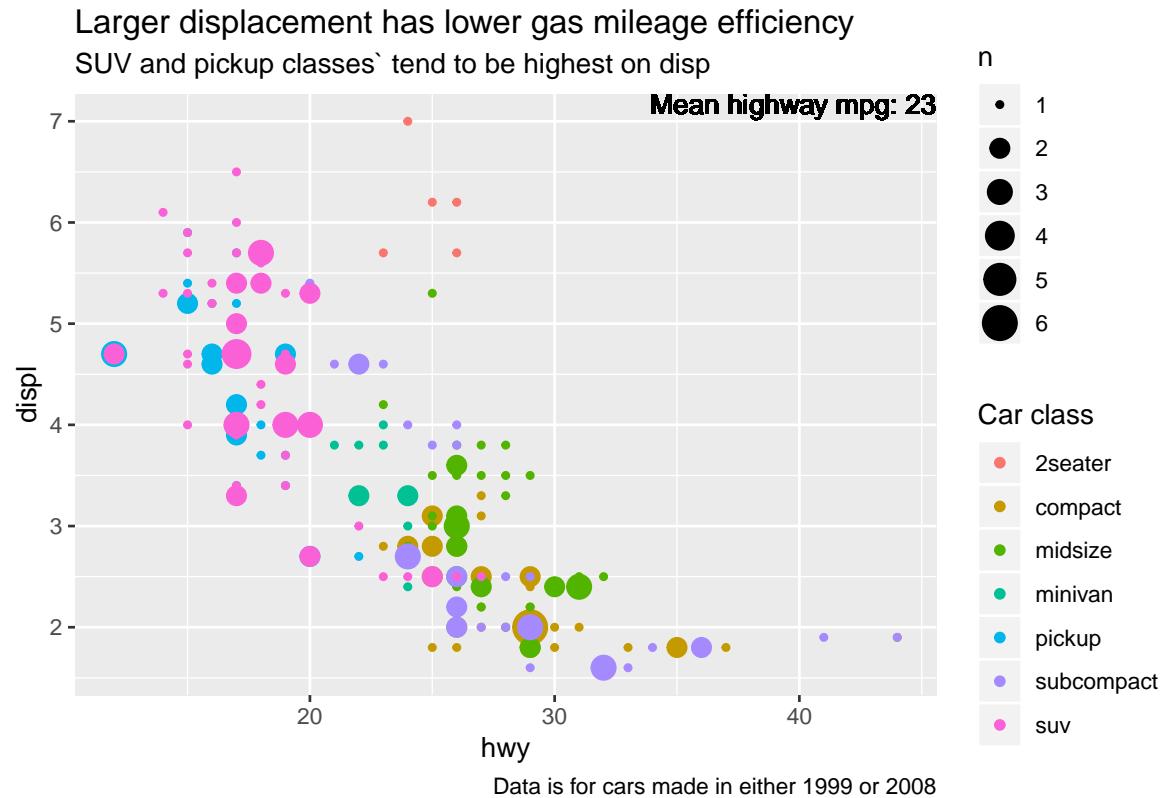
```
data_label <- tibble(x = Inf, y = Inf, label = paste0("Mean highway mpg: ", round(mean(mpg$hwy))))
```

```
mpg %>%
 ggplot(aes(x = hwy, displ)) +
 geom_count(aes(colour = class)) +
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class") +
 geom_text(aes(x = x, y = y, label = label), data = data_label, vjust = "top", hjust = "right")
```



You could technically create the label w/o the tibble, though it will print multiple times for each row:

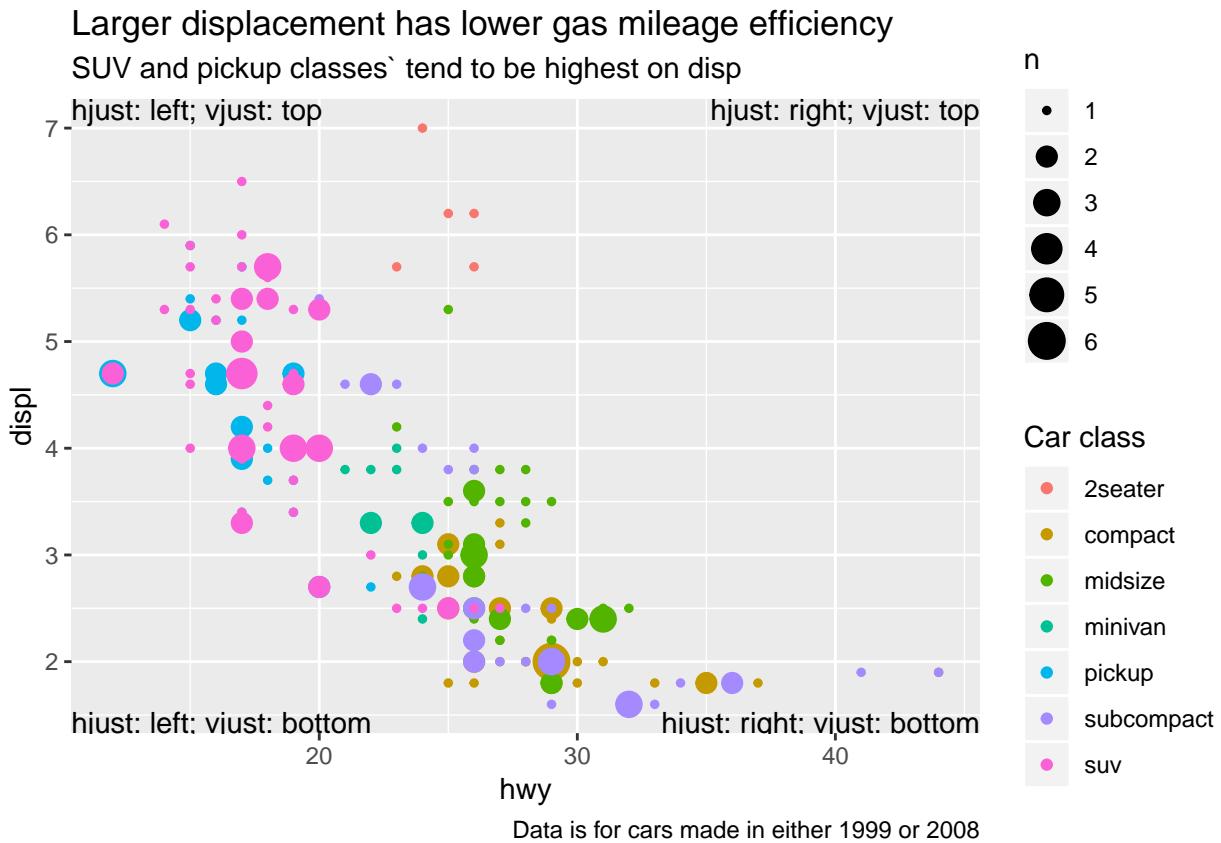
```
mpg %>%
 ggplot(aes(x = hwy, displ)) +
 geom_count(aes(colour = class)) +
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class") +
 geom_text(x = Inf, y = Inf, label = paste0("Mean highway mpg: ", round(mean(mpg$hwy))), vjust = 1)
```



Place label in each of four corners:

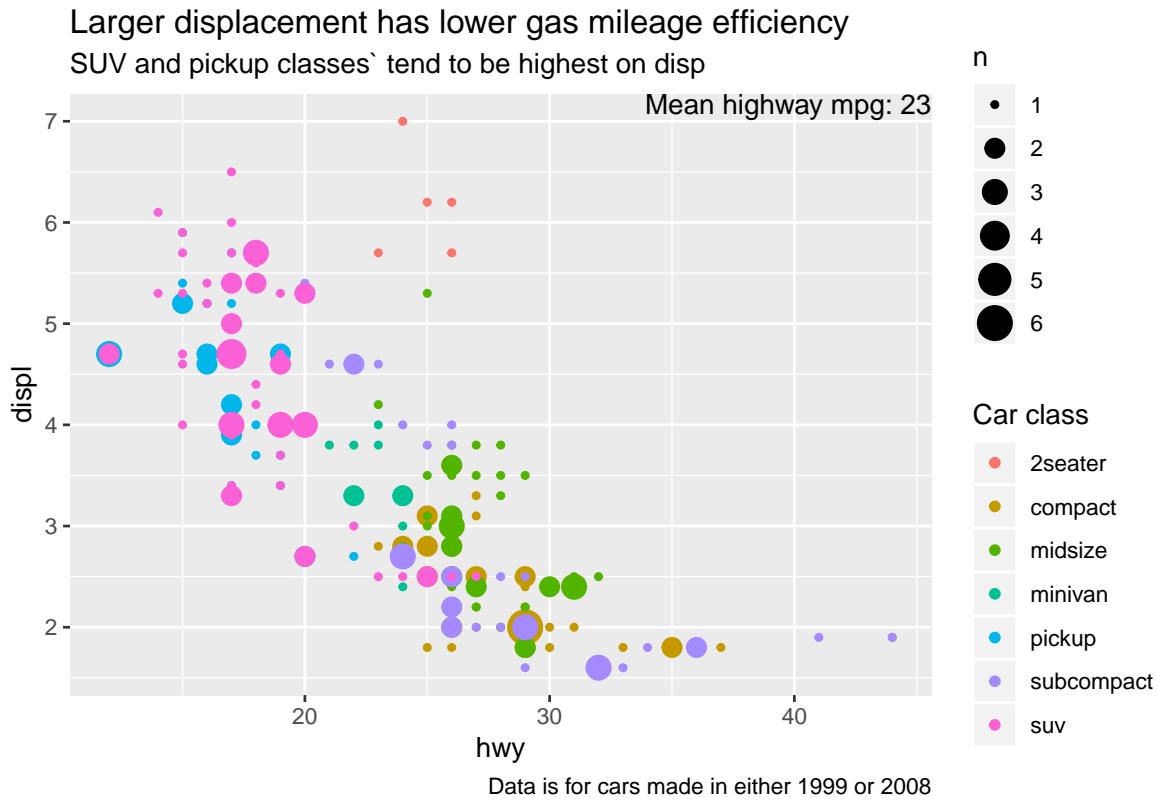
```
data_label <- tibble(x = c(Inf, -Inf),
 hjust = c("right", "left"),
 y = c(Inf, -Inf),
 vjust = c("top", "bottom")) %>%
 expand(nesting(x, hjust), nesting(y, vjust)) %>%
 mutate(label = glue::glue("hjust: {hjust}; vjust: {vjust}"))

mpg %>%
 ggplot(aes(x = hwy, displ))+
 geom_count(aes(colour = class))+
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class")+
 geom_text(aes(x = x, y = y, label = label, hjust = hjust, vjust = vjust),
 data = data_label)
```



1. Read the documentation for `annotate()`. How can you use it to add a text label to a plot without having to create a tibble?

```
mpg %>%
 ggplot(aes(x = hwy, displ)) +
 geom_count(aes(colour = class)) +
 labs(title = "Larger displacement has lower gas mileage efficiency",
 subtitle = "SUV and pickup classes` tend to be highest on disp",
 caption = "Data is for cars made in either 1999 or 2008",
 colour = "Car class") +
 annotate("text", x = Inf, y = Inf, label = paste0("Mean highway mpg: ", round(mean(mpg$hwy))), v
```



- function adds geoms, but not mapped from variables of a data frame, so can pass in small items or single labels
  - can specify the geom type with `annotate`
2. How do labels with `geom_text()` interact with facetting? How can you add a label to a single facet? How can you put a different label in each facet? (Hint: think about the underlying data.)
- ```
data_label_single <- tibble(x = Inf, y = Inf, label = paste0("Mean highway mpg: ", round(mean(mpg$hwy, na.rm = TRUE), 1)))
```
- ```
data_label <- mpg %>%
 group_by(class) %>%
 summarise(hwy = round(mean(hwy))) %>%
 mutate(label = paste0("hwy mpg for ", class, ":", hwy)) %>%
 mutate(x = Inf, y = Inf)
```
- ```
mpg %>%
  ggplot(aes(x = hwy, displ)) +
  geom_count(aes(colour = class)) +
  labs(title = "Larger displacement has lower gas mileage efficiency",
       subtitle = "SUV and pickup classes` tend to be highest on disp",
       caption = "Data is for cars made in either 1999 or 2008",
       colour = "Car class") +
  facet_wrap(~class) +
  geom_smooth() +
  geom_text(aes(x = x, y = y, label = label), data = data_label, vjust = "top", hjust = "right")
```
- ```
Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : span too small. fewer data values than degrees of freedom.
```

```

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : pseudoinverse used at 22.985

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : neighborhood radius 2.015

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : reciprocal condition number 0

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : There are other near singularities as well. 1.0302

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : span too small.
fewer data values than degrees of freedom.

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : pseudoinverse used
at 22.985

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : neighborhood radius
2.015

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : reciprocal
condition number 0

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : There are other
near singularities as well. 1.0302

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : pseudoinverse used at 24.035

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : neighborhood radius 2.035

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : reciprocal condition number 7.8765e-017

Warning in simpleLoess(y, x, w, span, degree = degree, parametric =
parametric, : There are other near singularities as well. 1

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : pseudoinverse used
at 24.035

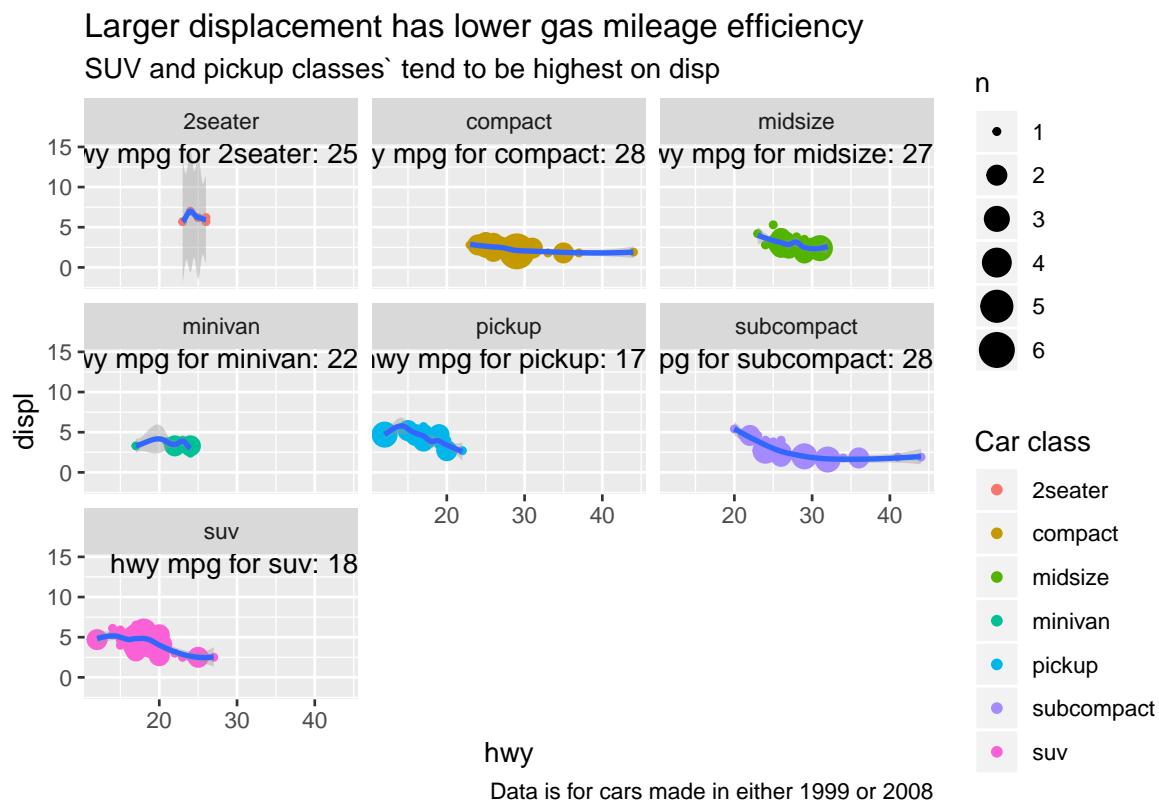
Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object))), : neighborhood radius
2.035

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))

```

```
as.matrix(model.frame(delete.response(terms(object)), : reciprocal
condition number 7.8765e-017

Warning in predLoess(object$y, object$x, newx = if
(is.null(newdata)) object$x else if (is.data.frame(newdata))
as.matrix(model.frame(delete.response(terms(object)), : There are other
near singularities as well. 1
```

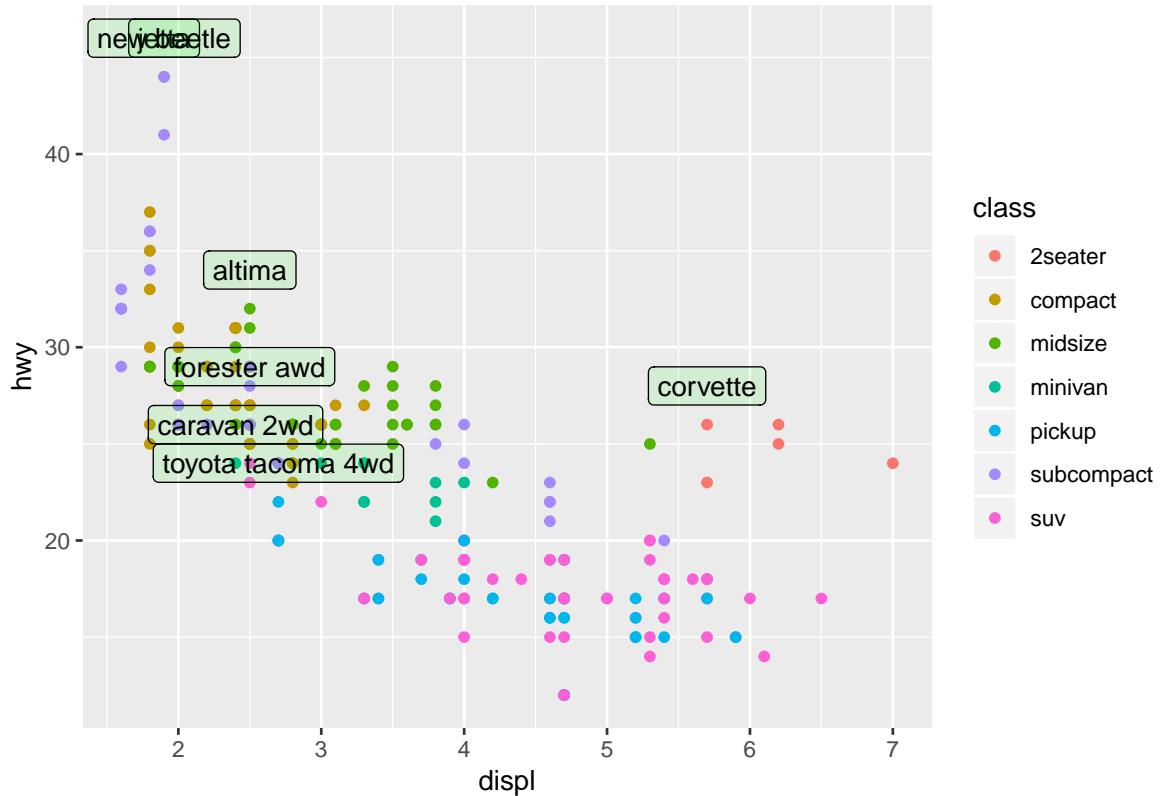


3. What arguments to `geom_label()` control the appearance of the background box?

- `fill` argument controls background color
- `alpha` controls it's relative brightness

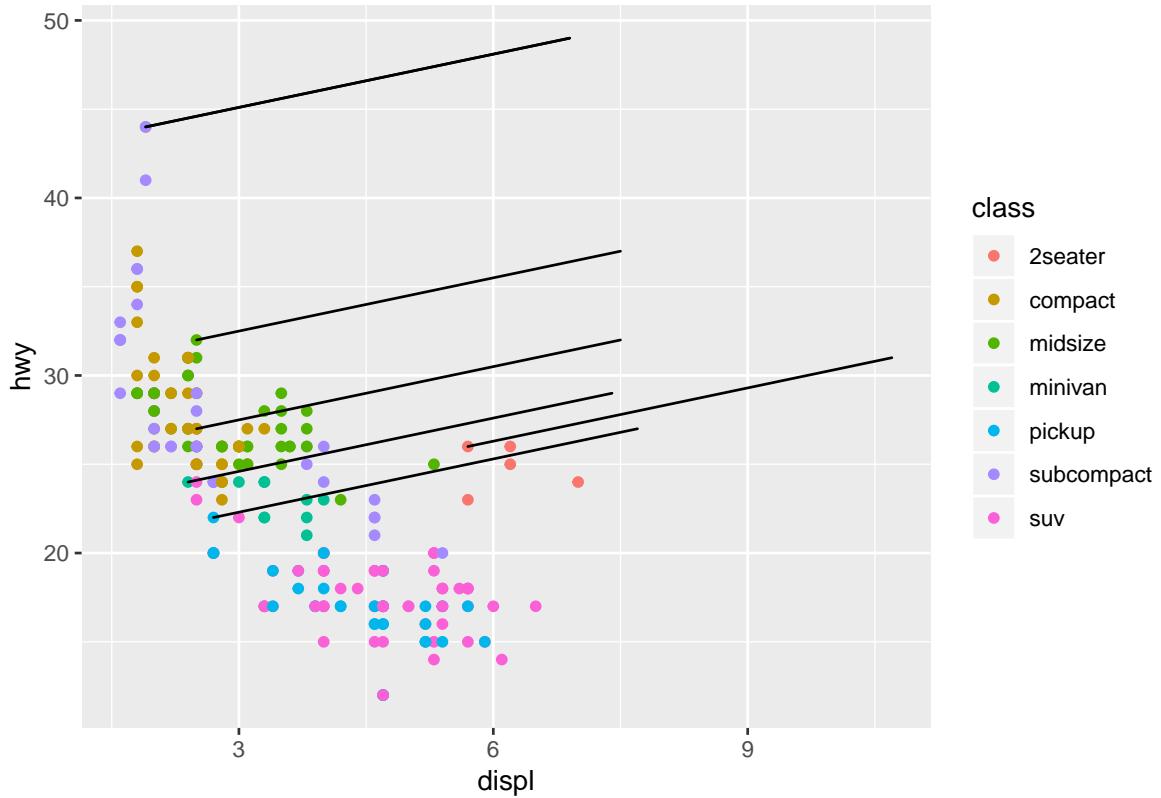
```
best_in_class <- mpg %>%
 group_by(class) %>%
 filter(row_number(desc(hwy)) == 1)

ggplot(mpg, aes(displ, hwy)) +
 geom_point(aes(colour = class)) +
 geom_label(aes(label = model), data = best_in_class, nudge_y = 2, alpha = 0.1, fill = "green")
```



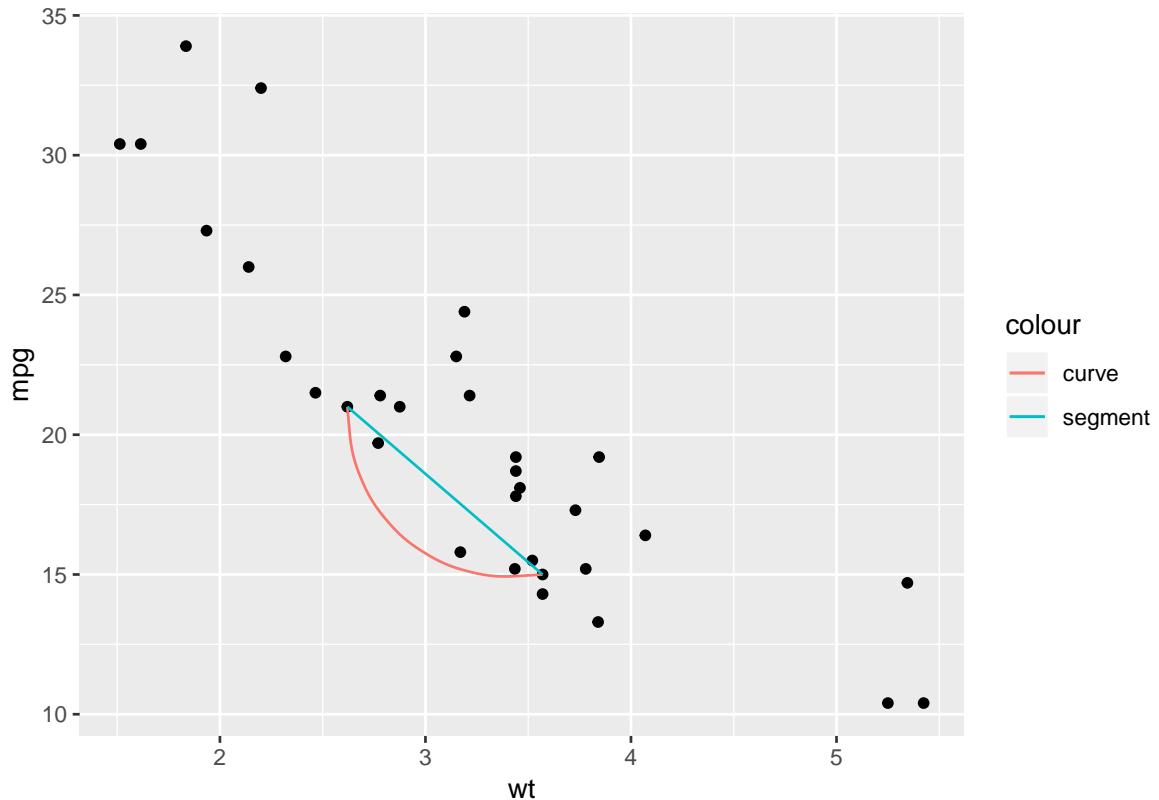
4. What are the four arguments to `arrow()`? How do they work? Create a series of plots that demonstrate the most important options.

```
ggplot(mpg, aes(displ, hwy)) +
 geom_point(aes(colour = class)) +
 geom_segment(aes(xend = displ + 5, yend = hwy + 5), data = best_in_class, lineend = "round")
```

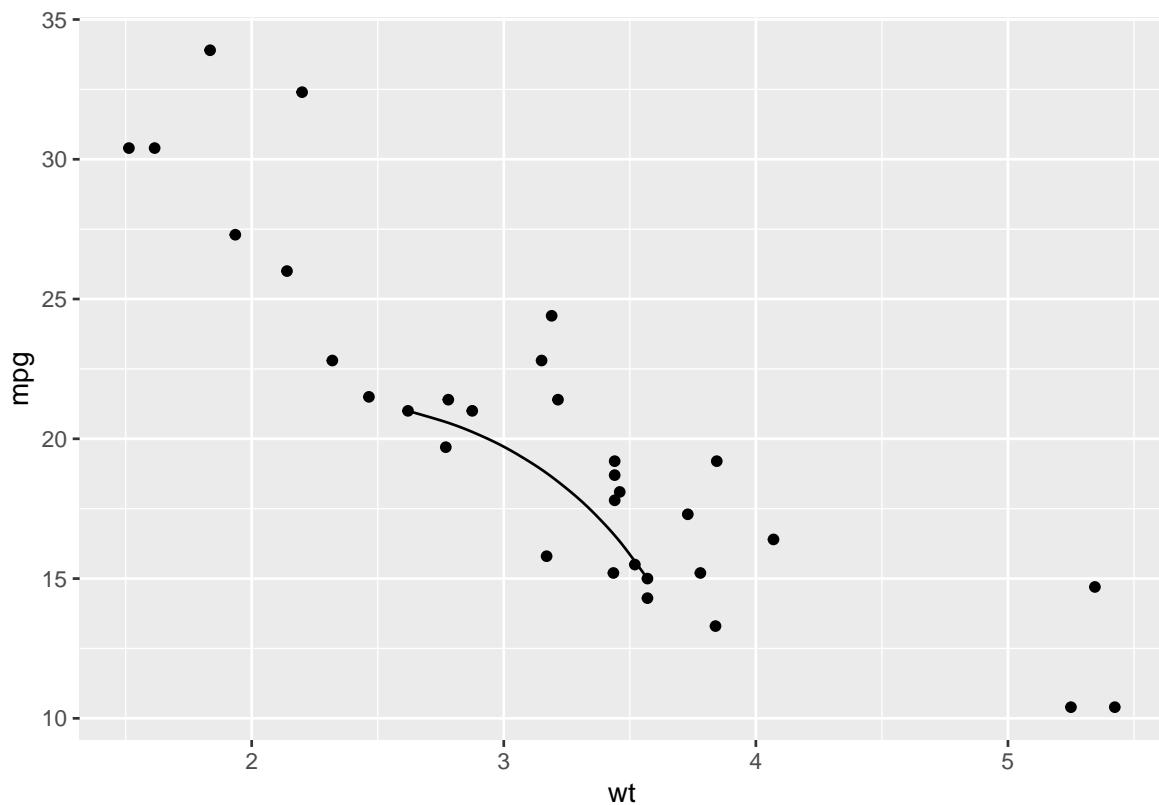


```
b <- ggplot(mtcars, aes(wt, mpg)) +
 geom_point()

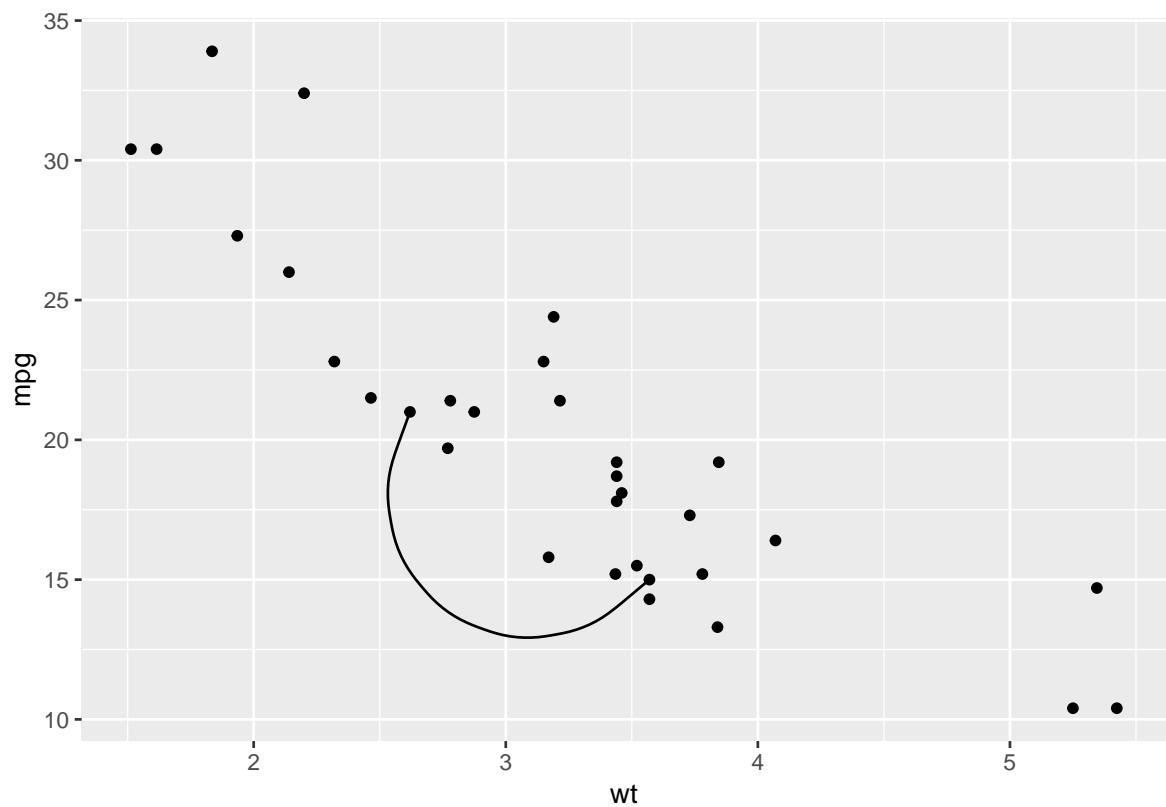
df <- data.frame(x1 = 2.62, x2 = 3.57, y1 = 21.0, y2 = 15.0)
b +
 geom_curve(aes(x = x1, y = y1, xend = x2, yend = y2, colour = "curve"), data = df) +
 geom_segment(aes(x = x1, y = y1, xend = x2, yend = y2, colour = "segment"), data = df)
```



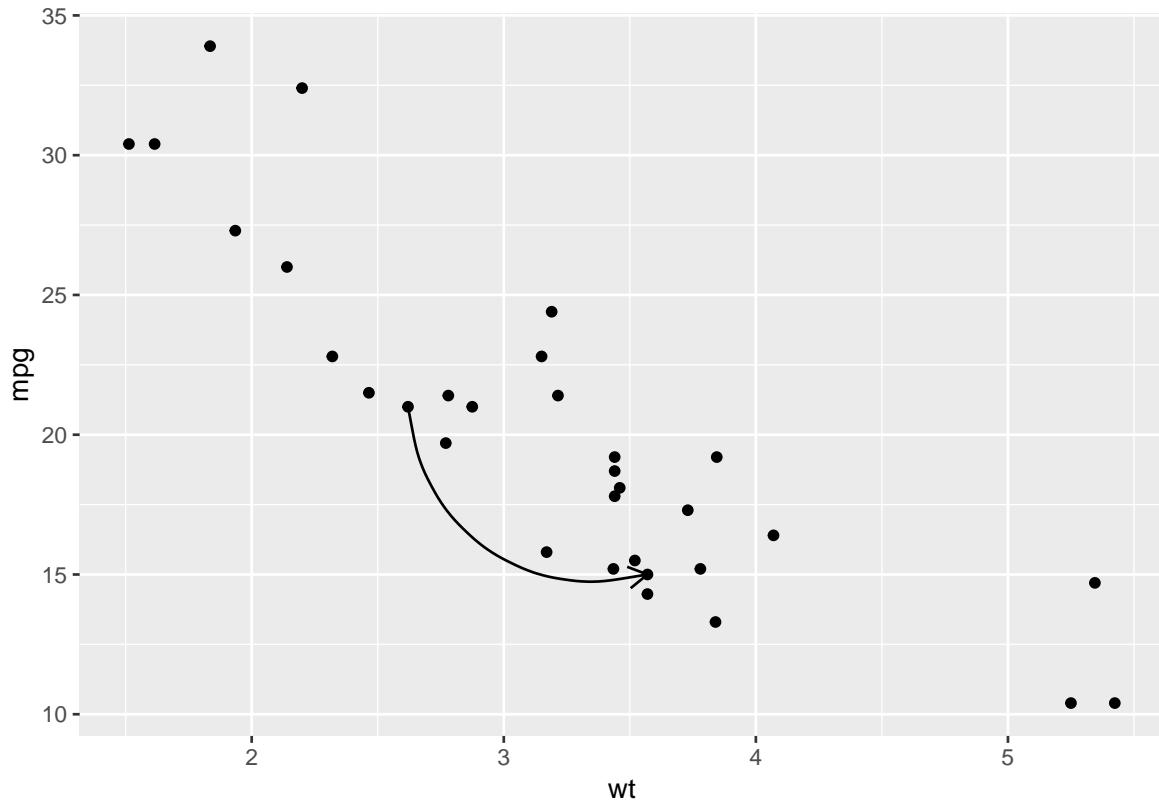
```
b + geom_curve(aes(x = x1, y = y1, xend = x2, yend = y2), data = df, curvature = -0.2)
```



```
b + geom_curve(aes(x = x1, y = y1, xend = x2, yend = y2), data = df, curvature = 1)
```



```
b + geom_curve(
 aes(x = x1, y = y1, xend = x2, yend = y2),
 data = df,
 arrow = arrow(length = unit(0.03, "npc"))
)
```



- `angle` (in degrees), `length` (use `unit()` function to specify with number and type, e.g. “inches”), `ends` (“last”, “first”, or “both” – specifying which end), `type` (“open” or “closed”)

### 34.3 28.4: Scales

#### 34.3.1 28.4.4

1. Why doesn't the following code override the default scale?

```
df <- tibble(x = rnorm(100), y = rnorm(100))

ggplot(df, aes(x, y)) +
 geom_hex() +
 scale_colour_gradient(low = "white", high = "red") +
 coord_fixed()
```

- `geom_hex` uses `fill`, not `colour`

```
df <- tibble(x = rnorm(100), y = rnorm(100))

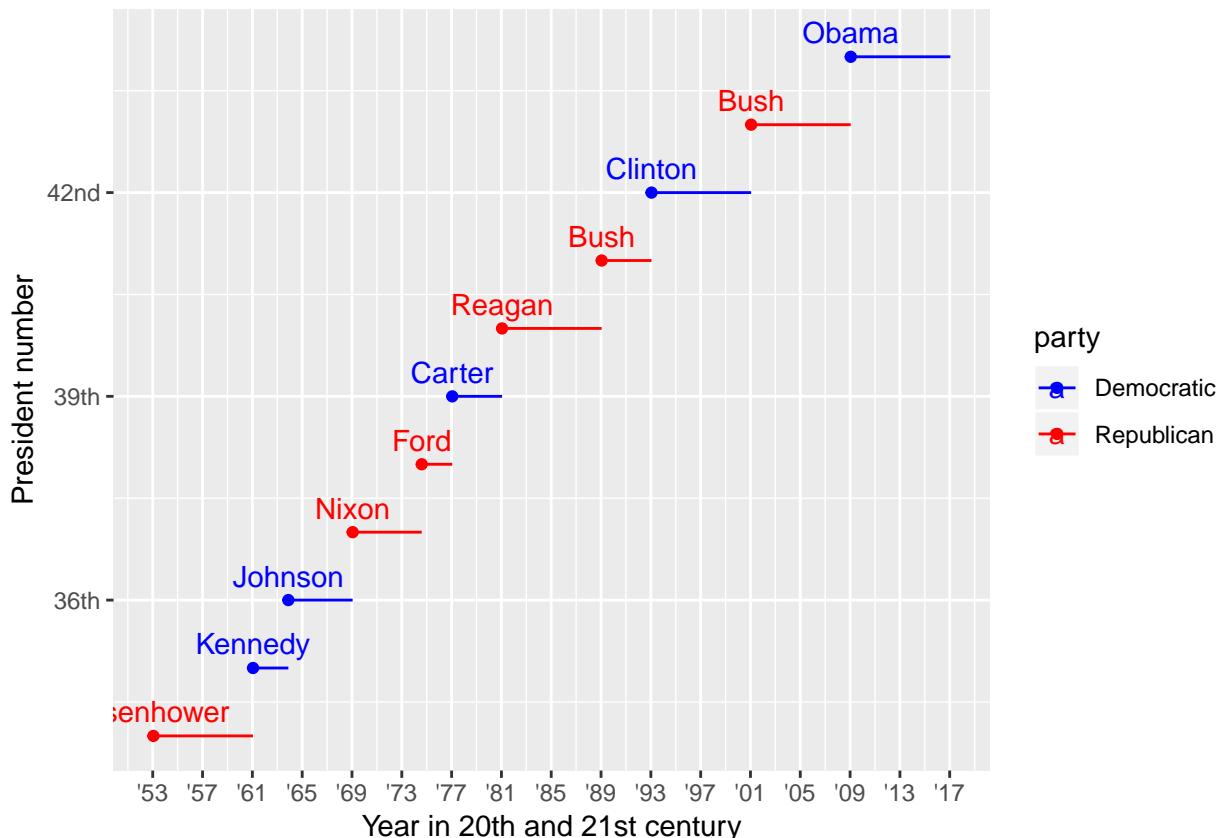
ggplot(df, aes(x, y)) +
 geom_hex() +
 scale_fill_gradient(low = "white", high = "red") +
 coord_fixed()

ggplot(df, aes(x, y)) +
 geom_hex() +
```

```
scale_fill_gradient(low = "white", high = "red") +
coord_fixed()
```

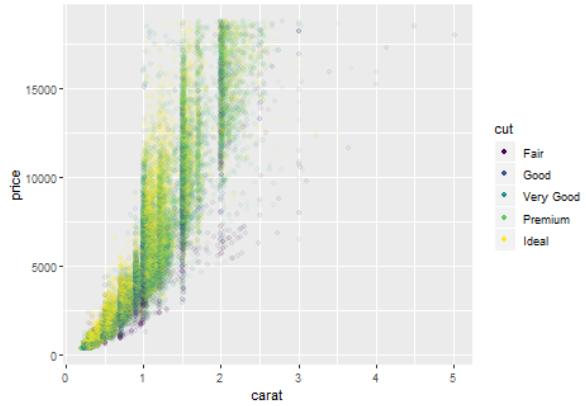
2. What is the first argument to every scale? How does it compare to `labs()`?
  - `name`, i.e. what the title will be for that axis/legend/... `labs` first argument is ... so requires you to name the input
3. Change the display of the presidential terms by:
  1. Combining the two variants shown above.
  2. Improving the display of the y axis.
  3. Labelling each term with the name of the president.
  4. Adding informative plot labels.
  5. Placing breaks every 4 years (this is trickier than it seems!).

```
presidential %>%
 mutate(id = 33L + row_number()) %>%
 ggplot(aes(start, id, colour = party)) +
 geom_point() +
 geom_segment(aes(xend = end, yend = id)) +
 geom_text(aes(label = name), vjust = "bottom", nudge_y = 0.2) +
 scale_colour_manual(values = c(Republican = "red", Democratic = "blue")) +
 scale_x_date("Year in 20th and 21st century", date_breaks = "4 years", date_labels = "%y") +
 # scale_x_date(NULL, breaks = presidential$start, date_labels = "%y") +
 scale_y_continuous(breaks = c(36, 39, 42), labels = c("36th", "39th", "42nd")) +
 labs(y = "President number", x = "Year")
```



1. Use `override.aes` to make the legend on the following plot easier to see.

```
diamonds %>%
 ggplot(aes(carat, price)) +
 geom_point(aes(colour = cut), alpha = 1/20) +
 guides(colour = guide_legend(override.aes = list(alpha = 1)))
```



# Bibliography