Chapter 1: data cleaning, wrangling & visualization

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1 Data, tabulation and visualisation

Before you dive in, first load the libraries (if you need to install any, do this first):

```
library(modelr)
library(kableExtra)
library(ggplot2)
library(ggthemes)
library(dplyr)
library(knitr)
library(nycflights13)
library(forcats)
library(tidyverse)
```

1.1 Data: reading, cleaning, summarizing

The first thing to do when we start a data analysis, is to load the data (there are many easily googlable options for this, depending on what file format you're using). For now, let's use a longitudinal set connecting heights to earnings coming from the modelr package. It's already loaded, and we start with reading about the data set (sometimes, such information is available) and inspecting the first few lines (in our case, 10 of them). Then, it might be worthwhile to look at the structure of the dataset.

```
#?heights  # find the information about the dataset
          # (this will not show in PDF, check the help tab in RStudio)
heights <- as.data.frame(heights)   # convert to a standard data frame format

             # str() function displays the structure of an R object
             # with that we can check some basic information about an object
str(heights) # number of variables, data types, column names etc.
```

```
## 'data.frame':    7006 obs. of  8 variables:
##  $ income   : int  19000 35000 105000 40000 75000 102000 0 70000 60000 150000 ...
##  $ height   : num  60 70 65 63 66 68 74 64 69 69 ...
##  $ weight   : int  155 156 195 197 190 200 225 160 162 194 ...
##  $ age      : int  53 51 52 54 49 49 48 54 55 54 ...
##  $ marital  : Factor w/ 5 levels "single","married",..: 2 2 2 2 2 4 2 4 4 4 ...
##  $ sex      : Factor w/ 2 levels "male","female": 2 2 1 2 1 2 1 2 1 1 ...
##  $ education: int  13 10 16 14 14 18 16 12 12 13 ...
##  $ afqt     : num  6.84 49.44 99.39 44.02 59.68 ...
```

```
          # now a more elegant tool
          # inspect the first few lines to get a feel for the dataset,
          # note the pipe "%>%" operator (google it and learn to use it)
          # note also I used kable to plot a nice table in the pdf file
          # you don't have to do this if you're working using an R script.
head(heights, n = 6) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

income	height	weight	age	marital	sex	education	afqt
19000	60	155	53	married	female	13	6.841
35000	70	156	51	married	female	10	49.444
105000	65	195	52	married	male	16	99.393
40000	63	197	54	married	female	14	44.022
75000	66	190	49	married	male	14	59.683
102000	68	200	49	divorced	female	18	98.798

We can view the means and medians of variables of interest as follows:

```
mean(heights$height)
```

```
## [1] 67.10434
```

```
#if a varable has NAs, you might choose or need to ignore them with na.rm
median(heights$weight, na.rm=TRUE)
```

```
## [1] 184
```

Note the use of the dollar sign between the data name and variable name. For data frames dollar sign enables a choice of a particular column by its name.

We can select parts of the data by a logical condition, using square brackets appropriately. For instance, the mean of weight for people with height>68 and the median of weight of people with height=69 can be obtained as follows:

```
mean(heights$weight[heights$height > 68], na.rm=TRUE)
```

```
## [1] 210.8534
```

```
#note double identity symbol for comparison
median(heights$weight[heights$height == 69], na.rm=TRUE)
```

```
## [1] 190
```

Exercise 1

I now load the smallpox dataset for you. View 6 first entries and data structure, this should give you a feel for what the dataset is about. Note that you have to set your working directory to the directory containing the teachingData folder (you can use setwd() function for that purpose).

```
smallpox <- read.csv("teachingData/CsvFiles/GlobalSmallpoxCases.csv",
                     header = TRUE)
```

Exercise 2

Display the head of the dataset.

Exercise 3

Note that one column name is informative but ugly. We can rename it, complete the following code to do so and view the dataset structure. Are you sure you know why we used [4]?

```
names(smallpox)[4] <- "___"
```

Exercise 4

We don't care about the code, complete the code to remove this column and view the head to make sure your move worked. Are you sure you know why we used [,-2]?

```
___________ <- _________[,-2]
```

Exercise 5

View the mean and median of the cases variable.

Exercise 6

What are the mean and median occurrences of smallpox in years 1920-1930? Use & for conjunction in the logical condition.

Exercise 7

What are the means and medians for periods 1930-1950 and 1950-1970?

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Exercise 8

I now load the DrunkAndDriving dataset for you. View 5 first entries and data structure, this should give you a feel for what the dataset is about. Note that you have to set your working directory to the directory containing the teachingData folder (you can use setwd() function for that purpose). Also, what is the purpose of "sep=" parameter?

```
drunkDriving <- read.csv("DrunkAndDrivingPoland.csv", sep = ";")
```

Exercise 9

Display the head of the dataset.

Exercise 10

Note that the first column name is informative but ugly. We can make it simpler, complete the following code to do so and view the dataset structure. Are you sure you know why we used [1]?

```
names(drunkDriving)[1] <- "____"
```

Exercise 11

Proportions given in percentages are not very informative in this case, complete the code to remove this column and view the head to make sure your move worked. Are you sure you know why we used [,-4]?

```
_____________ <- ___________[,-4]
```

Exercise 12

View the mean and median of the knownCases variable.

Exercise 13

What are the mean and median occurrences of known drunk and driving cases in years 2001-2006? Use & for conjunction in the logical condition.

Exercise 14

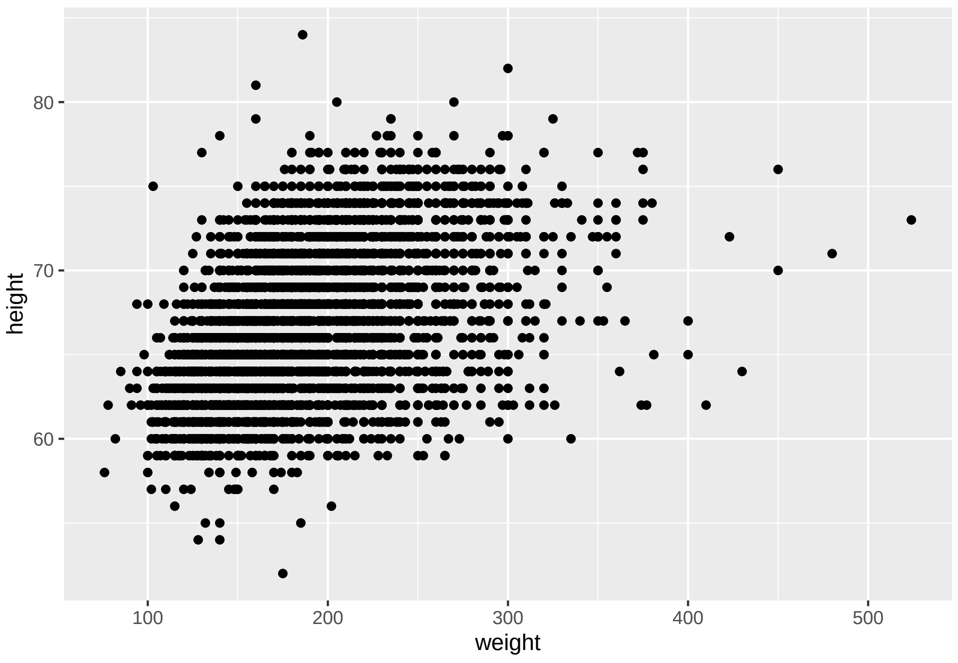
What are the means and medians for periods 2001-2010 and 2011-2021? Is, according to this data, drunk driving increasing or decreasing problem?

1.2 Basic plots with ggplot2

It is almost always useful to visualize the data, for various reasons. This action should precede any statistical analysis or inference. Here is one simple method: **scatterplot**. It works for two variables. We will use one of the most popular visualization packages in R, **ggplot2**. Let's do this for height and weight in the heights dataset:

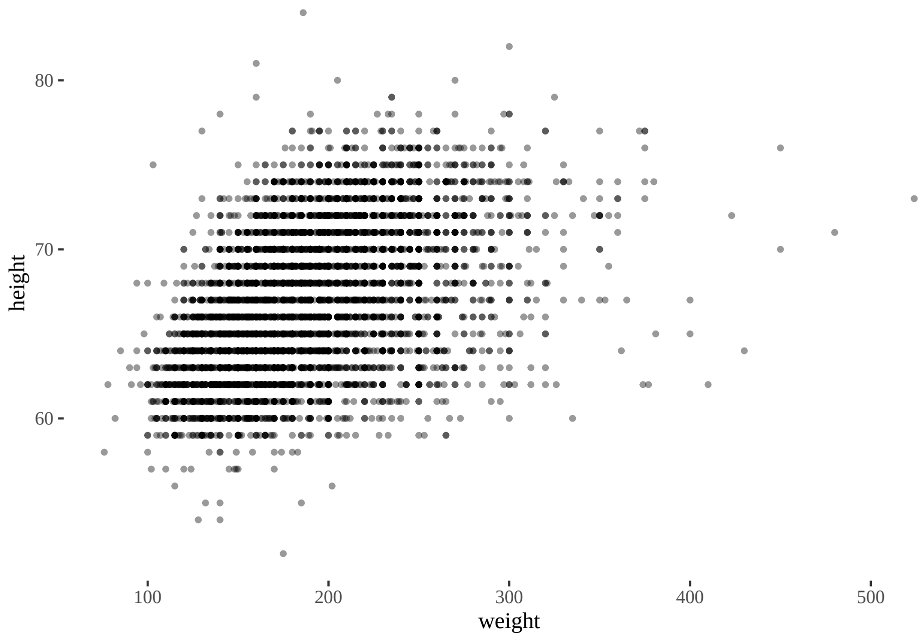
```
# You can find a cheatsheet for using ggplot2, check out:
# https://www.rstudio.com/resources/cheatsheets/

#specify the basics
ggplot(heights, aes(x = weight, y = height)) +
 geom_point()    # add a layer of points
```

```
## Warning: Removed 95 rows containing missing values ('geom_point()').
```



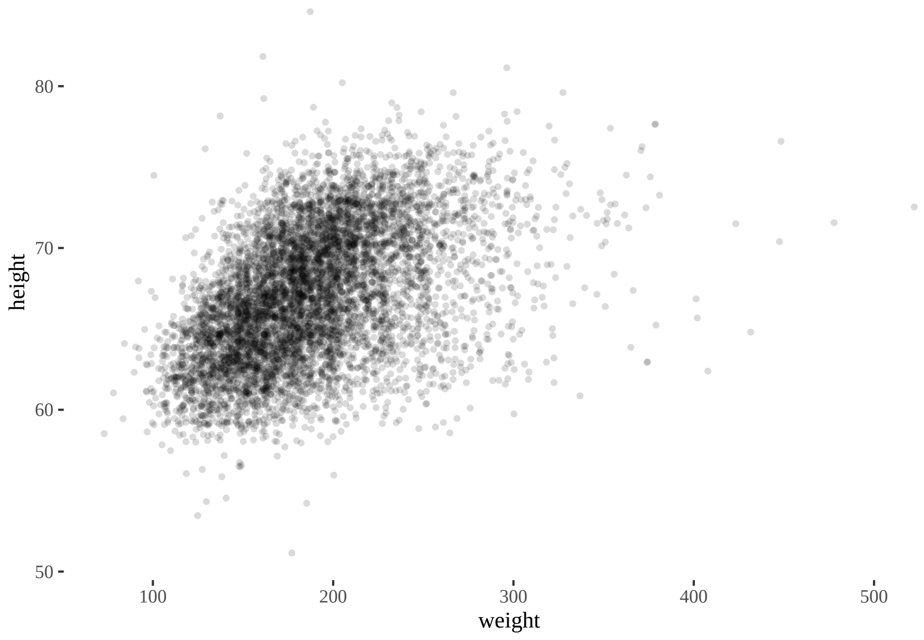
Notice also that you got a warning: the dataset contained NAs. The points are a bit large, we will make them a bit smaller and slightly transparent (alpha parameter) to better see how densely they occur. We also use the tufte theme instead of the default ggplot theme:

```
#we first specify the basics
ggplot(heights, aes(x = weight, y = height)) +
 geom_point(size = .9, alpha = .4)+
 theme_tufte()# we add a layer of points
```



To get more clarity, we can "shake" the points a bit with a jitter. Sometimes you need to get creative and play around with the parameters to make the plot look nice.

```
ggplot(heights, aes(x = weight, y = height)) +
 geom_jitter(size = .9, alpha = .15, width = 4, height = 1)+
 theme_tufte()
```



We can add lines to the plot. Sometimes, we add exact values, as when we already have some summaries. To show you how to work with vectors I'll give you a simple example, make sure you understand how the vector constructions worked, observe the use of three different functions (":" operator, rep(), seq()). I also use length to make sure I created vectors of equal weight. Remember that you can always use "?" (e.g ?rep()) to check the details about the R function in question.

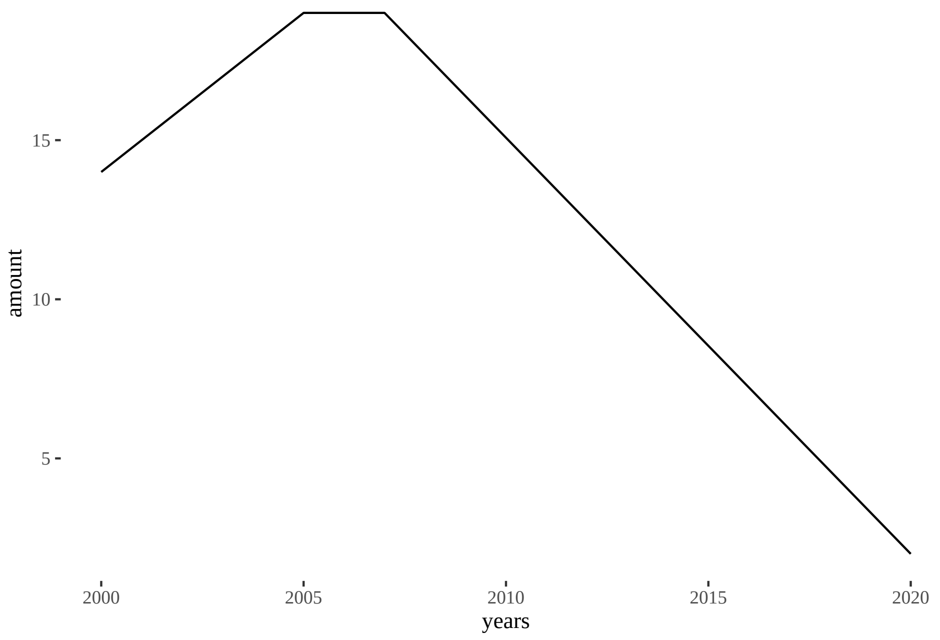
```
years <- 2000:2020
amount <- c(14:18, rep(19,2), seq(19,2, length.out = 14))
length(years)
```

```
## [1] 21
```

```
length(amount)
```

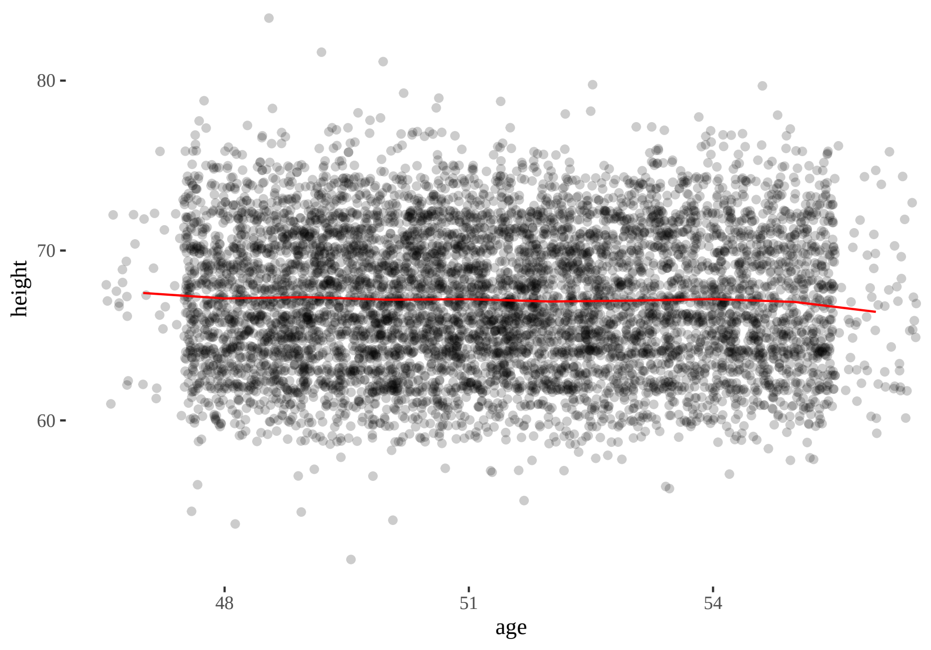
```
## [1] 21
```

```
ggplot() + geom_line(aes(x= years, y = amount))+
  theme_tufte()
```



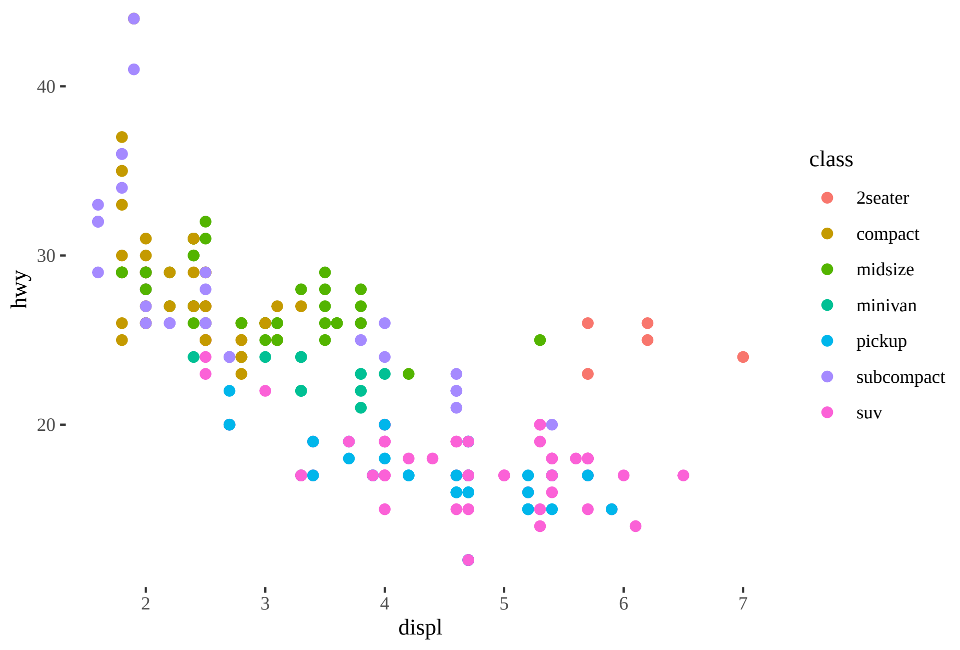
On some other occasions we want to focus on some statistics, such as mean. For instance, for heights we can do this as follows:

```
ggplot(heights, aes(x= age, y = height))+
  geom_jitter(width = 0.5, alpha = 0.2)+
  stat_summary(fun=mean, colour="red", geom="line", aes(group = 1))+
  theme_tufte()
```



Now we look at mpg dataset to illustrate how we can also color the points by grouping. Feel free to take a look at its help description to see what data and variables it contains.

```
ggplot(mpg) + geom_point(aes(x = displ, y = hwy,
            color = class), size = 2)+
  theme_tufte()
```



Observe the extreme outliers when it comes to fuel efficiency. Grouping by color makes it easy to see that these are subcompact cars.

Exercise 15

Back to the smallpox dataset. Plot cases against years with a line. Use the tufte theme and color "skyblue".

Exercise 16

Plot income against education using the heights dataset. Use points and add a line representing the mean.

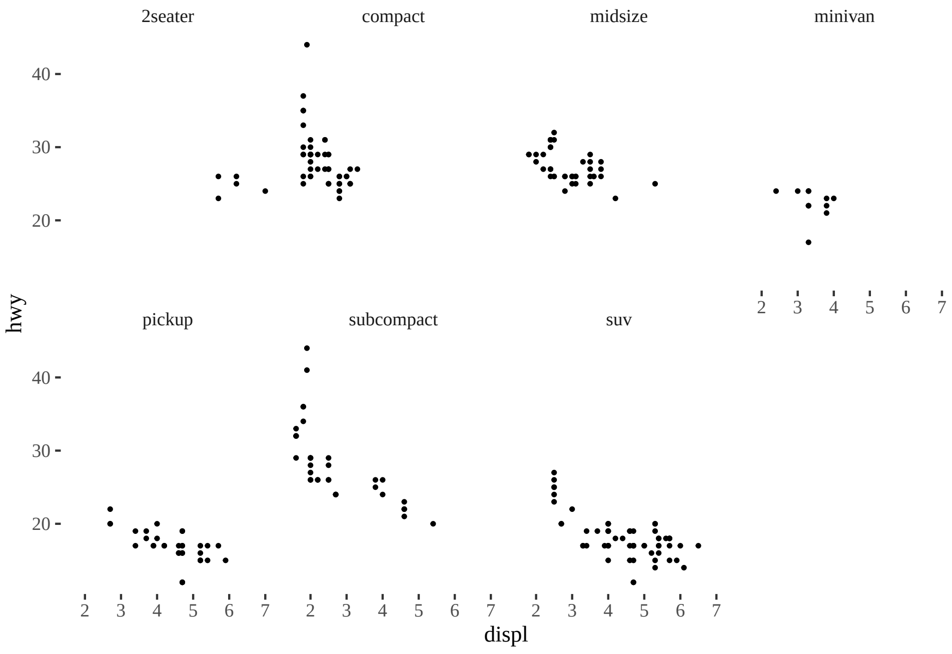
Exercise 17

In the heights dataset plot income versus education coloring by sex. Keep the mean lines (this time, don't specify group or color for the stat separately, but specify size = 2). Is there anything that you find striking?

Remember that mean might be a misleading indicator with outliers, so plot the same data with a median instead.

Another useful feature is splitting the plots by a categorical variable. For instance, for the mpg database we can do:

```
ggplot(mpg) + geom_point(aes(x = displ, y = hwy), size = 0.6) +
      facet_wrap(~ class, nrow = 2) + theme_tufte()
```



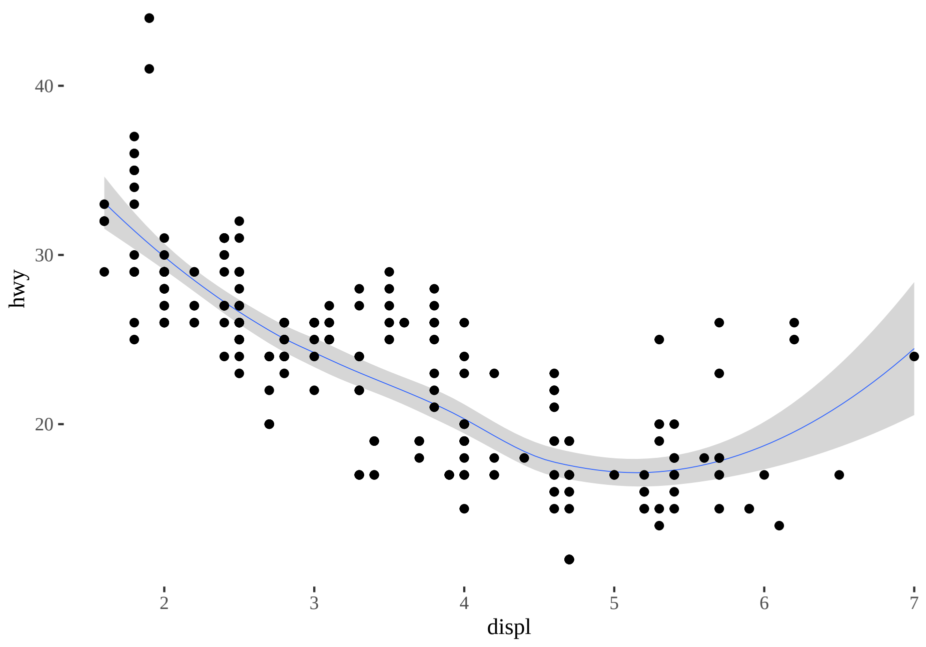
Exercise 18

Use the plot you developed for income by sex (median), but also now divide the plot by the marital status.FInd parameters that make the plot look decent.

Notice how separated and divorced females fare similarly to males, single females are better off than married females, and educated widowed females are doing pretty awesome (note however the potential impact of outliers for this class).

Lines of another type result from smoothing. These, usually, will not be straight lines and they are useful if the tendencies change non-linearly. Here's an example:

```
ggplot(mpg,aes(x = displ, y = hwy)) +
  geom_smooth(size=0.2)+geom_point()+theme_tufte()
```



Exercise 19

Plot income vs education by sex with smoothing.

Exercise 20

Look at the dataset on the eruptions of Old Faithful (google if you don't know what that is). Prepare a scatterplot of eruption times vs. waiting times. What strikes you?

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Exercise 21

Drunk driving again, plot cases against years with a line. Use the tufte theme and color "skyblue".

Exercise 22

Create a scatterplot of the number of occurrences versus the month of the year using the NYPD dataset. Note that the set is slightly more complicated, I will wrangle the data for you, so don't stress (be sure to execute the given code first!).

```
# just run the code below
nypd$MONTH <- as.integer(format(nypd$OCCUR_DATE, "%m"))
nypd_monthly_counts <- nypd %>%
  mutate(MONTH = format(OCCUR_DATE, "%Y-%m")) %>%
  group_by(MONTH) %>%
  summarise(OCCURRENCES = n()) %>%
  ungroup()

# use the nypd_monthly_counts as your table to create the requested plot:

____ <- ggplot(nypd_monthly_counts,                    ) +
```

Exercise 23

Make a similar plot (months against occurrences), use the table below, and add points colored by borough (it's a district, there are 6 of them in New York). Is there any borough that stands out in terms of occurrence rates?

```r
# run this code
nypd_monthly_counts_boro <- nypd %>%
  mutate(MONTH = format(OCCUR_DATE, "%Y-%m")) %>%
  group_by(MONTH, BORO) %>%
  summarise(OCCURRENCES = n()) %>%
  ungroup()

# use nypd_monthly_counts_boro to proceed with your visualization
```

Exercise 24

Again, on the same plot (months against occurrences) represent the age of victims with a color (similarly as you did with borough). Compare your findings with the previous plot, do you see any pattern?

```r
nypd_monthly_counts_age <- nypd %>%
  mutate(MONTH = format(OCCUR_DATE, "%Y-%m")) %>%
  group_by(MONTH, VIC_AGE_GROUP) %>%
  summarise(OCCURRENCES = n()) %>%
  ungroup()
```

Exercise 25

Create a scatterplot of the number of occurrences versus the month of the year using the NYPD dataset, with points colored by the borough and smoothed with a line of best fit. Is there any trend in the data over the year, in terms of the occurrence rates in each borough?

```r
nypd_monthly_counts_boro <- nypd %>%
  mutate(MONTH = format(OCCUR_DATE, "%Y-%m")) %>%
  group_by(MONTH, BORO) %>%
  summarise(OCCURRENCES = n()) %>%
  ungroup()
```

Exercise 26

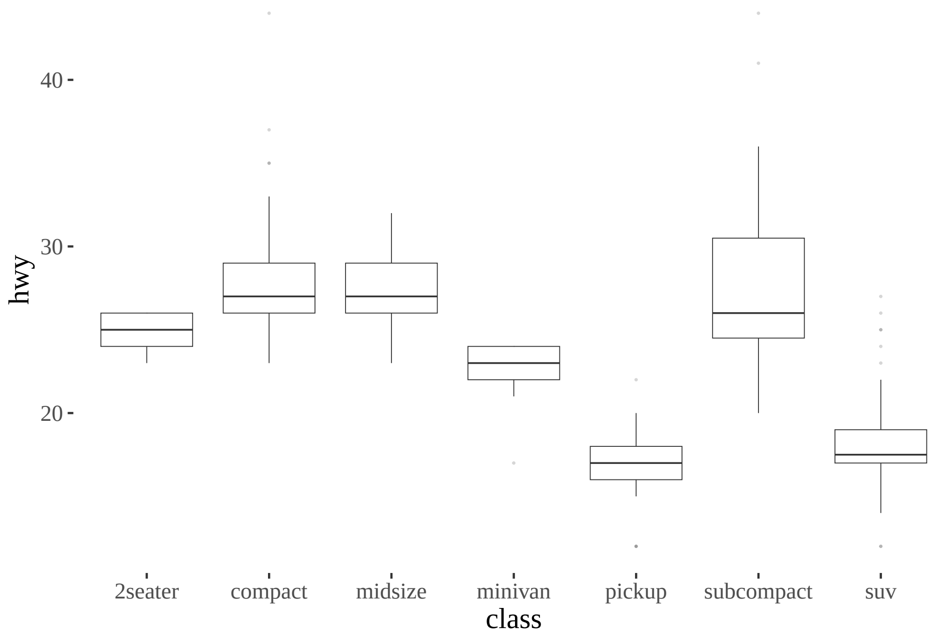
Look at the dataset on the eruptions of Old Faithful (google if you don't know what that is). Prepare a scatterplot of eruption times vs. waiting times. What strikes you?

```r
old_faithful <- faithful
```

1.3 Boxplots

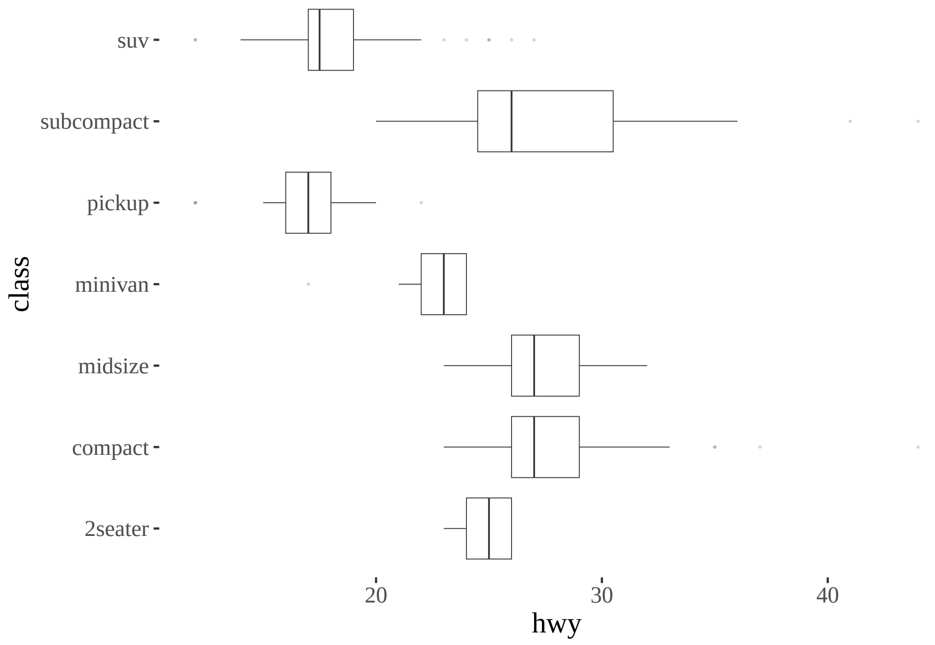
Another way to represent data is with boxplots, which nicely show the median, quartiles, IQR and can be used to detect potential outliers. Here's an example.

```
ggplot(mpg, aes(x = class, y = hwy)) +
          geom_boxplot(size=0.2,alpha=0.2,outlier.size = 0.1) +
          theme_tufte() +
          theme(text = element_text(size=14))
# In the last line I have increased the font size for better visibility
```



Observe we can flip the coordinates if we find this useful:

```
ggplot(mpg, aes(x = class, y = hwy)) +
          geom_boxplot(size=0.2,alpha=0.2,outlier.size = 0.1) +
          theme_tufte() + coord_flip() +
          theme(text = element_text(size=14))
```



Exercise 27

Prepare a boxplot of income vs sex using the heights dataset.

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Exercise 28

Create a box plot of the number of incidents per month against borough.

1.4 Using dplyr

The dplyr package has quite a few useful tools, we'll see them in action looking at the NYC flights dataset available in the nycflights13 package. The key ones are:

- filter, which pick observations by their values.
- arrange, which reorders the rows.
- select, which picks variables by their names.
- mutate, which creates new variables with functions of existing variables.
- summarize, which collapse many values down to a single summary.

First, let's inspect the head of the dataset (there are quite a few variables, so it's not going to look user-friendly):

```
head(flights) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped","scale_down", "HOLD_position"))  %>%
          kable_styling(font_size = 14)
```

year	month	day	dep_time	sched_dep_time	dep_delay	arr_time	sched_arr_time	arr_delay	carrier	flight	tailnum	origin	dest	air_time	distance	hour	minute	time_hour
2013	1	1	517	515	2	830	819	11	UA	1545	N14228	EWR	IAH	227	1400	5	15	2013-01-01 05:00:00
2013	1	1	533	529	4	850	830	20	UA	1714	N24211	LGA	IAH	227	1416	5	29	2013-01-01 05:00:00
2013	1	1	542	540	2	923	850	33	AA	1141	N619AA	JFK	MIA	160	1089	5	40	2013-01-01 05:00:00
2013	1	1	544	545	-1	1004	1022	-18	B6	725	N804JB	JFK	BQN	183	1576	5	45	2013-01-01 05:00:00
2013	1	1	554	600	-6	812	837	-25	DL	461	N668DN	LGA	ATL	116	762	6	0	2013-01-01 06:00:00
2013	1	1	554	558	-4	740	728	12	UA	1696	N39463	EWR	ORD	150	719	5	58	2013-01-01 05:00:00

Another way to inspect the variables is to look at column names:

```
names(flights)
```

```
##  [1] "year"           "month"          "day"            "dep_time"
##  [5] "sched_dep_time" "dep_delay"      "arr_time"       "sched_arr_time"
##  [9] "arr_delay"      "carrier"        "flight"         "tailnum"
## [13] "origin"         "dest"           "air_time"       "distance"
## [17] "hour"           "minute"         "time_hour"
```

For instance, we can pick only the flights that took place on Jan 1 by saying:

```
Jan1 <- filter(flights, month == 1, day == 1)
head(Jan1) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped","scale_down",
                                          "HOLD_position"))  %>%
          kable_styling(font_size = 14)
```

year	month	day	dep_time	sched_dep_time	dep_delay	arr_time	sched_arr_time	arr_delay	carrier	flight	tailnum	origin	dest	air_time	distance	hour	minute	time_hour
2013	1	1	517	515	2	830	819	11	UA	1545	N14228	EWR	IAH	227	1400	5	15	2013-01-01 05:00:00
2013	1	1	533	529	4	850	830	20	UA	1714	N24211	LGA	IAH	227	1416	5	29	2013-01-01 05:00:00
2013	1	1	542	540	2	923	850	33	AA	1141	N619AA	JFK	MIA	160	1089	5	40	2013-01-01 05:00:00
2013	1	1	544	545	-1	1004	1022	-18	B6	725	N804JB	JFK	BQN	183	1576	5	45	2013-01-01 05:00:00
2013	1	1	554	600	-6	812	837	-25	DL	461	N668DN	LGA	ATL	116	762	6	0	2013-01-01 06:00:00
2013	1	1	554	558	-4	740	728	12	UA	1696	N39463	EWR	ORD	150	719	5	58	2013-01-01 05:00:00

Exercise 29

Use filter to pick the flights from the last two months. Remember that | stands for disjunction, display the result and save as twoLast.

We can arrange flights by variables. For instance, by year, month and day of the flight:

```
YearMonthDay <- arrange(flights, year, month, day)
head(YearMonthDay) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped","scale_down", "HOLD_position"))  %>%
          kable_styling(font_size = 14)
```

year	month	day	dep_time	sched_dep_time	dep_delay	arr_time	sched_arr_time	arr_delay	carrier	flight	tailnum	origin	dest	air_time	distance	hour	minute	time_hour
2013	1	1	517	515	2	830	819	11	UA	1545	N14228	EWR	IAH	227	1400	5	15	2013-01-01 05:00:00
2013	1	1	533	529	4	850	830	20	UA	1714	N24211	LGA	IAH	227	1416	5	29	2013-01-01 05:00:00
2013	1	1	542	540	2	923	850	33	AA	1141	N619AA	JFK	MIA	160	1089	5	40	2013-01-01 05:00:00
2013	1	1	544	545	-1	1004	1022	-18	B6	725	N804JB	JFK	BQN	183	1576	5	45	2013-01-01 05:00:00
2013	1	1	554	600	-6	812	837	-25	DL	461	N668DN	LGA	ATL	116	762	6	0	2013-01-01 06:00:00
2013	1	1	554	558	-4	740	728	12	UA	1696	N39463	EWR	ORD	150	719	5	58	2013-01-01 05:00:00

Exercise 30

Order your twoLast set and order by departure delay.

Notice also how we can select columns to focus on:

```
head(select(flights,year:day,dep_time)) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

year	month	day	dep_time
2013	1	1	517
2013	1	1	533
2013	1	1	542
2013	1	1	544
2013	1	1	554
2013	1	1	554

Now we put some things together. To do so, we first select certain columns from the flights dataset, and then use the pipe to pass the result to create new columns with mutate. The final result is called flightsMutated.

```
flightsMutated <- select(flights,year:day,ends_with("delay"),
                         distance,air_time)%>%
mutate(gain = arr_delay - dep_delay,
       hours = air_time/60,
       gain_per_hour = gain/hours)
head(flightsMutated) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

year	month	day	dep_delay	arr_delay	distance	air_time	gain	hours	gain_per_hour
2013	1	1	2	11	1400	227	9	3.783333	2.378855
2013	1	1	4	20	1416	227	16	3.783333	4.229075
2013	1	1	2	33	1089	160	31	2.666667	11.625000
2013	1	1	-1	-18	1576	183	-17	3.050000	-5.573771
2013	1	1	-6	-25	762	116	-19	1.933333	-9.827586
2013	1	1	-4	12	719	150	16	2.500000	6.400000

Quite usefully we can first group data and then summarize. In this case we first group by year, month and day, and then order by mean delay on a given day.

```
byDay <- group_by(flights,year, month,day)
delayByDay<- summarize(byDay, delay = mean(dep_delay, na.rm = TRUE))
```

```
## `summarise()` has grouped output by 'year', 'month'. You can override using the
## `.groups` argument.
```

```
head(delayByDay) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

year	month	day	delay
2013	1	1	11.548926
2013	1	2	13.858823
2013	1	3	10.987832
2013	1	4	8.951595
2013	1	5	5.732218
2013	1	6	7.148014

Exercise 31

Use this dataset to create a line plot of mean daily delay against day of the year (1:365). Use alpha. Note some increase in the holiday season and in winter.

Now, notice how we can do a few things in a step-wise manner. This time we group by destination first, then add three columns: the number of flights, mean distance, and mean delay. Then we eliminate those which had at most 20 flights. and "HNL" because flights to Honolulu are unusual and we don't care about them.

```
byDest <- group_by(flights,dest)
delay <- summarize(byDest,count=n(),
                   dist=mean(distance,na.rm=TRUE),
                   delay = mean(arr_delay,na.rm=TRUE))
delay <- filter(delay,count>20,dest !="HNL")
head(delay) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

dest	count	dist	delay
ABQ	254	1826.0000	4.381890
ACK	265	199.0000	4.852273
ALB	439	143.0000	14.397129
ATL	17215	757.1082	11.300113
AUS	2439	1514.2530	6.019909
AVL	275	583.5818	8.003831

The same things can be achieved by means of a pipe, which makes this shorter and more transparent:

```
delay2 <- flights %>%
      group_by(dest) %>%
      summarize(count = n(),
                dist = mean(distance, na.rm = TRUE),
                delay = mean(arr_delay, na.rm = TRUE) ) %>%
      filter(count > 20, dest != "HNL")
head(delay2) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

dest	count	dist	delay
ABQ	254	1826.0000	4.381890
ACK	265	199.0000	4.852273
ALB	439	143.0000	14.397129
ATL	17215	757.1082	11.300113
AUS	2439	1514.2530	6.019909
AVL	275	583.5818	8.003831

Exercise 32

Use the delay dataset to create a scatterplot of delay against distance, with smoothing. Specify size = count in the aesthetic. Remove standard error from smoothing by setting se = FALSE, make the line skyblue.

Now, we can pick flights that haven't been canceled, (think `!is.na(dep_delay), !is.na(arr_delay)`), group by tail number, and summarize adding counts and mean delays.

```
not_cancelled <- flights %>%
      filter(!is.na(dep_delay), !is.na(arr_delay))
delays <- not_cancelled %>%
      group_by(tailnum) %>%
      summarize(
        n=n(),
        delay = mean(arr_delay)
      )
head(delays) %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped", "HOLD_position"))  %>%
          kable_styling(font_size = 9)
```

tailnum	n	delay
D942DN	4	31.500000
N0EGMQ	352	9.982954
N10156	145	12.717241
N102UW	48	2.937500
N103US	46	-6.934783
N104UW	46	1.804348

Criminology exercises

Exercise 33

Use filter to pick the incidents from the last two months of 2021 from the dataset NYPD shootings. Remember that the date format is YYYY-MM-DD, display the result and save as "twoLast". Hint, use ">=" and "<=" operators.

```
# firstly just run this code to change the date format in our data frame
nypd$OCCUR_DATE <- as.Date(nypd$OCCUR_DATE, "%Y-%m-%d")

# fill the blank places to complete the task
twoLast <- _____ %>% filter(______________&______________)
```

Exercise 34

Order your twoLast table from the exercise above by Borough.

Exercise 35

Using the nypd dataset create a plot of average number of incidents per month (for 12 months). Fill the code below to achieve that.

```
# firstly let's add two columns representing month and day number
nypd$MONTH <- format(nypd$OCCUR_DATE, "%m")
nypd$DAY <- format(nypd$OCCUR_DATE, "%d")

# Now we will count the number of incidents per month
# then create column for the mean
monthly_incidents <- _____ %>%
  group_by(____,____) %>%
  ________(INCIDENT_COUNT = n()) %>%
  group_by(MONTH) %>%
  summarise(MEAN_INCIDENTS = mean(_________))

# view how this table looks like
head(monthly_incidents)
```

```
# using the table above, create a plot that shows
# the mean number of incidents per month
ggplot(__________)+
  _________________________
```

Exercise 36

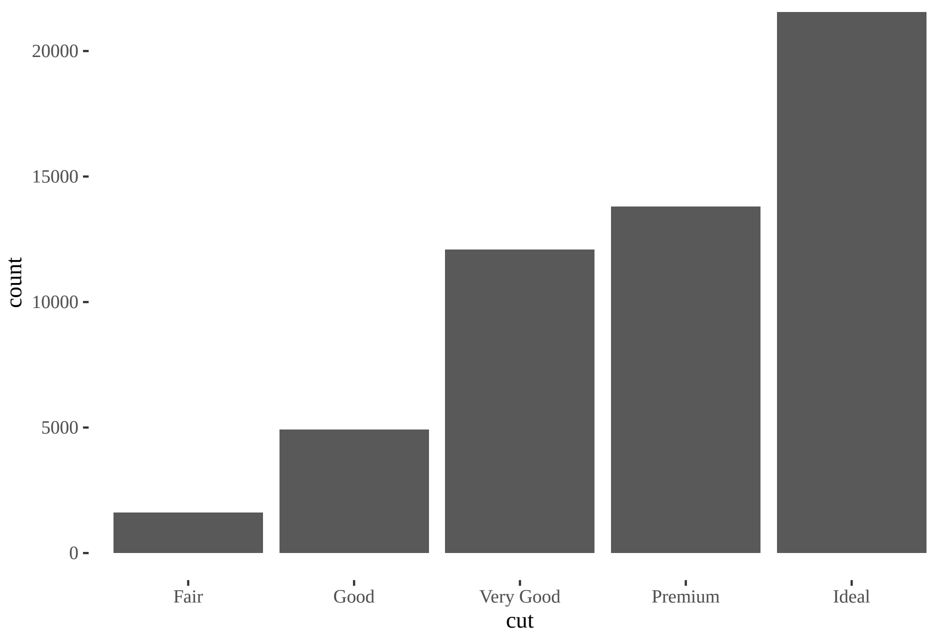
Create a scatter plot, colored by borough, of average number of incidents per month. Add two lines, red one representing the mean and skyblue one representing the median. Support yourself with the provided dyplyr code.

```
monthly_borough <- nypd %>%
  group_by(_____, _____) %>%
  summarize(MEAN_INCIDENTS = n()/n_distinct(OCCUR_DATE)) %>%
  ungroup()



# hint: you can try using scale_x_continuous(breaks = 1:12)
# to make your x axis look good
```

1.5 Counts and barplots

These are used usually to display counts or statistics against a categorical variable. We'll take a look at the diamonds dataset, which is built in. Feel free to check the help file and look at the head of the dataset. Let's prepare a barplot picturing the counts per cut type.

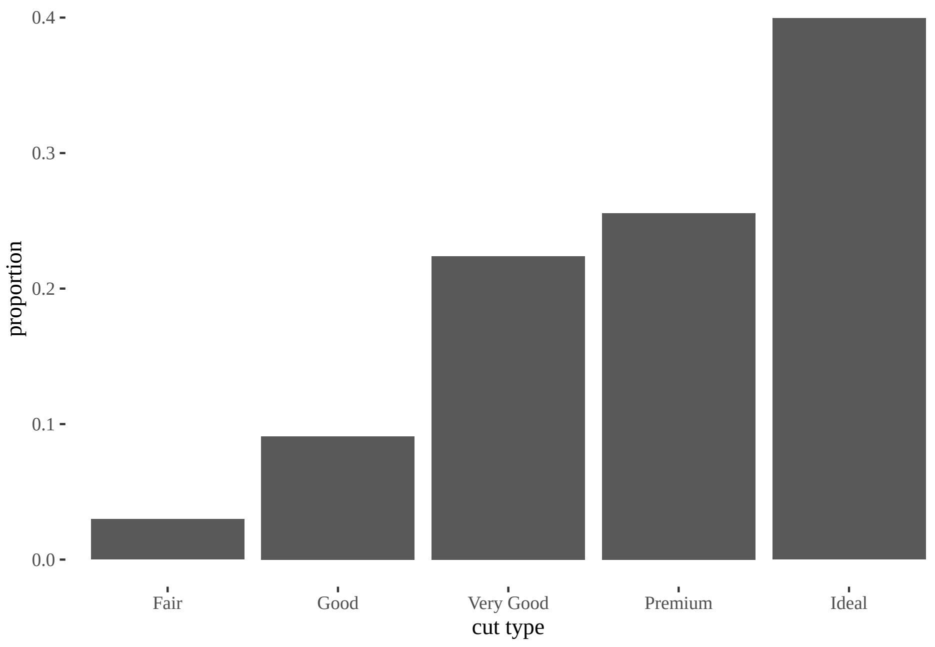
```
ggplot(diamonds) +
  geom_bar(aes(x = cut))+
  theme_tufte()
```



Alternatively, we can focus on proportions instead. Note how we can manually edit axis labels.

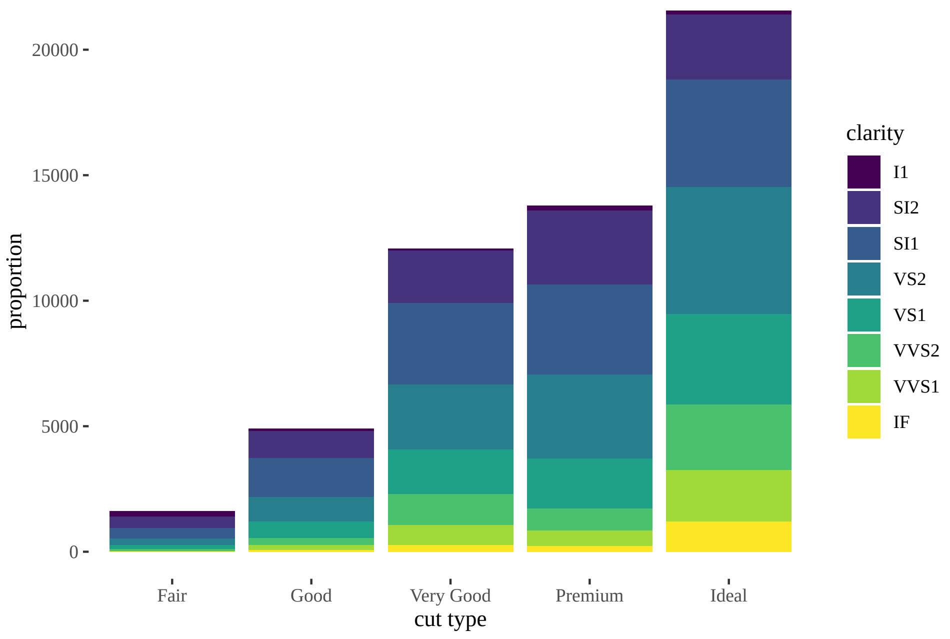
```
ggplot(diamonds) +
      geom_bar(aes(x = cut,y=..prop..,group=1))+
  theme_tufte()+
  xlab("cut type")+
  ylab("proportion")
```

```
## Warning: The dot-dot notation (`..prop..`) was deprecated in ggplot2 3.4.0.
## i Please use `after_stat(prop)` instead.
```



We can also fill with color by clarity:

```
ggplot(diamonds) +
      geom_bar(aes(x = cut,fill = clarity))+
  theme_tufte()+
  xlab("cut type")+
  ylab("proportion")
```



Now, let's look at data from General Social Survey (google if you don't know what this is), this is in the library forcats. Feel free to check the help file for this dataset.

```
head(gss_cat)  %>% kable("latex", booktabs = T, linesep = "") %>%
          kable_styling(latex_options = c("striped","scale_down", "HOLD_position"))  %>%
          kable_styling(font_size = 14)
```

year	marital	age	race	rincome	partyid	relig	denom	tvhours
2000	Never married	26	White	$8000 to 9999	Ind,near rep	Protestant	Southern baptist	12
2000	Divorced	48	White	$8000 to 9999	Not str republican	Protestant	Baptist-dk which	NA
2000	Widowed	67	White	Not applicable	Independent	Protestant	No denomination	2
2000	Never married	39	White	Not applicable	Ind,near rep	Orthodox-christian	Not applicable	4
2000	Divorced	25	White	Not applicable	Not str democrat	None	Not applicable	1
2000	Married	25	White	$20000 - 24999	Strong democrat	Protestant	Southern baptist	NA

One thing we might be interested in is counts by a single categorical variable. For instance, we can use count from package tidyverse:

```
gss_cat %>%  count(race) %>%
  kable("latex", booktabs = T, linesep = "") %>%
  kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

race	n
Other	1959
Black	3129
White	16395

Alternatively, we can use the native table method, but it's a bit more messy:

```
table(gss_cat$race) %>%
  kable("latex", booktabs = T, linesep = "") %>%
  kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

Var1	Freq
Other	1959
Black	3129
White	16395
Not applicable	0

Exercise 37

Use the dataset to prepare a barplot by race.

Exercise 38

Group gss_cat by religion, and summarize creating mean age, mean tvhours and count. Use pipe, group_by, and summarize, create a new object called relig.

Exercise 39

Use the object you created and geom_point to plot religion vs. tvhours.

Exercise 40

Do the same for reported income level and tvhours.

Criminology exercises

Exercise 41

Create a barplot using nypd dataset, show the number of incidents for every victim's type of race. Fill the provided code to achieve it. Observe the use of "labs()" and how we can easily add titles to our plot, for this reason you can also use "ggtitle()". What strikes you in this example?

```
nypd_by_race <- _____ %>%
  group_by(_____) %>%
  summarise(total_incidents = n())

______________________ +
  _______(stat = "identity") +
  labs(title = "Number of Shooting Incidents by Victim's Race",
       x = "Victim's Race",
       y = "Total Incidents")
```

Exercise 42

Create a barplot of total number of incidents per borough, fill the columns with victim's race and add a title. Fill the gaps in the provided code to achieve it, make the plot look nice.

```
nypd_borough_race <- ______ %>%
  group_by(______, ________) %>%
  summarize(___________)

ggplot(_________, aes(x = _____, y = ______, fill = _____)) +
  geom_bar(_____) +
  ________________
```

Exercise 43

Now we will do something similar. Firstly add the provided lines to your previous code that was used to create nypd_borough_race. Print first 6 records of this new table. Then, modify previous ggplot code, instead of "total_incidents" use "percent". What does it change? Also, try adding "position= "dodge"" inside "geom_bar()".

```
nypd_borough_race_perc <- ______ %>%
  group_by(______, ________) %>%
  summarize(___________) %>%
   group_by(BORO) %>%
  mutate(percent = (total_incidents/sum(total_incidents)) * 100)
```

Exercise 44

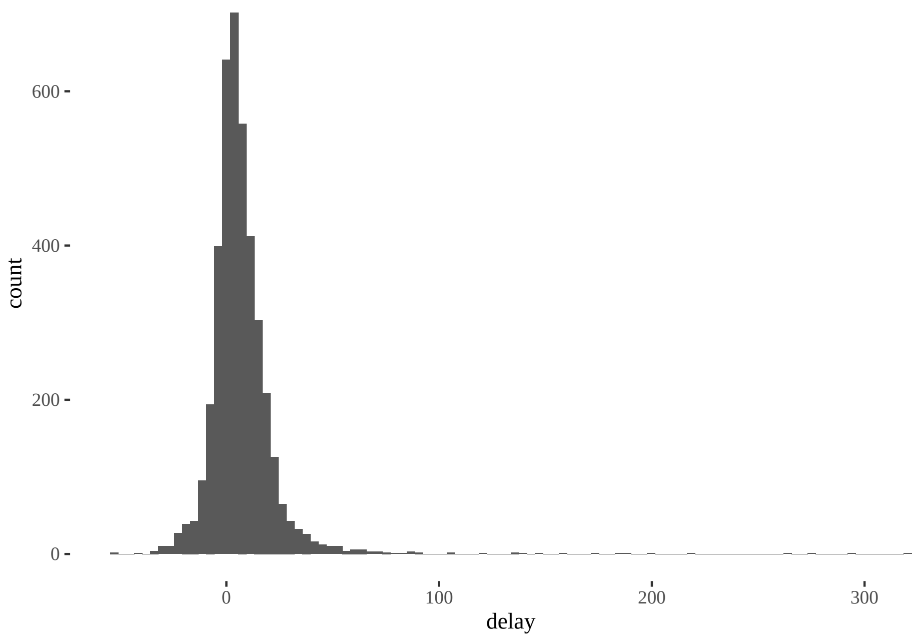
Create a barplot, months against total number of incidents, with columns colored by borough. Add a title and make it look good. What months are the most dangerous according to this plot and why?

```
monthly_boro_incidents <- _______
  group_by(_________, ___________) %>%
  ______________________

ggplot(monthly_boro_incidents, ____________) +
  __________+
  labs(____________)
```

1.6 Histograms

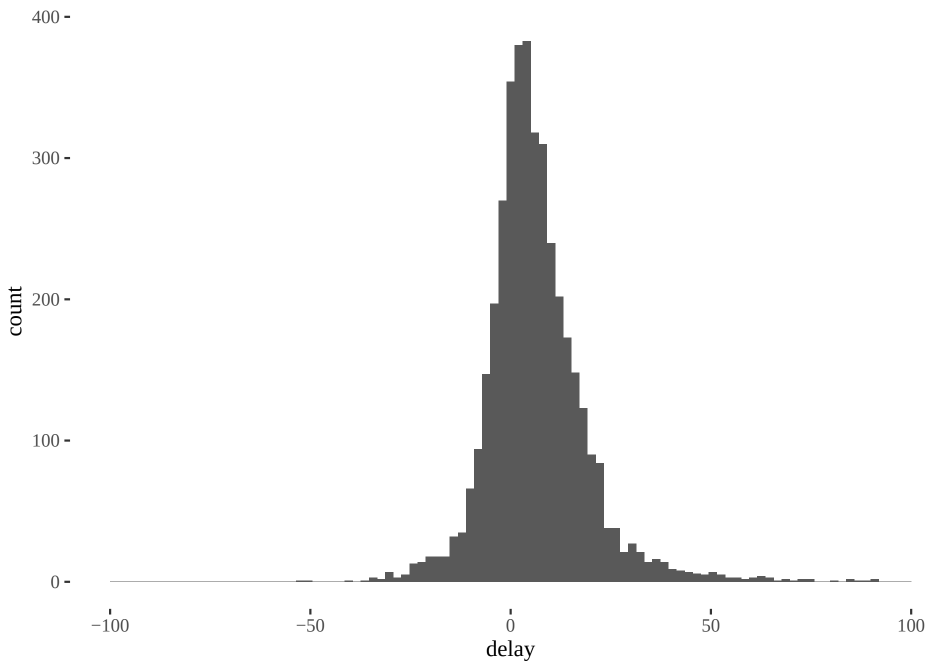
For a continuous variable we can first bin values in a certain number of intervals, and then plot a histogram. Like this (we're using mean delays by tail number, 10 bins):

```
ggplot(delays, aes(x = delay)) +
      geom_histogram(bins = 100)+
  theme_tufte()
```



We can focus on a certain range along the x axis. Like this:

```
ggplot(delays, aes(x = delay)) +
      geom_histogram(bins = 100)+
  theme_tufte()+
  xlim(c(-100,100))
```



Criminology exercises

Exercise 45

I prepared for you the "hour" column in nypd dataset (24h format), view it and understand what does it represent. Create a histogram of number of occurrences against hours (24 hours). Change the color of bars. What hour of the day is the safest in New York? Hint: bins number should be equal to 24, in "aes()" you will need only "x" variable.

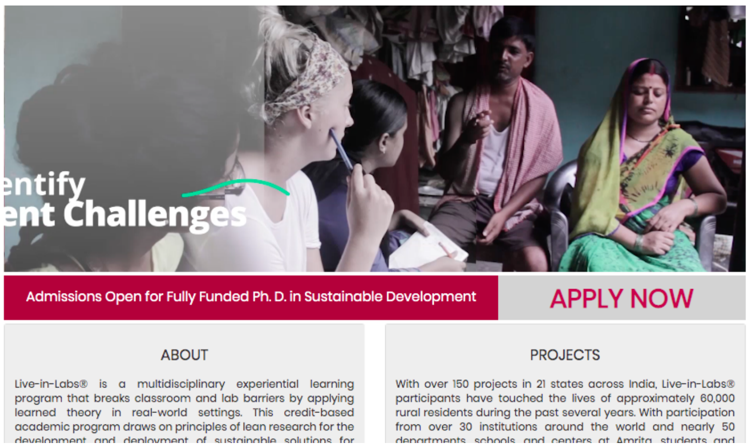
```
nypd$hour <- as.numeric(substring(nypd$OCCUR_TIME, 1, 2)

ggplot(nypd, aes(x=_____)) +
  ____________________________________
```

1.7 Miniproject: water distribution in New Thariyal

This is a dataset based on interviews with the inhabitants of a small village in India, New Thariyal, who have been experiences problems with water distribution.

Mazari Sharif
Kabul
nistan
Peshawar
Islamabad
JAMMU AND KASHMIR
Leh
Kandahar
Amritsar
HIMACHAL PRADESH
Faisalabad
Lahore
Jalandhar
TIBET
Quetta
Multan
CHANDIGARH
PUNJAB
Pakistan
Bahawalpur
UTTARAKHAND
HARYANA
Bareilly
Bikaner
New Delhi
Nepal
Khairpur
UTTAR PRADESH
Lakhimpur
Kathmandu
Jaipur
Gorakhpur
SIKKIM
Nawabshah
RAJASTHAN
Gwalior
Siliguri
Jodhpur
Ajmer
Kanpur
Prayagraj
Jaunpur
Patna
Kishanganj
Kota
BIHAR
Karachi
Badin
Udaipur
Varanasi
Gaya

The project has been run by Live In Labs:



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ABOUT

Live-in-Labs® is a multidisciplinary experiential learning program that breaks classroom and lab barriers by applying learned theory in real-world settings. This credit-based academic program draws on principles of lean research for the development and deployment of sustainable solutions for

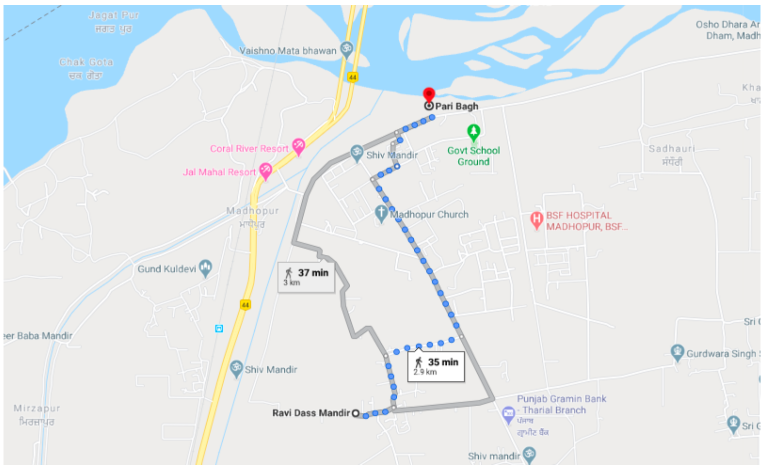
PROJECTS

With over 150 projects in 21 states across India, Live-in-Labs® participants have touched the lives of approximately 60,000 rural residents during the past several years. With participation from over 30 institutions around the world and nearly 50 departments, schools and centers at Amrita, students and

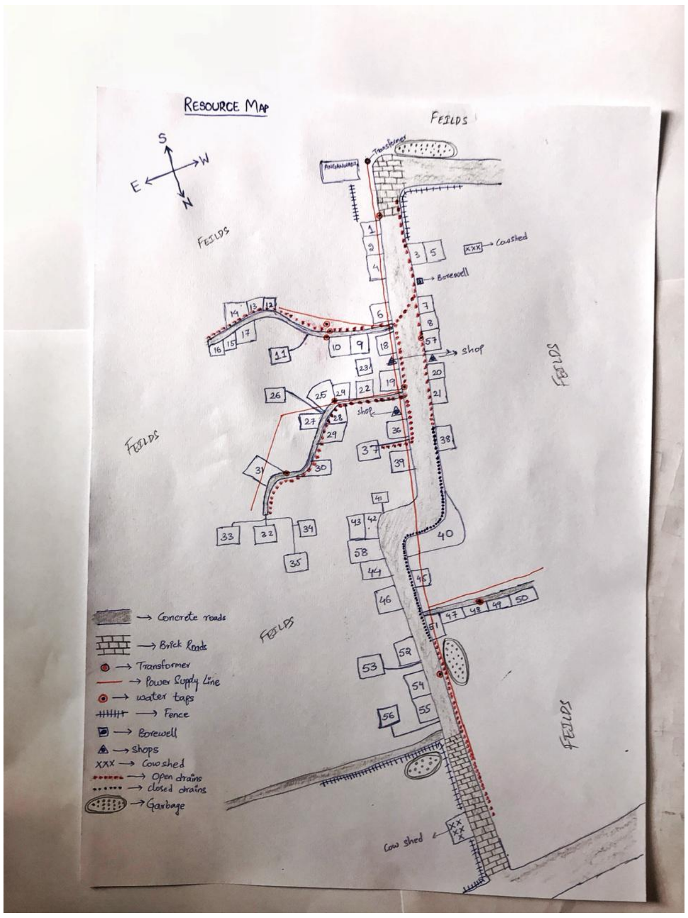
within the Data Science for Social Good project.

Life there looks like this:

Quite importantly, if you want to bring water from the river, it's a bit of a walk:



And the plan of the village is:



The important thing to notice is that the borewell is in the south. Houses in the north have difficulty getting water if the pressure is low, and some houses illegaly use their own pumps for assistance.

First, import and inspect the column names from dataset called WaterSurveyData.csv in the teachingData folder, using read.csv() (with header = TRUE) and names().

```
WaterSurvey <- read.csv("teachingData/CsvFiles/WaterSurveyDataset.csv",
                        header = TRUE)

names(WaterSurvey)
```

```
## [1] "House.No."
## [2] "Sector.No."
## [3] "Choice.of.Storage"
## [4] "Capacity.ltrs.number..For..Cans...Buckets...we.have.encoded.count.of.both"
## [5] "Motor.."
## [6] "No..of.people"
## [7] "Borewell.."
## [8] "Thariyal.."
## [9] "Major.Source"
```

One issue is that names are a bit ugly and long. Let's change them. Use names(…) <- c("name",..) Our wishlist is:

- House.No. -> House
- Sector.No. -> Sector
- Choice.of.Storage -> Storage
- Capacity… -> Capacity
- Motor.. -> Pump
- No..of..people -> Inhabitants
- Borewell.. -> Borewell
- Thariyal.. -> Thariyal
- Major.Source -> MajorSource

Make the changes and inspect the head of the dataset now.

```
names(WaterSurvey) <- c("House", "Sector", "Storage", "Capacity",
                        "Pump", "Inhabitants", "Borewell", "Thariyal",
                        "MajorSource")
head(WaterSurvey)%>%
  kable("latex", booktabs = T, linesep = "") %>%
  kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

House	Sector	Storage	Capacity	Pump	Inhabitants	Borewell	Thariyal	MajorSource
1	3	Tank	500	1	13	1	1	B
2	3	Buckets	12	0	12	1	1	B
3	3	Controls the borewell	-	0	17	1	1	B
4	3	Buckets	15	0	7	1	0	B
6	3	Buckets	15	0	5	1	0	B
7	3	Buckets	10	0	2	1	0	B

Things to note:

- There are "controls the borewell" and NAs in capacity
- Capacity is a factor, In fact, it has a non-uniform because it mixes litres with numbers of buckets and tanks. The measure is litres for tank or "control", but counts of units for other sources/containers).
- Cans (metal barrels) have 50l, buckets 20l.

We need to clean the structure of the dataset. Check it with str. Notice that Pump, Borewell, and Thariyal should be logical values, make them so using as.logical() and assignment in **R**. Sector should be a factor, make it so using as.factor(). Check the structure again.

```
#check structure
str(WaterSurvey)
```

```
## 'data.frame':    47 obs. of  9 variables:
##  $ House      : int  1 2 3 4 6 7 10 11 12 13 ...
##  $ Sector     : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ Storage    : chr  "Tank " "Buckets" "Controls the borewell" "Buckets" ...
##  $ Capacity   : chr  "500" "12" "-" "15" ...
##  $ Pump       : int  1 0 0 0 0 0 1 0 0 0 ...
##  $ Inhabitants: int  13 12 17 7 5 2 4 7 6 10 ...
##  $ Borewell   : int  1 1 1 1 1 1 0 1 0 1 ...
##  $ Thariyal   : int  1 1 1 0 0 0 1 1 1 0 ...
##  $ MajorSource: chr  "B" "B" "B" "B" ...
```

```
#Notice the integer vectors which should be logical
WaterSurvey$Pump <- as.logical(WaterSurvey$Pump)
WaterSurvey$Borewell <- as.logical(WaterSurvey$Borewell)
WaterSurvey$Thariyal <- as.logical(WaterSurvey$Thariyal)
#Notice sectors are a factor
WaterSurvey$Sector <- as.factor(WaterSurvey$Sector)
WaterSurvey$Storage <- as.factor(WaterSurvey$Storage)
str(WaterSurvey)
```

```
## 'data.frame':    47 obs. of  9 variables:
##  $ House      : int  1 2 3 4 6 7 10 11 12 13 ...
##  $ Sector     : Factor w/ 2 levels "2","3": 2 2 2 2 2 2 2 2 2 2 ...
##  $ Storage    : Factor w/ 6 levels "Buckets","Cans",..: 6 1 4 1 1 1 6 3 2 1 ...
##  $ Capacity   : chr  "500" "12" "-" "15" ...
##  $ Pump       : logi  TRUE FALSE FALSE FALSE FALSE FALSE ...
##  $ Inhabitants: int  13 12 17 7 5 2 4 7 6 10 ...
##  $ Borewell   : logi  TRUE TRUE TRUE TRUE TRUE TRUE ...
##  $ Thariyal   : logi  TRUE TRUE TRUE FALSE FALSE FALSE ...
##  $ MajorSource: chr  "B" "B" "B" "B" ...
```

Now, we need to have a uniform measure of storage. We have transformed this variable into a factor, let's check its levels with levels. Notice that "Tank" contains a redundant space.

```
levels(WaterSurvey$Storage)
```

```
## [1] "Buckets"               "Cans"                          "Cans + Buckets"
## [4] "Controls the borewell" "Sump"                          "Tank "
```

Now I'll walk you through cleaning up the storage variable.

```
#this will be our final vetor,
                    #for now it's empty
Amount <- numeric(nrow(WaterSurvey))

#logical vector locating Tanks
tanks <- WaterSurvey$Storage == "Tank "

#for tanks we extract their capacities
WaterSurvey$Capacity <- as.factor(WaterSurvey$Capacity)

TankCapacities <- as.numeric(levels(WaterSurvey$Capacity[tanks])
                             )[WaterSurvey$Capacity[tanks]]

 #and we write them down to our target vector
Amount[tanks] <- TankCapacities

#locate cans
cans <- WaterSurvey$Storage == "Cans"

#for cans/barrels we multiply their counts by 50 liters

CansCapacities <- as.numeric(levels(
  WaterSurvey$Capacity[cans]))[WaterSurvey$Capacity[cans]]*50

#save to our target vector
Amount[cans] <- CansCapacities

#locate buckets
buckets <- WaterSurvey$Storage == "Buckets"

#for bucket we multiply counts by 20 liters
BucketsCapacities <- as.numeric(levels(
  WaterSurvey$Capacity[buckets]))[WaterSurvey$Capacity[buckets]]*20

#add to our target vector
Amount[buckets] <- BucketsCapacities

#For sumps (large underground tanks under the houses)
# we use their capacity in liters

#locate sumps
sumps <- WaterSurvey$Storage == "Sump"

#extract their capacities
SumpCapacities <- as.numeric(levels(
  WaterSurvey$Capacity[sumps]))[WaterSurvey$Capacity[sumps]]

#write in our targed vector
Amount[sumps] <- SumpCapacities

#check what we missed
WaterSurvey[Amount==0,]  %>% kable("latex", booktabs = T, linesep = "") %>%
  kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

	House	Sector	Storage	Capacity	Pump	Inhabitants	Borewell	Thariyal	MajorSource
3	3	3	Controls the borewell	-	FALSE	17	TRUE	TRUE	B
8	11	3	Cans + Buckets	1,10	FALSE	7	TRUE	TRUE	T
20	23	3	Cans + Buckets	2,10	FALSE	5	TRUE	FALSE	B
23	26	3	Cans + Buckets	3,3	FALSE	3	TRUE	TRUE	B
28	32	3	Cans + Buckets	1,2	FALSE	4	TRUE	FALSE	B
37	43	2	Cans + Buckets	7,1	TRUE	11	FALSE	TRUE	T

```
#finish manually: Controlls the borwell is, say 10000
Amount[WaterSurvey$Storage == "Controls the borewell"] <- 10000
Amount[8] <- 50 + 10 *20
Amount[20] <- 2+50 + 10*20
Amount[23] <- 3*50 + 3*20
Amount[28] <- 50 + 2*20
Amount[37] <- 7*50 + 20

#inspect the vector:
#head(WaterSurvey$Amount)
Amount
```

```
##  [1]   500   240 10000   300   300   200   500   250   150   100   500   360
## [13]   200    80   140   100    60   200    80   252   120   140   210   350
## [25]    80    60 12743    90  1000   120    80    80  4247   100   100   120
## [37]   370   500   100    80    80   350   300   200   500   350   500
```

```
# And finally let's add the Amount vector as a column to the data frame
head(cbind(WaterSurvey, Amount)) %>% kable("latex", booktabs = T, linesep = "") %>%
  kable_styling(latex_options = c("striped", "HOLD_position"),font_size = 9)
```

House	Sector	Storage	Capacity	Pump	Inhabitants	Borewell	Thariyal	MajorSource	Amount
1	3	Tank	500	TRUE	13	TRUE	TRUE	B	500
2	3	Buckets	12	FALSE	12	TRUE	TRUE	B	240
3	3	Controls the borewell	-	FALSE	17	TRUE	TRUE	B	10000
4	3	Buckets	15	FALSE	7	TRUE	FALSE	B	300
6	3	Buckets	15	FALSE	5	TRUE	FALSE	B	300
7	3	Buckets	10	FALSE	2	TRUE	FALSE	B	200

The result of this process is a cleaned up data frame with the column that fairly represents the amount of water for a household. Data in such form can be used for a further analysis.

1.8 Freefall exercise

Before starting with the exercises please ensure that those libraries are loaded. If one of them is not installed run the following command to install it install.packages("packageName").

```
library(ggplot2)
library(ggthemes)
library(ggcorrplot)
library(gridExtra)
library(reshape2)
```

(A) Look at the descriptioncitation.html and the 038488-001-Codebook.pdf (the latter is in the DS0001 folder) to see what a data documentation should look like.

(B) Load the dataset, and use tools you know to inspect its structure.

```
library(haven)

data <- as.data.frame(read_xpt("DS0001/08488-0001-Data.xpt"))
```

(C) Use the following code to inspect some correlations in the set. What's the lesson?

```
cors <- cor(______, method = 'spearman')

ggcorrplot(______, method="square")
```

Too many variables to run without first thinking about what we are interested in and what the potential predictors we're interest in are.

(D) Go back to the codebook, see what variables 5:38 mean, do corrplot for these.

- Why do you think V12 is negatively correlated with other variables?
- Why do you think are V26 and V27 slightly negatively correlated with most previous variables, but not with the latter ones?

(E) Let's focus on V38; do corrplot of this variable and variables V39-84.

- Are there any variables that might be very good predictors?
- What are the four best predictor candidates for V38 from this set? (do this programatically, that is extract the line corresponding to V38 and use sort(____, decreasing = TRUE) to find top five entries other than V38 itself).
- How good predictors are they, separately taken?
- Hint: ?sort

(F) Prepare four plots using ggplot, assigning them to variables, make sure the axes have informative names, of V38 against those variables and put them together using grid.arrange(plot1, plot2, plot3, plot4)

- Use: V54, V69, V70, V75
- Note points will overlap, you need to deal with this!

(G) Now, would you say that V69, V70 and V75 provide independent pieces of information?

- Do corrplot to check first, then two plots of V70 and of V75 against V69.
- What does it tell you about using them in the same model?

(H) Extract columns 13-27, then use t() to rotate the frame to have persons as columns, then use melt() to convert to long format, then plot lines with a geom_line(), with years on x, grouping by person ID (which is the other variable); use scale_x_discrete(labels = 10:24), add appropriate axes labels.

- Do you think the triangular shapes give us an insight?
- Do you see any clear evidence for the grouping effect (intensive short term vs long-term)?

(I) Now look at the codebook. Try to find at least three interesting questions that you could try to at least get some insight into by looking into data, not necessarily about convictions, and prepare three visualizations that address them; try to make the visualizations look good!