BasicR Course

15 – 19 February 2021

DAY 2

Molecular Biotechnology
- Master

UNIVERSITÄT
HEIDELBERG
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COURSE INSTRUCTOR

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DAY 2 AND 3

Data Import

Wrangling

- Tidy + Manipulating
- Summarizing
- Cleaning

Exploration

- Visualization
- Descriptive Statistics

Day 2

Statistical Inference

- Foundation of inference
- Basic statistical tests
- Linear regression

Day 3

DAY 2 AND 3

Data Import

Wrangling

- Tidy + Manipulating
- Summarizing
- Cleaning

Exploration

- Visualization
- Descriptive Statistics

Statistical Inference

- Foundation of inference
- Basic statistical tests
- Linear regression

FOCUS IS ON APPLICATION IN R

NOT A STATISTICS COURSE

Course does not cover:

- Principles of study design
  - Types of experiments/ studies
  - Reducing bias in study design
- Statistical theory
  - Probability and random variables
  - Statistical distributions
  - Central Limit Theorem
  - Hypothesis testing
  - Type1 and Type 2 error
  - Test statistic and standard error
  - Confidence intervals and p-values

DAY 2

`tidyverse`

- Data Import
- Wrangling
  - Tidying, Cleaning, Summarizing
- Exploration
  - Visualization and Descriptive Statistics

`tidyverse`

- All packages within `tidyverse` use the same language/ grammar
- Designed for streamlined data exploration and analysis
- Rigid and expects data to be in specific format

Can also use Base R

- More flexible than `tidyverse`

IMPORTING DATA

METHODS OF DATA IMPORT

- Import electronic spreadsheets
- Datasets stored as R objects (via packages)
- Download files from the internet using R
- …

IMPORTING SPREADSHEETS

Txt/ csv file

murders.csv

```
state,abb,region,population,total
Alabama,AL,South,4779736,135
Alaska,AK,West,710231,19
Arizona,AZ,West,6392017,232
Arkansas,AR,South,2915918,93
California,CA,West,37253956,1257
Colorado,CO,West,5029196,65
Connecticut,CT,Northeast,3574097,97
Delaware,DE,South,897934,38
District of Columbia,DC,South,601723,99
Florida,FL,South,19687653,669
Georgia,GA,South,9920000,376
Hawaii,HI,West,1360301,7
Idaho,ID,West,1567582,12
Illinois,IL,North Central,12830632,364
Indiana,IN,North Central,6483802,142
Iowa,IA,North Central,3046355,21
Kansas,KS,North Central,2853118,63
Kentucky,KY,South,4339367,116
Louisiana,LA,South,4533372,351
Maine,ME,Northeast,1328361,11
Maryland,MD,South,5773552,293
Massachusetts,MA,Northeast,6547629,118
Michigan,MI,North Central,9883640,413
Minnesota,MN,North Central,5303925,53
Mississippi,MS,South,2967297,120
Missouri,MO,North Central,5988927,321
Montana,MT,West,989415,12
Nebraska,NE,North Central,1826341,32
Nevada,NV,West,2700551,84
```

Excel file

	A	B	C	D	E	F	G	H
1	state	abb	region	population	total			
2	Alabama	AL	South	4779736	135			
3	Alaska	AK	West	710231	19			
4	Arizona	AZ	West	6392017	232			
5	Arkansas	AR	South	2915918	93			
6	California	CA	West	37253956	1257			
7	Colorado	CO	West	5029196	65			
8	Connecticut	CT	Northeast	3574097	97			
9	Delaware	DE	South	897934	38			
10	District of Co	DC	South	601723	99			
11	Florida	FL	South	19687653	669			
12	Georgia	GA	South	9920000	376			
13	Hawaii	HI	West	1360301	7			
14	Idaho	ID	West	1567582	12			
15	Illinois	IL	North Centra	12830632	364			
16	Indiana	IN	North Centra	6483802	142			
17	Iowa	IA	North Centra	3046355	21			
18	Kansas	KS	North Centra	2853118	63			
19	Kentucky	KY	South	4339367	116			
20	Louisiana	LA	South	4533372	351			
21	Maine	ME	Northeast	1328361	11			
22	Maryland	MD	South	5773552	293			
23	Massachuset	MA	Northeast	6547629	118			
24	Michigan	MI	North Centra	9883640	413			
25	Minnesota	MN	North Centra	5303925	53			
26	Mississippi	MS	South	2967297	120			
27	Missouri	MO	North Centra	5988927	321			
28	Montana	MT	West	989415	12			
29	Nebraska	NE	North Centra	1826341	32			

HEADER - The first row contains column names rather than data.

IMPORTING SPREADSHEETS

readr library

The following functions are available to read-in spreadsheets:

Function	Format	Typical suffix
read_table	white space separated values	txt
read_csv	comma separated values	csv
read_csv2	semicolon separated values	csv
read_tsv	tab delimited separated values	tsv
read_delim	general text file format, must define delimiter	txt

https://github.com/rafalab/dsbook↩

IMPORTING SPREADSHEETS

readxl library

The package provides functions to read-in Microsoft Excel formats:

Function	Format	Typical suffix
read_excel	auto detect the format	xls, xlsx
read_xls	original format	xls
read_xlsx	new format	xlsx

https://github.com/rafalab/dsbook↩

WRANGLING –

TIDY +

MANIPULATING

TIDY FORMAT

Tidy format

Hadley Wickham defines "tidy data" for data storage by analysts

DOs

1. Each variable forms a column, and that column contains one "type" of data
2. Each observation forms a row
3. Each type of observational unit forms a table

DON'Ts

- Column headers contain values, rather than names
- Multiple variables are stored in a single column
- Variables are stored in both rows and columns
- Multiple observational types are stored in a single table
- A single observational unit is stored in multiple tables.

http://vita.had.co.nz/papers/tidy-data.pdf

TIDY FORMAT

country	year	m014	m1524	m2534	m3544	m4554	m5564	m65	mu	f014
AD	2000	0	0	1	0	0	0	0	—	—
AE	2000	2	4	4	6	5	12	10	—	3
AF	2000	52	228	183	149	129	94	80	—	93
AG	2000	0	0	0	0	0	0	1	—	1
AL	2000	2	19	21	14	24	19	16	—	3
AM	2000	2	152	130	131	63	26	21	—	1
AN	2000	0	0	1	2	0	0	0	—	0
AO	2000	186	999	1003	912	482	312	194	—	247
AR	2000	97	278	594	402	419	368	330	—	121
AS	2000	—	—	—	—	1	1	—	—	—

Table 9: Original TB dataset. Corresponding to each 'm' column for males, there is also an 'f' column for females, `f1524`, `f2534` and so on. These are not shown to conserve space. Note the mixture of 0s and missing values (—). This is due to the data collection process and the distinction is important for this dataset.

http://vita.had.co.nz/papers/tidy-data.pdf

TIDY FORMAT

country	year	column	cases
AD	2000	m014	0
AD	2000	m1524	0
AD	2000	m2534	1
AD	2000	m3544	0
AD	2000	m4554	0
AD	2000	m5564	0
AD	2000	m65	0
AE	2000	m014	2
AE	2000	m1524	4
AE	2000	m2534	4
AE	2000	m3544	6
AE	2000	m4554	5
AE	2000	m5564	12
AE	2000	m65	10
AE	2000	f014	3

(a) Molten data

country	year	sex	age	cases
AD	2000	m	0-14	0
AD	2000	m	15-24	0
AD	2000	m	25-34	1
AD	2000	m	35-44	0
AD	2000	m	45-54	0
AD	2000	m	55-64	0
AD	2000	m	65+	0
AE	2000	m	0-14	2
AE	2000	m	15-24	4
AE	2000	m	25-34	4
AE	2000	m	35-44	6
AE	2000	m	45-54	5
AE	2000	m	55-64	12
AE	2000	m	65+	10
AE	2000	f	0-14	3

(b) Tidy data

Table 10: Tidying the TB dataset requires first melting, and then splitting the `column` column into two variables: `sex` and `age`.

http://vita.had.co.nz/papers/tidy-data.pdf

TIBBLE

Introduced to **`data.frame`**

```
> as.data.frame(dat)
                  state abb        region population total
1               Alabama  AL         South    4779736   135
2                Alaska  AK          West     710231    19
3               Arizona  AZ          West    6392017   232
4              Arkansas  AR         South    2915918    93
5            California  CA          West   37253956  1257
6              Colorado  CO          West    5029196    65
7           Connecticut  CT     Northeast    3574097    97
8              Delaware  DE         South     897934    38
9  District of Columbia  DC         South     601723    99
10              Florida  FL         South   19687653   669
11              Georgia  GA         South    9920000   376
12               Hawaii  HI          West    1360301     7
13                Idaho  ID          West    1567582    12
14             Illinois  IL North Central   12830632   364
15              Indiana  IN North Central    6483802   142
16                 Iowa  IA North Central    3046355    21
17               Kansas  KS North Central    2853118    63
18             Kentucky  KY         South    4339367   116
19            Louisiana  LA         South    4533372   351
20                Maine  ME     Northeast    1328361    11
21             Maryland  MD         South    5773552   293
22        Massachusetts  MA     Northeast    6547629   118
23             Michigan  MI North Central    9883640   413
24            Minnesota  MN North Central    5303925    53
25          Mississippi  MS         South    2967297   120
26             Missouri  MO North Central    5988927   321
27              Montana  MT          West     989415    12
28             Nebraska  NE North Central    1826341    32
29               Nevada  NV          West    2700551    84
```

https://github.com/rafalab/dsbook↩

TIBBLE

Introduced to **`data.frame`**

```
36          Ohio OH North Central 11536504  310
37      Oklahoma OK         South  3751351  111
38        Oregon OR          West  3831074   36
39  Pennsylvania PA     Northeast 12702379  457
40  Rhode Island RI     Northeast  1052567   16
41 South Carolina SC        South  4625364  207
42  South Dakota SD North Central   814180    8
43     Tennessee TN         South  6346105  219
44         Texas TX         South 25145561  805
45          Utah UT          West  2763885   22
46       Vermont VT     Northeast   625741    2
47      Virginia VA         South  8001024  250
48    Washington WA          West  6724540   93
49 West Virginia WV         South  1852994   27
50     Wisconsin WI North Central  5686986   97
51       Wyoming WY          West   563626    5
>
```

`tibble` are like **`data.frame`**

More properties

- Displays better

```
> as_tibble(dat)
# A tibble: 51 x 5
   state                abb   region    population total
   <chr>                <chr> <chr>          <dbl> <dbl>
 1 Alabama              AL    South        4779736   135
 2 Alaska               AK    West          710231    19
 3 Arizona              AZ    West         6392017   232
 4 Arkansas             AR    South        2915918    93
 5 California           CA    West        37253956  1257
 6 Colorado             CO    West         5029196    65
 7 Connecticut          CT    Northeast    3574097    97
 8 Delaware             DE    South         897934    38
 9 District of Columbia DC    South         601723    99
10 Florida              FL    South       19687653   669
# … with 41 more rows
```

- Subsets of tibbles are tibbles
- Tibbles can have complex entries
- Tibbles can be grouped

https://github.com/rafalab/dsbook↩

WRANGLING with dplyr

dplyr is a grammar of data manipulation

- `mutate()` adds new variables that are functions of existing variables
- `select()` picks variables based on their names.
- `filter()` picks cases based on their values.
- `summarise()` reduces multiple values down to a single summary.
- `arrange()` changes the ordering of the rows.

pipe: %>%

dataset
→ select
→ filter

in R

```
dataset %>% select %>% filter
```

https://dplyr.tidyverse.org/

WRANGLING with dplyr

One table verbs

`arrange()`	Arrange rows by column values
`count()` `tally()` `add_count()` `add_tally()`	Count observations by group
`distinct()`	Subset distinct/unique rows
`filter()`	Subset rows using column values
`mutate()` `transmute()`	Create, modify, and delete columns
`pull()`	Extract a single column
`relocate()`	Change column order
`rename()` `rename_with()`	Rename columns
`select()`	Subset columns using their names and types
`summarise()` `summarize()`	Summarise each group to fewer rows
`slice()` `slice_head()` `slice_tail()` `slice_min()` `slice_max()` `slice_sample()`	Subset rows using their positions

Two table verbs

`bind_rows()` `bind_cols()`	Efficiently bind multiple data frames by row and column
`reexports`	Objects exported from other packages
`inner_join()` `left_join()` `right_join()` `full_join()`	Mutating joins
`nest_join()`	Nest join
`semi_join()` `anti_join()`	Filtering joins

Grouping

`group_by()` `ungroup()`	Group by one or more variables
`group_cols()`	Select grouping variables
`rowwise()`	Group input by rows

https://dplyr.tidyverse.org

dplyr cheatsheet - https://rstudio.com/resources/cheatsheets/

SUMMARISE – 1 NUMERICAL VARIABLE

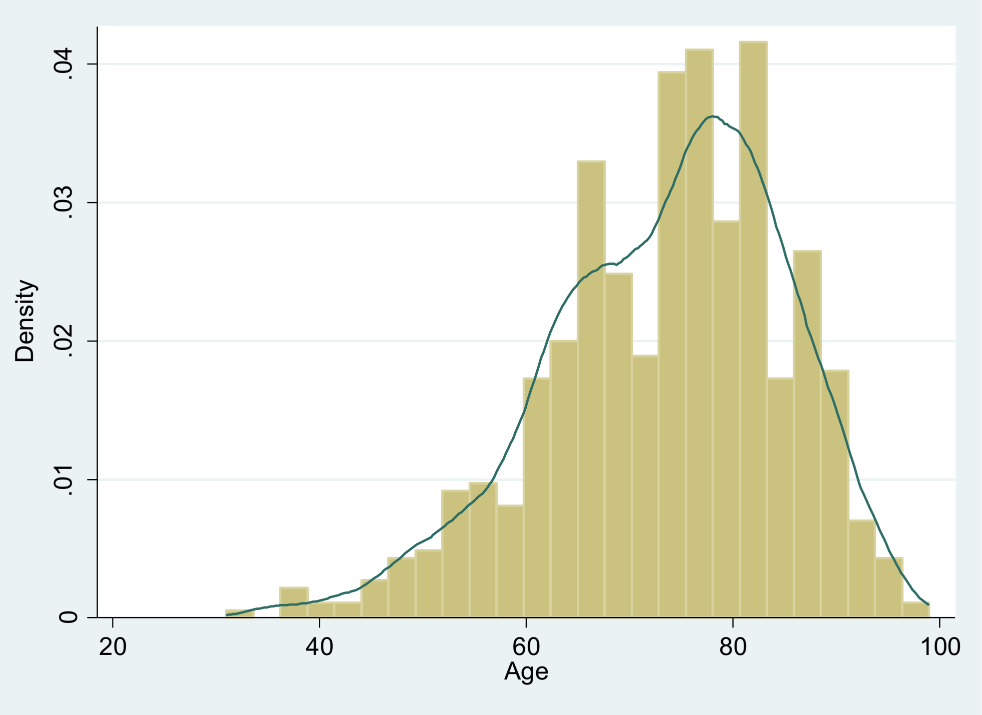
HISTOGRAM – graphical

- Histograms provide a view of the ***data density***. Higher bars represent where the data are relatively more common.
- Histograms are especially convenient for describing the ***shape*** of the data distribution.
- The chosen ***bin width*** can alter the story the histogram is telling.

Can use summarise() function for numerical summaries like
Mean, Standard deviation

https://www.openintro.org/book/os/

Age (years) in patients



SUMMARISE – 1 CATEGORICAL VARIABLE

TABLE

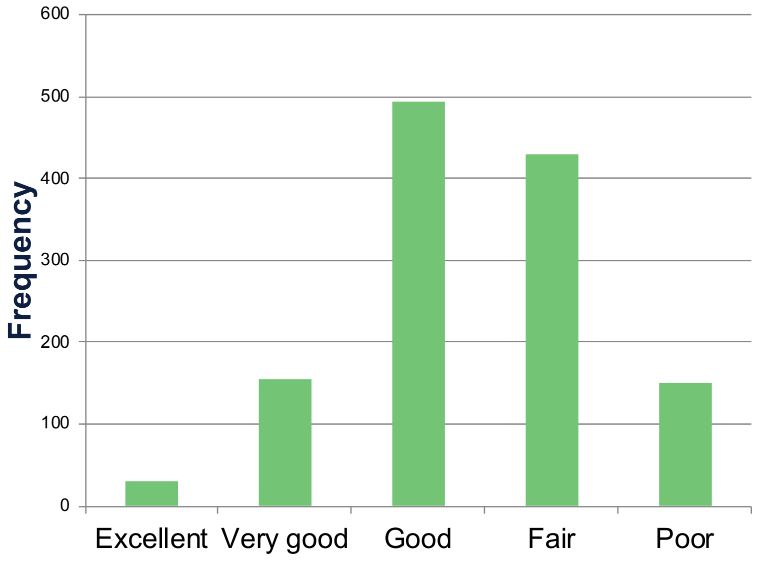
- A table summarizes data for one categorical variable with frequency and proportions (%)

In general would you say your health is:	Frequency	Percentage	Cumulative %
Excellent	31	2.46	2.46
Very good	155	12.3	14.76
Good	494	39.21	53.97
Fair	430	34.13	88.1
Poor	150	11.9	100
Total	1,260	100	

Can use table() function for numerical summaries

BAR PLOT - graphical

- A bar plot is a common way to display a single categorical variable.
- Pie chart is not recommended since we cannot compare areas as accurately as heights.



EXERCISE

Day2_1.ImportingandWrangling_Exercise.Rmd

WRANGLING –

CLEANING DATA

DATA CLEANING

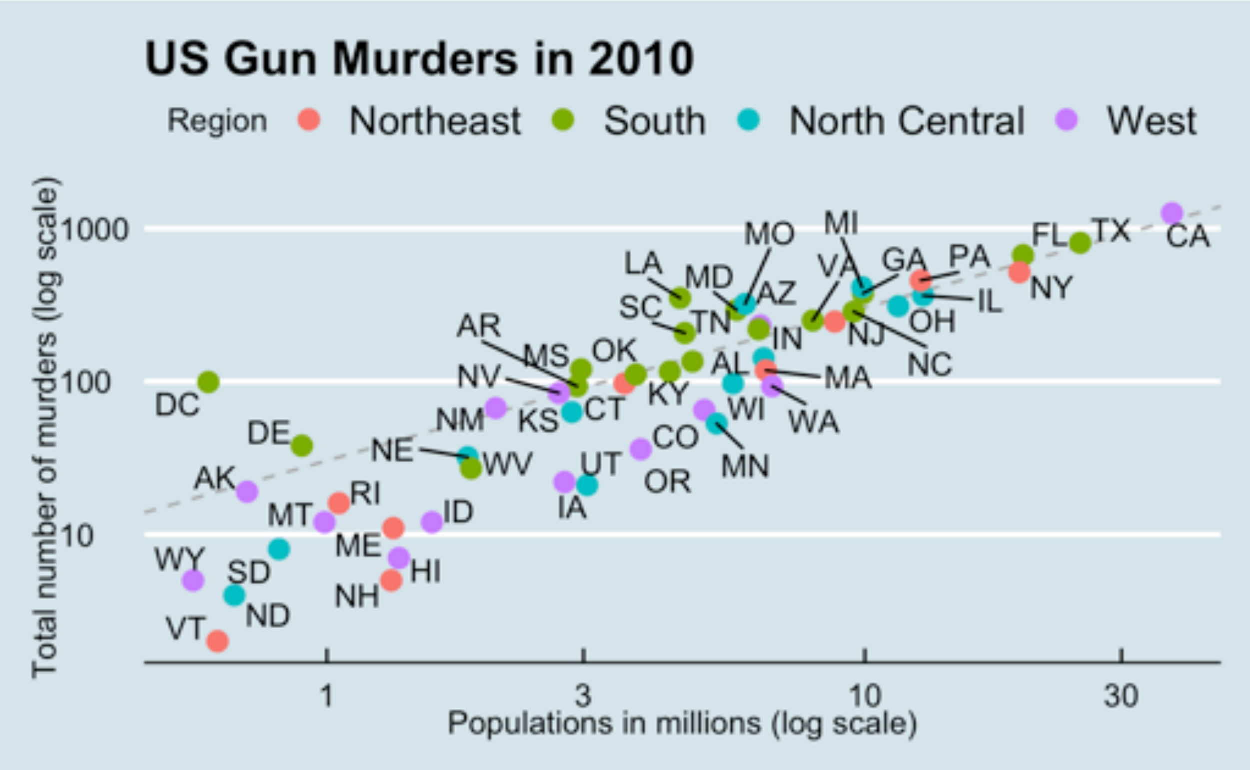
- Follows a ***tidy data*** structure
- Remove duplicate rows/values
- Error-free (e.g. free of misspellings)
- Variables should have appropriate data type
- e.g. numeric, character, factor etc
- Factors (categorical/ ordinal) should have relevant levels
- Remove incorrect/ non-relevant outliers
- Missing data should be set as NA

EXERCISE

Day2_2_Cleaning_Exercise.Rmd

EXPLORATION – VISUALISATION WITH GGPLOT2

VISUALISATION with ggplot2

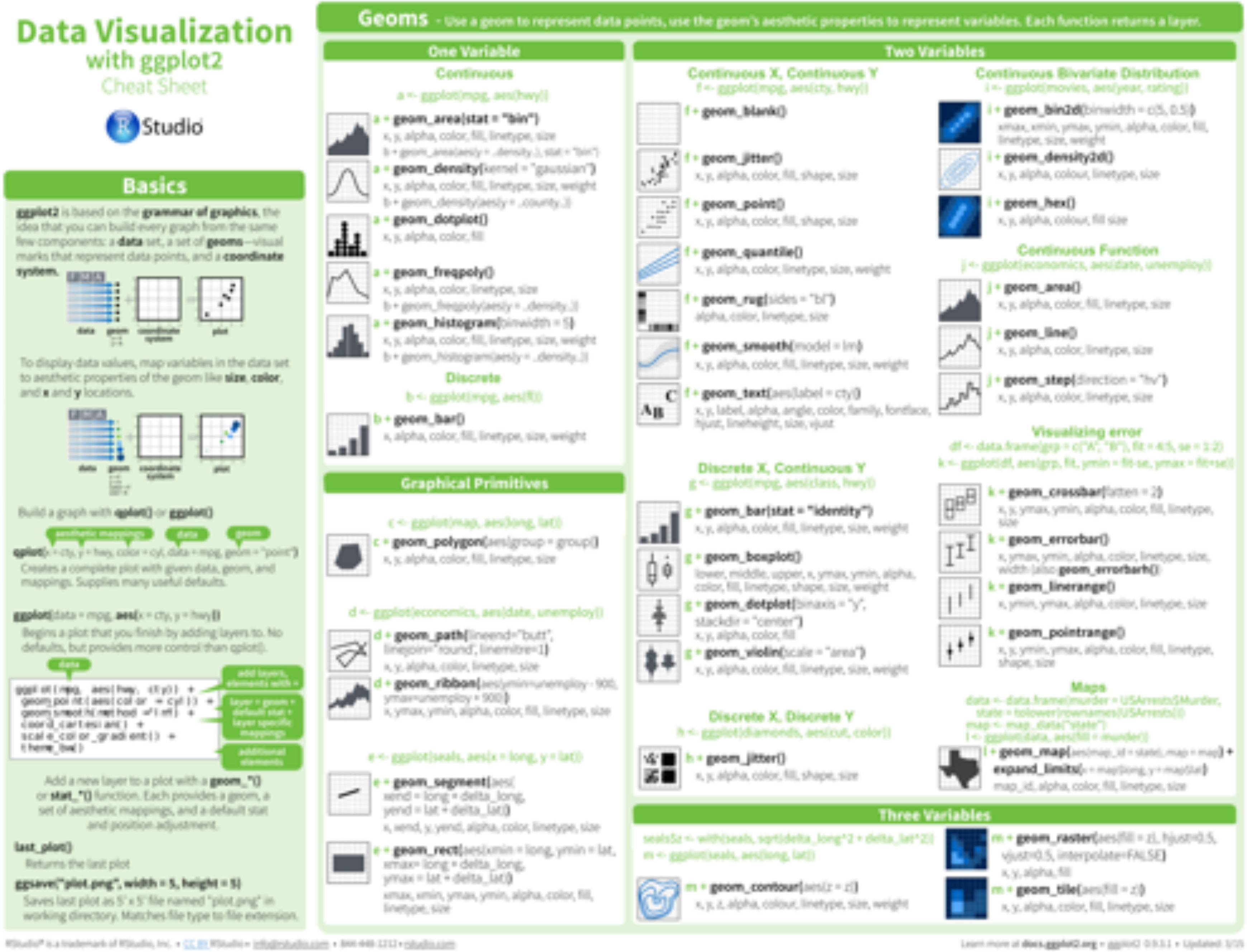


3 main building blocks to ggplot

1. **Data**
   US Gun Murders in 2010
2. **Geometric object (type of plot)**
   Scatter plot (x and y)
3. **Aesthetic mapping**
   - 2 layers - points + labels of states
   - colored by Region
4. **Other elements**
   - Scale – logged
   - Dotted Line of best fit
   - Legend
   - Style and background theme

https://github.com/rafalab/dsbook↩

EXPLORATION – DESCRIPTIVE STATISTICS



https://rstudio.com/resources/cheatsheets/

EXERCISE

Day2_3_Visualisationwithggplot2_Exercise.Rmd

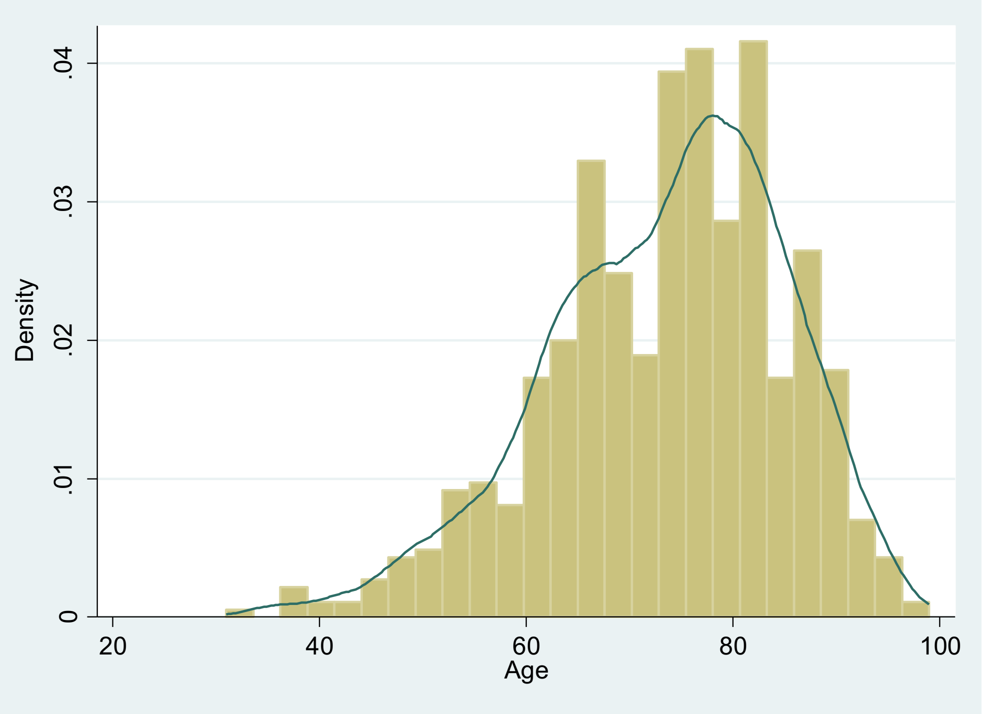
NUMERICAL - DESCRIPTIVE STATISTICS

DISTRIBUTIONS

What is a distribution

- describes the frequency (or probability) of occurrence for a given value
- describes the shape of the data

Probability distributions for Continuous variables
e.g. Normal, skewed
Frequency distributions for Discrete variables
e.g. Poisson, Binomial

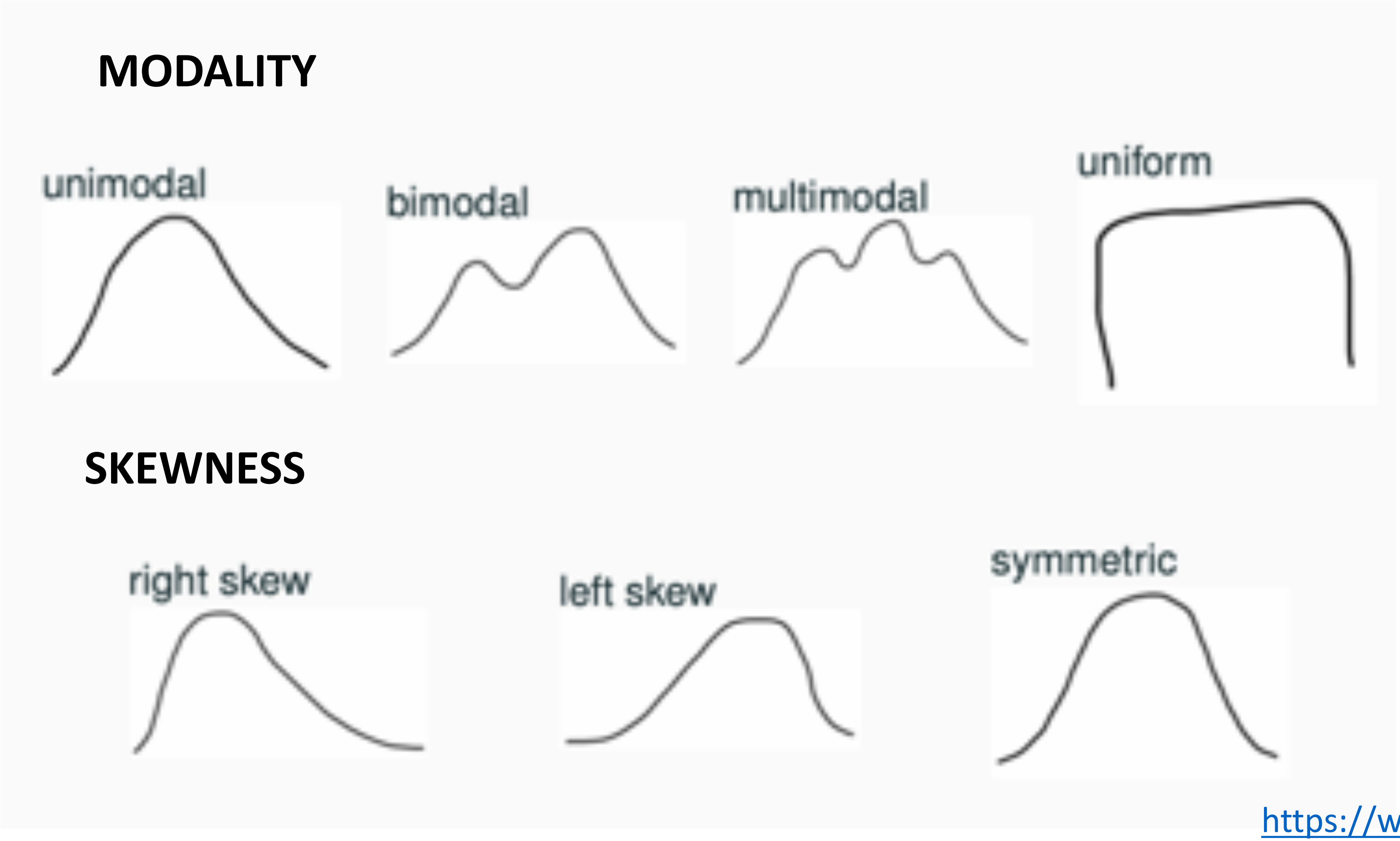


Vital in determining which statistical tests are applicable

PARAMETRIC (based on the specific distributional assumptions) – easy to model

NON-PARAMETRIC – no assumptions on distribution – not easy to model

TYPES OF DISTRIBUTIONS

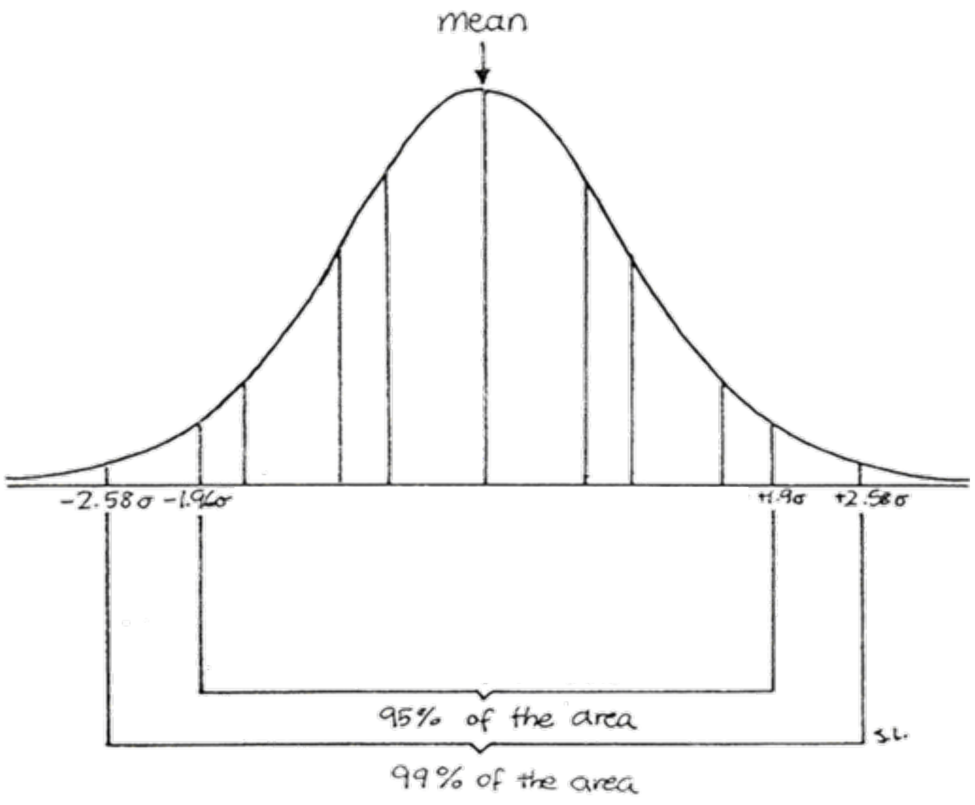


https://www.openintro.org/book/os/

NORMAL DISTRIBUTION

- Unimodal and symmetric, bell shaped curve
- 2 parameters
  i. MEAN (μ) – measure of central tendency
  ii. STANDARD DEVIATION (σ) - measure of spread

These characteristics allow the use of parametric statistical tests on normal distributions

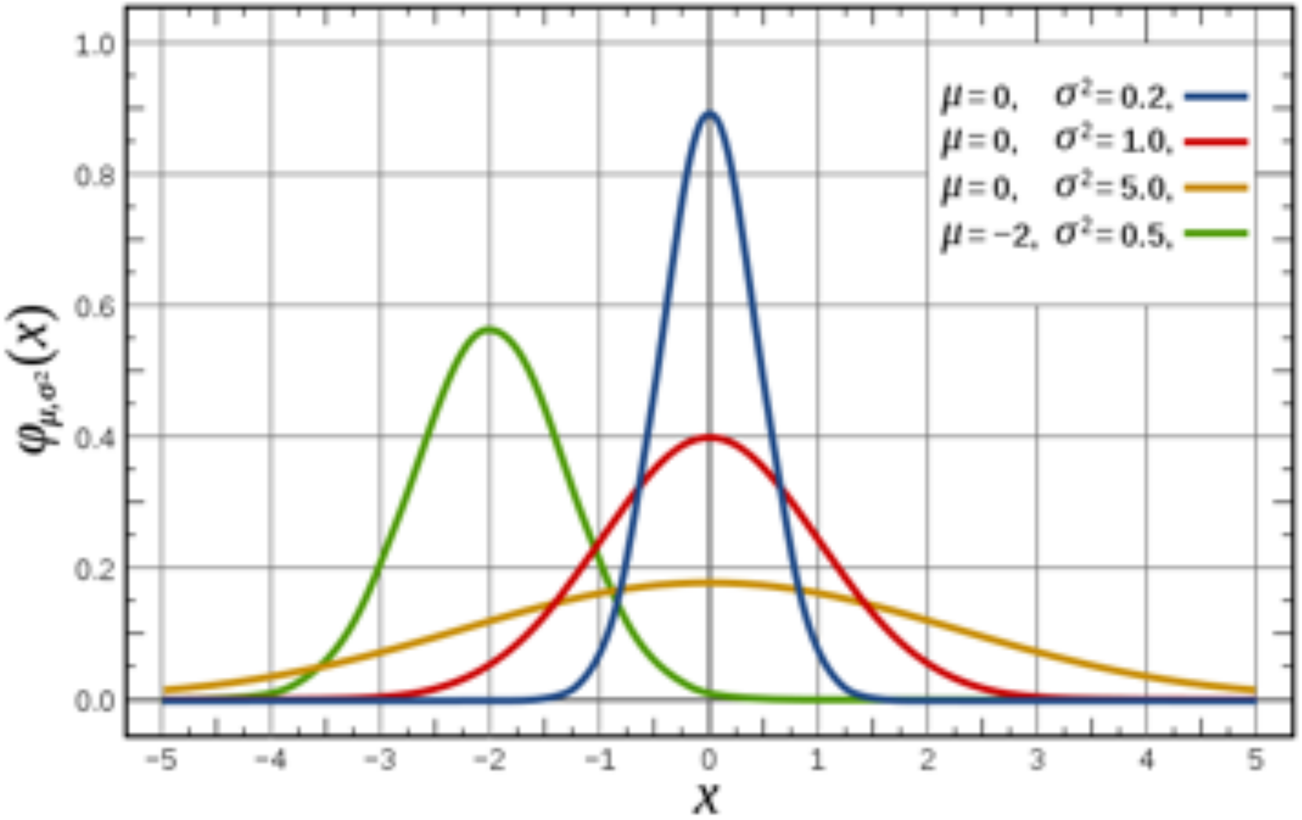


DIFFERENT NORMAL DISTRIBUTIONS

2 parameters can be different to give different shapes

i. MEAN (μ) – measure of central tendency

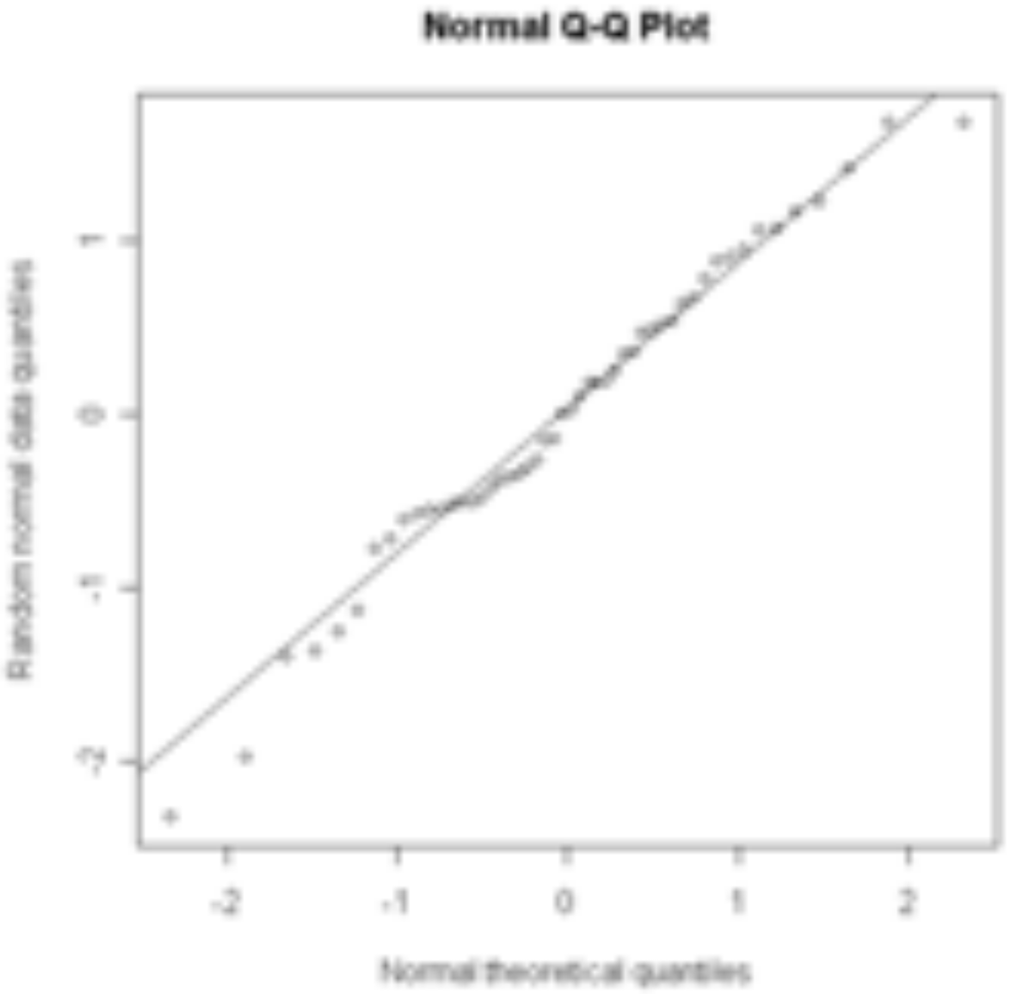
ii. STANDARD DEVIATION (σ) - measure of spread



TESTING FOR NORMALITY

QQ PLOT

Graphically determines if a data sets come from a specified distribution e.g. *Normal distribution*



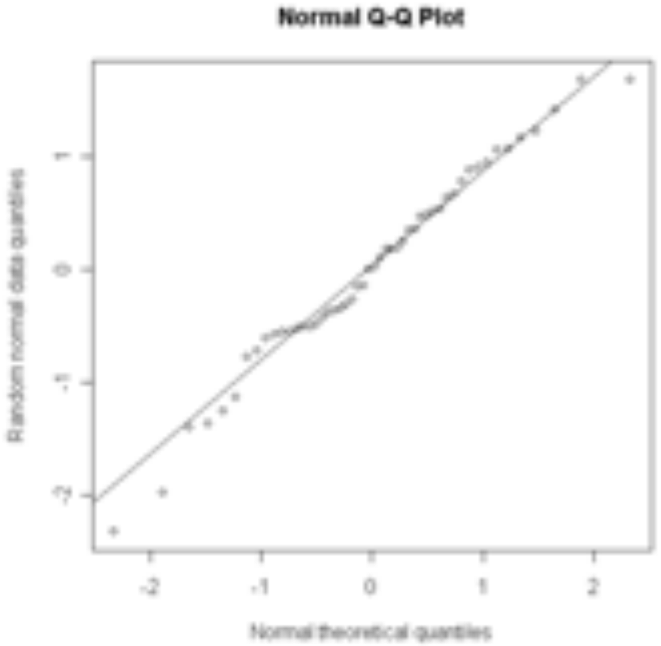
4. Quantile-Quantile Plot

QQ-plot

•Graphically determines if two data sets come from populations with a common distribution.
•Used to test for normality

Quantile is the fraction (or percent) of points below a given value. i.e. 0.2 quantile has 20% of values below this point and 80% of values above this point.

Advantage
- the sample sizes do not need to be equal.
- reveals distributional aspects such as shifts in scale, location, change in symmetry.



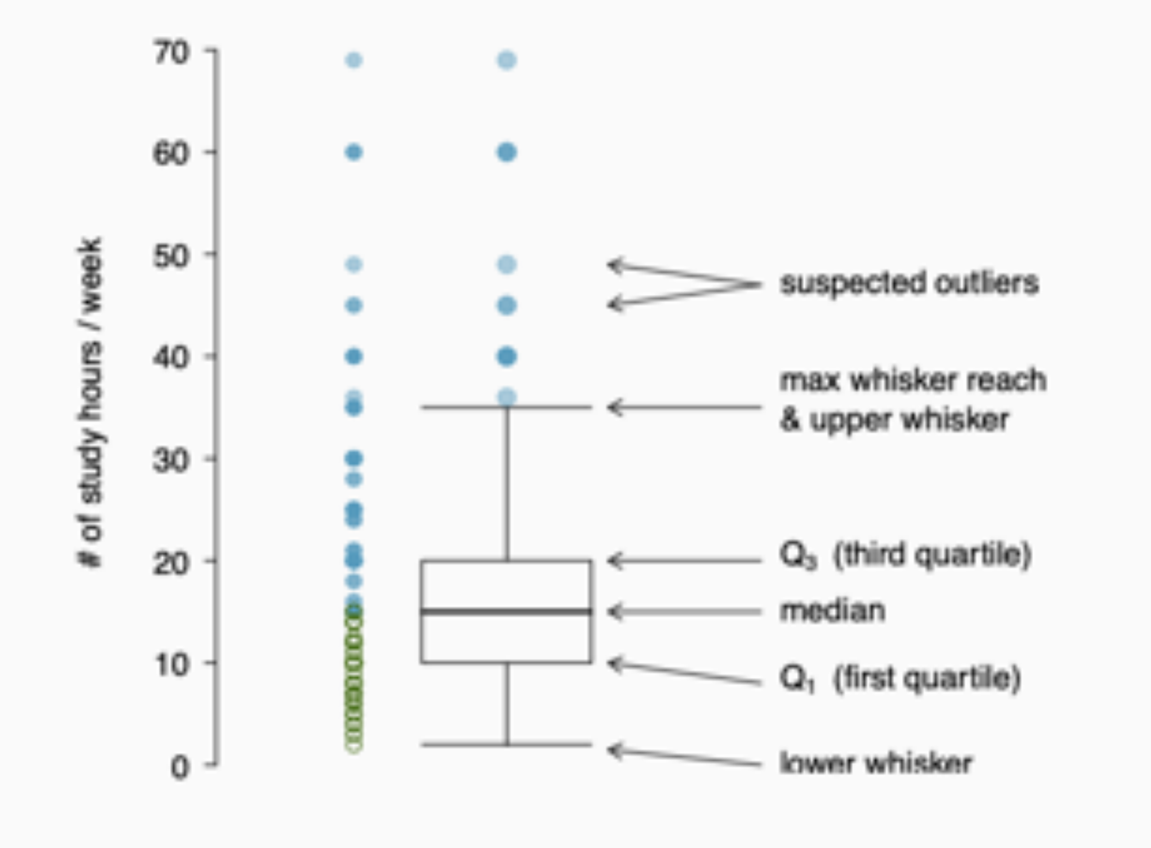
NON-NORMAL DISTRIBUTIONS

MEDIAN - value that splits the data in half. 50th percentile
Q1 – 1st quartile – 25th percentile
Q3 – 3rd quartile – 75th percentile

INTERQUARTILE RANGE (IQR)
Between Q1 and Q3 is the middle 50% of the data.
IQR = Q3 − Q1

OUTLIERS
- Identify extreme skew in the distribution.
- Identify data collection and entry errors.
- Provide insight into interesting features of the data.

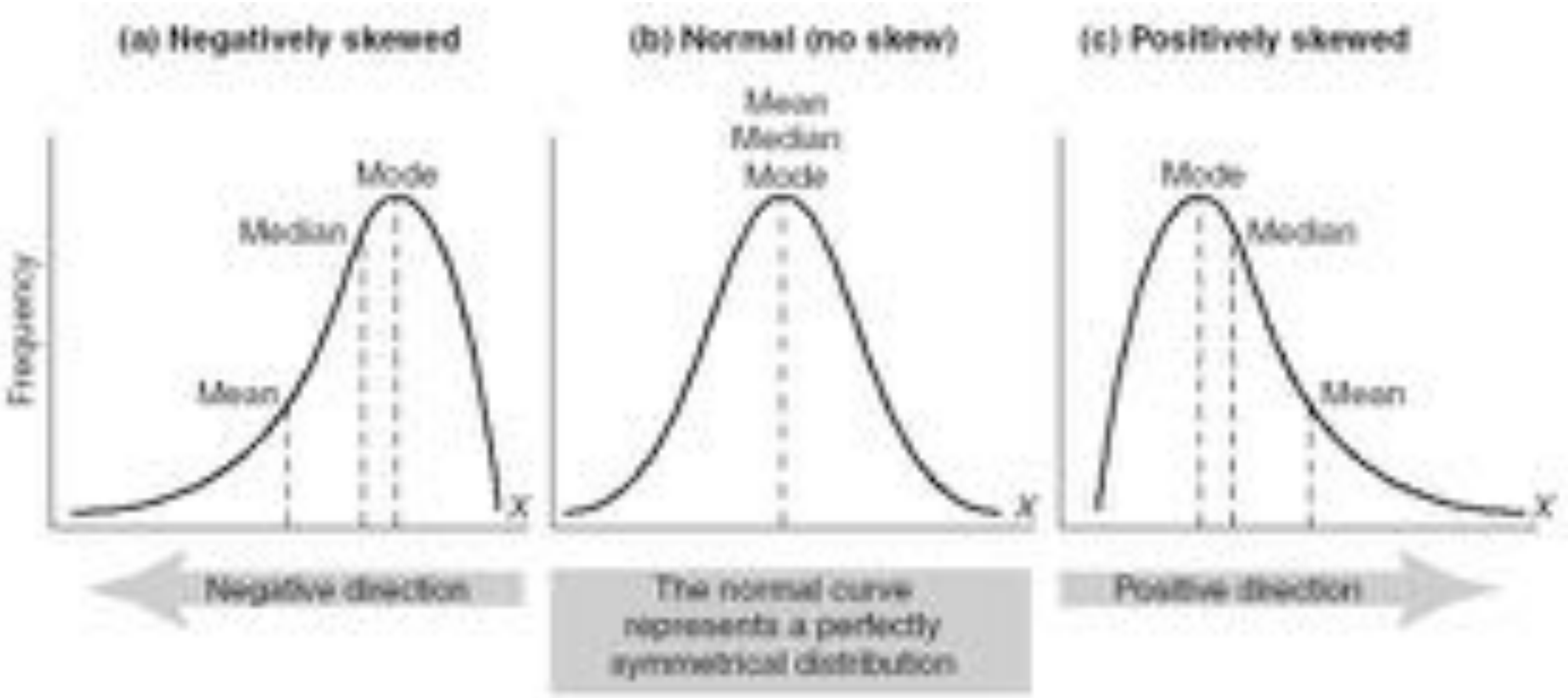
BOX PLOT



https://www.openintro.org/book/os/

ROBUST STATISTICS

Mean is affected by outliers. Median is more robust



- for symmetric distributions it is more helpful to use the mean and SD to describe the centre and spread
- for skewed distributions it is more helpful to use median and IQR to describe the centre and spread

TRANSFORMING SKEWED DATA

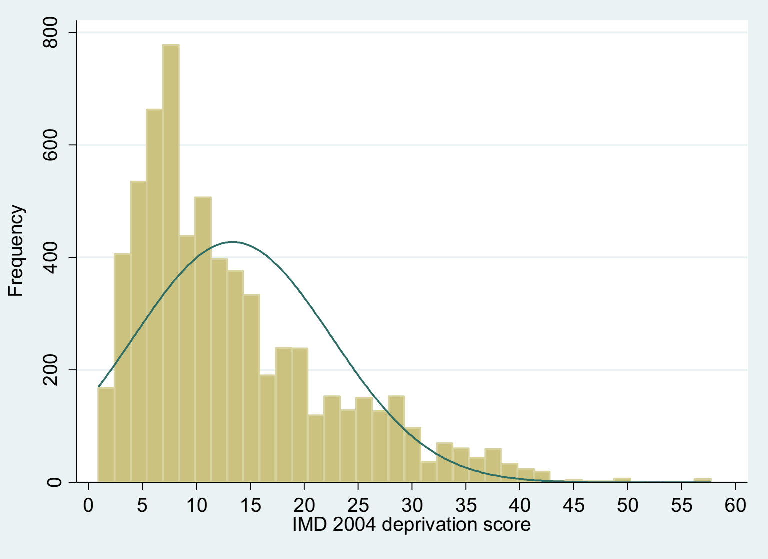
When data are extremely skewed, transforming them could

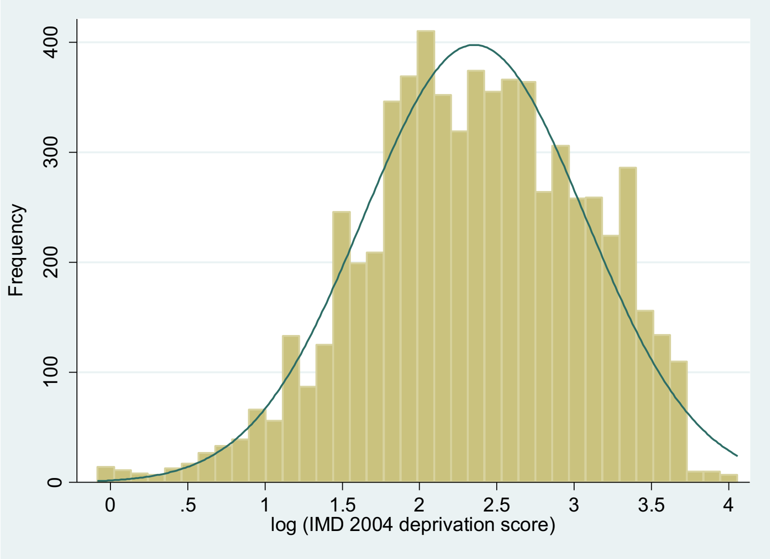
- make the data normally distributed
- PRO: allows use of parametric statistical tests that make modelling easier
- CON: However, interpretation will be trickier

LOG TRANSFORMATION

A common transformation is the log transformation for positively skewed data

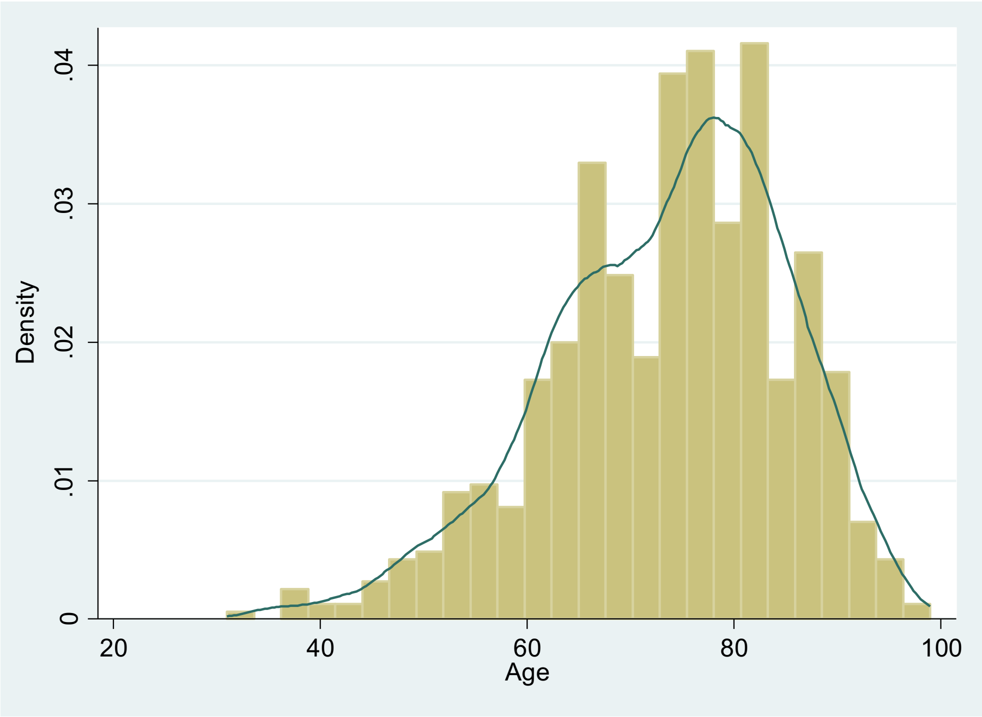
- takes values between (0, ∞) and converts it to the range (-∞ , ∞)
- the transformed data becomes symmetric about mean (closer to normal)





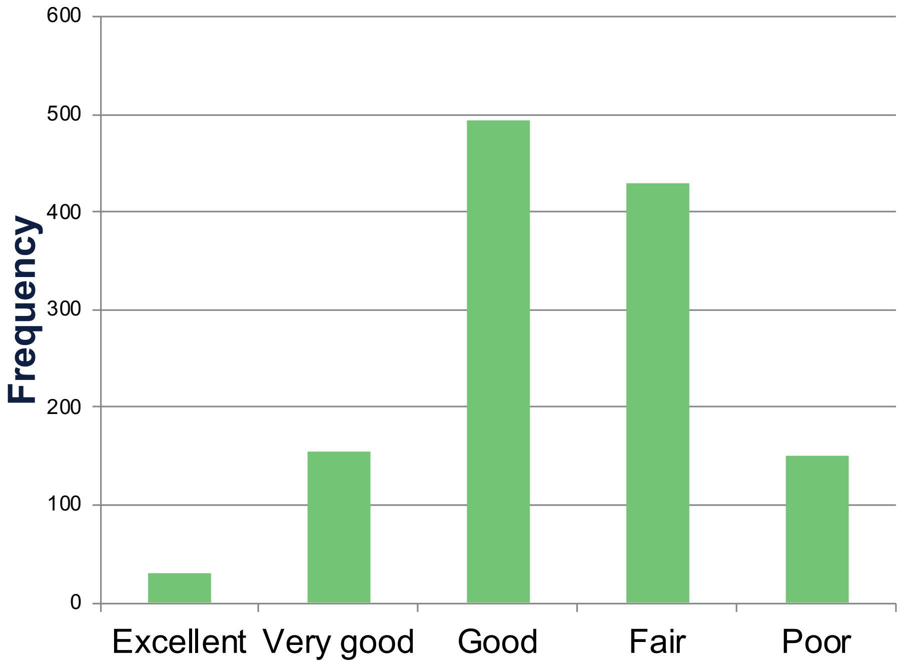
SUMMARISE – RECAP

BAR PLOT – NUMERICAL VARIABLE



Age (years) in patients

BAR PLOT – CATEGORICAL VARIABLE

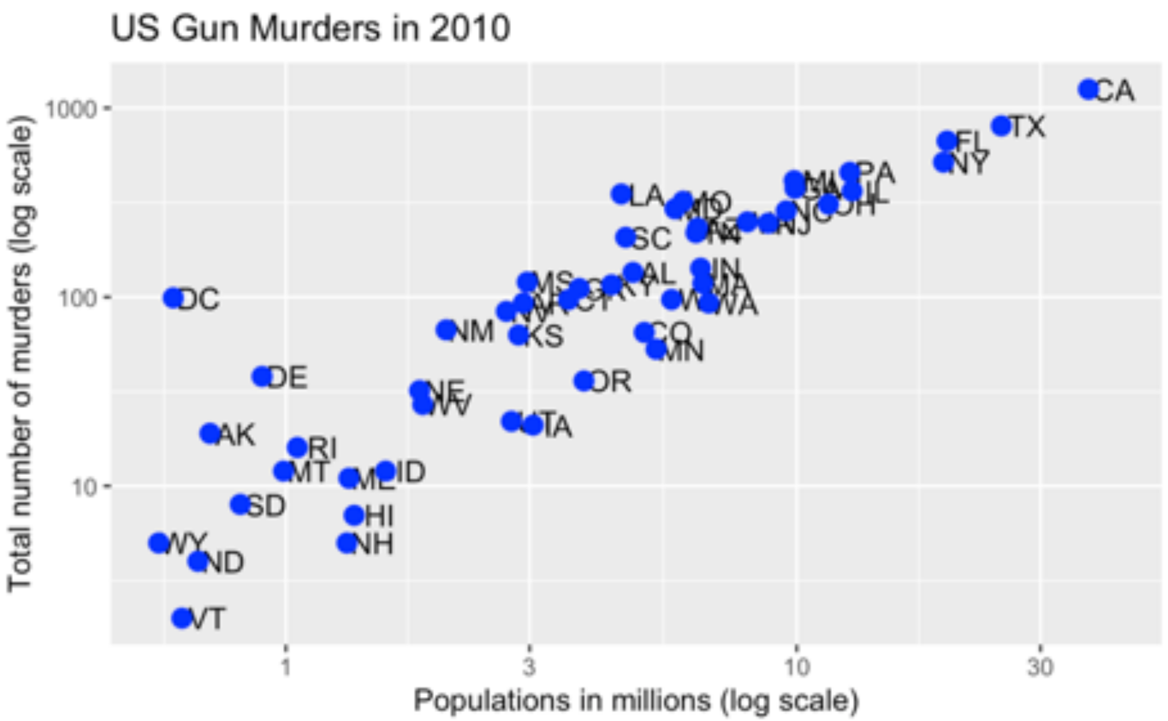


ASSOCIATION – 2 NUMERICAL VARIABLES

SCATTER PLOT

are useful for visualizing the relationship between two numerical variables.

Association between total number of murders and population of US states



Appear to be linearly and positively associated: as population increases, total number of murders increases.

ASSOCIATION – 2 CATEGORICAL VARIABLES

CONTINGENCY TABLE

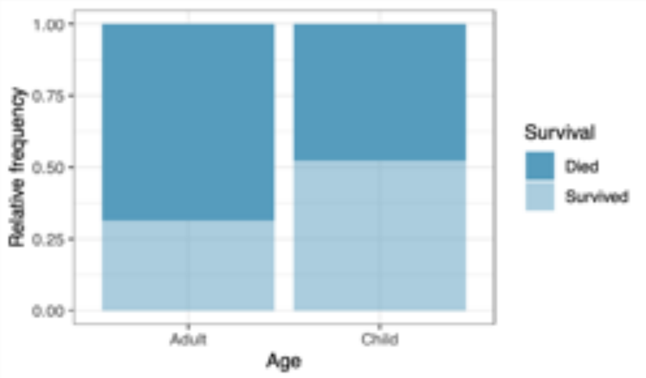
- A table that summarizes data for two categorical variables is called a contingency table.

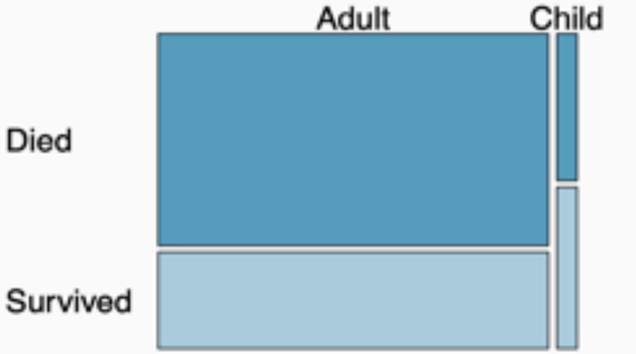
The contingency table below shows the distribution of survival and ages of passengers on the Titanic.

		Survival		
		Died	Survived	Total
Age	Adult	1438	654	2092
	Child	52	57	109
	Total	1490	711	2201

BAR PLOT/ MOSAIC

- A bar plot is a common way to display a single categorical variable.
- A bar plot where proportions instead of frequencies are shown is called a relative frequency bar plot.
- A mosaic plot has width in proportion to the marginal total (row or column).





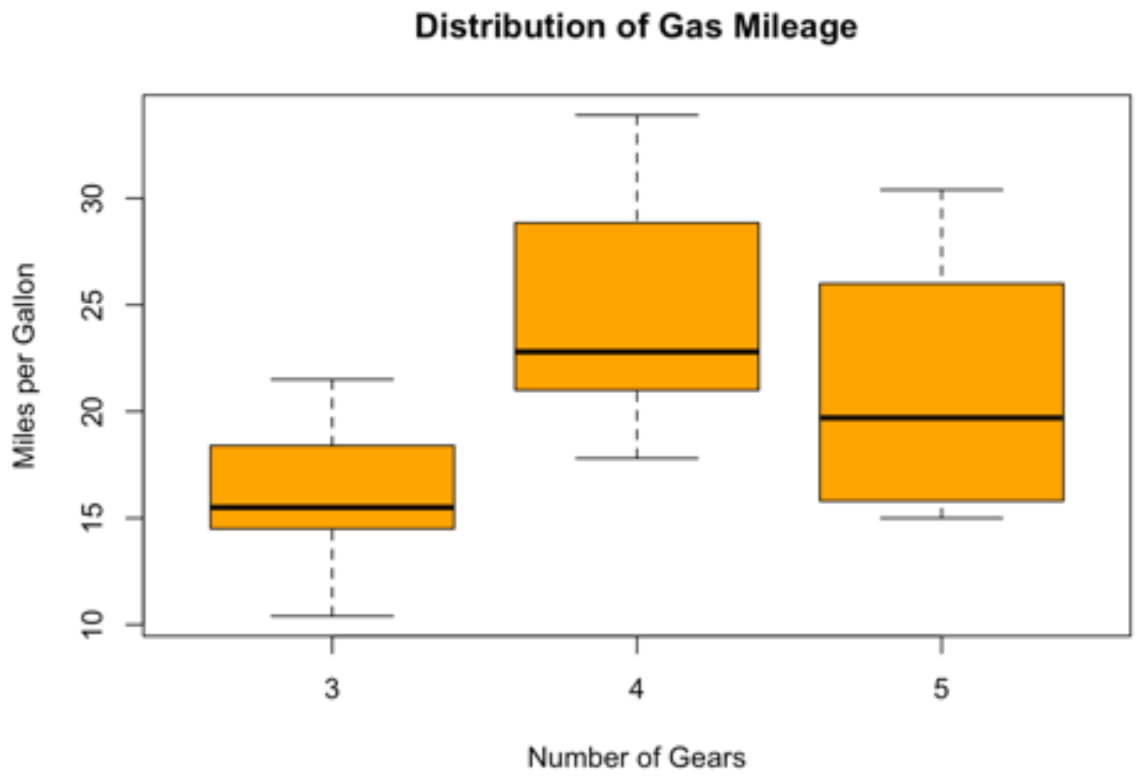
https://www.openintro.org/book/os/

ASSOCIATION – 1 NUMERICAL AND 1 CATEGORICAL VARIABLE

SIDE-BY-SIDE BOX PLOTS

Association between gas mileage and number of gears in the car

A Boxplot is a method for graphically depicting groups of numerical data through their quartiles



EXERCISE

Day2_4_DescriptiveStatistics_Exercise.Rmd

DAY 2 AND 3

Data Import

Wrangling

- Tidy + Manipulating
- Summarizing
- Cleaning

Exploration

- Visualization
- Descriptive Statistics

Statistical Inference

- Foundation of inference
- Basic statistical tests
- Linear regression

Day 2

Day 3