FIT3152 Data analytics – Lecture 2

Visualising data

- Recent examples
- Inspiration

Visualisation using R

- First steps: getting to know a data set
- Graphing your data in R (base graphics)
- Visualising more variables (base + lattice)
- Presentation quality graphics (ggplot2

Quick review of last week:

What is data science?

Overview of the unit

Using R

A few quick review questions:

Question 1

Predict the output from the following commands:

```
> X <- c(9, 16)
> sqrt(X)
```

A. 3
B. 3, 4
C. 4
D. 7

Question 2

Predict the output from the following commands:

```
> X <- c(1, 2)
> Y <- c(3, 4)
> X + Y
```

A. 4, 6
B. 3, 7
C. 10
D. 1, 2, 3, 4

X = c(1, 2, 3)
Y = c(3, 4)
X + Y = 4, 6, 6

recycling

Question 3

Predict the output from the following commands:

```
> X <- c(1, 2)
> Y <- c(3, 4)
> X * Y
```

A. 3, 8
B. 2, 12
C. 14
D. 24

Question 4

Predict the output from the following commands:

```
> X <- c(9, 16)
> class(X)
```

A. numeric

B. character

Question 5

Predict the output from the following commands:

```
> X <- c(9, 16, "monkey")
> class(X)
```

A. numeric

B. character

C. numeric, character

Unit outline (week-by-week)

Clayton lecture is Wednesday 11:00am – 1:00pm (AEDT).

Tutorials begin Week 2 and follow lecture by a week.

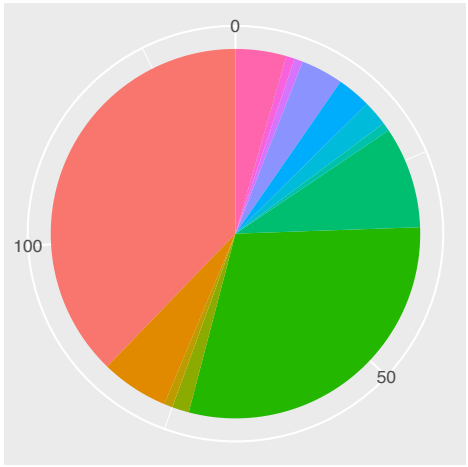
Week Starting	Lecture	Topic	Tutorial	A1 25	A2 30	Q/P 25	A3 20	Due	
27/2/23	1	Intro to Data Science, review of basic statistics using R	...						
6/3/23	2	Exploring data using graphics in R	T1						
13/3/23	3	Data manipulation in R	T2						
20/3/23	4	Regression modelling	T3						
27/3/23	5	Clustering	T4						
3/4/23	6	Data Science methodologies, dirty/clean/tidy data	T5						
10/4/23	-	Mid-semester Break	-	-	-	-	-	-	
17/4/23	7	Classification using decision trees	T6					17/4/23	Mo
24/4/23	8	Naïve Bayes, evaluating classifiers	T7						
1/5/23	9	Ensemble methods, artificial neural networks	T8						
8/5/23	10	Text analysis	T9					12/5/23	Fr
15/5/23	11	Network analysis	T10					19/5/23	Fr
22/5/23	12	Review of course	T11						
29/5/23		SWOT VAC							
5/6/23		EXAM PERIOD						9/6/23	Fr

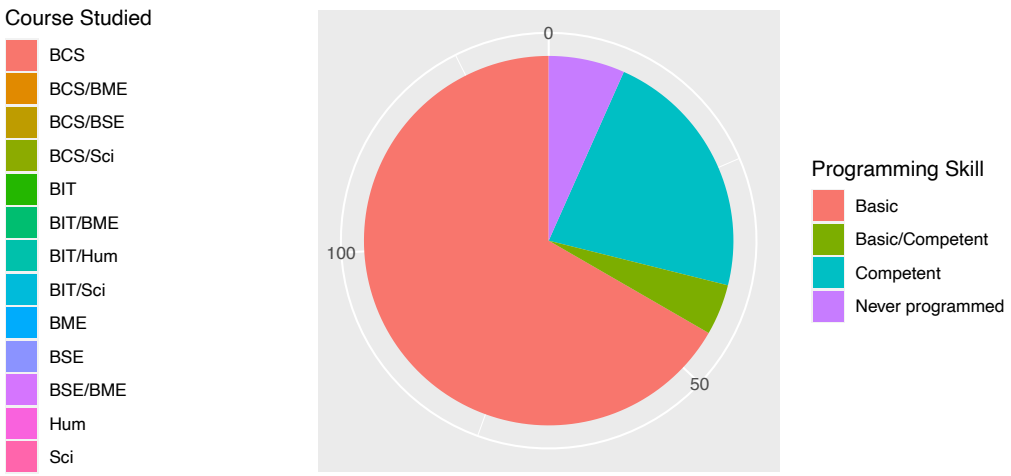
Visualizing data

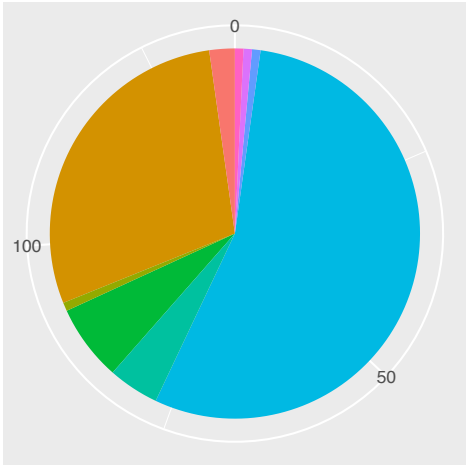
Some examples of data graphics follow. For each image think about:

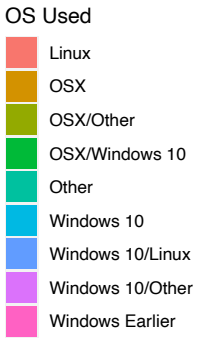
- What information is being conveyed? *What story (if any) is being told by the data?*
- How is information being conveyed? What is the main device: size, shape, colour, position...?
- How many dimensions (*number of variables associated with each data point*) represented?
- How is space used?

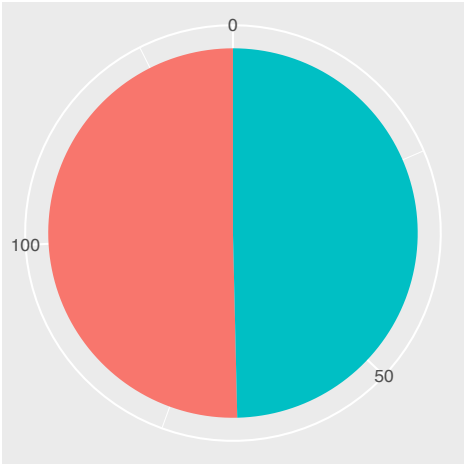
Class survey results (Pie Charts)





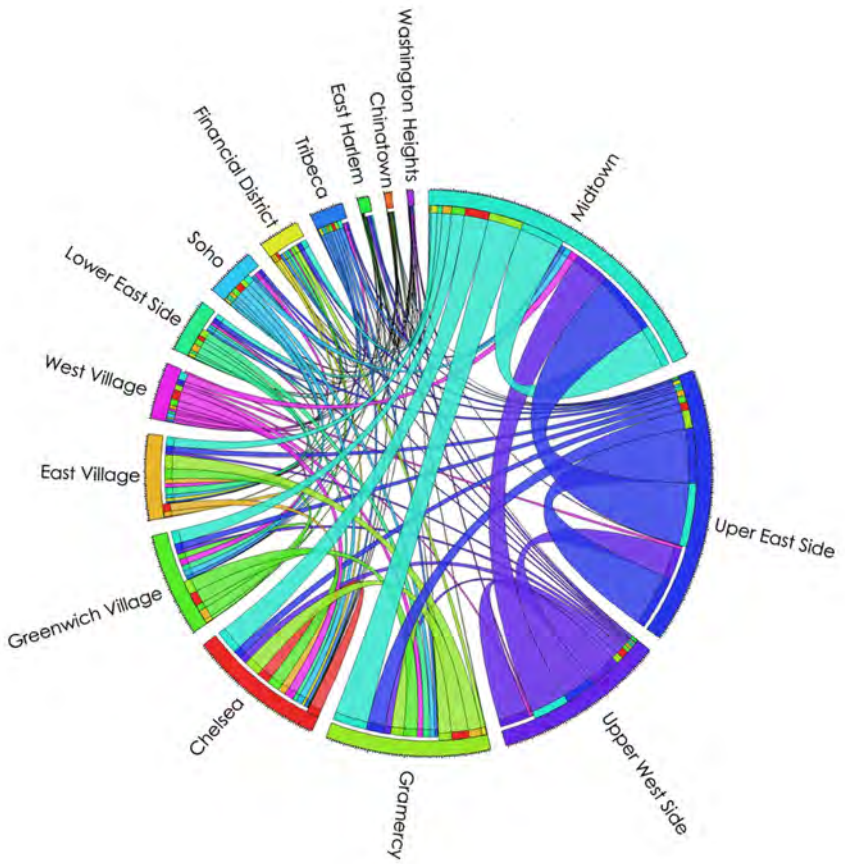






New York taxi trips by neighbourhood

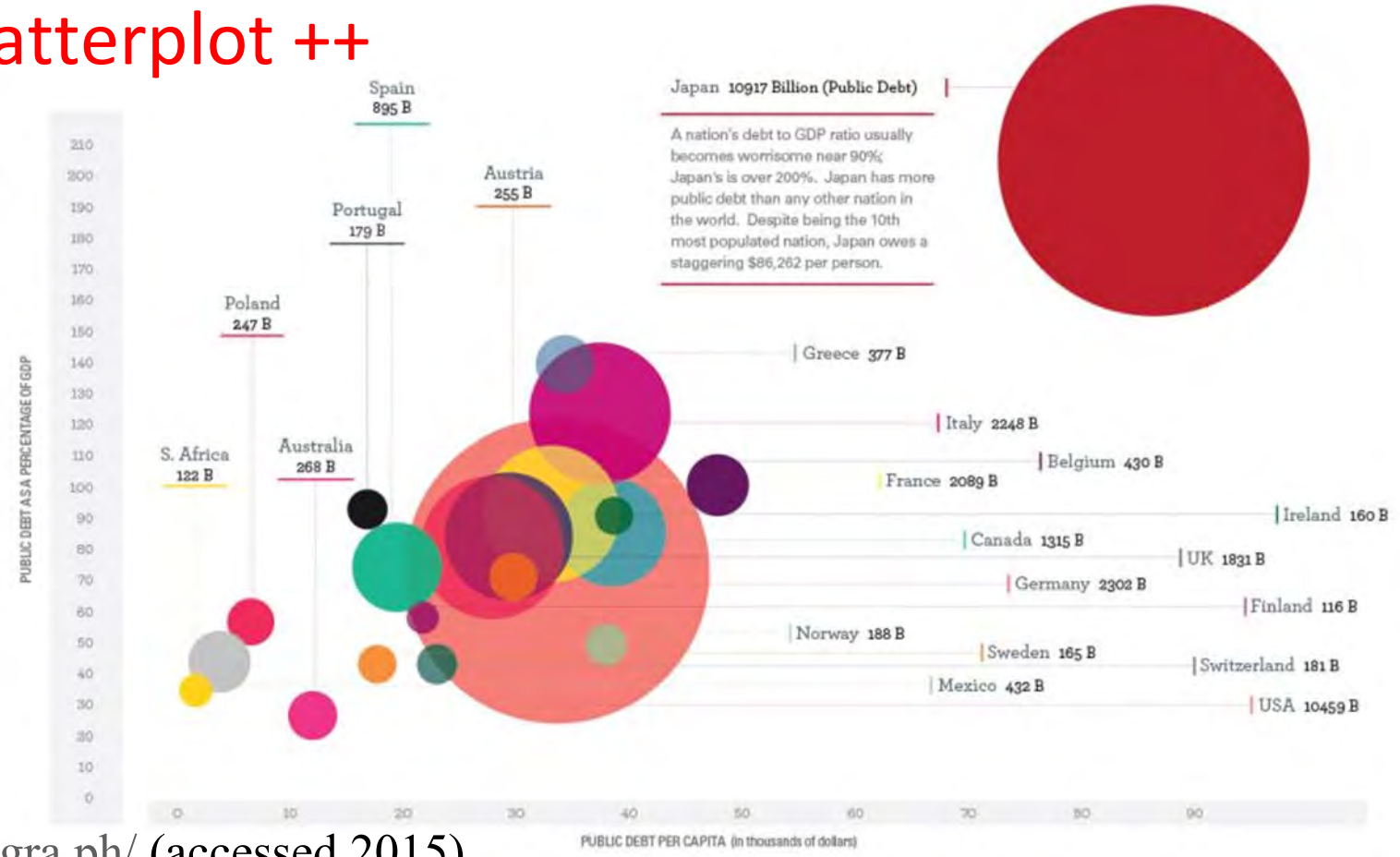
Network



binaryspark.com/

Debt crisis: Japan

Scatterplot ++



infogra.ph/ (accessed 2015)

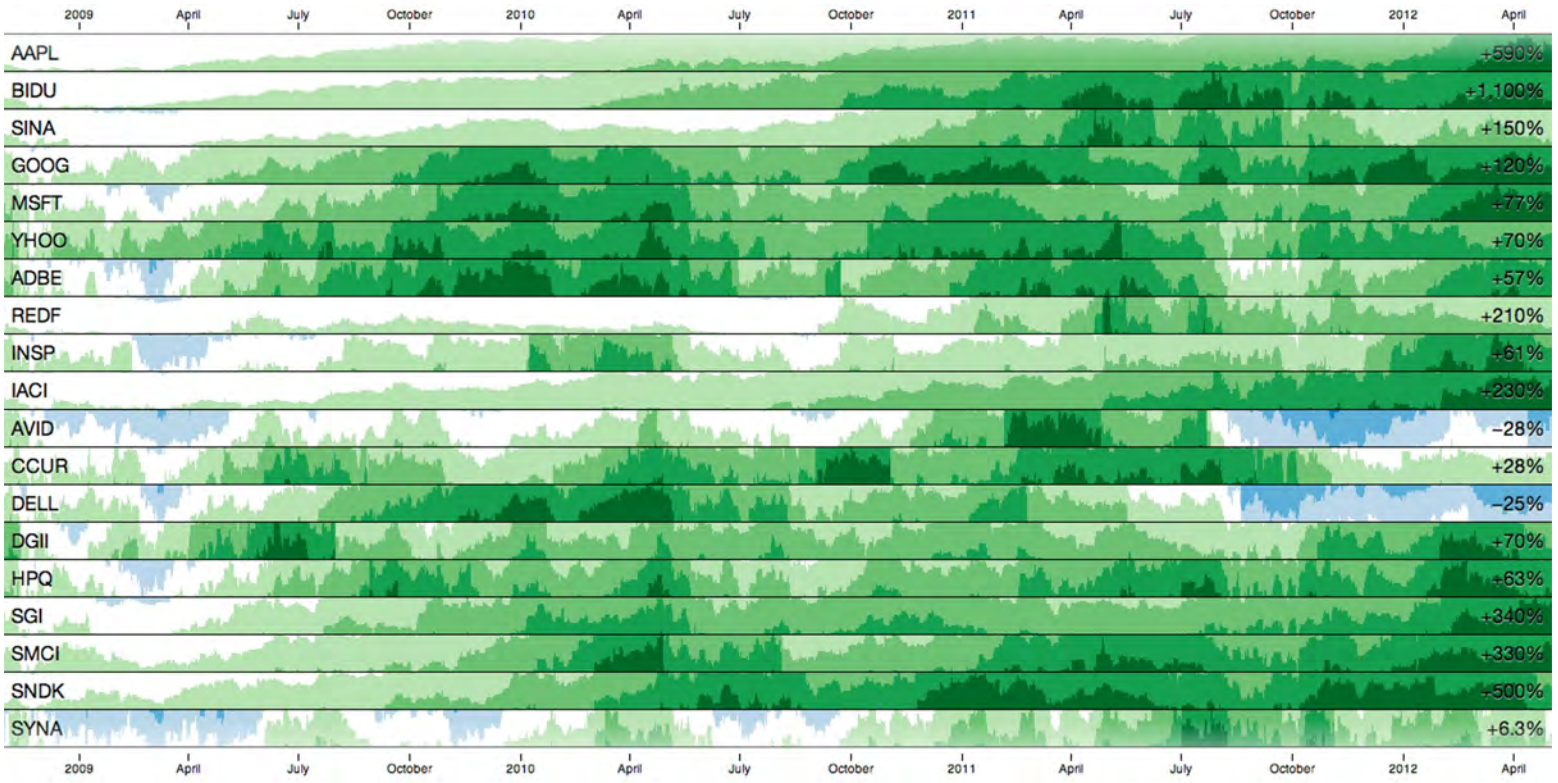
Security visualization

Mosaic

secviz.org/ (accessed 2020)

Share prices

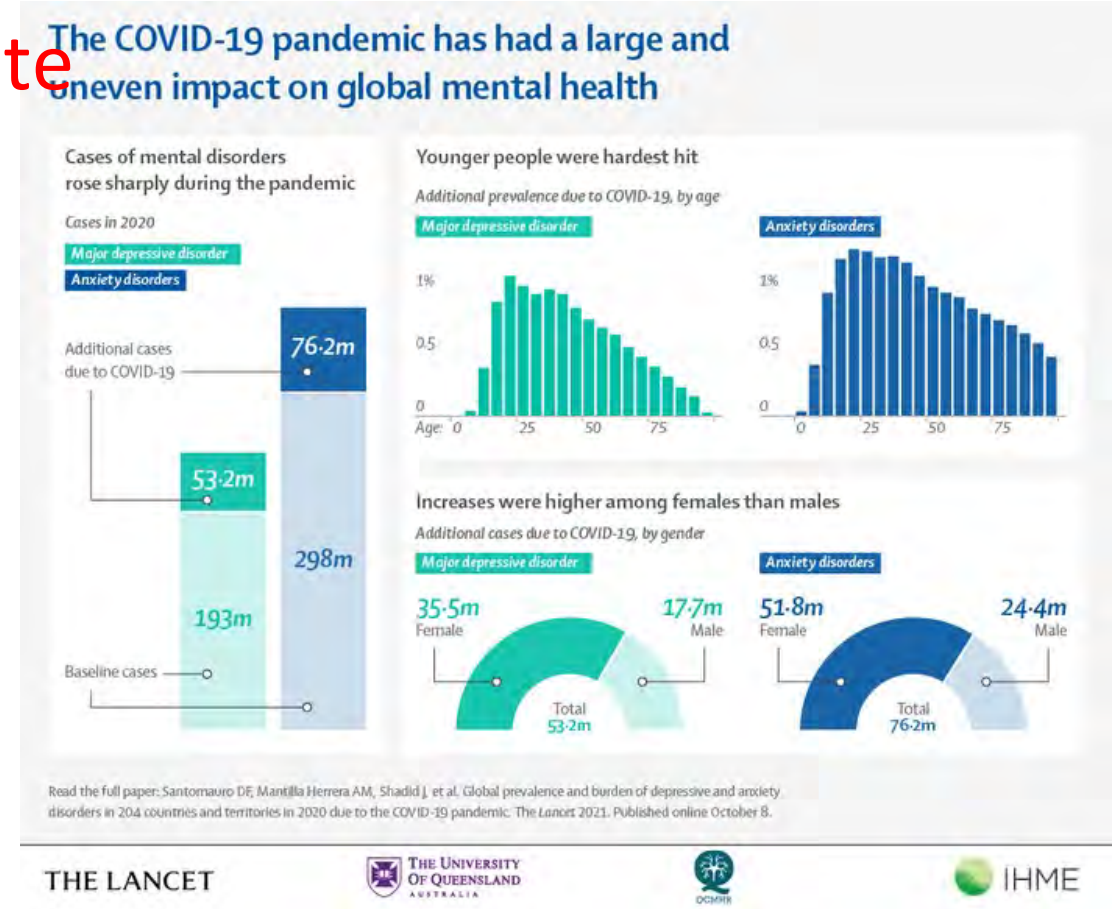
Horizon



bost.ocks.org/

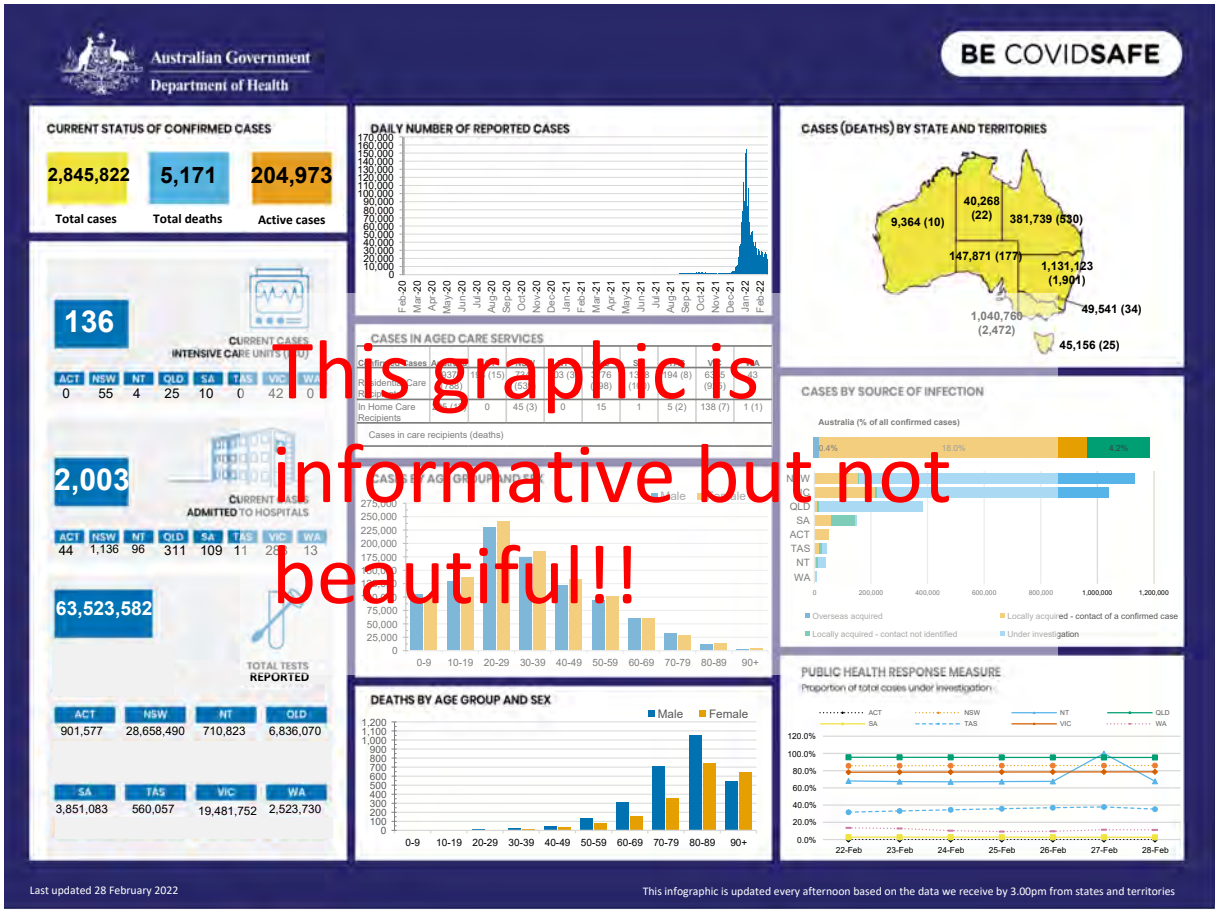
Effect of COVID-19 on mental health

Composite



eurekalert.org

COVID-19 stats 28th Feb 2022 *



This graphic is informative but not beautiful!!

health.gov.au/

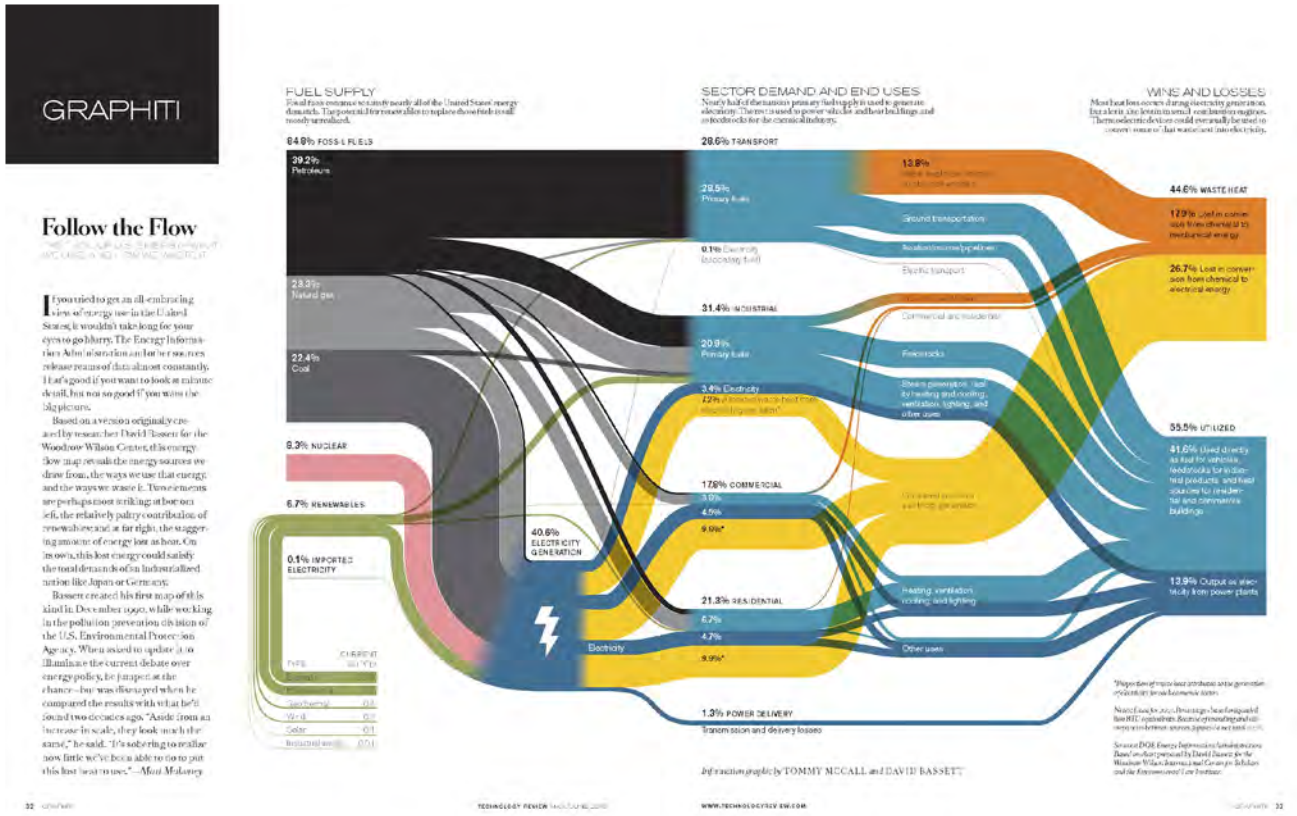
Coronavirus Graphics: best/worst *

- The MIT Technology Review has collected the best and worst (in their view) Coronavirus dashboards

technologyreview.com/

US energy production/consumption

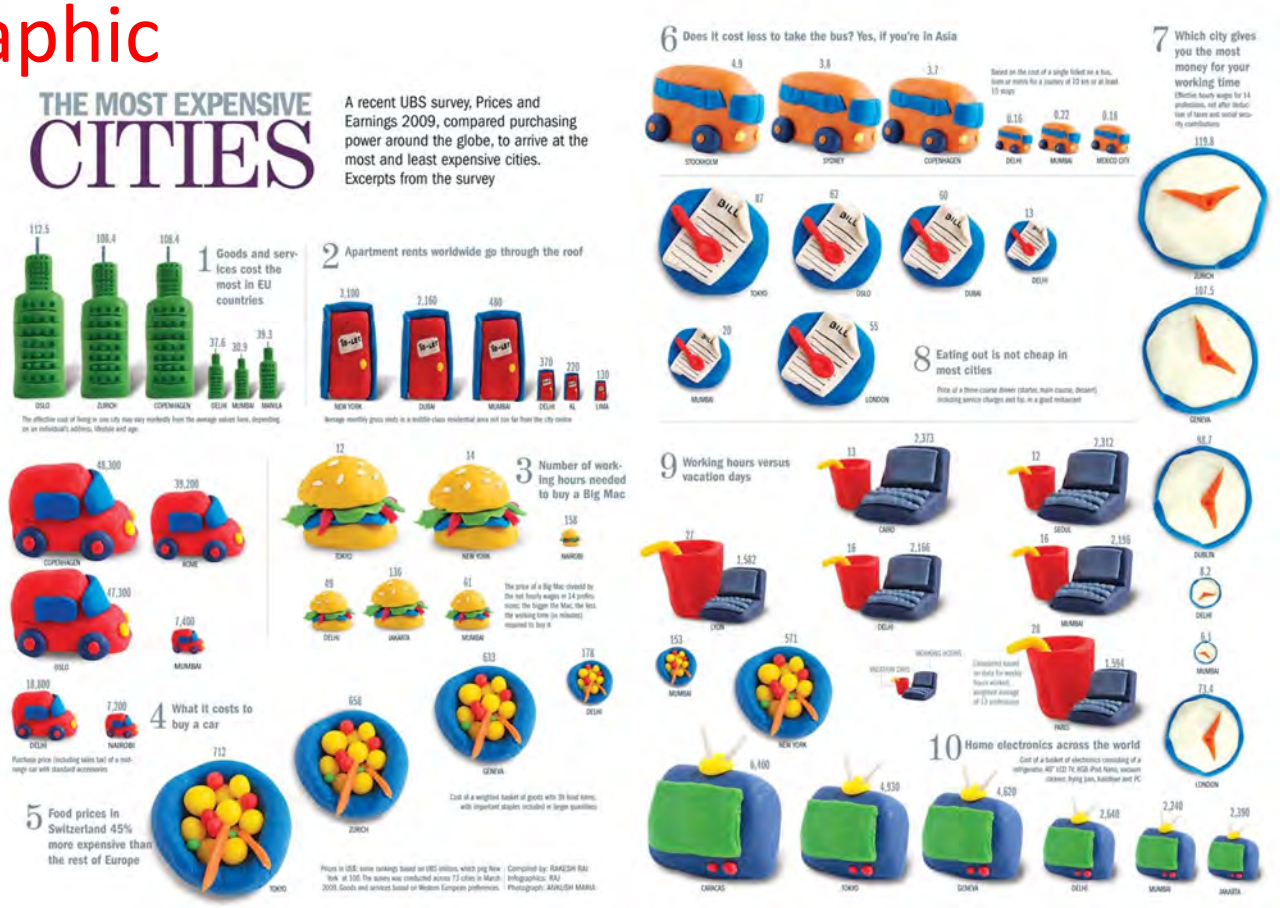
Sankey Diagram



visual.ly/

Most expensive cities

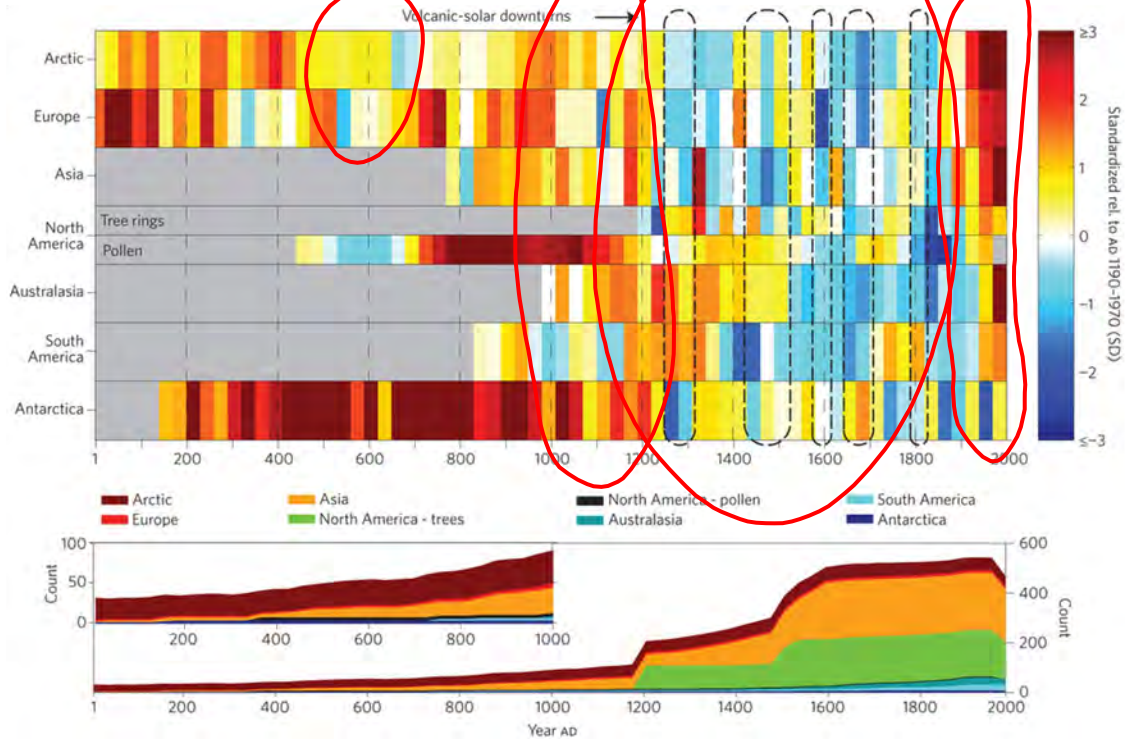
Infographic



infographiclist.com/ (accessed 2022)

Climate change

Continental-scale temperature variability during the past two millennia



nature.com/

Climate change

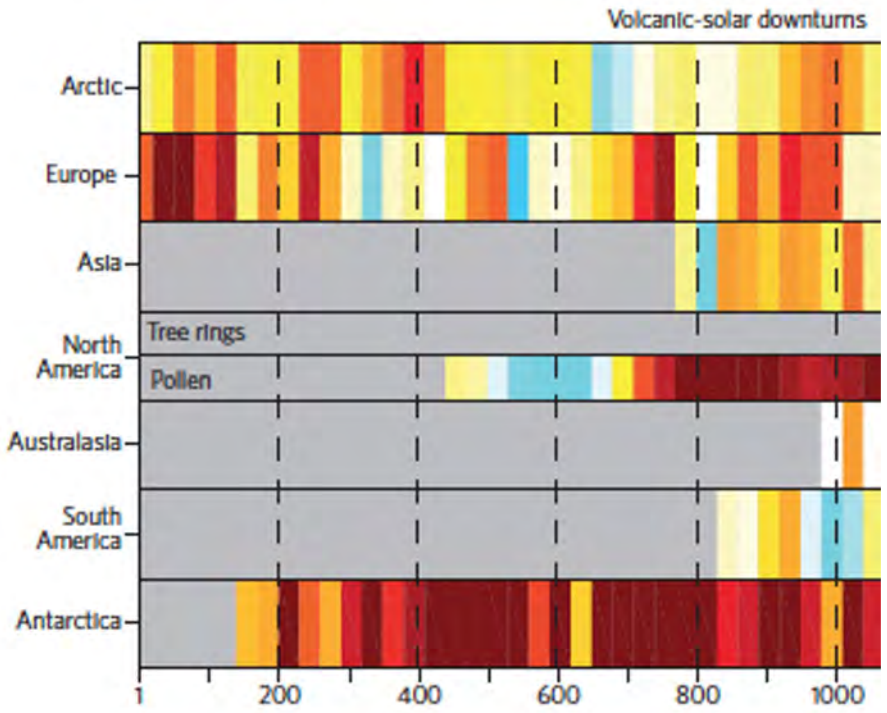
...

The '2k Network' of the IGBP Past Global Changes (PAGES) project aims to produce a global array of regional climate reconstructions for the past 2000 years. ... Nine PAGES 2k working groups represent eight continental-scale regions and the oceans. Regional representation brings critical expert knowledge of individual proxy data sets, which is essential for improving palaeoclimate reconstructions. The PAGES 2k Network is coordinated with the National Oceanic and Atmospheric Administration (NOAA) World Data Center for Paleoclimatology to establish a benchmark database of proxy climate records for the past two millennia ...

Question 6

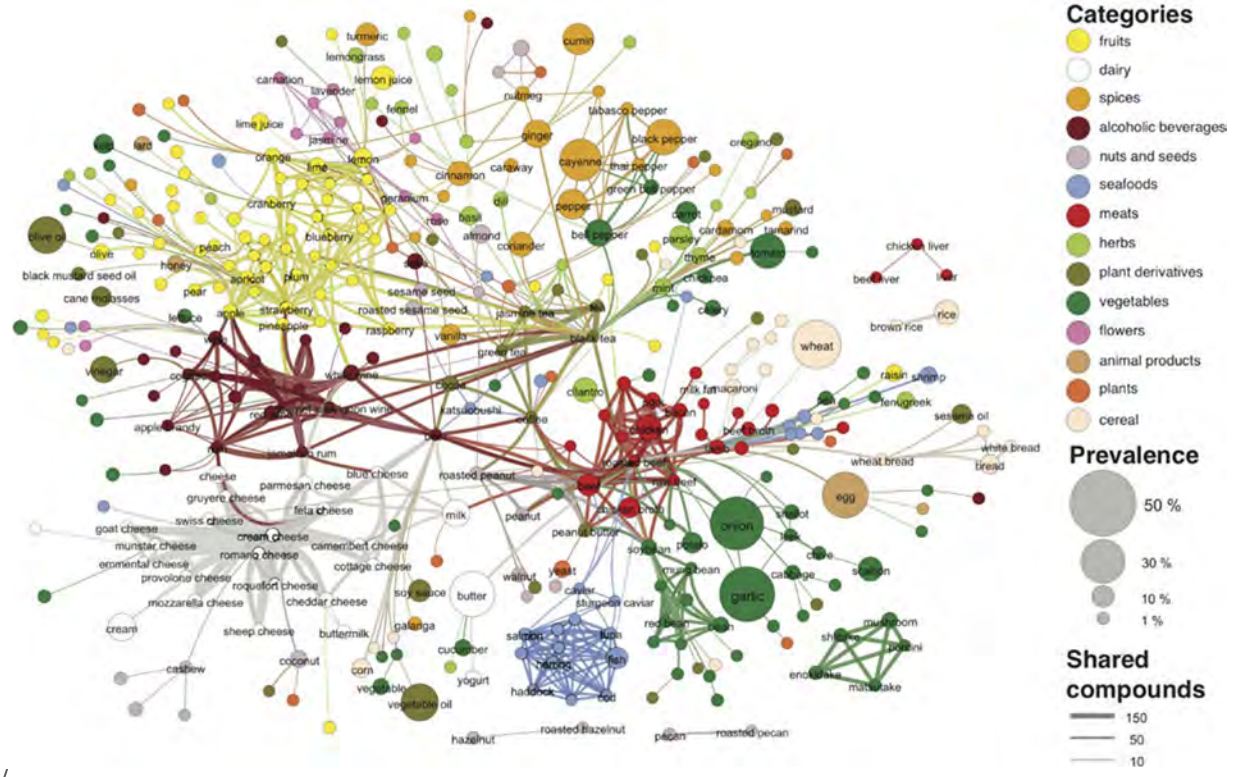
How many dimensions does the figure show?

A. 1
B. 2
C. 3
D. 4
E. More than 4



Food networks

Flavor network and the principles of food pairing



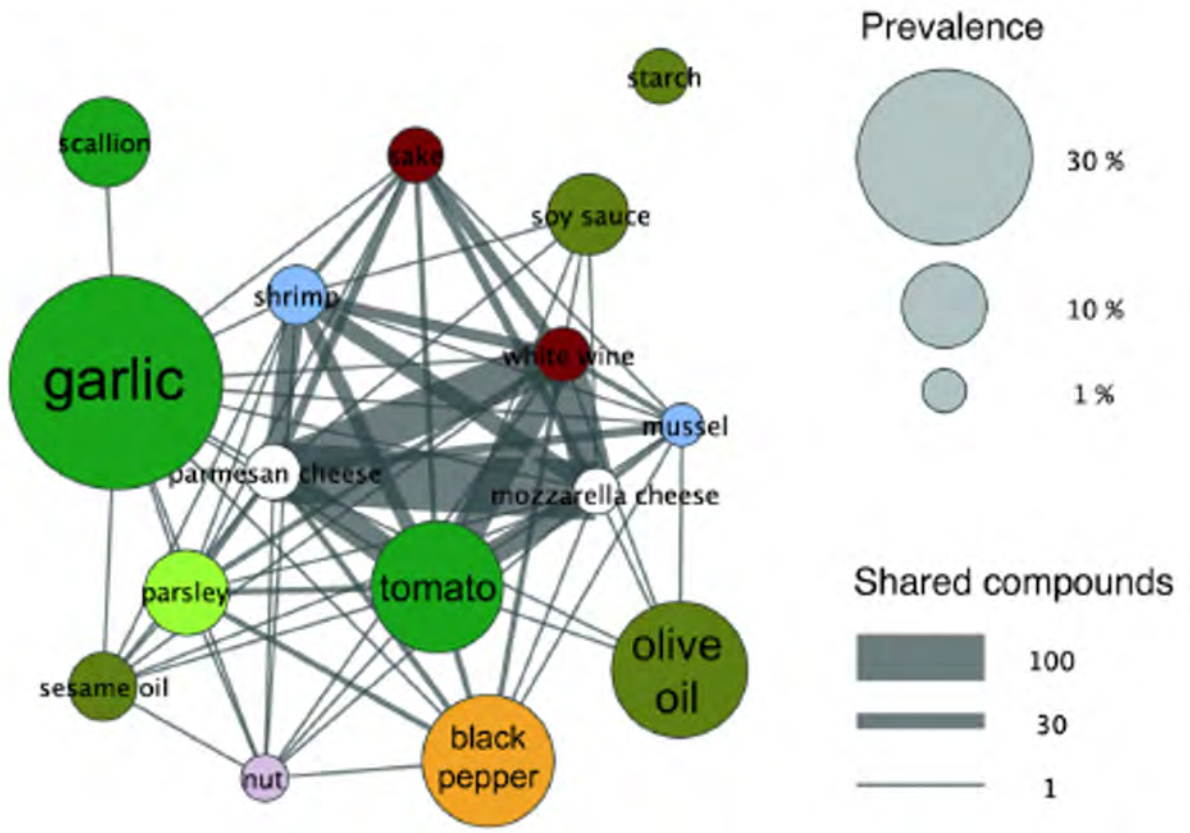
nature.com/

Question 7

How many dimensions does the figure show?

A. 1
B. 2
C. 3
D. 4
E. More than 4

Think about how many variables are associated with each data point...



Inspiration:

What type of graphic do you want to create?

What data do you have, and what story do you want the graphic to tell?

Some starting points:

The Visualization Zoo…

A tour through the visualization zoo

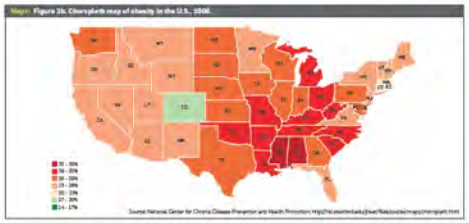
http://dl.acm.org/citation.cfm?id=1743567

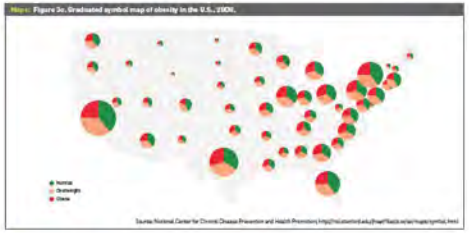
Identifies the major graphic types and their subtypes.

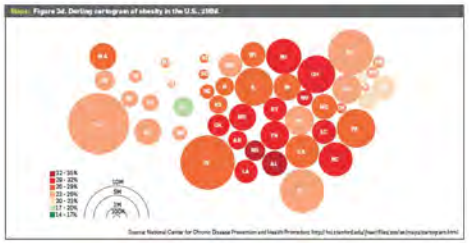
- Time Series
- Statistical distributions
- Maps
- Hierarchies
- Networks

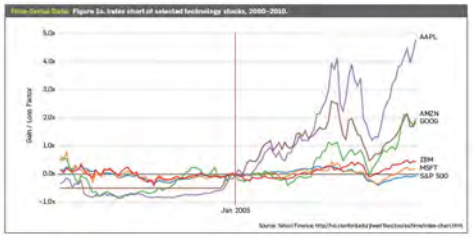
The Visualization Zoo…

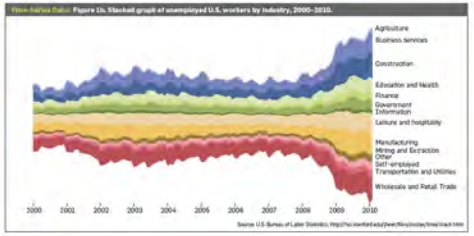
Maps Time series Stats.

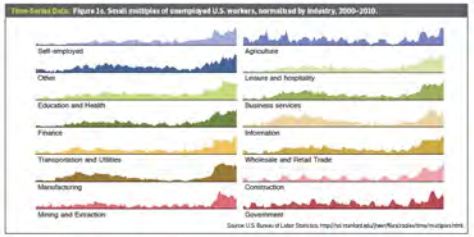


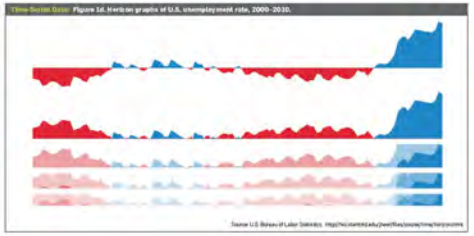


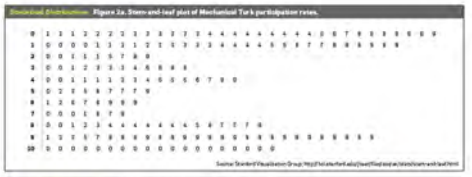


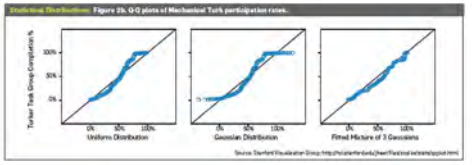


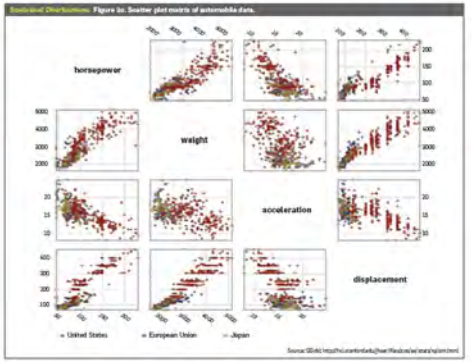


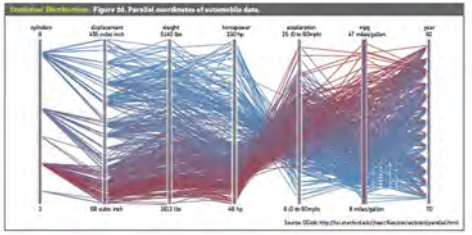






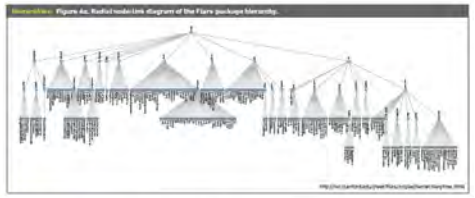


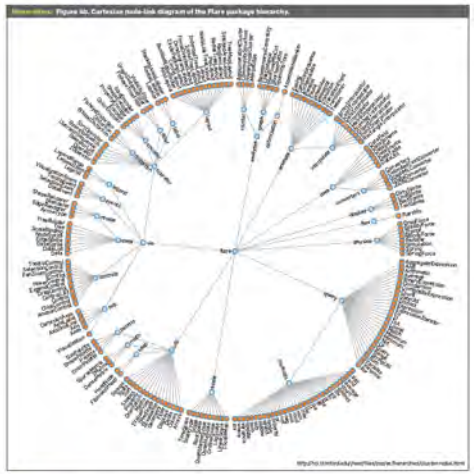


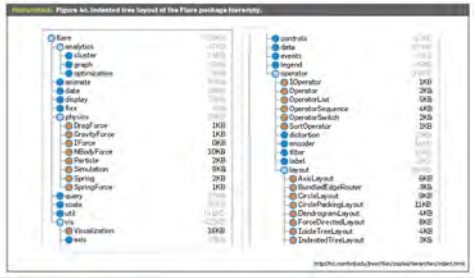


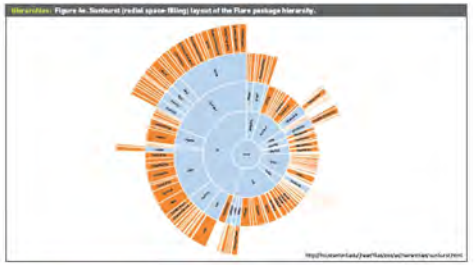
The Visualization Zoo…

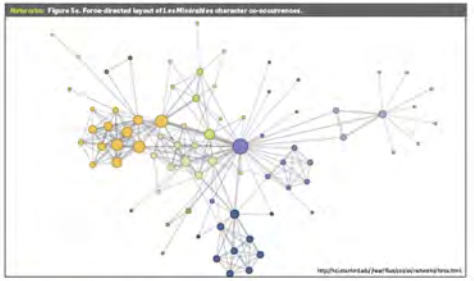
hierarchy network

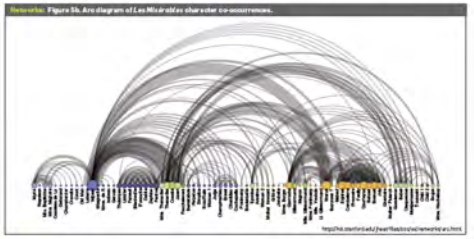


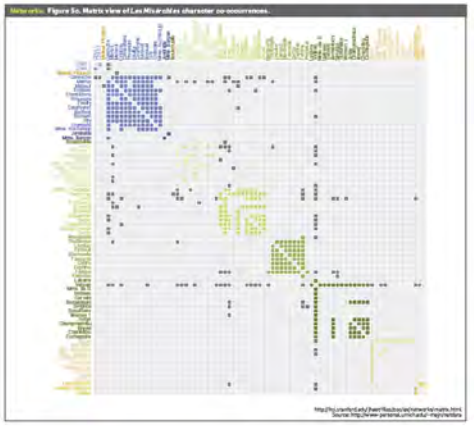




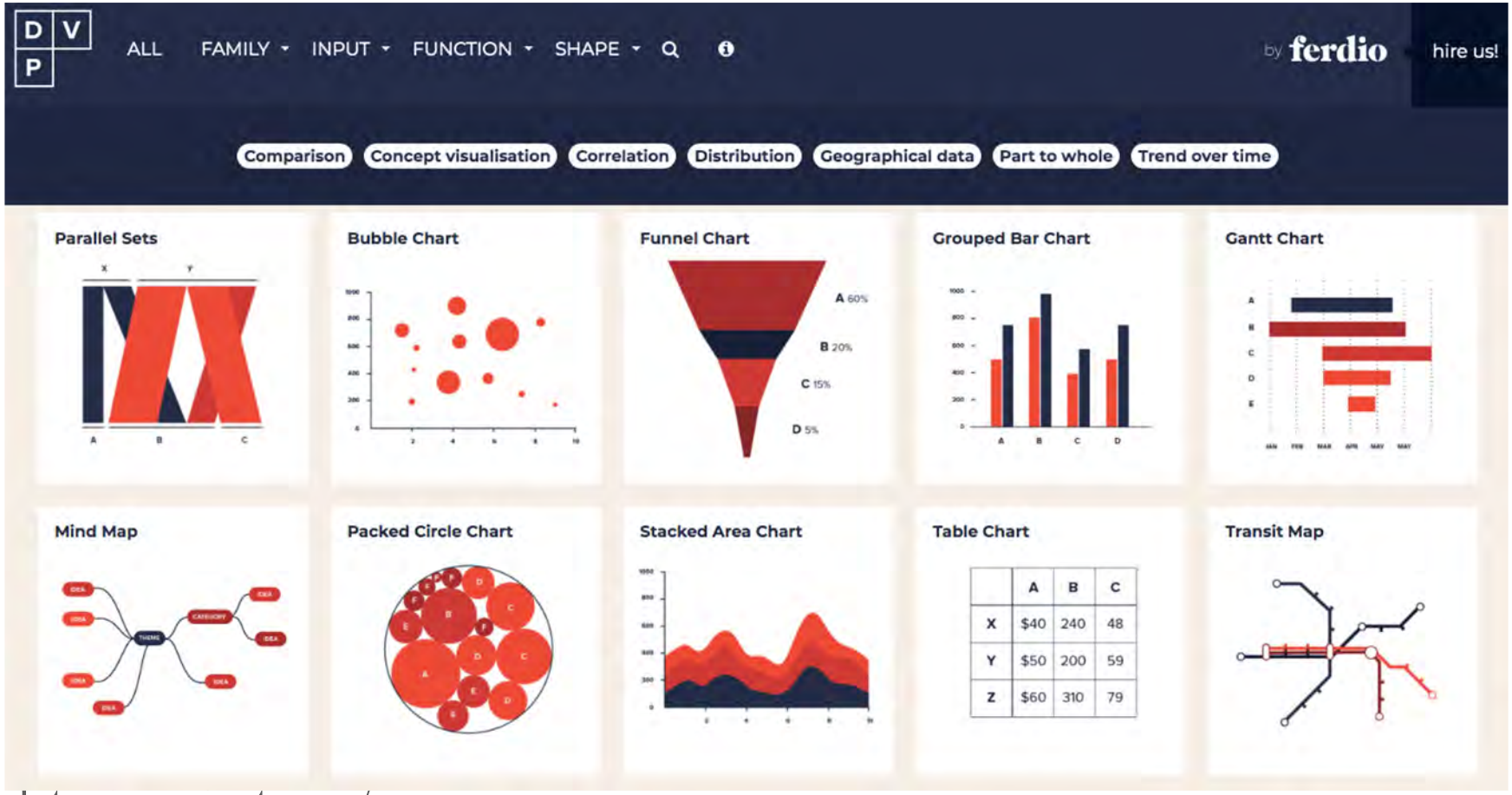








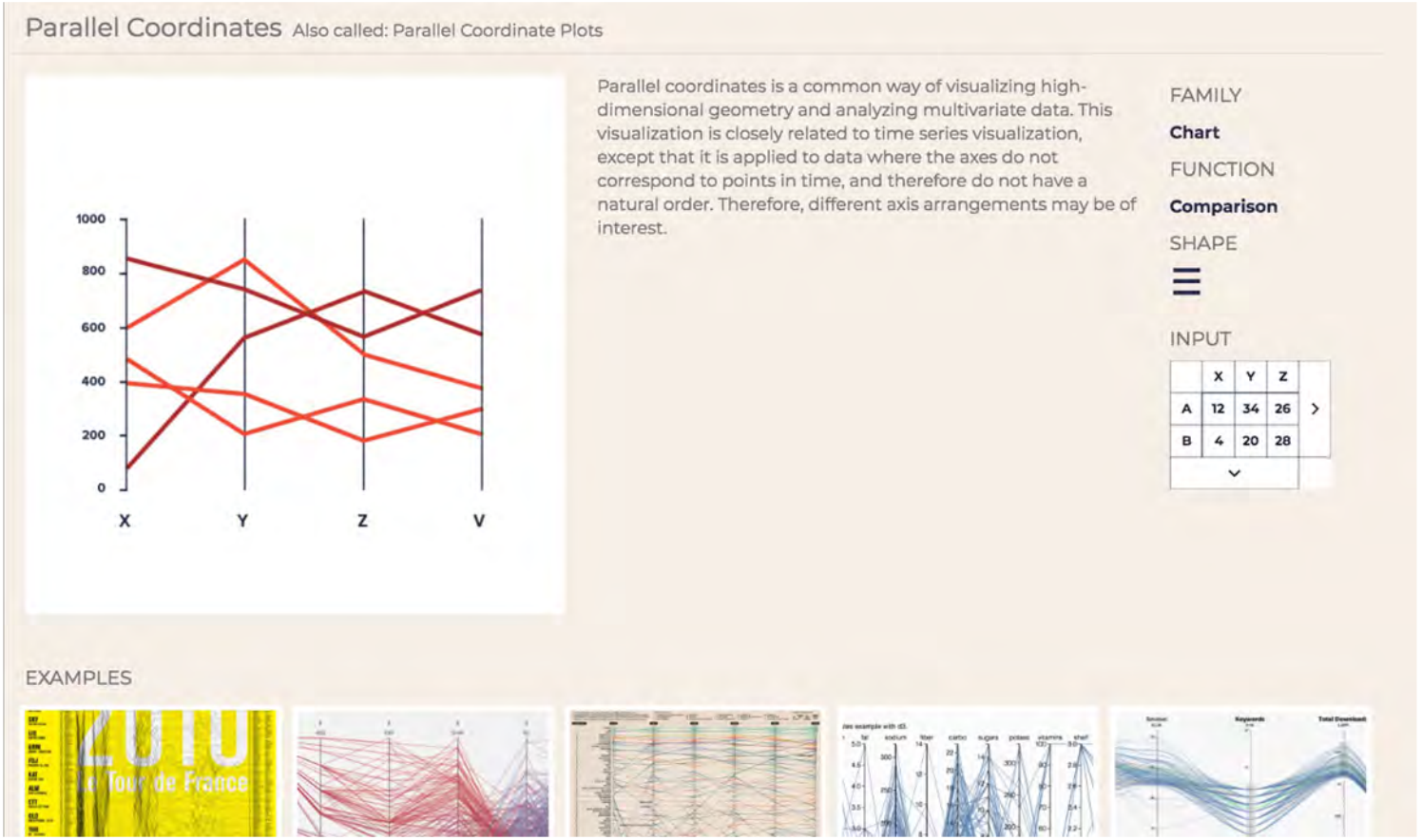
Data Viz Project



	A	B	C
X	$40	240	48
Y	$50	200	59
Z	$60	310	79

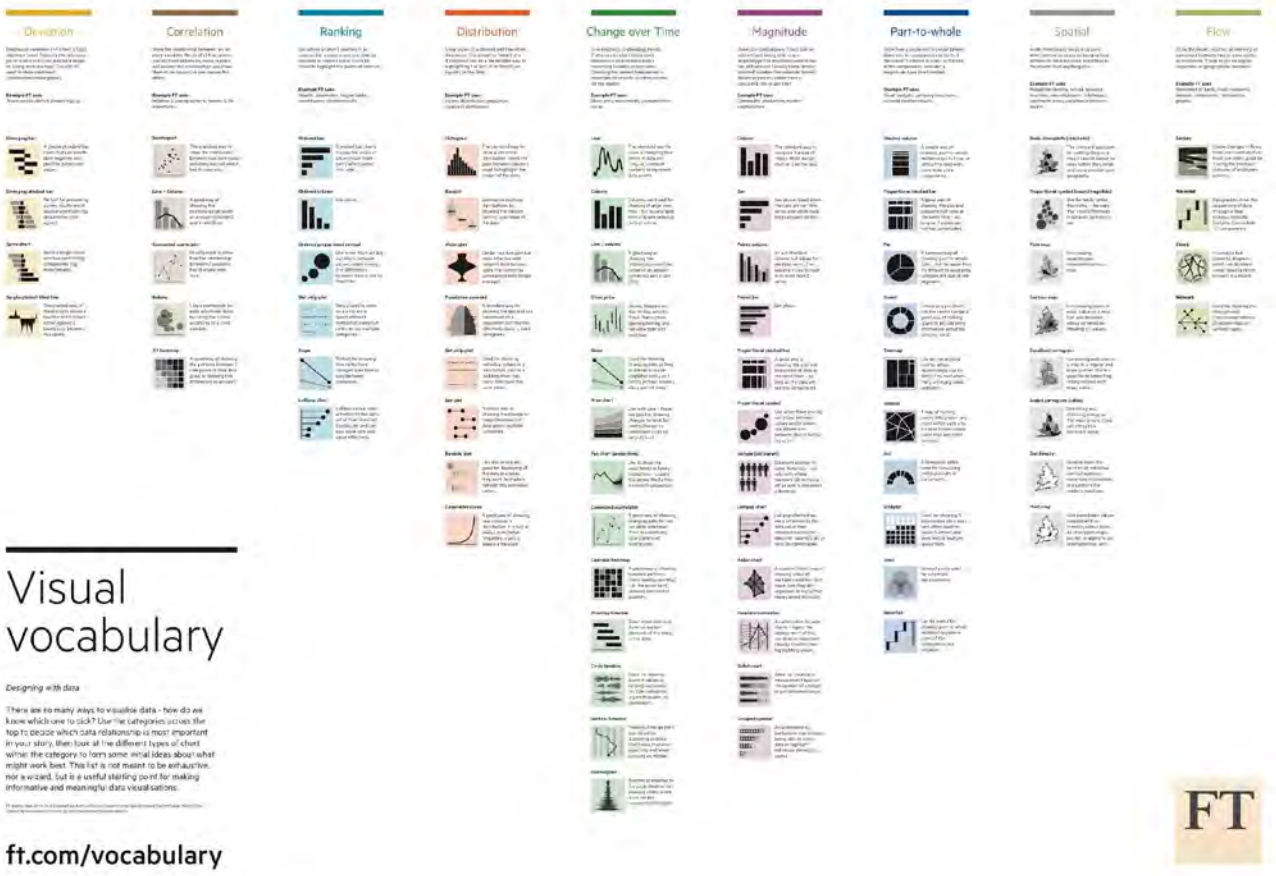
datavizproject.com/

Data Viz Project



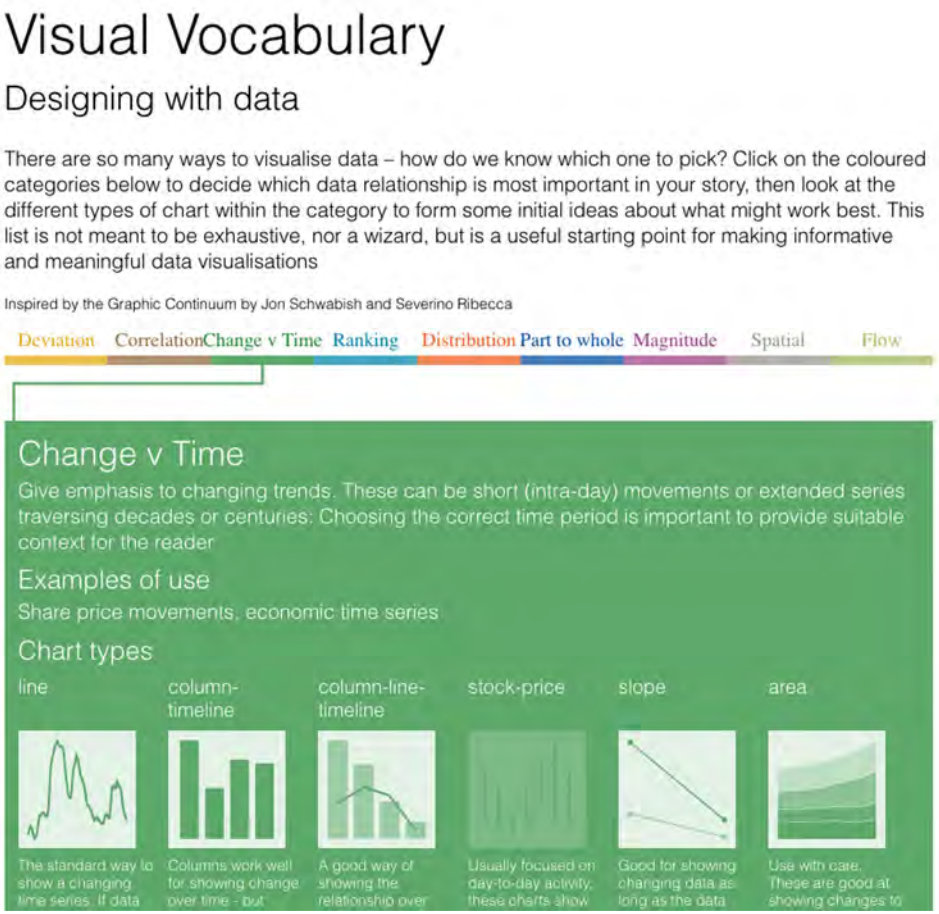
datavizproject.com/

FT: visual vocabulary



github.com/ft-interactive/

Visual vocabulary interactive *



ft-interactive.github.io/

The R Graph Gallery

Has lots of graph styles on display with reproduceable code. www.r-graph-gallery.com/

TED talks on data science

Playlist on data and data science: Making sense of too much data

https://www.ted.com/playlists/56/making_sense_of_too_much_data

In particular: Hans Rosling, David McCandless, Deb Roy, Nate Silver, Mona Chalabi, Jennifer Golbeck – but all worth watching...

MONA CHALABI

3 ways to spot a bad statistic

TOMMY MCCALL

The simple genius of a good graphic

HANS ROSLING

The best stats you've ever seen

Getting to know a data set

Edgar Anderson's Iris data

50 samples from 3 species:

- Iris setosa, – virginica, – versicolor

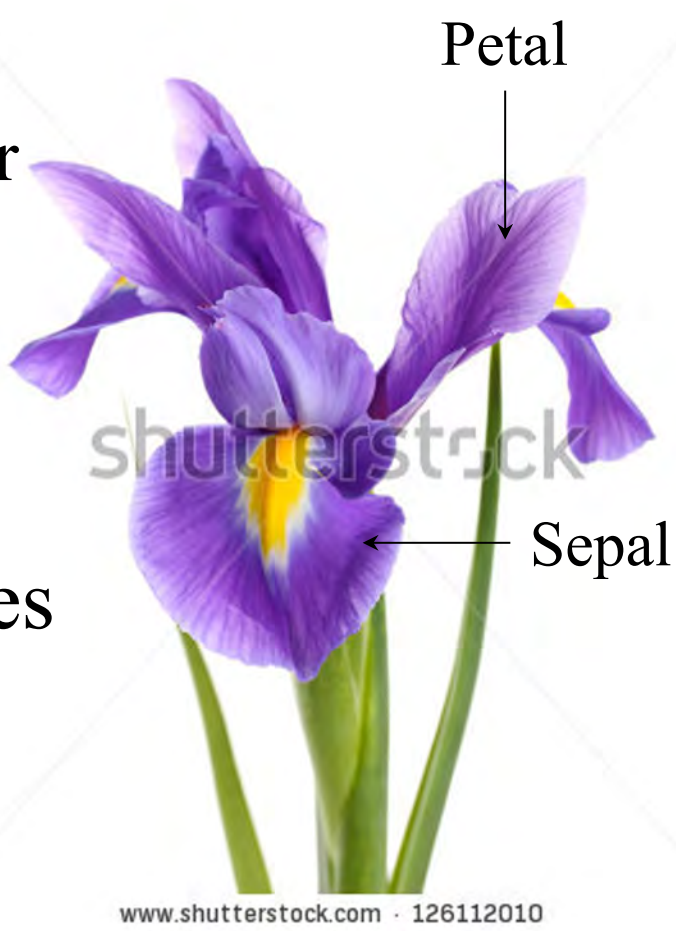
Four features measured:

- Sepal width and length
- Petal width and length

Is it possible to distinguish species using physical measurements?

- Data is packaged with R: "iris"

wikipedia.org/



Print

> iris *# = prints out the data set. Ok for small data sets*

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5.0	3.4	1.5	0.2	setosa
9	4.4	2.9	1.4	0.2	setosa
10	4.9	3.1	1.5	0.1	setosa
11	5.4	3.7	1.5	0.2	setosa
12	4.8	3.4	1.6	0.2	setosa
13	4.8	3.0	1.4	0.1	setosa
14	4.3	3.0	1.1	0.1	setosa
15	5.8	4.0	1.2	0.2	setosa
...					

Row numbers

Numeric data

Factor

Question 8

How many dimensions in the Iris data?

A. 1
B. 2
C. 3
D. 4
E. More than 4

Dimension, column names, structure

```
> dim(iris)
[1] 150 5
> names(iris)
[1] "Sepal.Length" "Sepal.Width" "Petal.Length" "Petal.Width"
"Species"
> str(iris)
'data.frame': 150 obs. of 5 variables:
$ Sepal.Length: num 5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
$ Sepal.Width : num 3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
$ Petal.Length: num 1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
$ Petal.Width : num 0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
$ Species : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1
1 1 1 1 ...
```

Print head and tail

> head(iris)

```
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
```

> tail(iris)

```
    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
145          6.7         3.3          5.7         2.5 virginica
146          6.7         3.0          5.2         2.3 virginica
147          6.3         2.5          5.0         1.9 virginica
148          6.5         3.0          5.2         2.0 virginica
149          6.2         3.4          5.4         2.3 virginica
150          5.9         3.0          5.1         1.8 virginica
```

Selection of rows and/or columns

Use this syntax: DataFrame[rows,columns].
Blank means select all rows/columns.

```
> iris[10:15,] # multiple rows
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
10          4.9         3.1          1.5         0.1  setosa
11          5.4         3.7          1.5         0.2  setosa
12          4.8         3.4          1.6         0.2  setosa
13          4.8         3.0          1.4         0.1  setosa
14          4.3         3.0          1.1         0.1  setosa
15          5.8         4.0          1.2         0.2  setosa
```

```
> iris[11,] # single row
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
11          5.4         3.7          1.5         0.2  setosa
```

Part of a single column

```
> iris[10:20, "Sepal.Length"] # identify column by name
[1] 4.9 5.4 4.8 4.8 4.3 5.8 5.7 5.4 5.1 5.7 5.1
> # or
> iris[10:20,1] # identify column by number
> [1] 4.9 5.4 4.8 4.8 4.3 5.8 5.7 5.4 5.1 5.7 5.1
> # or
> iris$Sepal.Length[10:20] # identify column first then
  select rows
> [1] 4.9 5.4 4.8 4.8 4.3 5.8 5.7 5.4 5.1 5.7 5.1
```

Summary

Create a mean + 5-point summary of each numerical column, and list of types for factors.

```
> summary(iris)
```

```
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width          Species
Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100   setosa     :50
1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300   versicolor:50
Median :5.800   Median :3.000   Median :4.350   Median :1.300   virginica :50
Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
```

The real irises

dataaspirant.com/

Question 9

Which species is easiest to differentiate?

A. versicolor
B. virginica
C. setosa
D. Too hard to tell.

Class activity

The data set ‘mpg’ is contained in the ggplot2 package. Let’s get to know it (how many dimensions, types of variables, range etc.) without any graphics.

```
> ?mpg # information about the data
> head(mpg)
> Str(mpg)
> summary(mpg)
> tail(mpg)
> unique(mpg$column) #particular columns
```

- See worksheet (MPG Summary) on Moodle

Class activity

```
> str(mpg)
Classes 'tbl_df', 'tbl' and 'data.frame':      234 obs. of  11 variables:
 $ manufacturer: chr  "audi" "audi" "audi" "audi" ...
 $ model       : chr  "a4" "a4" "a4" "a4" ...
 $ displ       : num  1.8 1.8 2 2 2.8 2.8 3.1 1.8 1.8 2 ...
 $ year        : int  1999 1999 2008 2008 1999 1999 2008 1999 1999 2008 ...
 $ cyl         : int  4 4 4 4 6 6 6 4 4 4 ...
 $ trans       : chr  "auto(l5)" "manual(m5)" "manual(m6)" "auto(av)" ...
 $ drv         : chr  "f" "f" "f" "f" ...
 $ cty         : int  18 21 20 21 16 18 18 18 16 20 ...
 $ hwy         : int  29 29 31 30 26 26 27 26 25 28 ...
 $ fl          : chr  "p" "p" "p" "p" ...
 $ class       : chr  "compact" "compact" "compact" "compact" ...

> head(mpg)
# A tibble: 6 x 11
  manufacturer model displ  year   cyl      trans   drv   cty   hwy
         <chr> <chr> <dbl> <int> <int>      <chr> <chr> <int> <int>
1         audi    a4   1.8  1999     4   auto(l5)     f    18    29
2         audi    a4   1.8  1999     4 manual(m5)     f    21    29
3         audi    a4   2.0  2008     4 manual(m6)     f    20    31
4         audi    a4   2.0  2008     4   auto(av)     f    21    30
5         audi    a4   2.8  1999     6   auto(l5)     f    16    26
6         audi    a4   2.8  1999     6 manual(m5)     f    18    26
# ... with 2 more variables: fl <chr>, class <chr>
```

Class activity

```
> summary(mpg)
 manufacturer          model               displ            year
 Length:234         Length:234         Min.   :1.600   Min.   :1999
 Class :character   Class :character   1st Qu.:2.400   1st Qu.:1999
 Mode  :character   Mode  :character   Median :3.300   Median :2004
                                       Mean   :3.472   Mean   :2004
                                       3rd Qu.:4.600   3rd Qu.:2008
                                       Max.   :7.000   Max.   :2008
      cyl            trans               drv
 Min.   :4.000   Length:234         Length:234
 1st Qu.:4.000   Class :character   Class :character
 Median :6.000   Mode  :character   Mode  :character
 Mean   :5.889
 3rd Qu.:8.000
 Max.   :8.000
      cty             hwy              fl
 Min.   : 9.00   Min.   :12.00   Length:234
 1st Qu.:14.00   1st Qu.:18.00   Class :character
 Median :17.00   Median :24.00   Mode  :character
 Mean   :16.86   Mean   :23.44
 3rd Qu.:19.00   3rd Qu.:27.00
 Max.   :35.00   Max.   :44.00
    class
 Length:234
 Class :character
 Mode  :character
```

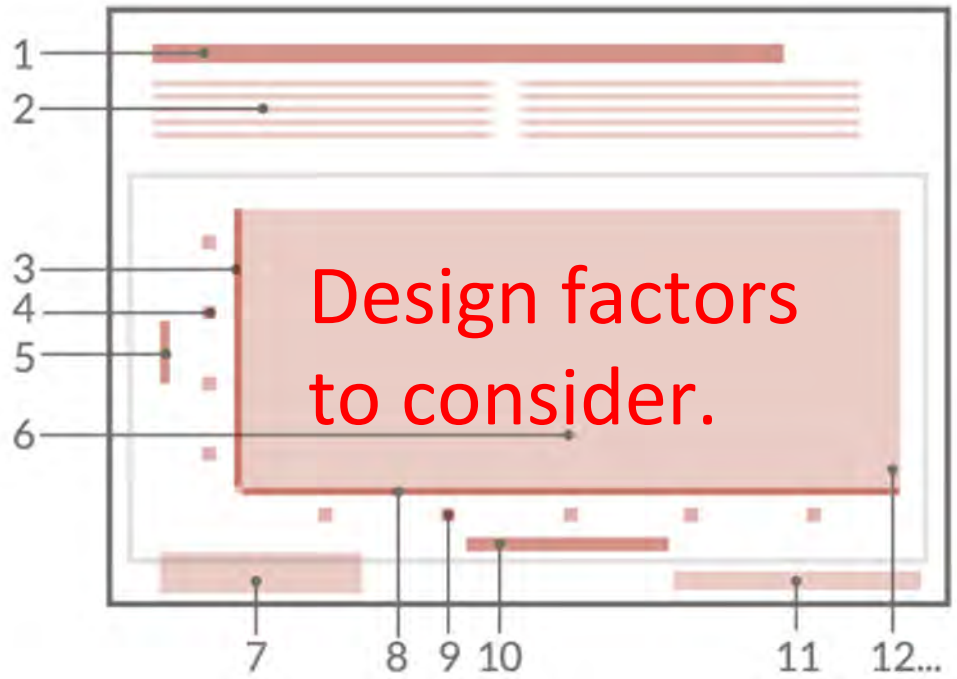
Class activity

```
> tail(mpg)
# A tibble: 6 x 11
  manufacturer  model displ  year   cyl      trans   drv   cty   hwy
         <chr>  <chr> <dbl> <int> <int>      <chr> <chr> <int> <int>
1   volkswagen passat   1.8  1999     4   auto(l5)     f    18    29
2   volkswagen passat   2.0  2008     4   auto(s6)     f    19    28
3   volkswagen passat   2.0  2008     4 manual(m6)     f    21    29
4   volkswagen passat   2.8  1999     6   auto(l5)     f    16    26
5   volkswagen passat   2.8  1999     6 manual(m5)     f    18    26
6   volkswagen passat   3.6  2008     6   auto(s6)     f    17    26
# ... with 2 more variables: fl <chr>, class <chr>

> unique(mpg$manufacturer)
 [1] "audi"       "chevrolet"  "dodge"      "ford"       "honda"
 [6] "hyundai"    "jeep"       "land rover" "lincoln"    "mercury"
[11] "nissan"     "pontiac"    "subaru"     "toyota"     "volkswagen"
```

Graphing your data in R

Elements of a figure



Typical elements: title (1), subtitle (2), y-axis (3), label (4), name (5), data area (6), legend (7), X-axis (8), label (9), and name (10), sources (11). Further elements: annotations/lines/symbols (12).

Thomas Rahlf: Data Visualisation with R

Base graphics

These are the graphic functions built into the basic R installation.

- High level graphic functions create new graphs with axis, labels and titles.
- Low level graphic functions then annotate plots with points, lines and text.

Useful references:

- A Tiny Handbook of R, Chapter 3.
- Also, Exploratory Analysis with R, Chapter 9:

https://bookdown.org/rdpeng/exdata/the-base-plotting-system-1.html

Base graphics: high level functions

Some or the more common plot types are:

> plot *# Scatterplot*
> pairs *# Scatterplot matrix*
> hist *# Histogram*
> stem *# Stem-and-leaf plot*
> boxplot *# Box-and-whisker plot*
> barplot *# Bar plot*
> dotchart *# Dot plot*

- See ATHR page 49

Base graphics: low level functions

Some low-level plotting functions include:

> lines *# Draw lines between given coordinates*

> text *# Draw text at given coordinates*

> abline *# Line y = ax + b, horizontal or vertical*

> axis *# Add an axis*

> arrows *# Draw arrows*

> grid *# Add a rectangular grid*

> legend *# Add a legend (a key)*

- See ATHR page 50

Base graphics: graphics parameters

Some low-level additions/controls include:

> main *# Title of the plot*

> ylab, xlab *# Labels for the y-axis and x-axis*

> type *# Plot type (points, lines, both, ...),*

> pch *# Plot character (circles, dots, , symbols, ...)*

> lty *# Line type (solid, dots, dashes, ...)*

> lwd *# Line width*

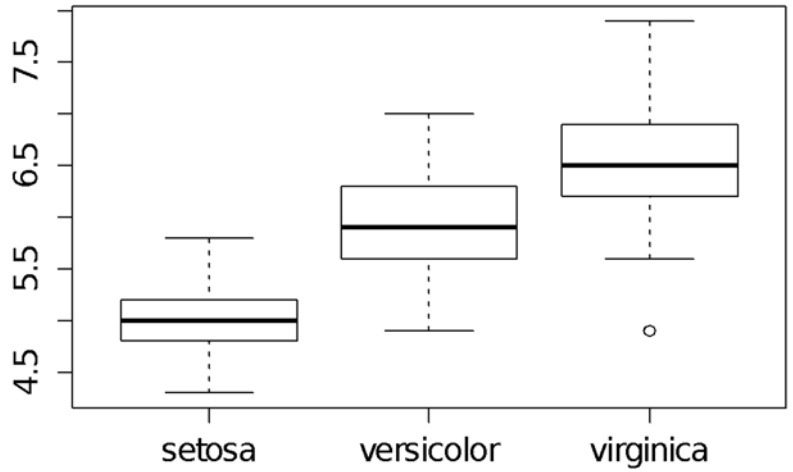
> col *# Colour of plot characters… and many others*

- See ATHR page 50

Boxplot

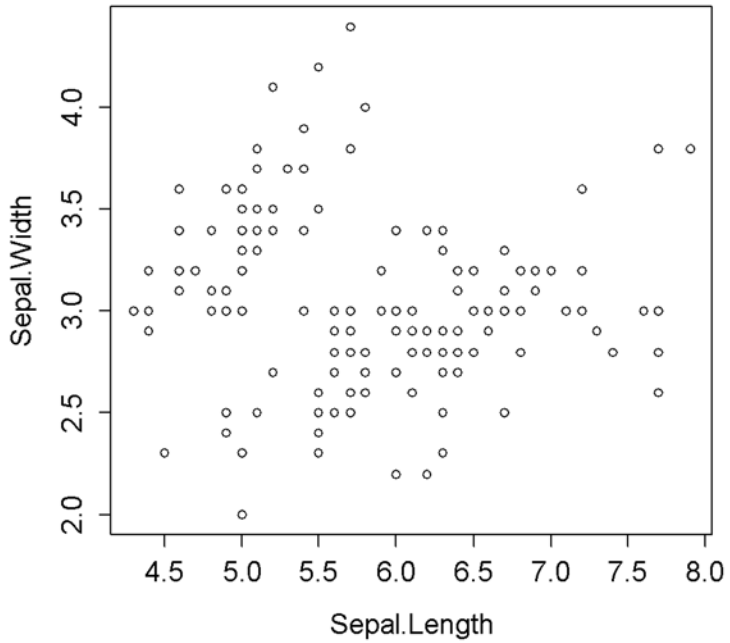
Each variable can be viewed as a boxplot distinguished by level:

```
> boxplot(Sepal.Length ~ Species, data = iris)
> # note ~ indicates grouping variable
```



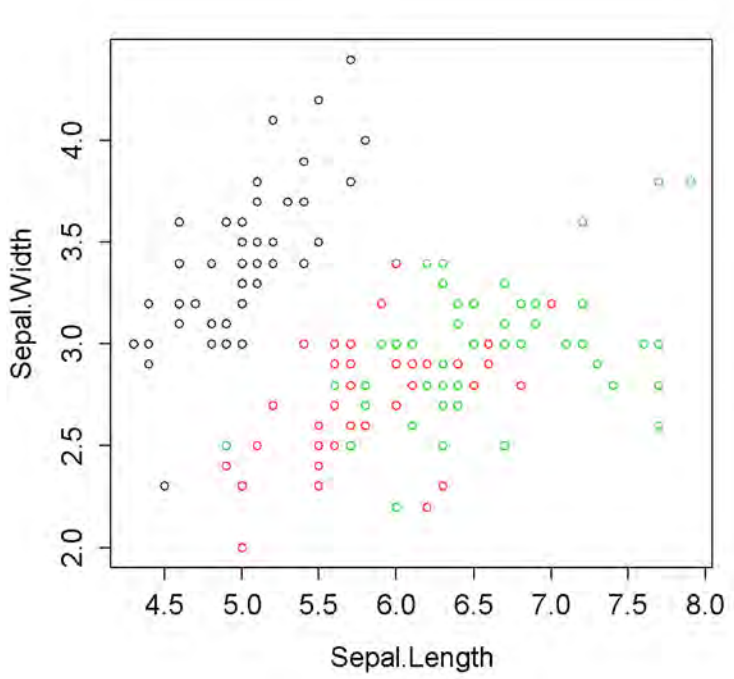
Scatterplot

```
> with(iris, plot(Sepal.Length, Sepal.Width))
> # using 'with' simplifies column names etc.
> # another alternative is to "attach"
```



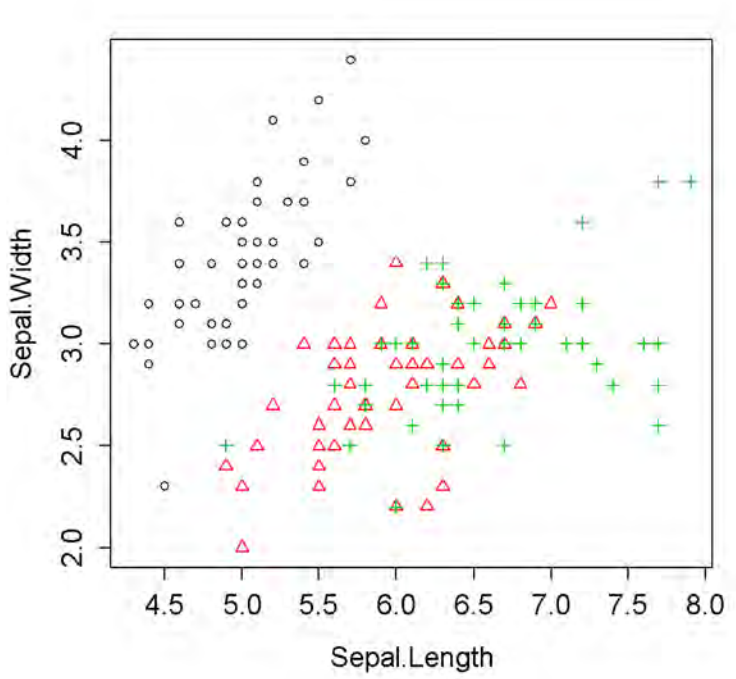
Scatterplot + colour

> with(iris, plot(Sepal.Length, Sepal.Width, col = Species))



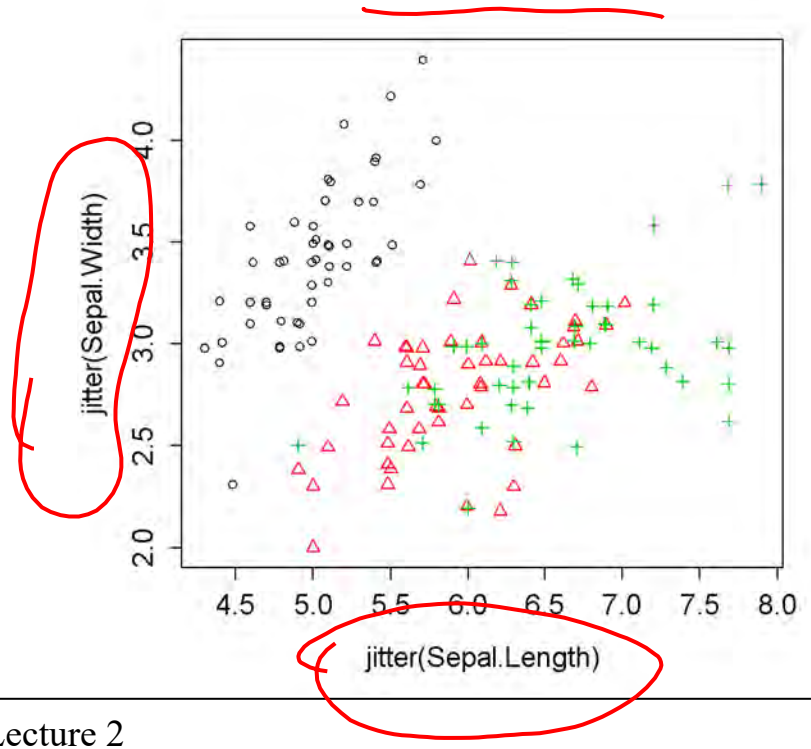
Scatterplot + plot symbol

> with(iris, plot(Sepal.Length, Sepal.Width, col = Species, pch=as.numeric(Species)))



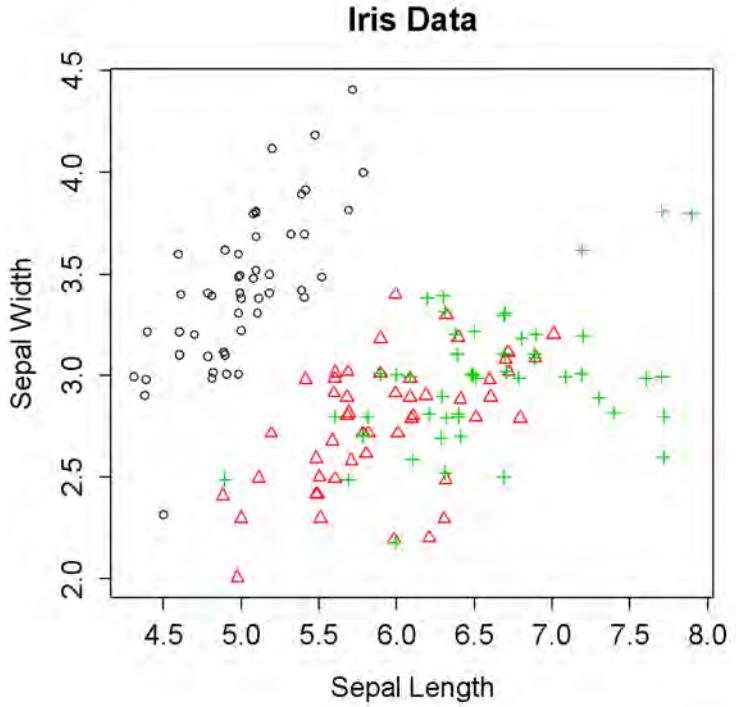
Scatterplot + jitter

```
> with(iris, plot(jitter(Sepal.Length), jitter(Sepal.Width),
  col = Species, pch=as.numeric(Species)))
> # jittering reveals some of the overlapping data points
```



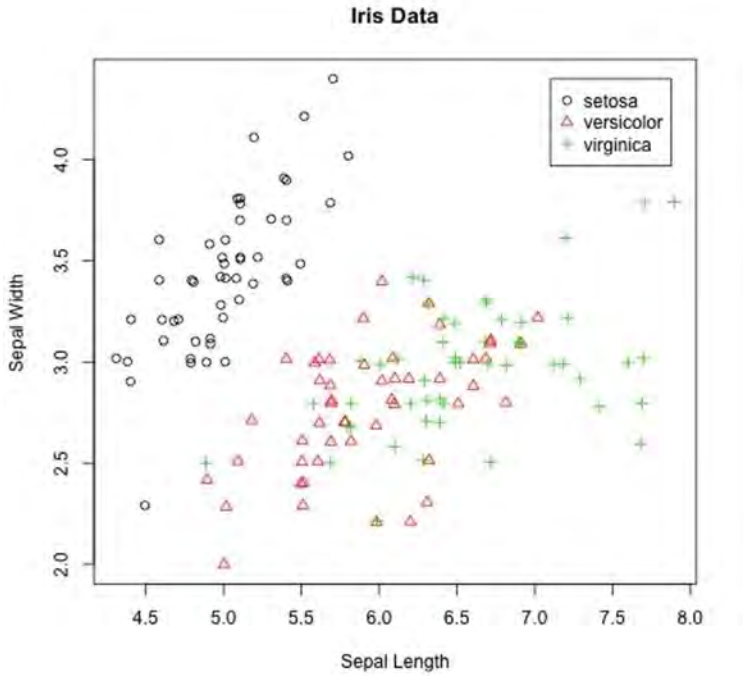
Scatterplot + labels

```
> with(iris, plot(jitter(Sepal.Length), jitter(Sepal.Width),
  col = Species, pch=as.numeric(Species), main = ("Iris
  Data"), xlab = "Sepal Length", ylab = ("Sepal Width")))
```



Scatterplot + legend

```
> # Follow the plot command with:
> with(iris, legend(7.1, 4.4, as.vector(unique(Species)),
  pch=unique(Species), col = unique(Species)))
```



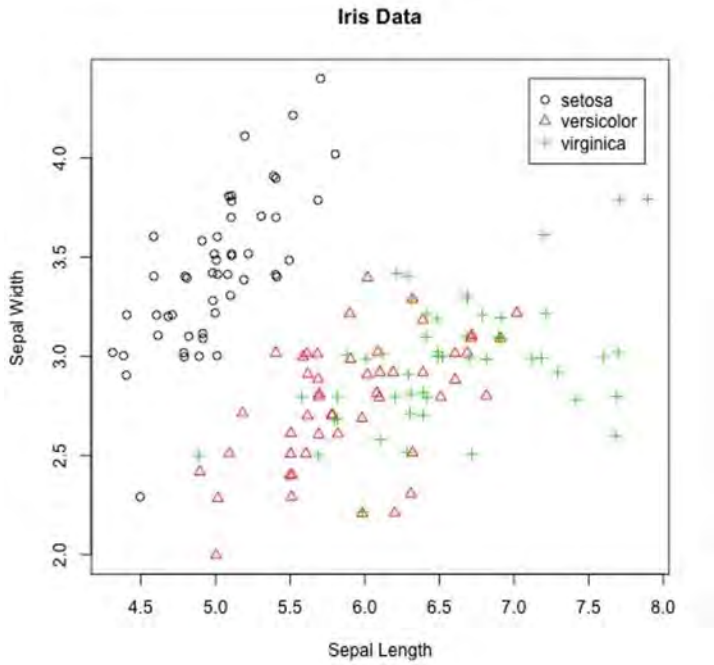
Complete plot command

```
> with(iris, plot(jitter(Sepal.Length), jitter(Sepal.Width),
  col = Species, pch=as.numeric(Species), main = ("Iris
  Data"), xlab = "Sepal Length", ylab = ("Sepal Width")))
> with(iris, legend(7.1, 4.4, as.vector(unique(Species)),
  pch=unique(Species), col = unique(Species)))
```

Question 10

Which species is easiest to differentiate based on sepal size and shape?

A. versicolor
B. virginica
C. setosa
D. Too hard to tell.



Saving graphics

Diverting graphics from RStudio to a file:

- The code below opens a file, diverts the output from RStudio to a named file (of type jpg in this case) and saves it in the working directory.

```
> jpeg("filename.jpg")
> plot(x,y) # put your plotting commands here
> dev.off()
```

- A simpler method is to use "Export" command under the plot tile in the "help/display" window in Rstudio.

Visualising more variables: lattice

The lattice package has multi-panel graphing functions conditioned on variables, including:

> xyplot *# Multi-panel conditioning scatterplot*
> barchart *# Bar plot*
> dotplot *# Dot plot*
> splom *# Scatterplot matrix*
> bwplot *# Box-and-whisker plot*
> histogram *# Histogram*
> densityplot *# Smoothed histogram*

- See ATHR page 54

lattice

The lattice package comes with the base installation of R.

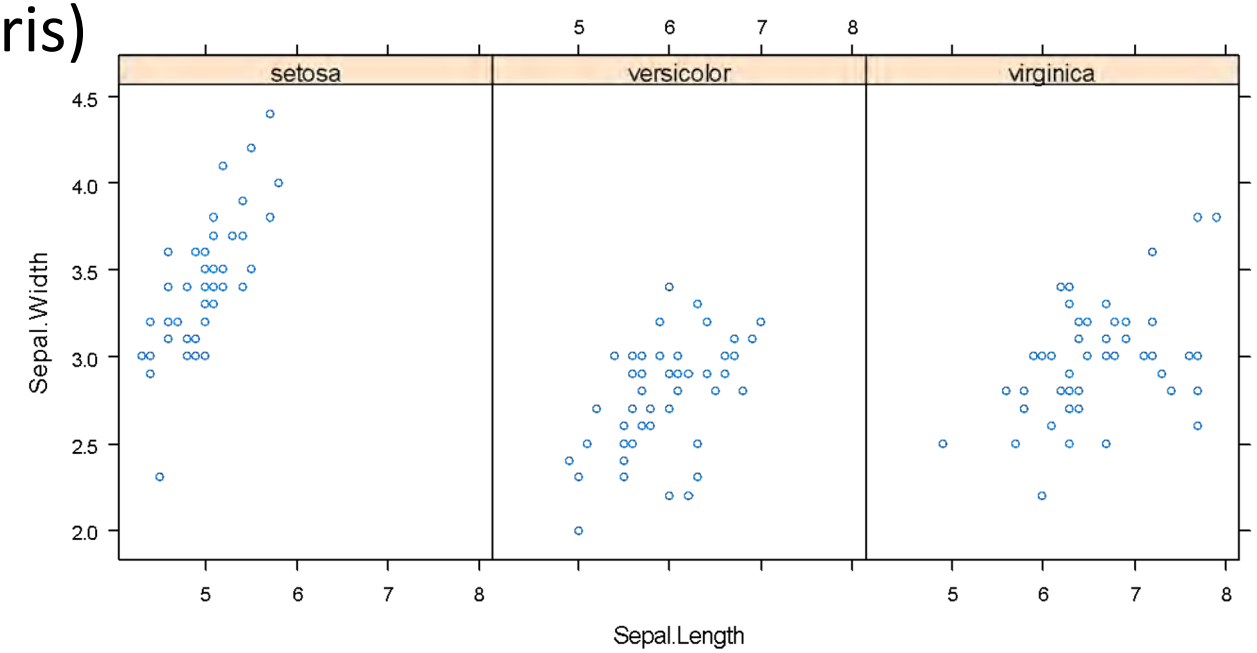
To run add it to the library of packages in the current environment:

```
> library(lattice)
```

xyplot

Conditioning on species:

- Syntax: xyplot(y ~ x | g) : *plot y on x grouped by g*
  - > xyplot(Sepal.Width ~ Sepal.Length | Species, data = iris)

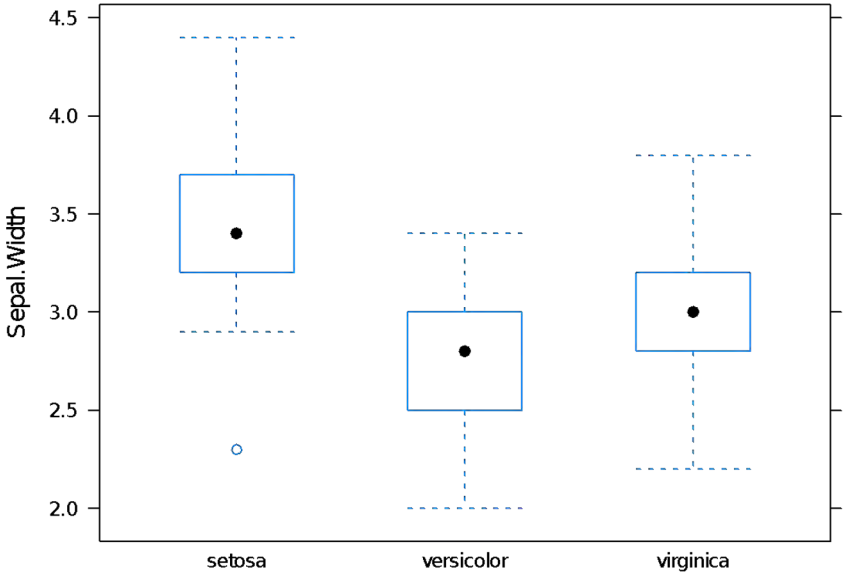


bwplot

Conditioning on species:

- Syntax: bwplot(y ~ g) : *plot y grouped by g*

  > bwplot(Sepal.Width ~ Species, data = iris)



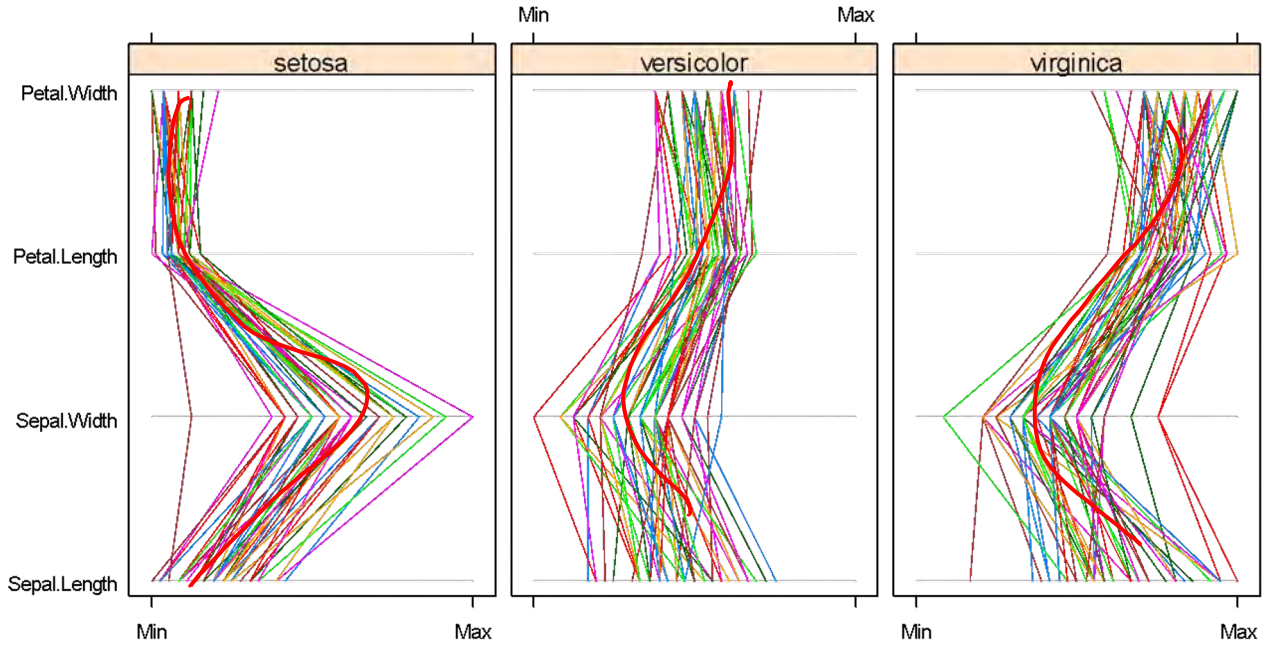
Parallel coordinates

The main reason we still use lattice

Each data point plotted across 4 numeric variables

- Syntax: parallelplot(~y|g): *plot columns y grouped by g*

  > parallelplot(~iris[1:4] | Species, data = iris)



Presentation quality graphs

ggplot2

- One of the most commonly used packages for display quality graphics.
- Written by Hadley Wickham and Winston Chang, it is an implementation of *The Grammar of Graphics* by Leland Wilkinson and views a graphic as being made up of data points + scales + annotations + statistical summaries… in a structured way, a grammar. See:

http://vita.had.co.nz/papers/layered-grammar.pdf

ggplot2: graphic objects

Some main classes of graphic objects:

- Geoms (geometric objects: think of as type of plot)
- Statistics (summaries, data transformations)
- Scales/coordinate systems
- Faceting (conditional grouping of subsets of data)
- Position adjustments (jitter etc.)
- Annotation
- Aesthetics (colours, line styles etc.)

ggplot2

To install package and add to library:

```
> install.packages("ggplot2")
> library(ggplot2)
```

?qplot (from R help)

- Quick plot

  ```
  qplot is the basic plotting function in the
  ggplot2 package ...
  ```

- Usage

  ```
  qplot(x, y = NULL, ..., data, facets = NULL,
  margins = FALSE, geom = "auto",
  stat = list(NULL), position = list(NULL),
  xlim = c(NA, NA), ylim = c(NA, NA),
  log = "", main = NULL,
  xlab = deparse(substitute(x)),
  ylab = deparse(substitute(y)), asp = NA)
  ```

?qplot

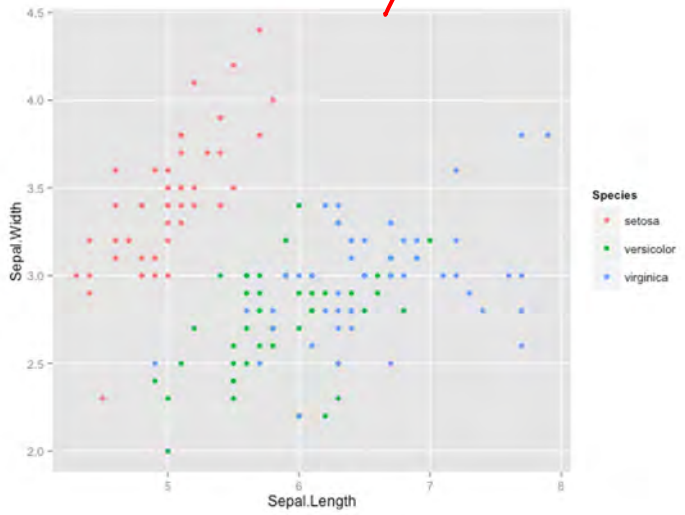
- Arguments

```
x, y
...
data
facets
margins
geom
stat
position
xlim, ylim
log
main
xlab, ylab, asp
```

Basic qplot

You can very quickly create a basic plot:

```
> qplot(Sepal.Length, Sepal.Width, data = iris, color =
  Species)
```

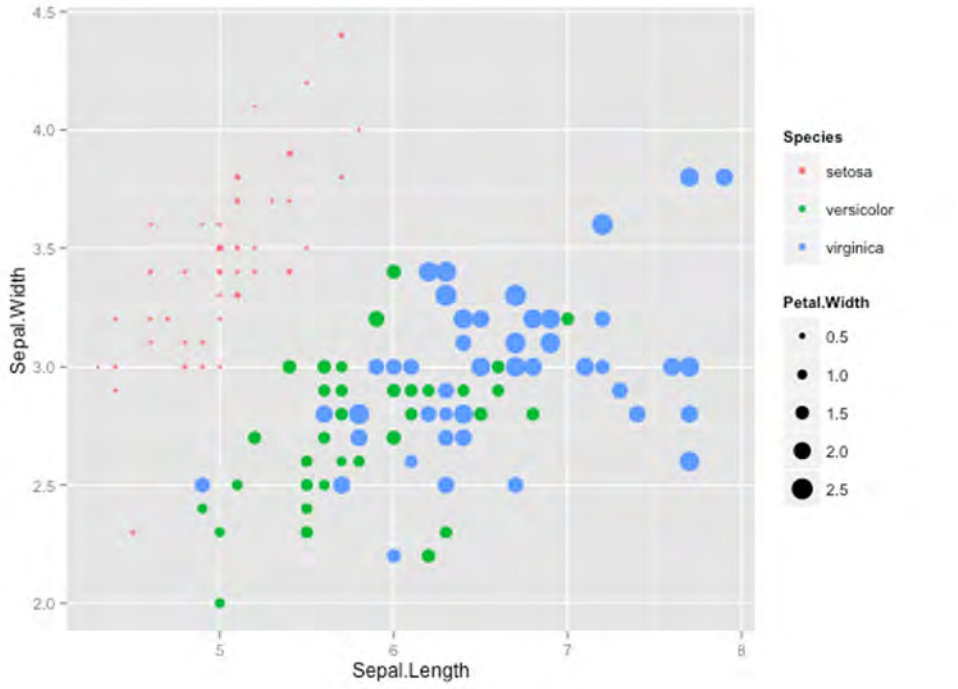


You can add additional dimensions to the plot by specifying other features of each point.

Basic qplot + size

Use size to show petal width

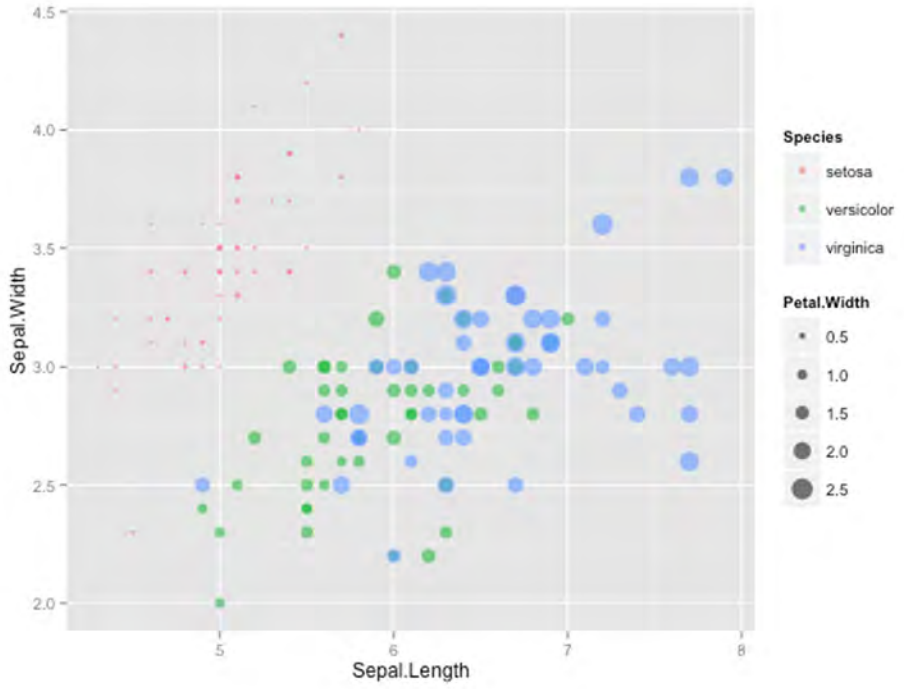
> qplot(Sepal.Length, Sepal.Width, data = iris, color = Species, size = Petal.Width)



Basic qplot + size + alpha channel

Use transparency to reveal overlapping points

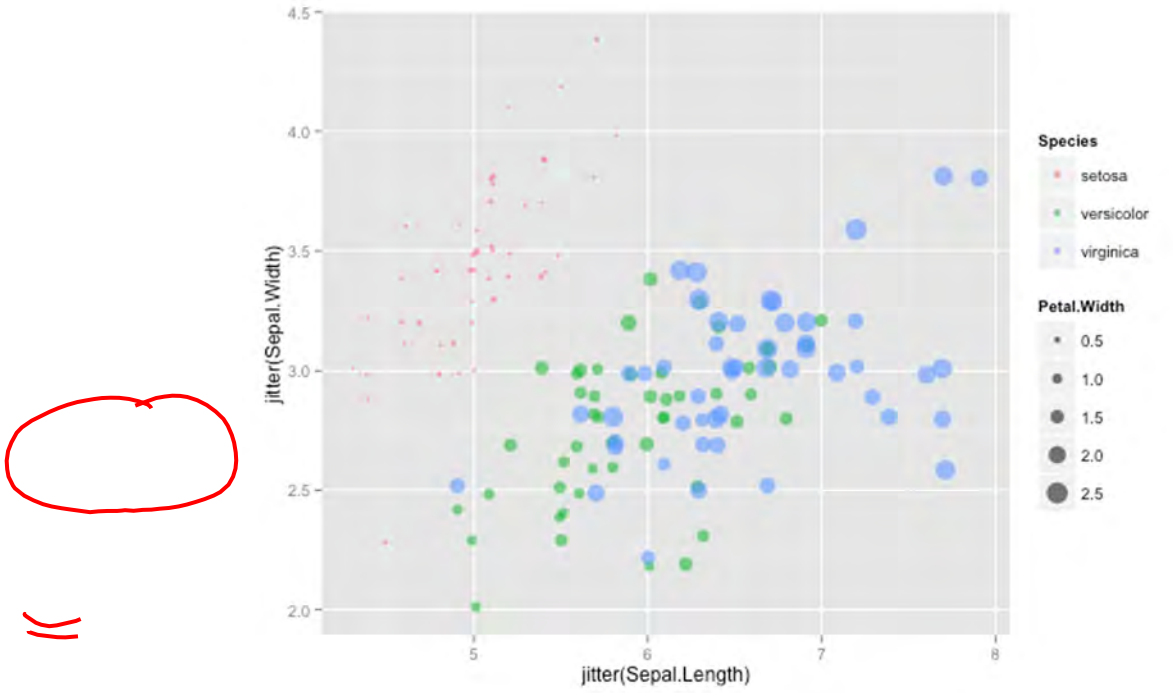
> qplot(Sepal.Length, Sepal.Width, data = iris, color = Species, size = Petal.Width, alpha = I(0.6))



... + jitter

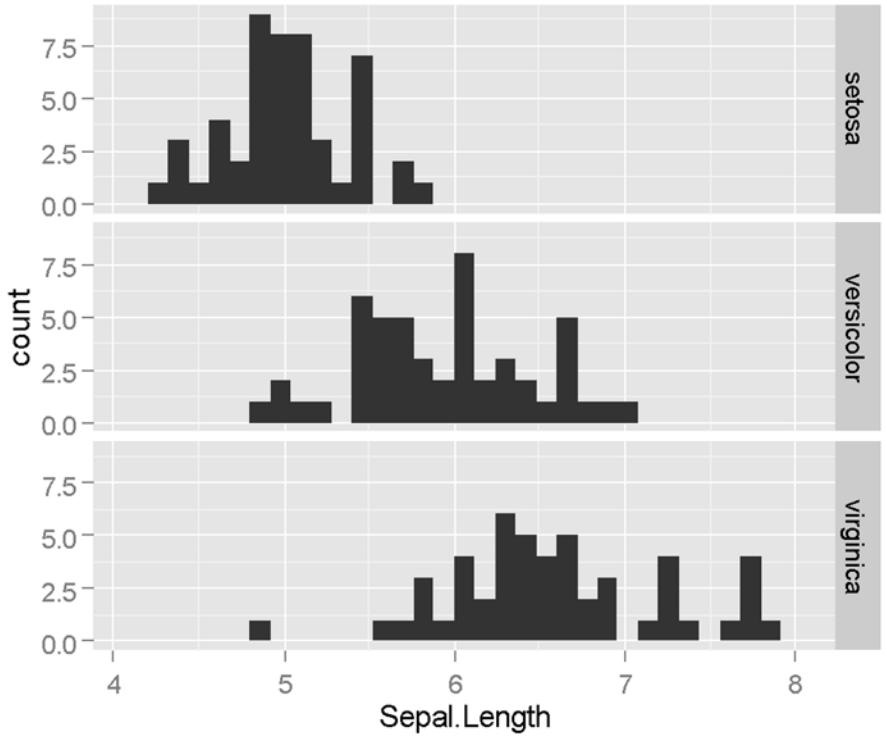
Use jitter to separate the points slightly

> qplot(jitter(Sepal.Length), jitter(Sepal.Width), data = iris, color = Species, size = Petal.Width, alpha = I(0.6))



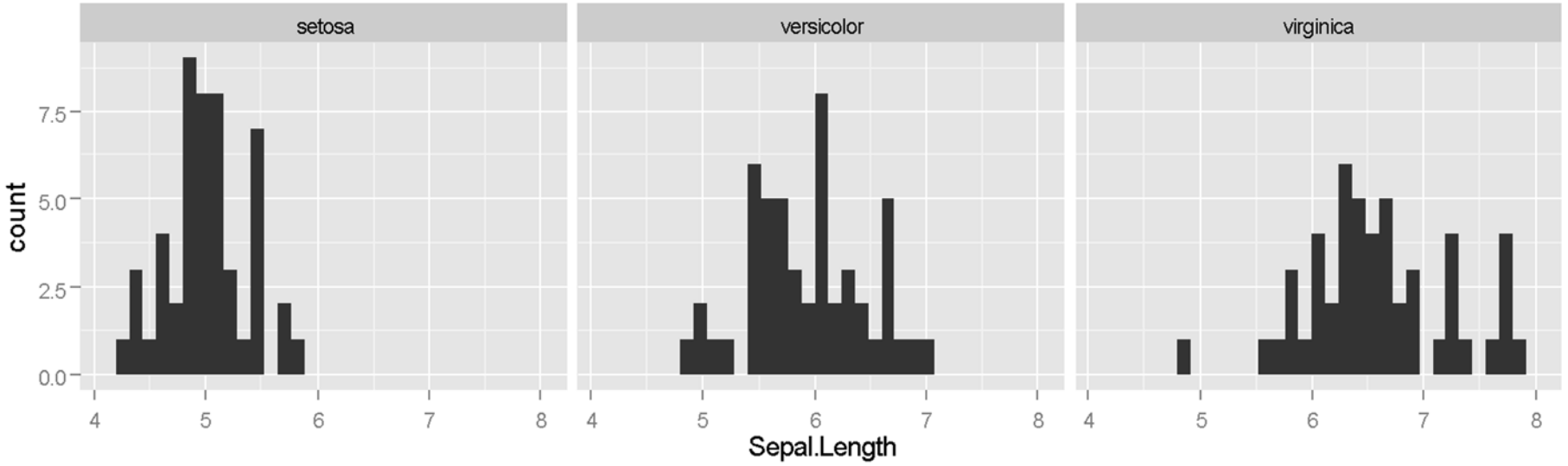
Histogram + facets

```
> qplot(Sepal.Length, data = iris, geom = "histogram",
  facets = Species ~ .)
```



Histogram + facet_wrap

```
> qplot(Sepal.Length, data = iris, geom = "histogram",
  facets = Species ~ .) + facet_wrap(~ Species, ncol = 3)
```



Creating plots by name

To improve your graphs first define them by name (as a graph object)

- You can progressively add features.
- Use a script to make this process easier.

For the previous plot:

```
> g <- qplot(Sepal.Length, data = iris, geom =
  "histogram", facets = Species ~ .)
> g <- g + facet_wrap(~ Species, ncol = 3)
> g # this displays the plot
```

ggplot2: Grammar

Graphs are constructed first with a

- Geom, which specifies the type of plot and the data

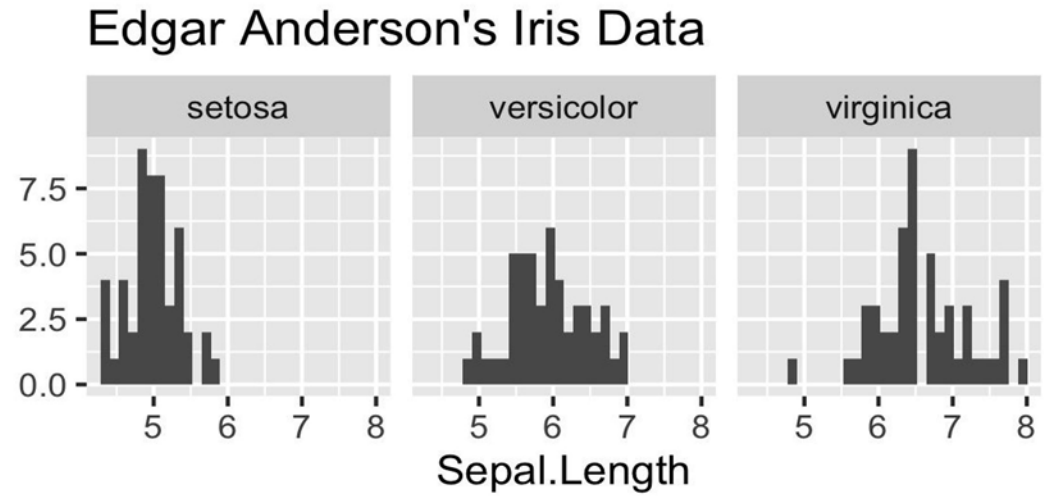
Following this, aesthetic elements are added

- Statistics (summaries, data transformations)
- Scales/coordinate systems
- Faceting (conditional grouping of subsets of data)
- Position adjustments (jitter etc.)
- Annotation
- Aesthetics

Adding a title and saving

To add a title, and save:

```
>  …
>  g <- g + ggtitle("Edgar Anderson's Iris Data")
>  ggsave("EAI.jpg", g, width = 10, height = 5, units = "cm")
```



Viewing correlation between variables

Correlation:

- Gives us an idea of the strength of the (linear) relationship between variables.
- Knowing the strength of this relationship lets us reduce the number of variables we need to analyse. That is, *if two variables are strongly correlated, we may only need to analyse one of them!*
- We'll look at several options for viewing the correlation between variables.

Correlation matrix

The pairwise correlation between each numeric variable

```
> round(cor(iris[1:4]), digits = 3)
```

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width
Sepal.Length	1.000	-0.118	0.872	0.818
Sepal.Width	-0.118	1.000	-0.428	-0.366
Petal.Length	0.872	-0.428	1.000	0.963
Petal.Width	0.818	-0.366	0.963	1.000

Correlation matrix – by factor

Pairwise correlation by species

```
> by(iris[1:4], factor(iris$Species), cor)
```

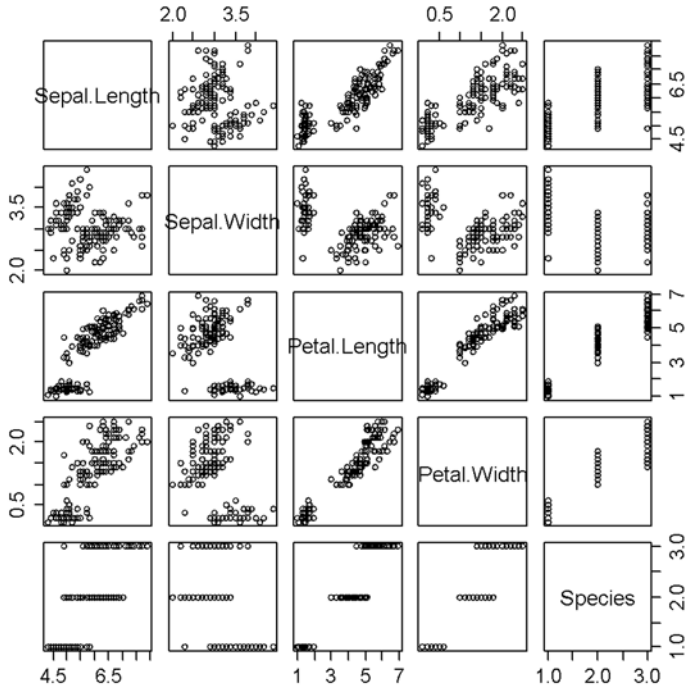
"by" function is very useful!

```
factor(iris$Species): setosa
             Sepal.Length Sepal.Width Petal.Length Petal.Width
Sepal.Length    1.0000000   0.7425467    0.2671758   0.2780984
Sepal.Width     0.7425467   1.0000000    0.1777000   0.2327520
Petal.Length    0.2671758   0.1777000    1.0000000   0.3316300
Petal.Width     0.2780984   0.2327520    0.3316300   1.0000000
------------------------------------------------------------
factor(iris$Species): versicolor
             Sepal.Length Sepal.Width Petal.Length Petal.Width
Sepal.Length    1.0000000   0.5259107    0.7540490   0.5464611
Sepal.Width     0.5259107   1.0000000    0.5605221   0.6639987
Petal.Length    0.7540490   0.5605221    1.0000000   0.7866681
Petal.Width     0.5464611   0.6639987    0.7866681   1.0000000
------------------------------------------------------------
factor(iris$Species): virginica
             Sepal.Length Sepal.Width Petal.Length Petal.Width
Sepal.Length    1.0000000   0.4572278    0.8642247   0.2811077
Sepal.Width     0.4572278   1.0000000    0.4010446   0.5377280
Petal.Length    0.8642247   0.4010446    1.0000000   0.3221082
Petal.Width     0.2811077   0.5377280    0.3221082   1.0000000
```

All interactions: scatterplot matrix

The default method for a scatterplot matrix using base graphics is

```
> pairs(iris)
```

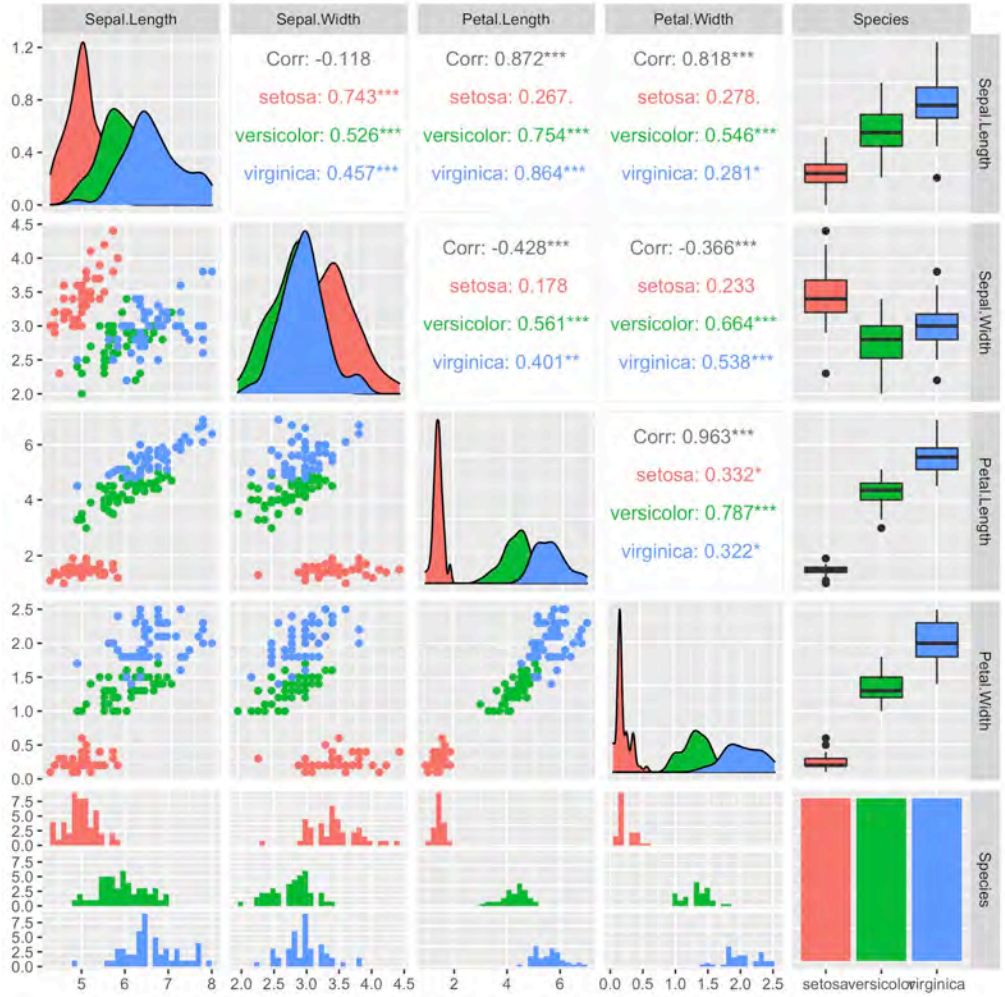


All interactions & summary

Using the package GGally to extend ggplot:

```
> install.packages("GGally")
> library(GGally)
> g = ggpairs(iris, ggplot2::aes(color = Species))
> g
> ggsave("Iris Multi Plot.jpg", g, width = 20, height = 20, units = "cm")
```

All interactions & summary



Scripts

Scripts allow you to save your working from session to session.

- Use them to automate environment settings etc.
- Create a new script: File > New File > R Script
- Save with a filename
- Use “Source” to evaluate on the fly
- Note: # comments, pre-emptive text
- Next slide shows previous example as a script…

Scripts: example from today's lecture

Lecture 02.R

Source on Save

```
1  # LECTURE 2 examples
2  rm(list = ls()) #clean up environment
3  #install.packages("ggplot2")
4  #install.packages("lattice")
5  #install.packages("GGally")
6  library(ggplot2); library(lattice); library(GGally)
7
8  g <- qplot(Sepal.Length, data = iris, geom = "histogram", facets = Species ~ .)
9  g <- g + facet_wrap(~ Species, ncol = 3)
10 g <- g + ggtitle("Edgar Anderson's Iris Data")
11 g
12 ggsave("Edgar Anderson's Iris Data.jpg", g, width = 10, height = 5, units = "cm")
13
14
15
```

Summary

Visualising data

- Recent examples
- Inspiration

Visualisation using R

- First steps: getting to know a data set
- Graphing your data in R
- Visualising more variables
- Presentation quality graphics

Reference: *ggplot2*

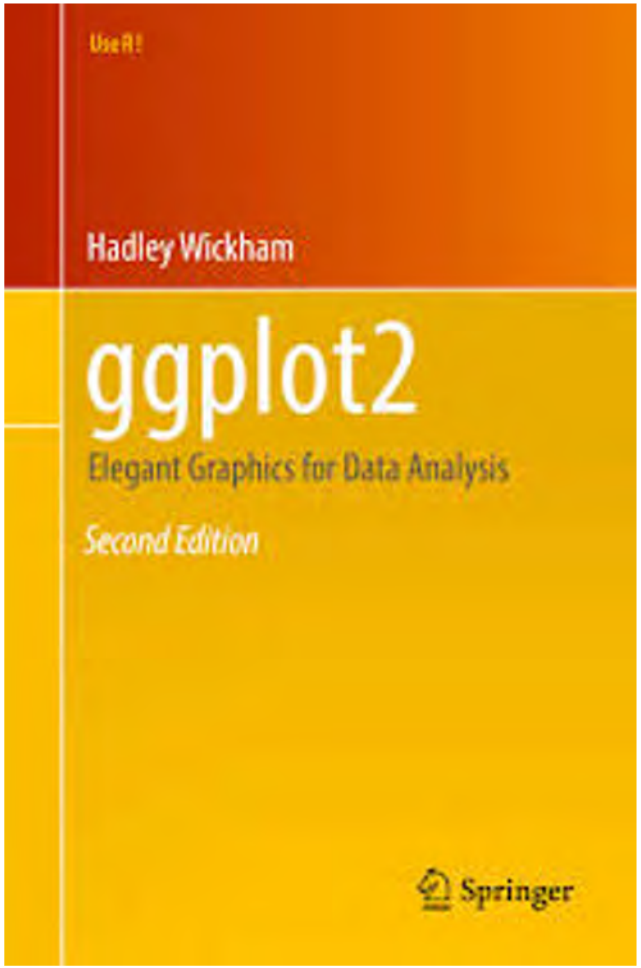
Access book via Monash library, or help from links below:

- ggplot2 is a plotting system for R, based on the grammar of graphics.

https://ggplot2.tidyverse.org/

- Online help links from main page and is a useful reference. Many examples with code are given.

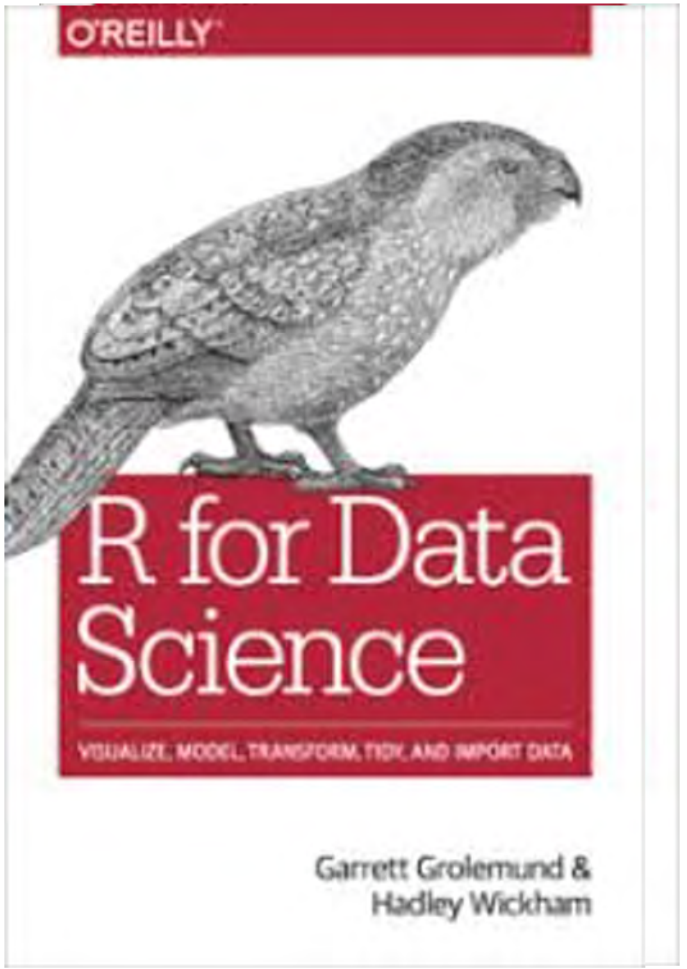
https://ggplot2.tidyverse.org/reference/



Reference: *R for Data Science*

- A physical and web-based book by the author of ggplot2, Hadley Wickham, and Garrett Grolemund: https://r4ds.had.co.nz/
- The book takes you through all aspects of the data science workflow.
- Good chapter on ggplot2, (Ch. 3) including the syntax for all plot types, for example:

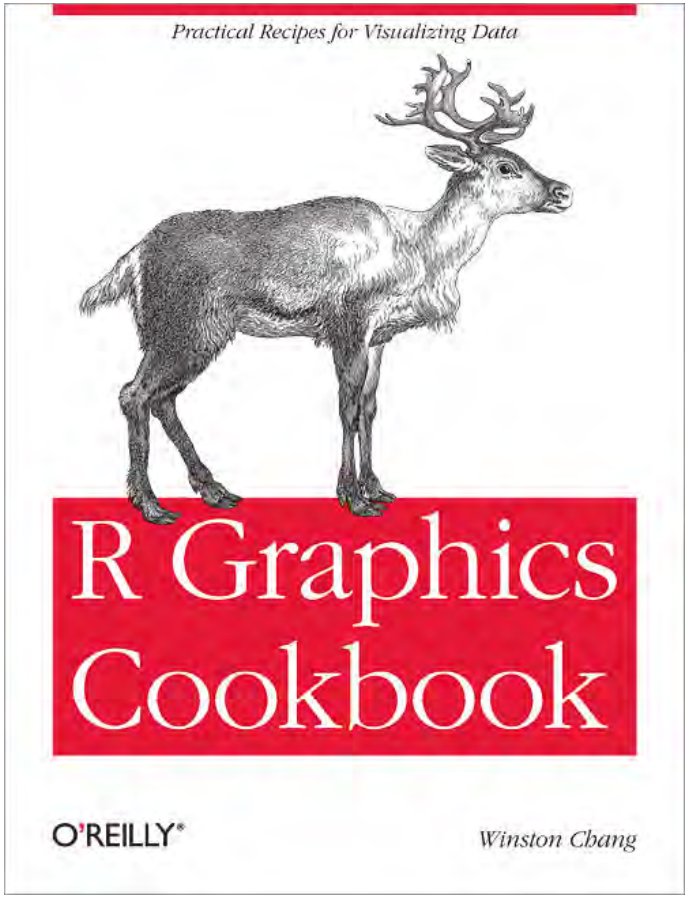
```
> ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping =
  aes(<MAPPINGS>))
```



Reference: *R Graphics Cookbook*

- The R Graphics Cookbook has 150 recipes for graph drawing.
- It covers ggplot and base graphics.
- It explains the reasoning behind the recipe.
- Available online for free at

r-graphics.org/



Next Week: Data manipulation in R

Read this week:

- A tour through the visualization zoo,
- R for Data Science, Chapter 3,
- Lecture 3 pre-reading.

References

Books – online from the Monash Library

- Wickham, H., ggplot2 elegant graphics for data analysis
- Wilkinson, L., and Wills, G., The grammar of graphics
- Rahlf, T., Data visualisation with R, Springer.

R for data science https://r4ds.had.co.nz/

R Graphics Cookbook r-graphics.org/

Paper by Wickham: Layered grammar of graphics
http://vita.had.co.nz/papers/layered-grammar.pdf

A tour through the visualization zoo
https://dl.acm.org/doi/10.1145/1743546.1743567

ggplot2 Cheat Sheet
https://github.com/rstudio/cheatsheets/blob/main/data-visualization-2.1.pdf