How to effectively use visualisation while doing Exploratory Data Analysis

Kaspar Märtens

18 October 2018

Today:

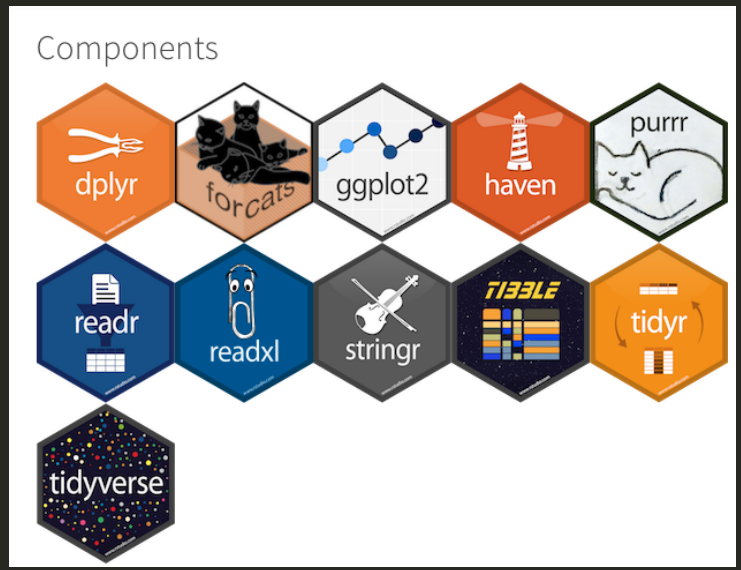
1. Why I think R is really great
2. Why visualise data at all?
3. Good practices and design choices involved when making graphs
4. Focus on the use of visualisations as part of data exploration -- ggplot2 is especially useful for this

Why I think R is great

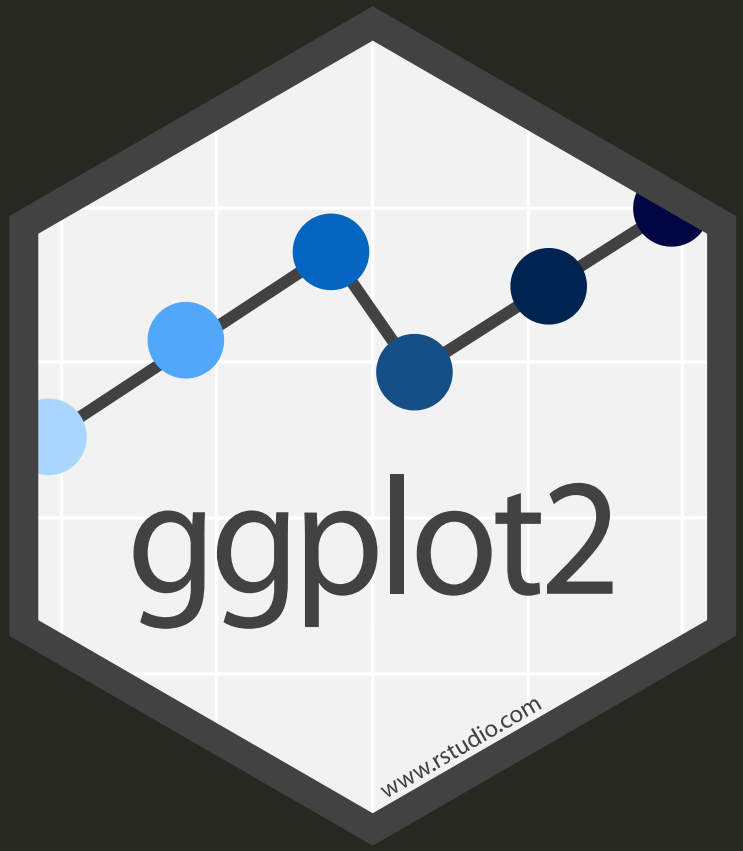
Tidyverse

A popular collection of R packages for data import, manipulation, exploration and visualization.

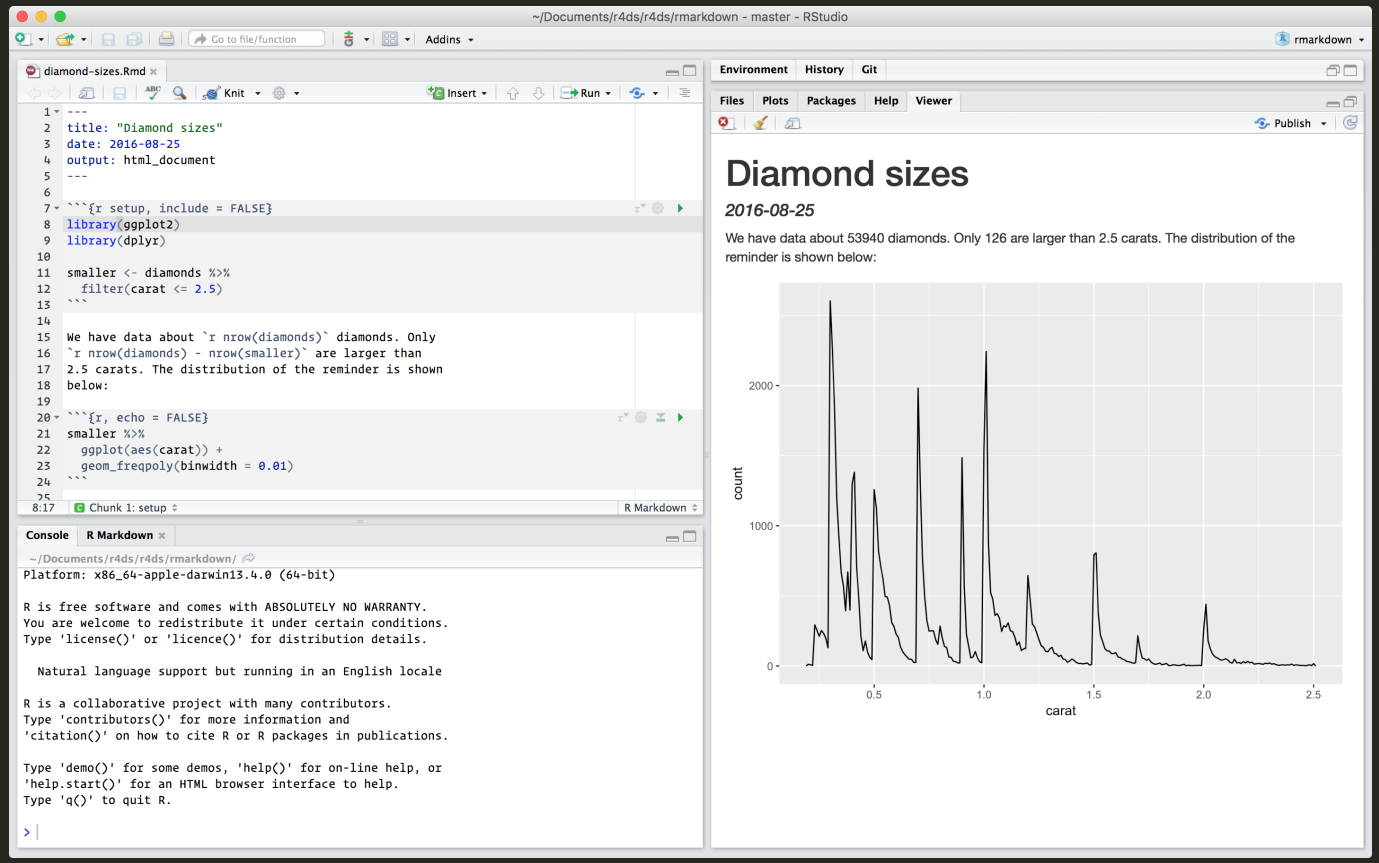
- Unified and consistent design and API (unlike base R)
- Intuitive underlying philosophy
- Easy-to-learn
- Easy to get help: large community on stackoverflow, twitter #rstats etc



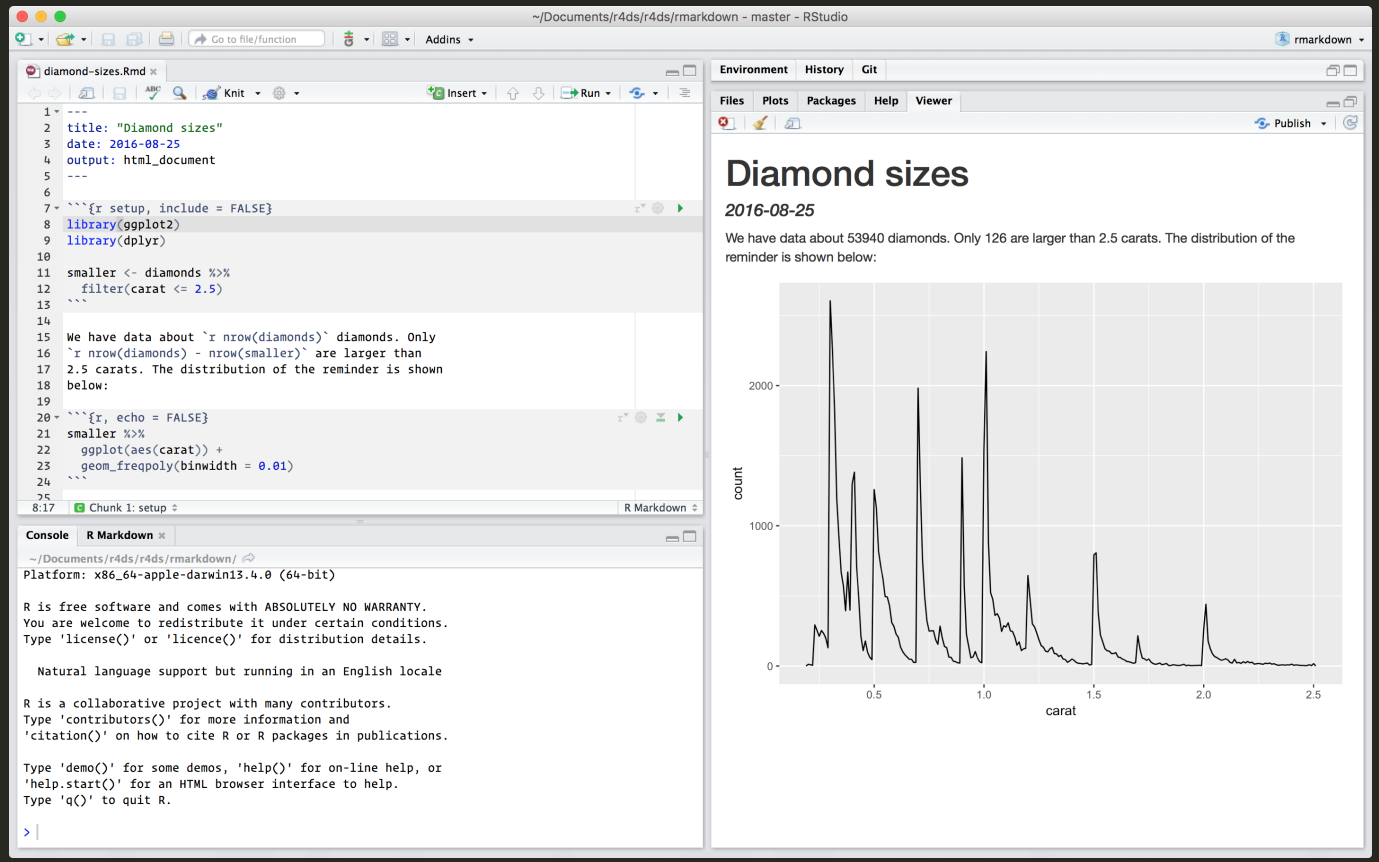
ggplot2



R Markdown


~/Documents/r4ds/r4ds/rmarkdown - master - RStudio
Addins
rmarkdown
diamond-sizes.Rmd
Knit
Insert
Run
1 ---
2 title: "Diamond sizes"
3 date: 2016-08-25
4 output: html_document
5 ---
6
7 ```{r setup, include = FALSE}
8 library(ggplot2)
9 library(dplyr)
10
11 smaller <- diamonds %>%
12 filter(carat <= 2.5)
13 ```
14
15 We have data about `r nrow(diamonds)` diamonds. Only
16 `r nrow(diamonds) - nrow(smaller)` are larger than
17 2.5 carats. The distribution of the reminder is shown
18 below:
19
20 ```{r, echo = FALSE}
21 smaller %>%
22 ggplot(aes(carat)) +
23 geom_freqpoly(binwidth = 0.01)
24 ```
8:17
Chunk 1: setup
R Markdown
Console
R Markdown
~/Documents/r4ds/r4ds/rmarkdown/
Platform: x86_64-apple-darwin13.4.0 (64-bit)
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.
Natural language support but running in an English locale
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
>
Environment
History
Git
Files
Plots
Packages
Help
Viewer
Publish
Diamond sizes
2016-08-25
We have data about 53940 diamonds. Only 126 are larger than 2.5 carats. The distribution of the reminder is shown below:
count
2000
1000
0
0.5
1.0
1.5
2.0
2.5
carat

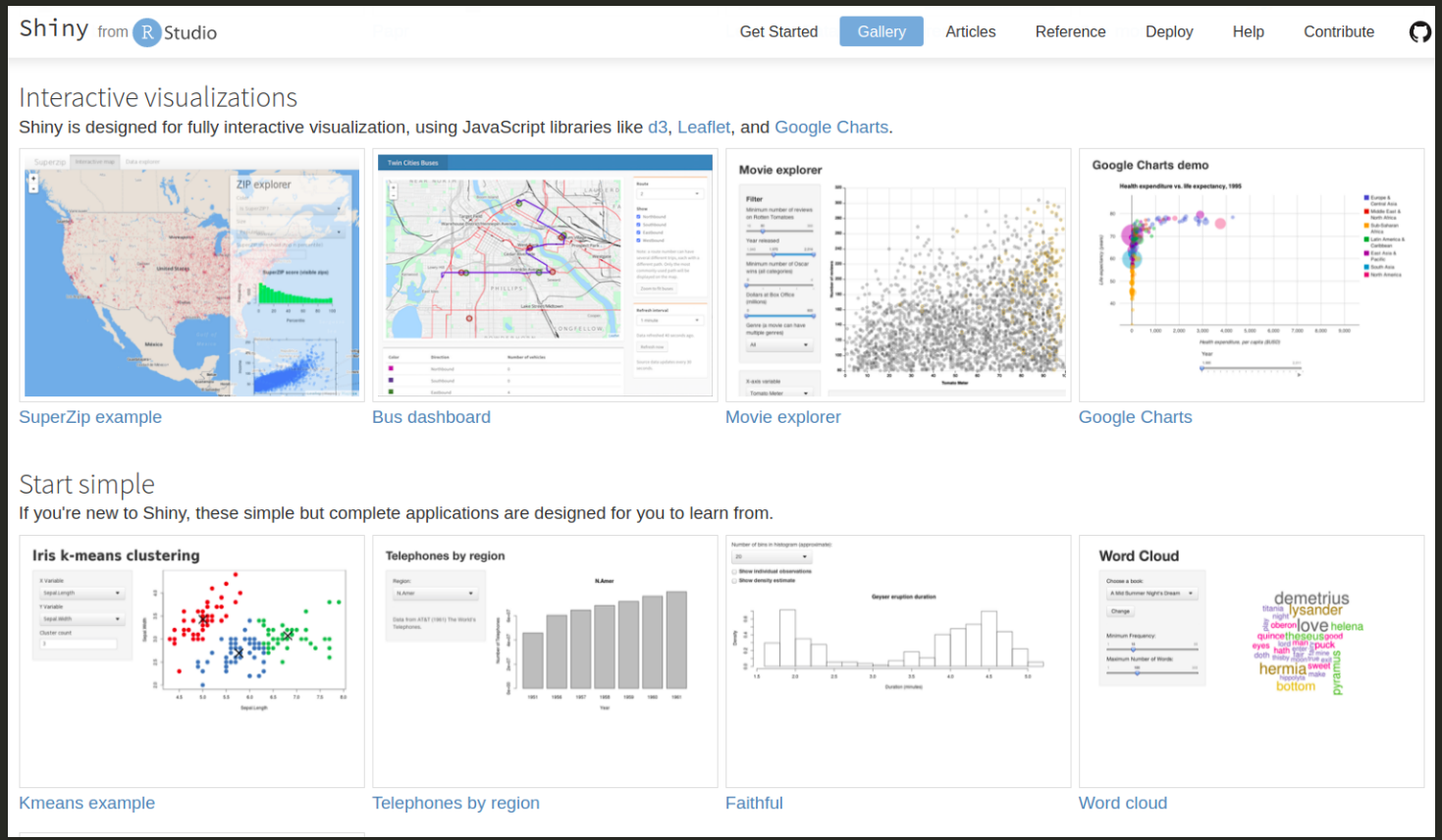
R Markdown



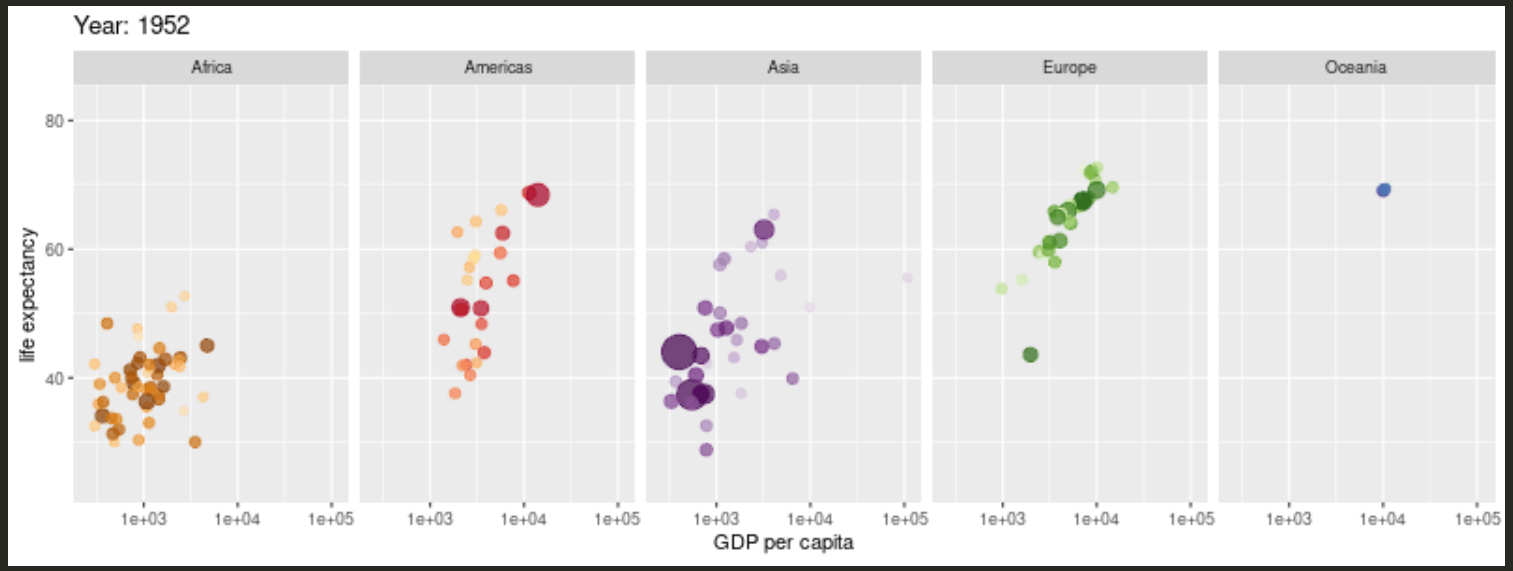
Note that these slides have been written in RMarkdown, using the xaringan package https://github.com/yihui/xaringan

Shiny

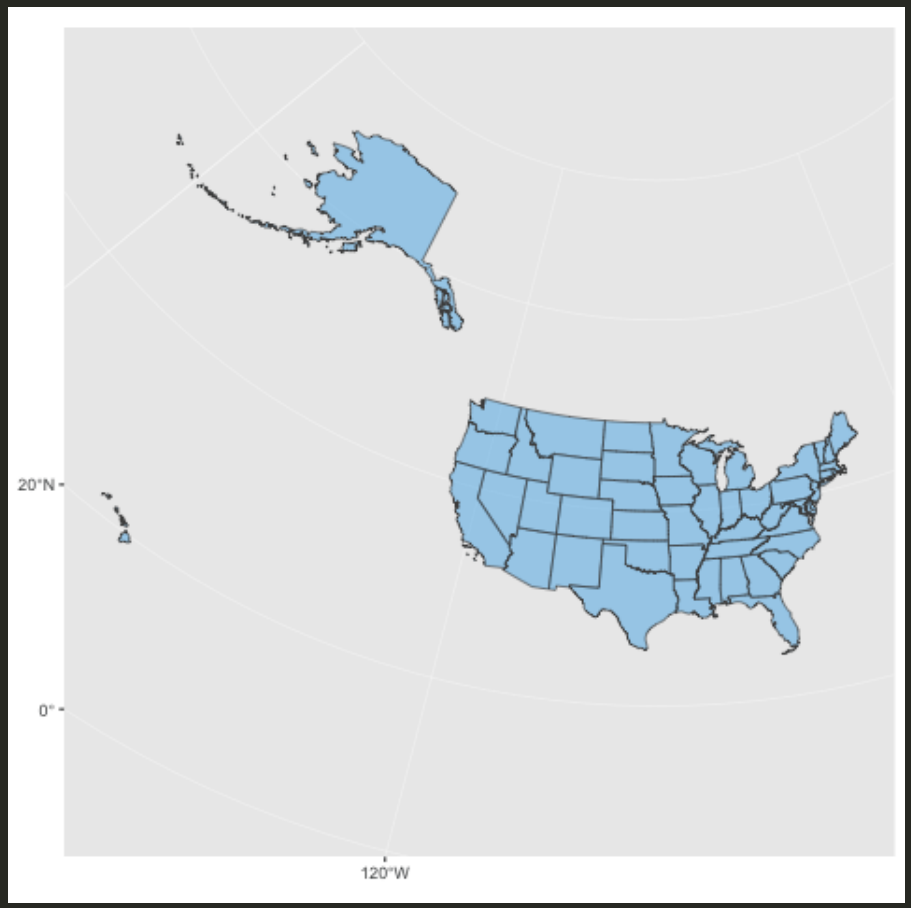
Turn your static figures into an interactive app with little effort using Shiny
https://shiny.rstudio.com/gallery/



gganimate


Year: 1952
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

gganimate



Source: https://github.com/thomasp85/gganimate/wiki/Moving-Hawaii-and-Alaksa

Are visualisations useful?

Consider the following data (N=20, p=2)

x	y
1.851	0.757
0.891	1.791
0.598	1.909
0.546	1.924
-0.195	1.991
-1.388	1.440
-1.458	1.369
-1.493	1.331
-2.000	0.029
-1.794	-0.884

	x	y
11	-1.377	-1.450
12	-1.063	-1.694
13	-0.771	-1.845
14	-0.404	-1.959
15	0.249	-1.984
16	1.593	-1.209
17	1.606	-1.192
18	1.676	-1.091
19	1.880	-0.681
20	1.997	-0.102

```
mean(x)
```

```
## [1] 0.04724152
```

```
mean(y)
```

```
## [1] -0.07760144
```

```
cor(x, y)
```

```
## [1] -0.0304444
```

```
mean(x)
```

```
## [1] 0.04724152
```

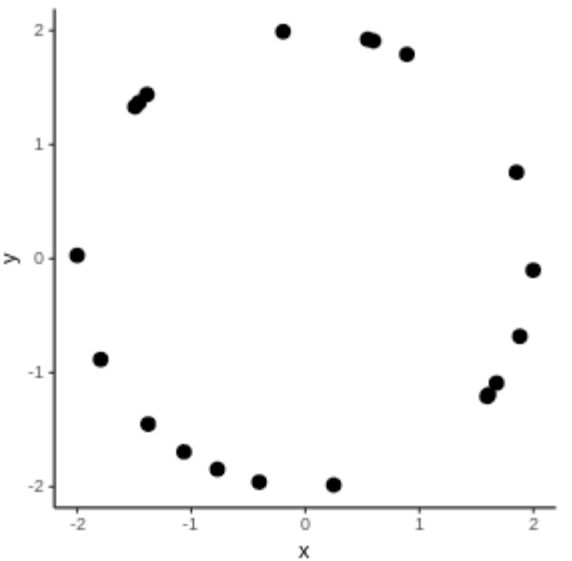
```
mean(y)
```

```
## [1] -0.07760144
```

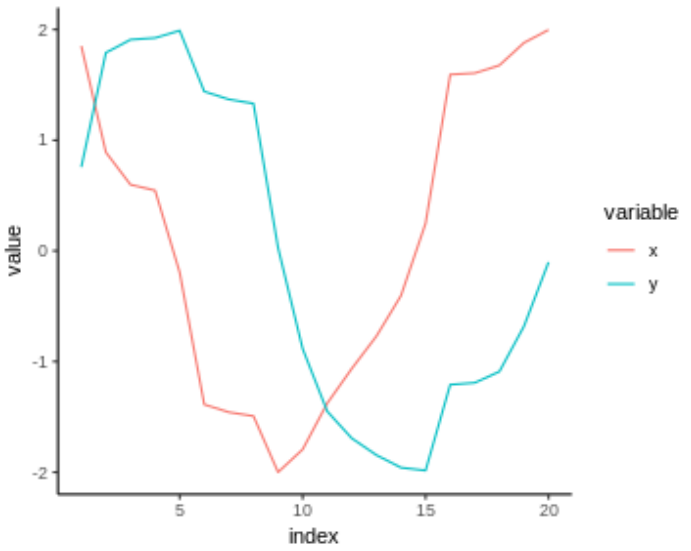
```
cor(x, y)
```

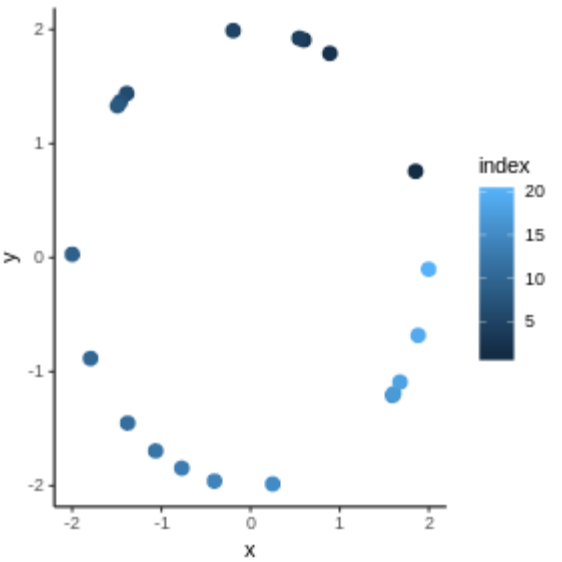
```
## [1] -0.0304444
```

Scatterplot immediately reveals the structure



Some visualisations are more useful than others





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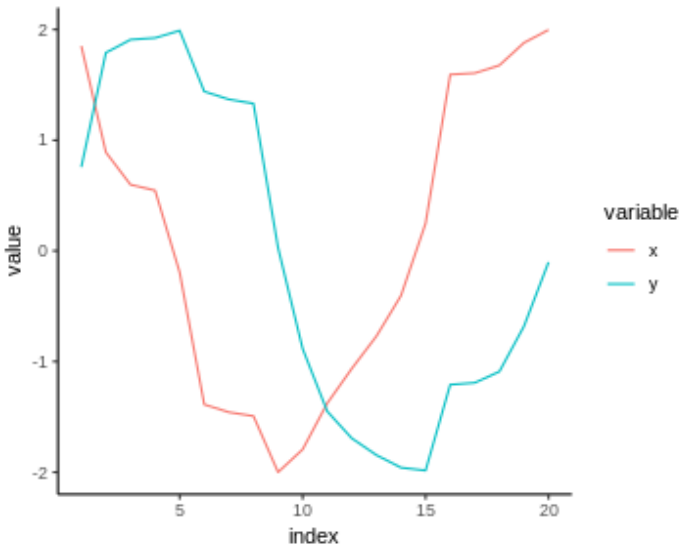
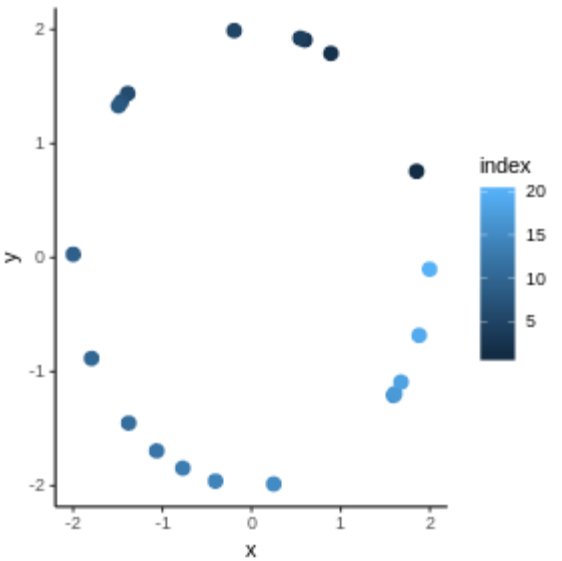




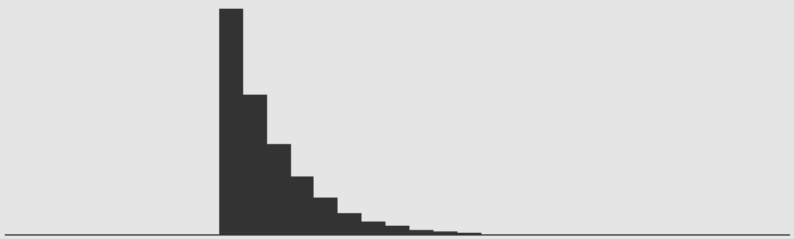
Inspired by the talk "How Humans See Data" by John Rauser

How can we visualise the distribution of a continuous variable?

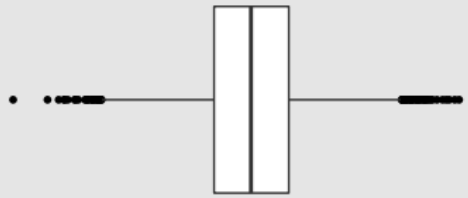
histogramm 1

histogramm 2

histogramm 3

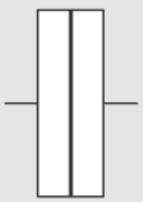


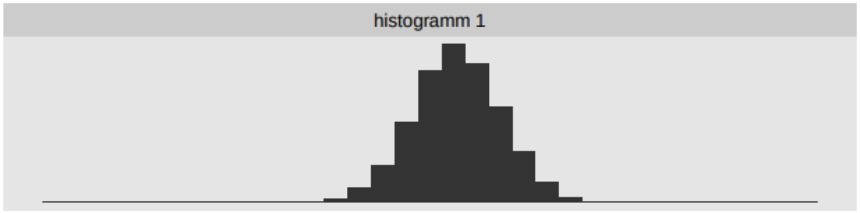
A

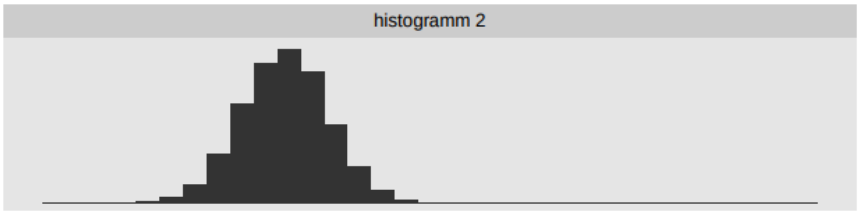


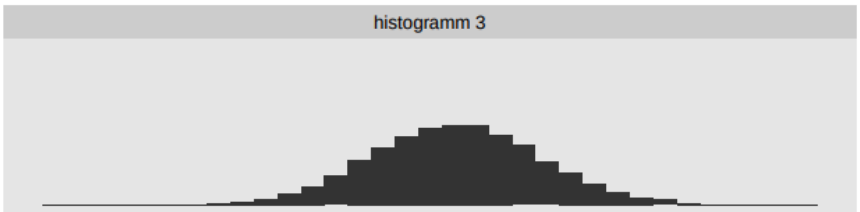
B

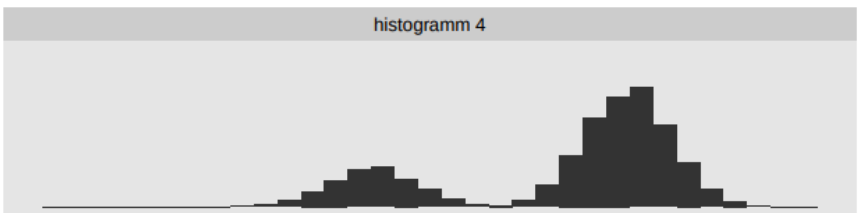
C

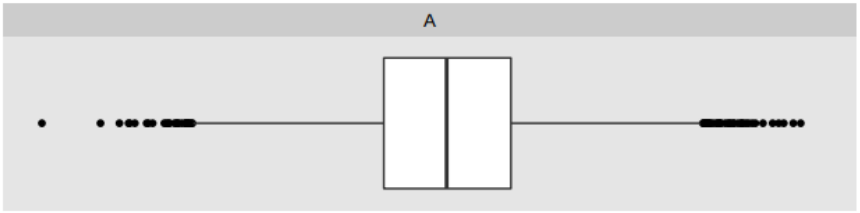


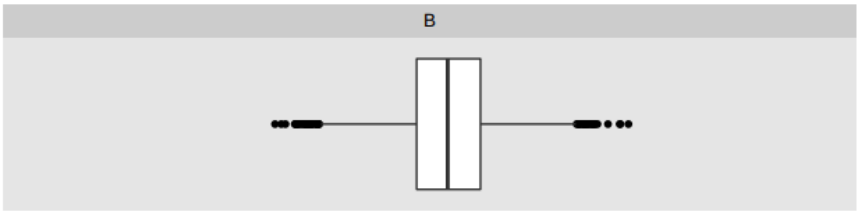

histogramm 1

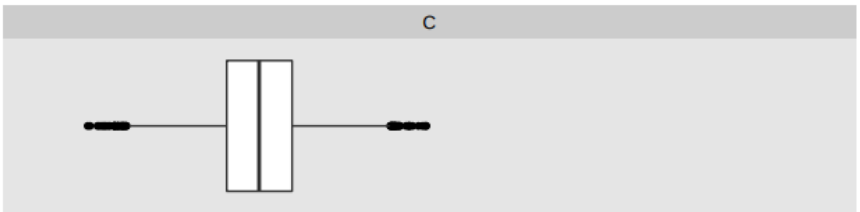

histogramm 2

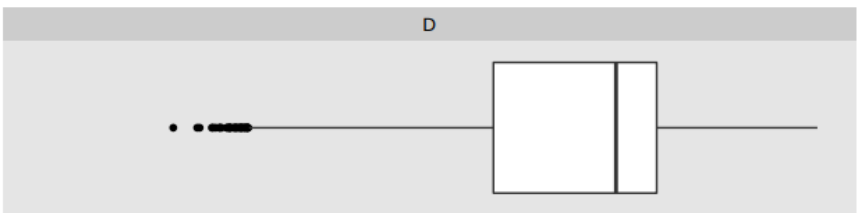

histogramm 3


histogramm 4


A


B


C


D

Can a histogram be misleading?

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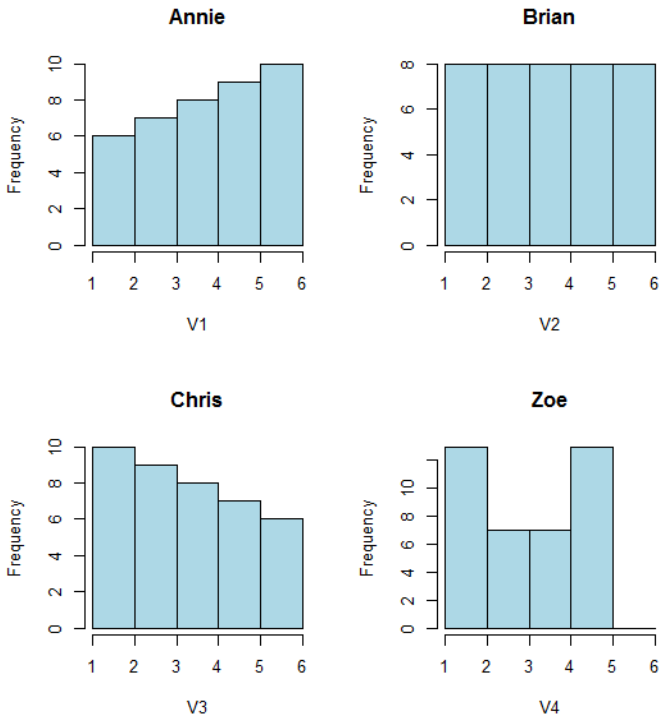

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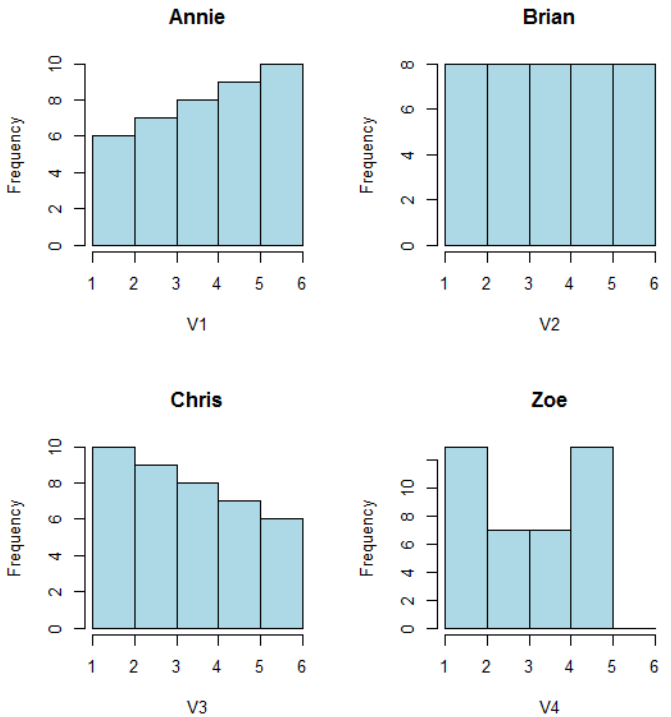

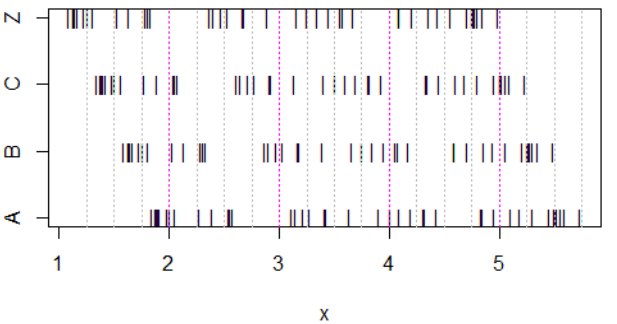

Source: https://stats.stackexchange.com/a/51753

How can we visualise the distribution of a continuous variable, compared across two (or more) groups?

Try to think of as many different approaches as you can. What are the pros and cons of each?

What if there are more than two or three variables?

That is, how to visualise high-dimensional data?

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That is, how to visualise high-dimensional data?

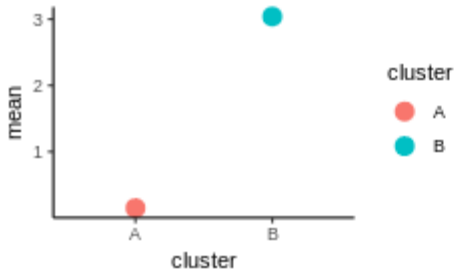
Options include:

- visualise a subset of variables,
  - randomly selected
  - selection based on summary statistics
- compute summary statistics and visualise those instead
- apply a dimensionality reduction method such as PCA

Do summary statistics capture everything?

Do summary statistics capture everything?

Do groups A and B have a significantly different measurements x?



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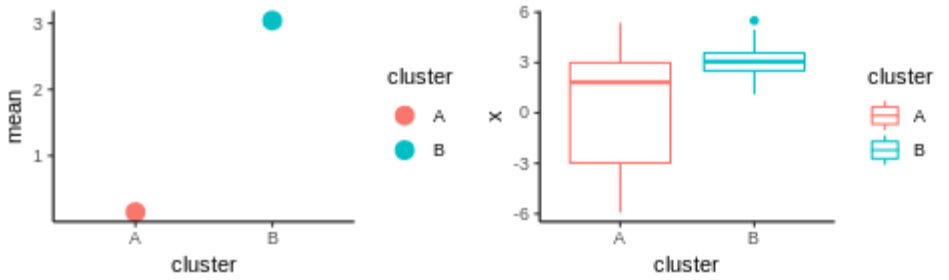

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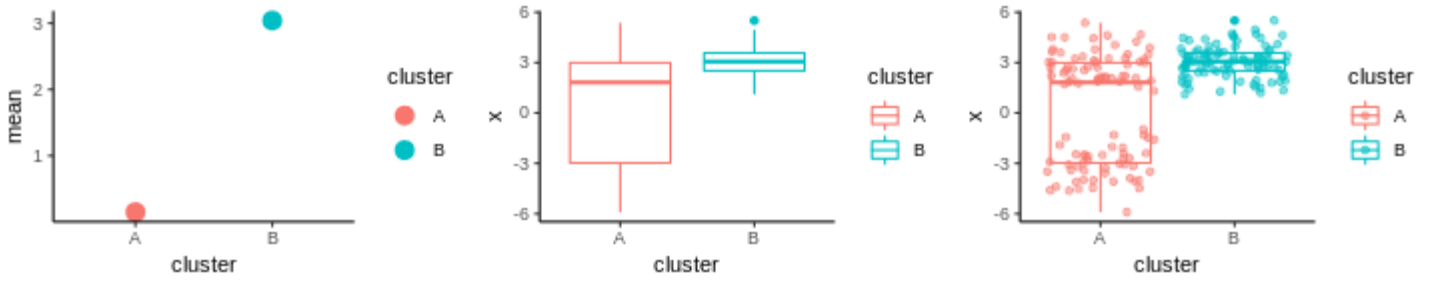

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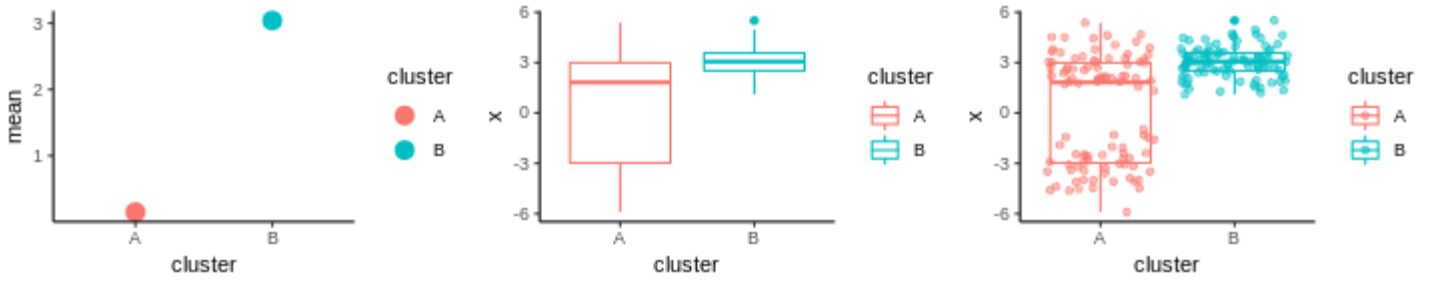
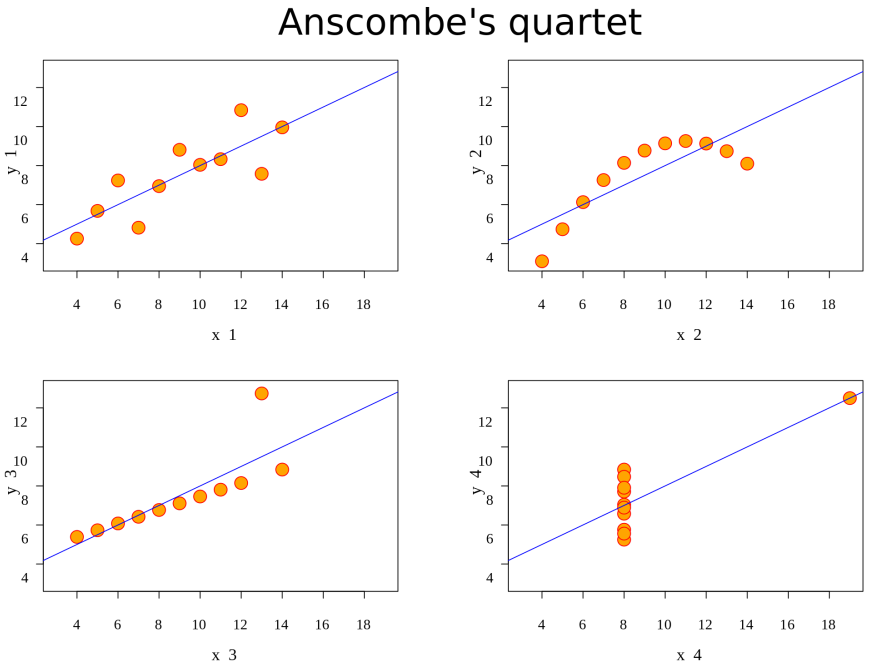


single summary statistic < multiple summary statistics < data

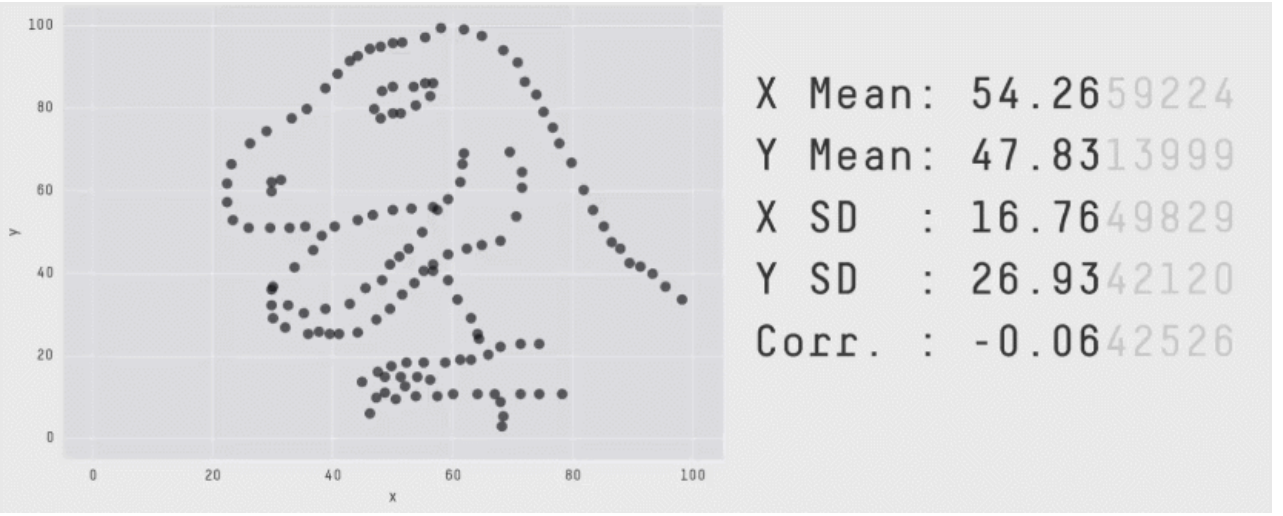
Do summary statistics capture everything?

Is there a significant association between two continuous variables x and y?



Source: https://en.wikipedia.org/wiki/Anscombe%27s_quartet

Do summary statistics capture everything?

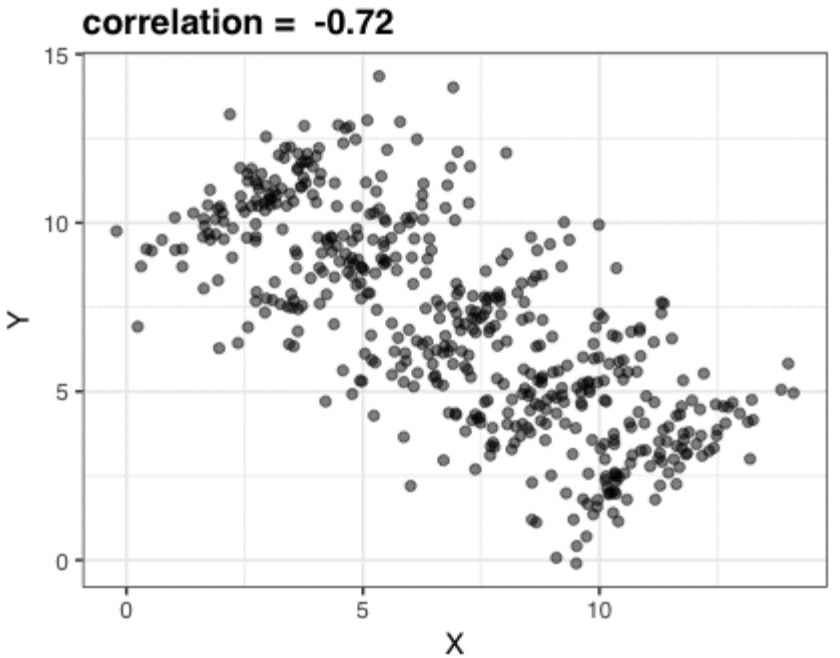


Source: https://www.autodeskresearch.com/publications/samestats

Simpson's paradox

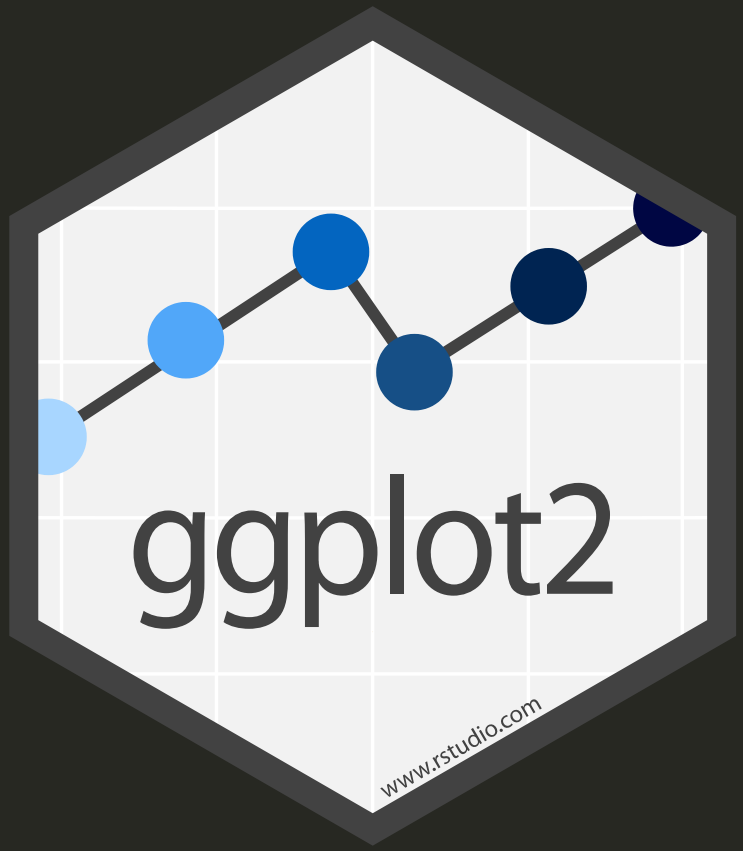
Can we trust the patterns that we see?

Subgroup structure (or other variables) may help to explain the patterns



Source: https://simplystatistics.org/2017/08/08/code-for-my-educational-gifs/

ggplot2

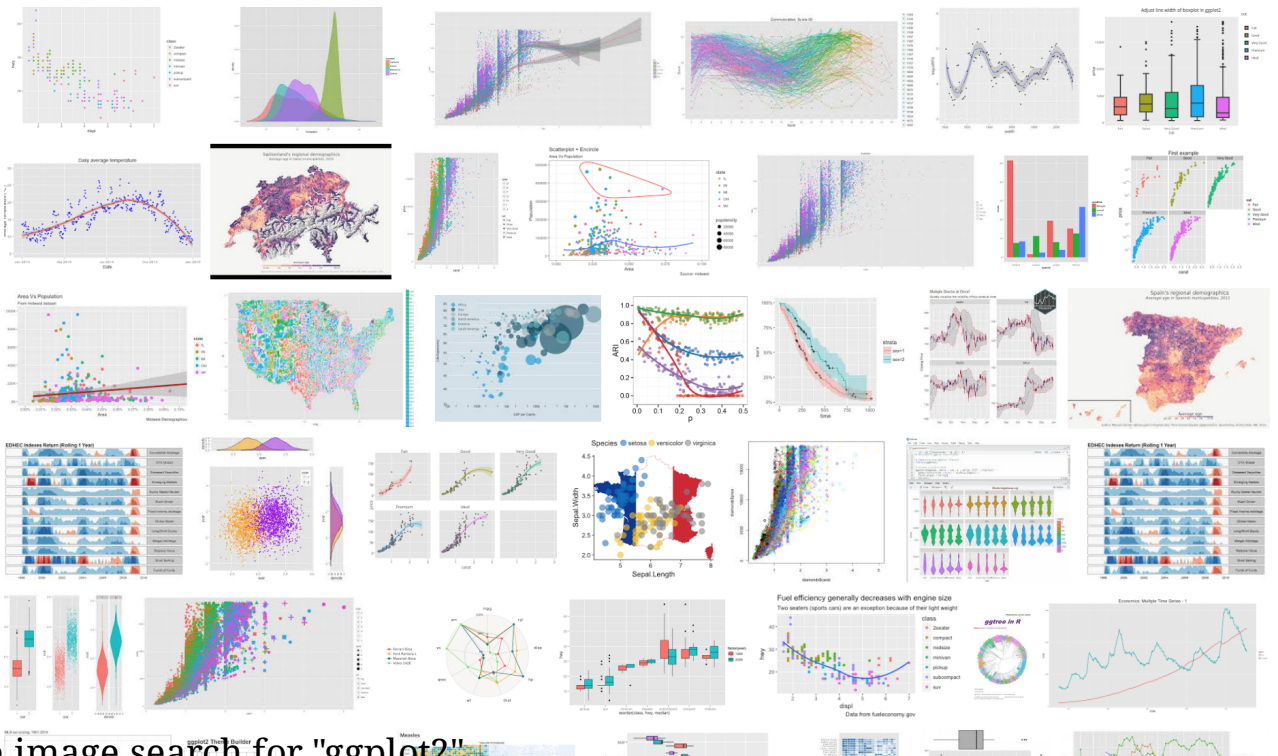


Hadley Wickham (http://hadley.nz/):

- author of many widely used R packages
  - including ggplot2
  - introduced the concept of tidy data
  - key contributor to the tidyverse
- author of many excellent books, including
  - R for Data Science http://r4ds.had.co.nz/
  - Advanced R http://adv-r.had.co.nz/
  - etc

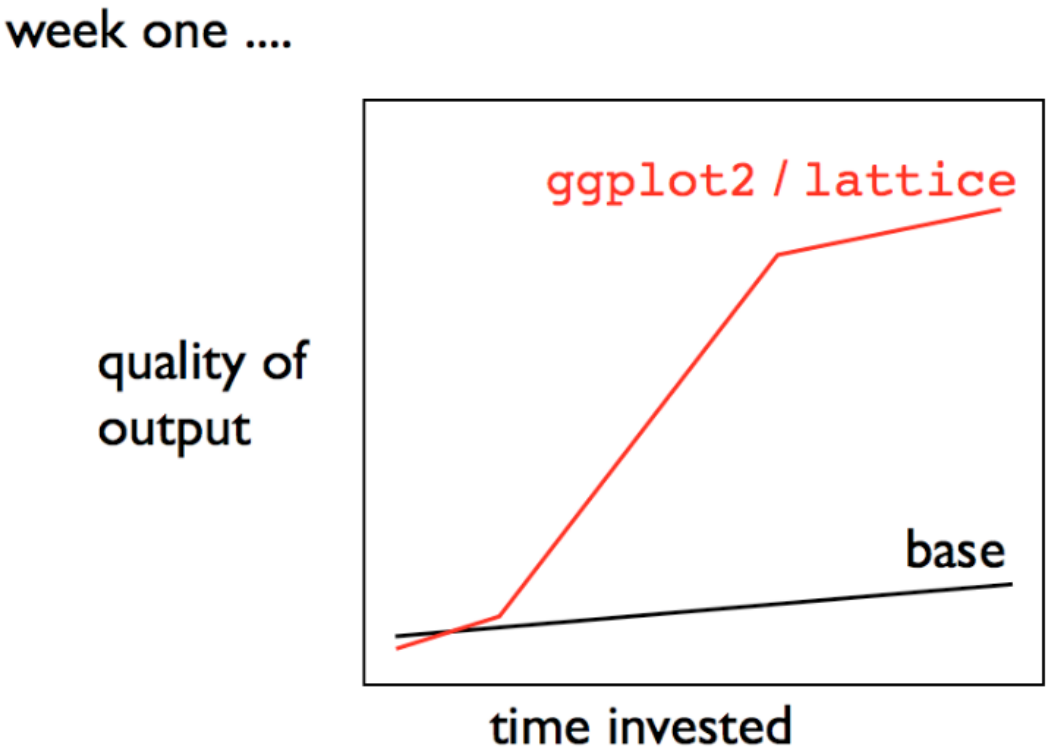
ggplot2

- Quickly iterate over a variety of plots (only making minimal changes to the code).
- Create publication-quality plots with minimal tweaking.



google image search for "ggplot2"

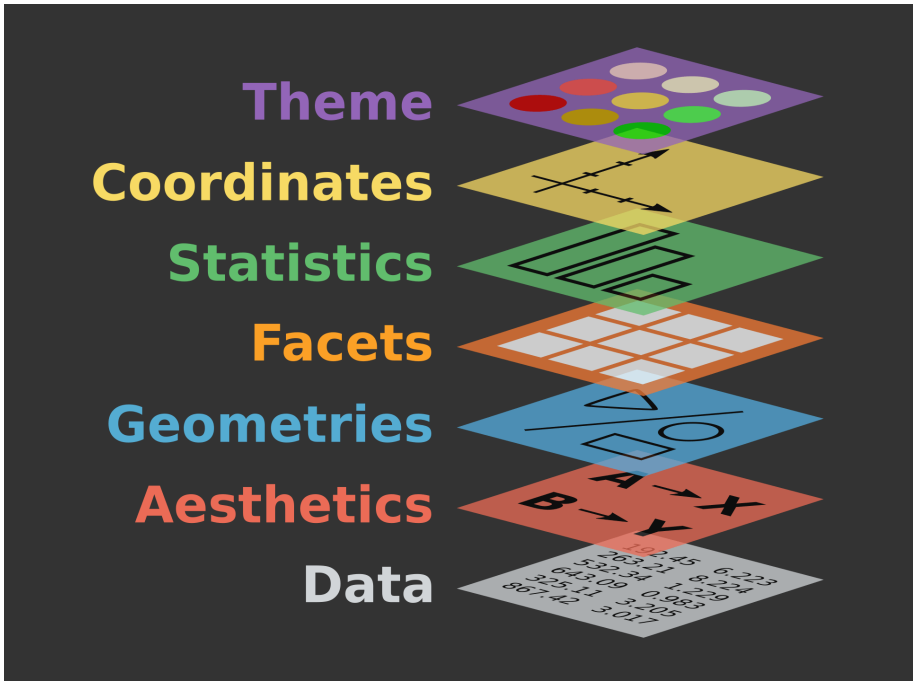
ggplot2 learning curve



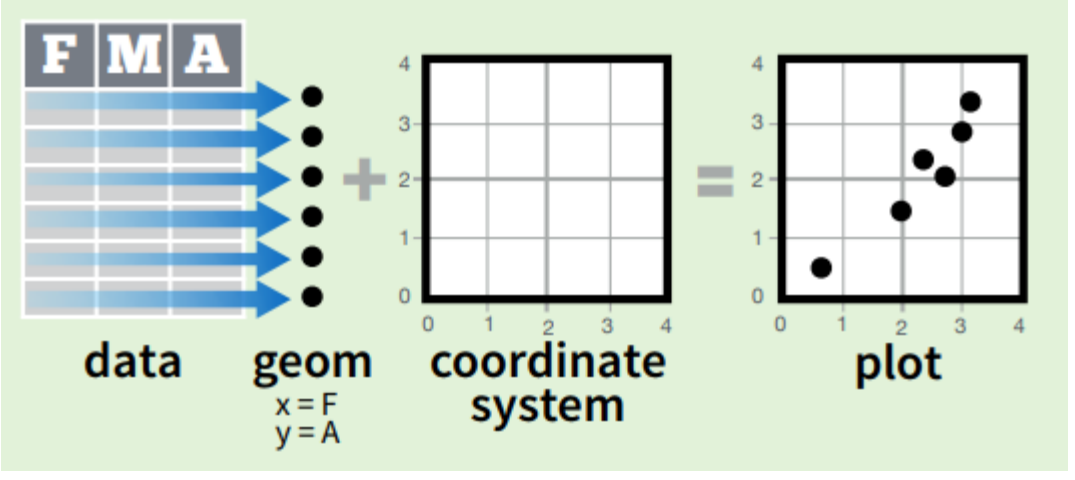
Source: https://github.com/jennybc/ggplot2-tutorial * figure is totally fabricated but, I claim, still true

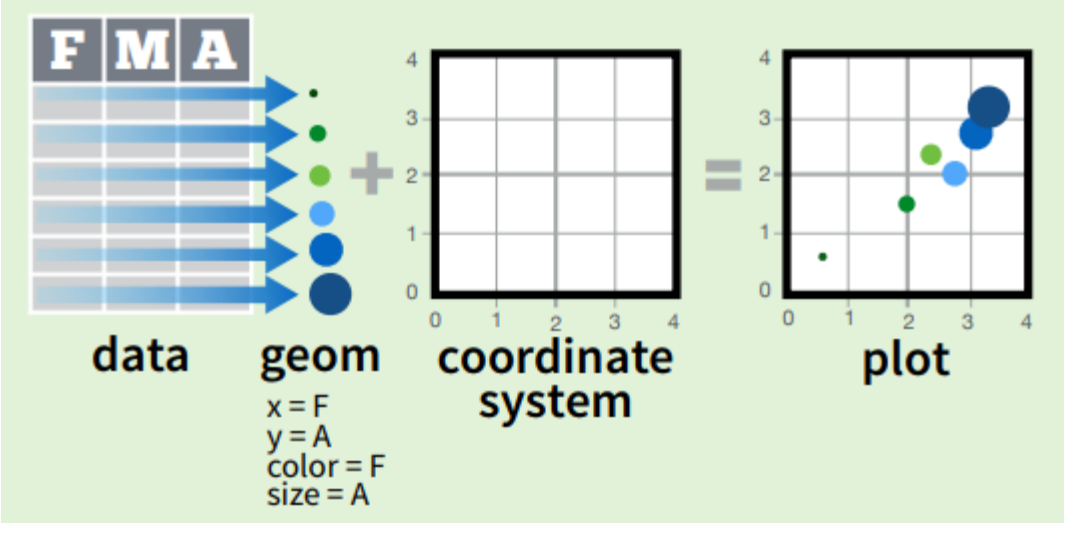
ggplot2

Based on the Grammar of Graphics (book by Leland Wilkinson, 1999/2005) -- idea that every graph can be built from the same components. Results in a very flexible framework for plotting.



ggplot2


F M A
data
geom
x = F
y = A
coordinate system
plot


F M A
data
geom
x = F
y = A
color = F
size = A
coordinate system
plot

Gapminder data

- See the famous TED talk by Hans Rosling
  https://www.ted.com/talks/hans_rosling_shows_the_best_stats_you_ve_ever_seen
- R package "gapminder" conveniently provides a subset of that data
  https://github.com/jennybc/gapminder

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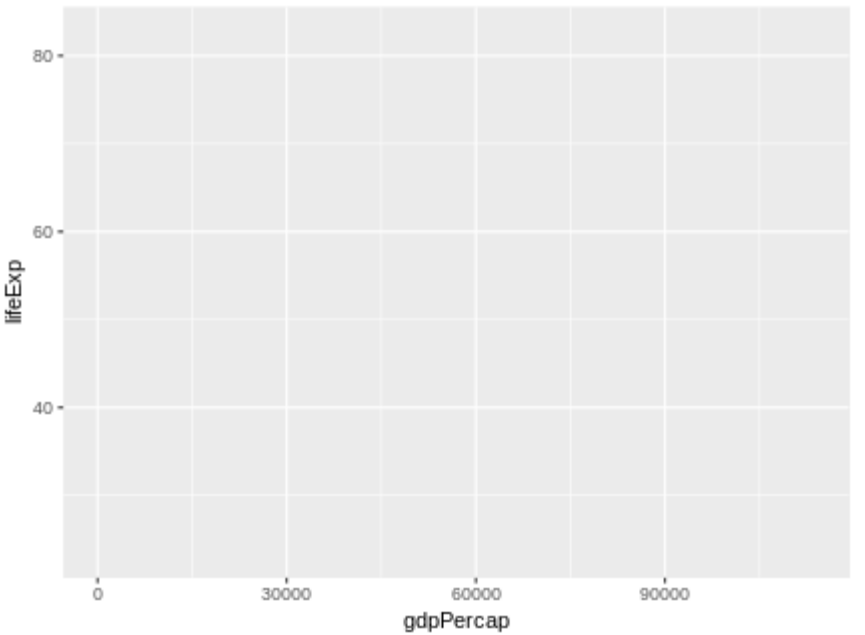
  https://github.com/jennybc/gapminder

```
library(gapminder)

head(gapminder)
```

```
## # A tibble: 6 x 6
##   country     continent  year lifeExp      pop gdpPercap
##   <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
## 1 Afghanistan Asia       1952    28.8  8425333      779.
## 2 Afghanistan Asia       1957    30.3  9240934      821.
## 3 Afghanistan Asia       1962    32.0 10267083      853.
## 4 Afghanistan Asia       1967    34.0 11537966      836.
## 5 Afghanistan Asia       1972    36.1 13079460      740.
## 6 Afghanistan Asia       1977    38.4 14880372      786.
```

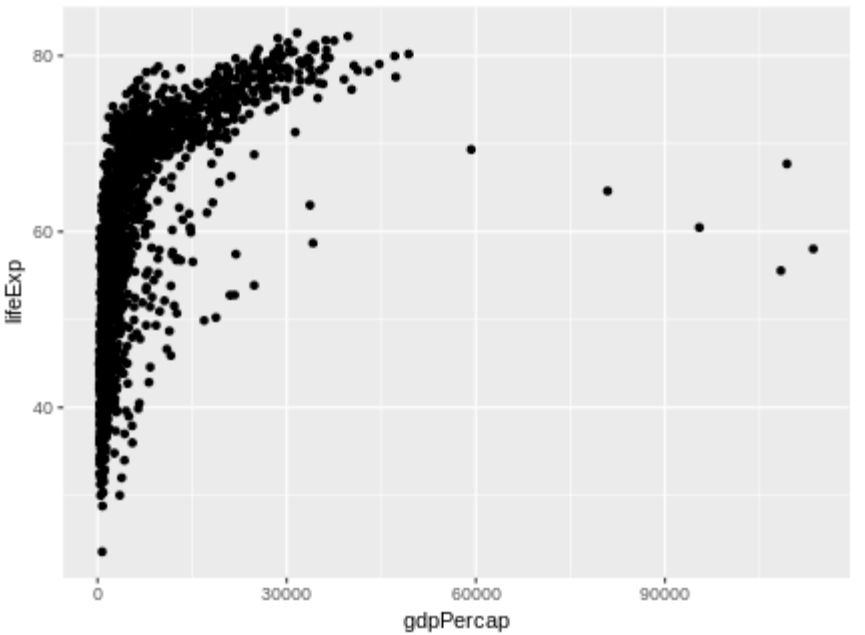
ggplot2 call

```
library(ggplot2)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp))
```



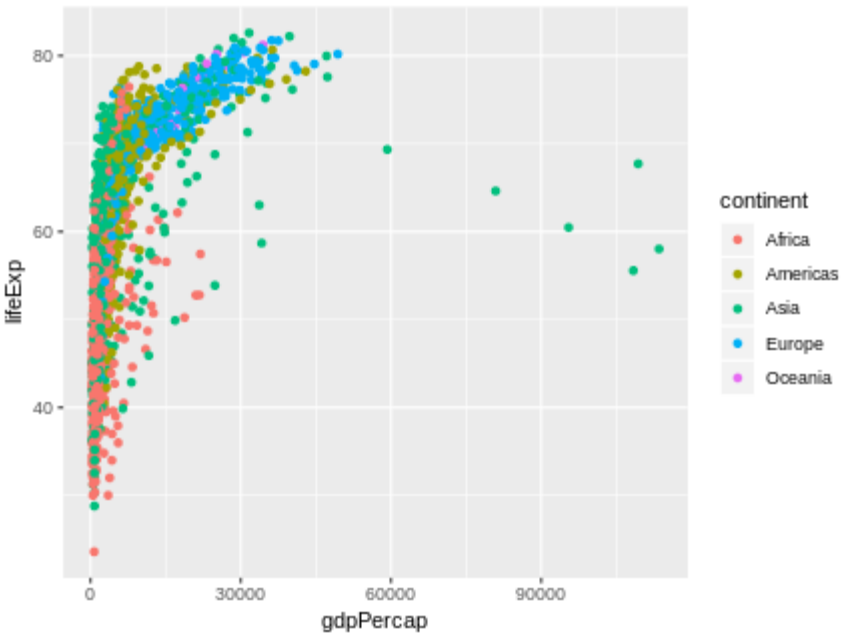
ggplot2 call: scatterplot

```
library(ggplot2)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp)) +
  geom_point()
```



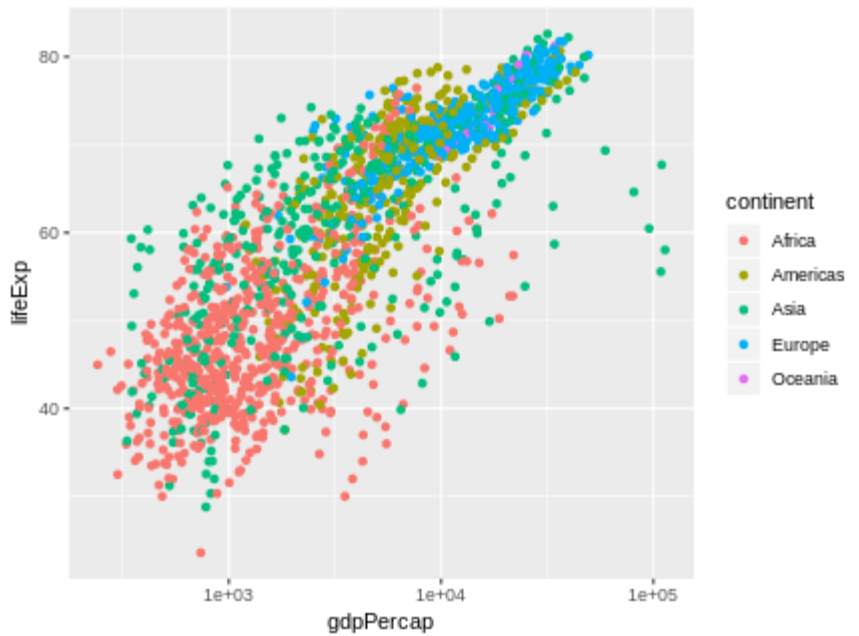
colour by continent

```
library(ggplot2)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp, col = continent))
  geom_point()
```



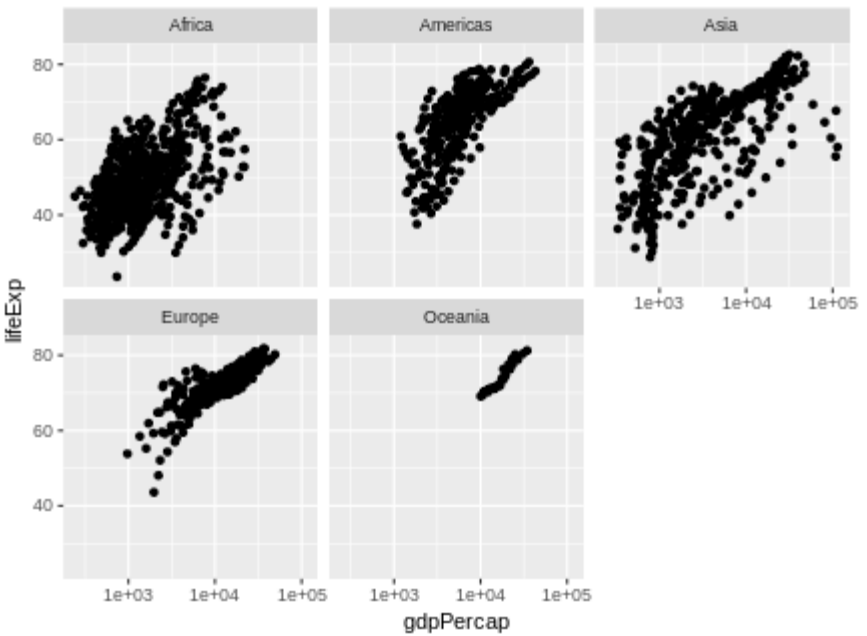
change x-axis scale

```
library(ggplot2)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp, col = continent))
  geom_point() +
  scale_x_log10()
```



facet by continent

```
library(ggplot2)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp)) +
  geom_point() +
  facet_wrap(~ continent) +
  scale_x_log10()
```



Let's explore life expectancy

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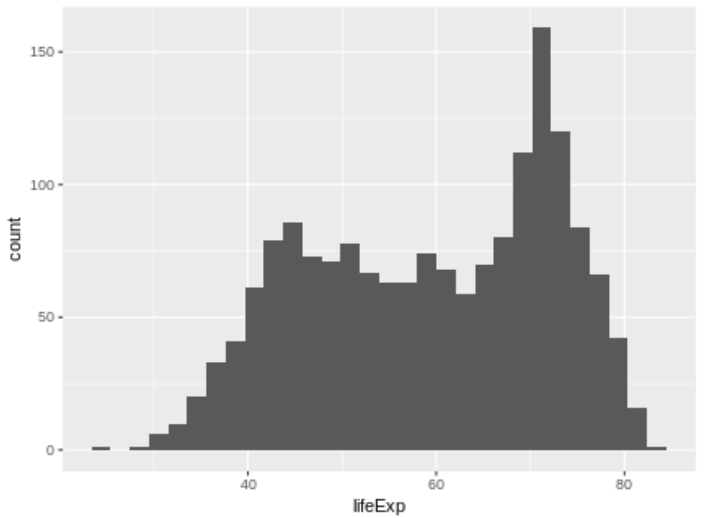
```
ggplot(gapminder, aes(x = lifeE
  geom_histogram()
```



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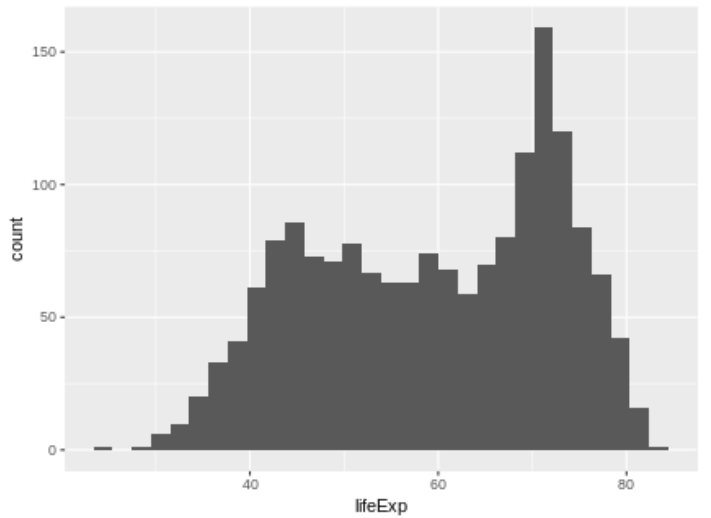
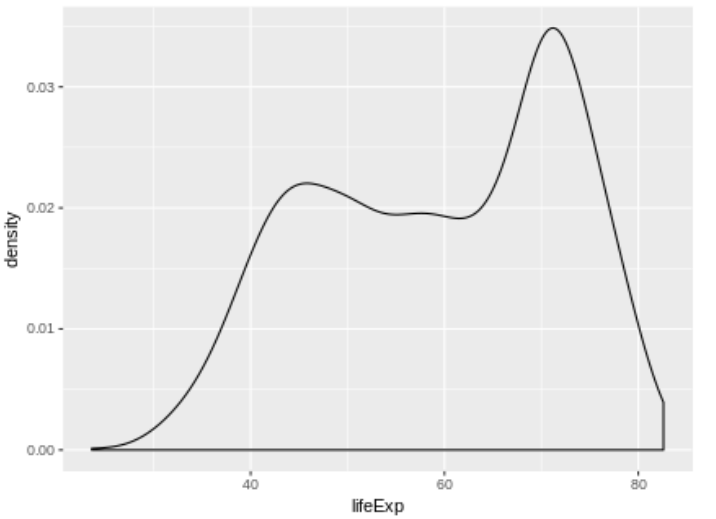



```
ggplot(gapminder, aes(x = lifeE
  geom_density()
```



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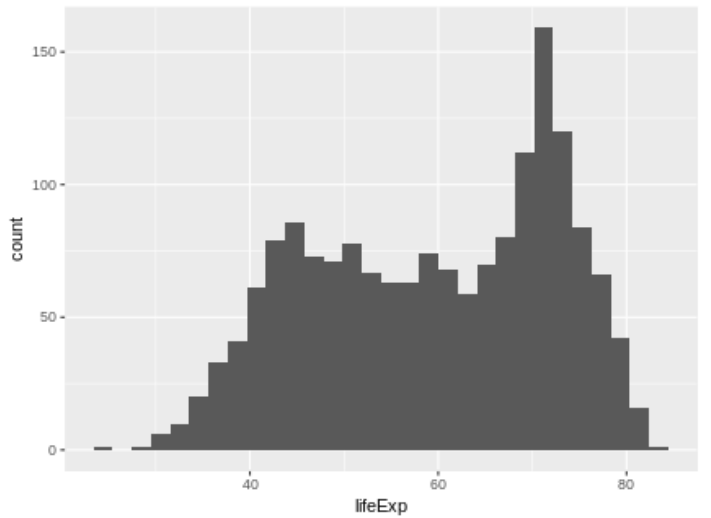


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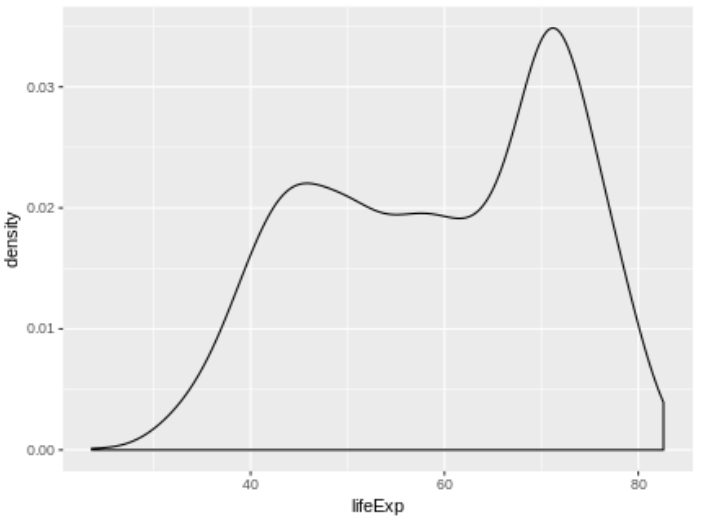
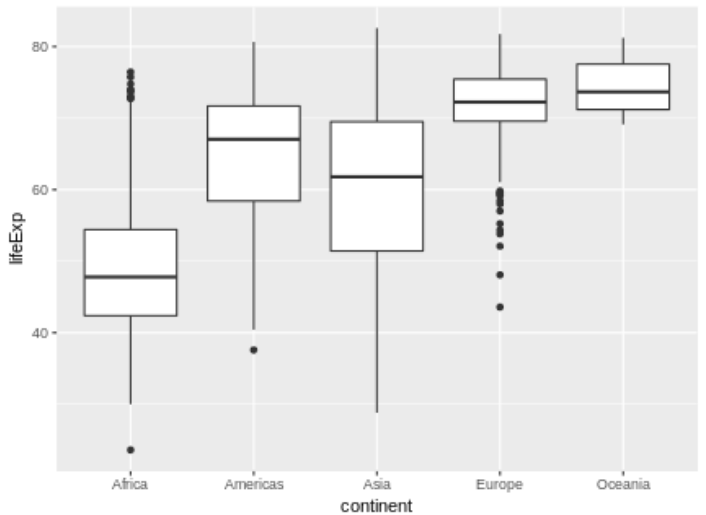


How does this compare across continents? Across years?

Let's explore life expectancy (across continents)

```
ggplot(gapminder, aes(x = conti
  geom_boxplot()
```

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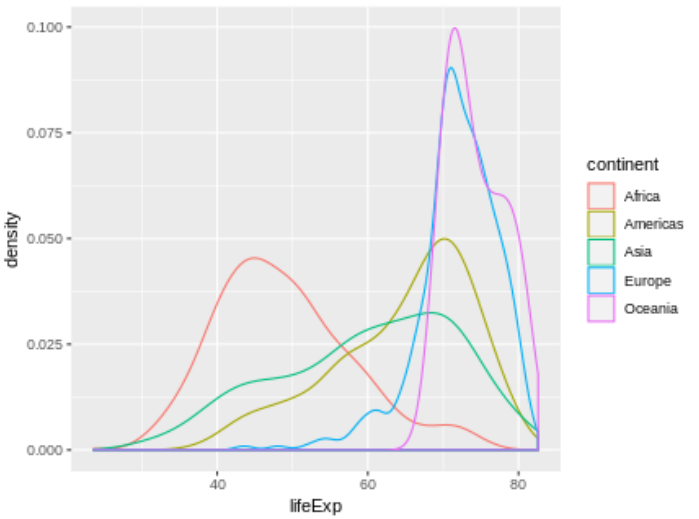

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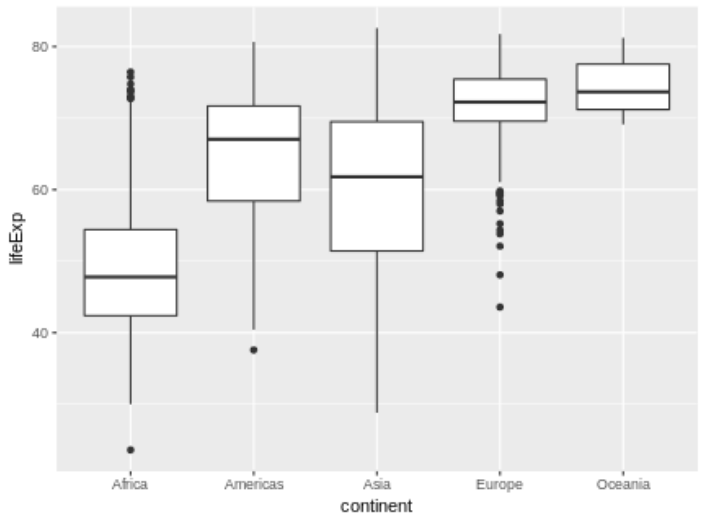


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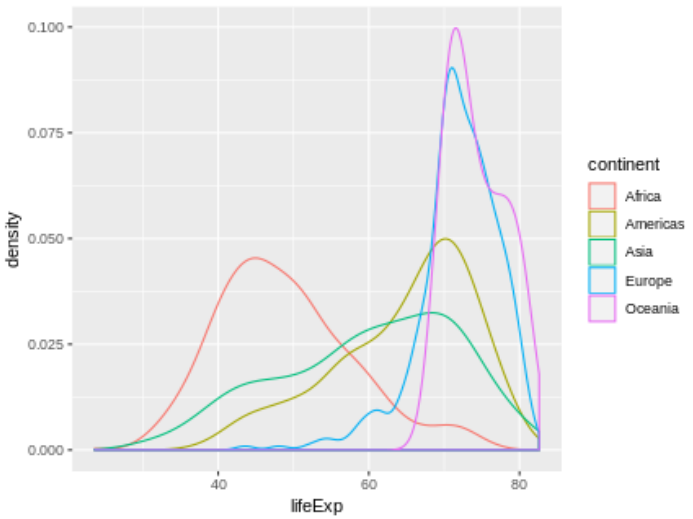


Can you think of other ways? Try them out!

aes() for different layers

Every layer can have its own aesthetics.

Here, we have only one layer `geom_point()`, so all of the following are equivalent

```
ggplot(gapminder, aes(x = gdpPercap, y = lifeExp, col = continent))
  geom_point()
```

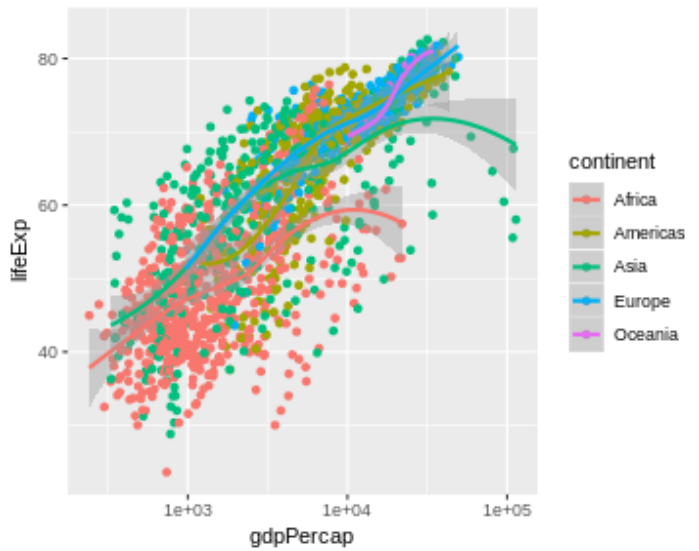
```
ggplot(gapminder, aes(x = gdpPercap, y = lifeExp)) +
  geom_point(aes(col = continent))
```

```
ggplot(gapminder) +
  geom_point(aes(x = gdpPercap, y = lifeExp, col = continent))
```

aes() for different layers

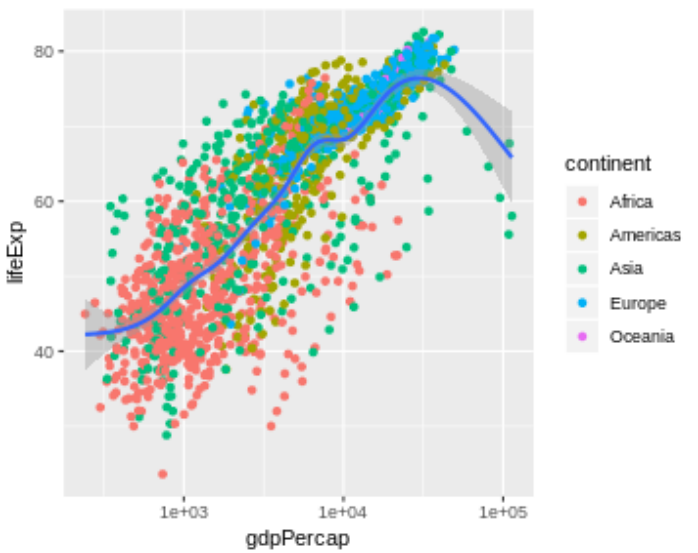
Here `aes(col = continent)` is shared for both layers.

```
ggplot(gapminder, aes(gdpPercap
  geom_point() +
  geom_smooth() +
  scale_x_log10()
```



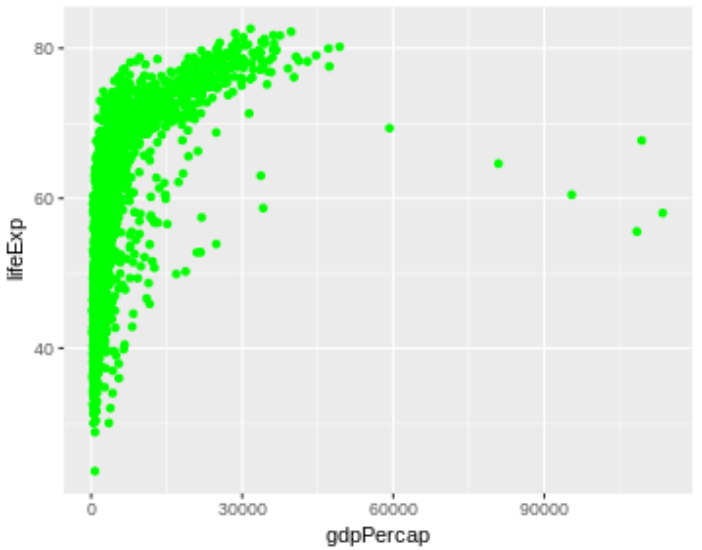
Here `aes(col = continent)` is specified for `geom_point()` only.

```
ggplot(gapminder, aes(gdpPercap
  geom_point(aes(col = continen
  geom_smooth() +
  scale_x_log10()
```



aes(): specifying colour manually

```
ggplot(gapminder, aes(gdpPercap
  geom_point(col = "green")
```

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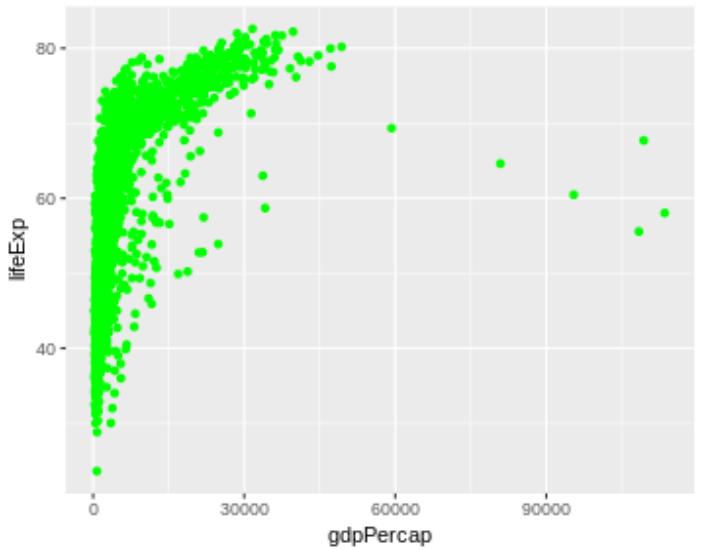


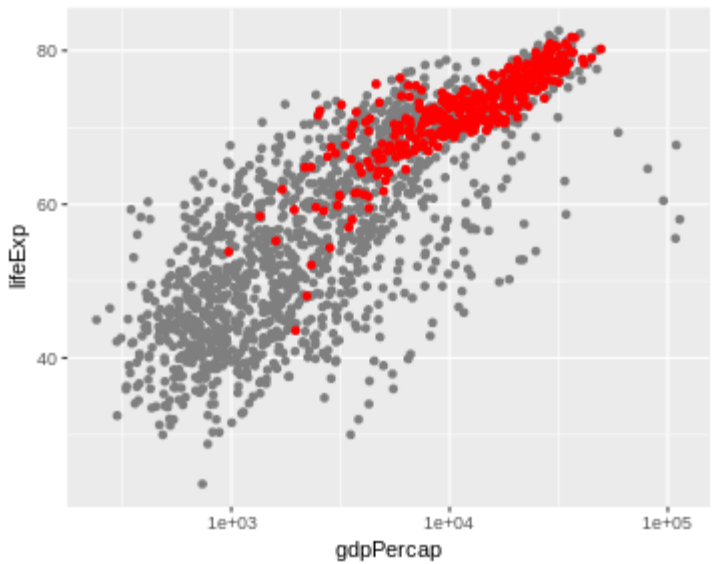

```
ggplot(gapminder, aes(gdpPercap
  geom_point(aes(col = "green")
```

Good resource for choosing colours: http://colorbrewer2.org

Similarly: every layer can be based on different data

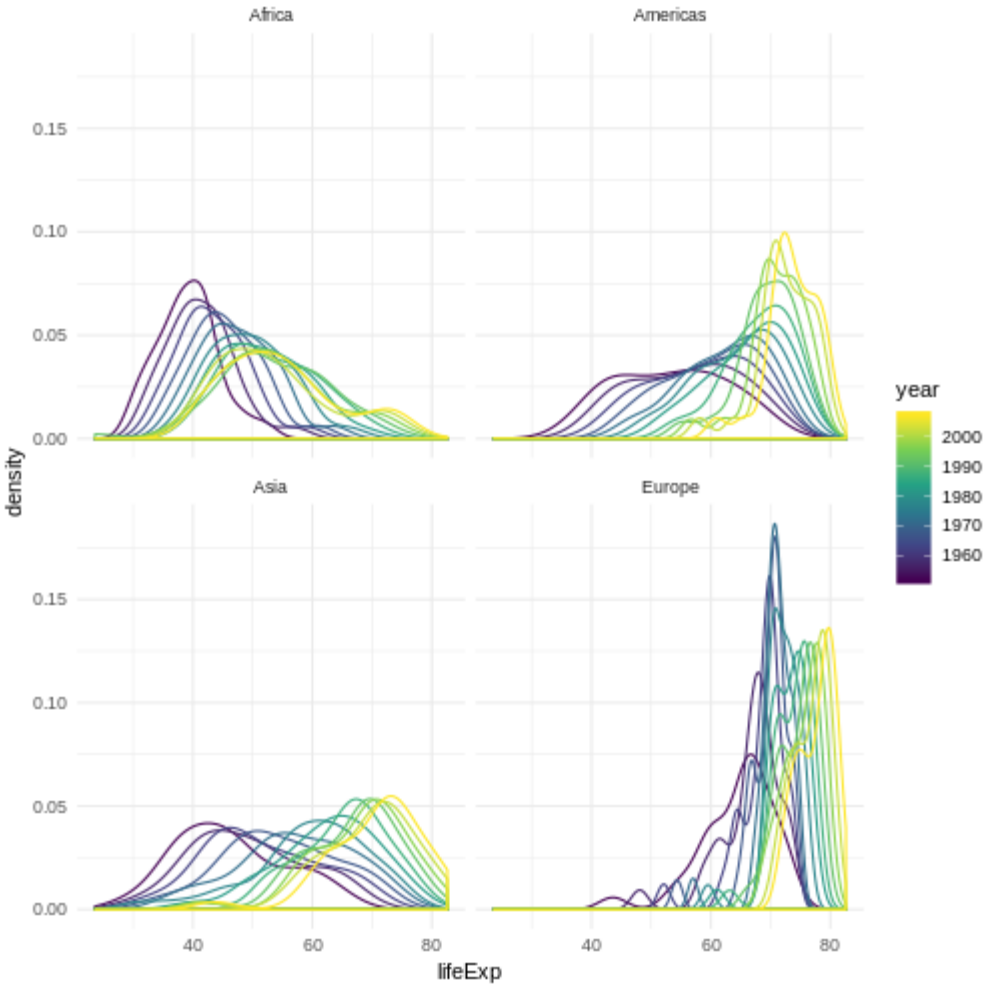
```
df_europe <- subset(gapminder, continent == "Europe")

ggplot() +
  geom_point(aes(gdpPercap, lifeExp), data = gapminder, col = "grey
  geom_point(aes(gdpPercap, lifeExp), data = df_europe, col = "red"
  scale_x_log10()
```



Tweaking your plot appearance

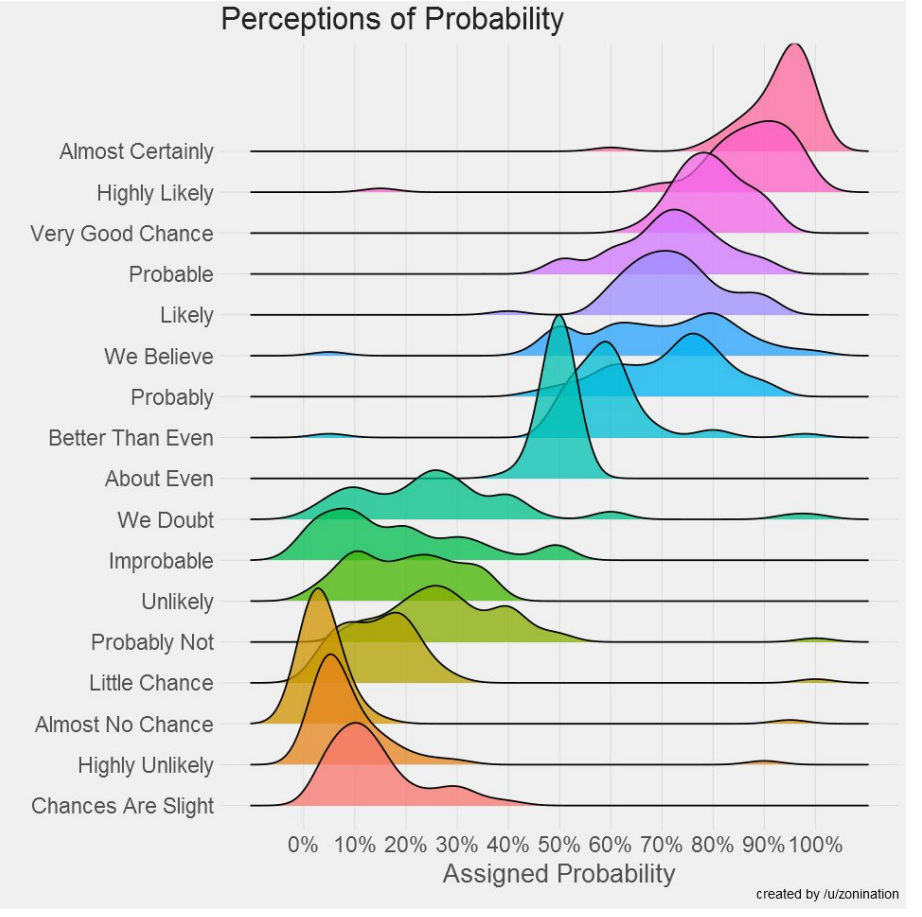
- Combining layers
- Add transparency using `alpha = 0.5`
- Changing the default theme:
  - `+ theme_bw()`
  - `+ theme_classic()`
  - etc, see also the ggthemes package
- Check out the ggplot2 cheat sheet by RStudio
- Axis limits
  - `+ coord_cartesian(ylim = c(-3, 5))`
- Title, subtitle, caption
  - `+ labs(title = "", subtitle = "")`


Africa
Americas
Asia
Europe
density
0.15
0.10
0.05
0.00
40
60
80
lifeExp
year
2000
1990
1980
1970
1960

ggplot2 extensions

http://www.ggplot2-exts.org/

ggridges



ggplot2 extensions

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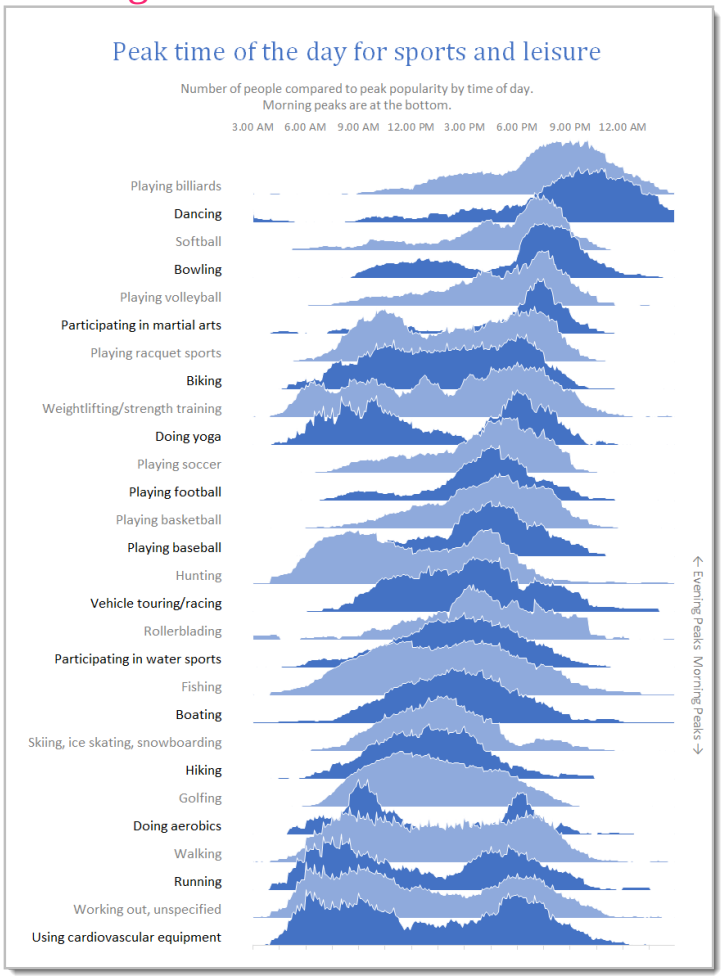
ggridges



Very brief introduction:

Data transformation using dplyr

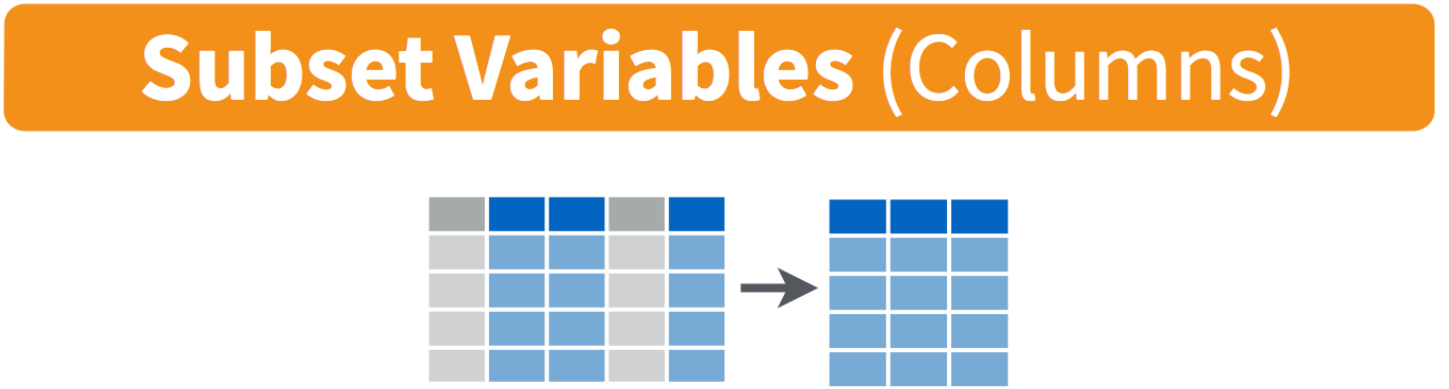
Subset rows with filter()

Example:

```
filter(gapminder, continent == "Europe")
```

```
filter(gapminder, continent == "Europe", year > 2000)
```

Subset columns with select()



Example:

```
select(gapminder, year, continent, lifeExp)
```

Or exclude certain columns

```
select(gapminder, -gdpPercap)
```

Add a new column with mutate()

Example:

```
mutate(gapminder, total_gdp = pop * gdpPercap)
```

group_by() and summarise()

Example:

```
grouped_df <- group_by(gapminder, continent)
summarise(grouped_df, count = n(), mean_lifeExp = mean(lifeExp))
```

```
## # A tibble: 5 x 3
##   continent count mean_lifeExp
##   <fct>     <int>        <dbl>
## 1 Africa      624         48.9
## 2 Americas    300         64.7
## 3 Asia        396         60.1
## 4 Europe      360         71.9
## 5 Oceania      24         74.3
```

Pipes %>%

Introducing `%>%`, to help you write code in a way that easier to read and understand.

`g(f(x))` can be rewritten using the pipe `x %>% f() %>% g()`

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E.g. the following

```
filtered_df <- filter(gapminder, continent != "Oceania")
grouped_df <- group_by(filtered_df, continent)
summarise(grouped_df, count = n(), mean_lifeExp = mean(lifeExp))
```

can be rewritten

```
gapminder %>%
  filter(continent != "Oceania") %>%
  group_by(continent) %>%
  summarise(count = n(), mean_lifeExp = mean(lifeExp))
```

Pipes %>%

Introducing %>%, to help you write code in a way that easier to read and understand.

`g(f(x))` can be rewritten using the pipe `x %>% f() %>% g()`

E.g. the following

```
filtered_df <- filter(gapminder, continent != "Oceania")
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summarise(grouped_df, count = n(), mean_lifeExp = mean(lifeExp))
```

can be rewritten

```
gapminder %>%
  filter(continent != "Oceania") %>%
  group_by(continent) %>%
  summarise(count = n(), mean_lifeExp = mean(lifeExp))
```

- No need for storing intermediate variables.
- Easier to read and write.

Great Resources:

- R for Data Science http://r4ds.had.co.nz/
- Fundamentals of Data Visualization https://serialmentor.com/dataviz
- TED talk by Hans Rosling https://www.ted.com/talks/hans_rosling_shows_the_best_stats_you_ve_ever_seen
- Talk by John Rauser on How Humans See Data https://www.youtube.com/watch?v=fSgEeI2Xpdc

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