INTRODUCTION TO R

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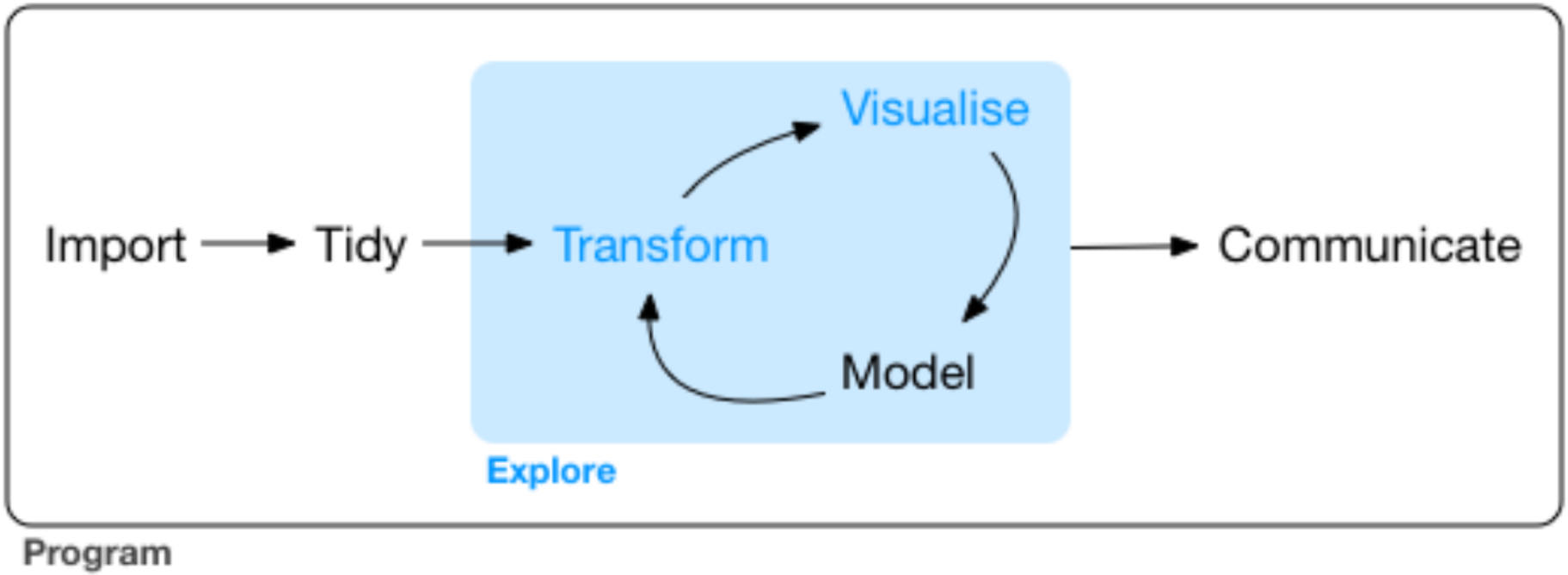
Data Science Flow



Wickham H, Grolemund G (2010). *R for Data Science*. O'Reilly.

It is often said that 80% of data analysis is spent on the process of cleaning and preparing the data (Dasu and Johnson 2003).

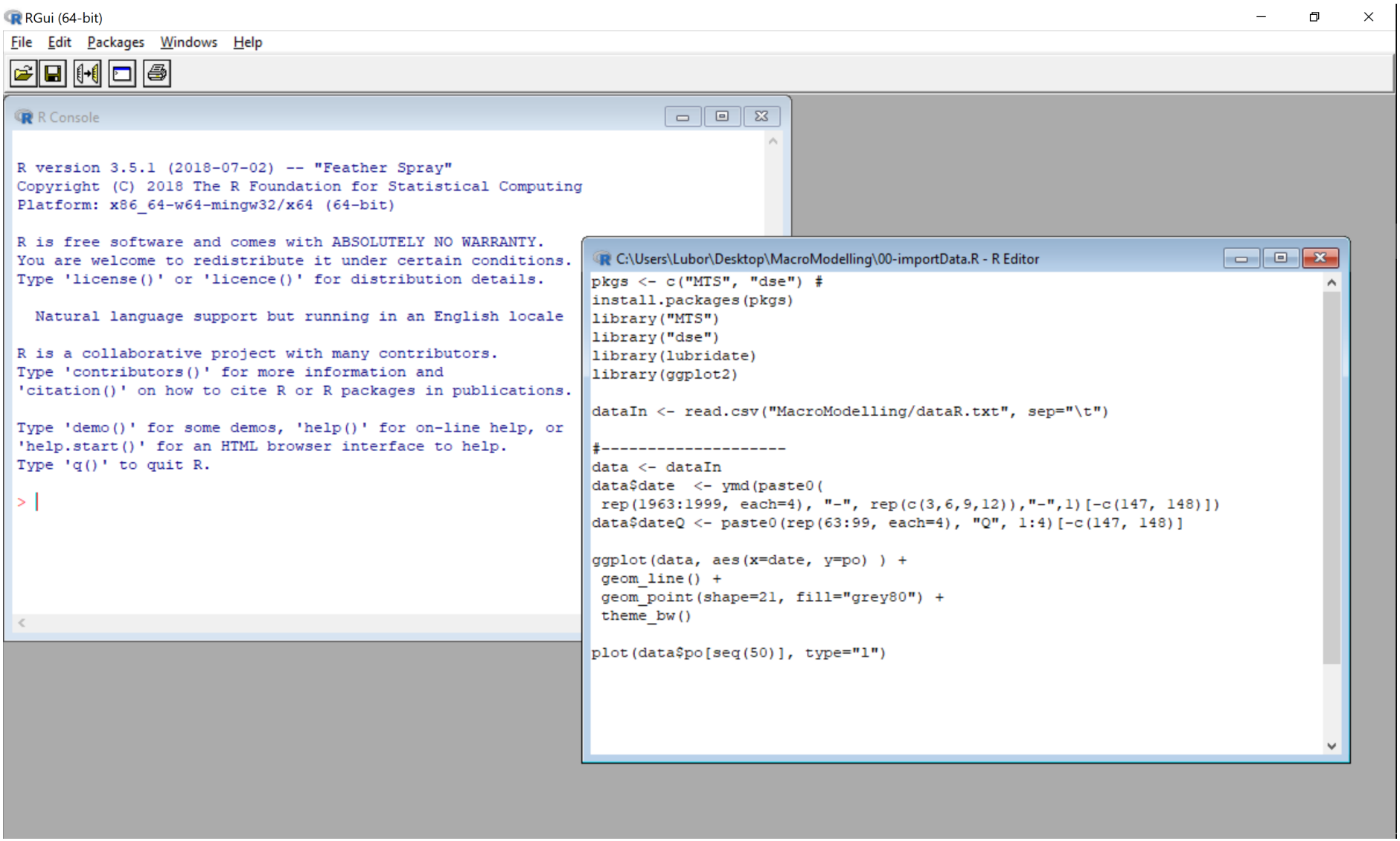
Dasu T, Johnson T (2003). *Exploratory Data Mining and Data Cleaning*. John Wiley & Sons.

Obligatory intro to R and R language...

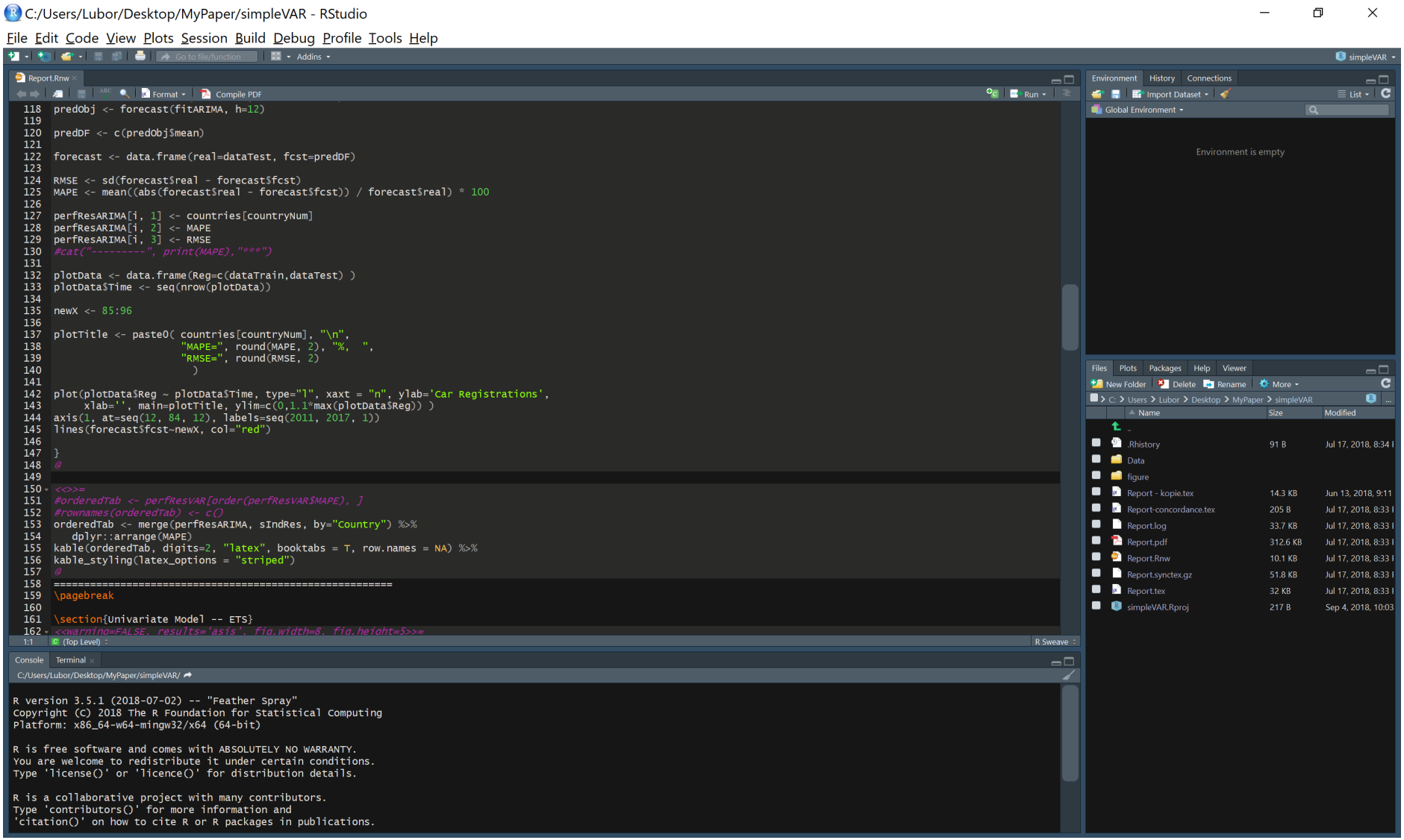
Before we start experimenting, we need to talk about:

- what is R
- basics of object-oriented programming

R GUI - here you spend the most time...



... until you need start doing reproducible research



Object Oriented Programming

We have 4 students (Alice, Bob, Chelsea and Alice) who form a study group.

```
names <- c("Alice", "Bob", "Chelsea", "Alice")
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`names` is an object.

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`names` is an object. We apply functions on objects:

```
unique(names)

## [1] "Alice"   "Bob"     "Chelsea"
```

Your turn - open R

- compute $1 + 1$

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- Click on File $\rightarrow$ New Script. Type $1 + 1$ into the script and press ctrl+R

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```
simpleSum <- 1+1
```

- take $\sqrt{simpleSum}$, use sqrt() function

```
sqrt(simpleSum)

## [1] 1.414214
```

Data Types

- numeric
- character, factor (important for variable coding, allows ordering)

```
a <- 1
b <- "male"
c <- "1"

class(a)

## [1] "numeric"

class(b)

## [1] "character"

class(c)

## [1] "character"
```

Other Important Types

What if we want to work with more values at the same time?

- column = `c()`
- matrix = `matrix()`
- data frame = `data.frame()`
- list = `list()`
- tibble = `tibble()`

Do you remember motivating example?

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```

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names <- c("Alice", "Bob", "Chelsea", "Alice")
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1. Create similar column called `scores`, which contains number of points from the test on a scale from 0–100 for each student.

   ```
   scores <- c(60, 40, 55, 70)
   ```

2. Create `data.frame(names, scores)` and name it `classData`

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   ```
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3. See what is inside of the `classData` object
4. Inspect `classData` by function `str()`

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```

3. See what is inside of the `classData` object
4. Inspect `classData` by function `str()`

```
str(classData)

## 'data.frame': 4 obs. of  2 variables:
##  $ names : Factor w/ 3 levels "Alice","Bob",..: 1 2
##  $ scores: num  60 40 55 70
```

5. Inspect `classData` by function `summary()`

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```
summary(classData)
```

```
##      names       scores
##  Alice  :2   Min.   :40.00
##  Bob    :1   1st Qu.:51.25
##  Chelsea:1   Median :57.50
##              Mean   :56.25
##              3rd Qu.:62.50
##              Max.   :70.00
```

5. Inspect `classData` by function `summary()`

```
summary(classData)

##       names        scores
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##              Mean   :56.25
##              3rd Qu.:62.50
##              Max.   :70.00
```

Summary of the data is an object:

```
summaryTab <- summary(classData)
class(summaryTab) # ident. class(summary(classData))

## [1] "table"
```

Try it by yourself

1. generate 200 values from Normal distribution by function `rnorm(n=200)` and store values in `normData1`
2. compute standard deviation `sd()` and mean value `mean()`
3. create a histogram by `hist()`
4. generate another 200 values from Normal distribution and store them in object `normData2`
5. create `data.frame()` with 2 columns – normData1 and normData2 and call it `normalData`
6. create a scatter plot by `plot(normalData)`
7. compute a correlation of normData1 and normData2, by function `cor()`. If you need help for function, type `?cor`

Import

Data Import

There are several ways how to read data into R:

- from your file (text file, Excel file)
- from online sources (Eurostat)
- other (web scraping through XML)

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- from your file (text file, Excel file)
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Warning

Keeping data in MS Excel makes doing (untracable) changes too tempting!

Recommendation

Create one data file in .txt or .csv filetype. DON'T change it. Read it into R. Do all manipulations in R. All steps are recorded in the script.

- Store the file in ./myRproject/Data folder

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Create one data file in .txt or .csv filetype. DON'T change it. Read it into R. Do all manipulations in R. All steps are recorded in the script.

- Store the file in ./myRproject/Data folder
- change R working directory

```
getwd() #to find current WD

## [1] "C:/Users/Lubor/Disk Google/Work/2018/R_workshop"
```

Recommendation

Create one data file in .txt or .csv filetype. DON'T change it. Read it into R. Do all manipulations in R. All steps are recorded in the script.

- Store the file in ./myRproject/Data folder
- change R working directory

```
getwd() #to find current WD

## [1] "C:/Users/Lubor/Disk Google/Work/2018/R_workshop"
```

Set the working directory one folder under data folder:

```
setwd("C:/Users/Lubor/Rworkshop")
```

if your data folder is in "C:/Users/Lubor/Rworkshop/Data"

Open carsData.txt

carsData – Poznámkový blok

Soubor Úpravy Formát Zobrazení Nápověda

```
name;mpg;cyl;disp;hp;drat;wt;qsec;vs;am;gear;carb
Mazda RX4;21;6;160;110;3.9;2.62;16.46;0;1;4;4
Mazda RX4 Wag;21;6;160;110;3.9;2.875;17.02;0;1;4;4
Datsun 710;22.8;4;108;93;3.85;2.32;18.61;1;1;4;1
Hornet 4 Drive;21.4;6;258;110;3.08;3.215;19.44;1;0;3;1
Hornet Sportabout;18.7;8;360;175;3.15;3.44;17.02;0;0;3;2
Valiant;18.1;6;225;105;2.76;3.46;20.22;1;0;3;1
Duster 360;14.3;8;360;245;3.21;3.57;15.84;0;0;3;4
Merc 240D;24.4;4;146.7;62;3.69;3.19;20;1;0;4;2
Merc 230;22.8;4;140.8;95;3.92;3.15;22.9;1;0;4;2
Merc 280;19.2;6;167.6;123;3.92;3.44;18.3;1;0;4;4
Merc 280C;17.8;6;167.6;123;3.92;3.44;18.9;1;0;4;4
Merc 450SE;16.4;8;275.8;180;3.07;4.07;17.4;0;0;3;3
Merc 450SL;17.3;8;275.8;180;3.07;3.73;17.6;0;0;3;3
Merc 450SLC;15.2;8;275.8;180;3.07;3.78;18;0;0;3;3
Cadillac Fleetwood;10.4;8;472;205;2.93;5.25;17.98;0;0;3;4
Lincoln Continental;10.4;8;460;215;3;5.424;17.82;0;0;3;4
Chrysler Imperial;14.7;8;440;230;3.23;5.345;17.42;0;0;3;4
Fiat 128;32.4;4;78.7;66;4.08;2.2;19.47;1;1;4;1
Honda Civic;30.4;4;75.7;52;4.93;1.615;18.52;1;1;4;2
Toyota Corolla;33.9;4;71.1;65;4.22;1.835;19.9;1;1;4;1
Toyota Corona;21.5;4;120.1;97;3.7;2.465;20.01;1;0;3;1
Dodge Challenger;15.5;8;318;150;2.76;3.52;16.87;0;0;3;2
AMC Javelin;15.2;8;304;150;3.15;3.435;17.3;0;0;3;2
Camaro Z28;13.3;8;350;245;3.73;3.84;15.41;0;0;3;4
Pontiac Firebird;19.2;8;400;175;3.08;3.845;17.05;0;0;3;2
Fiat X1-9;27.3;4;79;66;4.08;1.935;18.9;1;1;4;1
```

Open carsData.txt

carsData – Poznámkový blok

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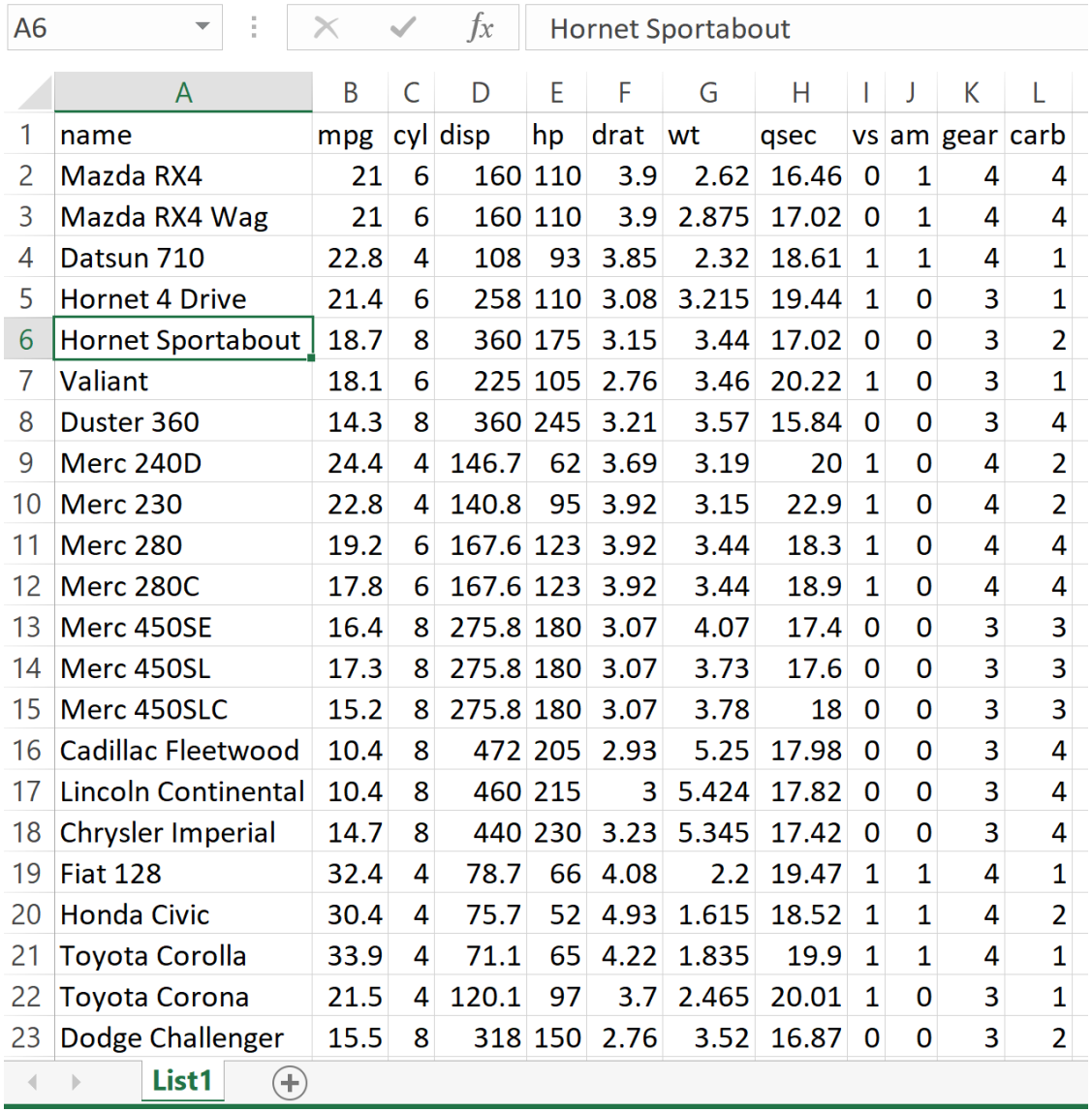
How can I create similar file?

Use MS Excel



A6 | Hornet Sportabout

	A	B	C	D	E	F	G	H	I	J	K	L
1	name	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
2	Mazda RX4	21	6	160	110	3.9	2.62	16.46	0	1	4	4
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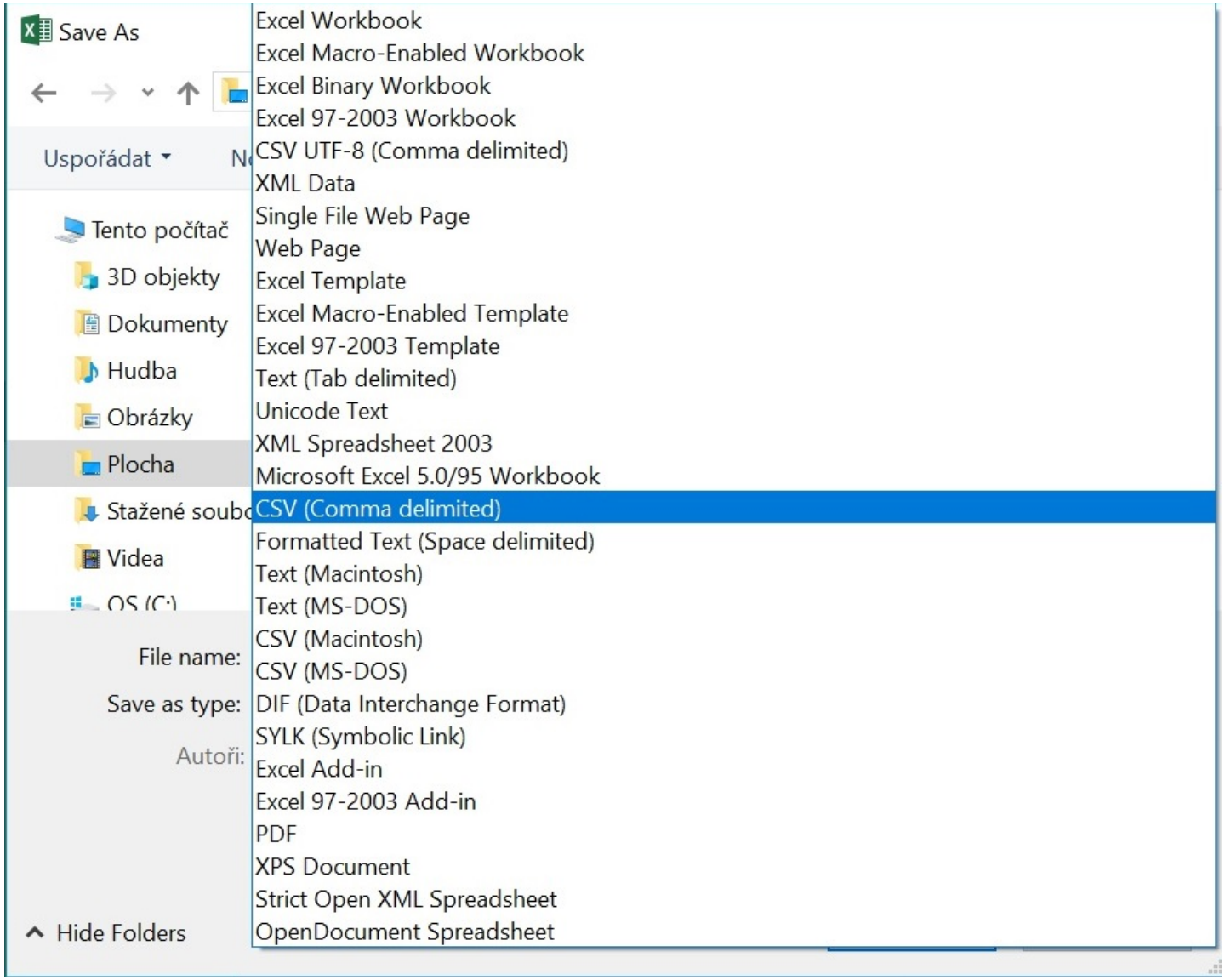
List1

Save File as...


Save As
Uspořádat
Tento počítač
3D objekty
Dokumenty
Hudba
Obrázky
Plocha
Stažené soubo
Videa
OS (C:)
File name:
Save as type:
Autoři:
Hide Folders
Excel Workbook
Excel Macro-Enabled Workbook
Excel Binary Workbook
Excel 97-2003 Workbook
CSV UTF-8 (Comma delimited)
XML Data
Single File Web Page
Web Page
Excel Template
Excel Macro-Enabled Template
Excel 97-2003 Template
Text (Tab delimited)
Unicode Text
XML Spreadsheet 2003
Microsoft Excel 5.0/95 Workbook
CSV (Comma delimited)
Formatted Text (Space delimited)
Text (Macintosh)
Text (MS-DOS)
CSV (Macintosh)
CSV (MS-DOS)
DIF (Data Interchange Format)
SYLK (Symbolic Link)
Excel Add-in
Excel 97-2003 Add-in
PDF
XPS Document
Strict Open XML Spreadsheet
OpenDocument Spreadsheet

Let's do it!

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```

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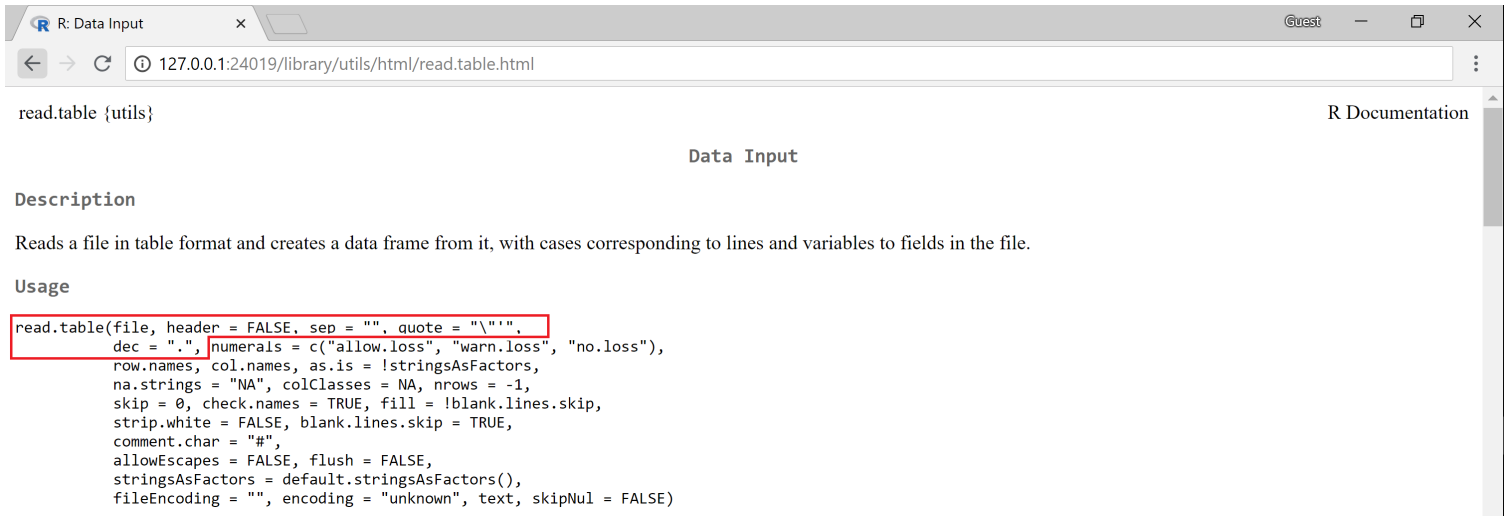
Check the help file of the function:

```
?read.table
```



In our case:

```
dataIn <- read.table("./Data/carsData.txt",
                     header = TRUE, sep=";")
```

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dataIn <- read.table("./Data/carsData.txt",
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Inspect the first 6 rows by function `head()`

```
head(dataIn)
```

```
##                  name  mpg cyl disp  hp drat    wt  qsec
## 1           Mazda RX4 21.0   6  160 110 3.90 2.620 16.46
## 2       Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02
## 3          Datsun 710 22.8   4  108  93 3.85 2.320 18.61
## 4      Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44
## 5 Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02
## 6             Valiant 18.1   6  225 105 2.76 3.460 20.22
```

Tidy Data

We talk about the tidy data when:

1. Each variable forms a column,
2. Each observation forms a row.
3. All data is stored in one table.

```
head(dataIn)
```

```
##                   name  mpg cyl disp  hp drat    wt  qsec vs am gea
## 1            Mazda RX4 21.0   6  160 110 3.90 2.620 16.46  0  1    
## 2        Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    
## 3           Datsun 710 22.8   4  108  93 3.85 2.320 18.61  1  1    
## 4       Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44  1  0    
## 5    Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    
## 6              Valiant 18.1   6  225 105 2.76 3.460 20.22  1  0
```

Transform

Welcome to the Tidyverse

Tidyverse is a collection of packages designed to work with tidy data.

```
library(tidyverse)
```

The most important libraries:

- dplyr – manipulation and transformation
- ggplot – advanced plotting
- tidyr – data reshaping tools

dplyr library

Core functions used in data manipulation:

- select
- filter
- mutate
- summarise
- group_by

But first, let's talk about pipes.

Pipes

Pipe %>% is a flow operator. It indicates how the data is passed from one function to another.

Consider following analysis:

```
rnorm(100) %>% abs() %>% sqrt() %>% hist()
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is equivalent to:

```
hist(sqrt(abs(rnorm(100))))
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Consider following analysis:

```
rnorm(100) %>% abs() %>% sqrt() %>% hist()
```

is equivalent to:

```
hist(sqrt(abs(rnorm(100))))
```

or even to:

```
normData <- rnorm(100)
absData  <- abs(normData)
sqrtData <- sqrt(absData)
hist(sqrtData)
```

Function: select

You want to do an analysis of cyl and am from the car dataset.

```
dataIn %>%
  select(cyl, am) %>%
  table()

##     am
## cyl  0  1
##   4  3  8
##   6  4  3
##   8 12  2
```

Function: `filter`

You want to do the same analysis as before, but only with $hp < 150$

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```
dataIn %>%
  filter(hp < 150) %>%
  select(cyl, am) %>%
  table()

##    am
## cyl 0 1
##   4 3 8
##   6 4 2
```

Function: `filter`

You want to do the same analysis as before, but only with $hp < 150$

```
dataIn %>%
  filter(hp < 150) %>%
  select(cyl, am) %>%
  table()

##    am
## cyl 0 1
##   4 3 8
##   6 4 2
```

What is this? $hp == 150$, $hp != 150$, $hp >= 150$

Function: `filter` - continued

- `A & B` means A AND B
- `A | B` means A OR B

You want to do the same analysis as before, but only with $hp < 150$ AND $mpg > 14$

Function: `filter` - continued

- `A & B` means A AND B
- `A | B` means A OR B

You want to do the same analysis as before, but only with $hp < 150$ AND $mpg > 14$

```
dataIn %>%
  filter(hp < 150 & mpg > 14) %>%
  select(cyl, am) %>%
  table()

##    am
## cyl 0 1
##   4 3 8
##   6 4 2
```

Function: mutate.

Miles per gallon? We are in Europe! Let's convert it to units which make sense: 1 mile $\sim$ 1.61 kilometer, 1 gallon $\sim$ 3.79 liters. 1 mpg $\sim$ 0.42 kmpl

```
carsData <- dataIn %>%
  mutate(kmpl = 0.42*mpg)
```

Check whether it worked by displaying head of carsData. Show only name, mpg a and kmpl columns:

Function: mutate.

Miles per gallon? We are in Europe! Let's convert it to units which make sense: 1 mile $\sim$ 1.61 kilometer, 1 gallon $\sim$ 3.79 liters. 1 mpg $\sim$ 0.42 kmpl

```
carsData <- dataIn %>%
  mutate(kmpl = 0.42*mpg)
```

Check whether it worked by displaying head of carsData. Show only name, mpg a and kmpl columns:

Function: mutate.

Miles per gallon? We are in Europe! Let's convert it to units which make sense: 1 mile $\sim$ 1.61 kilometer, 1 gallon $\sim$ 3.79 liters. 1 mpg $\sim$ 0.42 kmpl

```
carsData <- dataIn %>%
  mutate(kmpl = 0.42*mpg)
```

Check whether it worked by displaying head of carsData. Show only name, mpg a and kmpl columns:

```
carsData %>% select(name, mpg, kmpl) %>% head()
```

```
##                   name  mpg  kmpl
## 1            Mazda RX4 21.0 8.820
## 2        Mazda RX4 Wag 21.0 8.820
## 3           Datsun 710 22.8 9.576
## 4       Hornet 4 Drive 21.4 8.988
## 5    Hornet Sportabout 18.7 7.854
## 6              Valiant 18.1 7.602
```

Function: summarise

We want to know:

1. mean value of kmpl = meanKMPL
2. mean value of hp = meanHP

```
carsData %>%
  summarise(
    meanKMPL = mean(kmpl),
    meanHP   = mean(hp)
  )

##   meanKMPL   meanHP
## 1 8.438062 146.6875
```

We have created a new data frame with 2 columns.

Function: group_by

Let's continue with the previous example. You want to do the analysis on subsets/groups by variable: group_by(cyl)

```
carsData %>%
  group_by(cyl) %>%
  summarise(
    meanKMPL = mean(kmpl),
    meanHP   = mean(hp)
  )

## # A tibble: 3 x 3
##     cyl meanKMPL meanHP
##   <int>    <dbl>  <dbl>
## 1     4    11.2    82.6
## 2     6     8.29  122.
## 3     8     6.34  209.
```

Visualise

Data Overview

```
str(dataIn)

## 'data.frame': 32 obs. of  12 variables:
##  $ name: Factor w/ 32 levels "AMC Javelin",..: 18 19 5 13 14 31 
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : int  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : int  110 110 93 110 175 105 245 62 95 123 ...
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ..
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : int  0 0 1 1 0 1 0 1 1 1 ...
##  $ am  : int  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: int  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: int  4 4 1 1 2 1 4 2 2 4 ...
```

Library ggplot

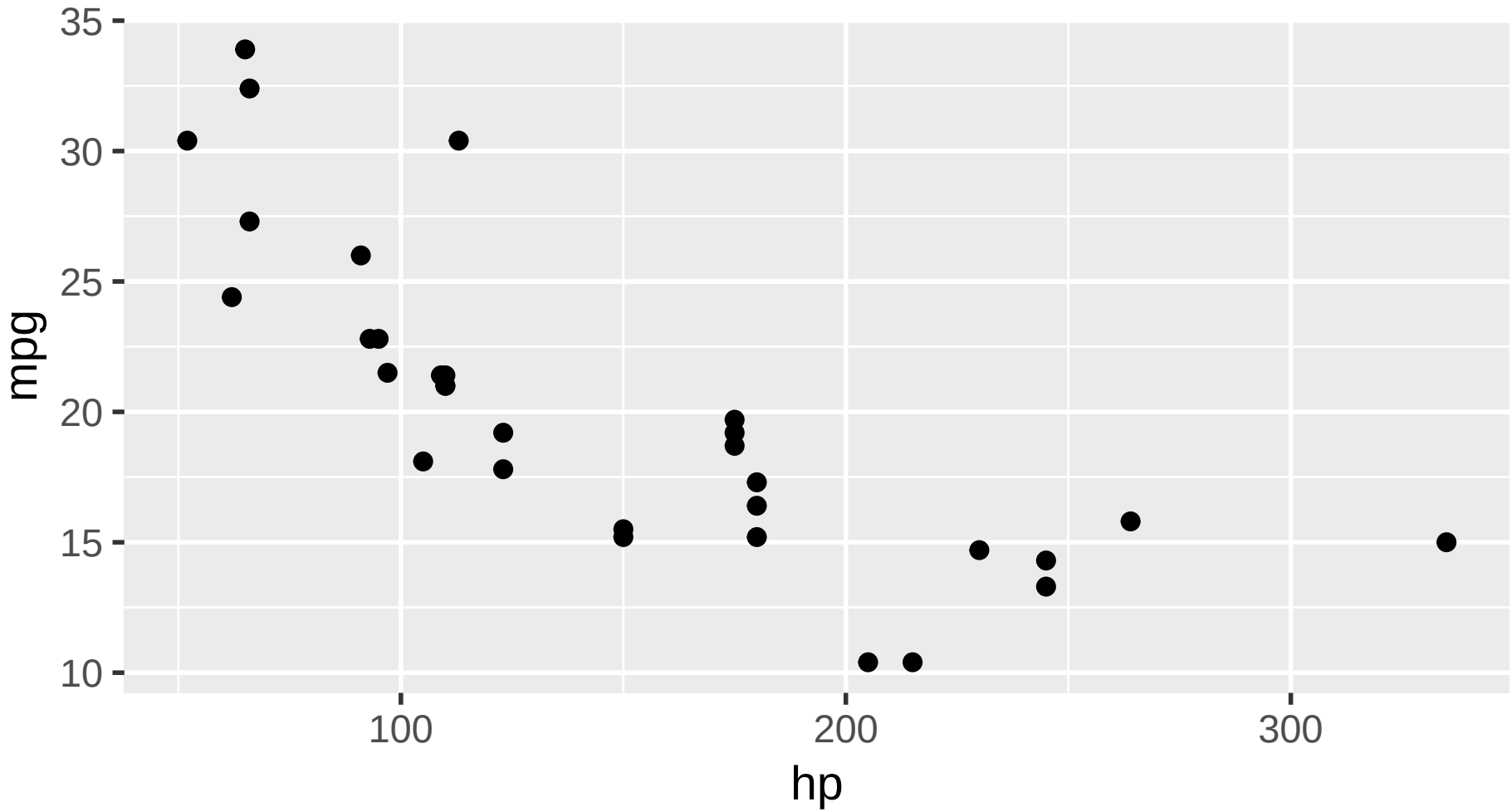
Library ggplots introduces plotting by layers.

1. Define underying layer (data + variables)
2. Add **layers** (points, boxplots,...)

Every ggplot() plot contains data reference and **aes**thetic mapping.

```
ggplot(dataIn, aes(x=hp, y=mpg)) +
  geom_point()
```

```
library(ggplot2)
ggplot(dataIn, aes(x=hp, y=mpg)) +
  geom_point()
```



Library ggplot

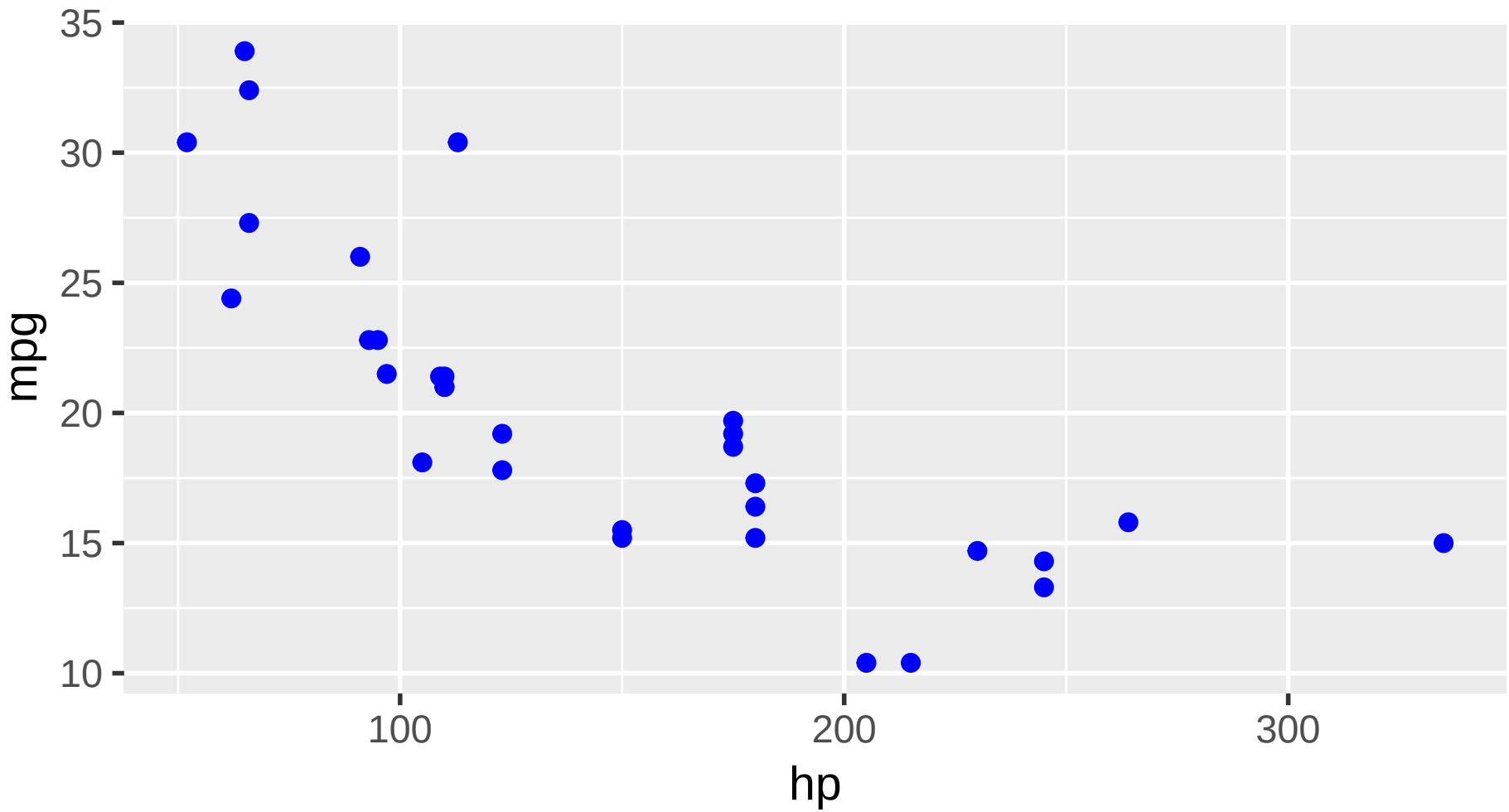
What makes ggplot powerful is an application of aestethics:

- color
- fill
- size
- shape
- linetype

Take a look at following two plots.

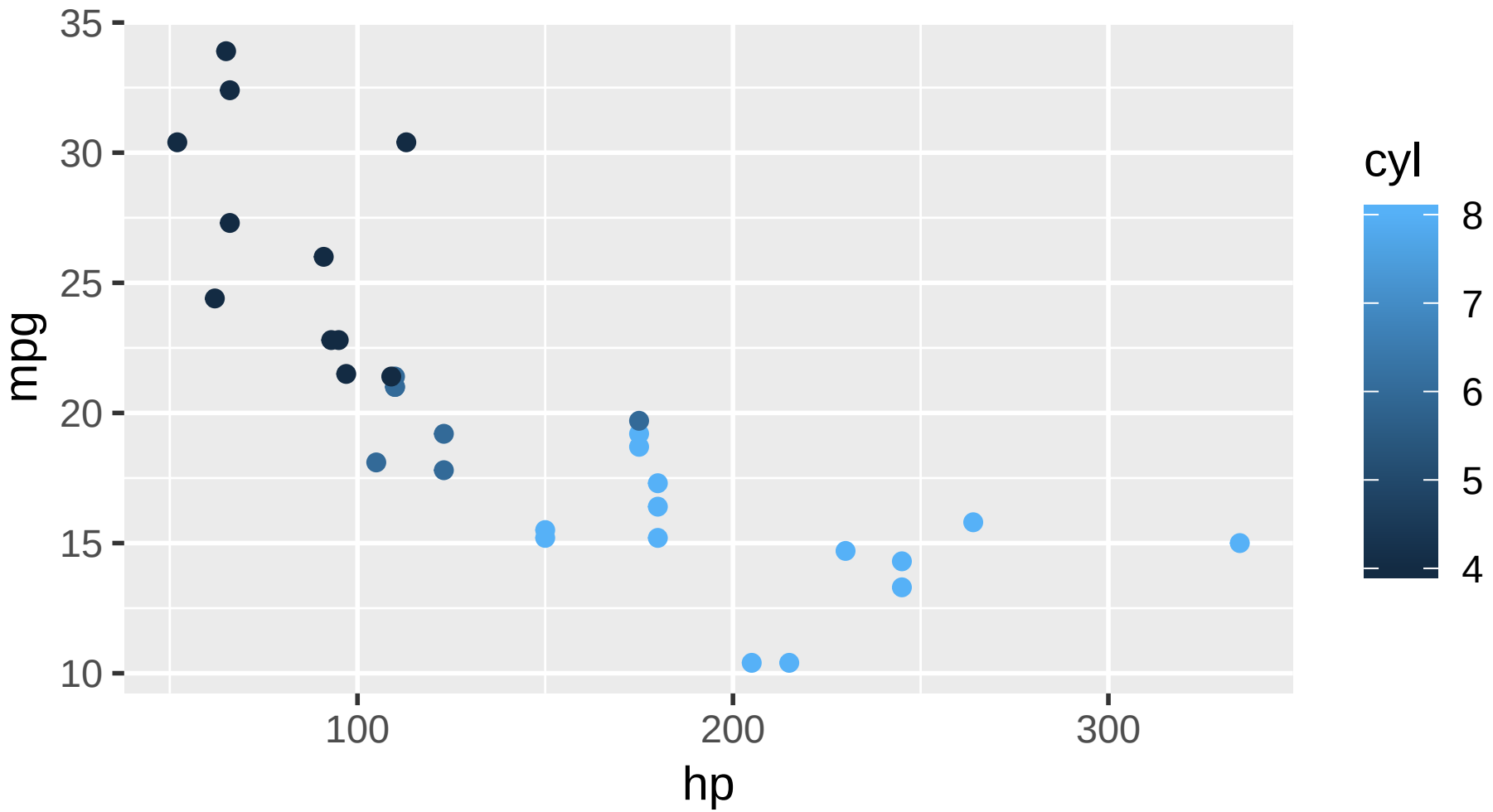
color as a Graphical Parameter

```
ggplot(dataIn, aes(x=hp, y=mpg)) +
  geom_point(color="blue")
```

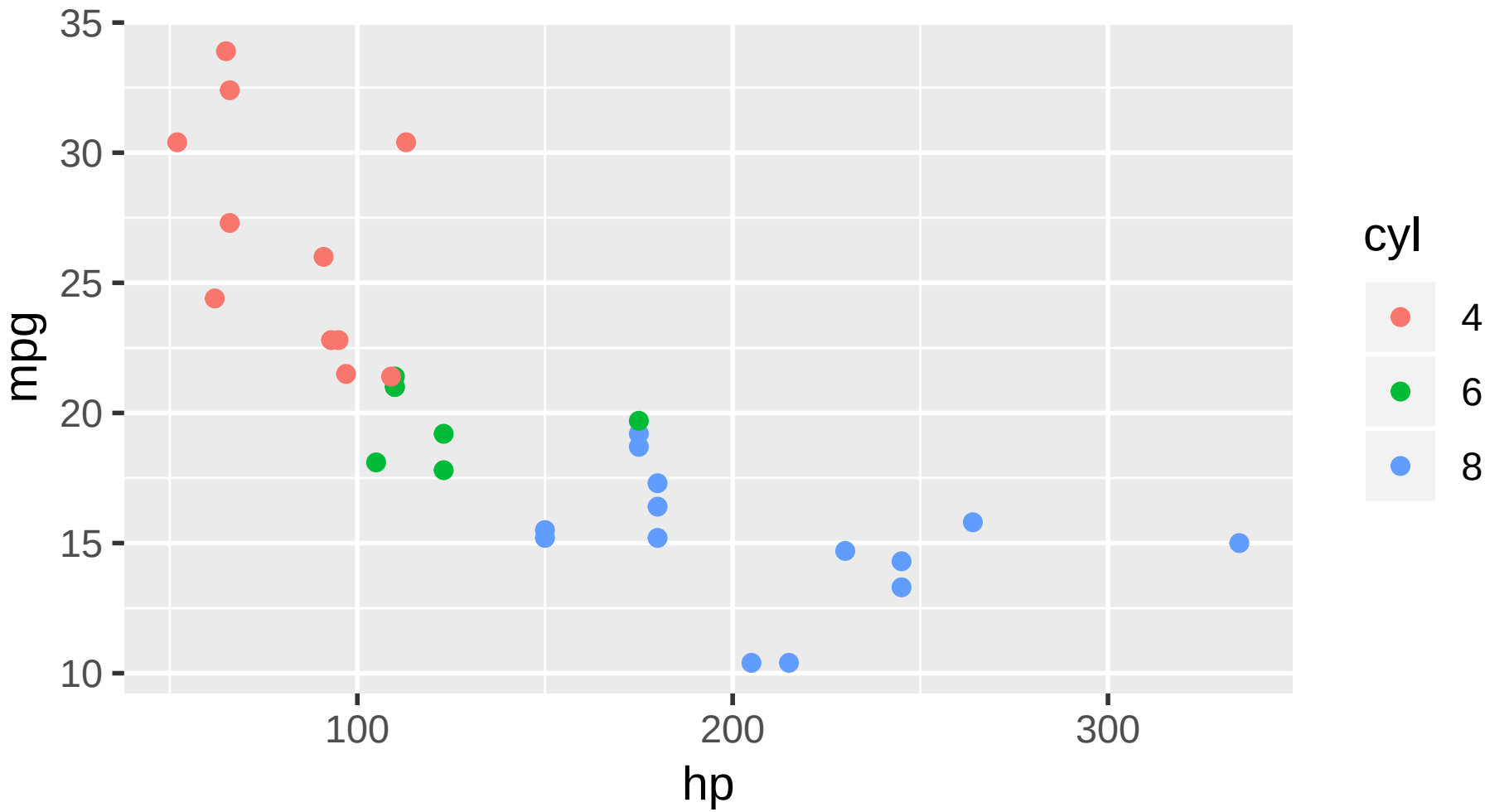


color as an aestetics

```
ggplot(dataIn, aes(x=hp, y=mpg, color=cyl)) +
  geom_point()
```



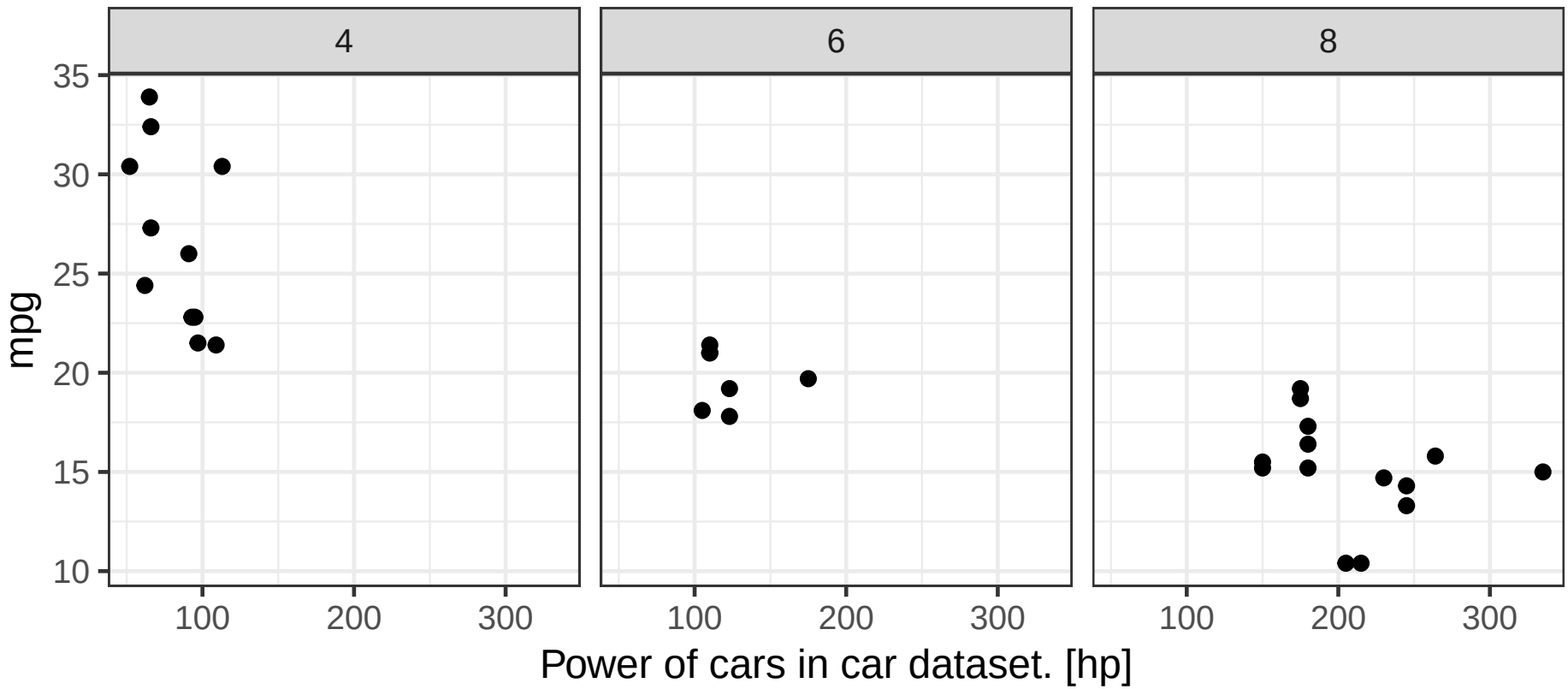
```
dataIn %>%
  mutate(cyl = factor(cyl)) %>%
 ggplot(., aes(x=hp, y=mpg, color=cyl)) +
  geom_point()
```



We can adjust (almost) everything in ggplot through additional functions (just to mention few):

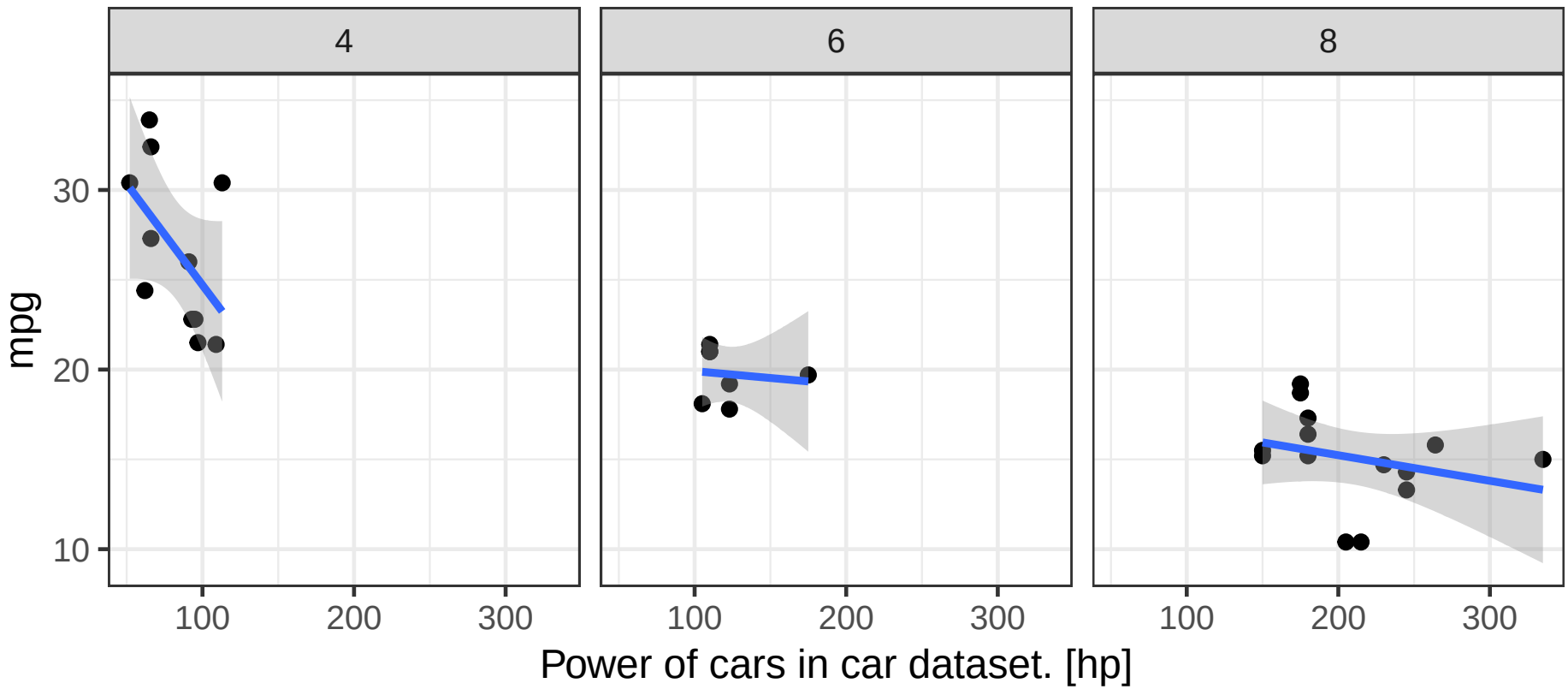
- `facet_grid()`
- `scale_y_continuous(name, limits, ...)`, `scale_x_discrete()`
- `theme_bw()`

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(., aes(x=hp, y=mpg)) +
  geom_point() +
  scale_x_continuous("Power of cars in car dataset. [hp]") +
  facet_grid(.~cyl) +
  theme_bw()
```



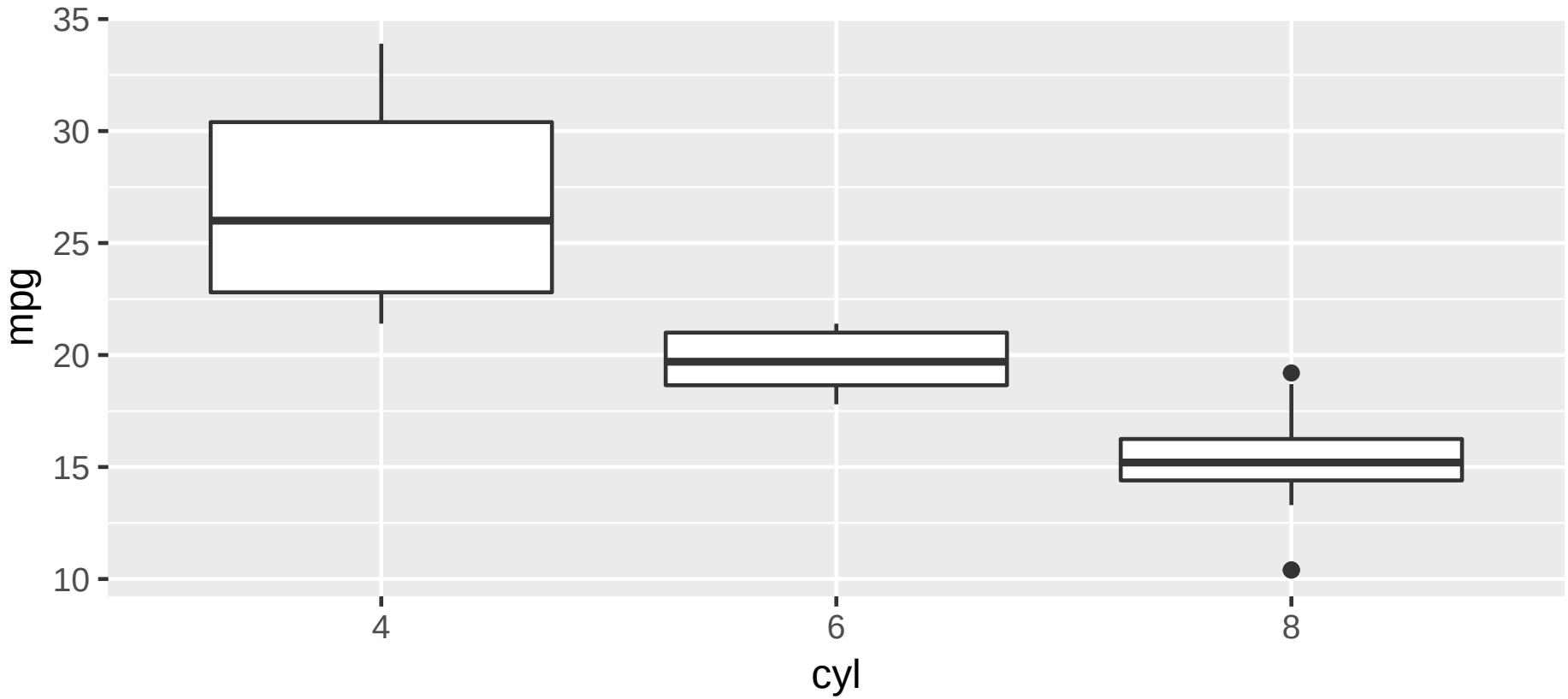
Why not to add regressions by geom_smooth()?

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(., aes(x=hp, y=mpg)) + geom_point() +
  scale_x_continuous("Power of cars in car dataset. [hp]") +
  facet_grid(.~cyl) + theme_bw() + geom_smooth(method="lm")
```



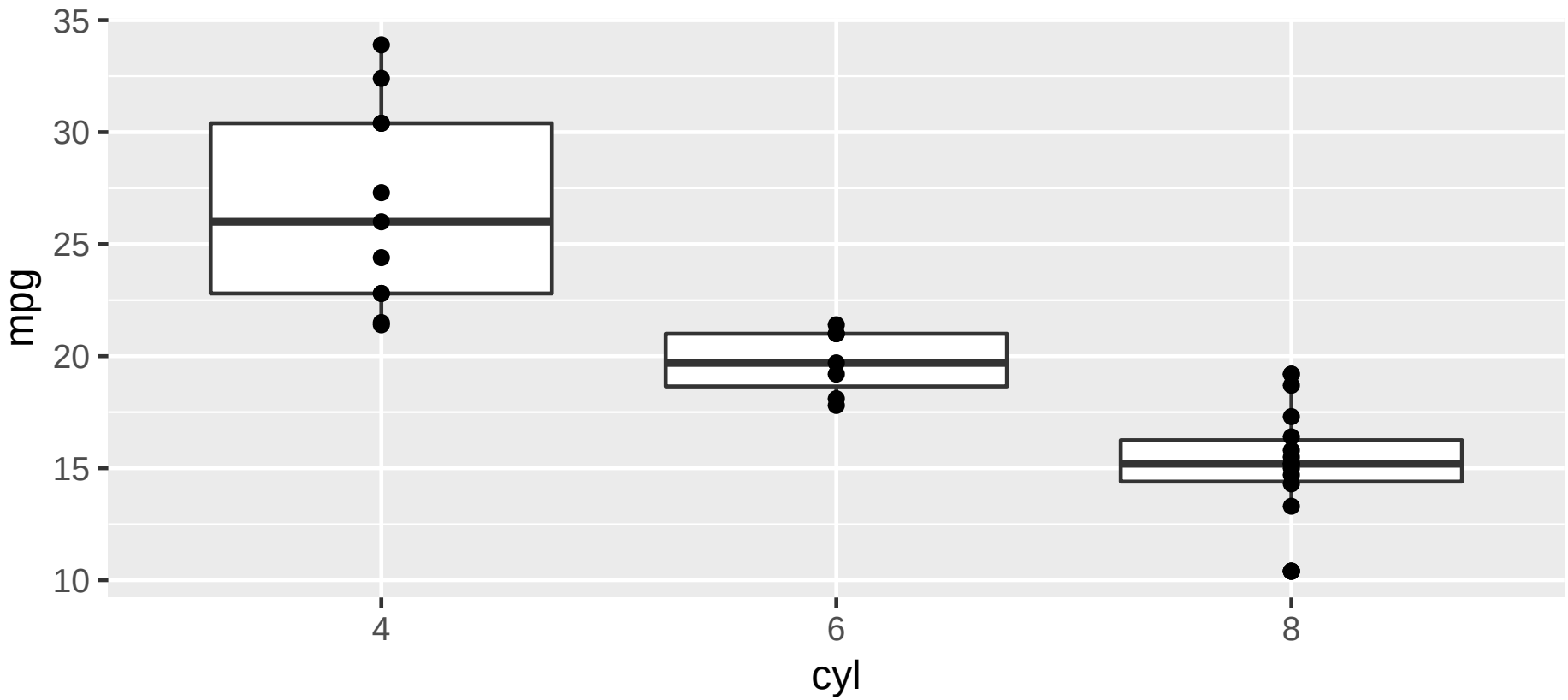
geom_boxplot

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(aes(x=cyl, y=mpg) ) +
  geom_boxplot()
```



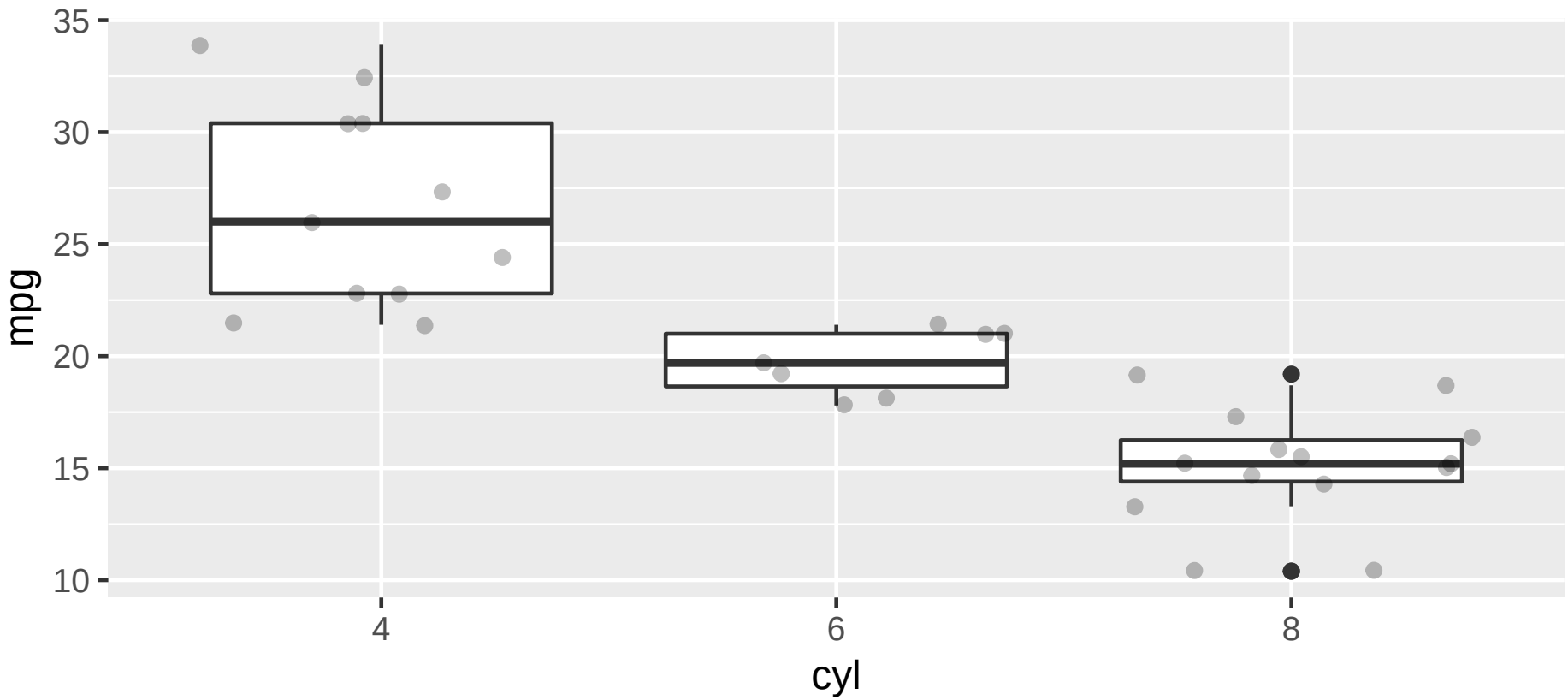
Let's add additional layer

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(aes(x=cyl, y=mpg) ) +
  geom_boxplot() +
  geom_point()
```



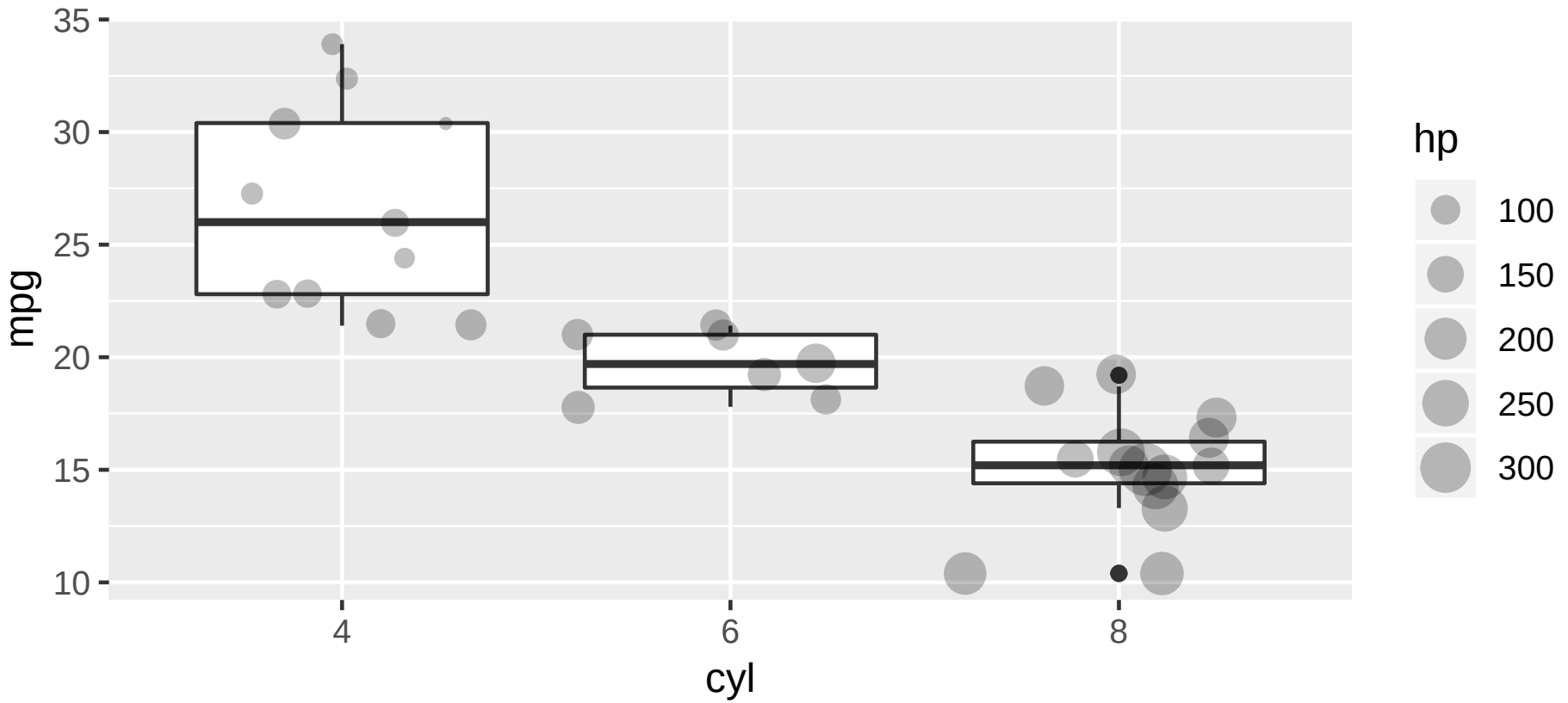
Add geom-specific aes

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(aes(x=cyl, y=mpg) ) +
  geom_boxplot() +
  geom_jitter(alpha=0.25)
```



Add geom-specific aes

```
dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(aes(x=cyl, y=mpg) ) +
  geom_boxplot() +
  geom_jitter(aes(size=hp), alpha=0.25)
```



Processing ggplots

```
plot1 <- dataIn %>%
  mutate(cyl = as.factor(cyl)) %>%
 ggplot(aes(x=cyl, y=mpg) ) +
  geom_boxplot() +
  geom_point()

plot1
ggsave("./images/myPlot1.pdf", width=6, height = 4) # png
```

Try following:

```
library(plotly)
ggplotly(plot1)
```

Your Turn

There is a dataset in ggplot library called `diamonds`.

1. familiarise yourselves with the dataset: `?diamonds`
2. how many observations is in the dataset? Find this information in R!
3. Create a table from the main dataset which analyses price of diamonds and visualise it in ggplot.
4. Try to combine filter, group_by and **summarise**

- Book about R
- and good DS practices.
- Available for free online