CME/STATS 195

Lecture 3: Importing and manipulating data

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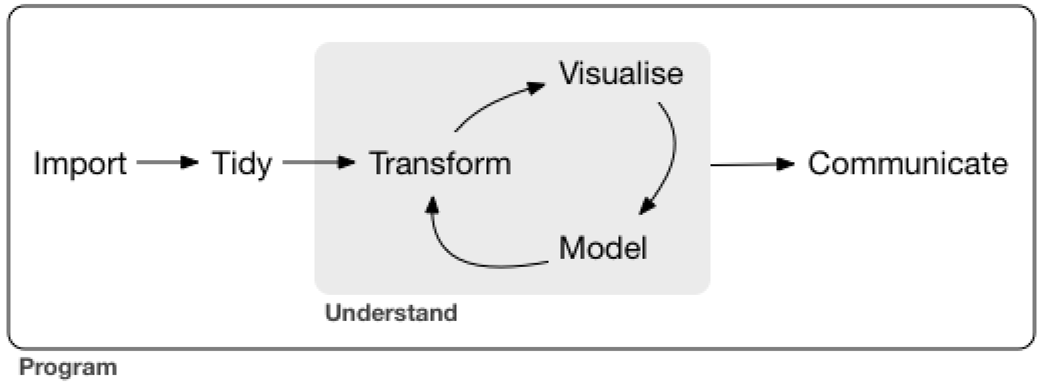
Data Science

Data Science Workflow

> *Data science is an exciting discipline that allows you to turn raw data into understanding, insight, and knowledge.* [1]

1. Import
2. Wrangle (tidy & transform)
3. Visualize
4. Model
5. Communicate



tidyverse

> *The `tidyverse` is an opinionated collection of R packages designed for data science. All packages share an underlying design philosophy, grammar, and data structures.* [2]

`tidyverse` includes packages for **importing, wrangling, exploring and modeling data**.

The system is intended to make data scientists more productive. To use `tidyverse` do the following:

```r
# Install the package
install.packages("tidyverse")
# Load it into memory
library("tidyverse")
```

The `tibble` package

The `tibble` package is part of the core `tidyverse`.

> *Tibbles are a modern take on data frames. They keep the features that have stood the test of time, and drop the features that used to be convenient but are now frustrating.*

`tibbles` are data frames, tweaked to make life a little easier. Unlike regular `data.frames` they:

- never change the type of the inputs (e.g. do not convert strings to factors!)
- never changes the names of variables
- never creates row.names()
- only recycles inputs of length 1

Using tibbles

To use functions from tibble and other tidyverse packages:

```
# load it into memory
library(tidyverse)
```

Printing tibble is much nicer, and always fits into your window:

```
# e.g. a built-in dataset 'diamonds' is a tibble:
class(diamonds)
```

```
## [1] "tbl_df"     "tbl"        "data.frame"
```

```
diamonds
```

```
## # A tibble: 53,940 x 10
##    carat cut       color clarity depth table price     x     y     z
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1 0.23  Ideal     E     SI2      61.5    55   326  3.95  3.98  2.43
##  2 0.21  Premium   E     SI1      59.8    61   326  3.89  3.84  2.31
##  3 0.23  Good      E     VS1      56.9    65   327  4.05  4.07  2.31
##  4 0.290 Premium   I     VS2      62.4    58   334  4.2   4.23  2.63
##  5 0.31  Good      J     SI2      63.3    58   335  4.34  4.35  2.75
##  6 0.24  Very Good J     VVS2     62.8    57   336  3.94  3.96  2.48
##  7 0.24  Very Good I     VVS1     62.3    57   336  3.95  3.98  2.47
##  8 0.26  Very Good H     SI1      61.9    55   337  4.07  4.11  2.53
##  9 0.22  Fair      E     VS2      65.1    61   337  3.87  3.78  2.49
## 10 0.23  Very Good H     VS1      59.4    61   338  4     4.05  2.39
## # … with 53,930 more rows
```

Using `tibbles`

Subsetting `tibbles` is strickter than subsetting `data.frames`, and ALWAYS returns objects with expected class, i.e. with a single `[` you get back a `tibble`, with double `[[` you get a vector.

```r
class(diamonds$carat)
```

```
## [1] "numeric"
```

```r
class(diamonds[["carat"]])
```

```
## [1] "numeric"
```

```r
class(diamonds[, "carat"])
```

```
## [1] "tbl_df"     "tbl"        "data.frame"
```

```r
diamonds.df <- data.frame(diamonds)
class(diamonds.df[["carat"]])
```

```
## [1] "numeric"
```

```r
class(diamonds.df[, "carat"])
```

```
## [1] "numeric"
```

More on `tibbles`

You can read more about other `tibble` features by calling on your R console:

```r
vignette("tibble")
```

Importing data

Working Directory

- The **current working directory** (cmd) is the location which R is currently pointing to
- Whenever you try to read or save a file without specifying the path explicitly, the cmd will be used by default.
- When are executing code from an R markdown/notebook code chunk, the cmd is **the location of the document**.
- To see the current working directory use `getwd()`:

```r
getwd()    # with no arguments
```

```
## [1] "/home/lanhuong/MEGA/Teaching/cme195_intro_to_R/cme195.github.io/assets/lectures"
```

- To change the working directory use `setwd(path_name)` with a specified path as na argument:

```r
setwd("path/to/directory")
```

Paths and directory names

- R inherits its file and folder **naming conventions from unix**, and uses forward slashes for the directories, e.g. `/home/lan/folder/`
- This is, because backslashes serve a different purpose; they are used as escape characters to isolate special characters and stop them from being immediately interpreted.
- When working with R on **Windows**, you can use either: `C:/Path/To/A/File` or `C:\\Path\\To\\A\\File`
- Use a "`Tab`" for autocompletion to find file paths more easily.
- To avoid problems, directory names should NOT contain spaces and special characters.

Importing text data

- **Text Files in a table format** can be read and saved to a selected variable using a `read.table()` function. Use `?read.table` to learn more about the function.
- A common text file format is a **comma delimited text file**, `.csv`. These files use a comma as column separators, e.g:

```
Year,Student,Major
2009, John Doe,Statistics
2009, Bart Simpson, Mathematics I
```

- To read these files use the following command:

```
mydata <- read.table("path/to/filename.csv", header=TRUE,  sep = ",")

# read.csv() has covenient argument defaults for '.csv' files
mydata <- read.csv("path/to/filename.csv")
```

- Optionally, use `row.names` or `col.names` arguments to set the row and column names.

The `readr` package

Many R packages provide examples of data. However, sooner or later you will need to work with your own data.

`readr` is for reading rectangular text data into R.

`readr` supports several file formats with seven `read_<...>` functions:

- `read_csv()`: comma-separated (CSV) files
- `read_tsv()`: tab-separated files
- `read_delim()`: general delimited files
- `read_fwf()`: fixed-width files
- `read_table()`: tabular files where colums are separated by white-space
- `read_log()`: web log files

In many cases it just works: supply path to a file and get a tibble back.

Comparison with base R

Why are we learning the readr package?

- it is up to 10x faster
- it produces tibbles instead of data.frames
- better parsing (e.g. does not convert strings to factors)
- more reproducible on different systems
- progress bar for large files

Reading comma-separated files

All `read_<...>()` functions have a similar syntax, so we focus on `read_csv`

```
# Get path to example dataset
readr_example("mtcars.csv")
```

```
## [1] "/home/lanhuong/R/x86_64-pc-linux-gnu-library/3.4/readr/extdata/mtcars.csv"
```

```
mtcars <- read_csv(readr_example("mtcars.csv"))
```

```
## Parsed with column specification:
## cols(
##   mpg = col_double(),
##   cyl = col_integer(),
##   disp = col_double(),
##   hp = col_integer(),
##   drat = col_double(),
##   wt = col_double(),
##   qsec = col_double(),
##   vs = col_integer(),
##   am = col_integer(),
##   gear = col_integer(),
##   carb = col_integer()
## )
```

`mtcars` is a dataset on fuel consumption, and other 10 aspects of design and performance (`?mtcars`).

The `read_csv()` function

Also works with inline csv files (useful for experimenting).

```r
read_csv(
  "a,b,c
  1,2,3
  4,5,6"
)
```

```
## # A tibble: 2 x 3
##       a     b     c
##   <int> <int> <int>
## 1     1     2     3
## 2     4     5     6
```

```r
read_csv(
  "a,b,c
  1,2,3
  4,5,6",
  col_names=FALSE
)
```

```
## # A tibble: 3 x 3
##   X1    X2    X3
##   <chr> <chr> <chr>
## 1 a     b     c
## 2 1     2     3
## 3 4     5     6
```

Other useful arguments: skip lines, symbol for missing data.

Now you can read most CSV files, also easily adapt to `read_tsv()`, `read_fwf()`. For the others, you need to know how `readr` works inside.

How `readr` parses data?

```
parse_logical(c("TRUE","FALSE"))
```

```
## [1]  TRUE FALSE
```

```
parse_integer(c("1","2","3","NA"))
```

```
## [1]  1  2  3 NA
```

Parsing vectors:

- `parse_logical()`, `parse_integer()`
- `parse_double()`, `parse_number()`: for numbers from other countries
- `parse_character()`: for character encodings.
- `parse_datetime()`, `parse_date()`, `parse_time()`
- `parse_factor()`

Potential difficulties

Parsing data is not always trivial:

- Numbers are written differently in different parts of the world (“,” vs “.” for separatimg thousands)
- Numbers are often surrounded by other characters (“$1000”, “10%”)
- Numbers often contain “grouping” characters (“1,000,000”)
- There are many different ways of writing dates and times
- Times can be in different timezones
- Encodings: special characters in other languages

Locales

A locale specifies common options varying between languages and places

To create a new locale, you use the locale() function:

```
locale(
  date_names = "en",
  date_format = "%AD",
  time_format = "%AT",
  decimal_mark = ".",
  grouping_mark = ",",
  tz = "UTC",
  encoding = "UTF-8",
  asciify = FALSE)
```

```
## <locale>
## Numbers:  123,456.78
## Formats:  %AD / %AT
## Timezone: UTC
## Encoding: UTF-8
## <date_names>
## Days:   Sunday (Sun), Monday (Mon), Tuesday (Tue), Wednesday (Wed), Thursday
##         (Thu), Friday (Fri), Saturday (Sat)
## Months: January (Jan), February (Feb), March (Mar), April (Apr), May (May),
##         June (Jun), July (Jul), August (Aug), September (Sep), October
##         (Oct), November (Nov), December (Dec)
## AM/PM:  AM/PM
```

More on locales can be found in a vignette

```
vignette("locales")
```

Parsing dates

`parse_date()` expects a four digit year, month, day separated by “-” or “/”:

```
parse_date("2010-10-01")
```

```
## [1] "2010-10-01"
```

Example: French format with full name of month:

```
parse_date("1 janvier 2010")
```

```
## Warning: 1 parsing failure.
## row # A tibble: 1 x 4 col     row   col expected     actual         expected    <int> <int> <chr>          <c
```

```
## [1] NA
```

```
parse_date("1 janvier 2010", format="%d %B %Y", locale=locale("fr"))
```

```
## [1] "2010-01-01"
```

Learn more by typing `?parse_date`

Parsing times

`parse_time()` expects an “hour : minutes” pair
(optionally proceeded by “:seconds”, and “am/pm” specifier).

```
parse_time("01:10 am")
```

```
## 01:10:00
```

Parsing dates and times:

```
parse_datetime("2001-10-10 20:10", locale = locale(tz = "Europe/Dublin"))
```

```
## [1] "2001-10-10 20:10:00 IST"
```

For more details, see the book R for data science or use the documentation.

Parsing numbers

`parse_number()` ignores non-numeric characters before and after.

```
parse_number("20%")
```

```
## [1] 20
```

```
parse_number("$100")
```

```
## [1] 100
```

```
parse_number("cost: $123.45")
```

```
## [1] 123.45
```

Parsing numbers with locales

```
# Separation used in Switzerland
parse_number("123'456'789", locale = locale(grouping_mark = "'"))
```

```
## [1] 123456789
```

Parsing real numbers

Real numbers using a different decimal mark

```
parse_double("1,23")
```

```
## Warning: 1 parsing failure.
## row # A tibble: 1 x 4 col     row   col expected               actual expected   <int> <int> <chr>
```

```
## [1] NA
## attr(,"problems")
## # A tibble: 1 x 4
##     row   col expected               actual
##   <int> <int> <chr>                  <chr>
## 1     1    NA no trailing characters ,23
```

```
parse_double("1,23", locale = locale(decimal_mark = ","))
```

```
## [1] 1.23
```

`readr's` strategy for parsing files

`readr` uses a heuristic to determine column type, using the first 1000 rows.

You can emulate this process with two functions:

- `guess_parser()`: returns readr's best guess
- `parse_guess()`: uses that guess to parse the column

The heuristic tries a sequence of types, stopping when it finds a match.

If none of these rules apply, then the column will stay as a vector of strings.

```r
guess_parser("15:01")
```

```
## [1] "time"
```

```r
guess_parser("Oct 10, 2010; 15:01")
```

```
## [1] "character"
```

```r
parse_guess("12,352,561")
```

```
## [1] 12352561
```

```r
parse_guess(c("TRUE", "FALSE"))
```

```
## [1]  TRUE FALSE
```

When the default strategy fails

The default strategy does not always work, e.g. if the first 1000 rows might be a special case. Suppose, your dataset with two columns:

```
# Top 1000 lines are (integer, missing)
readLines(readr_example("challenge.csv"), 10)
```

```
##  [1] "x,y"      "404,NA"  "4172,NA" "3004,NA" "787,NA
##  [8] "2489,NA" "1449,NA" "3665,NA"
```

```
# The remaining are (real number, date)
tail(readLines(readr_example("challenge.csv"), 300(
```

```
## [1] "0.4719389763195067 6,2014-08-04" "0.7183186
## [3] "0.269878588849678 64,2020-02-04" "0.6082371
```

```
challenge <- read_csv(readr_example("challenge.csv"))
```

```
## Parsed with column specification:
## cols(
##   x = col_integer(),
##   y = col_character()
## )
```

```
## Warning in rbind(names(probs), probs_f): number of columns of result is not a
## multiple of vector length (arg 1)
```

```
## Warning: 1000 parsing failures.
## row # A tibble: 5 x 5 col     row col   expected        actual      file
## ... .................. ... ..........................................................................
## See problems(...) for more details.
```

Examining what went wrong

See problems(...) for more details.

```
problems(challenge)
```

```
## # A tibble: 1,000 x 5
##      row col   expected        actual      file
##    <int> <chr> <chr>           <chr>       <chr>
##  1  1001 x     no trailing ch… .238379750… '/home/lanhuong/R/x86_64-pc-linux-g…
##  2  1002 x     no trailing ch… .411679971… '/home/lanhuong/R/x86_64-pc-linux-g…
##  3  1003 x     no trailing ch… .746071676… '/home/lanhuong/R/x86_64-pc-linux-g…
##  4  1004 x     no trailing ch… .723450553… '/home/lanhuong/R/x86_64-pc-linux-g…
##  5  1005 x     no trailing ch… .614524137… '/home/lanhuong/R/x86_64-pc-linux-g…
##  6  1006 x     no trailing ch… .473980569… '/home/lanhuong/R/x86_64-pc-linux-g…
##  7  1007 x     no trailing ch… .578461039… '/home/lanhuong/R/x86_64-pc-linux-g…
##  8  1008 x     no trailing ch… .241593722… '/home/lanhuong/R/x86_64-pc-linux-g…
##  9  1009 x     no trailing ch… .114378662… '/home/lanhuong/R/x86_64-pc-linux-g…
## 10  1010 x     no trailing ch… .298344632… '/home/lanhuong/R/x86_64-pc-linux-g…
## # … with 990 more rows
```

Fixing the column specifications

Automatic colomn specifications are:

```
challenge <- read_csv(readr_example("challenge.csv"),
  col_types = cols(x = col_integer(), y = col_character()) )
```

```
## Warning in rbind(names(probs), probs_f): number of columns of result is not a
## multiple of vector length (arg 1)
```

```
## Warning: 1000 parsing failures.
## row # A tibble: 5 x 5 col     row col   expected        actual      file
## ... .................. ... ...............................................................................
## See problems(...) for more details.
```

It seems that first column should be a real number:

```
( challenge <- read_csv(readr_example("challenge.csv"),
    col_types = cols(x = col_double(), y = col_character()) ) )
```

```
## # A tibble: 2,000 x 2
##         x y    
##     <dbl> <chr>
##  1    404 <NA> 
##  2   4172 <NA> 
##  3   3004 <NA> 
##  4    787 <NA> 
##  5     37 <NA> 
##  6   2332 <NA> 
##  7   2489 <NA> 
##  8   1449 <NA> 
##  9   3665 <NA> 
## 10   3863 <NA> 
## # … with 1,990 more rows
```

Fixing the column specifications

Are we done? Check the “y” column

```r
tail(challenge)
```

```
## # A tibble: 6 x 2
##         x y
##   <dbl> <chr>
## 1 0.805 2019-11-21
## 2 0.164 2018-03-29
## 3 0.472 2014-08-04
## 4 0.718 2015-08-16
## 5 0.270 2020-02-04
## 6 0.608 2019-01-06
```

Not yet: dates are stored as strings. To fix this, we use:

```r
challenge <- read_csv(readr_example("challenge.csv"),
  col_types = cols(x = col_double(), y = col_date() ) )
```

Every `parse_<...>()` function has a corresponding `col_<...>()` function
`col_<...>()` tells readr how to load the data.

Diagnosing problems

Maybe easier to diagnose problems if all columns are read as characters:

```
challenge2 <- read_csv(readr_example("challenge.csv"),
  col_types = cols(.default = col_character()) )
head(challenge2, 3)
```

```
## # A tibble: 3 x 2
##   x     y    
##   <chr> <chr>
## 1 404   <NA> 
## 2 4172  <NA> 
## 3 3004  <NA> 
```

Then use `type_convert()`, which applies the parsing heuristics to the charac
columns.

```
type_convert(challenge2)
```

```
## Parsed with column specification:
## cols(
##   x = col_double(),
##   y = col_date(format = "")
## )
```

```
## # A tibble: 2,000 x 2
##         x y     
##    <dbl> <date>
##  1   404 NA    
##  2  4172 NA    
##  3  3004 NA    
##  3  3004 NA
##  4   787 NA
##  5    37 NA
##  6  2332 NA
##  7  2489 NA
##  8  1449 NA
##  9  3665 NA
## 10  3863 NA
## # … with 1,990 more rows
```

Importing other types of data

We will not go into the details in this course. We only list a few other useful packages for importing data.

Rectangular data:

- Package `haven` reads SPSS, Stata, and SAS files.
- Package `readxl` reads excel files (both .xls and .xlsx).
- Package `DBI`, along with a database specific backend (e.g. RMySQL, RSQLite, RPostgreSQL etc) allows you to run SQL queries against a database and return a data frame.

Hierarchical data:

- `jsonlite` for json (common for browser-server communications)
- `xml2` for XML (common for textual data in web services)

And many more are available.

Exercise 1

- Download “Lec3_Exercises.Rmd” file from the Lectures tab on class website.
- Open the file in RStudio.
- Do Exercise 1.

Tidying and manipulating data

The `dplyr` package

The `dplyr` package is also a part of the core `tidyverse`, which:

- Introduces **a grammar of data manipulation.**
- Gives a **code-efficient** for way for data exploration and transformation.
- Is **fast on data frames** (written in C++): has speed of C and ease of R.
- **Intuitive to write and easy to read**, esp. when using the *chaining* syntax.

You should use `dplyr` even as a beginner R user, and here is why.

`dplyr` verbs (functions)

`dplyr` utilities handle the vast majority of your data manipulation needs:

- `filter()` - for picking observations by their values,
- `select()` - for picking variables by their names,
- `arrange()` - for reorder the rows,
- `mutate()` - for creating new variables with functions on existing variables,
- `summarise()` - for collapse many values down to a single summary.

All of the above can be done using **base R functions, but they would be less computationally efficient, and require writing more lines of (ugly) code.**

The structure of `dplyr` functions

All verbs work similarly:

- The first argument is a tibble (or data frame)
- The subsequent ones describe what to do, using the variable names
- The result is a new tibble

Learn more about `dplyr` from a turtorial written by its creator, Hadley Wickha

The movie industry dataset

`movies.csv` contains information on last three decades of movies.

The data has been scraped from the IMDb website and can be accessed from a github repo.

```r
url <- "https://raw.githubusercontent.com/Juanets/movie-stats/master/movies.csv"
movies <- read_csv(url)
movies
```

```
## # A tibble: 6,820 x 15
##     budget company country director genre   gross name  rating released runtime
##      <dbl> <chr>   <chr>   <chr>    <chr>   <dbl> <chr> <chr>  <chr>      <int>
##  1 8.00e6 Columb… USA     Rob Rei… Adve… 5.23e7 Stan… R      1986-08…      89
##  2 6.00e6 Paramo… USA     John Hu… Come… 7.01e7 Ferr… PG-13  1986-06…     103
##  3 1.50e7 Paramo… USA     Tony Sc… Acti… 1.80e8 Top … PG     1986-05…     110
##  4 1.85e7 Twenti… USA     James C… Acti… 8.52e7 Alie… R      1986-07…     137
##  5 9.00e6 Walt D… USA     Randal … Adve… 1.86e7 Flig… PG     1986-08…      90
##  6 6.00e6 Hemdale UK      Oliver … Drama 1.39e8 Plat… R      1987-02…     120
##  7 2.50e7 Henson… UK      Jim Hen… Adve… 1.27e7 Laby… PG     1986-06…     101
##  8 6.00e6 De Lau… USA     David L… Drama 8.55e6 Blue… R      1986-10…     120
##  9 9.00e6 Paramo… USA     Howard … Come… 4.05e7 Pret… PG-13  1986-02…      96
## 10 1.50e7 SLM Pr… USA     David C… Drama 4.05e7 The … R      1986-08…      96
## # … with 6,810 more rows, and 5 more variables: score <dbl>, star <chr>,
## #   votes <int>, writer <chr>, year <int>
```

`filter()`: retain rows matching a criteria

`filter()` allows you to subset observations based on their values.

```
# note: both comma and "&" represent AND condition
filter(movies, genre == "Comedy", director == "Woody Allen")
```

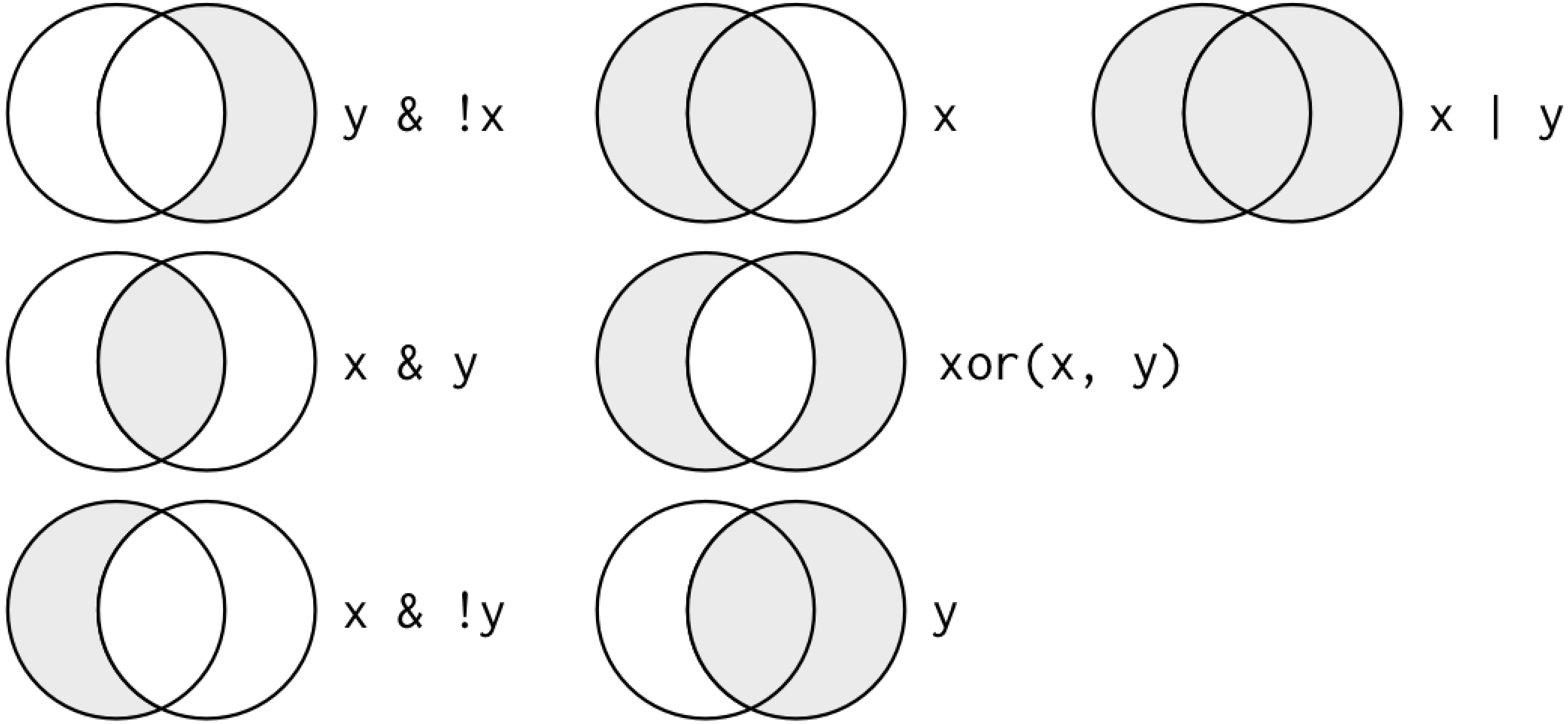
```
## # A tibble: 27 x 15
##     budget company country director genre   gross name  rating released runtime
##      <dbl> <chr>   <chr>   <chr>    <chr>   <dbl> <chr> <chr>  <chr>      <int>
##  1 6.40e6 Orion … USA     Woody A… Come… 4.01e7 Hann… PG-13  1986-03…     107
##  2 1.60e7 Orion … USA     Woody A… Come… 1.48e7 Radi… PG     1987-01…      88
##  3 1.90e7 Jack R… USA     Woody A… Come… 1.83e7 Crim… PG-13  1989-11…     104
##  4 1.50e7 Touchs… USA     Woody A… Come… 1.08e7 New … PG     1989-03…     124
##  5 1.20e7 Orion … USA     Woody A… Come… 7.33e6 Alice PG-13  1991-01…     106
##  6 1.40e7 Orion … USA     Woody A… Come… 2.74e6 Shad… PG-13  1992-03…      85
##  7 2.00e7 TriSta… USA     Woody A… Come… 1.06e7 Husb… R      1992-09…     103
##  8 1.35e7 TriSta… USA     Woody A… Come… 1.13e7 Manh… PG     1993-08…     104
##  9 2.00e7 Miramax USA     Woody A… Come… 1.34e7 Bull… R      1995-02…      98
## 10 1.50e7 Sweetl… USA     Woody A… Come… 6.70e6 Migh… R      1995-11…      95
## # … with 17 more rows, and 5 more variables: score <dbl>, star <chr>,
## #   votes <int>, writer <chr>, year <int>
```

```
# base R approach would be more wordy:
movies[movies$genre == "Comedy" & movies$director == "Woody Allen", ]
```

Package `dplyr` executes the filtering and returns a new data frame. **It never modifies the original one.**

Logical operators

Multiple arguments to `filter()` are combined with “and”: all expressions mu true, for a row to be included in the output. For other types of combinations, yc need to use Boolean operators yourself: & is “and”, | is “or”, and ! is “not”:



Source: R for data science

```r
# Using AND operator
filter(movies, country == "USA", budget > 2.5e8)
# same as filter(movies, country == "USA" & budget > 2.5e8)

# Using OR operator
filter(movies, country == "USA" | budget > 2.5e8)

# Using xor()
filter(movies, xor(score > 9, budget > 2.5e8))
```

```r
# you can also use %in% operator
filter(movies, country %in% c("Argentina", "Colombia", "Chile"))
```

```
## # A tibble: 19 x 15
##    budget company country director genre  gross name  rating released runtime
##     <dbl> <chr>   <chr>   <chr>    <chr>  <dbl> <chr> <chr>  <chr>      <int>
##  1 0.     Cinequ… Argent… Eliseo … Drama 7.25e5 Man … R      1987-03…     105
##  2 0.     "GEA C… Argent… "Mar\xe… Drama 5.21e4 I, t… R      1995-11…     105
##  3 0.     Not sp… Argent… Adolfo … Drama 1.01e5 A Pl… PG     1994         120
##  4 0.     Aleph … Argent… Betty K… Drama 1.97e4 De a… R      1996-05…     100
##  5 1.50e6 FX Sou… Argent… "Fabi\x… Crime 1.22e6 Nine… R      2000-08…     114
##  6 0.     Instit… Argent… "Juan J… Come… 6.24e5 Son … R      2003-01…     123
##  7 0.     4k Fil… Argent… Lucreci… Come… 1.03e5 "La … NOT R… 2001-04…     103
##  8 0.     FilmFo… Argent… Walter … Adve… 1.68e7 The … R      2004-10…     126
##  9 3.00e6 HBO Fi… Colomb… Joshua … Crime 6.52e6 Mari… R      2004-08…     101
## 10 0.     Cinefa… Argent… Ricardo… Drama 2.80e6 La m… R      2006-04…     100
## 11 0.     Aura F… Argent… "Fabi\x… Crime 5.61e4 The … UNRAT… 2006-06…     134
## 12 0.     Histor… Argent… "Luc\xe… Drama 4.60e4 XXY   UNRAT… 2008-05…      86
## 13 2.00e6 Tornas… Argent… "Juan J… Drama 2.02e7 The … R      2010-05…     129
## 14 0.     Partic… Chile   "Pablo … Drama 2.34e6 No    R      2012-11…     118
## 15 3.30e6 Corner… Argent… "Dami\x… Come… 3.11e6 Rela… R      2014-12…     122
## 16 2.60e7 Alcon … Chile   Patrici… Biog… 1.22e7 Los … PG-13  2015-11…     127
## 17 1.40e6 Buffal… Colomb… Ciro Gu… Adve… 1.33e6 Embr… NOT R… 2015-05…     125
## 18 9.00e6 Fox Se… Chile   "Pablo … Biog… 1.40e7 Jack… R      2016-12…     100
## 19 0.     AZ Fil… Chile   "Pablo … Biog… 9.39e5 Neru… R      2017-03…     107
## # … with 5 more variables: score <dbl>, star <chr>, votes <int>, writer <chr>,
## #   year <int>
```

`select()`: pick columns by name

`select()` let’s you choose a subset variables, specified by name.

Note, there is no need for quotation marks in `dplyr`:

```r
# dplyr approach
select(movies, name, country, year, genre)
```

```
## # A tibble: 6,820 x 4
##    name                      country  year genre    
##    <chr>                     <chr>   <int> <chr>    
##  1 Stand by Me               USA      1986 Adventure
##  2 Ferris Bueller's Day Off  USA      1986 Comedy   
##  3 Top Gun                   USA      1986 Action   
##  4 Aliens                    USA      1986 Action   
##  5 Flight of the Navigator   USA      1986 Adventure
##  6 Platoon                   UK       1986 Drama    
##  7 Labyrinth                 UK       1986 Adventure
##  8 Blue Velvet               USA      1986 Drama    
##  9 Pretty in Pink            USA      1986 Comedy   
## 10 The Fly                   USA      1986 Drama    
## # … with 6,810 more rows
```

```r
# base R approach would be:
movies[, c("name", "year", "genre")]
```

```
# use colon to select multiple contiguous columns,
select(movies, name, genre:score)
```

```
## # A tibble: 6,820 x 7
##    name                      genre          gross rating released   runtime score
##    <chr>                     <chr>          <dbl> <chr>  <chr>        <int> <dbl>
##  1 Stand by Me               Adventure   52287414 R      1986-08-22      89   8.1
##  2 Ferris Bueller's Day Off  Comedy      70136369 PG-13  1986-06-11     103   7.8
##  3 Top Gun                   Action     179800601 PG     1986-05-16     110   6.9
##  4 Aliens                    Action      85160248 R      1986-07-18     137   8.4
##  5 Flight of the Navigator   Adventure   18564613 PG     1986-08-01      90   6.9
##  6 Platoon                   Drama      138530565 R      1987-02-06     120   8.1
##  7 Labyrinth                 Adventure   12729917 PG     1986-06-27     101   7.4
##  8 Blue Velvet               Drama        8551228 R      1986-10-23     120   7.8
##  9 Pretty in Pink            Comedy      40471663 PG-13  1986-02-28      96   6.8
## 10 The Fly                   Drama       40456565 R      1986-08-15      96   7.5
## # … with 6,810 more rows
```

```
# To drop columns use a minus, "-"
select(movies, -(star:writer))
```

```
## # A tibble: 6,820 x 12
##     budget company country director genre   gross name  rating released runtime
##      <dbl> <chr>   <chr>   <chr>    <chr>   <dbl> <chr> <chr>  <chr>      <int>
##  1 8.00e6 Columb… USA     Rob Rei… Adve… 5.23e7 Stan… R      1986-08…      89
##  2 6.00e6 Paramo… USA     John Hu… Come… 7.01e7 Ferr… PG-13  1986-06…     103
##  3 1.50e7 Paramo… USA     Tony Sc… Acti… 1.80e8 Top … PG     1986-05…     110
##  4 1.85e7 Twenti… USA     James C… Acti… 8.52e7 Alie… R      1986-07…     137
##  5 9.00e6 Walt D… USA     Randal … Adve… 1.86e7 Flig… PG     1986-08…      90
##  6 6.00e6 Hemdale UK      Oliver … Drama 1.39e8 Plat… R      1987-02…     120
##  7 2.50e7 Henson… UK      Jim Hen… Adve… 1.27e7 Laby… PG     1986-06…     101
##  8 6.00e6 De Lau… USA     David L… Drama 8.55e6 Blue… R      1986-10…     120
##  9 9.00e6 Paramo… USA     Howard … Come… 4.05e7 Pret… PG-13  1986-02…      96
## 10 1.50e7 SLM Pr… USA     David C… Drama 4.05e7 The … R      1986-08…      96
## # … with 6,810 more rows, and 2 more variables: score <dbl>, year <int>
```

`select()` helpers

You can use the following functions to help select the columns:

- `starts_with()`
- `ends_with()`
- `contains()`
- `matches()` (matches a regular expression)
- `num_range("x", 1:4)`: pickes variables x1, x2, x3, x4

Examples:

```
select(movies, starts_with("r"))
select(movies, ends_with("e"))
select(movies, contains("re"))
```

`arrange()`: reorder rows

`arrange()` takes a data frame and a set of column names to order by.
For descending order, use the function `desc()` around the column name.

```r
print(arrange(movies, runtime), n = 4)
```

```
## # A tibble: 6,820 x 15
##   budget company country director genre   gross name  rating released runtime
##    <dbl> <chr>   <chr>   <chr>    <chr>   <dbl> <chr> <chr>  <chr>      <int>
## 1 0.     Iwerks… France  Jean-Ja… Adve… 1.51e7 Wing… G      1996-09…      50
## 2 1.25e7 Univer… USA     Don Blu… Anim… 4.81e7 The … G      1988-11…      69
## 3 6.00e3 Next W… UK      Christo… Crime 4.85e4 Foll… R      1999-11…      69
## 4 0.     Hyperi… USA     Bruce W… Anim… 8.44e6 "B\x… PG-13  1992-07…      70
## # … with 6,816 more rows, and 5 more variables: score <dbl>, star <chr>,
## #   votes <int>, writer <chr>, year <int>
```

```r
# use `desc` for descending
print(arrange(movies, desc(budget)), n = 4)
```

```
## # A tibble: 6,820 x 15
##   budget company country director genre   gross name  rating released runtime
##    <dbl> <chr>   <chr>   <chr>    <chr>   <dbl> <chr> <chr>  <chr>      <int>
## 1 3.00e8 Walt D… USA     Gore Ve… Acti… 3.09e8 Pira… PG-13  2007-05…     169
## 2 2.60e8 Walt D… USA     Nathan … Anim… 2.01e8 Tang… PG     2010-11…     100
## 3 2.58e8 Columb… USA     Sam Rai… Acti… 3.37e8 Spid… PG-13  2007-05…     139
## 4 2.50e8 Warner… UK      David Y… Adve… 3.02e8 Harr… PG     2009-07…     153
## # … with 6,816 more rows, and 5 more variables: score <dbl>, star <chr>,
## #   votes <int>, writer <chr>, year <int>
```

mutate(): add new variables

mutate() adds new columns that are a function of the existing ones

```
movies <- mutate(movies, profit = gross - budget)
select(movies, name, gross, budget, profit)
```

```
## # A tibble: 6,820 x 4
##    name                          gross   budget     profit
##    <chr>                         <dbl>    <dbl>      <dbl>
##  1 Stand by Me                52287414  8000000   44287414
##  2 Ferris Bueller's Day Off   70136369  6000000   64136369
##  3 Top Gun                   179800601 15000000  164800601
##  4 Aliens                     85160248 18500000   66660248
##  5 Flight of the Navigator    18564613  9000000    9564613
##  6 Platoon                   138530565  6000000  132530565
##  7 Labyrinth                  12729917 25000000  -12270083
##  8 Blue Velvet                 8551228  6000000    2551228
##  9 Pretty in Pink             40471663  9000000   31471663
## 10 The Fly                    40456565 15000000   25456565
## # … with 6,810 more rows
```

To discard old variables, use transmute() instead of mutate().

```
# base R approach to create a new variable 'profit'
movies$profit <- movies$gross - movies$budget
```

```r
# Generating multiple new variables
movies <- mutate(
  movies,
  profit = gross - budget,
  gross_in_mil = gross/10^6,
  budget_in_mil = budget/10^6,
  profit_in_mil = profit/10^6
)
select(movies, name, year, country, contains("_in_mil"), profit)
```

```
## # A tibble: 6,820 x 7
##    name          year country gross_in_mil budget_in_mil profit_in_mil   profit
##    <chr>        <int> <chr>          <dbl>         <dbl>         <dbl>    <dbl>
##  1 Stand by Me   1986 USA            52.3            8            44.3   4.43e7
##  2 Ferris Buel…  1986 USA            70.1            6            64.1   6.41e7
##  3 Top Gun       1986 USA           180.            15           165.    1.65e8
##  4 Aliens        1986 USA            85.2           18.5          66.7   6.67e7
##  5 Flight of t…  1986 USA            18.6            9             9.56  9.56e6
##  6 Platoon       1986 UK            139.             6           133.    1.33e8
##  7 Labyrinth     1986 UK             12.7           25           -12.3  -1.23e7
##  8 Blue Velvet   1986 USA             8.55           6             2.55  2.55e6
##  9 Pretty in P…  1986 USA            40.5            9            31.5   3.15e7
## 10 The Fly       1986 USA            40.5           15            25.5   2.55e7
## # … with 6,810 more rows
```

Any vectorized function can be used with `mutate()`, including:

- arithmetic operators (+,-,*,/, %, %%),
- logical operators (<,<=,>,>=,==,!=),
- logarithmic and exponential transfomations (`log, log10, exp`),
- offsets (`lead, lag`),
- cummulative rolling aggregates (`cumsum`, `cumprod`, `cummin`, `cummax`),
- ranking (`min_rank`, `percent_rank`).

`summarise()`: reduce variables to values

`summarize()` can be used to aggregate data or to compute a summarizing val of interest.

```
summarise(movies,
  tot_gross_in_bil = sum(gross)/1e9,
  mean_gross_in_mil = mean(gross)/1e6,
  mean_profit_in_mil = mean(profit)/1e6
)
```

```
## # A tibble: 1 x 3
##   tot_gross_in_bil mean_gross_in_mil mean_profit_in_mil
##              <dbl>             <dbl>              <dbl>
## 1             228.              33.5               8.92
```

`summarize()` is **more useful on data previously grouped by one or more variables** using `group_by()`.

```
by_genre <- group_by(movies, genre)
summarize(by_genre, tot_gross_in_bil = sum(gross)/1e9,
          mean_gross_in_mil = mean(gross)/1e6,
          mean_profit_in_mil = mean(profit)/1e6)
```

Grouping and summarizing

Grouing allows you to compute summaries for each categories separately:

```r
by_genre <- group_by(movies, genre)
summarize(
  by_genre,
  tot_gross_in_bil = sum(gross)/1e9,
  mean_gross_in_mil = mean(gross)/1e6,
  mean_profit_in_mil = mean(profit)/1e6
)
```

```
## # A tibble: 17 x 4
##    genre     tot_gross_in_bil mean_gross_in_mil mean_profit_in_mil
##    <chr>                <dbl>             <dbl>              <dbl>
##  1 Action            74.8                56.2                7.30
##  2 Adventure         20.9                53.3               16.0
##  3 Animation         25.3                91.5               27.2
##  4 Biography          8.62               24.0                7.05
##  5 Comedy            53.5                25.7               10.8
##  6 Crime             10.2                19.6                3.30
##  7 Drama             25.2                17.5                4.19
##  8 Family             0.118               8.44              -0.101
##  9 Fantasy            0.645              20.1                4.38
## 10 Horror             7.12               25.7               13.8
## 11 Musical            0.00809             2.02              -0.476
## 12 Mystery            1.38               36.3                9.47
## 13 Romance            0.146               9.72               4.24
## 14 Sci-Fi             0.308              23.7                6.79
## 15 Thriller           0.0996              5.53              -0.356
## 16 War                0.00151             0.755              0.755
## 17 Western            0.0185              9.26               3.26
```

Elementary but useful summary functions

- `min(x)`, `median(x)`, `max(x)`, `quantile(x, p)`
- `n()`, `n_distinct()`, `sum(x)`, `mean(x)`
- `sum(x > 10)`, `mean(x > 0)`
- `sd(x)`, `var(x)`

Counting observations

`tally()` function can be used to generate a group frequency table, (number o
observations in each category)

```r
tally(group_by(movies, genre))
```

```
## # A tibble: 17 x 2
##    genre         n
##    <chr>     <int>
##  1 Action     1331
##  2 Adventure   392
##  3 Animation   277
##  4 Biography   359
##  5 Comedy     2080
##  6 Crime       522
##  7 Drama      1444
##  8 Family       14
##  9 Fantasy      32
## 10 Horror      277
## 11 Musical       4
## 12 Mystery      38
## 13 Romance      15
## 14 Sci-Fi       13
## 15 Thriller     18
## 16 War           2
## 17 Western       2
```

```r
tally(group_by(movies, genre, country))
```

```
## # A tibble: 238 x 3
## # Groups:   genre [17]
##    genre  country            n
##    <chr>  <chr>          <int>
##  1 Action Aruba              1
##  2 Action Australia         12
##  3 Action Austria            1
##  4 Action Belgium            1
##  5 Action Brazil             2
##  6 Action Canada            26
##  7 Action China             13
##  8 Action Czech Republic     1
##  9 Action Denmark            2
## 10 Action France            41
## # … with 228 more rows
```

Window Functions

- Aggregation functions such as `mean()`, `n()` return 1 value per group.
- **Window functions return multiple values per group**, e.g. `top_n()`, `lead` and `lag` or `cummean`:

```
# rewrite more simply with the `top_n` function
movies2 <- select(movies, name, genre, country, year, budget, gross, profit, rating, score)
top2 <- top_n(group_by(movies2, genre), n = 2, wt = score)
arrange(top2, genre, year, score)
```

```
## # A tibble: 35 x 9
## # Groups:   genre [17]
##    name                 genre   country    year budget  gross   profit rating score
##    <chr>                <chr>   <chr>     <int>  <dbl>  <dbl>    <dbl> <chr>  <dbl>
##  1 The Dark Knight      Action  USA        2008 1.85e8 5.35e8  3.50e8 PG-13    9  
##  2 Inception            Action  USA        2010 1.60e8 2.93e8  1.33e8 PG-13    8.8
##  3 The Lord of the …    Advent… New Zeal…  2001 9.30e7 3.16e8  2.23e8 PG-13    8.8
##  4 The Lord of the …    Advent… USA        2003 9.40e7 3.78e8  2.84e8 PG-13    8.9
##  5 The Lion King        Animat… USA        1994 4.50e7 3.13e8  2.68e8 G        8.5
##  6 Spirited Away        Animat… Japan      2001 1.90e7 1.01e7 -8.94e6 PG       8.6
##  7 Your name            Animat… Japan      2016 0.     5.02e6  5.02e6 PG       8.5
##  8 Schindler's List     Biogra… USA        1993 2.20e7 9.61e7  7.41e7 R        8.9
##  9 The Intouchables     Biogra… France     2011 0.     1.32e7  1.32e7 R        8.6
## 10 Forrest Gump         Comedy  USA        1994 5.50e7 3.30e8  2.75e8 PG-13    8.8
## # … with 25 more rows
```

Other useful functions in `dplyr`

```r
# Renaming variables
print(rename(movies2, gross_revenue = gross), n = 5)
```

```
## # A tibble: 6,820 x 9
##   name           genre   country  year budget gross_revenue  profit rating score
##   <chr>          <chr>   <chr>   <int>  <dbl>         <dbl>   <dbl> <chr>  <dbl>
## 1 Stand by Me    Advent… USA      1986 8.00e6      52287414 4.43e7 R        8.1
## 2 Ferris Buell… Comedy  USA      1986 6.00e6      70136369 6.41e7 PG-13    7.8
## 3 Top Gun        Action  USA      1986 1.50e7     179800601 1.65e8 PG       6.9
## 4 Aliens         Action  USA      1986 1.85e7      85160248 6.67e7 R        8.4
## 5 Flight of th… Advent… USA      1986 9.00e6      18564613 9.56e6 PG       6.9
## # … with 6,815 more rows
```

```r
# Unique values
distinct(movies2, rating)
```

```
## # A tibble: 13 x 1
##    rating
##    <chr>
##  1 R
##  2 PG-13
##  3 PG
##  4 UNRATED
##  5 Not specified
##  6 G
##  7 NC-17
##  8 NOT RATED
##  9 TV-PG
## 10 TV-MA
## 11 B
## 12 B15
## 13 TV-14
```

```r
# Using multiple variables, returns distinct varia
distinct(movies2, rating, genre)
```

```
## # A tibble: 83 x 2
##    rating  genre
##    <chr>   <chr>
##  1 R       Adventure
##  2 PG-13   Comedy
##  3 PG      Action
##  4 R       Action
##  5 PG      Adventure
##  6 R       Drama
##  7 PG-13   Adventure
##  8 PG-13   Action
##  9 R       Crime
## 10 UNRATED Comedy
## # … with 73 more rows
```

Sampling observations

```
sample_n(movies, 8)                     # fixed number of rows, without replacement
```

```
## # A tibble: 8 x 19
##   budget company country director genre  gross name  rating released runtime
##    <dbl> <chr>   <chr>   <chr>    <chr>  <dbl> <chr> <chr>  <chr>      <int>
## 1 0.      Incent… USA     Don Roos Drama 2.06e4 Love… R      2011-03…     119
## 2 3.20e7 David … USA     Mark Di… Anim… 3.56e6 Cats… G      1997-03…      75
## 3 8.00e6 Avenue… USA     Robert … Come… 2.17e7 The … R      1992-05…     124
## 4 1.10e7 Motlys  Norway  Joachim… Drama 1.62e5 "M\x… R      2016-07…     109
## 5 0.      Britis… UK      Terence… Biog… 1.61e5 The … PG     1993-05…      85
## 6 2.10e7 Scott … USA     Trey Pa… Anim… 5.20e7 Sout… R      1999-06…      81
## 7 0.      Scary … USA     Jeffrey… Come… 2.75e6 Dead… R      1986-11…      93
## 8 4.50e7 R.P. P… France  Roman P… Drama 1.55e7 The … PG-13  2010-03…     128
## # … with 9 more variables: score <dbl>, star <chr>, votes <int>, writer <chr>,
## #   year <int>, profit <dbl>, gross_in_mil <dbl>, budget_in_mil <dbl>,
## #   profit_in_mil <dbl>
```

```
sample_frac(movies, 0.005, replace=TRUE) # fraction of rows, with replacement
```

```
## # A tibble: 34 x 19
##     budget company country director genre  gross name  rating released runtime
##      <dbl> <chr>   <chr>   <chr>    <chr>  <dbl> <chr> <chr>  <chr>      <int>
##  1 1.00e7 Avenue… USA     Martin … Crime 3.84e5 Amer… R      1993-05…     113
##  2 8.00e6 Odeon … Canada  David C… Drama 1.64e6 Spid… R      2002-11…      98
##  3 2.50e7 Twenti… USA     Jim Abr… Acti… 3.89e7 Hot … PG-13  1993-05…      86
##  4 5.50e7 Paramo… USA     Robert … Come… 3.30e8 Forr… PG-13  1994-07…     142
##  5 2.50e7 Fox 20… USA     Jonatha… Drama 1.01e7 Brok… PG-13  1999-08…     100
##  6 0.      Rysher… USA     John He… Come… 1.11e7 2 Da… R      1996-09…     104
##  7 1.35e8 DreamW… USA     Kirk De… Anim… 1.87e8 The … PG     2013-03…      98
##  8 2.50e7 Screen… USA     Dwight … Acti… 3.22e7 Anac… PG-13  2004-08…      97
##  9 0.      Davros… USA     Euzhan … Drama 3.77e6 A Dr… R      1989-09…      97
## 10 2.50e5 Paramo… USA     Drake D… Drama 3.41e6 Like… PG-13  2012-01…      86
## # … with 24 more rows, and 9 more variables: score <dbl>, star <chr>,
## #   votes <int>, writer <chr>, year <int>, profit <dbl>, gross_in_mil <dbl>,
## #   budget_in_mil <dbl>, profit_in_mil <dbl>
## #   budget_in_mil <dbl>, profit_in_mil <dbl>
```

Chaining operations

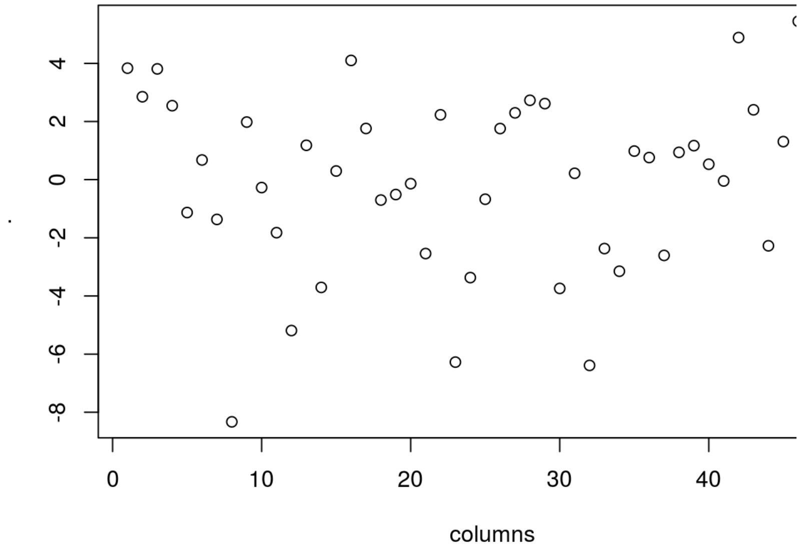
The `magrittr` package

> *The magrittr (to be pronounced with a sophisticated french accent) package has two aims: decrease development time and improve readability and maintainability of code*

`magrittr` provides a “pipe”-like operator, %>%:

- The %>% is used **pipe values forward into an expression or function call.**
- In the pipe notation, you use `x %>% f(y)`, rather than `f(x, y)`.
- This is similar to the Unix pipes, `|`, used to send the output of one program to another program for further processing.

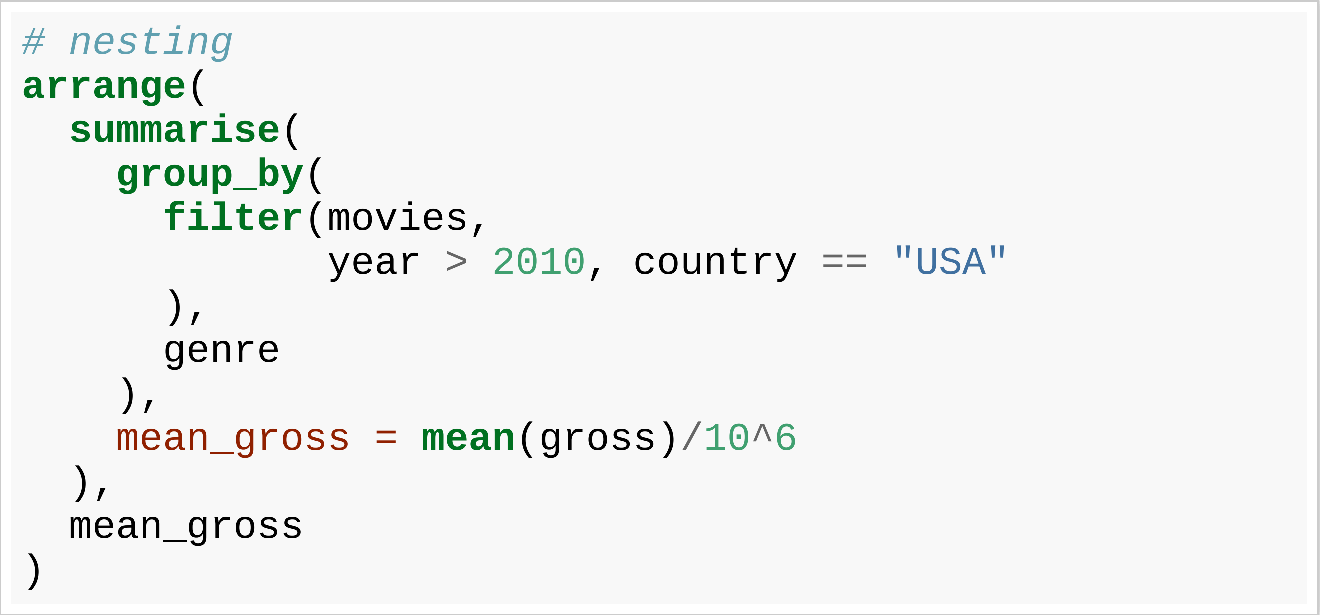
```
columns <- 1:50
rnorm(500) %>%
  matrix(ncol = 50) %>%
  colSums() %>%
  plot(x = columns)
```



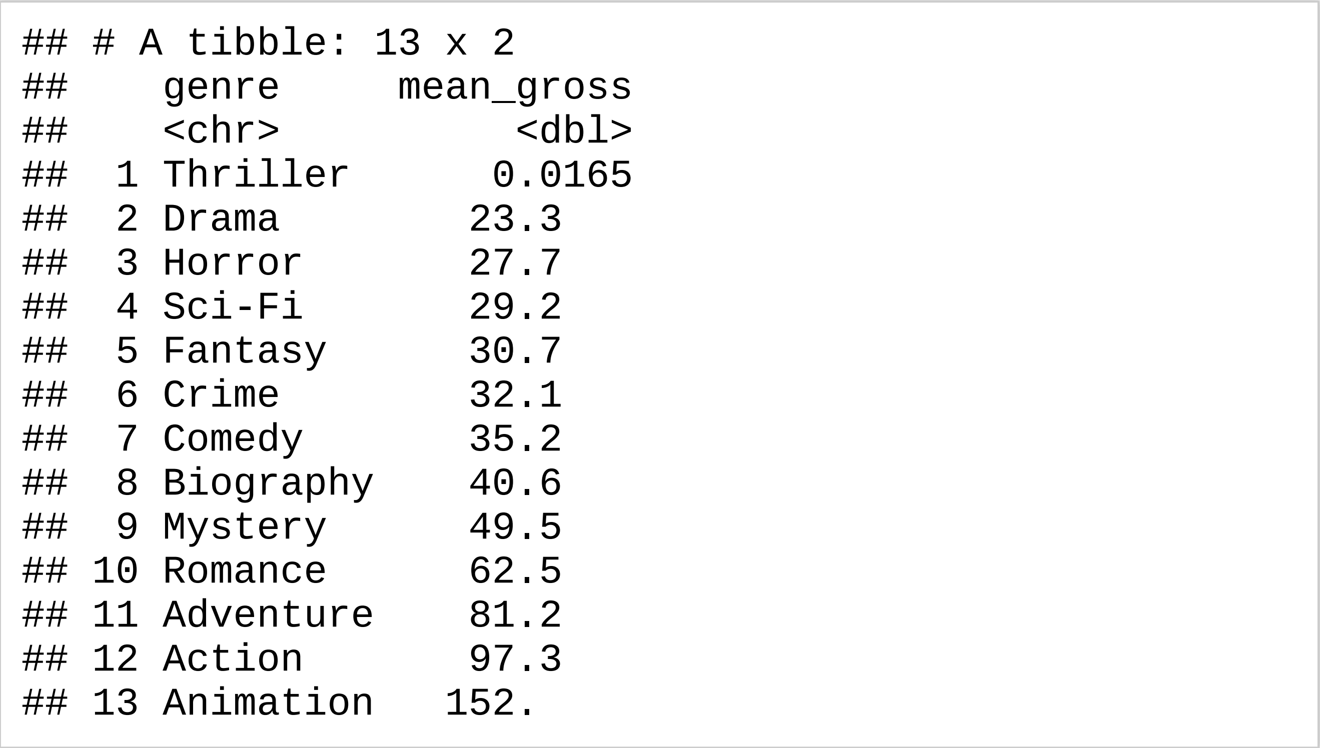
Chaining operations

- Pipe operators used together with `dplyr` functions make a large difference as they semantically change your code in a way that **makes it more intuitive to both read and write**.
- The pipes allow users to chain operators which reflects the **sequential nature of data-processing tasks**.
- **Chaining increases readability** significantly when there are many commands
- `%>%` operator is automatically imported into `dplyr`

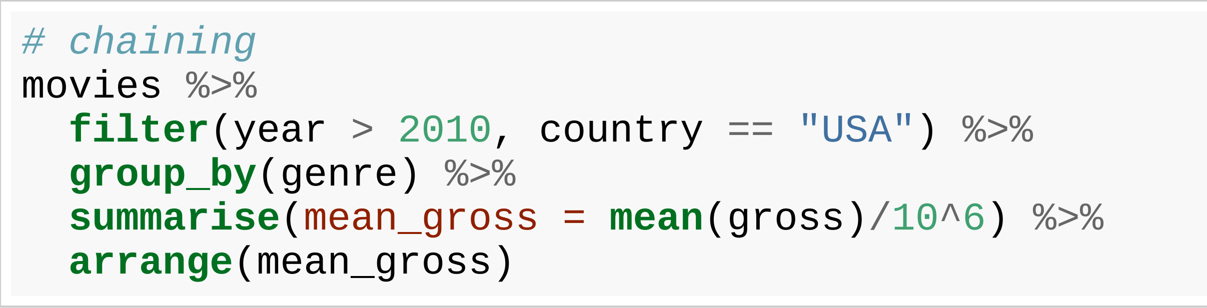
1. Find movies from USA produced after 2010. (2) Group by genre and
2. compute the group mean gross revenue in million dollars. Then print the genre mean ‘gross’ revenue (4) arranged in a descending order:



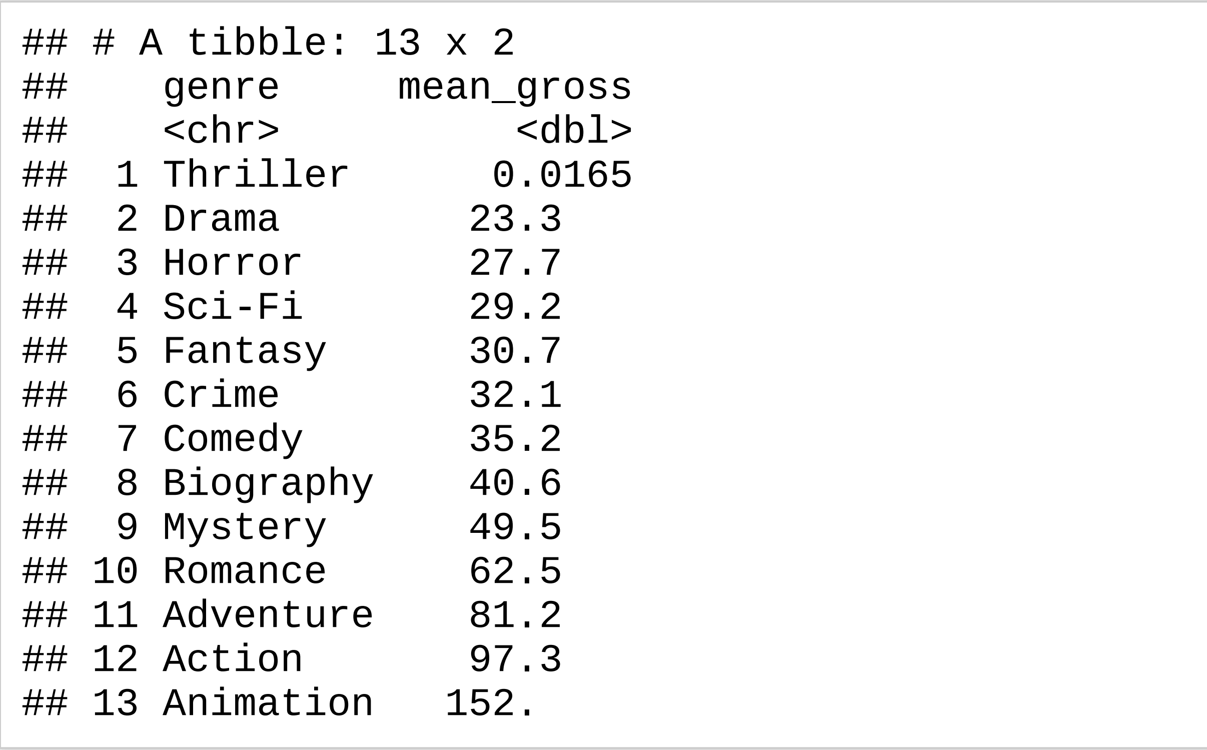
```
# nesting
arrange(
  summarise(
    group_by(
      filter(movies,
             year > 2010, country == "USA"
      ),
      genre
    ),
    mean_gross = mean(gross)/10^6
  ),
  mean_gross
)
```



```
## # A tibble: 13 x 2
##    genre     mean_gross
##    <chr>          <dbl>
##  1 Thriller      0.0165
##  2 Drama        23.3
##  3 Horror       27.7
##  4 Sci-Fi       29.2
##  5 Fantasy      30.7
##  6 Crime        32.1
##  7 Comedy       35.2
##  8 Biography    40.6
##  9 Mystery      49.5
## 10 Romance      62.5
## 11 Adventure    81.2
## 12 Action       97.3
## 13 Animation   152.
```



```
# chaining
movies %>%
  filter(year > 2010, country == "USA") %>%
  group_by(genre) %>%
  summarise(mean_gross = mean(gross)/10^6) %>%
  arrange(mean_gross)
```



```
## # A tibble: 13 x 2
##    genre     mean_gross
##    <chr>          <dbl>
##  1 Thriller      0.0165
##  2 Drama        23.3
##  3 Horror       27.7
##  4 Sci-Fi       29.2
##  5 Fantasy      30.7
##  6 Crime        32.1
##  7 Comedy       35.2
##  8 Biography    40.6
##  9 Mystery      49.5
## 10 Romance      62.5
## 11 Adventure    81.2
## 12 Action       97.3
## 13 Animation   152.
```

Saving the workspace

- You can choose to **save all objects** currently in the workspace (variables, functions, etc.) into a file e.g. `filename.rda`.
- The file `filename.rda` can be loaded next time you work with R.
- You can also save a single object or a subset of specified objects currently in the workspace.

```r
# save the workspace to file
save.image(file = "path/to/filename.rda")

# save specific objects to a file
save(object_list, file = "path/to/filename.rda")

# save just a single object
saveRDS(object, file = "path/to/filename.rds")
```

- Saved objects/workspace can be loaded back in a new R session.

```r
# load a workspace into the current session
load("path/to/filename.rda")

# read just the previously saved 1 object
object <- readRDS("path/to/filename.rds")
```

Exercises 2

- Go to the “Lec3_Exercises.Rmd” file, which can be downloaded from the class website under the Lecture tab.
- Complete Exercise 2.

1. R for Data Science↩

2. Tidyverse website↩