3 - The *Tidyverse*

Data Science with R · Summer 2021

Uli Niemann · Knowledge Management & Discovery Lab

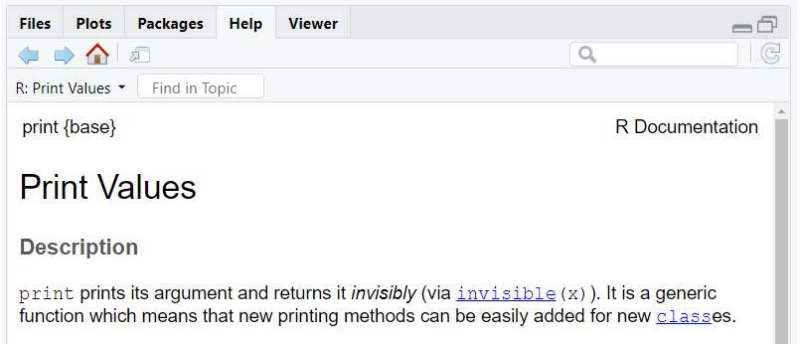
https://brain.cs.uni-magdeburg.de/kmd/DataSciR/

Photo courtesy of Ulrich Arendt

Why is (base) `R` hard to learn?

`R` has some idiosyncrasies that make it hard for learners who are used to other programming languages, e.g.:

- unhelpful help `?print`
- too many functions `colnames()`, `names()`
- inconsistent names `read.csv()`, `load()`, `readRDS()`
- clumsy console output `print(iris)`
- high flexibility (*is this bad?*)
- too many ways to select variables: `df$x`, `df$"x"`, `df[,"x"]`, or `df[[1]]`



❓ *"invisibly"?*
❓ *"generic function"?*
❓ *"class"?*

See a more comprehensive list:
Robert A. Muenchen. "Why R is Hard to Learn". r4stats.com. Accessed 19.07.2018.

Base `R` vs. tidyverse code

🤔 *"What does this base `R` code?"*

```
aggregate(iris[, "Sepal.Length"],
          list(Species = iris[, "Species"]),
          mean)
```

```
##      Species     x
## 1     setosa 5.006
## 2 versicolor 5.936
## 3  virginica 6.588
```

🤓 **tidyverse** equivalent:

```
library(dplyr)
group_by(iris, Species) %>%
    summarize(avg_sl = mean(Sepal.Length))
```

```
## # A tibble: 3 x 2
##   Species    avg_sl
##   <fct>       <dbl>
## 1 setosa       5.01
## 2 versicolor   5.94
## 3 virginica    6.59
```

❓ *"What are the square brackets [for?"* ⟶ They are used for subsetting a data frame.

❓ *"What is list()?"* ⟶ It's a type of R object.

❓ *"Why is the mean() function seemingly applied without argument?"* ⟶ It is being passed to the subsets of the data frame.

❓ *"In the second line, why does the first "Species" does not need to be quoted, but the second "Species" does?"* ...

The Tidyverse

Quote from the Tidyverse website:

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

→ collection of open-source `R` packages mainly for data wrangling and visualization
→ shared conventions and common APIs across all Tidyverse packages

Installation

```
# Install all Tidyverse packages
install.packages("tidyverse")

# Attach core packages
library(tidyverse)
```

The meta-package `tidyverse` contains 26 packages. When running `library(tidyverse)`, only the **core** tidyverse packages become available in your current `R` session. The core packages are:

Core-Packages:

- `ggplot2`: creation of graphics
- `dplyr`: data wrangling
- `tidyr`: data reshaping
- `readr`: import of flat data files, e.g. csv
- `tibble`: enhanced data frames
- `stringr`: string manipulation
- `forcats`: factor manipulation
- `purrr`: functions for working with list columns

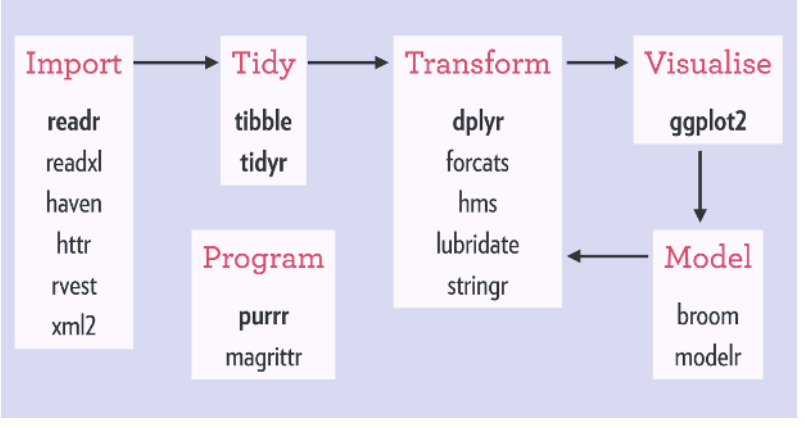


Figure source: Joseph Rickert. "What is the tidyverse?". R Views. Accessed 13.07.2019.


dplyr
dplyr.tidyverse.org

Data wrangling with `dplyr` 🛠

🤔 *"What can I do with `dplyr`?"*

- get an overview of a tibble with `glimpse()`
- select a subset of columns with `select()`
- filter a subset of rows with `filter()`
- add new or change existing columns with `mutate()`
- pick a subset of rows with `slice()`
- reorder rows with `arrange()`
- group rows by a grouping column with `group_by()`
- calculate a summary (per group) with `summarize()`
- join two distinct tibbles by a common column with `*join()`
- ... (and more)

Consistent API design:

- first argument of each of these **verbs** is a data frame
- the output is (usually) also a data frame

Case study: customer bookings data

The company behind a travel price aggregator website wants to analyze its booking data to optimize the website's usability and thus improve their customers' travel experience.

The data is organized into two files:

- `bookings.csv`: hotel bookings
- `properties.csv`: hotel facilities


```
library(tidyverse)
```

```
bookings <- read_csv("../data/bookings.csv")
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   booker_id = col_character(),
##   property_id = col_double(),
##   room_nights = col_double(),
##   price_per_night = col_double(),
##   checkin_day = col_character(),
##   for_business = col_logical(),
##   status = col_character(),
##   review_score = col_double()
## )
```

Data source.

Get an overview wit `glimpse()`

```
glimpse(bookings)
```

```
## Rows: 10,000
## Columns: 8
## $ booker_id       <chr> "215934017ba98c09f30dedd29237b43dad5c7b5f", "7f590fd6d318248a486~
## $ property_id     <dbl> 2668, 4656, 4563, 4088, 2188, 4171, 2907, 5141, 1696, 1901, 2188~
## $ room_nights     <dbl> 4, 5, 6, 7, 4, 2, 4, 4, 1, 7, 1, 9, 6, 4, 5, 5, 2, 2, 2, 2, 1, 3~
## $ price_per_night <dbl> 91.46696, 106.50500, 86.99137, 92.36562, 104.83894, 109.98188, 1~
## $ checkin_day     <chr> "mon", "tue", "wed", "fri", "tue", "fri", "fri", "wed", "wed", "~
## $ for_business    <lgl> FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, F~
## $ status          <chr> "cancelled", "cancelled", "stayed", "stayed", "stayed", "cancell~
## $ review_score    <dbl> NA, NA, 6.258123, 5.953598, 6.434745, NA, 7.599461, NA, 6.972698~
```

Select columns with `select()`

Select one column | Select multiple columns | Exclude columns

Select the column `review_score`.

```
select(bookings, review_score)
```

```
## # A tibble: 10,000 x 1
##    review_score
##           <dbl>
##  1           NA
##  2           NA
##  3         6.26
##  4         5.95
##  5         6.43
##  6           NA
##  7         7.60
##  8           NA
##  9         6.97
## 10           NA
## # ... with 9,990 more rows
```

The output is **always** a `data.frame` or `tibble`, regardless of whether a single or multiple columns are selected.

Select columns with `select()`

Select one column | **Select multiple columns** | Exclude columns

Select multiple columns by specifying column names as additional arguments.

```
select(bookings, review_score, status)
```

```
## # A tibble: 10,000 x 2
##    review_score status
##           <dbl> <chr>
##  1           NA cancelled
##  2           NA cancelled
##  3         6.26 stayed
##  4         5.95 stayed
##  5         6.43 stayed
##  6           NA cancelled
##  7         7.60 stayed
##  8           NA cancelled
##  9         6.97 stayed
## 10           NA cancelled
## # ... with 9,990 more rows
```

Select columns with `select()`

Select one column | Select multiple columns | **Exclude columns**

Negative selection: select all but specific columns using `-`.

```
select(bookings, -booker_id)
```

```
## # A tibble: 10,000 x 7
##    property_id room_nights price_per_night checkin_day for_business status    review_score
##          <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>            <dbl>
##  1        2668           4            91.5 mon         FALSE        cancelled           NA
##  2        4656           5           107.  tue         FALSE        cancelled           NA
##  3        4563           6            87.0 wed         FALSE        stayed               6.26
##  4        4088           7            92.4 fri         FALSE        stayed               5.95
##  5        2188           4           105.  tue         FALSE        stayed               6.43
##  6        4171           2           110.  fri         FALSE        cancelled           NA
##  7        2907           4           116.  fri         FALSE        stayed               7.60
##  8        5141           4           111.  wed         FALSE        cancelled           NA
##  9        1696           1           106.  wed         FALSE        stayed               6.97
## 10        1901           7            82.3 sat         FALSE        cancelled           NA
## # ... with 9,990 more rows
```

Helper functions for `select()`

Helper functions facilitate selecting multiple columns whose names satisfy a specific criterion.

Helper function	Description
`contains("abc")`	Names containing `"abc"`
`starts_with("abc")`	Names starting with `"abc"`
`ends_with("abc")`	Names ending with `"abc"`
`num_range("a", 1:3)`	Names matching the numerical range `a1`, `a2`, `a3`
`any_of(c("ab", "c"))`	Any of the names within a character vector
`all_of(c("ab", "c"))`	All of the names within a character vector
`matches(".id")`	Names matching the regular expr. `".id"`
`everything()`	All (remaining) names
`last_col()`	Last column

Examples of `select()` with helper functions

Combined helpers | any_of() | all_of()

> *"Select all columns whose names either contain 'id' or end with 'night'."*

```
select(bookings, contains("id"), ends_with("night"))
```

```
## # A tibble: 10,000 x 3
##    booker_id                                property_id price_per_night
##    <chr>                                          <dbl>           <dbl>
##  1 215934017ba98c09f30dedd29237b43dad5c7b5f        2668            91.5
##  2 7f590fd6d318248a48665f7f7db529aca40c84f5        4656           107.
##  3 10f0f138e8bb1015d3928f2b7d828cbb50cd0804        4563            87.0
##  4 7b55021a4160dde65e31963fa55a096535bcad17        4088            92.4
##  5 6694a79d158c7818cd63831b71bac91286db5aff        2188           105.
##  6 d0358740d5f15e85523f94ab8219f25d8c017347        4171           110.
##  7 944e568a0b511b9140bcc7c7c80c68c3edd3a86f        2907           116.
##  8 95476c2ef6bb9e3c227b46f1283310737fa13b7a        5141           111.
##  9 df235631a4c281c01e007b6a4c364e07f5843994        1696           106.
## 10 ff610140227d40d27daa01f0dcd5d64ea82e833d        1901            82.3
## # ... with 9,990 more rows
```

Examples of `select()` with helper functions

Combined helpers | any_of() | all_of()

> *"Select any of the two columns `room_nights`, `this_column_is_not_there`."*

```
select(bookings, any_of(c("room_nights", "this_column_is_not_there")))
```

```
## # A tibble: 10,000 x 1
##    room_nights
##          <dbl>
##  1           4
##  2           5
##  3           6
##  4           7
##  5           4
##  6           2
##  7           4
##  8           4
##  9           1
## 10           7
## # ... with 9,990 more rows
```

Examples of `select()` with helper functions

Combined helpers | any_of() | all_of()

> *"Select both columns `room_nights`, `this_column_is_not_there`."*

```
select(bookings, all_of(c("room_nights", "this_column_is_not_there")))
```

```
## Error: Can't subset columns that don't exist.
## x Column `this_column_is_not_there` doesn't exist.
```

Filter rows with `filter()`

Filter bookings which stayed, i.e., didn't cancel.

```
filter(bookings, status == "stayed")
```

```
## # A tibble: 7,775 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 10f0f138e8bb10~        4563           6            87.0 wed         FALSE        stayed
##  2 7b55021a4160dd~        4088           7            92.4 fri         FALSE        stayed
##  3 6694a79d158c78~        2188           4           105.  tue         FALSE        stayed
##  4 944e568a0b511b~        2907           4           116.  fri         FALSE        stayed
##  5 df235631a4c281~        1696           1           106.  wed         FALSE        stayed
##  6 aeff2e2d3d23b1~        2188           1           109.  wed         FALSE        stayed
##  7 5a1442f4c7237e~        2307           9            84.2 sat         FALSE        stayed
##  8 39804a2e3fb2e4~        2907           6           112.  sun         FALSE        stayed
##  9 e150e559405ef2~        2870           4           127.  sat         FALSE        stayed
## 10 4e9c7c21dfcf27~        1674           5           102.  sun         FALSE        stayed
## # ... with 7,765 more rows, and 1 more variable: review_score <dbl>
```

```
# the same as:
filter(bookings, status != "cancelled")
```

Filter rows with `filter()`

Combine multiple conditions with `&`.

```
filter(
  bookings,
  status == "stayed" &
    !is.na(review_score) &
    between(price_per_night, 90, 120)
)
```

```
## # A tibble: 3,032 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 7b55021a4160dd~        4088           7            92.4 fri         FALSE        stayed
##  2 6694a79d158c78~        2188           4           105.  tue         FALSE        stayed
##  3 944e568a0b511b~        2907           4           116.  fri         FALSE        stayed
##  4 df235631a4c281~        1696           1           106.  wed         FALSE        stayed
##  5 39804a2e3fb2e4~        2907           6           112.  sun         FALSE        stayed
##  6 4e9c7c21dfcf27~        1674           5           102.  sun         FALSE        stayed
##  7 8537874da3fa74~        4420           2           106.  sat         FALSE        stayed
##  8 0fcce2f5be8e34~        1951           3           110.  wed         FALSE        stayed
##  9 9864af3aba5bcb~        1981           3            96.9 sun         FALSE        stayed
## 10 ccd24f993579b4~        2307           3           115.  fri         FALSE        stayed
## # ... with 3,022 more rows, and 1 more variable: review_score <dbl>
```

Sort rows with `arrange()`

```
arrange(bookings, price_per_night) # default: sort in ascending order
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 028c395e745c41~        3096           1            39.4 tue         FALSE        stayed
##  2 037bec01b4f11d~        3619           1            45.8 wed         TRUE         stayed
##  3 7341b69d8de545~        3983           1            47.7 thu         TRUE         stayed
##  4 cbedb290616cb7~        1172           2            53.2 thu         TRUE         stayed
##  5 dff926426fdf09~        4354           6            54.2 fri         FALSE        stayed
##  6 b28ca9bd608e46~        3118           2            54.8 sun         TRUE         stayed
##  7 e2aff0e6df1abe~        4116           5            55.7 tue         FALSE        stayed
##  8 28421366c10d89~        4391           4            56.6 fri         FALSE        stayed
##  9 a07a0a8a9d8924~        4150           2            57.7 sat         FALSE        cance~
## 10 97a4a1dcdce1ab~        1172           2            61.0 tue         TRUE         stayed
## # ... with 9,990 more rows, and 1 more variable: review_score <dbl>
```

```
arrange(bookings, desc(price_per_night))
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 3d62487f31468b~        4931           1            273. tue         TRUE         cance~
##  2 dc6add0d9538bf~        2305           1            272. fri         TRUE         stayed
##  3 c57c799c4fa86c~        5034           1            263. tue         TRUE         stayed
##  4 0dbc70d94f448b~        1819           1            259. fri         TRUE         cance~
##  5 1d0d33ccf02e4e~        2306           1            257. fri         FALSE        cance~
##  6 6b70130a6cd8bb~        3916           1            256. tue         TRUE         stayed
##  7 c478924be4be9c~        2464           1            255. sun         FALSE        stayed
```

Select rows by position with `slice()`

```
x <- arrange(bookings, desc(review_score))
slice(x, 1:10)
```

```
## # A tibble: 10 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 51c3e2e855240f~        1970           3            126. fri         FALSE        stayed
##  2 99f91abc431bad~        2175           1            189. wed         FALSE        stayed
##  3 1d7930a998f002~        3089           6             77.4 thu         FALSE        stayed
##  4 58c94e9418fe51~        3089           5             91.5 sat         FALSE        stayed
##  5 164c4797e41a32~        3890           1            232. sat         TRUE         stayed
##  6 3119d16c994efc~        3089           6             93.4 fri         FALSE        stayed
##  7 10f0f138e8bb10~        3089           1            175. sun         FALSE        stayed
##  8 714d7f95f1766d~        1855           2            129. thu         FALSE        stayed
##  9 b4d77fe4ea2472~        3089           2             83.3 sat         FALSE        stayed
## 10 68686391598302~        3089           5            106. fri         FALSE        stayed
## # ... with 1 more variable: review_score <dbl>
```

Chaining multiple operations 🔗

`dplyr` code is very intuitive and expressive, but also quite verbose.

🤔 *"How to organize the code so that it remains readable even for a high number of operations?"*

> *Example: For all bookers who didn't cancel their trip and checked in on a friday, we are interested in the 5 highest review scores. Only the columns `price_per_night` and `review_score` should be included in a new tibble which is sorted by `review_score` in descending order.*

Chaining multiple operations 🕸

Nesting | Save & overwrite intermediate results | Save result of each operation as new object

Solution 1 (nesting):

```
select(
  slice(
    arrange(
      filter(
        bookings, !status == "cancelled" & checkin_day == "fri"),
      desc(review_score)
    ),
    1:5
  ),
  price_per_night, review_score
)
```

```
## # A tibble: 5 x 2
##   price_per_night review_score
##             <dbl>        <dbl>
## 1            126.         10
## 2             93.4         9.80
## 3            106.          9.77
## 4            148.          9.64
## 5            225.          9.49
```

Chaining multiple operations

Nesting | Save & overwrite intermediate results | Save result of each operation as new object

Solution 2 (save and overwrite intermediate results):

```
x <- filter(bookings, !status == "cancelled" & checkin_day == "fri")
x <- arrange(x, review_score)
x <- slice(x, 1:5)
x <- select(x, price_per_night, review_score)
x
```

```
## # A tibble: 5 x 2
##   price_per_night review_score
##             <dbl>        <dbl>
## 1            123.         2.79
## 2            109.         3.31
## 3            127.         3.75
## 4            111.         4.09
## 5             79.1        4.15
```

Chaining multiple operations 🔗

Nesting | Save & overwrite intermediate results | Save result of each operation as new object

Solution 3 (save each intermediate results as new object):

```
x1 <- filter(bookings, !status == "cancelled" & checkin_day == "fri")
x2 <- arrange(x1, desc(review_score))
x3 <- slice(x2, 1:5)
x4 <- select(x2, price_per_night, review_score)
x4
```

There is a mistake in the above code. Can you spot it?

The pipe operator `%>%`

- The **pipe operator** `%>%` is used to pass information from one operation to the next.
- Its main purpose is to **express a sequence of operations**.
- Using the pipe, a function's output becomes the first argument of the subsequent function.
- Thus, the pipe operator helps to write **code that is easy to read and understand**.


```
bookings %>%
  filter(!status == "cancelled" & checkin_day == "fri") %>%
  arrange(desc(review_score)) %>%
  slice(1:5) %>%
  select(price_per_night, review_score)
```

"From table `bookings`, filter all non-canceled bookings with check-in on a Friday
THEN sort by review score in descending order
THEN take the top-5 bookings
THEN return price per night and review score."

- In RStudio, the shortcut for `%>%` is **Ctrl+⇧Shift+M**.
- Although the pipe operator is implemented in the package `magrittr`, we do not need to load this package explicitly when we have loaded `tidyverse`.

Adding new columns with `mutate()` +

Create a new column for the **total price** of a booking, which is the product of `price_per_night` and `room_nights`.

mutate() | mutate() + select() | mutate(..., .before = ...) | mutate(..., .after = ...)

```
bookings %>%
  mutate(total_price = price_per_night * room_nights)
```

```
## # A tibble: 10,000 x 9
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 215934017ba98c~        2668           4            91.5 mon         FALSE        cance~
##  2 7f590fd6d31824~        4656           5           107.  tue         FALSE        cance~
##  3 10f0f138e8bb10~        4563           6            87.0 wed         FALSE        stayed
##  4 7b55021a4160dd~        4088           7            92.4 fri         FALSE        stayed
##  5 6694a79d158c78~        2188           4           105.  tue         FALSE        stayed
##  6 d0358740d5f15e~        4171           2           110.  fri         FALSE        cance~
##  7 944e568a0b511b~        2907           4           116.  fri         FALSE        stayed
##  8 95476c2ef6bb9e~        5141           4           111.  wed         FALSE        cance~
##  9 df235631a4c281~        1696           1           106.  wed         FALSE        stayed
## 10 ff610140227d40~        1901           7            82.3 sat         FALSE        cance~
## # ... with 9,990 more rows, and 2 more variables: review_score <dbl>, total_price <dbl>
```

Note that a new variable will be appended as the last column of the data frame.

Adding new columns with `mutate()` +

Create a new column for the **total price** of a booking, which is the product of `price_per_night` and `room_nights`.

mutate() | mutate() + select() | mutate(..., .before = ...) | mutate(..., .after = ...)

(Only show `price_per_night`, `room_nights`, `total_price`)

```
bookings %>%
  mutate(total_price = price_per_night * room_nights) %>%
  select(price_per_night, room_nights, total_price)
```

```
## # A tibble: 10,000 x 3
##    price_per_night room_nights total_price
##              <dbl>       <dbl>       <dbl>
##  1            91.5           4        366.
##  2           107.            5        533.
##  3            87.0           6        522.
##  4            92.4           7        647.
##  5           105.            4        419.
##  6           110.            2        220.
##  7           116.            4        465.
##  8           111.            4        446.
##  9           106.            1        106.
## 10            82.3           7        576.
## # ... with 9,990 more rows
```

Adding new columns with `mutate()` +

Create a new column for the **total price** of a booking, which is the product of `price_per_night` and `room_nights`.

mutate() | mutate() + select() | **mutate(..., .before = ...)** | mutate(..., .after = ...)

(Insert the new column before `booker_id`.)

```
bookings %>%
  mutate(total_price = price_per_night * room_nights, .before = booker_id)
```

```
## # A tibble: 10,000 x 9
##    total_price booker_id  property_id room_nights price_per_night checkin_day for_business
##          <dbl> <chr>            <dbl>       <dbl>           <dbl> <chr>       <lgl>
##  1         366. 215934017~        2668           4            91.5 mon         FALSE
##  2         533. 7f590fd6d~        4656           5           107.  tue         FALSE
##  3         522. 10f0f138e~        4563           6            87.0 wed         FALSE
##  4         647. 7b55021a4~        4088           7            92.4 fri         FALSE
##  5         419. 6694a79d1~        2188           4           105.  tue         FALSE
##  6         220. d0358740d~        4171           2           110.  fri         FALSE
##  7         465. 944e568a0~        2907           4           116.  fri         FALSE
##  8         446. 95476c2ef~        5141           4           111.  wed         FALSE
##  9         106. df235631a~        1696           1           106.  wed         FALSE
## 10         576. ff6101402~        1901           7            82.3 sat         FALSE
## # ... with 9,990 more rows, and 2 more variables: status <chr>, review_score <dbl>
```

Adding new columns with `mutate()` +

Create a new column for the **total price** of a booking, which is the product of `price_per_night` and `room_nights`.

mutate() | mutate() + select() | mutate(..., .before = ...) | **mutate(..., .after = ...)**

(Insert the new column after the second column (`property_id`).)

```
bookings %>%
  mutate(total_price = price_per_night * room_nights, .after = 2)
```

```
## # A tibble: 10,000 x 9
##    booker_id  property_id total_price room_nights price_per_night checkin_day for_business
##    <chr>            <dbl>       <dbl>       <dbl>           <dbl> <chr>       <lgl>
##  1 215934017~        2668        366.           4            91.5 mon         FALSE
##  2 7f590fd6d~        4656        533.           5           107.  tue         FALSE
##  3 10f0f138e~        4563        522.           6            87.0 wed         FALSE
##  4 7b55021a4~        4088        647.           7            92.4 fri         FALSE
##  5 6694a79d1~        2188        419.           4           105.  tue         FALSE
##  6 d0358740d~        4171        220.           2           110.  fri         FALSE
##  7 944e568a0~        2907        465.           4           116.  fri         FALSE
##  8 95476c2ef~        5141        446.           4           111.  wed         FALSE
##  9 df235631a~        1696        106.           1           106.  wed         FALSE
## 10 ff6101402~        1901        576.           7            82.3 sat         FALSE
## # ... with 9,990 more rows, and 2 more variables: status <chr>, review_score <dbl>
```

Replacing existing columns with `mutate()` +

Convert the column `property_id` from `character` into `factor`.

```
bookings %>%
  mutate(property_id = as.factor(property_id))
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>           <fct>              <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 215934017ba98c~ 2668                   4            91.5 mon         FALSE        cance~
##  2 7f590fd6d31824~ 4656                   5           107.  tue         FALSE        cance~
##  3 10f0f138e8bb10~ 4563                   6            87.0 wed         FALSE        stayed
##  4 7b55021a4160dd~ 4088                   7            92.4 fri         FALSE        stayed
##  5 6694a79d158c78~ 2188                   4           105.  tue         FALSE        stayed
##  6 d0358740d5f15e~ 4171                   2           110.  fri         FALSE        cance~
##  7 944e568a0b511b~ 2907                   4           116.  fri         FALSE        stayed
##  8 95476c2ef6bb9e~ 5141                   4           111.  wed         FALSE        cance~
##  9 df235631a4c281~ 1696                   1           106.  wed         FALSE        stayed
## 10 ff610140227d40~ 1901                   7            82.3 sat         FALSE        cance~
## # ... with 9,990 more rows, and 1 more variable: review_score <dbl>
```

`mutate(across(...))`

Apply a transformation to **multiple columns**.

Select columns by name | Select columns by logical condition

Transform columns whose names end with "id" to factor variables.

```
bookings %>%
  mutate(across(ends_with("id"), as.factor))
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <fct>           <fct>              <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 215934017ba98c~ 2668                   4            91.5 mon         FALSE        cance~
##  2 7f590fd6d31824~ 4656                   5           107.  tue         FALSE        cance~
##  3 10f0f138e8bb10~ 4563                   6            87.0 wed         FALSE        stayed
##  4 7b55021a4160dd~ 4088                   7            92.4 fri         FALSE        stayed
##  5 6694a79d158c78~ 2188                   4           105.  tue         FALSE        stayed
##  6 d0358740d5f15e~ 4171                   2           110.  fri         FALSE        cance~
##  7 944e568a0b511b~ 2907                   4           116.  fri         FALSE        stayed
##  8 95476c2ef6bb9e~ 5141                   4           111.  wed         FALSE        cance~
##  9 df235631a4c281~ 1696                   1           106.  wed         FALSE        stayed
## 10 ff610140227d40~ 1901                   7            82.3 sat         FALSE        cance~
## # ... with 9,990 more rows, and 1 more variable: review_score <dbl>
```

`mutate(across(...))`

Apply a transformation to **multiple columns**.

Select columns by name | Select columns by logical condition

Transform all columns of type `character` to factor variables.

```
bookings %>%
  mutate(across(where(is.character), as.factor))
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <fct>                 <dbl>       <dbl>           <dbl> <fct>       <lgl>        <fct>
##  1 215934017ba98c~        2668           4            91.5 mon         FALSE        cance~
##  2 7f590fd6d31824~        4656           5           107.  tue         FALSE        cance~
##  3 10f0f138e8bb10~        4563           6            87.0 wed         FALSE        stayed
##  4 7b55021a4160dd~        4088           7            92.4 fri         FALSE        stayed
##  5 6694a79d158c78~        2188           4           105.  tue         FALSE        stayed
##  6 d0358740d5f15e~        4171           2           110.  fri         FALSE        cance~
##  7 944e568a0b511b~        2907           4           116.  fri         FALSE        stayed
##  8 95476c2ef6bb9e~        5141           4           111.  wed         FALSE        cance~
##  9 df235631a4c281~        1696           1           106.  wed         FALSE        stayed
## 10 ff610140227d40~        1901           7            82.3 sat         FALSE        cance~
## # ... with 9,990 more rows, and 1 more variable: review_score <dbl>
```

Summarize many rows with `summarize()`

`summarize()` (or `summarise()`) performs some kind of aggregation and returns a summary table with fewer rows and removes all columns that are irrelevant to the calculation.

A single one-valued stat | Multiple one-valued stats | Multiple n-valued stats

What is the average review score over all bookings?

```
bookings %>%
  summarize(review_score = mean(review_score, na.rm = TRUE))
```

```
## # A tibble: 1 x 1
##   review_score
##          <dbl>
## 1         7.22
```

(one row, one column)

Summarize many rows with `summarize()`

`summarize()` (or `summarise()`) performs some kind of aggregation and returns a summary table with fewer rows and removes all columns that are irrelevant to the calculation.

A single one-valued stat | **Multiple one-valued stats** | Multiple n-valued stats

> *What is the total number of bookings, the number of bookings without review score, and the average review score over all bookings?*

```
bookings %>%
  summarize(n = n(), # Total no. of bookings
            n_miss = sum(is.na(review_score)), # No. of bookings w/o review score
            review_score = mean(review_score, na.rm = TRUE)) # Avg. review score
```

```
## # A tibble: 1 x 3
##       n n_miss review_score
##   <int>  <int>        <dbl>
## 1 10000   3817         7.22
```

(one row, multiple columns)

Summarize many rows with `summarize()`

`summarize()` (or `summarise()`) performs some kind of aggregation and returns a summary table with fewer rows and removes all columns that are irrelevant to the calculation.

A single one-valued stat | Multiple one-valued stats | **Multiple n-valued stats**

> *What is the price range over all bookings?*

```
bookings %>%
  summarize(statistic = c("min", "max"), value = range(price_per_night))
```

```
## # A tibble: 2 x 2
##   statistic value
##   <chr>     <dbl>
## 1 min        39.4
## 2 max       273.
```

(multiple rows, multiple columns)

Grouping with `group_by()`

`group_by()` lets us perform operations for each *group* separately.

```
bookings %>%
  group_by(for_business) %>%
  summarize(n = n(), review_avg = mean(review_score, na.rm = TRUE))
```

```
## # A tibble: 2 x 3
##   for_business     n review_avg
##   <lgl>        <int>      <dbl>
## 1 FALSE         6285       7.50
## 2 TRUE          3715       6.85
```

```
class(bookings)
```

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

```
bookings %>% group_by(for_business) %>% class()
```

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

Use `ungroup()` to undo the grouping.

Group by multiple columns

```
# Average score by travel type and check-in day of the week
bookings %>%
  group_by(for_business, checkin_day) %>%
  summarize(mean_review = mean(review_score, na.rm = TRUE))
```

```
## # A tibble: 14 x 3
## # Groups:   for_business [2]
##    for_business checkin_day mean_review
##    <lgl>        <chr>             <dbl>
##  1 FALSE        fri                7.60
##  2 FALSE        mon                7.34
##  3 FALSE        sat                7.57
##  4 FALSE        sun                7.57
##  5 FALSE        thu                7.42
##  6 FALSE        tue                7.32
##  7 FALSE        wed                7.43
##  8 TRUE         fri                7.04
##  9 TRUE         mon                6.87
## 10 TRUE         sat                7.05
## 11 TRUE         sun                6.93
## 12 TRUE         thu                6.79
## 13 TRUE         tue                6.75
## 14 TRUE         wed                6.84
```

Count the number of rows per group with `count()`

Syntax:

```
bookings %>%
  count(x, y, ...)
```

...is a shortcut for...

```
bookings %>%
  group_by(x, y, ...) %>%
  summarize(n = n())
```

```
bookings %>%
  count(for_business, status)
```

```
## # A tibble: 4 x 3
##   for_business status        n
##   <lgl>        <chr>     <int>
## 1 FALSE        cancelled  1762
## 2 FALSE        stayed     4523
## 3 TRUE         cancelled   463
## 4 TRUE         stayed     3252
```

```
bookings %>%
  group_by(for_business, status) %>%
  summarize(n = n())
```

```
## # A tibble: 4 x 3
## # Groups:   for_business [2]
##   for_business status        n
##   <lgl>        <chr>     <int>
## 1 FALSE        cancelled  1762
## 2 FALSE        stayed     4523
## 3 TRUE         cancelled   463
## 4 TRUE         stayed     3252
```

Combining multiple data frames

Customer bookings data

> *What is the number of bookings per destination (city)?*

To answer this question, we have to combine the two data frames `bookings` and `properties`.

bookings | properties

```
bookings <- read_csv("../data/bookings.csv")
```

```
## # A tibble: 10,000 x 8
##    booker_id       property_id room_nights price_per_night checkin_day for_business status
##    <chr>                 <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
##  1 215934017ba98c~        2668           4            91.5 mon         FALSE        cance~
##  2 7f590fd6d31824~        4656           5           107.  tue         FALSE        cance~
##  3 10f0f138e8bb10~        4563           6            87.0 wed         FALSE        stayed
##  4 7b55021a4160dd~        4088           7            92.4 fri         FALSE        stayed
##  5 6694a79d158c78~        2188           4           105.  tue         FALSE        stayed
##  6 d0358740d5f15e~        4171           2           110.  fri         FALSE        cance~
##  7 944e568a0b511b~        2907           4           116.  fri         FALSE        stayed
##  8 95476c2ef6bb9e~        5141           4           111.  wed         FALSE        cance~
##  9 df235631a4c281~        1696           1           106.  wed         FALSE        stayed
## 10 ff610140227d40~        1901           7            82.3 sat         FALSE        cance~
## # ... with 9,990 more rows, and 1 more variable: review_score <dbl>
```

Customer bookings data

> *What is the number of bookings per destination (city)?*

To answer this question, we have to combine the two data frames `bookings` and `properties`.

bookings | properties

```
properties <- read_csv("../data/properties.csv")
properties
```

```
## # A tibble: 4,178 x 5
##    property_id destination property_type nr_rooms facilities
##          <dbl> <chr>       <chr>            <dbl> <chr>
##  1        2668 Brisbane    Hotel               32 airport shuttle,free wifi,garden,breakf~
##  2        4656 Brisbane    Hotel               39 on-site restaurant,pool,airport shuttle~
##  3        4563 Brisbane    Apartment            9 laundry
##  4        4088 Brisbane    Apartment            9 kitchen,laundry,free wifi
##  5        2188 Brisbane    Apartment            4 parking,kitchen,bbq,free wifi,game cons~
##  6        4171 Brisbane    Apartment            5 kitchen,pool,laundry,parking,free wifi,~
##  7        2907 Brisbane    Hotel               22 airport shuttle,on-site restaurant,brea~
##  8        5141 Brisbane    Hotel               20 breakfast,free wifi,on-site restaurant,~
##  9        1696 Brisbane    Apartment            5 free wifi,laundry,pool,game console,par~
## 10        1901 Brisbane    Apartment           11 free wifi,bbq,laundry,breakfast,pool,pa~
## # ... with 4,168 more rows
```

Joining data frames

Data | Basic syntax | Inner | Left | Left 2 | Right | Full | Semi | Anti

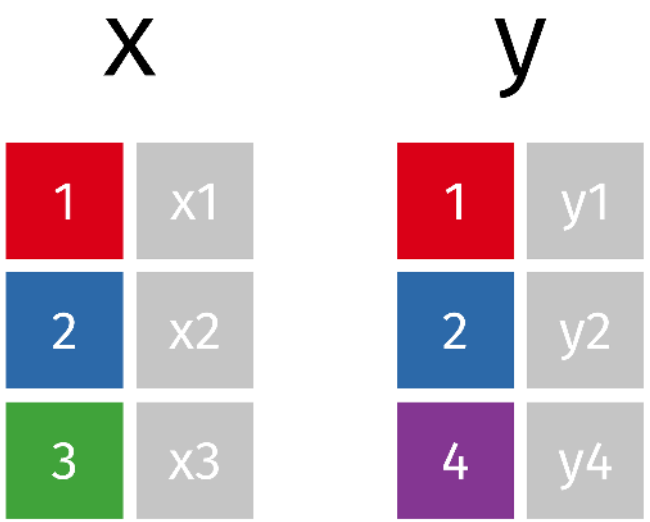
Consider the following two toy data frames `x` and `y`:

```
(x <- tibble(id = c(1L, 2L, 3L), x = c("x1", "x2", "x3")))
```

```
## # A tibble: 3 x 2
##      id x
##   <int> <chr>
## 1     1 x1
## 2     2 x2
## 3     3 x3
```

```
(y <- tibble(id = c(1L, 2L, 4L), y = c("y1", "y2", "y4")))
```

```
## # A tibble: 3 x 2
##      id y
##   <int> <chr>
## 1     1 y1
## 2     2 y2
## 3     4 y4
```



Source of the figures on this and the following slides: https://github.com/gadenbuie/tidyexplain

Joining data frames

Data | Basic syntax | Inner | Left | Left 2 | Right | Full | Semi | Anti

Basic syntax:

```
**_join(df1, df2, by = "<ID>")
```

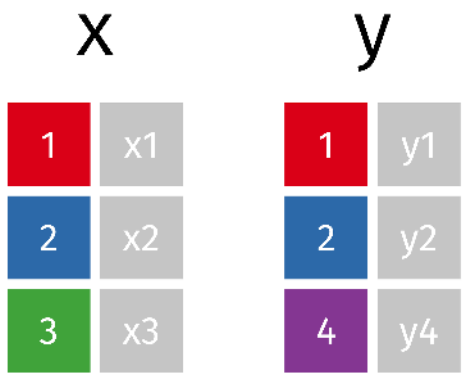
Joining data frames

Data | Basic syntax | **Inner** | Left | Left 2 | Right | Full | Semi | Anti

Join two data frames `x` and `y`. The result is a data frame containing all rows from `x` with matching values in `y` for column `id` and all columns from `x` and `y`.

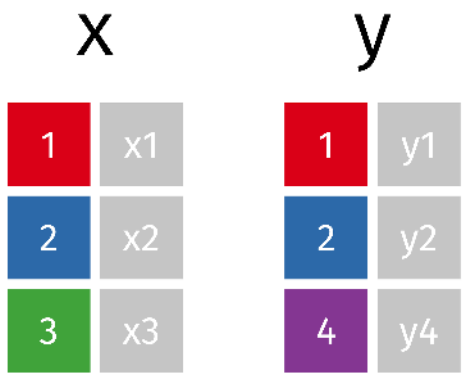
```
inner_join(x, y, by = "id")
```

```
## # A tibble: 2 x 3
##      id x     y
##   <int> <chr> <chr>
## 1     1 x1    y1
## 2     2 x2    y2
```



Joining data frames

Join two data frames `x` and `y`. The result is a data frame containing all rows from `x` and all columns from `x` and `y`. In rows where there are no matching values in `y` for column `id`, the values of the columns that are present only in `y` are set to `NA`.

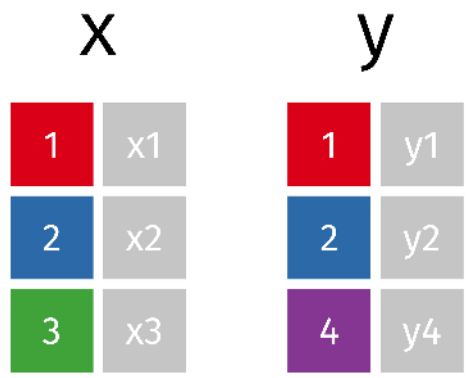



```
left_join(x, y, by = "id")
```

```
## # A tibble: 3 x 3
##      id x     y
##   <int> <chr> <chr>
## 1     1 x1    y1
## 2     2 x2    y2
## 3     3 x3    <NA>
```

Joining data frames

In case of multiple matches, **all** combinations of the matches are returned:




```
(y_extra <- bind_rows(y, tibble(id = 2L, y = "y5")))
```

```
## # A tibble: 4 x 2
##      id y
##   <int> <chr>
## 1     1 y1
## 2     2 y2
## 3     4 y4
## 4     2 y5
```

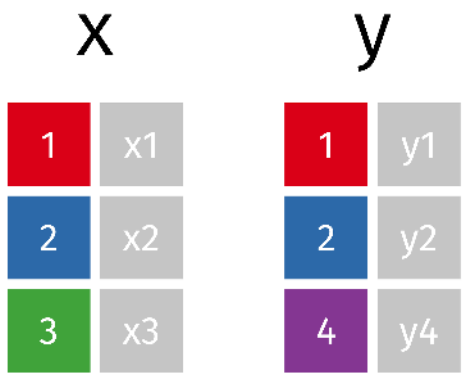
```
left_join(x, y_extra, by = "id")
```

```
## # A tibble: 4 x 3
##      id x     y
##   <int> <chr> <chr>
## 1     1 x1    y1
## 2     2 x2    y2
## 3     2 x2    y5
## 4     3 x3    <NA>
```

Joining data frames

Data | Basic syntax | Inner | Left | Left 2 | **Right** | Full | Semi | Anti

Join two data frames `x` and `y`. The result is a data frame containing all rows from `y` and all columns from `x` and `y`. In rows where there are no matching values in `x` for column `id`, the values of the columns that are present only in `x` are set to `NA`.

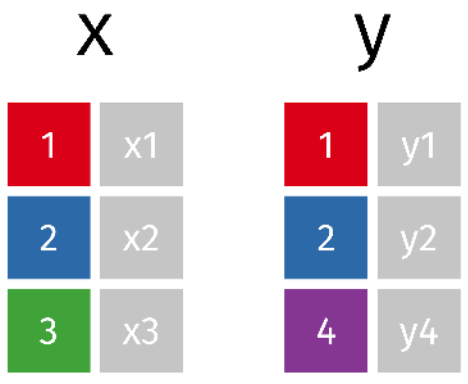



```
right_join(x, y, by = "id")
```

```
## # A tibble: 3 x 3
##      id x     y
##   <int> <chr> <chr>
## 1     1 x1    y1
## 2     2 x2    y2
## 3     4 <NA>  y4
```

Joining data frames

Join two data frames `x` and `y`. The result is a data frame containing all rows and all columns from `x` and `y`. In rows where there are no matching values for column `id`, the values of the columns from the other data frame are set to `NA`.




```
full_join(x, y, by = "id")
```

```
## # A tibble: 4 x 3
##      id x     y
##   <int> <chr> <chr>
## 1     1 x1    y1
## 2     2 x2    y2
## 3     3 x3    <NA>
## 4     4 <NA>  y4
```

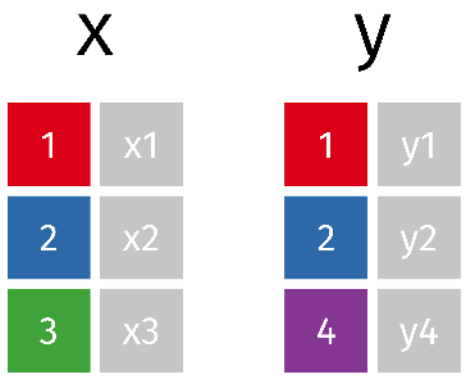
Joining data frames

Data | Basic syntax | Inner | Left | Left 2 | Right | Full | **Semi** | Anti

Return all rows and columns from `x` with matching rows in `y`.

```
semi_join(x, y, by = "id")
```

```
## # A tibble: 2 x 2
##      id x
##   <int> <chr>
## 1     1 x1
## 2     2 x2
```

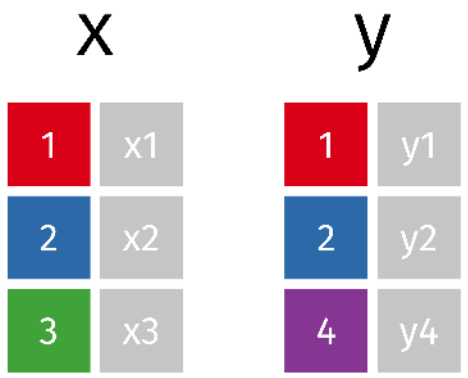


Joining data frames

Return all rows and columns from `x` **without** matching rows in `y`.

```
anti_join(x, y, by = "id")
```

```
## # A tibble: 1 x 2
##      id x
##   <int> <chr>
## 1     3 x3
```




tidyr
tidyr.tidyverse.org

	A	B	C	D	E	F	G	H	I	J
	Gesamtübersicht: Daten zum Kriminalitätsatlas (PKS 2019)									
	Fallzahlen der Bezirke und Bezirksregionen									
	Hinweis: Aufgrund einer zum 1. Januar 2019 durchgeführten Anpassung beim Gebietszuschnitt im Bereich Allende-Viertel (Bezirk Treptow-Köpenick) sind bei den gelb markier									
	LOR-Schlüssel (Bezirksregion)	**Bezeichnung (Bezirksregion)**	**Straftaten -insgesamt-**	**Raub**	**Straßenraub, Handtaschen-raub**	**Körper-verletzungen -insgesamt-**	**Gefährl. und schwere Körper-verletzung**	**Freiheits-beraubung, Nötigung, Bedrohung,**	**Diebstahl -insgesamt-**	**Diebstahl von Kraftwagen**
	010000	**Mitte**	**84.357**	**707**	**407**	**7.595**	**1.951**	**2.157**	**35.601**	**401**
	010111	Tiergarten Süd	5.009	60	35	365	92	128	2.271	15
	010112	Regierungsviertel	7.950	42	20	554	136	152	3.692	13
	010113	Alexanderplatz	22.974	173	102	1.966	500	420	11.233	63
0	010114	Brunnenstraße Süd	4.252	40	29	268	64	79	1.859	39
1	010221	Moabit West	7.197	66	29	685	210	202	2.107	47
2	010222	Moabit Ost	9.626	48	29	652	150	231	3.672	27
3	010331	Osloer Straße	6.011	61	30	727	168	214	2.474	46
4	010332	Brunnenstraße Nord	6.600	62	42	692	201	209	2.537	58
5	010441	Parkviertel	6.413	64	45	699	159	218	2.779	50
6	010442	Wedding Zentrum	8.090	86	42	968	264	299	2.883	43
7	019900	Bezirk (Mi), nicht zuzuordnen	235	5	4	19	7	5	94	0
8	**020000**	**Friedrichshain-Kreuzberg**	**60.290**	**820**	**579**	**5.006**	**1.752**	**1.237**	**25.650**	**387**
9	020101	Südliche Friedrichstadt	8.923	125	70	716	200	255	3.973	43
0	020202	Tempelhofer Vorstadt	12.527	119	82	872	283	271	5.797	113
1	020303	nördliche Luisenstadt	5.484	94	67	524	215	99	2.509	27
2	020304	südliche Luisenstadt	6.653	182	150	530	251	125	2.343	37
3	020405	Karl-Marx-Allee-Nord	2.551	38	26	225	58	61	1.260	50
4	020407	Karl-Marx-Allee-Süd	8.741	98						
5	020506	Frankfurter Allee Nord	4.229	30						
6	020508	Frankfurter Allee Süd FK	11.092	132						
7	029900	Bezirk (Fh-Kb), nicht zuzuordnen	90	2						
8	**030000**	**Pankow**	**36.710**	**284**						
9	030101	Buch	1.829	9						
0	030202	Blankenfelde/Niederschönhausen	1.633	7	5	106	14	59	671	31

Tidy and untidy data

Data source

Data come in different shapes...

table1 | table2 | table3 | table4a & table4b

```
## # A tibble: 6 x 4
##   country      year  cases population
##   <chr>       <int>  <int>      <int>
## 1 Afghanistan  1999    745   19987071
## 2 Afghanistan  2000   2666   20595360
## 3 Brazil       1999  37737  172006362
## 4 Brazil       2000  80488  174504898
## 5 China        1999 212258 1272915272
## 6 China        2000 213766 1280428583
```

Data come in different shapes...

table1 | **table2** | table3 | table4a & table4b

```
## # A tibble: 12 x 4
##    country      year type            count
##    <chr>       <int> <chr>           <int>
##  1 Afghanistan  1999 cases             745
##  2 Afghanistan  1999 population   19987071
##  3 Afghanistan  2000 cases            2666
##  4 Afghanistan  2000 population   20595360
##  5 Brazil       1999 cases           37737
##  6 Brazil       1999 population  172006362
##  7 Brazil       2000 cases           80488
##  8 Brazil       2000 population  174504898
##  9 China        1999 cases          212258
## 10 China        1999 population 1272915272
## 11 China        2000 cases          213766
## 12 China        2000 population 1280428583
```

Data come in different shapes...

table1 table2 **table3** table4a & table4b

```
## # A tibble: 6 x 3
##   country      year rate
## * <chr>       <int> <chr>
## 1 Afghanistan  1999 745/19987071
## 2 Afghanistan  2000 2666/20595360
## 3 Brazil       1999 37737/172006362
## 4 Brazil       2000 80488/174504898
## 5 China        1999 212258/1272915272
## 6 China        2000 213766/1280428583
```

Data come in different shapes...

table1 table2 table3 **table4a & table4b**

```
## # A tibble: 3 x 3
##   country     `1999` `2000`
## * <chr>        <int>  <int>
## 1 Afghanistan    745   2666
## 2 Brazil       37737  80488
## 3 China       212258 213766
```

```
## # A tibble: 3 x 3
##   country         `1999`     `2000`
## * <chr>            <int>      <int>
## 1 Afghanistan   19987071   20595360
## 2 Brazil       172006362  174504898
## 3 China       1272915272 1280428583
```

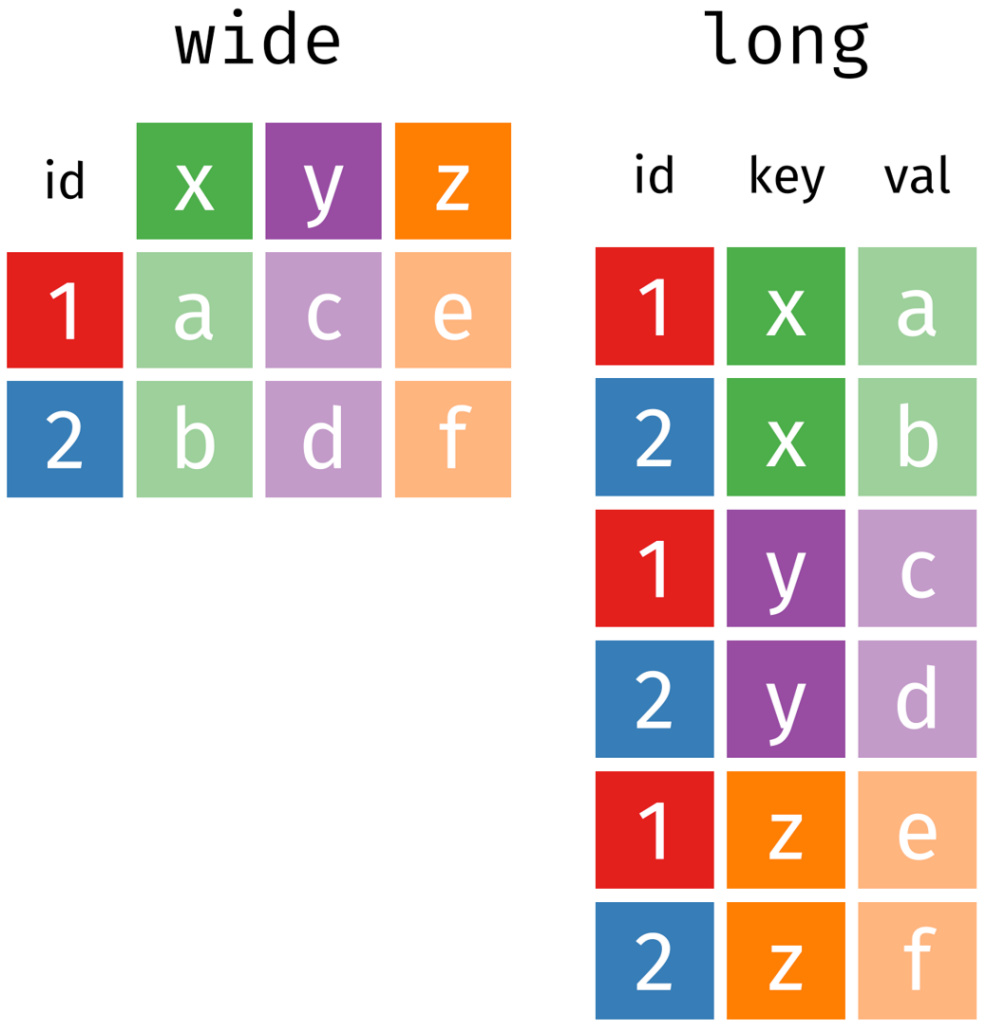
Reshape data frames with `tidyr`

The `tidyverse` inherits its name from the term **tidy data**. Tidy data refers to a specific standardized dataset structure.

Characteristics of tidy data:

1. Each **variable** must have its own column.
2. Each **observation** must have its own row.
3. Each **value** must have its own cell.

Many of the tidyverse functions require a *tidy* data frame input. The `tidyr` package contains functions to reshape "messy" into tidy data frames.



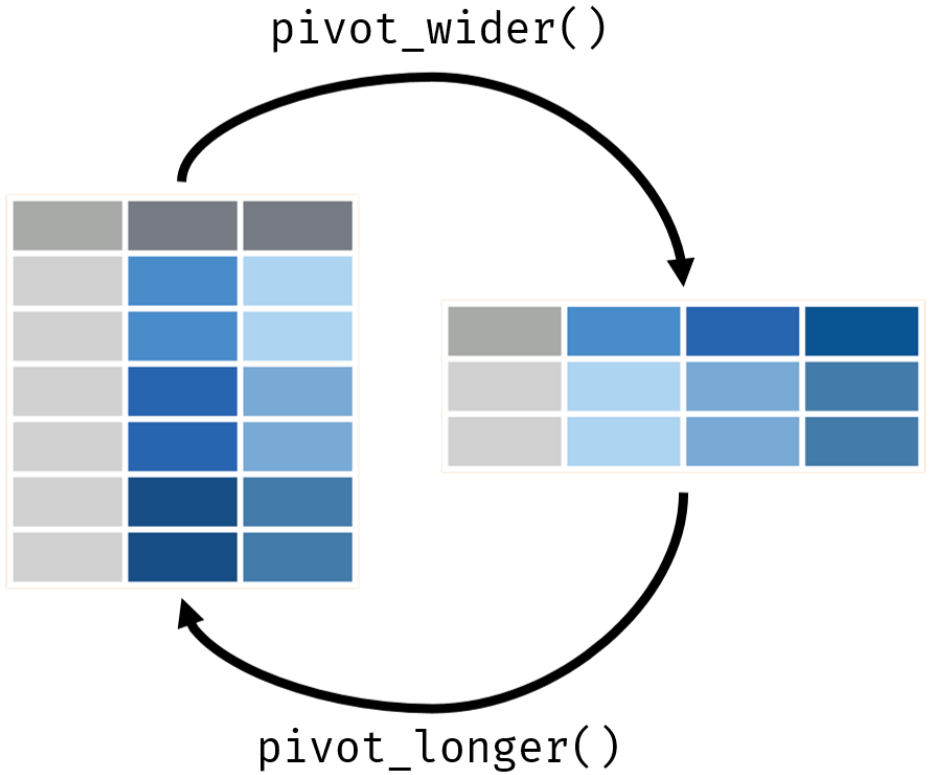
Further reading:

- R for Data Science: Tidy data
- Function overview: RStudio's Data import cheat sheet

`pivot_longer()` and `pivot_wider()`

`tidyr`'s two main functions are `pivot_longer()` and `pivot_wider()`.

- `pivot_longer()` takes multiple columns and collapses them into **key-value pairs**.
- `pivot_wider()` takes two or more columns (i.e., a key-value pair) and spreads them into **multiple columns**.



`pivot_longer()` and `pivot_wider()`

```
(wide <- tibble(name = c("Alex","Ben","Cedric"), DataSciR = c(2.0,1.7,1.0), VisAnalytics = c(3.3,1.3,2.0)))
```

```
## # A tibble: 3 x 3
##   name   DataSciR VisAnalytics
##   <chr>     <dbl>        <dbl>
## 1 Alex        2            3.3
## 2 Ben         1.7          1.3
## 3 Cedric      1            2
```

This data frame is in **wide** format: there are 3 variables (name of student, course name, grade), but only the student's name has its own column.

Use `pivot_longer()` to collapse the two course columns into key-value pairs `course` and `grade`.

```
tidy <- wide %>%
  pivot_longer(cols = -name,
    names_to = "course", values_to = "grade")
tidy
```

```
## # A tibble: 6 x 3
##   name   course       grade
##   <chr>  <chr>        <dbl>
## 1 Alex   DataSciR       2
## 2 Alex   VisAnalytics   3.3
## 3 Ben    DataSciR       1.7
## 4 Ben    VisAnalytics   1.3
## 5 Cedric DataSciR       1
## 6 Cedric VisAnalytics   2
```

Use `pivot_wider()` to "unpivot" a data frame. It is useful when there are variables that form rows instead of columns.

```
tidy %>%
  pivot_wider(names_from = course,
              values_from = grade)
```

```
## # A tibble: 3 x 3
##   name   DataSciR VisAnalytics
##   <chr>     <dbl>        <dbl>
## 1 Alex        2            3.3
## 2 Ben         1.7          1.3
## 3 Cedric      1            2
```

Reshaping from "long" to "wide"

Long data | Wide data | Code | Wide data with correct order | Undo

Compute the number of bookings per city and day:

```
day_order <- c("mon", "tue", "wed", "thu", "fri", "sat", "sun")
df <- bookings %>% inner_join(properties, by = "property_id")
checkin_count <- df %>%
  count(destination, checkin_day) %>%
  mutate(checkin_day = factor(checkin_day, levels = day_order))
checkin_count
```

```
## # A tibble: 21 x 3
##    destination checkin_day     n
##    <chr>       <fct>       <int>
##  1 Amsterdam   fri          1074
##  2 Amsterdam   mon           517
##  3 Amsterdam   sat           889
##  4 Amsterdam   sun           813
##  5 Amsterdam   thu           667
##  6 Amsterdam   tue           498
##  7 Amsterdam   wed           542
##  8 Brisbane    fri           162
##  9 Brisbane    mon           133
## 10 Brisbane    sat           114
## # ... with 11 more rows
```

Reshaping from "long" to "wide"

Long data | **Wide data** | Code | Wide data with correct order | Undo

🤔 *"How can we create the following table from* `checkin_count`*?"*

```
## # A tibble: 3 x 8
##   destination   mon   tue   wed   thu   fri   sat   sun
##   <chr>       <int> <int> <int> <int> <int> <int> <int>
## 1 Amsterdam     517   498   542   667  1074   889   813
## 2 Brisbane      133   148   128   162   162   114   153
## 3 Tokyo         718   655   560   718   451   322   576
```

Reshaping from "long" to "wide"

Long data | Wide data | **Code** | Wide data with correct order | Undo

```
checkin_count %>%
  pivot_wider(names_from = checkin_day, values_from = n)
```

```
## # A tibble: 3 x 8
##   destination   fri   mon   sat   sun   thu   tue   wed
##   <chr>       <int> <int> <int> <int> <int> <int> <int>
## 1 Amsterdam    1074   517   889   813   667   498   542
## 2 Brisbane      162   133   114   153   162   148   128
## 3 Tokyo         451   718   322   576   718   655   560
```

`pivot_wider()` creates the new columns in the order the keys appear in the data. Hence, we can sort the rows by `checkin_day` to obtain a data frame with the day-of-week columns in the correct order.

Reshaping from "long" to "wide"

Long data | Wide data | Code | Wide data with correct order | Undo

Arrange by `checkin_day` before reshaping the data frame into wide format:

```
checkin_count %>%
  arrange(checkin_day) %>%
  pivot_wider(names_from = checkin_day, values_from = n)
```

```
## # A tibble: 3 x 8
##   destination   mon   tue   wed   thu   fri   sat   sun
##   <chr>       <int> <int> <int> <int> <int> <int> <int>
## 1 Amsterdam     517   498   542   667  1074   889   813
## 2 Brisbane      133   148   128   162   162   114   153
## 3 Tokyo         718   655   560   718   451   322   576
```

Reshaping from "long" to "wide"

Long data | Wide data | Code | Wide data with correct order | Undo

Bring the data back into long format:

```
checkin_count %>%
  pivot_wider(names_from = checkin_day,
              values_from = n) %>%
  pivot_longer(cols = c(mon, tue, wed, thu,
                        fri, sat, sun),
               names_to = "checkin_day",
               values_to = "n")
```

```
## # A tibble: 21 x 3
##    destination checkin_day     n
##    <chr>       <chr>       <int>
##  1 Amsterdam   mon           517
##  2 Amsterdam   tue           498
##  3 Amsterdam   wed           542
##  4 Amsterdam   thu           667
##  5 Amsterdam   fri          1074
##  6 Amsterdam   sat           889
##  7 Amsterdam   sun           813
##  8 Brisbane    mon           133
##  9 Brisbane    tue           148
## 10 Brisbane    wed           128
## # ... with 11 more rows
```

Alternative variables selection:

```
checkin_count %>%
  pivot_wider(names_from = checkin_day,
              values_from = n) %>%
  pivot_longer(cols = -destination,
               names_to = "checkin_day",
               values_to = "n")
```

```
## # A tibble: 21 x 3
##    destination checkin_day     n
##    <chr>       <chr>       <int>
##  1 Amsterdam   fri          1074
##  2 Amsterdam   mon           517
##  3 Amsterdam   sat           889
##  4 Amsterdam   sun           813
##  5 Amsterdam   thu           667
##  6 Amsterdam   tue           498
##  7 Amsterdam   wed           542
##  8 Brisbane    fri           162
##  9 Brisbane    mon           133
## 10 Brisbane    sat           114
## # ... with 11 more rows
```

`separate()`

```
properties %>% head()
```

```
## # A tibble: 6 x 5
##   property_id destination property_type nr_rooms facilities
##         <dbl> <chr>       <chr>            <dbl> <chr>
## 1        2668 Brisbane    Hotel               32 airport shuttle,free wifi,garden,breakfa~
## 2        4656 Brisbane    Hotel               39 on-site restaurant,pool,airport shuttle,~
## 3        4563 Brisbane    Apartment            9 laundry
## 4        4088 Brisbane    Apartment            9 kitchen,laundry,free wifi
## 5        2188 Brisbane    Apartment            4 parking,kitchen,bbq,free wifi,game conso~
## 6        4171 Brisbane    Apartment            5 kitchen,pool,laundry,parking,free wifi,g~
```

Have a look at the `facilities` column. It indicates the availability of various facilities in the accommodation.

separate()

`separate()` splits up two or more variables that are clumped together in one column.

```
properties %>%
  # Split `facilities` by `,` into multiple columns.
  separate(facilities, into = paste0("facility_", 1:9), sep = ",") %>%
  head(5)
```

```
## Warning: Expected 9 pieces. Missing pieces filled with `NA` in 4091 rows [1, 2, 3, 4, 5,
## 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, ...].
```

```
## # A tibble: 5 x 13
##   property_id destination property_type nr_rooms facility_1       facility_2 facility_3
##         <dbl> <chr>       <chr>            <dbl> <chr>            <chr>      <chr>
## 1        2668 Brisbane    Hotel               32 airport shuttle  free wifi  garden
## 2        4656 Brisbane    Hotel               39 on-site restaur~ pool       airport shut~
## 3        4563 Brisbane    Apartment            9 laundry          <NA>       <NA>
## 4        4088 Brisbane    Apartment            9 kitchen          laundry    free wifi
## 5        2188 Brisbane    Apartment            4 parking          kitchen    bbq
## # ... with 6 more variables: facility_4 <chr>, facility_5 <chr>, facility_6 <chr>,
## #   facility_7 <chr>, facility_8 <chr>, facility_9 <chr>
```

We get a warning because the number of facilities differ across properties. The maximum number of facilities is 9. If a property has less than 9 facilities, the remaining columns are filled with `NA`.

✅ `unite()` is the inverse function of `separate()` and combines multiple variables into one. For example, this operation could be useful for combining day, month and year columns into one date column.

Nesting tables

Common data structures are **hierarchical**, e.g. patient-centric data with repeat observations.

Nesting allows to store collapsed data frames and simplifies data management.

First, reshape `properties` into a tidy format:

```
tp <- properties %>%
  separate(facilities, into = paste0("facility_", 1:9), sep = ",") %>%
  pivot_longer(cols = starts_with("facility_"), names_to = "facility_nr", values_to = "facility")
```

```
## Warning: Expected 9 pieces. Missing pieces filled with `NA` in 4091 rows [1, 2, 3, 4, 5,
## 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, ...].
```

```
head(tp)
```

```
## # A tibble: 6 x 6
##   property_id destination property_type nr_rooms facility_nr facility
##         <dbl> <chr>       <chr>            <dbl> <chr>       <chr>
## 1        2668 Brisbane    Hotel               32 facility_1  airport shuttle
## 2        2668 Brisbane    Hotel               32 facility_2  free wifi
## 3        2668 Brisbane    Hotel               32 facility_3  garden
## 4        2668 Brisbane    Hotel               32 facility_4  breakfast
## 5        2668 Brisbane    Hotel               32 facility_5  pool
## 6        2668 Brisbane    Hotel               32 facility_6  on-site restaurant
```

Now, the data frame contains a lot of duplicate information: 9x destination, property type and number of rooms for each property id.

Nesting tables

Use `nest()` to create a nested data frame. The nested data frame contains a column `facilities` which is a **list of data frames**:

```
nested_tp <- tp %>%
  nest(facilities = c(facility_nr, facility))
nested_tp
```

```
## # A tibble: 4,178 x 5
##    property_id destination property_type nr_rooms facilities
##          <dbl> <chr>       <chr>            <dbl> <list>
##  1        2668 Brisbane    Hotel               32 <tibble [9 x 2]>
##  2        4656 Brisbane    Hotel               39 <tibble [9 x 2]>
##  3        4563 Brisbane    Apartment            9 <tibble [9 x 2]>
##  4        4088 Brisbane    Apartment            9 <tibble [9 x 2]>
##  5        2188 Brisbane    Apartment            4 <tibble [9 x 2]>
##  6        4171 Brisbane    Apartment            5 <tibble [9 x 2]>
##  7        2907 Brisbane    Hotel               22 <tibble [9 x 2]>
##  8        5141 Brisbane    Hotel               20 <tibble [9 x 2]>
##  9        1696 Brisbane    Apartment            5 <tibble [9 x 2]>
## 10        1901 Brisbane    Apartment           11 <tibble [9 x 2]>
## # ... with 4,168 more rows
```

Use `unnest()` to expand a list column, such that each element of the list becomes a row.

drop_na()

Some of the rows in the nested `facilities` column contain `NA`'s. How can we remove them?

Access nested data frame | drop_na() on list columns | drop_na() before nesting

```
nested_tp$facilities[1]
```

```
## [[1]]
## # A tibble: 9 x 2
##   facility_nr facility
##   <chr>       <chr>
## 1 facility_1  airport shuttle
## 2 facility_2  free wifi
## 3 facility_3  garden
## 4 facility_4  breakfast
## 5 facility_5  pool
## 6 facility_6  on-site restaurant
## 7 facility_7  <NA>
## 8 facility_8  <NA>
## 9 facility_9  <NA>
```

drop_na()

Some of the rows in the nested `facilities` column contain `NA`'s. How can we remove them?

Access nested data frame | drop_na() on list columns | drop_na() before nesting

The function `drop_na()` removes all rows with at least one missing value.

```
nested_tp_wo_na <- nested_tp %>%
  drop_na(facilities)
# Did it work?
nested_tp_wo_na$facilities[1]
```

```
## [[1]]
## # A tibble: 9 x 2
##   facility_nr facility
##   <chr>       <chr>
## 1 facility_1  airport shuttle
## 2 facility_2  free wifi
## 3 facility_3  garden
## 4 facility_4  breakfast
## 5 facility_5  pool
## 6 facility_6  on-site restaurant
## 7 facility_7  <NA>
## 8 facility_8  <NA>
## 9 facility_9  <NA>
```

drop_na()

Some of the rows in the nested `facilities` column contain `NA`'s. How can we remove them?

Access nested data frame | drop_na() on list columns | drop_na() before nesting

`dplyr`/`tidyr` functions don't work recursively. Thus, we apply `drop_na()` before nesting.

```
nested_without_missing <- tp %>%
  drop_na() %>%
  nest(facilities = c(facility_nr, facility))
nested_without_missing$facilities[[1]]
```

```
## # A tibble: 6 x 2
##   facility_nr facility
##   <chr>       <chr>
## 1 facility_1  airport shuttle
## 2 facility_2  free wifi
## 3 facility_3  garden
## 4 facility_4  breakfast
## 5 facility_5  pool
## 6 facility_6  on-site restaurant
```


readr
www.rstudio.com

Data import

The first step of every data analysis project is to import one or more datasets. The tidyverse provides seven packages for the import of various data formats:

- `readr`: flat files (.csv, .tsv, ...)
- `DBI`: databases (SQLite, MySQL, PostgreSQL, MonetDB, ...)
- `haven`: foreign statistical formats (.sas, .sav, .dta)
- `jsonlite`: json files
- `readxl`: Excel files (.xls, .xlsx)
- `rvest`: websites (.html)
- `xml2`: xml files

Function reference: RStudio's Data import cheat sheet

Data import: `bookings.csv` and `properties.csv`

bookings.csv | properties.csv

```
# library(readr) # readr is a core tidyverse package and hence doesn't need to be loaded separately.
bookings <- read_csv("../data/bookings.csv")
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   booker_id = col_character(),
##   property_id = col_double(),
##   room_nights = col_double(),
##   price_per_night = col_double(),
##   checkin_day = col_character(),
##   for_business = col_logical(),
##   status = col_character(),
##   review_score = col_double()
## )
```

```
head(bookings, 3)
```

```
## # A tibble: 3 x 8
##   booker_id        property_id room_nights price_per_night checkin_day for_business status
##   <chr>                  <dbl>       <dbl>           <dbl> <chr>       <lgl>        <chr>
## 1 215934017ba98c0~        2668           4            91.5 mon         FALSE        cance~
## 2 7f590fd6d318248~        4656           5           107.  tue         FALSE        cance~
## 3 10f0f138e8bb101~        4563           6            87.0 wed         FALSE        stayed
## # ... with 1 more variable: review_score <dbl>
```

Data import: `bookings.csv` and `properties.csv`

bookings.csv | properties.csv

```
properties <- read_csv("../data/properties.csv")
properties
```

```
## # A tibble: 4,178 x 5
##    property_id destination property_type nr_rooms facilities
##          <dbl> <chr>       <chr>            <dbl> <chr>
##  1        2668 Brisbane    Hotel               32 airport shuttle,free wifi,garden,breakf~
##  2        4656 Brisbane    Hotel               39 on-site restaurant,pool,airport shuttle~
##  3        4563 Brisbane    Apartment            9 laundry
##  4        4088 Brisbane    Apartment            9 kitchen,laundry,free wifi
##  5        2188 Brisbane    Apartment            4 parking,kitchen,bbq,free wifi,game cons~
##  6        4171 Brisbane    Apartment            5 kitchen,pool,laundry,parking,free wifi,~
##  7        2907 Brisbane    Hotel               22 airport shuttle,on-site restaurant,brea~
##  8        5141 Brisbane    Hotel               20 breakfast,free wifi,on-site restaurant,~
##  9        1696 Brisbane    Apartment            5 free wifi,laundry,pool,game console,par~
## 10        1901 Brisbane    Apartment           11 free wifi,bbq,laundry,breakfast,pool,pa~
## # ... with 4,168 more rows
```

Comparison with Base R import functions

Base `R` already has functions for loading flat files, e.g. `read.csv()`, `read.delim()`.

Advantages of the Tidyverse implementations include:

- higher speed
- ~~characters are not coerced to factors by default (see `stringsAsFactors` argument)~~
  (This is not the case anymore since `R` version 4.0)
- generates tibbles instead of data frames


TIBBLE
www.rstudio.com

Tibbles

A tibble (class `tbl_df`) is "a modern reimagining" of the data frame.
Advantages over traditional data frames include:

- improved print method that shows...
  - ...only the first 10 rows
  - ...all the columns that fit on screen + names of the remaining ones
  - ...column types
- more consistent subsetting
- less type coercion
- prohibits partial matching

Use `as_tibble()` to convert a data frame to a tibble.

Tibble vs. data frame

Print data.frame | Print tbl_df | Line width | Build function | Rowwise construction: tribble()

```
class(iris)
```

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

```
iris
```

```
##     Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
## 1            5.1         3.5          1.4         0.2     setosa
## 2            4.9         3.0          1.4         0.2     setosa
## 3            4.7         3.2          1.3         0.2     setosa
## 4            4.6         3.1          1.5         0.2     setosa
## 5            5.0         3.6          1.4         0.2     setosa
## 6            5.4         3.9          1.7         0.4     setosa
## 7            4.6         3.4          1.4         0.3     setosa
## 8            5.0         3.4          1.5         0.2     setosa
## 9            4.4         2.9          1.4         0.2     setosa
## 10           4.9         3.1          1.5         0.1     setosa
## 11           5.4         3.7          1.5         0.2     setosa
## 12           4.8         3.4          1.6         0.2     setosa
## 13           4.8         3.0          1.4         0.1     setosa
## 14           4.3         3.0          1.1         0.1     setosa
## 15           5.8         4.0          1.2         0.2     setosa
## 16           5.7         4.4          1.5         0.4     setosa
## 17           5.4         3.9          1.3         0.4     setosa
## 18           5.1         3.5          1.4         0.3     setosa
```

Tibble vs. data frame

Print data.frame | Print tbl_df | Line width | Build function | Rowwise construction: tribble()

```
as_tibble(iris)
```

```
## # A tibble: 150 x 5
##    Sepal.Length Sepal.Width Petal.Length Petal.Width Species
##           <dbl>       <dbl>        <dbl>       <dbl> <fct>
##  1          5.1         3.5          1.4         0.2 setosa
##  2          4.9         3            1.4         0.2 setosa
##  3          4.7         3.2          1.3         0.2 setosa
##  4          4.6         3.1          1.5         0.2 setosa
##  5          5           3.6          1.4         0.2 setosa
##  6          5.4         3.9          1.7         0.4 setosa
##  7          4.6         3.4          1.4         0.3 setosa
##  8          5           3.4          1.5         0.2 setosa
##  9          4.4         2.9          1.4         0.2 setosa
## 10          4.9         3.1          1.5         0.1 setosa
## # ... with 140 more rows
```

Tibble vs. data frame

Print data.frame | Print tbl_df | Line width | Build function | Rowwise construction: tribble()

Tibbles adjust to the available line width!

```
as_tibble(iris)
```

```
## # A tibble: 150 x 5
##    Sepal.Length Sepal.Width Petal.Length
##           <dbl>       <dbl>        <dbl>
##  1          5.1         3.5          1.4
##  2          4.9         3            1.4
##  3          4.7         3.2          1.3
##  4          4.6         3.1          1.5
##  5          5           3.6          1.4
##  6          5.4         3.9          1.7
##  7          4.6         3.4          1.4
##  8          5           3.4          1.5
##  9          4.4         2.9          1.4
## 10          4.9         3.1          1.5
## # ... with 140 more rows, and 2 more variables:
## #   Petal.Width <dbl>, Species <fct>
```

Tibble vs. data frame

Print data.frame | Print tbl_df | Line width | **Build function** | Rowwise construction: tribble()

```
df <- data.frame(
  `bad name` = 1:3, # syntactically invalid name because of SPACE
  x = rep(letters[1:2], length.out = 3)
)
str(df)
```

```
## 'data.frame':    3 obs. of  2 variables:
##  $ bad.name: int  1 2 3
##  $ x       : chr  "a" "b" "a"
```

Tibbles don't coerce character vectors to factors.

```
ti <- tibble(
  `bad name` = 1:3, # no "auto repair" of invalid column name
  x = rep(letters[1:2], length.out = 3)
)
str(ti)
```

```
## tibble [3 x 2] (S3: tbl_df/tbl/data.frame)
##  $ bad name: int [1:3] 1 2 3
##  $ x       : chr [1:3] "a" "b" "a"
```

Tibble vs. data frame

Print data.frame | Print tbl_df | Line width | Build function | **Rowwise construction: tribble()**

Tibbles can also be created in a spreadsheet-like rowwise fashion:

```
tribble(
  ~x, ~y,
  1, "b",
  2, "a"
)
```

```
## # A tibble: 2 x 2
##       x y
##   <dbl> <chr>
## 1     1 b
## 2     2 a
```

Use the tilde operator (~) to signify column names.

Very useful tidyverse packages we did not cover

For an introduction, see the following chapters from
Hadley Wickham and Garrett Grolemund. "R for Data Science". O'Reilly, 2017.

- Strings with stringr
- Factors with forcats
- Dates and Times with lubridate

Session info

```
##  setting  value
##  version  R version 4.0.4 (2021-02-15)
##  os       Windows 10 x64
##  system   x86_64, mingw32
##  ui       RTerm
##  language EN
##  collate  English_United States.1252
##  ctype    English_United States.1252
##  tz       Europe/Berlin
##  date     2021-04-13
```

package	version	date	source
dplyr	1.0.5	2021-03-05	CRAN (R 4.0.4)
forcats	0.5.1	2021-01-27	CRAN (R 4.0.3)
ggplot2	3.3.3	2020-12-30	CRAN (R 4.0.3)
purrr	0.3.4	2020-04-17	CRAN (R 4.0.2)
readr	1.4.0	2020-10-05	CRAN (R 4.0.3)
stringr	1.4.0	2019-02-10	CRAN (R 4.0.2)
tibble	3.1.0	2021-02-25	CRAN (R 4.0.3)
tidyr	1.1.3	2021-03-03	CRAN (R 4.0.4)
tidyverse	1.3.0	2019-11-21	CRAN (R 4.0.2)

Thank you! Questions?

Photo courtesy of Stefan Berger