Data frames and tibbles: tables in R

Introduction to R - Day 1

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Data frames

The built-in data structure for tables in R is a `data frame`.

- vectors in R can't represent a table with data that is connected via rows

> Data frames are one of the **biggest and most important ideas** in R, and one of the things that make R different from other programming languages.
>
> (Wickham, Advanced R)

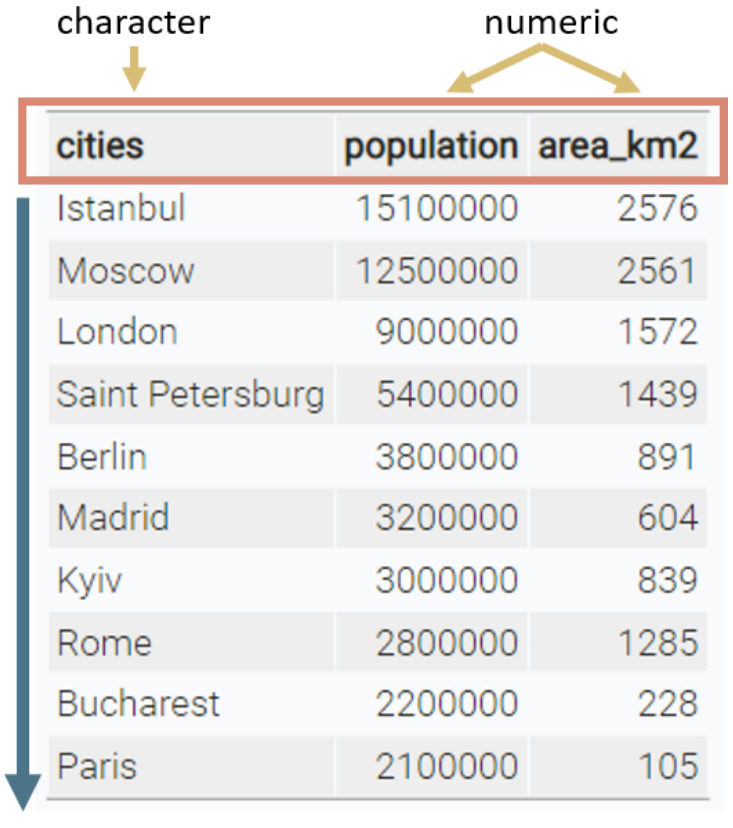
cities	population	area_km2
Istanbul	15100000	2576
Moscow	12500000	2561
London	9000000	1572
Saint Petersburg	5400000	1439
Berlin	3800000	891
Madrid	3200000	604
Kyiv	3000000	839
Rome	2800000	1285
Bucharest	2200000	228
Paris	2100000	105

Data frames

A data frame is a **named list of vectors** of the same length.

Basic properties of a data frame

- every column is a vector
- columns have a header
  - this is the name of the vector in the list
- within one column, all values are of the same data type
- every column has the same length



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Data frames

Data frames are created with the function `data.frame()`:

```
cities <- c(
  "Istanbul", "Moscow", "London",
  "Saint Petersburg", "Berlin","Madrid",
  "Kyiv", "Rome", "Bucharest","Paris")

population <- c(
  15.1e6, 12.5e6, 9e6, 5.4e6, 3.8e6,
  3.2e6, 3e6, 2.8e6, 2.2e6, 2.1e6)

area_km2 <- c(2576, 2561, 1572, 1439,
  891, 604, 839, 1285, 228, 105)
```

```
data.frame(
  cities = cities,
  population = population,
  area_km2 = area_km2
  )
```

```
##                cities population area_km2
## 1            Istanbul   15100000     2576
## 2              Moscow   12500000     2561
## 3              London    9000000     1572
## 4  Saint Petersburg     5400000     1439
## 5              Berlin    3800000      891
## 6              Madrid    3200000      604
## 7                Kyiv    3000000      839
## 8                Rome    2800000     1285
## 9           Bucharest    2200000      228
## 10              Paris    2100000      105
```

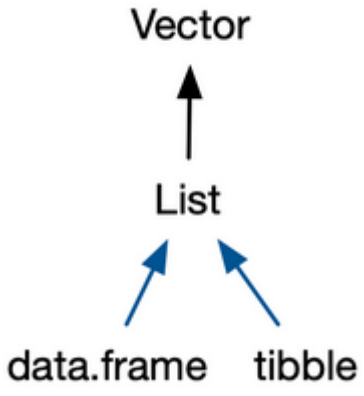
Tibbles

Tibbles are

> a **modern reimagining of the data frame**. Tibbles are designed to be (as much as possible) **drop-in replacements** for data frames.
>
> (Wickham, Advanced R)

Have a look at this book chapter for a full list of the differences between data frames and tibbles and the advantages of using tibbles.

- tibbles have the same basic properties as data frames (named list of vectors)
- everything that you can do with data frames, you can do with tibbles



Tibbles

Tibbles are a available from the `tibble` package.

Before we use tibbles, we need to install the package once using the function `install.packages`:

```
# This has do be once
install.packages("tibble")
```

Then, we need to load and attach the package to our current R session using `library`:

```
# This has to be done every time R restarts
# Put it at the beginning of a script
library(tibble)
```

Tibbles

Create a tibble using the `tibble()` function:

```
library(tibble)

tibble(
  cities = cities,
  population = population,
  area_km2 = area_km2
)
```

```
## # A tibble: 10 x 3
##    cities           population area_km2
##    <chr>                 <dbl>    <dbl>
##  1 Istanbul           15100000     2576
##  2 Moscow             12500000     2561
##  3 London              9000000     1572
##  4 Saint Petersburg    5400000     1439
##  5 Berlin              3800000      891
##  6 Madrid              3200000      604
##  7 Kyiv                3000000      839
##  8 Rome                2800000     1285
##  9 Bucharest           2200000      228
## 10 Paris               2100000      105
```

Note: If you want to use a function from a package you can attach it using `library(package)` or you can use `package::function` to tell R where a function is from (e.g. `tibble::tibble()`). I will sometimes do this to clearly distinguish between base R and package functions.

Exploring tibbles

Look at the structure of an object using `str()`:

```
str(cities_tbl)
```

```
## tibble [10 x 3] (S3: tbl_df/tbl/data.frame)
##  $ cities    : chr [1:10] "Istanbul" "Moscow" "London" "Saint Petersburg" ...
##  $ population: num [1:10] 15100000 12500000 9000000 5400000 3800000 3200000 3000000 2800000
2200000 2100000
##  $ area_km2  : num [1:10] 2576 2561 1572 1439 891 ...
```

- This function shows you:
  - data type of object (`tbl_df/tbl/data.frame`)
  - extent of the data (10 rows times 3 columns)
  - column names and data types
- This function works for every R object and is very useful if code doesn't work and you don't know why

Exploring tibbles

How many rows?

```
nrow(cities_tbl)
```

```
## [1] 10
```

How many columns?

```
ncol(cities_tbl)
```

```
## [1] 3
```

What are the column headers?

```
names(cities_tbl)
```

```
## [1] "cities"     "population" "area_km2"
```

Exploring tibbles

Look at the entire table in a separate window with `view()`:

```
tibble::view(cities_tbl)
```

Get a quick summary of all columns:

```
summary(cities_tbl)
```

```
##     cities             population          area_km2
##  Length:10          Min.   : 2100000   Min.   : 105.0
##  Class :character   1st Qu.: 2850000   1st Qu.: 662.8
##  Mode  :character   Median : 3500000   Median :1088.0
##                     Mean   : 5910000   Mean   :1210.0
##                     3rd Qu.: 8100000   3rd Qu.:1538.8
##                     Max.   :15100000   Max.   :2576.0
```

Indexing tibbles

Indexing tibbles works similar to indexing vectors but with two dimensions instead of 1:

tibble [row_index, col_index or col_name]

- Missing row_index or col_index means *all rows* or *all columns* respectively.
- Indexing a tibble using `[]` always returns another tibble.

Indexing tibbles

```
# First row and first column
cities_tbl[1, 1]
```

```
## # A tibble: 1 x 1
##   cities
##   <chr>
## 1 Istanbul
```

This is the same as

```
cities_tbl[1, "cities"]
```

Indexing tibbles: rows

```
# rows 1 & 5, all columns:
cities_tbl[c(1, 5), ]
```

Indexing tibbles: columns

```
# All rows, first 2 columns
cities_tbl[ ,1:2]
# same as
cities_tbl[ ,c("cities", "population")]
```

```
## # A tibble: 10 x 2
##   cities   population
##   <chr>         <dbl>
## 1 Istanbul   15100000
## 2 Moscow     12500000
## 3 London      9000000
## # ... with 7 more rows
```

Indexing tibbles: columns

Indexing columns by name is usually preferred to indexing by position

```
cities_tbl[ ,1:2] # okay
cities_tbl[ ,c("cities", "population")] # better
```

Why?

- code is much easier to read
- code is more robust against
    - changes in column order
    - mistakes in the code (e.g. typos)

```
cities_tbl[ ,c(1,3)] # 3 instead of 2 -> wrong but no error
cities_tbl[ ,c("cities", "popluation")] # typo -> wrong and error
```

General rule: Good code produces errors when something unintended or wrong happens

Tibbles: Select columns with `$`

Select an entire column from a tibble using `$` (this returns a vector instead of a tibble):

```
cities_tbl$cities
```

```
##  [1] "Istanbul"        "Moscow"          "London"          "Saint Petersburg"
##  [5] "Berlin"          "Madrid"          "Kyiv"            "Rome"
##  [9] "Bucharest"       "Paris"
```

Adding new columns

New columns can be added as vectors using the `$` operator. The vectors need to have the same length as the tibble has rows.

```
# add a country column
cities_tbl$country <- c(
  "Turkey", "Russia", "UK", "Russia", "Germany", "Spain",
  "Ukraine", "Italy", "Romania", "France"
)
```

```
## # A tibble: 10 x 4
##    cities           population area_km2 country
##    <chr>                 <dbl>    <dbl> <chr>
##  1 Istanbul           15100000     2576 Turkey
##  2 Moscow             12500000     2561 Russia
##  3 London              9000000     1572 UK
##  4 Saint Petersburg    5400000     1439 Russia
##  5 Berlin              3800000      891 Germany
##  6 Madrid              3200000      604 Spain
##  7 Kyiv                3000000      839 Ukraine
##  8 Rome                2800000     1285 Italy
##  9 Bucharest           2200000      228 Romania
## 10 Paris               2100000      105 France
```

Adding new columns

Adding a new column **based on other columns**:

```
cities_tbl$density <- cities_tbl$population / cities_tbl$area_km2
```

```
## # A tibble: 10 x 5
##    cities           population area_km2 country density
##    <chr>                 <dbl>    <dbl> <chr>     <dbl>
##  1 Istanbul           15100000     2576 Turkey    5862.
##  2 Moscow             12500000     2561 Russia    4881.
##  3 London              9000000     1572 UK        5725.
##  4 Saint Petersburg    5400000     1439 Russia    3753.
##  5 Berlin              3800000      891 Germany   4265.
##  6 Madrid              3200000      604 Spain     5298.
##  7 Kyiv                3000000      839 Ukraine   3576.
##  8 Rome                2800000     1285 Italy     2179.
##  9 Bucharest           2200000      228 Romania   9649.
## 10 Paris               2100000      105 France   20000
```

Adding new columns

Adding new columns **based on a condition**:

```
cities_tbl$category <- ifelse(cities_tbl$population > 5e6, # test
                              "very large", # yes
                              "large") # no
```

```
## # A tibble: 10 x 6
##    cities           population area_km2 country density category
##    <chr>                 <dbl>    <dbl> <chr>     <dbl> <chr>
##  1 Istanbul           15100000     2576 Turkey    5862. very large
##  2 Moscow             12500000     2561 Russia    4881. very large
##  3 London              9000000     1572 UK        5725. very large
##  4 Saint Petersburg    5400000     1439 Russia    3753. very large
##  5 Berlin              3800000      891 Germany   4265. large
##  6 Madrid              3200000      604 Spain     5298. large
##  7 Kyiv                3000000      839 Ukraine   3576. large
##  8 Rome                2800000     1285 Italy     2179. large
##  9 Bucharest           2200000      228 Romania   9649. large
## 10 Paris               2100000      105 France   20000  large
```

Logical indexing

As with vectors, we can use us logical tests to **select rows** from a tibble. The basic structure is:

tibble [logical indexing vector of length nrow(tibble), cols to select]

Only rows that match `TRUE` in the indexing vector get selected.

```
# select all rows for which the population exceeds 15 M
cities_tbl[ cities_tbl$population > 15e6, ]
```

```
## # A tibble: 1 x 6
##   cities   population area_km2 country density category
##   <chr>         <dbl>    <dbl> <chr>     <dbl> <chr>
## 1 Istanbul   15100000     2576 Turkey    5862. very large
```

Logical indexing

What is happening in detail?

```
cities_tbl[cities_tbl$population > 15e6, ]
```

```
cities_tbl$population # vector with population
```

```
##  [1] 15100000 12500000  9000000  5400000  3800000  3200000  3000000  2800000  2200000
## [10]  2100000
```

```
cities_tbl$population > 15e6 # logical vector after relational test
```

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

So we actually subset the tibble like this:

```
cities_tbl[c(TRUE, FALSE, FALSE, FALSE, FALSE,
             FALSE, FALSE, FALSE, FALSE, FALSE), ]
```

Logical indexing

Some more examples:

```
cities_tbl[cities_tbl$cities != "Istanbul" & cities_tbl$area_km2 > 1000, ]
```

```
## # A tibble: 4 x 6
##   cities           population area_km2 country density category
##   <chr>                 <dbl>    <dbl> <chr>     <dbl> <chr>
## 1 Moscow              12500000     2561 Russia    4881. very large
## 2 London               9000000     1572 UK        5725. very large
## 3 Saint Petersburg     5400000     1439 Russia    3753. very large
## 4 Rome                 2800000     1285 Italy     2179. large
```

Logical indexing

Some more examples:

```
cities_tbl[cities_tbl$cities != "Istanbul" & cities_tbl$area_km2 > 1000, ]
cities_tbl[cities_tbl$cities %in% c("Istanbul", "Madrid", "Paris"), ]
```

```
## # A tibble: 3 x 6
##   cities   population area_km2 country density category
##   <chr>         <dbl>    <dbl> <chr>     <dbl> <chr>
## 1 Istanbul   15100000     2576 Turkey    5862. very large
## 2 Madrid      3200000      604 Spain     5298. large
## 3 Paris       2100000      105 France   20000  large
```

Changing values in tibbles

As with vectors, we can use indexing to change specific values in the tibble.

Idea:

1. Index row and column or the values you want to change
2. Overwrite them using the assignment operator `<-`

For example, the population of Madrid changed but we don't know the new population.

We can replace the population value from Madrid with NA:

```
cities_tbl[cities_tbl$cities == "Madrid", "population"] <- NA
```

```
cities_tbl[6, ] # row 6 is Madrid
```

```
## # A tibble: 1 x 6
##   cities population area_km2 country density category
##   <chr>       <dbl>    <dbl> <chr>     <dbl> <chr>
## 1 Madrid         NA      604 Spain     5298. large
```

Now you

Task 3: Tibbles

Find the task description here

Summary I

data frames and tibbles

- can be used to represent tables in R
- are pretty similar, however tibbles are slightly conventient and modern
- are named lists of vectors of the same length
  - every column is a vector
  - columns have a header which is the name of the vector in the list
  - within one column, values are of same data type
  - every column has the same length

tibbles

- to use tibbles, install the package once with `install.packages("tibble")`
- put `library(tibble)` at the beginning of your script to load package

Summary II

Creating tibbles and data frames

```
# data frame
data.frame(
  a = 1:3,
  b = c("a", "b", "c"),
  c = c(TRUE, FALSE, FALSE)
)
# tibble
tibble(
  a = 1:3,
  b = c("a", "b", "c"),
  c = c(TRUE, FALSE, FALSE)
)
# convert data frame to tibble
as_tibble(df)
```

Summary III

Looking at tibble structure

```
# structure of tibble and data types of columns
str(tbl)
# number of rows
nrow(tbl)
# number of columns
ncol(tbl)
# column headers
names(tbl)
# look at the data in a new window
tibble::view(tbl)
# summary of values from each column
summary(tbl)
```

Summary IV

Indexing tibbles and selecting columns

Return result as tibble:

```
# rows and columns by position
tbl[1:3, c(1, 3)]
tbl[1:3, ] # all columns
tbl[, 3] # column 3, all rows
tbl[3] # same as above

# columns by name
tbl[, c("colA", "colB")]
tbl[c("colA", "colB")]
```

Return result as vector:

```
tbl$colA # select colA
```

Summary V

Logical indexing to select rows

- Index tibbles with a vector of the same length
- Use
  - logical and relational operators
  - `%in%`

```
tbl[tbl$colA == 5, ] # only rows where colA is 5 (all columns)
tbl[tbl$colA >= 10, ]
tbl[tbl$colB %in% c("hello", "cat", "apple"), ] # only rows where colB is "hello", "cat" or
"apple"
tbl[tbl$colB == "hello" | tbl$colB == "cat" | tbl$colB == "apple", ] # same as above
```

Logical indexing to select columns

```
select_cols <- c("colA", "colB", "colC")
tbl[names(tbl) %in% select_cols]
tbl[c("colA", "colB", "colC")] # same as above
```

Summary VI

Add and remove columns

```
tbl$new_col <- c(1, 2, 3)
tbl$new_col <- tbl$colA / tbl$colB # new column based on other columns
tbl$new_col <- NULL # remove new_col
```