

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

The diagram shows a table representing a data frame. Above the table, the word 'character' has a yellow arrow pointing down to the 'cities' column. The word 'numeric' has two yellow arrows pointing down to the 'population' and 'area_km2' columns. A red rectangular box highlights the header row. A blue arrow on the left side points downwards, indicating the rows of the data.

| 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

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 reimaging 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 available from the `tibble` package.

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

```
# This has to be done 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" "Berlin"
## [6] "Madrid"        "Kyiv"           "Rome"           "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 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 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 convenient 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
```