TRES Tidyverse Tutorial

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Contents

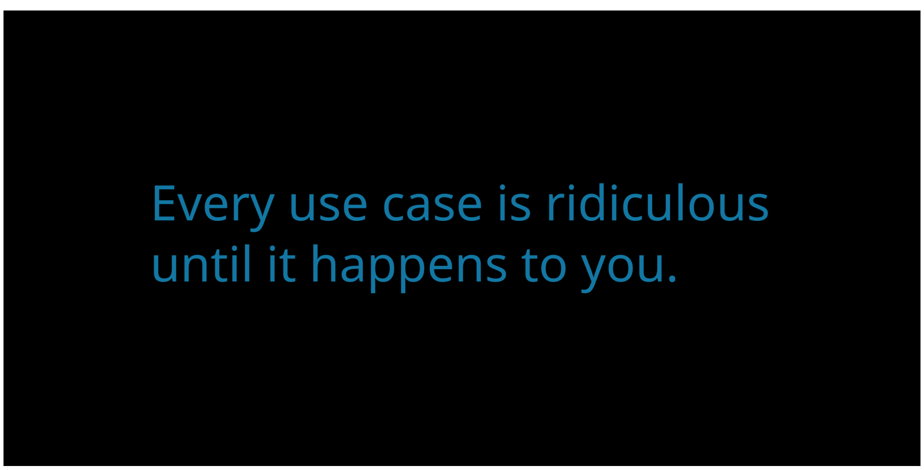
Outline

This is the readable version of the TRES tidyverse tutorial, with these sections:

1. Reading data and string manipulation with readr, stringr, and glue
2. The new data frames with tibble and wrangling them into shape with tidyr
3. Manipulating data with dplyr
4. Iteration and functional programming with purrr
5. Plotting with ggplot2

Chapter 1

Reading files and string manipulation




```r
library(readr)
library(stringr)
library(glue)
```

1.1 Section on `readr`

1.2 String manipulation with `stringr`

`stringr` is the tidyverse package for string manipulation, and exists in an interesting symbiosis with the `stringi` package. For the most part, stringr is a wrapper around stringi, and is almost always more than sufficient for day-to-day needs.

`stringr` functions begin with `str_`.

1.2.1 Putting strings together

Concatenate two strings with `str_c`, and duplicate strings with `str_dup`. Flatten a list or vector of strings using `str_flatten`.

```
# str_c works like paste(), choose a separator
str_c("this string", "this other string", sep = "_")
```

```
## [1] "this string_this other string"
```

```
# str_dup works like rep
str_dup("this string", times = 3)
```

```
## [1] "this stringthis stringthis string"
```

```
# str_flatten works on lists and vectors
str_flatten(string = as.list(letters), collapse = "_")
```

```
## [1] "a_b_c_d_e_f_g_h_i_j_k_l_m_n_o_p_q_r_s_t_u_v_w_x_y_z"
```

```
str_flatten(string = letters, collapse = "-")
```

```
## [1] "a-b-c-d-e-f-g-h-i-j-k-l-m-n-o-p-q-r-s-t-u-v-w-x-y-z"
```

`str_flatten` is especially useful when displaying the type of an object that returns a list when `class` is called on it.

```
# get the class of a tibble and display it as a single string
class_tibble = class(tibble::tibble(a = 1))
str_flatten(string = class_tibble, collapse = ", ")
```

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

1.2.2 Detecting strings

Count the frequency of a pattern in a string with `str_count`. Returns an inteegr. Detect whether a pattern exists in a string with `str_detect`. Returns a logical and can be used as a predicate.

Both are vectorised, i.e, automatically applied to a vector of arguments.

```
# there should be 5 a-s here
str_count(string = "ababababa", pattern = "a")
```

```
## [1] 5
```

```
# vectorise over the input string
# should return a vector of length 2, with integers 5 and 3
str_count(string = c("abababbaba", "banana"), pattern = "a")
```

```
## [1] 5 3
```

```
# vectorise over the pattern to count both a-s and b-s
str_count(string = "ababababa", pattern = c("a", "b"))
```

```
## [1] 5 4
```

Vectorising over both string and pattern works as expected.

```
# vectorise over both string and pattern
# counts a-s in first input, and b-s in the second
str_count(string = c("ababababa", "banana"),
          pattern = c("a", "b"))
```

```
## [1] 5 1
```

```
# provide a longer pattern vector to search for both a-s
# and b-s in both inputs
str_count(string = c("ababababa", "banana"),
         pattern = c("a", "b",
                     "b", "a"))
```

```
## [1] 5 1 4 3
```

`str_locate` locates the search pattern in a string, and returns the start and end as a two column matrix.

```
# the behaviour of both str_locate and str_locate_all is
# to find the first match by default
str_locate(string = "banana", pattern = "ana")
```

```
##      start end
## [1,]     2   4
```

```
# str_detect detects a sequence in a string
str_detect(string = "Bananageddon is coming!",
           pattern = "na")
```

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

```
# str_detect is also vectorised and returns a two-element logical vector
str_detect(string = "Bananageddon is coming!",
           pattern = c("na", "don"))
```

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

```
# use any or all to convert a multi-element logical to a single logical
# here we ask if either of the patterns is detected
any(str_detect(string = "Bananageddon is coming!",
               pattern = c("na", "don")))
```

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

Detect whether a string starts or ends with a pattern. Also vectorised. Both have a `negate` argument, which returns the negative, i.e., returns `FALSE` if the search pattern is detected.

```
# taken straight from the examples, because they suffice
fruit <- c("apple", "banana", "pear", "pineapple")
# str_detect looks at the first character
str_starts(fruit, "p")
```

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

```
# str_ends looks at the last character
str_ends(fruit, "e")
```

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

```
# an example of negate = TRUE
str_ends(fruit, "e", negate = TRUE)
```

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

`str_subset` [WHICH IS NOT RELATED TO `str_sub`] helps with subsetting a character vector based on a `str_detect` predicate. In the example, all elements containing "banana" are subset.

`str_which` has the same logic except that it returns the vector position and not the elements.

```
# should return a subset vector containing the first two elements
str_subset(c("banana",
             "bananageddon is coming",
             "applegeddon is not real"),
           pattern = "banana")
```

```
## [1] "banana"                 "bananageddon is coming"
```

```
# returns an integer vector
str_which(c("banana",
             "bananageddon is coming",
             "applegeddon is not real"),
           pattern = "banana")
```

```
## [1] 1 2
```

1.2.3 Matching strings

`str_match` returns all positive matches of the patttern in the string. The return type is a `list`, with one element per search pattern.

A simple case is shown below where the search pattern is the phrase "banana".

```
str_match(string = c("banana",
                     "bananageddon",
                     "bananas are bad"),
          pattern = "banana")
```

```
##      [,1]
## [1,] "banana"
## [2,] "banana"
## [3,] "banana"
```

The search pattern can be extended to look for multiple subsets of the search pattern. Consider searching for dates and times.

Here, the search pattern is a `regex` pattern that looks for a set of four digits (`\\d{4}`) and a month name (`\\w+`) seperated by a hyphen. There's much more to be explored in dealing with dates and times in `[lubridate](https://lubridate.tidyverse.org/)`, another `tidyverse` package.

The return type is a list, each element is a character matrix where the first column is the string subset matching the full search pattern, and then as many columns as there are parts to the search pattern. The parts of interest in the search pattern are indicated by wrapping them in parentheses. For example, in the case below, wrapping `[-.]` in parentheses will turn it into a distinct part of the search pattern.

```
# first with [-.] treated simply as a separator
str_match(string = c("1970-somemonth-01",
                     "1990-anothermonth-01",
                     "2010-thismonth-01"),
          pattern = "(\\d{4})[-.](\\w+)")
```

```
##      [,1]                 [,2]   [,3]
## [1,] "1970-somemonth"    "1970" "somemonth"
## [2,] "1990-anothermonth" "1990" "anothermonth"
## [3,] "2010-thismonth"    "2010" "thismonth"
```

```
# then with [-.] actively searched for
str_match(string = c("1970-somemonth-01",
                     "1990-anothermonth-01",
                     "2010-thismonth-01"),
          pattern = "(\\d{4})([-.])(\\w+)")
```

```
##      [,1]                 [,2]   [,3] [,4]
## [1,] "1970-somemonth"    "1970" "-"  "somemonth"
## [2,] "1990-anothermonth" "1990" "-"  "anothermonth"
## [3,] "2010-thismonth"    "2010" "-"  "thismonth"
```

Multiple possible matches are dealt with using `str_match_all`. An example case is uncertainty in date-time in raw data, where the date has been entered as `1970-somemonth-01 or 1970/anothermonth/01`.

The return type is a list, with one element per input string. Each element is a character matrix, where each row is one possible match, and each column after the first (the full match) corresponds to the parts of the search pattern.

```
# first with a single date entry
str_match_all(string = c("1970-somemonth-01 or maybe 1990/anothermonth/01"),
          pattern = "(\\d{4})[\\-\\/]([a-z]+)")
```

```
## [[1]]
##      [,1]                 [,2]   [,3]
## [1,] "1970-somemonth"    "1970" "somemonth"
## [2,] "1990/anothermonth" "1990" "anothermonth"
```

```
# then with multiple date entries
str_match_all(string = c("1970-somemonth-01 or maybe 1990/anothermonth/01",
                         "1990-somemonth-01 or maybe 2001/anothermonth/01"),
          pattern = "(\\d{4})[\\-\\/]([a-z]+)")
```

```
## [[1]]
##      [,1]                 [,2]   [,3]
## [1,] "1970-somemonth"    "1970" "somemonth"
## [2,] "1990/anothermonth" "1990" "anothermonth"
##
## [[2]]
##      [,1]                 [,2]   [,3]
## [1,] "1990-somemonth"    "1990" "somemonth"
## [2,] "2001/anothermonth" "2001" "anothermonth"
```

1.2.4 Simpler pattern extraction

The full functionality of `str_match_*` can be boiled down to the most common use case, extracting one or more full matches of the search pattern using `str_extract` and `str_extract_all` respectively.

`str_extract` returns a character vector with the same length as the input string vector, while `str_extract_all` returns a list, with a character vector whose elements are the matches.

```
# extracting the first full match using str_extract
str_extract(string = c("1970-somemonth-01 or maybe 1990/anothermonth/01",
```

```
                      "1990-somemonth-01 or maybe 2001/anothermonth/01"),
          pattern = "(\\d{4})[\\-\\/]([a-z]+)")
```

```
## [1] "1970-somemonth" "1990-somemonth"
```

```
# extracting all full matches using str_extract all
str_extract_all(string = c("1970-somemonth-01 or maybe 1990/anothermonth/01",
                      "1990-somemonth-01 or maybe 2001/anothermonth/01"),
          pattern = "(\\d{4})[\\-\\/]([a-z]+)")
```

```
## [[1]]
## [1] "1970-somemonth"    "1990/anothermonth"
##
## [[2]]
## [1] "1990-somemonth"    "2001/anothermonth"
```

1.2.5 Breaking strings apart

`str_split`, str__sub, In the above date-time example, when reading filenames from a path, or when working sequences separated by a known pattern generally, `str_split` can help separate elements of interest.

The return type is a list similar to `str_match`.

```
# split on either a hyphen or a forward slash
str_split(string = c("1970-somemonth-01",
            "1990/anothermonth/01"),
          pattern = "[\\-\\/]")
```

```
## [[1]]
## [1] "1970"      "somemonth" "01"
##
## [[2]]
## [1] "1990"         "anothermonth" "01"
```

This can be useful in recovering simulation parameters from a filename, but may require some knowledge of `regex`.

```
# assume a simulation output file
filename = "sim_param1_0.01_param2_0.05_param3_0.01.ext"

# not quite there
str_split(filename, pattern = "_")
```

```
## [[1]]
## [1] "sim"      "param1"   "0.01"     "param2"   "0.05"     "param3"   "0.01.ext"
```

```
# not really
str_split(filename,
          pattern = "sim_")
```

```
## [[1]]
## [1] ""
## [2] "param1_0.01_param2_0.05_param3_0.01.ext"
```

```r
# getting there but still needs work
str_split(filename,
          pattern = "(sim_)|_*param\\d{1}_|(.ext)")
```

```
## [[1]]
## [1] ""     ""     "0.01" "0.05" "0.01" ""
```

`str_split_fixed` split the string into as many pieces as specified, and can be especially useful dealing with filepaths.

```r
# split on either a hyphen or a forward slash
str_split_fixed(string = "dir_level_1/dir_level_2/file.ext",
          pattern = "/",
          n = 2)
```

```
##      [,1]          [,2]
## [1,] "dir_level_1" "dir_level_2/file.ext"
```

1.2.6 Replacing string elements

`str_replace` is intended to replace the search pattern, and can be co-opted into the task of recovering simulation parameters or other data from regularly named files. `str_replace_all` works the same way but replaces all matches of the search pattern.

```r
# replace all unwanted characters from this hypothetical filename with spaces
filename = "sim_param1_0.01_param2_0.05_param3_0.01.ext"
str_replace_all(filename,
            pattern = "(sim_)|_*param\\d{1}_|(.ext)",
            replacement = " ")
```

```
## [1] "  0.01 0.05 0.01 "
```

`str_remove` is a wrapper around `str_replace` where the replacement is set to `""`. This is not covered here.

Having replaced unwanted characters in the filename with spaces, `str_trim` offers a way to remove leading and trailing whitespaces.

```r
# trim whitespaces from this filename after replacing unwanted text
filename = "sim_param1_0.01_param2_0.05_param3_0.01.ext"
filename_with_spaces = str_replace_all(filename,
                                       pattern = "(sim_)|_*param\\d{1}_|(.ext)",
                                       replacement = " ")
filename_without_spaces = str_trim(filename_with_spaces)
filename_without_spaces
```

```
## [1] "0.01 0.05 0.01"
```

```r
# the result can be split on whitespaces to return useful data
str_split(filename_without_spaces, " ")
```

```
## [[1]]
## [1] "0.01" "0.05" "0.01"
```

1.2.7 Subsetting within strings

When strings are highly regular, useful data can be extracted from a string using `str_sub`. In the date-time example, the year is always represented by the first four characters.

```r
# get the year as characters 1 - 4
str_sub(string = c("1970-somemonth-01",
                   "1990-anothermonth-01",
                   "2010-thismonth-01"),
        start = 1, end = 4)
```

```
## [1] "1970" "1990" "2010"
```

Similarly, it's possible to extract the last few characters using negative indices.

```r
# get the day as characters -2 to -1
str_sub(string = c("1970-somemonth-01",
                   "1990-anothermonth-21",
                   "2010-thismonth-31"),
        start = -2, end = -1)
```

```
## [1] "01" "21" "31"
```

Finally, it's also possible to replace characters within a string based on the position. This requires using the assignment operator `<-`.

```r
# replace all days in these dates to 01
date_times = c("1970-somemonth-25",
               "1990-anothermonth-21",
               "2010-thismonth-31")

# a strictly necessary use of the assignment operator
str_sub(date_times,
        start = -2, end = -1) <- "01"

date_times
```

```
## [1] "1970-somemonth-01"    "1990-anothermonth-01" "2010-thismonth-01"
```

1.2.8 Padding and truncating strings

Strings included in filenames or plots are often of unequal lengths, especially when they represent numbers. `str_pad` can pad strings with suitable characters to maintain equal length filenames, with which it is easier to work.

```
# pad so all values have three digits
str_pad(string = c("1", "10", "100"),
        width = 3,
        side = "left",
        pad = "0")
```

```
## [1] "001" "010" "100"
```

Strings can also be truncated if they are too long.

```
str_trunc(string = c("bananas are great and wonderful
                     and more stuff about bananas and
                     it really goes on about bananas"),
          width = 27,
          side = "right", ellipsis = "etc. etc.")
```

```
## [1] "bananas are great etc. etc."
```

1.2.9 Stringr aspects not covered here

Some `stringr` functions are not covered here. These include:
- `str_wrap` (of dubious use),
- `str_interp`, `str_glue*` (better to use `glue`; see below),
- `str_sort`, `str_order` (used in sorting a character vector),
- `str_to_case*` (case conversion), and
- `str_view*` (a graphical view of search pattern matches).

`stringi`, of which `stringr` is a wrapper, offers a lot more flexibility and control.

1.3 String interpolation with `glue`

The idea behind string interpolation is to procedurally generate new complex strings from pre-existing data.

`glue` is as simple as the example shown.

```
# print that each car name is a car model
cars = rownames(head(mtcars))
glue('The {cars} is a car model')
```

```
## The Mazda RX4 is a car model
## The Mazda RX4 Wag is a car model
## The Datsun 710 is a car model
## The Hornet 4 Drive is a car model
## The Hornet Sportabout is a car model
## The Valiant is a car model
```

This creates and prints a vector of car names stating each is a car model.

The related `glue_data` is even more useful in printing from a dataframe. In this example, it can quickly generate command line arguments or filenames.

```r
# use dataframes for now
parameter_combinations = data.frame(param1 = letters[1:5],
                                    param2 = 1:5)

# for command line arguments or to start multiple job scripts on the cluster
glue_data(parameter_combinations,
          'simulation-name {param1} {param2}')
```

```
## simulation-name a 1
## simulation-name b 2
## simulation-name c 3
## simulation-name d 4
## simulation-name e 5
```

```r
# for filenames
glue_data(parameter_combinations,
          'sim_data_param1_{param1}_param2_{param2}.ext')
```

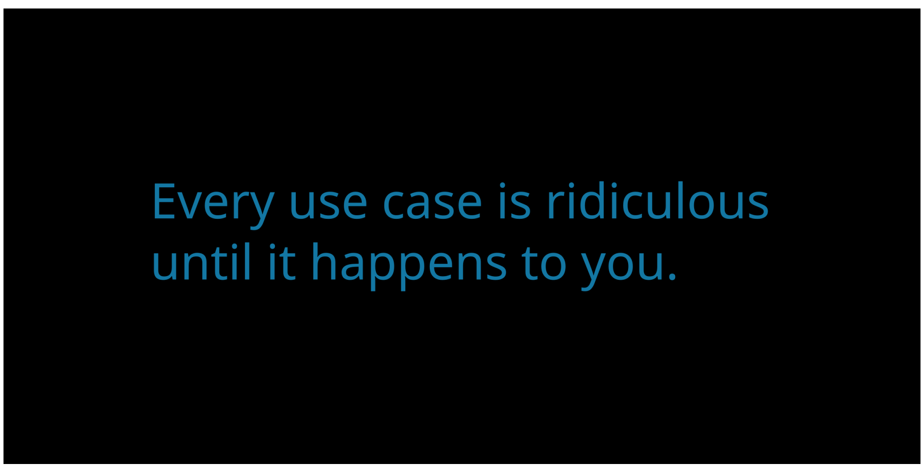
```
## sim_data_param1_a_param2_1.ext
## sim_data_param1_b_param2_2.ext
## sim_data_param1_c_param2_3.ext
## sim_data_param1_d_param2_4.ext
## sim_data_param1_e_param2_5.ext
```

Finally, the convenient `glue_sql` and `glue_data_sql` are used to safely write SQL queries where variables from data are appropriately quoted. This is not covered here, but it is good to know it exists.

`glue` has some more functions — `glue_safe`, `glue_collapse`, and `glue_col`, but these are infrequently used. Their functionality can be found on the `glue` github page.

Chapter 2

Working with lists and iteration




```r
# load the tidyverse
library(tidyverse)
```

2.1 Basic iteration with `map`

Iteration in base `R` is commonly done with `for` and `while` loops. There is no readymade alternative to `while` loops in the tidyverse. However, the functionality of `for` loops is spread over the `map` family of functions.

`purrr` functions are *functionals*, i.e., functions that take another function as an argument. The closest equivalent in `R` is the `*apply` family of functions: `apply`, `lapply`, `vapply` and so on.

A good reason to use `purrr` functions instead of base `R` functions is their consistent and clear naming, which always indicates how they should be used. This is explained in the examples below.

These reasons, as well as how `map` is different from `for` and `lapply` are best explained in the Advanced R book.

2.1.1 `map` basic use

`map` works on any list-like object, which includes vectors, and always returns a list. `map` takes two arguments, the object on which to operate, and the function to apply to each element.

```
# get the square root of each integer 1 - 10
some_numbers = 1:10
map(some_numbers, sqrt)
```

```
## [[1]]
## [1] 1
##
## [[2]]
## [1] 1.414214
##
## [[3]]
## [1] 1.732051
##
## [[4]]
## [1] 2
##
## [[5]]
## [1] 2.236068
##
## [[6]]
## [1] 2.44949
##
## [[7]]
## [1] 2.645751
##
## [[8]]
## [1] 2.828427
##
## [[9]]
## [1] 3
##
## [[10]]
```

```
## [1] 3.162278
```

2.1.2 map variants returning vectors

Though `map` always returns a list, it has variants named `map_*` where the suffix indicates the return type. `map_chr`, `map_dbl`, `map_int`, and `map_lgl` return character, double (numeric), integer, and logical vectors.

```r
# use map_dbl to get a vector of square roots
some_numbers = 1:10
map_dbl(some_numbers, sqrt)
```

```
##  [1] 1.000000 1.414214 1.732051 2.000000 2.236068 2.449490 2.645751 2.828427
##  [9] 3.000000 3.162278
```

```r
# map_chr will convert the output to a character
map_chr(some_numbers, sqrt)
```

```
##  [1] "1.000000" "1.414214" "1.732051" "2.000000" "2.236068" "2.449490"
##  [7] "2.645751" "2.828427" "3.000000" "3.162278"
```

```r
# map_int will NOT round the output to an integer

# map_lgl returns TRUE/FALSE values
some_numbers = c(NA, 1:3, NA, NaN, Inf, -Inf)
map_lgl(some_numbers, is.na)
```

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

Integrating map and tidyr::nest

The example show how each map variant can be used. This integrates `tidyr::nest` with `map`, and the two are especially complementary.

```r
# nest mtcars into a list of dataframes based on number of cylinders
some_data = as_tibble(mtcars, rownames = "car_name") %>%
  group_by(cyl) %>%
  nest()

# get the number of rows per dataframe
# the mean mileage
# and the first car
some_data = some_data %>%
  mutate(n_rows = map_int(data, nrow),
         mean_mpg = map_dbl(data, ~mean(.$mpg)),
         first_car = map_chr(data, ~first(.$car_name)))
```

```r
some_data
```

```
## # A tibble: 3 x 5
## # Groups:   cyl [3]
##     cyl data               n_rows mean_mpg first_car
##   <dbl> <list>              <int>    <dbl> <chr>
## 1     6 <tibble [7 x 11]>       7     19.7 Mazda RX4
## 2     4 <tibble [11 x 11]>     11     26.7 Datsun 710
## 3     8 <tibble [14 x 11]>     14     15.1 Hornet Sportabout
```

`map` accepts multiple functions that are applied in sequence to the input list-like object, but this is confusing to the reader and ill advised.

2.1.3 `map` variants returning dataframes

`map_df` returns data frames, and by default binds dataframes by rows, while `map_dfr` does this explicitly, and `map_dfc` does returns a dataframe bound by column.

```r
# split mtcars into 3 dataframes, one per cylinder number
some_list = split(mtcars, mtcars$cyl)

# get the first two rows of each dataframe
map_df(some_list, head, n = 2)
```

```
##    mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1 22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## 2 24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## 3 21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## 4 21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## 5 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## 6 14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
```

`map` accepts arguments to the function being mapped, such as in the example above, where `head()` accepts the argument `n = 2`.

`map_dfr` behaves the same as `map_df`.

```r
# the same as above but with a pipe
some_list %>%
  map_dfr(head, n = 2)
```

```
##    mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## 1 22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## 2 24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## 3 21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## 4 21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## 5 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
```

```
## 6 14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
```

`map_dfc` binds the resulting 3 data frames of two rows each by column, and automatically repairs the column names, adding a suffix to each duplicate.

```
some_list %>%
  map_dfc(head, n = 2)
```

```
##    mpg cyl  disp hp drat   wt  qsec vs am gear carb mpg1 cyl1 disp1 hp1 drat1
## 1 22.8   4 108.0 93 3.85 2.32 18.61  1  1    4    1   21    6   160 110   3.9
## 2 24.4   4 146.7 62 3.69 3.19 20.00  1  0    4    2   21    6   160 110   3.9
##     wt1 qsec1 vs1 am1 gear1 carb1 mpg2 cyl2 disp2 hp2 drat2  wt2 qsec2 vs2 am2
## 1 2.620 16.46   0   1     4     4 18.7    8   360 175  3.15 3.44 17.02   0   0
## 2 2.875 17.02   0   1     4     4 14.3    8   360 245  3.21 3.57 15.84   0   0
##   gear2 carb2
## 1     3     2
## 2     3     4
```

2.1.4 Selective mapping

- `map_at` and `map_if`

2.2 More `map` variants

2.2.1 `map2`

`imap` here

2.2.2 `pmap`

2.2.3 `walk`

`walk2` and `pwalk`

2.3 Modification in place

`modify`

2.4 Working with lists

2.4.1 Filtering lists

2.4.2 Summarising lists

2.4.3 Reduction and accumulation

2.4.4 Miscellaneous operation

Chapter 3

Data manipulation with `dplyr`

```r
# load the tidyverse
library(tidyverse)
```