

# Functional programming & purrr

Lecture 08

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# Functional Programming

# Functions as objects

We have mentioned in passing that in R functions are treated as 1st class objects (like vectors), meaning they can be assigned names, stored in lists, etc.

```
1 f = function(x) {  
2   x*x  
3 }  
4  
5 f(2)
```

```
[1] 4
```

```
1 g = f  
2  
3 g(2)
```

```
[1] 4
```

```
1 l[1](3)
```

```
Error in eval(expr, envir, enclos): attempt to apply non-function
```

```
1 l = list(f = f, g = g)  
2  
3 l$f(3)
```

```
[1] 9
```

```
1 l[[2]](4)
```

```
[1] 16
```

# Functions as arguments

We can pass in functions as arguments to other functions,

```
1 do_calc = function(v, func) {  
2   func(v)  
3 }
```

```
1 do_calc(1:3, sum)
```

```
[1] 6
```

```
1 do_calc(1:3, mean)
```

```
[1] 2
```

```
1 do_calc(1:3, sd)
```

```
[1] 1
```

# Anonymous functions

These are short functions that are created without ever assigning a name,

```
1 function(x) {x+1}
```

```
function(x) {x+1}
```

```
1 (function(y) {y-1})(10)
```

```
[1] 9
```

this can be particularly helpful for implementing certain types of tasks,

```
1 integrate(function(x) x, 0, 1)
```

```
0.5 with absolute error < 5.6e-15
```

```
1 integrate(function(x) x^2-2*x+1, 0, 1)
```

```
0.3333333 with absolute error < 3.7e-15
```

# Base R anonymous function (lambda) shorthand

Along with the base pipe (`|>`), R v4.1.0 introduced a shortcut for anonymous functions using `\()`, we won't be using this for the same reason but it is useful to know that it exists.

```
1 (\(x) {1+x})(1:5)
```

```
[1] 2 3 4 5 6
```

```
1 (\(x) x^2)(10)
```

```
[1] 100
```

```
1 integrate(\(x) sin(x)^2, 0, 1)
```

```
0.2726756 with absolute error < 3e-15
```

Use of this with the base pipe helps avoid the need for `.`, e.g.

```
1 data.frame(x = runif(10), y = runif(10)) |>  
2   {\(d) lm(y~x, data = d)}()
```

Call:

```
lm(formula = y ~ x, data = d)
```

Coefficients:

(Intercept)	x
0.4136	-0.2926

# **apply (base R)**



# Apply functions

The apply functions are a collection of tools for functional programming in base R, they are variations of the `map` function found in many other languages and apply a function over the elements of an input (vector).

```
1  ??base::apply
2  ---
3
4  ##
5  ## Help files with alias or concept or title matching 'apply' using fuzzy
6  ## matching:
7  ##
8  ## base::apply           Apply Functions Over Array Margins
9  ## base::subset         Internal Objects in Package 'base'
10 ## base::by              Apply a Function to a Data Frame Split by Factors
11 ## base::eapply          Apply a Function Over Values in an Environment
12 ## base::lapply          Apply a Function over a List or Vector
13 ## base::mapply          Apply a Function to Multiple List or Vector Arguments
14 ## base::rapply          Recursively Apply a Function to a List
15 ## base::tapply          Apply a Function Over a Ragged Array
```

# lapply

Usage: `lapply(X, FUN, ...)`

`lapply` returns a list of the same length as `X`, each element of which is the result of applying `FUN` to the corresponding element of `X`.

```
1 lapply(1:8, sqrt) %>%  
2   str()
```

List of 8

```
$ : num 1  
$ : num 1.41  
$ : num 1.73  
$ : num 2  
$ : num 2.24  
$ : num 2.45  
$ : num 2.65  
$ : num 2.83
```

```
1 lapply(1:8, function(x) (x+1)^2) %>%  
2   str()
```

List of 8

```
$ : num 4  
$ : num 9  
$ : num 16  
$ : num 25  
$ : num 36  
$ : num 49  
$ : num 64  
$ : num 81
```

# Argument matching

```
1 lapply(1:8, function(x, pow) x^pow, pow=3) %>% str()
```

List of 8

```
$ : num 1
$ : num 8
$ : num 27
$ : num 64
$ : num 125
$ : num 216
$ : num 343
$ : num 512
```

```
1 lapply(1:8, function(x, pow) x^pow, x=2) %>% str()
```

List of 8

```
$ : num 2
$ : num 4
$ : num 8
$ : num 16
$ : num 32
$ : num 64
$ : num 128
$ : num 256
```

# sapply

Usage: `sapply(X, FUN, ..., simplify = TRUE, USE.NAMES = TRUE)`

`sapply` is a *user-friendly* version and wrapper of `lapply`, it is a *simplifying* version of `lapply`. Whenever possible it will return a vector, matrix, or an array.

```
1 sapply(1:8, sqrt)
```

```
[1] 1.000000 1.414214 1.732051 2.000000 2.236068 2.449490 2.645751 2.828427
```

```
1 sapply(1:8, function(x) (x+1)^2)
```

```
[1] 4 9 16 25 36 49 64 81
```

```
1 sapply(1:8, function(x) c(x, x^2, x^3))
```

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]	[,7]	[,8]
[1,]	1	2	3	4	5	6	7	8
[2,]	1	4	9	16	25	36	49	64
[3,]	1	8	27	64	125	216	343	512

# Legnth mismatch?

```
1 sapply(1:6, seq)
```

```
[[1]]
```

```
[1] 1
```

```
[[2]]
```

```
[1] 1 2
```

```
[[3]]
```

```
[1] 1 2 3
```

```
[[4]]
```

```
[1] 1 2 3 4
```

```
##5##
```

```
1 lapply(1:6, seq)
```

```
[[1]]
```

```
[1] 1
```

```
[[2]]
```

```
[1] 1 2
```

```
[[3]]
```

```
[1] 1 2 3
```

```
[[4]]
```

```
[1] 1 2 3 4
```

```
##5##
```

# Type mismatch?

```
1 l = list(a = 1:3, b = 4:6, c = 7:9, d = list(10, 11, "A"))
```

```
1 sapply(l, function(x) x[1]) %>% str()
```

List of 4

```
$ a: int 1  
$ b: int 4  
$ c: int 7  
$ d: num 10
```

```
1 sapply(l, function(x) x[[1]]) %>% str()
```

```
Named num [1:4] 1 4 7 10  
- attr(*, "names")= chr [1:4] "a" "b" "c" "d"
```

```
1 sapply(l, function(x) x[[3]]) %>% str()
```

```
Named chr [1:4] "3" "6" "9" "A"  
- attr(*, "names")= chr [1:4] "a" "b" "c" "d"
```

# \*apply and data frames

We can use these functions with data frames, the key is to remember that a data frame is just a fancy list.

```
1 df = data.frame(  
2   a = 1:6,  
3   b = letters[1:6],  
4   c = c(TRUE, FALSE)  
5 )
```

```
1 lapply(df, class) %>% str()
```

List of 3

```
$ a: chr "integer"  
$ b: chr "character"  
$ c: chr "logical"
```

```
1 sapply(df, class)
```

a	b	c
"integer"	"character"	"logical"

# A more useful example

Some sources of data (e.g. the US government) will encode missing values with **-999**, if want to replace these with **NA**s lapply is not a bad choice.

```
1 d = tibble::tribble(  
2   ~patient_id, ~age, ~bp, ~o2,  
3     1,    32,  110,  97,  
4     2,    27,  100,  95,  
5     3,    56,  125, -999,  
6     4,    19, -999, -999,  
7     5,    65, -999,  99  
8 )
```



```

1 fix_missing = function(x) {
2   x[x == -999] = NA
3   x
4 }
5 lapply(d, fix_missing)

```

\$patient\_id

[1] 1 2 3 4 5

\$age

[1] 32 27 56 19 65

\$bp

[1] 110 100 125 NA NA

\$o2

[1] 97 95 NA NA 99

```

1 lapply(d, fix_missing) %>%
2   as_tibble()

```

# A tibble: 5 × 4

	patient_id	age	bp	o2
	<dbl>	<dbl>	<dbl>	<dbl>
1	1	32	110	97
2	2	27	100	95
3	3	56	125	NA
4	4	19	NA	NA
5	5	65	NA	99

# dplyr alternative

dplyr is also a viable option here using the `across()` helper,

```
1 d %>%
2   mutate(
3     across(
4       bp:o2,
5       fix_missing
6     )
7   )
```

# A tibble: 5 × 4

	patient_id	age	bp	o2
	<dbl>	<dbl>	<dbl>	<dbl>
1	1	32	110	97
2	2	27	100	95
3	3	56	125	NA
4	4	19	NA	NA
5	5	65	NA	99

```
1 d %>%
2   mutate(
3     across(
4       where(is.numeric),
5       fix_missing
6     )
7   )
```

# A tibble: 5 × 4

	patient_id	age	bp	o2
	<dbl>	<dbl>	<dbl>	<dbl>
1	1	32	110	97
2	2	27	100	95
3	3	56	125	NA
4	4	19	NA	NA
5	5	65	NA	99

# other less common apply functions

- `apply()` - applies a function over the rows or columns of a data frame, matrix or array
- `vapply()` - is similar to `sapply`, but has a enforced return type and size
- `mapply()` - like `sapply` but will iterate over multiple vectors at the same time.
- `rapply()` - a recursive version of `lapply`, behavior depends largely on the `how` argument
- `eapply()` - apply a function over an environment.



# Map functions

Basic functions for looping over objects and returning a value (of a specific type) - replacement for `lapply/sapply/vapply`.

- `map()` - returns a list, equivalent to `lapply()`
- `map_lgl()` - returns a logical vector.
- `map_int()` - returns a integer vector.
- `map_dbl()` - returns a double vector.
- `map_chr()` - returns a character vector.
- `map_dfr()` - returns a data frame by row binding.
- `map_df()` - returns a data frame by column binding.
- `walk()` - returns nothing, used for side effects

# Type Consistency

R is a weakly / dynamically typed language which means there is no syntactic way to define a function which enforces argument or return types. This flexibility can be useful at times, but often it makes it hard to reason about your code and requires more verbose code to handle edge cases.

```
1 x = list(rnorm(1e3), rnorm(1e3), rnorm(1e3))
```

```
1 map_dbl(x, mean)
```

```
[1] -0.01614633  0.01443330 -0.04476643
```

```
1 map_chr(x, mean)
```

```
[1] "-0.016146" "0.014433" "-0.044766"
```

```
1 map_int(x, mean)
```

```
Error: Can't coerce element 1 from a double to a integer
```

```
1 map(x, mean) %>% str()
```

```
List of 3
 $ : num -0.0161
 $ : num 0.0144
 $ : num -0.0448
```

```
1 lapply(x, mean) %>% str()
```

```
List of 3
 $ : num -0.0161
 $ : num 0.0144
 $ : num -0.0448
```

# Working with Data Frames

`map_dfr` and `map_dfc` are particularly useful when working with and/or creating data frames.

```
1 d = tibble::tribble(  
2   ~patient_id, ~age, ~bp, ~o2,  
3     1,    32,  110,  97,  
4     2,    27,  100,  95,  
5     3,    56,  125, -999,  
6     4,    19, -999, -999,  
7     5,    65, -999,  99  
8 )
```

```
1 fix_missing = function(x) {  
2   x[x == -999] = NA  
3   x  
4 }
```

```
1 purrr::map_dfc(d, fix_missing)
```

# A tibble: 5 × 4

	patient_id	age	bp	o2
	<dbl>	<dbl>	<dbl>	<dbl>
1	1	32	110	97
2	2	27	100	95
3	3	56	125	NA
4	4	19	NA	NA
5	5	65	NA	99

# Building by row

```
1 map_dfr(sw_people, function(x) x[1:5])
```

```
# A tibble: 87 × 5
```

	name	height	mass	hair_color	skin_color
	<chr>	<chr>	<chr>	<chr>	<chr>
1	Luke Skywalker	172	77	blond	fair
2	C-3PO	167	75	n/a	gold
3	R2-D2	96	32	n/a	white, blue
4	Darth Vader	202	136	none	white
5	Leia Organa	150	49	brown	light
6	Owen Lars	178	120	brown, grey	light
7	Beru Whitesun lars	165	75	brown	light
8	R5-D4	97	32	n/a	white, red
9	Biggs Darklighter	183	84	black	light
10	Obi Wan Kenobi	182	77	auburn	white, fair

```
1 map_dfr(sw_people, function(x) x)
```

```
Error in `vctrs::data_frame()`:
```

```
! Can't recycle `name` (size 5) to match `vehicles` (size 2).
```



# purrr style anonymous functions

purrr lets us write anonymous functions using one sided formulas where the argument is given by `.` or `.x` for `map` and related functions.

```
1 map_dbl(1:5, function(x) x/(x+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

```
1 map_dbl(1:5, ~ ./(.+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

```
1 map_dbl(1:5, ~ .x/(.x+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

Generally, the latter option is preferred to avoid confusion with magrittr.

# Multiargument anonymous functions

Functions with the `map2` prefix work the same as the `map` functions but they iterate over two objects instead of one. Arguments in an anonymous function are given by `.x` and `.y` (or `..1` and `..2`) respectively.

```
1 map2_dbl(1:5, 1:5, function(x,y) x / (y+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

```
1 map2_dbl(1:5, 1:5, ~ .x/(.y+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

```
1 map2_dbl(1:5, 1:5, ~ ..1/(..2+1))
```

```
[1] 0.5000000 0.6666667 0.7500000 0.8000000 0.8333333
```

```
1 map2_chr(LETTERS[1:5], letters[1:5], paste0)
```

```
[1] "Aa" "Bb" "Cc" "Dd" "Ee"
```

# Lookups

Very often we want to extract only certain (named) values from a list, `purrr` provides a shortcut for this operation - if instead of a function you provide either a character or numeric vector, those values will be used to sequentially subset the elements being iterated.

```
1 purrr::map_chr(sw_people, "name") %>% head()
```

```
[1] "Luke Skywalker" "C-3PO"          "R2-D2"          "Darth Vader"
[5] "Leia Organa"    "Owen Lars"
```

```
1 purrr::map_chr(sw_people, 1) %>% head()
```

```
[1] "Luke Skywalker" "C-3PO"          "R2-D2"          "Darth Vader"
[5] "Leia Organa"    "Owen Lars"
```

```
1 purrr::map_chr(sw_people, list("films", 1)) %>% head(n=10)
```

```
[1] "http://swapi.co/api/films/6/" "http://swapi.co/api/films/5/"
[3] "http://swapi.co/api/films/5/" "http://swapi.co/api/films/6/"
[5] "http://swapi.co/api/films/6/" "http://swapi.co/api/films/5/"
[7] "http://swapi.co/api/films/5/" "http://swapi.co/api/films/1/"
[9] "http://swapi.co/api/films/1/" "http://swapi.co/api/films/5/"
```

# Length coercion?

```
1 purrr::map_chr(sw_people, list("starships", 1))
```

Error in `stop\_bad\_type()`:

! Result 2 must be a single string, not NULL of length 0

```
1 sw_people[[2]]$name
```

```
[1] "C-3PO"
```

```
1 sw_people[[2]]$starships
```

```
NULL
```

```
1 purrr::map_chr(sw_people, list("starships", 1), .default = NA) %>% head()
```

```
[1] "http://swapi.co/api/starships/12/" NA
```

```
[3] NA "http://swapi.co/api/starships/13/"
```

```
[5] NA NA
```

```
1 purrr::map(sw_people, list("starships", 1)) %>% head() %>% str()
```

List of 6

```
$ : chr "http://swapi.co/api/starships/12/"
```

```
$ : NULL
```

```
$ : NULL
```

```
$ : chr "http://swapi.co/api/starships/13/"
```

# list columns

```
1 (chars = tibble(  
2   name = purrr::map_chr(  
3     sw_people, "name"  
4   ),  
5   starships = purrr::map(  
6     sw_people, "starships"  
7   )  
8 ))
```

# A tibble: 87 × 2

name	starships
<chr>	<list>
1 Luke Skywalker	<chr [2]>
2 C-3PO	<NULL>
3 R2-D2	<NULL>
4 Darth Vader	<chr [1]>
5 Leia Organa	<NULL>
6 Owen Lars	<NULL>
7 Beru Whitesun lars	<NULL>
8 R5-D4	<NULL>
9 Biggs Darklighter	<chr [1]>
10 Obi-Wan Kenobi	<chr [5]>

# ... with 77 more rows

```
1 chars %>%  
2   mutate(  
3     n_starships = map_int(  
4       starships, length  
5     )  
6   )
```

# A tibble: 87 × 3

name	starships	n_starships
<chr>	<list>	<int>
1 Luke Skywalker	<chr [2]>	2
2 C-3PO	<NULL>	0
3 R2-D2	<NULL>	0
4 Darth Vader	<chr [1]>	1
5 Leia Organa	<NULL>	0
6 Owen Lars	<NULL>	0
7 Beru Whitesun lars	<NULL>	0
8 R5-D4	<NULL>	0
9 Biggs Darklighter	<chr [1]>	1
10 Obi-Wan Kenobi	<chr [5]>	5

# ... with 77 more rows

# Example

List columns and approximating pi

# Example

`discog` - purrr vs tidyr

# Complex heirarchical data

Often we may encounter complex data structures where our goal is not to rectangle every value (which may not even be possible) but rather to rectangle a small subset of the data.

```
1 str(repurrrsive::discog, max.level = 3)
```

List of 155

\$ :List of 5

..\$ instance\_id : int 354823933

..\$ date\_added : chr "2019-02-16T17:48:59-08:00"

..\$ basic\_information:List of 11

.. ..\$ labels :List of 1

.. ..\$ year : int 2015

.. ..\$ master\_url : NULL

.. ..\$ artists :List of 1

.. ..\$ id : int 7496378

.. ..\$ thumb : chr

"https://img.discogs.com/vEVegHrMNTsP6xG\_K6OuFXz4h\_U=/fit-

in/150x150/filters:strip\_icc()/format(img):mode\_rgb/" | truncated