Functions: Part 1

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Agenda

- Everything is a function
- Components of a function
- Function Workflows

Learning objectives

- Understand and be able to fluently refer to the three fundamental components of a function
- Understand the workflows that often lead to writing functions, and how you iterate from interactive work to writing a function
- Be able to write a few basic functions

Functions

Anything that carries out an operation in R is a function. For example

```
3 + 5
```

```
## [1] 8
```

The + is a function (what's referred to as an *infix* function).

Any ideas on how we could re-write the above to make it look more "function"-y?

```
`+`(3, 5)
```

```
## [1] 8
```

What about this?

```
3 + 5 + 7
```

```
## [1] 15
```

```
`+`(7, `+`(3, 5))
```

```
## [1] 15
```

or

```
library(magrittr)
`+`(3, 5) %>%
    `+`(7)
```

```
## [1] 15
```

What's going on here?

- The + operator is a function that takes two arguments (both numeric), which it sums.
- The following are also the same

```
a <- 7
a
```

```
## [1] 7
```

```
`<-`(a, 7)
a
```

```
## [1] 7
```

Everything is a function!

Being devious

- Want to introduce a devious bug? Redefine `+`

```
`+` <- function(x, y) {
    if(runif(1) < 0.01) {
        sum(x, y) * -1
    } else {
        sum(x, y)
    }
}
table(map2_dbl(1:500, 1:500, `+`) > 0)
```

```
##
## FALSE  TRUE
##     5   495
```

```
rm(`+`, envir = globalenv())
table(map2_dbl(1:500, 1:500, `+`) > 0)
```

```
##
## TRUE
##  500
```

Tricky...

Functions are also (usually) objects!

```
a <- lm
a(hp ~ drat + wt, data = mtcars)
```

```
##
## Call:
## a(formula = hp ~ drat + wt, data = mtcars)
##
## Coefficients:
## (Intercept)         drat           wt
##     -27.782        5.354       48.244
```

What does this all mean?

- Anything that carries out ANY operation in R is a function
- Functions are generally, but not always, stored in an object (otherwise known as binding the function to a name)

Anonymous functions

- The function for computing the mean is bound the name `mean`
- When running things through loops, you may often want to apply a function without binding it to a name

Example

```
vapply(mtcars, function(x) length(unique(x)), FUN.VALUE = double(1))
```

```
##  mpg  cyl disp   hp drat   wt qsec   vs   am gear carb
##   25    3   27   22   22   29   30    2    2    3    6
```

Another possibility

- If you have a bunch of functions, you might consider storing them all in a list.
- You can then access the functions in the same way you would subset any list

```
funs <- list(
  quarter = function(x) x / 4,
  half = function(x) x / 2,
  double = function(x) x * 2,
  quadruple = function(x) x * 4
)
```

```
funs$quarter(100)
```

```
## [1] 25
```

```
funs[["half"]](100)
```

```
## [1] 50
```

```
funs[[4]](100)
```

```
## [1] 400
```

What does this imply?

- If we can store functions in a vector (list), then we can loop through the vector just like any other!

```
smry <- list(n = length,
             n_miss = function(x) sum(is.na(x)),
             n_valid = function(x) sum(!is.na(x)),
             mean = mean,
             sd = sd)
```

```
map_dbl(smry, ~.x(mtcars$mpg))
```

```
##          n    n_miss   n_valid      mean        sd
## 32.000000  0.000000 32.000000 20.090625  6.026948
```

Careful though

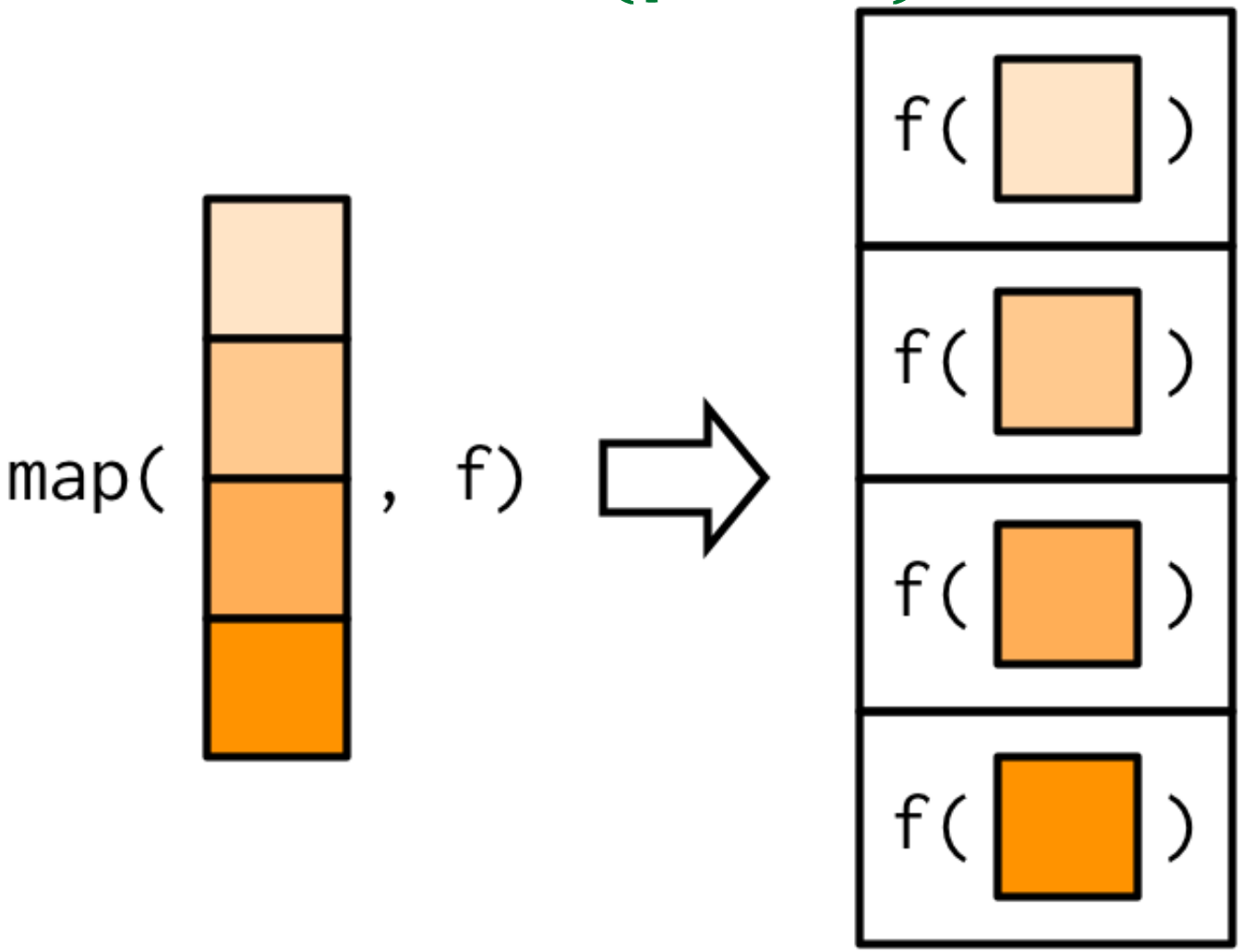
This doesn't work

```
map_dbl(smry, mtcars$mpg)
```

```
## Error: Can't pluck from a builtin
```

Why?

Remember what {purrr} does



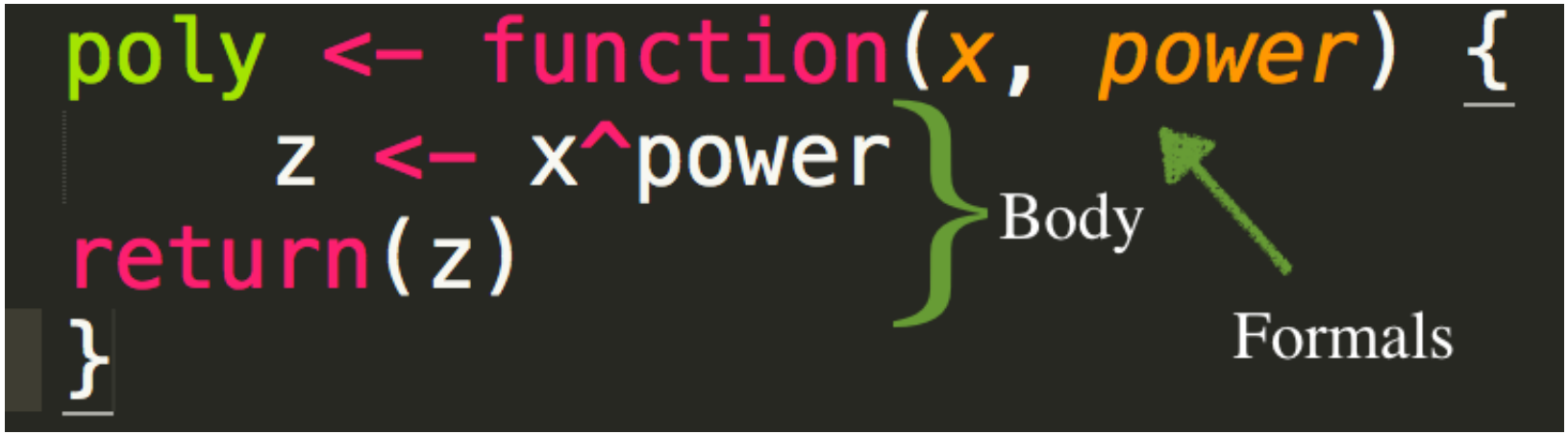
Challenge

- Can you extend the previous looping to supply the summary for every column? Hint: You'll need `purrr::map2`.

Function components

Three components

- `body()`
- `formals()`
- `environment()` (we won't focus so much here for now)



Formals

- The arguments supplied to the function
- What's one way to identify the formals for a function - say, `lm`?

`?`: Help documentation!

Alternative - use a function!

```
formals(lm)
```

```
## $formula
##
##
## $data
##
##
## $subset
##
##
## $weights
##
##
```

How do you see the body?

- Something I just learned... In RStudio: Super (command on mac, cntrl on windows) + click!

(demo)

- Alternative - just print to screen

Or use body

```
body(lm)
```

```
## {
##     ret.x <- x
##     ret.y <- y
##     cl <- match.call()
##     mf <- match.call(expand.dots = FALSE)
##     m <- match(c("formula", "data", "subset", "weights", "na.action",
##         "offset"), names(mf), 0L)
##     mf <- mf[c(1L, m)]
##     mf$drop.unused.levels <- TRUE
##     mf[[1L]] <- quote(stats::model.frame)
##     mf <- eval(mf, parent.frame())
##     if (method == "model.frame")
##         return(mf)
##     else if (method != "qr")
##         warning(gettextf("method = '%s' is not supported. Using 'qr'",
##             method), domain = NA)
##     mt <- attr(mf, "terms")
##     y <- model.response(mf, "numeric")
##     w <- as.vector(model.weights(mf))
##     if (!is.null(w) && !is.numeric(w))
##         stop("'weights' must be a numeric vector")
```

Environment

- As I mentioned, we won't focus on this too much, but if you get deep into programming it's pretty important

```
double <- function(x) x*2
environment(double)
```

```
## <environment: R_GlobalEnv>
```

```
environment(lm)
```

```
## <environment: namespace:stats>
```

Why this matters

What will the following return?

```
x <- 10
f1 <- function() {
  x <- 20
  x
}

f1()
```

```
## [1] 20
```

What will this return?

```
x <- 10
y <- 20
f2 <- function() {
  x <- 1
  y <- 2
  sum(x, y)
}
f2()
```

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

Last one

What do each of the following return?

```
x <- 2
f3 <- function() {
  y <- 1
  sum(x, y)
}

f3()

y
```

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

```
## [1] 20
```

Environment summary

- The previous examples are part of *lexical scoping*.
- Generally, you won't have to worry too much about it
- If you end up with unexpected results, this could be part of why

Scoping

- Part of what's interesting about these scoping rules is that your function can, and very often do, depend upon things in your global workspace, or your specific environment.
- If this is the case, the function will be a "one-off", and unlikely to be useful in any other script

Example 1

Extracting information

- This is a real example

```
extract_grades <- function(dif_mod, items) {
  item_names <- names(items)
  delta  <- -2.35*(log(dif_mod$alphaMH))
  grades <- symnum(abs(delta),
                   c(0, 1, 1.5, Inf),
                   symbols = c("A", "B", "C"))
  tibble(item = item_names, delta, grades) %>%
    mutate(grades = as.character(grades))
}
```

Example 2

Reading in data

```
read_sub_files <- function(file) {
  read_csv(file) %>%
    mutate(content_area =
             str_extract(file, "[Ee][Ll][Aa]|[Rr]dg|[Ww]ri|[Mm]ath|[Ss]ci"),
           grade = gsub(".+g(\\d\\d*).+", "\\1", file),
           grade = as.numeric(grade)) %>%
    select(content_area, grade, everything()) %>%
    clean_names()
}

ifiles <- map_df(ifiles, read_sub_files)
```

Simple example

Pull out specific coefficients

```
mods <- mtcars %>%
    group_by(cyl) %>%
    nest() %>%
    mutate(model = map(data, ~lm(mpg ~ disp + hp + drat, data = .x)))
mods
```

```
## # A tibble: 3 x 3
##     cyl data               model
##   <dbl> <list>             <list>
## 1     6 <tibble [7 × 10]>  <S3: lm>
## 2     4 <tibble [11 × 10]> <S3: lm>
## 3     8 <tibble [14 × 10]> <S3: lm>
```

Pull a specific coef

Find the solution for one model

```
m <- mods$model[[1]]
coef(m)
```

```
## (Intercept)        disp          hp        drat
## 6.284507434 0.026354099 0.006229086 2.193576546
```

```
coef(m)["disp"]
```

```
##      disp
## 0.0263541
```

```
coef(m)["(Intercept)"]
```

```
## (Intercept)
##    6.284507
```

Generalize it

```
pull_coef <- function(model, coef_name) {
    coef(model)[coef_name]
}
mods %>%
    mutate(intercept = map_dbl(model, pull_coef, "(Intercept)"),
           disp      = map_dbl(model, pull_coef, "disp"),
           hp        = map_dbl(model, pull_coef, "hp"),
           drat      = map_dbl(model, pull_coef, "drat"))
```

```
## # A tibble: 3 x 7
##     cyl data              model  intercept        disp           hp       drat
##   <dbl> <list>            <list>     <dbl>       <dbl>        <dbl>      <dbl>
## 1     6 <tibble [7 × … <S3: …  6.284507  0.02635410  0.006229086  2.193577
## 2     4 <tibble [11 ×… <S3: … 46.08662  -0.1225361  -0.04937771  -0.6041857
## 3     8 <tibble [14 ×… <S3: … 19.00162  -0.01671461 -0.02140236   2.006011
```

Make it more flexible

- Since the intercept is a little difficulty to pull out, we could have it return that by default.

```
pull_coef <- function(model, coef_name = "(Intercept)") {
    coef(model)[coef_name]
}
mods %>%
    mutate(intercept = map_dbl(model, pull_coef))
```

```
## # A tibble: 3 x 4
##     cyl data               model    intercept
##   <dbl> <list>             <list>       <dbl>
## 1     6 <tibble [7 × 10]>  <S3: lm>  6.284507
## 2     4 <tibble [11 × 10]> <S3: lm> 46.08662
## 3     8 <tibble [14 × 10]> <S3: lm> 19.00162
```

Return all coefficients

```
pull_coef <- function(model) {
    coefs <- coef(model)
    data.frame(coefficient = names(coefs),
               value       = coefs)
}
mods %>%
    mutate(coefs = map(model, pull_coef))
```

```
## # A tibble: 3 x 4
##     cyl data              model    coefs
##   <dbl> <list>            <list>   <list>
## 1     6 <tibble [7 × 10]> <S3: lm> <data.frame [4 × 2]>
## 2     4 <tibble [11 × 10]> <S3: lm> <data.frame [4 × 2]>
## 3     8 <tibble [14 × 10]> <S3: lm> <data.frame [4 × 2]>
```

```
mods %>%
    mutate(coefs = map(model, pull_coef)) %>%
    unnest()
```

```
## All nested columns must have the same number of elements.
```

```
mods %>%
    mutate(coefs = map(model, pull_coef)) %>%
    select(cyl, coefs) %>%
    unnest()
```

```
## # A tibble: 12 x 3
##      cyl coefficient         value
##    <dbl> <fct>               <dbl>
##  1     6 (Intercept)   6.284507
##  2     6 disp          0.02635410
##  3     6 hp            0.006229086
##  4     6 drat          2.193577
##  5     4 (Intercept)  46.08662
##  6     4 disp         -0.1225361
##  7     4 hp           -0.04937771
##  8     4 drat         -0.6041857
##  9     8 (Intercept)  19.00162
## 10     8 disp         -0.01671461
## 11     8 hp           -0.02140236
## 12     8 drat          2.006011
```

Create nice table

```
mods %>%
    mutate(coefs = map(model, pull_coef)) %>%
    select(cyl, coefs) %>%
    unnest() %>%
    spread(coefficient, value)
```

```
## # A tibble: 3 x 5
##     cyl `(Intercept)`        disp       drat           hp
##   <dbl>         <dbl>       <dbl>      <dbl>        <dbl>
## 1     4      46.08662  -0.1225361  -0.6041857 -0.04937771
## 2     6       6.284507  0.02635410  2.193577   0.006229086
## 3     8      19.00162  -0.01671461  2.006011  -0.02140236
```

When to write a function?

Example

```
set.seed(42)
df <- tibble::tibble(
  a = rnorm(10, 100, 150),
  b = rnorm(10, 100, 150),
  c = rnorm(10, 100, 150),
  d = rnorm(10, 100, 150)
)

df
```

```
## # A tibble: 10 x 4
##             a          b           c           d
##         <dbl>      <dbl>       <dbl>       <dbl>
##  1 305.6438   295.7304    54.00421   168.3175
##  2  15.29527  442.9968  -167.1963    205.7256
##  3 154.4693  -108.3291    74.21240   255.2655
##  4 194.9294    58.18168  282.2012      8.661044
##  5 160.6402    80.00180  384.2790    175.7433
##  6  84.08132  195.3926    35.42963  -157.5513
##  7 326.7283    57.36206   61.40959   -17.66885
##  8  85.80114 -298.4683  -164.4745    -27.63614
##  9 402.7636  -266.0700   169.0146   -262.1311
## 10  90.59289  298.0170     4.000769  105.4184
```

Rescale each column to 0/1

Do it for one column

```
df %>%
    mutate(a = (a - min(a, na.rm = TRUE)) /
                  (max(a, na.rm = TRUE) - min(a, na.rm = TRUE)))
```

```
## # A tibble: 10 x 4
##             a          b           c           d
##         <dbl>      <dbl>       <dbl>       <dbl>
##  1 0.7493478  295.7304    54.00421   168.3175
##  2 0          442.9968  -167.1963    205.7256
##  3 0.3591881 -108.3291    74.21240   255.2655
##  4 0.4636099   58.18168  282.2012      8.661044
##  5 0.3751145   80.00180  384.2790    175.7433
##  6 0.1775269  195.3926    35.42963  -157.5513
##  7 0.8037639   57.36206   61.40959   -17.66885
##  8 0.1819655 -298.4683  -164.4745    -27.63614
##  9 1         -266.0700   169.0146   -262.1311
## 10 0.1943323  298.0170     4.000769  105.4184
```

Do it for all columns

```
df %>%
    mutate(a = (a - min(a, na.rm = TRUE)) /
                 (max(a, na.rm = TRUE) - min(a, na.rm = TRUE)),
           b = (b - min(b, na.rm = TRUE)) /
                 (max(b, na.rm = TRUE) - min(b, na.rm = TRUE)),
           c = (c - min(c, na.rm = TRUE)) /
                 (max(c, na.rm = TRUE) - min(c, na.rm = TRUE)),
           d = (d - min(d, na.rm = TRUE)) /
                 (max(d, na.rm = TRUE) - min(d, na.rm = TRUE)))
```

```
## # A tibble: 10 x 4
##             a          b           c         d
##         <dbl>      <dbl>       <dbl>     <dbl>
##  1 0.7493478 0.8013846  0.4011068   0.8319510
##  2 0         1          0           0.9042516
##  3 0.3591881 0.2564372  0.4377506   1
##  4 0.4636099 0.4810071  0.8149005   0.5233744
##  5 0.3751145 0.5104355  1           0.8463031
##  6 0.1775269 0.6660608  0.3674252   0.2021270
##  7 0.8037639 0.4799017  0.4145351   0.4724852
##  8 0.1819655 0          0.004935493 0.4532209
##  9 1         0.04369494 0.6096572   0
## 10 0.1943323 0.8044685  0.3104346   0.7103825
```

An alternative

- What's an alternative we could use *without* writing a function?

```
map_df(df, ~(.x - min(.x, na.rm = TRUE)) /
              (max(.x, na.rm = TRUE) - min(.x, na.rm = TRUE)))
```

```
## # A tibble: 10 x 4
##             a          b           c         d
##         <dbl>      <dbl>       <dbl>     <dbl>
##  1 0.7493478 0.8013846  0.4011068   0.8319510
##  2 0         1          0           0.9042516
##  3 0.3591881 0.2564372  0.4377506   1
##  4 0.4636099 0.4810071  0.8149005   0.5233744
##  5 0.3751145 0.5104355  1           0.8463031
##  6 0.1775269 0.6660608  0.3674252   0.2021270
##  7 0.8037639 0.4799017  0.4145351   0.4724852
##  8 0.1819655 0          0.004935493 0.4532209
##  9 1         0.04369494 0.6096572   0
## 10 0.1943323 0.8044685  0.3104346   0.7103825
```

Tidyverse is making examples of when you **need** a function without creating new functionality *almost* obsolete

Write a function

- What are the arguments going to be?
- What will the body be?

Arguments

- One formal argument - A numeric vector to rescale

Body

- You try first

```
(x - min(x, na.rm = TRUE)) /
  (max(x, na.rm = TRUE) - min(x, na.rm = TRUE))
```

Create the function

```
rescale01 <- function(x) {
    (x - min(x, na.rm = TRUE)) /
      (max(x, na.rm = TRUE) - min(x, na.rm = TRUE))
}
```

Test it!

```
rescale01(c(0, 5, 10))
```

```
## [1] 0.0 0.5 1.0
```

```
rescale01(c(seq(0, 100, 10)))
```

```
##  [1] 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
```

Make it a cleaner

- There's nothing inherently "wrong" about the prior function, but it is a bit hard to read
- How could we make it easier to read?
    - remove missing data once
    - Don't calculate things multiple times

A little cleaned up

```
rescale01b <- function(x) {
    z <- na.omit(x)
    min_z <- min(z)
    max_z <- max(z)

    (z - min_z) / (max_z - min_z)
}
```

Test it!

```
rescale01b(c(0, 5, 10))
```

```
## [1] 0.0 0.5 1.0
```

```
rescale01b(c(seq(0, 100, 10)))
```

```
##  [1] 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
```

Make sure they give the same output

```
identical(rescale01(c(0, 1e5, .01)), rescale01b(c(0, 1e5, 0.01)))
```

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

```
rand <- rnorm(1e3)
identical(rescale01(rand), rescale01b(rand))
```

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

Final solution

```
map_df(df, rescale01b)
```

```
## # A tibble: 10 x 4
##             a          b           c         d
##         <dbl>      <dbl>       <dbl>     <dbl>
##  1 0.7493478 0.8013846  0.4011068   0.8319510
##  2 0         1          0           0.9042516
##  3 0.3591881 0.2564372  0.4377506   1
##  4 0.4636099 0.4810071  0.8149005   0.5233744
##  5 0.3751145 0.5104355  1           0.8463031
##  6 0.1775269 0.6660608  0.3674252   0.2021270
##  7 0.8037639 0.4799017  0.4145351   0.4724852
##  8 0.1819655 0          0.004935493 0.4532209
##  9 1         0.04369494 0.6096572   0
## 10 0.1943323 0.8044685  0.3104346   0.7103825
```

Getting more complex

- What if you want a function to behave different depending on the input?

Add conditions

```
function() {
    if (condition) {

  # code executed when condition is TRUE

    } else {
  # code executed when condition is FALSE

    }
}
```

Lots of conditions?

```
function() {
    if (this) {

  # do this

    } else if (that) {

  # do that

    } else {

    # something else

    }
}
```

Easy example

- Given a vector, return the mean if it's numeric, and `NULL` otherwise

```
mean2 <- function(x) {
    if(is.numeric(x)) {
        mean(x)
    }
    else {
        return()
    }
}
```

Test it

```
mean2(rnorm(12))
```

```
## [1] -0.441614
```

```
mean2(letters[1:5])
```

```
## NULL
```

Mean for all numeric columns

- The prior function can now be used within a new function to calculate the mean of all columns of a data frame that are numeric

```
means_df <- function(df) {
    means <- map(df, mean2) # calculate means
    nulls <- map_lgl(means, is.null) # find null values
    means_l <- means[!nulls] # subset list to remove nulls

    as.data.frame(means_l) # return a df
}
```

```
head(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
```

```
means_df(iris)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width
## 1     5.843333    3.057333        3.758    1.199333
```

We have a problem though!

```
head(airquality)
```

```
##   Ozone Solar.R Wind Temp Month Day
## 1    41     190  7.4   67     5   1
## 2    36     118  8.0   72     5   2
## 3    12     149 12.6   74     5   3
## 4    18     313 11.5   62     5   4
## 5    NA      NA 14.3   56     5   5
## 6    28      NA 14.9   66     5   6
```

```
means_df(airquality)
```

```
##   Ozone Solar.R     Wind     Temp    Month      Day
## 1    NA      NA 9.957516 77.88235 6.993464 15.80392
```

Why is this happening?

How can we fix it?

Easiest way in this case . . .

Pass the dots!

Redefine `means2`

```
mean2 <- function(x, ...) {
    if(is.numeric(x)) {
        mean(x, ...)
    }
    else {
        return()
    }
}
```

Reefine means_df

```
means_df <- function(df, ...) {
    means <- map(df, mean2, ...) # calculate means
    nulls <- map_lgl(means, is.null) # find null values
    means_l <- means[!nulls] # subset list to remove nulls

    as.data.frame(means_l) # return a df
}
```

```
means_df(airquality)
```

```
##   Ozone Solar.R     Wind     Temp    Month      Day
## 1    NA      NA 9.957516 77.88235 6.993464 15.80392
```

```
means_df(airquality, na.rm = TRUE)
```

```
##      Ozone  Solar.R     Wind     Temp    Month      Day
## 1 42.12931 185.9315 9.957516 77.88235 6.993464 15.80392
```

Next time

Lab 3