Functions: Parts 1 & 2

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Week 6

Agenda

- Review take–home midterm
- 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

Review Take-home

Functions

Functions

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

```r
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?

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

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

What about this?

```r
3 + 5 + 7
```

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

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

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

or

```r
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 (minus what's being assigned)

```r
a <- 7
a
```

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

```r
`<-`(a, 5)
a
```

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

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
##     6   494
```

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

```
##
## FALSE  TRUE
##     4   496
```

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
```

```
##  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
)
```

This is kind of weird...

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

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

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

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

```r
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
)
```

```r
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

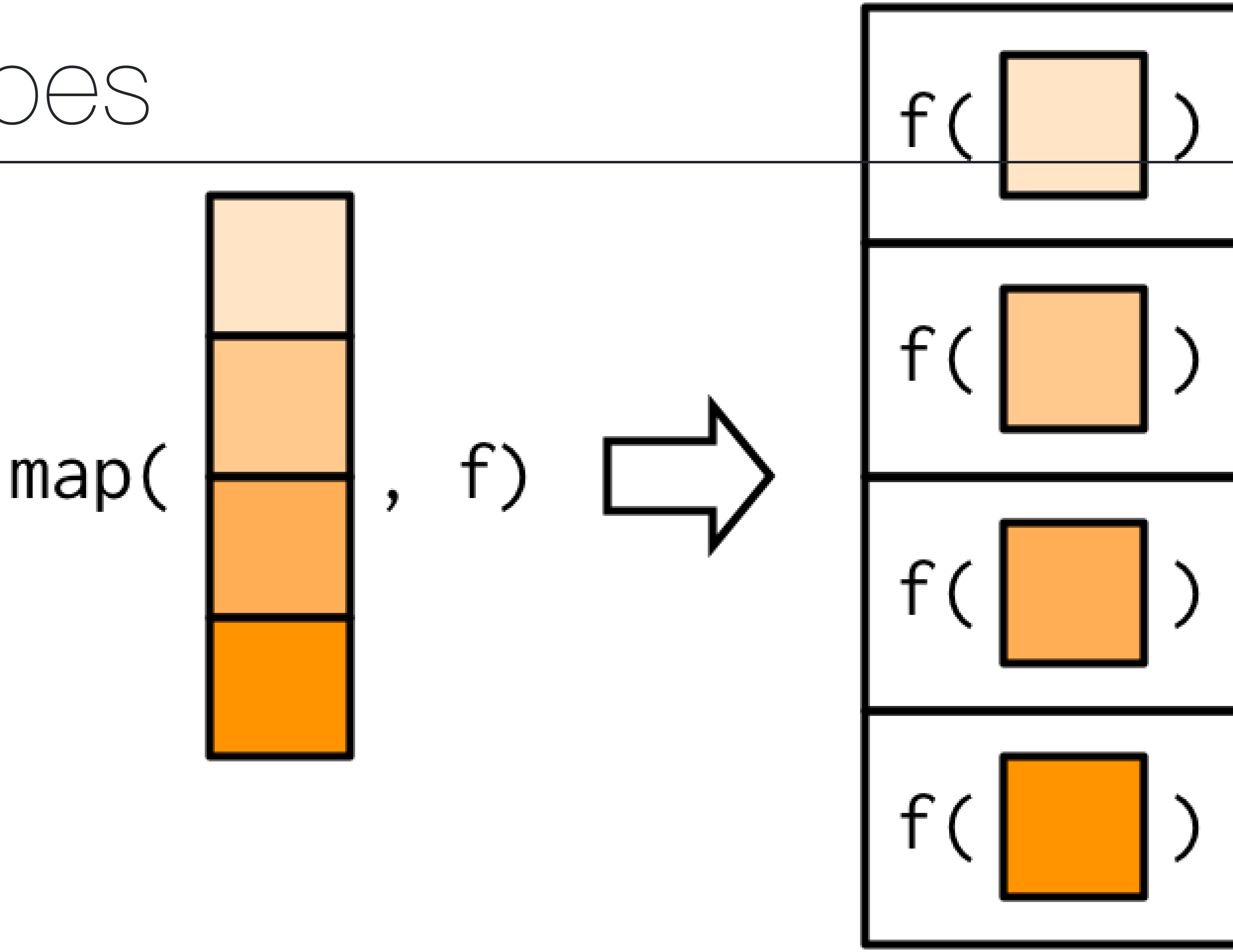
This doesn't work

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

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

Why?

Remember what {purrr} does



With map_df

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

```
## # A tibble: 1 × 5
##       n n_miss n_valid     mean       sd
##   <int>  <int>   <int>    <dbl>    <dbl>
## 1    32      0      32 20.09062 6.026948
```

```
map_df(smry, ~.x(mtcars$cyl))
```

```
## # A tibble: 1 × 5
##       n n_miss n_valid   mean       sd
##   <int>  <int>   <int>  <dbl>    <dbl>
## 1    32      0      32 6.1875 1.785922
```

What if we wanted this for all columns?

Challenge

- Can you extend the previous looping to supply the summary for every column? Hint: You'll need to make a nested loop (loop each function through each column)

```r
map_df(mtcars, function(col) map_df(smry, ~.x(col)),
       .id = "column")
```

```
## # A tibble: 11 × 6
##    column     n n_miss n_valid       mean         sd
##    <chr>  <int>  <int>   <int>      <dbl>      <dbl>
##  1 mpg       32      0      32  20.09062    6.026948
##  2 cyl       32      0      32   6.1875     1.785922
##  3 disp      32      0      32 230.7219   123.9387
##  4 hp        32      0      32 146.6875    68.56287
##  5 drat      32      0      32   3.596562   0.5346787
##  6 wt        32      0      32   3.21725    0.9784574
##  7 qsec      32      0      32  17.84875    1.786943
##  8 vs        32      0      32   0.4375     0.5040161
##  9 am        32      0      32   0.40625    0.4989909
## 10 gear      32      0      32   3.6875     0.7378041
## 11 carb      32      0      32   2.8125     1.615200
```

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Easier * more readable

- Avoid nested loops
- Instead, turn (at least) one of the loops into a function

```
summarize_col <- function(column) {
  map_df(smry, ~.x(column))
}
```

Now we can just loop this function through each column

```r
map_df(mtcars, summarize_col, .id = "column")
```

```
## # A tibble: 11 × 6
##    column     n n_miss n_valid      mean         sd
##    <chr>  <int>  <int>   <int>     <dbl>      <dbl>
##  1 mpg       32      0      32  20.09062   6.026948
##  2 cyl       32      0      32   6.1875    1.785922
##  3 disp      32      0      32 230.7219  123.9387
##  4 hp        32      0      32 146.6875   68.56287
##  5 drat      32      0      32   3.596562  0.5346787
##  6 wt        32      0      32   3.21725   0.9784574
##  7 qsec      32      0      32  17.84875   1.786943
##  8 vs        32      0      32   0.4375    0.5040161
##  9 am        32      0      32   0.40625   0.4989909
## 10 gear      32      0      32   3.6875    0.7378041
## 11 carb      32      0      32   2.8125    1.615200
```

Wrap the whole thing in a function

```
summarize_df <- function(df) {
  map_df(df, summarize_col, .id = "column")
}
```

```
summarize_df(airquality)
```

```
## # A tibble: 6 × 6
##   column      n n_miss n_valid      mean        sd
##   <chr>   <int>  <int>   <int>     <dbl>     <dbl>
## 1 Ozone     153     37     116 NA         NA
## 2 Solar.R   153      7     146 NA         NA
## 3 Wind      153      0     153  9.957516  3.523001
## 4 Temp      153      0     153 77.88235   9.465270
## 5 Month     153      0     153  6.993464  1.416522
## 6 Day       153      0     153 15.80392   8.864520
```

Notice the missing data. Why? What should we do?

Deep breaths

So far, this has just been a high-level overview.

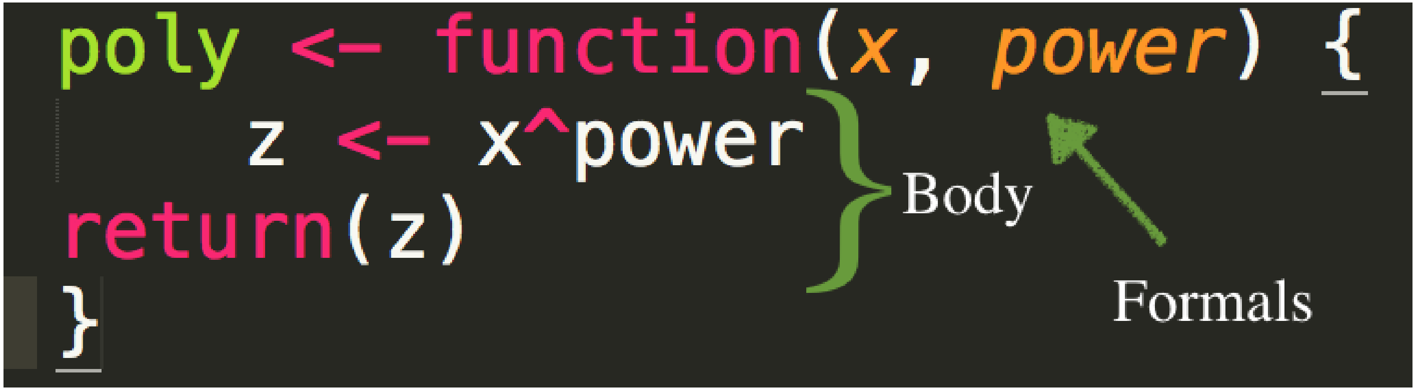
I wanted to show *why* you might want to write functions first.

Let's dig into the particulars

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?

- 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")
##     offset <- model.offset(mf)
##     mlm <- is.matrix(y)
##     ny <- if (mlm)
```

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: 0x7ff20b2b1898>
```

```
environment(lm)
```

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

Why this matters

What will the following return?

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

f1()
```

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

What will this return?

```r
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
```

```
## Error in eval(expr, envir, enclos): object 'y' not found
```

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 functions 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

- Note that our `summarize_df()` function depended on the global `smry` list object.

A few real examples

Example 1

Return the item "scores" for a differential item functioning analysis

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

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

Simple example

Please follow along

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

Pull a specific coef

Find the solution for one model

```r
# pull just the first model
m <- mods$model[[1]]

# extract all coefs
coef(m)
```

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

```r
# extract specific coefs
coef(m)["disp"]
```

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

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

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

Challenge

Can you write a function that returns a *specific* coefficient from a model?

Try using the code on the previous slide as you guide

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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 × 7
## # Groups:   cyl [3]
##     cyl data               model  intercept        disp           hp
##   <dbl> <list>             <list>     <dbl>       <dbl>        <dbl>
## 1     6 <tibble [7 × 10]>  <lm>    6.284507  0.02635410  0.006229086  2.
## 2     4 <tibble [11 × 10]> <lm>   46.08662  -0.1225361  -0.04937771  -0.
## 3     8 <tibble [14 × 10]> <lm>   19.00162  -0.01671461 -0.02140236   2.
```

Make it more flexible

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

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

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

Return all coefficients

First, figure it out for a single case

```r
coef(m)
```

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

```r
names(coef(m))
```

```
## [1] "(Intercept)" "disp"        "hp"          "drat"
```

Put them in a data frame

```
tibble(
  term = names(coef(m)),
  coefficient = coef(m)
)
```

```
## # A tibble: 4 × 2
##   term        coefficient
##   <chr>             <dbl>
## 1 (Intercept) 6.284507
## 2 disp        0.02635410
## 3 hp          0.006229086
## 4 drat        2.193577
```

Challenge

Can you generalize this to a function?

```
pull_coef <- function(model) {
    coefs <- coef(model)
    tibble(
      term = names(coefs),
      coefficient = coefs
      )
}
```

Test it out

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

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

unnest

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

```
## # A tibble: 12 × 5
## # Groups:   cyl [3]
##      cyl data                 model  term        coefficient
##    <dbl> <list>               <list> <chr>             <dbl>
##  1     6 <tibble [7 × 10]>  <lm>   (Intercept)  6.284507
##  2     6 <tibble [7 × 10]>  <lm>   disp         0.02635410
##  3     6 <tibble [7 × 10]>  <lm>   hp           0.006229086
##  4     6 <tibble [7 × 10]>  <lm>   drat         2.193577
##  5     4 <tibble [11 × 10]> <lm>   (Intercept) 46.08662
##  6     4 <tibble [11 × 10]> <lm>   disp        -0.1225361
##  7     4 <tibble [11 × 10]> <lm>   hp          -0.04937771
##  8     4 <tibble [11 × 10]> <lm>   drat        -0.6041857
##  9     8 <tibble [14 × 10]> <lm>   (Intercept) 19.00162
## 10     8 <tibble [14 × 10]> <lm>   disp        -0.01671461
## 11     8 <tibble [14 × 10]> <lm>   hp          -0.02140236
## 12     8 <tibble [14 × 10]> <lm>   drat         2.006011
```

Slightly nicer

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

```
## # A tibble: 12 × 3
## # Groups:   cyl [3]
##      cyl term         coefficient
##    <dbl> <chr>              <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

```r
mods %>%
    mutate(coefs = map(model, pull_coef)) %>%
    select(cyl, coefs) %>%
    unnest(coefs) %>%
    pivot_wider(
      names_from = "term",
      values_from = "coefficient"
  ) %>%
  arrange(cyl)
```

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

When to write a function?

Example

```r
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 × 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

We do this by subtracting the minimum value from each observation, then dividing that by the difference between the min/max values. For example

```
tibble(
  v1 = c(3, 4, 5),
  numerator = v1 - 3,
  denominator = 5 - 3,
  scaled = numerator / denominator
)
```

```
## # A tibble: 3 × 4
##      v1 numerator denominator scaled
##   <dbl>     <dbl>       <dbl>  <dbl>
## 1     3         0           2    0
## 2     4         1           2    0.5
## 3     5         2           2    1
```

One column

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

```
## # A tibble: 10 × 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 × 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
```

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 × 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
```

Another alternative

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))
```

03:00

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 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 (rather than every time)
    - Don't calculate things multiple times

A little cleaned up

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

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

Test it!

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

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

```r
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

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

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

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

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

Final solution

Could use `modify` here too

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

```
## # A tibble: 10 × 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 differently 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)) {
        out <- mean(x)
    }
    else {
        return()
    }
  out
}
```

Test it

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

```
## [1] 0.1855869
```

```r
mean2(c("a", "b", "c"))
```

```
## 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

- First, let's do it "by hand", then we'll wrap it in a function. We'll use `ggplot2::mpg`

```
head(mpg, n = 3)
```

```
## # A tibble: 3 × 11
##   manufacturer model displ  year   cyl trans      drv     cty   hwy fl
##   <chr>        <chr> <dbl> <int> <int> <chr>      <chr> <int> <int> <chr
## 1 audi         a4      1.8  1999     4 auto(l5)   f        18    29 p
## 2 audi         a4      1.8  1999     4 manual(m5) f        21    29 p
## 3 audi         a4      2    2008     4 manual(m6) f        20    31 p
```

Calculate all means

```
means_mpg <- map(mpg, mean2)
means_mpg
```

```
## $manufacturer
## NULL
##
## $model
## NULL
##
## $displ
## [1] 3.471795
##
## $year
## [1] 2003.5
##
## $cyl
## [1] 5.888889
##
## $trans
## NULL
##
## $drv
## NULL
##
## $cty
```

Drop NULL's

- First identify which are null

```
is_null <- map_lgl(means_mpg, is.null)
is_null
```

```
## manufacturer        model        displ         year          cyl
##         TRUE         TRUE        FALSE        FALSE        FALSE
##           fl        class
##         TRUE         TRUE
```

Subset

Use the `is_null` object to subset

```
means_mpg[!is_null]
```

```
## $displ
## [1] 3.471795
##
## $year
## [1] 2003.5
##
## $cyl
## [1] 5.888889
##
## $cty
## [1] 16.85897
##
## $hwy
## [1] 23.44017
```

Transform to a df

```
as.data.frame(means_mpg[!is_null])
```

```
##      displ   year      cyl      cty      hwy
## 1 3.471795 2003.5 5.888889 16.85897 23.44017
```

Challenge

Can you wrap all of the previous into a function?

05:00

```r
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
}
```

```r
head(mpg)
```

```
## # A tibble: 6 × 11
##   manufacturer model displ  year   cyl trans      drv     cty   hwy fl
##   <chr>        <chr> <dbl> <int> <int> <chr>      <chr> <int> <int> <chr
## 1 audi         a4      1.8  1999     4 auto(l5)   f        18    29 p
## 2 audi         a4      1.8  1999     4 manual(m5) f        21    29 p
## 3 audi         a4      2    2008     4 manual(m6) f        20    31 p
## 4 audi         a4      2    2008     4 auto(av)   f        21    30 p
## 5 audi         a4      2.8  1999     6 auto(l5)   f        16    26 p
## 6 audi         a4      2.8  1999     6 manual(m5) f        18    26 p
```

```r
means_df(mpg)
```

```
##      displ   year      cyl      cty      hwy
## 1 3.471795 2003.5 5.888889 16.85897 23.44017
```

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 ...

Pass the dots!

Redefine `means2`

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

Redefine 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
}
```

```r
means_df(airquality)
```

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

```r
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
```

Break

Functions: Part 2 upcoming

Functions: Part 2

Agenda

- Purity (quickly)
- Function conditionals
  - `if (condition) {}`
  - embedding warnings, messages, and errors
- Return values

Learning objectives

- Understand the concept of purity, and why it is often desirable
    - And be able to define a side effect
- Be able to change the behavior of a function based on the input
- Be able to embed warnings/messages/errors

Purity

A function is pure if

1. Its output depends *only* on its inputs
2. It makes no changes to the state of the world

Any behavior that changes the state of the world is referred to as a *side–effect*

Note – state of the world is not a technical term, just the way I think of it

Common side effect functions

- We've talked about a few... what are they?

A couple examples

- `print`
- `plot`
- `write.csv`
- `read.csv`
- `Sys.time`
- `options`
- `library`
- `install.packages`

Conditionals

Example

From an old lab:

> Write a function that takes two vectors of the same length and returns the total number of instances where the value is NA for both vectors. For example, given the following two vectors

```
c(1, NA, NA, 3, 3, 9, NA)
c(NA, 3, NA, 4, NA, NA, NA)
```

> The function should return a value of 2, because the vectors are both NA at the third and seventh locations. Provide at least one additional test that the function works as expected.

How do you *start* to this problem?

04:00

~~Start with writing a function~~

Solve it on a test case, then generalize!

Use the vectors to solve!

```r
a <- c(1, NA, NA, 3, 3, 9, NA)
b <- c(NA, 3, NA, 4, NA, NA, NA)
```

You try first. See if you can use these vectors to find how many elements are NA in both (should be 2).

One approach

```
is.na(a)
```

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

```
is.na(b)
```

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

```
is.na(a) & is.na(b)
```

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

```
sum(is.na(a) & is.na(b))
```

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

Generalize to function

```r
both_na <- function(x, y) {
    sum(is.na(x) & is.na(y))
}
```

What happens if not same length?

03:00

Test it

```
both_na(a, b)
```

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

```
both_na(c(a, a), c(b, b))
```

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

```
both_na(a, c(b, b)) # ???
```

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

What's going on here?

Recycling

- R will *recycle* vectors if they are divisible

```
data.frame(nums = 1:4,
           lets = c("a", "b"))
```

```
##   nums lets
## 1    1    a
## 2    2    b
## 3    3    a
## 4    4    b
```

- This will not work if they are not divisible

```
data.frame(nums = 1:3,
           lets = c("a", "b"))
```

```
## Error in data.frame(nums = 1:3, lets = c("a", "b")): arguments imply dif
```

Unexpected results

- In the `both_na` function, recycling can lead to unexpected results, as we saw
- What should we do?
- Check that they are the same length, return an error if not

Check lengths

- Stop the evaluation of a function and return an error message with `stop`, but only if a condition has been met.

Basic structure

```
both_na <- function(x, y) {
    if(condition) {
        stop("message")
    }
    sum(is.na(x) & is.na(y))
}
```

Challenge

Modify the code below to check that the vectors are of the same length. Return a *meaningful* error message if not. Test it out to make sure it works!

```
both_na <- function(x, y) {
    if(condition) {
        stop("message")
    }
    sum(is.na(x) & is.na(y))
}
```

02:00

Attempt 1

- Did yours look something like this?

```
both_na <- function(x, y) {
    if(length(x) != length(y)) {
        stop("Vectors are of different lengths")
    }
    sum(is.na(x) & is.na(y))
}
both_na(a, b)
```

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

```
both_na(a, c(b, b))
```

```
## Error in both_na(a, c(b, b)): Vectors are of different lengths
```

More meaningful error message?

What would make it more meaningful?

State the lengths of each

```
both_na <- function(x, y) {
    if(length(x) != length(y)) {
        v_lngths <- paste0("x = ", length(x),
                           ", y = ", length(y))
        stop("Vectors are of different lengths:", v_lngths)
    }
    sum(is.na(x) & is.na(y))
}
both_na(a, c(b, b))
```

```
## Error in both_na(a, c(b, b)): Vectors are of different lengths:x = 7, y
```

Clean up

- Often we don't need/want to echo the function. Set `call. = FALSE`
- We also can state the lengths on new lines

```
both_na <- function(x, y) {
    if(length(x) != length(y)) {
        v_lngths <- paste0("x = ", length(x),
                           "\n",
                           "y = ", length(y))
        stop(
          "Vectors are of different lengths:\n",
          v_lngths,
          call. = FALSE
      )
    }
    sum(is.na(x) & is.na(y))
}
```

```r
both_na(a, c(b, b))
```

```
## Error: Vectors are of different lengths:
## x = 7
## y = 14
```

Quick error messages

- For quick checks, with usually less than optimal messages, use `stopifnot`
- Often useful if the function is just for you

```
z_score <- function(x) {
  stopifnot(is.numeric(x))
  x <- x[!is.na(x)]
  (x - mean(x)) / sd(x)
}
z_score(c("a", "b", "c"))
```

```
## Error in z_score(c("a", "b", "c")): is.numeric(x) is not TRUE
```

```
z_score(c(100, 115, 112))
```

```
## [1] -1.1338934  0.7559289  0.3779645
```

warnings

If you want to embed a warning, just swap out `stop()` for `warning()`

Extension

- Let's build out a warning if the vectors are different lengths, but the ARE recyclable.

Modulo operator

`%%` returns the remainder in a division problem. So `8 %% 2` and `8 %% 4` both return zero (because there is no remainder), while and `7 %% 2` returns 1 and `7 %% 4` returns 3.

One approach

Note the double condition

```
both_na <- function(x, y) {
    if(length(x) != length(y)) {
        lx <- length(x)
        ly <- length(y)

        v_lngths <- paste0("x = ", lx, ", y = ", ly)

        if(lx %% ly == 0 | ly %% lx == 0) {
            warning("Vectors were recycled (", v_lngths, ")")
        }
        else {
            stop("Vectors are of different lengths and are not re
                 v_lngths)
        }
    }
    sum(is.na(x) & is.na(y))
}
```

Test it

```
both_na(a, c(b, b))
```

```
## Warning in both_na(a, c(b, b)): Vectors were recycled (x = 7, y = 14)
```

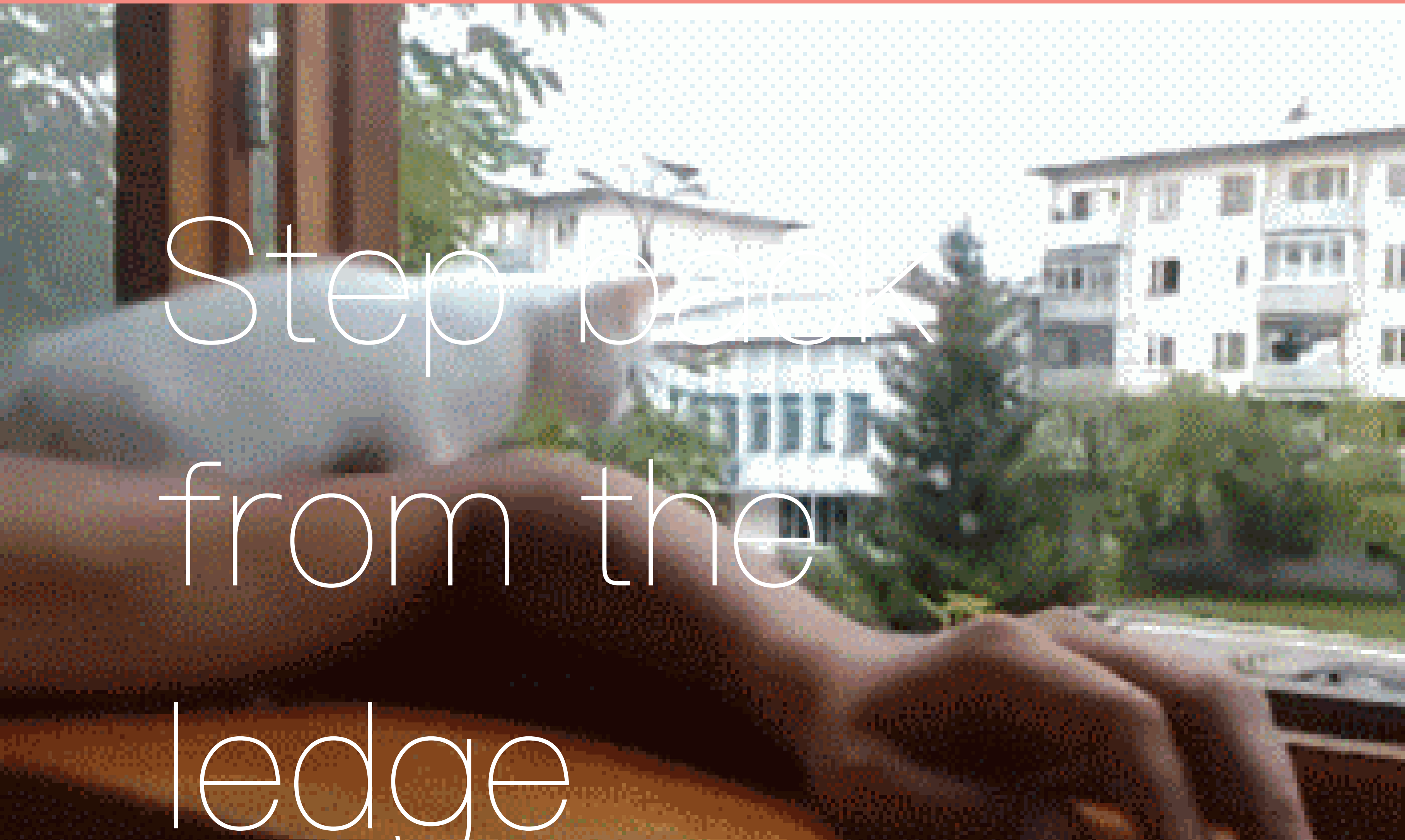
```
## [1] 4
```

```
both_na(a, c(b, b)[-1])
```

```
## Error in both_na(a, c(b, b)[-1]): Vectors are of different lengths and a
```

Refactoring

- Refactoring means changing the internals, but the output stays the same
- Next week, we'll refactor this function to make it more readable


Step back
from the
ledge

How important is this?

- For most of the work you do? Not very
- Develop a package? Very!
- Develop functions that others use, even if not through a package? Sort of.

Return values

Thinking more about return values

- By default the function will return the last thing that is evaluated
- Override this behavior with `return`
- This allows the return of your function to be conditional
- Generally the last thing evaluated should be the "default", or most common return value

Pop quiz

- What will the following return?

```
add_two <- function(x) {
    result <- x + 2
}
```

Answer: Nothing! Why?

```
add_two(7)
add_two(5)
```

Specify the return value

The below are all equivalent, and all result in the same function behavior

```r
add_two.1 <- function(x) {
    result <- x + 2
    result
}
add_two.2 <- function(x) {
    x + 2
}
```

```r
add_two.3 <- function(x) {
    result <- x + 2
    return(result)
}
```

When to use `return`?

Generally reserve `return` for you're returning a value prior to the full evaluation of the function. Otherwise, use `.1` or `.2` methods from prior slide.

Thinking about function names

Which of these is most intuitive?

```
f <- function(x) {
    x <- sort(x)
    data.frame(value = x,
               p = ecdf(x)(x))
}

ptile <- function(x) {
    x <- sort(x)
    data.frame(value = x,
               ptile = ecdf(x)(x))
}
percentile_df <- function(x) {
    x <- sort(x)
    data.frame(value = x,
               percentile = ecdf(x)(x))
}
```

Output

- The descriptive nature of the output can also help

- Maybe a little too tricky but...

```
percentile_df <- function(x) {
    arg <- as.list(match.call())
    x <- sort(x)
    d <- data.frame(value = x,
                    percentile = ecdf(x)(x))

    names(d)[1] <- paste0(as.character(arg$x), collapse = "_")
    d
}
```

```r
random_vector <- rnorm(100)
tail(percentile_df(random_vector))
```

```
##     random_vector percentile
## 95       1.777044       0.95
## 96       1.827628       0.96
## 97       1.905176       0.97
## 98       2.222762       0.98
## 99       2.602469       0.99
## 100      2.633710       1.00
```

```r
head(percentile_df(rnorm(50)))
```

```
##    rnorm_50 percentile
## 1 -2.454277       0.02
## 2 -2.428808       0.04
## 3 -2.035993       0.06
## 4 -1.508518       0.08
## 5 -1.226605       0.10
## 6 -1.114624       0.12
```

How do we do this?

- I often debug functions and/or figure out how to do something within the function by changing the return value & re-running the function multiple times

[demo]

Thinking about dependencies

- What's the purpose of the function?
    - Just your use? Never needed again? Don't worry about it at all.
    - Mass scale? Worry a fair bit, but make informed decisions.
- What's the likelihood of needing to reproduce the results in the future?
    - If high, worry more.
- Consider using name spacing (`::`)

Next time

More functions and Lab 3