Expressing yourself in R

February 2015

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HELLO

my name is

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Goals:

Learn effective strategies for writing functions.

Learn how to use functional programming to make your code clearer & easier to write.

Warmups

Your turn

Introduce yourself to your neighbours. Who are you and what are you using R for?

What does this function return?

```
y <- 10
g <- function() {
  x <- 5
  c(x = x, y = y)
}
g()
```

```
y <- 10
g <- function() {
  x <- 5
  c(x = x, y = y)
}
g()
#> x  y
#> 5 10
```

What does this function return the 1st time it's run?

The 2nd time?

```
j <- function() {
  if (!exists("a")) {
    a <- 5
  } else {
    a <- a + 1
  }
  a
}
j()

j()
```

```
j <- function() {
  if (!exists("a")) {
    a <- 5
  } else {
    a <- a + 1
  }
  a
}
j()
#> [1] 5
j()
#> [1] 5
```

Your turn

Every function has three key properties that defines its behaviour. What are they?

```r
add <- function(x, y) {
  x + y
}
formals(add)
body(add)
environment(add)
# Environment controls scoping
# (value lookup)

# Is the name important?
```

Your turn

How would you normally write this code?

```
`+`(1, `*`(2, 3))
```

```
`+` <- function(x, y) {
  if (runif(1) < 0.01) {
    sum(x, y) * 1.1
  } else {
    sum(x, y)
  }
}
```

To understand computations in R, two slogans are helpful:

- Everything that **exists** is an object.
- Everything that **happens** is a **function call**.

—*John Chambers*

How to write a function

Your turn

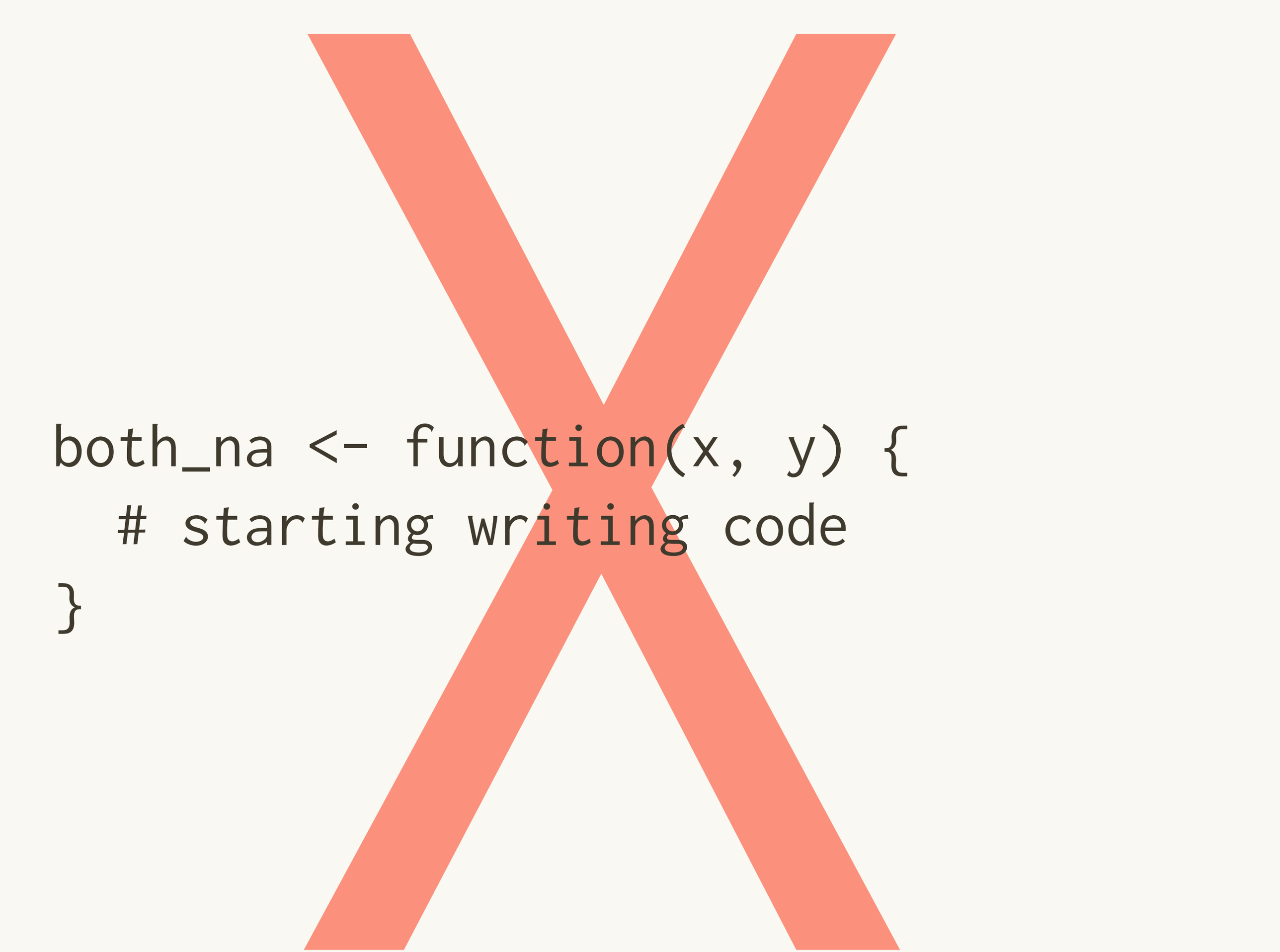
Which is easier?

a) Figure out how to solve a problem in general, then use that understand to solve a specific problem?

b) Solve an example and then figure out how to generalise?

Challenge

Given two vectors (of the same length) how many positions have an NA in the same place in both vectors?



```
both_na <- function(x, y) {
  # starting writing code
}
```

Your turn

```
# Write code to determine how many positions
# have an NA in both vectors.
```

```
x <- c(1, 1, NA, NA)
y <- c(1, NA, 1, NA)

# Correct answer is 1
```

There are two approaches to solve this problem:

```r
# Think about positions
length(intersect(which(is.na(x)), which(is.na(y))))
length(which(which(is.na(x)) %in% which(is.na(y))))
```

```r
# Boolean algebra
is.na(x) & is.na(y)
sum(is.na(x) & is.na(y))
```

Create a function after you've solved the problem!

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

```
both_na(x, y)

# What happens if x and y aren't the same length?
# What should happen?
```

Why write a function?

Duplicated code hides intent

```
sum(is.na(df$age1) & is.na(df$age2))
sum(is.na(df$year1) & is.na(df$year2))
sum(is.na(df$sex1) & is.na(df$year2))
sum(is.na(df$trt1) & is.na(df$trt2))
sum(is.na(df$year1) & is.na(df$year2))
sum(is.na(df$sex1) & is.na(df$sex2))
sum(is.na(df$bar1) & is.na(df$bar2))
sum(is.na(df$foobar1) & is.na(df$foobar2))
sum(is.na(df$xyz1) & is.na(df$xyz2))
sum(is.na(df$abc1) & is.na(df$abc2))
sum(is.na(df$def1) & is.na(df$def2))
sum(is.na(df$ghi1) & is.na(df$ghi2))
```

Duplicated code = opportunities for errors

Rule of thumb: 3 copies is ok

```
sum(is.na(df$abc1) & is.na(df$abc2))
sum(is.na(df$def1) & is.na(df$def2))
sum(is.na(df$ghi1) & is.na(df$ghi2))
```

Time to write a function:

```
sum(is.na(df$abc1) & is.na(df$abc1))
sum(is.na(df$def1) & is.na(df$def2))
sum(is.na(df$ghi1) & is.na(df$ghi2))
sum(is.na(df$jkl1) & is.na(df$jkl2))
```

Duplicated code = opportunities for errors

Rule of thumb: 3 copies is ok

```
sum(is.na(df$abc1) & is.na(df$abc2))
sum(is.na(df$def1) & is.na(df$def2))
sum(is.na(df$ghi1) & is.na(df$ghi2))
```

Time to write a function:

```
both_na(df$abc1, df$abc2)
both_na(df$def1, df$def2)
both_na(df$ghi1, df$ghi2)
both_na(df$jkl1, df$jkl2)
```

(We'll learn how to deal with duplicated function calls later)

What does this code do?

```
passionn <- min(comp$passion,na.rm=T)
passionx <- max(comp$passion,na.rm=T)-passionn

leadershipn <- min(comp$leadership,na.rm=T)
leadershipx <- max(comp$leadership,na.rm=T)-leadershipn

loyaltyn <- min(comp$loyalty,na.rm=T)
loyaltyx <- max(comp$loyalty,na.rm=T)-loyaltyn

basicServn <- min(comp$basicServ,na.rm=T)
basicServx <- max(comp$basicServ,na.rm=T)-basicServn

educationn <- min(comp$education,na.rm=T)
educationx <- max(comp$education,na.rm=T)-educationn

safetyn <- min(comp$safety,na.rm=T)
safetyx <- max(comp$safety,na.rm=T)-safetyn

...
```

What does this code do?

```
cityagg <- ddply(dat,.(city),summarise,
  wt=sum(svywt),
  people=length(svywt),
  passion=sum(svywt*((passion-passionn)/passionx),na.rm=T)/sum(svywt[!is.na(passion)]),
  leadership=sum(svywt*((leadership-leadershipn)/leadershipx),na.rm=T)/sum(svywt[!is.na(leadership)]),
  loyalty=sum(svywt*((loyalty-loyaltyn)/loyaltyx),na.rm=T)/sum(svywt[!is.na(loyalty)]),
  basicServ=sum(svywt*((basicServ-basicServn)/basicServx),na.rm=T)/sum(svywt[!is.na(basicServ)]),
  education=sum(svywt*((education-educationn)/educationx),na.rm=T)/sum(svywt[!is.na(education)]),
  safety=sum(svywt*((safety-safetyn)/safetyx),na.rm=T)/sum(svywt[!is.na(safety)]),
  aesthetic=sum(svywt*((aesthetic-aestheticn)/aestheticx),na.rm=T)/sum(svywt[!is.na(aesthetic)]),
  economy=sum(svywt*((economy-economyn)/economyx),na.rm=T)/sum(svywt[!is.na(economy)]),
  socialOff=sum(svywt*((socialOff-socialOffn)/socialOffx),na.rm=T)/sum(svywt[!is.na(socialOff)]),
  civicInv=sum(svywt*((civicInv-civicInvn)/civicInvx),na.rm=T)/sum(svywt[!is.na(civicInv)]),
  openness=sum(svywt*((openness-opennessn)/opennessx),na.rm=T)/sum(svywt[!is.na(openness)]),
  socialCap=sum(svywt*((socialCap-socialCapn)/socialCapx),na.rm=T)/sum(svywt[!is.na(socialCap)]),
  domains=sum(svywt*((domains-domainsn)/domainsx),na.rm=T)/sum(svywt[!is.na(domains)]),
  comOff=sum(svywt*((comOff-comOffn)/comOffx),na.rm=T)/sum(svywt[!is.na(comOff)]),
  comAttach=sum(svywt*((comAttach-comAttachn)/comAttachx),na.rm=T)/sum(svywt[!is.na(comAttach)])
)
```

What variables do you need?

```
passionn <- min(comp$passion,na.rm=T)
passionx <- max(comp$passion,na.rm=T)-passionn
```

```
sum(comp$svywt*((comp$passion-passionn)/
passionx),na.rm=T)/sum(comp$svywt[!is.na(comp
$passion)])
```

What variables do you need?

```
passionn <- min(comp$passion,na.rm=T)
passionx <- max(comp$passion,na.rm=T)-passionn

sum(comp$svywt*((comp$passion-passionn)/
passionx),na.rm=T)/sum(comp$svywt[!is.na(comp
$passion)])
```

What should you call them?

```
passionn <- min(comp$passion,na.rm=T)
passionx <- max(comp$passion,na.rm=T)-passionn
sum(comp$svywt*((comp$passion-passionn)/
passionx),na.rm=T)/sum(comp$svywt[!is.na(comp
$passion)])
```

What should you call them?

```
min_x <- min(x,na.rm=T)
rng_x <- max(x,na.rm=T)-min_x
sum(wt*((x-min_x)/rng_x),na.rm=T)/sum(wt[!is.na(x)])
```

How can you improve this function?

```
f <- function(x, wt) {
  min_x <- min(x, na.rm = TRUE)
  rng_x <- max(x, na.rm = TRUE) - min_x

  sum(wt * ((x - min_x)/rng_x), na.rm = TRUE) /
    sum(wt[!is.na(x)])
}
```

What's the intent of `na.rm = TRUE`?

```
rescale01 <- function(x) {
  rng <- range(x, na.rm = TRUE)
  (x - rng[1]) / (rng[2] - rng[1])
}
```

```
f <- function(x, wt) {
  sum(wt * rescale01(x), na.rm = TRUE) /
    sum(wt[!is.na(x)])
}
```

```r
rescale01 <- function(x) {
  rng <- range(x, na.rm = TRUE)
  (x - rng[1]) / (rng[2] - rng[1]
}

# Is this better?
f <- function(x, wt) {
  wt <- wt[!is.na(x)]
  x <- x[!is.na(x)]

  sum(wt * rescale01(x)) / sum(wt)
}
```

```r
rescale01 <- function(x) {
  rng <- range(x, na.rm = TRUE)
  (x - rng[1]) / (rng[2] - rng[1]
}

# Is this better?
f <- function(x, wt) {
  # First, remove rows correspond to missing x
  wt <- wt[!is.na(x)]
  x <- x[!is.na(x)]

  sum(wt * rescale01(x)) / sum(wt)
}
```

Is this better?

```
rescale01 <- function(x) {
  rng <- range(x, na.rm = TRUE)
  (x - rng[1]) / (rng[2] - rng[1]
}
```

```
f <- function(x, wt) {
  wt_not_miss <- wt[!is.na(x)]
  x_not_miss <- x[!is.na(x)]

  sum(wt_not_miss * rescale01(x_not_miss)) /
    sum(wt_not_miss)
}
```

Is this better?

```
rescale01 <- function(x) {
  rng <- range(x, na.rm = TRUE)
  (x - rng[1]) / (rng[2] - rng[1]
}
```

```
f <- function(x, wt) {
  weighted.mean(rescale01(x), wt, na.rm = TRUE)
}
```

How do you write a good function?

Your turn

With your neighbours, brainstorm what makes a good (or bad!) function.

What makes a good function?

Correct

Understandable

Obviously correct

Fast (enough)

Important to think about other tensions

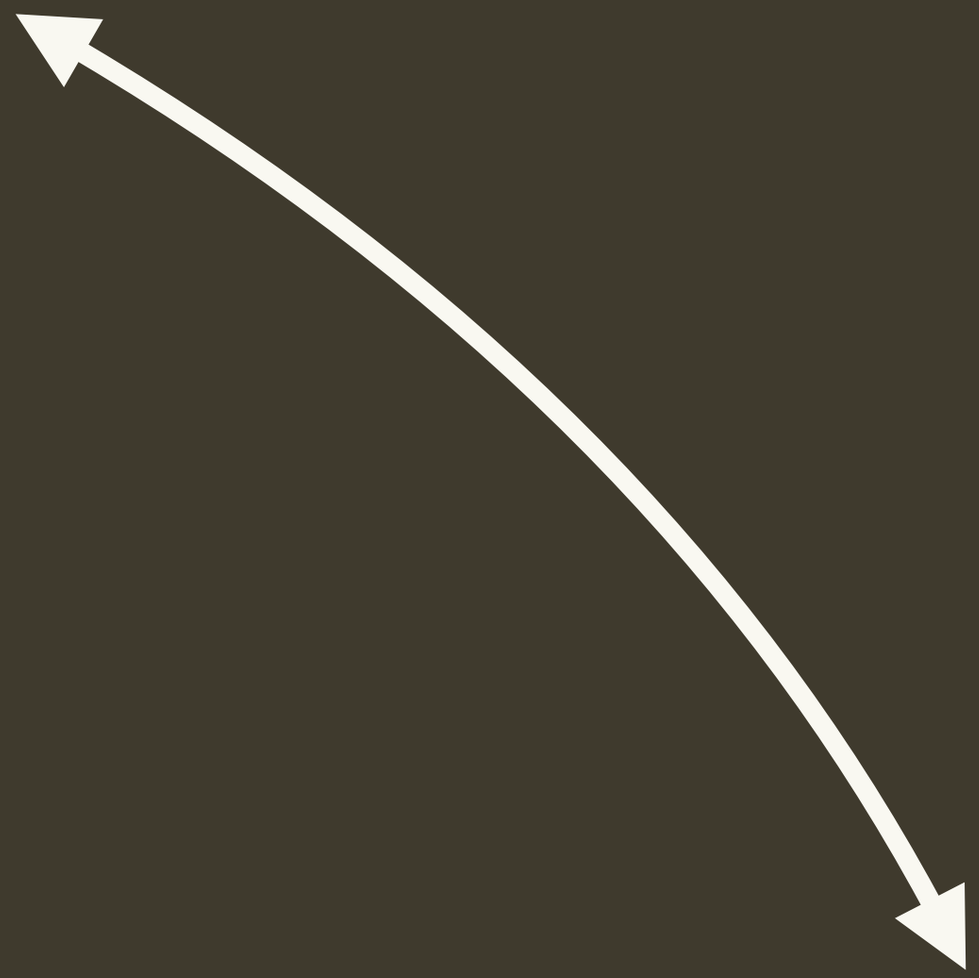
Fast to write ⟷ Fast to read

Easy ⟷ Robust

Verbose ⟷ Clever

Simple ⟷ General

Verbose



Clever

```
# Imagine you have a vector of events that you
# want to divide into groups. You know when
# an event ends. How could you generate a
# unique integer for each group?

x <- sample(c(TRUE, FALSE), prob = c(0.2, 0.8),
  100, replace = TRUE)

# Brainstorm for 2 minutes
```

Uses very simple ideas, but many places to make mistakes

```
group <- 1
out <- numeric(length(x))
out[1] <- group
for (i in 2:length(x)) {
  if (x[i]) {
    group <- group + 1
  }
  out[i] <- group
}
out
```

```r
# Too clever?
cumsum(x) + !x[1]

# Little less clever
cumsum(x) + if(!x[1]) 1 else 0

# Reasonably obvious & has place for comment
grp <- cumsum(x)
if (!x[1]) # first group should start at 1
  grp <- grp + 1
```

```r
f1 <- function(x, y, z) {
  if (x) {
    out <- y
  } else {
    out <- z
  }
  return(out)
}
```

```r
f2 <- function(x, y, z) {
  if (x) {
    return(y)
  } else {
    return(z)
  }
}
```

```r
f3 <- function(x, y, z) {
  if (x) {
    y
  } else {
    z
  }
}
```

```r
f4 <- function(x, y, z) {
  if (x) y else z
}
```

Which is best?

Use explicit return() only for early exit

```
f <- function(x, y) {
  if (x == 0) {
    return(NA)
  }

  y / x
}
```

Other common complications

```
x[-which(is.na(x))]
x[which(!is.na(x))]
x[!is.na(x)]

x == TRUE
x

x == FALSE
!x

y == "a" | y == "b" | y == "c"
y %in% c("a", "b", "c")
```

```r
# What does this code do?
paste0(
  "Good ",
  if (time <= 12) "morning" else "afternoon",
  ".",
  if (some_var) "This is extra text."
)

# What does (if (FALSE) 3) return?
# What does paste0("x", NULL) return?
```

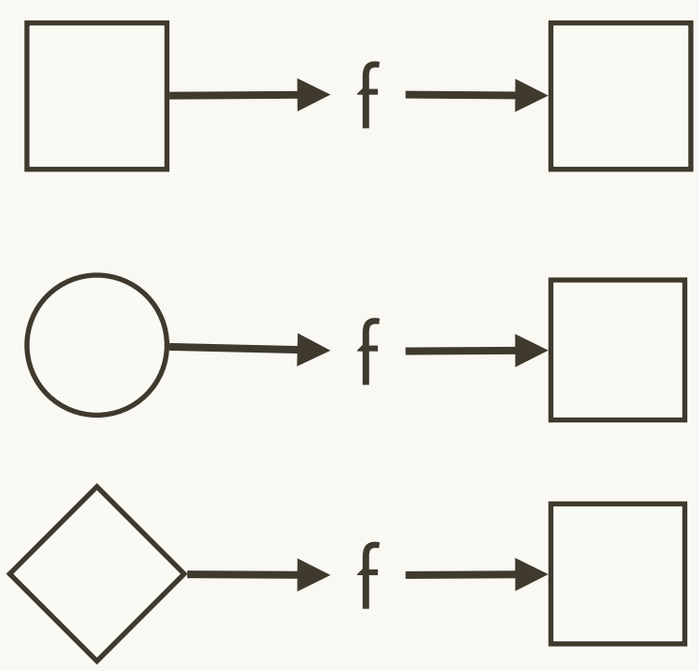
Easy

Robust

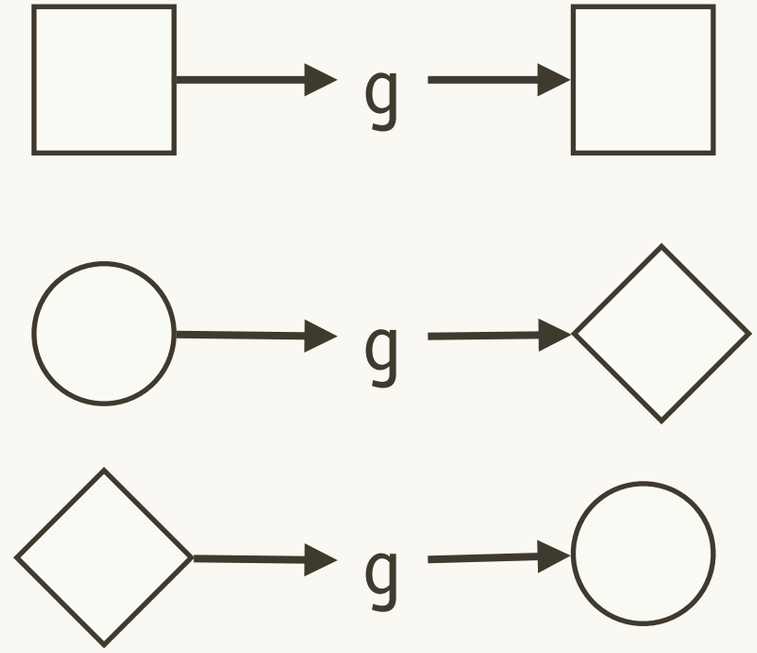
When does this function break down?

```
col_means <- function(df) {
  numeric <- sapply(df, is.logical)
  numeric_cols <- df[, numeric]

  data.frame(lapply(numeric_cols, mean))
}
```

For robust code, prefer type-stable functions



Regardless of the input, a type-stable function gives the same type of output



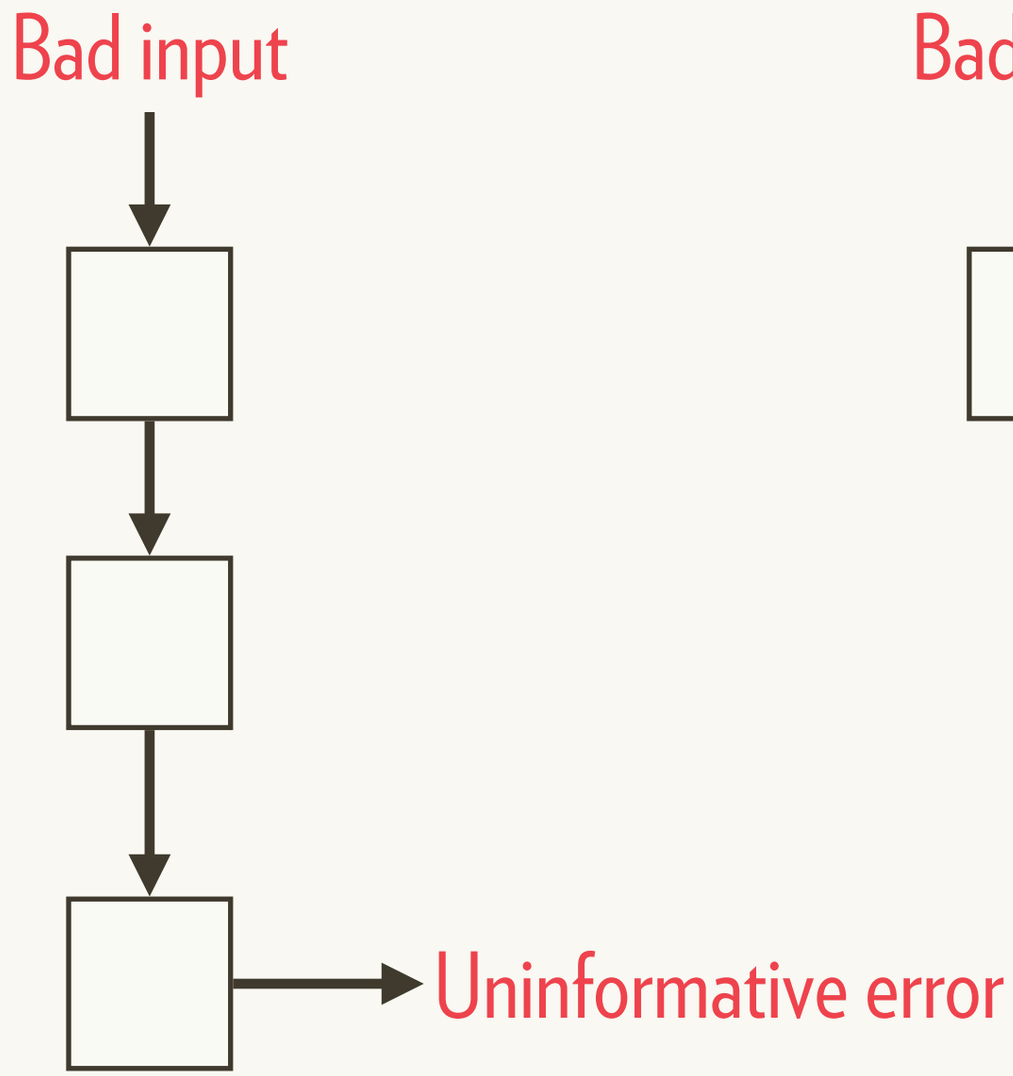
A type-unstable function is like a box of chocolates...

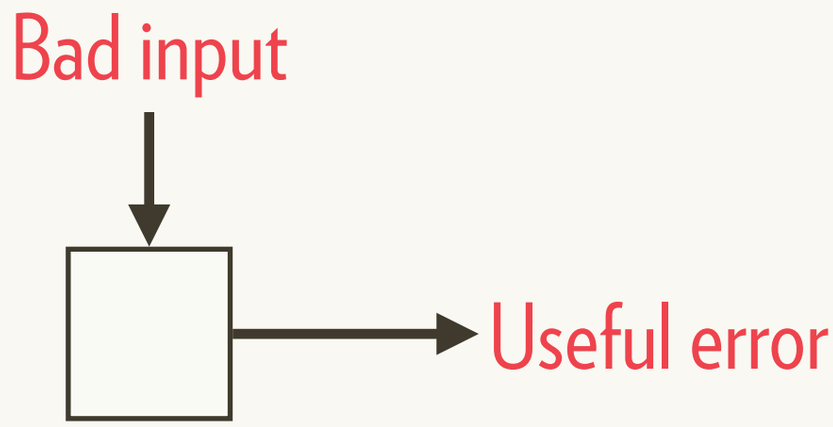
Your turn?

What are some common type-unstable functions in base R?

```
# Many very important functions are impure
$, [[, [

# Others are fine for interactive use
# but can blow up in production code
[.data.frame()
sapply()
cbind()

# Dangerous because they always succeed
unlist()
c()
```

For robust code, fail early

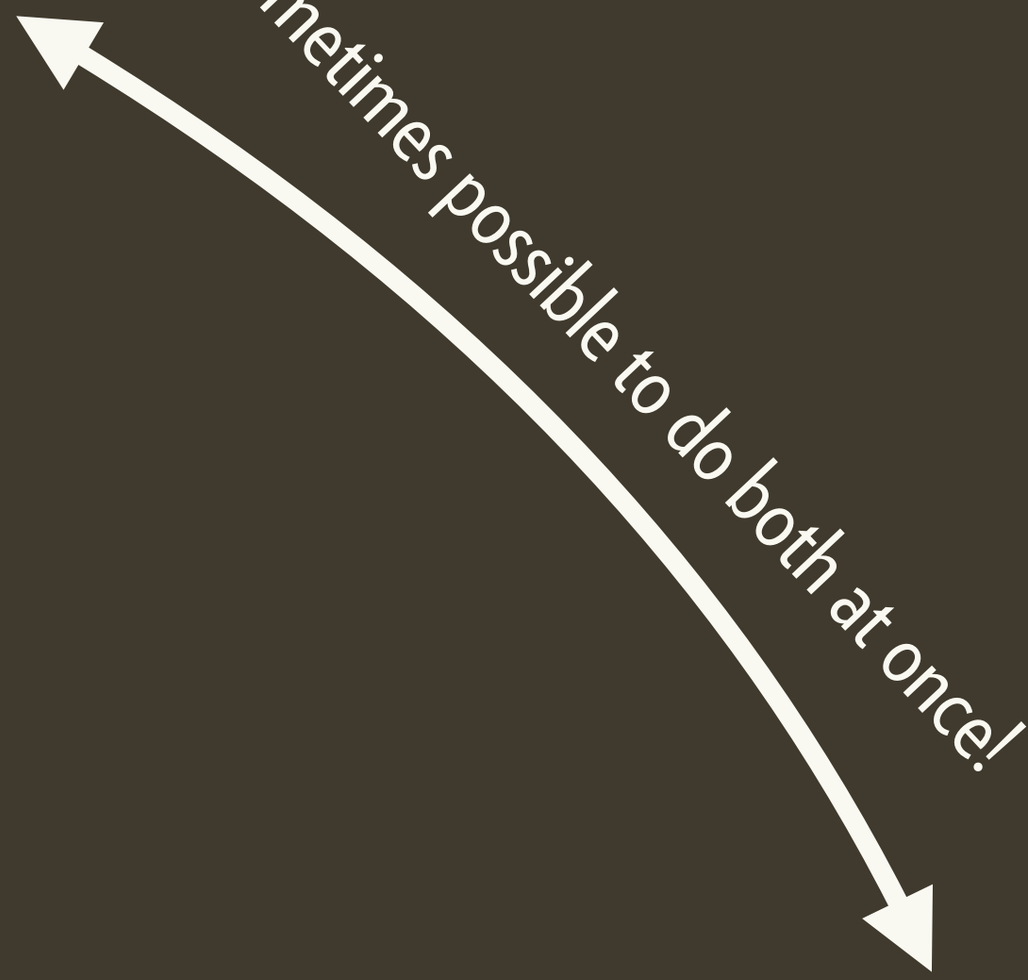




```r
both_na <- function(x, y) {
  stopifnot(length(x) == length(y))

  sum(is.na(x) & is.na(y))
}
```

```r
both_na <- function(x, y) {
  if (length(x) != length(y))
    stop("`x` and `y` must be the same length.")

  sum(is.na(x) & is.na(y))
}

both_na(c(TRUE, FALSE), c(T, F, F, T))
```

Simple



General

What's the goal of this function?

```
impute_na1 <- function(x) {
  for (i in 2:length(x)) {
    if (x[i] == "NA") {
      x[i] <- (x[i - 1] + x[i + 1]) / 2
    } else {
      x[i] <- x[i]
    }
  }
  x
}
impute_na1(c(1, 4, 5, "NA", 10, 13, 10))
```

What's wrong with this function?

```
impute_na1 <- function(x) {
  for (i in 2:length(x)) {
    if (x[i] == "NA") {
      x[i] <- (x[i - 1] + x[i + 1]) / 2
    } else {
      x[i] <- x[i]
    }
  }
  x
}
impute_na1(c(1, 4, 5, "NA", 10, 13, 10))
```

```
impute_na2(c(1, 4, 5, "NA", 10, 13, 10))
```

```
impute_na2(c(1, 4, 5, NA, 10, 13, 10))
```

Your turn

For what other inputs will `input_na2()` fail? (Think about boundaries)

What should the answers be?

```
impute_na2(numeric())
impute_na2(NA_real_)

impute_na2(c(1, NA))
impute_na2(c(1, NA, NA, 2))
impute_na2(c(NA, 2))
```

A more general implementation

```
impute_na3 <- function(x) {
  miss <- is.na(x)
  interp <- approxfun(which(!miss), x[!miss])

  x[miss] <- interp(which(miss))
  x
}
```

Your turn

Discuss how the function works.

Argue about the behaviour of:

```
impute_na3(c(NA, NA))
impute_na3(c(NA, NA, 1))
impute_na3(c(NA, NA, 1, 2))
```

Vocabulary is important!

Documented

Tested

Existing function ›› New function

Standard name

More general

Name

"A rose by any other name
would smell as sweet."

— *Shakespeare*

"A function by any other name
would not smell as sweet."

— *Hadley Wickham*