Functions

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Warmups

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()
```

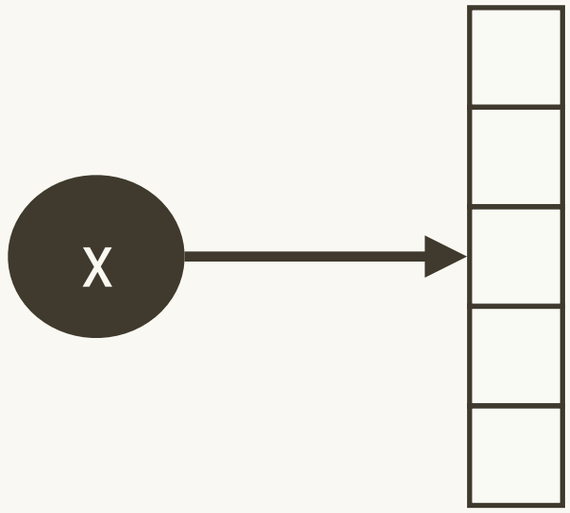
```
j <- function() {
  if (!exists("a")) {
    a <- 5
  } else {
    a <- a + 1
  }
  a
}
j()
#> [1] 5
j()
#> [1] 5
```

Your turn

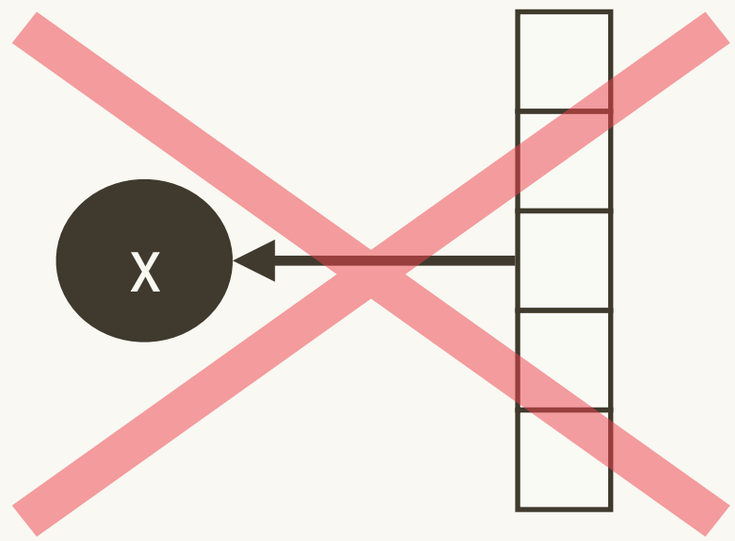
Every function has three key properties that defines its behaviour. What are they?

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

# Is the name important?
# How many names can a function have?
```

Remember:



A name “has” an object



An object doesn’t have a name

Your turn

How would you normally write this code?

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

In R, any function can use **prefix** form

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

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

```
1 + 2 * 3
```

This lets you do crazy things like redefine +

```
`+` <- 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

# If you finish early make a function,
# then think about what should happen if
# x and y aren't the same lengths
```

There are two approaches to solve this problem:

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

# 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?
```

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 in the next section)

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)])
}
```

Is this better?

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

```
f <- function(x, wt) {
  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) {
  # 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) {
  missing <- is.na(x) | is.na(wt)

  sum(wt[!missing] * rescale01(x[!missing])) /
    sum(wt[!missing])
}
```

Is this better?

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

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

  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) {
  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

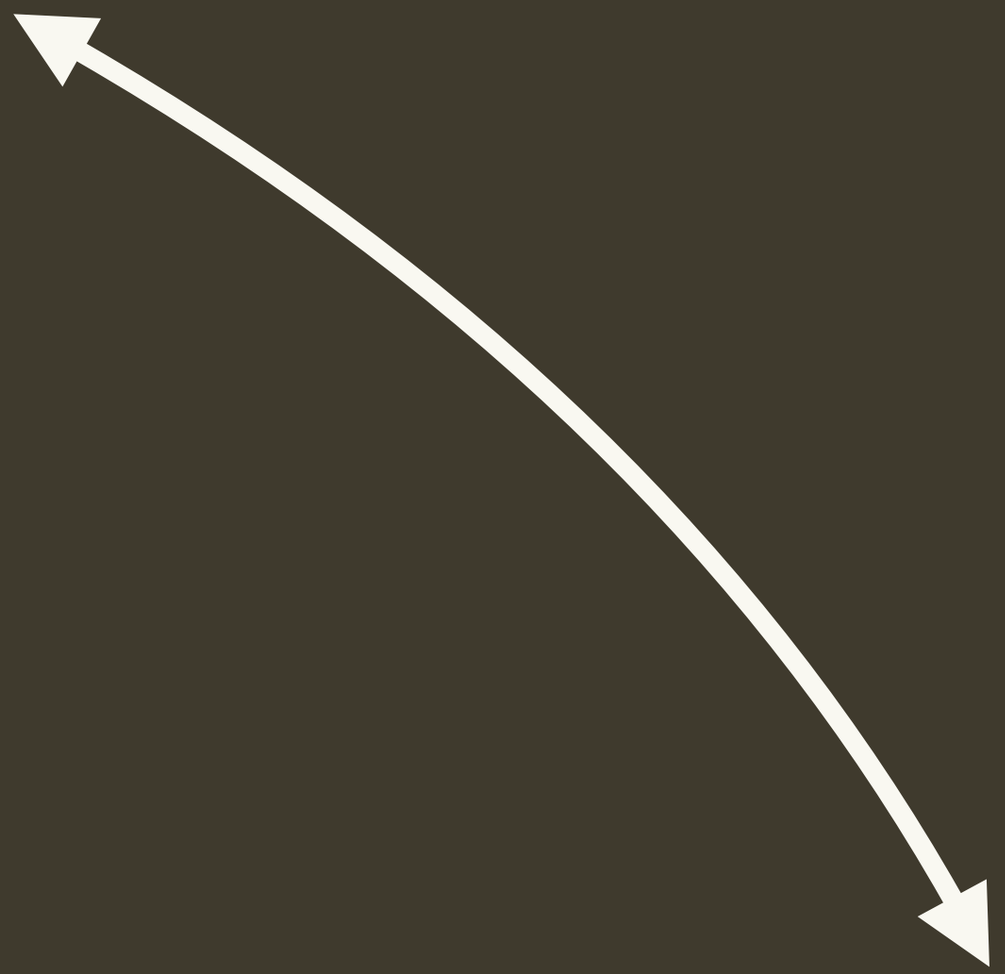
Helpful ⟷ Strict

Verbose ⟷ Clever

Specialised ⟷ General

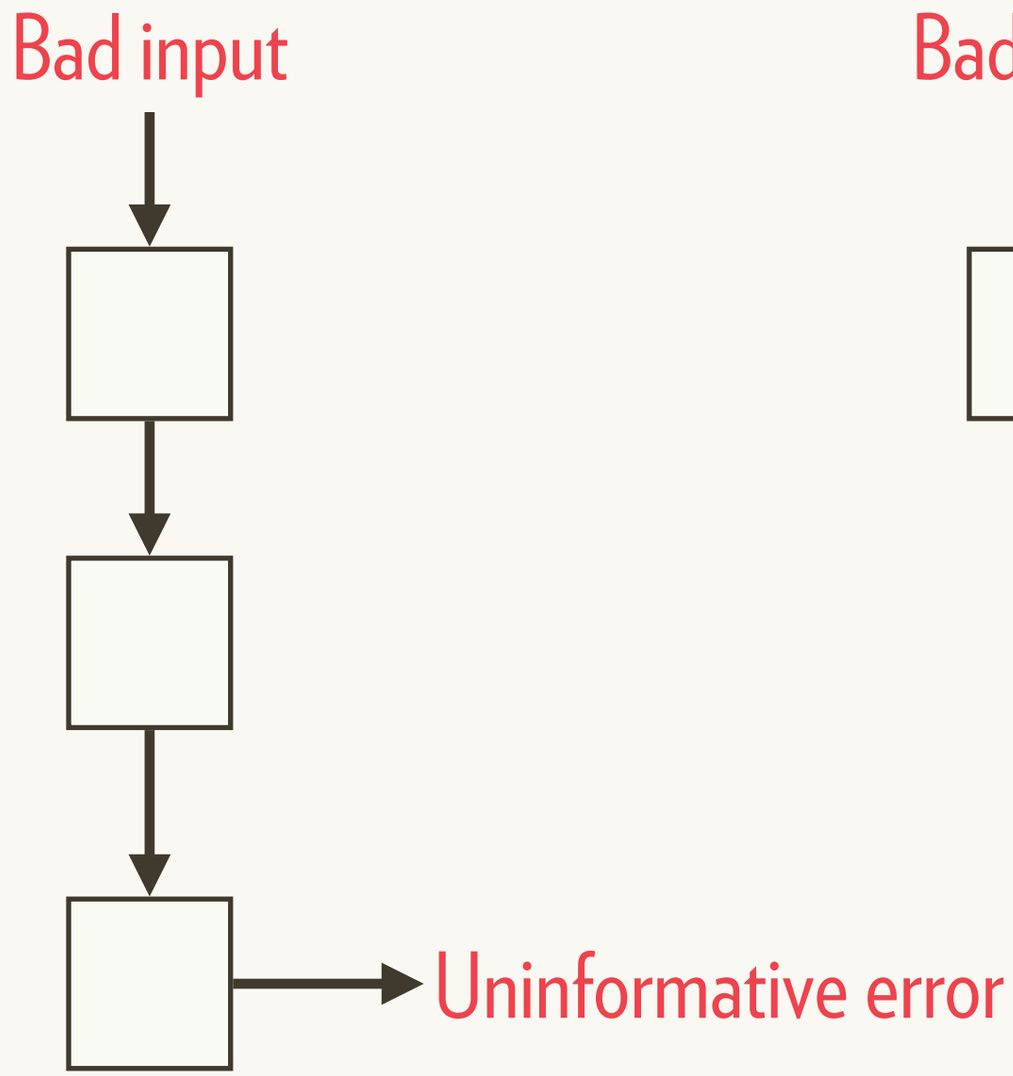
Isolated ⟷ Contextual

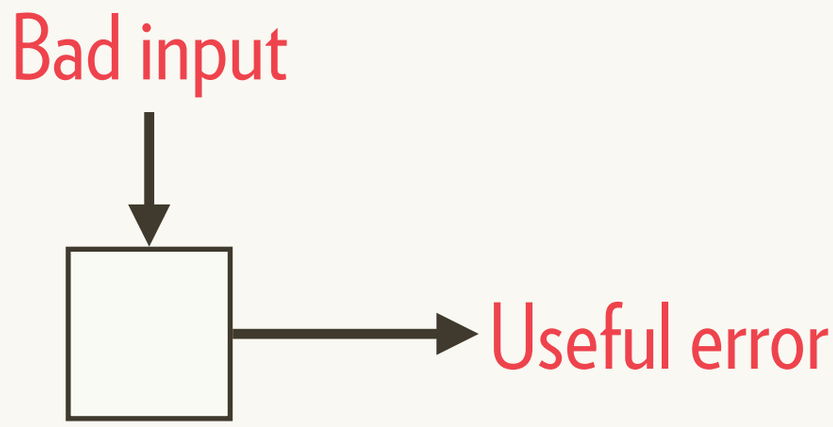
Helpful



Strict

For robust code, fail early





Best

Right answer

Useful error

Not useful error

Worst

Wrong answer

```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))
```

Some specialised packages exist to make this easier

```
gapminder %>%
  verify(nrow(.) == 1704) %>%
  verify(ncol(.) == 6) %>%
  verify(is.factor(.$continent)) %>%
  verify(length(levels(.$continent)) == 5)
```

assertr

assertthat

assertive

ensurer

testdat

valdeece

http://biol548o.github.io/assert.html

Data frames are helpful

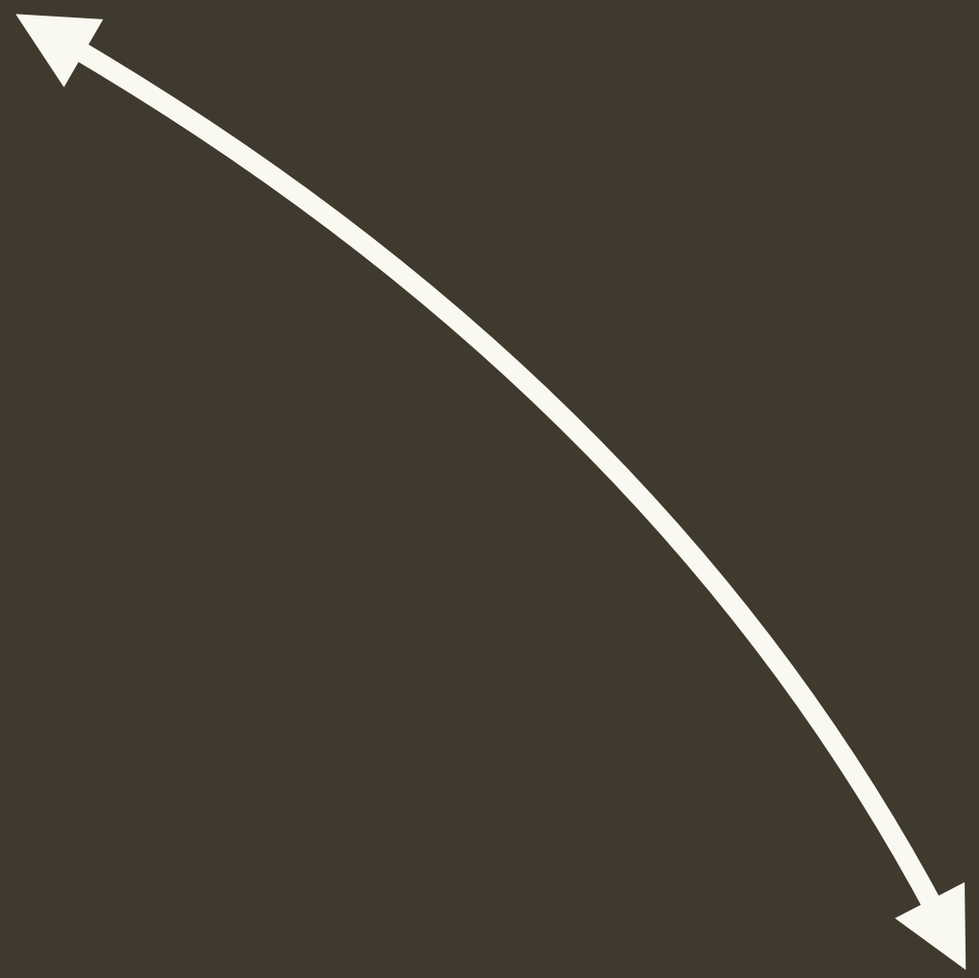
```r
df <- data.frame(xy = c("x", "y"))
# Character vectors work hard to work with for a long
# time, so R helpfully converts to a factor for you:
class(df$xy)

# If you're only selecting a single column, R tries to
# be helpful and give you that column, rather than
# giving you a single column data frame
class(df[, "xy"])

# If you have long variable names, R is "helpful" and
# lets you select them with a unique prefix
df$x
```

tibbles are strict

```
library(tibble)

df2 <- as_data_frame(xy = c("x", "y"))

# Never coerces
class(df2$xy)

# Always returns another tibble
class(df2[, "xy"])

# Complains if variable doesn't exist
df2$x
df2$z
```

https://blog.rstudio.org/2016/03/24/tibble-1-0-0/

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 <- c(F, F, T, F, F, F, F, T, F, T)
# want to get:
y <- c(1, 1, 2, 2, 2, 2, 2, 3, 3, 4)

# Brainstorm for 1 minute
```

Uses very simple ideas, but many places to make mistakes

```
  out <- numeric(length(x))
  out[1] <- group <- 1
  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]) 0 else 1
```

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

Use explicit return() only for early exit

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

  y / x
}
```

```r
f <- function(x, y) {
  if (x == 0) {
    NA
  } else { # x != 0
   # Many lines
   # of complicated
   # code go
   # here
   # even more than this
   y / x
  } # end x != 0
}
```

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")
```

Isolated

Contextual

Principle: less context needed = clearer code

```
baz <- foo(bar, qux)
```

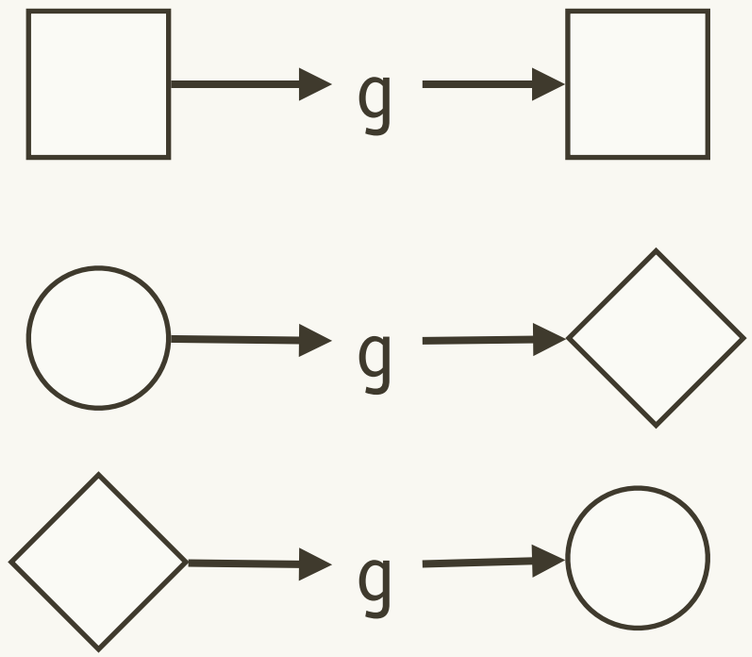
vs

```
df2 <- arrange(df, qux)
```

Your turn: what will these calls do?

```
df[, vars]
filter(df, x == y)
data.frame(x = "a")
```

Three classes of surprises




```
filter(df, x == y)
```

Non-standard evaluation

Unstable types

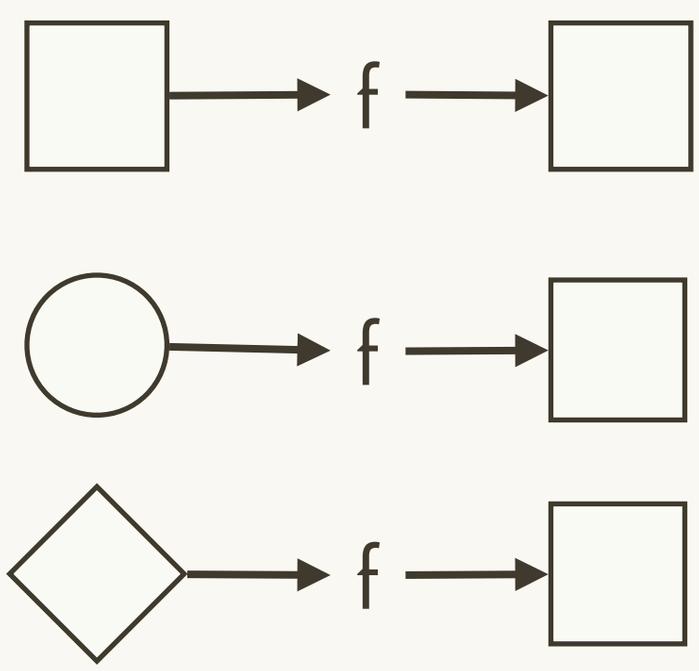
```
getOption("stringsAsFactors")
```

```
data.frame()
```

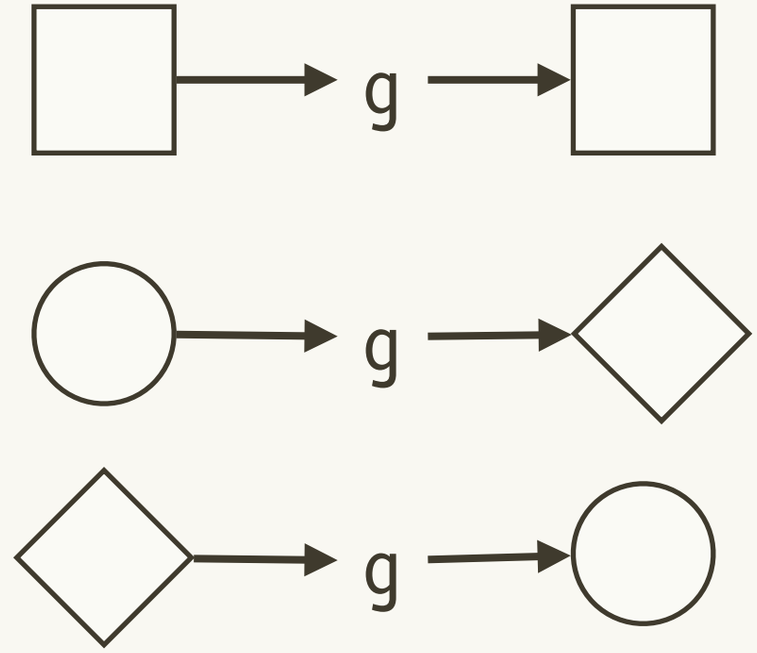
Hidden arguments

Unstable types

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...

This function uses two type-unstable functions

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

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

We'll come back to this code later

Non-standard evaluation

How can this function fail?

```
big_x <- function(df, threshold) {
  dplyr::filter(df, x > threshold)
}
```

Two modes of silent failure

```
x <- 1
big_x(mtcars, 10)
```

```
df <- dplyr::data_frame(x = 1:10, threshold = 100)
big_x(df, 5)
```

Currently have to do

```
big_x <- function(df, threshold) {
  if (!"x" %in% names(df))
    stop("`df` must contain variable called `x`.", call. = FALSE)

  if ("threshold" %in% names(df))
    stop("`df` must not contain variable called `threshold`.",
      call. = FALSE)

  dplyr::filter(df, x > threshold)
}
```

In future version:

```
big_x <- function(df, threshold) {
  dplyr::filter(df, .data$x > .env$threshold)
}
```

See http://rpubs.com/hadley/lazyeval for more details

Alternative in base R

```
big_x <- function(df, threshold) {
  rows <- df[["x"]] > threshold
  df[rows & !is.na(rows), , drop = FALSE]
}

# But have to remember all the details of
# exactly what filter() does; and remember
# that $ is helpful
```

Hidden parameters

Biggest offenders

`stringsAsFactors`

System language

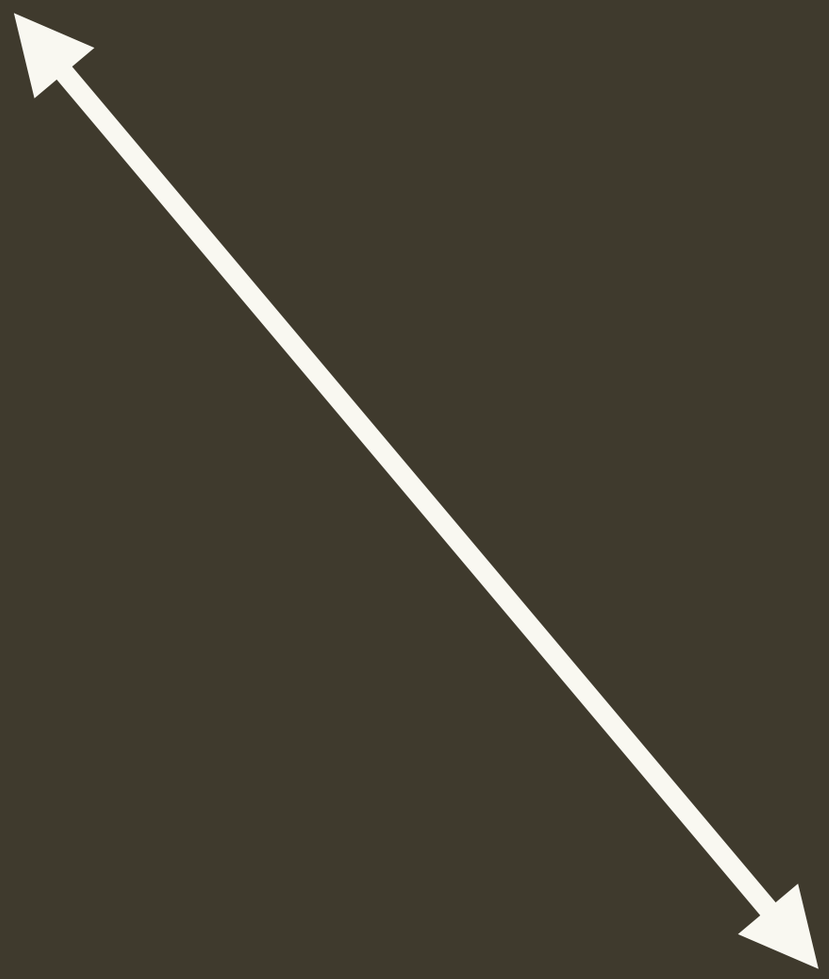
`na.action`

Time zone

Default text encoding

Only use options() to control side-effects of a function. The value of an option should **never** affect the return value of a function

Specialised



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
    }
  }
  x
}
```

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
    }
  }
  x
}
impute_na1(c(1, 4, 5, "NA", 10, 13, 10))
```

When will this function fail?

```
impute_na2 <- function(x) {
  for (i in 2:(length(x) - 1)) {
    if (is.na(x[i])) {
      x[i] <- (x[i - 1] + x[i + 1]) / 2
    }
  }
  x
}
impute_na2(c(1, 4, 5, NA, 10, 13, 10))
```

Your turn

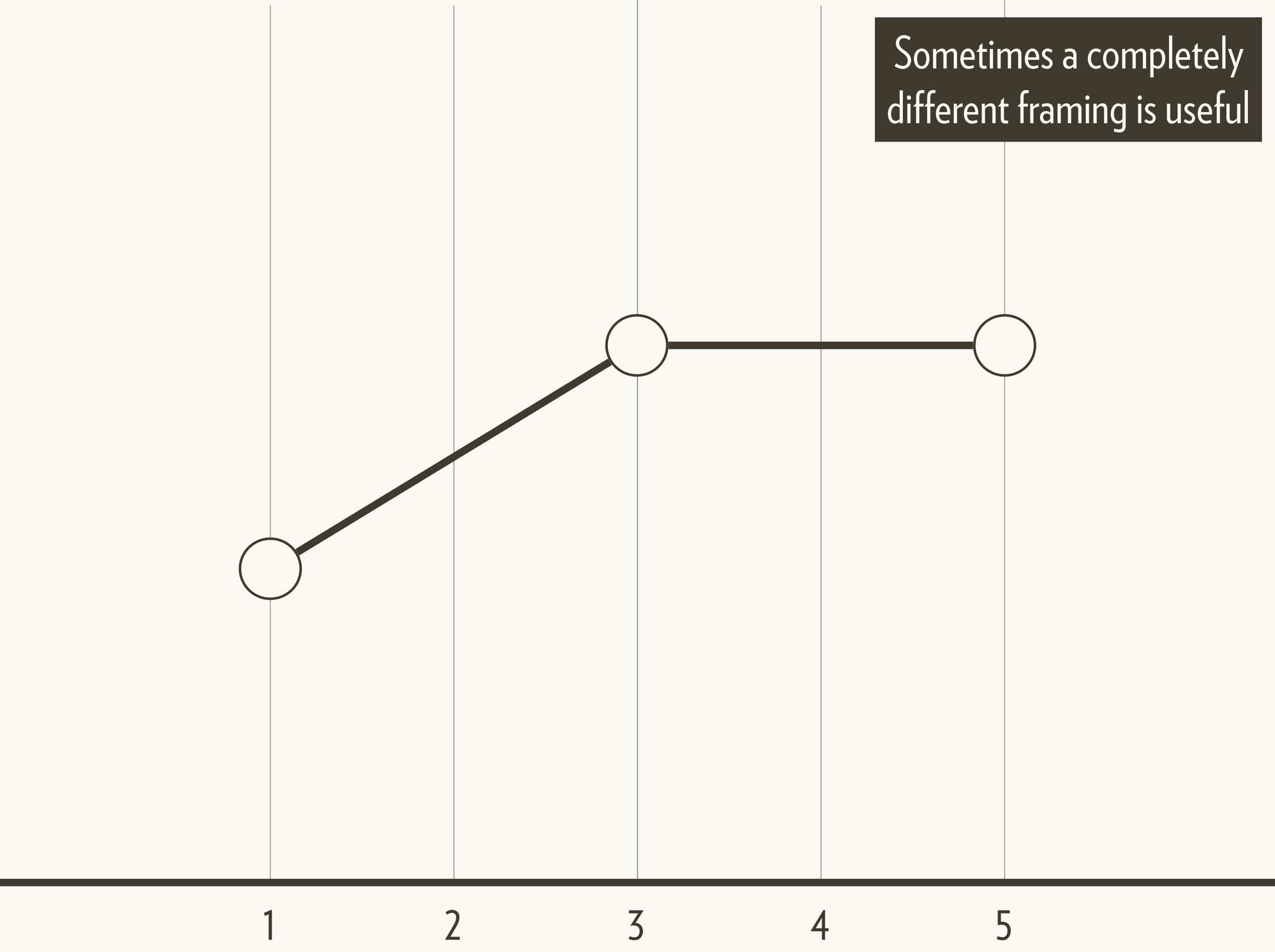
Modify `input_na2()` so that it works for all inputs.

Think about the ideas on the next slide

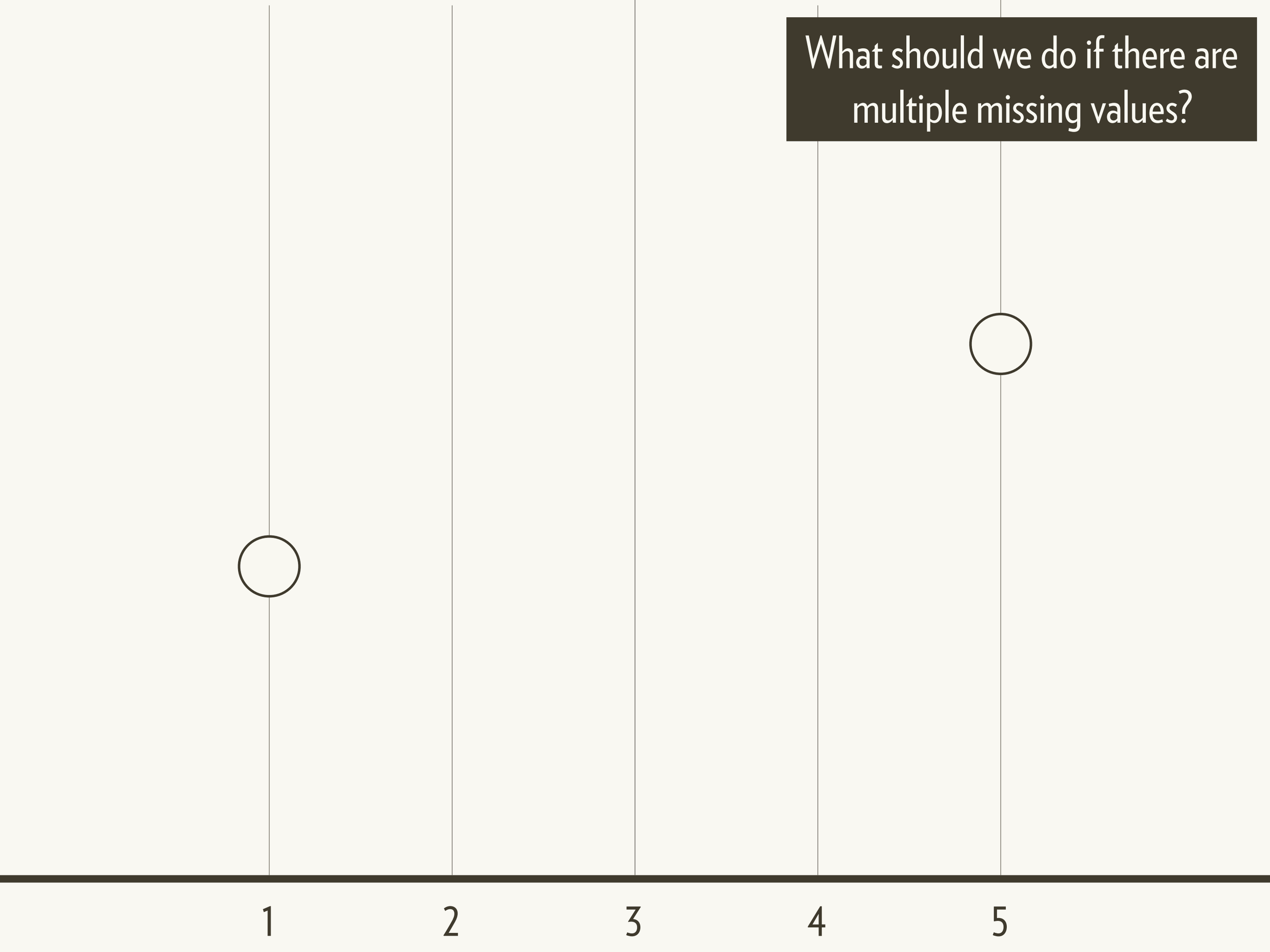
What should the answers be?

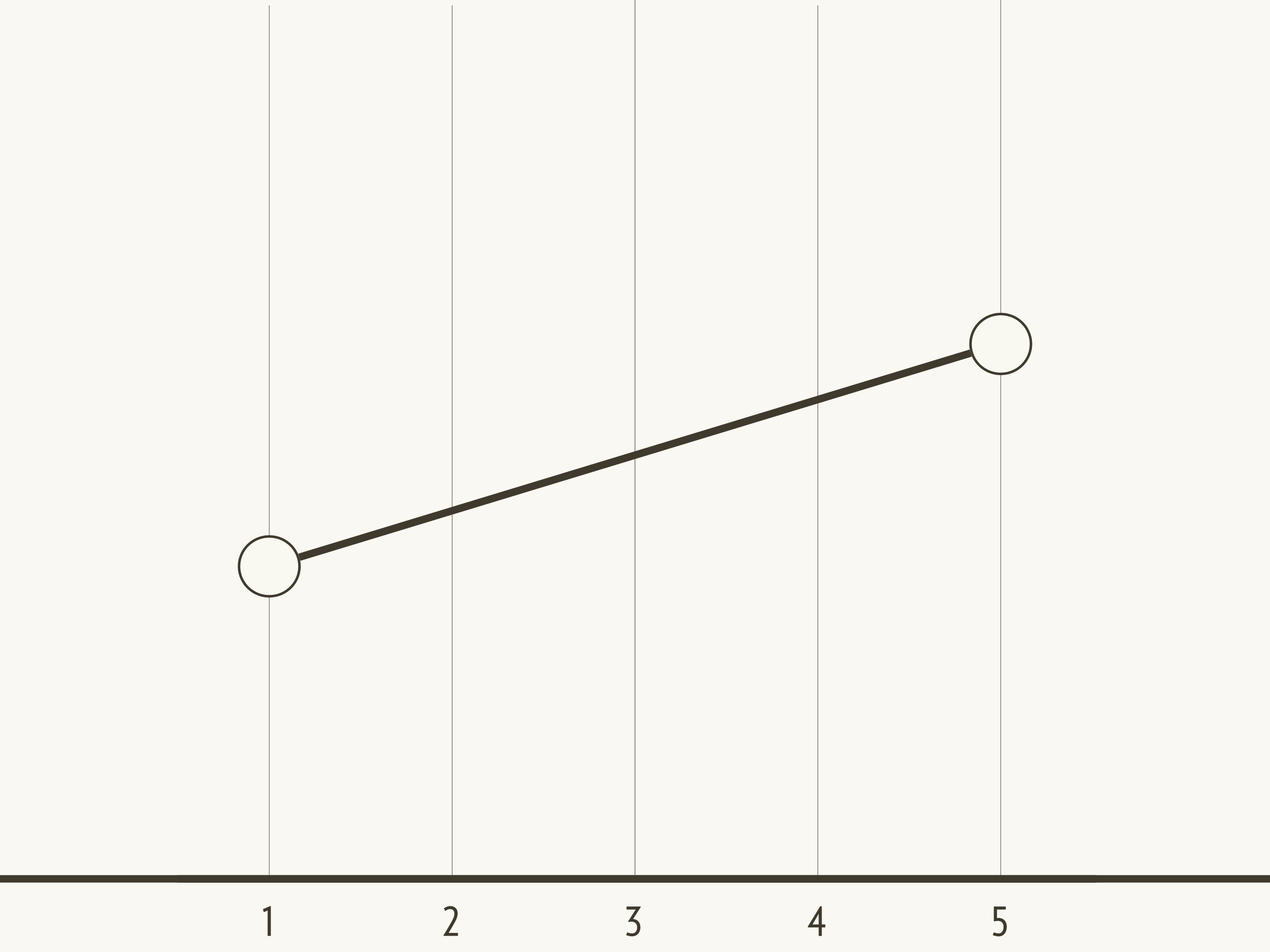
```
impute_na2(numeric())
impute_na2(NA_real_)

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

Sometimes a completely different framing is useful



What should we do if there are multiple missing values?




1
2
3
4
5

A more general implementation

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

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

Vocabulary is important!

Documented

Tested

Existing function ›› New function

Standard name

More general

Name

Knowledge!

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

— *Shakespeare*

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

— *Hadley Wickham*