Basic base R

Week 2

AEM 2850: R for Business Analytics
Cornell Dyson
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Acknowledgements: Grant McDermott

Announcements

If you are new to the class, please review Hui's canvas announcement to help get up to speed

Reminders:

- New course content will be posted regularly at aem2850.toddgerarden.com
- Bookmark the schedule and visit often
- Submit assignments via canvas
  - Lab 1 was due yesterday (Monday) at 11:59pm
  - Reflection - Week 2 is due Wednesday at 11:59pm
  - No penalties for late submissions this week

We will have an undergraduate TA, Sophie McComb (sm2397@cornell.edu)

- Poll: what times do you prefer for additional office hours?

Plan for today

The plan for this week is to introduce ourselves to **base** R

Prologue: where we're from

Introduction to base R

Object-oriented programming in R

"Everything is an object"

"Everything has a name"

Indexing

Cleaning up

Prologue

How we feel about the course, in a few words

- excited
- curious
- the vibes of this class are immaculate!
- nervous

Where we're from

How can we use your 36 PDF submissions to construct our origin story without having to read them one by one?

- **Caveat:** This is based on submissions as of 10:07pm Monday night

We can use R for this!

I won't go through details now, but here is one way to approach it:

- convert PDFs to plain text using `pdftools::pdf_text`
- use tools from `readr` and `stringr` packages to clean up text and extract relevant bits
- use `dplyr` functions to manipulate data
- make maps using `maps` and `ggplot2::ggplot`

By the end of the course you will be able to do most, if not all, of this

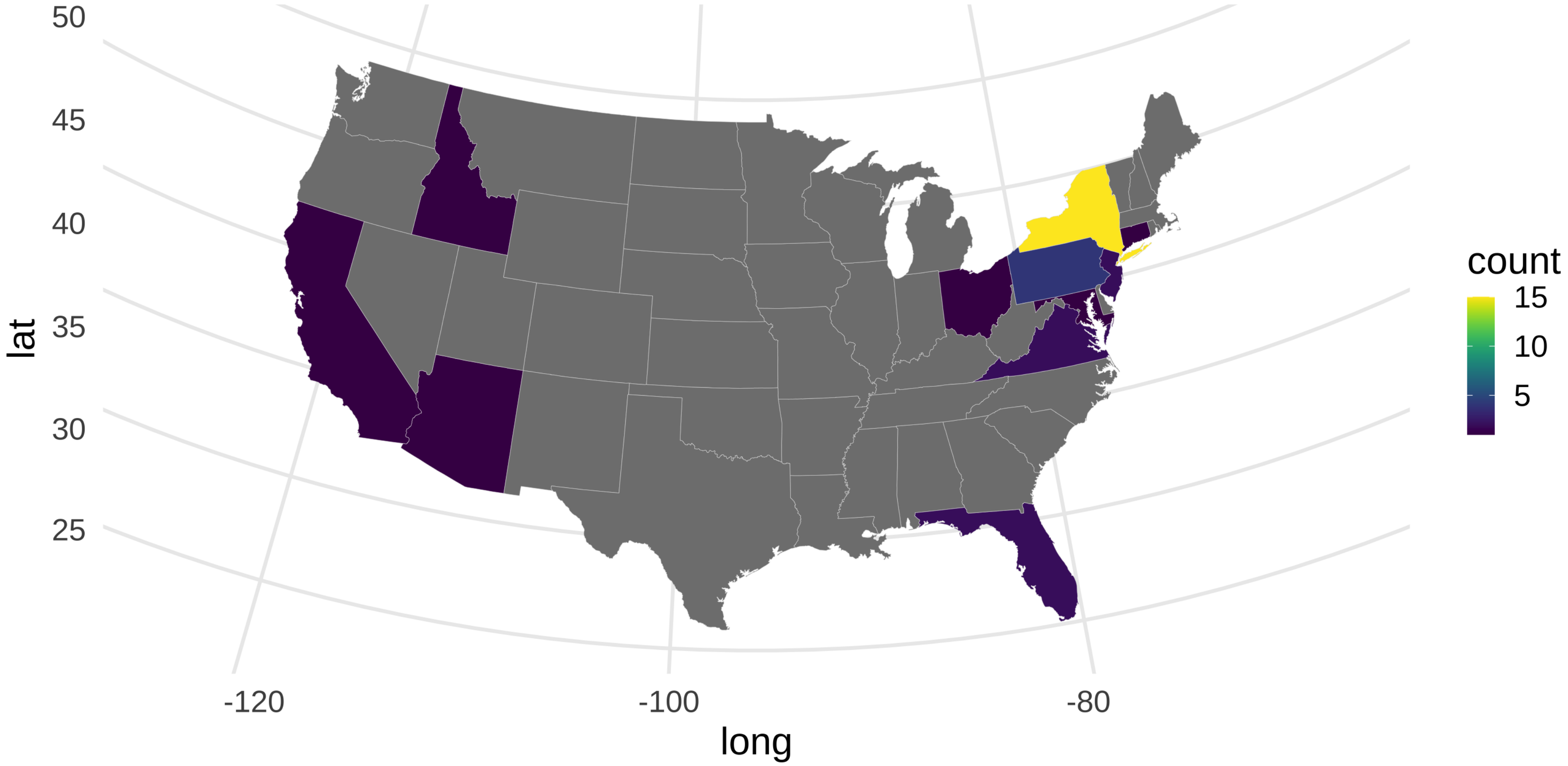
Are we all from New York?

Are more or less than half of us from the state of New York?

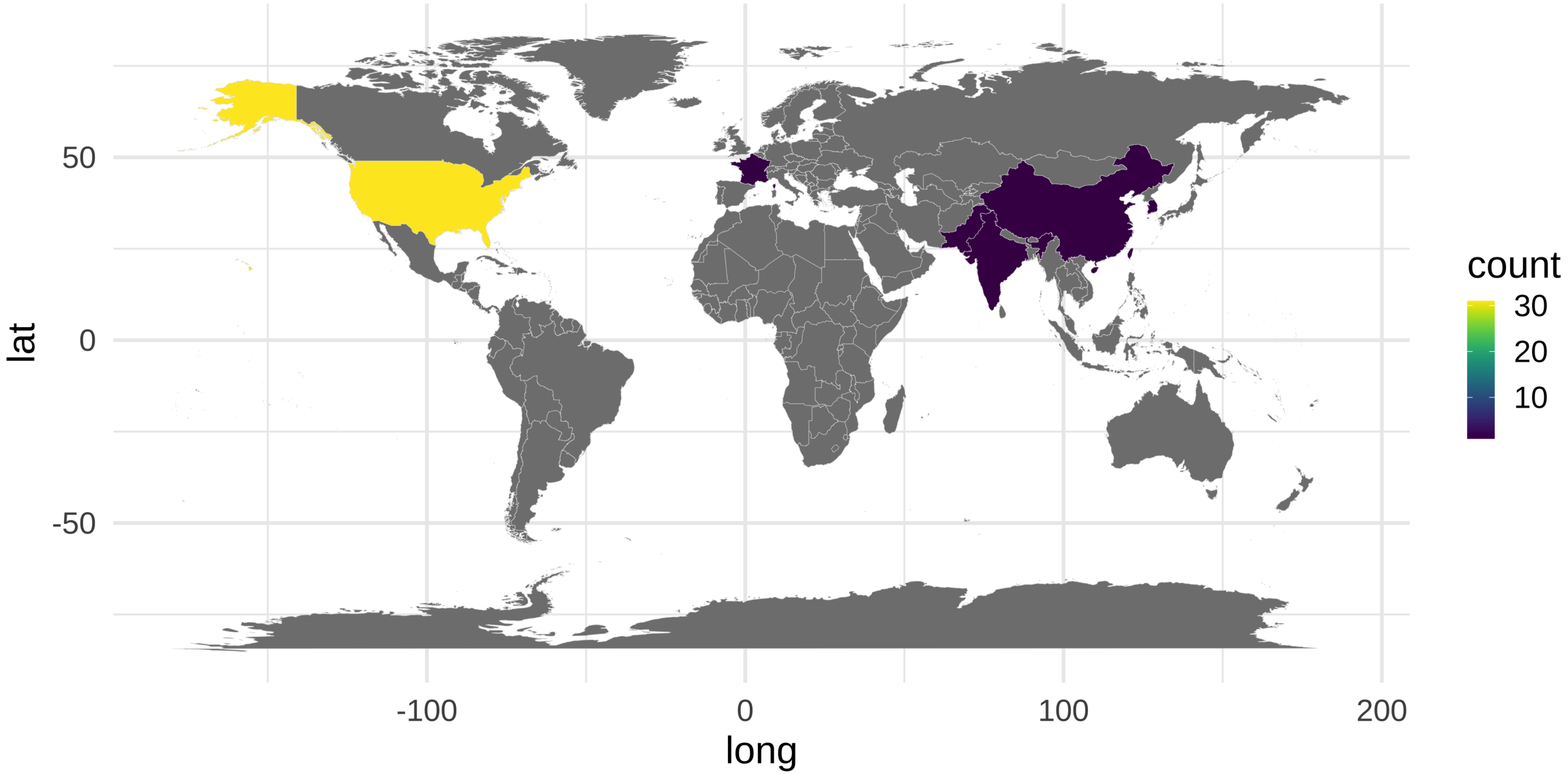
```
# step 1: do a bunch of data prep that's omitted for clarity
# step 2: show us the answer!
ny_share
```

```
## # A tibble: 2 × 2
##   origin   percent
##   <chr>      <dbl>
## 1 new york    40.5
## 2 other       59.5
```

Are we all from New York?



Are we all from the U.S.?



Introduction to base R

(Some of this is review from Week 1)

Basic arithmetic

R is a powerful calculator and recognizes all of the standard arithmetic operators:

```
1+2 # add / subtraction
```

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

```
5/2 # divide
```

```
## [1] 2.5
```

```
2^3 # exponentiate
```

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

```
2+4*1^3 # standard order of precedence (`*` before `+`, etc.)
```

```
## [1] 6
```

Logic

R also comes equipped with a full set of logical operators and Booleans

```r
1 > 2
```

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

```r
(1 > 2) & (1 > 0.5) # "&" is the "and" operator
```

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

```r
(1 > 2) | (1 > 0.5) # "|" is the "or" operator
```

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

Logic

We can negate expressions with: `!`

This is helpful for filtering data

```r
is.na(1:10)
```

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

```r
!is.na(1:10)
```

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

`NA` means **not available** (i.e., missing)

Logic

For value matching we can use: `%in%`

To see whether an object is contained within (i.e., matches one of) a list of items, use `%in%`:

```
4 %in% 1:10
```

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

```
4 %in% 5:10
```

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

Logic

To evaluate whether two expressions are equal, we need to use **two** equal signs

```
1 = 1 # This doesn't work
```

```
## Error in 1 = 1: invalid (do_set) left-hand side to assignment
```

```
1 == 1 # This does.
```

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

```
1 != 2 # Note the single equal sign when combined with a negation.
```

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

Logic

Evaluation caveat: What do you think will happen if we evaluate `0.1 + 0.2 == 0.3`?

```
0.1 + 0.2 == 0.3
```

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

Uh-oh! What went wrong here?

Problem: Computers represent numbers as binary (i.e., base 2) floating-points. More here

- Fast and memory efficient, but can lead to unexpected behavior
- Similar to how standard decimals can't precisely capture certain fractions (e.g., $\frac{1}{3} = 0.3333...$)

Solution: Use `all.equal()` for evaluating floats (i.e., fractions)

```
all.equal(0.1 + 0.2, 0.3)
```

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

Assignment

In R, we can use either `<-` or `=` to handle assignment

Assignment with `<-`

`<-` is normally read aloud as "gets". You can think of it as a (left-facing) arrow saying *assign in this direction*.

```r
a <- 10 + 5
a
```

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

Assignment

Assignment with =

You can also use `=` for assignment.

```
b = 10 + 10
b
```

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

Which assignment operator should you use?

Most R users prefer `<-`, which can be inserted using the keyboard shortcut Alt/Option + -

It doesn't really matter for our purposes, other languages use `=`

Bottom line: Use whichever you prefer, just be consistent

Help

For more information on a (named) function or object in R, consult the "help" documentation using `?`

For example:

```
?plot
```

Vignettes

For some packages, `vignette()` will provide a detailed intro

```
# Try this:
vignette("dplyr")
```

Vignettes are a great way to learn how and when to use a package

Comments

Comments in R code are demarcated by `#`

Use comments to document your logic in `.R` scripts and within `.Rmd` code chunks

```
# THIS IS A CODE SECTION ----
# this is a comment
vibe <- "immaculate" # iykyk
```

Comments should be concise and used only when necessary (unlike the comments above)

Using at least four trailing dashes (`----`) creates a code section, which simplifies navigation and code folding

- Also works with trailing equals (`====`) or pound signs (`====`)

Keyboard shortcut: use `Ctrl/Cmd+Shift+c` in RStudio to (un)comment whole sections of highlighted code.

Object-oriented programming in R

Object-oriented programming

In R:

> **"Everything is an object and everything has a name."**

"Everything is an object"

What are objects?

There are many different *types* (or *classes*) of objects

Here are some objects that we'll be working with regularly:

- vectors
- matrices
- data frames
- lists
- functions

Data frames

The most important object we will be working with is the **data frame**

You can think of it basically as an Excel spreadsheet

```
# Create a small data frame called "d"
d <- data.frame(x = 1:2, y = 3:4)
d
```

```
##   x y
## 1 1 3
## 2 2 4
```

This is essentially just a table with columns named `x` and `y`

Each row is an observation telling us the values of both `x` and `y`

Aside: built-in data frames

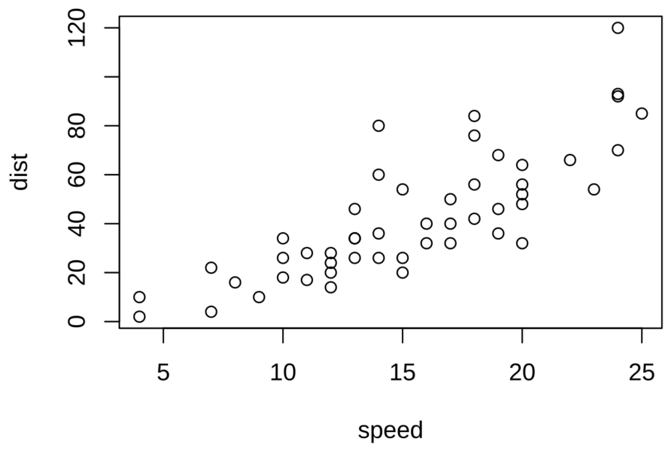
Base R and packages have a bunch of built in data frames with special names you can call on

As you may recall, we used `cars` on Thursday:

```
head(cars)
```

```
##   speed dist
## 1     4    2
## 2     4   10
## 3     7    4
## 4     7   22
## 5     8   16
## 6     9   10
```

```
plot(cars)
```



Back to objects

Each object class has its own set of rules for determining valid operations

```r
# Create a small data frame called "d"
d <- data.frame(x = 1:2, y = 3:4)
d
```

```
##   x y
## 1 1 3
## 2 2 4
```

At the same time, you can (usually) convert an object from one type to another

```r
# Convert it to (i.e., create) a matrix call "mat"
mat <- as.matrix(d)
mat
```

```
##      x y
## [1,] 1 3
## [2,] 2 4
```

Working with multiple objects

In R we can have multiple data frames in memory at once

Even though we just made `mat`, `d` still exists:

```
d
```

```
##   x y
## 1 1 3
## 2 2 4
```

Ways to learn about objects

Printing an object directly in the console is often handy

- e.g., Type `d` and hit Enter

`View()` is very helpful, and has the same effect as clicking on the object in your RStudio *Environment* pane

- e.g., Type `View(d)` and hit Enter

Use the `str` command to learn about an object's **str**ucture

```
# d <- data.frame(x = 1:2, y = 3:4) # Create a small data frame called "d"
str(d) # Evaluate its structure
```

```
## 'data.frame':    2 obs. of  2 variables:
##  $ x: int  1 2
##  $ y: int  3 4
```

You can also use `class` to get an object's class without all the other details

Global environment

Let's go back to the simple data frame that we created a few slides earlier.

```
d
```

```
##   x y
## 1 1 3
## 2 2 4
```

Now, let's try to do a logical comparison of these "x" and "y" variables:

```
x < y
```

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

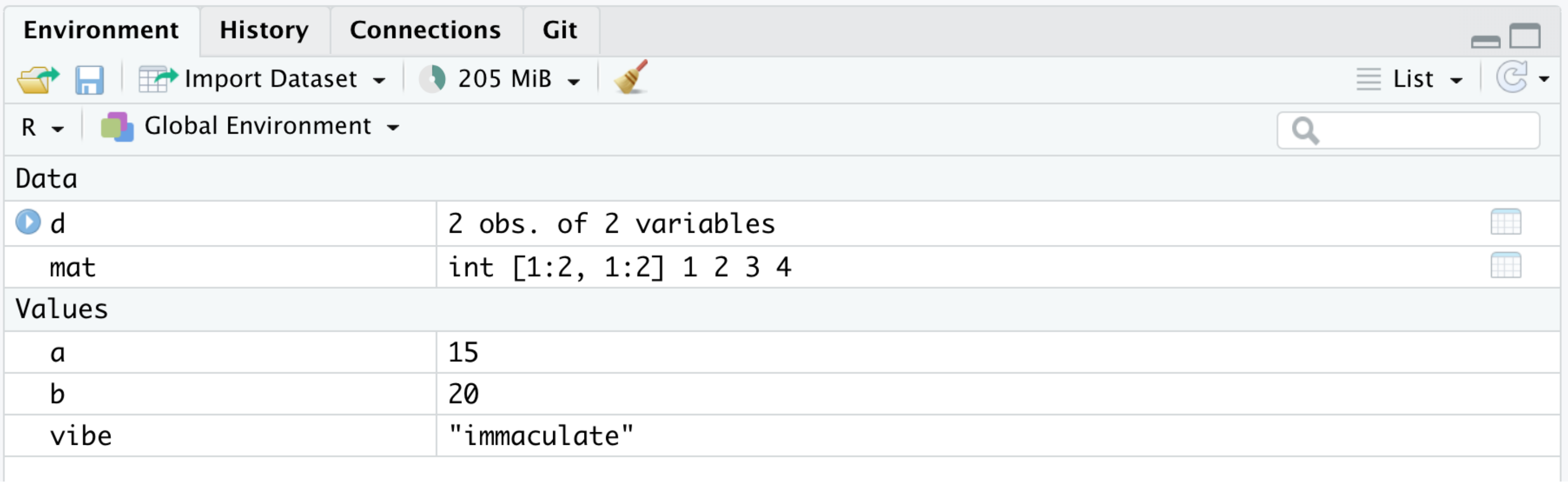
Uh-oh. What went wrong here?

Global environment

The error message provides the answer to our question:

```
## Error in eval(predvars, data, env): object 'x' not found
```

R looked in our *Global Environment* and couldn't find x



We have to tell R that x and y belong to the object d

We will come back to this

"Everything has a name"

Reserved words

R has a bunch of key/reserved words that serve specific functions

- You can't (re)assign these, even if you wanted to

See here for a full list, including (but not limited to):

```
if
else
while # looping
function
for # looping
TRUE
FALSE
NULL # null/undefined
Inf #infinity
NaN # not a number
NA # not available / missing
```

Semi-reserved words

There are other words that are sort of reserved, in that they have a particular meaning

- These are named functions or constants (e.g., `pi`) that you can re-assign if you really want to... but that already come with important meanings from base R

The most important example is `c()`, which binds and concatenates objects together

```
my_vector <- c(1, 2, 5)
my_vector
```

```
## [1] 1 2 5
```

What do you think will happen if you type the following?

```
c <- 4
c(1, 2 ,5)
```

```
## [1] 1 2 5
```

In this case, R is "smart" enough to distinguish between the variable `c` and the built-in function `c()`

Semi-reserved words (cont.)

But R won't always be able to distinguish between conflicting definitions! For example:

```r
pi
```

```
## [1] 3.141593
```

```r
pi <- 2
pi
```

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

Bottom line: Don't use (semi-)reserved words!

Namespace conflicts

Try loading the `dplyr` package in RStudio

```r
library(dplyr)
```

What warning gets reported?

```
The following objects are masked from ‘package:stats’:

    filter, lag

The following objects are masked from ‘package:base’:

    intersect, setdiff, setequal, union
```

The warning *masked from 'package:X'* is about a **namespace conflict**

Here, both `dplyr` and the `stats` package (which gets loaded automatically when you start R) have functions named `filter` and `lag`

Namespace conflicts

Whenever a namespace conflict arises, the most recently loaded package will gain preference

The `filter()` function now refers specifically to the `dplyr` variant

What if we want the `stats` variant?

1. Use `stats::filter()`
2. Assign `filter <- stats::filter`

Solving namespace conflicts

1. Use `package::function()`

Explicitly call a conflicted function from a package using the `package::function()` syntax

We can also use `::` to clarify the source of a function or dataset in our code

```
dplyr::starwars # Print the starwars data frame from the dplyr package
scales::comma(c(1000, 1000000)) # Use the comma function, which comes from the scales package
```

The `::` syntax also allows us to call functions without loading the package (as long as it is installed)

Solving namespace conflicts

2. Assign `function <- package::function`

A more permanent option is to assign a conflicted function name to a particular package

```
filter <- stats::filter # Note the lack of parentheses
filter <- dplyr::filter # Change it back again
```

User-side namespace conflicts

Namespace conflicts don't just arise from loading packages

Users like you and me can (and probably will!) create them through assignment

Indexing

Indexing

How do we index in R?

We've already seen an example of indexing in the form of R console output:

```
1+2
```

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

The `[1]` above denotes the first (and, in this case, only) element of our output

In this case, a vector of length one equal to the value "3"

Indexing

Try the following in your console to see a more explicit example of indexed output:

```
rnorm(n = 50, mean = 0, sd = 1) # take 50 draws from the standard normal distribution
```

```
##  [1]  0.545198045 -0.619600547  1.209571808 -0.132840767  0.840999948
##  [6] -0.468676041 -0.580237221 -0.265704209 -0.613325542  1.048953465
## [11] -0.954470128 -0.045977243 -0.110652274  0.706633294  2.008543131
## [16] -1.393752021 -2.539802733  1.716771642 -0.098661232  0.655789925
## [21]  0.381928265 -0.144288830  0.918098912  0.331458268  0.123943352
## [26] -0.301788408 -1.376325610  0.579831256  0.981289233 -0.097011852
## [31] -0.372632427 -0.138483262  0.442479778  0.001620147  0.384330356
## [36] -1.248803567  0.466651947  0.083950497 -0.341662378  1.571210441
## [41] -1.938701742 -0.891181462 -0.990556079  1.455840058  0.241397814
## [46]  0.016646627  0.791288703  2.391992830 -0.240861450 -0.468641462
```

Option 1: []

We can use `[]` to index objects that we create in R

```r
a = 1:10
a[4] ## Get the 4th element of object "a"
```

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

```r
a[c(4, 6)] ## Get the 4th and 6th elements
```

```
## [1] 4 6
```

Option 1: []

This also works on larger arrays (vectors, matrices, data frames, and lists)

```r
starwars[1, 1] ## Show the cell corresponding to the 1st row & 1st column of the data frame.
```

```
## # A tibble: 1 × 1
##   name
##   <chr>
## 1 Luke Skywalker
```

What does `starwars[1:3, 1]` give you?

```
## # A tibble: 3 × 1
##   name
##   <chr>
## 1 Luke Skywalker
## 2 C-3PO
## 3 R2-D2
```

Option 1: [[]]

We haven't discusssed them yet, but **lists** are a more complex type of array object in R

They can contain a collection of objects that don't share the same structure

For example, you can have lists containing:

- a scalar, a string, and a data frame
- a list of data frames
- a list of lists

Option 1: []

The relevance to indexing is that lists require two square brackets `[[]]` to index the parent list item and then the standard `[]` within that parent item. An example might help to illustrate:

```
my_list <- list(
  a = "hello",
  b = c(1,2,3),
  c = data.frame(x = 1:5, y = 6:10))
my_list[[1]] # Return the 1st list object
```

```
## [1] "hello"
```

```
my_list[[2]][3] # Return the 3rd element of the 2nd list object
```

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

Option 2: $

Lists provide a nice segue to our other indexing operator: `$`.

- Let's continue with the `my_list` example from the previous slide

```
my_list
```

```
## $a
## [1] "hello"
##
## $b
## [1] 1 2 3
##
## $c
##   x  y
## 1 1  6
## 2 2  7
## 3 3  8
## 4 4  9
## 5 5 10
```

Notice how our (named) parent list objects are demarcated: `$a`,`$b` and `$c`

Option 2: $

We can call these objects directly by name using the dollar sign, e.g.

```
my_list$a ## Return list object "a"
```

```
## [1] "hello"
```

```
my_list$b[3] ## Return the 3rd element of list object "b"
```

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

```
my_list$c$x ## Return column "x" of list object "c"
```

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

Option 2: $

The $ form of indexing also works for other object types

In some cases, you can also combine the two index options:

```
starwars$name[1]
```

```
## [1] "Luke Skywalker"
```

Option 2: $

Finally, `$` provides another way to avoid the "object not found" problem that we ran into earlier

```
x < y # Doesn't work
```

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

```
d$x < d$y # Works!
```

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

Cleaning up

Removing objects

Use `rm()` to remove an object or objects from your working environment

```
a <- "hello"
b <- "world"
rm(a, b)
```

You can use `rm(list = ls())` to remove all objects in your working environment, though this is frowned upon

- Better just to start a new R session