SISG/SISMID Module 3

Introduction to R

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University of Washington

Seattle, July 2021

Introduction: Course Aims

This is a *first* course in R. We aim to cover;

- Reading in, summarizing & managing data
- Use of functions in R – doing jobs by programming, not by using drop-down menus (much)
- *Some* standard functions for statistical analysis – but minimal statistics in this module
- How to use other people's code, how to get help, what to learn next

We assume no previous use of R, also non-extensive programming skills in other languages. If this is *not* your level, please consider switching to a later module.

Introduction: Resources

Most importantly, the class site is

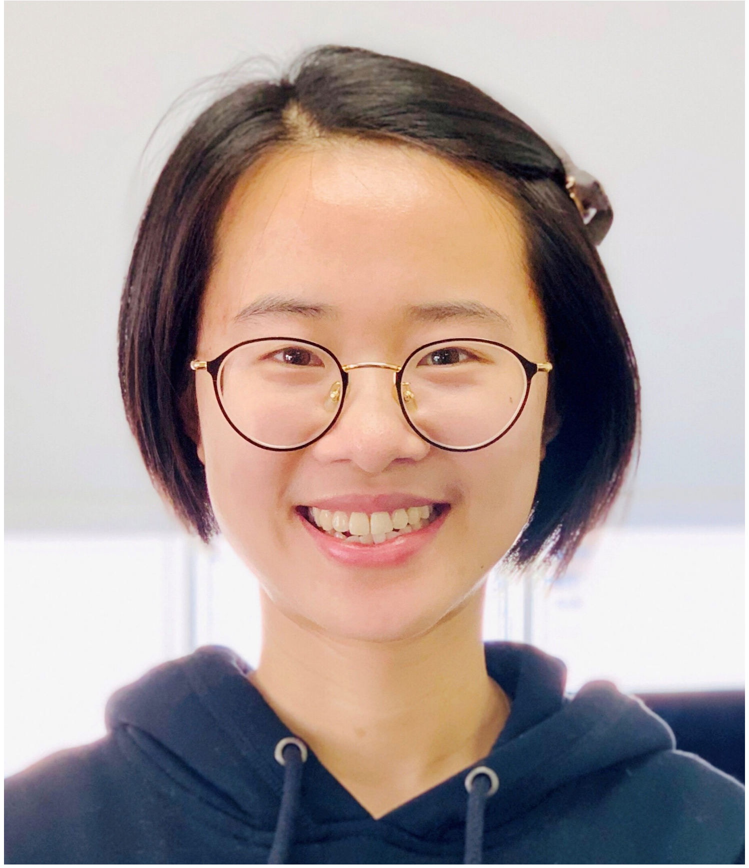
http://faculty.washington.edu/kenrice/rintro

Contains (or will contain);

- Links to all Zoom sessions, and their recordings
- PDF copies of slides (in color, and contains a few hyperlinks)
- All datasets needed for exercises
- Exercises for you to try
- Our solutions to exercises (later!)
- Links to other software, other courses, book, and places to get R help
- Links to a few helpful websites/email list archives

Of course, search engines will find much more than this, and can be a useful start, when tackling analyses with R.

Introduction: About Ting



- Assistant Professor, UW Biostat
- A useR and an instructoR
- Causal inference (clinical trials and observational studies)

Introduction: About Ken

- Professor, UW Biostat
- AuthoR of a few R packages, useR, teacheR
- Genetic/Genomic research in Cardiovascular Epidemiology

Introduction: Teaching Assistants

Our department's finest – here to help you:

Jake Alfieri

Niki Petrakos

Expect to 'see' them on Zoom chat, and our Slack channel.

Introduction: Course structure

10 sessions over 2.5 days

- Day 1; (Mostly RStudio) Data management, using functions
- Day 2; (Standard R) More about programming
- Day 3; More advanced ideas

Web page: `http://faculty.washington.edu/kenrice/rintro/`

Introduction: Session structure

What to expect in a typical 80 minute session;

- 45 mins teaching (please ask questions, on Zoom and/or Slack)
- 25 mins hands-on; in Zoom breakout rooms, please discuss as you go
- 10 mins summary, discussion/extensions (questions again!)

Please note: the 2.5 day course moves quickly, and later material builds on earlier material. So, **please ask questions!** – as 'chat' in Zoom calls, or on our Slack channel.

1. Reading in data

Ken Rice
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What is R?

R is a ‘programming environment for statistics and graphics’

- Does *basically* everything, can also be extended
- It’s the default when statisticians implement new methods
- Free, open-source

But;

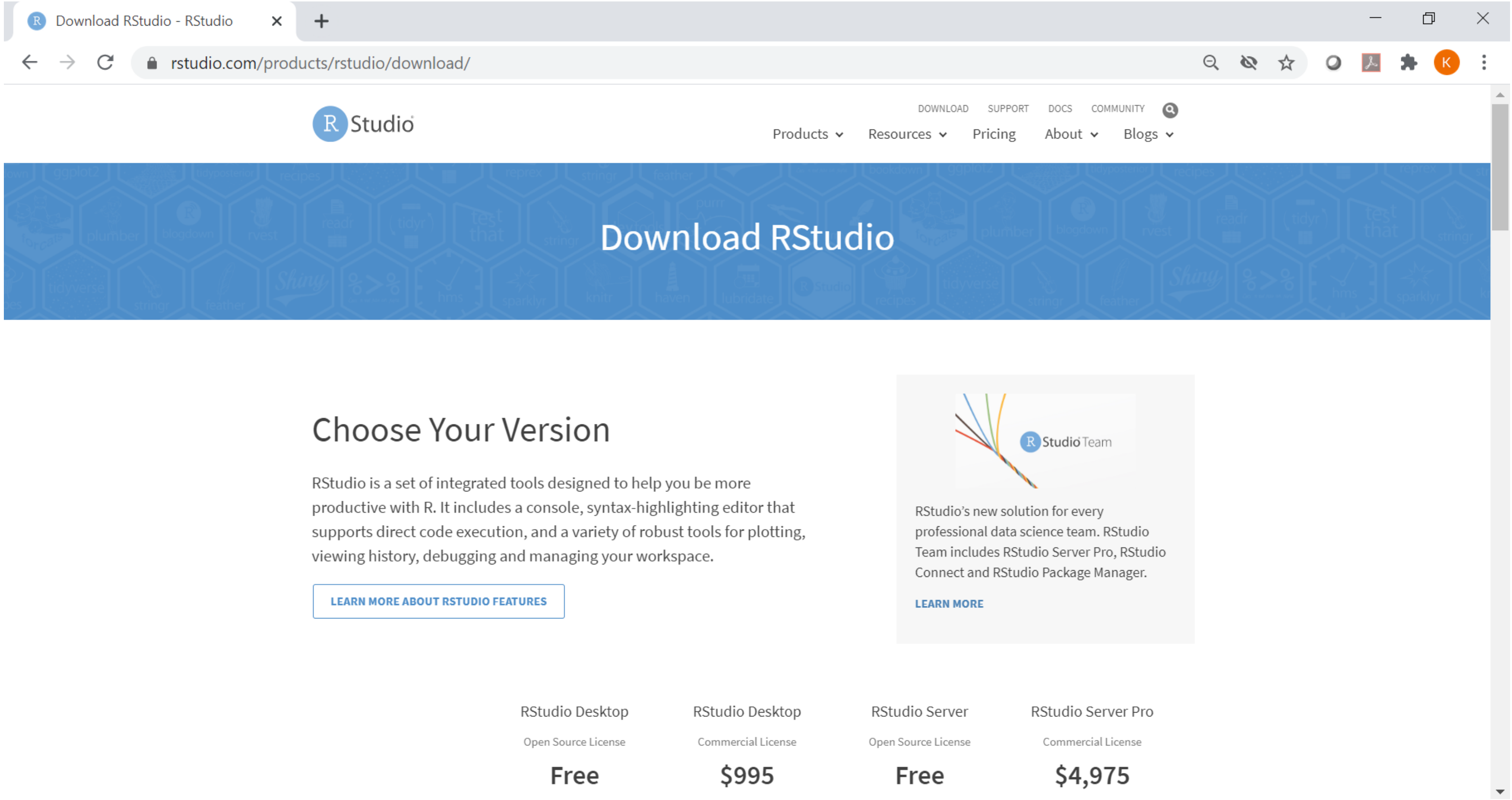
- Steeper learning curve than e.g. Excel, Stata
- Command-line driven (programming, not drop-down menus)
- Gives only what you ask for!

To help with these difficulties, we will begin with RStudio, a graphical user interface (front-end) for R that is slightly more user-friendly than ‘Classic’ R’s GUI.

So **after** you have installed the latest version of R...

RStudio

In your favorite web browser, download RStudio for Desktop;



Download RStudio

Choose Your Version

RStudio is a set of integrated tools designed to help you be more productive with R. It includes a console, syntax-highlighting editor that supports direct code execution, and a variety of robust tools for plotting, viewing history, debugging and managing your workspace.

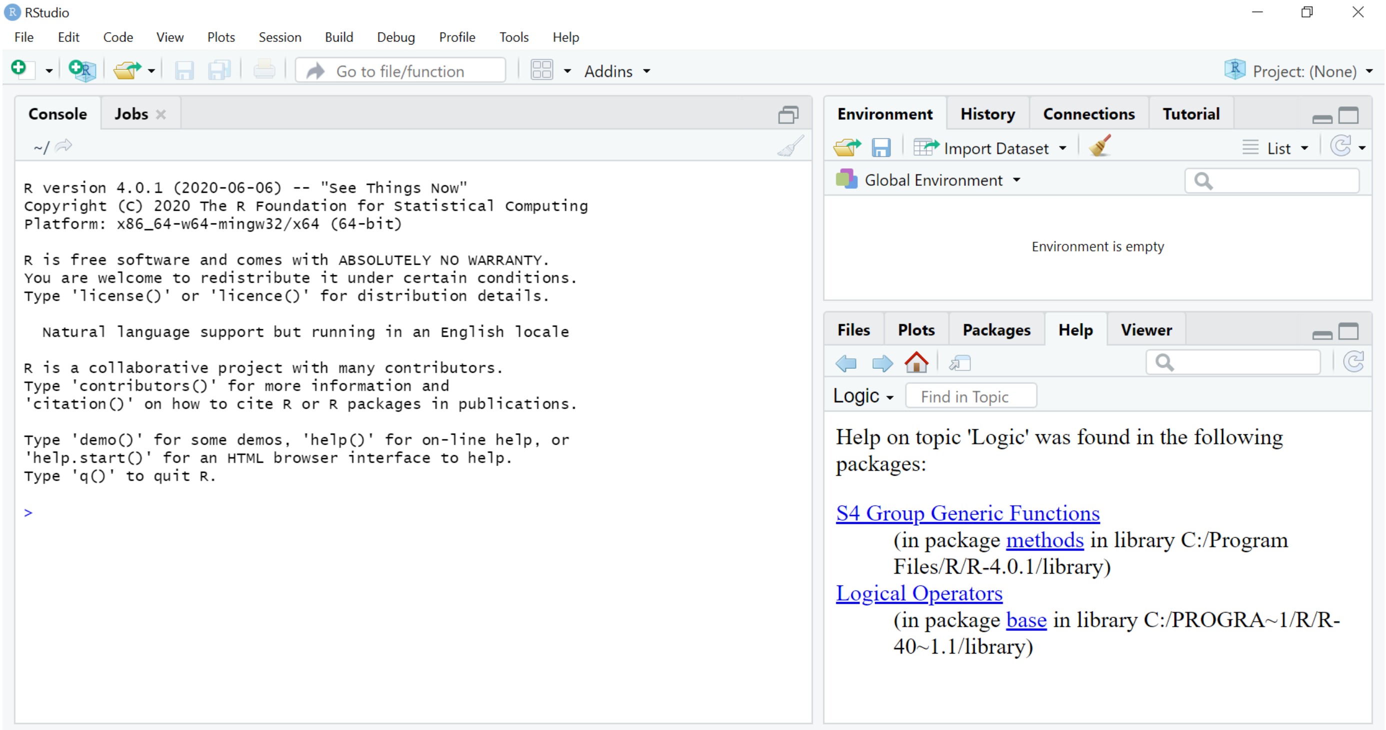
RStudio's new solution for every professional data science team. RStudio Team includes RStudio Server Pro, RStudio Connect and RStudio Package Manager.

RStudio Desktop	RStudio Desktop	RStudio Server	RStudio Server Pro
Open Source License	Commercial License	Open Source License	Commercial License
Free	$995	Free	$4,975

- Select& download the FREE installer for *your* system
- Default installation is fine

RStudio

RStudio is a ‘front end’ to R itself, so needs you to install R. On first startup, RStudio should look like this; (up to version and Mac/PC differences)



```
R version 4.0.1 (2020-06-06) -- "See Things Now"
Copyright (C) 2020 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
```

Help on topic 'Logic' was found in the following packages:

S4 Group Generic Functions
(in package methods in library C:/Program Files/R/R-4.0.1/library)

Logical Operators
(in package base in library C:/PROGRA~1/R/R-40~1.1/library)

If you’ve used it before, RStudio defaults to remembering what you were doing.

RStudio

We'll use the 'Console' window first – as a (fancy!) calculator

```
> 2+2
[1] 4
> 2^5+7
[1] 39
> 2^(5+7)
[1] 4096
> exp(pi)-pi
[1] 19.9991
> log(20+pi)
[1] 3.141632
> 0.05/1E6   # a comment; note 1E6 = 1,000,000
[1] 5e-08
```

- All common math functions are available; parentheses (round brackets) work as per high school math
- Try to get used to bracket matching. A '+' prompt means the line isn't finished – hit Escape to get out, then try again.

RStudio

R stores data (and everything else) as *objects*. New objects are created when we *assign* them values;

```
> x <- 3
> y <- 2 # now check the Environment window
> x+y
[1] 5
```

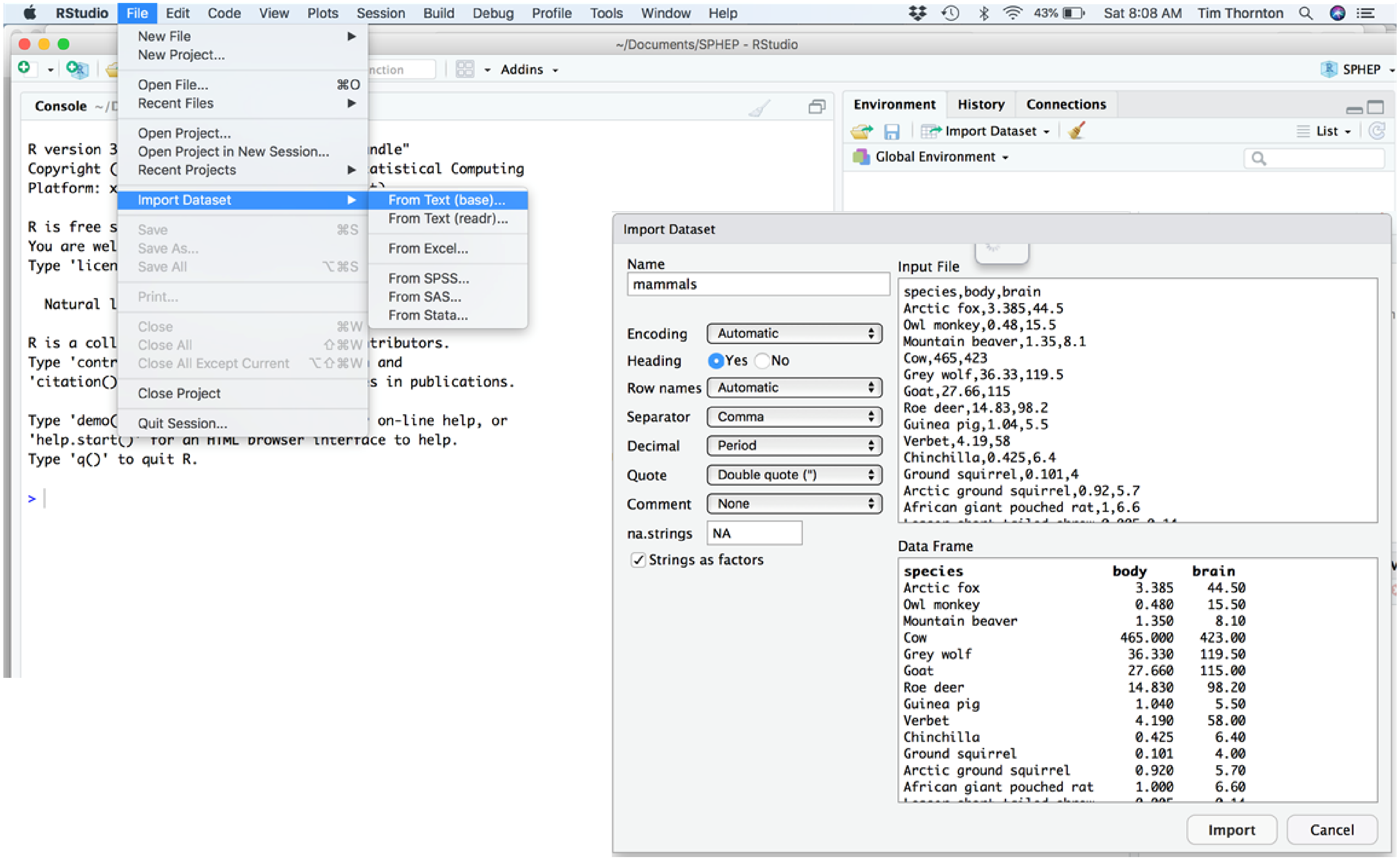
Assigning new values to existing objects over-writes the old version – and be aware there is no Ctrl-Z 'undo';

```
> y <- 17.4 # check the Environment window again
> x+y
[1] 20.4
```

- Anything after a hash (#) is ignored – e.g. comments
- Spaces don't matter
- Capital letters *do* matter

RStudio: Reading in data

To import a dataset, follow pop-ups from the File tab;



```
R version 3                               ndle"
Copyright (                               atistical Computing
Platform: x

R is free s
You are wel
Type 'licen

  Natural l

R is a coll                               tributors.
Type 'contr                               and
'citation()                               s in publications.

Type 'demo(                               on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
```

Import Dataset

Name: mammals

Encoding: Automatic

Heading: ● Yes ○ No

Row names: Automatic

Separator: Comma

Decimal: Period

Quote: Double quote (")

Comment: None

na.strings: NA

☑ Strings as factors

Input File

```
species,body,brain
Arctic fox,3.385,44.5
Owl monkey,0.48,15.5
Mountain beaver,1.35,8.1
Cow,465,423
Grey wolf,36.33,119.5
Goat,27.66,115
Roe deer,14.83,98.2
Guinea pig,1.04,5.5
Verbet,4.19,58
Chinchilla,0.425,6.4
Ground squirrel,0.101,4
Arctic ground squirrel,0.92,5.7
African giant pouched rat,1,6.6
```

Data Frame

```
species                       body     brain
Arctic fox                   3.385     44.50
Owl monkey                   0.480     15.50
Mountain beaver              1.350      8.10
Cow                        465.000    423.00
Grey wolf                   36.330    119.50
Goat                        27.660    115.00
Roe deer                    14.830     98.20
Guinea pig                   1.040      5.50
Verbet                       4.190     58.00
Chinchilla                   0.425      6.40
Ground squirrel              0.101      4.00
Arctic ground squirrel       0.920      5.70
African giant pouched rat    1.000      6.60
```

RStudio: Reading in data

More on those options;

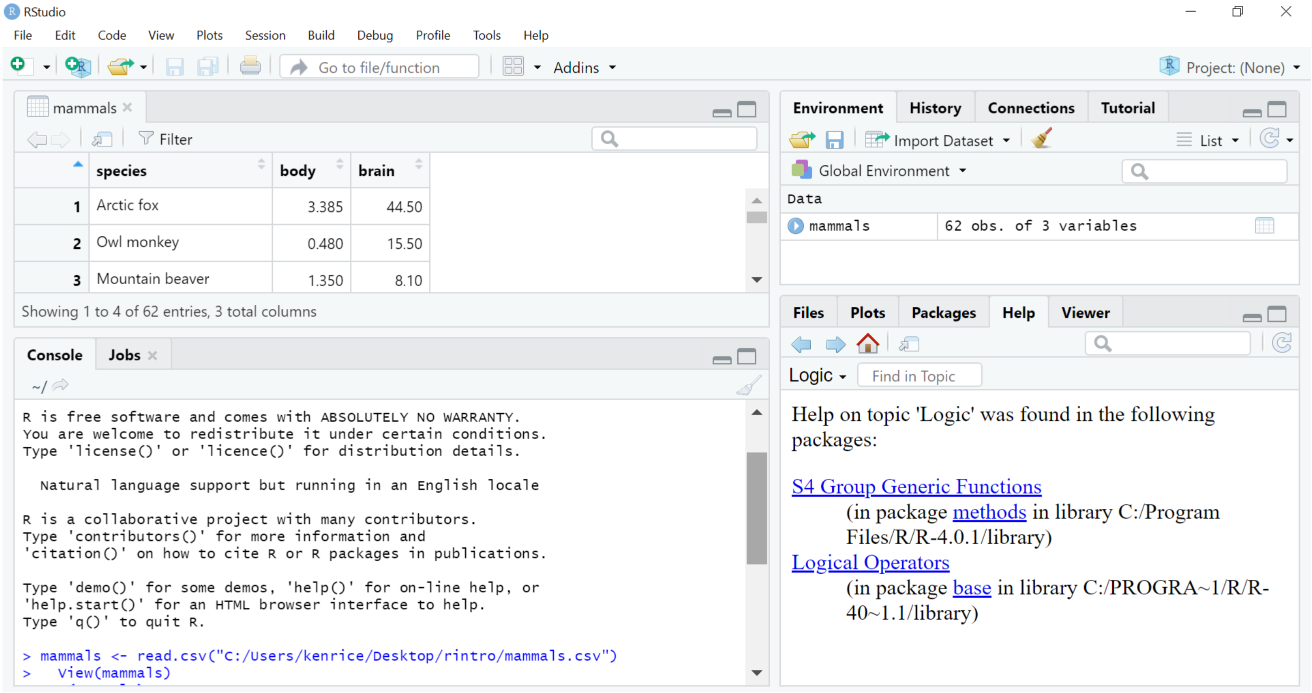
- **Name**: Name of the object that will store the whole dataset, when it's read in
- **Heading**: Does the first row contain column names?
- **Row names**: are there names for each row?
- **Separator**: what's between items on a single line?
- **na.strings**: How are missing values denoted?

The defaults are sensible, but R assumes you *know* what your data *should* look like – and whether it has named columns, numeric/character data, etc. *No* software is smart enough to cope with every format that might be used by you/your colleagues to store data.

RStudio: Reading in data

After successfully reading in the data;

- The environment now includes a `mammals` object – or whatever you called the data read from file
- A copy of the data can be examined in the Excel-like data viewer (below) – if it looks weird, find out why & fix it!



	species	body	brain
1	Arctic fox	3.385	44.50
2	Owl monkey	0.480	15.50
3	Mountain beaver	1.350	8.10

Showing 1 to 4 of 62 entries, 3 total columns

Data

mammals	62 obs. of 3 variables

```
R is free software and comes with ABSOLUTELY NO WARRANTY.
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Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> mammals <- read.csv("C:/Users/kenrice/Desktop/rintro/mammals.csv")
>   View(mammals)
```

Help on topic 'Logic' was found in the following packages:

S4 Group Generic Functions
(in package methods in library C:/Program Files/R/R-4.0.1/library)

Logical Operators
(in package base in library C:/PROGRA~1/R/R-40~1.1/library)

... we'll return later, to `read.csv()` in the Console window

RStudio: Reading in data

What’s a good name for my new object?

- Something memorable (!) and not easily-confused with other objects, e.g. `X` isn’t a good choice if you already have `x`
- Names must start with a letter or period (”.”), after that any letter, number or period is okay
- Avoid other characters; they get interpreted as math (”-”,”*”) or are hard to read (”_”) so should not be used in names
- Avoid names of existing functions – e.g. `summary`. Some one-letter choices (`c`, `C`, `F`, `t`, `T` and `S`) are already used by R as names of functions, it’s best to avoid these too

Operating on data

To operate on data, type commands in the Console window, just like our earlier calculator-style approach;

```
> str(mammals)
’data.frame’: 62 obs. of  3 variables:
 $ species: chr  "Arctic fox" "Owl monkey" "Mountain beaver" "Cow" ...
 $ body   : num  3.38 0.48 1.35 465 36.33 ...
 $ brain  : num  44.5 15.5 8.1 423 119.5 ...
> summary(mammals)
   species               body              brain
 Length:62          Min.   :   0.005   Min.   :   0.14
 Class :character   1st Qu.:   0.600   1st Qu.:   4.25
 Mode  :character   Median :   3.342   Median :  17.25
                    Mean   : 198.790   Mean   : 283.13
                    3rd Qu.:  48.202   3rd Qu.: 166.00
                    Max.   :6654.000   Max.   :5712.00
```

- `str()` tells us the `str`ucture of an object
- `summary()` summarizes the object

Can also use these commands on any object – e.g. the single numbers we created earlier (try it!)

Operating on data: columns

Individual columns in data frames are identified using the $ symbol – just seen in the `str()` output.

```
> mammals$brain
 [1]   44.50   15.50    8.10  423.00  119.50  115.00   98.20    5.50   58.00
[10]    6.40    4.00    5.70    6.60    0.14    1.00   10.80   12.30    6.30
[19] 4603.00    0.30  419.00  655.00    3.50  115.00   25.60    5.00   17.50
[28]  680.00  406.00  325.00   12.30 1320.00 5712.00    3.90  179.00   56.00
[37]   17.00    1.00    0.40    0.25   12.50  490.00   12.10  175.00  157.00
[46]  440.00  179.50    2.40   81.00   21.00   39.20    1.90    1.20    3.00
[55]    0.33  180.00   25.00  169.00    2.60   11.40    2.50   50.40
> summary(mammals$brain)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   0.14    4.25   17.25  283.10  166.00 5712.00
```

Think of $ as 'apostrophe-S', i.e. `mammals`'S `brain`.

Unlike many other statistical packages, R can handle *multiple* datasets at the same time – helpful if your data are e.g. phenotypes & genotypes, or county & disease outbreak data. This isn't possible without $, or *some* equivalent syntax.

Operating on data: columns

New columns are created when you assign their values – here containing the brain weights in kilograms;

```
> mammals$brainkg <- mammals$brain/1000
> str(mammals)
'data.frame': 62 obs. of  4 variables:
 $ species: chr  "Arctic fox" "Owl monkey" "Mountain beaver" "Cow" ...
 $ body   : num  3.38 0.48 1.35 465 36.33 ...
 $ brain  : num  44.5 15.5 8.1 423 119.5 ...
 $ brainkg: num  0.0445 0.0155 0.0081 0.423 0.1195 ...
> str(mammals$brainkg)
 num [1:62] 0.0445 0.0155 0.0081 0.423 0.1195 ...
> mammals$brainkg <- NULL
```

- Assigning values to existing columns over-writes existing values – again, with no warning
- With e.g. `mammals$newcolumn <- 0`, the new column has every entry zero; R *recycles* this single value, for every entry
- It's unusual to delete columns... but if you *must*;
  `mammals$brainkg <- NULL`

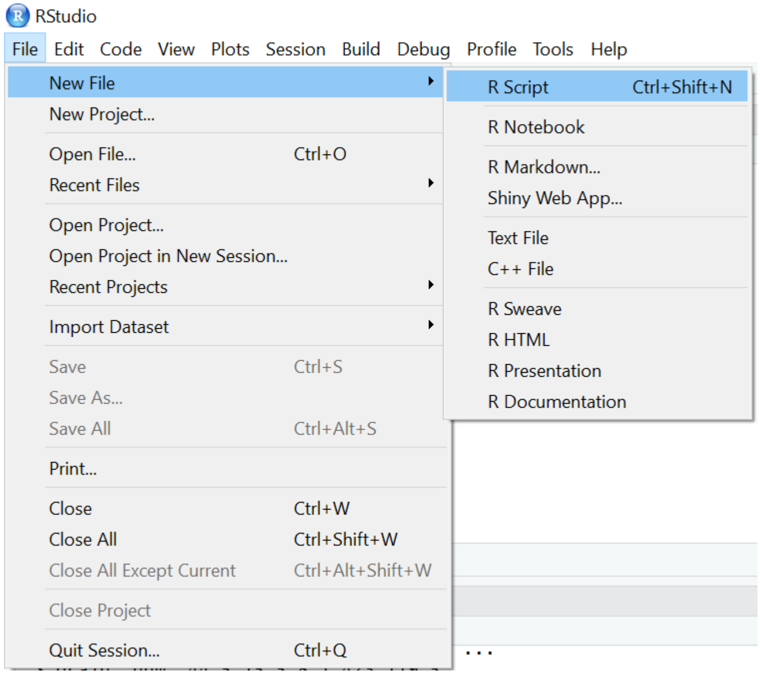
Operating on data: columns

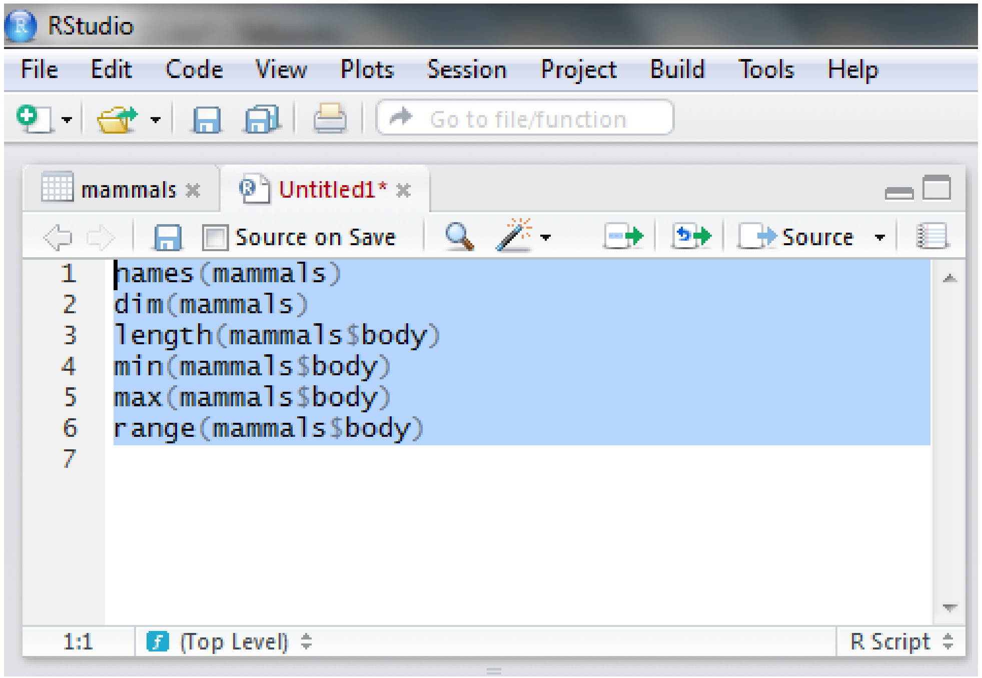
Some other functions useful for summarizing data frames, and their columns;

```
> names(mammals)
[1] "species" "body"    "brain"
> dim(mammals)      # dim is short for dimension
[1] 62  3
> length(mammals$body) # how many rows in our dataset?
[1] 62
> min(mammals$body)
[1] 0.005
> max(mammals$body)
[1] 6654
> range(mammals$body)
[1]    0.005 6654.000
> mean(mammals$brain)
[1] 283.1342
> sd(mammals$brain) # sd is short for standard deviation
[1] 930.2789
> median(mammals$brain)
[1] 17.25
```

RStudio: the Script window

While fine for occasional use, entering *every* command ‘by hand’ is error-prone, and quickly gets tedious. A *much* better approach is to use a Script window – open one with Ctrl-Shift-N, or the drop-down menus;





```
names(mammals)
dim(mammals)
length(mammals$body)
min(mammals$body)
max(mammals$body)
range(mammals$body)

```

- Opens a nice editor, enables saving code (.R extension)
- Run current line (or selected lines) with Ctrl-Enter, or Ctrl-R

RStudio: the Script window

An important notice: from now on, we assume you are using a script editor.

- First-time users tend to be reluctant to switch! – but it's worth it, ask any experienced user
- Some code in slides may be formatted for cut-and-paste into scripts – it may not look exactly like what appears in the Console window
- Exercise 'solutions' given as .R files
- Scripts make it easy to run slightly modified code, without re-typing everything – remember to save them as you work
- Also remember the Escape key, if e.g. your bracket-matching goes wrong

For a very few jobs, e.g. changing directories, we'll still use drop-down menus. But commands *are* available, for all tasks.

Operating on data: subsets

To identify general subsets – not just the columns selected by $ – R uses square brackets. Selecting individuals elements;

```
> mammals$brain[32] # 32nd element of mammals$brain
[1] 1320
> mammals$species[32]
[1] "Human"
> mammals$body[32]
[1] 62
```

Can also select entire columns or entire rows this way – and ‘blank’ entries indicate you want everything.

```
> mammals[32,2] # subtable with just 32nd row, 2nd column
[1] 62
> mammals[32,] # everything in the 32nd row
   species body brain
32   Human   62  1320
> sum(mammals[,3])  # sum of all the brains masses...
[1] 17554.32
```

Operating on data: subsets

Suppose we were interested in the body weight (i.e. 2nd column) for mammals (i.e. rows) 14, 55, & 61. How to select these multiple elements?

```
> mammals[c(14,55,61),2]
[1] 0.005 0.048 0.104
```

But what is `c(14,55,61)`? It's a *vector* of numbers – `c()` is for *combine*;

```
> length(c(14,55,61))
[1] 3
> str(c(14,55,61))
 num [1:3] 14 55 61
```

We can select these rows and all the columns;

```
> mammals[c(14,55,61),]
                      species  body brain
14 Lesser short-tailed shrew 0.005  0.14
55                 Musk shrew 0.048  0.33
61                 Tree shrew 0.104  2.50
```

Operating on data: subsets

A very useful special form of vector;

```
> 1:10
 [1]  1  2  3  4  5  6  7  8  9 10
> 6:2
[1] 6 5 4 3 2
> -1:-3
[1] -1 -2 -3
```

R expects you know this shorthand – see e.g. its use of `1:3` in the output from `str()`, on the previous slide. For a ‘rectangular’ selection of rows and columns;

```
> mammals[20:22, 1:3]
         species    body brain
20 Big brown bat   0.023   0.3
21        Donkey 187.100 419.0
22         Horse 521.000 655.0
```

Negative values correspond to *dropping* those rows/columns;

```
> mammals[-3:-62, c(1,3)] # everything but the first two rows, & columns c(1,3)
     species brain
1 Arctic fox  44.5
2 Owl monkey  15.5
```

Operating on data: subsets

As well as storing numbers and character strings (like `"Donkey"`, `"Big brown bat"`) R can also store *logicals* – TRUE and FALSE.

To make a new vector, with elements that are TRUE if body mass is above 500kg and FALSE otherwise;

```
> is.heavy <- mammals$body > 500
> table(is.heavy)  # another useful data summary command
is.heavy
FALSE  TRUE
   58     4
```

Which mammals were these? (And what were their masses?)

```
> mammals[is.heavy,] # just the rows for which is.heavy is TRUE
            species body brain
19   Asian elephant 2547  4603
22            Horse  521   655
28          Giraffe  529   680
33 African elephant 6654  5712
```

Use e.g. `mammals[is.heavy,2]` to combine TRUE/FALSE (rows) and numbers (columns)

Operating on data: subsets

One final method... for now! Instead of specifying columns of interest by number, or through vectors of TRUEs/FALSEs, we can also just give the names – as *character strings*, or vectors of character strings.

```
> mammals[1:3, "body"]
[1] 3.385 0.480 1.350
> mammals[is.heavy,"body"]
[1] 2547  521  529 6654
```

– this is more typing than the other methods, but is *much* easier to debug/reuse. Neither is 'right' or 'wrong' – R is just flexible.

Quitting time (almost)

When you're finished with RStudio;

- Ctrl-Q, or the drop-down menus, or entering `q()` at the command line all start the exit process
- You will be asked "Save workspace image to ∼/.RData?"
  - No/Don't Save: nothing is saved, and is not available when you re-start. *This is recommended*, because you will do different things in each session
  - Yes: Everything in memory is stored in R's internal format (.Rdata) and will be available when you re-start RStudio
  - Cancel: don't quit, go back
- Writing about what you did (output from a script) often takes much longer than re-running that script's analyses – so often, a 'commented' script is all the R you need to store

To get rid of *objects* in your current session, use `rm()`, e.g. `rm(is.heavy, mammals, x, y)` ... or RStudio's 'broom' button.

Summary

- In RStudio, read in data from the pop-up menu in the Environment window (or Tools menu)

- Data frames store data; can have many of these objects – and multiple other objects, too

- Identify vectors with $, subsets with square brackets

- Many useful summary functions are available, with sensible names

- Scripts are an important drudgery-avoidance tool!