

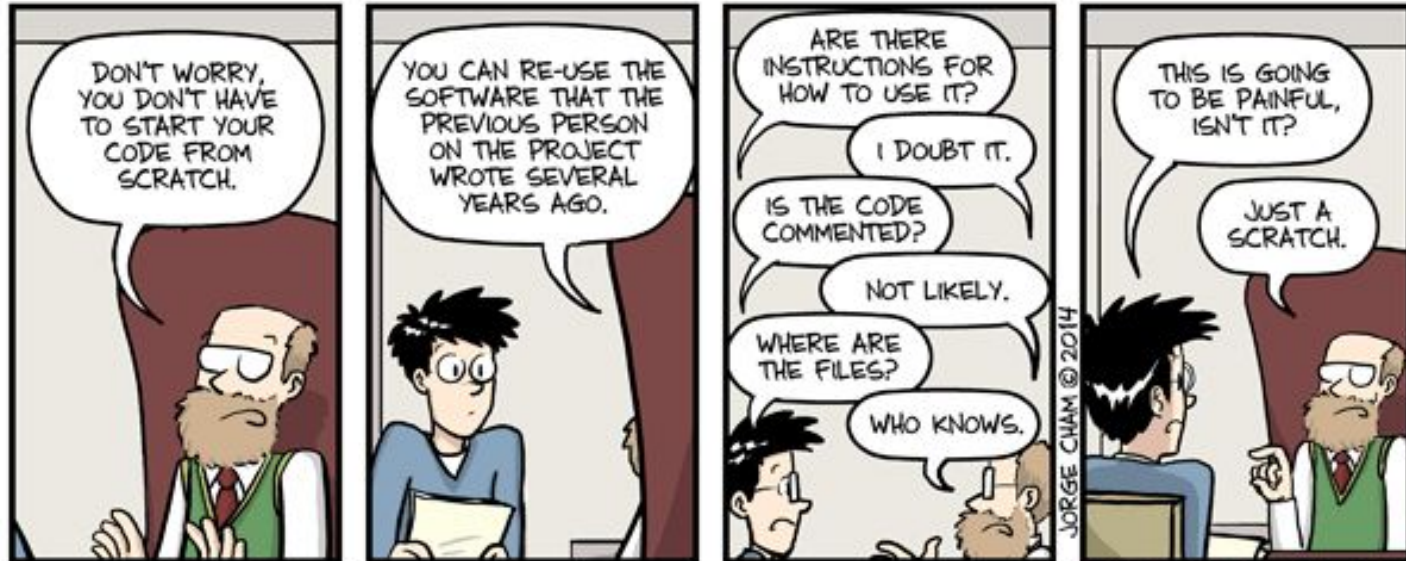


# Introduction to R, RStudio, and RStudio Server

The Data Lab

Powered by Alex's Lemonade Stand Foundation

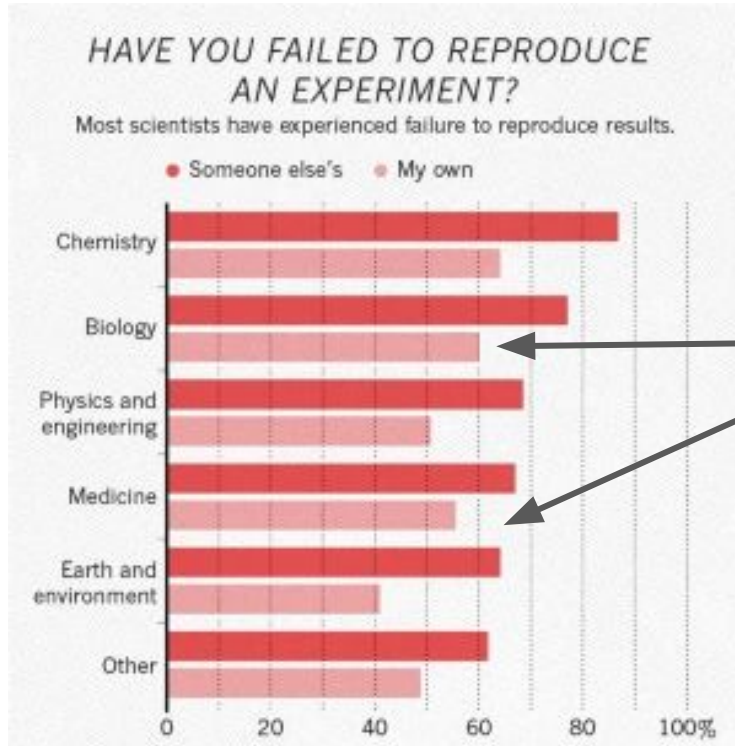
# Who's been here before?



WWW.PHDCOMICS.COM

"Piled Higher and Deeper" by Jorge Cham  
[www.phdcomics.com](http://www.phdcomics.com)  
Used here with permission.

# Reproducibility in 2016



55% and 60% of biologists and clinicians, respectively, could not reproduce their own results.

Baker, M. 1,500 scientists lift the lid on reproducibility. *Nature* 533, 452–454 (2016).  
<https://doi.org/10.1038/533452a>

# One in five genetics papers contains errors thanks to Microsoft Excel

By [Jessica Boddy](#) | Aug. 29, 2016, 1:45 PM

<b>What you type</b>	<b>What you see</b>	<b>How Excel stores it</b>
MARCH1	1-MAR	42430
SEPT2	2-SEP	42615

<https://www.sciencemag.org/news/2016/08/one-five-genetics-papers-contains-errors-thanks-microsoft-excel>  
Ziemann et al. Genome Biology (2016) 17:177 DOI 10.1186/s13059-016-1044-7

# The problem continues...

NEWS | 13 August 2021 | Correction [25 August 2021](#)

## Autocorrect errors in Excel still creating genomics headache

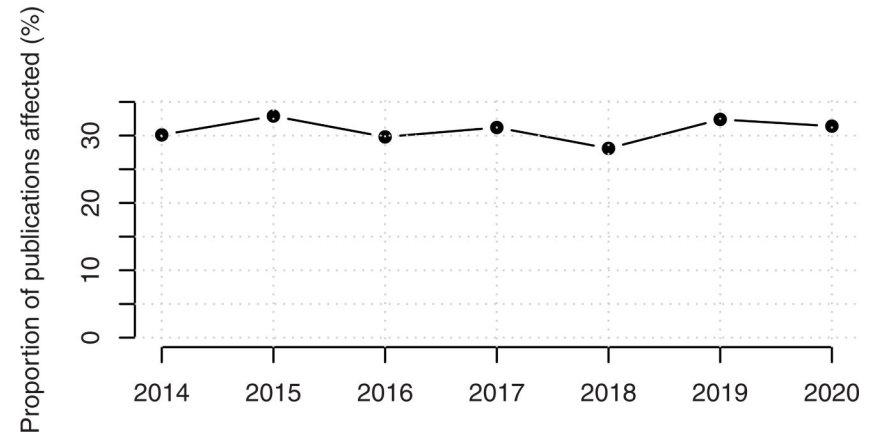
**Despite geneticists being warned about spreadsheet problems, 30% of published papers contain mangled gene names in supplementary data.**

[Dyani Lewis](#)



Embarrassing autocorrect mistakes are common fodder for Internet listicles and Twitter threads. But they are also the bane of geneticists using spreadsheet programs such as Microsoft Excel. Five years after a study showed that [autocorrect problems](#) were widespread, the academic literature is still littered with error-riddled spreadsheets, according to an

<https://www.nature.com/articles/d41586-021-02211-4>



<https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1008984>

# Command line vs GUI (graphics user interface)

- An interface is how you interact with a program
- GUI's have buttons you can *click* to do things, but...
- Command-line interfaces (CLI) have you *type* out things to do them

# RStudio Server: A basic guide

R version 4.2.3 (2023-03-15) -- "Shortstop Beagle"  
Copyright (C) 2023 The R Foundation for Statistical Computing  
Platform: x86\_64-pc-linux-gnu (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.

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.

```
> |
```

Name	Size
.Rhistory	0 B
R	
shared-data	
training-modules	

(FYI, we're now  
at R 4.4.0)

The image shows a screenshot of the RStudio web interface. The top menu bar includes File, Edit, Code, View, Plots, Session, Build, Debug, Profile, Tools, and Help. The main workspace is divided into several panes. The Console pane, highlighted with a red border, displays the R startup message and a prompt. The Environment pane shows an empty global environment. The Files pane shows the current directory structure.

File Edit Code View Plots Session Build Debug Profile Tools Help

datalab

Project: (None)

Console Terminal x Jobs x

R 4.2.3 . ~/ ↗

R version 4.2.3 (2023-03-15) -- "Shortstop Beagle"  
Copyright (C) 2023 The R Foundation for Statistical Computing  
Platform: x86\_64-pc-linux-gnu (64-bit)

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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.

> |

**The Console:**  
where you tell R what to do through  
command line instructions

Environment History Connections Tutorial

114 MiB

Global Environment

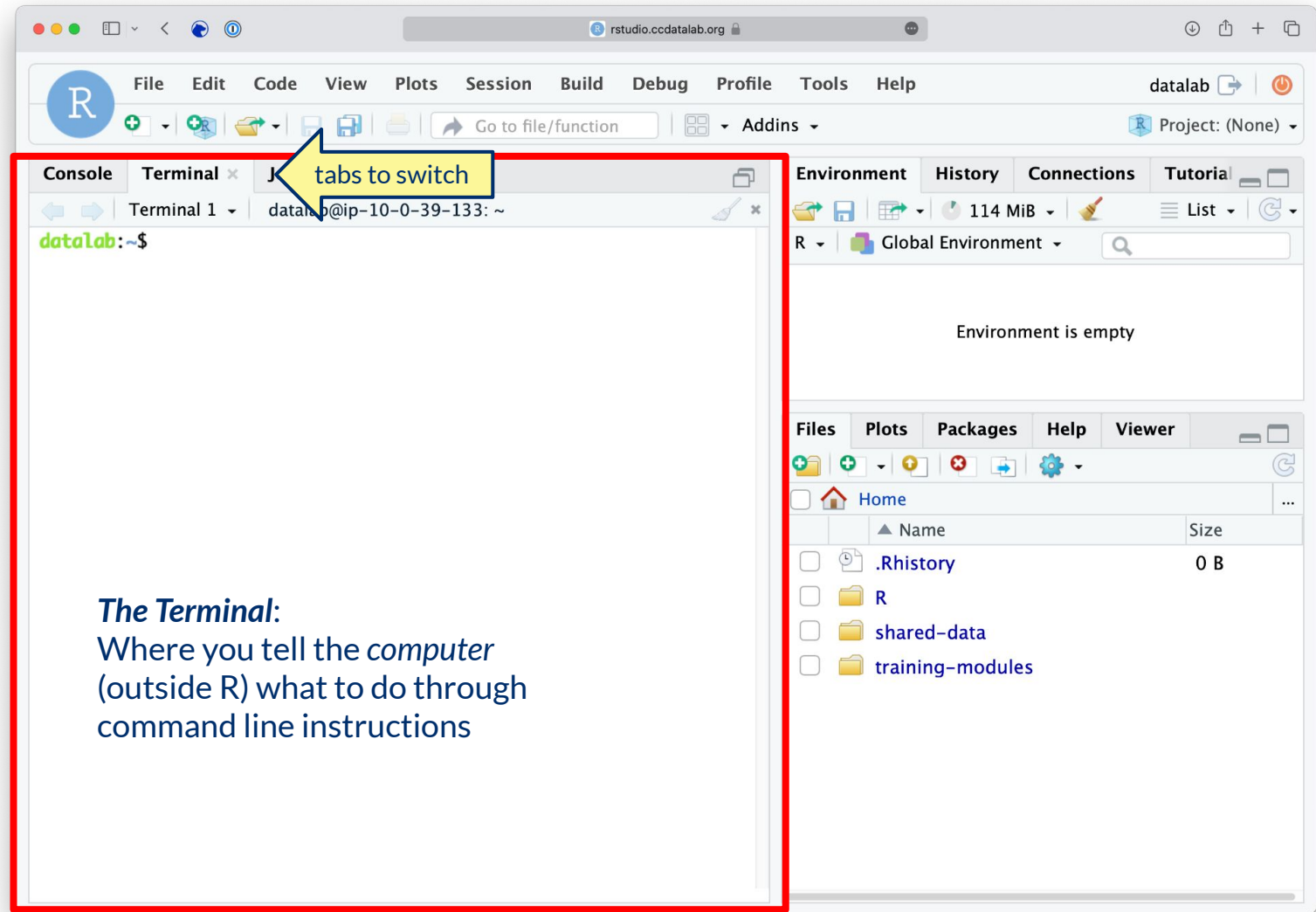
Environment is empty

Files Plots Packages Help Viewer

Home

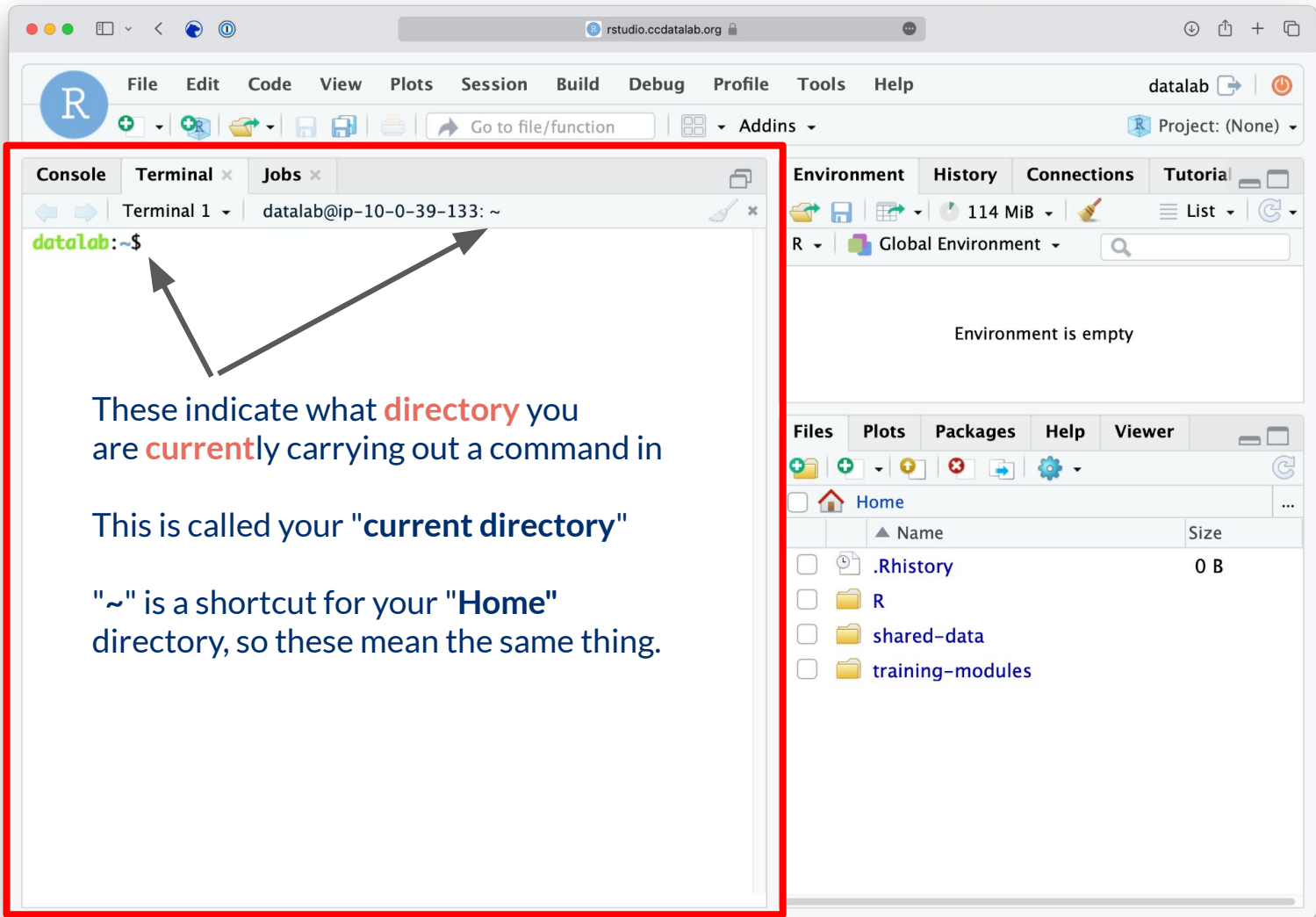
	Name	Size
<input type="checkbox"/>	.Rhistory	0 B
<input type="checkbox"/>	R	
<input type="checkbox"/>	shared-data	
<input type="checkbox"/>	training-modules	



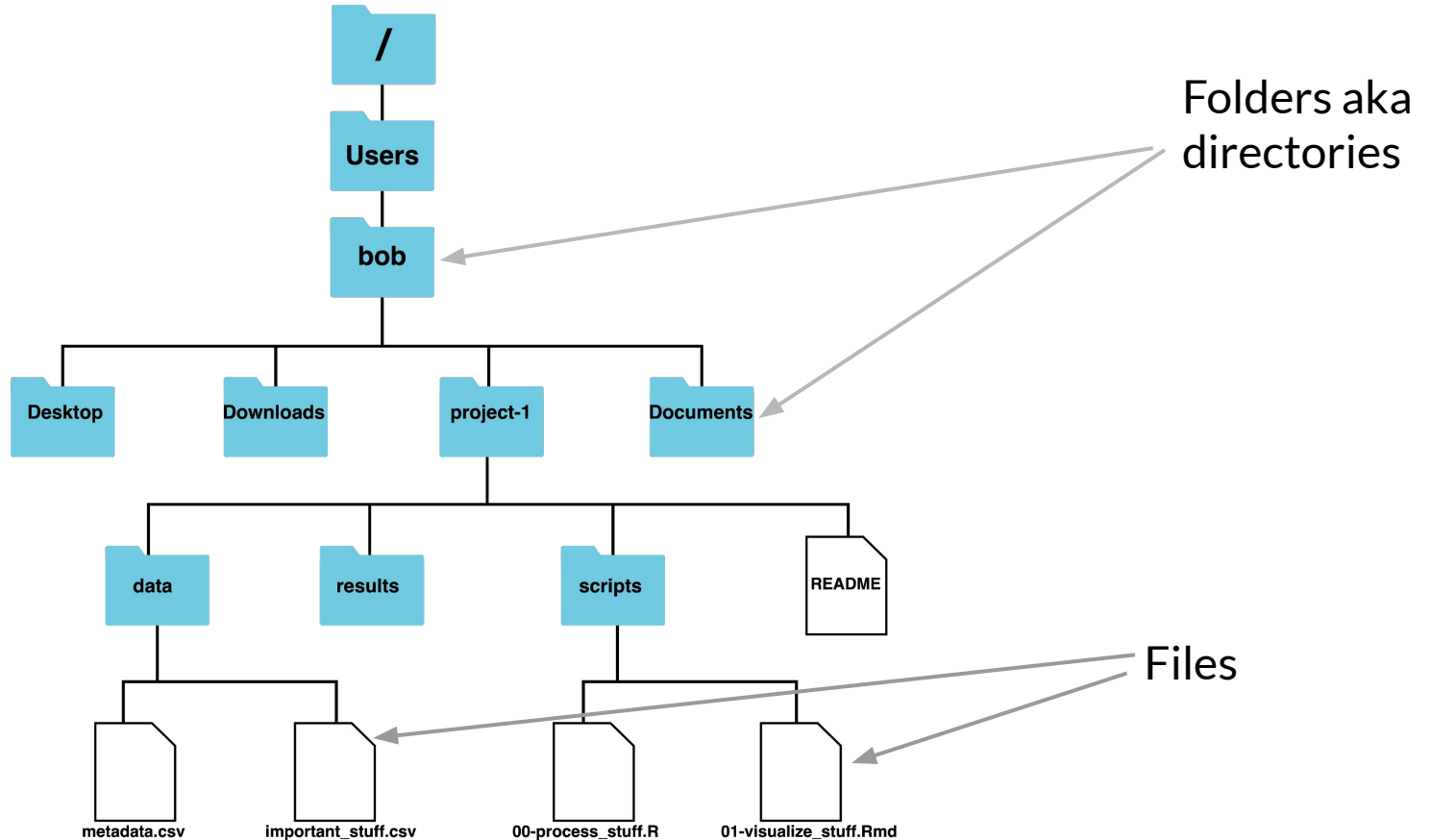


### ***The Terminal:***

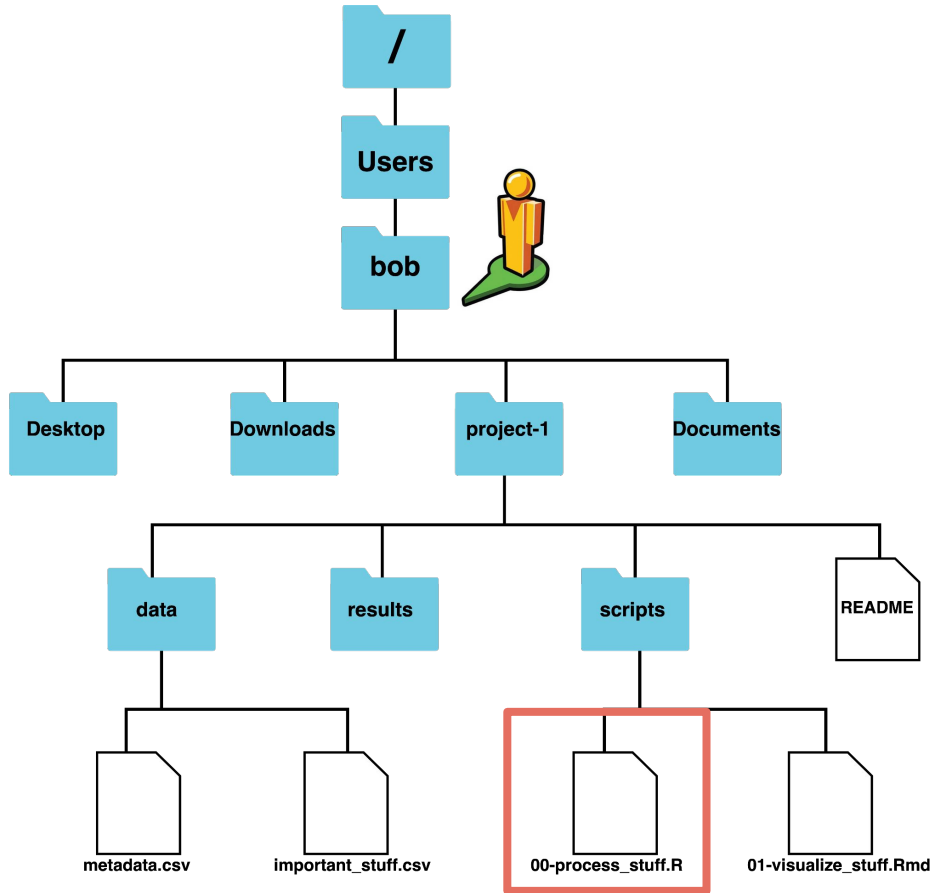
Where you tell the *computer* (outside R) what to do through command line instructions



# Example of a filesystem hierarchy



# We are always working somewhere!



Assume we are working “from” the **bob** directory.  
This means **bob** is the *current (working) directory*

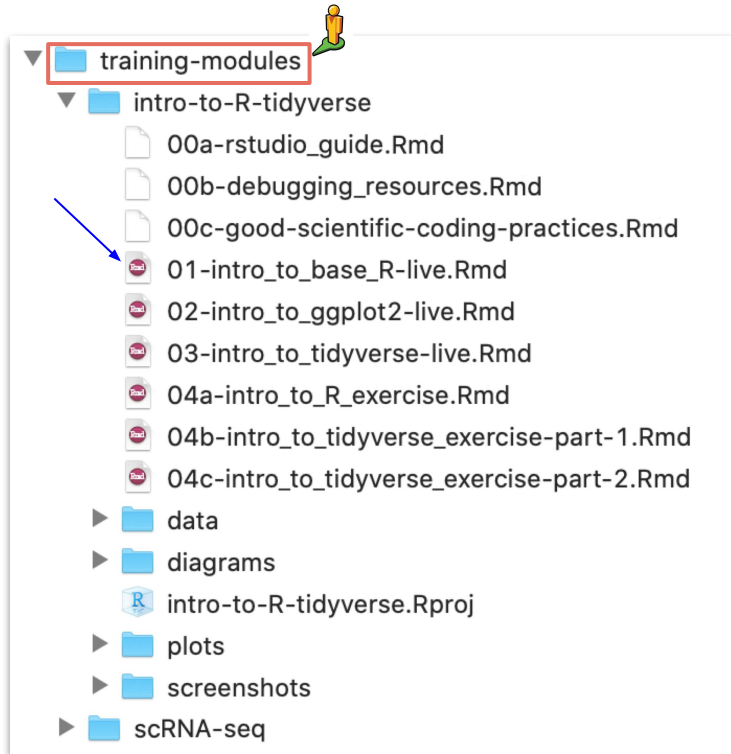
We therefore need to know the **paths** to files we are working with, relative to our working directory, to be able to use those files in our code.

The file we are working on

Relative path: **project-1/scripts/00-process\_stuff.R**

# Let's look at our workshop files

Let's say we want access to `01-intro_to_base_R-live.Rmd`

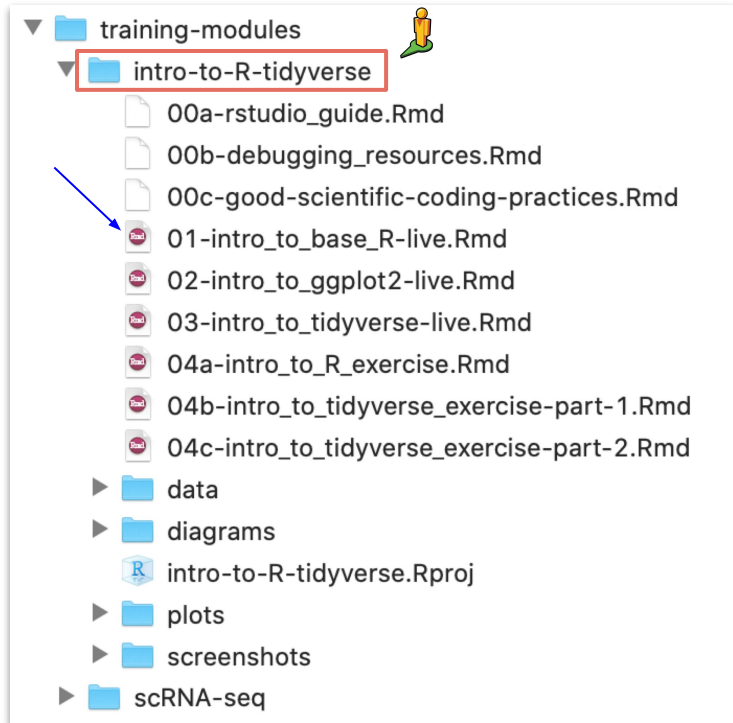


Current/working directory = `training-modules`

File path = `intro-to-R-tidyverse/01-intro_to_base_R-live.Rmd`

# Relative paths depend on your working directory

Let's say we want access to `01-intro_to_base_R-live.Rmd`



Current/working directory = `training-modules/intro-to-R-tidyverse`

File path = `intro-to-R-tidyverse/01-intro_to_base_R-live.Rmd`

dataLab:~\$

These indicate what **directory** you are **currently** carrying out a command in

This is called your "**current directory**"

"~" is a shortcut for your "**Home**" directory, so these mean the same thing.

Environment is empty

Name	Size
.Rhistory	0 B
R	
shared-data	
training-modules	

The image shows the RStudio interface with the following components:

- Terminal:** Shows the execution of `ls` and `cd training-modules/` commands.
- Environment:** Shows the Global Environment is empty.
- Files:** Shows a file explorer view of the Home directory with the following files and folders:

	Name	Size	Modified
<input type="checkbox"/>	.Rhistory	0 B	Jan 31, 2023,
<input type="checkbox"/>	R		
<input type="checkbox"/>	shared-data		
<input type="checkbox"/>	training-modules		

Some common **Terminal** commands:

**ls** - list the files and folders in a directory (files that start with a '.' are not shown by default)

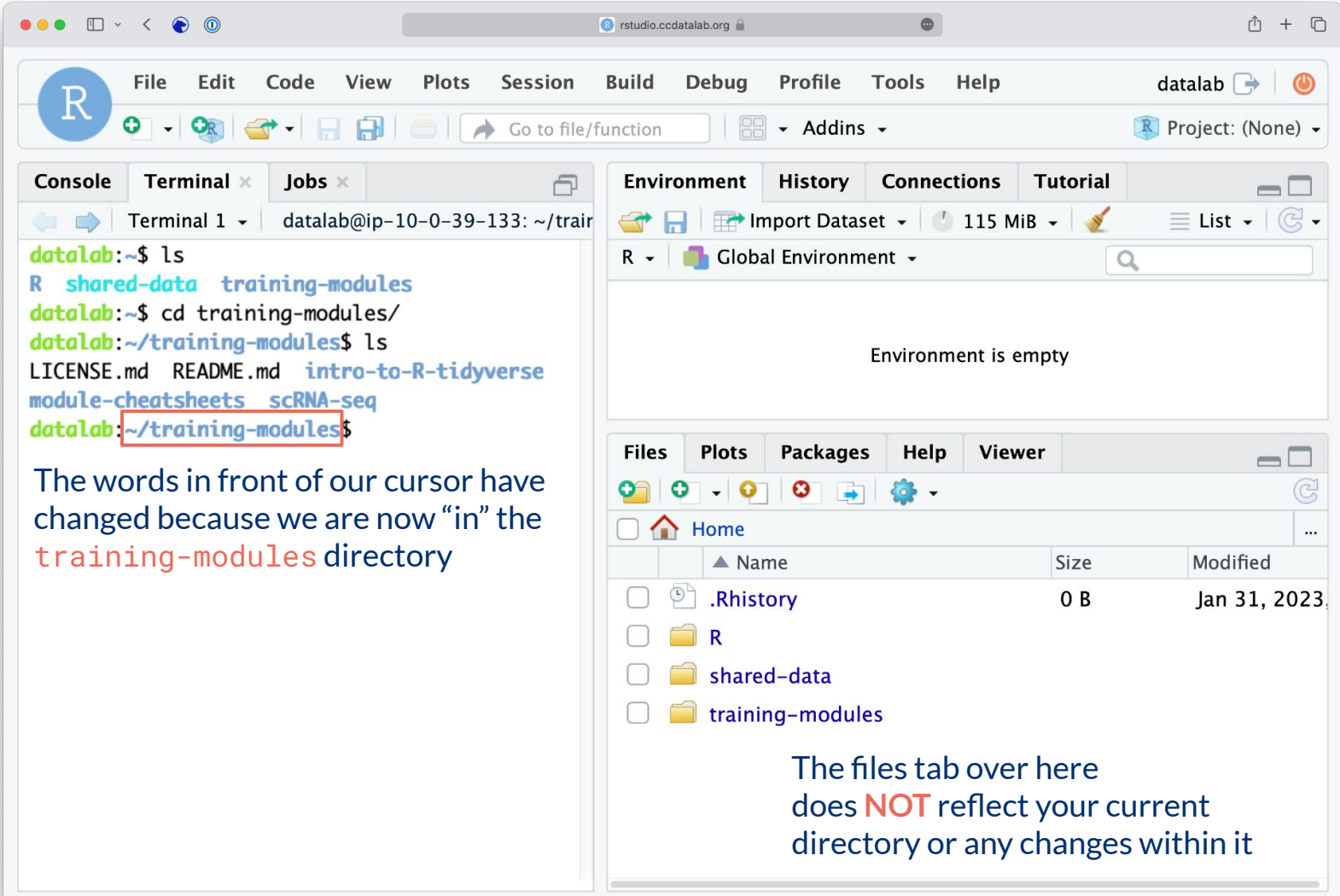
**cd** - change directories



The screenshot shows the RStudio interface with the following components:

- Terminal:** Shows a sequence of commands: `ls`, `cd training-modules/`, and `ls`. The output of the second `ls` command is: `LICENSE.md README.md intro-to-R-tidyverse module-cheatsheets scrna-seq`. The current directory path `~/training-modules` is highlighted with a red box.
- Environment Panel:** Shows "Global Environment" and "Environment is empty".
- Files Panel:** Shows the file explorer for the current directory, listing: `.Rhistory` (0 B, Jan 31, 2023), `R`, `shared-data`, and `training-modules`.

The words in front of our cursor have changed because we are now "in" the `training-modules` directory





# Introduction to R

The Data Lab

# R programming

Programming: making executable scripts for accomplishing a task  
(in this case, data analysis is our task)

Scripts allow others to see, step-by-step, what you did.

## Why we use R:

- It's free and open-source
- People make cool packages that do stuff for us
- Many researchers in genomics use it (as well as Python)

# R, RStudio, and RStudio Server

R is a statistical programming language.



RStudio is an IDE for working in R

- IDE: Integrated Development Environment
- We write R code using the (free!) RStudio IDE



RStudio Server allows us to run the RStudio IDE from a browser

The screenshot shows the RStudio interface with a notebook titled "01-intro\_to\_base\_R-live.Rmd". The code in the notebook includes instructions on how to run code chunks and a code chunk that calculates  $5 * 6$ . The console output shows the result  $[1] 30$ . The Environment pane is empty, and the Files pane shows a directory structure with various R Markdown files. A red box highlights the "Console" button in the bottom right corner of the R Markdown editor, with a red arrow pointing to it and a text box that says "Click here to show the Console".

```
84 | Divide | ` / ` |
85 | Exponentiate | ` ^ ` or ` ** ` |
86
87 For example, we can do some simple multiplication like this.
88 When you execute code within the notebook, the results appear beneath
89 the code.
90 Try executing this chunk by clicking the *Run* button within the chunk
91 or by
92 placing your cursor inside it and pressing *Cmd+Shift+Enter*.
93
94 ```{r calculator}
95 5 * 6
96 ```
```

[1] 30

```
97
98 Use the console to calculate other expressions. Standard order of
99 operations applies (mostly), and you can use parentheses `(`) as you
100 might expect (but not brackets `[` or braces `{}`, which have special
101 meanings). Note however, that you must **always** specify multiplication
102 with `*`; implicit multiplication such as `10(3 + 4)` or `10x` will not
103 work and will generate an error, or worse.
104
105 ```{r expressions, live = TRUE}
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105:193 # Defining and using variables R Markdown

Console

Name	Size	Modified
00a-intro_to_tidyverse.md	13.6 KB	Apr 7, 2023
00b-debugging_resources.md	3.9 KB	Apr 7, 2023
00c-good-scientific-coding-pr...	19 KB	Apr 7, 2023
01-intro_to_base_R-live.Rmd	11.5 KB	Apr 7, 2023
02-intro_to_ggplot2-live.Rmd	21.3 KB	Apr 7, 2023
03-intro_to_tidyverse-live.Rmd		
exercise_01a-intro_to_tidyvers...	6.2 KB	Apr 7, 2023
exercise_02a-intro_to_tidyvers...	1.8 KB	Apr 7, 2023
exercise_03b-intro_to_tidyvers...		
README.md		

Click here to show the Console

The screenshot displays the RStudio interface. The main editor window shows a script titled "01-intro\_to\_base\_R-live.Rmd" with the following code:

```
95  
96 Use the console to calculate other expressions. Standard order of  
operations applies (mostly), and you can use parentheses `()` as you  
might expect (but not brackets `[]` or braces `{}`, which have special  
meanings). Note however, that you must **always** specify multiplication  
with `*`; implicit multiplication such as `10(3 + 4)` or `10x` will not  
work and will generate an error, or worse.  
97  
98 ```{r expressions, live = TRUE}  
99 x <- 5.5  
100  
101 x  
102 ```
```

The Environment pane on the right shows the Global Environment with a variable `x` having a value of `5.5`.

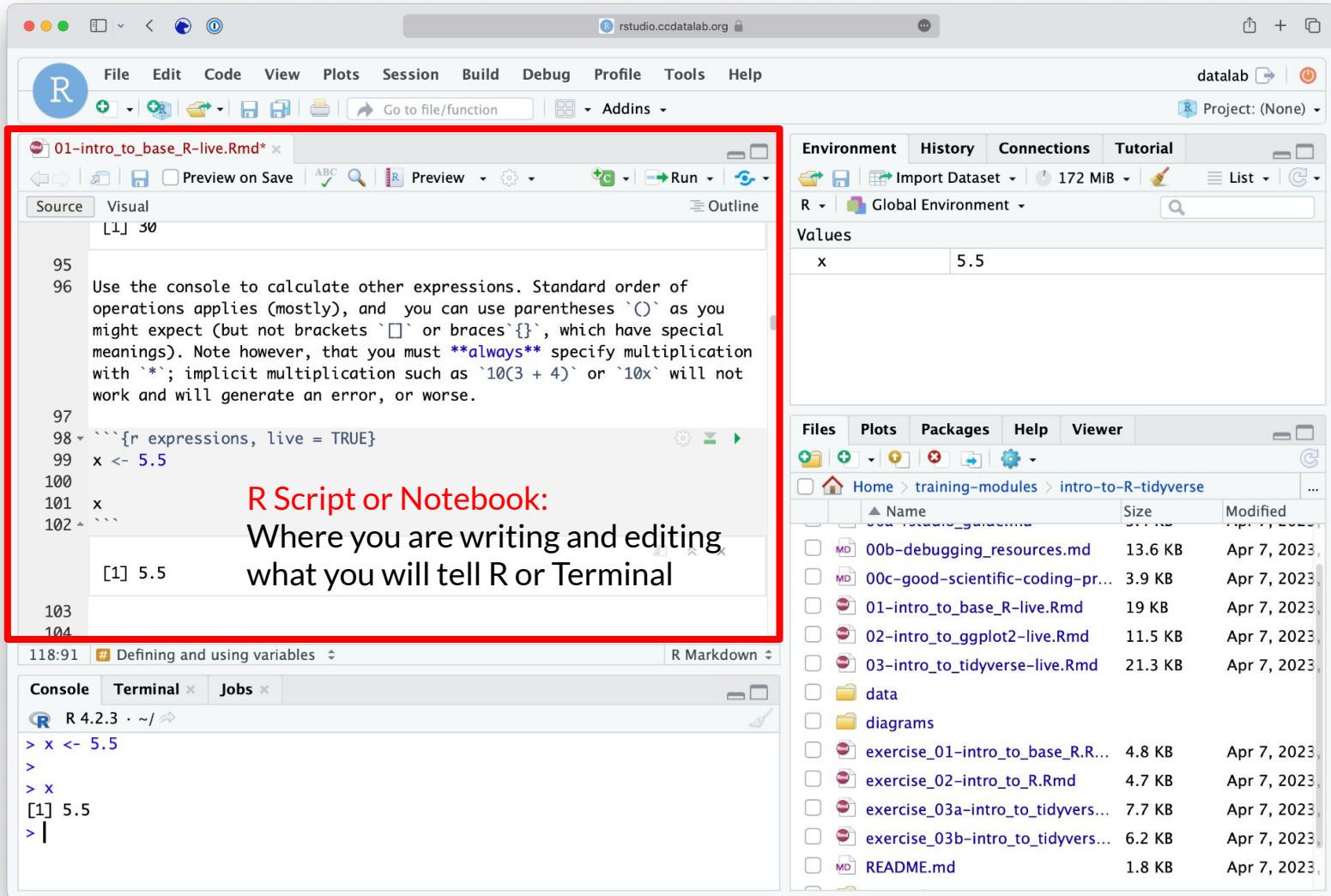
The Files pane on the right shows a directory listing for `training-modules > intro-to-R-tidyverse`:

Name	Size	Modified
00a-creating_variables.md	13.6 KB	Apr 7, 2023
00b-debugging_resources.md	3.9 KB	Apr 7, 2023
00c-good-scientific-coding-pr...	19 KB	Apr 7, 2023
01-intro_to_base_R-live.Rmd	11.5 KB	Apr 7, 2023
02-intro_to_ggplot2-live.Rmd	21.3 KB	Apr 7, 2023
03-intro_to_tidyverse-live.Rmd		
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exercise_01-intro_to_base_R.R...	4.8 KB	Apr 7, 2023
exercise_02-intro_to_R.Rmd	4.7 KB	Apr 7, 2023
exercise_03a-intro_to_tidyvers...	7.7 KB	Apr 7, 2023
exercise_03b-intro_to_tidyvers...	6.2 KB	Apr 7, 2023
README.md	1.8 KB	Apr 7, 2023

The Console pane at the bottom, highlighted with a red border, shows the R session output:

```
R 4.2.3 · ~/ /  
> x <- 5.5  
>  
> x  
[1] 5.5  
> |
```

**R Console:**  
What you are actually telling R to do



**R Script or Notebook:**  
Where you are writing and editing  
what you will tell R or Terminal

```
95  
96 Use the console to calculate other expressions. Standard order of  
operations applies (mostly), and you can use parentheses `()` as you  
might expect (but not brackets `[]` or braces `{}`, which have special  
meanings). Note however, that you must **always** specify multiplication  
with `*`; implicit multiplication such as `10(3 + 4)` or `10x` will not  
work and will generate an error, or worse.  
97  
98 ```{r expressions, live = TRUE}  
99 x <- 5.5  
100  
101 x  
102 ```  
  
[1] 5.5  
  
103  
104
```

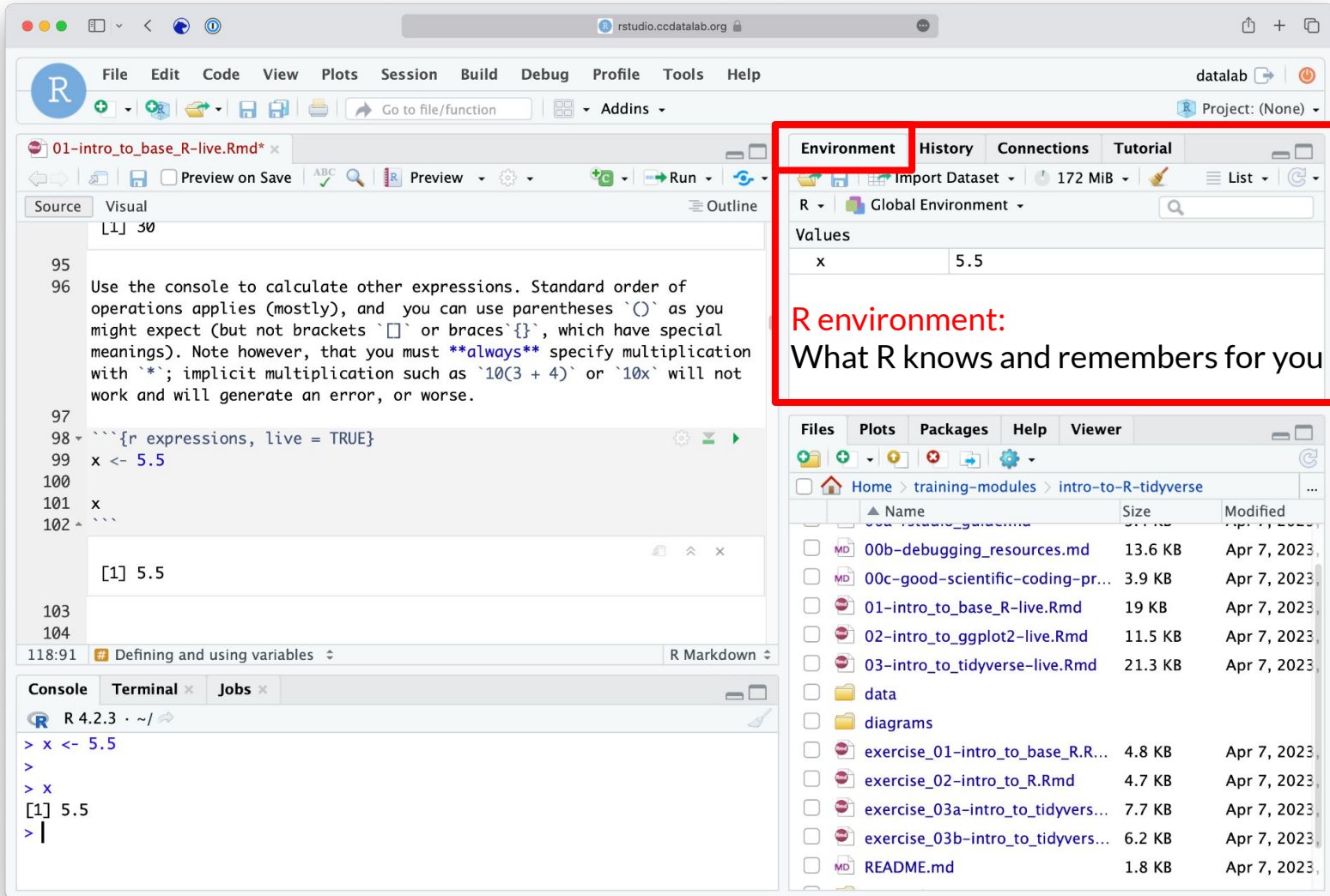
```
118:91 # Defining and using variables  
R 4.2.3 ~/  
> x <- 5.5  
>  
> x  
[1] 5.5  
> |
```

Environment History Connections Tutorial  
Import Dataset 172 MiB  
R Global Environment  
Values  
x 5.5

Files Plots Packages Help Viewer  
Home > training-modules > intro-to-R-tidyverse

Name	Size	Modified
00a-tidyverse_guidance		
00b-debugging_resources.md	13.6 KB	Apr 7, 2023
00c-good-scientific-coding-pr...	3.9 KB	Apr 7, 2023
01-intro_to_base_R-live.Rmd	19 KB	Apr 7, 2023
02-intro_to_ggplot2-live.Rmd	11.5 KB	Apr 7, 2023
03-intro_to_tidyverse-live.Rmd	21.3 KB	Apr 7, 2023
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exercise_01-intro_to_base_R.R...	4.8 KB	Apr 7, 2023
exercise_02-intro_to_R.Rmd	4.7 KB	Apr 7, 2023
exercise_03a-intro_to_tidyvers...	7.7 KB	Apr 7, 2023
exercise_03b-intro_to_tidyvers...	6.2 KB	Apr 7, 2023
README.md	1.8 KB	Apr 7, 2023





File Edit Code View Plots Session Build Debug Profile Tools Help

datalab Project: (None)

01-intro\_to\_base\_R-live.Rmd\*

Source Visual Outline

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[1] 30

95
96 Use the console to calculate other expressions. Standard order of
operations applies (mostly), and you can use parentheses `()` as you
might expect (but not brackets `[]` or braces `{}`, which have special
meanings). Note however, that you must **always** specify multiplication
with `*`; implicit multiplication such as `10(3 + 4)` or `10x` will not
work and will generate an error, or worse.
97
98 ```{r expressions, live = TRUE}
99 x <- 5.5
100
101 x
102 ```

[1] 5.5

103
104
```

118:91 # Defining and using variables R Markdown

Console Terminal Jobs

```
R 4.2.3 ~/>
> x <- 5.5
>
> x
[1] 5.5
> |
```

Environment History Connections Tutorial

Import Dataset 172 MiB List

R Global Environment

Values

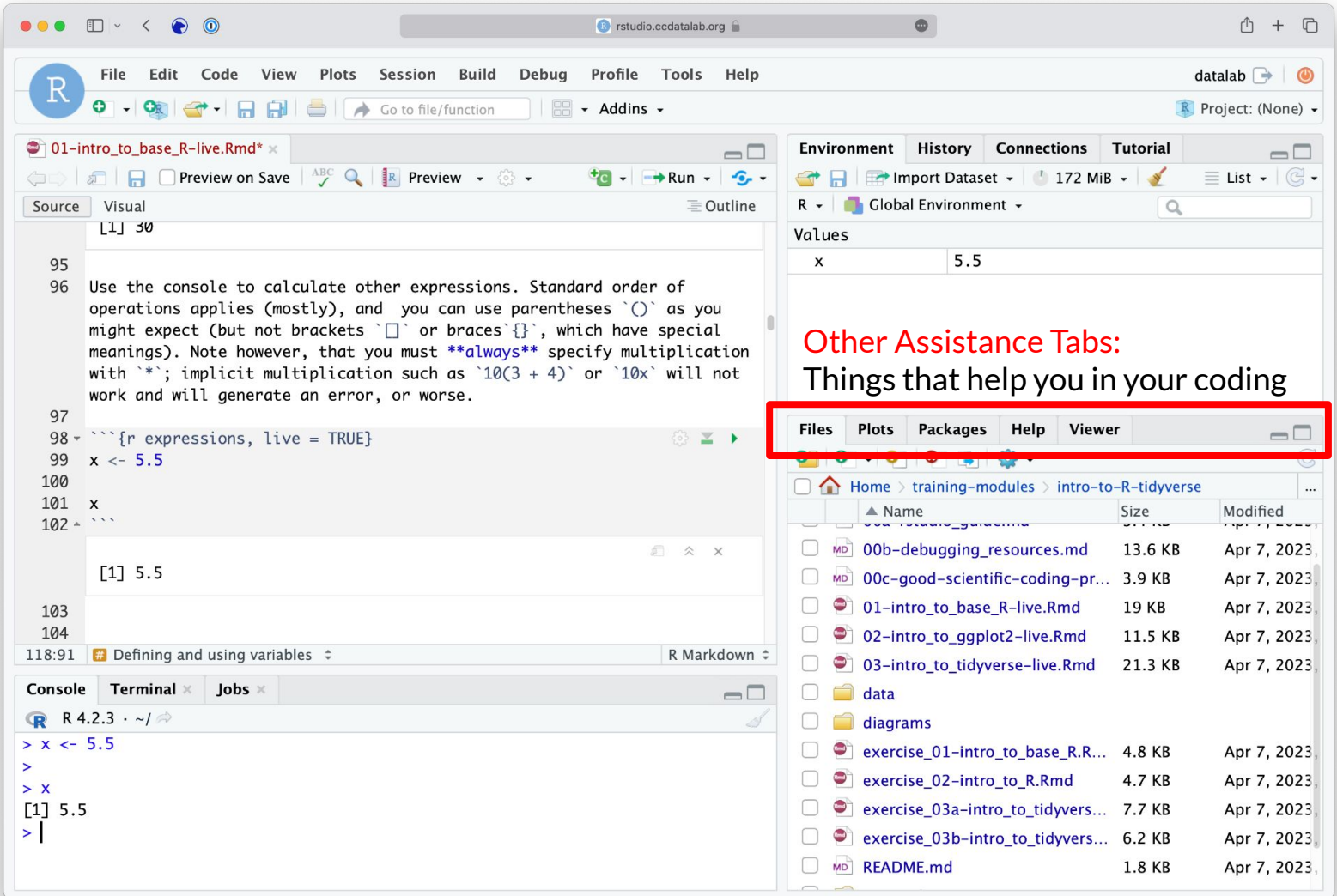
x	5.5
---	-----

**R environment:**  
What R knows and remembers for you

Files Plots Packages Help Viewer

Home > training-modules > intro-to-R-tidyverse

Name	Size	Modified
00a-intro_to_base_R-live.Rmd	4.8 KB	Apr 7, 2023
00b-debugging_resources.md	13.6 KB	Apr 7, 2023
00c-good-scientific-coding-pr...	3.9 KB	Apr 7, 2023
01-intro_to_base_R-live.Rmd	19 KB	Apr 7, 2023
02-intro_to_ggplot2-live.Rmd	11.5 KB	Apr 7, 2023
03-intro_to_tidyverse-live.Rmd	21.3 KB	Apr 7, 2023
data		
diagrams		
exercise_01-intro_to_base_R.R...	4.8 KB	Apr 7, 2023
exercise_02-intro_to_R.Rmd	4.7 KB	Apr 7, 2023
exercise_03a-intro_to_tidyvers...	7.7 KB	Apr 7, 2023
exercise_03b-intro_to_tidyvers...	6.2 KB	Apr 7, 2023
README.md	1.8 KB	Apr 7, 2023



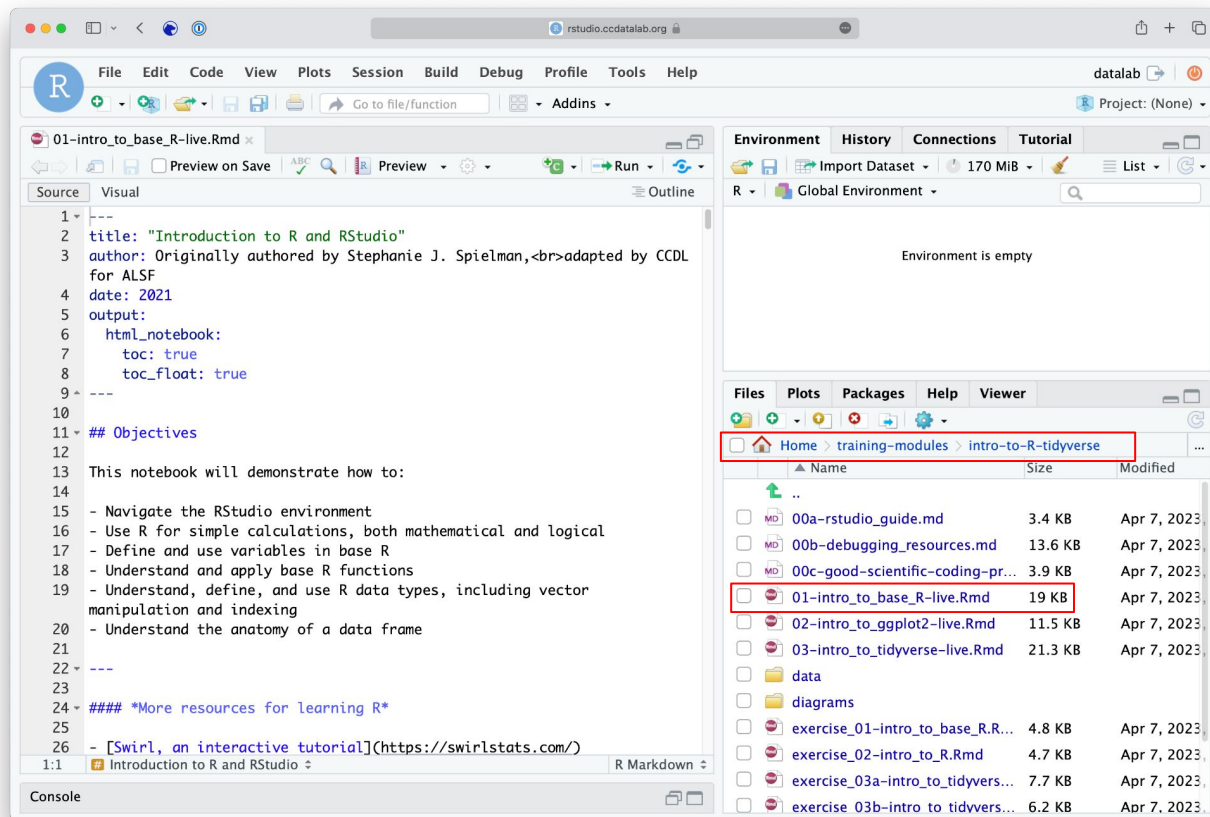
Other Assistance Tabs:  
Things that help you in your coding



Name	Size	Modified
00b-debugging_resources.md	13.6 KB	Apr 7, 2023
00c-good-scientific-coding-pr...	3.9 KB	Apr 7, 2023
01-intro_to_base_R-live.Rmd	19 KB	Apr 7, 2023
02-intro_to_ggplot2-live.Rmd	11.5 KB	Apr 7, 2023
03-intro_to_tidyverse-live.Rmd	21.3 KB	Apr 7, 2023
data		
diagrams		
exercise_01-intro_to_base_R.R...	4.8 KB	Apr 7, 2023
exercise_02-intro_to_R.Rmd	4.7 KB	Apr 7, 2023
exercise_03a-intro_to_tidyvers...	7.7 KB	Apr 7, 2023
exercise_03b-intro_to_tidyvers...	6.2 KB	Apr 7, 2023
README.md	1.8 KB	Apr 7, 2023

# R Notebooks

Use the "Files" tab to open: `training-modules/intro-to-R-tidyverse/01-intro_to_base_R-live.Rmd`



The screenshot displays the RStudio interface. The main editor shows the R Notebook content, which includes a title, author information, and a list of objectives. The 'Files' pane on the right shows the directory structure, with the file `01-intro_to_base_R-live.Rmd` highlighted.

```
1 ---
2 title: "Introduction to R and RStudio"
3 author: Originally authored by Stephanie J. Spielman, <br> adapted by CC DL
  for ALSF
4 date: 2021
5 output:
6   html_notebook:
7     toc: true
8     toc_float: true
9 ---
10
11 ## Objectives
12
13 This notebook will demonstrate how to:
14
15 - Navigate the RStudio environment
16 - Use R for simple calculations, both mathematical and logical
17 - Define and use variables in base R
18 - Understand and apply base R functions
19 - Understand, define, and use R data types, including vector
  manipulation and indexing
20 - Understand the anatomy of a data frame
21
22 ---
23
24 #### *More resources for learning R*
25
26 - [Swirl, an interactive tutorial](https://swirlstats.com/)
```

The 'Files' pane shows the following directory structure:

- Home > training-modules > intro-to-R-tidyverse
- ..
- 00a-rstudio\_guide.md (3.4 KB, Apr 7, 2023)
- 00b-debugging\_resources.md (13.6 KB, Apr 7, 2023)
- 00c-good-scientific-coding-pr... (3.9 KB, Apr 7, 2023)
- 01-intro\_to\_base\_R-live.Rmd (19 KB, Apr 7, 2023)**
- 02-intro\_to\_ggplot2-live.Rmd (11.5 KB, Apr 7, 2023)
- 03-intro\_to\_tidyverse-live.Rmd (21.3 KB, Apr 7, 2023)
- data
- diagrams
- exercise\_01-intro\_to\_base\_R.R... (4.8 KB, Apr 7, 2023)
- exercise\_02-intro\_to\_R.Rmd (4.7 KB, Apr 7, 2023)
- exercise\_03a-intro\_to\_tidvers... (7.7 KB, Apr 7, 2023)
- exercise\_03b-intro\_to tidvers... (6.2 KB, Apr 7, 2023)

# R Notebooks

R Notebooks allow you to have files that show both your code and results

Executable code chunk

Can click here to run a code chunk

The screenshot shows the RStudio interface with an R Notebook open. The notebook content includes:

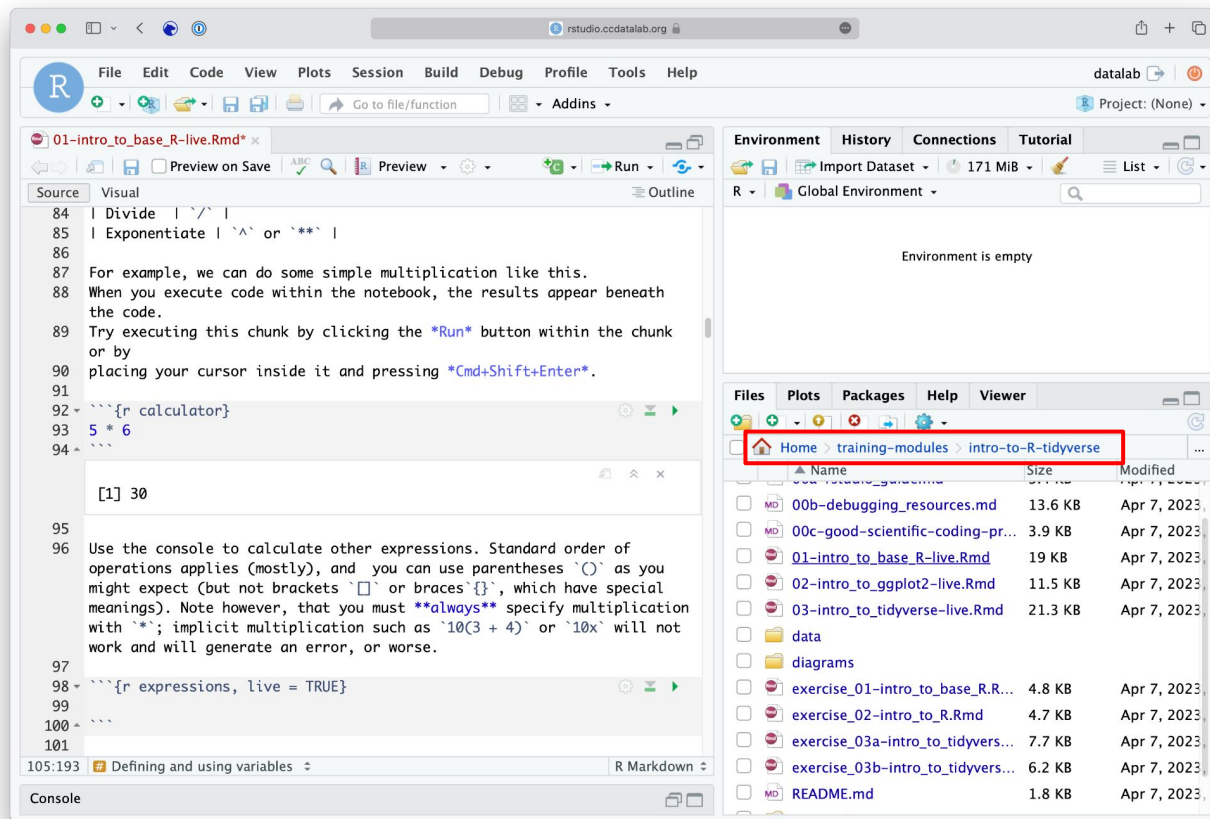
```
84 | Divide | \ / |
85 | Exponentiate | ^ or ** |
86
87 For example, we can do some simple multiplication like this.
88 When you execute code within the notebook, the results appear beneath
89 the code.
90 Try executing this chunk by clicking the *Run* button within the chunk
91 or by
92 placing your cursor inside it and pressing *Cmd+Shift+Enter*.
93
94 {r calculator}
95 5 * 6
96
97 [1] 30
98
99 Use the console to calculate other expressions. Standard order of
100 operations applies (mostly), and you can use parentheses `()` as you
101 might expect (but not brackets `[]` or braces `{}`, which have special
102 meanings). Note however, that you must **always** specify multiplication
103 with `*`; implicit multiplication such as `10(3 + 4)` or `10x` will not
104 work and will generate an error, or worse.
105
106 {r expressions, live = TRUE}
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```

The code chunk is highlighted with a blue box, and the output `[1] 30` is highlighted with a red box. A blue arrow points from the text "Executable code chunk" to the code chunk. A green arrow points from the text "Can click here to run a code chunk" to the Run button in the code chunk. A red arrow points from the text "Output from above code chunk" to the output box.

Output from above code chunk

# R Notebooks

- Code that runs in R Notebooks uses wherever the file is saved as its current directory
- **Warning!** That may not be the directory shown in the files pane or the console!



# RStudio Sessions

- On the server, R is running many times at once
  - Each user has their own “**Session**” running, with its own memory and processes
- We will usually want to start new sessions between notebooks to keep the environment clean

Log out of website



End the current session and start new session