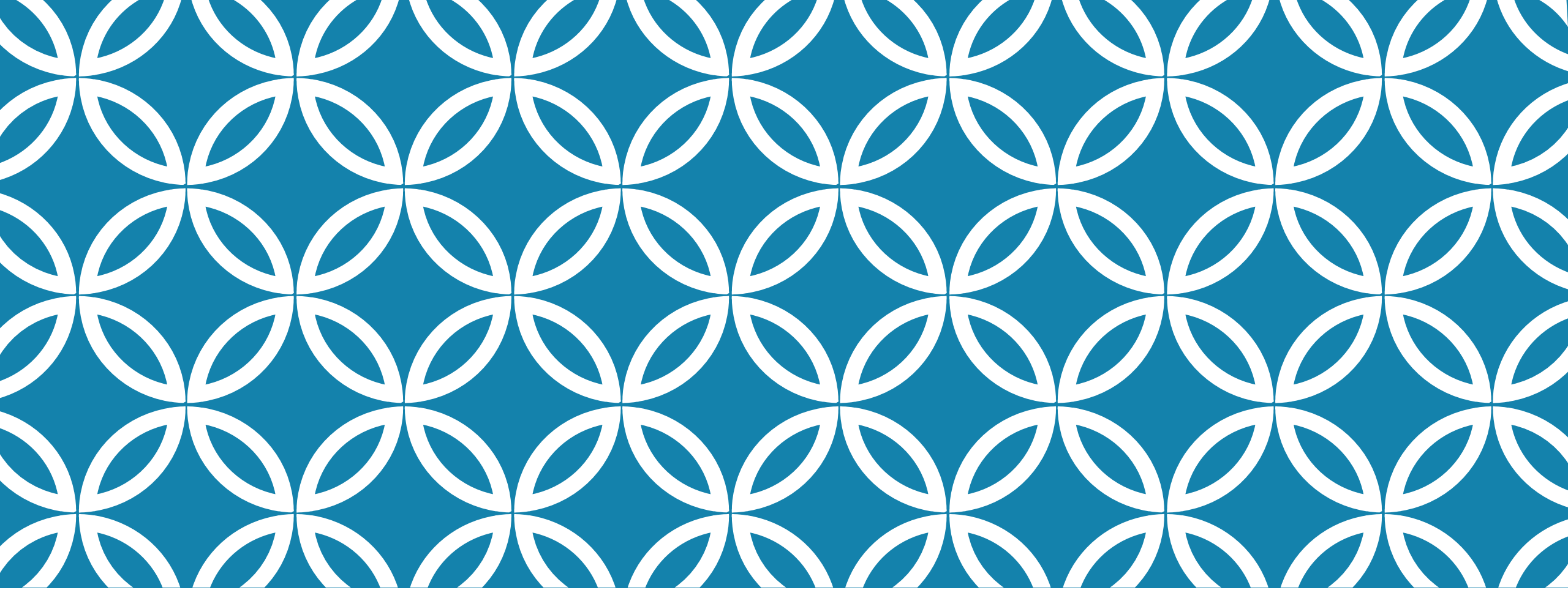


Introduction to R and Reproducible Reporting

Patrick Mathias

Lesson 1

DLMP Fall 2021

Course Introduction

Goals and Objectives

- Advocate for the use of R as a means of improving reproducibility in clinical data analysis
- Demonstrate how R is used to perform analyses of laboratory operational data
- Establish a basis of understanding in the 'tidy' approach to data analysis within the framework of R

Workshop Workflow

Sessions

Loading Data to Create a Dataframe

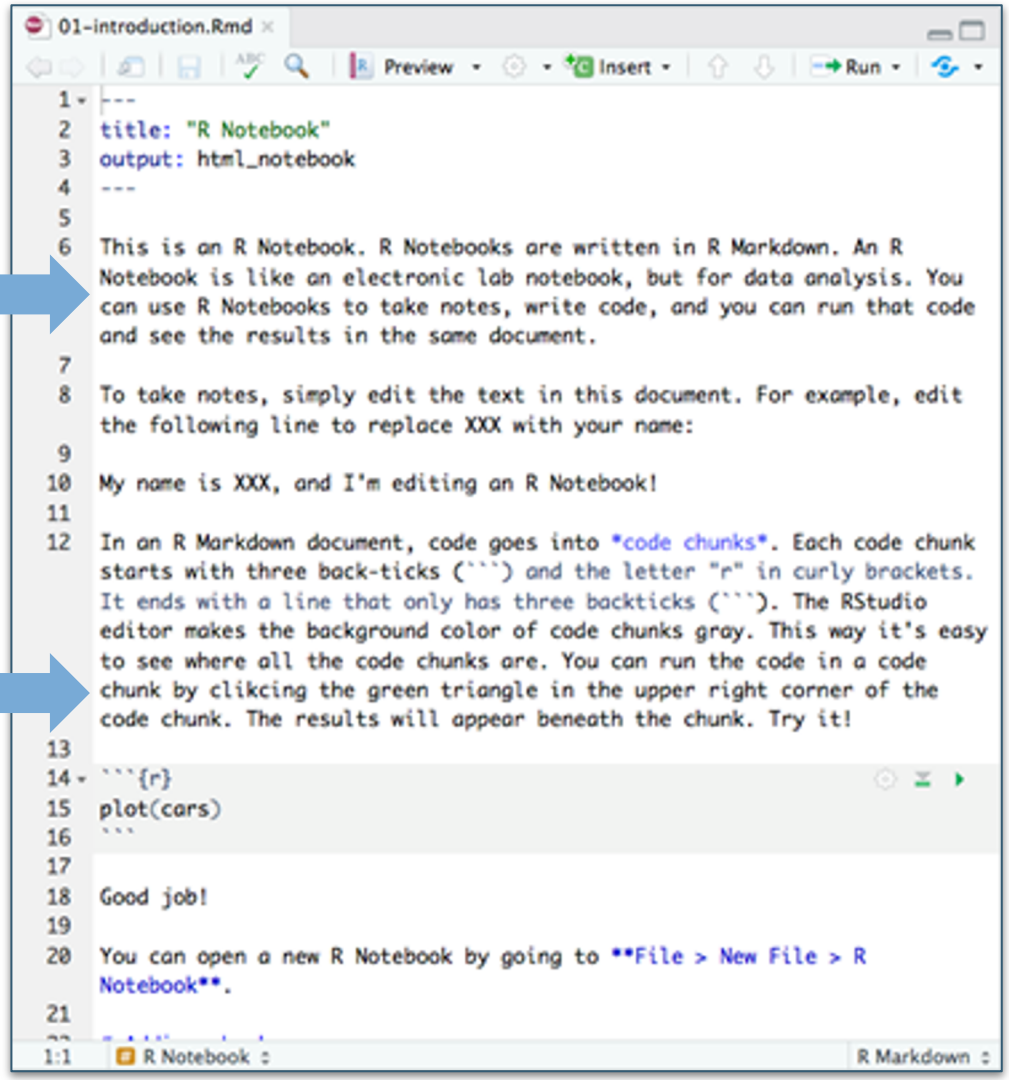
```
data_frame <- read_csv("file_name")
```

Your Turn

Introduce yourself to your neighbors

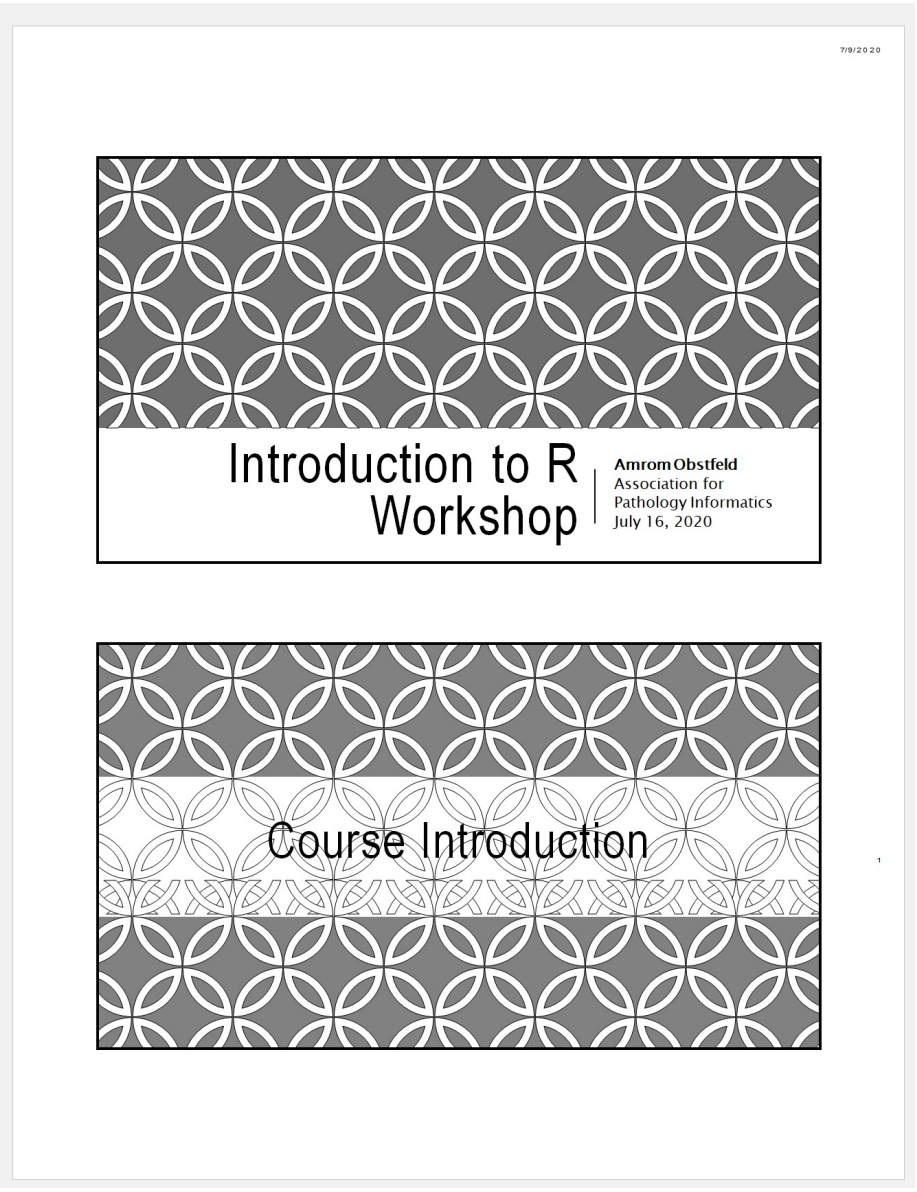
- Who are you?
- Where are you from?
- What do you do with data?
- Have you ever used R?

3:00



Workshop Coursebook

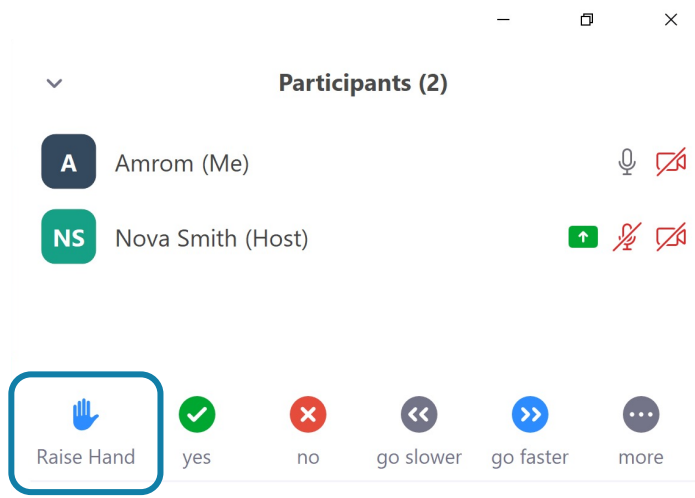
- Coursepack folder on website contains:
  - PDFs for slides
  - Cheatsheets



Using Zoom

- Participants muted
- Chat window
- Non-verbal feedback
- Breakout sessions

Getting Help



- Simple question – Chat window
- More complicated - Raise hand, instructor will message
- Really complicated – Breakout session

Tips for learning

- Cheatsheets show how to do common things – orient yourself with them early
- The best way to learn to code is by doing
- Practice is key!
- Programming is hard, even for those with a lot of experience. Find resources and ask for help!

Lesson Goals

1. Get oriented to the R programming environment
2. Appreciate the importance of reproducible data analysis

Lesson Objectives

1. Define R, RStudio and R Markdown
2. Log in and navigate RStudio Cloud
3. Discuss the risks of unreproducible data analysis
4. Create a R Markdown document

R

Programming language for data analysis

RStudio

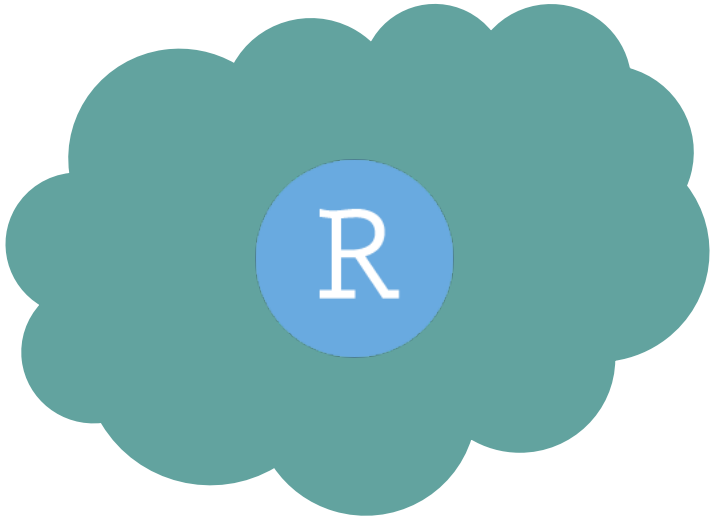
Interactive development environment (IDE)

R Markdown

Computational document format

Getting Started with RStudio

RStudio: On the Web and In Your Home



RStudio Cloud
Hosted on a server
(in the cloud)

RStudio Desktop
Installed locally on
your computer

Note: Use RStudio Cloud only for this course. Do not upload protected health information to the cloud!

Your Turn

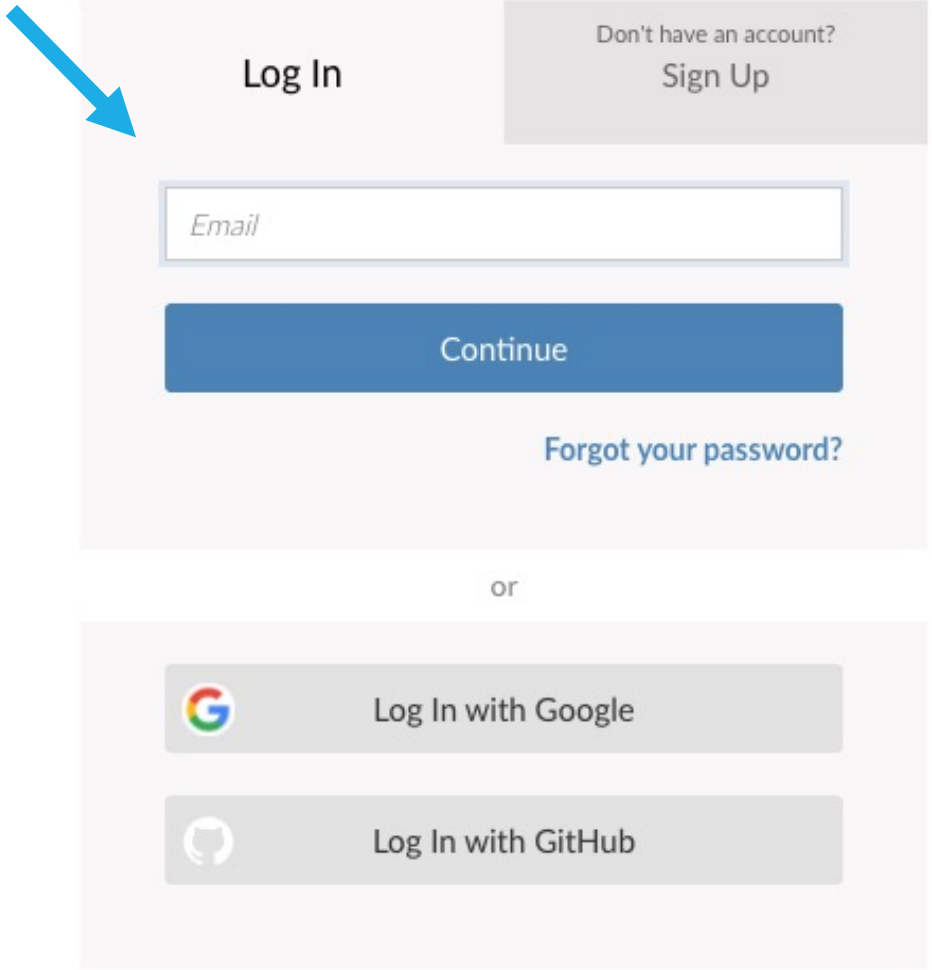
Navigate to: https://bit.ly/dlmp-fall-2021

Enter your log in credentials

Join Space

Make a copy of the Core Exercises for yourself

RStudio


Log In
Don't have an account?
Sign Up
Email
Continue
Forgot your password?
or
Log In with Google
Log In with GitHub

Join Space?

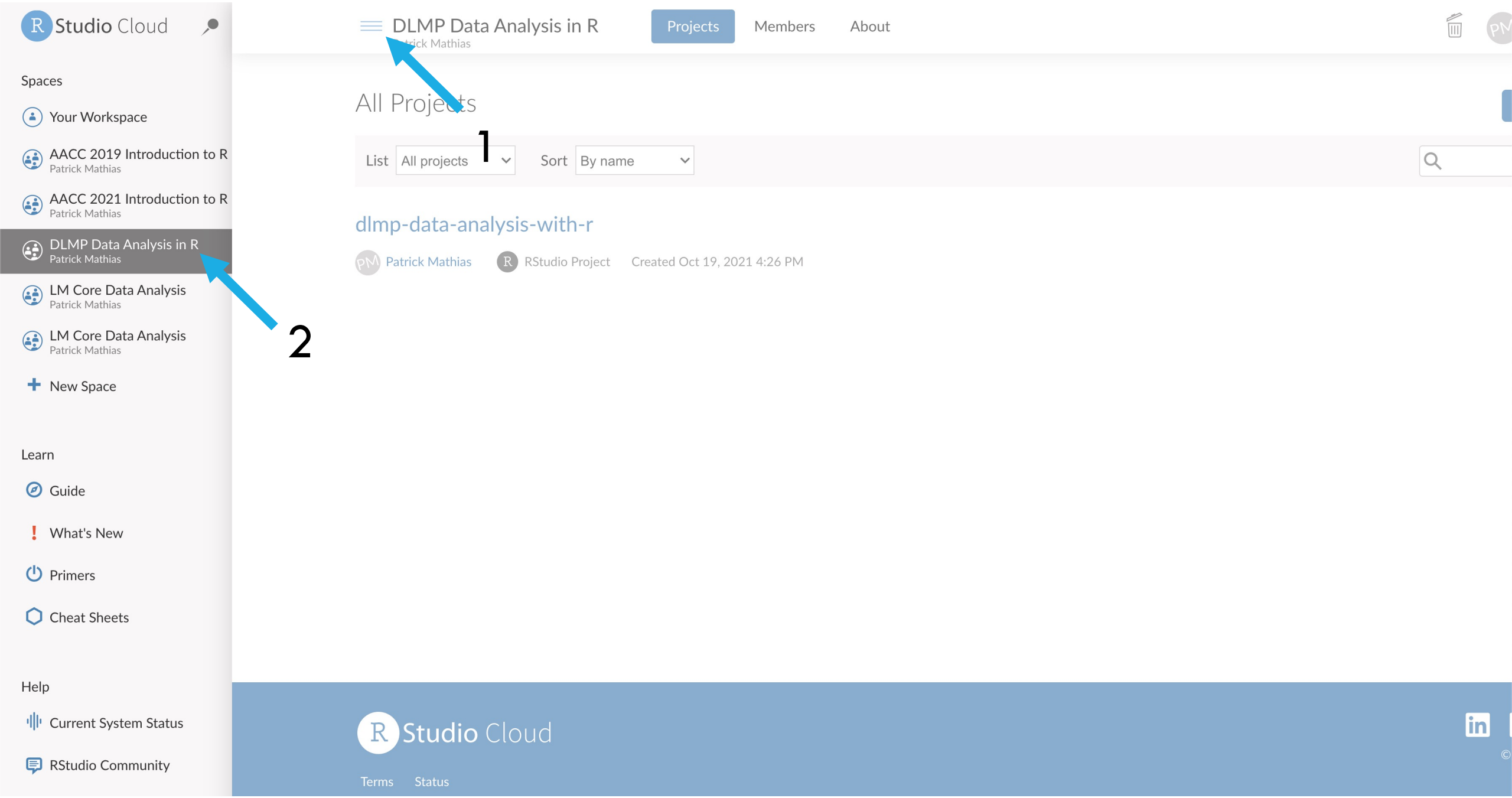
Joining a space gives you access to it and to its contents.

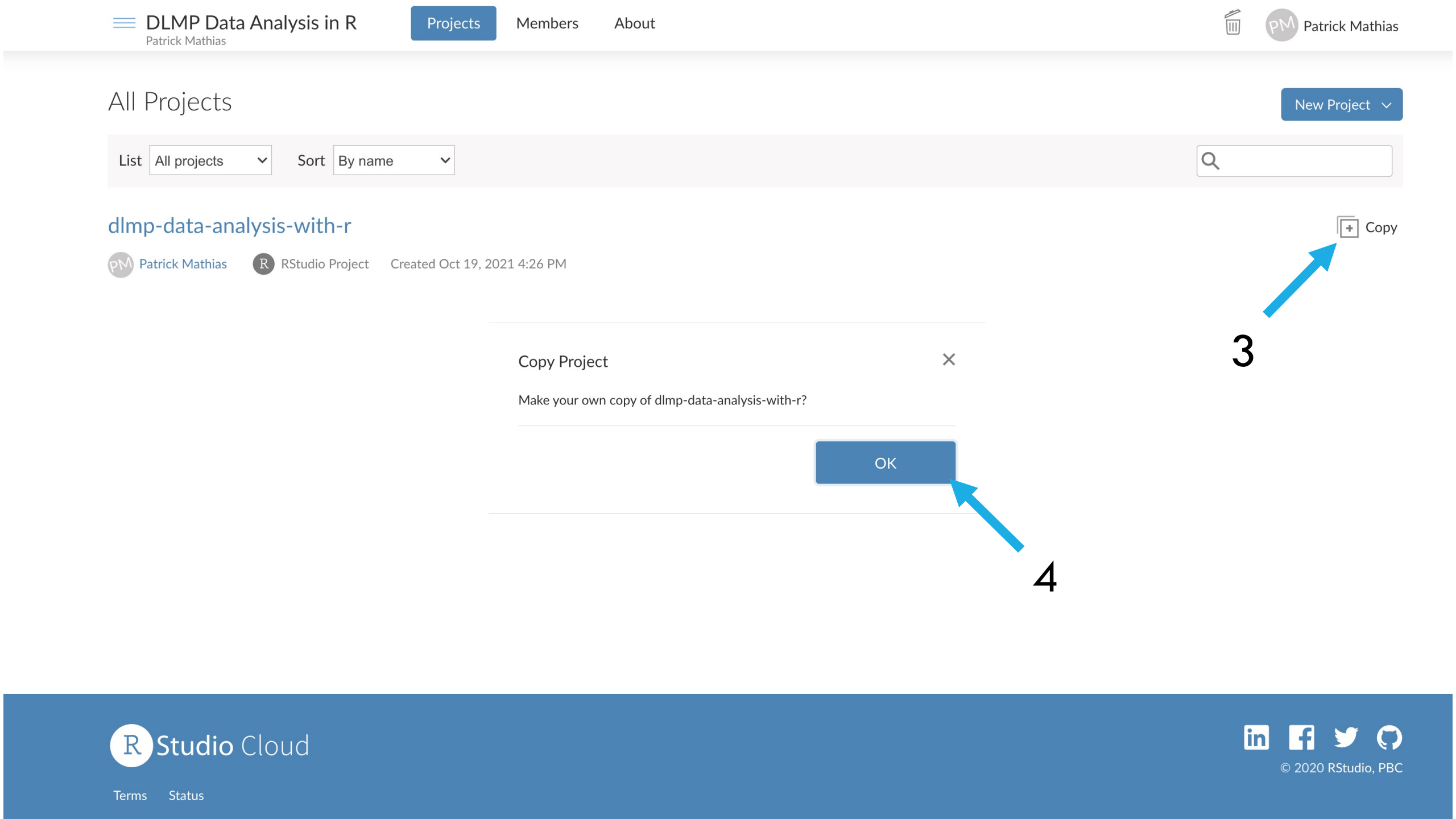
Once you join, admins will be able to see your email address.

Would you like to join this space?

Join Space

Cancel


Studio Cloud
Spaces
Your Workspace
AACC 2019 Introduction to R
Patrick Mathias
AACC 2021 Introduction to R
Patrick Mathias
DLMP Data Analysis in R
Patrick Mathias
LM Core Data Analysis
Patrick Mathias
LM Core Data Analysis
Patrick Mathias
New Space
Learn
Guide
What's New
Primers
Cheat Sheets
Help
Current System Status
RStudio Community
DLMP Data Analysis in R
Projects
Members
About
All Projects
1
List
All projects
Sort
By name
dlmp-data-analysis-with-r
Patrick Mathias
RStudio Project
Created Oct 19, 2021 4:26 PM
2
Studio Cloud
Terms
Status


DLMP Data Analysis in R
Patrick Mathias
Projects
Members
About
Patrick Mathias
All Projects
New Project
List
All projects
Sort
By name
dlmp-data-analysis-with-r
Patrick Mathias
RStudio Project
Created Oct 19, 2021 4:26 PM
Copy
3
Copy Project
Make your own copy of dlmp-data-analysis-with-r?
OK
4
RStudio Cloud
Terms
Status
© 2020 RStudio, PBC

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Console | Terminal | Jobs

R 4.1.0 · /cloud/project/

```
R version 4.1.0 (2021-05-18) -- "Camp Pontanezen"
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'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.

>
```

Environment | History | Connections | Git | Tutorial

Import Dataset | 123 MiB | List

R | Global Environment

Environment is empty

Files | Plots | Packages | Help | Viewer

New Folder | Upload | Delete | Rename | More

Cloud > project

Name	Size	Modified
..		
.gitignore	40 B	Oct 19, 2021, 4:26 PM
.Rhistory	0 B	Oct 19, 2021, 4:26 PM
coursepack		
exercises		
LICENSE	1 KB	Oct 19, 2021, 4:26 PM
presentations		
project.Rproj	205 B	Oct 19, 2021, 9:35 PM
README.md	4.8 KB	Oct 19, 2021, 4:26 PM

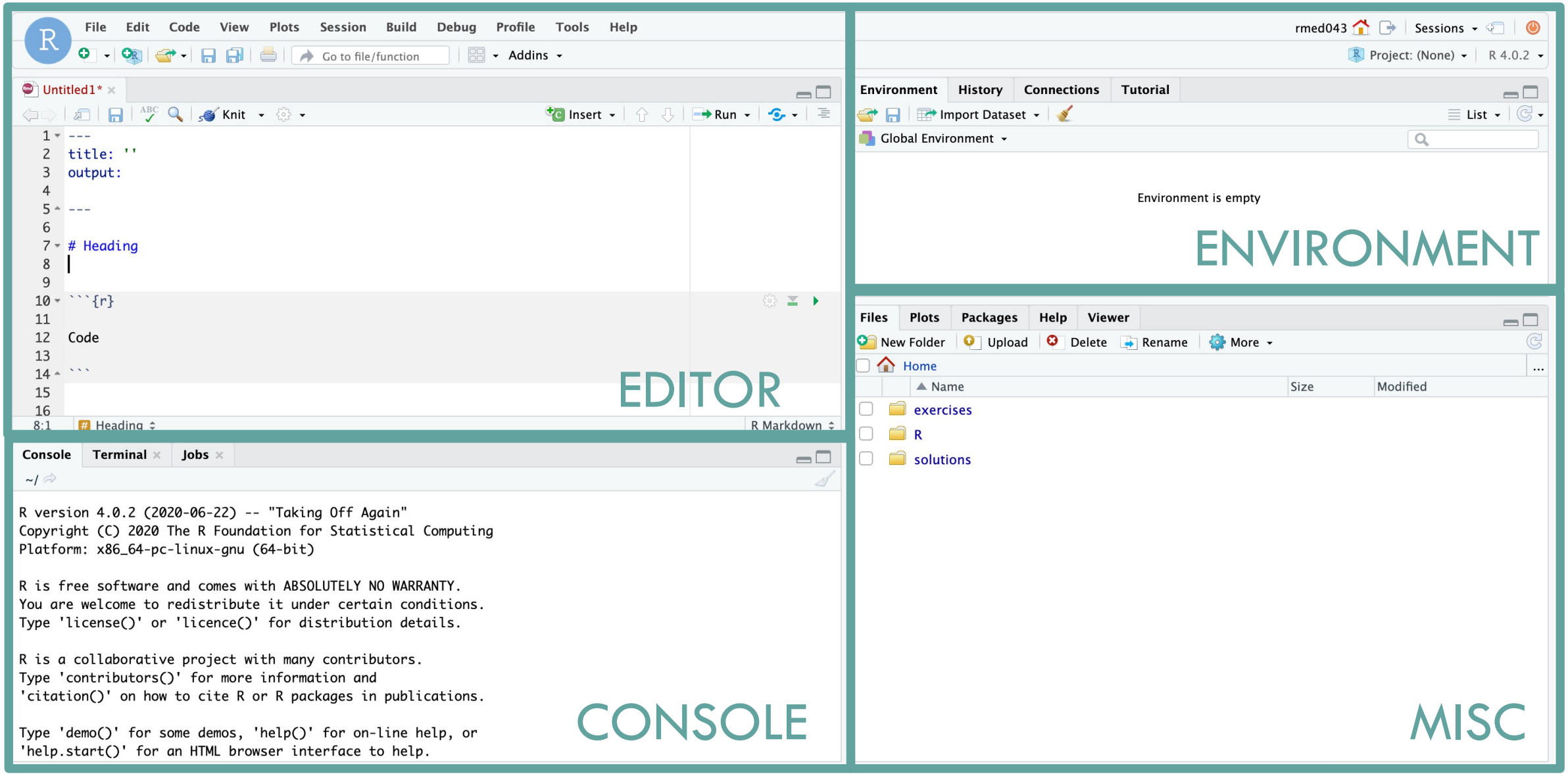
Your Turn

Navigate to: https://bit.ly/dlmp-fall-2021

Enter your log in credentials

Join Space

Make a copy of the Core Exercises for yourself


File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
Untitled1*
Knit
Insert
Run
1 ---
2 title: ''
3 output:
4
5 ---
6
7 # Heading
8
9
10 ```{r}
11
12 Code
13
14 ```
15
16
8:1
Heading
R Markdown
EDITOR
rmed043
Sessions
Project: (None)
R 4.0.2
Environment
History
Connections
Tutorial
Import Dataset
List
Global Environment
Environment is empty
ENVIRONMENT
Files
Plots
Packages
Help
Viewer
New Folder
Upload
Delete
Rename
More
Home
Name
Size
Modified
exercises
R
solutions
MISC
Console
Terminal
Jobs
~/
R version 4.0.2 (2020-06-22) -- "Taking Off Again"
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CONSOLE

Reproducible Data Analysis and R Markdown

The Duke Cancer Scandal

- Chemo sensitivity from microarrays
- Errors first, then cover-up
- Clinical trials based on flawed models
- Papers retracted, lawsuits settled

Duke	MD Anderson
"1881_at"	"1882_g_at"
"31321_at"	"31322_at"
"31725_s_at"	"31726_at"
"32307_r_at"	"32308_r_at"
...	

Off-by-one indexing error

“Common problems are simple…

Off-by-one **indexing error**

Sensitive / resistant **label reversal**

Confounding in experimental design

Inclusion of data from **non-reported sources**

Wrong figure shown

… and simple problems are common.”

Highly recommended Keith Baggerly lecture: **https://bit.ly/duke_scandal**

Point-and-click is not reproducible

Computer code can precisely document each step of the analysis

Why YOU should analyze your data reproducibly

"Can we redo the analysis with this month's data?"

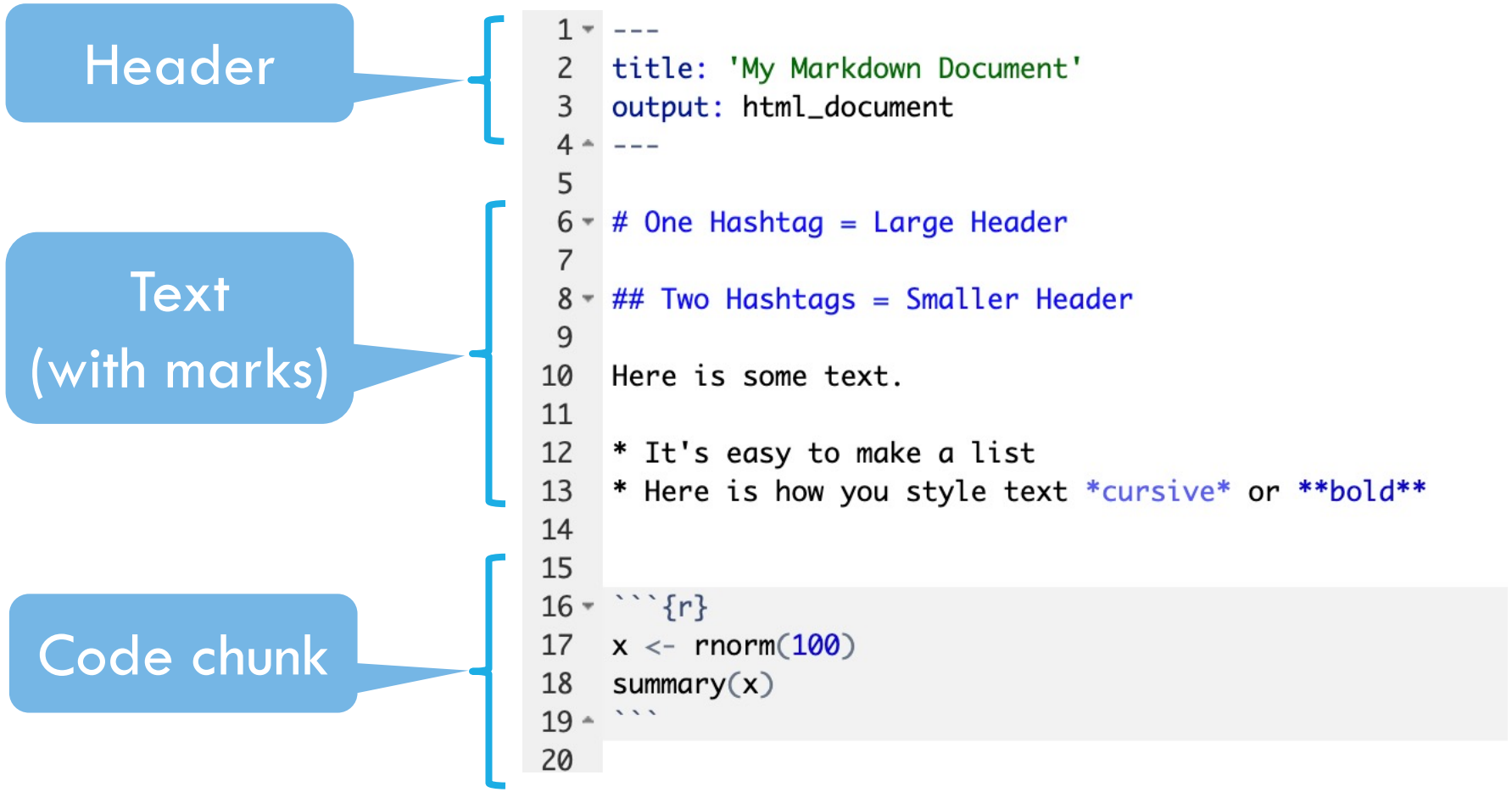
"Why do the data in Table 1 not seem to agree with Figure 2?"

"Why did I decide to omit these six samples from my analysis?"

YOUR CLOSEST COLLABORATOR IS **YOU** FROM 6 MONTHS AGO


rmarkdown
www.rstudio.com

Anatomy of an R Markdown Document



```
---
title: 'My Markdown Document'
output: html_document
---


# One Hashtag = Large Header

## Two Hashtags = Smaller Header

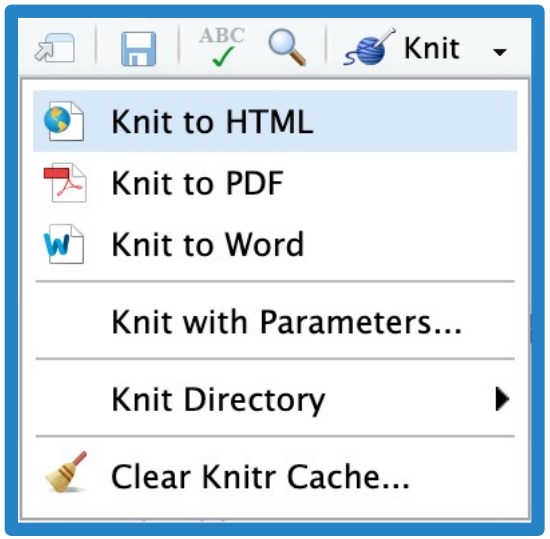
Here is some text.

* It's easy to make a list
* Here is how you style text *cursive* or **bold**


```{r}
x <- rnorm(100)
summary(x)
```


Including Plots

```{r, echo=FALSE}
hist(x)
```
```



My Markdown Document

One Hashtag = Large Header

Two Hashtags = Smaller Header

Here is some text.

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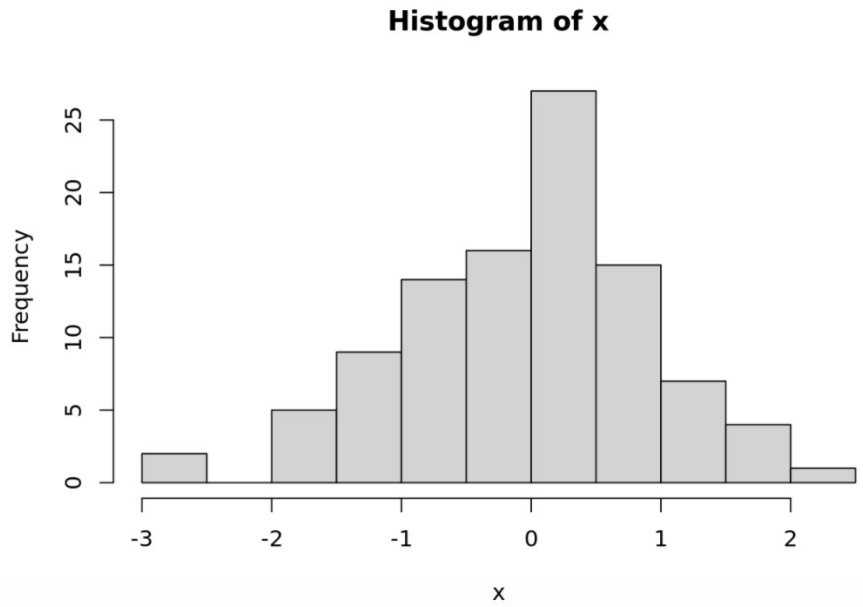
- Here is how you style text *cursive* or **bold**

```
x <- rnorm(100)
summary(x)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
## -2.99204 -0.64726  0.14853 -0.02832  0.58218  2.07410
```

Including Plots



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## -2.99204 -0.64726  0.14853 -0.02832  0.58218  2.07410
```
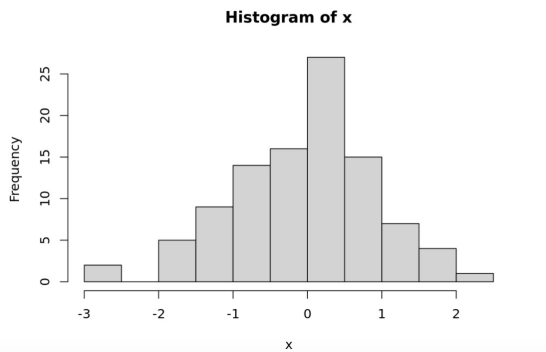

Including Plots



Your Turn #2

Open a sample R Markdown document (File -> New File -> R Markdown).

Enter a title for the document, e.g. My First Markdown.

Review the format of the document: header, text, code chunks

Execute the individual code chunks by selecting the Run Current Chunk arrow.

Knit the document to HTML (Preview or Knit Button -> Knit to HTML). You may be prompted to save your R Markdown first. In this case select a name for your document and click save. Review the knitted document.

File Edit Code View Plots Session Build Debug Profile Tools Help

New File
Open File... ⌘O
Open File in New Column...
Recent Files
Import Dataset
Save ⌘S
Save As...
Save All ⌥⌘S
Print...
Close ⌘W
Close All ⇧⌘W
Close All Except Current ⌥⇧⌘W

R Script ⌥⇧⌘N
R Notebook
R Markdown...
Shiny Web App...
Plumber API...
C File
C++ File
Header File
Markdown File
HTML File
CSS File
JavaScript File
D3 Script
Python Script
Shell Script
SQL Script
Stan File
Text File
R Sweave
R HTML
R Presentation
R Documentation...

Create a new R Markdown document

Addins

R 4.1.0

```
'help.start()' for an HTML brows
Type 'q()' to quit R.

>
```

Environment History Connections Git Tutorial

Import Dataset 222 MiB List

R Global Environment

Environment is empty

Files Plots Packages Help Viewer

New Folder Upload Delete Rename More

Cloud > project

Name	Size	Modified
..		
.gitignore	40 B	Oct 19, 2021, 4:26 PM
.Rhistory	0 B	Oct 19, 2021, 4:26 PM
coursepack		
exercises		
LICENSE	1 KB	Oct 19, 2021, 4:26 PM
presentations		
project.Rproj	205 B	Oct 19, 2021, 10:00 PM
README.md	4.8 KB	Oct 19, 2021, 4:26 PM

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Console Terminal Jobs

R 4.1.0 · /cloud/project/

```
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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.

>
```

Environment History Connections Git Tutorial

Import Dataset | 183 MiB | List

R | Global Environment

Environment is empty

Help Viewer

Upload | Delete | Rename | More

	Size	Modified
	40 B	Oct 19, 2021, 4:26 PM
	0 B	Oct 19, 2021, 4:26 PM
exercises		
LICENSE	1 KB	Oct 19, 2021, 4:26 PM
presentations		
project.Rproj	205 B	Oct 19, 2021, 10:00 PM
README.md	4.8 KB	Oct 19, 2021, 4:26 PM

Install Required Packages

Creating R Markdown documents requires an updated version of the markdown package.

Do you want to install this package now?

Yes No

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Console | Terminal | Jobs

R 4.1.0 · /cloud/project/

```
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>
```

Environment | History | Connections | Git | Tutorial

Import Dataset | 221 MiB | List

R | Global Environment

Environment is empty

Viewer

lete | Rename | More

	Size	Modified
	40 B	Oct 19, 2021, 4:26 PM
	0 B	Oct 19, 2021, 4:26 PM
	1 KB	Oct 19, 2021, 4:26 PM
	205 B	Oct 19, 2021, 10:00 PM
	4.8 KB	Oct 19, 2021, 4:26 PM

New R Markdown

- Document
- Presentation
- Shiny
- From Template

Title: Untitled

Author:

Default Output Format:

- (•) HTML
  Recommended format for authoring (you can switch to PDF or Word output anytime).
- ( ) PDF
  PDF output requires TeX (MiKTeX on Windows, MacTeX 2013+ on OS X, TeX Live 2013+ on Linux).
- ( ) Word
  Previewing Word documents requires an installation of MS Word (or Libre/Open Office on Linux).

Create Empty Document | OK | Cancel

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Untitled1

Knit | Run

```
1  ---
2  title: "My First Markdown"
3  output: html_document
4  ---
5
6  ```{r setup, include=FALSE}
7  knitr::opts_chunk$set(echo = TRUE)
8  ```
9
10 ## R Markdown
11
12 This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF,
   and MS Word documents. For more details on using R Markdown see <http://rmarkdown.rstudio.com>.
13
14 When you click the **Knit** button a document will be generated that includes both content as well
   as the output of any embedded R code chunks within the document. You can embed an R code chunk
   like this:
```

2:1 | My First Markdown | R Markdown

Knit button

Scroll down

Execute code chunk

Console Terminal Jobs

R 4.1.0 · /cloud/project/

```
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```

Environment History Connections Git Tutorial

Import Dataset | 222 MiB | List

R | Global Environment

Environment is empty

Files Plots Packages Help Viewer

New Folder | Upload | Delete | Rename | More

Cloud > project

Name	Size	Modified
..		
.gitignore	40 B	Oct 19, 2021, 4:26 PM
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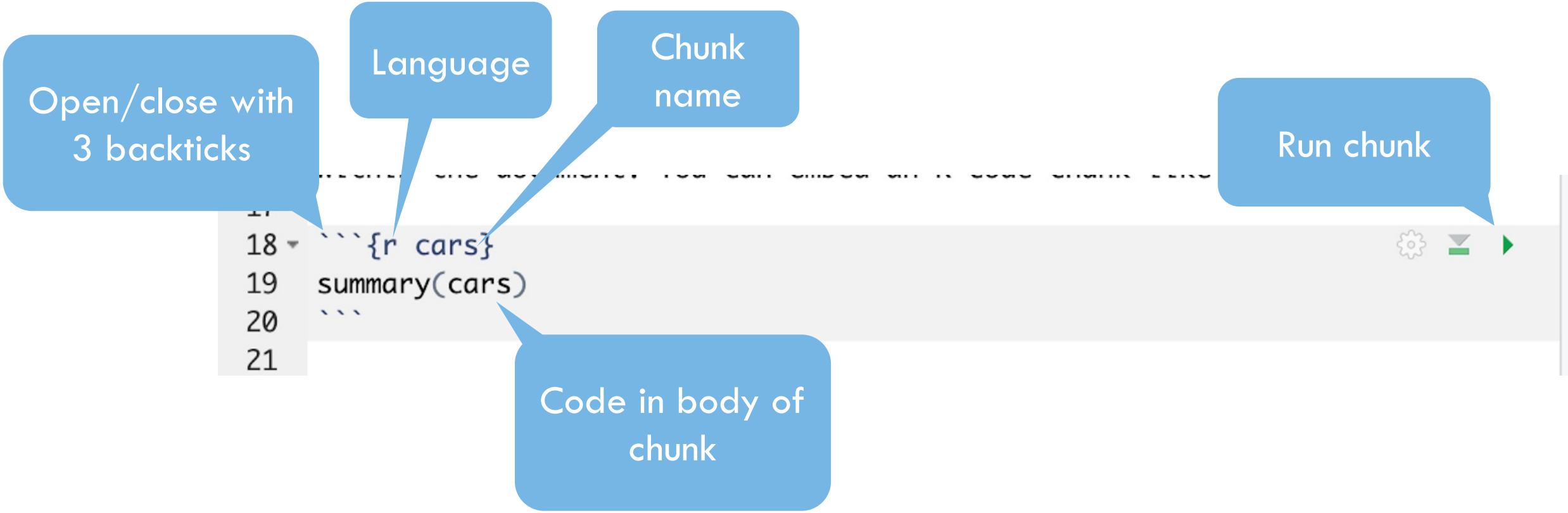
Code chunks


Open/close with 3 backticks
Language
Chunk name
Run chunk
18 ```{r cars}
19 summary(cars)
20 ```
21
Code in body of chunk

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Untitled1*

Knit | Run

```
16 ```{r cars}
17 summary(cars)
18 ```
19
20 ## Including Plots
21
22 You can also embed plots, for example:
23
24 ```{r pressure, echo=FALSE}
25 plot(pressure)
26 ```
27
28 Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R
   code that generated the plot.
29
30
31
```

R
Bash
D3
Python
Rcpp
SQL
Stan

Insert code chunk

Place cursor in document

30:1 | Including Plots | R Markdown

Console | Terminal | Jobs

R 4.1.0 · /cloud/project/

```
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```

Environment | History | Connections | Git | Tutorial

Import Dataset | 228 MiB | List

R | Global Environment

Environment is empty

Files | Plots | Packages | Help | Viewer

New Folder | Upload | Delete | Rename | More

Cloud > project

Name	Size	Modified
..		
.gitignore	40 B	Oct 19, 2021, 4:26 PM
.Rhistory	0 B	Oct 19, 2021, 4:26 PM
coursepack		
exercises		
LICENSE	1 KB	Oct 19, 2021, 4:26 PM
presentations		
project.Rproj	205 B	Oct 19, 2021, 10:00 PM
README.md	4.8 KB	Oct 19, 2021, 4:26 PM

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function | Addins | R 4.1.0

Untitled1*

Knit | Run

```
19
20 ## Including Plots
21
22 You can also embed plots, for example:
23
24 ```{r pressure, echo=FALSE}
25 plot(pressure)
26 ```
27
28 Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R
   code that generated the plot.
29
30 ```{r}
31
32 ```
33
34
```

New code chunk

31:1 | Chunk 4 | R Markdown

Console Terminal Jobs

R 4.1.0 · /cloud/project/

```
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```

Environment History Connections Git Tutorial

Import Dataset | 228 MiB | List

R | Global Environment

Environment is empty

Files Plots Packages Help Viewer

New Folder | Upload | Delete | Rename | More

Cloud > project

Name	Size	Modified
..		
.gitignore	40 B	Oct 19, 2021, 4:26 PM
.Rhistory	0 B	Oct 19, 2021, 4:26 PM
coursepack		
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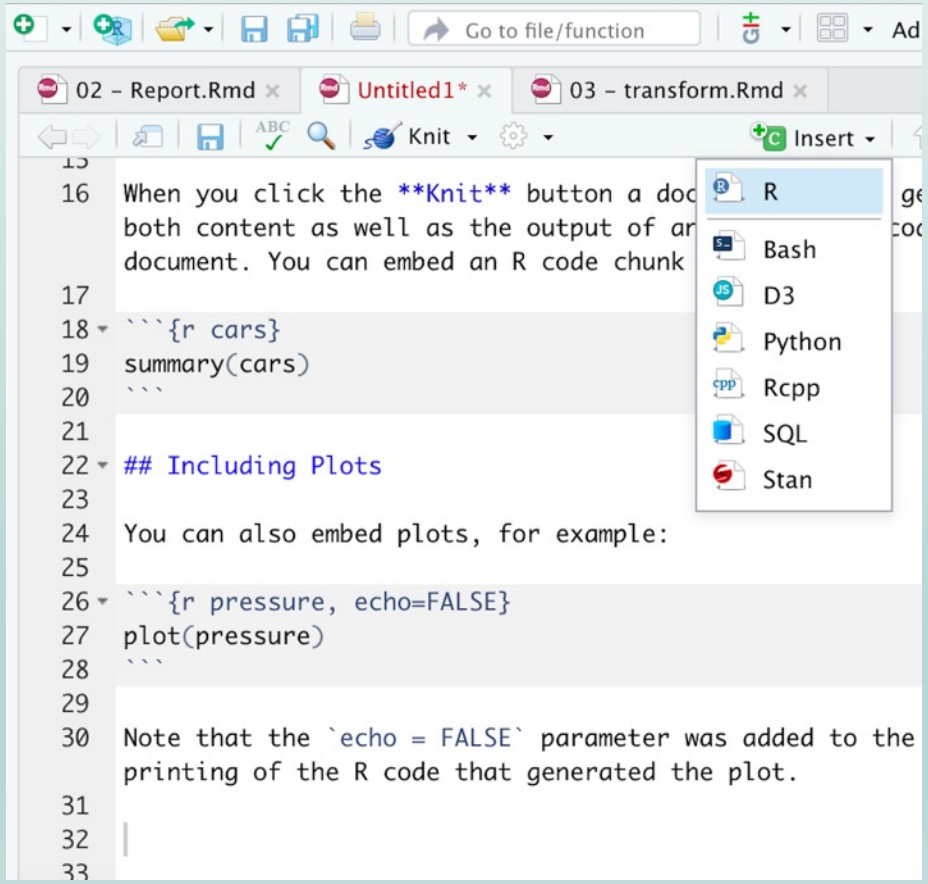
Your Turn #3



1. At the bottom of your document insert a code chunk into white space using Insert button on top right of code window

2. Type the following into your new code chunk:

```
mean(c(10, 20, 30))
```

3. Execute code chunk by pressing Run button on top right of code chunk

Recap

Programming Language

IDE

Document Format

The **RStudio Panes** include editor (writing code), environment (interact with objects), misc (interact with files), and console (enter individual commands).

Reproducible Data Analysis is a best practice for working with clinical and research data.

R Markdown provides us with an electronic notebook to mix executable data analysis code elements with annotation for effective reproducibility.

What else?

rmarkdown : : CHEAT SHEET

What is rmarkdown?

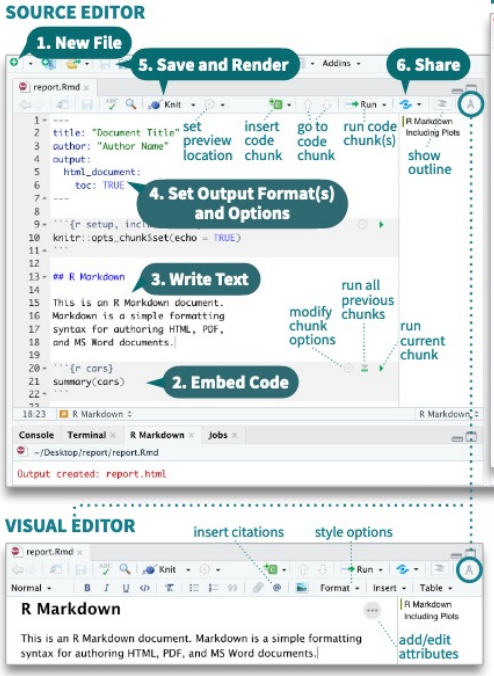
.Rmd files • Develop your code and ideas side-by-side in a single document. Run code as individual chunks or as an entire document.

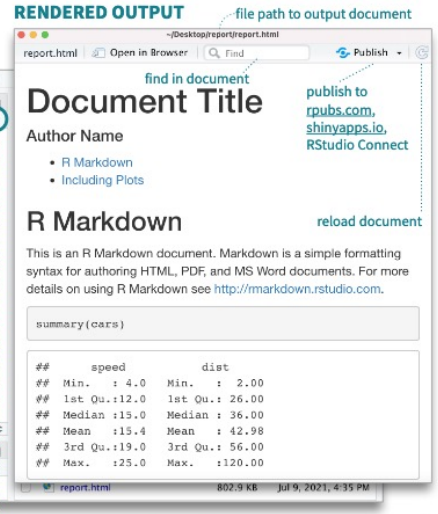
Dynamic Documents • Knit together plots, tables, and results with narrative text. Render to a variety of formats like HTML, PDF, MS Word, or MS Powerpoint.

Reproducible Research • Upload, link to, or attach your report to share. Anyone can read or run your code to reproduce your work.

Workflow

1. Open a **new .Rmd file** in the RStudio IDE by going to *File > New File > R Markdown*.
2. **Embed code** in chunks. Run code by line, by chunk, or all at once.
3. **Write text** and add tables, figures, images, and citations. Format with Markdown syntax or the RStudio Visual Markdown Editor.
4. **Set output format(s) and options** in the YAML header. Customize themes or add parameters to execute or add interactivity with Shiny.
5. **Save and render** the whole document. Knit periodically to preview your work as you write.
6. **Share your work!**





Embed Code with knitr

CODE CHUNKS

Surround code chunks with ```` ```{r} ```` and ```` ``` ```` or use the Insert Code Chunk button. Add a chunk label and/or chunk options inside the curly braces after **r**.

````
```{r chunk-label, include=FALSE}
summary(mtcars)
```
````

SET GLOBAL OPTIONS

Set options for the entire document in the first chunk.

````
```{r include=FALSE}
knitr::opts_chunk$set(message = FALSE)
```
````

INLINE CODE

Insert **`r <code>`** into text sections. Code is evaluated at render and results appear as text.

"Built with `` `r getRversion()` `` " --> "Built with 4.1.0"

OPTION	DEFAULT	EFFECTS
echo	TRUE	display code in output document
error	FALSE	TRUE (display error messages in doc) FALSE (stop render when error occurs)
eval	TRUE	run code in chunk
include	TRUE	include chunk in doc after running
message	TRUE	display code messages in document
warning	TRUE	display code warnings in document
results	"markup"	"asis" (passthrough results) "hide" (don't display results) "hold" (put all results below all code)
fig.align	"default"	"left", "right", or "center"
fig.alt	NULL	alt text for a figure
fig.cap	NULL	figure caption as a character string
fig.path	"figure/"	prefix for generating figure file paths
fig.width & fig.height	7	plot dimensions in inches
out.width		rescales output width, e.g. "75%", "300px"
collapse	FALSE	collapse all sources & output into a single block
comment	"##"	prefix for each line of results
child	NULL	files(s) to knit and then include
purl	TRUE	include or exclude a code chunk when extracting source code with knitr::purl()

See more options and defaults by running **str(knitr::opts_chunk$get())**

Insert Citations

Create citations from a bibliography file, a Zotero library, or from DOI references.

BUILD YOUR BIBLIOGRAPHY

- Add BibTeX or CSL bibliographies to the YAML header.

```
---
title: "My Document"
bibliography: references.bib
link-citations: TRUE
---
```

- If Zotero is installed locally, your main library will automatically be available.
- Add citations by DOI by searching "from DOI" in the **Insert Citation** dialog.

INSERT CITATIONS

- Access the **Insert Citations** dialog in the Visual Editor by clicking the **@** symbol in the toolbar or by clicking **Insert > Citation**.
- Add citations with markdown syntax by typing **[@cite]** or **@cite**.

Insert Tables

Output data frames as tables using **kable**(data, caption).

Table with kable	
eruptions	waiting
3.600	79
1.800	54
3.333	74
2.283	62

````
```{r}
data <- faithful[1:4, ]
knitr::kable(data,
             caption = "Table with kable")
```
````

Other table packages include **flextable**, **gt**, and **kableExtra**.

Write with Markdown

The syntax on the left renders as the output on the right.

Plain text. End a line with two spaces to start a new paragraph. Also end with a backslash\ to make a new line.	Plain text. End a line with two spaces to start a new paragraph. Also end with a backslash to make a new line.
italics and **bold** superscript^2^/subscript~2~ ~~strikethrough~~ escaped: * _ \\ endash: --, emdash: ---	*italics* and **bold** superscript^2/subscript$_2$ ~~strikethrough~~ escaped: * _ \ endash: –, emdash: —
# Header 1 ## Header 2 ... ###### Header 6	**Header 1** **Header 2** ... **Header 6**
- unordered list - item 2 - item 2a (indent 1 tab) - item 2b	• unordered list • item 2 • item 2a (indent 1 tab) • item 2b
1. ordered list 2. item 2 - item 2a (indent 1 tab) - item 2b	1. ordered list 2. item 2 • item 2a (indent 1 tab) • item 2b
<link url> [This is a link.](link url) [This is another link][id]. At the end of the document: [id]: link url	http://www.rstudio.com/ This is a link. This is another link.
![Caption](image.png) or ![Caption][id2] At the end of the document: [id2]: image.png	 Caption.
`verbatim code` ``` multiple lines of verbatim code ```	`verbatim code` multiple lines of verbatim code
> block quotes	> block quotes
equation: $e^{i \pi} + 1 = 0$ equation block: $$E = mc^{2}$$	equation: $e^{i\pi} + 1 = 0$ equation block: $$E = mc^2$$
horizontal rule: ---	horizontal rule:
| Right | Left | Default | Center | |-------:|:------|----------|:--------:| | 12 | 12 | 12 | 12 | | 123 | 123 | 123 | 123 | | 1 | 1 | 1 | 1 |	Right Left Default Center 12 12 12 12 123 123 123 123 1 1 1 1

HTML Tabsets

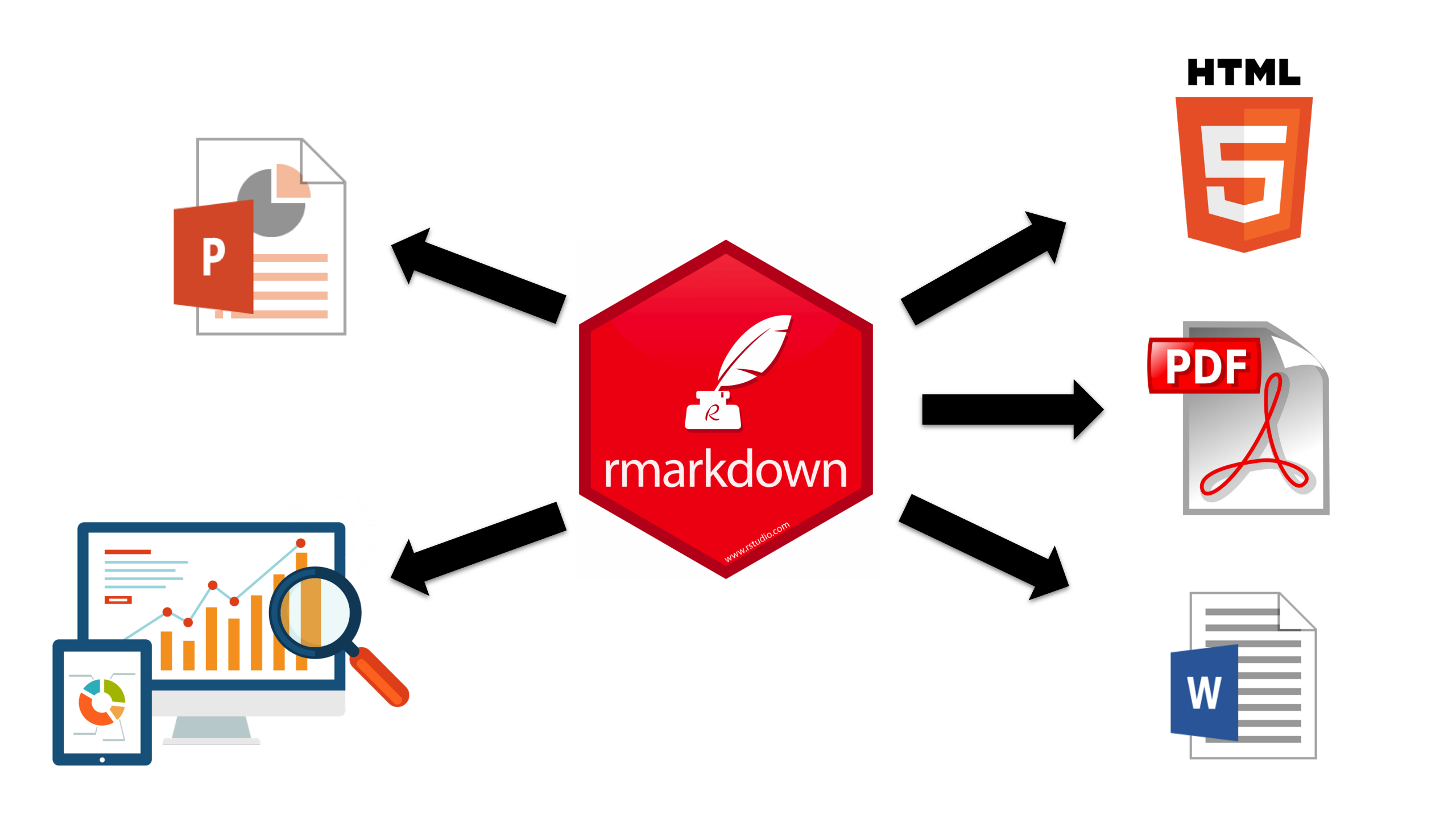
```
# Results {.tabset}
## Plots text
text

## Tables
more text
```

Results

Plots | Tables

text


HTML
rmarkdown
www.rstudio.com
PDF