

# Week 11 - Binder for fully reproducible research in R (data, code, and computational environment)

Andrew Stewart

Andrew.Stewart@manchester.ac.uk



@ajstewart\_lang



<https://github.com/ajstewartlang>

Week	Topic
1	Introduction, Open Science, and Power
2	Introduction to R
3	Data Wrangling and Visualisation
4	General Linear Model - Regression
5	General Linear Model - Regression
6	No Timetabled Lecture - Reading Week
7	Consolidation Lab
8	General Linear Model - ANOVA
9	General Linear Model - ANOVA
10	Tidy Thursday Data Wrangling & Visualisation Challenge
11	Reproducing your Computational Environment using Binder
12	Dynamic, Reproducible Presentations Using xaringan

## **Semester 1 Assignments**

Data wrangling and visualisation – Due December 5th

ANOVA/ANCOVA – Due January 17th

# Open and Reproducible Research

- Shared Data - we already know this is important for reproducibility.
- Shared Code - we already know this is important for reproducibility.
- Shared Computational environment - why is this important and how do we do it?

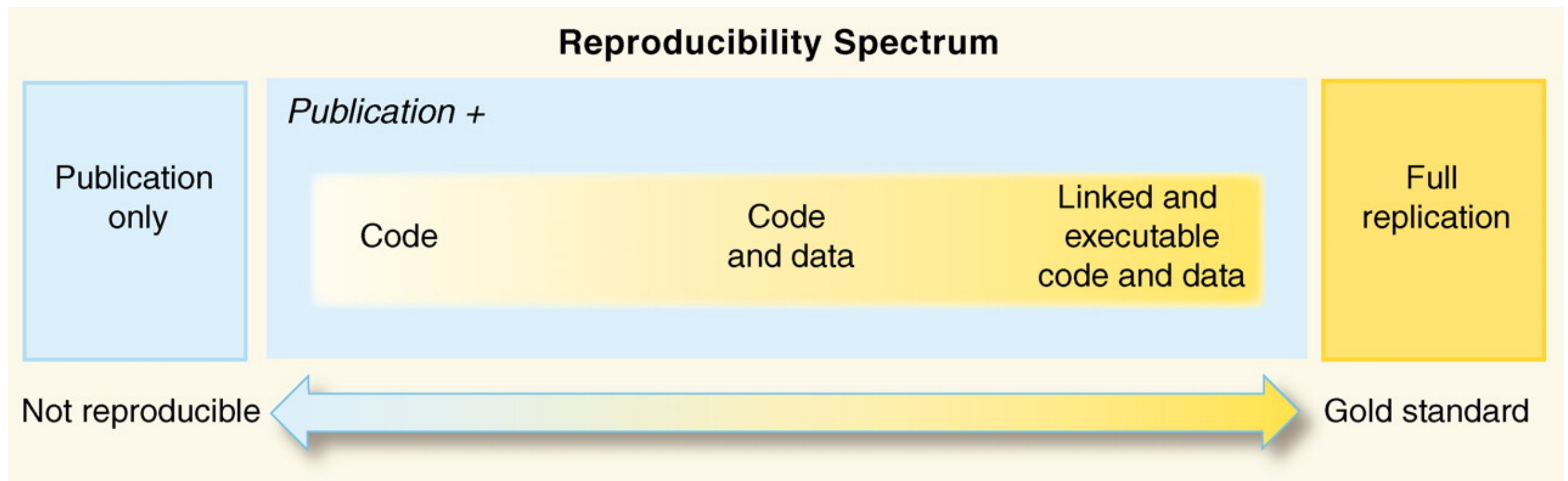
PERSPECTIVE

# Reproducible Research in Computational Science

Roger D. Peng

+ See all authors and affiliations

Science 02 Dec 2011:  
Vol. 334, Issue 6060, pp. 1226-1227  
DOI: 10.1126/science.1213847



# Why do we need to reproduce the computational environment?

- Quite often analysis code ‘breaks’ - often in one of two ways:
- Code that worked previously now doesn’t - maybe a function in an R package was updated (e.g., `lsmeans` became `emmeans` so old code using `lsmeans` wouldn’t now run).
- Code that worked previously still works - but produces a slightly different result or now throws a warning where it didn’t previously (e.g., convergence/singular fit warnings in `lme4` version 1.1-19 vs. version 1.1-20).

# Capturing your local computational environment

- You need to capture the versions of the different R packages (plus their dependencies).
- May sound trivial but trying running some old R code and be amazed at how many things now don't work as they once did!

# Docker for beginners

Docker packages your data, code and all its dependencies in the form called a docker container to ensure that your application works seamlessly in any environment.

When you run a docker container it's like running your analysis on a virtual computer that has the same configuration as our own one at the point in time when you ran the analysis.



<https://medium.com/the-andela-way/docker-for-beginners-61e8e0ce6a19>

# So what's Binder?

- Binder is powered by BinderHub, which is an open-source tool that deploys the Binder service in the cloud.
- Binder works by pulling a repository that you set up on GitHub into a Docker container - `repo2docker`.
- Think of a repository as a folder containing your R code, your data, and a few other small bits and pieces - but it sits in the cloud rather than on your computer.



github.com/ajstewartlang/Turing\_way2

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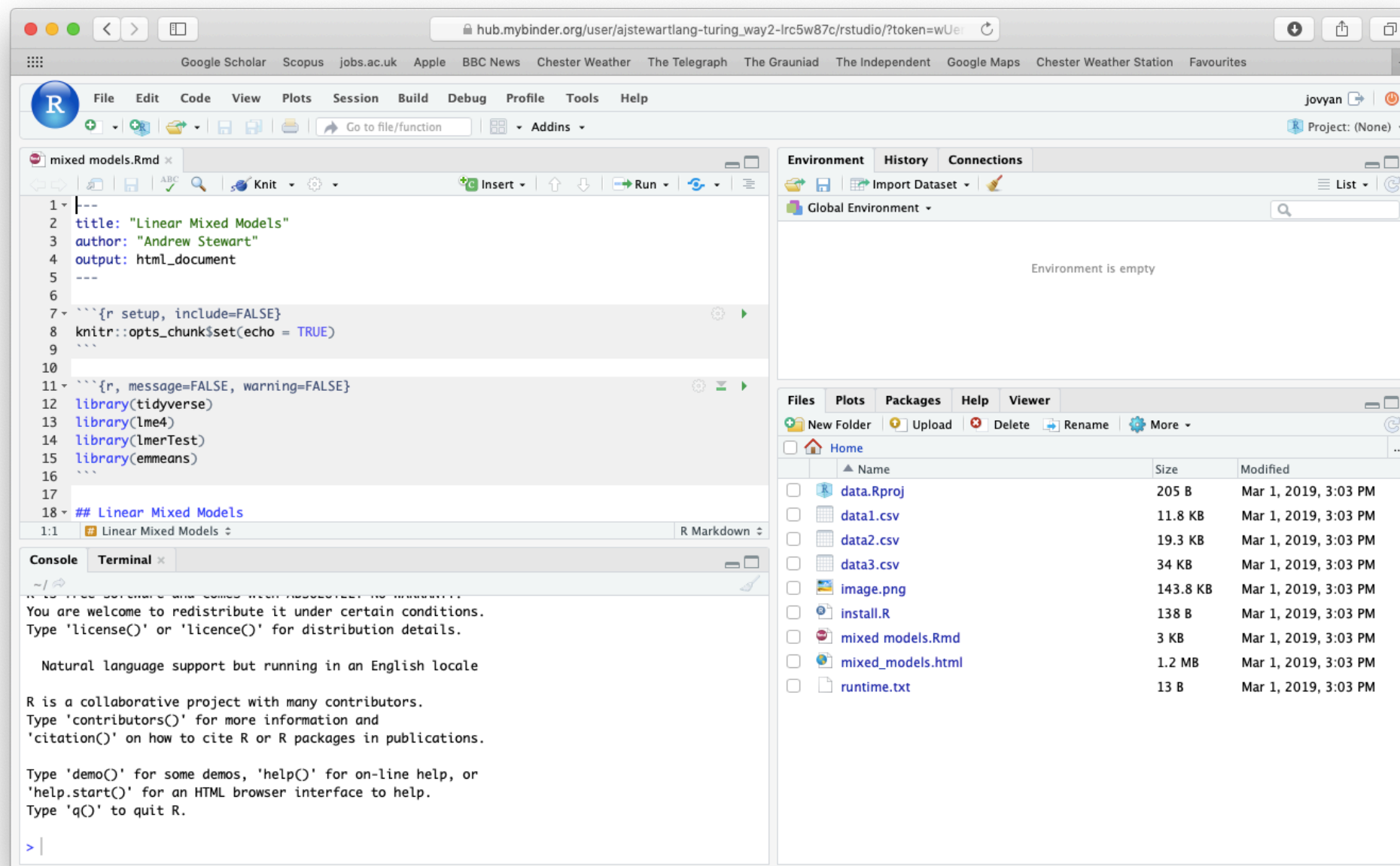
6 commits 1 branch 0 releases 1 contributor

Branch: master New pull request Create new file Upload files Find file Clone or download

ajstewartlang	Create install.R	Latest commit 36d3181 2 hours ago
.Rproj.user	commit	2 hours ago
data.Rproj	first commit	3 hours ago
data1.csv	first commit	3 hours ago
data2.csv	first commit	3 hours ago
data3.csv	first commit	3 hours ago
image.png	first commit	3 hours ago
install.R	Create install.R	2 hours ago
mixed models.Rmd	commit	2 hours ago
mixed_models.html	first commit	3 hours ago
runtime.txt	Update runtime.txt	GitHub Desktop 2 hours ago

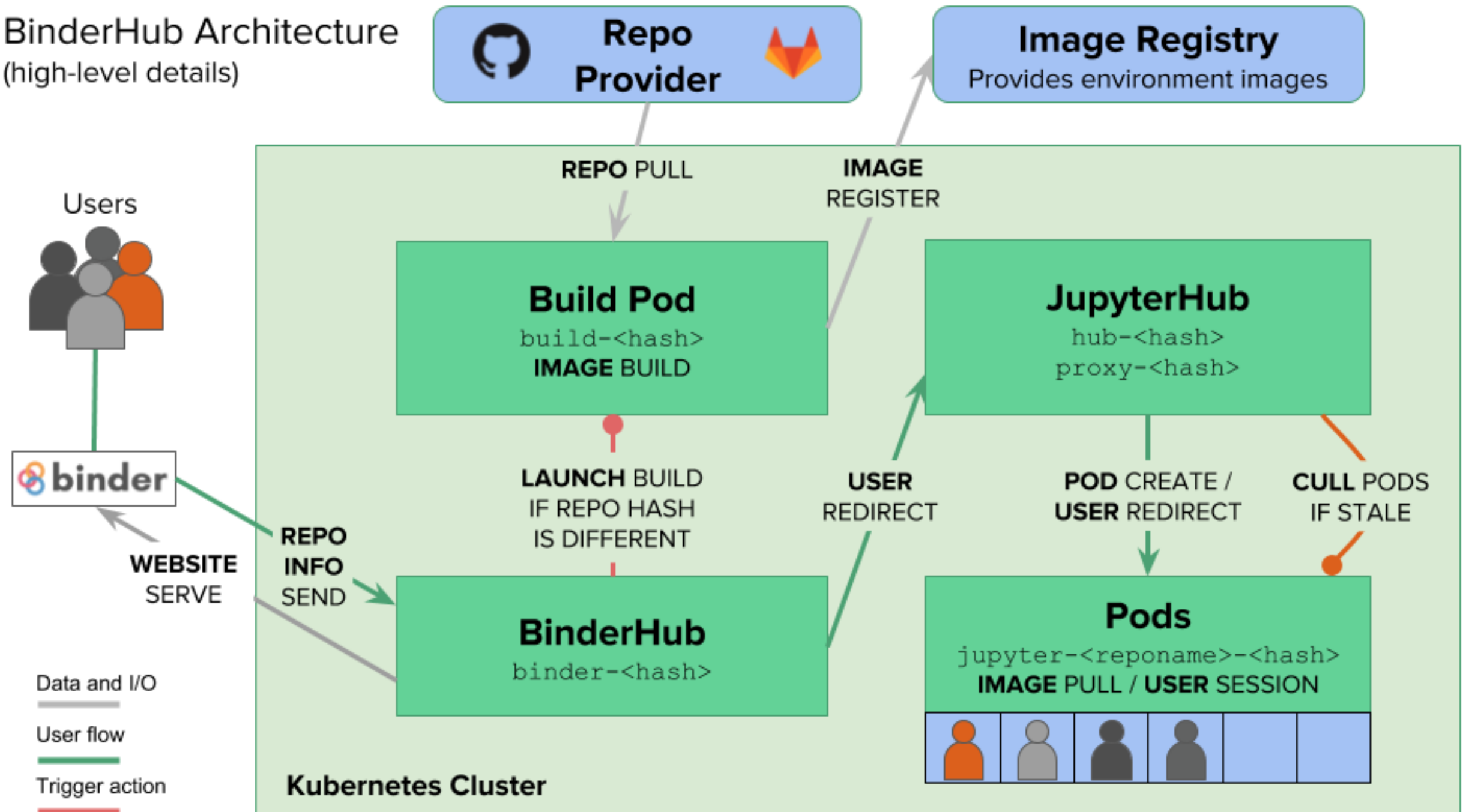
My R code and data files.

- When I link my GitHub repository to Binder and launch it I then get the following in my web browser.
- This is RStudio running the cloud using my code, my data and the appropriate versions of the packages that I was using when I did the analysis originally!



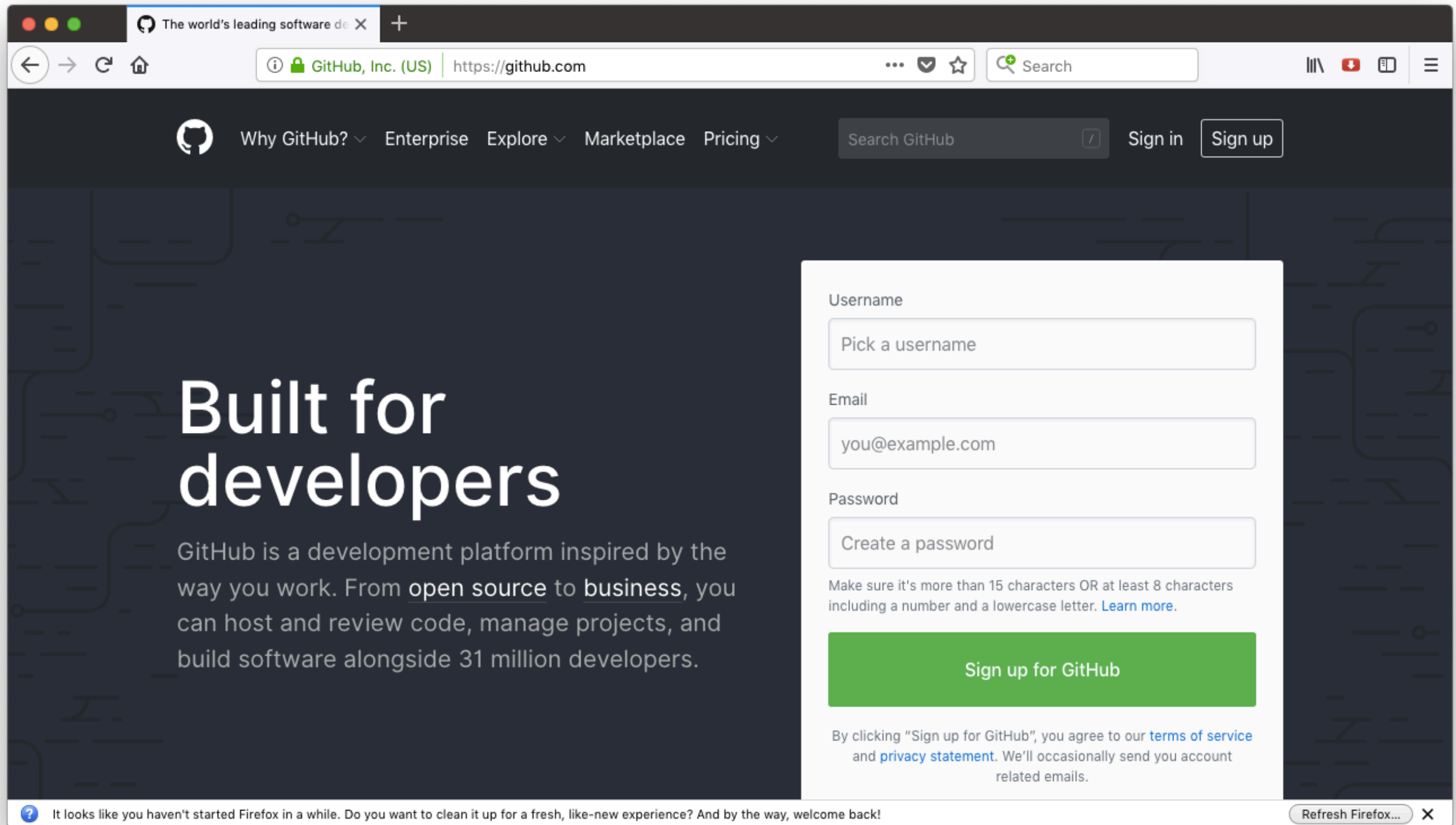
[https://mybinder.org/v2/gh/ajstewartlang/Turing\\_way2/master?urlpath=rstudio](https://mybinder.org/v2/gh/ajstewartlang/Turing_way2/master?urlpath=rstudio)

## BinderHub Architecture (high-level details)



<https://binderhub.readthedocs.io/en/latest/index.html>

# Step 1 - Set up a GitHub account



The screenshot shows the GitHub homepage in a web browser. The browser's address bar displays "https://github.com". The page features a dark blue header with the GitHub logo, navigation links ("Why GitHub?", "Enterprise", "Explore", "Marketplace", "Pricing"), a search bar, and "Sign in" and "Sign up" buttons. The main content area has a large heading "Built for developers" and a subheading "GitHub is a development platform inspired by the way you work. From open source to business, you can host and review code, manage projects, and build software alongside 31 million developers." On the right side, there is a white sign-up form with fields for "Username", "Email", and "Password". The "Username" field contains the placeholder text "Pick a username". The "Email" field contains "you@example.com". The "Password" field contains the placeholder text "Create a password". Below the password field, there is a note: "Make sure it's more than 15 characters OR at least 8 characters including a number and a lowercase letter. [Learn more.](#)". A large green button labeled "Sign up for GitHub" is positioned below the form. At the bottom of the form, there is a disclaimer: "By clicking 'Sign up for GitHub', you agree to our [terms of service](#) and [privacy statement](#). We'll occasionally send you account related emails." At the very bottom of the browser window, a Firefox notification bar states: "It looks like you haven't started Firefox in a while. Do you want to clean it up for a fresh, like-new experience? And by the way, welcome back!" with a "Refresh Firefox..." button and a close icon.

Username

Pick a username

Email

you@example.com

Password

Create a password

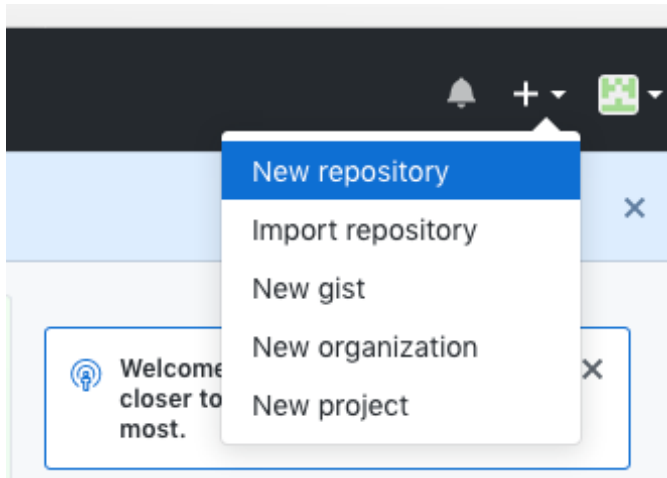
Make sure it's more than 15 characters OR at least 8 characters including a number and a lowercase letter. [Learn more.](#)

Sign up for GitHub

By clicking "Sign up for GitHub", you agree to our [terms of service](#) and [privacy statement](#). We'll occasionally send you account related emails.

It looks like you haven't started Firefox in a while. Do you want to clean it up for a fresh, like-new experience? And by the way, welcome back! Refresh Firefox...

# Step 2 - Create a new repository



## Create a new repository

A repository contains all project files, including the revision history.

Owner

 andrewstewarttest ▾

Repository name \*

first\_binder ✓

Great repository names are short and memorable. Need inspiration? How about **probable-funicular**?

Description (optional)

☒  **Public**

Anyone can see this repository. You choose who can commit.

☐  **Private**

You choose who can see and commit to this repository.

☒ **Initialize this repository with a README**

This will let you immediately clone the repository to your computer. Skip this step if you're importing an existing repository.

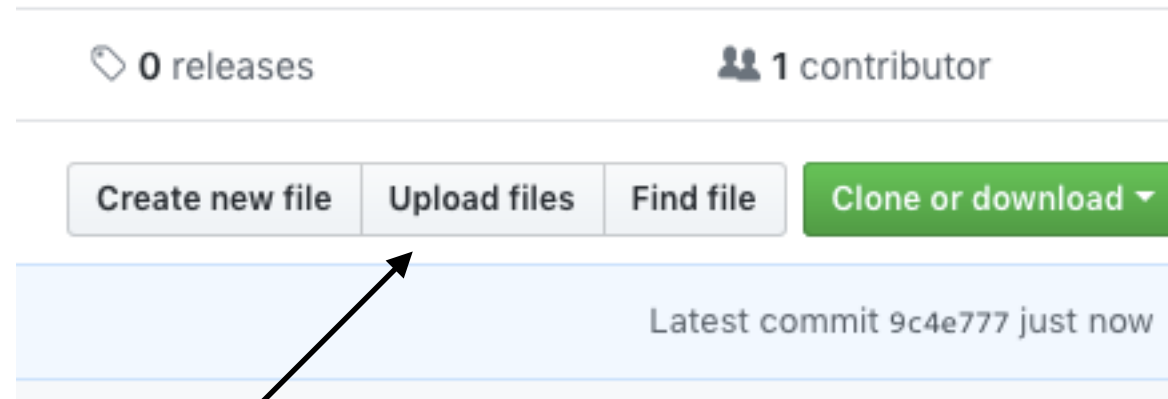
Add .gitignore: **None** ▾

Add a license: **None** ▾

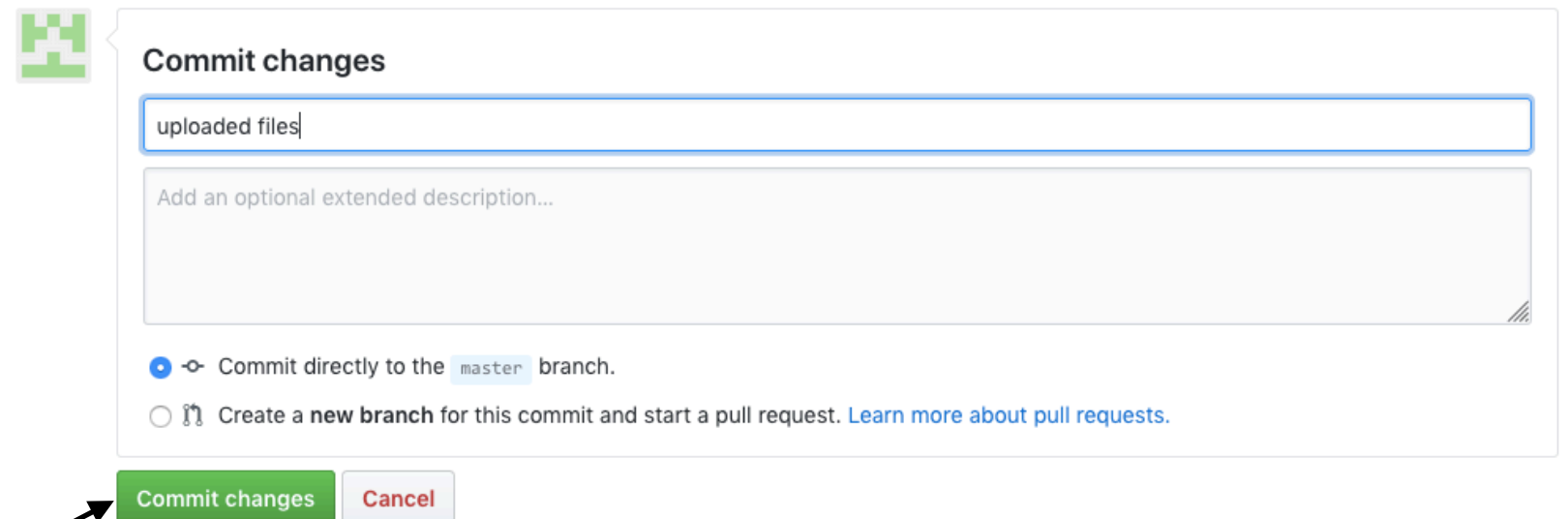


Create repository

# Step 3 - Upload your R script and data and make your first “Commit”



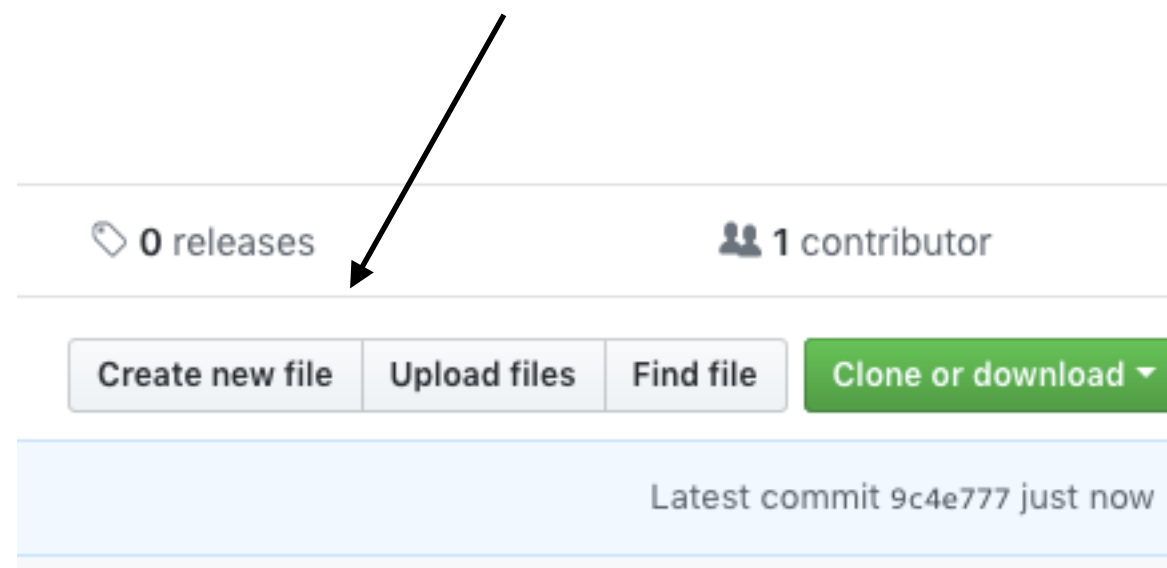
Click here to upload



Click here to Commit

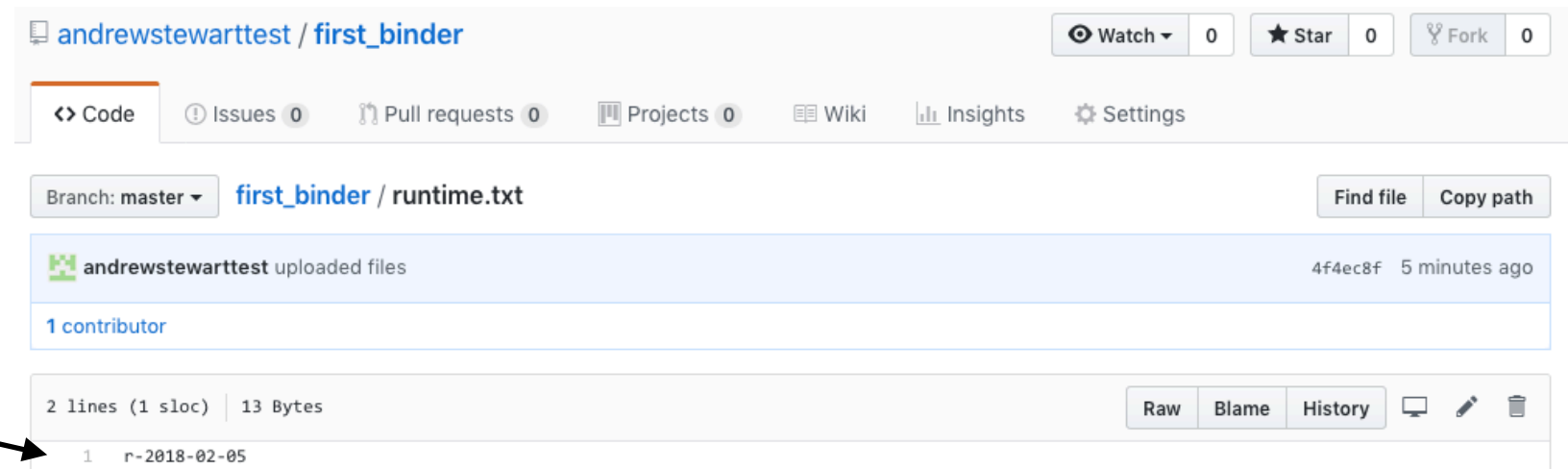
# Step 3 - Upload your R script and data and make your first “Commit”

- We need two other files at this point - one is called “runtime.txt” and contains the date of R and its associated packages that you want to simulate.
- The other is called “install.R” and contains the list of R packages that need to be installed in order for your script to run.
- To create a new file select “Create new file”





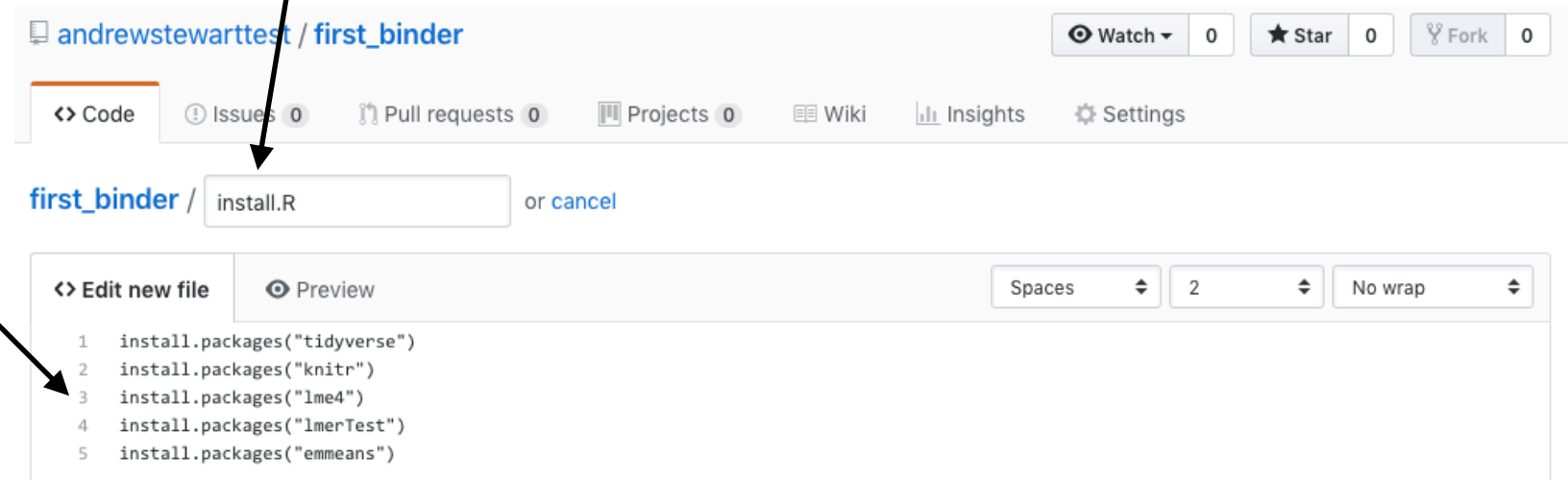
In the  
runtime.txt file  
type the date  
you want in the  
format r-YYYY-  
MM-DD



The screenshot shows the GitHub interface for a repository named 'first\_binder' by user 'andrewstewarttest'. The file 'runtime.txt' is selected, showing its content: 'r-2018-02-05'. The file is 13 bytes and has 2 lines. The interface includes tabs for Code, Issues, Pull requests, Projects, Wiki, Insights, and Settings. A 'Find file' button and 'Copy path' link are visible. The file was uploaded 5 minutes ago by the repository owner.

Name your file

List your  
packages like  
this in the  
install.R file



The screenshot shows the GitHub interface for the same repository, with the 'install.R' file being created. The file name is entered in the input field. The content of the file is listed in the editor: 'install.packages("tidyverse")', 'install.packages("knitr")', 'install.packages("lme4")', 'install.packages("lmerTest")', and 'install.packages("emmeans")'. The interface includes tabs for Edit new file and Preview, and a 'Spaces' dropdown set to 2.

Don't forget to click "Commit" after you've created each file!

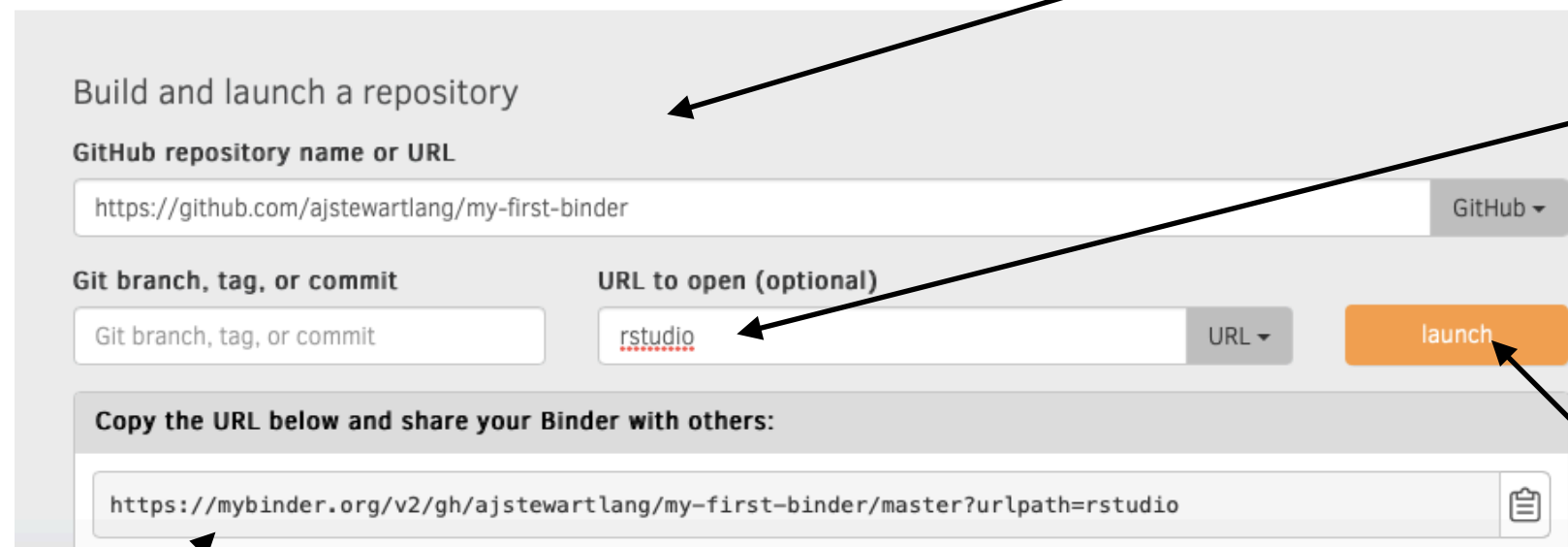


# Step 5 - Now we need to link our repo to Binder (mybinder.org)



Turn a Git repo into a collection of interactive notebooks

Have a repository full of Jupyter notebooks? With Binder, open those notebooks in an executable environment, making your code immediately reproducible by anyone, anywhere.

A screenshot of the Binder web interface. It shows a form to "Build and launch a repository". The "GitHub repository name or URL" field contains "https://github.com/ajstewartlang/my-first-binder". The "Git branch, tag, or commit" field is empty. The "URL to open (optional)" field contains "rstudio". An orange "launch" button is visible. Below the form, a text box displays the generated URL: "https://mybinder.org/v2/gh/ajstewartlang/my-first-binder/master?urlpath=rstudio". Arrows from the numbered instructions point to these specific elements: the repository URL, the "rstudio" text, the "launch" button, and the final URL box.

1. Paste the link to your repo here.

2. Type rstudio here and select "URL"

3. Then click on "launch"

4. This is the URL to share with others.

Copy the text below, then paste into your README to show a binder badge: 

m

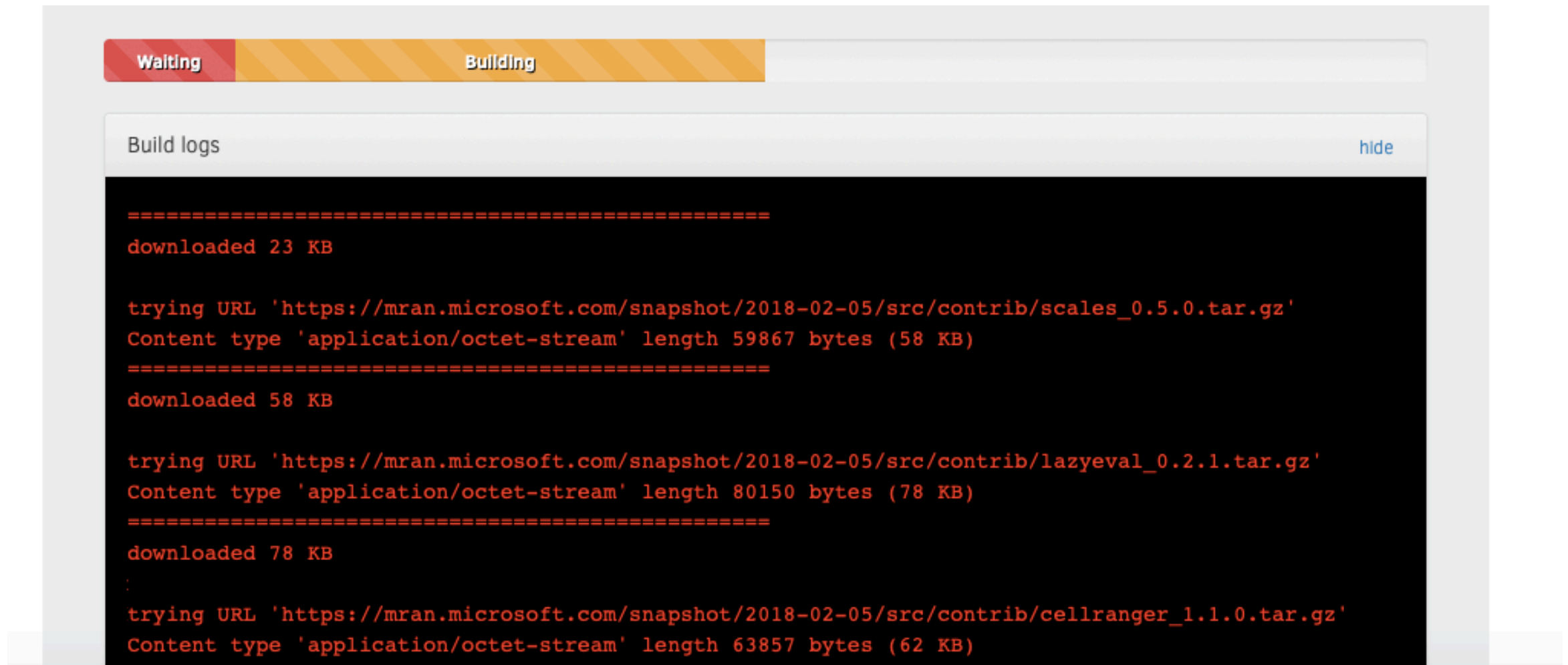
```
[![Binder](https://mybinder.org/badge_logo.svg)](https://mybinder.org/v2/gh/ajstewartlang/Binder_demo/master?urlpath=rstudio)
```

.rst

```
.. image:: https://mybinder.org/badge_logo.svg
   :target: https://mybinder.org/v2/gh/ajstewartlang/Binder_demo/master?urlpath=rstudio
```

- Paste this code into your GitHub repo README.md - you'll then be able to click on the 'launch binder' button in your repository to launch the actual binder once it has been built - makes it easy for others to go from you GitHub repo to your code running in Binder.

# Once you click ‘Launch’...



You can check the progress of the build by clicking on the “Build logs” bar.

- If Binder can find an image that you've built previously, it will simply launch that.
- If you've made changes to your GitHub repo, it will rebuild the Docker image and create a new Binder.
- Either way, once Binder launches you get the following in your browser (even on mobile devices so you can even R away on your phone)...

# And then...

The screenshot displays the RStudio web interface running on mybinder.org. The browser address bar shows the URL: `hub.mybinder.org/user/andrewstewarttest-first_binder-z4kwp6gl/rstudio/?token=`. The RStudio interface includes a menu bar (File, Edit, Code, View, Plots, Session, Build, Debug, Profile, Tools, Help) and a toolbar with icons for file operations and running code. The main editor window shows a file named `mixed models.Rmd` with the following R Markdown code:

```
1 ---
2 title: "Linear Mixed Models"
3 author: "Andrew Stewart"
4 output: html_document
5 ---
6
7 ```{r setup, include=FALSE}
8 knitr::opts_chunk$set(echo = TRUE)
9 ```
10
11 ```{r, message=FALSE, warning=FALSE}
12 library(tidyverse)
13 library(lme4)
14 library(lmerTest)
15 library(emmeans)
16 ```
17
18 ## Linear Mixed Models
```

The console window at the bottom shows the R startup messages:

```
~/
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.

> |
```

The file explorer on the right shows the following files and folders:

Name	Size	Modified
data.Rproj	205 B	Mar 1, 2019, 5:39 PM
data1.csv	11.8 KB	Mar 1, 2019, 5:39 PM
data2.csv	19.3 KB	Mar 1, 2019, 5:39 PM
data3.csv	34 KB	Mar 1, 2019, 5:39 PM
image.png	143.8 KB	Mar 1, 2019, 5:39 PM
install.R	138 B	Mar 1, 2019, 5:39 PM
mixed models.Rmd	3 KB	Mar 1, 2019, 5:39 PM
mixed_models.html	1.2 MB	Mar 1, 2019, 5:39 PM
README.md	14 B	Mar 1, 2019, 5:39 PM
runtime.txt	13 B	Mar 1, 2019, 5:39 PM

[https://mybinder.org/v2/gh/ajstewartlang/SIPS\\_visualisation\\_6/master?urlpath=rstudio](https://mybinder.org/v2/gh/ajstewartlang/SIPS_visualisation_6/master?urlpath=rstudio)

# A few other things...

- Installing the entire Tidyverse in a Binder can take a long time - better to install only the packages you use (e.g., ggplot2, dplyr, readr etc.) - this will also ensure the packages are consistent with the date in your runtime.txt file.
- Even with just a couple of packages it can take ~15 minutes or so for your Binder to be built.
- To change the version of R that Binder builds (to 3.6 say) change the runtime.txt file to "r-3.6-YYYY-MM-DD"

# A few other things...

- Some R packages need system-level packages to also be installed - you can do that via an additional apt.txt file which lists those packages - this is used by apt-install to install those packages from the Ubuntu apt repository.
- You can close your laptop if Binder is taking too long - the image and your Binder will continue to be built in the Cloud. And it's always a good excuse for another coffee...



# For Ultimate Reproducibility

- Make sure you have updated all your packages before you run your script.
- Build your Binder and specify the day you ran your analysis in the runtime.txt file - and add a version of R if you don't want it to default to 3.5
- Patience while your Binder builds...

**Your turn to build a Binder!**  
**Take a script you've already**  
**written, and start at slide 12...**

# Advanced...

- If you use Binder via the repo2docker route, you will notice that some Binders take quite a long time to build initially - oftentimes this happens when you're wanting to install the entire tidyverse or lots of packages with dependencies..
- By writing a Dockerfile, you're able to pull a pre-built Docker (Rocker) image into Binderhub so it will launch a lot more quickly. Typically this image will include the Tidyverse packages (and others) so things don't need to be built on-the-fly.
- More about Rocker here:

<https://www.rocker-project.org>

# How?

- The `holepunch::` package by Karthik Ram allows you to write a Dockerfile, and build your GitHub repo from within RStudio.

`https://github.com/karthik/holepunch`

- The Dockerfile will capture the date of the last time you updated any file of your project and then pull a pre-built Rocker image associated with that date into Binderhub when you launch Binder.
- You need to initialise the local R project folder with Git version control (or clone a repo from GitHub).

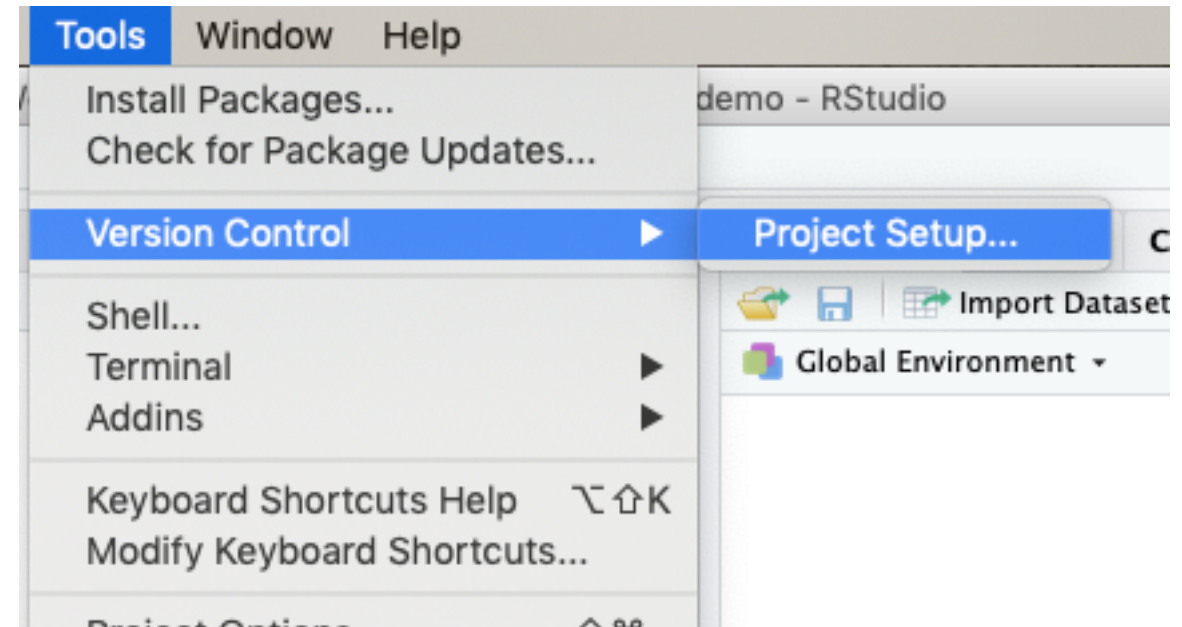
- First install the latest version of "holepunch" from GitHub - you may be prompted to update some other packages - please do so.

```
> remotes::install_github("karthik/holepunch")
```

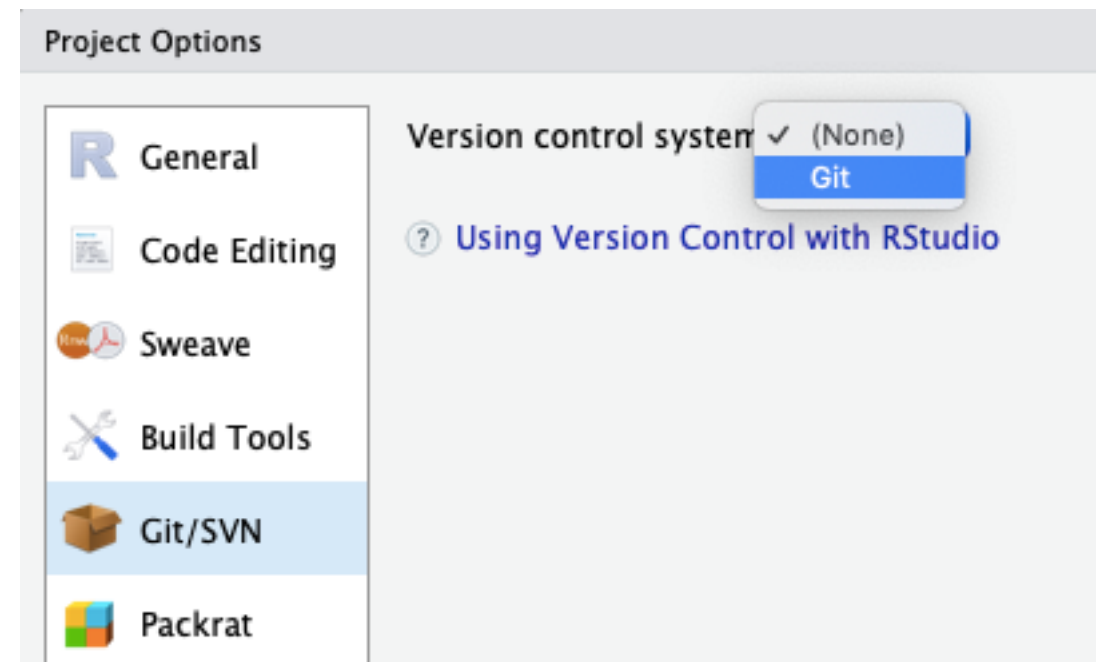
```
> library(holepunch)
```

- You can either clone a pre-existing repo from GitHub, or create a new R Project and turn that folder into a git version controlled repo - in which case...

First we need to ensure our folder associated with a project is a repository with git version control.



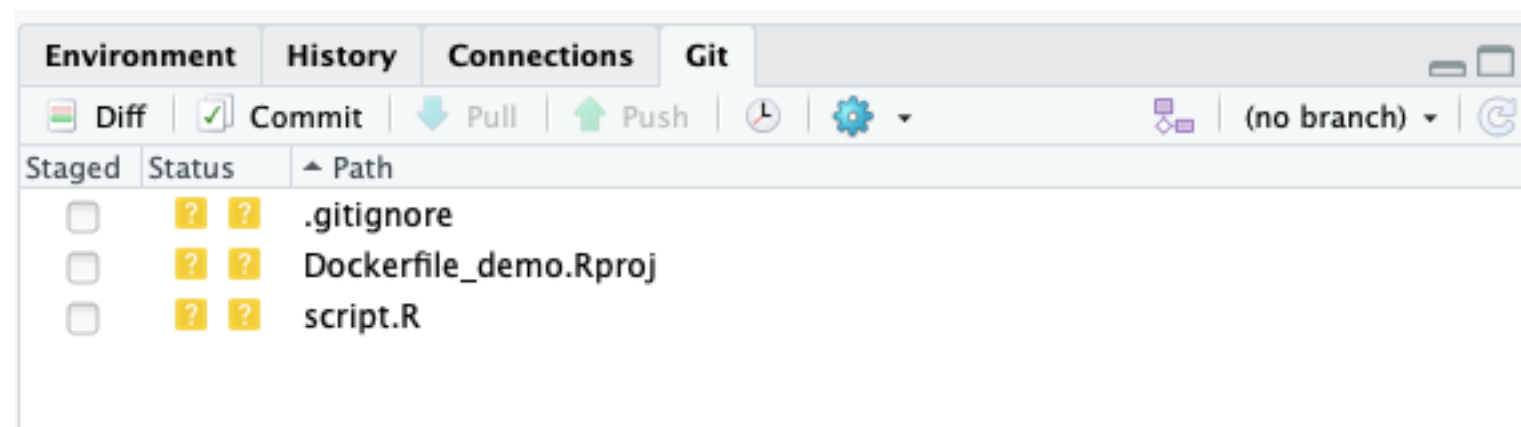
Select Git - you will need to restart your R session at this point.



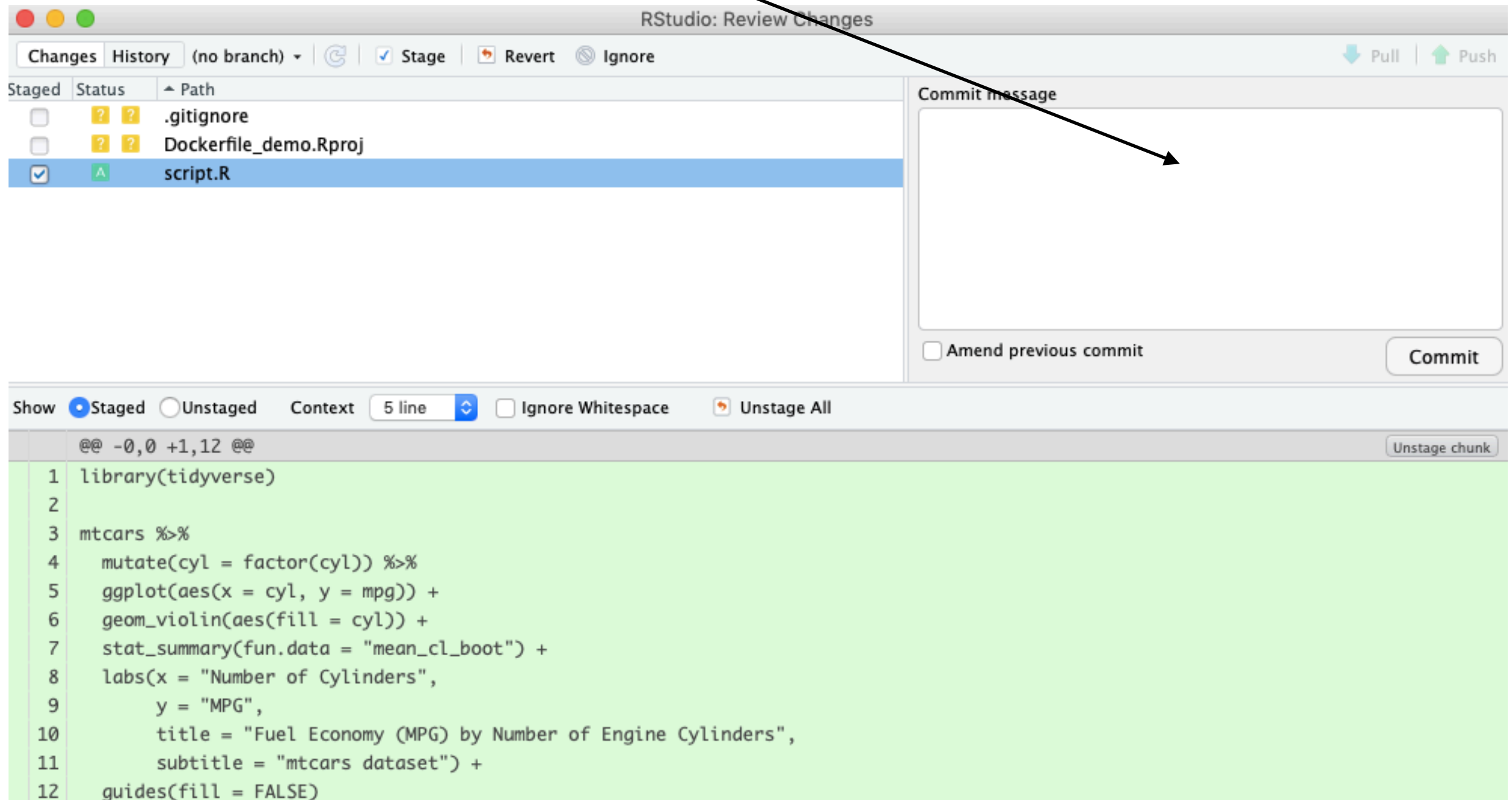
When you restart, you'll see you now have a new Git tab in your Environment window.



If you click on the Tab you'll see the contents of your folder.



In this example, I've selected the script.R file, saved it (you can't Commit without saving first), and then clicked on Commit - the following window now appears. Write a meaningful Commit message in here and then click on the 'Commit' button underneath.





- Once you have a git repository set up locally, push it to GitHub either within RStudio or via GitHub desktop (or the command line).
- Alternatively, you can set up a repo on GitHub and then clone it locally - but you'll still need to push changes to GitHub.
- You can then write your Dockerfile via the console in RStudio.

# Step 1 - write a Dockerfile

```
> write_dockerfile(maintainer = "your_name",  
r_date = "2019-06-27")
```

- If you leave out the date, `holepunch` will create a Dockerfile associated with the date you last changed your repo. It uses the version of R and packages on MRAN associated with the date you specify (or the last change date if you don't specify an actual date).

# Step 2 - generate a binder badge

```
> generate_badge()
```

- this will generate the code you need to paste in your repo README that will launch Binder upon clicking.

# Step 3 - build your binder

```
> build_binder()
```

- will start building your Binder in the background - this will still be much quicker than building from scratch as the Dockerfile will pull a Rocker image and associated R packages for the date you specified during `write_dockerfile()`

# Any caveats?

- `holepunch::` is very much still in development but Karthik responds super quickly to issues, enhancement suggestions, and bug reports - and it will be on CRAN (and therefore more stable) sooner rather than later...
- Great `rstudio::conf 2019` video of Karthik talking about reproducibility in general and `holepunch::`

<https://resources.rstudio.com/rstudio-conf-2019/a-guide-to-modern-reproducible-data-science-with-r>