

Developing a Workflow to Maximize Reproducibility and Research Impact: Managing Data, Computer Code, and Projects for Success

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Welcome!

Developing a Workflow to Maximize Reproducibility and Research Impact: Managing Data, Computer Code, and Projects for Success

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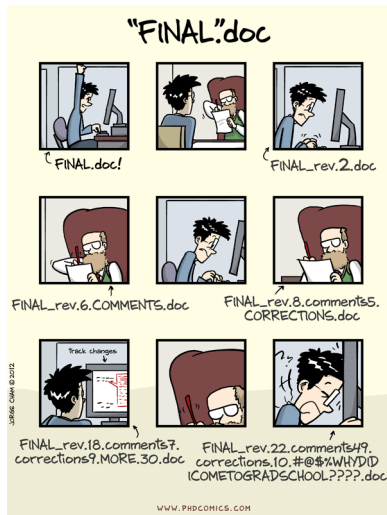
Before we begin, please open up the `reproducible_workshop` repository in RStudio and install these packages:

- ▶ `knitr`
- ▶ `ezknitr`
- ▶ `devtools`

Why worry about reproducibility?

Working towards future reproducibility makes my code easier for my collaborators (and me) to read, run, and debug today, and that's why I think reproducibility is a **win-win for all researchers.**"

-Althea



Why worry about reproducibility?

“[Reproducibility] provides security, saves time, and forces me to be more thoughtful about my workflow.” - Ethan Young

- ▶ make your life easier! Now, and in the future
- ▶ collaborations
- ▶ broader research impact
- ▶ increased citations
- ▶ transparency
- ▶ grant and journal requirements

Is my research reproducible?

- ▶ Are your research documents stored in these formats?

- ▶ .csv

- ▶ .txt

- ▶ .pdf

- ▶ .html

- ▶ .R/.Rdata

- ▶ YES!

- ▶ .doc/.docx

- ▶ .sas

- ▶ .xls/.xlsx

- ▶ any other proprietary file format

- ▶ NO!

Is my research reproducible?

- ▶ Is your code linear?
 - ▶ Clear environment often and at beginning of script
 - ▶ Don't save .Rdata or history
 - ▶ Each program should focus on one main task or analysis
 - ▶ Don't rely on manual commenting/uncommenting

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So, what's wrong here?

```
# What variables are significant?  
lm.out <- lm(weight ~ height, data = trial.data)  
remove(lm.out) # clear previous lm.out for each  
                # new lm() definition above  
  
# Is the relationship significant?  
# (If not, clear and try a new regressor)  
summary(lm.out)
```

Is my research reproducible?

- ▶ Are your files easily shared with others?
 - ▶ Organized directory structure
 - ▶ Files relatively linked
 - ▶ Well-documented & commented
 - ▶ Consistency in coding practices

“The point of having style guidelines is to have a common vocabulary of coding so people can concentrate on *what* you are saying, rather than on *how* you are saying it.” - Google’s R Style Guide

Workshop Outline

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2. R-Markdown and R-Oxygen for documenting your code and creating reproducible reports

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1. RStudio Projects for organizing data, code, and output
2. R-Markdown and R-Oxygen for documenting your code and creating reproducible reports
3. GitHub for version-control, collaborating and archiving

1. RStudio Projects

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- ▶ Raw data
- ▶ Processed data
- ▶ Analysis scripts
- ▶ Paper/Manuscript-related documents
- ▶ Sharing documents (“transmittals”)
- ▶ Metadata
- ▶ Maps or other deliverables

RStudio Projects provide an opportunity for you to organize and manage all of these types of folders in **one place** in a way that **relatively links** everything together and **eases sharing**.

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Up next, Activity 1!

Activity 1: Data management and updating

Here, we will read in and process three weeks of experimental data and do some preliminary analysis. Then, we will get a final (4th) week of data, which we will merge with the original data.

The goals are to:

1. Be introduced to RStudio
2. Create a framework for keeping data organized and up-to-date
3. Automatically update our analyses based on the master dataset

Context: Abundance data from ~75 invertebrate species sampled on various beaches along the Dutch coast.

Zuur, A.F., E.N. Ieno, and G.M. Smith (2007) Analysing Ecological Data. Springer, New York.

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Before we begin today, we need sync your individual versions of the workshop documents with Althea's master branch:

1. Open RStudio and your reproducibility_workshop.rproj. (File > Open Project...)
2. Open shell (Tools > Shell...)
3. Type in exactly, then press enter:

```
$ git fetch upstream
```

4. Type in exactly, then press enter:

```
$ git checkout master
```

5. Type in exactly, then press enter:

```
$ git merge upstream/master
```

Activity 1: Data management and updating

Now create a new folder in `student_folders/` for all of today's activities. Name the folder after yourself (or an alias).

Open a new R Script file and save it to that new folder as **“activity1a_data_processing.R”**

First, we will read in first three weeks of data and combine them, process the data a little bit, and save the merged/processed data for analysis.

Secondly, we will save another new R Script file as **“activity1b_data_analysis.R”** and do (preliminary) regression analysis.

Finally, we will pretend to have just gotten the final week's data in and update everything in a “reproducible” way.

1. RStudio Projects

Other links

<https://swcarpentry.github.io/r-novice-gapminder/02-project-intro/>

Data Management Tips

- ▶ Treat data as read-only
 - ▶ Don't use Excel, etc, to manipulate raw data
 - ▶ Use a single R program for all manipulation
 - ▶ Save “cleaned” or “processed” data in easily loadable formats
- ▶ Differentiate data types with folders *raw* versus *processed* versus *output* (e.g., linear regression objects, etc)
- ▶ Write dates in YYYYMMDD or equivalent format

Tips

- ▶ Don't use github with large files :-)
- ▶ Create new projects in GitHub first, then sync them with RStudio

Why R-Markdown for manuscripts?

“I can do reproducible work in R (making me happy) and format the output report in Word (making my collaborators happy)” - Richard Layton http://rmarkdown.rstudio.com/articles_docx.html

Documenting Code

Native R Scripts (.R extensions) (or any analysis code) are generally not designed for reading, but the **knitr** library has been designed for converting R scripts into readable reports, such as Word, PDF, and/or html documents.

Not only do these types of reports help with collaborating, they provide a great framework for archiving your analyses and results.

Example:

<https://conservancy.umn.edu/handle/11299/181607>

Documenting Code

General tips for better coding:

- ▶ Consistent and meaningful naming conventions
 - ▶ `a = b*c`
 - ▶ `weekly.pay = hours.worked*pay.rate` (not cross-compatible)
 - ▶ `weekly_pay = hours_worked*pay_rate`
 - ▶ `weeklyPay = hoursWorked*payRate`
- ▶ Using YYYYMMDD or equivalent for dates
- ▶ When possible, bundle data, code, figures/tables together with **knitr** package using R-Markdown or R-Oxygen languages

Documenting Code: R-Markdown

R-Markdown combines `markdown` language, which is “an easy-to-write plain text format” and embedded `R code chunks` that are “run so their output can be included in the final document” [1]

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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>.

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:

```
summary(cars)
```

##	speed	dist
##	Min. : 4.0	Min. : 2.00
##	1st Qu.:12.0	1st Qu.: 26.00
##	Median :15.0	Median : 36.00
##	Mean :15.4	Mean : 42.98
##	3rd Qu.:19.0	3rd Qu.: 56.00
##	Max. :25.0	Max. :120.00

[1] www.rmarkdown.rstudio.com

Documenting code: R-Markdown

Exercise 2a: Introduction to R-Markdown

- ▶ File > New File > R Markdown...
- ▶ Choose “html” - optionally put in a title and press “OK”
- ▶ This R-Markdown template is ready to “knit” into an html as-is
 - ▶ Click the blue Knit button
 - ▶ Save in your student_project folder as “activity2a_intro_rmarkdown.Rmd”
 - ▶ See the resultant html
- ▶ Take a few minutes to modify the .Rmd and view how the changes appear in the knit html document.

<https://www.rstudio.com/wp-content/uploads/2015/02/rmarkdown-cheatsheet.pdf>

Documenting code: ezknitr

What folder did the html end up in?

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Now imagine if you wanted to keep the programs/scripts in a folder separate from reports (**highly recommended!**)? You can easily direct the output html file into a different folder using **ezknitr** package.

```
library(ezknitr)
ezknit("student_folders/yours/activity2a_intro_rmarkdown.Rmd",
      out_dir = "student_folders/archmilller_a/reports",
      fig_dir = "figures",
      keep_md = F)
```

Documenting Code: R-Oxygen

Instead of using the R-Markdown language, you can also use **pure R scripts** plus **Roxygen comments** (`#'`) to create fully reproducible reports!

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Documenting Code: R-Oxygen

Activity 2b: Introduction to R-Oxygen

Here, we'll quickly convert “activity1b_data_analysis.R” into an html document!

1. Open “activity1b_data_analysis.R”
2. Save As. . .
“student_folder/yours/activity2b_intro_roxygen.R”

LaTeX

(Page 75 begins the mathematical symbols)

<https://tobi.oetiker.ch/lshort/lshort.pdf>