EEB 603 – Chapter 1: Using the R Markdown language to promote Reproducible Science

Part A: Basics of R Markdown

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Figure 1: The spectrum of reproducibility.

**Learning outcomes**

This tutorial is devoted to part A and provides students with opportunities to learn procedures to:

• Install R Markdown on your computer.

• Create and render (or knitting) your first R Markdown document.

• Execute basic R Markdown syntax and protocols.

**Associated files supporting this tutorial**

Although less used in part A, a set of files are provided to support teaching of material presented in this chapter. These files are deposited in the shared Google Drive at this path:

• Reproducible\_Science/Chapters/Chapter\_1/Tutorial\_files

Files are as follows:

• EEB603\_Syllabus\_BUERKI.Rmd: This is the .Rmd file used to compile the syllabus of this class. This file provides a good source of information for the syntax and protocols described in this tutorial.

• Bibliography\_Reproducible\_Science\_2.bib: This file contains references cited in BibTex format.

• AmJBot.csl: This citation style language (CSL) file allows formatting citations and bibliography following citation style of *American Journal of Botany*.

• Bioinformatic workflow\_PART2.pdf: A pdf file containing the bioinformatic workflow taught in this class. This file will be used to learn how to incorporate a figure into R Markdown file.

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**Aim of chapter 1**

The overarching aim of chapter 1 is to provide students with the bioinformatic skills allowing them to link and execute data and code into a unified environment making research reproducible (Figure 1). This chapter focuses on learning the R Markdown syntax and protocols allowing to include text, code, figures, tables and bibliography into a document. This document will then be compiled into an output file (in either pdf, HTML or Word formats) allowing sharing your research. More specifically, this tutorial provides students with the minimum knowledge allowing them to complete their bioinformatic tutorials (PART 2) and individual projects (PART 3). The chapter will be subdivided into four parts as follows:

• **Part A:** Basics of R Markdown (1-Sept).

• **Part B:** Tables, Figures and References (3-Sept).

• **Part C:** Advanced R Markdown settings (8-Sept).

• **Part D:** User Defined Functions in R (10-Sept).

**Install R Markdown software**

Software and packages required to perform this tutorial are detailed below. Students should install those software and packages on their personal computers to be able to complete this course. Additional packages might need to be installed and the instructor will provide guidance on how to install those as part of the forthcoming tutorials.

• **R**: https://www.r-project.org

• **R packages**: bookdown, knitr and R Markdown. Use the following R command to install those packages: **install.packages**(**c**("bookdown", "knitr", "rmarkdown"))

• **RStudio**: https://www.rstudio.com/products/rstudio/download/

• **TeX**: This software is required to compile document into pdf format. Please install MiKTeX on Windows, MacTeX on OS X and TeXLive on Linux.

**RStudio: An Integrated Development Environment (IDE) for R**

RStudio is an integrated development environment (IDE) that allows you to interact with R more readily. RStudio is similar to the standard RGUI, but it is considerably more user friendly. It has more drop-down menus, windows with multiple tabs, and many customization options (see Figure 2). Detailed information on using RStudio can be found at at RStudio’s website.

Figure 2: Snapshot of the RStudio environment showing the four windows and their content.

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**Web resources**

Please find below URLs to webpages that are providing key information for chapter 1:

• **R Markdown:** https://RMarkdown.rstudio.com

• **R Markdown: The Definitive Guide (by Yihui Xie, J. J. Allaire, Garrett Grolemund):** https://bookdown.org/yihui/RMarkdown/

• **Write HTML, PDF, ePub, and Kindle books with R Markdown:** https://bookdown.org

• **bookdown: Authoring Books and Technical Documents with R Markdown (by Yihui Xie):** https://bookdown.org/yihui/bookdown/

• **knitr:** http://yihui.name/knitr/

• **Pandoc: A universal document converter:** https://pandoc.org

• **Bibliographies and Citations in R Markdown:** https://RMarkdown.rstudio.com/authoring\_ bibliographies\_and\_citations.html

• **Tutorial on knitr with R Markdown (by Karl Broman):** http://kbroman.org/knitr\_knutshell/ pages/RMarkdown.html

**Create and render (or knitting) your first R Markdown document**

**Introduction to R Markdown**

Markdown is a simple formatting syntax language used for authoring HTML, PDF, and MS Word documents, which is implemented in the rmarkdown package. An R Markdown document is usually subdivided into three sections (Figure 3):

1. **YAML metadata section:** This section provides high level information about the output format of the R Markdown file. Information stored in this section will be used by the Pandoc program to format the output document (see Figure 5). 2. **Publication core text:** This section represents the core of your document/publication and uses

Markdown syntax. 3. **Code chunk:** This section allows to import and analyze data as well as produce figures and tables that will be directly displayed in the output file.4

Figure 4: Snapshot of window to create an R Markdown file.

To create an R Markdown document execute the following steps in RStudio:

1. Select: File -> New File -> R Markdown... 2. Provide title for the document and define Default output format (Figure 4). If you want to knit your document in pdf format, a version of the TeX program has to be installed on your computer (see Figure 4). 3. Save the .Rmd document (using File -> Save As...). Save this file in a new folder devoted to the

project (**Warning:** Knitting the document will generate several files).

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**YAML metadata section**

**Publication core text**

**Code chunk: Importing data**

**Code chunk: Analyze data and output figures and tables**

Figure 3: Example of an R Markdown file showing the three major sections.

**Creating an R Markdown file**

your R Markdown document/script into the format specified in the YAML metadata section do the following steps in RStudio:

1. Select the Knit button (Figure 3) in the upper bar of your window to render document. 2. There are several options depending on the output format; however if you just push the button it will automatically knit the document following settings provided in the YAML metadata section (Figure 3). 3. The output file will automatically be created in the same directory as the .Rmd file. You can track progress in the R Markdown console. If the knitting fails, error messages will be printed in the R Markdown console (including information on which line of the script the error occurred, but it might not always be the case). Error messages are very useful to debug your R Markdown document.

**How does the knitting process work?**

When you knit your document, R Markdown will feed the .Rmd file to the R *knitr* package, which executes all of the code chunks and creates a new markdown (.md) document. This latter document includes the code and its output (Figure 5). The markdown file generated by knitr is then processed by the Pandoc program, which is responsible for creating the finished format (Figure 5).

Figure 5: R Markdown flow.

**Basic R Markdown syntax and protocols**

We will focus here on learning the syntax and protocols to produce:

• Headers.

• Lists.

• Italicize and bold words.

• Embed code chunks and inline code.

• Check spelling.

More syntax are available in the R Markdown Reference Guide. You can access this document as follows in RStudio:

• Select: Help -> Cheatsheets -> R Markdown Reference Guide

**Notice:** The Cheatsheet section also allows accessing additional supporting documents related to R Markdown and Data manipulation. Those documents will be very useful for this class.

**Headers**

Please find below the syntax to create headers (3 levels):

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**Rendering (or knitting) an R Markdown document**

To render or knit

Syntax: The "#" refers to the level of the header *# Header 1 ## Header 2 ### Header 3*

**Lists**

There are two types of lists:

• Unordered

• Ordered

**Syntax for unordered lists**

Syntax: **\*** unordered list **\*** item 2

**+** sub**-**item 1 **+** sub**-**item 2

Output:

• unordered list

• item 2

**–** sub-item 1 **–** sub-item 2

**Syntax for ordered lists**

Syntax: 1. ordered list 2. item 2

**+** sub**-**item 1 **+** sub**-**item 2

Output:

1. ordered list 2. item 2

• sub-item 1

• sub-item 2

**Italicize and bold words**

The following syntax will render text in italics or bold: *#Syntax for italics* **\***italics**\***

*#Syntax for bold* **\*\***bold**\*\***

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**Embed code chunks and inline code**

One of the most exciting features of working with the R Markdown format is the implementation of functions allowing to directly “plug” the output of R code into the compiled document (see Figure 5). In other words, when you compile your .Rmd file, R Markdown will automatically run and process each code chunk and code lines and embed their results in your final document. If the output of the code is a table or a figure, you will be able to assign a label to this item (by adding information in the code chunk; see part B) and refer to it (=cross-referencing) in your pdf document. Cross-referencing is possible thanks to the \autoref{} function implemented in TeX.

**Code chunk**

A code chunk could easily be inserted in your document as follows:

• Using the keyboard shortcut **Ctrl + Alt + I** (OS X: **Cmd + Option + I**).

• Pressing on the Insert button

in the editor toolbar.

• Typing {r} and .

By default the code chunk will expect R code, but you can also insert code chunks supporting different computer languages (e.g. Bash, Python).

**Chunk options**

Chunk output can be customized with *knitr* options arguments set in the {} of a chunk header. In the examples displayed in Figure 6 five arguments are used:

• include = FALSE prevents code and results from appearing in the finished file. R Markdown still runs the code in the chunk, and the results can be used by other chunks.

• echo = FALSE prevents code, but not the results from appearing in the finished file. This is a useful way to embed figures.

• message = FALSE prevents messages that are generated by code from appearing in the finished file.

• warning = FALSE prevents warnings that are generated by code from appearing in the finished.

• fig.cap = "..." adds a caption to graphical results.

We will delve more into chunk options in part C of chapter 1, but in the meantime please see the R Markdown Reference Guide for more details.

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Figure 6: Example of code chunks.

**Inline code**

Code results can be inserted directly into the text of a .Rmd file by enclosing the code with r .

R Markdown will always:

• Display the results of inline code, but not the code.

• Apply relevant text formatting to the results.

As a result, inline output is indistinguishable from the surrounding text. **Warning:** Inline expressions do not take *knitr* options and is therefore less versatile. We usually use inline code to perform simple stats (e.g. 4x4; 16)**Check spelling**

There are three ways to access spell checking in an R Markdown document in RStudio:

1. A spell check button

to the right of the save button. 2. Edit > Check Spelling... 3. The F7 key.

**Exercises**

Students will work individually to complete the following exercises:

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1. Create an \*.Rmd file entitled Exercises chapter 1: part A and select HTML as output format. 2. Save this document as Exe\_chap1\_partA.Rmd in a sub-folder called Exercises located in:

• Reproducible\_Science/Chapters/Chapter\_1

3. Practice syntax to do:

• headers,

• lists,

• include R code chunk and inline code.

4. Confirm that your syntax works by knitting your document and inspecting the output.

To further learn syntax and protocols, please look at associated files provided by the instructor (see above for more details).

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