

USING L^AT_EX AND MARKDOWN FOR REPRODUCIBLE RESEARCH

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R USER GROUP WORKSHOP

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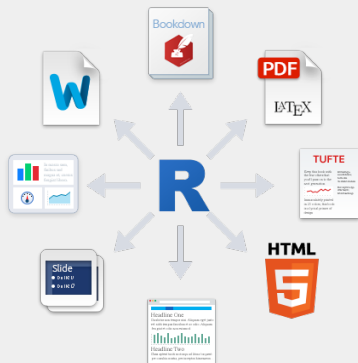


TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources

Using LaTeX and Markdown for Reproducible Research

Day	Time	Room
Tues, Sept 11	8:30-11:30am	C111C

- This 1/2-day workshop will provide attendees with hands-on experience using the basics of LaTeX, Markdown, and the R package knitr.
- After attending this workshop, you will be able to use these tools to facilitate reproducible reports and research with R.

STEPS/AGENDA

We will try to use our three hours as effectively as possible.

Rough Agenda

#	Time	Topic
1	8:30	System checks & agenda
2	8:45	Intro to LaTeX
3	9:00	Intro to Markdown
4	9:15	Markdown & LaTeX
5	9:40	Reproducible Research
	9:50	<i>BREAK</i>
6	10:00	Dynamic documents with Sweave and knitr
7	10:30	Markdown & LaTeX with R
8	11:20	Wrap-up & additional resources

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX**
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources

LaTeX is a tool for high-quality typesetting based on the idea that it is better to leave document design to document designers, and to let authors get on with writing documents.

How do you pronounce “LaTeX”?

TeX is usually pronounced tech, making 'lah-teck, lah-'teck, and 'lay-teck the logical choices; but language is not always logical, so 'lay-'tecks is also possible.

— Leslie B. Lamport, original developer of L^AT_EX

LaTeX is widely used in academia for the publication of scientific documents in many fields, including mathematics, statistics, computer science, engineering, chemistry, physics, economics, and political science.

1. **TeX engines have excellent quality output.** This especially holds for complex documents such as those with mathematics, with many tables, or many cross-references or hyperlinks, or just with many pages.
2. **TeX is fast.**
3. **TeX is stable.** It will never eat your document. *Ever.*

— <https://www.ctan.org/tex/>

L^AT_EX: MINIMAL EXAMPLE

Here is a minimal example of a full document written in LaTeX.

```
\documentclass{article}  
\title{A Minimal LaTeX Example}  
\author{Emily Li}  
  
\begin{document}  
\maketitle  
  
Hello world!  
  
\end{document}
```

LEVELS OF L^AT_EX: A DISAMBIGUATION

Help! There are too many words with “T_EX” in them!

If you are wondering, “*Should I use L^AT_EX or M_IK_TE_X?*”, allow us to clear that up. These two slides will cover four types of T_EX-related terms: distributions, editors, engines, and formats.

1. **Distributions:** *M_IK_TE_X, T_EX Live, etc.* This is T_EX-related software to be downloaded and installed. When someone says, “I need to install T_EX on my machine,” they’re usually looking for a distribution.
2. **Editors:** *Emacs, T_EXworks, T_EXShop, T_EXStudio, etc.* These editors are what you use to create a document file. Some (e.g., T_EXShop) are devoted specifically to T_EX, while others (e.g., Emacs) can be used to edit any sort of file.

— <http://www.tug.org/levels.html>

LEVELS OF L^AT_EX: A DISAMBIGUATION

A quick note on editors

You can also use Notepad to edit plaintext, including LaTeX code.

3. **Engines:** *TeX*, *pdfTeX*, *XeTeX*, *LuaTeX*, etc. These are the executable binaries which implement different TeX variants. When someone says, “TeX can’t find my fonts,” they usually mean an engine.
4. **Formats:** *LaTeX*, *plain TeX*, etc. These are the TeX-based languages in which one actually writes documents. When someone says, “TeX is giving me a mysterious error,” they usually mean a format. (Incidentally, “LaTeX” has meant “LaTeX2e” for many years now.)

— <http://www.tug.org/levels.html>

To compile LaTeX, your computer needs one of these TeX distributions installed:

TeX Distributions

Distribution	Operating System
MiKTeX	Windows OS
TeX Live	Linux and other UNIX-like systems
MacTeX	Mac OS X

You can also use an on-line, ready-to-use option like ShareLaTeX or Overleaf.

Try compiling this LaTeX

```
\documentclass{article}  
\title{A Minimal LaTeX Example}  
\author{Emily Li}  
  
\begin{document}  
\maketitle  
  
Hello world!  
  
\end{document}
```

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown**
- 4 Markdown & LaTeX
- 5 Reproducible Research
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- 7 Markdown & LaTeX with R
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INTRO TO MARKDOWN



- An **.Rmd file** is an R Markdown file
- Contains the code that a scientist needs to reproduce your work, along with the narration that a reader needs to understand your work.
- Choose to export the finished report in a variety of formats, including HTML, PDF, or MS Word.

<https://rmarkdown.rstudio.com/>

INTRO TO MARKDOWN

- Markdown allows us to write using an easy-to-read, easy-to-write plain text format.
- As long as you know how to write emails, you can learn it in a few minutes.
- `https://en.wikipedia.org/wiki/Markdown#Example`

Limitations of Markdown

Markdown was primarily designed to be simple.
For more complicated typesetting, LaTeX may be preferred.

A short example of Markdown

```
# First level header
```

```
Hello world!
```

```
## Second level header
```

```
This is bold, and italic.
```

- ```
- list item
```
- ```
- list item
```

```
You can write an ordered list:
```

- ```
1. item 1
```
- ```
1. item 2 # this line will render as "2."
```

WORKFLOW IN MARKDOWN

Using RStudio:

Open a new .Rmd file, which pre-populates with a template

Write a document by editing the template

Knit the document to create a report; use the knitr button or `render()` to knit

Preview output in IDE window

Publish to web server (optional)

Use output file that is saved alongside .Rmd

Helpful link:

<https://rmarkdown.rstudio.com/lesson-2.html>

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX**
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research**
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources

REPRODUCIBLE RESEARCH

IS THERE A REPRODUCIBILITY CRISIS?

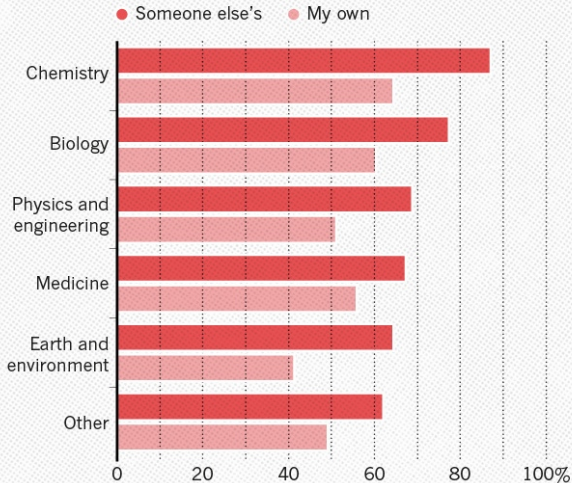


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REPRODUCIBLE RESEARCH

HAVE YOU FAILED TO REPRODUCE AN EXPERIMENT?

Most scientists have experienced failure to reproduce results.



Results must be reproducible to be trustworthy.

*An article about computational science in a scientific publication is not the scholarship itself, it is merely the advertising of the scholarship. The actual scholarship is the complete software development environment **and the complete set of instructions which generated the figures.***

— 1995, David L. Donoho, professor of statistics at Stanford University

This chunk of R code produces a figure that illustrates a simulation of Brownian motion for 100 steps.

Try running this in RStudio

```
set.seed(1213) # for reproducibility
x <- cumsum(rnorm(100))
plot(x, type = 'l',
      ylab = '$x_{i+1}=x_i+\\epsilon_{i+1}$',
      xlab = 'step')
```



```
set.seed(1213)
x <- cumsum(rnorm(100))
plot(x, type = 'l',
      ylab = '$x_{i+1}=x_i+\\epsilon_{i+1}$',
      xlab = 'step')
```

To put this into a document by hand, we would have to open RStudio, compile the code to draw the plot, save it as an image, then insert it into a document with `\includegraphics{}` in LaTeX or 'Insert Image' in Word.

Then what if we want to change the random seed in `set.seed()`, or the y-axis label?

- Instead of separating results from computing, we can put everything in one document, including the computational steps and narratives.
- When we compile this document, the computer code will be executed, giving us the results directly.
- Dynamic report generation by integrating code with narratives is not only easier, but also closely related to reproducible research.
- It does not guarantee RR, but RR is one possible by-product of dynamic documents.

BREAK FOR 10 MINUTES



IMAGE SOURCE [HTTPS://GETCUBEFIT.COM/](https://getcubefit.com/). NOT AN ENDORSEMENT OF THE COMPANY.

WELCOME BACK!

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr**
- 7 Markdown & LaTeX with R
- 8 Additional Resources

SWEAVE

Sweave has been a longstanding tool for dynamic documents since 2002.

- Deals with Rnw documents, combining the power of R with the production value of LaTeX to enable reproducible research
- Part of base R—in the **utils** package as the `Sweave()` function
- Two ways to run Sweave:
 - ▶ From your R session: `Sweave("your_file.Rnw")`
 - ▶ From the command line: `R CMD Sweave your_file.Rnw`

However...

- Development has plateaued in recent years
- Extensions based on core code are no longer synchronized with Sweave development, have become incompatible.
- LaTeX (to produce Rnw documents) is more complicated than RMarkdown (Rmd), and documents rarely need to be produced as PDFs unless submitting a manuscript to journals

knitr was largely motivated by Sweave First of all, knitr uses Rmarkdown, a set of intuitive human-readable code to do the formatting. While LaTeX is by no means as complicated as its reputation seems to suggest, Rmarkdown is actually easy. By human-readable I mean that anyone who has never even heard of Rmarkdown can understand what is happening to some extent. Sweave is great for producing PDF, but that's one of the biggest drawbacks of LaTeX in the social sciences: while the PDF may look good, they are not the format we need when collaborating with Word-only colleagues, and with rare exceptions when submitting a manuscript to journals. Knitr works very well with Pandoc, so creating a Word document or an ODF is just as easy as creating a PDF. The other day I had to submit a supplementary file as a *.doc file, even though it'll end up as a PDF on Dataverse or so. With knitr this didn't take long.

WHY KNITR BEATS SWEAVE



TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
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- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
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Apples & Oranges?

The next few slides will show a side-by-side comparison of Markdown and LaTeX using the exact same analysis.

EXAMPLE L^AT_EX WITH ANALYSIS

```
\documentclass{article}  
\begin{document}  
\title{Speed and Stopping Distance}  
\author{Yihui Xie, creator of knitr}  
  
\maketitle
```

We examine the relationship between speed and stopping distance. The model is:

$$Y = \beta_0 + \beta_1 x + \epsilon$$

```
<<model, fig.width=4, fig.height=3, fig.align='center'  
par(mar = c(4, 4, 1, 1), mgp = c(2, 1, 0), cex = 0.8)  
plot(cars, pch = 20, col = 'darkgray')  
fit <- lm(dist ~ speed, data = cars)  
abline(fit, lwd = 2)  
@
```

The slope of a simple linear regression is β_1 .

When embedding R code in LaTeX, start a code chunk with `«»=` and terminate it with `@`.

EXAMPLE MARKDOWN WITH ANALYSIS

title: Speed and Stopping Distance

We examine the relationship between speed and stopping distance. The model is:

$$Y = \beta_0 + \beta_1 x + \epsilon$$

```
'''{r fig.width=4, fig.height=3, fig.align='center'}
par(mar = c(4, 4, 1, 1), mgp = c(2, 1, 0), cex = 0.8)
plot(cars, pch = 20, col = 'darkgray')
fit <- lm(dist ~ speed, data = cars)
abline(fit, lwd = 2)
```

The slope of a simple linear regression is `r coef(fit)`.

- Quickly insert chunks with the keyboard shortcut Ctrl + Alt + I (OS X: Cmd + Option + I).
- By comparison, Markdown has simpler commands.

- Write code chunks between ````\{r}` and `````
- Inline R code is written in ```
- Chunk options are written before closing brace in the chunk header.

QUICK REPORTING IN MARKDOWN

It is also possible to generate a quick report from R script using knitr's `stitch()` function.

Usage of `stitch()` for quick reports

```
library(knitr)
stitch("your-script.R")
```

- `stitch()` provides a template so the user only feeds the template with one R script and knitr will compile the template to a report.
- Currently it has built-in templates for LaTeX, HTML, and Markdown.

TABLE OF CONTENTS

- 1 Agenda
- 2 Introduction to LaTeX
- 3 Introduction to Markdown
- 4 Markdown & LaTeX
- 5 Reproducible Research
- 6 Dynamic documents with Sweave and knitr
- 7 Markdown & LaTeX with R
- 8 Additional Resources**

RESOURCES

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- <https://www.rstudio.com/resources/cheatsheets/>
- <https://support.rstudio.com/hc/en-us/articles/200552056-Using-Sweave-and-knitr>
- knitr document source + output examples:
<https://yihui.name/knitr/demos/>
- To Markdown or LaTeX, that is the question:
<https://yihui.name/en/2013/10/markdown-or-latex/>

THANKS FOR COMING!