# Literate Statistical Programming with knitr

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# Problems, Problems

- Authors must undertake considerable effort to put data/results on the web
- Readers must download data/results individually and piece together which data go with which code sections, etc.
- Authors/readers must manually interact with websites
- There is no single document to integrate data analysis with textual representations; i.e. data, code, and text are not linked

# Literate Statistical Programming

- Original idea comes from Don Knuth
- An article is a stream of **text** and **code**
- Analysis code is divided into text and code “chunks”
- Presentation code formats results (tables, figures, etc.)
- Article text explains what is going on
- Literate programs are **weaved** to produce human-readable documents and **tangled** to produce machine-readable documents

# Literate (Statistical) Programming

- Literate programming is a general concept that requires
  1. A documentation language (human readable)
  2. A programming language (machine readable)
- Sweave uses LaTeX and R as the documentation and programming languages
- Sweave was developed by Friedrich Leisch (member of the R Core) and is maintained by R core
- Main web site:
  `http://www.statistik.lmu.de/~leisch/Sweave`

# Sweave Limitations

- Sweave has many limitations
- Focused primarily on LaTeX, a difficult to learn markup language used only by weirdos
- Lacks features like caching, multiple plots per chunk, mixing programming languages and many other technical items
- Not frequently updated or very actively developed

# Literate (Statistical) Programming

- knitr is an alternative (more recent) package
- Brings together many features added on to Sweave to address limitations
- knitr uses R as the programming language (although others are allowed) and variety of documentation languages
  - LaTeX, Markdown, HTML
- knitr was developed by Yihui Xie (while a graduate student in statistics at Iowa State)
- See http://yihui.name/knitr/

# Literate Statistical Programming

- Literate programming is a general concept. We need
  - A documentation language
  - A programming language
- The original **Sweave** system developed by Friedrich Leisch used LaTeX and R
- **knitr** supports a variety of documentation languages

# How Do I Make My Work Reproducible?

- Decide to do it (ideally from the start)
- Keep track of things, perhaps with a version control system to track snapshots/changes
- Use software whose operation can be coded
- Don’t save output
- Save data in non-proprietary formats

# Literate Programming: Pros

- Text and code all in one place, logical order
- Data, results automatically updated to reflect external changes
- Automatic “regression test” when building a document

# Literate Programming: Cons

- Text and code all in one place; can make documents difficult to read, especially if there is a **lot** of code
- Can substantially slow down processing of documents (although there are tools to help)

# What is knitr?

- An R package written by Yihui Xie (while he was a grad student at Iowa State)
  - Available on CRAN
- Supports RMarkdown, LaTeX, and HTML as documentation languages
- Can export to PDF, HTML
- Built right into RStudio for your convenience

# Requirements

- A recent version of R
- A text editor (the one that comes with RStudio is okay)
- Some support packages also available on CRAN
- Some knowledge of Markdown, LaTeX, or HTML
- We will use Markdown here

# What is Markdown?

- A simplified version of “markup” languages
- No special editor required
- Simple, intuitive formatting elements
- Complete information available at http://goo.gl/MUt9i5

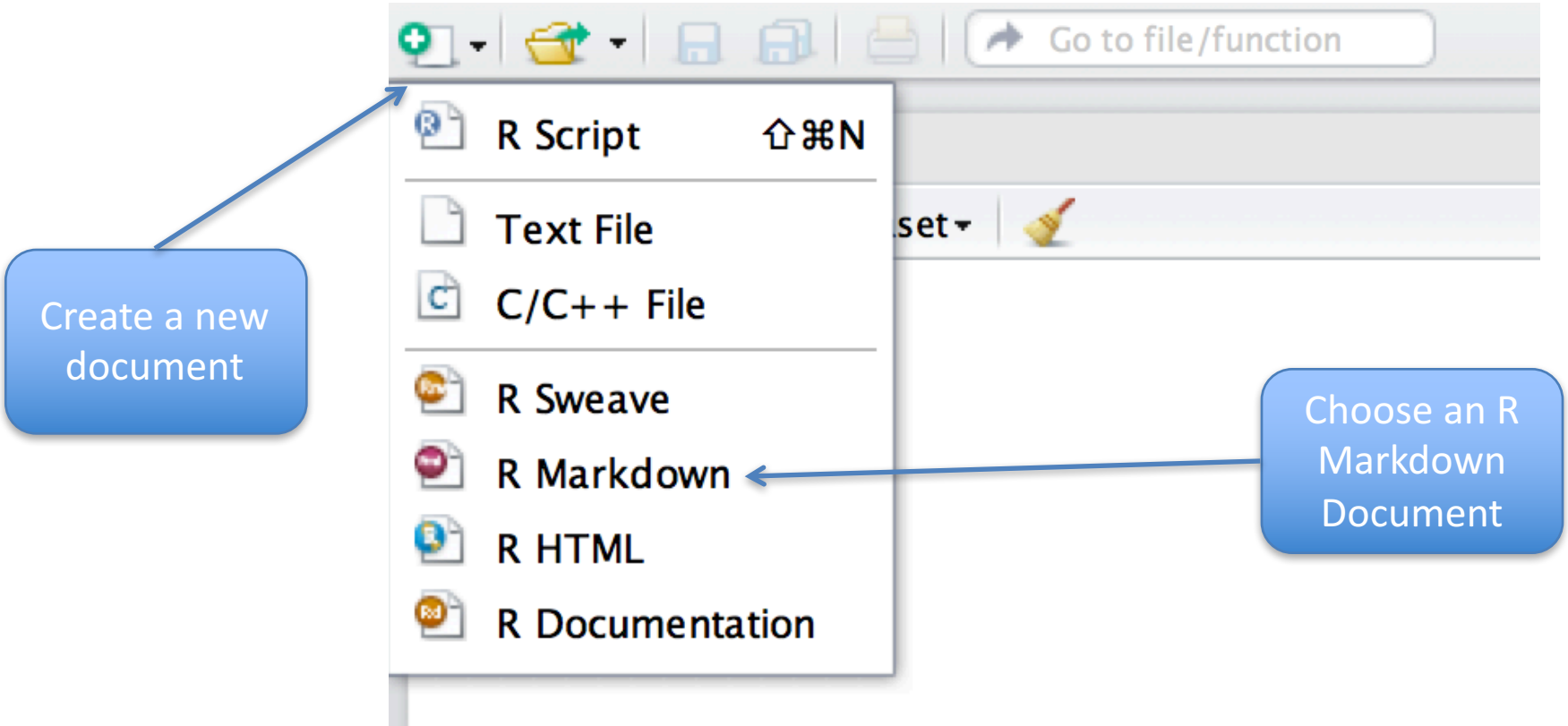
# What is knitr Good For?

- Manuals
- Short/medium-length technical documents
- Tutorials
- Reports (esp. if generated periodically)
- Data preprocessing documents/summaries

# What is knitr NOT Good For?

- Very long research articles
- Complex time-consuming computations
- Documents that require precise formatting

# My First knitr Document

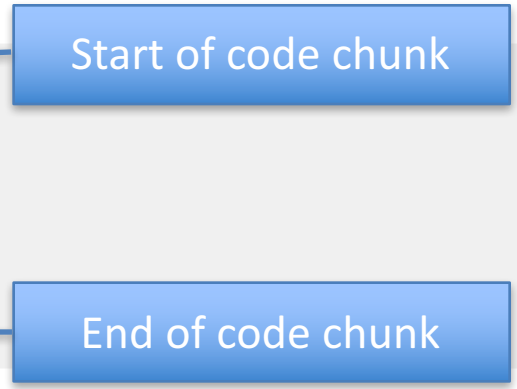


# My First knitr Document

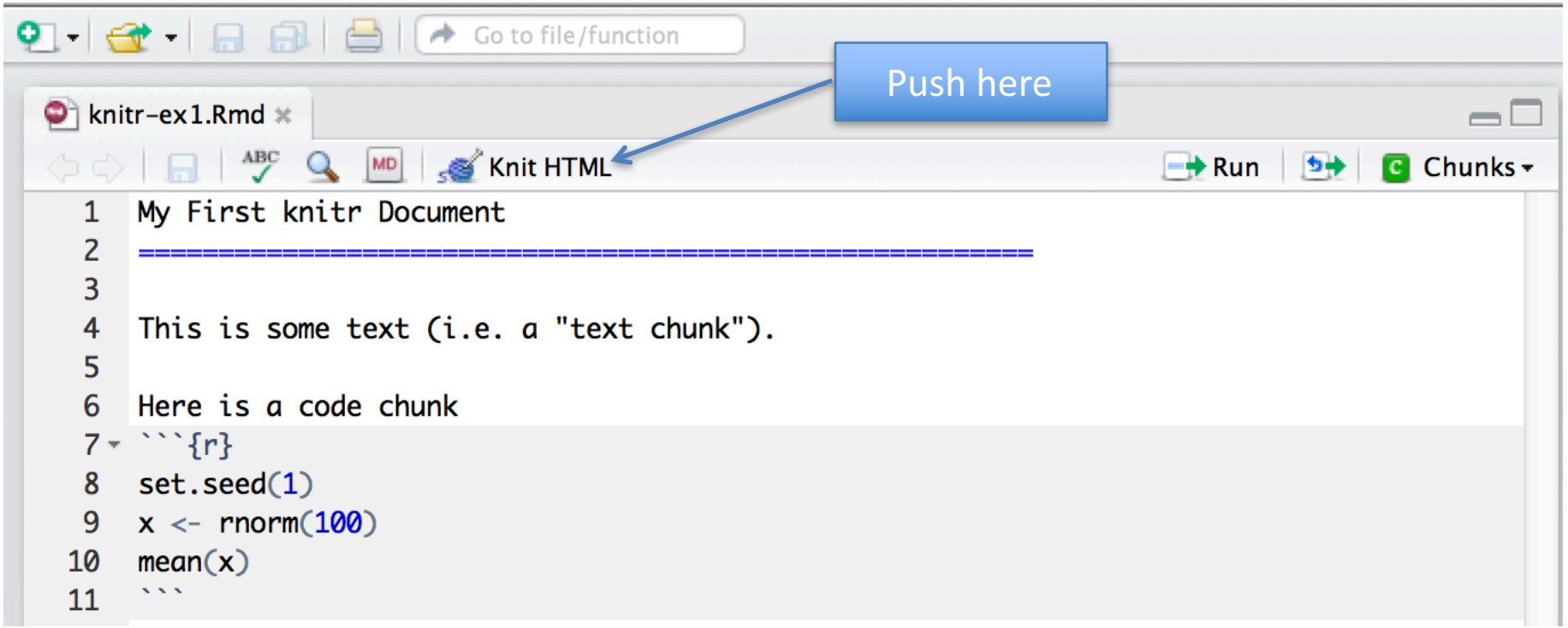
````
My First knitr Document
==========================================================

This is some text (i.e. a "text chunk").

Here is a code chunk
```{r}
set.seed(1)
x <- rnorm(100)
mean(x)
```
````



# Processing a knitr Document



# More Complicated Way

```
library(knitr)
setwd(<working directory>)
knit2html(“document.Rmd”)
browseURL(“document.html”)
```

# HTML Output

## My First knitr Document

This is some text (i.e. a “text chunk”).

Here is a code chunk

```
set.seed(1)
x <- rnorm(100)
mean(x)
```

Code input

```
## [1] 0.1089
```

Numerical output

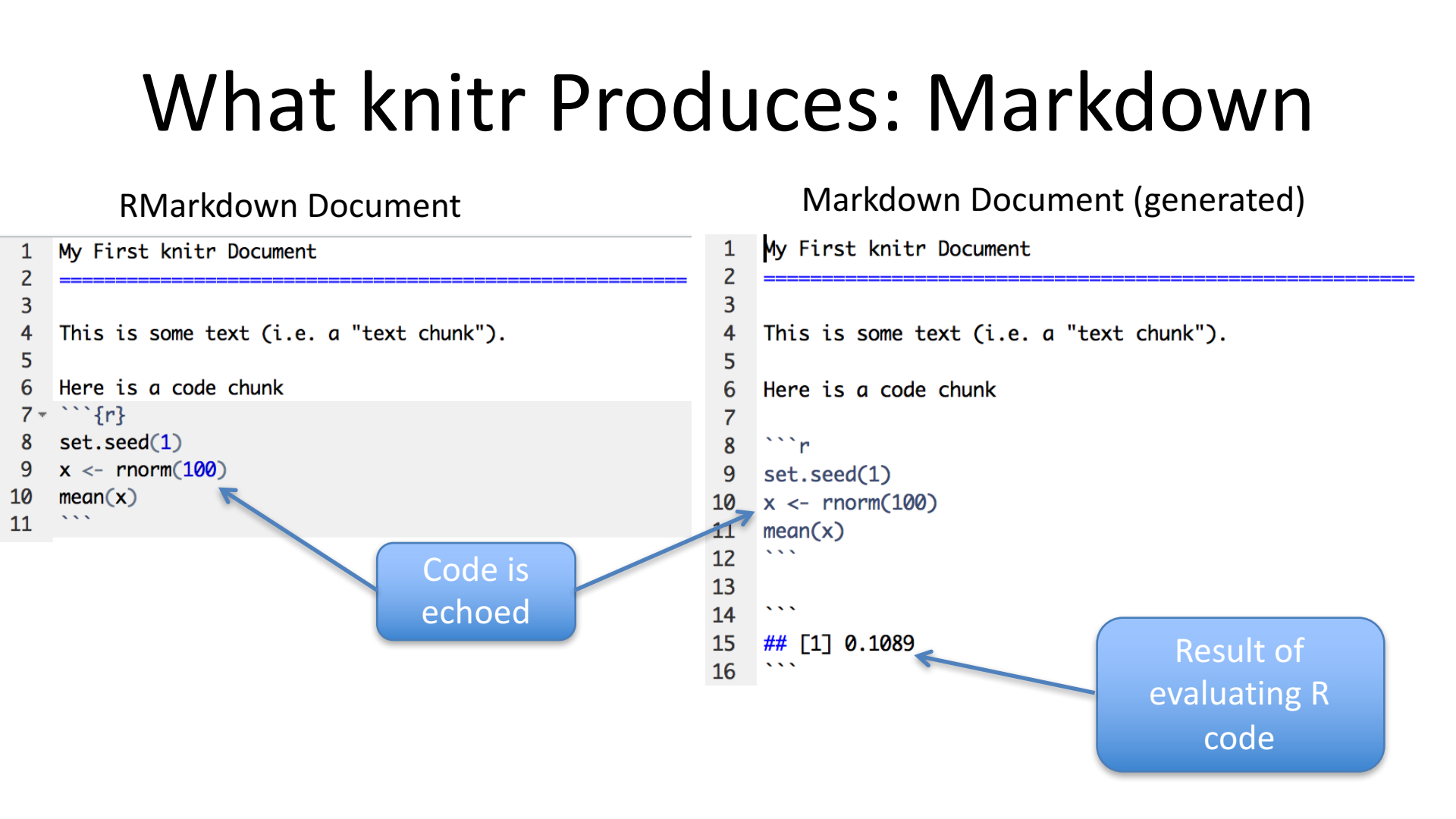
# What knitr Produces: Markdown

RMarkdown Document

```
1  My First knitr Document
2  ==========================================================
3
4  This is some text (i.e. a "text chunk").
5
6  Here is a code chunk
7  ```{r}
8  set.seed(1)
9  x <- rnorm(100)
10 mean(x)
11 ```
```

Markdown Document (generated)

```
1  My First knitr Document
2  ==========================================================
3
4  This is some text (i.e. a "text chunk").
5
6  Here is a code chunk
7
8  ```r
9  set.seed(1)
10 x <- rnorm(100)
11 mean(x)
12 ```
13
14 ```
15 ## [1] 0.1089
16 ```
```



# A Few Notes

- knitr will fill a new document with filler text; delete it
- Code chunks begin with ```` ```{r} ```` and end with ```` ``` ````
- All R code goes in between these markers
- Code chunks can have **names**, which is useful when we start making graphics

````
```{r firstchunk}
## R code goes here
```
````

- By default, code in a code chunk is echoed, as will the results of the computation (if there are results to print)

# Processing of knitr Documents (what happens under the hood)

- You write the RMarkdown document (.Rmd)
- knitr produces a Markdown document (.md)
- knitr converts the Markdown document into HTML (by default)
- .Rmd → .md → .html
- You should NOT edit (or save) the .md or .html documents until you are finished

# Another Example

```
# My First knitr Document
Roger D. Peng

## Introduction

This is some text (i.e. a "text chunk"). Here is a code chunk.
```{r simulation,echo=FALSE}
set.seed(1)
x <- rnorm(100)
mean(x)
```
```

Level 1 heading

Level 2 heading

Do not echo code

# Output

# My First knitr Document

Roger D. Peng

## Introduction

This is some text (i.e. a “text chunk”). Here is a code chunk.

```
## [1] 0.1089
```

# Hiding Results

```
# My First knitr Document
Roger D. Peng

## Introduction

This is some text (i.e. a "text chunk"). Here is a code chunk but it doesn't print
anything!
```{r simulation,echo=FALSE,results="hide"}
set.seed(1)
x <- rnorm(100)
mean(x)
```
```

# Output

# My First knitr Document

Roger D. Peng

## Introduction

This is some text (i.e. a “text chunk”). Here is a code chunk but it doesn't print anything!

# Inline Text Computations

```
# My First knitr Document

## Introduction

```{r computetime,echo=FALSE}
time <- format(Sys.time(), "%a %b %d %X %Y")
rand <- rnorm(1)
```

The current time is `r time`. My favorite random number is `r rand`.
```

# Inline Text Computations

## My First knitr Document

### Introduction

The current time is Wed Sep 04 16:42:09 2013. My favorite random number is 1.1829.

# Incorporating Graphics

````
## Introduction

Let's first simulate some data.
```{r simulatedata,echo=TRUE}
x <- rnorm(100); y <- x + rnorm(100, sd = 0.5)
```

Here is a scatterplot of the data.
```{r scatterplot,fig.height=4}
par(mar = c(5, 4, 1, 1), las = 1)
plot(x, y, main = "My Simulated Data")
```
````

# What knitr Produces in HTML

```
<body>
<h2>Introduction</h2>

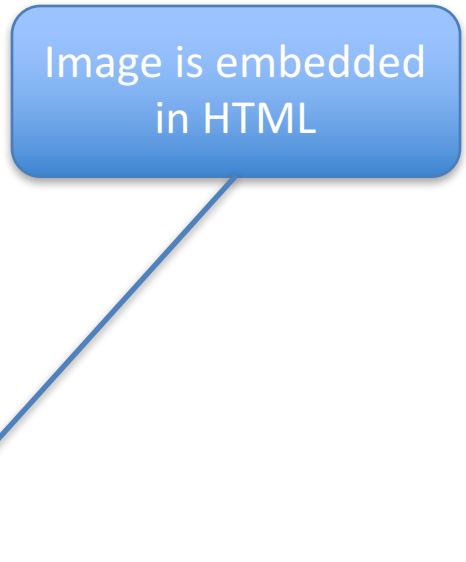
<p>Let&#39;s first simulate some data.</p>

<pre><code class="r">x &lt;- rnorm(100)
y &lt;- x + rnorm(100, sd = 0.5)
</code></pre>

<p>Here is a scatterplot of the data.</p>

<pre><code class="r">par(mar = c(5, 4, 1, 1), las = 1)
plot(x, y, main = &quot;My Simulated Data&quot;)
</code></pre>

<p><img src="
lDQ1BJQ0MgUHJvZmlsZQAAOBGFVd9v21QUPolvUqQWPyBYR4eKxa9VU1u5GxqtxgZJk6XtShal6dgqJOQ6N4m
pGwfb6baqT3uBNwb8AUDZAw9IPCENBmJ72fbAtElThyqqSUh76MQPISbtBVXhu3ZiJ1PEXPX6yznfOec7517b
RD1fabWaGVWIlquunc8klZOnFpSeTYrSs9RLA9Sr6U4tkcvNEi7BFffO6+EdigjL7ZHu/k72I796i9zRiSJPw
G4VHX0Z+AxRzNRrtksUvwf7+Gm3BtzzHPDTNgQCqwKXfZwSeNHHJz1OIT8JjtAq6xWtCLwGPLzYZi
```



# Incorporating Graphics

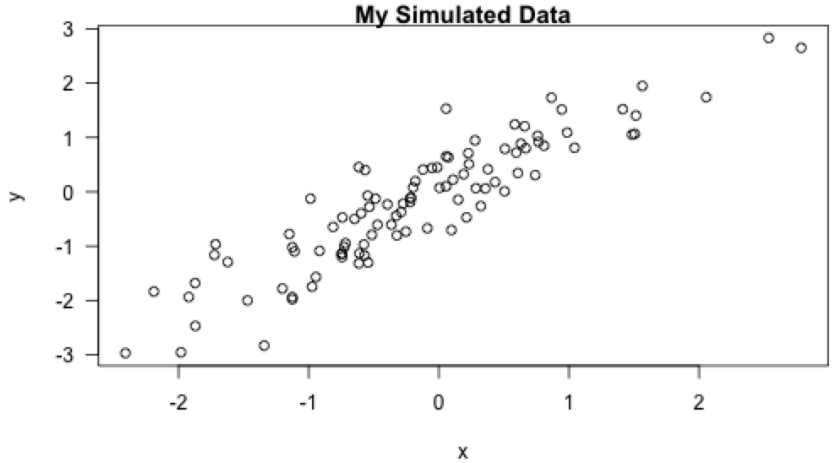
## Introduction

Let's first simulate some data.

```
x <- rnorm(100)
y <- x + rnorm(100, sd = 0.5)
```

Here is a scatterplot of the data.

```
par(mar = c(5, 4, 1, 1), las = 1)
plot(x, y, main = "My Simulated Data")
```



# Making Tables with xtable

````
## Introduction

```{r fitmodel}
library(datasets)
data(airquality)
fit <- lm(Ozone ~ Wind + Temp + Solar.R, data = airquality)
```

Here is a table of regression coefficients.

```{r showtable,results="asis"}
library(xtable)
xt <- xtable(summary(fit))
print(xt, type = "html")
```
````

# Making Tables with xtable

## Introduction

```
library(datasets)
data(airquality)
fit <- lm(Ozone ~ Wind + Temp + Solar.R, data = airquality)
```

Here is a table of regression coefficients.

```
library(xtable)
xt <- xtable(summary(fit))
print(xt, type = "html")
```

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | -64.3421 | 23.0547 | -2.79 | 0.0062 |
| Wind | -3.3336 | 0.6544 | -5.09 | 0.0000 |
| Temp | 1.6521 | 0.2535 | 6.52 | 0.0000 |
| Solar.R | 0.0598 | 0.0232 | 2.58 | 0.0112 |

# Setting Global Options

- Sometimes we want to set options for **every** code chunk that are different from the defaults
- For example, we may want to suppress all code echoing and results output
- We have to write some code to set these global options

# Setting Global Options

```
## Introduction

```{r setoptions,echo=FALSE}
opts_chunk$set(echo = FALSE, results = "hide")
```

First simulate data
```{r simulatedata,echo=TRUE}
x <- rnorm(100); y <- x + rnorm(100, sd = 0.5)
```

Here is a scatterplot of the data.

```{r scatterplot,fig.height=4}
par(mar = c(5, 4, 1, 1), las = 1)
plot(x, y, main = "My Simulated Data")
```
```

Set default to NOT echo code

Override default

Don't echo code here

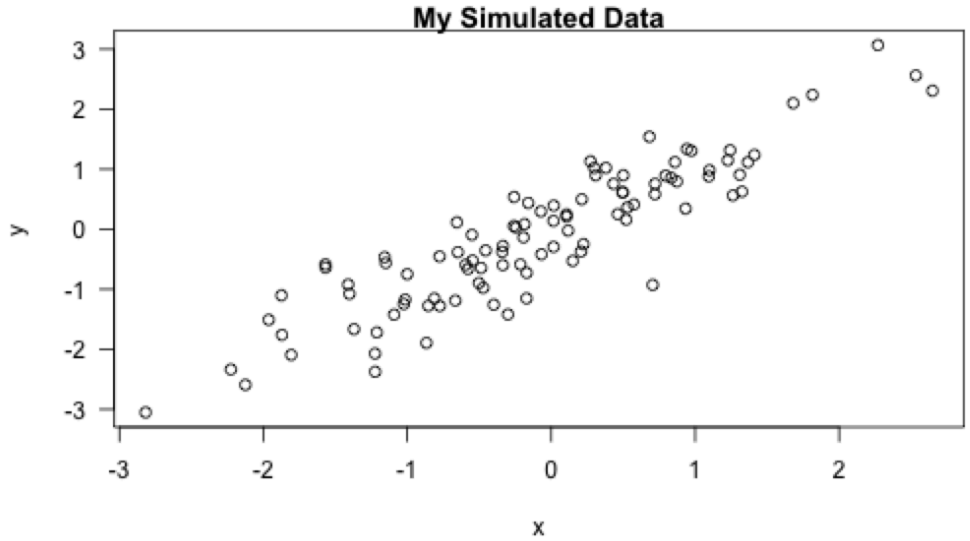
# Setting Global Options

## Introduction

First simulate data

```
x <- rnorm(100)
y <- x + rnorm(100, sd = 0.5)
```

Here is a scatterplot of the data.



# Some Common Options

- Output
  - results: “asis”, “hide”
  - echo: TRUE, FALSE
- Figures
  - fig.height: numeric
  - fig.width: numeric

# Caching Computations

- What if one chunk takes a long time to run?
- All chunks have to be re-computed every time you re-knit the file
- The `cache=TRUE` option can be set on a chunk-by-chunk basis to store results of computation
- After the first run, results are loaded from cache

# Caching Caveats

- If the data or code (or anything external) changes, you need to re-run the cached code chunks
- Dependencies are not checked explicitly
- Chunks with significant *side effects* may not be cacheable

# Summary

- Literate statistical programming can be a useful way to put text, code, data, output all in one document
- knitr is a powerful tool for integrating code and text in a simple document format