

Gov 50: 2. R, RStudio, and Rmarkdown

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Roadmap

1. Working in Plain Text
2. Let's take a tour
3. Using Rmarkdown
4. Getting R bearings
5. Our first visualizations

1/ Working in Plain Text

The two computer revolutions



The frontier of computing

- Touch-based interfaces



Where statistical computing lives

The two computer revolutions



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- Single app at a time



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- Hides the file system



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- Windows and pointers
- Multi-tasking, multiple windows

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Where statistical computing lives

- Windows and pointers
- Multi-tasking, multiple windows
- Works heavily with the file system
- Underneath it's UNIX and the command line

Plain-text tools for data analysis

**The Plain
Person's Guide**

~/>_

**to Plain Text
Social Science**

Kieran Healy

- Often free, open-sourced, and powerful.

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- But... far from the touch-based paradigm of modern computing
- So why use them?

**The process of data
science is intrinsically
messy**

Office vs engineering model of computing

What's real in the project? How are changes managed?

Office vs engineering model of computing

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In the Office model

- Formatted documents are real.

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- Intermediate outputs are produced via code, often inside documents.
- Changes are tracked outside files.
- Final outputs are assembled programmatically and converted to desired output format.

Pros and cons to each approach

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We'll tend toward the Engineering model because it's better suited to keep the mess in check.

2/ Let's take a touR

R versus RStudio

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R
R version 4.2.1 (2022-06-23) -- "Funny-Looking Kid"
Copyright (C) 2022 The R Foundation for Statistical Computing
Platform: aarch64-apple-darwin20 (64-bit)

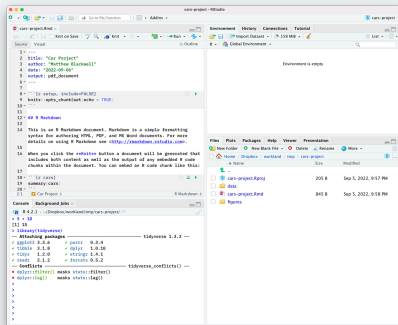
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

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.

>
```



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>
```

```
cars-project.Rmd
1 title: "Car Project"
2 author: "Matthew Eckhoff"
3 date: "2022-09-05"
4 output: pdf_document
5 ---
6
7
8 "" (To create, include file.Rmd)
9 knitr: apply_chunked_code = TRUE
10
11 ## R Notebook
12
13 This is an R Notebook document. R Notebook is a simple formatting
14 system for authoring HTML, PDF, and MS Word documents. For more
15 details on using R Notebook see <http://rmarkdown.rstudio.com>.
16
17 When you click the refresh button a document will be generated that
18 includes both content as well as the output of any embedded R code
19 chunks within the document. You can embed an R code chunk like this:
20
21 <pre>
22 [R code]
23 </pre>
24
25 Summary stats
26
27
28 ## Car Project
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```

cars-project - RStudio

cars-project

cars-project.Rmd

```
1 ---
2 title: "Car Project"
3 author: "Matthew Blackwell"
4 date: "2022-09-06"
5 output: pdf_document
6 ---
7
8 '''[r setup, include=FALSE]
9 knitr::opts_chunk$set(echo = TRUE)
10 '''
11
12 ## R Markdown
13
14 This is an R Markdown document. Markdown is a simple formatting
15 syntax for authoring HTML, PDF, and MS Word documents. For more
16 details on using R Markdown see http://rmarkdown.rstudio.com.
17
18 When you click the Knit button a document will be generated that
19 includes both content as well as the output of any embedded R code
20 chunks within the document. You can embed an R code chunk like this:
21
22 '''[r cars]
23 summary(cars)
24 '''
25 Car Project
```

Environment History Connections Tutorial

Global Environment

Environment is empty

Files Plots Packages Help Viewer Presentation

New Folder New Blank File Delete Rename More

Home > Dropbox > workland > tmp > cars-project

Name	Size	Modified
..		
cars-project.Rproj	205 B	Sep 5, 2022, 9:57 PM
data		
cars-project.Rmd	845 B	Sep 5, 2022, 9:58 PM
figures		

Console Background Jobs

```
R 4.2.1 - ~/Dropbox/workland/tmp/cars-project/
> 5 + 10
[1] 15
> library(tidyverse)
— Attaching packages ————— tidyverse 1.3.2 —
✔ ggplot2 3.3.6 ✔ purrr 0.3.4
✔ tibble 3.1.8 ✔ dplyr 1.0.10
✔ tidyr 1.2.0 ✔ stringr 1.4.1
✔ readr 2.1.2 ✔ forcats 0.5.2
— Conflicts ————— tidyverse_conflicts() —
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag() masks stats::lag()
>
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>
```

cars-project - RStudio

cars-project

Environment History Connections Tutorial

Import Dataset 158 MiB

Global Environment

Environment is empty

Files Plots Packages Help Viewer Presentation

New Folder New Blank File Delete Rename More

Home > Dropbox > workland > tmp > cars-project

Name	Size	Modified
..		
cars-project.Rproj	205 B	Sep 5, 2022, 9:57 PM
data		
cars-project.Rmd	845 B	Sep 5, 2022, 9:58 PM
figures		

```
1 ---
2 title: "Car Project"
3 author: "Matthew Blackwell"
4 date: "2022-09-06"
5 output: pdf_document
6 ---
7
8 '''[r setup, include=FALSE]
9 knitr::opts_chunkset(echo = TRUE)
10 '''
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20 chunks within the document. You can embed an R code chunk like this:
21
22 '''[r cars]
23 summary(cars)
24 '''
25
26 Car Project R Markdown
```

```
R 4.2.1 ~ ~/Dropbox/workland/tmp/cars-project/
> 5 + 10
[1] 15
> library(tidyverse)
Attaching packages: tidyverse 1.3.2
ggplot2 3.3.6 purrr 0.3.4
tibble 3.1.8 dplyr 1.0.10
tidyr 1.2.0 stringr 1.4.1
readr 2.1.2 forcats 0.5.2
Conflicts: tidyverse_conflicts()
* dplyr::filter() masks stats::filter()
* dplyr::lag() masks stats::lag()
>
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```

Write notes,
paper in
Rmarkdown

The screenshot displays the RStudio interface for a project named 'cars-project'. The source editor shows an R Markdown file with the following content:

```
1 ---
2 title: "Car Project"
3 author: "Matthew Blackwell"
4 date: "2022-09-06"
5 output: pdf_document
6 ---
7
8 '''[r setup, include=FALSE]
9 knitr::opts_chunk$set(echo = TRUE)
10 '''
11
12 ## R Markdown
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14 This is an R Markdown document. Markdown is a simple formatting
15 syntax for authoring HTML, PDF, and MS Word documents. For more
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17
18 When you click the Knit button a document will be generated that
19 includes both content as well as the output of any embedded R code
20 chunks within the document. You can embed an R code chunk like this:
21
22 '''[r cars]
23 summary(cars)
24 '''
25
26 Car Project
```

The console window shows the execution of the following R code:

```
R 4.2.1 - ~/Dropbox/workland/tmp/cars-project/
> 5 + 10
[1] 15
> library(tidyverse)
Attaching packages:
  ggplot2 3.3.6    purrr  0.3.4
  tidbale 3.1.8    dplyr  1.0.10
  tidyr  1.2.0     stringr 1.4.1
  readr  2.1.2     forcats 0.5.2
tidyverse 1.3.2
Conflicts:
  dplyr::filter() masks stats::filter()
  dplyr::lag()    masks stats::lag()
>
>
>
>
>
```

An orange box highlights the console area with the text: **Console: run code, send code to here, inspect output**

The image shows the RStudio interface with an R Markdown document open. The document content is as follows:

```
1 ---
2 title: "Car Project"
3 author: "Matthew Blackwell"
4 date: "2022-09-06"
5 output: pdf_document
6 ---
7
8 '''[r setup, include=FALSE]
9 knitr::opts_chunk$set(echo = TRUE)
10 '''
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12 ## R Markdown
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15 syntax for authoring HTML, PDF, and MS Word documents. For more
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19 includes both content as well as the output of any embedded R code
20 chunks within the document. You can embed an R code chunk like this:
21
22 '''[r cars]
23 summary(cars)
24 '''
25
```

The console shows the following output:

```
R 4.2.1 ~ ~/Dropbox/workland/tmp/cars-project/
> 5 + 10
[1] 15
> library(tidyverse)
Attaching packages: tidyverse 1.3.2
ggplot2 3.3.6    purrr 0.3.4
tibble 3.1.8    dplyr 1.0.10
tidyr 1.2.0     stringr 1.4.1
readr 2.1.2     forcats 0.5.2
Conflicts: tidyverse_conflicts()
* dplyr::filter() masks stats::filter()
* dplyr::lag() masks stats::lag()
>
>
>
>
>
```

An orange-bordered window is overlaid on the bottom right, showing a file explorer for the project directory. The window title is "cars-project" and it contains the following table:

Name	Size	Modified
..		
cars-project.Rproj	205 B	Sep 5, 2022, 9:57 PM
data		
cars-project.Rmd	845 B	Sep 5, 2022, 9:58 PM
figures		

Project files, plots, and help

The image shows the RStudio interface with a project named 'cars-project'. The editor window displays an R Markdown file with the following content:

```
1 ---
2 title: "Car Project"
3 author: "Matthew Blackwell"
4 date: "2022-09-06"
5 output: pdf_document
6 ---
7
8 ''[r setup, include=FALSE]
9 knitr::opts_chunkset(echo = TRUE)
10 ''
11
12 ## R Markdown
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18 When you click the Knit button a document will be generated that
19 includes both content as well as the output of any embedded R code
20 chunks within the document. You can embed an R code chunk like this:
21
22 ''[r cars]
23 summary(cars)
24 ''
25
```

The console window shows the following R session:

```
R 4.2.1 ~ ~/Dropbox/workland/tmp/cars-project /
> 5 + 10
[1] 15
> library(tidyverse)
Attaching packages: tidyverse 1.3.2
ggplot2 3.3.6    purrr 0.3.4
tibble 3.1.8     dplyr 1.0.10
tidyr 1.2.0     stringr 1.4.1
readr 2.1.2     forcats 0.5.2
Conflicts: tidyverse_conflicts()
* dplyr::filter() masks stats::filter()
* dplyr::lag() masks stats::lag()
>
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>
```

The file explorer on the right shows the project structure:

Name	Size	Modified
cars-project.Rproj	205 B	Sep 5, 2022, 9:57 PM
data		
cars-project.Rmd	845 B	Sep 5, 2022, 9:58 PM
figures		

An orange box highlights the Environment pane, which contains the text: "Environment is empty". Overlaid on this box is the text: "Interacting with R objects, working with git, running local tutorials".

3/ Using Rmarkdown

The acts of coding

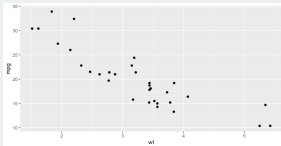
```
library(ggplot2)
ggplot(mtcars, aes(x = wt, y = mpg)) +
  geom_point()
```

Figure: 1. Writing code

The acts of coding

```
library(ggplot2)  
ggplot(mtcars, aes(x = wt, y = mpg)) +  
  geom_point()
```

Figure: 1. Writing code



The acts of coding

```
library(ggplot2)
ggplot(mtcars, aes(x = wt, y = mpg)) +
  geom_point()
```

Figure: 1. Writing code

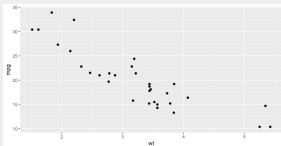


Figure: 2. Looking at output

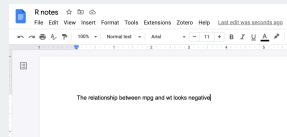


Figure: 3. Taking notes

The acts of coding

```
library(ggplot2)
ggplot(mtcars, aes(x = wt, y = mpg)) +
  geom_point()
```

Figure: 1. Writing code

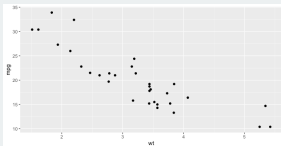


Figure: 2. Looking at output

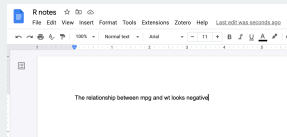
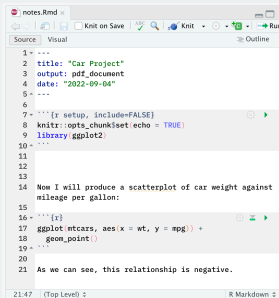


Figure: 3. Taking notes

How to do all of these efficiently?

Rmarkdown files to the rescue

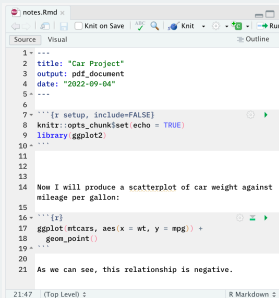


```
1 - ---
2   title: "Car Project"
3   output: pdf_document
4   date: "2022-09-04"
5 - ---
6
7 - {r setup, include=FALSE}
8   knitr::opts_chunk$set(echo = TRUE)
9   library(ggplot2)
10 - {r}
11
12
13
14 Now I will produce a scatterplot of car weight against
15 mileage per gallon:
16
17 {r}
18   ggplot(mtcars, aes(x = wt, y = mpg)) +
19     geom_point()
20 - {r}
21 As we can see, this relationship is negative.
```

Figure: Rmarkdown file

Keep code and notes
together in plain text

Rmarkdown files to the rescue



```
1 ---
2 title: "Car Project"
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4 date: "2022-09-04"
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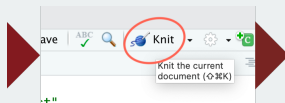
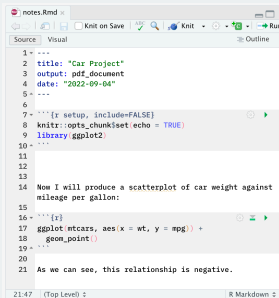


Figure: Knit in R

Rmarkdown files to the rescue



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Figure: Rmarkdown file
Keep code and notes
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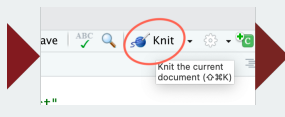


Figure: Knit in R

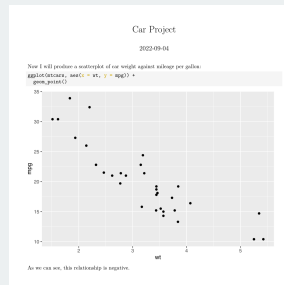



Figure: PDF output
Produce nice-looking
outputs in different
formats

Markdown: formatting in plain text

Non-code text in Rmd files is plain text with formatting instructions

syntax	becomes
<pre>Plain text End a line with two spaces to start a new paragraph. *italics* and <i>_italics_</i> **bold** and __bold__ superscript^2^ ~~strikethrough~~ [link](www.rstudio.com) # Header 1 ## Header 2 ### Header 3 #### Header 4 ##### Header 5 ##### Header 6 endash: -- emdash: --- ellipsis: ... inline equation: \$A = \pi*r^{2}\$ image: horizontal rule (or slide break): *** > block quote * unordered list * item 2 + sub-item 1 + sub-item 2 1. ordered list 2. item 2 + sub-item 1 + sub-item 2</pre>	<pre>Plain text End a line with two spaces to start a new paragraph. <i>italics</i> and <i>italics</i> bold and bold superscript² strikethrough link Header 1 Header 2 Header 3 Header 4 Header 5 Header 6 endash: – emdash: — ellipsis: … inline equation: $A = \pi * r^2$ image:  horizontal rule (or slide break): > block quote • unordered list • item 2 ◦ sub-item 1 ◦ sub-item 2 1. ordered list 2. item 2 ◦ sub-item 1 ◦ sub-item 2</pre>

```
---
title: "Car Project"
author: "Matthew Blackwell"
date: "2022-09-06"
output: pdf_document
---
```

Header contains metadata and sets options about the whole document

```
```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```
```

Code Chunk

R Markdown

Plain text with markdown formatting

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:

```
```{r cars}
summary(cars)
```
```

Can "play" chunks interactively

Including Plots

Chunks can have names and options

You can also embed plots, for example:

```
```{r pressure, echo=FALSE}
plot(pressure)
```
```

Code chunks replaced with output when Knitted

Remember what's real

The screenshot shows the RStudio Options dialog box with the 'Basic' tab selected. The 'Workspace' section is highlighted with an orange border. The 'Workspace' section contains the following options:

- Restore .RData into workspace at startup
- Save workspace to .RData on exit:

The 'R Sessions' section contains the following options:

- Restore most recently opened project at startup
- Restore previously open source documents at startup

The 'History' section contains the following options:

- Always save history (even when not saving .RData)
- Remove duplicate entries in history

The 'Other' section contains the following options:

- Wrap around when navigating to previous/next tab
- Automatically notify me of updates to RStudio
- Send automated crash reports to RStudio

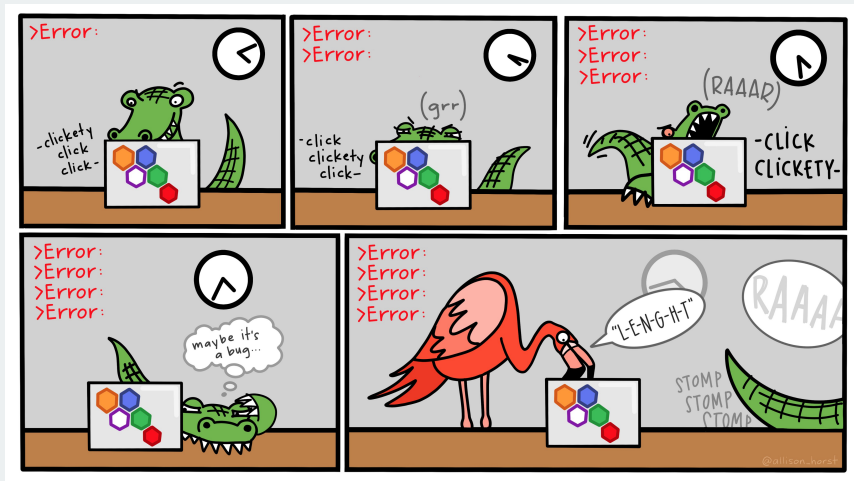
The left sidebar of the Options dialog box lists the following categories:

- General
- Code
- Console
- Appearance
- Pane Layout
- Packages
- R Markdown
- Python
- Sweave
- Spelling
- Git/SVN
- Publishing
- Terminal
- Accessibility

4/ Getting R bearings

**Try to type your code by
hand**

Typing speeds up the try-fail cycle



Physically typing the code is best way to familiarize yourself with R and the try-fail-try-fail-try-succeed cycle

What R looks like

Code that you can type and run:

```
## Any R code that begins with the # character is a comment  
## Comments are ignored by R  
  
my_numbers <- c(4, 8, 15, 16, 23, 42) # Anything after # is also a comment
```

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Output from code prefixed by ## by convention:

```
my_numbers
```

```
## [1] 4 8 15 16 23 42
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Output from code prefixed by ## by convention:

```
my_numbers
```

```
## [1] 4 8 15 16 23 42
```

Output also has a counter in brackets when over one line:

```
letters
```

```
## [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l"
## [13] "m" "n" "o" "p" "q" "r" "s" "t" "u" "v" "w" "x"
## [25] "y" "z"
```

Everything in R has a name

```
my_numbers # just created this
```

```
## [1] 4 8 15 16 23 42
```

```
letters # this is built into R
```

```
## [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l"
```

```
## [13] "m" "n" "o" "p" "q" "r" "s" "t" "u" "v" "w" "x"
```

```
## [25] "y" "z"
```

```
pi # also built in
```

```
## [1] 3.14
```

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```
## [1] 4 8 15 16 23 42
```

```
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```
## [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l"  
## [13] "m" "n" "o" "p" "q" "r" "s" "t" "u" "v" "w" "x"  
## [25] "y" "z"
```

```
pi # also built in
```

```
## [1] 3.14
```

Some names are forbidden (NA, TRUE, FALSE, etc) or strongly not recommended (c, mean, table)

We do things in R with functions

Functions take in objects, perform actions, and return outputs:

```
mean(x = my_numbers)
```

```
## [1] 18
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We do things in R with functions

Functions take in objects, perform actions, and return outputs:

```
mean(x = my_numbers)
```

```
## [1] 18
```

- `x` is the argument name,
- `my_numbers` is what we're passing to the that argument

If you omit the argument name, R will assume the default order:

```
mean(my_numbers)
```

```
## [1] 18
```


Getting help with R

How do we know the default argument order? Look to help files:

```
help(mean)  
?mean # shorter
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- Get help **early** before becoming too frustrated!
 - Easy to overlook small issues like missing commas, etc.

Functions live in packages

Packages are bundles of functions written by other users that we can use.

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Install packages using `install.packages()` to have them on your machine:

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Load them into your R session with `library()`:

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install.packages("ggplot2")
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Load them into your R session with `library()`:

```
library(ggplot2)
```

Now we can use any function provided by `ggplot2`.

Functions live in packages

We can also use the `mypackage::` prefix to access package functions without loading:

```
knitr::kable(head(mtcars))
```

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|----------------|------|-----|------|-----|------|------|------|----|----|------|------|
| Mazda RX4 | 21.0 | 6 | 160 | 110 | 3.90 | 2.62 | 16.5 | 0 | 1 | 4 | 4 |
| Mazda RX4 | 21.0 | 6 | 160 | 110 | 3.90 | 2.88 | 17.0 | 0 | 1 | 4 | 4 |
| Wag | | | | | | | | | | | |
| Datsun 710 | 22.8 | 4 | 108 | 93 | 3.85 | 2.32 | 18.6 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258 | 110 | 3.08 | 3.21 | 19.4 | 1 | 0 | 3 | 1 |
| Hornet | 18.7 | 8 | 360 | 175 | 3.15 | 3.44 | 17.0 | 0 | 0 | 3 | 2 |
| Sportabout | | | | | | | | | | | |
| Valiant | 18.1 | 6 | 225 | 105 | 2.76 | 3.46 | 20.2 | 1 | 0 | 3 | 1 |

5/ Our first visualizations

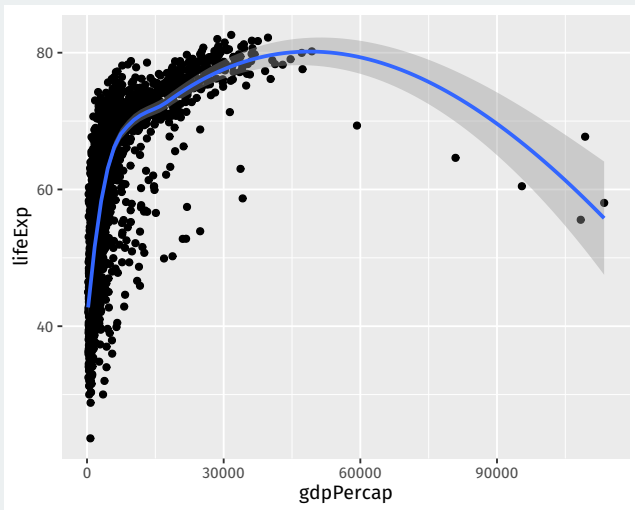
Gapminder data

```
library(gapminder)
gapminder
```

```
## # A tibble: 1,704 x 6
##   country      continent  year lifeExp      pop gdpPe~1
##   <fct>        <fct>    <int> <dbl>    <int> <dbl>
## 1 Afghanistan Asia      1952  28.8  8425333  779.
## 2 Afghanistan Asia      1957  30.3  9240934  821.
## 3 Afghanistan Asia      1962  32.0 10267083  853.
## 4 Afghanistan Asia      1967  34.0 11537966  836.
## 5 Afghanistan Asia      1972  36.1 13079460  740.
## 6 Afghanistan Asia      1977  38.4 14880372  786.
## 7 Afghanistan Asia      1982  39.9 12881816  978.
## 8 Afghanistan Asia      1987  40.8 13867957  852.
## 9 Afghanistan Asia      1992  41.7 16317921  649.
## 10 Afghanistan Asia      1997  41.8 22227415  635.
## # ... with 1,694 more rows, and abbreviated variable
## #   name 1: gdpPercap
```

Plotting life expectancy over time

```
ggplot(gapminder, mapping = aes(x = gdpPercap, y = lifeExp)) +  
  geom_point() + geom_smooth(method = "loess")
```



A histogram of GDP per capita

```
ggplot(gapminder, mapping = aes(x = gdpPercap)) +  
  geom_histogram()
```

