

Gov 50: 2. R, RStudio, and Rmarkdown

Matthew Blackwell

Harvard University

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
- Single app at a time
- Little multitasking between apps
- Hides the file system



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.
- Large, friendly communities around them.
- Tons of resources
- 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?

In the Office model

- Formatted documents are real.
- Intermediate outputs copy/pasted into documents.
- Changes are tracked inside files.
- Final output is the file you are working on (e.g., Word file or maybe converted to a PDF).

In the Engineering model

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

Pros and cons to each approach

- Office model:
 - Everyone knows Word, Excel, Google Docs.
 - “Track changes” is powerful and easy.
 - Wait, how did I make this figure?
 - Which version of my code made this table?
 - `Blackwell_report_final_submitted_edits_FINAL_v2.docx`
- Engineering model:
 - Plain text is universally portable.
 - Push button, recreate analysis.
 - Why won't R just do what I want!
 - Version control is a pain.
 - Object of type 'closure' is not subsettable

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

```
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.

>
```

```
cars-project.Rmd
1 title: "Car Project"
2 author: "Matthew Eckhoff"
3 date: "2022-09-09"
4 output: pdf_document
5 ---
6
7
8 --- [R output: include(Rplots.pdf)]
9 knitr: apply_chunked_code = TRUE
10
11 ## R Notebook
12
13 This is an R Notebook document. R Markdown is a simple formatting
14 system for authoring HTML, PDF, and MS Word documents. For more
15 details on using R Markdown 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 ```{r}
22 # Example code
23 ```
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25 ## R Notebook
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cars-project - RStudio

cars-project.Rmd x

Environment History Connections Tutorial

Import Dataset 158 MiB

Global Environment

Environment is empty

```
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 ```
```

2:1 Car Project R Markdown

Console Background Jobs x

```
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()
>
>
>
>
>
```

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		

cars-project - RStudio

cars-project.Rmd x

Source Visual Outline

```
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
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22 ***[r cars]
23 summary(cars)
24 ***
```

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		

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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>
```

Write notes,
paper in
Rmarkdown

The screenshot shows the RStudio interface with a file named 'cars-project.Rmd' open. The editor contains a markdown document with a title 'Car Project', author 'Matthew Blackwell', date '2022-09-06', and output 'pdf_document'. It includes an R code chunk for setting up the environment and another chunk for loading the 'cars' dataset. The console shows the execution of the R code, including loading the 'tidyverse' package and displaying its dependencies and conflicts.

```
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>.
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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 ```
```

Console 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()
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```

Console: run code,
send code to here,
inspect output

The image shows the RStudio interface for 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_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 ```
```

The console shows the execution of the code chunk:

```
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 window 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		

The text "Project files, plots, and help" is overlaid in orange on the bottom right of the file explorer window.

The image shows the RStudio interface with a project named "cars-project". The main editor displays an R Markdown document 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
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 ## [r cars]
19 summary(cars)
20 ---
21 Car Project
```

The terminal window shows the execution of the R code:

```
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()
>
>
>
>
>
```

The Environment pane on the right shows "Environment is empty". The Files pane on the bottom 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		

Overlaid on the Environment pane 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

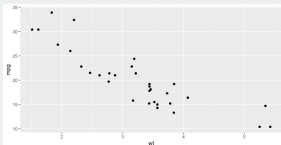


Figure: 2. Looking at output

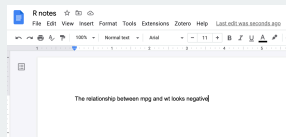
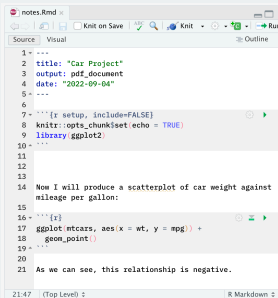


Figure: 3. Taking notes

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
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
21 As we can see, this relationship is negative.
```

Figure: Rmarkdown file

Keep code and notes together in plain text

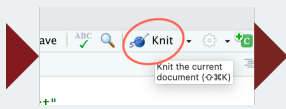


Figure: Knit in R

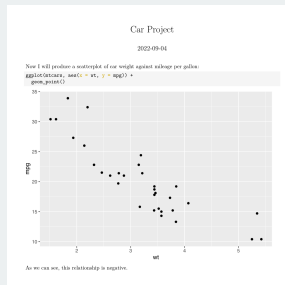


Figure: PDF output

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

```
Plain text
End a line with two spaces to start a new paragraph.
*italics* and _italics_
**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
```

becomes

```
Plain text
End a line with two spaces to start a new paragraph.
italics and italics
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

```
---
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 image shows the RStudio Options dialog box, specifically the Basic tab. The left sidebar lists various categories: General, Code, Console, Appearance, Pane Layout, Packages, R Markdown, Python, Sweave, Spelling, Git/SVN, Publishing, Terminal, and Accessibility. The main area is titled 'Basic' and contains several sections: 'R Sessions', 'Workspace', and 'History'. The 'Workspace' section is highlighted with an orange border. It includes a checkbox for 'Restore .RData into workspace at startup' (unchecked) and a dropdown menu for 'Save workspace to .RData on exit:' set to 'Never'. The 'History' section has a checked checkbox for 'Always save history (even when not saving .RData)' and an unchecked checkbox for 'Remove duplicate entries in history'. The 'Other' section has checked checkboxes for 'Wrap around when navigating to previous/next tab' and 'Automatically notify me of updates to RStudio', and an unchecked checkbox for 'Send automated crash reports to RStudio'.

Options

Basic Graphics Advanced

R Sessions

Default working directory (when not in a project):
~ Browse...

Restore most recently opened project at startup

Restore previously open source documents at startup

Workspace

Restore .RData into workspace at startup

Save workspace to .RData on exit: Never ▾

History

Always save history (even when not saving .RData)

Remove duplicate entries in history

Other

Wrap around when navigating to previous/next tab

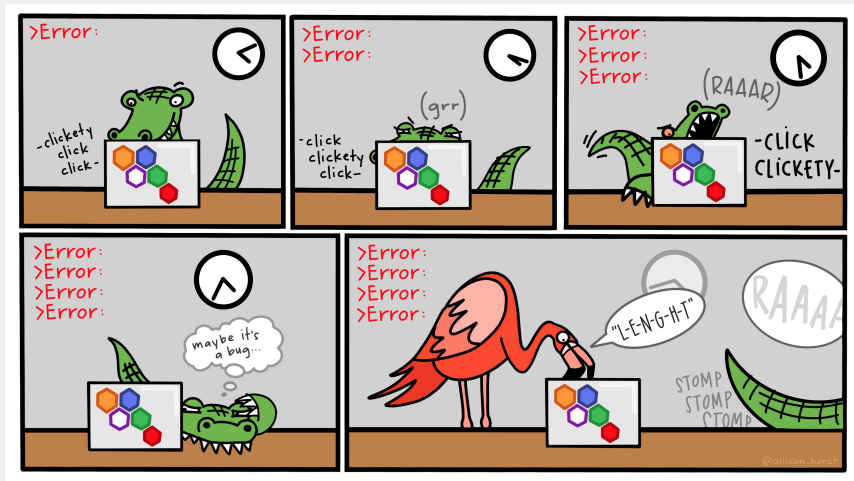
Automatically notify me of updates to RStudio

Send automated crash reports to RStudio

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
```

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

```
## [15] "o" "p" "q" "r" "s" "t" "u" "v" "w" "x" "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
```

- `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
```

- Sometimes inscrutable, so look elsewhere:
 - Google, StackOverflow, Twitter, RStudio Community.
 - Ask on Ed or on class Slack.
 - Come to section, office hours, study hall.
- 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.

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

```
install.packages("ggplot2")
```

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

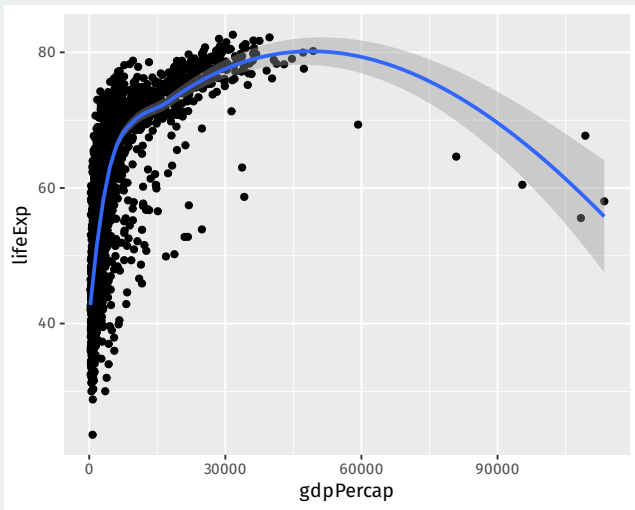
Gapminder data

```
library(gapminder)
gapminder
```

```
## # A tibble: 1,704 x 6
##   country      continent  year lifeExp      pop gdpPercap
##   <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.
## # i 1,694 more rows
```


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()
```

