

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



Where statistical computing lives

The two computer revolutions



The frontier of computing

- Touch-based interfaces
- Single app at a time



Where statistical computing lives

The two computer revolutions



The frontier of computing

- Touch-based interfaces
- Single app at a time
- Little multitasking between apps



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



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Where statistical computing lives

- Windows and pointers

The two computer revolutions



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Where statistical computing lives

- Windows and pointers
- Multi-tasking, multiple windows

The two computer revolutions



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Where statistical computing lives

- Windows and pointers
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The two computer revolutions



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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

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

In the Office model

- Formatted documents are real.

In the Engineering model

Office vs engineering model of computing

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In the Engineering model

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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

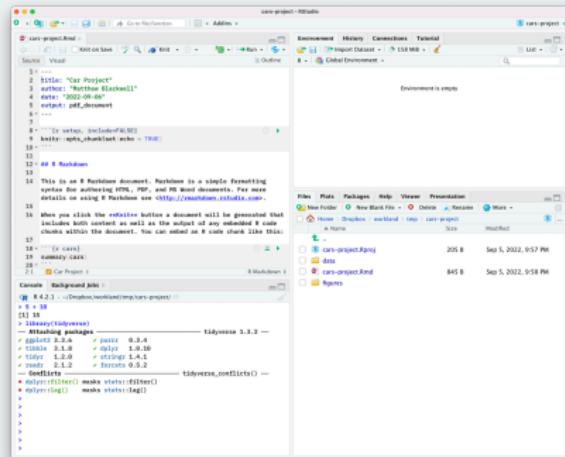
```
R version 4.2.1 (2022-06-23) -- "Funny-Looking Kid"
Copyright (C) 2022 The R Foundation for Statistical Computing
Platform: aarch64-apple-darwin20 (64-bit)

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.
```



R versus RStudio

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The screenshot shows the RStudio interface. The code editor at the top contains R code related to 'Markdown'. The file browser on the left shows a directory structure with files like 'car-project.Rmd', 'car-project.html', and 'car-project.pdf'. The global environment at the bottom lists packages such as tidyverse, purrr, dplyr, stringr, forcats, and dtestfilter.



cars-project - RStudio

Addins

cars-project.Rmd

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: ## R Markdown
12:
13:
14: 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>.
15:
16: 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:
17:
18: ````{r cars}
19: summary(cars)
20: ````
```

R Markdown

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()
>
>
>
>
>
>
```

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		

cars-project - RStudio

cars-project - Addins

cars-project - Environment

cars-project - History

cars-project - Connections

cars-project - Tutorial

Import Dataset - 158 MiB

Global Environment - Environment is empty

Source Visual

Outline

Write notes,
paper in
Rmarkdown

```
1 ---  
2 title: "Car Project"  
3 author: "Matthew Blackwell"  
4 date: "2022-09-06"  
5 output: pdf_document  
6 ---  
7  
8 ---[x setup, include=FALSE]  
9 knitr::opts_chunk$set(echo = TRUE)  
10 ---  
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R Markdown

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✓ readr 2.1.2 ✓ forcats 0.5.2  
-- Conflicts -- tidyverse_conflicts() --  
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>  
>  
>  
>  
>
```

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cars-project - RStudio

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

cars-project - RStudio

Addins

cars-project.Rmd

Knit | Run | Outline

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Project files, plots, and help

cars-project - RStudio

cars-project

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Environment History Connections Tutorial

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Interacting with R objects, working with git, running local tutorials

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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

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library(ggplot2)  
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Figure: 1. Writing code

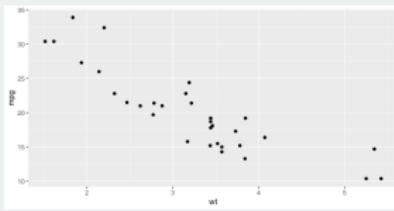


Figure: 2. Looking at output

The acts of coding

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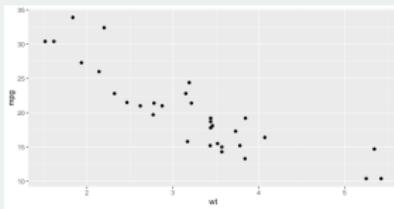


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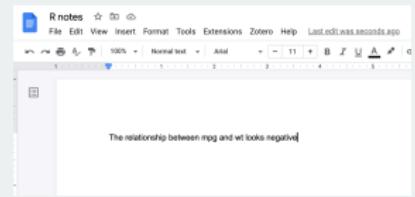


Figure: 3. Taking notes

The acts of coding

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Figure: 1. Writing code

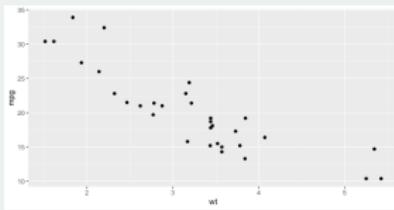


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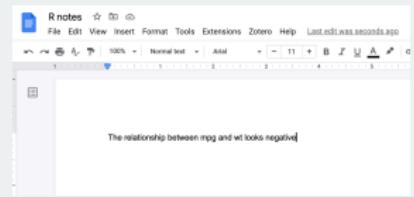
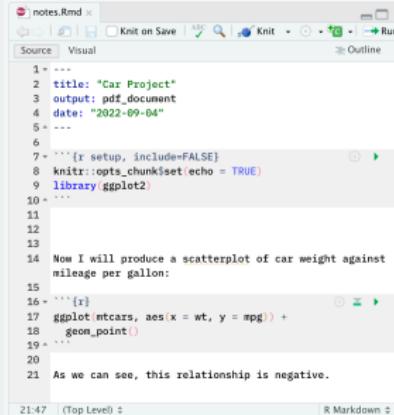


Figure: 3. Taking notes

How to do all of these efficiently?

Rmarkdown files to the rescue



The screenshot shows the RStudio interface with an RMarkdown file open. The title bar says "notes.Rmd". The toolbar includes "Knit on Save", "Knit", and "Run". The code editor contains the following RMarkdown code:

```
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 ````{r}  
17 ggplot(mtcars, aes(x = wt, y = mpg)) +  
18   geom_point()  
19 ````  
20  
21 As we can see, this relationship is negative.
```

At the bottom, there are buttons for "Top Level" and "R Markdown". The status bar shows "21:47".

Figure: Rmarkdown file

Keep code and notes
together in plain text

Rmarkdown files to the rescue

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

The status bar at the bottom left shows the time as 21:47 and the top right shows 'R Markdown'.

Figure: Rmarkdown file

Keep code and notes
together in plain text



Figure: Knit in R

Rmarkdown files to the rescue

```
notes.Rmd x
Source Visual
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

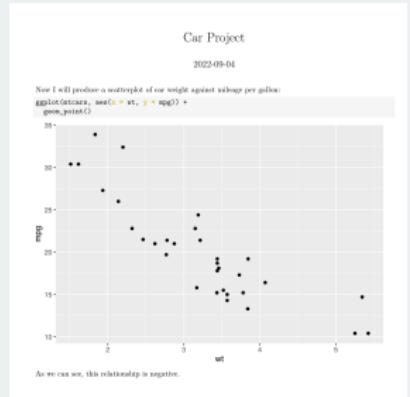


Figure: PDF output

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	becomes
<pre>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</pre>	<p>Plain text End a line with two spaces to start a new paragraph. <i>italics</i> and <u>italics</u> bold and <u>bold</u> superscript² strikethrough link</p> <h1>Header 1</h1> <h2>Header 2</h2> <h3>Header 3</h3> <h4>Header 4</h4> <h5>Header 5</h5> <h6>Header 6</h6> <p>endash: – emdash: — ellipsis: ... inline equation: $A = \pi * r^2$ image: </p> <hr/> <p>horizontal rule (or slide break):</p> <hr/> <p>> block quote</p> <ul style="list-style-type: none">* unordered list<ul style="list-style-type: none">* item 2<ul style="list-style-type: none">+ sub-item 1+ sub-item 21. ordered list<ul style="list-style-type: none">2. item 2<ul style="list-style-type: none">+ 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
```

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>>.

Plain text with markdown formatting

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

Options

General Basic Graphics Advanced

R Sessions

Default working directory (when not in a project):

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:

History

Always save history (even when not saving .RData)

Remove duplicate entries in history

Other

Wrap around when navigating to previous/next tab

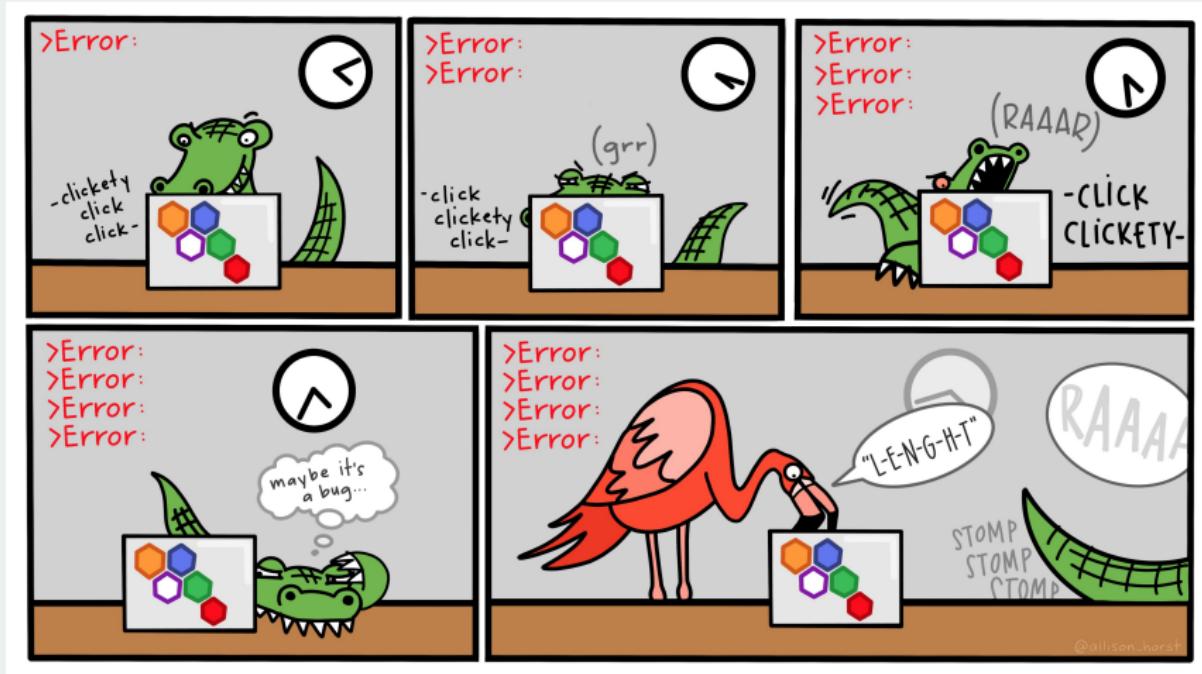
Automatically notify me of updates to RStudio

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
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Output from code prefixed by ## by convention:

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```

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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"
```

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

```
pi # also built in
```

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

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## [25] "y" "z"  
  
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## [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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- `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)  
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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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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 Wag | 21.0 | 6 | 160 | 110 | 3.90 | 2.88 | 17.0 | 0 | 1 | 4 | 4 |
| 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 Sportabout | 18.7 | 8 | 360 | 175 | 3.15 | 3.44 | 17.0 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225 | 105 | 2.76 | 3.46 | 20.2 | 1 | 0 | 3 | 1 |

5/ Our first visualizations

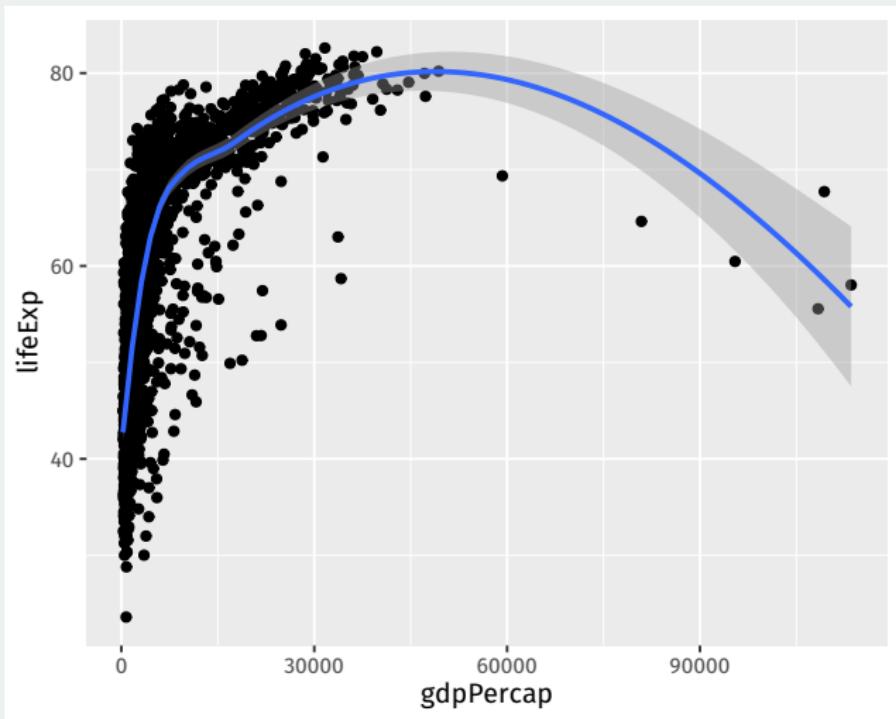
Gapminder data

```
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()
```

