Introduction to Data Analysis and Reporting with R

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Course Information

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- We'll cover tools that should be helpful in nearly any analysis

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  - Graphing, data manipulation, etc

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- We'll cover tools that should be helpful in nearly any analysis
  - Graphing, data manipulation, etc
- We won't cover specialized, specific tools. But you should get a good enough understanding of how R works to be able to teach yourself these

Outline

1. What is R?

Outline

1. What is R?
2. Graphics

Outline

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2. Graphics
3. Basic R

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2. Graphics
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4. Data manipulation

Outline

1. What is R?
2. Graphics
3. Basic R
4. Data manipulation
5. Reporting (time permitting)

What is R?

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- "R is a language and environment for statistical computing and graphics"
- Derived from S, designed at Bell Laboratories
  - S first appeared in 1976!

What is R?

- This is a course about R... *mais qu'est-ce que c'est*?
- "R is a language and environment for statistical computing and graphics"
- Derived from S, designed at Bell Laboratories
  - S first appeared in 1976!
- *R is a language* ... so be prepared for it to hurt a bit to learn!

Advantages of R

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- Free

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- Open-source

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Running code

- How to use this R thing?

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- If you have R and Rstudio installed, open Rstudio.

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- You should see three panes.

Running code

- How to use this R thing?
- If you have R and Rstudio installed, open Rstudio.
- You should see three panes.
- We'll focus for now on the console, which is on the left and should look something like this:

The console

```
R version 3.4.0 (2017-06-15) -- "You Stupid Darkness"
Copyright (C) 2017 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

[ ... ]

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 is a big giant calculator

- R can do math
- Really, really fancy math
- Try typing `3 + 3` in the console
- After pressing enter, R will return `6`
- R understands the order of operations
  - `3 + 3 * 9` is different from `(3 + 3) * 9`

A quiz

- Time for a quiz!

A quiz

- Time for a quiz!
- What's 7 times 149?

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- What's the square root of the previous answer?

A quiz

- Time for a quiz!
- What's 7 times 149?
- What's the square root of the previous answer?
- Tip: You can hit the up arrow to get whatever you entered last

Answers

```
7 * 149
```

```
[1] 1043
```

```
(7 * 149) ^ (1 / 2)
```

```
[1] 32.29551
```

Packages

- At this point, please install a few packages. You'll need an internet connection.
- `install.packages(c("tidyverse", "gapminder"))`
  - If you have already installed some packages, make sure they're up-to-date:
    - `update.packages()`
- Tip: just type `ins` then hit TAB for tab-completion
- Don't worry about what is going on here, I'll explain it later.
- Depending on your exact setup, R may ask you a few questions about using a personal library. Do so.
- If you get an error, make sure you can access the internet (`https://cloud.r-project.org` in particular)

R scripts

- While those packages are installing, let's go ahead and open up an R script.
- Allows you to save code so it doesn't disappear into the ether
- If using Rstudio, File, new file, R script (or Ctrl+shift+n)
- Tip: can send a line from R script to console for evaluation using ctrl+enter
- Strongly recommend that you type into a script and use a keyboard shortcut to evaluate code
  - Easier to edit & rerun
  - Allows you to save code
  - You may make comments

```
## This adds 3 + 3
3 + 3
3 * 2 # same
```

Graphics in R

- We need some data to work with

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- We're going to use some data that comes with the `gapminder` package you just installed
- To access the data, you need to load it into memory:

```
library(gapminder)
```

Exploring our data

- `gapminder` is a data.frame

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```
View(gapminder)
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```
View(gapminder)
```

```
head(gapminder)
```

```
      country continent year lifeExp      pop gdpPercap
1 Afghanistan      Asia 1952  28.801  8425333  779.4453
2 Afghanistan      Asia 1957  30.332  9240934  820.8530
3 Afghanistan      Asia 1962  31.997 10267083  853.1007
4 Afghanistan      Asia 1967  34.020 11537966  836.1971
```

Descriptive statistics

- R has lots of built-in functions for getting a sense of the data.
- Try running `summary(gapminder)`
- What's the average life expectancy?

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```
summary(gapminder)
```

```
       country        continent        year         lifeExp
Afghanistan:  12   Africa  :624   Min.   :1952   Min.   :23.60
Albania    :  12   Americas:300   1st Qu.:1966   1st Qu.:48.20
Algeria    :  12   Asia    :396   Median :1980   Median :60.71
Angola     :  12   Europe  :360   Mean   :1980   Mean   :59.47
Argentina  :  12   Oceania : 24   3rd Qu.:1993   3rd Qu.:70.85
Australia  :  12                  Max.   :2007   Max.   :82.60
(Other)    :1632
```

Graphics in R

- Let's start making graphs
- This is the fun part!
- We're going to rely on the 'ggplot2' package, which we installed earlier (as a part of the tidyverse package)
- "The Grammar of Graphics"
- load it up with

```
library(ggplot2)
```

Our question

What's the relationship between wealth (gdp) and average life expectancy?

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- Scatterplot is a good way to get started looking at data!

- Use the `ggplot()` function to start a plot.
- The first *argument* is to tell it the *data*
- Tip: use `?ggplot` to look at the help page, where you can see the names of the arguments

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```
ggplot(data = gapminder) # Please use gapminder data
```

geom_point

- `ggplot()` by itself is pretty useless, it just starts a plot
- We then have to tell `ggplot` what to draw!
- Tip: `?geom_point`

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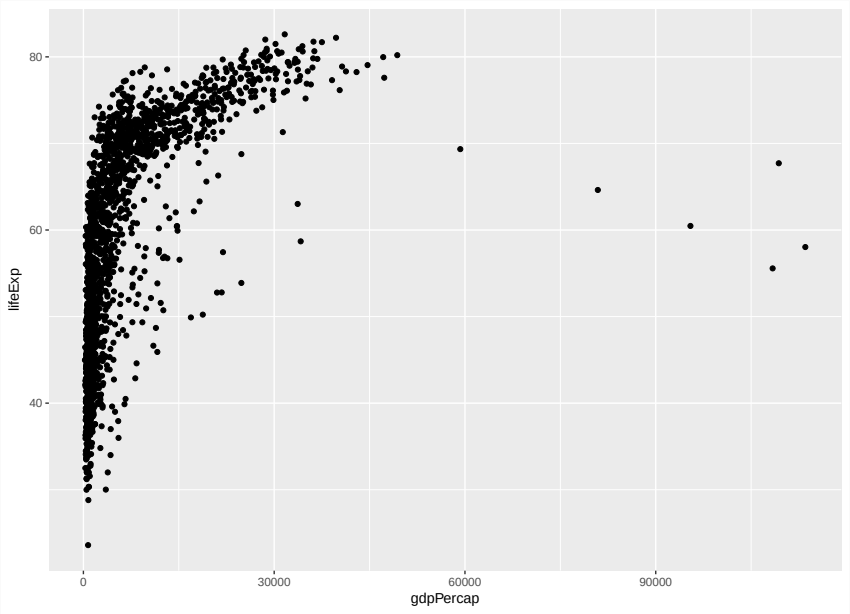
```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = gdpPercap, # Put gdp on x axis
                           y = lifeExp))  # Put lifeExp on y
```


80
60
40
lifeExp
0
30000
60000
90000
gdpPercap

Fix that x axis!

- Is there a better way to show this relationship?

Fix that x axis!

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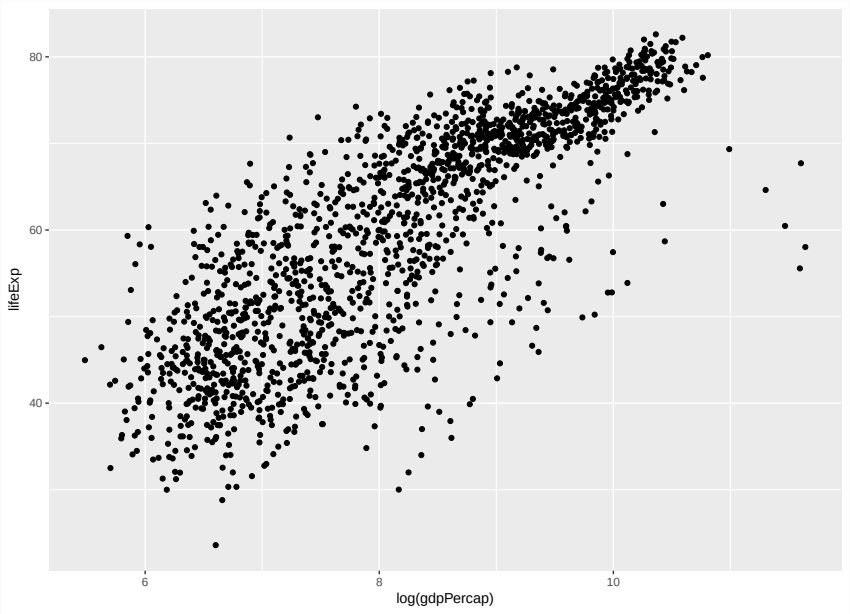
```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = log(gdpPercap), # Log x-axis
                           y = lifeExp))
```


80
60
40
lifeExp
6
8
10
log(gdpPercap)

Aesthetics

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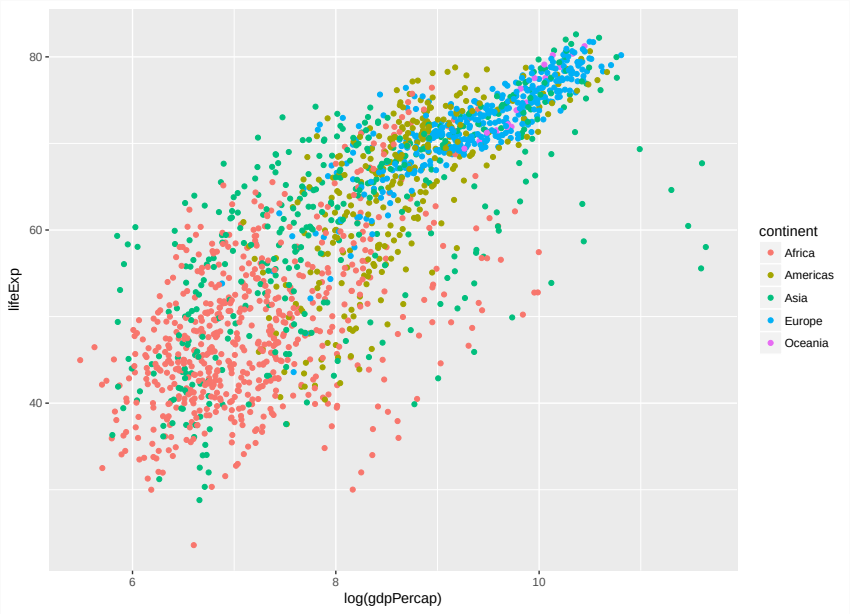
- Example: What if we want to convey info about relationship between wealth and life expectancy by continent?
- One solution: add color by continent

Color

```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = log(gdpPercap),
                           y = lifeExp,
                           ## colour for the Brits
                           color = continent))
```


80
60
40
lifeExp
6
8
10
log(gdpPercap)
continent
Africa
Americas
Asia
Europe
Oceania

Multiple aesthetics - color & shape

- Of course, some people are colorblind, and others don't print things in color, so may be nice to use something like shape in addition:

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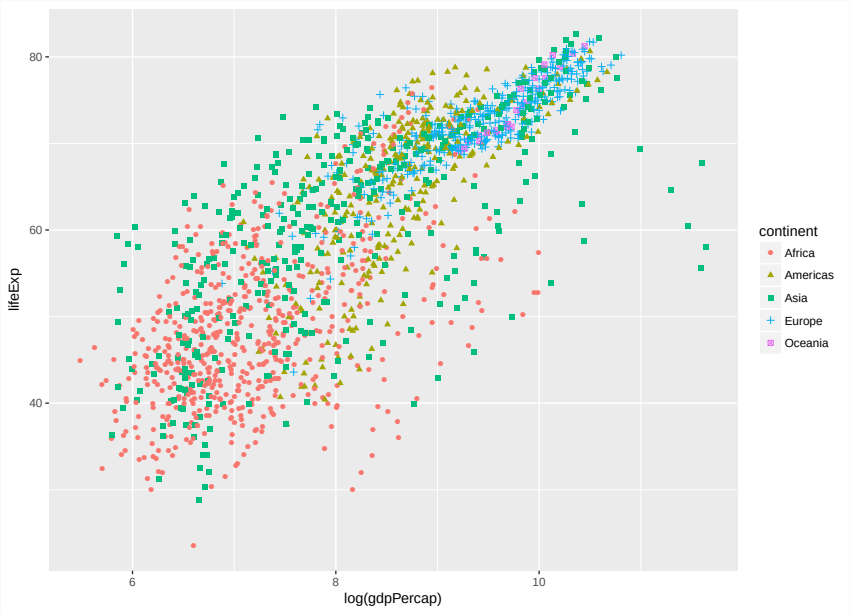
```
ggplot(gapminder) +
  geom_point(aes(x = log(gdpPercap),
                 y = lifeExp,
                 color = continent,
                 shape = continent))
```


80
60
40
lifeExp
6
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10
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More about aesthetics

- There are more aesthetic mappings
- Try `size`, and `alpha` (transparency) for yourself

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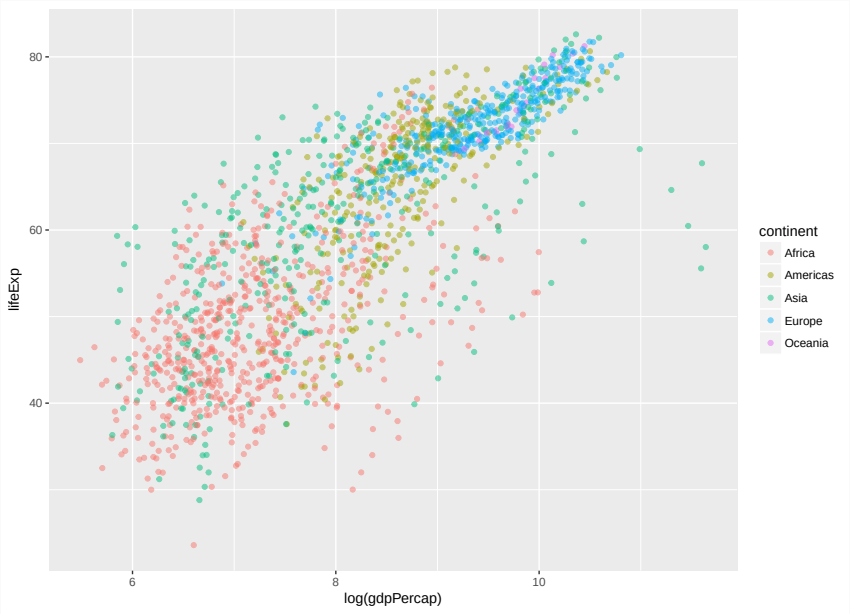
- Try `size`, and `alpha` (transparency) for yourself

- You can set aesthetics directly by mapping the aesthetic to a value *outside* the call to `aes()`
- For example, we may want to make the dots slightly transparent to avoid overplotting

Aesthetics not mapped to variable

```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = log(gdpPercap),
                           y = lifeExp,
                           color = continent),
             alpha = 0.5)
```


80
60
40
lifeExp
6
8
10
log(gdpPercap)
continent
Africa
Americas
Asia
Europe
Oceania

Facets

- So we can use aesthetics to add variables to our graph like `color`.
- We might also want to add variables by splitting up the graph based on values of another variables — e.g. subfigures
- If we want to use just one variable, use `facet_wrap()`

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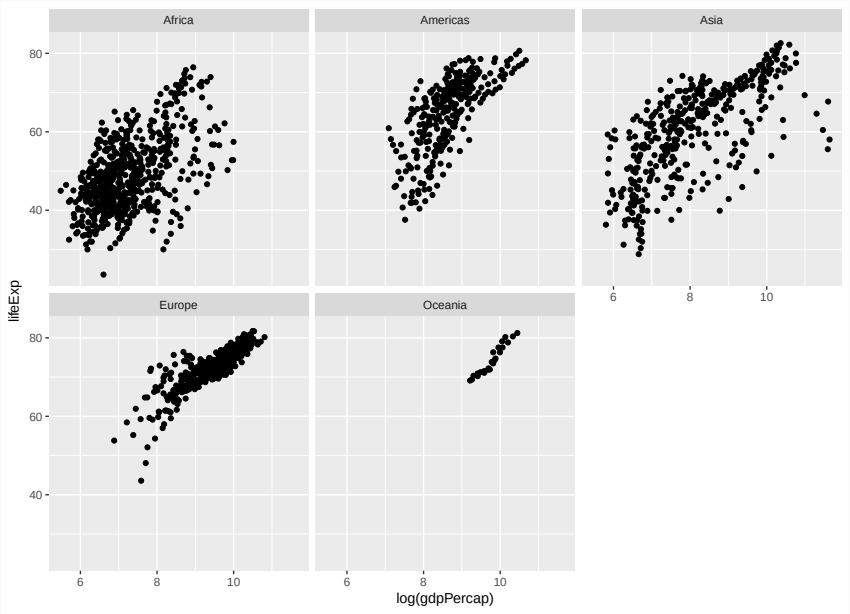
```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = log(gdpPercap),
                           y = lifeExp)) +
  facet_wrap( ~ continent, nrow = 2)
```


Africa
Americas
Asia
Europe
Oceania
lifeExp
log(gdpPercap)
80
60
40
6
8
10

Facets with two variables

- ggplot can facet with two variables with one by row and the other by column
- Use `facet_grid(row ~ column)` to do so
- Our `gapminder` data aren't very well suited for this, but you could do something like:

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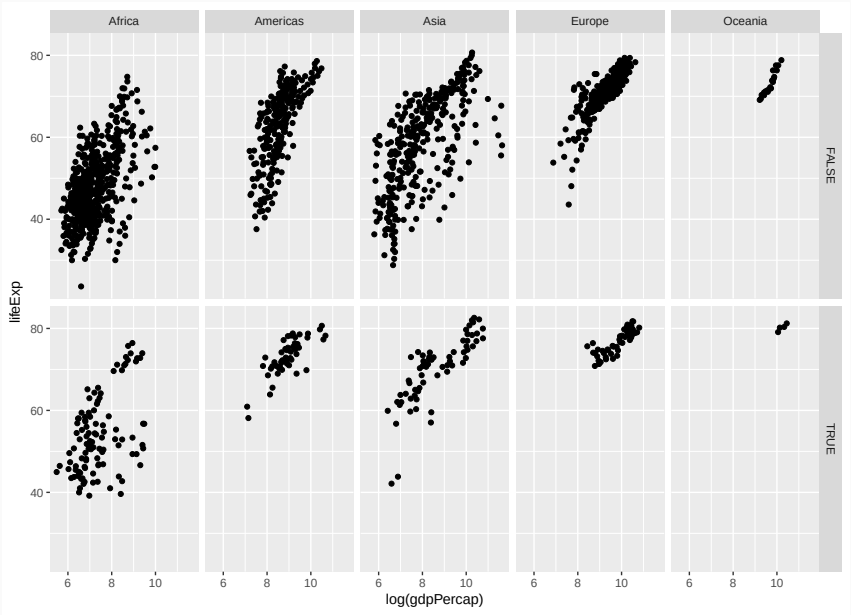
```
ggplot(data = gapminder) +
  geom_point(mapping = aes(x = log(gdpPercap),
                           y = lifeExp)) +
  ## year >= 2000 will be TRUE or FALSE;
  ## we'll learn more about logical statements later on:
  facet_grid(year >= 2000 ~ continent)
```


Africa
Americas
Asia
Europe
Oceania
FALSE
TRUE
lifeExp
log(gdpPercap)
80
60
40
6
8
10

- Review of what we've learned so far:
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- `aes()` helps us map variables to visual properties (x/y location, color, shape, etc)

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- But what about plots other than the scatterplot?

GEOMS

- A `geom` (geometrical object) is `ggplot`'s way of representing data

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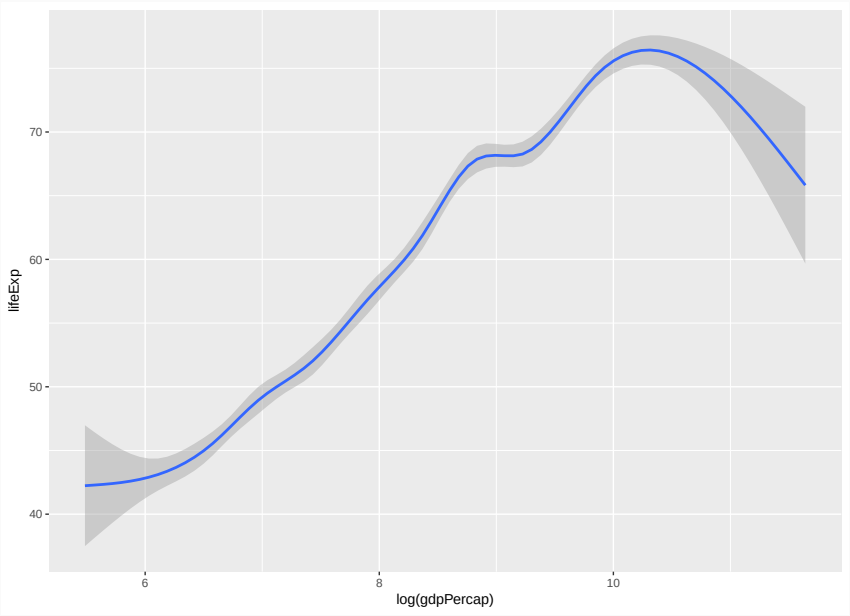
- Let's plot the same relationship between wealth and life expectancy but using `geom_smooth()` rather than `geom_point()`:

```
ggplot(data = gapminder) +
  geom_smooth(mapping = aes(x = log(gdpPercap),
                            y = lifeExp))
```


lifeExp
70
60
50
40
6
8
10
log(gdpPercap)

- Hey, that last plot looked pretty linear
- We can use OLS instead:

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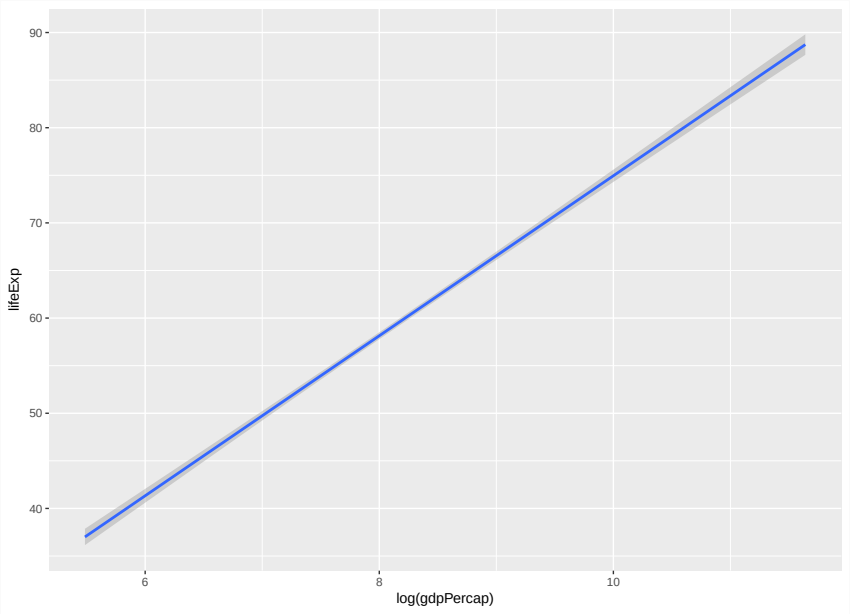
- We can use OLS instead:

```
ggplot(data = gapminder) +
  geom_smooth(mapping = aes(x = log(gdpPercap),
                            y = lifeExp),
              method = "lm")
```


90
80
70
60
50
40
lifeExp
6
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10
log(gdpPercap)

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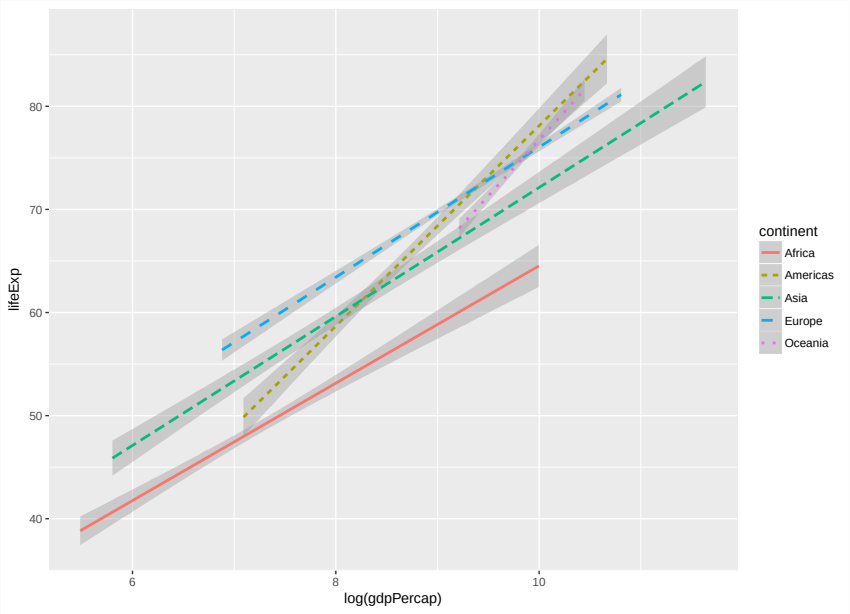
```
ggplot(data = gapminder) +
  geom_smooth(mapping = aes(x = log(gdpPercap),
                            y = lifeExp,
                            color = continent,
                            linetype = continent),
              method = "lm")
```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MULTIPLE GEOMS

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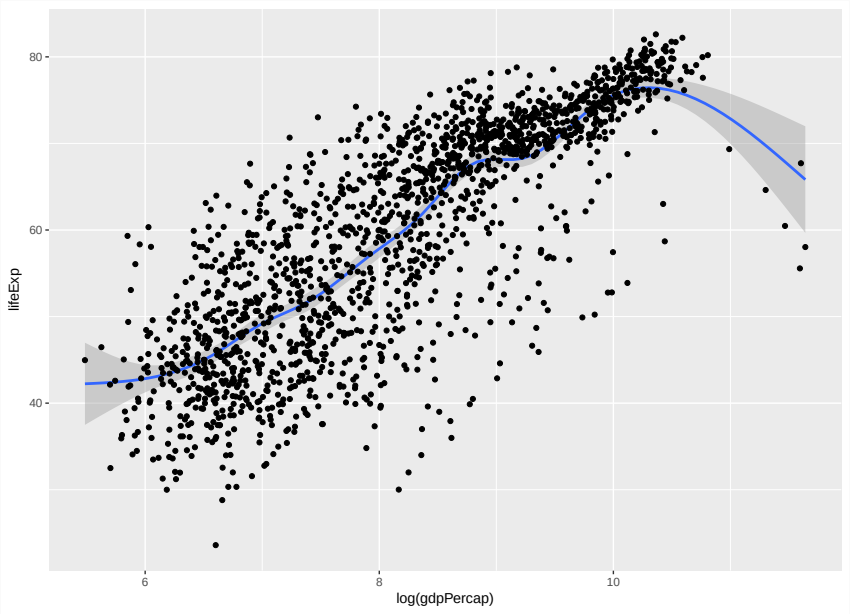
```
ggplot(data = gapminder) +
  geom_smooth(mapping = aes(x = log(gdpPercap),
                            y = lifeExp)) +
  geom_point(mapping = aes(x = log(gdpPercap),
                           y = lifeExp))
```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lifeExp
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10
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- Instead of retyping the `aes` mapping, we can specify a set of defaults in the `ggplot()` call, and overwrite (or add) then in each `geom` call:

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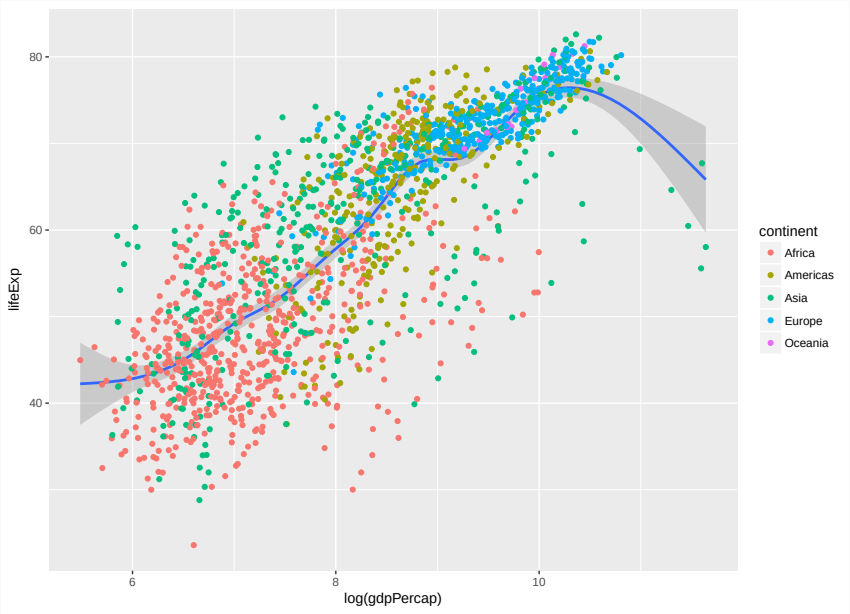
```
ggplot(data = gapminder,
       mapping = aes(x = log(gdpPercap),
                     y = lifeExp)) +
  geom_smooth() +
  geom_point(mapping = aes(color = continent))
```


80
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  - Changing scales

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  - Position

Review

- ggplot2 provides a very flexible way to make high-quality graphics
- stuff we didn't look at:
  - Lots of different geoms
  - Changing scales
  - Position
  - How to save to include in your paper (later, I promise!)

Basic R

- We skipped all of this because plotting is more fun & I wanted to start with something fun

Basics

- We skipped all of this because plotting is more fun & I wanted to start with something fun
- Let's talk about basic R

Calculator

- Remember R can be a calculator:

```
3 * 3 + 29 ^ 4 + 7
```

```
[1] 707297
```

Calculator

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```
x <- 3 * 3 + 29 ^ 4 + 7
my_name <- "Alex Branham"
```

Calculator

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```

```
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- You must *assign* the output to an object in order for R to remember it:

```
x <- 3 * 3 + 29 ^ 4 + 7
my_name <- "Alex Branham"
```

- Tip: In Rstudio, use alt+- (option+-) to get `<-`

Wait, what?

- Yeah, I just assigned letters to an object

Wait, what?

- Yeah, I just assigned letters to an object
- We can inspect the contents of an object by typing it into the R console:

```
x
```

```
[1] 707297
```

Wait, what?

- Yeah, I just assigned letters to an object
- We can inspect the contents of an object by typing it into the R console:

```
x
```

```
[1] 707297
```

- Here, type `my_` then hit tab to have autocompletion

```
my_name
```

```
[1] "Alex Branham"
```

- If you forgot the closing `"` — `my_name <- "Alex Branham`
- The R prompt will change from `>` to `+`
- This indicates that R is waiting for you.
- Cancel by mashing `ESC`

R is pedantic

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- You have to be really specific with R:

```
x
```

```
[1] 707297
```

R is pedantic

- You have to be really specific with R:

```
x
```

```
[1] 707297
```

```
X
```

```
Error: object 'X' not found
```

R is pedantic

- You have to be really specific with R:

```
x
```

```
[1] 707297
```

```
X
```

```
Error: object 'X' not found
```

```
my_nam
```

```
Error: object 'my_nam' not found
```

Things don't happen magically

```
x
```

```
[1] 707297
```

```
x / 1000
```

```
[1] 707.297
```

Things don't happen magically

```
x

[1] 707297

x / 1000

[1] 707.297

x

[1] 707297
```

Missing values

- Missing data is represented by `NA` in R
- R thinks about this as “something that’s there, but whose value we do not know”
- Missingness propagates

Missing values

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- Missingness propagates

```
mean(c(1, 2, NA))
```

```
[1] NA
```

Missingness quiz

- What will be the result?
- We'll learn more about logical statements in a bit, this asks "Is 3 equal to NA"?

```
3 == NA
NA == NA
```

Missingness quiz answer

```
3 == NA
```

```
[1] NA
```

```
NA == NA
```

```
[1] NA
```

Functions

- Functions in R can take zero or more arguments

```
function(arg1 = object1, arg2 = object2, arg3 = object3)
```

Functions

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```
function(arg1 = object1, arg2 = object2, arg3 = object3)
```

```
my_vector <- seq(from = 1, to = 10, by = 1)
my_vector
```

```
[1]  1  2  3  4  5  6  7  8  9 10
```

Functions

- Functions in R can take zero or more arguments

```
function(arg1 = object1, arg2 = object2, arg3 = object3)
```

```
my_vector <- seq(from = 1, to = 10, by = 1)
my_vector
```

```
[1]  1  2  3  4  5  6  7  8  9 10
```

```
mean(x = my_vector)
```

```
[1] 5.5
```

```
my_vector <- c(1, 2, 3, NA, NA, NA, 3, 2, 1)
mean(x = my_vector)
```

```
[1] NA
```

Functions, continued

```
my_vector <- c(1, 2, 3, NA, NA, NA, 3, 2, 1)
mean(x = my_vector)
```

```
[1] NA
```

```
mean(x = my_vector, na.rm = TRUE)
```

```
[1] 2
```

Function arguments

- You don't have to specify argument names if you type them in order.
- Since `x` is the first argument of `mean()`, no need to type `mean(x = my_vector)`
- Instead, can just type `mean(my_vector)`
- This cuts down on the amount you have to type

- OK, so now we know how to assign stuff and functions

Data

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- Let's learn about how R thinks about data

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Data

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- Let's learn about how R thinks about data
  - "data" here doesn't have to mean data from e.g. a survey
- R cares about the class (type) of data and its dimension(s)

Data types

- We'll discuss the four most common data types:
  - Numeric
  - Logical
  - Character
  - Factor
- We'll also cover NA

Numeric

- Numeric is how R thinks about numbers!
- These can also be called “integer” (if round numbers) or “double”

```
class(c(1, 2, 3))
```

```
[1] "numeric"
```

Numeric

- Numeric is how R thinks about numbers!
- These can also be called “integer” (if round numbers) or “double”

```
class(c(1, 2, 3))
```

```
[1] "numeric"
```

```
sum(c(1, 2, 3))
```

```
[1] 6
```

Numeric

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class(c(1, 2, 3))
```

```
[1] "numeric"
```

```
sum(c(1, 2, 3))
```

```
[1] 6
```

```
class(sum(c(1, 2, 3)))
```

```
[1] "numeric"
```

Logical

- Logical can take two values — TRUE or FALSE

Logical

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Logical

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- This is useful for dummy variables and tests

```
1:10 > 5
```

```
[1] FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE
```

Character

- Characters represent text
- Sometimes these are called “strings”

```
c("This", "vector", "is", "of", "length", "what?")
c("How about this one?")
```

Factor

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Factor

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- We already worked with these when we used the `continent` variable from `gapminder`

```
head(gapminder$continent)
```

```
[1] Asia Asia Asia Asia Asia Asia
Levels: Africa Americas Asia Europe Oceania
```

Data type quiz

What type of data are the following?

```
182
c("My name is Alex")
"TRUE"
FALSE
c(1, 2, 3)
c(1, "Alex", TRUE)
```

What's the difference?

```
[1] 1 2 3 4 5 6
```

```
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
```

What's the difference?

```
[1] 1 2 3 4 5 6
```

```
     [,1] [,2]
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[2,]    2    5
[3,]    3    6
```

- Data can have dimensions
- Numeric, logical, character, and factors are single dimensions (so are lists)

What's the difference?

```
[1] 1 2 3 4 5 6
```

```
     [,1] [,2]
[1,]    1    4
[2,]    2    5
[3,]    3    6
```

- Data can have dimensions
- Numeric, logical, character, and factors are single dimensions (so are lists)

- That matrix is a 3 by 2 matrix
- Why might we want to have two-dimensional data?

- Matrices must have the same type, but we can mix and match types with a `data.frame`
- Remember `gapminder` from earlier?
- We used a `data.frame` to store columns with different data types

- Matrices must have the same type, but we can mix and match types with a `data.frame`
- Remember `gapminder` from earlier?
- We used a `data.frame` to store columns with different data types

- We can access (index, subset) `data.frame` objects using notation similar to matrix notation:

Indexing data.frame

```
gapminder[2, 1] # get whatever is in the second row, 1st col
gapminder[1, ]  # get the first col (all)
gapminder[, 1]  # get the first row (all)
gapminder[, "country"] # select by name
gapminder$country # slightly different
```

Review

- What we learned

Review

- What we learned
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- Functions & arguments

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Review

- What we learned
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- Functions & arguments
- Basic vectors: numeric, logical, character, factor
- Dimensions & the data.frame

Data import & manipulation

Importing data

- Importing data in R is either trivially easy (usually) or super specific and difficult (rarely), so we won't actually be doing this

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- R has a lot of build in functions: `read.csv()`, `read.table()`, etc
- Packages provide still more: `readr::read_csv()`, `haven::read_dta()`, etc

Importing data

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- R has a lot of build in functions: `read.csv()`, `read.table()`, etc
- Packages provide still more: `readr::read_csv()`, `haven::read_dta()`, etc

- I prefer the `rio` package because I don't have to think
- Always gives you a `data.frame`:

```
library(rio)
csv_data <- import("file.csv")
stata_data <- import("file.dta")
```

Working directories & project structure

- R has the concept of a “working directory”
- You can see where this is by typing `getwd()` into the console
- I like to store data and code in separate folders:
- Tip: Rstudio can manage “projects” that take care of a lot of this

Simple project structure

```
my-paper-project/
|--- code/
|    |--- my-script.R
|    |--- my-alt-script.R
|--- data/
|    |--- awesome-data.csv
|--- output/
|    |--- figure1.eps
|    |--- figure2.eps
|    |--- table1.tex
|    |--- table2.tex
|--- my-paper.tex
```

Relative paths

- If you have code like that, you need to know what a relative path is so that code in your `code/` directory can load data in your `data/` directory!

Relative paths

- If you have code like that, you need to know what a relative path is so that code in your `code/` directory can load data in your `data/` directory!

- So if we're running a file from `code/` (that's the working directory), we can load data by doing:

```
my_awesome_data <- import("../data/awesome_data.csv")
```

Relative paths

- If you have code like that, you need to know what a relative path is so that code in your `code/` directory can load data in your `data/` directory!

- So if we're running a file from `code/` (that's the working directory), we can load data by doing:

```
my_awesome_data <- import("../data/awesome_data.csv")
```

- Two dots `..` says "go up one directory", we could chain them to go up two: `../..`

- We are going to use dplyr, another package you've installed, to help us transform data

[1] Technically, a `tibble`, but the difference isn't very much, so we'll ignore that

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- `select()` selects columns

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- `filter()` drops rows based on columns
- `select()` selects columns

- `mutate()` creates new variables
- `summarize()` return statistics

- `group_by()` allows us to do the above by groups

-These functions take data as the first argument and always return a data.frame[1]

```
library(dplyr)
```

[1] Technically, a `tibble`, but the difference isn't very much, so we'll ignore that

filter

- `filter()` uses logical statements (that are TRUE) to return rows:

```
filter(gapminder, continent == "Asia")
filter(gapminder, continent == "Asia" & year >= 2000)
filter(gapminder, continent == "Asia" & year != 2000)
filter(gapminder, continent == "Asia" | year == 2000)
```

Quiz

- Use filter to return all the rows containing observations from Asia or Africa

Quiz

- Use filter to return all the rows containing observations from Asia or Africa

```
filter(gapminder, continent == "Asia" | continent == "Africa")
filter(gapminder, continent %in% c("Asia", "Africa"))
```

select

- The `select` function selects one or more columns:

```
select(gapminder, country)
select(gapminder, country, year, continent)
select(gapminder, -continent)
```

- several helper functions (e.g. `starts_with`), see `?select` for examples

mutate

- Mutate creates new variables:

```
mutate(gapminder, gdp = pop * gdpPercap)
```

```
# A tibble: 1,704 x 1
       country
        <fctr>
 1 Afghanistan
 2 Afghanistan
 3 Afghanistan
 4 Afghanistan
 5 Afghanistan
 6 Afghanistan
 7 Afghanistan
```

summarize

- `summarize` (or `summarise` if you prefer) creates summary statistics:

```
summarize(gapminder, mean_life = mean(lifeExp))
```

```
# A tibble: 1 x 1
  mean_life
      <dbl>
1  59.47444
```

summarize

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```
summarize(gapminder, mean_life = mean(lifeExp))
```

```
# A tibble: 1 x 1
  mean_life
      <dbl>
1  59.47444
```

- Though whoop-de-doo, we could've just done `mean(gapminder$lifeExp)` to get that!

summarize

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summarize(gapminder, mean_life = mean(lifeExp))
```

```
# A tibble: 1 x 1
  mean_life
      <dbl>
1  59.47444
```

- Though whoop-de-doo, we could've just done `mean(gapminder$lifeExp)` to get that!

- Much more useful if we do this by groups

group_by

- All the functions we just learned can be performed by groups!
- This is really exciting and makes life much easier
- Calculate mean life expectancy by year:

group_by

- All the functions we just learned can be performed by groups!
- This is really exciting and makes life much easier
- Calculate mean life expectancy by year:

```
summarize(group_by(gapminder, year), mean_life = mean(lifeExp))
## Or, to add it to the data:
mutate(group_by(gapminder, year), year_mean_life = mean(lifeExp))
```

```
# A tibble: 12 x 2
    year mean_life
   <int>     <dbl>
 1  1952  49.05762
 2  1957  51.50740
 3  1962  53.60925
```

group_by, CONTINUED

- Calculate change in life expectancy by country:

- Calculate change in life expectancy by country:

```
mutate(group_by(gapminder, country),
       life_change = lifeExp - lag(lifeExp))
```

```
# A tibble: 1,704 x 7
# Groups:   country [142]
       country continent  year lifeExp      pop gdpPercap life_ch
        <fctr>    <fctr> <int>   <dbl>    <int>     <dbl>       <
 1 Afghanistan      Asia  1952  28.801  8425333  779.4453
 2 Afghanistan      Asia  1957  30.332  9240934  820.8530       1
 3 Afghanistan      Asia  1962  31.997 10267083  853.1007       1
 4 Afghanistan      Asia  1967  34.020 11537966  836.1971       2
 5 Afghanistan      Asia  1972  36.088 13079460  739.9811       2
```

group_by, CONTINUED

- You can group by multiple variables

```
summarize(group_by(gapminder, continent, year),
          mean_life = mean(lifeExp))
```

```
# A tibble: 60 x 3
# Groups:   continent [?]
   continent  year mean_life
      <fctr> <int>     <dbl>
 1    Africa  1952  39.13550
 2    Africa  1957  41.26635
 3    Africa  1962  43.31944
 4    Africa  1967  45.33454
 5    Africa  1972  47.45094
```

Chaining

- What if we want to select all countries in Africa and calculate mean life expectancy by year?

Chaining

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Chaining

- What if we want to select all countries in Africa and calculate mean life expectancy by year?

- This is easy to do because the dplyr functions always take the data as their first argument and always return a data.frame

Chaining, continued

Chaining, continued

- One option:

```
summarize(group_by(filter(gapminder,
                          continent == "Africa"),
                   year),
          mean_life = mean(lifeExp))
```

Chaining, continued

- One option:

```
summarize(group_by(filter(gapminder,
                          continent == "Africa"),
                   year),
          mean_life = mean(lifeExp))
```

- Or we could assign to objects along the way

```
just_africa <- filter(gapminder,continent == "Africa"),
africa_by_year <- group_by(just_africa, year)
summarize(africa_by_year, mean_life = mean(lifeExp))
```

Piping

- Both of those have downsides, though

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- We'll use the *pipe* **%>%** to "pipe" the thing on the left into the thing on the right:
- Tip: In Rstudio, use Ctrl+shift+m (Cmd+shift+m) to get **%>%**

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- Tip: In Rstudio, use Ctrl+shift+m (Cmd+shift+m) to get `%>%`

```
gapminder %>%
  filter(continent == "Africa") %>%
```

- Both of those have downsides, though
- We'll use the *pipe* `%>%` to "pipe" the thing on the left into the thing on the right:
- Tip: In Rstudio, use Ctrl+shift+m (Cmd+shift+m) to get `%>%`

```
gapminder %>%
  filter(continent == "Africa") %>%

group_by(year) %>%
```

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- We'll use the *pipe* `%>%` to "pipe" the thing on the left into the thing on the right:
- Tip: In Rstudio, use Ctrl+shift+m (Cmd+shift+m) to get `%>%`

```
gapminder %>%
  filter(continent == "Africa") %>%

group_by(year) %>%

summarize(meanlife = mean(lifeExp))
```

Quiz

- Create a data.frame containing the continent, year, avg life expectancy, and change in avg life expectancy

```
gapminder %>%
  group_by(continent, year) %>%
  summarize(avg_life = mean(lifeExp)) %>%
  mutate(change_life = avg_life - lag(avg_life))

# A tibble: 60 x 4
# Groups:   continent [5]
   continent  year avg_life change_life
      <fctr> <int>    <dbl>       <dbl>
 1    Africa  1952 39.13550          NA
 2    Africa  1957 41.26635  2.13084615
 3    Africa  1962 43.31944  2.05309615
 4    Africa  1967 45.33454  2.01509615
 5    Africa  1972 47.45094  2.11640385
```

Ungrouping

- Note that our answer had “continent” as a group
- It’s easy to forget about this, so if you’re saving the object for use later, you may want to run `ungroup()` to undo the grouping on the data.frame.

Other data manipulation

- Those commands take care of the most common data manipulation tasks

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- There's tons more but we don't have the time to go over them all

Other data manipulation

- Those commands take care of the most common data manipulation tasks
- There's tons more but we don't have the time to go over them all
- Search engines and R's help are your friend

Review

- We learned how to use some of the most common `dplyr` functions to manipulate data (filter, select, mutate, summarize)
- `group_by` makes doing this by groups super easy
- Piping can make it easier to read code

Reporting from R

Reporting

- We've learned most of what you need to do data analysis!

Reporting

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- Now let's do a new analysis on how to report, so we'll learn

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  - How to report
  - Review much of what we learned

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Reporting

- We've learned most of what you need to do data analysis!
- Now let's do a new analysis on how to report, so we'll learn
  - How to report
  - Review much of what we learned
  - Learn a few more tricks and tips
- Right now is a good time to "restart" R (close and reopen is one way)

New data

- Let's change the dataset we're using, just for something new:
- We'll use the `midwest` dataset from `ggplot2`, which has info on some U.S. midwest counties:

```
library(dplyr); library(ggplot2)
midwest
```

- Let's look at the relationship between college education and the percent living in poverty. And maybe this looks different in metro areas, so let's keep that in mind too.

- Let's look at the relationship between college education and the percent living in poverty. And maybe this looks different in metro areas, so let's keep that in mind too.

- I always like to show some descriptive statistics:

```
midwest %>%
  select(percbelowpoverty, percollege, inmetro) %>%
  summarize_all(funs(mean, sd))
```

- Let's look at the relationship between college education and the percent living in poverty. And maybe this looks different in metro areas, so let's keep that in mind too.

- I always like to show some descriptive statistics:

```
midwest %>%
  select(percbelowpoverty, percollege, inmetro) %>%
  summarize_all(funs(mean, sd))
```

- But what if we want to show that in our paper?

- There are several packages that let you easily make LaTeX tables, let's use `stargazer`:

```
library(stargazer)
```

- Can handle Word too, need to do an html dance. See package docs.

Descriptive stats, latex table:

```
midwest %>%
  select(percbelowpoverty, percollege, inmetro) %>%
  ## stargazer is picky about tibbles vs data.frames
  as.data.frame %>%
  stargazer(out = "../output/desc-stats.tex",
            title = "Descriptive Statistics")
```

- use `\input{output/desc-stats.tex}` to import the table into your paper

Table 1: Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
percbelowpoverty	437	12.511	5.150	2.180	48.691
percollege	437	18.273	6.262	7.336	48.079
inmetro	437	0.343	0.475	0	1

Plot 1

- Let's make a scatterplot!

Plot 1

- Let's make a scatterplot!
- Make a scatterplot with `percbelowpoverty` on the y-axis and include info on `percollege` and `inmetro`

Plot 1, simple

```
midwest %>%
  select(percbelowpoverty, percollege, inmetro) %>%
  ## inmetro is a number but needs to be discrete.
  ## as.logical will convert so that a 0 is FALSE
  mutate(inmetro = as.logical(inmetro)) %>%
  ggplot(aes(percbelowpoverty, percollege,
             color = inmetro,
             shape = inmetro)) +
  geom_point()
```

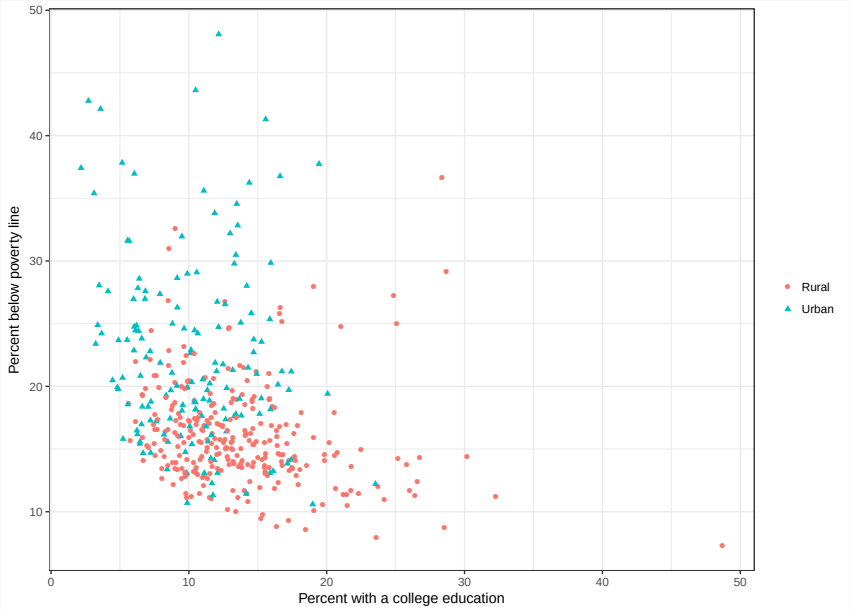
Plot 1, full

```
midwest %>%
  select(percbelowpoverty, percollege, inmetro) %>%
  mutate(inmetro = as.logical(inmetro)) %>%
  ggplot(aes(percbelowpoverty, percollege,
             color = inmetro,
             shape = inmetro)) +
  geom_point() +
  scale_color_discrete(labels = c("Rural", "Urban"), name = "") +
  scale_shape_discrete(labels = c("Rural", "Urban"), name = "") +
  labs(y = "Percent below poverty line",
       x = "Percent with a college education") +
  theme_bw()
```

How to save ggplots

- The `ggsave` function saves a plot (by default, the last one you plotted)
- It's important to specify the width and height

```
ggsave("../output/my-scatterplot.eps",
       ## Important to specify!!!
       width = 9, height = 6.5)
```


Percent below poverty line
50
40
30
20
10
0
10
20
30
40
50
Percent with a college education
Rural
Urban

- Let's run a linear predicting poverty with education and include an interaction term for inmetro
  - Yes, I'm ignoring all kinds of issues with this particular model

```
my_reg <- lm(percbelowpoverty~percollege * inmetro,
             data= midwest)
summary(my_reg)
```

Linear regression table

```
stargazer(my_reg,
          out = "../output/my-reg.tex")
```

```
stargazer(my_reg,
          out = "../output/my-reg.tex")
```

- Use `\input{output/my-reg.tex}` in your LaTeX document to import the table!

Table 2:

	Dependent variable:
	percbelowpoverty
percollege	−0.231***
	(0.069)
inmetro	−5.144***
	(1.707)
percollege:inmetro	0.144*
	(0.087)
Constant	17.383***
	(1.151)
Observations	437
R^2	0.125
Adjusted R^2	0.119
Residual Std. Error	4.835 (df = 433)
F Statistic	20.581*** (df = 3; 433)
Note:	*p<0.1; **p<0.05; ***p<0.01

Thanks for coming!