GW Libraries/STEMWorks
Introduction to R for Data Analysis

Part 0: Setup

- Install R from: r-project.org
- Install RStudio from: rstudio.com

If you already have R and RStudio installed, please reinstall using the latest versions.

We're also going to install the 'tidyverse' set of packages. Open RStudio. In the Console pane (left side), enter:

```
install.packages('tidyverse')
```

This may take a few minutes, as R is downloading the packages from CRAN.

We also have to load the newly installed packages so they are enabled for us to use:

```
library('tidyverse')
```

Part 1: Tour of R Studio

Part 2: Variables

Assign using `<-`
For example: `x <- 5.4`

Simply type the name of the variable to evaluate it.

Try creating some variables with values like:

- `"This is some text"`
- `TRUE`
- `FALSE`
- `6.5`
- `pi`
- `5+3i`

Use `typeof()` to inspect the type of a variable. For example, what's the result of:

```
x <- "abc"
typeof(x)
```

Watch the Environment pane as you create variables!

Part 3: Logical Expressions

Working in R, you'll also need to build logical expressions. Logical expressions resolve to either `TRUE` or `FALSE`.

Some of the basic logical operators include: ==, <, >, ! (not), & (and), | (or), etc..

For example, verify that if you evaluate:

```
x <- 10
4 < y & y < 12
```

the result should be `TRUE`.

Part 4: Vectors

Combine into a vector using `c()`
(Note: There are also lists, which you can make with `list() )`

Try:

Creating vectors with mixed types. For example, what's the result of:

```
vec <- c(1, 2, "a", "b")
vec
```

Accessing elements of vectors:

```
vec[1]
vec[2:3]
vec[0]
vec[-2]
```

Reassign elements of vectors:

```
vec[3] <- 'g'
```

Applying functions to vectors:

```
primes <- c(2, 3, 5, 7, 11)
primes*2
sqrt(primes)
```

```
mean(primes)
```

Operations on two vectors:

```
primes <- c(2, 3, 5, 7, 11, 13)
twos <- c(2, 4, 6, 8, 10, 12)
primes + twos
primes / twos
```

What happens if the vectors are of unequal length?

What does `4:10` create?

What do you get when you try something like:

```
primes > 6
```

How might you get back a subset of the primes vector, with only the elements whose values are > 6 ?

Coercion

Let's say we try to create a vector with values of: 1, 2, 9, "TBD", 4

```
y <- c(1, 2, 9, "TBD", 4)
```

Now look at `y`. What happened to it?

We can *coerce* (i.e. force) values into new types, using functions that start with `as.` **such as** `as.numeric()`, `as.character()`, `as.logical()`, etc.

Try coercing `y` using `as.numeric()` :

```
y <- as.numeric(y)
```

Part 5: Data Frames

Data frames are very central to the way R is used. Data frames contain rectangular data, with rows and columns. Rows correspond to observations, and columns correspond to variables.

Let's create a test `data.frame` (Later we will use tibbles instead, but you should get used to also seeing data.frames):

```
obs_time <- c(1, 3, 4, 9, 11, 20, 24)
distance <- c(0, 0.5, 0.6, 1, 1.1, 1.2, 1.5)
snailrace_data <- data.frame(obs_time, distance)
```

Clicking on the `snailrace_data` variable in the Environment pane, you can look at the contents of `snailrace_data`.

Soon, we'll be doing more with data frames (and tibbles).

Let's get organized and do our work in an RStudio project.

Part 6: Setting up an RStudio Project

In the menu bar: File → New Project

In the Files pane, use the New Folder button to create new folders called "data" and "output".

Create a new R script file, and give it a name by saving it.

Part 7: Reading in Data

Browse to go.gwu.edu/gwlibrworkshop and scroll down to the link to the two data files. Right-click on the link for "gapminder.csv" and choose "Save Link As" to save the file to your computer. Save it to your R project's "data" folder. Let us know if you need assistance accomplishing this.

There are two ways to read a CSV file into R:

Basic R:	`read.csv()` -- gives you a `data.frame`
Improved:	`read_csv()` -- gives you a `tibble` (from the `readr` package, part of `tidyverse`)

We have read_csv() because we installed tidyverse packages earlier.

Part 8: Exploring Data

Now that we have read_csv (as part of tidyverse's `readr` package), let's use it to load in our data:

```
gapminder <- read_csv('data/gapminder.csv')
```

Click on the gapminder object in the Environment pane.

Try using these and see if you can figure out what they do:

```
head(gapminder)
tail(gapminder)
dim(gapminder)
colnames(gapminder)
gapminder[0]
gapminder[1]
gapminder[2:5]
gapminder[2:5, 3:4]
gapminder[,3:4]
gapminder[3:6, c('country', 'year', 'pop')]
gapminder$country
```

Remember above how we retrieved only the vector elements that met a particular logical criterion (for example, `primes[primes > 6]` ?

In a very similar way, we can get back only the rows from a data frame that meet a criterion. Try these:

```
gapminder[gapminder$country == 'France', c('year','lifeExp')]
gapminder[gapminder$country == 'France' & gapminder$year > 1970, ]
```

How would you get back only rows where the population is greater than 100,000,000 but the country is *not* located in Asia?

Part 9: Data Wrangling

A brief bit on **Data Cleaning**:

Let's create a test `data.frame` (We could make this as a tibble, but you should get used to also seeing data.frames):

```
x1 <- c(1, 5, 7, 99, 8, 10, 99)
x2 <- c(0, 0.5, 0.6, 1, NA, 1.2, 1.5)
data <- data.frame(x1, x2)
```

Try computing `mean(data$x2)`
Now try but add a second argument of `na.rm = TRUE`

Now, let's say that for the 'x1' variable, observations of '99' are actually invalid and we want to recast them as NAs. Try this and see what `data` looks like afterwards:

```
data$x1[x1 == 99] <- NA
```

Notice that `NA` is a special value in R for 'not available'. There's also `NaN` (not a number), and `Inf` (infinite).

There's much more one can do to clean data in R. This is just an introduction!

Data Filtering:

Let's go back to our `gapminder` tibble and use the `dplyr` package. We have a number of handy functions at our disposal, including: `filter()`, `arrange()`, `select()`, `rename()`, `mutate()`, `summarize()`, `group_by()`

We can use `select()` to get back just certain columns (with or without renaming). Let's use `rename()` to keep all columns, but rename the "pop" column to "population".

```
rename(gapminder, population = pop)
```

If we look at the `gapminder` tibble (in RStudio, by clicking on it in the Environment tab), nothing changed. Why do you think that is, and how can you accomplish renaming it in `gapminder`?

Now let's say that we want to create a subset of this data that only looks at 2007 observations. We can use filter for that. We're also going to use something called a "pipe", denoted by %>% that sends the output of one function as input into the next.

```
gapminder_2007 <- gapminder %>%
    filter(year == 2007)
```

Let's say we also want to reorder the rows in order to life expectancy. Try adding another pipe and use `arrange()` to reorder the rows.

Data Tidying/Reshaping:

Now we're going to tidy some data that, like much data in the real world, is not so tidy. The data set is located here - but *don't download it just yet*:

https://raw.githubusercontent.com/gwu-libraries/gwlibraries-workshops/master/r-for-data-analysis/data/education.xlsx

There's a nice way to do this in R which doesn't involve your browser. You can use `download.file`:

```
download.file("https://raw.githubusercontent.com/gwu-libraries/gwlibraries-workshops/master/r-for-data-analysis/data/education.xlsx",
"data/education.xlsx")
```

The first argument is the URL of the file; the second argument is where you want to save it to. (Alternatively, go to go.gwu.edu/gwlibrworkshop, scroll down, and download `education.xlsx` to your "data" folder)

This is an Excel file, so you'll need to enable the '`readxl`' library in RStudio.

Read in the data set using the read_excel function:

```
education <- read_excel("data/education.xlsx")
```

This gets us back a `tibble`. Great!

First, let's fix the name of the country column. That's what column 1 actually is.

```
colnames(education)[1] <- 'country'
```

Now, let's use `gather()` to move the years as column names into a 'year' variable:

```
education_tidy <- education %>%
  gather(colnames(education)[2:ncol(education)],
         key ='year',
```

```
          value = 'expenditure per student')

  countries_continents <- gapminder %>%
    +     select(country, continent) %>% distinct()

education_with_continents <- left_join(education_tidy,
countries_continents)
```

Another common situation is where you have one variable that is a mashup that contains two (or more) pieces of information that you'd like to treat separately.

Let's construct a data.frame like this:

```
subject <- c('DA-01', 'DA-10', 'DA-05', 'DX-08', 'DX-11')
vaccine <- c('PL', 'AX', 'AX', 'PL', 'None')
trialdata <- data.frame(subject, vaccine)
```

Take a look at `trialdata`.

Now let's try using `separate()` to break up the 'subject' variable into two variables: cohort, and subjnum

```
trialdata <- trialdata %>% separate(subject, into=c('cohort',
'subjnum'))
```

Check out what happened with `trialdata`.

Part 10: Data Visualization

We can do a quick plot using R's base graphics package:

```
plot(data = gapminder, y = lifeExp, x = gdpPercap)
```

But we can also use the newer `ggplot2` package (included in tidyverse)...

If we do this:

```
ggplot(data = gapminder, aes(x = gdpPercap, y = lifeExp))
```

We get axes and a grid - a canvas - but where are the points? With ggplot, we need to add (using +) layers for points, lines, etc.:

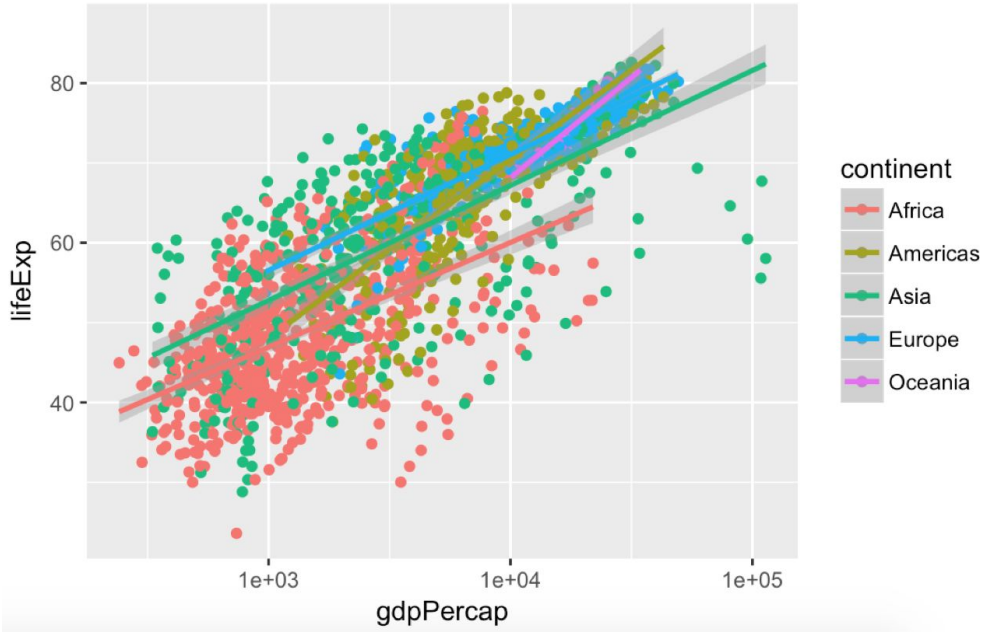
```
ggplot(data = gapminder, aes(x = gdpPercap, y = lifeExp)) +
      geom_point()
```

Let's color code the points by continent:

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

Now add `scale_x_log10()` to change the x scale to log base 10.

Last but not least, we'll do some linear regression line fitting; try adding `geom_smooth(method="lm")`



Part 11: Data Analysis

Let's do a bit of linear regression.

For this section, we're going to use R's `lm()` function designed for fitting linear models to data.

First, let's do some data wrangling where our goal is to get a global average of life expectancy by year.

We can use group_by() and summarize() to accomplish this.

```
lifeexp_by_year <- gapminder %>%
  group_by(year) %>%
  summarize(weighted_avg_lifeExp = sum(pop*lifeExp)/sum(pop))
```

Let's look at what we have now:

```
      year weighted_avg_lifeExp
   <int>              <dbl>
 1  1952              48.94424
 2  1957              52.12189
 3  1962              52.32438
 4  1967              56.98431
 5  1972              59.51478
 6  1977              61.23726
 7  1982              62.88176
 8  1987              64.41635
 9  1992              65.64590
10  1997              66.84934
11  2002              67.83904
12  2007              68.91909
```

We can use R's `lm()` to fit linear models. The basic form for specifying the relationship is with the tilde (~) symbol: `y ~ x`

```
lifeexp.lm <- lm(data = lifeexp_by_year, weighted_avg_lifeExp ~ year)
```

Now let's check out the slope and intercept that R calculated:

```
coefficients(lifeexp.lm)
```

In fact, we can get *lots* of detail about the model:

```
summary(lifeexp.lm)
```

You can also inspect all the internal contents of `lifeexp.lm` by clicking on it in the Environment pane!

Let's make a very simple scatterplot of the data:

```
plot(y = lifeexp_by_year$weighted_avg_lifeExp, x =
lifeexp_by_year$year)
```

and then add the line from our regression model:

```
abline(lifeexp.lm)
```

We can also do something similar using ggplot2:

```
ggplot(data = lifeexp_by_year,
       aes(y = weighted_avg_lifeExp, x = year)) +
  geom_point() +
  geom_smooth(method = "lm", formula = y ~ x)
```

Part 12: Creating Functions

We've been using functions, like class(), sqrt(), summary(), read_csv(), etc., and these all came with either base R or with installed packages. But often, you'll want to create your very own functions, especially when you have something you want to do or calculate many times. Let's try that.

A function can be stored in a variable, and is defined using function.

Let's say you needed to write a function to convert from degrees Fahrenheit to degrees Celsius.

First we need to pick a name for the function. Let's call it fahr_to_celsius.

Our function will take just one value (degrees Fahreinheit), but functions can have multiple arguments (as well as options).

```
fahr_to_celsius <- function(temp_f) { # note the curly brackets
  temp_c <- (temp_f-32)*5/9
  temp_c  # the last line is the value the function returns
}
```

Challenge: Can you write a function, `curve.grades`, that takes a vector of test grades, and "curves" them, i.e. scales them based on the highest grade in the class -- and rounds the result to the nearest 0.1 ?

It should work like this:

```
> grades.midterm <- c(51, 70, 65, 88, 72)
> curve.grades(grades.midterm)
[1]  58.0  79.5  73.9 100.0  81.8
```