Lecture 5: Meet R

ECON 480 - Econometrics - Fall 2018

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September 12, 2018

Writing and Saving R Code

Objects in R

Data Frames

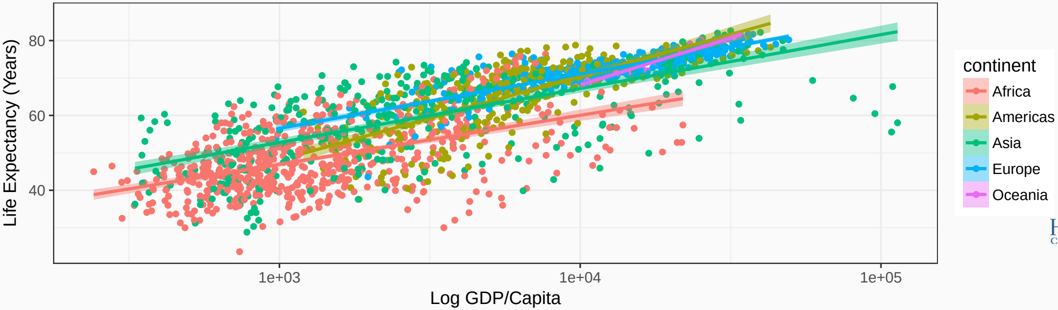
Quick Data Analysis Example

Excel, Stata, R

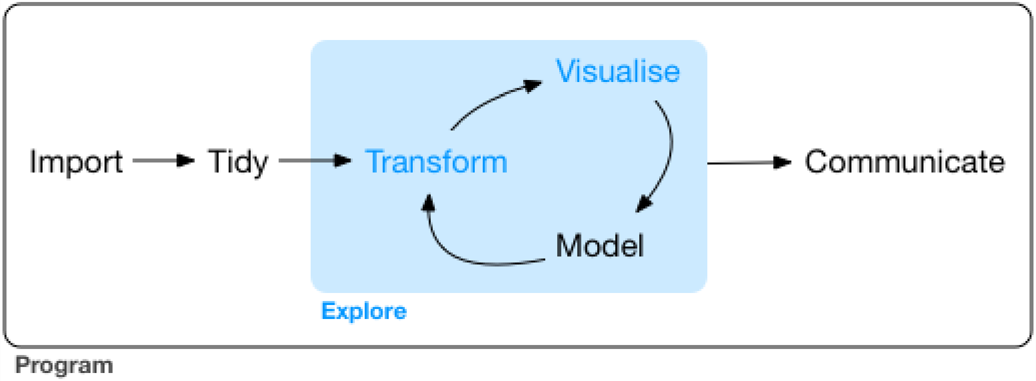
Excel	Stata	R
MS Office License	Expensive License	Free!
Proprietary	Proprietary	Open Source
Default, used in finance	Primary for economists	Largest use by data scientists
Not reproducible	Reproducible (.do files)	Reproducible (.R files)
Can't incorporate into docs	Can't incorporate into docs	Can run in chunks within docs
Very limited extensions	Many packages	Most packages written for R first
Point-and-click	Point-and-click or command line	Almost exclusively command line
Limited formulas	Just one command per task	Many alternative commands

Stata and Excel Can’t Do This (Right in the Slides)

```
ggplot(data = gapminder, aes(x = gdpPercap,
    y = lifeExp, color = continent, fill= continent))+
    geom_point()+geom_smooth(method = ”lm”) +
    scale_x_log10()+ylab(”Life Expectancy (Years)”)+
    xlab(”Log GDP/Capita”)
```



York Workflow for Data Analysis



Workflow

- Need software that can import, tidy, analyze, plot, and present data

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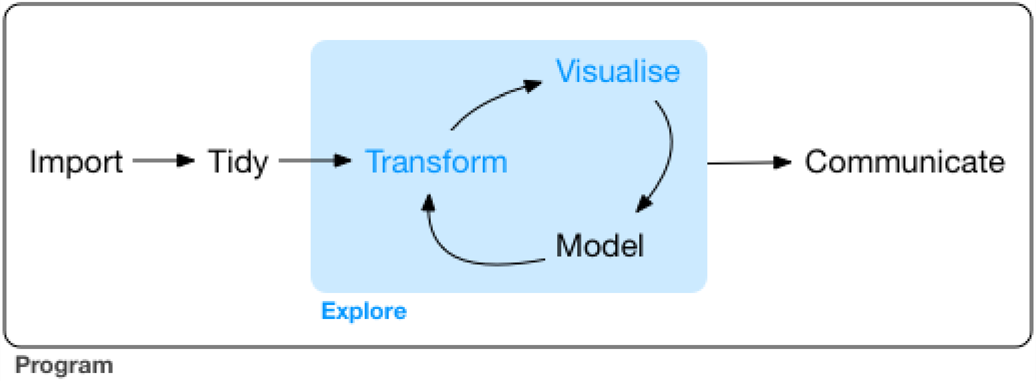

Workflow

- Need software that can import, tidy, analyze, plot, and present data
- R can do all of this (with *R Markdown*, all in the same document)

Learning to Code

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- R like all command line programming is *very literal*, a single typo or misplaced comma will lead to a different outcome than you intended, or fail completely

Learning to Code II

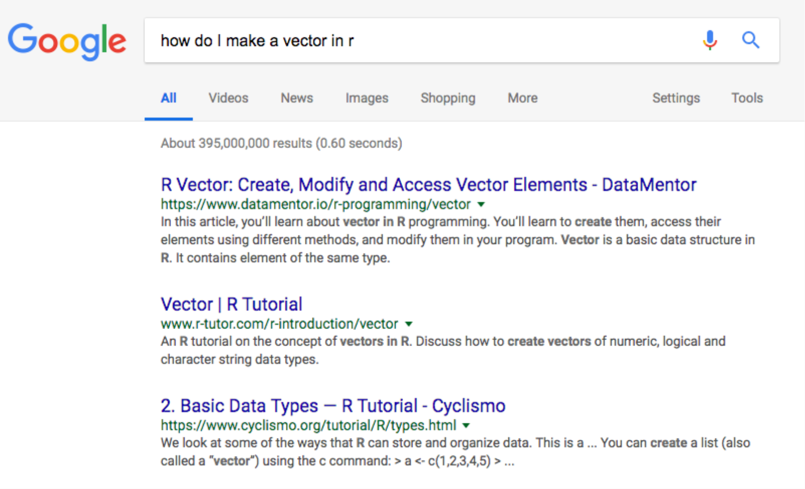
”There’s an implied contract between you and R: it will do the tedious computation for you, but in return, you must be completely precise in your instructions. Typos matter. Case matters.”

R for Data Science

Hadley Wickham

Chief Scientist, R Studio

Say Hello to My Little Friend



how do I make a vector in r

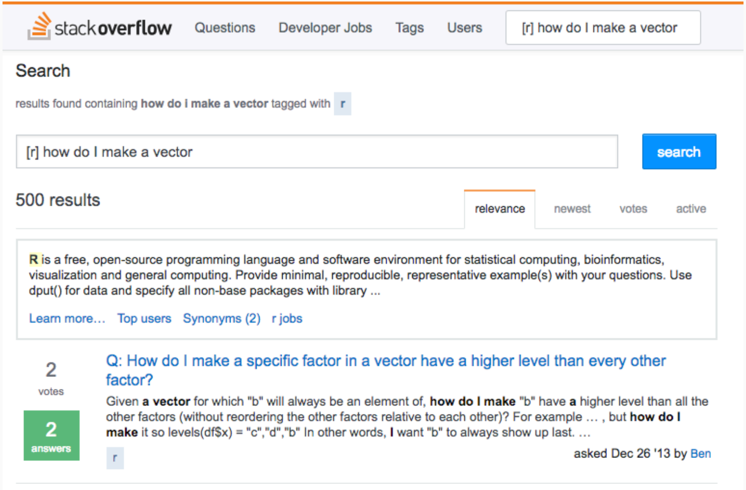
About 395,000,000 results (0.60 seconds)

R Vector: Create, Modify and Access Vector Elements - DataMentor
https://www.datamentor.io/r-programming/vector
In this article, you'll learn about **vector in R** programming. You'll learn to **create** them, access their elements using different methods, and modify them in your program. **Vector** is a basic data structure in **R**. It contains element of the same type.

Vector | R Tutorial
www.r-tutor.com/r-introduction/vector
An **R** tutorial on the concept of **vectors in R**. Discuss how to **create vectors** of numeric, logical and character string data types.

2. Basic Data Types — R Tutorial - Cyclismo
https://www.cyclismo.org/tutorial/R/types.html
We look at some of the ways that **R** can store and organize data. This is a ... You can **create** a list (also called a "**vector**") using the c command: > a <- c(1,2,3,4,5) > ...

Say Hello to Your New BEST Friend



Search

results found containing **how do I make a vector** tagged with r

500 results

R is a free, open-source programming language and software environment for statistical computing, bioinformatics, visualization and general computing. Provide minimal, reproducible, representative example(s) with your questions. Use dput() for data and specify all non-base packages with library ...

2 votes

2 answers

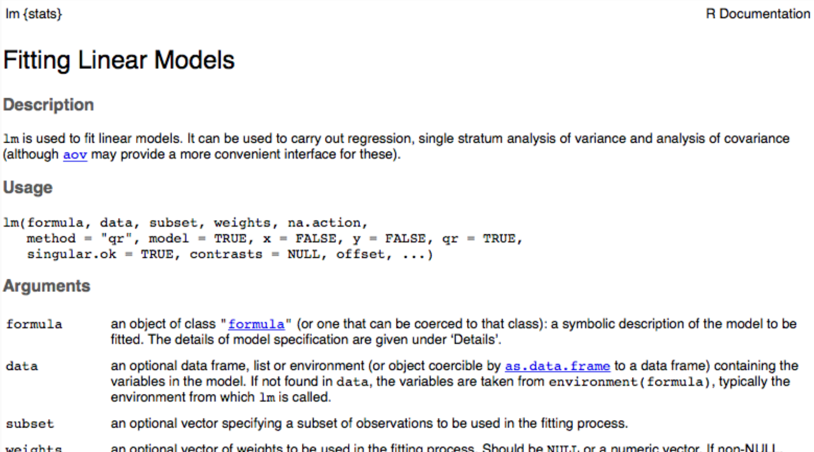
Q: How do I make a specific factor in a vector have a higher level than every other factor?

Given **a vector** for which "b" will always be an element of, **how do I make** "b" have **a** higher level than all the other factors (without reordering the other factors relative to each other)? For example … , but **how do I make** it so levels(df$x) = "c","d","b" In other words, **I** want "b" to always show up last. …

asked Dec 26 '13 by Ben

R Also Plays Along Pretty Nicely

```
#type help("functionname") to get documentation on the command
help("lm")
```



lm {stats} R Documentation

Fitting Linear Models

Description

`lm` is used to fit linear models. It can be used to carry out regression, single stratum analysis of variance and analysis of covariance (although `aov` may provide a more convenient interface for these).

Usage

```
lm(formula, data, subset, weights, na.action,
   method = "qr", model = TRUE, x = FALSE, y = FALSE, qr = TRUE,
   singular.ok = TRUE, contrasts = NULL, offset, ...)
```

Arguments

`formula` an object of class "`formula`" (or one that can be coerced to that class): a symbolic description of the model to be fitted. The details of model specification are given under 'Details'.

`data` an optional data frame, list or environment (or object coercible by `as.data.frame` to a data frame) containing the variables in the model. If not found in `data`, the variables are taken from `environment(formula)`, typically the environment from which `lm` is called.

`subset` an optional vector specifying a subset of observations to be used in the fitting process.

`weights` an optional vector of weights to be used in the fitting process. Should be `NULL` or a numeric vector. If non-NULL

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- It will be wise to adopt some consistent standard for demarcating names:

```
i.use.snake.case
otherPeopleUseCamelCase
some_people_use_underscores
And_aFew.People_RENOUNCEconvention
```

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    - OS-specific to Windows vs. Mac vs. Linux

Writing and Saving R Code: Tips

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```r
# Run regression of y on x, save as reg1
reg1<-lm(y~x, data=data) #runs regression
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    - Better yet, ask me about version control and GitHub (later)

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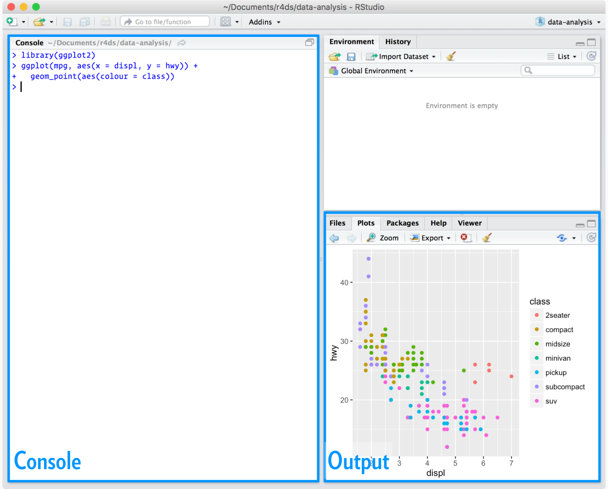
    - Can write an entire document (text, equations, R commands, figures, tables, etc) with one file!
    - Can export to html, MS Word, Beamer, etc!
    - Markdown is a language that is intuitive, simple, human- and machine-readable

R Studio



```
> library(ggplot2)
> ggplot(mpg, aes(x = displ, y = hwy)) +
+   geom_point(aes(colour = class))
>
```

Environment is empty

Rstudio Windows

Agenda for Today and for the Future

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- **Today**: practice using the Command Line/Console in *R*
  - Learn different commands and results relevant to data analysis
  - By the end, saving a script as a .*R* file
- **Later**: *R Markdown* and the benefits to plain text, literate programming, and workflow management

Coding Basics

- First, ecognize that R can be used as a simple calculator

```
2+2
```

```
## [1] 4
```

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sqrt(100/4)
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- This will be helpful later when we want to transform variables

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- If you do not have a package, they are easy to install with (yes, note the plural “s”)

```
install.packages(”packagename”)
```

Using Packages

- Here is a list of the most important packages you will probably use for things relevant to econometrics

Package name	Use
`ggplot2`	Rendering beautiful graphics (scatterplots, histograms, etc)
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- We will explore each of these in more detail later

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```
1:5
```

```
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Vectors II

- We can perform mathematical operations on a vector as a whole:

```
sum(1:5)
```

```
## [1] 15
```

```
mean(1:5)
```

```
## [1] 3
```

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```
list
```

```
## [1] ”red”    ”blue”   ”purple”
```

```
print(list)
```

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## [1] ”red”    ”blue”   ”purple”
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Variable/Data Classes

- Vectors **must** contain the same type of elements (e.g. numerical or text)

```
mixed<-c(5, pi, TRUE, 4.3, ”cabbage”)
class(mixed)
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- You can always check the type of vector using **class()**

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```

- Logical is a series of binary elements that can either be TRUE or FALSE

```
logical<-c(TRUE,FALSE,FALSE,TRUE)
```

Variable/Data Classes

- Numeric (aka “double”), as it sounds, can perform mathematical operations

```r
numeric<-c(1,2,3,4,5)
```

- Logical is a series of binary elements that can either be TRUE or FALSE

```r
logical<-c(TRUE,FALSE,FALSE,TRUE)
```

- Character is a string of text: letters, numbers, and symbols, cannot perform mathematical operations

```r
character<-c(”one”,”two”,”7”,”orange”)
```

Factors

- Factor is a special type of character variable, often used to indicate membership in one of several possible categories, called **levels** (e.g. for plotting, or conditional statistics and data work)

```
students<-factor(c(”freshman”, ”senior”, ”senior”, ”junior”, ”freshman”,
                   ”sophomore”, ”freshman”))
levels(students) #extract unique levels
```

```
## [1] ”freshman”  ”junior”    ”senior”    ”sophomore”
```

```
nlevels(students) #count the number of levels
```

```
## [1] 4
```

Factors II

```r
table(students) #tabulate number of values for each level
```

```
## students
##  freshman    junior    senior sophomore
##         3         1         2         1
```

Changing Variable/Data Classes

- Again, check the type of data with **class()**

```
class(x)
```

```
## [1] ”numeric”
```

```
x<-as.character(x)
class(x)
```

```
## [1] ”character”
```

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

Changing Variable/Data Classes

- Again, check the type of data with **class()**
- Change the type with **as.classname()**

```
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```

```
## [1] ”numeric”
```

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x<-as.character(x)
class(x)
```

```
## [1] ”character”
```

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

Changing Variable/Data Classes

- Again, check the type of data with **class()**
- Change the type with **as.classname()**
  - Note you can’t turn characters into numeric (if there’s no numbers), but you can turn numeric into characters

```
class(x)
```

```
## [1] ”numeric”
```

```
x<-as.character(x)
class(x)
```

```
## [1] ”character”
```

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

Storing Objects and Indexing

- Use **[square brackets]** to isolate elements of a vector for commands

```
print(list) #Our original list
```

```
## [1] ”red”    ”blue”   ”purple”
```

```
list[1] #Inspect first element
```

```
## [1] ”red”
```

```
list[c(1,3)] #Inspect first and third elements
```

```
## [1] ”red”    ”purple”
```

Storing Objects and Indexing II

- Use **[square brackets]** to isolate elements of a vector for commands

```
list[2]<-”orange” #Change second element
print(list) #Our new list
```

```
## [1] ”red”    ”orange” ”purple”
```

Vector Operations

- Keeping our first vector *x*, let's create another object *y*

```
y<-10
```

Vector Operations

- Keeping our first vector *x*, let's create another object *y*

```
y<-10
```

- Let's create a third object *z*, which is the product of *x* and *y*

```
z<-x*y
z
```

```
## [1] 10 20 30 40 50
```

Redefining Objects

- Objects and variables maintain their value until they are changed. We can redefine x as 6 simply with another command to define x.

```
x
```

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

```
x<-6
x
```

```
## [1] 6
```

Functions

- Most of R: `functionname(objectname)`

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Functions

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- A function produces a (hopefully useful) output based on the input that it recieves.
- Functions can be recognized by the parentheses () at the end of their names.
- The `c()` command that produces a vector, was an example of a function.

Some Useful Functions

- Mathematical/Statistical Functions

Function	Use	Example
`sum()`	Takes the sum of an object	`sum(1:10)`
`mean()`	Takes the arithmetic mean of an object	`mean(1:10)`
`rnorm()`	Takes a number of draws (e.g. 5) from a normal distribution	`rnorm(5)`
`round()`	Rounds an object (e.g. x) to (e.g. 2) decimal places	`round(x,2)`

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`round()`	Rounds an object (e.g. x) to (e.g. 2) decimal places	`round(x,2)`

- Note functions can have functions in their arguments, e.g. `round(rnorm(5),2)`

Data Frames

Data Frames

- The most important object in R is a data frame, used for statistics, plots, regressions, etc

```
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.
```

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    - “Rectangular” data (i.e. “spreadsheet”): rows are observations, columns are variables

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##    <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
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```

Data Frames

- The most important object in R is a data frame, used for statistics, plots, regressions, etc
    - “Rectangular” data (i.e. “spreadsheet”): rows are observations, columns are variables
    - Can hold variables of different classes, but all columns must have the same length

```
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.
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```

Data Frames: From Scratch

- We often import existing data into a dataframe (see importing data below)

```
v1<-c(10,20,30,45,60) # A list of integers
v2<-LETTERS[1:5] # The first 5 letters
v3<-round(rnorm(5),2) #5 random draws from normal distr, rounded to 2 decimals
v4<-c(”Apples”,”Oranges”,”Bananas”,”Kiwi”,”Watermelon”) #Fruits
mydf<-data.frame(v1,v2,v3,v4) #make dataframe called mydf
```

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- We could construct a data frame from scratch using **data.frame()**

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```

Data Frames: From Scratch

- We often import existing data into a dataframe (see importing data below)
- We could construct a data frame from scratch using **data.frame()**
- Suppose we have 4 different vectors, v1, v2, v3, and v4

```r
v1<-c(10,20,30,45,60) # A list of integers
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mydf<-data.frame(v1,v2,v3,v4) #make dataframe called mydf
```

Data Frames: From Scratch

- Check the structure of a data frame with `str()`

```
str(mydf) #examine structure
```

```
## 'data.frame':    5 obs. of  4 variables:
##  $ v1: num  10 20 30 45 60
##  $ v2: Factor w/ 5 levels ”A”,”B”,”C”,”D”,..: 1 2 3 4 5
##  $ v3: num  0.75 -1.23 -0.89 -0.37 0.62
##  $ v4: Factor w/ 5 levels ”Apples”,”Bananas”,..: 1 4 2 3 5
```

```
class(mydf) #check it's a dataframe
```

```
## [1] ”data.frame”
```

Data Frames: From Scratch

- Note instead of making the vectors first and then combining them into a data frame, we could have done it all at once with one command:

```
mydf<-data.frame(v1=c(10,20,30,45,60),
                v2=LETTERS[1:5],
                v3=round(rnorm(5),2),
                v4=c(”Apples”,”Oranges”,”Bananas”,”Kiwi”,”Watermelon”))
```

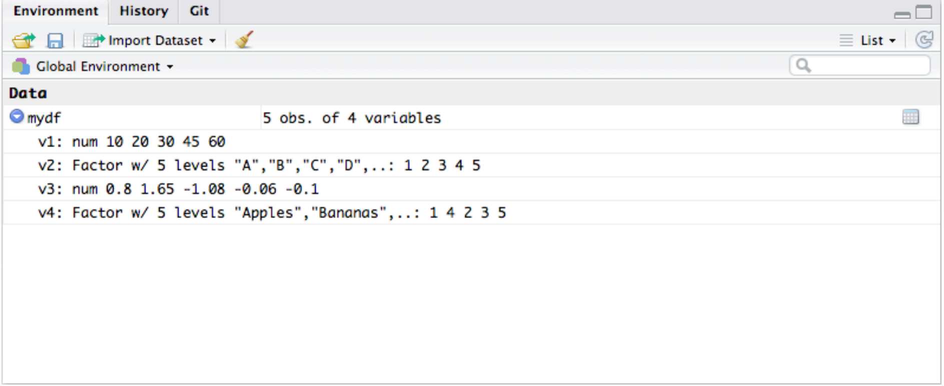
Data Frames: From Scratch

- Note instead of making the vectors first and then combining them into a data frame, we could have done it all at once with one command:
    - The string in front of the = (e.g. v1, v2, etc.) give the **name** for each column (variable)

```
mydf<-data.frame(v1=c(10,20,30,45,60),
                v2=LETTERS[1:5],
                v3=round(rnorm(5),2),
                v4=c(”Apples”,”Oranges”,”Bananas”,”Kiwi”,”Watermelon”))
```

Data Frames: Viewing I

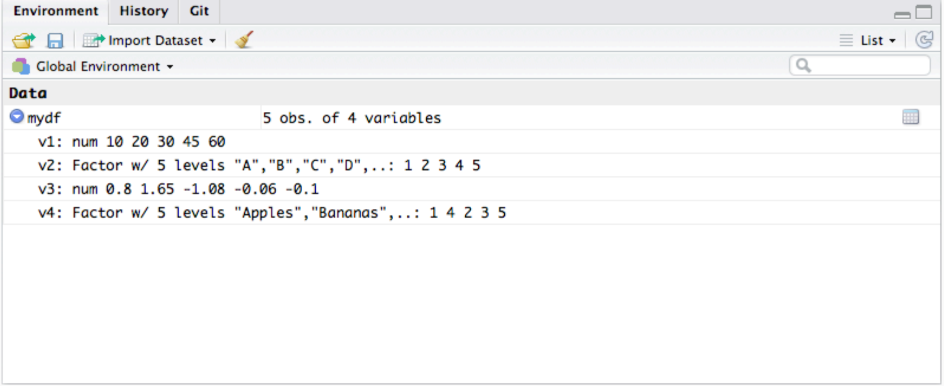
- Note, once you save an object, it shows up in the **Environment Pane** in the upper right window



```
mydf                          5 obs. of 4 variables
    v1: num 10 20 30 45 60
    v2: Factor w/ 5 levels "A","B","C","D",..: 1 2 3 4 5
    v3: num 0.8 1.65 -1.08 -0.06 -0.1
    v4: Factor w/ 5 levels "Apples","Bananas",..: 1 4 2 3 5
```

Data Frames: Viewing I

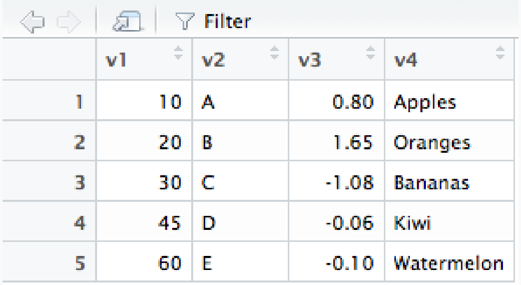
- Note, once you save an object, it shows up in the **Environment Pane** in the upper right window
- Click the arrow button in front of the object for some more information



```
mydf                          5 obs. of 4 variables
    v1: num 10 20 30 45 60
    v2: Factor w/ 5 levels "A","B","C","D",..: 1 2 3 4 5
    v3: num 0.8 1.65 -1.08 -0.06 -0.1
    v4: Factor w/ 5 levels "Apples","Bananas",..: 1 4 2 3 5
```

Data Frames: Viewing II

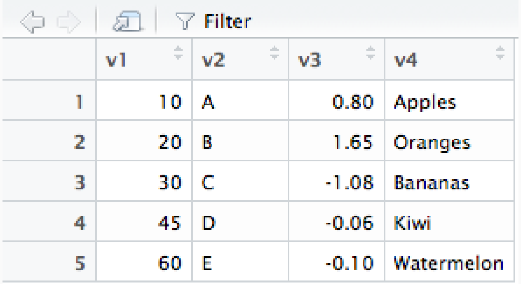
- `data.frame` objects can be viewed in their own panel by clicking on the name of the object



	v1	v2	v3	v4
1	10	A	0.80	Apples
2	20	B	1.65	Oranges
3	30	C	-1.08	Bananas
4	45	D	-0.06	Kiwi
5	60	E	-0.10	Watermelon

Data Frames: Viewing II

- `data.frame` objects can be viewed in their own panel by clicking on the name of the object
- Note you cannot edit anything in this pane, it is for viewing only



	v1	v2	v3	v4
1	10	A	0.80	Apples
2	20	B	1.65	Oranges
3	30	C	-1.08	Bananas
4	45	D	-0.06	Kiwi
5	60	E	-0.10	Watermelon

Data Frames: Quick Look

- We will use the existing `gapminder` dataset as a quick example, note we need to load (or install it) first

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- str() will give us a sense of the structure

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- **str()** will give us a sense of the structure

```
library(”gapminder”) #load gapminder
str(gapminder) #examine structure of dataset
```

```
## Classes 'tbl_df', 'tbl' and 'data.frame':    1704 obs. of  6 variables:
##  $ country  : Factor w/ 142 levels ”Afghanistan”,..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ continent: Factor w/ 5 levels ”Africa”,”Americas”,..: 3 3 3 3 3 3 3 3 3 3
##  $ year     : int  1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 ...
##  $ lifeExp  : num  28.8 30.3 32 34 36.1 ...
##  $ pop      : int  8425333 9240934 10267083 11537966 13079460 14880372 12881
##  $ gdpPercap: num  779 821 853 836 740 ...
```

Data Frames: Quick Look

- **head()** will show us the top 6 rows (observations)

```
head(gapminder)
```

```
## # A tibble: 6 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.
```

Data Frames: Quick Look

- **summary()** will give us a summary statistics of each variable (columns)

```
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
##       pop              gdpPercap
##  Min.   :6.001e+04   Min.   :   241.2
```

Data Frames: Selecting Columns (Variables)

- Each variable is stored as a part of a data frame that can be called with the $ sign

Data Frames: Selecting Columns (Variables)

- Each variable is stored as a part of a data frame that can be called with the $ sign
  - e.g. with the **`gapminder`** data, *GDP per capita* (coded in the dataset as **`gdpPercap`**) can be called with **`gapminder$gdpPercap`**:

```
summary(gapminder$gdpPercap)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
##    241.2   1202.1   3531.8   7215.3   9325.5 113523.1
```

```
mean(gapminder$gdpPercap)
```

```
## [1] 7215.327
```

Quick Data Analysis Example

Summary Statistics

- Learn about a variable's distribution quickly (example variable called `distr`):

Function	Result
`min(distr)`	Find minimum value
`max(distr)`	Find maximum value
`range(distr)`	Find the range
`sort(distr)`	Sort values of distribution from smallest to largest
`sort(distr)[1]`	Find first value when sorted (equvalient to finding min)
`sort(distr, decreasing=TRUE)`	Sort from largest to smallest
`median(distr)`	Find the median
`mean(distr)`	Find the mean
`var(distr)`	Find the variance
`sd(distr)`	Find the standard deviation

Summary Statistics II

Function	Result
`table(distr)`	Gives frequency table of categorical variable values
`fivenum(distr)`	Five number summary (min, q1, median, q3, max)
`summary(distr)`	Gives min, q1, median, mean, q3, max
`quantile(distr, 0.32)`	Find specific (e.g. 32^{nd}) percentile
`summary(factor(distr))`	Lists all unique values in distr
`sum(distr)`	Takes the sum of all values in distr

Summary Statistics: Example

```
summary(gapminder$gdpPercap)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
##    241.2   1202.1   3531.8   7215.3   9325.5 113523.1
```

```
mean(gapminder$pop)
```

```
## [1] 29601212
```

```
table(gapminder$continent)
```

```
##
##   Africa Americas     Asia   Europe  Oceania
##      624      300      396      360       24
```

Plotting

- Base R is very powerful and intuitive to plot, but not very sexy

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```
plottype(data.frame.name$variable)
```

- If using multiple variables, you can avoid $ by typing the variable names and then telling R where the variables come from (a data frame)

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- Base R is very powerful and intuitive to plot, but not very sexy
- Basic syntax:

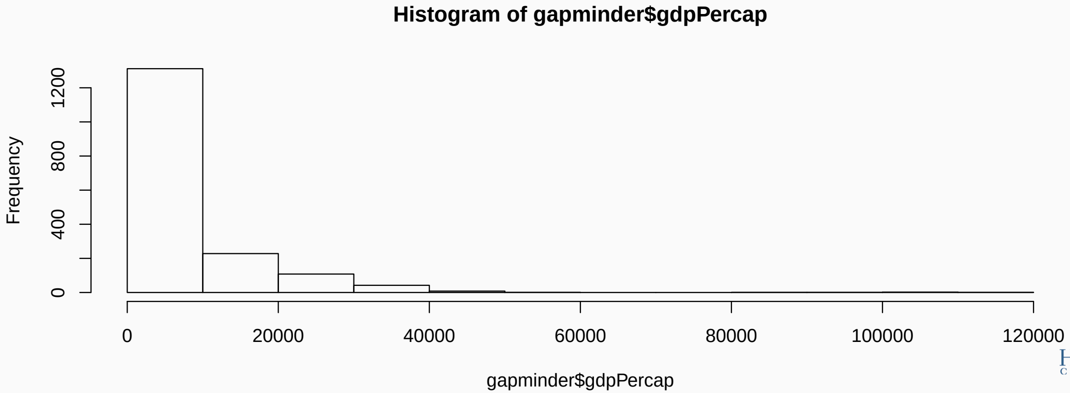
```
plottype(data.frame.name$variable)
```

- If using multiple variables, you can avoid $ by typing the variable names and then telling R where the variables come from (a data frame)

```
plottype(variable1,variable2, data=data.frame.name)
```

Plotting: Histogram

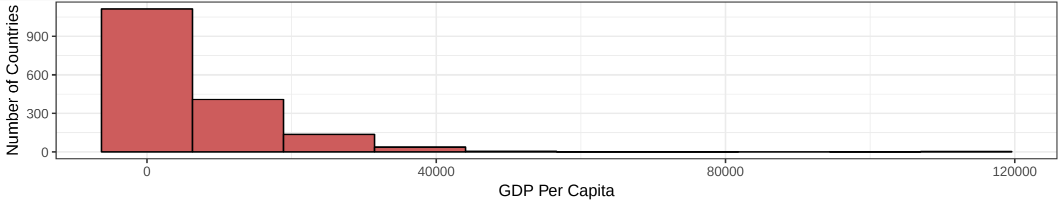
```
hist(gapminder$gdpPercap)
```



Plotting: Histogram with ggplot2

- Packages (like ggplot2) come in to make things prettier, but we'll have to learn later

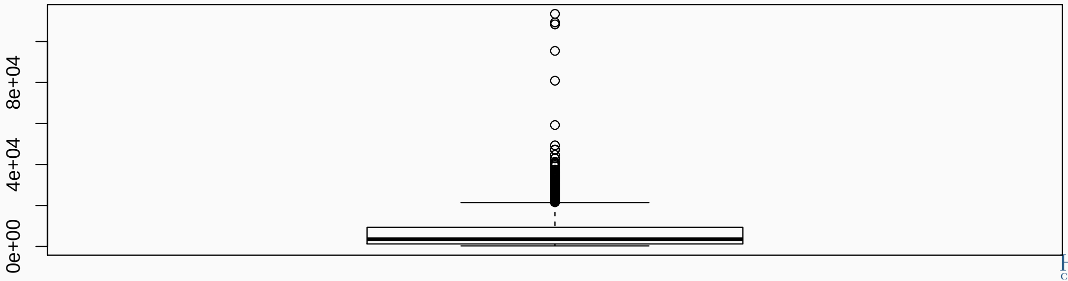
```
library("ggplot2")
ggplot(gapminder, aes(x=gdpPercap))+
  geom_histogram(bins=10, color="black",fill="indianred")+
  xlab("GDP Per Capita")+ylab("Number of Countries")+
  theme_bw()
```



Plotting: Boxplot

- Boxplots are similar syntax

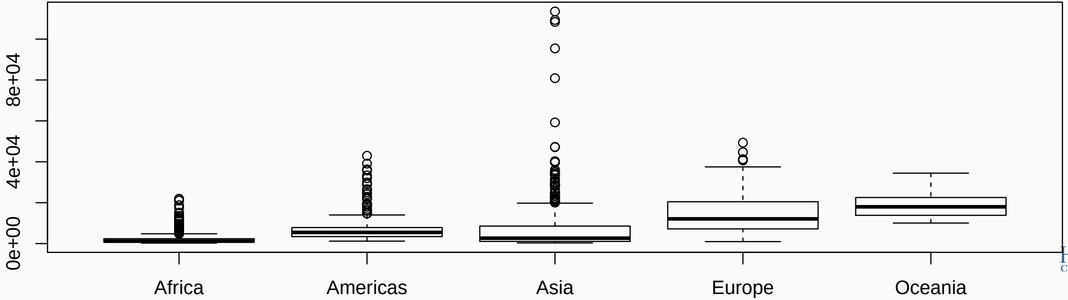
```
boxplot(gapminder$gdpPercap)
```



Plotting: Boxplot II

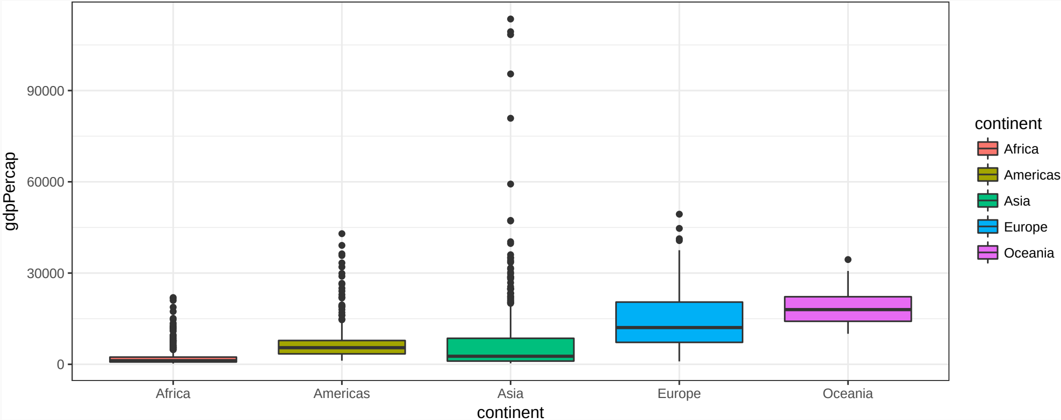
- If we want a boxplot for each category, use `variable.name~category.variable.name` to tell R to plot a boxplot **by** category

```r
boxplot(gdpPercap~continent,data=gapminder)
```



Plotting: Boxplot with ggplot2

```r
ggplot(gapminder, aes(x=continent,y=gdpPercap ,fill=continent))+
    geom_boxplot()+ theme_bw()
```


gdpPercap
Africa
Americas
Asia
Europe
Oceania
continent
continent
Africa
Americas
Asia
Europe
Oceania