Welcome!

1. Log in using Windows
2. Go to github.com/sjfox/R_intro, and download the materials
3. Open up RStudio

Introduction to R

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31 March 2015

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Workshop goals

Workshop goals

- Learn to run code in R

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- Learn to run code in R
- Play with R without getting bogged down with programming

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- Learn to run code in R
- Play with R without getting bogged down with programming
- Become familiar enough to google

Workshop goals

- Learn to run code in R
- Play with R without getting bogged down with programming
- Become familiar enough to google
- Make a few nice looking graphics

Workshop outline

Workshop outline

- Introductory information (Slides)

Workshop outline

- Introductory information (Slides)
- First coding session
  - Using R

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- Introductory information (Slides)
- First coding session
  - Using R
- Basics of R programming (Slides)

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- Introductory information (Slides)
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  - Using R
- Basics of R programming (Slides)
- Second coding session
  - R data structures and coding

Workshop outline

- Introductory information (Slides)
- First coding session
  - Using R
- Basics of R programming (Slides)
- Second coding session
  - R data structures and coding
- Basics of plotting (Slides)

Workshop outline

- Introductory information (Slides)
- First coding session
  - Using R
- Basics of R programming (Slides)
- Second coding session
  - R data structures and coding
- Basics of plotting (Slides)
- Final coding session
  - ggplot

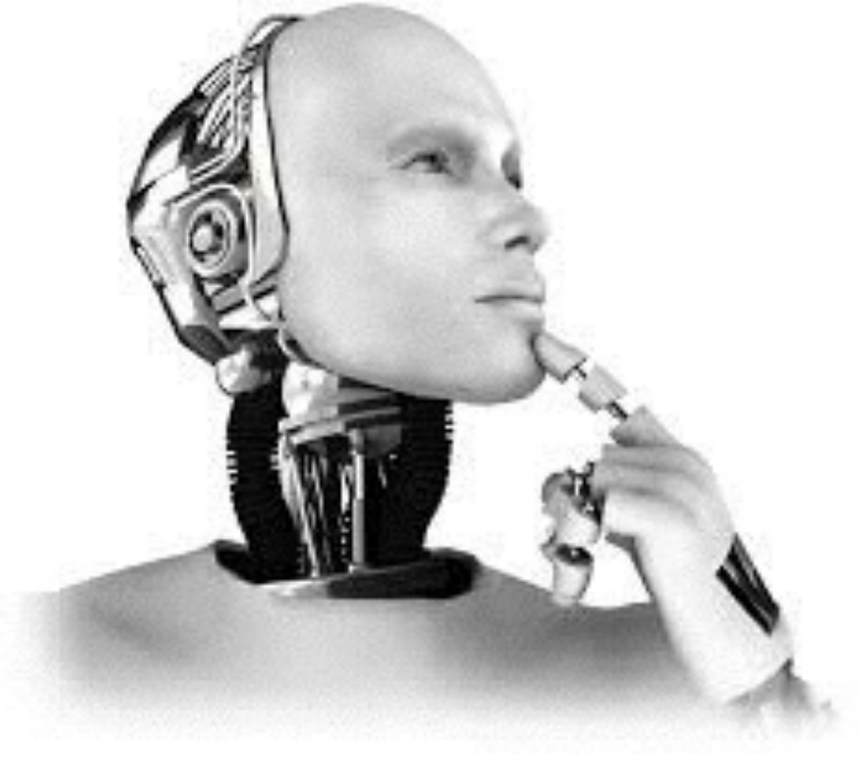
Why program?

Why program?

- Reproducibility

Why program?

- Reproducibility
- Automation



What is R?

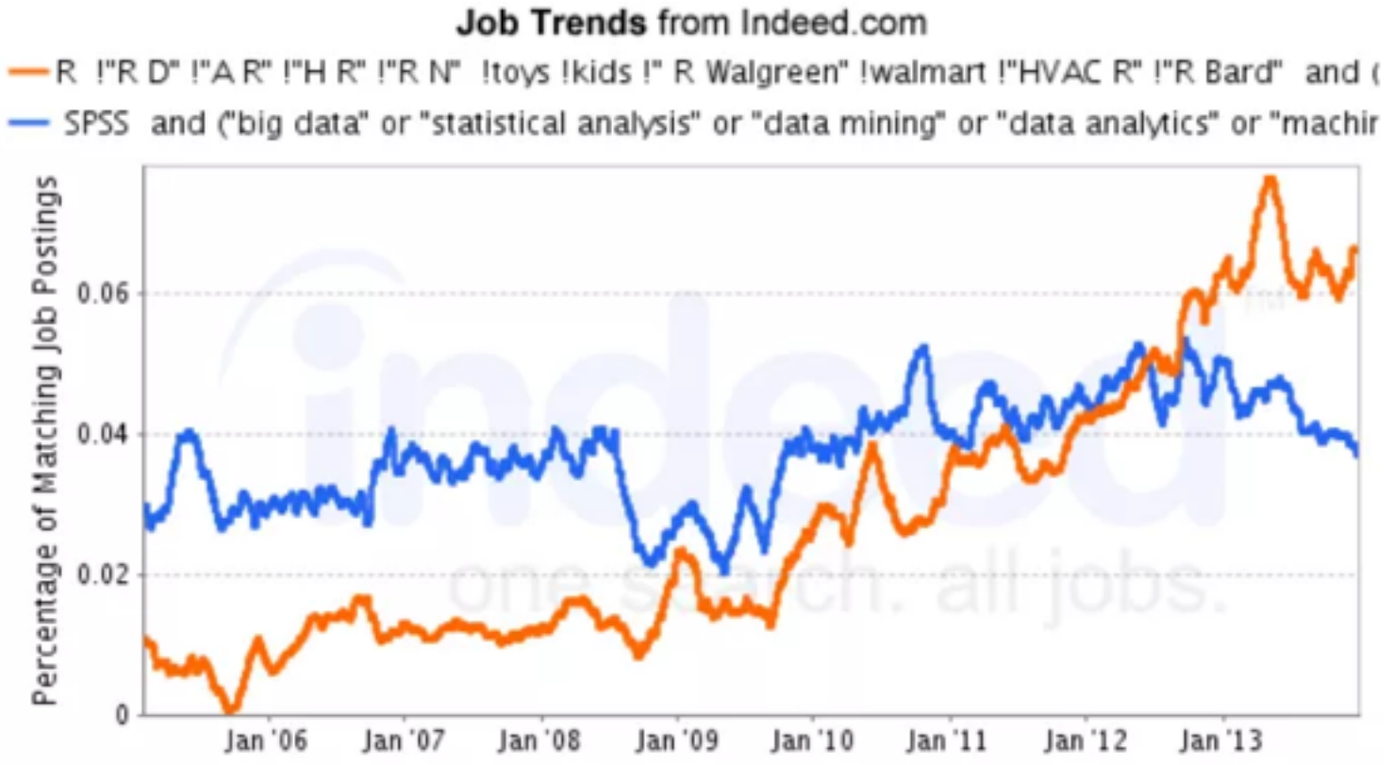
What is R?

- Flexible programming language made by statisticians

What is R?

- Flexible programming language made by statisticians

- Open source and in demand



Why use R?

Why use R?

- Relatively simple

Why use R?

- Relatively simple
- Free

Why use R?

- Relatively simple
- Free
- Powerful

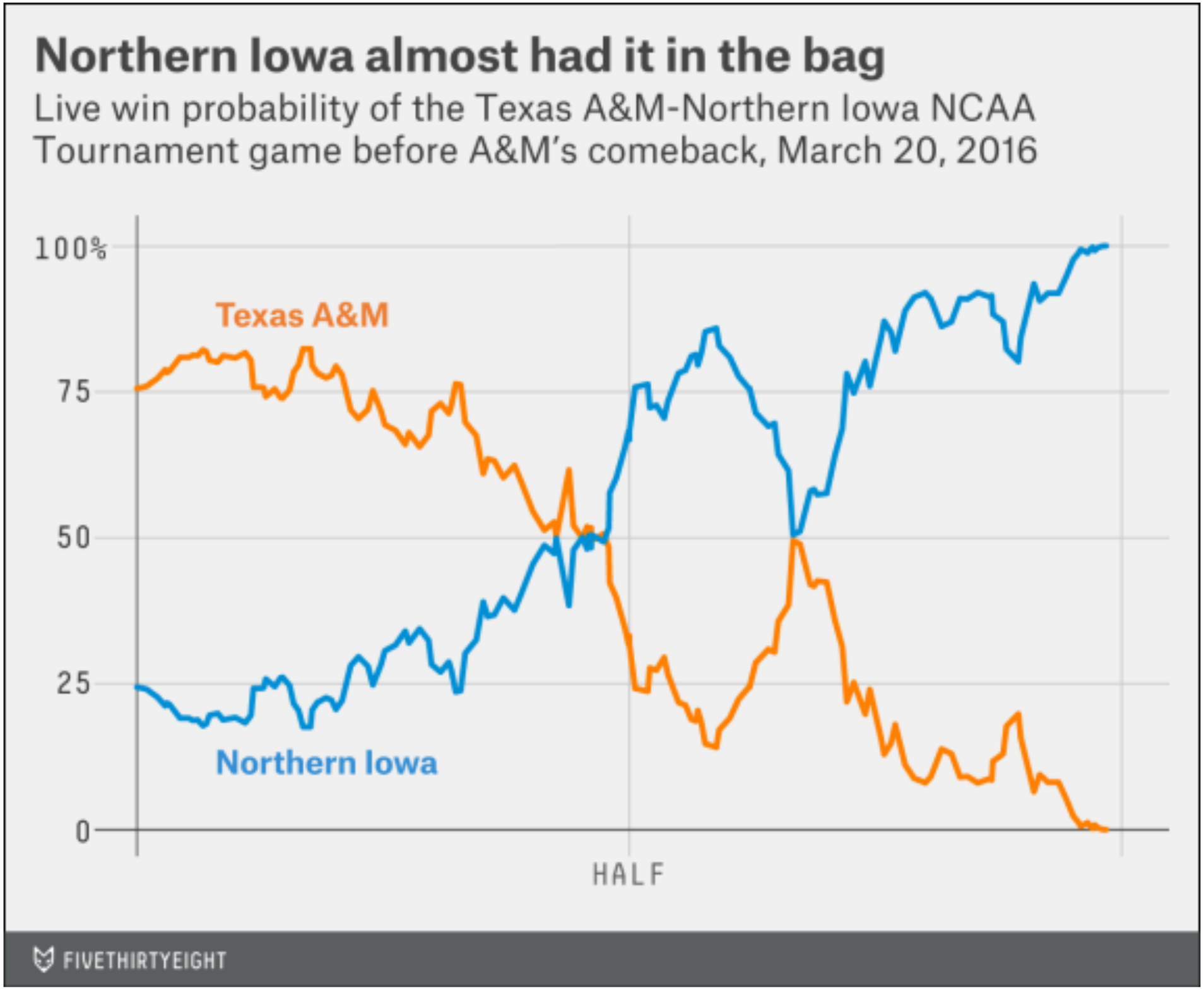
Why use R?

- Relatively simple
- Free
- Powerful
- Packages, packages, and more packages!

Why use R?

- Relatively simple
- Free
- Powerful
- Packages, packages, and more packages!
- Great visualization tools

Visualizing data



Example R “Pipeline”

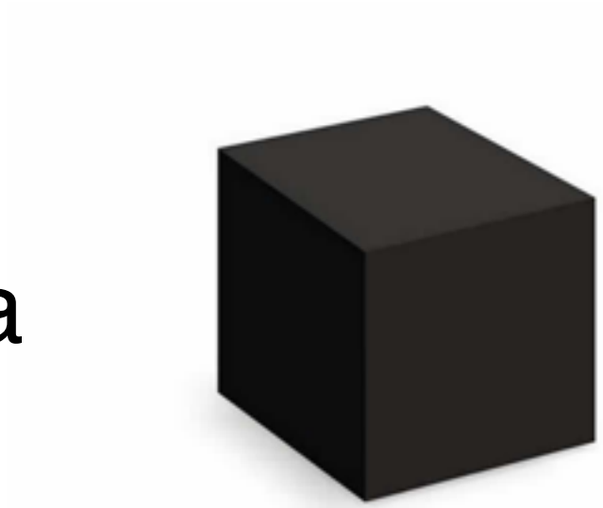
Example R “Pipeline”

1. Generate data

Example R “Pipeline”

1. Generate data

2. Analyze data

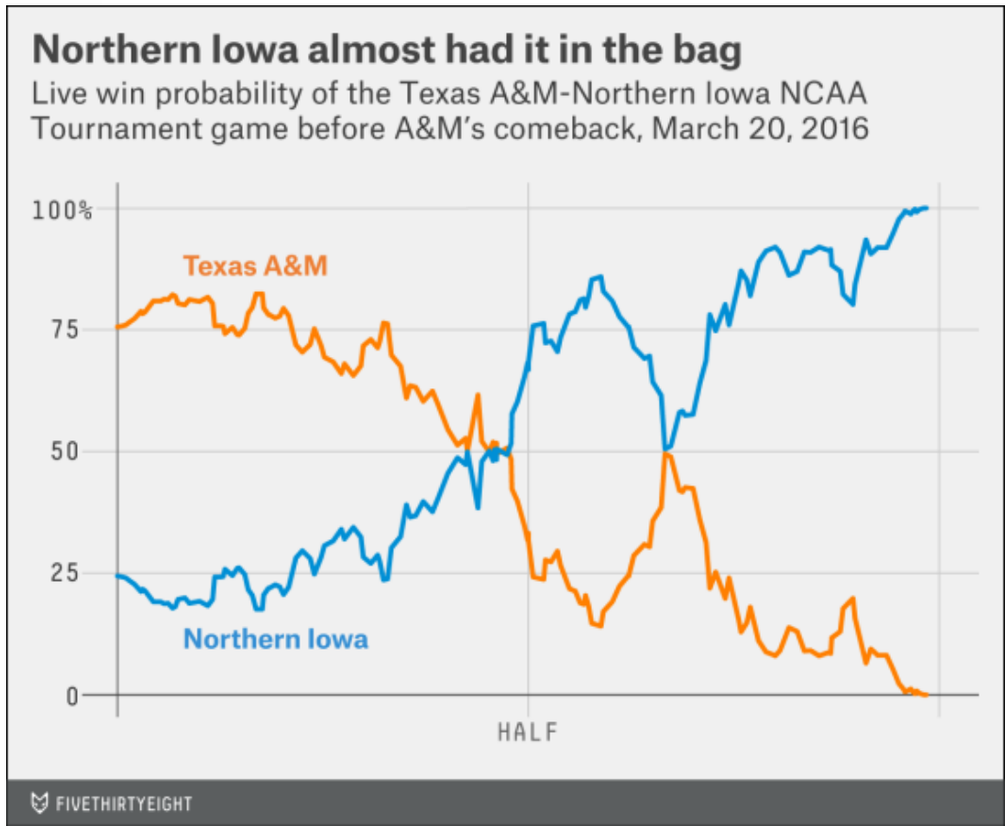


Example R “Pipeline”

1. Generate data

2. Analyze data

3. Show analysis



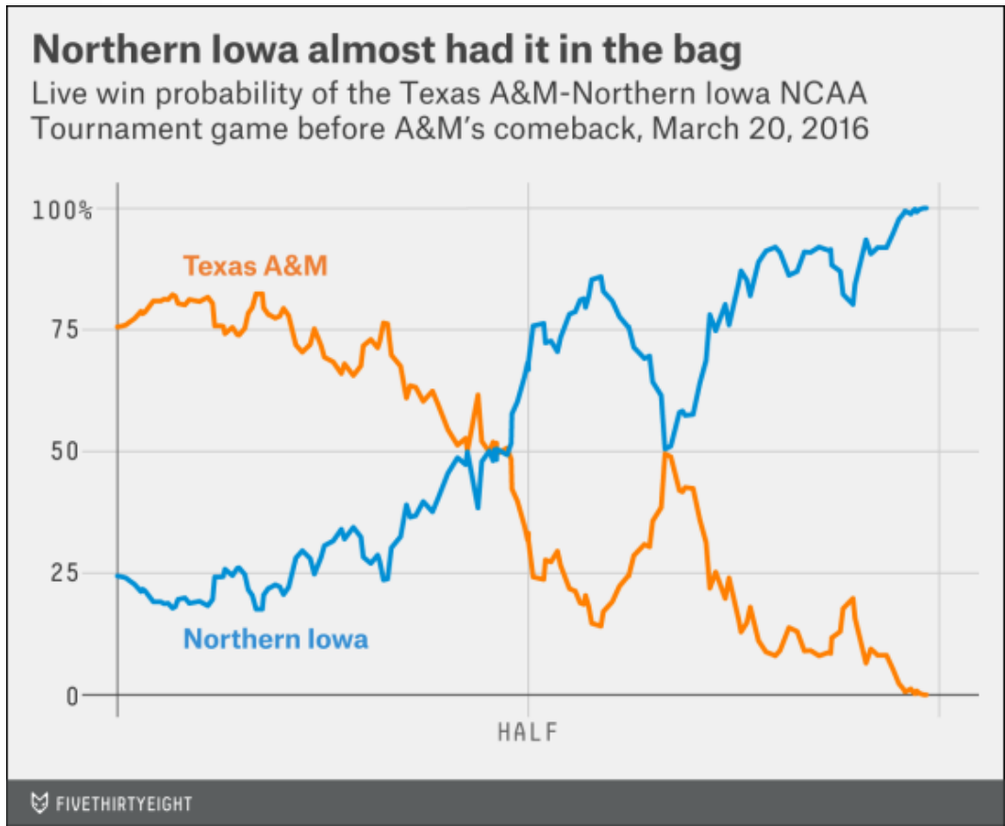
Example R “Pipeline”

1. Generate data

in R

2. Analyze data

3. Show analysis



Cooking a meal with R

Cooking a meal with R

What is the desired end product?

Cooking a meal with R

What is the desired end product?

What do we need to get it?

- Turkey
- Stuffing
- Green Beans
- Mashed Potatoes
- Gravy

Every dish has a function

Every dish has a function

Convert data to usable format

Every dish has a function

Convert data to usable format

Run a statistical analysis

Every dish has a function

Convert data to usable format

Run a statistical analysis

Run a 2nd stat analysis

Every dish has a function

Convert data to usable format

Make a summary plot

Run a statistical analysis

Run a 2nd stat analysis

Every function has a recipe

Every function has a recipe

1. Ingredients
    1. Green beans
    2. Creamy mushroom soup
    3. French fried onions

Every function has a recipe

1. Ingredients
    1. Green beans
    2. Creamy mushroom soup
    3. French fried onions
2. Instructions
    1. Heat oven to 350
    2. etc.

Every function has a recipe

1. Ingredients
    1. Green beans
    2. Creamy mushroom soup
    3. French fried onions
2. Instructions
    1. Heat oven to 350
    2. etc.
3. Output
    1. Green bean casserole!

I thought I was learning R!!!!

Every function has a “recipe”: Calculating a mean

Every function has a “recipe”: Calculating a mean

1. Ingredients

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers
    2. Sum all of the numbers

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers
    2. Sum all of the numbers
3. Output

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers
    2. Sum all of the numbers
3. Output
    1. Return Sum/Count

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers
    2. Sum all of the numbers
3. Output
    1. Return Sum/Count

```
get_mean = function(numbers){...}
```

Every function has a “recipe”: Calculating a mean

1. Ingredients
    1. List of numbers
2. Instructions
    1. Count numbers
    2. Sum all of the numbers
3. Output
    1. Return Sum/Count

```
get_mean = function(numbers){...}
```

```
> get_mean(numbers=c(2,4,6,8,10))
[1] 6
```

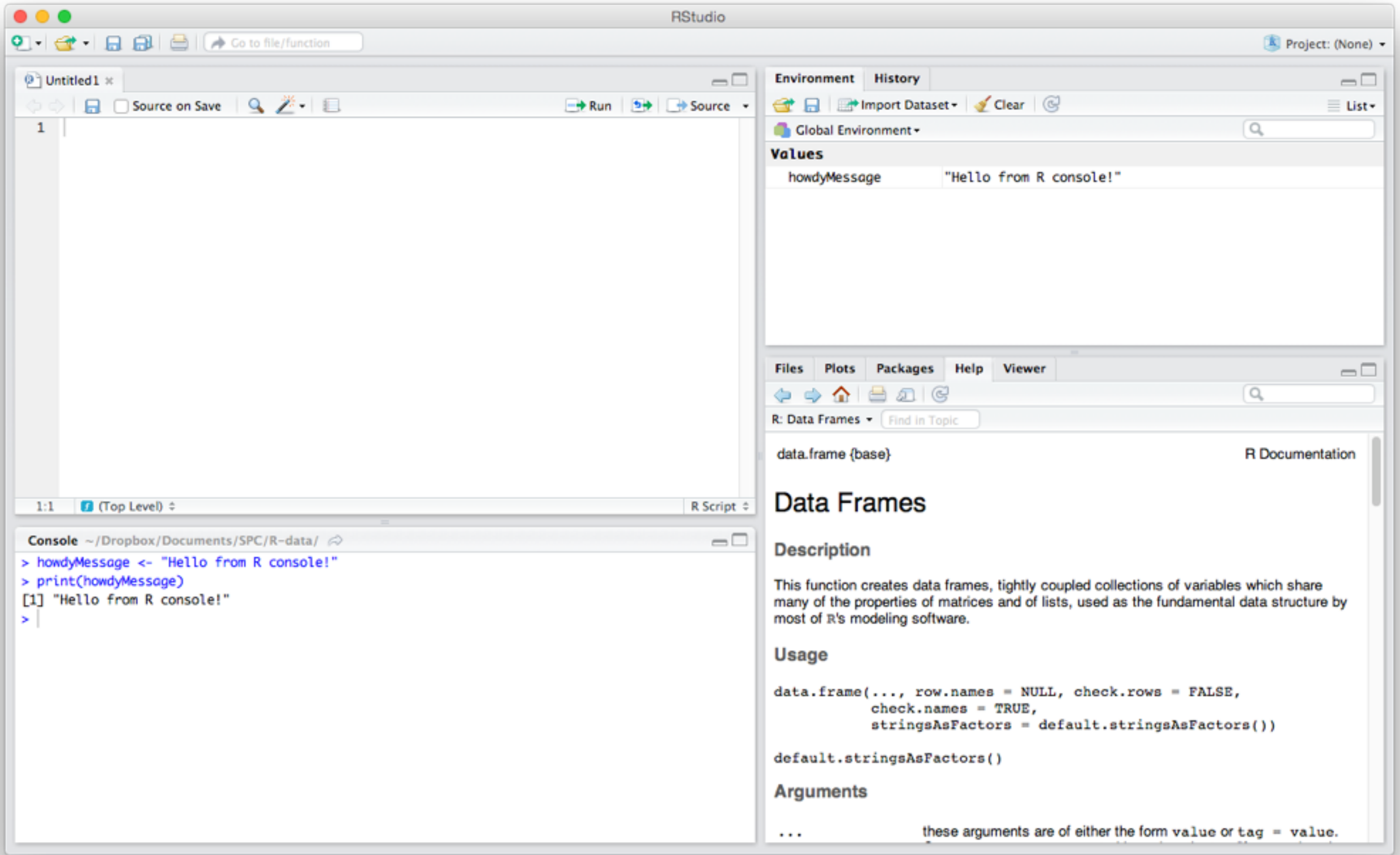
Why are packages so great?

Why are packages so great?

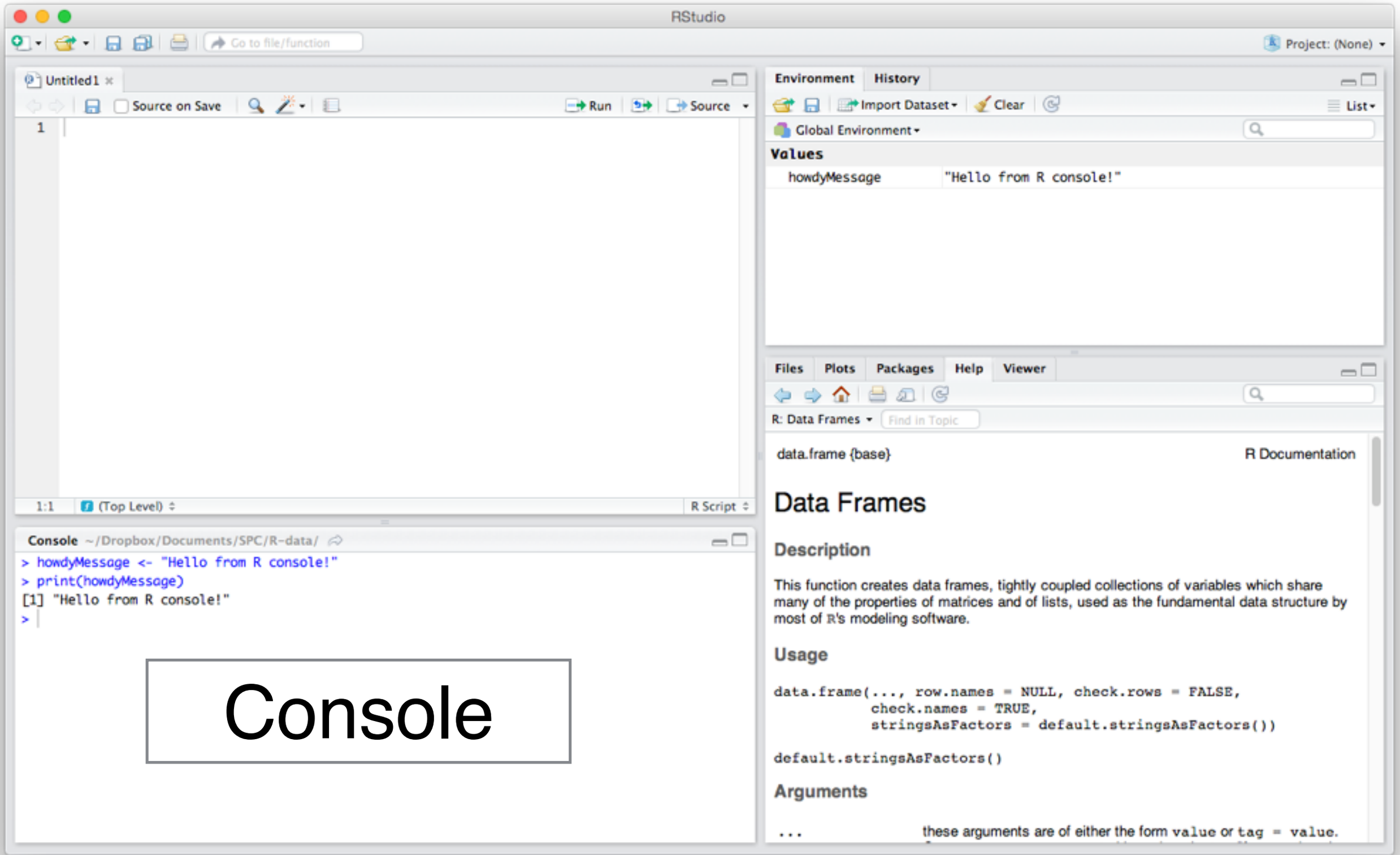
Why are packages so great?

Just need to understand inputs and outputs, and the rest is done for you.

Using R (RStudio)

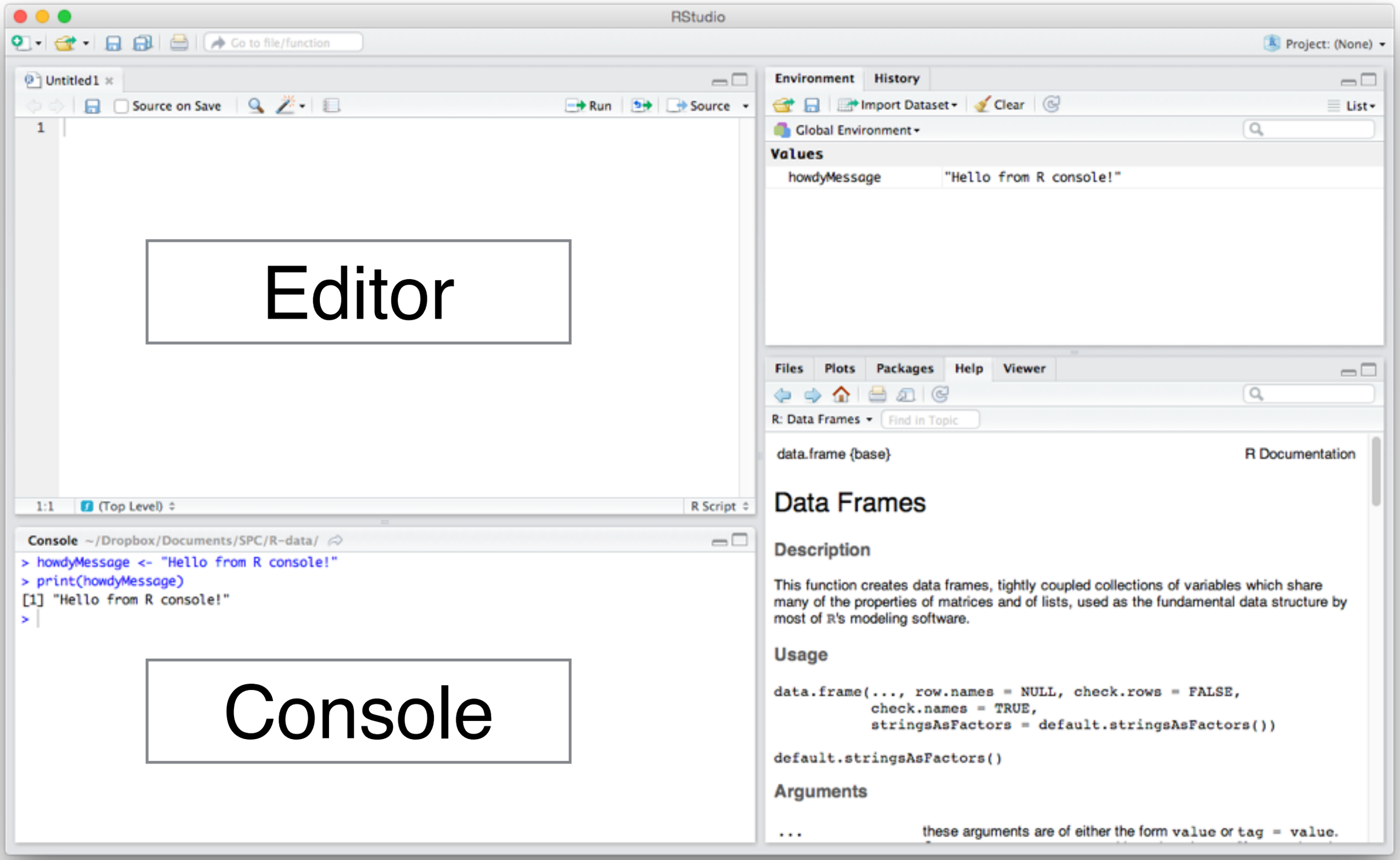


Using R (RStudio)

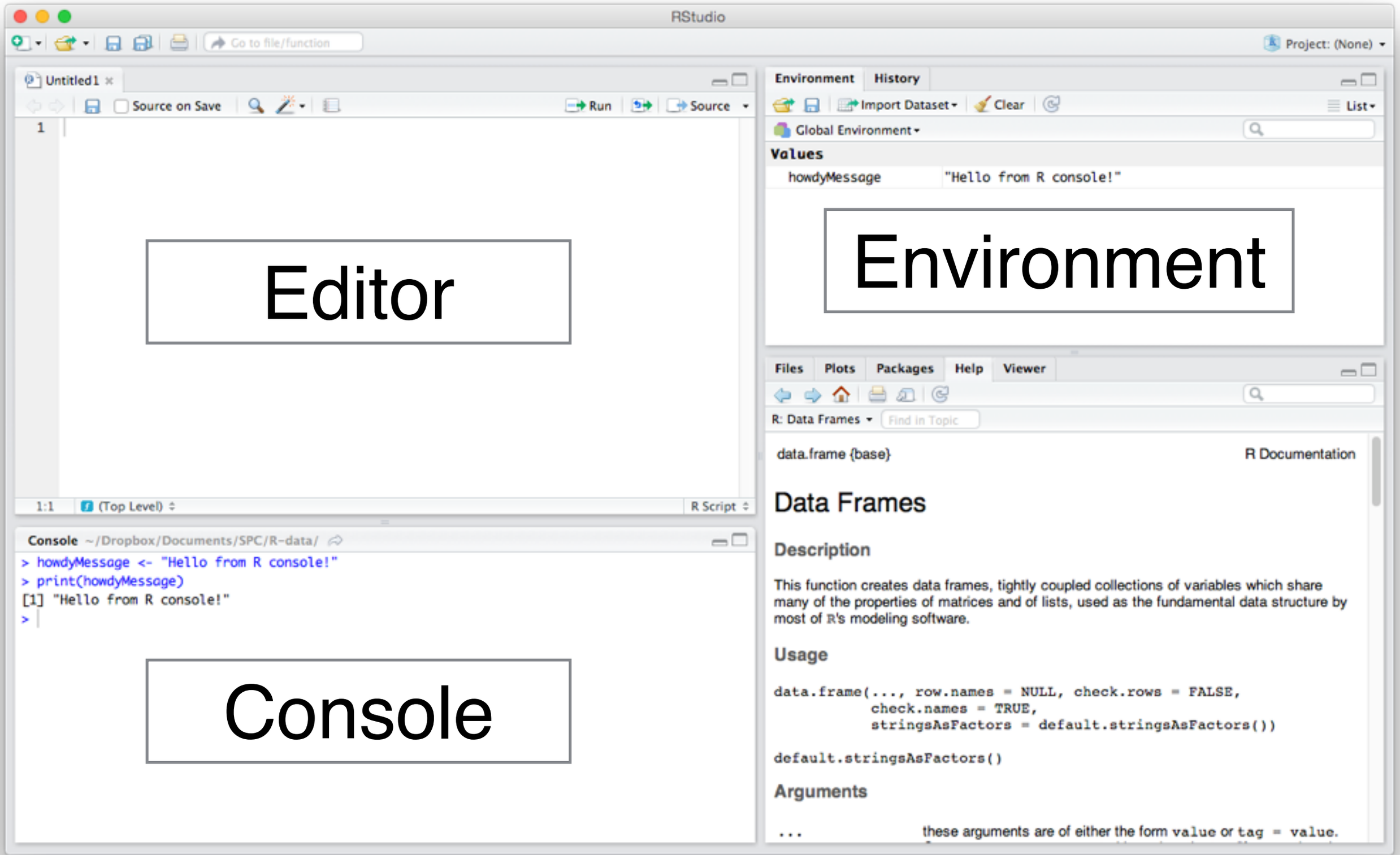


Console

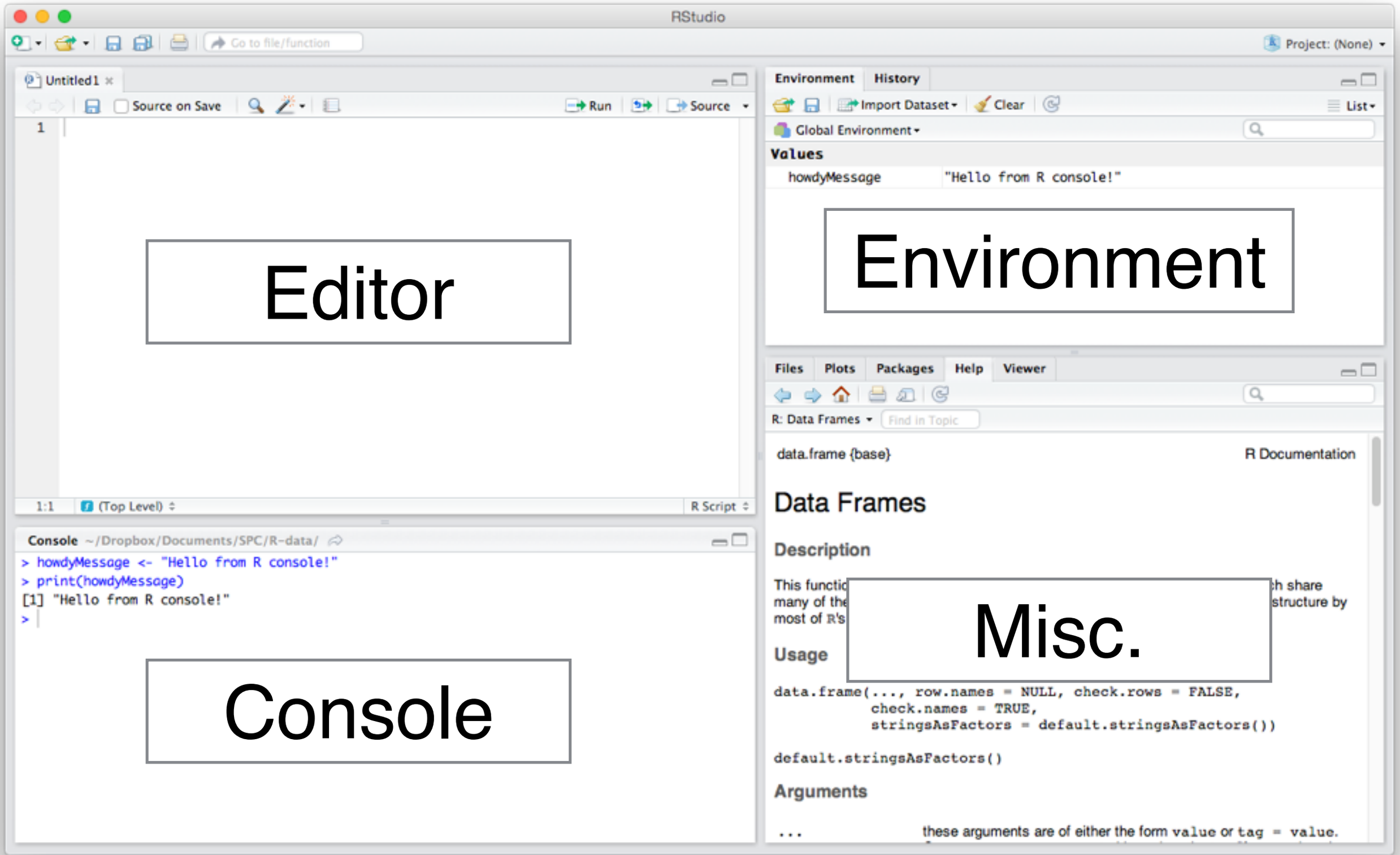
Using R (RStudio)



Using R (RStudio)



Using R (RStudio)



1st Programming Exercise

1. open up 1_package_intro.R in Rstudio
2. Start playing with code
    1. Do: run code, change things and see what happens
    2. Don't: change code until it works and move on without understanding why

How to run code:

1. Highlight line(s) of code in editor
2. Type, ctrl+enter (windows) or cmd+enter (mac)
3. See code running in console
4. View output/figures

R building blocks

At a basic level, R is a calculator

```
> 5+5
[1] 10
> 7*3
[1] 21
```

R building blocks

At a basic level, R is a calculator

```
> 5+5
[1] 10
> 7*3
[1] 21
```

But it's a smart calculator

```
> x = 5
> y = 3
> x*y
[1] 15
> x+y
[1] 8
```

R building blocks

A very smart calculator

```
> x = 1:10
> x
 [1]  1  2  3  4  5  6  7  8  9 10
> z = x*3
> z
```

R building blocks

A very smart calculator

```
> x = 1:10
> x
 [1]  1  2  3  4  5  6  7  8  9 10
> z = x*3
> z
 [1]  3  6  9 12 15 18 21 24 27 30
```

R data structures

Four basic atomic types

1. Character
2. Integer
3. Numeric
4. Logical

```
> x = "xyz"
> class(x)
[1] "character"
> x = 5L
> class(x)
[1] "integer"
> x = 5
> class(x)
[1] "numeric"
> x = TRUE
> class(x)
[1] "logical"
```

Four main data structures to hold atomic types

1. Vector
2. Matrix
3. Data frame
4. List

Four main data structures to hold atomic types

1. Vector
2. Matrix
3. Data frame
4. List

```
> x = vector("numeric", 10)
> x
 [1] 0 0 0 0 0 0 0 0 0 0
```

Four main data structures to hold atomic types

1. Vector
2. Matrix
3. Data frame
4. List

```
> x = vector("numeric", 10)
> x
 [1] 0 0 0 0 0 0 0 0 0 0
> x = matrix(2, nrow= 3, ncol = 8)
> x
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
[1,]    2    2    2    2    2    2    2    2
[2,]    2    2    2    2    2    2    2    2
[3,]    2    2    2    2    2    2    2    2
```

Four main data structures to hold atomic types

1. Vector
2. Matrix
3. Data frame
4. List

```
> x = vector("numeric", 10)
> x
 [1] 0 0 0 0 0 0 0 0 0 0
```

```
> x = matrix(2, nrow= 3, ncol = 8)
> x
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
[1,]    2    2    2    2    2    2    2    2
[2,]    2    2    2    2    2    2    2    2
[3,]    2    2    2    2    2    2    2    2
```

```
> x = data.frame(vec=vec, vec1=vec+1)
> x
  vec vec1
1   1    2
2   2    3
3   3    4
4   4    5
5   5    6
```

Four main data structures to hold atomic types

1. Vector
2. Matrix
3. Data frame
4. List

```
> x = vector("numeric", 10)
> x
 [1] 0 0 0 0 0 0 0 0 0 0
```

```
> x = matrix(2, nrow= 3, ncol = 8)
> x
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
[1,]    2    2    2    2    2    2    2    2
[2,]    2    2    2    2    2    2    2    2
[3,]    2    2    2    2    2    2    2    2
```

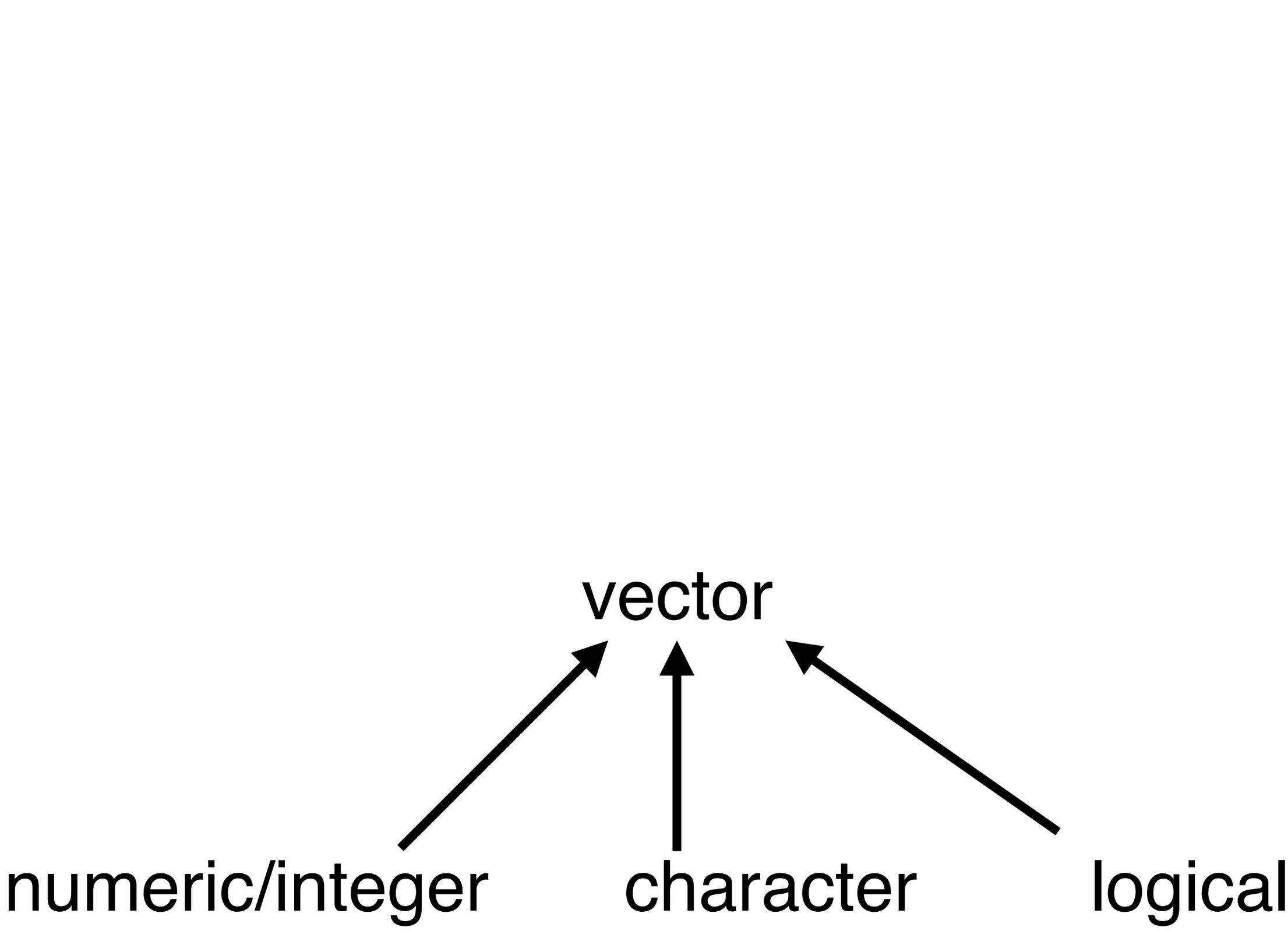
```
> x = data.frame(vec=vec, vec1=vec+1)
> x
  vec vec1
1   1    2
2   2    3
3   3    4
4   4    5
5   5    6
```

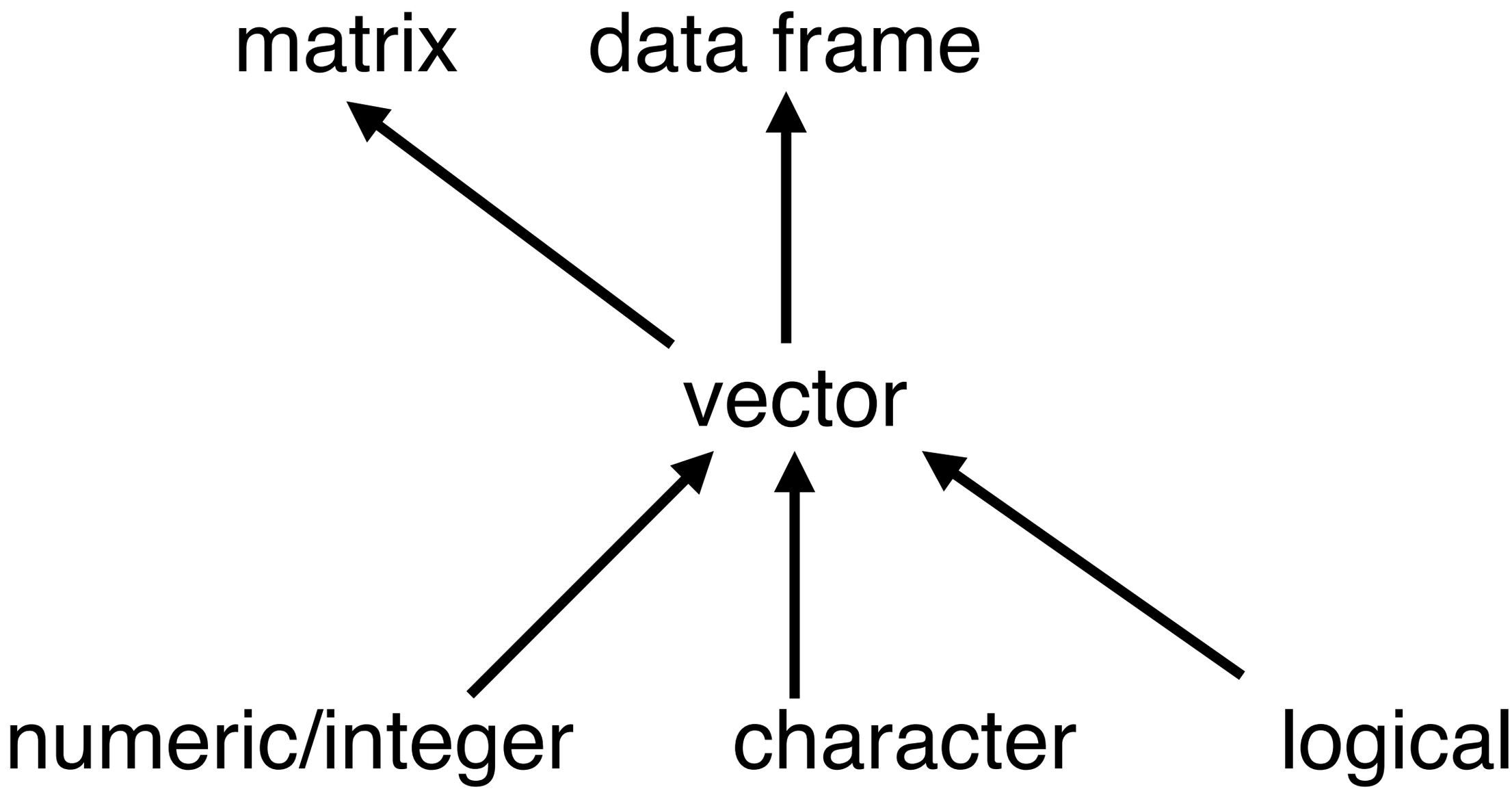
```
> list(1:5, 1:7, 1:3)
[[1]]
[1] 1 2 3 4 5

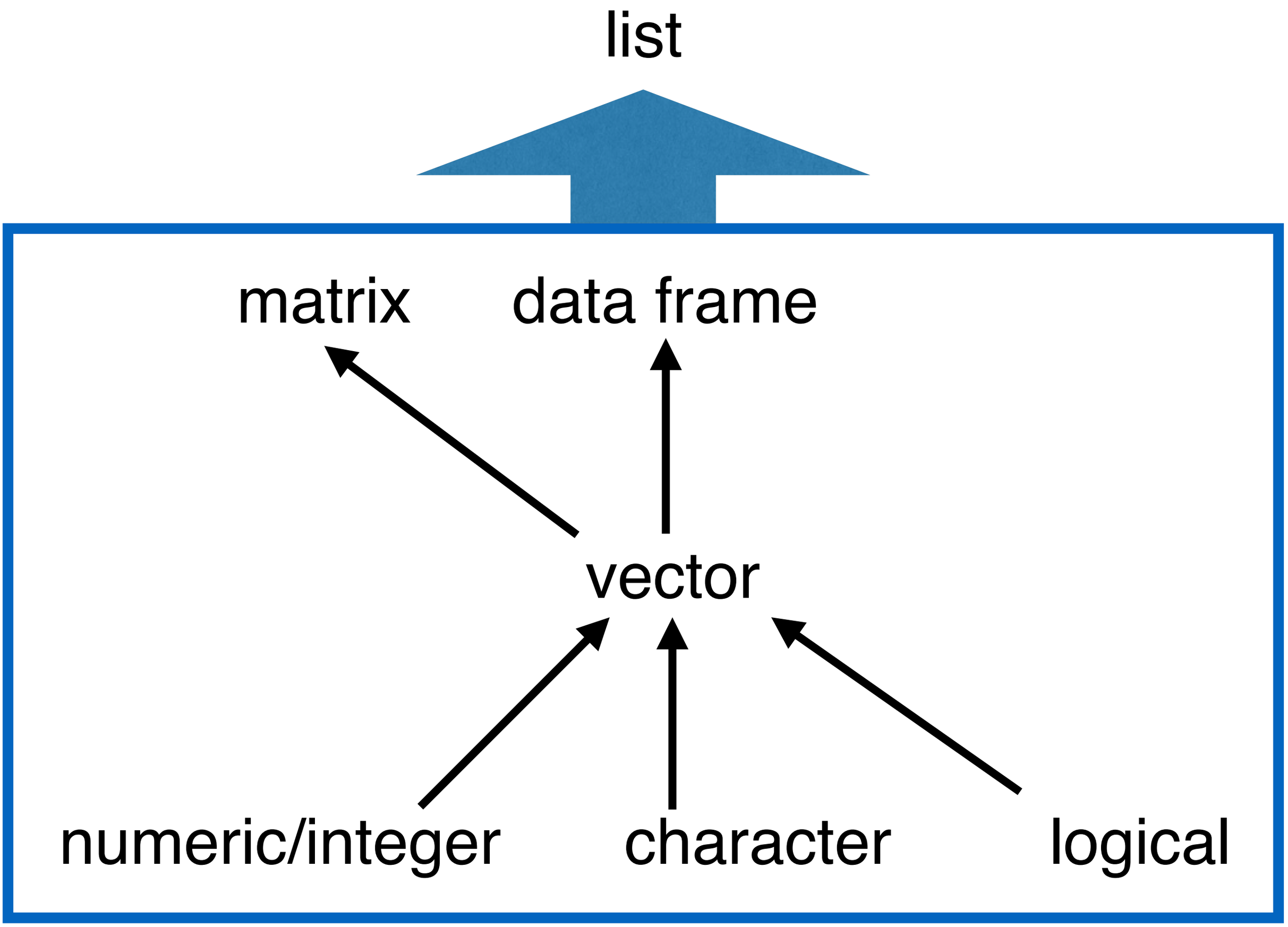
[[2]]
[1] 1 2 3 4 5 6 7

[[3]]
[1] 1 2 3
```

numeric/integer character logical


vector
numeric/integer
character
logical


matrix
data frame
vector
numeric/integer
character
logical


list
matrix
data frame
vector
numeric/integer
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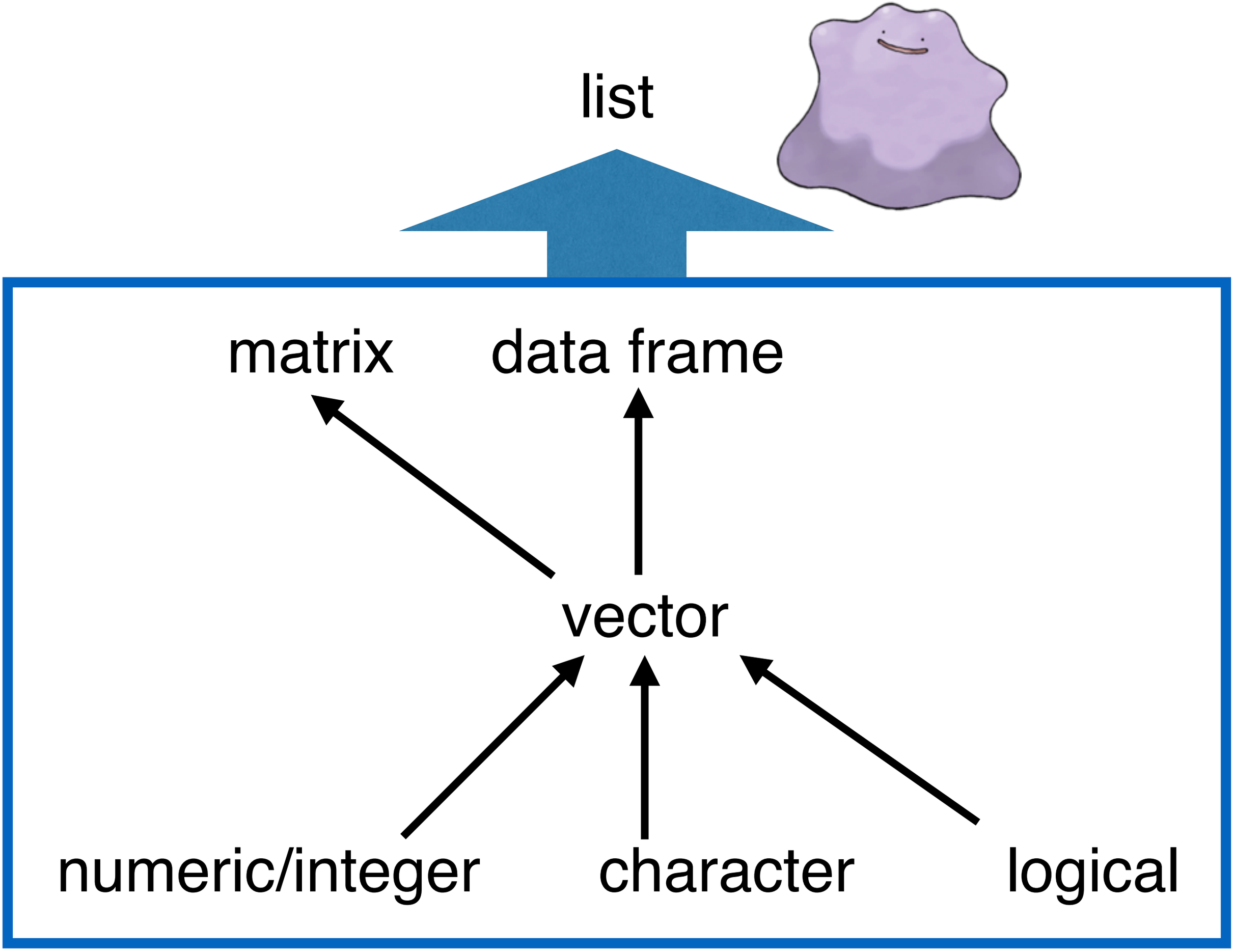
list
matrix
data frame
vector
numeric/integer
character
logical

You now have all of the main ingredients for your recipes

1. Numeric/character/logical
2. Vector
3. Matrix
4. Data frame
5. List

R cooking techniques (some of them)

1. Manipulating data
2. Flow control
3. Calling functions

Warning: A lot of information is coming.

Please ask questions as they come!

manipulating data: vectors

```
> vec = c("a", "b", "c", "d", "b", "f")
> vec
[1] "a" "b" "c" "d" "b" "f"
> vec[-1]
[1] "b" "c" "d" "b" "f"
> vec[3:6]
[1] "c" "d" "b" "f"
```

manipulating data: vectors

```
> vec = c("a", "b", "c", "d", "b", "f")
> vec
[1] "a" "b" "c" "d" "b" "f"
> vec[-1]
[1] "b" "c" "d" "b" "f"
> vec[3:6]
[1] "c" "d" "b" "f"
> vec=="b"
[1] FALSE  TRUE FALSE FALSE  TRUE FALSE
> indices = vec=="b"
> vec[indices]
[1] "b" "b"
```

manipulating data: vectors

```
> vec = c("a", "b", "c", "d", "b", "f")
> vec
[1] "a" "b" "c" "d" "b" "f"
> vec[-1]
[1] "b" "c" "d" "b" "f"
> vec[3:6]
[1] "c" "d" "b" "f"
> vec=="b"
[1] FALSE  TRUE FALSE FALSE  TRUE FALSE
> indices = vec=="b"
> vec[indices]
[1] "b" "b"
> which(vec=="b")
[1] 2 5
> vec[which(vec=="b")]
[1] "b" "b"
```

manipulating data: matrices

```
> matrix(1:25, ncol=5)
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    6   11   16   21
[2,]    2    7   12   17   22
[3,]    3    8   13   18   23
[4,]    4    9   14   19   24
[5,]    5   10   15   20   25
> mat = matrix(1:25, ncol=5)
> mat[2,3]
[1] 12
> mat[2:5,3]
[1] 12 13 14 15
> mat[1,]
[1]  1  6 11 16 21
> mat[,1]
[1] 1 2 3 4 5
```

manipulating data: matrices (cont)

```
> mat
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    6   11   16   21
[2,]    2    7   12   17   22
[3,]    3    8   13   18   23
[4,]    4    9   14   19   24
[5,]    5   10   15   20   25
> mat[,2]
[1]  6  7  8  9 10
> mat[which(mat[,2]==6), ]
[1]  1  6 11 16 21
```

manipulating data: data frames

```
> df
  temps water
1    70  1500
2    85  1495
3    79  1490
4    83  1450
5    90  1400
> df[,1]
[1] 70 85 79 83 90
> df$temps
[1] 70 85 79 83 90
```

manipulating data: data frames

```
> df
  temps water
1    70  1500
2    85  1495
3    79  1490
4    83  1450
5    90  1400
```

manipulating data: data frames

```
> df
  temps water
1    70  1500
2    85  1495
3    79  1490
4    83  1450
5    90  1400
> which(df$water<1490)
[1] 4 5
> df$temps[which(df$water<1490)]
[1] 83 90
```

manipulating data: data frames

```
> df
  temps water
1    70  1500
2    85  1495
3    79  1490
4    83  1450
5    90  1400
```

```
> which(df$water<1490)
[1] 4 5
> df$temps[which(df$water<1490)]
[1] 83 90
> df[which(df$water<1490),"temps"]
[1] 83 90
```

manipulating data: lists

```
> l
[[1]]
[1] 1 2 3 4 5

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

[[3]]
[1] 5 4 3

> l[1]
```

manipulating data: lists

```
> l
[[1]]
[1] 1 2 3 4 5

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

[[3]]
[1] 5 4 3
```

```
> l[1]
[[1]]
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```

```
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```

manipulating data: lists

```
> l
[[1]]
[1] 1 2 3 4 5

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[1]  3  4  5  6  7  8  9 10

[[3]]
[1] 5 4 3

> l[1]
[[1]]
[1] 1 2 3 4 5

> l[[1]]
[1] 1 2 3 4 5
```

manipulating data: lists

```
> l
[[1]]
[1] 1 2 3 4 5

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

[[3]]
[1] 5 4 3
```

```
> l[1]
[[1]]
[1] 1 2 3 4 5
```

```
> l[[1]]
[1] 1 2 3 4 5
```

```
> l[1:2]
[[1]]
[1] 1 2 3 4 5

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

flow control: if/else

```
x = 10
if(x==10){
  print("x equals 10")
}

x = 7
if(x==10){
  print("x equals 10")
} else if(x==7){
  print("x equals 7")
} else {
  print("x doesn't equal either 7 or 10")
}
```

flow control: for loop

```
vector = c(15, 30, 23, 23,12, 24, 54, 64, 23)
count = 0
for(ii in vector){
  count = count + ii
}
count
```

```
[1] 268
```

flow control: for loop

```
vector = c(15, 30, 23, 23,12, 24, 54, 64, 23)
count = 0
for(ii in vector){
  count = count + ii
}
count
```

```
[1] 268
```

```
count = 0
for(ii in 1:length(vector)){
  count = count + vector[ii]
}
count
```

```
[1] 268
```

functions

```
vector = c(15, 30, 23, 23,12, 24, 54, 64, 23)
> sum(vector)
[1] 268
> mean(vector)
[1] 29.77778
> max(vector)
[1] 64
> min(vector)
[1] 12
> summary(vector)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  12.00   23.00   23.00   29.78   30.00   64.00
```

functions

```
vector = c(15, 30, 23, 23,12, 24, 54, 64, 23)
> sum(vector)
[1] 268
> mean(vector)
[1] 29.77778
> max(vector)
[1] 64
> min(vector)
[1] 12
> summary(vector)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  12.00   23.00   23.00   29.78   30.00   64.00
```

There are a million useful functions, Google is your friend: “How to find number of rows in data frame in R?”

functions

```
vector = c(15, 30, 23, 23,12, 24, 54, 64, 23)
> sum(vector)
[1] 268
> mean(vector)
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[1] 12
> summary(vector)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  12.00   23.00   23.00   29.78   30.00   64.00
```

There are a million useful functions, Google is your friend: “How to find number of rows in data frame in R?”

```
nrow()
```

functions

Input and output

```
> ?sum
```

functions

Input and output

```
> ?sum
```

sum {base}

Sum of Vector Elements

Description

`sum` returns the sum of all the values present in its arguments.

Usage

```
sum(..., na.rm = FALSE)
```

Arguments

`...`	numeric or complex or logical vectors.
`na.rm`	logical. Should missing values (including `NaN`) be removed?

functions: creating your own

```
my_sum = function(vec){
  count = 0
  for(ii in vec){
    count = count + ii
  }
  count
}
```

functions: creating your own

```
my_sum = function(vec){
  count = 0
  for(ii in vec){
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  }
  count
}
```

```
> my_sum(vector)
[1] 268
```

functions: creating your own

```
my_sum = function(vec){
  count = 0
  for(ii in vec){
    count = count + ii
  }
  count
}
```

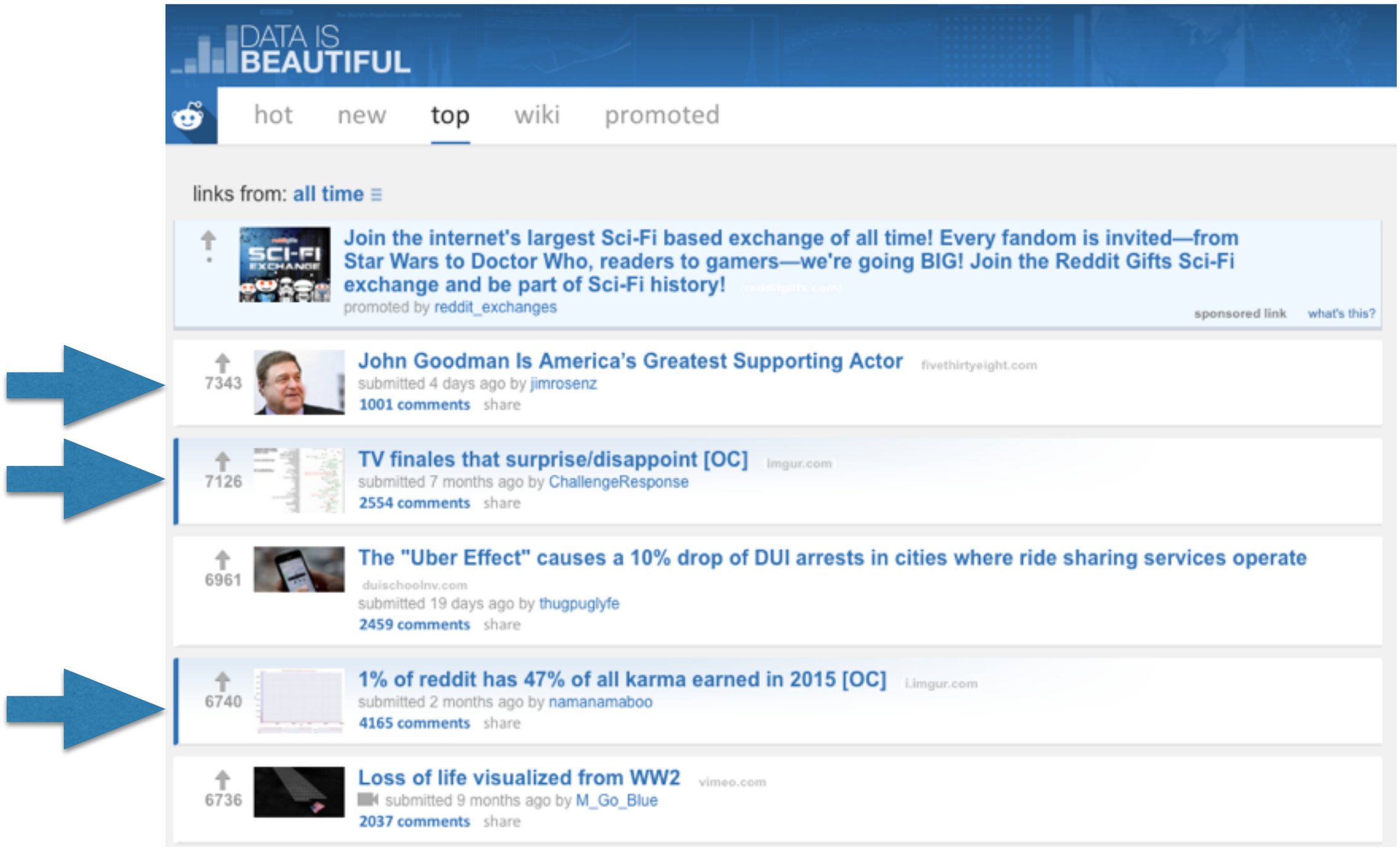
```
> my_sum(vector)
[1] 268
```

```
> new_vec = c(vector, 12, 15, 23, 13, 16, 23, 43)
> new_vec
 [1] 15 30 23 23 12 24 54 64 23 12 15 23 13 16 23 43
> my_sum(new_vec)
[1] 413
```

2nd Programming Exercise

1. open up 2_data_structures.R in Rstudio
2. Start playing with code

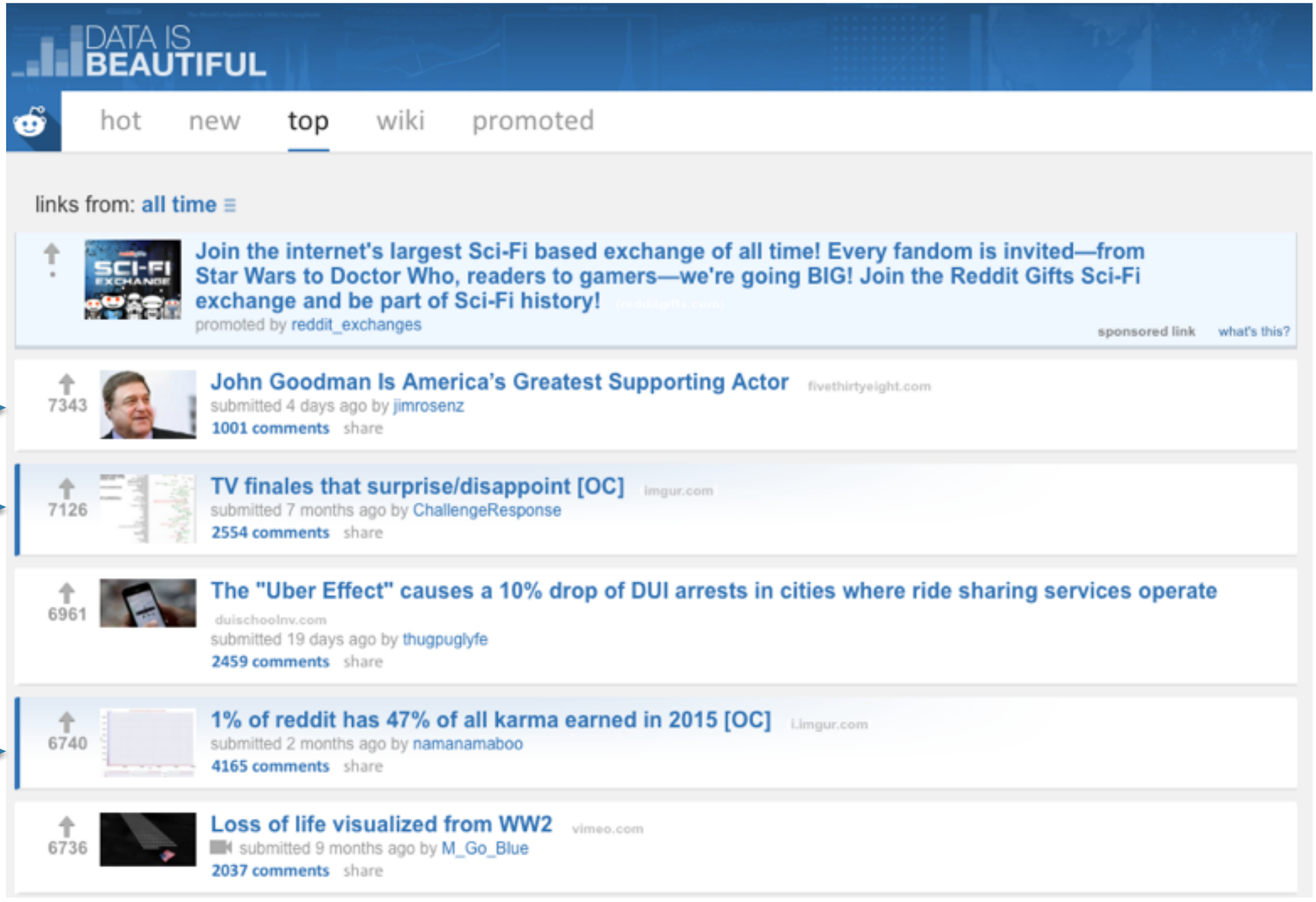
Visualizing data



www.reddit.com/r/dataisbeautiful

Visualizing data

ggplot2



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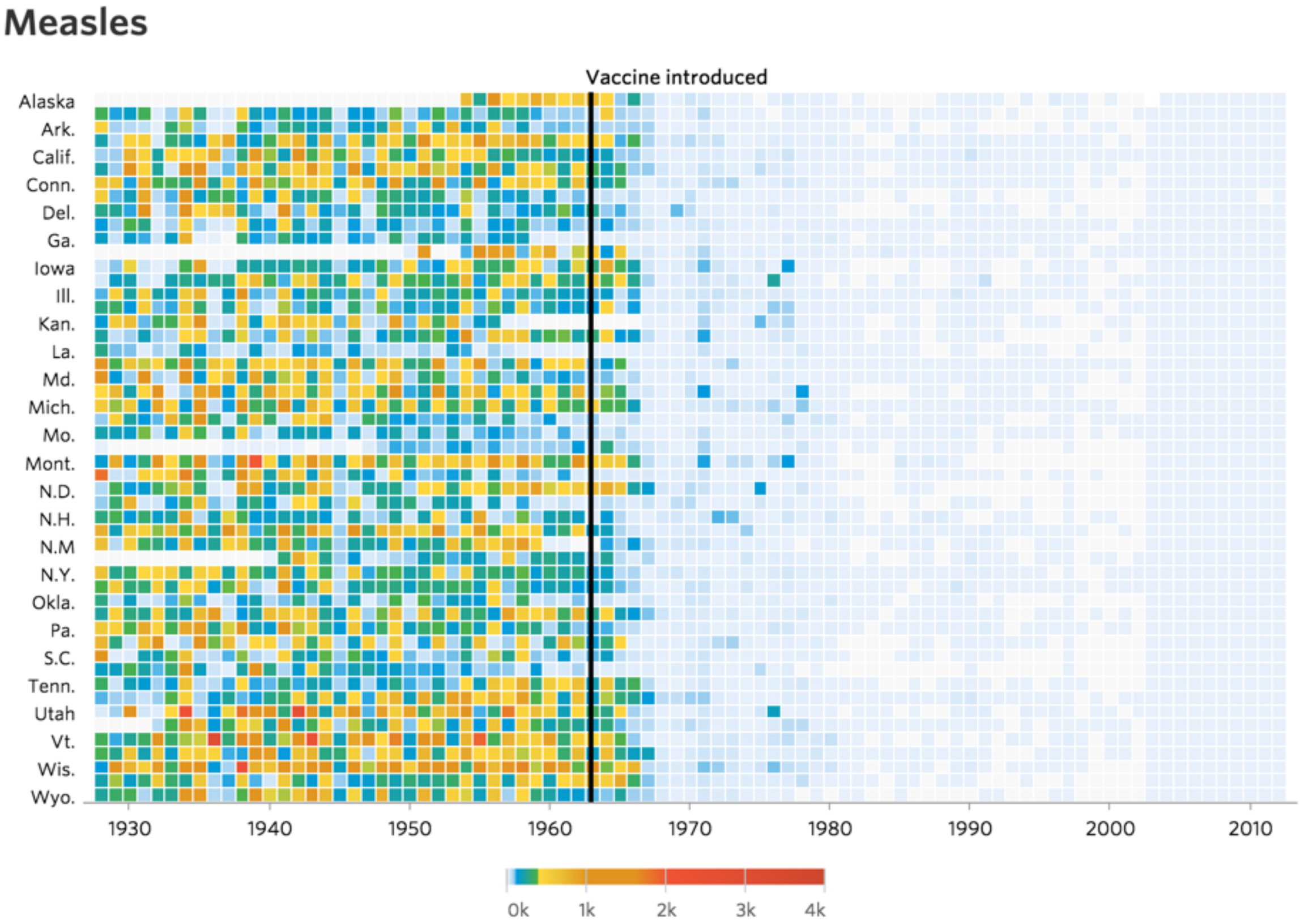
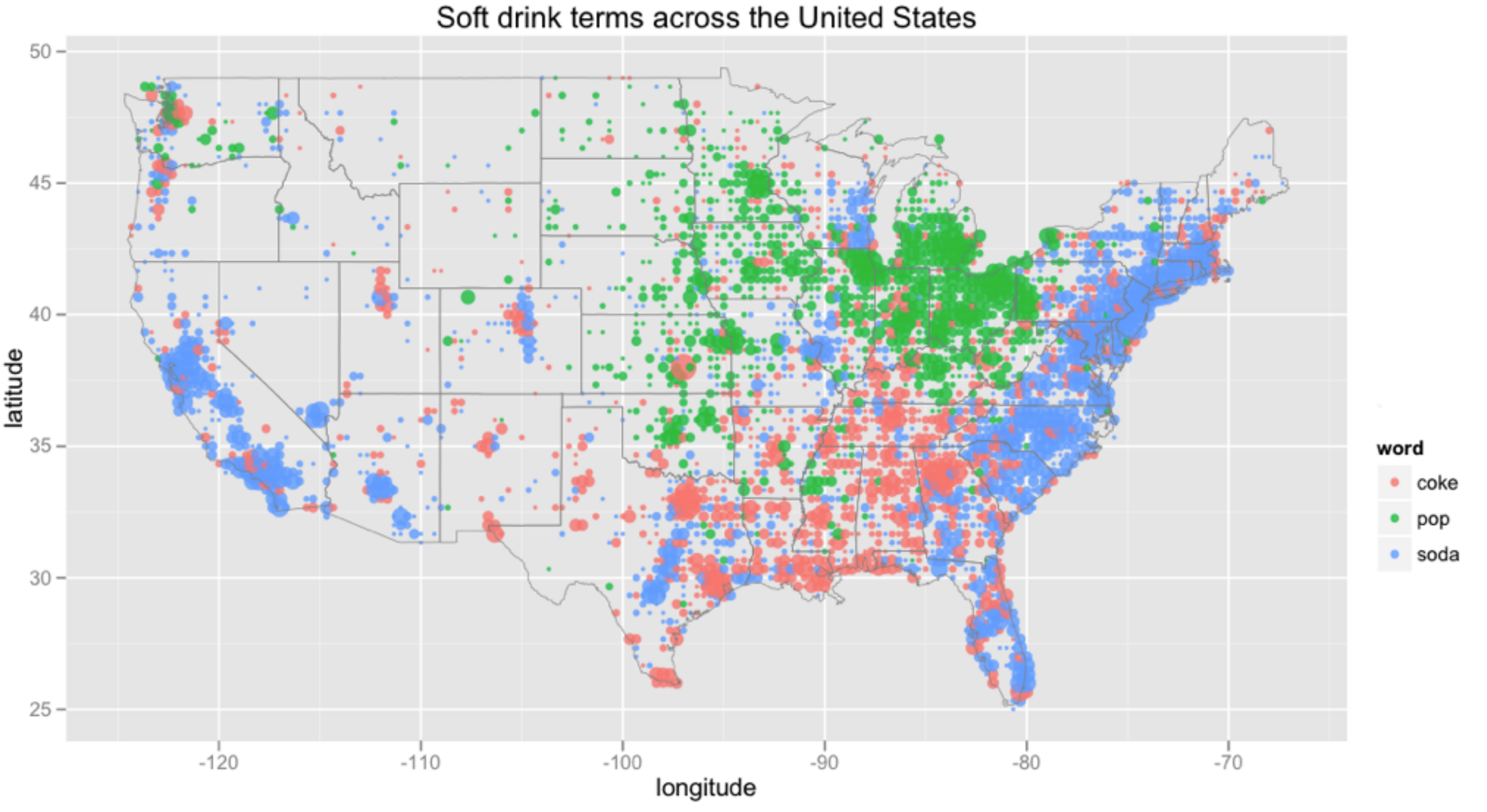
ggplot2 visualizations



ggplot2 visualizations



The grammar of graphics (ggplot)

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1. Data
    - Raw data for plotting

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    - The shape that will represent the data
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1. Data
    - Raw data for plotting
2. Geometries
    - The shape that will represent the data
    - point, line, bar, etc.
3. Aesthetics
    - Color, size, shape, etc.
4. Scales
    - Mapping data to aesthetic (how to color geoms, data range to plot, etc)

A simple example

```
> head(CO2)
  Plant   Type  Treatment conc uptake
1   Qn1 Quebec nonchilled   95   16.0
2   Qn1 Quebec nonchilled  175   30.4
3   Qn1 Quebec nonchilled  250   34.8
4   Qn1 Quebec nonchilled  350   37.2
5   Qn1 Quebec nonchilled  500   35.3
6   Qn1 Quebec nonchilled  675   39.2
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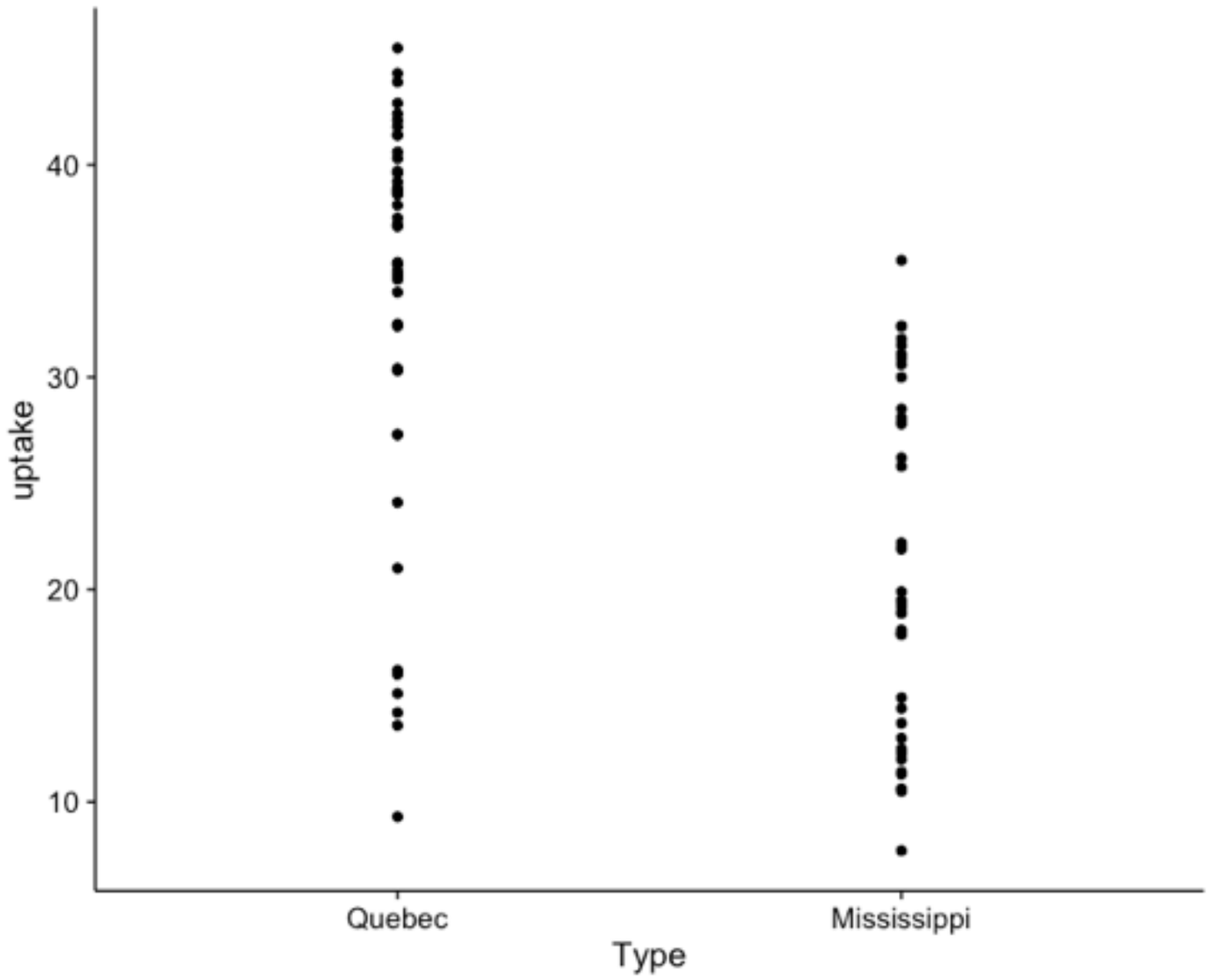
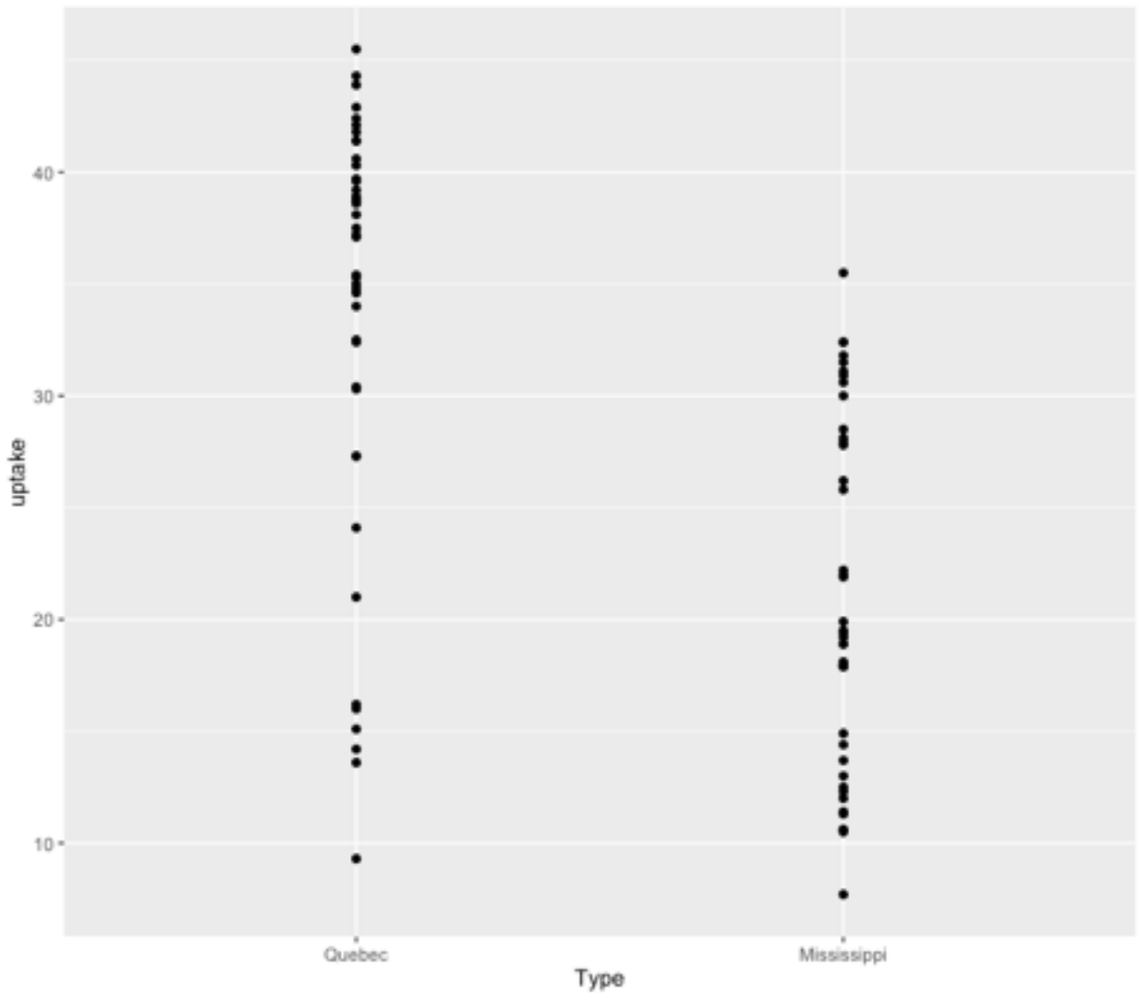



```
ggplot(CO2, aes(x=Type, y=uptake))+geom_point()
```

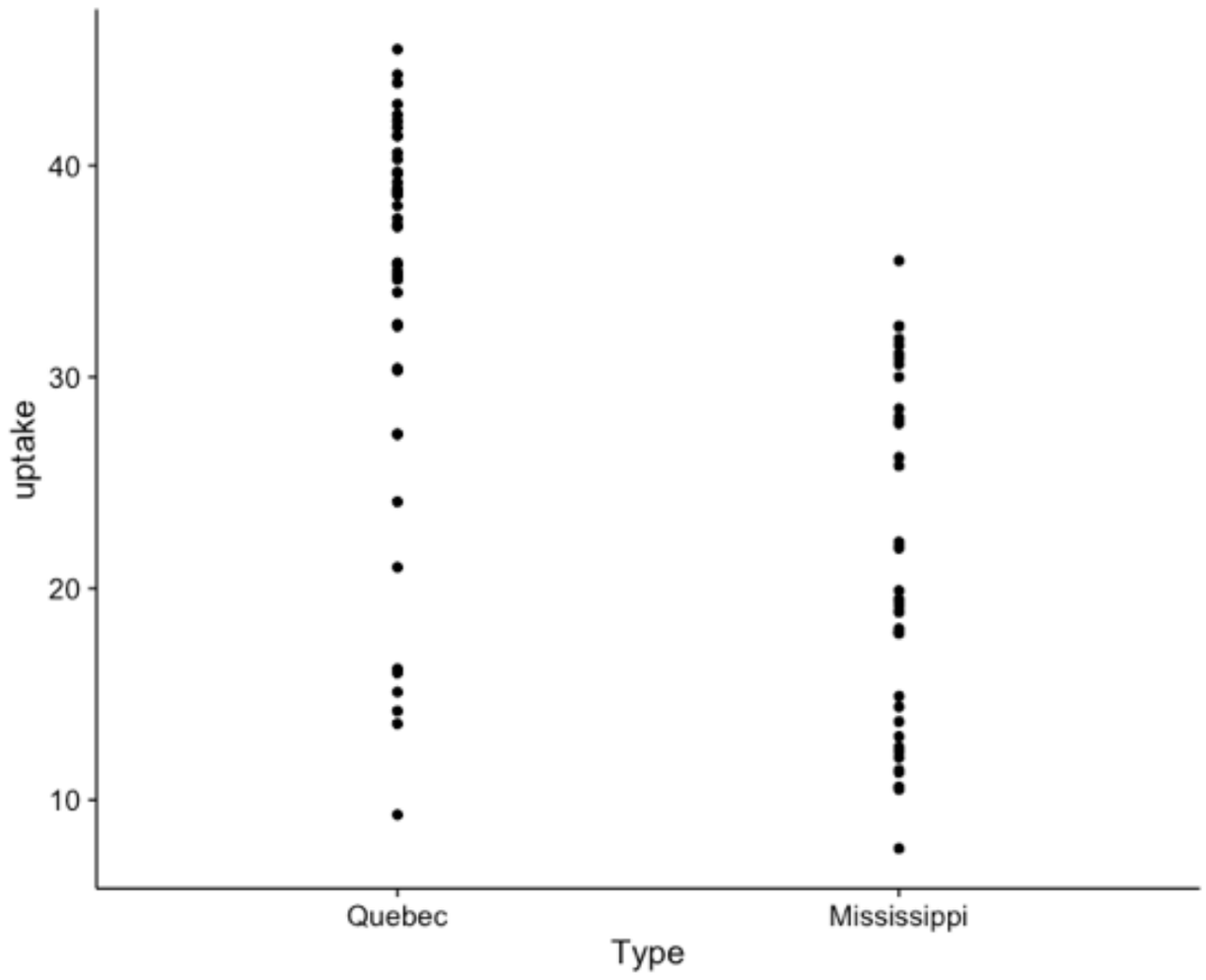
A simple example

note that this uses “cowplot,” because I can’t stand ggplot2 default themes

ggplot2 default



cowplot default

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Data frame

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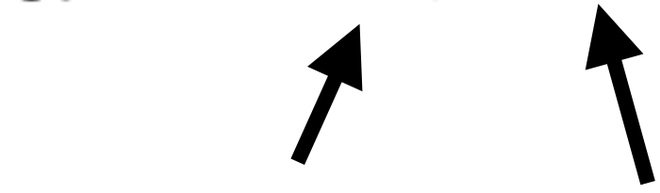

Data frame

Aesthetics

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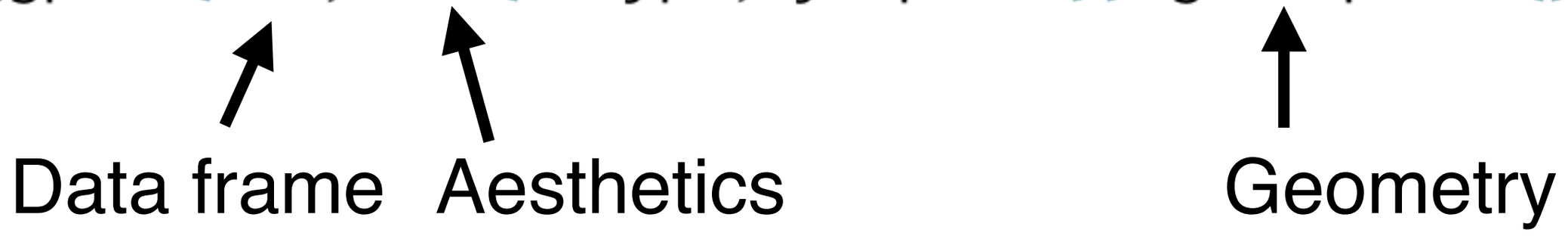

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Data frame

Aesthetics

Link with +

Geometry

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```

data column names

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```

Data frame

Aesthetics

Link with +

Geometry

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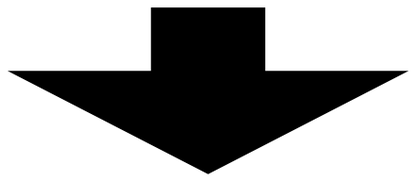
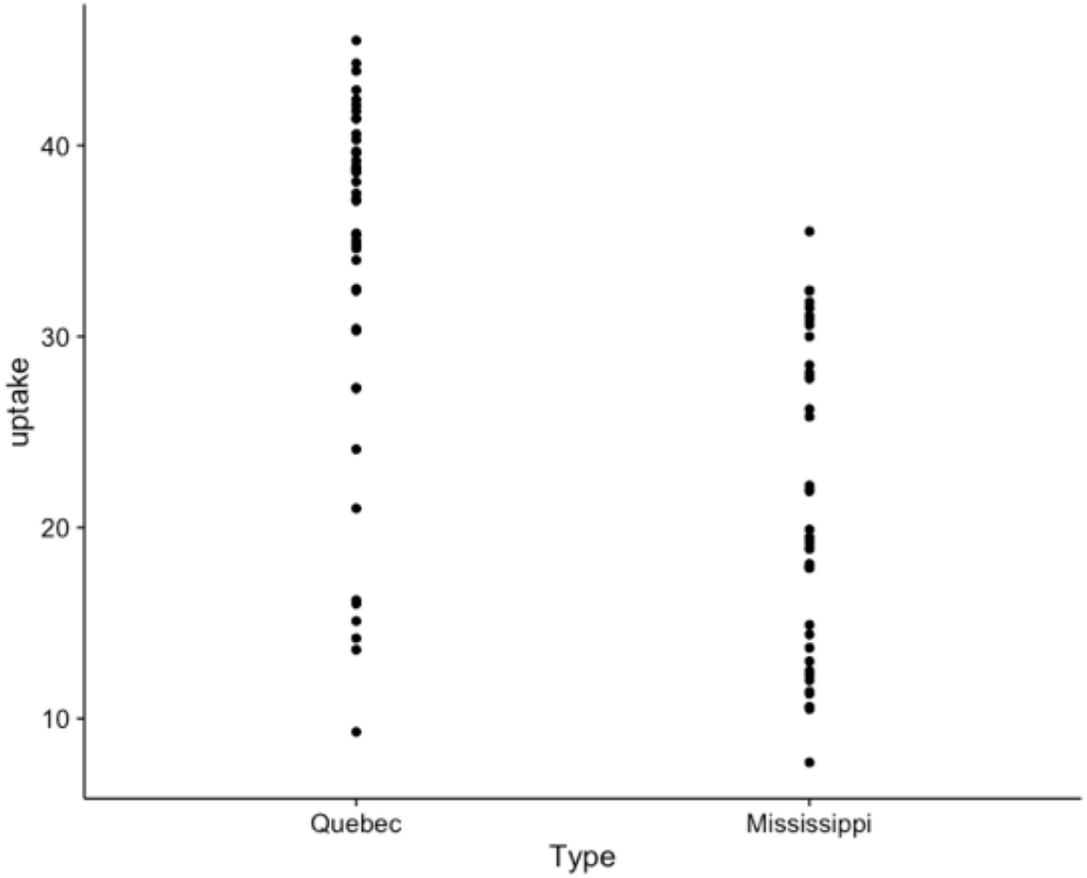


```
ggplot(CO2, aes(x=Type, y=uptake))+geom_boxplot()
```



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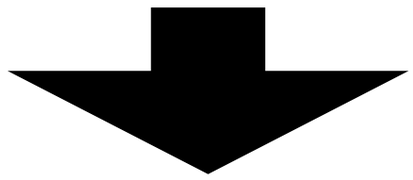

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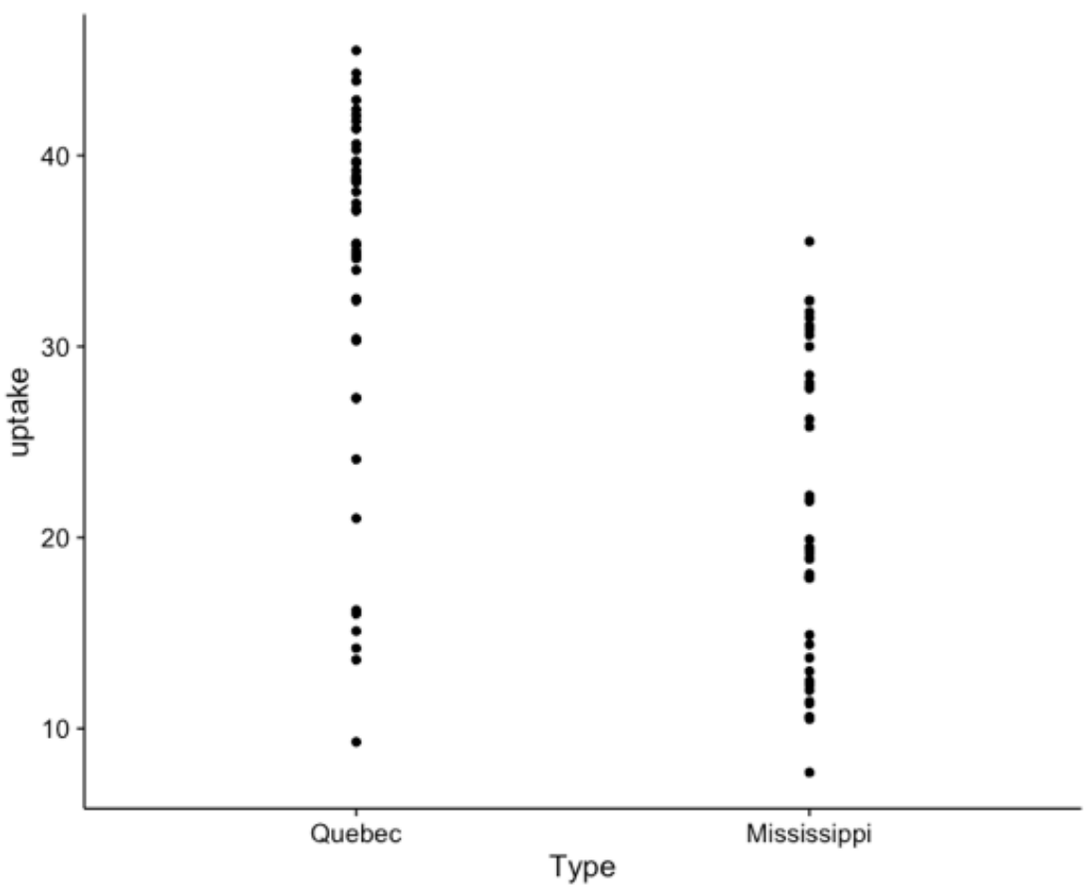
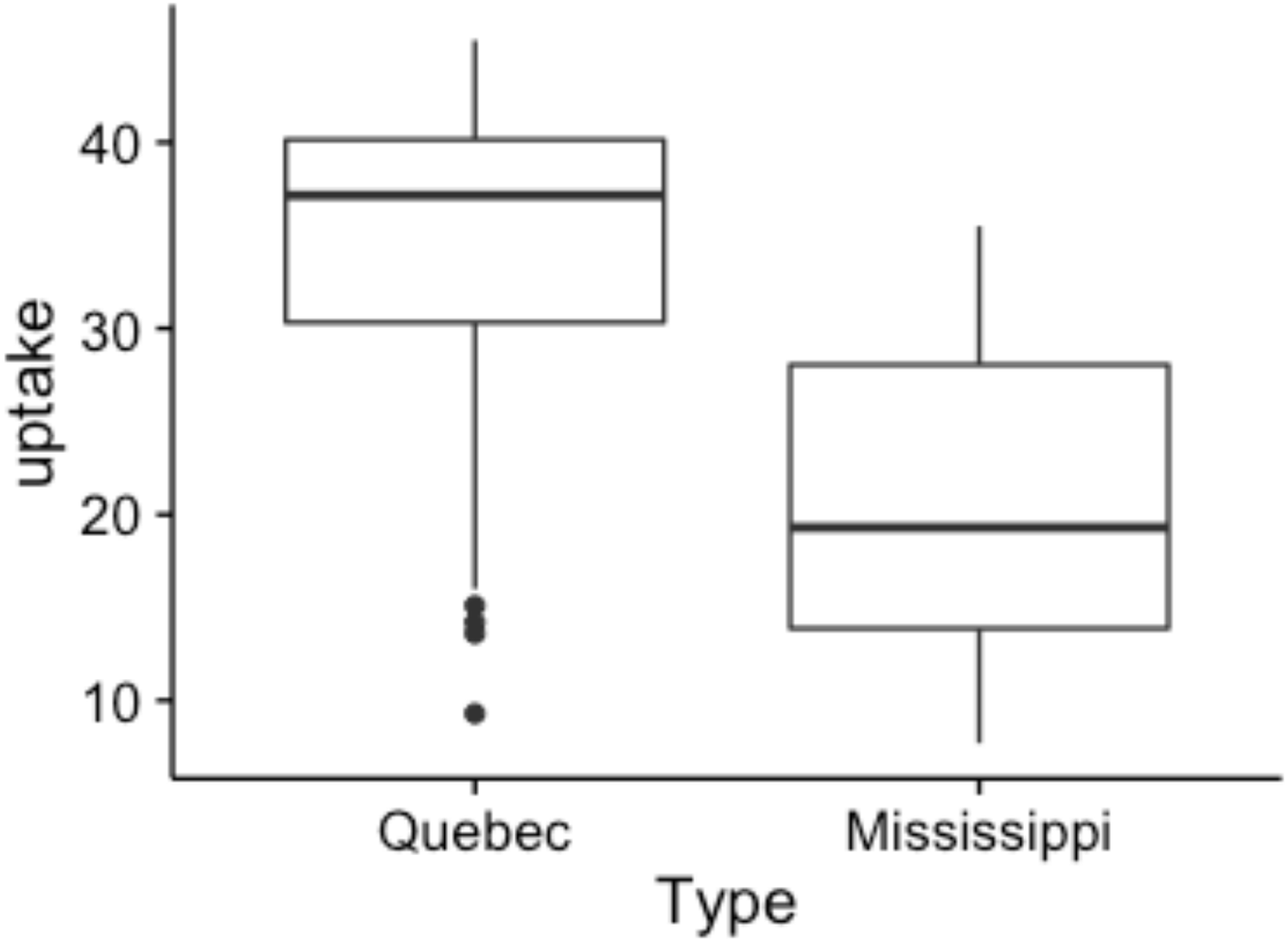
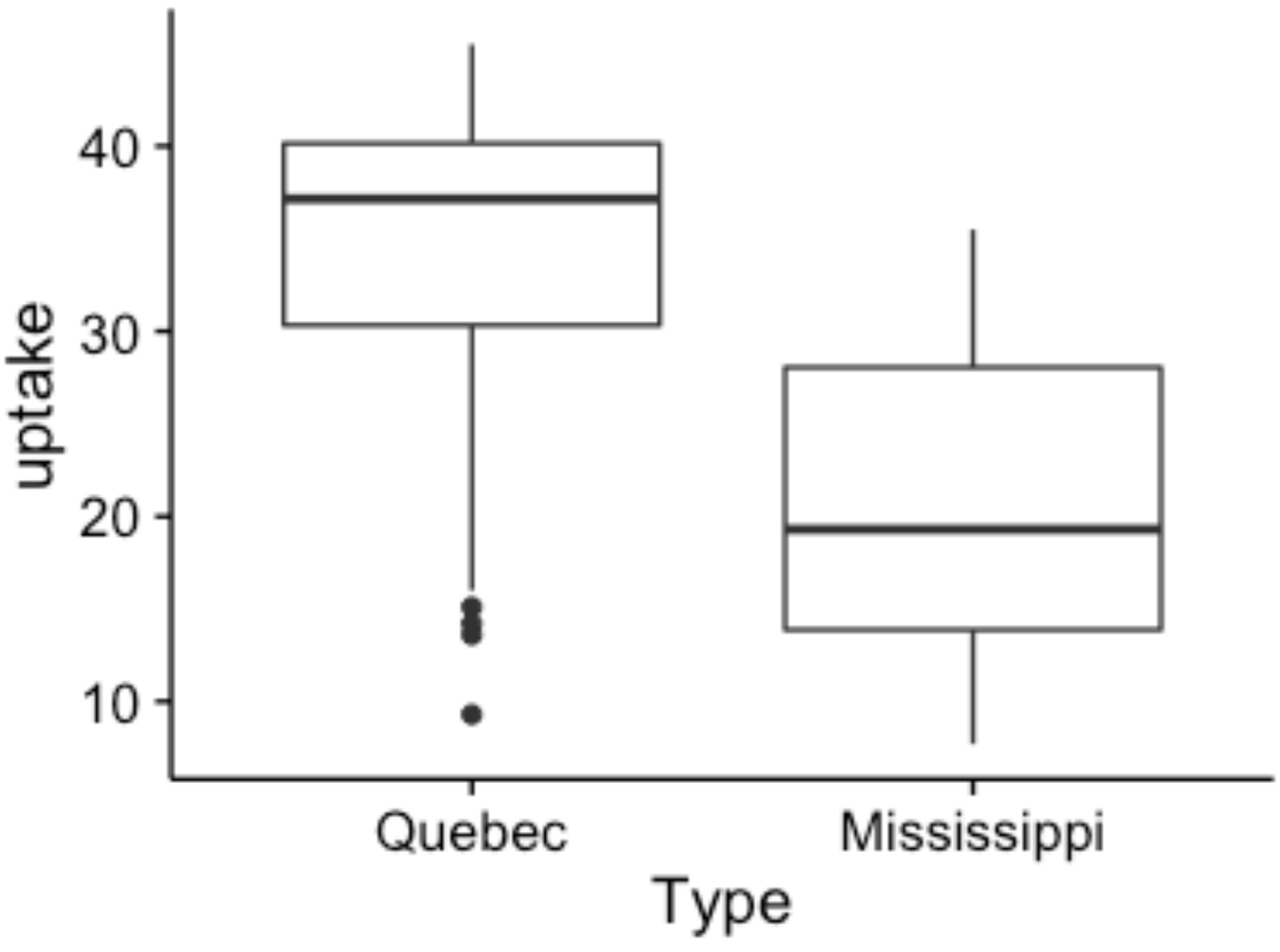




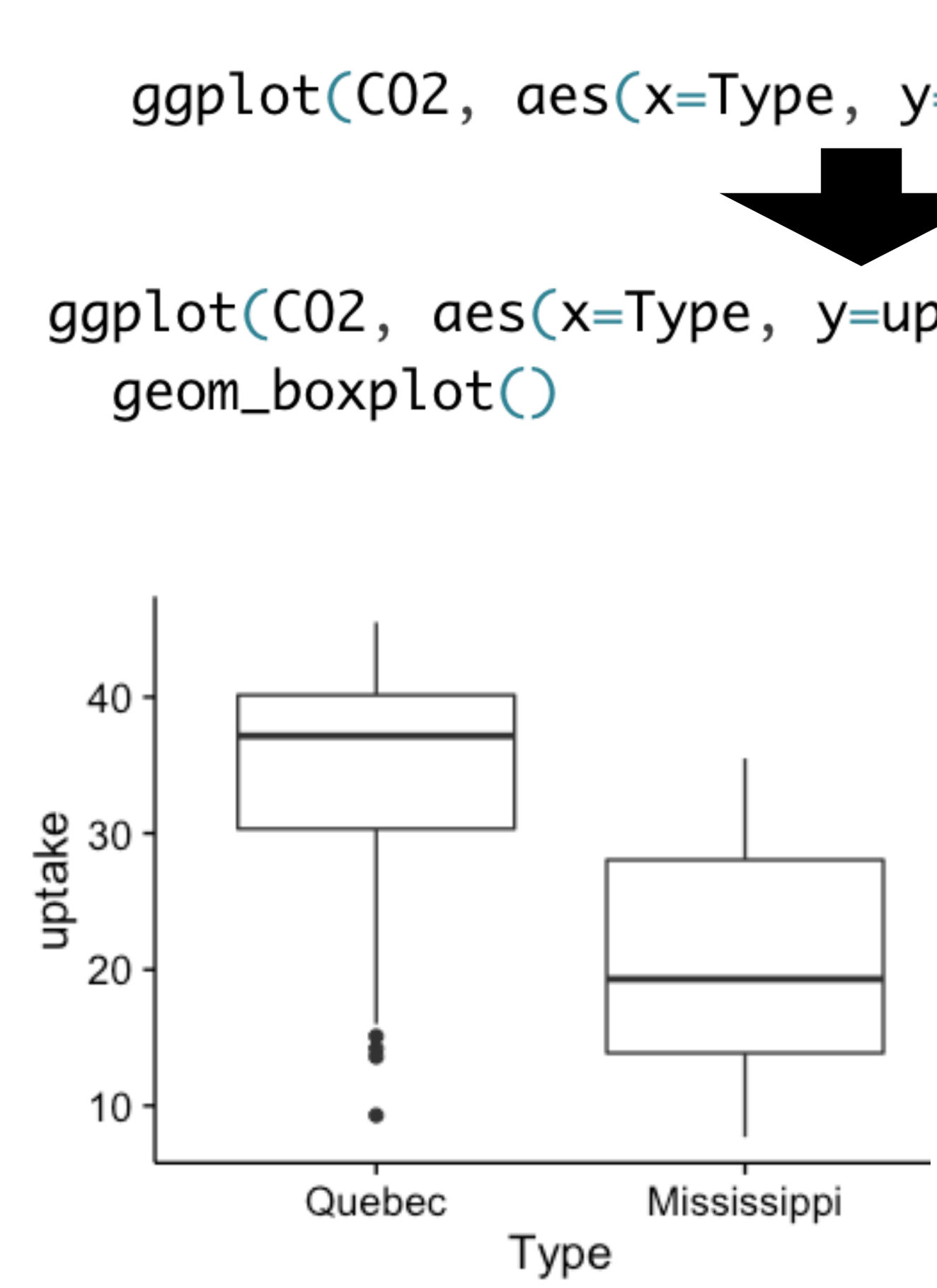
```
ggplot(CO2, aes(x=Type, y=uptake))+geom_boxplot()
```



```
ggplot(CO2, aes(x=Type, y=uptake, color = Treatment))+
  geom_boxplot()
```



```r
ggplot(CO2, aes(x=Type, y=uptake))+geom_boxplot()
```

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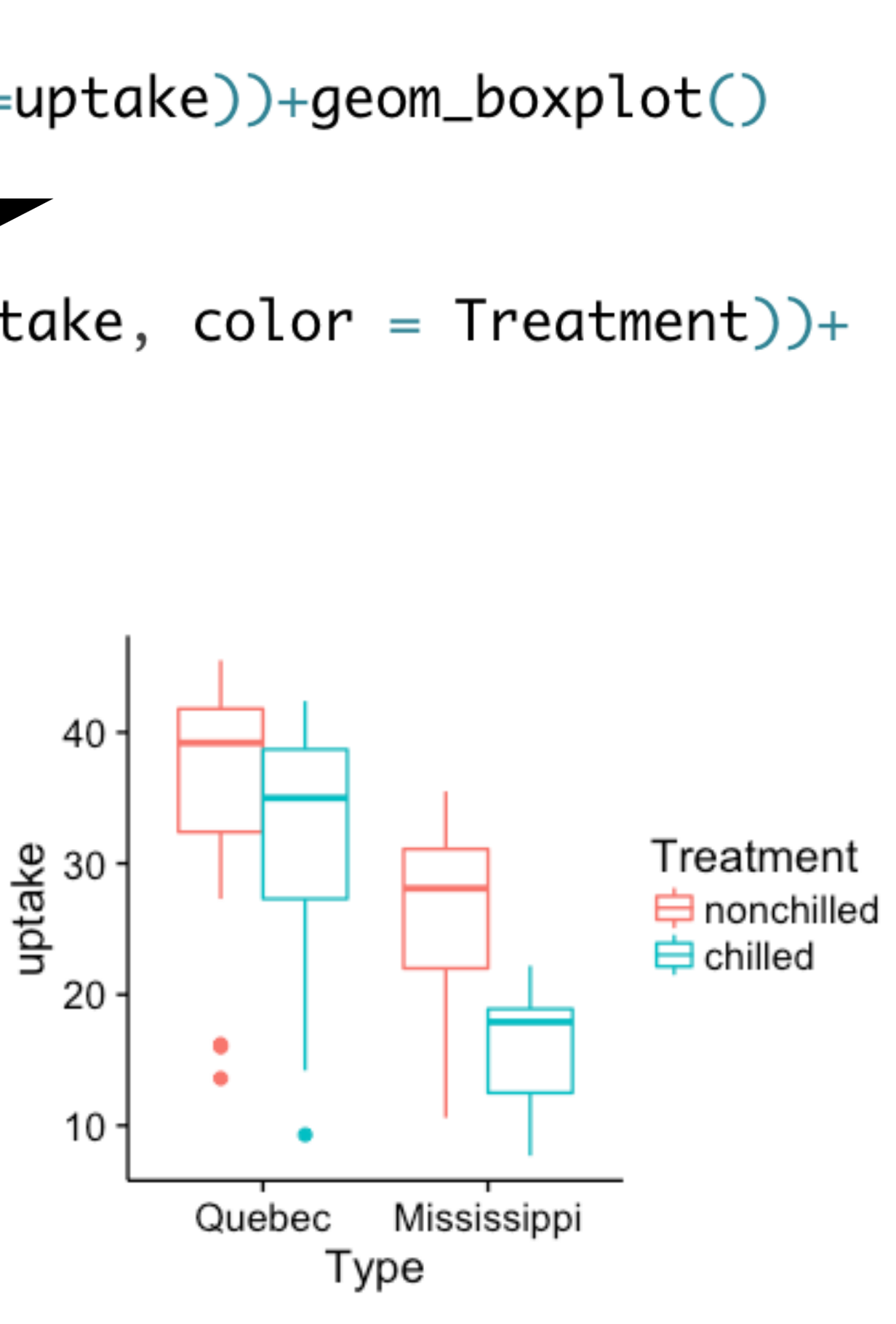

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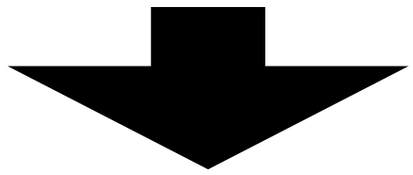
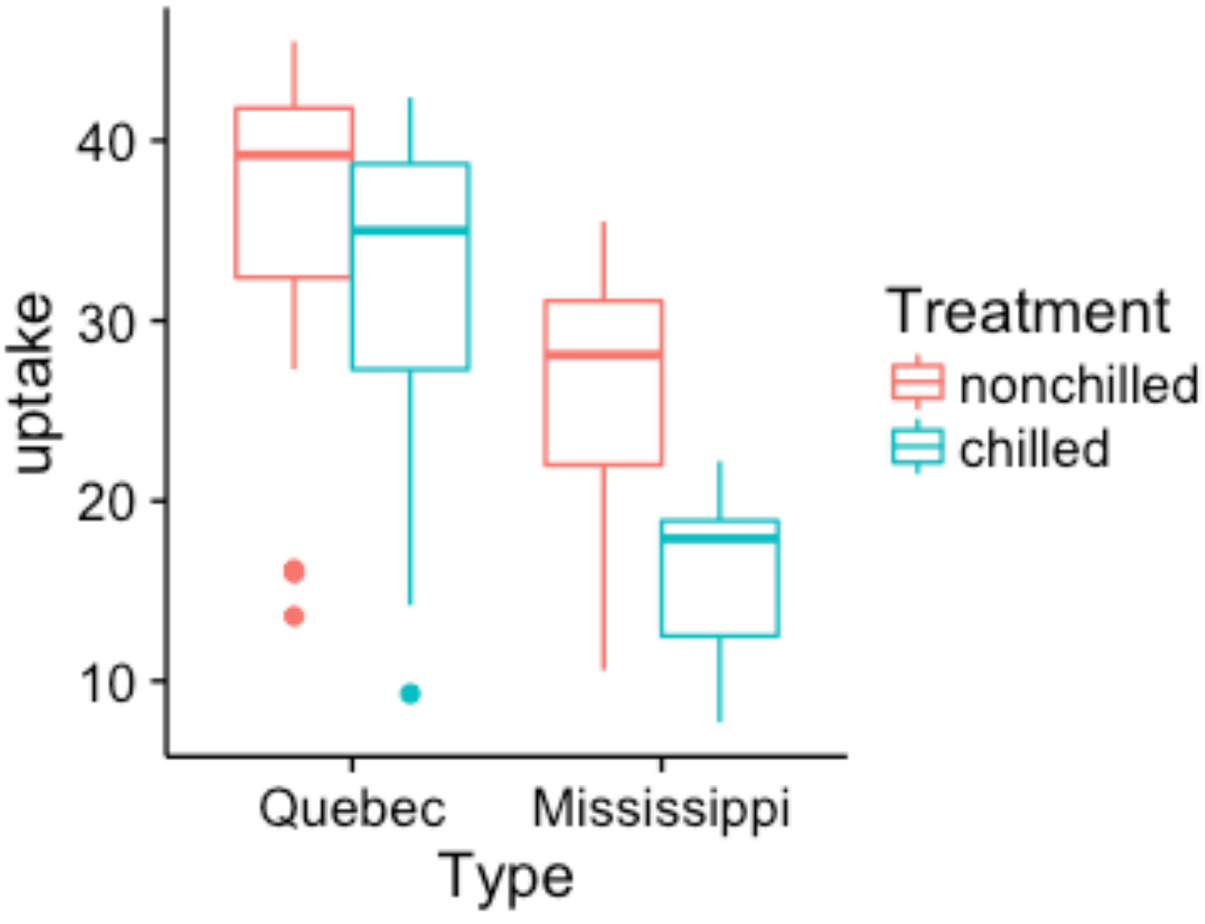


```
ggplot(CO2, aes(x=Type, y=uptake, color = Treatment))+
  geom_boxplot() + scale_color_brewer(type = "qual")
```



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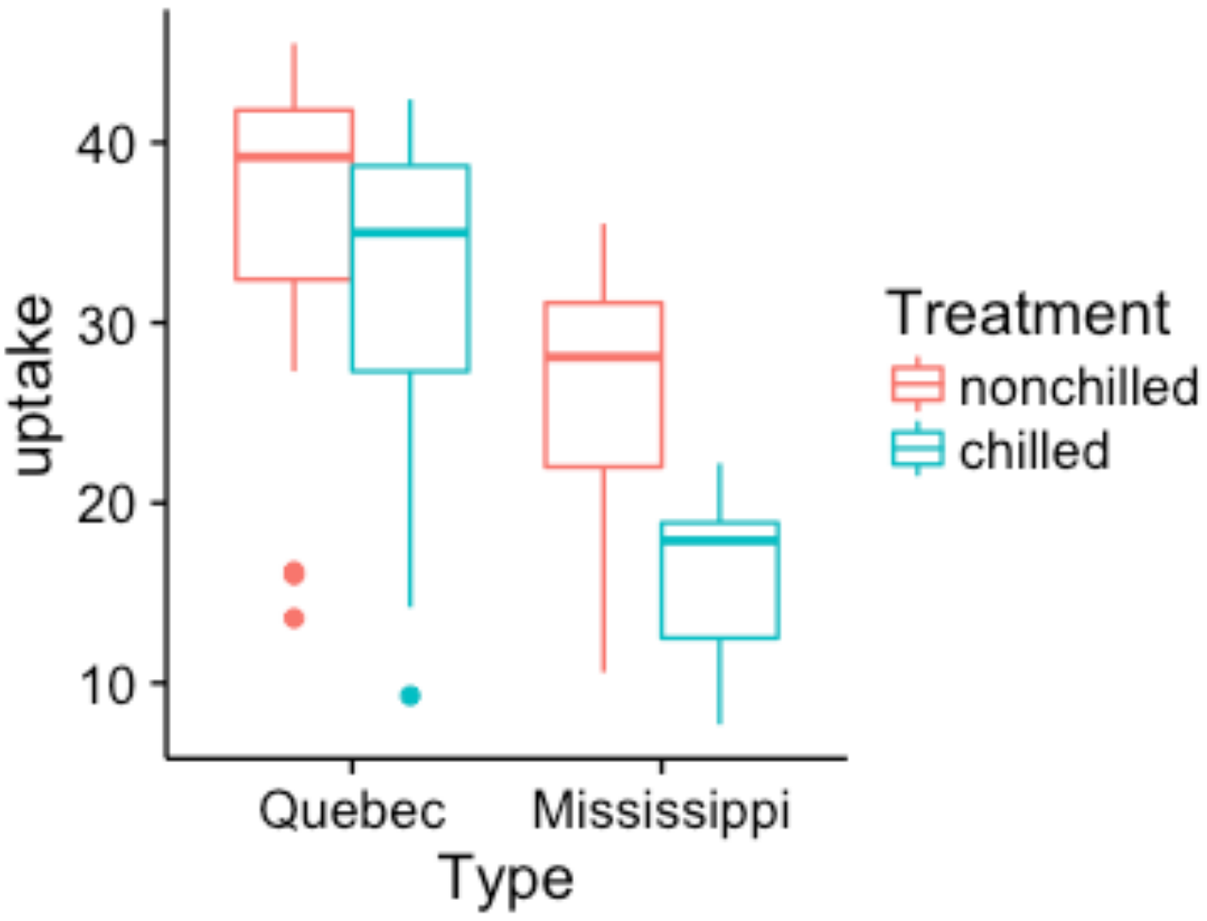

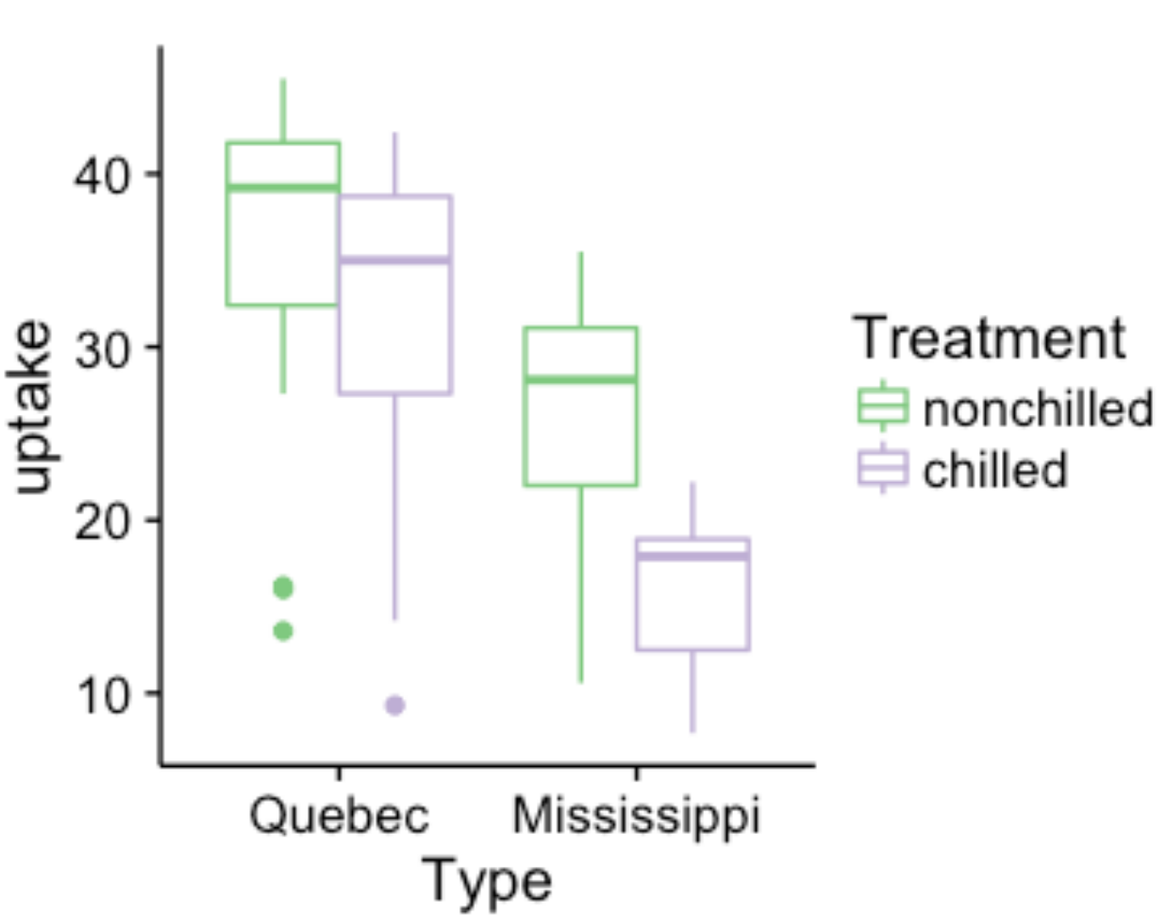

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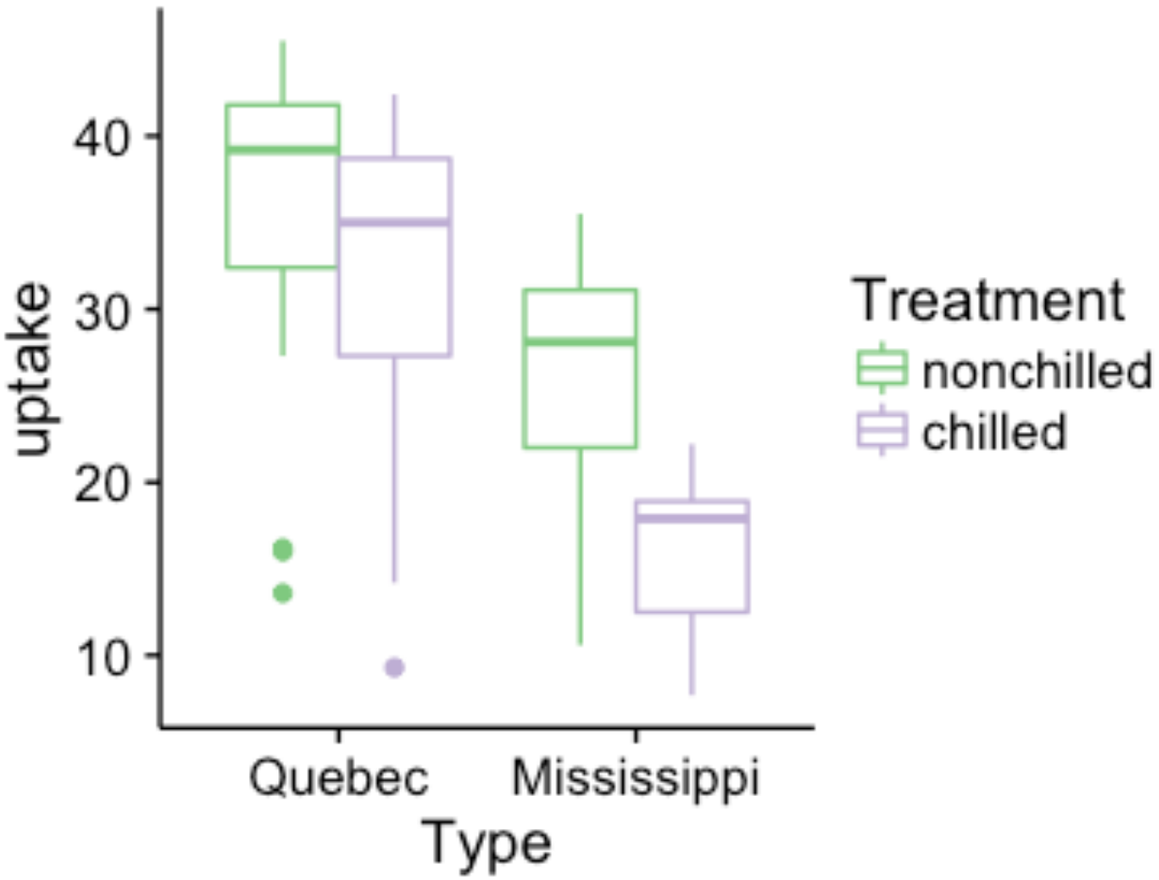

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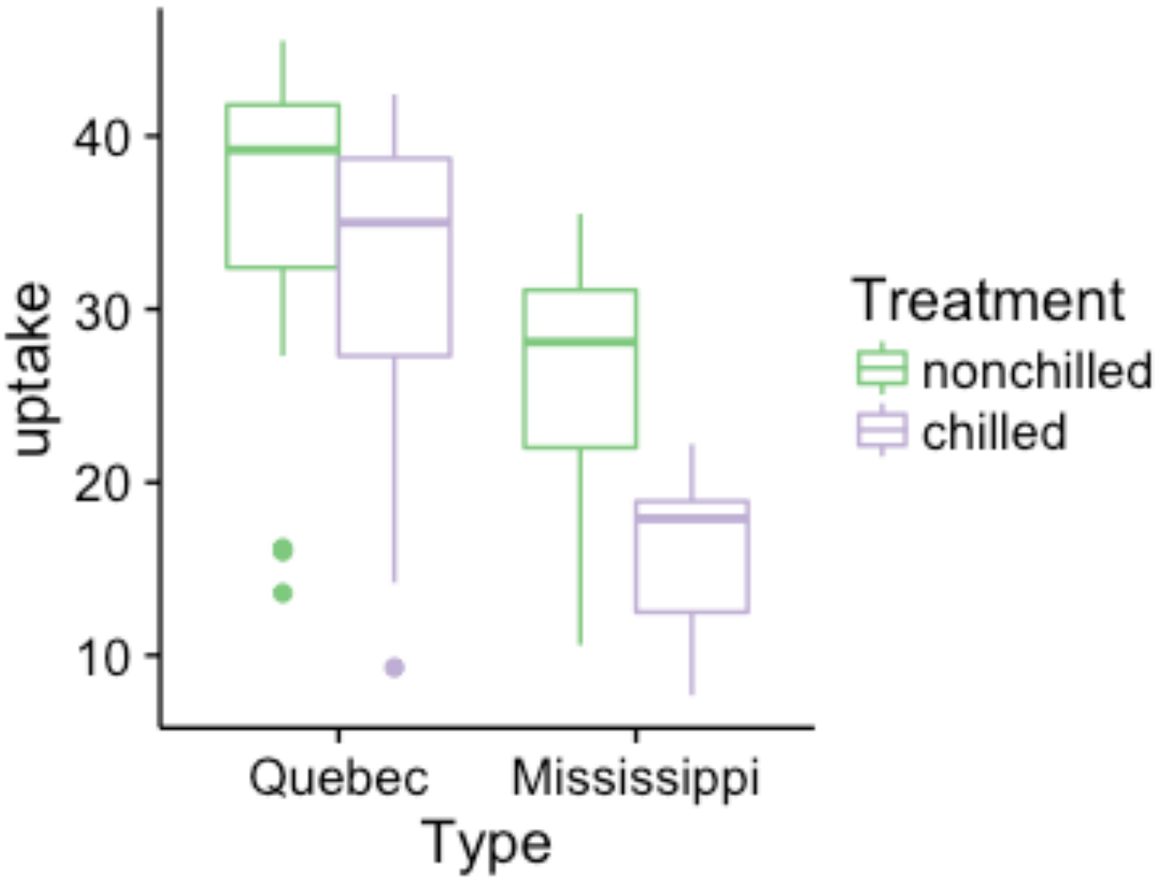


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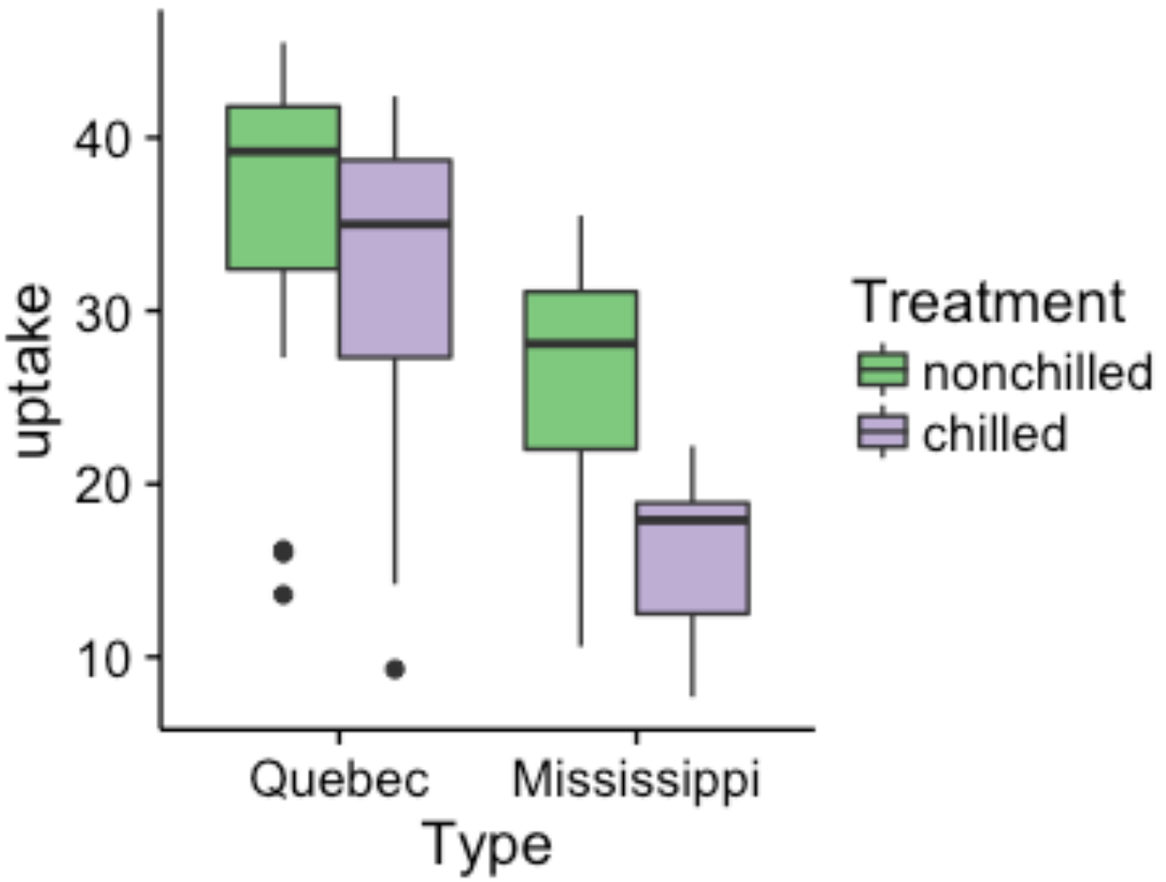

Frequently used geoms + aesthetics

- geom_bar()
- geom_line()
- geom_point()
- geom_histogram()
- geom_ribbon()
- geom_text()
- geom_boxplot()

- color
- size
- fill
- alpha
- shape
- linetype
- group

http://docs.ggplot2.org/current/

Second example

```
> head(txhousing)
     city year month sales   volume median listings inventory     date
1 Abilene 2000     1    72  5380000  71400      701       6.3 2000.000
2 Abilene 2000     2    98  6505000  58700      746       6.6 2000.083
3 Abilene 2000     3   130  9285000  58100      784       6.8 2000.167
4 Abilene 2000     4    98  9730000  68600      785       6.9 2000.250
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```
ggplot(txhousing, aes(date, median)) + geom_line()
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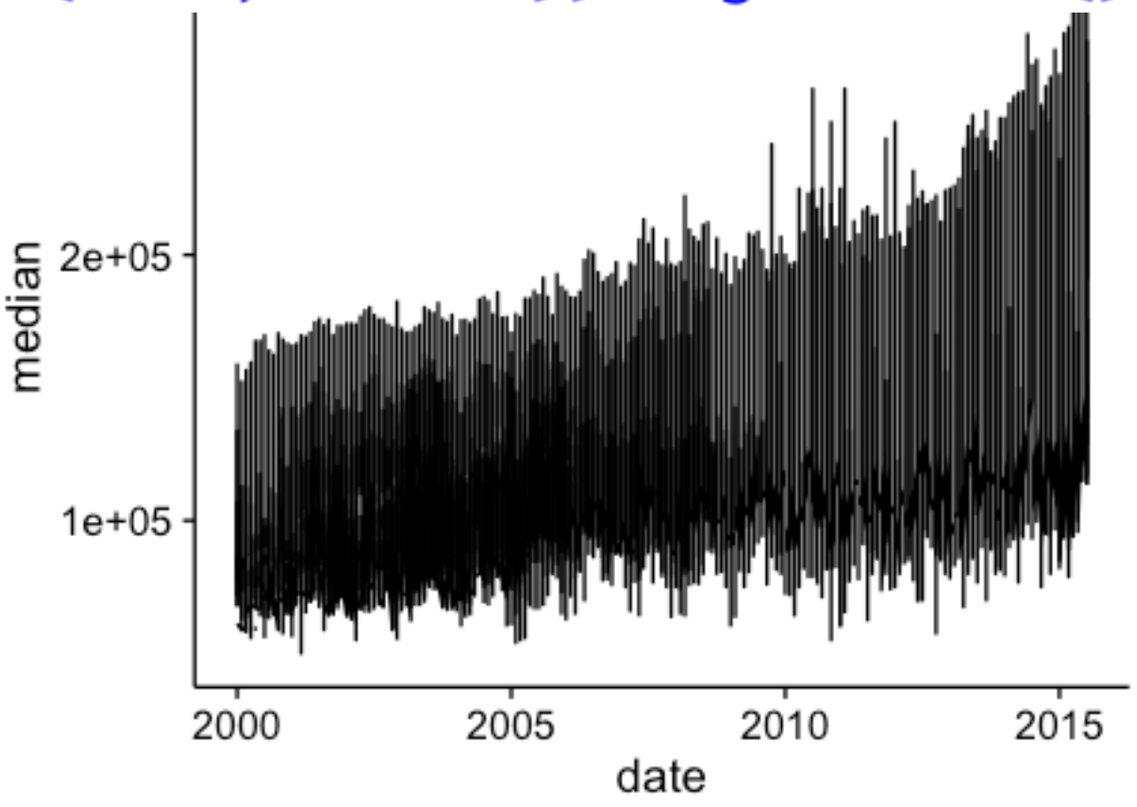

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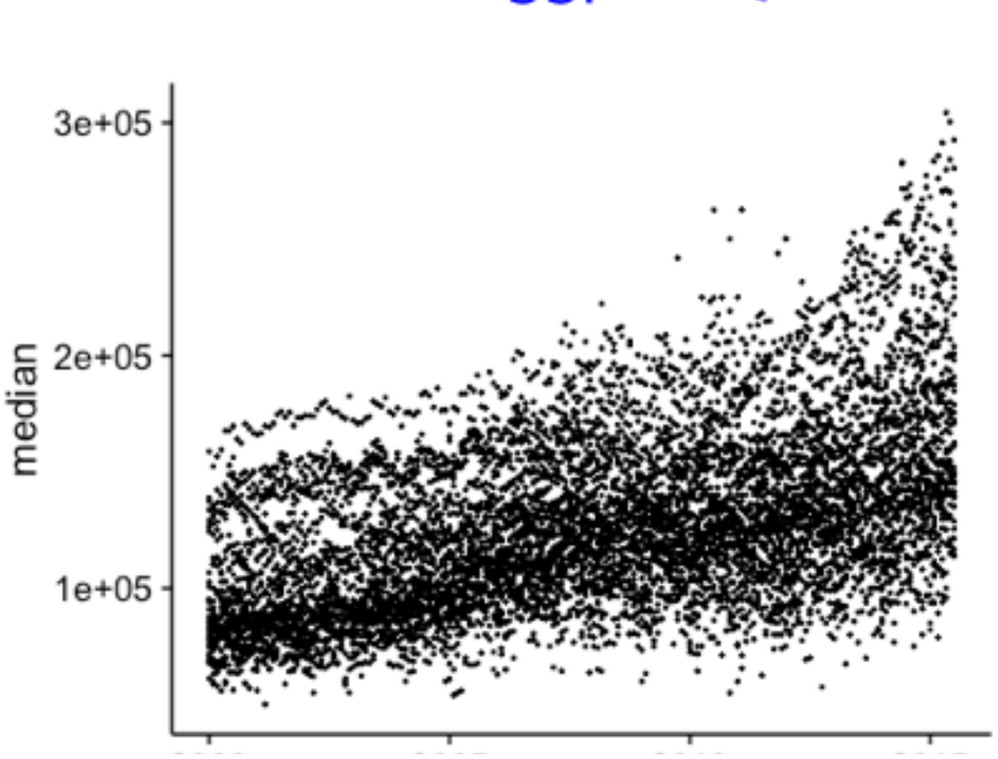
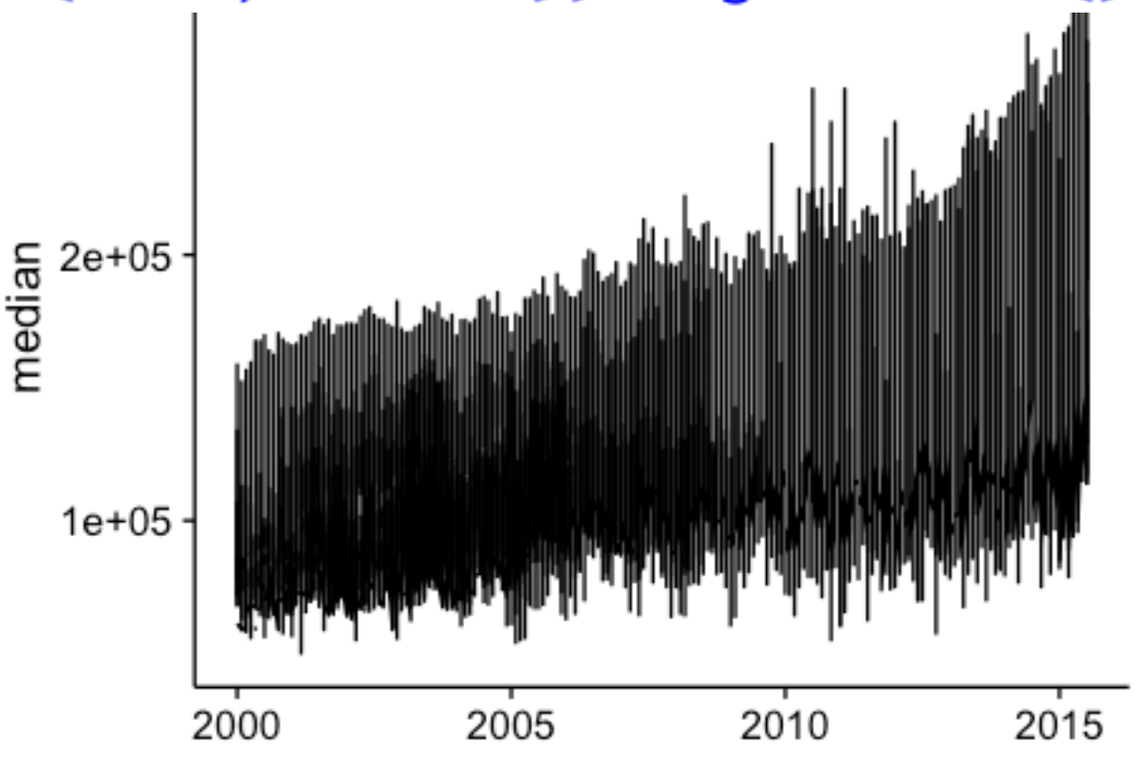
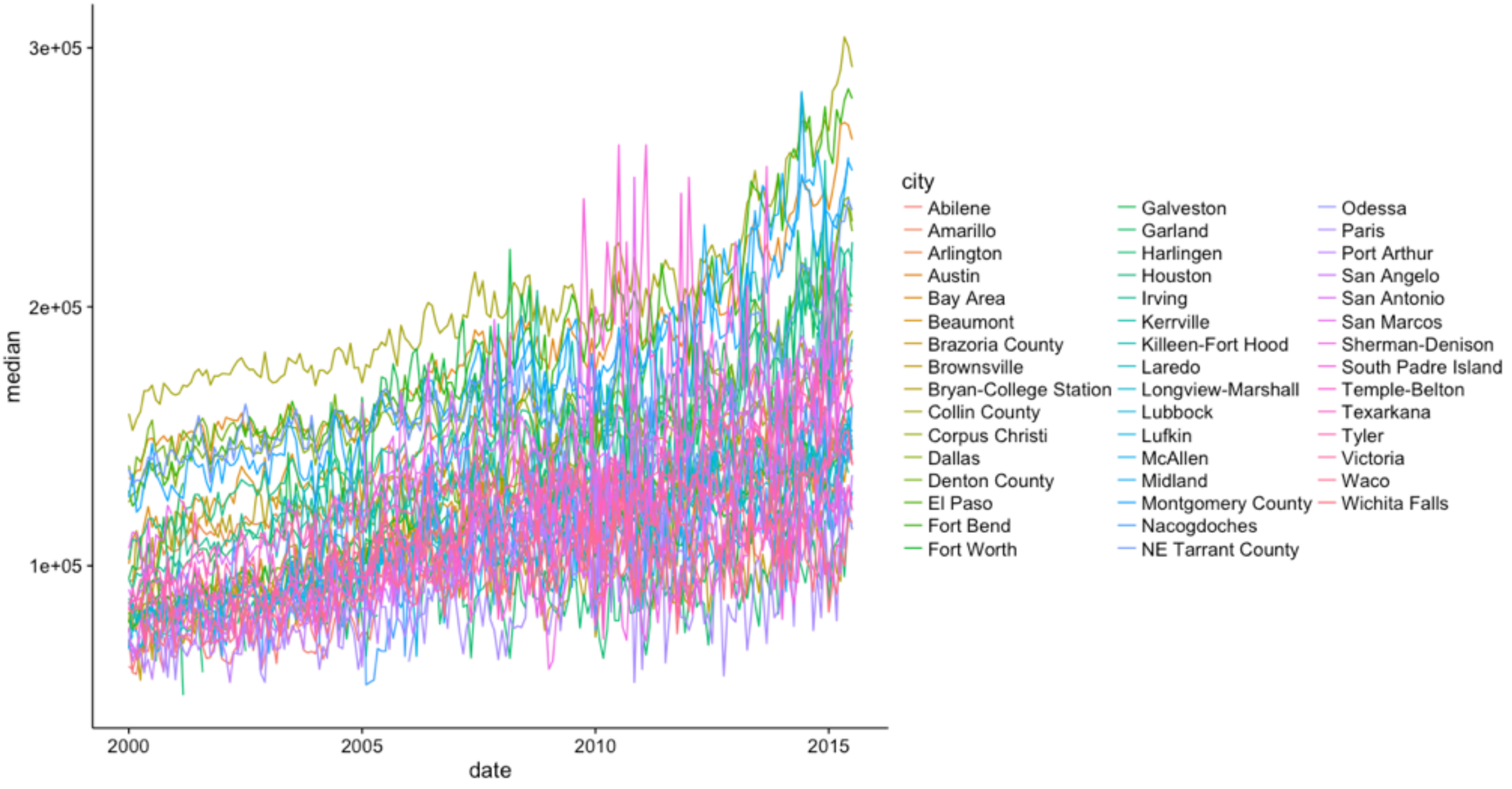




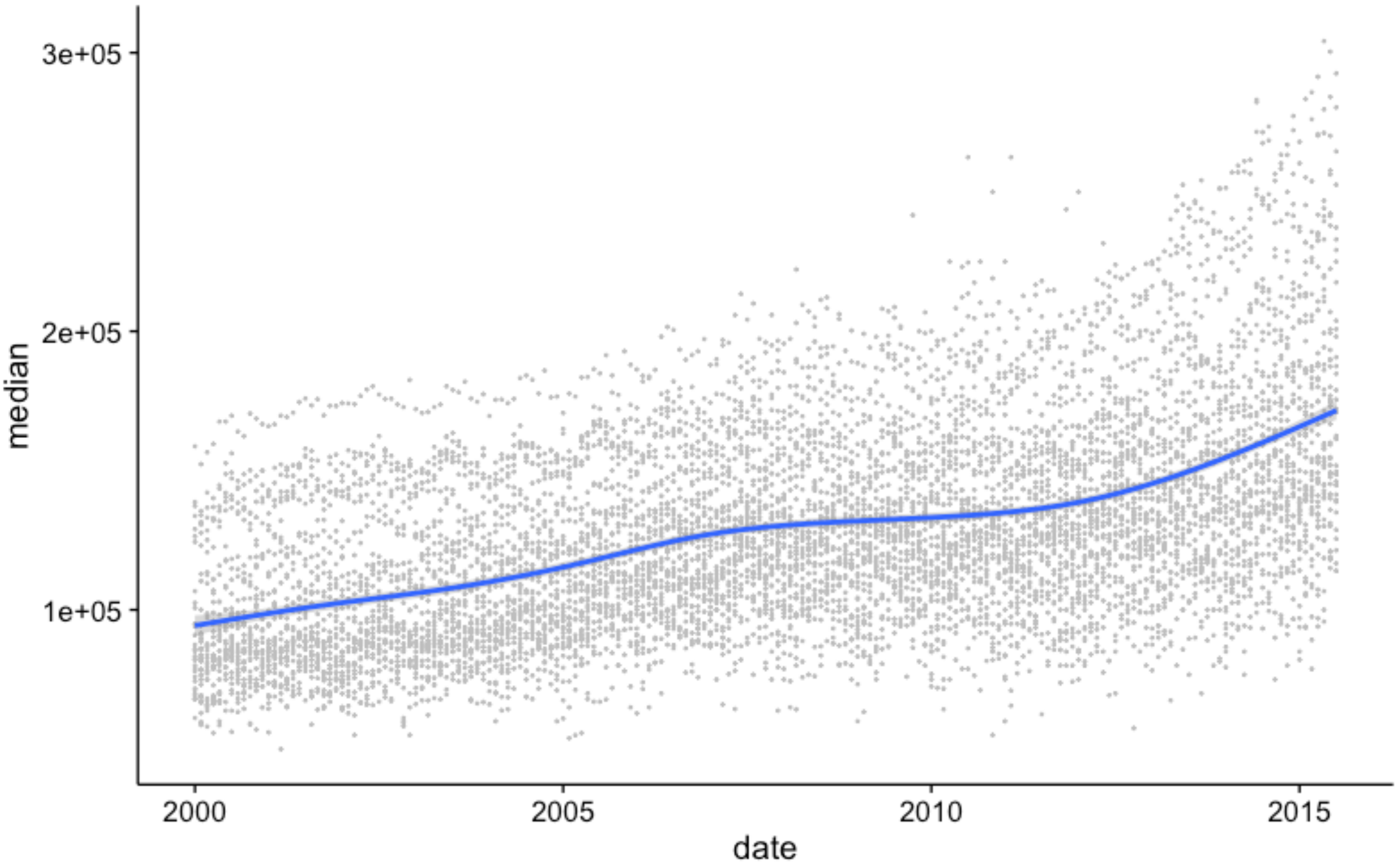

```
ggplot(txhousing, aes(date, median)) + geom_point(size=.2)
```

```
ggplot(txhousing, aes(date, median, color = city)) + geom_line()
```



What if we want to understand all Texas trends?

```
ggplot(txhousing, aes(date, median)) +
  geom_point(size=.2,color="grey") + stat_smooth()
```



What if instead we're only interested in Austin?

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housing = txhousing[which(txhousing$city=="Austin"), ]
ggplot(housing, aes(date, median)) + geom_line()
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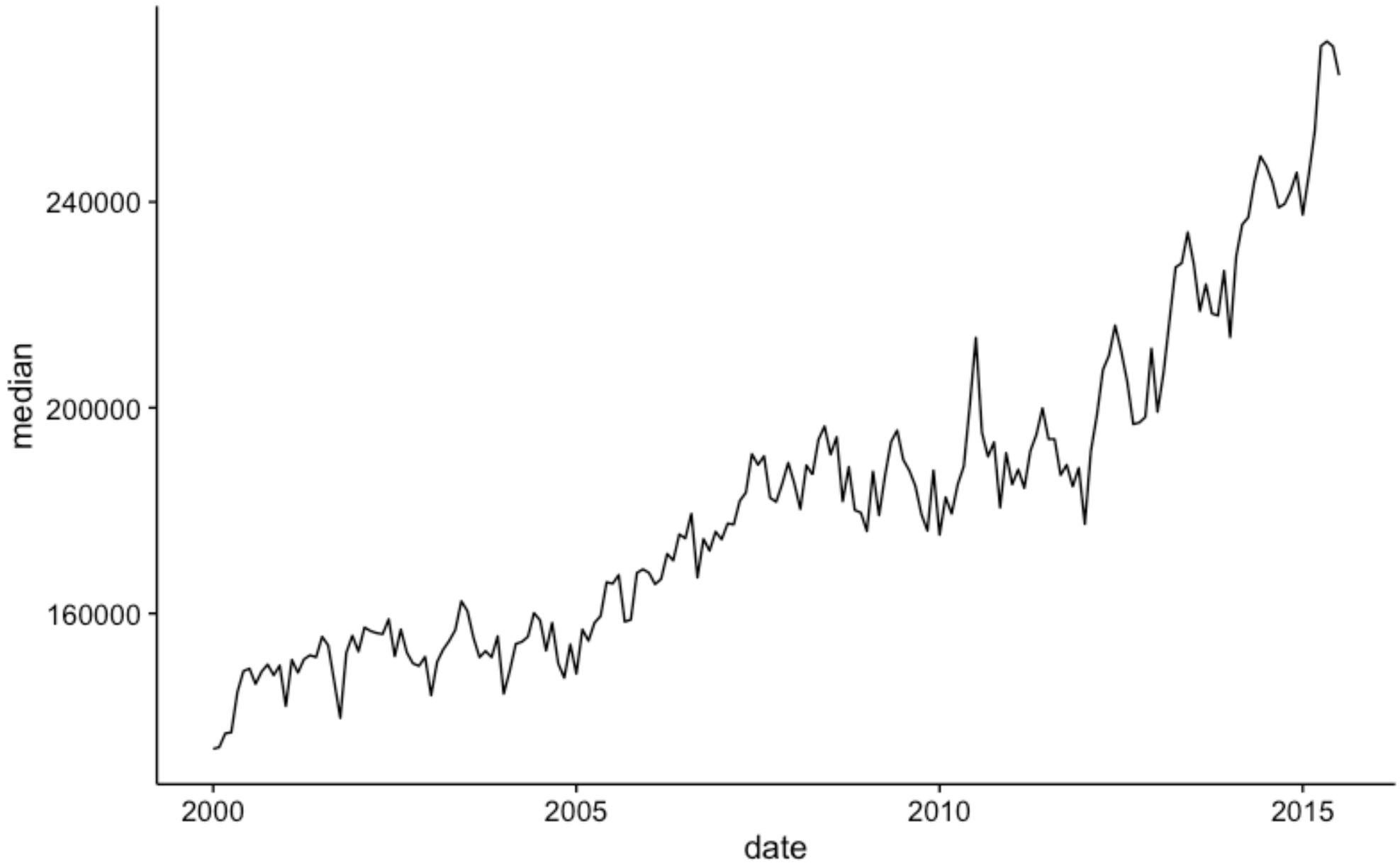

3rd Programming Exercise

1. open up 3_ggplot2.R in Rstudio
2. Start playing with code
3. get addicted to ggplot

R resources

- stack overflow (google)
- Hadley Wickham's website - http://hadley.nz/
- http://www.r-bloggers.com/how-to-learn-r-2/
- A Beginner's Guide to R (Use R!) by Alain Zuur, Elena N. Ieno, and Erik Misters
- The Art of R Programming: A Tour of Statistical Software Design by Norman Matloff
- ggplot2: Elegant Graphics for Data Analysis (Use R!) by Hadley Wickham. — Maybe wait for the second edition (it's slightly outdated)