Data Summarization

Introduction to R for Public Health Researchers

Data Summarization

- Basic statistical summarization
  - `mean(x)`: takes the mean of x
  - `sd(x)`: takes the standard deviation of x
  - `median(x)`: takes the median of x
  - `quantile(x)`: displays sample quantities of x. Default is min, IQR, max
  - `range(x)`: displays the range. Same as `c(min(x), max(x))`
  - `sum(x)`: sum of x
  - **all have a** `na.rm` for missing data - discussed later
- Transformations
  - `log` - log (base `e`) transformation
  - `log2` - log base 2 transform
  - `log10` - log base 10 transform
  - `sqrt` - square root

Some examples

We can use the `jhu_cars` to explore different ways of summarizing data. The `head` command displays the first `6` (default) rows of an object:

```
library(jhur)
head(jhu_cars)
```

```
                car  mpg cyl disp  hp drat    wt  qsec vs am gear carb
1         Mazda RX4 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
2     Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
3        Datsun 710 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
4    Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
5 Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
6           Valiant 18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

Statistical summarization

Note - the `$` references/selects columns from a `data.frame/tibble`:

```
mean(jhu_cars$hp)
```

```
[1] 146.6875
```

```
quantile(jhu_cars$hp)
```

```
   0%   25%   50%   75%  100% 
 52.0  96.5 123.0 180.0 335.0 
```

Statistical summarization

```
median(jhu_cars$wt)
```

```
[1] 3.325
```

```
quantile(jhu_cars$wt, probs = 0.6)
```

```
 60% 
3.44 
```

Statistical summarization

`t.test` will be covered more in detail later, gives a mean and 95% CI:

```
t.test(jhu_cars$wt)
```

```

	One Sample t-test

data:  jhu_cars$wt
t = 18.6, df = 31, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 2.864478 3.570022
sample estimates:
mean of x 
  3.21725 
```

```
broom::tidy(t.test(jhu_cars$wt))
```

```
# A tibble: 1 x 8
  estimate statistic  p.value parameter conf.low conf.high method
     <dbl>     <dbl>    <dbl>     <dbl>    <dbl>     <dbl> <chr> 
1     3.22      18.6 2.26e-18        31     2.86      3.57 One S…
# … with 1 more variable: alternative <chr>
```

Statistical summarization

Note that many of these functions have additional inputs regarding missing data, typically requiring the `na.rm` argument ("remove NAs").

```
x = c(1,5,7,NA,4,2, 8,10,45,42)
mean(x)
```

```
[1] NA
```

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

```
[1] 13.77778
```

```
quantile(x, na.rm = TRUE)
```

```
  0%   25%   50%   75% 100% 
   1     4     7    10    45 
```

Data Summarization on matrices/data frames

- Basic statistical summarization
  - `rowMeans(x)`: takes the means of each row of x
  - `colMeans(x)`: takes the means of each column of x
  - `rowSums(x)`: takes the sum of each row of x
  - `colSums(x)`: takes the sum of each column of x
  - `summary(x)`: for data frames, displays the quantile information
- The `matrixStats` package has additional `row*` and `col*` functions
  - Like `rowSds`, `colQuantiles`

Lab Part 1

Website

TB Incidence

Please download the TB incidence data:

http://johnmuschelli.com/intro_to_r/data/tb_incidence.xlsx

Here we will read in a `tibble` of values from TB incidence:

```
library(readxl)
# tb <- read_excel("http://johnmuschelli.com/intro_to_r/data/tb_incidence.xlsx
tb = jhur::read_tb()
colnames(tb)
```

```
 [1] "TB incidence, all forms (per 100 000 population per year)"
 [2] "1990"
 [3] "1991"
 [4] "1992"
 [5] "1993"
 [6] "1994"
 [7] "1995"
 [8] "1996"
 [9] "1997"
[10] "1998"
[11] "1999"
[12] "2000"
[13] "2001"
[14] "2002"
[15] "2003"
```

Indicator of TB

We can rename the first column to be the country measured using the `rename` function in `dplyr` (we have to use the ` things because there are spaces in the name):

```
library(dplyr)
tb = tb %>% rename(country = `TB incidence, all forms (per 100 000 population
```

`colnames` will show us the column names and show that country is renamed:

```
colnames(tb)
```

```
 [1] "country" "1990"    "1991"    "1992"    "1993"    "1994"    "1995"   
 [8] "1996"    "1997"    "1998"    "1999"    "2000"    "2001"    "2002"   
[15] "2003"    "2004"    "2005"    "2006"    "2007"   
```

Summarize the data: `dplyr` `summarize` function

`dplyr::summarize` will allow you to summarize data. Format is `new = SUMMARY`. If you don't set a `new` name, it will be a messy output:

```
tb %>%
  summarize(mean_2006 = mean(`2006`, na.rm = TRUE),
            media_2007 = median(`2007`, na.rm = TRUE),
            median(`2004`, na.rm = TRUE))
```

```
# A tibble: 1 x 3
  mean_2006 media_2007 `median(\`2004\`, na.rm = TRUE)`
      <dbl>      <dbl>                              <dbl>
1      135.         53                                 56
```

Column and Row means

`colMeans` and `rowMeans` must work on **all numeric data**. We will subset years before 2000 (starting with 1):

```
avgs = select(tb, starts_with("1"))
colMeans(avgs, na.rm = TRUE)
```

```
    1990     1991     1992     1993     1994     1995     1996     1997 
105.5797 107.6715 108.3140 110.3188 111.9662 114.1981 115.3527 118.8792 
    1998     1999 
121.5169 125.0435 
```

```
tb$before_2000_avg = rowMeans(avgs, na.rm = TRUE)
head(tb[, c("country", "before_2000_avg")])
```

```
# A tibble: 6 x 2
  country        before_2000_avg
  <chr>                    <dbl>
1 Afghanistan              168  
2 Albania                   26.3
3 Algeria                   41.8
4 American Samoa             8.5
5 Andorra                   28.8
6 Angola                   225. 
```

Summarize the data: **`dplyr summarize`** function

`dplyr::summarize` will allow you to summarize data. If you would like to summarize **all** columns, you can use `summarize_all` and pass in a function (with other arguments):

```
summarize_all(DATASET, FUNCTION, OTHER_FUNCTION_ARGUMENTS) # how to use
```

```
summarize_all(avgs, mean, na.rm = TRUE)
```

```
# A tibble: 1 x 10
  `1990` `1991` `1992` `1993` `1994` `1995` `1996` `1997` `1998` `1999`
   <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>
1   106.   108.   108.   110.   112.   114.   115.   119.   122.   125.
```

Summary Function

Using `summary` can give you rough snapshots of each column, but you would likely use `mean`, `min`, `max`, and `quantile` when necessary (and number of NAs):

```
summary(tb)
```

```
   country                1990            1991            1992      
 Length:208         Min.   :  0.0   Min.   :  4.0   Min.   :  2.0  
 Class :character   1st Qu.: 27.5   1st Qu.: 27.0   1st Qu.: 27.0  
 Mode  :character   Median : 60.0   Median : 58.0   Median : 56.0  
                    Mean   :105.6   Mean   :107.7   Mean   :108.3  
                    3rd Qu.:165.0   3rd Qu.:171.0   3rd Qu.:171.5  
                    Max.   :585.0   Max.   :594.0   Max.   :606.0  
                    NA's   :1       NA's   :1       NA's   :1      
      1993            1994           1995            1996      
 Min.   :  4.0   Min.   :  0   Min.   :  3.0   Min.   :  0.0  
 1st Qu.: 27.5   1st Qu.: 26   1st Qu.: 26.5   1st Qu.: 25.5  
 Median : 56.0   Median : 57   Median : 58.0   Median : 60.0  
 Mean   :110.3   Mean   :112   Mean   :114.2   Mean   :115.4  
 3rd Qu.:171.0   3rd Qu.:174   3rd Qu.:177.5   3rd Qu.:179.0  
 Max.   :618.0   Max.   :630   Max.   :642.0   Max.   :655.0  
 NA's   :1       NA's   :1     NA's   :1       NA's   :1      
      1997            1998            1999            2000      
 Min.   :  0.0   Min.   :  0.0   Min.   :  0.0   Min.   :  0.0  
 1st Qu.: 24.5   1st Qu.: 23.5   1st Qu.: 22.5   1st Qu.: 21.5  
 Median : 64.0   Median : 63.0   Median : 66.0   Median : 60.0  
 Mean   :118.9   Mean   :121.5   Mean   :125.0   Mean   :127.8  
 3rd Qu.:181.0   3rd Qu.:188.5   3rd Qu.:192.5   3rd Qu.:191.0  
```

Youth Tobacco Survey

Here we will be using the Youth Tobacco Survey data: http://johnmuschelli.com/intro_to_r/data/Youth_Tobacco_Survey_YTS_Data.csv .

```
yts = jhur::read_yts()
head(yts)
```

```
# A tibble: 6 x 31
   YEAR LocationAbbr LocationDesc TopicType TopicDesc MeasureDesc
  <dbl> <chr>        <chr>        <chr>     <chr>     <chr>
1  2015 AZ           Arizona      Tobacco … Cessatio… Percent of…
2  2015 AZ           Arizona      Tobacco … Cessatio… Percent of…
3  2015 AZ           Arizona      Tobacco … Cessatio… Percent of…
4  2015 AZ           Arizona      Tobacco … Cessatio… Quit Attem…
5  2015 AZ           Arizona      Tobacco … Cessatio… Quit Attem…
6  2015 AZ           Arizona      Tobacco … Cessatio… Quit Attem…
# … with 25 more variables: DataSource <chr>, Response <chr>,
#   Data_Value_Unit <chr>, Data_Value_Type <chr>, Data_Value <dbl>,
#   Data_Value_Footnote_Symbol <chr>, Data_Value_Footnote <chr>,
#   Data_Value_Std_Err <dbl>, Low_Confidence_Limit <dbl>,
#   High_Confidence_Limit <dbl>, Sample_Size <dbl>, Gender <chr>,
#   Race <chr>, Age <chr>, Education <chr>, GeoLocation <chr>,
#   TopicTypeId <chr>, TopicId <chr>, MeasureId <chr>,
#   StratificationID1 <chr>, StratificationID2 <chr>,
#   StratificationID3 <chr>, StratificationID4 <chr>, SubMeasureID <chr>,
#   DisplayOrder <dbl>
```

Length and unique

`unique(x)` will return the unique elements of `x`

```
unique(yts$LocationDesc)[1:10]
```

```
 [1] "Arizona"                     "Connecticut"
 [3] "Georgia"                     "Hawaii"
 [5] "Illinois"                    "Louisiana"
 [7] "Mississippi"                 "Utah"
 [9] "Missouri"                    "National (States and DC)"
```

`length` will tell you the length of a vector. Combined with `unique`, tells you the number of unique elements:

```
length(unique(yts$LocationDesc))
```

```
[1] 50
```

Table

`table(x)` will return a frequency table of unique elements of `x`

```
table(yts$LocationDesc)[1:5]
```

```
   Alabama    Arizona   Arkansas California   Colorado 
       378        240        210         96         48 
```

dplyr: count

```
yts %>% count(LocationDesc)
```

```
# A tibble: 50 x 2
   LocationDesc             n
   <chr>                <int>
 1 Alabama                378
 2 Arizona                240
 3 Arkansas               210
 4 California              96
 5 Colorado                48
 6 Connecticut            384
 7 Delaware               312
 8 District of Columbia    48
 9 Florida                 96
10 Georgia                282
# … with 40 more rows
```

dplyr: count

```
yts %>% count(LocationDesc, Age)
```

```
# A tibble: 50 x 3
   LocationDesc         Age          n
   <chr>                <chr>    <int>
 1 Alabama              All Ages   378
 2 Arizona              All Ages   240
 3 Arkansas             All Ages   210
 4 California           All Ages    96
 5 Colorado             All Ages    48
 6 Connecticut          All Ages   384
 7 Delaware             All Ages   312
 8 District of Columbia All Ages    48
 9 Florida              All Ages    96
10 Georgia              All Ages   282
# … with 40 more rows
```

Subsetting to specific columns

Let’s just take smoking status measures for all genders in middle school current smoking using `filter`, and the columns that represent the year, state and percentage using `select`:

```
library(dplyr)
sub_yts = filter(yts, MeasureDesc == "Smoking Status",
                 Gender == "Overall", Response == "Current",
                 Education == "Middle School")
sub_yts = select(sub_yts, YEAR, LocationDesc, Data_Value, Data_Value_Unit)
head(sub_yts, 4)
```

```
# A tibble: 4 x 4
   YEAR LocationDesc Data_Value Data_Value_Unit
  <dbl> <chr>             <dbl> <chr>
1  2015 Arizona             3.2 %
2  2015 Connecticut         0.8 %
3  2015 Hawaii              3   %
4  2015 Illinois            2   %
```

Perform Operations By Groups: dplyr

`group_by` allows you group the data set by grouping variables:

```
sub_yts = group_by(sub_yts, YEAR)
head(sub_yts)
```

```
# A tibble: 6 x 4
# Groups:   YEAR [1]
   YEAR LocationDesc Data_Value Data_Value_Unit
  <dbl> <chr>             <dbl> <chr>          
1  2015 Arizona             3.2 %              
2  2015 Connecticut         0.8 %              
3  2015 Hawaii              3   %              
4  2015 Illinois            2   %              
5  2015 Louisiana           5.2 %              
6  2015 Mississippi         4.7 %              
```

- doesn't change the data in any way, but how **functions operate on it**

Summarize the data

It’s grouped!

```
sub_yts %>% summarize(year_avg = mean(Data_Value, na.rm = TRUE))
```

```
# A tibble: 17 x 2
    YEAR year_avg
   <dbl>    <dbl>
 1  1999    14.6
 2  2000    12.5
 3  2001     9.84
 4  2002     9.60
 5  2003     7.49
 6  2004     8.2
 7  2005     7.27
 8  2006     7.37
 9  2007     6.68
10  2008     5.95
11  2009     5.84
12  2010     5.6
13  2011     5.15
14  2012     4.72
15  2013     3.76
16  2014     2.93
17  2015     2.86
```

Using the `pipe`

Pipe `sub_yts` into `group_by`, then pipe that into `summarize`:

```
yts_avgs = sub_yts %>%
  group_by(YEAR) %>%
  summarize(year_avg = mean(Data_Value, na.rm = TRUE),
            year_median = median(Data_Value, na.rm = TRUE))
head(yts_avgs)
```

```
# A tibble: 6 x 3
   YEAR year_avg year_median
  <dbl>    <dbl>       <dbl>
1  1999    14.6        14.4
2  2000    12.5        12
3  2001     9.84        9.3
4  2002     9.60        8.7
5  2003     7.49        7
6  2004     8.2         8.55
```

Ungroup the data

You usually want to perform operations on groups and may want to redefine the groups. The `ungroup` function will allow you to clear the groups from the data:

```
sub_yts = ungroup(sub_yts)
sub_yts
```

```
# A tibble: 222 x 4
    YEAR LocationDesc   Data_Value Data_Value_Unit
   <dbl> <chr>               <dbl> <chr>          
 1  2015 Arizona               3.2 %              
 2  2015 Connecticut           0.8 %              
 3  2015 Hawaii                3   %              
 4  2015 Illinois              2   %              
 5  2015 Louisiana             5.2 %              
 6  2015 Mississippi           4.7 %              
 7  2015 Missouri              2.4 %              
 8  2015 New Jersey            1.2 %              
 9  2015 North Carolina        2.3 %              
10  2015 North Dakota          3.6 %              
# … with 212 more rows
```

`group_by` with `mutate` - just add data

We can also use `mutate` to calculate the mean value for each year and add it as a column:

```
sub_yts %>%
  group_by(YEAR) %>%
  mutate(year_avg = mean(Data_Value, na.rm = TRUE)) %>%
  arrange(LocationDesc, YEAR) # look at year 2000 value
```

```
# A tibble: 222 x 5
# Groups:   YEAR [17]
    YEAR LocationDesc Data_Value Data_Value_Unit year_avg
   <dbl> <chr>             <dbl> <chr>              <dbl>
 1  2000 Alabama            19.1 %                  12.5 
 2  2002 Alabama            15.6 %                   9.60
 3  2004 Alabama            13.1 %                   8.2 
 4  2006 Alabama            13   %                   7.37
 5  2008 Alabama             8.7 %                   5.95
 6  2010 Alabama             7   %                   5.6 
 7  2012 Alabama             7.5 %                   4.72
 8  2014 Alabama             6.4 %                   2.93
 9  2000 Arizona            11.4 %                  12.5 
10  2003 Arizona             8.7 %                   7.49
# … with 212 more rows
```

Counting

Standard statistics can be calculated. There are other functions, such as `n()` count the number of observations.

```
sub_yts %>%
  group_by(YEAR) %>%
  summarize(n = n(),
            mean = mean(Data_Value, na.rm = TRUE)) %>%
  head
```

```
# A tibble: 6 x 3
   YEAR     n  mean
  <dbl> <int> <dbl>
1  1999    10 14.6
2  2000    27 12.5
3  2001    11  9.84
4  2002    23  9.60
5  2003    12  7.49
6  2004    14  8.2
```

Lab Part 3

Website

Data Summarization/Visualization: ggplot2

`ggplot2` is a package of plotting that is very popular and powerful (using the **g**rammar of **g**raphics). We will use `qplot` (“quick plot”) for most of the basic examples:

```
qplot
```

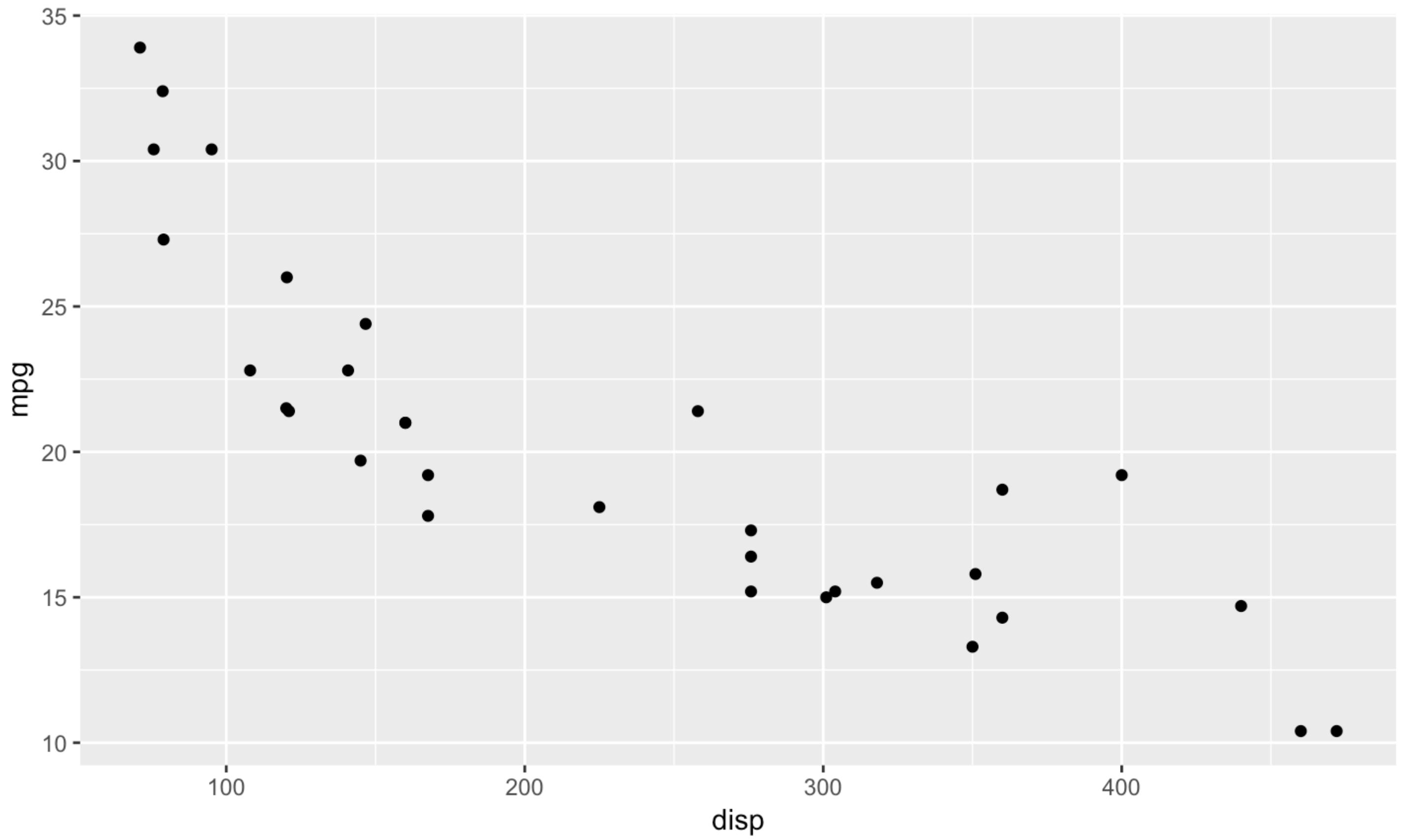
```
function (x, y, ..., data, facets = NULL, margins = FALSE, geom = "auto",
    xlim = c(NA, NA), ylim = c(NA, NA), log = "", main = NULL,
    xlab = NULL, ylab = NULL, asp = NA, stat = NULL, position = NULL)
NULL
```

Basic Plots

Plotting is an important component of exploratory data analysis. We will review some of the more useful and informative plots here. We will go over formatting and making plots look nicer in additional lectures.

Scatterplot

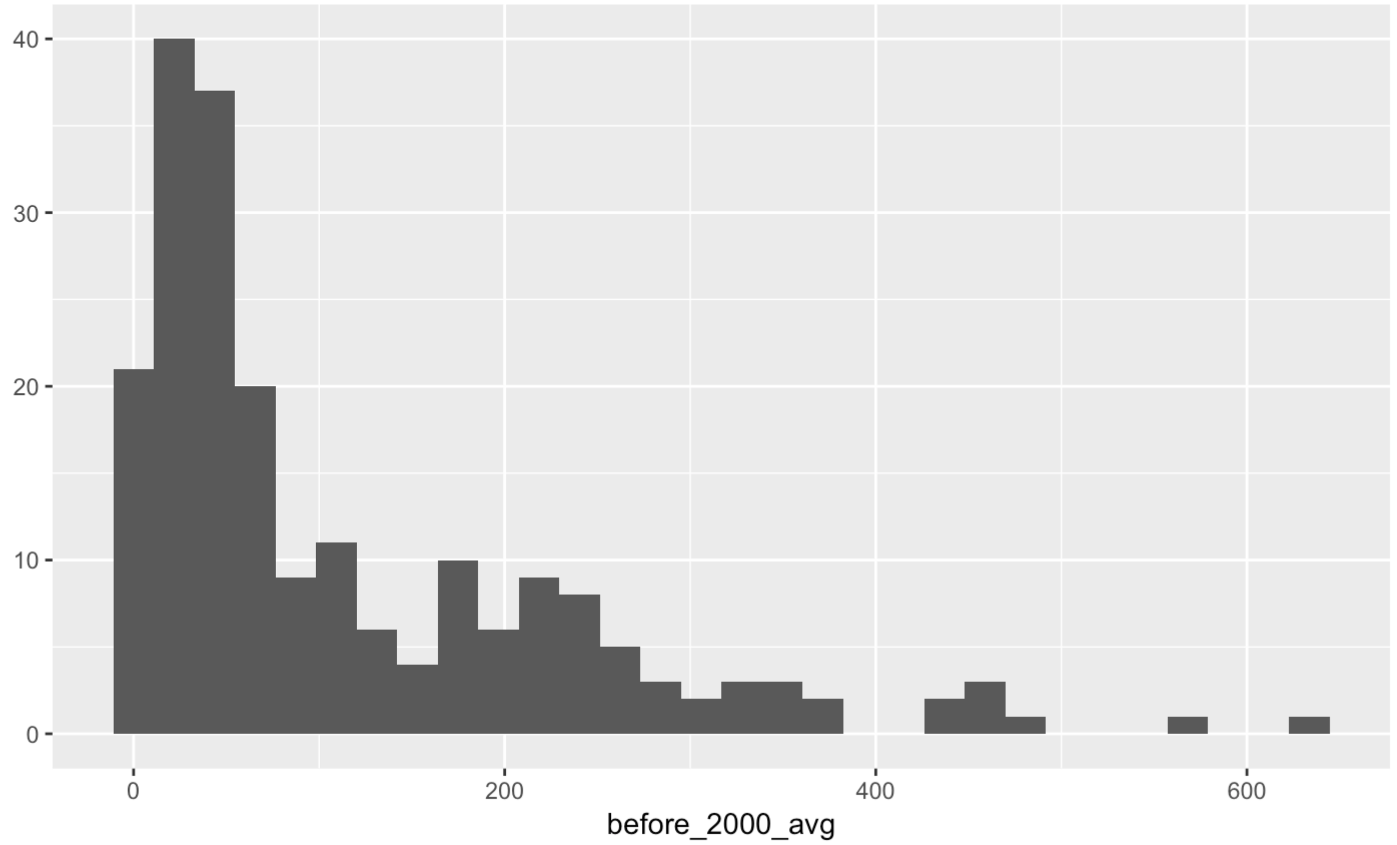
```
library(ggplot2)
qplot(x = disp, y = mpg, data = jhu_cars)
```



Histograms

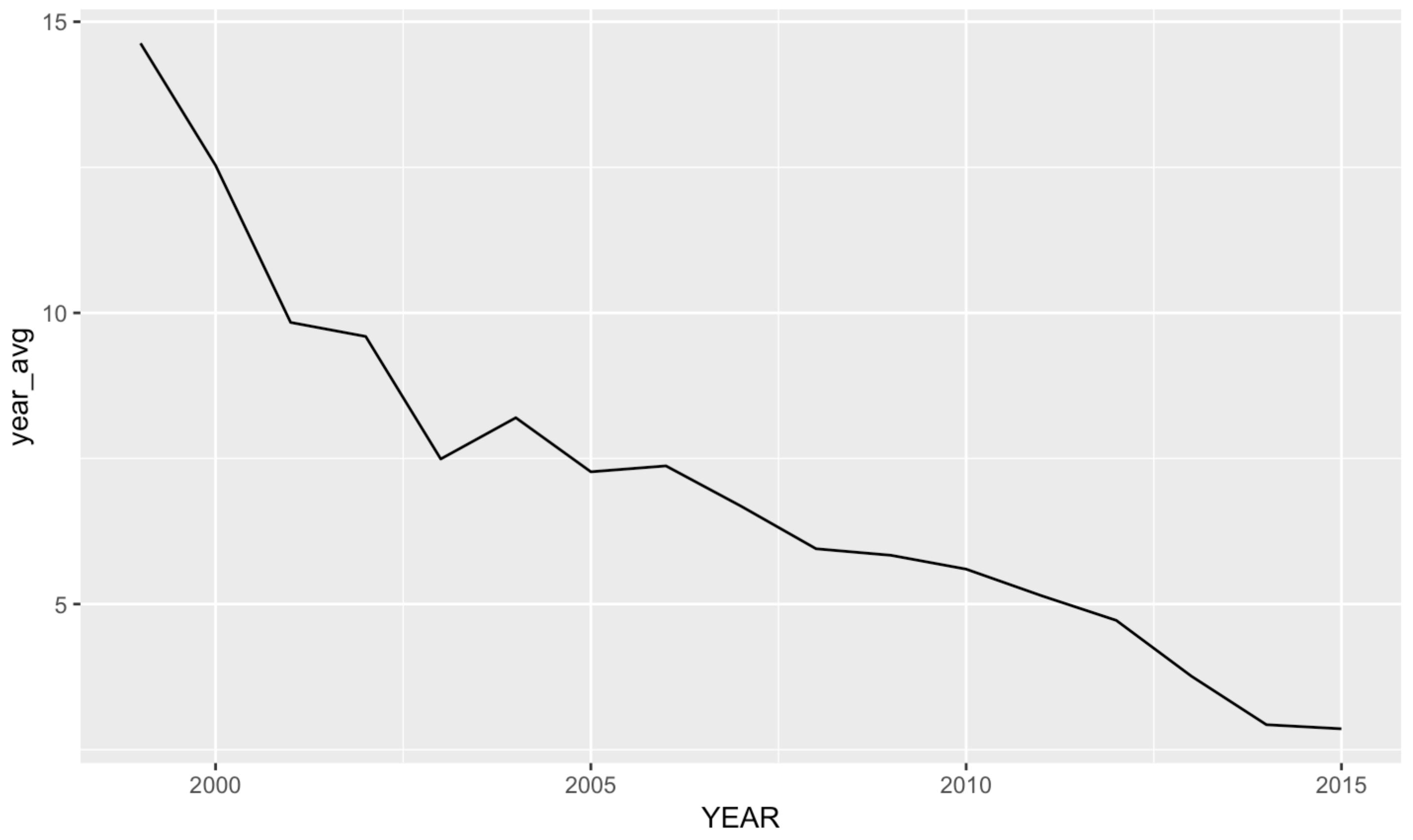
```r
qplot(x = before_2000_avg, data = tb, geom = "histogram")
```

```
Warning: Removed 1 rows containing non-finite values (stat_bin).
```



Plot with a line

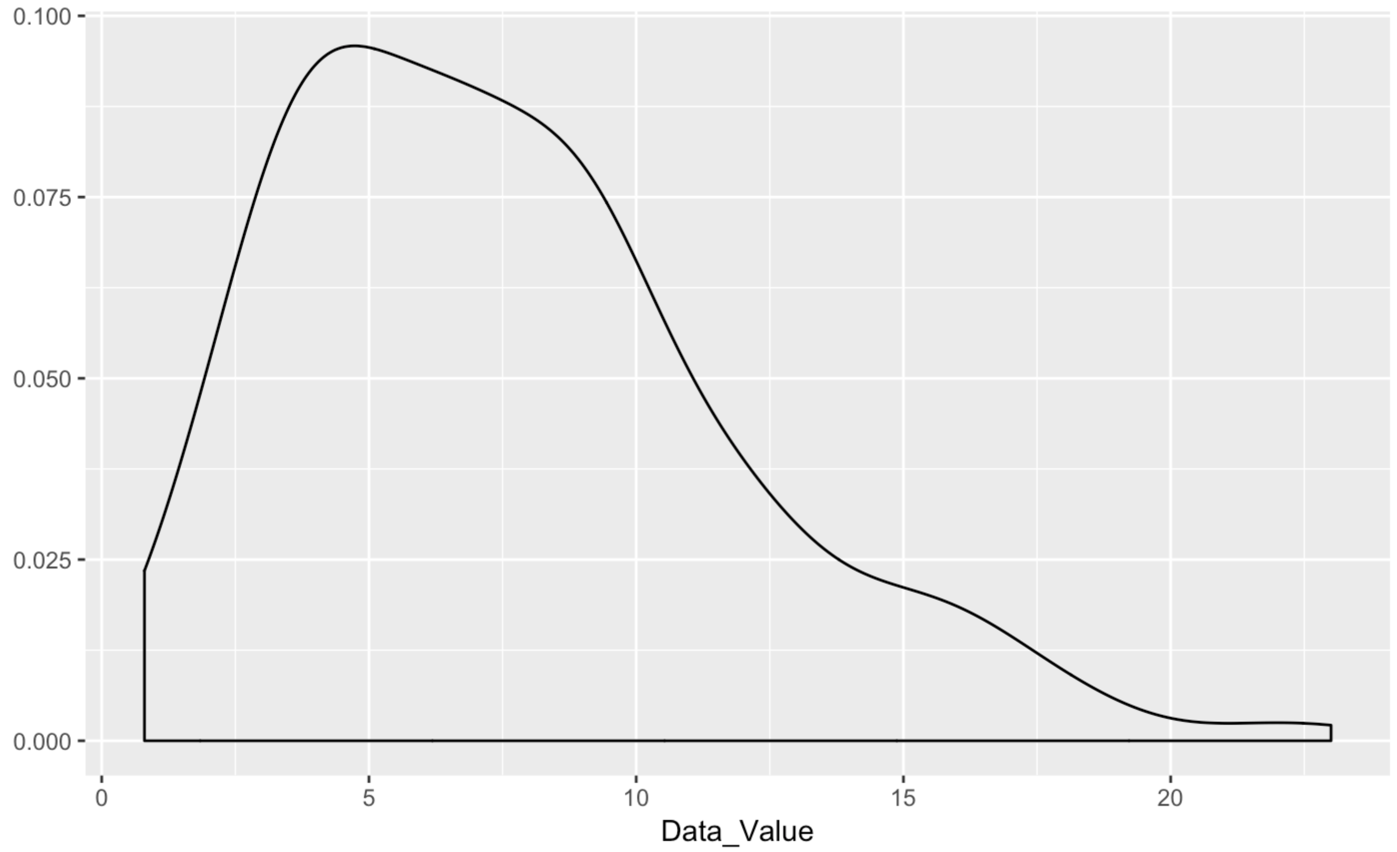
```r
qplot(x = YEAR, y = year_avg, data = yts_avgs, geom = "line")
```



Density

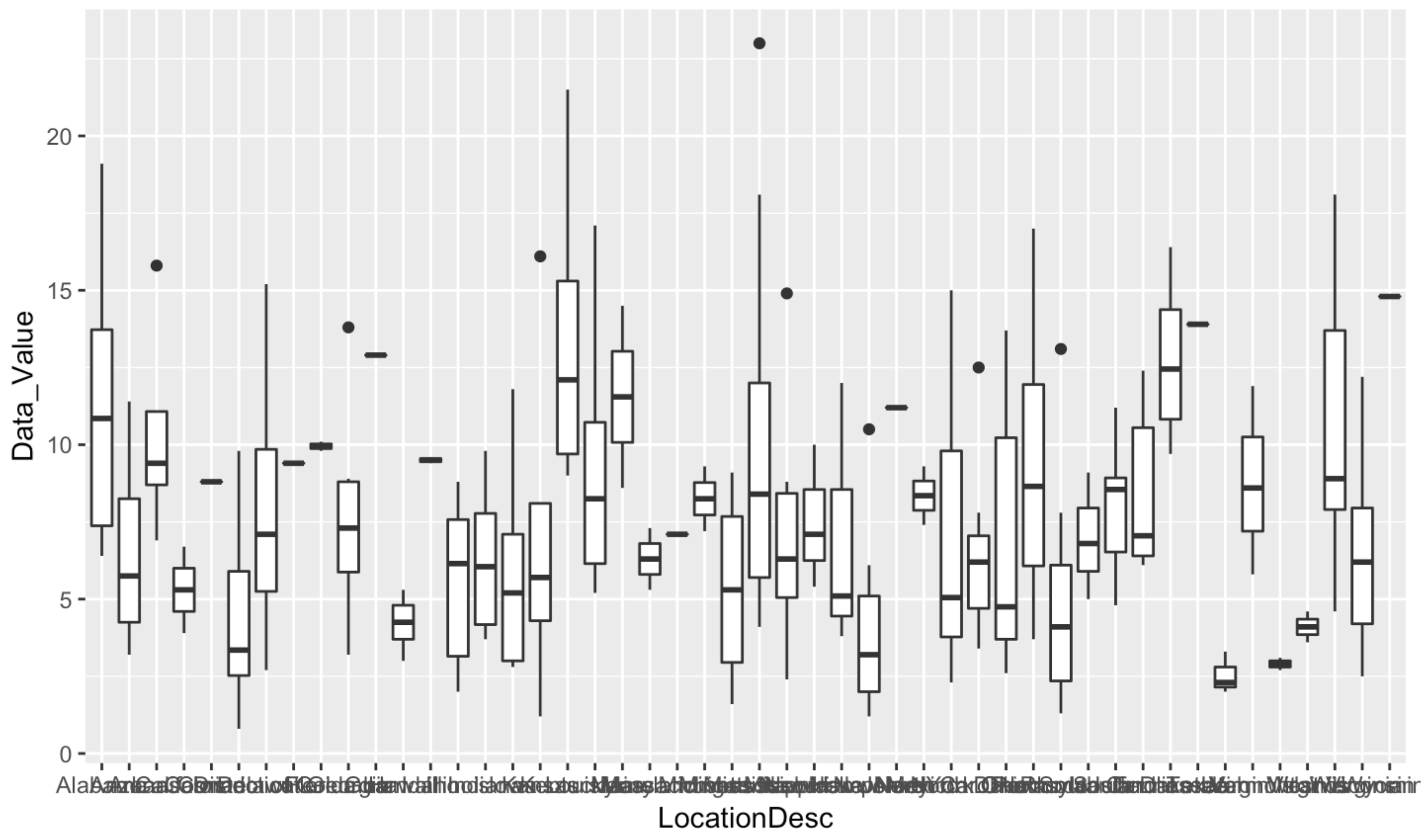
Over all years and states, this is the density of smoking status incidence:

```r
qplot(x = Data_Value, data = sub_yts, geom = "density")
```



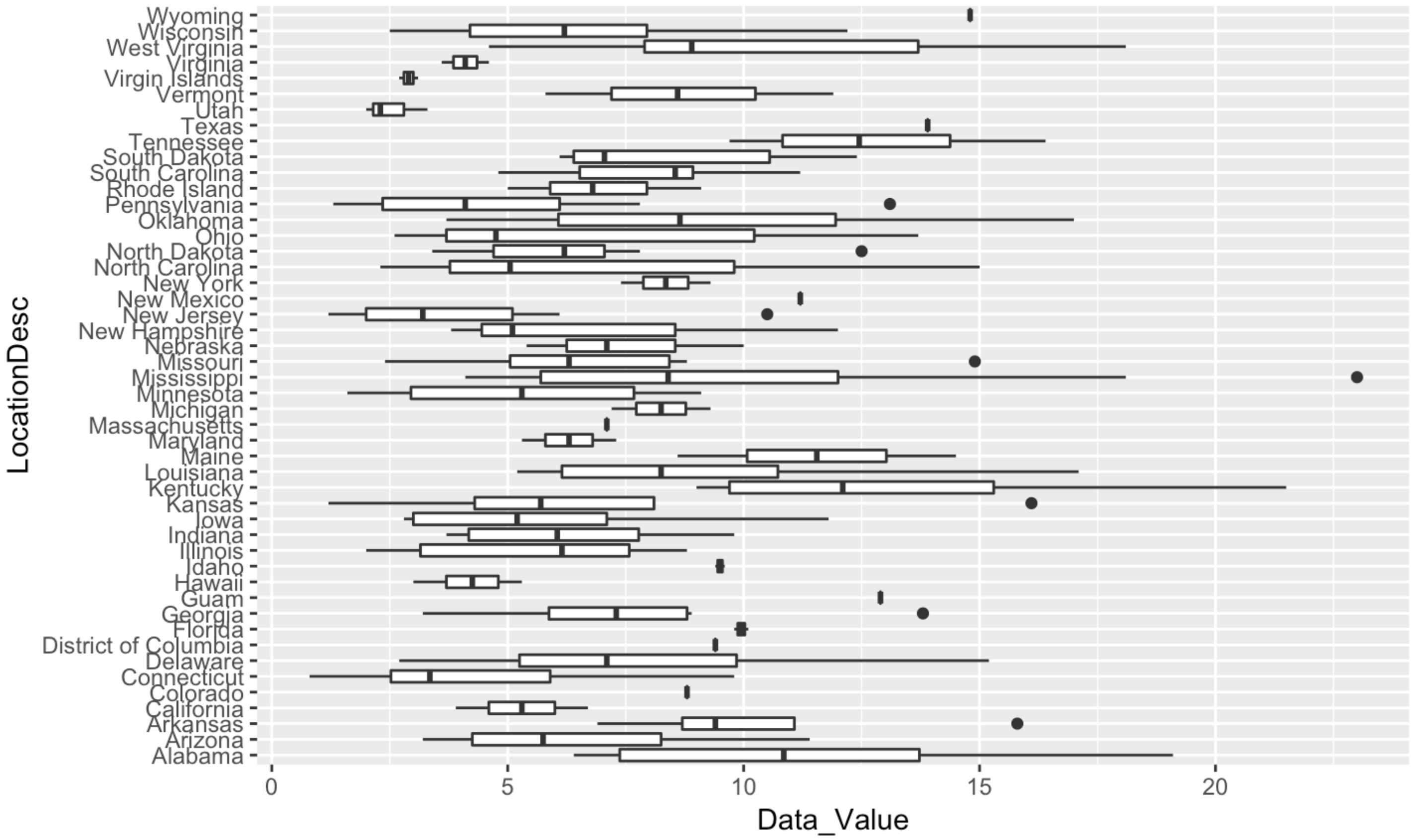
Boxplots

```
qplot(x = LocationDesc, y = Data_Value, data = sub_yts, geom = "boxplot")
```



Boxplots

```
qplot(x = LocationDesc, y = Data_Value,
      data = sub_yts, geom = "boxplot") + coord_flip()
```



Lab Part 4

Website

Base functions for plotting

- Basic summarization plots:
    - `plot(x,y)`: scatterplot of x and y
    - `boxplot(y~x)`: boxplot of y against levels of x
    - `hist(x)`: histogram of x
    - `density(x)`: kernel density plot of x

Conclusion

- `group_by` is very powerful, especially with `summarise/summarize`
- Using `group_by` and `mutate` keeps all the rows and repeates a value, `summarize` reduces the number of rows
- The `matrixStats` package extends this to `colMedians`, `colMaxs`, etc.

Website

[Website]

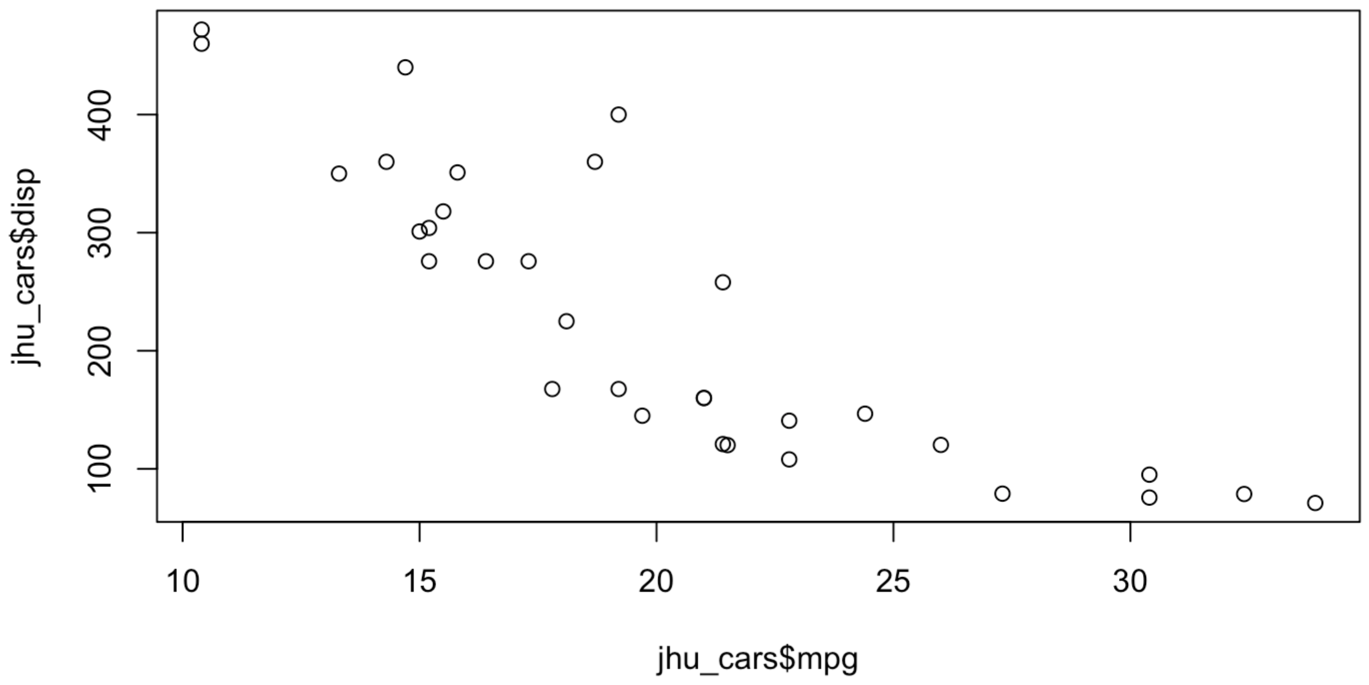
Base R Plots - not covered

Basic Plots

Plotting is an important component of exploratory data analysis. We will review some of the more useful and informative plots here. We will go over formatting and making plots look nicer in additional lectures.

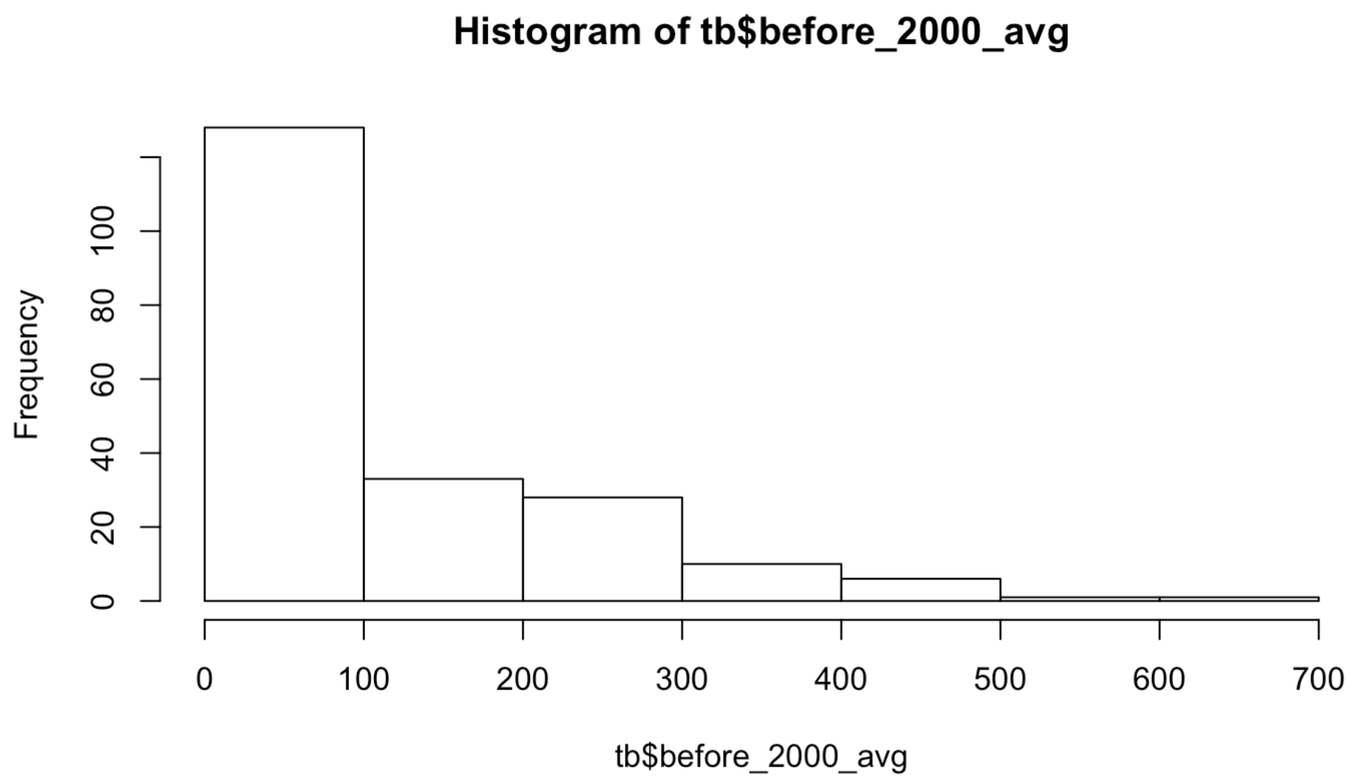
Scatterplot

```
plot(jhu_cars$mpg, jhu_cars$disp)
```



Histograms

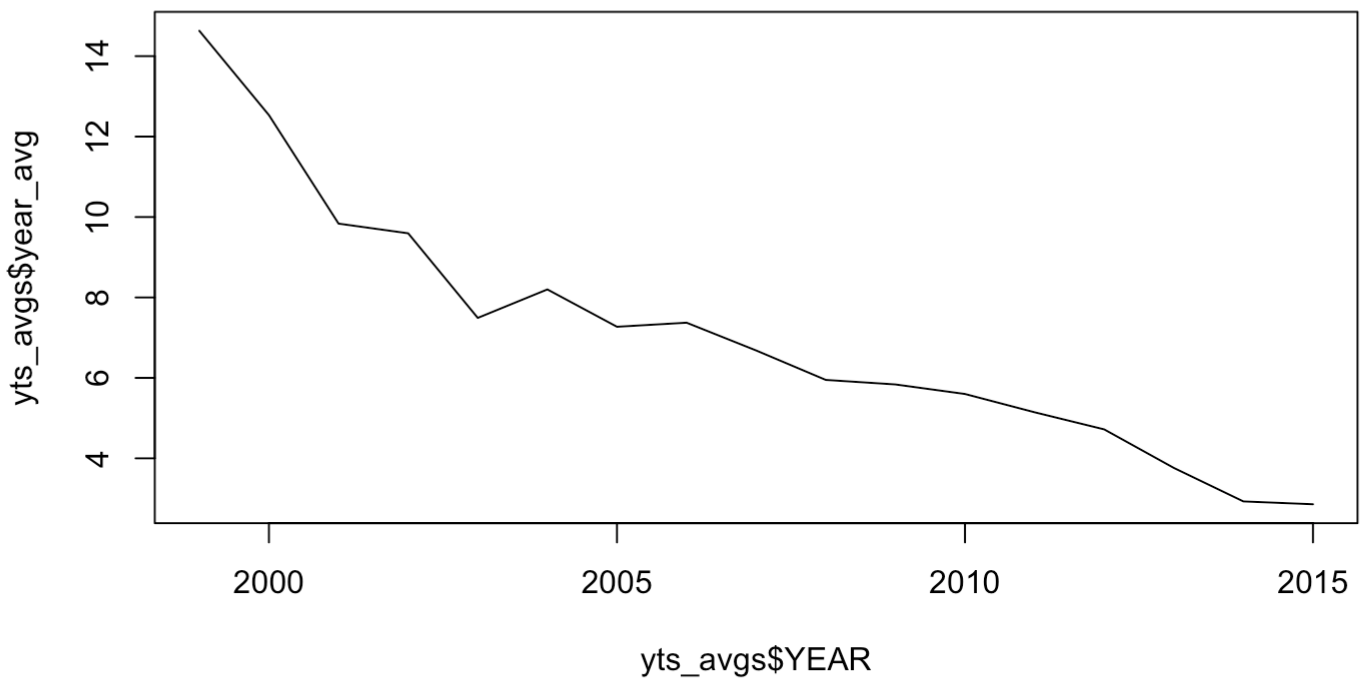
```
hist(tb$before_2000_avg)
```



Plot with a line

`type = "l"` means a line

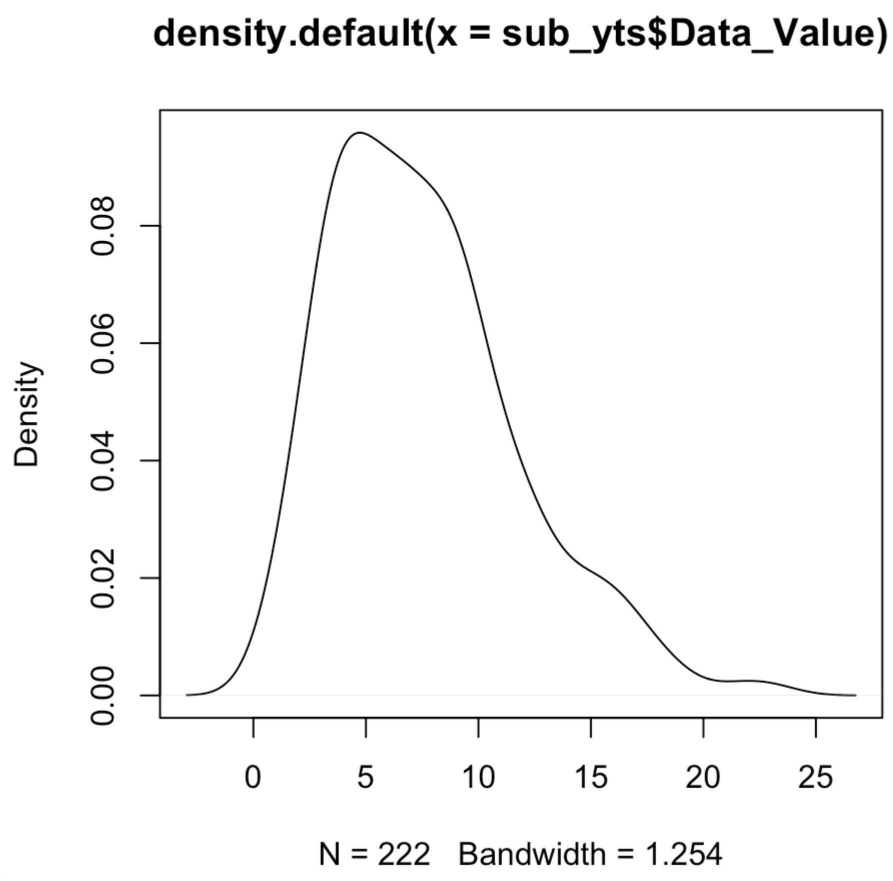
```
plot(yts_avgs$YEAR, yts_avgs$year_avg, type = "l")
```



Density

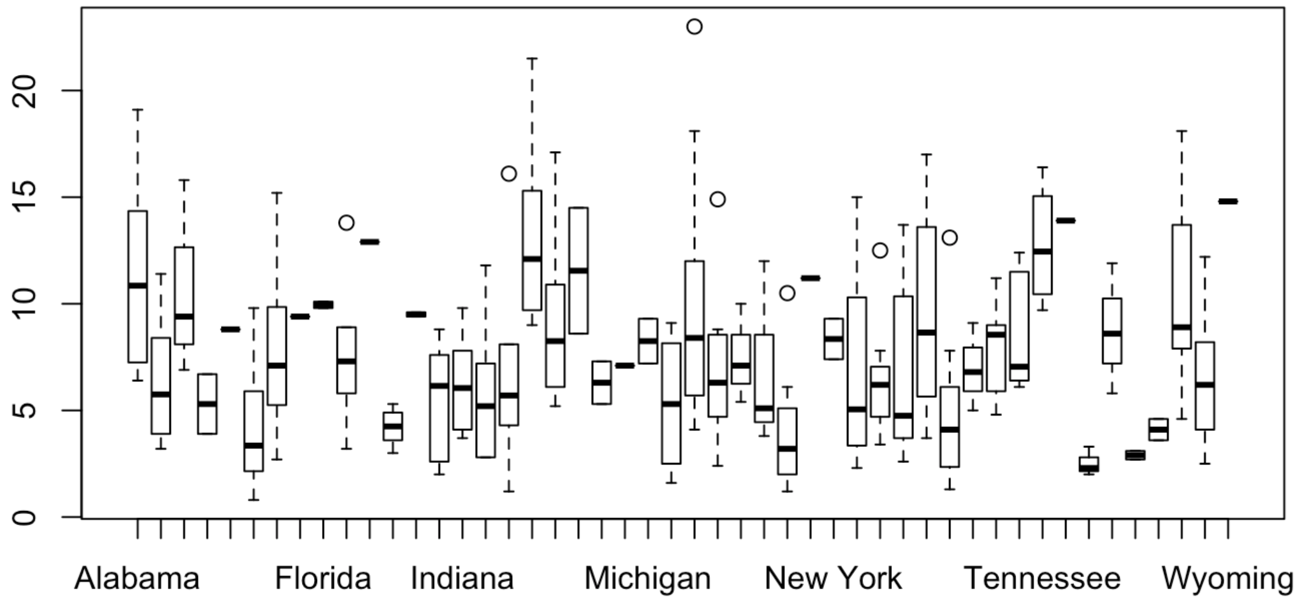
Over all years and states, this is the density of smoking status incidence:

```
plot(density(sub_yts$Data_Value))
```



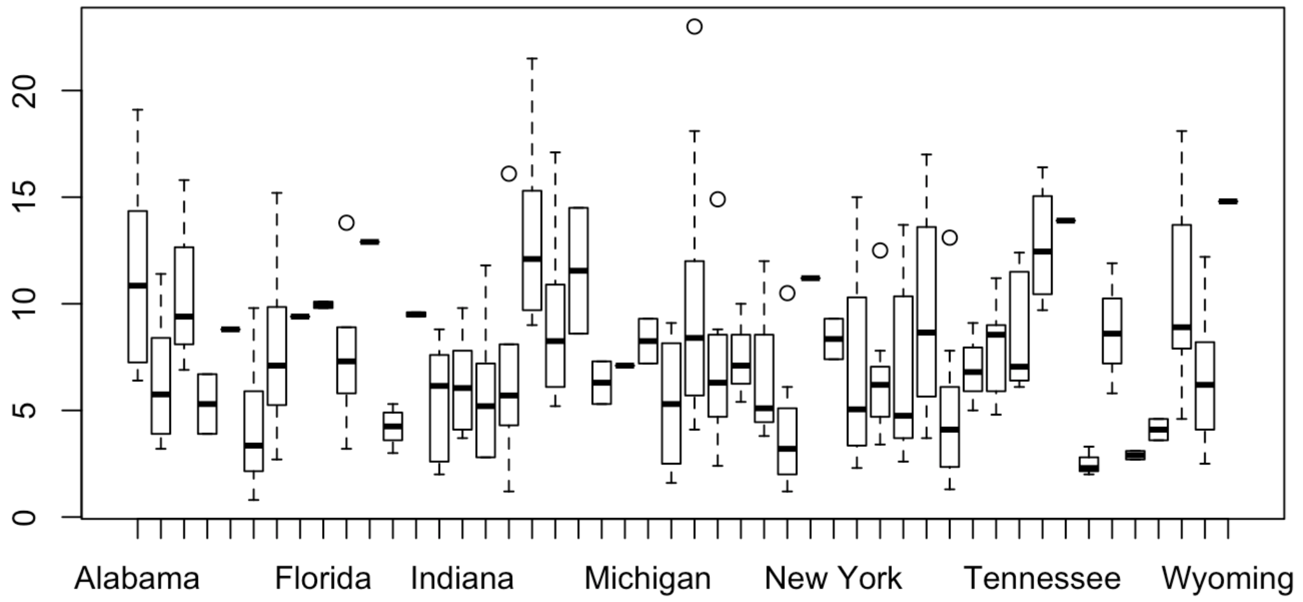
Boxplots

```
boxplot(sub_yts$Data_Value ~ sub_yts$LocationDesc)
```



Boxplots

```
boxplot(Data_Value ~ LocationDesc, data = sub_yts)
```

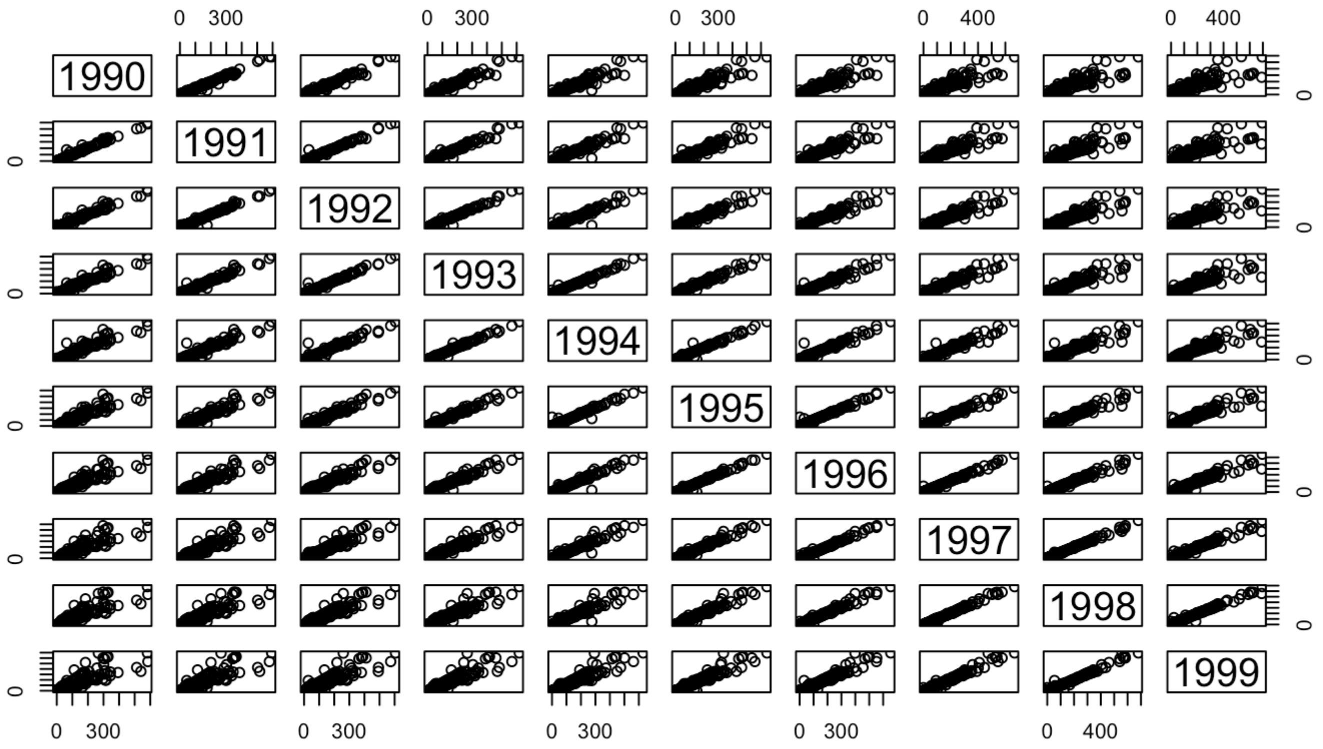


Data Summarization for data.frames

- Basic summarization plots
  - `matplot(x,y)`: scatterplot of two matrices, x and y
  - `pairs(x,y)`: plots pairwise scatter plots of matrices x and y, column by column

Matrix plot

```
pairs(avgs)
```



Lab Part 4

Website

Apply statements

You can apply more general functions to the rows or columns of a matrix or data frame, beyond the mean and sum.

```
apply(X, MARGIN, FUN, ...)
```

X : an array, including a matrix.

MARGIN : a vector giving the subscripts which the function will be applied over. E.g., for a matrix 1 indicates rows, 2 indicates columns, c(1, 2) indicates rows and columns. Where X has named dimnames, it can be a character vector selecting dimension names.

FUN : the function to be applied: see ‘Details’.

… : optional arguments to FUN.

Apply statements

```r
apply(avgs,2,mean, na.rm=TRUE) # column means
```

```
    1990     1991     1992     1993     1994     1995     1996     1997 
105.5797 107.6715 108.3140 110.3188 111.9662 114.1981 115.3527 118.8792 
    1998     1999 
121.5169 125.0435 
```

```r
head(apply(avgs,1,mean, na.rm=TRUE)) # row means
```

```
[1] 168.0  26.3  41.8   8.5  28.8 224.6
```

```r
apply(avgs,2,sd, na.rm=TRUE) # columns sds
```

```
    1990     1991     1992     1993     1994     1995     1996     1997 
110.6440 112.7687 114.4853 116.6744 120.0931 122.7119 126.1800 131.0858 
    1998     1999 
137.3754 146.0755 
```

```r
apply(avgs,2,max, na.rm=TRUE) # column maxs
```

```
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 
 585  594  606  618  630  642  655  668  681  695 
```

Other Apply Statements

- `tapply()`: ‘grouping’ apply
- `lapply()`: ‘list’ apply [tomorrow]
- `sapply()`: ‘simple’ apply [tomorrow]
- Other less used ones…

See more details here: http://nsaunders.wordpress.com/2010/08/20/a-brief-introduction-to-apply-in-r/

- Commonly used, but we will discuss how to do all steps in `dplyr`