

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`
- 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 `mtcars` to explore different ways of summarizing data. The `head` command displays the first 6 (default) rows of an object:

```
head(mtcars)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
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(mtcars$hp)
```

```
[1] 146.6875
```

```
quantile(mtcars$hp)
```

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

Statistical summarization

```
median(mtcars$wt)
```

```
[1] 3.325
```

```
quantile(mtcars$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(mtcars$wt)
```

One Sample t-test

```
data:  mtcars$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
```

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

TB Incidence

Please download the TB incidence data:

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

Here we will read in a `data.frame` of values from TB incidence:

```
library(readxl)
tb <- read_excel("../data/tb_incidence.xlsx")
head(tb)
```

```
# A tibble: 6 x 19
#   `TB incidence, all forms (per 100 000 population per year)` `1990`
#   <chr> <dbl>
1 Afghanistan 168
2 Albania 25
3 Algeria 38
4 American Samoa 21
5 Andorra 36
6 Angola 205
# ... with 17 more variables: `1991` <dbl>, `1992` <dbl>, `1993` <dbl>,
#   `1994` <dbl>, `1995` <dbl>, `1996` <dbl>, `1997` <dbl>, `1998` <dbl>,
#   `1999` <dbl>, `2000` <dbl>, `2001` <dbl>, `2002` <dbl>, `2003` <dbl>,
#   `2004` <dbl>, `2005` <dbl>, `2006` <dbl>, `2007` <dbl>
```

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 = rename(tb,
            country = `TB incidence, all forms (per 100 000 population per year)`)
```

`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"
```

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    168.0
2 Albania         26.3
3 Algeria        41.8
4 American Samoa   8.5
5 Andorra        28.8
6 Angola        224.6
```

Summary

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

```
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

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

```
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						

```
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						

```
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/>

Youth Tobacco Survey

Please download the Youth Tobacco Survey data. You can also read it in directly from the web:

```
library(readr)
smoke = read_csv(
  "http://johnmuscchelli.com/intro_to_r/data/Youth_Tobacco_Survey_YTS_Data.csv"
)
head(smoke)
```

```
# A tibble: 6 x 31
  YEAR LocationAbbr LocationDesc TopicType
<int>      <chr>      <chr>      <chr>
1  2015          AZ    Arizona Tobacco Use - Survey Data
2  2015          AZ    Arizona Tobacco Use - Survey Data
3  2015          AZ    Arizona Tobacco Use - Survey Data
4  2015          AZ    Arizona Tobacco Use - Survey Data
5  2015          AZ    Arizona Tobacco Use - Survey Data
6  2015          AZ    Arizona Tobacco Use - Survey Data
# ... with 27 more variables: TopicDesc <chr>, MeasureDesc <chr>,
#   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 <int>, Gender <chr>,
#   Race <chr>, Age <chr>, Education <chr>, GeoLocation <chr>,
#   TopicTypeId <chr>, TopicId <chr>, MeasureId <chr>,
#   StratificationID1 <chr>, StratificationID2 <chr>,
```


Length and unique

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

```
unique(smoke$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(smoke$LocationDesc))
```

```
[1] 50
```

Table

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

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

Alabama	Arizona	Arkansas	California	Colorado
378	240	210	96	48

Subsetting to specific columns

Let's just take smoking status measures for all genders using `filter`, and the columns that represent the year, state using `select`:

```
library(dplyr)
sub_smoke = filter(smoke,
                   MeasureDesc == "Smoking Status",
                   Gender == "Overall",
                   Response == "Current")
sub_smoke = select(sub_smoke, YEAR, LocationDesc, Data_Value)
head(sub_smoke, 4)
```

```
# A tibble: 4 x 3
  YEAR LocationDesc Data_Value
<int>      <chr>      <dbl>
1  2015      Arizona         3.2
2  2015 Connecticut         0.8
3  2015 Connecticut         5.6
4  2015      Georgia        10.8
```

`tapply()`

From the help file: "Apply a function to each cell of a ragged array, that is to each (non-empty) group of values given by a unique combination of the levels of certain factors."

```
tapply(X, INDEX, FUN = NULL, ..., simplify = TRUE)
```

Simply put, you can apply function `FUN` to `x` within each categorical level of `INDEX`. It is very useful for assessing properties of continuous data by levels of categorical data.

`tapply()`

For example, we can estimate the average current smoking statuses over all states for each year:

```
tapply(sub_smoke$Data_Value, sub_smoke$YEAR, mean, na.rm = TRUE)
```

1999	2000	2001	2002	2003	2004	2005
20.493333	19.878431	15.661111	16.802326	13.176190	13.926923	14.128571
2006	2007	2008	2009	2010	2011	2012
14.113636	13.013636	12.159091	11.663333	12.290000	11.773913	9.954545
2013	2014	2015				
7.782759	7.157143	6.579167				

Perform Operations By Groups: dplyr

`group_by` allows you group the data in a more intuitive way than `apply`

We will use `group_by` to group the data by line, then use `summarize` (or `summarise`) to get the mean percentage of current smokers:

```
summarize(group_by(sub_smoke, YEAR), year_avg = mean(Data_Value, na.rm = TRUE))
```

```
# A tibble: 17 x 2
  YEAR year_avg
  <int>   <dbl>
1  1999 20.493333
2  2000 19.878431
3  2001 15.661111
4  2002 16.802326
5  2003 13.176190
6  2004 13.926923
7  2005 14.128571
8  2006 14.113636
9  2007 13.013636
10 2008 12.159091
11 2009 11.663333
12 2010 12.290000
13 2011 11.773913
14 2012  9.954545
15 2013  7.782759
```

Using the `pipe` (comes with `dplyr`):

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

```
smoke_avgs = sub_smoke %>%  
  group_by(YEAR) %>%  
  summarize(year_avg = mean(Data_Value, na.rm = TRUE))  
head(smoke_avgs)
```

```
# A tibble: 6 x 2  
  YEAR year_avg  
  <int>   <dbl>  
1  1999 20.49333  
2  2000 19.87843  
3  2001 15.66111  
4  2002 16.80233  
5  2003 13.17619  
6  2004 13.92692
```

Counting

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

```
sub_smoke %>%  
  group_by(YEAR) %>%  
  summarize(n = n()) %>%  
  head
```

```
# A tibble: 6 x 2  
  YEAR      n  
  <int> <int>  
1  1999     15  
2  2000     51  
3  2001     18  
4  2002     43  
5  2003     21  
6  2004     26
```

```
sub_smoke %>%  
  group_by(YEAR) %>%  
  tally() %>%  
  head
```

```
# A tibble: 6 x 2  
  YEAR      n  
  <int> <int>
```


Data Summarization/Visualization

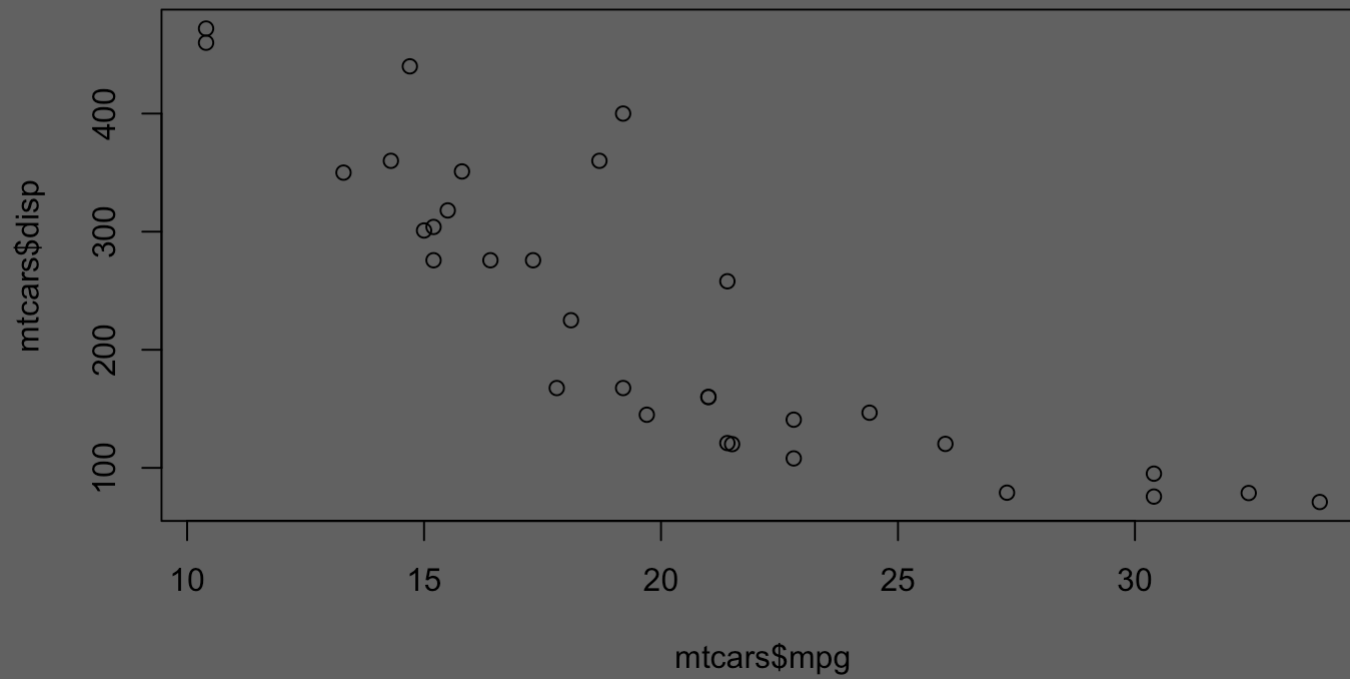
- Basic summarization plots
 - `plot(x, y)`: scatterplot of x and y
 - `boxplot(y~x)`: boxplot of y against levels of x
 - `hist(x)`: histogram of x
 - `density(x)`: kernel density plot of x

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

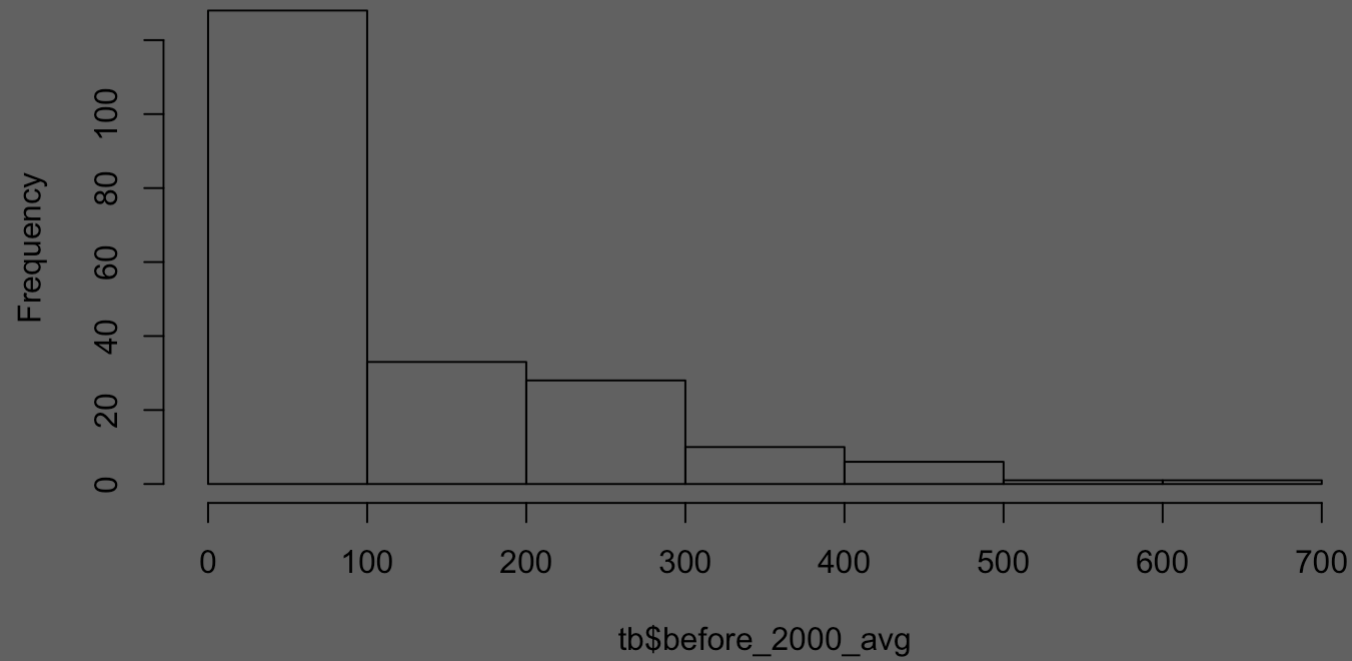
```
plot(mtcars$mpg, mtcars$disp)
```



Histograms

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

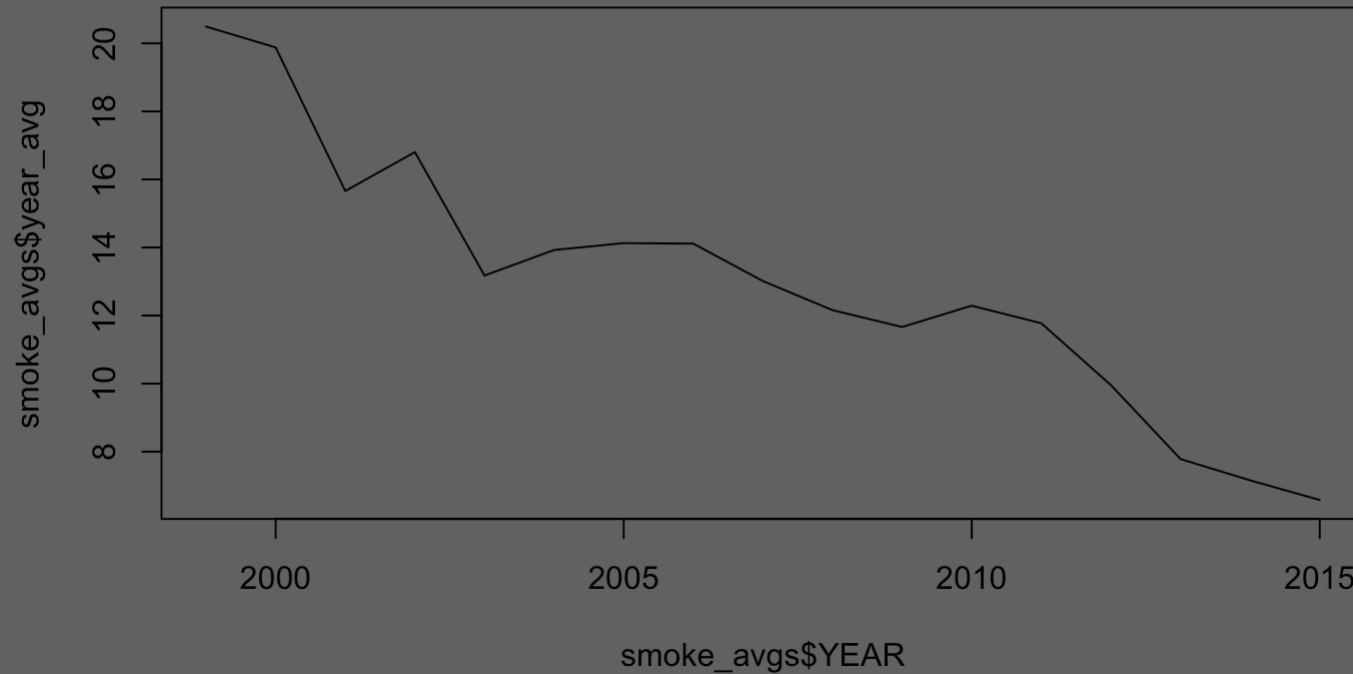
Histogram of tb\$before_2000_avg



Plot with a line

`type = "l"` means a line

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

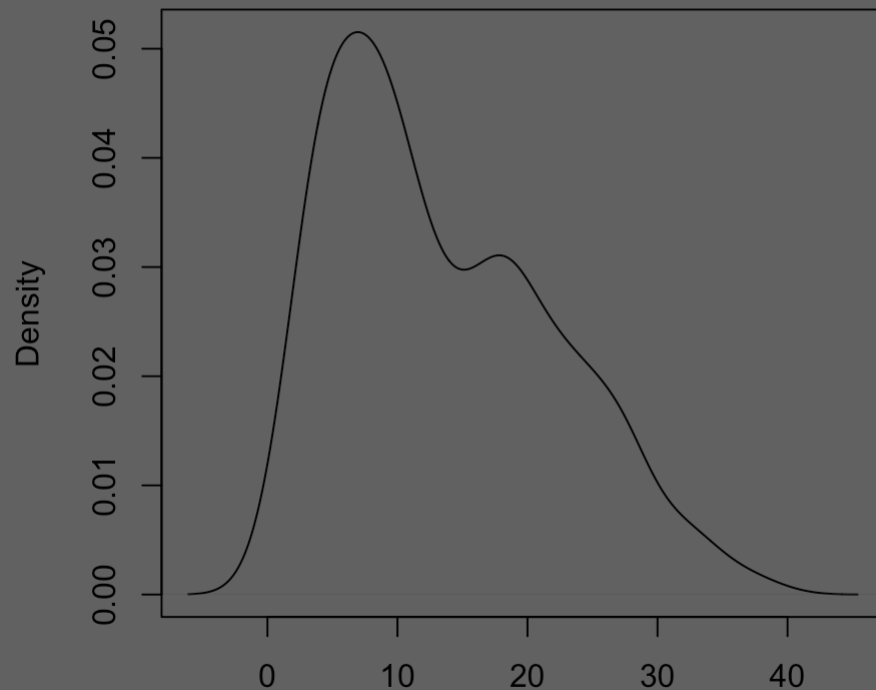


Density

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

```
plot(density(sub_smoke$Data_Value))
```

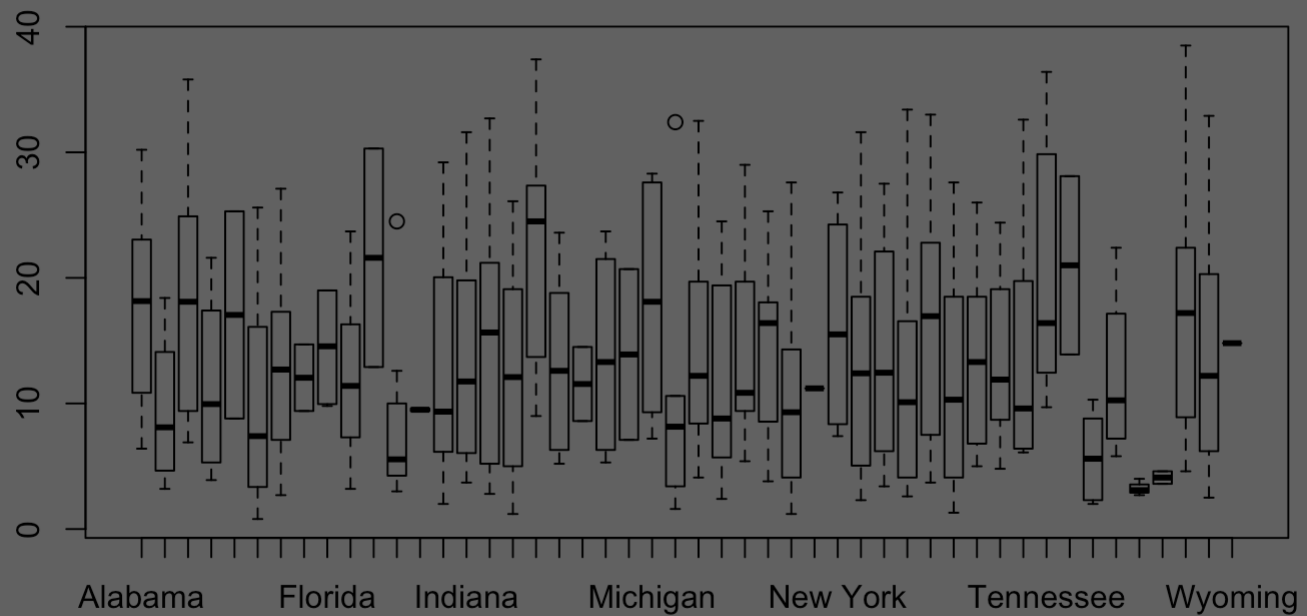
density.default(x = sub_smoke\$Data_Value)



N = 419 Bandwidth = 2.294

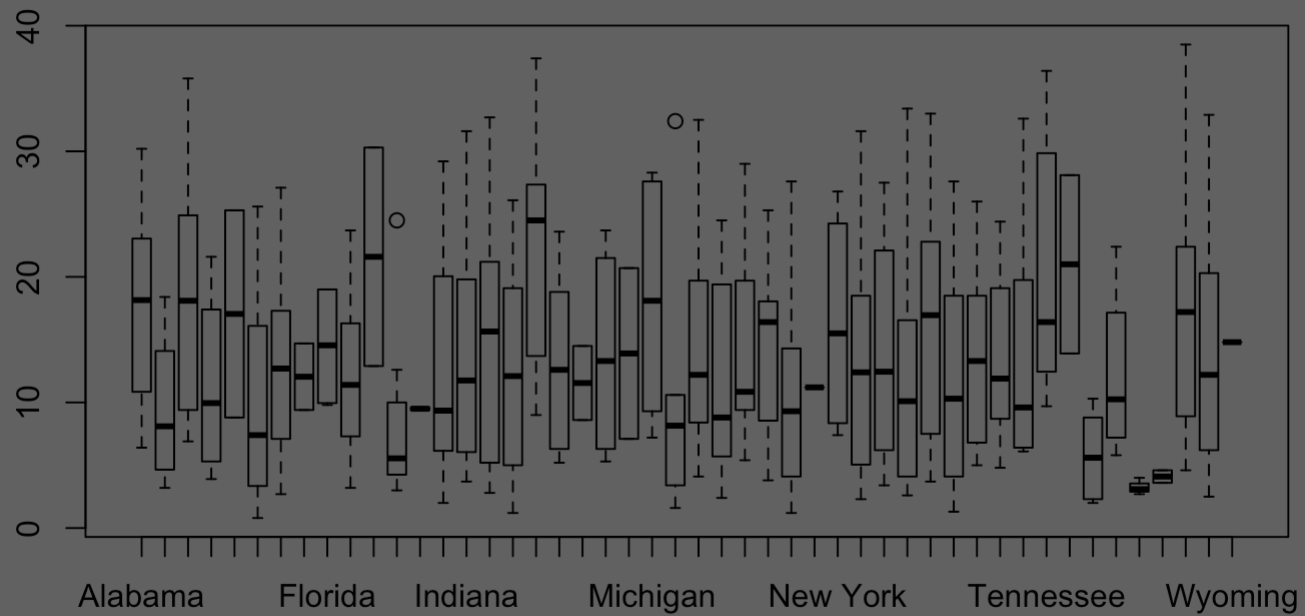
Boxplots

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



Boxplots

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

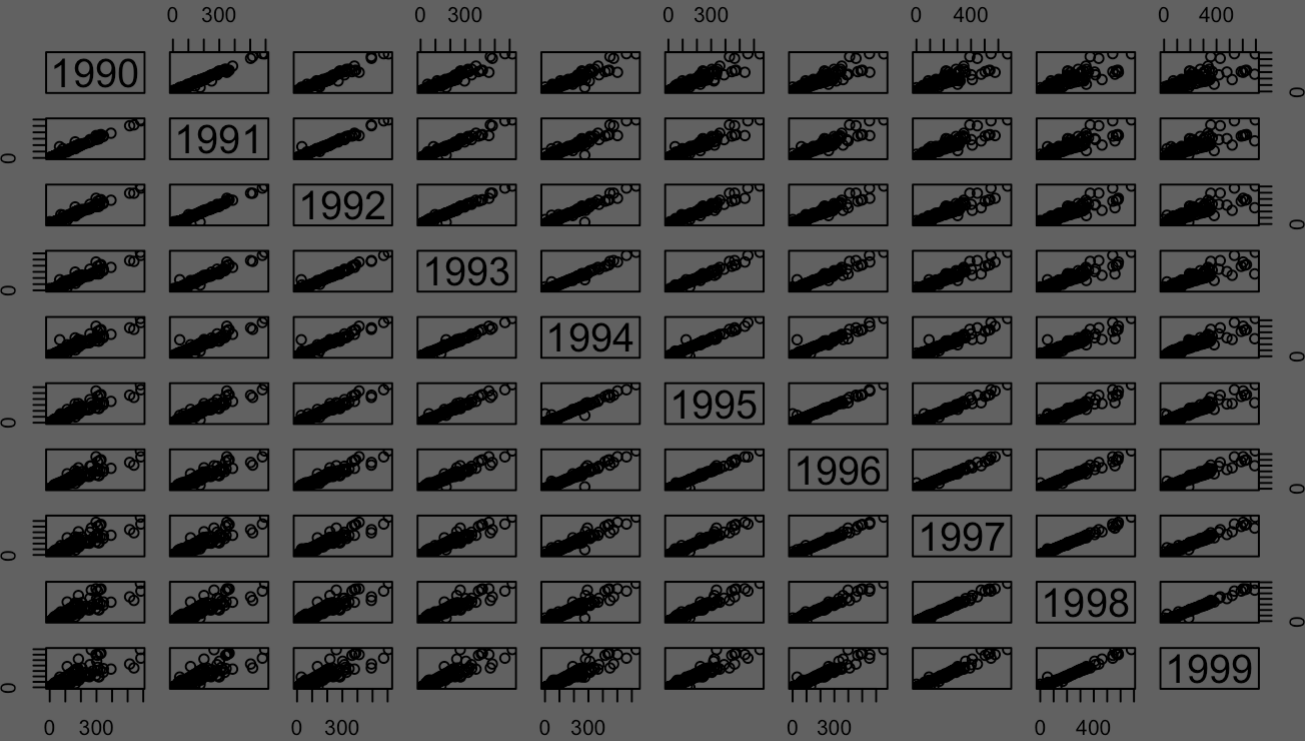


Data Summarization for data.frames

- 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)`



Conclusion

- Base R has apply statements that perform things repeatedly.
- `dplyr` has a lot of more intuitive syntax.
 - `group_by` is very powerful, especilly with `summarise/summarize`
- Base R has good things for quickly summarizing rows or colummns of all numeric data.
 - The `matrixStats` package extends this to `colMedians`, `colMaxs`, etc.

Website

Website