STA 517 3.0 Programming and Statistical Computing with R

🚦 Built-in functions in R

Dr Thiyanga Talagala

Function Anatomy

```
vec1 <- c(1, 2, 3, 4, 5)
mean(vec1)
```

```
[1] 3
```

```
vec2 <- c(1, 2, NA, 3, 4, 5)
mean(vec2)
```

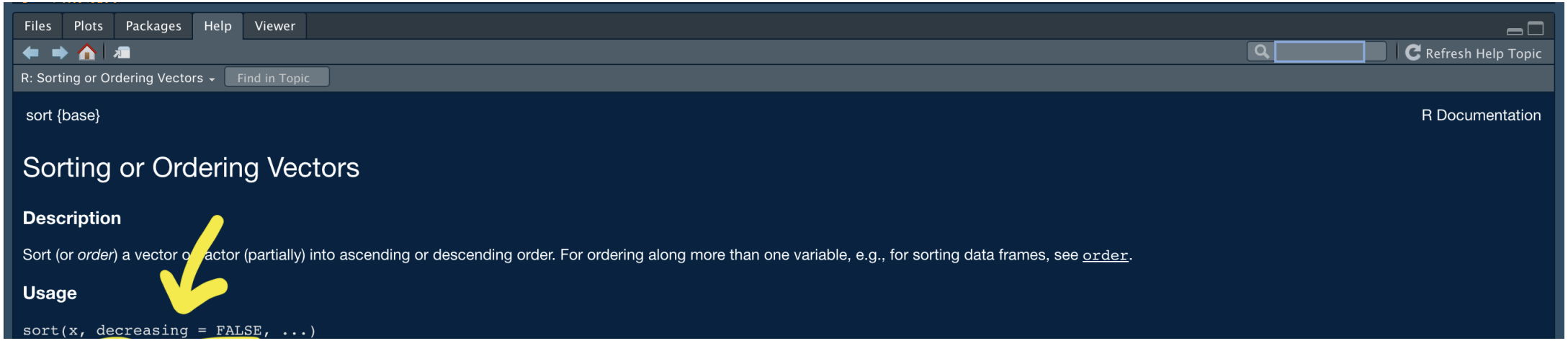
```
[1] NA
```

Help

```
?mean
```

help: mean

help: sort


Files
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R: Sorting or Ordering Vectors
Find in Topic
sort {base}
R Documentation
Sorting or Ordering Vectors
Description
Sort (or order) a vector or factor (partially) into ascending or descending order. For ordering along more than one variable, e.g., for sorting data frames, see order.
Usage
sort(x, decreasing = FALSE, ...)

The name of the function

mean with additional inputs

```
vec1 <- c(1, 2, 3, 4, 5)
mean(vec1)
```

```
[1] 3
```

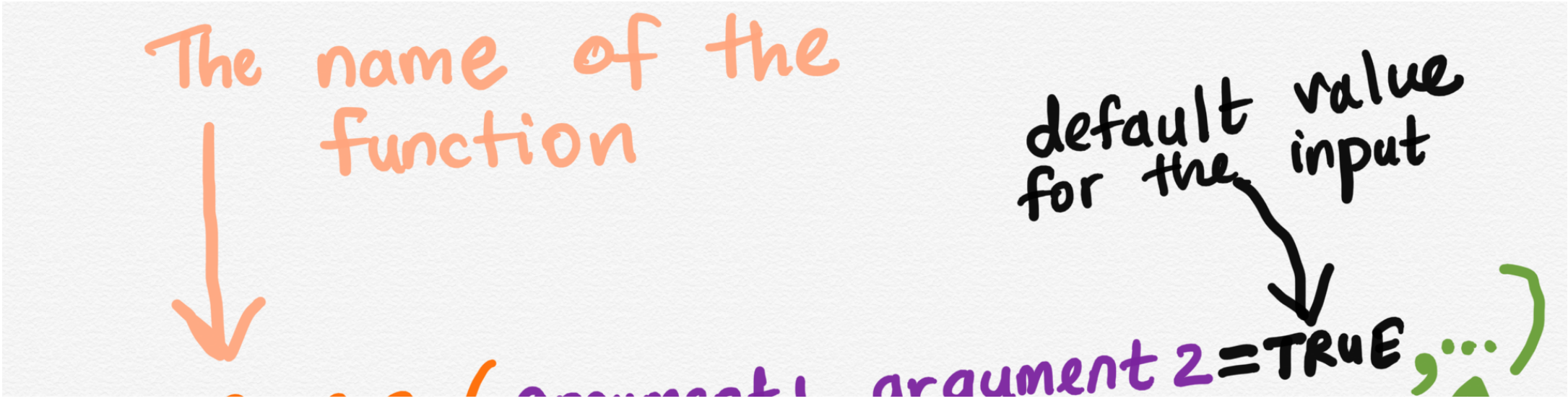
```
vec2 <- c(1, 2, NA, 3, 4, 5)
mean(vec2)
```

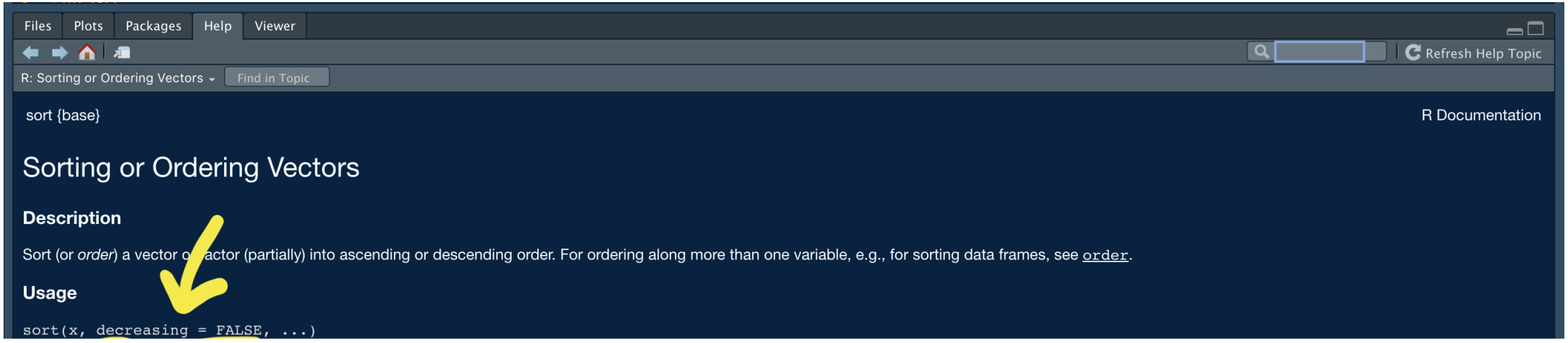
```
[1] NA
```

```
mean(vec2, na.rm=TRUE)
```

```
[1] 3
```

The name of the function


The name of the function
default value for the input
argument 2=TRUE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Description
Sort (or order) a vector or factor (partially) into ascending or descending order. For ordering along more than one variable, e.g., for sorting data frames, see order.
Usage
sort(x, decreasing = FALSE, ...)

```
vec <- c(10, 1, 2, 4, 100, 15)
sort(vec)
```

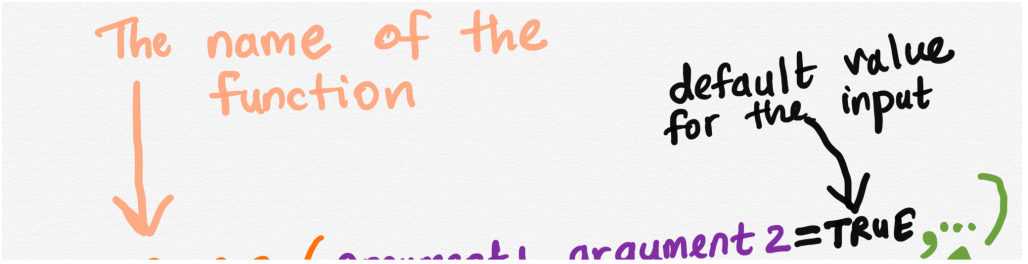
```
[1]   1   2   4  10  15 100
```

```
sort(vec, decreasing = TRUE)
```

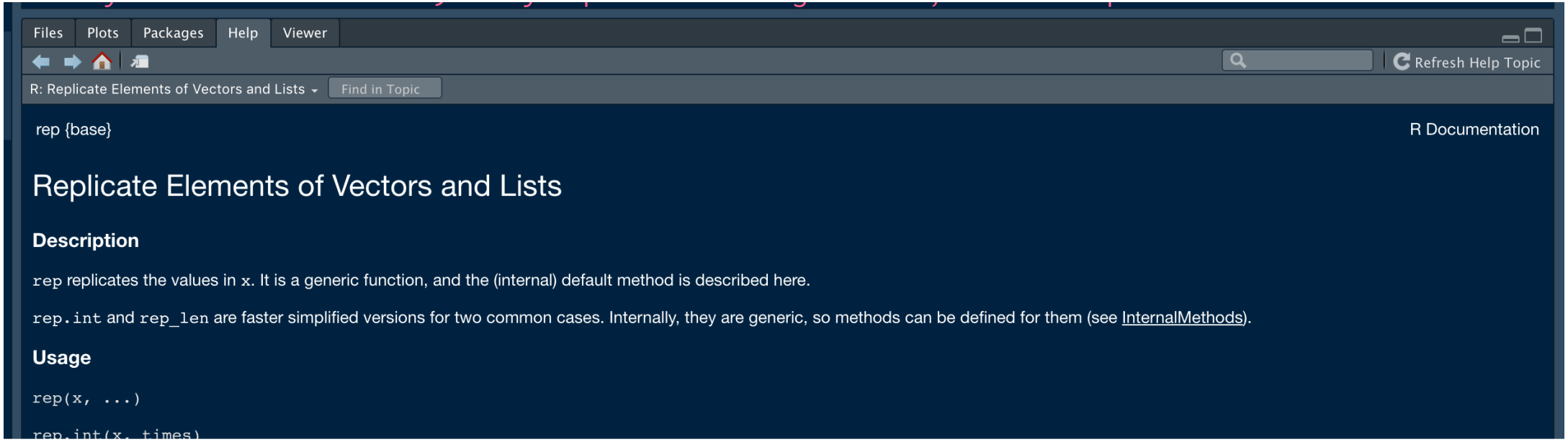
```
[1] 100  15  10   4   2   1
```

```
sort(vec, decreasing = FALSE)
```

```
[1]   1   2   4  10  15 100
```



rep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Packages
Help
Viewer
Refresh Help Topic
R: Replicate Elements of Vectors and Lists
Find in Topic
rep {base}
R Documentation
Replicate Elements of Vectors and Lists
Description
rep replicates the values in x. It is a generic function, and the (internal) default method is described here.
rep.int and rep_len are faster simplified versions for two common cases. Internally, they are generic, so methods can be defined for them (see InternalMethods).
Usage
rep(x, ...)
rep.int(x, times)

Vector creation with `rep` function in R!

Working with built-in functions in R

- How to call a built-in function
- Arguments matching
- Basic functions
- Test and type conversion functions
- Probability distribution functions
- Reproducibility of scientific results
- Data visualization: `qplot`

Functions in R

- 👉 Perform a specific task according to a set of instructions.
- 👉 Some functions we have discussed so far,

> `c`, `matrix`, `array`, `list`, `data.frame`, `str`, `dim`, `length`, `nrow`, `which.max`, `diag`, `summary`

- 👉 In R, functions are **objects** of **class** *function*.

```
class(length)
```

```
[1] "function"
```

Functions in R (cont.)

👉 There are basically two types of functions:

> 💻 Built-in functions

Already created or defined in the programming framework to make our work easier.

> 👨 User-defined functions

Sometimes we need to create our own functions for a specific purpose.

How to call a built-in function in R

```
function_name(arg1 = 1, arg2 = 3)
```

Argument matching

The following calls to `mean` are all equivalent

```
mydata <- c(rnorm(20), 100000)
mean(mydata) # matched by position
mean(x = mydata) # matched by name
mean(mydata, na.rm = FALSE)
mean(x = mydata, na.rm = FALSE)
mean(na.rm = FALSE, x = mydata)
mean(na.rm = FALSE, mydata)
```

```
[1] 4762.105
```

Argument matching (cont.)

- some arguments have default values

```
mean(mydata, trim=0)
```

```
[1] 4762.105
```

```
mean(mydata) # Default value fo
```

```
[1] 4762.105
```

```
mean(mydata, trim=0.1)
```

```
[1] 0.2973882
```

```
mean(mydata, tr=0.1) # Partial
```

```
[1] 0.2973882
```

R: Arithmetic Mean

?mean

mean {base}

Arithmetic Mean

Description

Generic function for the (trimmed) arithmetic mean.

Usage

```
mean(x, ...)

## Default S3 method:
mean(x, trim = 0, na.rm = FALSE, ...)
```

Arguments

`x`	An `R` object. Currently there are methods for numeric/logical vectors and date, date-time and time interval objects. Complex vectors are allowed for `trim = 0`, only.
`trim`	the fraction (0 to 0.5) of observations to be trimmed from each end of `x` before the mean is computed. Values of trim outside that range are taken as the nearest endpoint.
`na.rm`	a logical value indicating whether `NA` values should be stripped before the computation proceeds.
`...`	further arguments passed to or from other methods.

Value

If `trim` is zero (the default), the arithmetic mean of the values in `x` is computed, as a numeric or complex vector of length one. If `x` is not logical (coerced to numeric), numeric (including integer) or complex, `NA_real_` is returned, with a warning.

If `trim` is non-zero, a symmetrically trimmed mean is computed with a fraction of `trim` observations deleted from each end before the mean is computed.

References

Becker, R. A., Chambers, J. M. and Wilks, A. R. (1988) *The New S Language*. Wadsworth & Brooks/Cole.

See Also

`weighted.mean`, `mean.POSIXct`, `colMeans` for row and column means.

Examples

```
x <- c(0:10, 50)
xm <- mean(x)
c(xm, mean(x, trim = 0.10))
```

Your turn

1. Calculate the mean of 1, 2, 3, 8, 10, 20, 56, NA.

2. Arrange the numbers according to the descending order and ascending order.

3. Compute standard error of the above numbers.

Basic maths functions

Operator	Description
abs(x)	absolute value of x
log(x, base = y)	logarithm of x with base y; if base is not specified, returns the natural logarithm
exp(x)	exponential of x
sqrt(x)	square root of x
factorial(x)	factorial of x

Basic statistic functions

Operator	Description
mean(x)	mean of x
median(x)	median of x
mode(x)	mode of x
var(x)	variance of x
sd(x)	standard deviation of x
scale(x)	z-score of x
quantile(x)	quantiles of x
summary(x)	summary of x: mean, minimum, maximum, etc.

Test and Type conversion functions

Test	Convert
is.numeric()	as.numeric()
is.character()	as.character()
is.vector()	as.vector()
is.matrix()	as.matrix()
is.data.frame()	as.data.frame()
is.factor()	as.factor()
is.logical()	as.logical()
is.na()	

```
a <- c(1, 2, 3); a
```

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

```
is.numeric(a)
```

```
[1] TRUE
```

```
is.vector(a)
```

```
[1] TRUE
```

Test and Type conversion functions

Test	Convert
is.numeric()	as.numeric()
is.character()	as.character()
is.vector()	as.vector()
is.matrix()	as.matrix()
is.data.frame()	as.data.frame()
is.factor()	as.factor()
is.logical()	as.logical()
is.na()	

```
b <- as.character(a); b
```

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

```
is.vector(b)
```

```
[1] TRUE
```

```
is.character(b)
```

```
[1] TRUE
```

Your turn

Remove missing values in the following vector

```
a
```

```
 [1]  0.61940020 -0.93808729  0.95518590 -0.22663938  0.29591186
 [7]  0.36788089  0.71791098  0.71202022  0.22765782          NA
[13] -0.74024324  0.02081516 -0.14979979 -0.22351308  0.98729725
[19]          NA          NA          NA          NA          NA
[25]          NA          NA          NA -1.50016003  0.18682734  0.208
[31]  0.70102264 -0.10633074 -1.18460046  0.06475501  0.11568817 -0.043
[37] -0.22020064  0.02764713  0.10165760 -0.18234246  1.32914659 -1.297
[43]  1.05317749 -0.70109051  0.09798707  0.10457263 -0.21449845
```

Probability distribution functions

- Each probability distribution in R is associated with four functions.
- Naming convention for the four functions:

  For each function there is a root name. For example, the **root name** for the normal distribution is `norm`. This root is prefixed by one of the letters `d`, `p`, `q`, `r`.

  - **d** prefix for the **distribution** function
  - **p** prefix for the **cumulative probability**
  - **q** prefix for the **quantile**
  - **r** prefix for the **random** number generator
- Example: `dnorm`, `pnorm`, `qnorm`, `rnorm`


dname
Pname
q-name
rname

Illustration with Standard normal distribution

The general formula for the probability density function of the normal distribution with mean μ and variance σ is given by

$$ f_X(x) = \frac{1}{\sigma\sqrt{(2\pi)}} e^{-(x-\mu)^2/2\sigma^2} $$

If we let the mean $\mu=0$ and the standard deviation $\sigma=1$, we get the probability density function for the standard normal distribution.

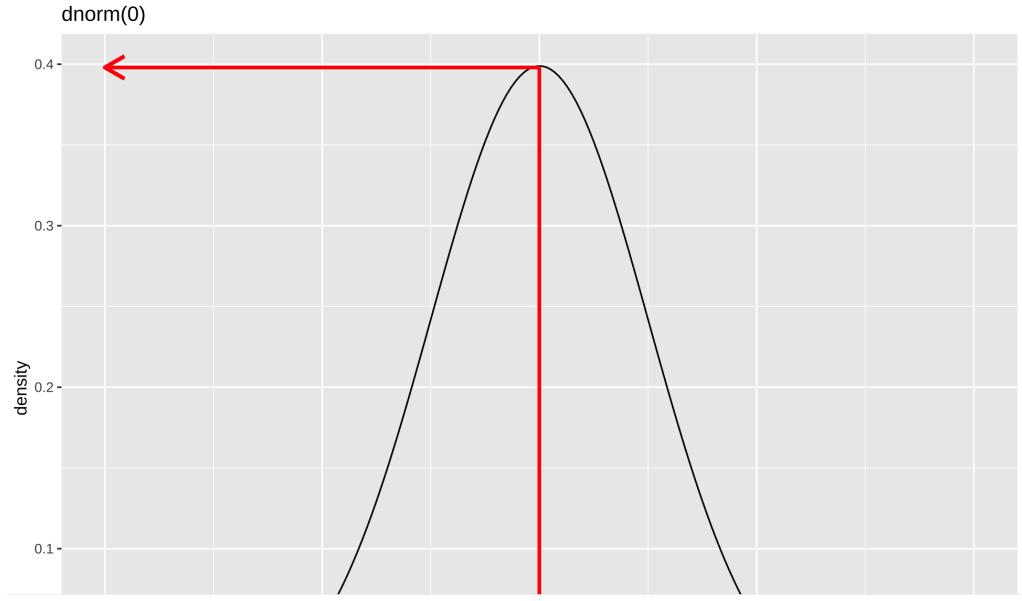
$$ f_X(x) = \frac{1}{\sqrt{(2\pi)}} e^{-(x)^2/2} $$

Standard Normal Distribution

$$ f_X(x) = \frac{1}{\sqrt{(2\pi)}} e^{-(x)^2/2} $$

```
dnorm(0)
```

```
[1] 0.3989423
```



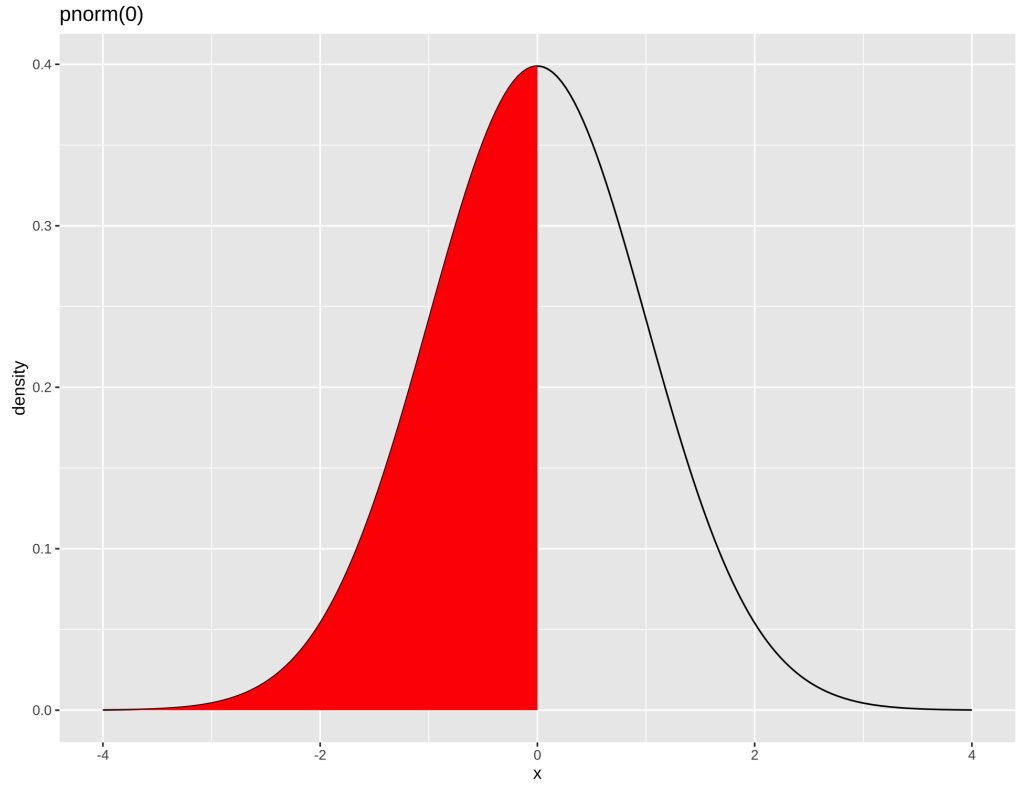
Standard normal probability density function: dnorm(0)

Standard Normal Distribution

$$ f_X(x) = \frac{1}{\sqrt{(2\pi)}} e^{-(x)^2/2} $$

```
pnorm(0)
```

```
[1] 0.5
```



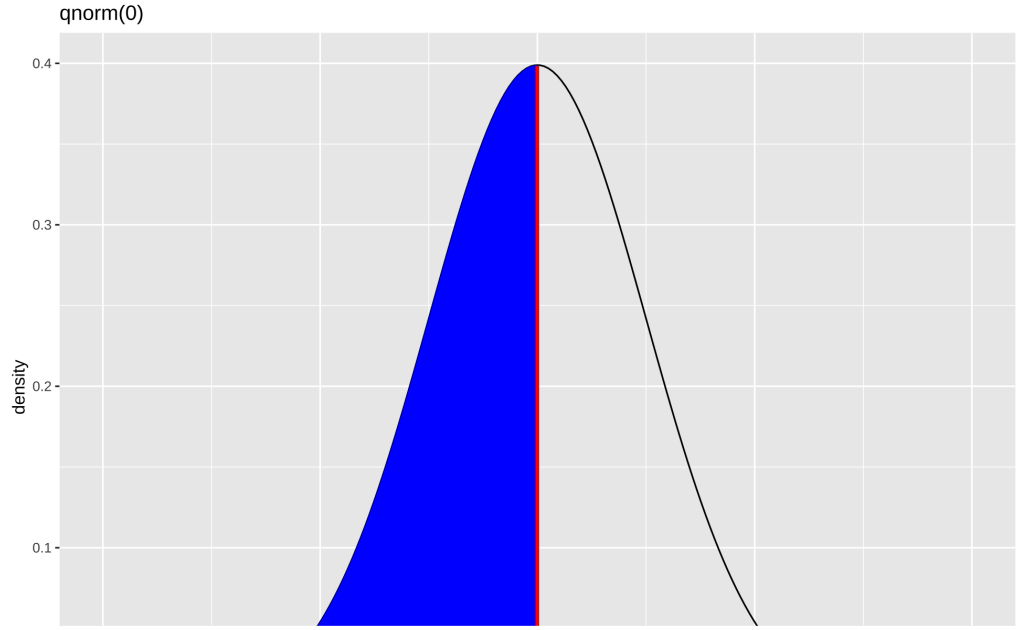
Standard normal probability density function: pnorm(0)

Standard Normal Distribution

$$ f_X(x) = \frac{1}{\sqrt{(2\pi)}} e^{-(x)^2/2} $$

```
qnorm(0.5)
```

```
[1] 0
```



Standard normal probability density function: qnorm(0.5)

Normal distribution: norm

```
pnorm(3)
```

```
[1] 0.9986501
```

```
pnorm(3, sd=1, mean=0)
```

```
[1] 0.9986501
```

```
pnorm(3, sd=2, mean=1)
```

```
[1] 0.8413447
```

Binomial distribution

```
dbinom(2, size=10, prob=0.2)
```

```
[1] 0.3019899
```

```
a <- dbinom(0:10, size=10, prob=0.2)
a
```

```
 [1] 0.1073741824 0.2684354560 0.3019898880 0.2013265920 0.0880803840
 [6] 0.0264241152 0.0055050240 0.0007864320 0.0000737280 0.0000040960
[11] 0.0000001024
```

```
cumsum(a)
```

```
 [1] 0.1073742 0.3758096 0.6777995 0.8791261 0.9672065 0.9936306 0.9991
 [8] 0.9999221 0.9999958 0.9999999 1.0000000
```

```
cumsum(a)
```

```
 [1] 0.1073742 0.3758096 0.6777995 0.8791261 0.9672065 0.9936306 0.9991
 [8] 0.9999221 0.9999958 0.9999999 1.0000000
```

```
pbinom(0:10, size=10, prob=0.2)
```

```
 [1] 0.1073742 0.3758096 0.6777995 0.8791261 0.9672065 0.9936306 0.9991
 [8] 0.9999221 0.9999958 0.9999999 1.0000000
```

```
qbinom(0.4, size=10, prob=0.2)
```

```
[1] 2
```

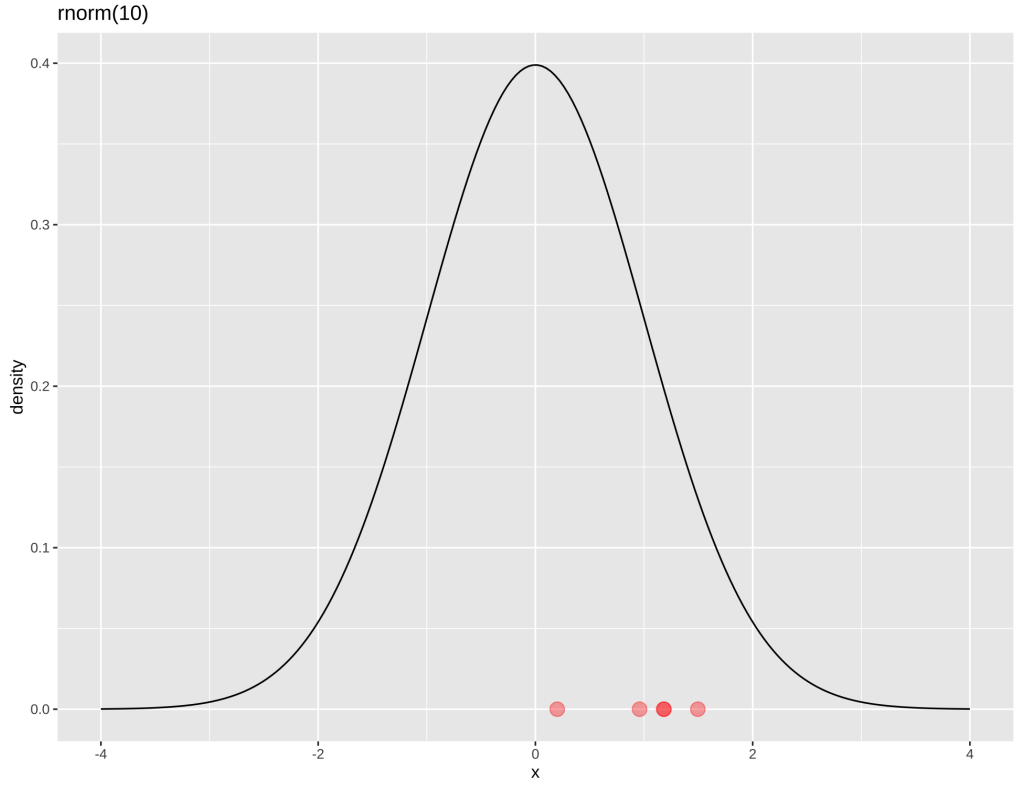
Standard Normal Distribution: rnorm

```
set.seed(262020)
random_numbers <- rnorm(5)
random_numbers
```

```
[1] 0.2007818 0.9587335 1.1836906 1
```

```
sort(random_numbers) ## sort th
```

```
[1] 0.2007818 0.9587335 1.1810922 1
```



Other distributions in R

- **`beta`**: beta distribution
- **`binom`**: binomial distribution
- **`cauchy`**: Cauchy distribution
- **`chisq`**: chi-squared distribution
- **`exp`**: exponential distribution
- **`f`**: F distribution
- **`gamma`**: gamma distribution
- **`geom`**: geometric distribution
- **`hyper`**: hyper-geometric distribution
- **`lnorm`**: log-normal distribution
- **`multinom`**: multinomial distribution
- **`nbinom`**: negative binomial distribution
- **`norm`**: normal distribution
- **`pois`**: Poisson distribution
- **`t`**: Student's t distribution
- **`unif`**: uniform distribution
- **`weibull`**: Weibull distribution

💁‍♀️ Getting help with R:

Your turn

Q1 Suppose $Z \sim N(0,1)$. Calculate the following standard normal probabilities.

- $P(Z \le 1.25)$,
- $P(Z > 1.25)$,
- $P(Z \leq -1.25)$,
- $P(-.38 \leq Z \leq 1.25)$.

Q2 Find the following percentiles for the standard normal distribution.

- 90th,
- 95th,
- 97.5th,

Q3 Determine the Z_α for the following

- $\alpha = 0.1$
- $\alpha = 0.95$

Q4 Suppose $X \sim N(15, 9)$. Calculate the following probabilities

- $P(X \leq 15)$,
- $P(X < 15)$,
- $P(X \geq 10)$.

02:00

Q5 A particular mobile phone number is used to receive both voice messages and text messages. Suppose 20% of the messages involve text messages, and consider a sample of 15 messages. What is the probability that

- At most 8 of the messages involve a text message?
- Exactly 8 of the messages involve a text message.

02:00

Q6 Generate 20 random values from a Poisson distribution with mean 10 and calculate the mean. Compare your answer with others.

02:00

Reproducibility of scientific results

```
rnorm(10) # first attempt
```

```
 [1]  1.6582609 -1.8912734 -2.8471112 -2.1617741  0.6401224 -0.4295948
 [7] -0.3122580 -1.0267992  1.4231150  0.8661058
```

```
rnorm(10) # second attempt
```

```
 [1] -0.91879540 -0.06053766 -0.20263170 -0.26301690  0.97964620 -0.460
 [7]  0.81826880 -0.60935778  1.71086661  0.49294451
```

As you can see above you will get different results.

Reproducibility of scientific results (cont.)

```
set.seed(1)
rnorm(10) # First attempt with set.seed
```

```
 [1] -0.6264538  0.1836433 -0.8356286  1.5952808  0.3295078 -0.8204684
 [7]  0.4874291  0.7383247  0.5757814 -0.3053884
```

```
set.seed(1)
rnorm(10) # Second attempt with set.seed
```

```
 [1] -0.6264538  0.1836433 -0.8356286  1.5952808  0.3295078 -0.8204684
 [7]  0.4874291  0.7383247  0.5757814 -0.3053884
```

R Apply family and its variants

- **`apply()`** function

```
marks <- data.frame(maths=c(10, 20, 30), chemistry=c(100, NA, 60))
```

```
  maths chemistry
1    10       100
2    20        NA
3    30        60
```

```
apply(marks, 1, mean)
```

```
[1] 55 NA 45
```

```
apply(marks, 2, mean)
```

```
    maths chemistry 
       20        NA 
```

```
apply(marks, 1, mean, na.rm=TRUE)
```

```
[1] 55 20 45
```

Your turn

Calculate the row and column wise standard deviation of the following matrix

```
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
```

03:00

Your turn

Your turn

Find about the following variants of apply family functions in R **`lapply()`**, **`sapply()`**, **`vapply()`**, **`mapply()`**, **`rapply()`**, and **`tapply()`** functions.

Resourses: You can follow the DataCamp tutorial here.

- You should clearly explain,
  - syntax for each function/ Provide your own example for each function
  - function inputs
  - how each function works?/ The task of the function.
  - output of the function.
  - differences between the functions (apply vs lapply, apply vs sapply, etc.)

Data Visualization: qplot()

?qplot

Installing R Packages

Method 1

Installing R Packages

Method 2

```
install.packages("ggplot2")
```

Load package

```
library(ggplot2)
```

Now search `?qplot`

Note: You shouldn't have to re-install packages each time you open R. However, you do need to load the packages you want to use in that session via `library`.

`install.packages` vs `library`

Images sourced from https://www.wikihow.com/Change-a-Light-Bulb

Image credit: Professor Di Cook

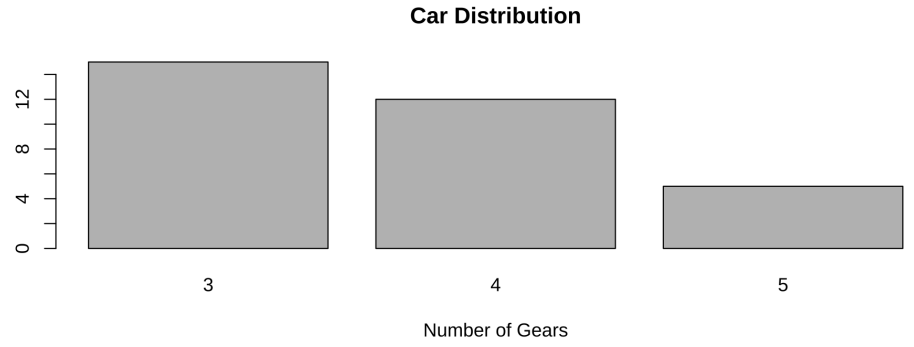
mozzie dataset

```
library(mozzie)
data(mozzie)
```

Data Visualization with R

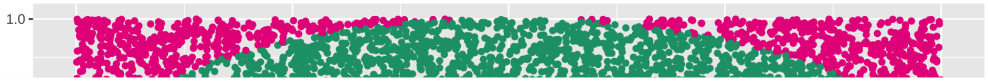
```
boxplot(mpg ~ cyl, data = mtcar
        xlab = "Quantity of Cyl
        ylab = "Miles Per Gallo
        main = "Boxplot Example
        notch = TRUE,
        varwidth = TRUE,
        col = c("green","yellow
        names = c("High","Mediu
)
```

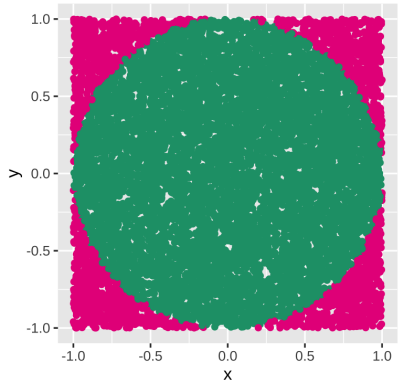
```
counts <- table(mtcars$gear)
barplot(counts, main="Car Distr
   xlab="Number of Gears")
```

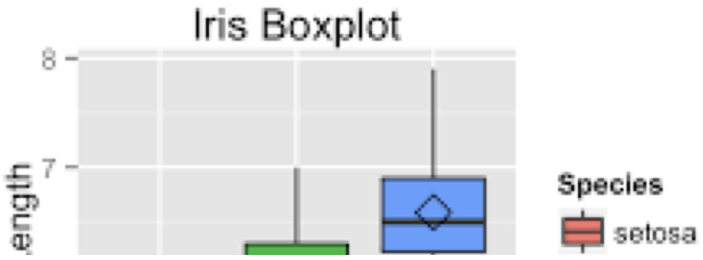


Default R installation: graphics package

```
 [1] "abline"           "arrows"           "assocplot"        "axis"
 [5] "Axis"             "axis.Date"        "axis.POSIXct"     "axTicks"
 [9] "barplot"          "barplot.default"  "box"              "boxplot"
[13] "boxplot.default"  "boxplot.matrix"   "bxp"              "cdplot"
[17] "clip"             "close.screen"     "co.intervals"     "contour"
[21] "contour.default"  "coplot"          "curve"            "dotchart"
[25] "erase.screen"     "filled.contour"   "fourfoldplot"     "frame"
[29] "grconvertX"       "grconvertY"       "grid"             "hist"
[33] "hist.default"     "identify"         "image"            "image.defau
[37] "layout"           "layout.show"      "lcm"              "legend"
[41] "lines"            "lines.default"    "locator"          "matlines"
[45] "matplot"          "matpoints"        "mosaicplot"       "mtext"
[49] "pairs"            "pairs.default"    "panel.smooth"     "par"
[53] "persp"            "pie"              "plot"             "plot.defaul
[57] "plot.design"      "plot.function"    "plot.new"         "plot.window
[61] "plot.xy"          "points"           "points.default"   "polygon"
```


1.0


1.0
0.5
0.0
-0.5
-1.0
y
-1.0
-0.5
0.0
0.5
1.0
x




```
R 4.1.0 · ~/Lecturer/1_TEACHING/2021_s1/Rprogramming/
> iris
    Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
1            5.1         3.5          1.4         0.2     setosa
2            4.9         3.0          1.4         0.2     setosa
3            4.7         3.2          1.3         0.2     setosa
4            4.6         3.1          1.5         0.2     setosa
5            5.0         3.6          1.4         0.2     setosa
6            5.4         3.9          1.7         0.4     setosa
7            4.6         3.4          1.4         0.3     setosa
8            5.0         3.4          1.5         0.2     setosa
9            4.4         2.9          1.4         0.2     setosa
10           4.9         3.1          1.5         0.1     setosa
11           5.4         3.7          1.5         0.2     setosa
12           4.8         3.4          1.6         0.2     setosa
13           4.8         3.0          1.4         0.1     setosa
```

mozzie

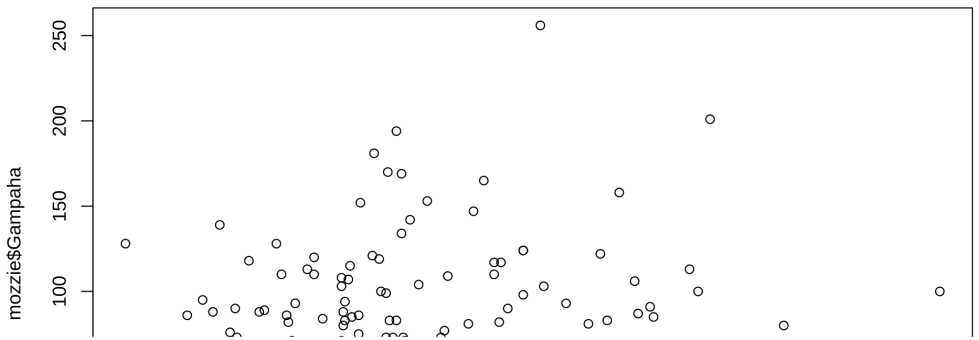
```
head(mozzie)
```

```
# A tibble: 6 × 28
     ID  Year  Week Colombo Gampaha Kalutara Kandy Matale `Nuwara Eliya
  <int> <int> <int>   <int>   <int>     <int> <int>  <int>          <int
1     1  2008    52      15       7         1    11      4
2     2  2009     1      44      23         5    16     21
3     3  2009     2      39      19        11    42      9
4     4  2009     3      57      23        12    28      3
5     5  2009     4      53      24        19    32     20
6     6  2009     5      29      17        10    21      6
# … with 18 more variables: Hambantota <int>, Matara <int>, Jaffna <int
#   Kilinochchi <int>, Mannar <int>, Vavuniya <int>, Mulative <int>,
#   Batticalo <int>, Ampara <int>, Trincomalee <int>, Kurunagala <int>,
#   Puttalam <int>, Anuradhapura <int>, Polonnaruwa <int>, Badulla <int
```

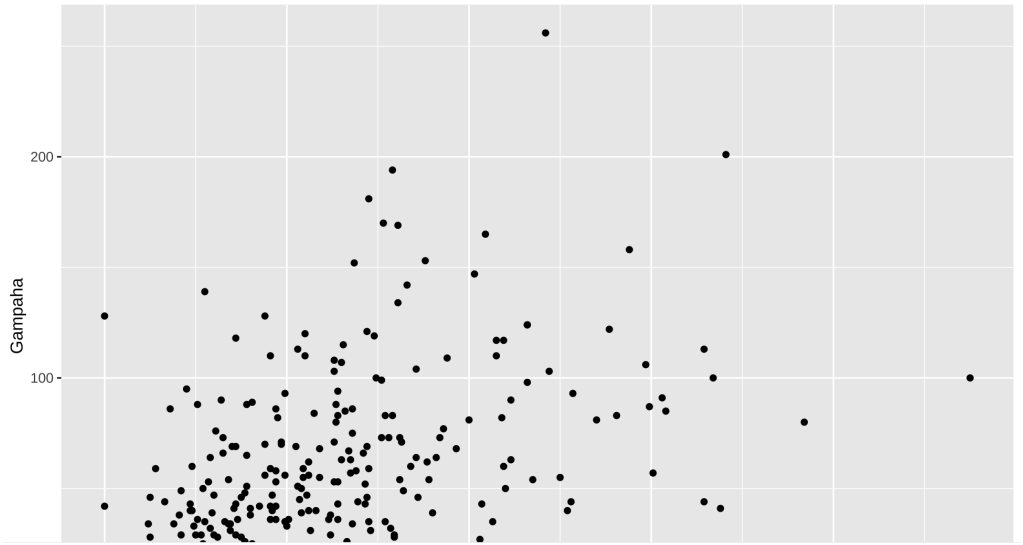
Data Visualization with qplot

plot vs qplot

```
plot(mozzie$Colombo, mozzie$Gam
```

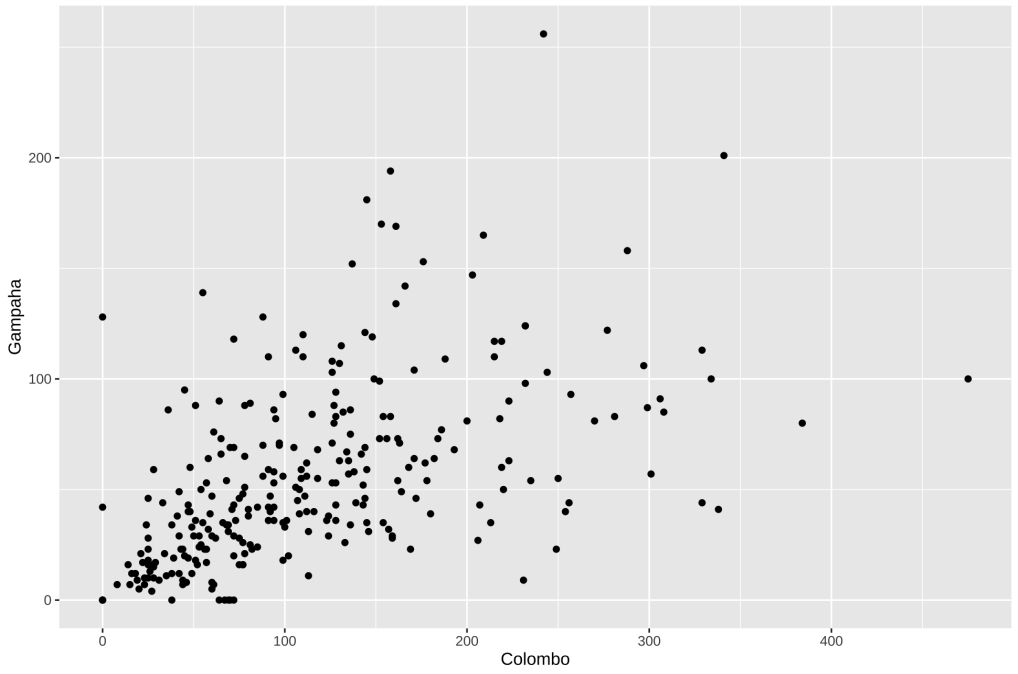



```
qplot(Colombo, Gampaha, data=mo
```

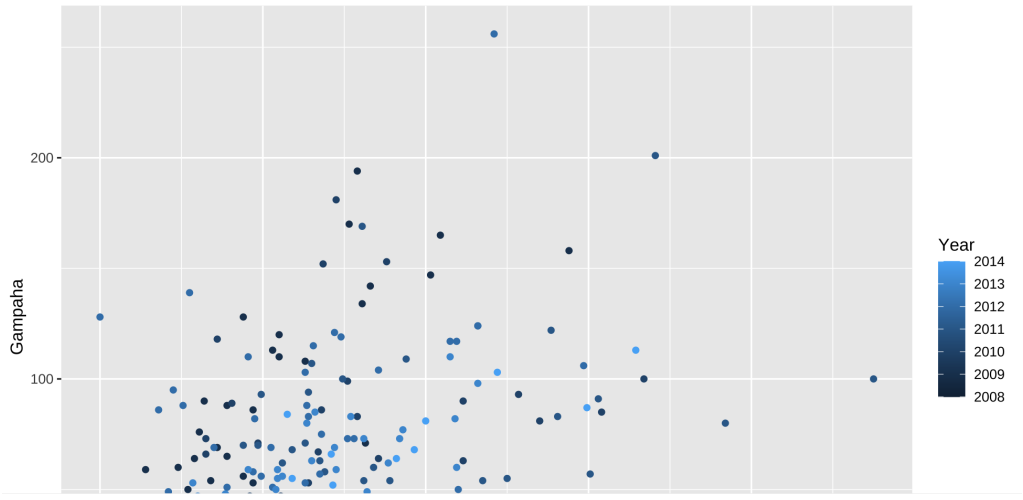


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
```

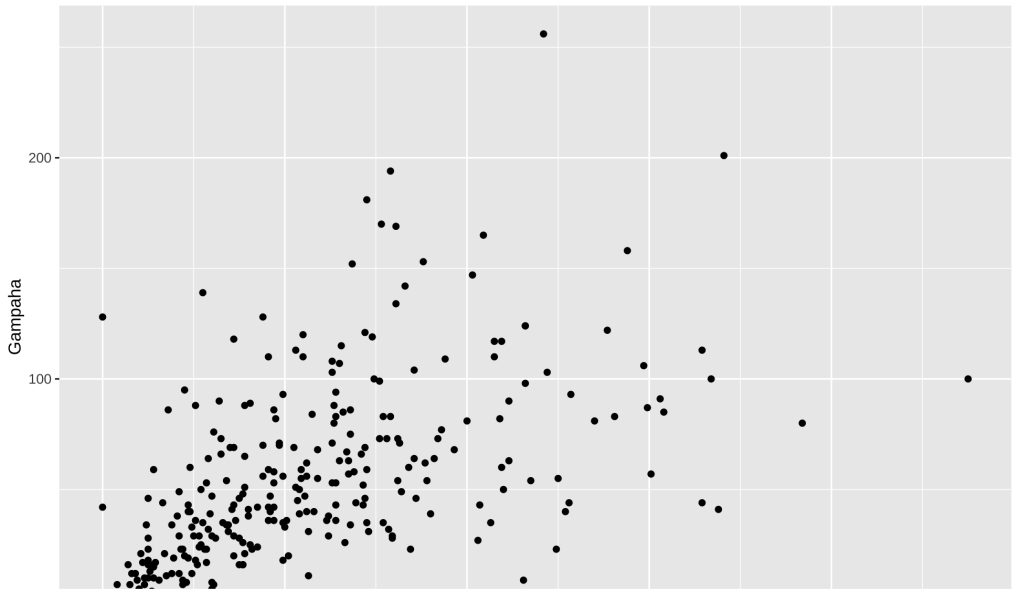



```
qplot(Colombo, Gampaha, data=mc
      colour=Year)
```

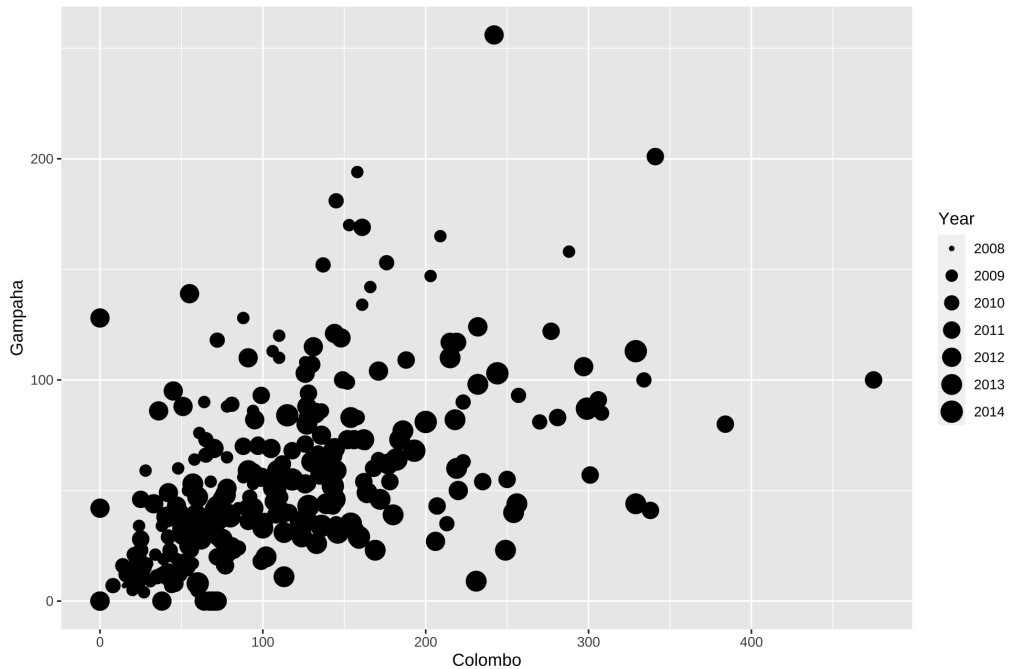


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
```

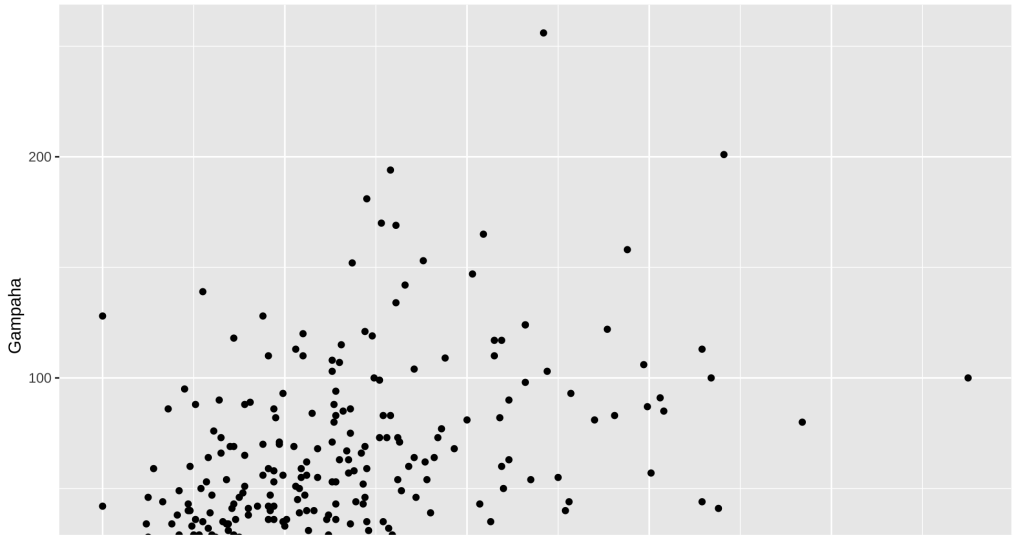



```
qplot(Colombo, Gampaha, data=mc
      size=Year)
```

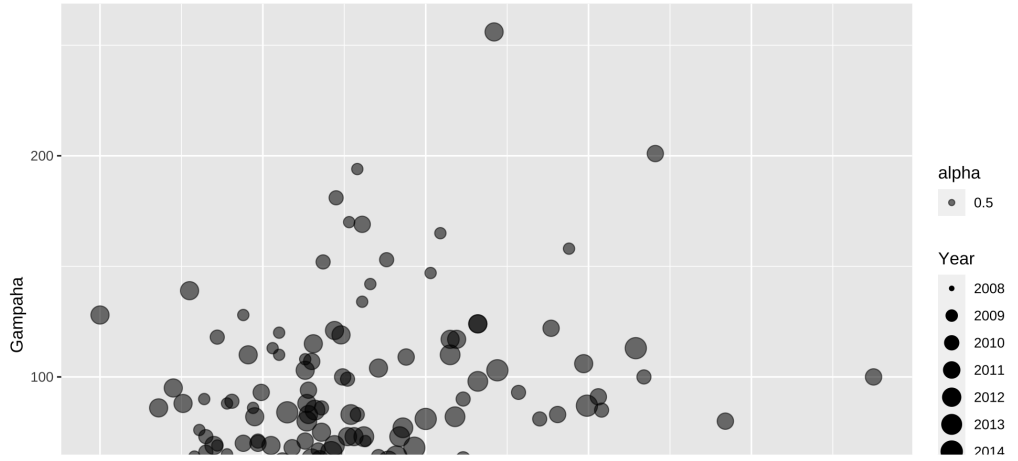


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
```

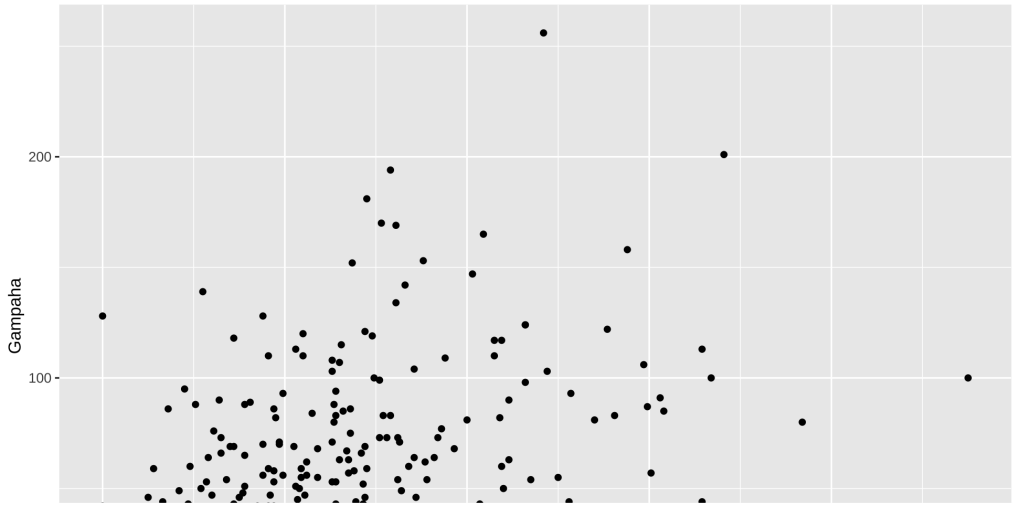



```
qplot(Colombo, Gampaha, data=mc
      size=Year, alpha=0.5)
```

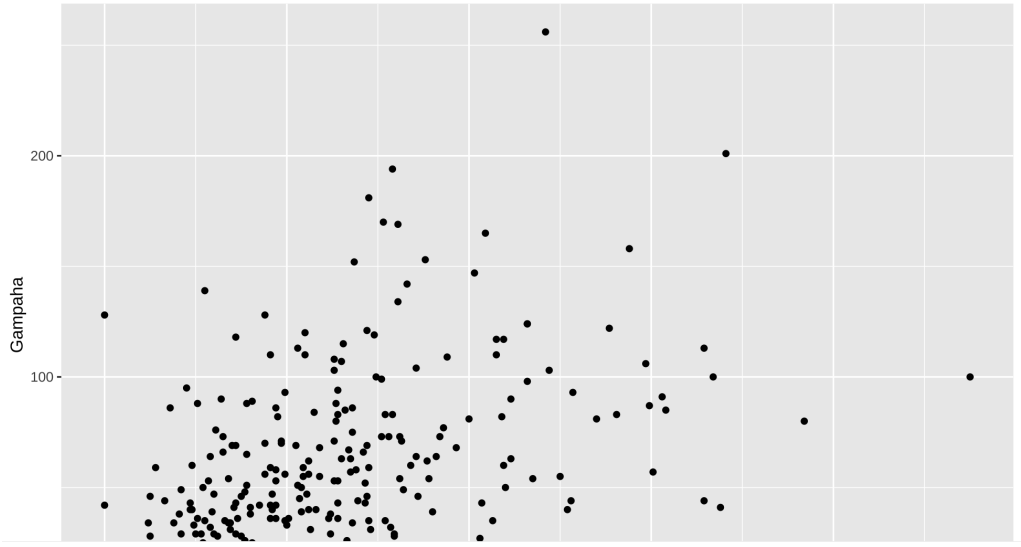


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
```

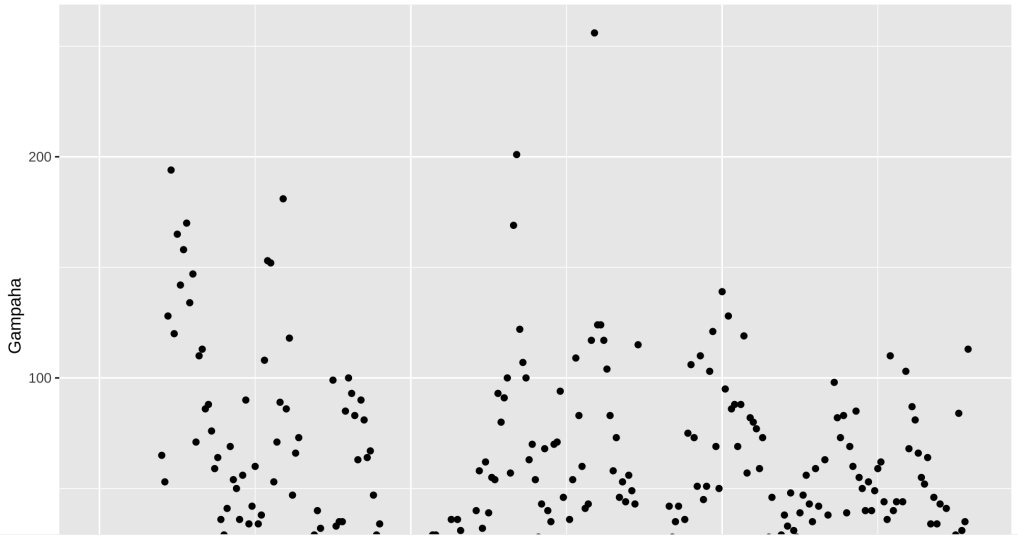



```
qplot(Colombo, Gampaha, data=mc
      geom="point")
```

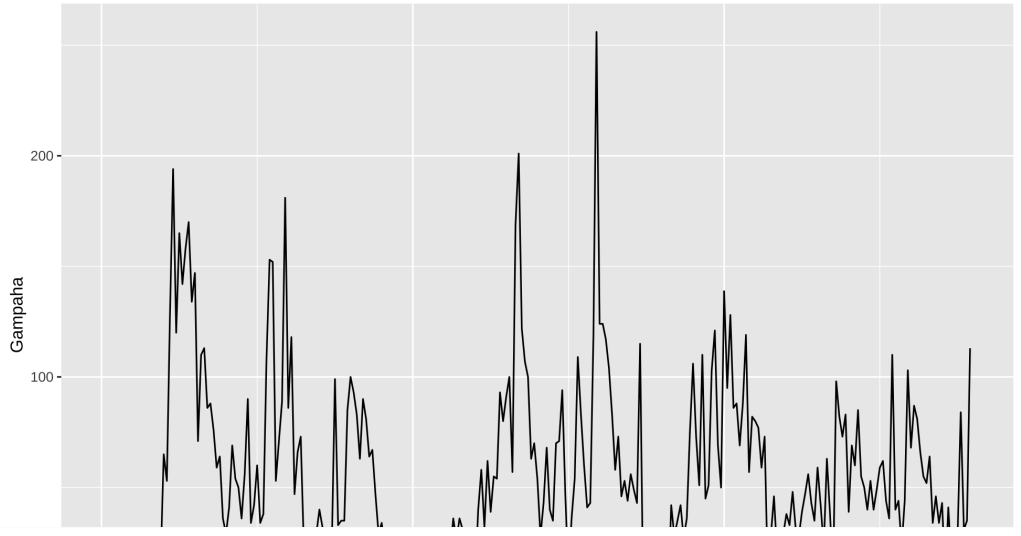


Data Visualization with qplot

```
qplot(ID, Gampaha, data=mozzie)
```

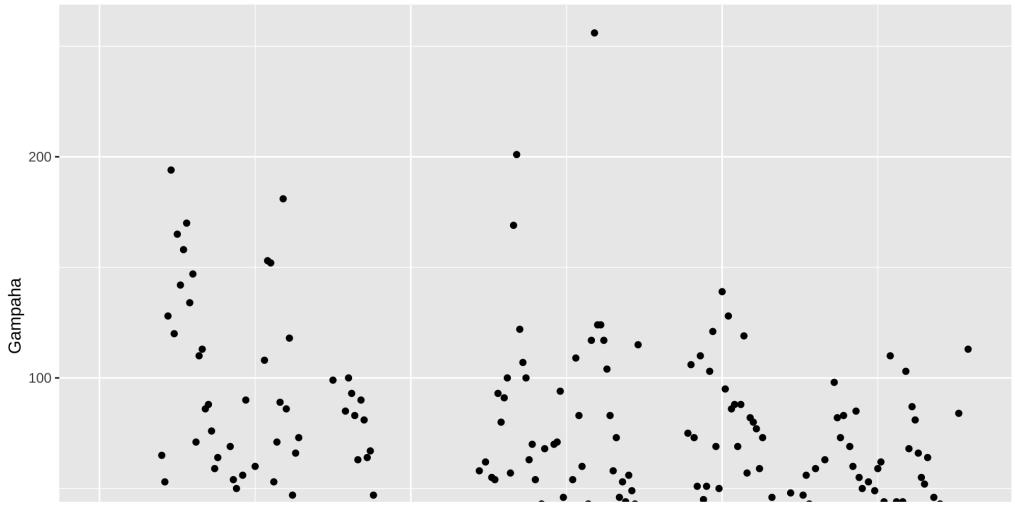



```
qplot(ID, Gampaha, data=mozzie,
      geom="line")
```

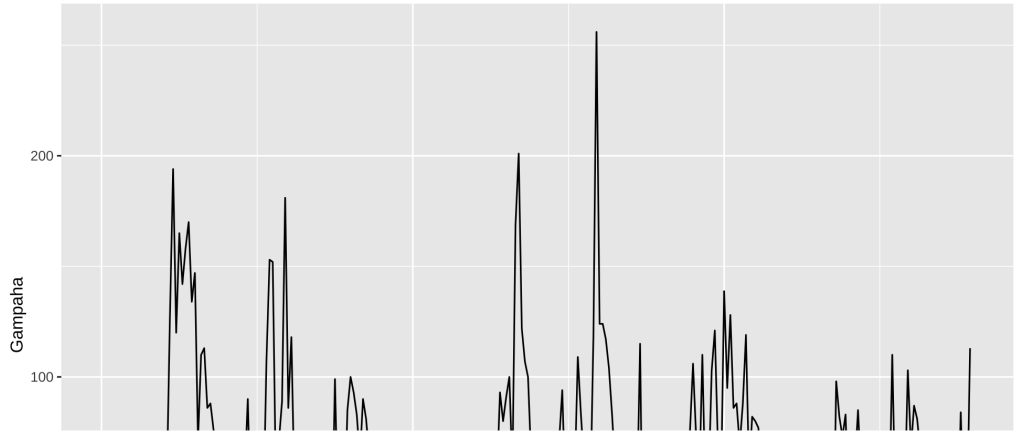


Data Visualization with qplot

```
qplot(ID, Gampaha, data=mozzie)
```

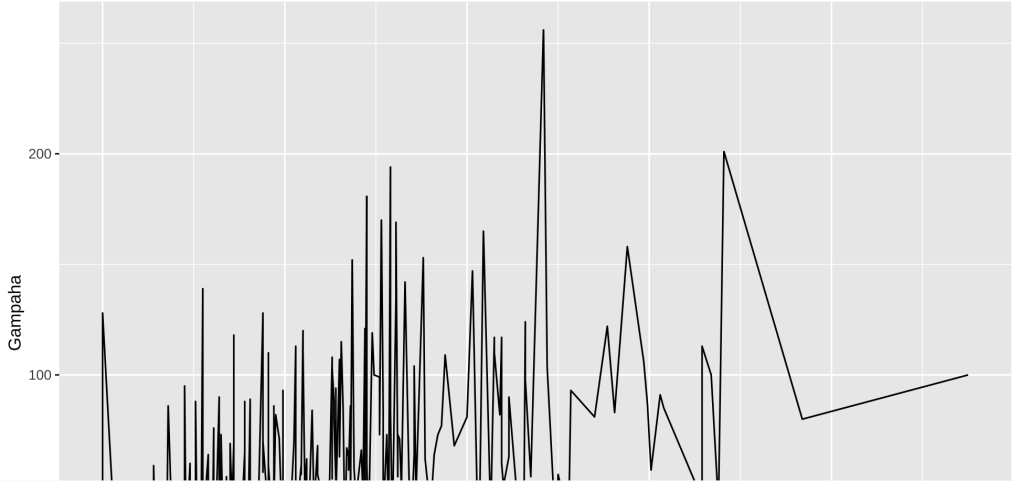



```
qplot(ID, Gampaha, data=mozzie,
      geom="path")
```

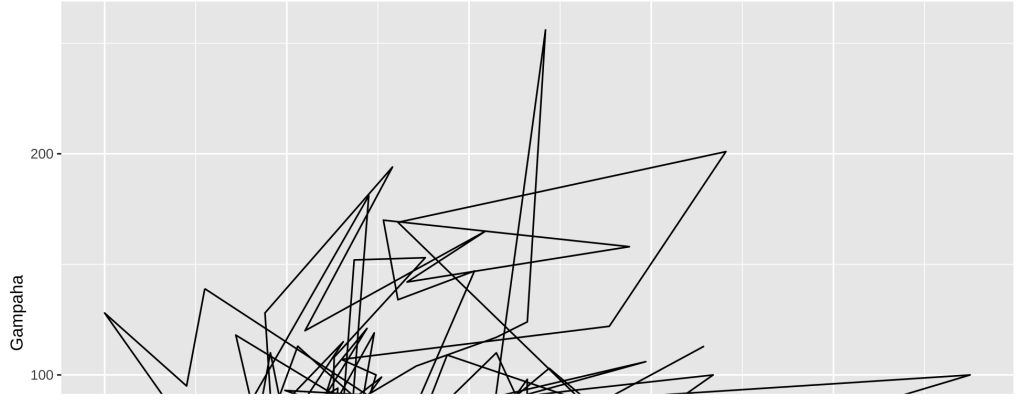


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
      geom="line")
```

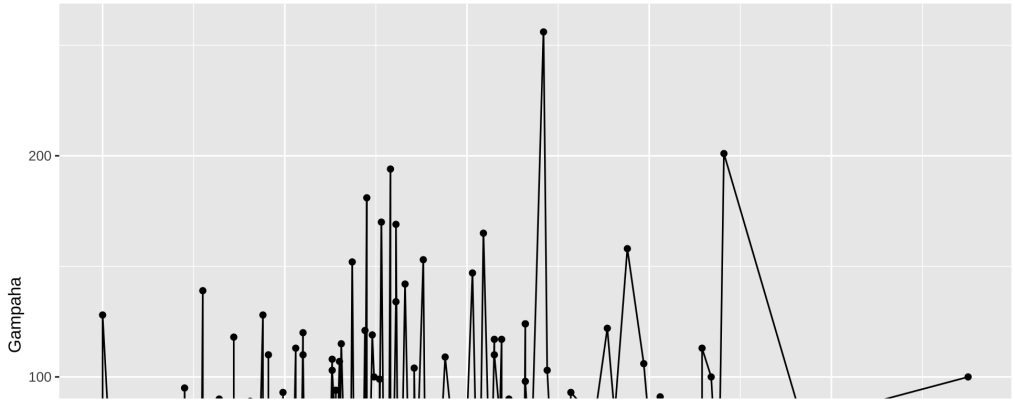



```
qplot(Colombo, Gampaha, data=mc
      geom="path")
```

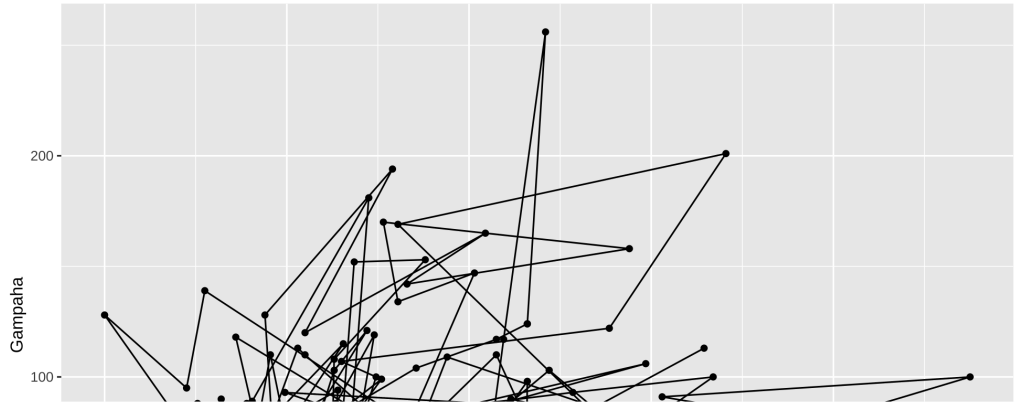


Data Visualization with qplot

```
qplot(Colombo, Gampaha, data=mc
      geom=c("line", "point"))
```

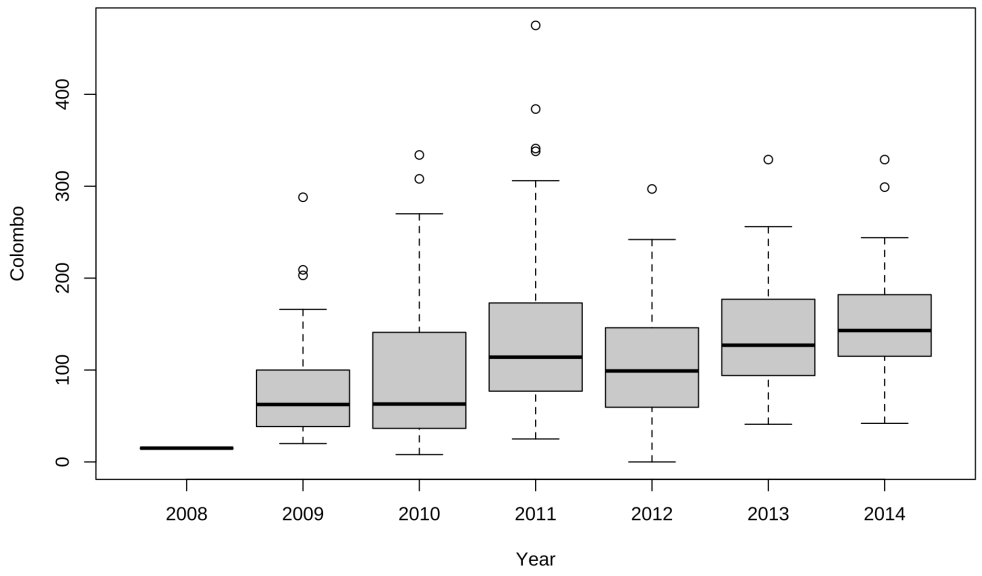



```
qplot(Colombo, Gampaha, data=mc
      geom=c("path", "point"))
```

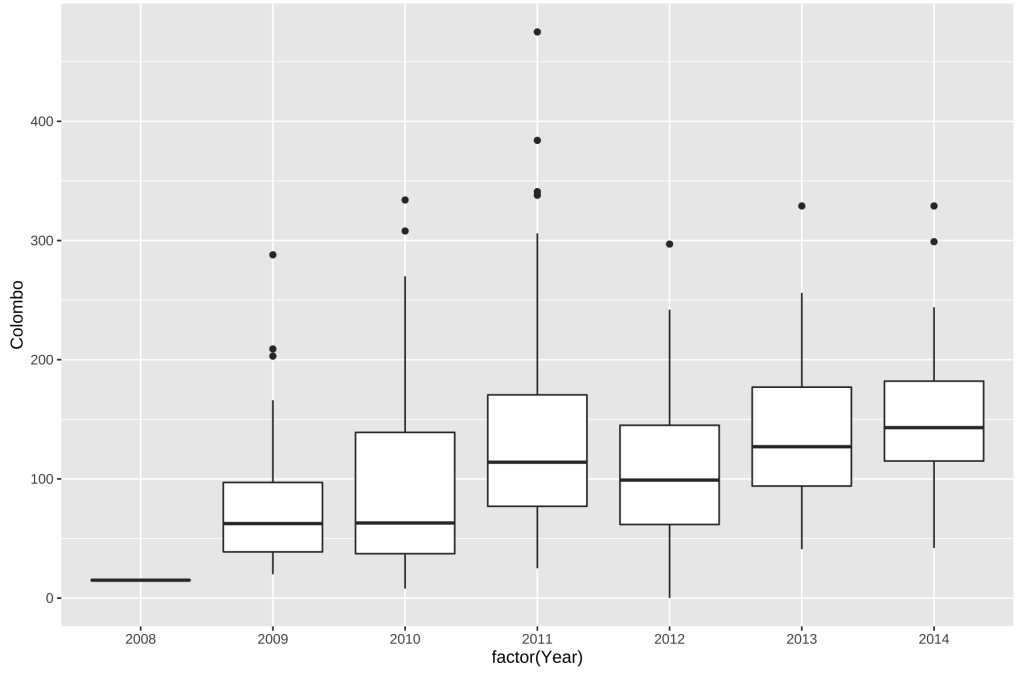


Data Visualization with qplot

```
boxplot(Colombo~Year, data=mozz
```

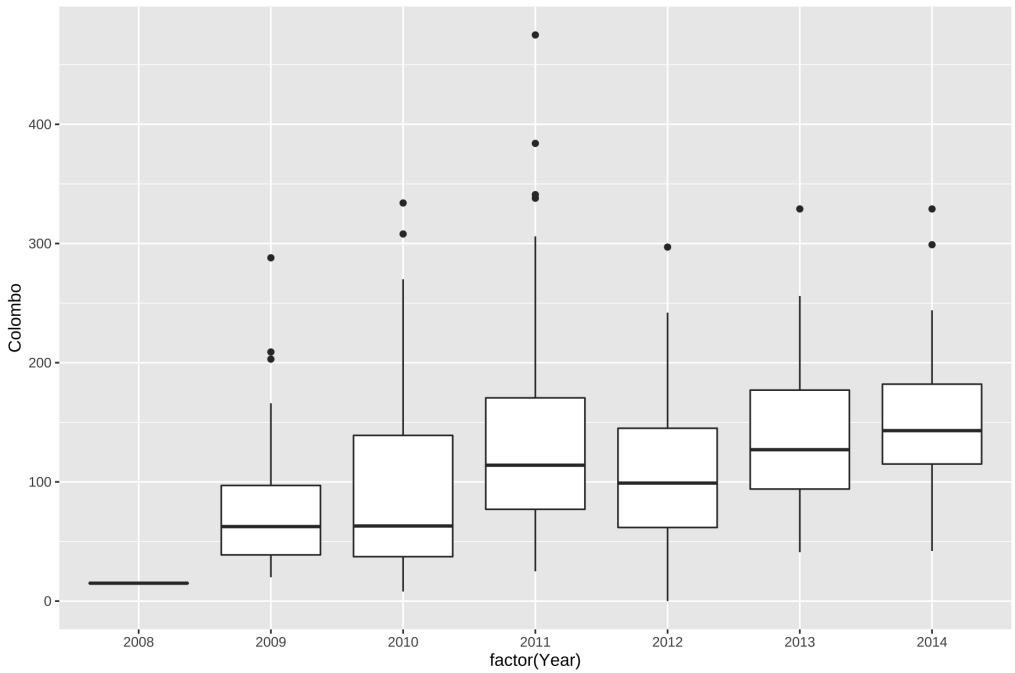



```
qplot(factor(Year), Colombo, da
      geom="boxplot")
```

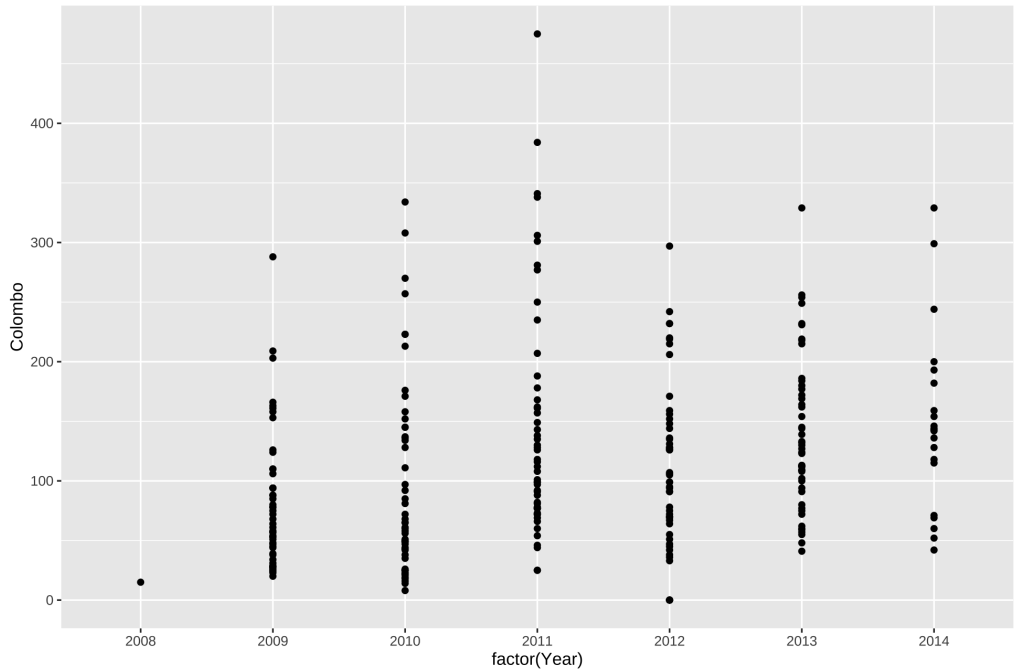


Data Visualization with qplot

```
qplot(factor(Year), Colombo, da
      geom="boxplot")
```

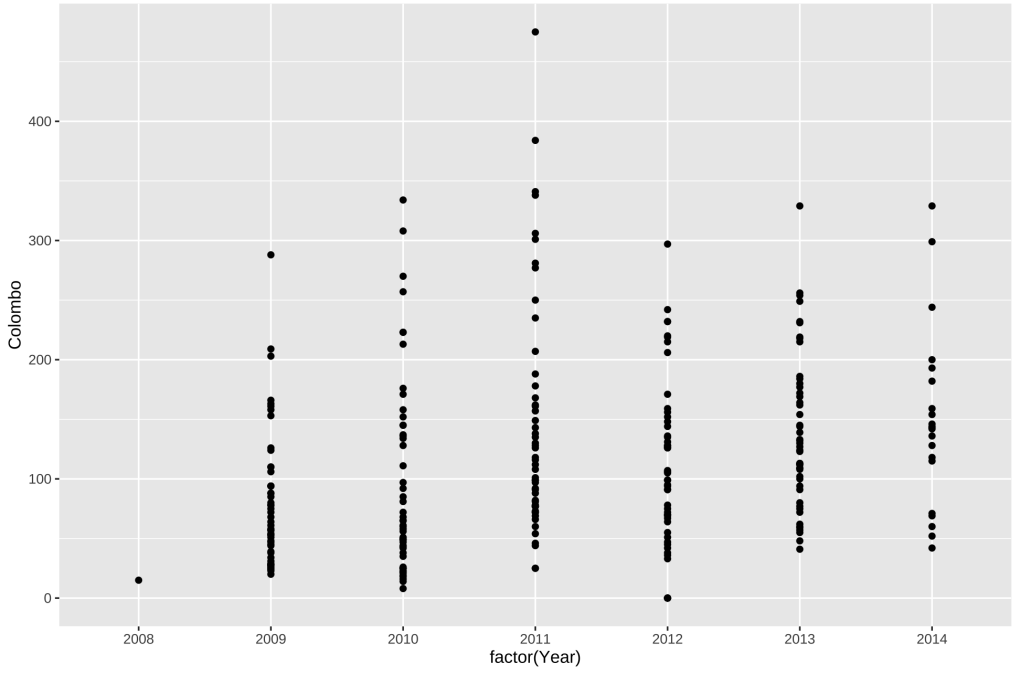



```
qplot(factor(Year), Colombo, da
```

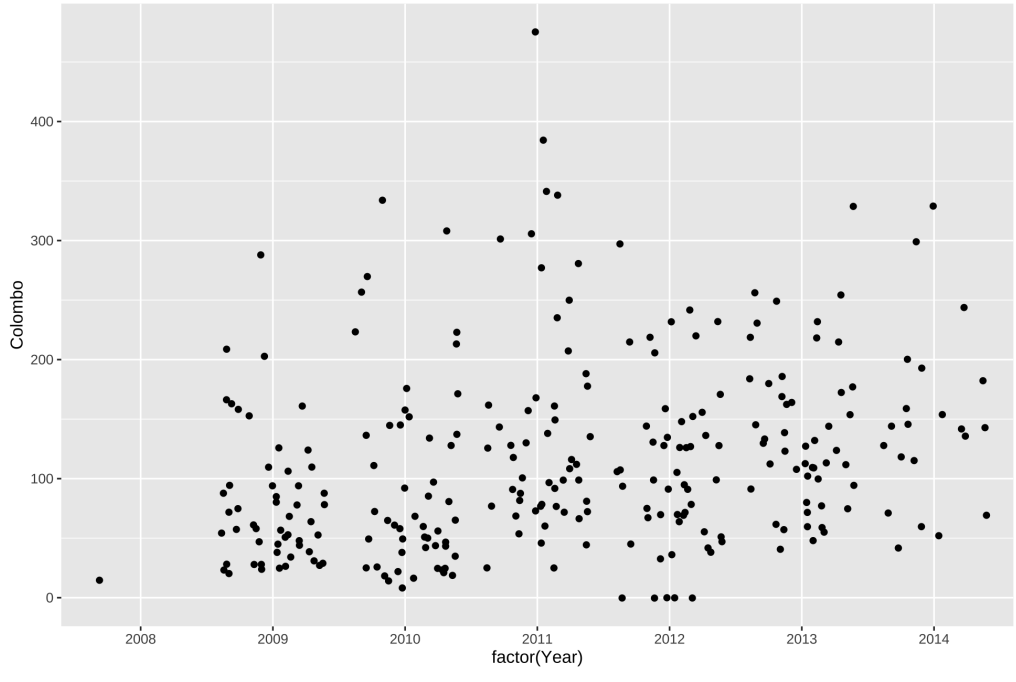


Data Visualization with qplot

```
qplot(factor(Year), Colombo, da
      geom="point")
```

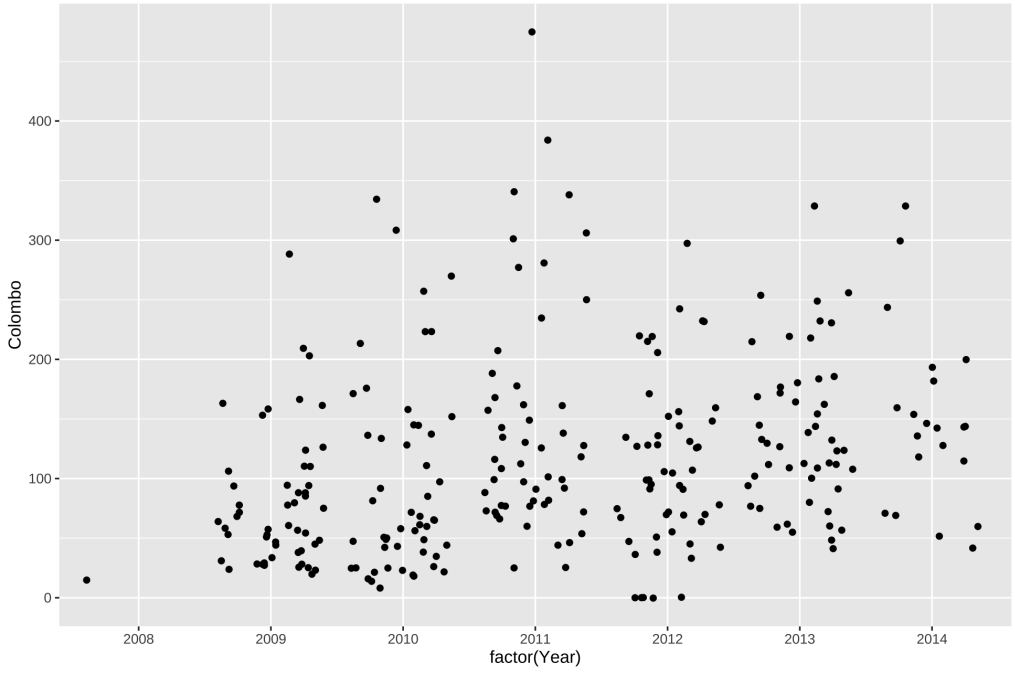



```
qplot(factor(Year), Colombo, da
      geom="jitter") # geom="po
```

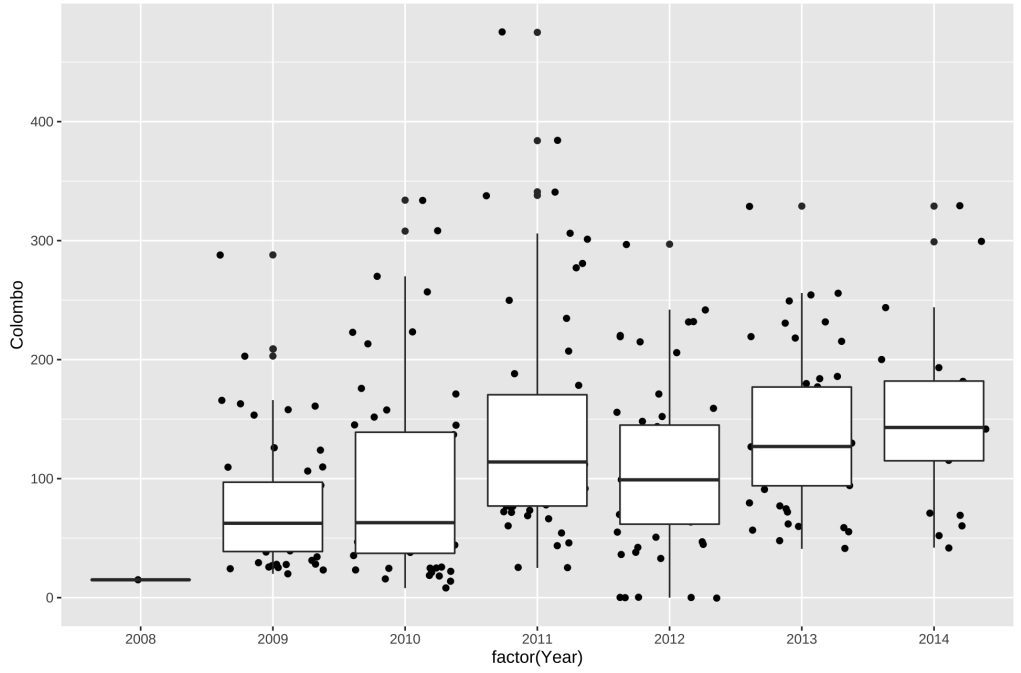


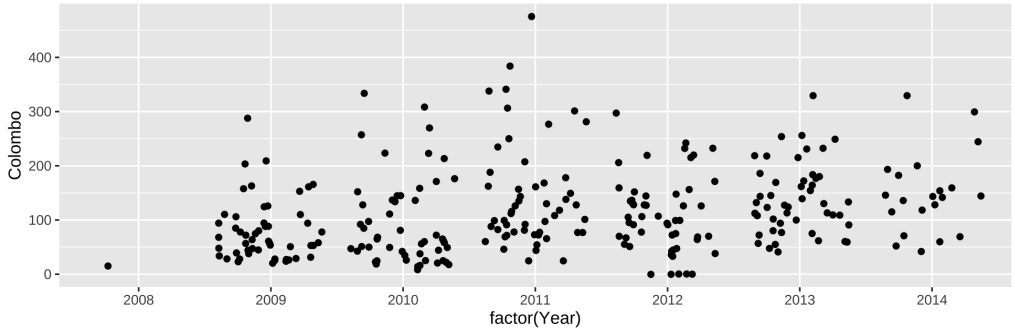
Data Visualization with qplot

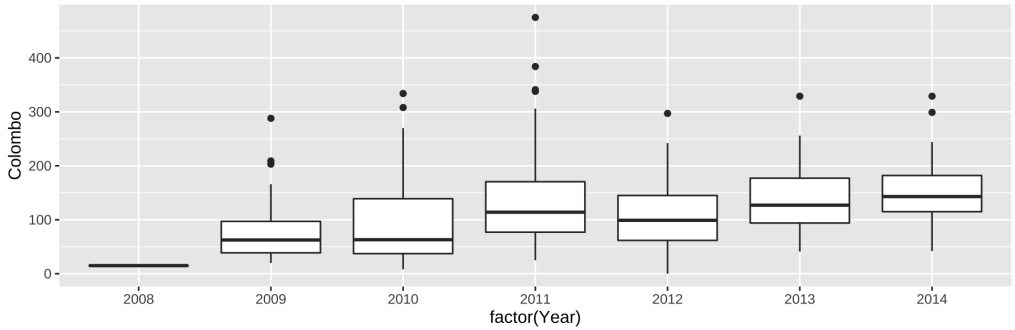
```
qplot(factor(Year), Colombo, da
      geom="jitter")
```



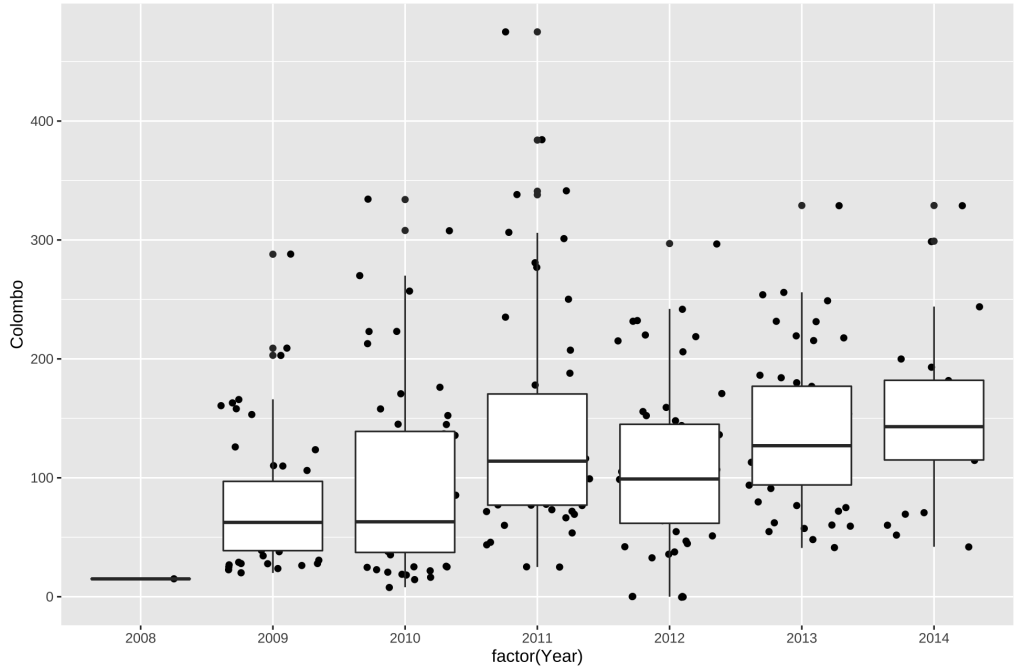

```
qplot(factor(Year), Colombo, da
      geom=c("jitter", "boxplot
```



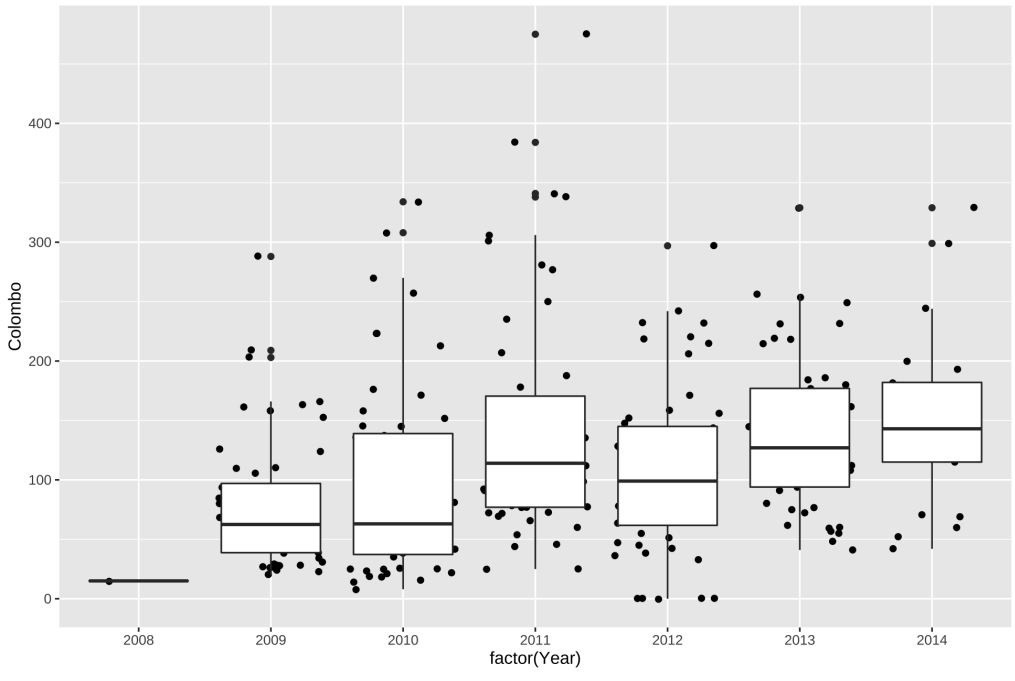




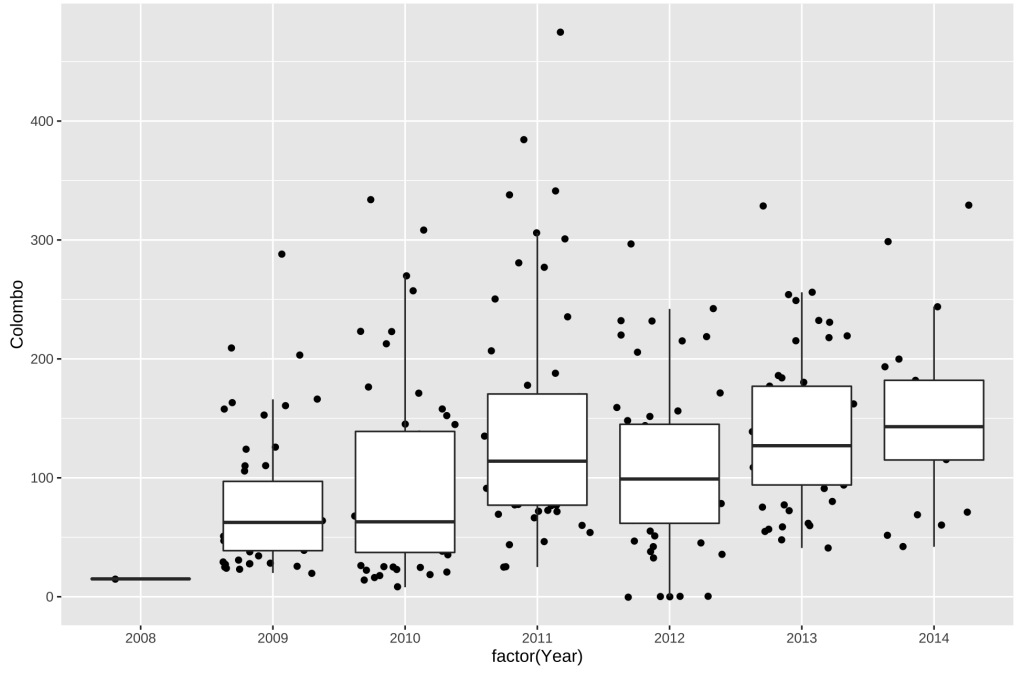

```
qplot(factor(Year), Colombo, da
      geom=c("jitter", "boxplot
```



```
qplot(factor(Year), Colombo, da
      geom=c("jitter", "boxplot
```

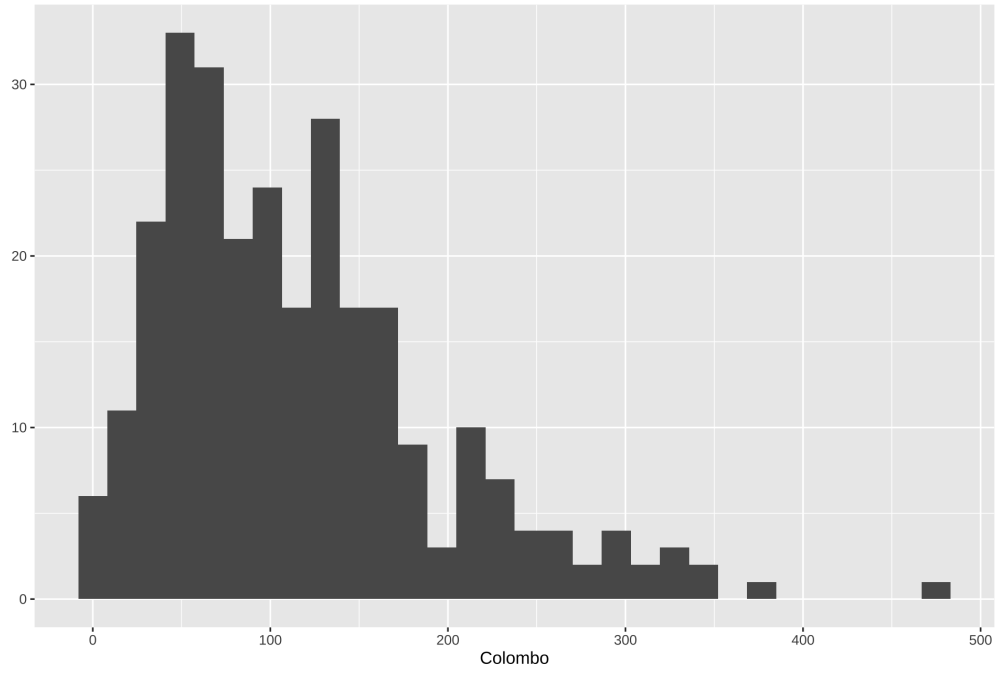



```
qplot(factor(Year), Colombo, da
      geom=c("jitter", "boxplot
      outlier.shape = NA) # geo
```

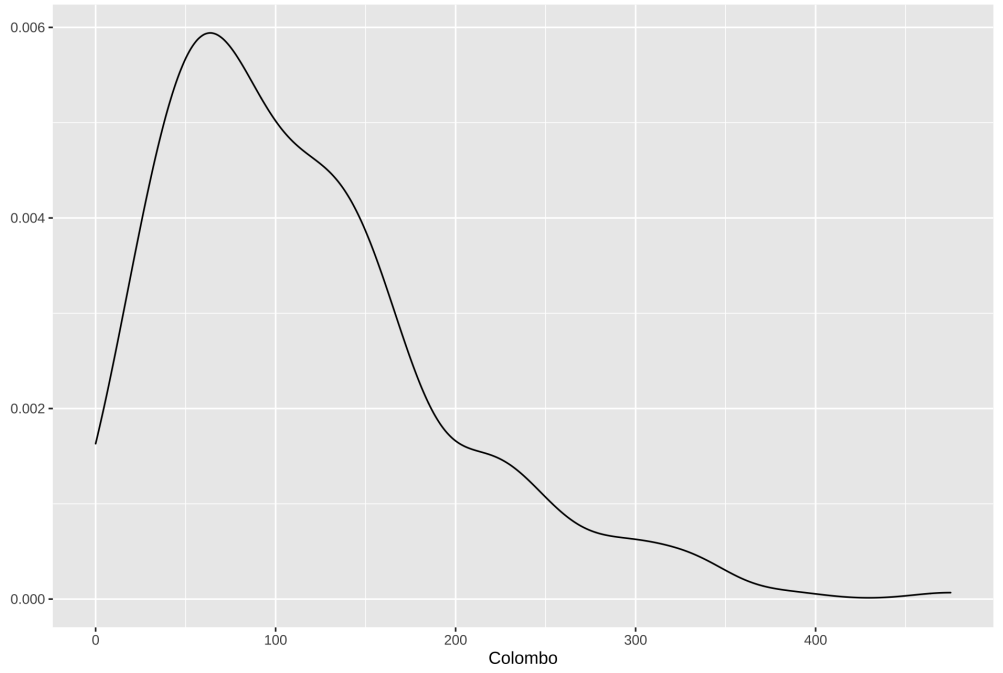


Data Visualization with qplot

```
qplot(Colombo, data=mozzie)
```




```
qplot(Colombo, data=mozzie, geo
```



Your turn

Explore `iris` dataset with suitable graphics.

```
head(iris)
```

```
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
```