

Basic Statistics for Scientists in R and python

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Chapter 1

Using R Studio

1.1 Windows in R Studio

- Text Editor window
- Console
- Environment window
- Help and Plots Window

1.2 Getting help

Help/documentation viewer

Hitting F1 on a function shows help.

Chapter 2

Basic Data Types in R

2.1 vectors and strings

```
x = 1

x
## [1] 1

x[1]
## [1] 1

y = c(1:10) # vector

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

y[2]
## [1] 2

y + 5
## [1] 6 7 8 9 10 11 12 13 14 15

y * 3.0
## [1] 3 6 9 12 15 18 21 24 27 30

y + rnorm(10)
## [1] 0.6374798 2.4877361 2.2808411 3.4852089 4.5054190 5.9702962
## [7] 8.8630991 8.4325286 9.7377612 10.0362543

a_string = "hello world" # string

a_string
## [1] "hello world"
```

2.1.1 matrix

```
a_mtr = matrix(y, nrow=2)

a_mtr

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

2.1.2 list

```
a_lst = list("A", 1)

a_lst

## [[1]]
## [1] "A"
##
## [[2]]
## [1] 1
```

2.1.3 data frame

```
x = (1:10)
my_first_data_frame_df = data.frame("x"=x, "y"=x*0.1 )

my_first_data_frame_df

##      x  y
## 1   1 0.1
## 2   2 0.2
## 3   3 0.3
## 4   4 0.4
## 5   5 0.5
## 6   6 0.6
## 7   7 0.7
## 8   8 0.8
## 9   9 0.9
## 10  10 1.0
```

This shows how to access the data of the data frame

```
my_first_data_frame_df[,1] # first column

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

```

my_first_data_frame_df$x # first column by name

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

my_first_data_frame_df[1,] # first line

## x y
## 1 1 0.1

my_first_data_frame_df[2,2] # second element of second line

## [1] 0.2

```

```

x <- c(1:10)
w <- 20 + 10*x
w

## [1] 30 40 50 60 70 80 90 100 110 120

linear_sample_df <- data.frame(x=x, y=w + rnorm(10)*10)

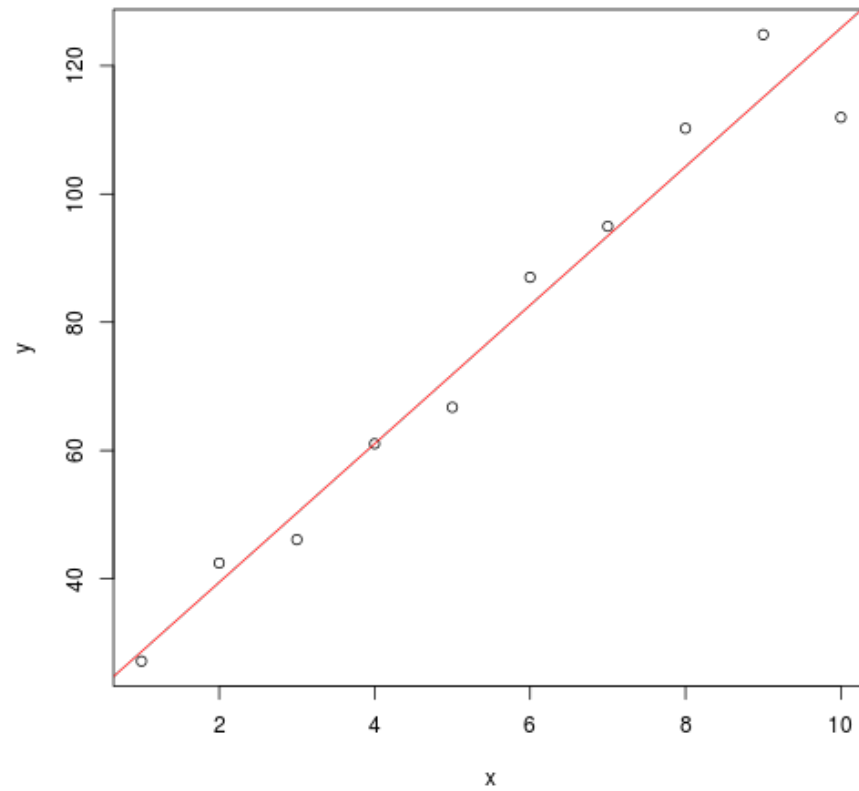
plot(linear_sample_df)

linear_model_lm <- lm(y ~ x, data=linear_sample_df)
summary(linear_model_lm)

##
## Call:
## lm(formula = y ~ x, data = linear_sample_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.9197  -3.4702   0.7557   4.0191   9.7962
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  17.8326     4.8370   3.687  0.00616 **
## x           10.8042     0.7796  13.859  7.1e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.081 on 8 degrees of freedom
## Multiple R-squared:  0.96, Adjusted R-squared:  0.955
## F-statistic: 192.1 on 1 and 8 DF, p-value: 7.103e-07

abline(linear_model_lm, col="red")

```



2.1.4 Examples of in-built data sets for testing

```
library(help = "datasets")
```

Iris

```
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
```

```
head(iris3)
```

```
## [1] 5.1 4.9 4.7 4.6 5.0 5.4
```


women

```
## height weight
## 1      58     115
## 2      59     117
## 3      60     120
## 4      61     123
## 5      62     126
## 6      63     129
```

ELISA - DNase

```
## Run      conc density
## 1  1 0.04882812  0.017
## 2  1 0.04882812  0.018
## 3  1 0.19531250  0.121
## 4  1 0.19531250  0.124
## 5  1 0.39062500  0.206
## 6  1 0.39062500  0.215
```

Mean, Average, Summary

```
## [1] 60.1
## [1] 4.998889
##   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   51.0   57.5   61.0   60.1   62.5   69.0
## [1] 61 59 55
##
## One Sample t-test
##
## data: wtcsf[1:4]
## t = 31.6563, df = 3, p-value = 6.927e-05
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  53.74326 65.75674
## sample estimates:
## mean of x
##    59.75
##
## One Sample t-test
##
## data: wtcsf
## t = 38.019, df = 9, p-value = 2.991e-11
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
```

```
## 56.52401 63.67599
## sample estimates:
## mean of x
##      60.1
## [1] 45.5
## [1] 7.382412
##      Min. 1st Qu.  Median      Mean 3rd Qu.     Max.
##      34.00   40.25   46.50   45.50   49.50   59.00
```

Reading/Writing Data from a File

```
setwd(".")

input_df = read.csv("demo_data.csv")

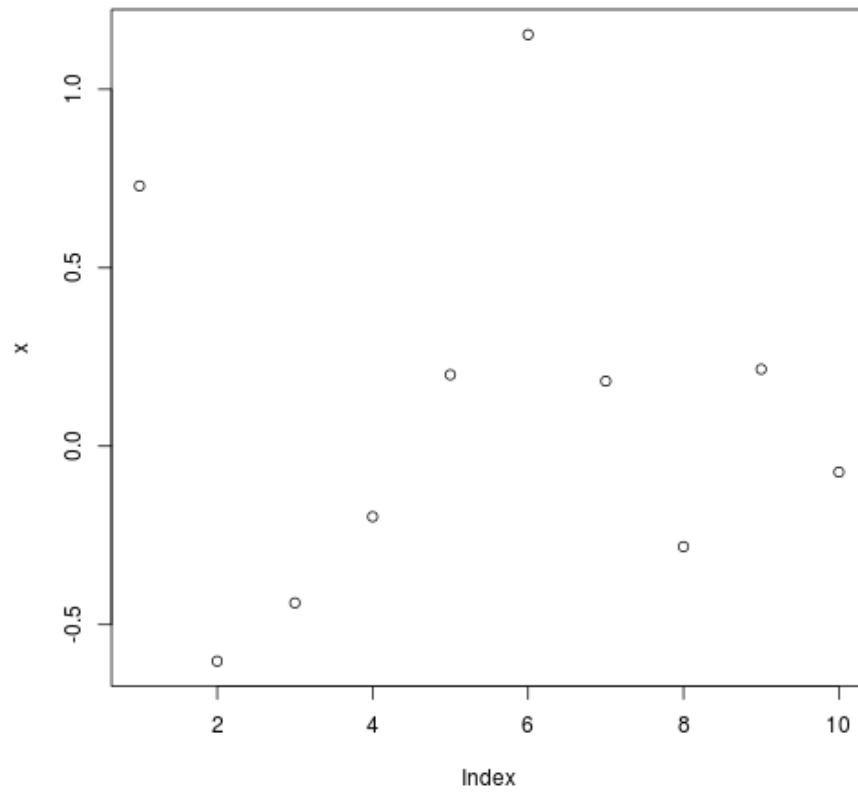
input_df

##      time absorbtion
## 1      1          0.4
## 2      2          1.0
## 3      3          1.5
```

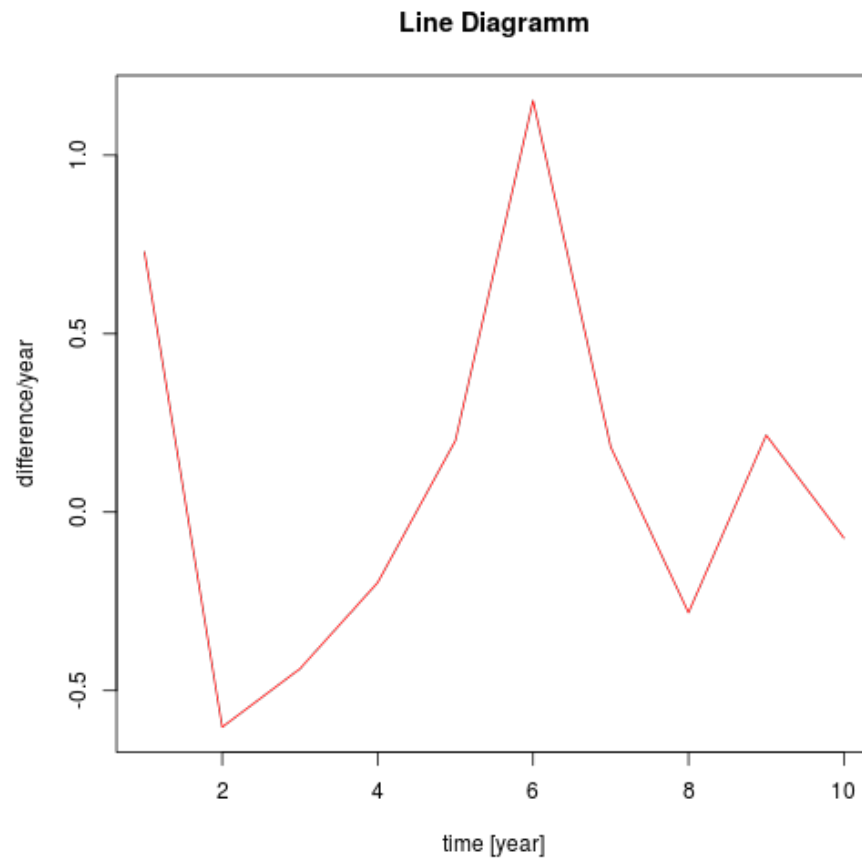
Basic Plotting in R

```
x <- rnorm(10);

plot(x)
```



```
plot(x, type="l", col="red", main="Line Diagramm", xlab="time [year]", ylab="difference/year")
```

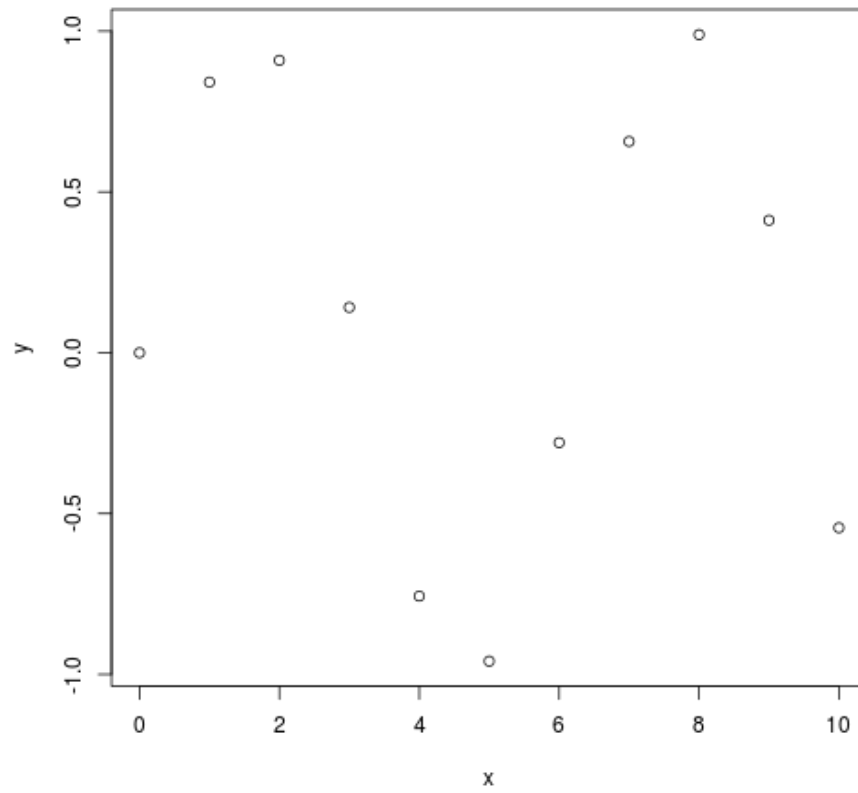


```
x <- c(0:10)
y <- sin(x)

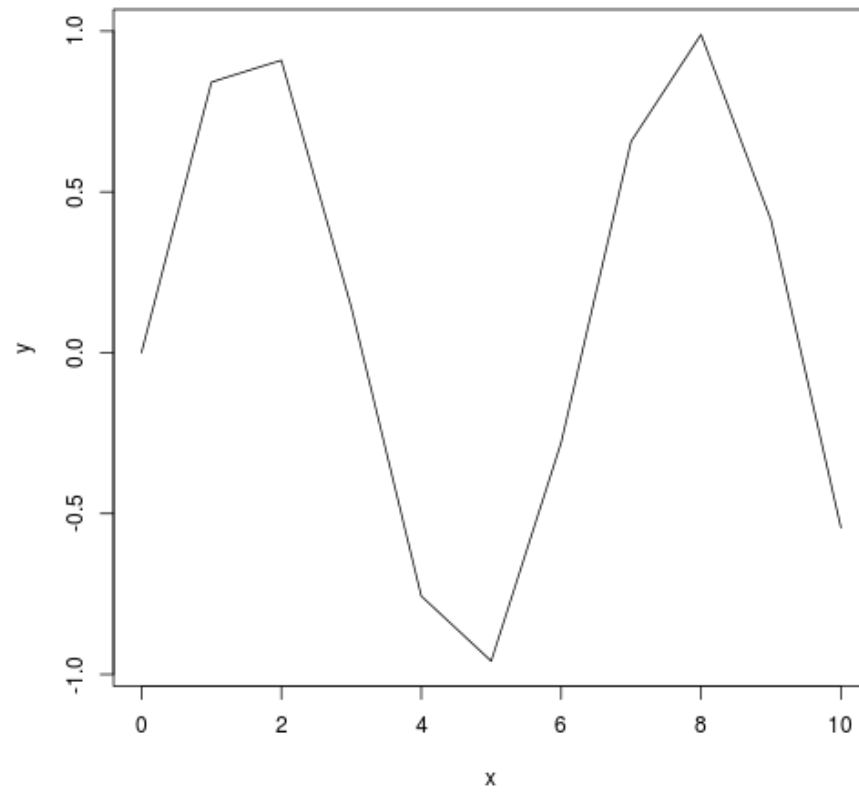
x
## [1] 0 1 2 3 4 5 6 7 8 9 10

y
## [1] 0.0000000 0.8414710 0.9092974 0.1411200 -0.7568025 -0.9589243
## [7] -0.2794155 0.6569866 0.9893582 0.4121185 -0.5440211

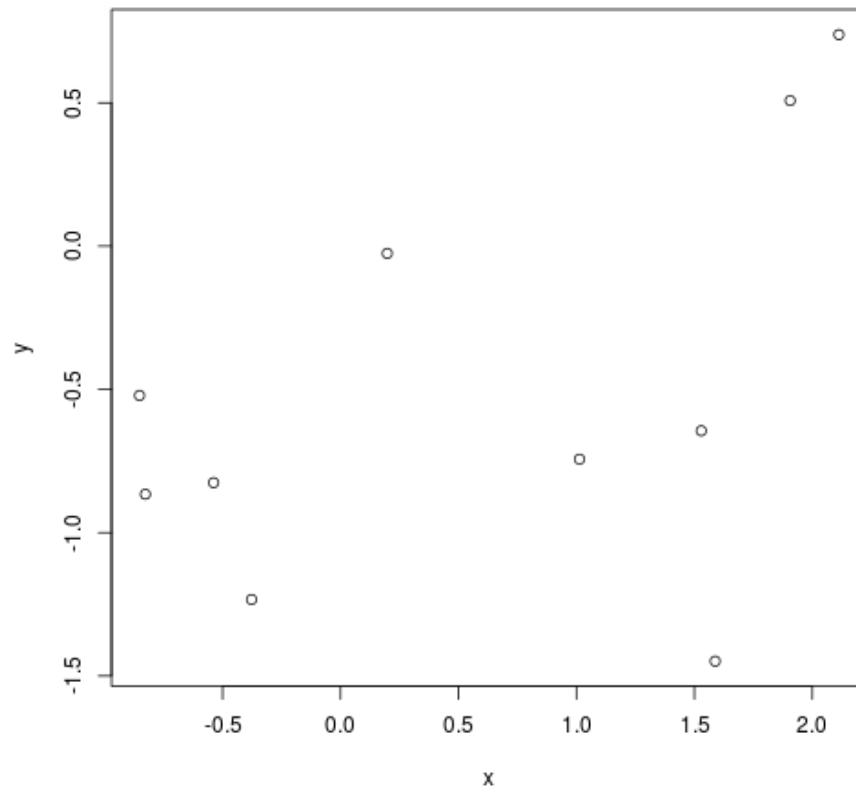
plot(x, y)
```



```
plot(x, y, type="l")
```



```
x <- rnorm(10); y <- rnorm(10)
plot(x,y)
```



```
x <- 1:10
w <- 20 + 10*x
w

## [1] 30 40 50 60 70 80 90 100 110 120

linear_sample_df <- data.frame(x=x, y=w + rnorm(10)*10)

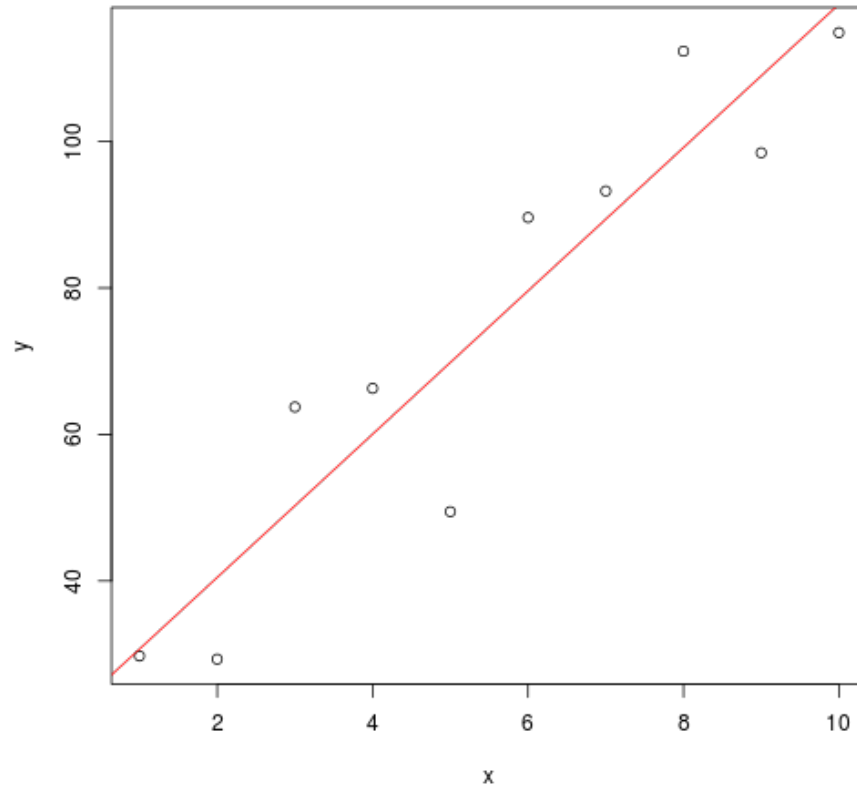
plot(linear_sample_df)

linear_model_lm <- lm(y ~ x, data=linear_sample_df)
summary(linear_model_lm)

##
## Call:
## lm(formula = y ~ x, data = linear_sample_df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -20.359  -8.826   1.460   9.079  13.487
```

```
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  20.906      8.276   2.526  0.0355 *
## x            9.783      1.334   7.334 8.12e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.11 on 8 degrees of freedom
## Multiple R-squared:  0.8705, Adjusted R-squared:  0.8544
## F-statistic: 53.79 on 1 and 8 DF,  p-value: 8.115e-05

abline(linear_model_lm, col="red")
```



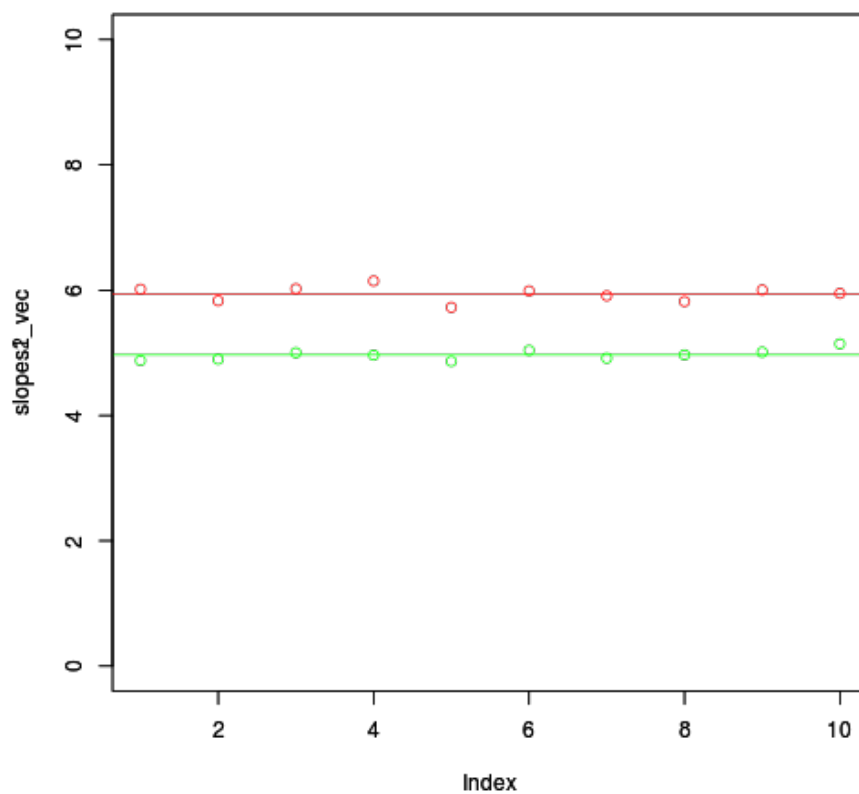
Variance Tests

2.2 Standard error of mean

$$std_{err} = \frac{\sigma}{\sqrt{n}}$$

Significance Tests

```
##          x          x          x          x          x          x          x          x
## 4.878039 4.898131 5.001908 4.963385 4.865152 5.039916 4.915391 4.967199
##          x          x
## 5.011863 5.143463
## [1] 4.926026
## [1] 4.943482
```



```
## null device
##          1
##          x          x          x          x          x          x          x          x
## 6.633215 4.788317 6.564807 4.293721 5.508849 7.236327 6.170890 7.604209
##          x          x          x          x          x          x          x          x
## 6.925911 4.918605 6.894344 5.304487 7.868806 6.028642 6.597790 3.969378
##          x          x          x          x          x          x          x          x
## 5.057931 5.934552 5.572611 5.996545 5.790477 5.044538 6.403426 6.347024
##          x          x          x          x          x          x          x          x
## 5.769051 5.934021 6.020292 5.088790 5.250880 6.963147 5.464096 6.782621
```

```
##      x      x      x      x      x      x      x      x
## 6.066908 7.673906 6.939877 7.019042 4.931284 6.173563 4.651887 6.691128
##      x      x      x      x      x      x      x      x
## 7.009119 3.656224 4.491341 6.065214 5.839561 6.883683 6.906737 6.652464
##      x      x      x      x      x      x      x      x
## 7.820647 3.540934 6.166658 5.700559 7.591898 6.652741 7.921243 6.288685
##      x      x      x      x      x      x      x      x
## 5.957211 8.048820 3.515428 7.021463 4.386782 6.693037 5.730710 6.975457
##      x      x      x      x      x      x      x      x
## 7.015954 4.121238 6.529941 5.379626 4.578788 7.423382 7.243624 6.728267
##      x      x      x      x      x      x      x      x
## 6.674536 5.336379 6.671007 5.926893 5.077445 4.617998 5.333302 7.197559
##      x      x      x      x      x      x      x      x
## 5.970053 6.749064 5.432250 5.726665 5.319985 6.191697 7.161806 4.326466
##      x      x      x      x      x      x      x      x
## 7.821321 8.199272 6.247738 7.238579 6.652328 5.265595 7.371791 6.090606
##      x      x      x      x      x      x      x      x
## 6.894554 7.281851 4.414942 5.539930 6.461284 7.997193 6.739139 5.244401
##      x      x      x      x      x      x      x      x
## 5.543579 4.362779 7.055318 4.148007 6.757095 6.108999 3.532744 8.597092
##      x      x      x      x      x      x      x      x
## 6.808105 5.154026 5.192849 5.963575 7.106009 4.673242 7.899543 5.896776
##      x      x      x      x      x      x      x      x
## 5.051282 7.855268 5.917299 5.270159 4.374018 7.148634 6.646142 5.985828
##      x      x      x      x      x      x      x      x
## 5.392014 7.959309 7.137490 5.869403 5.216463 5.657004 8.457798 6.117051
##      x      x      x      x      x      x      x      x
## 7.137074 5.983939 4.966572 6.611491 6.701773 3.682370 6.321364 5.480326
##      x      x      x      x      x      x      x      x
## 7.178663 5.384898 6.454023 4.663807 6.813953 8.276855 6.914378 4.777376
##      x      x      x      x      x      x      x      x
## 4.669981 6.286059 5.211112 5.845204 7.017776 5.303125 5.778031 4.139510
##      x      x      x      x      x      x      x      x
## 6.928433 4.776578 5.481079 4.300668 7.738094 7.249896 6.138496 5.908348
##      x      x      x      x      x      x      x      x
## 6.236917 3.952352 4.849091 4.505747 5.937471 4.803286 6.296130 6.283912
##      x      x      x      x      x      x      x      x
## 5.259352 6.574691 6.578854 6.543309 4.961092 5.902736 7.057898 4.390489
##      x      x      x      x      x      x      x      x
## 6.609685 4.001016 5.201956 6.414713 5.367128 4.695895 6.644379 6.475499
##      x      x      x      x      x      x      x      x
## 7.309984 5.053425 6.675257 4.120202 8.502521 3.872859 5.146316 8.226373
##      x      x      x      x      x      x      x      x
## 5.832223 6.298610 5.817216 7.001010 4.918371 6.925648 6.699227 5.858782
##      x      x      x      x      x      x      x      x
## 5.969560 4.494519 5.354410 5.248249 5.964316 6.128931 3.547553 7.250608
##      x      x      x      x      x      x      x      x
## 7.101789 6.086488 8.828973 7.132082 6.328513 5.169690 7.839465 5.998314
##      x      x      x      x      x      x      x      x
```

```

## 5.100835 4.683628 5.480282 5.113487 7.197281 4.539325 5.835717 4.809028
##          x          x          x          x          x          x          x          x
## 5.944766 6.123840 4.874292 6.999433 5.519544 8.486489 6.998997 7.476167
##          x          x          x          x          x          x          x          x
## 5.618549 5.349998 8.510682 4.650422 5.395324 7.258597 6.618358 6.833651
##          x          x          x          x          x          x          x          x
## 5.637604 8.739205 6.043609 6.111779 4.748342 6.306319 5.435800 4.386106
##          x          x          x          x          x          x          x          x
## 5.975222 5.963062 7.091659 7.326738 5.628269 4.176892 5.096718 4.945763
##          x          x          x          x          x          x          x          x
## 6.527198 7.866604 5.169389 7.017064 5.347666 5.815217 6.559017 6.414656
##          x          x          x          x          x          x          x          x
## 6.222825 5.529066 4.400618 7.282579 7.130538 6.218649 5.859840 7.368537
##          x          x          x          x          x          x          x          x
## 5.644839 5.050639 6.610478 5.700705 4.229926 5.171289 5.222146 5.976755
##          x          x          x          x          x          x          x          x
## 9.255901 5.770924 5.718133 5.117175 7.431181 7.757344 4.576024 4.472422
##          x          x          x          x          x          x          x          x
## 5.467818 6.841580 6.116077 5.874174 4.572537 5.441059 5.252198 7.384380
##          x          x          x          x          x          x          x          x
## 4.833404 4.739104 6.250259 4.714518 6.900422 3.071000 6.311957 7.397706
##          x          x          x          x          x          x          x          x
## 6.611213 6.284456 5.315780 4.718704 4.331423 8.607132 5.589709 6.100584
##          x          x          x          x          x          x          x          x
## 4.706567 4.785617 4.870260 5.665058 5.632976 7.816111 6.228144 4.314221
##          x          x          x          x          x          x          x          x
## 6.502263 6.504632 3.506665 5.091048 6.726389 6.146463 5.666936 4.383317
##          x          x          x          x          x          x          x          x
## 4.971351 5.678894 7.496118 5.099310 5.687912 4.507340 5.711398 5.356120
##          x          x          x          x          x          x          x          x
## 6.720504 5.214713 6.289229 7.162573 5.693606 5.433234 5.380128 3.773646
##          x          x          x          x          x          x          x          x
## 4.814044 6.274255 5.916852 5.258286 7.596261 6.614370 5.412557 5.364938
##          x          x          x          x          x          x          x          x
## 6.916393 6.079993 4.287155 5.959862 8.182566 6.765683 5.745985 4.766965
##          x          x          x          x          x          x          x          x
## 5.883848 6.237248 5.485364 5.016054 6.230862 5.754859 6.184249 4.656401
##          x          x          x          x          x          x          x          x
## 7.054912 5.049881 4.920125 4.312934 9.347927 5.856003 6.162362 6.934177
##          x          x          x          x          x          x          x          x
## 5.367681 6.079733 5.217114 6.126061 6.272530 6.693240 6.926406 5.150406
##          x          x          x          x          x          x          x          x
## 6.935914 4.224596 5.846245 6.300594 6.993754 4.611154 5.849242 5.181972
##          x          x          x          x          x          x          x          x
## 5.960690 6.494583 5.899182 4.824400 6.588167 6.125606 7.030498 4.386730
##          x          x          x          x          x          x          x          x
## 5.547385 5.716860 8.261368 6.926722 6.472021 6.964376 7.520469 7.393662
##          x          x          x          x          x          x          x          x
## 6.397276 5.346445 5.791765 5.178942 8.069783 7.005463 6.813694 7.143943

```

```
##      x      x      x      x      x      x      x      x
## 6.152886 7.006442 5.968636 6.756043 6.721083 4.112648 5.151108 4.961611
##      x      x      x      x      x      x      x      x
## 6.310731 5.393227 6.973407 7.978294 6.141162 5.758322 6.734541 5.900392
##      x      x      x      x      x      x      x      x
## 5.890840 5.154838 5.974008 6.693459 5.518933 5.659240 5.857371 3.615370
##      x      x      x      x      x      x      x      x
## 5.754333 5.764966 6.487216 5.806702 5.965437 2.911689 7.842647 5.730676
##      x      x      x      x      x      x      x      x
## 5.651047 4.993584 5.497040 4.856241 4.925623 7.198017 6.258210 6.580150
##      x      x      x      x      x      x      x      x
## 5.754581 7.079957 6.165422 7.316085 5.869389 7.371217 5.822049 5.836825
##      x      x      x      x      x      x      x      x
## 5.947603 5.606890 7.173730 7.650584 6.328949 9.206136 6.038092 4.991058
##      x      x      x      x      x      x      x      x
## 5.974441 5.134662 3.600499 7.071465 6.730517 5.283426 7.217478 4.086986
##      x      x      x      x      x      x      x      x
## 6.546429 6.531580 7.280436 4.964366 7.063508 5.216528 6.284643 7.212003
##      x      x      x      x      x      x      x      x
## 5.481468 5.447068 7.586464 7.917930 5.321203 6.605097 4.603185 5.712363
##      x      x      x      x      x      x      x      x
## 4.004316 6.766822 5.386436 7.901153 3.839627 5.516816 7.725775 6.296264
##      x      x      x      x      x      x      x      x
## 4.343344 5.218314 5.773110 6.764194 6.212806 4.939099 7.145879 5.733833
##      x      x      x      x      x      x      x      x
## 5.083573 6.095184 7.172060 5.350787 5.525354 7.639660 5.468447 7.013681
##      x      x      x      x      x      x      x      x
## 4.613622 6.978951 3.250197 6.758168 6.394883 5.496417 5.189468 6.803351
##      x      x      x      x      x      x      x      x
## 7.647161 6.287195 7.119439 5.826228 5.415372 6.196327 5.258465 5.865903
##      x      x      x      x      x      x      x      x
## 9.017262 4.645893 5.691494 5.530826 6.400432 5.956419 5.337943 7.958646
##      x      x      x      x      x      x      x      x
## 5.899143 7.387483 7.999113 6.199795 7.554486 8.682160 8.129822 6.618527
##      x      x      x      x      x      x      x      x
## 7.832470 6.075511 7.683983 5.149024 6.467616 6.790115 7.581328 6.176001
##      x      x      x      x      x      x      x      x
## 5.365099 5.745535 7.338776 3.511925 6.423100 5.654990 5.003216 7.398339
##      x      x      x      x      x      x      x      x
## 7.515275 6.571452 5.280032 5.427637 3.713573 6.490435 5.489943 6.272458
##      x      x      x      x      x      x      x      x
## 7.109898 6.011729 7.197734 5.612124 5.564341 8.556501 6.404908 5.430494
##      x      x      x      x      x      x      x      x
## 3.812981 6.204877 6.487712 5.045345 4.397444 5.867503 6.174278 6.570901
##      x      x      x      x      x      x      x      x
## 5.836637 4.301452 6.133982 6.965545 4.975986 6.305867 6.307292 5.006600
##      x      x      x      x      x      x      x      x
## 4.620029 7.033118 7.740930 7.416174 5.920335 6.038781 5.200304 4.683279
##      x      x      x      x      x      x      x      x
```

```

## 6.762616 6.675335 4.448918 6.003859 4.444205 5.139782 6.530174 6.534671
##      x      x      x      x      x      x      x      x
## 5.138994 9.879072 5.672069 4.847482 5.630891 6.480100 6.458911 4.031154
##      x      x      x      x      x      x      x      x
## 5.377086 4.416692 6.176550 5.776476 6.137279 5.067155 5.845513 7.565095
##      x      x      x      x      x      x      x      x
## 5.606817 5.987778 5.843451 7.795528 6.171393 6.724335 4.729066 4.878995
##      x      x      x      x      x      x      x      x
## 6.689884 5.637008 7.340749 5.658075 6.060801 4.554430 7.499406 8.771331
##      x      x      x      x      x      x      x      x
## 5.443652 6.705081 6.371633 6.819507 6.384440 5.913313 6.491552 6.743260
##      x      x      x      x      x      x      x      x
## 6.473194 7.171726 6.419220 5.298364 6.071700 5.939316 5.812694 5.712709
##      x      x      x      x      x      x      x      x
## 8.266121 5.239768 6.316725 6.891424 5.122243 6.010414 4.108041 6.162332
##      x      x      x      x      x      x      x      x
## 4.490935 4.851258 5.983388 6.627054 7.547646 5.849962 6.560651 5.592865
##      x      x      x      x      x      x      x      x
## 6.585348 5.785172 6.734177 4.283046 4.930979 7.071574 7.318983 5.410255
##      x      x      x      x      x      x      x      x
## 7.050024 6.600702 6.896533 5.895504 5.772629 5.377827 5.193694 5.845309
##      x      x      x      x      x      x      x      x
## 5.668282 8.922333 7.415670 5.801911 4.120051 5.449626 5.616978 6.751938
##      x      x      x      x      x      x      x      x
## 7.260377 5.962501 7.154565 6.996775 6.526983 6.260875 4.094262 6.902596
##      x      x      x      x      x      x      x      x
## 5.562348 6.289427 5.220367 6.187734 6.764851 5.253351 6.466079 5.943651
##      x      x      x      x      x      x      x      x
## 7.602303 5.544052 4.842486 6.234347 6.014683 4.391724 6.324261 7.235703
##      x      x      x      x      x      x      x      x
## 5.338380 6.466421 5.931657 7.440010 4.978962 5.562469 6.404893 5.824208
##      x      x      x      x      x      x      x      x
## 4.756970 6.125380 7.900846 5.943764 6.121605 4.624660 3.474887 4.817322
##      x      x      x      x      x      x      x      x
## 6.067557 7.682102 6.788394 8.326937 6.838999 7.768922 7.665760 7.371332
##      x      x      x      x      x      x      x      x
## 6.838388 5.420367 4.908942 6.423635 6.227033 4.206352 4.890770 5.882252
##      x      x      x      x      x      x      x      x
## 2.694324 4.383511 5.114433 3.968780 4.068316 5.431364 6.492427 6.003484
##      x      x      x      x      x      x      x      x
## 5.906331 5.696961 6.301158 5.951798 6.682034 8.343025 4.509552 5.835774
##      x      x      x      x      x      x      x      x
## 4.009303 5.207232 7.648334 6.482344 6.976461 5.188281 5.463998 6.135375
##      x      x      x      x      x      x      x      x
## 4.767877 5.672646 4.768121 6.970008 5.846739 8.190827 5.215679 9.187442
##      x      x      x      x      x      x      x      x
## 7.098978 4.471632 7.075224 6.078041 4.983577 6.360214 7.417014 5.613655
##      x      x      x      x      x      x      x      x
## 5.649960 7.723875 7.051665 7.330656 5.996690 4.837733 4.979790 5.367279

```

```
##      x      x      x      x      x      x      x      x
## 6.620637 9.839912 7.653952 6.299701 6.656421 4.852433 5.724487 8.068591
##      x      x      x      x      x      x      x      x
## 5.882074 5.430940 6.023168 3.772338 4.448916 6.201028 6.455661 5.396081
##      x      x      x      x      x      x      x      x
## 6.218427 5.614147 6.617425 3.823399 5.128108 7.218187 5.945134 4.948836
##      x      x      x      x      x      x      x      x
## 5.751537 5.889968 8.356241 5.313880 5.300218 5.493623 6.397312 7.159329
##      x      x      x      x      x      x      x      x
## 7.080151 6.241000 5.687398 4.972173 5.543828 6.770620 6.149179 8.299276
##      x      x      x      x      x      x      x      x
## 4.596703 5.216252 7.438065 5.726462 5.470028 5.231864 5.841823 6.854155
##      x      x      x      x      x      x      x      x
## 6.630346 6.278897 5.321159 6.758856 5.454460 4.659087 6.360846 8.617120
##      x      x      x      x      x      x      x      x
## 4.380969 7.162638 6.223872 6.409403 7.796951 6.575313 8.535814 5.257989
##      x      x      x      x      x      x      x      x
## 8.008628 4.350024 5.284162 7.509888 5.859762 5.451276 4.205663 4.021753
##      x      x      x      x      x      x      x      x
## 6.102902 6.472612 5.684691 4.522206 6.898558 5.915559 7.487977 7.578742
##      x      x      x      x      x      x      x      x
## 7.403190 8.483313 6.649650 6.324126 5.146509 6.829402 6.083478 6.289214
##      x      x      x      x      x      x      x      x
## 8.582850 4.249021 5.439125 6.609703 4.221955 8.476141 5.588820 5.979076
##      x      x      x      x      x      x      x      x
## 6.329652 5.349262 3.763847 5.905847 7.894596 4.914516 5.913087 5.775230
##      x      x      x      x      x      x      x      x
## 4.905805 7.074284 6.838783 5.184352 6.954504 4.498552 4.336881 6.135319
##      x      x      x      x      x      x      x      x
## 7.881243 6.385289 5.830712 5.358614 5.519402 5.782606 4.308220 6.379695
##      x      x      x      x      x      x      x      x
## 7.969214 3.624269 6.254574 6.857339 5.288958 6.159485 7.693558 5.121095
##      x      x      x      x      x      x      x      x
## 5.948630 6.142501 4.966284 6.461057 5.303808 7.541781 6.876944 4.491322
##      x      x      x      x      x      x      x      x
## 5.538304 6.016512 6.351624 5.674514 5.666393 6.293538 6.997619 5.832906
##      x      x      x      x      x      x      x      x
## 6.752950 6.594031 4.043095 6.370716 5.438127 4.744680 7.632040 4.809244
##      x      x      x      x      x      x      x      x
## 8.110126 6.741220 5.005849 4.691669 6.278835 6.622859 6.865675 5.997258
##      x      x      x      x      x      x      x      x
## 6.665872 5.502224 5.917804 6.521073 6.603712 5.589992 5.870916 7.677957
##      x      x      x      x      x      x      x      x
## 6.413044 8.165048 5.189015 4.843692 4.978158 6.347204 4.505004 5.114362
##      x      x      x      x      x      x      x      x
## 5.587586 6.880224 7.125208 6.230918 6.544492 7.273761 3.910725 5.387873
## [1] 6.037644
## [1] 5.995446
## [1] 5.455792
```

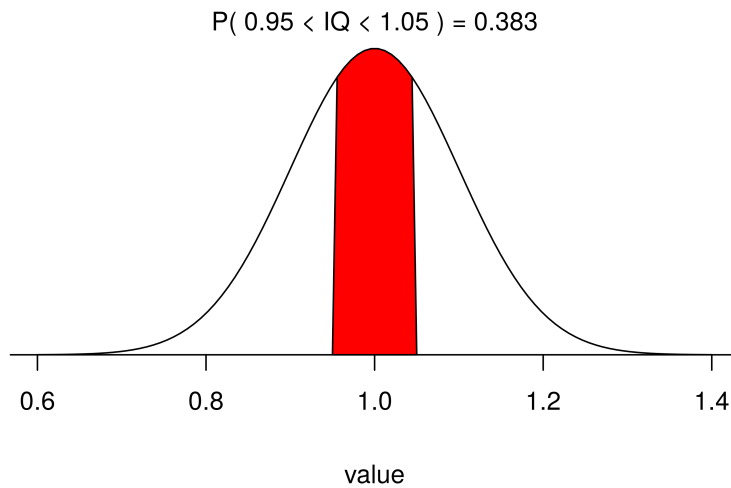


Figure 2.1: Normal Distribution.

```
## [1] 5.949386
## [1] 6.105875
## [1] 6.038583
## [1] 5.965687
```

Distributions

Normal Distribution

Normal Distribution

Based on the equation

$$f(x) = e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

μ = mean σ = standard deviation

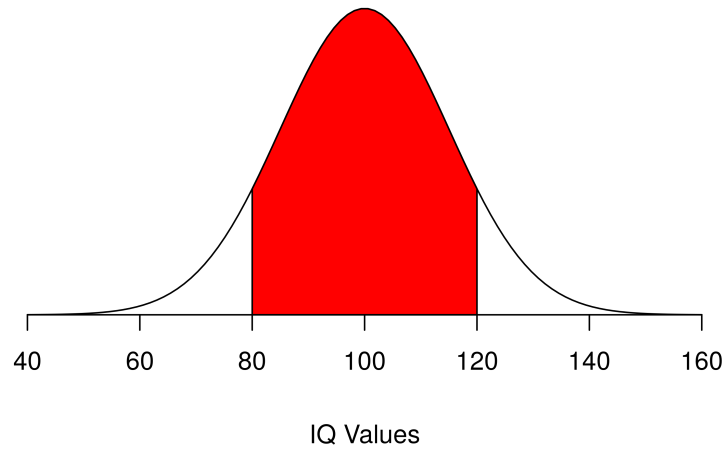
with $mean = 1$, $\sigma = 0.1$

Example of a Normal Distribution

Children's IQ scores are normally distributed with a mean of 100 and a standard deviation of 15. What proportion of children are expected to have an IQ between 80 and 120?

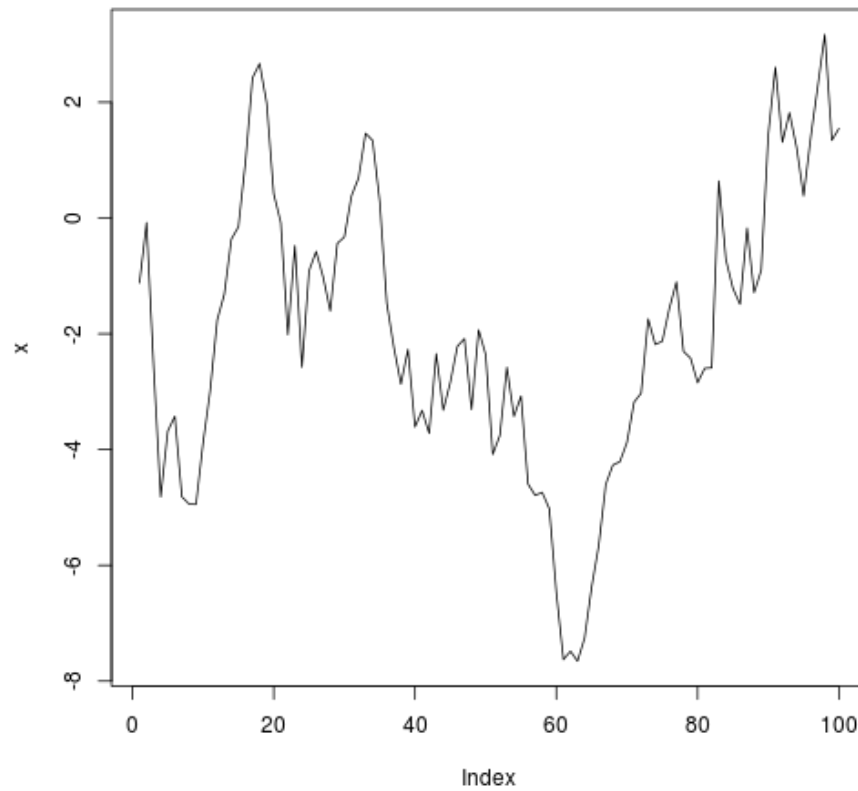
Normal Distribution of IQ Values

$$P(80 < IQ < 120) = 0.818$$



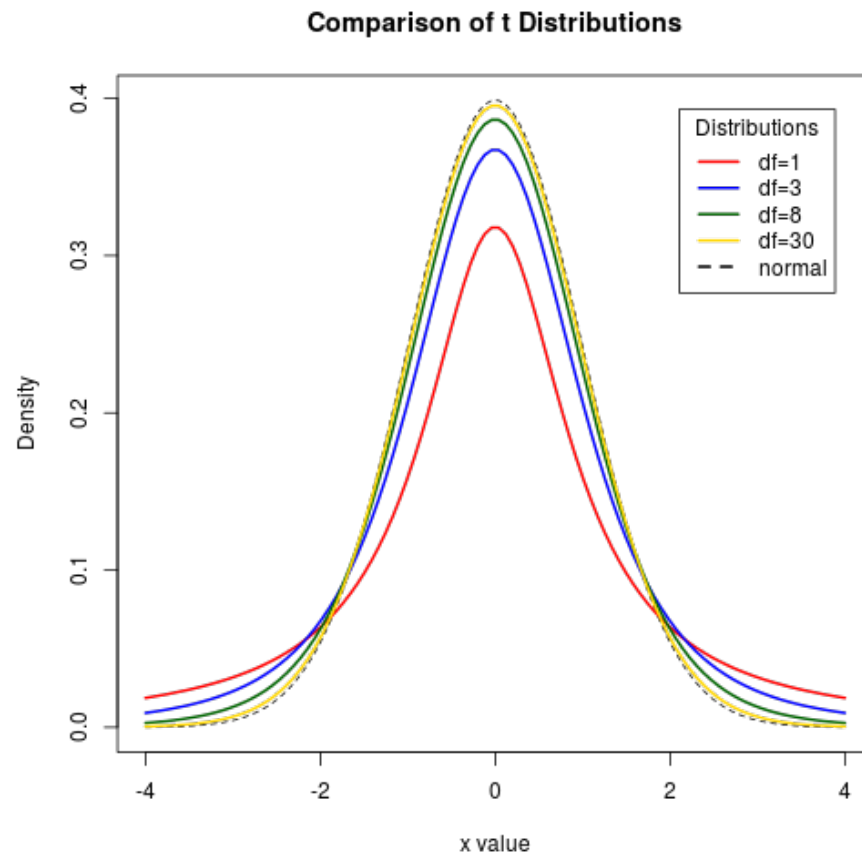
Cusum Example

```
## [1] -1.939758
```

Student Distribution

Display the Student's t distributions with various degrees of freedom and compare to the normal distribution



2.3 Integration

```
int_func <- function(x) {  
  y = sin(x) ** 2  
  return(y)  
}  
  
integrate(int_func, lower=1 , upper=4)  
  
## 1.479985 with absolute error < 1.6e-14
```