

Stat 135 Lab1

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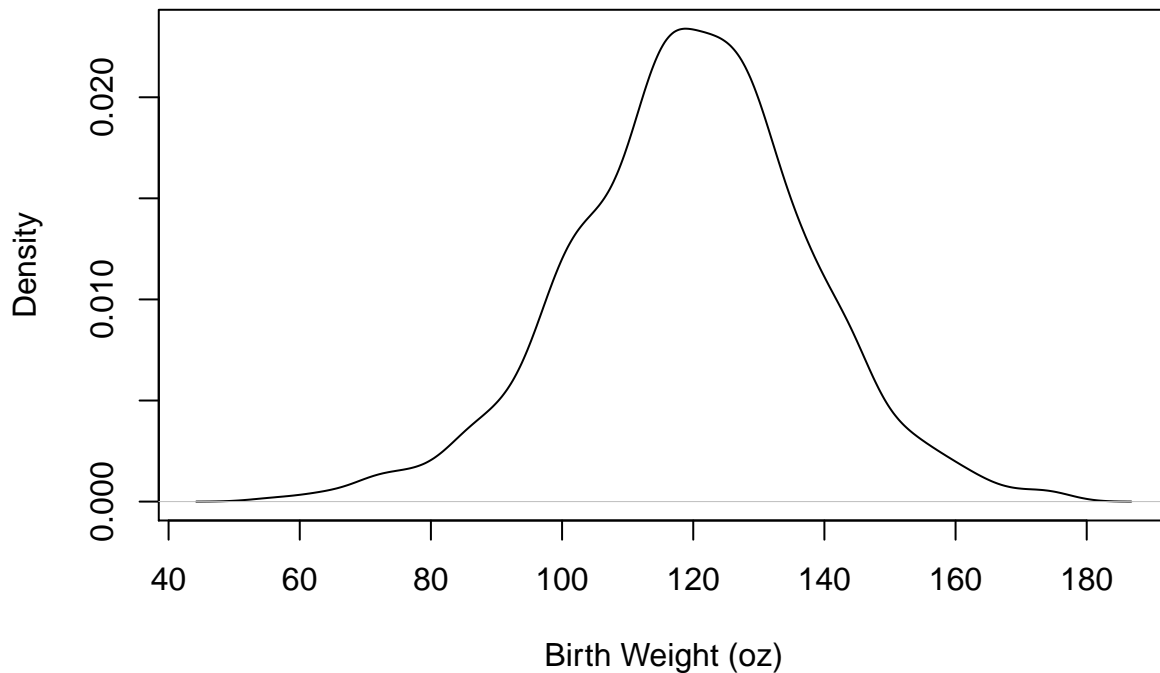
R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see <http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

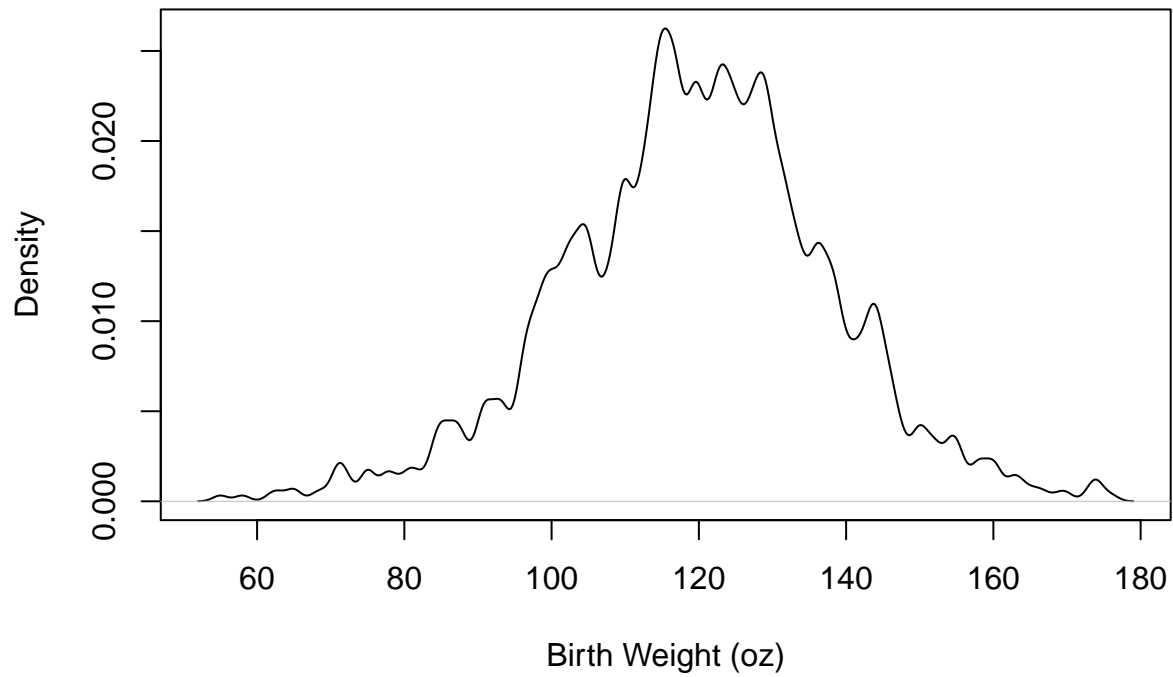
```
load("/Users/Leomart/Desktop/Stat135/KaiserBabies.rda")
plot(density(infants$bwt), xlab = "Birth Weight (oz)", main = "Male Babies, Oakland Kaiser 1960s")
```

Male Babies, Oakland Kaiser 1960s



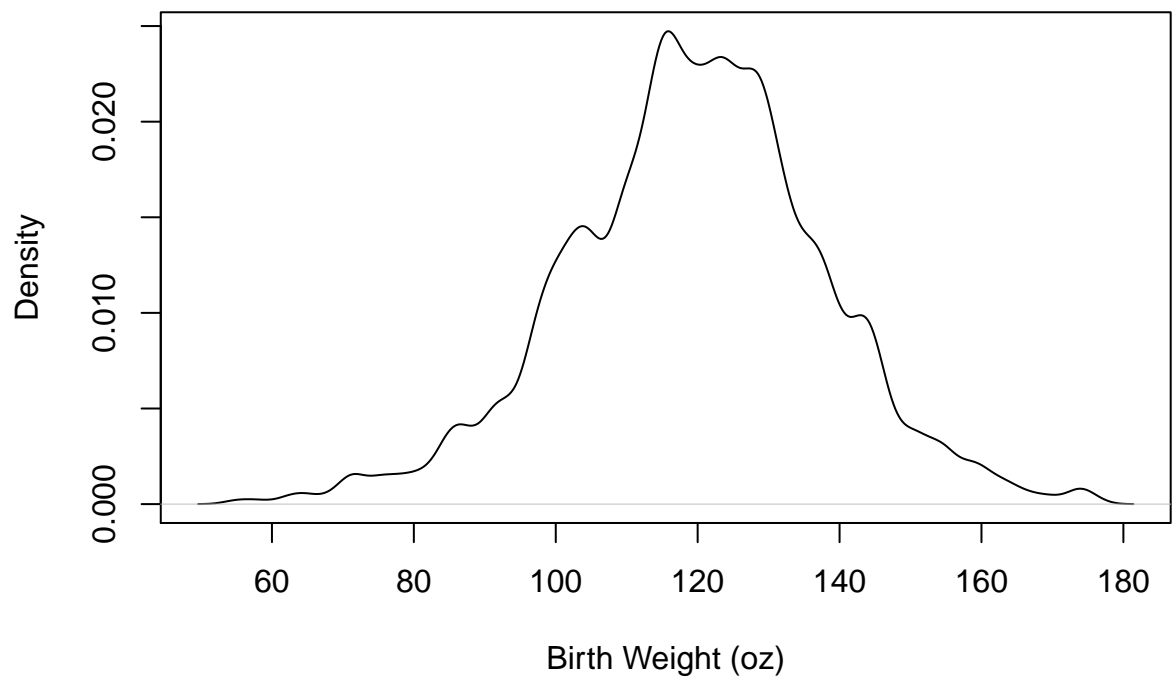
```
plot(density(infants$bwt,bw=1), xlab = "Birth Weight (oz)", main = "Male Babies, Oakland Kaiser 1960s")
```

Male Babies, Oakland Kaiser 1960s



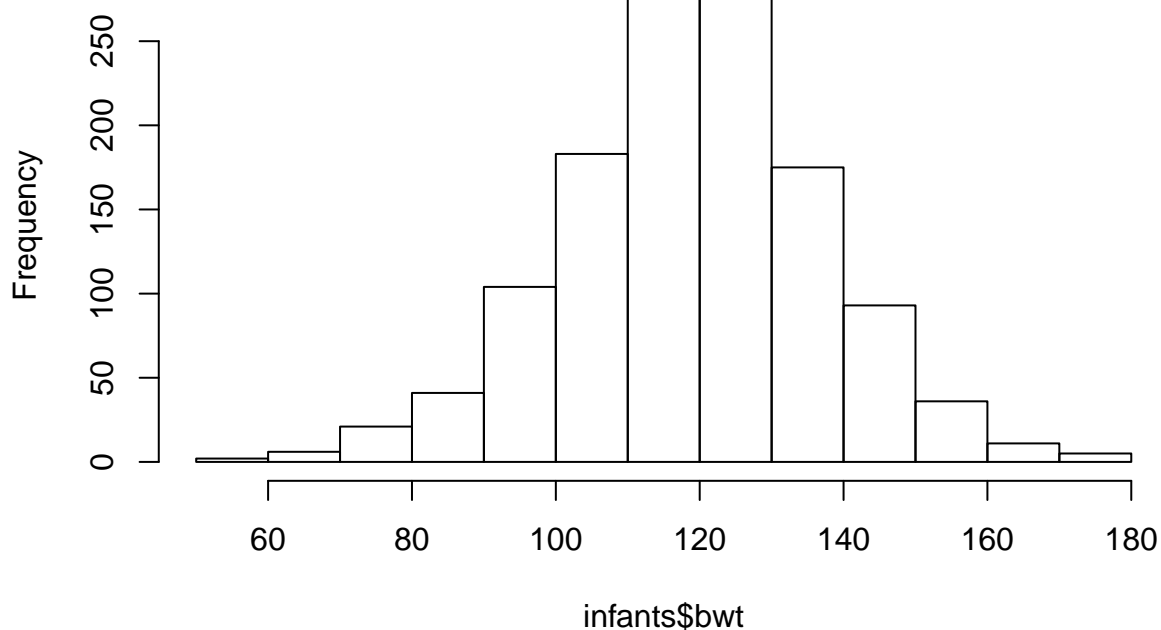
```
plot(density(infants$bwt,adjust=0.5), xlab = "Birth Weight (oz)", main = "Male Babies, Oakland Kaiser 1960s")
```

Male Babies, Oakland Kaiser 1960s



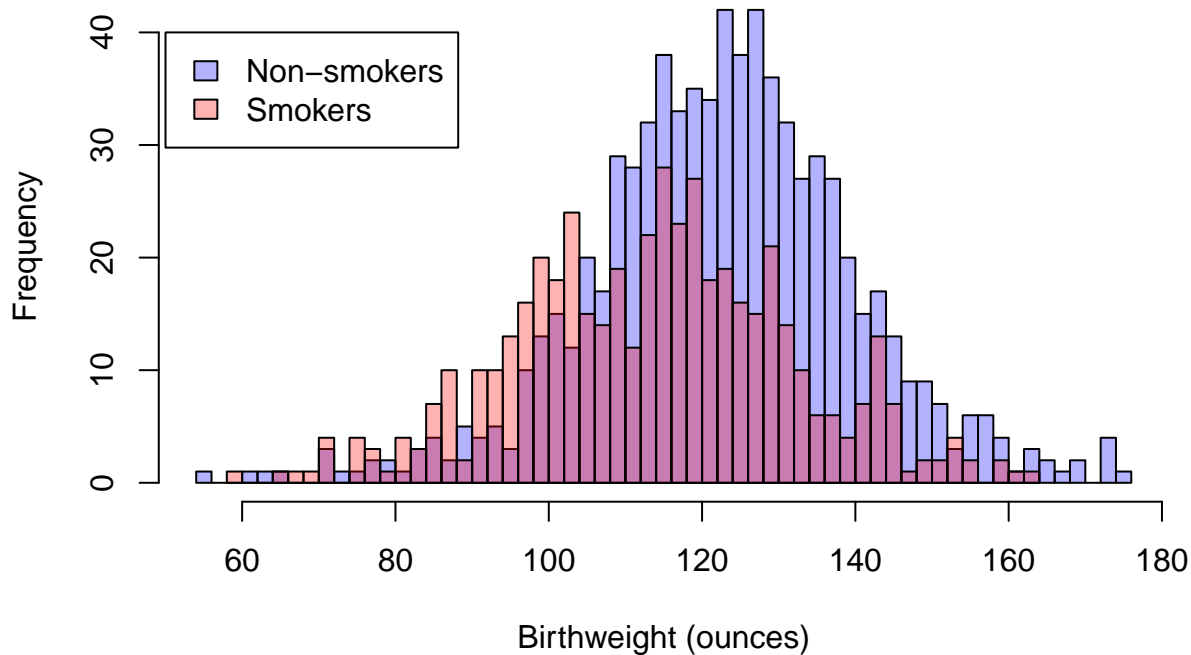
```
hist(infants$bwt)
```

Histogram of infants\$bwt



```
hist(infants$bwt[!infants$smoke=="Now"],breaks=50,col=rgb(0,0,1,.3),
xlab="Birthweight (ounces)",main="Birthweight")
hist(infants$bwt[infants$smoke=="Now"],breaks=50,col=rgb(1,0,0,.3),add=T)
legend(50,40,legend=c("Non-smokers","Smokers"),
fill=c(rgb(0,0,1,.3),rgb(1,0,0,.3)))
```

Birthweight



```
mean(infants$bwt)
```

```
## [1] 119.5769
```

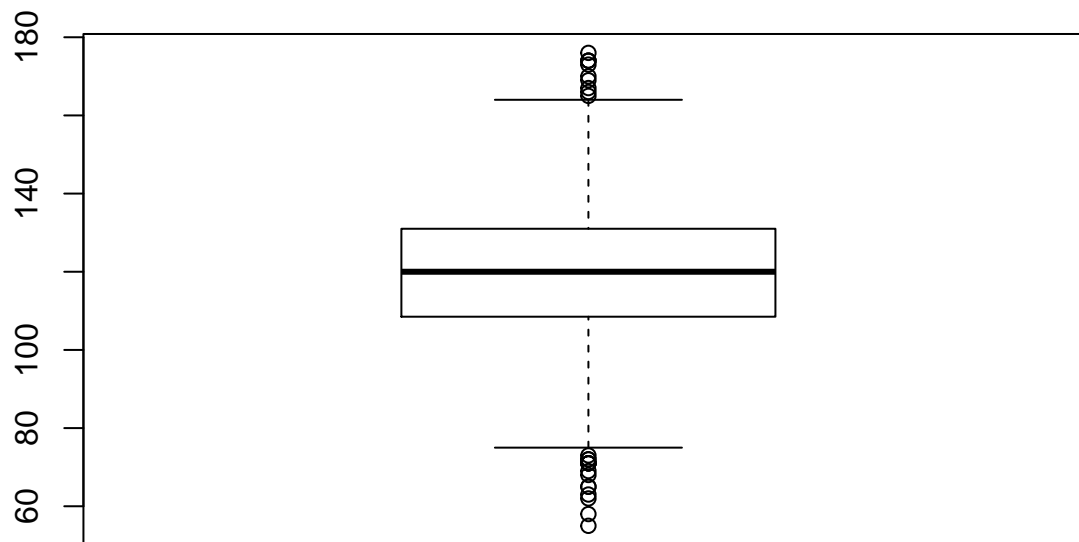
```
sd(infants$bwt)
```

```
## [1] 18.23645
```

```
summary(infants$bwt)
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##      55.0   108.8   120.0   119.6   131.0   176.0
```

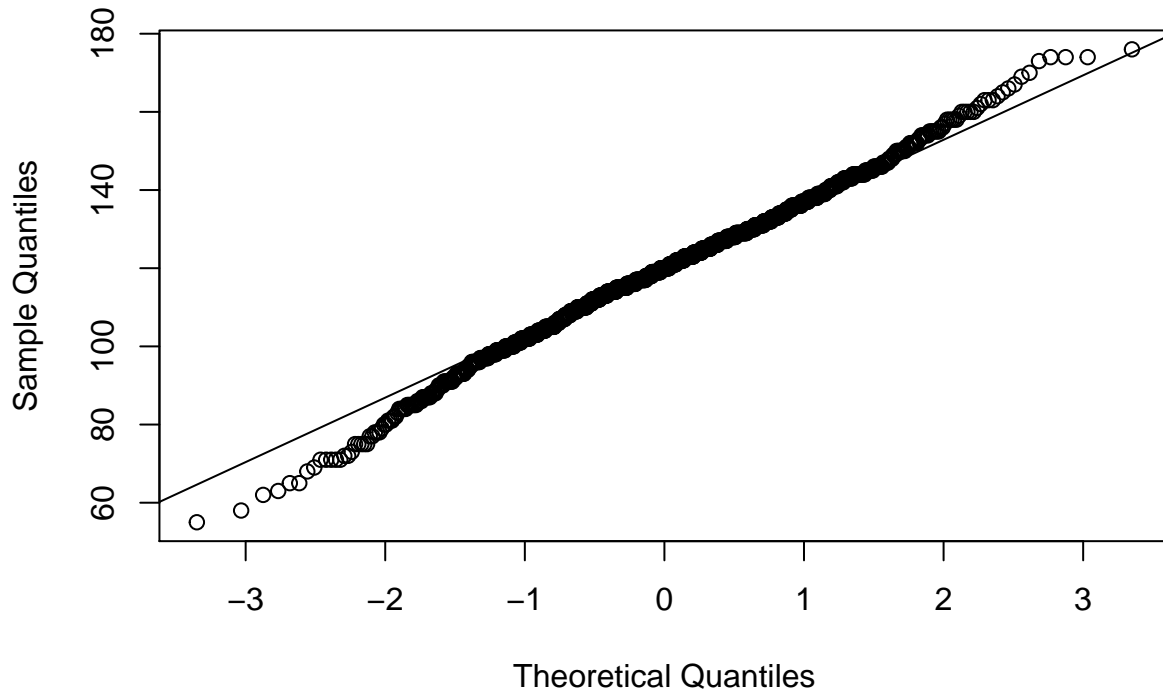
```
boxplot(infants$bwt)
```



```
qqnorm(infants$bwt)
```

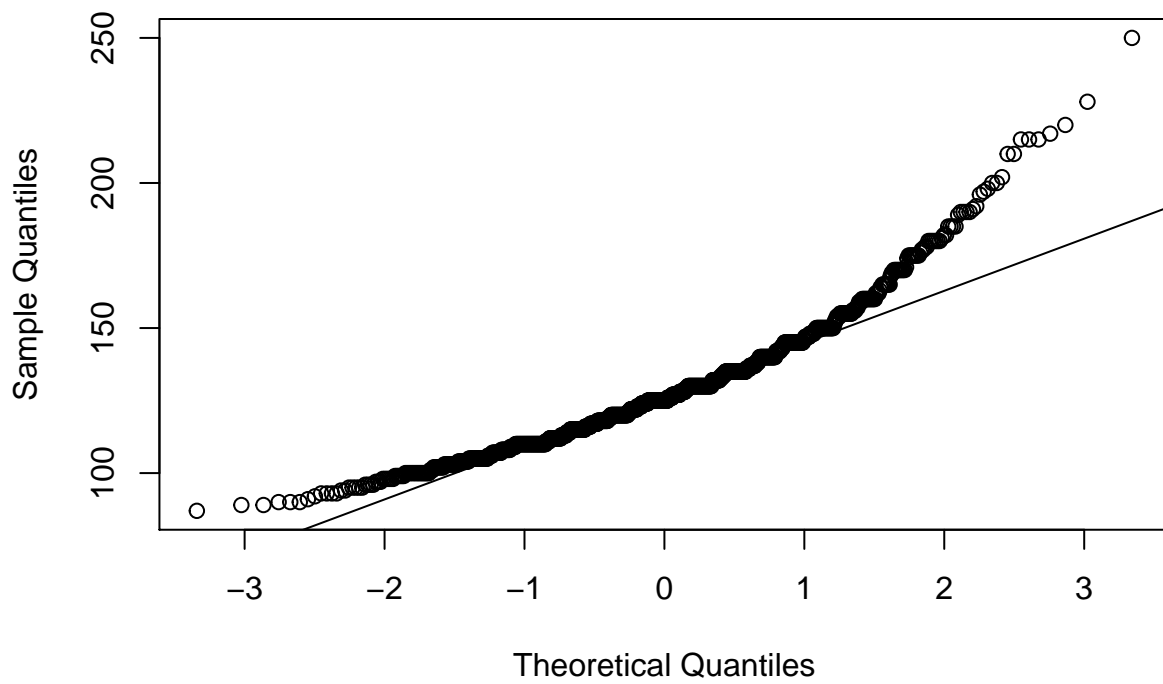
```
qqline(infants$bwt)
```

Normal Q-Q Plot



```
qqnorm(infants$wt)  
qqline(infants$wt)
```

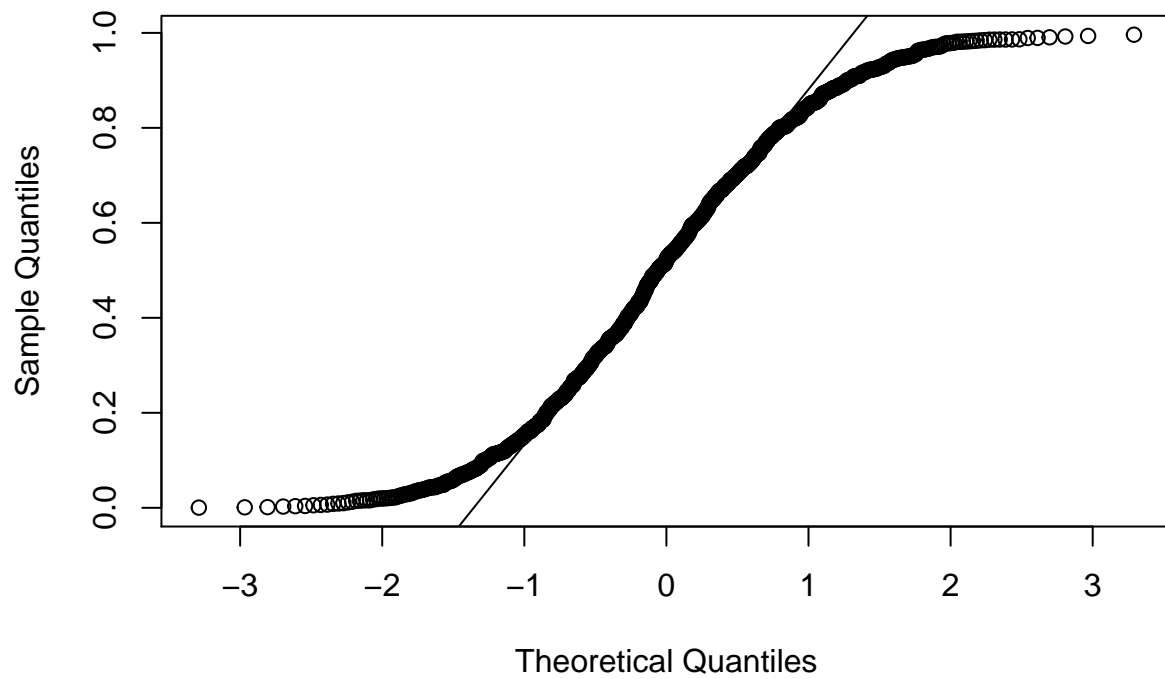
Normal Q-Q Plot



```
X=runif(1000)  
qqnorm(X)
```

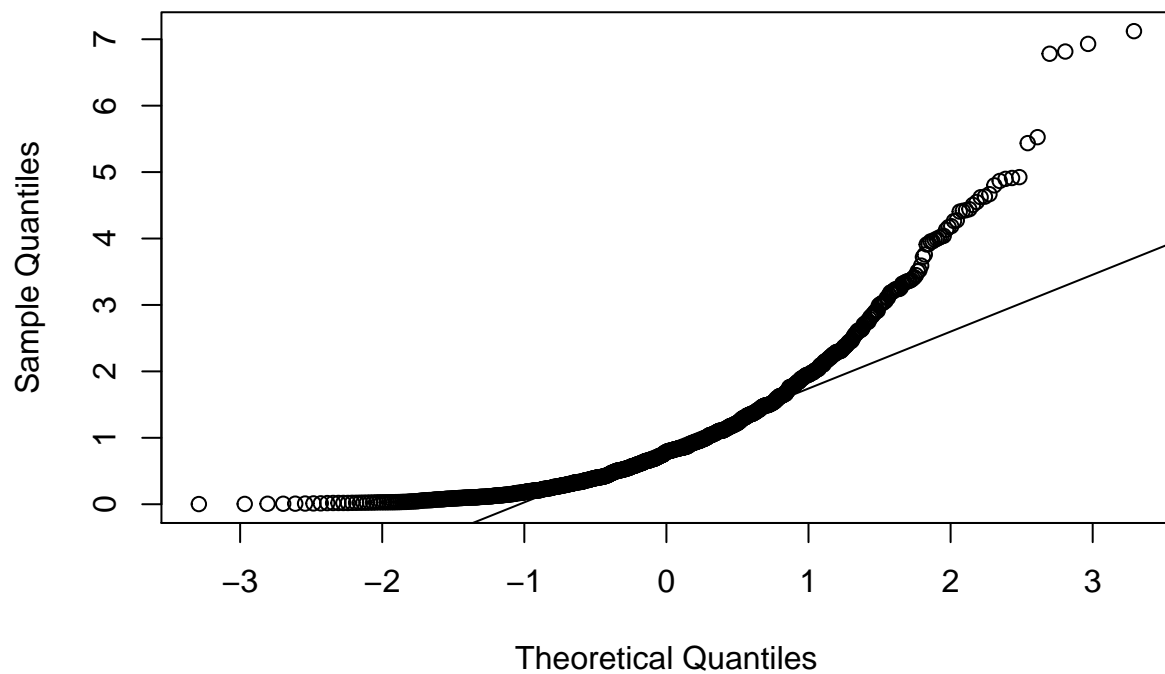
```
qqline(X)
```

Normal Q-Q Plot



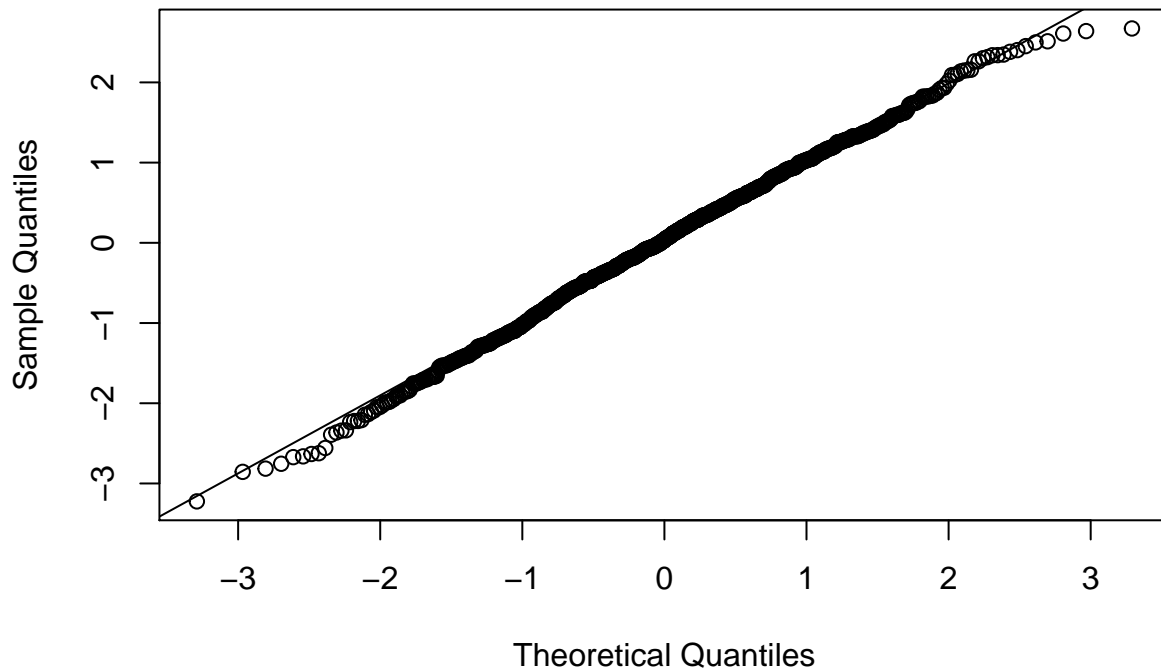
```
X=rexp(1000)  
qqnorm(X)  
qqline(X)
```

Normal Q-Q Plot



```
X=rnorm(1000)
qqnorm(X)
qqline(X)
```

Normal Q-Q Plot



```
set.seed(7)
mysample=sample(na.omit(infants$wt),10)
# Part 1
# 1a
true_average = mean(infants$bwt)
x_bar = mean(mysample)
estimated_se = sd(mysample) / sqrt(length(mysample))
# 95% CI Interval
interval = c(x_bar - 1.96*estimated_se, x_bar + 1.96*estimated_se)
interval
```

```
## [1] 125.0711 144.3289
```

```
# 1b
# creates 1000 95% Confidence Interval
thousand_interval = c()
thousand_averages = c()
num_interval = 0
for (i in 1:1000)
{
sample = sample(na.omit(infants$wt),10)
std_error = sd(sample) / sqrt(length(sample))
thousand_averages = c(thousand_averages, mean(sample))
ci_interval = c(mean(sample) - 1.96*std_error, mean(sample) + 1.96*std_error )
thousand_interval = c(thousand_interval, ci_interval)
if(ci_interval[1] <= true_average & ci_interval[2] >= true_average){
```

```

num_interval = num_interval +1
}
}
# I expect 95% (950 intervals) of the intervals cover the true average
cat("I expect 95% (950 intervals) of the intervals cover the true average")

## I expect 95% (950 intervals) of the intervals cover the true average
# The number of 95% CI that has true average is in num_interval
cat("The number of 95% CI that has true average is", num_interval)

## The number of 95% CI that has true average is 736
# 1c
sd_averages = sd(thousand_averages)
sd_averages

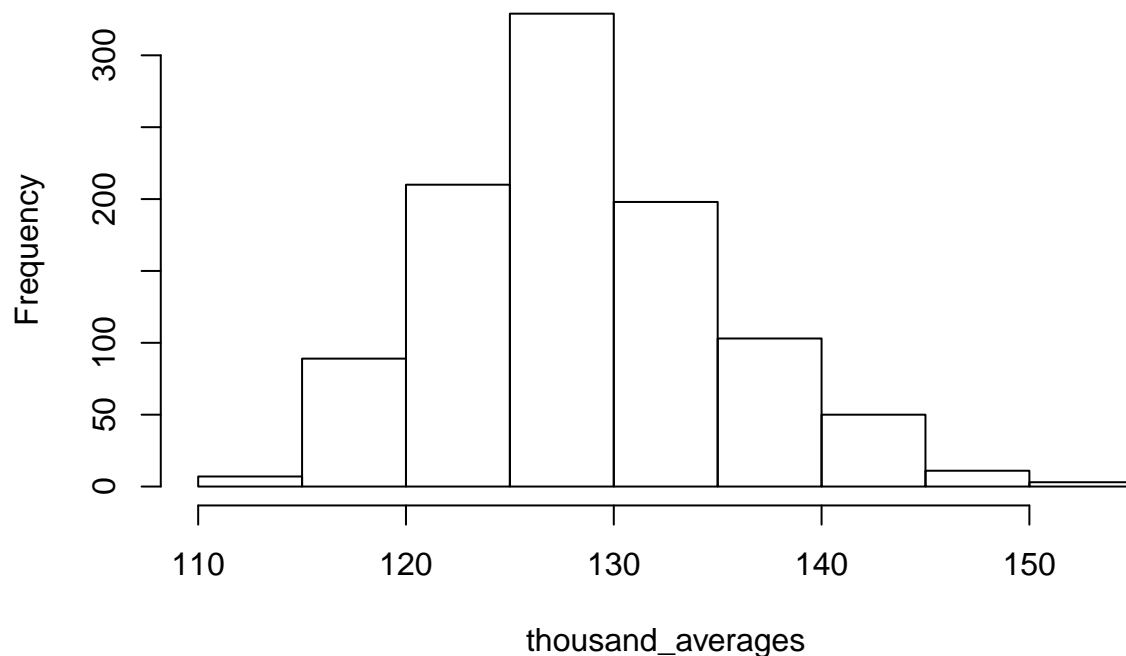
## [1] 6.740372
estimated_se

## [1] 4.912682
cat('The SD of the sample averages, ' , sd_averages, ', is not very close to the estimated standard error',
estimated_se)

## The SD of the sample averages, 6.740372 , is not very close to the estimated standard error, 4.912682
hist(thousand_averages)

```

Histogram of thousand_averages

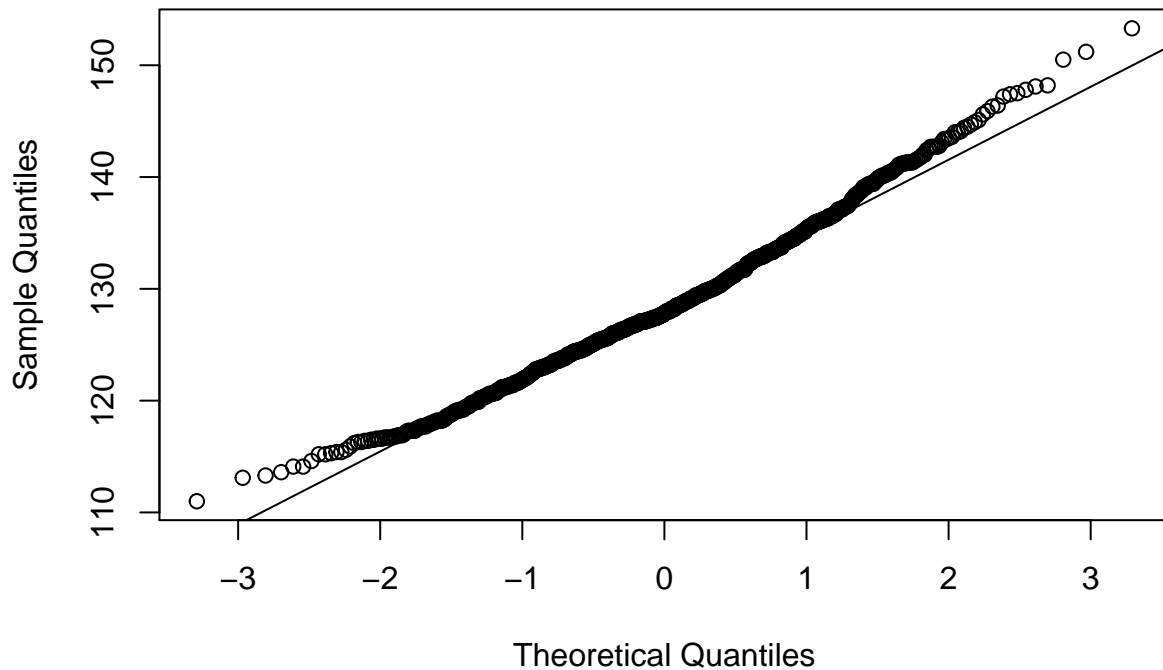


```

qqnorm(thousand_averages)
qqline(thousand_averages)

```


Normal Q-Q Plot



```
cat('As we can see in the histogram, the shape looks very close to a bell shaped curve, normal distribution.
The qq plot shows that most of the points are in the line, so the sample average follows the normal curve.
')
```

```
## As we can see in the histogram, the shape looks very close to a bell shaped curve, normal distribution.
## The qq plot shows that most of the points are in the line, so the sample average follows the normal curve.
```

```
# the confidence interval seems not valid
# Part 2
# 2a
bootStrap = function(mySample, popSize = NULL, B = 1000, repl = FALSE){
  if (repl) {
    # Bootstrap should be done the same way as original sample, usually without replacement
    return(replicate(B, mean(sample(mySample, length(mySample), TRUE))))
  } else {
    vals = sort(unique(mySample))
    counts = table(mySample)
    # makes the bootstrap pop as rounded version of sample, not quite right
    bootPop = rep(vals, round(counts * popSize / length(mySample)))
    return(list(bootPop,
      bootSamps = replicate(B, mean(sample(bootPop, length(mySample), FALSE))))
    )
  }
}
bootstrap_averages = bootStrap(mysample, 10, repl = TRUE)
bootstrap_averages
```

```
##      [1] 139.3 141.5 128.3 133.4 131.2 122.8 141.6 130.6 139.0 138.9 141.0
##      [12] 142.3 135.9 140.2 135.2 130.5 135.7 135.3 134.5 135.7 129.1 132.0
##      [23] 135.9 133.1 135.7 129.1 131.0 130.1 126.7 135.8 130.1 137.4 136.8
##      [34] 131.8 138.5 148.2 131.6 125.7 134.6 134.6 133.1 137.3 128.7 135.7
```

```

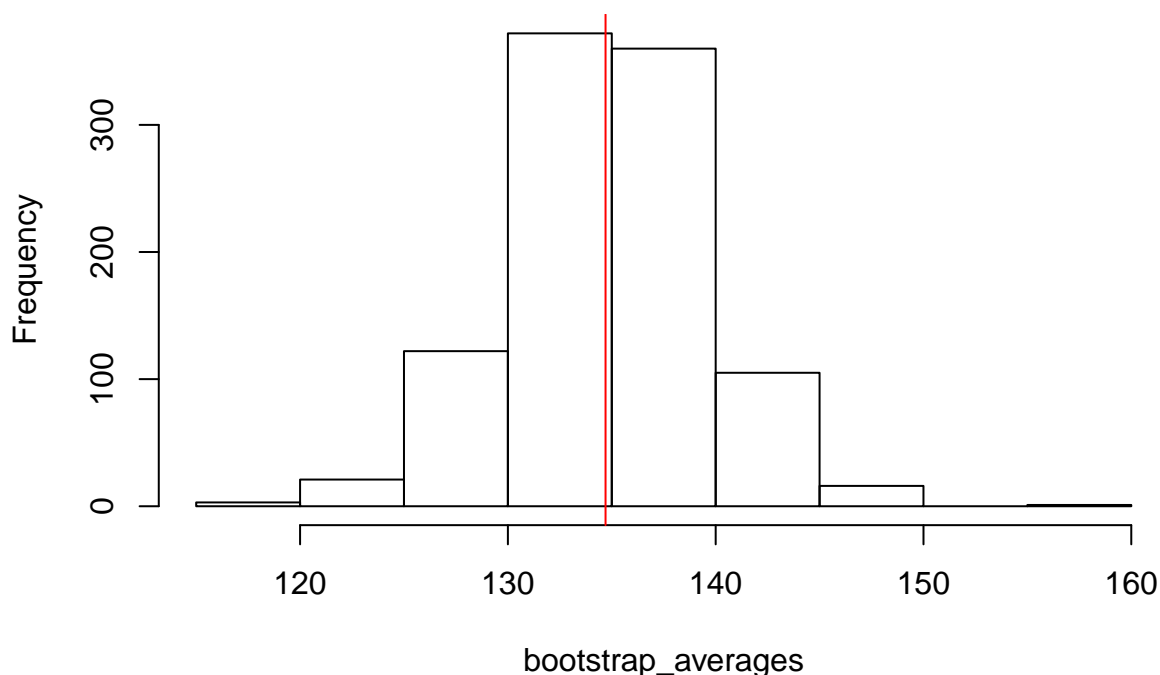
## [45] 131.7 135.2 142.6 134.4 130.9 132.6 132.8 126.7 132.6 129.9 143.1
## [56] 131.5 137.5 135.3 133.3 131.0 133.6 134.5 137.9 142.0 130.5 136.1
## [67] 136.6 140.4 136.7 138.5 133.8 141.6 138.3 132.7 124.9 137.6 136.7
## [78] 132.8 137.7 134.1 128.5 126.9 137.9 136.6 131.4 130.8 133.8 127.3
## [89] 131.5 130.2 141.4 131.0 128.2 136.1 137.0 137.2 137.6 133.8 134.1
## [100] 136.5 142.3 143.2 135.0 133.1 134.7 133.2 129.2 134.3 129.9 136.2
## [111] 136.8 135.5 135.9 135.3 132.5 137.6 138.2 132.7 133.1 132.1 131.4
## [122] 136.4 131.8 124.9 135.9 137.0 139.5 140.4 138.1 139.2 129.3 144.4
## [133] 135.0 149.1 131.1 134.0 136.9 136.4 134.1 134.2 137.6 128.2 138.7
## [144] 142.5 140.7 132.5 126.1 131.9 137.7 135.2 137.6 131.2 135.1 131.8
## [155] 136.2 133.5 133.2 126.8 134.0 127.1 130.0 137.0 132.1 135.6 126.6
## [166] 138.4 136.4 145.6 140.5 136.0 136.4 141.3 140.6 130.8 139.1 132.4
## [177] 134.9 132.4 135.5 134.3 139.8 129.0 139.2 134.9 129.1 138.0 125.7
## [188] 136.1 135.9 139.3 137.2 141.4 138.4 137.1 140.0 136.6 137.8 132.9
## [199] 126.1 132.6 136.3 126.7 130.8 139.7 141.7 133.6 130.8 130.8 140.2
## [210] 133.2 136.5 132.8 133.1 137.9 134.9 144.2 133.3 131.6 140.6 136.6
## [221] 135.2 133.7 129.9 135.5 138.5 139.8 124.4 129.4 135.6 126.3 124.6
## [232] 132.8 129.9 130.1 139.2 133.0 140.4 130.9 134.7 134.5 135.2 144.1
## [243] 137.5 140.8 131.9 138.1 130.8 133.7 140.1 132.0 134.2 129.1 131.2
## [254] 136.1 136.9 126.4 133.6 142.2 132.2 133.1 132.0 135.0 137.5 133.4
## [265] 132.4 132.0 124.4 135.2 133.6 137.0 132.1 122.3 135.7 136.0 140.3
## [276] 129.4 136.8 131.7 126.5 139.1 131.1 146.7 133.9 129.8 123.9 142.9
## [287] 136.7 131.1 137.3 135.8 136.1 128.7 130.9 133.7 135.5 136.7 139.9
## [298] 128.5 126.5 134.2 121.6 139.8 140.0 133.7 144.4 132.2 142.5 128.2
## [309] 135.4 137.2 128.0 139.6 133.8 140.9 129.6 142.7 126.5 134.7 134.6
## [320] 130.7 135.4 136.3 138.8 126.0 139.7 138.4 138.2 130.1 132.4 133.4
## [331] 139.3 137.2 131.4 135.6 134.3 130.8 133.4 130.4 135.9 140.5 138.8
## [342] 127.6 148.1 129.2 133.6 124.2 137.2 139.5 131.7 130.8 137.7 135.7
## [353] 136.3 138.1 126.6 134.6 148.2 136.5 147.0 143.4 134.8 137.5 129.0
## [364] 139.5 127.9 134.0 141.3 128.8 140.9 137.7 135.5 135.8 137.4 129.3
## [375] 131.5 128.1 132.6 136.9 131.3 138.0 128.6 137.6 138.8 133.7 131.8
## [386] 134.8 137.9 133.0 144.4 129.0 136.6 130.0 135.1 145.7 133.4 135.6
## [397] 145.8 131.1 129.5 134.8 136.9 132.1 136.6 126.2 135.6 140.2 129.6
## [408] 141.3 133.5 133.3 136.7 141.9 129.9 136.8 128.3 131.7 129.8 138.8
## [419] 136.1 130.4 131.5 138.1 135.0 134.2 128.8 137.0 139.6 133.3 143.5
## [430] 126.5 137.7 125.3 139.4 134.2 141.0 133.0 133.9 136.0 139.8 135.1
## [441] 135.4 136.0 136.7 135.8 137.8 138.6 128.0 126.2 136.1 140.3 129.2
## [452] 132.3 137.8 129.2 133.6 147.8 130.6 128.4 139.9 131.3 135.8 143.4
## [463] 131.1 130.8 124.6 133.0 132.1 133.7 135.0 134.2 139.9 137.9 130.6
## [474] 134.3 137.7 133.3 135.9 136.2 139.1 131.2 139.1 135.0 129.1 139.4
## [485] 134.6 136.8 130.9 136.7 133.9 141.8 135.5 141.2 124.9 139.7 131.5
## [496] 136.6 138.0 132.2 134.7 133.1 136.0 132.8 136.9 145.3 144.1 137.0
## [507] 141.5 134.9 133.1 134.7 141.3 132.8 131.8 139.3 134.3 135.4 128.9
## [518] 137.7 138.3 140.9 135.3 140.0 129.8 130.9 136.5 140.0 129.5 135.0
## [529] 137.3 130.9 137.4 127.4 133.3 131.7 133.7 129.0 141.9 136.5 140.8
## [540] 141.5 134.5 126.8 137.7 134.2 139.7 135.4 136.1 137.5 130.7 134.0
## [551] 136.4 140.2 136.7 134.9 140.3 135.7 139.6 135.0 142.3 131.7 136.6
## [562] 133.1 131.9 134.9 131.4 129.2 133.6 136.7 137.7 142.2 118.8 140.1
## [573] 117.6 135.5 130.6 140.0 132.8 143.0 135.1 137.0 137.0 130.8 143.1
## [584] 138.3 125.4 130.6 134.4 134.8 130.6 133.5 137.6 129.2 135.4 130.1
## [595] 137.2 137.1 133.9 140.9 143.2 138.1 138.0 133.8 135.5 134.5 135.5
## [606] 133.2 131.4 130.8 138.6 138.2 139.1 129.7 138.4 124.0 133.1 135.5
## [617] 138.1 136.4 135.3 133.3 138.5 135.6 132.1 138.9 138.0 130.2 138.6
## [628] 136.8 138.2 130.6 132.2 139.6 131.4 141.9 132.0 138.8 135.6 131.7

```

```
## [639] 139.1 142.3 131.2 131.4 130.6 135.9 128.2 136.3 140.4 134.2 127.3
## [650] 129.5 121.3 130.5 144.9 138.5 140.1 130.4 140.3 131.4 136.1 140.6
## [661] 126.5 135.6 127.6 133.0 135.6 140.6 139.5 132.7 137.2 135.5 138.4
## [672] 142.8 132.2 139.9 136.4 127.9 136.4 143.7 134.6 134.2 136.4 137.1
## [683] 129.2 137.2 132.6 135.4 132.6 134.5 139.5 134.5 136.4 132.3 139.1
## [694] 139.2 132.3 142.7 134.4 132.5 141.0 131.7 130.9 136.1 120.0 138.0
## [705] 133.8 130.2 134.4 149.3 127.9 132.4 139.6 126.7 133.3 132.5 138.8
## [716] 130.7 138.5 138.2 132.7 133.3 135.2 138.8 134.8 131.7 133.9 135.9
## [727] 125.1 131.0 130.8 125.1 137.1 128.1 144.2 139.5 132.7 133.8 139.4
## [738] 139.7 135.5 138.1 132.5 132.3 128.6 135.8 133.3 129.9 136.7 135.4
## [749] 134.5 131.7 134.7 131.9 130.3 131.9 132.9 136.3 136.5 134.0 135.7
## [760] 139.8 138.7 136.3 132.4 141.7 136.1 133.4 139.9 133.9 138.1 136.8
## [771] 133.4 135.9 137.0 131.9 136.4 134.9 131.2 134.1 131.8 132.1 131.6
## [782] 137.4 130.9 141.1 133.2 143.1 132.7 132.3 131.0 138.7 137.6 142.1
## [793] 130.4 128.6 135.4 137.2 130.2 131.0 137.9 132.7 132.6 135.3 133.9
## [804] 134.7 134.0 138.0 129.6 137.4 133.1 145.6 142.8 129.2 142.4 135.6
## [815] 130.8 133.2 131.9 140.0 133.6 128.6 125.5 131.3 140.3 141.1 144.8
## [826] 132.2 136.9 147.5 143.1 132.5 137.4 134.0 133.7 132.7 136.5 139.1
## [837] 134.6 142.2 132.0 134.2 136.6 136.9 133.4 139.7 123.1 141.2 134.7
## [848] 141.0 126.8 141.4 132.0 130.0 129.0 131.6 128.4 142.9 135.6 129.4
## [859] 134.3 133.0 133.3 128.6 134.5 128.7 138.1 134.6 130.8 126.0 134.9
## [870] 130.8 129.9 133.9 137.0 137.9 137.8 135.3 140.5 135.5 130.2 131.3
## [881] 140.3 127.6 127.9 130.8 126.6 122.4 132.3 137.5 155.1 135.0 137.5
## [892] 137.5 125.6 147.6 138.4 131.9 133.4 131.5 124.5 129.5 127.2 137.9
## [903] 132.8 128.1 128.8 124.8 134.5 135.5 137.6 130.9 137.4 143.3 140.1
## [914] 130.9 134.9 136.1 133.0 135.7 132.0 140.3 133.6 130.4 135.1 136.8
## [925] 137.1 137.8 133.7 132.5 134.5 138.5 141.3 140.2 139.6 137.6 132.3
## [936] 128.4 124.6 135.2 131.9 131.7 132.3 140.4 129.4 133.4 131.3 140.1
## [947] 145.1 131.0 123.6 137.8 138.0 131.2 134.6 143.3 142.4 137.1 129.4
## [958] 135.5 137.8 135.6 137.2 132.8 133.0 123.1 129.7 137.4 134.2 135.0
## [969] 138.9 129.0 134.6 138.2 130.7 128.3 136.9 135.2 133.5 130.6 132.9
## [980] 137.5 132.0 131.6 128.5 137.7 135.8 138.1 137.2 134.1 138.6 136.4
## [991] 138.5 136.5 136.8 132.1 136.6 132.4 133.3 134.0 132.3 134.8
```

```
hist(bootstrap_averages)
abline(v=x_bar,col="red")
```

Histogram of bootstrap_averages



```
bootstrap_sd = sd(bootstrap_averages)
cat('The SD of the sample averages from using bootstrap, ', bootstrap_sd, ', is very close to the estimated_se)
```

```
## The SD of the sample averages from using bootstrap, 4.721071, is very close to the estimated standard deviation
```

```
# 2b
quantile(bootstrap_averages, probs = c(0.025, 0.975))
```

```
## 2.5% 97.5%
## 125.1 144.1
```

```
ci_interval
```

```
## [1] 123.048 146.752
```

```
cat("The 95% confidence interval from the bootstrap is closer to the 95% confidence interval of the bootstrap")
```

```
## The 95% confidence interval from the bootstrap is closer to the 95% confidence interval of the bootstrap
```

```
# Part 3
set.seed(7)
mysample=sample(na.omit(infants$wt),100)
mysample
```

```
## [1] 116 162 115 117 135 140 132 145 150 135 145 157 122 103 170 108 160
## [18] 120 145 145 113 147 130 146 150 103 147 155 115 138 112 136 106 115
## [35] 149 127 110 122 127 135 124 145 175 120 137 115 110 135 130 106 102
## [52] 107 175 122 191 158 147 128 125 120 117 107 116 108 112 111 155 134
## [69] 115 130 157 116 110 165 111 110 200 110 140 135 110 115 103 113 135
## [86] 112 154 110 117 135 103 136 128 115 107 135 115 139 115 145
```

```

# 1a
true_average = mean(infants$bwt)
x_bar = mean(mysample)
estimated_se = sd(mysample) / sqrt(length(mysample))
# 95% CI Interval
interval = c(x_bar - 1.96*estimated_se, x_bar + 1.96*estimated_se)
interval

## [1] 125.7439 133.8161

# 1b
# creates 1000 95% Confidence Interval
thousand_interval = c()
thousand_averages = c()
num_interval = 0
for (i in 1:1000)
{
sample = sample(na.omit(infants$wt),100)
std_error = sd(sample) / sqrt(length(sample))
thousand_averages = c(thousand_averages, mean(sample))
ci_interval = c(mean(sample) - 1.96*std_error, mean(sample) + 1.96*std_error )
thousand_interval = c(thousand_interval, ci_interval)
if(ci_interval[1] <= true_average & ci_interval[2] >= true_average){
num_interval = num_interval +1
}
}
# I expect 95% (950 intervals) of the intervals cover the true average
cat("I expect 95% (950 intervals) of the intervals cover the true average")

## I expect 95% (950 intervals) of the intervals cover the true average

# The number of 95% CI that has true average is in num_interval
cat("The number of 95% CI that has true average is", num_interval)

## The number of 95% CI that has true average is 2

x_bar

## [1] 129.78

thousand_averages

##      [1] 126.70 127.08 128.28 130.08 126.35 127.36 127.68 127.46 130.15
##     [10] 127.74 127.55 128.99 129.69 127.58 127.85 131.19 130.27 127.57
##     [19] 126.43 127.60 129.11 129.75 125.91 126.69 130.13 129.92 129.83
##     [28] 128.87 127.53 129.20 129.20 127.51 127.75 133.98 131.75 131.60
##     [37] 131.44 130.41 125.09 129.21 126.58 125.76 128.39 132.07 129.53
##     [46] 129.06 130.36 130.79 129.29 126.03 126.36 131.09 128.78 128.84
##     [55] 127.54 126.18 129.73 128.14 128.91 127.36 130.18 125.60 129.54
##     [64] 128.65 130.05 125.20 127.24 128.38 128.83 131.62 128.25 130.14
##     [73] 125.77 128.96 125.73 127.17 130.61 128.05 130.14 127.68 130.27
##     [82] 129.24 125.94 128.71 130.55 126.70 128.88 128.45 128.56 125.05
##     [91] 130.42 130.87 125.00 125.79 131.45 131.20 128.77 127.77 132.44
##    [100] 129.35 131.30 129.83 131.06 127.58 127.45 128.56 127.09 131.13
##   [109] 129.88 124.63 132.65 129.15 131.96 128.16 132.33 132.07 132.85
##  [118] 128.98 130.69 127.94 126.54 126.94 125.97 128.27 130.66 129.64
##  [127] 126.18 130.44 127.47 128.35 135.41 128.30 128.84 131.07 135.08

```

```

## [136] 126.46 125.51 129.39 131.00 129.71 125.76 129.43 129.77 128.35
## [145] 128.64 128.27 129.17 130.67 132.21 125.68 126.88 128.96 126.94
## [154] 128.11 126.77 129.94 129.51 126.80 129.80 129.68 128.46 128.92
## [163] 129.36 127.57 127.90 127.18 127.28 125.24 130.81 125.09 128.16
## [172] 129.24 126.04 131.86 130.08 130.12 129.94 126.20 126.37 125.80
## [181] 130.45 130.86 128.26 126.11 128.87 129.52 128.73 133.02 128.08
## [190] 132.05 128.34 131.78 126.74 126.24 129.16 127.41 131.40 128.86
## [199] 126.31 128.46 126.16 126.65 132.99 130.02 126.08 127.09 128.05
## [208] 127.43 124.35 130.88 130.30 131.27 126.48 127.51 130.86 128.19
## [217] 132.14 130.94 126.58 128.84 128.40 127.93 127.79 130.17 130.90
## [226] 129.24 129.19 127.95 129.98 126.91 128.65 129.00 127.23 128.20
## [235] 127.87 128.34 125.83 129.56 128.21 130.62 125.07 130.71 127.86
## [244] 132.10 125.78 131.63 130.14 127.91 127.35 126.14 128.31 129.98
## [253] 130.90 128.75 123.58 125.02 128.01 127.21 128.19 128.77 131.08
## [262] 130.24 129.76 130.57 126.19 125.56 130.31 125.52 127.58 130.38
## [271] 128.06 125.93 128.71 128.69 130.10 128.13 128.22 130.50 129.98
## [280] 131.97 127.59 128.21 127.21 125.39 130.11 132.93 132.55 129.98
## [289] 129.49 126.02 129.96 123.87 126.64 131.83 129.61 127.05 128.66
## [298] 129.81 129.64 131.03 134.04 128.54 128.19 128.63 128.70 130.08
## [307] 129.50 129.30 131.44 130.21 128.32 130.52 128.06 129.19 131.79
## [316] 130.92 129.06 126.39 127.97 129.90 129.16 128.72 126.98 127.64
## [325] 128.86 127.93 128.67 129.83 127.62 130.74 130.05 133.06 126.93
## [334] 126.24 125.17 127.48 128.71 131.73 127.75 130.22 131.00 126.76
## [343] 127.65 130.29 129.82 127.29 131.80 128.79 132.19 128.71 130.19
## [352] 126.61 130.43 128.77 127.28 129.56 126.47 127.90 131.02 128.42
## [361] 127.39 126.98 124.84 129.11 130.98 130.40 125.64 128.35 129.40
## [370] 131.81 127.72 125.91 128.45 128.36 126.20 129.60 131.80 126.42
## [379] 127.78 129.75 126.14 127.42 124.96 126.87 127.25 124.87 131.56
## [388] 129.82 131.18 126.79 129.99 129.29 129.98 126.07 128.67 127.62
## [397] 128.93 130.03 129.35 129.03 128.85 123.35 127.84 130.40 130.00
## [406] 130.25 124.61 129.41 129.72 129.66 126.91 129.59 129.98 129.11
## [415] 129.94 129.84 128.87 131.04 128.99 127.46 125.56 130.12 126.41
## [424] 129.16 127.71 128.59 127.13 129.43 131.32 130.02 131.04 128.33
## [433] 129.86 126.89 129.41 126.39 131.33 133.48 131.80 126.69 129.99
## [442] 127.04 128.99 128.15 127.12 127.82 130.24 130.87 125.45 127.28
## [451] 130.34 125.07 128.88 127.96 127.79 129.44 128.67 129.24 128.67
## [460] 123.25 125.90 132.54 127.11 124.38 128.57 123.88 127.69 130.23
## [469] 133.44 132.59 129.80 130.35 129.11 128.57 128.36 126.57 127.55
## [478] 127.20 129.82 129.04 130.59 130.53 128.61 125.79 130.55 127.29
## [487] 129.53 130.36 128.78 131.30 127.68 126.80 128.10 130.11 131.79
## [496] 130.81 132.56 126.60 128.05 127.78 128.29 128.03 127.49 130.29
## [505] 131.87 127.01 133.64 127.54 126.69 129.32 127.41 131.39 130.67
## [514] 126.31 130.26 126.92 128.13 129.08 131.20 125.77 127.75 127.15
## [523] 125.56 132.18 128.98 126.89 123.17 127.48 129.27 128.29 129.37
## [532] 129.97 130.24 128.02 130.24 132.94 123.21 127.14 129.41 129.75
## [541] 130.12 129.14 133.82 130.15 130.01 130.87 128.21 127.51 129.20
## [550] 126.97 126.51 126.32 132.43 128.20 125.59 127.72 126.60 129.02
## [559] 131.51 124.63 129.61 128.63 126.94 127.11 125.79 127.42 127.34
## [568] 128.54 127.47 130.52 126.47 128.70 128.18 126.13 127.93 131.85
## [577] 128.99 131.38 126.55 129.14 129.11 129.46 127.52 125.18 130.69
## [586] 128.05 129.26 127.30 130.96 126.47 130.71 132.02 126.18 130.20
## [595] 125.34 128.12 127.49 128.03 125.84 126.68 127.33 127.96 130.31
## [604] 129.26 129.44 125.89 129.14 128.68 126.97 132.27 129.09 127.74
## [613] 128.98 128.42 127.19 131.70 126.02 127.25 126.46 127.72 128.17

```

```
## [622] 127.96 129.02 130.05 126.15 129.72 130.11 126.55 126.59 128.22
## [631] 128.51 127.66 128.52 127.75 125.14 128.42 127.51 129.06 126.55
## [640] 129.02 128.73 129.49 126.65 130.31 131.37 125.07 126.60 131.25
## [649] 126.10 130.25 128.52 130.89 129.09 127.08 128.06 128.94 127.24
## [658] 128.84 128.69 128.99 129.55 128.09 128.80 128.58 130.12 126.23
## [667] 129.16 127.55 131.17 129.70 132.20 125.42 133.63 127.14 130.68
## [676] 128.62 128.86 127.58 124.25 127.12 126.69 128.32 128.06 128.27
## [685] 127.51 128.09 128.32 125.77 125.79 130.11 131.95 125.38 132.12
## [694] 129.57 130.13 126.53 126.36 129.82 129.00 129.42 128.73 129.67
## [703] 125.10 125.11 127.88 127.91 128.35 125.66 130.18 128.96 129.73
## [712] 126.91 125.34 127.68 129.41 130.37 128.04 127.22 129.95 126.04
## [721] 128.73 130.69 129.97 133.06 127.30 127.81 130.77 129.60 126.83
## [730] 129.64 126.80 128.95 129.88 130.03 128.11 127.62 125.56 128.76
## [739] 129.71 124.73 128.37 126.08 131.92 128.95 130.06 127.73 128.82
## [748] 130.89 126.84 127.38 130.15 131.23 127.13 132.12 130.01 131.98
## [757] 122.52 126.08 129.59 126.65 128.02 127.81 128.30 128.62 129.44
## [766] 129.48 126.18 129.09 125.53 124.62 127.43 128.73 125.24 128.02
## [775] 129.85 127.81 129.12 130.13 125.24 129.46 128.17 129.70 131.57
## [784] 127.31 130.94 132.28 130.26 130.30 130.57 131.84 127.32 125.89
## [793] 126.47 130.94 128.17 127.00 129.93 125.51 125.56 129.68 130.28
## [802] 125.55 129.84 130.68 129.64 129.12 126.23 128.55 130.57 127.66
## [811] 130.92 128.56 128.92 128.94 128.38 126.95 128.15 127.18 126.87
## [820] 131.63 128.89 129.34 128.27 126.15 125.33 127.81 127.19 125.37
## [829] 128.34 134.45 135.00 127.90 128.28 127.59 128.88 128.73 130.02
## [838] 130.48 131.53 126.38 130.29 127.80 130.64 127.20 131.87 125.42
## [847] 127.58 126.65 125.72 126.92 126.30 129.59 127.71 130.31 129.91
## [856] 129.32 130.84 129.49 127.35 130.25 126.37 133.26 129.29 126.82
## [865] 126.57 128.52 128.22 129.24 131.93 128.75 129.53 125.70 125.59
## [874] 129.22 127.59 126.35 129.93 126.35 125.78 132.25 129.98 131.82
## [883] 132.06 127.92 126.28 126.29 128.58 129.77 128.01 129.28 130.05
## [892] 131.40 128.41 127.22 130.04 125.42 131.56 129.16 128.18 131.92
## [901] 126.09 128.86 128.70 127.56 131.56 126.65 125.83 131.82 129.47
## [910] 125.73 127.35 128.19 127.92 127.44 124.96 129.05 128.92 134.41
## [919] 130.57 128.58 127.56 129.00 130.00 128.55 128.06 125.94 126.83
## [928] 127.73 127.99 128.97 125.19 126.60 127.14 129.49 126.19 130.86
## [937] 125.23 130.28 129.46 128.01 131.43 127.24 129.58 127.04 128.75
## [946] 129.23 126.67 127.90 127.81 130.35 128.21 127.89 127.79 127.44
## [955] 127.99 129.29 125.98 128.64 127.56 131.21 128.02 129.90 130.50
## [964] 134.10 126.09 130.07 128.71 124.74 128.69 127.46 129.61 131.07
## [973] 127.16 130.35 127.66 125.42 131.72 126.58 128.18 125.87 127.02
## [982] 127.22 127.54 128.88 129.06 130.61 129.87 125.95 128.00 127.31
## [991] 128.55 128.60 129.57 127.89 131.04 126.83 129.34 128.71 129.46
## [1000] 128.70
```

```
# 1c
```

```
sd_averages = sd(thousand_averages)
sd_averages
```

```
## [1] 2.000529
```

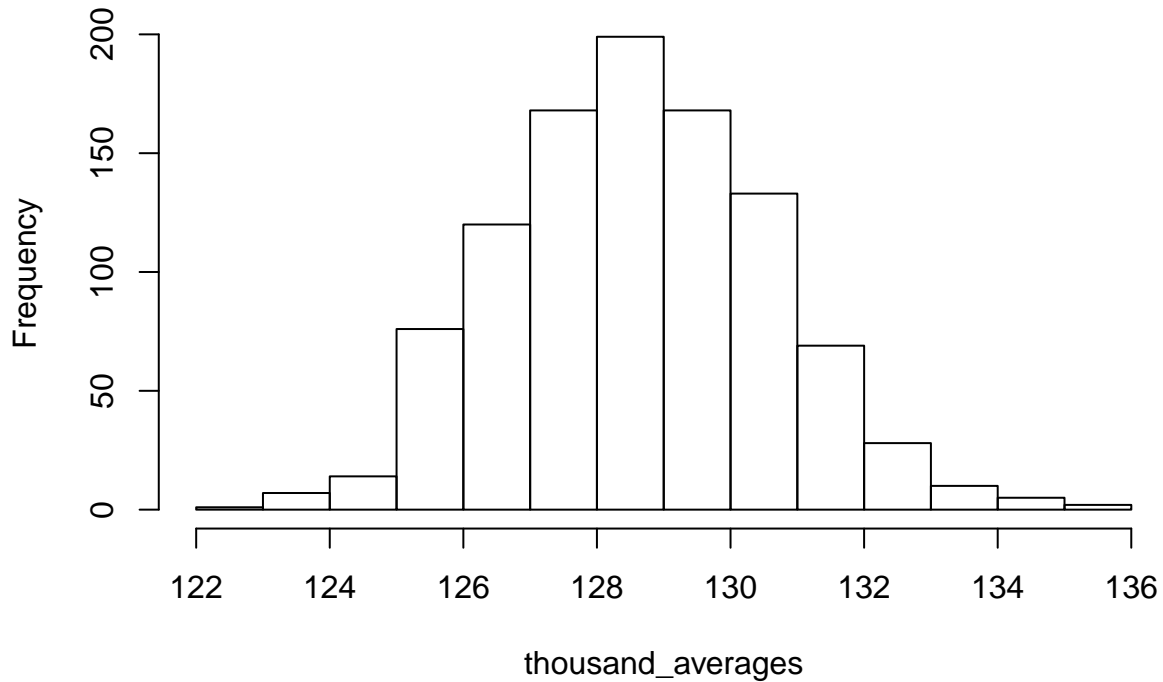
```
estimated_se
```

```
## [1] 2.059253
```

```
cat('The SD of the sample averages, ', sd_averages, ', is very close to the estimated standard error,
estimated_se)
```

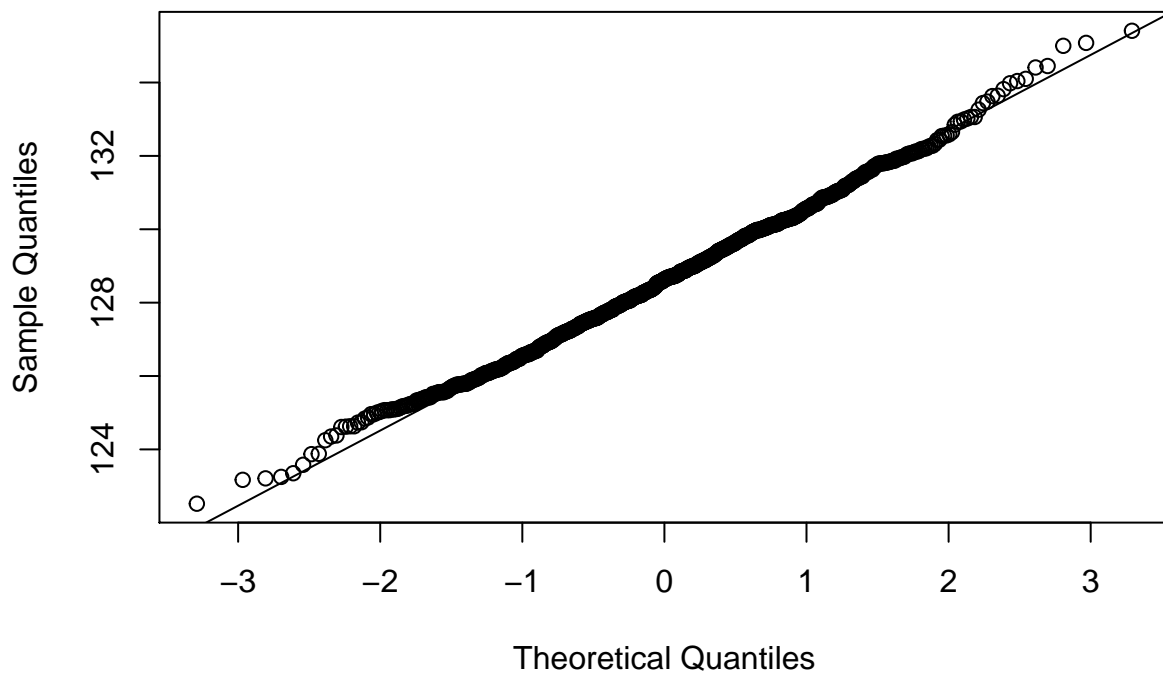
```
## The SD of the sample averages, 2.000529 , is very close to the estimated standard error, 2.059253  
hist(thousand_averages)
```

Histogram of thousand_averages



```
qqnorm(thousand_averages)  
qqline(thousand_averages)
```

Normal Q-Q Plot




```
cat('As we can see in the histogram, the shape looks very close to a bell shaped curve, normal distribution.
The qq plot shows that most of the points are in the line, so the sample average follows the normal curve.')
```

```
## As we can see in the histogram, the shape looks very close to a bell shaped curve, normal distribution.
## The qq plot shows that most of the points are in the line, so the sample average follows the normal curve.
```

```
# The confidence interval is valid
```

```
# Part 2
```

```
# 2a
```

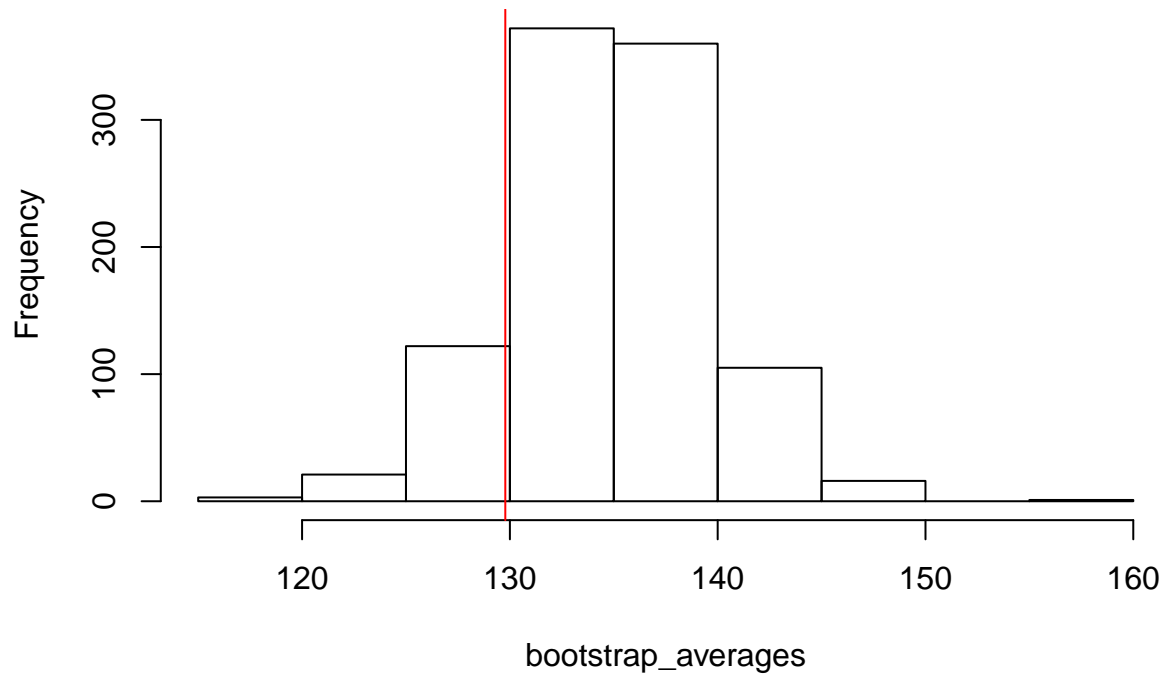
```
bootstrap_averages
```

```
##      [1] 139.3 141.5 128.3 133.4 131.2 122.8 141.6 130.6 139.0 138.9 141.0
##     [12] 142.3 135.9 140.2 135.2 130.5 135.7 135.3 134.5 135.7 129.1 132.0
##     [23] 135.9 133.1 135.7 129.1 131.0 130.1 126.7 135.8 130.1 137.4 136.8
##     [34] 131.8 138.5 148.2 131.6 125.7 134.6 134.6 133.1 137.3 128.7 135.7
##     [45] 131.7 135.2 142.6 134.4 130.9 132.6 132.8 126.7 132.6 129.9 143.1
##     [56] 131.5 137.5 135.3 133.3 131.0 133.6 134.5 137.9 142.0 130.5 136.1
##     [67] 136.6 140.4 136.7 138.5 133.8 141.6 138.3 132.7 124.9 137.6 136.7
##     [78] 132.8 137.7 134.1 128.5 126.9 137.9 136.6 131.4 130.8 133.8 127.3
##     [89] 131.5 130.2 141.4 131.0 128.2 136.1 137.0 137.2 137.6 133.8 134.1
##    [100] 136.5 142.3 143.2 135.0 133.1 134.7 133.2 129.2 134.3 129.9 136.2
##    [111] 136.8 135.5 135.9 135.3 132.5 137.6 138.2 132.7 133.1 132.1 131.4
##    [122] 136.4 131.8 124.9 135.9 137.0 139.5 140.4 138.1 139.2 129.3 144.4
##    [133] 135.0 149.1 131.1 134.0 136.9 136.4 134.1 134.2 137.6 128.2 138.7
##    [144] 142.5 140.7 132.5 126.1 131.9 137.7 135.2 137.6 131.2 135.1 131.8
##    [155] 136.2 133.5 133.2 126.8 134.0 127.1 130.0 137.0 132.1 135.6 126.6
##    [166] 138.4 136.4 145.6 140.5 136.0 136.4 141.3 140.6 130.8 139.1 132.4
##    [177] 134.9 132.4 135.5 134.3 139.8 129.0 139.2 134.9 129.1 138.0 125.7
##    [188] 136.1 135.9 139.3 137.2 141.4 138.4 137.1 140.0 136.6 137.8 132.9
##    [199] 126.1 132.6 136.3 126.7 130.8 139.7 141.7 133.6 130.8 130.8 140.2
##    [210] 133.2 136.5 132.8 133.1 137.9 134.9 144.2 133.3 131.6 140.6 136.6
##    [221] 135.2 133.7 129.9 135.5 138.5 139.8 124.4 129.4 135.6 126.3 124.6
##    [232] 132.8 129.9 130.1 139.2 133.0 140.4 130.9 134.7 134.5 135.2 144.1
##    [243] 137.5 140.8 131.9 138.1 130.8 133.7 140.1 132.0 134.2 129.1 131.2
##    [254] 136.1 136.9 126.4 133.6 142.2 132.2 133.1 132.0 135.0 137.5 133.4
##    [265] 132.4 132.0 124.4 135.2 133.6 137.0 132.1 122.3 135.7 136.0 140.3
##    [276] 129.4 136.8 131.7 126.5 139.1 131.1 146.7 133.9 129.8 123.9 142.9
##    [287] 136.7 131.1 137.3 135.8 136.1 128.7 130.9 133.7 135.5 136.7 139.9
##    [298] 128.5 126.5 134.2 121.6 139.8 140.0 133.7 144.4 132.2 142.5 128.2
##    [309] 135.4 137.2 128.0 139.6 133.8 140.9 129.6 142.7 126.5 134.7 134.6
##    [320] 130.7 135.4 136.3 138.8 126.0 139.7 138.4 138.2 130.1 132.4 133.4
##    [331] 139.3 137.2 131.4 135.6 134.3 130.8 133.4 130.4 135.9 140.5 138.8
##    [342] 127.6 148.1 129.2 133.6 124.2 137.2 139.5 131.7 130.8 137.7 135.7
##    [353] 136.3 138.1 126.6 134.6 148.2 136.5 147.0 143.4 134.8 137.5 129.0
##    [364] 139.5 127.9 134.0 141.3 128.8 140.9 137.7 135.5 135.8 137.4 129.3
##    [375] 131.5 128.1 132.6 136.9 131.3 138.0 128.6 137.6 138.8 133.7 131.8
##    [386] 134.8 137.9 133.0 144.4 129.0 136.6 130.0 135.1 145.7 133.4 135.6
##    [397] 145.8 131.1 129.5 134.8 136.9 132.1 136.6 126.2 135.6 140.2 129.6
##    [408] 141.3 133.5 133.3 136.7 141.9 129.9 136.8 128.3 131.7 129.8 138.8
##    [419] 136.1 130.4 131.5 138.1 135.0 134.2 128.8 137.0 139.6 133.3 143.5
##    [430] 126.5 137.7 125.3 139.4 134.2 141.0 133.0 133.9 136.0 139.8 135.1
##    [441] 135.4 136.0 136.7 135.8 137.8 138.6 128.0 126.2 136.1 140.3 129.2
##    [452] 132.3 137.8 129.2 133.6 147.8 130.6 128.4 139.9 131.3 135.8 143.4
##    [463] 131.1 130.8 124.6 133.0 132.1 133.7 135.0 134.2 139.9 137.9 130.6
```

```
## [474] 134.3 137.7 133.3 135.9 136.2 139.1 131.2 139.1 135.0 129.1 139.4
## [485] 134.6 136.8 130.9 136.7 133.9 141.8 135.5 141.2 124.9 139.7 131.5
## [496] 136.6 138.0 132.2 134.7 133.1 136.0 132.8 136.9 145.3 144.1 137.0
## [507] 141.5 134.9 133.1 134.7 141.3 132.8 131.8 139.3 134.3 135.4 128.9
## [518] 137.7 138.3 140.9 135.3 140.0 129.8 130.9 136.5 140.0 129.5 135.0
## [529] 137.3 130.9 137.4 127.4 133.3 131.7 133.7 129.0 141.9 136.5 140.8
## [540] 141.5 134.5 126.8 137.7 134.2 139.7 135.4 136.1 137.5 130.7 134.0
## [551] 136.4 140.2 136.7 134.9 140.3 135.7 139.6 135.0 142.3 131.7 136.6
## [562] 133.1 131.9 134.9 131.4 129.2 133.6 136.7 137.7 142.2 118.8 140.1
## [573] 117.6 135.5 130.6 140.0 132.8 143.0 135.1 137.0 137.0 130.8 143.1
## [584] 138.3 125.4 130.6 134.4 134.8 130.6 133.5 137.6 129.2 135.4 130.1
## [595] 137.2 137.1 133.9 140.9 143.2 138.1 138.0 133.8 135.5 134.5 135.5
## [606] 133.2 131.4 130.8 138.6 138.2 139.1 129.7 138.4 124.0 133.1 135.5
## [617] 138.1 136.4 135.3 133.3 138.5 135.6 132.1 138.9 138.0 130.2 138.6
## [628] 136.8 138.2 130.6 132.2 139.6 131.4 141.9 132.0 138.8 135.6 131.7
## [639] 139.1 142.3 131.2 131.4 130.6 135.9 128.2 136.3 140.4 134.2 127.3
## [650] 129.5 121.3 130.5 144.9 138.5 140.1 130.4 140.3 131.4 136.1 140.6
## [661] 126.5 135.6 127.6 133.0 135.6 140.6 139.5 132.7 137.2 135.5 138.4
## [672] 142.8 132.2 139.9 136.4 127.9 136.4 143.7 134.6 134.2 136.4 137.1
## [683] 129.2 137.2 132.6 135.4 132.6 134.5 139.5 134.5 136.4 132.3 139.1
## [694] 139.2 132.3 142.7 134.4 132.5 141.0 131.7 130.9 136.1 120.0 138.0
## [705] 133.8 130.2 134.4 149.3 127.9 132.4 139.6 126.7 133.3 132.5 138.8
## [716] 130.7 138.5 138.2 132.7 133.3 135.2 138.8 134.8 131.7 133.9 135.9
## [727] 125.1 131.0 130.8 125.1 137.1 128.1 144.2 139.5 132.7 133.8 139.4
## [738] 139.7 135.5 138.1 132.5 132.3 128.6 135.8 133.3 129.9 136.7 135.4
## [749] 134.5 131.7 134.7 131.9 130.3 131.9 132.9 136.3 136.5 134.0 135.7
## [760] 139.8 138.7 136.3 132.4 141.7 136.1 133.4 139.9 133.9 138.1 136.8
## [771] 133.4 135.9 137.0 131.9 136.4 134.9 131.2 134.1 131.8 132.1 131.6
## [782] 137.4 130.9 141.1 133.2 143.1 132.7 132.3 131.0 138.7 137.6 142.1
## [793] 130.4 128.6 135.4 137.2 130.2 131.0 137.9 132.7 132.6 135.3 133.9
## [804] 134.7 134.0 138.0 129.6 137.4 133.1 145.6 142.8 129.2 142.4 135.6
## [815] 130.8 133.2 131.9 140.0 133.6 128.6 125.5 131.3 140.3 141.1 144.8
## [826] 132.2 136.9 147.5 143.1 132.5 137.4 134.0 133.7 132.7 136.5 139.1
## [837] 134.6 142.2 132.0 134.2 136.6 136.9 133.4 139.7 123.1 141.2 134.7
## [848] 141.0 126.8 141.4 132.0 130.0 129.0 131.6 128.4 142.9 135.6 129.4
## [859] 134.3 133.0 133.3 128.6 134.5 128.7 138.1 134.6 130.8 126.0 134.9
## [870] 130.8 129.9 133.9 137.0 137.9 137.8 135.3 140.5 135.5 130.2 131.3
## [881] 140.3 127.6 127.9 130.8 126.6 122.4 132.3 137.5 155.1 135.0 137.5
## [892] 137.5 125.6 147.6 138.4 131.9 133.4 131.5 124.5 129.5 127.2 137.9
## [903] 132.8 128.1 128.8 124.8 134.5 135.5 137.6 130.9 137.4 143.3 140.1
## [914] 130.9 134.9 136.1 133.0 135.7 132.0 140.3 133.6 130.4 135.1 136.8
## [925] 137.1 137.8 133.7 132.5 134.5 138.5 141.3 140.2 139.6 137.6 132.3
## [936] 128.4 124.6 135.2 131.9 131.7 132.3 140.4 129.4 133.4 131.3 140.1
## [947] 145.1 131.0 123.6 137.8 138.0 131.2 134.6 143.3 142.4 137.1 129.4
## [958] 135.5 137.8 135.6 137.2 132.8 133.0 123.1 129.7 137.4 134.2 135.0
## [969] 138.9 129.0 134.6 138.2 130.7 128.3 136.9 135.2 133.5 130.6 132.9
## [980] 137.5 132.0 131.6 128.5 137.7 135.8 138.1 137.2 134.1 138.6 136.4
## [991] 138.5 136.5 136.8 132.1 136.6 132.4 133.3 134.0 132.3 134.8
```

```
hist(bootstrap_averages)
abline(v=x_bar,col="red")
```

Histogram of bootstrap_averages



```
bootstrap_sd = sd(bootstrap_averages)
cat('The SD of the sample averages from using bootstrap, ', bootstrap_sd, ', is very close to the estimated
estimated_se)

## The SD of the sample averages from using bootstrap,  4.721071 , is very close to the estimated standard deviation

# 2b
quantile(bootstrap_averages, probs = c(0.025, 0.975))

## 2.5% 97.5%
## 125.1 144.1

ci_interval

## [1] 125.1747 132.2253

cat("The 95% confidence interval from the bootstrap is closer to the 95% confidence interval of the bootstrap")

## The 95% confidence interval from the bootstrap is closer to the 95% confidence interval of the bootstrap
```