Kevlar Lifetime Analysis

Chapter 10 Problem 43 Barlow, Toland, and Freeman (1984) studied the lifetimes of Kevlar 49/epoxy strands subjected to sustained stress. (The space shuttle uses Kevlar/expoxy spherical vessels in an environment of sustained pressure.) The files kevlar70, kevlar80, and kevlar90 contain the times of failure (in hours) of strands tested at 70%, 80%, and 90% stress levels. We will explore, analyze, and record the descriptive summaries and graphical summaries for the times of failures as it relates the the different stress levels. In our analysis, we will describe the distributions of the times of failures at different stress levels. Then, we will determine the nature of the distribution of lifetimes and the effect of increasing stress.

1. Read kevlar70.xls, kevlar80.xls, and kevlar90.xls, files into R

```
setwd("~/Desktop")
library(readxl)
```

```
## Warning: package 'readxl' was built under R version 3.4.4
```

```
kevlar70 <- read_excel("kevlar70.xls", col_names = FALSE)
kevlar80 <- read_excel("kevlar80.xls", col_names = FALSE)
kevlar90 <- read_excel("kevlar90.xls", col_names = FALSE)
```

2. Read kevlar_combined.xls into R

```
kevlar_combined <- read_excel("kevlar_combined.xlsx")
```

```
## Warning in strptime(x, format, tz = tz): unknown timezone 'zone/tz/2018c.
## 1.0/zoneinfo/America/Los_Angeles'
```

```
# file_list <- list.files(pattern="^kevlar.*\\.xls", recursive = TRUE)[-4]
#
# for (file in file_list){
#
#         # if the merged dataset doesn't exist, create it
#         if (!exists("kevlar_combined")){
#                 kevlar_combined <- read_excel(file, col_names = FALSE)
#         }
#         # if the merged dataset does exist, append to it
#         else {
#                 temp_dataset <-read_excel(file, col_names = FALSE)
#                 kevlar_combined<-rbind(kevlar_combined, temp_dataset)
#                 rm(temp_dataset)
#         }
#
# }
```

3. Summary Statistics at Stress Level 70%

Examine the summary statistics for times of failure at 70% stress level.

```
summary(kevlar70)
```

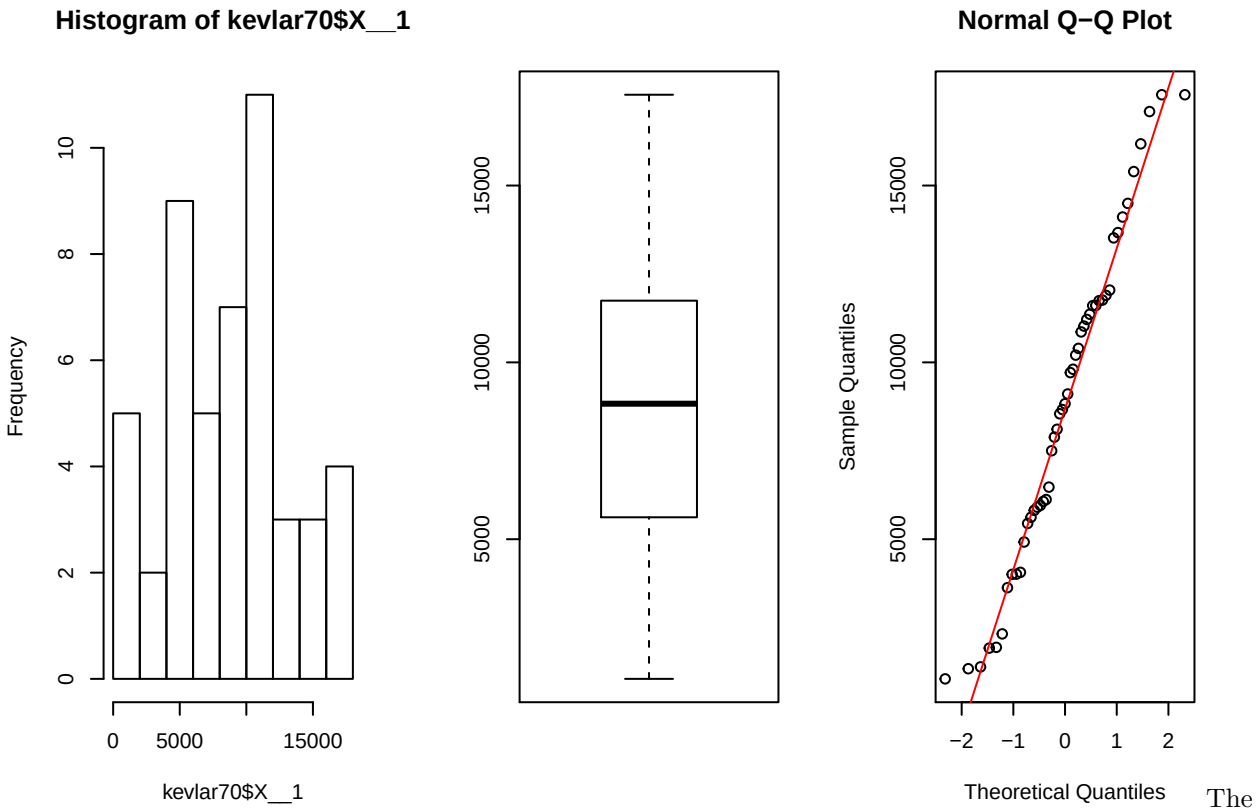
```
##       X__1
##  Min.   : 1051
##  1st Qu.: 5620
##  Median : 8831
##  Mean   : 8806
##  3rd Qu.:11745
##  Max.   :17568
```

The mean is 8806 hours and the median is 8831 hours. Since the mean and the median are similar, it seems as though the distribution seems to be symmetric. The IQR (interquartile range) is (75th percentile - 25th percentile), or (3rd quartile - 1st quartile), is 6125. The range is 16517.

4. Graphical Summaries at Stress Level 70%

Create a histogram, boxplot, and Q-Q plot to examine the distribution of the times of failures at stress level 70%.

```
par(mfrow=c(1,3))
hist(kevlar70$X__1)
boxplot(kevlar70$X__1)
qqnorm(kevlar70$X__1)
qqline(kevlar70$X__1, col = 2)
```



The box plot suggests that the distribution is symmetric. The Q-Q plot shows that the distribution is approximately normal.

5. Summary Statistics at Stress Level 80%

Examine the summary statistics for times of failure at 80% stress level.

```
mean(kevlar80$X__1, na.rm = TRUE)
```

```
## [1] 209.1828
```

```
median(kevlar80$X__1, na.rm = TRUE)
```

```
## [1] 150.7
```

```
quantile(kevlar80$X__1, probs = 0.75, na.rm = TRUE)-quantile(kevlar80$X__1, probs = 0.25, na.rm = TRUE)
```

```
##     75%
## 191.825
```

```
max(kevlar80, na.rm = TRUE) - min(kevlar80, na.rm = TRUE)
```

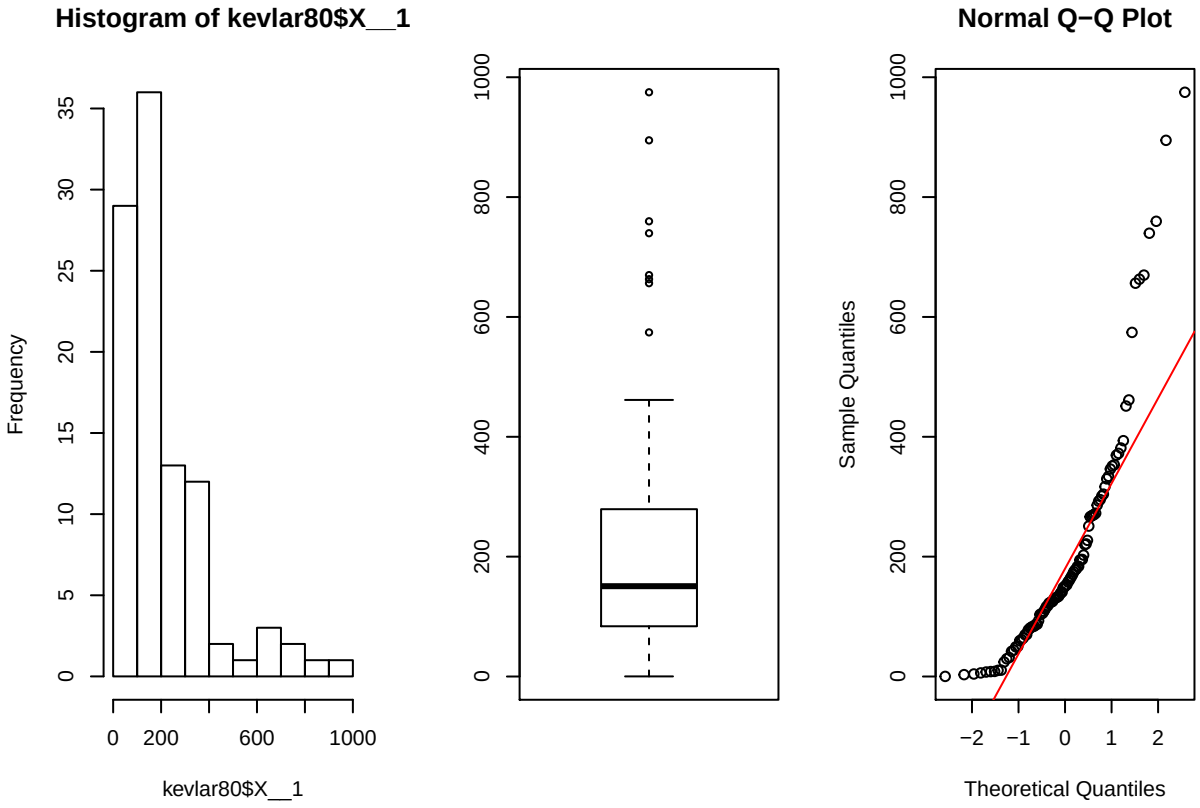
```
## [1] 974.72
```

The mean is 209.18 hours and the median is 150.70 hours. Since the mean is greater than the median, it seems as though the distribution is right skewed. The IQR (interquartile range) is (75th percentile - 25th percentile), or (3rd quartile - 1st quartile), is 191.825. The range is 974.72.

6. Graphical Summaries at Stress Level 80%

Create a histogram, boxplot, and Q-Q plot to examine the distribution of the times of failures at stress level 80%.

```
par(mfrow=c(1,3))
hist(kevlar80$X__1)
boxplot(kevlar80$X__1)
qqnorm(kevlar80$X__1)
qqline(kevlar80$X__1, col = 2)
```



All three plots indicate that the distribution is right skewed.

7. Summary Statistics at Stress Level 90%

Examine the summary statistics for times of failure at 90% stress level.

```
summary(kevlar90)
```

```
##       X__1
##  Min.   :0.010
##  1st Qu.:0.240
##  Median :0.800
##  Mean   :1.024
##  3rd Qu.:1.450
##  Max.   :7.890
```

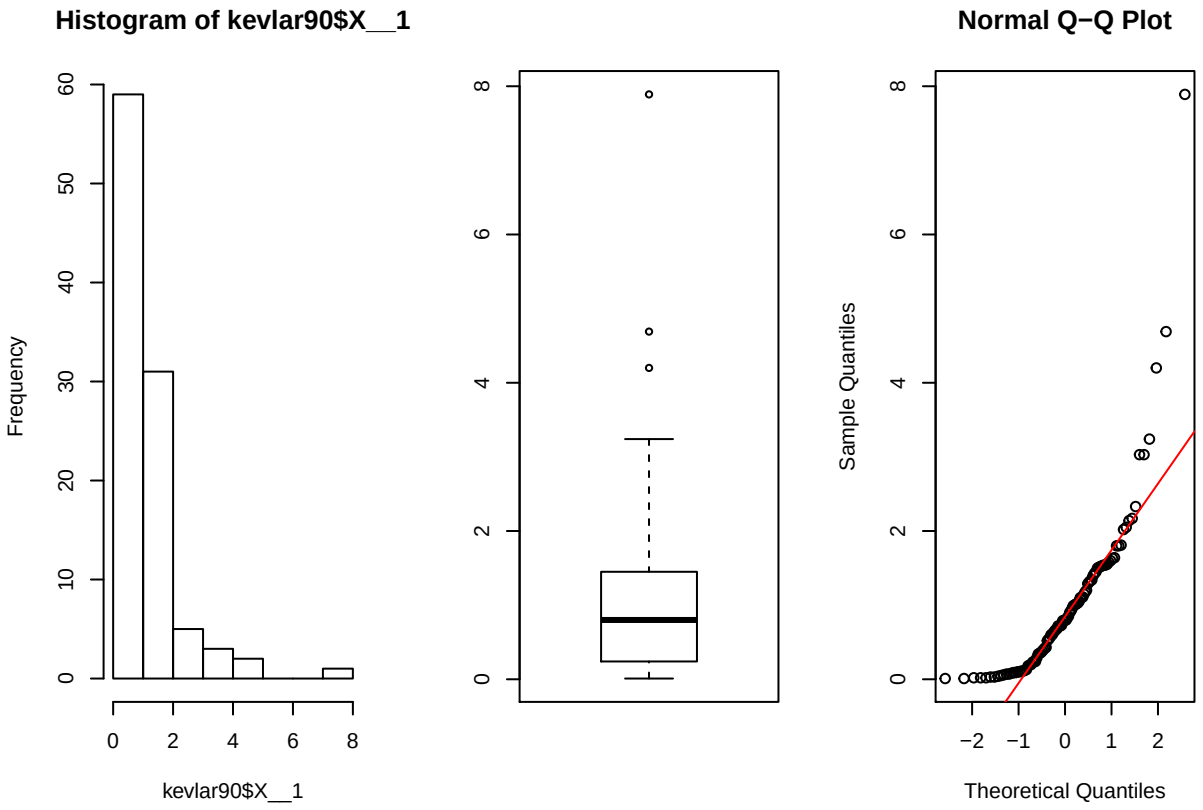
The mean is 1.024 hours and the median is 0.800 hours. Since the mean is greater than the median, it seems as though the distribution is right skewed. The IQR (interquartile range) is (75th percentile - 25th percentile), or (3rd quartile - 1st quartile), is 1.21. The range is 7.88

8. Graphical Summaries at Stress Level 90%

Create a histogram, boxplot, and Q-Q plot to examine the distribution of the times of failures at stress level 90%.

```
par(mfrow=c(1,3))
hist(kevlar90$X__1)
```

```r
boxplot(kevlar90$X__1)
qqnorm(kevlar90$X__1)
qqline(kevlar90$X__1, col = 2)
```



All three plots indicate that the distribution is right skewed. It seems to be an approximately exponential distribution.

9. Summary Statistics for All Three Stress Levels

Compare the mean and the median of the times of failures at each stress level.

```r
mean(kevlar70$X__1, na.rm = TRUE)
```

```
## [1] 8805.694
```

```r
mean(kevlar80$X__1, na.rm = TRUE)
```

```
## [1] 209.1828
```

```r
mean(kevlar90$X__1, na.rm = TRUE)
```

```
## [1] 1.023861
```

```r
median(kevlar70$X__1, na.rm = TRUE)
```

```
## [1] 8831
```

```r
median(kevlar80$X__1, na.rm = TRUE)
```

```
## [1] 150.7
```

```
median(kevlar90$X__1, na.rm = TRUE)
```

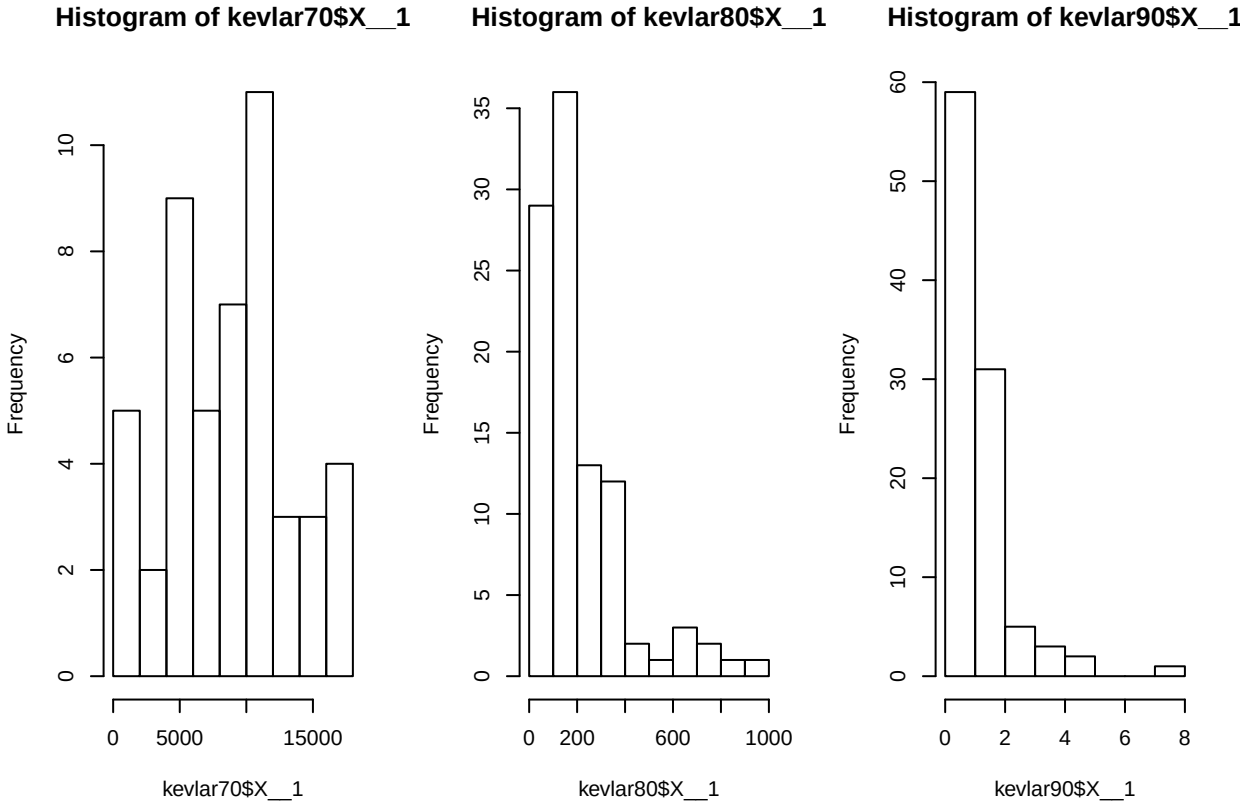
```
## [1] 0.8
```

As the stress level increases from 70% to 80% to 90%, there seems to be a dramatic decrease in time until failure. Looking at the mean and the median of each stress level, it seems as though an increase in stress level results in decreased time until failure.

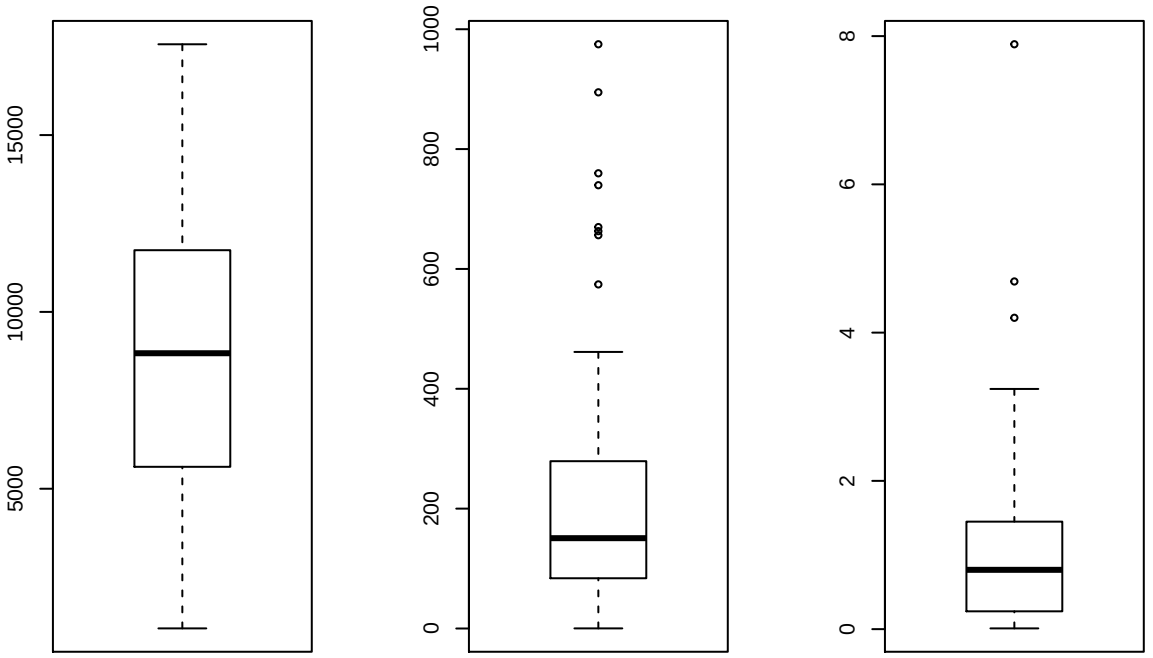
10. Graphical Summaries for All Three Stress

Levels Compare the histograms and the boxplots for the times of failures at each stress level.

```
par(mfrow=c(1,3))
hist(kevlar70$X__1)
hist(kevlar80$X__1)
hist(kevlar90$X__1)
```




```
boxplot(kevlar70$X__1)
boxplot(kevlar80$X__1)
boxplot(kevlar90$X__1)
```

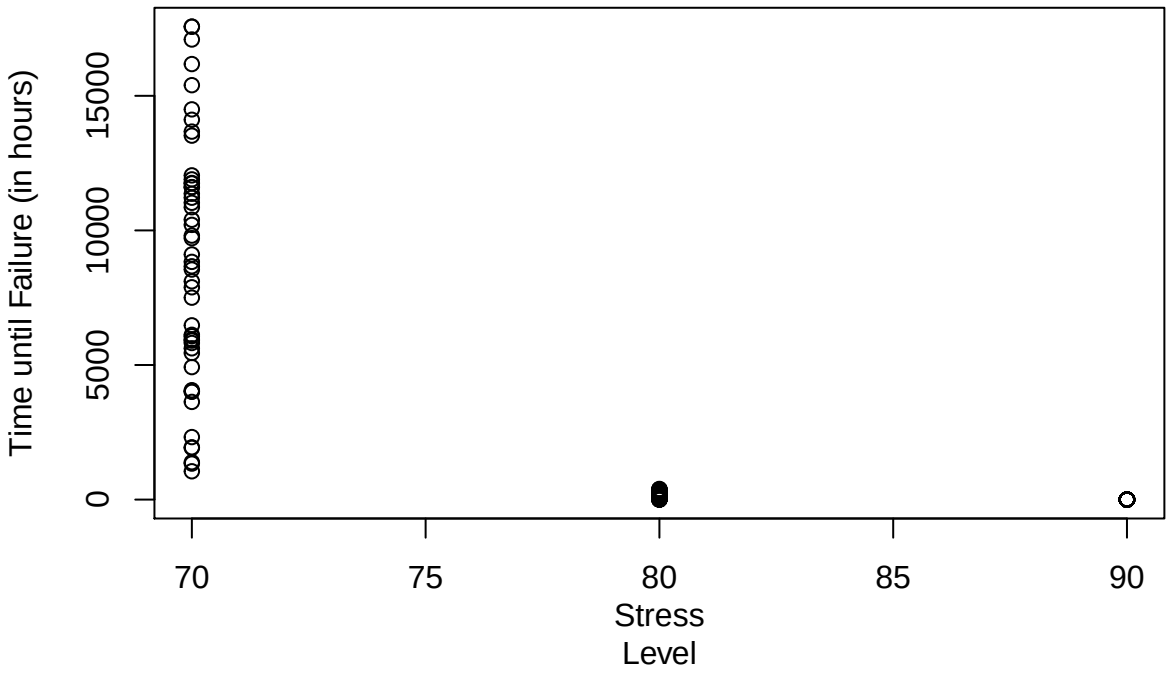


The histograms and the boxplots show that the distribution of lifetimes of kevlar decreases as the stress increases. The box plot shows that the variability of the distribution decreases as the the stress level increases. The variability can be measured by the IQR.The IQRs for the 70%, 80%, and 90% stress levels are 6125, 191.825, and 1.21, respectively. Notice that the IQRs decrease as the stress levels increase. That suggests that the variability decreases as the stress level increases. The ranges for 70%, 80%, and 90% stress levels are 16517, 974.72, and 7.88. The range also decreases as the stress levels increase.

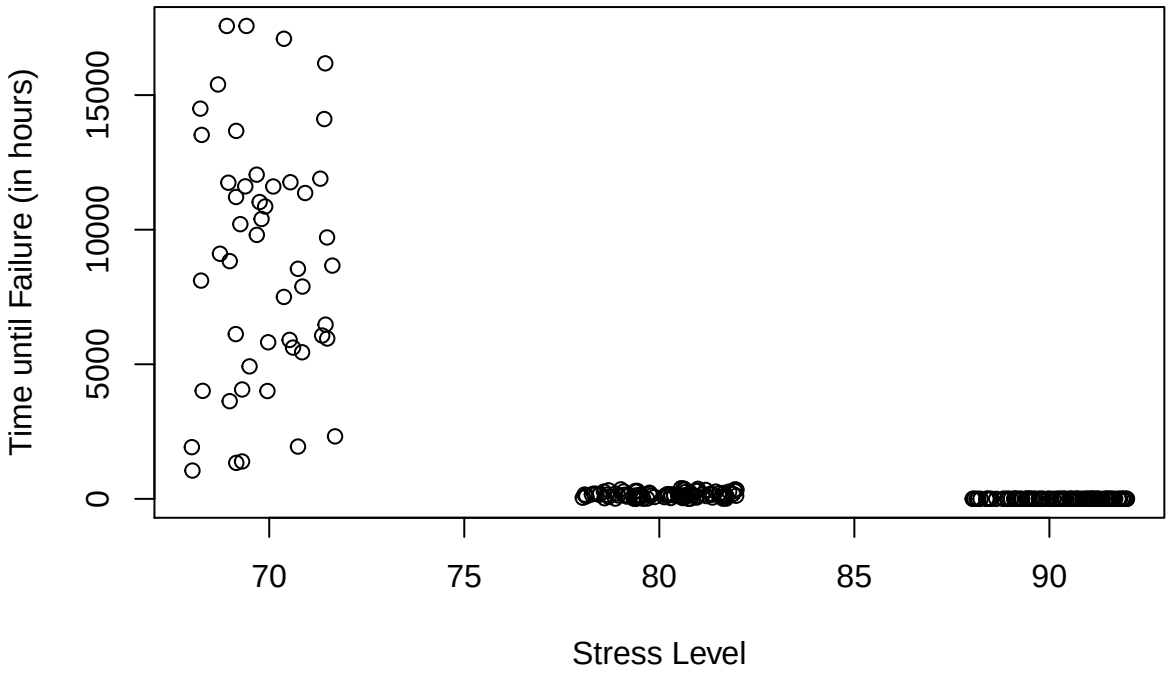
11. Scatter Plot of Lifetime of Kevlars vs Different Stress Levels

Plot points using kevlar_combined file.

```
#Plot the points on a scatter plot.
plot(kevlar_combined$Stress_Level, kevlar_combined$Lifetime, xlab = "Stress
Level", ylab = "Time until Failure (in hours)")
```




```
#I also tried using jitter plot to show the number of points for each stress
#level that are overlapping in the previous plot.
plot(kevlar_combined$Lifetime ~ jitter(kevlar_combined$Stress_Level, 1),
xlab = "Stress Level", ylab = "Time until Failure (in hours)")
```



It is clear from both of the scatter plots that the lifetime of the kevlar dramatically decreases as stress level is increased. In fact, from 70% stress level to 80% stress level, which is a 14.3% increase in stress level, there is a 97.6% decrease in the the mean time until failure. In terms of the median, it is a 98.3% decrease. That is almost a 100% decrease for both the mean and the median. Likewise, from 80% stress level to 90% stess level, which is a 12.5% increase, there is a 99.5% decrease in terms of both the mean and the median time until failure.