Life Expectancy Prediction

Load Libraries

```
library(car)
```

```
## Loading required package: carData
```

```
library(olsrr)
```

```
##
## Attaching package: 'olsrr'
```

```
## The following object is masked from 'package:datasets':
##
##     rivers
```

Load Dataset

```
life = read.csv('Life Expectancy Data.csv')
```

The Life Expectancy Dataset contains the following fields:

- `Country` - Country Observed.
- `Year` - Year Observed.
- `Status` - Developed or Developing status.
- `Life.expectancy` - Life Expectancy in age.
- `Adult.Mortality` - Adult Mortality Rates on both sexes (probability of dying between 15-60 years/1000 population).
- `infant.deaths` - Number of Infant Deaths per 1000 population.
- `Alcohol` - Alcohol recorded per capita (15+) consumption (in litres of pure alcohol).
- `percentage.expenditure` - Expenditure on health as a percentage of Gross Domestic Product per capita (%).
- `Hepatitis.B` - Hepatitis B (HepB) immunization coverage among 1-year-olds (%).
- `Measles` - Number of reported Measles cases per 1000 population.
- `BMI` - Average Body Mass Index of entire population.
- `under.five.deaths` - Number of under-five deaths per 1000 population.
- `Polio` - Polio (Pol3) immunization coverage among 1-year-olds (%).
- `Total expenditure` - General government expenditure on health as a percentage of total government expenditure (%).
- `Diphtheria` - Diphtheria tetanus toxoid and pertussis (DTP3) immunization coverage among 1-year-olds (%).
- `HIV.AIDS` - Deaths per 1000 live births HIV/AIDS (0-4 years).
- `GDP` - Gross Domestic Product per capita (in USD).
- `Population` - Population of the country.
- `thinness..1.19.years` - Prevalence of thinness among children and adolescents for Age 10 to 19 (%).
- `thinness.5.9.years` - Prevalence of thinness among children for Age 5 to 9 (%).
- `Income.composition.of.resources` - Human Development Index in terms of income composition of resources (index ranging from 0 to 1).
- `Schooling` - Number of years of Schooling (years).

In total, there are 22 variables with 20 of them being numerical and 2 categorical.
We will predict the `Life.expectancy` using the given dependent variables in the dataset.

Clean Data

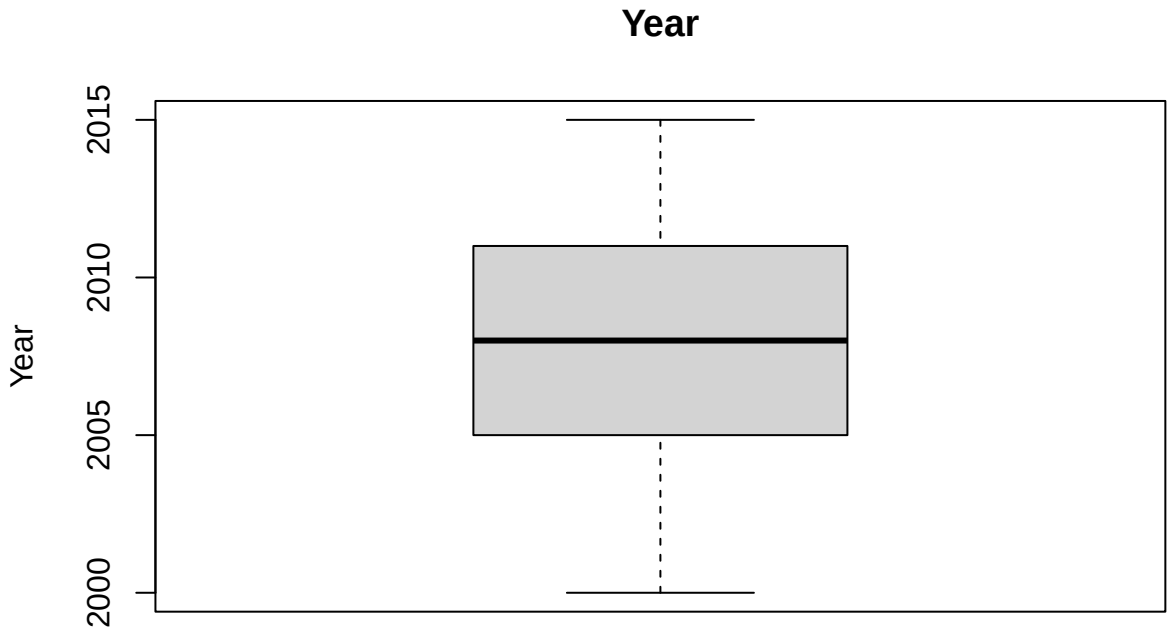
```
life = na.omit(life)
```

Data Exploration

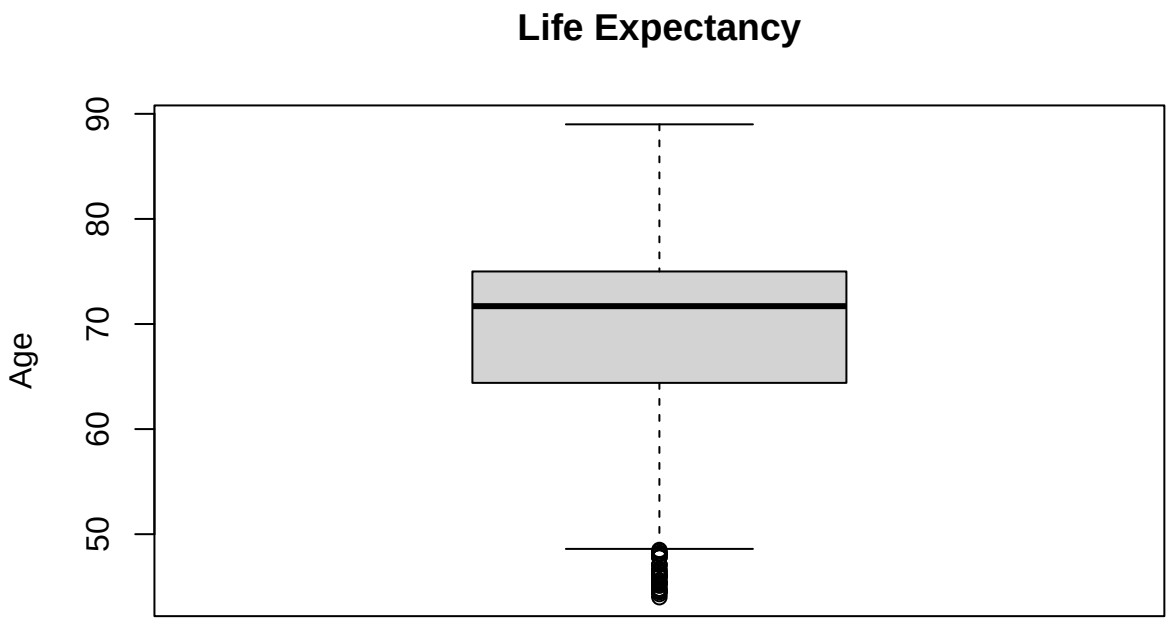
```
summary(life)
```

```
##    Country               Year         Status          Life.expectancy
##  Length:1649        Min.   :2000   Length:1649        Min.   :44.0
##  Class :character   1st Qu.:2005   Class :character   1st Qu.:64.4
##  Mode  :character   Median :2008   Mode  :character   Median :71.7
##                     Mean   :2008                      Mean   :69.3
##                     3rd Qu.:2011                      3rd Qu.:75.0
##                     Max.   :2015                      Max.   :89.0
##  Adult.Mortality infant.deaths        Alcohol       percentage.expenditure
##  Min.   :  1.0   Min.   :   0.00   Min.   : 0.010   Min.   :    0.00
##  1st Qu.: 77.0   1st Qu.:   1.00   1st Qu.: 0.810   1st Qu.:   37.44
##  Median :148.0   Median :   3.00   Median : 3.790   Median :  145.10
##  Mean   :168.2   Mean   :  32.55   Mean   : 4.533   Mean   :  698.97
##  3rd Qu.:227.0   3rd Qu.:  22.00   3rd Qu.: 7.340   3rd Qu.:  509.39
##  Max.   :723.0   Max.   :1600.00   Max.   :17.870   Max.   :18961.35
##   Hepatitis.B       Measles            BMI        under.five.deaths
##  Min.   : 2.00   Min.   :     0   Min.   : 2.00   Min.   :   0.00
##  1st Qu.:74.00   1st Qu.:     0   1st Qu.:19.50   1st Qu.:   1.00
##  Median :89.00   Median :    15   Median :43.70   Median :   4.00
##  Mean   :79.22   Mean   :  2224   Mean   :38.13   Mean   :  44.22
##  3rd Qu.:96.00   3rd Qu.:   373   3rd Qu.:55.80   3rd Qu.:  29.00
##  Max.   :99.00   Max.   :131441   Max.   :77.10   Max.   :2100.00
##      Polio       Total.expenditure   Diphtheria       HIV.AIDS
##  Min.   : 3.00   Min.   : 0.740    Min.   : 2.00   Min.   : 0.100
##  1st Qu.:81.00   1st Qu.: 4.410    1st Qu.:82.00   1st Qu.: 0.100
##  Median :93.00   Median : 5.840    Median :92.00   Median : 0.100
##  Mean   :83.56   Mean   : 5.956    Mean   :84.16   Mean   : 1.984
##  3rd Qu.:97.00   3rd Qu.: 7.470    3rd Qu.:97.00   3rd Qu.: 0.700
##  Max.   :99.00   Max.   :14.390    Max.   :99.00   Max.   :50.600
##       GDP              Population        thinness..1.19.years
##  Min.   :     1.68   Min.   :3.400e+01   Min.   : 0.100
##  1st Qu.:   462.15   1st Qu.:1.919e+05   1st Qu.: 1.600
##  Median :  1592.57   Median :1.420e+06   Median : 3.000
##  Mean   :  5566.03   Mean   :1.465e+07   Mean   : 4.851
##  3rd Qu.:  4718.51   3rd Qu.:7.659e+06   3rd Qu.: 7.100
##  Max.   :119172.74   Max.   :1.294e+09   Max.   :27.200
##  thinness.5.9.years Income.composition.of.resources   Schooling
##  Min.   : 0.100     Min.   :0.0000                  Min.   : 4.20
##  1st Qu.: 1.700     1st Qu.:0.5090                  1st Qu.:10.30
##  Median : 3.200     Median :0.6730                  Median :12.30
##  Mean   : 4.908     Mean   :0.6316                  Mean   :12.12
##  3rd Qu.: 7.100     3rd Qu.:0.7510                  3rd Qu.:14.00
##  Max.   :28.200     Max.   :0.9360                  Max.   :20.70
```

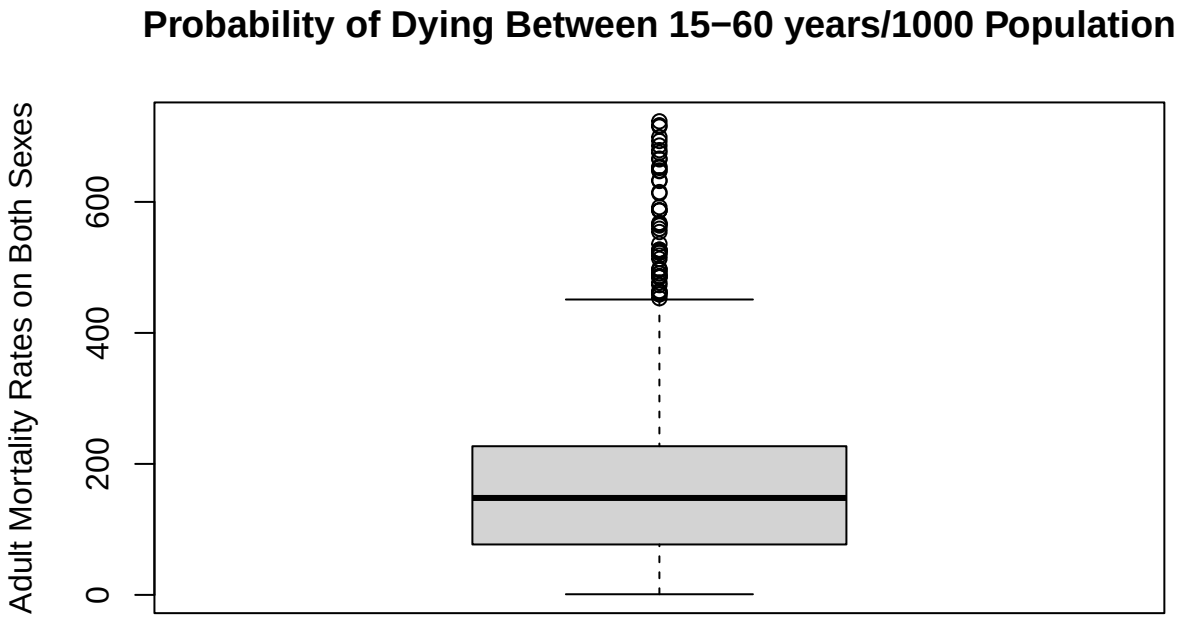
```
boxplot(life$Year, main='Year', ylab='Year')
```



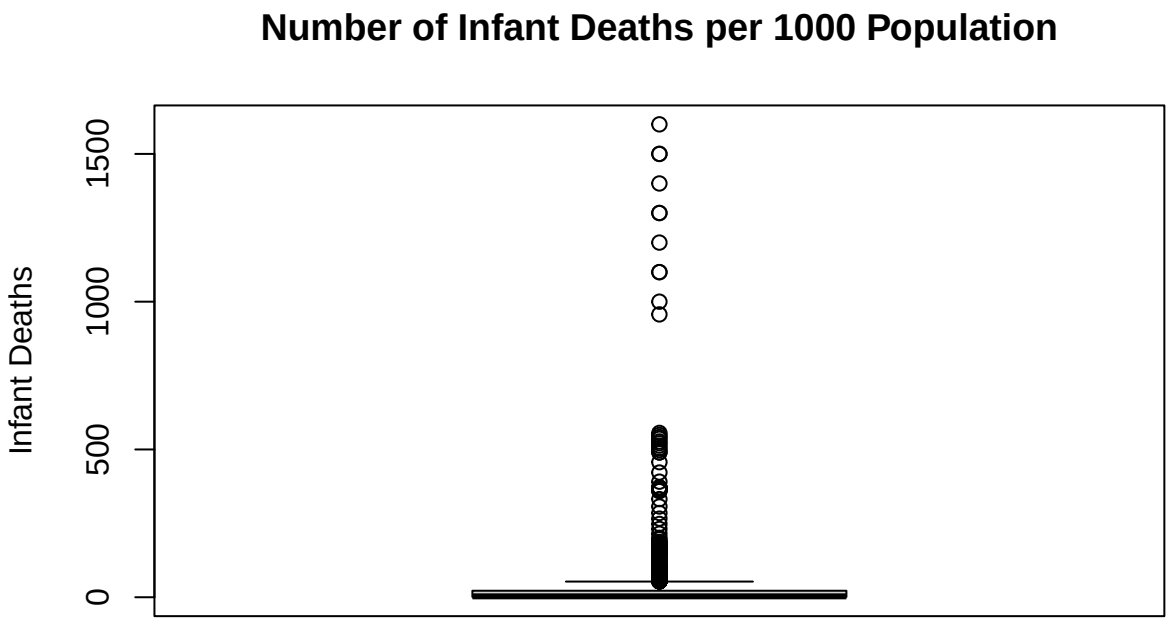

```
boxplot(life$Life.expectancy, main='Life Expectancy', ylab='Age')
```



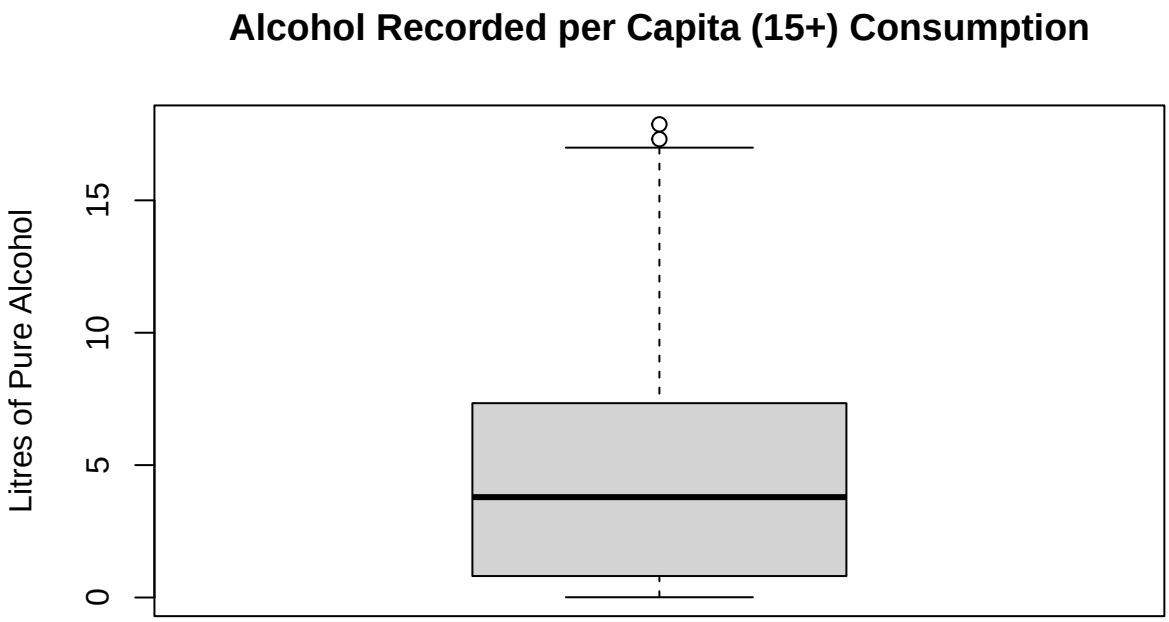

```
boxplot(life$Adult.Mortality, main='Probability of Dying Between 15-60 years/1000 Population', ylab='Adu
```



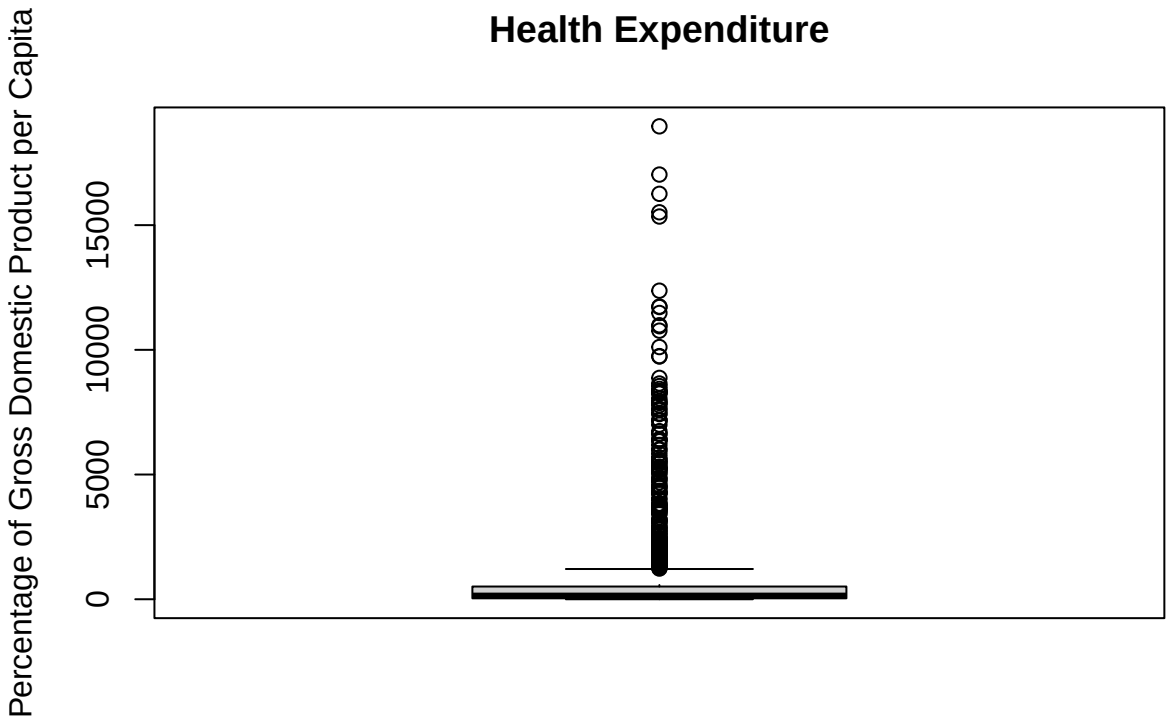

```
boxplot(life$infant.deaths, main='Number of Infant Deaths per 1000 Population', ylab='Infant Deaths')
```



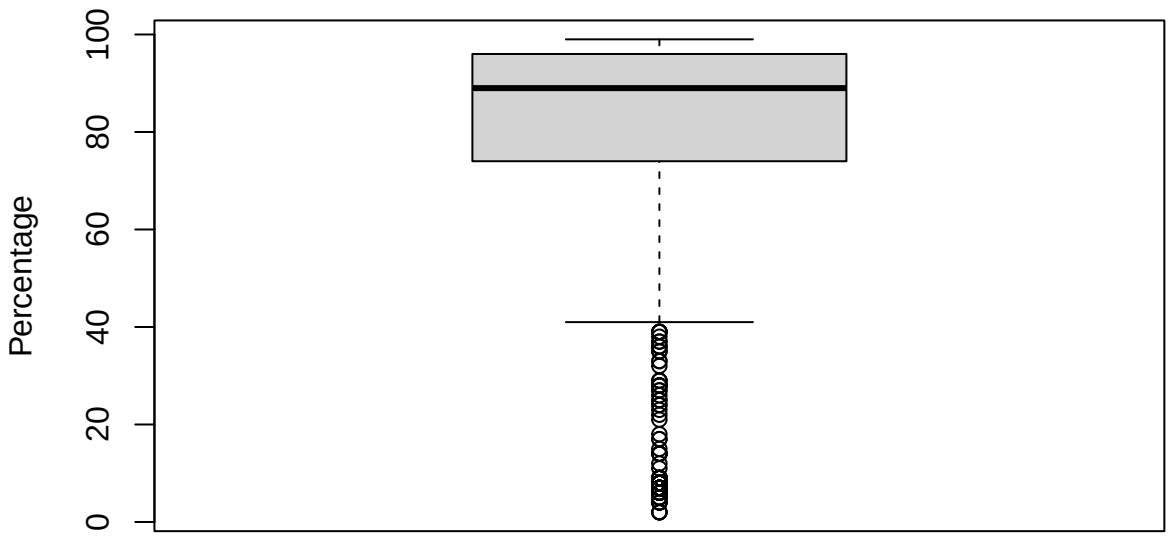

```
boxplot(life$Alcohol, main='Alcohol Recorded per Capita (15+) Consumption', ylab='Litres of Pure Alcohol
```



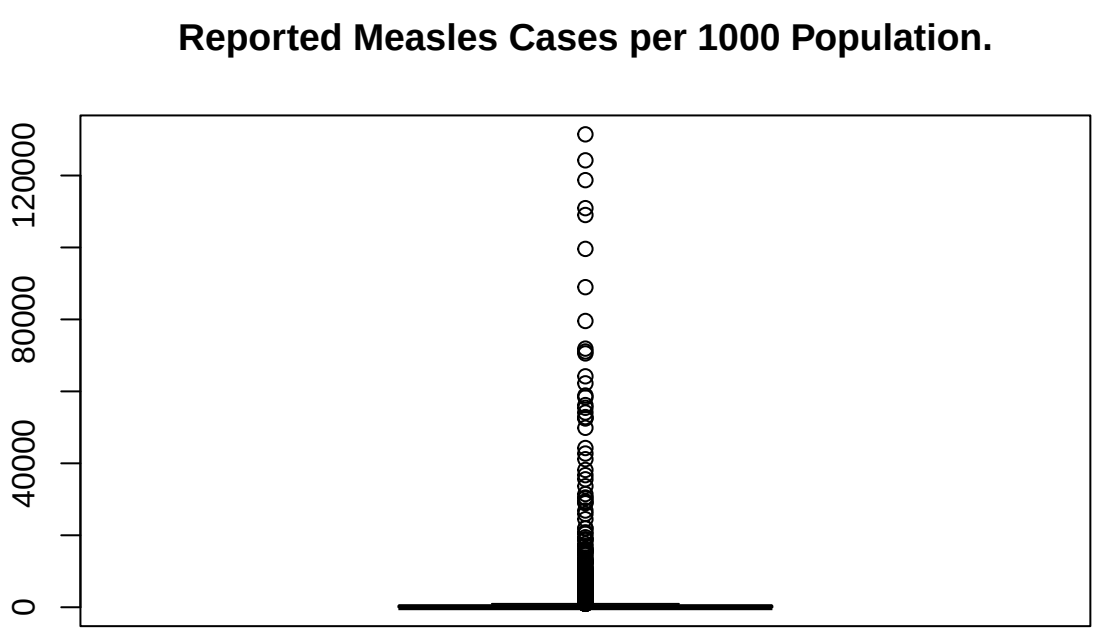

```
boxplot(life$percentage.expenditure, main='Health Expenditure', ylab='Percentage of Gross Domestic Produ
```



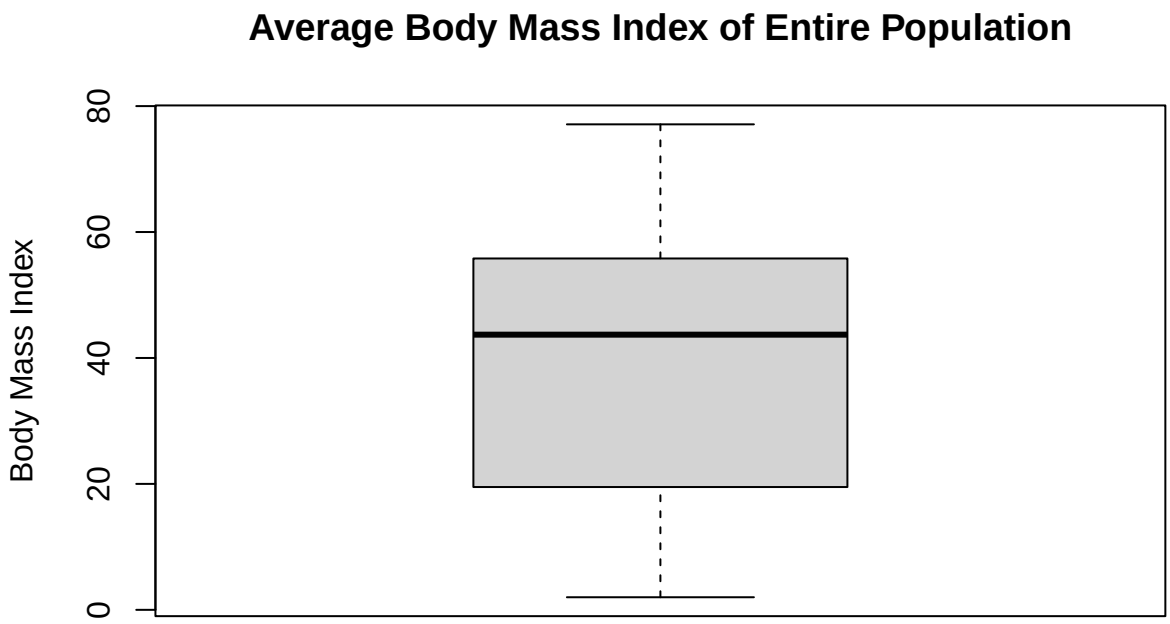

```
boxplot(life$Hepatitis.B, main='Hepatitis B (HepB) Immunization Coverage Among 1-Year-Olds', ylab='Perc
```



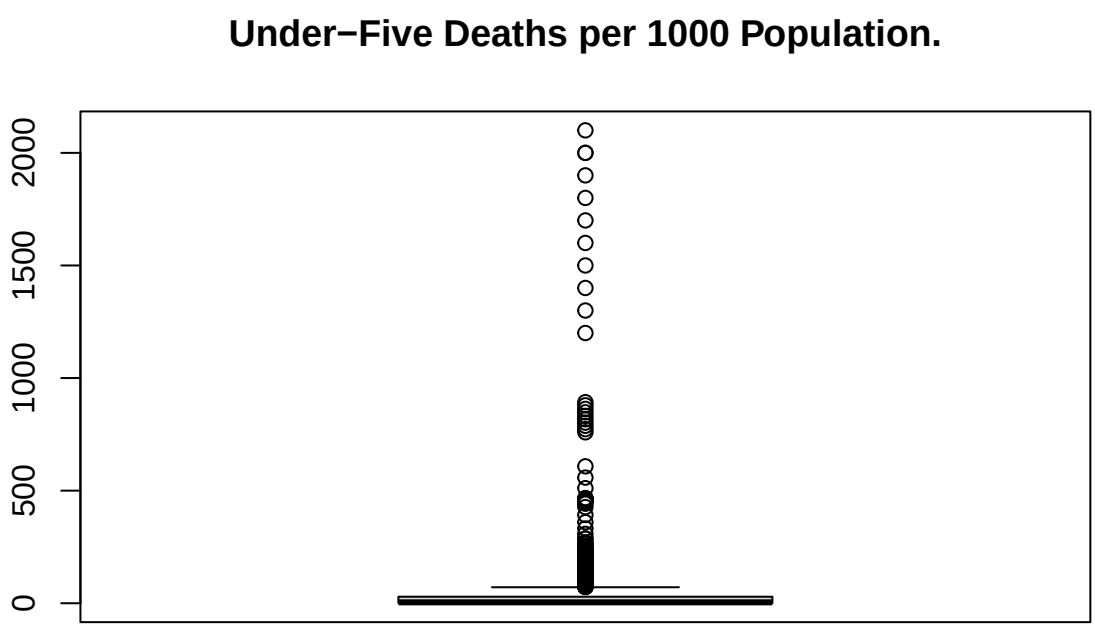

```
boxplot(life$Measles, main='Reported Measles Cases per 1000 Population.')
```



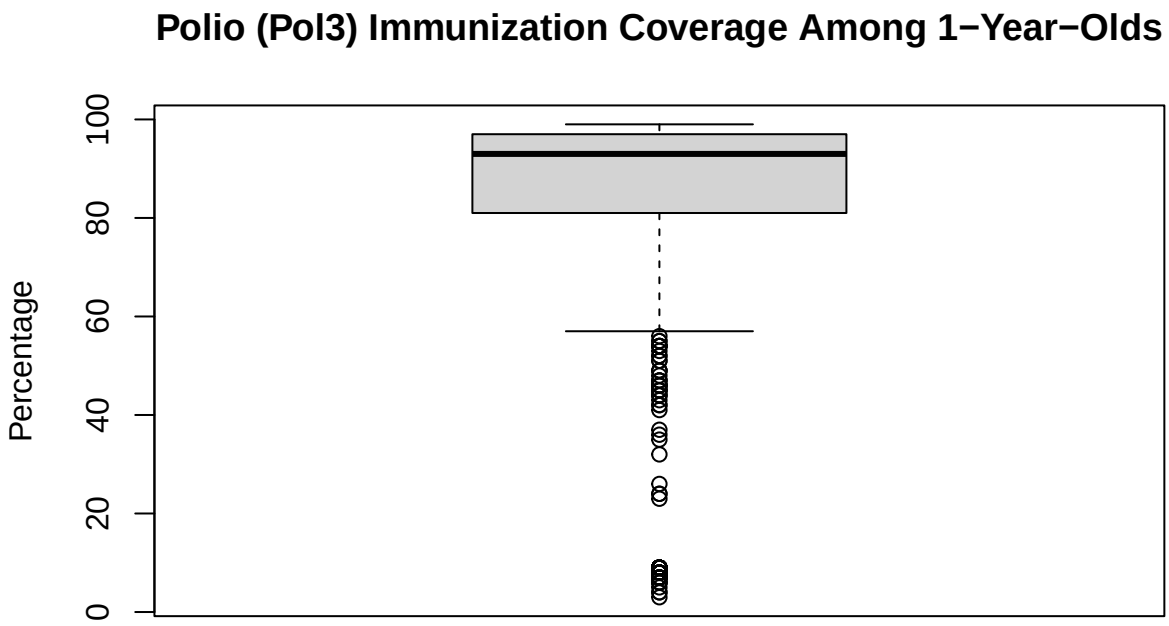

```
boxplot(life$BMI, main='Average Body Mass Index of Entire Population', ylab='Body Mass Index')
```



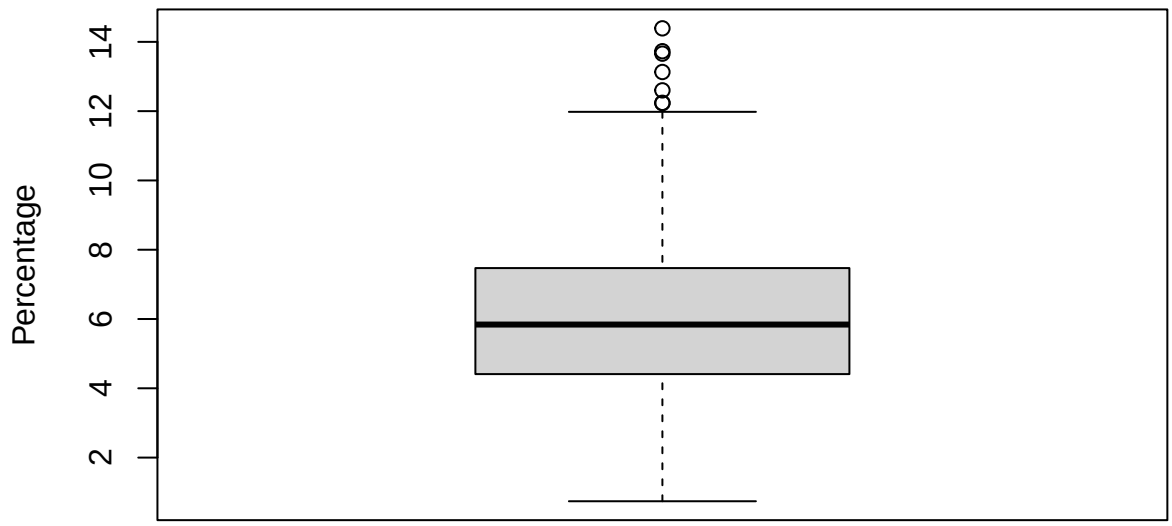

```
boxplot(life$under.five.deaths, main='Under-Five Deaths per 1000 Population.')
```



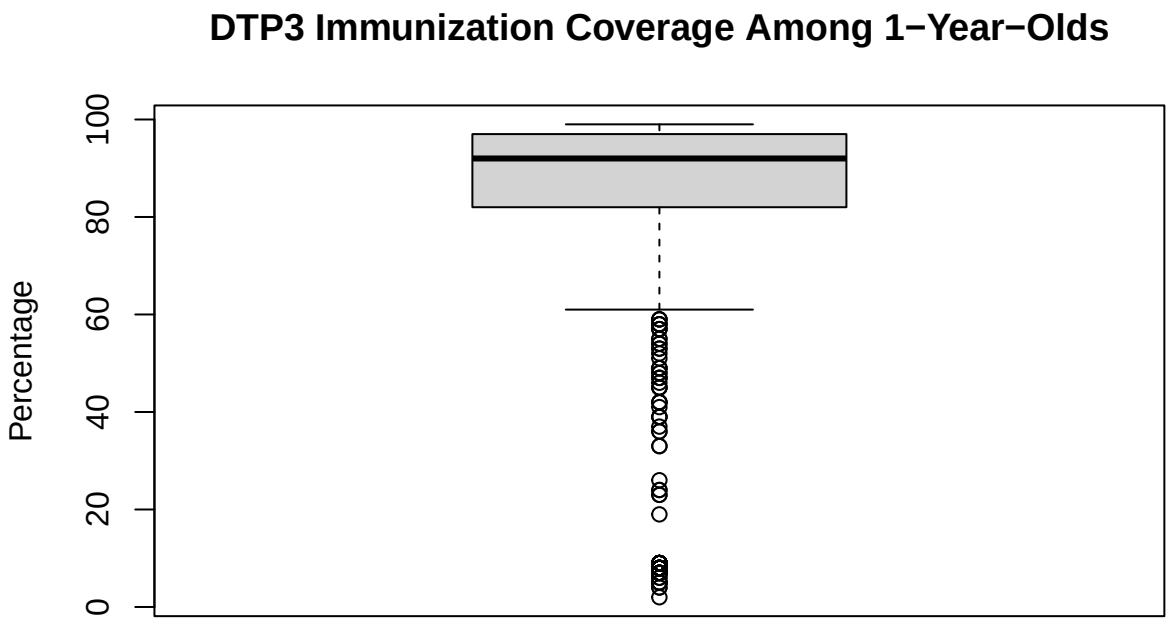

```
boxplot(life$Polio, main='Polio (Pol3) Immunization Coverage Among 1-Year-Olds', ylab='Percentage')
```



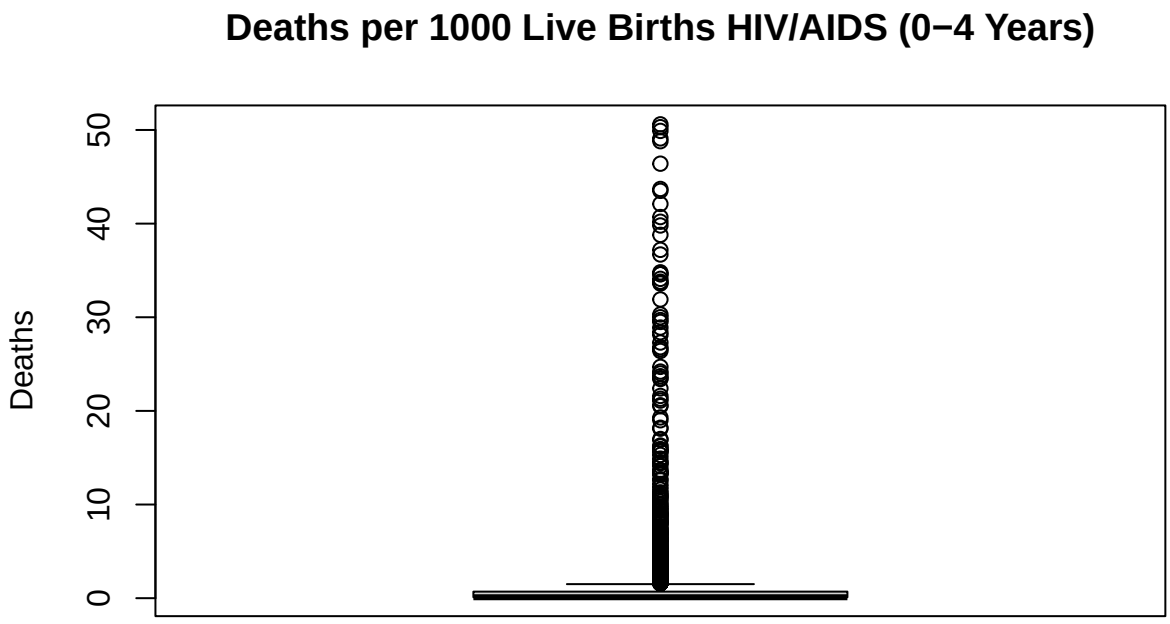

```
boxplot(life$Total.expenditure, main='General Government Health Expenditure as a Percentage of Total Gov
```



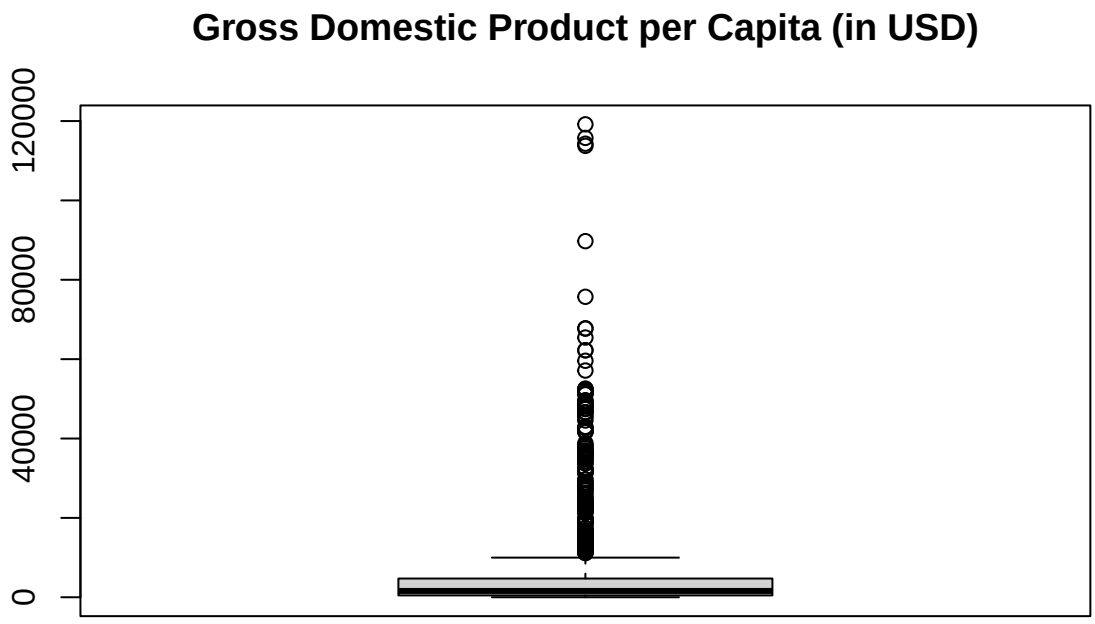

```
boxplot(life$Diphtheria, main='DTP3 Immunization Coverage Among 1-Year-Olds', ylab='Percentage')
```



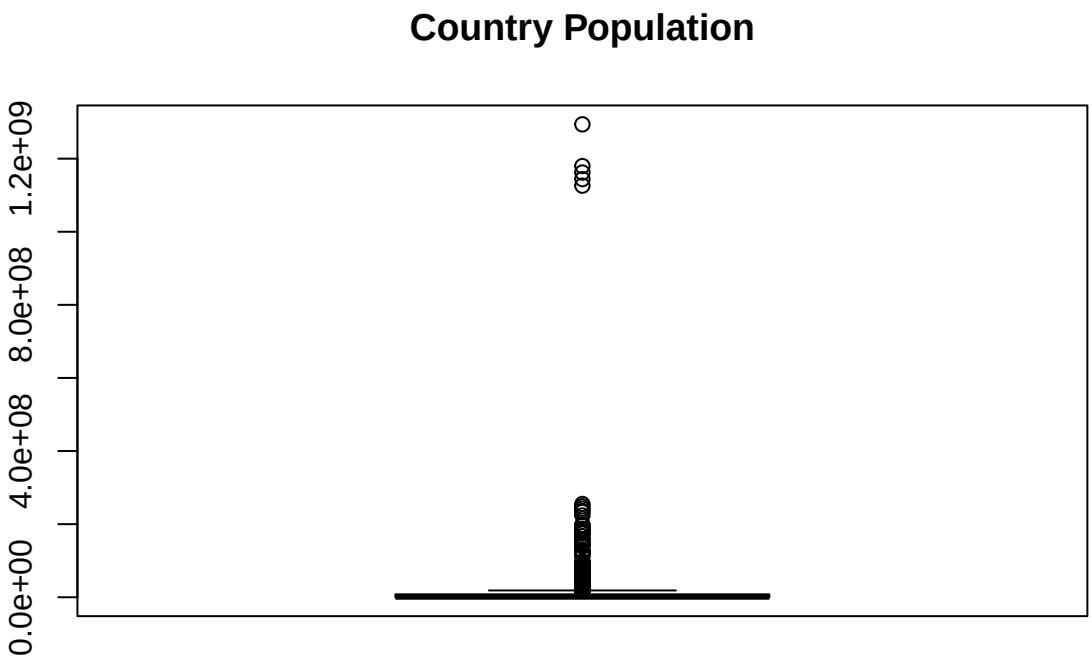

```
boxplot(life$HIV.AIDS, main='Deaths per 1000 Live Births HIV/AIDS (0-4 Years)', ylab='Deaths')
```



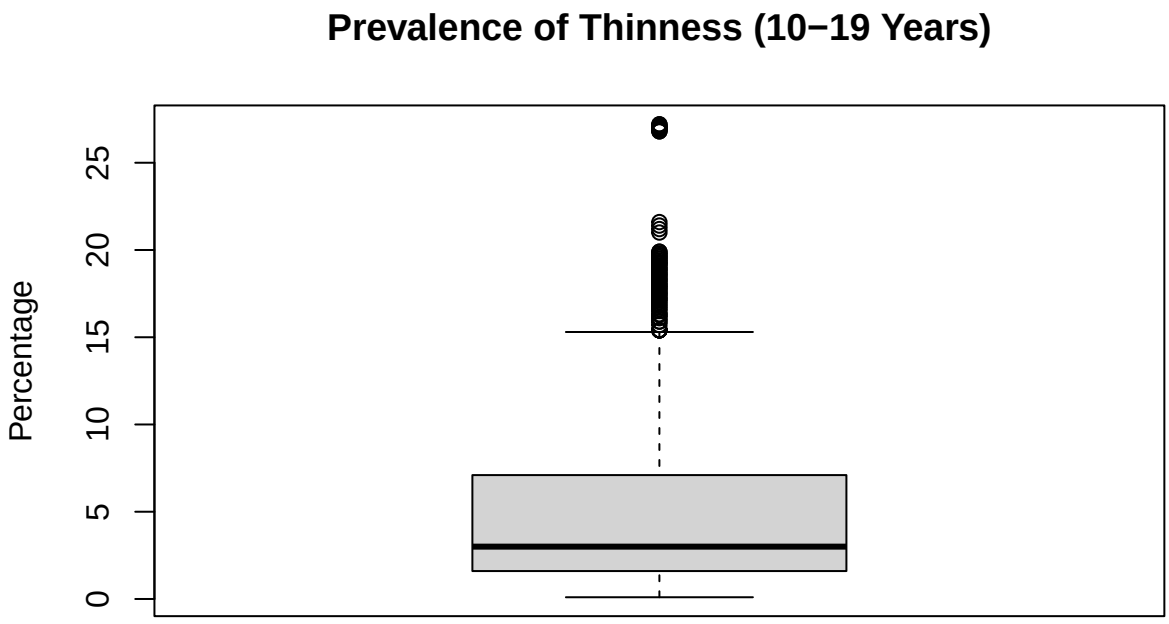

```
boxplot(life$GDP, main='Gross Domestic Product per Capita (in USD)')
```



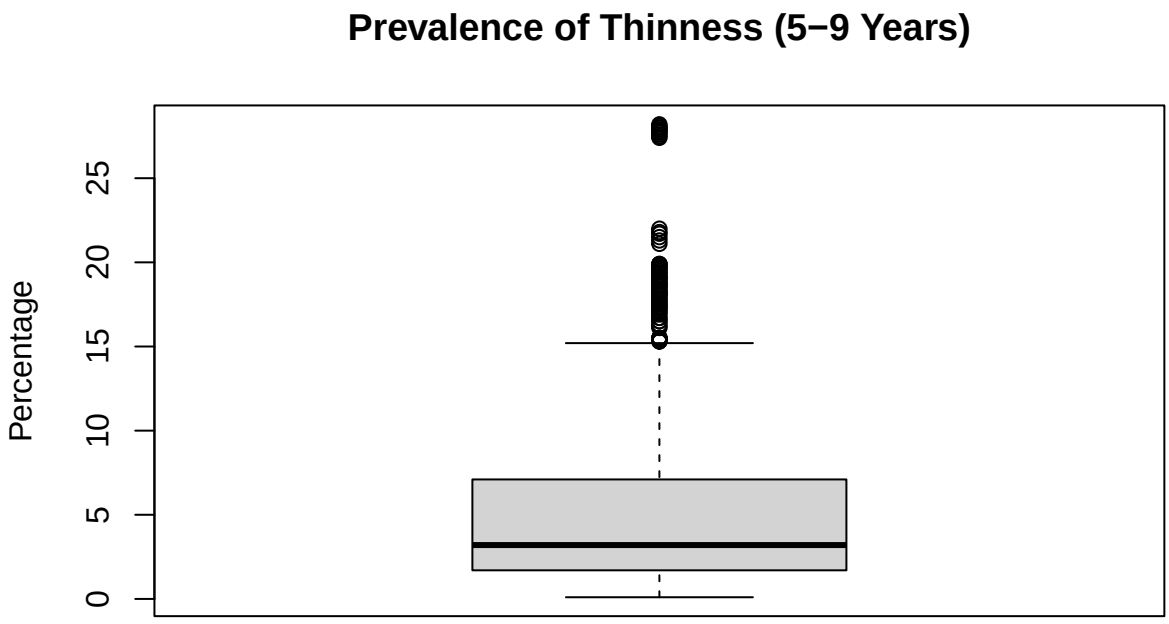

```
boxplot(life$Population, main='Country Population')
```



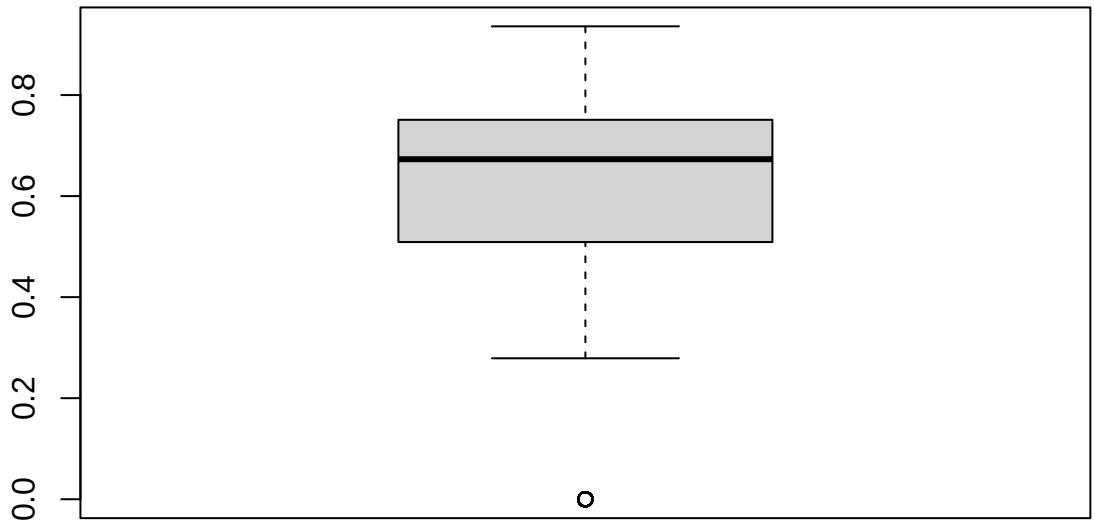

```
boxplot(life$thinness..1.19.years, main='Prevalence of Thinness (10-19 Years)', ylab='Percentage')
```



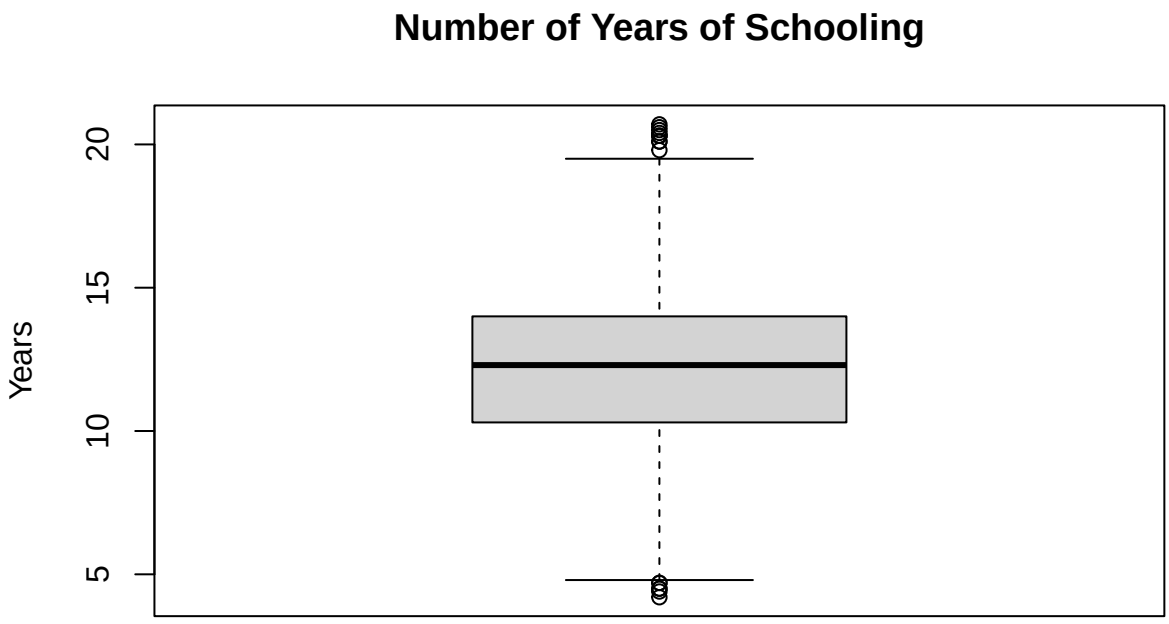

```
boxplot(life$thinness.5.9.years, main='Prevalence of Thinness (5-9 Years)', ylab='Percentage')
```




```
boxplot(life$Income.composition.of.resources, main='HDI in Terms of Income Composition of Resources (0-
```




```
boxplot(life$Schooling, main='Number of Years of Schooling', ylab='Years')
```



Feature Selection

We will be removing some of the variables for building the model due to the reasons mentioned below:
`Country` - Contains too many levels with no additional information to predict `Life.expectancy`.
`Year` - Contains time series data with no additional information to predict `Life.expectancy`.

```
life = life[, !(names(life) %in% c('Country', 'Year'))]
```

We will be mutating `Hepatitis.B`, `Polio` and `Diphteria` for building the model since their range between the minimum value and the 1st Quartile is too wide.

```
life$Hepatitis.B = ifelse(life$Hepatitis.B < 90, '90% Covered', '>=90% Covered')
life$Polio = ifelse(life$Polio < 90, '90% Covered', '>=90% Covered')
life$Diphtheria = ifelse(life$Diphtheria < 90, '90% Covered', '>=90% Covered')
```

```
summary(life)
```

```
##     Status          Life.expectancy Adult.Mortality infant.deaths
##  Length:1649        Min.   :44.0    Min.   :  1.0   Min.   :   0.00
##  Class :character   1st Qu.:64.4    1st Qu.: 77.0   1st Qu.:   1.00
##  Mode  :character   Median :71.7    Median :148.0   Median :   3.00
##                     Mean   :69.3    Mean   :168.2   Mean   :  32.55
##                     3rd Qu.:75.0    3rd Qu.:227.0   3rd Qu.:  22.00
##                     Max.   :89.0    Max.   :723.0   Max.   :1600.00
##     Alcohol       percentage.expenditure Hepatitis.B          Measles
##  Min.   : 0.010   Min.   :    0.00       Length:1649        Min.   :     0
##  1st Qu.: 0.810   1st Qu.:   37.44       Class :character   1st Qu.:     0
##  Median : 3.790   Median :  145.10       Mode  :character   Median :    15
```

```
##  Mean   : 4.533   Mean   :  698.97                          Mean   :  2224
##  3rd Qu.: 7.340   3rd Qu.:  509.39                          3rd Qu.:   373
##  Max.   :17.870   Max.   :18961.35                          Max.   :131441
##       BMI        under.five.deaths    Polio           Total.expenditure
##  Min.   : 2.00   Min.   :   0.00   Length:1649        Min.   : 0.740
##  1st Qu.:19.50   1st Qu.:   1.00   Class :character   1st Qu.: 4.410
##  Median :43.70   Median :   4.00   Mode  :character   Median : 5.840
##  Mean   :38.13   Mean   :  44.22                      Mean   : 5.956
##  3rd Qu.:55.80   3rd Qu.:  29.00                      3rd Qu.: 7.470
##  Max.   :77.10   Max.   :2100.00                      Max.   :14.390
##   Diphtheria          HIV.AIDS           GDP              Population
##  Length:1649        Min.   : 0.100   Min.   :     1.68   Min.   :3.400e+01
##  Class :character   1st Qu.: 0.100   1st Qu.:   462.15   1st Qu.:1.919e+05
##  Mode  :character   Median : 0.100   Median :  1592.57   Median :1.420e+06
##                     Mean   : 1.984   Mean   :  5566.03   Mean   :1.465e+07
##                     3rd Qu.: 0.700   3rd Qu.:  4718.51   3rd Qu.:7.659e+06
##                     Max.   :50.600   Max.   :119172.74   Max.   :1.294e+09
##  thinness..1.19.years thinness.5.9.years Income.composition.of.resources
##  Min.   : 0.100       Min.   : 0.100     Min.   :0.0000
##  1st Qu.: 1.600       1st Qu.: 1.700     1st Qu.:0.5090
##  Median : 3.000       Median : 3.200     Median :0.6730
##  Mean   : 4.851       Mean   : 4.908     Mean   :0.6316
##  3rd Qu.: 7.100       3rd Qu.: 7.100     3rd Qu.:0.7510
##  Max.   :27.200       Max.   :28.200     Max.   :0.9360
##    Schooling
##  Min.   : 4.20
##  1st Qu.:10.30
##  Median :12.30
##  Mean   :12.12
##  3rd Qu.:14.00
##  Max.   :20.70
```

Correlations and Variances

```
life_nums = unlist(lapply(life, is.numeric), use.names = FALSE)
cor(life[, life_nums])
```

```
##                                 Life.expectancy Adult.Mortality infant.deaths
## Life.expectancy                      1.00000000    -0.702523062  -0.169073804
## Adult.Mortality                     -0.70252306     1.000000000   0.042450237
## infant.deaths                       -0.16907380     0.042450237   1.000000000
## Alcohol                              0.40271832    -0.175535086  -0.106216917
## percentage.expenditure               0.40963082    -0.237609890  -0.090764632
## Measles                             -0.06888122    -0.003966685   0.532679832
## BMI                                  0.54204159    -0.351542478  -0.234425154
## under.five.deaths                   -0.19226530     0.060365026   0.996905622
## Total.expenditure                    0.17471764    -0.085226535  -0.146951117
## HIV.AIDS                            -0.59223629     0.550690745   0.007711547
## GDP                                  0.44132181    -0.255034733  -0.098092020
## Population                          -0.02230498    -0.015011838   0.671758310
## thinness..1.19.years                -0.45783819     0.272230044   0.463415256
## thinness.5.9.years                  -0.45750829     0.286722882   0.461907925
## Income.composition.of.resources      0.72108259    -0.442203288  -0.134753863
## Schooling                            0.72763003    -0.421170523  -0.214371900
```

```
##                                    Alcohol percentage.expenditure      Measles
## Life.expectancy                 0.40271832             0.40963082 -0.068881222
## Adult.Mortality                -0.17553509            -0.23760989 -0.003966685
## infant.deaths                  -0.10621692            -0.09076463  0.532679832
## Alcohol                         1.00000000             0.41704736 -0.050110235
## percentage.expenditure          0.41704736             1.00000000 -0.063070789
## Measles                        -0.05011023            -0.06307079  1.000000000
## BMI                             0.35339621             0.24273824 -0.153245464
## under.five.deaths              -0.10108216            -0.09215806  0.517505563
## Total.expenditure               0.21488509             0.18387236 -0.113582738
## HIV.AIDS                       -0.02711264            -0.09508499 -0.003521854
## GDP                             0.44343279             0.95929886 -0.064767590
## Population                     -0.02888023            -0.01679214  0.321946377
## thinness..1.19.years           -0.40375499            -0.25503460  0.180641506
## thinness.5.9.years             -0.38620819            -0.25563544  0.174946217
## Income.composition.of.resources  0.56107433             0.40216974 -0.058277256
## Schooling                       0.61697481             0.42208845 -0.115660481
##                                        BMI under.five.deaths Total.expenditure
## Life.expectancy                 0.54204159       -0.19226530        0.17471764
## Adult.Mortality                -0.35154248        0.06036503       -0.08522653
## infant.deaths                  -0.23442515        0.99690562       -0.14695112
## Alcohol                         0.35339621       -0.10108216        0.21488509
## percentage.expenditure          0.24273824       -0.09215806        0.18387236
## Measles                        -0.15324546        0.51750556       -0.11358274
## BMI                             1.00000000       -0.24213740        0.18946896
## under.five.deaths              -0.24213740        1.00000000       -0.14580310
## Total.expenditure               0.18946896       -0.14580310        1.00000000
## HIV.AIDS                       -0.21089675        0.01947593        0.04310066
## GDP                             0.26611397       -0.10033126        0.18037347
## Population                     -0.08141598        0.65867969       -0.07996224
## thinness..1.19.years           -0.54701751        0.46478470       -0.20987232
## thinness.5.9.years             -0.55409398        0.46228938       -0.21786479
## Income.composition.of.resources  0.51050483       -0.14809728        0.18365319
## Schooling                       0.55484390       -0.22601262        0.24378345
##                                    HIV.AIDS          GDP   Population
## Life.expectancy                -0.592236293  0.44132181 -0.022304978
## Adult.Mortality                 0.550690745 -0.25503473 -0.015011838
## infant.deaths                   0.007711547 -0.09809202  0.671758310
## Alcohol                        -0.027112636  0.44343279 -0.028880232
## percentage.expenditure         -0.095084991  0.95929886 -0.016792141
## Measles                        -0.003521854 -0.06476759  0.321946377
## BMI                            -0.210896746  0.26611397 -0.081415982
## under.five.deaths               0.019475927 -0.10033126  0.658679691
## Total.expenditure               0.043100657  0.18037347 -0.079962237
## HIV.AIDS                        1.000000000 -0.10808060 -0.027800562
## GDP                            -0.108080600  1.00000000 -0.020368964
## Population                     -0.027800562 -0.02036896  1.000000000
## thinness..1.19.years            0.172591767 -0.27749835  0.282529280
## thinness.5.9.years              0.183146727 -0.27795855  0.277913374
## Income.composition.of.resources -0.248589855  0.44685551 -0.008132466
## Schooling                      -0.211840201  0.46794697 -0.040312419
##                                thinness..1.19.years thinness.5.9.years
## Life.expectancy                          -0.4578382         -0.4575083
## Adult.Mortality                           0.2722300          0.2867229
```

```
## infant.deaths                          0.4634153          0.4619079
## Alcohol                               -0.4037550         -0.3862082
## percentage.expenditure                -0.2550346         -0.2556354
## Measles                                0.1806415          0.1749462
## BMI                                   -0.5470175         -0.5540940
## under.five.deaths                      0.4647847          0.4622894
## Total.expenditure                     -0.2098723         -0.2178648
## HIV.AIDS                               0.1725918          0.1831467
## GDP                                   -0.2774983         -0.2779586
## Population                             0.2825293          0.2779134
## thinness..1.19.years                   1.0000000          0.9279134
## thinness.5.9.years                     0.9279134          1.0000000
## Income.composition.of.resources       -0.4536789         -0.4384837
## Schooling                             -0.4911992         -0.4724820
##                                 Income.composition.of.resources   Schooling
## Life.expectancy                                     0.721082593  0.72763003
## Adult.Mortality                                    -0.442203288 -0.42117052
## infant.deaths                                      -0.134753863 -0.21437190
## Alcohol                                             0.561074332  0.61697481
## percentage.expenditure                              0.402169736  0.42208845
## Measles                                            -0.058277256 -0.11566048
## BMI                                                 0.510504831  0.55484390
## under.five.deaths                                  -0.148097276 -0.22601262
## Total.expenditure                                   0.183653190  0.24378345
## HIV.AIDS                                           -0.248589855 -0.21184020
## GDP                                                 0.446855511  0.46794697
## Population                                         -0.008132466 -0.04031242
## thinness..1.19.years                               -0.453678854 -0.49119921
## thinness.5.9.years                                 -0.438483721 -0.47248203
## Income.composition.of.resources                     1.000000000  0.78474058
## Schooling                                           0.784740581  1.00000000
```

`Life.expectancy` has a somewhat strong positive correlation with `Income.composition.of.resources` and `Schooling`.
`Life.expectancy` has a negative correlation with `Adult.Mortality`, which makes sense since if the mortality rate of adult is high, then obviously life expectancy will be low.
`Life.expectancy` has a very weak correlation with `Measles` and `Population`.

There is a very strong correlation between `infant.deaths` and `under.five.deaths`, indicating multicollinearity between them. Therefore, we will remove `under.five.deaths` for building the model.

```
life = life[, !(names(life) %in% c('under.five.deaths'))]
```

Model Building

Build Linear Regression Model using all the remaining variables.

```
lmod = lm(Life.expectancy~., data=life)
summary(lmod)
```

```
##
## Call:
## lm(formula = Life.expectancy ~ ., data = life)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
```

```
## -17.0291  -2.1529   0.0557   2.3893  11.5018
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     5.584e+01  8.661e-01  64.479  < 2e-16 ***
## StatusDeveloping               -9.815e-01  3.464e-01  -2.834  0.00466 **
## Adult.Mortality                -1.780e-02  9.674e-04 -18.399  < 2e-16 ***
## infant.deaths                  -3.007e-03  1.266e-03  -2.376  0.01762 *
## Alcohol                        -1.552e-01  3.380e-02  -4.590 4.77e-06 ***
## percentage.expenditure          3.491e-04  1.862e-04   1.875  0.06094 .
## Hepatitis.B90% Covered          6.372e-01  3.192e-01   1.996  0.04611 *
## Measles                         1.683e-05  1.079e-05   1.560  0.11906
## BMI                             3.585e-02  6.161e-03   5.819 7.13e-09 ***
## Polio90% Covered               -5.680e-01  4.439e-01  -1.280  0.20087
## Total.expenditure               6.994e-02  4.179e-02   1.674  0.09439 .
## Diphtheria90% Covered          -9.097e-01  4.899e-01  -1.857  0.06352 .
## HIV.AIDS                       -4.279e-01  1.849e-02 -23.142  < 2e-16 ***
## GDP                             9.181e-06  2.925e-05   0.314  0.75368
## Population                      2.496e-09  1.766e-09   1.414  0.15769
## thinness..1.19.years           -5.018e-02  5.469e-02  -0.918  0.35899
## thinness.5.9.years              1.519e-03  5.374e-02   0.028  0.97745
## Income.composition.of.resources  1.048e+01  8.507e-01  12.316  < 2e-16 ***
## Schooling                       8.843e-01  6.172e-02  14.328  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.686 on 1630 degrees of freedom
## Multiple R-squared:  0.8263, Adjusted R-squared:  0.8244
## F-statistic: 430.9 on 18 and 1630 DF,  p-value: < 2.2e-16
```

The p-value of the model is <0.05, indicating that it is significant.
From the model we can interpret that `StatusDeveloping`, `Adult.Mortality`, `infant.deaths`, `Alcohol`, `HIV.AIDS`, and `thinness..1.19.years` may have a negative effect on life expectancy.
From the model we can interpret that `Income.composition.of.resources` has a strong positive effect on life expectancy.
A peculiar result we can interpret from the model is that `Hepatitis.B90% Covered` and `Schooling` also have a negative effect on life expectancy.
The Adj R-squared value of the model is 0.8244, indicating that about 82.44% of the observed variation can be explained by the variables in the model, which is quite a good result and can be improved even further with model selection. `Adult.Mortality`, `Alcohol`, `BMI`, `HIV.AIDS`, `Income.composition.of.resources` and `Schooling` are the most significant variables with p-value < 0.5.

Model Selection

Build Model using Forward Selection Method.

```
ols_step_forward_p(lmod)
```

```
##
##                                       Selection Summary
## ------------------------------------------------------------------------------------------------
##         Variable                                    Adj.
## Step                Entered                R-Square    R-Square      C(p)          AIC         RMSE
## ------------------------------------------------------------------------------------------------
##    1    Schooling                             0.5294      0.5292    2771.7513    10612.7157    6.0362
```

```
##    2    HIV.AIDS                          0.7304      0.7301     887.6286     9696.3271    4.5704
##    3    Adult.Mortality                   0.7871      0.7867     357.3801     9308.9473    4.0627
##    4    Income.composition.of.resources   0.8092      0.8087     152.1307     9130.3986    3.8474
##    5    percentage.expenditure            0.8147      0.8141     102.1617     9083.8457    3.7924
##    6    BMI                               0.8201      0.8194      54.0203     9037.6049    3.7384
##    7    Diphtheria                        0.8218      0.8211      39.2920     9023.1915    3.7210
##    8    Alcohol                           0.8231      0.8222      29.5343     9013.5567    3.7090
##    9    thinness..1.19.years              0.8240      0.8230      22.9694     9007.0292    3.7006
##   10    Status                            0.8249      0.8238      16.6366     9000.6904    3.6924
##   11    Hepatitis.B                       0.8252      0.8240      15.5038     8999.5443    3.6900
##   12    Total.expenditure                 0.8255      0.8242      14.8813     8998.9062    3.6881
##   13    infant.deaths                     0.8257      0.8243      14.8516     8998.8614    3.6870
##   14    Measles                           0.8259      0.8244      14.7734     8998.7652    3.6858
##   15    Population                        0.8262      0.8246      14.7661     8998.7380    3.6846
##   16    Polio                             0.8263      0.8246      15.0990     8999.0524    3.6839
## ----------------------------------------------------------------------------------------------
```

Build Model using Backward Elimination Method.

```
lmod_backward = ols_step_backward_p(lmod)
lmod_backward
```

```
##
##
##                                Elimination Summary
## ------------------------------------------------------------------------------------
##         Variable                            Adj.
## Step         Removed          R-Square    R-Square     C(p)         AIC         RMSE
## ------------------------------------------------------------------------------------
##    1    thinness.5.9.years      0.8263      0.8245    17.0008    9000.9530    3.6849
##    2    GDP                     0.8263      0.8246    15.0990    8999.0524    3.6839
## ------------------------------------------------------------------------------------
```

Build Model using Stepwise Selection Method.

```
lmod_stepwise = ols_step_both_p(lmod)
lmod_stepwise
```

```
##
##                                      Stepwise Selection Summary
## ------------------------------------------------------------------------------------------------
##                                          Added/                   Adj.
## Step               Variable              Removed     R-Square    R-Square      C(p)          AIC
## ------------------------------------------------------------------------------------------------
##    1               Schooling             addition       0.529       0.529    2771.7510    10612.715
##    2               HIV.AIDS              addition       0.730       0.730     887.6290     9696.327
##    3           Adult.Mortality           addition       0.787       0.787     357.3800     9308.947
##    4    Income.composition.of.resources  addition       0.809       0.809     152.1310     9130.398
##    5        percentage.expenditure       addition       0.815       0.814     102.1620     9083.845
##    6                   BMI               addition       0.820       0.819      54.0200     9037.604
##    7              Diphtheria             addition       0.822       0.821      39.2920     9023.191
##    8                Alcohol              addition       0.823       0.822      29.5340     9013.550
##    9         thinness..1.19.years        addition       0.824       0.823      22.9690     9007.029
##   10                Status               addition       0.825       0.824      16.6370     9000.690
##   11             Hepatitis.B             addition       0.825       0.824      15.5040     8999.544
## ------------------------------------------------------------------------------------------------
```

Build Model using All Possible Regressions Method.

```
#ols_step_all_possible(lmod, sbc = TRUE)
```

Model chosen by Forward Selection Method: Schooling, HIV.AIDS, Adult.Mortality, Income.composition.of.resources, percentage.expenditure, BMI, Diphtheria, Alcohol, thinness..1.19.years, Status, Hepatitis.B, Total.expenditure, infant.deaths, Measles, Population, Polio.
Model chosen by Backward Elimination Method: StatusDeveloping, Adult.Mortality, infant.deaths, Alcohol, percentage.expenditure, HepatitisB90% Covered, Measles, BMI, Polio90% Covered, Total.expenditure, Diphtheria90% Covered, HIV.AIDS, Population, thinness..1.19.years, Income.composition.of.resources, Schooling.
Model chosen by Stepwise Selection Method: Schooling, HIV.AIDS, Adult.Mortality, Income.compsition.resources, percentage.expenditure, BMI, Diphtheria, Alcohol, thinness..1.19.years, Status, Hepatitis.B.

```
lmod_forward = lm(
  Life.expectancy ~  Schooling + HIV.AIDS + Adult.Mortality + Income.composition.of.resources + percenta
    BMI + Diphtheria + Alcohol + thinness..1.19.years + Status + Hepatitis.B +
    Total.expenditure + infant.deaths + Measles + Population + Polio,
  data = life
)
summary(lmod_forward)
```

```
##
## Call:
## lm(formula = Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality +
##     Income.composition.of.resources + percentage.expenditure +
##     BMI + Diphtheria + Alcohol + thinness..1.19.years + Status +
##     Hepatitis.B + Total.expenditure + infant.deaths + Measles +
##     Population + Polio, data = life)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -17.0291  -2.1512   0.0485   2.3846  11.4744
##
## Coefficients:
##                                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      5.584e+01  8.654e-01  64.527  < 2e-16 ***
## Schooling                        8.858e-01  6.141e-02  14.426  < 2e-16 ***
## HIV.AIDS                        -4.279e-01  1.848e-02 -23.157  < 2e-16 ***
## Adult.Mortality                 -1.779e-02  9.656e-04 -18.428  < 2e-16 ***
## Income.composition.of.resources  1.050e+01  8.481e-01  12.378  < 2e-16 ***
## percentage.expenditure           4.043e-04  6.128e-05   6.597 5.64e-11 ***
## BMI                              3.579e-02  6.096e-03   5.871 5.24e-09 ***
## Diphtheria90% Covered           -9.024e-01  4.888e-01  -1.846  0.06505 .
## Alcohol                         -1.551e-01  3.378e-02  -4.591 4.75e-06 ***
## thinness..1.19.years            -4.903e-02  2.788e-02  -1.758  0.07885 .
## StatusDeveloping                -9.882e-01  3.454e-01  -2.861  0.00428 **
## Hepatitis.B90% Covered           6.299e-01  3.180e-01   1.981  0.04780 *
## Total.expenditure                6.940e-02  4.169e-02   1.664  0.09621 .
## infant.deaths                   -2.996e-03  1.259e-03  -2.379  0.01746 *
## Measles                          1.682e-05  1.077e-05   1.561  0.11869
## Population                       2.486e-09  1.764e-09   1.409  0.15892
## Polio90% Covered                -5.728e-01  4.433e-01  -1.292  0.19657
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 3.684 on 1632 degrees of freedom
## Multiple R-squared:  0.8263, Adjusted R-squared:  0.8246
## F-statistic: 485.3 on 16 and 1632 DF,  p-value: < 2.2e-16
```

```
lmod_backward = lm(
  Life.expectancy ~ Status + Adult.Mortality + infant.deaths + Alcohol +
    percentage.expenditure + Hepatitis.B + Measles + BMI + Polio + Total.expenditure +
    Diphtheria + HIV.AIDS + Population + thinness..1.19.years + Income.composition.of.resources +
    Schooling,
  data = life
)
summary(lmod_backward)
```

```
##
## Call:
## lm(formula = Life.expectancy ~ Status + Adult.Mortality + infant.deaths +
##     Alcohol + percentage.expenditure + Hepatitis.B + Measles +
##     BMI + Polio + Total.expenditure + Diphtheria + HIV.AIDS +
##     Population + thinness..1.19.years + Income.composition.of.resources +
##     Schooling, data = life)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -17.0291  -2.1512   0.0485   2.3846  11.4744
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     5.584e+01  8.654e-01  64.527  < 2e-16 ***
## StatusDeveloping               -9.882e-01  3.454e-01  -2.861  0.00428 **
## Adult.Mortality                -1.779e-02  9.656e-04 -18.428  < 2e-16 ***
## infant.deaths                  -2.996e-03  1.259e-03  -2.379  0.01746 *
## Alcohol                        -1.551e-01  3.378e-02  -4.591 4.75e-06 ***
## percentage.expenditure          4.043e-04  6.128e-05   6.597 5.64e-11 ***
## Hepatitis.B90% Covered          6.299e-01  3.180e-01   1.981  0.04780 *
## Measles                         1.682e-05  1.077e-05   1.561  0.11869
## BMI                             3.579e-02  6.096e-03   5.871 5.24e-09 ***
## Polio90% Covered               -5.728e-01  4.433e-01  -1.292  0.19657
## Total.expenditure               6.940e-02  4.169e-02   1.664  0.09621 .
## Diphtheria90% Covered          -9.024e-01  4.888e-01  -1.846  0.06505 .
## HIV.AIDS                       -4.279e-01  1.848e-02 -23.157  < 2e-16 ***
## Population                      2.486e-09  1.764e-09   1.409  0.15892
## thinness..1.19.years           -4.903e-02  2.788e-02  -1.758  0.07885 .
## Income.composition.of.resources  1.050e+01  8.481e-01  12.378  < 2e-16 ***
## Schooling                       8.858e-01  6.141e-02  14.426  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.684 on 1632 degrees of freedom
## Multiple R-squared:  0.8263, Adjusted R-squared:  0.8246
## F-statistic: 485.3 on 16 and 1632 DF,  p-value: < 2.2e-16
```

```
lmod_stepwise = lm(
  Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.composition.of.resources +
    percentage.expenditure + BMI + Diphtheria + Alcohol + thinness..1.19.years +
```

```
    Status + Hepatitis.B,
  data = life
)
summary(lmod_stepwise)
```

```
##
## Call:
## lm(formula = Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality +
##     Income.composition.of.resources + percentage.expenditure +
##     BMI + Diphtheria + Alcohol + thinness..1.19.years + Status +
##     Hepatitis.B, data = life)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -17.2593  -2.1481   0.0745   2.4046  11.5838
##
## Coefficients:
##                                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      5.622e+01  8.257e-01  68.088  < 2e-16 ***
## Schooling                        9.061e-01  6.102e-02  14.848  < 2e-16 ***
## HIV.AIDS                        -4.239e-01  1.833e-02 -23.122  < 2e-16 ***
## Adult.Mortality                 -1.779e-02  9.636e-04 -18.464  < 2e-16 ***
## Income.composition.of.resources  1.037e+01  8.444e-01  12.280  < 2e-16 ***
## percentage.expenditure           4.098e-04  6.119e-05   6.698 2.90e-11 ***
## BMI                              3.610e-02  6.071e-03   5.946 3.36e-09 ***
## Diphtheria90% Covered           -1.439e+00  3.443e-01  -4.181 3.05e-05 ***
## Alcohol                         -1.605e-01  3.353e-02  -4.788 1.84e-06 ***
## thinness..1.19.years            -7.223e-02  2.491e-02  -2.900  0.00378 **
## StatusDeveloping                -1.014e+00  3.454e-01  -2.934  0.00339 **
## Hepatitis.B90% Covered           5.567e-01  3.149e-01   1.768  0.07723 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.69 on 1637 degrees of freedom
## Multiple R-squared:  0.8252, Adjusted R-squared:  0.824
## F-statistic: 702.7 on 11 and 1637 DF,  p-value: < 2.2e-16
```

Adj. R-squared values of above models:

```
data.frame(
  model = c('lmod', 'lmod_forward', 'lmod_backward', 'lmod_stepwise'),
  AdjRsquare = c(
    summary(lmod)$adj.r.square,
    summary(lmod_forward)$adj.r.square,
    summary(lmod_backward)$adj.r.square,
    summary(lmod_stepwise)$adj.r.square
  )
)
```

```
##           model AdjRsquare
## 1          lmod  0.8244244
## 2  lmod_forward  0.8246289
## 3 lmod_backward  0.8246289
## 4 lmod_stepwise  0.8240486
```

We will be choosing the model chosen by Forward Selection method `lmod_forward` as it has the highest Adj.

R-squared value.

```
lmod_final = lmod_forward
summary(lmod_final)
```

```
##
## Call:
## lm(formula = Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality +
##     Income.composition.of.resources + percentage.expenditure +
##     BMI + Diphtheria + Alcohol + thinness..1.19.years + Status +
##     Hepatitis.B + Total.expenditure + infant.deaths + Measles +
##     Population + Polio, data = life)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -17.0291  -2.1512   0.0485   2.3846  11.4744
##
## Coefficients:
##                                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      5.584e+01  8.654e-01  64.527  < 2e-16 ***
## Schooling                        8.858e-01  6.141e-02  14.426  < 2e-16 ***
## HIV.AIDS                        -4.279e-01  1.848e-02 -23.157  < 2e-16 ***
## Adult.Mortality                 -1.779e-02  9.656e-04 -18.428  < 2e-16 ***
## Income.composition.of.resources  1.050e+01  8.481e-01  12.378  < 2e-16 ***
## percentage.expenditure           4.043e-04  6.128e-05   6.597 5.64e-11 ***
## BMI                              3.579e-02  6.096e-03   5.871 5.24e-09 ***
## Diphtheria90% Covered           -9.024e-01  4.888e-01  -1.846  0.06505 .
## Alcohol                         -1.551e-01  3.378e-02  -4.591 4.75e-06 ***
## thinness..1.19.years            -4.903e-02  2.788e-02  -1.758  0.07885 .
## StatusDeveloping                -9.882e-01  3.454e-01  -2.861  0.00428 **
## Hepatitis.B90% Covered           6.299e-01  3.180e-01   1.981  0.04780 *
## Total.expenditure                6.940e-02  4.169e-02   1.664  0.09621 .
## infant.deaths                   -2.996e-03  1.259e-03  -2.379  0.01746 *
## Measles                          1.682e-05  1.077e-05   1.561  0.11869
## Population                       2.486e-09  1.764e-09   1.409  0.15892
## Polio90% Covered                -5.728e-01  4.433e-01  -1.292  0.19657
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.684 on 1632 degrees of freedom
## Multiple R-squared:  0.8263, Adjusted R-squared:  0.8246
## F-statistic: 485.3 on 16 and 1632 DF,  p-value: < 2.2e-16
```

Model Error Estimation

```
result = predict(lmod_final, life)
```

Mean Squared Error:

```
mse = mean((life$Life.expectancy - result)^2)
mse
```

```
## [1] 13.43106
```

Root Mean Squared Error:

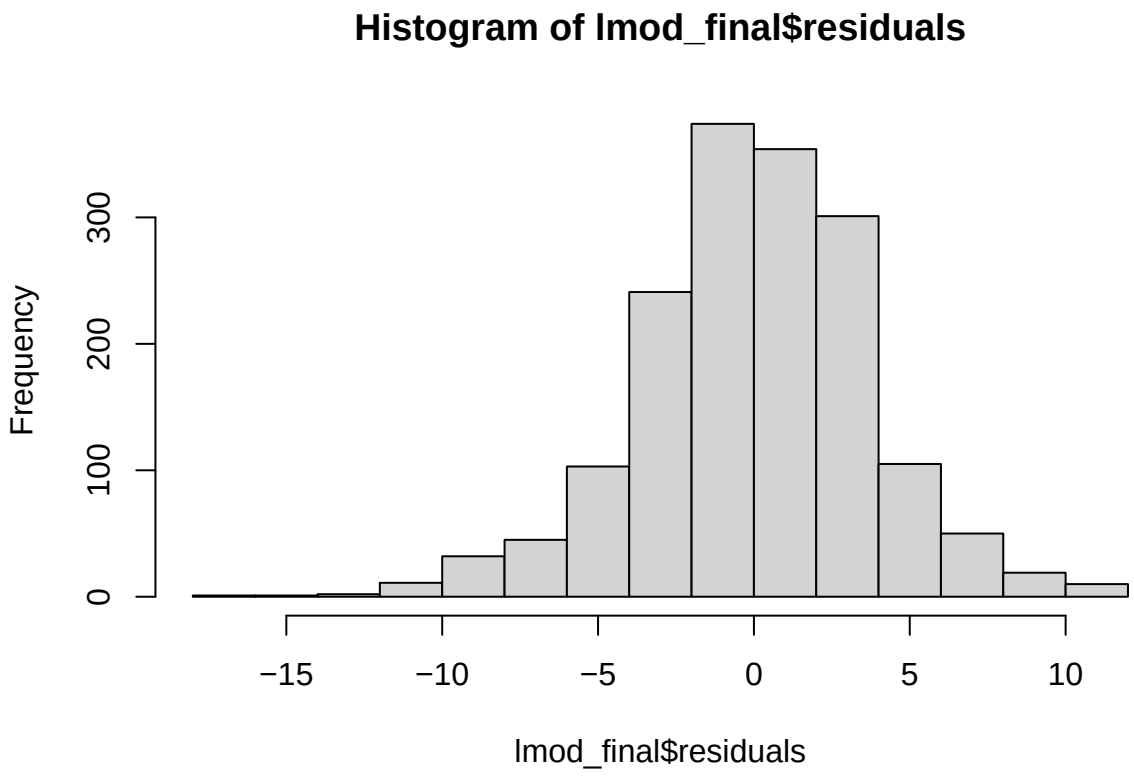
```
rmse = sqrt(mse)
rmse
```

```
## [1] 3.664841
```

Model Adequacy Checking

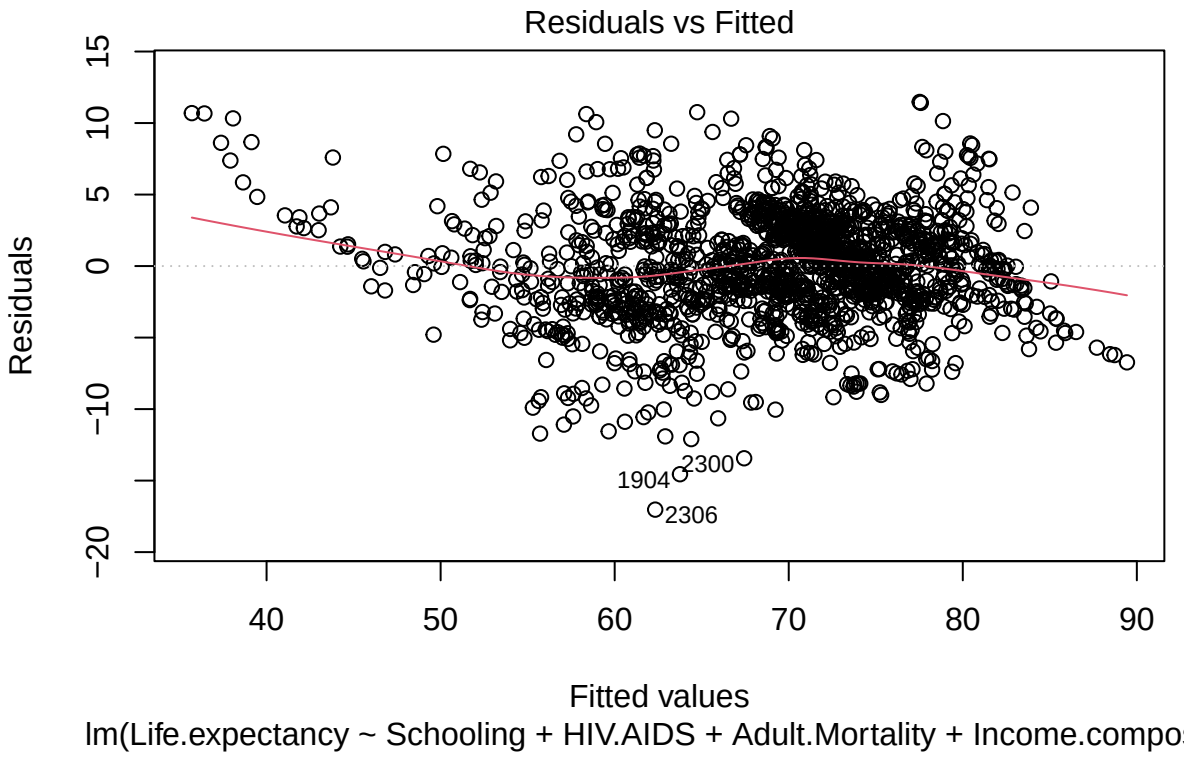
Normality Testing:

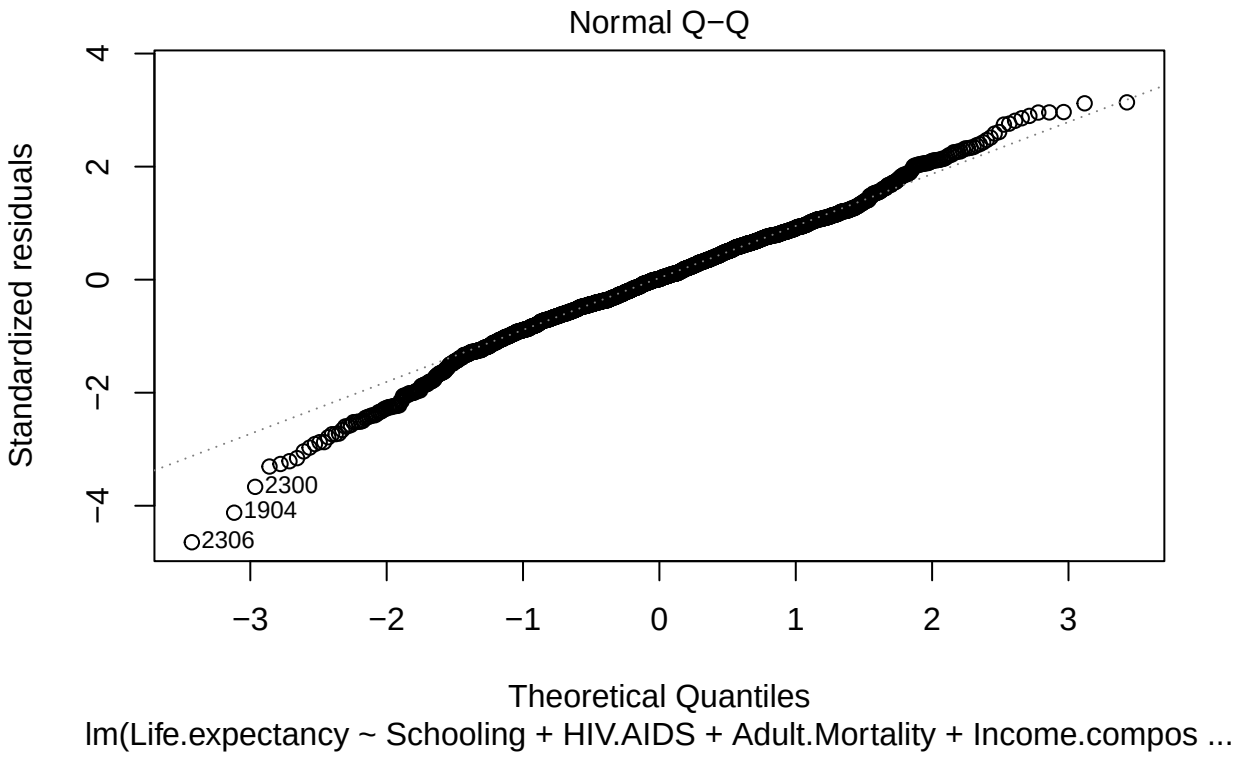
```
hist(lmod_final$residuals, breaks = 20)
```

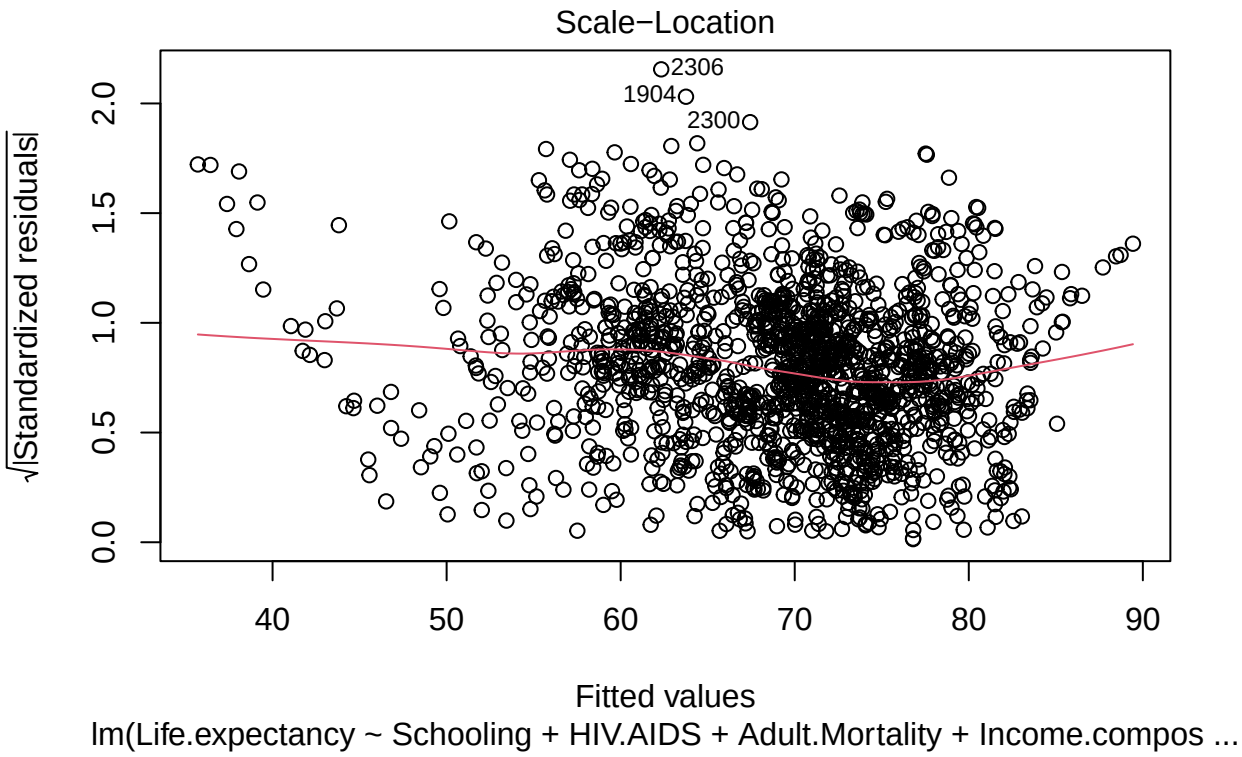


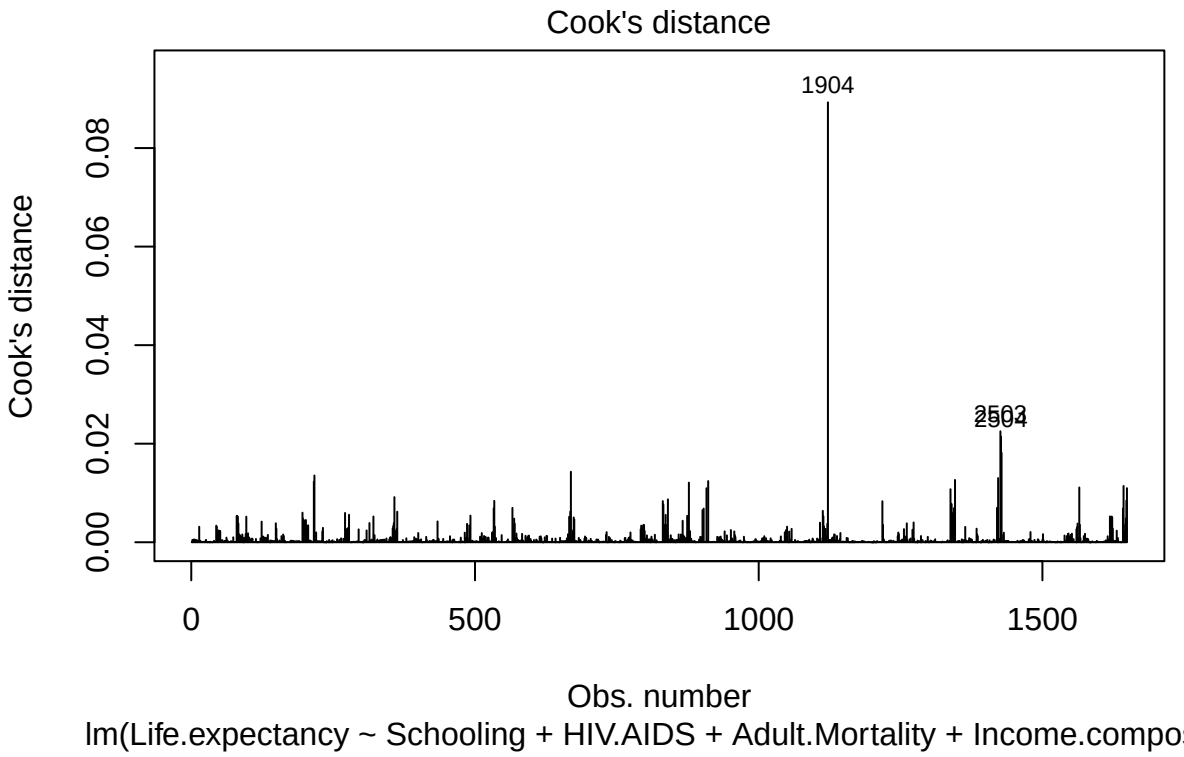
Most of the residuals seem to be distributed in the center, indicating that they are distributed normally.

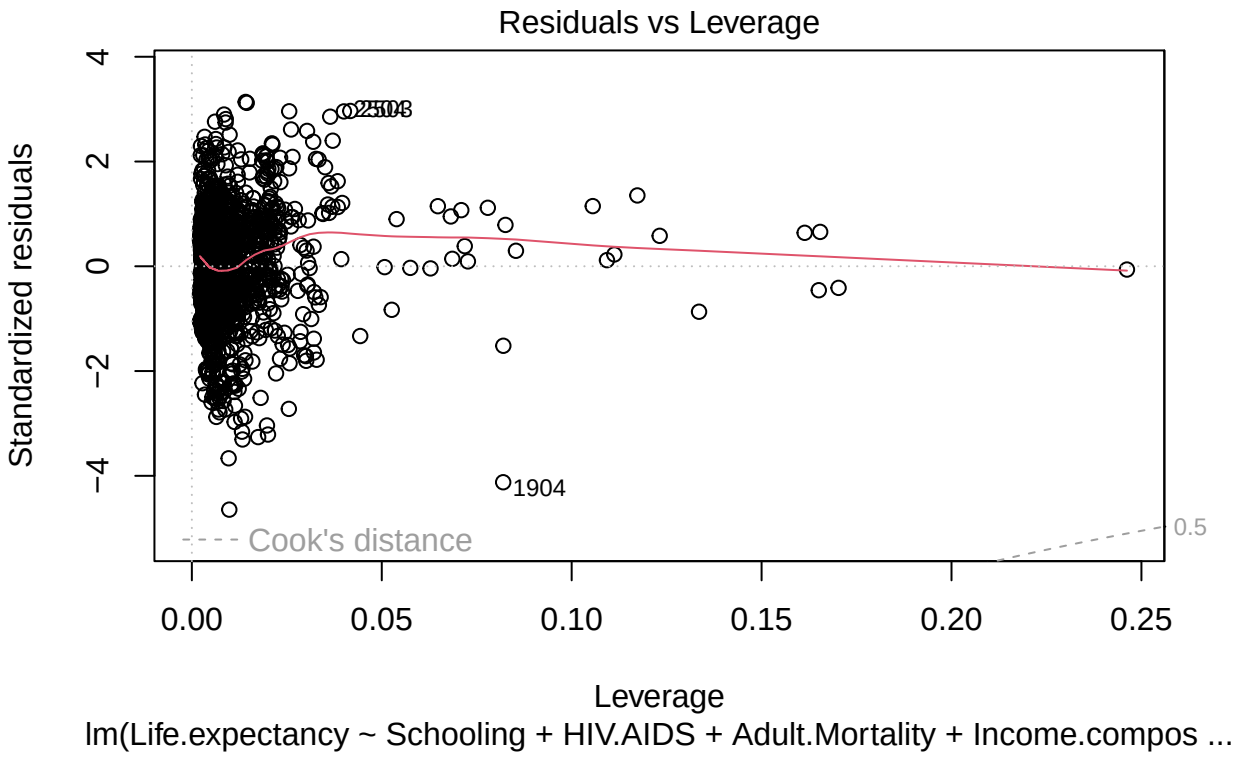
```
plot(lmod_final, which = c(1:6))
```

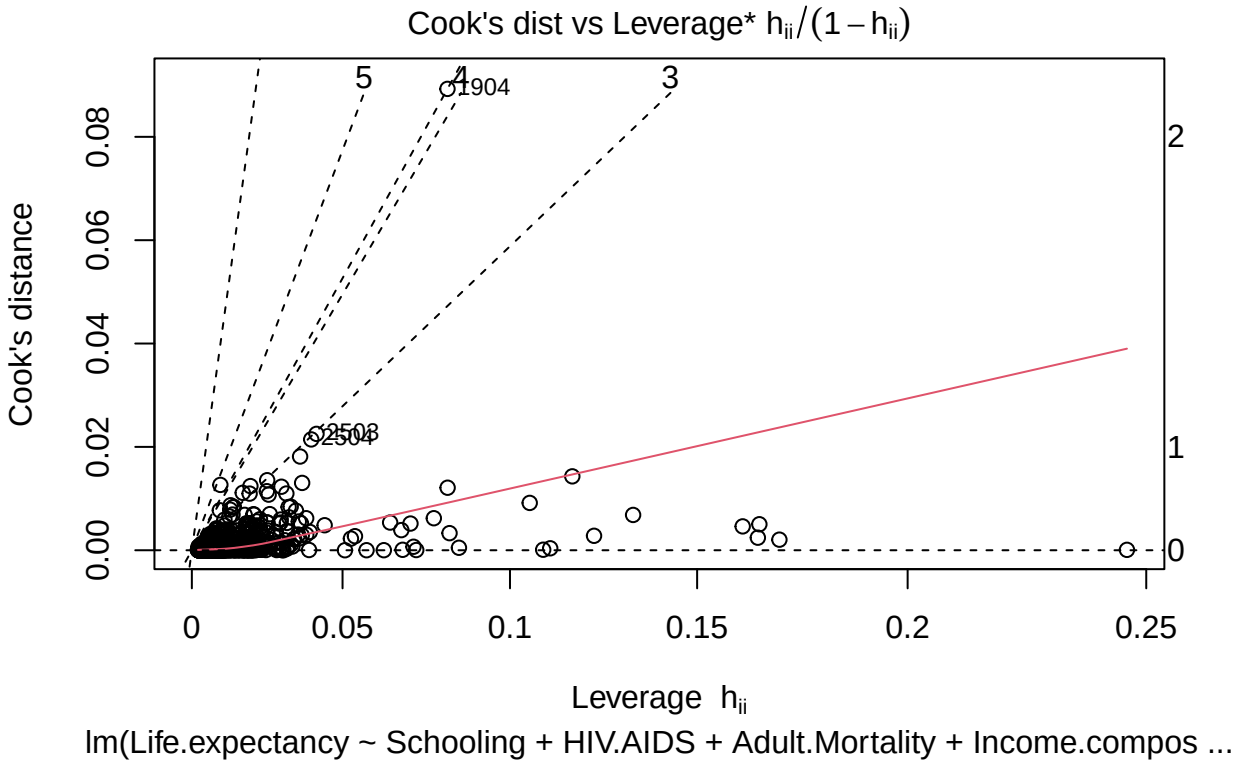

Residuals vs Fitted
Residuals
15
10
5
0
−10
−20
40
50
60
70
80
90
2300
1904
2306
Fitted values
lm(Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.compos ...


Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.compos ...
2300
1904
2306
4
2
0
−2
−4
−3
−2
−1
0
1
2
3


Scale−Location
2306
1904
2300
√|Standardized residuals|
0.0
0.5
1.0
1.5
2.0
40
50
60
70
80
90
Fitted values
lm(Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.compos ...


Cook's distance
1904
2503
2504
Cook's distance
0.00
0.02
0.04
0.06
0.08
0
500
1000
1500
Obs. number
lm(Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.compos ...


Residuals vs Leverage
Standardized residuals
4
2
0
−2
−4
2504
1904
Cook's distance
0.5
0.00
0.05
0.10
0.15
0.20
0.25
Leverage
lm(Life.expectancy ~ Schooling + HIV.AIDS + Adult.Mortality + Income.compos ...



Multicollinearity Test:

```
vif(lmod_final)
```

```
##                       Schooling                        HIV.AIDS
##                        3.578091                        1.509013
##                Adult.Mortality Income.composition.of.resources
##                        1.778090                        2.927679
##          percentage.expenditure                             BMI
##                        1.411270                        1.761017
##                      Diphtheria                         Alcohol
##                        7.102613                        2.249650
##            thinness..1.19.years                          Status
##                        1.996547                        1.815140
##                     Hepatitis.B                Total.expenditure
##                        3.072344                        1.116175
##                   infant.deaths                         Measles
##                        2.811727                        1.433389
##                      Population                           Polio
##                        1.876386                        5.834447
```

A VIF > 10 implies serious problems with multicollinearity.
Since the VIF for all of the predictors is less than 10, there seems to be no issue with multicollinearity.