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Question 1-Reproduce the results

> state.x77 # output not shown

	Population	Income	Illiteracy	Life Exp	Murder	HS Grad
Alabama	3615	3624	2.1	69.05	15.1	41.3
Alaska	365	6315	1.5	69.31	11.3	66.7
Arizona	2212	4530	1.8	70.55	7.8	58.1
Arkansas	2110	3378	1.9	70.66	10.1	39.9
California	21198	5114	1.1	71.71	10.3	62.6
Colorado	2541	4884	0.7	72.06	6.8	63.9
Connecticut	3100	5348	1.1	72.48	3.1	56.0
Delaware	579	4809	0.9	70.06	6.2	54.6
Florida	8277	4815	1.3	70.66	10.7	52.6
Georgia	4931	4091	2.0	68.54	13.9	40.6
Hawaii	868	4963	1.9	73.60	6.2	61.9
Idaho	813	4119	0.6	71.87	5.3	59.5
Illinois	11197	5107	0.9	70.14	10.3	52.6
Indiana	5313	4458	0.7	70.88	7.1	52.9
Iowa	2861	4628	0.5	72.56	2.3	59.0
Kansas	2280	4669	0.6	72.58	4.5	59.9
Kentucky	3387	3712	1.6	70.10	10.6	38.5
Louisiana	3806	3545	2.8	68.76	13.2	42.2
Maine	1058	3694	0.7	70.39	2.7	54.7
Maryland	4122	5299	0.9	70.22	8.5	52.3
Massachusetts	5814	4755	1.1	71.83	3.3	58.5
Michigan	9111	4751	0.9	70.63	11.1	52.8
Minnesota	3921	4675	0.6	72.96	2.3	57.6

Mississippi	2341	3098	2.4	68.09	12.5	41.0
Missouri	4767	4254	0.8	70.69	9.3	48.8
Montana	746	4347	0.6	70.56	5.0	59.2
Nebraska	1544	4508	0.6	72.60	2.9	59.3
Nevada	590	5149	0.5	69.03	11.5	65.2
New Hampshire	812	4281	0.7	71.23	3.3	57.6
New Jersey	7333	5237	1.1	70.93	5.2	52.5
New Mexico	1144	3601	2.2	70.32	9.7	55.2
New York	18076	4903	1.4	70.55	10.9	52.7
North Carolina	5441	3875	1.8	69.21	11.1	38.5
North Dakota	637	5087	0.8	72.78	1.4	50.3
Ohio	10735	4561	0.8	70.82	7.4	53.2
Oklahoma	2715	3983	1.1	71.42	6.4	51.6
Oregon	2284	4660	0.6	72.13	4.2	60.0
Pennsylvania	11860	4449	1.0	70.43	6.1	50.2
Rhode Island	931	4558	1.3	71.90	2.4	46.4
South Carolina	2816	3635	2.3	67.96	11.6	37.8
South Dakota	681	4167	0.5	72.08	1.7	53.3
Tennessee	4173	3821	1.7	70.11	11.0	41.8
Texas	12237	4188	2.2	70.90	12.2	47.4
Utah	1203	4022	0.6	72.90	4.5	67.3
Vermont	472	3907	0.6	71.64	5.5	57.1
Virginia	4981	4701	1.4	70.08	9.5	47.8
Washington	3559	4864	0.6	71.72	4.3	63.5
West Virginia	1799	3617	1.4	69.48	6.7	41.6
Wisconsin	4589	4468	0.7	72.48	3.0	54.5
Wyoming	376	4566	0.6	70.29	6.9	62.9

	Frost	Area
Alabama	20	50708

Alaska	152	566432
Arizona	15	113417
Arkansas	65	51945
California	20	156361
Colorado	166	103766
Connecticut	139	4862
Delaware	103	1982
Florida	11	54090
Georgia	60	58073
Hawaii	0	6425
Idaho	126	82677
Illinois	127	55748
Indiana	122	36097
Iowa	140	55941
Kansas	114	81787
Kentucky	95	39650
Louisiana	12	44930
Maine	161	30920
Maryland	101	9891
Massachusetts	103	7826
Michigan	125	56817
Minnesota	160	79289
Mississippi	50	47296
Missouri	108	68995
Montana	155	145587
Nebraska	139	76483
Nevada	188	109889
New Hampshire	174	9027
New Jersey	115	7521

```
New Mexico       120 121412
New York          82  47831
North Carolina    80  48798
North Dakota     186  69273
Ohio             124  40975
Oklahoma          82  68782
Oregon            44  96184
Pennsylvania     126  44966
Rhode Island     127   1049
South Carolina    65  30225
South Dakota     172  75955
Tennessee         70  41328
Texas             35 262134
Utah             137  82096
Vermont          168   9267
Virginia          85  39780
Washington        32  66570
West Virginia    100  24070
Wisconsin        149  54464
Wyoming          173  97203
> str(state.x77)                    # clearly not a data frame!
 num [1:50, 1:8] 3615 365 2212 2110 21198 ...
 - attr(*, "dimnames")=List of 2
  ..$ : chr [1:50] "Alabama" "Alaska" "Arizona" "Arkansas" ...
  ..$ : chr [1:8] "Population" "Income" "Illiteracy" "Life Exp" ...
> st = as.data.frame(state.x77)       # so we'll make it one
> str(st)
'data.frame':    50 obs. of  8 variables:
 $ Population: num  3615 365 2212 2110 21198 ...
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 $ Income    : num  3624 6315 4530 3378 5114 ...
 $ Illiteracy: num  2.1 1.5 1.8 1.9 1.1 0.7 1.1 0.9 1.3 2 ...
 $ Life Exp  : num  69 69.3 70.5 70.7 71.7 ...
 $ Murder    : num  15.1 11.3 7.8 10.1 10.3 6.8 3.1 6.2 10.7 13.9 ...
 $ HS Grad   : num  41.3 66.7 58.1 39.9 62.6 63.9 56 54.6 52.6 40.6 ...
 $ Frost     : num  20 152 15 65 20 166 139 103 11 60 ...
 $ Area      : num  50708 566432 113417 51945 156361 ...
> colnames(st)[4] = "Life.Exp"        # no spaces in variable names, please
> colnames(st)[6] = "HS.Grad"
> st[,9] = st$Population * 1000 / st$Area
> colnames(st)[9] = "Density"         # create and name a new column
> str(st)
'data.frame':	50 obs. of  9 variables:
 $ Population: num  3615 365 2212 2110 21198 ...
 $ Income    : num  3624 6315 4530 3378 5114 ...
 $ Illiteracy: num  2.1 1.5 1.8 1.9 1.1 0.7 1.1 0.9 1.3 2 ...
 $ Life.Exp  : num  69 69.3 70.5 70.7 71.7 ...
 $ Murder    : num  15.1 11.3 7.8 10.1 10.3 6.8 3.1 6.2 10.7 13.9 ...
 $ HS.Grad   : num  41.3 66.7 58.1 39.9 62.6 63.9 56 54.6 52.6 40.6 ...
 $ Frost     : num  20 152 15 65 20 166 139 103 11 60 ...
 $ Area      : num  50708 566432 113417 51945 156361 ...
 $ Density   : num  71.291 0.644 19.503 40.62 135.571 ...
> summary(st)
   Population       Income       Illiteracy       Life.Exp
 Min.   :  365   Min.   :3098   Min.   :0.500   Min.   :67.96
 1st Qu.: 1080   1st Qu.:3993   1st Qu.:0.625   1st Qu.:70.12
 Median : 2838   Median :4519   Median :0.950   Median :70.67
 Mean   : 4246   Mean   :4436   Mean   :1.170   Mean   :70.88
 3rd Qu.: 4968   3rd Qu.:4814   3rd Qu.:1.575   3rd Qu.:71.89
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 Max.   :21198   Max.   :6315   Max.   :2.800   Max.   :73.60  
     Murder          HS.Grad          Frost             Area       
 Min.   : 1.400   Min.   :37.80   Min.   :  0.00   Min.   :  1049  
 1st Qu.: 4.350   1st Qu.:48.05   1st Qu.: 66.25   1st Qu.: 36985  
 Median : 6.850   Median :53.25   Median :114.50   Median : 54277  
 Mean   : 7.378   Mean   :53.11   Mean   :104.46   Mean   : 70736  
 3rd Qu.:10.675   3rd Qu.:59.15   3rd Qu.:139.75   3rd Qu.: 81162  
 Max.   :15.100   Max.   :67.30   Max.   :188.00   Max.   :566432  
    Density        
 Min.   :  0.6444  
 1st Qu.: 25.3352  
 Median : 73.0154  
 Mean   :149.2245  
 3rd Qu.:144.2828  
 Max.   :975.0033  
> cor(st)                         # correlation matrix
            Population     Income   Illiteracy    Life.Exp     Murder
Population  1.00000000  0.2082276  0.107622373 -0.06805195  0.3436428
Income      0.20822756  1.0000000 -0.437075186  0.34025534 -0.2300776
Illiteracy  0.10762237 -0.4370752  1.000000000 -0.58847793  0.7029752
Life.Exp   -0.06805195  0.3402553 -0.588477926  1.00000000 -0.7808458
Murder      0.34364275 -0.2300776  0.702975199 -0.78084575  1.0000000
HS.Grad    -0.09848975  0.6199323 -0.657188609  0.58221620 -0.4879710
Frost      -0.33215245  0.2262822 -0.671946968  0.26206801 -0.5388834
Area        0.02254384  0.3633154  0.077261132 -0.10733194  0.2283902
Density     0.24622789  0.3299683  0.009274348  0.09106176 -0.1850352
               HS.Grad       Frost        Area      Density
Population -0.09848975 -0.332152454  0.02254384  0.246227888
Income      0.61993232  0.226282179  0.36331544  0.329968277
```

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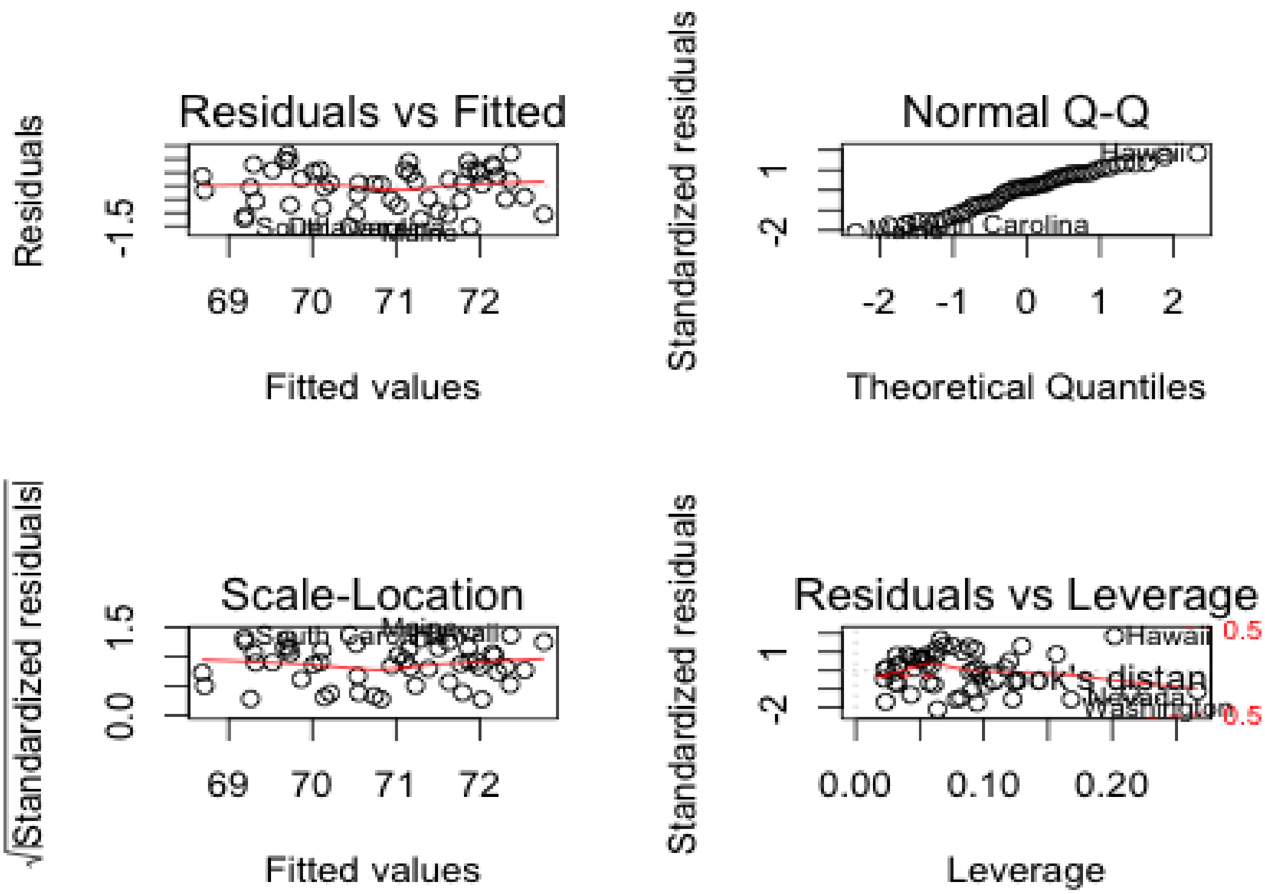
Illiteracy -0.65718861 -0.671946968  0.07726113  0.009274348
Life.Exp    0.58221620  0.262068011 -0.10733194  0.091061763
Murder     -0.48797102 -0.538883437  0.22839021 -0.185035233
HS.Grad     1.00000000  0.366779702  0.33354187 -0.088367214
Frost       0.36677970  1.000000000  0.05922910  0.002276734
Area        0.33354187  0.059229102  1.00000000 -0.341388515
Density    -0.08836721  0.002276734 -0.34138851  1.000000000
> pairs(st)                        # scatterplot matrix
```

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> #The Maximal Model (Sans Interactions)
> options(show.signif.stars=F)        # I don't like significance stars!
```

```
> names(st)                    # for handy reference
[1] "Population" "Income"    "Illiteracy" "Life.Exp"   "Murder"
[6] "HS.Grad"    "Frost"     "Area"       "Density"
> model1 = lm(Life.Exp ~ Population + Income + Illiteracy + Murder +
+ +                    HS.Grad + Frost + Area + Density, data=st)
> summary(model1)

Call:
lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
   +HS.Grad + Frost + Area + Density, data = st)

Residuals:
    Min      1Q   Median      3Q     Max
-1.47514 -0.45887 -0.06352  0.59362  1.21823

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  6.995e+01  1.843e+00  37.956  < 2e-16
Population   6.480e-05  3.001e-05   2.159   0.0367
Income       2.701e-04  3.087e-04   0.875   0.3867
Illiteracy   3.029e-01  4.024e-01   0.753   0.4559
Murder      -3.286e-01  4.941e-02  -6.652 5.12e-08
HS.Grad      4.291e-02  2.332e-02   1.840   0.0730
Frost       -4.580e-03  3.189e-03  -1.436   0.1585
Area        -1.558e-06  1.914e-06  -0.814   0.4205
Density     -1.105e-03  7.312e-04  -1.511   0.1385

Residual standard error: 0.7337 on 41 degrees of freedom
Multiple R-squared:  0.7501,      Adjusted R-squared:  0.7013
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F-statistic: 15.38 on 8 and 41 DF,  p-value: 3.787e-10

> lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
+ HS.Grad + Frost + Area + Density, data = st)

Call:
lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
    HS.Grad + Frost + Area + Density, data = st)

Coefficients:
(Intercept)   Population      Income   Illiteracy      Murder
  6.995e+01    6.480e-05    2.701e-04    3.029e-01   -3.286e-01
    HS.Grad        Frost         Area      Density
  4.291e-02   -4.580e-03   -1.558e-06   -1.105e-03

> summary.aov(model1)
           Df Sum Sq Mean Sq F value   Pr(>F)
Population   1  0.409   0.409   0.760  0.38849
Income       1 11.595  11.595  21.541 3.53e-05
Illiteracy   1 19.421  19.421  36.081 4.23e-07
Murder       1 27.429  27.429  50.959 1.05e-08
HS.Grad      1  4.099   4.099   7.615  0.00861
Frost        1  2.049   2.049   3.806  0.05792
Area         1  0.001   0.001   0.002  0.96438
Density      1  1.229   1.229   2.283  0.13847
Residuals   41 22.068   0.538
> #The Minimal Adequate Model
> model2 = update(model1, .~.-Area)
> summary(model2)
```

```
Call:
lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
    HS.Grad + Frost + Density, data = st)

Residuals:
     Min       1Q   Median       3Q      Max
-1.50252 -0.40471 -0.06079  0.58682  1.43862

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.094e+01  1.378e+00  51.488  < 2e-16
Population   6.249e-05  2.976e-05   2.100   0.0418
Income       1.485e-04  2.690e-04   0.552   0.5840
Illiteracy   1.452e-01  3.512e-01   0.413   0.6814
Murder      -3.319e-01  4.904e-02  -6.768 3.12e-08
HS.Grad      3.746e-02  2.225e-02   1.684   0.0996
Frost       -5.533e-03  2.955e-03  -1.873   0.0681
Density     -7.995e-04  6.251e-04  -1.279   0.2079

Residual standard error: 0.7307 on 42 degrees of freedom
Multiple R-squared:  0.746,	Adjusted R-squared:  0.7037
F-statistic: 17.63 on 7 and 42 DF,  p-value: 1.173e-10

> lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
+ HS.Grad + Frost + Density, data = st)

Call:
lm(formula = Life.Exp ~ Population + Income + Illiteracy + Murder +
```

```
    HS.Grad + Frost + Density, data = st)

Coefficients:
(Intercept)   Population      Income   Illiteracy       Murder
  7.094e+01    6.249e-05    1.485e-04    1.452e-01   -3.319e-01
    HS.Grad        Frost      Density
  3.746e-02   -5.533e-03   -7.995e-04

> anova(model1, model2)
Analysis of Variance Table

Model 1: Life.Exp ~ Population + Income + Illiteracy + Murder + +HS.Grad +
    Frost + Area + Density
Model 2: Life.Exp ~ Population + Income + Illiteracy + Murder + HS.Grad +
    Frost + Density
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1     41 22.068
2     42 22.425 -1  -0.35639 0.6621 0.4205
> model3 = update(model2, .~.-Illiteracy)
> summary(model3)

Call:
lm(formula = Life.Exp ~ Population + Income + Murder + HS.Grad +
    Frost + Density, data = st)

Residuals:
     Min       1Q   Median       3Q      Max
-1.49555 -0.41246 -0.05336  0.58399  1.50535
```

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.131e+01  1.042e+00  68.420  < 2e-16
Population   5.811e-05  2.753e-05   2.110   0.0407
Income       1.324e-04  2.636e-04   0.502   0.6181
Murder      -3.208e-01  4.054e-02  -7.912 6.32e-10
HS.Grad      3.499e-02  2.122e-02   1.649   0.1065
Frost       -6.191e-03  2.465e-03  -2.512   0.0158
Density     -7.324e-04  5.978e-04  -1.225   0.2272

Residual standard error: 0.7236 on 43 degrees of freedom
Multiple R-squared:  0.745,	Adjusted R-squared:  0.7094
F-statistic: 20.94 on 6 and 43 DF,  p-value: 2.632e-11

> lm(formula = Life.Exp ~ Population + Income + Murder + HS.Grad +
+ Frost + Density, data = st)

Call:
lm(formula = Life.Exp ~ Population + Income + Murder + HS.Grad +
    Frost + Density, data = st)

Coefficients:
(Intercept)   Population      Income      Murder     HS.Grad
  7.131e+01    5.811e-05    1.324e-04   -3.208e-01    3.499e-02
      Frost      Density
 -6.191e-03   -7.324e-04

> model4 = update(model3, .~.-Income)
> summary(model4)
```

```
Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost +
    Density, data = st)

Residuals:
     Min       1Q   Median       3Q      Max
-1.56877 -0.40951 -0.04554  0.57362  1.54752

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.142e+01  1.011e+00  70.665  < 2e-16
Population   6.083e-05  2.676e-05   2.273  0.02796
Murder      -3.160e-01  3.910e-02  -8.083 3.07e-10
HS.Grad      4.233e-02  1.525e-02   2.776  0.00805
Frost       -5.999e-03  2.414e-03  -2.485  0.01682
Density     -5.864e-04  5.178e-04  -1.132  0.26360

Residual standard error: 0.7174 on 44 degrees of freedom
Multiple R-squared:  0.7435,	Adjusted R-squared:  0.7144
F-statistic: 25.51 on 5 and 44 DF,  p-value: 5.524e-12

> lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost +
+ Density, data = st)

Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost +
    Density, data = st)
```

```
Coefficients:
(Intercept)   Population      Murder     HS.Grad       Frost
  7.142e+01    6.083e-05   -3.160e-01    4.233e-02   -5.999e-03
    Density
 -5.864e-04

> model5 = update(model4, .~.-Density)
> summary(model5)

Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost,
    data = st)

Residuals:
     Min       1Q   Median       3Q      Max
-1.47095 -0.53464 -0.03701  0.57621  1.50683

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.103e+01  9.529e-01  74.542  < 2e-16
Population   5.014e-05  2.512e-05   1.996  0.05201
Murder      -3.001e-01  3.661e-02  -8.199 1.77e-10
HS.Grad      4.658e-02  1.483e-02   3.142  0.00297
Frost       -5.943e-03  2.421e-03  -2.455  0.01802

Residual standard error: 0.7197 on 45 degrees of freedom
Multiple R-squared:  0.736,	Adjusted R-squared:  0.7126
F-statistic: 31.37 on 4 and 45 DF,  p-value: 1.696e-12
```

```
> lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost,
+ data = st)

Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost,
    data = st)

Coefficients:
(Intercept)   Population      Murder     HS.Grad       Frost
  7.103e+01    5.014e-05   -3.001e-01    4.658e-02   -5.943e-03

> anova(model5, model4)
Analysis of Variance Table

Model 1: Life.Exp ~ Population + Murder + HS.Grad + Frost
Model 2: Life.Exp ~ Population + Murder + HS.Grad + Frost + Density
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1     45 23.308
2     44 22.648  1   0.66005 1.2823 0.2636
> model6 = update(model5, .~.-Population)
> summary(model6)

Call:
lm(formula = Life.Exp ~ Murder + HS.Grad + Frost, data = st)

Residuals:
    Min      1Q  Median      3Q     Max
-1.5015 -0.5391  0.1014  0.5921  1.2268
```

```
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 71.036379   0.983262  72.246  < 2e-16
Murder      -0.283065   0.036731  -7.706 8.04e-10
HS.Grad      0.049949   0.015201   3.286  0.00195
Frost       -0.006912   0.002447  -2.824  0.00699

Residual standard error: 0.7427 on 46 degrees of freedom
Multiple R-squared:  0.7127,	Adjusted R-squared:  0.6939
F-statistic: 38.03 on 3 and 46 DF,  p-value: 1.634e-12

> lm(formula = Life.Exp ~ Murder + HS.Grad + Frost, data = st)

Call:
lm(formula = Life.Exp ~ Murder + HS.Grad + Frost, data = st)

Coefficients:
(Intercept)       Murder      HS.Grad        Frost
  71.036379    -0.283065     0.049949    -0.006912

> #Stepwise Regression
> step(model1, direction="backward")
Start:  AIC=-22.89
Life.Exp ~ Population + Income + Illiteracy + Murder + +HS.Grad +
    Frost + Area + Density

            Df Sum of Sq    RSS     AIC
- Illiteracy  1    0.3050 22.373 -24.208
- Area        1    0.3564 22.425 -24.093
```

```
- Income      1    0.4120 22.480 -23.969
<none>                   22.068 -22.894
- Frost       1    1.1102 23.178 -22.440
- Density     1    1.2288 23.297 -22.185
- HS.Grad     1    1.8225 23.891 -20.926
- Population  1    2.5095 24.578 -19.509
- Murder      1   23.8173 45.886  11.707

Step:  AIC=-24.21
Life.Exp ~ Population + Income + Murder + HS.Grad + Frost + Area +
    Density

             Df Sum of Sq    RSS     AIC
- Area        1    0.1427 22.516 -25.890
- Income      1    0.2316 22.605 -25.693
<none>                   22.373 -24.208
- Density     1    0.9286 23.302 -24.174
- HS.Grad     1    1.5218 23.895 -22.918
- Population  1    2.2047 24.578 -21.509
- Frost       1    3.1324 25.506 -19.656
- Murder      1   26.7071 49.080  13.072

Step:  AIC=-25.89
Life.Exp ~ Population + Income + Murder + HS.Grad + Frost + Density

             Df Sum of Sq    RSS     AIC
- Income      1     0.132 22.648 -27.598
- Density     1     0.786 23.302 -26.174
<none>                   22.516 -25.890
```

```
- HS.Grad     1     1.424 23.940 -24.824
- Population  1     2.332 24.848 -22.962
- Frost       1     3.304 25.820 -21.043
- Murder      1    32.779 55.295  17.033

Step:  AIC=-27.6
Life.Exp ~ Population + Murder + HS.Grad + Frost + Density

             Df Sum of Sq    RSS     AIC
- Density     1     0.660 23.308 -28.161
<none>                    22.648 -27.598
- Population  1     2.659 25.307 -24.046
- Frost       1     3.179 25.827 -23.030
- HS.Grad     1     3.966 26.614 -21.529
- Murder      1    33.626 56.274  15.910

Step:  AIC=-28.16
Life.Exp ~ Population + Murder + HS.Grad + Frost

             Df Sum of Sq    RSS     AIC
<none>                    23.308 -28.161
- Population  1     2.064 25.372 -25.920
- Frost       1     3.122 26.430 -23.877
- HS.Grad     1     5.112 28.420 -20.246
- Murder      1    34.816 58.124  15.528

Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost,
    data = st)
```

```
Coefficients:
(Intercept)   Population      Murder     HS.Grad       Frost
  7.103e+01    5.014e-05   -3.001e-01    4.658e-02   -5.943e-03

> lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost, data = st)

Call:
lm(formula = Life.Exp ~ Population + Murder + HS.Grad + Frost,
    data = st)

Coefficients:
(Intercept)   Population      Murder     HS.Grad       Frost
  7.103e+01    5.014e-05   -3.001e-01    4.658e-02   -5.943e-03

> #Confidence Limits on the Estimated Coefficients
> confint(model6)
                 2.5 %       97.5 %
(Intercept) 69.05717472 73.015582905
Murder      -0.35700149 -0.209128849
HS.Grad      0.01935043  0.080546980
Frost       -0.01183825 -0.001985219
> #Predictions
> predict(model6, list(Murder=10.5, HS.Grad=48, Frost=100))
       1
69.77056
> #Regression Diagnostics
> par(mfrow=c(2,2))                   # visualize four graphs at once
> plot(model6)
```

```
> par(mfrow=c(1,1))                # reset the graphics defaults
> #Extracting Elements of the Model Object
> model6[[1]]                      # extract list item 1: coefficients
 (Intercept)      Murder     HS.Grad       Frost
71.036378813 -0.283065168  0.049948704 -0.006911735
> model6[[2]]
       Alabama         Alaska        Arizona       Arkansas
    0.36325842    -0.80873734    -1.07681421     0.93888883
    California       Colorado    Connecticut       Delaware
    0.60063821     0.90409006     0.48472687    -1.23666537
       Florida        Georgia         Hawaii          Idaho
    0.10114571    -0.17498630     1.22680042     0.23279723
      Illinois        Indiana           Iowa         Kansas
    0.26968086     0.05432904     0.19534036     0.61342480
      Kentucky      Louisiana          Maine       Maryland
    0.79770164    -0.56481311    -1.50150772    -0.32455693
 Massachusetts       Michigan      Minnesota    Mississippi
   -0.48235430     0.96231978     0.80350324    -1.11037437
      Missouri        Montana       Nebraska         Nevada
    0.59509781    -0.94669741     0.38328311    -0.70837880
 New Hampshire     New Jersey     New Mexico       New York
   -0.54666731    -0.46189744     0.10159299     0.53349703
North Carolina   North Dakota           Ohio       Oklahoma
   -0.05444180     0.91307523     0.07808745     0.18464735
        Oregon   Pennsylvania   Rhode Island South Carolina
   -0.41031105    -0.51622769     0.10314800    -1.23162114
  South Dakota      Tennessee          Texas           Utah
    0.05138438     0.58330361     1.19135836     0.72277428
       Vermont       Virginia     Washington  West Virginia
```

```
   0.46958000    -0.06731035    -1.04976581    -1.04653483
    Wisconsin        Wyoming
   0.60046076    -0.73927257
> sort(model6$resid)                  # extract residuals and sort them
        Maine       Delaware South Carolina    Mississippi
  -1.50150772    -1.23666537    -1.23162114    -1.11037437
      Arizona     Washington  West Virginia        Montana
  -1.07681421    -1.04976581    -1.04653483    -0.94669741
       Alaska        Wyoming         Nevada      Louisiana
  -0.80873734    -0.73927257    -0.70837880    -0.56481311
 New Hampshire   Pennsylvania  Massachusetts     New Jersey
  -0.54666731    -0.51622769    -0.48235430    -0.46189744
       Oregon       Maryland        Georgia       Virginia
  -0.41031105    -0.32455693    -0.17498630    -0.06731035
North Carolina   South Dakota        Indiana           Ohio
  -0.05444180     0.05138438     0.05432904     0.07808745
      Florida     New Mexico   Rhode Island       Oklahoma
   0.10114571     0.10159299     0.10314800     0.18464735
         Iowa          Idaho       Illinois        Alabama
   0.19534036     0.23279723     0.26968086     0.36325842
     Nebraska        Vermont    Connecticut       New York
   0.38328311     0.46958000     0.48472687     0.53349703
    Tennessee       Missouri      Wisconsin     California
   0.58330361     0.59509781     0.60046076     0.60063821
       Kansas           Utah       Kentucky      Minnesota
   0.61342480     0.72277428     0.79770164     0.80350324
     Colorado   North Dakota       Arkansas       Michigan
   0.90409006     0.91307523     0.93888883     0.96231978
        Texas         Hawaii
```

```
   1.19135836     1.22680042
> #Beta Coeffieicents
> model7 = lm(scale(Life.Exp) ~ scale(Murder) + scale(HS.Grad) + scale(Frost), data=st)
> summary(model7)

Call:
lm(formula = scale(Life.Exp) ~ scale(Murder) + scale(HS.Grad) +
    scale(Frost), data = st)

Residuals:
     Min       1Q   Median       3Q      Max
-1.11853 -0.40156  0.07551  0.44111  0.91389

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    -4.604e-15  7.824e-02   0.000  1.00000
scale(Murder)  -7.784e-01  1.010e-01  -7.706 8.04e-10
scale(HS.Grad)  3.005e-01  9.146e-02   3.286  0.00195
scale(Frost)   -2.676e-01  9.477e-02  -2.824  0.00699

Residual standard error: 0.5532 on 46 degrees of freedom
Multiple R-squared:  0.7127,       Adjusted R-squared:  0.6939
F-statistic: 38.03 on 3 and 46 DF,  p-value: 1.634e-12

> lm(formula = scale(Life.Exp) ~ scale(Murder) + scale(HS.Grad) +
+ scale(Frost), data = st)

Call:
lm(formula = scale(Life.Exp) ~ scale(Murder) + scale(HS.Grad) +
```

```
    scale(Frost), data = st)

Coefficients:
   (Intercept)   scale(Murder)  scale(HS.Grad)    scale(Frost)
    -4.604e-15      -7.784e-01       3.005e-01      -2.676e-01

> -0.283 * sd(st$Murder) / sd(st$Life.Exp)
[1] -0.778241
> #Partial Correlations
> ### Partial correlation coefficient
> ### From formulas in Sheskin, 3e
> ### a,b=variables to be correlated, c=variable to be partialled out of both
> pcor = function(a,b,c)
+ {
+ (cor(a,b)-cor(a,c)*cor(b,c))/sqrt((1-cor(a,c)^2)*(1-cor(b,c)^2))
+ }
> ### end of script
> pcor(st$Life.Exp, st$Murder, st$HS.Grad)
[1] -0.6999659
> #Making Predictions From a Model
> rm(list=ls())                    # clean up (WARNING! this will wipe your workspace!)
> data(airquality)                 # see ?airquality for details on these data
> na.omit(airquality) -> airquality    # toss cases with missing values
> lm(Ozone ~ Solar.R + Wind + Temp + Month,
+ data=airquality) -> model
> coef(model)
 (Intercept)      Solar.R        Wind        Temp       Month
-58.05383883   0.04959683  -3.31650940   1.87087379  -2.99162786
> (prediction <- c(1,200,11,80,6) * coef(model))
```

(Intercept) Solar.R Wind Temp Month

-58.053839 9.919365 -36.481603 149.669903 -17.949767

> ### Note: putting the whole statement in parentheses not only stores the values but also prints them to the Console.

> sum(prediction)

[1] 47.10406

> ### Prediction of mean response for cases like this...

> predict(model, list(Solar.R=200,Wind=11,Temp=80,Month=6), interval="conf")

fit lwr upr

1 47.10406 41.10419 53.10393

> ### Prediction for a single new case...

> predict(model, list(Solar.R=200,Wind=11,Temp=80,Month=6), interval="pred")

fit lwr upr

1 47.10406 5.235759 88.97236

Question 2- R results

```
mySweep <- function(A, m)
+ {
+   n <- dim(A)[1]
+
+   for (k in 1:m)
+   {
+     for (i in 1:n)
+       for (j in 1:n)
+         if (i!=k  & j!=k)
+           A[i,j] <- A[i,j] - A[i,k]*A[k,j]/A[k,k]
+
+         for (i in 1:n)
+           if (i!=k)
+             A[i,k] <- A[i,k]/A[k,k]
+
+           for (j in 1:n)
+             if (j!=k)
+               A[k,j] <- A[k,j]/A[k,k]
+
+             A[k,k] <- - 1/A[k,k]
+   }
```

```
+   return(A)
+ }
>
> mylm_sweep <- function(X, Y)
+ {
+   X = cbind(a = 1,X)
+   #Z=(XY)T(XY)
+   value_ii=t(X)%*%X
+   value_ij=t(X)%*%Y
+   value_ji=t(Y)%*%X
+   value_jj=t(Y)%*%Y
+
+   #row bind value_ii and value_ji
+   rb_for_sweep_one=rbind(value_ii,value_ji)
+   rb_for_sweep_two=rbind(value_ij,value_jj)
+
+   #column bind rb_for_sweep_one and rb_for_sweep_two
+   input_forsweep= cbind(rb_for_sweep_one,rb_for_sweep_two)
+
+   #Applying sweep function
+   ans=mySweep(input_forsweep,8)
+
+   #Extracting Betahat
+   beta_hat=ans[,c(9)]
+
+   return(beta_hat)
+ }
>
> myqr <- function(A)
+ {
+   n = nrow(A)
+   m = ncol(A)
+   R = A
+   Q = diag(n)
+
+   for (k in 1:(m-1))
+   {
+     x = matrix(rep(0, n), nrow = n)
+     x[k:n, 1] = R[k:n, k]
+     g = sqrt(sum(x^2))
+     v = x
+     v[k] = x[k] + sign(x[k,1])*g
+
+     s = sqrt(sum(v^2))
+     if (s != 0)
+     {
+       u = v / s
+       R = R - 2 * u %*% t(u) %*% R
+       Q = Q - 2 * u %*% t(u) %*% Q
+     }
+   }
+   result <- list(t(Q), R)
+   names(result) <- c("Q", "R")
+   result
+ }
>
>
```

```
> my_Solve <- function(X,Y)
+ {
+   a = nrow(X)
+   m = ncol(X)
+   x_vector <- cbind(X,Y)
+   y_vector <- cbind(t(Y),1)
+   Z <- rbind(x_vector,y_vector)
+   S = mySweep(Z,m)
+   print(ncol(S))
+   inverse = S[,(m+1)]
+   return(inverse)
+ }
>
> mylm_qr <- function(X,Y)
+ {
+   #adding a weighted column of 1s to perform AX=B
+   X1 = cbind(a = 1,X)
+   p = 7
+   final = cbind(X1,Y)
+   R = myqr(final)$R
+   R1 = R[1:(p+1), 1:(p+1)]
+   Y1 = R[1:(p+1), p+2]
+   beta = my_Solve(R1,Y1)
+   return(beta)
+
+ }
>
> state.x77
               Population Income Illiteracy Life Exp Murder HS Grad Frost    A
rea
Alabama              3615   3624        2.1    69.05   15.1    41.3    20   50
708
Alaska                365   6315        1.5    69.31   11.3    66.7   152  566
432
Arizona              2212   4530        1.8    70.55    7.8    58.1    15  113
417
Arkansas             2110   3378        1.9    70.66   10.1    39.9    65   51
945
California          21198   5114        1.1    71.71   10.3    62.6    20  156
361
Colorado             2541   4884        0.7    72.06    6.8    63.9   166  103
766
Connecticut          3100   5348        1.1    72.48    3.1    56.0   139    4
862
Delaware              579   4809        0.9    70.06    6.2    54.6   103    1
982
Florida              8277   4815        1.3    70.66   10.7    52.6    11   54
090
Georgia              4931   4091        2.0    68.54   13.9    40.6    60   58
073
Hawaii                868   4963        1.9    73.60    6.2    61.9     0    6
425
Idaho                 813   4119        0.6    71.87    5.3    59.5   126   82
677
Illinois            11197   5107        0.9    70.14   10.3    52.6   127   55
748
```

Indiana	5313	4458	0.7	70.88	7.1	52.9	122	36097
Iowa	2861	4628	0.5	72.56	2.3	59.0	140	55941
Kansas	2280	4669	0.6	72.58	4.5	59.9	114	81787
Kentucky	3387	3712	1.6	70.10	10.6	38.5	95	39650
Louisiana	3806	3545	2.8	68.76	13.2	42.2	12	44930
Maine	1058	3694	0.7	70.39	2.7	54.7	161	30920
Maryland	4122	5299	0.9	70.22	8.5	52.3	101	9891
Massachusetts	5814	4755	1.1	71.83	3.3	58.5	103	7826
Michigan	9111	4751	0.9	70.63	11.1	52.8	125	56817
Minnesota	3921	4675	0.6	72.96	2.3	57.6	160	79289
Mississippi	2341	3098	2.4	68.09	12.5	41.0	50	47296
Missouri	4767	4254	0.8	70.69	9.3	48.8	108	68995
Montana	746	4347	0.6	70.56	5.0	59.2	155	145587
Nebraska	1544	4508	0.6	72.60	2.9	59.3	139	76483
Nevada	590	5149	0.5	69.03	11.5	65.2	188	109889
New Hampshire	812	4281	0.7	71.23	3.3	57.6	174	9027
New Jersey	7333	5237	1.1	70.93	5.2	52.5	115	7521
New Mexico	1144	3601	2.2	70.32	9.7	55.2	120	121412
New York	18076	4903	1.4	70.55	10.9	52.7	82	47831
North Carolina	5441	3875	1.8	69.21	11.1	38.5	80	48798
North Dakota	637	5087	0.8	72.78	1.4	50.3	186	69273
Ohio	10735	4561	0.8	70.82	7.4	53.2	124	40975
Oklahoma	2715	3983	1.1	71.42	6.4	51.6	82	68782
Oregon	2284	4660	0.6	72.13	4.2	60.0	44	96184
Pennsylvania	11860	4449	1.0	70.43	6.1	50.2	126	44966
Rhode Island	931	4558	1.3	71.90	2.4	46.4	127	1049
South Carolina	2816	3635	2.3	67.96	11.6	37.8	65	30225
South Dakota	681	4167	0.5	72.08	1.7	53.3	172	75955

```
Tennessee             4173   3821        1.7    70.11   11.0    41.8    70  41
328
Texas                12237   4188        2.2    70.90   12.2    47.4    35 262
134
Utah                  1203   4022        0.6    72.90    4.5    67.3   137  82
096
Vermont                472   3907        0.6    71.64    5.5    57.1   168   9
267
Virginia              4981   4701        1.4    70.08    9.5    47.8    85  39
780
Washington            3559   4864        0.6    71.72    4.3    63.5    32  66
570
West Virginia         1799   3617        1.4    69.48    6.7    41.6   100  24
070
Wisconsin             4589   4468        0.7    72.48    3.0    54.5   149  54
464
Wyoming                376   4566        0.6    70.29    6.9    62.9   173  97
203
> str(state.x77)
 num [1:50, 1:8] 3615 365 2212 2110 21198 ...
 - attr(*, "dimnames")=List of 2
  ..$ : chr [1:50] "Alabama" "Alaska" "Arizona" "Arkansas" ...
  ..$ : chr [1:8] "Population" "Income" "Illiteracy" "Life Exp" ...
> state_matrix = as.data.frame(state.x77)
> row.names(state_matrix)=NULL
> str(state_matrix)
'data.frame':	50 obs. of  8 variables:
 $ Population: num  3615 365 2212 2110 21198 ...
 $ Income    : num  3624 6315 4530 3378 5114 ...
 $ Illiteracy: num  2.1 1.5 1.8 1.9 1.1 0.7 1.1 0.9 1.3 2 ...
 $ Life Exp  : num  69 69.3 70.5 70.7 71.7 ...
 $ Murder    : num  15.1 11.3 7.8 10.1 10.3 6.8 3.1 6.2 10.7 13.9 ...
 $ HS Grad   : num  41.3 66.7 58.1 39.9 62.6 63.9 56 54.6 52.6 40.6 ...
 $ Frost     : num  20 152 15 65 20 166 139 103 11 60 ...
 $ Area      : num  50708 566432 113417 51945 156361 ...
> MatrixA=data.matrix(state_matrix)
>
> # X such that life expectency is removed
>
> X=MatrixA[,-c(4)]
> Y=MatrixA[,c(4)]
> print("Betahat using mylm_sweep")
[1] "Betahat using mylm_sweep"
> beta_hat_ans=mylm_sweep(X,Y)
> beta_hat_ans
            a    Population        Income    Illiteracy        Murder        H
S Grad         Frost          Area
 7.094322e+01  5.180036e-05 -2.180424e-05  3.382032e-02 -3.011232e-01  4.8929
48e-02 -5.735001e-03 -7.383166e-08

 2.329714e+01
>
> print("Betahat using mylm_QR")
[1] "Betahat using mylm_QR"
> ans_final=mylm_qr(X,Y)
[1] 9
> ans_final
```

```
[1]  7.094322e+01  5.180036e-05 -2.180424e-05  3.382032e-02 -3.011232e-01  4.
892948e-02 -5.735001e-03 -7.383166e-08
[9]  3.555838e+04
>
> print("Regression results using lm(Y~X)")
[1] "Regression results using lm(Y~X)"
> lm(Y~X)

Call:
lm(formula = Y ~ X)

Coefficients:
(Intercept)  XPopulation      XIncome  XIlliteracy      XMurder     XHS Grad
XFrost        XArea
  7.094e+01    5.180e-05   -2.180e-05    3.382e-02   -3.011e-01    4.893e-02
-5.735e-03   -7.383e-08
```

Q-2 Python results

```
MY_lm_sweep results
[  7.09432241e+01   5.18003638e-05  -2.18042378e-05   3.38203214e-02
  -3.01123170e-01   4.89294789e-02  -5.73500110e-03  -7.38316614e-08]
My_lm_QR results
[  7.09432241e+01   5.18003638e-05  -2.18042378e-05   3.38203214e-02
  -3.01123170e-01   4.89294789e-02  -5.73500110e-03  -7.38316615e-08]
```